Stillwater Sciences

P.O. Box 904, Santa Barbara, CA 93102
Phone: 206-914-5031

Kear Groundwater
PO Box 2601, Santa Barbara, CA 93120
phone: 805-845-2700

TECHNICAL MEMORANDUM

DATE: April 9, 2012

TO: Michael Bowen, Ocean Protection Council

FROM: Derek Booth, Stillwater Sciences, and Jordan Kear, Kear Groundwater

SUBJECT: Potential for aquifer storage and recovery in the Santa Maria River basin

1 BACKGROUND

1.1 Additional Water Needs in the Santa Maria River

The *Southern California Steelhead Recovery Plan* (NMFS 2012) identifies the Santa Maria River as a key priority for recovery, but upstream migrating fish must first traverse the typically dry 24 miles of mainstem below the joining of its two major tributaries, the Cuyama and Sisquoc rivers. The Cuyama River flows through the agricultural lands of Cuyama Valley and the Sierra Madre Mountains before being intercepted by Twitchell Dam. Twitchell Dam was built in 1959 and first began operation in 1962 for the explicit purpose of storing water during winter storms and then releasing it at a rate to maximize percolation into the riverbed of the mainstem Santa Maria River, recharging groundwater and minimizing surface flows to the ocean (flood control and water conservation, as termed in the Santa Maria Project enabling legislature). In contrast, the Sisquoc River has no major dams or water diversions, and it supports a persistent population of *Oncorhynchus mykiss* with abundant spawning and rearing habitat throughout its upper watershed.

Analysis of pre- and post-Twitchell Dam flow regimes in the mainstem Santa Maria River in Stillwater Sciences (2012) indicated that discharges in the range necessary for adult fish passage have declined, on average, by about 1.5–2.5 days per year between the two periods. Additional inputs of water to the mainstem river in the range of 1,000–1,500 acre-ft/year are projected to recover all or nearly all of the passage opportunities previously available in the pre-dam period. The presumptive source of this additional surface flow, as analyzed in Stillwater Sciences (2012), was Twitchell Reservoir.

This technical memorandum explores the potential feasibility of an alternative source for such water, namely discharges in the Sisquoc River that are not already required to maintain surface flows suitable for fish passage, and that are not presently required to sustain those conditions. This water would not be used directly to augment flows during passage events, but instead would be diverted to provide additional recharge into the Santa Maria Valley groundwater basin, replacing the 1,000–1,500 acre-ft/year of water from Twitchell Reservoir that historically has been released to increase recharge but might instead be needed to increase surface-water flows to the ocean. Should antecedent conditions in the Sisquoc not exist to support fish passage in any given year, any spread water would still be of benefit to the users of the groundwater basin.

We have internally referred to this effort as the Santa Maria Habitat Augmentation Recharge Project (SHARP), in that promoting additional groundwater recharge is a typically welcomed outcome, while the additional surface-water flows would be available to augment fish passage in the mainstem of the Santa Maria River.

1.2 Aquifer Storage and Recovery

Artificial recharge of groundwater aquifers, or more specifically *aquifer storage and recovery,* constitutes the managed introduction of surface waters into subsurface aquifers. Most generally, this can occur for a variety of reasons, but the most common is to reserve the water for use at a later date without the associated costs, impacts, and limitations of above-ground storage. This approach has been explored for more than a century; for example, the following definition of artificial recharge was offered by Todd (1959):

> Artificial recharge may be defined for the purpose of this bibliography as the practice of increasing by artificial means the amount of water that enters a ground-water reservoir. Artificial recharge may be divided into direct and indirect methods. Direct methods include water spreading flooding an area or admitting water into shallow basins, ditches, or furrows; extending the time during which water is recharged from a naturally influent channel; applying excess water for irrigation; recharge through pits and other excavations of moderate depth; and recharge through relatively deep wells and shafts. (p. 1)

Weeks (2002) reported that "In California, artificial recharge of alluvial aquifers with storm runoff by use of spreading basins began about the turn of the century, and was a widespread practice by the 1930s." Multiple studies through to the present day (e.g., Sheng 2005, Hanson et al. 2009) demonstrate the widespread application of this approach throughout semi-arid regions of the US and beyond, suggesting the value of an initial assessment of this approach to water-resources management. Several local projects include the diversion of stream water at high flows for the purpose of either spreading via recharge basins (Freeman Diversion of United Water Conservation District on the Santa Clara River) or passive recharge wells (San Antonio Creek Spreading Grounds on San Antonio Creek, a tributary to the Ventura River). Each of these projects consider minimum fish passage requirements in setting thresholds for stream-flow diversion.

1.3 Initial Assessment of Feasibility

The following discussion is not intended to be a fully developed feasibility analysis, and in particular it does not evaluate detailed costs nor quantify economic benefits, identify specific sites for off-take or infiltration, anticipate permitting concerns, nor address detailed engineering issues. Instead, it offers a general evaluation of the hydrology, physiography, and geology of the watershed in the context of the identified water needs for fish passage. The following analysis suggests that such an approach is likely feasible, though not without logistical and operational challenges, and that further evaluation of more detailed and site-specific alternatives are probably warranted if augmenting instream flows in the Santa Maria River to support fish passage remains a broader management objective.

The following elements of this alternative approach are discussed in greater detail below:

1. Required water,

2. Water availability in the Sisquoc River,
3. Collection and transmission of flows,
4. Opportunities and constraints on infiltration, and
5. Order-of-magnitude costs.

2 KEY ELEMENTS OF THE ALTERNATIVE

2.1 Required Water

Stillwater Sciences (2012) explored both generalized and more event-specific evaluations of how fish-passable flows have changed in the mainstem Santa Maria River as a result of dam operations. Using the flow record from the mainstem gage at Guadalupe (USGS 11141000), they found most generally that flows in the range necessary for fish passage (150 cfs for downstream juveniles, 250 cfs for upstream adults) had declined on average about 2 days per year (Figure 1). Two days of 250 cfs flow represent about 1,000 acre-ft of water, each year, that would be discharged to the estuary and so "lost" from the groundwater basin as recharge. In Stillwater Sciences (2012), this annual volume of water was identified as an objective benchmark for the volume of water needed to recover historic passage conditions.

