Guam Groundwater-Availability Study

Technical Working Group Meeting
September 13, 2012

This information is preliminary and is subject to revision. It is being provided to meet the need for timely 'best science' information. The assessment is provided on the condition that neither the U.S. Geological Survey nor the United States Government may be held liable for any damages resulting from the authorized or unauthorized use of the assessment.
Outline of Meeting

• Project goals, products, timeline
  • Review of water budget and aquifer properties
  • Numerical modeling – preliminary findings
    – Calibration to baseline condition
    – Drought condition (driest 5-year period)
    – Pumping scenarios
      • Scenario 1 – additional 11.5 Mgal/d
      • Scenario 2 – additional 6.9 Mgal/d
  • Expanded monitoring needs
  • Next steps
Study Objectives

• Obtain a better understanding of the regional groundwater flow system in northern Guam
• Update estimates of groundwater recharge for the entire island
• Estimate effects of selected withdrawal scenarios within northern Guam, using a numerical groundwater flow and transport model, on water levels and the transition zone between freshwater and saltwater
Study Approach

1. Compile, review, and analyze existing data
2. Collect additional groundwater data in northern Guam
3. Develop daily water budget to estimate groundwater recharge rates
4. Develop numerical groundwater flow and transport model for northern Guam
Timelines

Planned schedule for the various activities and products of the groundwater-availability study of northern Guam.
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**USGS**

*science for a changing world*
1. Recharge estimated for the northern aquifer subbasins is 32% to 49% greater than recharge estimated by the Northern Guam Lens Study (1982)

2. Recharge is about 40%-60% of water input in limestone areas and less than 30% in volcanic areas

3. Potential land-cover changes incurred during the proposed military buildup likely will not reduce overall recharge to Guam

4. Compared to long-term average, recharge is 34% lower during drought conditions
Aquifer Properties of Northern Guam

- Use tidal fluctuations in monitoring wells to determine aquifer properties
- Compared results using numerical model
- Led to a refined conceptual model of the aquifer
- Nearing final publication in Hydrogeology Journal
Tidal Efficiency and Lag
Aquifer properties from numerical model
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- Next steps
Model Calibration-Baseline Condition

• Hydrologic conditions
  – 2010 pumping rates

• Calibration targets
  – Average 2010 water levels and tidal fluctuations
  – December 2009 salinity profiles
Observed and Modeled Water Levels

- Observed water level, in feet:
- Modeled water level, in feet:

Simulated water level, in feet:

- Observed average water level, in feet
Observed and Modeled Salinity Profiles
EXPLANATION

0.25
less than 1%

0.5
from 1 to 2.5%

1.0 Mgal/d
more than 2.5%

Well location indicating withdrawal rate and modeled salinity—area proportional to rate in million gallons per day (Mgal/d) and color indicating percentage seawater salinity (%), pink is cautionary and red is threatened.

SUBBASIN
BOUNDARY
AND NAME

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PUMPAGE, in Mgal/d

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Simulated change (relative to pre-development) in (A) water level, (B) 2-percent seawater salinity depth, and (C) 50-percent seawater salinity depth with withdrawal at 2010 rates with long-term average recharge, Guam.
Drought Condition

• Hydrologic conditions
  – Driest 5-yr period (34% reduction in recharge)
    • 1969-73 rainfall
    • 2004 land cover
  – 2010 pumping rates

• Results after 5 years of pumping at steady rates
5-YR DROUGHT (1969-73)
32% recharge reduction

EXPLANATION

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<td>from 1 to 2.5%</td>
<td>more than 2.5%</td>
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Well location indicating withdrawal rate and modeled salinity — area proportional to rate in million gallons per day (Mgal/d) and color indicating percentage seawater salinity (%), pink is cautionary and red is threatened.

SUBBASIN BOUNDARY AND NAME

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PUMPAGE, in Mgal/d

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Threatened

Cautionary

| | | |
| Threatened | 18.9 | 16.5 | 0.9 | 1.5 |
| Cautionary | 10.4 | 10.0 | 0.2 | 0.2 |
Simulated change (relative to baseline) in (A) water level, (B) 2-percent seawater salinity depth, and (C) 50-percent seawater salinity depth with withdrawal at 2010 rates after 5 years of drought recharge (1969-73), Guam.
Drought Condition

