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Hydrogeologic Assessment of the Pixley National Wildlife Refuge

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HydroGeologic Assessment of the Pixley National Wildlife Refuge

Prepared for : US Bureau of Reclamation

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This report was prepared for the US Bureau of Reclamation to assist the agency make planning decisions with respect to groundwater conjunctive use planning for Pixley National Wildlife Refuge. The author gratefully acknowledges the financial support provided by Dan Meier and Michael Heaton, MP-410 who initiated the project and to Mona Jeffries who was project manager when the work was started. Nick Stanley, Refuge Biologist at the Kern National Wildlife Refuge, who also manages water deliveries to the Pixley, was very helpful in agreeing to monitor well levels a short distance from the production well and provide other background data. David Hardt, Pixley Refuge Manager, provided essential information with respect to potential groundwater conjunctive use options. Dr Kenneth Schmidt provided invaluable access to reports and data as well as advice based on his many years of groundwater quality consulting in the Valley.

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY …………………………………………………………… 1

2. HYDROGEOLOGICAL ASSESSMENT
    2.1 Introduction ……………………………………………………………… …. 1
    2.2 Location and basin description………………………………………………. 2
    2.3 Surface water resources ……………………………………………………... 3
    2.4 Soils and surficial geology…………………………………………………… 6
    2.5 Regional geology …………………………………………………………….. 7
    2.6 Local hydrogeology …………………………………………………………… 10
    2.7 Water table monitoring within Pixley NWR and vicinity……………………….. 16
    2.8 Groundwater quality ………. …………………………………………………… 17

3. OPTIONS FOR PROVIDING ADDITIONAL REFUGE WATER SUPPLY ……….. 18
    3.1 Comparison of Level IV water supply alternatives……………………………… 19
    3.2 Groundwater monitoring and modeling…………………………………………. 20

4. FINDINGS AND RECOMMENDATIONS ……………………………………………….. 20

5. REFERENCES …………………………………………………………………………… 21

1. EXECUTIVE SUMMARY

A hydrogeological assessment of Pixley National Wildife Refuge was conducted using published reports from the USGS and private engineering consultants that pertained to land in close proximity to the Refuge and from monitoring conducted by refuge staff in collaboration with Reclamation. The compiled data clearly show that there are a large number of agricultural wells throughout the Basin and that water levels are responsive to rates of pumping – in some cases declining more than 100 ft in a matter of a few years. Aquifer properties support a groundwater conjunctive use solution to the provision of additional water supply to the Refuge. The report provides justification for this approach.

2. HYDROGEOLOGICAL ASSESSMENT

2.1 Introduction

The goal of this hydrogeological report is to provide an assessment of the groundwater resource conditions in Pixley National Wildlife Refuge within Tulare County. Pixley NWR was formed from former homestead tracts whose titles reverted to the U.S Department of Agriculture in the 1920's and 1930's. The Refuge was ceded to the US Fish and Wildlife Service on November 17, 1959 under Secretary of the Interior Order 2843 (USFWS, 2005). The purpose of the Refuge was to provide wintering habitat for migratory birds and provide safe habitat for the endangered blunt-nosed leopard lizard (USFWS, 2004).

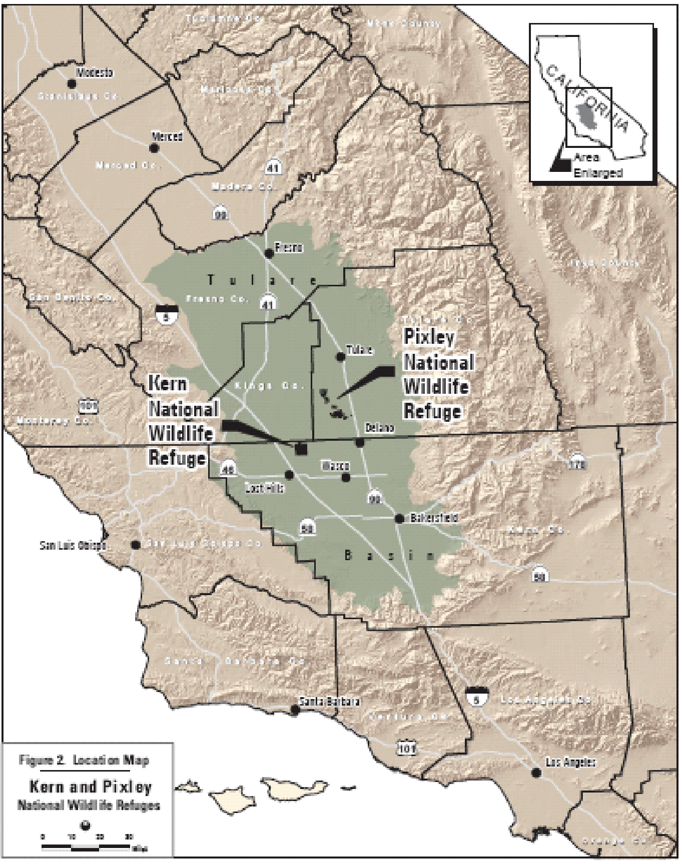


Figure 1. Location of Pixley National Wildlife Refuge (NWR) in the Tulare Basin of California. Pixley NWR is comprised of several non-contiguous tracts between Highways 43 and 99 that collectively form the wildlife management area (USFWS, 2005).

Between 1964 and 1966 the USFWS added to its holdings within the Pixley NWR boundary by exchanging 607 acres of federal land for 410 acres of private land in order to consolidate its land holdings. The NWR boundary was expanded in 1980 and again in 1985 as part of the USFWS's master plan for refuge development.

2.2 Location and basin description

The Pixley NWR is part of a Refuge Complex that includes the Kern National Wildlife Refuge. Both refuges help to replace a fraction of the 520,000 acres of permanent and seasonal wetlands which were estimated to have existed in the Tulare Basin at the turn of the last century. Pixley NWR is surrounded by agricultural enterprises – with large dairy farms becoming dominant in the past decade. The NWR is bounded by Highway 99 (approximately 9 miles to the east), Highway 43 (to the west) and Avenue 56 to the south. The nearest towns are Alpaugh (population, 900), located 8 miles to the west and Earlimart (population 900), located 8 miles to the east (USFWS, 2005).

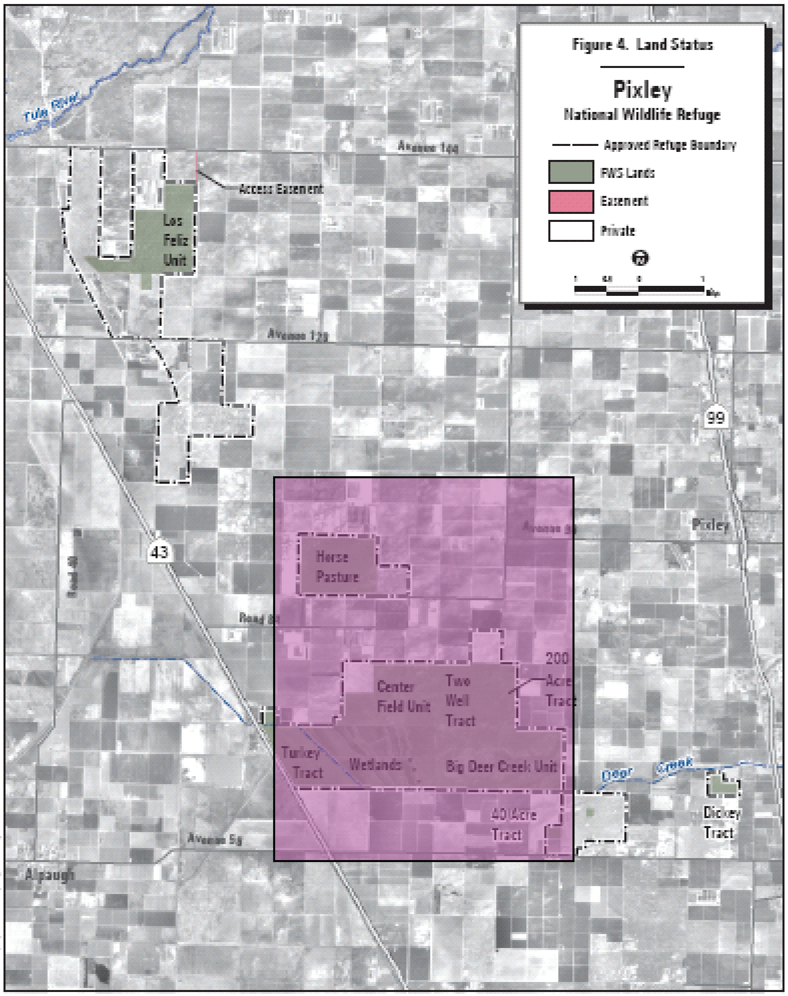


Figure 2. Detailed map of Pixley NWR showing Deer Creek and Las Feliz Units. Managed grasslands within and adjacent to the Deer Creek Unit are highlighted in purple to provide a reference in subsequent figures (USFWS, 2005).

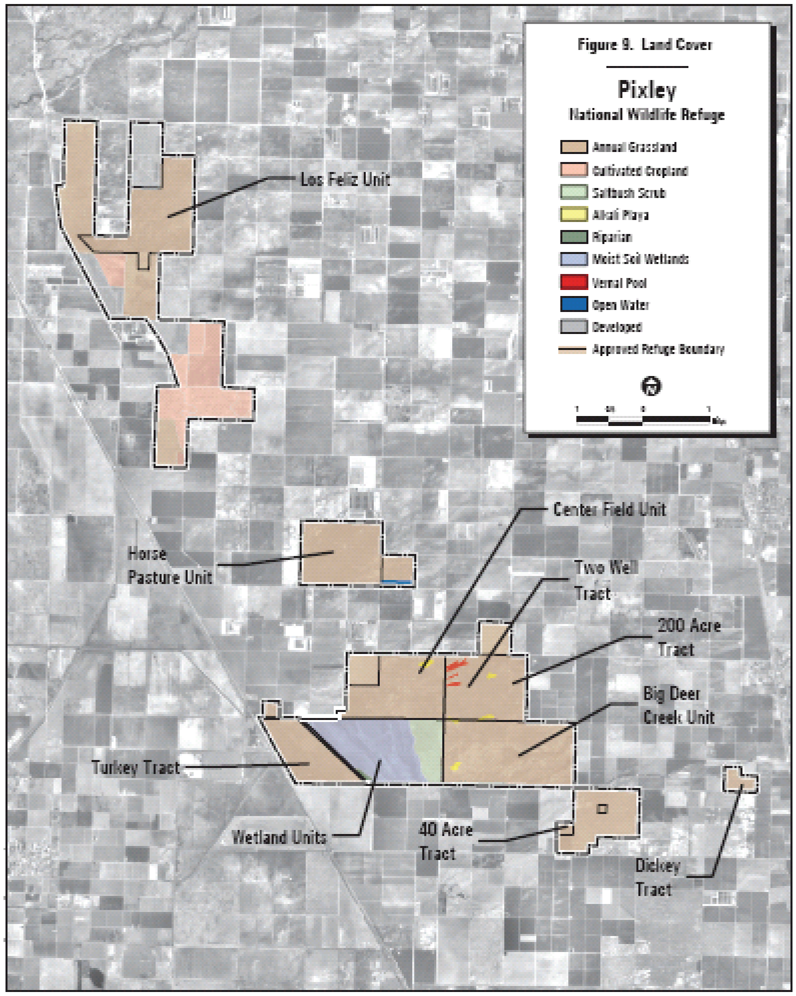


Figure 3. Current land use on the Pixley NWR showing current dedicated wetland acreage contained within the largest tract under management (USFWS, 2005).

The Pixley NWR is comprised of a number of smaller federally owned tracts. The Big Deer Creek Unit, Center Field Unit, Two Well Tract, 200 Acre Tract and Turkey Tract make up the largest contiguous area of the federal upland habitat in the NWR boundary. The only managed moist soil habitat for waterfowl is contained within the wetland units in the south-west of the Refuge – lack of water supply has limited the ability to provide optimal habitat management. One mile to the north of this complex is the Horse Pasture and one and a half miles to the east is the Dickey Tract, which borders Deer Creek. Approximately six miles NNW of the largest tract within the Pixley NWR is the Los Feliz Unit. Because of the geographic separation of the northern tracts only the wetland units and the adjacent tracts containing upland vegetation are considered in the hydrogeological assessment.

