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Interpretation of the potentiometric surface along the Rio Grande at selected locations in Albuquerque, New Mexico

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INTERPRETATION OF THE POTENTIOMETRIC SURFACE ALONG THE RIO GRANDE AT SELECTED LOCATIONS IN ALBUQUERQUE, NEW MEXICO

BY

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ABSTRACT

The U.S. Geological Survey installed over 240 piezometers and 27 surface-water gages along the Rio Grande in Albuquerque, NM from 2003 to 2009 to monitor groundwater and surface-water levels and water temperatures. Spanning a 20 mile distance between the bridges at Alameda Blvd. and Interstate 25, there were 8 selected locations each consisting of paired east-west transects situated perpendicular to the river (Figure 1). Paired transects comprise two parallel cross-sections of the Rio Grande inner valley that were positioned approximately 500 ft. apart and extend to the riverside drains on both sides of the river. Each transect consisted of piezometers installed at various depths along the riverside drains, and in the Rio Grande riparian zone known as the bosque, and also included surface-water-stage gages installed in the Rio Grande and at both riverside drains. In the riparian zone, riverside piezometers were situated within 20 ft of the river bank whereas bosque piezometers were placed about halfway between the river bank and the riverside drain. Each transect contained piezometers along the river-side of the east and west riverside drains, on the side closer to the river and many of the transects contained piezometers located outside of the drains. Six transects contained piezometers located over 300 ft from the river. Every groundwater and surface-water site was instrumented with an electronic pressure transducer programmed to collect hourly water-level data. Depth to water data were processed through the USGS Automated Data Processing System (ADAPS), and later converted to water surface elevation. These water level elevations were then used to calculate horizontal and vertical groundwater gradients as related to seasonal variations in surface-water discharge in the Rio Grande. It is shown in this study that seasonal extremes of discharge significantly influence the direction and magnitude of groundwater gradients in the bosque. This study calculated hydraulic gradients at eight approximately equidistant locations in the study area, on both sides of the river, and from the river to the outside of both riverside drains at most locations. Gradients near the drains are particularly important because groundwater leakage from the river may at times flow at levels significantly below

the drain invert elevations. When groundwater levels adjacent to the drains are well below the drain invert elevations, the drains cannot be recharged with river leakage - in fact, the drains here are implied to be losing surface water flow down into the groundwater system. There are likely several reasons for this. Pumpage from nearby municipal production wells may intermittently lower adjacent groundwater levels enough along drains to cause this. In addition, river water diverted out of the Rio Grande through the San Juan-Chama Drinking Water Project may reduce channel discharge and consequent leakage to the groundwater system enough to lower water levels in drain reaches as well as in the bosque through much of the Albuquerque area. Additionally, vertical and horizontal gradients at three locations in this study were analyzed for changes due to the influence of municipal production well pumpage from three of the nearest Albuquerque well fields. Other contributing factors to declining groundwater levels likely include climate change, bosque vegetation, soil stratigraphy, riverside drains, irrigation ditches, and domestic groundwater pumpage.

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INTRODUCTION

Flow in the Rio Grande is allocated to a variety of agricultural, domestic, recreational and environmental uses and there is a wide interest in fully understanding the functioning of the river and its associated surface and subsurface flow systems. Recent changes to Rio Grande flow through Albuquerque, including those resulting from the San Juan-Chama Drinking Water Project and climate fluctuations, establish an increased necessity to understand groundwater and surface-water interactions. A number of agencies and groups are working in the area on projects concerned with the establishment and maintenance of biologic communities, the relation between evapotranspiration and water elevation, and the effect that groundwater pumping has on water-table elevation and on shallow groundwater storage. According to Wilcox and others (2007), the Rio Grande is the 24th longest river in the world and its watershed covers 11% of the continental United States. Therefore, maintaining adequate streamflow through this vast area is essential for the preservation of aquatic and riparian habitats which have come to depend on river water. The Rio Grande is the primary source of water for irrigated agriculture (McAda, 1996) and it became the principle source of water for municipal, domestic, commercial, and industrial uses in the Albuquerque area in 2008.

In 2003, the USGS began a detailed characterization of the hydrogeology of the riparian zone, along the Rio Grande in the Albuquerque area, to enhance the understanding of river leakage through the inner valley alluvium to riverside drains and the Santa Fe Group aquifer system. The USGS study will be referred to as the Bosque Project in this report. A large network of water-monitoring sites was needed to acquire the data necessary for analysis of variable hydrogeologic conditions within the study area and continuous data collection was necessary for analysis at multiple time scales. A network of piezometers and surface-water stage gages was established to arrive at a better understanding of groundwater and surface-water interactions in the Albuquerque area. In late 2011, the network contained over 240 instrumented piezometers and 27 surface-water stage gages. All sites were instrumented with In-Situ pressure transducers programmed to collect hourly water-level-below-land-surface data and many of them also collected hourly water temperature.

Quantification of water exchanged between the Rio Grande, the Santa Fe Group aquifer, and the riverside drains was a major goal of the Bosque Project. Rankin and others (2012) indicated that riverside drains were designed to intercept lateral groundwater flow from the surrounding area, return the water to the river at a downstream location, and prevent waterlogged-soil conditions.

Purpose and Scope

The first objective of the present study was to calculate horizontal and vertical gradients of groundwater in the bosque at depths less than 30 ft. Daily water-level data was used for the computations and the gradients will be analyzed on yearly and seasonal scales. Due to hydrologic variability in this large study area, gradients will also be analyzed by location. The second objective is to continue a study that Isaacson (2009) began that measured vertical distances of separation between riverside drain invert elevations and adjacent groundwater heads. If separations exist, this implies that drain invert elevations are above adjacent groundwater heads which likely indicates that drains lose surface water as leakage to the underlying aquifer. Groundwater levels adjacent to the riverside drains and measurements of drain geometries will be examined to confirm whether separations occur on either side of the river at any of the eight locations in Albuquerque. Rio Grande discharge and municipal groundwater-pumping data were also evaluated for their effects on groundwater flow.

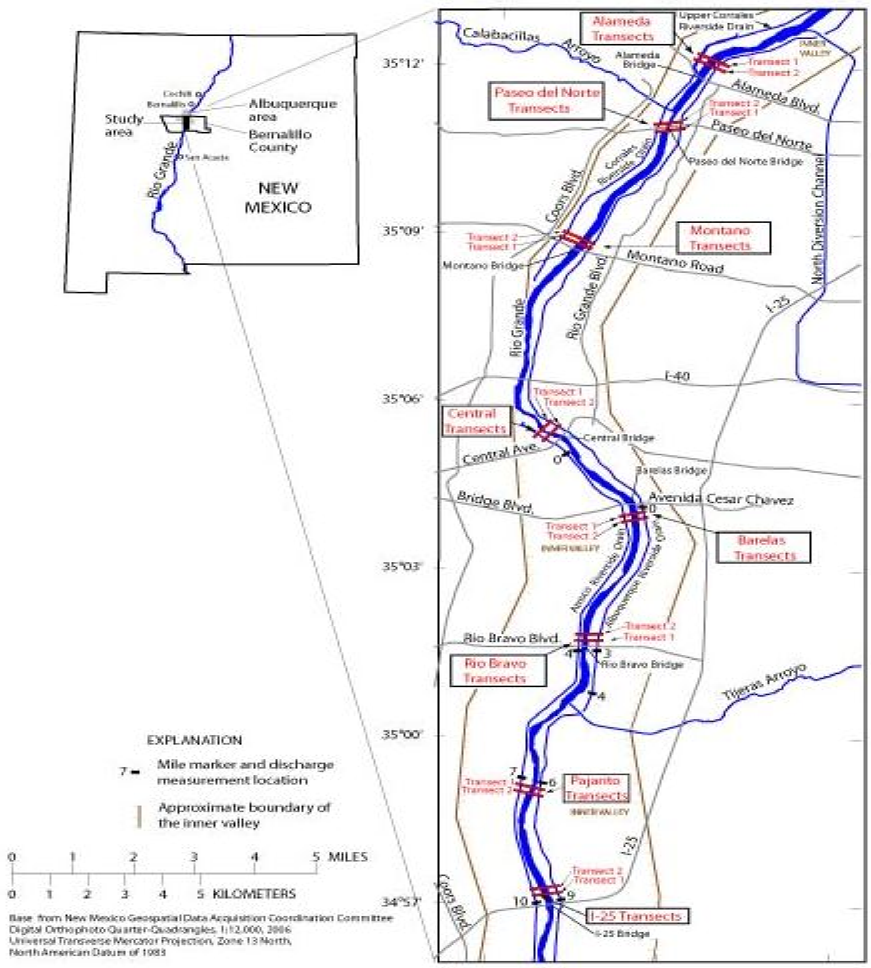
Description of Study Area

The study area extends about 20 mi along the Rio Grande and the surrounding riparian area in Albuquerque, NM from just north of the bridge at Alameda Blvd. to the bridge at the Interstate 25 river crossing. The east and west edges of the study area are limited to areas within the inner valley adjacent to the Corrales, Albuquerque, and Atrisco Riverside Drains (Figure 1). The riverside drains are ditches placed along the east and west boundaries of the riparian zone, separated from the river by levees, and are designed to intercept lateral groundwater flow from the surrounding area and prevent waterlogged-soil conditions. The riparian zone, known to locals as the bosque, is primarily made up of Cottonwood, Russian Olive, and Salt Cedar trees.

The inner valley alluvium consists of coarse-grained axial channel deposits and post-Santa Fe Group sediments that underlie the present-day Rio Grande flood plain (Hawley and Haase, 1992). In the Albuquerque area, the alluvium consists of unconsolidated to poorly consolidated, fine- to coarse-grained sand and rounded gravel with subordinate, discontinuous lens-shaped interbeds of fine-grained sand, silt, and clay (Connell and others, 2007). These deposits form an extensive shallow aquifer zone along the Rio Grande in the Albuquerque area and represent the last cut-and-fill cycle of the expansion of the Rio Grande fluvial system. Hawley and Haase (1992) indicate these channel and flood-plain sediments may be as much as 120-ft thick with an average thickness of 80 ft. Connell and others (2007) suggest that excavation of the inner valley probably occurred during the Pleistocene epoch (1.8 million years to 10,000 years before present) and subsequently filled to near its present level by the middle Holocene epoch (5,000 years to present). The inner valley alluvium is overlain by and interfingers with valley border deposits of late Pleistocene and Holocene age derived from the major tributary drainages. The top of this unit has formed through deposition and includes the flood plain and channel of the Rio Grande.

The Santa Fe Group aquifer system is composed primarily of gravel, sand, silt, and clay. Most of these sediments were transported into fault-bounded basins of the Rio Grande by rivers and drainages from surrounding areas (Bartolino and Cole, 2002). The spatial distribution of sedimentary facies of these deposits tends to be complex and three-dimensional rather than a simple, layered system (Bartolino and Cole, 2002).

Figure 1. Location of study area and transects in the Albuquerque area, New Mexico (Borrowed from Rankin and others 2012).



The Santa Fe Group aquifer is approximately 14,000-ft thick in parts of the basin and is divided into upper, middle and lower hydrostratigraphic units (Hawley and Haase, 1992). Sediments in the upper Santa Fe unit were deposited during the development of the ancestral Rio Grande and contain intertongued piedmont-slope and fluvial basin-floor deposits as thick as 1,200 ft (Hawley and Haase, 1992). Coarse-grain sediments comprise the ancestral Rio Grande axial-channel deposits contained in the upper unit of the Santa Fe Group. Sediments in the middle Santa Fe unit include piedmont-slope deposits, fluvial basin-floor deposits, and basin-floor playa deposits (Hawley and Haase, 1992). This middle unit contains the largest accumulation of deposits and is as much as 10,000-ft thick. Sediments in the lower Santa Fe unit are predominantly piedmont-slope, eolian, and basin-floor playa deposits and are as much as 3,500-ft thick (Hawley and Haase, 1992).

Background

The interaction of groundwater and surface water in the Albuquerque area has been the topic of many investigations. In 1986, Kues (1986) examined water levels in 44 wells along the Rio Grande in Albuquerque to determine groundwater flow directions. Anderholm and Bullard (1987) described well cuttings from piezometer installations in the Rio Grande riparian zone at Rio Bravo Blvd. and Montano Rd. Peter (1987) analyzed water level and lithologic data from wells in the inner valley of the Rio Grande in southern Albuquerque to determine groundwater flow and temporal variation. McAda (1996) described hydrologic interactions between the Rio Grande and the Santa Fe Group aquifer in Albuquerque and prioritized activities to better understand the systems. Bartolino (2003) evaluated groundwater and surface-water interactions near the Paseo Del Norte Bridge by using water temperature as a tracer. It was shown that the transport of heat led to a better understanding of the mechanisms of ground and surface-water exchanges. Falk and others (2011) used potentiometric head data from predevelopment conditions to 2008 to determine the impact of urban groundwater pumping on the regional potentiometric surfaces and consequent changes in the direction of groundwater flow in the upper Santa Fe Group aquifer.

Groundwater movement in the Middle Rio Grande Basin was described by Kernodle and others (1995) and Bexfield and McAda (2003) using groundwater-flow models. The model simulations were focused on ground and surface-water response to groundwater pumping in the City of Albuquerque. In 1999, Bartolino and Niswonger used a heat and water transport model to quantify vertical flux between ground and surface-water systems between the Paseo Del Norte and Rio Bravo bridges. Electromagnetic surveys were performed by Bartolino and Sterling (2000) along the Rio Grande inner valley to identify the presence of hydrologically significant clay-rich layers buried in the alluvium. Using a transect of wells perpendicular to the Rio Grande and two surface water stage gages near the Rio Bravo Bridge, Roark (2001) modeled groundwater flow in response to flood pulses in the river. McAda and Barroll (2002) used a three-dimensional groundwater-flow model to simulate groundwater flow in the Santa Fe Group aquifer system within the Middle Rio Grande Basin between Cochiti and San Acacia. Sanford and others (2003) used environmental tracers to constrain parameter values used in a predevelopment ground-water-flow model of the Middle Rio Grande Basin. Engdahl and others (2010) modeled lithologic heterogeneity near the Rio Bravo Bridge to estimate the exchange of water between the surface and the subsurface.

Shafike (2005) developed and calibrated a regional-scale model of surface water/groundwater interactions in the Rio Grande from San Acacia to Elephant Butte reservoir to evaluate potential system-wide depletions that resulted from operational changes. MODBRANCH, a USGS program, was calibrated using surface-water-flow measurements and groundwater levels to present the physical processes of surface-water routing, surface water/groundwater interaction, discharge from springs, riparian and crop depletions, groundwater withdrawals and groundwater levels. Prior to this study, Shafike used the model to estimate average annual water depletion in the Socorro reach of the Rio Grande. Delineation of the model indicated a strong hydraulic connection between the river and the Santa Fe Group aquifer and provided a better understanding of the system for improved efficiency and maintenance of river flow. Later simulations using the model by Wilcox and others (2007) evaluated specific management alternatives to improve conveyance efficiency in the Socorro reach.

Isaacson (2009) used ArcGIS and HEC-RAS to model riparian groundwater surfaces as a function of river discharge. She used groundwater-level data from the Bosque Project and the Bosque Ecological Monitoring Program (BEMP) to calculate gradients from the river to the riverside drains. Her study focused on the reach of the Rio Grande between the North Diversion Channel and the bridge at Central Ave. Figures 4-5 and 4-6 of her report show that river leakage conveys below the riverside drain just north of the Montano Bridge on the west side of the river. In her study, the separation between drain invert elevations and adjacent groundwater heads existed before and after irrigation diversions had begun. She also discusses how evapotranspiration and climate change are affecting groundwater levels in the bosque. Samson (2012) used a two-dimensional groundwater model (HYDRUS-2D) to analyze bank storage in the bosque and its response to flood events in the Rio Grande. His study concentrated on a bosque area on the east side of the river just north of the bridge at Rio Bravo Blvd. and he used water-level data from the Bosque Project to determine gradients in the area. Samson had much data to use for model calibration as this location has been the focus of previous studies. Administering multiple model scenarios helped Samson discover the importance of hydraulic conductivity to the movement and storage of water after a flood event.

From 2003 to 2011, the Bosque Project acquired continuous water level and temperature data in over 240 monitoring wells. Lithologic information from 36 sites was collected at five locations (Paseo Del Norte, Montano, Barelas, Rio Bravo, and I-25) with a Geoprobe while installing piezometers and the samples were examined and described. Vertical-temperature profiles were collected at 62 piezometers once/month for one year during 2008 and 2009. These data were used to establish horizontal and vertical gradients, groundwater flux from the river, and define a conceptual model of flow in the shallow aquifer adjacent to the river. The Bosque Project presented two methods to quantify the Darcy flux at depths less than 30 ft., the first using Darcy's law and the second using the Suzuki-Stallman equation for heat transport. To test the validity of the results from the two approaches, discharge was measured in selected parts of the east and west riverside drains. Aquifer properties were estimated using the data from 47 slug tests at all eight locations and on both sides of the river. Hydraulic-conductivity estimates were determined with type-curve matching techniques and the Bouwer and Rice (1976) and Butler (1998) methods for slug-test analysis in unconfined aquifers.

Hydraulic conductivity from the slug tests conducted by Rankin and others (2012) at multiple sites within each location ranged from 3 ft/d at Pajarito to 240 ft/d at Central. The median hydraulic conductivity value for all transects was 50 ft/d. These values are, for the most part, within the range of estimated hydraulic conductivities used in previous investigations to evaluate aquifer properties, which varied from 10 to 150 ft/d (Kernodle and others, 1995; Tiedeman and others, 1998; and McAda, 2001). The response at 17 piezometers to slug testing was nonoscillatory and was best analyzed by the Bouwer and Rice (1976) method. The response at 30 piezometers was oscillatory and was best analyzed by the Butler (1998) method. The hydraulic conductivities measured using slug tests were not substantially different between the east and west sides of the river. Complex geology and local scale heterogeneities, analyzed from the core samples, are partly responsible for the differences in hydraulic conductivities in the study area. Data from the vertical-temperature profiles were used to evaluate the depth of the aquifer that is influenced by leakage from the river. Results indicate that heat is generally transported with horizontal river-water flux to depths greater than 50 ft. The conceptual model established from these data illustrates a groundwater table that slopes downward from the river to the riverside drains and at depths less than 30 ft, the flow is primarily horizontal. Median groundwater flux through the riparian zone, using the Darcy equation, ranged from 0.04 to 1.08 ft/d whereas median flux, calculated with the Suzuki-Stallman approach, ranged from 0.1 to 0.5 ft/d. A general decrease in flux downstream from Alameda to I-25 corresponds to a decrease in the horizontal gradients. Discharge measurements taken along the riverside drains indicated that flow in the drains only accounts for 26 to 27 percent of the calculated groundwater flux. One possible explanation given is that hydraulic-conductivity values used in the calculations were too low. Another possibility, which this study investigated, is that an unknown quantity of groundwater flux occurs at depths below the riverside drain invert elevations.

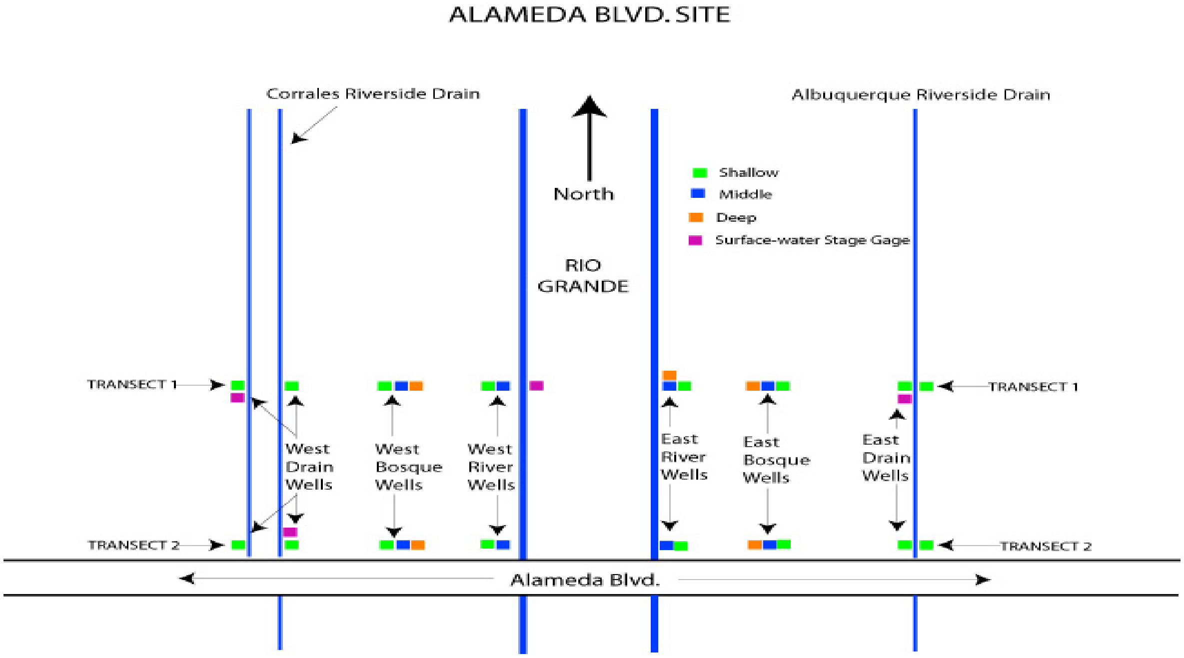
Specifically, gradients in this study will help to identify where and when this separation is most prevalent. Other data collected for the Bosque Project may be used to explain why the separation is occurring.

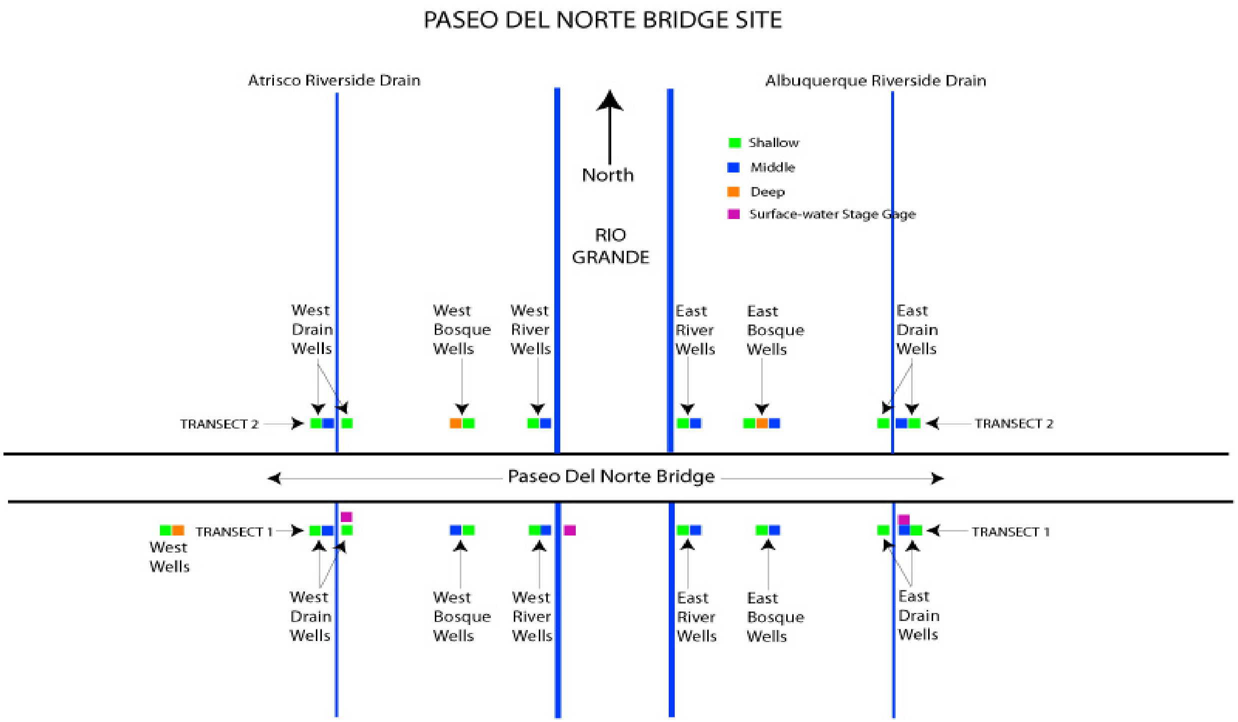
METHODS

Piezometer and Surface-Water Gage installation

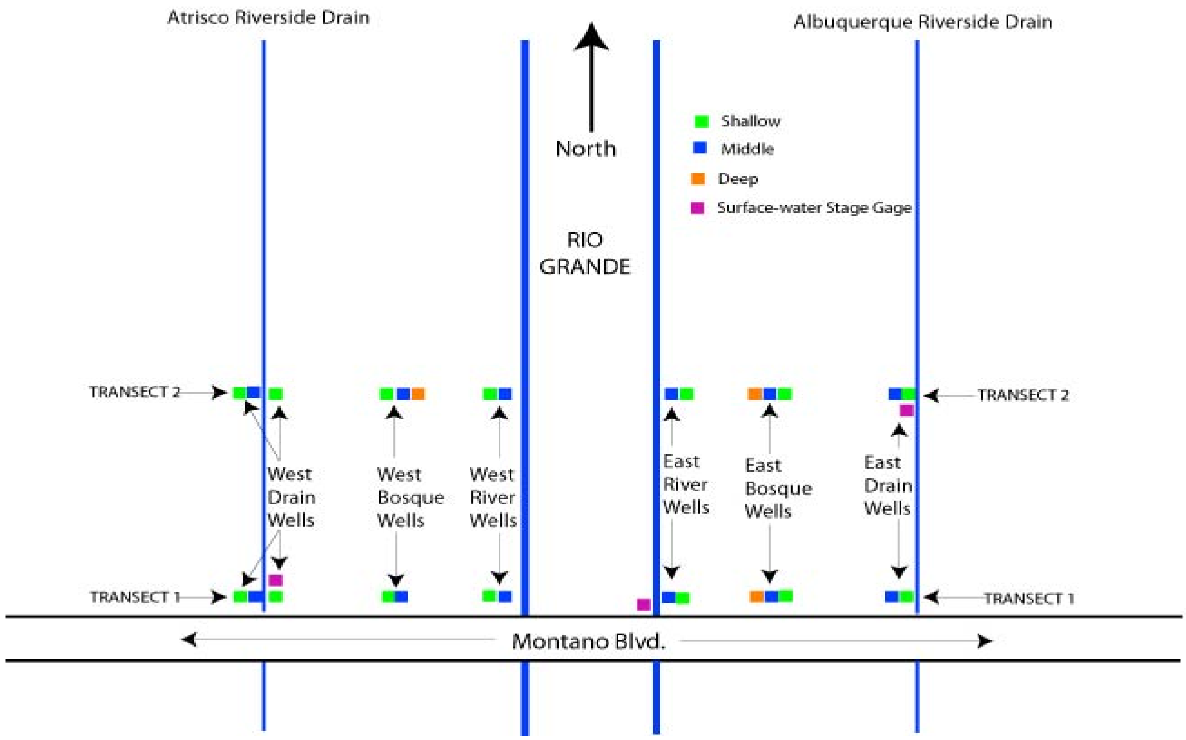
Piezometers and surface-water-stage gages were installed at 8 locations along a 20-mile reach of the Rio Grande in the Albuquerque area (Figure 1) between the years of 2003 and 2010. Seven of these locations were positioned at major river crossings and all locations consisted of two cross-sections of the Rio Grande inner valley that were oriented perpendicular to the river at a distance of about 500 ft apart. Along each transect, there were nested piezometers (monitoring wells drilled and screened at different depths) placed within 20 ft of the river bank and in the bosque located about halfway between the river bank and the riverside drain. Each transect consisted of piezometers within the inner flood plain of the river (the side nearest to the river) of the riverside drains and most transects included piezometers outside of the drains. Surface-water-stage gages were installed in the river and in both riverside drains at each location. Along each transect, piezometers were placed in four distinct zones of hydraulic influence: the river's edge, the riparian area between the river and drain, the inside bank of the riverside drain, and the outside bank. The paired-transect configurations and nested-piezometer completions were chosen to facilitate calculations of horizontal and vertical gradients, respectively. Bridges were chosen for site locations due to easy access; and distances between bridges was approximately equal (Figure 2).

Figure 2(a-h). Piezometer and surface-water-stage gage layout at each location (not to scale; modified from Rankin and others 2012).

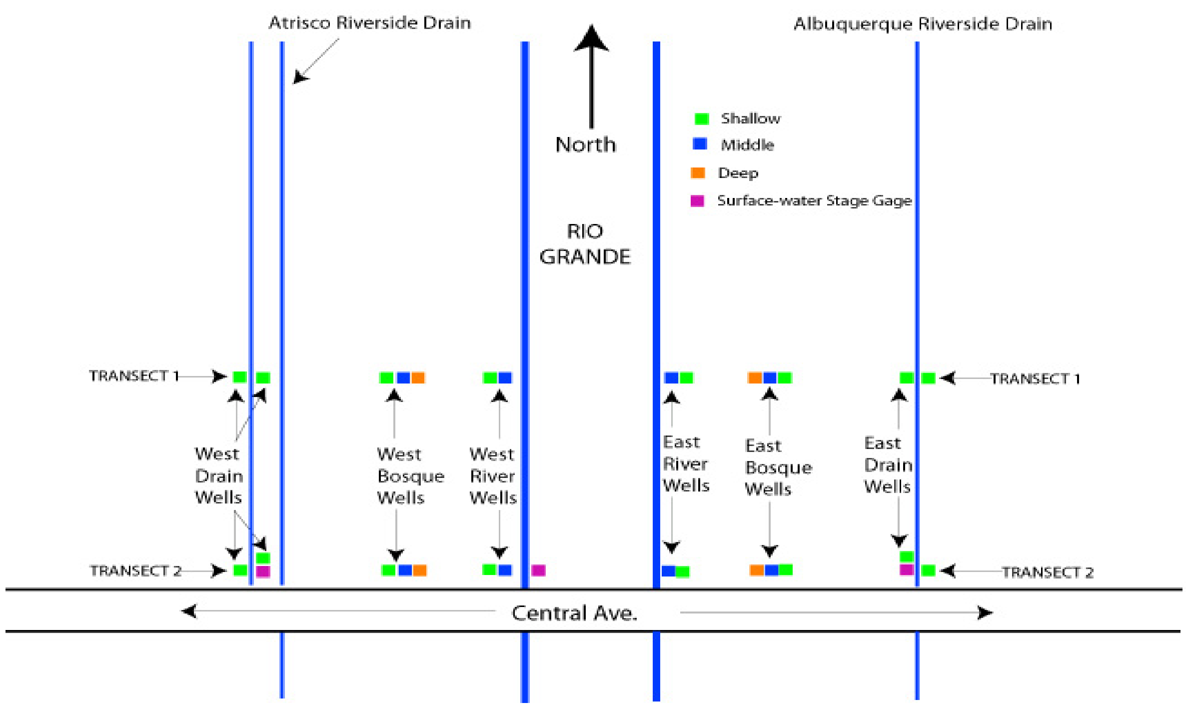


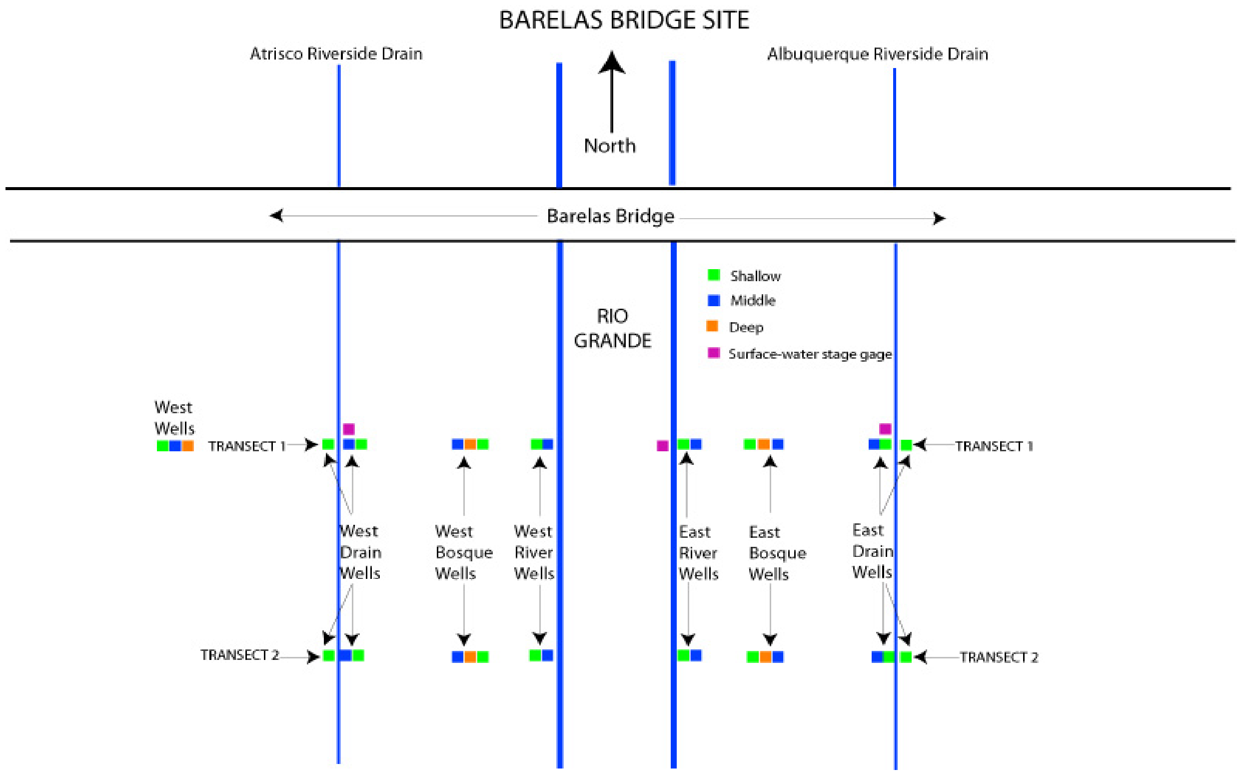


MONTANO BLVD. SITE

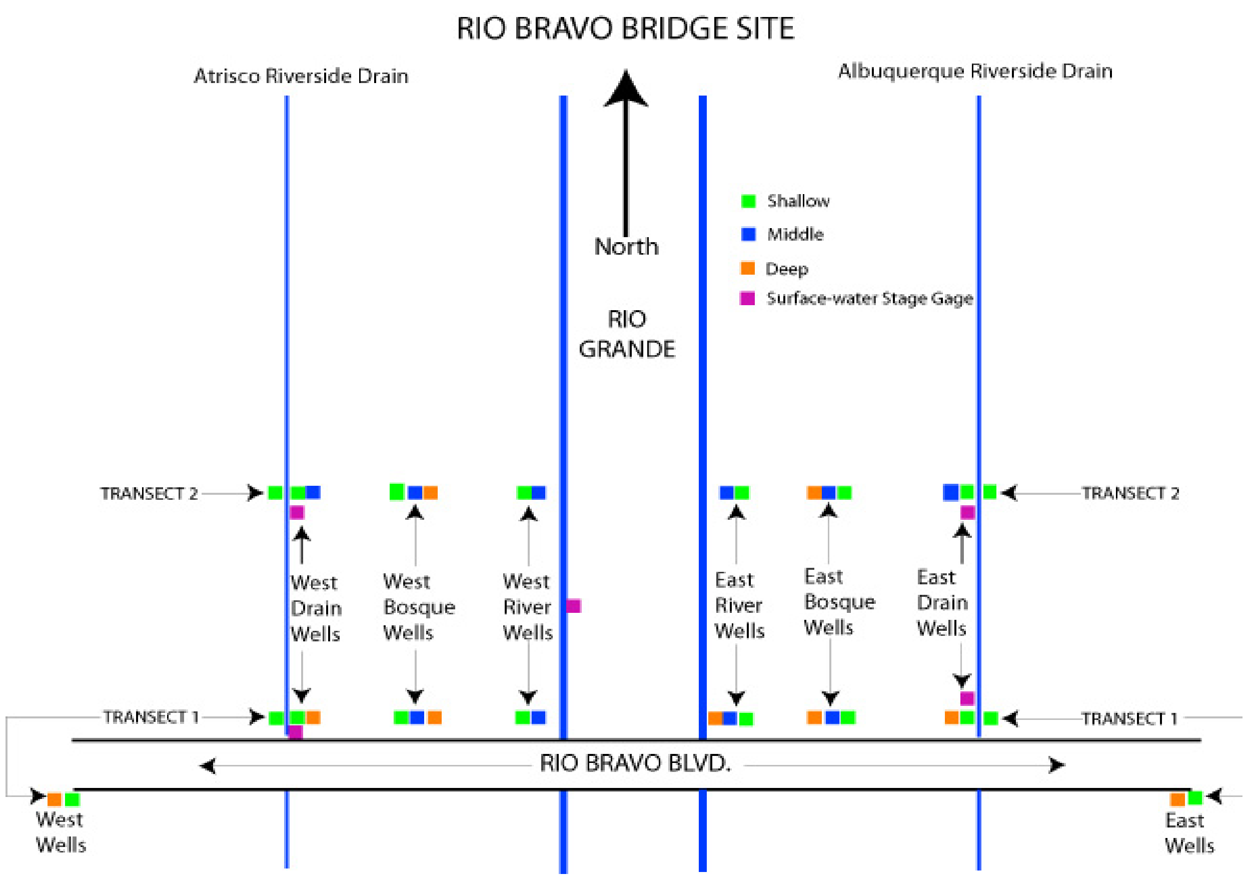


CENTRAL AVE. SITE

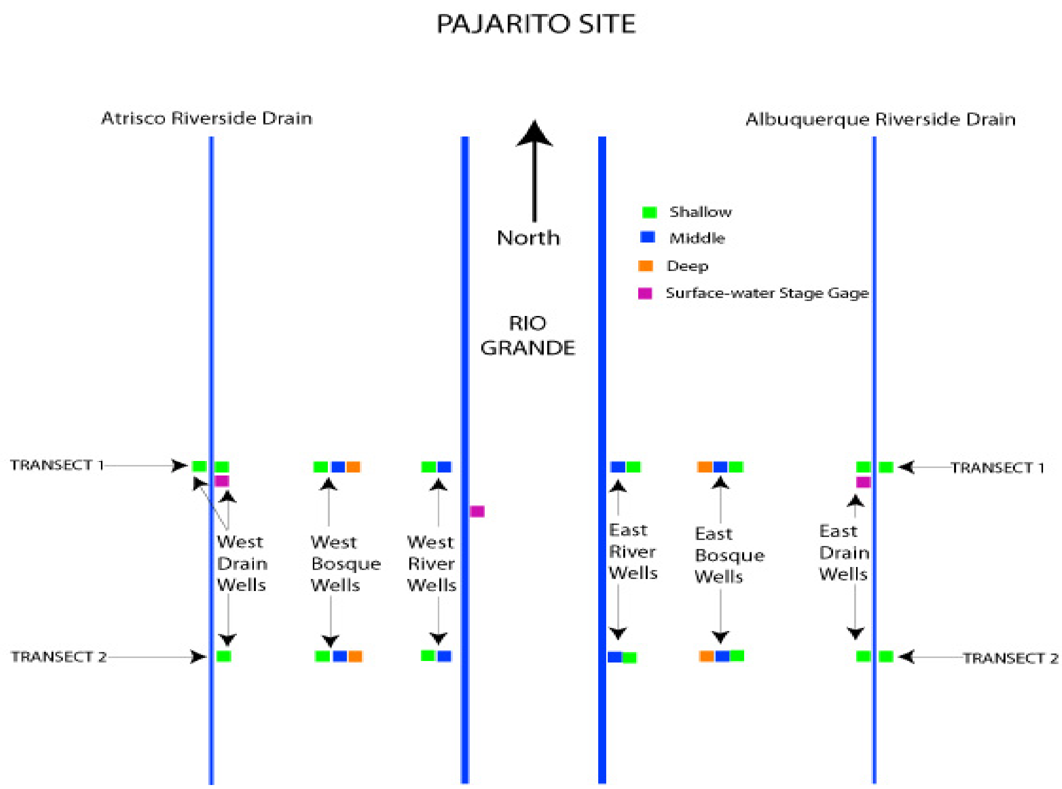


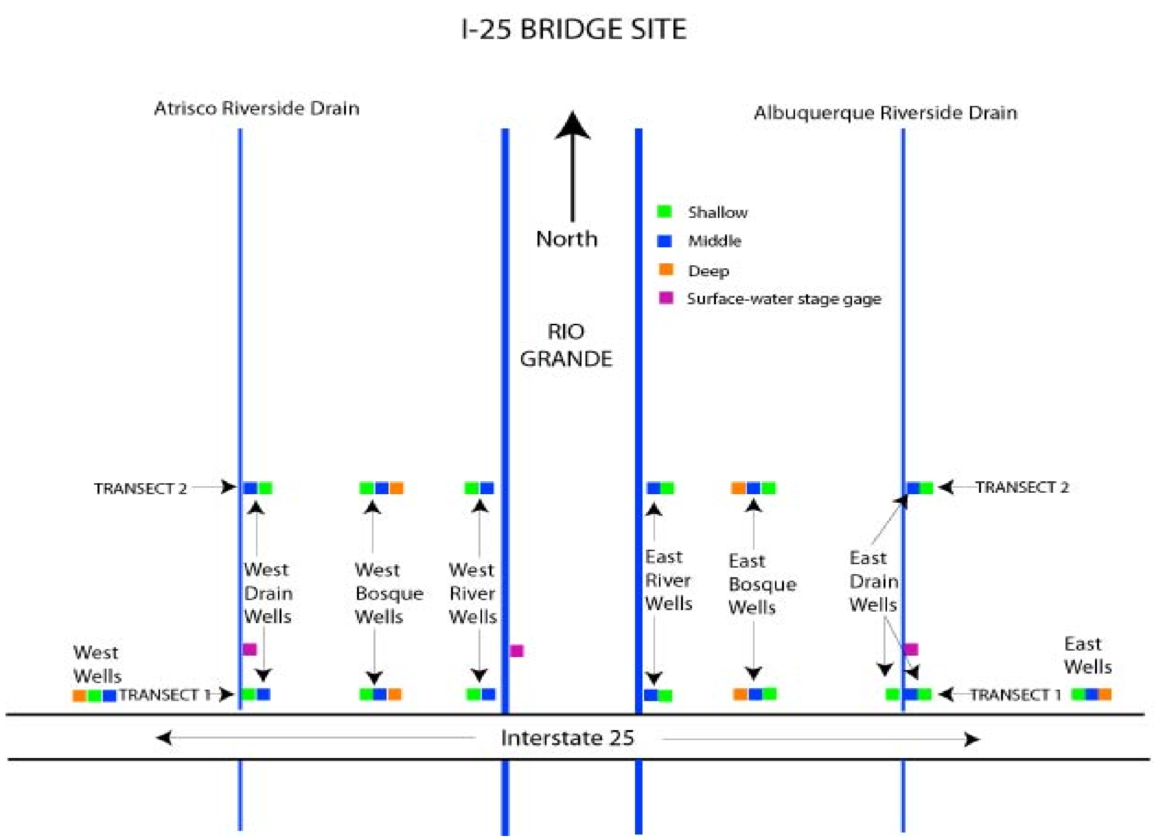


BARELAS BRIDGE SITE
Atrisco Riverside Drain
Albuquerque Riverside Drain
North
Barelas Bridge
RIO GRANDE
Shallow
Middle
Deep
Surface-water stage gage
West Wells
TRANSECT 1
TRANSECT 2
West Drain Wells
West Bosque Wells
West River Wells
East River Wells
East Bosque Wells
East Drain Wells



RIO BRAVO BRIDGE SITE
Atrisco Riverside Drain
Albuquerque Riverside Drain
North
RIO GRANDE
Shallow
Middle
Deep
Surface-water Stage Gage
TRANSECT 2
TRANSECT 1
West Drain Wells
West Bosque Wells
West River Wells
East River Wells
East Bosque Wells
East Drain Wells
RIO BRAVO BLVD.
West Wells
East Wells


PAJARITO SITE
Atrisco Riverside Drain
Albuquerque Riverside Drain
North
RIO GRANDE
Shallow
Middle
Deep
Surface-water Stage Gage
TRANSECT 1
TRANSECT 2
West Drain Wells
West Bosque Wells
West River Wells
East River Wells
East Bosque Wells
East Drain Wells
TRANSECT 1
TRANSECT 2


I-25 BRIDGE SITE
Atrisco Riverside Drain
Albuquerque Riverside Drain
North
RIO GRANDE
Shallow
Middle
Deep
Surface-water stage gage
TRANSECT 2
TRANSECT 2
West Drain Wells
West Bosque Wells
West River Wells
East River Wells
East Bosque Wells
East Drain Wells
West Wells
East Wells
TRANSECT 1
TRANSECT 1
Interstate 25

Most of the bosque piezometer nests consisted of 3 monitoring wells drilled to different depths: a deep well with a depth of 45-55 feet below land surface (bls), a mid-depth well with a depth of 30-40 feet and a shallow well with a depth of 15-25 feet. Most riverside nests and some drain nests consisted of 2 monitoring wells: a mid-depth and shallow-depth well. Individual wells were drilled at many other locations. At the piezometer nests, deep wells were drilled first and the water-table elevation in that well determined what the depths of the other wells would be. Each well contained 5 ft of screen placed 5 ft above the bottom of the well. In the shallow wells, screens were placed at a suitable depth to intercept groundwater under variable seasonal water levels. Piezometers were installed with a direct-push Geoprobe drill rig using 1-inch diameter, schedule 40 polyvinyl chloride (PVC) pipe. Each piezometer consists of a 5 ft section of blank casing below the screen and blank casing from the top of the screen to the land surface. Annular space above the screens in piezometers were filled with soil and bentonite pellets; these were then developed with compressed air. In-Situ Minitroll, Troll 300 and Troll 500 pressure transducers were installed in each piezometer and were programmed to record water level and water temperature. Since February 2009, over 240 piezometers in the network remained in service.

Surface-water-stage gages were constructed with 3-inch diameter PVC pipe along the banks of the Rio Grande and east/west riverside drains at each location (Figure 2). Most of these gages were built using a vertical pipe anchored several feet deep in the channel floor and supported with a horizontal pipe above the water’s surface. The lower portion of the vertical pipe was drilled out to allow unobstructed water entry and exit. Gages were instrumented with In-Situ pressure transducers programmed to record hourly water level and temperature. 27 gages remain in service since February 2009.

Piezometers and surface-water-stage gages were identified according to their location along the Rio Grande (A, Alameda; PDN, Paseo Del Norte; M, Montano; C, Central; B, Barelas; RB, Rio Bravo; P, Pajarito; and I25, Interstate-25), east or west side of the river (E, East; and W, West), placement along transect (R, River; B, Bosque; and D, Drain), the depth of the well (S, Shallow; M, Mid-depth; and D, Deep), and which transect it is part of (1, Transect 1; and 2, Transect 2). Examples include AEBS1 (Alameda East Bosque Shallow-Depth Transect 1) and PDNWDES2 (Paseo Del Norte West Drain East Shallow Transect 2). The first one is a shallow-depth well in the bosque on the east side of the river near Alameda Blvd. and it is in transect 1. The second one is a shallow-depth well on the east side of the riverside drain situated on the west side of the river near Paseo Del Norte Blvd. and it is in transect 2. Surface-water gages were similarly named other than placement along transect (RG, Rio Grande; and D, Drain), no coding for depth, and SW in the name for Surface Water. An example includes RBWDSW1 which is a surface-water gage along the west drain near Rio Bravo Blvd. at transect 1. The status of all piezometers and surface-water-stage gages is presented in Table A-1 of Appendix A.

Groundwater Levels Data Collection and Processing

All piezometers and surface-water-stage gages were instrumented with In-Situ pressure transducers. The transducers were programmed to record hourly measurements of water-level-below-land-surface and water temperature. The transducers consisted of a mix of vented Troll 500s and unvented MiniTrolls and Troll 300s which were hung in wells and surface-water gages by their communication cables. During site visits, transducer data was downloaded to a laptop computer, hand water-level measurements were taken, and general maintenance was carried out. After the data was downloaded, the instrument would be relaunched using the hand-measured water level taken during the visit as the reference water level. Sites were occasionally disrupted by vandalism, riverside drain dredging activities, and natural phenomena such as high stream flow, floating debris, eroding stream-side banks, and fires. While the typical site was visited two to four times during a span of one year, some sites required visits more often.

Following a site visit, the downloaded data was processed using various software including Excel and the USGS Automated Data Processing System (ADAPS). First, the data would be examined for erroneous values and when necessary, water-level data would be compensated for local barometric air pressure. While submerged under water, unvented transducers are physically disconnected from the air pressure above land surface and consequently, the water levels recorded are not necessarily accurate. After the data was converted to barometrically-corrected water levels, the final value of the data file was compared to the hand-measured reference water level taken during the site visit. When necessary, datum corrections were applied to the hourly water levels linearly to facilitate a higher level of accuracy. The final computed water levels were saved as water-levels-below land surface datum. During site installation, land surface elevations were established with an elevation level and GPS. For gradient calculations in this study, water-level-below land surface data was converted to water-level elevation, or hydraulic head, by subtracting the vertical distance between land surface and water table from the land surface datum at each site. Furthermore, because of the abundance of water-level data, all hourly unit values were converted to daily values for calculations in this study. Daily values are computed by averaging the hourly values of one full day and when more than two unit values in a day were missing, the daily value would be discarded.

Static Groundwater Elevations

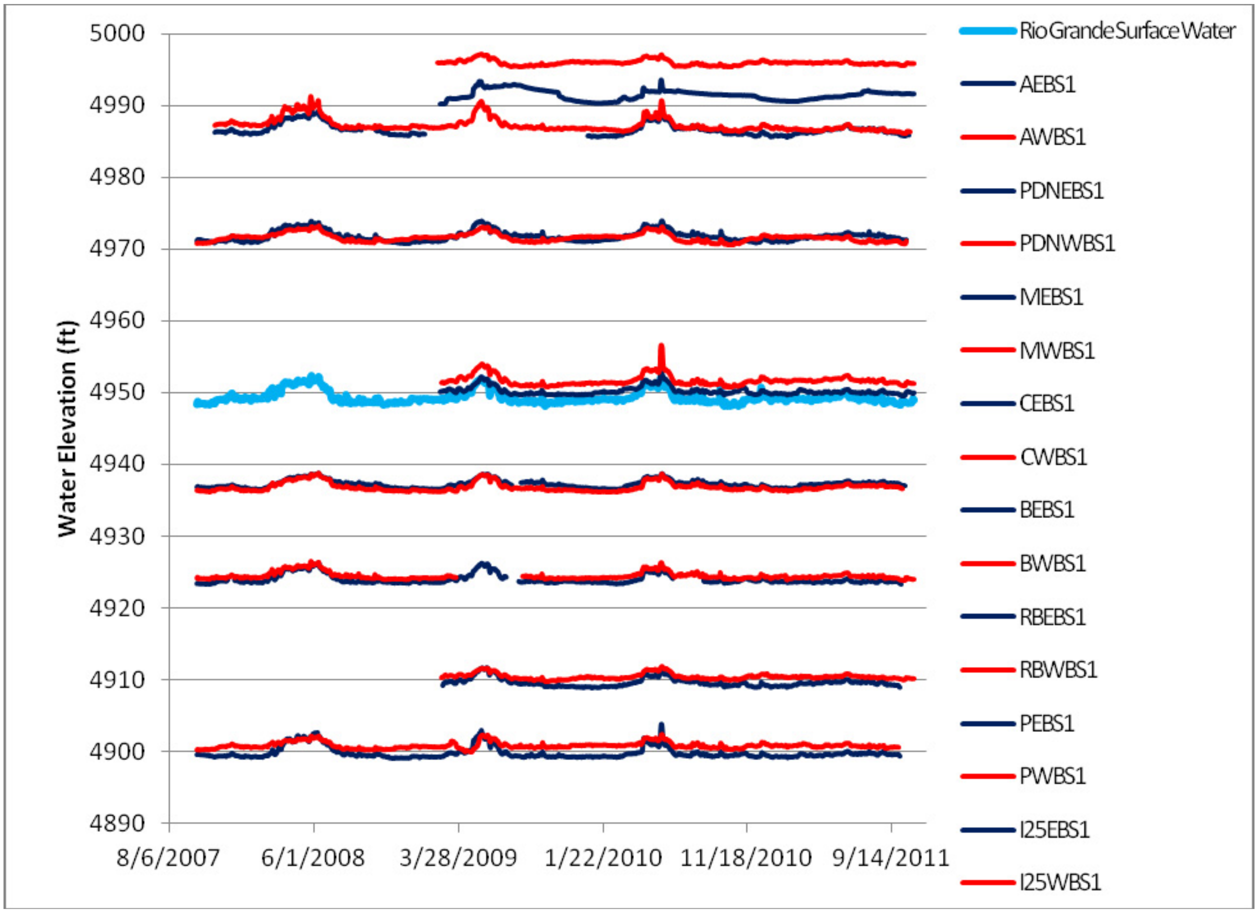
The U.S. Geological Survey maintains a surface-water stage gage on the Rio Grande at the Central Ave. Bridge and the data is available on their website in 15-minute intervals dating back to October 1, 2007. The gage-height data was retrieved for the interval 10/1/2007 to 10/31/2011, marking the end to the Bosque Project, and converted to surface-water elevation using the gage measuring point as the elevation datum. The chart in Figure 3 displays the surface-water elevation at this gage relative to static groundwater elevations in the transect 1 bosque piezometers at each location.

The chart demonstrates a strong correlation between Rio Grande water levels and groundwater levels near the river. The spring snow melt during three of the years in this period, 2008, 2009, and 2010, displayed an increase in river stage and after a short lag time, a rise in groundwater levels at every bosque piezometer. In 2011, the spring snow melt was effectively nonexistent due to drought and as a result, groundwater levels did not rise either.

The water-level data here demonstrate a profound association between Rio Grande surface water and the groundwater within the surrounding riparian zone. Only one set of piezometers, the bosque piezometers in transect 1, were chosen to present this condition. It is likely that every piezometer in the network would demonstrate similar characteristics with a dampened effect further from the river. Therefore, the riverside piezometers are likely to show the strongest and most immediate response to river stage with little dampening by the soil or distance from the river.

A thorough analysis of static groundwater levels is valuable and ought to be pursued in the future using Bosque Project data. A strong correlation between Rio Grande surface water and groundwater was shown here. However, gage-height data was only accessible going back to 2007 and since Bosque Project data dates back to 2003, river discharge data was used instead for correlations. Besides river stage, other contributing factors to changing groundwater levels near the river likely include climate conditions, localized soil stratigraphy, and farm irrigation. The primary focus of the present study is, however, the movement of groundwater near the Rio Grande (as opposed to static groundwater levels). Gradients, measured and discussed later in this report, are integrals of the static water levels. Gradients were measured in this study as the change in hydraulic head per unit distance between two sites.

Figure 3. Chart displays Rio Grande surface-water elevation at the Central Ave. Bridge relative to static groundwater elevations at the transect 1 bosque piezometers at each location; North to south transects are also highest to lowest in elevation.



Geometry of the Riverside Drains

As stated before, the riverside drains were constructed to intercept groundwater from the surrounding agricultural fields and convey the water to the river at a downstream location. Additionally, the drains can function by intercepting river leakage. Much of the groundwater flowing in the inner valley to the drains is leakage from the Rio Grande. When the process works correctly, groundwater moves slowly from the river outward toward the riverside drains and the unlined beds of the drains are permeable to the groundwater which percolates into the channel and flows downstream where it is returned to the river. At some locations, the distance between the river and the drain is small and the interaction between drain and aquifer is adequate. At some locations, however, the distance between the river and the drain is large and/or the invert elevation of the drain is not situated vertically low enough to intercept groundwater flow. When the water table drops below the drain floor elevation, the drains will likely lose water to the aquifer. Seepage investigations were conducted by the USGS on February 26, 2009 to quantify the gain or loss of surface water in both riverside drains (Rankin and others, 2012). The study determined that the westside drain gained water for several miles downstream of the Alameda Bridge; however, from just north of the Montano Bridge downstream about two miles to the discharge point of the drain, there was a decrease in surface-water flow. Isaacson (2009) acknowledges a separation between the drain-floor elevation and aquifer surface elevation at this location which could account for at least part of this water loss. The USGS investigation also concluded that the east-side drain, between the Paseo Del Norte Bridge and the Montano Bridge, was a gaining reach due to recharge from the underlying aquifer. It was not specified if the water gained originated as river leakage or agricultural irrigation.

Measurements of groundwater levels adjacent to the drains and of the geometry of both drains at every location will identify where separations occur and help to locate reaches of gain or loss in the channel. Geometries were measured at every surface-water gage along the east and west side drains. The measuring point on each gage had established elevations which were used to measure the elevation of the channel bed below (Table 1). An assessment of water table elevations adjacent to the channel relative to drain-floor elevations indicated when and where separations were occurring. Table A-2 in Appendix A provides more measurements that were taken in the bosque, some using ArcGIS, to obtain an improved understanding of the drain geometry. These measurements include horizontal distances between the river and drains, vertical distances between the hydraulic head in the riverside piezometers and the drain floor, and vertical distances between the drain floor and the hydraulic head in adjacent drain piezometers. Connectivity measured between drain floors and groundwater elevation in adjacent piezometers was analyzed by location, period of record (POR), season, and year.

Table 1. Riverside drain measurements taken at each surface-water-stage gage: the deepest surface-water measurement was used to determine drain floor elevation at that location.

Site Name	Gage MP elevation (in feet above NAVD 88)	Drain floor elevation (in feet above NAVD 88)	Distance between gage MP and water surface (in feet)	Width of riverside drain at water surface (in feet)	Depth at left bank	Depth at 1/2 left	Depth at middle (in feet)	Depth at 1/2 right	Depth at right bank
AEDSW1	4992.718	4985.58	4.80	28.6	0.20	1.28	2.34	1.76	0.50
AWDSW1	5001.262	4996.16	3.80	19.2	0.20	1.30	1.25	0.90	0.10
AWDSW2	4998.174	4992.96	4.01	18.9	0.10	1.05	1.20	0.90	0.10
PDNEDSW1	4984.21	4976.41	5.30	31.0	0.15	1.64	2.50	2.19	0.50
PDNWDSW1	4989.62	4984.36	4.61	16.5	0.08	0.45	0.65	0.30	0.11
MEDSW1	4972.61	4965.84	3.77	44.5	0.10	2.35	3.00	2.85	0.70
MWDSW1	4979.11	4973.29	3.02	26.5	0.90	1.70	2.80	2.10	1.05
CEDSW1	4951.723	4945.50	4.92	22.0	0.10	1.30	1.15	1.00	0.10
CWDSW1	4956.983	4951.69	3.39	18.5	0.20	1.90	1.60	1.40	0.10
BEDSW1	4942.04	4937.74	1.60	33.0	0.30	1.70	2.45	2.70	0.50
BWDSW1	4935.89	4929.72	4.77	17.0	0.20	1.40	0.50	0.75	0.10
RBEDSW1	4925.22	4920.33	3.75	29.0	0.30	1.00	1.14	1.12	0.10
RBEDSW2	4926.52	4920.95	3.62	20.1	0.20	1.40	1.50	1.95	0.55
RBWDSW1	4927.49	4920.66	5.73	23.5	0.20	0.85	1.10	1.05	0.10
RBWDSW2	4928.69	4920.54	6.20	24.0	0.20	1.95	0.80	0.85	0.20
PEDSW1	4909.473	4903.28	3.89	30.0	0.30	2.30	2.10	2.00	0.60
PWDSW1	4909.48	4904.94	3.34	19.5	0.20	1.20	0.95	0.70	0.10
I25EDSW1	4903.63	4896.92	4.71	31.0	0.10	2.00	1.95	1.85	0.20
I25WDSW1	4902.04	4896.89	4.00	32.5	0.05	0.95	1.15	0.95	0.20

Vertical-Hydraulic Gradients

Vertical-hydraulic gradients were computed at piezometer nests with water-table elevation data and with known vertical distance between the depths of two adjacent piezometers. The vertical-hydraulic gradient is calculated as:

$$^{dh}/_{dl} = (h_2 - h_1) / (z_2 - z_1)$$

or the change in hydraulic head per unit vertical distance, where piezometer 1 is the shallowest at the piezometer nest. Calculations were carried out for every piezometer nest in the network and included analysis of all shallow to mid-depth and mid to deep-depth piezometers. A positive vertical gradient indicates an upward gradient and a negative value indicates a downward gradient. For example, at the Pajarito location, on the west side of the river at the riverside piezometer nest in transect 1, the water-table elevation value for March 2, 2009 in the shallow-depth piezometer is 4912.73; and in the mid-depth peizometer, the daily value is 4912.75. The difference between these two hydraulic heads is 0.02 ft and the vertical distance between piezometer depths is 15 ft. Dividing 15 ft into 0.02 ft gives a vertical gradient value of 0.00133 which indicates upward flow. Computed gradient values were evaluated by period of record, year, and season for each piezometer nest.

Horizontal-Hydraulic Gradients

Horizontal gradients were calculated using potentiometric surface data from riverside well to inside -drain well, adjacent to the drain on the side closest to the river, along each transect. Data from shallow-depth piezometers were used for these computations. At all 16 transects, gradients were measured between the riverside and bosque wells and between the bosque and inside-drain wells. Where available, gradients were also measured between the inside and outside drain wells. At times when riverside drain bed elevations lay below water-table elevations in adjacent piezometers, horizontal gradients calculated between inside and outside piezometers were used with some confidence in determining the east or west direction of groundwater flow beneath the drain. Along reaches where there is downward flow from a drain, the shape of groundwater mounding below the drain might distort local flow to the point that use of the inside and outside water-table elevations provides less confidence in the direction and magnitude of the gradient.

