3.1 Master Response on Groundwater Recharge Estimates and Evaporation Estimates

3.1.1 Introduction

Overview

A number of comments raise concerns over groundwater recharge and evaporation estimates used in the groundwater impact analysis. Commenters express concern that the recharge and evaporation estimates might be overestimating the actual rates and cite previous estimates from other investigators that have presented lower estimates. The responses to comments on estimated recharge and evaporation are both included in this master response because the estimated volume of recharge to groundwater flowing through the Fenner Gap is approximately equal to the volume of water evaporation from the Dry Lakes.

This master response is organized by the following subtopics:

3.1.2 Recharge Estimates
3.1.3 Evaporation Estimates

3.1.2 Recharge Estimates

Summary of Issues Raised by Commenters

Commenters express concerns over groundwater recharge estimates used in the groundwater impact analysis. Commenters express concerns that the recharge estimate might be overestimating the actual recharge rate, cite previous estimates from other investigators that have presented lower estimates of recharge and suggest that the previous recharge estimates should be included in the analysis. In addition, commenters express concern that the areas west, south, and east of the Dry Lakes are not included in the recharge estimate, that groundwater from the carbonate unit should not be included in the recharge estimate, and that potential climate change of less snow and more rain would reduce recharge.

Response

As described in the Draft EIR Vol. 1, Section 4.9.1 Hydrology and Water Quality, pp. 4.9-32 to 4.9-39, numerous studies to determine estimates of groundwater recharge have been conducted over the years for the Fenner Watershed (Watershed) and the surrounding local area. The Draft EIR summarizes these recharge estimates and acknowledges that the historical range of estimated recharge for this Watershed is broad. However, the Draft EIR also notes that earlier efforts to estimate recharge were either general in nature (descriptive but with no actual recharge calculations) or relied on minimal sets of data and were consequently forced to make assumptions to account for the lack of extensive site specific data. For example, the California Department of

Water Resources' (DWR) Bulletin 118[1] estimated a total of 5,900 acre-feet per year (AFY) of recharge for Fenner, Bristol, and Cadiz Valleys. However, the estimate was based on minimal data from a few scattered wells (none of which were located within the Fenner Gap) and the DWR itself described the degree of knowledge possessed by the DWR back in 1975 when the estimate was made was "superficial for geology and limited for hydrology and water quality."

The primary reason for the broad range of prior estimates cited in the Draft EIR is the general lack of data available to previous investigators on which to base their estimates. The Fenner Watershed is vast, the underground geology is complex, and the earlier recharge estimates did not have available sufficient data or the modeling tools that are available today to account for these complexities. Therefore, earlier estimates did not have what was needed to render accurate calculations. Several of these prior estimates involved simple applications of Darcy's Law to groundwater flow through the Fenner Gap, in the absence of site specific data. Darcy's Law is an observationally-derived equation that describes the flow of a fluid through a porous medium. The law was formulated by Henry Darcy in the nineteenth century based on the results of experiments on the flow of water through beds of sand. It also forms the scientific basis of fluid permeability used in the earth sciences, particularly in hydrogeology. The accuracy of calculations based on Darcy's Law increases with the use of more site-specific information for its input parameters, as defined below.

The application of Darcy's Law involves computing the quantity of flow through the Fenner Gap with the following equation:

$$Q = TiL$$

- Q is the quantity of groundwater flow through the Fenner Gap (a volume over a specified time period, such as acre-feet per year) assumed to be equal to long-term average recharge,
- T is transmissivity which is hydraulic conductivity (e.g., in units of feet per year) multiplied by the average thickness (e.g., in units of feet) of the alluvium through the Fenner Gap),
- i is the hydraulic gradient (which is the average drop in groundwater levels (e.g., given in feet) over a specified distance (e.g., also given in feet) as determined from wells upgradient and downgradient of the Fenner Gap, and
- L is the average width (e.g., in units of feet) of the cross-section where underflow is being calculated.

