

TECHNICAL MEMORANDUM

INFILTRATION POTENTIAL OF PRECIPITATION FALLING ON
DEVELOPED LANDS
AND THE FATE OF APPLIED GROUNDWATER WITHIN UWCD

UNITED WATER CONSERVATION DISTRICT
SEPTEMBER 2013

This Technical Memorandum is preliminary and is subject to modification based on future analysis and evaluation. This document has been prepared for the use of the Board of Directors of United Water Conservation District.

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1 INTRODUCTION

The United Water Conservation District (UWCD or District) Board of Directors is empowered to establish groundwater extraction fees (dollars/acre-foot of pumped groundwater) in conjunction with the annual budget review and approval process. Per Water Code Section 75594, the ratio between municipal and industrial (M&I) to agricultural (AG) extraction fees can vary from 3:1 to 5:1 at the discretion of the Board of Directors. This Technical Memorandum has been prepared to provide the Board of Directors with additional information that can be considered during the ratio selection process.

This Technical Memorandum assesses the infiltration potential of precipitation falling on developed lands, and the fate of applied groundwater used for beneficial uses both in urban environments and on agricultural lands. Soil infiltration capacity and groundwater basin setting (unconfined vs. confined) are considered in the analyses. Staff has evaluated hydrological data from 2010, 2011 and 2012 for this Technical Memorandum. The climatic conditions in 2011 were overall slightly wetter than normal, and 2012 was drier than normal for the District. Among these recent years, data from 2010 are believed to be more representative of “normal climatic conditions.”

2 OBJECTIVES

Management of the groundwater resources within the District is the fundamental tenant that directs the District’s operational and management efforts. The objective of the analyses performed in this Technical Memorandum is to establish a protocol for evaluating the potential for groundwater recharge among the developed landscapes (urban and agricultural) within the basins in the District. The potential for recharge is evaluated for both rain falling on developed lands and for applied water sourcing from wells within the District and used in both urban settings and for agriculture.

3 METHODOLOGY

A major component of the mission of UWCD is the replenishment of the groundwater aquifers within its boundaries. Replenishment of the aquifers can occur by natural and artificial methods. Major recharge mechanisms include, but are not necessarily limited to, the following:

- ◆ Infiltration of precipitation;
- ◆ Infiltration of irrigation water;
- ◆ Infiltration of surface water from stream channels; and
- ◆ Infiltration of effluent from waste water treatment plants (WWTP).

A number of variables are recognized to affect the quantity of the infiltrated waters listed above:

- Land use (agricultural and urban land uses have characteristic properties of infiltration and runoff);
- Soil hydrologic classification (general classifications of the inherent infiltration potential for water on the land surface [irrigation or precipitation]); and
- General aquifer conditions.

These variables were used to estimate the magnitude of potential aquifer recharge from precipitation falling on developed lands and recharge associated with surface-applied groundwater under various land uses within the District in years 2010, 2011 and 2012.

The analytical methodology used for this technical memorandum differs somewhat from that outlined in the Annual Investigation and Report of Groundwater Conditions within United Water Conservation District (UWCD, 2013). The hydrologic balance contained in UWCD (2013) is a simplified, regional evaluation. The analyses performed for this study are more detailed for several of the critical variables. More rigorous analyses are contained herein for land use, crop patterns, infiltration of precipitation, the fate of applied irrigation waters, and effluent from waste water treatment plants. The modeling approach presented here is similar to other detailed local watershed runoff and infiltration models in that the evaluation estimates inputs to the subsurface/underlying aquifers, but does not include flow modeling within the groundwater system.

Figures 1 and 2 are diagrammatic depictions of the analytical methodology used in this Technical Memorandum (unconfined and confined basins, respectively). The methodology used to calculate runoff and infiltration from developed lands, return flows from pumped groundwater, and the limited downward leakage of water in the confined basins of the District are detailed in attachments to this Technical Memorandum. Evapotranspiration, while shown in the diagrams, was not estimated.

While the analyses performed as a part of this Technical Memorandum characterize groundwater replenishment in recent years according to the variables listed above, the analyses of the groundwater replenishment is segregated by major land use category (i.e., agricultural v. urban). It is not possible to perform these analyses on each parcel that extracts groundwater. The groundwater extracted for urban use is typically not used on the parcel where the pumping well is located, but is distributed via a common pipeline to multiple parcels. The common pipeline can be served by one or more groundwater production wells. So identification of which well is serving an individual urban parcel is not possible. Likewise, irrigation wells often serve more than one agricultural parcel and the irrigation water applications by parcel are not typically available. Consequently, the analyses in this Technical Memorandum focused on aggregating the groundwater replenishment potential at the major land use category level (i.e., urban and agricultural).

3.1 GENERAL AQUIFER CONDITIONS

Each of the groundwater basins within the District boundaries were assigned a general aquifer condition based on the hydrogeology. Each groundwater basin was assigned a confined or unconfined condition. With the exception of the Santa Paula basin, confinement among the groundwater basins of the District are well established in various groundwater reports detailing groundwater conditions in southern Ventura County.

In unconfined basins, water near the land surface can migrate freely downward from the land surface to the underlying water table (aquifer). Unconfined basins are generally free of thick or laterally-extensive clays and other low-permeability units that limit the vertical migration of water. Sediments above the water table remain unsaturated as water from recharge events moves downward through the vadose (unsaturated) zone. The Piru, Fillmore and Oxnard Forebay basins are routinely characterized as unconfined groundwater basins (SWRB, 1953).

Basins that exhibit confined hydrogeologic conditions contain extensive units of low permeability that significantly limit the ability of near-surface waters to move downward to underlying aquifers used for groundwater production. The presence of confining layers of low permeability is often accompanied by a shallow “perched” water table aquifer that may be recharged by surface-applied waters (i.e., precipitation, irrigation water, WWTP effluent). There may be some downward leakage of water through the basin confining layer or layers, and as such the term “semi-perched aquifer” is often favored. Most recharge to confined aquifers often takes place along the margins of the basin where aquifers may be in contact with a constant or intermittent source of recharge. The Oxnard Plain is a prime example, where a majority of the recharge to the confined aquifers of the Oxnard Plain comes from the adjacent and up-gradient Oxnard Forebay. Pressures in confined aquifers can be highly variable in response to large recharge events and pumping stresses. Artesian conditions exist when heads in the confined aquifers are greater than the land surface elevation (and greater than in the shallow perched aquifer). During periods of heavy pumping, heads in confined aquifers commonly fall in response to regional pumping stresses. The water-producing (or “production”) aquifers of the Oxnard Plain, Mound, Pleasant Valley, and West Las Posas basins are classified as confined (SWRB, 1953).

The Santa Paula basin is interpreted to be unconfined in the eastern portion and to have some degree of confinement in the west. The Santa Paula basin was characterized as unconfined for the evaluations in this report.

3.1.1 DOWNWARD LEAKAGE OF SEMI-PERCHED WATER

As mentioned in the prior section, the thick layers of fine-grained sediment that serve to confine production aquifers often result in the formation of an overlying perched or semi-perched water table aquifer. The sediments form an imperfect barrier that prevents the rapid equalization of pressure between the two aquifers, but likely allows some limited amount leakage of water down through the confining layers. Several publications on the hydrogeology of the Oxnard

Plain characterize the confining layers or “clay cap” in similar fashion, including: Mann (1959) who states “it is doubtful that such layers would permit extensive water movements. Generally speaking, the clay cap is an effective barrier to vertical movements of water between the Oxnard Aquifer and the semi-perched zone,” and the SWRB (1953) states “the presence of extensive beds of clay and other materials of low permeability between the pumped aquifers and the semi-perched water bodies has been assumed to preclude supply to the pumped aquifers of water applied to the ground surface, direct precipitation, and other surface waters including the semi-perched water.”

Many researchers do however suggest there is some leakage of water through the confining layers on the Oxnard Plain. Mann (1959) and CA DWR (1965) focus on areas where the confining layers are thin or discontinuous, while many later publications stress that most leakage probably occurs through abandoned or improperly constructed wells (CA DWR, 1968; Predmore, 1993; USGS, 1996; Hanson et al, 2003). The rapid leakage of water from semi-perched aquifers is seen as undesirable due to the characteristic poor quality of the perched waters. The County of Ventura’s well construction and destruction guidelines include special requirements for wells in confined basins, and are intended to prevent the downward movement water within the well casing or gravel pack.

The varied distribution of both thin spots in the confining sediments and abandoned or leaky wells makes estimates of leakage through the clay cap on the Oxnard Plain difficult. Few estimates can be found in the literature. Attachment C presents estimations of the potential downward leakage of water through confining layers in the confined basins of the District. The estimates however are based on limited hydrogeologic information and do not account for local variability that likely is a significant variable.

3.2 PRECIPITATION

The precipitation records from the Ventura County Watershed Protection District (VCWPD website, Hydrologic Data Server) were used for the infiltration analyses detailed in Attachment A. Table 1 shows rainfall records from various rainfall stations within the groundwater basins of the study area for the years 2010, 2011 and 2012. In groundwater basins with more than one precipitation station, the average of the total water year precipitation for all available stations is shown. Annual rainfall totals generally increase with distance from the coast.

3.3 LAND USE

Detailed land use mapping for Ventura County was last updated by Southern California Association of Governments in 2008 and these data were used in the land use analysis (SCAG, 2010). The land use data are expected to be updated in late 2013, however, these data are not available for use in this technical memorandum. The SCAG land use mapping uses parcels as the mapping units, and land use is determined from aerial photographs. The SCAG data set uses the Anderson land use classification scheme. Anderson Level 2 categories were used to determine areas of urban land (residential, commercial, industrial, etc.) and are shown in Figure 3.

UWCD staff reviewed the SCAG land use mapping and used aerial imagery from 2010 to correct a number of mis-classifications. The most common error was agricultural lands classified as “general office use.” In addition, some very large parcels are classified as heavy industrial due to oil production activities on a small portion of the property. Heavy industrial uses are not very prevalent within the study area, and these parcels were excluded from the analysis (all other industrial parcels were included in the analysis). “Flood waterways and structures” are mapped within the Transport, Communication and Utilities Anderson Level 2 category. United’s recharge facilities were mapped within this category, but in terms of runoff and applied water these lands are better characterized as undeveloped lands, and were therefore excluded from the infiltration analysis detailed in Attachment A.

The total area of active agricultural land within the study area is over-estimated by the SCAG data, as the entire area of the parcel is classed and mapped as agriculture, but often only a portion of the property is irrigated for crop production. Areas of agricultural lands were instead determined using the Ventura County Agricultural Commissioner’s CropsNow mapping, which maps active orchard and crop production areas instead of the entire area of the parcel (VCAC, 2013). The CropsNow mapping is shown in Figure 4.

3.4 GROUNDWATER EXTRACTION AND WATER IMPORTS

Groundwater extraction totals for each groundwater basin were tabulated from Groundwater Extraction Reports filed by pumpers with United Water Conservation District. Water use is reported as either for agriculture or for municipal, industrial or domestic use (also referred to as urban use). In a number of areas, development located on the hillsides adjacent mapped groundwater basins is supplied with water pumped from the basin. Mapping of sub-watersheds within the study area was used to associate areas of water use above the valley floor with water produced from the adjacent groundwater basin (VCWPD, 2004). The distribution of wells reported as active in calendar year 2012 are shown in Figure 5.

3.4.1 SURFACE WATER DIVERSIONS

In some areas within the District, diverted surface water is used to irrigate agricultural lands. Diversions are commonly operated on Piru Creek, Sespe Creek, Santa Paula Creek, and along the banks of the Santa Clara River within the Fillmore and Santa Paula basin. Diversions totals for these private operations are not readily available, and diversion rates are generally not measured. Available estimates suggest diversion rates are relatively minor and irrigation water from these operations is not included in return flow calculations for irrigated agriculture in the Piru, Fillmore and Santa Paula basins. The exclusion of irrigation by diverted surface water in the unconfined basins of the District results in an underestimation of agricultural return flows in these areas.

The Freeman Diversion is a large surface water diversion structure located on the Santa Clara River near the upstream portion of the Oxnard Forebay. The facility was constructed and is operated by United. Some of the surface water diverted from the river is distributed to recharge basins in order to replenish the aquifers that underlie the Oxnard Forebay and the confined groundwater basins of the greater Oxnard Plain. The remainder of the diverted water is distributed to irrigation pipelines to offset pumping demands in overdrafted areas of the Oxnard Plain and Pleasant Valley basins. Freeman Diversion surface water deliveries for irrigation totaled 17,462, 19,817, and 15,792 acre-feet in the 2010, 2011 and 2012 calendar years, respectively.

In addition to Santa Clara River water deliveries from United, Pleasant Valley County Water District (PVCWD) receives surface water deliveries from the Conejo Creek Diversion, operated by Camrosa Water District. Reported annual deliveries from the Conejo Creek to PVCWD totaled 5,041 acre-feet in 2010, 6,657 acre-feet in 2011 and 4,785 acre-feet in 2012.

Agricultural return flows from these significant surface water “imports” to the confined Oxnard Plain and Pleasant Valley basins are not considered in the calculations of agricultural return flow. United supports and helps facilitate water imports that reduce pumping demands within the District, but the District chooses not to consider secondary benefits such as return flow from these water imports when establishing fees for water actually extracted from aquifers within the District boundaries.

3.4.2 IMPORTED MUNICIPAL AND INDUSTRIAL WATER

Water from the California State Water Project is also imported for use within the boundaries of United Water Conservation District. United holds an allocation for 5,000 acre-feet of State Water, 1,850 of which is leased to and imported by the Port Hueneme Water Agency. Since the late 1990s United has purchased its full allocation each year and receives delivery of the water in middle Piru Creek upstream of Santa Felicia Dam. The purchased State water co-mingles with natural runoff from the Piru Creek watershed in Lake Piru and is typically released down the Santa Clara River in the fall of the year. The reservoir releases serve to replenish the

groundwater basins of the District and surface water deliveries alleviate groundwater pumping in the fall when stress on the aquifers is commonly greatest.

State Water is also imported by pipeline for direct municipal and industrial use on the Oxnard Plain. The City of Oxnard and the Port Hueneme Water Agencies are the principal importers, via water purchase and delivery arrangements with Calleguas Municipal Water District. A return flow component is not calculated for imported State Water, as this water supply sources from outside the boundaries of United.

The City of Ventura at times imports water from the Ventura River watershed to portions of the City that lie within United's District boundaries. The magnitude of these imports from the Casitas MWD service area are not known, but distribution is believed to be limited to areas overlying the confined Mound and Oxnard Plain groundwater basins. Imports are believed to have increased in recent years as a number of the City's wells have suffered problems with poor water quality or poor production.

The magnitudes of these municipal water imports vary from year-to-year, and like surface water deliveries for agriculture are excluded from the return flow calculations in this Technical Memorandum. Further, as detailed in the attachments to this document, the estimated capacity for the downward leakage of water through basin confining layers of silts and clays is considerably less than the amount of soil infiltration generated by precipitation falling on the confined groundwater basins within the District. All return flow from groundwater pumped from the confined groundwater basins of the District is essentially surplus water that cannot flow downward and instead flows laterally in the aquifers of the Semi-Perched Zone and ultimately discharges to either stream channels leading to the ocean or directly to the Pacific Ocean.

While groundwater pumping for urban uses within the District is reported to United, imports of municipal and industrial water supplies are not. Lacking the total water supply scenario for urban areas overlying the confined basins, it is not possible to calculate urban water usage on a per-area basis.

3.5 INFILTRATION

The replenishment of underground waters within the District by infiltration within developed land areas was considered with the analyses of the following major infiltration sources:

- ◆ Direct precipitation
- ◆ Irrigation; and
- ◆ Waste water treatment plant effluent.

The following sections detail United's estimates of how land development influences the infiltration (recharge) of precipitation, and how various percentages of pumped groundwater make it back into the soil after beneficial use in either an urban setting or as irrigation of agricultural lands. Natural land areas are excluded from the infiltration analysis; infiltration is

estimated only for land where urban or agricultural development uses groundwater for beneficial uses and land development has altered the water infiltration characteristics from that of the native landscape.

3.5.1 DIRECT PRECIPITATION

Developed land generally produces more runoff from rainfall than an undeveloped or natural landscape. The creation of impervious surfaces and the intentional routing of increased runoff to flood control structures, channels, and eventually the region's natural waterways effectively reduces the inundation of developed lands during large rainfall events, but also reduces the infiltration of precipitation into soils. The deep percolation of infiltrating precipitation serves as an important recharge mechanism in unconfined groundwater basins (and a limited recharge component in confined groundwater basins). The reduction in rainfall infiltration on developed lands as compared to natural infiltration on native landscapes is a contributing component to the groundwater overdraft in the connected sub-basins ("basins") within the District.

It is possible to make an accurate prediction of recharge and runoff in areas of both urban and agricultural land uses. Mapping of land use practices over the entire District allow the use of standard runoff curves that are routinely used to estimate runoff from developed lands. The mapping of soil infiltration characteristics in the study area improves the calculation of infiltration and recharge associated with the various local land uses. Precipitation records are available for all rainfall events from recent years, allowing the application of the methodology detailed in Attachment A of this report. This methodology is standard practice in flood control and drainage evaluations, but this study focuses on the infiltration component of precipitation rather than the runoff component. The analysis accounts for land use practices in both the unconfined and confined groundwater basins within the District.

This study does not evaluate the fate of precipitation that runs off from each land use, but rather the component that soaks into the ground. A portion of the water running off developed land areas will either percolate in nearby unlined channels, river channels, or possibly be diverted from the Santa Clara River at the Freeman Diversion. In small rainfall events, runoff from urban areas commonly percolates in the nearby stream and river channels, and flow in the Santa Clara River does not increase significantly (effectively, local runoff becomes local recharge). In larger storm events, runoff is generated over much of the watershed and streamflow sourcing from areas beyond local developed lands becomes dominant. In large storm events when water was not diverted at the Freeman Diversion no estimation of channel recharge is calculated, and local areas are not credited for downstream groundwater recharge from runoff (see further discussion in Attachment A).

3.5.2 IRRIGATION

There is also a component of recharge for pumped groundwater used for both landscape irrigation in urban settings and from the irrigation of commercial agricultural crops. A majority of

applied irrigation water is transpired by the plant or used for plant growth, but a portion of the applied irrigation water infiltrates down past the root zone, as required to flush salts from the soil. Soil moisture that migrates down below the root zone is termed “return flow.” Return flows are a component of groundwater recharge in the groundwater basins within the District. Calculated estimates of return flow from irrigation in agricultural areas and for landscape irrigation in urban areas are detailed in Attachment B of this report.