The equation used here states that horizontal-hydraulic gradient is:

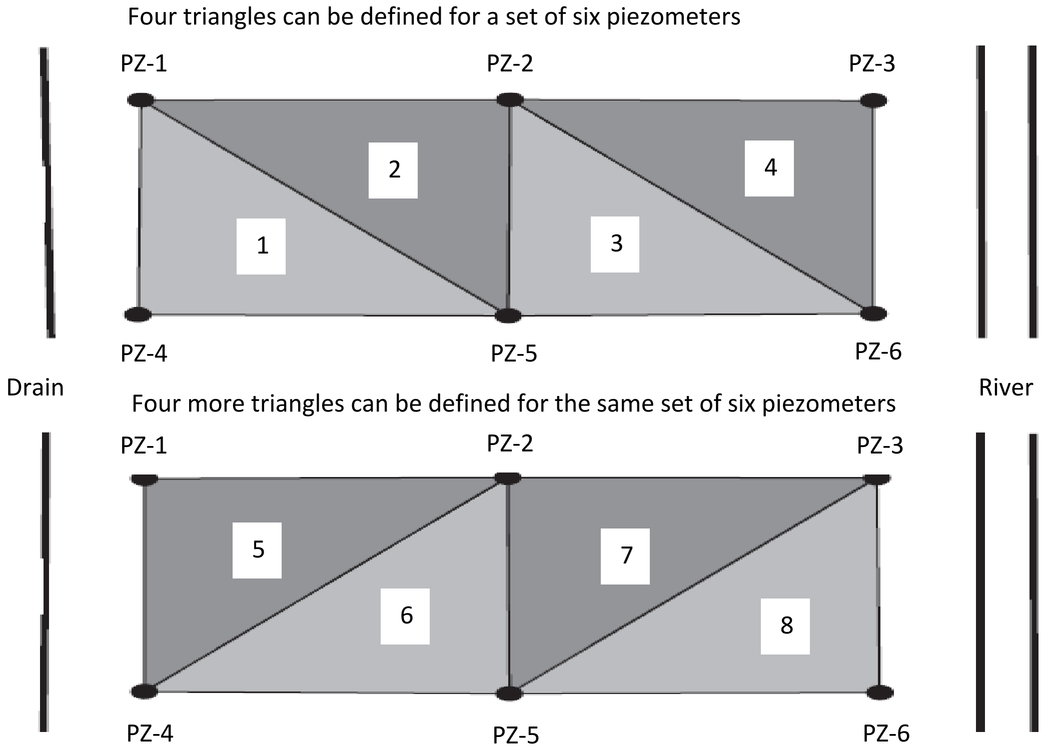
$$^{dh}/_{dl} = (h_2 - h_1) / L$$

or change in head per unit horizontal distance, where piezometer 1 is furthest from the river and L is the horizontal distance, measured with ArcGIS, between the piezometers. Positive horizontal-hydraulic-gradient values indicate a gradient away from the river. This method cannot be used to determine the regional direction of flow, only the component of flow near each transect. In addition, there are fluctuations in horizontal and vertical gradients from year to year and through the seasons so values here were averaged for the period of record of each site with no further analysis on the basis of season or time. Due to the lack of detail in these computations, the values were only used as a reference for more advanced calculations.

Complex calculations were carried out in Excel to determine magnitudes and directions of horizontal-hydraulic gradients. Again, all data used here was acquired from shallow-depth piezometers. The procedure works by triangulating the area in question with a piezometer at each point. Since there are two transects at each location, separated by about 500 ft, and each transect consists of a riverside, bosque and drain-side piezometer, a total of eight triangles were used at each location (Figure 4). The motive for using this method to calculate horizontal gradients was that gradient directions would be computed. Direction of groundwater flow in relation to other influential factors (geology, municipal groundwater pumping, etc.) is an important indicator of hydraulic changes and this method could be used to trace the flow of contaminants through groundwater.

Horizontal gradients were calculated in Excel first by establishing Cartesian coordinates for each site and then using multiple functions within a matrix. An inverse matrix is computed with the MINVERSE function and the slopes are calculated using the MMULT function and the groundwater elevation data points. Finally, gradient magnitudes and directions are determined through a series of trigonometric functions. For example, three sites located on Alameda's east side are AERS1, AEBS1, and AERS2 and their locations can be connected on a map view with straight lines forming a triangle. Each of these three sites comprise an x, y, and z coordinate (z = -1); therefore, a 3x3 matrix is created. Next, the MINVERSE function calculates the inverse of this function and displays a new 3x3 matrix beside the first one. The MMULT function calculates the matrix product of the two matrices and when all three data points are present (water elevation data for all three sites are available), the slopes of the x, y, and z planes are computed. The gradient magnitude is then calculated from the slopes using the simple trigonometric formula for the length of one side of a triangle: gradient = square root ($x\ slope^2 + y\ slope^2$) and the direction (relative to 0^o north) is calculated from a simple arctangent (ATAN in Excel) function. The given daily magnitude at this Alameda location on 3/5/2009 was 0.02865 and the direction was 128.27^o. Since the Rio Grande does not flow exactly north to south, the river bank orientation was established in ArcGIS and the calculated horizontal-gradient direction was calculated as an angle relative to the river bank. The river bank orientation had a bearing of about 36^o so the gradient direction was about 92^o relative to the river bank (on the upstream side) on 3/5/2009. To calculate angles relative to the downstream side, this angle is simply subtracted from 180^o to get 88^o counter-clockwise from the east bank.

Figure 4. Layout of triangles at each transect which are used for horizontal gradient calculations; PZ is piezometer (borrowed from Rankin and others 2012).



Requirements of this process include, 1) known geographic positions of the wells, 2) known distances between the wells, and 3) water-level data from each well. Values were computed for magnitude and direction using this method. Line segments were created and analyzed in ArcGIS at every river-bank piezometer location to determine the orientation of the east and west-side river banks between the two riveside piezometers of the transect. Horizontal-gradient-direction values at each location were calculated using eight associated triangles, and were given in degrees relative to 0° north and later converted to degrees relative to the river bank orientation on the downstream side at that location. Gradient magnitudes for the eight triangles were calculated as daily values and then were averaged over the location's period-of-record to obtain the stated value for each location. Horizontal gradient magnitude and direction values were analyzed by location, site, period of record, season, and year.

The triangulation of sites used in these calculations is similar to Triangular Irregular Networks (TIN) which are used in GIS to establish surface morphology. According to Azagra (1999), TINs are useful for representing surface elevation and terrain modeling especially when the represented surfaces are highly variable and contain discontinuities. If triangulation of sites were based on static groundwater elevations in the present study then TINs would be comparable in methodology and the use of both techniques would be conducted for validation purposes. However, the present study involves the integrals of static groundwater elevations or the movement of groundwater. As stated before, a future study using Bosque Project static groundwater levels would be meaningful and the use of TINs in ArcGIS would be an excellent way of displaying the data.

Rio Grande Discharge

Hourly Rio Grande surface-water discharge data was downloaded from the USGS website to help determine the river's impact on groundwater gradients. Spring runoff typically brings high amounts of snowmelt to the Rio Grande and these high flows were assessed for their influence on groundwater flows in the bosque. Increased monsoon-driven discharges in the late summer, decreased discharges during early summer and winter conditions, and significant climactic events such as El Nino-Southern Oscillation will impact river stage and flows. Daily surface-water discharge data from the Rio Grande at Albuquerque (Central Ave. bridge crossing) site was used for correlations with groundwater flow because the site existed throughout the entire Bosque Project study period, it has consistently provided reliable data, and it is located approximately equidistant from the north and south extents of the study area. Discharge data was combined with vertical and horizontal gradient data in charts and analyzed by season and year for the duration of the Bosque Project, 2003 to 2011.

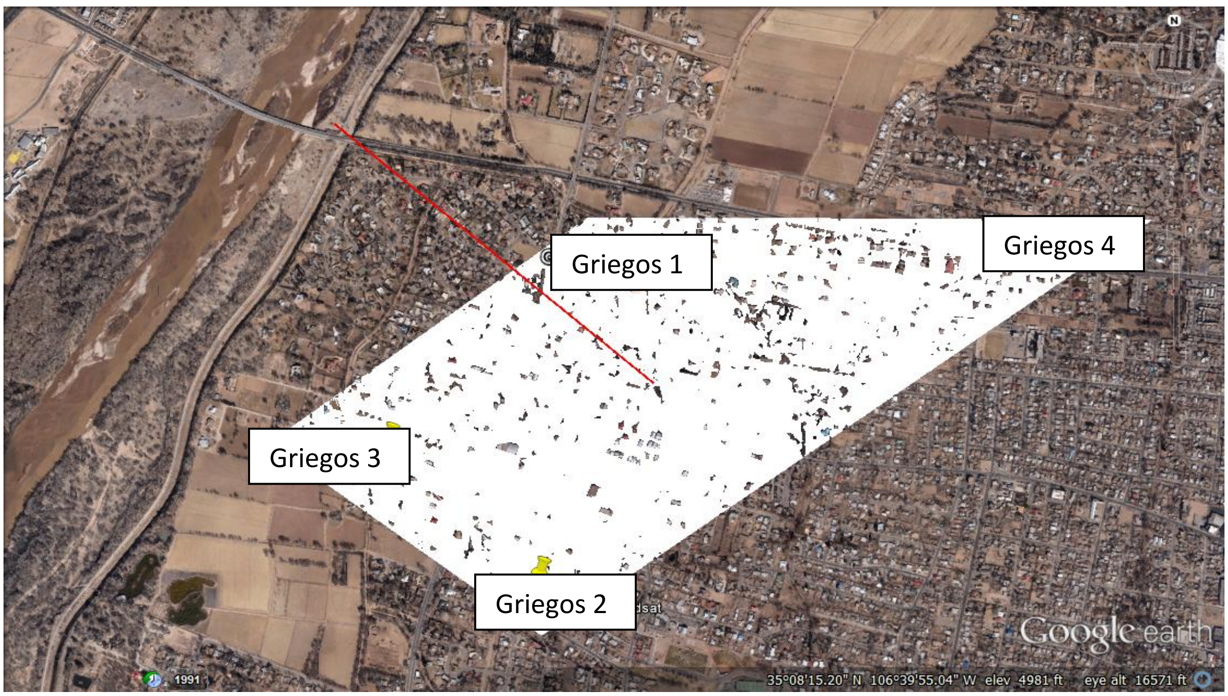
Municipal Groundwater Pumping

Prior to surface-water diversion through the San Juan-Chama Drinking Water Project in 2008, Albuquerque relied completely on groundwater pumping for its municipal drinking water supply. Since the city began diverting surface water from the Rio Grande just south of the Alameda Bridge, the amount of surface water in the river between the Alameda Bridge and the Rio Bravo Bridge has decreased slightly. The pupose of the project was to use surface water to reduce the community's dependence on groundwater. Municipal production wells, controlled by the Albuquerque Bernalillo County Water Utility Authority (ABCWUA), are still used during drought conditions and some of these wells may be located close enough to the river to have an effect on groundwater flow in the bosque. Production well locations and pumping schedules were accessed from ABCWUA and the data was observed for their impact on groundwater in the bosque. Exact locations of the production wells are not disclosed here due to national security concerns therefore images in Figure 5(a-c) have been partially masked. These figures contain a red line that extends from the approximate center of the well field to the closest Bosque Project piezometer located in the bosque. These red lines represent horizontal distance, in feet, which is listed in Table 2 and the bosque piezometers were chosen as measurement endpoints because they lie approximately halfway between the riverside and drainside piezometers. Table 2 also contains depth and screened interval specifications for each production well.

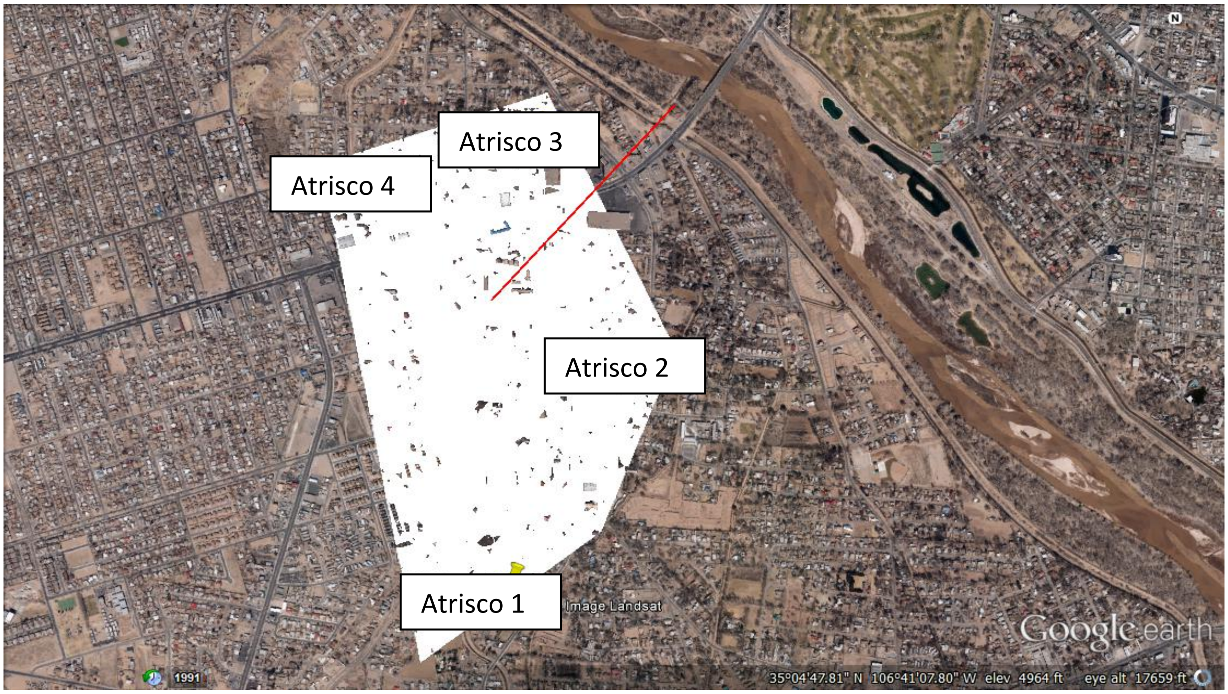
The pumping rates for three production well fields, Griegos, Atrisco, and San Jose, were used to determine if correlations exist with vertical and horizontal gradient magnitudes calculated at the three nearest Bosque Project locations, Montano, Central, and Barelas respectively. The three well fields are located less than a mile from the nearest Bosque Project location. There are many other production wells in Albuquerque but they are located further from Bosque Project sites and therefore, likely do not have much effect on gradients at those locations. Production well pumping data was available in total gallons pumped per month; therefore, analysis was carried out on a monthly scale for the period of record at each of the three locations. There are also numerous relatively shallow private wells in the inner valley that are likely to affect shallow groundwater levels. These were not considered in this study. The effects of seasonal operation of irrigation ditches by the Middle Rio Grande Conservancy District (MRGCD) on shallow groundwater levels was also not considered.

Figure 5(a-c). Images showing approximate locations of production well fields and lines used to measure distance between well fields and nearest Bosque Project piezometers.

Griegos Well Field and Montano transect 1 east-side piezometers:



Atrisco Well Field and Central transect 2 west-side piezometers:



San Jose Well Field and Barelas transect 2 east-side piezometers:

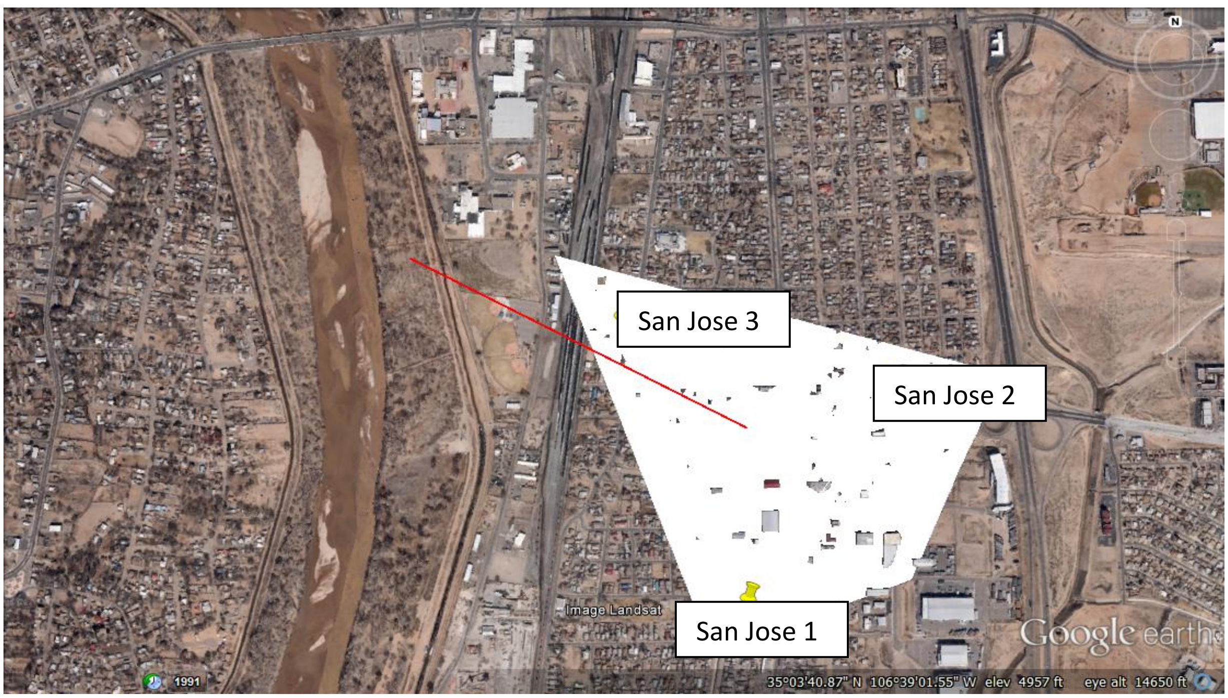


Table 2. Depth specifications of specific wells located in well field; and distances between well fields and nearest Bosque Project piezometers.

Production	Total	Screened	Distance between production well

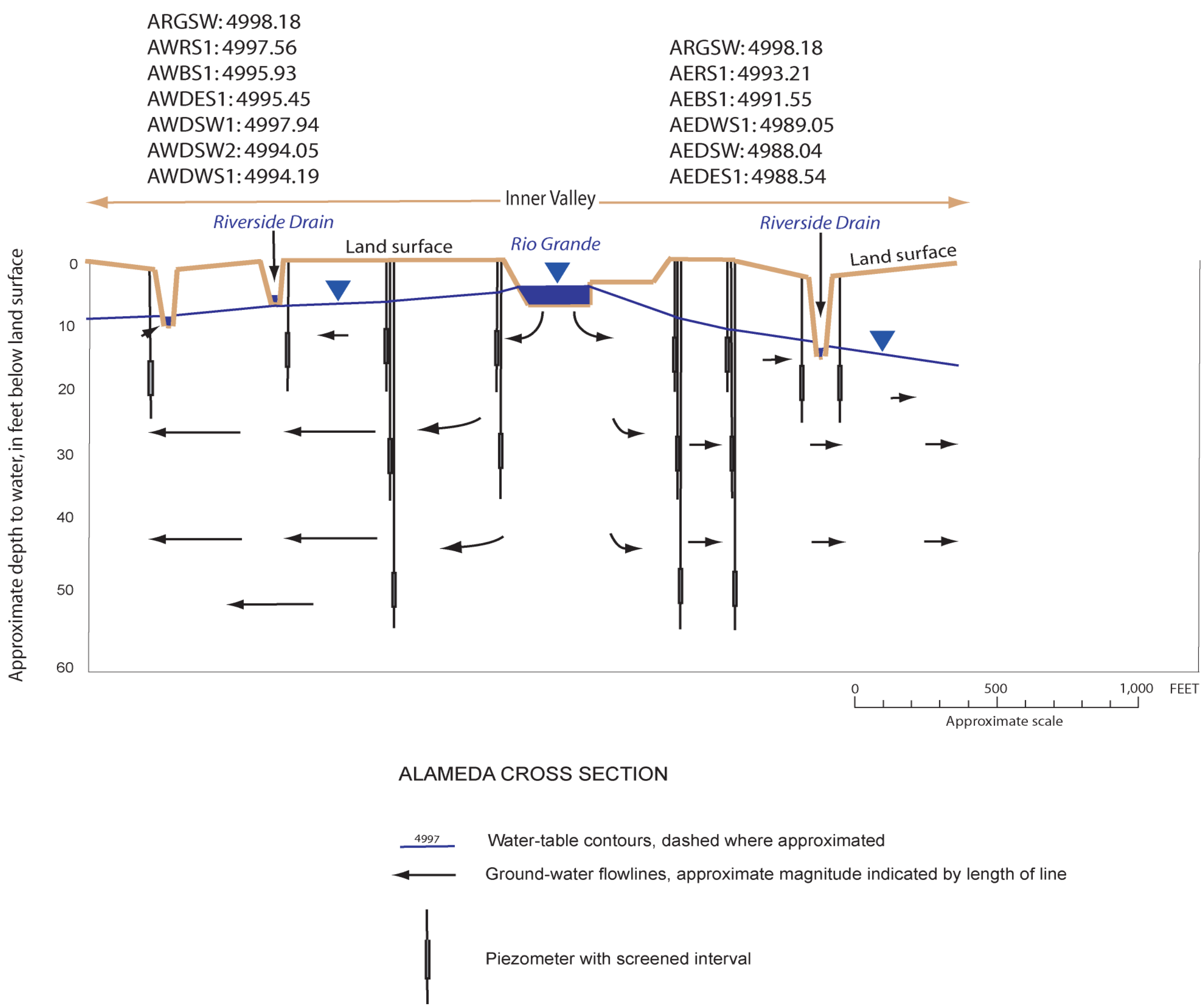
well	depth (ft)	interval (ft)	field and nearest Bosque Project wells (ft)
Griegos 1	802	232-802	4613
Griegos 2	820	164-820	
Griegos 3	916	260-916	
Griegos 4	804	218-804	
Atrisco 1	1295	280-1283	3332
Atrisco 2	544	108-250	
Atrisco 3	804	180-804	
Atrisco 4	500	98-475	
San Jose 1	600	----	3493
San Jose 2	996	264-996	
San Jose 3	1032	192-1032	

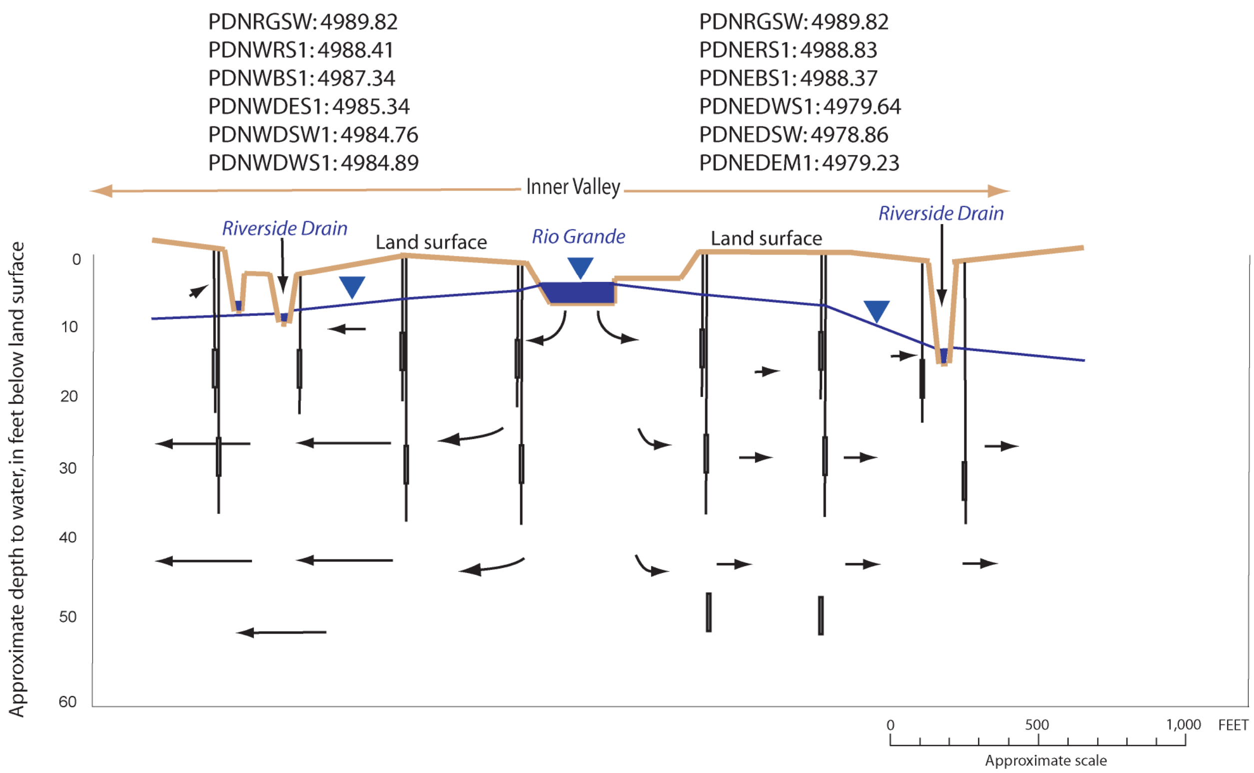
RESULTS AND DISCUSSION

Riverside Drains

In the Albuquerque area, there is a varying extent of connection between the riverside drains and the underlying aquifer. In some areas, the water table adjacent to the drain is several feet higher than the invert elevation of the drain and at these locations and times there is a strong connection between the river and the drain. Groundwater from the aquifer, under this situation, percolates through the floor and sides of the drain so that much of the water in the drain is from the river. In other areas, the water table adjacent to the drain is several feet lower than the drain's invert elevation. Under this circumstance, groundwater in the bosque has little to no effect on the surface water of the riverside drain. When no recharge takes place, the drain loses water to the aquifer which causes groundwater mounding under the channel instead of returning water to the river. Seepage investigations for the Bosque Project demonstrate this activity. This results in a zone of unsaturated soil between the drain and aquifer which diminishes infiltration from the drain because the unsaturated hydraulic conductivity is less than for saturated conditions. See Table 3 for period-of-record extents of connection at every location and Tables B-1 and B-2 in Appendix B for a complete table of these values partitioned by season and year respectively. Illustrations in Figure 6 provide a picture of the inner valley cross sections at each location. These are not drawn perfectly to scale; however, they do provide a reasonable representation of the groundwater elevation especially on both sides of the drains. Charts in Figure 7 demonstrate the continuous extents of connection between the drain floor elevations and the adjacent piezometer groundwater elevations.

Figure 6(a-h). Illustrations of inner valley cross sections at every location; groundwater and surface-water elevations are based on mean values; water surfaces are not drawn precisely to scale (modified from Rankin and others).



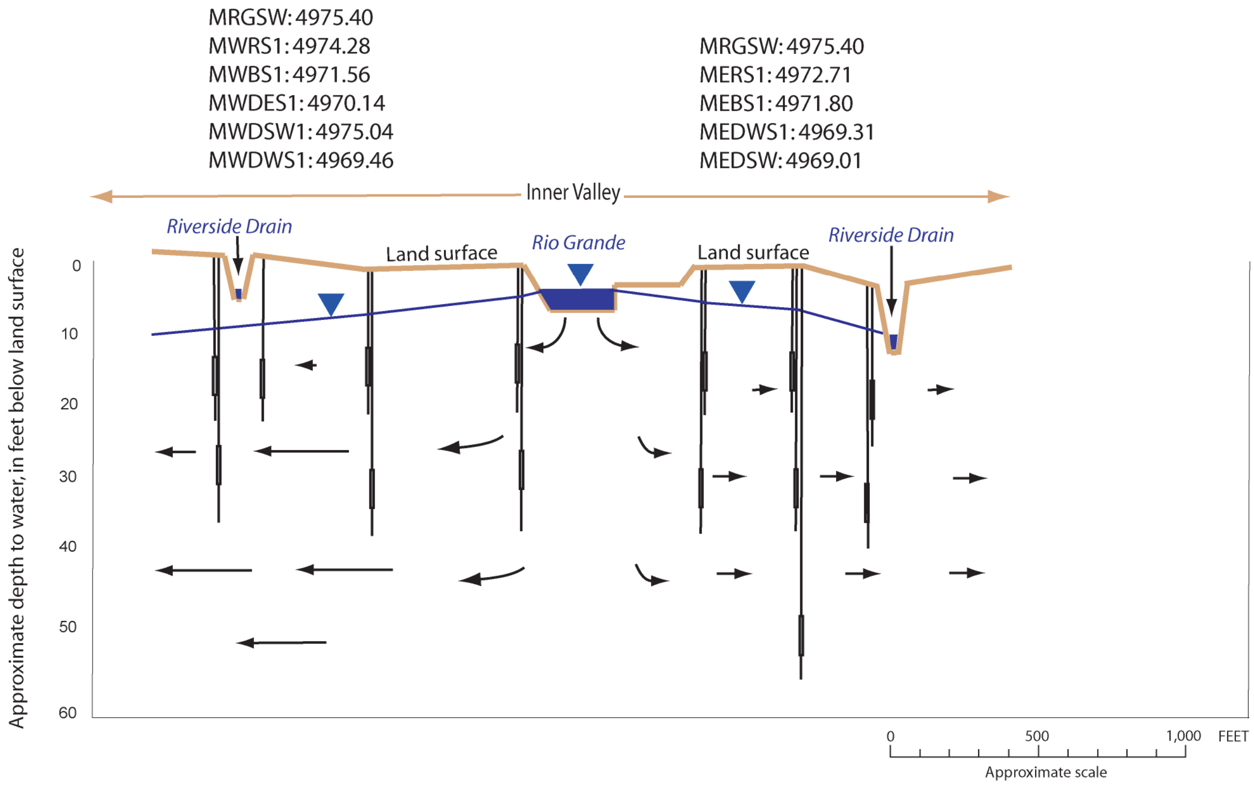


PASEO DEL NORTE CROSS SECTION

Water-table contours, dashed where approximated

Ground-water flowlines, approximate magnitude indicated by length of line

Piezometer with screened interval

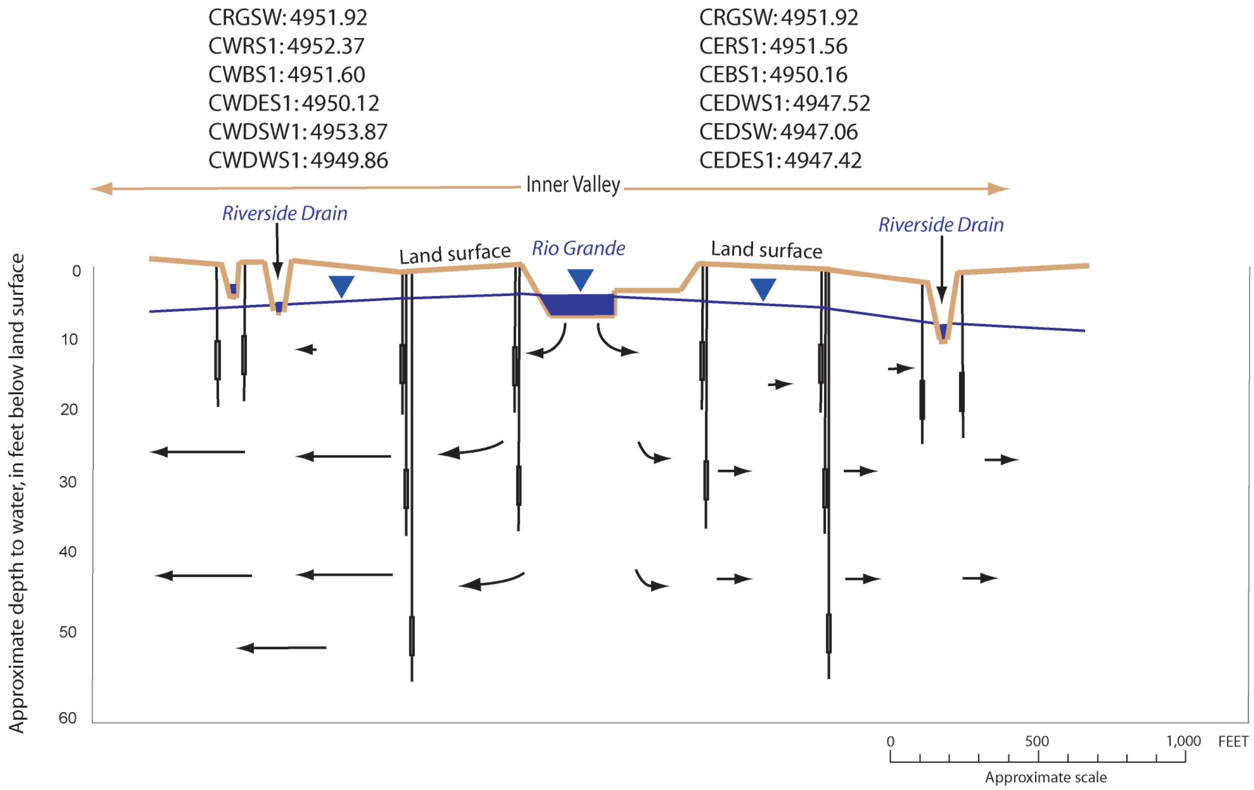


MONTANO CROSS SECTION

Water-table contours, dashed where approximated

Ground-water flowlines, approximate magnitude indicated by length of line

Piezometer with screened interval

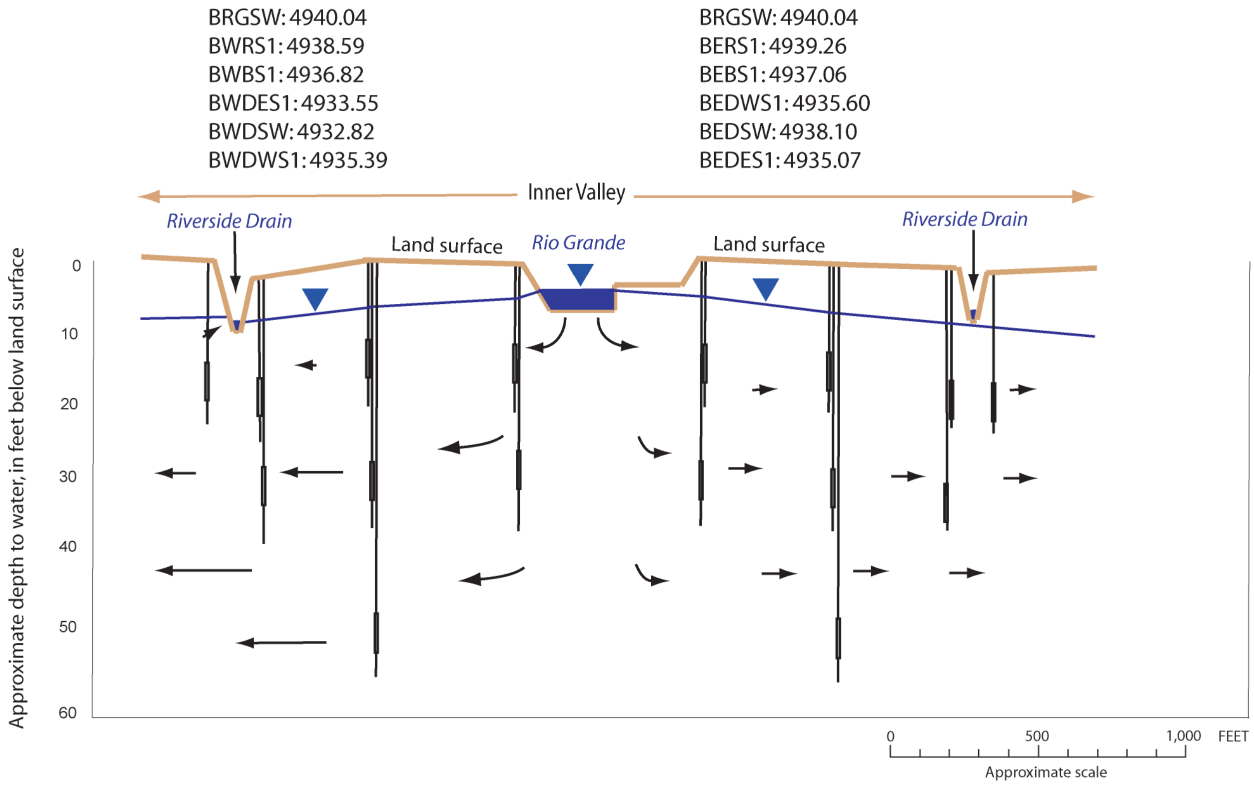


CENTRAL CROSS SECTION

Water-table contours, dashed where approximated

Ground-water flowlines, approximate magnitude indicated by length of line

Piezometer with screened interval

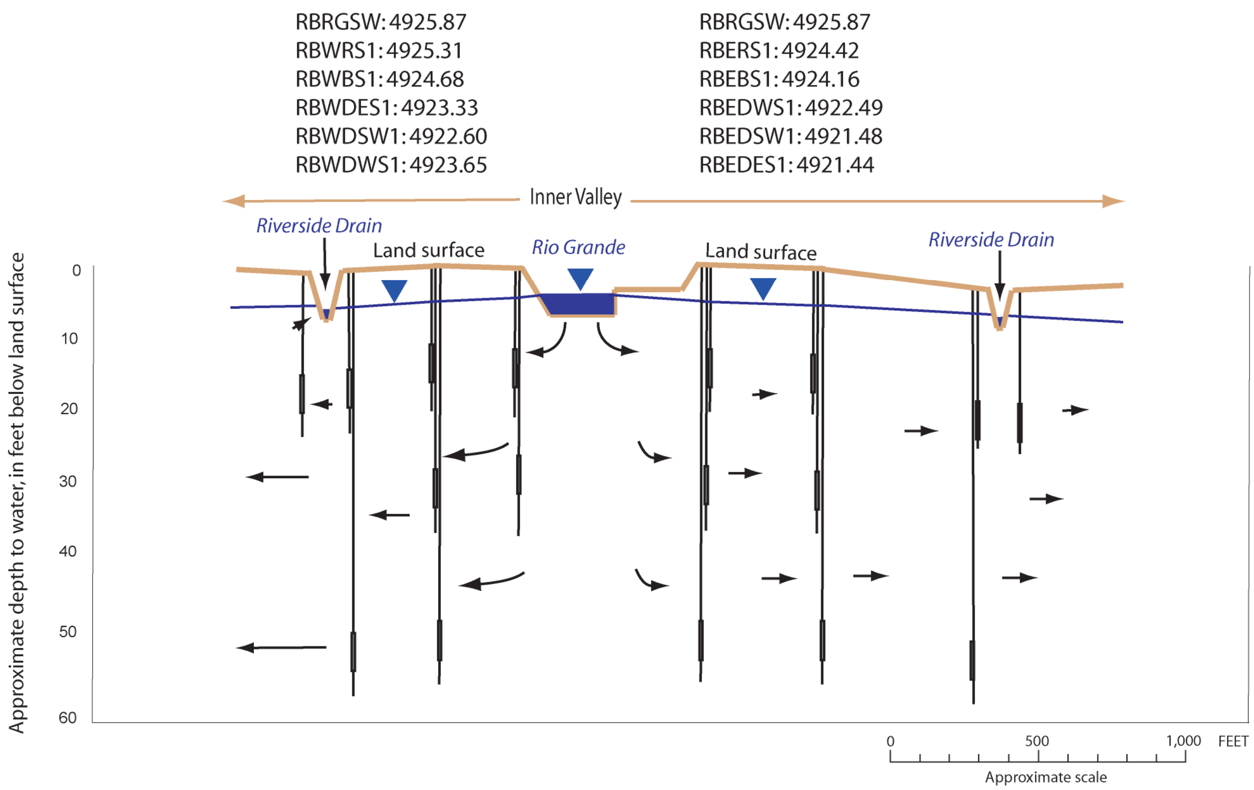


BARELAS CROSS SECTION

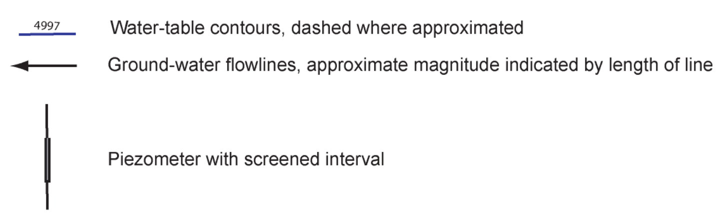
4997 Water-table contours, dashed where approximated

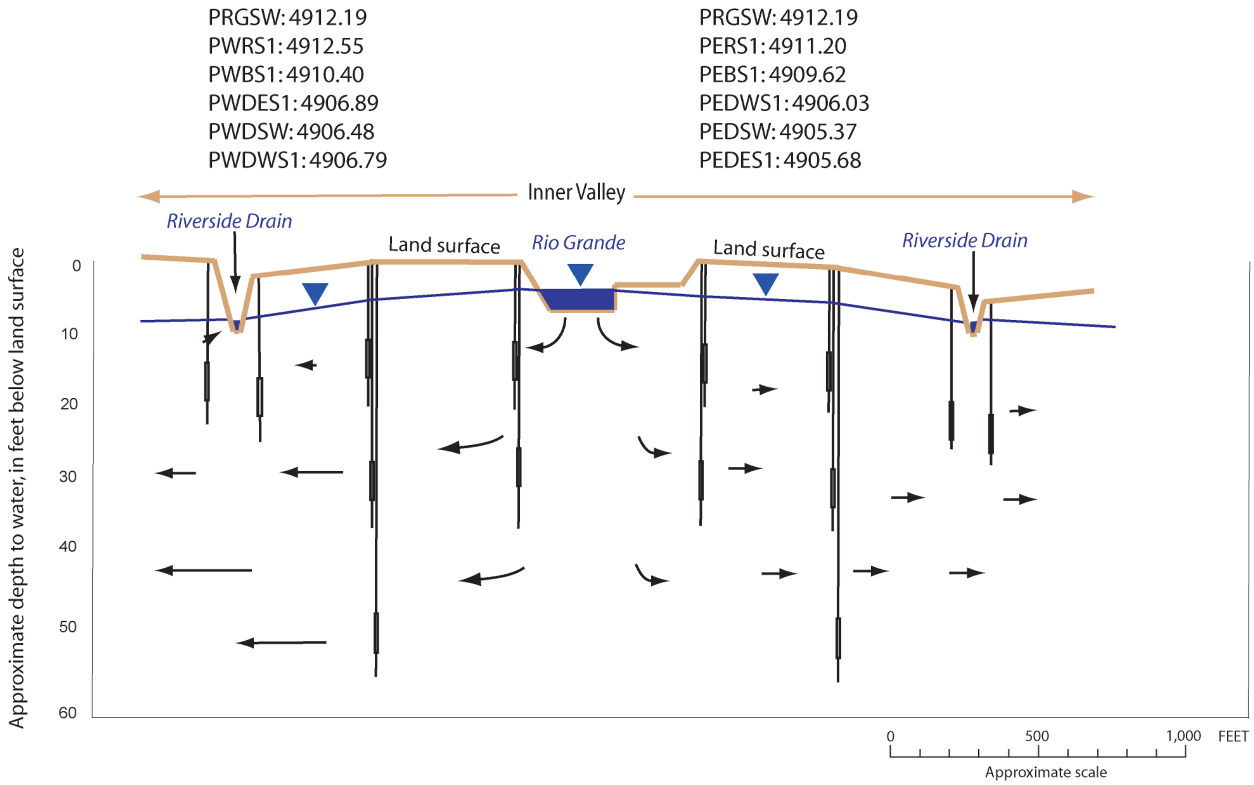
Ground-water flowlines, approximate magnitude indicated by length of line

Piezometer with screened interval



RIO BRAVO CROSS SECTION



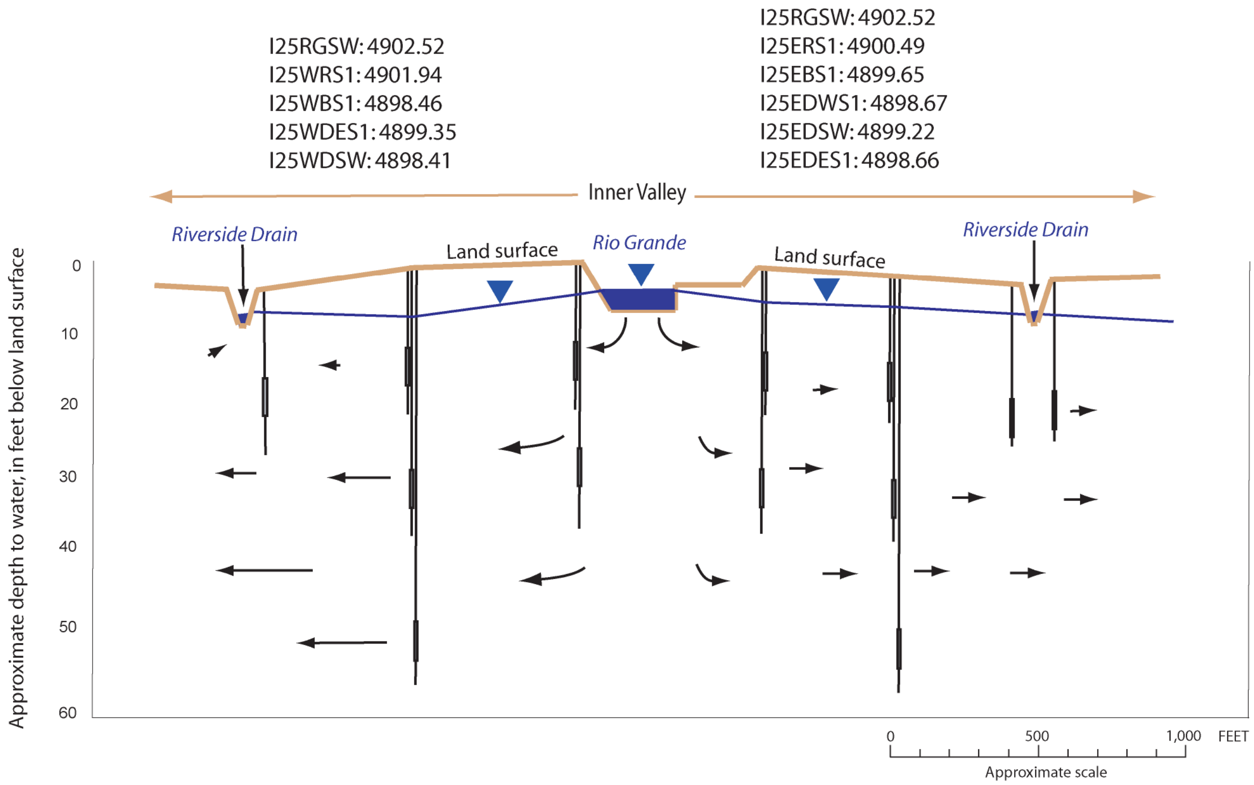


PAJARITO CROSS SECTION

4997 Water-table contours, dashed where approximated

Ground-water flowlines, approximate magnitude indicated by length of line

Piezometer with screened interval



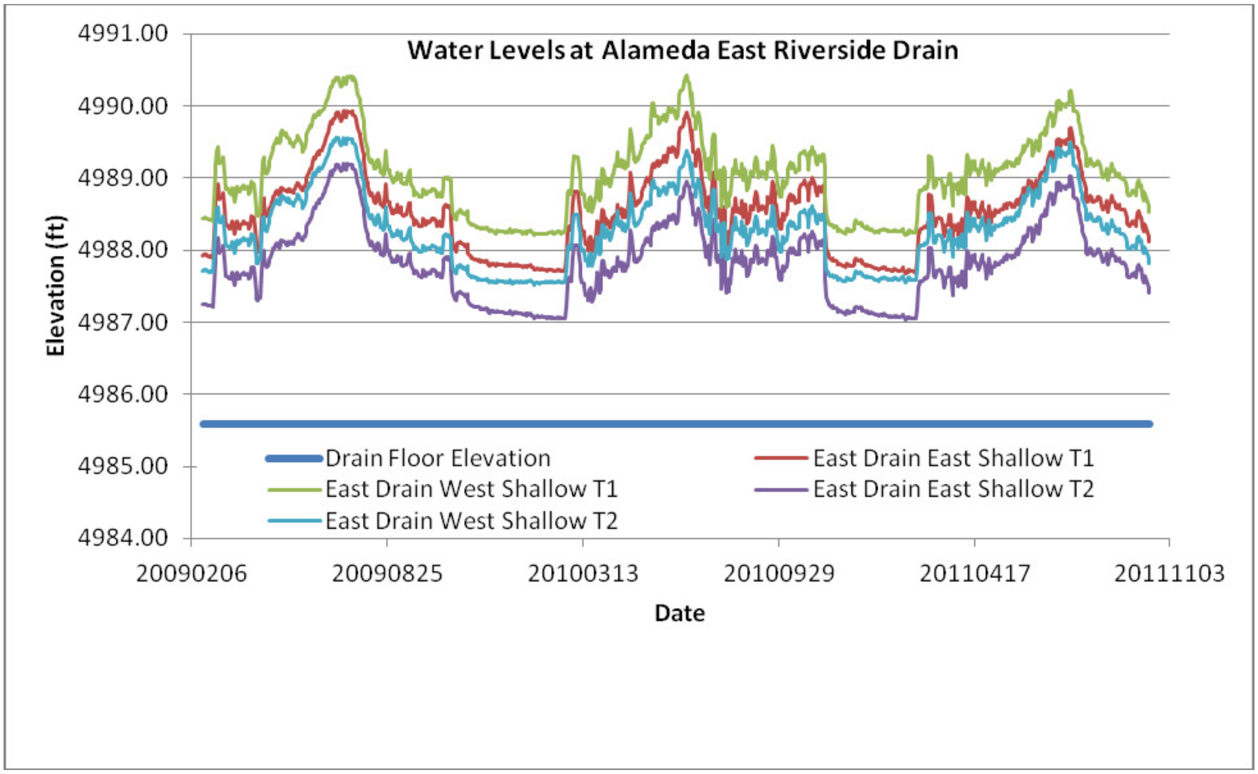
INTERSTATE 25 CROSS SECTION

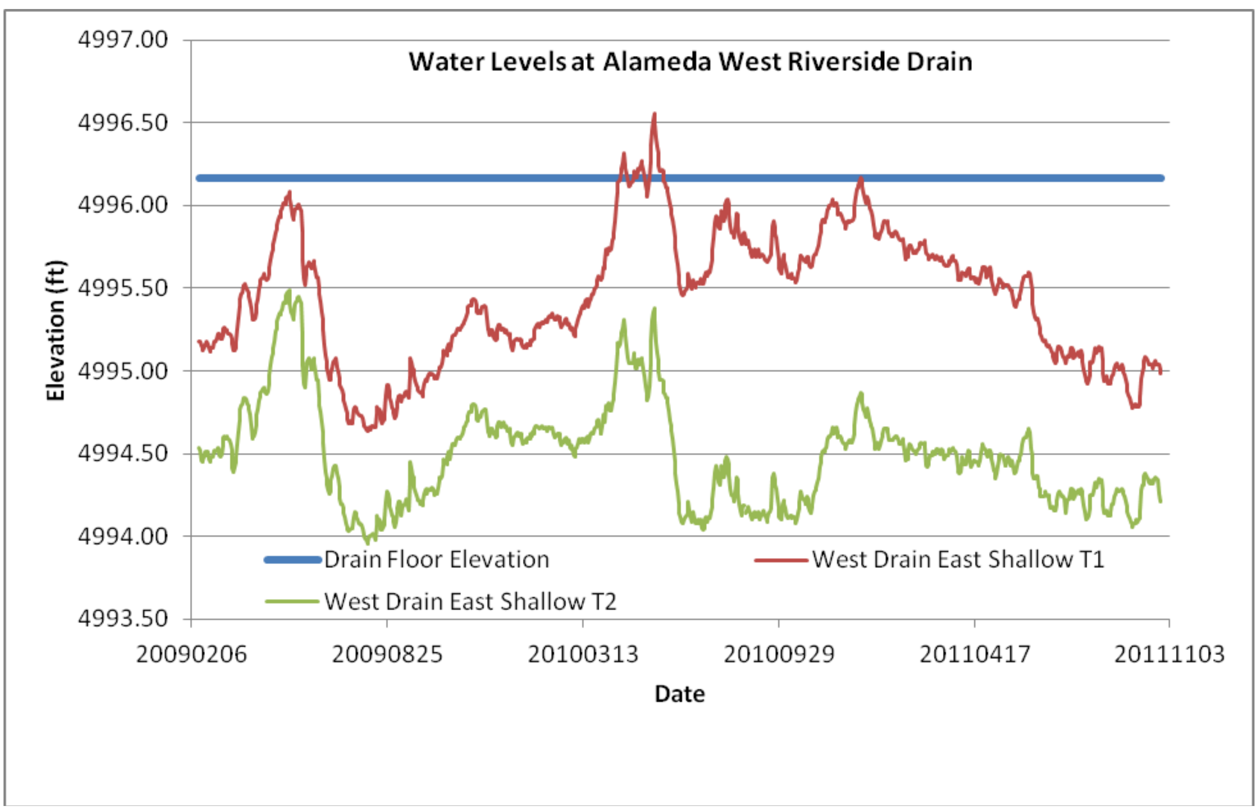
4997 — Water-table contours, dashed where approximated

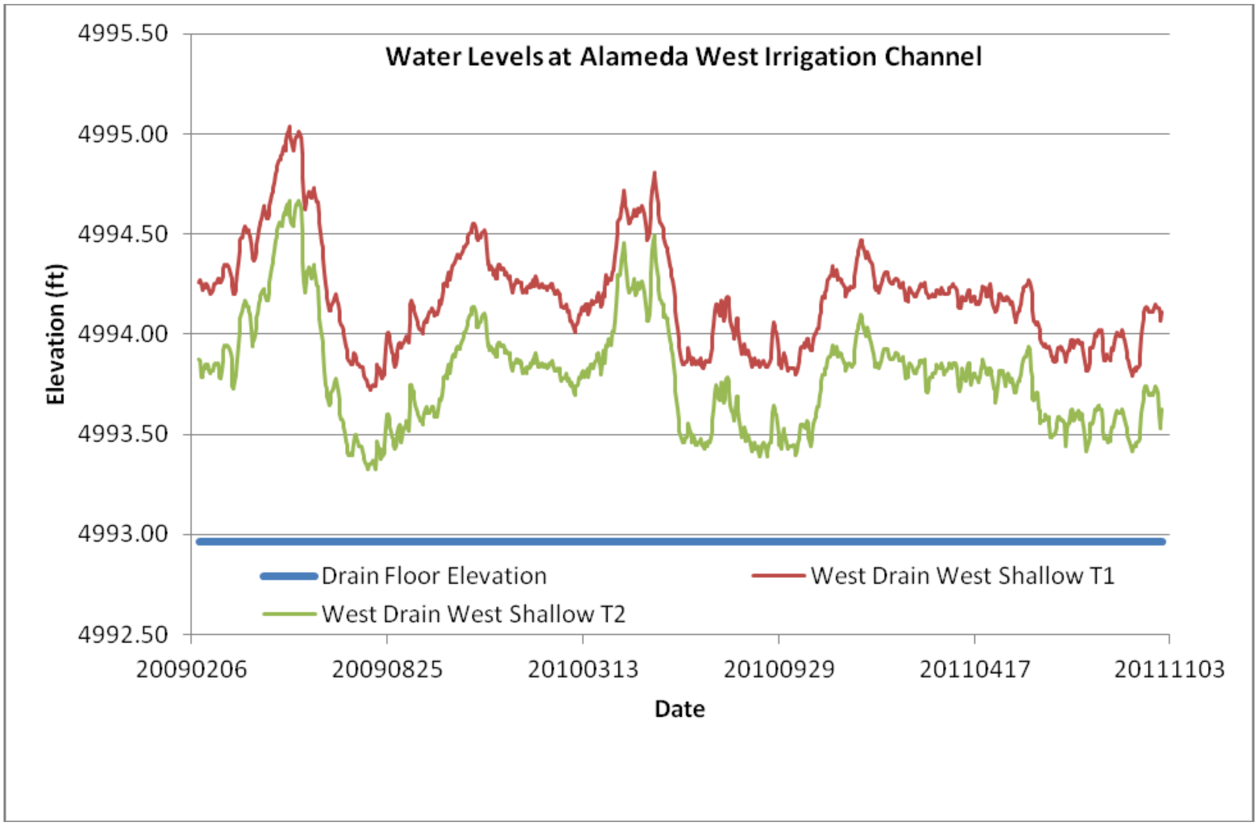
Ground-water flowlines, approximate magnitude indicated by length of line

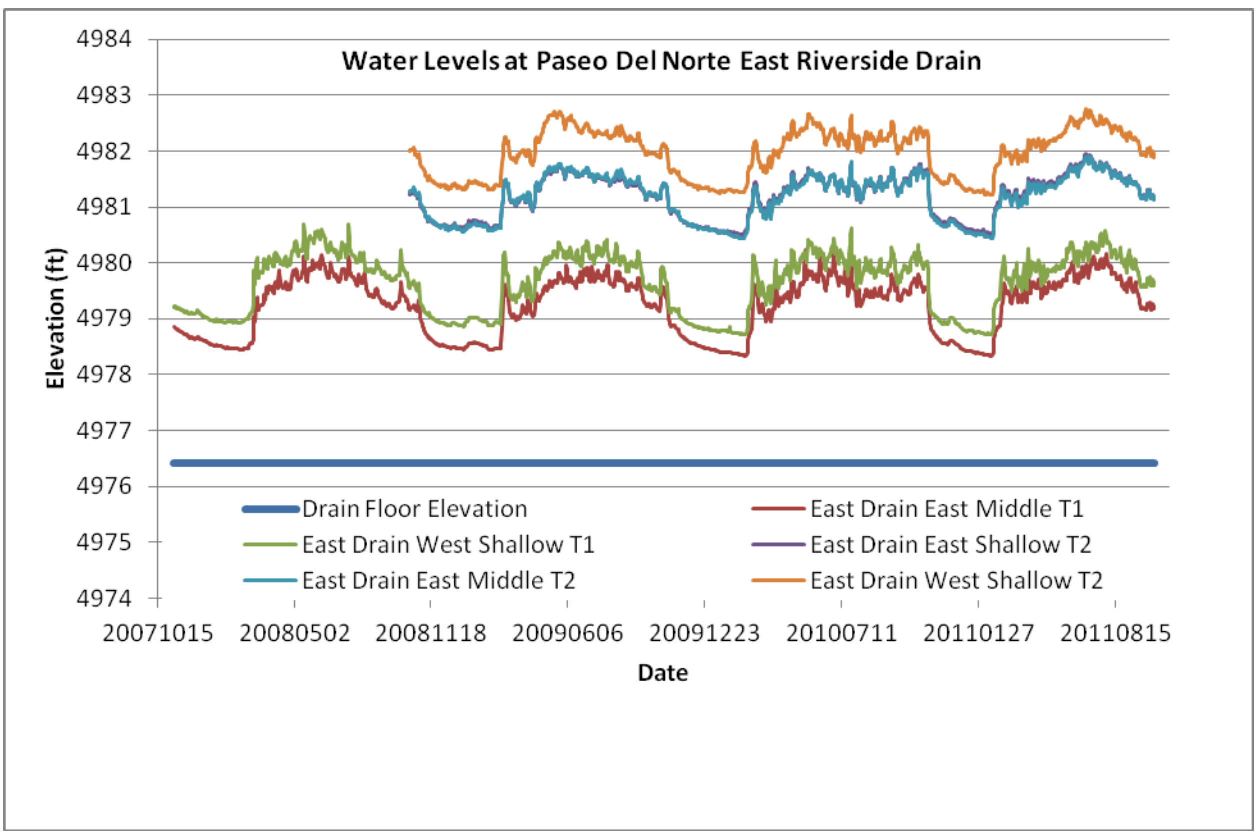
Piezometer with screened interval

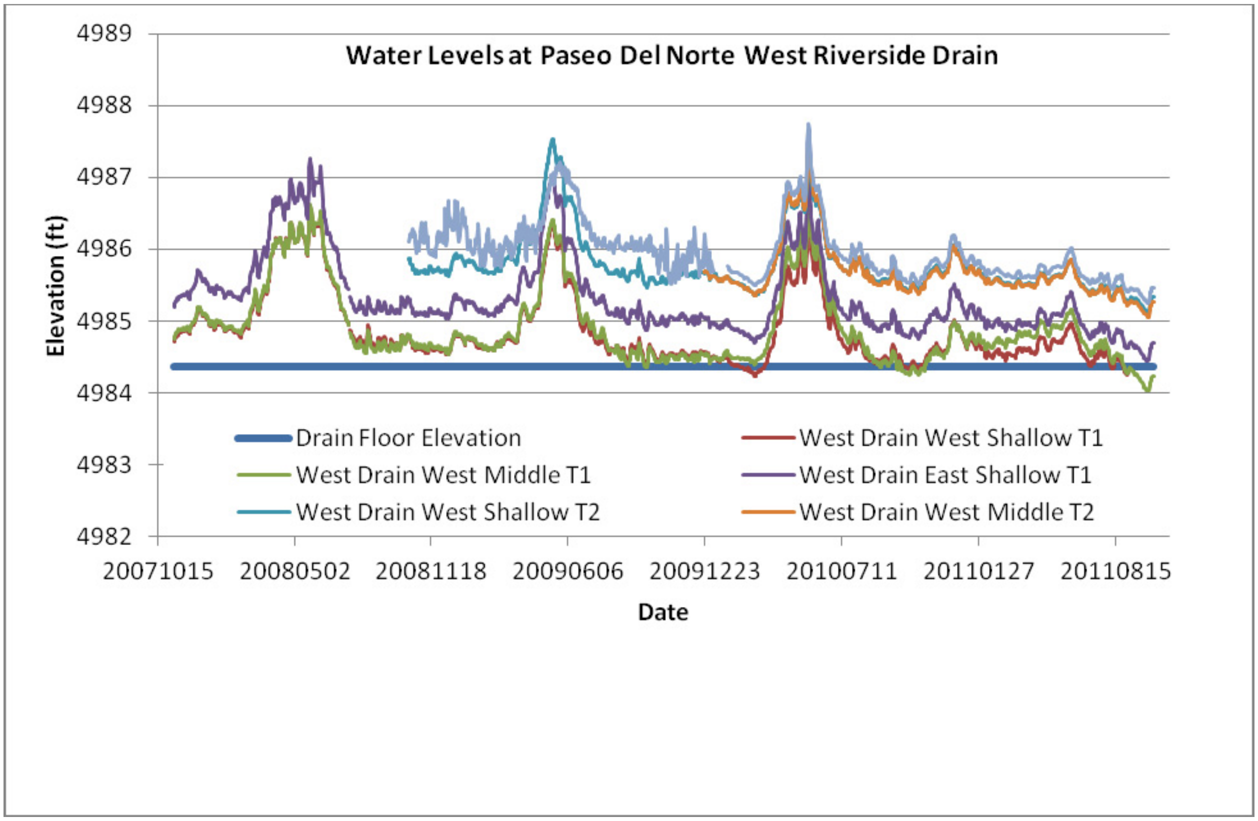
Figure 7(a-s). Charts demonstrate extents of connection or separation between riverside drain floor elevation and adjacent piezometer daily groundwater elevations.

