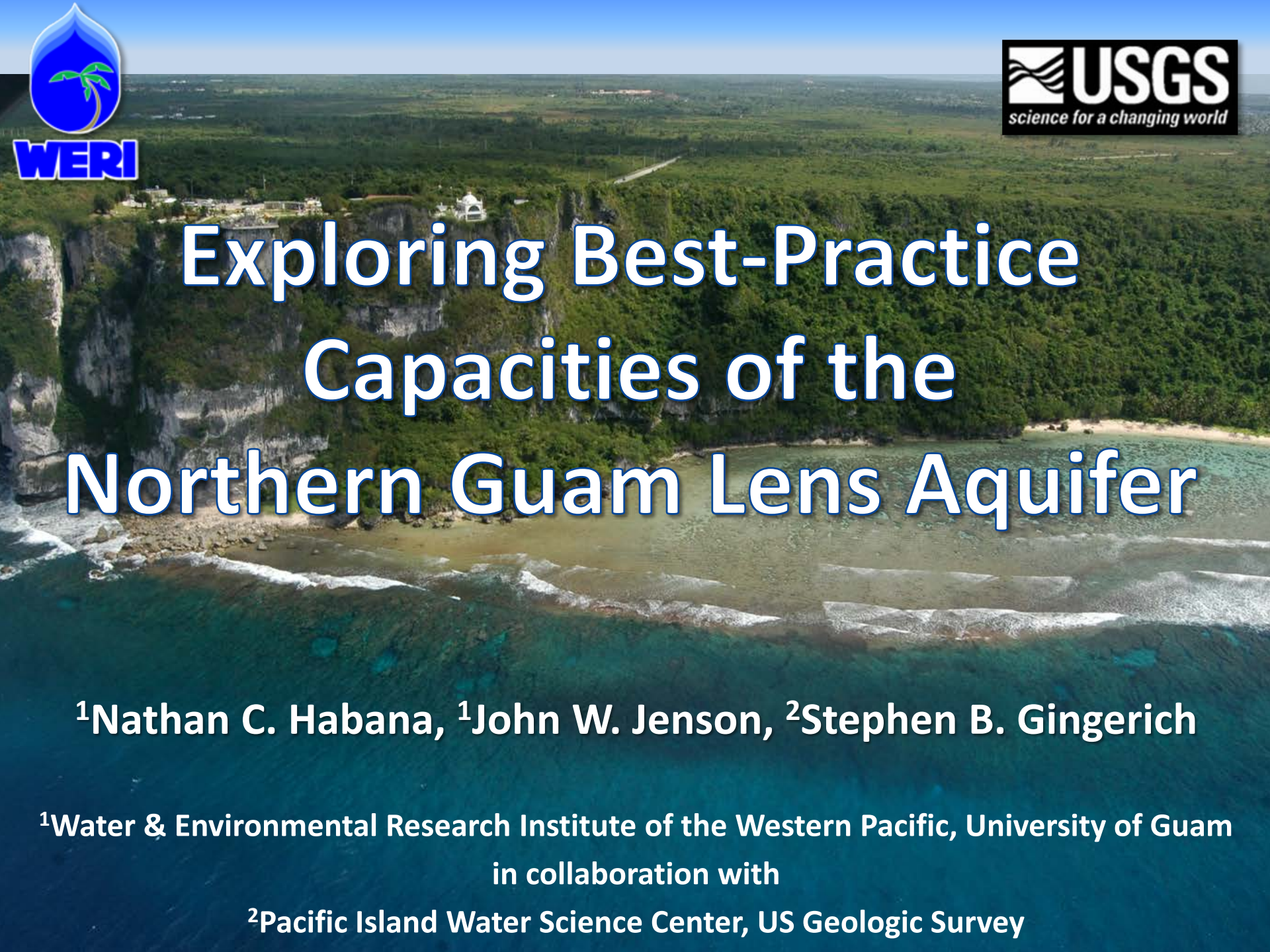

Exploring Best-Practice Capacities of the Northern Guam Lens Aquifer

[1]Nathan C. Habana, [1]John W. Jenson, [2]Stephen B. Gingerich

[1]Water & Environmental Research Institute of the Western Pacific, University of Guam

in collaboration with

[2]Pacific Island Water Science Center, US Geologic Survey

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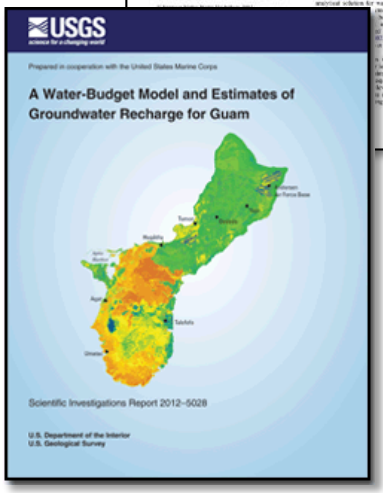
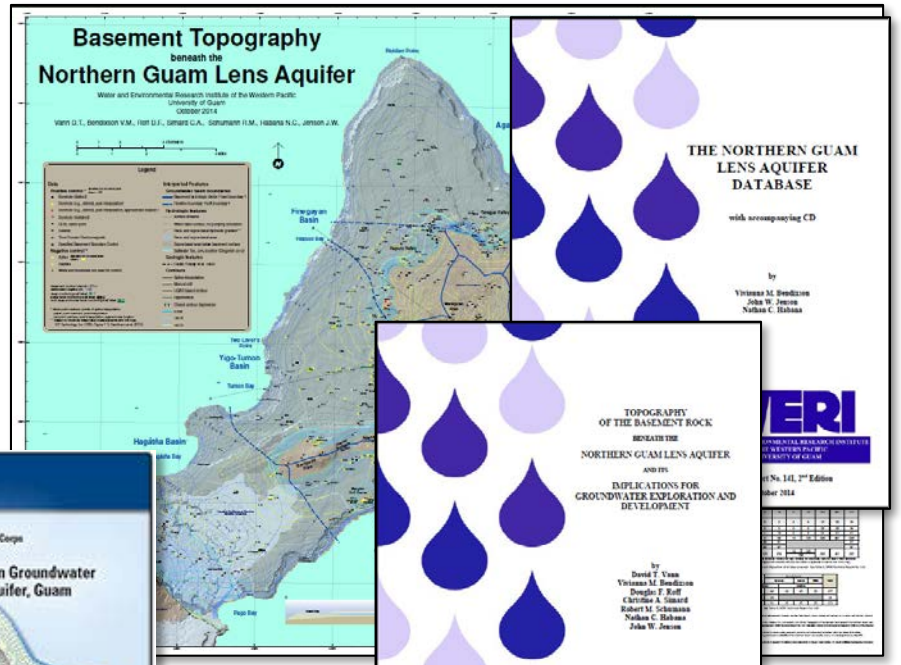
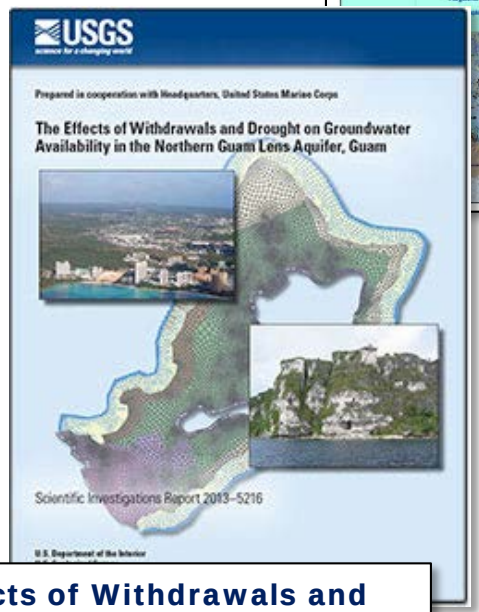
Previous Works – 2010 to 2013

