Appendix G
Water Quality Supporting Documents

Appendix G1

Ocean Dilution Analysis Technical Memorandum

Technical Memorandum

Malibu Civic Center Wastewater Treatment Facility Project

Subject: **Ocean Dilution Analysis**

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This Technical Memorandum (TM) was prepared to evaluate the potential impacts of recycled water injections into the Malibu Valley Groundwater Basin on offshore (ocean) water quality as a result of the groundwater transport to and diffusion of injected water into Santa Monica Bay.

1 Introduction

On-site wastewater disposal systems (OWDS) have allegedly contributed to the non-point source pollution of Malibu Creek and Lagoon, resulting in the Los Angeles Regional Water Quality Control Board (RWQCB) adopting Resolution R4-2009-007 in November 2009. This resolution approved an amendment to Chapter IV of the *Water Quality Control Plan for the Coastal Watersheds of Los Angeles and Ventura Counties* (Basin Plan) prohibiting OWDS and OWDS discharges in the Malibu Civic Center Area. In 2010, the State Water Resources Control Board (SWRCB) adopted Resolution 2010-0045 which approved the amendment and established a phased schedule for compliance. The resolutions prohibit all new OWDSs and discharges from existing systems based on a phased schedule to cease discharges from Phase 1 systems by November 5, 2015 and Phase 2 systems by November 5, 2019. A third phase may be implemented, if necessary, following operation of Phase 1 and 2, and upon completion of a water quality sampling program to determine if implementation of Phases 1 and 2 have resulted in a meaningful decrease in Bacteria and Nitrogen in Malibu Lagoon.

The Phase 1 and 2 OWDS systems were defined in the resolutions and have become known as "The Prohibition Zone." An August 2011 Memorandum of Understanding (MOU), signed by both the City of Malibu (City) and the LA RWQCB, memorializes the requirements of the resolutions and defines the Prohibition Zone areas. Following execution of the MOU, the City embarked on a program to design and construct a centralized wastewater collection, treatment and disposal system for the Civic Center area of the City and a small portion of unincorporated Los Angeles County. This program includes the construction of the Civic Center Wastewater Treatment Facility (CCWTF), where wastewater from the Prohibition Zone will be collected and treated to a standard set forth in Title 22 of the California Code of Regulations (CCR) for unrestricted reuse of disinfected tertiary recycled water. The resultant recycled water will be used for landscape irrigation within the Civic Center and surrounding areas to the maximum extent possible; however, anticipated irrigation demands are not expected to utilize all recycled water generated by the CCWTF. Recycled water not used for landscape irrigation will be injected into the underlying Malibu Valley Groundwater Basin for disposal or percolated into the aquifer in Winter Canyon.

2 Background and Project Design

Over the past five years, several hydrogeological field investigations and studies have been conducted in the Malibu Valley Groundwater Basin to understand the structure of the basin's aquifers and flow system. These investigations and studies have included field sampling programs (including the installation of monitoring wells and aquifer pumping and injection testing), geophysical surveys (seismic reflection and electrical resistivity surveys) and paleo-hydrogeologic analyses (including the carbon-dating of wood samples found in the subsurface during boring). Data generated by these studies have resulted in the mapping of an ancient buried channel of Malibu Creek, estimated to be 60,000 years old. This channel appears to be located predominantly on the west side of the groundwater basin, and continues offshore (the red channel delineated in Figure 1). 'Fresh' groundwater appears to be flowing in this subsurface channel from the inland portions of the groundwater basin to the Pacific Ocean (offshore groundwater gradient), with 'fresh' water emerging offshore from the ocean floor at distances between 300 feet (based on the electrical resistivity survey conducted on the near-shore and offshore environment (Figure 2) and 1,000 feet (based on the ocean seismic reflection survey, (Figure 3) offshore. Figure 4 is a conceptual block diagram of the near-shore hydrogeology.

