Revised Draft Environmental Impact Statement

Commonwealth of the Northern Mariana Islands Joint Military Training

Appendix M: Part 1

June 2025

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Appendix M – Part 1
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The appendices of this Revised Draft EIS are compliant with Section 508 of the Rehabilitation Act. This allows assistive technology to be used to obtain the available information from the document. However, accessibility is limited to a descriptive title for some graphics, figures, tables, images, and attachments. Individuals who require assistance may submit a request through the Section 508 link on the project website at CNMIJointMilitaryTrainingEIS.com

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POTABLE WATER STUDY UPDATE
IN SUPPORT OF THE
COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS
JOINT MILITARY TRAINING ENVIRONMENTAL IMPACT STATEMENT

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1 INTRODUCTION

1.1 BACKGROUND

The islands of the Commonwealth of the Northern Mariana Islands (CNMI) are strategically located in the United States (U.S.) Department of Defense (DoD) Indo-Pacific area of operations, as shown in Figure 1. Figure 2 shows the Military Lease Area on Tinian where the U.S. military has trained for several decades.

The Proposed Action would support the ongoing and evolving training requirements of U.S. Armed Forces forward deployed to the Western Pacific, and U.S. allies and partners, specifically for distributed operations training within the Military Lease Area on Tinian. Proposed training events would include both ground and aviation training within the Military Lease Area.

Non-live-fire offensive and defensive training actions would continue to be conducted in the Military Lease Area with an increase in existing land-based training events, including both ground and aviation training, which are the same or similar to those currently being conducted on Tinian.

Live-fire training would be conducted at two ranges that would be developed within the Exclusive Military Use Area:

- **Multi-Purpose Maneuver Range.** A live-fire range occupying approximately 200 acres at the northern tip of Tinian to support platoon-size live-fire and maneuver, including three surface radar facilities.
- **Explosives Training Range.** A live-fire range on approximately 2.5 acres for the employment of demolitions and military explosives in support of offensive and defensive training events.

The following are also included in the Proposed Action to support training events:

- Establishment of 13 Landing Zones, areas cleared of vegetation to 6–8 inches, and associated access roads to conduct training events and to provide staging, bivouac, and gathering and rendezvous areas.
- Ground and aviation improvements at North Field, including establishment of a drop zone and the placement of a metal airfield surface.
- Construction and operation of a Base Camp.
- Clearance and improvements of roads within the Military Lease Area.

1.2 PURPOSE

The purpose of this study is to estimate the potable water demand and infrastructure required for the proposed CNMI Joint Military Training Environmental Impact Statement and to recommend potable water solutions to avoid significant impacts. Potable water solutions would be made part of the Proposed Action.

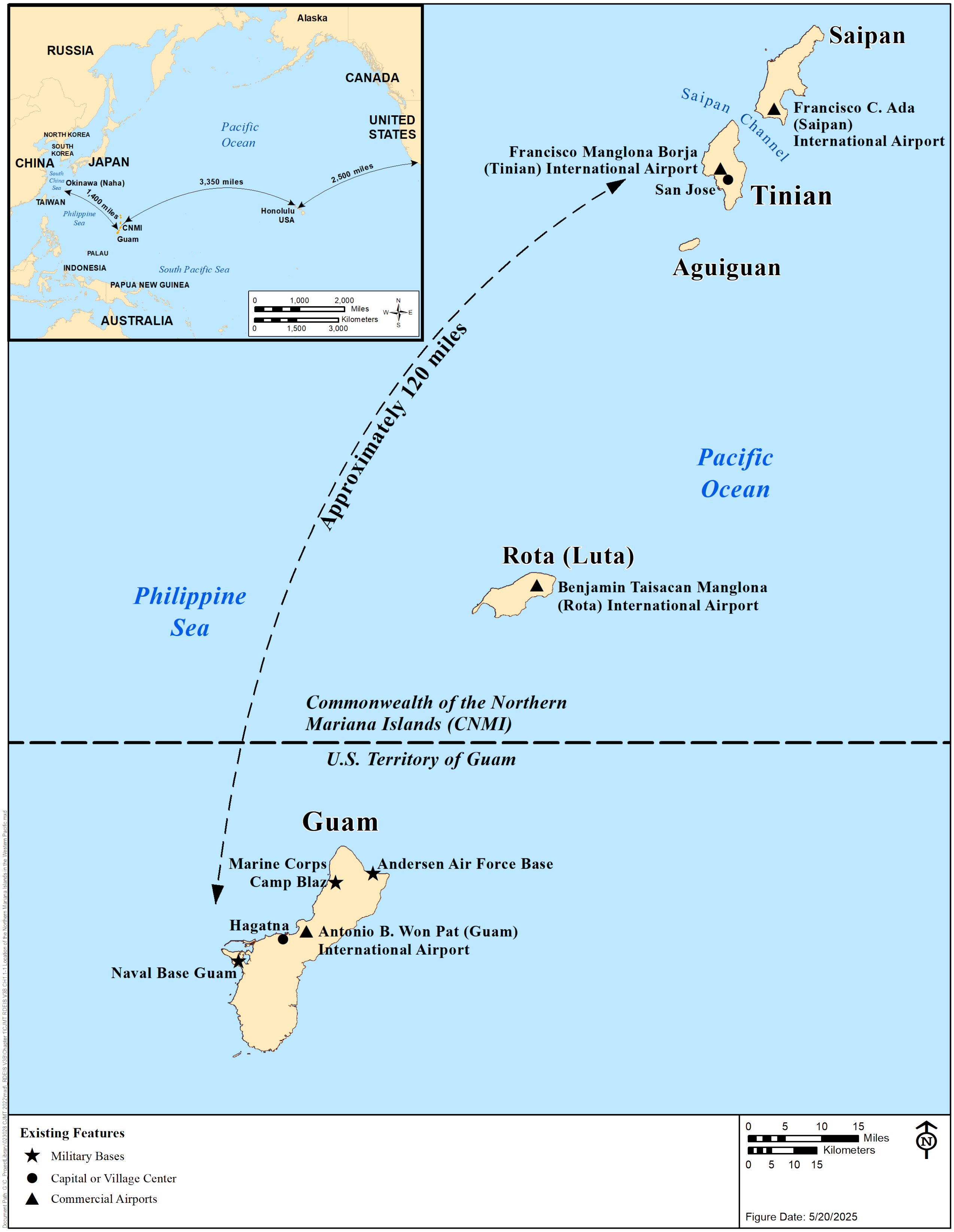

Figure 1. Island of Tinian – Location

Figure 2. Island of Tinian – Military Lease Area Boundaries

1.3 GROUNDWATER SUPPLY

Rainfall is the primary source of fresh groundwater on Tinian. The U.S. Geological Survey estimates the average annual groundwater recharge for Tinian to be approximately 30 inches per year (Gingerich 2002). This translates into approximately 62,000 acre-feet per year of recharge.

The rapid downward percolation of rainwater into porous limestone rock (Doan et al. 1960) recharges Tinian's basal freshwater aquifer. Fresh groundwater on Tinian is primarily classified as basal, which is a body of fresh groundwater that floats on saline groundwater. The portion of the basal freshwater lens that is usable for potable water, which has chloride concentrations less than 250 parts per million, is thickest south and southwest of Mount Lasso and becomes increasingly thinner approaching the coastline (Figure 3).

The groundwater table on Tinian ranges from sea level around the perimeter of the island to over 3 feet above mean sea level in the central portions of the island. Groundwater flows outward from the North Central Highland and the southeastern ridge, and generally seaward around the island (Department of the Navy [DON] 2015). Figure 3 depicts groundwater table elevation contours and the general directions of groundwater flow. Most of the fresh groundwater slowly discharges naturally from springs around the perimeter of the island and submarine coastal springs.

The basal freshwater lens underlying Tinian is the principal source of drinking water and meets the definition of an aquifer in CNMI Title 65, Chapter 65-90-010.

1.4 CNMI BUREAU OF ENVIRONMENTAL AND COASTAL QUALITY

The CNMI Bureau of Environmental and Coastal Quality is the regulatory agency responsible for permitting and enforcement of groundwater, potable water, and non-potable water. The CNMI Bureau of Environmental and Coastal Quality regulates potable water systems per CNMI Drinking Water Regulations, Chapter 65-20. Construction of new wells and operation of existing groundwater wells are subject to an annual permit that limits extraction to protect both availability and quality of groundwater. As part of the permitting process, well owners must conduct the following at each well each year, per CNMI Title 65, Chapter 140:

- Pump test
- Aquifer recovery test
- Water quality testing at a Bureau of Environmental and Coastal Quality-certified laboratory

The maximum quantity of groundwater that can be extracted each month is set by Bureau of Environmental and Coastal Quality in the permit for each well, which must be renewed each year.

1.5 COMMONWEALTH UTILITIES CORPORATION

The Commonwealth Utilities Corporation, a public utility governed by a Board of Directors appointed by the CNMI governor, owns and operates Tinian's only public potable water system. The water system on Tinian consists of approximately 33 miles of pipelines, three aboveground steel reservoirs, and approximately 800 metered service connections (Commonwealth Utilities Corporation 2015a). It is supplied by a single groundwater well (Maui Well No. 2). Figure 4 shows the physical layout of the Commonwealth Utilities Corporation water system.

Figure 3. Tinian Groundwater Wells, Elevation, and Flow Direction

Figure 4. Commonwealth Utilities Corporation Existing Potable Water System

1.5.1 Wells

Maui Well No. 2 is a Maui-style infiltration gallery, which obtains freshwater from the basal lens (Figure 5 and Figure 6) and is the sole source of potable water; there are no redundant or backup supplies. The well is located adjacent to the Marpo wetland area. Maui Well No. 2 is equipped with four 75-horsepower pumps, each capable of pumping approximately 350 gallons per minute. With one pump allowed to be out of service, the pumping capacity is 1.5 million gallons per day.

Figure 5. Maui Well No. 2 Pump House

Figure 6. Maui Well No. 2 Pump Equipment

1.5.2 Storage

The Commonwealth Utilities Corporation water system includes a total of 1.25 million gallons of storage between three existing aboveground reservoirs. Two reservoirs are located adjacent to each other in Carolinas Heights. Each reservoir has a volume of 0.50 million gallons (Figure 7 and Figure 8).

Figure 7. Carolinas Tank 1 (0.50 Million Gallons)

Figure 8. Carolinas Tank 2 (0.50 Million Gallons)

The third reservoir is located in Marpo Heights and has a capacity of 0.25 million gallons (Figure 9). In September 2024, the Marpo Tank appeared to be abandoned. It was surrounded by thick vegetation and not accessible (Figure 10). During this site visit, staff heard the sound of a significant amount of flowing water and speculated that the tank may be overflowing (D. Cronquist, AECOM, Personal Communication, September 9, 2024).

Figure 9. Marpo Tank (0.25 Million Gallons) in 2013

Figure 10. Marpo Tank (0.25 Million Gallons) in 2024

1.5.3 Distribution System

The distribution system consists of approximately 33 miles of water pipelines that vary in diameter from 4 to 12 inches. According to the currently available draft final version of the Commonwealth Utilities Corporation drinking water and wastewater master plan for its facilities on Tinian (Commonwealth Utilities Corporation 2015a), most of the pipelines were constructed of polyvinyl chloride and are in relatively good condition (Commonwealth Utilities Corporation 2015a). Shorter lengths of pipelines were constructed using fiber-reinforced polymer polyvinyl chloride and galvanized iron.

1.6 FRANCISCO MANGLONA BORJA/TINIAN INTERNATIONAL AIRPORT

The Commonwealth Ports Authority owns and operates Francisco Manglona Borja/Tinian International Airport. The airport is a customer of the Commonwealth Utilities Corporation and receives all of its potable water from Maui Well No. 2. Downstream of the Commonwealth Utilities Corporation water meter, the Commonwealth Ports Authority operates its own water system within the airport property. This system includes a 0.2-million-gallon storage reservoir and booster pump station (Figure 11).

Figure 11. Water Tank and Booster Pump Station at Francisco Manglona Borja/Tinian International Airport

1.7 U.S. AGENCY FOR GLOBAL MEDIA

The U.S. Agency for Global Media, formerly International Broadcasting Bureau, operated radio transmitting facilities on Tinian and Saipan. The Tinian facility is not connected to the Commonwealth Utilities Corporation system. Rainwater is captured from a portion of the roof and stored in two aboveground tanks with a total capacity of 8,500 gallons (Figure 12). All water used at the facility is non-potable except for a point-of-use reverse osmosis system that treats water for potable use in the kitchen. Rainwater harvesting provides the majority of water used except during dry months. Approximately 5,000 gallons per year are purchased from Commonwealth Utilities Corporation and trucked in bulk.

Figure 12. Non-potable Water Storage Tank at U.S. Agency for Global Media Facility on Tinian

1.8 TINIAN MAYOR'S OFFICE

The Tinian Mayor's Office owns groundwater and charges a fee for the quantity of water extracted. The Tinian Mayor's Office owns and operates two non-potable water wells: M-21 and M-26 (see Figure). Neither well is connected to pipe networks. Both wells are permitted by Bureau of Environmental and Coastal Quality. The wells are described as follows:

- **Well M-21** is primarily used by the construction contractor for the U.S. Air Force's Tinian Divert Infrastructure Improvements at the Francisco Manglona Borja/Tinian International Airport. This well includes a water meter and a 40,000-gallon tank. This well was permitted in 2024 to extract no more than 1.8 million gallons per month (J. Aldieri, NAVFAC Marianas, Personal Communication, September 10, 2024).
- **Well M-26** is primarily used by cattle ranchers and is not metered. For the purposes of this report, it is assumed that the quantity of water used at this well is equal to the permitted extraction of Well M-21.

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2 EXISTING WATER SYSTEM

2.1 EXISTING WATER DEMANDS

Table 1 summarizes water production (i.e., extraction) quantities from Maui Well No. 2 as recorded by the Commonwealth Utilities Corporation at the well site. Production includes water delivered into the distribution system, which is inclusive of water billed to customers, unmetered uses, leaks, losses, and overflows.

Table 1. Commonwealth Utilities Corporation Water Production from Maui Well No. 2

Year	*Total Annual (MG)*	*Average Daily (MGD)*
2019	313	0.86
2020	312	0.85
2021	307	0.84
2022	321	0.88
2023	306	0.84
Average		**0.85**

Legend: MG = million gallons; MGD = million gallons per day.
Source: Commonwealth Utilities Corporation 2024b.

Table 2 summarizes billing records for all Commonwealth Utilities Corporation customers combined based on meter readings. All registered connections served by the Commonwealth Utilities Corporation are metered and read monthly.

Table 2. Commonwealth Utilities Corporation Billed Water Demand

Year	*Total Annual (MG)*	*Average Daily (MGD)*
2019	88	0.24
2020	77	0.21
2021	81	0.22
2022	84	0.23
2023	87	0.24
Average		**0.23**

Legend: MG = million gallons; MGD = million gallons per day.
Source: Commonwealth Utilities Corporation 2024c.

The U.S. Environmental Protection Agency has stated that the sustainable yield at Maui Well No. 2 in drought conditions is 1.0 million gallons per day. The average production at Maui Well No. 2 for the last 5 years was 0.85 million gallons per day. However, this only applies to the Maui Well No. 2 location and therefore is not an indication of the sustainable yield of all of Tinian.

2.2 WATER QUALITY AND COMPLIANCE WITH REGULATORY STANDARDS

2.2.1 National Primary Drinking Water Standards

The Bureau of Environmental and Coastal Quality has adopted the National Primary Drinking Water Standards, which establish a maximum contaminant level for various constituents in public water systems to protect human health (CNMI Drinking Water Regulations, Chapter 65-20). Compliance with these standards is mandatory and requires the Commonwealth Utilities Corporation to have analytical laboratory testing performed on the water supply. The results of these tests are provided to the public in the form of a water quality report issued annually by the Commonwealth Utilities Corporation. The reports issued between 2012 and 2023 indicate that the Commonwealth Utilities Corporation water system meets the primary drinking water standards (Commonwealth Utilities Corporation 2013, 2014, 2015b, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024a).

Nitrogen, both nitrate and nitrite, is a common contaminant of concern in areas where wastewater is primarily treated in septic tanks and in agricultural areas. The Commonwealth Utilities Corporation reports that total nitrogen levels are below the maximum contaminant level of 10 milligrams per liter. In 2023, the concentration of total nitrogen was 4.8 milligrams per liter (Commonwealth Utilities Corporation 2024a).

2.2.2 National Secondary Drinking Water Standards

The Bureau of Environmental and Coastal Quality has also adopted the National Secondary Drinking Water Standards, which provide non-mandatory water quality standards for 15 additional contaminants (CNMI Drinking Water Regulations, Chapter 65-20). The secondary standards are established "…as guidelines to assist public water systems in managing their drinking water for aesthetic considerations, such as taste, color, and odor" (U.S. Environmental Protection Agency 2018). These contaminants are not considered a risk to public health.

As discussed previously, the freshwater basal lens floats on top of the denser seawater. The transition between freshwater and seawater is gradual, with salt content generally increasing with depth. Chloride concentration is an important secondary standard for Maui Well No. 2 because it has the potential to indicate the quantity of freshwater available at that location. The secondary maximum contaminant level for chloride is 250 milligrams per liter. Table 3 provides chloride concentrations at Maui Well No. 2 between 2012 and 2023.

Table 3. Chloride Concentrations at Maui Well No. 2

Year	*Chloride (ppm)*	
	Average	*Range*
2012	196	175–223
2013	190	172–217
2014	213	212–214
2015	213	212–214
2016	190	184–196
2017	184	184
2018	176	176
2019	146	n/a
2020	145*	n/a
2021	176*	158–176
2022	176*	158–176
2023	177*	n/a

Note: * = Value reported as highest instead of average.
Legend: ppm = part per million; n/a = not available.
Source: Commonwealth Utilities Corporation 2013, 2014, 2015b, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024a.

2.2.3 Treatment

The Commonwealth Utilities Corporation does not treat water produced at Maui Well No. 2 other than disinfection, which is accomplished using gaseous chlorine injection.

3 WATER DEMANDS FOR PROPOSED ACTION

3.1 POTABLE WATER DEMANDS WITHIN THE MILITARY LEASE AREA

The following section estimates the water demands due to the Proposed Action located within the Military Lease Area and outside the existing service area of the Commonwealth Utilities Corporation water system.

3.1.1 Design Population

The maximum number of personnel on island at any one time from the Proposed Action would be 1,070 (estimates for this study used 1,100 to be conservative) and consists of the following types:

- Up to a maximum of 1,000 military personnel participating in training.
- Between 30 and 50 permanent support personnel, who would maintain and operate the facility. It is assumed that 20 individuals would relocate to Tinian and that the on-island local workforce could fill 30 positions.
- Up to 50 construction workers, who are assumed to relocate to Tinian from off-island. Construction would occur in phases over approximately 10 to 15 years.

Dependents are not included in the estimates above based on the experience of other DoD construction projects on Tinian. Potable water used for existing military training and military construction projects is already obtained from Commonwealth Utilities Corporation and included in the existing Commonwealth Utilities Corporation water demand data.

3.1.2 Domestic Demands

Domestic demands consist of all water necessary for human consumption, bathing, laundry, food preparation, and other miscellaneous uses that are calculated on a per capita basis. Table 4 summarizes the average day domestic demands located within the Military Lease Area using Unified Facilities Criteria 3-230-03 (DoD 2020) unit demands. The maximum population value was used in these calculations from the design population discussed above.

Table 4. Average Day Domestic Demand Within the Military Lease Area Under Alternative 1

Personnel Type	*Use Category* [a]	*Unit Demand (gpcd)*	*Population*	*Demand (gpd)*
Military Personnel	Military Training Camps	50	1,000	50,000
Construction Workers (8-hour shift)	Nonresident Personnel and Civilian Employees (per 8-hour shift)	30	50	1,500
Permanent Support Personnel (8-hour shift)	Nonresident Personnel and Civilian Employees (per 8-hour shift)	30	50	1,500
			Total	**53,000**

Note: [a]Per UFC 3-230-03 Table 3-1.
Legend: gpcd = gallon per capita per day; gpd = gallon per day; UFC = United Facilities Criteria.

3.1.3 Industrial Demands: Operation

A portable vehicle wash facility is proposed to be constructed at the Base Camp. Vehicles used in the maintenance and operation of the facilities would be washed here in addition to those military vehicles transported off-island on aircraft at the airport. The wash facility is a contained concrete facility where multiple vehicles can be washed simultaneously using portable cleaning equipment. Wash water is contained during the washing cycle and recycled. Once the wash cycles are complete, wash water is pumped out and disposed of in conformance with CNMI regulations.[1]

A new central vehicle wash facility, J609 Embark Facility, was recently constructed at Naval Base Guam. This facility, although larger than the facility proposed for Tinian, provides a reliable estimate of the amount of water that would be required to clean military vehicles in a climate similar to that of Tinian. The central vehicle wash facility on Guam was designed with a demand of 4,800 gallons per day for 230 vehicles per day (DON 2023). This yields approximately 21 gallons per vehicle for a similar climate to the proposed wash facility on Tinian.

The Proposed Action includes a wash capacity for the following vehicles:

- 15 military vehicles
- 30 maintenance and operation vehicles

The maximum water demand is 945 gallons per day. Military vehicles are estimated to be transported by air 4 times per year. Maintenance and operation vehicles are estimated to be washed 3 times per month (36 times per year). This results in an average annual water demand of 23,940 gallons per year.

3.1.4 Industrial Demands: Construction

Industrial demands during construction would include concrete mixing, earthwork compaction, dust control, hydrostatic pressure testing, and cleaning. Non-potable water used for this purpose is proposed to be obtained from Well M-21.

3.1.5 Average Annual Water Demand

The previous tables provided average day demands at the peak training population, which is a maximum potential adverse effect used to size the proposed water infrastructure. Because military training may occur intermittently throughout the year, the water used annually would be significantly lower than the average daily demand.

Table 5 provides the long-term average annual water demand within the Military Lease Area by the Proposed Action under Alternative 1 after construction is complete.

[1] See the *Final Memorandum: Wastewater Analysis in Support of the CNMI Joint Military Training* for information regarding disposal of wash water.

Table 5. Average Annual Water Demands Within the Military Lease Area Under Alternative 1

Description	*Demand*	*Cycles Per Year*	*Persons x Day*	*Unit Water Demand (gpcd)*	*Demand (gallons/year)*
Large Training Group	1,000 persons × 30 days	4	120,000	50	6,000,000
Medium Training Group	250 persons × 14 days	4	14,000	50	700,000
Small Training Group	100 persons × 14 days	10	14,000	50	700,000
Permanent Support Personnel (8-hour shift)	50 persons × 365 days	1	18,250	30	547,500
Portable Vehicle Wash Facility					23,940
				Total	**7,971,440**

Note: These demands represent the maximum of the training durations and personnel per year identified in the revised draft EIS.
Legend: gpcd = gallon per capita per day.

Training tempo under Alternative 2 is 10 percent less than under Alternative 1, which would result in a proportional decrease in water use by 10 percent. As a result, the average annual water demand under Alternative 2 is 7,174,296 gallons per year.

3.2 POTABLE WATER DEMANDS OUTSIDE THE MILITARY LEASE AREA

The following section estimates the water demands due to the Proposed Action located outside the Military Lease Area. This area is within the existing service area of the Commonwealth Utilities Corporation water system. It is anticipated that the Commonwealth Utilities Corporation would meet potable water demands in this area.

3.2.1 Domestic Demands

It is anticipated that construction workers and permanent support personnel would live outside the Military Lease Area in homes, apartments, or hotels. Table 6 summarizes the additional average day domestic demands due to the Proposed Action under Alternative 1 that the Commonwealth Utilities Corporation would meet. Per capita unit demand is estimated using Unified Facilities Criteria 3-230-03 (DoD 2020).

Table 6. Average Day Domestic Demand on Commonwealth Utilities Corporation Water System Under Alternative 1

Personnel Type	*Use Category* [a]	*Unit Demand (gpcd)*	*Population*	*Demand (gpd)*
Construction Workers (24-hour)	Family Housing	125	50	6,250
Permanent Support Personnel (24-hour) [b]	Family Housing	125	20	2,500
			Total	**8,750**

Notes: [a]Per UFC 3-230-03, Table 3-1.
[b]Only personnel relocating from off-island are included here.
Legend: gpcd = gallon per capita per day; gpd = gallon per day; UFC = Unified Facilities Criteria.

3.2.2 Industrial Demands: Operation

A central vehicle wash facility is proposed to be constructed at the Port of Tinian. Military vehicles would be washed here after training is complete and prior to loading on vessels for transport off-island. The wash facility would be a contained concrete facility where multiple vehicles can be washed simultaneously using permanently mounted cleaning equipment. Wash water would be contained during the washing cycle and recycled. Once the wash cycles are complete, wash water would be pumped out and disposed of in conformance with CNMI regulations.[2] No domestic demand is proposed at the Port of Tinian as the wash facility would not have a restroom.

A new central vehicle wash facility, J609 Embark Facility, was recently constructed at Naval Base Guam. This facility, although larger than the facility proposed for Tinian, provides a reliable estimate of the amount of water that would be required to clean military vehicles in a climate similar to that of Tinian. The central vehicle wash facility on Guam was designed with a demand of 4,800 gallons per day for 230 vehicles per day (DON 2023). This yields approximately 21 gallons per vehicle for a similar climate to the proposed wash facility on Tinian.

The Proposed Action includes a wash capacity of 44 vehicles per day, which is based on 87 total vehicles for a 1,000-person training exercise and a 2-day retrograde period. The prorated industrial demand for the proposed wash facility would be 924 gallons per day.

3.2.3 Industrial Demands: Construction

Industrial demands during construction would include mixing concrete, earthwork compaction, dust control, hydrostatic pressure testing, and cleaning. Non-potable water used for this purpose is proposed to be obtained from Well M-21. No water is proposed to be purchased from the Commonwealth Utilities Corporation for construction purposes.

3.2.4 Average Annual Water Demand

The water demand by the Proposed Action is anticipated to remain consistent and not vary significantly throughout a given year. Because of this, the average annual water demand is the sum of the existing and proposed demands. Table 7 summarizes impacts of the Proposed Action under Alternative 1 on the CUC water system.

Table 7. Summary of Existing and Proposed Water Demands on Commonwealth Utilities Corporation Under Alternative 1

Category	*Average Day Demand (MGD)*
Existing CUC Production [a]	0.85
Proposed Additional Domestic Demand	0.0088
Proposed Additional Industrial Demand [b]	0.0009
Total Demand on CUC Water System	**0.86**

Notes: [a]Average of production at Maui Well No. 2 from 2019 to 2023.
[b]Assume one wash per day at the Central Vehicle Wash Facility at the Port of Tinian.
Legend: CUC = Commonwealth Utilities Corporation; MGD = million gallons per day.

As discussed in Section 2, the average day production from Maui Well No. 2 between 2019 and 2023 is 0.85 million gallons per day, which is less than the estimated aquifer drought capacity at

[2] See the *Final Memorandum: Wastewater Analysis in Support of the CNMI Joint Military Training* for information regarding disposal of wash water.

Maui Well No. 2 of 1.0 million gallons per day. The Proposed Action under Alternative 1 is estimated to increase water production at Maui Well No. 2 by 1.14 percent. The sum of existing water production and proposed water demand is approximately 0.86 million gallons per day, which results in 0.14 million gallons per day in remaining aquifer drought capacity.

The water demands on the Commonwealth Utilities Corporation are the same for both Alternative 1 and Alternative 2.

3.3 NON-POTABLE WATER DEMANDS

3.3.1 Construction Water (Well M-21)

Industrial demands during construction would include mixing concrete, earthwork compaction, dust control, hydrostatic pressure testing, and cleaning. The U.S. Air Force is currently constructing the Tinian Divert Infrastructure Improvements at the Francisco Manglona Borja/Tinian International Airport. The contractor purchases all water for that construction from the Tinian Mayor's Office at Well M-21. This well has an extraction capacity of 1.8 million gallons per month in 2024 (J. Aldieri, NAVFAC Marianas, Personal Communication, September 10, 2024), or 21.6 million gallons per year. All water used at this well is used for construction purposes.

The construction contractor is responsible for obtaining non-potable water used in construction. Construction of the Tinian Divert Infrastructure Improvements would be completed prior to starting construction of the Proposed Action. It is anticipated that the contractor for the Proposed Action would make arrangements with the Tinian Mayor's Office to use Well M-21 for construction water.

The Proposed Action is significantly smaller in size and scope than the Tinian Divert Infrastructure Improvements and would use substantially less water during construction. To be conservative, it is assumed that the same quantity of water, 21.6 million gallons per year, would be used in construction of the Proposed Action.

3.3.2 North Field Wells

Non-potable water infrastructure is proposed to be constructed at North Field for firefighting purposes. Water infrastructure at North Field is proposed to be separate from the Base Camp and would not be interconnected. Water would be used for firefighting purposes and would not be operated continuously. Based on wildland firefighting recommendations, it is estimated that the volume of non-potable water used would not exceed 800,000 gallons per year.

3.3.3 U.S. Air Force's Tinian Divert Infrastructure Improvements

The U.S. Air Force has constructed a groundwater well to supply water to the Tinian Divert Infrastructure Improvements at the Francisco Manglona Borja/Tinian International Airport. The primary purpose for this well is to provide water for fire protection purposes. It is estimated this well would use an average of 800,000 gallons per year. This project was permitted separately and is not included in the Proposed Action.

3.3.4 U.S. Air Force's North Field Rehabilitation

The U.S. Air Force is planning to rehabilitate an existing groundwater well or construct a new groundwater in North Field to supply non-potable water for construction of their North Field Rehabilitation project. The U.S. Air Force estimates they would use 12,000 gallons per day for construction, which is 4,380,000 gallons per year. This project was permitted separately and is not included in the Proposed Action.

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4 NEW WATER INFRASTRUCTURE

4.1 OPTIONS EVALUATED

The following options were evaluated to supply water in order to meet the needs of the Proposed Action within the Military Lease Area. Water demands outside the Military Lease Area are proposed to be met by the Commonwealth Utilities Corporation.

No construction activities would be conducted at the former U.S. Agency for Global Media site on Saipan and no changes to water use are proposed. Because of this, there is no impact to potable water on Saipan.

4.1.1 Option A, Connection to Commonwealth Utilities Corporation

Under Option A, a pipeline would be constructed to supply water from the Commonwealth Utilities Corporation to meet the needs of the Proposed Action within the Military Lease Area. However, this was not deemed feasible because the Commonwealth Utilities Corporation does not comply with the DoD requirements for water supply as described in Unified Facilities Criteria 3-230-01 (DoD 2020). Unified Facilities Criteria 3-230-01 incorporates the *Ten State Standards* (Great Lakes 2012), which requires a minimum of two sources of groundwater to be provided.

The Commonwealth Utilities Corporation water system on Tinian only has one source of groundwater with no redundancy and does not comply with these requirements.

4.1.2 Option B, Construct Separate Water Infrastructure

Under Option B, new water infrastructure would be constructed that would operate independently of the existing Commonwealth Utilities Corporation water system and avoid impacts to it. The Proposed Action includes construction of new water infrastructure at two different locations:

- Base Camp
- North Field

Water infrastructure at the Base Camp would consist of new groundwater wells, aboveground storage tanks, and distribution piping to meet potable water and fire protection demands. Water infrastructure at North Field would consist of new groundwater wells and aboveground storage tanks for fire protection demand only. Groundwater production from these wells would conform to extraction limitations and requirements stated in the operation permit by the Bureau of Environmental and Coastal Quality. Excess capacity could also be made available for agricultural or other uses approved by the U.S. Marine Corps (USMC).

4.1.3 Option C, Interconnection Between Water Systems

Under Option C, a pipeline would be constructed between the new water infrastructure described in Option B and the Commonwealth Utilities Corporation to provide emergency water supply. However, this was not deemed feasible because the combined system would not comply with the DoD requirements for water supply as described in Unified Facilities Criteria 3-230-01 (DoD 2020). Unified Facilities Criteria 3-230-01 incorporates the *Ten State Standards* (Great Lakes 2012), which requires the total developed groundwater source capacity to equal or exceed the design maximum day demand with the largest producing well out of service.

The groundwater wells proposed in Option B do not have sufficient capacity to meet the needs of the Commonwealth Utilities Corporation water system if the largest producing well, Maui Well No. 2, were out of service and therefore would not comply with these requirements.

4.2 BASE CAMP WATER INFRASTRUCTURE

The Proposed Action includes construction of a Base Camp at the U.S. Agency for Global Media site on Tinian. As envisioned, Administration, Range Control, and Training Support functions proposed in the Base Camp would use the existing operation and administration building, and warehouse requirements would be partially met with the existing warehouse facilities. Other previously disturbed, cleared areas within the site would accommodate other new construction needs of the proposed Base Camp.

The Proposed Action includes construction of new water infrastructure to fully support the USMC's proposed CNMI Joint Military Training and to avoid impacts on the Commonwealth Utilities Corporation water system. This proposed new water infrastructure would supply the domestic, industrial, and fire protection demands of military training activities within the Military Lease Area. This proposed new water infrastructure would comply with the Federal Safe Drinking Water Act and the CNMI Drinking Water Regulations and be operated by USMC with a CNMI-certified water operator. No connection to the Commonwealth Utilities Corporation water system is proposed. Excess capacity could also be made available for agricultural or other uses approved by USMC. The existing non-potable rainwater harvesting system may also be retained for non-potable uses.

Potable water would be supplied to the Base Camp from new groundwater wells at one of the two following locations:

- Wellfield Option A is located east of Broadway at 86th Street.
- Wellfield Option B is located between West End Drive and 8th Avenue at 86th Street.