3.5.3 PERCOLATION OF TREATMENT PLANT EFFLUENT

It is recognized that the effluent from waste water treatment plants (WWTPs) in the District can provide recharge to underlying aquifers. Effluent discharged from the Piru (County Water Works District #16), City of Fillmore WWTP, City of Santa Paula WWTP, and Saticoy WWTP is routed to percolation basins for disposal, as opposed to being discharged to the channel of the Santa Clara River. Effluent totals from the plants were compared to the municipal groundwater extractions within the respective service areas of treatment facilities in the unconfined basins within the District. The ratio of the volume of waste water effluent to groundwater extractions was used to estimate the amount of water potentially available for recharging the underlying basins. It is assumed that pumped water not returning to the WWTP was used for landscape irrigation.

As mentioned above, waste water effluent from the treatment plants in Piru, Fillmore, Santa Paula and Saticoy is discharged to percolation ponds so that a portion of pumped municipal water is returned to the basin. In confined groundwater basins, this return mechanism is not present because percolations basins cannot be effectively used for wastewater disposal. Effluent from the City of Ventura and City of Oxnard treatment plants is not available for groundwater recharge, as it is discharged to the Santa Clara River estuary and the Pacific Ocean via an ocean outfall, respectively.

The percentage of pumped municipal water available for potential groundwater recharge as treatment plant effluent was estimated as follows for each of the unconfined groundwater basins within the District:

- ◆ Piru basin – 57%;
- ◆ Fillmore basin – 43%;
- ◆ Santa Paula basin – 50%;
- ◆ Forebay basin – 50%.

Effluent potentially available for groundwater recharge was assumed to be zero for the confined Mound, Oxnard Plain, Pleasant Valley, and West Las Posas basins.

4 SIGNIFICANT VARIABLES AND OTHER CONSIDERATIONS

United's district boundaries encompass nearly 213,000 acres in southern Ventura County. A multitude of water supply projects and management strategies exist in this area. Some water supply facilities and practices are significant enough that they were specifically addressed in order to improve the accuracy of the infiltration and recharge analyses detailed in this Technical Memorandum.

The significant groundwater extractions associated with the Fillmore Fish Hatchery operations near the boundary between the Piru and Fillmore groundwater basins must be handled differently than other extractions in the unconfined basins. Pumped groundwater flows through the rearing pens at the fish hatchery and discharges to a ditch at the downstream end of the facility. This flow is redirected to adjacent watercress fields for use as irrigation water. Much of the groundwater pumped by the fish hatchery percolates back into the alluvium of the Santa Clara River, so the consumptive use for this facility is much less than that associated with other agricultural land uses. Transpiration of water by the watercress is estimated and deducted from the return flow from the fish hatchery wells. See Attachment B for additional details.

United's OH wellfield is located in the (unconfined) Oxnard Forebay groundwater basin. Groundwater pumped from this facility is delivered to water users on the confined portions of the Oxnard Plain. Accordingly, pumping totals from the OH wellfield were applied to urban water users in the confined basins of the District and not to the unconfined basin from which it was extracted.

United's Saticoy wellfield intermittently pumps water from the unconfined Oxnard Forebay for agricultural use on the Oxnard Plain. As with the OH wells, use of the water extracted from the Forebay is applied to confined areas of the Oxnard Plain.

In November 2010 the County of Ventura passed an ordinance requiring that new developments capture and recharge the first 0.75 inches of rainfall in a storm event. Relatively few developments have been built within the District since 2010, related to a general downturn in both the local and statewide economy. While these management practices are not yet widely applied in southern Ventura County, United's analysis applies infiltration credit to urban and agricultural area in small rainfall events. During the years 2010-2012, the smallest storm that prompted United to turn out at the Freeman Diversion was 0.66 inches, a rainfall amount slightly less than the stormwater capture criteria recommended for urban areas. Stated otherwise, these new best management practices for urban rainfall infiltration are not itemized in United's infiltration analysis, but local infiltration of urban runoff is already included for all small storm events. See Attachment A for additional details related to infiltration calculations for small storm events.

In the unconfined basins, all treatment plant effluent is credited as return to the basins. The City of Fillmore distributes some reclaimed water to fields and landscaping around the City, but this flow is not treated differently than water distributed to percolation basins (it all is credited as

recharge to the basins). In the confined groundwater basins, reclaimed water use is not accounted for. This omission is considered acceptable as reclaimed water constitutes a small percentage of total urban water use, and calculated return flows (from precipitation alone, without adding irrigation returns) to semi-perched aquifers overlying the confined basins routinely exceed the amount of water that can effectively leak down to the confined aquifers.

Perhaps the greatest uncertainty in any of the calculations presented in this Technical Memorandum is associated with estimates of the downward leakage of waters through groundwater confining layers (Attachment C). Unlike the detailed lands use and soils mapping relied upon to predict infiltration to the subsurface, documentation of the extent and depths of perched groundwater systems is lacking for areas outside of the Oxnard Plain. For the purposes of this report, United assumes perched systems are present in the Mound, Pleasant Valley and West Las Posas groundwater basins. Estimations of downward leakage are included to credit underlying aquifers with some recharge component from overlying land uses. United feels the leakage estimates presented are likely greater than what actually occur, in part because it is assumed that a semi-perched aquifer system exists over the entirety of the confined basins within the District (see Attachment C for the analysis and further discussion).

On the Oxnard Plain, where a semi-perched aquifer is documented to exist, saturated soil conditions may exist at shallow depths near the land surface. In this event the accumulation of water in the shallow subsurface is generally viewed as problematic (and not as beneficial aquifer storage). In agricultural areas saturated conditions are a problem if they extend into the root zone of trees or other crops. In urban areas, saturated soil conditions complicated construction activities and necessitate waterproofing or dewatering around basements and subsurface vaults. In some cases subsurface drainage systems (or “tile drains”) are installed to locally lower the water table by several feet. These systems commonly use sump pumps to lift water from the buried collection system and rout the water to surface drainages for disposal. Tile drains are installed in areas where the infiltration of surface water exceeds the capacity of the underlying sediments to convey water to deeper aquifers, accordingly, the presence of tile drains does not significantly reduce downward leakage from shallow semi-perched aquifers.

Water resource managers have traditionally viewed perched waters, which tend to be highly mineralized and vulnerable to contamination from land use activities, as a water quality threat to underlying aquifers. The characteristic poor quality of shallow perched water is the main reason they are not utilized directly as water supply for domestic or agricultural uses. Anomalous poor quality water produced by Oxnard aquifer wells on the confined Oxnard Plain is often an indication that water from the semi-perched zone is somehow making its way into the well.

In a regional water infiltration analysis such as that presented here there are bound to be some errors in mapping and some necessary simplification of the complex hydrologic interactions that take place throughout the District. Regardless, United is confident that the analysis presented in this Technical Memorandum relies on sound assumptions, detailed land use mapping and reasonable routing and accounting of water within the study area.

5 SUMMARY AND CONCLUSIONS

Estimations of groundwater extraction and net groundwater extraction were prepared for the M&I and AG land use categories in each of the confined and unconfined groundwater basins within the District. Tables 2, 3, and 4 provide summaries of these values on a District-wide basis. The total quantities of groundwater extracted for agricultural land use are larger than for urban (MI&D) land use, in part due to the larger amount of agricultural land use in the District. Agricultural groundwater use on a per-acre basis is greater than for MI&D and remains greater after crediting the hydrologic system with estimates of infiltrated water from irrigation return flows and waste water treatment plant effluent. As expected, the amount of annual precipitation has a marked impact on the quantity of groundwater pumped for agricultural irrigation and a much lesser influence on M&I pumping. The potential downward leakage of water from the shallow semi-perched aquifer to deeper confined production aquifers varies annually as head differentials change between these aquifers.

Tables 2, 3 and 4 summarize the major findings of this Technical Memorandum. The annual values of rainfall infiltration, groundwater pumping and return flows to groundwater presented here were generated to support additional work related to the determination of rates for groundwater extraction within the District.

Overall, as summarized in Attachment B, the percentage of agricultural pumping that is available for return flow to underlying aquifers ranges from about 22.2% (in 2012) to 25.6% (in 2010) with MI&D percentages being somewhat lower (15.2% in 2012; 13.8% in 2010). The total quantity of agricultural return flow available as recharge to underlying aquifers ranges from about 29,308 AF (in 2011) to 30,243 AF (in 2012) which is 4.8 to 5.2 times greater than that from MI&D over the period from 2010-2012.

It is also recognized that infiltration of precipitation on developed urban and agricultural land areas is an important contributor to the sustainability of the groundwater resources in the District (see Attachment A for rainfall infiltration analysis). On a district-wide basis, the agricultural areas are estimated to have allowed the infiltration of 135,425 AF of water in years 2010-2012, while urban areas allowed the infiltration of 43,108 AF. However, not all of this infiltrated water is available as groundwater recharge, as some is extracted by plant roots, and in confined areas downward leakage is limited by the low permeability of basin confining layers.

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7 FIGURES

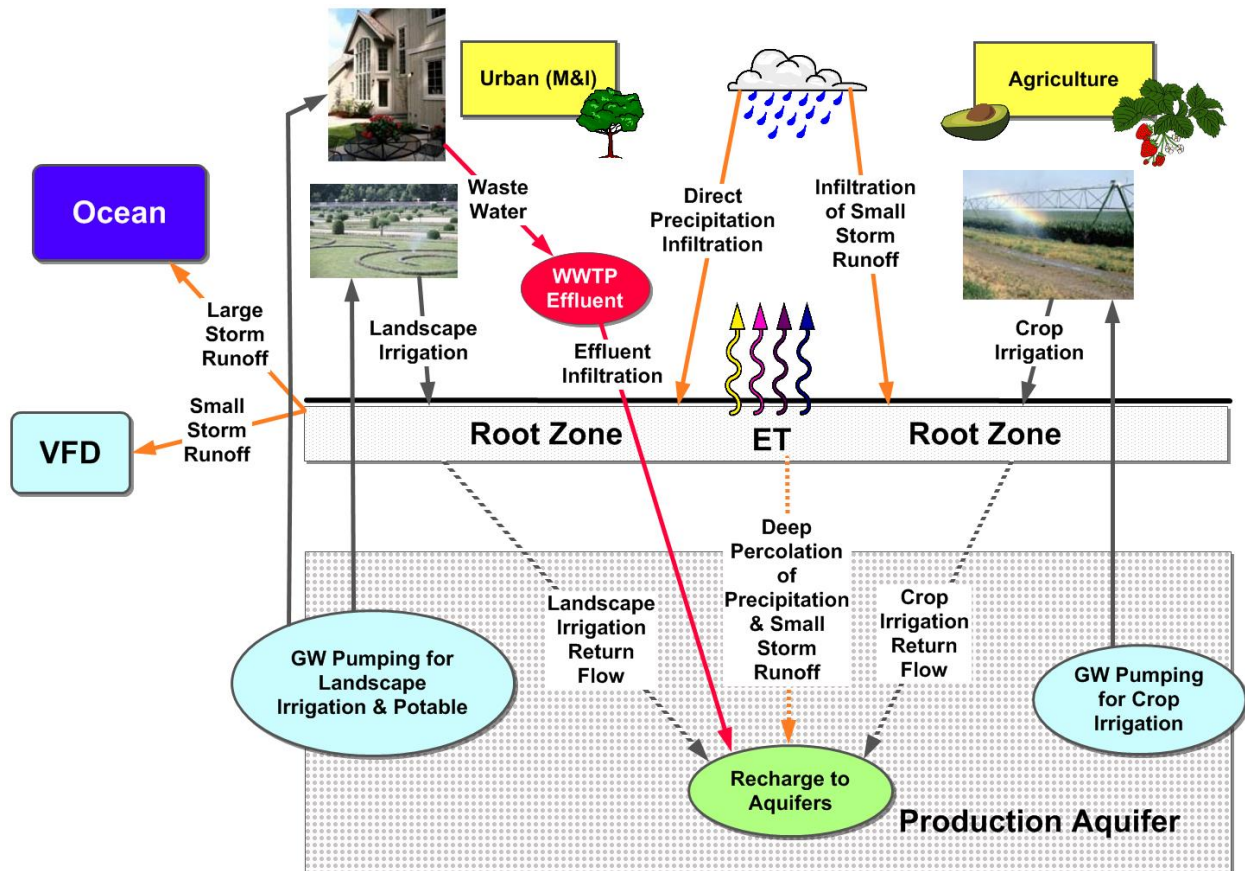


Figure 1. Diagrammatic representation of infiltration, pumping and recharge, unconfined basins.

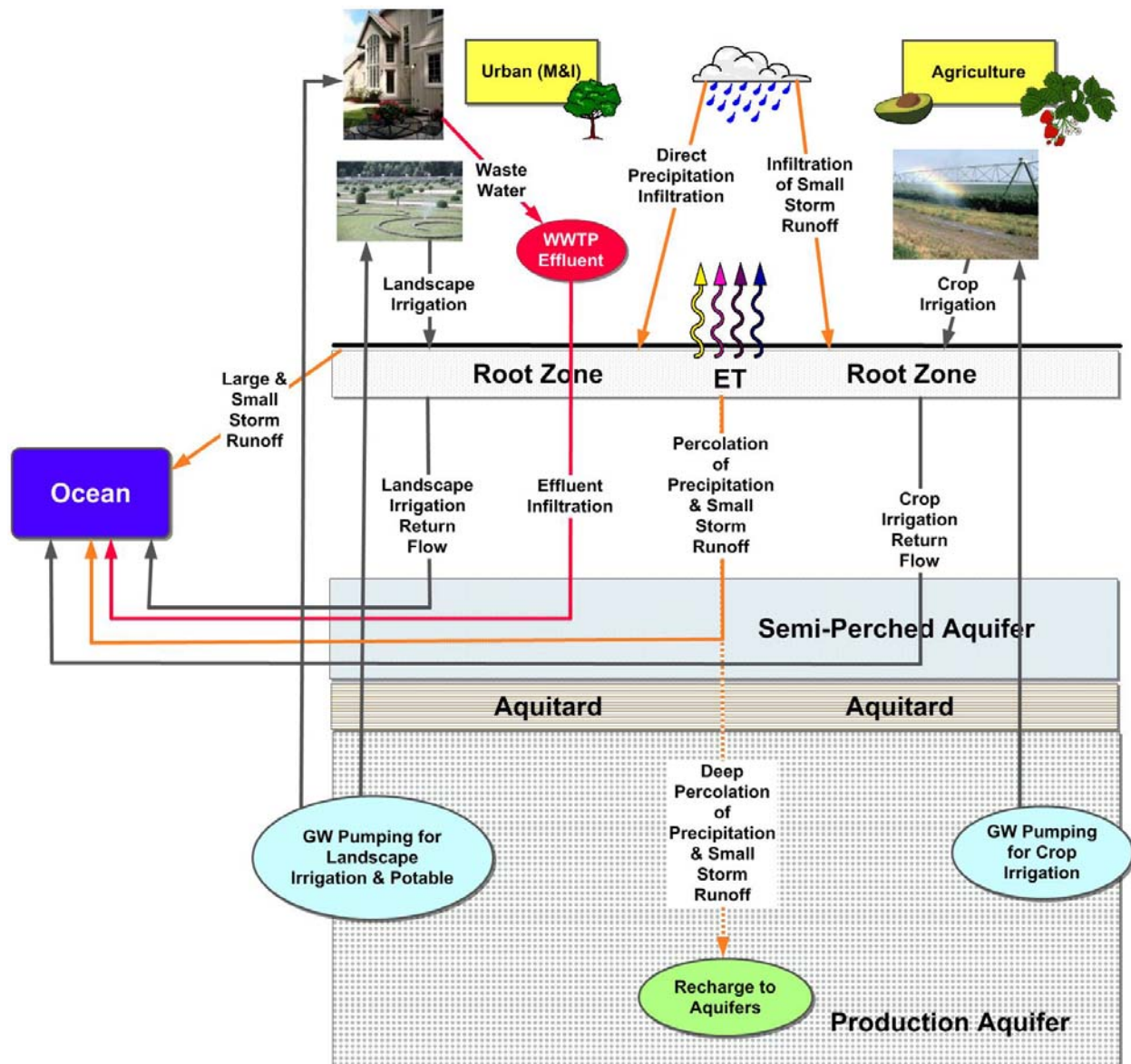


Figure 2. Diagrammatic representation of infiltration, pumping and recharge, confined basins.

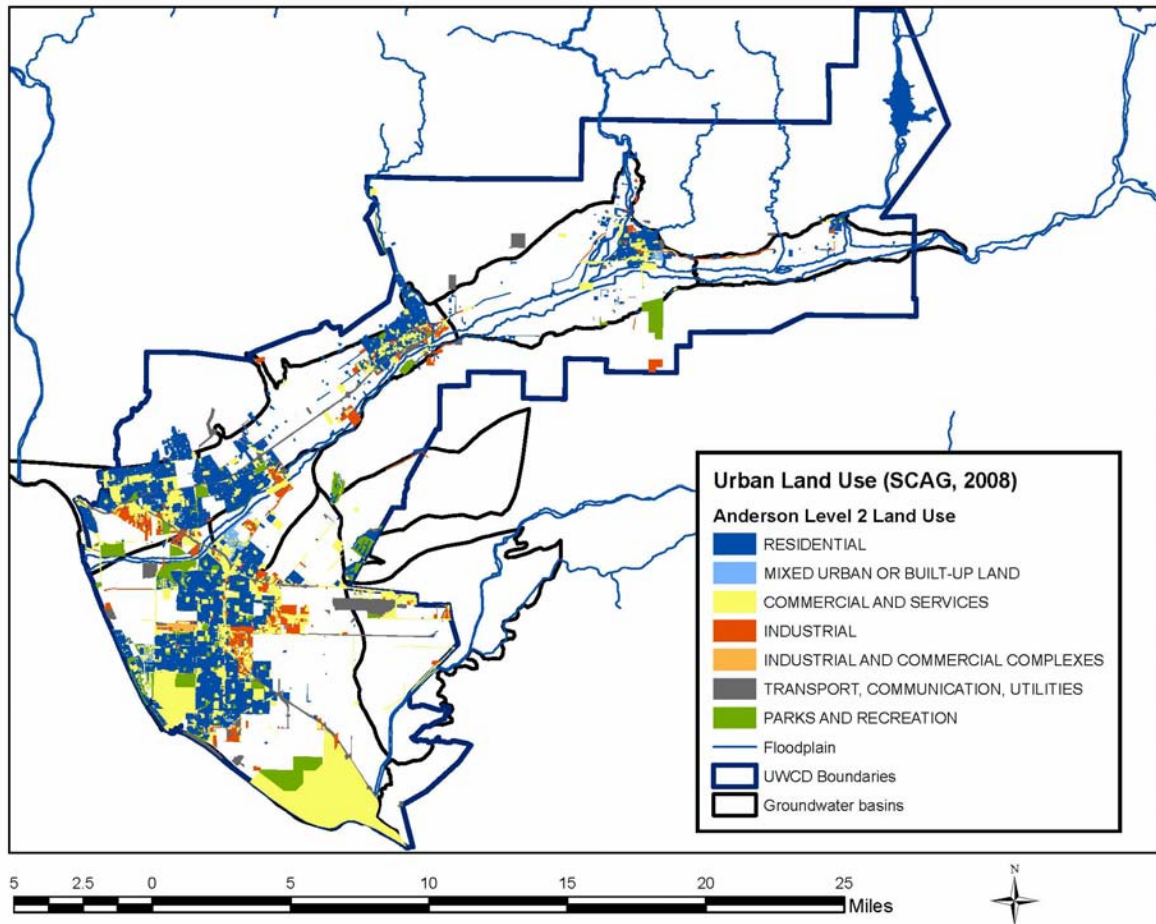


Figure 3. Urban land use within UWCD as mapped by SCAG, 2010.

