3.3 WATER RESOURCES

Section 3.3 describes the existing conditions of the water resources on Tinian and Pagan. Water resources include surface waters, groundwater, and nearshore waters. The region of influence includes the surface waters, groundwater, and nearshore waters immediately adjacent to these islands.

3.3.1 Definition

Surface waters, groundwater, nearshore waters and other key terms are defined below:

- **Surface waters** include lakes, streams, rivers, springs, and wetlands; some of these features may be considered "Waters of the U.S." The discussion of surface waters also incorporates the analysis of watersheds and floodplains. A detailed discussion of stormwater runoff is provided in Sections 3.14 and 4.14, *Utilities*; however, potential impacts to water quality due to stormwater runoff are discussed under water resources.
    - **Waters of the U.S.** are defined under 40 CFR 230.3(s) and 33 CFR Part 328 as: "(1) all waters which are currently used, or were used in the past, or may be susceptible to use in interstate or foreign commerce, including all waters which are subject to the ebb and flow of the tide; (2) all interstate waters including interstate wetlands; (3) all other waters such as intrastate lakes, rivers, streams (including intermittent streams), mudflats, sandflats, wetlands, sloughs, prairie potholes, wet meadows, playa lakes, or natural ponds, the use, degradation or destruction of which could affect interstate or foreign commerce including any such waters: (i) which are or could be used by interstate or foreign travelers for recreational or other purposes; or (ii) from which fish or shellfish are or could be taken and sold in interstate or foreign commerce; or (iii) which are used or could be used for industrial purposes by industries in interstate commerce…"
    - **Wetlands** are defined by Section 404 of the Clean Water Act as: "areas that are inundated or saturated by surface water or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas." The CNMI Water Quality Standards define wetlands as "waters of the Commonwealth," and state that all wetlands are subject to the provisions of the standards. Areas described and mapped as wetland communities may also contain small streams, shallow ponds, and lake edges.
    - **Watersheds** are typically defined by topographic ridges and their respective drainage areas contributing runoff to surface waters, including the sea, lakes, estuaries, or wetlands.
    - **Sub-watersheds** are smaller geographic units of a larger watershed.
    - **Floodplains** are low-lying areas subject to flooding as a result of excessive rains, stormwater runoff, or inundation from storm-induced waves.

- **Water Quality** describes the chemical and physical composition of water as affected by natural conditions and human activities.
- **Groundwater** is water beneath the ground surface in soil pore spaces and in the fractures of rock formations. An **aquifer** is an underground layer of water-bearing permeable rock or materials (gravel, sand, or silt) from which groundwater can be extracted using a well.
- **Nearshore waters** are all areas extending seaward from the coast out to a depth of 330 feet (100 meters).

3.3.2 Regulatory Framework

The U.S. Army Corps of Engineers, the U.S. Environmental Protection Agency, and the U.S. Maritime Administration are the primary federal agencies with jurisdiction over water resources. Within the CNMI, the CNMI Bureau of Environmental and Coastal Quality is the administrative authority for the Clean Water Act and some activities under Section 10 of the Rivers and Harbors Act. Federal and local regulations that serve to protect, conserve, and manage water resources are listed below.

3.3.2.1 Federal Regulation

- Clean Water Act
  - Section 401
  - Section 402
  - Section 404
- Water Pollution Control Act
- Fish and Wildlife Coordination Act
- Safe Drinking Water Act
- Coastal Zone Management Act
- Rivers and Harbor Act
  - Section 10
- Energy Independence and Security Act
- Executive Order 11990, Protection of Wetlands
- Executive Order 11988, Floodplain Management

3.3.2.2 CNMI Regulation

- CNMI Earthmoving and Erosion Control Regulations
- CNMI Wastewater Treatment and Disposal Rules and Regulations
- Water Quality Standards
- Groundwater Recharge Requirements
- Drinking Water Regulations
- Well Drilling and Well Operation Regulations
- Northern Mariana Islands Administrative Code Chapter 65-120: Wastewater Treatment and Disposal

A complete listing of applicable regulations is provided in Appendix E, *Applicable Federal and Local Regulations*.

3.3.3 Methodology

Reports and studies prepared by or for the federal government, the CNMI government, and independent researchers that address natural resources (e.g., water, geology, biology) and infrastructure (e.g., utilities) on Tinian and Pagan were reviewed for information related to the existing condition of water resources. Federal and CNMI regulations were reviewed for regulations that serve to protect, conserve, and manage water resources (see Section 3.3.2). In addition, an aquifer study is underway to evaluate potential well capacity and existing water quality in notional well fields; well setbacks and potential for saltwater intrusion (the movement of saline water into freshwater aquifers); and man-made contaminant migration into notional well fields on Tinian. This study will provide information needed to design and space wells in the notional well field. Information from this study will be added to the Final Environmental Impact Statement (EIS)/Overseas Environmental Impact Statement (OEIS).

Water resources identified during the literature review which could be potentially affected by the proposed action are described below. The CNMI government performs regular water quality monitoring of Tinian's coastal waters. The results of recent nearshore water quality monitoring are summarized in Section 3.3.4.3, *Nearshore Waters*. The CNMI government does not perform regular water quality monitoring of Pagan's coastal waters and does not perform water quality monitoring of surface waters or groundwater on either island. Information on nearshore water quality was summarized from the Mariana Archipelago Reef Assessment and Monitoring Program (Brainard 2012).

3.3.4 Tinian

3.3.4.1 Surface Water Resources

Rainfall on Tinian averages 83 inches (212 centimeters) per year (Water and Environmental Research Institute 2003), 58% of which typically occurs from July to November while only 14% typically occurs during the dry season from January to April (Department of the Navy [DoN] 2010a). Much of the precipitation on Tinian evaporates, transpirates, or percolates into openings in the limestone and volcanic rock beneath the thin soil surface (Gingerich 2002).

3.3.4.1.1 Surface Water Features

There are three known inland water features within the Military Lease Area (Table 3.3-1 and Figure 3.3-1): (1) Lake Hagoi; (2) Mahalang Complex; and (3) Bateha Isolated Wetlands. Because Tinian is formed almost entirely of permeable limestone karst, there are few springs and no perennial (permanently flowing) streams. Drainage throughout most of Tinian is underground where rainwater generally percolates downward into porous rock (Doan et al. 1960), with the exception of during heavy rain events that occasionally result in stormwater runoff entering the surface and nearshore waters via short-lived ephemeral streams. Surface water features occur on Tinian in areas of impermeable clay that prevent infiltration of surface water, or at perched water tables (temporary pockets of groundwater located above unsaturated soil or rock, not connected to the permanent groundwater table). These areas are entirely dependent on rainfall as a water source for sustaining productivity and habitat quality.