Wellfield Option B is the preferred option to locate new groundwater wells due to its proximity to the Base Camp. Water pipelines from the well field to the Base Camp would be located in 86th Street and 8th Avenue, or along West End Drive (Figure 13). It is not feasible to construct groundwater wells closer to the former U.S. Agency for Global Media site due to the site geology.

4.2.1 Design Flow

Water demands are calculated in accordance with Unified Facilities Criteria 3-230-03, *Water Treatment* (DoD 2020). Design flow is the greater of peak hourly demand or maximum daily domestic demand plus industrial demand. Maximum daily and peak hourly demands are calculated as the product of the average daily domestic demand and the coefficient "K." The coefficient "K" for maximum daily demand is 2.25 for populations of less than 5,000 people. The coefficient "K" for peak hourly demand is 4.0 for populations of less than 5,000 people.

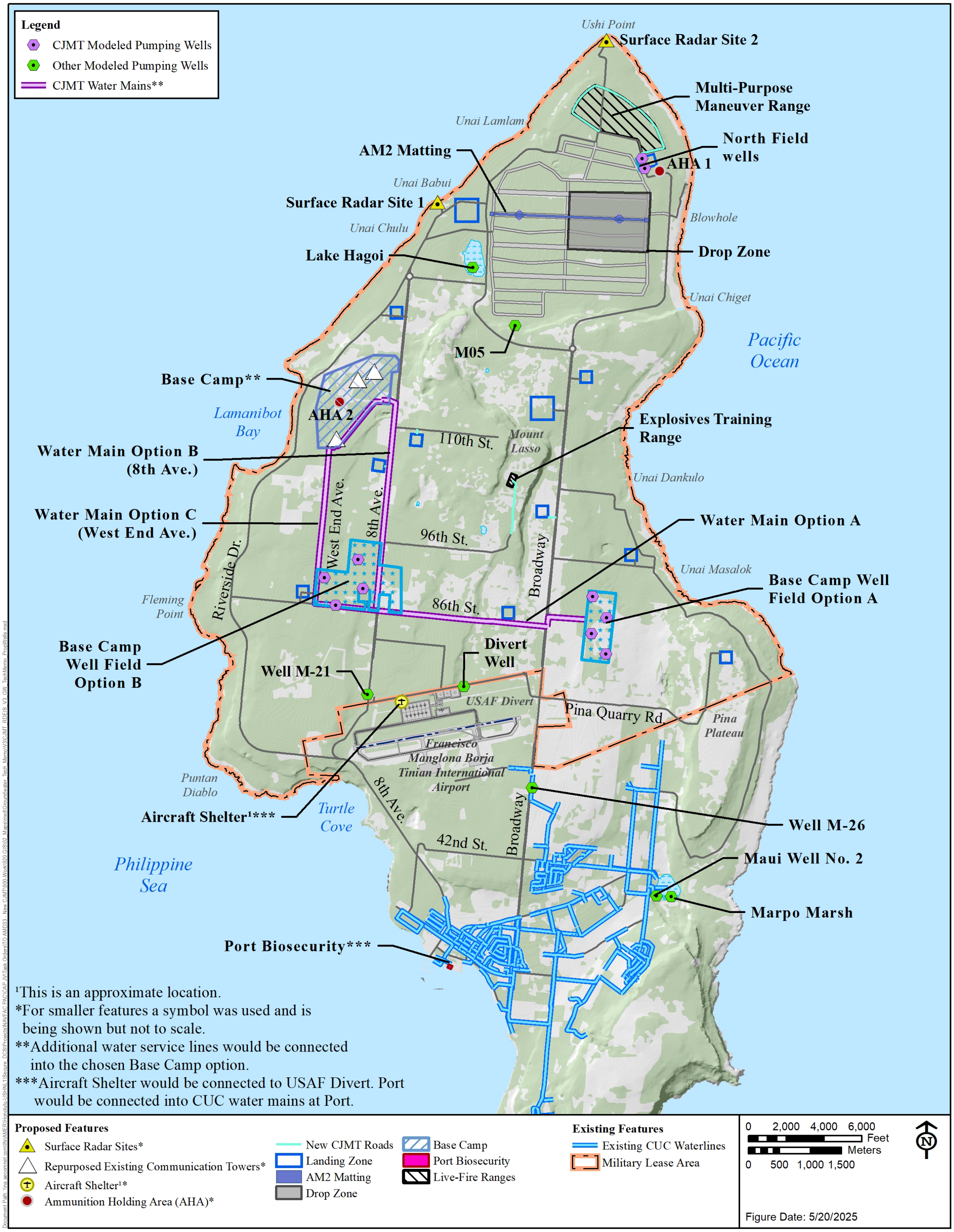

Figure 13. Water Infrastructure Included in Proposed Action

Fire demand requirements are described in Unified Facilities Criteria 3-600-01, *Fire Protection Engineering for Facilities* (DoD 2021a). The fire demand is a minimum of 1,000 gallons per minute for a 2-hour duration at 20 pounds per square inch, which is a volume of 120,000 gallons.

The design flow is then calculated as:

- Peak Hourly Demand = 53,945 gallons per day × 4.0 = 215,780 gallons per day
- Maximum Daily Demand + Fire Flow = 53,945 gallons per day × 2.25 + 120,000 gallons per day = 241,376 gallons per day

The controlling design flow is 241,376 gallons per day and the proposed water infrastructure would be designed to provide this flowrate.

4.2.2 Groundwater Wells

New groundwater wells could be constructed to operate with a capacity of 120 gallons per minute. To reduce impacts to the aquifer, a larger number of wells operating at lower flowrates is proposed. The proposed equipped pumping capacity would be limited to 60 gallons per minute, which is equal to 86,400 gallons per day. Three groundwater wells can provide 259,200 gallons per day, which would meet the design flow of 241,376 gallons per day. *Ten State Standards* (Great Lakes 2012) require a fourth, redundant well to be constructed so that design flow can be met with the largest source of water out of service. It is planned that all four wells would operate on a rotating cycle. The specific location of the wells would be determined as part of engineering design.

Construction and operation of each groundwater well would be subject to an annual permit from Bureau of Environmental and Coastal Quality. Bureau of Environmental and Coastal Quality would determine extraction limitations based on the results of pump tests, aquifer recovery tests, and water quality testing. The extraction limitations would be subject to change each year based on test results.

4.2.3 Water Treatment

Groundwater is not anticipated to require filtration or treatment, other than disinfection, based on the analytical testing results of groundwater performed in 2015 (DON 2015).

4.2.4 Storage Requirements

Water storage requirements are described in Unified Facilities Criteria 3-230-01 (DoD 2021b). The required storage is the sum of the maximum daily demand for 24 hours, which is 121,376 gallons, and fire demand of 120,000 gallons:

- Required Storage Volume = 121,376 gallons + 120,000 gallons = 241,376 gallons

One possible hypothetical tank configuration that would meet this requirement has a diameter of 40 feet and a height of 32 feet with a gross volume of 300,810 gallons and a usable volume of 253,808 gallons. To meet the required storage, two tanks are recommended so that one tank can be removed from service for maintenance and repair while the other is in operation. Additionally, Unified Facilities Criteria 3-600-01 (DoD 2021a) requires that water storage tanks be refilled within 48 hours of normal consumption and within 24 hours if normal consumption is curtailed.

4.2.5 Booster Pump Station

A booster pump station would be required downstream of the storage tanks to pressurize the water infrastructure. Per Unified Facilities Criteria 3-230-01 (DoD 2021b), pumps would be required to maintain a residual pressure of 40 pounds per square inch at average day demand and 30 pounds per square inch during design flow. Minimum residual pressure at fire hydrants must be at least 20 psi while supplying fire flow. It is recommended that the booster pumps be designed to supply both domestic and fire demands. Stand-alone fire demand pumps could fail in an emergency because they do not operate regularly.

The booster pump station and disinfection are proposed to be located inside a 1,200-square-foot pump building.

4.3 NORTH FIELD WATER INFRASTRUCTURE

Non-potable water infrastructure is proposed to be constructed at North Field for firefighting purposes. Water infrastructure at North Field is proposed to be separate from the Base Camp and not interconnected. Water infrastructure is planned to include up to two new or rehabilitated groundwater wells, two 100,000-gallon aboveground water tanks, a booster pump station, and a 1,200-square-foot pump house. The overall land disturbance for this infrastructure is anticipated to be 100 feet square (10,000 square feet) and the specific locations would be determined during engineering design.

New groundwater wells could be constructed to operate with a capacity of 120 gallons per minute. To reduce impacts to the aquifer, it is proposed to limit the equipped pumping capacity to 60 gallons per minute, which is equal to 86,400 gallons per day. Water would be used for firefighting purposes and would not be operated continuously. Based on wildland firefighting recommendations, it is estimated that the volume of non-potable water used would not exceed 800,000 gallons per year.

Construction and operation of each groundwater well would be subject to an annual permit from Bureau of Environmental and Coastal Quality. Bureau of Environmental and Coastal Quality would determine extraction limitations based on the results of pump tests, aquifer recovery tests, and water quality testing. The extraction limitations would be subject to change each year based on test results. Even though this is intended as a non-potable water, Bureau of Environmental and Coastal Quality requires that the wells be designed and constructed to potable standards.

4.4 AIRCRAFT SHELTER WATER INFRASTRUCTURE

The proposed aircraft shelter is located at the Tinian Divert Infrastructure Improvements at the Francisco Manglona Borja/Tinian International Airport. Fire protection requirements for the aircraft shelter would be met by the water system being constructed as part of the Tinian Divert Infrastructure Improvements. This water system would include a groundwater well, storage tank, and booster pump for fire protection purposes. A pipeline would be constructed from this water system to the proposed aircraft shelter. No potable water uses are proposed at the aircraft shelter. No changes in demand or usage on this water system are proposed.

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5 SUMMARY

5.1 NEW WATER INFRASTRUCTURE

The Proposed Action on Tinian includes construction of potable water infrastructure at the Base Camp that includes new groundwater wells, water storage tanks, and a pipeline distribution system to provide water for military trainees. This action, designed and managed in a manner that would avoid adversely affecting the sustainable yield of the aquifer, would avoid demands on the Commonwealth Utilities Corporation water system. The new water infrastructure would be sized in accordance with government regulations to provide a maximum day demand of 121,376 gallons per day plus fire demand of 120,000 gallons per day.

While the new water infrastructure would be sized to provide the maximum day demand and fire demand occurring simultaneously, the actual water usage during the year would be substantially less. The average annual water demand of the new water infrastructure would be 8,518,940 gallons per year under Alternative 1. The average annual water demands under Alternative 2 would be 7,174,296 gallons per year.

Non-potable water infrastructure is proposed to be constructed at North Field for firefighting purposes. Water infrastructure at North Field is proposed to be separate from the Base Camp and would not be interconnected. It is estimated that 800,000 gallons per year would be used. This demand would be the same under both Alternative 1 and Alternative 2.

Construction and operation of each groundwater well would be subject to an annual permit from Bureau of Environmental and Coastal Quality. Bureau of Environmental and Coastal Quality would determine extraction limitations based on the results of pump tests, aquifer recovery tests, and water quality testing. The extraction limitations would be subject to change each year based on test results to protect the aquifer.

5.2 COMMONWEALTH UTILITIES CORPORATION

Construction workers and permanent support personnel would reside outside the Military Lease Area and become customers of the Commonwealth Utilities Corporation. As customers, they would be responsible for paying all charges and rates adopted by the Commonwealth Utilities Corporation. The Proposed Action under Alternative 1 and Alternative 2 is estimated to increase water production at Maui Well No. 2 by 9,674 gallons per day, which is 1.14 percent. The estimated total production at Maui Well No. 2 with the Proposed Action is approximately 0.86 million gallons per day, which is below the aquifer drought capacity at Maui Well No. 2 of 1.0 million gallons per day.

5.3 GROUNDWATER IMPACTS

Impacts to groundwater availability and quality are evaluated in the Groundwater Modeling Technical Memorandum. Table 8 provides a summary of water demands evaluated in the groundwater model.

Table 8. Summary of Average Annual Water Demands on Tinian

Owner	*Facility*	*Type*	*Average Annual Water Demand [b] (gallons per year)*	*No. Wells*
Military	CJMT Base Camp	Potable	7,971,440	4
Military	CJMT North Field	Non-Potable	800,000	2
Military	U.S. Air Force North Field Rehabilitation	Non-Potable	4,380,000	1
Military	Tinian Divert Infrastructure Improvements	Potable	800,000	1
CUC	Maui Well No. 2 [a]	Potable	314,727,702	1
Tinian Mayor's Office	Well M-21 (CJMT Construction)	Non-Potable	21,600,000	1
Tinian Mayor's Office	Well M-26 (Existing Agriculture)	Non-Potable	21,600,000	1

Notes: [a]Average of production at Maui Well No. 2 from 2019 to 2023 and proposed CJMT demands on the CUC water system.
[b]Total demand for all the wells.

Legend: CJMT = Commonwealth of the Northern Mariana Islands Joint Military Training; CUC = Commonwealth Utilities Corporation; gpd = gallon per day; U.S. = United States.

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ATTACHMENT A
FEBRUARY 2016 MEETING MINUTES

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Background, Summary, and Follow-up from 03 and 04 February 2016 on Next Steps in Addressing Potable Water and Groundwater Issues on Tinian, Commonwealth of the Northern Mariana Islands (CNMI)

Meeting Locations: Commonwealth Utilities Corporation (CUC) Conference Room Saipan (03 February 2016 Meeting) and CUC Conference Room Tinian and Field (04 February 2016)

Attendees:

CNMI Bureau of Environmental and Coastal Quality (BECQ):
Captain Derek Chambers †
CUC:
James Benevente, Engineer †
John Reigel, Manager*
Winston Omar, Operator**
Environmental Protection Agency (EPA):
Carl Goldstein, Program Manager †
Mike Lee, Water Division †
John McCarroll, Pacific Islands †

Marine Corps Activity Guam:
Gunnery Sergeant Donald McClester †
Major Chris Merrill †

Marine Corps Forces Pacific (MARFORPAC), Defense Policy Review Initiative (DPRI):
Sherri Eng, Environmental †
Tim Robert, Operations †
Martha Spengler, Environmental*
Marine Corps Headquarters
Stephen Wenderoth, Legal Counsel †
Naval Facilities Engineering Command Pacific:
Brian Whitehouse, Project Manager †
Pacific Air Forces:
Mark Petersen, Project Manager †

Joint Venture TEC-AECOM (JV):
Daniel Cronquist, Engineer*
Douglas Roff, Hydrogeologist*

†=attended meetings on 03 February only * = attended meetings on 03 February and 04 February; **= attended meeting on 04 February only

Background: Two meetings were held in the CNMI the first week of February 2016 to discuss the next steps in addressing the EPA's concerns related to potable water and groundwater issues on Tinian. These meetings are a follow-on action related to the EPA's comments on the Draft CNMI Joint Military Training (CJMT) Environmental Impact Statement (EIS)/Overseas EIS (OEIS) (hereinafter referred to as the "DEIS"). The Department of Defense (DoD) released the DEIS in April 2015. After an initial review, the EPA agreed to withhold an adverse rating on the DEIS provided the DoD addresses its concerns related to the CJMT proposed action. These concerns included issues related to potable water and groundwater alternatives on Tinian. The DoD agreed to prepare a Revised DEIS (RDEIS) in order to address the EPA's and others' comments on the DEIS. Towards this end, MARFORPAC and the EPA met in December 2015 and January 2016 to discuss potable water demands, potable water production, sustainable production of groundwater aquifer sub-basins on Tinian, and potential potable water alternatives to be evaluated for possible analysis in the RDEIS.

At the DoD's request, the EPA coordinated a meeting with the CUC and BECQ in the CNMI. The purpose of the meeting on 3 February 2016 was to get the CUC's and BECQ's feedback on assumptions that went into a Water Demands Memo that the JV prepared to estimate potable water production from the CUC System and projected water demands on Tinian through 2027. In addition, the DoD wanted to discuss the sustainable production of fresh groundwater on the island, gain a better understanding of the unaccounted for water (UFW) from the CUC System, and CUC's plans and desires to address UFW and other CUC System issues. The purpose of the 4 February 2016 meeting was for the JV and DoD to meet with CUC operators and to examine key CUC infrastructure and gather data needed to further evaluate potable water and groundwater alternatives on Tinian.

I. Water Demands Memo

Background: DPRI Environmental directed the JV to prepare a Water Demands Memo that outlines the production rate of the CUC's sole freshwater production well on Tinian (Maui Well No. 2) and the various projected water demands on Tinian from the present through 2027. The Water Demands Memo was intended to address EPA comments related to the sustainable production of freshwater on the island, provide a breakdown of the CJMT construction and operation water demands and how those demands and other projected water demands could be met (i.e., potable water and groundwater options/alternatives). Toward that end, the memo memorializes the CUC's daily and annual production pumped from Maui Well No. 2 and metered potable water (i.e., assumed consumption rate of potable water) as reported by the CUC. The memo also provides estimated agricultural water demands on the island, projected CJMT water demands broken down by year of construction through operation, projected Divert water demands, projected Plumeria Resort and Tinian Ocean View Resort water demands, and anticipated water demands from induced population growth. The Water Demands Memo is a starting point in the reevaluation of potable water and groundwater options on Tinian. The DoD shared the draft Water Demands Memo with the EPA in their 14 January 2016 meeting and received feedback on assumptions made in preparing the Water Demands Memo.

Discussion Summary:

- **General Feedback on the Water Demands Memo.** The CUC and BECQ were pleased with the draft Water Demands Memo as it helped them to better understand the water demands on Tinian and the current production rates of Maui Well No. 2. Both agencies would like a copy of the Water Demands Memo once it is finalized.
- **Projected Water Demands on Tinian**
    - **Feed-back on Water Demand Assumptions.** The CUC and BECQ had few comments on the assumptions that went into the projected water demands outlined in the Water Demands Memo except for the following:
        - While they had no formal documentation or permit application, the CUC understands that the proposed Tinian Ocean View Resort intends to meet their operational water demands via reverse osmosis.
        - The CUC and BECQ had no specific knowledge of agricultural water demands on Tinian.
    - **Follow Up on Water Demands.** The JV will follow up with the Tinian Ocean View Resort developers (Alter City Group and Bridge Investment Group, respectively) to confirm that water demands are adequately represented. Plumeria Resort water demands for operation were obtained from the development's Environmental Impact Assessment (EIA). The Tinian Ocean View Resort, which has begun construction, does not have an EIA; thus, all construction and operation water demands were estimated based on descriptions available from the local newspaper. The JV will follow up with the Tinian agricultural extension agent (Lawerence Duponcheel) and with the CNMI Department of Agriculture to get a better sense of the water demands from agriculture off of the Military Lease Area (MLA).
- **Freshwater Production on Tinian**
    - **Sustainable Freshwater Production from Maui Well No. 2.** The CUC agreed with an EPA recommendation that it would be prudent to assume that the CUC sustainable production capacity from Maui Well No. 2 is 1.0 Million Gallons per Day (MGD). The CJMT DEIS had used an average sustainable production capacity of 1.26 MGD in order to assess impacts from the CJMT project, noting that production rate ranges from 1.0 MGD during dry periods to about 1.50 MGD

during wet periods. Based on the discussion, the DoD agreed to use the 1.0 MGD in its impact analysis for the RDEIS (unless further analysis of CUC extraction rates indicates another reasonable value). [Note: CUC operators on Tinian have kept hourly hydraulic head (groundwater levels) from Maui Well No. 2 since its inception along with pump rates.]

- **Sustainable Freshwater Yield on Tinian.** All agreed that the aquifer sub-basins on Tinian could accommodate the projected freshwater pumping demands outlined in the Water Demands Memo provided that the extraction of groundwater was sufficiently dispersed to avoid impacting water quality (i.e., siltation, chloride content).
  - **Maui Well No. 2 Water Quality Issues.** Presently, the CUC System pumps exclusively from the Makpo sub-basin aquifer which is thought to be hydraulically connected to the Makpo Wetland. [Note: Maui Well No. 2 is a horizontal well or "Maui-style infiltration gallery well"]. The CUC confirmed that water quality during periods of heavy rainfall coincided with increased turbidity in the well thought to be due to runoff into the wetland. In their comments on the DEIS, the EPA expressed concern that increasing pump rates to accommodate project CJMT could further affect water quality at Maui Well No. 2. In addition, the chloride content at Maui Well No. 2 is recorded at greater than 200 milligrams per liter (mg/l) which is close to the SDWA Secondary Drinking Water Level of 250 mg/l. As noted in EPA comments and discussions, CUC System customers have registered complaints about water quality/taste. All agreed that pumping from other wells either within the Makpo aquifer sub-basin or other aquifer sub-basins would be one way to avoid impacting water quality at Maui Well No. 2.
  - **Other Potential Production Wells in the Makpo Aquifer Sub-basin.** As described by the U.S. Geological Survey (*Geohydrology and Numerical Simulation of Alternative Pumping Distributions and the Effects of Drought on Ground-Water Flow System of Tinian, Commonwealth of the Northern Mariana Islands*, Gingerich et al 2002) , the CUC had two vertical wells in operation in the Makpo aquifer sub-basin into the 1990s. During the site visit on 4 February 2016, the CUC operators showed the JV and DoD the locations of these inactive wells – both of which were capped and are reportedly in marginal to poor condition. The CUC indicated that the wells were taken off-line because the CUC could not afford to continue to maintain the wells. Reportedly, there are other vertical wells that may tap into the Makpo aquifer sub-basin that may be used for agricultural or other water demands (these are described in the 2002 USGS report).
  - **Potential Freshwater Production from the Masalok Aquifer Sub-basin.** The JV explained why they believe that pumping in the MLA (i.e., primarily in the Masalok aquifer sub-basin), as proposed in the DEIS, would not likely affect the water quality and quantity in the Makpo sub-basin aquifer. The maximum CJMT projected water demands, as described in the DEIS, would be between 0.240 MGD and 0.460 MGD. Mr. Roff explained that the USGS (2002) modeled pumping in both the northern and southern portions of Tinian during drought periods and at pumping rates that are below those projected water demands described in the Water Demands Memo.

II. Impacts to Water Quality from Increased Groundwater Extraction on Tinian

Background. In their comments on the DEIS, the EPA stated that the DEIS did not adequately address the potential for saltwater intrusion on drinking water and the effects on drinking water quality. The DEIS concludes that the additional construction-period and operation-period water demands (off of the MLA) would require increased pumping from the CUC's Maui Well No. 2 and this could result in temporary increased chloride levels as a result of saltwater intrusion. The DEIS concludes that these impacts are less than significant because the limited times this would occur and because of the size and recharge characteristics of the freshwater basal lens. The EPA believes that the information in the DEIS allows for uncertainty regarding the potential for saltwater intrusion in the aquifer. The DEIS conclusions regarding potential salinity increases were based largely on the USGS 2002 groundwater model. This steady-state groundwater flow model is based on pumping data from the late 1990's and, while it was the best available tool for predicting the possible hydrologic effects of additional groundwater withdrawals at that time, more sophisticated models currently exist. The model cannot predict the salinity distribution within the aquifer and it is not capable of predicting the quality of the water pumped from a given well. The model can simulate the location of the freshwater/saltwater interface; however, it cannot simulate local up-coning atpumped wells.

Furthermore, the EPA indicated in their comments that the DEIS does not specifically discuss the combined impacts to the aquifer, during operations, from pumping in the MLA (Masalok aquifer sub-basin) and outside the MLA (Makpo aquifer sub-basin). The EPA is concerned that the two sub-basins have a high degree of connectivity and thus pumping from one sub-basin would lower the freshwater availability in the other sub-basin. The EPA noted that groundwater withdrawal on Tinian and the potential effects it could have on Makpo Wetland are not discussed in the DEIS. Maui Well No. 2, Tinian's sole public water supply well, pumps freshwater from Makpo Wetland's basal groundwater lens. The project water demand would be between 0.033 to 0.058 MGD during the construction period. During the operation period the project water demand would be on average 0.240 MGD and maximum of 0.460 MGD. The DoD System's well field would be within the Masalok sub-watershed, with a small portion located within the Makpo sub-watershed where the CUC System well is located. The EPA believes that the two sub-watersheds are connected (i.e., share the same limestone aquifer and the two basins are connected); thus, the EPA believes that the wells and wetlands in one sub-watershed could be influenced by groundwater withdrawal from wells in the neighboring sub-watershed.

The DoD in subsequent discussions with the EPA responded that structural features, which define the Median Valley, likely result in significant conduit flow to the north and southwest of the MLA. These were not accounted for in the 2002 model.

Discussion Summary:

- **Aquifer Modelling on Tinian.** Following the discussion on the sustainable yield of freshwater on Tinian, Mr. Lee (EPA) indicated that an updated aquifer model could help address the EPA's concerns about water quality as a result of projected and proposed water extraction from the DoD, CUC, and Plumeria Resort on drinking water quality.

III. Unaccounted for Water from the CUC System on Tinian

The EPA in its comments on the DEIS recommended that UFW be targeted for improvement as it would have a beneficial impact by helping the CUC and the municipality. The EPA recommended that options for correcting the deficiencies in the CUC System should be evaluated in the RDEIS as the EPA believes that it represents a reasonable alternative that could reduce potentially significant impacts on the potable water utility (and groundwater aquifer).

Presently, the CUC pumps between 0.890 MGD to 1.32 MGD from Maui Well No. 2; however, they currently bill only 0.320 MGD. This means that approximately 0.570 MGD to 1.00 MGD is UFW lost to the environment or utilized by customers at unmetered or unregistered facilities. The CUC, in response to a Stipulated Order with the EPA, prepared a draft drinking water master plan ("Master Plan"). The Master Plan identified several potential sources of UFW including faulty water meters, over-topping of water storage tanks, leaking pipes, and unmetered/unregistered connections. At the 03 February 2016 meeting, the CUC acknowledged that they do not fully understand the quantities of UFW that can be attributed to various sources. The following provides a summary of the various UFW sources and the CUC's general understanding and identified approach for addressing UFW from these sources:

- **Faulty Water Meters.** The CUC acknowledged that their water meters are not reliable and often undercount the amount of water delivered to service connections resulting in UFW. Often water bills are estimated based upon use when the meters were functional. Sources of inaccuracy, according to the Master Plan, include improper installation and lack of maintenance.
- **Over-Topping of Storage Tanks.** The CUC operates two aboveground water storage tanks, 0.250 million gallon (MG) and 0.500 MG in size. The 0.250 MG tank's flow control system has failed, resulting in UFW of 0.144 to 0.216 MGD according to the Master Plan. Currently the tank is operated manually and the master valve to the tank was closed during our field visit. The 0.500 MG storage tank has a telemetric connection to Maui Well No. 2 which is controls operation of the pumps; however, due to power supply irregularity, the telemetry can be unreliable and thus result in over topping of the tank. The CUC has programmed projects to replace the 0.500 MG tank and telemetry system at the tank. The CUC has not yet programmed a project to address deficiencies at the 0.250 MG tank. The Master Plan recommends that the CUC abandon the 0.250 MG tank.
- **Leaking Transmission and Distribution Pipes.** Leaking pipes are a source of UFW that are exacerbated by non-functional pressure reducing valves (PRVs) which over pressurize portions of the pipeline system. The CUC has programmed a project to replace several of the PRVs in accordance with the Master Plan recommendations. Additionally, CUC has identified pipelines for replacement including the seaport area where the proposed CJMT port operations would be located. The CUC has identified a need to perform leak detection and repair or replacement throughout Tinian – particularly areas of San Jose Village.
- **Unmetered and Unregistered Connections to the CUC System.** Neither unmetered nor unregistered connections have water meters and both contribute to UFW. The primary difference between the two is that unmetered connections are known and authorized by CUC whereas the unregistered connections are not known and are not authorized. CUC has not attempted a comprehensive review of their service area to determine occupied properties without a meter.

IV. CUC System Improvements

In their comments on the DEIS, the EPA noted that it has issued a Stipulated Order to the CUC to bring its drinking water system back into compliance with Safe Drinking Water Act (SDWA). Furthermore, the EPA noted that the CUC is in severe financial distress. In the EPA's comments, they stated that if the DoD action would place an additional financial burden on the CUC, this would be an unacceptable impact to the CUC and could compromise the public's access to drinking water. The EPA recommended that the DoD describe any improvements that the DoD would make to the CUC System in the RDEIS. These improvements could include any additional pumping capacity that would be needed to the CUC System to ensure that sufficient drinking water would be available to the public, nature and extent of CUC System improvements, and an explanation of how the DoD would support CUC in making these improvements.

- **Programmed CUC System Improvements.** The CUC provided the DoD with a list of programmed improvements (i.e., funding has been approved) to the CUC System.
    - PRV replacements. The CUC has a project in place to replace and, in some case, move several PRVs. This project will go a long way in reducing water pressure and help reduce additional pipeline failures.
    - 0.500 MG Storage Tank Replacement. The CUC has a project programmed to replace the existing 0.500 MG storage tank including the liquid control telemetry. This project will help in with the reliability of the CUC System.

- **Unprogrammed CUC System Improvements.** The CUC provided the DoD with a list of potential construction projects in order of importance that they are looking for funding to implement. They believe that one or some combination of projects from this list could be used as mitigation for DoD actions on Tinian. These improvements are not presently programmed.
  - Install altitude valve at the 0.250 MG storage tank. This improvement would reduce leakage by approximately 0.144 MGD to 0.150 MGD when the tank is in operation.
  - Replace 8-inch fiberglass-reinforced pipe (FRP) transmission/distribution line between Maui Well No. 2 and the 0.500 MG storage tank with 10-inch ductile iron pipe for resistance to pressure transients (4,620 linear feet); install dedicated polyvinyl chloride (PVC) distribution pipe from 0.500 MG tank to intersection with Maui Well No. 1 (currently off-line, inactive) (5,370 linear feet), sized to accommodate proposed DoD demand.
  - Replace 6-inch FRP distribution piping between Maui Well No. 1 intersection and the 0.250 MG tank with new PVC sized to accommodate proposed DoD demand (DoD point of connection on this pipeline) (8,270 linear feet).
  - Replace galvanized iron (GI) and cast iron piping in Makpo Valley with new 6-inch PVC (6,000 linear feet).
  - Replace 10-inch FRP distribution piping from 0.500 MGD to San Jose Village (10,720 linear feet) with new PVC, sized to accommodate increased demand.
  - Replace GI pipe to seaport with new PVC sized to accommodate proposed military seaport demand.
  - Perform leak detection and repair throughout Tinian, focus first on FRP distribution piping in San Jose Village.

V. Follow-up Actions

The DPRI provided follow-up actions to the JV following the meetings in the CNMI in order to continue to address the EPA's comments related to potable water and groundwater on Tinian. The following is a summary of those actions which will enable DPRI to have discussions with DoD leadership in Washington D.C. to discuss the potable water/groundwater alternatives/options for Tinian and the studies necessary to make these evaluations. In addition, the JV will provide DPRI with rough order of magnitude costs for the non-programmed CUC System improvements. The intent is to meet with DoD leadership in March followed by a meeting with the EPA later (the same week) in order advise them of the way forward for related to potable water/groundwater issues on Tinian.

1. **Water Demands Memo.** JV to update and finalize the Water Demands Memo to reflect refinements to the projected agricultural water demands, Tinian Ocean View Resort, updates to the CJMT as it relates to potential changes resulting from the "Day-in-the-Life" (i.e., relocation of washracks, any increases in firefighting demands), Divert (based on new information from Mark Petersen), induced growth from DoD and proposed resort development, and existing CUC metering data (i.e., does the existing metering water demand match the Tinian population plus the Tinian Dynasty tourist demands?).
2. **Unaccounted For Water.** JV to provide an outline for assessing UFW including traditional methods of how this could be achieved (e.g., water flow measurements on fire hydrants or other locations) and adaptive methods (e.g., study of the water meters). Provide pros and cons of each including the fact that the CUC has some repair and replacement projects that would change the UFW results in the future.
3. **Aquifer Model.** JV to provide an outline of the objectives of the groundwater modelling, inputs, and outputs, costs, and how this would address the EPA's recommendations.
4. **Potable Water/Groundwater Alternatives/Options to Evaluate.** The JV to provide a write up on the possible potable water/groundwater alternatives or options for possible evaluation.

- **All CUC System.** Based on the updated water demands and the 1.0 MGD water production capacity from Maui Well No. 2, is an "All CUC System" a practicable potable water/groundwater alternative for meeting CJMT demands? JV to provide a discussion of the critical vulnerabilities for an All CUC System. These could include: (1) UFW correction (15% to 25% have been discussed as optimal UFW) and what it would take to get the UFW under control and maintain it (rough costs); (2) the need for redundancy for DoD potable water system; (3) requirements for firefighting (i.e., ability to replenish the water storage tank in base camp within 48 hours in the event of a fire); (4) Groundwater Under the Direct Influence (GUDI) concerns for Maui Well No. 2 (requires back-up wells in the event water quality is not compliant); and (5) memo from Schergardus on water quality requirements for military installations; etc.
- **Potential Hybrid System Options.** JV to identify potential Hybrid System options and rough costs. These could include: (1) DEIS Option which includes a DoD System to meet most demands with improvements to CUC System to meet port improvements and personnel living on the economy (i.e., construction workers and base operations personnel); (2) Connection of a DoD System to the CUC System to allow for DoD to provide potable water in the event the CUC System has a shortfall in meeting their demands; (3) DoD System water trucked down to the port to meet port improvement demands and some improvements or pay assessment fees for personnel living on the economy.
- **All DoD System.** Preliminarily, an "All DoD System" does not appear to be a viable solution as at least some of the CJMT demands – personnel living on the economy – would need to be met by the CUC System.

