Appendix A: Methodology

1.0 Groundwater Monitoring

1.1 Land Disturbance

The groundwater monitoring installation consists of drilling a borehole, installing the well, and development and testing of the aquifer, and is done according to ASTM standards D 6151-08, ASTM D 5092-04 E01 and ASTM D5784-95 R06.

The drilling activities for the groundwater monitoring wells will utilize standard drill rigs and standard drilling investigation methods. Groundwater Monitoring Wells are installed using Hollow Stem Auger methods and a truck-mounted or track-mounted drill rig.

Upon completion of the boreholes, a 2 inch diameter PVC pipe serves as a well casing. A sand or gravel filter is installed between the casing and the borehole walls, and a bentonite clay seal of at least 1 foot thickness is installed above the sand or gravel filter. The remaining void between the casing and the borehole walls is filled with concrete to the ground surface. Well development will occur after a minimum of 12 hours of completion to remove fine-grained materials from the well. This can be accomplished by bailing, surging, and pumping water until the water in the well is reasonably sediment free. After completion of each monitoring well, battery powered pressure transducers and data loggers may be installed in some wells to begin measuring continuous groundwater levels.

1.2 Data Collection

Monitoring Well core samples are logged for soil texture information using USCS methods according to ASTM D 2487-06 E01, ASTM D 2488-06 and Reclamation's Engineering Geology Field Manual. Several of the SJRRP-installed monitoring wells, and all hand-augered boreholes are logged according to USDA methods as specified in USDA Agriculture Handbook Number 436. The USCS and USDA methods use different sand fraction grain size limits; however, comparison of soil textures determined using both methods can be done to closely approximate the soil texture classification using the other method.

Water levels in many of these wells are measured electronically at an hourly frequency via the installation of battery powered pressure transducers and data loggers, and manual measurements will be made using electric sounders periodically (generally weekly, some monthly). Groundwater level measurements are recorded as depth below ground surface.

1.3 Calculations

Soil texture data are used to evaluate soil water holding capacity, soil and aquifer permeability, depth to restrictive soil layers, and the storage capacity of shallow aquifers. Soil texture information is needed to interpret EM38 readings and evaluate the hydraulic properties of the soil for the design of surface or subsurface drains or shallow wells. Soil textural information allows soil and drainage personnel to evaluate natural drainage factors and limitations.

Reclamation soil scientists and drainage engineers prefer to use the USDA soil textural system and nomenclature. Soils logged using the Unified (USCS) system have been assigned a USDA estimated texture for use in soil and drainage analyses purposes.

The USCS classification system is a comprehensive system that is used by geologists and civil engineers for structure design and many other purposes. This system includes many soil properties other than texture such as liquid limits and the plasticity index.

Water level elevation data are used to evaluate the interaction of surface water and shallow groundwater at the project site.

2.0 Surface Water Monitoring

2.1 Land Disturbance

Streamgages are located at most structures and divisions between Reaches along the San Joaquin River. In addition to streamgages, several stage recorders with pressure transducers have been deployed in the river channel collecting hourly data. Also, staff gages - t-posts pushed into the river bottom - can be read with periodic manual measurements. Finally, periodic water surface profile surveys are conducted throughout the river by boat using an Acoustic Doppler Current Profiler and a real-time kinematic GPS.

Most streamgages measure stage using a stilling well or a bubbler. The stage is measured inside the stilling well using a float or a pressure, optic, or acoustic sensor. As an alternative, stage can be determined by measuring the pressure required to maintain a small flow of gas through a tube and bubbled out at a fixed location under water in the stream. The measured stage value is stored in an electronic data recorder on a regular interval, usually every 15 minutes.

2.2 Data Collection

The basic measurement made at each stream gaging station is the river stage, which is the height of the water surface above a reference elevation. Stream discharge (flow) is derived from stage data through use of a relation between stage and discharge. The stage-discharge relation for a specific stream location is defined from periodic discharge measurements made at known stages.