Until the recent studies for the proposed Project, there was no data on the transmissivity of the carbonate aquifer. Site specific data was collected from boreholes and geophysical surveys (to estimate the thickness and extent of the alluvium), aquifer testing (to estimate hydraulic

[1] Department of Water Resources, California's Groundwater Bulletin 118, Joshua Tree Groundwater Basin, http://www.water.ca.gov/pubs/groundwater/bulletin_118/basindescriptions/7-62.pdf, accessed May 2012.

conductivity), and monitoring wells (to estimate hydraulic gradient). Recent aquifer testing revealed the carbonate aquifer as well as the faulted and fractured bedrock underlying the alluvium to be extremely transmissive, including the highly fractured zones parallel to the flow direction in the Fenner Gap. Traditionally, “bedrock” is considered non-water bearing. However in some cases the nature of the bedrock is such that it is able to transmit significant amounts of water through secondary porosity features (e.g., along fracture and fault zones). Detailed geologic mapping conducted for this investigation shows that the Fenner Gap has been subject to at least several distinct periods of faulting, resulting in bedrock units that show extensive fracture systems, with major fracture zones parallel to the flow of groundwater. Previous investigators did not have access to detailed geologic mapping because detailed maps based on field mapping and borehole data, including cores, did not exist. This additional information reveals that there is significantly more transmissive geologic material, and thus more flow through the Fenner Gap than previously estimated. In addition, precipitation estimates used in the earlier estimates were averaged over the entire 1,100 square mile Fenner Watershed. In contrast, Project modeling used localized data to more accurately estimate precipitation rates specific to each area of the Watershed.

The Draft EIR uses the most current and comprehensive estimate of recharge. The analysis employs the most recent recharge soil moisture budget model available (INFIL3.0), which was made available by the U.S. Geological Survey (USGS) in 2008. This 2008 model employs substantially more local data than was utilized for any other previous estimate. The new data include local precipitation and temperature data, as well as locally interpolated data by the Climate Prediction Center of the National Oceanic Atmospheric Administration (CPC NOAA), new geologic mapping of the specific area, data from many new exploratory borings and groundwater wells, water quality analysis, aquifer tests, and precipitation and elevation data. This data can be found in the Draft EIR Vol. 4, Appendix H1 Cadiz Groundwater Modeling and Impact Analysis. The INFIL3.0 soil moisture budget model results estimated the annual recharge of the Fenner and Orange Blossom Wash Watersheds to be 32,447 AFY based on extensive local precipitation records and accounting for increased precipitation with elevation.

This recharge estimate was used in the regional groundwater model (see Cadiz Groundwater Model Draft EIR Vol. 4, Appendix H1 Cadiz Groundwater Modeling and Impact Analysis) of the Fenner, Bristol, and Cadiz groundwater basins and was calibrated against historical groundwater level data as another means of assessing its validity. The data incorporated the watershed infiltration model (INFIL3.0) into the Cadiz Groundwater Model (based on MODFLOW) to estimate Project-related recharge and groundwater drawdown over a 50-year period. **Master Response 3.2** Groundwater Modeling provides additional detail on the modeling methods, input parameters, calibration methods, sensitivity analyses, and output results.

The work performed to calculate the recharge estimate, rounded down to 32,000 AFY was peer reviewed by leading experts on the Groundwater Stewardship Committee (GSC). The GSC was formed to review and evaluate the technical analysis conducted by CH2M Hill and Geoscience Support Services, Inc. (Geoscience) for the Project (that analysis is included in the Draft EIR Vol.4, Appendix H1 Cadiz Groundwater Modeling and Impact Analysis). The previous estimates did not undergo the same high level of peer review and verification. The GSC consists of twelve technical experts, university scholars, water utility providers, and non-profit professionals, described in the Draft EIR Vol. 2, Appendix B2 Groundwater Stewardship Committee October 2011 Summary of Findings and Recommendations, pp. 5 to11. In April 2012, the GSC reviewed the groundwater modeling and impact analysis and composed a Final Report regarding the proposed Project that is included in the Final EIR (Vol. 7, Appendix B1 Updated GMMMP, Sub-Appendix A Groundwater Stewardship Committee April 2012 Summary of Findings and Recommendations). The GSC affirmed the model results and proposed monitoring and mitigation strategies that were incorporated into the draft Groundwater Management, Monitoring, and Mitigation Plan (Draft GMMMP) (Final EIR Vol. 7, Appendix B1 Updated GMMMP). In summary, the extensive and detailed data generated from the site-specific investigations provides for a far more accurate estimate of recharge than previously possible.

In anticipation of concerns that the recharge rate estimate could be too high and may not adequately assess potential impacts of groundwater extraction and in recognition of the historical record of widely variable recharge estimates, the Draft EIR also evaluates and analyzes potential impacts at a broad range of recharge rates, including 32,000 AFY, 16,000 AFY, and 5,000 AFY. As a result, the Draft EIR evaluates and compares potential impacts inclusive of a broad range of groundwater estimates while using the same threshold of significance to evaluate each scenario.

The Draft EIR found that even at the most conservative recharge rate of 5,000 AFY, potential impacts from groundwater pumping are less than significant or less than significant with mitigation.