- **Deadlines.** The JV was tasked to provide items 2 and 4 (UFW and Potable Water/Groundwater Options) in time for meetings with DoD leadership in early March and items 1 and 3 (Water Demands Memo and Aquifer Model) in time for the EPA meeting (mid March).

ATTACHMENT B
ADDITIONAL UNIFIED FACILITIES CRITERIA DISTRIBUTION SYSTEM REQUIREMENTS

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ADDITIONAL UNIFIED FACILITIES CRITERIA DISTRIBUTION SYSTEM REQUIREMENTS

Unified Facilities Criteria 3-230-01, *Water Storage and Distribution* (Department of Defense [DoD] 2021b):

- Design criteria should be in accordance with the following precedence:
  - State waterworks regulations
  - Utility provider's requirements
  - *Recommended Standards for Water Works*, latest edition
  - Conservation alternatives to meet current DoD conservation policies
- Minimum storage volume required is the sum of 50 percent of the average daily domestic requirements, plus any industrial demand that cannot be reduced during the fire period and the required fire demand.
- Distribution mains should be sized based on maximum hourly demand or the maximum daily demand plus the fire flow requirement, whichever is greater.
- A pipe network should be provided where flow to a single course is available from two or more directions.
- Demand projections should be based on anticipated demand not less than 5 years in the future.
- The Best Practice Documents American Water Works Association Manual M32, *Distribution Network Analysis for Water Utilities*, and Manual M31, *Distribution System Requirements for Fire Protection*, can be consulted for additional guidance.
- Velocities should range from 2–5 feet (8 meters) per second at maximum daily demand and the largest fire flow requirement.
- Minimum ground-level residual pressures at fire hydrants must be at least 40 pounds per square inch during normal flow conditions, 30 pounds per square inch during hourly maximum demand, and 20 pounds per square inch while supplying fire flow and hose-stream demand.
- Areas of excessively high or low pressures require that the system be divided into multiple pressure levels.
- Minimum pipe cover must be 2.5 feet (0.8 meter).
- When distribution is pumped from storage, transmission mains must have capacities equal to maximum day demand plus industrial demand and fire flow requirements.
- Without storage, transmission mains must meet maximum hourly demand.
- Shutoff valve spacing should not exceed 5,000 feet (1,524 meters) on long lines and 15,000 feet (5,572 meters) on loops.
- Velocities should not exceed 5 feet (1.5 meter) per second in transmission mains.

Unified Facilities Criteria 3-230-03, *Water Treatment* (DoD 2020):

- Domestic uses include drinking water, household uses, and household lawn irrigation.
  - Industrial flows include cooling, issues to ships, irrigation, swimming pools, shops, laundries, dining, processing, flushing, air conditioning, wash racks, rinse racks, and boiler makeup.

Unified Facilities Criteria 3-600-01, *Fire Protection Engineering for Facilities* (DoD 2021a):

- Additional distribution system requirements:
  - Must be sized to accommodate fire flows plus domestic and industrial for flushing demands that cannot be restricted during fires.
  - Must be looped to provide at least 50 percent of the required fire flow in case of a single break.
  - Must be able to support 150 percent of the building fire pump–rated capacity with a minimum pressure of 20 pounds per square inch at the suction side of the pump.
- Hydrant installation requirements:
  - Must be installed adjacent to paved areas, accessible to fire department apparatus.
  - Must not be closer than 3 feet (1 meter) or farther than 7 feet (2 meters) from the roadway, shoulder, or curb line.
  - Must be installed with a minimum 6-inch connection to the supply main and valves at the connection.
  - Must be in accordance with National Fire Protection Association 24, except as modified by the Unified Facilities Criteria.
- Hydrant spacing requirements:
  - All parts of the building must be within 350 feet (107 meters) of a hydrant.
  - At least one hydrant must be located within 150 feet (46 meters) of the fire department connection.
  - Hydrants protecting warehouses must be spaced a maximum of 300 feet (91 meters) apart.
  - Hydrants protecting aircraft hangars must be spaced a maximum of 300 feet (91 meters) apart with at least one hydrant at each corner of the hangar.
  - Hydrants protecting petroleum, oil, and lubricants storage and distribution facilities must be spaced a maximum of 300 feet (91 meters) apart, with a minimum of two hydrants.
  - Hydrants protecting exterior storage must be spaced at 300-foot (91-meter) maximum intervals around the perimeter.
  - Hydrant spacing must not exceed 600 feet (183 meters) for family housing developments without sprinkler protection and must not exceed 1,000 feet (305 meters) for family housing developments with sprinkler protection.

GROUNDWATER MODELING TECHNICAL MEMORANDUM

IN SUPPORT OF THE

COMMONWEALTH OF THE NORTHERN MARIANA ISLANDS JOINT MILITARY TRAINING ENVIRONMENTAL IMPACT STATEMENT

Department of the Navy
Naval Facilities Engineering Systems Command, Pacific
258 Makalapa Drive, Suite 100
JBPHH HI 96860-3134

June 2025

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1 INTRODUCTION

1.1. Background

The islands of the Commonwealth of the Northern Mariana Islands (CNMI) are strategically located in the United States (U.S.) Department of Defense (DoD) Indo-Pacific area of operations, as shown in Figure 1. Figure 2 shows the Military Lease Area on Tinian where the U.S. military has trained for several decades.

The Proposed Action would support the ongoing and evolving training requirements of U.S. Armed Forces forward deployed to the Western Pacific, and U.S. allies and partners, specifically for distributed operations training within the Military Lease Area on Tinian. Proposed training events would include both ground and aviation training within the Military Lease Area.

Non-live-fire offensive and defensive training actions would continue to be conducted in the Military Lease Area with an increase in existing land-based training events, including both ground and aviation training, which are the same or similar to those currently being conducted on Tinian.

Live-fire training would be conducted at two ranges that would be developed within the Exclusive Military Use Area:

- **Multi-Purpose Maneuver Range.** A live-fire range occupying approximately 200 acres at the northern tip of Tinian to support platoon-size live-fire and maneuver, including three surface radar facilities.
- **Explosives Training Range.** A live-fire range on approximately 2.5 acres for the employment of demolitions and military explosives in support of offensive and defensive training events.

The following are also included in the Proposed Action to support training events:

- Establishment of 13 Landing Zones, areas cleared of vegetation to 6–8 inches, and associated access roads to conduct training events and to provide staging, bivouac, and gathering and rendezvous areas.
- Ground and aviation improvements at North Field, including establishment of a drop zone and the placement of a metal airfield surface.
- Construction and operation of a Base Camp.
- Clearance and improvements of roads within the Military Lease Area.

1.2. Purpose

The purpose of this study is to evaluate the potential impact to the groundwater resources on Tinian associated with groundwater extraction to support the proposed CNMI Joint Military Training (CJMT).

1.3. Scope of Study

The goal of this study was to evaluate potential impacts to water quality on Tinian associated with the Proposed Action. The Proposed Action includes the installation of two optional CJMT well fields to provide potable and non-potable water for construction and operation of the proposed Base Camp and CJMT.

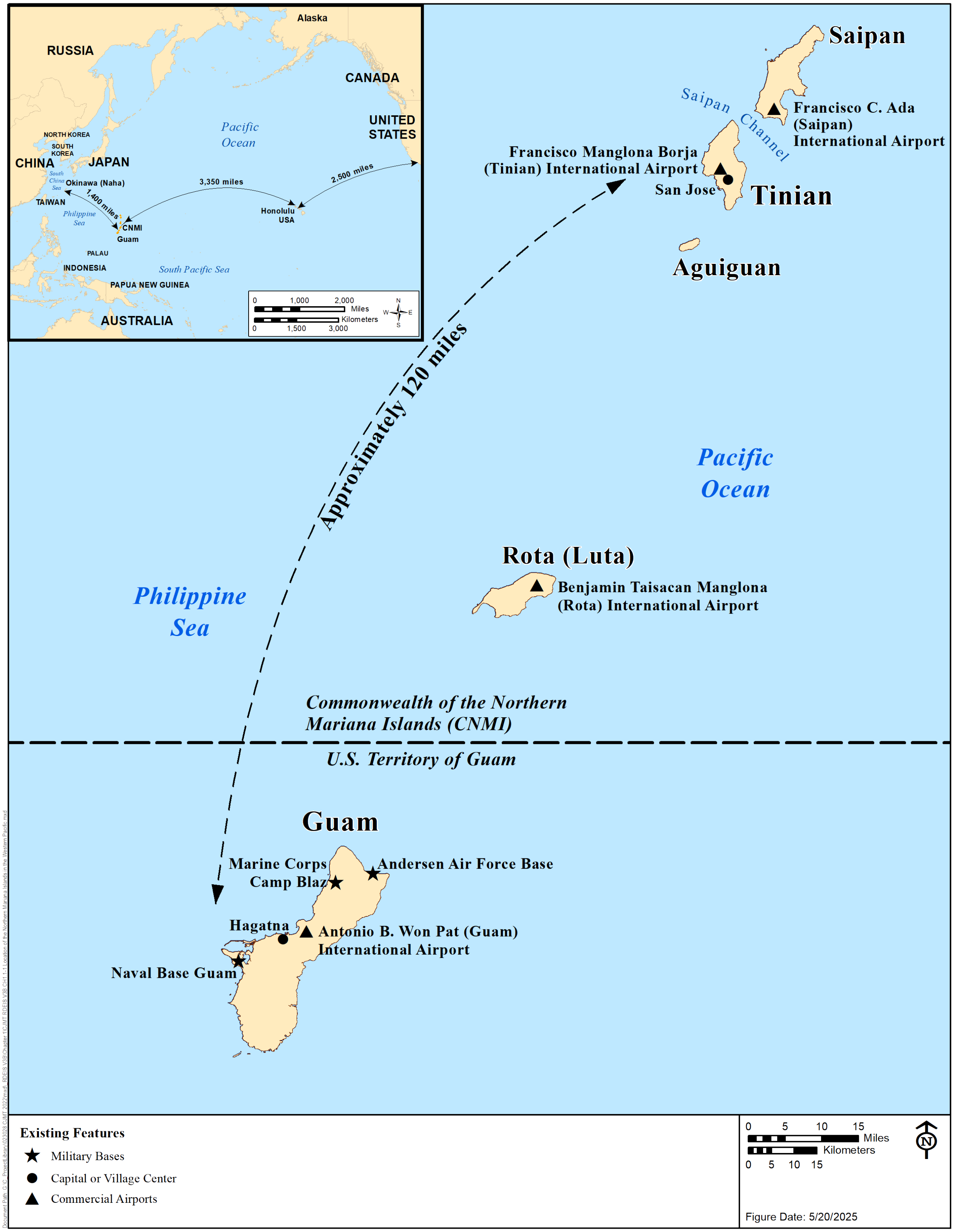

Figure 1. Island of Tinian – Location

Figure 2. Island of Tinian – Military Lease Area Boundaries

The scope of this study is presented below:

- Develop a new groundwater flow model based on the U.S. Geological Survey 2002 model.
- Use available data from Doan et al. 1960, Gingerich and Yeatts (U.S. Geological Survey) 2000, and Gingerich (U.S. Geological Survey) 2002.
- Use data from the CJMT *Aquifer Study Technical Memorandum* (Department of the Navy [DON] 2015).
- Use available head and production data for Maui Well No. 2 provided by the Commonwealth Utilities Corporation.
- Develop model scenarios based on water demands over the course of a typical training year.
- Use the model input sources, calibration, and sensitivity analysis primarily from the U.S. Geological Survey 2002 report. No additional sensitivity analysis will be performed.
- Use model output to evaluate directions of groundwater flow on island.
- Use the model to simulate chloride concentrations under five scenarios.
- Summarize model development, input sources, calibration, sensitivity, model limitations, and modeling results in a *Groundwater Modeling Technical Memorandum*. Include discussion of sea level rise's potential effects on the availability of freshwater via existing and proposed water wells that may assist planners in strategizing future contingency actions.

2 EXISTING AND PROPOSED WATER SYSTEMS

2.1 EXISTING WELLS

Currently, one potable water well and two groundwater wells are in use on Tinian. The agricultural wells are owned by the CNMI and are provided with electrical power by the Tinian Mayor's Office for the benefit of the cattle ranchers, who can fill potable containers used to provide water to cattle and construction contractors.

2.1.1 Current Potable Supply Wells

The sole supply of potable water on Tinian comes from the Makpo Marsh potential wetland complex's basal groundwater lens. Water is collected from the lens by Maui Well No. 2, discussed below. Tinian's public water system is owned and operated by the Commonwealth Utilities Corporation and serves the southern third of Tinian where the island's entire population resides. The currently operating public system consists of one horizontal Maui well for water supply, three storage tanks, one chlorine injection point, and approximately 38 miles of distribution pipes. A small distribution system serving Francisco Manglona Borja/Tinian International Airport is owned by the Commonwealth Ports Authority. The Commonwealth Ports Authority distribution system consists of a 60,000-gallon (227,100-liter) storage tank and a piping system that receives water from the Commonwealth Utilities Corporation's Maui well subsystem. In the past, additional wells for potable water supply were in operation, but they have since been taken offline and are not maintained in operable condition. Figure 3 shows existing wells on the island.

Maui Well No. 1, also located at the Makpo Marsh potential wetland complex, is currently out of service because the equipment is old and its repair parts have been difficult to obtain. The Maui Well No. 1 pump house was equipped with two 75-horsepower pumps and one 50-horsepower pump, and was originally designed to pump water to the Marpo Heights Tank. Previous plans to refurbish Maui Well No. 1 have been abandoned. Maui Well No. 1 is a Maui-type infiltration gallery constructed in Marpo Marsh within the Median Valley by the U.S. military in 1945. This well is the only well that was not abandoned after World War II; it supplied all of the potable water for Tinian until 1999, when two vertical wells were added to the system. Maui Well No. 1 produced about 1 million gallons per day from the shallow limestone aquifer. The well drew from the upper part of the aquifer over a large area, which tends to maximize the amount of freshwater that can be withdrawn from an area while minimizing upconing of the saltwater.

In 2000–2001, a new 400-foot-long infiltration gallery well (Maui Well No. 2) was constructed near Maui Well No. 1 to replace that well. According to the *2012 Water Quality Report* (Commonwealth Utilities Corporation 2013), Maui Well No. 2 supplied all Commonwealth Utilities Corporation water in 2012. Maui Well No. 2 has four 75-hp pumps, each capable of pumping about 350 gallons per minute for a total of 1,400 gallons per minute to both the Marpo Heights and Carolinas Tanks as well as the Commonwealth Port Authority Airport Tank. Currently, Maui Well No. 2 supplies the Commonwealth Utilities Corporation's entire Tinian water system, operating three of its four pumps almost constantly (Commonwealth Utilities Corporation 2013). Because one pump is kept on standby for maintenance purposes, Maui Well

No. 2 operates at near-full capacity. Additional information on Tinian's potable water system is provided in the *Potable Water Study* (DON 2025).

At various times, other vertical wells (e.g., TH-06 [capable of 60 gallons per minutes] and TH-04 [capable of 50 gallons per minute]) have been in use by the Commonwealth Utilities Corporation. Additional details, including ownership of the individual wells, are included in Attachment A – Known Current and Former Wells.

2.1.2 Existing Non-potable Supply Wells

Well M-21 was previously used by cattle ranchers. Currently, it is used primarily by the construction contractor for the U.S. Air Force Tinian Divert Activities and Exercises (Divert) Infrastructure Improvements at the Francisco Manglona Borja/Tinian International Airport. This well was permitted in 2024 to extract not more than 1.8 million gallons per month (DON 2025).

Well M-26 is primarily used by cattle ranchers and is not metered. Well M-26 agricultural water demand has been estimated at 59,178 gallons per day.

These wells are labeled M-21 and M-26 in Figure 3. Except for these two, no other wells within the Military Lease Area (the northern roughly two-thirds of the island) are known to be in use. During the aquifer study, M-21 and M-26 were used to produce about 25 gallons per minute each to cattle ranchers.

2.1.3 Existing Monitoring Wells

Some of the historical literature suggests that the Japanese military may have dug more than 100 wells during their occupation of Tinian. Most of these were reportedly filled in. The U.S. military constructed approximately 40 (M-series) groundwater wells in 1944 and 1945 on the island for water supply, including Maui Well No. 1. Most of these were reportedly drilled to 10 or 15 feet below mean sea level. The majority of the M-series wells have been inactive since shortly after World War II (Doan et al. 1960).

Between 1993 and 1997, the U.S. Geological Survey rehabilitated 16 of the inactive U.S. military wells. Rehabilitation involved retrieving the original pump and pipe, re-drilling as necessary, cleaning out the hole to near the original depth, and installing new surface casing/well head features, if necessary. In addition, between 1993 and 1997, U.S. Geological Survey drilled 17 new (TH-series) wells for groundwater monitoring in the Median Valley and the adjacent Southeast Ridge and Central Plateau. Of the 17 wells, 12 are open holes and 5 are cased with polyvinyl chloride pipe and screened below the water table. All wells were drilled into the top of the freshwater lens except wells TH-02, TH-04X, TH-08, and TH-09, which were drilled into the transition zone. The freshwater lens thickness and underlying transition zone fluctuate as a result of seasonal rainfall and groundwater withdrawal (U.S. Geological Survey 2000). At least one of the M-series wells (M-29) was deepened through the transition zone (to a depth of 168 feet below mean sea level) and used as a transition zone monitoring well for a period of time. However, no records of this transition zone monitoring have been located despite searches by U.S. Geological Survey staff.

Figure 3. Tinian Existing Wells

In 2012, a hydrogeologic assessment of groundwater conditions was completed at the planned Tinian landfill site and surrounding area (Tetra Tech 2012). The Tinian landfill site was a proposed municipal solid waste landfill northwest of the airport. The scope of work for the assessment included installation of three monitoring wells: WOP-197-01, WOP-197-02, and WOP-197-03. Although the basis for the well nomenclature used by the Bureau of Environmental and Coastal Quality is unknown, it is understood that these three refer to monitoring wells at the proposed landfill.

2.1.4 CJMT Proposed Action Water Wells

Potable and non-potable water for the Proposed Action are expected to come from four new wells located in Well Field A or B located northeast or northwest of the Tinian International Airport, respectively (Figure 4). Groundwater elevations in the area are generally less than 1 to about 2 feet above msl in the notional DoD well field.

Other On-island Wells

Following construction for U.S. Air Force's Tinian Divert Infrastructure Improvements at the Francisco Manglona Borja/Tinian International Airport, U.S. Air Force would use a newly installed firefighting well. The average demand for this well is estimated at 2,192 gpd.

U.S. Air Force plans to rehabilitate an existing well (assumed to be existing well M-05) for construction at North Field. The average demand for this well is estimated at 12,000 gallons per day.

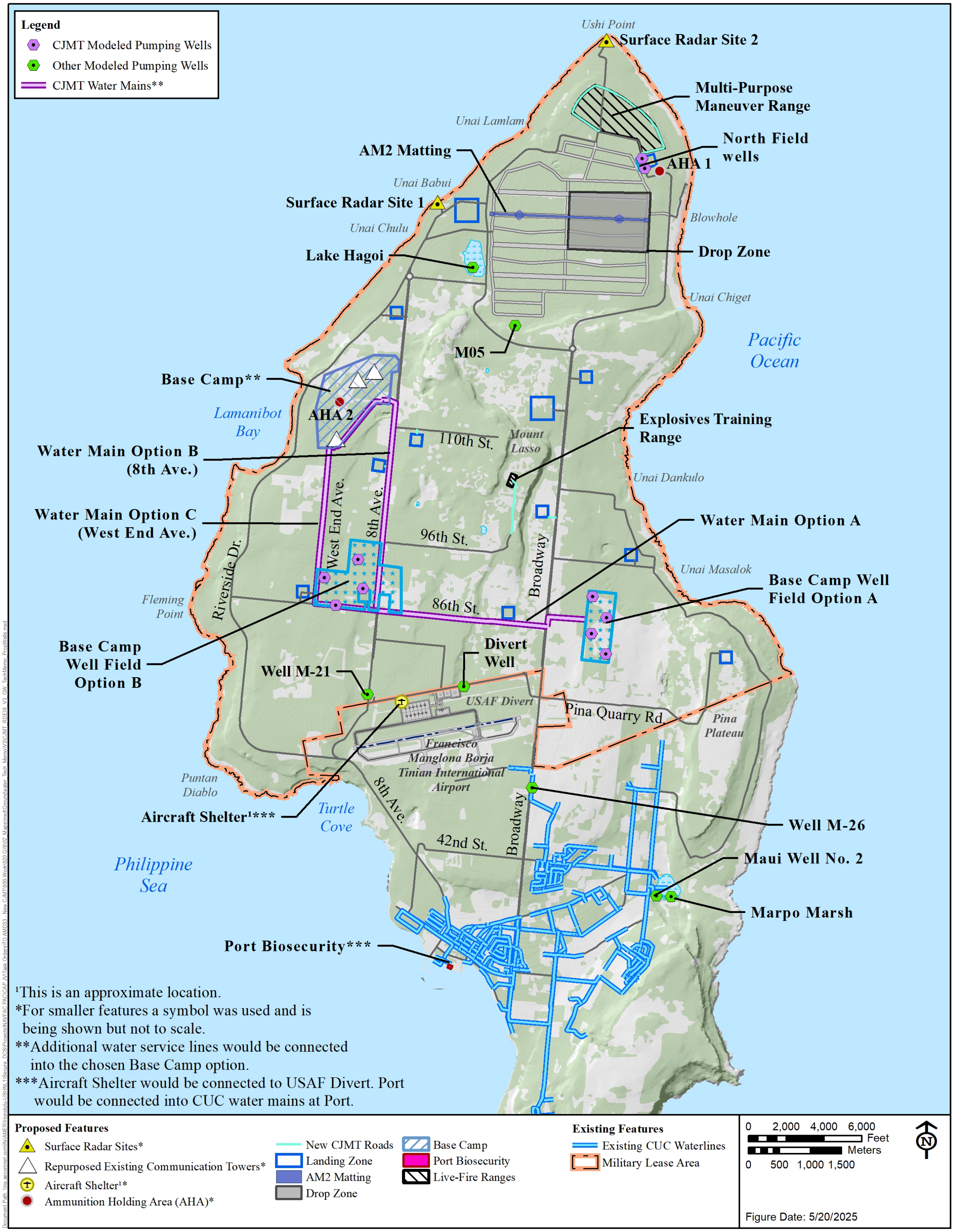

Figure 4. Tinian Future Wells

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3 WATER DEMANDS FOR PROPOSED ACTION

The Proposed Action includes construction of new water infrastructure to fully support the U.S. Marine Corps' (USMC) proposed CJMT and to avoid impacts on the Commonwealth Utilities Corporation water system. This proposed new water infrastructure would supply the domestic, industrial, and fire protection demands of military training activities and the majority of water used during construction. This proposed new water infrastructure would be operated by the DoD and would not be connected to the Commonwealth Utilities Corporation water system.

Domestic demand on the Commonwealth Utilities Corporation water system would also increase because of the Proposed Action. Operations staff and construction workers would live outside the Military Lease Area or stay in hotels and become customers of the Commonwealth Utilities Corporation water system.

These future demands are summarized in Table 1.

Table 1. Summary of Average Future Annual Water Demands on Tinian

Owner	*Facility*	*Type*	*Average Annual Water Demand (gallons per year)*	*No. Wells*
Military	CJMT Base Camp [a]	Potable	7,971,440	4
Military	CJMT North Field	Non-Potable	800,000	2
Military	USAF North Field Rehabilitation	Non-Potable	4,380,000	1
Military	Tinian Divert Infrastructure Improvements	Potable	800,000	1
CUC	Maui Well No. 2 [b]	Potable	314,727,702	1
Tinian Mayor's Office	Well M-21 (CJMT Construction)	Non-Potable	21,600,000	1
Tinian Mayor's Office	Well M-26 (Existing Agriculture)	Non-Potable	21,600,000	1

Notes: [a]Total demand for all the wells.
[b]Average of production at Maui Well No. 2 from 2019 to 2023 and proposed CJMT demands on the CUC water system.
Legend: CJMT = Commonwealth of the Northern Mariana Islands Joint Military Training; CUC = Commonwealth Utilities Corporation; gpd = gallon per day; U.S. = United States; USAF = United States Air Force.
Source: *Potable Water Study Update* (DON 2025).

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4 GROUNDWATER AND GEOLOGY

4.1 GROUNDWATER SUPPLY

Rainfall is the primary source of fresh groundwater on Tinian. The U.S. Geological Survey estimates the average annual groundwater recharge for Tinian to be approximately 30 inches per year (U.S. Geological Survey 2002). This translates into approximately 62,000 acre-feet per year of recharge. The rapid downward percolation of rainwater into porous limestone rock (Doan et al. 1960) recharges Tinian's basal freshwater aquifer. Fresh groundwater on Tinian is primarily classified as basal, which is a body of fresh groundwater that floats on saline groundwater. The portion of the basal freshwater lens that is usable for potable water, which has chloride concentrations less than 250 milligrams per liter, is thickest south and southwest of Mount Lasso and becomes increasingly thinner approaching the coastline. The groundwater table on Tinian ranges from sea level around the perimeter of the island to over 3 feet above msl in the central portions of the island. Groundwater flows outward from the North Central Highland and the southeastern ridge, and generally seaward around the island (DON 2015). Most of the fresh groundwater slowly discharges naturally from springs around the perimeter of the island and submarine coastal springs. The basal freshwater lens underlying Tinian is the principal source of drinking water and meets the definition of an aquifer found in CNMI Title 65, Chapter 65-90-010, and U.S. Environmental Protection Agency (EPA) regulations.

4.1.1 Physical Environment of Tinian

Physical features relevant to the groundwater modeling include topography, climate, geology, hydrogeology, and the existing well network and water supply systems. These features are detailed in the *Aquifer Study Technical Memorandum* (DON 2015).

4.1.2 Topography

Tinian is about 12 miles long and 6 miles wide. It is separated from Saipan by the approximately 3-mile-wide Tinian Channel. Tinian comprises a series of limestone plateaus separated by steep slopes and cliffs (U.S. Department of Agriculture Soil Conservation Service 1989). The surface landforms (Figure 5) are divided into five major physiographic areas based on topography and spatial relations, as described below (U.S. Geological Survey 1999). These are depicted along with representative spot elevation in Figure 5:

- **Southeastern Ridge.** This land area is the southernmost and highest part of the island, with a maximum elevation of 614 feet at Mount Kastiyu. Steep slopes and cliffs up to 500 feet in height on the southeast characterize this area.
- **Median or Marpo or Makpo Valley.** This land area is a low, broad, elongated depression northwest of the Southeastern Ridge with a maximum elevation of 150 feet. In the valley, the land surface intersects the water table, resulting in a small potential wetland complex known as the Makpo Wetland or Makpo Marsh.
- **Central Plateau.** This land area extends northward from the Makpo Valley and includes central Tinian and portions of northern Tinian. The plateau is broad and gently sloping, with most of the vertical relief at its southern and northern boundaries.

- **North-Central Highland.** This land area is located within the northern part of the Central Plateau and midway between the east and west coasts of the island. The maximum elevation of the highland at Mount Lasso is 545 feet.
- **North Lowland.** This land area is located at the northern tip of Tinian. It is generally flat with an average elevation of approximately 100 feet, except for the Lake Hagoi wetland, where the land elevation is approximately at sea level.

4.1.3 Climate

The seasons on Tinian are defined by distinct differences in rainfall. During the wet season, which occurs between the months of July and October, the island receives roughly 60 percent of its annual precipitation. February through May comprise the dry season, when only about 10 percent of Tinian’s annual rainfall occurs. The remaining months (November, December, January, and June) are the transitional months when the island receives the remaining 30 percent of its rainfall. Rainfall from tropical storms and typhoons, in years when they occur, can comprise a significant percentage of the total annual rainfall, and a lack of storms can significantly contribute to drought conditions. Typical temperatures range from 76 degrees Fahrenheit to 88 degrees Fahrenheit (U.S. Geological Survey 2002).

Precipitation averaged about 81 inches per year at the airport weather station from 1988 to 1994 and in 1996, years for which complete daily rainfall records were available. Because the highest point on Tinian is only 614 feet above mean sea level, orographic effects (increased rainfall related to mountain ranges) appear to be minimal. Gingerich and Yeatts measured rainfall at four sites on Tinian from 1993 to 1996, and the measured amounts ranged from 72 to 82 inches across the island (U.S. Geological Survey 2000). Gingerich used an average rainfall of 82 inches per year in the water budget for the numerical groundwater flow model (U.S. Geological Survey 2002).

Figure 5. Tinian Physiographic Areas

4.1.4 Geology

Tinian is a composite carbonate island (Jenson et al. 2006) consisting of geologically young coralline and algal limestone strata overlying an older core of volcanic tuff and breccias, small portions of which crop out at the surface in two small places on the island (Figure 6). The limestone retains substantial primary porosity but also exhibits regional- to local-scale fractures (secondary porosity) associated with regional tectonic stresses and local loading/unloading from uplift-subsidence and deposition-erosion cycles. Regional high-angle normal faults result in offset limestone plateaus that characterize the island (Figure 6). Figure 7 shows geologic cross sections of Tinian.

Tinian comprises the following four major geologic units, shown in Figure 6 (U.S. Geological Survey 2002):

- **Tinian Pyroclastic Rocks.** Tinian Pyroclastic rocks are the oldest rocks exposed on the island (Late Eocene age; about 38 million years old), which likely underlie all other exposed rock units there. These fine- to coarse-grained ash and angular fragments represent explosive volcanic materials ejected from an ancient volcano that formed the core of the island. These rocks are exposed on the North-Central Highland and Southeastern Ridge where they occupy about 2 percent of the surface of Tinian today. Surface exposures are generally highly weathered and typically altered to clay minerals.
- **Tagpochau Limestone.** Of Early Miocene age (approximately 23–20 million years old), Tagpochau Limestone rocks are exposed on about 15 percent of Tinian’s surface, generally in the North-Central Highland and the southern part of the Southeastern Ridge. These rocks range up to about 600 feet in thickness. They are composed of fine- to coarse-grained, partially recrystallized broken limestone fragments, and about 5 percent reworked volcanic fragments and clays. Surface exposures are highly weathered, and this unit extends from the unconformity with the volcanic rocks below to the ground surface in the North-Central Highland and the southern part of the Southeastern Ridge, mentioned above. Across most of the island, this unit is capped by the Mariana Limestone.
- **Mariana Limestone.** These Pliocene to Pleistocene age (about 5–3 million years old), Mariana Limestone rocks cover approximately 80 percent of Tinian’s surface, forming nearly all of the North Lowland, the Central Plateau, and the Makpo Valley. These rocks range up to about 450 feet in thickness. They are composed of fine- to coarse-grained fragmented limestone, with some fossil and algal remains, and small amounts of clay particles. Small voids and caverns (tertiary porosity) are common in surface exposures. Overall, the Mariana Limestone has a higher coral content than the Tagpochau Limestone.
- **Beach Deposits, Alluvium, and Colluvium.** Shallow Pleistocene to Holocene age (approximately 2 million years old to the present) sediments mantle less than 1 percent of Tinian’s surface and range up to approximately 15 feet thick. The deposits consist of poorly consolidated sediments, which are mostly calcareous sand and gravel deposited by waves. However, they also contain clays and silts deposited inland surrounding Lake Hagoi and the Makpo Marsh potential wetland complex. Loose soil and rock material (talus) are found at the base of slopes.

Figure 6. Tinian Generalized Surficial Geology

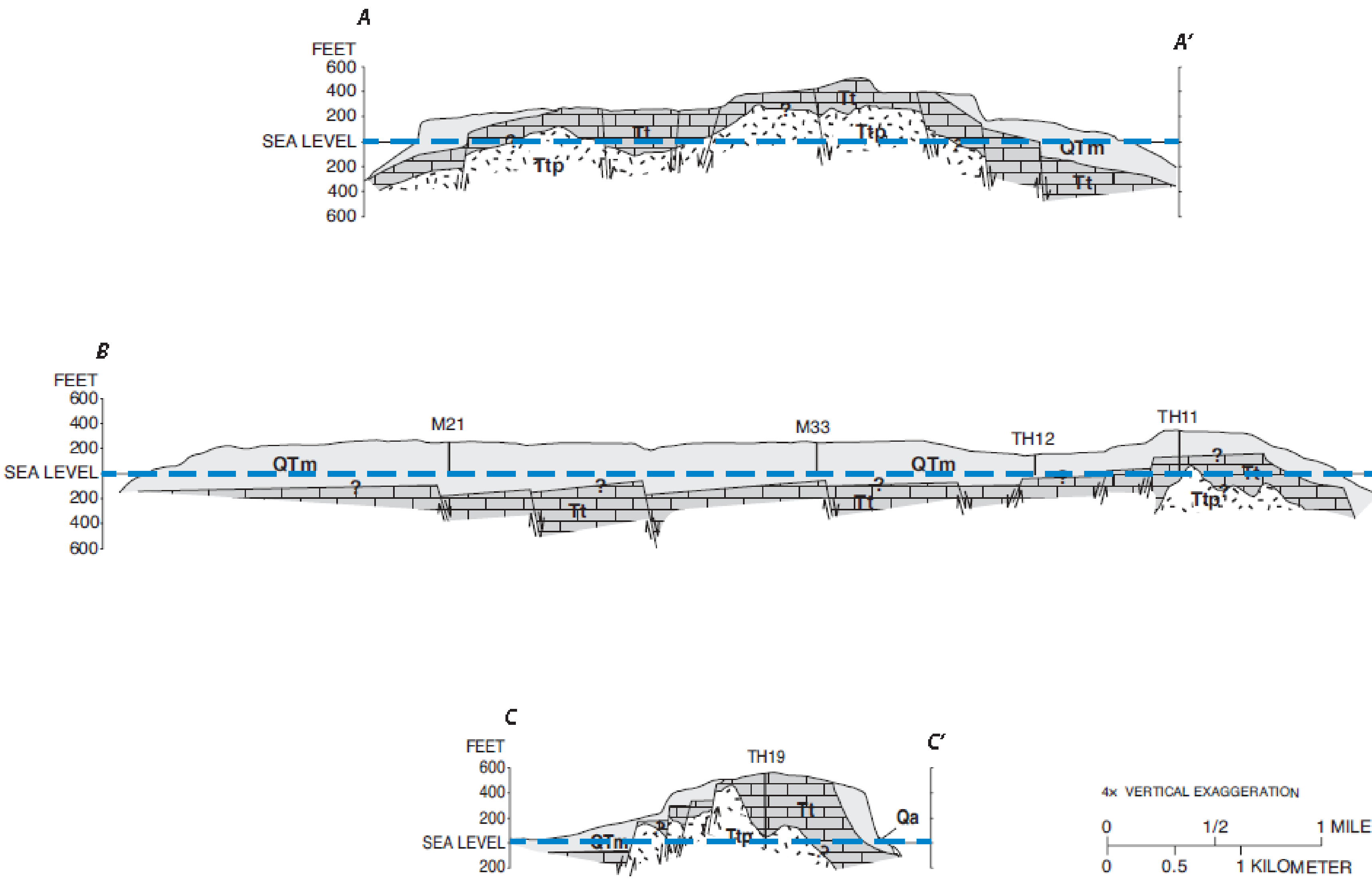

Figure 7. Tinian Geologic Cross Sections

Source: U.S. Geological Survey 2000 (after Doan et al. 1960).