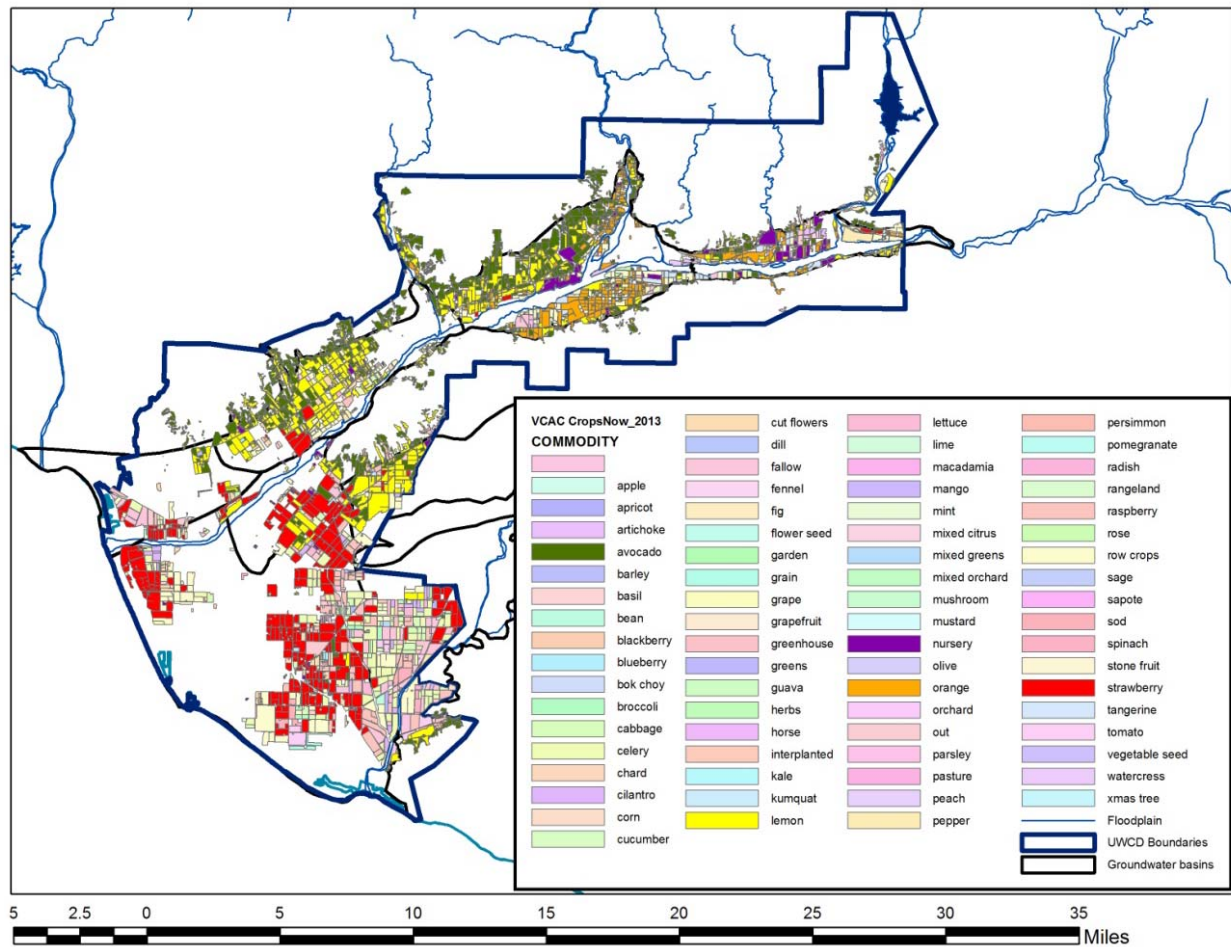


Figure 4. Agricultural land use within UWCD as mapped by Ventura County Agricultural Commissioner, 2013

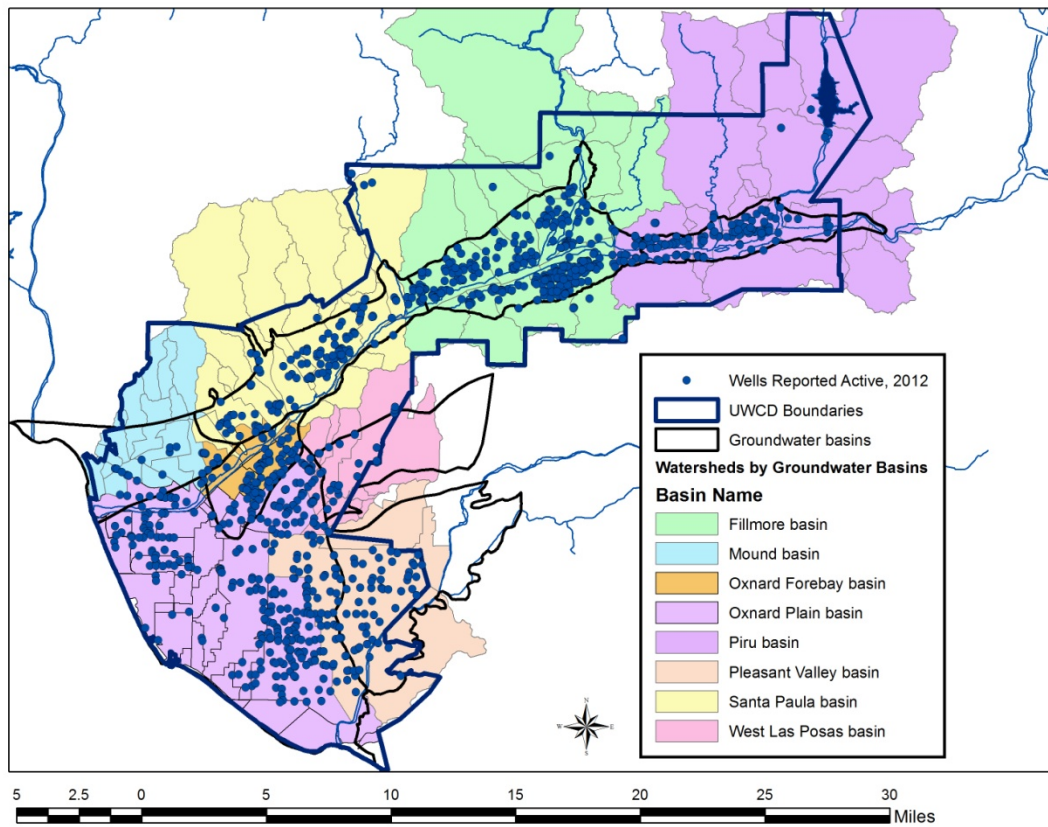


Figure 5. Wells reported as active within UWCD boundaries, calendar year 2012

8 TABLES

Table 1. Approximate annual precipitation by year and groundwater basin

Groundwater Basin	Water Year Precipitation, inches			Precipitation Stations used
	2010	2011	2012	
Piru	20.47	22.90	11.35	Camulos Ranch, County Fire Station, Piru RAWS
Fillmore	18.48	22.60	11.12	Fillmore Sanitation District, Fish Hatchery
Santa Paula	23.44	27.35	9.85	Limoneira Ranch, Wilson Ranch
Oxnard Forebay	16.78	20.09	9.29	County Yard, UWCD Recharge Facility, UWCD El Rio
Mound	16.62	19.53	9.55	County Government Center, Ventura Harbor, Hall Canyon
Oxnard Plain	14.63	20.05	8.38	Oxnard NWS, Oxnard Airport, Channel Islands Harbor, Oxnard Sewer Plant, Point Mugu-USN
Pleasant Valley	14.03	18.42	8.68	Hauser, Adohr Sanitation Plant
West Las Posas	16.86	21.56	10.18	Deboni

Table 2. Summary of Pumping and District Hydrology, 2010 (all values reported in acre-feet)

Basin Classification	Aquifer Classification	Land Use	Acres ¹	Groundwater Extractions	GW Recharge ² from WWTP effluent	GW Recharge ³ from fish hatchery	Return Flow GW pumped for irrigation	Total Recharge/Return ⁴ Flow from pumped groundwater	Net GW Change (pumping less return flow)	Available Rainfall ⁵ Infiltration	Downward Leakage ⁶ Irrigation Return Flow in Confined basins
unconfined	unconfined	Urban	9,653	8,949 ⁹	4,210 ⁷	0	1,555 ⁷	5,763 ⁹	-3,185	7,451 ¹¹	N.A.
unconfined	unconfined	Agriculture	31,863	70,877 ⁹	0	10,274 ⁸	19,764 ⁸	30,038 ⁹	-40,838	37,597 ¹¹	N.A.
confined	semi-perched	Urban	31,265	0	0	0		5,120 ¹⁰	5,120	23,996 ¹²	N.A.
confined	semi-perched	Agriculture	48,215	0	0	0		14,479 ¹⁰	14,479	36,201 ¹²	N.A.
confined	confined (production)	Urban	31,265	32,823 ¹⁰	0	0		0	-32,823	9,129 ¹²	0
confined	confined (production)	Agriculture	48,215	46,406 ¹⁰	0	0		0	-46,406	14,078 ¹²	0

Footnotes:

¹ the semi-perched aquifer is assumed to entirely overlie deeper confined production aquifers

² Groundwater recharge from WWTP percolation ponds

³ includes 10,619 ac-ft of return flow from Fillmore Fish Hatchery pumped groundwater minus 345 ac-ft of ET from watercress farming

⁴ Calculated Irrigation return flow plus itemized returns

⁵ return flow to confined aquifers is limited by downward leakage through confining aquitard

⁶ Available downward leakage assigned to rainfall infiltration

⁷ data from Table B6a

⁸ data from Table B6b

⁹ data from Table B2

¹⁰ data from Table B4

¹¹ data from Table A9

¹² data from Table A10

Table 3. Summary of Pumping and District Hydrology, 2011 (all values reported in acre-feet)

Basin Classification	Aquifer Classification	Land Use	Acres ¹	Groundwater Extractions	GW Recharge ² from WWTP effluent	GW Recharge ³ from fish hatchery	Return Flow GW pumped for irrigation	Total Recharge/Return ⁴ Flow from pumped groundwater	Net GW Change (pumping less return flow)	Available Rainfall ⁵ Infiltration	Downward Leakage ⁶ Irrigation Return Flow in Confined basins
unconfined	unconfined	Urban	9,653	9,451 ⁹	4,426 ⁷	0	1,649 ⁷	6,074 ⁹	-3,377	8,421 ¹¹	N.A.
unconfined	unconfined	Agriculture	31,863	71,665 ⁹	0	8,801 ⁸	20,507 ⁸	29,308 ⁹	-42,348	42,170 ¹¹	N.A.
confined	semi-perched	Urban	31,265	0	0	0		4,686 ¹⁰	4,686	26,237 ¹²	N.A.
confined	semi-perched	Agriculture	48,215	0	0	0		15,137 ¹⁰	15,137	39,617 ¹²	N.A.
confined	confined (production)	Urban	31,265	30,036 ¹⁰	0	0		0	-30,036	5,836 ¹²	0
confined	confined (production)	Agriculture	48,215	48,517 ¹⁰	0	0		0	-48,517	9,001 ¹²	0

Footnotes:

¹ the semi-perched aquifer is assumed to entirely overlie deeper confined production aquifers

² Groundwater recharge from WWTP percolation ponds

³ includes 9,146 ac-ft of return flow from Fillmore Fish Hatchery pumped groundwater minus 345 ac-ft of ET from watercress farming

⁴ Calculated Irrigation return flow plus itemized returns

⁵ return flow to confined aquifers is limited by downward leakage through confining aquitard

⁶ Available downward leakage assigned to rainfall infiltration

⁷ data from Table B7a

⁸ data from Table B7b

⁹ data from Table B2

¹⁰ data from Table B4

¹¹ data from Table A9

¹² data from Table A10

Table 4. Summary of Pumping and District Hydrology, 2012 (all values reported in acre-feet)

Basin Classification	Aquifer Classification	Land Use	Acres ¹	Groundwater Extractions	GW Recharge ² from WWTP effluent	GW Recharge ³ from fish hatchery	Return Flow GW pumped for irrigation	Total Recharge/Return ⁴ Flow from pumped groundwater	Net GW Change (pumping less return flow)	Available Rainfall ⁵ Infiltration	Downward Leakage ⁶ Irrigation Return Flow in Confined basins
unconfined	unconfined	Urban	9,653	9,820 ⁹	4,618 ⁷	0	1,705 ⁷	6,324 ⁹	-3,495	5,956 ¹¹	N.A.
unconfined	unconfined	Agriculture	31,863	77,125 ⁹	0	7,529 ⁸	22,714 ⁸	30,243 ⁹	-46,882	22,820 ¹¹	N.A.
confined	semi-perched	Urban	31,265	0	0	0		4,950 ¹⁰	4,950	17,144 ¹²	N.A.
confined	semi-perched	Agriculture	48,215	0	0	0		18,402 ¹⁰	18,402	25,996 ¹²	N.A.
confined	confined (production)	Urban	31,265	31,732 ¹⁰	0	0		0	-31,732	6,314 ¹²	0
confined	confined (production)	Agriculture	48,215	58,980 ¹⁰	0	0		0	-58,980	9,737 ¹²	0

Footnotes:

¹ the semi-perched aquifer is assumed to entirely overlie deeper confined production aquifers

² Groundwater recharge from WWTP percolation ponds

³ includes 7,874 ac-ft of return flow from Fillmore Fish Hatchery pumped groundwater minus 345 ac-ft of ET from watercress farming

⁴ Calculated Irrigation return flow plus itemized returns

⁵ return flow to confined aquifers is limited by downward leakage through confining aquitard

⁶ Available downward leakage assigned to rainfall infiltration

⁷ data from Table B8a

⁸ data from Table B8b

⁹ data from Table B2

¹⁰ data from Table B4

¹¹ data from Table A9

¹² data from Table A10

9 ATTACHMENTS

- A - Comparison of Urban and Agricultural Runoff/Available Infiltration within UWCD Boundaries using NRCS Curve Numbers
- B - Estimation of Return Flow from Groundwater Pumped within UWCD
- C - Estimation of Leakage through the Upper Aquitard in the Confined Basins of the District

Comparison of Urban and Agricultural Runoff/Available Infiltration within UWCD Boundaries using NRCS Curve Numbers

Overview:

Developed land usually produces more runoff from rainfall than undeveloped land. The creation of impervious surfaces and the routing of runoff to defined channels reduces the infiltration of precipitation into soils. Deep percolation of infiltrating precipitation serves as a recharge mechanism for unconfined groundwater basins. The loss of the natural infiltration due to development is a contributing component to the groundwater overdraft among the connected groundwater basins within the District. The following analysis calculates the runoff rates from agricultural land and the municipal and industrial (M&I or urban) land uses within the District. The Technical Memorandum then compares the losses of potential recharge from rainfall for water years 2010 to 2012 associated with the two major land use categories (Agriculture and Urban). The comparisons include the two land use categories overlying both unconfined and confined groundwater basins. A comparison of land use categories over the entire District gives the net contribution of recharge per acre of the land uses with respect to location.

This Technical Memorandum considers the fate of precipitation that runs off from each land use, in the unconfined basins above the Freeman Diversion. During small storms a portion of the local runoff will either percolate in the unlined channels, rivers, or possibly be intercepted at the Freeman Diversion. This Technical Memorandum calculates the potential benefit that the Freeman Diversion has on capturing runoff from both land classes by using the actual operations records at the Freeman Diversion during each storm in calendar years 2010, 2011 and 2012. Runoff in the watershed comes from a much greater land area than the developed lands within the District evaluated here. A detailed analysis of channel recharge sourcing from developed lands within the District and compared to total runoff in the watershed was not undertaken, except when analyzing the benefits at the Freeman Diversion in smaller storms when local recharge of runoff from developed lands is calculated.

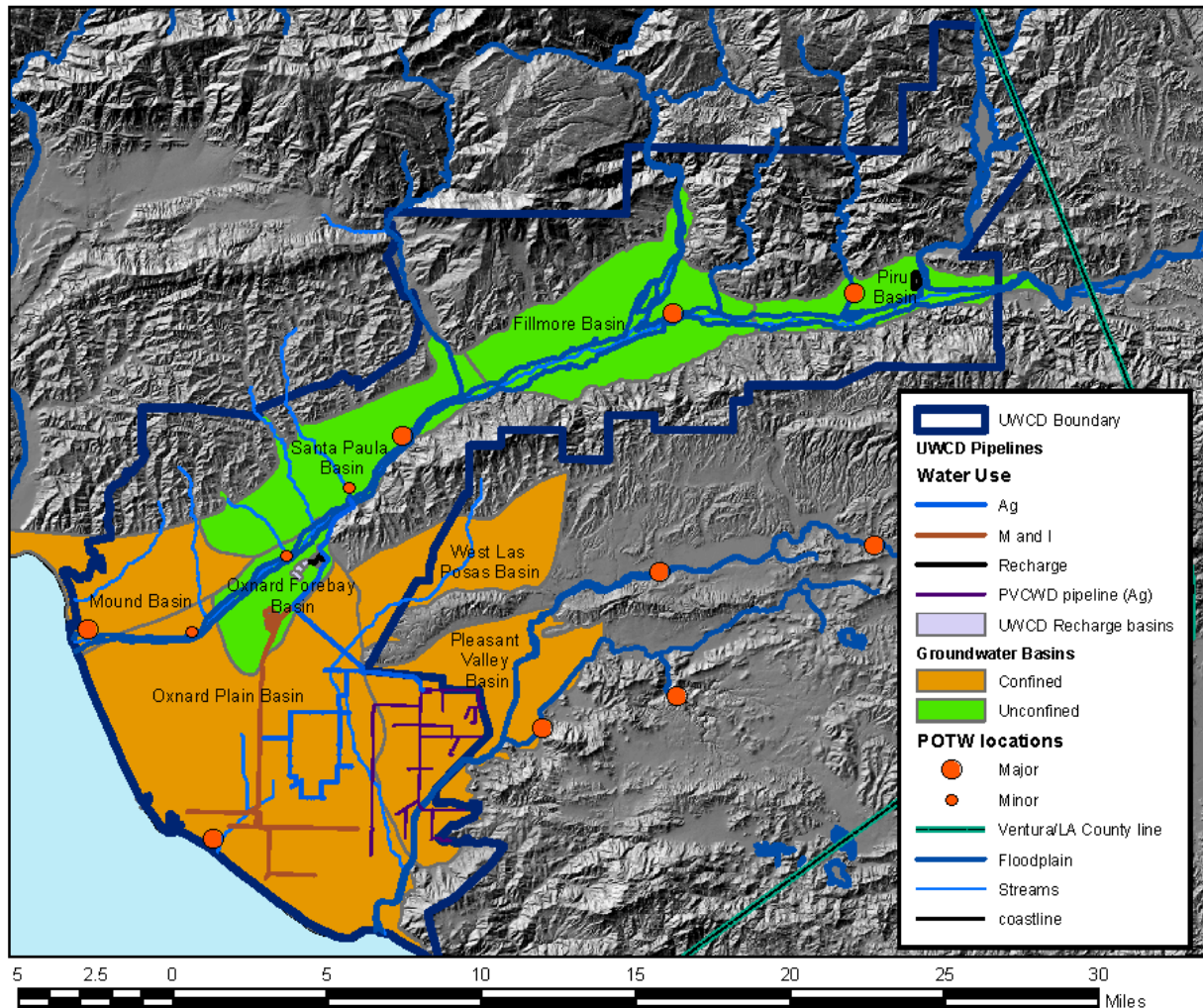


Figure A1. District boundaries with confined and unconfined groundwater basins

Method:

The methodology used to estimate runoff was developed by the National Resource Conservation Service (NRCS). The NRCS has developed a set of runoff curve numbers (CNs) that estimates the amount of runoff from various land uses for a rain event of a given size. This method is widely used for predicting direct runoff from small basins. The Ventura County Watershed Protection District has produced its own set of CNs to better predict runoff from the different local land uses. The parameters effecting the CNs include the soil infiltration properties, land use and rainfall magnitude.