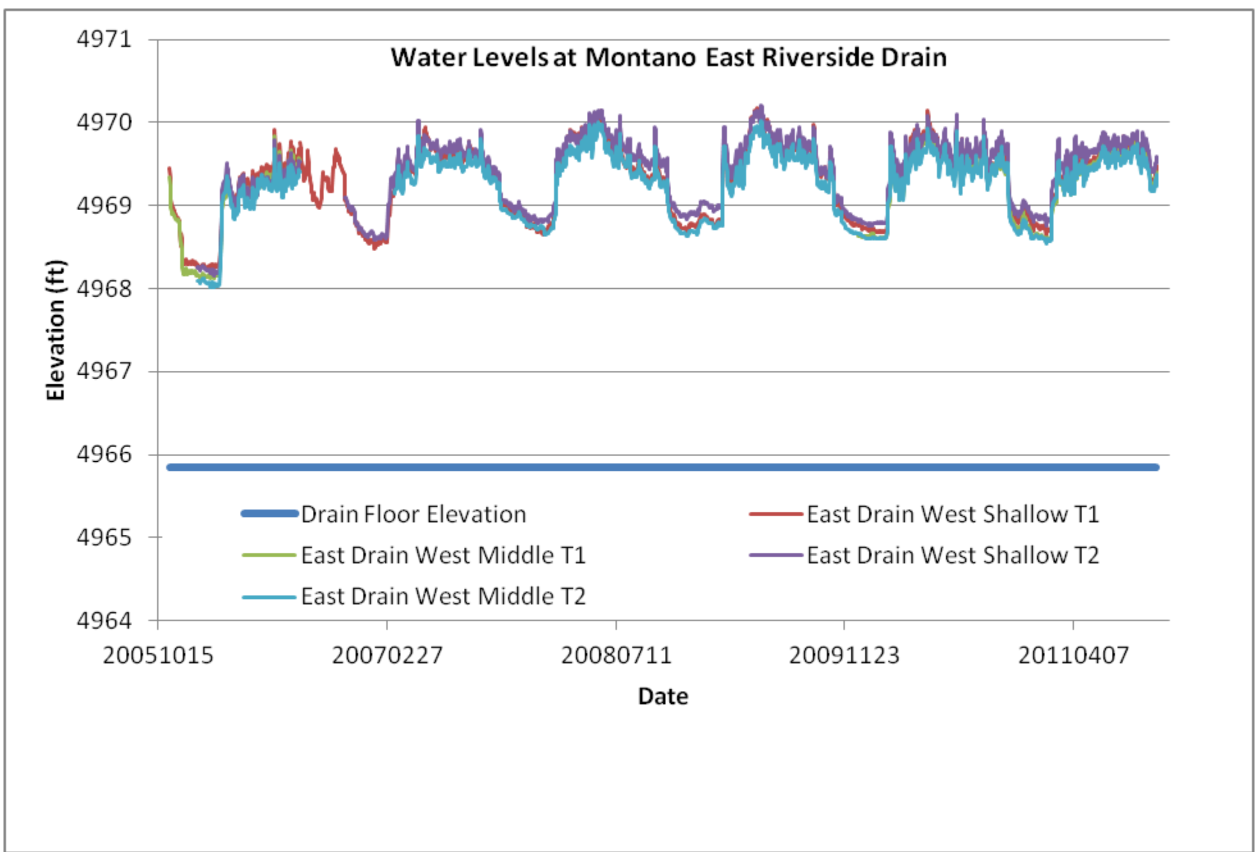


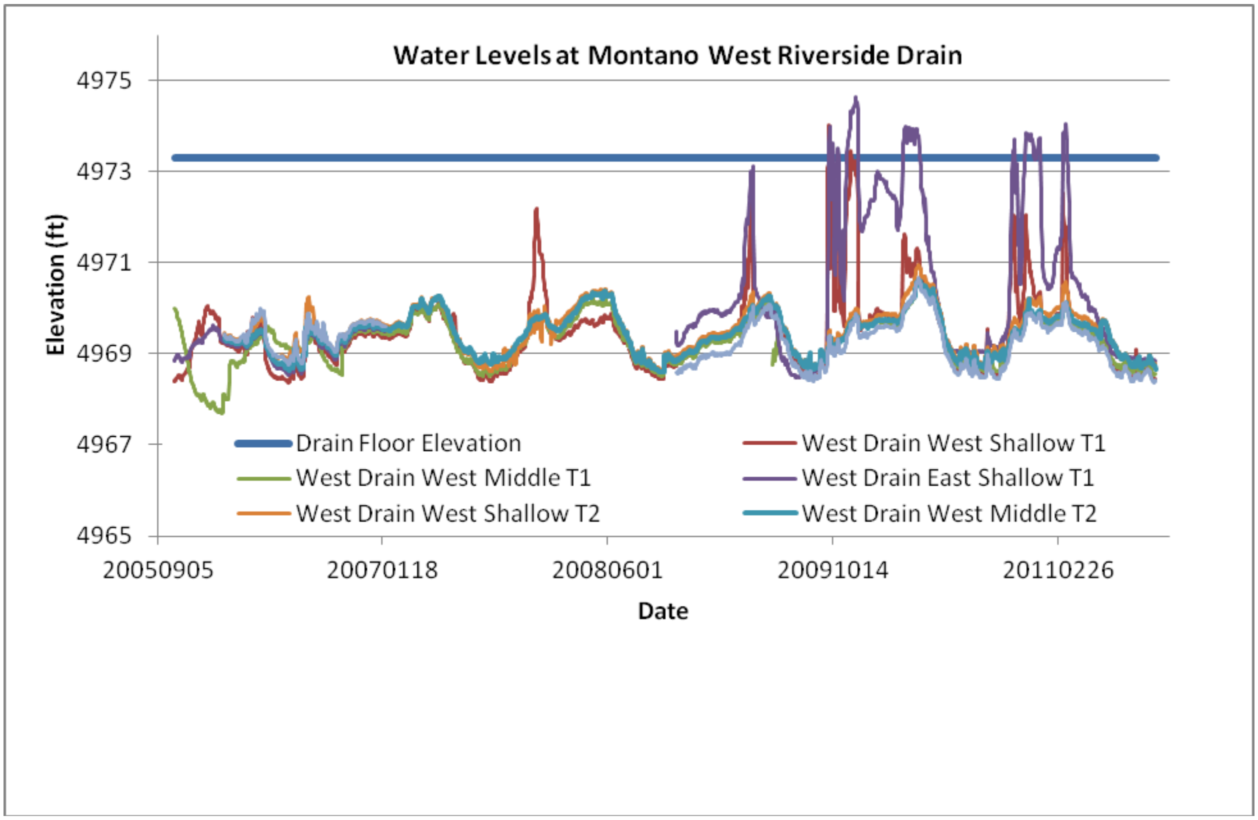


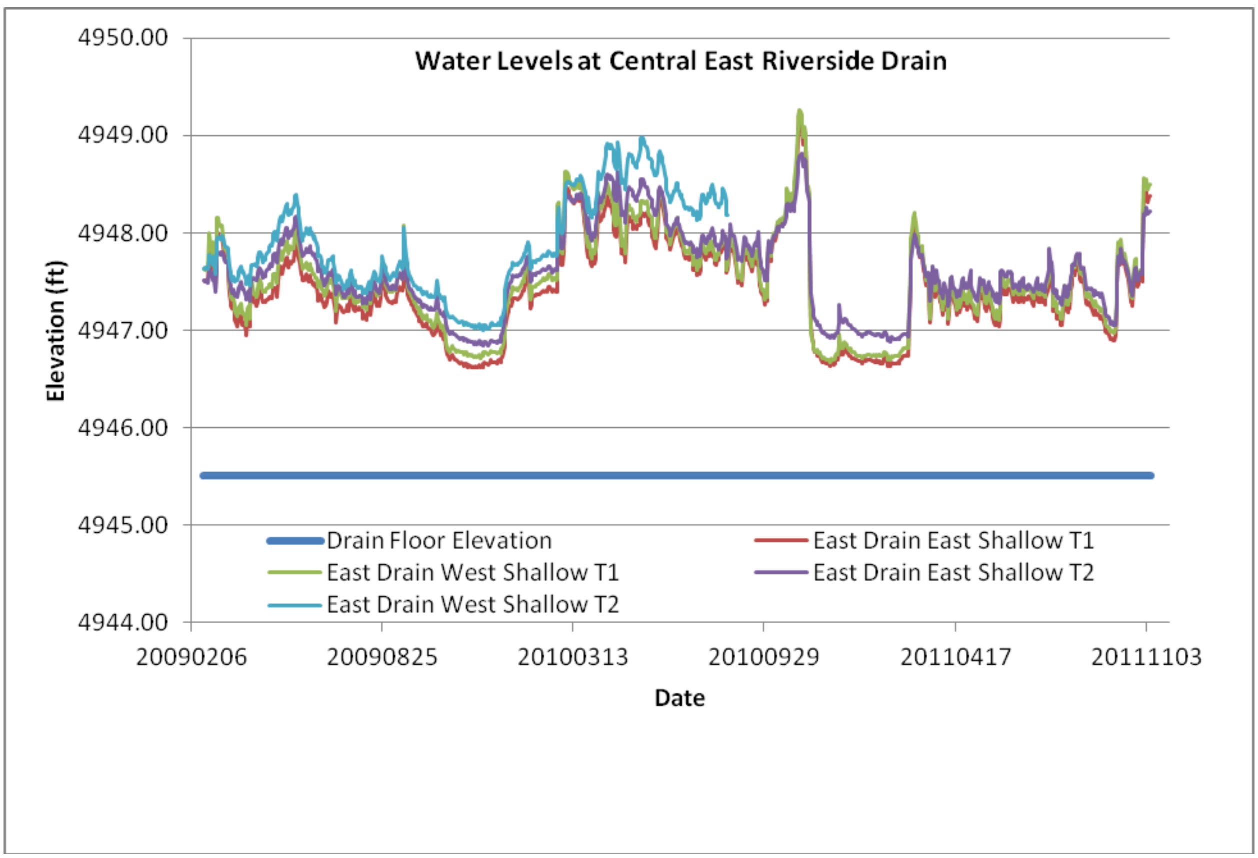

Water Levels at Alameda West Irrigation Channel
Elevation (ft)
4995.50
4995.00
4994.50
4994.00
4993.50
4993.00
4992.50
Drain Floor Elevation
West Drain West Shallow T1
West Drain West Shallow T2
20090206
20090825
20100313
20100929
20110417
20111103
Date

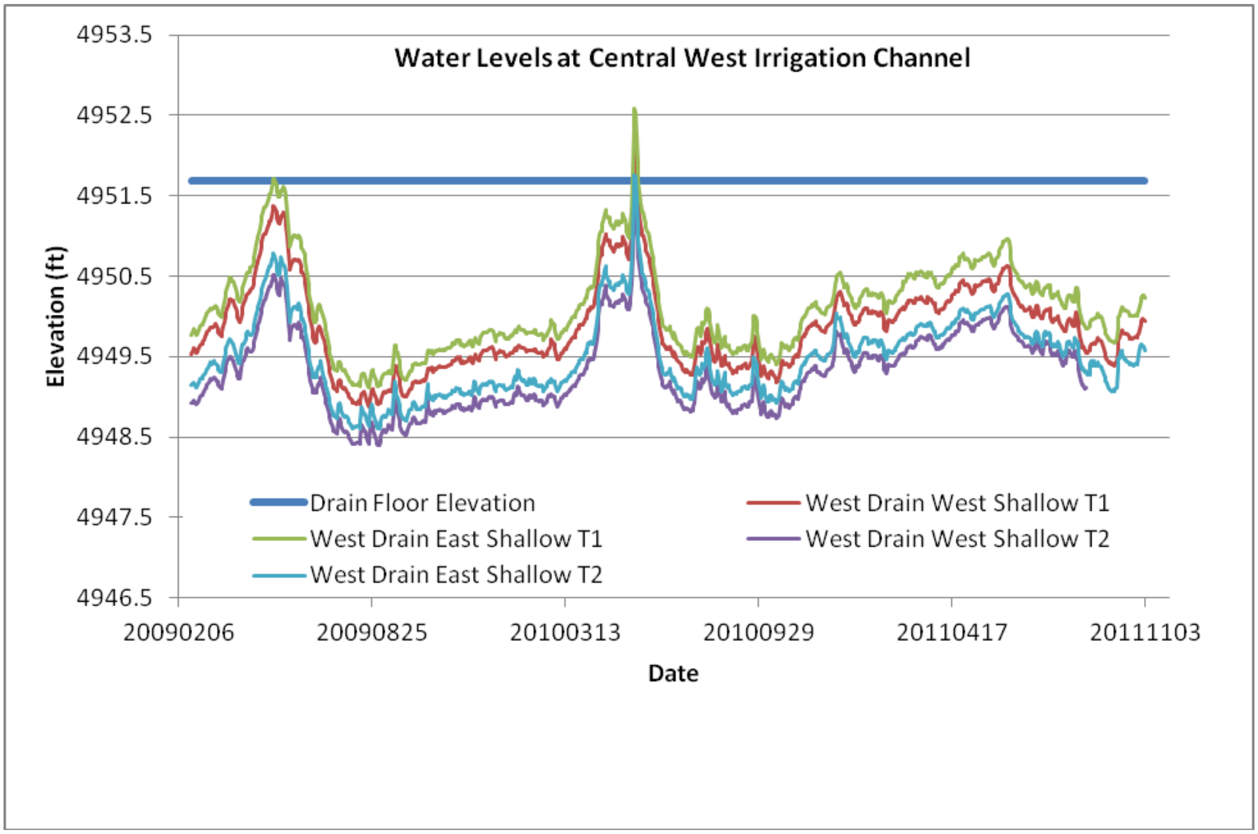

Water Levels at Paseo Del Norte East Riverside Drain
Elevation (ft)
4984
4983
4982
4981
4980
4979
4978
4977
4976
4975
4974
Drain Floor Elevation
East Drain East Middle T1
East Drain West Shallow T1
East Drain East Shallow T2
East Drain East Middle T2
East Drain West Shallow T2
20071015
20080502
20081118
20090606
20091223
20100711
20110127
20110815
Date

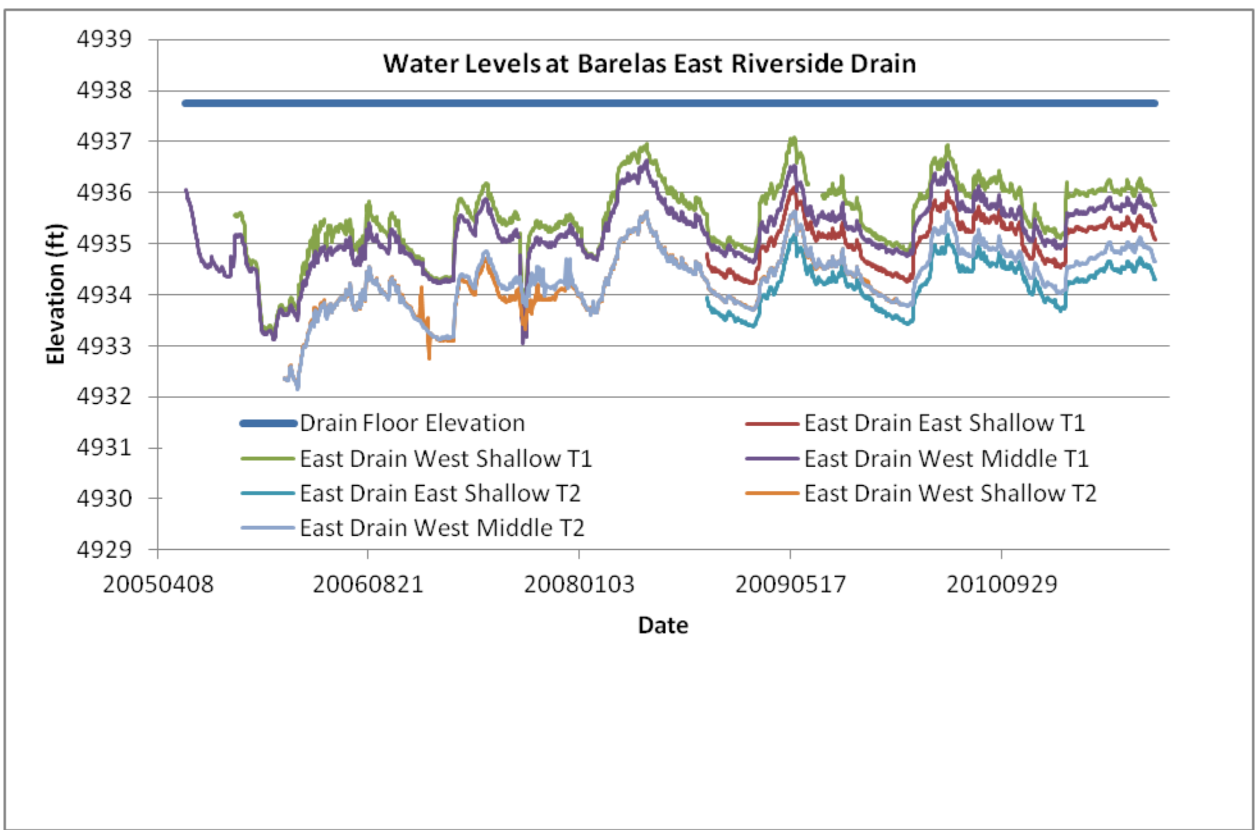

Water Levels at Paseo Del Norte West Riverside Drain
4989
4988
4987
4986
4985
4984
4983
4982
Elevation (ft)
Drain Floor Elevation
West Drain West Shallow T1
West Drain West Middle T1
West Drain East Shallow T1
West Drain West Shallow T2
West Drain West Middle T2
20071015
20080502
20081118
20090606
20091223
20100711
20110127
20110815
Date

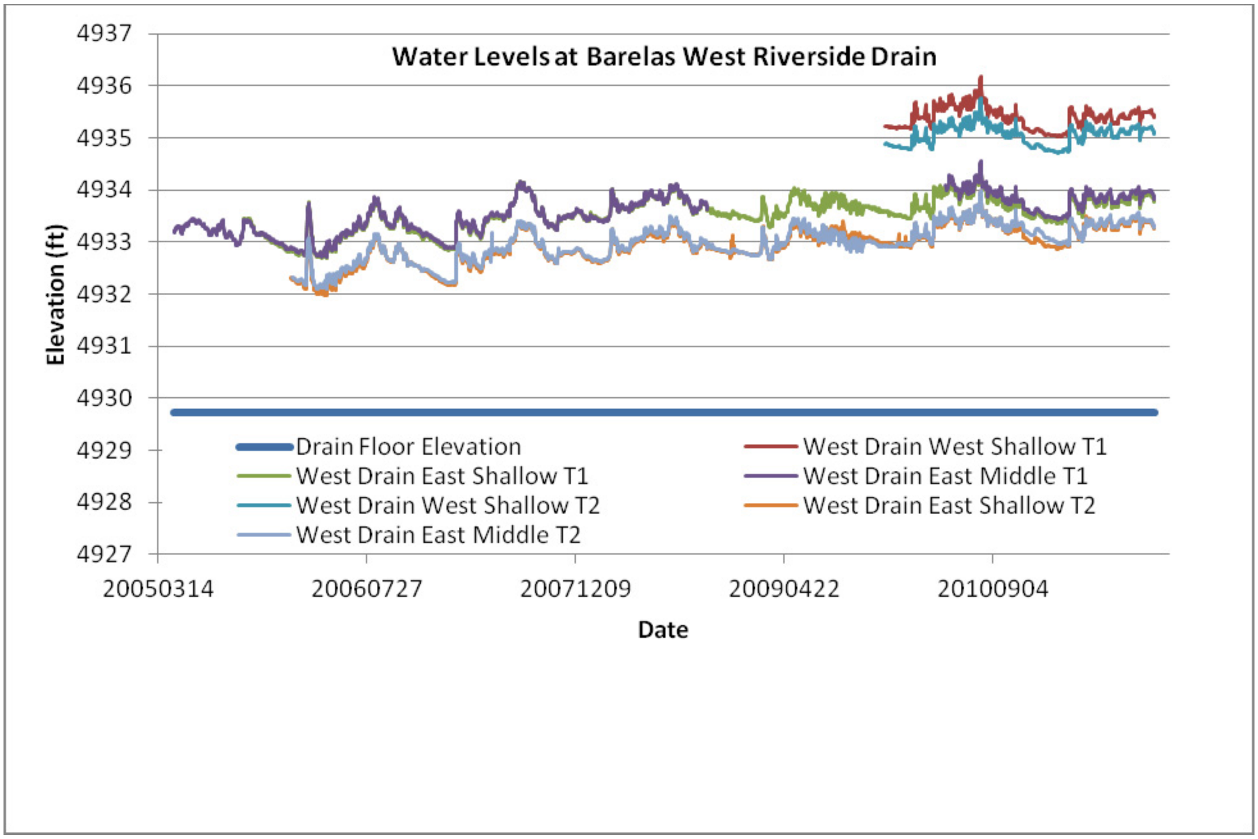

Water Levels at Montano East Riverside Drain
4971
4970
4969
4968
4967
4966
4965
4964
Elevation (ft)
Drain Floor Elevation
East Drain West Shallow T1
East Drain West Middle T1
East Drain West Shallow T2
East Drain West Middle T2
20051015
20070227
20080711
20091123
20110407
Date

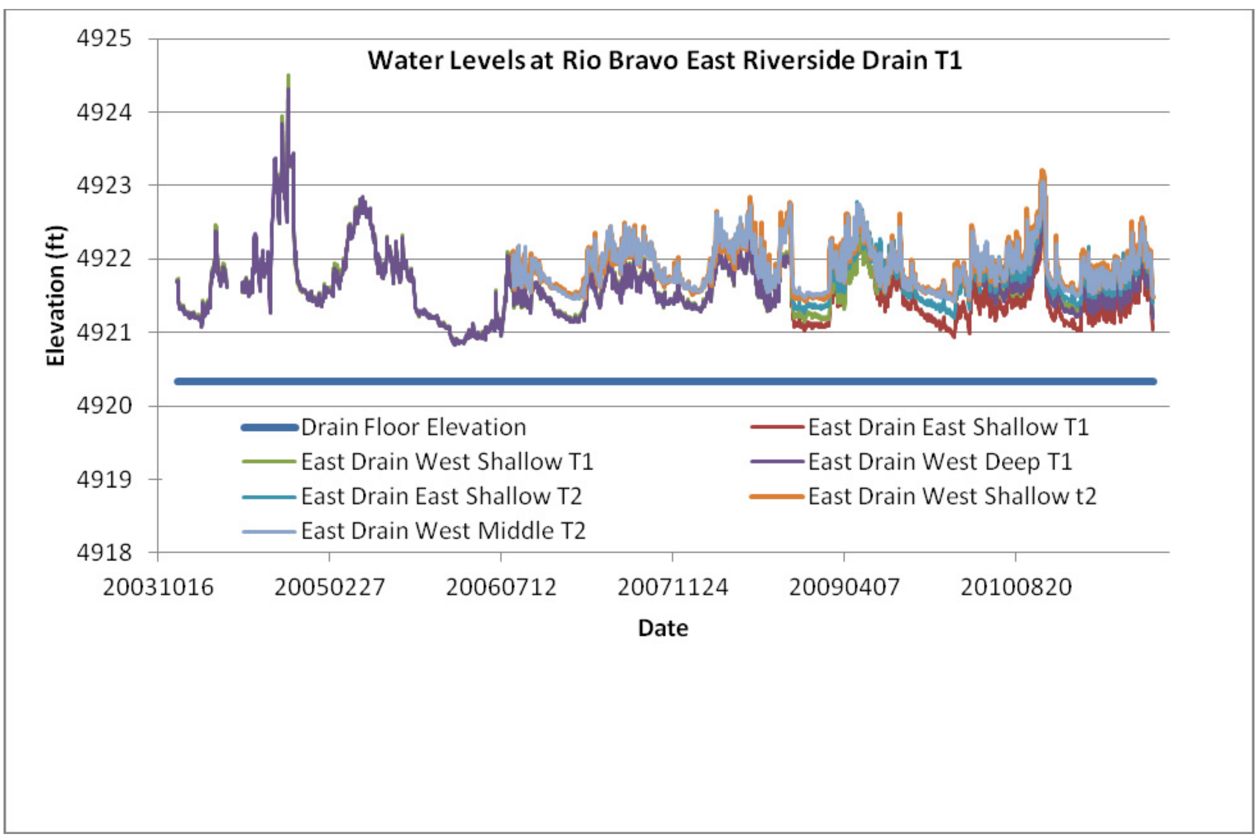

Water Levels at Montano West Riverside Drain
4975
4973
4971
4969
4967
4965
Elevation (ft)
Drain Floor Elevation
West Drain West Shallow T1
West Drain West Middle T1
West Drain East Shallow T1
West Drain West Shallow T2
West Drain West Middle T2
20050905
20070118
20080601
20091014
20110226
Date

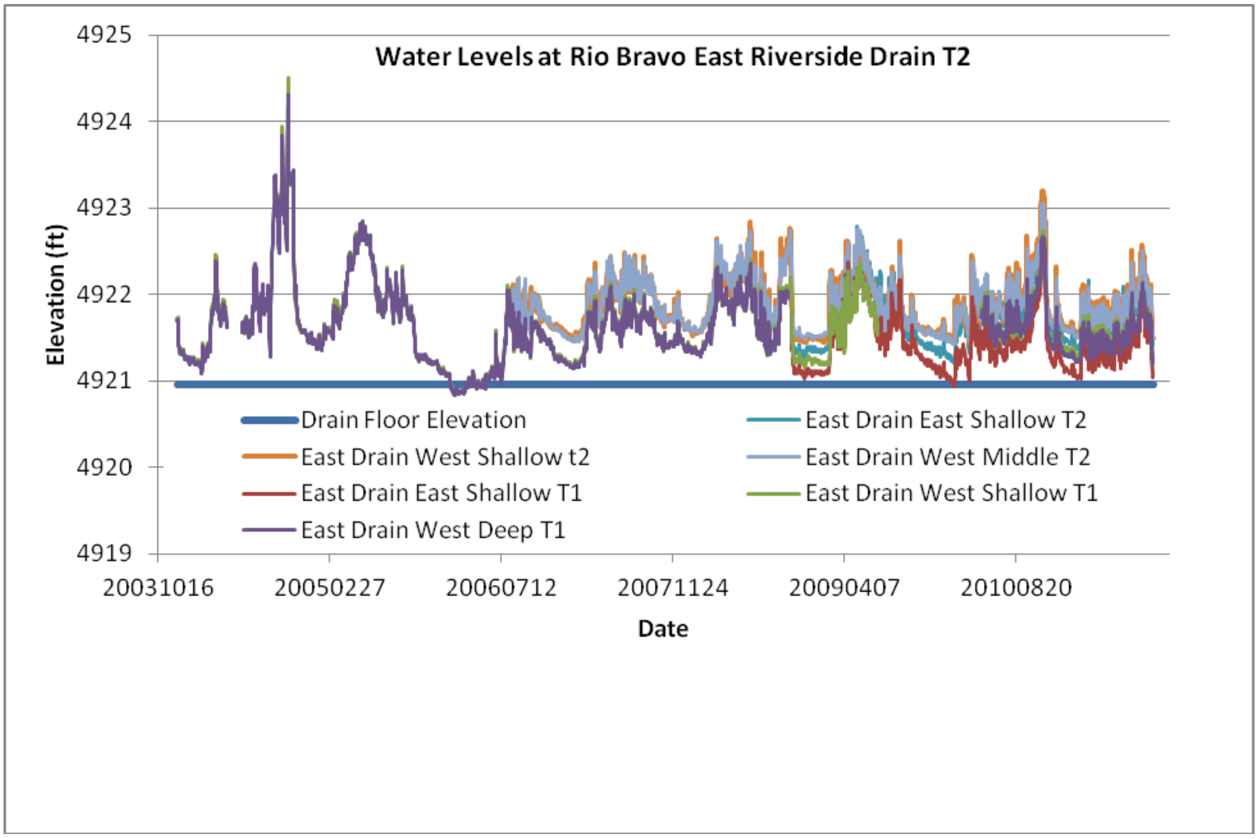

Water Levels at Central East Riverside Drain
4950.00
4949.00
4948.00
4947.00
4946.00
4945.00
4944.00
Elevation (ft)
Drain Floor Elevation
East Drain East Shallow T1
East Drain West Shallow T1
East Drain East Shallow T2
East Drain West Shallow T2
20090206
20090825
20100313
20100929
20110417
20111103
Date

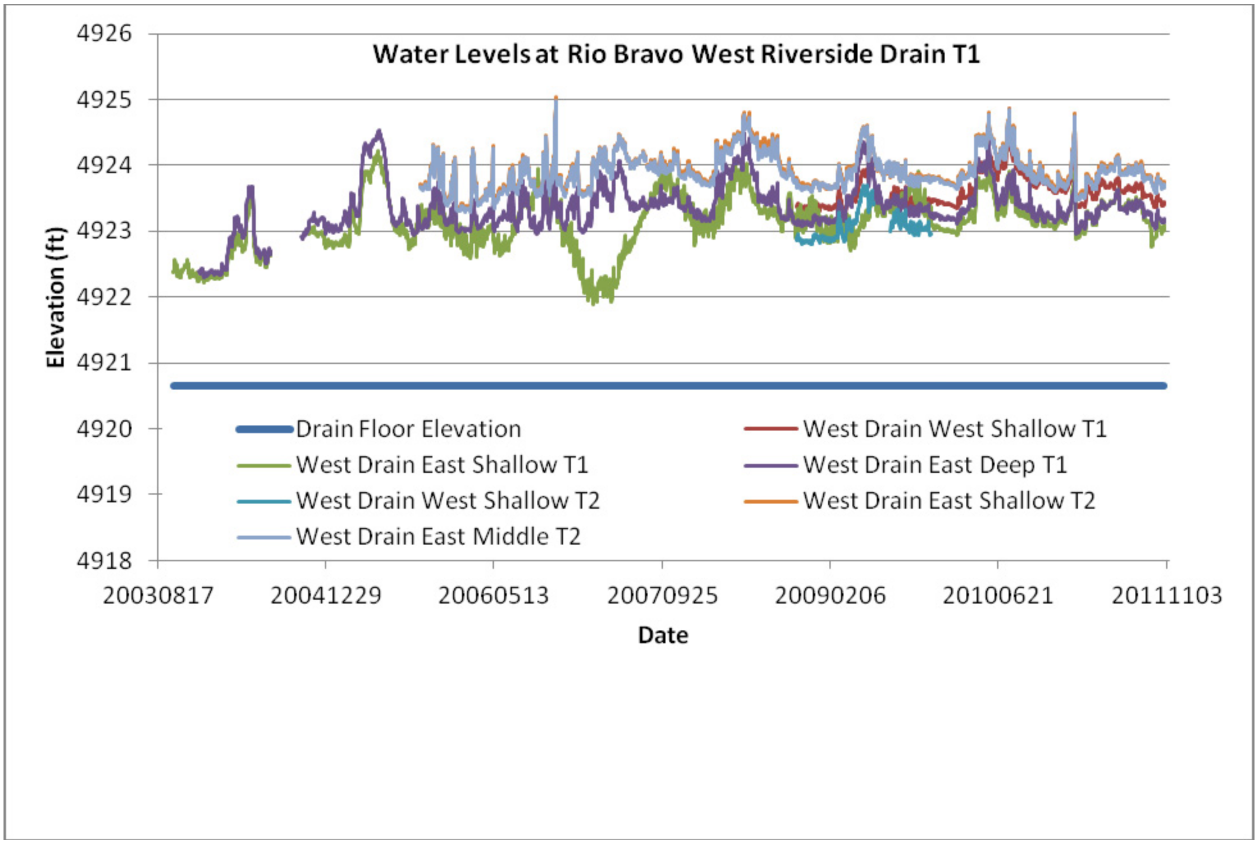

Water Levels at Central West Irrigation Channel
Elevation (ft)
4953.5
4952.5
4951.5
4950.5
4949.5
4948.5
4947.5
4946.5
20090206
20090825
20100313
20100929
20110417
20111103
Date
Drain Floor Elevation
West Drain West Shallow T1
West Drain East Shallow T1
West Drain West Shallow T2
West Drain East Shallow T2


Water Levels at Barelas East Riverside Drain
Elevation (ft)
4939
4938
4937
4936
4935
4934
4933
4932
4931
4930
4929
20050408
20060821
20080103
20090517
20100929
Date
Drain Floor Elevation
East Drain East Shallow T1
East Drain West Shallow T1
East Drain West Middle T1
East Drain East Shallow T2
East Drain West Shallow T2
East Drain West Middle T2

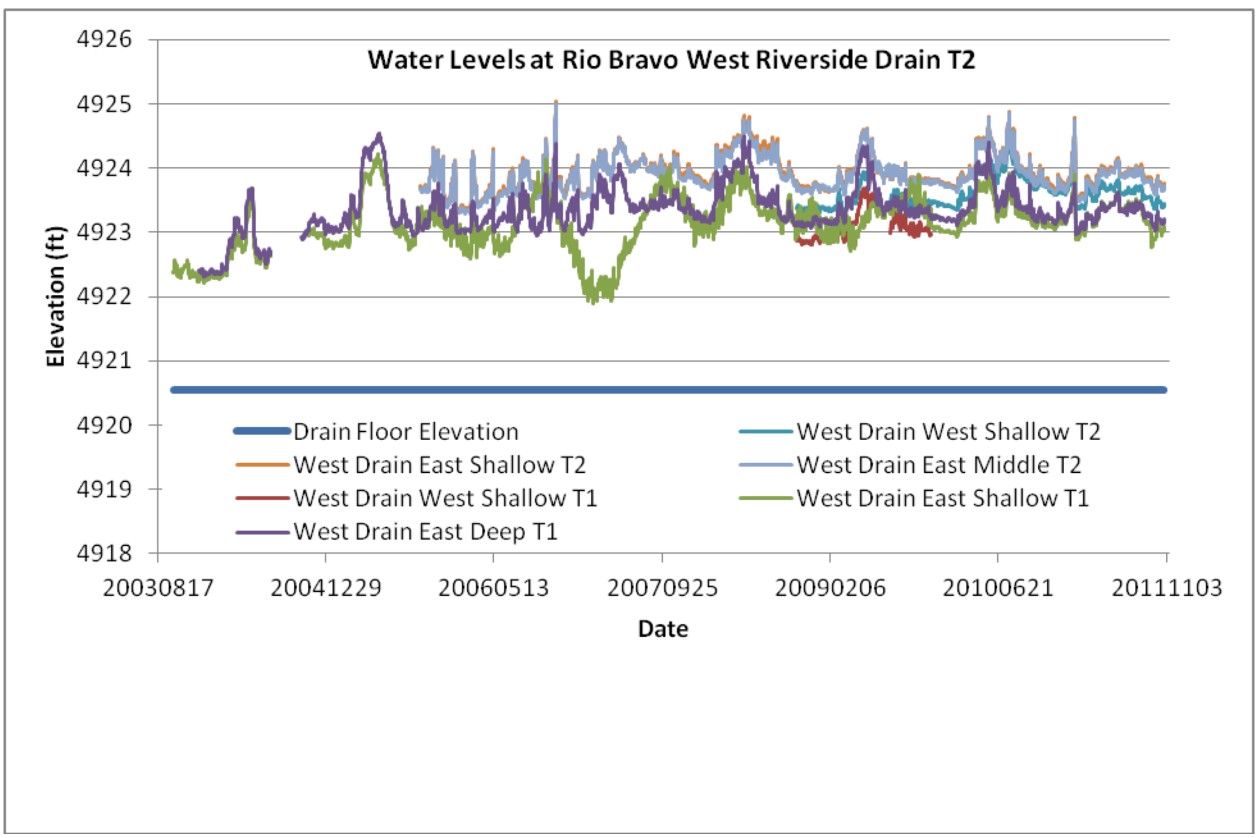

Water Levels at Barelas West Riverside Drain
4937
4936
4935
4934
4933
4932
4931
4930
4929
4928
4927
Elevation (ft)
Drain Floor Elevation
West Drain West Shallow T1
West Drain East Shallow T1
West Drain East Middle T1
West Drain West Shallow T2
West Drain East Shallow T2
West Drain East Middle T2
20050314
20060727
20071209
20090422
20100904
Date


Water Levels at Rio Bravo East Riverside Drain T1
4925
4924
4923
4922
4921
4920
4919
4918
Elevation (ft)
Drain Floor Elevation
East Drain East Shallow T1
East Drain West Shallow T1
East Drain West Deep T1
East Drain East Shallow T2
East Drain West Shallow t2
East Drain West Middle T2
20031016
20050227
20060712
20071124
20090407
20100820
Date

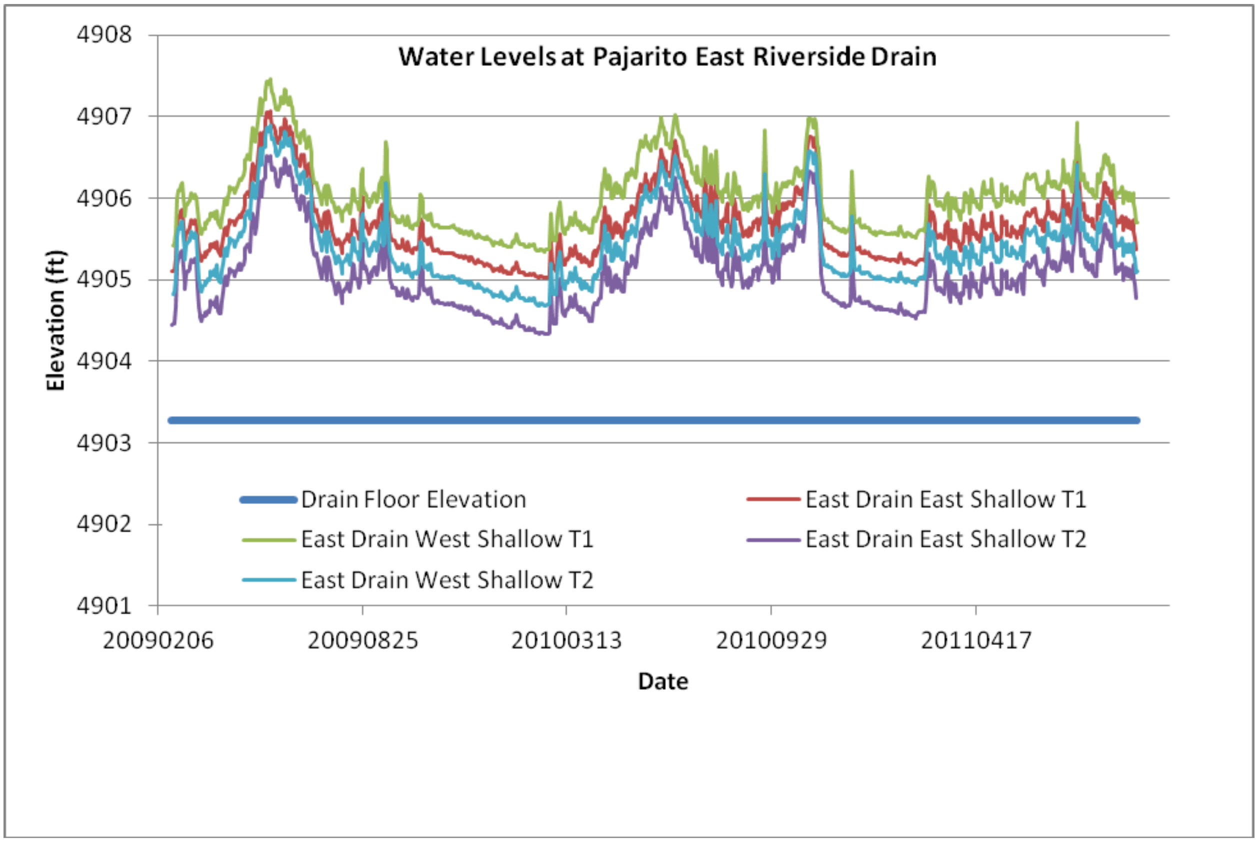

Water Levels at Rio Bravo East Riverside Drain T2
4925
4924
4923
4922
4921
4920
4919
Elevation (ft)
Drain Floor Elevation
East Drain East Shallow T2
East Drain West Shallow t2
East Drain West Middle T2
East Drain East Shallow T1
East Drain West Shallow T1
East Drain West Deep T1
20031016
20050227
20060712
20071124
20090407
20100820
Date

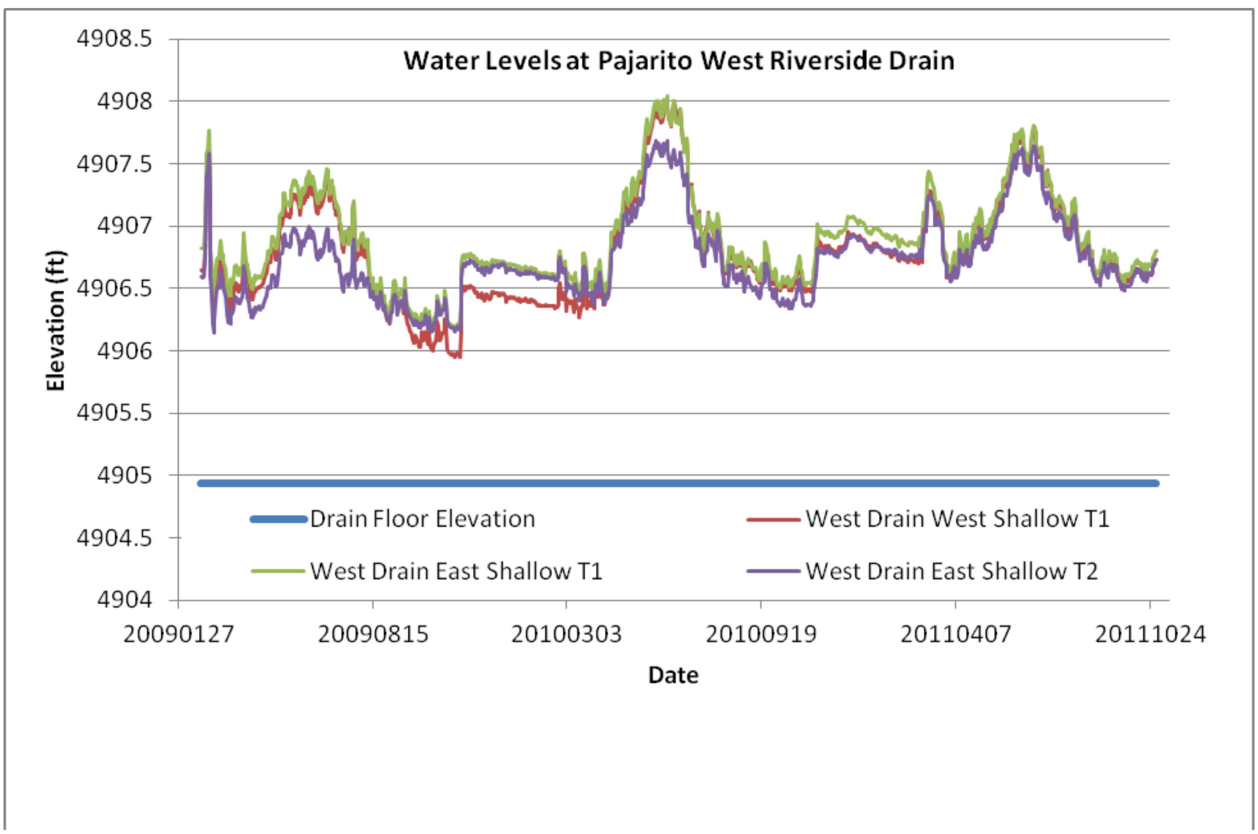


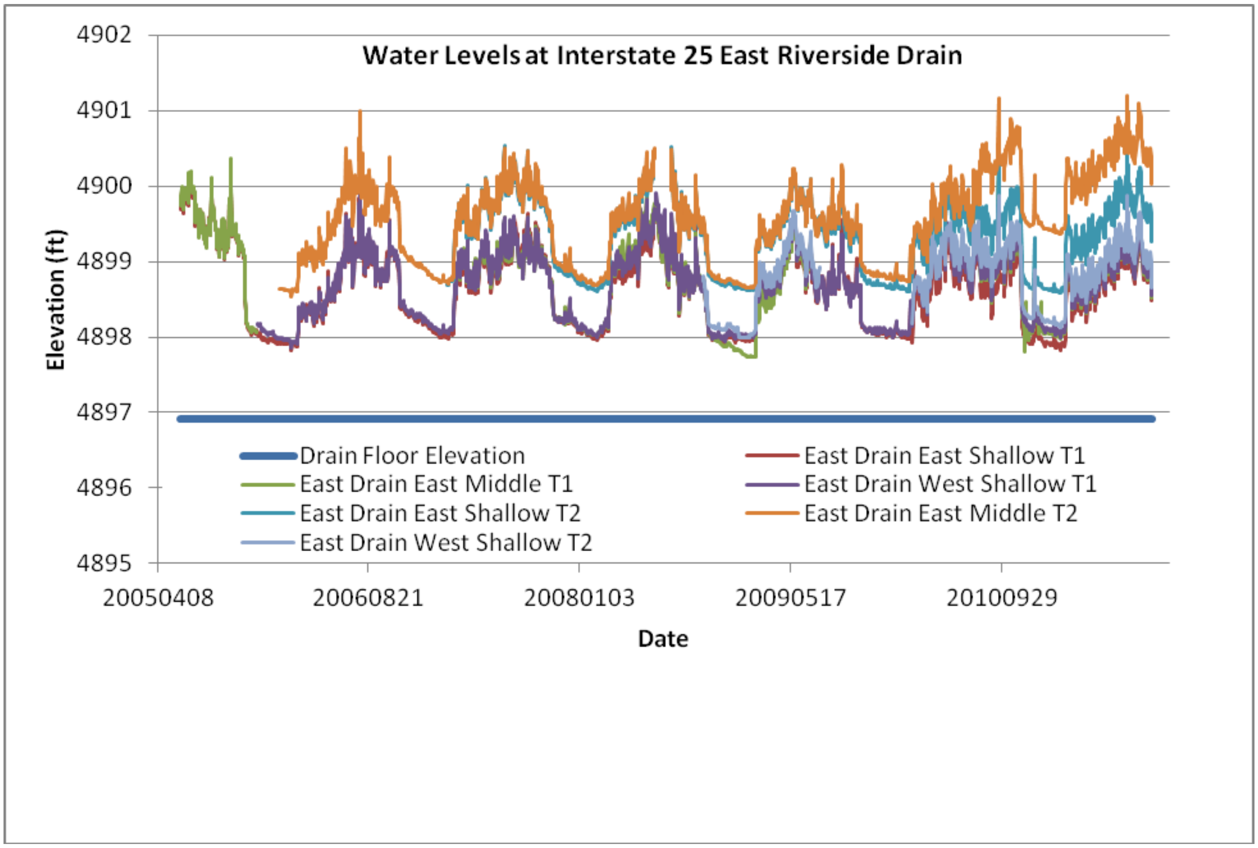
Water Levels at Rio Bravo West Riverside Drain T1
Elevation (ft)
4926
4925
4924
4923
4922
4921
4920
4919
4918
20030817
20041229
20060513
20070925
20090206
20100621
20111103
Date
Drain Floor Elevation
West Drain West Shallow T1
West Drain East Shallow T1
West Drain East Deep T1
West Drain West Shallow T2
West Drain East Shallow T2
West Drain East Middle T2



Water Levels at Rio Bravo West Riverside Drain T2
Elevation (ft)
4926
4925
4924
4923
4922
4921
4920
4919
4918
20030817
20041229
20060513
20070925
20090206
20100621
20111103
Date
Drain Floor Elevation
West Drain West Shallow T2
West Drain East Shallow T2
West Drain East Middle T2
West Drain West Shallow T1
West Drain East Shallow T1
West Drain East Deep T1


Water Levels at Pajarito East Riverside Drain
Elevation (ft)
4908
4907
4906
4905
4904
4903
4902
4901
Drain Floor Elevation
East Drain East Shallow T1
East Drain West Shallow T1
East Drain East Shallow T2
East Drain West Shallow T2
20090206
20090825
20100313
20100929
20110417
Date


Water Levels at Pajarito West Riverside Drain
Elevation (ft)
4908.5
4908
4907.5
4907
4906.5
4906
4905.5
4905
4904.5
4904
Drain Floor Elevation
West Drain West Shallow T1
West Drain East Shallow T1
West Drain East Shallow T2
20090127
20090815
20100303
20100919
20110407
20111024
Date


Water Levels at Interstate 25 East Riverside Drain
Elevation (ft)
4902
4901
4900
4899
4898
4897
4896
4895
Drain Floor Elevation
East Drain East Shallow T1
East Drain East Middle T1
East Drain West Shallow T1
East Drain East Shallow T2
East Drain East Middle T2
East Drain West Shallow T2
20050408
20060821
20080103
20090517
20100929
Date

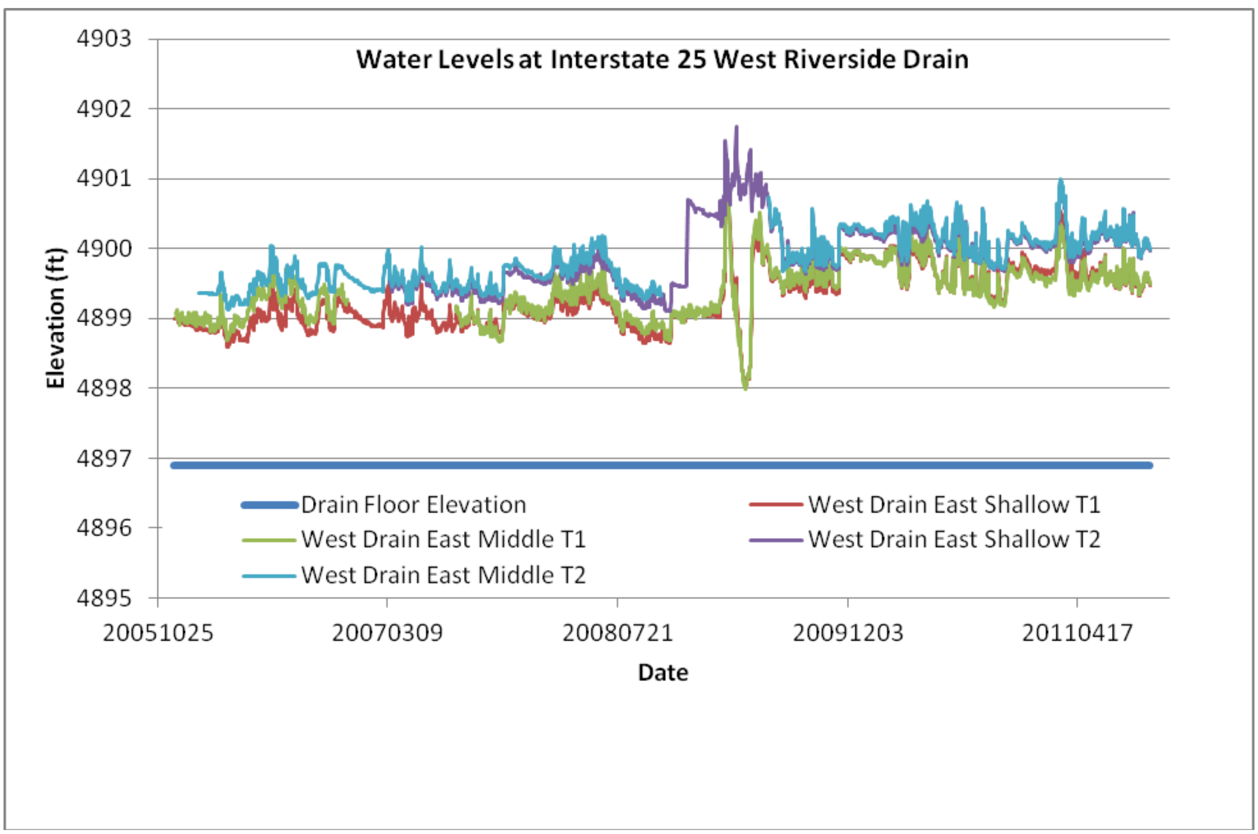

Water Levels at Interstate 25 West Riverside Drain
Elevation (ft)
4903
4902
4901
4900
4899
4898
4897
4896
4895
Drain Floor Elevation
West Drain East Shallow T1
West Drain East Middle T1
West Drain East Shallow T2
West Drain East Middle T2
20051025
20070309
20080721
20091203
20110417
Date

Table 3. Extents of connection and status of separation between riverside drain floors and adjacent piezometer groundwater elevations.

SW site name	Associated GW site name	Average Difference between adjacent piezometer water level and drain floor (in feet)	Status of drain and water table, if Separated
AEDSW1			
	AEDWS1	3.4714174	
	AEDES1	2.9586674	
	AEDWS2	2.6996302	
	AEDES2	2.2503161	
AWDSW1			
	AWDES1	-0.7096585	Separated for most of record
	AWDES2	-1.6678525	Separated for entire record
AWDSW2			
	AWDWS1	1.2226650	
	AWDWS2	0.8298325	
PDNEDSW1			
	PDNEDWS1	3.2301395	
	PDNEDEM1	2.8236192	
	PDNEDWS2	5.5574656	
	PDNEDES2	4.7794766	
	PDNEDEM2	4.7637925	
PDNWDSW1			
	PDNWDES1	0.9735010	
	PDNWDWS1	0.5081903	Separated for part of record
	PDNWDWM1	0.5445874	Separated for part of record
	PDNWDES2	1.6136389	
	PDNWDWS2	1.4186777	
	PDNWDWM2	1.3179635	
SW site name	**Associated GW site name**	**Average Difference between adjacent piezometer water level and drain floor (in feet)**	**Status of drain and water table, if Separated**
MEDSW1			
	MEDWS1	3.4648583	
	MEDWM1	3.3395629	
	MEDWS2	3.5462970	
	MEDWM2	3.4072337	
MWDSW1			
	MWDES1	-3.1543351	Separated for most of record
	MWDWS1	-3.8461249	Separated for most of record
	MWDWM1	-4.0184324	Separated for entire record
	MWDES2	-4.0336868	Separated for entire record

	MWDWS2	-3.7794538	Separated for entire record
	MWDWM2	-3.8604833	Separated for entire record
CEDSW1			
	CEDWS1	2.0116183	
	CEDES1	1.9201309	
	CEDWS2	2.3821273	
	CEDES2	2.0935539	
CWDSW1			
	CWDES1	-1.5731582	Separated for most of record
	CWDWS1	-1.8308641	Separated for most of record
	CWDES2	-2.2001542	Separated for most of record
	CWDWS2	-2.3831783	Separated for entire record

SW site name	**Associated GW site name**	**Average Difference between adjacent piezometer water level and drain floor (in feet)**	**Status of drain and water table, if Separated**
BEDSW1			
	BEDWS1	-2.2333442	Separated for entire record
	BEDWM1	-2.5491376	Separated for entire record
	BEDES1	-2.6689568	Separated for entire record
	BEDWS2	-3.6034765	Separated for entire record
	BEDWM2	-3.4061859	Separated for entire record
	BEDES2	-3.5128881	Separated for entire record
BWDSW1			
	BWDES1	3.8205229	
	BWDEM1	3.7960799	
	BWDWS1	5.6730078	
	BWDES2	3.2197245	
	BWDEM2	3.2548548	
	BWDWS2	5.3362481	
RBEDSW1			
	RBEDWS1	1.2995056	
	RBEDWD1	1.2991271	
	RBEDES1	1.1018379	
	RBEDWS2	1.5553187	
	RBEDWM2	1.5462025	
	RBEDES2	1.4107721	
RBEDSW2			
	RBEDWS2	0.9353187	
	RBEDWM2	0.9262025	
	RBEDES2	0.7907721	
	RBEDWS1	0.6795056	Separated for part of record
	RBEDWD1	0.6791271	Separated for part of record
	RBEDES1	0.4818379	

RBWDSW1			
	RBWDES1	2.4704730	
	RBWDED1	2.6897695	
	RBWDWS1	2.9669141	
	RBWDES2	3.2701945	
	RBWDEM2	3.2378969	
	RBWDWS2	2.4180627	
RBWDSW2			
	RBWDES2	3.3901945	
	RBWDEM2	3.3578969	
	RBWDWS2	3.0869141	
	RBWDES1	2.5904730	
	RBWDED1	2.8097695	
	RBWDWS1	2.5380627	

SW site name	**Associated GW site name**	**Average Difference between adjacent piezometer water level and drain floor (in feet)**	**Status of drain and water table, if Separated**
PEDSW1			
	PEDWS1	2.7506695	
	PEDES1	2.3934905	
	PEDWS2	2.1395890	
	PEDES2	1.7973337	
PWDSW1			
	PWDES1	1.9500905	
	PWDWS1	1.8517009	
	PWDES2	1.7971526	
I25EDSW1			
	I25EDWS1	1.7455739	
	I25EDES1	1.7328491	
	I25EDEM1	1.8675505	
	I25EDWS2	1.8888639	
	I25EDES2	2.4342359	
	I25EDEM2	2.6225381	
I25WDSW1			
	I25WDES1	2.3996192	
	I25WDEM1	2.4940713	
	I25WDES2	3.0454771	
	I25WDEM2	2.9332570	

At the Alameda location, there is ample connection between the eastside drain and the alluvial aquifer as the average hydraulic head in the east drain-side well is 3.47 ft above the drain floor in transect 1 and 2.70 ft in transect 2 (Table 3). This implies that groundwater is flowing to the east-side drain year round and no separations occur from February 2009 to October 2011. The strong connection at this location can be attributed to several factors: 1) Relatively short horizontal distance between the east riverside well and the east inside-drain well (340 ft and 228 ft at transects 1 and 2, respectively); 2) The drain floor is low relative to the hydraulic head in the riverside well (7.6 ft and 7.2 ft of vertical distance at transects 1 and 2, respectively); 3) There are no municipal pumping wells in the vicinity though there are lots of private domestic wells; 4) The diversion dam just south of the Alameda Bridge tends to back water up in the river and create waterlogged conditions near the Alameda transects unlike those at other locations in the network. The illustration in Figure 6 shows relative elevations of the water table and riverside drain floors on the east and west sides of the river. The chart in Figure 7 demonstrates that water levels in piezometers adjacent to the drain remain elevated above the drain floor throughout the period of record with significant rises in water table elevations during the spring and summer months as expected. Seasonal values in Table B-1 indicate that groundwater in east-side drain piezometers reach its highest elevation during the summer months. Due to the short horizontal distance between the river and east-side drain, there is little lag time between high river discharge and seepage induced rise in groundwater elevations at the drain. On the contrary, there is much separation between the alluvial aquifer and the inside of the west riverside drain floor at Alameda. Since the outside of this drain is not instrumented, it is unknown if the drain is connected with the aquifer outside of the drain. The irrigation ditch west of the drain is strongly connected with the aquifer. From 2009 to 2011, the average difference between the hydraulic head in the drain-side well and the drain floor is -0.71 and -1.67 ft at transects 1 and 2 respectively (Table 3) which implies the groundwater surface lies below the drain floor and very little, if any, recharge is occurring. The reason for this can be attributed to a larger horizontal distance between the river and drain (528 and 585 ft at transects 1 and 2 respectively) and very little vertical difference between the drain floor and the hydraulic head in the west riverside well (1.4 and 1.2 ft at transects 1 and 2 respectively). Another influence to declining groundwater levels may be excessive groundwater pumping from residential and municipal production wells. A deeper riverside drain would reduce the separation at this location. Residential water pumping in Corrales may also contribute to lower groundwater elevations. On the west side, the highest groundwater levels are seen during the spring months. This is likely due to high surface water discharge in the drain, loss of water from the drain as seepage, and groundwater mounding below the channel. Figure 7 shows the water table at the Transect 1 West Drain East Shallow-Depth piezometer only raised to an elevation above the drain floor for a couple weeks during the spring of 2010.