Figure 1: Location of Buried Ancient Malibu Creek Channel

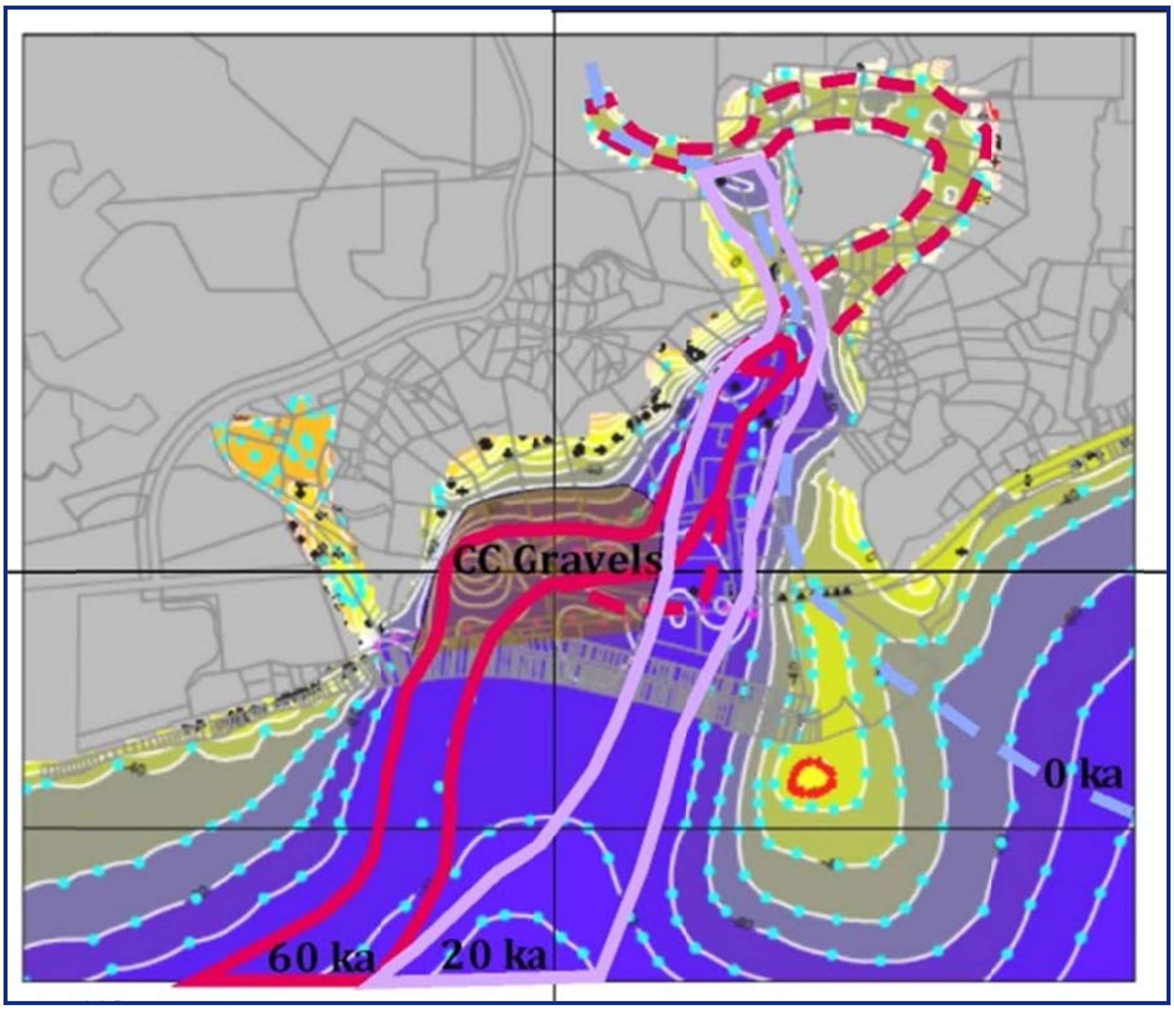