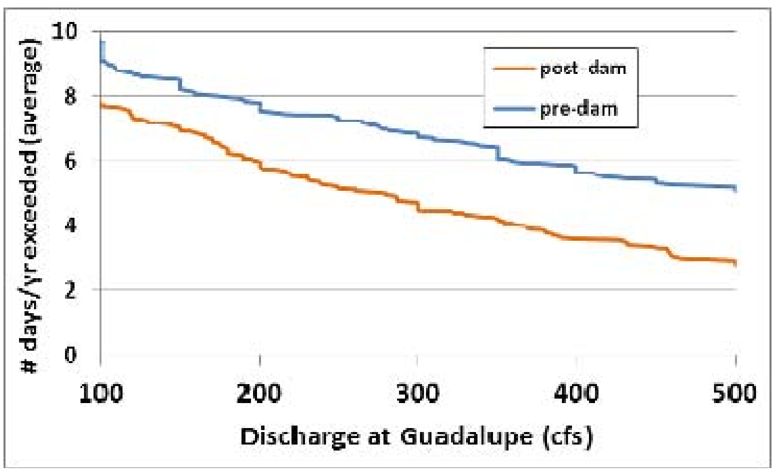

Figure 1. Flow-duration curve for daily discharges of the Santa Maria River at the Guadalupe gage (USGS 11141000), with the fraction of daily discharges above the specified discharge expressed as the average number of days per year (e.g., 3.65 days ≈ 1% of the time). The curves for the pre-dam (orange line; February 1, 1941—February 15, 1962) and post-dam (blue line; February 16, 1962—September 1987) indicate a reduction of about 1.5 to 2.5 days per year, on average, in the duration of critical fish-passable discharges (Figure 4.4-6 of Stillwater Sciences 2012).

However, average daily flows and flow durations do not fully characterize the changes that have occurred to conditions necessary for passage, because at least three days of continuous passage-supporting discharges were also determined to be needed for successful upstream adult migration. These conditions do not occur for a fixed number of days every year; indeed, many years passed where they did not occur at all in both the pre-dam and post-dam periods (e.g., Figure 2).

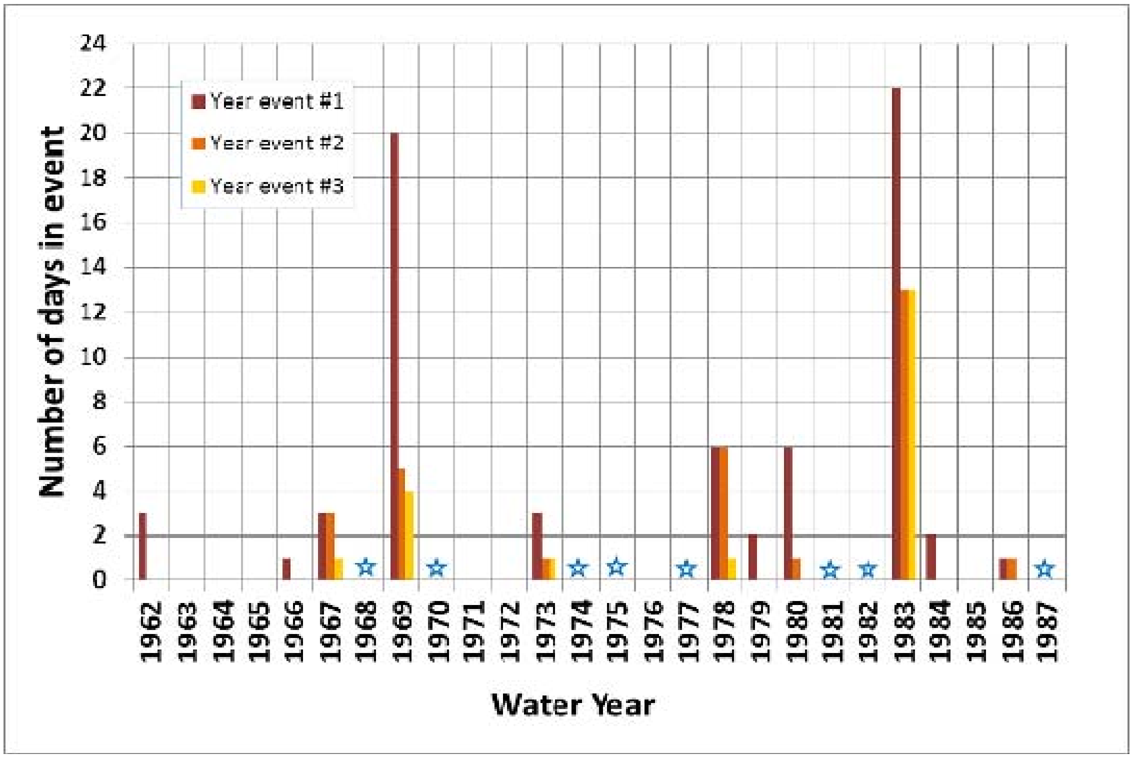

Figure 2. Duration (in days) and distribution (by water year) of ≥250-cfs flow events at the Guadalupe gage (USGS 11141000). Multiple bars for a single year indicate multiple flow events, arranged in order of decreasing duration (2 additional events of 2–6 days' duration occurred in both 1969 and 1983). Starred years had one or more recorded flows but all less than 250 cfs. Blank years (7, in total) had no days of recorded flow whatsoever (Figure 4.4-17 of Stillwater Sciences 2012).

Finally, the *a posteriori* recognition of flows that would require augmentation to achieve fish passage cannot directly translate into fail-safe rules to optimize the use of stored water to recover pre-dam passage conditions. For example, a one-day flow event on the (unregulated) Sisquoc River that would have historically resulted in sufficient flow for passage on the mainstem may or may not be followed by two additional such days. If flow augmentation was provided on Day 1 but natural discharges declined such that passage was no longer possible on Days 2 and 3, then the augmented water would have been "wasted"—because, despite its release, no net increase in passage conditions resulted. Thus, achieving a pre- and post-dam equivalency of *passage conditions* (e.g., Figure 2) does not necessarily coincide with an equivalent *quantity of water* (Figure 1). Stillwater Sciences (2012), for example, found that to achieve equivalent frequency and duration of passage conditions in the post-dam period required an average addition of 1,500 acre-ft/yr for the period 1962–1987. It also found a lower amount (1,020 acre-ft/yr) required for the period 1988–2011, reflecting both the imprecision inherent in this analysis and an apparent trend of modestly increasing flows in the Sisquoc River over the past 70 years, the implications of which are explored further in Section 3.

2.2 Water Availability in the Sisquoc River

The Sisquoc River is a flashy, episodic river, particularly in its lowermost 10 miles where it enters the alluvial valley that ultimately expands to include the mainstem Santa Maria River.

About one mile upstream of the confluence with the Cuyama River, the Garey gage (USGS 11140000) provides a 70-year record of flows on the lower Sisquoc River (Figure 3).