The analysis presented below follows the methodology laid out in the National Engineering Handbook Part 630 Hydrology (NRCS, 2004) and the Ventura County Watershed Protection District's Hydrology Manual (2010). The analysis relies on detailed land use mapping so that separate parcels can be accounted for based on their area and the infiltration properties of the soils they overlie. The centroid of each mapped parcel was used to determine the soil type for

the analysis. Each parcel was then assigned a land classification that can be matched with a CN. Parcels were then grouped together by land use and soil type so that runoff associated with a given CN can be assigned. An area-weighted CN was then obtained for all of the land classifications to determine an appropriate average CN for all agricultural and urban areas over the unconfined groundwater basins. Each CN was then used to determine the estimated runoff from every storm exceeding 0.2 inches within the study period. Storms smaller than this threshold value do not produce appreciable infiltration or runoff. The various land classifications for the urban areas came from mapping sponsored by Southern California Association of Governments (SCAG). The land use mapping for the various agricultural crops was developed by the Ventura County Agricultural Commissioner.

The study area was defined by mapping the developed areas of the watersheds that either overlie or drain into an unconfined groundwater basin, and separately the confined groundwater basins. The unconfined basins include Piru, Fillmore, Santa Paula and the Oxnard Forebay basins (Figure A2). The confined basins include Mound, Oxnard Plain, West Las Posas, and the Pleasant Valley basins. Santa Paula basin is considered to be confined in portions of the basin, and unconfined in others. For the purposes of this study, it is classified as unconfined because infiltration into the shallow aquifers in the confined western portion of the basin likely benefits the adjacent down-gradient Oxnard Forebay and Mound groundwater basins. Similarly, water that infiltrates in the developed portions of the unconfined basins of the Santa Clara River Valley also benefit the confined groundwater basins located downstream. These interconnected basins are formally considered sub-basins of the groundwater flow system within the Santa Clara River Valley but are commonly referred to simply as basins (DWR, 2003).

Discussion of sources used:

Soil Mapping

A soil classification map based on the infiltration capacity of local soils was developed by the United States Department of Agriculture (USDA). The map consists of four different classifications based on infiltration capacity that are used to establish the curve numbers by the NRCS. The classifications include soil types 'A' through 'D', with 'A' being the most permeable and 'D' the least (USDA, 1970). The mapping obtained from the USDA covered all the developed land within the study area, except for a small area of agriculture that exists in the valley of Santa Paula Creek near the northern boundary of the District. This area of unmapped soil type was assumed to be type 'B' soils that matched most closely with the nearby mapped areas. Figure A2 shows the soil mapping within the District. The predominant soil type in the study area and within the unconfined basins was type 'B'. Type 'B' soils are considered to have moderate infiltration capacity with transmission of 0.15 to 0.30 inches per hour.

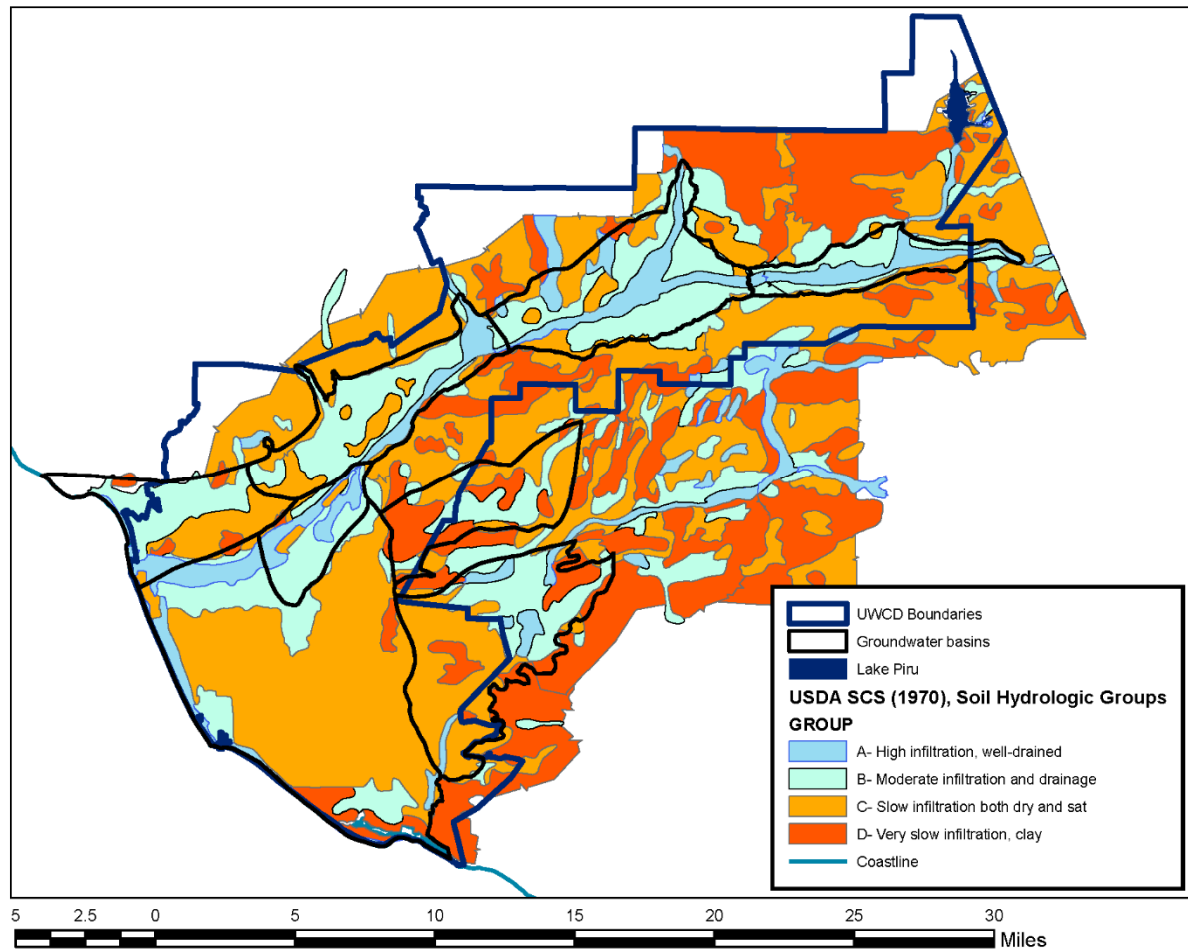


Figure A2. Soils hydrologic group map by the USDA , with groundwater basins

Land Use Mapping

The land use mapping for agriculture was developed by The Ventura County Agricultural Commissioner (VCAC). The data were compiled from various permits and field verification. Much of the mapping effort took place as late as 2012 and was compiled in 2013. Figure A3 shows the unconfined agricultural areas in different shades of blue. The different shades delineate the soils type the agricultural land overlies. The land classifications within the study area consisted of 76 different types of crops, with 7 crop types making up almost 90% of the land area (VCAC, 2013). Each crop type was then put into various categories so that they correspond with a CN land use designation. For the various crop types and the associated areas see Table A1.

The urban land use mapping was developed by the Southern California Associations of Governments (SCAG). This mapping was created in 2008 from aerial photography. The red shaded areas in Figure A3 show urban land use in the unconfined basins. There were 87 different land classifications designated within the study area, of which 13 land uses cover

nearly 90% of the area (SCAG, 2010). See Table A2 for the various urban land classifications and acreage overlying each soil type. Figure A4 shows urban and agricultural lands, and the soil type they overlie, in the confined basins of the District.

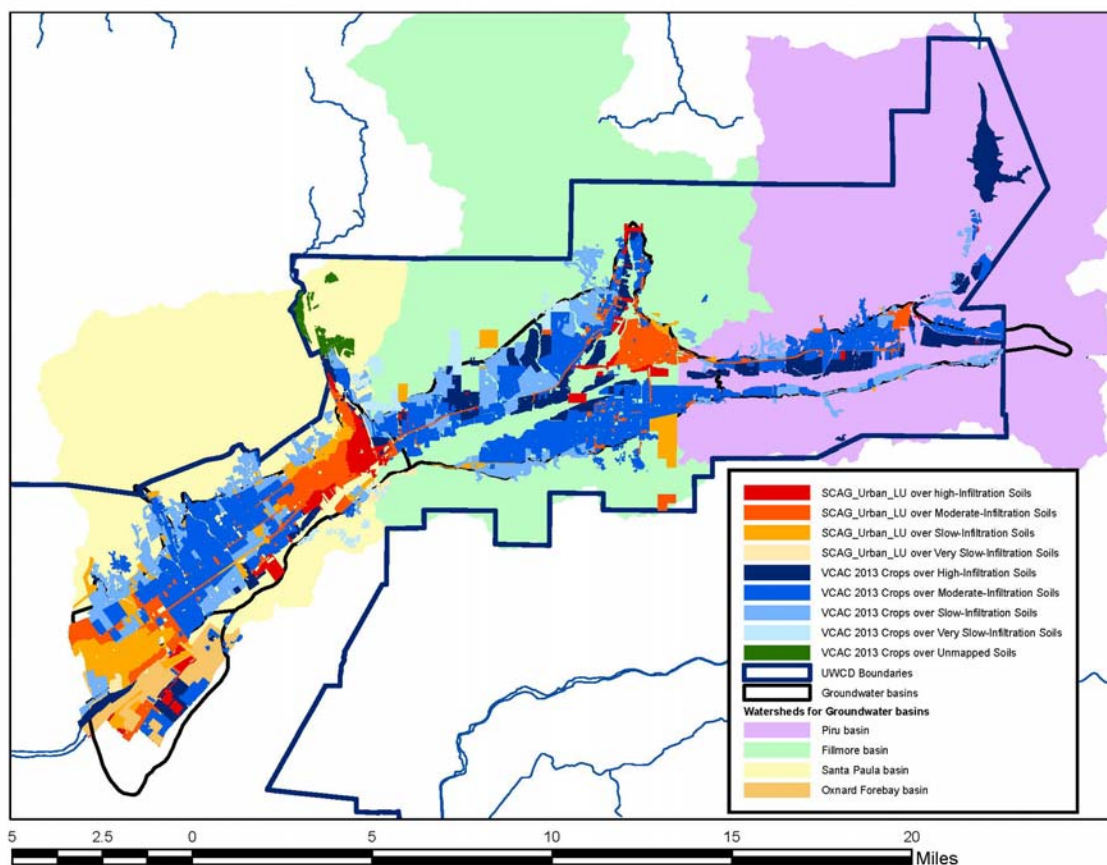


Figure A3. Land use classification with soil types within the study area and above the unconfined groundwater basins

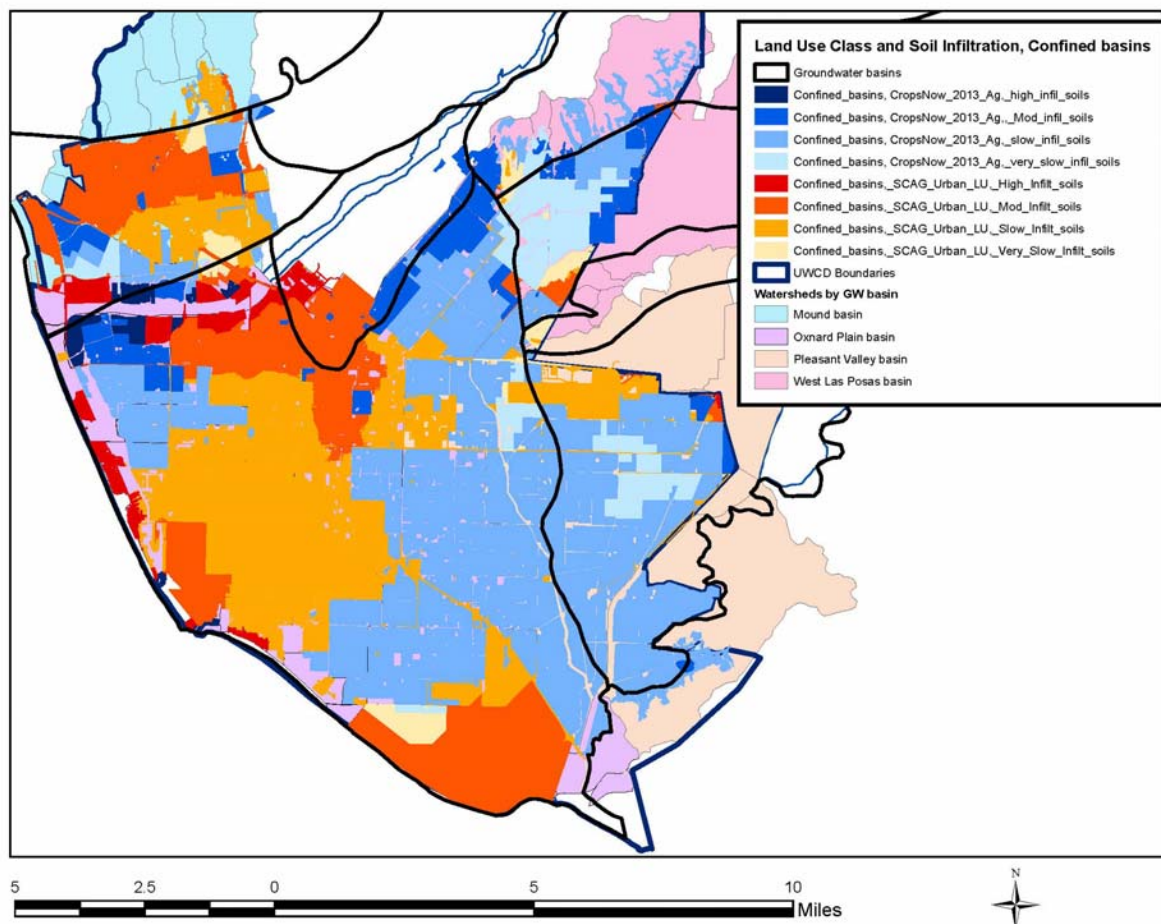


Figure A4. Land use classification with soil types within the study area and above the confined groundwater basins

Rainfall

Rainfall records were obtained from the Ventura County Watershed Protection District (VCWPD website). The average precipitation from four rain gages (see Figure A-5), distributed throughout the District, was used to determine the rainfall events occurring in the 2010 through 2012 water years. See Tables A3-A5 for the rainfall quantities of each storm. These stations included:

Oxnard Airport #168
 Saticoy Yard #175 A
 Santa Paula #245 B
 Piru Camulos #101 A

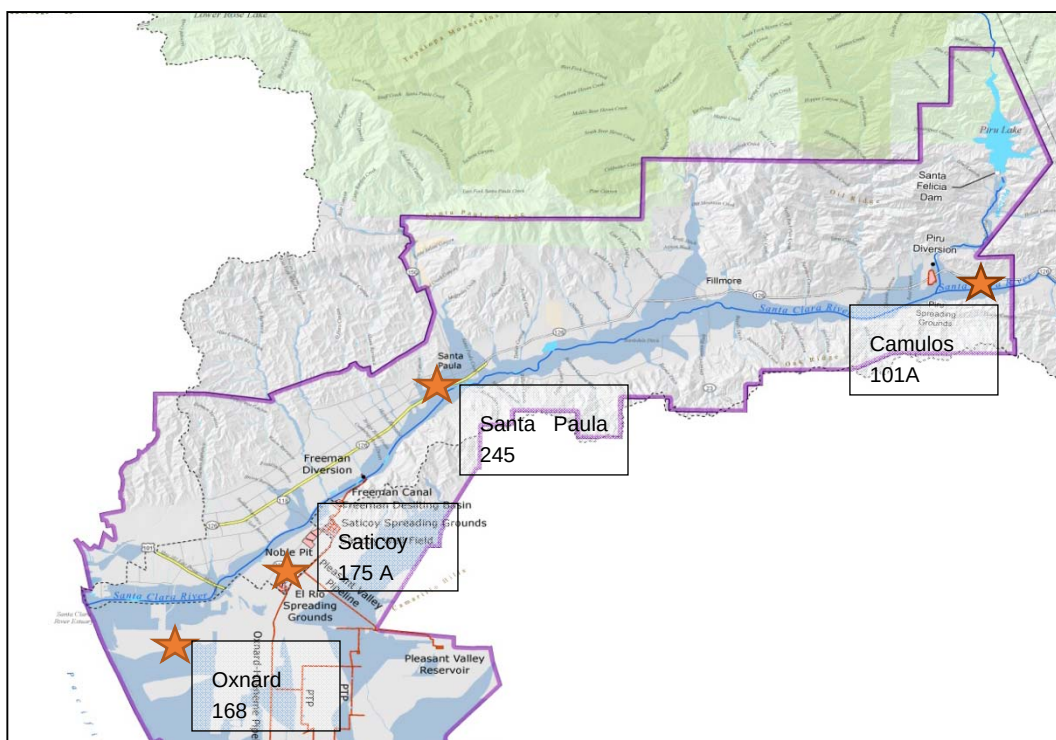


Figure A5. Rainfall stations used to determine average rainfall in the district

Curve Numbers

The Curve Numbers used to determine the runoff in this study were published by the Ventura County Watershed Protection District's Design Hydrology Manual. There are 41 different land uses delineated in the Manual, of which 12 are related to agricultural land uses and 18 are related to urban lands, with the remainder being classifications for undeveloped lands. Some land classifications were further divided into three conditions: poor, fair, and good. VCWPD gave a range of two CNs for each soils type. The average of the two numbers for each soil type was used for this study based on information that was in the USDA mapping soils classifications. The average CN from the County's table matched the average curve numbers in the NRCS tables for their land classifications and soils type. The curve numbers published by Ventura County Watershed Protection District (VCWPD) did not always match the exact land use classifications developed by SCAG for the urban areas or by the VCAC for agriculture. The unmatched land classifications from SCAG and VCAC were assigned land classifications that best match the VCWPD land use designation. See Tables A1 and A2 for the matched classifications.