The following sections highlight the data used in previous estimates compared to the recent analysis and identify their deficiencies. This is followed with responses to comments on recharge from the areas west, south, and east of the Dry Lakes; groundwater within the carbonate unit; and the potential effects of climate change that may modify future precipitation trends.

National Park Service Recharge References

The National Parks Service (NPS) submitted a summary of recharge studies that have been conducted for the Fenner Watershed over the years by “other Investigators,” as listed below. The NPS list is a subset of the studies described in detail in the Draft EIR Vol. 1, Section 4.9.1 Hydrology and Water Quality, pp. 4.9-32 to 4.9-39.

INVESTIGATION METHOD	ANNUAL RECHARGE ESTIMATE (AFY)
Maxey-Eakin Method	
USGS	2,550-11,200
Durbin	5,000
Fenner Gap Groundwater Flow	
Friewald	270
La Moreaux	3,700
USGS	2,600-4,300
Chloride Mass Balance Method	
USGS	1,700-9,000
Durbin	2,000
Drawdown Associated with Cadiz Pumping	
Boyle	4,000
Evaporative Discharge from Dry Lakes	
NPS	4,700-7,800

The following sections describe these methods and results and analyze their reliability.

Maxey-Eakin Method

The Maxey-Eakin model is a basic empirical model that utilizes estimates of recharge for ranges of elevation zones based on average annual precipitation. NPS cites the following two reports that used the Maxey-Eakin method for estimating recharge:

- U.S. Geological Survey (USGS), *Review of the Cadiz Groundwater Storage and Dry-Year Supply Program Draft Environmental Planning Technical Report, Groundwater Resources, Volumes 1 and 2, 2000, Memorandum from J.F. Devine to M.S. Brady*, February 2000, estimates recharge at 2,550 to 11,200 acre-feet per year (AFY).

- Durbin, Timothy, *Comments on Draft EIR/EIS Cadiz Groundwater Storage Project Cadiz and Fenner Valleys, San Bernardino County, California*: Prepared for County of San Bernardino, February 21, 2000, in Bredehoeft, John, *Cadiz Groundwater Storage Project, Cadiz and Fenner Valleys, San Bernardino County, California*, August 2001, estimates recharge at 5,000 AFY.

These estimates of recharge based on the Maxey-Eakin Method are more than 10 years old. These studies were reviewed by Davisson and Rose of the U.S. Department of Energy Lawrence Livermore National Laboratory (LLNL) in 2000[2] who concluded that the estimates were too low because of incomplete assumptions. Davisson and Rose concluded that the USGS had underestimated recharge to the Fenner Watershed due to a lack of geographic scale and context in their analysis of precipitation-elevation data, a lack of observational experience in the Fenner

2 Davisson, M.L. and T.P. Rose, *Estimating Annual Precipitation in the Fenner Basin of the Eastern Mojave Desert, California*, U.S. Dept. of Energy, May 2000.

Watershed, and use of an uncalibrated Maxey-Eakin model. Neither of these estimates use recent site-specific geological and hydrological parameters.

In addition, Davisson and Rose pointed out that the eastern portion of the Mojave Desert, in which the Fenner Valley is located, receives relatively more precipitation than the western portion of the Mojave due to various environmental factors. Consequently, precipitation and recharge estimates from one particular area cannot necessarily be applied to another area, as is done with the Maxey-Eakin estimates in the two studies noted above.

All Maxey-Eakin estimates using data simply extrapolated from one geographic region to another are not as accurate as methods that are based on site-specific data. In 2000, when Davisson and Rose developed a separate, new Maxey-Eakin model of the Fenner Watershed employing only local precipitation data, as opposed to regional precipitation data trends from drier parts of the Mojave Desert, and developed Fenner Watershed-specific relations between precipitation and recharge, they estimated a recharge rate of up to 29,815 AFY and noted that the recharge rate could still be higher. This estimate is consistent with the 32,000 AFY estimated using site specific data and the INFIL3.0 soil moisture model.

Davisson and Rose suggested that a recharge rate of 7,864 AFY (which is based on very conservative assumptions, such as using regional precipitation trends instead of local precipitation and eliminating any recharge-resulting precipitation below 200 mm) would provide a "worst-case scenario" for environmental impact analysis. The Draft EIR modeled an even lower value of 5,000 AFY (Sensitivity Scenario 2, Draft EIR Vol. 4, Appendix H1 Cadiz Groundwater Modeling and Impact Analysis, p. 44) for an environmental worst-case assessment and concluded that the impacts would be less than significant or less than significant after mitigation.