The most common method of measuring the stage of a river is through use of a stilling well. Stilling wells are located on the bank of a stream or on a bridge pier and are topped by a shelter that holds recorders and other instruments associated with the station. The well is connected to the stream by several intakes such that when the water level changes in the stream, the level simultaneously changes in the well. Thus, the water surface in the well is maintained at the same level (stage) as the water surface of the stream. The well damps out momentary fluctuations in the water surface in the stream because of waves and surging action that may be present in the river. An outside reference gage, typically a graduated staff gage, is read periodically to verify that the water level in the well is indeed the same as the water level in the stream, and that the intakes are not plugged. As the water level in the well rises or falls, a float in the well also, rises or falls. A graduated tape or beaded cable attached to the float, and with a counterweight on the other end, is hung over a pulley. This pulley drives a recording device. Historically, the recording device would have used a pen that recorded a graph of the river stage as it changed with time. The gaging stations at Friant Dam, Gravelly Ford, and the Chowchilla Bifurcation Structure are equipped with stilling wells.

In some cases, stilling wells are impractical because of difficulties either in installation or operation. Stations that use a bubbler system are an alternative because the shelter and recorders can be located hundreds of feet from the stream. In a bubbler system, an orifice is attached securely below the water surface and connected to the instrumentation by a length of tubing. Pressurized gas (usually nitrogen or air) is forced through the tubing and out through the orifice. Because the pressure in the tubing is a function of the depth of water over the orifice, a change in the stage of the river produces a corresponding change in pressure in the tubing. Changes in the pressure in the tubing are recorded and are converted to a record of the river stage. USGS streamgage standards, used by the SJRRP, provide stage measurements that are accurate to the nearest 0.01 foot or 0.2 percent of stage, whichever is greater. Determining discharge from stage requires defining the stage-discharge relationship by measuring discharge at a wide range of river stages. Discharge measurements are made using a Pygmy or Price AA current meter or an Acoustic Doppler Current Profiler. Streamflow measurements are generally made every week to develop a rating curve and ensure correction of the rating curve for changing river conditions. (Olson, 2005).

The most practical method of measuring the discharge of a stream is through the velocity-area method. This method requires the physical measurement of the cross-sectional area and the velocity of the flowing water. Discharge is determined as the product of the area times the velocity. Velocity is measured by using a current meter. The meter consists of a propeller that is rotated by the action of flowing water. The rotation depends on the velocity of the water passing by the propeller. With each complete rotation, an electrical circuit is completed and recorded in some fashion. Given the number of revolutions in a given time interval, velocity can be determined for the location of the current meter.

Measuring the average velocity of an entire cross section is impractical; therefore, an incremental method is used. The width of the stream is divided into a number of increments; the size of the increments depends on the depth and velocity of the stream. The purpose is to divide the section into about 25 increments with approximately equal discharges. For each incremental width, the stream depth and average velocity of flow are measured. For each incremental width, the meter is placed at a depth where average velocity is expected to occur. That depth has been determined to be about 0.6 of the distance from the water surface to the streambed when depths are shallow. When depths are large, the average velocity is best represented by averaging velocity readings at 0.2 and 0.8 of the distance from the water surface to the streambed. The product of the width, depth, and velocity of the section is the discharge through that increment of the cross section. The total of the incremental section discharges equals the discharge of the river.

When the stage is low, and the stream can be waded, measurements are made by wading with the current meter mounted on a wading rod. The meter is positioned at the appropriate depth on the wading rod, which also is used to measure the water depth. If the water is too deep for wading, the measurement is made either from a boat, bridge, or cableway across the stream. If the measurement is made from a boat, bridge, or cableway, the meter is suspended on a thin cable wound on a reel. A torpedo-shaped weight is attached below the meter to permit it to be lowered into the water and to hold it in position once submerged. If measuring from a bridge, the reel is mounted on a wheeled frame (or crane) that permits the lowering of the meter assembly over the bridge rail; from a cableway, the reel is mounted in a cable car suspended from the cableway that crosses the river.