The NRCS CN tables provide 3 sets of CNs to address antecedent runoff conditions (ARC). The additional curve numbers attempt to address some of the variability in rainfall intensity and duration, soil moisture conditions, cover density, stage of growth, and temperature. The curve numbers are divided into three classes called ARC I through ARC III, with ARC II being average

conditions. This study used the values provided by the VCWPD that are consistent with the average condition by the NRCS (ARC II).

The curve numbers are used to estimate the total amount of runoff from a site when storm intensity has been identified and land use and soil conditions are known. The amount of water available for infiltration is generally the total precipitation less the runoff. Rain events smaller than 0.2 inches were excluded from this analysis. CNs predict (and local observations confirm) very little runoff from these small rain events, and it was assumed that very little if any of the precipitation would ever percolate down past the root zone.

Fate of runoff:

The water that is calculated to run off using the NRCS method can also eventually percolate in the drainage channels, the zones of percolation in the Santa Clara River, and in United's percolation basins after being diverted at the Freeman Diversion. Below is an explanation of how these potential sources of recharge are addressed in the calculations.

Potential contribution of small drainage channels leading to the river:

Small drainage channels have the potential to contribute recharge to the underlying aquifers in the unconfined basins (potential contributions in the confined basins are discussed in Attachment C). Agriculture has a fairly large network of ditches and drainage channels throughout the Piru, Fillmore and Santa Paula Basins. The agricultural drainage channels in this area are typically unlined, although they normally have a narrow floor with a fair amount of fine-grained sediment in them that may preclude the full potential for percolation.

The cities overlying the unconfined basins tend to have concrete drainage channels such as Pole Creek drainage, B St. drain in Fillmore and the Peck Road drain in Santa Paula. This analysis does not include an attempt to estimate the potential recharge from small drains and channels associated with either the agriculture and urban land use classes, although if assessed it would likely increase the potential infiltration factors for agriculture more than for urban areas (where channels are more likely to be lined).

Potential contribution from large drainages:

Both land use classes produce runoff that can potentially drain to either Sespe Creek or the Santa Clara River and infiltrate through the hydraulically transmissive sands of the river channel. Figure A6 shows a map with the various land uses and the zones of percolation that are observed in the riverbed. United has conducted several studies measuring the percolation rates of the various reaches in the Santa Clara River. These studies reveal that typically the zones of percolation are in the upper reaches of each groundwater basin, with little to no percolation in the downstream portions of the basins where river flow tends to increase due to groundwater discharge to the river channel. The upper portions of the Piru and Fillmore basins have high potential recharge rates. Two percolation studies were done on the Santa Paula Creek and the Santa Clara River within the Santa Paula Basin (UWCD, 2013a and UWCD 2013b). Both of these studies documented very little percolation occurring in either reach during

low flow conditions. Comprehensive analysis of percolation of flow in the Santa Clara River would require a more complex modeling effort than what was conducted for this Technical Memorandum. Because a much higher percentage of developed land located upstream of the Piru and Fillmore percolation zones is agricultural land, the results of the modeling presented here likely underestimates the potential for agricultural runoff to be recaptured by percolation in the upstream reaches of the Santa Clara River.

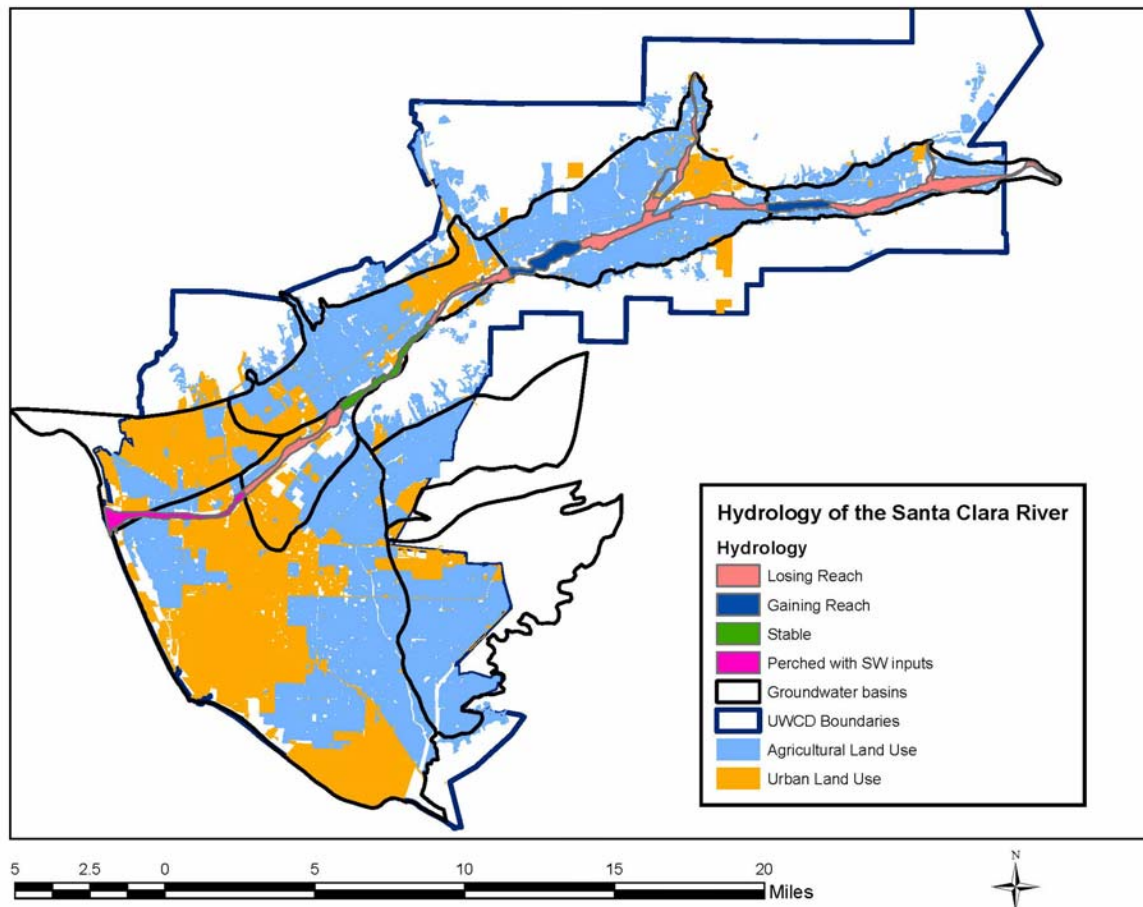


Figure A6. Hydrology, reaches of the Santa Clara River

Potential recharge, Freeman Diversion:

The additional runoff associated with developed lands upstream of the Freeman Diversion can also be captured at United's diversion and percolated in recharge basins in the Oxnard Forebay. When storms produce a substantial amount of runoff, turbidity will typically spike up very early in the storm, making it necessary to stop diverting the water. United's current protocol is to stop diverting water when turbidity rises above 500 NTUs, and to commence diverting again for groundwater recharge when the turbidity drops to about 3,000 NTUs on the receding limb of the storm. Most storms that cause United's operators to stop diverting and reject (turn out) the

turbid storm water will typically produce flows well beyond United's diversion limit of 375 cfs. Diversions are restored once the turbidity drops and the sediment load in the river water can be managed by the desilting basin located upstream of the recharge basins.

The analysis of the potential to capture runoff from areas upstream of the Freeman Diversion included review of the actual operations records to determine when United's operators turned out for each storm in years 2010-2012. If the Freeman Diversion did not reject the turbid water in smaller rainfall events, then all calculated runoff from developed lands above the Freeman Diversion were credited as potential recharge within the study area.

Results:

The developed land within the unconfined groundwater basins was calculated to total 41,516 acres, of which 9,653 acres are urban and 31,863 acres are agriculture. Within the 9,653 acres of urban land use there were 2,681 parcels that were broken down into 69 land classifications and assigned to one of the four different soil infiltration classifications. Each of the land use classifications was then assigned a coverage type that matched the VCWPD curve number classifications. The soils classification of type 'B' (moderate infiltration rate) was the predominant soil type, covering about 50% of the area. Type 'D' had the least coverage, with less than 3%. A weighted CN was determined by calculating the sum of land use areas with various soil designations multiplied by the associated CN for all land areas in either urban or agriculture, then dividing by the total area.

The weighted CN for all the urban parcels and the agricultural parcels in the unconfined groundwater basins came out to be 85.15 and 62.9, respectively. The higher CN from the urban areas means that a greater portion of any rain event will runoff urban land compared to agricultural land, therefore leaving less water for infiltration.

The developed land in the confined basins totaled 79,500 acres, with the urban land use covering 31,265 acres and agriculture covering 48,215 acres. After adjusting the land use designations for the underlying soils in the confined basins the two land uses came up to have a very similar CN. The Urban CN in the confined basins was calculated to be 84.7, and agriculture was 85.2. The slightly higher CN calculated for agricultural land would predict that a slightly greater portion of a rain event on the coastal plain will run off agricultural land compared to the urban land. The change in the CNs as compared to the unconfined basins can mostly be explained by the different agricultural cropping patterns on the Oxnard Plain overlying the confined basins. A significant percentage of this land is currently growing either strawberries or raspberries, and the current practice is to cover a large percentage of the berry fields with plastic sheeting which increases runoff and reduces the potential for infiltration during rain events.

For water years 2010, 2011 and 2012, a total of 30 storms with rainfall greater than 0.20 inches were recorded in the District. Storms totaling less than 0.20 inches were excluded from the study because most of the precipitation from such a small storm will either be retained on the surface and evaporated, or be taken up by plants. Of those 30 storms, 15 did not result in river water being turned out at the Freeman Diversion, allowing for all precipitation from those storms to be credited to the unconfined basins as either local infiltration or as water diverted at the Freeman Diversion and routed to United's recharge basins in the Oxnard Forebay. The runoff from all larger storms was estimated from the measured precipitation from each storm and the CNs established by each land use/soil type. The calculation for runoff is:

$$Q = (P - I_a)^2 / P - I_a + S \quad \text{where } P > I_a$$

Q= calculated runoff (in.)

P= precipitation (in.)

S= potential maximum retention after runoff begins $S = (1000/CN) - 10$

I_a = Initial abstraction (in.)

Initial abstraction consists mainly of water stored in surface water depressions, interception and infiltration from the initial part of the storm. The initial abstraction is estimated at 20% of the potential maximum retention from the storm (derived from the CN). This formula is consistent with the method described in the NRSC manual and the Ventura County Watershed Protection District's 2010 Design Hydrology Manual.

Tables A3 through A8 show the average rainfall (from the four selected rain gages in the study area) of each individual storm within the study period and the predicted runoff in inches from the developed urban and agricultural land within both the unconfined and confined basins. The smaller storm events shown in red type denote where the Freeman Diversion did not turn out and runoff from the entire storm was diverted. The total rainfall depths from these storms were considered as potential infiltration in the unconfined basins. The confined basins are located downstream of the Freeman Diversion: infiltration is estimated for these areas but runoff is not available for capture and groundwater recharge.

Attachment A

Table A1. Agricultural land use in the unconfined basins, by soil group and CN designation

Agriculture in the Unconfined Basins					
LAND_USE_C	Soil Type				CN Designation
	Type A	Type B	Type C	Type D	
	AC	AC	AC	AC	
lemon	869.1	4,443.8	2,256.7	60.5	Orchard tree farm good
orange	513.9	2,634.6	429.7	0.0	Orchard tree farm good
tangerine	38.7	441.7	125.4	10.7	Orchard tree farm good
avocado	714.2	3,300.9	3,856.8	836.4	Orchard tree farm good
row crops	1,109.2	2,419.1	1,106.6	0.0	agri. Straight row good
macadamia	0.0	2.0	1.0	0.0	Orchard tree farm good
nursery	560.4	704.7	210.1	0.0	agri. Straight row good
grapefruit	55.2	43.6	12.1	0.0	Orchard tree farm good
herbs	141.1	290.5	24.6	0.0	agri. Straight row good
out	24.7	104.3	8.2	0.0	orchard tree farm fair
orchard	0.0	0.4	0.0	0.0	orchard tree farm fair
vegetable seed	0.0	14.1	0.0	0.0	agri. Straight row good
lettuce	0.0	124.7	0.0	0.0	agri. Straight row good
cut flowers	52.0	223.4	133.7	0.0	agri. Straight row good
unknown	71.2	129.6	31.7	10.0	agri. Straight row good
horse	0.0	3.4	0.0	0.0	Pasture or range
olive	0.0	1.2	0.0	0.0	orchard tree farm fair
kale	0.0	9.1	0.0	0.0	agri. Straight row good
mixed citrus	0.2	0.3	2.5	0.0	orchard tree farm fair
interplanted	0.0	15.3	0.0	0.0	agri. Straight row good
blueberry	0.0	14.5	0.0	0.0	Strawberries
pasture	0.0	10.0	0.2	1.0	Pasture or range
grape	0.0	2.7	3.2	0.0	agri. Straight row good
celery	0.0	154.8	55.7	0.0	agri. Straight row good
strawberry	449.5	959.3	453.5	0.0	Strawberries
pomegranate	0.0	8.2	0.0	0.0	orchard tree farm fair
raspberry	0.0	74.8	0.0	0.0	Strawberries
cabbage	0.0	67.6	0.0	0.0	agri. Straight row good
chard	0.0	19.2	0.0	0.0	agri. Straight row good
artichoke	0.0	117.8	0.0	0.0	agri. Straight row good
pepper	356.6	169.5	43.8	0.0	agri. Straight row good
tomato	1.8	33.7	0.0	0.0	agri. Straight row good
fallow	17.3	178.0	11.7	0.0	Fallow - Bare soil
fennel	0.0	36.3	2.1	0.0	agri. Straight row good
watercress	190.9	12.1	0.0	0.0	Strawberries
basil	0.0	4.5	0.0	0.0	agri. Straight row good
sage	0.0	2.0	0.0	0.0	agri. Straight row good
dill	0.0	1.3	0.0	0.0	agri. Straight row good
parsley	0.0	49.3	0.0	0.0	agri. Straight row good
greens	0.0	16.1	0.0	0.0	agri. Straight row good
xmas tree	0.0	9.5	0.0	0.0	orchard tree farm fair
fig	0.0	17.4	0.0	0.0	orchard tree farm fair
lime	4.9	0.5	0.0	0.0	Orchard tree farm good
mint	0.0	1.3	0.0	0.0	agri. Straight row good
apricot	0.8	0.0	0.0	0.0	Orchard tree farm good
cucumber	0.0	0.3	0.0	0.0	agri. Straight row good
cilantro	0.0	3.8	0.0	0.0	agri. Straight row good
spinach	0.0	53.3	22.0	0.0	agri. Straight row good
stone fruit	0.0	1.3	0.3	0.0	Orchard tree farm good
mixed orchard	0.0	0.0	0.3	0.2	Orchard tree farm good
apple	0.0	0.0	2.3	0.0	Orchard tree farm good
kumquat	0.0	0.0	0.3	0.0	Orchard tree farm good
guava	0.0	0.0	1.7	0.0	Orchard tree farm good
sapote	0.0	0.0	2.1	0.0	Orchard tree farm good
peach	0.0	0.0	0.1	0.0	Orchard tree farm good
sod	0.0	0.0	0.2	0.0	Orchard tree farm good
persimmon	0.0	0.0	0.5	0.0	orchard tree farm fair
mustard	0.0	0.0	6.5	0.0	agri. Straight row good
rose	0.0	0.0	0.5	0.0	agri. Straight row good
rangeland	0.0	0.0	1.6	0.0	Pasture or range
flower seed	0.0	0.0	37.4	0.0	agri. Straight row good
blackberry	0.0	0.0	0.9	0.0	Strawberries
mango	0.0	0.0	0.0	1.6	orchard tree farm fair
Totals (AC)	5,171.8	16,925.5	8,845.8	920.3	

Attachment A

Table A2. Urban land use in the unconfined basins, by soil type and CN designation.