At the Paseo Del Norte location, the drains are connected to the aquifer on both sides despite a large horizontal distance between the river and drain (over 800 ft at both transects on the east side and over 500 ft at both transects on the west side). The strong connection is due to low-lying drain floors relative to the hydraulic head in riverside wells (over 12 ft at both transects on the east side and over 4 ft at both transects on the west side (Table A-2)) and a lack of municipal groundwater pumping in the area. On the east side, the average water table elevation in the East Drain West Shallow-Depth piezometers is several feet above the drain floor elevation and on the west side, the water table in the West Drain East Shallow-Depth piezometers is about a foot above the drain floor elevation (Table 3). This difference is likely attributed to the much lower lying drain floor on the east side which is illustrated in Figure 6. Like the east side at Alameda, the piezometers adjacent to the inside of both drains at Paseo Del Norte remain strongly connected to the drain all year with elevated peaks during the summer months (Figure 7). Therefore, more flow to the drains is taking place during the summer months.

The riverside drain on the east side at Montano is well connected to the shallow aquifer due to a short horizontal distance between river and drain (~300-400 ft) and a low-lying drain floor (~7 ft below groundwater elevation in the riverside well). The drain on the west side, however, receives very little recharge from Rio Grande leakage because the horizontal distance between the river and drain is large (over 1400 ft) and there is very little vertical distance between the drain floor and hydraulic head at the west riverside well. From June 2005 to October 2011, the average vertical distance between the west-side drain floor and groundwater elevation in the West Drain East Shallow-Depth piezometers is -3.2 and -4.0 ft at transect 1 and 2 respectively. Because of this year-round separation and lack of groundwater infiltration, it is likely that surface water in the drain is being lost to the alluvial aquifer. There are municipal production wells near the east side of the river at Montano which may contribute to lowering of groundwater levels in the area. The chart in Figure 7 shows several peaks for the Transect 1 West Drain East Shallow-Depth piezometer during summer and winter months which appear to demonstrate that the groundwater table does at times rise above the west-side drain floor elevation which would indicate some recharge may take place during these times. According to the seasonal values in Table B-1, the spring time average presents the lowest separation between drain floor and the aquifer. The same trend was seen at Alameda on the west side where the drain floor is also separated from the alluvial aquifer. Similar to the west side at Alameda, it is very likely that surface water from the drain is being lost to the aquifer on the west side at Montano especially during the high discharge irrigation months of spring. Results from a seepage investigation in early 2009 as well as the results from Isaacson's study support this conclusion.

The east side location at Central, similar to the east side at Montano, demonstrates adequate connection due to proximity of the riverside drain to the river and a low-lying drain floor. There is separation on the west side at Central; however, the channel instrumented here is not the riverside drain. Rather, it is a shallow irrigation ditch that lies just west of the riverside drain (away from the river). The illustration in Figure 6 shows both channels, the piezometer layout, and how the average water table elevation lies below the west-side irrigation ditch floor elevation. Since the data corresponds to an irrelevant channel and measurements are not available for the west riverside drain, the measurements at this location are suspect. The decision was made in 2008 to instrument the irrigation ditch rather than the drain because there was zero discharge in the drain (channel begins about one mile upstream therefore it had not acquired adequate recharge to constitute flowing conditions) and it presented an unsafe working environment. The chart in Figure 7 and the seasonal values in Table B-1 do demonstrate a similarity however to conditions at Alameda's and Montano's west side where the water table lies below the drain floor year-round. Comparable to these locations, groundwater rises to its highest levels during the spring months. Unfortunately, it is not known from the water levels alone where the groundwater is coming from. It is possible the groundwater table is rising along the irrigation ditch due to increased irrigation, loss of water from the adjacent west-side drain or from the irrigation ditch itself, or likely a combination of these sources.

The east-side sites at Barelas show large separation between the drain floor and the alluvial aquifer in part due to horizontal distance between river and drain (over 400 ft) but primarily due to a lack of depth in the riverside drain floor (the drain floor lies about 1 ft below the hydraulic head in the east riverside well). The average vertical distance from June 2005 to October 2011 between the drain floor and hydraulic head in the drain-side well is -2.2 and -3.6 ft at transects 1 and 2 respectively (Table 3). There are municipal production wells nearby which may influence declining groundwater levels. Despite a large horizontal distance between river and drain on the west side, the drain remains strongly connected to the aquifer due to the drain floor's low-lying position.

The remaining locations, Rio Bravo, Pajarito and I-25, demonstrate strong connections between riverside drains and the alluvial aquifer on both sides of the river. Transect 1 on the west side at Pajarito is over 920 ft between river and drain; however, the drain floor lies 7.6 ft below the average hydraulic head in the west riverside well. Because of the low-lying drain floor, the groundwater elevation in the drain-side piezometer is, on average, almost 2 ft above the drain floor elevation.

Elevation data in Table 3 show the east-side drain floor in transect 1 at Rio Bravo is 0.62 ft below the drain floor at transect 2 and on the west side, the drain floor at transect 1 lies 0.12 ft above the drain floor at transect 2. Rio Bravo was the only location where surface-water-stage gages were constructed along the drains at both transects. The drain floor elevations and adjacent drain-side piezometer water table elevations were cross referenced here (between transects 1 and 2) to determine an approximate error involved by relating measurements from transects 1 and 2. In other words, because of the 500 ft distance between transects 1 and 2, there is an associated elevation difference which should be accounted for when relating transect 1 drain floor elevations to transect 2 drain-side piezometer water table elevations. Since downstream drain floor elevations are typically a little lower than upstream drain floor elevations, a correction should be applied to measurements when cross referencing transect 1 and 2 measurements. Due to these elevation differences and unknown drain floor elevations at transect 2 for all locations other than Rio Bravo, more confidence resides in measurements relating riverside drain floors with water table elevations in the same transect. Therefore, since the riverside drain floor at Rio Bravo’s transect 1 averages about 0.5 ft lower than transect 2 on both sides of the river, this value should be applied to measurements that cross reference the two transects. For example, in Table 3 at the Central East Drain Surface Water Transect 1 site, more confidence lies in measurements related to associated groundwater sites in transect 1 than in transect 2.

Vertical Gradients

Vertical gradients are generally negligible in the bosque as shown by the period-of-record values in Table 4. This table lists an average of all the nested piezometer sites on one side of the river at a particular location. A more complete table in Appendix B (Tables B-3 and B-4) provide vertical gradient values partitioned by location, site, season, and year; and a more visually appealing representation of the vertical gradients in table 4 is available in Figure 8.

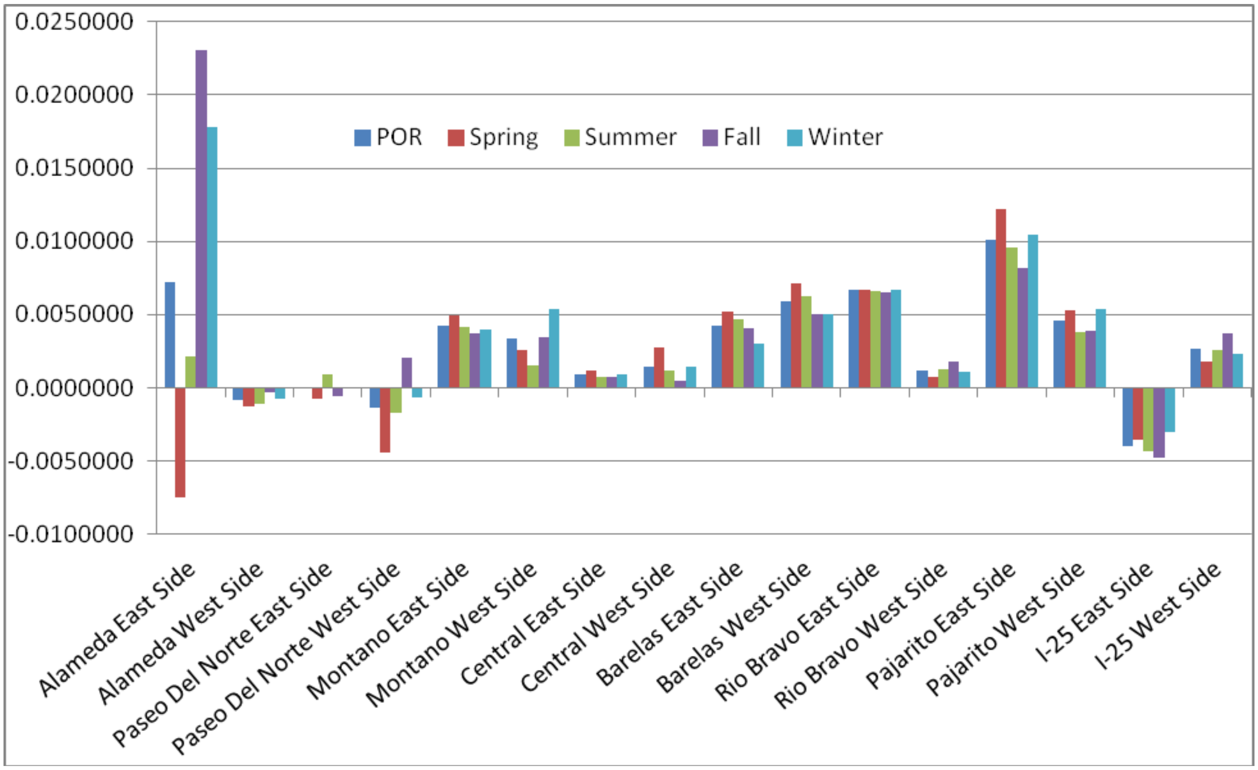
Average period-of-record vertical gradient values range from -0.004 on the east side of the I-25 location to 0.01 on the east side of the Pajarito location. Negative vertical gradients signify downward flow whereas positive values signify upward flow. All of these values appear to be somewhat negligible indicating that most groundwater flow in the bosque moves in the horizontal direction. However, in some areas, the vertical gradient is larger than the horizontal or approximately the same. For example, the vertical gradient on Montano's west side is 0.00333 (Table 4) and the horizontal gradient is 0.00361 (Table 6) which indicates a very slightly greater influence on horizontal groundwater flow. On Rio Bravo's east side, the vertical gradient is 0.00670 and the horizontal is 0.00458 which indicates the greater influence is on vertical groundwater flow. The vertical and horizontal gradients on Pajarito's east side, like Montano's west side, are almost equal with a slightly greater effect on the horizontal aspect. On I-25's east side, the vertical gradient is -0.00394 which signifies downward movement and the horizontal gradient is 0.00282 so the downward component is stronger than the horizontal component. The remaining locations experience a greater influence of groundwater movement from the horizontal component.

At five locations (Paseo Del Norte, Montano, Barelas, Rio Bravo, and I-25), there are nested piezometers along the riverside drains and four of these locations contain nested piezometers some distance (>900 ft) from the river. The other three locations (Alameda, Central, and Pajarito) do not contain nested piezometers anywhere except along the river and midway through the bosque. Since more piezometer nests and a greater surface area were used at the former locations, direct comparisons between locations may not be practical. Localized conditions such as flood irrigation, residential water pumping, or levee construction may greatly impact the water levels in one or two piezometers which would affect the average vertical gradient calculated for that location. Furthermore, many piezometer nests are made up of mid and deep-depth wells which range from 30-55 ft deep. The vertical gradients calculated from those nests could contradict the gradients calculated within the study area which is up to 30 ft of depth. Analyzing individual sites from Tables B-3 and B-4 in Appendix B is, therefore, a more feasible method of comparison.

Table 4. Vertical-hydraulic gradients measured at piezometer nests; partitioned by location, period-of-record (POR), and season.

	POR	Spring	Summer	Fall	Winter
Alameda East Side	0.0071907	-0.0074739	0.0021294	0.0230089	0.0177732
Alameda West Side	-0.0008256	-0.0012442	-0.0011291	-0.0002984	-0.0007622
Paseo Del Norte East Side	-0.0000643	-0.0007054	0.0009586	-0.0005536	-0.0000839
Paseo Del Norte West Side	-0.0013256	-0.0044495	-0.0017240	0.0020498	-0.0006187
Montano East Side	0.0042219	0.0049743	0.0041959	0.0037087	0.0039831
Montano West Side	0.0033340	0.0025367	0.0015377	0.0034182	0.0054209
Central East Side	0.0009049	0.0011788	0.0007140	0.0007705	0.0009618
Central West Side	0.0014752	0.0027758	0.0011548	0.0005178	0.0014291
Barelas East Side	0.0042616	0.0051632	0.0046799	0.0041042	0.0030402
Barelas West Side	0.0059014	0.0071494	0.0062654	0.0050354	0.0049968
Rio Bravo East Side	0.0066968	0.0066836	0.0066197	0.0065212	0.0066695
Rio Bravo West Side	0.0011934	0.0007598	0.0012705	0.0018126	0.0010593
Pajarito East Side	0.0101436	0.0121719	0.0096027	0.0082058	0.0104131
Pajarito West Side	0.0045672	0.0053271	0.0038433	0.0039124	0.0053539
I-25 East Side	-0.0039437	-0.0035476	-0.0042920	-0.0047445	-0.0030275
I-25 West Side	0.0026312	0.0018259	0.0025597	0.0037342	0.0022916

Figure 8. Vertical-hydraulic gradients measured at piezometer nests; partitioned by location and season.



According to Table B-3, the vertical gradient at Alameda's east riverside piezometers (shallow to middle-depth) in both transects is negative during spring months and highly positive during fall and winter months. The values indicate a slight downward flow during snowmelt runoff and a slight upward flow during the cooler months. The bosque piezometer nests in Transect 1, however, demonstrate a slight upward flow year round. Figure 8 shows extremely high gradients during the fall and winter months and a relatively low gradient during spring months. Upon closer examination of Table B-3, it is the bosque piezometers (shallow to middle-depth) in transect 1 which are causing this deviation. At this site, the fall months experience the highest vertical gradient (0.06137) whereas spring months experience the lowest (0.00262). During the spring months, this is one of only two sites on the east side that displayed positive values. No transducer problems were noted at these piezometers; therefore, this irregularity is likely due to localized soil heterogeneity. Yearly comparisons for Alameda's east-side sites in Table B-4 do not show significant change from year to year (2009-2011). Reasons for the seasonal changes are difficult to ascertain; analysis with municipal groundwater pumping and Rio Grande discharge, later in this study, may provide more answers. The west-side vertical gradients at Alameda are very slight (no greater than 0.0010) and do not appear to experience any significant changes by season or year.

Vertical gradients appear to have some correlation to vegetation density. The two more densely vegetated areas on the west sides of the Alameda and Pajarito transects have low vertical gradients (-0.00083 and 0.00457 respectively) relative to the east sides (0.00719 and 0.01014) which are not densely vegetated. In other words, some of the densely vegetated areas present large upward gradients whereas some of the thinly vegetated areas present small downward gradients. Similar but more transparent correlations are presented with horizontal gradients in the next section.

Most of the relevant vertical gradients (shallow to mid-depth wells in the bosque) at Barelas on the east side are negative with little change due to season or year. These negative values indicate downward flow which may correlate with a prior discovery that the east riverside drain floor is generally at a higher elevation than the water table. This does not appear to be occurring at Montano's west side where the riverside drain floor is also separated from the water table. At Montano, only one site, West Bosque Shallow and Mid-Depth Transect 1, consistently provides negative vertical gradient values and they are very slight (-0.00244 for period-of-record). Alameda's west side which also experiences drain floor and water table separation does not demonstrate consistently negative vertical gradients. Therefore, it is likely that something is causing the downward movement on Barelas's east side unlike what is seen on the west side at Alameda and Montano.

Vertical gradients at the remaining sites do not experience significant changes due to season or year and it is not intuitively clear what is causing the small changes that are occurring. It is possible that municipal groundwater pumping or Rio Grande discharge impact these gradients and later analyses will attempt to demonstrate this. There are other components which no doubt have influence on these gradients as well: soil stratigraphy and hydraulic conductivity, residential groundwater pumping, farm irrigation, biologic health, and evapotranspiration just to name a few.

Horizontal Gradients

Horizontal gradients typically have a greater influence than vertical gradients on groundwater movement in the bosque as shown by the values in Tables 5 and 6. As stated before, component horizontal gradients, in Table 5, are calculated from well to well with no regard to the actual direction of groundwater flow. The values in this table are period-of-record averages for both sides of the river at every location with no seasonal or yearly partitioning. The magnitude values in Table 6, however, are calculated as a function of groundwater flow direction. The values in this table list gradient magnitude and direction of period-of-record averages for both sides of the river at every location with seasonal partitioning. Table B-5 in Appendix B demonstrates gradient magnitudes and directions at every site which are partitioned by season and year. Figures 9 and 10 are more visually appealing representations of horizontal-hydraulic gradient magnitudes and directions respectively. In table 6, the horizontal gradient values range from 0.003 on the east side of the I-25 location to 0.01 on the east side of the Pajarito location. All period-of-record average horizontal gradients are positive, indicating that groundwater is generally moving from the river toward the riverside drains. Most of the gradient values in Tables 5 and 6 are in reasonable agreement; however, since the calculations underlying Table 6 take horizontal direction into account, these values will primarily be used for further examination.

Table 5. Horizontal-hydraulic gradient (component) magnitudes measured from river to drain; step-wise from piezometer to piezometer.

	Alameda	Paseo Del Norte	Montano	Central	Barelas	Rio Bravo	Pajarito	I-25
East Side Mean	0.0112449	0.0104319	0.0090959	0.0055239	0.0110364	0.0044588	0.0115538	0.0027477

ERS1-EBS1	0.0217152	0.0087793	0.0053927	0.0047722	0.0134096	0.0027175	0.0123115	0.0026688
EBS1-EDWS1	0.0093196	0.0143619	0.0098355	0.0072555	0.0055425	0.0046601	0.0171077	0.0020839
EDWS1-EDES1	0.0087736			0.0020250	0.0201363	0.0029198	0.0050522	0.0015280
ERS2-EBS2	0.0098981	0.0098663	0.0102146	0.0062764	0.0093789	0.0046004	0.0143853	0.0024824
EBS2-EDWS2	0.0124326	0.0067746	0.0109410	0.0072795	0.0087711	0.0047533	0.0139006	0.0033867
EDWS2-EDES2	0.0053303	0.0123775		0.0055347	0.0089799	0.0071018	0.0065657	0.0043362
West Side Mean	0.0046794	0.0079635	0.0037040	0.0059784	-0.0121345	0.0074295	0.0053329	0.0061686
WRS1-WBS1	0.0057191	0.0056548	0.0040211	0.0034317	0.0060727	0.0072686	0.0046708	0.0145445
WBS1-WDES1	0.0019480	0.0053377	0.0018734	0.0050131	0.0098853	0.0072286	0.0075469	0.0032563
WDES1-WDWS1	0.0061249	0.0203198	0.0172483	0.0069526	-0.0606502	0.0048422	0.0016057	
WRS2-WBS2	0.0049152	0.0053647	0.0022099	0.0030173	0.0115791	0.0057791	0.0051455	0.0027721
WBS2-WDES2	0.0048863	0.0053103	0.0042298	0.0047937	0.0256630	0.0076761	0.0076957	0.0041014
WDES2-WDWS2	0.0044828	0.0057936	-0.0073585	0.0126623	-0.0653570	0.0117826		

Table 6. Horizontal-hydraulic gradient magnitudes and directions; partitioned by location and season; directions are in degrees relative to the downstream river bank orientation; that is, degrees counter clockwise from the river-bank orientation for east-side locations, and degrees clockwise from river-bank orientation on the west-side locations.

Magnitude	POR	Spring	Summer	Fall	Winter
Alameda East Side	0.0279614	0.0291549	0.0252951	0.0275937	0.0307386
Alameda West Side	0.0045499	0.0049631	0.0047759	0.0041105	0.0041733
Paseo Del Norte East Side	0.0099237	0.0102568	0.0092748	0.0093389	0.0107255
Paseo Del Norte West Side	0.0054250	0.0062134	0.0054398	0.0049107	0.0051034
Montano East Side	0.0099322	0.0112617	0.0097123	0.0085745	0.0099057
Montano West Side	0.0036141	0.0036161	0.0036039	0.0035925	0.0036432
Central East Side	0.0064904	0.0073010	0.0062373	0.0058608	0.0064353
Central West Side	0.0041946	0.0046354	0.0041764	0.0038159	0.0039575
Barelas East Side	0.0094989	0.0102607	0.0090624	0.0084964	0.0101012
Barelas West Side	0.0090082	0.0102882	0.0088989	0.0079938	0.0087262
Rio Bravo East Side	0.0045831	0.0049718	0.0046974	0.0039193	0.0045201
Rio Bravo West Side	0.0084245	0.0106201	0.0101745	0.0056984	0.0071835
Pajarito East Side	0.0145680	0.0158324	0.0138080	0.0133873	0.0151394
Pajarito West Side	0.0066121	0.0073823	0.0061765	0.0062123	0.0066350
I-25 East Side	0.0028150	0.0042223	0.0021764	0.0018925	0.0028638
I-25 West Side	0.0053314	0.0059280	0.0050855	0.0050757	0.0051511
Direction	**POR**	**Spring**	**Summer**	**Fall**	**Winter**

Alameda East Side	87.21519	87.41507	85.65591	87.19995	89.23822
Alameda West Side	71.78782	78.77316	69.24898	63.32796	75.54057
Paseo Del Norte East Side	86.88853	87.98372	86.77925	85.73683	86.97731
Paseo Del Norte West Side	81.09615	84.08082	80.61265	79.00688	79.80584
Montano East Side	93.93909	96.12334	93.20975	92.01873	94.06121
Montano West Side	65.24151	59.82240	75.88008	68.15043	39.52979
Central East Side	85.78123	85.85102	86.74118	84.65219	85.72198
Central West Side	85.93176	86.78739	85.65285	85.19466	85.76337
Barelas East Side	82.17407	82.10844	82.44951	80.89975	83.16616
Barelas West Side	81.66279	83.06259	81.97404	79.80195	81.66164
Rio Bravo East Side	66.46001	68.65649	67.44519	63.02907	64.83006
Rio Bravo West Side	76.02341	75.51880	74.39701	75.89667	78.40470
Pajarito East Side	92.99721	92.98856	93.05928	92.87397	93.05392
Pajarito West Side	73.15662	72.09471	74.79123	74.21672	70.96830
I-25 East Side	78.41175	84.58949	75.43859	73.32602	79.60758
I-25 West Side	65.30341	66.71596	65.13423	64.61114	64.51357

Figure 9. Horizontal-hydraulic gradient magnitudes; partitioned by location and season.

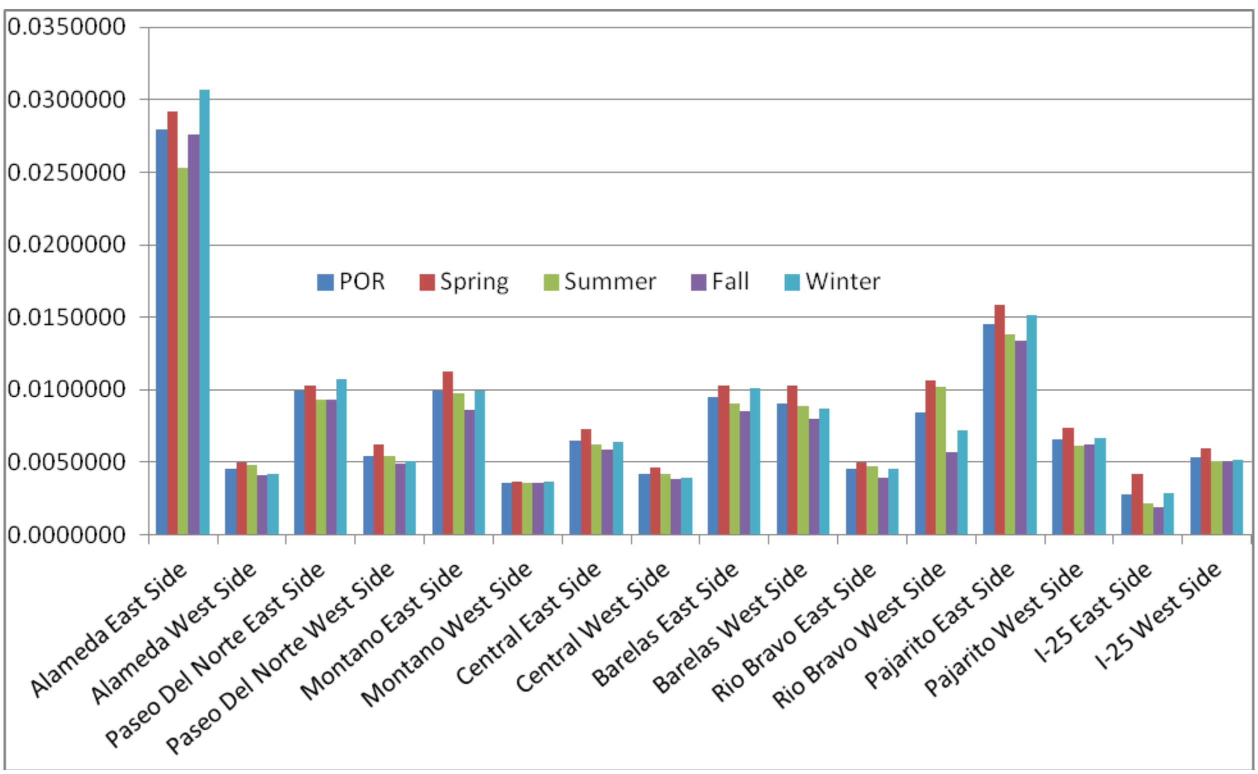
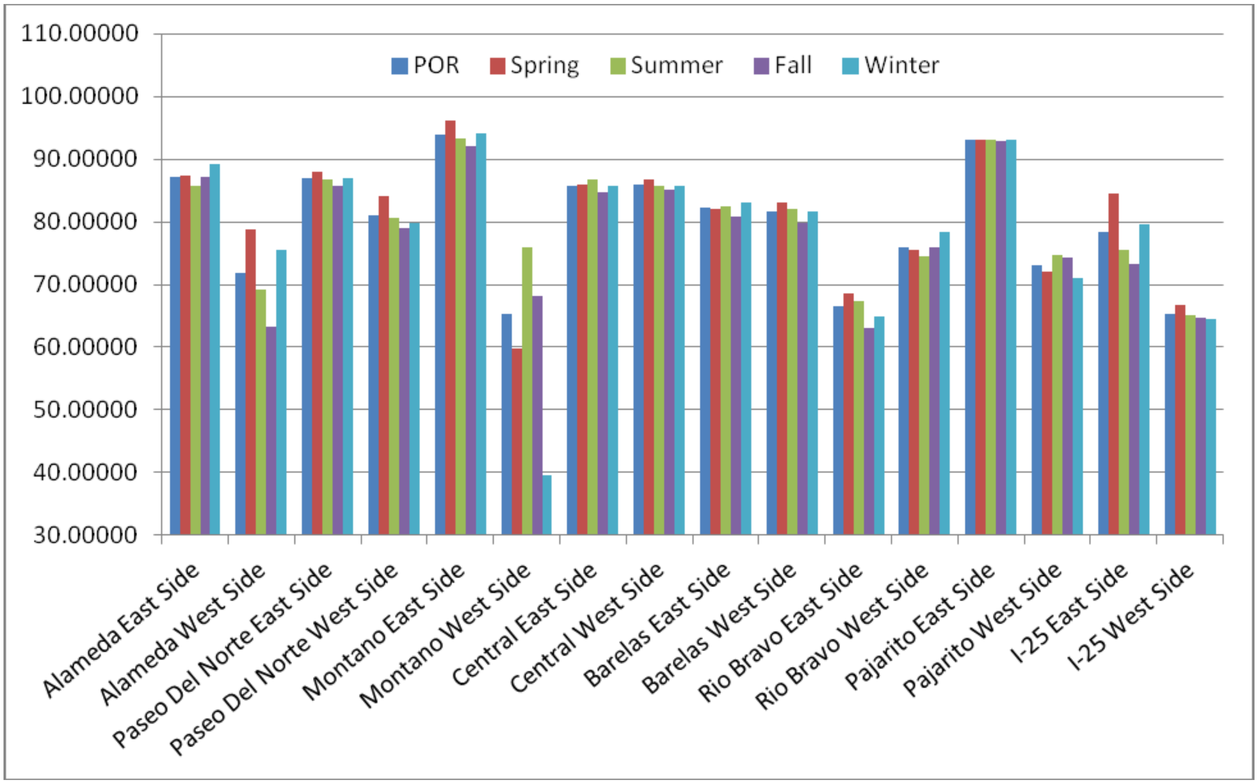


Figure 10. Horizontal-hydraulic gradient directions; partitioned by location and season.



There are no significant seasonal changes in horizontal gradient magnitude according to the values in Table 6; however, at five locations (Alameda, Paseo Del Norte, Montano, Rio Bravo, and Pajarito), there is a stark contrast between east and west-side gradients. Figure 9 displays this contrast well. The higher gradients are on the east side at these locations except for Rio Bravo and they range from 1.5 to almost 6 times the gradient magnitudes on the opposite side of the river. The Rio Grande generally flows along the banks at these locations, with little to no sand bars, even during periods of low discharge. However, the same condition is true at some locations with a much lower horizontal gradient.

The horizontal-gradient magnitudes on Alameda's east side are relatively extreme as are the vertical gradients. Unlike the vertical gradients however, it does not appear to be one site throwing off the average. The horizontal gradients on Alameda's east side are relatively high at most sites.

Another factor that appears to have a strong influence on the horizontal gradients is biological health. At all five locations, the side of the river with much higher gradient magnitude is also markedly less densely vegetated. Some of these areas have experienced devastating fires and other areas have been allowed to grow rampant with Russian Olive, Salt Cedar, and Cottonwood trees. Vegetation density at the other three locations is about equal on both sides of the river (Central, Barelas, and I-25). In 2006, a bosque fire near the I-25 transects burned much of the vegetation on both sides of the river but primarily on the west side. Accordingly, the horizontal gradient is somewhat higher on the west side at I-25. According to Table B-5, every site at the I-25 location, east and west sides, experiences the highest horizontal magnitude values on site record a year or two after the 2006 fire. After a couple years of recovery and the generous planting of new trees, the gradient values have decreased. Unfortunately, much of the I-25 record began in 2006 so there is not much data prior to this fire.

The Montano transects, if installed then, would have been impacted by a large bosque fire in 2003. The fire burned vegetation on both sides of the river which still appeared badly scarred in 2011. The transects at Montano were not constructed until 2006 so no pre-fire baseline is available. Horizontal gradients in 2011 are very similar to those in 2006. Burnt trees and light vegetation density on the east side at Pajarito indicate that a bosque fire occurred there many years before the transects were constructed in 2009; and horizontal gradient magnitudes remain relatively high throughout their period of operation (2009 to 2011). The fire on the east side at Barelas in 2011 burned several acres of vegetation and destroyed several Transect 2 piezometers. A good pre-fire baseline is available but the Bosque Project ended shortly after the fire was extinguished therefore no post-fire data is available.

The horizontal gradient directions in Table 6 indicate the directions that groundwater flow takes after it leaks from the Rio Grande. Darcy's Law,

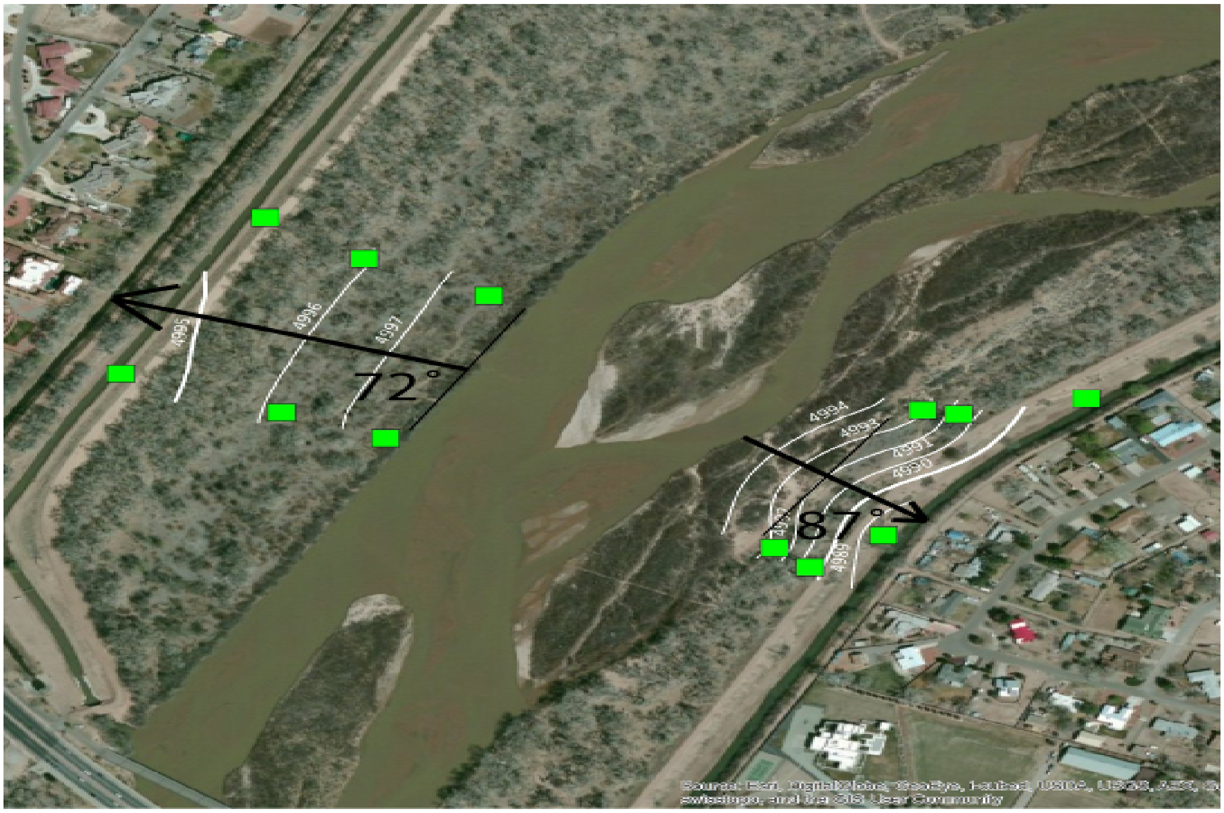
$$Q = -KA({}^{dh}/_{dl})$$

states that groundwater leakage moves perpendicular to its surface water source under ideal conditions. Generally, horizontal groundwater gradient directions in this study are close to perpendicular but with a slight downstream angle. The gradient angles calculated are relative to the downstream river bank: counter-clockwise on the east-side sites and clockwise on the west-side sites. The only sites with gradients consistently in the upstream direction (>90°) are on the east side of the river at Montano and Pajarito. Figure 11 illustrates period-of-record horizontal gradient directions at every location along with average static groundwater elevation contours and average gradient magnitudes. The arrow lengths in Figure 11 only refer to the study area boundaries and do not correspond to any gradient values.

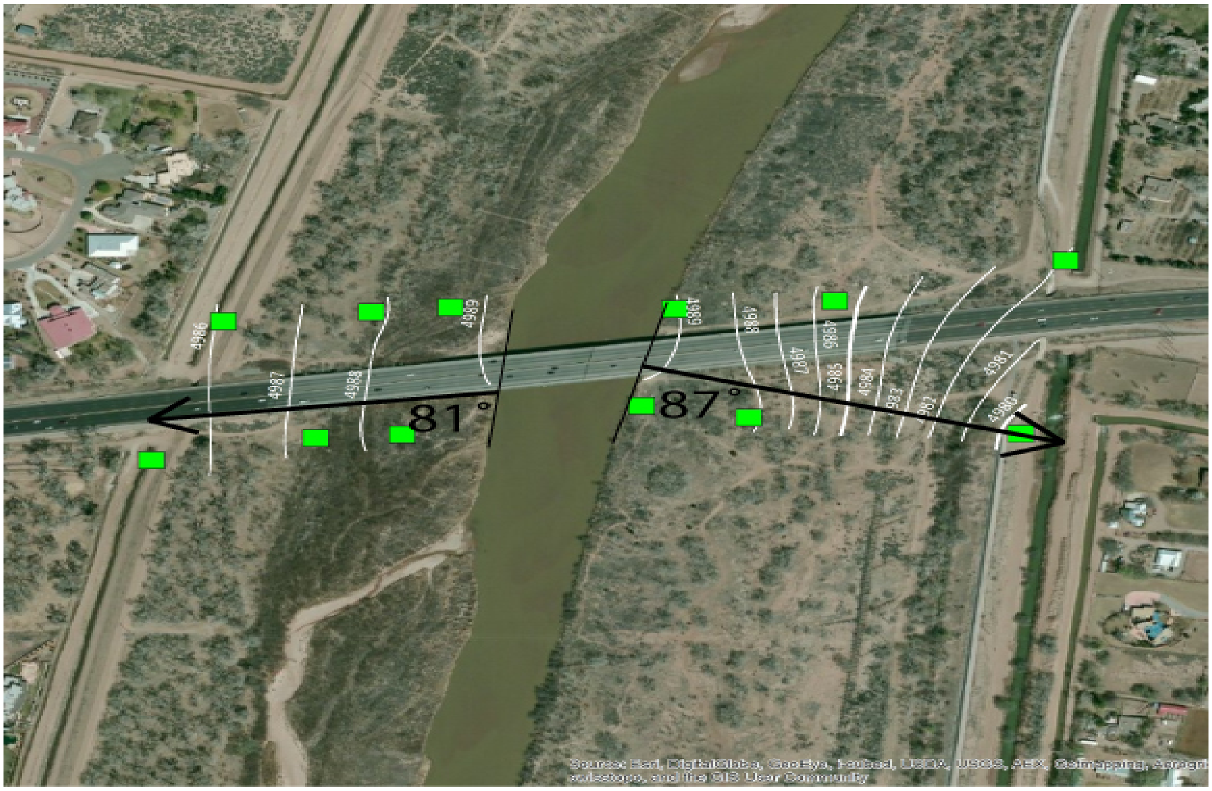
There are uncertainties associated with this method of calculating horizontal gradient directions especially arising from the arbitrary positioning of the angle along a river bank that fluctuates at some of the locations. On the east side at Alameda, for example, higher river flows during the spring bring the river bank to within 10 ft of the riverside piezometers. However, during lower flows, as is seen in Figure 11a, the river bank is closer to 30 ft from the piezometers. The shape of the bank fluctuates at this site as well. More accurate determination of the gradient angle at this location would require frequent aerial photographs to verify bank extent and shape fluctuations. This is a consideration at several other transects as well. Most of the river banks in this study, however, maintain their position year round making one-time satellite images effective in the alignment of angles at multiple time scales. Other uncertainties may exist with instrumentation drift.

Figure 11(a-h). Images of locations with piezometer and surface-water-stage gage markers; period-of-record horizontal gradient directions; static groundwater elevation contours; and horizontal gradient magnitudes.

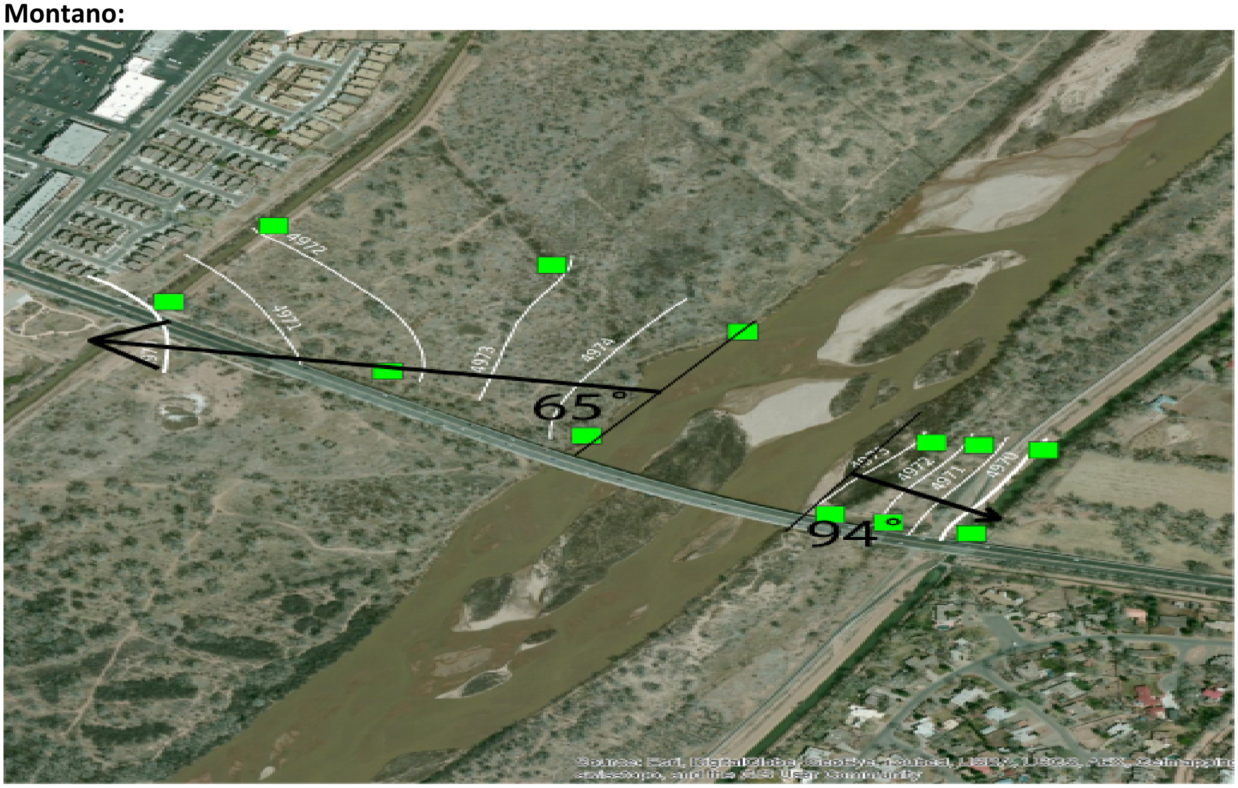
Alameda:



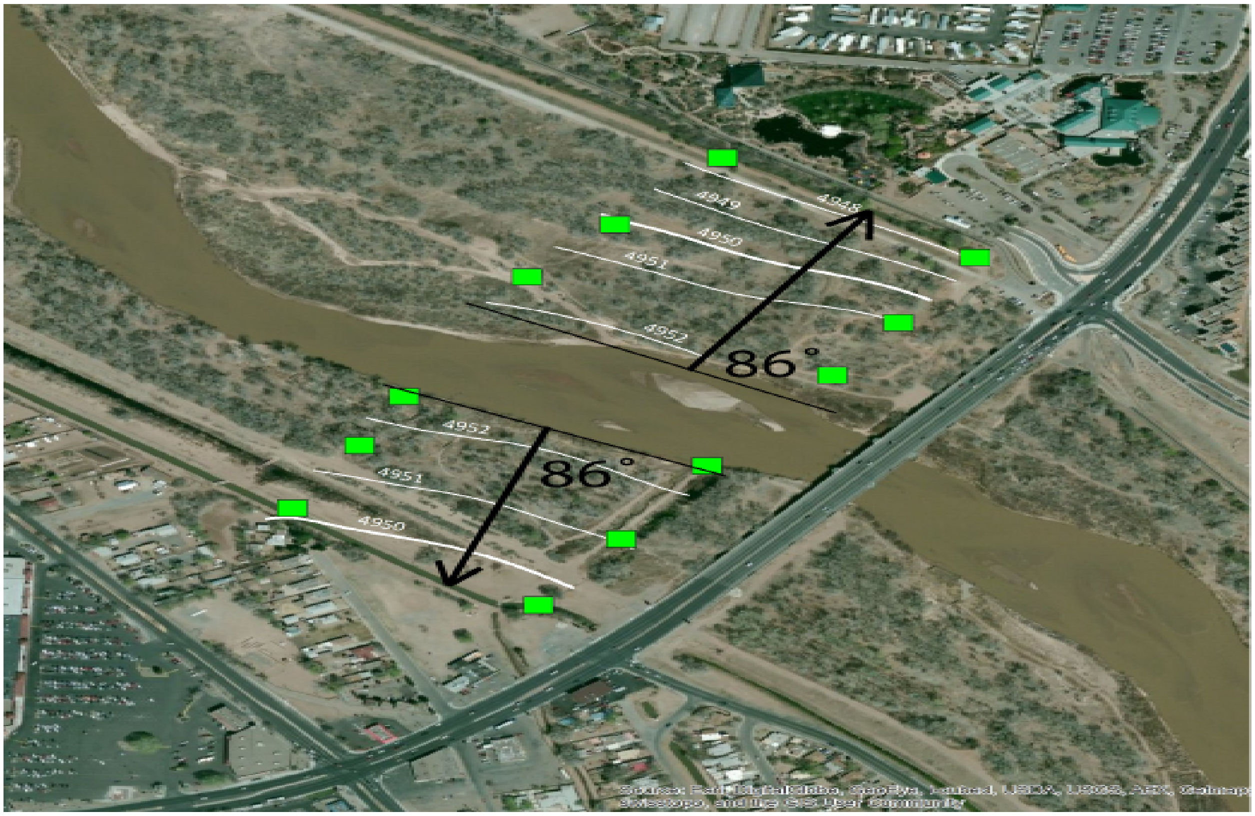
Paseo Del Norte:



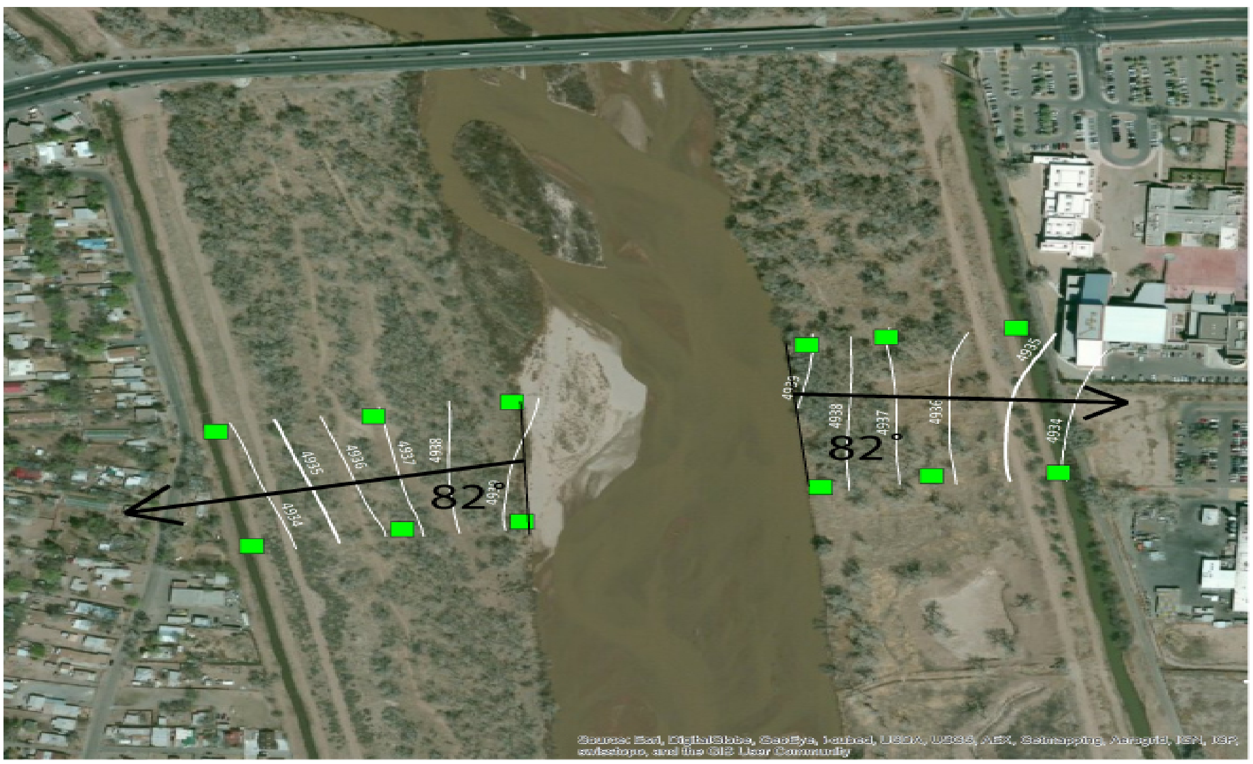
Montano:



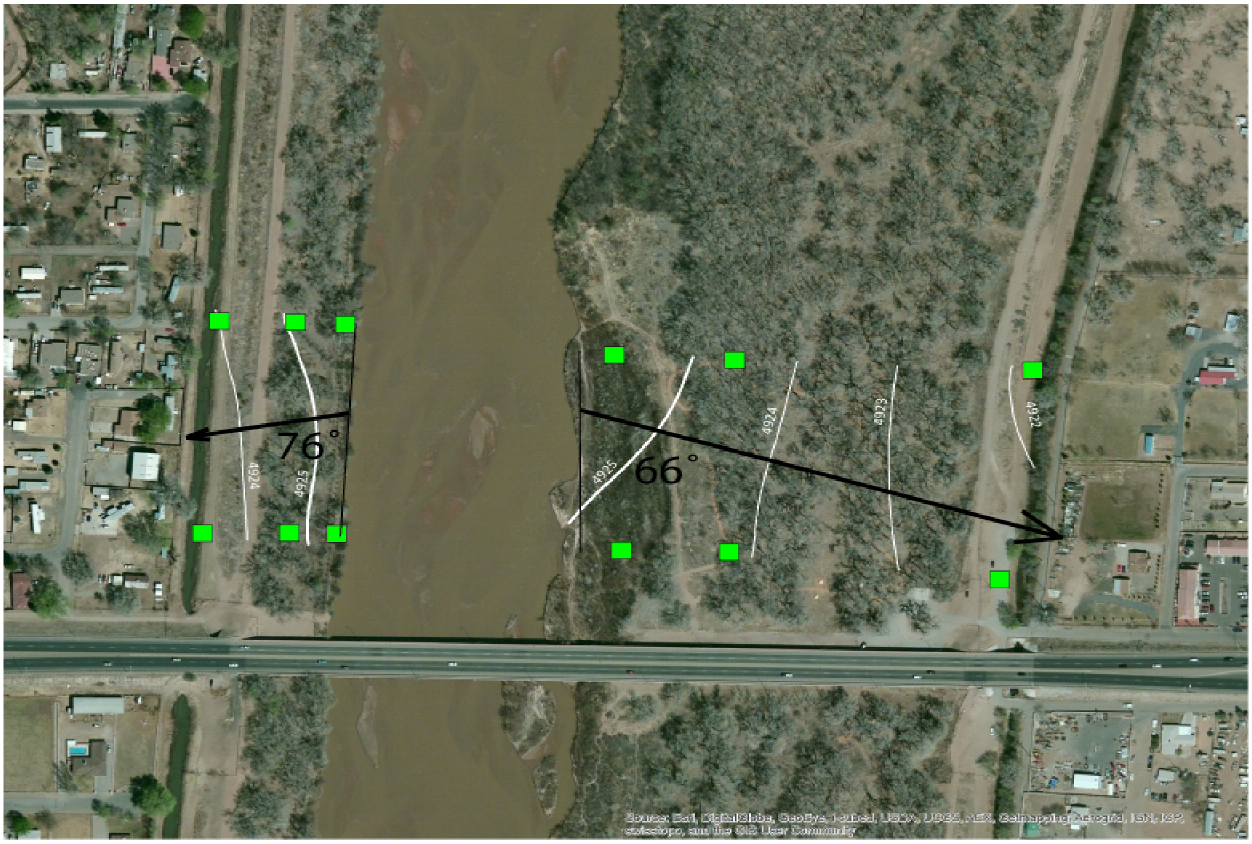
Central:



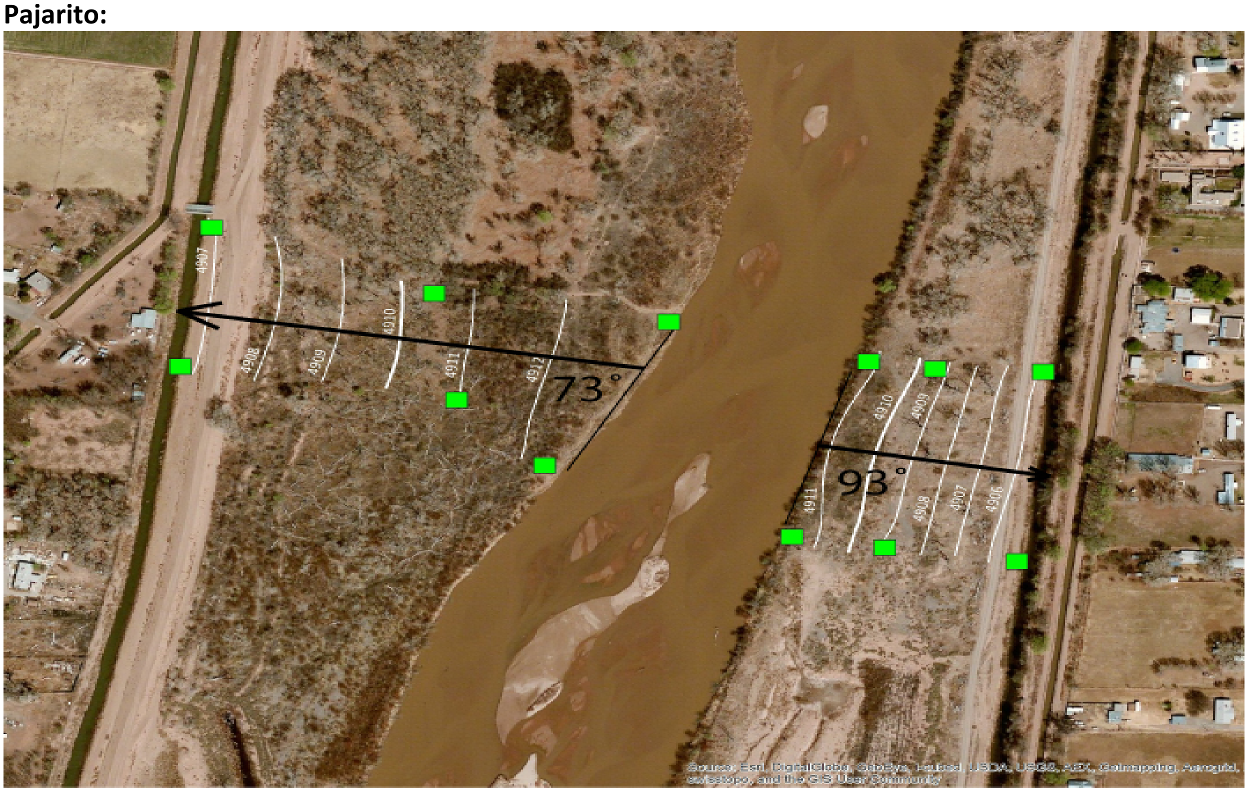
Barelas:



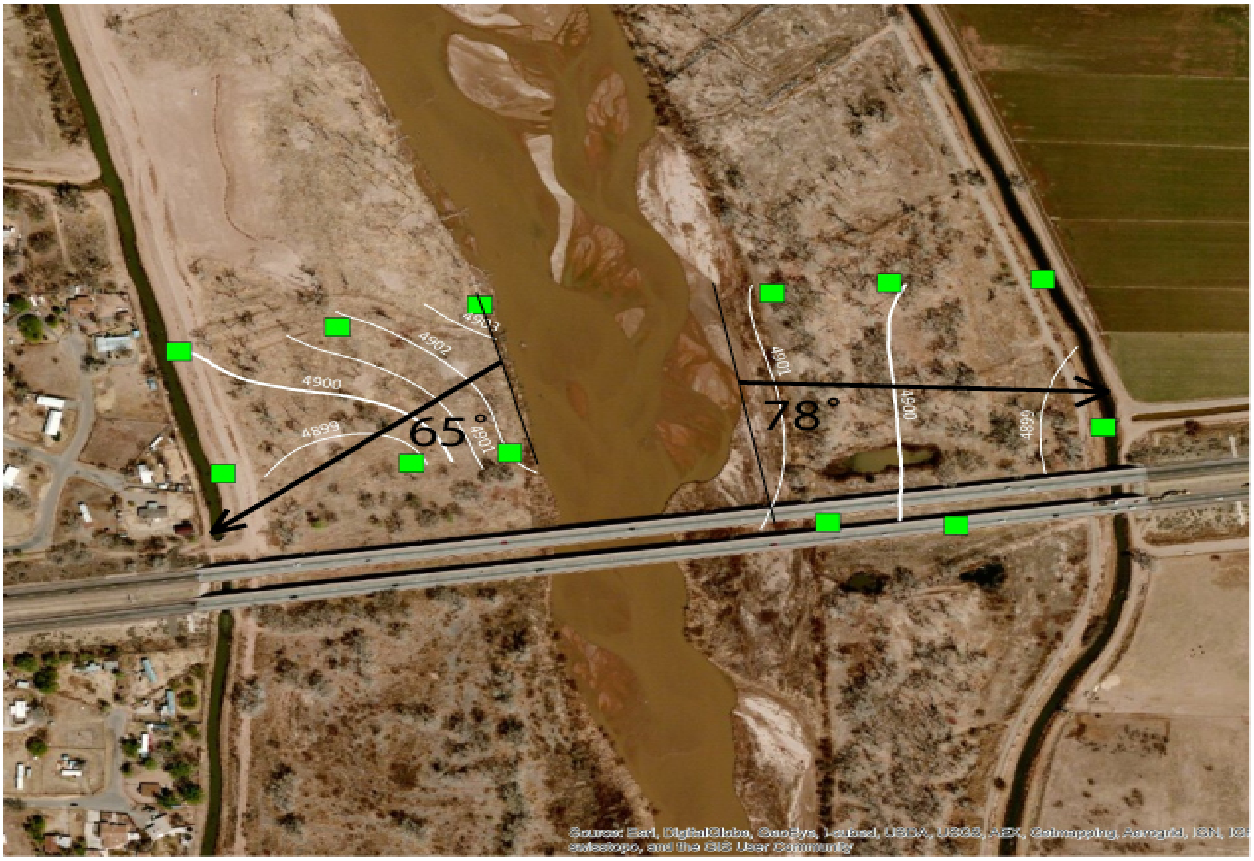
Rio Bravo:



Pajarito:



Interstate 25:



Many of the sites that experience higher magnitudes of gradient also experience higher angles of groundwater flow. For example, the west-side average period-of-record gradient direction at Alameda is 71.79° and the magnitude is 0.00455; whereas on the east side, direction is 87.22° and the magnitude is 0.02796. The densely vegetated bosque at Alameda's west side sites appears to shape lower gradient angles just as it seems to form lower gradient magnitudes. The average period-of-record gradient direction for all locations in the network is 79° (in a downstream direction relative to Rio Grande discharge). The two areas with the highest angles of flow are the east sides at Montano and Pajarito (93.94° and 93.00° respectively, in an upstream direction relative to Rio Grande discharge) which also have high gradient magnitudes and low vegetation density. The gradient directions at Central and Barelas (about 86° and 82° respectively) are approximately equal between the east and west sides. Gradient magnitudes and vegetation density at these two locations are also very similar. The season with the highest magnitudes and directions, at most locations, is spring which coincides with snowmelt runoff and higher discharge in the Rio Grande. Analysis of gradients with Rio Grande discharge is discussed in the next section.