4.2 GROUNDWATER RESOURCES OF TINIAN

4.2.1 Overview

Groundwater is recharged by rainfall infiltration over most of Tinian. Water that recharges the groundwater system flows from zones of higher to lower hydraulic head. Ideally, fresh groundwater (chloride less than 250 milligrams per liter) forms a double-convex lens in a cross section and is underlain by denser saltwater (chloride concentration of 19,000 to 20,000 milligrams per liter); however, the base is distorted where it contacts the relatively impermeable volcanic basement rock. The Ghyben-Herzberg relationship (Baydon-Ghyben 1888–1889, Herzberg 1901) is commonly used to relate the thickness of a freshwater lens in an ocean-island aquifer to the density difference between freshwater and saltwater. A generalized cross section of the freshwater lens is presented in Figure 8. Doan et al. (1960) reports the existence of such a basal freshwater lens in areas near the north end and center portion of the island. The theoretical interface between freshwater and saltwater will be at a depth below sea level about 40 times the height of the water table above sea level. Instead of a sharp freshwater/saltwater interface, however, freshwater is separated from saltwater by a transition zone in which salinity grades from freshwater to saltwater. In many field studies, the theoretical Ghyben-Herzberg interface depth within the transition zone is generally defined as the depth of about a 50 percent mix of freshwater and saltwater (i.e., roughly equal to a chloride concentration of 9,500 to 10,000 milligrams per liter). Under equilibrium flow conditions in permeable aquifer systems, the Ghyben--Herzberg relationship may provide a reasonable estimate of freshwater depth if the transition zone is comparatively thin (U.S. Geological Survey 2002). Pumping freshwater tends to disturb this equilibrium, resulting in a thinner freshwater lens and thicker transition zone. Freshwater lens thickness is affected by aquifer permeability and recharge rates. A reduction in recharge rate or an increase in permeability will reduce the thickness of the freshwater lens.

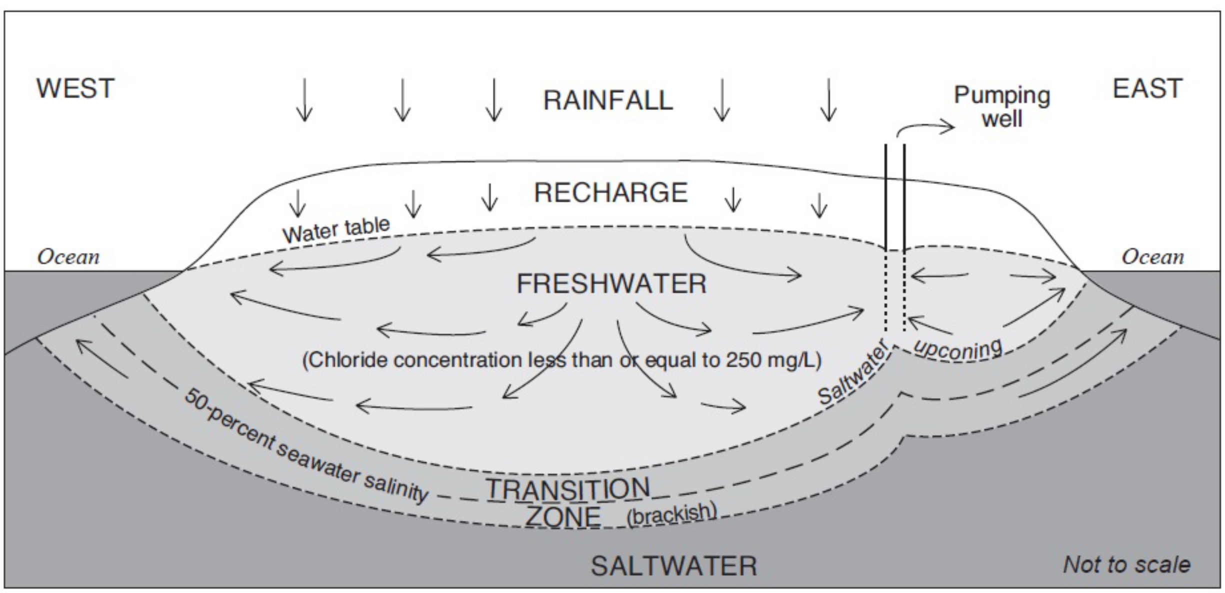

Figure 8. Generalized Depiction of a Freshwater Lens above Saltwater

Source: U.S. Geological Survey 2000.

In very permeable limestone, the water table is no more than a few feet above sea level, and the slope of the water table is nearly flat (U.S. Geological Survey 2002). Based on the Ghyben-Herzberg Principle, the depth to the 50% isochlor on Tinian should vary from a maximum of about 80 feet below mean sea level around the Central Plateau where the groundwater stands about 2 feet above mean sea level, decreasing radially to sea level around the perimeter of the island.

Potable and non-potable water for the proposed action is expected to come from one of two new well fields (Well Fields A and B, shown in Figure 4).

The groundwater surface has been mapped (Doan et al. 1960; USGS 2000) in the notional DoD well field to range from about 0.8 to 1.6 feet above mean sea level. Assuming an ideal freshwater lens, the 50 percent isochlor would vary from about 32 to 64 feet below mean sea level in the center of the island and would thin toward the coast. The portion of the lens that is useful for potable water (i.e., with a chloride concentration of less than 250 milligrams per liter [approximately 1 percent isochlor]) is likely thinner than the theoretical 50 percent isochlor depth.

Most of the fresh groundwater discharges naturally from the aquifer at onshore and submarine coastal springs. Stafford et al. (2004, 2005) documented caves, fractures, and coastal springs on Tinian, which can be locally important for groundwater development. A small amount of groundwater may be lost locally to evaporation and transpiration at the Makpo Marsh potential wetland complex and Hagoi Lake (U.S. Geological Survey 2002).

4.2.2 Hydrogeology

Hydraulic conductivity is a quantitative measure of the capacity of a rock to transmit water. Limestone units tend to have high hydraulic conductivities because of the porous and well-washed character of coral reefs, as well as secondary porosity as a result of dissolution. In contrast, pyroclastic rocks tend to have much lower hydraulic conductivities as a result of poor sorting and the high susceptibility of some volcanic minerals to chemical weathering and alteration to clays (U.S. Geological Survey 2002), as is the case on Tinian.

Tinian, a composite karst island aquifer (Jenson et al. 2006), is a triple-porosity aquifer. The young limestone retains substantial primary (interparticle or matrix) porosity, which makes the dominant contribution to storage and usually local transmission to wells. Regional transmissivity is dominated by widened fractures, which may develop along faults or along tension fractures. Where wells intercept the fracture network, performance can be one or more orders of magnitude higher than for wells that draw their production exclusively from local matrix porosity. The third source of porosity in composite islands is conduits (cave systems) that can develop along the contact between the overlying soluble limestone aquifer and the underlying insoluble volcanic basement. Such conduits can develop along the flanks of the basement rises and ridges where they stand above sea level or have been above sea level during ice-age, sea-level low-stands (Vann et al. 2013). Hydraulic conductivities in carbonate island karst aquifers can range from local values of 1 to 10^3 feet per day to regional values of 10^3 to 10^4 feet per day (Rotzoll et al. 2013).

The Tinian pyroclastic rocks are generally believed to have much lower permeability than limestone because of their texture and density and are essentially considered non–water-bearing for the purposes of this study. The overlying Tagpochau Limestone, where it exists beneath current ocean levels, and the Mariana Limestone that overlies it are both considered viable aquifers in this study. The minor beach deposits, alluvium, and colluvium are not situated in areas or at elevations that make them viable as groundwater resources for the purposes of this study. Doan et al. (1960) reported historical well productions from the military wells ranging from nil to 100 gallons per minute, with the majority being in the 60 to 100 gallons per minute range. The U.S. Geological Survey performed aquifer tests on Tinian between 1994 and 2000 to estimate the hydraulic conductivity of the Tinian aquifers (Tagpochau Limestone and Mariana Limestone). Pumping rates for the tests ranged from 3 to 165 gallons per minute. Resulting estimates of hydraulic conductivity in Tagpochau Limestone and Mariana Limestone on Tinian ranged from 21 to 23,000 feet per day.

The U.S. Geological Survey prepared a groundwater model in *Geohydrology and Numerical Simulation of Alternative Pumping Distributions and the Effects of Drought on the Ground-Water Flow System of Tinian, Commonwealth of the Northern Mariana Islands* (U.S. Geological Survey 2002). For modeling purposes, Tinian was divided into three horizontal hydraulic conductivity zones: (1) highly permeable limestone, (2) less permeable, clay-rich limestone, and (3) low-permeability volcanic rocks. The two-dimensional, steady-state groundwater flow model was developed to enhance the understanding of: (1) the distribution of aquifer hydraulic properties, (2) the conceptual framework of the groundwater flow system, and (3) the potential effects of various pumping distributions and drought on water levels and the freshwater/saltwater zones. For the modeling, the U.S. Geological Survey used values of 10,500 feet per day for highly permeable limestone, 800 feet per day for less permeable limestone, and 0.2 feet per day for volcanic rock (U.S. Geological Survey 2002). This 4 to 5 order-of-magnitude contrast is not unusual in composite islands. The U.S. Geological Survey monitored and contoured ambient groundwater elevations for further understanding of the groundwater flow regime (U.S. Geological Survey 2000). Groundwater generally flows radially away from the North-Central Highland and the Southeastern Ridge.

4.3 WATER QUALITY

Chloride concentration is an important secondary standard for Maui Well No. 2 because it has the potential to indicate the quantity of freshwater available at that location. The secondary maximum contaminant level for chloride is 250 milligrams per liter. Table 2 provides chloride concentrations at Maui Well No. 2 between 2012 and 2023.

Table 2. Chloride Concentrations at Maui Well No. 2

Year	***Chloride (mg/L)***	
	Average	***Range***
2012	196	175–223
2013	190	172–217
2014	213	212–214
2015	213	212–214
2016	190	184–196
2017	184	184
2018	176	176
2019	146	NA
2020	145 [a]	NA
2021	176 [a]	158–176
2022	176 [a]	158–176
2023	177	NA

Notes: [a]Value revised to highest instead of average.
Legend: mg/L = milligrams per liter; NA = not available; No. = Number.
Source: Commonwealth Utilities Corporation 2013, 2014, 2015, 2016, 2017, 2018, 2019, 2020, 2021, 2022, 2023, 2024.

U.S. Geological Survey 2002 reported that chloride concentration at the Municipal well [Maui Well No. 1] did not change significantly during 1992–1997, averaging about 180 milligrams per liter, and ranging from 160 to 220 milligrams per liter. The average chloride concentration is about 100 milligrams per liter higher than initially measured during non-pumping conditions after construction in 1945 (Lawlor 1946), and 100 milligrams per liter higher than at other wells in the median valley.

Salinity in a freshwater lens is gradational, consisting of an upper freshwater core through an underlying transition zone to saltwater below. However, depending on aquifer permeability and the strength of tidal influence, the transition from freshwater to saltwater can be gradual or sharp. On small islands, mixing in the transition zone results mainly from tidal fluctuations superimposed on the gravity-driven flow of freshwater toward the shore. In areas near the coast where mixing is thorough, a freshwater lens may not form and brackish water may exist even at the water table. Under conditions of steady recharge, no pumping, and no ocean-level effects, the steady-state lens would have fixed dimensions. In reality, rainfall is episodic and seasonal, and lens volume fluctuates naturally with time. Tidal fluctuations, variable recharge, and episodic pumping all combine to create a thicker transition zone than would be present without these influences (U.S. Geological Survey 2002). Figure 8 shows a generalized graphic depiction of a freshwater lens above a saltwater wedge on a small island.

Based on monitoring performed by the U.S. Geological Survey in the 1990s, the transition zones in wells TH-08 and TH-09 (monitoring wells installed by the U.S. Geological Survey in 1993) varied from approximately 30 to 50 feet thick in 1993 and 1994. Doan et al. (1960) report 20 pre-pumping chloride concentration results ranging from 16 milligrams per liter to 650 milligrams per liter. Two of the samples exceeded the EPA's secondary maximum concentration level for chloride of 250 milligrams per liter. Ten pairs of pre-pumping and post-pumping chloride concentration results are also reported (U.S. Geological Survey 2000). Prior to pumping, 1 of the 20 wells (with pre- and post-pumping data) exceeded the secondary maximum concentration level and, after pumping, 2 to 3 wells exceeded that standard. One of the post-pumping results was simply recorded as "high," but it is assumed this refers to a concentration higher than 250 milligrams per liter. Seven to 8 of 10 wells remained below the secondary maximum concentration level at the end of pumping.

Bureau of Environmental and Coastal Quality provided the following information in Captain Brian Bearden's email to Jacqueline Rice from Headquarters, USMC, forwarded to Doug Gilkey on March 3, 2025:

> [Bureau of Environmental and Coastal Quality]'s previous review comments raised a number of concerns with the proposed location near the airport, primarily related to the potential to contaminate valuable groundwater resources. That location was within an area where we have documentation and other data that would support classification as a Class I Aquifer Recharge Area/Groundwater Protection Zone as established or references [sic] in several CNMI regulations. Our primary documentation supporting this concern is the 2000 USGS Water investigations Report 00-4068 which shows the area on the north side of the airport as being within the boundaries of the +1.0 feet groundwater elevation contour, which the CNMI Well Drilling and Well operations regulations (NMIAC [Northern Mariana Islands Administrative Code] § [Section] 65-140-2010) utilize as the boundary of the Class II groundwater protection zones, which also contains the Class I zones which are more loosely defined to include "municipal wellfields" and other resources that are either currently in use for water supply, or meet specific other criteria.
>
> In contrast to this, the IBB [International Broadcasting Bureau] site is in an area that appears to not be within either a Class I or II Aquifer Recharge Area/Groundwater Protection Zone. Even though the USGS report does not show groundwater elevation contours in this particular area due to lack of data, the map contours can be reasonably extrapolated, supported by general knowledge of island freshwater lens hydrology, to strongly suggest that the IBB site is located outside the potential boundaries of any future Class I or II groundwater protection zone designation. Thus, the IBB site would not trigger the same level of concern stated in [the Bureau of Environmental and Coastal Quality]'s previous comments related to the locations closer to the airport and would be a preferred location to minimize such concerns.

Table 3 summarizes water production (i.e., extraction) quantities from Maui Well No. 2 as recorded by the Commonwealth Utilities Corporation at the well site. Production includes water delivered into the distribution system, which is inclusive of water billed to customers, unmetered uses, leaks, losses, and overflows.

Table 3. Commonwealth Utilities Corporation Water Production from Maui Well No. 2

Year	***Total Annual (MG)***	***Average Daily (MGD)***
2019	313	0.86
2020	312	0.85
2021	307	0.84
2022	321	0.88
2023	306	0.84
2019 to 2023 Average		0.85

Legend: CUC = Commonwealth Utilities Corporation; MG = million gallons; MGD = million gallons per day; No. = Number.
Source: Commonwealth Utilities Corporation 2024a.

The EPA has stated that the sustainable yield at Maui Well No. 2 in drought conditions is 1.0 million gallons per day. The average production at Maui Well No. 2 for the last 5 years was approximately 0.85 million gallons per day. This sustainable yield value from EPA only applies to the Maui Well No. 2 location and is not an indication of the sustainable yield of all of Tinian.

5 MODELING

5.1 MODELING APPROACH

The U.S. Geological Survey developed a groundwater flow model to simulate groundwater conditions on the island, with the results published in a 2002 report. The model was constructed using the quasi-three-dimensional SHARP computer program developed by H. I. Essaid for the U.S. Geological Survey (Essaid 1990). SHARP is a finite difference code that models both fresh and saltwater flow and approximates a sharp interface between the two solutions. In the model, each of the limestone and volcanic rock aquifers is represented by a single model layer, and flow within the layer is assumed to be horizontal.

The 2002 SHARP model has several limitations. It assumes that freshwater and saltwater do not mix, preventing it from predicting salinity distribution within the aquifer or the quality of water pumped from a specific well. While the model can simulate the location of the freshwater/saltwater interface, it cannot accurately predict local drawdown or rise in the interface beneath a pumped well. Additionally, since the groundwater flow model consists of only two relatively thick layers, it lacks the resolution needed to simulate vertical head gradients effectively.

5.1.1 Previous Modeling Effort

The U.S. Geological Survey developed a groundwater flow model to simulate groundwater conditions on the island, with the results published in a 2002 report. The model was constructed using the quasi-3-D SHARP computer program developed by H. I. Essaid for the U.S. Geological Survey (Essaid 1990). SHARP is a finite difference code that models both fresh and saltwater flow and approximates a sharp interface between the two solutions. Each aquifer in the model is represented by a single layer, and flow within the layer is assumed to be horizontal.

5.1.2 Model Selection

Many numerical modeling codes are capable of simulating variable density conditions, and the modeling process is typically approached in a phased manner. Several American Society for Testing and Materials International standards exist to guide the modeling process. American Society for Testing and Materials D6170-17 (2010b) and American Society for Testing and Materials D5447-04 (2010a) contain recommendations for selecting a groundwater modeling code and applying that code to a site-specific problem.

The computer code selected to model groundwater flow was the Modular Three-Dimensional Finite-Difference Groundwater Flow Model (MODFLOW) 2000, a 3-D, cell-centered, finite difference, saturated-flow model developed by the U.S. Geological Survey (originally developed by McDonald and Harbaugh 1988). The Groundwater Modeling System (GMS) provides an interface to the updated version of MODFLOW 2000 (Hill et al. 2000). Based on the information available, the uncertainty associated with site information, and the modeling objective, MODFLOW 2000 was considered an appropriate groundwater flow code.

Chloride transport simulations were conducted using the Modular Three-Dimensional Multispecies Transport Model for Simulation (MT3DMS) groundwater contaminant transport model code (Zheng and Wang 1999). MT3DMS is an improved version of the MT3D model developed in 1990 (Zheng 1990). This model has improved numerical solvers that make it more stable and prevent model-induced numerical oscillations. GMS provides a module that links MODFLOW groundwater flow information to MT3DMS. MT3DMS uses this information to simulate contaminant transport using the MODFLOW -simulated groundwater flow field.

SEAWAT (Version 4, U.S. Geological Survey 2008) was developed to simulate variable density flow resulting from high concentrations of solutes, typically salt. SEAWAT was built on the MT3DMS platform and solves iteratively for flow, transport, and the resulting density variations that impact flow.

The groundwater model software package selected for this effort was GMS (Version 10.8, Aquaveo 2021). GMS is a comprehensive graphical-user interface for performing groundwater simulations and provides various powerful tools for data interpolation and figure generation. The entire GMS consists of a graphical user interface (the GMS program) and a number of analysis codes (e.g., MODFLOW, MODPATH, MT3DMS, RT3D, SEAWAT). GMS was developed by the Environmental Modeling and Research Laboratory in partnership with Waterways Experiment Station and was used as a supplementary tool to assist with preparing and interpolating data, pre- and post-processing, and generating figures (Environmental Modeling and Research Laboratory 2005).

5.1.3 Model Construction

A model grid was created with a domain extent matching that outlined in the 2002 U.S. Geological Survey model document. The original SHARP input files were obtained from the U.S. Geological Survey, and the model layer elevations and properties were extracted for import into the new MODFLOW grid. Although the 2002 U.S. Geological Survey model files provided limited data on aquifer geometry and properties, the model results are deemed reasonable for the intended purposes.

5.2 MODEL DESIGN

The lateral extent of the modeled area is shown in Figure 9. The domain includes the entire island of Tinian, an area offshore extensive enough to minimize boundary interferences with simulated groundwater flow on the island, and the offshore area where fresh groundwater discharges to the ocean (U.S. Geological Survey 2002).

5.2.1 Grid and Layering

The model grid (Figure 9) is non-uniform, composed of 81 rows and 73 columns, and covers an area of approximately 58,400 feet east to west and 92,520 feet north to south. The total modeled area encompasses approximately 194 square miles). Maximum cell dimensions are approximately 2,336 feet by 3,700 feet, and the minimum cell size is 925 feet by 584 feet (localized to the island).

The initial U.S. Geological Survey model consisted of two layers that were later subdivided into eight model layers. Layers 1 through 3 represent the karst aquifer materials and some shallower volcanic rocks, while layers 4 through 8 only include volcanic basement material. The original and subdivided model cross sections are shown in Figure 10. To avoid dry cells, the bottom of model layer 1 was set to -15 feet mean sea level across the island, which matches the screen bottom elevation of the proposed four new CJMT water wells. However, in the area near Maui Well No.

2, the bottom of layer 1 was locally set to -2 feet mean sea level to align with the bottom screen elevation of Maui Well No. 2.

5.2.2 Boundary Conditions

Because the 2002 U.S. Geological Survey model layer 1 was divided into three model layers in the new model development, the ocean in model layer 1 was simply represented using a constant-head boundary. In model layers 2 through 8, the four edges of model were also applied to a constant-head boundary (Figure 11).

In the 2002 model, recharge was applied to layer 1 of the model over the island at a uniform rate of 29.7 inches per year. In the AECOM 2025 model, recharge was distributed spatially over the limestone areas, with low-permeability rock areas receiving a minimal recharge rate. This is discussed further in Section 5.3 of this report.

Figure 9. Groundwater Model Domain

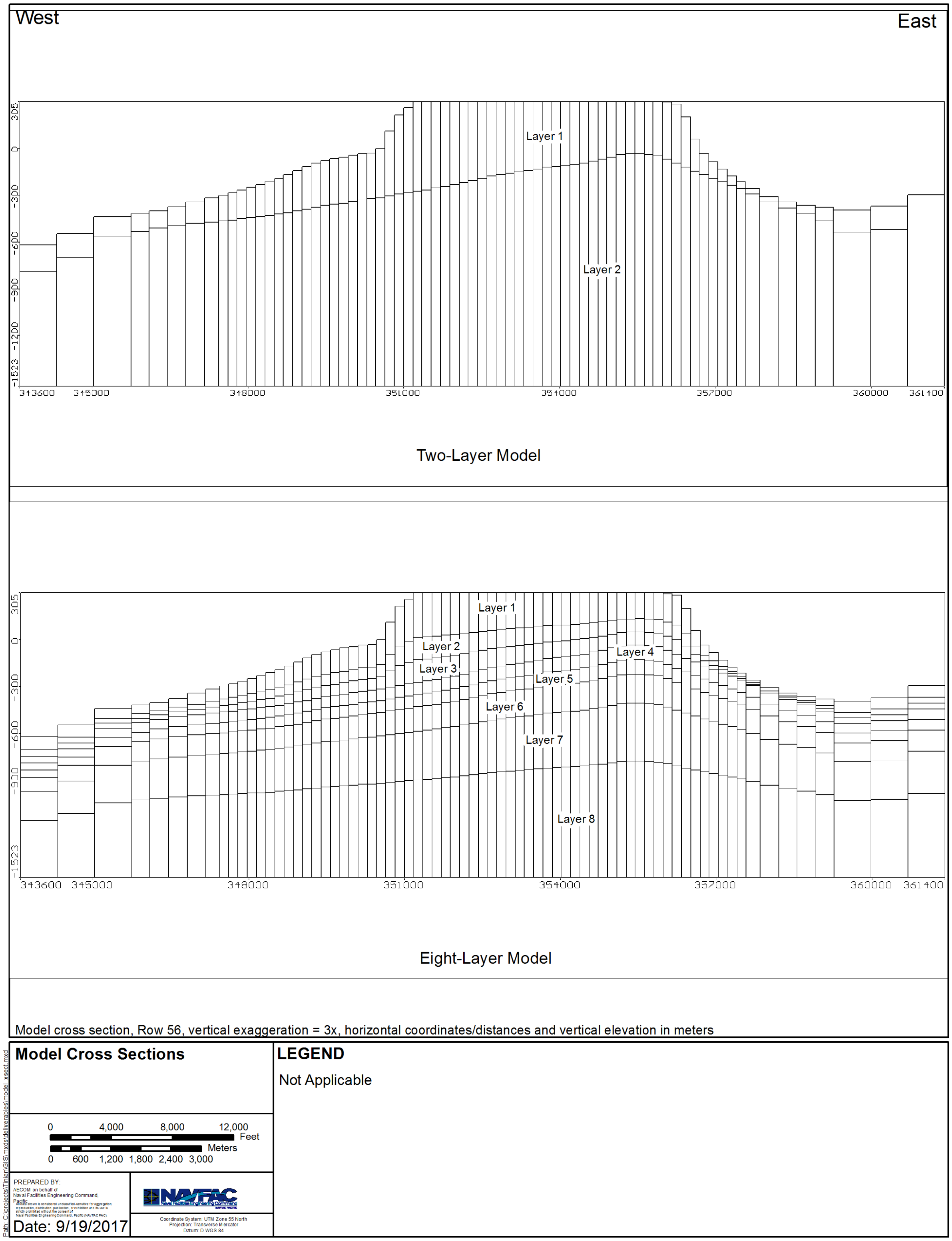

Figure 10. Model Cross Sections

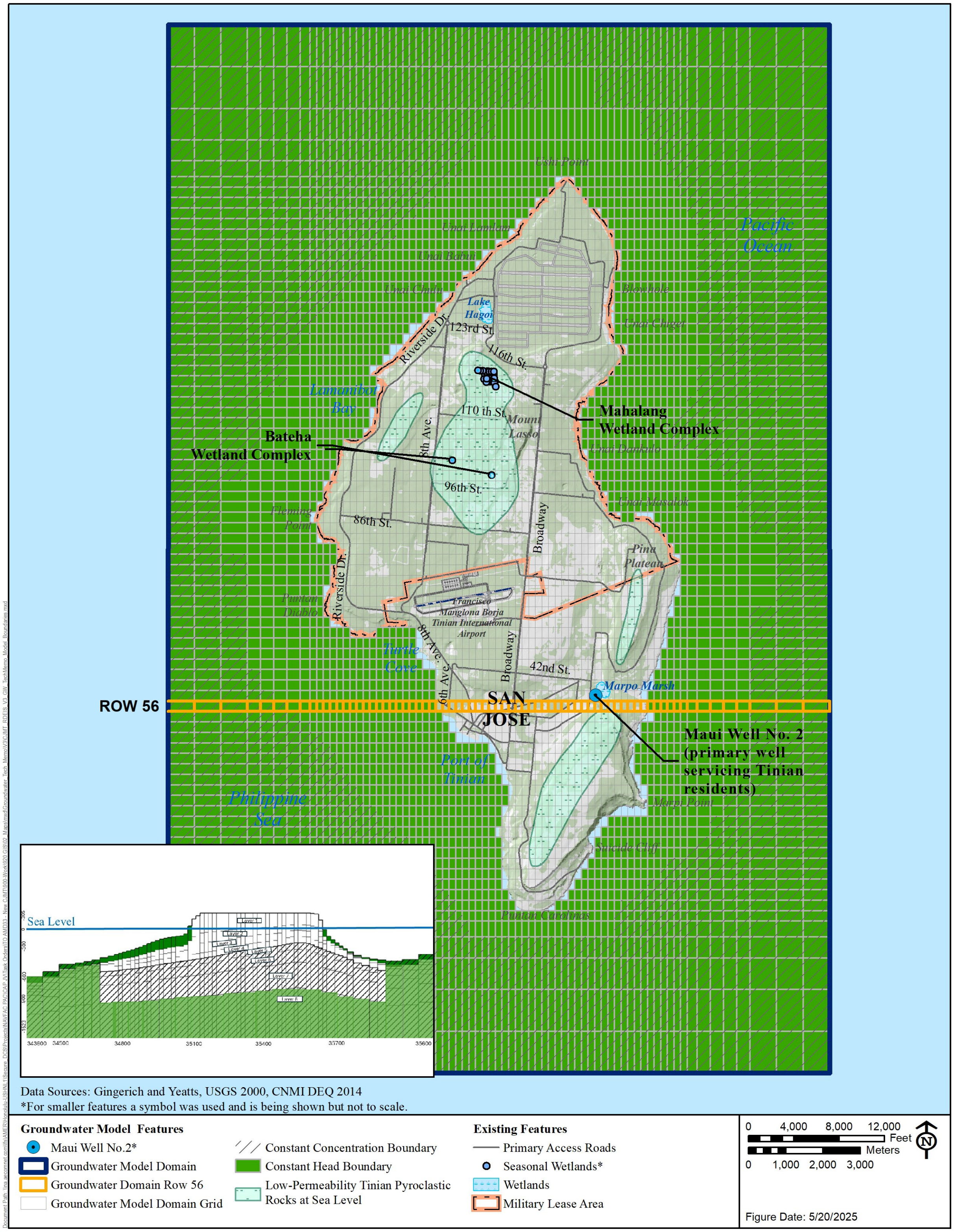

Figure 11. Model Boundaries

To account for the background chloride component, a concentration of 30 milligrams per liter was assigned to recharge on the island, as detailed in *The Effects of Withdrawals and Drought on Groundwater Availability in the Northern Guam Lens Aquifer, Guam* (U.S. Geological Survey 2013). Conditions in the Northern Guam Lens Aquifer were considered a reasonable analog for Tinian based on similarities in rainfall, temperature, aquifer geology and topography.

The bottom boundary of the model is no-flow. A constant concentration source of 19,000 milligrams per liter of chloride (representing salt) was assigned approximately 1.5 miles offshore of the island in all layers and in layer 8 beneath the island. The 1.5-mile distance was considered sufficient to prevent boundary effects while maintaining the constant concentration source. Constant concentration cells are shown in Figure 11.

5.2.3 Hydraulic Parameters

The hydraulic conductivities used in the 2002 U.S. Geological Survey model are as follows:

- High hydraulic conductivity zone representing limestone: 10,500 feet per day
- Lower hydraulic conductivity zone representing clay-rich limestone: 800 feet per day
- Low permeable zone representing the volcanic rocks: 0.2 feet per day

In the 2025 AECOM model, the hydraulic conductivity values in the high hydraulic conductivity zone representing limestone was distributed spatially, while hydraulic conductivity values in the low hydraulic conductivity zone representing clay-rich limestone and in the low hydraulic conductivity zone representing the volcanic rocks were applied uniformly. The hydraulic conductivity values in the 2002 U.S. Geological Survey model were applied to the new model and used as a starting point for calibration; the final hydraulic conductivity values were determined from model calibration.

5.3 FLOW MODEL CALIBRATION

5.3.1 Overview

Model calibration involves adjusting model parameters to achieve a reasonable match with observed data. Care was taken to avoid assigning unreasonable values to any parameter, preventing unrealistic model results. The goal of calibration is to achieve a match, as close as possible, between simulated and observed heads rather than replicate field conditions exactly. A model is generally considered well-calibrated for flow when the normalized root mean squared error is less than 10 percent between modeled and measured groundwater elevations for a set of data.

5.3.2 Steady State

Similar to U.S. Geological Survey 2002 model (two-layer model), the AECOM 2025 model (eight-layer model) was also calibrated to "steady state." The pilot-point interpolation method was used to calibrate the hydraulic conductivity distribution in the high-hydraulic conductivity limestone zone and recharge distribution in all limestone areas. The zonal method was used to calibrate K values in the low- hydraulic conductivity zone representing clay-rich limestone and in low-permeable zone representing the volcanic rocks. Average groundwater levels observed from 1990 to 1999, sourced from the 2002 U.S. Geological Survey model, were used for calibrating AECOM's 2025 model and are presented in Table 5. The USGS modified these water levels to account for tidal influences per the method outlined in the 2002 report. Calibration results of both the 2002 U.S. Geological Survey model and the 2025 AECOM model are shown are in Table 4. The measured and modeled water levels compare favorably. The head residuals of the 2025 AECOM calibration model are shown in Figure 12 and in Table 5. Figure 13 presents a scatter plot of simulated and measured water levels from the 2025 AECOM calibration. The plot shows a similar spread among all the data sets around the best fit line, indicating a strong correlation between simulated and observed values. Calibration statistics show a mean error close to zero, with a normalized error of 8.66 percent (root mean square error divided by the range of observed heads) well within the calibration criterion of 10 percent. Therefore, the 2025 AECOM model is considered to be well-calibrated and adequate for the intended purposes. Model limitations are discussed in Section 5.8. A summary of calibration statistics is presented in Table 6.