Urban in the Unconfined Basins					
LAND_USE_C	Soil Type				CN Designation
	Type A	Type B	Type C	Type D	
	AC	AC	AC	AC	
Airports	19.4	104.4	5.5	0.0	transportation and utilities
Bus terminals and yards	0.0	0.0	0.1	0.0	transportation and utilities
Commercial and services	0.0	0.4	0.0	0.0	commercial and Business
Commercial recreation	0.0	0.2	0.3	0.0	Public Facilities and Institutions
Commercial storage	2.5	1.2	0.0	0.0	Industrial Parks
Communication facilities	13.5	5.4	1.6	22.1	transportation and utilities
Duplexes and triplexes	0.0	15.3	20.3	0.0	Residential 1/5 ac lot
Educational institutions	76.7	165.8	49.4	0.0	Public Facilities and Institutions
Electrical power facilities	2.9	16.9	189.2	0.0	transportation and utilities
Elementary schools	5.0	16.9	36.5	10.0	Public Facilities and Institutions
Fire stations	0.0	8.1	0.5	0.0	Public Facilities and Institutions
Flood waterways and structures	0.0	0.0	0.0	0.0	transportation and utilities
Freeways and major roads	60.7	121.7	107.7	0.0	transportation and utilities
General office use	92.3	155.0	169.0	0.2	commercial and Business
Government offices	1.9	31.3	0.0	0.0	Public Facilities and Institutions
Heavy industrial open storage	0.4	3.4	0.0	0.0	commercial and Business
High schools	2.1	7.6	0.0	0.0	Public Facilities and Institutions
High-density single family residence	91.8	772.0	1,093.0	61.0	residential 1/8 ac lot
High-density trailer parks and mobile homes	2.1	30.3	13.4	0.0	Industrial Parks
High-rise major office use	0.0	0.4	0.0	0.0	commercial and Business
Hotels and Motels	0.0	7.2	0.0	0.0	Public Facilities and Institutions
Junior high schools	0.0	5.4	0.0	0.0	Public Facilities and Institutions
Light industrial	148.3	71.2	24.4	0.3	commercial and Business
Light manufacturing	179.1	225.4	77.8	47.4	commercial and Business
Liquid waste disposal facilities	10.0	10.5	0.0	0.0	commercial and Business
Low- to medium-rise major office use	0.0	25.8	3.2	0.0	commercial and Business
Low-density rural residential	3.7	74.8	29.3	0.0	residential 1 ac lot
Low-density single family residence	3.7	17.4	18.4	0.0	residential 1 ac lot
Low-rise apartments, condos, townhouses	2.4	39.9	100.4	22.7	residential Condo
Maintenance yards	0.3	1.3	4.2	0.0	Public Facilities and Institutions
Major health care facilities	0.0	10.8	12.7	0.1	Public Facilities and Institutions
Manufacturing	5.5	56.0	1.1	0.0	commercial and Business
Medium-rise apartments and condos	0.0	0.0	0.9	0.0	residential Condo
Mining	0.1	0.0	0.0	0.0	Public Facilities and Institutions
Misc. public facilities	40.1	15.8	7.0	0.0	Public Facilities and Institutions
Misc. special use facilities	0.0	0.0	3.0	0.0	Public Facilities and Institutions
Mixed commercial and industrial	0.0	1.6	0.8	0.0	commercial and Business
Mixed multi-family residence	0.8	0.0	0.0	0.0	residential Condo
Mixed residential	0.0	1.5	0.0	0.0	residential 1/8 ac lot
Mixed urban	1.4	0.0	0.0	0.0	residential 1/8 ac lot
Mobile homes and trailer parks	159.0	367.8	175.2	14.4	Industrial Parks
Modern strip development	9.1	38.1	18.1	0.0	commercial and Business
Motion picture industry	0.0	2.5	0.0	0.0	Public Facilities and Institutions
Multi-family residential	40.1	75.1	3.5	0.0	residential 1/8 ac lot
Natural gas and petroleum facilities	7.0	29.4	0.0	8.6	transportation and utilities
Oil and gas extraction	0.0	3.7	0.0	0.0	transportation and utilities
Older strip development	3.6	8.3	0.0	0.0	commercial and Business
Other commercial	10.9	18.6	0.0	0.0	commercial and Business
Packing houses	1.3	4.2	0.2	0.0	commercial and Business
Petroleum refining	3.0	0.0	0.0	0.0	transportation and utilities
Police and sheriff stations	2.2	0.0	0.0	0.0	Public Facilities and Institutions
Public facilities	4.7	60.6	49.8	0.0	Public Facilities and Institutions
Railroads	0.8	12.7	0.0	0.0	transportation and utilities
Regional shopping mall	0.0	0.0	0.9	0.0	commercial and Business
Religious facilities	5.1	38.1	18.7	0.0	Public Facilities and Institutions
Residential	0.0	0.7	1.1	0.0	Residential 1/5 ac lot
Retail Centers (non-strip malls)	0.0	7.7	16.4	0.0	commercial and Business
Retail stores and commercial	219.7	240.5	67.3	0.3	commercial and Business
Single family residential	331.7	989.7	350.1	0.0	Residential 1/5 ac lot
Solid waste disposal facilities	0.0	0.0	159.1	0.0	transportation and utilities
Special care facilities	0.0	0.5	3.7	0.1	commercial and Business
Truck terminals	1.7	0.0	0.0	0.0	Public Facilities and Institutions
Under construction	8.1	80.5	100.2	0.0	commercial and Business
Utility facilities	1.2	0.0	0.2	0.0	transportation and utilities
Warehousing and wholesaling	0.0	116.1	0.0	18.8	commercial and Business
Water storage facilities	4.9	10.8	7.0	0.0	transportation and utilities
Water transfer facilities	0.0	0.0	1.0	0.0	transportation and utilities
Local parks and recreation	24.2	65.3	35.7	6.5	Open space3s, lawns parks, golf, ect
Golf courses	0.0	71.8	553.0	0.0	Open space3s, lawns parks, golf, ect
Cemeteries	0.0	16.9	24.9	0.0	Open space3s, lawns parks, golf, ect
Total AC	1,604.8	4,280.4	3,555.6	212.6	

Table A3. Runoff events for 2010 WY, Unconfined Basins

2010 Results of Runoff and Available Infiltration Depths (Inches) of Unconfined Basins					
	Total Rainfall	Runoff from land use		Available for Percolation	
		Agriculture	Urban	Agriculture	Urban
	In.	In.	In.	In.	In.
10/15/2009	2.19	0.15	0.95	2.04	1.24
12/8/2009	1.04	*	*	1.04	1.04
12/14/2009	2.14	0.13	0.90	2.00	1.23
1/24/2010	6.04	2.20	4.36	3.84	1.68
2/8/2010	1.5	0.02	0.46	1.48	1.04
2/11/2010	0.49	*	*	0.49	0.49
3/4/2010	1.75	0.05	0.63	1.70	1.12
3/8/2010	0.23	*	*	0.23	0.23
4/7/2010	0.4	*	*	0.40	0.40
4/13/2010	0.93	0.01	0.15	0.92	0.78
Totals	16.71				
Totals with Freeman diversion recaptured runoff		2.56	7.44	14.15	9.26

* All runoff assumed to be available for percolation due to diversions at the Freeman throughout the storm.

Table A4. Runoff events for 2010 WY, Confined Basins

2010 Results of Runoff and Available Infiltration Depths (Inches) of the Confined Basins					
	Total Rainfall	Runoff from land use		Available for Percolation	
		Agriculture	Urban	Agriculture	Urban
	In.	In.	In.	In.	In.
10/15/2009	2.19	0.95	0.92	1.24	1.27
12/8/2009	1.04	0.20	0.18	0.84	0.86
12/14/2009	2.14	0.91	0.88	1.23	1.26
1/24/2010	6.04	4.37	4.31	1.67	1.73
2/8/2010	1.5	0.46	0.44	1.04	1.06
2/11/2010	0.49	0.01	0.01	0.48	0.48
3/4/2010	1.75	0.63	0.61	1.12	1.14
3/8/2010	0.23	0.00	0.00	0.23	0.23
4/7/2010	0.4	0.00	0.00	0.40	0.40
4/13/2010	0.93	0.15	0.14	0.78	0.79
Totals	16.71	7.68	7.48	9.02	9.22

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Table A5. Runoff events for 2011 WY, Unconfined Basins

2011 Results of Runoff and Available Infiltration Depths (Inches) of the Unconfined Basins					
		Runoff from land use		Available for Percolation	
	Total Rainfall	Agriculture	Urban	Agriculture	Urban
	In.	In.	In.	In.	In.
10/8/2010	0.93	*	*	0.93	0.93
10/26/2010	0.46	*	*	0.46	0.46
10/31/2010	0.61	*	*	0.61	0.61
11/9/2010	0.27	*	*	0.27	0.27
11/22/2010	0.78	*	*	0.78	0.78
12/6/2010	0.49	*	*	0.49	0.49
12/26/2010	8.31	3.90	6.53	4.41	1.78
1/3/2011	0.94	*	*	0.93	0.94
2/21/2011	1.92	0.08	0.75	1.84	1.18
2/28/2011	0.93	0.01	0.15	0.93	0.79
3/28/2011	5.16	1.60	3.53	3.56	1.63
5/18/2011	0.66	0.00	0.05	0.66	0.61
Totals	21.47				
Totals with Freeman diversion recaptured runoff		5.59	11.00	15.88	10.47

* All runoff assumed to be available for percolation due to diversions at the Freeman throughout the storm.

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Table A6. Runoff events for 2011 WY, Confined Basins

2011 Results of Runoff and Available Percolation Depths (Inches) of the Confined Basins					
		Runoff from land use		Available for Percolation	
	Total Rainfall	Agriculture	Urban	Agriculture	Urban
	In.	In.	In.	In.	In.
10/8/2010	0.93	0.15	0.14	0.78	0.80
10/26/2010	0.46	0.01	0.01	0.45	0.45
10/31/2010	0.61	0.04	0.03	0.58	0.58
11/9/2010	0.16	0.00	0.00	0.16	0.16
11/22/2010	0.78	0.09	0.08	0.69	0.70
12/6/2010	0.49	0.01	0.01	0.48	0.48
12/26/2010	8.31	6.54	6.47	1.77	1.84
1/3/2011	0.94	0.15	0.14	0.79	0.80
2/21/2011	1.92	0.75	0.72	1.17	1.20
2/28/2011	0.93	0.15	0.14	0.78	0.80
3/28/2011	5.16	3.54	3.48	1.62	1.68
5/18/2011	0.66	0.05	0.04	0.61	0.62
Totals	21.35	11.47	11.26	9.88	10.10

Table A7. Runoff events for 2012 WY, Unconfined Basins

2012 Results of Runoff and Available Infiltration Depths (Inches) of the Unconfined Basins					
		Runoff from land use		Available for Percolation	
	Total Rainfall	Agriculture	Urban	Agriculture	Urban
	In.	In.	In.	In.	In.
10/7/11	1.44	*	*	1.44	1.44
11/9/11	0.27	0.00	0.00	0.11	0.27
11/14/11	0.59	*	*	0.59	0.59
11/21/11	0.72	*	*	0.72	0.72
1/24/12	1.41	*	*	1.41	1.41
3/19/12	0.92	0.00	0.14	0.91	0.78
3/27/12	1.65	0.03	0.56	1.62	1.09
4/14/12	1.67	0.04	0.57	1.63	1.10
Totals	8.68				
Totals with Freeman diversion recaptured runoff		0.07	1.27	8.60	7.40

* All runoff assumed to be available for percolation due to diversions at the Freeman throughout the storm.

Table A8. Runoff events for 2012 WY, Confined Basins

2012 Results of Runoff and Available Percolation Depths (Inches) Confined Basins					
		Runoff from land use		Available for Percolation	
	Total Rainfall	Agriculture	Urban	Agriculture	Urban
	In.	In.	In.	In.	In.
10/7/11	1.44	0.42	0.40	1.02	1.04
11/9/11	0.27	0.00	0.00	0.27	0.27
11/14/11	0.59	0.03	0.03	0.56	0.56
11/21/11	0.72	0.07	0.06	0.66	0.66
1/24/12	1.41	0.40	0.38	1.01	1.03
3/19/12	0.92	0.14	0.13	0.78	0.79
3/27/12	1.65	0.56	0.54	1.09	1.11
4/14/12	1.67	0.58	0.55	1.10	1.12
Totals	8.68	2.21	2.09	6.47	6.58

As an example, in the unconfined basins for water year 2011, the total rainfall over the District was calculated to be 21.47 inches after removing all rain events of less than 0.2 inches (Table A5). After removing the storms where United was able to capture all the runoff from the upper watershed at the Freeman Diversion, the remaining storms produced a runoff depth totaling 11.0 inches over the urban areas, compared to 5.59 inches from agricultural areas. When doing this calculation for the confined basins, since they are below the Freeman Diversion, all rainfall events that produced runoff was included as runoff (Table A6).

The depth of rain from each storm that does not run off is retained water available for infiltration into the unconfined groundwater basins. Tables A3 through A8 also display the calculated depth of water that is available for infiltration. This depth is estimated by subtracting the calculated runoff from precipitation in a given storm. In 2011, the estimated average depth of water available for infiltration in the unconfined basins was 15.88 inches for agricultural lands and 10.47 inches for the urban areas. In the confined basins the two land use classes had a very similar estimated depth of water available for infiltration due to the calculated average CNs being similar. The depth of rain available for infiltration was 9.88 inches in agricultural area and 10.10 inches in urban areas.

The depths of water for potential infiltration reported above are an average depth in inches for each land use class. In Table A9 the available depth of water is multiplied by the total area of each land use class to come up with a total volume (acre-feet) that would be available for infiltration.

Table A9. Estimated infiltration of rainfall, unconfined basins

Water Year	Total Rainfall for Events>.2 in.	Available depth for rainfall infiltration Unconfined Basins*		Available volume for rainfall infiltration Unconfined Basins*	
		Urban	Ag.	Urban	Ag.
		(in.)	(in.)	(AF)	(AF)
2010	16.71	9.26	14.16	7,451	37,597
2011	21.47	10.47	15.88	8,421	42,170
2012	8.68	7.40	8.60	5,956	22,820
Area in Acres		9,653	31,863		

*Includes runoff water diverted at the Freeman for infiltration

Table A10 shows calculated values for rainfall infiltration for developed areas overlying the confined groundwater basins of the District. Estimates of infiltration to the semi-perched aquifers are listed, but only a portion of this recharge is considered to be beneficial recharge. Only the volume of water that can leak down through the confining aquitards of these basins is considered beneficial recharge (see Attachment C). The volume of water from rainfall for infiltration exceeds the calculated downward leakage capacity of the aquitard, and therefore the leakage volumes calculated in Attachment C are shown as the limit of the potential recharge contribution to the underlying production aquifers. The quantities of the infiltrated water were apportioned to each land use by the proportion of the surface area they overlie. Table A10 show a summary of the potential infiltrated water in the confined basins.

Table A10. Estimated infiltration of rainfall, confined basins

Water Year	Total Rainfall for Events>.2 in.	Available depth for rainfall infiltration, confined basins		Available total volume for rainfall infiltration, confined basins		Beneficial rainfall infiltration to confined basins (recharge potential from Attachment C)		
		Urban	Ag.	Urban	Ag.	Total	Urban	Ag.
		(in.)	(in.)	(AF)	(AF)	(AF)	(AF)	(AF)
2010	16.71	9.21	9.01	23,996	36,201	23,207	9,129	14,078
2011	21.47	10.07	9.86	26,237	39,617	14,837	5,836	9,001
2012	8.68	6.58	6.47	17,144	25,996	16,051	6,314	9,737
Area in Acres		31,265	48,215					

Table A11 shows the District-wide contribution of potential infiltration for the urban and agricultural land use classes. This is calculated by adding the total available water for infiltration from Tables A9 and A10 or the unconfined and confined basins contribution. The equivalent water depth for available infiltration was then calculated by dividing the total contribution of each land use class with the total area of each land use class.

Table A11. Estimated infiltration of rainfall, entire District

		Potential average rainfall infiltration, District Wide*		Average depth of available infiltration from rainfall, District Wide	
Water Year	Total Rainfall	Urban	Agriculture	Urban	Agriculture
	for Events>.2 in.	(AF)	(AF)	(In.)	(In.)
2010	16.71	16,580	51,675	4.86	7.74
2011	21.47	14,258	51,171	4.18	7.67
2012	8.68	12,270	32,579	3.60	4.88
Area in Acres		40,918	80,078		

*Includes runoff water diverted at the Freeman for infiltration

References:

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Digital data bases used:

Southern California Associations of Governments, land use mapping for Ventura County (2008): *GIS shape file* dated November 9, 2010.

Attachment A

United States Department of Agriculture, 1970, SSURGO mapping of hydrologic soil classifications: *GIS shape file* dated February 3, 2004.

Ventura County Agricultural Commissioner, land use mapping for agriculture in Ventura County: CropsNow *GIS shape file* dated May 8, 2013).

Attachment B

Estimation of Return Flow from Groundwater Pumped within UWCD

The following pages detail estimates of return flow to groundwater from pumped groundwater used for both Agricultural (Ag) and Municipal-Industrial & Domestic (MI&D) use within the boundaries of United Water Conservation District (District) for calendar years 2010, 2011 and 2012. The analysis is partitioned between the unconfined and confined groundwater basins within the District.

Return flow in the confined areas of the District move downward into the semi-perched aquifer, which generally has poor water quality and is not used for water supply. The amount of this return flow that flows into the underlying confined production aquifers is limited by the slow movement of water down through the confining layers. Estimates of the total annual volume of water that can leak through the upper confining aquitard to the underlying confined aquifers are detailed in Attachment C.

In this Attachment and the subsequent Attachment C, the term “MI&D” is favored over “urban” when discussing Municipal-Industrial & Domestic groundwater pumping. Pumping reported as MI&D is used in urban areas.

METHODOLOGY FOR ESTIMATING RETURN FLOW TO GROUNDWATER IN THE UNCONFINED BASINS OF UWCD

Agriculture Return Flow (unconfined areas)

The following section details the methodology used to estimate irrigation return flows from agriculture. The major components of agricultural return flow are related to salt leaching requirements and the uniformity of water delivery by irrigation systems. Special considerations related to groundwater use at Fillmore Fish Hatchery are also discussed.

Return Flow from Salt Leaching

When water is used for irrigation, it is common practice to apply slightly more water than is required for plant growth in order to flush accumulated salts down through the root zone.

The following analysis of irrigation return flows relies on the methodology presented in a 2010 publication by the Irrigation and Training Research Center (ITRC). The ITRC was retained by the Fox Canyon Groundwater Management Agency to study local irrigation practices and

characterize the water needs for various crops in southern Ventura County (ITRC, 2010). Water demand and a Leaching Requirement (LR) were established for various crops, which allow for an assessment of the irrigation efficiency of local growers. LR is the percentage of applied irrigation water for a specified crop that is needed to leach salts from the root zone. The LR is based on the crop salt tolerance, the EC (Electrical Conductivity, or salinity) of the applied water and a threshold EC of the soil. Irrigation water was assumed to have an average EC_w of 1.8 dS/m (~TDS of 1150 mg/L). An acreage-weighted average LR of 0.16 was determined for the unconfined basins within UWCD, based on crop mapping and the LRs of local crops as determined by the ITRC. The average LR of 0.16 was applied to the agricultural groundwater pumping in the unconfined groundwater basins to estimate what percentage of that pumping returns to the groundwater system from the leaching salts from the root zone. These calculations are summarized in Table B1.