The acoustic Doppler current profiler (ADCP) is an acoustic instrument used to measure water velocities, boat velocities, and water depths. Water-velocity measurements are made by transmitting sound at a known frequency into the water and measuring the Doppler shift, or change in sound frequency, from signals reflected off particles in the water. ADCPs also can measure water depths, and when deployed from a moving boat, can measure velocity of the boat. The capability of ADCPs to measure water velocity, depth, and boat velocity enables them to measure discharge in rivers. United States Department of the Interior agencies have used the ADCP to measure discharges in rivers and streams since the mid-1980s, and an ADCP was used during hydrographic surveys on the San Joaquin River in 2005. The primary advantages of making discharge measurements using the ADCP, compared with point velocity meters such as the Price AA current meter, are that in most situations (1) the time required to complete a measurement is reduced, which is an advantage for personnel safety and for making measurements in unsteady-flow conditions, (2) the ADCP allows data to be collected throughout most of the water column and cross section rather than at discrete points, (3) the ADCP is deployed at the water surface, thus appreciably reducing the chance of snagging by debris, another safety advantage, (4) the instrument can be boat-mounted, thus eliminating the installation, maintenance, and liability of costly manned cableways, (5) complex flow regimes, such as vertical bidirectional flow, can be accurately identified and measured, and (6) many parameters are available for analyzing measurement quality. Where it is appropriate, the ADCP will be used to supplement discharge measurements made on the San Joaquin River using point velocity meters. Discharge measurements made with the ADCP will follow quality assurance guidelines established by USGS (Oberg, Morlock, and Caldwell, 2005).

2.3 Calculations

Rating curves will be used to derive stream flow from stage data at each stream gage. The stage-discharge relation is used to relate river stage to an associated stream flow. The rating curve for each gage site will be developed by making successive steam flow measurements at many different stream stages to define and maintain a stage-discharge relation. These steam flow measurements, and their corresponding stages, are then plotted on a graph. Continuous stream flow throughout the year can be determined from the rating curve and the record of river stage. The rating curve is important because it allows the use of river stage, which is easily measured, to estimate the corresponding stream flow at virtually any stream stage.

The stage-discharge relationship for the stream gages located in the sand-bedded reaches of the San Joaquin River (i.e., Reaches 2 through 5) are not expected to be permanent. Scour and deposition, as well as the growth of riparian vegetation, can alter the channel cross section and roughness, thus changing the stage-discharge relation at the gage site. Discharge measurements will be made at least twice a month, and more frequently, if feasible, during and immediately following high flow events (i.e., spring and fall pulse flows and flood flows) to assess the stage-discharge relationship at the gage. Shift corrections (adjustments in stage) will be applied to the base stage-discharge rating in computing the final discharge record for the gage.

Real-time data provided by USGS are shift-corrected, incorporating mathematical adjustments for ease of use. The shift adjustments will be applied to individual ratings, as measured data become available, resulting in an adjusted rating. Some ratings may change as often as weekly; others may not change for months or years.

Because the relationship between stage and discharge may vary with time, discharge is known only with certainty at the time of discharge measurements. If the relationship is changing, then judgement must be used to determine the most probable status of the stage-discharge relationship for times between discharge measurements. In fact, changes in the stage-discharge relationship may not be evident until a whole series of measurements is available for analysis. Therefore, the computational process usually has the following steps:

1. Following a measurement, a preliminary evaluation is made of the degree to which the stage-discharge relationship has changed on the basis of measurements made to that time. Provisional discharges are determined, assuming that the most recent measurements define the channel condition.

2. This process is repeated following each measurement. However, with each measurement, more measurements are available to evaluate the stage-discharge relationship. This may lead to changes in the provisional discharges that were computed for previous months.

3. At the end of the year, all measurements are available for review. The entire set of measurements is used to reevaluate rating conditions for the year. Final decisions are made about the stage-discharge relationships in effect during the year, and the record is refined or recomputed, as necessary. This record is then passed through a rigorous review process and, once approved, the data are considered final and are placed in the archives and published.

3.0 Soil Salinity Sampling

3.1 Land Disturbance

The soil samples will be collected with a four inch diameter hand augur. The soil will be laid on a plastic tarp. The returns from each full augur advance will be laid out in a separate pile on the tarp. An equal volume of soil will be collected from each pile of soil. On soil profiles that require logging a tile spade exposure will be used to observe soil structure to a depth of 16-18 inches. The 12 inch spatial composite plow layer soil samples will be collected with a one inch diameter Dakota probe or in some cases an Oakfield probe. At least 20 increments will be collected in a stratified random manner within a 100 foot radius of the central soil borings. If surface soils are too hard to permit sampling with the probe a tile spade will be used to collect the composite soil samples. If a tile spade is used an equal volume of soil will be collected from each depth.