Because the entire shoreline is either limestone cliffs and rocky outcrops or sand beach, there are no mangroves or coastal wetlands present.

Table 3.3-1. Tinian Surface Water Features

Name	***Description****	***Area***
Lake Hagoi	Located on the northwest side of the Military Lease Area, Lake Hagoi is a permanent partially-open-water complex. It is situated on a limestone terrace over either an impervious layer or a perched water table. Lake Hagoi is dependent entirely on rainfall as a water source; in periods of drought the water level drops and the coverage of open water dramatically decreases (DoN 2010a). Since 2010, a rapid reduction of open surface water has been observed (Wenninger 2012). Due to sediment inflow, the open water area of Lake Hagoi is slowly transforming into a marsh, completely covering emergent vegetation (AECOS, Inc. and Wil Chee Planning, Inc. 2009).	34 acres (14 hectares)
Mahalang Complex	Located within the north central portion of the Military Lease Area, Mahalang comprises a cluster of craters and depressions, a subset of which pond water during the wet season. The complex is located on a plateau in an area of grasslands, tangantangan, and mixed secondary forest. Some of the features are characterized as likely bomb craters from World War II activities (DoN 2013a). Dominant vegetation within the craters consists of upland plant species, including introduced grass mixed with various weedy vines and herbaceous plants.	Approximately 24 individual sites; estimated the two largest features as approximately 1.2 acres (0.5 hectare) each
Bateha Isolated Wetlands	Located within the central portion of the Military Lease Area, these features consist of two shallow depressional areas that contain water during wet periods (U.S. Fish and Wildlife Service 1996; DoN 2013a). They are broad depressions or "moats" that have evolved as eroded clay and silt filled depressions in limestone bedrock (DoN 1997). Vegetation within and surrounding these features is dominated by introduced species.	1.5 acres (0.6 hectare) each

**Note:* Vegetation is described in Section 3.9, *Terrestrial Biology.*

3.3.4.1.1.1 Wetlands Communities

In support of the EIS/OEIS, all three surface water features were surveyed for wetland characteristics. Consistent with the definition of a wetland under the Clean Water Act, Lake Hagoi has hydric soils (soil which are permanently or seasonally saturated, resulting in anaerobic conditions), hydrophytic vegetation (plants adapted to life in water or waterlogged soils), and has surface water for most of the year (DoN 2013a). Vegetation within and surrounding the wetland is dominated by species native to Tinian. Based on the 2014 wetland surveys at the Mahalang Complex, one of the depressions (MD3) contains wetland vegetation and is a depressional isolated wetland (Figure 3.3-1). Other sites surveyed at the Mahalang Complex (MC1, M7, MC2, M10, and M11) in 2014 did not contain wetland vegetation and are ephemeral surface waters. The 2014 wetland survey documented wetland vegetation at both sites within the Bateha Isolated Wetlands. Table 3.3-2 provides a summary of the surface water areas determined to maintain wetland characteristics. The survey report is provided in Appendix L, Wetland Study Report.

Figure 3.3-1
Tinian Surface Waters and Flood Zones

Sources: Federal Emergency Management Agency 2006, DoN 2010a, DoN 2013

Table 3.3-2. Summary of Potential Wetlands of the Bateha and Mahalang Complexes

Site	Presence of Obligate Wetland Vegetation	Presence of Hydrological Conditions	Test Pit and Presence of Hydric Soils	Site Connected to Stream System	Ponded Water Present
Bateha BD1	Yes: *Ipomoea aquatic* (minor)	Yes; depressional	No. 1 – hydric soils No. 2 – hydric soils No. 3 – hydric soils No. 4 – hydric soils No. 5 – hydric soils	No	Yes
Bateha BD2	Yes: *Ipomoea aquatic* (minor)	Yes; depressional	No. 1 – no hydric soils No. 2 – no hydric soils No. 3 – no hydric soils No. 4 – hydric soils present	No	Yes
Mahalang MC1	No	Yes; crater	No. 1 – hydric soils No. 2 – hydric soils	No	Yes
Mahalang M7	No	Yes; crater	No. 1 – no hydric soils (*too far upslope due to high water levels?*) No. 2 – no hydric soils (*too far upslope due to high water levels?*)	No	Yes
Mahalang MC2	No	Yes; crater	No. 1 – no hydric soils (*too far upslope due to high water levels?*) No. 2 – hydric soils	No	Yes
Mahalang M10	No	Yes; crater	No. 1 – no hydric soils (*too far upslope due to high water levels?*) No. 2 – hydric soils	No	Yes
Mahalang M11	No	Yes; depressional	No. 1 – no hydric soils No. 2 – no hydric soils	No	No; *No saturated grounds*
Mahalang MD3	Yes: *Ipomoea aquatic* (dominant)	Yes; depressional	No. 1 – hydric soils No. 2 – no hydric soils (*too far upslope due to high water levels*)	No	Yes

Note: No. = number.

3.3.4.1.1.2 Sub-watersheds

The U.S. Department of Agriculture identified five sub-watershed areas on Tinian: Makpo Valley, Puntan Diaplo-Lamanibot, Carolinas, Masalok, and Puntan Tahgong. The designated sub-watershed areas are based on Island Resource Steering Committee concern areas, topography, and principal land uses. The Island Resource Steering Committee originated in 1991 and included government agencies and members of the Tinian community (U.S. Department of Agriculture 1994). Sub-watersheds areas are shown in Figure 3.3-1. Contamination due to human activity has the potential to impact surface water and groundwater in these sub-watersheds. Examples of existing or past human activities/land uses which have the potential to contaminate water resources include: agriculture/crop production and harvesting; auto mechanic shops; vehicle fuel stations; fuel storage; cattle ranching; pesticide storage and application; chemical storage; asphalt plant; landfill; grounds maintenance; and land disturbance/grading/construction. Details on historic and current sites of potential environmental concern are discussed in Section 3.16, *Hazardous Materials and Waste*.