Fenner Gap Groundwater Flow

NPS cites the following reports that attempted to estimate groundwater flow through the Fenner Gap:

- Friewald, David A., *Ground-Water Resources of Lanfair and Fenner Valleys and Vicinity, San Bernardino County, California*, USGS Water Resources Investigation Report 83-4082, July 1984, estimates groundwater outflow at the Fenner Gap at 270 AFY.

- LaMoreaux and Associates, 1995, *Technical Comments on Groundwater Recharge and Projected Drawdown Computations for Bristol-Cadiz Valley*, estimates groundwater outflow at the Fenner Gap at 3,700 AFY.

- USGS (2000) estimates groundwater outflow at the Fenner Gap at 2,600 to 4,300 AFY.

Friewald's 1984 USGS study estimated the groundwater outflow at the Fenner Gap at 270 AFY. However, this estimate used assumptions for the groundwater gradient, cross-section of the Fenner Gap, and transmissivity in a simple Darcy's Law equation calculation without localized data, as explained above. Data collected in support of the Draft EIR and derived from extensive geophysical testing, geologic mapping, test hole drilling, and aquifer testing in the Fenner Gap area has demonstrated that the assumptions used by Friewald are not representative of the hydrogeology of the

Fenner Gap. The transmissivity and cross-sectional area for groundwater flow assumptions made by Friewald were based on the specific capacity estimated from just one driller's well log. The estimates calculated for the Draft EIR were based on the extensive field testing and groundwater flow modeling that integrates all the available data and validates it through comparisons to historical and current measured groundwater levels. As a result, the Friewald estimate is not credible and far less reliable than the estimates in the Draft EIR.

The NPS comments also refer to a 1995 LaMoreaux study and another 2000 USGS study that estimated the groundwater outflow at the Fenner Gap at 3,700 AFY and 2,600 to 4,300 AFY, respectively. The NPS did not provide copies of these studies or directions on where to find them, and the USGS 2000 citation was incomplete. A diligent but unsuccessful effort was made to locate the documents but the studies do not appear to be readily or publically available. Nevertheless, both studies predate the site-specific investigations conducted in 2009 through 2011, as well as current USGS modeling software. Consequently, these estimates are not as accurate as the Project modeling methods, which are based on recent site-specific data and current USGS modeling techniques.

During the search for the referenced LaMoreaux study, two other LaMoreaux studies were located:

- LaMoreaux and Associates, March 10, 1995, *Isotopic Study of Groundwater: Proposed Bolo Station Landfill Site and Adjacent Areas, San Bernardino County, California*
- LaMoreaux and Associates, September 28, 1995, letter providing review comments on Interim Report, Evaluation of Water Resources in Bristol, Cadiz, and Fenner Basins, prepared by Geoscience Support Services

The March 1995 LaMoreaux study uses isotopic signatures of water samples collected in the area to age date groundwater. The age dates are noted to be semi-quantitative, that is, approximate. The age dates range from 2,300 years before present (bp) in groundwater collected from a well at a ranch at the foot of the Providence Mountains to 12,700 years bp for water collected from Well HAL-1 located at the northeastern edge of the Bristol Playa. The report concludes that most of the groundwater recharge is from upland bedrock areas of the surrounding mountains, which is shared by the more recent analysis.

The September 1995 LaMoreaux comment letter is a review of two reports they describe as preliminary. One of the reviewed reports is a previous water isotope study by another consultant and the other is the draft Geoscience report cited above. In the LaMoreaux review of the Geoscience draft report, LaMoreaux provides various criticisms of the methods and results for evaluating groundwater flow, recoverable groundwater, hydraulic gradient, and hydraulic conductivity. It should be noted that this Geoscience draft report was prepared at an early stage of the investigation, occurring before the subsequent collection of site specific data, recent pump tests, and the use of recent modeling software. In the LaMoreaux review, values considered as outliers were removed from the table of recharge estimates. The report concluded that recoverable water (recharge) should be estimated between 2,000 and 4,300 AFY. LaMoreaux conducted no studies of their own and provided no new input parameters; they only reworked the Geoscience data by discarding data points they felt were outliers.

The current Cadiz Groundwater Model, as discussed further in **Master Response 3.2** Groundwater Modeling, is based on extensive recent site-specific data and current modeling software.

Chloride Mass Balance Method

The NPS refers to two studies that used the chloride mass balance (CMB) method for estimating recharge: a 2000 USGS study that estimated 1,700 to 9,000 AFY and a Durbin study that estimated 2,000 AFY, both of which were reviewed in the Draft EIR. Neither of the studies was based on data from the local area. The input precipitation chloride value used for the CMB was taken from chloride data collected from precipitation in the Amargosa Desert of west central Nevada, located almost 200 miles north of the Fenner Watershed and in an area receiving precipitation that is influenced by the rain shadow effect of the Sierra Nevada Mountains. The Fenner Valley is not influenced by this effect.