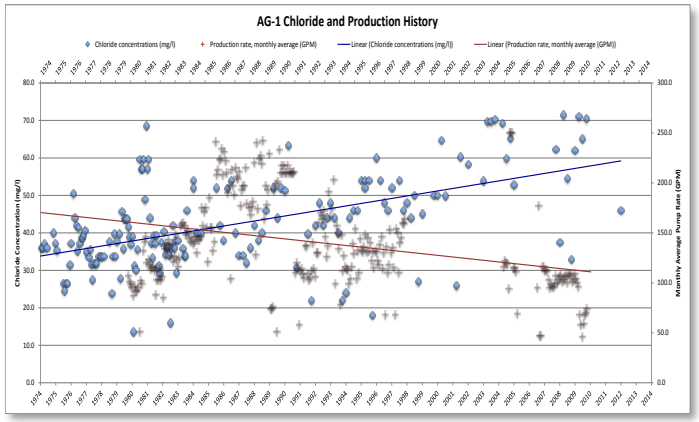


USGS
science for a changing world





The Effects of Withdrawals and Drought on Groundwater Availability in the Northern Guam Lens Aquifer, Guam
Gingerich (2013)



http://hi.water.usgs.gov/publications/pubsguam.html

Mozilla Firefox Start Page | (887 unread) - john.jenson... | CURE - Star Parker | Pandora's Box, E4: Goodb... | News forum

https://us-mg6.mail.yahoo.com/neo/launch?.rand=277artlabi35h#2674853093

Search

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Compose Search results Delete Move Spam More

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Drafts (3)
Sent
Spam (87)
Trash (8)
Smart Views
Important
Unread
Starred
People
Social
Travel
Shopping
Finance
Folders (718)
0-Today business
21st Century
AAFB
ACE Sinkhole

RE: Guam Groundwater Study Meeting - Sept. 11 at 9 AM (RSVP)

?

[redacted]

To john.jenson@yahoo.com

Håfa Adai John:

Quick question - According to USGS and WERI studies, what is the sustainable water supply per day on Guam (entire island)?

Thanks.

Sinseramente,

[redacted]

Study Plan

- **Concept design: Phase 1, 2014-2015**
  - Development and design of conceptual model
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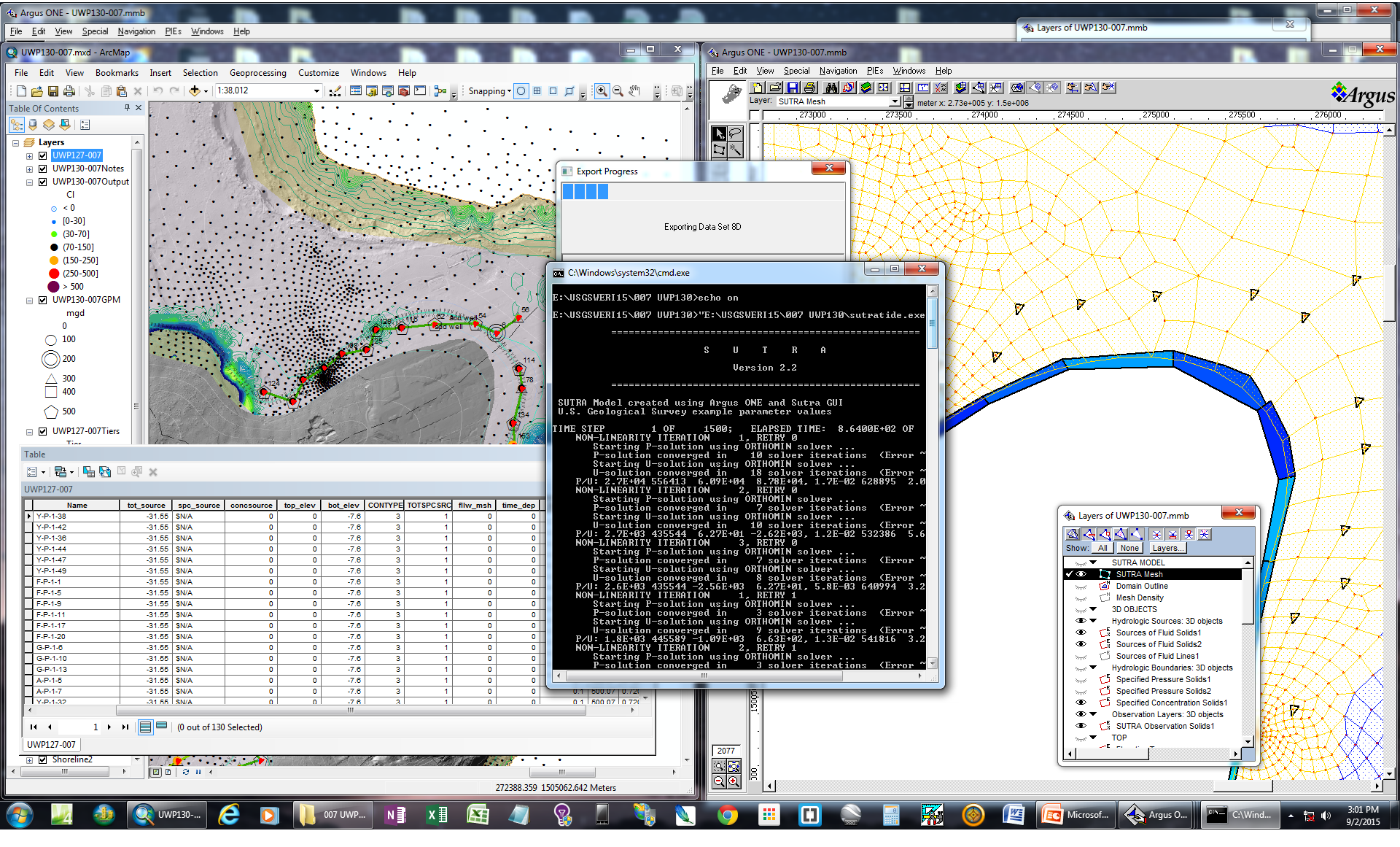
  - Configuration and testing of model
- **Application: Phase 3, 2016-2017**
  - Numerical simulations with model
    - Basin-by basin evaluation: assay curves
    - Takin' it to the limit—one more time….
      - More wells, higher pumping rates