Puntan Tahgong Sub-watershed. Located within the north end of the Military Lease Area, the Puntan Tahgong sub-watershed contains Lake Hagoi. It is the most disturbed of the Tinian sub-watersheds due to intensive sugar cane production prior to and during World War II; and due to nearly-complete vegetation clearing for runways and housing during World War II. The sub-watershed is underlain by porous limestone formations (primarily the Mariana Limestone) with small areas underlain by less permeable volcanic materials and more permeable beach deposits. Groundwater in Puntan Tahgong sub-watershed is vulnerable to surface contaminants due to the high permeability of the limestone substrate and the previous land use. Potential contaminants from World War II land uses and other historical land uses, as listed above, may still be present in Tinian's sub-watersheds (U.S. Department of Agriculture 1994).

Puntan Diaplo-Lamanibot Sub-watershed. The Puntan Diaplo-Lamanibot sub-watershed area includes the majority of the west side of the Military Lease Area, Tinian International Airport, and land south of Tinian International Airport. It supports secondary forest and portions of it are used for farming and ranching. The sub-watershed includes the location of the unlined Tinian municipal solid waste facility, and is therefore at risk for groundwater contamination due to that activity. The sub-watershed is underlain by porous limestone formations (primarily the Mariana Limestone) with small areas underlain by less permeable volcanic materials and more permeable beach deposits.

Masalok Sub-watershed. The Masalok sub-watershed is located largely within the east side of the Military Lease Area and is used mainly for livestock grazing. Residual contaminants from material storage during and following World War II and overgrazing are existing concerns for the Masalok sub-watershed (DoN 2010a). The sub-watershed is underlain by porous limestone formations (primarily the Mariana Limestone).

Makpo Valley Sub-watershed. The Makpo Valley sub-watershed currently supplies all of the municipal potable water supply and a portion of the agricultural water supply for the island. A small portion of the sub-watershed is situated within the south-central side of the Military Lease Area and Tinian International Airport. This sub-watershed is primarily underlain by porous limestone formations (primarily the Mariana Limestone).

Carolinas Sub-watershed. The Carolinas sub-watershed supports limestone forest cliffs along the southeastern shoreline including a small portion of the southeastern end of the Military Lease Area. The watershed is underlain by porous limestone formations (primarily the Mariana Limestone).

3.3.4.1.2 Flood Zones

The Federal Emergency Management Agency classifies areas that are likely to be inundated in a 100-year flood event as Flood Zone A. Areas along coasts subject to inundation by the 100-year flood event and with storm-induced wave hazards are classified as Flood Zone V. The Federal Emergency Management Agency has identified 19 isolated areas that are designated as Flood Zone A. These zones are located in areas including Hagoi, portions of North Field, Tinian International Airport, and Makpo Sub-watershed (Commander, U.S. Naval Forces Marianas 2004). The entire Tinian coastline extending from approximately 400 feet (120 meters) offshore to the shoreline cliff face or to the inland limit of primary flat sand beaches along open coastlines is designated as Flood Zone V and may be subject to storm-induced wave hazards. Tinian flood zones are shown in Figure 3.3-1.

3.3.4.1.3 Surface Water Quality

The CNMI Water Quality Standards establish criteria designed to protect the designated uses for each classification of waters (i.e., coastal waters, fresh waters, and wetlands). Coastal water quality is discussed in Section 3.3.4.3, *Nearshore Waters.* Designated uses of fresh surface waters include: aquatic life, fish consumption, recreation, aesthetic enjoyment, and potable water supply. The CNMI Bureau of Environmental and Coastal Quality maintains a monitoring program for water quality. However, this monitoring program on Tinian is limited to coastal waters. To date, surface water quality data has not been assessed for the three known surface water features on Tinian and the CNMI Bureau of Environmental and Coastal Quality performs no regular monitoring of surface water quality (Bearden et al. 2012).

3.3.4.2 Groundwater Resources

3.3.4.2.1 Groundwater Availability

Rainfall percolates rapidly downward into porous limestone rock and is the primary recharge source of fresh groundwater on Tinian (Doan et al. 1960). The average annual groundwater recharge for Tinian is estimated to be about 30 inches (76 centimeters) per year (Gingerich 2002). Groundwater is plentiful in Tinian’s basal groundwater lens (lenses of fresh groundwater that floats on top of denser saltwater below) (Doan et al. 1960). This freshwater, Ghyben-Herzberg groundwater lens (fresh water that “floats” on top of saltwater forming a profile that has the appearance of a lens) is in both limestone and volcanic rocks, with the most important sources coming from limestone formations (Gingerich 2002). The interface between the freshwater and saltwater is a transition zone at a depth below sea level (Figure 3.3-2 and Figure 3.3-3). The portion of the lens that is used for potable water (i.e., with chloride concentrations less than 250 parts per million) is thickest in the North-Central Highland and Central Plateau and grows increasingly thinner approaching the coastline. See Appendix P, *Utilities Study*, for additional information about the Ghyben-Herzberg lens relationship. Tinian geologic units including Mariana and Tagpochau limestones are shown in Section 3.2, *Geology and Soils*, Figure 3.2-3. The freshwater lens extends from a maximum recorded 3.42 feet (1.04 meters) above MSL to about 140 feet (42 meters) below MSL at its deepest point (Gingerich 2002). Groundwater table elevation contours and the general direction of groundwater flow are shown in Figure 3.3-4.