SALINITY, IN PERCENT SEAWATER

YEARS

Drought | Average

SALINITY, IN PERCENT SEAWATER

YEARS

Drought Average

A-26

M-04

Y-16

NCS-09

NCS-12

Years
Outline of Meeting

- Project goals, products, timeline
- Review of water budget and aquifer properties
- Numerical modeling – preliminary findings
  - Calibration to baseline condition
  - Drought condition (driest 5-year period)
  - **Pumping scenarios**
    - Scenario 1—additional 11.5 Mgal/d
    - Scenario 2—additional 6.9 Mgal/d
- Expanded monitoring needs
- Next steps
Scenario 1

- Hydrologic conditions
  - Average long-term recharge
  - 2011 GWA and other pumping rates
  - DoD additional 11.5 Mgal/d
    - 18 Proposed AECOM wells
Final Guam Water Well Testing Study to Support U.S. Marine Corps Relocation to Guam

April 2011

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

Contract Number N62742-06-D-1870, TO 0036
SCENARIO 1 PUMPAGE
Additional 11.5 Mgal/d by DoD

EXPLANATION

0.25 0.5 1.0 Mgal/d
less than 1% from 1 to 2.5% more than 2.5%

Well location indicating withdrawal rate and modeled salinity—area proportional to rate in million gallons per day (Mgal/d) and color indicating percentage seawater salinity (%), pink is cautionary and red is threatened.

Yigo-Tumon
SUBBASIN BOUNDARY AND NAME

Hagatña

PUMPAGE, in Mgal/d

<table>
<thead>
<tr>
<th>Subbasin</th>
<th>TOTAL</th>
<th>GWA</th>
<th>DOD</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agafo Gumas</td>
<td>8.5</td>
<td>0.7</td>
<td>6.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Andersen</td>
<td>6.6</td>
<td>0.8</td>
<td>5.8</td>
<td>0</td>
</tr>
<tr>
<td>Finegayn</td>
<td>6.3</td>
<td>5.4</td>
<td>0.9</td>
<td>0.4</td>
</tr>
<tr>
<td>Hagatña</td>
<td>9.4</td>
<td>8.6</td>
<td>0.4</td>
<td>0.7</td>
</tr>
<tr>
<td>Mangilao</td>
<td>2.6</td>
<td>2.2</td>
<td>0</td>
<td>0.4</td>
</tr>
<tr>
<td>Yigo</td>
<td>18.3</td>
<td>17.6</td>
<td>0</td>
<td>0.7</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>51.7</strong></td>
<td><strong>35.3</strong></td>
<td><strong>14.0</strong></td>
<td><strong>2.4</strong></td>
</tr>
</tbody>
</table>

Threatened Cautionary

| Threatened | 1.2 | 0.5 | 0.0 | 0.7 |
| Cautionary | 11.1 | 5.8 | 5.2 | 0.1 |
2010 AVERAGE PUMPAGE

EXPLANATION

0.25 0.5 1.0 Mgal/d
less than 1% from 1 to 2.5% more than 2.5%

Well location indicating withdrawal rate and modeled salinity—area proportional to rate in million gallons per day (Mgal/d) and color indicating percentage seawater salinity (%). Pink is cautionary and red is threatened.

SUBBASIN BOUNDARY AND NAME

Yigo-Tumon

PUMPAGE, in Mgal/d

<table>
<thead>
<tr>
<th>Subbasin</th>
<th>TOTAL</th>
<th>GWA</th>
<th>DOD</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agafo Gumas</td>
<td>2.0</td>
<td>0.8</td>
<td>0.4</td>
<td>0.8</td>
</tr>
<tr>
<td>Andersen</td>
<td>0.8</td>
<td>0.8</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Finegayan</td>
<td>6.2</td>
<td>5.2</td>
<td>1.0</td>
<td>0</td>
</tr>
<tr>
<td>Hagåtña</td>
<td>9.5</td>
<td>8.3</td>
<td>0.3</td>
<td>0.9</td>
</tr>
<tr>
<td>Mangilao</td>
<td>1.9</td>
<td>1.9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Yigo</td>
<td>17.8</td>
<td>17.7</td>
<td>0</td>
<td>0.1</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>38.2</strong></td>
<td><strong>34.7</strong></td>
<td><strong>1.7</strong></td>
<td><strong>1.8</strong></td>
</tr>
</tbody>
</table>

| Threatened    | 1.5   | 0.8 | 0   | 0.7   |
| Cautionary    | 3.7   | 3.4 | 0.2 | 0.1   |

US science for a changing world
Simulated change (relative to baseline) in (A) water level, (B) 2-percent seawater salinity depth, and (C) 50-percent seawater salinity depth with withdrawal at Scenario 1 rates and long-term average recharge, Guam.
SCENARIO 1 PUMPAGE
5-YR DROUGHT (1969-73)

EXPLANATION

Well location indicating withdrawal rate and modeled salinity—area proportional to rate in million gallons per day (Mgal/d) and color indicating percentage seawater salinity (%), pink is cautionary and red is threatened.