Phase 2, Implementation: Reconfiguration of USGS 2010-2013 Model (Gingerich, 2013)



The Objective

"Ultimate Theoretical Capacity"

(Jenson, Habana & Gingerich in prep.)

"The potential capacity that *could* be achieved by an *ideal* production system, given perfect knowledge of the natural limiting conditions"

Requires identifying:

The natural limits imposed by
aquifer recharge and geology

An ideal production system, i.e.,
one utilizing the best available technology
to deliver maximum extraction
while maintaining a given quality standard

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Sustainable Yield

Has always been a slippery concept…

Sustainable Yield (Mink 1982)

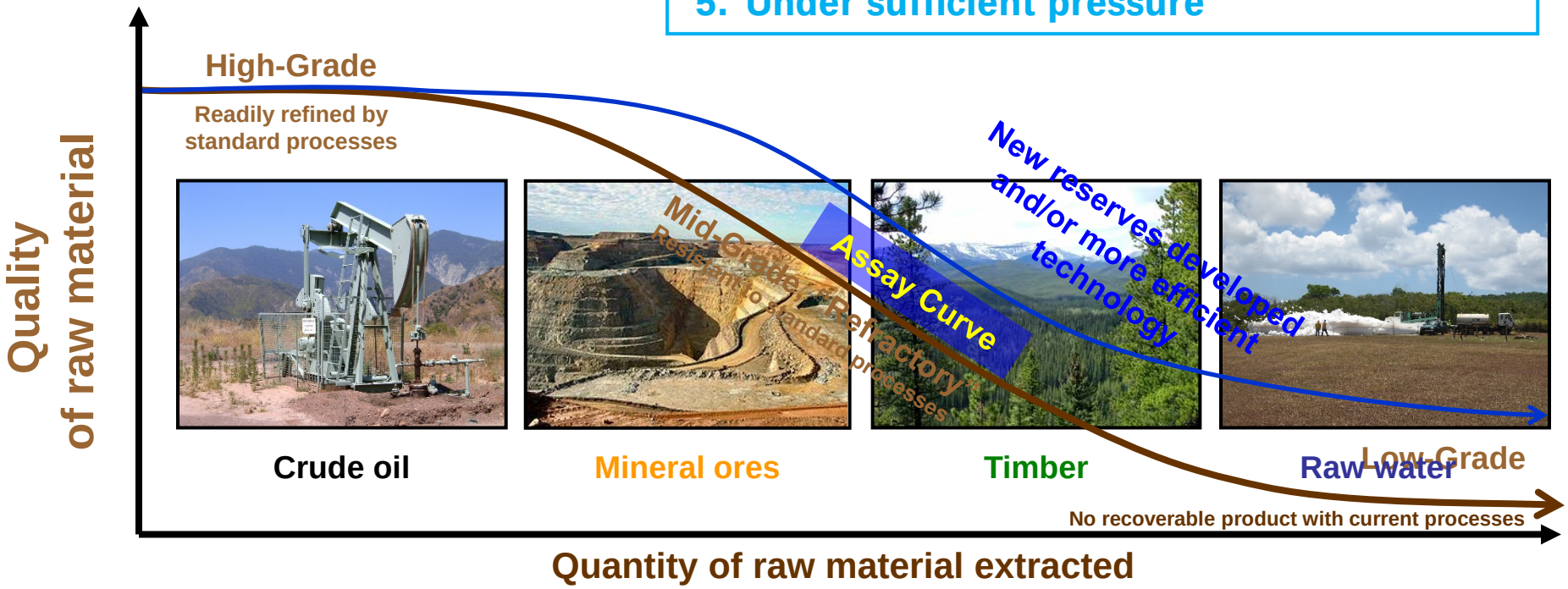
"The rate of production that can be sustained without unacceptably degrading water quality"