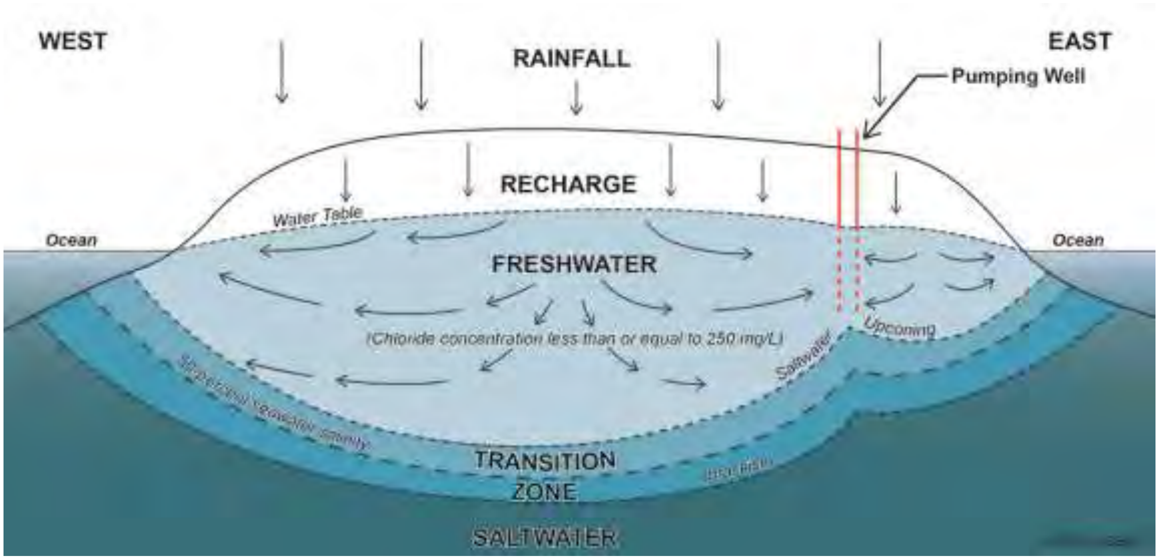

Figure 3.3-2 Graphic Depiction of a Freshwater Lens above a Saltwater Wedge – Standard, Vertical Pumping Well

Note: This figure is intended as a simple representation of interface between the freshwater and saltwater.

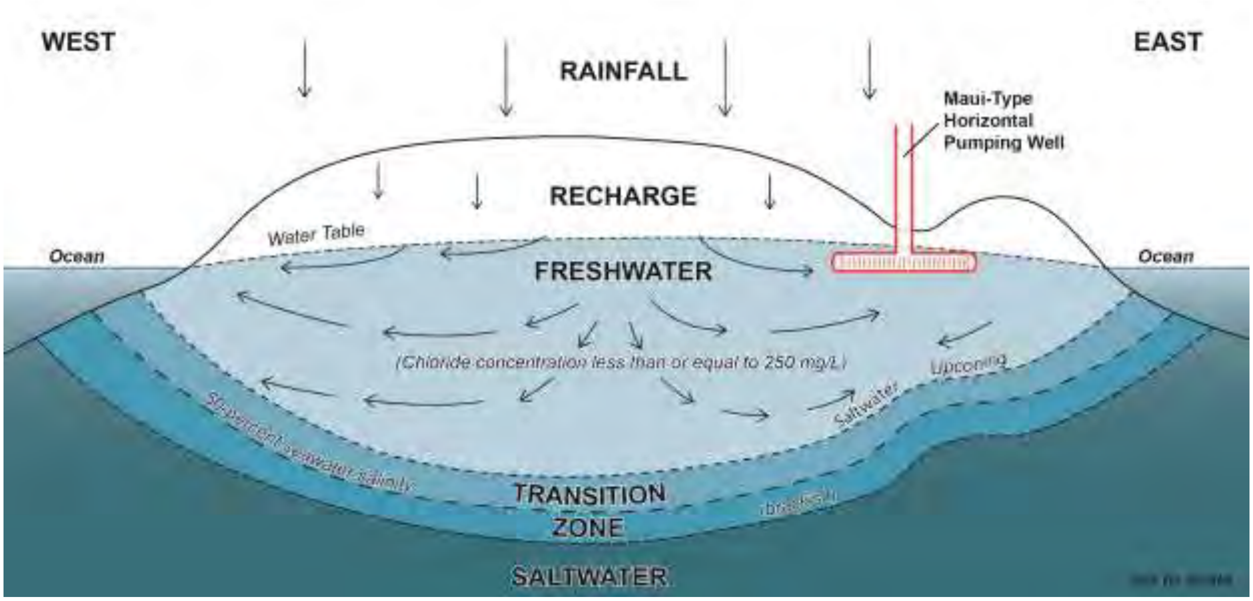

Figure 3.3-3 Graphic Depiction of a Freshwater Lens above Saltwater Wedge – Horizontal, Maui-Type Pumping Well

Note: This figure is intended as a simple representation of interface between the freshwater and saltwater.

Figure 3.3-4
Tinian Groundwater Wells, Elevation, and Flow Direction

The U.S. Environmental Protection Agency has not identified a sole-source aquifer (i.e., the principal source of drinking water) underlying Tinian. Per the CNMI *Wastewater Treatment and Disposal Rules and Regulations*, a Class I Aquifer Recharge Area is defined as an "area contributing surface infiltration to a geologic formation, or part of a formation, that is water bearing and which currently transmits, or is believed capable of transmitting water to supply pumping wells or springs." While not formally designated, based on this definition, the CNMI Bureau of Environmental and Coastal Quality considers all of Tinian a Class I Aquifer Recharge Area per the CNMI Rules and Regulations.

Figure 3.3-4 shows the locations of known groundwater wells. The Commonwealth Utilities Corporation public system extracts water from one horizontal Maui-type well (Maui Well #2) located in the Makpo sub-watershed (a Maui-type well has a horizontal collector trench constructed near the top of the water table). Before Maui Well #2 was put into service, the public system extracted water from Maui Well #1. Maui Well #1 is currently out of service due to old equipment and difficulty obtaining repair parts. See Appendix P, *Utilities Study*, for additional information on Tinian's public water system and discussion of the sustainable yield (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) of Tinian's aquifers. In addition to pumping from Maui Well #2 for the public water system, water is currently pumped from two wells (rehabilitated by a private party) to fill containers for providing water to cattle, labeled M21 and M26 in Figure 3.3-4.

Historically, the Japanese may have dug more than 100 wells during occupation of Tinian; most of which were reportedly abandoned and filled. The U.S. military constructed approximately 44 groundwater wells between 1944 and 1945 on the island for water supply for the U.S. military, including Maui Well #1. All of these wells were abandoned shortly after World War II. It is not known if (or how) these wells were properly closed when abandoned. A total of 33 wells were used for groundwater monitoring between 1993 and 1997 by the U.S. Geological Survey. Of the 33 wells, 16 were rehabilitated and 17 were newly developed for groundwater monitoring on the island. Rehabilitation involved retrieving the original pump and pipe, redrilling if necessary, cleaning out the hole to near the original depth, and installing new surface casings/well head features, if necessary.

The CNMI government owns Maui Well #1 and Maui Well #2. There are other wells located on Tinian that are used for groundwater monitoring, agricultural use, or have been abandoned.