SUBBASIN BOUNDARY AND NAME

PUMPAGE, in Mgal/d

<table>
<thead>
<tr>
<th>Location</th>
<th>TOTAL</th>
<th>GWA</th>
<th>DOD</th>
<th>OTHER</th>
</tr>
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<tbody>
<tr>
<td>Agafo Gumas</td>
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<td>6.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Andersen</td>
<td>6.6</td>
<td>0.8</td>
<td>5.8</td>
<td>0</td>
</tr>
<tr>
<td>Finegayan</td>
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<td>5.4</td>
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<td>8.6</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Mangilao</td>
<td>2.6</td>
<td>2.2</td>
<td>0</td>
<td>0.4</td>
</tr>
<tr>
<td>Yigo</td>
<td>18.3</td>
<td>17.6</td>
<td>0</td>
<td>0.7</td>
</tr>
<tr>
<td>TOTAL</td>
<td>51.7</td>
<td>35.3</td>
<td>14.0</td>
<td>2.4</td>
</tr>
</tbody>
</table>

Threatened 25.9  15.9  7.8  2.2
Cautionary 11.1  8.6  0.0  0.2
Scenario 2

• Hydrologic conditions
  – Average long-term recharge
  – 2011 GWA and other pumping rates
  – DoD additional 6.9 Mgal/d
    • Tumon tunnel – 1.5 Mgal/d
    • AF01-05 – 1.4 Mgal/d
    • 18 Proposed AECOM wells – 4 Mgal/d
**SCENARIO 2 PUMPAGE**

Additional 6.9 Mgal/d by DoD

**EXPLANATION**

- **0.25 Mgal/d**: less than 1%
- **0.5 Mgal/d**: from 1 to 2.5%
- **1.0 Mgal/d**: more than 2.5%

Well location indicating withdrawal rate and modeled salinity—area proportional to rate in million gallons per day (Mgal/d) and color indicating percentage seawater salinity (%). Pink is cautionary and red is threatened.

---

**PUMPAGE, in Mgal/d**

<table>
<thead>
<tr>
<th>Location</th>
<th>TOTAL</th>
<th>GWA</th>
<th>DOD</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agafo Gumas</td>
<td>5.4</td>
<td>0.7</td>
<td>3.8</td>
<td>0.9</td>
</tr>
<tr>
<td>Andersen</td>
<td>2.8</td>
<td>0.8</td>
<td>2.0</td>
<td>0</td>
</tr>
<tr>
<td>Finegayan</td>
<td>6.3</td>
<td>5.4</td>
<td>0.9</td>
<td>0</td>
</tr>
<tr>
<td>Hagåtña</td>
<td>9.4</td>
<td>8.6</td>
<td>0.4</td>
<td>0.4</td>
</tr>
<tr>
<td>Mangilao</td>
<td>2.6</td>
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<td>0.4</td>
</tr>
<tr>
<td>Yigo</td>
<td>19.8</td>
<td>17.6</td>
<td>1.5</td>
<td>0.7</td>
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<tr>
<td><strong>TOTAL</strong></td>
<td>46.3</td>
<td>35.3</td>
<td>8.6</td>
<td>2.4</td>
</tr>
</tbody>
</table>

**Threatened** 2.7 Mgal/d

**Cautionary** 7.0 Mgal/d
Modeling implications

- Subbasins cannot be managed independently; for example, withdrawal from Agafa Gumas causes salinity increase in Finegayan
- Distribution and rates of proposed DoD wells need further refinement to minimize salinity increases in existing wells
- Impact to GWA and DoD groundwater sources, in Mgal/d:

<table>
<thead>
<tr>
<th>Condition</th>
<th>Total</th>
<th>Threatened</th>
<th>Cautionary</th>
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</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>36.4</td>
<td>0.8</td>
<td>3.4</td>
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<tr>
<td>Drought</td>
<td>36.3</td>
<td>17.4</td>
<td>10.2</td>
</tr>
<tr>
<td>Scenario 1</td>
<td>49.3</td>
<td>0.5</td>
<td>11.0</td>
</tr>
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<td>Scenario 2</td>
<td>43.9</td>
<td>2.0</td>
<td>6.9</td>
</tr>
</tbody>
</table>
Remaining tasks