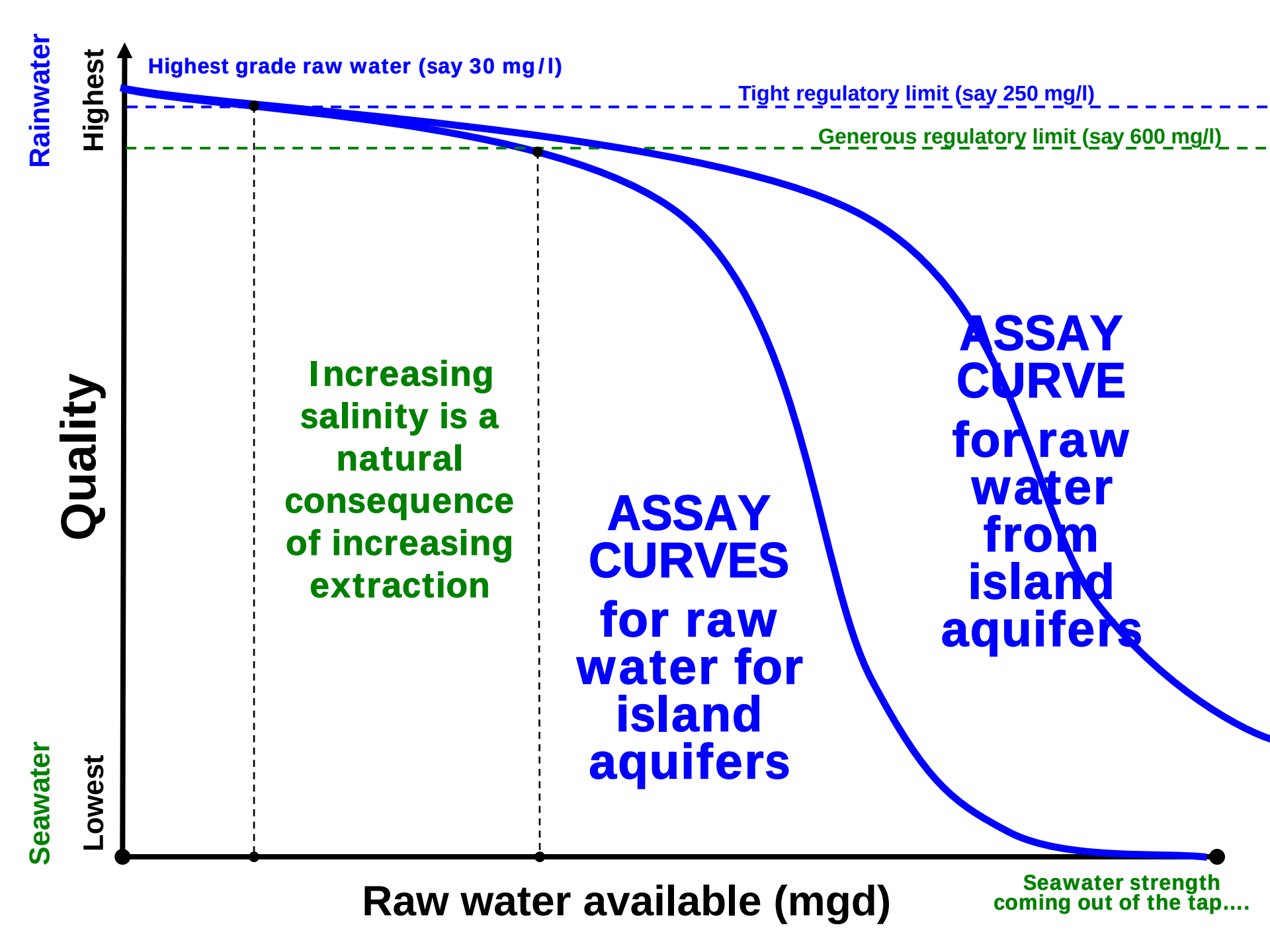
- **Expressed as a percent of recharge (20-25%)**
- **Relied on professional judgement**
- **Entirely subjective**

Extraction

Refined Product = Drinking Water

1. Potable fresh water (non-saline)
2. Safe to drink
3. Tastes, smells, looks good
4. Delivered to your tap 24/7
5. Under sufficient pressure




Rainwater
Highest
Highest grade raw water (say 30 mg/l)
Tight regulatory limit (say 250 mg/l)
Generous regulatory limit (say 600 mg/l)
Quality
Increasing salinity is a natural consequence of increasing extraction
ASSAY CURVES for raw water for island aquifers
ASSAY CURVE for raw water from island aquifers
Seawater
Lowest
Raw water available (mgd)
Seawater strength coming out of the tap....