2.3 Surface water resources

The Pixley NWR is situated within the historic flood plain of Deer Creek, on the eastern edge of Tulare Lake. It has been suggested that the west portion of Turkey Tract may have been a part of the original wetland area of Tulare Lake, the remaining land area likely comprising riparian habitat, seasonally flooded wetlands, vernal pools, and wet meadows, depending on the annual precipitation and the timing of snowmelt (USFWS, 2005).

The Pixley NWR began operations in 1963 starting with a number of wetland impoundments in Sections 19, 20 and 21 amounting to 750 acres (USFWS, 2005). An irrigation production well was drilled in 1962 but its yield was insufficient to supply water to the entire NWR area. Surface water supply to the Pixley NWR has been limited to seasonal runoff from the Deer Creek watershed – however this water is only available in years of high precipitation and typically late in the winter or early spring (Figure 4). A deeper high production well was drilled and developed in 1992 allowing the initiation of a moist soil management program and active management of approximately one-half of the wetland area within Pixley NWR. This well is just west of County Road 88, east of the Pixley NWR wetland units. The well allows the operation and maintenance of approximately 300 acres of seasonal wetlands (USFWS, 2005).

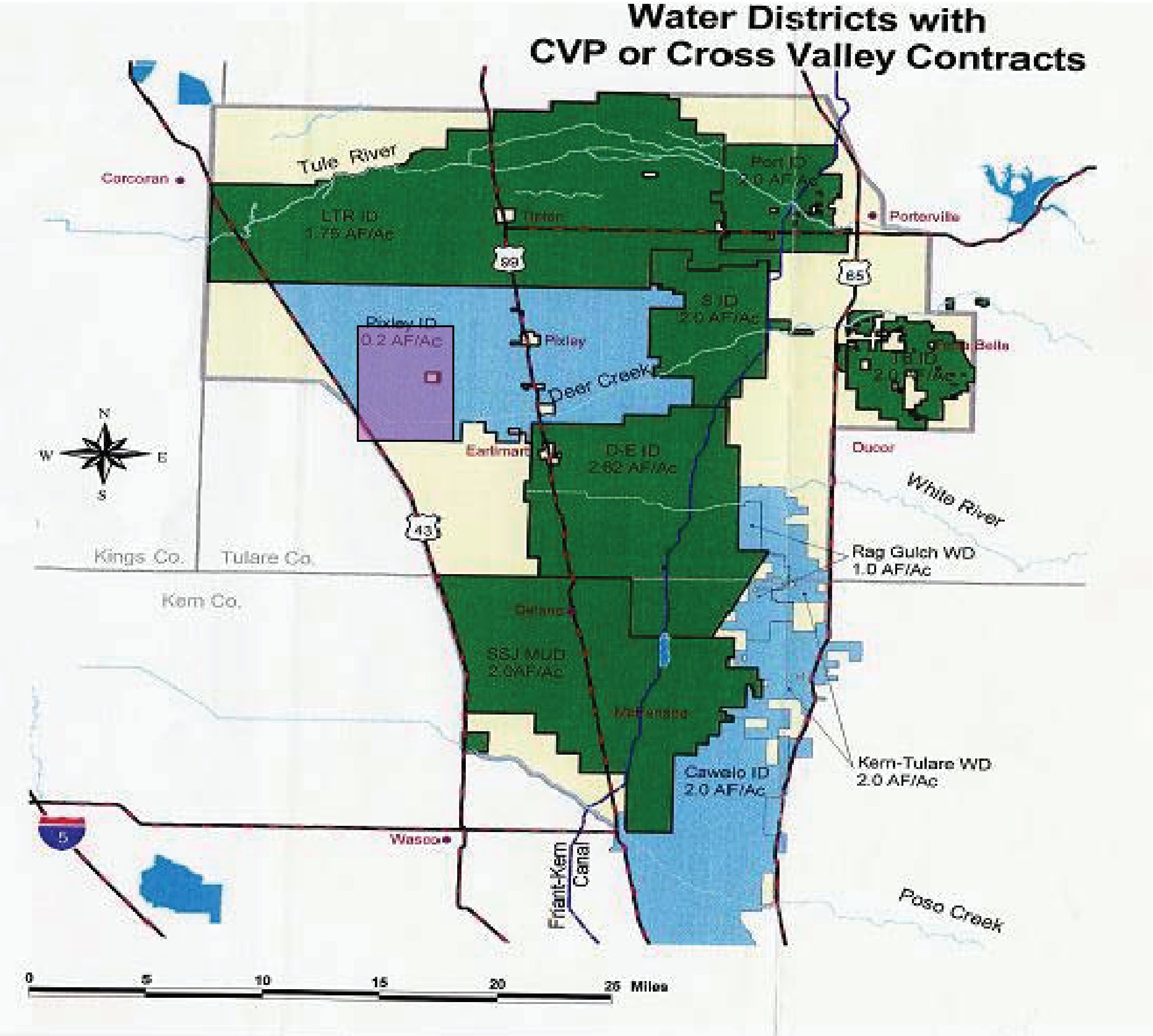


Figure 4. Location of Pixley NWR relative to surrounding water districts with CVP or Cross-Valley Canal contracts. Pixley ID occasionally banks flood flows from Deer Creek on lands within the Pixley NWR. (Schmidt, 2001).

During wet years when irrigation water is more widely available within the Tulare Basin, the Pixley Irrigation District has coordinated with the Pixley NWR to use Refuge lands for groundwater recharge, providing habitat for water birds as a secondary benefit. Although the habitat created has been beneficial for waterfowl, the water is typically available in late spring and early summer, which is too late for beneficial use by fall and winter migrant waterfowl species.

As a result of the passage of the Central Valley Project Improvement Act in 1992 (CVPIA), the Pixley NWR was provided an annual water allocation of 6,000 acre-feet, including 1,280 acre-feet of Level 2 water and 4,720 acre-feet of Level 4 water (USFWS, 2005). This allocation was intended to be sufficient to allow the development and maintenance of 750 acres of seasonal wetlands, including 25 acres of riparian habitat, and 545 acres of irrigated pastures and croplands to be used by waterfowl, primarily the lesser and greater sandhill cranes (USFWS, 2005). Because of the Refuge's isolated location, the most logical source for accessing CVPIA water supplies (as well as the most cost-effective and appealing to the refuge staff) allocation has traditionally been the Friant-Kern Canal. This alternative involved constructing an extension to the existing Delano-Earlimart Irrigation District conveyance system from a point just west of Highway 99 to the refuge boundary. Since there are no existing surface conveyance canals or pipelines that connect the NWR to the water supply, and with the high costs projected for pipeline construction, a number of alternative solutions have been considered.

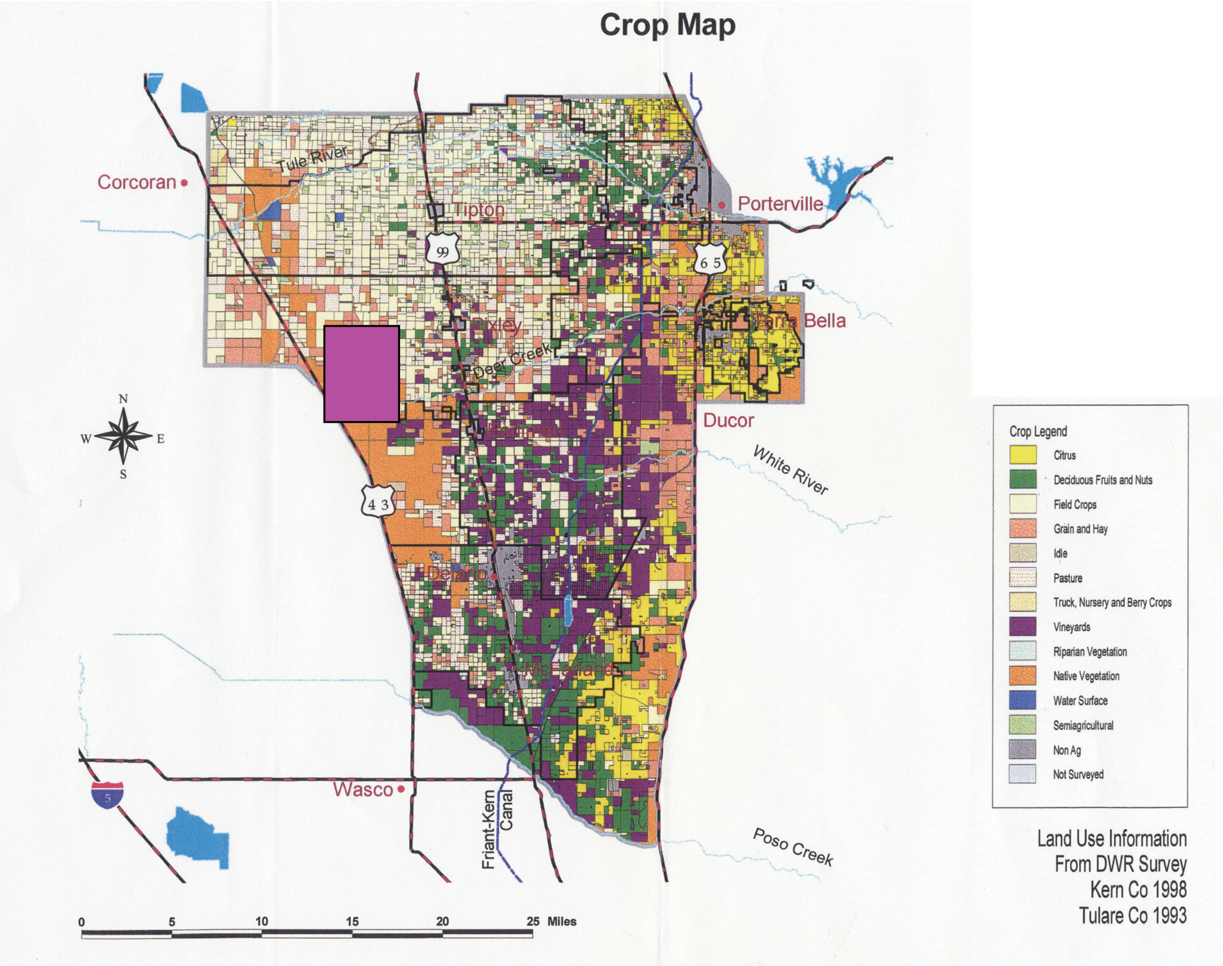
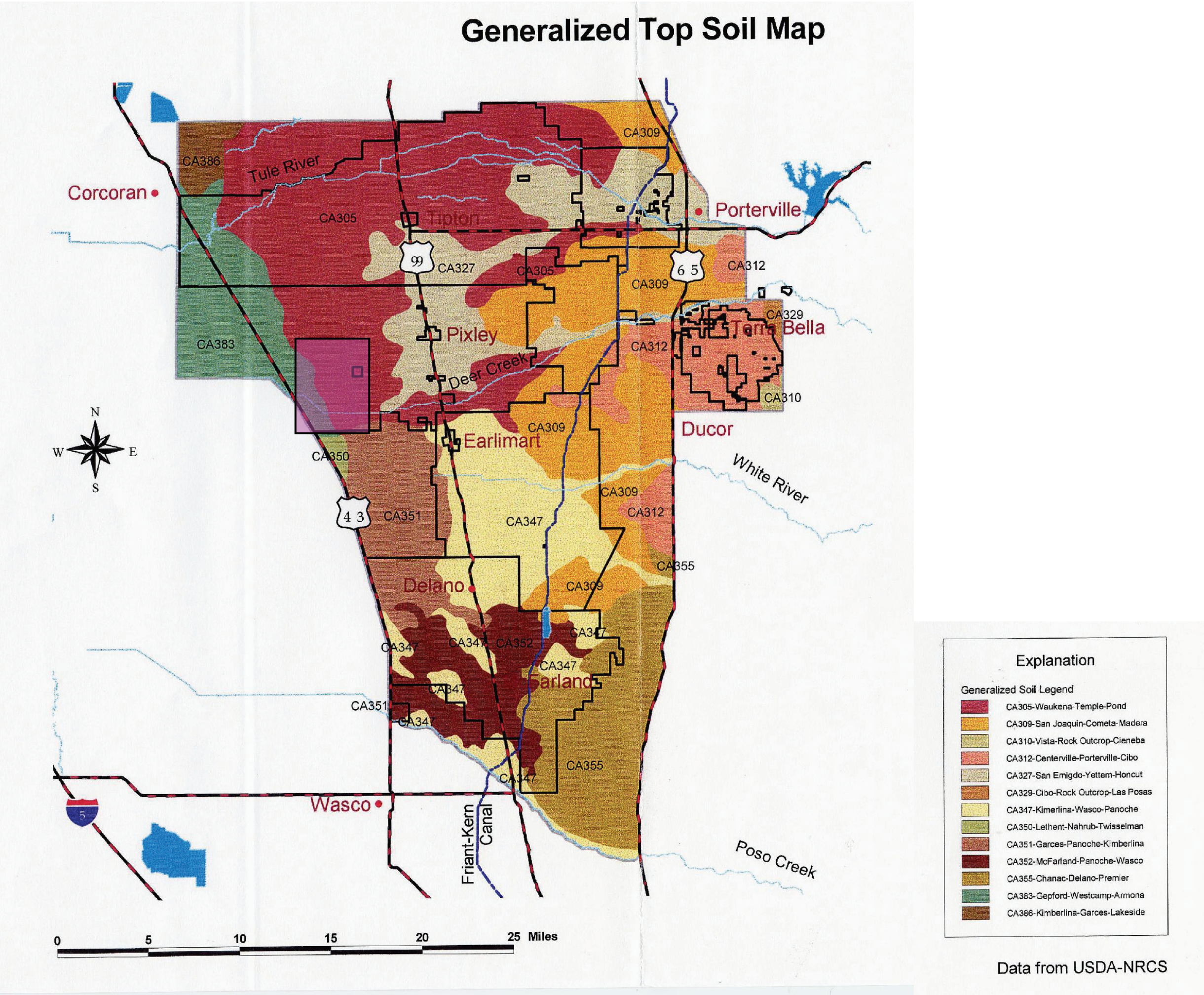