3.3.4.2.2 Groundwater Quality

While it is not currently a problem, Tinian has the potential for high chloride levels in groundwater due to seawater intrusion into the freshwater lens from excessive pumping (Gingerich 2002). The secondary drinking water standard for chloride is set at concentrations less than or equal to 250 parts per million. Chloride concentrations at the municipal water well (i.e., Maui Well #2) range from 160 to 220 parts per million, with an average of 180 parts per million; notably close to the secondary drinking water standard (i.e., non-mandatory drinking water quality standards for aesthetic considerations, such as taste, color, and odor) (U.S. Army Corps of Engineers 2003). Table 3.3-3 summarizes recent data.

Table 3.3-3. Tinian – Tinian Municipal Well Water Quality

Well #	*Year Tested*	*Chloride Concentrations Observed (ppm)*
Maui Well #2	2011	Mean 203, Range 195-210
	2012	Mean 196, Range 175-223
	2013	Mean 190, Range 172-217

Note: ppm= parts per million.

Surface activities (e.g., sewage spills, leachate from septic systems, and polluted stormwater runoff percolation) can also contaminate groundwater aquifers. As discussed in Section 3.14, *Utilities*, the Tinian existing solid waste facility consists of an unlined, open disposal site located about 0.5 mile (0.8 kilometer) north of San Jose on the west side of 8th Avenue (see Figure 3.3-1). The solid waste facility is believed to have been in use since 1944 and may contain World War II-era military waste, as well as municipal solid waste generated on Tinian. No trash pickup service is available on Tinian; therefore, residents take their municipal waste to the Tinian solid waste facility for disposal. The CNMI commercial entities (administrative offices, hotels, restaurants, etc.) including the Tinian Dynasty Hotel and Casino, transport their waste to the municipal solid waste facility as well. The facility does not comply with the Resource Conservation and Recovery Act Subtitle D regulations applicable to municipal solid waste landfills (40 CFR 258) and may be a source of groundwater contamination. It is not known if groundwater in the vicinity of the solid waste facility has been contaminated, but standard contaminants for municipal waste have not been detected in groundwater extracted for municipal water supply at Maui Well #1 and #2.

3.3.4.3 Nearshore Waters

Nearshore waters around Tinian are designated Class AA by the CNMI Bureau of Environmental and Coastal Quality, except for the nearshore waters of Tinian Harbor that are designated Class A. Class AA designation means these waters should remain in their natural pristine state with an absolute minimum of pollution or alteration of water quality from human related sources or actions. Class A designation waters under the jurisdiction of the CNMI Bureau of Environmental and Coastal Quality are protected for their recreational use and aesthetic enjoyment. Other uses of Class A waters are allowed as long as they are compatible with the protection and propagation of fish, shellfish, wildlife, and limited body contact recreation. Sewage outfalls, sewer collection overflows, sedimentation from unpaved roads and development, urban runoff, reverse osmosis brine discharges, and agriculture are the most significant stressors on the CNMI's marine water quality (Bearden et al. 2010). As discussed above, the Tinian municipal solid waste facility does not comply with the Resource Conservation and Recovery Act Subtitle D regulations and could be a source of nearshore water contamination. However, the solid waste facility was not identified as a source of contamination or a significant stressor to marine water quality (Bearden et al. 2012).

Beginning in 2004, the CNMI water quality for coastal waters has been assessed and reported once every 2 years in terms of water body segments based on established, named CNMI sub-watershed units (Bearden et al. 2012). As presented in Appendix I of the CNMI Bureau of Environmental and Coastal Quality's 2012 Water Quality Assessment Report (Bearden et al. 2012), the coastal waters of the Masalok, Makpo Valley, Puntan Diaplo-Lamanibot, and Puntan Tahgong sub-watersheds were listed as impaired by one or more pollutants during and the 2004, 2006, 2008, 2010, and 2012 reporting cycles. Masalok sub-watershed was reported as impaired by orthophosphate for the 2004 reporting cycle (20%

of the net reporting period). Makpo Valley sub-watershed was reported as impaired by enterococci bacteria, dissolved oxygen, biocriteria, and orthophosphate for the 2004, 2006, 2010 and 2012 reporting cycles (80% of the net reporting period). Puntan Diaplo-Lamanibot sub-watershed was reported as impaired by enterococci bacteria and orthophosphate for the 2004 and 2012 reporting cycles (40% of the net reporting period). Puntan Tahgong sub-watershed was reported as impaired by biocriteria and orthophosphate for the 2004 and 2006 reporting cycles (40% of the net reporting period). Only Makpo Valley and Puntan Diaplo-Lamanibot were listed as impaired during the 2012 assessment and reporting cycle. Table 3.3-4 provides a summary of the impaired Tinian coastal waters.

Table 3.3-4 Tinian Impaired Coastal Waters

Sub-watershed	*Pollutant(s)*	*Source*	*Year Listed*
Masalok	orthophosphate	unknown	2004
Makpo	enterococci, dissolved oxygen, biocriteria, orthophosphate	unknown, on-site treatment systems, urban runoff	2012 2010 2006 2004
Puntan Diaplo-Lamanibot	enterococci, orthophosphate	unknown	2012 2004
Puntan Tahgong	biocriteria, orthophosphate	unknown	2006 2004

Source: Bearden et al. 2012; APPENDIX II: Detailed 305b Listing of the CNMI Waters; Table II-5 Category 5: Coastal Waters Impaired by Pollutants (Total Maximum Daily Load Required).

The Makpo sub-watershed includes both Tinian's commercial harbor and its population center (San Jose). The absence of wastewater collection and treatment systems, stormwater quality treatment and erosion controls are existing concerns for the Makpo Valley sub-watershed. Makpo Valley sub-watershed coastal waters have been listed as impaired based on bacterial, nutrient, dissolved oxygen, and biological criteria. The sources of pollution include on-site treatment systems and urban runoff, as well as unidentified sources (B. Bearden, Consolidated Utilities Corporation, personal communication, December 4, 2012).