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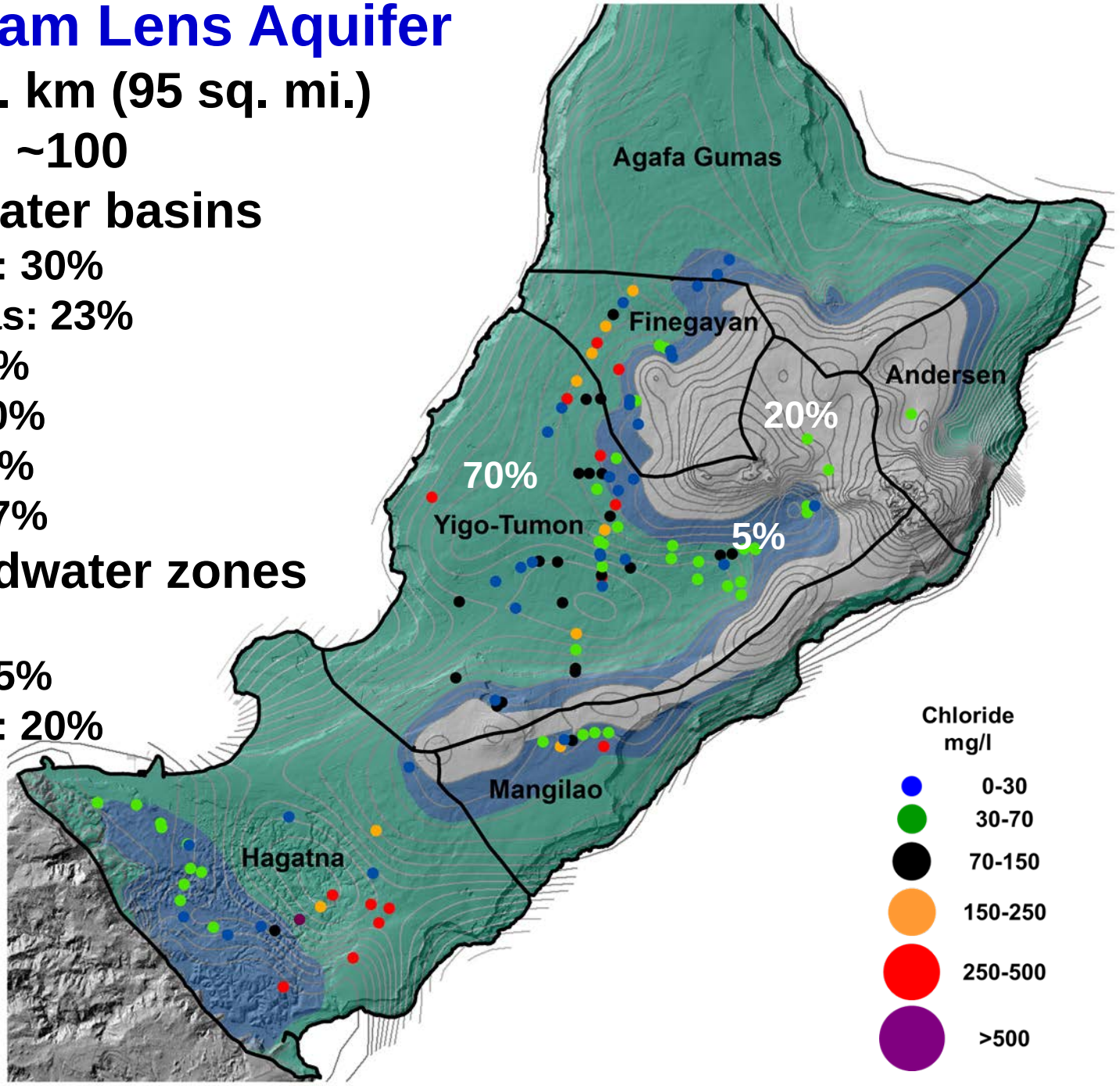
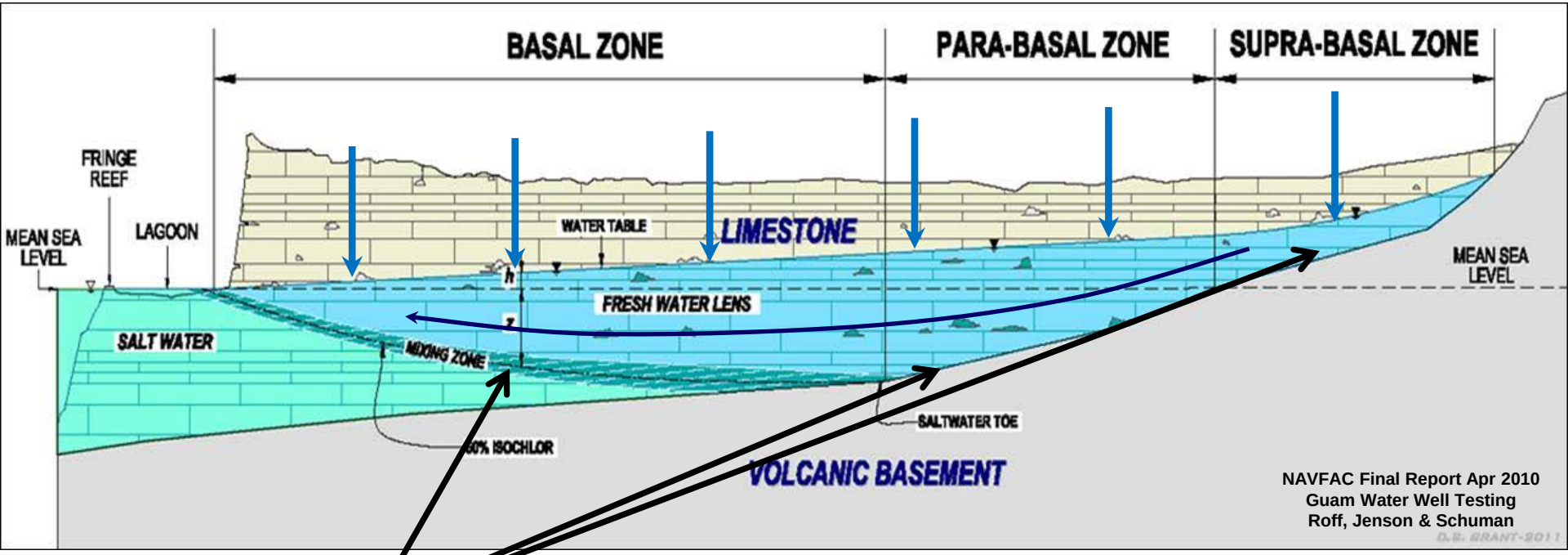
Northern Guam Lens Aquifer

- Area: 264 sq. km (95 sq. mi.)
- Active wells: ~100
- Six groundwater basins
  - Yigo-Tumon: 30%
  - Agafa Gumas: 23%
  - Hagåtña: 22%
  - Mangilao: 10%
  - Andersen: 8%
  - Finegayan: 7%
- Three groundwater zones
  - Basal: 70%
  - Para-basal: 5%
  - Supra-basal: 20%
- Recharge
  - 255 MGD
    - 65″/yr
  - 200 MGD
    - 51″/yr



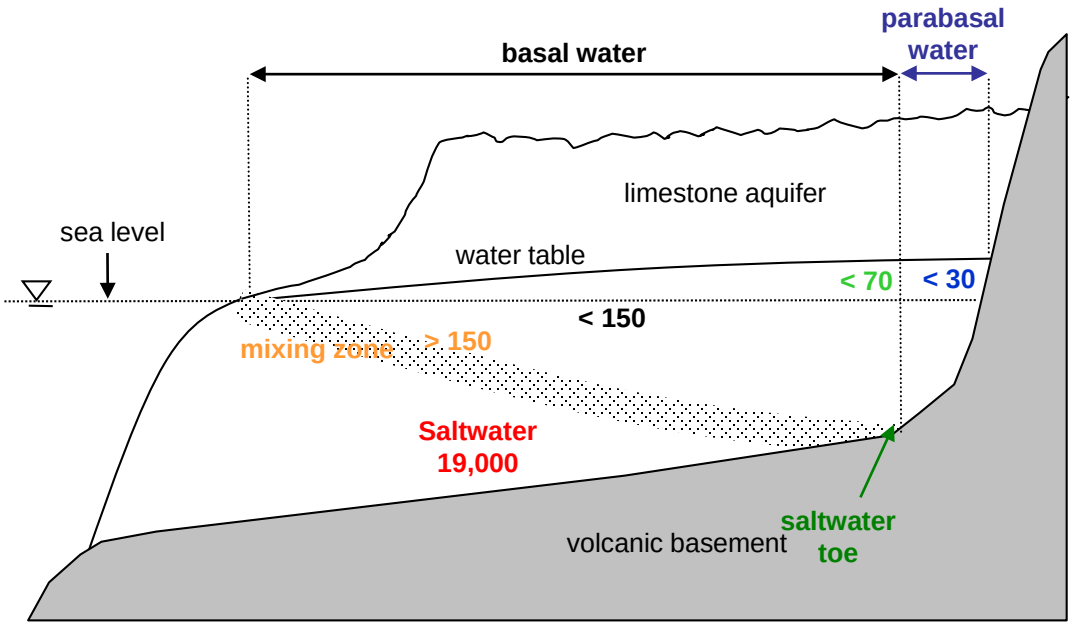
Groundwater Zones



- **Supra-basal water: underlain by basement rock and stands above sea level**
  - **Invulnerable to sea water contamination**
  - **Very high quality water—headwaters of the catchment**
  - **Most responsive to wet-dry cycles**
  - **Very hard to find (even with a map; occurs in patches)**