Figure 5. Land use in the vicinity of the Pixley NWR. Most agricultural cropland is located to the east of Highway 99. Footprint of the Pixley NWR is shown in purple shaded area. (Schmidt, 2001).

Alternatives that have been considered include drilling additional wells on the Refuge as part of a conjunctive use program that will permit the coordinated use of wells and surface delivered water to meet the water needs of the Refuge. When the final delivery system is in place, it is anticipated that the total wetland area will exceed 750 acres, more than twice the current flooded acreage (USFWS, 2005).

2.4 Soils and surficial geology

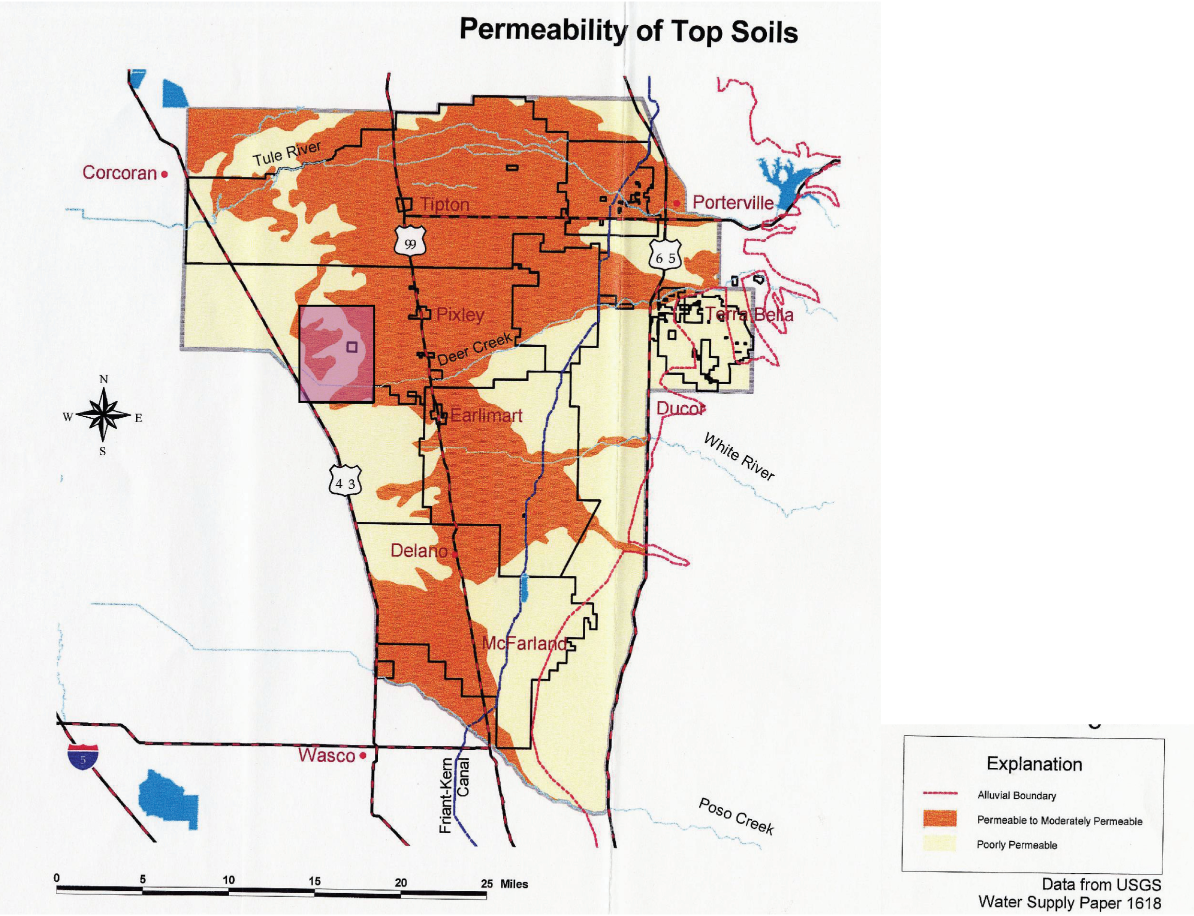
Eleven soils types have been mapped within Pixley NWR's approved boundary which include: Akers-Akers, Saline-Sodic Complex (18.3acres); Biggriz-Biggriz, Saline-Sodic Complex (101 acres); Gambogy loam (469 acres); Gambogy-Biggriz Saline-Sodic Association (4,157 acres); Gareck-Garces Association (2,101 acres); Hanford sandy loam (less than 1 acre); Houser silty clay (15 acres); Kimberlina fine sandy loam (580 acres); Lethent silt loam (2,193 acres); Nahrub silt loam (74 acres); and Riverwash (less than 1 acre) (USFWS, 2005). These soils are mostly derived from granitic Sierra Nevada sources located in fan terraces, alluvial fans, flood plains, and along the basin rim. With the exception of 300 to 600 acres of created wetlands



Data from USDA-NRCS

Figure 6. Generalized soils map for the Basin in the vicinity of the Pixley NWR. The majority of the Refuge soils fall within the Gambogy-Biggriz saline-sodic association, the Gareck-Garces association and the Lethent silt loam association. These are categorized in the USDA-NRCS survey as the Waukena-Temple-Pond soils (Schmidt, 2001).

within the Pixley NWR boundary (that include levees and roads) mostly on Lethent silt loam soils - the majority of the other soil types have not been significantly disturbed and support introduced grasses. Occasional flood flows in Deer Creek are diverted into the Refuge wetlands to provide habitat on a very limited basis – even with these additional supplies no more than 750 acres of wetland habitat can be supported. Grazing is practiced on about 4,730 acres of Pixley Refuge to provide more suitable habitat for listed species and to help establish and grow native vegetation. Soil associations that have been surveyed within this tract include Houser silty-clay, Kimberlina fine sandy-loam, Lethent silty-loam, Nahrub silt-loam, and a generalized soil association labelled Riverwash. All except Riverwash are categorized a prime agricultural soils.



Data from USGS Water Supply Paper 1618

Figure 7. Permeability of surface soils. Shaded area associated with Pixley NWR shows that most soils within the Refuge are poorly impermeable making them suitable as wetlands. The more permeable soils are better suited to surface recharge as part of a water banking scheme (Schmidt, 2001).

2.5 Regional geology

The regional groundwater basin containing the Pixley NWR covers southern Tulare and northern Kern Counties and can be visualized as a large structural trough filled with approximately 16,000 feet of eroded sediments from the granitic Sierra Nevada and the marine shales and siltstones of the Coast Range. These sediments derived from alluvial fans, rivers and shallow lakes that formed complex layered beds of various geologic materials that were later folded by landforming stresses in the earth's mantle. The upper

1,500 ft of sediments is comprised of both young and old alluvium, continental deposits and the Mehrten Formation (USGS, 1973). The Younger Alluvium consists of narrow bands of fine sand, sand and gravel with little or no hardpan and typically is found along river courses. This alluvial material ranges in thickness from 0 -100 feet (USGS, 1973).