• Finalize pumping scenarios – Nov. 15, 2012
  • NavFacPac, Kevin Oshiro
  • GWA, Martin Roush
• Present updated findings – Dec. 6, 2012
• Publish final report – June 2013
Outline of Meeting

• Project goals, products, timeline
• Review of water budget and aquifer properties
• Numerical modeling – preliminary findings
  – Calibration to baseline condition
  – Drought condition (driest 5-year period)
  – Pumping scenarios
    • Scenario 1—additional 11.5 Mgal/d
    • Scenario 2—additional 6.9 Mgal/d
• Expanded monitoring needs
• Next steps
Reasons for Expanded Monitoring

1. **Sustainable groundwater development** requires accurate and detailed data on aquifer hydrology and geology
   - Water levels and salinity

2. **Existing network inadequate** to support proposed groundwater development
   - Track responses to development and natural changes

3. **Evaluate model predictions** & improve future models
   - Models are only as good as the data that go into them
WERI-USGS Proposal for Hydrologic Data Collection Network Upgrade

Deep Monitor Wells
- 7 existing deep wells: 2 sub-basins
- Little/no coverage in 4 of 6 sub-basins where most DOD development planned
- 8 new deep monitor wells needed
  - Agafa-Gumas/Andersen (DM1, DM2)
  - Finegayan (DM4, DM5)
  - Yigo-Tumon (DM6, DM7, DM8)
  - Mangilao (DM3)

Monitoring Strategy
- **Groundwater levels, continuous**
  - 15 long-term index sites
  - 8 additional sites (7 days every 5 years)
- **Groundwater salinity**
  - Continuous monitoring at 2 fixed depths (above, below mid-point)
    - Long-term: 2 index sites
    - Short-term: 2 of the other 14 deep wells, rotated, 1-yr periods
  - Semi-annual monitoring of vertical profile of salinity in the water column
Proposed Funding Breakdown by Agency

<table>
<thead>
<tr>
<th>Agency</th>
<th>FY 2013</th>
<th>FY 2014</th>
<th>FY 2015</th>
<th>FY 2016</th>
<th>FY 2017</th>
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<tr>
<td>DoD</td>
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<td>57,000</td>
<td>73,000</td>
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<td>62,000</td>
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<tr>
<td>GovGuam</td>
<td>127,000</td>
<td>196,000</td>
<td>190,000</td>
<td>226,000</td>
<td>221,000</td>
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<tr>
<td>USGS</td>
<td>70,000</td>
<td>70,000</td>
<td>70,000</td>
<td>70,000</td>
<td>70,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>211,000</strong></td>
<td><strong>323,000</strong></td>
<td><strong>333,000</strong></td>
<td><strong>358,000</strong></td>
<td><strong>353,000</strong></td>
</tr>
</tbody>
</table>

Eight new deep monitor wells are needed for areas that lack a deep monitor well but are either already developed or planned for groundwater development.

Cost of design and construction for each new deep monitor well is estimated to be $100K.
Proposed Implementation in FY 2013

• GovGuam
  – Install 5 new deep monitor wells ($500K)
  – Rainfall, water-level and salinity monitoring at 19 existing sites
    • WERI = $127,000
    • USGS = $70,000

• DoD
  – Install 3 new deep monitor wells ($300K)
  – Water-level monitoring at 3 existing wells
    • DoD = $14,000
Next Steps

Sept. 2012
• Senior Advisory Group feedback on monitoring plan

Sept. – Nov. 2012
• Identify sources of funds for installation of new deep monitor wells and expanded monitoring
  – USGS and WERI will provide briefings as needed
  – Briefing for the DOI Office of Insular Affairs planned for Nov. 8th

Dec. 2012
• Develop implementation plan and cost-share agreements based on available funds
Wrap Up

• Next steps for Groundwater-Availability Study
  – Finalize pumping scenarios – Nov. 15, 2012
    ▪ NavFacPac/NavFacMar
    ▪ GWA
  – Present updated findings – Dec. 6, 2012
  – Publish final report – June 30, 2013

• Topics for consideration by Senior Advisory Group
  – New deep monitor wells and expanded monitoring
  – Groundwater modeling training for DoD and GovGuam