TABLE B1. Leaching Requirements for Crops in the Unconfined Areas of UWCD

CROP	ACRES¹	LR²	ACRES x LR
Avocado	8,708.27	0.19	1,654.57
Blueberries-Raspberries-Blackberries	90.16	0.16	14.43
Celery	210.41	0.13	27.35
Citrus	11,944.27	0.16	1,911.08
Miscellaneous trees, grape	72.39	0.16	11.58
Miscellaneous Vegetables	5,845.17	0.15	876.78
Nursery Container	1,475.27	0.1	147.53
Nursery Cut Flowers	446.95	0.08	35.76
Strawberries	1,862.31	0.14	260.72
Sod	0.23	0.05	0.01
Tomatoes and Peppers	605.35	0.06	36.32
Fallow-Pasture-Horse-Out	360.24		
Unknown	242.41		
Total Acres (excluding fallow-pasture-horse-out or unknown)	31,261		4,976
Area Weighted LR		0.16	

¹ from Ventura County Agricultural Commissioner , 2013

² adjusted Leaching Requirement from ITRC, 2010

Return flow from Excess Applied Irrigation Water Related to Distribution Uniformity

The ITRC 2010 study's recommended water allowance equation, in addition to including allowance for leaching, also includes an allowance for excess applied irrigation water due to the

non-uniformity common in irrigation systems. Non-uniformity is related to pressure differences, clogging and varied emitter sizes in the irrigation delivery systems. Irrigators commonly run their systems until the driest portions of the field get enough water, so other areas commonly get more water than is required for plant growth and salt leaching. ITRC selected a Distribution Uniformity (DU) value of 0.8 or 80% as representative of local values. This value was derived largely from 2009 and 2010 irrigation DU field studies conducted locally on drip and micro sprinkler irrigation systems by the Ventura County Resource Conservation District (VCRCD)

The ITRC study suggests that the irrigation non-uniformity most often results in the deep percolation of water past the root zone rather than surface runoff. The study considers a DU value of 0.8 as good and achievable with proper irrigation system design, installation and management. The study does not consider excess applied irrigation water from a field with a DU of 0.8 to be inefficient. A poorly designed or maintained irrigation system with a DU less than 0.8 would be considered inefficient.

The ITRC study distinguishes distribution uniformity from irrigation efficiency. Other regional studies, however, do not discuss irrigation distribution uniformity but rather discuss all excess applied water in terms of irrigation efficiency. The U.S. Geological Survey used an irrigation efficiency of 70% to estimate deep percolation/return flow (of 30%) as excess applied water for the Santa Clara-Calleguas groundwater flow model (USGS, 2003). An irrigation efficiency of 75% was selected by Aqua Terra Consultants (2009) for Hydrologic Modeling of the Santa Clara River Watershed based on information on irrigation efficiency provided by the Center for Irrigation Technology at California State University Fresno.

The ITRC (2010) equation for irrigation allowance incorporates terms for LR and DU, as shown below:

$$\text{Irrigation Allowance} = \text{Growing Period ET}_{iw} / [(\text{Irrigation Distribution Uniformity} + \text{Localized Deep Percolation on Drip}) \times (1 - \text{LR})]$$

Where:

Growing Period ET_{iw} = Crop Evapotranspiration of Irrigation Water During Growing Period Only

Irrigation Distribution Uniformity + Localized Deep Percolation on Drip = 0.8

LR = Leaching Requirement

The equation was rearranged and used in this evaluation to estimate agricultural return flow to groundwater. The adaption of the ITRC Irrigation Allowance Equation is shown below:

$$\text{Return Flow} = (\text{Applied Pumped Groundwater}) - [\text{Applied Pumped Groundwater} \times (0.8) \times (1 - \text{LR})]$$

The ITRC (2010) irrigation distribution uniformity factor of 0.8 was applied to Agricultural pumping for the unconfined areas of the District. Results for the calculated estimates of return flow from applied pumped irrigation water in the unconfined groundwater basins of UWCD are shown in Table B2.

Fillmore Fish Hatchery Return Flow

The Fillmore Fish Hatchery located near the west end of the Piru Basin essentially discharges all of its pumped groundwater into the Santa Clara River. This pumping is reported as use, but application of the LR factor of 0.16 is not appropriate. Rather, a percolation factor of 1, or 100% return flow, was applied. In 2010, 2011, 2012 the Fish Hatchery accounted for a significant percentage of the Agricultural return flow in the unconfined basins of the District. A Piru basin watercress grower located just west of the Fish Hatchery does however use some of the Fish Hatchery return flow as irrigation water. It is estimated, using historical average monthly ETo values from the Piru CIMIS station, that the watercress transpires approximately 345 ac-ft per year (CIMIS, 2013). This volume of water (345 ac-ft) is subtracted from the fish hatchery return flows for each year evaluated.

Saticoy Well Field Pumping

United's Saticoy Well Field is located in the unconfined Oxnard Forebay groundwater basin, but water pumped from this facility is piped to agricultural users on the Oxnard Plain. Accordingly, return flows for this pumped water were applied to the confined basins of the District and not the unconfined basin where it originated.

MI&D Return Flow (unconfined basins)

Recycled Waste Water

In urban settings, commonly about half the volume of water delivered to homes and businesses returns to wastewater treatment plants, and about half will be put onto the landscape (Alliance for Water Efficiency, 2013). Depending on locality, treated wastewater may serve to recharge underlying groundwater basins.

In the urban setting, domestic and industrial waste water is collected for treatment before either disposal or reuse. In the unconfined basins of the District percolation basins are the primary means for the disposal of waste water, although some recycled water is used for landscape irrigation. In more rural areas where sanitary sewer collection systems do not exist, domestic waste water is collected in septic tanks, from where water is percolated into the shallow subsurface via leach lines.

A recycled water factor for MI&D pumping was determined for each unconfined groundwater basin of the District. This was determined by calculating the percentage of groundwater used for municipal supply that returns to the groundwater system as treated waste water. For example, in 2012, Warring Water Company, the supplier of MI&D water for the town of Piru in

the Piru basin pumped and delivered a total of 355 ac-ft of water while the Piru Wastewater Treatment Plant discharged 202 ac-ft of waste water to percolation ponds adjacent to the Santa Clara River. So the recycled water factor for the Piru basin area is 0.57 or 57%. Similar calculations were made for the Fillmore and Santa Paula basin areas. The recycled water factor of 0.5 determined for the Santa Paula basin area was also applied to the Oxnard Forebay basin area. The recycled water factors were applied to MI&D pumping only in the unconfined areas of the District.

Return Flow from Salt Leaching

It is assumed that the percentage of water delivered in urban areas and not returning to a waste water reclamation plant was used for household and city landscape irrigation. An LR of 0.16, the same value that was calculated for agricultural users in these basins, was applied to the urban irrigation component of MI&D annual pumping.

Return Flow from Excess Applied Water

To be consistent with agricultural areas, an irrigation distribution uniformity factor of 0.8 was applied to the urban landscape irrigation component of pumped water in the unconfined basins.

OH Well Field

Pumping from the District's OH well field is exported from the unconfined Oxnard Forebay for use on the (confined) Oxnard Plain. Accordingly, urban landscape irrigation return flows for this water is applied to the confined basins of the District.

Summary of Return Flow in Unconfined Basins

Agricultural and MI&D groundwater production, reported to the District by calendar year, was used to estimate return flows in the unconfined portions of the District. The following table summarizes reported pumping and return flows per the methodologies described in the previous pages.

Table B2. Summary of Pumping and Return Flow Estimates for 2010, 2011 and 2012, Unconfined basins

Calendar Year	Agricultural Pumping, AF	Agricultural Return Flow, AF¹	% of Agricultural Pumping as Return Flow
2010	70,877	30,038	42.4%
2011	71,665	29,308	40.9%
2012	77,125	30,243	39.2%
	MI&D Pumping, AF	MI&D Return Flow, AF¹	% of MI&D Pumping as Return Flow
2010	8,949	5,763	64.4%
2011	9,451	6,074	64.3%
2012	9,820	6,324	64.4%

¹Tables B6a, B6b, B7a, B7b, B8a and B8b provide a summary of the calculations.

METHODOLOGY FOR ESTIMATING RETURN FLOW TO GROUNDWATER IN THE CONFINED BASINS OF UWCD

Agriculture and MI&D Return Flow (confined basins)

The methodology for estimating the amount of annual Agricultural and MI&D return flow for the confined areas of the District is the same as that for the unconfined areas of the District. However, in the confined basins the initial return flow is to the shallow semi-perched aquifer. The amount of return flow to the underlying confined production aquifers is constrained by the low permeability of underlying sediments (confining layers). Thus for the confined areas of the District the return flow to the underlying confined production aquifers is substantially less than the return flow to the semi-perched aquifer. Estimated of the potential for downward leakage from the semi-perched aquifer to the deeper confined aquifers is discussed in Attachment C.

As for the unconfined basins, a leaching requirement was estimated based on the area-weighted average for each crop type. An average leaching requirement of 0.14 was calculated for crops grown in the confined basins of the District, as shown in Table B3. An irrigation distribution uniformity factor of 0.8 was applied to the pumped groundwater that was applied in the confined areas, the same value as was used in the unconfined basins (ITRC, 2010).

The leaching requirement (LR) and irrigation distribution uniformity factor (DU) were applied to groundwater used for urban landscape irrigation and to groundwater used to irrigate agricultural lands in order to estimate the return flow to the semi-perched aquifer from groundwater pumping in the confined areas of the District.

TABLE B3. Leaching Requirements for Crops in the Confined Areas of UWCD

CROP	ACRES¹	LR²	ACRES x LR
Avocado	1,986.98	0.19	377.53
Blueberries-Raspberries-Blackberries	3,810.41	0.16	609.67
Celery	7,127.03	0.13	926.51
Citrus	3,481.3	0.16	557.01
Misc. Trees	16.16	0.16	2.59
Misc. Vegetables	12,217.67	0.15	1832.65
Nursery Container	107.04	0.1	10.7
Nursery Cut Flowers	710.08	0.08	56.81
Sod	1,212.71	0.05	60.64
Strawberries	10,927.33	0.14	1529.83
Tomatoes-Peppers	1,238.4	0.06	74.3
Fallow-Out	4,620.61		
No Designation	758.96		
Total Acres (not fallow-out or no designation)	42,835.11		6,038.24
Area Weighted LR		0.14	

¹ from Ventura County Agricultural Commissioner, 2013

² adjusted Leaching Requirement from ITRC, 2010

Fifty percent of MI&D groundwater use in the confined portion of the District was attributed to outdoor landscape irrigation (Alliance for Water Efficiency, 2013). This factor was also applied to United Water OH well field groundwater that is delivered for MI&D use on the confined Oxnard Plain.

Both the City of Ventura and the City of Oxnard discharge the majority of their waste water to the ocean. The City of Ventura delivers recycled water to nearby golf courses but this is reuse is considered insignificant in terms of the limited potential for recharge through the thick confining aquitards of the Mound basin.

Groundwater pumped from United's Saticoy Well Field was accounted for as applied agricultural groundwater on the Oxnard Plain, as water from this facility is pumped from the unconfined Oxnard Forebay basin and used on the confined Oxnard Plain basin.

Table B4 shows a summary of the estimated return flow of groundwater to the semi-perched aquifer for the confined areas of the District. The return flow of pumped groundwater and also of rainfall infiltration to the underlying confined production aquifers is significantly limited by the total annual volume of water that can leak through the confining upper aquitard.

The percentage of agricultural pumping as return flow and the percentage of MI&D pumping as return flow in the unconfined basins of the District is greater for each year than that for the semi-perched aquifer overlying the confined basins of the District (Tables B2 and B4). For agricultural return flow in the unconfined basins, a significant variable is the discharge of water pumped by the Fillmore Fish Hatchery back to the Santa Clara River where it commonly percolates to groundwater. MI&D return flow percentages are large in the unconfined basins because recycled wastewater discharged by wastewater reclamation plants to percolation basins near the Santa Clara River is considered 100% return flow. In the confined basin area, the City of Ventura and the City of Oxnard discharge the majority of their waste water to a coastal estuary or the ocean and therefore is not considered return flow.

Table B5 shows a summary of District-wide pumping and return flow estimates for 2010, 2011 and 2012. The summary Table B5 excludes return flow to the semi-perched aquifer, as capacity for leakage to the confined production aquifers is satisfied by rainfall infiltration.

Table B4. Summary of Pumping and Return Flow Estimates to the Semi-Perched Aquifer for 2010, 2011 and 2012, Confined Basins

	Agricultural Pumping, AF	Return Flow to Semi-Perched Aquifer from Agricultural Irrigation with Pumped Groundwater, AF^{1,2}	% of Agricultural Pumping as Return Flow
2010	46,406	14,479	31.2%
2011	48,517	15,137	31.2%
2012	58,980	18,402	31.2%
	MI&D Pumping, AF	Return Flow to Semi-Perched Aquifer from MI&D Irrigation with Pumped Groundwater AF¹	% of MI&D Pumping as Return Flow
2010	32,823	5,120	15.6%
2011	30,036	4,686	15.6%
2012	31,732	4,950	15.6%

¹Tables B9, B10 and B11 provide a summary of the calculations

²Return flow to the semi-perched aquifer does not benefit the underlying confined production aquifers

Table B5. Summary of District-wide Pumping and Return Flow Estimates for 2010, 2011 and 2012,

	Total District-Wide Agricultural Pumping, AF	Agricultural Return Flows, AF	% of Agricultural Pumping as Return Flow
2010	117,283	30,038	25.6%
2011	120,182	29,308	24.4%
2012	136,105	30,243	22.2%
	Total District-Wide MI&D Pumping, AF	MI&D Return Flows, AF	% of MI&D Pumping as Return Flow
2010	41,772	5,763	13.8%
2011	39,487	6,074	15.4%
2012	41,552	6,324	15.2%

References

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Hanson et. al, 2003, Simulation of Ground-Water/Surface-Water Flow in the Santa Clara-Calleguas Ground-Water Basin, Ventura County California, USGS Water Resources Investigation Report 02-4136.

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Attachment C

Estimation of Leakage through the Upper Aquitard in the Confined Basins of the District

For areas within the confined basins of the District water from rainfall infiltration and return flows from both agricultural and urban irrigation contribute water to the semi-perched aquifer. The volume of water that flows downward from the semi-perched aquifer into the underlying confined production aquifers is limited by the conductance of the aquitard that separates the two aquifers. The volume of water that can leak through the confining aquitard is controlled by groundwater head differentials, thickness of the aquitard, permeability of the aquitard, and area of the aquitard. United feels the leakage estimates presented are likely greater than what actually occur, in part because it is assumed that a semi-perched aquifer system exists in the shallow subsurface over the entirety of the confined basins within the District.

The volume of water from rainfall infiltration and irrigation return flow serving to recharge the semi-perched aquifer that exceeds the downward leakage capacity if the aquitard does not leak downward through the confining aquitard, flows laterally toward the ocean or discharges in surface channels. In the evaluation presented here, downward leakage through basin confining layers is estimated and then compared to estimations of return flow to the semi-perched aquifer from irrigation with pumped groundwater and estimations of available rainfall infiltration for the years 2010, 2011 and 2012.

Previous Investigations of Leakage through the Upper Aquitard

Several publications that characterize the shallow aquitards of the Oxnard Plain are available for review. California DWR Bulletin 63-4 published results of field pumping tests showing that the Oxnard Aquifer and its associated confining beds represent a leaky aquifer system (CA DWR, 1971). The investigation resulted in an estimate of 6,000 acre-feet per year of leakage from the semi-perched aquifer down through the upper aquitard of the confined Oxnard Plain Basin. They stated that this was over a 95 mi² area, so although not explicitly stated, it most likely also included some area of the adjacent Pleasant Valley basin. Parameters determined by the investigation included a groundwater gradient of 0.1 and a hydraulic conductivity of 0.02 gpd/ft² for the aquitard.

In their discussion of the semi-perched aquifer and clay cap above the Oxnard Aquifer, Mukae and Turner (1975) cite DWR Bulletin 63-4 and state that the study indicated that the “clay cap” is an aquitard through which significant quantities of water can migrate vertically under conditions of differential head. They made no attempt to quantify flow through the confining aquitard.

Mann (1959) opines that the chances for intercommunication increase in areas where the clay cap overlying the Oxnard Aquifer thins, but in other areas it forms a barrier to vertical flow. Mann did a groundwater inventory for the Oxnard Plain and Mound Basin and estimated an average annual leakage of 20,000 acre-feet per year from 1946-1957. He later states that 20,000 acre-feet of leakage is most likely an over-estimation of downward flow.

Hanson (2003) states that aerially extensive confining units retard irrigation return flow to the Upper Aquifer System in the Oxnard Plain and Mound basins, implying that some irrigation return flow to the confined Upper Aquifer System is occurring in these basins.

SWRB Bulletin 12 states that the Oxnard Aquifer of the Oxnard Plain is overlain by sediments of low permeability, which separates this... aquifer from a semi-perched ground water body of inferior mineral quality in the alluvium near the land surface. The relatively impermeable sediments result in confinement of water in the Oxnard aquifer. Whether or not there is complete severance in hydraulic continuity between the semi-perched ground water and the water of the Oxnard aquifer was not firmly established (SWRB, 1953).

California DWR Bulletin 63-1 states that the clay cap underlying the semi-perched aquifer is relatively impermeable over most of the pressure area, but also states that a significant amount of poor quality water in the semi-perched beds may find its way down to the Oxnard aquifer through the clay cap. In some areas, "holes" in the cap may be important conduits to downward flow (DWR, 1965).

More recent publications commonly stress that most leakage probably occurs through abandoned or improperly constructed wells (CA DWR, 1968; Predmore, 1993; USGS, 1996; Hanson et al, 2003). The rapid leakage of water from perched aquifers is seen as undesirable due to the characteristic poor quality of the perched waters. The County of Ventura's well construction and destruction guidelines include special requirements for wells in confined basins, and are intended to prevent the downward movement water within the well casing or gravel pack. The varied distribution of both thin spots in the confining sediments and abandoned or leaky wells makes estimates of leakage through the clay cap on the Oxnard Plain difficult, as these variables remain poorly documented.

Estimates of Leakage through the Upper Aquitard

The following pages detail United's preliminary evaluation into the volume of leakage that flowed down through the upper confining aquitard in the confined areas of the District in the years 2010, 2011, and 2012. The evaluation was somewhat hindered by the lack of semi-perched aquifer water level data, and sparse Upper Aquifer System water level data in the Mound, Pleasant Valley and West Las Posas basins. By assuming the existence of a shallow semi-perched aquifer in all areas of the confined basins the evaluation does however allow an estimation of the annual volume of return flow from applied pumped groundwater and rainfall infiltration that can leak vertically from the semi-perched aquifer downward through the upper

aquitard. Recharge to the semi-perched aquifer in excess of the amount that can flow downward to underlying confined aquifers is assumed to flow laterally towards the ocean or discharge to surface water channels.

The confined basins of the District were divided into “leakage zones” which are shown in Figure C1. These zones are referred to as the Coastal Oxnard Plain zone, Southeast Oxnard Plain zone, Central Oxnard Plain zone, Northwest Oxnard Plain zone, Mound basin zone, Pleasant Valley basin zone, and West Las Posas basin zone. Assessment is limited to areas within the boundaries of United Water Conservation District.

For the Oxnard Plain area, delineation of the various zones was based on locations where there is a semi-perched monitor well in close proximity to an Oxnard Aquifer well, and additionally on the recorded depth-to-water in additional upper aquifer wells. The other zones were based on the area of the groundwater basin within the District.