Figure 2: Results of Electrical Resistivity Survey

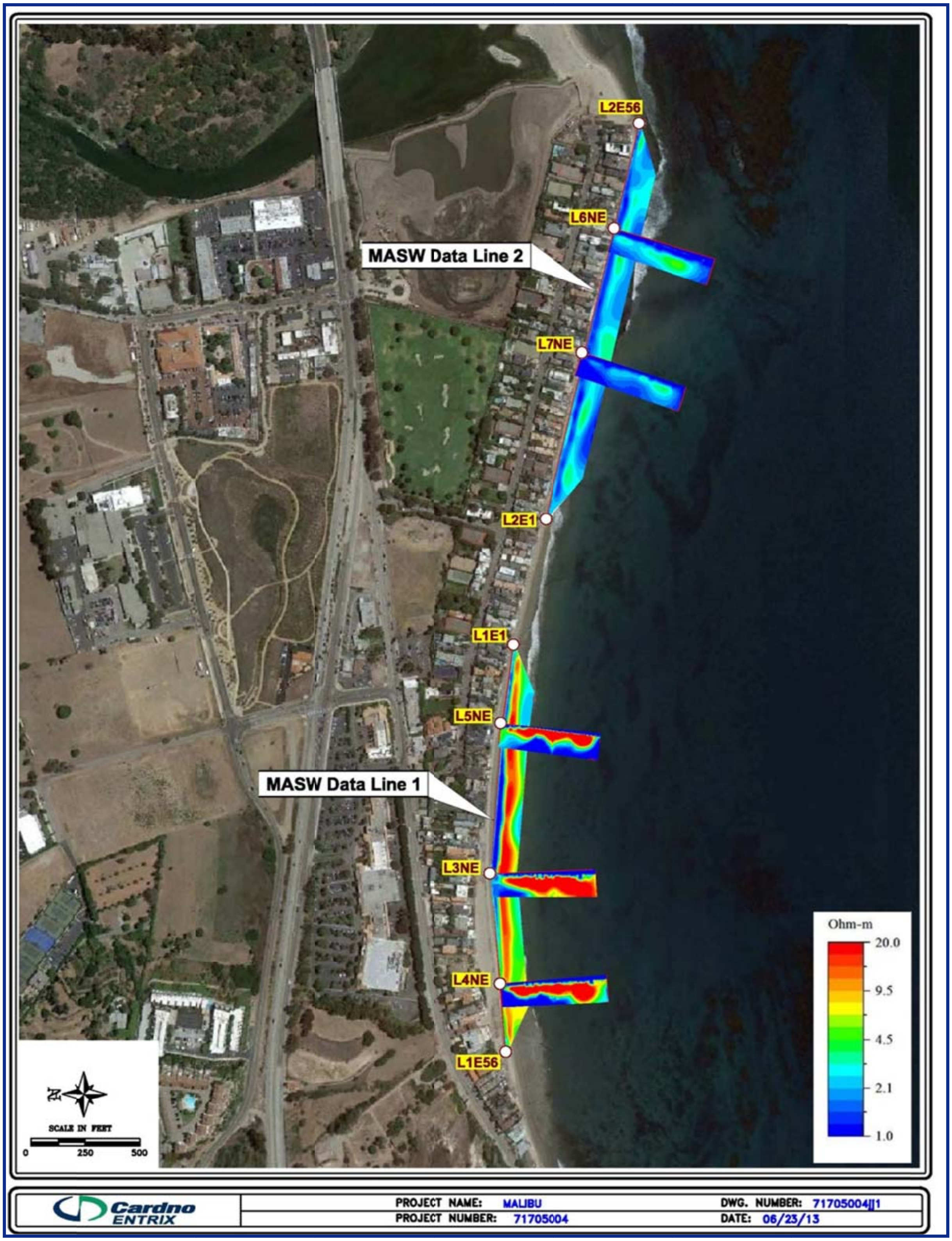


Figure 3: Results of Off-Shore