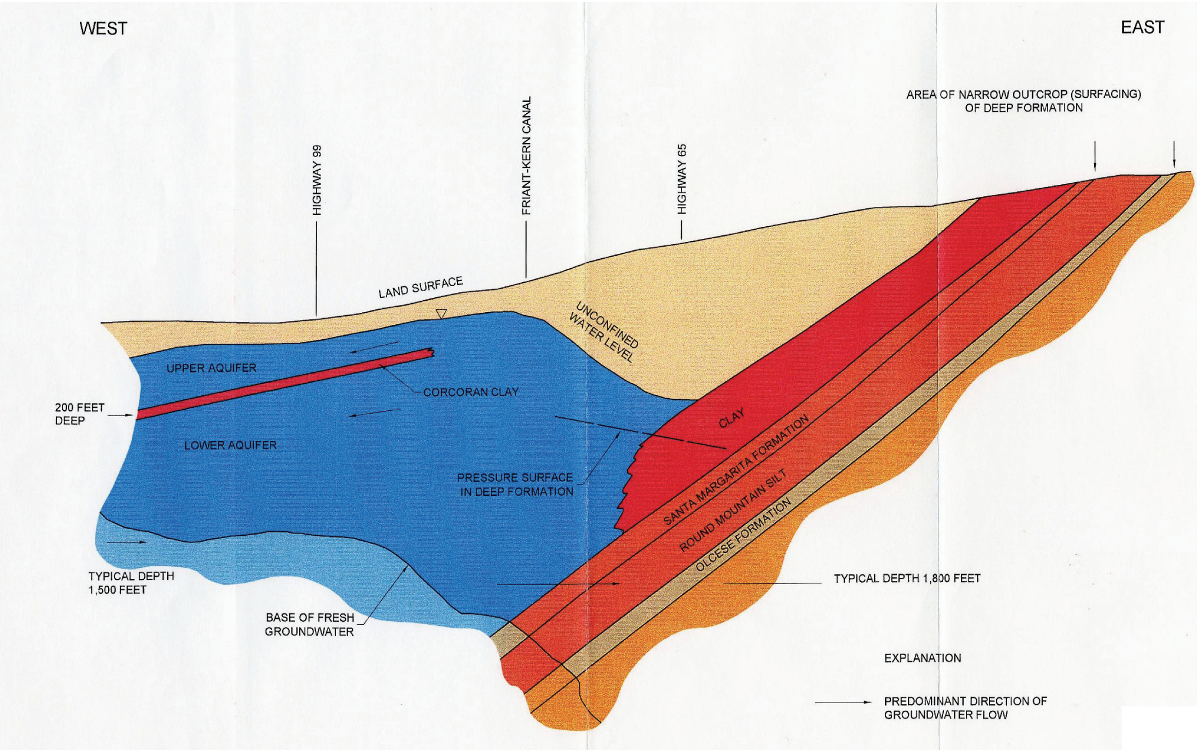
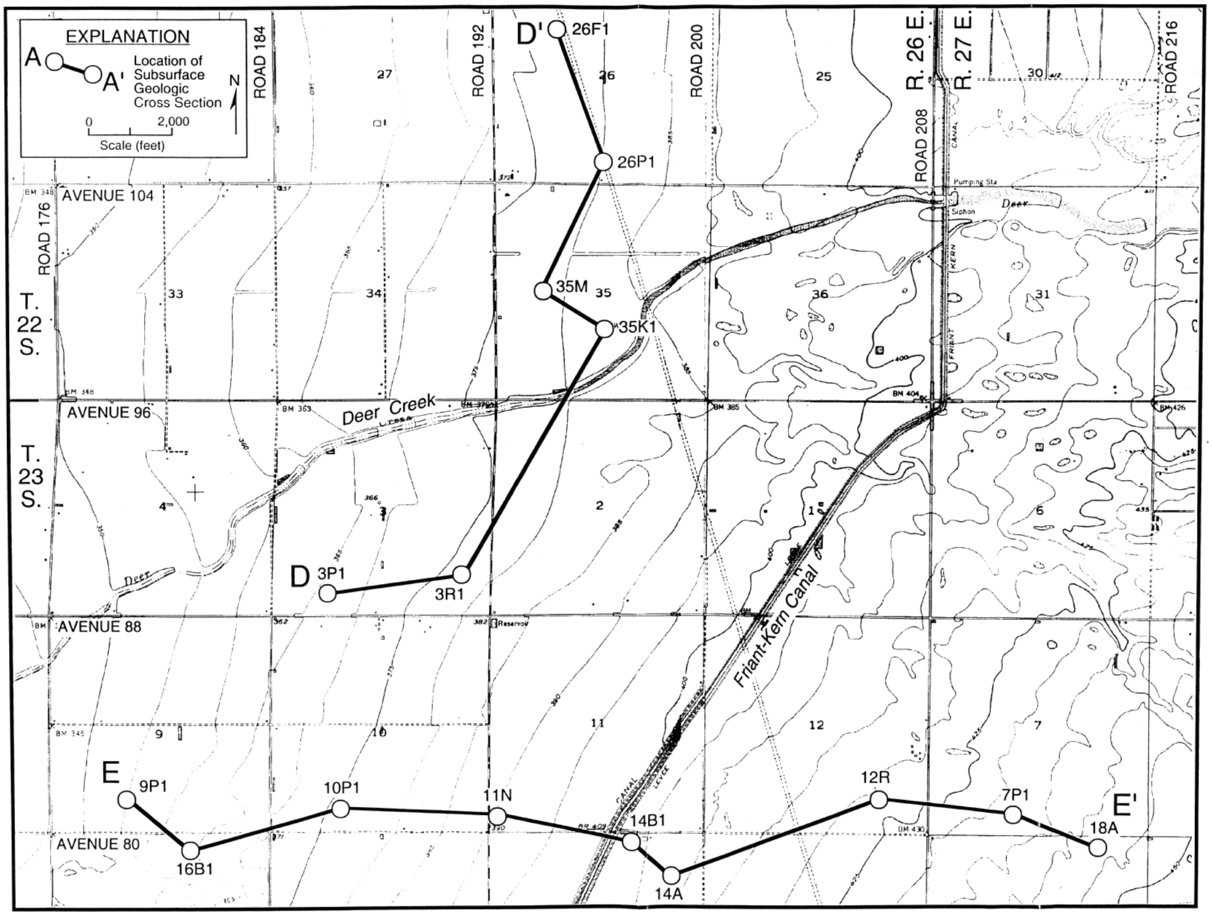


Figure 8. East-west cross-sectional profile of the Tulare Basin in the vicinity of the Pixley NWR. Cross-section shows the influence of the Corcoran Clay in the eastern sector of the Basin that pinches out between the alignment of Hwy. 99 and the Friant Kern Canal. The Pixley NWR is underlain by the Corcoran Clay which separates the upper semi-confined from the lower confined aquifer. (Schmidt, 2001).

The bottom of the Older Alluvium is typically between 400 ft and 1000 ft below sea level and is apparent in drillers logs as a transition from coarse grained to fine grained sediments (USGS, 1971, 1973). Embedded within the Older Alluvium are a number of continuous lacustrine deposits of gray and blue silts, silty clays and clays that display low permeability and act as impermeable barriers to vertical groundwater movement. The most significant of these deposits is the Corcoran “E” Clay which is regionally extensive in the San Joaquin Valley trough between Tracy and Kern County and which pinches out to the east – approximately along the alignment of Highway 99 and to the west in the vicinity of Highway I-5 in the san Joaquin Basin. In the Tulare Basin the Corcoran Clay extends further east and diminishes in thickness close to the alignment of Highway 99 and the Friant-Kern Canal. The Corcoran Clay is found at an average depth of about 200 ft at its eastern extent and about 500 ft at its western extent with a thickness ranging from 50 to 80 ft (Schmidt, 2001). Figure 8 developed by Lofgren and Klausing (1969) provides a general lateral cross section view of the Tulare Basin extending from the western Coast Range to the Sierra Nevada (Schmidt, 2001). This figure shows a basement complex of bedrock dipping towards the west at depths that exert little influence on the aquifers underlying the Pixley NWR.



LOCATION OF SUBSURFACE GEOLOGIC CROSS SECTIONS IN DEER CREEK AREA

Figure 9. Aquifer cross-sections within the Basin approximately 10 miles east of the Pixley NWR. The Friant-Kern Canal serves as a regional surface marker and intersects section E-E' a few miles west of well 14B1 (Schmidt, 2001).

Alluvuial streams deposits within the Older Alluvium extend to depths of between 400 ft and 1000 ft and are often relied upon for groundwater pumping. The Mehrten Formation, located beneath the Continental Deposits, is comprised of deposits of sandstone, tuff, siltstone, breccia, claystone and conglomerate often referred to by local drillers and "black sand and gravel" (Bookman-Edmonston, 2003; USGS, 1973). Although the depth of this formation is generally unknown it is an important aquifer in much of the Sacramento and San Joaquin Valleys and has permitted well production between 1,500 and 3,500 gpm (Bookman-Edmonston, 2003). Schmidt (2001) observed that within the continental deposits west of Highway 99, which would include the Pixley NWR, water quality is somewhat poorer containing salty and brackish water. Several marine layers such as the Santa Margarita Formation (shown in Figure 8) that underlies much of the Tulare Basin east of the area influenced by the Corcoran Clay also produces usable groundwater. However the fine-grained silt deposits that overlie this formation limit recharge from above and the importance of the aquifer as a groundwater resource. Schmidt (2001) describes a number of active deep production wells, located between Famoso Road and Deer Creek, which tap aquifers of the Santa Maragita and Olcese Formations. Most wells that draw water from these aquifers are located east of the Friant Kern Canal and close to the alignment of Highway 65. They also tend to be deeper than 2000 ft (Schmidt, 2001).

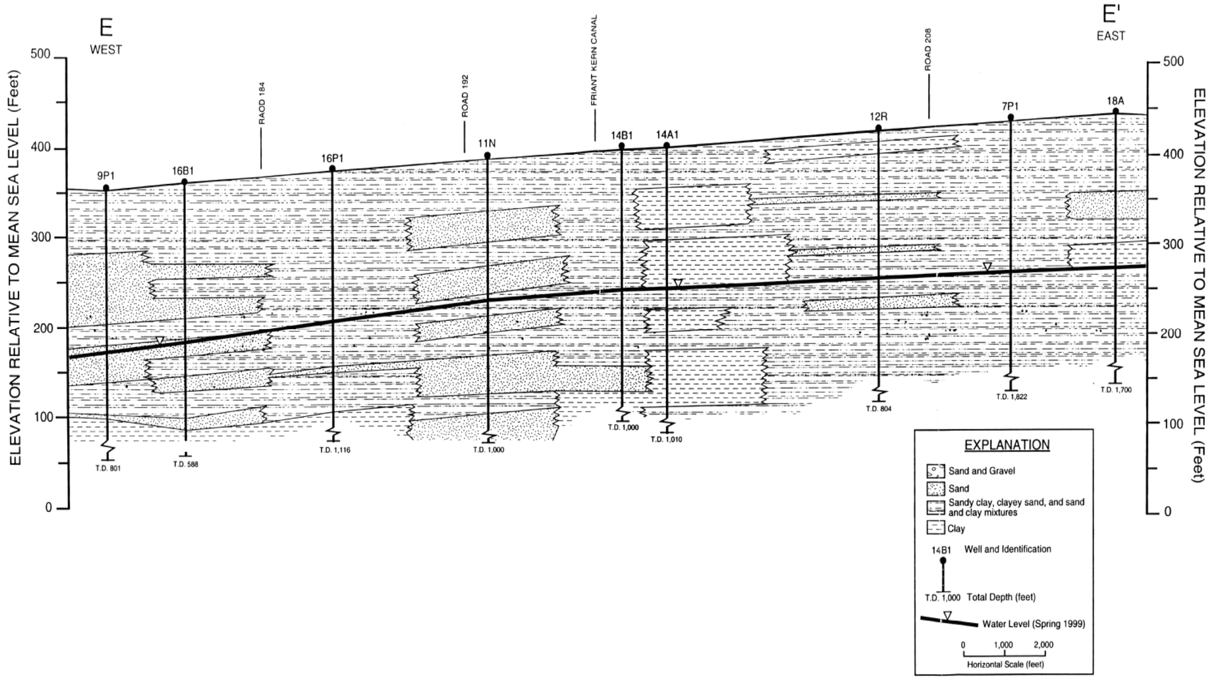


FIGURE 22 - SUBSURFACE GEOLOGIC CROSS SECTION E - E'

Figure 10. Aquifer cross-section E-E' which shows the patchwork of sand lenses within the sandy-clay alluvial aquifer. Figure shows the presence of the Corcoran Clay approximately 250 ft below the land surface and isolated outcroppings of clay to the east of the alignment of the Friant-Kern Canal. (Schmidt, 2001).

A cross-section of the Basin approximately 10 miles to the east of the Pixley NWR boundary and close to the alignment of Deer Creek (Figures 9 and 10) shows an alluvial aquifer comprising sands and clays with large outcroppings of sand in the areas west of the Friant Kern Canal and large outcroppings of poorly permeable clays to the east of the Friant-Kern Canal. The Corcoran Clay layer is visible in the bottom left of Figure 10 and effectively divides the regional aquifer into an upper and lower zone. Figure 10 also shows the effective depth to groundwater to the east of the Pixley NWR. The average depth to groundwater appears to be in the range of 150 to 200 ft.

2.6 Local hydrogeology

The local geology dictates the nature of the local groundwater system and can be inferred from well logs and hydrogeological investigations sponsored by area water districts. In Figure 11 the Basin map of groundwater elevations and groundwater flow direction for Spring 1987 shows a number of depressions in the water table where groundwater flow lines converge. These occur at the intersection of Highway 165 and the White River in the eastern part of the Basin where water tables drop 160 ft over 5 miles between the town of Richgrove and the deepest area of the groundwater depression and both below and to the north-east of the Pixley NWR where the water table drops 40 ft between the west-boundary of the Refuge and the deepest area of the groundwater depression.