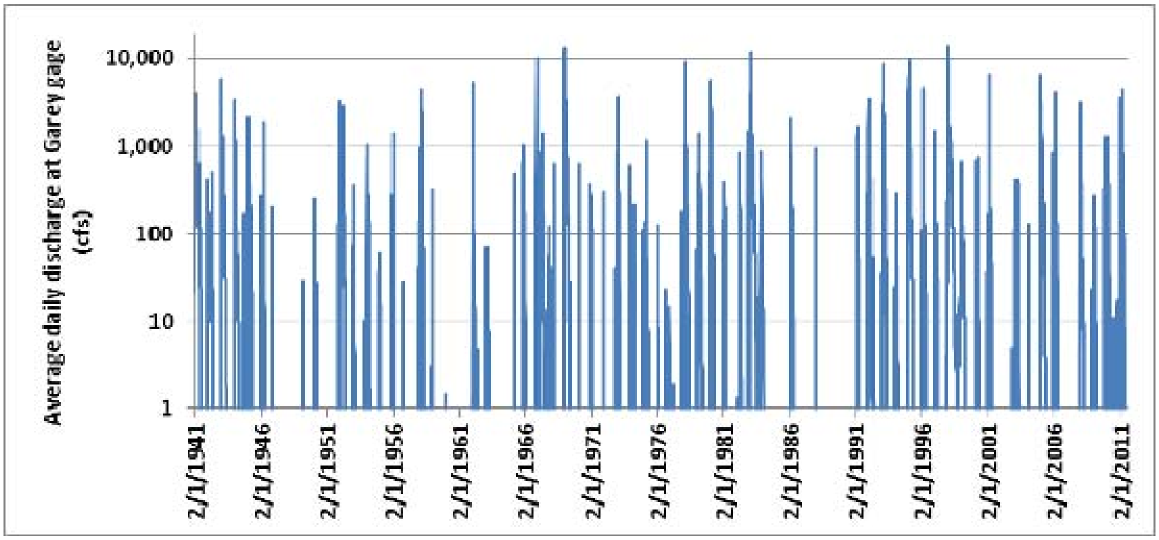

Figure 3. 70 years of average daily discharges in the Sisquoc River at Garey (USGS 1114000). Average flow for this period is 55 cfs (although the median flow is zero) (Figure 2.3-2 of Stillwater Sciences 2012).

Historically, flows from the Sisquoc and Cuyama rivers were well-correlated on a daily basis: high discharges in one typically corresponded with high discharges in the other, and their combination episodically gave rise to conditions suitable for fish passage in the mainstem Santa Maria River. The Sisquoc River was the greater contributor; gage records from the pre-dam period show that it provided an average of about 60% of the combined discharges. Gage records also show that infiltration losses between confluence of the two tributaries and the lower Santa Maria River, where fish passage is most limiting, vary over a range of more than 500 cfs and average about 350 cfs.

Thus, any diversion of surface flows from the Sisquoc River into an aquifer recharge facility (presumably an off-channel, surface-water pond; see next section) would need to meet the following conditions to avoid creating immediate impacts to fish passage in the pursuit of future benefits:

1. Flows remaining in the Sisquoc River must be adequate for passage in that channel (approximately 150–200 cfs; Stillwater Sciences 2012).
2. Flows remaining in the Sisquoc River at the mainstem should be sufficient to achieve passage conditions without augmentation by releases from Twitchell Reservoir (i.e., 250 cfs for passage + 350 cfs for typical infiltration losses = 600 cfs, depending on antecedent conditions and preexisting groundwater levels in the underlying aquifer).

Given the variability of historic infiltration losses during fish-passable conditions in the lower mainstem (Figure 4), a conservative minimum flow in the Sisquoc River remaining after any diversions is about 900 cfs, a minimum value that will be used in the following analyses to evaluate feasibility of this approach. A maximum flow rate must also be considered, since stream power issues, suspended loads, and other operational factors including safety may limit the feasibility of diversion during very high flows.

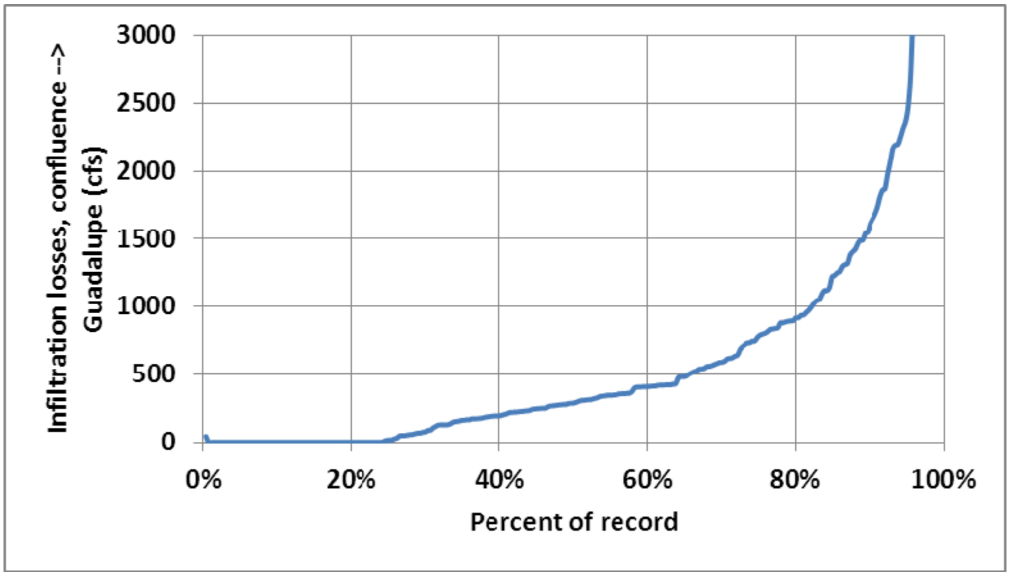

Figure 4. Infiltration losses for only those historical flows that achieved fish-passable conditions at the Guadalupe gage (11141000), calculated as the difference between the combined gaged flows of the Sisquoc + Cuyama rivers and the Guadalupe gage. The lowermost 25% show no losses or gains; the upper 5–10% show losses greater than a few thousand cfs, likely reflecting gage errors inherent in measuring these extreme discharges.