The amount of leakage through the upper aquitard was estimated for each zone for calendar years 2010, 2011 and 2012. A simple Darcy’s Law flux equation was used to calculate the leakage, as follows:

$$Q=Kia$$

Where:

K = hydraulic conductivity

i = hydraulic gradient

A = area of aquitard

A bulk hydraulic conductivity of 0.02 gal/ day/ft² is used in this evaluation for the upper confining aquitard for each leakage zone in the confined areas of the District. This is consistent with Neuman and Weatherspoon (CA DWR, 1971) estimations of hydraulic conductivity for the upper aquitard from aquifer tests near Port Hueneme, and published values for silt/clay (U.S Department of Interior, 1981; Fetter, 1988).

Vertical hydraulic gradients were established with the use of key wells within each zone. Depth-to-water data from semi-perched wells and Upper Aquifer wells (except for the Las Posas basin zone in which a lower aquifer well was used) were taken from United’s groundwater level database. In zones where no semi-perched aquifer depth-to-water measurements were available, a semi-perched aquifer depth to water was assumed to exist ten feet below the land surface. This assumption likely results in an over-estimation of the hydraulic gradient in some zones. Aquitard thicknesses were evaluated from the driller logs of the wells with water level records. The hydraulic gradients calculated from the key wells were averaged within the calendar year for the leakage calculation.

Each leakage zone is discussed below in more detail. Refer to Figure C-1 for the locations of the leakage zones and key wells. See Table C-3 for leakage calculation details.

Coastal Oxnard Plain Zone

The Coastal Oxnard Plain zone encompasses an area of approximately 21 mi² or approximately 13,300 acres within the Oxnard Plain.

This zone has been identified as an area with a slight upward gradient from the Oxnard aquifer to the semi-perched aquifer for the years 2010, 2011 and 2012. This was based on evaluation of semi-perched aquifer and Oxnard aquifer groundwater depths at the USGS drilled nested monitor well sites A2, Swift and SW. It was also based on depth-to-water of other Upper Aquifer wells within this zone.

In this zone there is estimated to be no significant leakage through the upper aquitard for the years 2010, 2011, and 2012.

Southeast Oxnard Plain Zone

The Southeast Oxnard Plain zone encompasses an area of approximately 21 mi² or approximately 13,700 acres within the Oxnard Plain.

Groundwater gradients were calculated by comparing water level depths from the semi-perched well and the Oxnard Aquifer well in the USGS-drilled SCE monitor well cluster. The semi-perched well, 01N21W19L14S, is perforated from 19 feet to 38 feet bgs. The Oxnard aquifer well, 01N21W19L13S, is perforated from 110 feet to 130 feet bgs. An aquitard thickness of 40 feet was taken from the SCE well's drillers log.

In this zone there is estimated to be 3,470, 1,468 and 1,602 acre-feet of leakage downward through the upper aquitard for the years 2010, 2011 and 2012, respectively.

Central Oxnard Plain Zone

The Central Oxnard Plain zone encompasses an area of approximately 20 mi² or approximately 12,800 acres within the Oxnard Plain.

Groundwater gradients were calculated with water level depths from wells located at the City of Oxnard well yard near Third Street. The semi-perched well, 01N22W03FMW1, is a dedicated monitor well located in the well yard, and perforated from 10 feet to 30 feet bgs. The Oxnard aquifer well, 01N22W03F08S, is a production well perforated from 120 feet to 220 feet bgs. An aquitard thickness of 50 feet was taken from the driller's log for well 01N22W03F08S.

In this zone there is estimated to be 7,127, 4,001 and 3,501 acre-feet of leakage downward through the upper aquitard for the years 2010, 2011 and 2012, respectively.

Northwest Oxnard Plain Zone

The Northwest Oxnard Plain zone encompasses an area of approximately 12 mi² or approximately 8,000 acres within the Oxnard Plain.

Groundwater gradients were calculated with water level depths from dedicated monitor wells at the Bailard Landfill which included semi-perched monitor well 02N22W30A03S, perforated from 35 feet bgs to 45 feet bgs and Oxnard aquifer monitor well 02N22W30A05S, perforated from 190 feet bgs to 200 feet bgs.

Driller's logs for semi-perched monitor wells at the landfill clearly show the top of the confining aquitard beneath the semi-perched aquifer. The logs also indicate that the wells were not drilled into the upper confined aquifer. Semi-perched monitor well 02N22W30H04S was only drilled into the upper 24 feet of the aquitard. Based on thicknesses shown in a geologic cross-section, located to the southeast (Mukae and Turner, 1975) it was determined to use a 40 foot thickness for the aquitard.

In this zone there is estimated to be 3,115, 1,012 and 1,558 acre-feet of leakage downward through the upper aquitard for the years 2010, 2011 and 2012, respectively.

Mound Basin Zone

The Mound Basin zone encompasses the portion of the Mound groundwater basin within United's district boundaries, and is approximately 14 mi² or approximately 9,000 acres. The zone or basin is dominated by a thick upper clay or aquitard.

The driller's log and e-log from the monitor well cluster at Camino Park, located in the north-central portion of the basin shows an upper clay extending from near land surface to 585 feet bgs. The e-log for the monitor wells at Community Park located near the east end of the basin shows a clay extending from near land surface to 305 feet bgs. The e-log for well 02N22W17Q4S located at the south end of the basin shows clay extending from near land surface to 180 feet bgs. The e-log for the Chevron Maxwell 1 Oil well which was drilled at the west end of the basin shows a clay extending from near land surface to 327 feet bgs.

Despite the absence of shallow water level data in this zone from a semi-perched monitor well, as was available for the zones located in the Oxnard Plain, an attempt was made to estimate leakage from the upper aquitard into the upper confined aquifer zone. Groundwater gradients were calculated using water level depths from upper aquifer zone well 02N22W16K01S, perforated 292 feet bgs to 345 feet bgs, located near the southeast basin boundary, and an assumed semi-perched aquifer water level depth of 10 feet bgs. There was one sand and gravel unit from 172 to 208 feet bgs within the upper 292 feet of sediment that was indicated on the driller's log for well 02N22W16K01S. A semi-perched aquifer thickness of 20 feet was assumed. An aquitard thickness of 270 feet was determined.

In this zone there is estimated to be 3,934, 3,322 and 3,672 acre-feet of leakage downward through the upper aquitard for the years 2010, 2011 and 2012, respectively.

Pleasant Valley Basin Zone

The Pleasant Valley Basin zone encompasses the area of the Pleasant Valley groundwater basin that is located within United Water Conservation District and is approximately 16 mi² or approximately 10,000 acres.

The drillers log for the USGS PV monitor well cluster located near the Pleasant Valley County Water District Reservoir shows a 30-foot sand unit extending from the surface. However a monitor well was not drilled in this shallow unconfined sand unit. To estimate the groundwater gradient a water level depth of 10 feet bgs was assumed for this sand unit. The Upper Aquifer water level depths were taken from the upper aquifer monitor well 02N21W34G05S, perforated from 170 feet to 190 feet bgs, located within the PV well nest. An aquitard thickness of 140 feet was determined from the driller's log from the USGS drilled monitor well nest, and from the driller's log for Pleasant Valley County Water District well 02N21W34G01S.

Most of the production wells in the Pleasant Valley basin are lower aquifer wells that are perforated deeper than 400 feet bgs. However, the PV monitor well cluster provides an upper aquifer well with good water level data and thus was used in this evaluation.

In this zone there is estimated to be 3,826, 3,335 and 4,022 acre-feet of leakage downward through the upper aquitard for the years 2010, 2011 and 2012, respectively.

West Las Posas Basin Zone

The Las Posas Basin zone encompasses the area of the West Las Posas groundwater basin that is located within United's district boundaries. It covers approximately 6 mi² or about 3,782 acres.

Like the Mound Basin zone and the Pleasant Valley Basin zone there were no semi-perched water level depth measurements available. However as was done for the other zones without the availability of semi-perched water level data, a 10-foot semi-perched water level depth was assumed. To calculate a groundwater gradient this assumed semi-perched groundwater level depth was used in combination with water level depths from lower aquifer well 02N21W09D02S, perforated 650 feet to 800 feet bgs. The drillers log for well 02N21W09D02S reports soil and sand from 40 feet bgs to 180 feet bgs. The lithology for the first 40 feet bgs is not shown on the log. The log shows mostly clay from 180 feet bgs to the top perforation of the well at 650 feet bgs. A 470 foot thick aquitard was determined.

A lower aquifer well was used in this evaluation due to the absence of upper aquifer wells with water level data in the West Las Posas basin zone. The majority of production wells within this zone have their top perforation below 500 feet bgs.

In this zone there is estimated to be 1,735, 1,698 and 1,698 acre-feet of leakage downward through the upper aquitard for the years 2010, 2011 and 2012, respectively.

Comparison of Estimated Recharge to Semi-Perched Aquifers and Estimated Leakage through Confining Aquitards

Table C-1 below shows estimates of annual recharge to semi-perched aquifers from irrigation return flow and available volume from rainfall infiltration to the semi-perched aquifer (see Attachment A for a discussion of available volume for rainfall infiltration). The table is partitioned between return flow from agricultural irrigation and return flow MI&D irrigation and is likewise partitioned between available volume for rainfall infiltration for agricultural lands and available volume for rainfall infiltration for urban lands. The table also shows the estimated amount water that can potentially leak downward from the semi-perched aquifers through the upper aquitard into the underlying confined production aquifers. For each year, the estimated capacity for downward leakage to the underlying confined aquifers is less than the combined estimated return flow and estimated available volume for rainfall infiltration to the semi-perched aquifer. When the combined volume of return flow and recharge from rainfall infiltration is greater than the capacity for downward leakage, water will flow laterally in the semi-perched aquifer towards the ocean or discharge to surface water channels.

Table C-1 Estimated Return Flow from Groundwater Pumping, and Available Water from Rainfall Infiltration to the Semi-Perched Aquifer with Potential Downward Leakage through Upper Aquitard

(All values in Acre-feet)

Year	Return Flow to Semi-perched Aquifer from Agricultural Irrigation with Pumped Groundwater	Return Flow to Semi-Perched Aquifer from Urban Irrigation with Pumped Groundwater	Available Volume for Rainfall Infiltration to Semi-Perched Aquifer for Agricultural Lands ²	Available Volume for Rainfall Infiltration for Urban Lands ²	Downward Leakage through Upper Aquitard ¹
2010	14,479	5,120	36,201	23,996	23,207
2011	15,137	4,686	39,617	26,237	14,837
2012	18,402	4,950	25,996	17,144	16,051

¹ see table C-3 for leakage estimation details;

²see Attachment A for discussion on available volume for rainfall infiltration

Table C-2 below shows that all of the water estimated for downward leakage to the underlying confined productive aquifers can be accounted for by rainfall infiltration. This allows the return flow from irrigation of pumped groundwater and the remainder of the water from rainfall infiltration to flow laterally in the semi-perched aquifer and eventually discharge to the ocean or surface water channels. Rainfall infiltration to the semi-perched aquifer is the natural and pre-existing process and therefore is prioritized in this assessment of recharge to the confined basins within the District.

Table C-2. Sources of Water Leaking Downward through the Upper Aquitard as Return Flow to the Underlying Confined Production Aquifers

(All values in Acre-feet)

Year	Return Flow to Underlying Confined Production Aquifers from Agricultural Irrigation with Pumped Groundwater	Return Flow to Underlying Confined Production Aquifers from Urban Irrigation with Pumped Groundwater	Recharge to Underlying Confined Production Aquifers from Rainfall Infiltration over Agricultural Lands	Recharge to Underlying Confined Production Aquifers from Rainfall Infiltration over Urban Lands
2010	0.0	0.0	14,078	9,129
2011	0.0	0.0	9,001	5,836
2012	0.0	0.0	9,737	6,314

Table C3. Estimations of Leakage through the Upper Confining Aquitard for the Confined Areas of the District

Leakage Zone ¹	Key Well(s) ¹	Year	Hydraulic K (gal/day/ft ²)	Hydraulic K (feet/day)	Aquitard Thickness (ft)	Average Gradient	Area (ft ²)	Acres	Area (mi ²)	Downward Leakage (gpd)	Downward Leakage (ac-ft/year)
Coastal Oxnard Plain						upward	577,399,000	13,255	21	0	0
Southeast Oxnard Plain	SCE Well Cluster	2010	0.02	0.0027	40	0.26	595,780,000	13,677	21	3,098,056	3,470
Central Oxnard Plain	Oxnard Well Yard	2010	0.02	0.0027	50	0.57	558,137,000	12,813	20	6,362,762	7,127
Northwest Oxnard Plain	Bailard Landfill	2010	0.02	0.0027	40	0.40	347,628,000	7,980	12	2,781,024	3,115
Mound Basin	02N22W16K01S	2010	0.02	0.0027	270	0.45	390,212,000	8,958	14	3,511,908	3,934
Pleasant Valley Basin	PV Well Cluster	2010	0.02	0.0027	140	0.39	437,858,000	10,052	16	3,415,292	3,826
West Las Posas Basin	02N21W09D02S	2010	0.02	0.0027	470	0.47	164,730,000	3,782	6	1,548,462	1,735
										Total	23,207
Coastal Oxnard Plain						upward	577,399,000	13,255	21	0	0
Southeast Oxnard Plain	SCE Well Cluster	2011	0.02	0.0027	40	0.11	595,780,000	13,677	21	1,310,716	1,468
Central Oxnard Plain	Oxnard Well Yard	2011	0.02	0.0027	50	0.32	558,137,000	12,813	20	3,572,077	4,001
Northwest Oxnard Plain	Bailard Landfill	2011	0.02	0.0027	34	0.13	347,628,000	7,980	12	903,833	1,012
Mound Basin	02N22W16K01S	2011	0.02	0.0027	270	0.38	390,212,000	8,958	14	2,965,611	3,322
Pleasant Valley Basin	PV Well Cluster	2011	0.02	0.0027	140	0.34	437,858,000	10,052	16	2,977,434	3,335
West Las Posas Basin	02N21W09D02S	2011	0.02	0.0027	470	0.46	164,730,000	3,782	6	1,515,516	1,698
										Total	14,837
Coastal Oxnard Plain						upward	577,399,000	13,255	21	0	0
Southeast Oxnard Plain	SCE Well Cluster	2012	0.02	0.0027	40	0.12	595,780,000	13,677	21	1,429,872	1,602
Central Oxnard Plain	Oxnard Well Yard	2012	0.02	0.0027	50	0.28	558,137,000	12,813	20	3,125,567	3,501
Northwest Oxnard Plain	Bailard Landfill	2012	0.02	0.0027	34	0.20	347,628,000	7,980	12	1,390,512	1,558
Mound Basin	02N22W16K01S	2012	0.02	0.0027	270	0.42	390,212,000	8,958	14	3,277,781	3,672
Pleasant Valley Basin	PV Well Cluster	2012	0.02	0.0027	140	0.41	437,858,000	10,052	16	3,590,436	4,022
West Las Posas Basin	02N21W09D02S	2012	0.02	0.0027	470	0.46	164,730,000	3,782	6	1,515,516	1,698
										Total	16,051

¹ see Figure C-1 for location of leakage zones and key wells

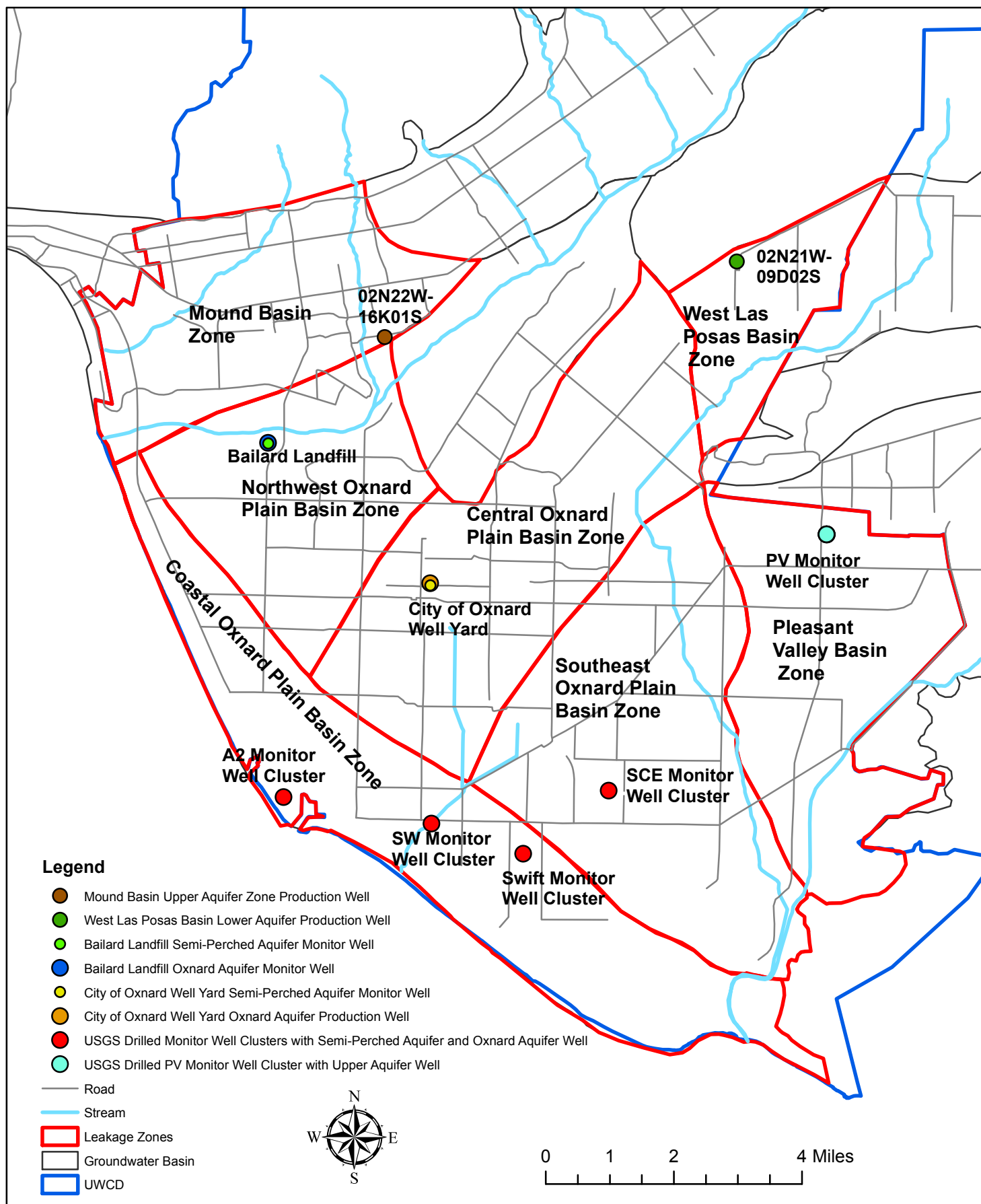


Figure C-1. Location of Leakage Zones and Key Wells

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