

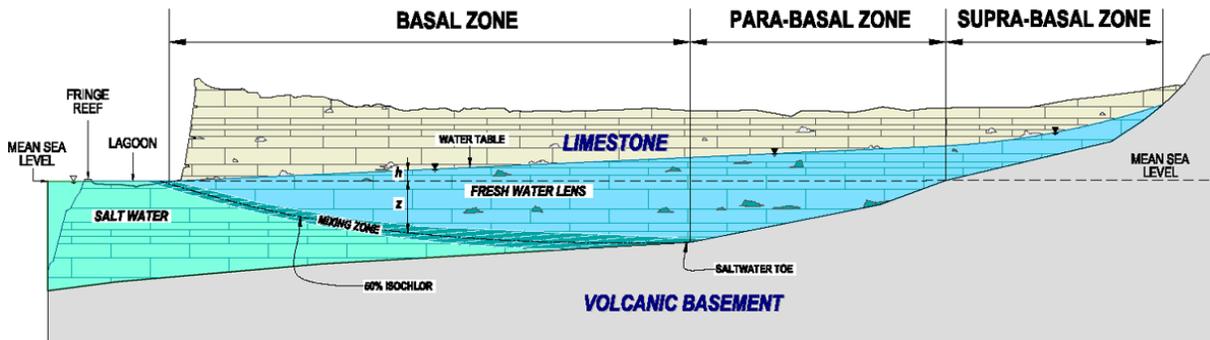
Groundwater Exploration on Guam

Groundwater Zones in the Freshwater Lens

The single most important tool for successful exploration and sustainable development of the Northern Guam Lens Aquifer is an accurate and precise map of the volcanic basement rock that forms the floor beneath the limestone bedrock aquifer. Rises and ridges in the relatively impermeable volcanic basement partition the aquifer into semi-contiguous subterranean groundwater *basins*. Where basement rises and ridges stand above sea level, rainwater percolating downward through the limestone eventually encounters the interface between the very permeable, and soluble, limestone above and the impermeable, insoluble, volcanic basement below. Water thus shunted down the basement slopes to sea level is termed *supra-basal* water. *Supra-basal* water is the freshest of the water in the aquifer. Because it is not in contact with seawater, it is invulnerable to contamination by seawater. *Supra-basal* water does not form a continuous sheet of water along the limestone-volcanic interface, however, but flows mainly through dissolution-widened bedrock fractures and cave networks that form through the dissolution of the overlying limestone along the interface. *Suprabasal* water moving down slope along such flow routes is



Sites for new water wells should be selected where our best knowledge of the basement geology indicates favorable odds for high quality water and high production.



The topography of the volcanic basement beneath limestone aquifer defines three groundwater zones (not to scale): 1) the basal zone, where the fresh water lens is underlain by sea water, 2) the para-basal zone, where the fresh water is underlain by the volcanic rock, and 3) the supra-basal zone, where the fresh water moving down-slope toward the para-basal zone is lies above sea level. (Graphic from AECOM, 2011)

thought to converge along the axes of the basement valleys, eventually recharging the rim of fresh water concentrated along the perimeter of the basement rises and ridges where they are flanked by the water table, just above sea level. Water transiting this zone on its way seaward is termed *para-basal* water. Like *supra-basal* water, *para-basal* water is underlain by basement rock rather than by sea water. Unlike *supra-basal* water, which lies entirely above sea level, however, most of the *para-basal* water lies below sea level, displacing the adjacent seawater down slope until it enters the *basal* zone, the portion of the fresh water lens that floats on the underlying sea water. As fresh water flows through the basal zone toward the coast, it mixes at its base with the underlying seawater and becomes progressively thinner until it discharges in brackish coastal springs and seeps.

Basal water underlies the entire plateau between the coast and the sea-level flanks of the basement rises and ridges. Locating basal water is therefore no challenge, but the quality is variable, and this portion of the lens is susceptible to salt-water contamination. Guidelines from the 1982 Northern Guam Lens Study (CDM, 1982) called for production wells in basal water to be set at shallow depths, i.e., <25-35 ft below sea level, and pumped at relatively modest rates of 200 gallons per minute (gpm) or lower to mitigate the risk of contamination by the underlying salt water.



Outcrop of weathered volcanic rock on the summit of Mt Alutom, which gives its name to the rock unit that comprises the basement beneath the limestone bedrock aquifer of the northern plateau.

Because it is fresher, thicker and much less vulnerable to salt-water contamination than the basal water downstream, the parabasal zone has historically been the zone of choice for exploration and development of groundwater on Guam. Wells in the parabasal zone can be set deeper than in the basal zone (historically, up to 50 ft), and can yield very high quality water (i.e., water with chloride concentrations <30 mg/l) at pumping rates of 500 gpm or more. In the absence of an accurate, high-resolution basement



The Northern Guam Plateau, in the background, as seen looking northwest from the summit of Nimitz Hill. The surface of the plateau stands at some 200 to 600 ft elevation, and is the catchment for the aquifer comprised of the limestone bedrock.

map, however, it is difficult to locate the parabasal zone.

Exploratory wells targeting parabasal water thus run the risk of missing the parabasal zone. Wells drilled to depths appropriate for parabasal water, but which are subsequently discovered to be in basal water, may thus be set too deep to achieve or maintain high water quality. Boreholes inadvertently drilled on the opposite side of the parabasal zone most often produce “dry holes,” intercepting basement rock above sea level, but missing the discrete pathways and localized subterranean impoundments of supra-basal water.

The few successful wells installed in the suprabasal zone today include some of the aquifer’s highest producing (>500 gpm) and highest quality (<30 g/ml chloride) wells. Without more precise knowledge of aquifer “plumbing” and finer resolution of the basement

topography within the supra-basal zone, however, exploration for supra-basal water carries high risk. Continuing improvements in our understanding of basement geology and flow routes of water along the aquifer-basement interface, however, will increase the prospects of successful development of areas where exploration is currently risky but where water quality and yield can also be exceptionally high when exploration is successful.

Besides improving prospects for successful exploration across the entire aquifer, investments in improving the accuracy and resolution of the basement map will also enable more accurate diagnoses and more effective remediation of salt water intrusion and other forms of contamination. Improvements in the reliability of the basement map are also essential to improving the reliability of numerical models of groundwater flow or contaminant transport.