Groundwater Quality

Chloride Benchmarks



CDM (Mink), 1982
McDonald & Jenson, 2003

parabasal range	**≤ 30 mg/l**
saltwater toe range	**> 30 to 70 mg/l**
basal range	**> 70 to < 150 mg/l**
saltwater intrusion	**≥ 150 mg/l**
USEPA standard	**250 mg/l**

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Imagineered Conditions

1. Quality target <150 mg/L chloride
   - Same as sought by Mink (1982)
2. Current technology of choice
   - vertical wells, 25 ft deep
3. Capped extraction at 500 gpm each well
4. About same number of wells as present
5. Assigned all wells to the para-basal zone
   - Suspended access considerations

The Maximum-Capacity (Imaginary) System

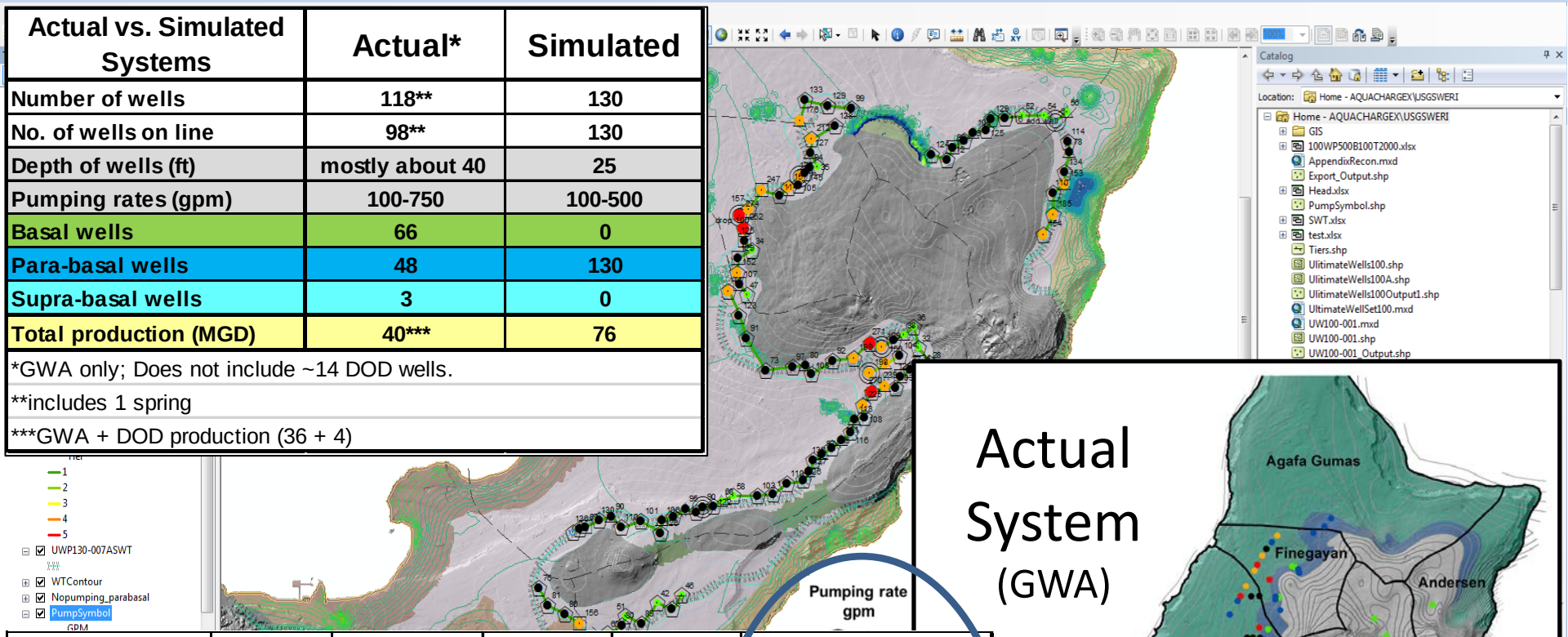
Takin' It to the Limit...!

Actual vs. Simulated Systems	Actual*	Simulated
Number of wells	118**	130
No. of wells on line	98**	130
Depth of wells (ft)	mostly about 40	25
Pumping rates (gpm)	100-750	100-500
Basal wells	66	0
Para-basal wells	48	130
Supra-basal wells	3	0
Total production (MGD)	40***	76

*GWA only; Does not include ~14 DOD wells.