Seismic Reflection Survey

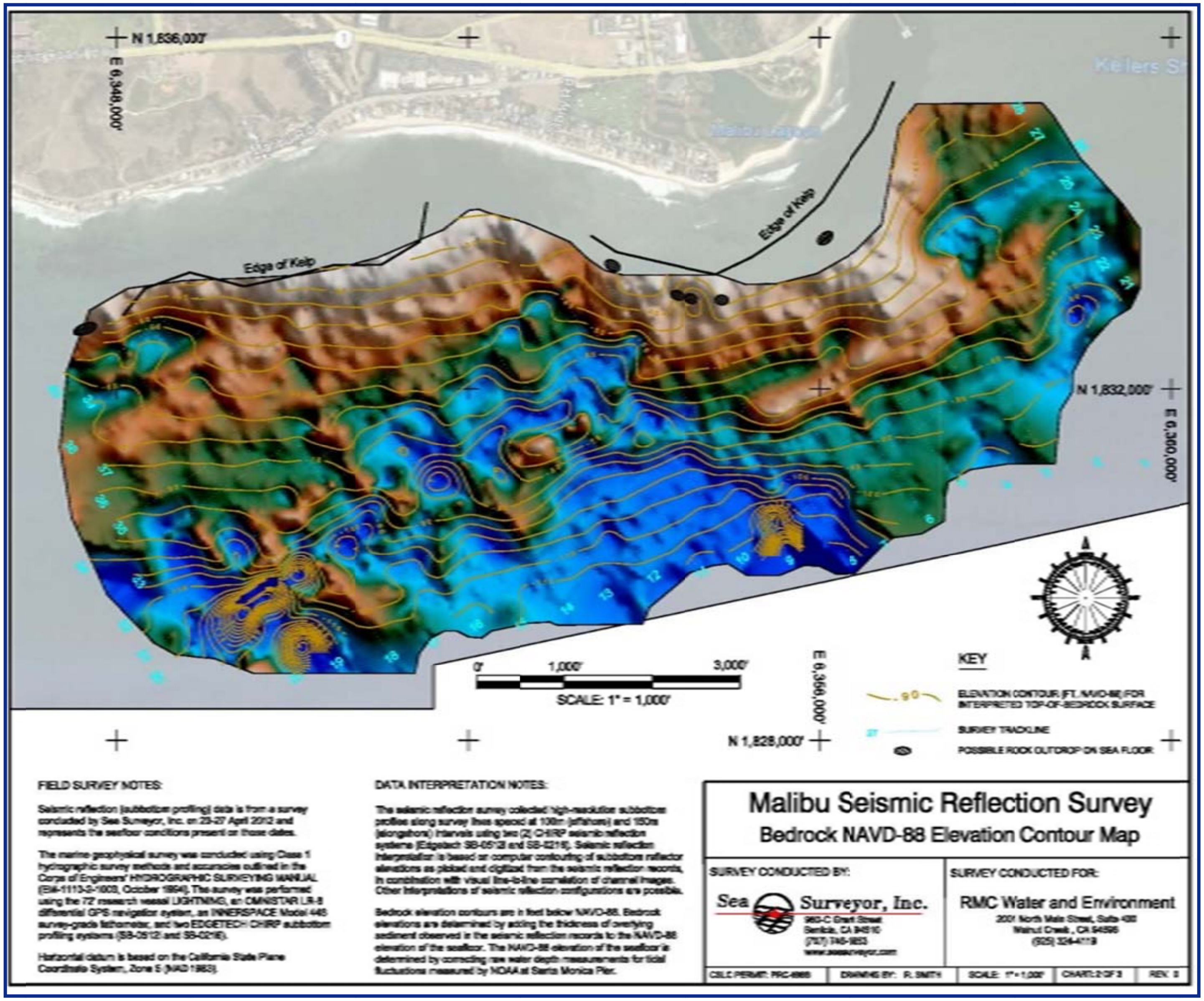
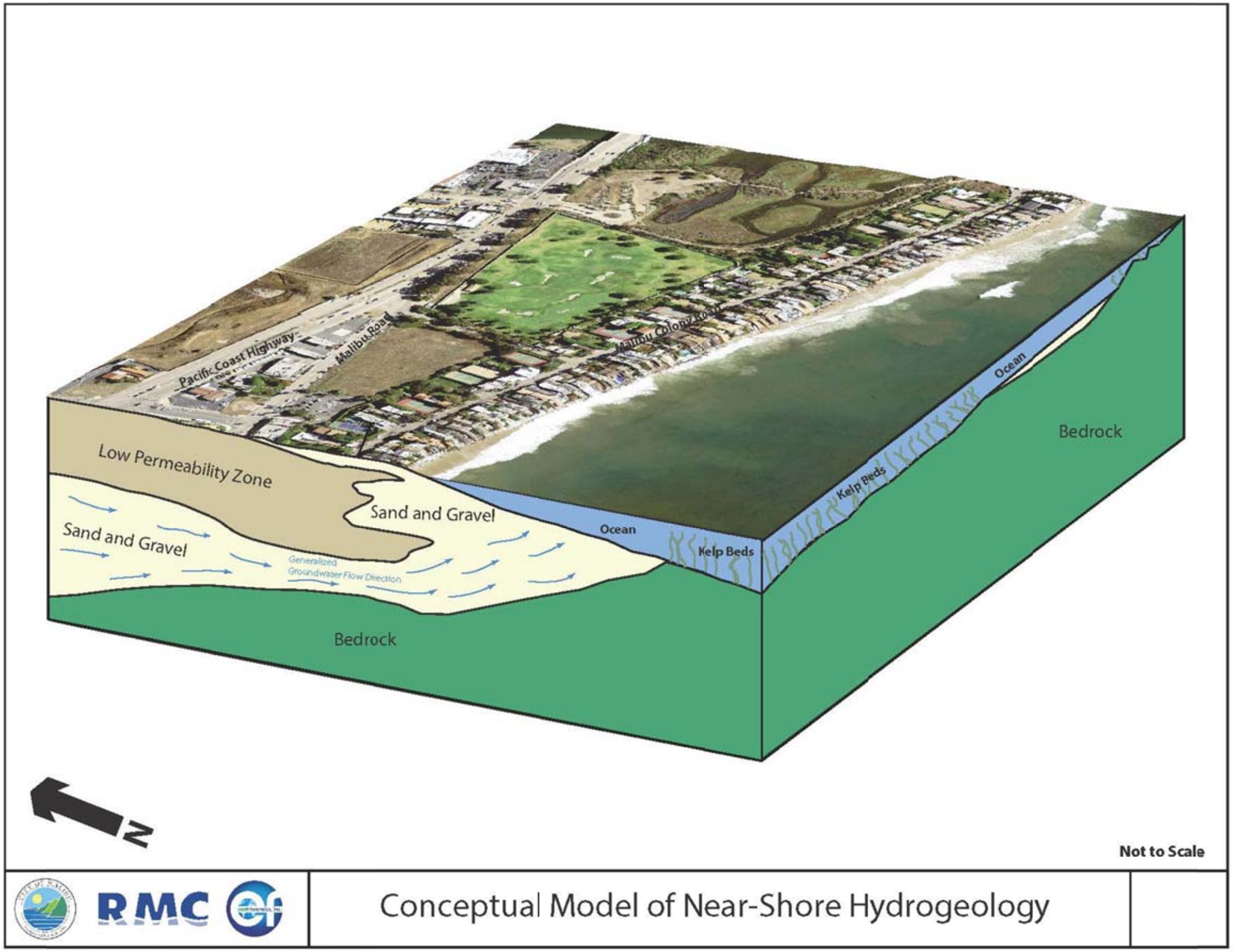