For purposes of a preliminary analysis, flows in the Sisquoc River are assumed to be untouched by diversion below 900 cfs; from 900–1,100 cfs, the amount above 900 cfs is diverted in full; and above 1,100 cfs, a maximum 200 cfs is diverted. By inspection of the flow-duration curve for the Garey gage on the lower Sisquoc River (Figure 5), conditions suitable for diversion will occur only about 4 days per year on average; the actual flow record of the river (Figure 3), however, indicates that many years will provide no such opportunities at all. Applying these rules to the entire record yields about 120,000 acre-ft of diverted water over the 70-year period, or about 1,700 acre-ft/year. As alternatives, if the maximum diversion is held to 100 cfs, the yield is 64,000 acre-ft (910 acre-ft/yr); maintaining a more conservative 1,000 cfs in the Sisquoc River with up to 200 cfs diversion provides a yield of 109,000 acre-ft (more than 1,500 acre-ft/yr). We therefore conclude that flows in the Sisquoc River are broadly sufficient to support the level of aquifer recharge and recovery necessary to provide substantive benefits to fish passage in the mainstem Santa Maria River.

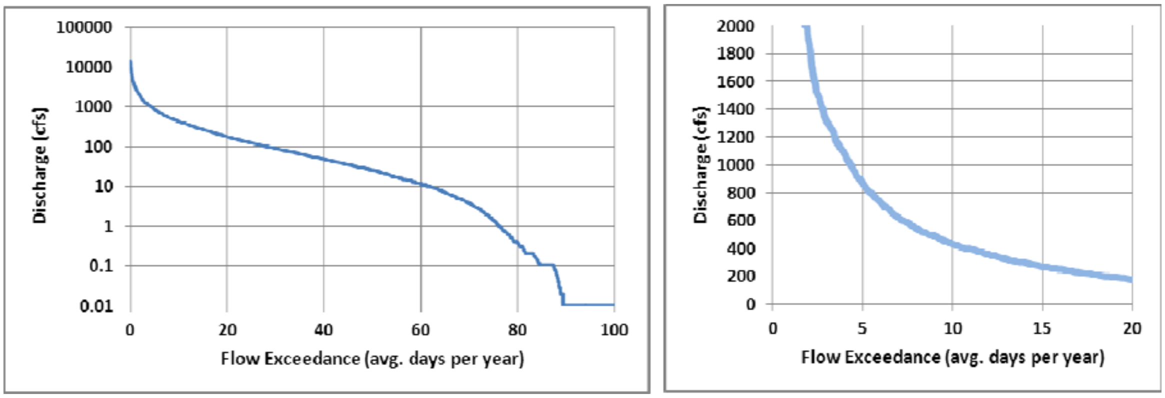

Figure 5. Flow-duration curve for the Sisquoc River at Garey (USGS 11140000). The curve on the left shows the full record; that on the right focuses on the discharge range of greatest interest. Note the change in y-axis scaling.

2.3 Opportunities and Constraints on Offtake and Infiltration

Fundamental constraints on the location of surface-water extraction from the river, and subsequent infiltration into the subsurface, are imposed by the topography, hydrology, and geology of the Santa Maria Valley. Because offtake would occur only during conditions of continuous surface-water flows from the Sisquoc River to the ocean, the precise location is relatively unconstrained—it only needs to be sufficiently upgradient of the infiltration site to maintain gravity-driven flow. The infiltration site should be located over sedimentary deposits of the modern Santa Maria River (unit Qa of Dibblee [1994], colored light gray on the geologic map below), outside of the levees to ensure protection of the facility in the case of future channel realignment and to minimize interactions with water infiltrating directly from the river, but otherwise as close to the river as possible to reduce the costs of conveyance channels (Figure 6).

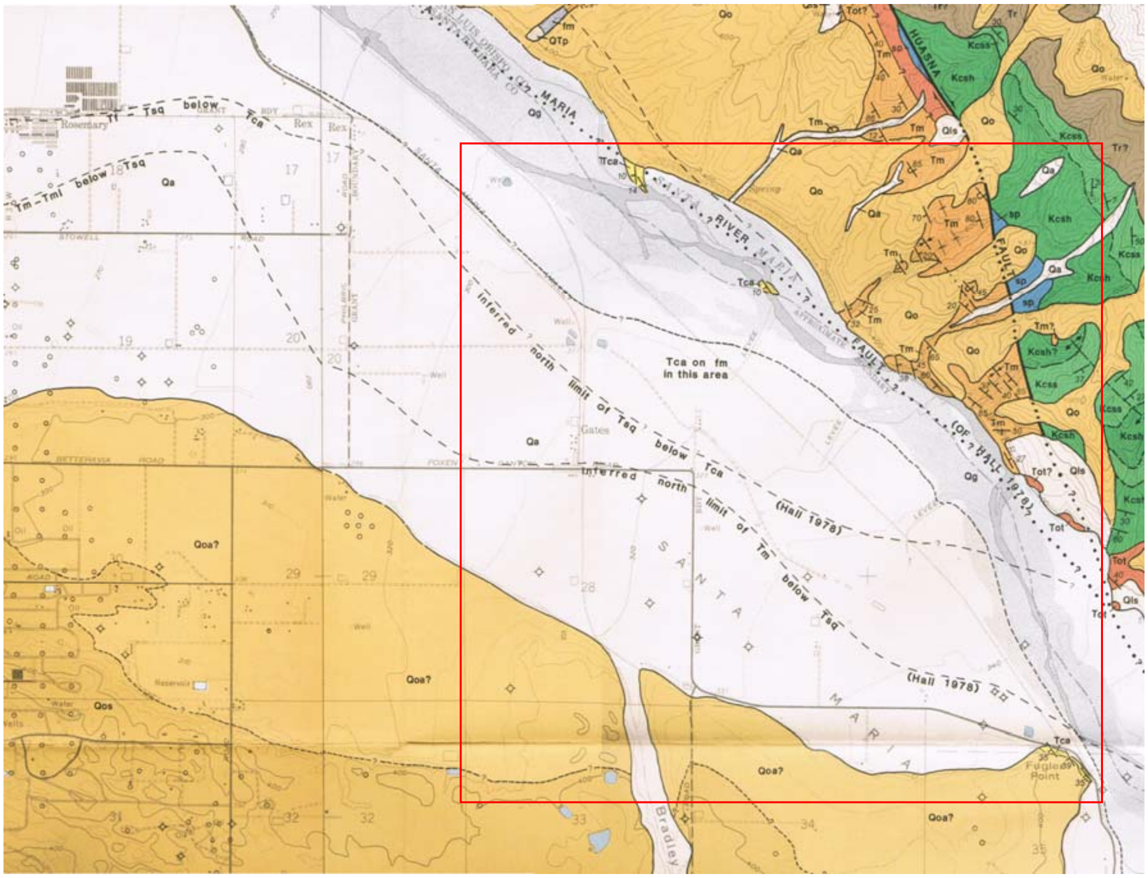

Figure 6. A portion of the geologic map of the Santa Maria River valley (Dibblee 1994). Approximate area covered by Figure 7 outlined in red.