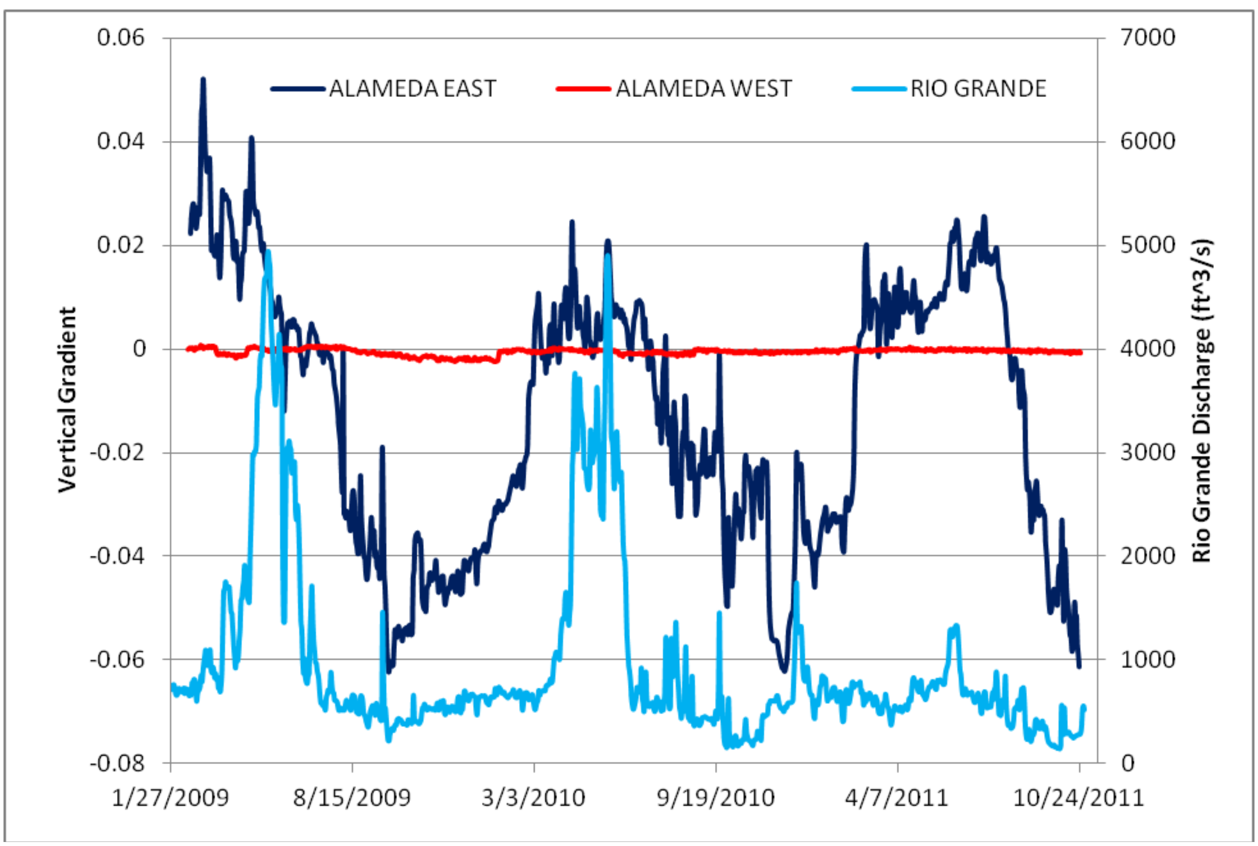
Rio Grande Discharge

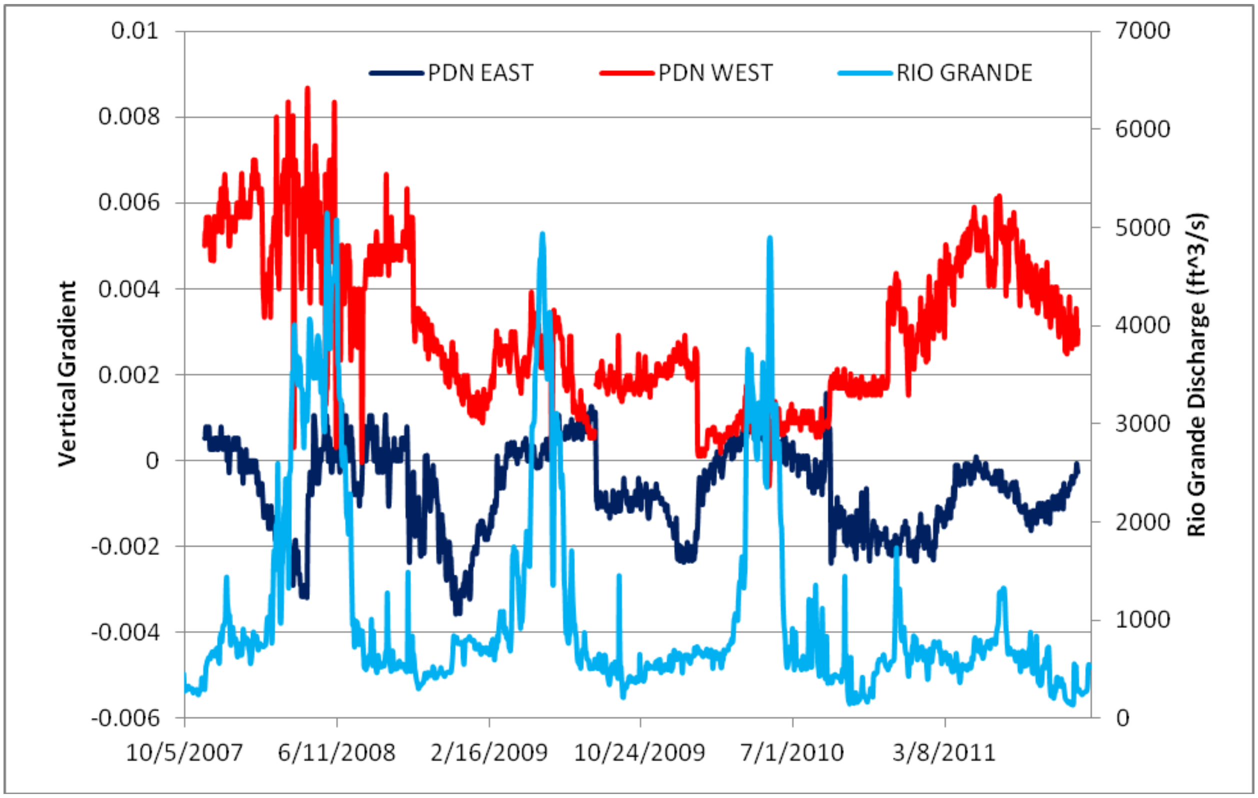
Surface-water discharge is the primary driver of groundwater gradients in the bosque as seen by the calculations in Table 7. Discharge was used for correlation analysis rather than river stage because the USGS provides a longer record of discharge and because daily values are readily available. Since high flow pulses in the river are described by discharge or stage, correlation analysis was carried out using discharge in this study. Higher gradients signify less separation between the riverside drain floors and the alluvial aquifer. Table 7 shows seasonal and yearly partitioning of Rio Grande discharge, east and west extents of drain floor/aquifer connectivity, vertical gradients, and horizontal gradient magnitudes and directions. High confidence resides with the seasonal values in this table; however, since many sites were not constructed until 2009, the yearly values should not be directly compared (prior to 2009 anyway). The charts in Figures 12 and 13 display Rio Grande discharge with east and west vertical gradients and horizontal gradients, respectively, at every location. These charts were used to display continuous correlations between surface-water discharge and gradient magnitudes.

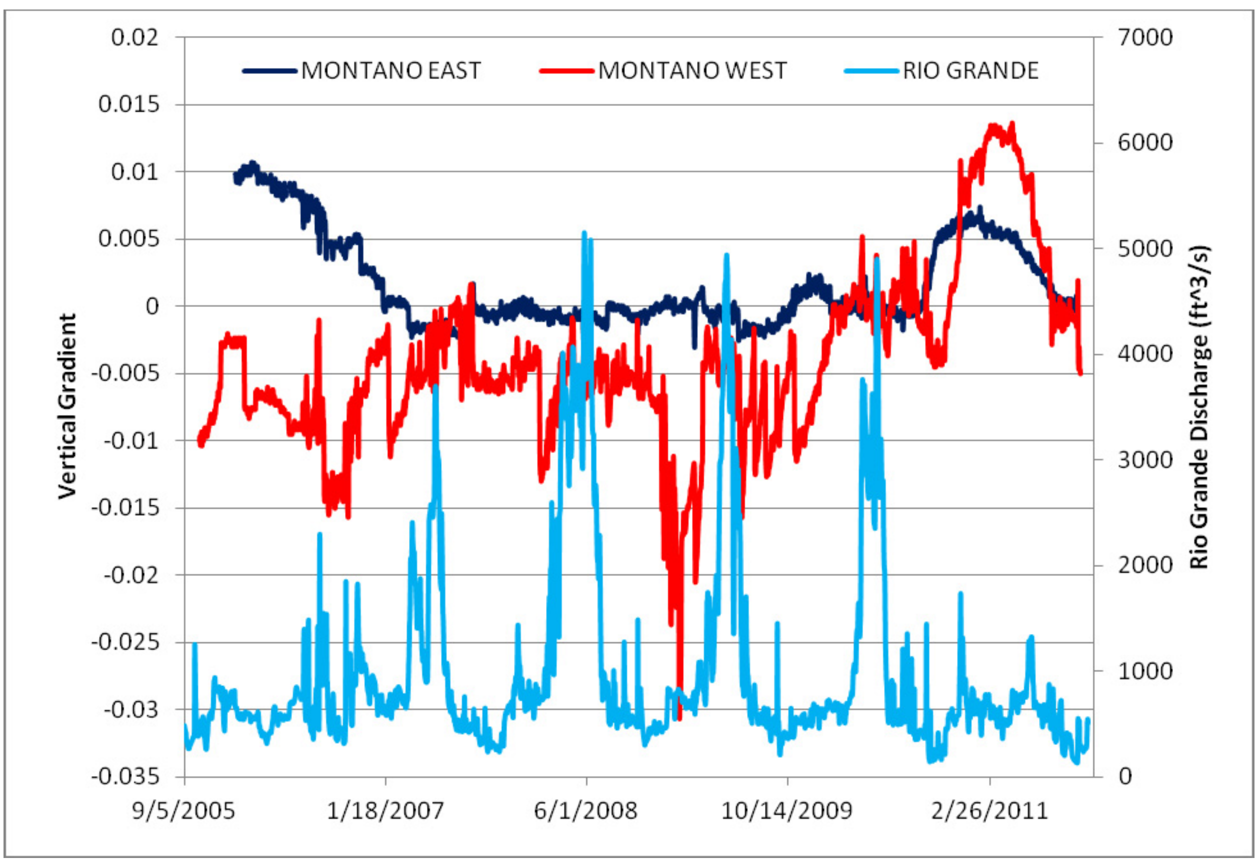
Table 7. Correlations of Rio Grande discharge with riverside drain extents of connectivity, vertical and horizontal gradient magnitudes, and horizontal gradient directions; partitioned by season and year.

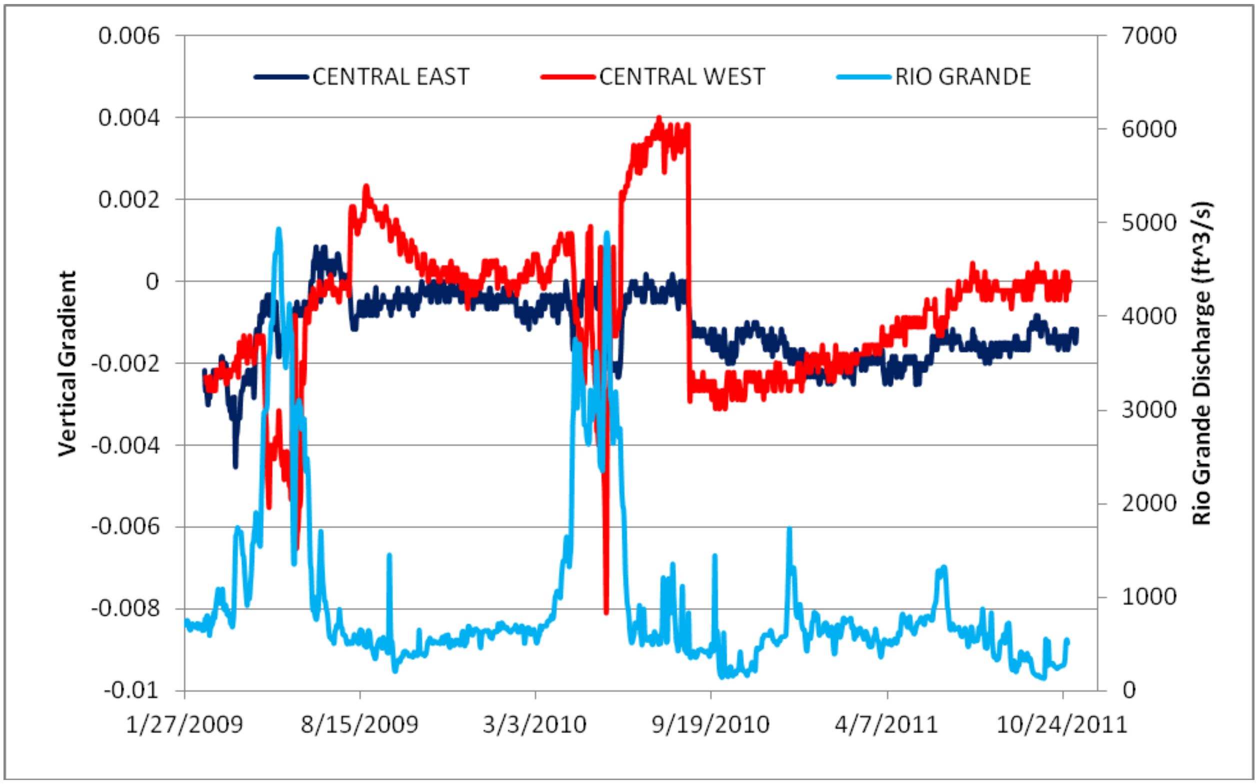
	Rio Grande Discharge (ft^3/s)	Eastside Riverside drain connectivity (ft)	Westside Riverside drain connectivity (ft)	Vertical Gradient (ft/ft)	Horizontal Gradient (ft/ft)	Eastside Horizontal Gradient Direction	Westside Horizontal Gradient Direction
POR	1035.66	1.96	0.68	0.00290	0.00831	84.23	75.03
Spring	1874.87	2.11	0.91	0.00207	0.00918	85.71	75.86
Summer	1041.03	2.28	0.63	0.00240	0.00804	83.85	75.96
Fall	474.24	1.93	0.48	0.00383	0.00753	82.47	73.78
Winter	711.76	1.41	0.66	0.00368	0.00844	84.58	72.02
2004	722.39	1.56	2.03	-0.00097			
2005	1600.48	1.53	2.58	0.00659	0.00392	54.96	
2006	707.63	0.41	0.83	0.00420	0.00649	84.52	76.50
2007	931.91	0.65	2.85	0.00253	0.00635	79.67	75.13
2008	1517.52	1.61	2.75	0.00399	0.00674	81.01	77.82
2009	1122.60	1.97	0.69	0.00456	0.00875	84.64	74.18
2010	1048.72	2.43	0.82	0.00279	0.00825	84.39	72.27
2011	583.20	2.35	0.70	0.00173	0.00759	83.94	75.41

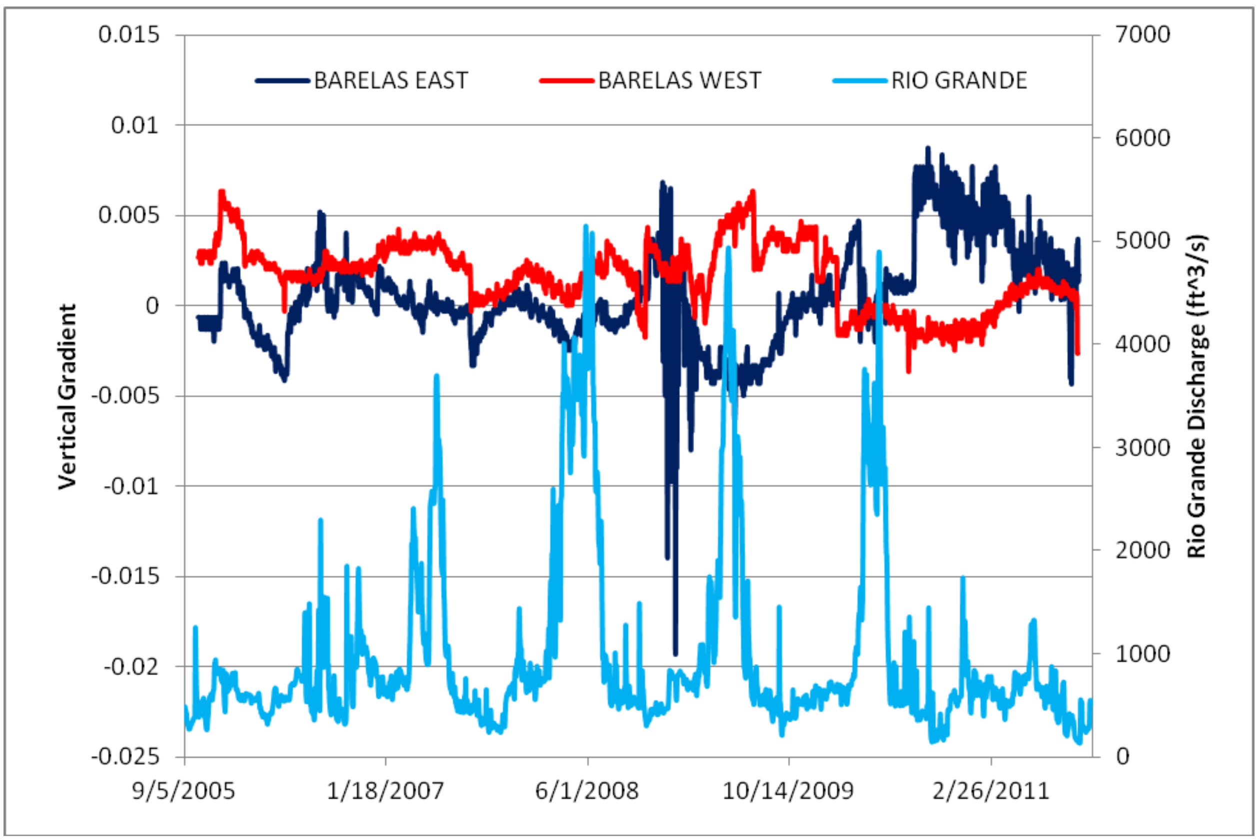
Figure 12(a-h). Charts demonstrate correlation between Rio Grande discharge and east/west vertical gradient magnitudes; continuous daily gradient on left axis and river discharge in ft^3/s on right axis.

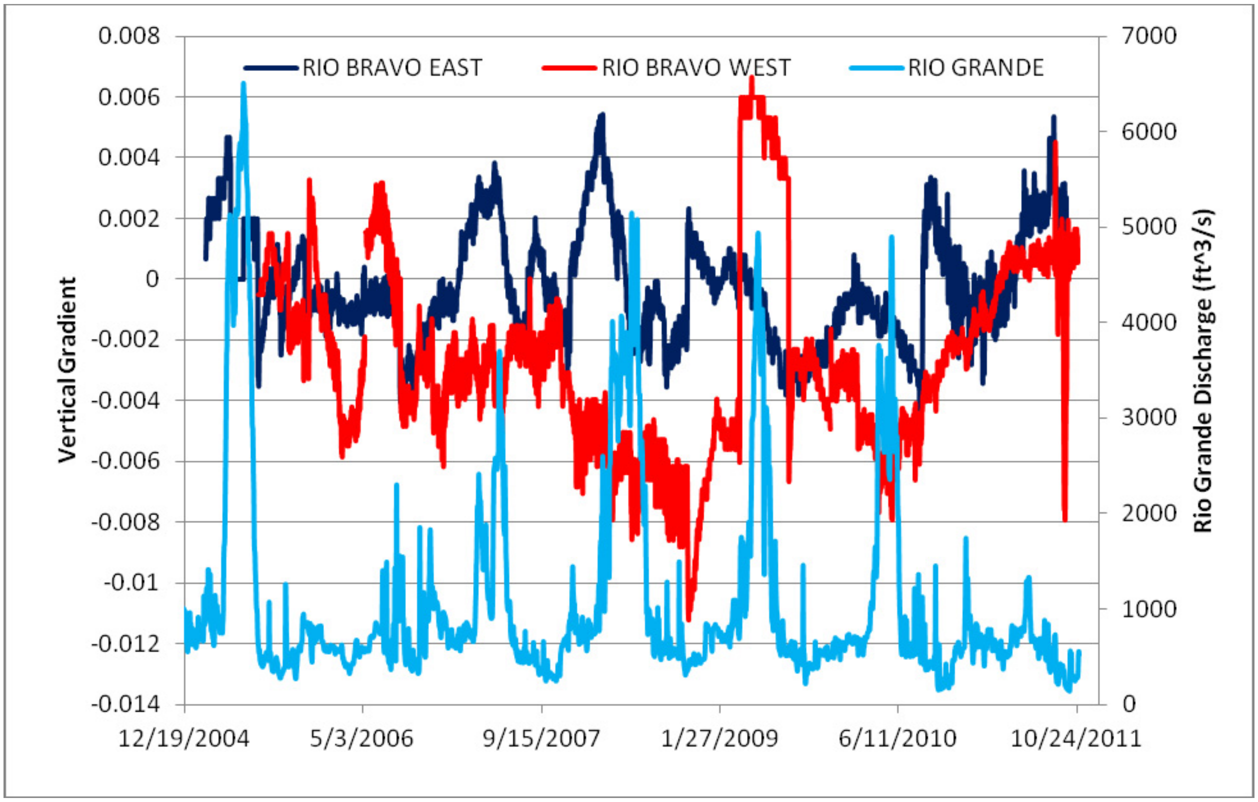


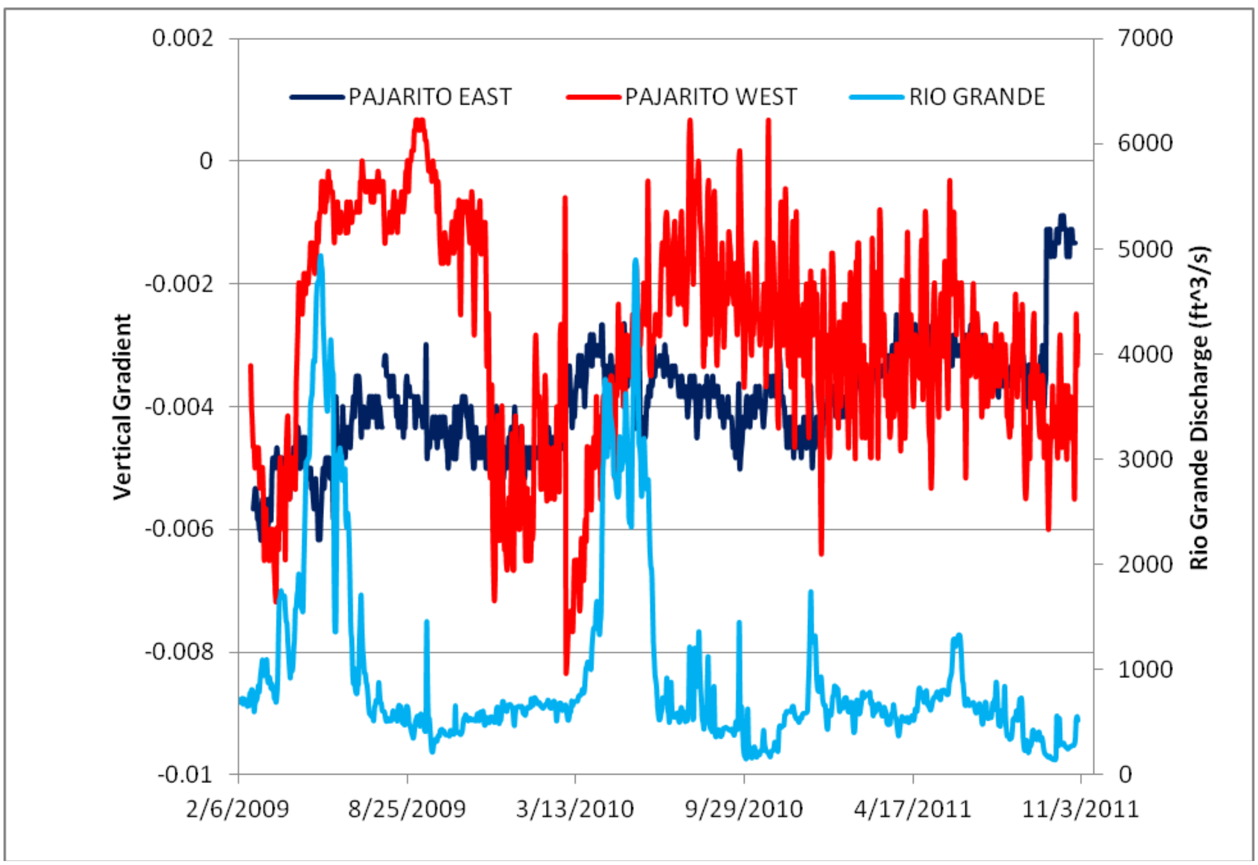

PDN EAST
PDN WEST
RIO GRANDE
Vertical Gradient
Rio Grande Discharge (ft^3/s)
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
7000
6000
5000
4000
3000
2000
1000
0
10/5/2007
6/11/2008
2/16/2009
10/24/2009
7/1/2010
3/8/2011


MONTANO EAST
MONTANO WEST
RIO GRANDE
Vertical Gradient
Rio Grande Discharge (ft^3/s)
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.025
-0.03
-0.035
7000
6000
5000
4000
3000
2000
1000
0
9/5/2005
1/18/2007
6/1/2008
10/14/2009
2/26/2011


CENTRAL EAST
CENTRAL WEST
RIO GRANDE
Vertical Gradient
Rio Grande Discharge (ft^3/s)
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
7000
6000
5000
4000
3000
2000
1000
0
1/27/2009
8/15/2009
3/3/2010
9/19/2010
4/7/2011
10/24/2011


BARELAS EAST
BARELAS WEST
RIO GRANDE
Vertical Gradient
Rio Grande Discharge (ft^3/s)
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.025
7000
6000
5000
4000
3000
2000
1000
0
9/5/2005
1/18/2007
6/1/2008
10/14/2009
2/26/2011


RIO BRAVO EAST
RIO BRAVO WEST
RIO GRANDE
Vertical Gradient
Rio Grande Discharge (ft^3/s)
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
-0.012
-0.014
7000
6000
5000
4000
3000
2000
1000
0
12/19/2004
5/3/2006
9/15/2007
1/27/2009
6/11/2010
10/24/2011


PAJARITO EAST
PAJARITO WEST
RIO GRANDE
Vertical Gradient
Rio Grande Discharge (ft^3/s)
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
7000
6000
5000
4000
3000
2000
1000
0
2/6/2009
8/25/2009
3/13/2010
9/29/2010
4/17/2011
11/3/2011

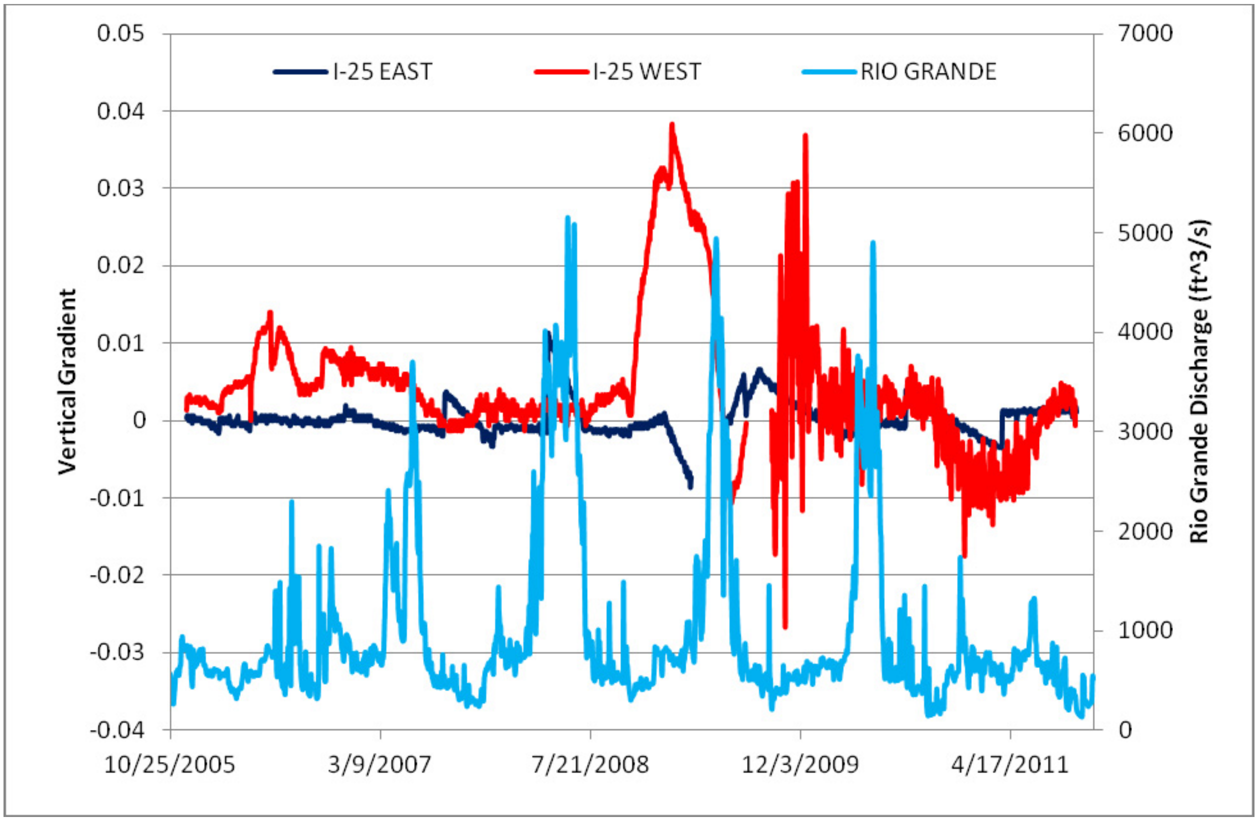
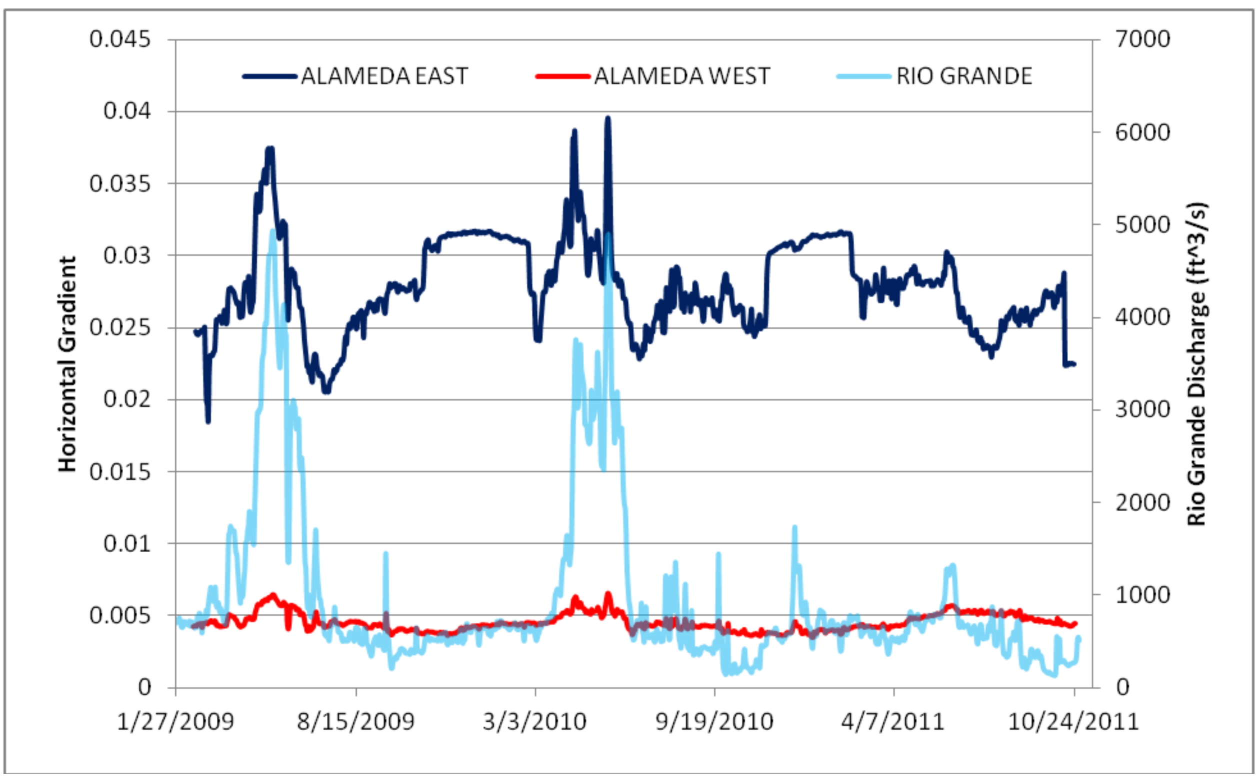
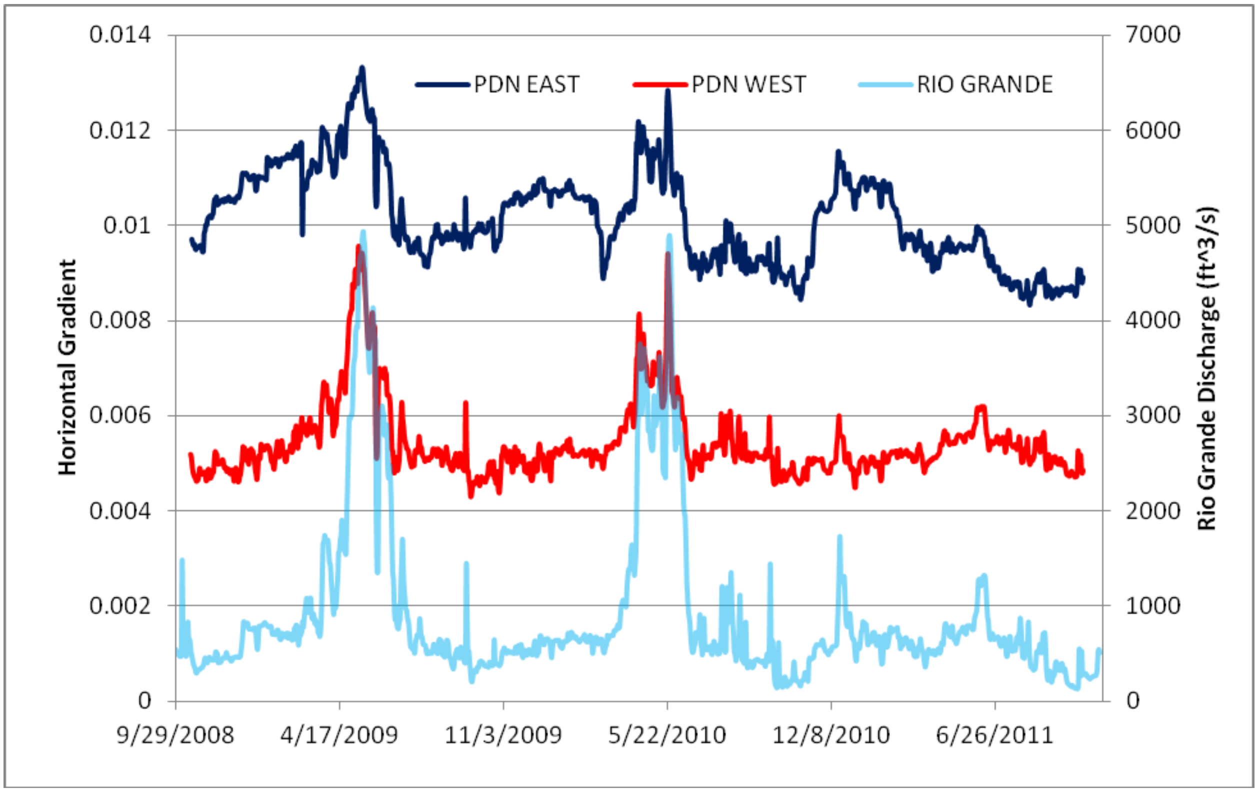
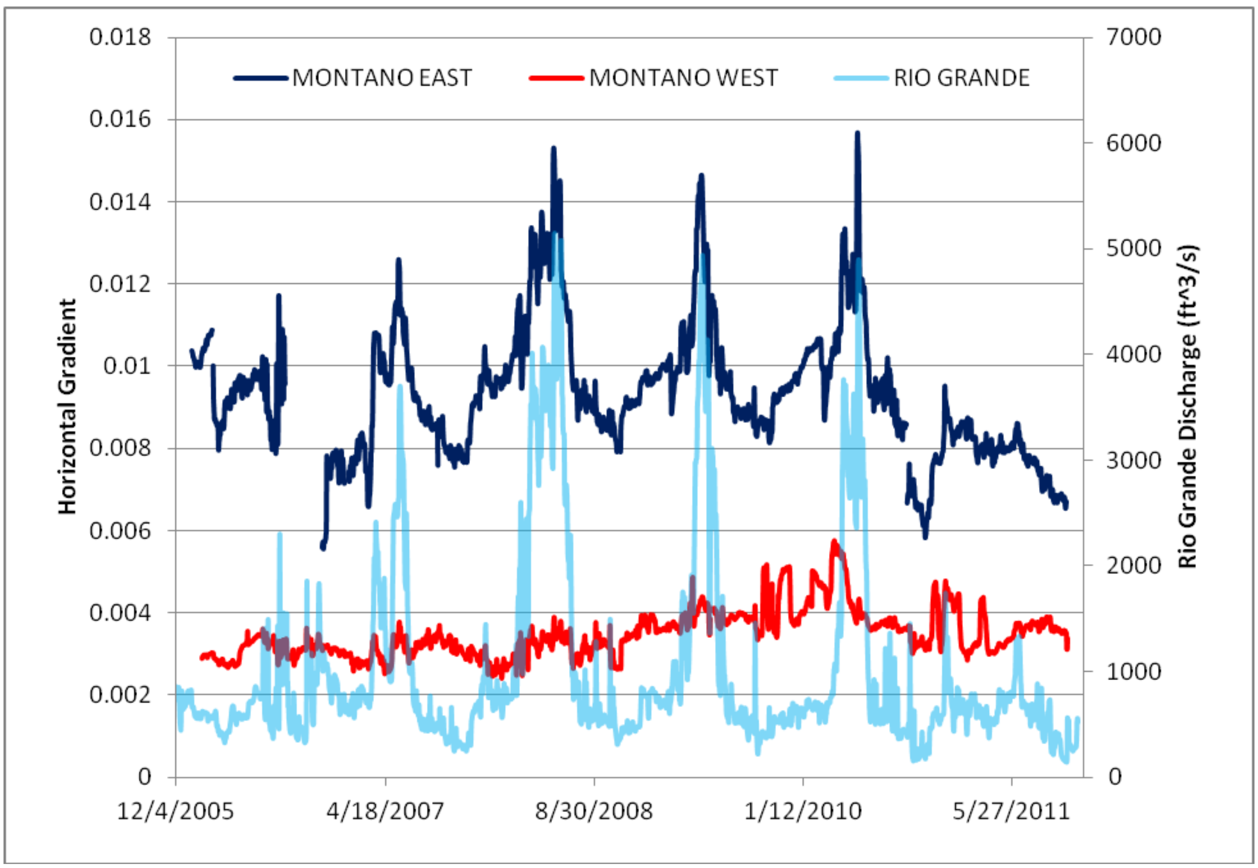


Figure 13(a-h). Charts demonstrate correlation between Rio Grande discharge and east/west horizontal gradient magnitudes; continuous daily gradient on left axis and river discharge in ft^3/s on right axis.

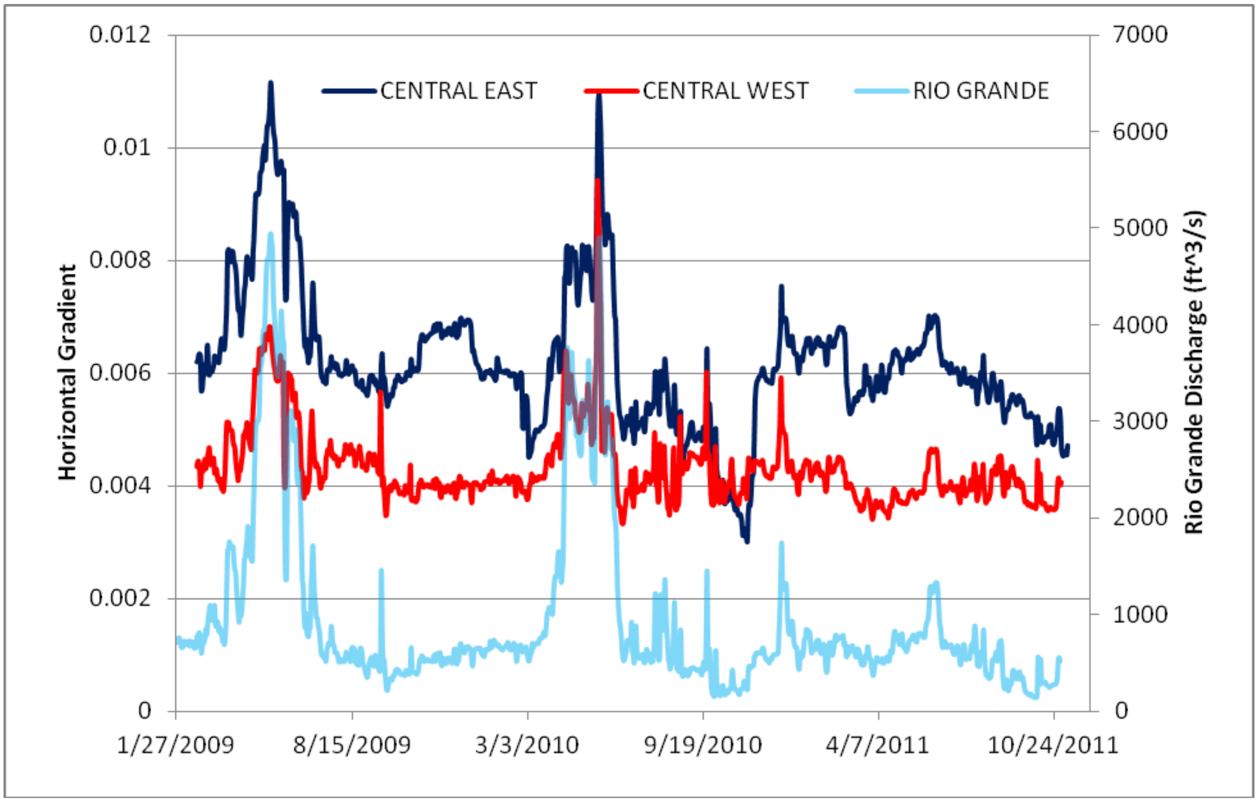


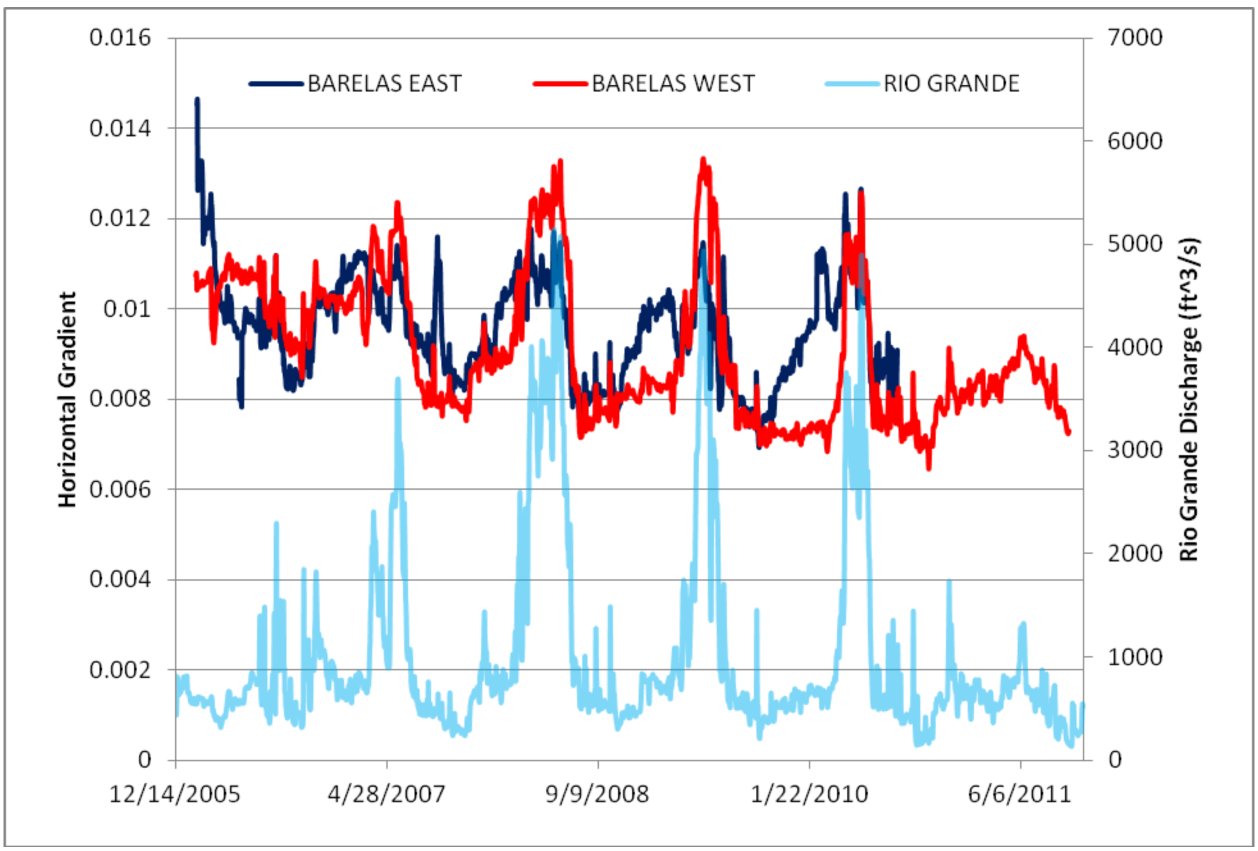


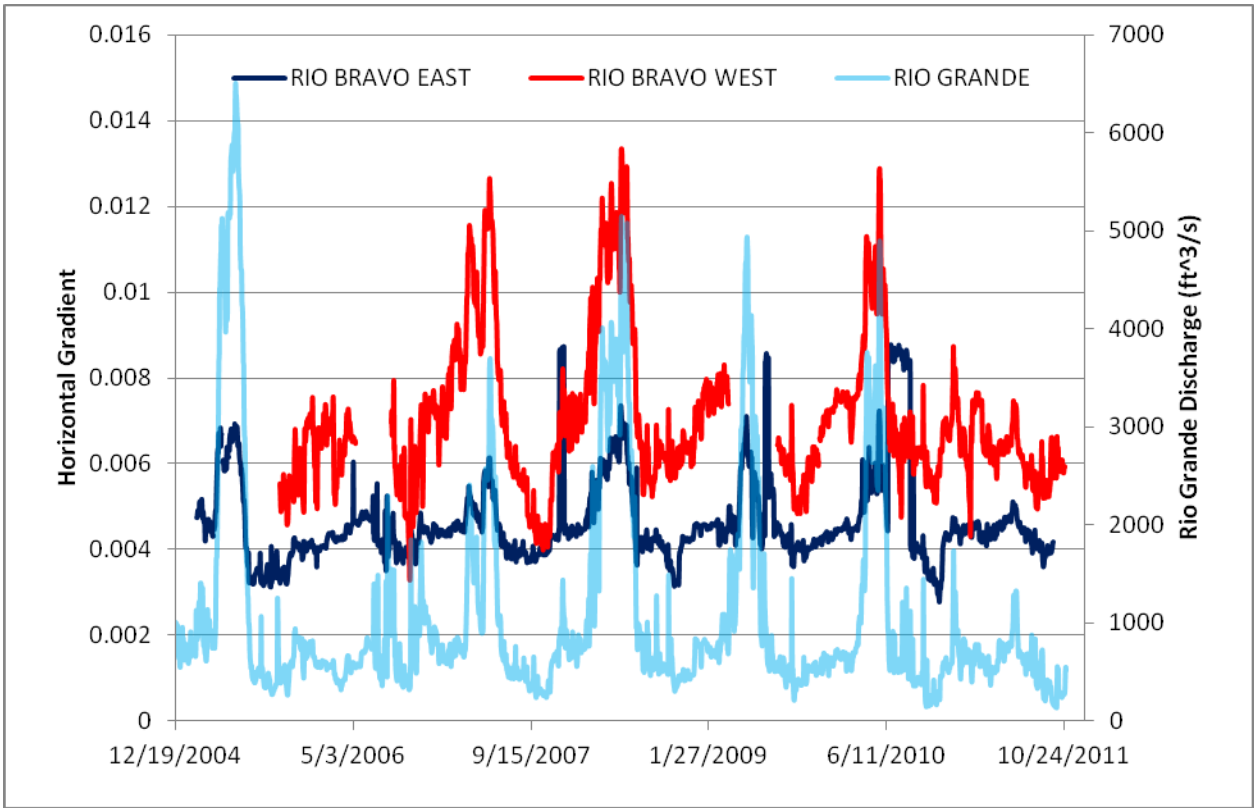
PDN EAST
PDN WEST
RIO GRANDE
Horizontal Gradient
Rio Grande Discharge (ft^3/s)
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
7000
6000
5000
4000
3000
2000
1000
0
9/29/2008
4/17/2009
11/3/2009
5/22/2010
12/8/2010
6/26/2011

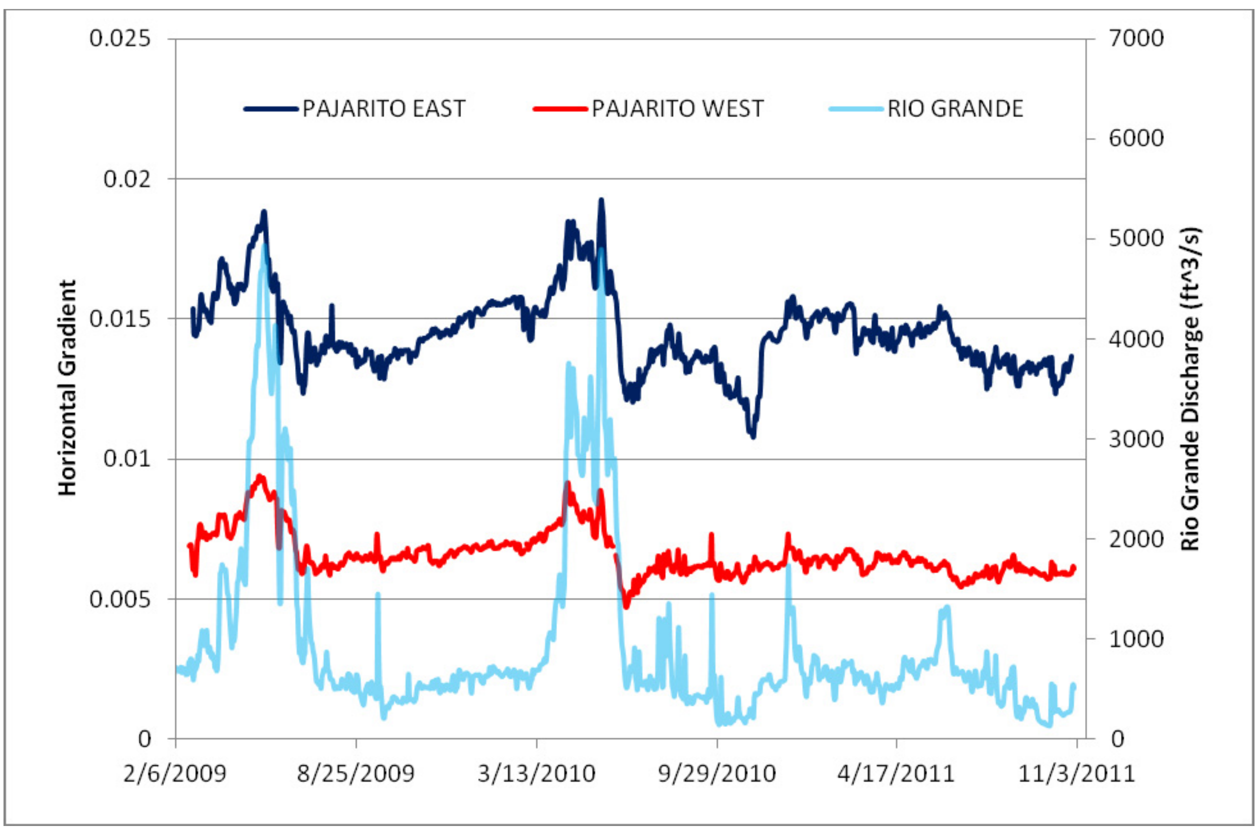


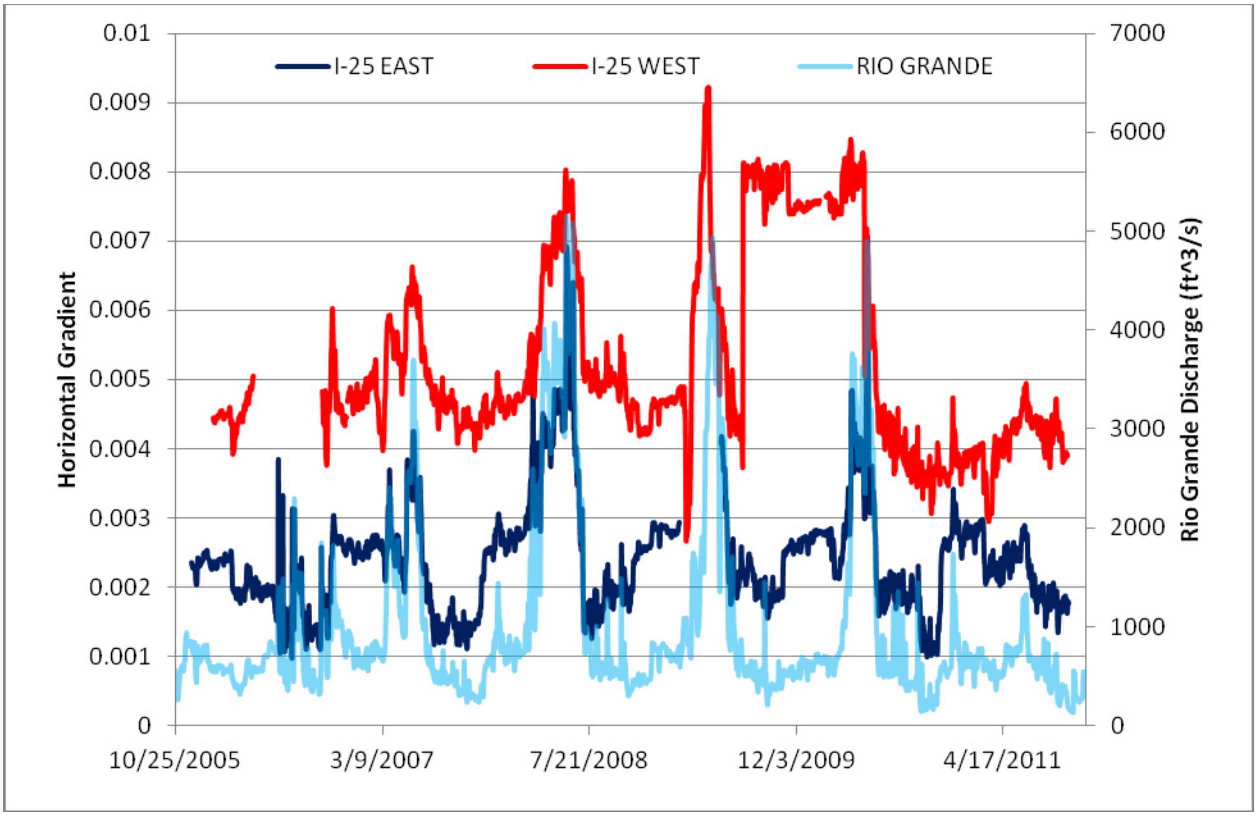
MONTANO EAST
MONTANO WEST
RIO GRANDE
Horizontal Gradient
Rio Grande Discharge (ft^3/s)
0.018
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
7000
6000
5000
4000
3000
2000
1000
0
12/4/2005
4/18/2007
8/30/2008
1/12/2010
5/27/2011


CENTRAL EAST
CENTRAL WEST
RIO GRANDE
Horizontal Gradient
Rio Grande Discharge (ft^3/s)
0.012
0.01
0.008
0.006
0.004
0.002
0
7000
6000
5000
4000
3000
2000
1000
0
1/27/2009
8/15/2009
3/3/2010
9/19/2010
4/7/2011
10/24/2011


BARELAS EAST
BARELAS WEST
RIO GRANDE
Horizontal Gradient
Rio Grande Discharge (ft^3/s)
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
7000
6000
5000
4000
3000
2000
1000
0
12/14/2005
4/28/2007
9/9/2008
1/22/2010
6/6/2011


RIO BRAVO EAST
RIO BRAVO WEST
RIO GRANDE
Horizontal Gradient
Rio Grande Discharge (ft^3/s)
0.016
0.014
0.012
0.01
0.008
0.006
0.004
0.002
0
7000
6000
5000
4000
3000
2000
1000
0
12/19/2004
5/3/2006
9/15/2007
1/27/2009
6/11/2010
10/24/2011


PAJARITO EAST
PAJARITO WEST
RIO GRANDE
Horizontal Gradient
Rio Grande Discharge (ft^3/s)
0.025
0.02
0.015
0.01
0.005
0
7000
6000
5000
4000
3000
2000
1000
0
2/6/2009
8/25/2009
3/13/2010
9/29/2010
4/17/2011
11/3/2011



The association between Rio Grande discharge and connectivity between the riverside drains and the alluvial aquifer is shown in Table 7. The results, as expected, demonstrate that spring and summer months bring about the highest values of connectivity since river discharge also experiences maximum values during those months.

Rio Grande discharge does not appear to have a strong influence on vertical gradients in the bosque according to most of the charts in Figure 12. Three exceptions include Alameda, Paseo Del Norte, and Pajarito which do appear to demonstrate some correlation to the less densely vegetated side of the river. At Alameda, two spring-time peaks of increased vertical gradients correlate nicely with Rio Grande discharge in 2009 and 2010 but not in 2011. This apparent disconnection between river discharge and vertical gradient in 2011 is not understood. Conversely, the vertical gradient for the densely vegetated west side at Alameda appears to have little correlation with river discharge.

The east side of the river at Paseo Del Norte and Pajarito also appear to show some correlation with river discharge. These two areas of relatively high correlation with river discharge are also less densely vegetated areas that demonstrate higher vertical and horizontal gradient magnitudes and higher horizontal gradient direction angles. Most of the charts in Figure 12 appear to show good associations during small periods of time. For example, on the west sides at Paseo Del Norte, Central, and Rio Bravo, some river discharge peaks line up well with gradient peaks. During most of the records at these areas, however, little to no correlation is observed. The west side vertical gradient curves for the Central and Rio Bravo locations contain shifts that require an explanation: occasionally piezometers are damaged or destroyed so data may be unavailable for prolonged periods of time and since the gradient data displayed in Figure 12 are averaged over all sites in that area, missing data at one site will cause a shift in the total average for that area. River bank erosion damaged the transect 2 west riverside piezometers at Central in 2010 and dead transducer batteries plagued some of the west-side sites at Rio Bravo during 2009.

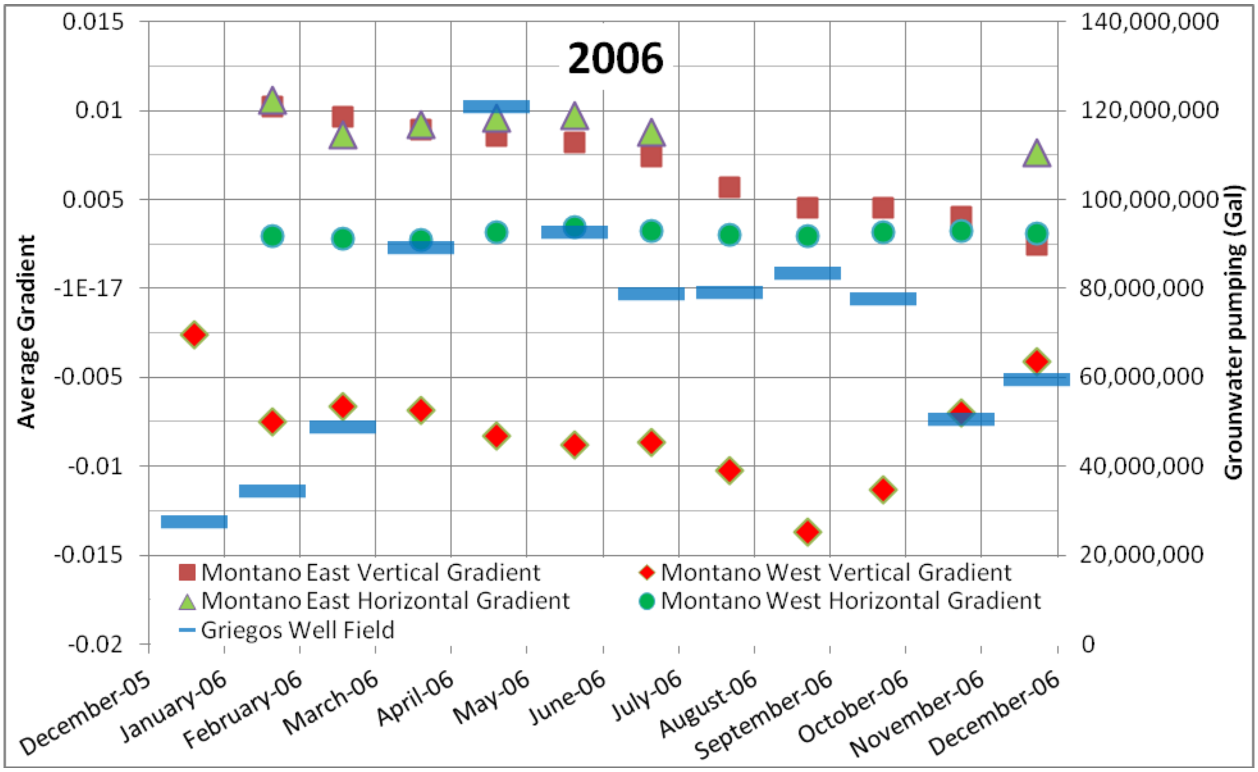
When the vertical gradient is averaged over both sides of the river at every location, the maximum gradient occurs during the fall months (0.00383) while Rio Grande discharge is at its maximum during the spring months (1875 ft^3/s) according to Table 7. Rio Grande discharge is lowest during the fall months (474 ft^3/s) while vertical gradient is lowest during the spring months (0.00207). Since infiltration of river water to the surrounding banks depends on stage rather than discharge, it is important to note that a change in discharge is comparable to a change in stage at a stationary location in the river. The stark contrast between discharge and vertical gradients is not fully understood but may have a lot to do with bosque vegetation and the period of time between initial surface-water leakage and arrival of that same water to piezometers in the bosque. At more vast areas of bosque such as Montano's west side, this lag time would be large relative to narrow areas of bosque such as Alameda's east side. Larger areas of bosque generally indicate larger lag times; therefore, gradient peaks are often delayed some period of time following discharge peaks. Vast areas of bosque also appear to have a dampening effect on the vertical gradients. For example, on Alameda's west side, vertical gradient values fluctuate very little according to the chart in Figure 12.