Figure 4: Conceptual Block Diagram of Near-Shore Hydrogeology



2.1 Project Simulation

Using data from the afore-mentioned field studies, a MODFLOW numerical groundwater flow model of the Malibu Valley Groundwater Basin was developed to simulate groundwater flow processes within the basin. The model was calibrated to existing groundwater elevation data and results from the 2013 injection testing. The calibrated MODFLOW model was then used to estimate the maximum volume of water that could be injected into the groundwater basin, and the best locations for that injection to occur. The flow paths for the injected recycled water were also simulated using a numerical particle tracking model called MODPATH6 to determine if any injected water is expected to reach either Malibu Creek or Lagoon.

2.2 Project Design

The model simulation results recommended that recycled water injection occur in three wells situated along Malibu Road (Figure 5). Table 1 summarizes the injection capacity needed for each project phase along with the maximum injection rates that were estimated by the MODFLOW model for each phase.

The maximum injection rates were used in the model to estimate combined groundwater-injected water flux (flow) rates from the groundwater basin to the ocean. Because the injected volume is, in all phases, more than that which will actually occur when the project is operational, the volume of injected water that could potentially migrate to and impact ocean water quality, as evaluated in this analysis, is conservative. Furthermore, the modeling indicated that all injected water will flow to the ocean in all phases of the project and will not impact Malibu Creek or Lagoon.

Figure 5: Location of Proposed Injection Wells

Table 1: Injection Capacity and Injection Requirements

	Phase 1	Phase 2	Phase 3
Injection rate needed for project operation (gpd)	191,000	170,000	146,000
Simulated injection rate (gpd)	311,135	497,642	611,654

gpd – gallons per day

In summary, when the CCWTF is operational, recycled water not used for irrigation purposes will be injected into the ancient buried Malibu Creek streambed channel at the locations shown in Figure 5, where it will blend with ambient groundwater as it flows offshore.