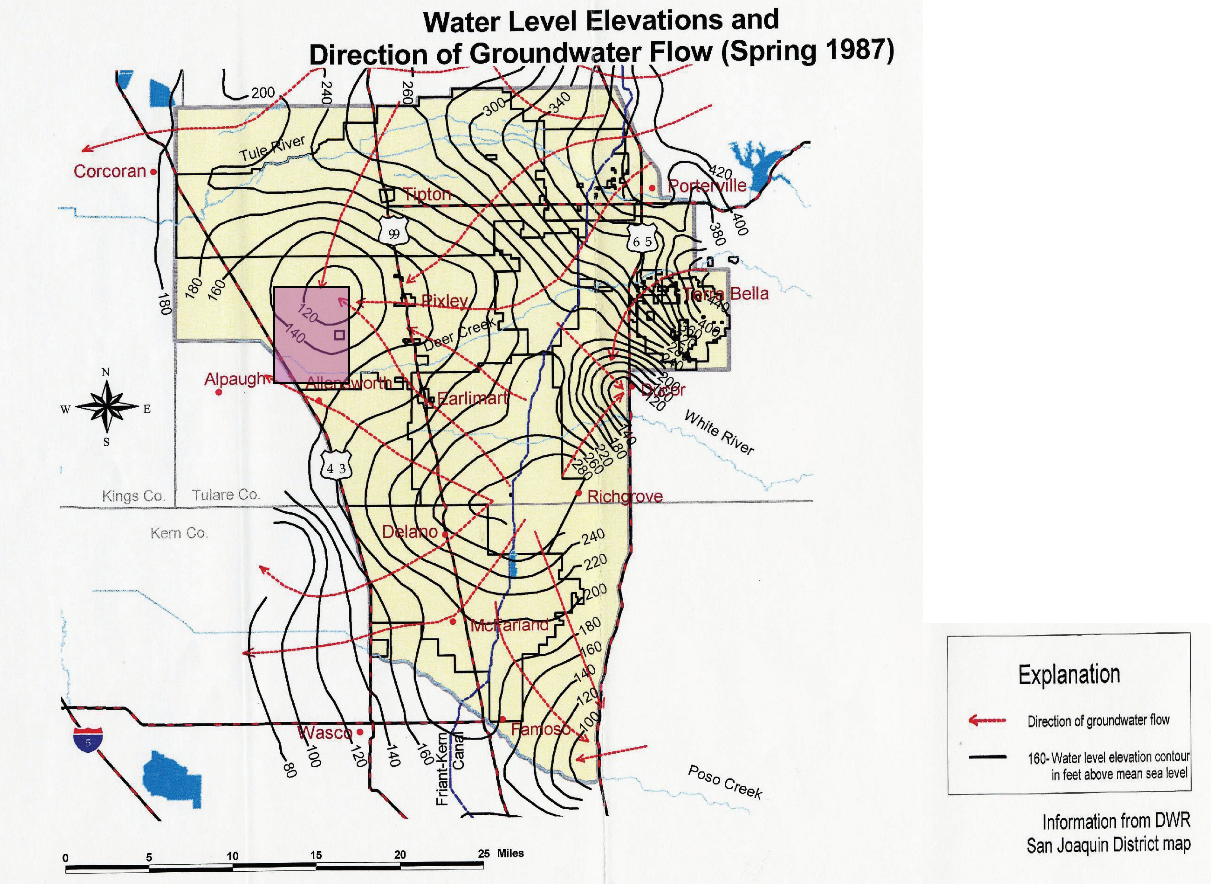


Figure 11. Water elevations and groundwater flow in the vicinity of the Pixley NWR. Contour map shows a local depression under and north-east of the Pixley NWR boundary and flow lines radiate into this depression (Schmidt, 2001).

The presence of reasonably stable groundwater gradients of the order of 10 ft per mile from the north and west of the Pixley NWR suggest mounding of the water table in the Pixley and Lower Tule Irrigation Districts in the vicinity of the Tule River and reasonably high transmissivity allowing water from the areas of groundwater recharge to the area west of the town of Pixley where stresses on the groundwater system are taking place. Flowlines radiate inward toward a point a few miles north of the Pixley NWR from the north, east and south-east. Given that the Pixley NWR lies in a local groundwater depression further suggests that any planned additional groundwater pumping of the above-Corcoran aquifer by Pixley NWR be considered with regard to the safe yield of the local groundwater basin. As has already been noted, the fast-paced development of the dairy industry in the Tulare Lake region combined with additional groundwater pumping for wildlife supply could turn a stable and renewable groundwater resource into one that is being mined with concomitant impacts of water shortage, aquifer subsidence, aquifer adjudication and litigation.

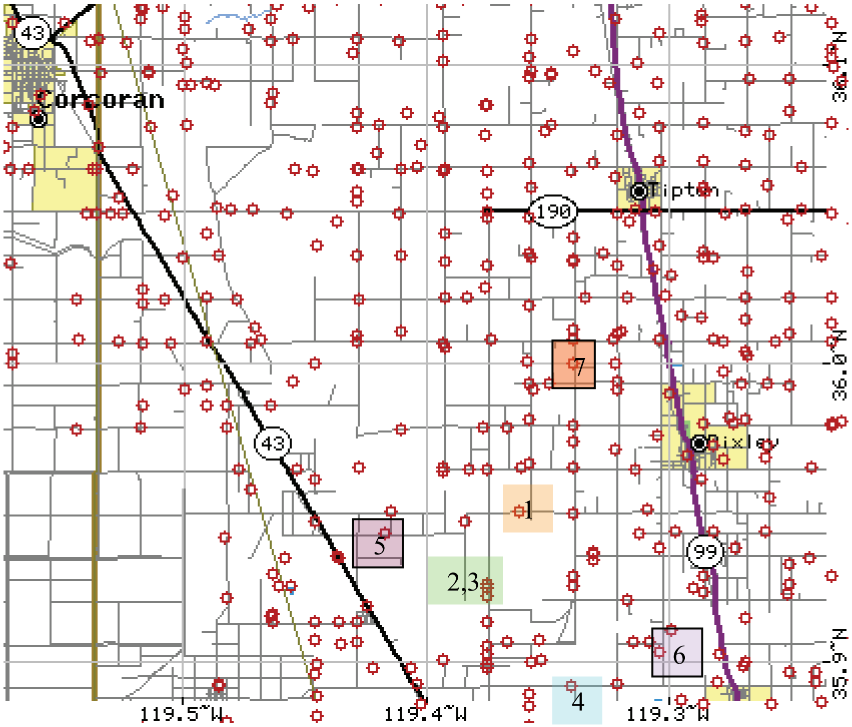


Figure 12. Groundwater well locator map available of the DWR Local Assistance website at : http://wdl.water.ca.gov/gw/map/quad_map.cfm? rgpr=1200,365&type= move&QuadX=1194&QuadY=360&MapType=GW

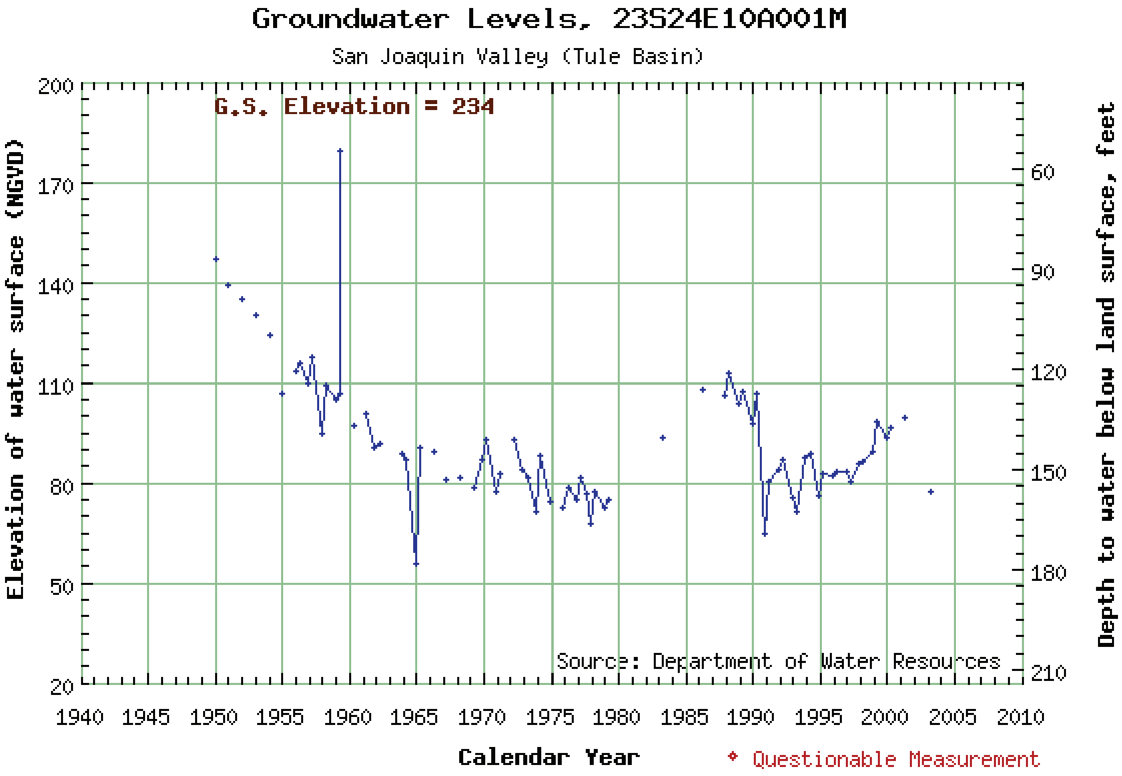


Figure 13. Groundwater well 1 in Figure 12 located in the vicinity of Pixley NWR.

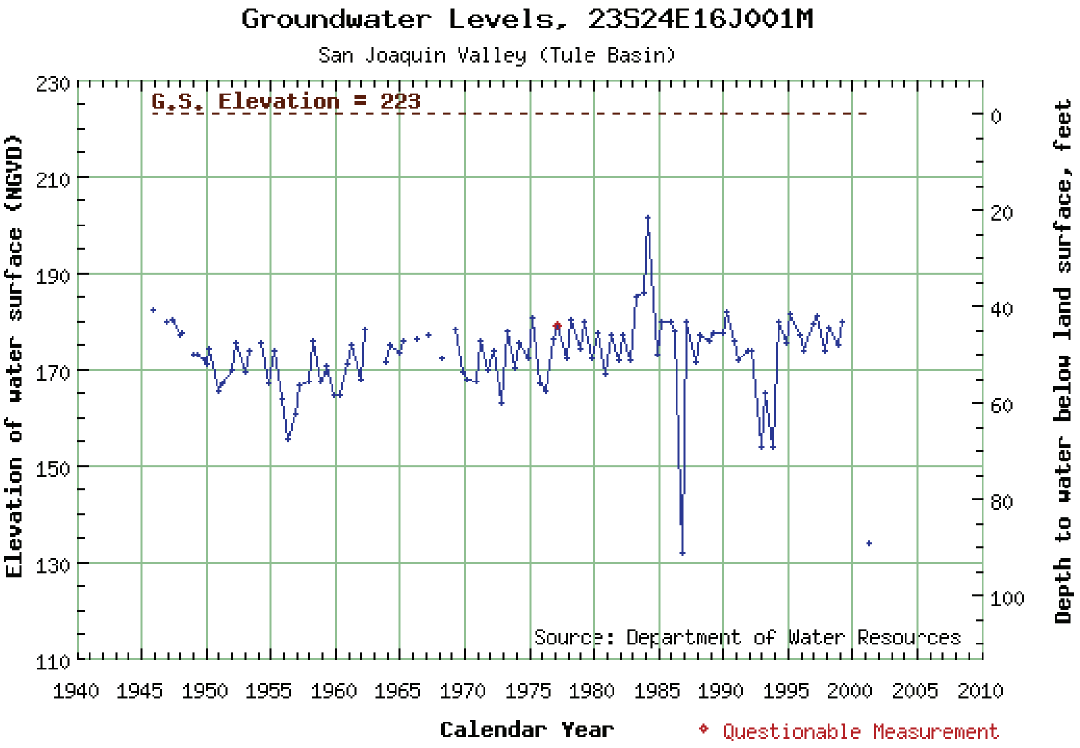


Figure 14. Groundwater well 2 in Figure 12 located in the vicinity of Pixley NWR.