**includes 1 spring

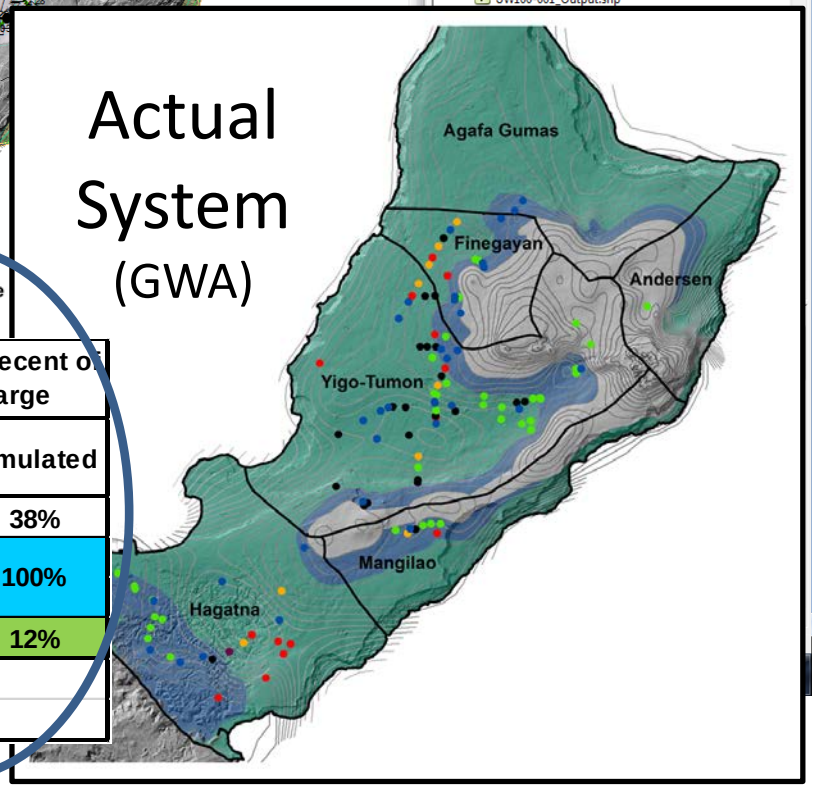
***GWA + DOD production (36 + 4)

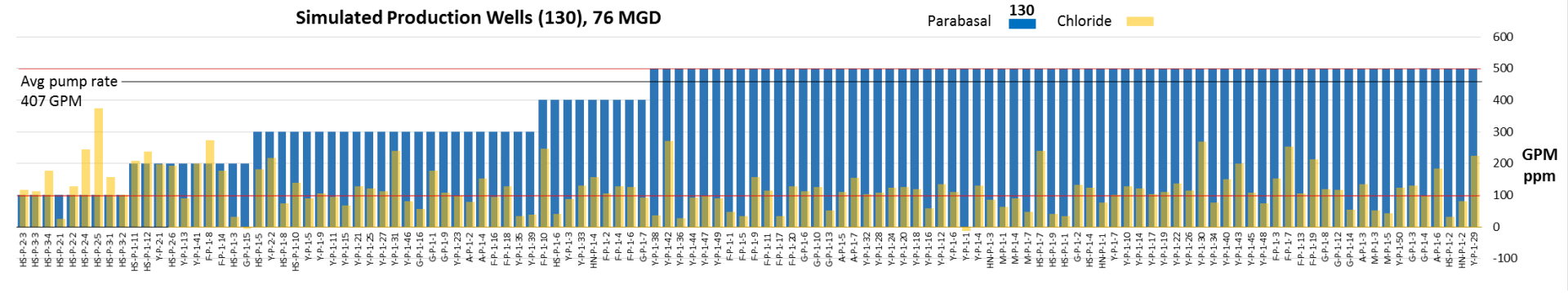


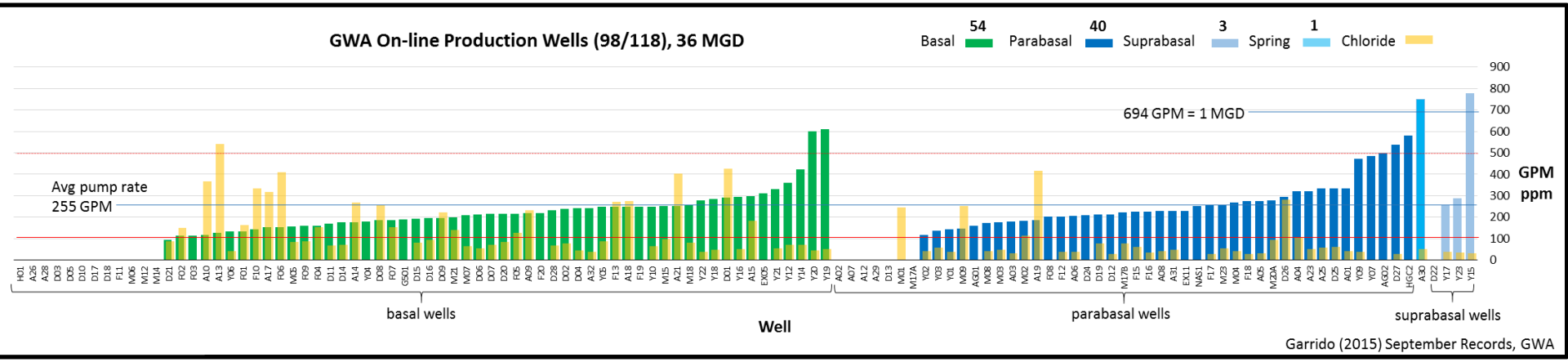
Recharge & Extraction by zone	Portion of aquifer	Recharge (MGD) by zone	Actual extraction (MGD) by zone*	Simulated extraction (MGD) by zone	Extraction as pecent of zonal recharge	
					Actual*	Simulated
Entire aquifer	1.00	200	36	76	18%	38%
Supra-basal zone	0.20	40	2	0	34%	100%
Para-basal zones**	0.05	10	15	58		
Basal zone	0.75	150	18	18	12%	12%