As part of the Mariana Archipelago Reef Assessment and Monitoring Program the National Oceanic and Atmospheric Administration, National Marine Fisheries Service conducted shallow-water conductivity, temperature, and depth casts in nearshore waters surrounding Tinian in August 2003, September 2005, and May 2007. Across all sample years and locations, at a depth of 33 feet (10 meters) water temperatures ranged from 82.71 to 85.86 degrees Fahrenheit (28.17 to 29.92 degrees Celsius) and salinity ranged from 34.22 to 34.60 practical salinity units. In 2003 cooler temperatures and higher salinity were recorded around the northeast end of Tinian relative to other areas of the island. In 2005 and 2007 spatial comparison suggest an east to west gradient in water properties, with warmer, more saline, and less turbid waters along the western half of the island compared to the eastern half (Brainard 2012).

In 2005 and 2007 water samples were collected to measure chlorophyll-*a*, total nitrogen, nitrate, nitrite, phosphate, and silicate levels. Measures of chlorophyll-*a*, nitrogen, nitrate, and nitrite concentration were lower in 2007 than in 2005. Phosphate and silicate concentration were higher in 2007 than in 2005. In 2005 all measured parameters showed higher concentrations in the southwest region of the island and total nitrogen was 4 times higher in the southwest as compared to other regions of the island.

Again in 2007 the highest concentration of nutrients was in the north regions of the island. However, in 2007 the highest chlorophyll-*a* values were in the southwest region (Brainard 2012).

3.3.5 Pagan

3.3.5.1 Surface Water Resources

3.3.5.1.1 Surface Water Features

Average annual rainfall on Pagan is 70 to 80 inches (178 to 203 centimeters). Surface water features on Pagan include two lakes: Laguna Sanhiyon and Laguna Sanhalom, shown in Figure 3.3-5, and springs found across the island. There are no permanent rivers or streams on the island. Though surface water drainage has not been studied, it is thought that most of the infiltrating rainwater percolates rapidly to a large basal fresh groundwater body; however, no testing has been conducted to confirm this (CNMI Office of Transition Studies and Planning 1978).

Laguna Sanhiyon (commonly known as Lower Lake) is an approximately 40-acre (16-hectare) brackish water lake on the western shore. The lake has a maximum depth of approximately 65 feet (20 meters) (CNMI Office of Transition Studies and Planning 1978). A sand bar composed of marine tuffs and basaltic sand separates the lake from the ocean (Photo 3.3-1). During storms, waves occasionally over top the sand bar (CNMI Office of Transition Studies and Planning 1978). A small tidally mediated freshwater wetland area is located on the north end of Laguna Sanhiyon (Polhemus 2010).

Photo 3.3-1. Laguna Sanhiyon and Sand Bar Separating the Lake from the Ocean

Laguna Sanhalom (commonly known as Upper Lake or Inner Lake) is a 43-acre (17-hectare) brackish lake at the foot of Mount Pagan. The lake has a maximum depth of about 75 feet (23 meters), reaching a depth of 65 to 70 feet (20 to 21 meters) below sea level (CNMI Office of Transition Studies and Planning 1978).

Watershed areas on Pagan have not been designated. Due to the generally high permeability and infiltration rates of surficial volcanic materials on Pagan, the contribution of stormwater runoff to recharge Pagan's major surface water bodies (Laguna Sanhalom and Laguna Sanhiyon) is minimal as compared to the contribution from groundwater (Doan et al. 1960). During their 3-month long field investigation of the island, Doan et al. (1960) did not observe any stream formations, even during moderately heavy rain events. However, Doan et al. 1960 did mention that some surface runoff on steep slopes and cliffs was observed during and following the rain events, which suggests that stormwater runoff does enter the surface waters in some areas and during some storm events. This runoff is expected to form channelized flow from heavy rainfall. In addition sub-surface flow from higher elevations within and around the volcano is also believed to influence these surface waters.