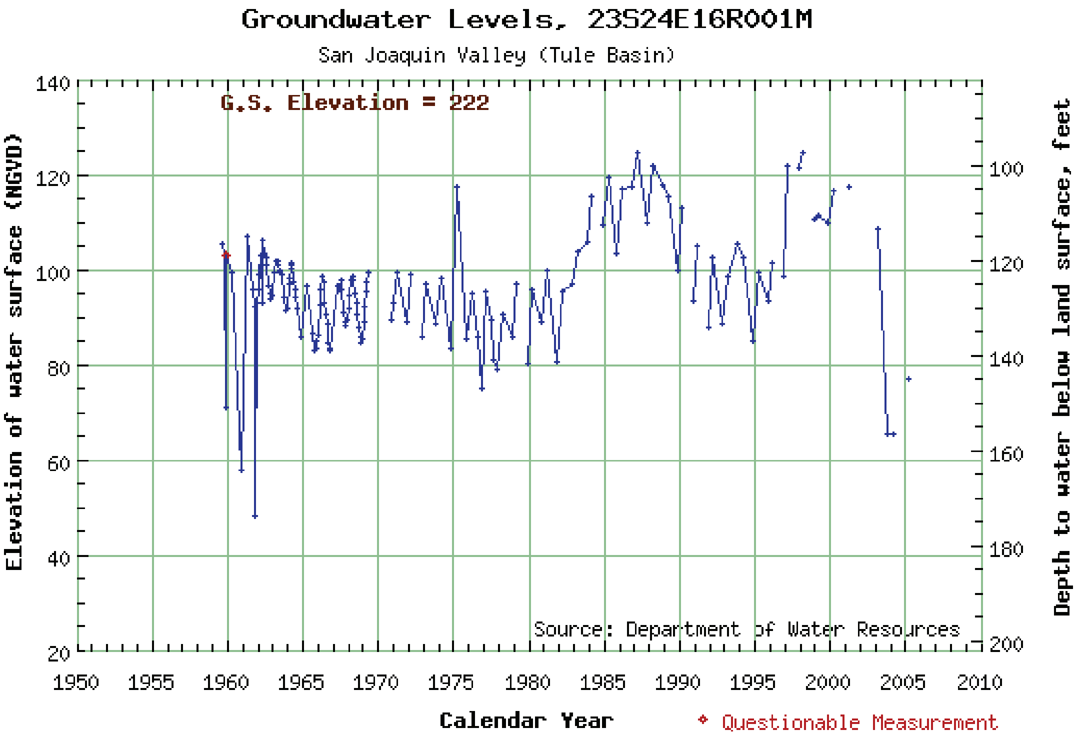
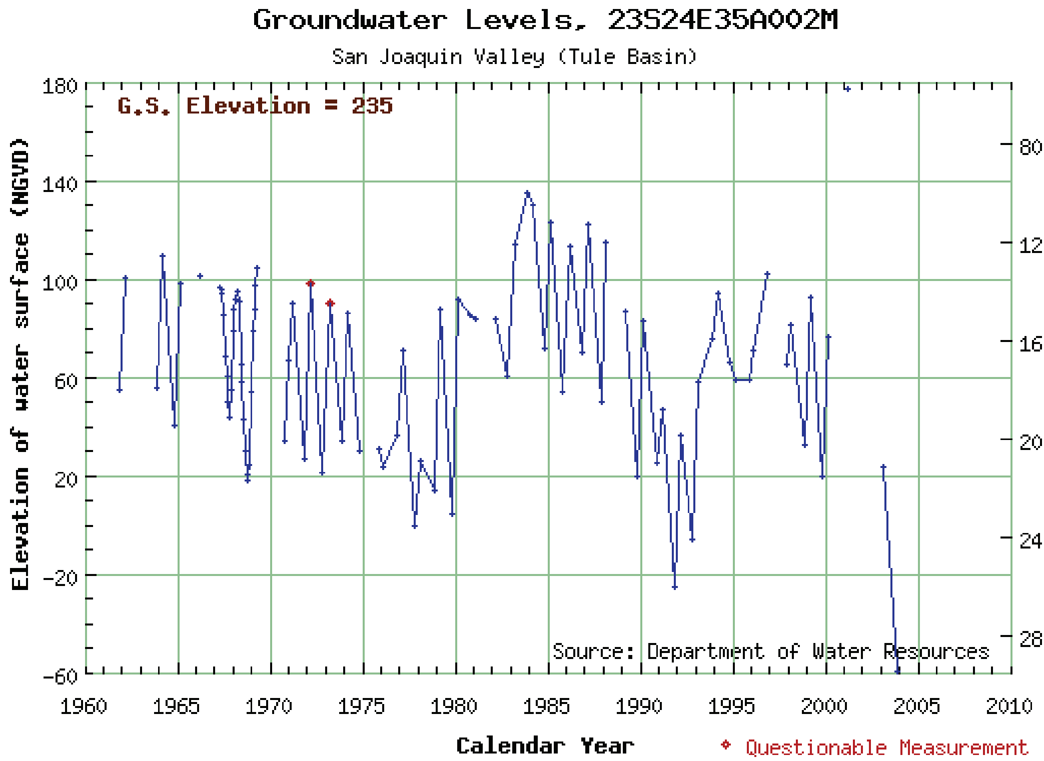


Figure 15. Groundwater well 3 in Figure 12 located in the vicinity of Pixley NWR.



Source: Department of Water Resources

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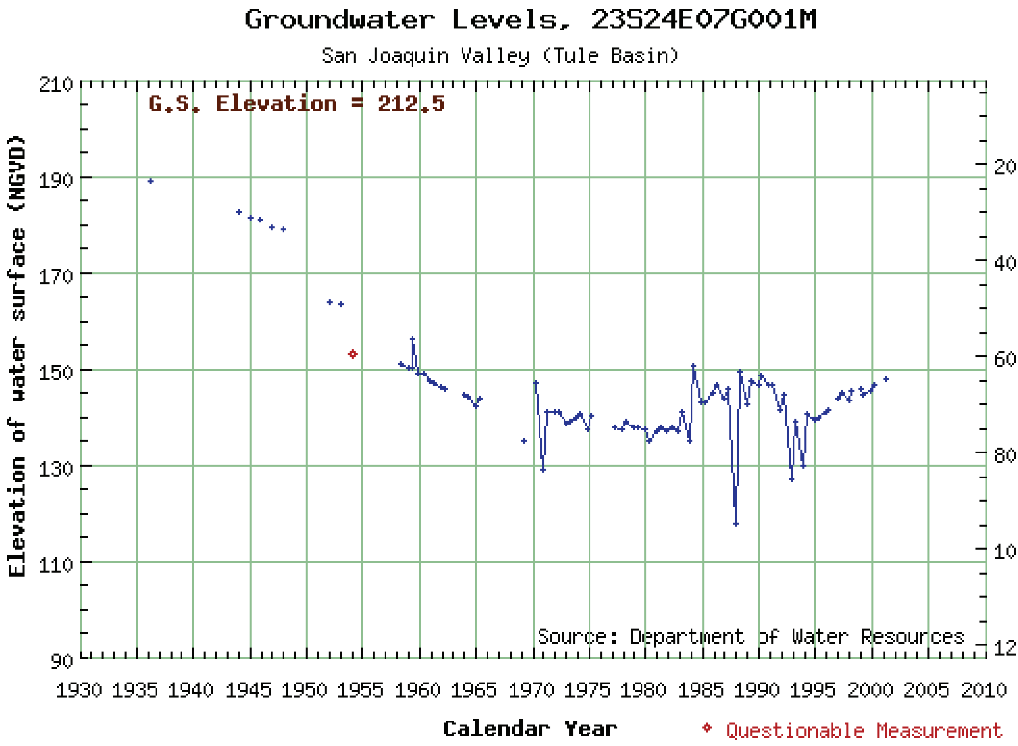
Figure 16. Groundwater well 4 in Figure 12 located in the vicinity of Pixley NWR.



Source: Department of Water Resources

Figure 17. Groundwater well 5 in Figure 12 located in the vicinity of Pixley NWR.

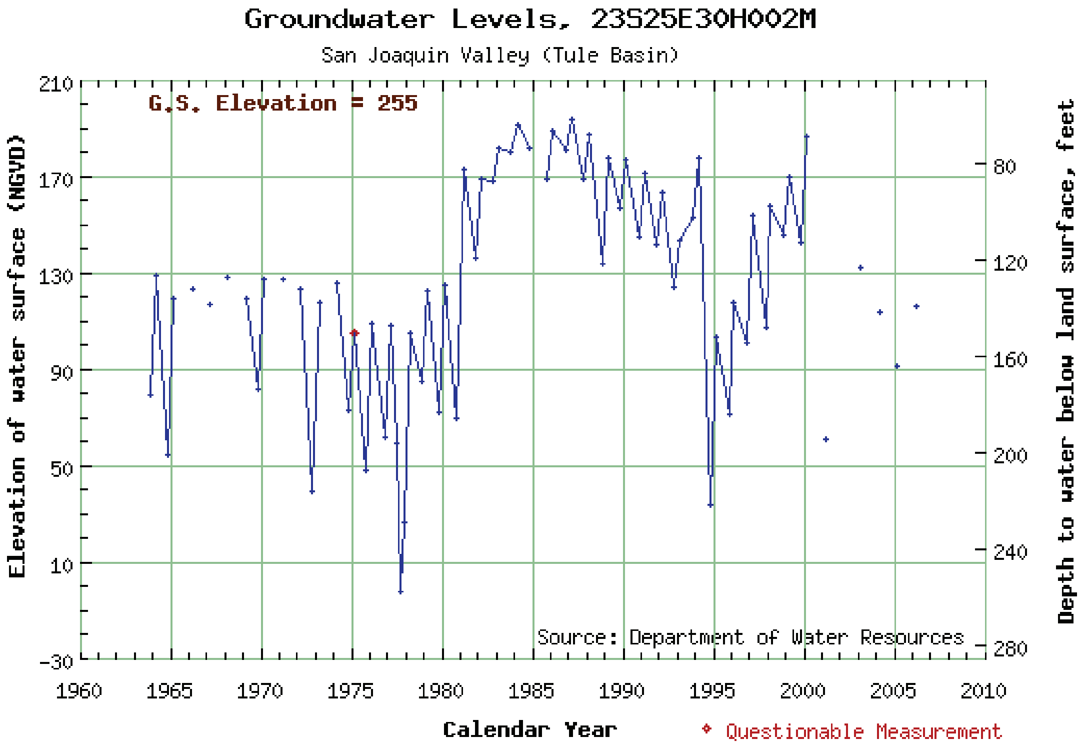


Figure 18. Groundwater well 6 in Figure 12 located in the vicinity of Pixley NWR.

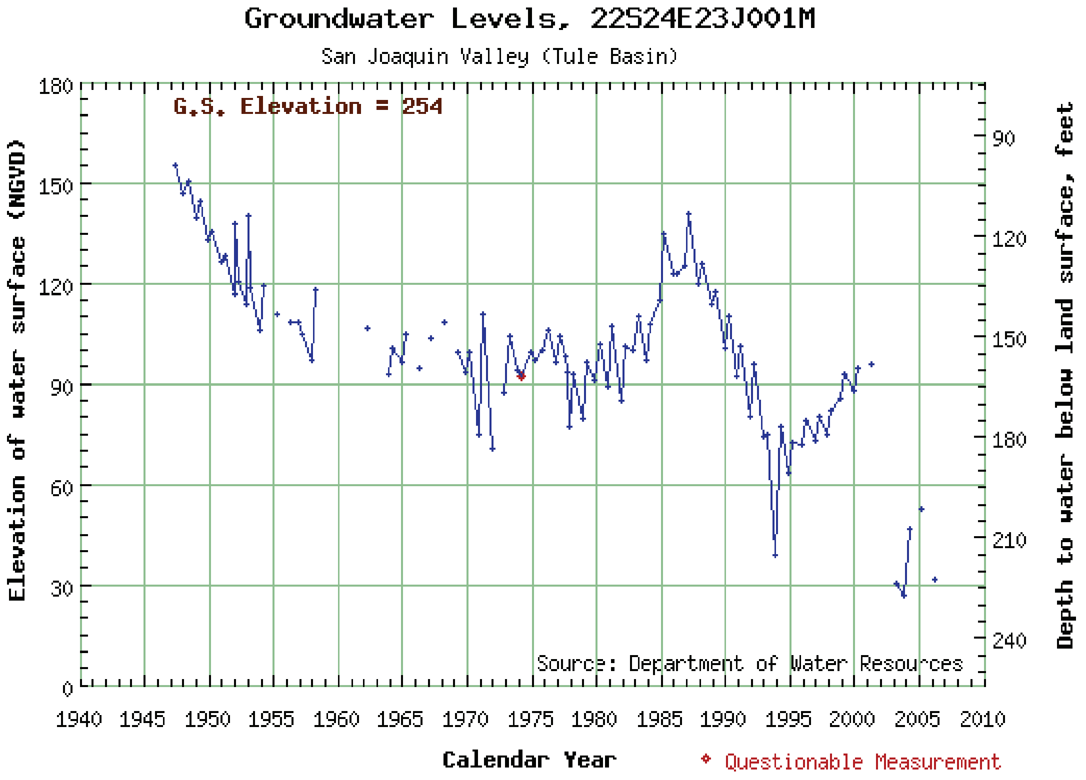


Figure 19. Groundwater well 7 in Figure 12 located in the vicinity of Pixley NWR.