Existing groundwater data in the Santa Maria Valley provide further guidance on the potential location and sizing of an infiltration facility. Available storage capacity, available infiltration capacity and rates, and hydrogeologic feasibility are discussed briefly below.

2.3.1 Water levels

Within the target areas of Figure 6, there are long-term water level records on several wells. Consistently over the available period of record, groundwater levels typically remain within a range of 20–140 feet below ground surface, indicating an unsaturated zone of at least 20 feet available for soil-aquifer treatment of any diverted surface water under such conditions. Using a conceptual excavation maximum of 10 feet, there would remain during the wettest years a 10-foot-thick vadose zone used for the treatment of diverted surface water. This is greater than the 7-foot minimum employed in other similar spreading areas allowed by the Department of Public Health (Rancho California Water, Temecula, Valle De Caballos), suggesting that pre-treatment of the infiltrated water would not be required. Hydrographs of key wells in the target infiltration area are shown on Figures A-1through A-6 (see Appendix A), as are the historic maximum groundwater elevations at wells with water level records.

2.3.2 Available infiltration capacity and rates

Historically, groundwater flows to the west and south from the river and toward the deeper portions of the basin where water levels are lower. An increase in recharge would add to the amount of groundwater in storage, increase water levels locally, potentially reduce total dynamic heads on pumps extracting groundwater, and potentially increase subsurface outflows from the basin toward the ocean (among several other hydrogeologic effects). There appears to be substantially more than adequate storage capacity to accept the additional ±1,500 acre-feet/year postulated by the spreading operations. Additional capacity may exist and provide an additional benefit to the groundwater basin in years of above-average flow on the Sisquoc River.

Locally, vadose zone material consists of a mixture of sand and gravel with occasional clay lenses, which are more prevalent in thickness and lateral continuity to the south and with depth. Figure 7 presents a sand thickness map in the most likely target infiltration area, based on a review of our collection and evaluation of water well records.

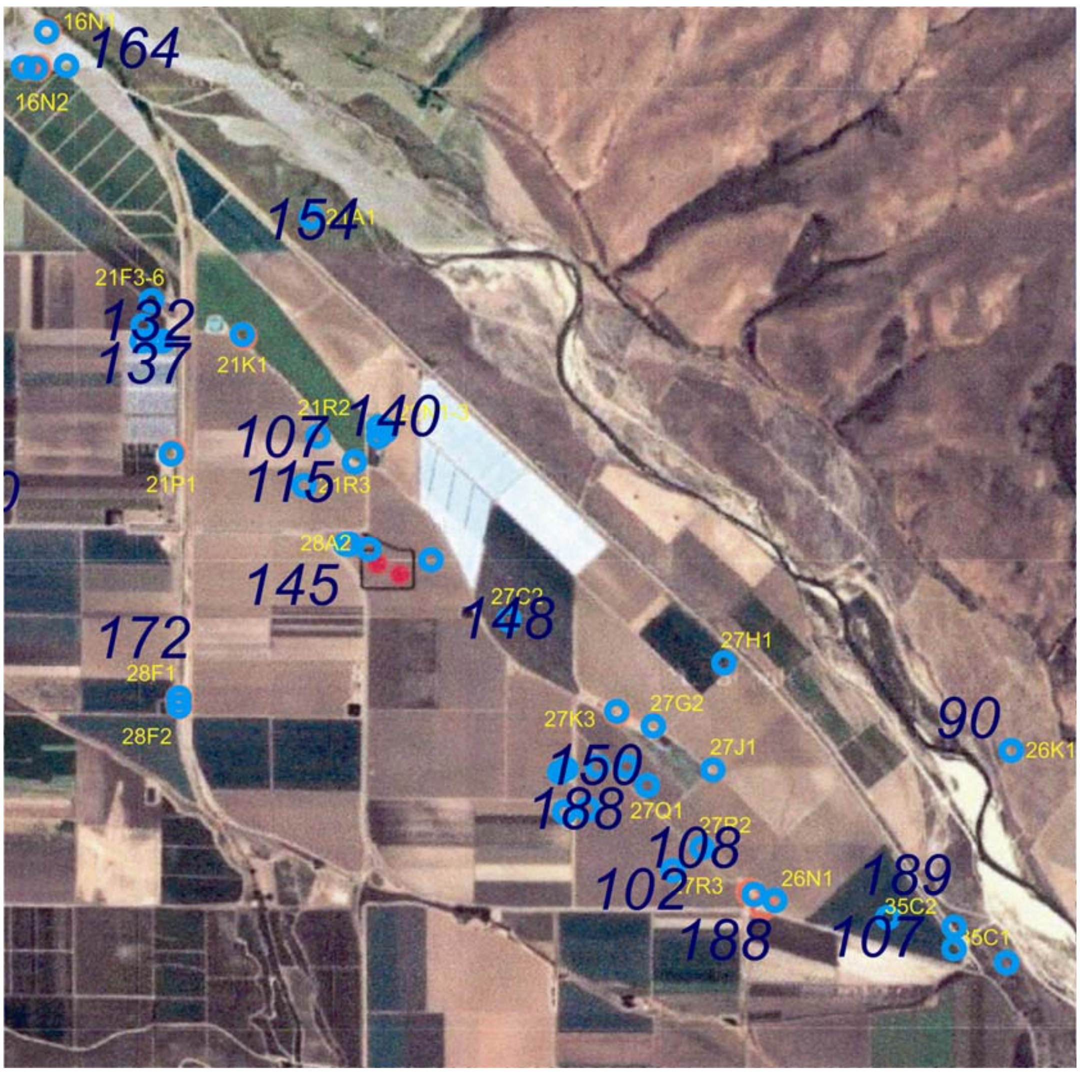

Figure 7. Sand thickness map, suffix of state well number (yellow text), wells (blue circles), and uppermost sand thickness (dark blue numbers, in feet from ground surface).

Infiltration rates, based on observations in the Santa Maria River, percolation tests at local properties, and well testing data, indicate a variable infiltration rate in the target area. Near and downstream of Fugler Point, infiltration rates are reported to range from 400 to 600 gpd/ft^2, which converts to roughly 50–75 acre-feet per day per acre.