3 Ocean Dilution Analyses

As blended groundwater-injected water moves offshore, density differences between the ‘fresh’ groundwater and surrounding ocean water will result in the diffusion of groundwater from the buried channel, through ocean floor, and into the ocean water column, as the ancient stream channel begins to thin as it moves further from land towards higher bedrock elevations located approximately 1,000 feet offshore (Figure 4). In order to evaluate the potential for ocean water quality impacts resulting from this diffusion, analyses were conducted to approximate the ratio of groundwater to ocean water column dilution that could potentially occur.

The ocean dilution analyses were conducted using a simplified analytical model assuming complete instantaneous mixing of ocean water with groundwater-injected recycled water diffusing up through the ocean floor. The analyses assumed that the groundwater would diffuse through the ocean floor over an area extending approximately 270 feet offshore (the length of the electrical resistivity survey), across an area approximately 1,320 feet along the shoreline (the approximate cross-sectional length identified by the electrical resistivity survey), and over a depth of approximately 30 feet, as shown in Figure 6, below. The volume of water encompassed by a ‘box’ this size and available for mixing is 10,692,000 cubic feet or 80 million gallons. Assuming that this volume or box is ‘flushed’ or changed out by daily tidal cycles (which occur, on average, twice a day), there is approximately 160 million gallons per day (mgd) of ocean water in the ‘box’ available for mixing.

Figure 6: Ocean Mixing Volume

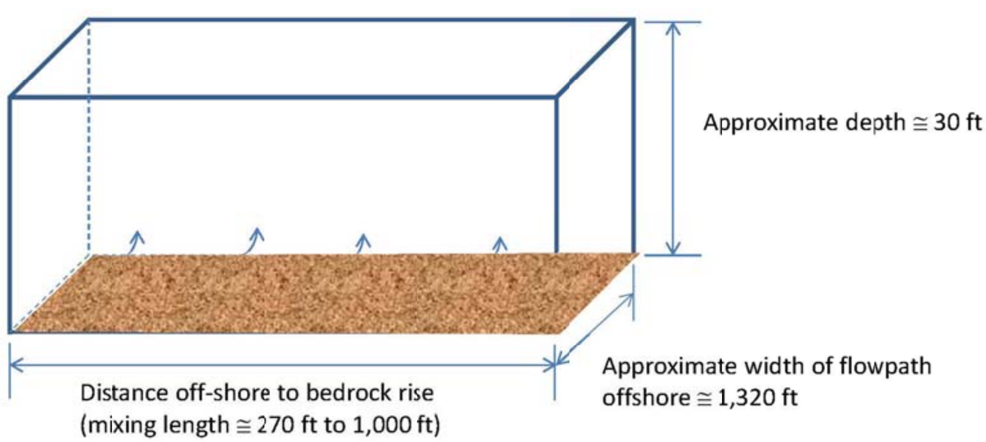


Table 2 summarizes the annual average flux (or flow) from the groundwater basin to the ocean as simulated by the MODFLOW model for each phase of the project. The larger increase in flux rates between current and Phase 1 conditions (versus Phase 1, Phase 2 and Phase 3 conditions) reflects discharges associated with the new planned commercial developments that would occur in the Civic Center area as a result of Project implementation. These flux values were compared to the volume of ocean water available for mixing (160 mgd) to provide an approximately ocean dilution ratio by project phase.

Table 2: Average Annual Flux to Ocean and Ocean Dilution Ratios

	Current Conditions	Phase 1	Phase 2	Phase 3
Annual average flux rate from groundwater basin to ocean (mgd)	0.88	0.98	1.00	1.02
Blended groundwater water to ocean dilution ratio[1]	1:182	1:163	1:160	1:157

Note:

1. Assuming 160 mgd of ocean dilution volume

A common 'rule of thumb' used in evaluating effluent discharges to water bodies is the requirement for complete dilution at a ratio of 1:10 effluent to surface/ocean water (Schnurbusch, 2000; Fischer et al., 1979; Wisconsin Department of Natural Resources, 1992). An additional analysis was therefore conducted to estimate the mixing depth required within the 'box' shown in Figure 6 to achieve this 1:10 dilution ratio. The results of this analysis are shown below in Table 3.