3.2 Data Collection

A soil profile log will be prepared using the USDA soil textural system and nomenclature. Special emphasis will be given to depth of mottling, and or gleying, capillary fringe thickness; and depth to shallow groundwater.

3.3 Calculations

Although the soil samples will be mixed somewhat in the field the analytical laboratory should thoroughly mix soil samples before splitting samples for analysis. ECe will be taken from the saturation extract after allowing the saturation paste to stand for 24 hours after extraction, in accordance with ASCE Manuals and Reports on Engineering Practice No. 71: Agricultural Salinity Assessment and Management, pg 271. Field moisture content will be taken based on drying in an 105 degree Celcius oven. PH will be taken of the saturated soil paste. SAR will be calculated from soluble calcium, magnesium and sodium content of the saturation extract; Exchangeable Sodium Percentage (ESP) will be estimated from the SAR using handbook 60 nomograph; pg 103. Soil gypsum content will be taken using handbook 60 methods 22b or 22c.

Estimation of sampling error will be done by the field sampling crew using replicate soil samples collected from the same sampling area. External quality control of laboratory analysis will be conducted by Reclamation's Sacramento Regional Office using reference soil samples of known concentration; duplicate soil samples, and other appropriate methods.

4.0 EM 38 Measurements

4.1 Land Disturbance

The final sampling site will be placed directly under a pair of EM measurements. Sites with unusually high or low EM readings will not be selected for central boring sites. The instrument measures bulk soil electrical conductivity of an area about 6 feet long, 5 feet deep, and about 3 feet wide. The EM38 can provide many real time soil salinity measurements and information on soil salinity levels, salt distribution in the profile, and spatial variation of soil salinity within a 100 foot radius of a boring site.

4.2 Data Collection

The EM38 in the horizontal position (EMh) generally measures the bulk soil electrical conductivity to a depth of about 30 inches while the vertical EM signal (EMv) generally reflects the bulk electrical conductivity of the 0-60 inch soil depth. Both readings can be used to estimate the soil salinity of the 0-36 inch soil zone. The number of measurements can be increased if the survey area has variable readings. The EM readings will be averaged and adjusted for soil temperature.

4.3 Calculations

The Em38 data will be adjusted to a standard temperature of 25C. The data will be analyzed using normal statistics. An excel spreedsheet program will be used to determine the following statistics:

- Average
- Standard deviation
- 95 percent confidence range.

If the 95 percent confidence ranges determined in different years do not overlap then a significant change in soil salinity at the site is indicated. Other confidence ranges can also be used if deemed appropriate.

5.0 Water Quality

5.1 Land Disturbance

Reclamation will cause no permanent and little temporary land disturbance during collection of water quality samples.

5.2 Data Collection

Water quality data will be collected in accordance with a QAPP that indentifies sampling methods, parameters, analytical procedures, data acceptance criteria and project management.

5.3 Calculations

Water quality data will help track the movement of salts throughout the parcel group under evaluation. Water Quality data will also be compared with irrigation suitability criteria and appropriate regulatory criteria in order to evaluate disposal alternatives for potential interceptor drains or shallow wells.

6.0 Hydraulic Conductivity Testing

6.1 Land Disturbance

Test locations for subsurface soil hydraulic conductivity testing consist of two borings each. First, a shallow exploratory pilot is drilled to determine the soil profile and static water level. Soils will be logged according to US Department of Agriculture soil classification standards (USDA, 1999) to determine soil texture layers. In some locations, soil logs from an existing nearby monitoring well will be used for this purpose. Then, a second drill hole is advanced no more than 10 feet away to target specific depths and soil textures for permeability testing.

Borings will usually have a maximum depth of 30 feet. Both the initial exploration hole and the permeability test hole will be backfilled with the material that was excavated from the hole. In most cases the exploration and testing is completed in one day, however, there are times when the holes are left open overnight to allow complete stabilization of the water levels. When a drill hole is left open and unattended it will be covered to prevent anything from falling in from the surface.