Assuming some degree of clogging and inefficiency in spreading basins, we estimate that 25–50 acre-feet per acre could be infiltrated within a recharge basin each day. Hence, a 10-acre basin could be part of a project to spread between 250 to 500 acre-feet per day, and with four days on average of spreading per year, a 10-acre basin should be adequate to target the infiltration volumes discussed above. The primary limitation is one of storage depth—such a basin could only hold about 100 acre-feet at a time, which would limit the maximum offtake rate to that of the infiltration rate. 500 acre-ft/day equals a day's flow of 250 cfs (beyond the range assumed for diversion); but 250 acre-ft/day equals just 125 cfs of flow for a day, which could impose an additional constraint on the design rate of flow extraction. As operations would be well-observed, actual infiltration rates would ultimately supersede these theoretical values. If feasible, additional spreading could further augment the recharge to basin beyond the volumes considered for habitat augmentation.

Property availability is a significant challenge, as many properties in the target area are either much larger than the target sizes or include buildings/offices/other infrastructure. While properties with existing wells would not preclude them as candidate sites for spreading, those without potential conduits to deeper zones may be more efficiently developed for spreading (e.g., costs for well destruction would not apply to properties without wells).

Properties nearest the levee with a minimum amount of conveyance distance would be considered superior to those a greater distance from the river, as this would minimize costs of channel construction and easement requirements. By removing the demand of a 10- to 20-acre agricultural property, typically planted to row crops in this area, an associated reduction in demand of 20 to 80 acre-feet per year would also be realized on the groundwater basin supply.

2.4 Collection and Transmission of Flows

Determining the engineering design of an intake structure that would not be effective below a chosen discharge on the Sisquoc River (e.g., 900 cfs) and would limit off-take to a fixed upper limit (i.e., 100–200 cfs) is beyond the scope of this memorandum. As a brief assessment of feasibility, however, we can readily estimate the dimensions of a channel necessary to convey flows of this magnitude from an intake on the river to a spreading basin some distance down valley and outside of the left-bank levee. With a typical valley slope of about 16 feet per mile (0.3%), a rectangular concrete channel can convey 200 cfs with (for example) a flow depth of 4 feet and a width of 6.3 feet, or a depth of 3 feet and a width of 8.4 feet. These dimensions are of a scale that is unlikely to pose a critical constraint to feasibility.

2.5 Order-of-Magnitude Costs

Based on our review and experience in similar recharge projects, an order of magnitude cost of $10M may be considered for the infiltration project. A more likely range would be $4M– 8M, depending on several factors. These factors and considerations include those presented below.

- Project design and engineering support, from a detailed feasibility study to bid plans and specifications and construction oversight.

- Property purchase for a property of a target 10–20 acre size.
- Legal fees, possibly including the eminent domain/condemnation/lot split of a target property or properties.
- Permitting and CEQA/NEPA compliance is anticipated, costs assume that an EIR would need to be prepared for the project.
- Construction costs, would vary depending on distances of conveyance, intake points, etc. Key components will be monitoring wells, fish screen, intake structure, diversion channel, jack-and-bore through the levee, control gates or locks, flow metering, and transfer infrastructure to the basins themselves.
- Operations and maintenance costs will vary depending on use and degrees of damage by storms and high flows. Typical yearly maintenance would involve scarifying of the basin floors and clearing of the channel.

3 POTENTIAL INFLUENCE OF CLIMATE CHANGE

As noted in Stillwater Sciences (2012), precipitation records suggest little systematic change to rainfall over the western portion of the watershed between the pre- and post-dam periods, although average annual discharge in the (unregulated) Sisquoc River suggests progressively wetter conditions over the last 70 years of record (Figure 8), likely reflecting the increased frequency of strong El Nino years. Much of the increasing trend in average annual discharges is a result of a few very wet, high-flow years, with discharges well beyond the range needed for successful steelhead passage. For analytical purposes in assessing instream flows, the pre- and post-Twitchell periods have been treated as equivalent. Potential decadal-scale climatological influences, however (both in the past and in the future), cannot be dismissed entirely, and if these changes were to result in an increase in total runoff from the Sisquoc River, the need for future flow augmentation to achieve pre-Twitchell Dam fish passage might be reduced.

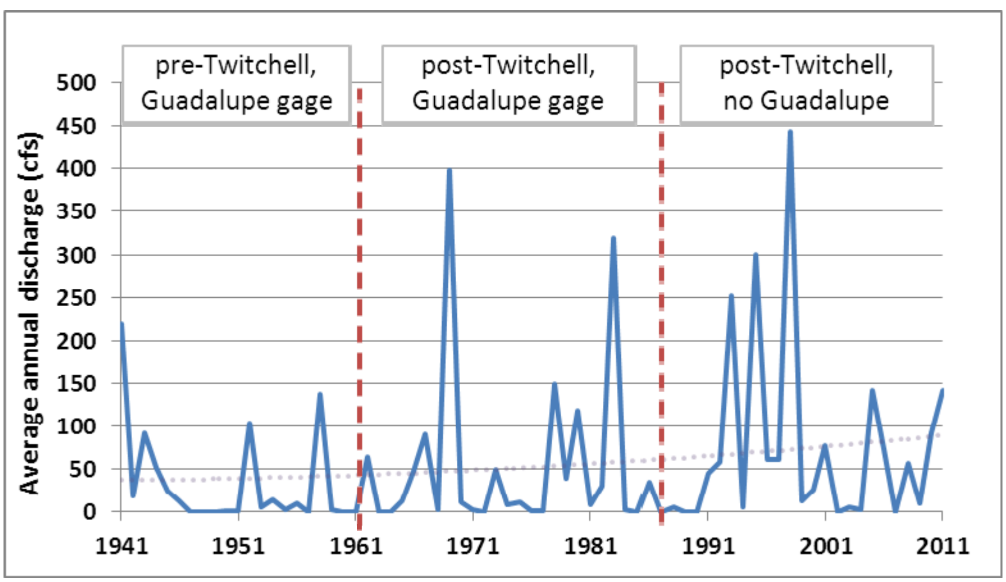

Figure 8. Average annual discharge in the lower Sisquoc River, as recorded at the Garey gage (USGS 11140000). Red dashed lines separate the major periods in the record; dotted light blue line is the second-order polynomial trend, which (in contrast to the rainfall

record) suggests progressively wetter conditions over this 70-year period (Figure 4.4-4 of Stillwater Sciences 2012).

Recent model simulations of precipitation changes under various future climate scenarios do not fully agree, but all suggest at most modest changes in the region that includes the Santa Maria River watershed as a whole. For example, ensemble models by Hayhoe et al. (2004) showed an average predicted decline in total precipitation of about one-half mm per day over the winter months December–February (i.e., a few inches); in contrast, Pan et al. (2011) predicts a virtually indiscernible increase. Although the observed increase in annual discharge of the Sisquoc River suggests the potential for reduced future need for supplemental water, little of the current research provides any basis for alternative planning.