Table 3: Mixing Depth to Achieve Ocean Dilution Ratio of 1:10

	Current Conditions	Phase 1	Phase 2	Phase 3
Annual average flux rate from groundwater basin to ocean for 1:10 ocean dilution (mgd)	8.8	9.8	10.0	10.2
Depth from ocean floor for 1:10 ocean dilution (feet)	1.65	1.83	1.87	1.91

To provide a similar analysis of potential impacts to groundwater quality, instantaneous mixing analyses were conducted assuming specified concentrations for constituents of concern: nitrate (as N) and residual chlorine. TDS was not analyzed due to the dominant seawater impacts on TDS concentrations.

3.1 Nitrate as N

In order to estimate potential changes in nitrate concentrations in the nearshore environment resulting from onshore recycled water injection, the afore-mentioned methodology was used in a mass balance approach. This analysis assumed that the injected water-groundwater blend had a nitrate concentration of 8 mg/L (the anticipated nitrate concentration of the treated recycled water) and that ambient (native) ocean water had a nitrate concentration of 1.5 mg/L (estimated based on groundwater data from wells screened in the Civic Center Gravels). This analysis is conservative in that it assumes that water diffusing up from the ocean floor would have the concentration of treated effluent, rather than a blend of native groundwater and treated effluent.

Assuming these concentrations, the following results were calculated (Table 4). While there is no watwer quality objective (WQO) for nitrate in the *Water Quality Control Plan, Ocean Waters of California* (Ocean Plan), overall, ocean water concentrations will increase negligibly as a result of the Project.

Table 4: Estimated Nitrate Concentration Impacts to Ocean Water Quality

	Current Conditions	Phase 1	Phase 2	Phase 3
Annual average flux rate from groundwater basin to ocean (cu.ft./day)	117,635	130,763	133,532	136,008
Groundwater nitrate contribution assuming 8 mg/L (lbs/day)	58.75	65.31	66.69	67.93
Volume of ocean water for mixing assuming 10 feet for mixing depth (cu.ft./day)	7,128,000	7,128,000	7,128,000	7,128,000
Volume of ocean water for mixing assuming 30 feet for mixing depth (cu.ft./day)	21,384,000	21,384,000	21,384,000	21,384,000
Ambient nitrate mass in 'Mixing Box' assuming 10 feet for mixing zone (lbs/day)	667.48	667.48	667.48	667.48
Ambient nitrate mass in 'Mixing Box' assuming 30 feet for mixing zone (lbs/day)	2,002.45	2,002.45	2,002.45	2,002.45
Nitrate concentration in 'Mixing Box' assuming 10 feet for mixing zone (mg/L)	1.61	1.62	1.62	1.62
Nitrate concentration in 'Mixing Box' assuming 30 feet for mixing zone (mg/L)	1.54	1.54	1.54	1.54

Notes:

1. Assumes mixing length of 270 feet offshore and twice-daily flushing due to tides.
2. Assumes a groundwater nitrate concentration of 8 mg/L and an ambient ocean water nitrate concentration of 1.5 mg/L.

3.2 Residual Chlorine

A similar analysis was then conducted to evaluate the potential movement of residual chlorine in the injected recycled water and subsequent changes in chlorine concentrations in the nearshore environment. The Ocean Plan contains the following WQOs for total residual chlorine:

- 2 µg/L 6-Month Median
- 8 µg/L Daily Maximum
- 60 µg/L Instantaneous Maximum

The same mass balance approach as previously described was applied for residual chlorine, assuming that the injected water-groundwater blend had a residual chlorine concentration of 2 mg/L (the planned residual chlorine concentration of the treated recycled water at the plant site) and that ambient (native) ocean water has a residual chlorine concentration of 0 mg/L. As before, this analysis was simply a mass balance and did not account for chlorine decay through transformation and chemical interactions as the recycled water moves through the distribution system and through the groundwater system. There will be significant time for chlorine decay because injected recycled water will take between approximately 5 and 15 years to reach the ocean. Residual chlorine decay follows a first order reaction that is dependent on several site-specific variables, including chlorine concentration, temperature, dissolved organic content concentration and the number of reducing sites on soils in the subsurface environment. In comparison, complete chlorine decay in water distribution pipelines can occur over a matter of days to weeks. Therefore, this analysis is conservative in that it assumes that water diffusing up from the ocean floor would have experienced no decay.