The CMB method has been used to estimate recharge in arid and semi-arid environments. Required data for employing this method include estimates of annual precipitation, total chloride input (from dry fallout and precipitation), and pore-water chloride concentrations. Typically, the CMB method has been used to estimate ancient groundwater (pre-dating the current climate conditions) but has also been used to estimate recharge from recent land-use changes. According to an evaluation of the method prepared by Gee et al (2004),[3] the CMB method is best used to predict recharge rates that are generally very low, below a few millimeters per year (mm/yr) or less than an inch. The method is less reliable for recharge that is above a few mm/yr. Based on the recommendations in Gee, the CMB method would be less accurate for the Project area because the precipitation ranges from 3 to 10 inches (76 to 254 mm) per year.

Also, Wood (1999)[4] discussed that the CMB method is not accurate where chloride is being concentrated in the aquifer system. In the case of the Project area, once groundwater migrates to the Bristol and Cadiz Dry Lakes area, salts including chloride precipitate (solidify) out of the aqueous solution, thus concentrating chloride and changing the flux of chloride in the system at large. Therefore, the CMB method of estimating recharge is inappropriate for this Project.

In summary, the dates of both CMB estimates predate the site-specific investigations and the current USGS modeling software used to estimate recharge. Further, neither was based on data from the Project area. Consequently, the CMB estimates are not as accurate as the Project modeling methods that are based on recent site-specific data and more robust current USGS modeling techniques.

Drawdown Associated with Cadiz Inc. Pumping

NPS cited a Boyle Engineering letter[5] that provided comments on the Geosciences recharge estimates. The Boyle letter states that their "views are based on initial observations of material in reports without benefit of detailed analyses of basic data, a complete knowledge of the assumptions used, and consultations with independent knowledgeable parties."

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3 G. W. Gee, Z. F. Zhang, S. W. Tyler, W. H. Albright, M. J. Singleton, *Chloride-Mass-Balance for Predicting Increased Recharge after Land-Use Change*, Lawrence Berkeley National Laboratory, Permalink: http://escholarship.org/uc/item/3w70793z , February 23, 2004.

4 Warren A. Wood, *Use and Misuse of the Chloride-Mass Balance Method in Estimating Ground Water Recharge,* Groundwater, Volume 37, Issue No. 1, pp. 2-3, 1999.

5 Boyle Engineering, *Technical Review of Cadiz Land Company Water Resources Investigations,* Letter to Waste Management Inc., November 2, 1995.

Nonetheless, Boyle then provided his own recharge estimate of less than 4,000 AFY using a simple Darcy's law calculation. However, based on Geosciences assessment[6] of the Boyle estimate, the estimate is incorrect given that it is based on water level data from two wells not located within Fenner Gap and is thus not representative of the flow regime within the Gap. As a consequence, Geoscience concluded that Boyle underestimated the hydraulic conductivity and miscalculated the hydraulic gradient. In addition, the well data used for those two wells were recorded in 1903 and 1962, respectively; separated by 60 years of time and pre-dating the current investigations by 50 to more than 100 years.

The 1995 Boyle letter predates the site-specific investigations conducted by the Project. In addition, the report pre-dates the current USGS modeling software and the Boyle analysis did not employ a model. Consequently, even if the Boyle estimate had not used erroneous data, the Boyle estimate would still not be as accurate as the Project modeling methods that are based on recent site-specific data and robust current USGS modeling techniques.

Evaporative Discharge from Dry Lakes

The NPS comment letter also provides a recharge estimate of 4,700 to 7,800 AFY that appears to be derived by interpolating evaporation data from Death Valley. The letter implies that the Death Valley Watershed is seven times larger than the Fenner Watershed and should therefore have seven times more recharge and corresponding evaporation.

As discussed above, the precipitation patterns in local subregions in the Mojave Region are not interchangeable. The rate of precipitation is much higher in the Cadiz Valley area at 3 to more than 10 inches per year (Draft EIR Vol. 1, Section 4.9.1 Hydrology and Water Quality, pp. 4.9-7 to 4.9-9) versus the less than 2 inches per year average in Death Valley (http://www.nps.gov/deva/naturescience/weather-and-climate.htm). Death Valley is located in a rain shadow caused by the steep-walled north-south mountains that form its basin. The Fenner Valley is not located in this rain shadow. The differences in precipitation and topography indicate the two areas are fundamentally different and cannot be compared with a simplistic arithmetic ratio.