4 NEXT STEPS

To further pursue the SHARP infiltration process, a variety of steps should be implemented. These coincide with internal and external steps relative to the instream flow study team.

Internal processes should include team discussions and meetings, refinement of the project as outlined herein. A review of the Santa Barbara County Integrated Regional Water Management Plan should be conducted to determine the relevance of the project to the IRWMP. Rough plans for funding should be considered.

External steps may include discussions with the IRWMP Team, Twitchell Management Authority, Santa Maria Valley Water Conservation District, stakeholder groups, and funding agencies.

Once a general consensus has been reached, and an avenue of funding sources is established, a series of increasingly detailed efforts should ensue:

1. A more detailed feasibility study than is presented herein should be conducted.
2. Properties should be identified and the feasibility of using them should be evaluated
3. The process of property acquisition/leasing/easement should commence.
4. Once properties are securely identified, a 30 percent level of design effort should be conducted.
5. Using the 30 percent design effort, the CEQA process should commence.
6. After CEQA/NEPA/EIR Certification, a 75 percent design should be conducted.
7. Upon review and deliberation of the 75 percent design, which may include the drilling of monitoring wells, a 90 percent design effort would ensue.
8. After final review of the 90 percent designs, a final design, including bid packages, plans, and specifications would be compiled.
9. Construction
10. Operation, maintenance, and monitoring.

5 REFERENCES

Dibblee, T. 1994. Geologic map of the Siquoc and Twitchell Dam quadrangles. Dibblee Geologic Foundation, scale 1:24,000.

Hanson, R. T., Izbicki, J. A., Reichard, E. G., Edwards, B. D., Land, M., Martin, P. 2009. Comparison of groundwater flow in Southern California coastal aquifers. Special Paper of the Geological Society of America 454: 345–373.

Hayhoe, K., Cayan, D., Field, C. B., Frumhoff, P. C., Maurer, E. P., Miller, N. L., Moser, S. C., Schneider, S. H., Cahill, K. N., Cleland, E. E., Dale, L., Drapek, R., Hanemann, R. M., Kalkstein, L. S., Lenihan, J., Lunch, C. K., Neilson, R. P., Sheridan, S. C., Verville, J. H. 2004. Emissions pathways, climate change, and impacts on California. Proceedings of the National Academy of Sciences of the United States of America 101: 12,422–12,427.

NMFS (National Marine Fisheries Service). 2012. Southern California steelhead recovery plan. Prepared by the Southwest Regional Office, Protected Resources Division, National Marine Fisheries Service, Long Beach, California.

Pan, L.-L., Chen, S.-H., Cayan, D., Lin, M.-Y., Hart, Q., Zhang, M.-H., Liu, Y., Wang, J. 2011. Influences of climate change on California and Nevada regions revealed by a high-resolution dynamical downscaling study. Climate Dynamics 37: 2,005–2,020.

Sheng, Z. 2005. An aquifer storage and recovery system with reclaimed wastewater to preserve native groundwater resources in El Paso, Texas. Journal of Environmental Management 75: 367–377.

Stillwater Sciences. 2012. Santa Maria River Instream Flow Study: flow recommendations for steelhead passage. Review Draft. Prepared by Stillwater Sciences, Santa Barbara, California and Kear Groundwater, Santa Barbara, California for California Ocean Protection Council and California Department of Fish and Game.

Todd, D. K. 1959. Annotated bibliography on artificial recharge of ground water through 1954. U.S. Geological Survey Water-Supply Paper 1477.

Weeks, E. P. 2002. A historical overview of hydrologic studies of artificial recharge in the U.S. Geological Survey. *In* G. R. Aiken and E. L. Kuniansky, editors. U.S. Geological Survey Artificial Recharge Workshop Proceedings, Sacramento, California, 2–4 April 2002.

Appendix A

Well Logs from the Vicinity of Figure 7

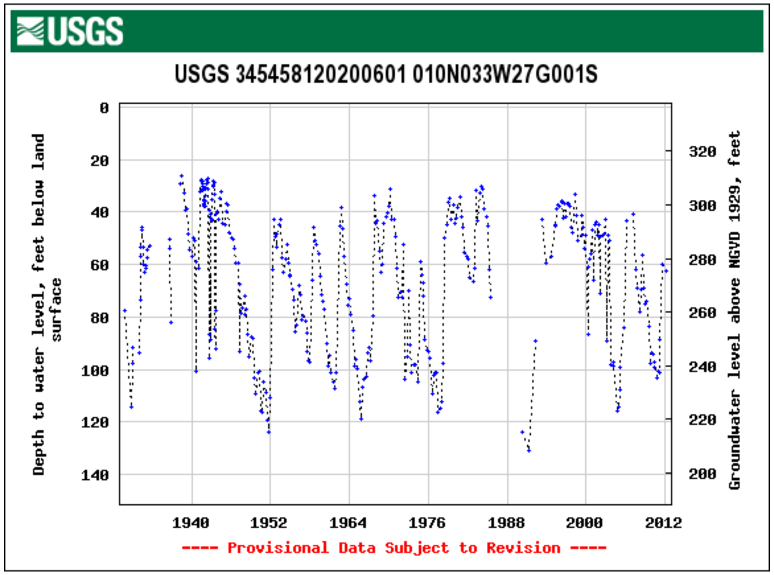

Figure A-1. Water Level Hydrograph of Well 27G1.

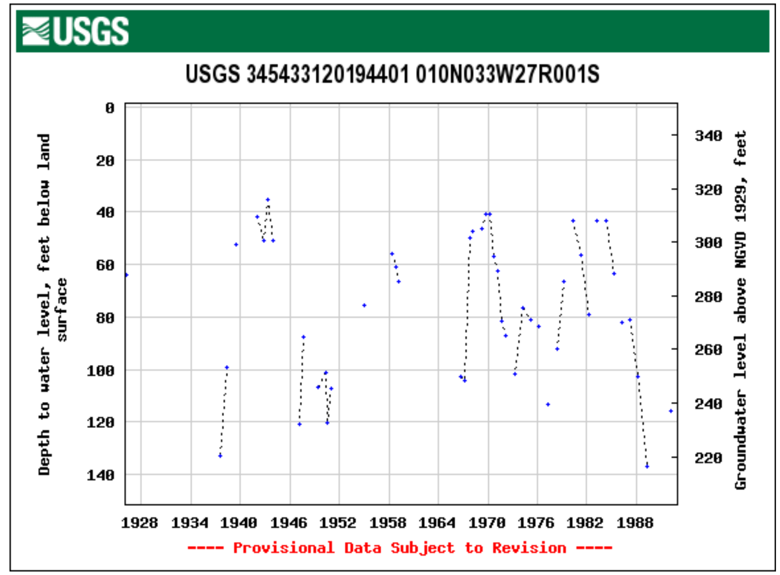

Figure A-2. Water Level Hydrograph of Well 27R1.