2.7 Water table monitoring within Pixley NWR and vicinity

The groundwater well hydrographs shown in Figures 13-19 are situated within a five mile radius of the Pixley NWR. In the period 1990 – 2005 several of the wells show quite dramatic changes in water level elevations – in the case of well 4 the water table dropped by over 100 ft in this 10 year period. However in all cases, over the 4 decade period many of these well records have been taken, water tables have both risen and fallen, suggesting that at the current level of groundwater development that they are operating within the safe yield of the aquifer

Evaluation of the potential impact of future conjunctive use of groundwater pumping within the Pixley NWR itself was facilitated by several months of water table observations in a well cluster located approximately ½ mile north of the existing groundwater production well. There was no information available on the owner of the observation wells nor of the depth and screened interval of the wells. Soundings taken of each observation well using sounding tape indicated total well depths of approximately 150 ft – the wells were constructed of galvanized steel and had a diameter of 1 inch.

Analysis of water levels in the cluster wells, taken between 4/30/05 and 6/15/06 by Refuge Operations Specialist Nick Stanley, shows a relatively small variation in groundwater levels for two of the three observation wells and a very large decline over the same time period in the third well. Without having any construction or well log information for this well cluster it is difficult to explain this anomalous result

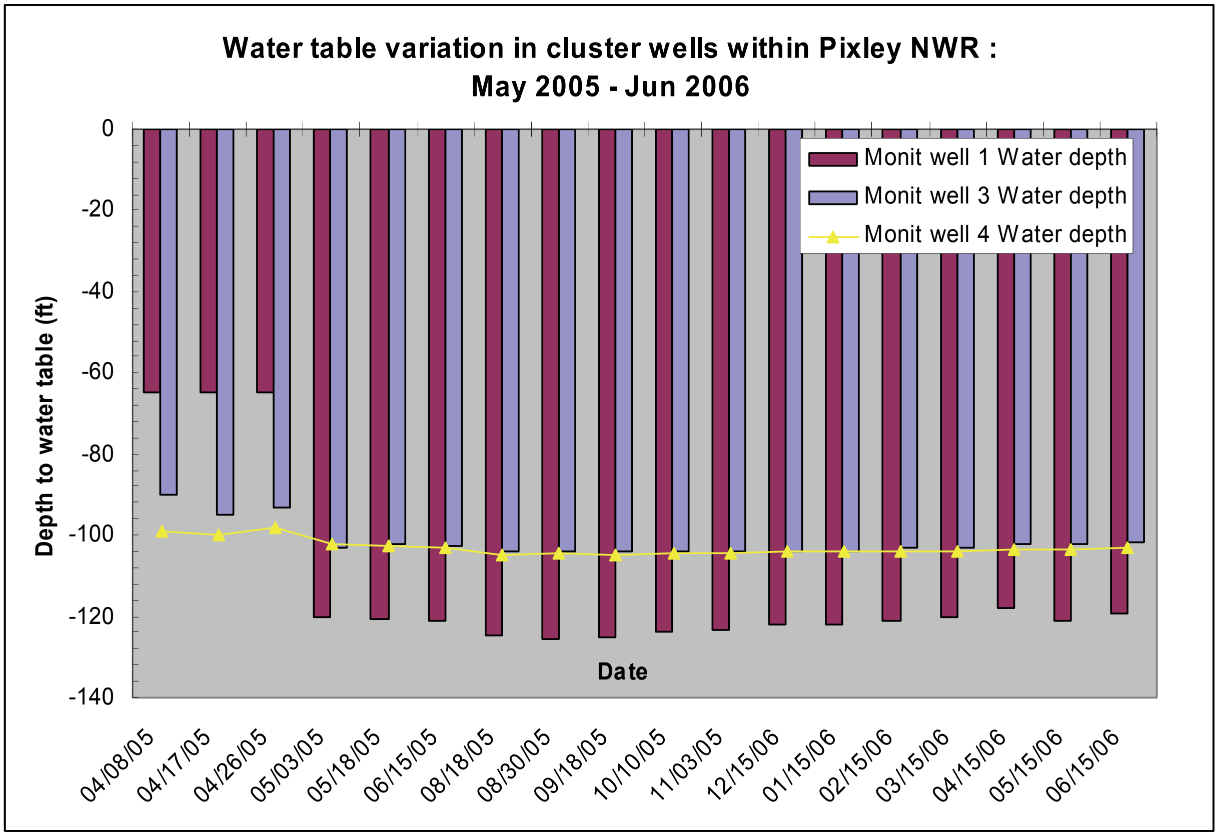


Figure 20. Monthly variation in observation well depth to water table recorded at a cluster well situated approximately ½ mile north of the production well within the Pixley NWR.

and the almost 60 ft decline that is observed in a single month. A possible explanation might be a leak in the well casing which caused a false reading in well 1 which was eliminated by the time of the 4th reading on May 15 or some other operator error. Ignoring the first three readings of well 1 then water levels would appear to be at their highest for the other wells in May of each year and at their lowest at the end of September. The annual variation in water levels (ignoring the anomalous well 1 readings) would be less than 10 ft annually.

Further analysis of the data suggests that the regional groundwater aquifer is capable of supplying a portion of Pixley NWR annual water requirements without affecting inter-annual groundwater storage. In other words the pumping regime appears to be within the aquifer safe yield under current land use of levels of development of groundwater extraction. Although new dairies have opened up within a 5 mile radius of the Refuge there does not appear to be a signal of this activity that shows up in the 2005/2006 data. The data further suggests that the local groundwater aquifer might be capable of supplying more than one well without exceeding aquifer safe yield – providing the second well was located a minimum of ¼ mile from the current well location. Issues of availability of electrical power and the proximity to the canal distribution network that supplies the wetland flooded areas will also need to be factored in to any decision to locate and develop a second production well.

2.8 Groundwater quality

Regional groundwater quality data has been collected and is available in survey reports by the USGS and DWR. DWR has also prepared maps of well water quality that include electrical conductivity, nitrate and arsenic. Salinity in groundwater is highly variable with higher concentrations found in shallow groundwater west of the town of Delano, McFarland and Corcoran. In these areas wells must draw from depths of between 1000 ft and 1400 ft to draw water of good quality (Schmidt, 2001). Water quality in the upper sections of the Continental Deposits is sufficient for many uses – the average electrical conductivity (EC) is well below 3,000 umhos/cm. In much of the eastern part of the Basin the salinity is less than 500 mg/l and tends to improve with depth. Good quality groundwater can be found in the alluvial fans areas within the Basin with a hydraulic connection to east side streams such as Deer Creek, the Tule River and the White River. The "base" of fresh water – typically defined as the interface between water with an EC below 3000 uS/cm and poorer quality water – is not well defined. High nitrate concentrations are associated with citrus cultivation on the east side of the Basin whereas arsenic concentrations are most commonly reported in groundwater on the west-side of the Basin in the vicinity of the Tulare Lake Bed (Schmidt, 2001). Elevated uranium concentrations have also been reported in shallow groundwater in the vicinity of the Tulare Lake bed.

Water samples taken in 2005 from the production well within the Pixley NWR showed water of exceptional quality with an EC of less than 300 uS/cm. The source of this water is assumed to be Sierran in origin based on its quality and is drawn into the Refuge through the relic channel of Deer Creek which is approximately aligned on an east-west axis with the production well. The depositional nature of Deer Creek and its relic channel, which is likely to extend west across the Valley trough, most likely contains sands, gravels and other coarse grade sediments. These riverine sediments are highly transmissive and provide an effective flowpath from the above-ground river bed to the site of groundwater extraction.

2.9 Current groundwater pumping

The deep groundwater production well was drilled and developed in 1992, as previously stated, allowing the establishment and maintenance of 300 acres of wetlands- an area approximately one-half of the surface area of Pixley NWR (USFWS, 2005). The well pumps at a rate ranging from 800 to 1800 gals/mingals/min and produces between 750 – 800 AF per year on average – although it is capable of annual pumping of as much as 1,300 AF (Dave Hardt, personal communication). Pumping usually starts in mid-August and flood-up occurs through September. The well is cycled on and off for about 3 ½ months after initial flood-up to fill and maintain the wetland footprint.

3.0 OPTIONS FOR ENHANCED REFUGE WATER SUPPLY

A number of options have been discussed over the past several years to increase the federal allocation of water supply to the Refuge as required under CVPIA legislation. Two options have been suggested by local entities to the US Bureau of Reclamation. The first option would enhance surface water deliveries by investing in improved distribution facilities that are maintained by nearby Irrigation Districts such as the Delano-Earlimart Irrigation District or Lower Tule River/Pixley Irrigation Districts (Figure 4) which are located south and east and north and east of the Pixley NWR, respectively. A second option would utilize an existing groundwater conjunctive use operation maintained by the Pixley Irrigation District. Enhanced water supply would be achieved by installing an additional groundwater production well and offsetting the additional groundwater extraction with groundwater recharge diverted into Deer Creek, currently used by Pixley ID as part of their surface water distribution system.

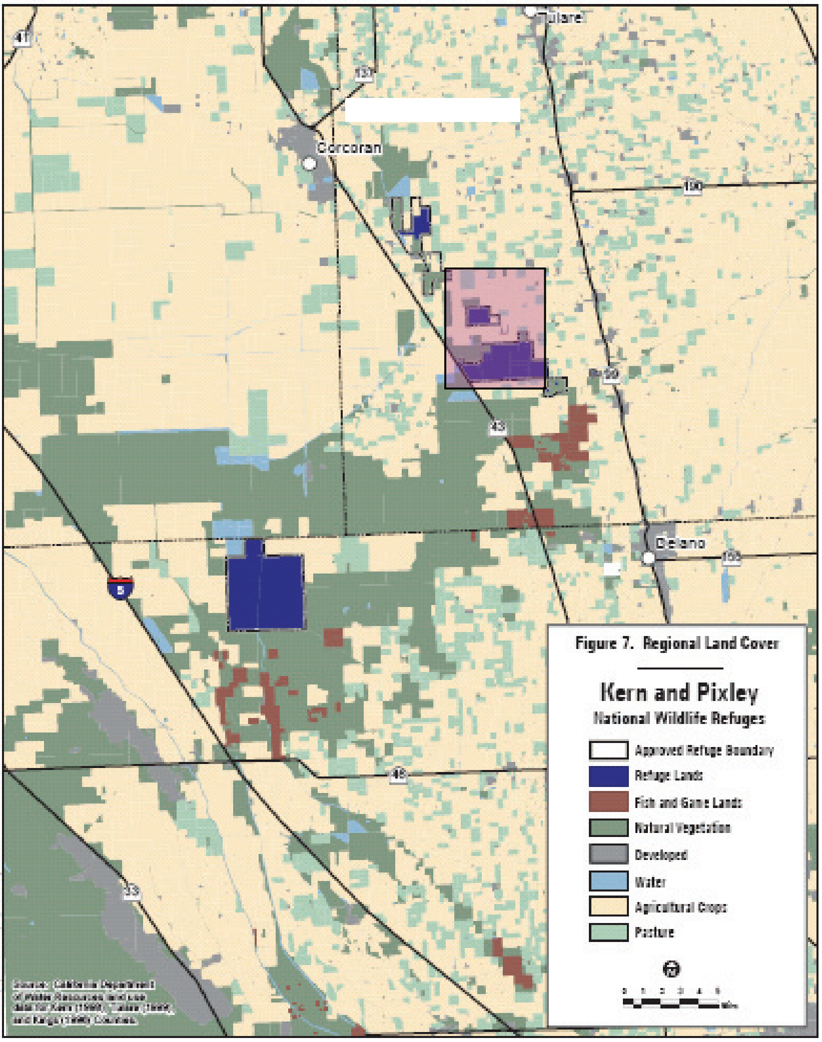


Figure 21. Current land use in the vicinity of the Pixley NWR. Colored rectangle shows location of ponded areas within Pixley NWR.