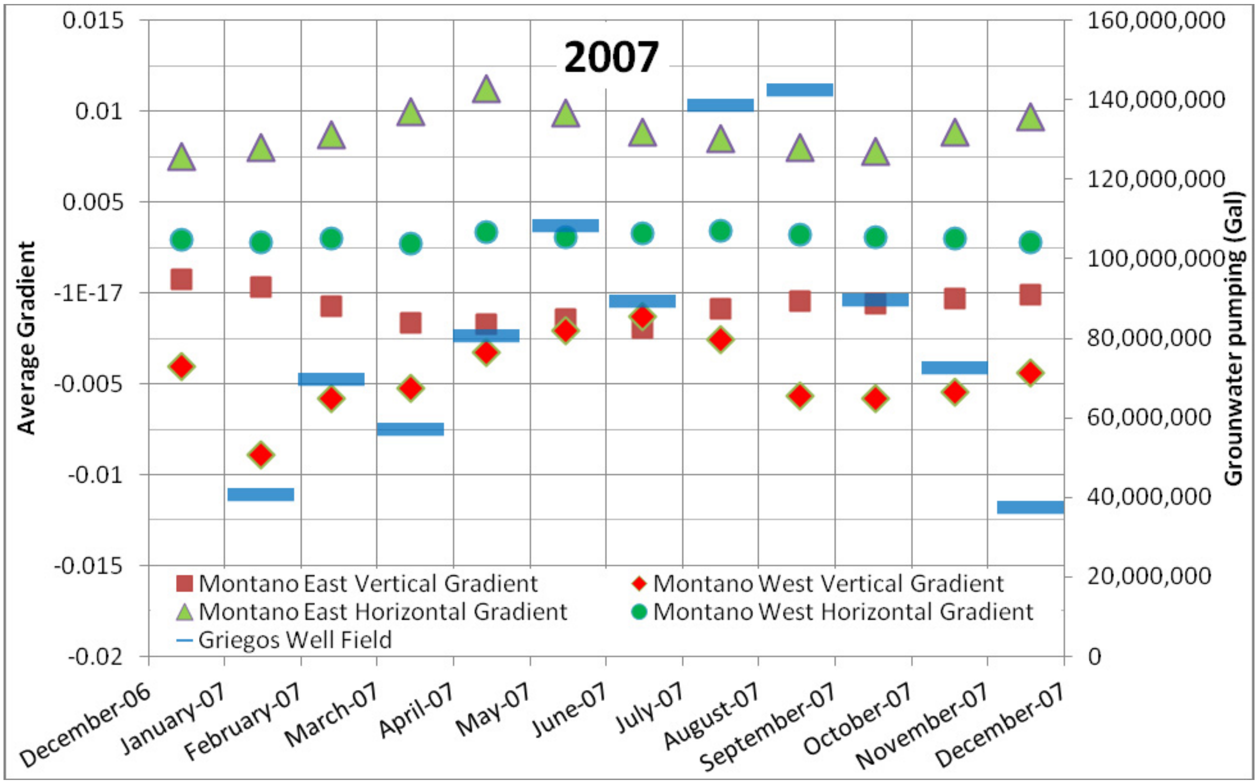
Rio Grande discharge does appear to have a strong correlation with horizontal gradient magnitudes as all of the charts in Figure 13 demonstrate. The strongest correlations appear to lie with the areas that hold the highest vertical and horizontal gradients (which also contain low vegetation density). The most notable examples are the east sides at Alameda, Paseo Del Norte, Montano, and Pajarito and the west side at Rio Bravo. Maximum horizontal gradient peaks, in Figure 13, correlate nicely with maximum river discharge peaks. Table 7 reveals this pattern in the same way; maximum gradients occur during the spring months. Winter months occupy the second highest horizontal gradients which can likely be described by lag time of water traveling from the river bank as surface-water leakage to the bosque piezometers as groundwater.

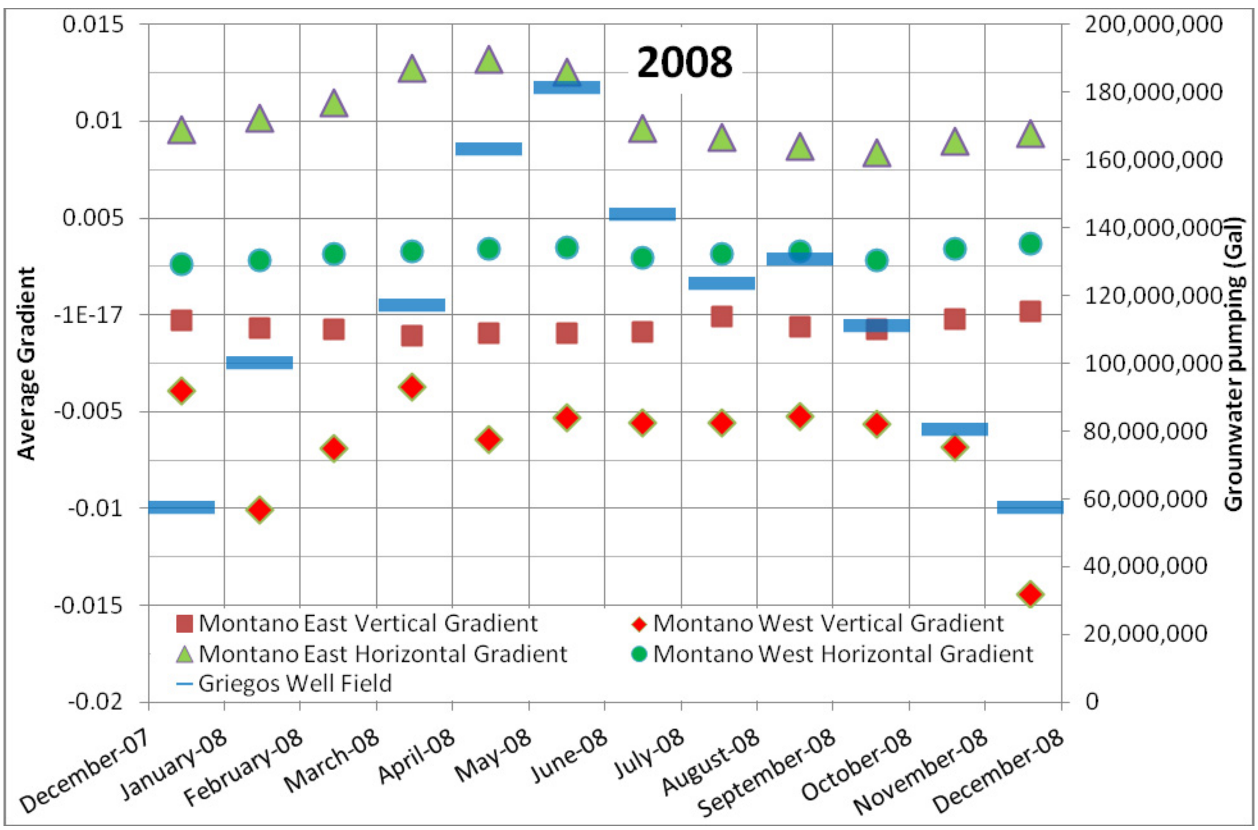
Municipal Groundwater Pumping

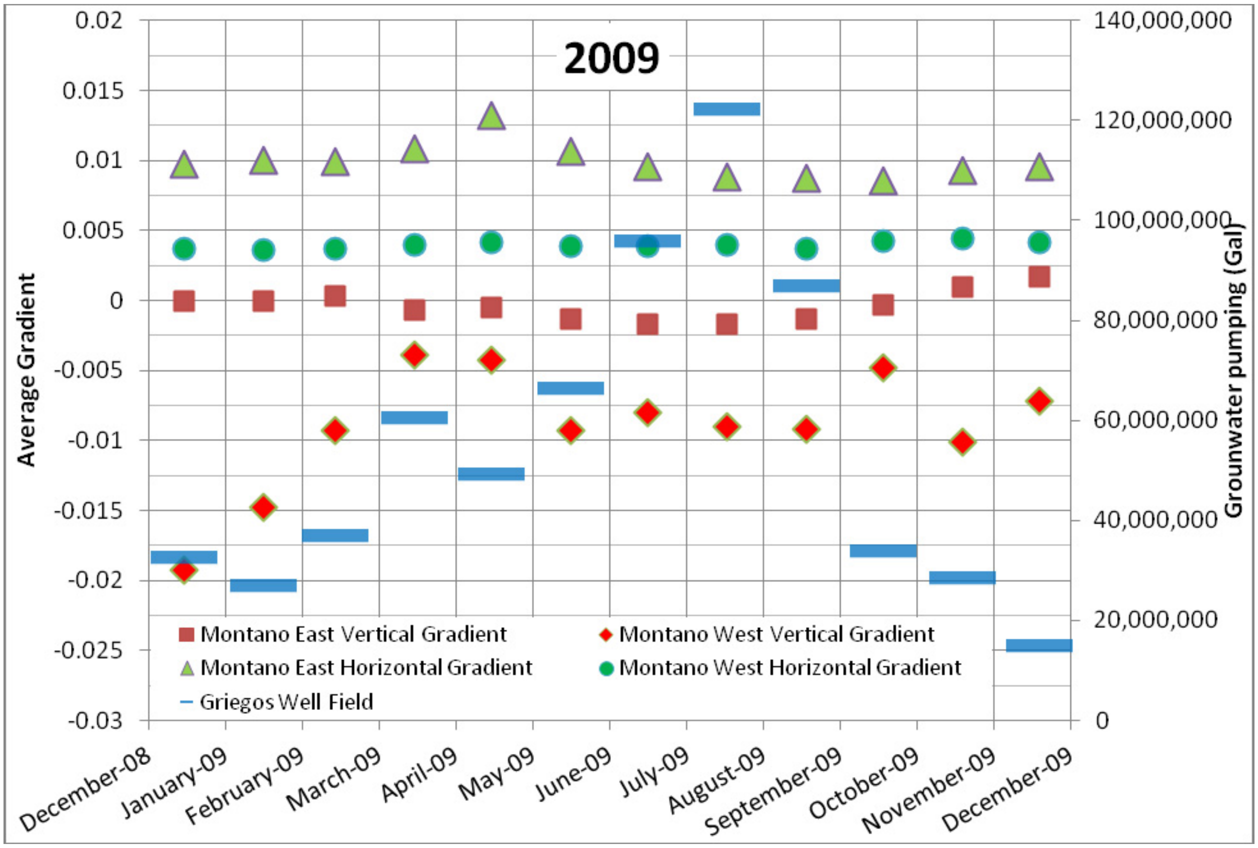
The production well pumping data presented here are from the three well fields located nearest to three Bosque Project locations: those being Griegos Well Field and Montano; Atrisco Well Field and Central; and San Jose Well Field and Barelas. The distances between the well fields and their respective Bosque Project locations are presented in Table 2 and shown graphically in Figure 5(a-c). Production well depth and screened interval specifications are also presented in Table 2 which indicates the shallowest screen-interval tops are 164, 98, and 192 ft (measured below land surface) at Griegos, Atrisco, and San Jose well fields respectively. The gradients in this study involve groundwater depths less than 30 ft below land surface; therefore, according to Figures 14(a-f), 15(a-c), and 16(a-f), there does not appear to be a strong correlation between municipal pumping and hydraulic gradients at these locations. Small localized correlations appear to be possible at times. The charts demonstrate total volume of groundwater pumped, in gallons, per month and corresponding average east/west vertical and horizontal gradients.

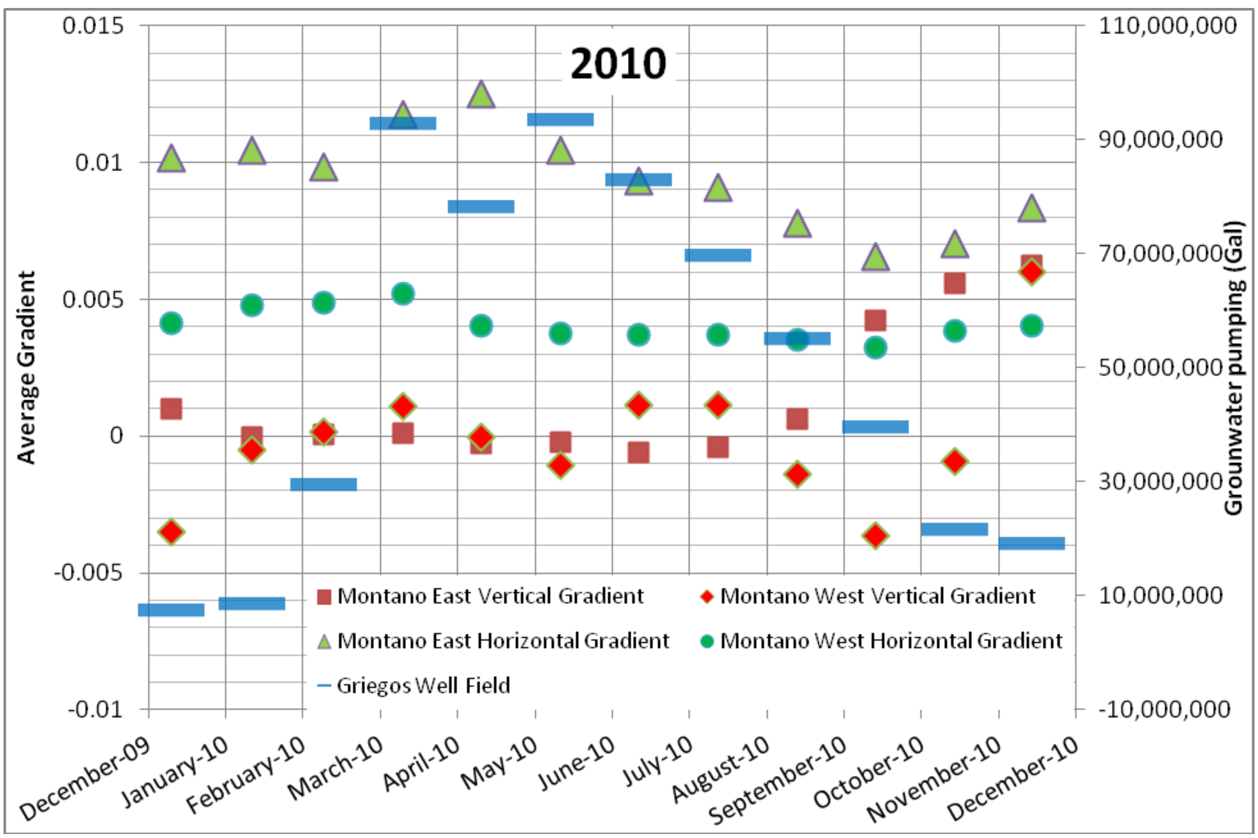
Figure 14(a-f). Charts demonstrate correlation between monthly production from wells (at Griegos Well Field) and east/west vertical and horizontal gradient magnitudes at Montano.

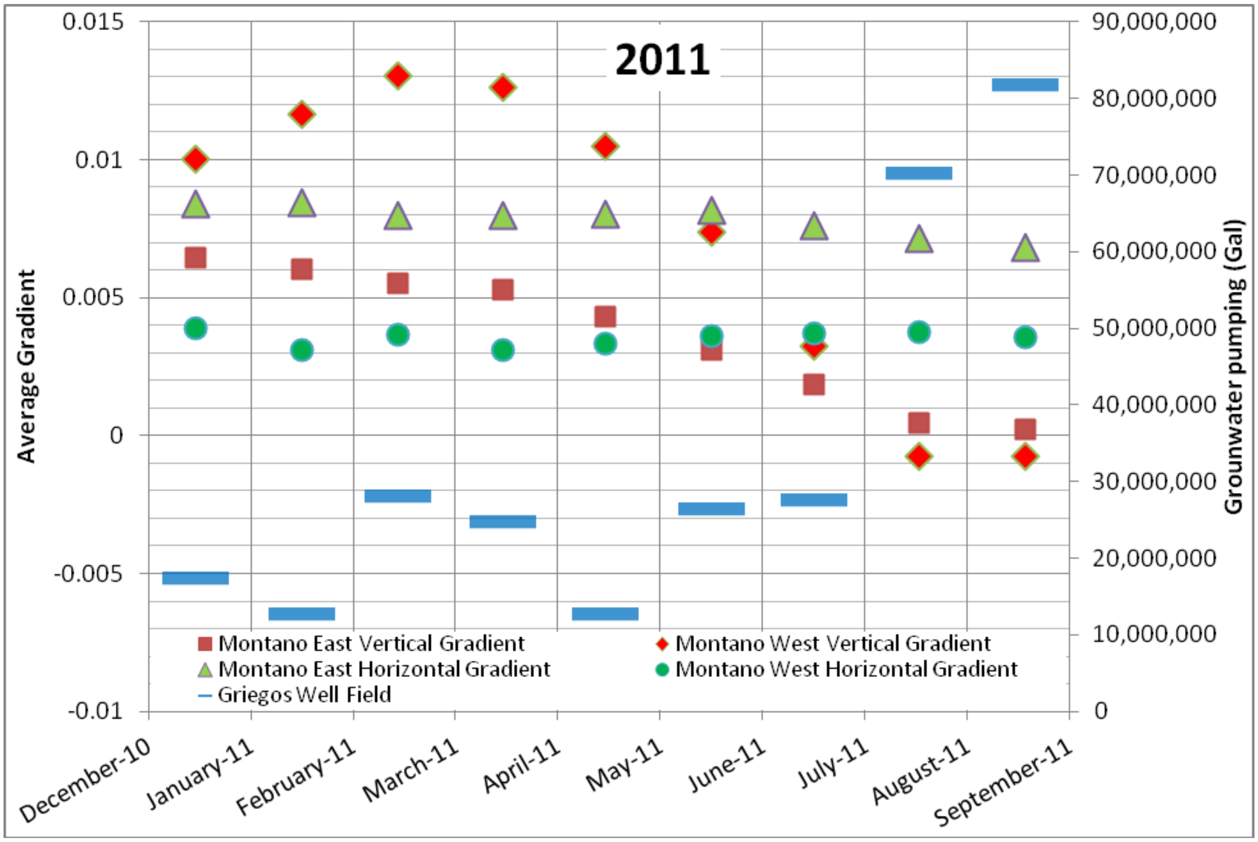



2007
Average Gradient
Grounwater pumping (Gal)
0.015
0.01
0.005
-1E-17
-0.005
-0.01
-0.015
-0.02
160,000,000
140,000,000
120,000,000
100,000,000
80,000,000
60,000,000
40,000,000
20,000,000
0
Montano East Vertical Gradient
Montano West Vertical Gradient
Montano East Horizontal Gradient
Montano West Horizontal Gradient
Griegos Well Field
December-06
January-07
February-07
March-07
April-07
May-07
June-07
July-07
August-07
September-07
October-07
November-07
December-07


2008
Average Gradient
Grounwater pumping (Gal)
0.015
0.01
0.005
-1E-17
-0.005
-0.01
-0.015
-0.02
200,000,000
180,000,000
160,000,000
140,000,000
120,000,000
100,000,000
80,000,000
60,000,000
40,000,000
20,000,000
0
Montano East Vertical Gradient
Montano West Vertical Gradient
Montano East Horizontal Gradient
Montano West Horizontal Gradient
Griegos Well Field
December-07
January-08
February-08
March-08
April-08
May-08
June-08
July-08
August-08
September-08
October-08
November-08
December-08


2009
Average Gradient
Grounwater pumping (Gal)
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.025
-0.03
140,000,000
120,000,000
100,000,000
80,000,000
60,000,000
40,000,000
20,000,000
0
Montano East Vertical Gradient
Montano West Vertical Gradient
Montano East Horizontal Gradient
Montano West Horizontal Gradient
Griegos Well Field
December-08
January-09
February-09
March-09
April-09
May-09
June-09
July-09
August-09
September-09
October-09
November-09
December-09

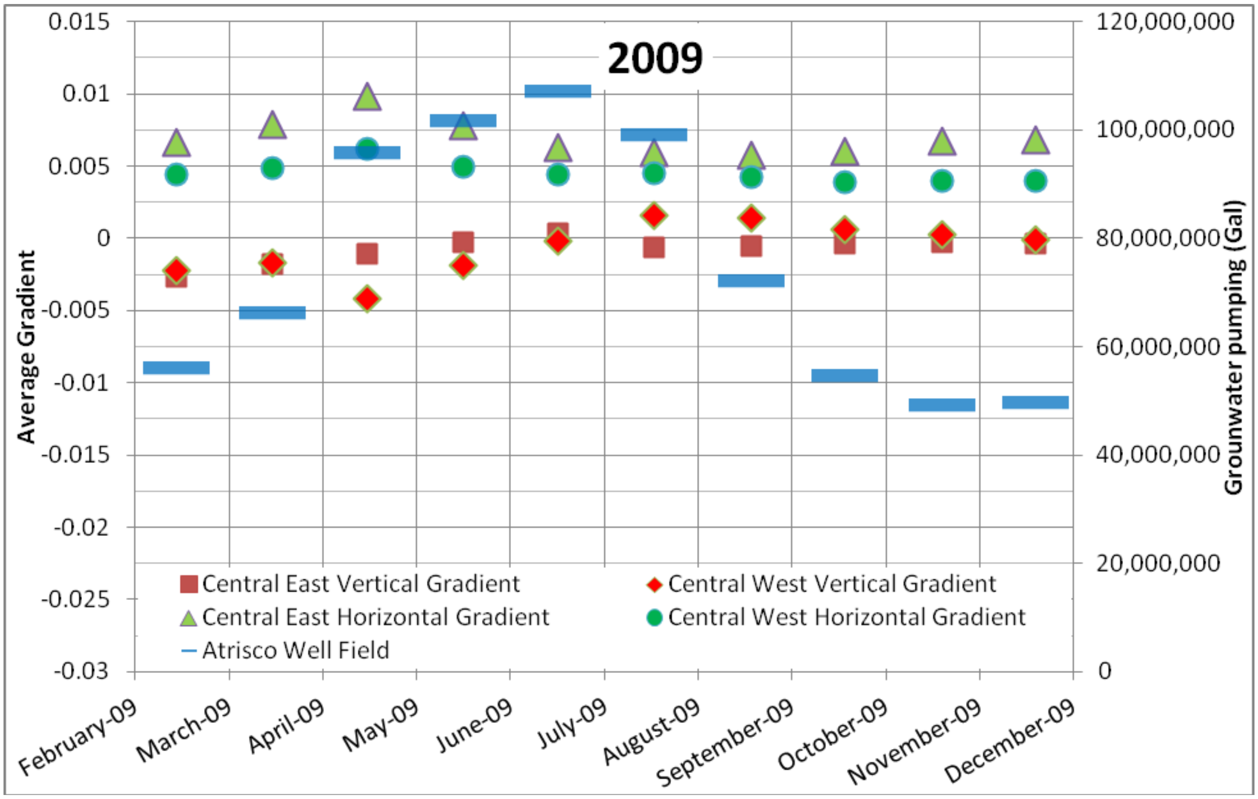

2010
Average Gradient
Grounwater pumping (Gal)
0.015
0.01
0.005
0
-0.005
-0.01
110,000,000
90,000,000
70,000,000
50,000,000
30,000,000
10,000,000
-10,000,000
Montano East Vertical Gradient
Montano West Vertical Gradient
Montano East Horizontal Gradient
Montano West Horizontal Gradient
Griegos Well Field
December-09
January-10
February-10
March-10
April-10
May-10
June-10
July-10
August-10
September-10
October-10
November-10
December-10

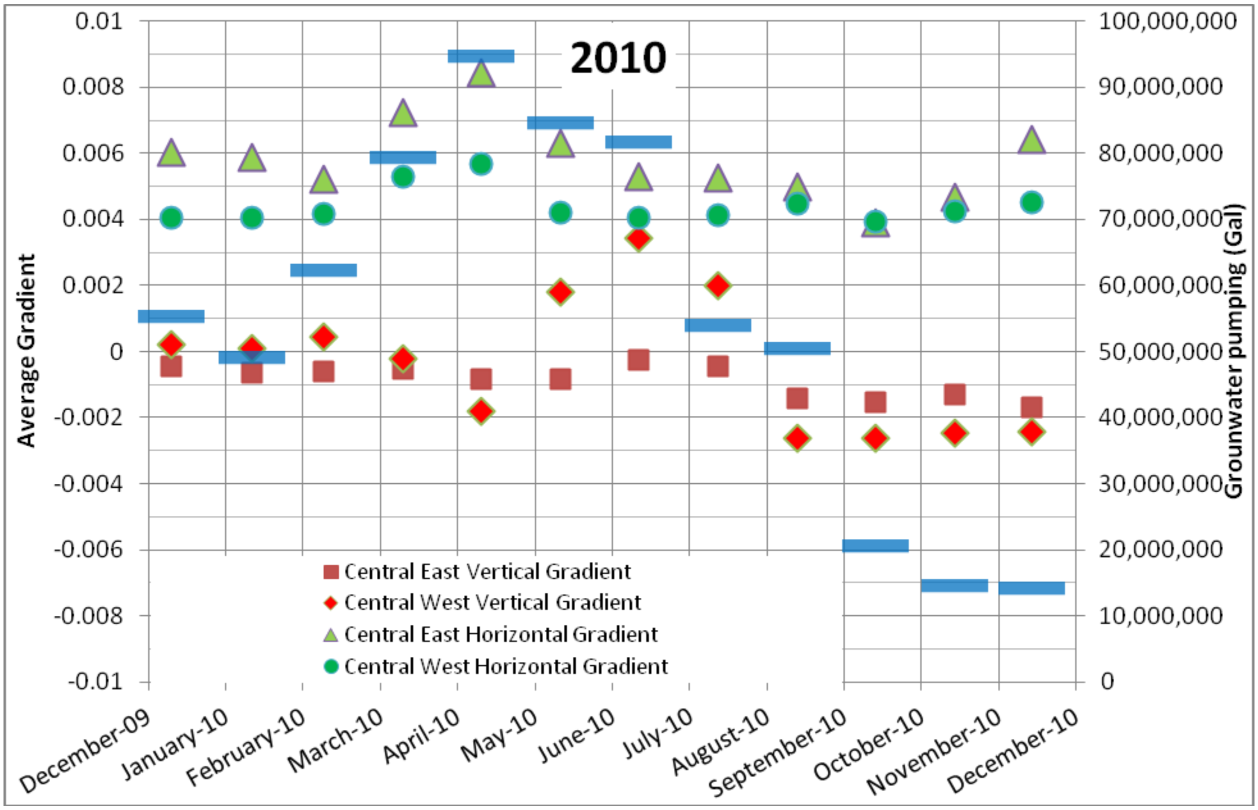


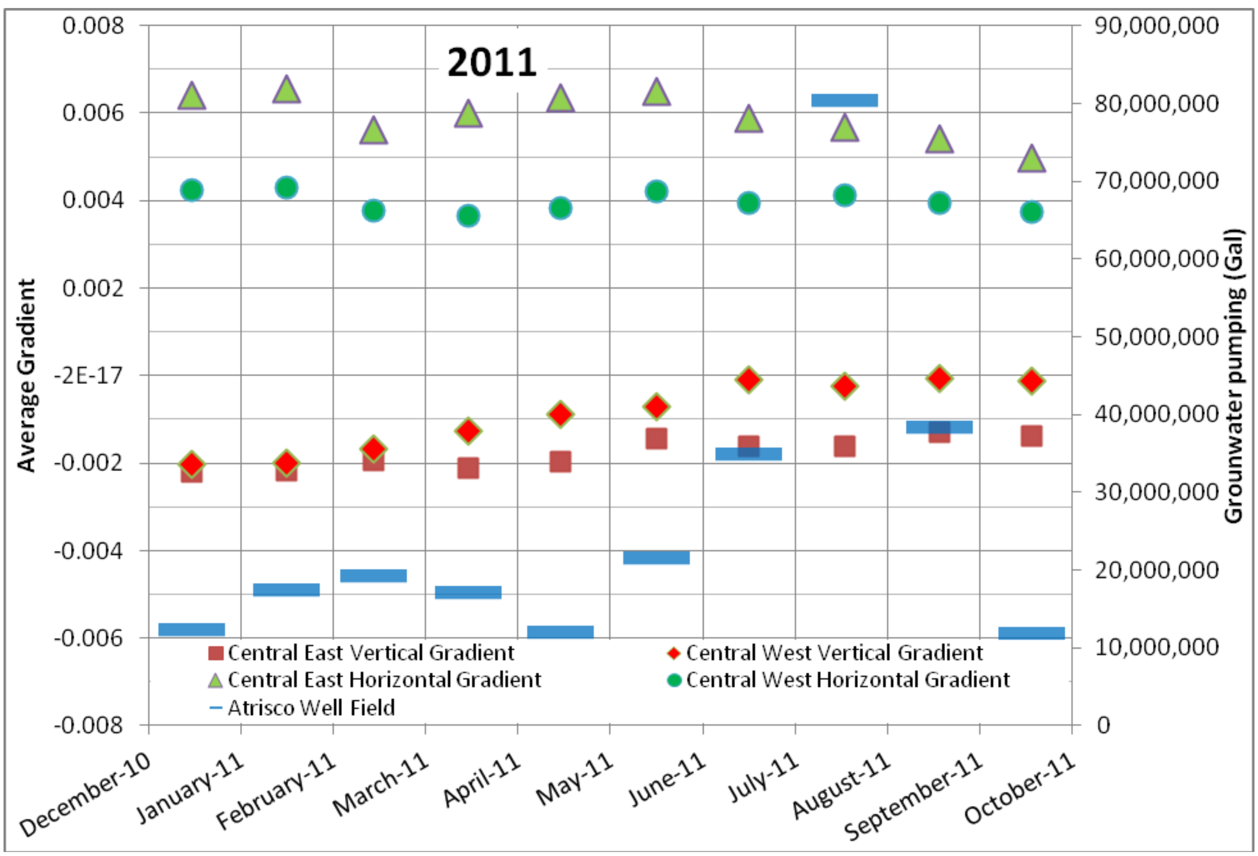
During some months, there does appear to be correlation between groundwater pumping at Griegos Well Field and gradients at Montano. From 2006 to 2011, maximum pumping generally occurred between the months of May and September whereas vertical gradient maximums, especially on the east side, generally occurred during January and February with slight declines over the next few months. The charts in Figures 14a and 14f (2006 and 2011 respectively) demonstrate this state. Furthermore, the horizontal gradient on the east side appears to react with declining magnitudes when pumping increases (all charts in Figure 14). The west side horizontal gradient seemingly remains unaffected by any pumping activity.

The image in Figure 5a shows that the Griegos well field is located closest to the Bosque Project piezometers on the east side of transect 1 at Montano. This well field contains 4 individual production wells and their screen intervals begin at 232, 164, 260, and 218 ft in depth. Although some possible correlations exist on the east side at Montano, close to the well field, pumping from water this deep under land surface appears to have very little effect on groundwater less than 30 ft deep in the bosque.

Figure 15(a-c). Charts demonstrate correlation between production well pumping (at Atrisco Well Field) and east/west vertical and horizontal gradient magnitudes at Central.



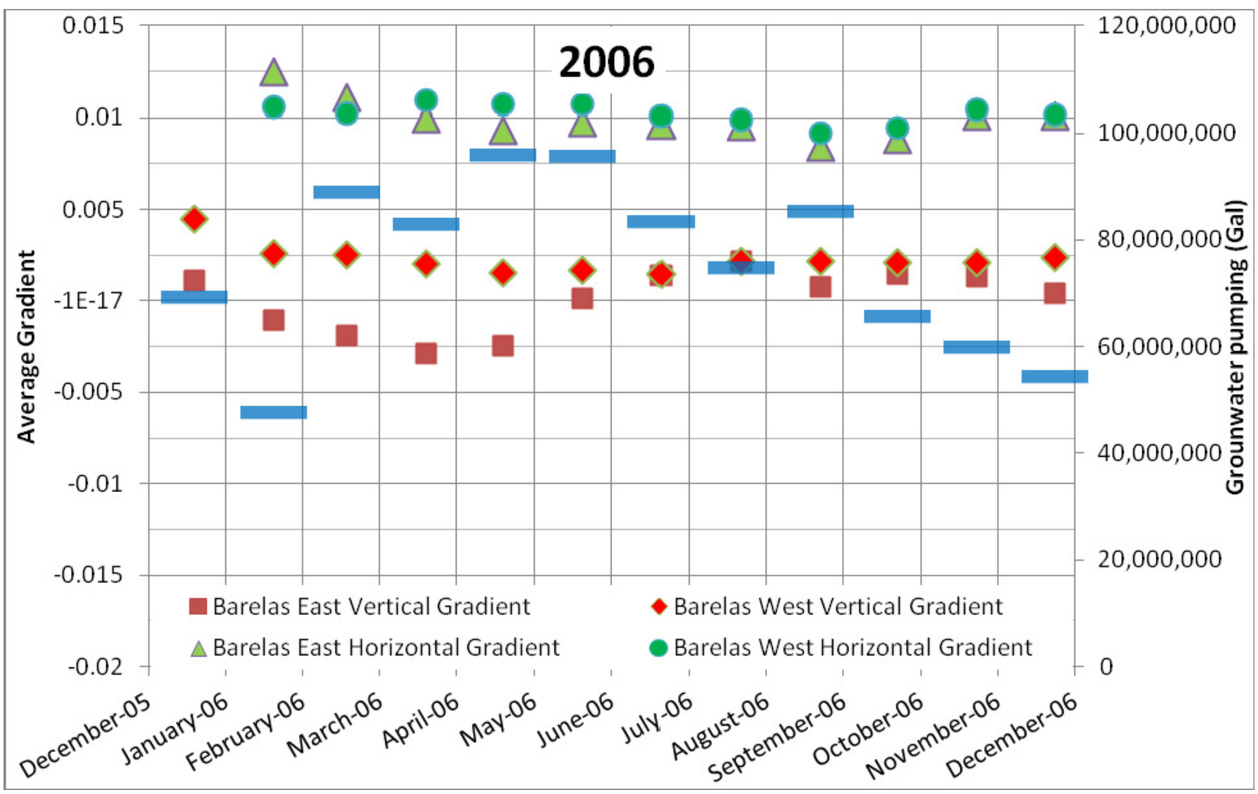

2010
Average Gradient
Grounwater pumping (Gal)
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
-0.01
100,000,000
90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
Central East Vertical Gradient
Central West Vertical Gradient
Central East Horizontal Gradient
Central West Horizontal Gradient
December-09
January-10
February-10
March-10
April-10
May-10
June-10
July-10
August-10
September-10
October-10
November-10
December-10

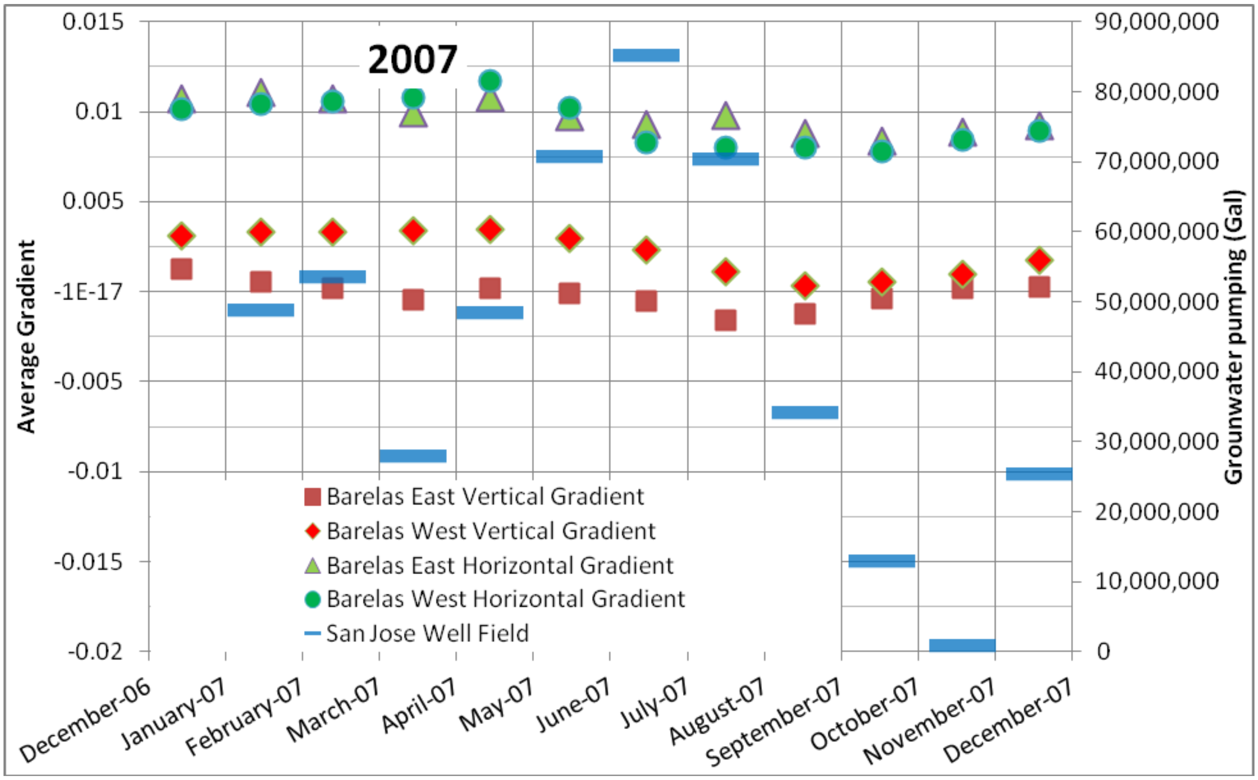

2011
Average Gradient
Grounwater pumping (Gal)
0.008
0.006
0.004
0.002
-2E-17
-0.002
-0.004
-0.006
-0.008
90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
Central East Vertical Gradient
Central West Vertical Gradient
Central East Horizontal Gradient
Central West Horizontal Gradient
Atrisco Well Field
December-10
January-11
February-11
March-11
April-11
May-11
June-11
July-11
August-11
September-11
October-11

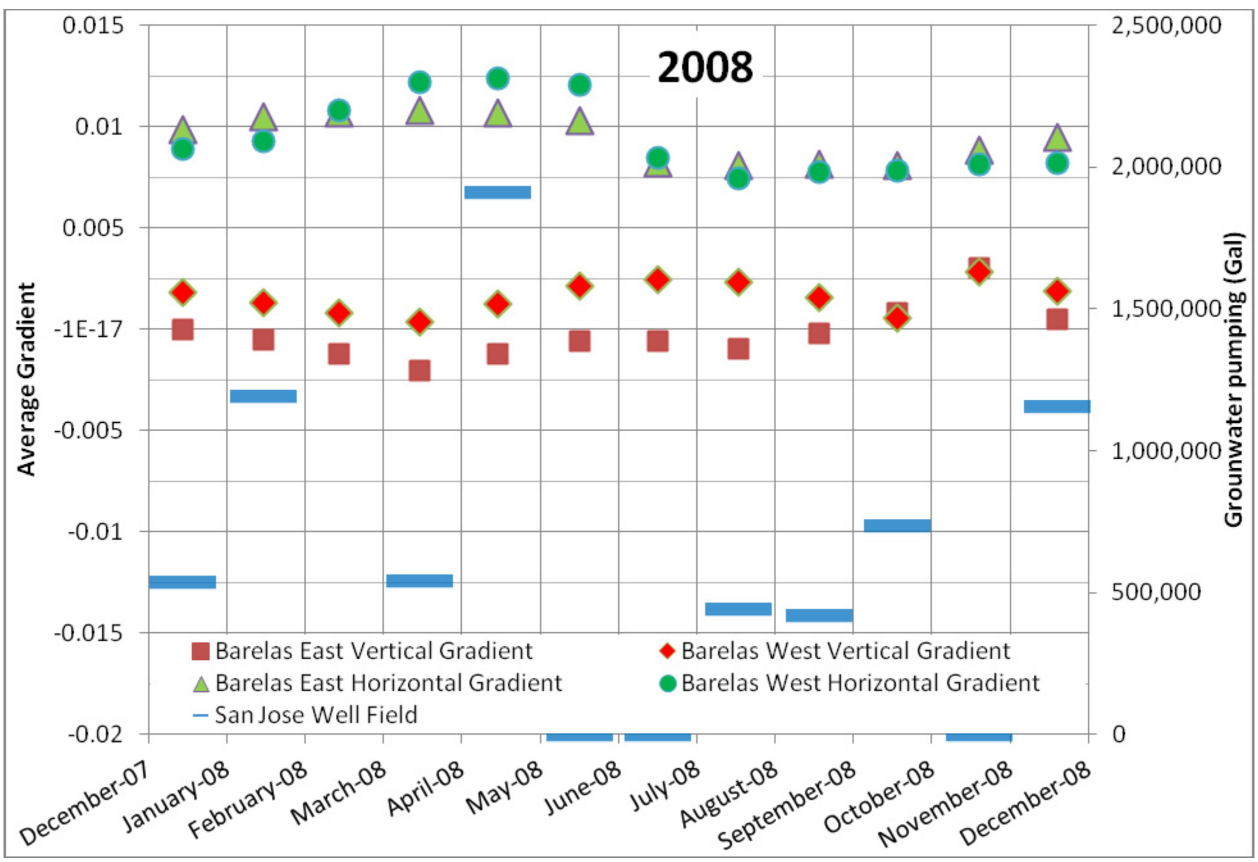
The short record of data from the Central location does not lend much to analysis but a few possible patterns are observed. Both the east and west-side horizontal gradients tend to decline after significant groundwater pumping months (all charts in Figure 15). In Figure 15b (2010), the west-side vertical gradient declines sharply a couple months after increased pumping occurred; however, in Figure 15a (2009), pumping was greater and the west-side vertical gradient appears unaffected.

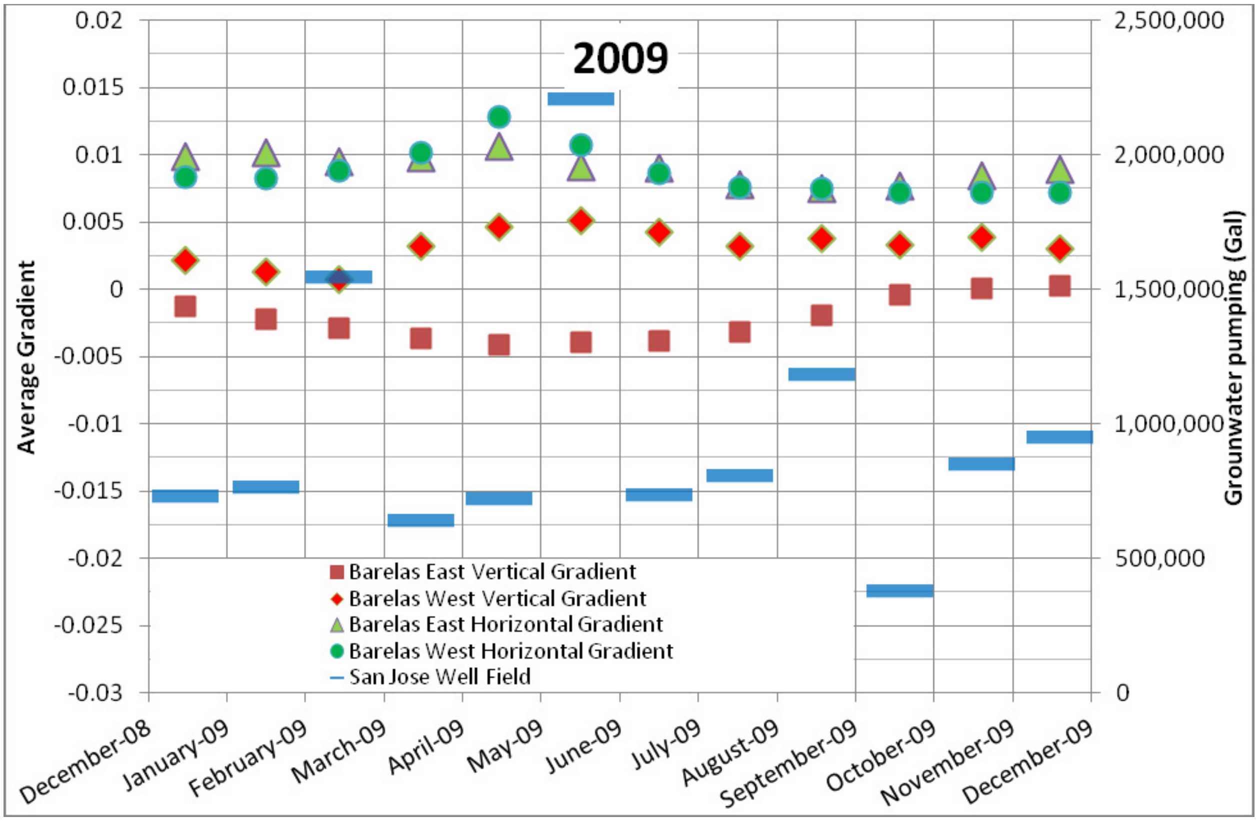
Figure 5b shows that the Atrisco well field is located closest to the Bosque Project piezometers on the west side of transect 2 at Central. This well field also contains 4 individual production wells and their screened intervals begin at 280, 108, 180, and 98 ft in depth. Possible correlations exist on the west side at Central, close to the well field, but they are not robust.

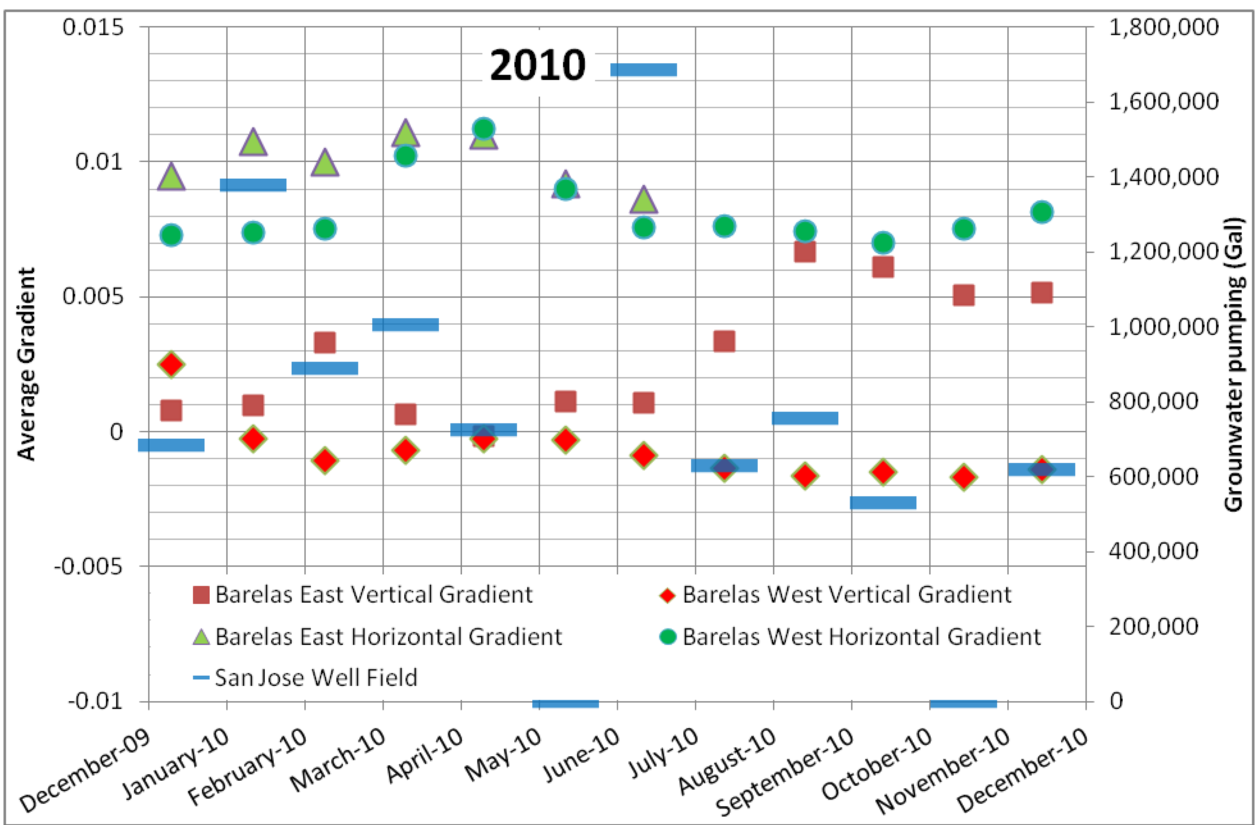
Figure 16(a-f). Charts demonstrate correlation between production well pumping (at San Jose Well Field) and east/west vertical and horizontal gradient magnitudes at Barelas.

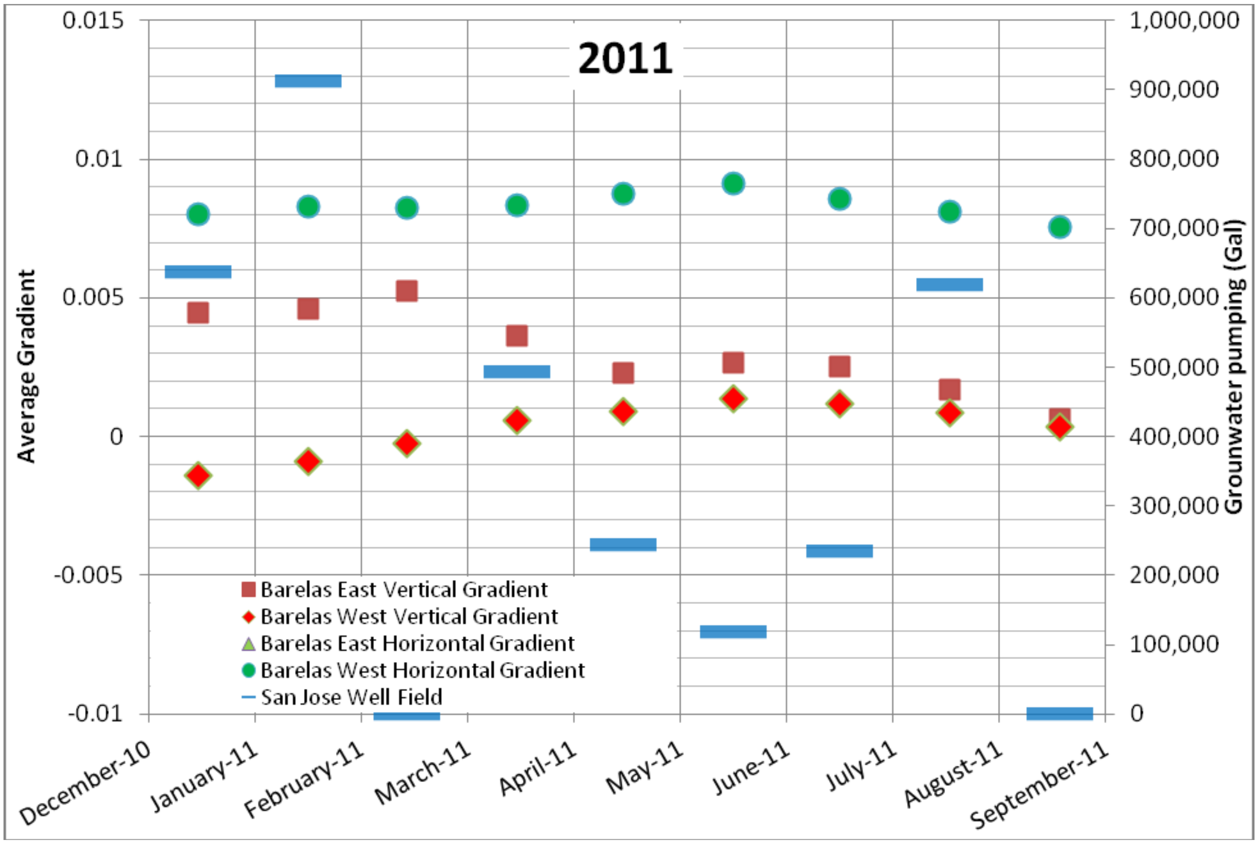



2007
Average Gradient
Grounwater pumping (Gal)
0.015
0.01
0.005
-1E-17
-0.005
-0.01
-0.015
-0.02
90,000,000
80,000,000
70,000,000
60,000,000
50,000,000
40,000,000
30,000,000
20,000,000
10,000,000
0
Barelas East Vertical Gradient
Barelas West Vertical Gradient
Barelas East Horizontal Gradient
Barelas West Horizontal Gradient
San Jose Well Field
December-06
January-07
February-07
March-07
April-07
May-07
June-07
July-07
August-07
September-07
October-07
November-07
December-07


2008
Average Gradient
Grounwater pumping (Gal)
0.015
0.01
0.005
-1E-17
-0.005
-0.01
-0.015
-0.02
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Barelas East Vertical Gradient
Barelas West Vertical Gradient
Barelas East Horizontal Gradient
Barelas West Horizontal Gradient
San Jose Well Field
December-07
January-08
February-08
March-08
April-08
May-08
June-08
July-08
August-08
September-08
October-08
November-08
December-08


2009
Average Gradient
Grounwater pumping (Gal)
0.02
0.015
0.01
0.005
0
-0.005
-0.01
-0.015
-0.02
-0.025
-0.03
2,500,000
2,000,000
1,500,000
1,000,000
500,000
0
Barelas East Vertical Gradient
Barelas West Vertical Gradient
Barelas East Horizontal Gradient
Barelas West Horizontal Gradient
San Jose Well Field
December-08
January-09
February-09
March-09
April-09
May-09
June-09
July-09
August-09
September-09
October-09
November-09
December-09


2010
Average Gradient
Grounwater pumping (Gal)
0.015
0.01
0.005
0
-0.005
-0.01
1,800,000
1,600,000
1,400,000
1,200,000
1,000,000
800,000
600,000
400,000
200,000
0
Barelas East Vertical Gradient
Barelas West Vertical Gradient
Barelas East Horizontal Gradient
Barelas West Horizontal Gradient
San Jose Well Field
December-09
January-10
February-10
March-10
April-10
May-10
June-10
July-10
August-10
September-10
October-10
November-10
December-10



According to pumping schedules, the San Jose Well Field pumps less groundwater than the other three fields discussed in this study. Figure 16 demonstrates that maximum pumping from 2006 to 2011 occurred in 2006 with several months reaching about 90 million gallons pumped per month. During the years that follow, pumping was generally far less. During those high pumping months of 2006 and several during 2007 east and west-side horizontal gradients declined only slightly (Figures 16a and 16b). In 2007, vertical gradients also declined during increased pumping but in 2006, vertical gradients increased during increased pumping. During 2008 and 2009, east/west horizontal gradients also declined during increased pumping although pumping maximums were far less than in 2006 and 2007. In 2010, horizontal gradients started declining during lows in groundwater pumping (less than 700,000 gallons per month).

Figure 5c shows that the San Jose well field is located closest to the Bosque Project piezometers on the east side of transect 2 at Barelas and 2 of the 3 individual production wells measure 264 and 192 ft below land surface to the top of the screen interval. The screen interval was unavailable for the production well San Jose 1. Localized correlations are especially difficult to ascertain at this location which is likely due to pumping from water much deeper than 30 ft and a relatively low frequency of pumping from these wells.

There appear to be some localized and short-term correlations between groundwater pumping and gradients in the bosque; however, the charts in Figures 14, 15, and 16 do not demonstrate a strong connection at any of these sites. Since pumping occurs at deep groundwater levels (generally over 100 ft below land surface) and the gradients calculated here are at depths less than 30 ft, it is likely that immediate responses of gradient to groundwater pumping are generally not observed in the bosque. There may and likely are delayed effects of pumping on shallow groundwater however many other contributing factors occur such as Rio Grande discharge and seasonal changes so it is difficult to censure groundwater pumping alone for the gradient fluctuations observed in the bosque.

CONCLUSION

This study presented a large collection of shallow groundwater-level data from a reach of the Middle Rio Grande inner valley at eight locations in Albuquerque, NM. Vertical and horizontal groundwater gradients were calculated and compared to river discharge and municipal production well pumpage. The gradients were calculated as daily values from 2003 to 2011 in some areas. By 2009, there were over 240 piezometers in the network collecting hourly water-level data. Calculated gradients were then averaged over the site’s period-of-record of operation and each season and year. The results, through figures, tables and charts, were then examined for distinctive relationships. Additionally, interactions between the riverside drains and the underlying alluvial aquifer were analyzed by measuring drain floor elevations and comparing them to continuous daily groundwater elevations adjacent to the drains. Data associated with connectivity between the drains and aquifer was also partitioned by period-of record and each season and year. The data was then analyzed for causes of variable connectivity under the drains.

Vertical gradients are negligible at most locations in the study area except for the east sides at the Alameda and Pajarito locations where the values are relatively high. These are areas with relatively low vegetation density especially at Pajarito which lies in a burn scar resulting from a fire many years before site construction in 2009. Other patterns and relationships concerning vertical gradients were difficult to ascertain. Sites at many locations have negative gradients whereas other nearby sites had positive gradients. Seasonal and yearly variations in climate also do not appear to have a strong influence on vertical gradients in the bosque.

Horizontal gradient magnitudes and directions are generally higher than vertical gradients indicating that groundwater flow is primarily in the horizontal direction and most horizontal gradients are positive indicating that groundwater generally moves from the river toward the riverside drains on both sides of the river. Higher gradient magnitudes are seen on the east sides at Alameda, Paseo Del Norte, Montano, and Pajarito and the west side at Rio Bravo which are areas of lower vegetation density than those opposite of the river. Areas in which vegetation density is similar on both sides of the river demonstrate horizontal gradients which are also similar.

Horizontal gradient directions follow much the same pattern as the magnitudes as lower vegetation density appeared to cause higher gradient angles. Two areas with the highest flow angles, the east sides at Montano and Pajarito, are burn scar areas which also have relatively high horizontal gradient magnitudes. The gradient angles at these two locations, both over 90°, indicate that groundwater flow is moving in an upstream direction relative to Rio Grande surface-water flow. The average flow angle for all sites is about 79° where the more densely vegetated areas generally have angles lower than this.

Based on the calculations in Table 6, horizontal gradient magnitudes, as well as directions, appear to be good indicators for biological health in the bosque. The data generally show higher magnitudes and flow angles in less densely vegetated areas in the bosque. Some of these areas are thin with vegetation due to wildfires and others because of levee construction where roads and banks have been built. The more densely vegetated areas are generally made up of Cottonwood, Russian Olive, and Salt Cedar trees. Small undergrowth does not appear to have a strong influence on the gradients.

It is not known when the wildfire occurred on the east side at Pajarito however the sites were constructed in 2009 and it appeared the fire occurred many years prior. The wildfire on both sides of the river at Montano occurred in 2003 and the sites at that location began construction in 2006. Due to a lack of baseline data, extremities at Pajarito and Montano cannot be definitively censured by the wildfire or lack of vegetation. The wildfire on both sides at Interstate 25 occurred in 2006 and many sites began recording water levels in 2005 so there was some baseline data however several piezometers were destroyed by the fire so the effects appear limited. The wildfire on the east side at Barelas occurred in 2010 and many of those sites were functioning since 2005 so there is substantial baseline data. However, several piezometers were destroyed by the fire and the project was defunded in 2011.

It was demonstrated that Rio Grande water has a strong effect on horizontal gradients at most locations in the study area; however, correlations with vertical gradients were minimal. From 2008 to 2010, the average river discharge was relatively high and the horizontal gradients were elevated as well. Furthermore, higher spring-time river discharge coincides with spring-time maximums in horizontal gradient. The flow angles generally increase with higher river discharge as well. Figures 9, 10, and 13 and also Table 7 demonstrate these certain correlations. In this losing reach of the Rio Grande, it is not river discharge that initiates leakage; rather, it is the depth of water in the river. Correlations with discharge were effective in this study because changes in discharge are analogous to changes in stage.

Neither vertical nor horizontal gradients appear to be strongly associated with municipal groundwater pumping activities. The charts in Figures 14, 15, and 16 demonstrate some possible localized and short-term correlations at Montano, Central, and Barelas. The strongest effects, although still negligible, are seen on vertical gradients at Montano and Central. Other Bosque Project sites are likely located far enough from production wells to be effected by groundwater pumping.

It was also shown that at four locations, the west sides at Alameda, Montano, and Central and on the east side at Barelas, the drain floors are elevated above the groundwater during most of the year. This separation does not indicate a lack of interaction between surface water and groundwater under the drains; rather, it indicates that recharge of the drains is not likely. Furthermore, it was shown that at two of these locations, the west side at Montano and the east side at Barelas, connectivity was poor on both sides of the drains. This implies that drains, at these locations, are not fulfilling their intended function of capturing and draining groundwater from agricultural areas located outside of the drains. The primary reason for this separation appears to be inadequate channel depth per unit distance the channel is from the river bank. The reaches of drain that are most capable of receiving recharge are also closest in distance from the river. In areas with great distance between the river and drain, recharge does still occur if the drain floor is situated vertically low enough to intercept groundwater from the alluvial aquifer.