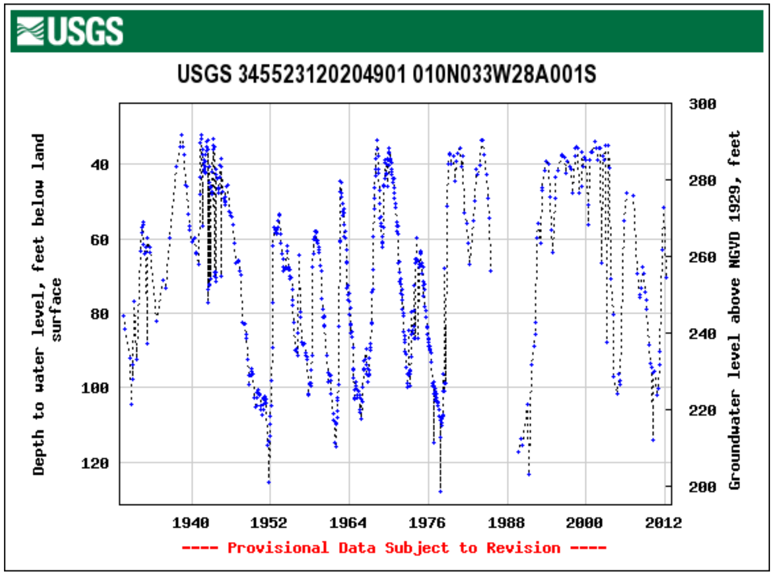

Figure A-3. Water Level Hydrograph of Well 28A1.

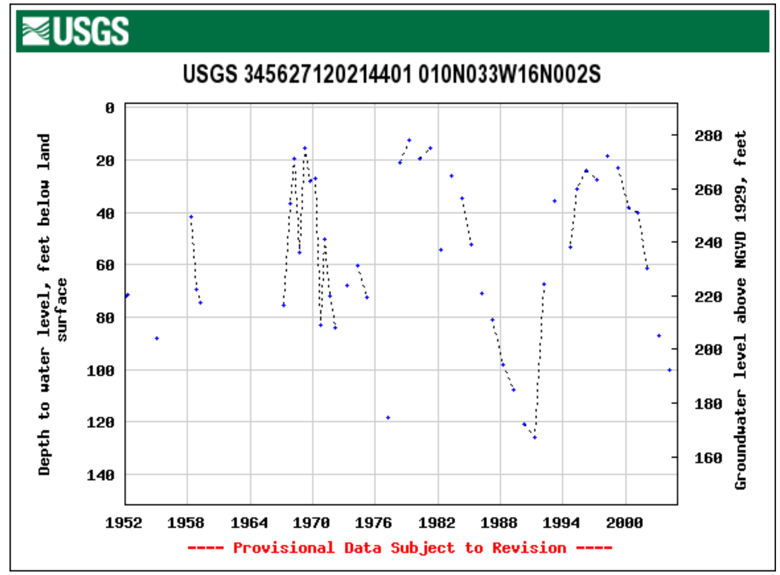

Figure A-5. Water Level Hydrograph of Well 16N2.

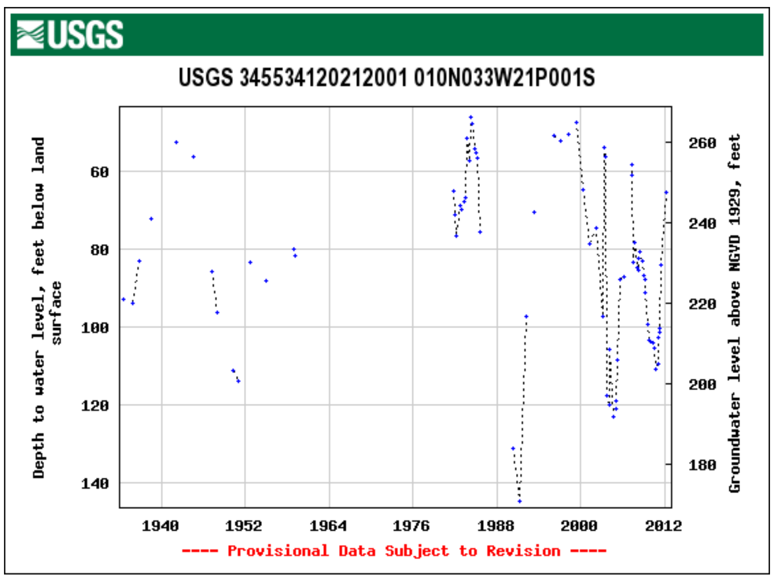

Figure A-4. Water Level Hydrograph of Well 21P1.

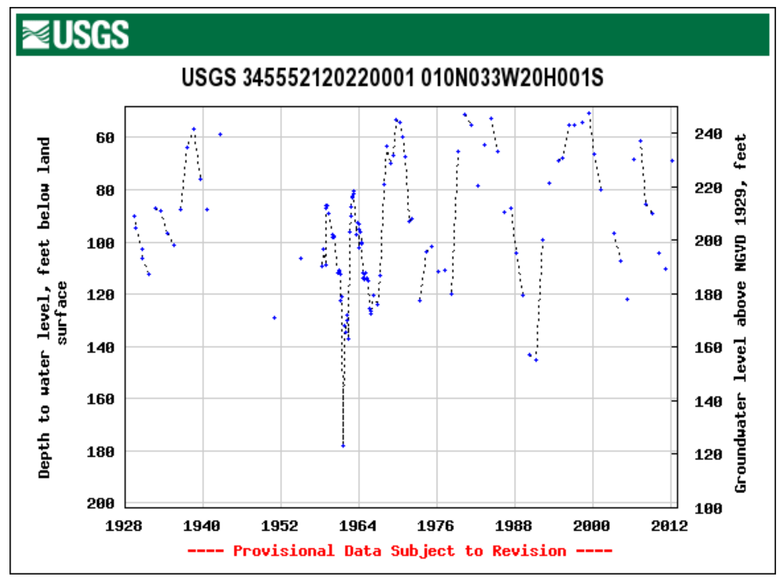

Figure A-6 Water Level Hydrograph of Well 20H1.