Both the 2002 U.S. Geological Survey model and the 2025 AECOM model produced similar calibration statistics and groundwater contours. Some of the discrepancies can be attributed to differences in model code and construction combined with sparse data. From this point forward, only the 2025 AECOM model was used for simulations.

The final calibrated hydraulic conductivity values of the 2025 AECOM model are as follows:

- High hydraulic conductivity zone representing limestone: 164–13,123 feet per day
- Lower hydraulic conductivity zone representing clay-rich limestone: 115 feet per day
- Low permeable zone representing the volcanic rocks: 0.17–0.53 feet per day

These values are presented in Figure 14. The high hydraulic conductivity values for limestone falls into the range of the aquifer test results (U.S. Geological Survey 2002). Transverse and longitudinal hydraulic conductivity were set equal to one another (no horizontal anisotropy). Vertical hydraulic conductivity was set equal to one-tenth horizontal hydraulic conductivity (horizontal to vertical anisotropy equal 10) as with the U.S. Geological Survey 2002 model. Although the calibrated values varied from the 2002 U.S. Geological Survey model, they are still within the range of values reported from aquifer pump testing on the existing wells. While the pump test results may understate regional hydraulic conductivities in a triple porosity system, the goodness of fit for heads indicates these calibrated values are appropriate for their intended purpose.

In the 2025 AECOM model, the uniform recharge rate of 29.7 inches per year used in the U.S. Geological Survey 2002 model was replaced with a spatially distributed recharge rates, with low-permeability rock areas receiving a minimal recharge rate. Using a pilot-point method, the overall recharge distribution was calibrated to maintain the same total annual recharge volume within the island. The final recharge rate distribution was determined through model calibration. The final calibrated recharge distribution is shown in Figure 15. The model used the following values uniformly across the domain: specific storage (1.52E-06 1/foot) and specific yield and effective porosity (28 percent).

Table 4. Measured and Calculated Water Levels

Well	Measured Water Levels	2002 USGS (Two-Layer) Model Calculated Water Level	2025 AECOM (Eight-Layer) Model Calculated Water Level
	ft msl	ft msl	ft msl
M-02	2.65	2.62	2.81
M-05	0.93	1.07	1.23
M-07	1.38	1.51	1.53
M-08	1.31	1.41	1.52
M-09	1.40	1.36	1.30
M-10	0.84	0.75	0.56
M-11	1.63	1.43	1.52
M-15	1.30	1.19	1.23
M-16	1.26	1.36	1.43
M-19	2.15	2.18	2.14
M-21	1.62	1.65	1.52
M-22	1.38	1.36	1.40
M-25	1.36	1.27	1.27
M-26	1.77	1.39	1.45
M-29	1.64	1.53	1.69
M-33	1.58	1.45	1.51
M-35	2.42	2.58	2.58
M-39	2.02	2.11	1.87
Municipal (a.k.a. Maui Well No. 1)	1.03	1.03	1.28
HagN	1.13	0.9	1.04
HagS	1.17	0.97	1.06
TH-01	1.11	1.29	1.41
TH-02	0.92	0.86	0.85
TH-04	1.30	1.19	1.30
TH-06	1.22	1.3	1.39
TH-07	1.29	1.36	1.45
TH-09	1.25	1.07	1.22
TH-10	1.27	1.29	1.41
TH-12	1.37	1.33	1.33
TH-22	1.25	1.05	1.14
Ushi	0.78	0.72	0.54

Legend: AECOM = AECOM Technical Services, Inc.; ft = foot/feet; msl = mean sea level; No. = Number.
Source: U.S. Geological Survey 2002 DON.

Table 5. Calculated Differences Between Measured and Modeled Results

Well	*Dates of Measurement*	*Number of Measurements*	*2002 USGS (Two-Layer) Model*	*2025 AECOM (Eight-Layer) Model*
M-02	September 25, 1997–April 16, 1999	15,700	0.03	-0.16
M-05	July 31, 1997–October 1, 1997	3	-0.14	-0.30
M-07	July 6, 1995–October 1, 1997	25	-0.13	-0.15
M-08	August 22, 1997–October 3, 1997	3	-0.10	-0.21
M-09	May 4, 1995–October 2, 1997	31	0.04	0.10
M-10	March 31, 1997–December 29, 1997	8	0.09	0.28
M-11	April 13, 1995–December 29, 1997	34	0.20	0.11
M-15	May 29, 1997–December 29, 1997	6	0.11	0.07
M-16	May 4, 1995–December 29, 1997	32	-0.10	-0.17
M-19	June 5, 1997–December 30, 1997	5	-0.03	0.01
M-21	September 30, 1990–February 1, 1996	45,443	-0.03	0.10
M-22	July 4, 1997–December 30, 1997	5	0.02	-0.02
M-25	November 1, 1994–September 5, 1997	28	0.09	0.09
M-26	November 1, 1994–September 5, 1997	20	0.38	0.32
M-29	July 30, 1997–April 16, 1999	14,524	0.11	-0.05
M-33	August 22, 1997–December 30, 1997	4	0.13	0.07
M-35	July 31, 1997–December 30, 1997	4	-0.16	-0.16
M-39	May 15, 1997–December 30, 1997	7	-0.09	0.15
Municipal (Maui Well No. 1)	November 22, 1990–April 16, 1999	67,952	0.00	-0.25
HagN	May 17, 1993–July 4, 1997	39	0.23	0.09
HagS	May 17, 1993–July 4, 1997	38	0.20	0.11
TH-01	September 17, 1996–December 29, 1997	4	-0.18	-0.30
TH-02	April 30, 1997–September 5, 1997	5	0.06	0.07
TH-04	January 10, 1994–December 29, 1997	48	0.11	0.00
TH-06	July 6, 1995–July 31, 1997	27	-0.08	-0.17
TH-07	September 17, 1997–April 16, 1999	9,233	-0.07	-0.16
TH-09	February 9, 1993–December 30, 1997	114	0.18	0.03
TH-10	October 10, 1996–December 29, 1997	18	-0.02	-0.14
TH-12	January 8, 1997–December 29, 1997	10	0.04	0.04
TH-22	October 31, 1996–December 29, 1997	17	0.20	0.11
Ushi	October 1, 1990–July 28, 1997	53,296	0.06	0.24

Legend: AECOM = AECOM Technical Services, Inc.; No. = Number; USGS = United States Geological Survey.

Table 6. Statistics of 2025 AECOM (Eight-Layer) Model

Mean Error	-0.01
Mean Absolute Error	0.14
Root Mean Square Error	0.16
Maximum Observed Head	2.65
Minium Observed Head	0.78
Range of Observed Heads	1.87
Normalized Error (Root Mean Square Error divided by Head Range)	8.66%
Correlation Coefficient between Observed and Modeled Heads	93.58%

Legend: % = percent; AECOM = AECOM Technical Services, Inc.

Figure 12. Model Head Residuals

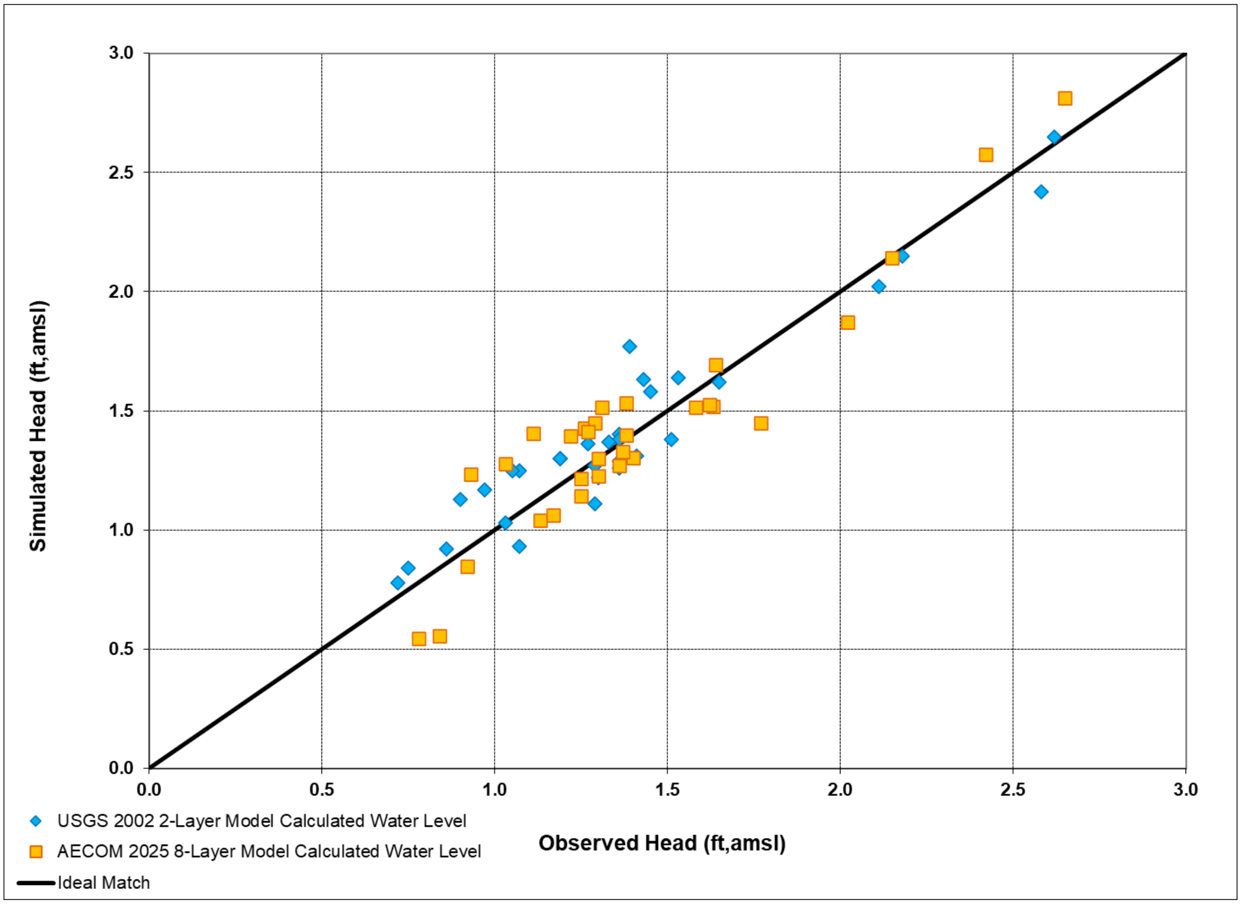

Figure 13. Scatter Plot of Observed Heads vs. Simulated Heads

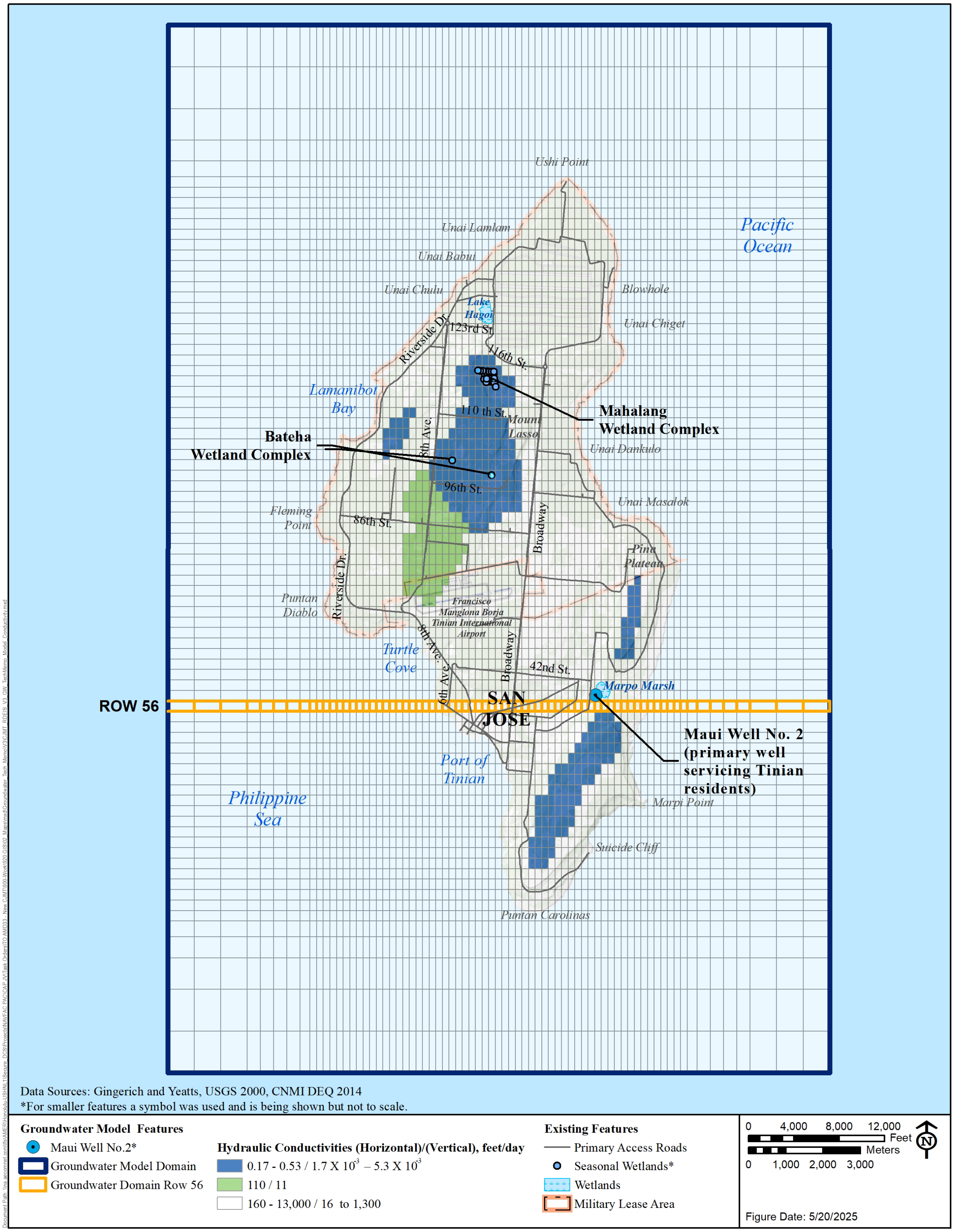

Figure 14. Model Hydraulic Conductivity Values and Distribution in Model Layer 1

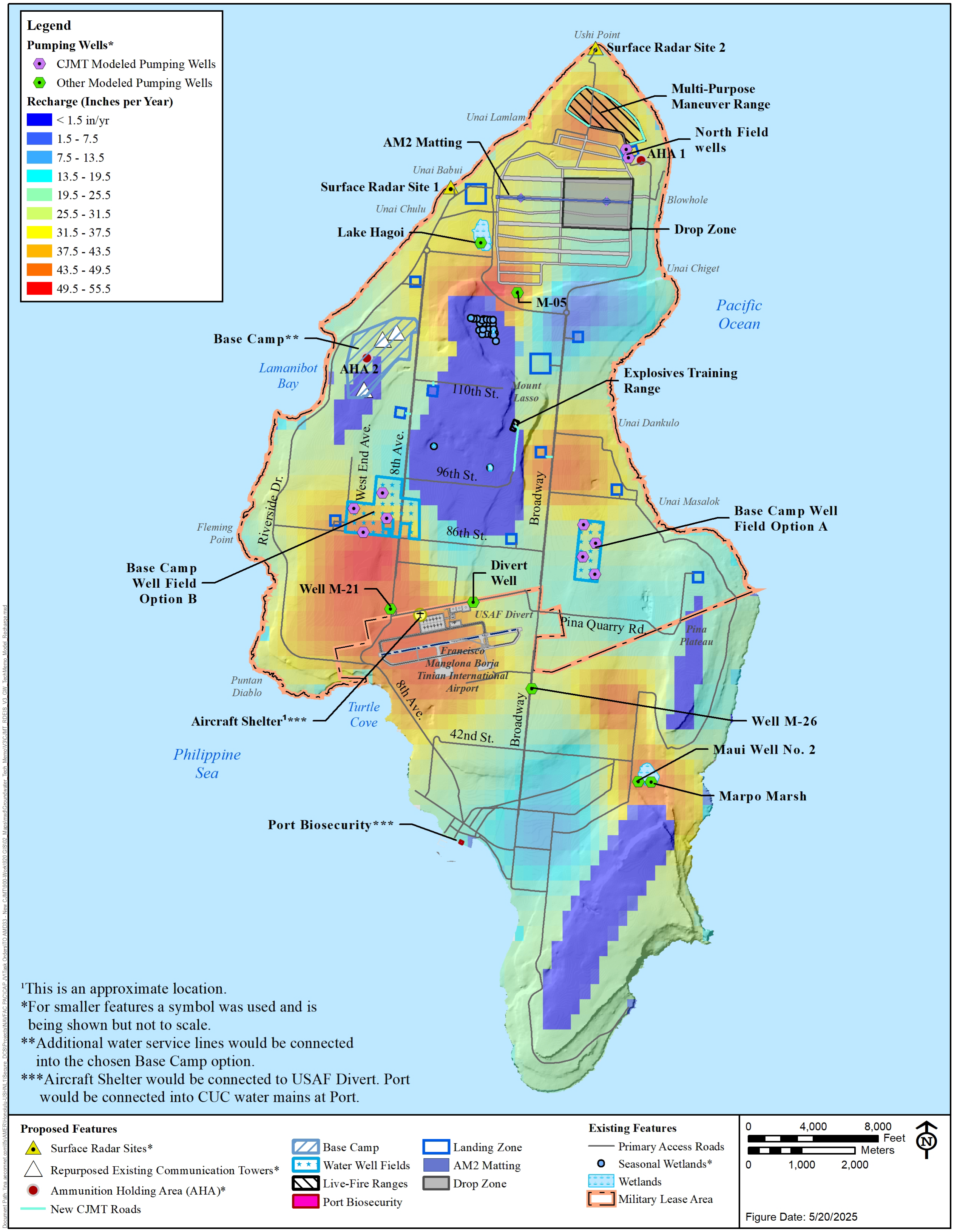

Figure 15. Model Recharge

5.4 MODEL SCENARIOS

The next step in the process was to run the model in a transient state using the SEAWAT module in the GMS modeling platform. An initial model run was conducted to establish steady-state conditions with regard to saltwater distribution. Prior to applying pumping conditions to the model, it is necessary to establish a steady-state baseline. The simulation time typically exceeds 100 years before equilibrium is reached, depending on several factors, including the defined initial concentrations. Steady state in this context refers to a stabilized condition in the flow and transport system, not the model code. The system was deemed to be at "steady state" when the modeled hydraulic heads and concentrations ceased to change over time throughout the model domain. The model run time to approximate "steady state" was 250 years.

The drought scenario is conservatively assumed to be two consecutive years of reduced rainfall, represented in the model by an infiltration of 10 percent of the modeled normal infiltration rate (approximately 30 inches per year). When simulating the drought, the model was run for 250 years (after reaching "steady state") during which a period of 2 years reduced recharge was applied in the time of 150–152 years. In SEAWAT, salt concentrations are modeled at the center of a model cell, unlike the SHARP code that calculates an interface between salt and freshwater with no diffuse concentrations above or below the modeled boundary. Note that model layering is different from aquifer or geologic layering. In this model, the layers are numbered from top to bottom (i.e., layer 1 is the shallowest and layer 8 is the deepest). The top three model layers (layers 1 through 3) represent the limestone aquifer system and the remaining five layers (4 through 8) represent the low-permeability volcanic material. Figure 16 through Figure 20 depict predicted chloride concentrations in model layers 1 through 3. These are the layers containing the existing and proposed well screens. Maui Well No. 2 and the CJMT wells were assigned to model layer 1.

The five scenarios are below; italicized text highlights the differences.

Scenario No. 1 (Baseline)

- Normal rainfall.
- Existing Commonwealth Utilities Corporation Water Demand (Maui Well No. 2) = 853,472 gallons per day (Average 2019–2023).
- Well M-21 using Divert construction water demands based on Bureau of Environmental and Coastal Quality permitted pumping limits per September 2024 field notes = 59,178 gallons per day.
- Well M-26 agricultural water demand = 59,178 gallons per day.

Scenario No. 2 (Proposed Action + Normal Rainfall + Well Field A)

- Normal rainfall.
- Existing Commonwealth Utilities Corporation Water Demand (Maui Well No. 2) = 853,472 gallons per day (taken from average 2019–2023 demand from Commonwealth Utilities Corporation).
- Proposed additional water demand on Commonwealth Utilities Corporation (Maui Well No. 2) due to CJMT = 9,046 gallons per day.

- Well M-21 CJMT construction water demand = 59,178 gallons per day – M-21 to be used for CJMT construction (No Divert and no agricultural at this well).
- Well M-26 agricultural water demand. = 59,178 gallons per day.
- CJMT water demand at *Well Field A* which includes concurrent construction and operational water demands = 21,777 gallons per day.
- Construction water at M-21, *Well Field A* would be 23,340 gallons per day. Will not be separately modeling the post-CJMT-construction demand at the new Well Field A or M-21.
- CJMT water wells at North Field. = 2,192 gallons per day.
- U.S. Air Force North Field construction (M-05) = 12,000 gallons per day.
- Divert Well (firefighting well at Tinian International Airport) = 2,192 gallons per day.

Scenario No. 3 (Proposed Action + Drought Rainfall + Well Field A)

- Drought conditions.
- Existing Commonwealth Utilities Corporation Water Demand (Maui Well No. 2) = 853,472 gallons per day (taken from average 2019 – 2023 demand from Commonwealth Utilities Corporation).
- Proposed additional water demand on Commonwealth Utilities Corporation (Maui Well No. 2) due to CJMT = 9,046 gallons per day.
- Well M-21 CJMT construction water demand = 59,178 gallons per day– M-21 to be used for CJMT construction (No Divert and no agricultural at this well).
- Well M-26 agricultural water demand = 59,178 gallons per day.
- CJMT water demand at *Well Field A* which includes concurrent construction and operational water demands = 21,777 gallons per day.
- Construction water is now at M-21, *Well Field A* would be 23,340 gallons per day. Will not be separately modeling the post-CJMT-construction demand at the new Well Field A or M-21.
- CJMT water wells at North Field = 2,192 gallons per day.
- U.S. Air Force North Field construction (M-05) = 12,000 gallons per day.
- Divert Well (firefighting well at Tinian International Airport) = 2,192 gallons per day.

Scenario No. 4 (Proposed Action + Normal Rainfall + Well Field B)

- Normal rainfall.
- Existing Commonwealth Utilities Corporation Water Demand (Maui Well No. 2) = 853,472 gallons per day (taken from average 2019 – 2023 demand from Commonwealth Utilities Corporation).
- Proposed additional water demand on Commonwealth Utilities Corporation (Maui Well No. 2) due to CJMT = 9,046 gallons per day.
- Well M-21 CJMT construction water demand = 59,178 gallons per day– M-21 to be used for CJMT construction (No Divert and no agricultural at this well).
- Well M-26 agricultural water demand = 59,178 gallons per day.
- CJMT water demand at *Well Field B* which includes concurrent construction and operational water demands = 21,777 gallons per day.

- Construction water is now at M-21, *Well Field B* would be 23,340 gallons per day. Will not be separately modeling the post-CJMT-construction demand at the new Well Field B or M-21.
- CJMT water wells at North Field = 2,192 gallons per day.
- U.S. Air Force North Field construction (M-05) = 12,000 gallons per day.
- Divert Well (firefighting well at Tinian International Airport) = 2,192 gallons per day.

Scenario No. 5 (Proposed Action + Drought Rainfall + Well Field B)

- Drought conditions.
- Existing Commonwealth Utilities Corporation Water Demand (Maui Well No. 2) = 853,472 gallons per day (taken from average 2019 – 2023 demand from Commonwealth Utilities Corporation).
- Proposed additional water demand on Commonwealth Utilities Corporation (Maui Well No. 2) due to CJMT = 9,046 gallons per day.
- Well M-21 CJMT construction water demand = 59,178 gallons per day – M-21 to be used for CJMT construction (No Divert and no agricultural at this well).
- Well M-26 agricultural water demand = 59,178 gallons per day.
- CJMT water demand at *Well Field B* which includes concurrent construction and operational water demands = 21,777 gallons per day.
- Construction water is now at M-21, *Well Field B* would be 23,340 gallons per day. Will not be separately modeling the post-CJMT-construction demand at the new Well Field B or M-21.
- CJMT water wells at North Field = 2,192 gallons per day.
- U.S. Air Force North Field construction (M-05) = 12,000 gallons per day.
- Divert Well (firefighting well at Tinian International Airport) = 2,192 gallons per day.

Pumping and evaporative/evapotranspirative losses from the lake and marsh for each of the scenarios are summarized in Table 7.

Table 7. Pumping Rates for Scenarios 1 through 5

<table>
<tr><th>Well</th><th>Scenario 1 (Baseline)</th><th>Scenario 2</th><th>Scenario 3</th><th>Scenario 4</th><th>Scenario 5</th></tr>
<tr><td>Lake Hagoi</td><td colspan="5">41,739</td></tr>
<tr><td>Makpo Marsh</td><td colspan="5">123,897</td></tr>
<tr><td>Maui Well No. 2</td><td>853,472</td><td>862,518</td><td>862,518</td><td>862,518</td><td>862,518</td></tr>
<tr><td>M-21</td><td>59,178</td><td>59,178</td><td>59,178</td><td>59,178</td><td>59,178</td></tr>
<tr><td>M-26</td><td>59,178</td><td>59,178</td><td>59,178</td><td>59,178</td><td>59,178</td></tr>
<tr><td>M-05</td><td>—</td><td>12,000</td><td>12,000</td><td>12,000</td><td>12,000</td></tr>
<tr><td>Divert Well</td><td>—</td><td>2,192</td><td>2,192</td><td>2,192</td><td>2,192</td></tr>
<tr><td>North Field-01</td><td>—</td><td rowspan="2">2,192</td><td rowspan="2">2,192</td><td rowspan="2">2,192</td><td rowspan="2">2,192</td></tr>
<tr><td>North Field-02</td><td>—</td></tr>
<tr><td>Well Field A-01</td><td>—</td><td rowspan="4">21,777</td><td rowspan="4">21,777</td><td>—</td><td>—</td></tr>
<tr><td>Well Field A-02</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>Well Field A-03</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>Well Field A-04</td><td>—</td><td>—</td><td>—</td></tr>
</table>

<table>
<tr><th>Well</th><th>Scenario 1 (Baseline)</th><th>Scenario 2</th><th>Scenario 3</th><th>Scenario 4</th><th>Scenario 5</th></tr>
<tr><td>Well Field B-01</td><td>—</td><td>—</td><td>—</td><td rowspan="4">21,777</td><td rowspan="4">21,777</td></tr>
<tr><td>Well Field B-02</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>Well Field B-03</td><td>—</td><td>—</td><td>—</td></tr>
<tr><td>Well Field B-04</td><td>—</td><td>—</td><td>—</td></tr>
</table>

Note: All units in gpd.
Legend: gpd = gallon per day; No. = Number.

5.5 MODEL RESULTS

Modeled pumping for the proposed DoD wells was evenly distributed among the listed wells. Divert construction is expected to be staggered from CJMT construction and is therefore not included. Long-term operational Divert demands are assumed to be incidental at the facility itself. Table 8 summarizes the resulting concentrations in model cells corresponding to the wells of interest, following the figures for each scenario.

Table 8. Predicted Chloride Concentrations for Scenarios 1 through 5

Well	*Scenario 1 (Baseline)*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*
Maui Well No. 1	32	32	33	32	33
Maui Well No. 2	149	150	168	150	168
M-21	48	48	107	48	107
M-26	32	51	100	51	100
M-05	41	42	70	42	70
Divert Well	32	32	33	32	33
North Field-01	590	590	897	590	897
North Field-02	665	664	1,120	664	1,197
Well Field A-01	37	37	40	37	40
Well Field A-02	35	35	49	35	40
Well Field A-03	32	32	39	32	33
Well Field A-04	34	34	38	34	35
Well Field B-01	30	32	30	30	30
Well Field B-02	30	30	30	30	30
Well Field B-03	30	30	30	30	30
Well Field B-04	30	30	30	30	30

Note: All units in mg/L.
Legend: mg/L = milligram per liter; No. = Number.

Modeled chloride concentrations in model layers 1, 2, and 3 for each scenario are presented in Figure 16 through Figure 20.

Many of these concentrations are not predicted to change or are predicted to change very little as a result of CJMT groundwater extraction. To evaluate the reasonableness of these results, data from the *Aquifer Study Technical Memorandum* (DON 2015) were reviewed. These included data from U.S. Geological Survey 2000, U.S. Geological Survey 2002, and DON (2015). These are summarized in Table 9 and Table 10. In both data sets, chloride concentrations were measured before and after single-day to multi-day pump tests.

Consistent with the current modeling results, during the 2015 aquifer study, wells M-21, M-25, and M-33 saw little to no change in chloride concentrations before and after pumping (Table 9). Additional data before and after pumping (Table 10) indicate that most locations (nine wells) did not change in chlorides before or after pumping. Two locations decreased in chloride concentrations and four locations increased in chloride concentrations.

Table 9. 2015 Aquifer Study Chloride Concentrations

Well	*Average Pumping Rate (gpm)*	*Maximum Drawdown During Pumping (ft)*	*Pre-Pumping Chloride Concentration (mg/L)*	*Post-Pumping Chloride Concentration (mg/L)*
M-21	31	0.12	220	220
M-25	112	0.25	720	710
M-33	104	1.92	39	44

Legend: ft = foot/feet; gpm = gallon per minute; mg/L = milligram per liter.
Source: DON 2015.

Table 10. Chloride Concentrations Observed Before and After Pumping

Well	*Observed Chlorides Before Pumping (mg/L)*	*Observed Chlorides After Pumping (mg/L)*	*Differences in Chlorides (mg/L)*
Ag30	130	130	0
HagS	148	160	12
M-08	100	600	500
M-15	35	70	35
M-16	106	45	-61
M-21	220	220	0
M-25	720	710	-10
M-33	39	44	5
Maui Well No. 1	100	100	0
Pala	200	200	0
W-1	85	85	0
W-14	40	40	0
W-20	600	600	0
W-4	35	35	0
W-6	100	100	0

Legend: No. = Number; mg/L = part per million.
Source: USGS 2000; DON 2015.

In both data sets (Table 9 and Table 10), many of the wells exhibited little to no chloride concentration change as a result of single-day to multi-day testing. Therefore, the modeling conclusions appear to be reasonable on the whole. However, some locations (especially those with vertical conduits that extend below the saltwater-freshwater interface) may exhibit rapid salinity increases. For that reason, Section 6 includes recommendations for pump testing and water quality testing. If some wells are observed to exhibit rapid salinity increases, those wells should be properly plugged and abandoned under permit from Bureau of Environmental and Coastal Quality.

5.6 GROUNDWATER FLOW DIRECTIONS

Modeled groundwater heads and groundwater flow directions under current conditions (Scenario 1) and the proposed action under drought conditions (Scenarios 3 and 5) from flow modeling are plotted in Figure 21 through Figure 23.