Using the assumptions described above, the following results were calculated (Table 5).

Table 5: Estimated Residual Chlorine Concentration Impacts to Ocean Water Quality

	Current Conditions	Phase 1	Phase 2	Phase 3
Annual average flux rate from groundwater basin to ocean (cu.ft./day)	117,635	130,763	133,532	136,008
Groundwater chlorine contribution assuming 2 mg/L (lbs/day)	0	5.19	8.31	10.21
Volume of ocean water for mixing assuming 10 feet for mixing depth (cu.ft./day)	7,128,000	7,128,000	7,128,000	7,128,000
Volume of ocean water for mixing assuming 30 feet for mixing depth (cu.ft./day)	21,384,000	21,384,000	21,384,000	21,384,000
Ambient chlorine mass in 'Mixing Box' assuming 10 feet for mixing zone (lbs/day)	0	0	0	0
Ambient chlorine mass in 'Mixing Box' assuming 30 feet for mixing zone (lbs/day)	0	0	0	0
Chlorine concentration in 'Mixing Box' assuming 10 feet for mixing zone (µg/L)	0	11.46	18.32	22.51
Chlorine concentration in 'Mixing Box' assuming 30 feet for mixing zone (µg/L)	0	3.87	6.18	7.60

Notes:

3. Assumes mixing length of 270 feet offshore and twice-daily flushing due to tides.
4. Assumes a groundwater residual chlorine concentration of 2 mg/L and an ambient ocean water residual chlorine concentration concentration of 0 mg/L.

While the resulting concentrations are higher than the 6-Month Median WQO, they remain within the Daily Maximum WQO. And more importantly, the values presented in Table 5, above, are extremely conservative in that they do not account for the additional decay of chlorine in the distribution system and in the groundwater system as the injected water moves over a period between 5 and 15 years to the ocean, nor do they account for additional mixing that will occur in the open ocean environment as a result of density differences and wind and tidal-related mixing influences. Considering these additional factors, it is extremely likely that the concentration of residual chlorine reaching the ocean, if measurable, will be extremely small and below the Ocean Plan WQOs.

4 Conclusions

The anticipated volume of mixed groundwater-injected water that will be diffusing from the ocean floor is very small relative to the column of ocean water that will be present above its flow path. Based on the analysis documented here, a 10 part ocean water dilution is expected to occur within less than 2 feet of the ocean floor. Therefore, the mixing of waters will occur quickly and will not likely result in any significant changes to ocean water quality. Additionally, the Waste Discharge Requirement (WDR) permit that the RWQCB will be issuing for the Project will require monitoring of both recycled water and groundwater quality as part of the compliance requirements. This monitoring will also ensure that groundwater quality, and therefore ocean water quality, impacts will not be significant.

This analysis was strictly a simplified analytical model assuming the complete instantaneous mixing of ocean and groundwater-injected recycled water and did not account for other ocean dynamics, such as density differences and wind and tidal-related mixing influences that would further stimulate the rapid mixing of waters.

5 References

Cardno Entrix. 2013. *The City of Malibu Shoreline Geophysical Survey Report*. July 10.

Fischer, Hugo B., E. John List, Robert C. Y. Koh, Jorg Imberger and Norman H. Brooks. 1979. *Mixing in Inland and Coastal Waters*. p. 391.

McDonald Morrissey and Associates. 2014. *Groundwater Modeling Analysis of Proposed Waste Water Dispersal – City of Malibu, California*.

RMC Water and Environment. 2012, Updated 013. *Conceptual Groundwater Injection Plan*. February 27.

Schnurbusch, Stephen A. 2000. *A Mixing Zone Guidance Document Prepared for the Oregon Department of Environmental Quality*.

Sea Surveyor, Inc. 2012. *Malibu Seismic Reflection Survey, Bedrock NAVD-88 Elevation Contour Map*. April

State Water Resources Control Board. 2012. *Water Quality Control Plan, Ocean Waters of California*. Adopted October 16, 2012.

Wisconsin Department of Natural Resources, Bureau of Water Resources Management. 1992. *Mixing Zone Guidance for Chronic Toxicity and Zones of Initial Dilution*. p. 16.