Similarly, evaporation estimates vary depending on site-specific conditions, such as depth to water, surface characteristics of the playa, soil properties, and groundwater quality. The NPS used evaporation data from Death Valley only. In addition, the USGS shows that evaporation from playas is much more variable than implied by the various commenters. Laczniak, et al. (2001),[7] who are also referenced by many of the USGS report authors, and DeMeo, et al. (2003),[8] cited by the NPS, present a broader study of evaporation rates of playas in California and Nevada. They

6 Geoscience Support Services Inc. Comments on Boyle Engineering Corporation's 2-Nov-95 Letter to Waste management Inc. Regarding Technical Review of Cadiz Land Company Water Resources Investigations, December 7, 1995

7 Laczniak, Randell J.; Smith, J. LaRue; Elliott, Peggy E.; DeMeo, Guy A.; Chatigny, Melissa A.; Roemer, Gaius J., 2001. *Ground-water discharge determined from estimates of evapotranspiration, Death Valley regional flow system, Nevada and California*. Water-Resources Investigations Report 2001-4195.

8 DeMeo, Guy A., Randal J. Laczniak, Robert A. Boyd, J. LaRue Smith and Walter E. Nylund, 2003. *Estimated Groundwater Recharge by Evapotranspiration from Death Valley, California, 1997-2001*. USGS Water-Resources Investigation Report 03-4254.

show evaporation rates ranging from 0.1 to 0.7 feet per year for bare soil playas and 0.7 to 1.8 feet per year for areas dominated by moist bare soils. As noted above, the aquifer modeling used in the Draft EIR is based on recent site-specific data and robust current USGS modeling techniques.

In the Fenner, Bristol, and Cadiz Watersheds, groundwater flows from the upper elevations toward the lowest points, which are the Bristol and Cadiz Dry Lakes. If it were not for the high evaporation rates in the desert, groundwater would exit the subsurface and form standing lakes at these low points in the valley. There are large areas on the Dry Lake surfaces where moist soils exist, demonstrating that the groundwater elevation is nearing ground surface elevations. However, the high evaporation rates prevent year-round ponding. In addition, capillary effects allow for evaporation of groundwater to the atmosphere when groundwater levels remain several feet below the surface, placing persistent evaporative pressure on the groundwater even when it is not visibly expressing to the surface.

In response to recommendations from commenters to conduct site-specific measurements of evaporation from the Bristol and Cadiz Dry Lakes, and upon recommendation by the Groundwater Stewardship Committee to collect such data, the Desert Research Institute (DRI) was retained to conduct measurements of evaporation from these playas (see Final EIR Vol. 7, Appendices L1 Estimated Evaporation From Bristol and Cadiz Dry Lakes and L2 Quantifying Evaporative Discharge from Bristol and Cadiz Dry Lakes). As discussed in the Draft EIR Vol. 1, Section 4.9.1 Hydrology and Water Quality, the estimated recharge of 32,000 AFY flowing through the Fenner Gap should be roughly the same as the evaporation rate.

DRI set up instrumentation on Bristol Dry Lake on May 4, 2011 and on Cadiz Dry Lake on July 20, 2011. This instrumentation is essentially identical to the instrumentation described by the USGS for measuring evaporation from Death Valley (DeMeo et. al., 2003). Based on DRI measurements, evaporation is estimated to be 0.18 feet per year and 0.48 feet per year from Bristol and Cadiz Dry Lakes, respectively, following within the range of Laczniak, et al. and DeMeo's estimates, as noted above. Using the evaporation foot print of these Dry Lakes, the annual evaporation is conservatively estimated to be 7,860 AFY for Bristol Dry Lake and 23,730 AFY for Cadiz Dry Lake for a combined volume of 31,950 AFY. This total evaporation estimate is roughly the same value as the recharge estimate of 32,000 AFY and therefore further supports the recharge estimate (see section 3.1.3 of this Master Response). As noted above, the evaporation rate for Cadiz Dry Lake is higher than for Bristol Dry Lake. This is consistent with the higher evaporation rate used in the Cadiz Groundwater Model to match the aquifer simulation with the observed water levels (see **Master Response 3.2** Groundwater Modeling). This assessment of evaporation rates from the Dry Lakes was subsequently peer reviewed by the GSC (Final EIR Vol. 7, Appendix B1 Updated GMMMP, Sub-Appendix A Groundwater Stewardship Committee April 2012 Summary of Findings and Recommendations). The DRI and CH2M Hill reports (with peer review) are included as Appendix L1 to the Final EIR. In summary, the DRI findings are consistent with the Draft EIR because the evaporation discharge study further supports the estimated recharge rate of 32,000 AFY. Because this information is consistent with the prior conclusions and impacts, it does not constitute significant new information that alters the outcome of the environmental analysis or require recirculation of the document (CEQA Guidelines § 15088.5).