3.1 Comparison of Level IV water supply alternatives

Past estimates of the capital cost of improving the water supply distribution system in either Delano-Earlimart Irrigation District or Pixley Irrigation District (operated jointly with the Lower Tule River Irrigation District) to accommodate additional water supply to meet the Level IV water supply requirement of 6,000 AF have been in the order of several million dollars. By way of contrast drilling and completion of a new production well might cost upwards of $250,000 depending on the pumping depth. Conveyance of the additional water supply would need to be made using lined irrigation ditches or closed pipes – the capital cost of which is significant given the conveyance distance. Timely deliveries of flood-up, maintenance and irrigation water supply would require scheduling by the irrigation district which would add to the operations costs of making deliveries. There would be an annual overhead on surface water deliveries made through either Delano-Earlimart or Lower Tule River/Pixley Irrigation Districts. In years when shortages or conveyance constraints were experienced contract water supply would likely be directly impacted unlike with groundwater supply which can act as a buffer against short-term shortages – provided provision is made to restore overdrafts and not exceed aquifer safe yield.

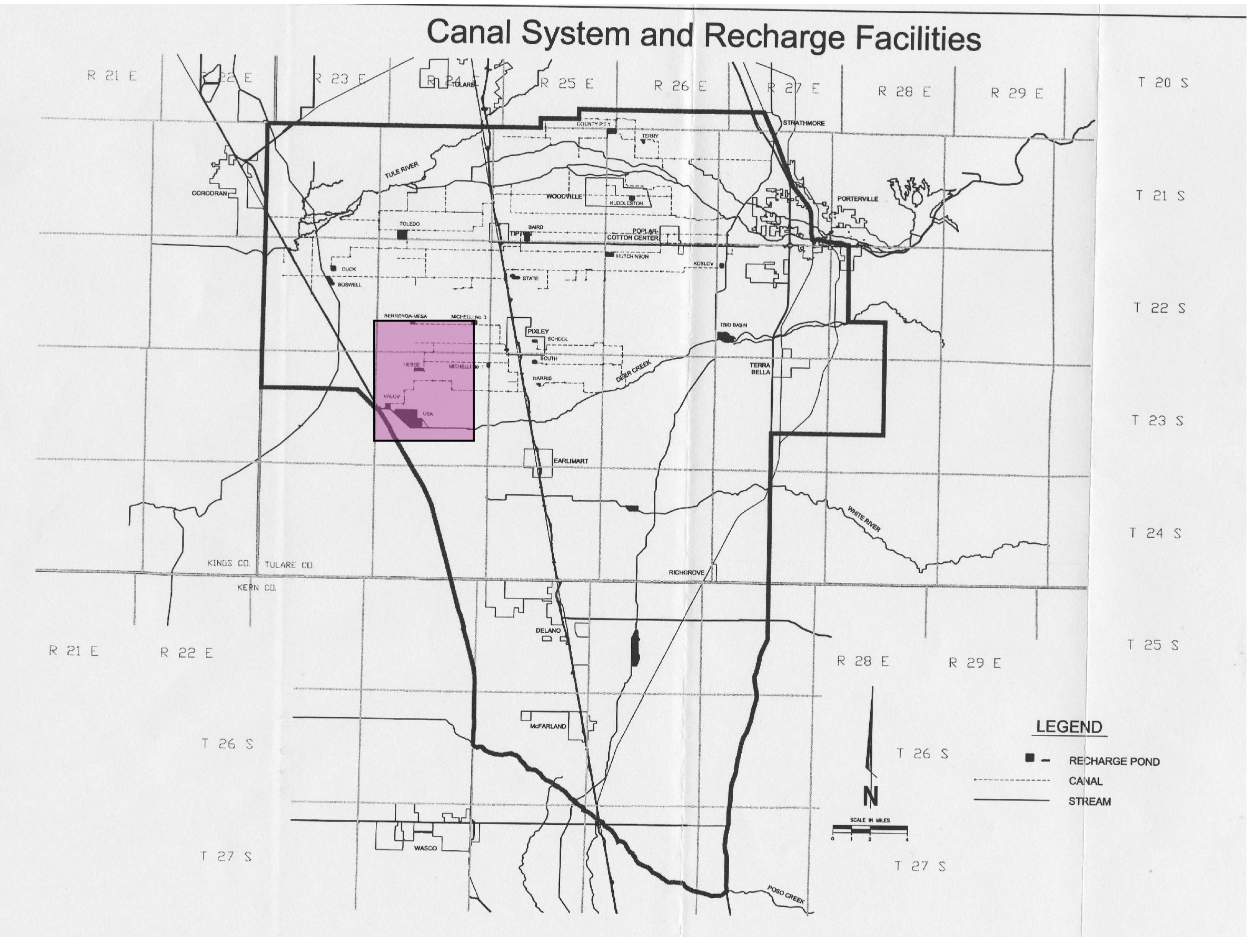


Figure 22. Diagram showing existing canal distribution system and source of groundwater recharge for possible groundwater conjunctive use system for supplying additional federal water supply to Pixley NWR. Diversions equivalent to groundwater extraction would be made from the Friant Kern Canal.

Groundwater conjunctive use can be an appropriate alternative to more structural water supply delivery solutions provided the groundwater basin is not currently stressed and where aquifer safe yields are not exceeded presently nor are unlikely to be exceeded in the future under current or projected levels of development. Groundwater conjunctive use is also appropriate in aquifers with good surface infiltration potential and in groundwater basins which are not subjected to large regional gradients, especially those that induce groundwater flux away from the active recharge area or the area of intended groundwater pumping. Another limitation to effective groundwater conjunctive use or groundwater banking projects is water quality – especially where recharged water is likely to mix with resident water of lower quality resulting in groundwater pumpage of degraded water quality. In the case of Pixley NWR none of these constraints appear to apply. In fact a groundwater conjunctive use solution to the water supply needs of the Refuge would appear to be consistent with water supply operations currently practiced by the Lower Tule River/ Pixley Irrigation District (Figure 22).

Groundwater conjunctive use would require the installation of a number of appropriately sited and spaced production wells, in addition to the current production well, to deliver the required Level IV supply requirement. Using the current production well as a guide to appropriate rates of groundwater extraction this would require an additional two production wells distributed across the Refuge lands at spacing no closer than ¼ mile. Since groundwater extractions from the production wells will be replenished by surface water recharge primarily from the east it is important that the wells interfere minimally with each other – which would cause excessive water level drawdown at the intersection of the radii of influence of adjacent wells. This might be accomplished by using Highway 99 as the approximate alignment for spacing the wells so that they are aligned perpendicular to east-west alignment of Deer Creek. This might help to minimize potential interference between the wells. Groundwater recharge would be accomplished by making periodic diversions along Deer Creek from the Friant Kern Canal at sufficient volume to move water to the western boundary of the delivery system and overcome distribution system losses. Depending on water year type and Reclamation operational criteria it may be possible to perform this water banking operation at times of water surplus in the Friant-Kern system, ideally during the non-irrigation season.

A first approach to implementation of a groundwater conjunctive use solution would use a 1 to 1 equivalency to offset groundwater extraction with diverted water from the Friant Kern Canal. Groundwater monitoring could be used to determine the adequacy of this formula and whether additional surface water diversion might be needed to offset conveyance and aquifer losses.

3.2 Groundwater monitoring and modeling

As was shown in Figure 12 there are a large number of actively pumped wells in the Tulare Basin within a 10 mile radius of the Pixley NWR – and hence an established network of monitoring well locations that can be used to monitor regional groundwater conditions. If full or partial implementation of a groundwater conjunctive use solution at Pixley NWR is envisaged - then a dedicated cluster of observation wells would be warranted. The deepest of the cluster wells should be drilled to a depth of about 300 ft and screened in a 20ft interval above the bottom of the well. An additional two wells would be appropriate – screened at 10 ft depth ranges in the interval between 160 ft and 300 ft in order to obtain pieziometric head data and hence allow analysis of the flow of groundwater. The cluster wells should be located within the Refuge boundary and a site chosen that minimizes the influence of private production wells located outside the Refuge Boundary. Data should be gathered from the Department of Water Resources that describes the pumping capacity of the production wells located within a 10 mile radius of the Pixley NWR.

There are no known groundwater models of the Tulare Basin that describe groundwater conditions at sufficient resolution to be useful to the study. The most recent regional groundwater modeling study is the C2VSIM model application, developed by the California Department of Water Resources, Planning Division, which covers the entire Central Valley. A ground water model would have utility in estimating potential unrecoverable losses that might need to be accounted for in estimating aquifer recharge to offset additional Pixley NWR groundwater withdrawls up to the Level IV supply requirement of 6,000 AF.

Given the large number of active groundwater production wells in the vicinity of the Pixley NWR – such a model would need to be provided with data on estimated monthly aquifer withdrawl from these wells as well as accurate maps of current land use in that portion of the basin that was to be included in the model. The model domain would need to be chosen carefully so as to establish realistic model boundary conditions. Poorly chosen model boundary conditions can greatly distort hydrologic mass balance in a numerical groundwater model.

4. FINDINGS AND RECOMMENDATION

Hydrogeological assessment of the Pixley NWR and preliminary analysis of the potential for groundwater conjunctive use was conducted using a combination of field investigations and a survey of available literature from agency reports, engineering consultants and nearby agricultural water districts. Results of the analysis show that the groundwater basin that contains the Pixley NWR and serves adjacent agricultural water districts contains a large number of active production wells which are mostly capable of supplying good quality groundwater. The highest quality groundwater is typically found in areas with direct hydraulic connection to Sierran streams such as Deer Creek, the Tule River and the White River. The salinity of the current groundwater supply to the Pixley NWR is typically better than 300 mg/l based on testing conducted in 2006. Analysis of groundwater levels in the production wells surrounding the Pixley NWR show annual fluctuations in water table elevations. However water table records over the last 5 years show no general decline in the water table in wells located within a 10 mile radius of Pixley NWR suggesting that the basin is currently in hydrologic balance with the average volume of recharge during this period being approximately equivalent to the volume of withdrawl. Contour maps of the groundwater show some areas of hydrologic stress which can be recognized by water levels significantly lower than surrounding areas which would induce regional groundwater flow toward the area of greatest stress. Such an area exists approximately 7 miles due east of the town of Pixley. The northern boundary of this groundwater stress area affects the most northerly portions of the Pixley NWR. The currently flooded area of the Pixley NWR overlies an area which does not appear stressed and which appears to obtain significant recharge from Deer Creek – the stream channel of Deer Creek lies due south of the Refuge.

This study suggests that the most cost-effective of various options for provision of Level IV water supply to Pixley NWR would be groundwater conjunctive use whereby additional groundwater withdrawal from the aquifer (over and above current average aquifer withdrawl) be matched by surface water recharge using the existing conveyance facilities owned and operated by the jointly managed consortium of Lower Tule ID/Pixley ID. Estimation of the amount of recharge necessary to prevent impacts to current users of the basin's groundwater would need to be determined by a combination of further analysis and through the installation of one or more observation wells. A first approach would be to divert additional supply equivalent to the volume of additional pumpage. This policy of offsetting additional groundwater through active recharge is likely to be more acceptable to local stakeholders and less likely to generate environmental impacts that might delay implementation. A groundwater conjunctive use approach is easier to manage administratively – takes advantage of periods of water surplus in the Friant-Kern system and provides significant operational flexibility.

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