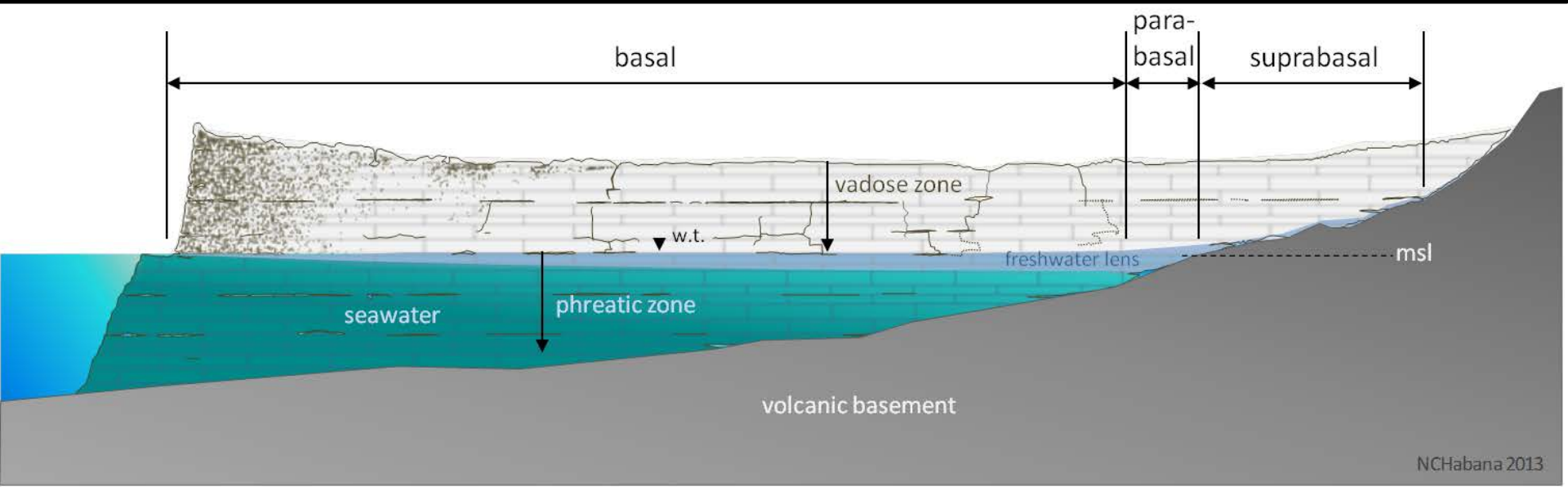
*GWA only; does not include DOD production.

**Interior rise and southern fault zone



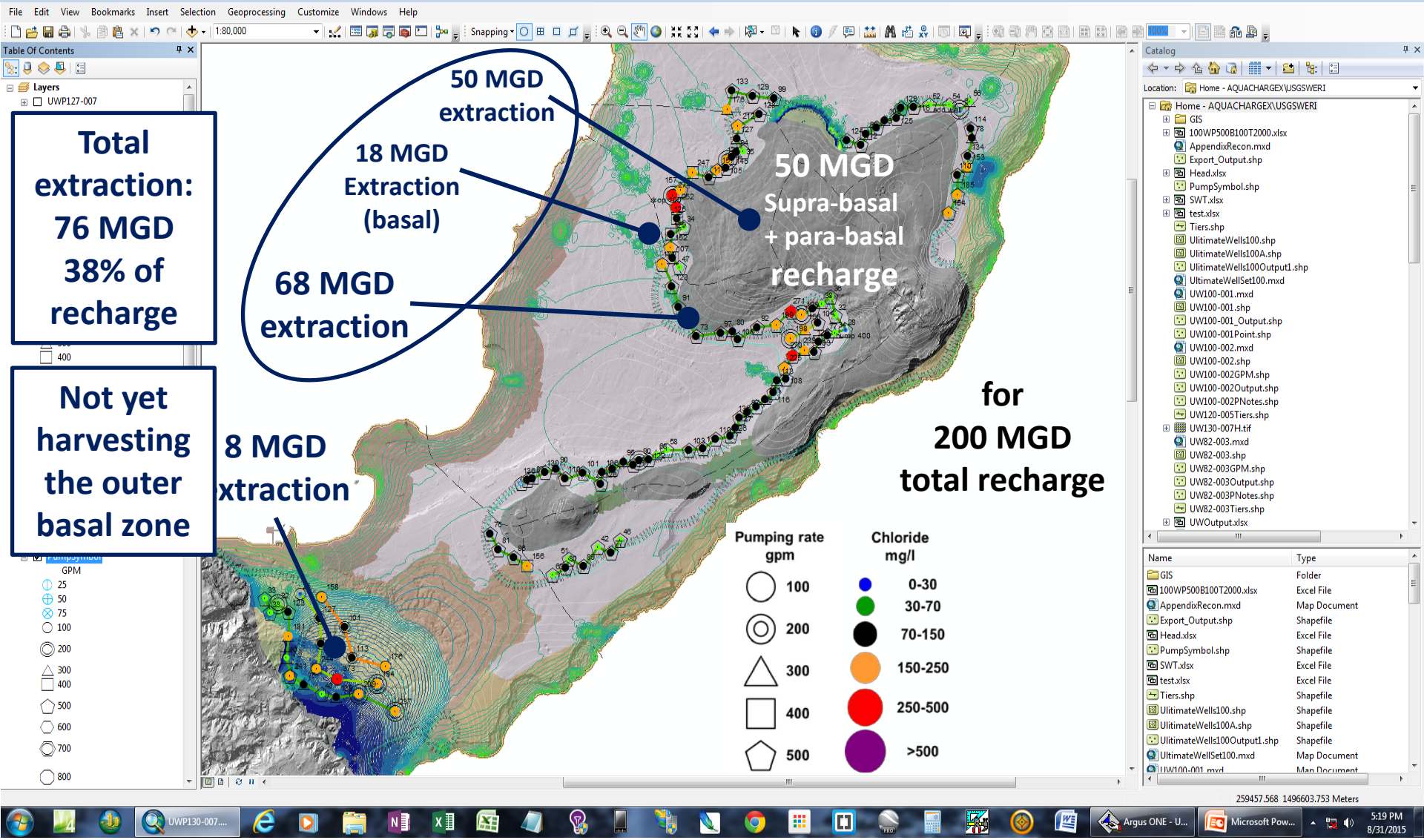

Simulated Production Wells (130), 76 MGD
Parabasal
130
Chloride
Avg pump rate
407 GPM
600
500
400
300
200
100
0
-100
GPM
ppm


GWA On-line Production Wells (98/118), 36 MGD
Basal
54
Parabasal
40
Suprabasal
3
Spring
1
Chloride
694 GPM = 1 MGD
Avg pump rate
255 GPM
900
800
700
600
500
400
300
200
100
0
GPM
ppm
basal wells
parabasal wells
suprabasal wells
Well
Garrido (2015) September Records, GWA


basal
para-
basal
suprabasal
vadose zone
w.t.
freshwater lens
msl
seawater
phreatic zone
volcanic basement
NCHabana 2013

Summary

Takin' It to the Limit...!



Total extraction: 76 MGD 38% of recharge

Not yet harvesting the outer basal zone

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Stay tuned…

Sustainable Management (Ponce 2008)

Social, economic, and legal constraints also set limits

- **"It's about more than just hydrology"**
- **Some areas are off limits, or inaccessible**
- **Or too expensive to develop with current technology…**