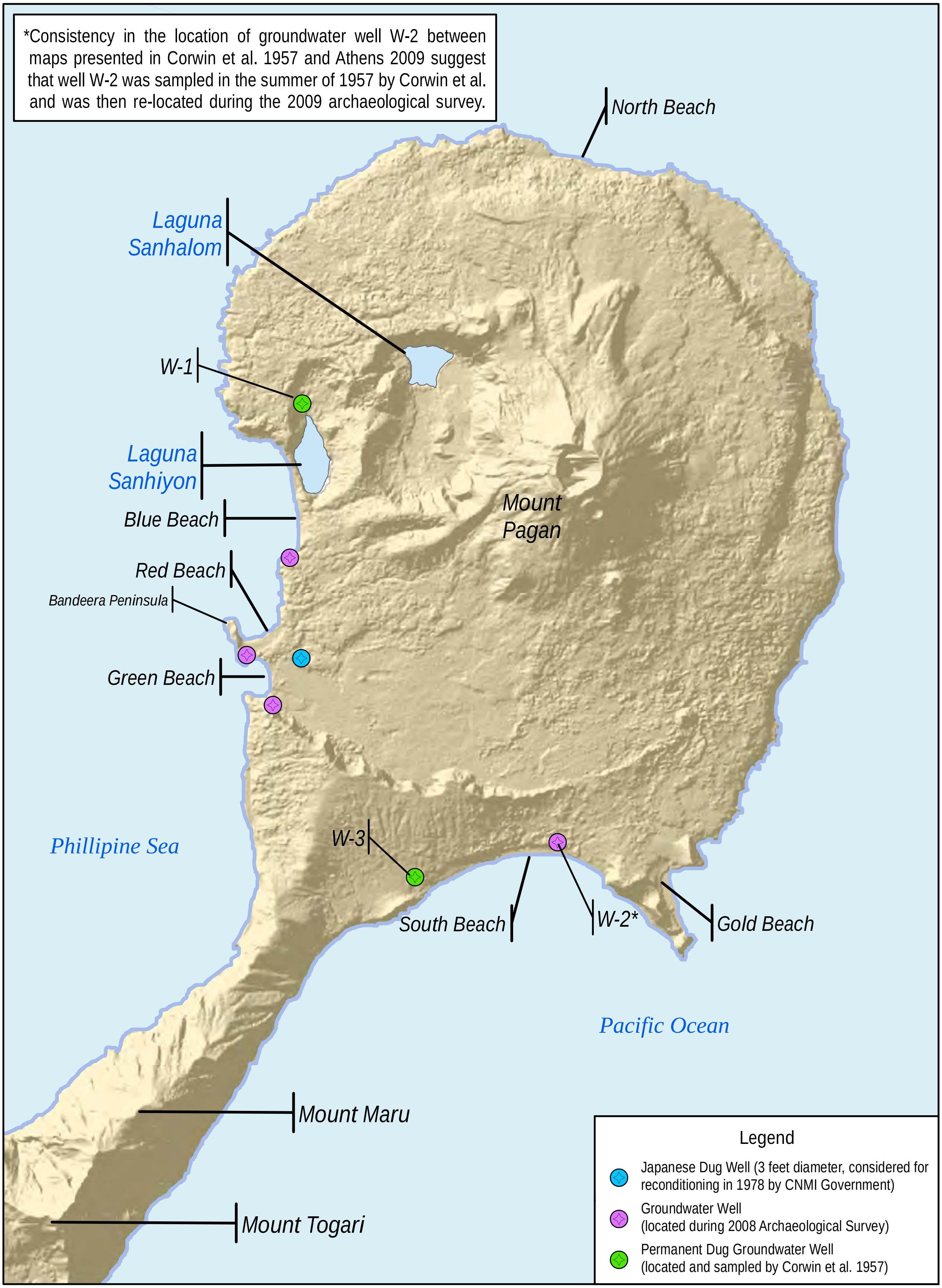

Figure 3.3-5
Pagan Surface Waters and Groundwater Well Locations

Sources: Corwin et al. 1957; CNMI 1978; Athens 2009

3.3.5.1.2 Flood Zones

No flood zone data are available for Pagan.

3.3.5.1.3 Surface Water Quality

As described in Section 3.2, *Geology and Soils*, the island's forests and grasslands have been "severely overgrazed" due to the abundance of feral cattle, goats, and pigs that have done considerable damage to island vegetation (Cruz et al. 2000; Kessler 2011). This overgrazing has resulted in large open areas susceptible to soil erosion.

Water quality of both lakes has never been fully assessed and is not actively monitored by the Bureau of Environmental and Coastal Quality due to the remoteness of the island (Bearden et al. 2012). However, water quality samples from the lakes were collected by the U.S. Geological Survey in 1983 and 2001 (U.S. Geological Survey 2014). The data are presented in Table 3.3-5.

Table 3.3-5. Pagan Surface Water Quality Data Summary

Surface Water Body	*Sample Date*	*Dissolved Solids (mg/L)*	*Nitrate (mg/L)*	*Ammonia (mg/L as NH_4)*	*Phosphorus (mg/L as P)*	*Sodium (mg/L)*	*Chloride (mg/L)*
Laguna Sanhiyon	3/12/1983	12400	-	-	-	3500	7000
Laguna Sanhiyon	5/25/2001	13200	0.221	0.032	0.003	3890	7260
Laguna Sanhalom	3/12/1983	6380	-	-	-	1800	3500
Laguna Sanhalom	5/24/2001	4230	0.221	0.052	0.004	1040	1910

Notes: mg/L = milligrams per liter; P = phosphorous; NH_4 = Ammonia; - = not analyzed.

Laguna Sanhiyon has a salinity of about half that of the ocean. Although biological contamination (elevated fecal coliform) of surface waters caused by migration of bacteria from animal waste through the hydrologic system of the island has been documented (CNMI Office of Transition Studies and Planning 1978), surface water samples collected from the lakes and springs above the upper lake by the U.S. Geological Survey in 1983 (U.S. Geological Survey 2014) were below the U.S. Environmental Protection Agency's recommended fecal coliform criterion (U.S. Environmental Protection Agency 1976).

Surface water samples collected from Laguna Sanhalom by the U.S. Geological Survey in 1983 and 2001 (U.S. Geological Survey 2014) indicate that the water is brackish with a salinity about 4 to 6 times the potable drinking water standard (CNMI Office of Transition Studies and Planning 1978). The mixing of saltwater may occur through vents, faults, and the bedrock substrate. Nitrogen-based compounds in samples from the U.S. Geological Survey data were below detectable levels, as were phosphates. Sulfate and silica concentrations were elevated in the 2001 samples for the lakes. Elevated concentrations of rare dissolved metals and metalloids in the 2001 sample from the lower lake are likely the result of the weathering young volcanic deposits on the island (U.S. Geological Survey 2014). Water from both lakes is not considered a viable potable source. Table 3.3-6 summarizes the 1983 and 2001 surface water data.

Table 3.3-6. Pagan Surface Water Quality Sample Report

Site Name	***Laguna Sanhiyon***		***Laguna Sanhalom***	
Sample Date	**3/12/1983**	**5/25/2001**	**3/12/1983**	**5/24/2001**
Sample Time	**4:10 PM**	**11:30 AM**	**3:45 PM**	**12:55 PM**
Total nitrogen, water, filtered, mg/L	-	< 0.21	-	< 0.20
Organic nitrogen, water, filtered, mg/L	-	E 0.13	-	< 0.15
Ammonia, water, filtered, mg/L as nitrogen	-	E 0.03	-	< 0.04
Nitrite, water, filtered, mg/L as nitrogen	-	< 0.006	-	< 0.006
Nitrate, water, filtered, mg/L as nitrogen	-	< 0.050	-	< 0.050
Ammonia plus organic nitrogen, water, filtered, mg/L as nitrogen	-	0.16	-	0.15
Nitrate plus nitrite, water, filtered, mg/L as nitrogen	< 0.100	< 0.05	< 0.100	< 0.05
Orthophosphate, water, filtered, mg/L		< 0.061	-	< 0.061
Phosphorus, water, filtered, mg/L as phosphorus	-	E 0.003	-	E 0.004
Orthophosphate, water, filtered, mg/L as phosphorus	-	< 0.02	-	< 0.02
Chloride, water, filtered, mg/L	7000	7260	3500	1910
Sulfate, water, filtered, mg/L	940	1000	390	693
Silica, water, filtered, mg/L as silicon dioxide	4.1	8	80	53.4
Barium, water, filtered, ug/L	-	20.2	-	4.68
Barium, water, unfiltered, recoverable, ug/L	100	-	< 100	-
Boron, water, filtered, ug/L	-	2290	-	1540
Chromium, water, unfiltered, recoverable, ug/L	20	-	20	-
Iron, suspended sediment, recoverable, ug/L	90	-	0	-
Iron, water, unfiltered, recoverable, ug/L	130	-	40	-
Manganese, water, filtered, ug/L	20	19.2	20	14.3
Strontium, water, filtered, ug/L	-	2600	-	558
Vanadium, water, filtered, ug/L	-	131	-	8.8
Zinc, water, filtered, ug/L	-	9.6	-	5.4
Zinc, water, unfiltered, recoverable, ug/L	20	-	20	-
Antimony, water, filtered, ug/L	-	0.53	-	E 0.140
Aluminum, water, unfiltered, recoverable, ug/L	200	-	M	-
Aluminum, water, filtered, ug/L	-	9.1	-	3.4
Lithium, water, filtered, ug/L	-	31.5	-	31.1
Lithium, water, unfiltered, recoverable, ug/L	50	-	110	-
Selenium, water, filtered, ug/L	-	13.8	-	3.1
Selenium, water, unfiltered, ug/L	2	-	2	-
Uranium (natural), water, filtered, ug/L	-	0.35	-	0.08
Total coliform, water, colonies per 100 milliliters	150	-	15	-