On the east side at Paseo Del Norte, the riverside drain floor lies over 12 ft below the average water table elevation in the east riverside piezometer. Despite over 800 ft of horizontal distance between the east-side drain and the river bank, the aquifer remains well connected to the drain year round because the drain floor lies very low. Conversely, on the west side at Montano, year-round separation between the drain floor and the aquifer occurs because the drain floor lies about 1 ft below the average water table elevation in the west riverside piezometer. The horizontal distance between the drain and river bank is over 1400 ft and in that distance, the water table drops about 5 ft. Therefore, the riverside drain floor must be dredged about 4 ft lower (than present) in elevation if recharge is to occur.

There are limitations to this study that need to be addressed. First, there are many contributing influences to bosque-area hydraulics. These include geology and stratification, hydraulic conductivity, residential groundwater pumping, agricultural surface-water diversion and irrigating, and climate fluctuations. Also, due to the multitude of data and the size of the study area, hourly gradient and water levels were converted to daily values for analysis and seasonal variations were calculated as the average of all respective seasons for the site's period-of-record rather than each individual season of operation. These limitations made efficient analysis at each location possible; however, diurnal variations and specific seasons were not considered in this study.

The Rio Grande is very important to the residents of Albuquerque and future studies for the beneficial use of all will persist. A continuation of this study may use hourly instead of daily water-level data and every season of the site's operation could be analyzed for variations. A complete correlation of bosque water levels with Rio Grande gage height would be more beneficial to understanding river leakage. Quantification of vegetation density and evapotranspiration data would help to verify the extent of influence that vegetation has on groundwater gradients and vice versa. The incorporation of other data gathered by the Bosque Project would reduce the limitations present in this study and the use of correlation matrices would help determine the factors of influence that each contributing influence has on bosque hydraulics.

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APPENDIX A

Table A-1. Status of all piezometers and surface-water-stage gages; elevations and well depths (where applicable).

Site ID	Site Name	Land Surface Elevation (in feet above NAVD 88)	Well Depth (in feet below land surface)	Period of Record used for this study Start Date	End Date
		Alameda Transects			
351205106381201	AEDES1	4999.71	20	2/17/2009	10/13/2011
351205106381202	AEDWS1	4998.05	20	2/17/2009	10/13/2011
351204106381601	AEBS1	5001.36	14	2/17/2009	10/24/2011
351204106381602	AEBM1	5001.36	29	2/17/2009	10/24/2011
351204106381603	AEBD1	5001.36	49	2/17/2009	10/24/2011
351205106381601	AERS1	5002.32	14	2/17/2009	10/24/2011
351205106381602	AERM1	5002.32	29	2/17/2009	10/24/2011
351205106381603	AERD1	5002.32	46	2/17/2009	10/24/2011
351208106382701	AWRS1	5001.51	14	2/13/2009	10/25/2011
351208106382702	AWRM1	5001.51	29	2/13/2009	10/25/2011
351209106383001	AWBS1	5000.95	14	2/13/2009	10/25/2011
351209106383002	AWBM1	5000.95	29	2/13/2009	10/25/2011
351209106383003	AWBD1	5000.95	44	2/13/2009	10/25/2011
351211106383301	AWDES1	5000.68	20	2/13/2009	10/25/2011
351211106383501	AWDWS1	4998.41	20	2/13/2009	10/25/2011
351200106381601	AEDES2	4998.79	20	2/17/2009	10/13/2011
351200106381701	AEDWS2	4996.07	20	2/17/2009	10/13/2011
351159106381901	AEBS2	5001.63	14	2/17/2009	10/24/2011
351159106381902	AEBM2	5001.63	29	2/17/2009	10/24/2011
351159106381903	AEBD2	5001.63	45	2/17/2009	10/24/2011
351200106382001	AERS2	5002.14	14	2/17/2009	10/24/2011
351200106382002	AERM2	5002.14	29	2/17/2009	10/24/2011
351203106383001	AWRS2	5001.23	14	2/13/2009	10/25/2011
351203106383002	AWRM2	5001.23	29	2/13/2009	10/25/2011
351204106383201	AWBS2	4999.98	14	2/13/2009	10/25/2011
351204106383202	AWBM2	4999.98	29	2/13/2009	10/25/2011
351204106383203	AWBD2	4999.98	49	2/13/2009	10/25/2011
351205106383601	AWDES2	5000.45	20	2/13/2009	10/25/2011
351206106383801	AWDWS2	4996.51	20	2/13/2009	10/25/2011
		MP Elevation			
351202106381601	AEDSW1	4992.72		2/17/2009	10/13/2011
351208106382601	ARGSW1	5001.41		2/13/2009	10/25/2011
351207106383501	AWDSW1	5001.26		2/13/2009	10/25/2011
351208106383601	AWDSW2	4998.17		2/13/2009	10/26/2011

Site ID	Site Name	Land Surface Elevation (in feet above NAVD 88)	Well Depth (in feet below land surface)	Period of Record used for this study Start Date	End Date
		Paseo Del Norte Transects			
351055106385101	PDNEDES1	4994.53	22	---------------	----------------

351055106385102	PDNEDEM1	4994.53	40	11/7/2007	10/11/2011
351054106385401	PDNEDWS1	4992.11	25	11/7/2007	10/11/2011
351054106390101	PDNEBS1	4993.29	16	11/7/2007	10/11/2011
351054106390102	PDNEBM1	4993.29	35	11/7/2007	10/11/2011
351054106390401	PDNERS1	4993.53	16	11/7/2007	10/11/2011
351054106390402	PDNERM1	4993.53	35	11/7/2007	10/11/2011
351055106391101	PDNWRS1	4992.03	16	11/7/2007	10/12/2011
351055106391102	PDNWRM1	4992.03	31	11/7/2007	10/12/2011
351054106391301	PDNWBS1	4993.47	16	11/7/2007	10/12/2011
351054106391302	PDNWBM1	4993.47	31	11/7/2007	10/12/2011
351052106391701	PDNWDES1	4990.86	16	11/7/2007	10/12/2011
351053106391701	PDNWDWS1	4996.34	23	11/7/2007	9/8/2011
351053106391702	PDNWDWM1	4996.34	27	11/7/2007	10/10/2011
351050106394001	PDNWS1	4991.09	22	11/13/2007	10/10/2011
351050106394002	PDNWD1	4991.09	46	12/21/2009	10/10/2011
351059106385201	PDNEDES2	4991.37	22	10/17/2008	10/13/2011
351059106385202	PDNEDEM2	4991.37	37	10/17/2008	10/13/2011
351059106385301	PDNEDWS2	4991.77	22	10/17/2008	10/13/2011
351058106385901	PDNEBS2	4993.36	17	10/17/2008	10/13/2011
351058106385902	PDNEBM2	4993.36	32	10/17/2008	10/13/2011
351058106385903	PDNEBD2	4993.36	52	10/17/2008	10/13/2011
351058106390301	PDNERS2	4993.76	15	10/17/2008	10/13/2011
351058106390302	PDNERM2	4993.76	30	10/17/2008	10/13/2011
351058106391001	PDNWRS2	4992.33	16	10/15/2008	10/11/2011
351058106391002	PDNWRM2	4992.33	31	10/15/2008	10/11/2011
351058106391101	PDNWBS2	4993.26	16	10/15/2008	10/11/2011
351058106391102	PDNWBD2	4993.26	40	10/15/2008	10/11/2011
351058106391501	PDNWDES2	4989.73	16	10/15/2008	10/11/2011
351058106391601	PDNWDWS2	4991.50	20	10/15/2008	10/11/2011
351058106391602	PDNWDWM2	4991.50	35	10/15/2008	10/11/2011
		MP Elevation			
351054106385310	PDNEDSW1	4984.21		10/17/2008	10/11/2011
351055106390810	PDNRGSW1	4992.69		10/15/2008	10/10/2011
351053106391710	PDNWDSW1	4989.62		10/15/2008	10/10/2011

Site ID	**Site Name**	**Land Surface Elevation (in feet above NAVD 88)**	**Well Depth (in feet below land surface)**	**Period of Record used for this study**	
				Start Date	**End Date**
		Montano Transects			
350843106402801	MEDWS1	4974.14	17	12/5/2005	10/4/2011
350843106402802	MEDWM1	4974.14	31	12/5/2005	10/4/2011
350842106403101	MEBS1	4978.85	15	1/9/2006	10/4/2011
350842106403102	MEBM1	4978.85	30	6/13/2005	10/4/2011
350842106403103	MEBD1	4978.85	49	6/13/2005	10/4/2011
350842106403201	MERS1	4978.20	15	1/9/2006	10/4/2011
350842106403202	MERM1	4978.20	32	6/13/2005	10/4/2011
350848106404703	MWRS1	4978.86	13	10/12/2005	10/5/2011
350848106404704	MWRM1	4978.86	28	10/12/2005	10/5/2011
350848106404701	MWBS1	4977.89	15	10/12/2005	10/5/2011
350848106404702	MWBM1	4977.89	30	10/12/2005	10/5/2011

350852106405601	MWDES1	4980.23	16	10/12/2005	10/2/2011
350853106405701	MWDWS1	4977.39	15	10/12/2005	10/2/2011
350853106405702	MWDWM1	4977.39	30	6/13/2005	10/2/2011
350847106402501	MEDWS2	4977.26	17	1/9/2006	10/5/2011
350847106402502	MEDWM2	4977.26	32	1/9/2006	10/5/2011
350846106402801	MEBS2	4977.37	16	3/16/2007	9/16/2010
350846106402802	MEBM2	4977.37	31	1/9/2006	9/27/2010
350846106402803	MEBD2	4977.37	47	1/9/2006	10/4/2011
350846106402804	MERS2	4979.83	18	11/17/2006	10/4/2011
350846106402805	MERM2	4979.83	33	1/13/2006	10/4/2011
350851106403801	MWRS2	4977.80	13	2/1/2006	10/11/2011
350851106403802	MWRM2	4977.80	28	2/1/2006	10/11/2011
350854106404201	MWBS2	4978.62	17	2/1/2006	10/11/2011
350854106404202	MWBM2	4978.62	32	2/1/2006	10/11/2011
350854106404203	MWBD2	4978.62	46	2/1/2006	10/11/2011
350855106405401	MWDES2	4978.65	18	2/1/2006	10/2/2011
350857106405401	MWDWS2	4978.17	18	2/1/2006	10/2/2011
350857106405402	MWDWM2	4978.17	33	2/1/2006	10/2/2011
		MP Elevation			
350846106402510	MEDSW1	4972.61		6/20/2006	10/5/2011
350841106403510	MRGSW1	4978.52		6/20/2006	10/4/2011
350854106405610	MWDSW1	4979.11		6/20/2006	10/2/2011

Site ID	Site Name	Land Surface Elevation (in feet above NAVD 88)	Well Depth (in feet below land surface)	Period of Record used for this study	
				Start Date	**End Date**
		Central Transects			
350534106405502	CEDES1	4956.23	22	2/18/2009	11/8/2011
350534106405501	CEDWS1	4954.70	22	2/18/2009	11/8/2011
350531106405801	CEBS1	4956.13	16	2/18/2009	11/8/2011
350531106405802	CEBM1	4956.13	31	2/18/2009	11/8/2011
350531106405803	CEBD1	4956.13	51	2/18/2009	11/8/2011
350529106410401	CERS1	4957.29	16	2/18/2009	11/8/2011
350529106410402	CERM1	4957.29	31	2/18/2009	11/8/2011
350524106410401	CWRS1	4956.66	16	2/19/2009	11/1/2011
350524106410402	CWRM1	4956.66	31	2/19/2009	11/1/2011
350522106410501	CWBS1	4955.70	16	2/19/2009	11/1/2011
350522106410502	CWBM1	4955.70	31	2/19/2009	11/1/2011
350522106410503	CWBD1	4955.70	51	2/19/2009	11/1/2011
350520106410701	CWDES1	4958.09	22	2/19/2009	11/2/2011
350519106410701	CWDWS1	4957.82	22	2/19/2009	11/2/2011
350530106404802	CEDES2	4954.78	22	2/18/2009	11/8/2011
350530106404801	CEDWS2	4955.44	22	2/18/2009	8/22/2010
350527106405101	CEBS2	4954.70	16	2/18/2009	11/8/2011
350527106405102	CEBM2	4954.70	31	2/18/2009	11/8/2011
350527106405103	CEBD2	4954.70	51	2/18/2009	11/8/2011
350525106405301	CERS2	4956.19	16	2/18/2009	11/8/2011
350525106405302	CERM2	4956.19	31	2/18/2009	11/8/2011
350521106405501	CWRS2	4954.32	16	2/19/2009	8/23/2010
350521106405502	CWRM2	4954.32	31	2/19/2009	11/1/2011

350519106405701	CWBS2	4957.11	16	2/19/2009	11/1/2011
350519106405702	CWBM2	4957.11	31	2/19/2009	11/1/2011
350519106405703	CWBD2	4957.11	49	2/19/2009	11/1/2011
350516106410001	CWDES2	4956.90	22	2/19/2009	11/2/2011
350516106410002	CWDWS2	4957.78	22	2/19/2009	11/2/2011
		MP Elevation			
350530106404803	CEDSW1	4951.72		2/18/2009	11/8/2011
350521106405503	CRGSW1	4955.09		2/19/2009	11/1/2011
350516106410003	CWDSW1	4956.98		2/19/2009	11/2/2011

Site ID	Site Name	Land Surface Elevation (in feet above NAVD 88)	Well Depth (in feet below land surface)	Period of Record used for this study	
				Start Date	End Date
		Barelas Transects			
350403106392201	BEDES1	4940.68	16	10/30/2008	9/29/2011
350403106392301	BEDWS1	4941.86	15	10/7/2005	9/29/2011
350403106392302	BEDWM1	4941.86	30	6/13/2005	9/29/2011
350402106392601	BEBS1	4942.18	16	10/7/2005	10/2/2011
350402106392602	BEBM1	4942.18	31	6/13/2005	10/2/2011
350402106392603	BEBD1	4942.18	52	6/13/2005	10/2/2011
350402106392901	BERS1	4943.08	15	10/7/2005	10/2/2011
350402106392902	BERM1	4943.08	30	6/13/2005	10/2/2011
350400106393701	BWRS1	4942.40	17	10/7/2005	9/27/2011
350400106393702	BWRM1	4942.40	32	6/13/2005	9/29/2011
350359106393901	BWBS1	4943.03	17	10/7/2005	9/27/2011
350359106393902	BWBM1	4943.03	32	4/21/2005	9/27/2011
350359106393903	BWBD1	4943.03	52	4/21/2005	9/27/2011
350359106394401	BWDES1	4940.23	16	10/5/2005	9/27/2011
350359106394402	BWDEM1	4940.23	34	4/21/2005	9/27/2011
350359106394501	BWDWS1	4943.21	20	12/21/2009	9/27/2011
350354106395201	BWS1	4940.77	17	6/27/2005	3/9/2009
350354106395202	BWM1	4940.77	32	7/13/2005	9/27/2011
350354106395203	BWD1	4940.77	48	7/13/2005	9/27/2011
350358106392201	BEDES2	4939.91	16	10/31/2008	9/29/2011
350358106392301	BEDWS2	4939.88	16	2/1/2006	2/7/2010
350358106392302	BEDWM2	4939.88	31	2/1/2006	9/29/2011
350358106392601	BEBS2	4941.91	15	1/30/2006	8/18/2010
350358106392602	BEBM2	4941.91	30	1/30/2006	9/29/2011
350358106392603	BEBD2	4941.91	40	1/30/2006	8/18/2010
350357106392901	BERS2	4943.41	15	1/30/2006	8/19/2010
350357106392902	BERM2	4943.41	30	1/30/2006	8/19/2010
350356106393601	BWRS2	4943.14	16	1/30/2006	9/29/2011
350356106393602	BWRM2	4943.14	31	1/30/2006	9/29/2011
350356106393901	BWBS2	4943.59	16	1/30/2006	9/29/2011
350356106393902	BWBM2	4943.59	31	1/30/2006	9/29/2011
350356106393903	BWBD2	4943.59	51	1/30/2006	9/29/2011
350354106394201	BWDES2	4939.60	16	1/27/2006	9/27/2011
350354106394202	BWDEM2	4939.60	31	1/30/2006	9/27/2011
350353106394301	BWDWS2	4943.14	20	12/21/2009	9/27/2011
		MP Elevation			

Site ID	Site Name	Land Surface Elevation (in feet above NAVD 88)	Well Depth (in feet below land surface)	Period of Record used for this study: Start Date	Period of Record used for this study: End Date
350403106392410	BEDSW1	4942.04		6/21/2006	9/29/2011
350402106392810	BRGSW1	4942.86		6/21/2006	10/2/2011
350359106394410	BWDSW1	4935.89		6/21/2006	5/13/2010
		Rio Bravo Transects			
350137106395101	RBES1	4931.35	27	12/11/2003	9/25/2011
350137106395102	RBED1	4931.35	59	12/11/2003	9/25/2011
350141106400701	RBEDES1	4927.27	16	10/28/2008	9/25/2011
350141106400801	RBEDWS1	4927.51	17	12/11/2003	9/25/2011
350141106400802	RBEDWD1	4927.51	57	12/11/2003	9/25/2011
350138106401102	RBEBS1	4929.91	22	12/12/2003	9/25/2011
350138106401104	RBEBM1	4929.91	30	7/12/2005	9/25/2011
350140106401701	RBEBD1	4929.91	56	12/12/2003	9/25/2011
350140106401704	RBERS1	4930.49	19	7/12/2005	9/25/2011
350140106401703	RBERM1	4930.49	30	7/12/2005	9/25/2011
350140106401702	RBERD1	4930.49	54	12/12/2003	9/25/2011
350143106402401	RBWRS1	4928.75	15	7/12/2005	9/26/2011
350143106402402	RBWRM1	4928.62	30	10/5/2005	9/26/2011
350143106402503	RBWBS1	4928.79	15	7/12/2005	10/27/2011
350143106402501	RBWBM1	4928.99	35	12/17/2003	10/27/2011
350143106402502	RBWBD1	4928.99	54	12/17/2003	10/27/2011
350142106402701	RBWDES1	4928.32	15	12/17/2003	10/27/2011
350142106402702	RBWDED1	4928.32	50	12/17/2003	10/27/2011
350142106402801	RBWDWS1	4927.73	14	10/29/2008	12/3/2009
350137106403501	RBWS1	4925.90	30	12/17/2003	8/15/2010
350137106403502	RBWD1	4925.90	49	12/17/2003	9/26/2011
350144106400703	RBEDES2	4926.48	18	10/28/2008	9/25/2011
350144106400701	RBEDWS2	4929.06	16	8/15/2006	9/25/2011
350144106400702	RBEDWM2	4929.06	31	8/15/2006	9/25/2011
350144106401101	RBEBS2	4929.13	15	2/15/2005	9/25/2011
350144106401102	RBEBM2	4929.13	30	2/16/2005	9/25/2011
350144106401103	RBEBD2	4929.13	56	2/16/2005	9/25/2011
350146106401801	RBERS2	4929.92	15	1/25/2005	9/25/2011
350146106401802	RBERM2	4929.69	30	1/25/2005	9/25/2011
350147106402601	RBWRS2	4929.77	15	10/5/2005	10/27/2011
350147106402602	RBWRM2	4929.77	30	6/2/2005	10/27/2011
350147106402501	RBWBS2	4928.70	15	10/5/2005	10/27/2011
350147106402502	RBWBM2	4928.70	30	6/2/2005	10/27/2011
350147106402503	RBWBD2	4928.70	54	6/2/2005	10/27/2011
350147106402801	RBWDES2	4928.18	16	10/5/2005	10/27/2011
350147106402802	RBWDEM2	4928.18	31	10/5/2005	10/27/2011
350147106402701	RBWDWS2	4929.11	15	10/29/2008	10/27/2011
		MP Elevation			
350141106400810	RBEDSW1	4925.22		9/29/2006	9/25/2011
350145106400810	RBEDSW2	4926.52		4/10/2006	9/25/2011
350143106402301	RBRGSW1	4934.74		10/1/2003	9/26/2011
350142106402810	RBWDSW1	4927.49		4/7/2006	10/27/2011

Site ID	Site Name	Land Surface Elevation (in feet above NAVD 88)	Well Depth (in feet below land surface)	Period of Record used for this study Start Date	End Date
350147106402810	RBWDSW2	4928.69		10/13/2006	10/27/2011

Site ID	Site Name	Land Surface Elevation (in feet above NAVD 88)	Well Depth (in feet below land surface)	Period of Record used for this study Start Date	End Date
		Pajarito Transects			
345904106410501	PEDES1	4909.79	20	2/19/2009	9/21/2011
345904106410601	PEDWS1	4912.53	20	2/20/2009	9/22/2011
345904106410901	PEBS1	4915.55	14	2/23/2009	9/22/2011
345904106410902	PEBM1	4915.55	29	2/23/2009	9/22/2011
345904106410903	PEBD1	4915.55	49	2/23/2009	9/22/2011
345904106411001	PERS1	4916.21	14	2/23/2009	10/27/2011
345904106411002	PERM1	4916.21	29	2/23/2009	10/27/2011
345905106411501	PWRS1	4915.80	14	2/20/2009	10/30/2011
345905106411502	PWRM1	4915.80	29	2/20/2009	10/30/2011
345906106412001	PWBS1	4915.91	14	2/20/2009	10/30/2011
345906106412002	PWBM1	4915.91	29	2/20/2009	10/30/2011
345906106412003	PWBD1	4915.91	49	2/20/2009	10/30/2011
345908106412501	PWDES1	4913.60	20	2/19/2009	10/30/2011
345908106412601	PWDWS1	4916.32	25	2/19/2009	10/30/2011
345859106410601	PEDES2	4911.19	20	2/19/2009	9/21/2011
345859106410701	PEDWS2	4913.10	20	2/20/2009	9/22/2011
345859106411001	PEBS2	4915.12	14	2/23/2009	10/27/2011
345859106411002	PEBM2	4915.12	29	2/23/2009	10/27/2011
345859106411003	PEBD2	4915.12	45	2/23/2009	10/27/2011
345900106411201	PERS2	4915.91	14	2/23/2009	10/27/2011
345900106411202	PERM2	4915.91	29	2/23/2009	10/27/2011
345901106411801	PWRS2	4915.27	14	2/20/2009	10/30/2011
345901106411802	PWRM2	4915.27	29	2/20/2009	10/30/2011
345903106412001	PWBS2	4915.56	14	2/20/2009	10/30/2011
345903106412002	PWBM2	4915.56	29	2/20/2009	10/30/2011
345903106412003	PWBD2	4915.56	49	2/20/2009	10/30/2011
345904106412601	PWDES2	4913.34	20	2/19/2009	10/30/2011
		MP Elevation			
345902106410701	PEDSW1	4909.47		2/20/2009	9/22/2011
345904106411501	PRGSW1	4916.41		2/20/2009	10/30/2011
345906106412601	PWDSW1	4909.48		2/19/2009	10/30/2011

Site ID	Site Name	Land Surface Elevation (in feet above NAVD 88)	Well Depth (in feet below land surface)	Period of Record used for this study Start Date	End Date
		Interstate 25 Transects			
350358106391301	I25ES1	4904.92	16	11/29/2005	9/21/2011
350358106391302	I25EM1	4904.92	31	6/1/2005	9/21/2011
350358106391303	I25ED1	4904.92	56	6/1/2005	3/1/2011
345703106403901	I25EDES1	4902.76	16	6/1/2005	9/21/2011
345703106403902	I25EDEM1	4902.76	31	6/1/2005	9/21/2011
345703106404001	I25EDWS1	4902.35	16	11/29/2005	9/22/2011
345701106404501	I25EBS1	4903.47	14	11/29/2005	9/22/2011
345701106404502	I25EBM1	4903.47	29	6/1/2005	9/22/2011

345701106404503	I25EBD1	4903.47	54	6/1/2005	12/11/2006
345701106404601	I25ERS1	4904.60	14	11/29/2005	9/22/2011
345701106404602	I25ERM1	4904.60	29	6/1/2005	9/22/2011
345707106410101	I25WRS1	4905.93	14	11/30/2005	9/19/2011
345707106410102	I25WRM1	4905.93	29	6/1/2005	9/19/2011
345706106410201	I25WBS1	4905.11	14	11/29/2005	9/19/2011
345706106410202	I25WBM1	4905.11	29	6/1/2005	9/19/2011
345706106410203	I25WBD1	4905.11	49	4/22/2005	9/19/2011
345704106410701	I25WDES1	4901.90	15	11/29/2005	9/19/2011
345704106410702	I25WDEM1	4901.90	30	6/1/2005	9/19/2011
345703106411201	I25WS1	4900.97	13	6/1/2005	9/19/2011
345703106411202	I25WM1	4900.97	28	6/1/2005	9/19/2011
345703106411203	I25WD1	4900.97	48	6/1/2005	9/19/2011
345707106404101	I25EDES2	4902.27	13	2/23/2007	9/21/2011
345707106404102	I25EDEM2	4902.27	23	1/20/2006	9/21/2011
345707106404103	I25EDWS2	4902.28	13	10/21/2008	9/22/2011
345706106404701	I25EBS2	4904.21	14	3/9/2007	9/22/2011
345706106404702	I25EBM2	4904.21	29	12/12/2006	9/22/2011
345706106404703	I25EBD2	4904.21	49	12/12/2006	9/22/2011
345706106404704	I25ERS2	4904.06	14	3/9/2007	9/22/2011
345706106404705	I25ERM2	4904.06	29	1/20/2006	9/22/2011
345713106410604	I25WRS2	4906.50	14	10/13/2006	9/20/2011
345713106410605	I25WRM2	4906.50	29	10/13/2006	9/20/2011
345713106410601	I25WBS2	4908.22	16	12/18/2009	9/20/2011
345713106410602	I25WBM2	4908.22	31	1/23/2006	9/20/2011
345713106410603	I25WBD2	4908.22	49	1/23/2006	9/20/2011
345713106411001	I25WDES2	4903.46	13	3/9/2007	9/20/2011
345713106411002	I25WDEM2	4903.46	28	1/23/2006	9/20/2011
		MP Elevation			
345703106404010	I25EDSW1	4903.63		4/7/2006	9/21/2011
345705106405810	I25RGSW1	4906.66		8/10/2005	6/17/2011
345705106410810	I25WDSW1	4902.04		4/7/2006	9/20/2011

Table A-2. Horizontal and vertical measurements taken in bosque for improved understanding of riverside drain geometry.

Piezometer Names	Horizontal distance between piezometers (ft)	Vertical distance drain floor lies below head in riverside piezometer (ft)	Average Difference between drain-side piezometer water level and drain floor (ft)
AEDWS1 - AERS1	340.38	7.63	3.47
AWDES1 - AWRS1	527.65	1.40	-0.71
AEDWS2 - AERS2	228.27	7.23	2.70
AWDES2 - AWRS2	584.98	1.21	-1.67
PDNEDWS1 - PDNERS1	849.39	12.42	3.23
PDNWDES1 - PDNWRS1	563.77	4.05	0.97
PDNEDWS2 - PDNERS2	883.95	12.67	5.56

PDNWDES2 - PDNWRS2	507.91	4.31	1.61
MEDWS1 - MERS1	426.16	6.87	3.46
MWDES1 - MWRS1	1411.51	0.99	-3.15
MEDWS2 - MERS2	333.43	7.00	3.55
MWDES2 - MWRS2	1483.84	1.05	-4.03
CEDWS1 - CERS1	656.65	6.06	2.01
CWDES1 - CWRS1	518.27	0.68	-1.57
CEDWS2 - CERS2	575.61	6.15	2.38
CWDES2 - CWRS2	681.48	0.52	-2.20
BEDWS1 - BERS1	438.26	1.52	-2.23
BWDES1 - BWRS1	622.42	8.87	3.82
BEDWS2 - BERS2	496.73	0.97	-3.60
BWDES2 - BWRS2	566.33	9.47	3.22
RBEDWS1 - RBERS1	747.42	4.09	1.30
RBWDES1 - RBWRS1	263.47	4.65	2.47
RBEDWS2 - RBERS2	823.53	4.78	0.94
RBWDES2 - RBWRS2	248.50	5.11	3.39
PEDWS1 - PERS1	339.17	7.92	2.75
PWDES1 - PWRS1	920.50	7.61	1.95
PEDWS2 - PERS2	441.17	8.35	2.14
PWDES2 - PWRS2	752.99	7.22	1.80
I25EDWS1 - I25ERS1	727.05	3.57	1.75
I25WDES1 - I25WRS1	693.42	5.05	2.40
I25EDWS2 - I25ERS2	652.51	3.89	1.89
I25WDES2 - I25WRS2	739.68	6.54	3.05

APPENDIX B

Table B-1. Extents of connection or separation between riverside drain floors and adjacent piezometer groundwater elevations; partitioned by season.

SW Site Name	Associated GW Site Name	Difference between riverside drain floor and adjacent piezometer groundwater elevation (in feet) POR	Spring	Summer	Fall	Winter
AEDSW1						
	AEDWS1	3.47142	3.54650	4.04049	3.30391	2.73793
	AEDES1	2.95867	2.96678	3.52721	2.86673	2.23369
	AEDWS2	2.69963	2.74842	3.24088	2.52982	2.04704
	AEDES2	2.25032	2.23675	2.81037	2.15487	1.57307
AWDSW1						
	AWDES1	-0.70966	-0.49147	-0.85408	-0.85777	-0.63405
	AWDES2	-1.66785	-1.40858	-1.85569	-1.84410	-1.55572
AWDSW2						
	AWDWS1	1.22266	1.42308	1.07192	1.10303	1.29838
	AWDWS2	0.82983	1.05536	0.67369	0.68220	0.91182
PDNEDSW1						
	PDNEDWS1	3.23014	3.46698	3.73628	3.20116	2.49981
	PDNEDEM1	2.82362	3.05179	3.33106	2.80926	2.08715
	PDNEDWS2	5.55747	5.72029	5.96928	5.56813	4.95952
	PDNEDES2	4.77948	4.90924	5.13957	4.81843	4.24022
	PDNEDEM2	4.76379	4.88315	5.14105	4.81685	4.20367
PDNWDSW1						
	PDNWDES1	0.97350	1.40389	0.99757	0.64631	0.81490
	PDNWDWS1	0.50819	0.90085	0.53837	0.20931	0.33111
	PDNWDWM1	0.54459	1.01948	0.61391	0.14589	0.36260
	PDNWDES2	1.61364	1.78428	1.65667	1.42970	1.57478
	PDNWDWS2	1.41868	1.69978	1.43558	1.20228	1.32851
	PDNWDWM2	1.31796	1.51239	1.33353	1.06924	1.27987
SW Site Name	**Associated GW Site Name**	**Difference between riverside drain floor and adjacent piezometer groundwater elevation (in feet) POR**	**Spring**	**Summer**	**Fall**	**Winter**
MEDSW1						
	MEDWS1	3.46486	3.69475	3.81286	3.49045	2.85298
	MEDWM1	3.33956	3.50221	3.70647	3.49272	2.67691
	MEDWS2	3.54630	3.74544	3.84641	3.59853	2.96200
	MEDWM2	3.40723	3.58379	3.68898	3.41812	2.79555

MWDSW1						
	MWDES1	-3.15434	-2.45421	-4.26103	-3.47250	-2.49783
	MWDWS1	-3.84612	-3.45707	-4.31323	-4.08211	-3.53211
	MWDWM1	-4.01843	-3.53056	-4.19401	-4.40743	-4.04692
	MWDES2	-4.03369	-3.61829	-4.34557	-4.31499	-3.87465
	MWDWS2	-3.77945	-3.31493	-4.01630	-4.19536	-3.61864
	MWDWM2	-3.86048	-3.44020	-4.08221	-4.23526	-3.70795
CEDSW1						
	CEDWS1	2.01162	2.25516	2.09614	2.00179	1.54805
	CEDES1	1.92013	2.15123	2.00551	1.92100	1.45926
	CEDWS2	2.38213	2.72648	2.49940	1.85113	2.02650
	CEDES2	2.09355	2.33383	2.17438	2.04806	1.68721
CWDSW1						
	CWDES1	-1.57316	-1.03824	-1.63918	-2.01076	-1.69064
	CWDWS1	-1.83086	-1.32725	-1.90320	-2.24943	-1.91808
	CWDES2	-2.20015	-1.75856	-2.25334	-2.55771	-2.30385
	CWDWS2	-2.38318	-1.95193	-2.42164	-2.75583	-2.49343

		Difference between riverside drain floor and adjacent piezometer groundwater elevation (in feet)				
SW Site Name	**Associated GW Site Name**	**POR**	**Spring**	**Summer**	**Fall**	**Winter**
BEDSW1						
	BEDWS1	-2.23334	-1.86205	-1.86248	-2.20848	-2.99288
	BEDWM1	-2.54914	-2.22811	-2.22831	-2.53454	-3.13645
	BEDES1	-2.66896	-2.40895	-2.34612	-2.68074	-3.25419
	BEDWS2	-3.60348	-3.45943	-3.31120	-3.54967	-4.09436
	BEDWM2	-3.40619	-3.28864	-3.08514	-3.34812	-3.97146
	BEDES2	-3.51289	-3.35558	-3.18605	-3.45324	-4.06104
BWDSW1						
	BWDES1	3.82052	3.81327	4.05100	3.83037	3.58381
	BWDEM1	3.79608	3.75825	4.00434	3.79941	3.51856
	BWDWS1	5.67301	5.72576	5.83082	5.68483	5.42057
	BWDES2	3.21972	3.17822	3.43185	3.25494	2.98959
	BWDEM2	3.25485	3.22696	3.47451	3.26031	3.02885
	BWDWS2	5.33625	5.36641	5.49168	5.38678	5.08396
RBEDSW1						
	RBEDWS1	1.29951	1.33169	1.40962	1.48943	0.98841
	RBEDWD1	1.29913	1.27423	1.40162	1.51901	0.98196
	RBEDES1	1.10184	1.17199	1.20331	1.23208	0.80522
	RBEDWS2	1.55532	1.63366	1.69794	1.61942	1.25392
	RBEDWM2	1.54620	1.64166	1.68521	1.59575	1.24599
	RBEDES2	1.41077	1.48452	1.56094	1.51862	1.08048
RBEDSW2						

	RBEDWS2	0.93532	1.01366	1.07794	0.99942	0.63392
	RBEDWM2	0.92620	1.02166	1.06521	0.97575	0.62599
	RBEDES2	0.79077	0.86452	0.94094	0.89862	0.46048
	RBEDWS1	0.67951	0.71169	0.78962	0.86943	0.36841
	RBEDWD1	0.67913	0.65423	0.78162	0.89901	0.36196
	RBEDES1	0.48184	0.55199	0.58331	0.61208	0.18522
RBWDSW1						
	RBWDES1	2.47047	2.45329	2.60252	2.59675	2.24198
	RBWDED1	2.68977	2.88679	2.78744	2.62085	2.45220
	RBWDWS1	2.96691	3.00891	3.17379	2.90063	2.82745
	RBWDES2	3.27019	3.37370	3.42122	3.21276	3.07135
	RBWDEM2	3.23790	3.34004	3.39299	3.17602	3.04031
	RBWDWS2	2.41806	2.58043	2.63860	2.36187	2.22978
RBWDSW2						
	RBWDES2	3.39019	3.49370	3.54122	3.33276	3.19135
	RBWDEM2	3.35790	3.46004	3.51299	3.29602	3.16031
	RBWDWS2	3.08691	3.12891	3.29379	3.02063	2.94745
	RBWDES1	2.59047	2.57329	2.72252	2.71675	2.36198
	RBWDED1	2.80977	3.00679	2.90744	2.74085	2.57220
	RBWDWS1	2.53806	2.70043	2.75860	2.48187	2.34978

		Difference between riverside drain floor and adjacent piezometer groundwater elevation (in feet)				
SW Site Name	**Associated GW Site Name**	**POR**	**Spring**	**Summer**	**Fall**	**Winter**
PEDSW1						
	PEDWS1	2.75067	2.79981	3.07039	2.69717	2.26720
	PEDES1	2.39349	2.39217	2.69804	2.40066	1.94299
	PEDWS2	2.13959	2.13267	2.47996	2.12383	1.66715
	PEDES2	1.79733	1.76308	2.14453	1.82840	1.30697
PWDSW1						
	PWDES1	1.95009	1.98199	2.24093	1.63395	1.88358
	PWDWS1	1.85170	1.88965	2.20378	1.53074	1.69310
	PWDES2	1.79715	1.80497	2.02041	1.53539	1.79488
I25EDSW1						
	I25EDWS1	1.74557	1.84853	2.15638	1.79700	1.17744
	I25EDES1	1.73285	1.75597	2.09107	1.74661	1.10819
	I25EDEM1	1.86755	1.91199	2.17745	1.80848	1.09823
	I25EDWS2	1.88886	1.98493	2.23669	1.92401	1.25111
	I25EDES2	2.43424	2.52467	2.86724	2.48353	1.76891
	I25EDEM2	2.62254	2.64815	3.09652	2.73838	1.98298
I25WDSW1						
	I25WDES1	2.39962	2.48044	2.44255	2.29634	2.36349
	I25WDEM1	2.49407	2.58534	2.58333	2.35268	2.45470

	I25WDES2	3.04548	3.23710	3.00465	2.76591	3.15626
	I25WDEM2	2.93326	2.97080	2.98013	2.82149	2.94902

Table B-2. Extents of connection or separation between riverside drain floors and adjacent piezometer groundwater elevations; partitioned by year.

SW Site Name	Associated GW Site Name	Difference between riverside drain floor and adjacent piezometer groundwater elevation (in feet) 2004	2005	2006	2007	2008	2009	2010	2011
AEDSW1									
	AEDWS1						3.52353	3.42488	3.47306
	AEDES1						3.02759	2.90629	2.94913
	AEDWS2						2.74779	2.62381	2.74302
	AEDES2						2.32921	2.17560	2.25822
AWDSW1									
	AWDES1						-0.95260	-0.44238	-0.77533
	AWDES2						-1.60104	-1.64163	-1.77186
AWDSW2									
	AWDWS1						1.33316	1.19875	1.13323
	AWDWS2						0.91708	0.81960	0.74865
PDNEDSW1									
	PDNEDWS1					3.27831	3.18378	3.22416	3.33627
	PDNEDEM1					2.82369	2.79222	2.82058	2.97155
	PDNEDWS2					5.14347	5.55671	5.56959	5.65218
	PDNEDES2					4.41800	4.76742	4.77323	4.89845
	PDNEDEM2					4.42307	4.77849	4.74710	4.85634
PDNWDSW1									
	PDNWDES1					1.31786	1.01772	0.87474	0.57827
	PDNWDWS1					0.80277	0.49449	0.40207	0.23606
	PDNWDWM1					0.80849	0.50868	0.48452	0.31505
	PDNWDES2						1.81060	1.62430	1.28696
	PDNWDWS2						1.58373	1.46357	1.15802
	PDNWDWM2							1.46077	1.13435
SW Site Name	Associated GW Site Name	Difference between riverside drain floor and adjacent piezometer groundwater elevation (in feet) 2004	2005	2006	2007	2008	2009	2010	2011
MEDSW1									
	MEDWS1			3.29093	3.44915	3.51129	3.55074	3.55170	3.55072
	MEDWM1			3.13382				3.46323	3.48597
	MEDWS2			3.18145	3.49299	3.61880	3.62843	3.60858	3.66730
	MEDWM2			3.09049	3.50124	3.43384	3.44712	3.42071	3.45939
MWDSW1									

	MWDES1			-4.09044			-2.90542	-2.17910	-3.06582
	MWDWS1			-4.17444	-3.94433	-4.00953	-3.38945	-3.56696	-3.94531
	MWDWM1			-4.26547	-3.99310	-3.93287	-3.76030	-3.85775	-4.00847
	MWDES2			-3.92333			-4.08879	-3.94808	-4.12898
	MWDWS2			-3.90120	-3.84351	-3.77068	-3.77342	-3.62896	-3.76644
	MWDWM2			-4.05066	-3.81225	-3.82388	-3.85233	-3.76975	-3.87418
CEDSW1									
	CEDWS1						1.82960	2.32484	1.82954
	CEDES1						1.71703	2.23986	1.75179
	CEDWS2						2.06196	2.81450	
	CEDES2						1.91170	2.41516	1.90149
CWDSW1									
	CWDES1						-1.73868	-1.61199	-1.35645
	CWDWS1						-1.98276	-1.85266	-1.64850
	CWDES2						-2.39787	-2.21436	-1.97968
	CWDWS2						-2.60086	-2.40904	-2.11964
	Associated GW	**Difference between riverside drain floor and adjacent piezometer groundwater elevation (in feet)**							
SW Site Name	**Site Name**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
BEDSW1									
	BEDWS1			-2.89560	-2.51115	-1.94978	-1.98365	-1.84019	-1.87999
	BEDWM1			-3.16250	-2.76986	-2.22768	-2.35784	-2.16635	-2.19846
	BEDES1						-2.75411	-2.56353	-2.55925
	BEDWS2			-4.07219	-3.85597	-3.21071	-3.28819		
	BEDWM2			-4.09880	-3.66855	-3.21172	-3.28671	-3.06663	-3.08575
	BEDES2						-3.61263	-3.38055	-3.42671
BWDSW1									
	BWDES1			3.42885	3.70451	3.96003	3.93345	4.04646	3.97800
	BWDEM1		3.49591	3.46277	3.72343	4.00122		4.20056	4.05556
	BWDWS1							5.72775	5.60552
	BWDES2			2.77456	3.02211	3.22292	3.30901	3.52978	3.49996
	BWDEM2			2.82782	3.05904	3.25683	3.29636	3.57679	3.55541
	BWDWS2							5.35929	5.31170
RBEDSW1									
	RBEDWS1	1.55914	1.53204	0.91316	1.22978	1.32098	1.33531	1.42216	1.21011
	RBEDWD1	1.58130	1.52060	0.90516	1.20412	1.37357		1.40466	1.16481
	RBEDES1						1.20918	1.09904	1.00649
	RBEDWS2			1.43587	1.54942	1.61284	1.53551	1.60038	1.51190
	RBEDWM2			1.42928	1.54737	1.61478	1.53997	1.57901	1.47496
	RBEDES2						1.43507	1.44526	1.38780
RBEDSW2									
	RBEDWS2			0.81587	0.92942	0.99284	0.91551	0.98038	0.89190
	RBEDWM2			0.80928	0.92737	0.99478	0.91997	0.95901	0.85496

	RBEDES2						0.81507	0.82526	0.76780
	RBEDWS1	0.93914	0.91204	0.29316	0.60978	0.70098	0.71531	0.80216	0.59011
	RBEDWD1	0.96130	0.90060	0.28516	0.58412	0.75357		0.78466	0.54481
	RBEDES1						0.58918	0.47904	0.38649
RBWDSW1									
	RBWDES1	2.03142	2.58052	2.47077	2.25493	2.68604	2.58482	2.63326	2.60013
	RBWDED1	2.18375	2.78474	2.57962	2.80157	2.85475	2.79142	2.78756	2.63730
	RBWDWS1						2.83274	3.12592	2.96000
	RBWDES2			3.05277	3.34214	3.43197	3.25564	3.34975	3.20373
	RBWDEM2			3.02049	3.31429	3.37806	3.24375	3.31814	3.16447
	RBWDWS2						2.46264		
RBWDSW2									
	RBWDES2			3.17277	3.46214	3.55197	3.37564	3.46975	3.32373
	RBWDEM2			3.14049	3.43429	3.49806	3.36375	3.43814	3.28447
	RBWDWS2						2.95274	3.24592	3.08000
	RBWDES1	2.15142	2.70052	2.59077	2.37493	2.80604	2.70482	2.75326	2.72013
	RBWDED1	2.30375	2.90474	2.69962	2.92157	2.97475	2.91142	2.90756	2.75730
	RBWDWS1						2.58264		

		Difference between riverside drain floor and adjacent piezometer groundwater elevation (in feet)							
SW Site Name	**Associated GW Site Name**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
PEDSW1									
	PEDWS1						2.79548	2.74541	2.70481
	PEDES1						2.44944	2.38929	2.33255
	PEDWS2						2.19982	2.13174	2.07904
	PEDES2						1.85990	1.79884	1.72061
PWDSW1									
	PWDES1						1.80332	1.97821	2.06881
	PWDWS1						1.66921	1.88321	2.00347
	PWDES2						1.60297	1.83105	1.95819
I25EDSW1									
	I25EDWS1			1.67047	1.81543	1.77622	1.67173	1.80953	1.79292
	I25EDES1			1.64670	1.78464	1.70896	1.63808	1.66604	1.67492
	I25EDEM1				1.94339		1.62357	1.83077	1.77402
	I25EDWS2						1.82981	2.04411	1.91614
	I25EDES2				2.64038	2.36891	2.35342	2.38679	2.44958
	I25EDEM2			2.45933	2.56148	2.41173	2.41364	2.80142	3.22462
I25WDSW1									
	I25WDES1			2.08309	2.10633	2.15863	2.59770	2.81397	2.79000
	I25WDEM1			2.27725		2.25471	2.64238	2.80459	2.72852
	I25WDES2				2.56690	2.67587	3.47315	3.22649	3.25551
	I25WDEM2			2.60418	2.63677	2.77443	3.17807	3.27107	3.29456

Table B-3. Vertical-Hydraulic Gradients measured at piezometer nests and partitioned by location, site, and season.

Alameda Sites	POR	Spring	Summer	Fall	Winter
Alameda East Side	0.0071907	-0.0074739	0.0021294	0.0230089	0.0177732
ERS1-ERM1	0.0106549	-0.0095784	-0.0004783	0.0316808	0.0307333
ERM1-ERD1	-0.0082100	-0.0096505	-0.0072813	-0.0069965	-0.0083922
EBS1-EBM1	0.0293899	0.0026208	0.0379418	0.0613701	0.0188519
EBM1-EBD1	-0.0076421	-0.0078986	-0.0073418	-0.0073729	-0.0080611
ERS2-ERM2	0.0067402	-0.0150314	-0.0033019	0.0304661	0.0267556
EBS2-EBM2	0.0060744	-0.0247198	-0.0222506	0.0370734	0.0573444
EBM2-EBD2	0.0133274	0.0119407	0.0176178	0.0148411	0.0071806
Alameda West Side	-0.0008256	-0.0012442	-0.0011291	-0.0002984	-0.0007622
WRS1-WRM1	0.0008171	0.0005097	0.0001256	0.0017159	0.0005270
WBS1-WBM1	0.0005068	0.0010314	0.0003140	-0.0001378	0.0017524
WBM1-WBD1	-0.0061829	-0.0076111	-0.0071763	-0.0043404	-0.0045143
WRS2-WRM2	0.0000610	-0.0011304	0.0002061	0.0011252	-0.0025206
WBS2-WBM2	0.0010003	0.0009058	0.0009624	0.0009817	0.0017587
WBM2-WBD2	-0.0011560	-0.0011703	-0.0012065	-0.0011350	-0.0015762

Paseo Del Norte Sites	POR	Spring	Summer	Fall	Winter
Paseo Del Norte East Side	-0.0000643	-0.0007054	0.0009586	-0.0005536	-0.0000839
ERS1-ERM1	-0.0007825	-0.0010283	0.0000157	-0.0011823	-0.0009724
EBS1-EBM1	0.0023322	0.0031808	0.0016209	0.0017123	0.0026563
ERS2-ERM2	0.0006544	-0.0012121	-0.0006908	0.0013507	0.0032370
EBS2-EBM2	-0.0013865	-0.0005072	0.0004734	-0.0031574	-0.0024222
EBM2-EBD2	-0.0022500	-0.0064048	0.0044312	-0.0021617	-0.0054391
EDES2-EDEM2	0.0010467	0.0017391	-0.0000990	0.0001165	0.0024370
Paseo Del Norte West Side	-0.0013256	-0.0044495	-0.0017240	0.0020498	-0.0006187
WRS1-WRM1	-0.0025784	-0.0027862	-0.0019692	-0.0028462	-0.0027368
WBS1-WBM1	-0.0085880	-0.0105961	-0.0093091	-0.0073225	-0.0072384
WDWS1-WDWM1	-0.0132248	-0.0299178	-0.0186035	0.0069572	-0.0078740
WS1-WD1	0.0149018	0.0131499	0.0178170	0.0159637	0.0126808
WRS2-WRM2	-0.0002881	-0.0003720	-0.0001836	-0.0007955	0.0001983
WBS2-WBD2	-0.0002639	-0.0000302	-0.0003050	-0.0003810	-0.0003441
WDWS2-WDWM2	0.0007619	-0.0005942	0.0004855	0.0027727	0.0009831

Montano Sites	POR	Spring	Summer	Fall	Winter
Montano East Side	0.0042219	0.0049743	0.0041959	0.0037087	0.0039831
ERS1-ERM1	-0.0040519	-0.0042445	-0.0035624	-0.0035005	-0.0049161
EBS1-EBM1	-0.0039300	-0.0040496	-0.0033116	-0.0038091	-0.0046085
EBM1-EBD1	0.0151761	0.0218798	0.0138298	0.0099636	0.0154936
EDWS1-EDWM1	0.0061661	0.0063043	0.0056233	0.0053644	0.0070683
ERS2-ERM2	0.0052935	0.0054493	0.0066358	0.0049152	0.0037333
EBS2-EBM2	0.0029647	0.0028447	0.0032268	0.0037993	0.0018795
EBM2-EBD2	0.0006639	0.0000476	0.0006319	0.0007944	0.0011318
EDWS2-EDWM2	0.0114929	0.0115626	0.0104935	0.0121420	0.0120827
Montano West Side	0.0033340	0.0025367	0.0015377	0.0034182	0.0054209
WRS1-WRM1	0.0063801	-0.0026792	0.0064221	0.0156089	0.0042005
WBS1-WBM1	-0.0024446	-0.0029988	-0.0035802	-0.0024250	-0.0007348

WDWS1-WDWM1	0.0042900	0.0064590	-0.0053319	-0.0001978	0.0151429
WRS2-WRM2	0.0020372	0.0007364	0.0012307	0.0016008	0.0048773
WBS2-WBM2	0.0110523	0.0117440	0.0115616	0.0098172	0.0109470
WBM2-WBD2	-0.0033789	-0.0038561	-0.0039325	-0.0031365	-0.0024402
WDWS2-WDWM2	0.0054020	0.0083514	0.0043937	0.0026598	0.0059540

Central Sites	**POR**	**Spring**	**Summer**	**Fall**	**Winter**
Central East Side	0.0009049	0.0011788	0.0007140	0.0007705	0.0009618
ERS1-ERM1	0.0007795	0.0023696	-0.0000266	-0.0001089	0.0008140
EBS1-EBM1	0.0036858	0.0041908	0.0035870	0.0034130	0.0034561
EBM1-EBD1	-0.0001339	-0.0001268	-0.0001775	-0.0000956	-0.0001316
ERS2-ERM2	-0.0001182	-0.0006449	-0.0004106	0.0002390	0.0006000
EBS2-EBM2	0.0002081	0.0001304	-0.0001304	0.0005179	0.0004035
EBM2-EBD2	0.0010081	0.0011540	0.0014420	0.0006574	0.0006289
Central West Side	0.0014752	0.0027758	0.0011548	0.0005178	0.0014291
WRS1-WRM1	0.0010883	0.0009517	-0.0002705	0.0018689	0.0022646
WBS1-WBM1	0.0000081	0.0010966	-0.0002343	-0.0012432	0.0003880
WBM1-WBD1	0.0059437	0.0100942	0.0081884	-0.0006209	0.0050794
WRS2-WRM2	-0.0001154	0.0019203	-0.0027848	0.0022857	-0.0013872
WBS2-WBM2	0.0008713	0.0022802	-0.0004921	0.0003470	0.0014744
WBM2-WBD2	0.0010553	0.0003120	0.0025221	0.0004690	0.0007554

Barelas Sites	**POR**	**Spring**	**Summer**	**Fall**	**Winter**
Barelas East Side	0.0042616	0.0051632	0.0046799	0.0041042	0.0030402
ERS1-ERM1	-0.0015195	-0.0016163	-0.0013945	-0.0008993	-0.0022061
EBS1-EBM1	-0.0014258	-0.0017143	-0.0017894	-0.0010670	-0.0010711
EBM1-EBD1	0.0170260	0.0180593	0.0207880	0.0162386	0.0113336
EDWS1-EDWM1	0.0200090	0.0243599	0.0244167	0.0217807	0.0095712
ERS2-ERM2	-0.0005178	-0.0000647	-0.0012168	-0.0019976	0.0010886
EBS2-EBM2	0.0022629	0.0052493	0.0039389	-0.0004487	-0.0006496
EBM2-EBD2	0.0009721	-0.0015543	-0.0023925	0.0034652	0.0065581
EDWS2-EDWM2	-0.0027139	-0.0014130	-0.0049112	-0.0042381	-0.0003034
Barelas West Side	0.0059014	0.0071494	0.0062654	0.0050354	0.0049968
WRS1-WRM1	-0.0052167	-0.0053783	-0.0058856	-0.0047823	-0.0049149
WBS1-WBM1	-0.0002375	-0.0003913	-0.0015017	0.0008150	-0.0002329
WBM1-WBD1	0.0234313	0.0280365	0.0262818	0.0197079	0.0201627
WDES1-WDEM1	-0.0020998	-0.0019943	-0.0020731	-0.0022304	-0.0020883
WS1-WM1	-0.0033624	-0.0036914	-0.0031847	-0.0029484	-0.0036787
WM1-WD1	0.0016015	0.0018659	0.0013969	0.0012064	0.0019720
WRS2-WRM2	0.0000865	-0.0003931	0.0006775	0.0001104	-0.0000613
WBS2-WBM2	0.0003850	0.0004758	0.0001292	0.0008333	0.0001135
WBM2-WBD2	0.0467394	0.0562409	0.0496576	0.0380000	0.0412687
WDES2-WDEM2	-0.0023130	-0.0032772	-0.0028442	-0.0003582	-0.0025732

Rio Bravo Sites	**POR**	**Spring**	**Summer**	**Fall**	**Winter**
Rio Bravo East Side	0.0066968	0.0066836	0.0066197	0.0065212	0.0066695
ERS1-ERM1	0.0028959	0.0030576	0.0035043	0.0029972	0.0019505
ERM1-ERD1	0.0358632	0.0419259	0.0358293	0.0300986	0.0324257
EBS1-EBM1	0.0011331	-0.0003304	0.0009765	0.0009544	0.0031016
EBM1-EBD1	0.0222313	0.0241707	0.0240555	0.0202324	0.0205300

EDWS1-EDWD1	0.0004672	0.0007496	0.0002892	0.0003506	0.0004788
ES1-ED1	-0.0006354	-0.0020121	-0.0011910	0.0002352	0.0003373
ERS2-ERM2	-0.0010023	-0.0010487	-0.0004979	-0.0011792	-0.0012864
EBS2-EBM2	-0.0030876	-0.0047512	-0.0025087	-0.0009546	-0.0041373
EBM2-EBD2	0.0084901	0.0056515	0.0048909	0.0108810	0.0127659
EDWS2-EDWM2	0.0006120	-0.0005768	0.0008487	0.0015964	0.0005292
Rio Bravo West Side	0.0011934	0.0007598	0.0012705	0.0018126	0.0010593
WRS1-WRM1	0.0149702	0.0170217	0.0140230	0.0138256	0.0150767
WBS1-WBM1	0.0006899	0.0014566	-0.0002877	0.0004438	0.0012512
WBM1-WBD1	0.0000054	-0.0006937	0.0017361	-0.0002823	-0.0008085
WDES1-WDED1	-0.0057733	-0.0124352	-0.0053012	0.0013322	-0.0055965
WS1-WM1	-0.0020096	-0.0023483	-0.0021972	-0.0018172	-0.0016504
WRS2-WRM2	-0.0054365	-0.0061283	-0.0046001	-0.0043509	-0.0067259
WBS2-WBM2	0.0024415	0.0023870	0.0026304	0.0020375	0.0027056
WBM2-WBD2	0.0036842	0.0053342	0.0035376	0.0026754	0.0032045
WDES2-WDEM2	0.0021686	0.0022440	0.0018935	0.0024495	0.0020765

Pajarito Sites	**POR**	**Spring**	**Summer**	**Fall**	**Winter**
Pajarito East Side	0.0101436	0.0121719	0.0096027	0.0082058	0.0104131
ERS1-ERM1	0.0004262	0.0003527	0.0002029	0.0002594	0.0010847
EBS1-EBM1	0.0146553	0.0156884	0.0141721	0.0139412	0.0146198
EBM1-EBD1	-0.0005957	-0.0008551	-0.0004236	-0.0003480	-0.0007378
ERS2-ERM2	0.0008770	0.0004203	0.0002778	0.0017043	0.0013838
EBS2-EBM2	0.0000014	-0.0009420	-0.0000797	0.0008536	0.0004288
EBM2-EBD2	0.0454976	0.0583673	0.0434669	0.0328243	0.0456993
Pajarito West Side	0.0045672	0.0053271	0.0038433	0.0039124	0.0053539
WRS1-WRM1	0.0019687	0.0010861	0.0022061	0.0027080	0.0019610
WBS1-WBM1	0.0082179	0.0129794	0.0043187	0.0041763	0.0121383
WBM1-WBD1	-0.0012408	-0.0015888	-0.0006522	-0.0011612	-0.0016968
WRS2-WRM2	0.0004908	0.0000411	0.0001932	0.0009835	0.0009539
WBS2-WBM2	0.0010048	0.0009324	0.0009034	0.0007328	0.0016099
WBM2-WBD2	0.0169618	0.0185127	0.0160906	0.0160351	0.0171569

Interstate 25 Sites	**POR**	**Spring**	**Summer**	**Fall**	**Winter**
I-25 East Side	-0.0039437	-0.0035476	-0.0042920	-0.0047445	-0.0030275
ERS1-ERM1	-0.0024943	-0.0029348	-0.0019266	-0.0038290	-0.0016962
EBS1-EBM1	0.0020578	0.0040124	0.0000277	0.0012821	0.0032769
EDES1-EDEM1	-0.0029861	-0.0038963	-0.0039188	-0.0030305	-0.0002608
ES1-EM1	-0.0084031	-0.0086293	-0.0095604	-0.0084171	-0.0064737
EM1-ED1	-0.0011896	-0.0017396	-0.0014633	-0.0009949	-0.0007663
ERS2-ERM2	0.0009133	0.0014021	0.0002779	0.0005564	0.0019448
EBS2-EBM2	-0.0005649	0.0000564	-0.0007006	-0.0013482	0.0000889
EBM2-EBD2	0.0013498	0.0011744	0.0013546	0.0008185	0.0022465
EDES2-EDEM2	-0.0241758	-0.0213739	-0.0227190	-0.0277377	-0.0256076
I-25 West Side	0.0026312	0.0018259	0.0025597	0.0037342	0.0022916
WRS1-WRM1	-0.0039209	-0.0042873	-0.0019855	-0.0050545	-0.0044815
WBS1-WBM1	-0.0033698	-0.0007757	-0.0006092	-0.0048399	-0.0073566
WBM1-WBD1	-0.0079776	-0.0178696	-0.0024509	-0.0025094	-0.0124729
WDES1-WDEM1	-0.0036969	-0.0030757	-0.0059726	-0.0036787	-0.0018744
WS1-WM1	-0.0021598	-0.0041359	-0.0032397	-0.0011272	0.0003023

WM1-WD1	0.0547764	0.0585516	0.0453559	0.0596816	0.0570351
WRS2-WRM2	-0.0033258	-0.0043822	-0.0014118	-0.0027586	-0.0049972
WBS2-WBM2	-0.0009849	-0.0019130	-0.0024819	0.0010270	0.0003909
WBM2-WBD2	0.0010682	0.0012512	0.0017246	0.0007133	0.0003895
WDES2-WDEM2	-0.0040970	-0.0051049	-0.0033318	-0.0041121	-0.0040197

Table B-4. Vertical-Hydraulic Gradients measured at piezometer nests and partitioned by location, site, and year.