6.2 Data Collection

The permeability tests, either auger-hole or piezometer, will consist of bailing water out of a casing in the boring and measuring the rate of return of ground water into the casing. Each test will normally be completed within a few hours. Tests will be conducted in accordance with the test standards in the US Bureau of Reclamation Drainage Manual, Chapter III, except with upgraded equipment utilizing pressure transducers and data loggers rather than the float assembly shown in the manual (USBR, 1993). The water level recovery will be measured and recorded using an In-situ Troll 200 pressure transducer and a field laptop computer.

6.3 Calculations

The calculation of hydraulic conductivity will be completed using the methods described in the USBR (1993) Drainage Manual. The hydraulic conductivity (or permeability) of the soil is one of the critical variables in computing ground water flow, drain spacing, and drainage flow rates.

Another key variable in the drainage calculations is the depth to the barrier (or slowly permeable soil layer). The barrier depth is estimated from the soil profile logs along with data from the hydraulic conductivity tests.

Calculations involving subsurface drain spacing and flow rates also require an estimate of the recharge to the water table. The typical water table recharge can be from rainfall, irrigation operations, seepage loss from the river, and canal seepage. These recharge events will be seen in the monitoring well data as water levels rise in response to the recharges. Depending upon the site of the monitoring well, the water table rise may represent a combination of all of the recharge factors and it may be difficult to separate out the individual influences.

7.0 Maps of Depth to Water and Water-Table Elevation

7.1 Input Data

The creation of groundwater maps involves using information from a variety of groundwater sources. These include the DWR and USGS databases, CCID wells, wells from the Mendota Pool Monitoring Group, and SJRRP wells. A database was developed containing water-level data from these sources and associated well construction and location/elevation information, where available.

A time series of maps of depth to water was developed and is presented in the Seepage Management Plan; these maps currently are being updated. Such maps, which help to identify areas historically subject to shallow-water conditions, will serve as a regional context for site investigations. Site maps will be developed to better understand local conditions.

Maps of water-table elevation will be developed at the regional and site scales to better understand local flow conditions in the regional setting. Accomplishing this requires known elevation of the top of each well casing, which is used to convert the measured depth to water from the top of casing to the elevation of the water surface. All existing SJRRP and CCID wells have been surveyed, and all wells installed at sites will be surveyed to ensure reasonable accuracy of this calculation.

7.2 Procedures

Given spatial depth to water or elevation data in an area of interest, interpolation techniques will be used to estimate values between known values, thus generating a surface. The better the spatial coverage at a site of investigation, the more accurate the interpolated surface.

7.3 Conclusions

Locations where groundwater mapping shows water-table elevation near the land surface elevation indicates the existence of historical, or potential for current seepage problems.

8.0 Groundwater Cross-Sections and Profiles

8.1 Input Data

Groundwater and surface water elevation data

8.2 Procedures

Groundwater elevations plotted with surface water elevations across a transect allow a description of gradients near the San Joaquin River.

8.3 Conclusions

Steep groundwater gradients away from the river may indicate minimal influence on groundwater levels in adjacent fields, whereas gradients towards the field may indicate potential for development of shallow groundwater water conditions near the river with increases in river stage. Groundwater gradients towards the river during low flow may indicate potential for development of shallow groundwater conditions in the field during high flow conditions, when (1) groundwater can no longer discharge to the river, and (2) the river may discharge to groundwater.

9.0 Modeling

9.1 Input Data

Input for parcel-scale models will include (where available, justified and warranted) irrigation, precipitation and other local sources of recharge; sediment properties from boreholes and other field investigations; and potentially various physical seepage management alternatives. Boundary conditions will be provided by a regional model (Mehl, 2005).

9.2 Procedures

Parcel-scale models will be constructed and embedded within a regional model currently being developed for this purpose. The model will be calibrated using groundwater levels collected at the site, and any other measured hydraulic response or indication of travel time.

9.3 Conclusions

Parcel-scale models will be used to interpret groundwater responses to individual sources of recharge, evaluate hydrologic responses to off-site activities, and potentially to evaluate the relative effectiveness of various physical seepage control alternatives.