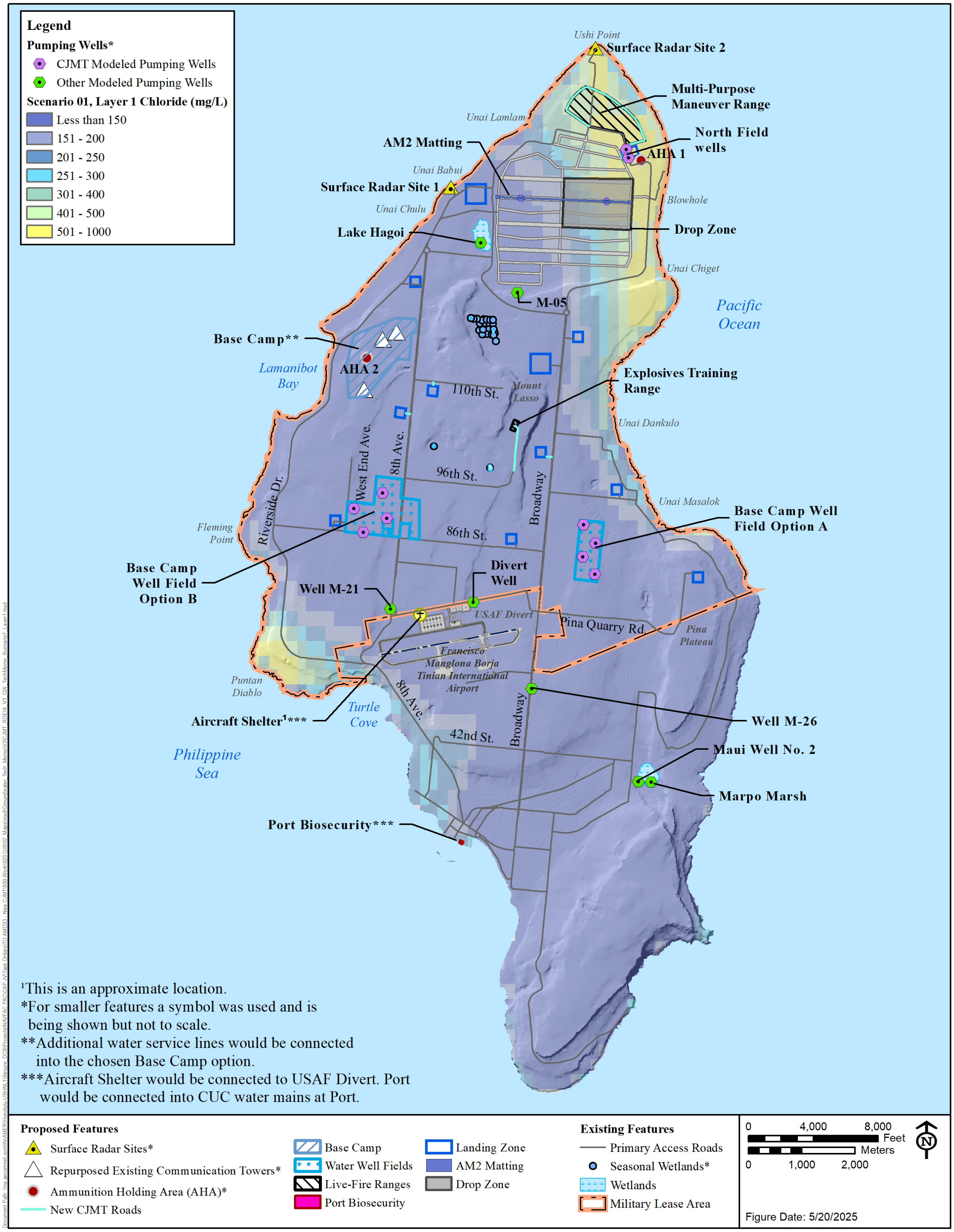

Figure 16.1. Modeled Chloride Concentrations for Layer 1 – Scenario 1

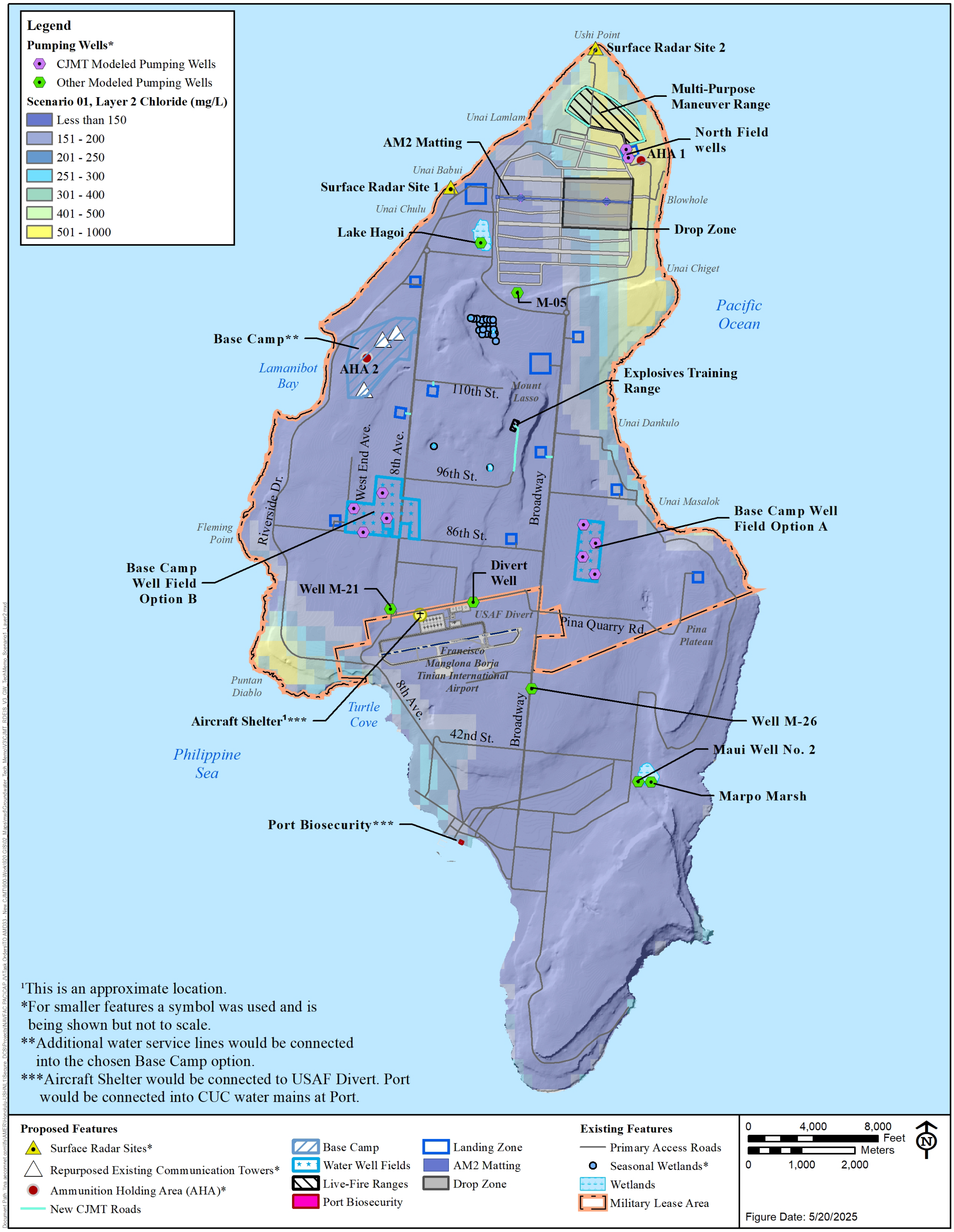

Figure 16.2. Modeled Chloride Concentrations for Layer 2 – Scenario 1

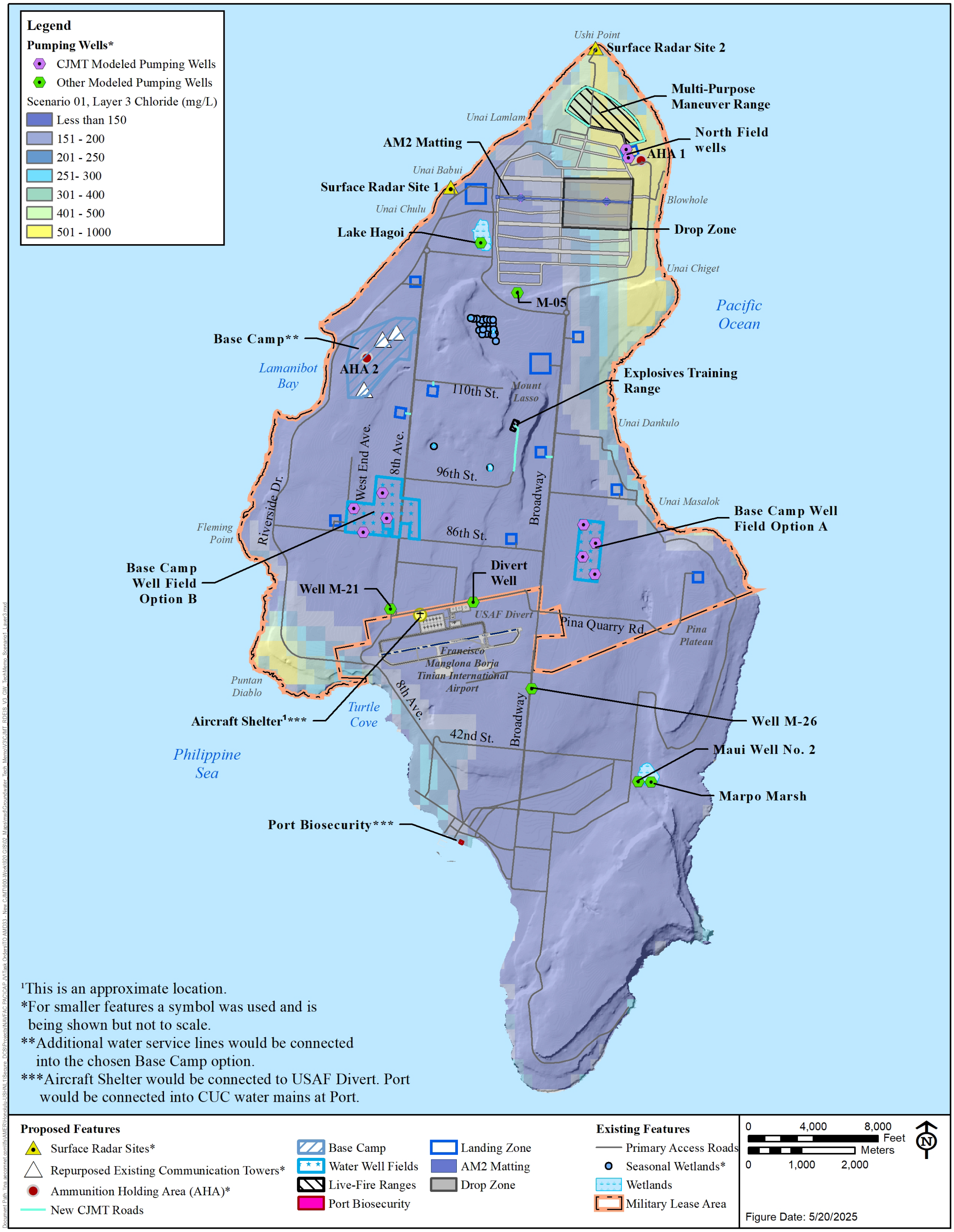

Figure 16.3. Modeled Chloride Concentrations for Layer 3 – Scenario 1

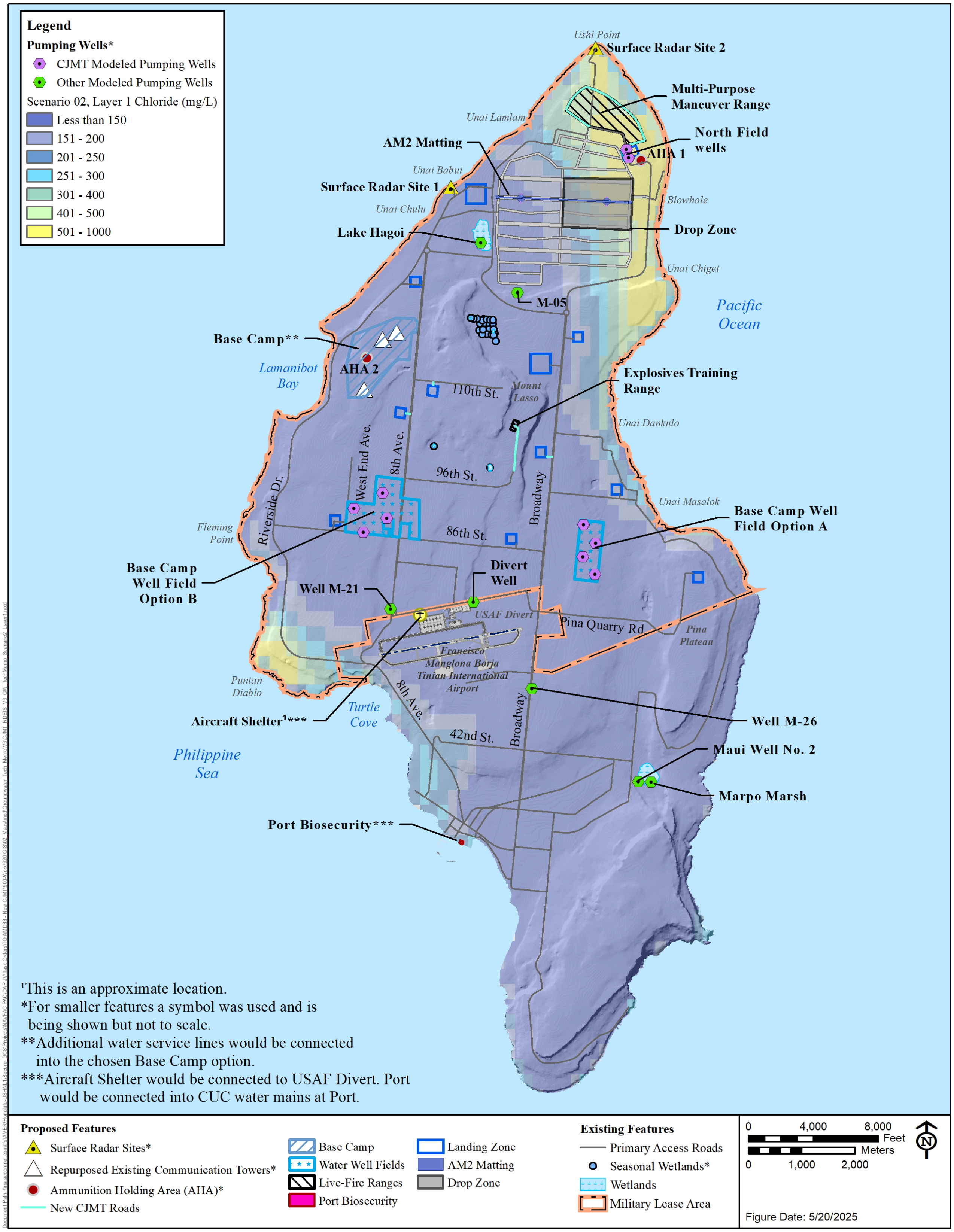

Figure 17.1. Modeled Chloride Concentrations for Layer 1 – Scenario 2

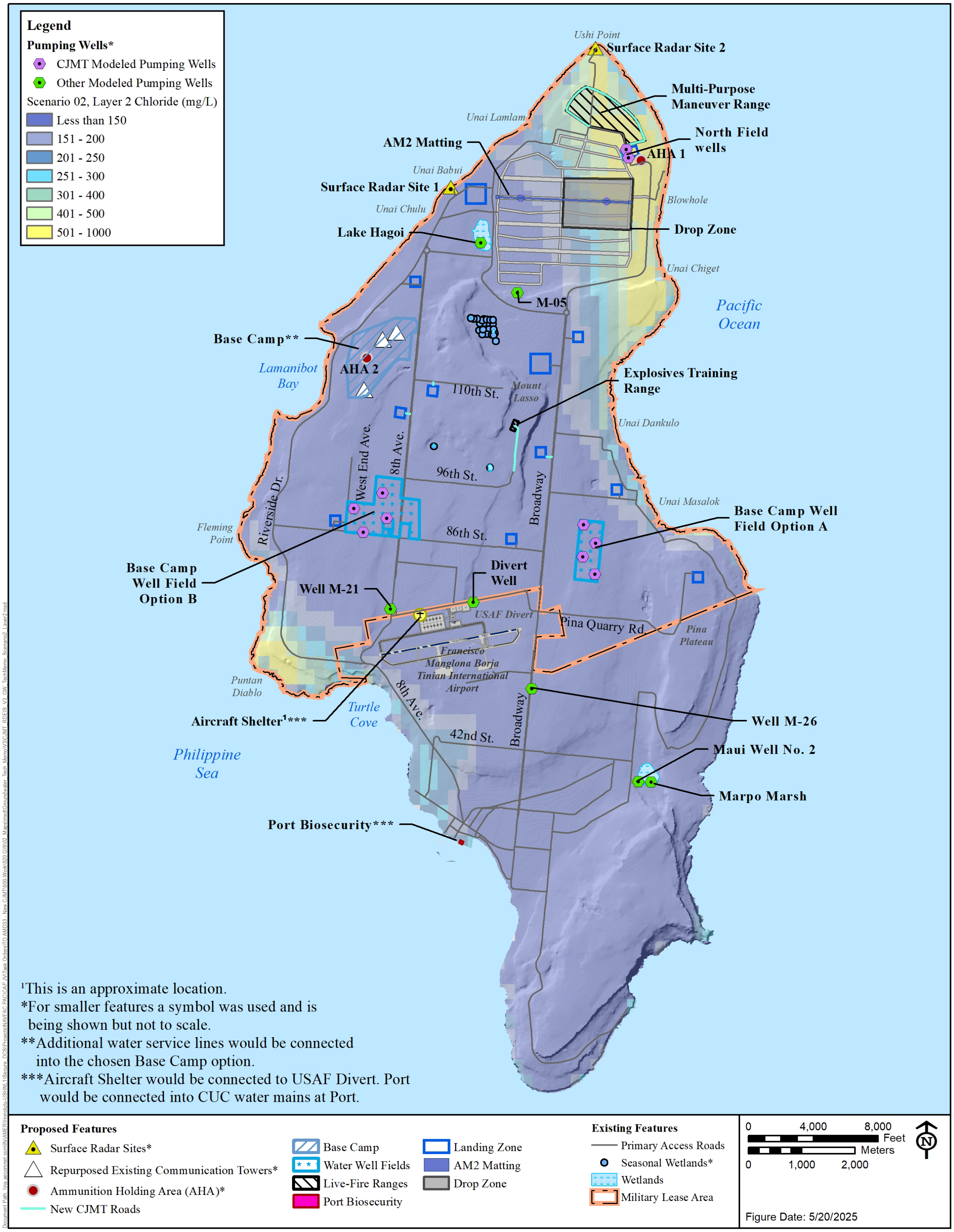

Figure 17.2. Modeled Chloride Concentrations for Layer 2 – Scenario 2

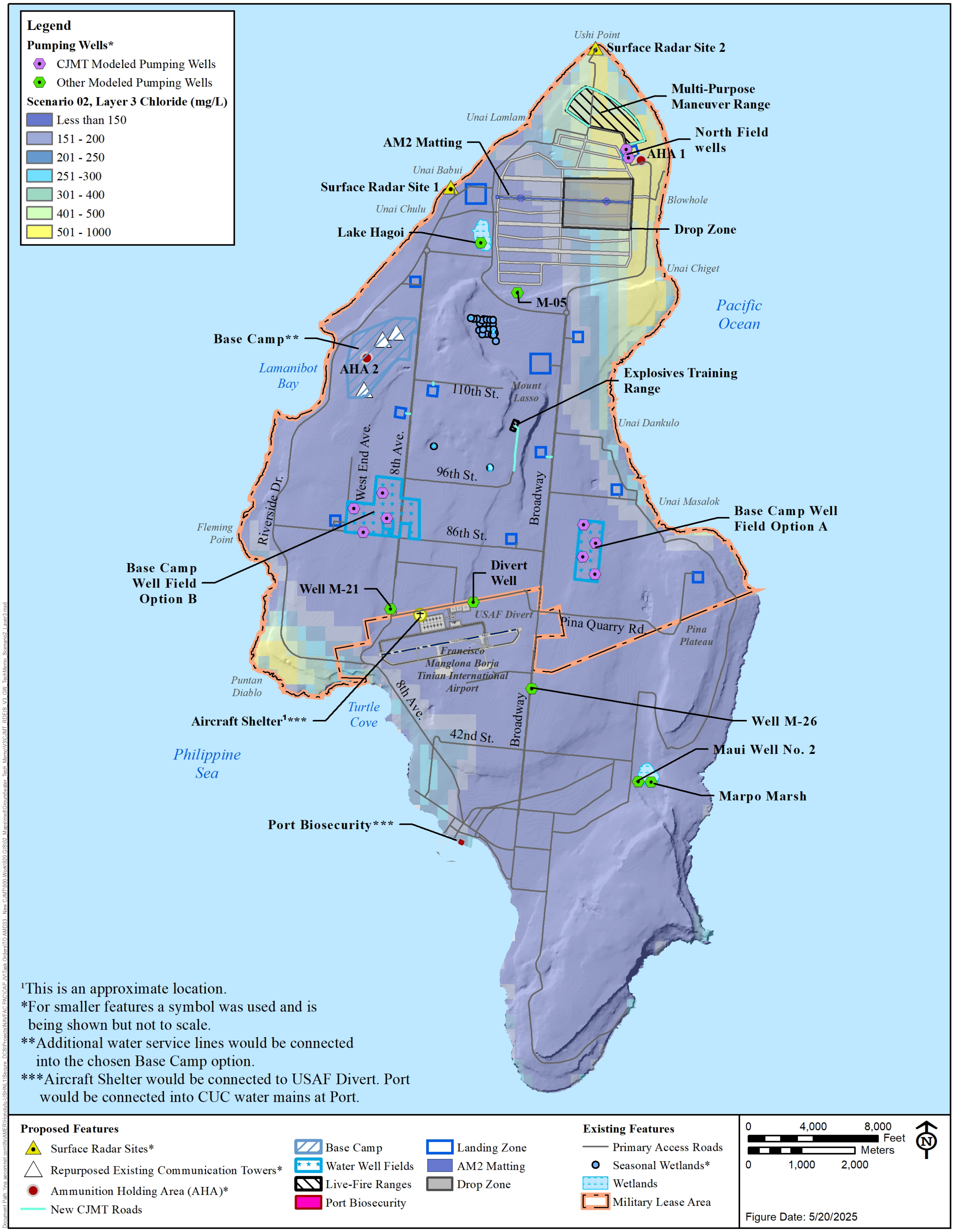

Figure 17.3. Modeled Chloride Concentrations for Layer 3 – Scenario 2

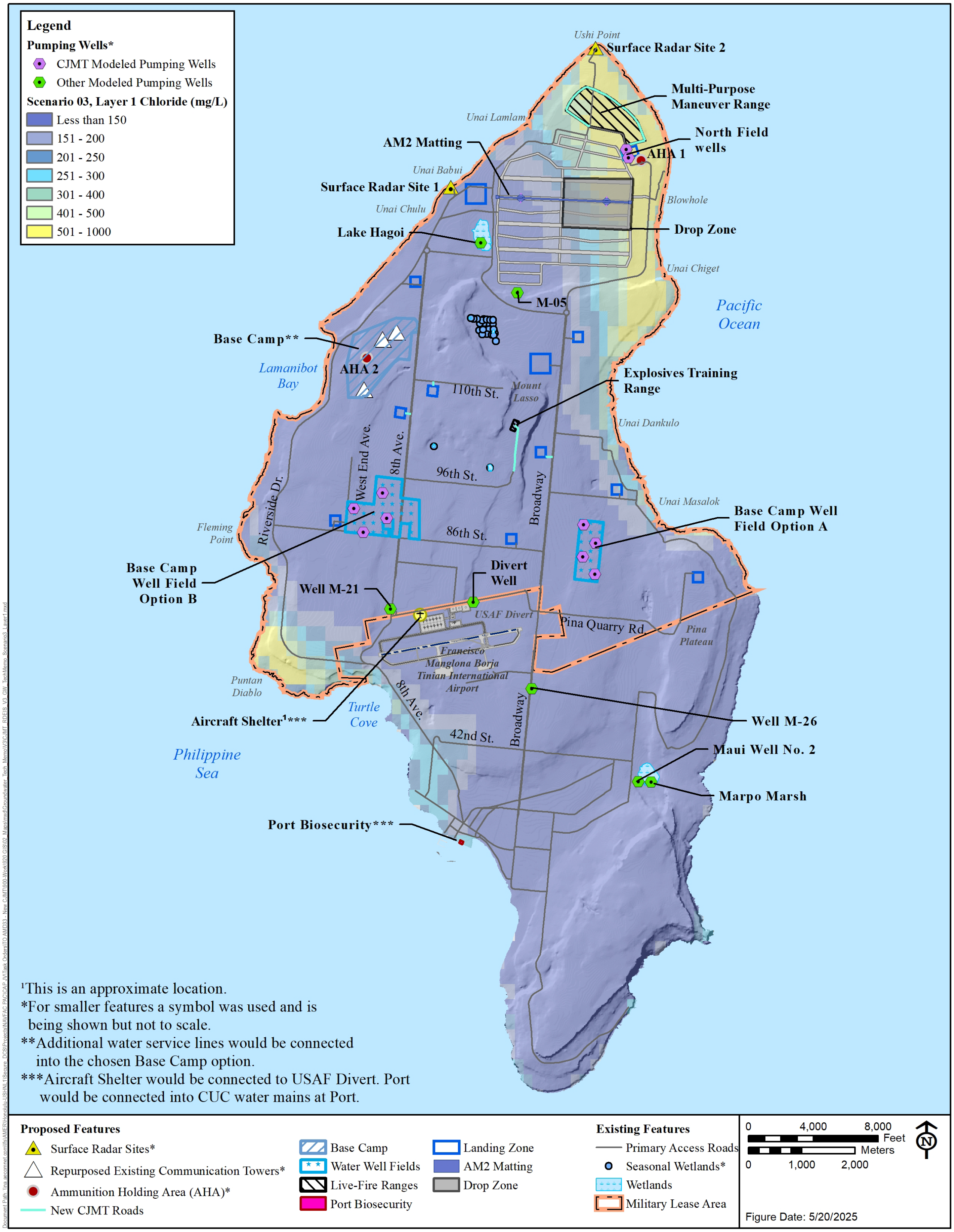

Figure 18.1. Modeled Chloride Concentrations for Layer 1 – Scenario 3

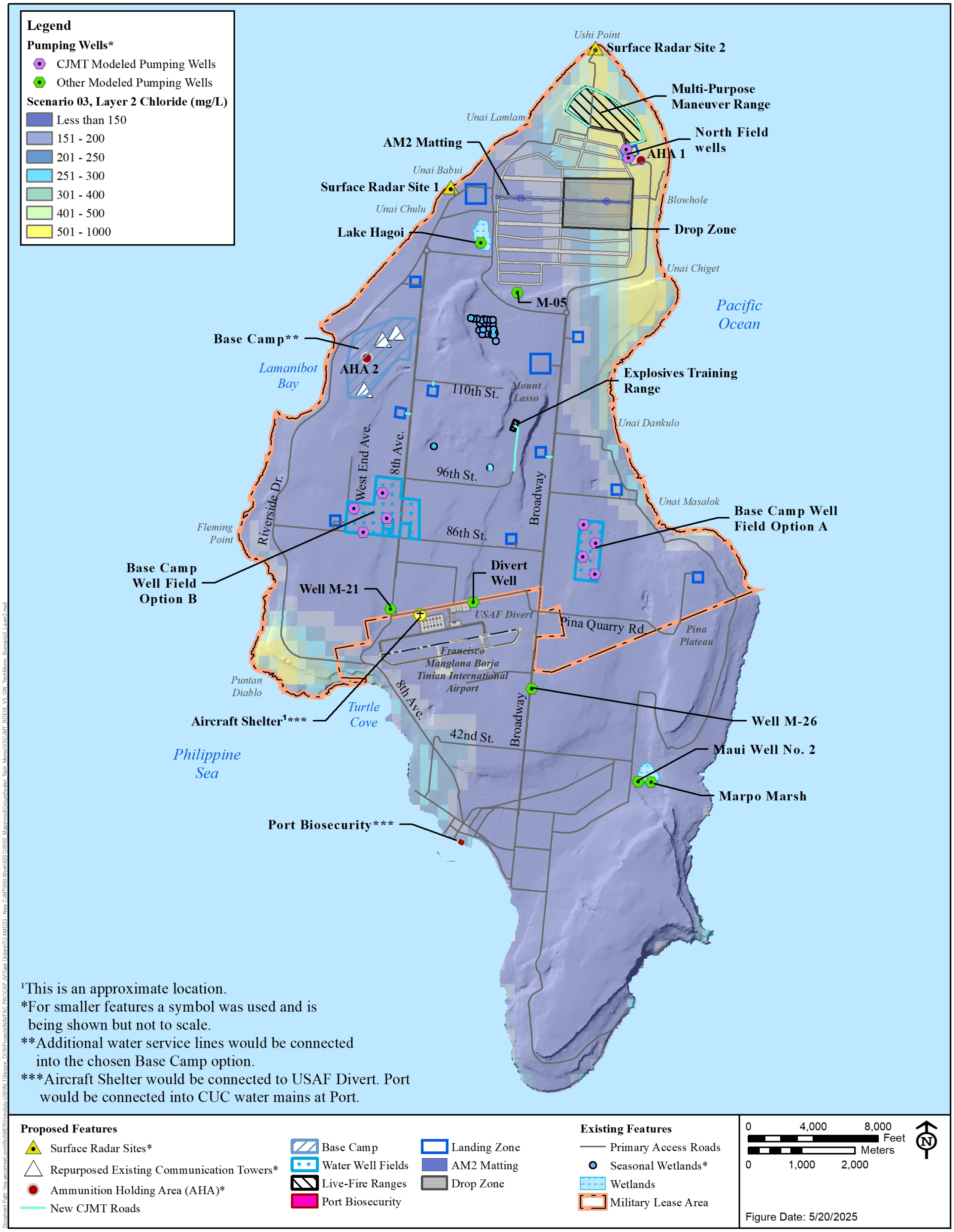

Figure 18.2. Modeled Chloride Concentrations for Layer 2 – Scenario 3

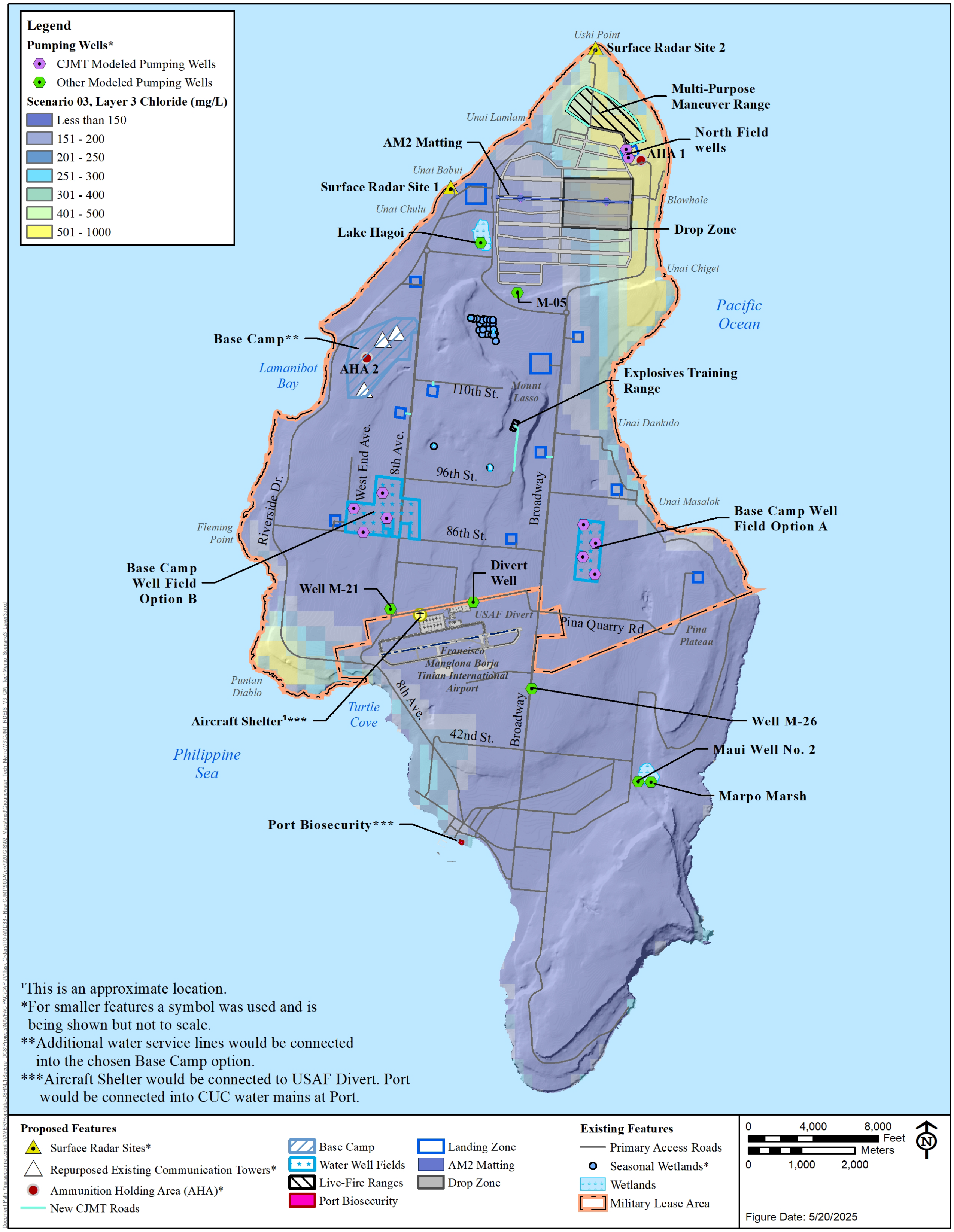

Figure 18.3. Modeled Chloride Concentrations for Layer 3 – Scenario 3

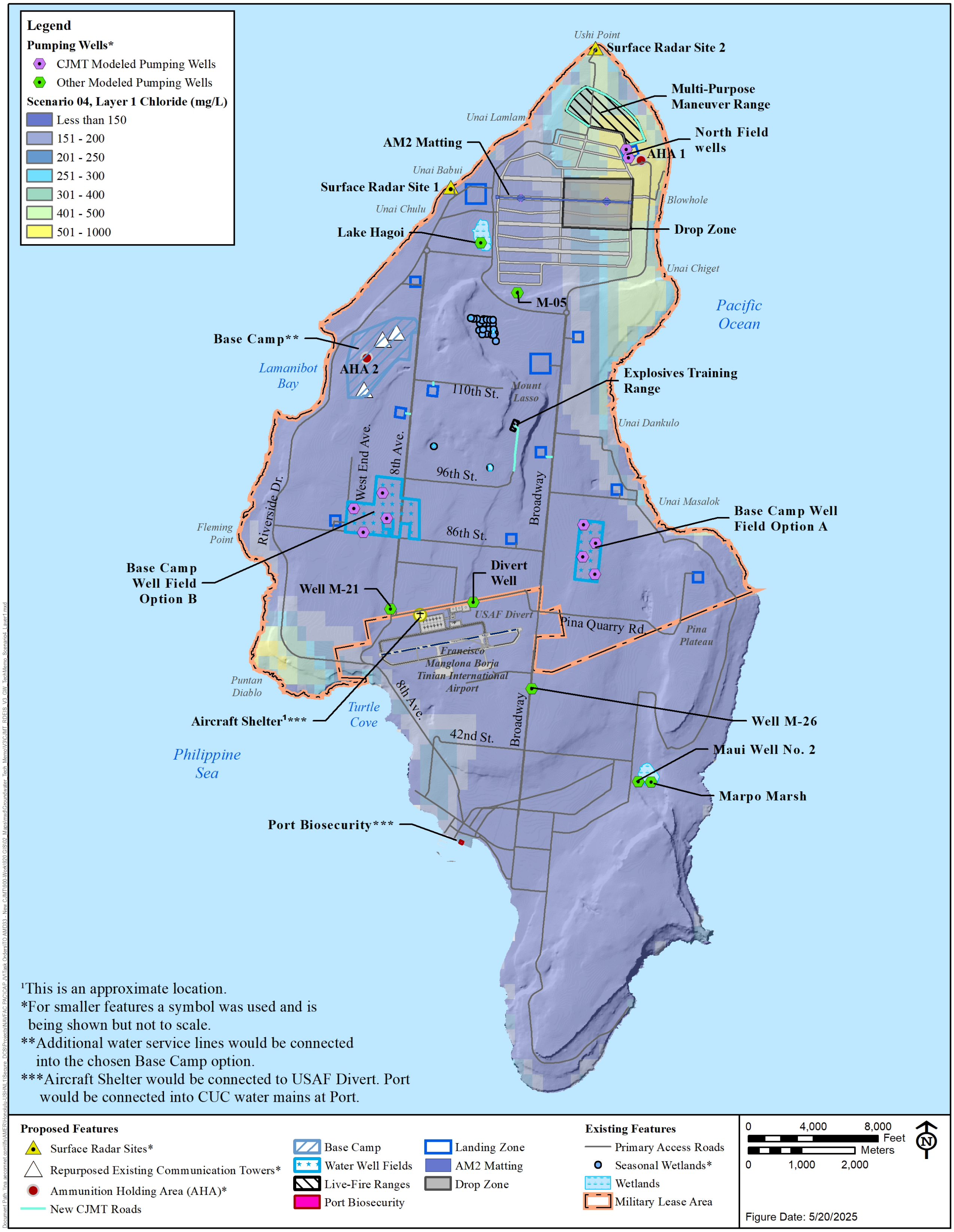

Figure 19.1. Modeled Chloride Concentrations for Layer 1 – Scenario 4

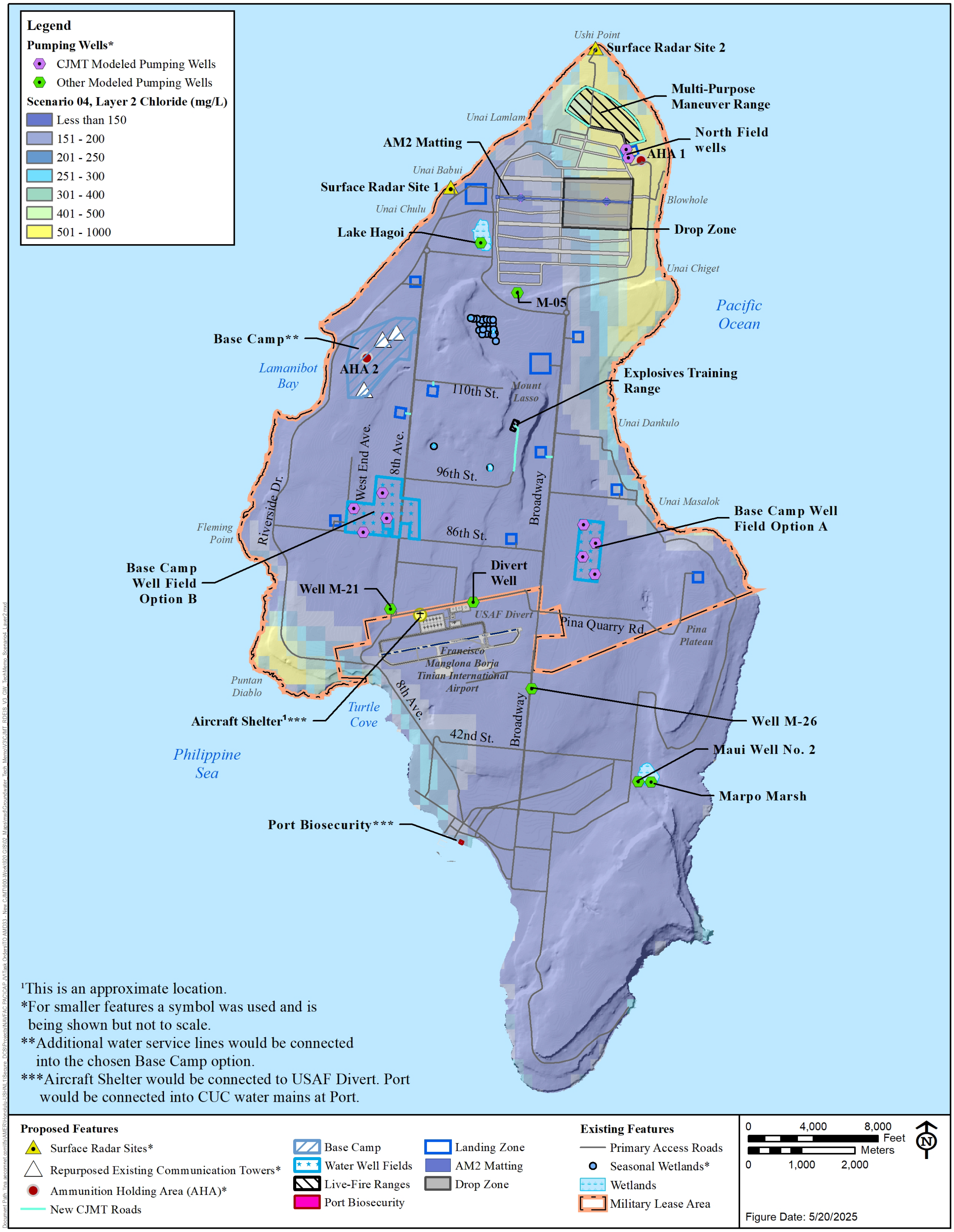

Figure 19.2. Modeled Chloride Concentrations for Layer 2 – Scenario 4

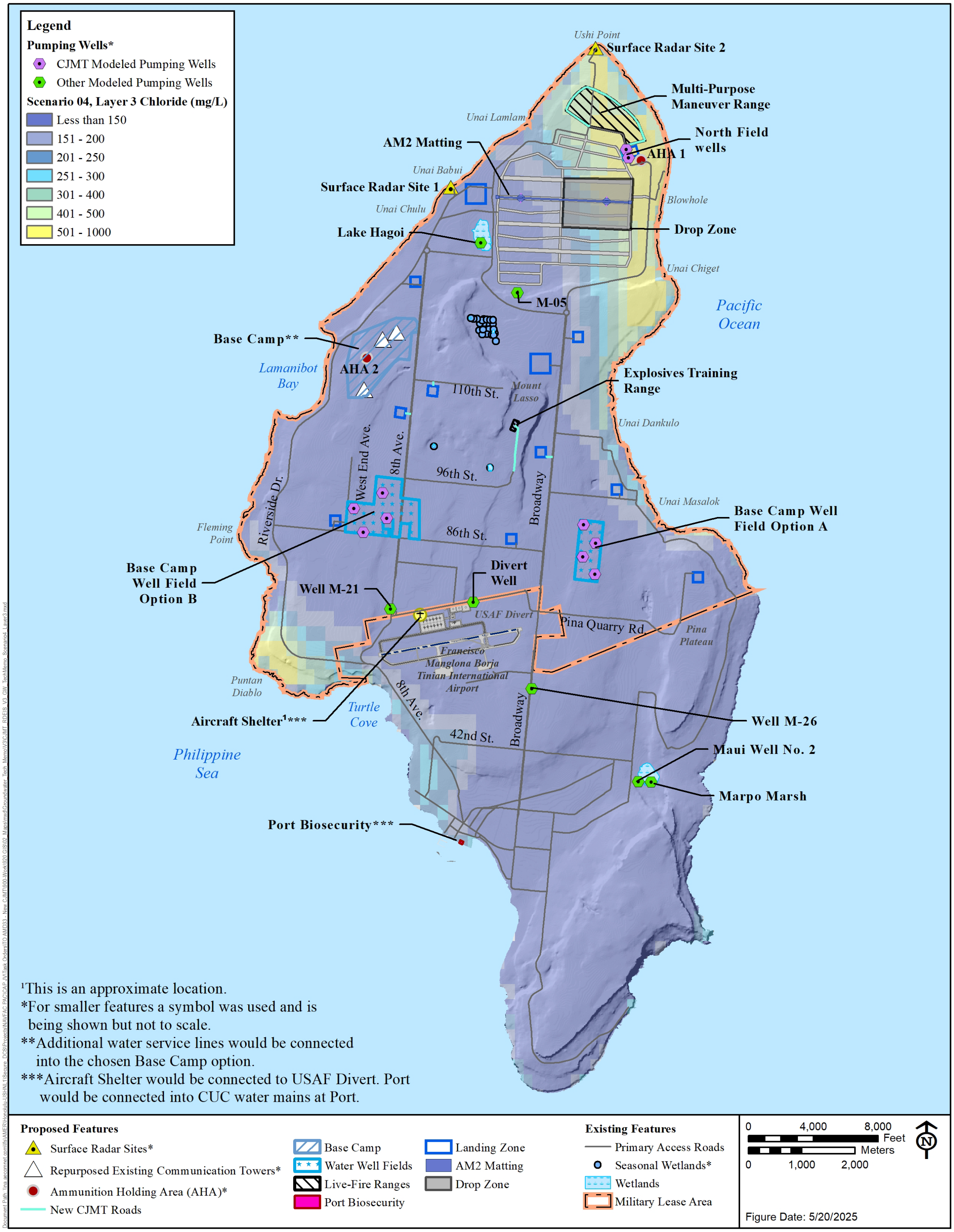

Figure 19.3. Modeled Chloride Concentrations for Layer 3 – Scenario 4

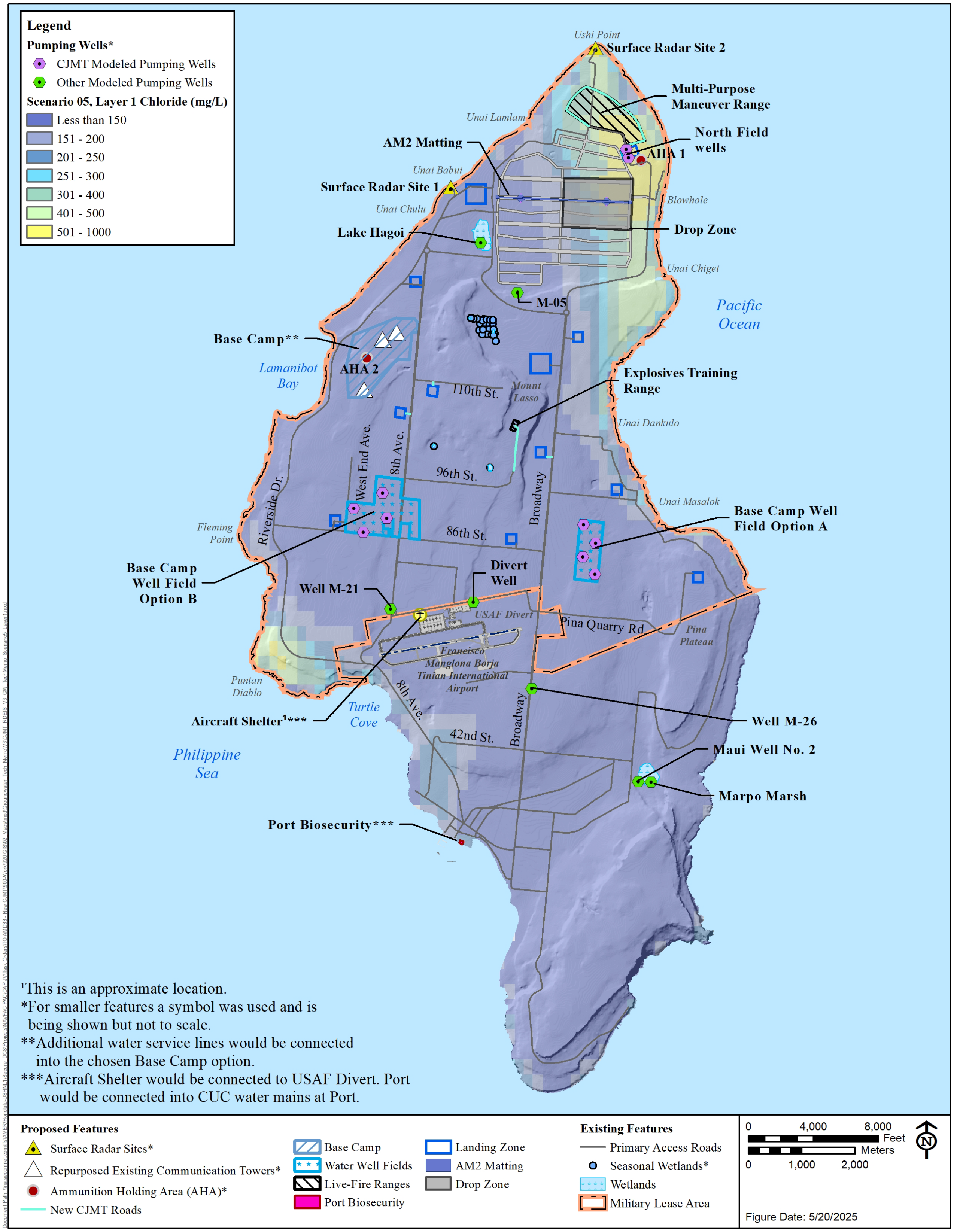

Figure 20.1. Modeled Chloride Concentrations for Layer 1 – Scenario 5

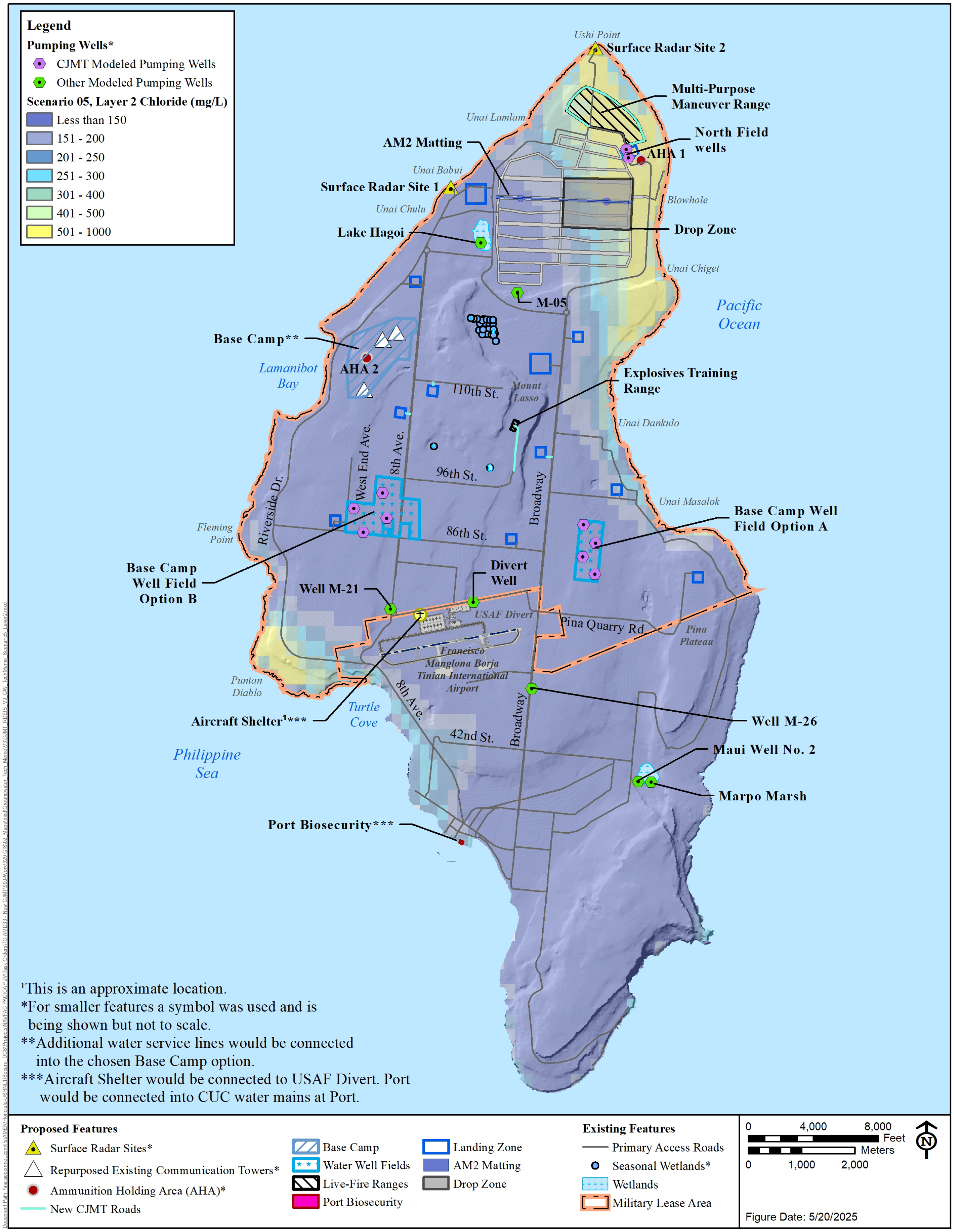

Figure 20.2. Modeled Chloride Concentrations for Layer 2 – Scenario 5