Alameda Sites	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Alameda East Side						0.0099794	0.0081991	0.0029825
ERS1-ERM1						0.0100287	0.0112676	0.0105387
ERM1-ERD1						-0.0109959	-0.0069621	-0.0067796
EBS1-EBM1						0.0431540	0.0268183	0.0179057
EBM1-EBD1						-0.0070063	-0.0075164	-0.0084731
ERS2-ERM2						-0.0045216	0.0110740	0.0134343
EBS2-EBM2						0.0079705	0.0177601	-0.0102649
EBM2-EBD2						0.0312263	0.0049521	0.0045160
Alameda West Side						-0.0005493	-0.0009493	-0.0009720
WRS1-WRM1						-0.0004444	0.0015068	0.0013311
WBS1-WBM1						-0.0001682	0.0006411	0.0010694
WBM1-WBD1						-0.0047726	-0.0073242	-0.0063043
WRS2-WRM2						0.0019481	0.0000861	-0.0020022
WBS2-WBM2						0.0015929	0.0005165	0.0009530
WBM2-WBD2						-0.0014517	-0.0011219	-0.0008792
Paseo Del Norte Sites	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Paseo Del Norte East Side					0.0008330	0.0001986	0.0002832	-0.0007637
ERS1-ERM1					-0.0009218	-0.0003259	-0.0002206	-0.0016846
EBS1-EBM1					0.0025878	0.0034503	0.0023028	0.0021887
ERS2-ERM2						0.0016740	-0.0008913	0.0002378
EBS2-EBM2						-0.0006502	-0.0013151	-0.0027949
EBM2-EBD2						-0.0022189	0.0000808	-0.0053287
EDES2-EDEM2						-0.0007379	0.0017425	0.0027995
Paseo Del Norte West Side					-0.0041290	-0.0022505	-0.0025678	-0.0048105
WRS1-WRM1					-0.0016430	-0.0016219	-0.0029479	-0.0046596
WBS1-WBM1					-0.0086961	-0.0067872	-0.0075641	-0.0108327
WDWS1-WDWM1					-0.0020479	-0.0033448	-0.0195799	-0.0359163
WS1-WD1							0.0133322	0.0170642
WRS2-WRM2						0.0009662	-0.0011996	-0.0010352
WBS2-WBD2						-0.0004646	-0.0001655	0.0001218
WDWS2-WDWM2							0.0001502	0.0015845
Montano Sites	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Montano East Side		0.0149280	0.0031284	0.0043570	0.0053960	0.0044590	0.0037659	0.0035633
ERS1-ERM1			-0.0055601	-0.0038018	-0.0027387	-0.0027897	-0.0042211	-0.0056190
EBS1-EBM1			-0.0089108	-0.0002838	0.0020874	-0.0009936	-0.0076183	-0.0092058

EBM1-EBD1		0.0149280	0.0174060	0.0164647	0.0161576	0.0135490	0.0134876	0.0137811
EDWS1-EDWM1			0.0077381				0.0063190	0.0046249
ERS2-ERM2				0.0056910		0.0057612	0.0060767	0.0039374
EBS2-EBM2				0.0044009	0.0029964	0.0022344	0.0023604	
EBM2-EBD2			0.0009375	-0.0014114	0.0016301	0.0012688	0.0011991	
EDWS2-EDWM2			0.0071599	0.0094394	0.0122429	0.0121832	0.0125242	0.0138609
Montano West Side			0.0038103	0.0023869	0.0034204	0.0070367	0.0042021	-0.0026482
WRS1-WRM1			0.0034322	0.0114982	0.0133516	0.0252081		-0.0278873
WBS1-WBM1			0.0072566	-0.0042910	-0.0015280	-0.0018484	-0.0092619	-0.0092302
WDWS1-WDWM1			-0.0025128	0.0032511	-0.0048558		0.0187022	0.0042109
WRS2-WRM2			0.0015442	0.0014959	0.0050000	0.0053443	-0.0012402	-0.0007015
WBS2-WBM2			0.0211752	0.0093041	0.0097559	0.0099233	0.0077772	0.0087606
WBM2-WBD2			-0.0141870	-0.0024658	-0.0013271	-0.0016673	-0.0001507	-0.0008727
WDWS2-WDWM2			0.0099640	-0.0020840	0.0035464	0.0052603	0.0093863	0.0071830

Central Sites	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Central East Side						0.0010178	0.0007093	0.0010193
ERS1-ERM1						0.0006519	0.0009863	0.0006667
EBS1-EBM1						0.0022637	0.0034868	0.0053590
EBM1-EBD1						0.0014066	-0.0002479	-0.0015609
ERS2-ERM2						-0.0000654	-0.0002119	-0.0000620
EBS2-EBM2						0.0004641	-0.0007562	0.0010769
EBM2-EBD2						0.0013861	0.0009986	0.0006362
Central West Side						0.0005797	0.0004521	0.0039906
WRS1-WRM1						0.0003788	0.0018831	0.0008699
WBS1-WBM1						-0.0018942	0.0005607	0.0013115
WBM1-WBD1						-0.0004937	0.0023438	0.0169000
WRS2-WRM2						0.0032569	-0.0046213	
WBS2-WBM2						0.0010540	0.0010256	0.0004984
WBM2-WBD2						0.0011764	0.0015205	0.0003734

Barelas Sites	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Barelas East Side			0.0044706	0.0023211	0.0049014	0.0061418	0.0051383	0.0076736
ERS1-ERM1			-0.0003445	-0.0026758	0.0000387		-0.0037700	-0.0010303
EBS1-EBM1			0.0000548	0.0011288	-0.0002200		-0.0059101	-0.0050958
EBM1-EBD1			0.0179605	0.0164430	0.0178225		0.0162899	0.0156121
EDWS1-EDWM1			0.0177443	0.0172000	0.0185264	0.0259082	0.0217070	0.0212083
ERS2-ERM2			-0.0037634	-0.0009792	0.0003277	0.0014612	-0.0005657	
EBS2-EBM2			0.0032020	0.0025005	0.0015064	0.0031233	0.0003565	
EBM2-EBD2			-0.0008627	-0.0025536	0.0011425	0.0003151	0.0078609	
EDWS2-EDWM2			0.0017738	-0.0124950	0.0000674	-0.0000986		
Barelas West Side		0.0284350	0.0069771	0.0050427	0.0067615	0.0067213	0.0060362	0.0064972
WRS1-WRM1			-0.0043032	-0.0048091	-0.0058069	-0.0068201	-0.0035491	-0.0055630
WBS1-WBM1			-0.0025333		0.0015277			-0.0005383
WBM1-WBD1		0.0284350	0.0266285		0.0212780			0.0219741
WDES1-WDEM1			-0.0018798	-0.0010487	-0.0005292			-0.0043086
WS1-WM1			-0.0034429	-0.0035507	-0.0030093			
WM1-WD1			0.0023288	0.0015497	0.0015967	0.0004201	0.0017328	0.0019977
WRS2-WRM2			-0.0024498	-0.0027616			0.0021516	0.0043309
WBS2-WBM2			0.0008498	-0.0004347	0.0002350	0.0002542	0.0010315	0.0004289

WBM2-WBD2			0.0580075	0.0538890	0.0479836	0.0389082	0.0379849	0.0438493
WDES2-WDEM2			-0.0034348	-0.0024921	-0.0024220	0.0008438	-0.0031342	-0.0036963

Rio Bravo Sites	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Rio Bravo East Side	0.0000489	0.0011419	0.0057146	0.0060171	0.0076749	0.0117892	0.0070656	0.0065983
ERS1-ERM1			0.0031352	0.0036993	0.0038954	0.0032903	0.0024631	0.0008671
ERM1-ERD1			0.0298332	0.0348159	0.0430820	0.0339030	0.0396399	0.0403686
EBS1-EBM1			0.0035537	-0.0002500	-0.0008487		0.0010902	0.0008240
EBM1-EBD1			0.0190870	0.0202751	0.0293284		0.0259071	0.0222546
EDWS1-EDWD1	0.0004197	0.0003588	0.0001993	0.0006397	0.0001742		0.0004375	0.0011325
ES1-ED1	-0.0003219	0.0020335	-0.0015126	-0.0004158	-0.0001656	0.0002637	-0.0041827	-0.0004082
ERS2-ERM2			-0.0008755	-0.0004419	-0.0016558	-0.0002152	-0.0014846	-0.0015067
EBS2-EBM2		-0.0024823	-0.0008883	-0.0048493	-0.0045096		-0.0009048	-0.0040299
EBM2-EBD2		0.0046577	0.0041178	0.0065606	0.0075785	0.0337912	0.0062655	0.0040184
EDWS2-EDWM2			0.0004964	0.0001370	-0.0001293	-0.0002977	0.0014247	0.0024627
Rio Bravo West Side	-0.0019913	-0.0026299	0.0015342	-0.0003571	0.0030834	0.0008030	0.0019429	0.0007768
WRS1-WRM1			0.0139121	0.0124540	0.0213956	0.0130907	0.0197231	0.0063661
WBS1-WBM1			0.0021275				0.0010571	-0.0003771
WBM1-WBD1	0.0003619	0.0000116	0.0000908				-0.0001255	-0.0001667
WDES1-WDED1	-0.0040575	-0.0059027	-0.0031112	-0.0156700	-0.0048273	-0.0059114	-0.0044149	-0.0010526
WS1-WM1	-0.0022783	-0.0019986	-0.0020608	-0.0026425	-0.0020837	-0.0016452	-0.0015766	
WRS2-WRM2			-0.0047509	-0.0051607	-0.0051239	-0.0048913	-0.0053973	-0.0062044
WBS2-WBM2			0.0020749	0.0024371	0.0044459	0.0033827	0.0021498	0.0016067
WBM2-WBD2			0.0033664	0.0042300	0.0041570		0.0039623	0.0034250
WDES2-WDEM2			0.0021593	0.0018521	0.0036201	0.0007927	0.0021078	0.0026178

Pajarito Sites	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Pajarito East Side						0.0108987	0.0101312	0.0093394
ERS1-ERM1						-0.0011426	0.0011671	0.0011511
EBS1-EBM1						0.0173419	0.0137461	0.0127648
EBM1-EBD1						-0.0011016	-0.0001274	-0.0006491
ERS2-ERM2						0.0018521	0.0006667	0.0001222
EBS2-EBM2						0.0002186	0.0001224	-0.0003711
EBM2-EBD2						0.0482235	0.0452123	0.0430187
Pajarito West Side						0.0044076	0.0048362	0.0044121
WRS1-WRM1						0.0011104	0.0018806	0.0029637
WBS1-WBM1						0.0040255	0.0104273	0.0099230
WBM1-WBD1						0.0010366	-0.0021164	-0.0025462
WRS2-WRM2						0.0006072	0.0005333	0.0003190
WBS2-WBM2						0.0026752	0.0001626	0.0002882
WBM2-WBD2						0.0169904	0.0181301	0.0155248

Interstate 25 Sites	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
I-25 East Side		-0.0012799	-0.0012228	-0.0002027	-0.0014146	-0.0011284	-0.0070365	-0.0095565
ERS1-ERM1			-0.0001758	-0.0000195	-0.0027723	-0.0028805	-0.0050733	-0.0037887
EBS1-EBM1			0.0002965	0.0010917	0.0022467	-0.0006644	0.0034725	0.0137625
EDES1-EDEM1		-0.0014593		-0.0009122	-0.0035781	0.0050531	-0.0123683	-0.0066061
ES1-EM1			-0.0067566				-0.0078041	-0.0113207
EM1-ED1		-0.0011005	-0.0006064				-0.0020509	-0.0015667
ERS2-ERM2				0.0011470	0.0008912		0.0003450	0.0011648

EBS2-EBM2			-0.0008105			0.0005760	-0.0013233
EBM2-EBD2		0.0011284	0.0019819			0.0010373	0.0011736
EDES2-EDEM2			-0.0038974	-0.0038607	-0.0060219	-0.0414630	-0.0775038
I-25 West Side	-0.0010749	0.0091979	0.0006409	0.0134034	0.0128485	0.0025032	-0.0004327
WRS1-WRM1		-0.0036860				-0.0044968	-0.0031628
WBS1-WBM1		-0.0063441		-0.0183683	-0.0251495	0.0037260	0.0257583
WBM1-WBD1	-0.0032864					-0.0043932	-0.0209618
WDES1-WDEM1		-0.0134713	-0.0010295	-0.0063912	-0.0029790	0.0009231	0.0040989
WS1-WM1	0.0006792	0.0017429	-0.0089004			0.0010636	-0.0013359
WM1-WD1	-0.0006174	0.0677479	0.0216332	0.1110810	0.1093315	0.0366898	-0.0015210
WRS2-WRM2			-0.0029589	-0.0001439	-0.0017404	-0.0062251	-0.0060659
WBS2-WBM2						-0.0002210	-0.0022281
WBM2-WBD2			0.0004295	0.0011551	-0.0002329	0.0009376	0.0036946
WDES2-WDEM2			-0.0053288	-0.0069122	-0.0021386	-0.0029717	-0.0026033

Table B-5. Horizontal-Hydraulic Gradient magnitudes and directions; partitioned by location, site, season, and year.

Alameda East Avg Magnitude:	**East Avg**	**1-2-4 (ERS1-ERS2)-EBS1**	**1-2-5 ERS1-(EBS1-EBS2)**	**1-4-5 (ERS1-ERS2)-EBS2**	**2-4-5 ERS2-(EBS1-EBS2)**	**2-3-5 (EBS1-EBS2)-EDWS1**	**2-3-6 EBS1-(EDWS1-EDWS2)**	**2-5-6 (EBS1-EBS2)-EDWS2**	**3-5-6 EBS2-(EDWS1-EDWS2)**
POR	0.0279614	0.0241778	0.0241741	0.0236219	0.0236374	0.0143149	0.0175941	0.0339754	0.0621953
Spring	0.0291549	0.0283573	0.0283754	0.0285019	0.0284282	0.0139503	0.0169381	0.0316251	0.0570629
Summer	0.0252951	0.0185721	0.0190928	0.0242957	0.0242562	0.0152258	0.0178449	0.0304955	0.0525777
Fall	0.0275937	0.0197866	0.0198112	0.0197850	0.0197854	0.0153767	0.0190630	0.0376292	0.0695127
Winter	0.0307386	0.0321835	0.0313088	0.0202526	0.0205865	0.0122794	0.0164495	0.0380599	0.0747887
2009	0.0274924	0.0202830	0.0202030	0.0184195	0.0186951	0.0154178	0.0191356	0.0378347	0.0699502
2010	0.0285731	0.0252988	0.0252296	0.0240761	0.0240990	0.0140233	0.0174303	0.0345119	0.0639157
2011	0.0275432	0.0267473	0.0269014	0.0283376	0.0283303	0.0134684	0.0160947	0.0290287	0.0514373
Avg Direction:									
POR	87.2151861	89.6255954	89.1141984	89.5708589	90.2318966	87.7360969	78.6537659	91.1886007	81.6004761
Spring	87.4150663	90.5180939	90.4868632	90.3897961	90.6049391	86.6115117	78.3330486	90.8659496	81.5103286
Summer	85.6559100	88.5728898	84.9455239	89.8027922	88.0064399	84.7581319	78.5494010	89.3119542	81.3001468
Fall	87.1999534	89.3072720	88.9261796	88.7157101	89.6302948	88.5233810	78.9900525	91.7439690	81.7627684
Winter	89.2382159	90.3025884	93.6321120	89.1014949	93.6287206	92.7057774	78.8718720	93.6927630	81.9703985
2009	86.6601183	87.8400687	87.0969935	87.8949515	89.2917247	88.7351508	78.9610388	91.7170977	81.7439206
2010	87.6791126	90.2877379	90.3863123	90.0248146	90.8887898	88.1693707	78.4837271	91.5727607	81.6193880
2011	87.1882085	90.6214253	89.5994821	90.7129742	90.4271327	86.0808076	78.5301949	90.1157361	81.4179154
Alameda West Avg Magnitude:	**West Avg**	**1-2-4 WBS1-(WDES1-WDES2)**	**1-2-5 (WBS1-WBS2)-WDES1**	**1-4-5 WBS2-(WDES1-WDES2)**	**2-4-5 (WBS1-WBS2)-WDES2**	**2-3-5 WRS1-(WBS1-WBS2)**	**2-3-6 (WRS1-WRS2)-WBS1**	**2-5-6 WRS2-(WBS1-WBS2)**	**3-5-6 (WRS1-WRS2)-WBS2**
POR	0.0045499	0.0029679	0.0022307	0.0049937	0.0049130	0.0057069	0.0057385	0.0049316	0.0049172
Spring	0.0049631	0.0029906	0.0023760	0.0052104	0.0051726	0.0063647	0.0063753	0.0056156	0.0055993
Summer	0.0047759	0.0030325	0.0022929	0.0053704	0.0053017	0.0061534	0.0062230	0.0049309	0.0049026
Fall	0.0041105	0.0029953	0.0022131	0.0046816	0.0045532	0.0049445	0.0049599	0.0042711	0.0042652
Winter	0.0041733	0.0028067	0.0019485	0.0045318	0.0044297	0.0050680	0.0050753	0.0047642	0.0047622
2009	0.0045248	0.0034080	0.0031902	0.0046597	0.0046579	0.0053790	0.0053924	0.0047590	0.0047522
2010	0.0044643	0.0026825	0.0015368	0.0050559	0.0048892	0.0057831	0.0058375	0.0049721	0.0049574
2011	0.0046807	0.0028396	0.0020403	0.0052785	0.0052179	0.0059697	0.0059813	0.0050704	0.0050481

Avg Direction:									
POR	71.7878153	45.0324433	51.1252423	69.7388708	83.6801073	82.7569832	79.4189170	83.7622240	78.7877343
Spring	78.7731596	53.5777568	95.4080537	71.3899370	84.0790795	82.7617690	79.9051422	83.5934366	79.4701017
Summer	69.2489797	42.3124432	27.4912350	70.2405801	85.6055339	84.4323855	79.3360078	86.2554500	78.3182024
Fall	63.3279647	37.8290522	-3.3429172	67.8955655	82.5277259	82.0791828	78.7151051	82.9370707	77.9829323
Winter	75.5405740	45.0509787	86.7347082	68.8363513	81.8059652	81.2155642	79.7126537	81.4917227	79.4766478
2009	79.1108486	69.8412975	84.8758860	75.0177623	82.3123320	81.5887193	78.7721537	82.3016658	78.1769720
2010	59.8570981	21.5913868	-18.4685035	65.0448039	84.3358684	83.2242800	79.7389943	84.2631972	79.1267578
2011	78.4757161	46.8705214	99.8346501	69.7732722	84.3640462	83.4536217	79.7332007	84.7347204	79.0416964

PDN East Avg Magnitude:	**East Avg**	**1-2-4 (ERS1-ERS2)-EBS1**	**1-2-5 ERS1-(EBS1-EBS2)**	**1-4-5 (ERS1-ERS2)-EBS2**	**2-4-5 ERS2-(EBS1-EBS2)**	**2-3-5 (EBS1-EBS2)-EDWS1**	**2-3-6 EBS1-(EDWS1-EDWS2)**	**2-5-6 (EBS1-EBS2)-EDWS2**	**3-5-6 EBS2-(EDWS1-EDWS2)**
POR	0.0099237	0.0087270	0.0085428	0.0108177	0.0102335	0.0114550	0.0123322	0.0071864	0.0100948
Spring	0.0102568	0.0088921	0.0087350	0.0114300	0.0104948	0.0117940	0.0126287	0.0075011	0.0105787
Summer	0.0092748	0.0073939	0.0072156	0.0094981	0.0089149	0.0113604	0.0121474	0.0075457	0.0101220
Fall	0.0093389	0.0080808	0.0078652	0.0101196	0.0095368	0.0109003	0.0117840	0.0068076	0.0096171
Winter	0.0107255	0.0103147	0.0101279	0.0122333	0.0117656	0.0117094	0.0126990	0.0069095	0.0100449
2009	0.0107283	0.0104715	0.0102719	0.0111986	0.0119629	0.0117583	0.0127161	0.0070703	0.0103772
2010	0.0100463	0.0088668	0.0087010	0.0107838	0.0103466	0.0116583	0.0125296	0.0073563	0.0101281
2011	0.0094750	0.0081632	0.0079662	0.0101532	0.0096823	0.0111286	0.0119894	0.0070091	0.0097078
Avg Direction:									
POR	86.8885297	84.0417578	95.0346821	85.6915721	92.3381311	90.8852278	76.8141179	98.0426266	72.2601220
Spring	87.9837242	85.1920003	96.3042681	86.2478019	93.3906263	91.8449468	77.8568753	99.3762444	73.6570307
Summer	86.7792465	83.3448434	96.1919986	85.5233169	92.9116811	89.9623435	77.3577117	95.4241315	73.5179454
Fall	85.7368305	82.5009212	94.0678701	84.8422551	91.4132635	89.8561609	75.8867331	96.3172845	71.0101553
Winter	86.9773148	84.9488828	93.6994593	86.1369162	91.6791186	91.7274413	76.1925291	100.6516972	70.7824742
2009	87.0109891	84.5779113	93.4554040	85.6801600	91.4314250	91.6408238	76.5304226	100.0426107	72.7291552
2010	87.2533974	84.7354430	95.3456234	86.2451632	92.6810670	91.1288607	77.1139338	98.4009610	72.3761270
2011	86.4641536	83.2670759	95.0651868	85.1484135	92.1980201	90.4595034	76.5767717	97.2101188	71.7881385

PDN West Avg Magnitude:	**West Avg**	**1-2-4 WBS1-(WDES1-WDES2)**	**1-2-5 (WBS1-WBS2)-WDES1**	**1-4-5 WBS2-(WDES1-WDES2)**	**2-4-5 (WBS1-WBS2)-WDES2**	**2-3-5 WRS1-(WBS1-WBS2)**	**2-3-6 (WRS1-WRS2)-WBS1**	**2-5-6 WRS2-(WBS1-WBS2)**	**3-5-6 (WRS1-WRS2)-WBS2**
POR	0.0054250	0.0052924	0.0052556	0.0054000	0.0053619	0.0056297	0.0056349	0.0054112	0.0054146
Spring	0.0062134	0.0059880	0.0058997	0.0063851	0.0063196	0.0061986	0.0061801	0.0063825	0.0063538
Summer	0.0054398	0.0052478	0.0052281	0.0053479	0.0053274	0.0057747	0.0057908	0.0053918	0.0054102
Fall	0.0049107	0.0049287	0.0049230	0.0049138	0.0048863	0.0051208	0.0051337	0.0046830	0.0046963
Winter	0.0051034	0.0049637	0.0049564	0.0048910	0.0048524	0.0054074	0.0054180	0.0051638	0.0051747
2009	0.0056235	0.0056241	0.0055989	0.0055750	0.0055207	0.0056665	0.0056617	0.0056756	0.0056658
2010	0.0054851	0.0053454	0.0052921	0.0055544	0.0055392	0.0057374	0.0057482	0.0053276	0.0053367
2011	0.0052375	0.0049015	0.0048432	0.0052614	0.0052248	0.0055691	0.0055812	0.0052526	0.0052664
Avg Direction:									
POR	81.0961542	80.8839236	80.1662158	80.5808811	80.3287600	81.5920834	82.5845208	80.6448670	81.9879822
Spring	84.0808154	85.3258933	82.2700955	86.1096573	83.3596215	84.2174640	83.6058378	84.0200984	83.7378555
Summer	80.6126460	81.1802529	78.7160350	81.9321468	79.7218722	80.5849588	82.1655147	79.3329415	81.2674459
Fall	79.0068785	78.3868615	78.7374466	77.5666444	78.4661329	79.4354666	81.4632003	77.7472433	80.2520325
Winter	79.8058409	78.5380683	79.4929700	77.1921588	78.8647150	80.9059309	81.9230353	80.1214117	81.4084368
2009	81.6303878	80.6521953	81.9483897	79.1148295	81.1058118	82.6368591	82.7367105	82.2409449	82.6073615
2010	81.6999471	82.1712959	80.0609040	82.9467016	81.0103178	81.6245710	83.4495062	79.9772294	82.3590512
2011	80.7809766	81.6817166	78.2961867	82.8485746	79.6762352	80.7057840	82.0076535	79.7236880	81.3079741

Montano East Avg Magnitude:	East Avg	1-2-4 (ERS1-ERS2)-EBS1	1-2-5 ERS1-(EBS1-EBS2)	1-4-5 (ERS1-ERS2)-EBS2	2-4-5 ERS2-(EBS1-EBS2)	2-3-5 (EBS1-EBS2)-EDWS1	2-3-6 EBS1-(EDWS1-EDWS2)	2-5-6 (EBS1-EBS2)-EDWS2	3-5-6 EBS2-(EDWS1-EDWS2)
POR	0.0099322	0.0060677	0.0054909	0.0125833	0.0113999	0.0104752	0.0101608	0.0117291	0.0115508
Spring	0.0112617	0.0066543	0.0063492	0.0139462	0.0127464	0.0126239	0.0114841	0.0131953	0.0130939
Summer	0.0097123	0.0056361	0.0050523	0.0122398	0.0110192	0.0102050	0.0099870	0.0118405	0.0117183
Fall	0.0085745	0.0054102	0.0046255	0.0111844	0.0100392	0.0086015	0.0083397	0.0103603	0.0100351
Winter	0.0099057	0.0065146	0.0058882	0.0127663	0.0116136	0.0100435	0.0103466	0.0111357	0.0109371
2006	0.0078153	0.0060439					0.0095867		
2007	0.0093935	0.0056978	0.0051607	0.0115334	0.0104771	0.0097924	0.0104034	0.0110467	0.0110365
2008	0.0102662	0.0062464	0.0056395	0.0131939	0.0119223	0.0107746	0.0106608	0.0119559	0.0117362
2009	0.0099080	0.0059765	0.0053699	0.0127596	0.0115065	0.0102548	0.0101929	0.0117333	0.0114709
2010	0.0102288	0.0063254	0.0058171	0.0126361	0.0115347	0.0111189	0.0102665	0.0121563	0.0119756
2011	0.0078116	0.0060908					0.0095325		
Avg Direction:									
POR	93.9390907	84.3933311	99.4706311	85.1261316	95.3128156	95.5259325	98.2374901	95.1916481	98.2547458
Spring	96.1233404	87.8026654	103.9574886	87.5498034	97.6761279	97.5990845	98.3967571	97.4511368	98.5536598
Summer	93.2097525	81.5256988	98.7182153	84.2228099	94.7472181	94.9392333	98.6285900	94.4932755	98.4029789
Fall	92.0187317	80.4094619	95.9818154	83.1635800	93.4806332	93.8108485	97.7840758	93.4062625	98.1131767
Winter	94.0612121	87.5139902	98.3738533	85.2842646	94.9566984	95.4458397	98.0035716	95.0936677	97.8178111
2006	99.9230226	100.0836476					99.7623976		
2007	94.5615175	87.7206127	99.6743992	85.4990031	95.5319267	95.6591049	98.4342449	95.3645403	98.6083084
2008	93.3279268	82.3916213	98.8621619	84.6992150	94.9905991	95.2096406	97.6538863	94.9871470	97.8291433
2009	93.1564960	81.8383228	98.5405281	84.3164782	94.6987501	95.0270228	98.0589143	94.5947508	98.1772010
2010	94.8658299	85.2104735	101.4118501	86.4541285	96.3883606	96.5233466	98.2431841	96.1262965	98.5689994
2011	90.0580989	82.5503910					97.5658067		

Montano West Avg Magnitude:	West Avg	1-2-4 WBS1-(WDES1-WDES2)	1-2-5 (WBS1-WBS2)-WDES1	1-4-5 WBS2-(WDES1-WDES2)	2-4-5 (WBS1-WBS2)-WDES2	2-3-5 WRS1-(WBS1-WBS2)	2-3-6 (WRS1-WRS2)-WBS1	2-5-6 WRS2-(WBS1-WBS2)	3-5-6 (WRS1-WRS2)-WBS2
POR	0.0036141	0.0038284	0.0029212	0.0060340	0.0042374	0.0035632	0.0034042	0.0026491	0.0022755
Spring	0.0036161	0.0038882	0.0027289	0.0062785	0.0041686	0.0034690	0.0033274	0.0026933	0.0023751
Summer	0.0036039	0.0032762	0.0033849	0.0049335	0.0044465	0.0038484	0.0036679	0.0028272	0.0024466
Fall	0.0035925	0.0038139	0.0029388	0.0059817	0.0041656	0.0036465	0.0034764	0.0025683	0.0021490
Winter	0.0036432	0.0043585	0.0026211	0.0069812	0.0041597	0.0032776	0.0031346	0.0024757	0.0021372
2006	0.0030805	0.0028209	0.0030737	0.0039534	0.0037685	0.0033151	0.0031064	0.0025057	0.0021005
2007	0.0031914	0.0026755	0.0029578	0.0040223	0.0037724	0.0037378	0.0035208	0.0026680	0.0021766
2008	0.0035724	0.0032080	0.0027398	0.0057944	0.0045335	0.0037162	0.0035573	0.0027009	0.0023289
2009	0.0039503	0.0044243	0.0031559	0.0067622	0.0045733	0.0038813	0.0037421	0.0027218	0.0023415
2010	0.0037664	0.0045150	0.0026847	0.0072914	0.0042607	0.0034222	0.0032595	0.0026057	0.0020916
2011	0.0035239	0.0035801	0.0027776	0.0061392	0.0043060	0.0030947	0.0030462	0.0026892	0.0025584
Avg Direction:									
POR	65.2415071	30.9638579	37.7555725	105.3684838	71.0589821	65.0992780	81.5123886	53.2601689	76.9133253
Spring	59.8224004	5.4240507	29.6070325	108.3513425	70.0867563	62.9096073	76.5197280	53.3295054	72.3511806
Summer	75.8800796	95.4528171	62.7957440	93.3751875	71.3813271	66.8142758	83.7149486	54.8407960	78.6655406
Fall	68.1504304	40.5392723	38.9610048	105.3893646	71.3311454	67.2423037	86.6884001	53.1898955	81.8620566
Winter	39.5297853	-33.0265227	2.2413499	91.2220356	51.1075363	47.4819909	62.0630736	37.1730048	57.9758138
2006	70.8300663	84.1194728	60.8085429	86.2546453	67.8168386	63.4997626	79.9165436	50.9831820	73.2415429
2007	72.8931863	88.0462312	58.9164822	89.3640386	67.6017384	65.3098381	84.7790147	50.5158746	78.6122727

2008	82.3580731	121.9116931	62.0235936	107.9255327	76.0598562	68.0966532	85.8235294	55.8309597	81.1927673
2009	66.8984420	21.4508579	36.2035992	108.1327506	73.1529159	68.7298216	87.8721867	55.3363207	84.3090836
2010	56.0976350	-30.7565402	13.0521556	117.2450875	71.1496608	64.8929074	82.6148599	52.6200666	77.9628822
2011	61.9090189	36.1953414	37.5243877	109.8525303	71.2979708	58.2032751	64.6189501	54.3200096	63.2596862

Central East Avg Magnitude:	**East Avg**	**1-2-4 (ERS1-ERS2)-EBS1**	**1-2-5 ERS1-(EBS1-EBS2)**	**1-4-5 (ERS1-ERS2)-EBS2**	**2-4-5 ERS2-(EBS1-EBS2)**	**2-3-5 (EBS1-EBS2)-EDWS1**	**2-3-6 EBS1-(EDWS1-EDWS2)**	**2-5-6 (EBS1-EBS2)-EDWS2**	**3-5-6 EBS2-(EDWS1-EDWS2)**
POR	0.0064904	0.0049548	0.0048483	0.0063264	0.0062844	0.0073621	0.0076057	0.0072533	0.0072882
Spring	0.0073010	0.0057310	0.0056027	0.0073547	0.0073029	0.0079747	0.0084219	0.0080073	0.0080124
Summer	0.0062373	0.0049089	0.0047999	0.0062161	0.0061693	0.0071232	0.0071495	0.0067133	0.0068181
Fall	0.0058608	0.0041874	0.0041388	0.0051586	0.0051378	0.0066501	0.0072737	0.0071693	0.0071709
Winter	0.0064353	0.0049080	0.0047826	0.0065325	0.0064839	0.0078035	0.0072042	0.0068822	0.0068854
2009	0.0069446	0.0053197	0.0052070	0.0067288	0.0066814	0.0078678	0.0078602	0.0079216	0.0079700
2010	0.0060291	0.0047007	0.0046073	0.0059958	0.0059625	0.0069828	0.0072620	0.0063538	0.0063676
2011	0.0059026	0.0048826	0.0047680	0.0063068	0.0062602	0.0072953			
Avg Direction:									
POR	85.7812312	89.2337081	83.4958734	88.7961493	84.1185976	84.4367715	85.6997761	84.4787442	85.9902291
Spring	85.8510227	89.9220222	83.5429403	89.2711515	84.2836990	84.4038814	85.4753874	84.1915212	85.7175790
Summer	86.7411786	90.4212635	84.9096702	89.7669889	85.1881851	85.3542150	86.4749961	84.8111102	87.0029998
Fall	84.6521851	86.5556424	82.0223482	86.6373484	82.7553760	83.4955288	85.3361492	85.0228649	85.3922228
Winter	85.7219833	90.0466267	83.3923602	89.4646435	84.1502083	84.4376008	85.0869165	83.9337678	85.2637425
2009	86.2268204	90.2061049	84.6481111	89.6292081	85.0112405	85.1993829	84.9513456	85.2038362	84.9653336
2010	84.9792942	87.5071362	81.6395694	87.2663087	82.6368928	83.1970343	86.7104770	83.5026589	87.3742761
2011	86.9171283	90.2687125	84.5041942	89.7447977	84.9507762	85.1171609			

Central West Avg Magnitude:	**West Avg**	**1-2-4 WBS1-(WDES1-WDES2)**	**1-2-5 (WBS1-WBS2)-WDES1**	**1-4-5 WBS2-(WDES1-WDES2)**	**2-4-5 (WBS1-WBS2)-WDES2**	**2-3-5 WRS1-(WBS1-WBS2)**	**2-3-6 (WRS1-WRS2)-WBS1**	**2-5-6 WRS2-(WBS1-WBS2)**	**3-5-6 (WRS1-WRS2)-WBS2**
POR	0.0041946	0.0050141	0.0050215	0.0048925	0.0048886	0.0034936	0.0038909	0.0031437	0.0032120
Spring	0.0046354	0.0052138	0.0052017	0.0054320	0.0053672	0.0039437	0.0044853	0.0036864	0.0037531
Summer	0.0041764	0.0051395	0.0051521	0.0049004	0.0049210	0.0034467	0.0037356	0.0030232	0.0030926
Fall	0.0038159	0.0047956	0.0048216	0.0043607	0.0044011	0.0031067	0.0034035	0.0027907	0.0028474
Winter	0.0039575	0.0048269	0.0048303	0.0047797	0.0047846	0.0034163	0.0035404	0.0027008	0.0027812
2009	0.0045538	0.0055793	0.0055870	0.0054238	0.0054374	0.0038567	0.0038974	0.0032990	0.0033498
2010	0.0042209	0.0051831	0.0051997	0.0049528	0.0049339	0.0036610	0.0038820	0.0029309	0.0030234
2011	0.0039838	0.0042309	0.0042270	0.0042716	0.0042683	0.0029210			
Avg Direction:									
POR	85.9317645	90.1037185	89.4030162	89.8671807	89.0973316	85.1894279	81.1001277	83.3287497	79.3645637
Spring	86.7873928	88.7495038	89.7793005	89.3055795	90.0729561	87.0065755	82.7739036	85.1489252	81.4623985
Summer	85.6528512	90.5822023	89.3791493	90.1396007	88.9374824	84.6814543	80.4847073	82.5298980	78.4883150
Fall	85.1946603	91.0954291	88.6964805	90.1298491	87.7319932	82.9423700	80.1855438	82.0936227	78.6819938
Winter	85.7633658	90.0664344	89.8104707	89.9503706	89.6945097	86.2266548	80.0085641	82.5932249	77.7566971
2009	86.7376750	90.8543791	90.0251578	90.5720164	89.6970418	85.9821367	81.9842468	83.9102501	80.8761713
2010	85.6663576	91.0201235	89.5282123	90.4458737	88.9344319	85.6862849	79.8892688	82.5323470	77.2943185
2011	87.5521403	88.2467877	88.6127040	88.4467013	88.6702337	83.7842746			

Barelas East Avg Magnitude:	**East Avg**	**1-2-4 (ERS1-ERS2)-EBS1**	**1-2-5 ERS1-(EBS1-EBS2)**	**1-4-5 (ERS1-ERS2)-EBS2**	**2-4-5 ERS2-(EBS1-EBS2)**	**2-3-5 (EBS1-EBS2)-EDWS1**	**2-3-6 EBS1-(EDWS1-EDWS2)**	**2-5-6 (EBS1-EBS2)-EDWS2**	**3-5-6 EBS2-(EDWS1-EDWS2)**
POR	0.0094989	0.0137701	0.0135337	0.0096341	0.0094254	0.0057189	0.0061992	0.0087926	0.0089171
Spring	0.0102607	0.0152508	0.0149829	0.0103855	0.0101190	0.0056908	0.0063409	0.0095846	0.0097310

Summer	0.0090624	0.0126345	0.0124176	0.0087093	0.0085226	0.0056485	0.0062516	0.0090857	0.0092291
Fall	0.0084964	0.0118298	0.0116120	0.0086179	0.0084166	0.0054706	0.0058560	0.0080170	0.0081516
Winter	0.0101012	0.0151181	0.0148768	0.0107666	0.0105410	0.0060674	0.0063552	0.0085004	0.0085838
2006	0.0099216	0.0143590	0.0140964	0.0100363	0.0097786	0.0061781	0.0065598	0.0091273	0.0092371
2007	0.0097614	0.0140391	0.0138037	0.0096945	0.0094729	0.0059080	0.0063786	0.0093424	0.0094524
2008	0.0094578	0.0140193	0.0137648	0.0096321	0.0093887	0.0056029	0.0060108	0.0085663	0.0086772
2009	0.0090040	0.0128720	0.0126648	0.0093571	0.0092290	0.0054117	0.0058718	0.0082370	0.0083882
2010	0.0090617	0.0134668	0.0132495	0.0094082	0.0091919	0.0053786	0.0059921	0.0078549	0.0079519
Avg Direction:									
POR	82.1740686	82.0233162	90.7615095	79.6864193	88.6469375	83.8790643	67.8342864	87.9791114	76.5819040
Spring	82.1084417	82.1846111	91.6035111	79.6741370	89.5455347	84.3356805	64.5840269	89.1347211	75.8053112
Summer	82.4495137	81.9540945	90.9146248	79.5444626	88.8415088	85.0323980	67.3786261	89.0605528	76.8698420
Fall	80.8997544	81.2434522	89.1343732	78.9422125	86.7285143	81.6935923	67.5659233	86.2233253	75.6666422
Winter	83.1661626	82.6577735	91.1638587	80.5786503	89.2021202	84.2379669	71.8486492	87.5833761	78.0569063
2006	82.4609821	81.8776495	90.8237781	79.2967418	88.5515794	84.2236388	69.5135545	88.0946137	77.3063012
2007	82.7898948	82.2981538	91.4073161	79.9772857	89.4300376	85.2348424	67.5989537	89.2985246	77.0740448
2008	82.2301048	81.8353905	91.0201535	79.2660306	88.7996083	84.0553445	68.0179558	88.1416647	76.7046902
2009	80.9624588	81.8577142	89.4840519	79.8351938	87.4414344	81.6452082	65.8163753	86.4980978	75.1215950
2010	82.7071544	82.3429560	91.1666342	80.2152788	89.1218649	84.1634932	71.1657724	86.2897428	77.1914927

Barelas West Avg Magnitude:	**West Avg**	**1-2-4 WBS1-(WDES1-WDES2)**	**1-2-5 (WBS1-WBS2)-WDES1**	**1-4-5 WBS2-(WDES1-WDES2)**	**2-4-5 (WBS1-WBS2)-WDES2**	**2-3-5 WRS1-(WBS1-WBS2)**	**2-3-6 (WRS1-WRS2)-WBS1**	**2-5-6 WRS2-(WBS1-WBS2)**	**3-5-6 (WRS1-WRS2)-WBS2**
POR	0.0090082	0.0100994	0.0099865	0.0107927	0.0106954	0.0061722	0.0060555	0.0092254	0.0090385
Spring	0.0102882	0.0112400	0.0111148	0.0121003	0.0119936	0.0074284	0.0073549	0.0106166	0.0104571
Summer	0.0088989	0.0103313	0.0102140	0.0110706	0.0109661	0.0057606	0.0056312	0.0087006	0.0085166
Fall	0.0079938	0.0092633	0.0091812	0.0097213	0.0096485	0.0052475	0.0050641	0.0080351	0.0077893
Winter	0.0087262	0.0093506	0.0092203	0.0100333	0.0099293	0.0061145	0.0061635	0.0095776	0.0094205
2006	0.0102047	0.0112366	0.0110915	0.0122018	0.0120729	0.0071572	0.0070860	0.0104810	0.0103101
2007	0.0094384	0.0103462	0.0101606	0.0115163	0.0113596	0.0062489	0.0062462	0.0098722	0.0097571
2008	0.0094989	0.0103777	0.0102187	0.0112739	0.0111368	0.0065214	0.0067256	0.0099694	0.0097675
2009	0.0079606	0.0096062	0.0095415	0.0099648	0.0099061	0.0059461	0.0047958	0.0071175	0.0068068
2010	0.0085548	0.0097196	0.0096693	0.0100472	0.0099996	0.0060682	0.0058809	0.0086447	0.0084085
2011	0.0080726	0.0093390	0.0092888	0.0097124	0.0096692	0.0052358	0.0051223	0.0081968	0.0080168
Avg Direction:									
POR	81.6627888	76.2471236	79.5809908	76.8662075	80.0636854	73.9026982	93.9296924	78.9190237	93.7928888
Spring	83.0625870	77.1499892	80.9202894	77.7740681	81.3827547	77.3288912	94.6981239	80.8780413	94.3685381
Summer	81.9740418	76.5700975	80.1067778	77.2066323	80.6085886	73.6961780	94.4728741	78.9007942	94.2303923
Fall	79.8019521	75.7543585	78.1262021	76.2376256	78.5522019	70.2971460	91.0238943	76.5158665	91.9083216
Winter	81.6616410	75.3197043	78.9041292	76.0486289	79.4469192	73.8189404	95.6703083	79.3577132	94.7267844
2006	82.9034832	76.6460377	80.8851111	77.3779474	81.4714748	76.7324454	95.1462548	80.4118316	94.5567627
2007	83.7068779	75.5719255	81.2624383	76.6444454	81.9746653	76.5407826	99.3095503	80.9088462	97.4423694
2008	80.6913157	74.5937831	78.8786220	75.5036192	79.5650015	73.0671274	92.5382477	78.6881637	92.6959613
2009	77.9274384	75.6739373	77.5009096	76.0415911	77.8671484	70.6682934	84.2265842	74.2412173	87.1998262
2010	80.3077884	76.9796407	78.6051330	77.2509327	78.8651575	72.8752223	89.6435407	77.4168725	90.8258080
2011	82.3958728	78.1196967	80.0631748	78.4033505	80.2996159	73.4569952	95.2449137	78.7026613	94.8765743

Rio Bravo East Avg Magnitude:	**East Avg**	**1-2-4 (ERS1-ERS2)-EBS1**	**1-2-5 ERS1-(EBS1-EBS2)**	**1-4-5 (ERS1-ERS2)-EBS2**	**2-4-5 ERS2-(EBS1-EBS2)**	**2-3-5 (EBS1-EBS2)-EDWS1**	**2-3-6 EBS1-(EDWS1-EDWS2)**	**2-5-6 (EBS1-EBS2)-EDWS2**	**3-5-6 EBS2-(EDWS1-EDWS2)**
POR	0.0045831	0.0038088	0.0032181	0.0051936	0.0048830	0.0045558	0.0051124	0.0050086	0.0048848

Spring	0.0049718	0.0040783	0.0035121	0.0055072	0.0052724	0.0049756	0.0053073	0.0055960	0.0055254
Summer	0.0046974	0.0037972	0.0031704	0.0053580	0.0050365	0.0044289	0.0063540	0.0047279	0.0047067
Fall	0.0039193	0.0033807	0.0028029	0.0045425	0.0042018	0.0038727	0.0038002	0.0044767	0.0042768
Winter	0.0045201	0.0037299	0.0031193	0.0049826	0.0046246	0.0045690	0.0048459	0.0052232	0.0050664
2005	0.0039229	0.0033404	0.0026262	0.0045163	0.0047210	0.0044103			
2006	0.0043574	0.0038127	0.0030714	0.0052383	0.0048176	0.0042369	0.0040804	0.0049103	0.0046919
2007	0.0044832	0.0038967	0.0033400	0.0051179	0.0047853	0.0044000	0.0046051	0.0049427	0.0047776
2008	0.0047901	0.0039743	0.0034938	0.0052749	0.0049909	0.0050479	0.0049471	0.0053396	0.0052527
2009	0.0048331	0.0037399	0.0031949	0.0052783	0.0049737	0.0053185	0.0057714	0.0050593	0.0053291
2010	0.0048096	0.0038009	0.0032657	0.0052382	0.0048763	0.0043876	0.0073491	0.0049583	0.0046004
2011	0.0043936	0.0038579	0.0032342	0.0053833	0.0050348	0.0042637	0.0041403	0.0046859	0.0045489
Avg Direction:									
POR	66.4600074	44.1565579	56.2085574	59.1946415	68.3866654	65.9261416	74.1788084	69.4598597	74.6392256
Spring	68.6564947	46.8259218	58.5363163	60.8296858	70.5670150	68.0673169	75.8105353	72.8688666	76.2166976
Summer	67.4451862	44.9036315	58.6002325	60.9567294	70.7587443	66.7135910	74.0817135	70.2717764	73.7454684
Fall	63.0290702	40.1007110	51.4868758	55.9583181	64.8429419	61.1863082	71.6265487	66.7209861	72.7802700
Winter	64.8300624	41.1251401	52.3018248	56.4399516	65.1922168	64.5175337	75.3118239	68.1982963	76.0241100
2005	54.9640592	33.4208087	44.9722801	52.6790712	67.6557737	63.8863609			
2006	63.3856893	38.2694534	50.6869873	55.8900577	65.4940688	62.2042786	73.7576555	66.3359885	74.9174226
2007	64.6015410	43.5350656	53.9834932	57.4009342	65.5194475	63.1388094	73.1275248	66.4289024	74.1485490
2008	68.7472311	48.9007578	59.8285111	61.4300508	69.5747664	69.5643116	74.7127967	71.1842397	75.2528126
2009	70.1832884	48.5011258	62.3256128	62.6805529	72.0814034	72.6126932	75.5301986	72.5983812	75.6067375
2010	67.4865671	46.3963309	58.4728367	60.7760658	69.1347727	67.4638675	74.7262503	69.6407324	73.7520788
2011	67.0309638	45.2502819	58.4840790	60.3294647	69.7464890	66.3961395	73.6320459	68.4947563	74.3848522

Rio Bravo West Avg Magnitude:	**West Avg**	**1-2-4 WBS1-(WDES1-WDES2)**	**1-2-5 (WBS1-WBS2)-WDES1**	**1-4-5 WBS2-(WDES1-WDES2)**	**2-4-5 (WBS1-WBS2)-WDES2**	**2-3-5 WRS1-(WBS1-WBS2)**	**2-3-6 (WRS1-WRS2)-WBS1**	**2-5-6 WRS2-(WBS1-WBS2)**	**3-5-6 (WRS1-WRS2)-WBS2**
POR	0.0084245	0.0089770	0.0090300	0.0078172	0.0079198	0.0107733	0.0107330	0.0061047	0.0060408
Spring	0.0106201	0.0130825	0.0131450	0.0097364	0.0098279	0.0126619	0.0125929	0.0070273	0.0068868
Summer	0.0101745	0.0106743	0.0107268	0.0079830	0.0082695	0.0158685	0.0158527	0.0060445	0.0059772
Fall	0.0056984	0.0049218	0.0050205	0.0062858	0.0063418	0.0064187	0.0063792	0.0051366	0.0050829
Winter	0.0071835	0.0072496	0.0072523	0.0072986	0.0072743	0.0079980	0.0079615	0.0062409	0.0061932
2006	0.0095155	0.0066363	0.0066859	0.0071343	0.0071367	0.0180512	0.0181854	0.0057956	0.0064985
2007	0.0073930	0.0093204	0.0092197	0.0073199	0.0071139	0.0074673	0.0074220	0.0056757	0.0056049
2008	0.0080027	0.0082896	0.0082396	0.0086568	0.0086649	0.0087088	0.0086529	0.0064511	0.0063580
2009	0.0120944	0.0159145	0.0162748	0.0086032	0.0093584	0.0168204	0.0165778	0.0070768	0.0061292
2010	0.0074294	0.0075272	0.0075502	0.0081460	0.0081732	0.0078764	0.0078299	0.0062018	0.0061304
2011	0.0062062	0.0064503	0.0064911	0.0074137	0.0074594	0.0053089	0.0053418	0.0055496	0.0056346
Avg Direction:									
POR	76.0234062	78.8515506	77.2249730	78.4183180	80.0740964	65.8858005	69.2298524	78.2300682	80.2725904
Spring	75.5188023	80.1468396	81.8247638	77.7054001	83.9122058	55.5546494	60.0201808	82.6128224	82.3735563
Summer	74.3970112	78.5562876	79.2297600	77.7241991	82.8145468	54.0863994	58.3991492	81.0076438	83.3581036
Fall	75.8966704	78.4014297	70.4173842	80.3657107	75.7359885	75.6776436	77.8413336	73.0117589	75.7221136
Winter	78.4046975	78.2957428	77.5313122	77.8055324	77.9265198	78.6814508	81.0698330	76.4182941	79.5088948
2006	81.0344746	79.6519827	75.2447261	79.8176752	77.9927415	79.9968239	84.8786013	76.1628751	94.5303709
2007	76.7512962	76.2761965	75.9343744	72.8895854	77.1214772	77.8484153	80.6196869	74.9497985	78.3708356
2008	78.0349005	78.4833679	77.0700734	78.7777448	77.8238663	78.0241770	81.1103105	74.5328012	78.4568631
2009	67.1252489	82.3281824	82.4241749	80.8988800	92.9980800	8.8357647	16.0112550	95.2511241	78.2545303
2010	77.4914056	78.1424715	76.8030214	78.8629617	77.4847245	77.1608977	79.5546979	74.4871143	77.4353560

2011	75.4850182	78.6801140	76.0642460	79.9293811	77.4663015	72.6264013	71.4674547	74.1011622	73.5450852

Pajarito East Avg Magnitude:	**East Avg**	**1-2-4 (ERS1-ERS2)-EBS1**	**1-2-5 ERS1-(EBS1-EBS2)**	**1-4-5 (ERS1-ERS2)-EBS2**	**2-4-5 ERS2-(EBS1-EBS2)**	**2-3-5 (EBS1-EBS2)-EDWS1**	**2-3-6 EBS1-(EDWS1-EDWS2)**	**2-5-6 (EBS1-EBS2)-EDWS2**	**3-5-6 EBS2-(EDWS1-EDWS2)**
POR	0.0145680	0.0123097	0.0123995	0.0144446	0.0145555	0.0176041	0.0172654	0.0140513	0.0139137
Spring	0.0158324	0.0132390	0.0133364	0.0155932	0.0156616	0.0192746	0.0189060	0.0153988	0.0152497
Summer	0.0138080	0.0112165	0.0112997	0.0132317	0.0132905	0.0171468	0.0168303	0.0137871	0.0136616
Fall	0.0133873	0.0113680	0.0114555	0.0134075	0.0135167	0.0160898	0.0157729	0.0128099	0.0126783
Winter	0.0151394	0.0135866	0.0136775	0.0158736	0.0159378	0.0174642	0.0171128	0.0138041	0.0136587
2009	0.0147713	0.0123009	0.0123952	0.0146765	0.0147387	0.0179609	0.0176178	0.0143084	0.0141718
2010	0.0146355	0.0125221	0.0126095	0.0146133	0.0146746	0.0175735	0.0172311	0.0140002	0.0138598
2011	0.0142438	0.0120273	0.0121154	0.0139996	0.0141763	0.0172276	0.0168990	0.0138200	0.0136849
Avg Direction:									
POR	92.9972072	93.7241826	89.9695513	93.1002293	90.8091005	91.6416964	97.5333268	90.6314707	96.5681000
Spring	92.9885622	93.6883813	89.9218830	93.0586554	90.7700044	91.6737314	97.5372664	90.6792744	96.5793013
Summer	93.0592785	93.7104016	89.9138245	93.0700359	90.7678338	91.8555159	97.5699130	90.9365473	96.6501561
Fall	92.8739743	93.6685148	89.8037535	93.0749158	90.6904689	91.4768803	97.4369566	90.4069788	96.4333256
Winter	93.0539215	93.8594645	90.3063301	93.2398376	91.0598083	91.4566513	97.5791342	90.3525595	96.5775863
2009	93.1913244	94.1358676	90.0411638	93.3913626	90.9338965	91.7673474	97.7060795	90.7814937	96.7733844
2010	92.9231001	93.5161952	89.9816131	92.9460147	90.7767042	91.5756652	97.5169658	90.5357429	96.5359001
2011	92.8737005	93.5290619	89.8691647	92.9870195	90.7072630	91.5851830	97.3531218	90.5872577	96.3715322

Pajarito West Avg Magnitude:	**West Avg**	**1-2-4 WBS1-(WDES1-WDES2)**	**1-2-5 (WBS1-WBS2)-WDES1**	**1-4-5 WBS2-(WDES1-WDES2)**	**2-4-5 (WBS1-WBS2)-WDES2**	**2-3-5 WRS1-(WBS1-WBS2)**	**2-3-6 (WRS1-WRS2)-WBS1**	**2-5-6 WRS2-(WBS1-WBS2)**	**3-5-6 (WRS1-WRS2)-WBS2**
POR	0.0066121	0.0078480	0.0078959	0.0077126	0.0077338	0.0047390	0.0048145	0.0065866	0.0055662
Spring	0.0073823	0.0084935	0.0085914	0.0082598	0.0083020	0.0052448	0.0053659	0.0082272	0.0065735
Summer	0.0061765	0.0073688	0.0071439	0.0075491	0.0075173	0.0047278	0.0047648	0.0053199	0.0050204
Fall	0.0062123	0.0077180	0.0077905	0.0076069	0.0076207	0.0044199	0.0044656	0.0052608	0.0048158
Winter	0.0066350	0.0077711	0.0081104	0.0072853	0.0073635	0.0044261	0.0045296	0.0077394	0.0058548
2009	0.0069982	0.0081824	0.0081693	0.0082313	0.0082347	0.0051964	0.0052615	0.0067983	0.0059117
2010	0.0066482	0.0079500	0.0079957	0.0076860	0.0077201	0.0046305	0.0047166	0.0068635	0.0056236
2011	0.0061686	0.0073786	0.0074934	0.0072071	0.0072310	0.0043946	0.0044683	0.0060363	0.0051391
Avg Direction:									
POR	73.1566220	68.1727935	66.8121621	68.1955370	66.8114427	75.7813197	83.6093926	71.0190390	84.8512890
Spring	72.0947149	68.0249813	65.3352141	67.9877830	65.5409942	72.8627439	84.4941624	66.2483614	86.2634794
Summer	74.7912337	66.5639146	70.8182849	66.7617040	69.8514664	80.2830092	82.8850051	77.7956537	83.3708315
Fall	74.2167184	69.2045479	67.5154579	69.1801037	67.7603139	78.7635247	82.7634227	74.9694224	83.5769543
Winter	70.9683038	69.4236560	62.2285743	69.3381589	63.0177196	69.6507444	84.4598991	63.0358003	86.5918780
2009	73.5382568	67.4472202	68.2872766	67.5658204	67.8679312	76.8126397	83.0930103	73.1149289	84.1172267
2010	73.0340494	68.2403962	66.0063455	68.2362388	66.0751111	75.1677888	84.5338308	70.1714275	85.8412561
2011	72.9062131	68.8432720	66.2462205	68.7990845	66.5963097	75.4455564	83.0400771	69.8597186	84.4194658

I-25 East Avg Magnitude:	**East Avg**	**1-2-4 (ERS1-ERS2)-EBS1**	**1-2-5 ERS1-(EBS1-EBS2)**	**1-4-5 (ERS1-ERS2)-EBS2**	**2-4-5 ERS2-(EBS1-EBS2)**	**2-3-5 (EBS1-EBS2)-EDWS1**	**3-4-5 ERS2-EBS2-EDWS1**	**1-2-3 ERS1-EBS1-EDWS1**	**1-3-4 (ERS1-ERS2)-EDWS1**
POR	0.0028150	0.0030120	0.0029173	0.0026580	0.0025135	0.0028054	0.0025616	0.0031530	0.0028991
Spring	0.0042223	0.0051738	0.0049346	0.0035833	0.0031421	0.0039166	0.0032114	0.0054510	0.0043655
Summer	0.0021764	0.0019793	0.0019739	0.0023112	0.0022841	0.0021968	0.0022913	0.0022123	0.0021622
Fall	0.0018925	0.0017770	0.0017681	0.0019560	0.0019411	0.0019696	0.0019701	0.0018357	0.0019224
Winter	0.0028638	0.0029722	0.0028739	0.0026935	0.0026312	0.0030373	0.0027256	0.0029301	0.0030467

2006	0.0024227		0.0024962			0.0026616		0.0021102	
2007	0.0022089	0.0020529	0.0021246	0.0022382	0.0022229	0.0023412	0.0022492	0.0022097	0.0022325
2008	0.0029068	0.0024196	0.0024432	0.0027660	0.0027733	0.0035560	0.0028583	0.0033262	0.0031116
2009	0.0041322	0.0057734	0.0053925	0.0032072	0.0025737	0.0030636	0.0026482	0.0063205	0.0040784
2010	0.0024707	0.0021985	0.0022043	0.0025250	0.0025170	0.0026965	0.0025479	0.0025423	0.0025336
2011	0.0022782	0.0021967	0.0021923	0.0024044	0.0023925	0.0021857	0.0024002	0.0022261	0.0022276
Avg Direction:									
POR	78.4117541	75.9816844	77.9623939	79.3894097	78.0294066	78.2300325	74.7599650	85.2662996	77.6748412
Spring	84.5894904	84.6112081	83.7988721	91.8053138	83.2240408	83.3154290	73.8620174	87.9411213	88.1579205
Summer	75.4385869	71.0928805	75.0006368	73.9693860	77.1439737	74.3768162	80.9424391	79.3287997	71.6537629
Fall	73.3260234	69.4307198	71.9762995	71.5811226	73.7405233	72.8347606	74.1536792	82.3315665	70.5595156
Winter	79.6075849	78.5241467	80.4531759	79.1185427	77.2489557	81.8268711	68.6694859	91.1882686	79.8312323
2006	92.3254553		93.5450772			93.3635516		90.0677370	
2007	76.7405558	71.9861726	77.6828833	74.4013663	76.7081539	78.4857788	76.7205798	84.7777491	73.1617625
2008	79.7275775	76.0852183	78.8529084	77.4260540	79.9797609	80.1592638	70.1670706	97.5431974	77.6071465
2009	79.7145078	82.4391737	78.6681748	91.5912016	76.8626799	77.8504157	69.6294203	73.9775288	86.6974676
2010	77.2046616	73.6896803	76.5243727	75.4944753	78.1290247	76.9000238	77.1507258	85.1868963	74.5620938
2011	77.0412056	74.5496721	77.0004323	76.2310932	78.2886750	76.5066641	82.6771203	76.4239355	74.6520523

I-25 West		**1-2-4**	**1-2-5**	**1-4-5**	**2-4-5**	**2-3-5**	**2-3-6**	**2-5-6**	**3-5-6**
Avg Magnitude:	**West Avg**	**WBS1-(WDES1-WDES2)**	**(WBS1-WBM2)-WDES1**	**WBM2-(WDES1-WDES2)**	**(WBS1-WBM2)-WDES2**	**WRS1-(WBS1-WBM2)**	**(WRS1-WRS2)-WBS1**	**WRS2-(WBS1-WBM2)**	**(WRS1-WRS2)-WBM2**
POR	0.0053314	0.0038739	0.0044169	0.0049711	0.0053755	0.0058927	0.0062848	0.0059729	0.0058635
Spring	0.0059280	0.0044948	0.0048993	0.0056529	0.0060309	0.0069837	0.0072081	0.0062492	0.0059054
Summer	0.0050855	0.0037319	0.0044662	0.0050202	0.0055792	0.0061551	0.0059819	0.0050598	0.0046893
Fall	0.0050757	0.0033423	0.0039780	0.0045132	0.0050171	0.0049092	0.0059377	0.0063531	0.0065553
Winter	0.0051511	0.0038380	0.0041410	0.0045242	0.0046762	0.0051143	0.0059823	0.0063743	0.0065587
2006	0.0045655		0.0040260			0.0049712	0.0046992		
2007	0.0049247	0.0040609	0.0047359	0.0054405	0.0059876	0.0058208	0.0052110	0.0042818	0.0038593
2008	0.0054203	0.0046106	0.0051723	0.0058015	0.0062121	0.0068490	0.0061818	0.0045310	0.0040043
2009	0.0064301	0.0042382	0.0044289	0.0047364	0.0048000	0.0061783	0.0084425	0.0090937	0.0095233
2010	0.0054990	0.0032041	0.0039328	0.0045086	0.0050300	0.0053098	0.0067567	0.0074399	0.0078103
2011	0.0040748	0.0030223	0.0037618	0.0042323	0.0047981	0.0054015	0.0047291	0.0036095	0.0030441
Avg Direction:									
POR	65.3034059	69.3310847	57.9818110	73.3628475	61.9502843	64.5218789	69.8230688	58.7904925	66.6657794
Spring	66.7159650	69.4707795	59.0675132	72.9467297	61.8587265	66.8275779	73.9495382	59.8448794	69.7619756
Summer	65.1342271	69.1054229	55.9622558	74.5491085	61.7030613	63.7318413	73.7673541	55.6402676	66.6145057
Fall	64.6111449	71.0396466	57.2036050	76.1803132	62.8768864	62.3899309	64.3168142	59.2735123	63.6084502
Winter	64.5135701	67.5713979	59.6585753	69.2363050	61.3991851	64.4581326	66.8344962	60.9088943	66.0415748
2006	71.2299608		68.4181086			71.1912025	74.0805713		
2007	67.1829711	73.3211268	59.5933094	77.7371760	64.6054993	63.9918229	74.8111055	56.9112167	66.4925123
2008	70.1787123	73.4551466	62.8461480	76.3911409	66.1248656	67.6135339	81.7621519	59.5571266	73.6795848
2009	60.4987696	62.1515033	54.8678869	63.5178801	57.0890735	63.0304935	57.0269173	61.9504118	64.3559901
2010	64.0067457	70.6438501	55.5987080	76.3315226	61.9817899	62.9514337	59.7317894	61.6117517	63.2031199
2011	63.7803127	67.3410097	52.9039901	73.9710942	59.8472387	62.6051084	76.8325241	51.6249038	65.1166329