Mean Estimate

The NPS comment letter averages the "other investigation" recharge estimates listed in their letter (which is not inclusive of all that have been reported) and offers the value of 4,100 AFY as a recharge estimate. This makes an invalid assumption that each of the recharge estimates is equally valid and comparable. Averaging such divergent estimates is not the best scientific practice when site-specific data and more robust methodologies are available. As discussed above, all of the other estimates relied on minimal sets of data, assumptions to account for the lack of extensive site-specific data, methods inappropriate for this location, and/or methods inappropriately applied. In summary, based on expert review, review of the most current scientific scholarship, none of the other estimates are as accurate as the Project modeling method that is based on recent and detailed site-specific data and robust current USGS modeling techniques. The mean average recharge estimate offered by NPS does not provide a useful or meaningful summary or an alternative to the far more rigorous estimate of 32,000 AFY.

Recharge from Areas West, South, and East of the Dry Lakes

Commenters express concern that recharge from areas west, south, and east of the Dry Lakes were not included in the recharge estimate. As discussed in **Master Response 3.2** Groundwater Modeling, the purpose of the recharge model is to estimate the volume of groundwater flowing through the Fenner Gap that could be recovered for beneficial use by the installation of a wellfield at Fenner Gap. The groundwater that flows through the Fenner Gap originates in the Fenner Valley, flows southward to and through the Fenner Gap, continues to the Dry Lakes where the water becomes saline and shallow, and ultimately evaporates.

Recharge to the areas west, south, and east of the Dry Lakes does not flow through the Fenner Gap and could not be recovered by the wellfield at the Fenner Gap since it is up-gradient to the northeast. It should be noted that although the combined areas west, south, and east of the Dry Lakes is a smaller area than the combined watershed areas of the Fenner and Orange Blossom Wash Watersheds (see Draft EIR Figure 4.9-1), these areas do contribute some recharge to the Dry Lakes which also would serve to reduce drawdown beneath the Dry Lakes caused by the pumping of groundwater at the Fenner Gap. However, this contribution of recharge would be relatively minor and would not affect the groundwater levels in the Fenner Gap.

Groundwater from the Carbonate Unit

Commenters express concern that the carbonate unit should not be included in the calculation of recharge estimate. As discussed in the Draft EIR (Vol. 1 Section 4.9 Hydrology and Water Quality, Section 4.9.1 Environmental Setting, p. 4.9-23 to 4.9-24), aquifer tests conducted in wells screened in the carbonate unit revealed that the carbonate unit contains groundwater available for recovery. The site-specific geological mapping and geophysical studies discussed in the Draft EIR (Vol. 4, Appendix H1 Cadiz Groundwater Modeling and Impact Analysis, Sub-Appendix B), show that the carbonate unit has secondary porosity from extensive fracturing and solution cavities. The pump test on Well TW-1, screened in the carbonate unit, indicated a discharge rate of 1,168 gallons per minute and a very high transmissivity of 3,083,500 gallons per day per foot (Draft EIR Vol. 4, Appendix H1 Cadiz Groundwater Modeling and Impact Analysis, Sub-Appendix C). Therefore, the carbonate unit is capable of producing significant volumes of groundwater for recovery and should be considered for an accurate calculation of recharge.

Potential Effects of Less Snow and More Rain on Recharge

Commenters express concern that if climate change results in increased temperatures that, in turn, result in changing the form of precipitation to less snow and more rain, that change could reduce seepage into the aquifer and thus reduce recharge. Winter precipitation that falls as rain instead of snow will still fall within a closed watershed (Draft EIR Vol. 1, Section 4.9.1 Hydrology and Water Quality, p. 4.9-18). As such, the runoff would still flow over the same bedrock fractures and permeable alluvial cover that the melted snow flow over once it melts in the warmer temperatures of the spring and summer. In addition, during the winter, the relatively cooler temperatures would also result in relatively low evaporation rates, which in turn would result in greater infiltration of surface water runoff into the aquifer system to depths.