Notes: M = presence verified but not quantified; E = estimated; - = not analyzed; mg/L = milligrams per liter; ug/L = micrograms per liter.

3.3.5.2 Groundwater Resources

Knowledge of the groundwater resources of Pagan is limited to a 1957 study of the geology and hydrogeology of the island (Corwin et al. 1957), a 1978 planning study by the CNMI Office of Transition Studies and Planning; and limited water sampling conducted by the U.S. Geological Survey in 1983 and 2001 (U.S. Geological Survey 2014). The hydrogeology (i.e., groundwater geology) of Pagan likely does not include any large bodies of fresh groundwater near sea level (i.e., basal groundwater lenses). This is evidenced by the very limited amount of groundwater seeping from soil or rock (i.e., perennial seeps, springs). One minor seep was located on a cliff face along the west coast approximately 0.5 mile (0.8 kilometer) south of Bandeera Peninsula (Corwin et al. 1957). A limited basal confined aquifer may exist beneath Mount Pagan caldera because of the density difference between freshwater (from rainfall) and saltwater (from the adjacent ocean). This lens is likely to have developed in the Mount Pagan caldera, because the less-dense freshwater, if undisturbed by other forces, will "float" on top of the more-dense saltwater. However, the 1981 eruption and subsequent temperature convection currents have likely mixed saltwater with portions of the freshwater lens to an extent that development of this lens as a freshwater resource is questionable.

No large high-level groundwater bodies have been identified although small bodies of perched water (isolated small bodies of water found above the regional water table) may occur at depth on the South Volcano, Mount Pagan, and within the several calderas associated with the ancestral volcanoes that form the island (Corwin et al. 1957; CNMI Office of Transition Studies and Planning 1978).

Other potential sources of potable water are within the volcanic rock of the plains surrounding Mount Pagan, because of the high rates of infiltration and rapid circulation through the rocks. Figure 3.3-5 shows the location of the known groundwater wells on Pagan: a former Japanese well located north of the Japanese runway, four wells identified during a 2008 archaeological survey (CNMI Office of Transition Studies and Planning 1978; Athens 2009), and two additional wells located and sampled by Corwin et al. (1957). The wells are subject to saltwater intrusion and their current status is unknown (DoN 2013b).

Six relatively broadly-distributed groundwater samples were collected from accessible wells on Pagan by the U.S. Geological Survey in 1983 and two were collected in 2001 (U.S. Geological Survey 2014). These data suggest groundwater for the Shomushon area (area just east of Green and Red Beach, north of the Pagan airfield) to be below the U.S. Environmental Protection Agency's regional screening levels for potable water for nutrients and dissolved metals (U.S. Environmental Protection Agency 2014). Three of the wells Corwin et al. (1957) tested (Wells 1, 2, and 3) had total dissolved solids below the secondary drinking water maximum contaminant level. Two of these wells (Wells 2 and 3) had nitrate concentrations below the primary drinking water (i.e., mandatory drinking water quality standards under the Safe Drinking Water Act) maximum contaminant level. Therefore these two wells might be considered potable; however both of these have water high in silica.

3.3.5.3 Nearshore Waters

Pagan has approximately 39 miles (63 kilometers) of undeveloped coastline that features diverse intertidal systems, with tide pools formed in basalt and limestone headlands exposed along the coast (Polhemus 2010). During coral surveys, visibility and apparent water quality was degraded in water along Green Beach (see Figure 3.3-5) relative to the other leeward beaches. Kitchen scraps found in shallow sediments of the bay at Green Beach during coral surveys suggests that use of the area by visitors to Pagan could also potentially influence nearshore water quality (DoN 2014).

Two sea water samples collected by the U.S. Geological Survey in 1983 and 2001 at the shoreline near the center of Red Beach were analyzed for standard water quality parameters (pH, conductance, temperature, turbidity) as well as nutrients and dissolved metals. Sodium and chloride levels were standard for the sea water samples, pH was basic (7.5-8.2) as would be expected for nearshore sea water, and was typical for bicarbonate concentrations. Dissolved nitrogen as nitrate and phosphorous concentrations were also standard for nearshore seawater (U.S. Geological Survey 2014).

As part of the Mariana Archipelago Reef Assessment and Monitoring Program the National Oceanic and Atmospheric Administration, National Marine Fisheries Service conducted shallow-water conductivity, temperature, and depth casts in nearshore waters surrounding Pagan in August and September 2003, September 2005, and June 2007. Across all sample years and locations, at a depth of 33 feet (10 meters) water temperatures ranged from 83.79 to 86.18 degrees Fahrenheit (28.77 to 30.10 degrees Celsius) and salinity ranged from 34.29 to 34.61 practical salinity units. Comparisons between surveys suggest a dynamic physical environment with few spatial similarities in water properties across sample years. In 2005 and 2007, temperature and salinity values were generally lower along the east side of the island as compared to the west (Brainard 2012).

In 2005 and 2007 water samples were collected to measure chlorophyll-a, total nitrogen, nitrate, nitrite, phosphate, and silicate levels. Water quality data suggests spatial and temporal variability in nutrient concentrations. Spatial pattern of measures nutrients varied between survey years, with the exception of phosphate, which was relatively consistent between survey years. Measured silicate values were higher in 2007 than in 2005. These differences may result from seasonal effects, with the 2005 survey occurring during a period of high precipitation and 2007 survey occurring in a period of low precipitation, or may be due to other processes unknown at this time (Brainard 2012).