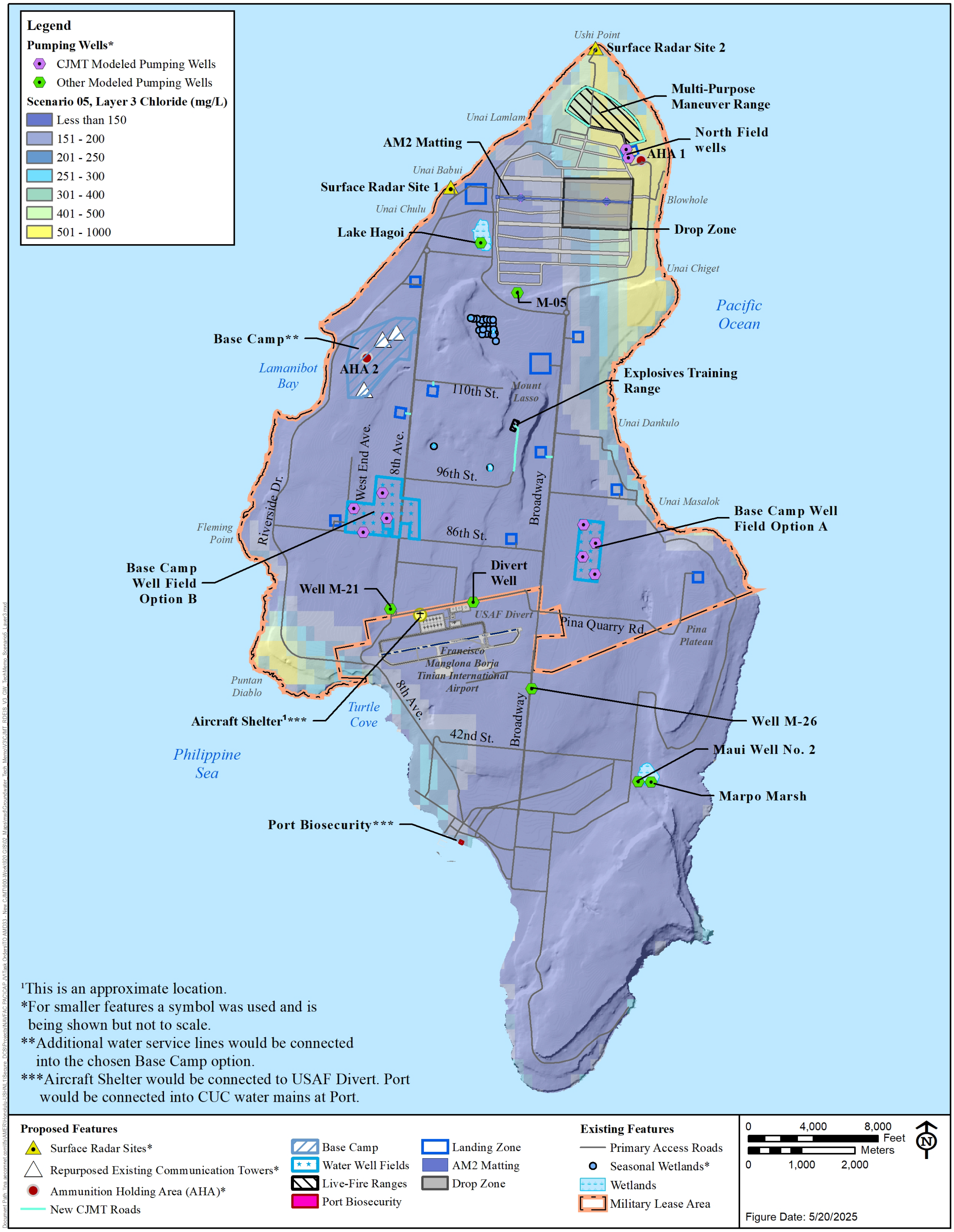

Figure 20.3. Modeled Chloride Concentrations for Layer 3 – Scenario 5

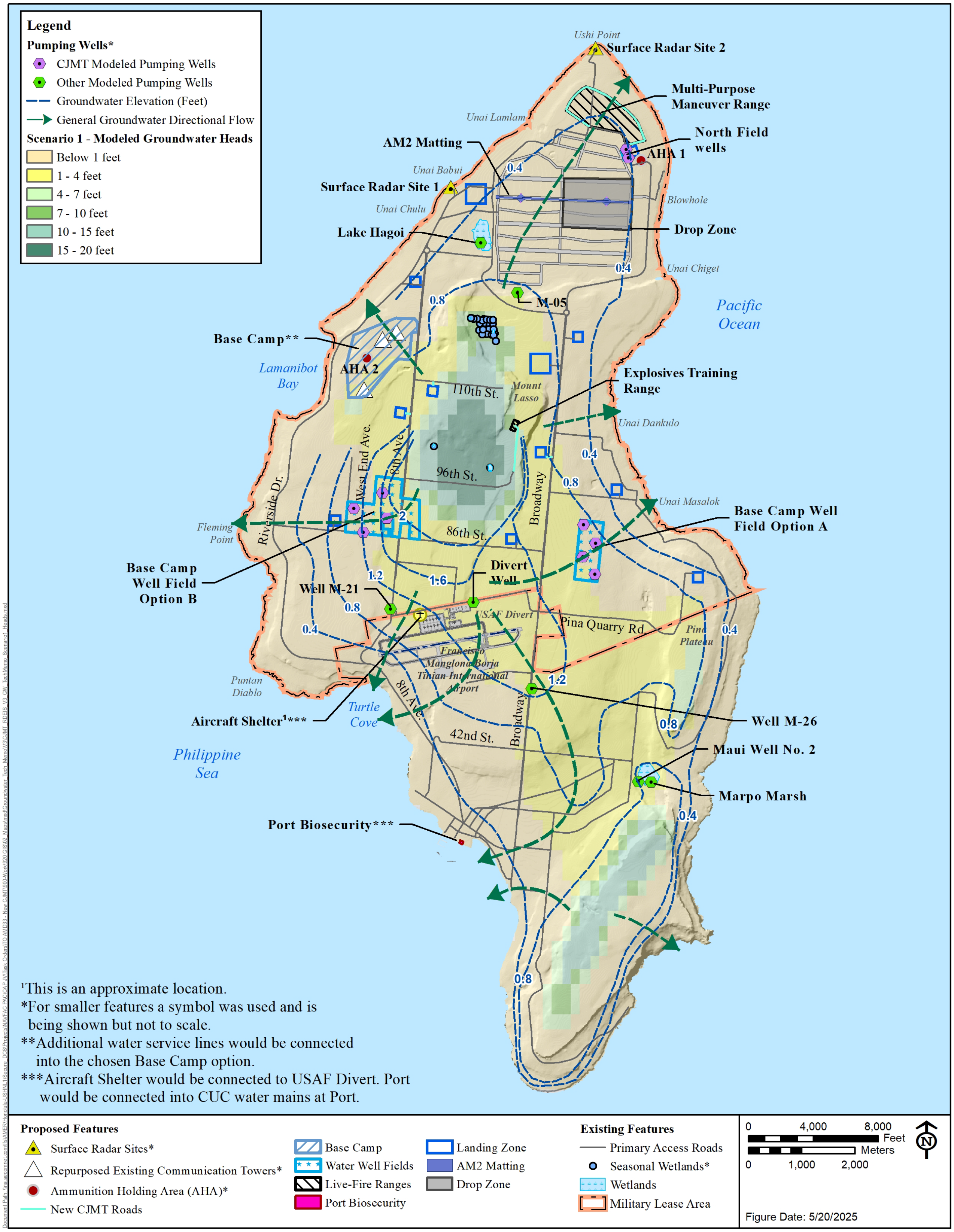

Figure 21. Modeled Groundwater Heads and Groundwater Flow Directions – Scenario 1

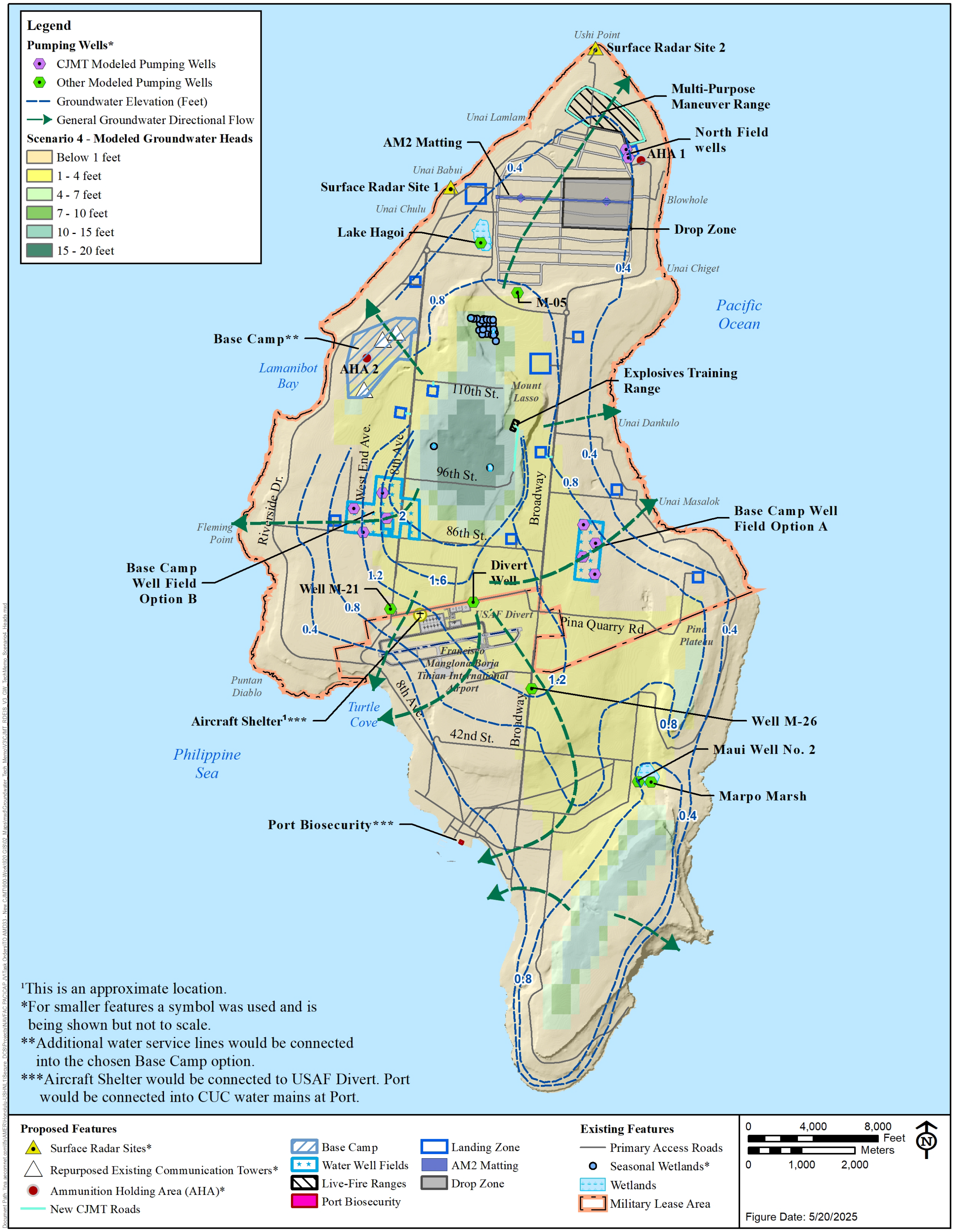

Figure 22. Modeled Groundwater Heads and Groundwater Flow Directions – Scenario 4

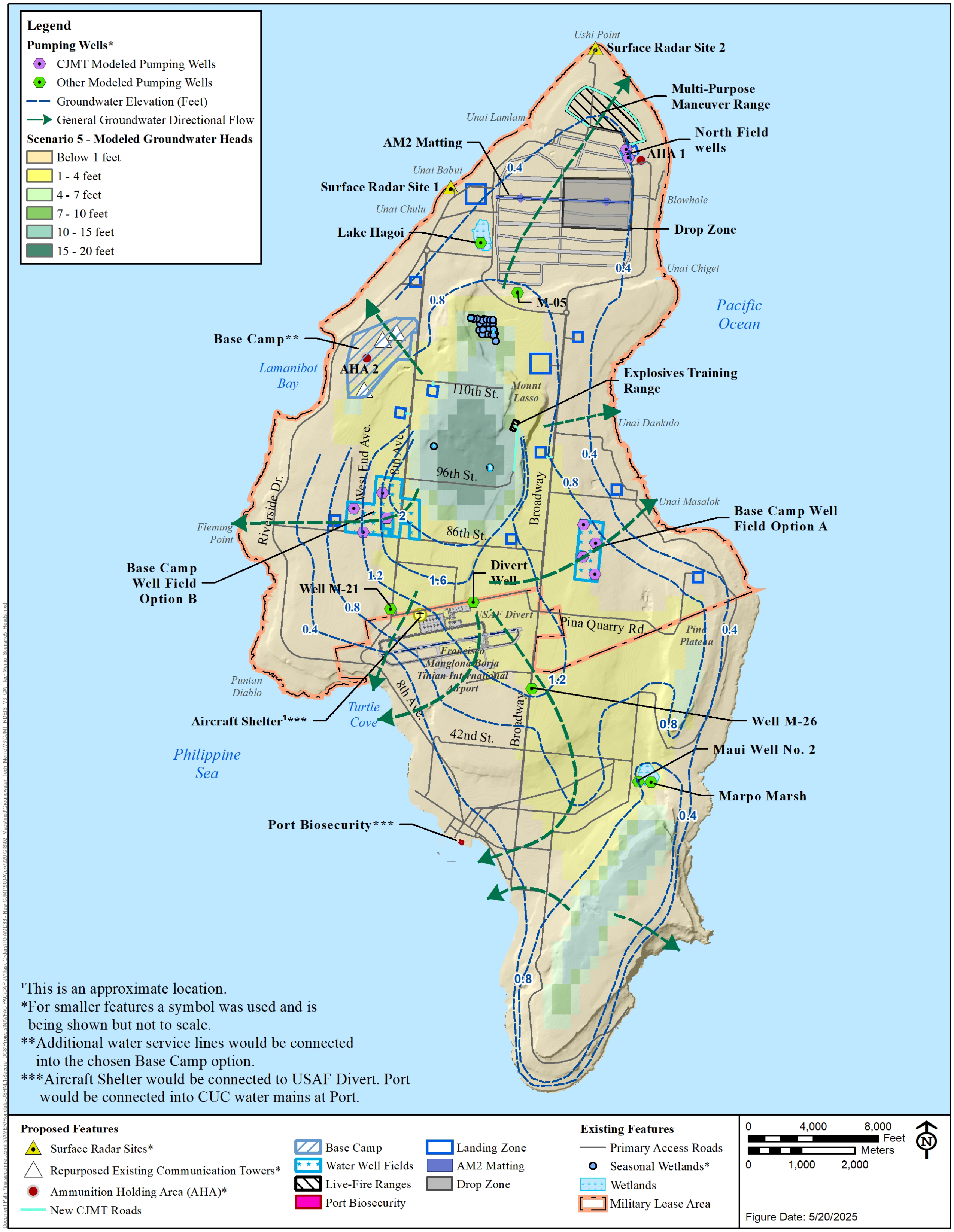

Figure 23. Modeled Groundwater Heads and Groundwater Flow Directions – Scenario 5

5.7 EFFECTS OF SEA LEVEL RISE

The scope of work for the study also included the following: "Provide technical basis (hydrogeological) for discussion of sea level rise's potential effects on the availability of freshwater via existing and proposed water wells that may assist planners in strategizing future contingency actions." While the groundwater modeling effort evaluated the short-term impact of drought on chloride concentrations, it did not address long-term changes such as sea level rise. In general, it is expected that sea level rise would result in a concomitant rise in the transition and saltwater zones. This phenomenon would not significantly change the amount of freshwater available especially in areas bounded by sea cliffs. However, a significant rise in sea level could necessitate changes in well screen depths. This could require drilling new wells. It is recommended that periodic groundwater samples be collected from the pumping wells and selected monitoring wells to allow for the assessment of fluctuations of both groundwater elevation and chloride concentration.