The groundwater to be extracted by the Project is already in storage, flowing toward the Dry Lakes as indicated by the hydraulic gradient from the upper Watershed to the Fenner Gap (illustrated in Figure 4.9-6 of the Draft EIR). Yearly precipitation in the upper elevations of the Watershed over the next 50 years will not substantially affect the flow rates through Fenner Gap during the same period. Given this, the impacts of groundwater extraction, even considering a precipitation pattern change, would remain less than significant or less than significant with implementation of Mitigation Measures **AQ-5**, **GEO-1**, **HYDRO-2**, **HYDRO-3**, and **MIN-1**.

3.1.3 Evaporation Estimates

Summary of Issues Raised by Commenters

A number of comments raise concerns about the estimates of evaporation occurring from the local Dry Lakes. Commenters express concern that the evaporation estimates might be overestimated and that the data used for the calculations estimating evaporation rates may have been incomplete. Commenters also suggested conducting on-site evaporation studies on the Dry Lakes, a task that has now been completed.

Response

As described in the Draft EIR Vol. 1, Section 4.9.1 Hydrology and Water Quality, p. 4.9-22, water that enters the aquifer system in the Fenner Valley flows southward under the force of gravity through the Fenner Gap at depths of hundreds of feet. Groundwater level data provided in the Draft EIR shows the gradient of groundwater is from the upper reaches of the Fenner Watershed toward the Dry Lakes. Those detailed gradient measurements in the Fenner Gap area support the conclusion that groundwater is indeed flowing from the upper Watershed to the lower Watershed and towards the Dry Lakes. The rate of flow is dependent on this gradient, the volume of water recharged (both historically and currently), the local area geology, and the transmissivity of underlying aquifer materials.

As noted above and discussed in the Draft EIR Vol. 1, Section 4.9.1 Hydrology and Water Quality, pp. 4.9-15 to 4.9-18, all of the groundwater that passes through the Fenner Gap must migrate to the Dry Lakes because the groundwater passing through Fenner Gap is too deep to evaporate or be accessed by vegetation. As discussed in Vol. 4, Appendix H1 Cadiz Groundwater Modeling and Impact Analysis, p. 18, this also means that the annual average of 32,000 AFY estimated to pass through the Fenner Gap and the Orange Blossom Wash areas must all end up at the low points of the Dry Lakes because the Watershed is a closed basin and there is nowhere else for the groundwater to drain. This groundwater ultimately evaporates (if it did not, there would be a year-round standing lake, which is not the case) (Draft EIR Vol. 1, Section 4.9.1 Hydrology and Water Quality, p 4.9-16). Therefore, the recharge rate of groundwater passing through Fenner Gap is approximately equal to the evaporation rate of that same water once it reaches the Dry Lakes and evaporates.

Some commenters express the concern that, similar to the recharge rate, the evaporation rate might be overestimated. For example, the NPS comment letter provides a recharge estimate of 4,700 to 7,800 AFY that appears to have been derived by interpolating evaporation data from Death Valley. The comment implies that the Death Valley Watershed is seven times larger than the Fenner Watershed and should therefore have seven times more recharge and corresponding evaporation. The Center for Biological Diversity-NPCA et al. comment letter also suggests an evaporation estimate of 8,947 AFY based on Death Valley data.

However, as discussed above, the precipitation patterns in local subregions in the Mojave Region are not interchangeable, as shown by the much higher rate of precipitation in the Cadiz Valley area (3 to more than 10 inches per year) compared to the less than 2 inches per year average in Death Valley (http://www.nps.gov/deva/naturescience/weather-and-climate.htm). The two areas are fundamentally different and cannot be compared with a simplistic arithmetic ratio. Similarly, evaporation estimates also vary depending on site-specific conditions. As with the recharge estimates, for evaporation estimates the NPS used evaporation data from Death Valley only. As previously noted, the USGS shows that evaporation from disparate playas is much more variable than implied by the various commenters and thus rates for one area are not necessarily interchangeable with another area.

As discussed above in section 3.1.2, in response to recommendations to conduct site-specific measurements of evaporation from the Bristol and Cadiz Dry Lakes, and upon recommendation by the Groundwater Stewardship Committee to collect such data, DRI was retained to conduct measurements of evaporation from these playas (see Final EIR Vol. 7, Appendices L1 Estimated Evaporation From Bristol and Cadiz Dry Lakes and L2 Quantifying Evaporative Discharge from Bristol and Cadiz Dry Lakes). Based on their measurements, the annual evaporation is conservatively estimated to be 31,590 AFY for Bristol and Cadiz Dry Lakes combined, which is roughly the same value as the recharge estimate (32,000 AFY) and therefore further supports the recharge estimate. The collection of site-specific evaporation data provides an accurate measurement of discharge at the Dry Lakes, one that does not rely on extrapolations from locations outside of the area.