5.8 SUSTAINABLE YIELD VS. SUSTAINABLE MANAGEMENT OF AQUIFERS

"Sustainable yield" (also sometimes called "Safe Yield") has traditionally been defined as the rate at which groundwater can be continuously withdrawn from an aquifer without impairing the quality or quantity of the pumped water or the environment. On Tinian, specific yield is not related to groundwater quantity. Overextraction (i.e., unsustainable extraction) could reduce the volume of freshwater and induce drawdown, leading to the replacement of freshwater with saltwater from beneath the transition zone and/or the inward migration of saltwater from the coast. Since saltwater from the ocean is effectively infinite, specific yield is not limited by the aquifer size or groundwater volume in storage, as is often the case in inland continental settings. Instead, the sustainable yield limit on Tinian would be the quantity of usable freshwater available without inducing significant salinity increases within the freshwater aquifer. Before groundwater modeling, and in the absence of a reliable model for a specific aquifer, sustainable yield had generally been estimated as a percentage (typically 20–25 percent) of estimated recharge. However, achieving the hypothetically available sustainable yield would require optimized groundwater withdrawal, which usually does not occur. Optimization would require using many small, shallow wells and/or several Maui-style wells distributed relatively uniformly around the island. Because this approach is not feasible nor proposed on Tinian, the full capacity of the aquifer is generally not available for development. In island aquifers, salinity can rise in proportion to the amount of groundwater extracted and as a percentage of recharge. Recognition of these limitations in the sustainable yield concept, along with the advent of new tools and technologies for aquifer management, such as numerical groundwater modeling, remote monitoring of production and water quality, and variable-rate pumps, has led to its supersession by the "sustainable use" or "sustainable management" concept (Alley and Leake 2004).

Reliable models provide useful tools for general estimates of the trade-offs between extraction and water quality. For any given well or well field, however, the most effective management practice involves frequent measurement and tracking of the relationship among water quality, extraction, and recharge, with appropriate adjustments of production as indicated by the data. Therefore, it is crucial for managers to obtain baseline and ongoing data on water quality and well performance.

For the proposed CJMT Base Camp and North Field wells, it is important to maintain running records of water quality, correlated with pumping rates and monthly and annual rainfall. Well fields and individual wells should be constructed so that managers, working with hydrogeologists familiar with the local climate and aquifer properties, can adjust or redistribute the production rates among wells as trends in performance and water quality evolve. Water production, water level and water quality data must be submitted to the CNMI Bureau of Environmental and Coastal Quality) upon initial well permitting and annually during re-permitting for operation. Based on that data, Bureau of Environmental and Coastal Quality assigns maximum extraction rates on a well-by-well basis.

The U.S. Geological Survey estimated Tinian's average annual groundwater recharge to be about 30 inches per year, using the bookkeeping method with daily rainfall data from 1987 to 1997 (U.S. Geological Survey 2002). This recharge rate represents approximately 37 percent of the total rainfall and equals to approximately 62,000 acre-feet per year or 55 million gallons per day. Doan et al. (1960) stated there were two air bases and one naval base on the island with a maximum total population of about 250,000 personnel near the end of World War II, and groundwater resources "were adequate" to supply this entire population. Demand at the time was estimated to be approximately 2.3 million gallons per day, which was not thought to be the "maximum exploitable yield." The existing wells at that time provided a maximum supply of 2.5 million gallons per day. It was estimated that a more "ambitious" extraction program (i.e., with additional wells) could yield 3 to 4 million gallons per day. Doan et al. (1960) also referenced a study from Piper (1946) that reported a maximum production of 12 million gallons per day at some unstated date. If this production occurred during World War II, it would represent 48 gallons per person per day with 250,000 personnel on island. No additional information about this report could be found.

The current island demand (including evaporation and evapotranspiration losses) is estimated at approximately 1.1 MGD. Total groundwater consumption, combining civilian use and DoD operations (CJMT, Divert and North Field wells), is estimated at approximately 1.3 MGD. That value represents about 2 percent of the estimated recharge, which is significantly below the theoretical maximum sustainable yield of 20 to 25 percent of recharge mentioned earlier and substantially lower than the 2.3 MGD or 12 MGD reported by Doan et al. (1960) and Piper (1946).

5.9 MODEL LIMITATIONS AND UNCERTAINTIES

A groundwater model is a simplification of the natural environment and inherently has limitations. Consequently, some degree of uncertainty exists in any numerical model's ability to fully predict groundwater flow and contaminant transport. Model output uncertainty arises from uncertainties in the conceptual model, input parameters, and the numerical model's ability to replicate field conditions.

To minimize uncertainty, AECOM used real-world data whenever available and conducted extensive model simulations for calibration. Where data were limited, conservative values were applied to high-uncertainty parameters. Despite these efforts, no warranty, expressed or implied, guarantees that this study accounts for all hydrogeological, hydrological, environmental, or other site-specific characteristics.

The groundwater model developed for this project provides a detailed representation of the subsurface hydrogeology of the island and an extended area beyond the island boundaries. This broader coverage minimizes boundary effects on model results. However, like all numerical models, it has inherent limitations and uncertainties due to data availability, assumptions, and necessary simplifications.

The 2025 AECOM model assumed equivalent porous media. The Tinian aquifer is recognized as a triple-porosity Carbonate Island Karst aquifer where fracture and conduit porosity may be present. Further, the precise locations and hydraulic properties of these features are nearly impossible to document comprehensively in the field and cannot be fully incorporated into current modeling codes, including those used in this study. As a result, salinity responses of individual wells to pumping and contaminant migrations from specific locations may show significant local deviations from the model's prediction. Table 11 summarizes factors that could influence the modeling results and their potential impacts on the results.

Table 11. Model Limitations

Model Limitations	***Potential Impact on Model***
Lack of Detailed Aquifer Data.	a) There are no field test data for specific yield for the limestone (Tagpochau Limestone and/or Mariana Limestone) or volcanic rocks (Tinian Pyroclastic Rock). There was no mention of response to pumping in unpumped observation wells. b) For hydraulic conductivity, there is significant variability (21 feet per day yo 23,000 feet per day) in the data from the limestone units and only one pump test in volcanic rocks. c) There are few temporal chloride concentration. Only one well (Maui Well Number 2) has temporal or recent chloride data. d) There is limited information on spatial distribution of rainfall recharge.
Insufficient Calibration Data: Head and chloride concentration data are spatially and temporally inadequate for calibration.	Limit the model's ability to be well-calibrated, thus reduce reduces confidence in model predictions.
Non-uniqueness Representation of Rock Distribution: Variability in rock extent and distribution introduces uncertainty.	Introduces uncertainty in aquifer properties and model results. Different plausible geologic interpretations yield different hydraulic properties and flow conditions, affecting predicted groundwater movement and solute transport.
Coarse Model Grid: The model grid is relatively coarse, leading to lateral discontinuity in cells that violate the 50% rule of thumb.	Coarse grid may lead to inaccuracies in representing hydrogeologic features (especially near sharp boundaries or abrupt lithologic changes). Lateral discontinuities in cell properties may violate the 50% rule of thumb, potentially distorting hydraulic gradients and solute.
Averaged Chloride Concentrations: Modeled chloride concentrations represent cell-wide averages, which may be too coarse to accurately track specific isochlor (e.g., the 250 mg/L contour).	Localized concentration variations may not be captured. This can lead to smoothed concentration distributions that may not accurately depict isochlors, such as the 250 mg/L contour, affecting the assessment of salinity intrusion.

Model Limitations	*Potential Impact on Model*
Simplified Geological Representation: Geologic features are modeled at a coarse resolution, potentially affecting hydrologic behavior and model accuracy.	May lead to over-simplifications in key hydrostratigraphic features, potentially affect the accuracy of simulated flow paths, aquifer connectivity, leading to inaccurate interpretation of groundwater movement and solute transport.
Conservative Chloride Assumptions: Background and recharge chloride concentrations are likely conservative.	Model results may overestimate chloride impacts, leading to potentially pessimistic projections of salinity intrusion or water quality degradation. While this approach may provide a protective estimate, it could also lead to overly restrictive management decisions.

Legend: % = percent; mg/L = milligram per liter.

As with any groundwater model used to make predictions, achieving more definitive results requires periodically revisiting the model as new data become available and comparing projections with observed conditions. This model in particular was constructed with numerous assumptions due to limited data availability and would benefit from additional data collection. Despite these issues the model results are useful for the purposes intended.

The 2002 USGS model was used as a starting point for developing a 3-D flow and transport model. Combined with the *Aquifer Study Technical Memorandum* (DON 2015) and the more recent Maui Well No. 2 data, this model is considered adequate for environmental evaluation purposes. However, spatial and temporal variation/fluctuation should be anticipated as it is not possible to capture all geologic heterogeneity in a numerical representation of the natural system.

The current model provides conservative projections because where data were limited or unavailable, conservative values were applied to high-uncertainty parameters. For example, relatively low specific yield (or effective porosity) of 28 percent was used in the model, although "the higher values of porosity (30 to 50 percent) seem more likely to be representative of actual aquifer properties (USGS 2002)." The use of a lower specific yield would result in less groundwater in storage, higher groundwater velocities and a shallower freshwater/saltwater interface.

5.10 MODEL SUMMARY

Based on the modeling described herein, the following conclusions are made:

- The Proposed Action (Scenario 2 or 4) is not predicted to increase chloride concentrations at Maui Well No. 2 from 2016 conditions. Under drought conditions (Scenario 3 or 5), the chloride concentration is expected to rise temporarily by less than 20 milligrams per liter and would still meet the secondary maximum concentration level. While the average chloride concentration is not expected to exceed the secondary maximum concentration level on average, seasonal variations in precipitation and pumping, along with analytical variability, could occasionally result in exceedances.
- Under all scenarios, water quality at the proposed Base Camp wells at either Well Field A or Well Field B is expected to meet the secondary chloride maximum concentration level.
- Although the secondary drinking water maximum concentration level does not strictly apply to agricultural, firefighting, or construction wells, the modeling indicates the chloride concentrations at M-21, M-26, M-05, and the Divert well would remain below this

threshold under all scenarios. However, chloride concentrations at the two North Field wells would exceed these standards under normal rainfall and drought conditions.

- The proposed CJMT pumping at either Base Camp well field option plus the new North Field wells is expected to have a less-than-significant impact on island potable groundwater quality.

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6 WELL SITING, INSTALLATION AND OPERATION RECOMMENDATIONS

6.1 RECOMMENDATIONS

Based on a total borehole depths of approximately 17 feet below msl and completed well screens from roughly msl to 15 feet below msl, it is anticipated that the CJMT wells shown in Figure 4 would provide water that complies with the EPA and CNMI drinking water regulations. These include permits and annual reporting required by Bureau of Environmental and Coastal Quality (Division of Environmental Quality 2005). The practical thickness of the freshwater lens (i.e., depth within which chloride is less than the secondary maximum concentration level of 250 milligrams per liter) is generally much thinner than the theoretical 50% isochlor (chloride concentration equal to approximately 9,700 milligrams per liter). The freshwater lens thickness can also vary seasonally and with change in annual rainfall. Past practice elsewhere on the Mariana Islands has been to screen or leave open wells from the water table down to 40–50 feet below mean sea level. However, accumulated experience with drilling and well development elsewhere on the Mariana Islands (Camp, Dresser and McKee, Inc. 1982), along with more recent developments (Gulley et al. 2012), suggest that most of the production in productive wells comes from the first 15–20 feet below mean sea level due to the preferential development of phreatic caves near the freshwater table. Prospects for saltwater contamination could be reduced by limiting well completion depths. Consistent with the sustainable management concept in the *Aquifer Study Technical Memorandum* (DON 2015), increasing the number of wells, setting them at shallower depths, and operating them at more modest rates than traditionally sought would enhance the water quality while achieving overall production goals.

Based on the specific capacities from the pump tests cited in the *Aquifer Study Technical Memorandum* (DON 2015), it is expected that drawdown associated with pumping approximately 60 gallons per minute could range from about 0.1 to 19 feet. To maintain well performance and water quality, drawdown should not be allowed to exceed approximately 0.5 foot. Therefore, boreholes should be pump tested to confirm adequate specific capacity prior to well completion. Significant seawater intrusion (lateral migration and/or upconing) is not expected to cause noncompliance with the secondary drinking water maximum concentration levels for total dissolved solids and chloride if well screens are set no deeper than 15 feet below msl and pumping rates are limited to produce no more than the drawdown listed above. However, this should be monitored frequently throughout the life of each well, and wells should be constructed with adjustable pumping capabilities to optimize both production and water quality. Given the characteristics of this aquifer, water quality from wells is likely to respond rapidly to changes in pumping rates. Even with conscientious management, occasional increases in salinity may occur in individual wells, particularly during extended dry periods or long-term sea level fluctuations. In such cases, reduced pumping or replacing the affected well may be necessary to maintain water quality.

The CJMT wells should draw water primarily from the Tagpochau Limestone and the Mariana Limestone. Because the limestone may be thinner in some areas (i.e., the basement rock is shallower), lithologic and geophysical logging should be performed at each pilot hole to confirm adequate limestone thickness. Locations outside of well fields A or B were not evaluated. Additional recommendations for well siting, setbacks, installation, testing, and operation are provided in the *Aquifer Study Technical Memorandum* (DON 2015).

6.2 WELL SITING AND INSTALLATION

Prior to finalizing location of any of the exploratory wells at candidate sites the following should be performed:

- Review of the following figures from the *Aquifer Study Technical Memorandum* (DON 2015): Figure 5.7-1 (Analytical Results on Gingerich and Yeatts 2000 Groundwater Levels), Figure 5.7-2 (Hydraulic Head and Groundwater Flow Direction), Figure 5.7-3 (Surface Geology and Proposed Well Network), Figure 5.7-4 (Topography, Hydrology and Depressions on U.S. Navy 2010 Aerial Photo), and Figure 6.1-1 (Proposed Wells on Doan and Other, 1960 Groundwater Resources Map).
- Site reconnaissance before and after vegetation clearing to find any surface debris, tanks, piping, soil discoloration, or collapse features.
- Unexploded ordnance, munitions and explosives of concern, and utility clearance.
- Mapping of any surface geologic exposures collapse features or manmade features.
- Any future wells should be sited within the well fields A or B shown in Figure 4. The wells would be located outside of proposed training constraints, proposed water disposal/infiltration features, biological constraints, cultural constraints, hazardous waste/hazardous materials constraints, fractures, joints, faults, and karst features.
- Step testing and constant-rate pump testing of pilot holes and completed wells. Pilot borings with expected drawdown of 2 feet or more and/or a specific capacity of less than 30 gallons per minute per foot of drawdown should not be completed. Such holes could be considered for monitoring wells by which to observe changes in water levels and quality.
- Water quality testing of a whole water sample collected near the end of pump testing for all Safe Drinking Water Act analytes.
- Periodic samples should also be collected during pilot-hole and completed-well step- and constant-rate pump testing and analyzed in accordance with the CNMI *Well Drilling and Well Operation Regulations* (Department of Environmental Quality 2005). Hourly samples should be collected throughout the pumping phase for chloride analysis. Transducers that record water level and specific conductivity should be used to augment hourly samples.
- Video-logging of new boreholes and completed wells. Logging of new holes, and archiving of the video, would provide a basis for the hydrogeologist(s) to make informed predictions and diagnoses of well performance, as well as subsequent mitigation decisions regarding causes and appropriate responses to changes in salinity.
- Well field and well design include the following considerations: Wells should be spaced no closer than allowed by the setbacks by Bureau of Environmental and Coastal Quality, and wells should not be placed any closer than 500 feet from each other or karst collapse features.
- Minimum 12-inch-diameter pilot holes should be drilled to no more than 17 feet below sea level.

- Pilot holes should be geologically logged based on cuttings and geophysically logged using tools (i.e., spontaneous potential, resistivity, gamma, guard resistivity, acoustic [sonic] log) to include character of limestone and evidence of faults, joints, fractures, and solution cavities. Tools should selected and positioned to optimize geophysical signals.
- The well screens should extend from sea level to a nominal depth of 15 feet below mean sea level.
- Following geophysical logging, the pilot hole should be reamed to a minimum 18-inch diameter. A caliper log should be performed of the reamed borehole (if the caliper survey shows the hole to be less than the specified diameter at any point, the hole should be re-reamed and resurveyed).
- Completed well borings should be at least 18 inches in diameter.
- Wells should be constructed of 12-inch-diameter, 5/16-inch thick, high-strength, low-alloy casing (ground surface down to 20 feet above mean sea level) and 304L stainless steel casing (20 feet above mean sea level down to mean sea level) connected with a di-electric coupler approximately 20 feet above mean sea level and 12-inch-diameter, 5/16-inch 304L, stainless steel Roscoe Moss Ful Flo screen, and a 2-foot-long by 18 5/16-inch stainless steel casing well sump.
- Screen aperture and filter pack/formation stabilizer gradation should be designed by the hydrogeologist and engineer designing the wells.
- The casing should be round, straight, and plumb. The deviation of the casing is measured from a plumb vertical line centered at the top of the inner casing and is calculated as the actual deviation of the well casing from this centerline at the depth of the caging tool. Testing should be conducted to verify the plumbness and alignment of the casing. The completed well should be drilled in such vertical alignment that a line drawn from the center of the well casing at ground surface to the center of the well casing at the bottom depth below ground surface should not deviate from the vertical more than 2/3 of the inside diameter of the well casing per 100 feet of depth (American Water Works Association A100). Two plots of plumbness and alignment of the completed well should be completed in planes oriented at 90 degrees with respect to each other.
- The design flow rate should be no more than 60 gallons per minute per well. To reduce the risk of pump cavitation, provide adequate pump cooling, and accommodate seasonal and decadal ocean water elevation changes, the pump intake should be placed a nominal 14 feet below mean sea level. Well pumping rates should be modulated to prevent drawdown greater than 0.5 feet in each well.
- It is also assumed that Bureau of Environmental and Coastal Quality would require monitoring wells associated with the new production wells as described in the CNMI *Well Drilling and Well Operations Regulations* (Department of Environmental Quality 2005). Although the final numbers and locations cannot be determined before consultation with Bureau of Environmental and Coastal Quality and possibly additional investigation for planning purposes, it is recommended that at least one deep monitoring well (through the transition zone) at the new CJMT well field be installed to allow profiling of the salinity and tracking of its response to changes in well pumping, rainfall recharge, and ocean water levels.

- Any wells or boreholes not to be used as production or monitoring wells should be properly abandoned under the direction of Bureau of Environmental and Coastal Quality.
- Production wells should include a 3-inch-diameter gravel feed tube and 2-inch-diameter sounding tube. The filter pack/formation stabilizer and transition sand should be installed. The filter pack/formation stabilizer should be installed a minimum of 15 feet above the top of the screen interval.
- The filter pack/formation stabilizer should be placed by pumping through a tremie pipe extending to the bottom of the casing hole annulus. The tremie pipe should be gradually withdrawn as the filter pack/formation stabilizer is placed. Swabbing and circulating should be continued during placement of the filter pack/formation stabilizer.
- After the filter pack/formation stabilizer has been swabbed into place to the proper depth, the transition sand should be installed a minimum of 10 feet above the top of the filter pack/formation stabilizer.
- The filter pack/formation stabilizer should be disinfected with chlorine during placement as per specifications. The completed well, pumping equipment, and piping should be disinfected in accordance with the CNMI *Well Drilling and Well Operation Regulations* (Department of Environmental Quality 2005).
- After the transition sand is installed, the annular space between the borehole and the well casing should then be filled with cement grout from the top of the filter pack/formation stabilizer to 18 inches below the ground surface.
- A total of 48 hours after completion of installation of cement-bentonite grout, the well should be carefully swabbed to properly settle the sand pack.
- The completed well should be developed by surge-block-and-air-lift method for a minimum of 6 hours.
- The completed well should be video-logged from top to bottom to document well conditions.
- A submersible or line-shaft turbine test pump should be installed.
- An 8-hour step test should be performed with steps at 50 percent, 75 percent, 100 percent, and 125 percent of design capacity.
- Following review of drilling logs, geophysical logs, video log, and step test data, a 48-hour constant rate test should be performed at a rate determined from the step test.

7 MODELING TEAM

The groundwater team members and team roles are listed below:

- **Groundwater Team Leader.** Doug Roff, PG, CEG, CHg.
- **Modeling Team.** Jim Zhang, PhD, PE (lead); Bianca Mintz, PG; Doug Roff, PG, CEG, CHg.
- Geology/Hydrogeology Team. Doug Roff, PG, CEG, CHg.
- **Reviewer.** Joe Harrigan, PG.

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ATTACHMENT A
KNOWN CURRENT AND FORMER WELLS ON THE ISLAND OF TINIAN

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Table A-1. Known Current and Former Wells on the Island of Tinian

Well Name	*Other Well Names*	*Owner*	*Installed By*	*Date Well Drilled*	*Type*	*Wellhead or Measuring Point Elevation (ft)*	*Well Depth Below msl (Negative Values = Above msl)*	*Chloride Content (Various Sources)*		*Water Production (gpm) (Doan et al. 1960)*	*Water Production (gpm) (Various Sources)* [b]	*Original Function*	*Current Status*
						ft	*ft*	*Before Pumping (mg/L)*	*After Pumping (mg/L)*	*gpm*	*gpm*		
Ag-20	W-40B, Small Marpo (Japanese) Well	CNMI government	Japanese military	1930s	Dug, cement-lined trench	7.1	1.0					Watering cattle/ irrigation	Inactive
Ag-30	W-40A, Large Marpo (Japanese) Well	CNMI government	Japanese military	1930s	Dug, cement-lined trench	5.08	5.0	130	130	0	500	Watering cattle/ irrigation	Active agricultural well
Hag-N	W-43, North Hagoi		Japanese military	1930s	Dug, cement-lined trench	4.4	2.0	622				Watering cattle/ irrigation	Inactive
Hag-S	W-44, South Hagoi		Japanese military	1930s	Dug, cement-lined trench	7.54	1.0	148	360			Watering cattle/ irrigation	Inactive
M-02 [c]	W-2, Civilian Affairs Well	CNMI government	U.S. military	8/5/1997	Drilled, 6 in (15 cm) solid steel cased well	264.56	12.0		20	100		Water supply	Inactive
M-05 [c]	W-5, Asiga Well	CNMI government	U.S. military	7/31/1997	Drilled, 6 in (15 cm) solid steel cased well	108.8	13.0		75	75		Water supply	Inactive
M-07 [c]	W-7, W 100 St. Well	CNMI government	U.S. military	5/19/1995	Drilled, 6 in (15 cm) solid steel cased well	241.35	19.0			100	23	Water supply	Inactive
M-08 [c]	W-8, 110 St. Well	CNMI government	U.S. military	8/14/1997	Drilled, 6 in (15 cm) solid steel cased well	266.07	16.0	100	600	100		Water supply	Inactive
M-09 [c]	W-9, NAB #1	CNMI government	U.S. military	4/24/1995	Drilled, 6 in (15 cm) solid steel cased well	265.08	15.0		107		128	Water supply	Inactive
M-10 [c]	W-10	CNMI government	U.S. military	3/20/1997	Drilled, 6 in (15 cm) solid steel cased well	95	14.0		220	60		Water supply	Inactive
M-11 [c]	W-11, NAB #2	CNMI government	U.S. military	3/14/1995	Drilled, 6 in (15 cm) solid steel cased well	292.03	14.0				124	Water supply	Inactive
M-15 [c]	W-15, Broadway Well	CNMI government	U.S. military	5/29/1997	Drilled, 6 in (15 cm) solid steel cased well	193.84	17.0	35	70	70		Water supply	Inactive
M-16 [c]	W-16, 2nd Ave. Well	CNMI government	U.S. military	2/24/1995	Drilled, 8 in (20 cm) solid steel cased well	153.39	14.0	106	45		96	Water supply	Inactive
M-19 [c]	W-19, 8th Ave. Well	CNMI government	U.S. military	6/5/1997	Drilled, 6 in (15 cm) solid steel cased well	247.92	14.0				30	Water supply	Inactive
M-21 [c]	WOP-151/152, W-21, Mendiola Well, 67th St. Well	CNMI government	U.S. military	1/11/1997	Drilled, 6 in (15 cm) solid steel cased well	243.29	17.0	80		60	49	Water supply	Active agricultural well
M-22 [c]	W-22, 90th St. Well	CNMI government	U.S. military	6/30/1997	Drilled, 6 in (15 cm) solid steel cased well	222.73	8.0		150	40		Water supply	Inactive
M-25 [d]	W-25, East Side Well	Unknown	U.S. military	09/19/87?	Drilled, 6 in (15 cm) solid steel cased well	211.94	88.0	196		30		Water supply	Inactive
M-26 [d]	UPW-008, W-26, 59th St. Well	Unknown	U.S. military	1987?	Drilled, 6 in (15 cm) solid steel cased well	340.83	30.0	40		35		Water supply	Active agricultural well
M-29 [c]	W-29, West Field Well	CNMI government	U.S. military	2/12/1997	Drilled, 6 in (15 cm) solid steel cased well	247.04	168.0					Water supply	Inactive
M-33 [c]	W-33, 72nd St. Well	CNMI government	U.S. military	8/20/1997	Drilled, 6 in (15 cm) solid steel cased well	235.63	10.0	50				Water supply	Inactive
M-35 [c]	W-35	CNMI government	U.S. military	7/25/1997	Drilled, 6 in (15 cm) solid steel cased well	257.23	13.0					Water supply	Inactive
M-39 [c]	W-39	CNMI government	U.S. military	5/15/1997	Drilled, 6 in (15 cm) solid steel cased well	238.93	11.0		150			Water supply	Inactive

Well Name	Other Well Names	Owner	Installed By	Date Well Drilled	Type	Wellhead or Measuring Point Elevation (ft)	Well Depth Below msl (Negative Values = Above msl)	Chloride Content (Various Sources)		Water Production (gpm) (Doan et al. 1960)	Water Production (gpm) (Various Sources) [b]	Original Function	Current Status
						ft	ft	Before Pumping (mg/L)	After Pumping (mg/L)	gpm	gpm		
Maui Well No. 1	W-41, formerly Municipal Well, Marpo Well	CNMI government	U.S. military	1945	Dug, out-of-service municipal water supply well (Maui-type horizontal construction - constructed of 240 steel cylindrical bomb crates joined end to end and perforated)	9.76	-9.8	97	100		780	Drinking water supply well	Out of service
Maui Well No. 2	Municipal Well	CNMI government	CNMI government	2000	Municipal water supply well (Maui-type horizontal construction)						875	Drinking water supply well	Active use
ObsB		Unknown	USGS	2/2/1991	USGS 4 in (10 cm) monitoring piezometer (PVC pipe-cased)	7.45	0.5					Groundwater monitoring well	Unknown
Pala	W-45	Tinian Palacios family	Japanese military	1930s	3 ft (0.9 m) diameter, hand dug well	65	3.0	185	200				Active use
Taga		CNMI government	Ancient Chamorro	Unknown	Shallow-dug well								Unknown
TH-01		CNMI government	USGS	9/17/1996	USGS 12 in (30 cm) monitoring well	117.46	13				165	Groundwater monitoring well	Unknown
TH-02		CNMI government	USGS	4/28/1997	USGS 8 in (20 cm) monitoring well	158.86	94					Groundwater monitoring well	Unknown
TH-03		CNMI government	USGS	10/24/1996	USGS 8 in (20 cm) monitoring well	109.05	22				105	Groundwater monitoring well	Unknown
TH-04		CNMI government	USGS	12/13/1993	USGS 8 in (20 cm) monitoring well	72.18	18				108	Groundwater monitoring well	Unknown
TH-05		CNMI government	USGS	6/21/1995	USGS 8 in (20 cm) monitoring well	120.85	18				92	Groundwater monitoring well	Unknown
TH-06		CNMI government	USGS	3/2/1995	USGS 6 in (15 cm) monitoring well	309.07	13				57	Groundwater monitoring well	Unknown
TH-07		CNMI government	USGS	1/20/1995	USGS 6 in (15 cm) monitoring well	343.84	20				50	Groundwater monitoring well	Unknown
TH-08		CNMI government	USGS	1/29/1993	USGS 4 in (10 cm) monitoring well	8.24	92					Groundwater monitoring well	Unknown
TH-09		CNMI government	USGS	2/3/1993	USGS 4 in (10 cm) monitoring well	6.7	92					Groundwater monitoring well	Unknown
TH-10		CNMI government	USGS	10/9/1996	USGS 8 in (20 cm) monitoring well	163.74	16				68	Groundwater monitoring well	Unknown
TH-11		CNMI government	USGS	2/25/1997	USGS 6 in (15 cm) monitoring well	339.66	19				63	Groundwater monitoring well	Unknown
TH-12		CNMI government	USGS	1/8/1997	USGS 8 in (20 cm) monitoring well	146.41	13				72	Groundwater monitoring well	Unknown
TH1-9		CNMI government	USGS	7/26/1995	USGS 8 in (20 cm) monitoring well	550	29					Groundwater monitoring well	Unknown
TH-1X		CNMI government	USGS	10/1/1996	USGS 6 in (15 cm) monitoring well	116.99	15					Groundwater monitoring well	Unknown
TH-22		CNMI government	USGS	10/16/1996	USGS 8 in (20 cm) monitoring well	96.61	16				110	Groundwater monitoring well	Unknown

Well Name	Other Well Names	Owner	Installed By	Date Well Drilled	Type	Wellhead or Measuring Point Elevation (ft)	Well Depth Below msl (Negative Values = Above msl)	Chloride Content (Various Sources)		Water Production (gpm) (Doan et al. 1960)	Water Production (gpm) (Various Sources) [b]	Original Function	Current Status
						ft	ft	Before Pumping (mg/L)	After Pumping (mg/L)	gpm	gpm		
TH-24		CNMI government	USGS	4/10/1997	USGS 8 in (20 cm) monitoring well		9				3	Groundwater monitoring well	Unknown
TH-4X		CNMI government	USGS	5/5/1994	USGS 8 in (20 cm) monitoring well	71.89	268					Groundwater monitoring well	Unknown
Ushi		U.S. military	U.S. military	9/6/1987	Military water supply well	98.47	19.0					Non-potable water supply well	Unknown
W-1	Masalog	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	255.29	7.2	40	85	55		Water supply	Inactive
W-12	E 100 St. Well	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	184.43	14.6	100	High	60		Water supply	Inactive
W-13	Park Row Well	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	59.96	15.0					Water supply	Inactive
W-14	42nd St. Well	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	242.63	12.4	30	40	35		Water supply	Inactive
W-17	86th St. Well	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	244	4.0					Water supply	Inactive
W-18A	98th St. Well	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	289.3	100.7	38		8		Water supply	Inactive
W-18B	98th St. B Well	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	285	75.0	35		8		Water supply	Inactive
W-20	New 110th St. Well	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	258	10.0		600	10		Water supply	Inactive
W-23	Mil. Gov. #2	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	294.4	-126.4					Water supply	Inactive
W-24	Central Well	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	247.27	15.7	70				Water supply	Inactive
W-27	Mil. Gov. Well	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	284.5	30.5			0		Water supply	Inactive
W-28	West Side Well	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	253.75	12.3					Water supply	Inactive
W-3	Lasso	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	202.18	31.3					Water supply	Inactive
W-30	84th St. Well	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	255.5	-18.5					Water supply	Inactive
W-31	Hilo Well	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	257.58	11.4			0		Water supply	Inactive
W-32	113th St. Well	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	223	14.0					Water supply	Inactive
W-34 [a]	Island Well	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	298.24	17.8					Water supply	Inactive
W-36		U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	125	12.0					Water supply	Inactive
W-37		U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	100	14.0					Water supply	Inactive
W-38		U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	277.83	22.2			0		Water supply	Inactive
W-4	Gurgaon	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	225.31	6.7		35	60		Water supply	Inactive
W-46 [a]		U.S. military	U.S. military	WWII Period	Hand-dug well	50	-45.0	650				Water supply	Inactive

Well Name	*Other Well Names*	*Owner*	*Installed By*	*Date Well Drilled*	*Type*	*Wellhead or Measuring Point Elevation (ft)*	*Well Depth Below msl (Negative Values = Above msl)*	*Chloride Content (Various Sources)*		*Water Production (gpm) (Doan et al. 1960)*	*Water Production (gpm) (Various Sources)* [b]	*Original Function*	*Current Status*
						ft	*ft*	*Before Pumping (mg/L)*	*After Pumping (mg/L)*	*gpm*	*gpm*		
W-47 [a]		U.S. military	U.S. military	WWII Period	Hand-dug well	35	-20.0					Water supply	Inactive
W-6	96th St. Well	U.S. military	U.S. military	WWII Period	Drilled, 6 in (15 cm) solid steel cased well	239.41	15.1	16	100	100		Water supply	Inactive
WOP-197-01		CNMI government	Unknown	10/7/2011	4 in (10 cm) Schedule 80 PVC pipe							Groundwater monitoring well (for landfill siting study)	Unknown
WOP-197-02		CNMI government	Unknown	9/24/2011	4 in (10 cm) Schedule 80 PVC pipe						193	Groundwater monitoring well (for landfill siting study)	Unknown
WOP-197-03		CNMI government	Unknown	10/3/2011	Schedule 80 PVC pipe well							Groundwater monitoring well (for landfill siting study)	Unknown

Notes: [a] Present location of this well is unknown.
[b] Rates based on pump test data (mostly USGS 2002). Values do not necessarily represent maximum sustainable rates.
[c] Rehabilitated by USGS.
[d] Rehabilitated by private party.
Blanks = unknown

Legend: cm = centimeter; CNMI = Commonwealth of the Northern Mariana Islands; ft = foot/feet; gpm = gallon per minute; in = inch; lpm = liter per minute; m = meter; msl = mean sea level; NA = not applicable; mg/L = part per million; PVC = polyvinyl chloride; USGS = U.S. Geological Survey; WWII = World War II

Sources USGS 2000, 2002; Doan et al. 1960