Multilayer spatial analysis of water availability for shale resources development in Mexico

Carlos Galdeano

World Water Congress 2017, Cancun Mexico

May 29, 2017

Webber Energy Group

THE UNIVERSITY OF TEXAS AT AUSTIN

Background

Background

Mexico’s Energy Reform

Mexico's Energy Reform intends to attract private investment and technical expertise

Oil and Gas Sector

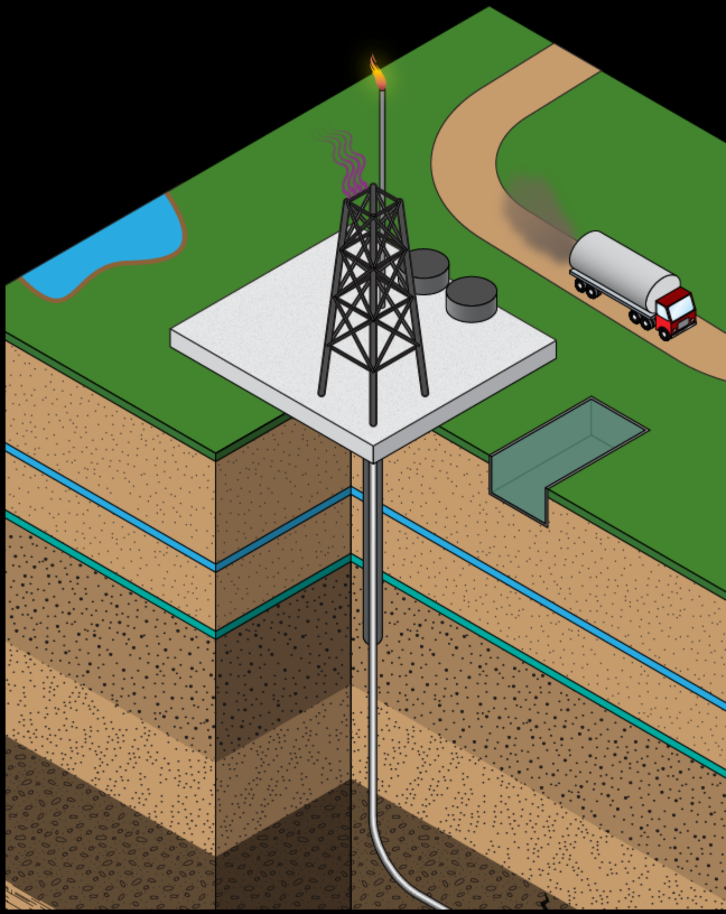
PEMEX

Electricity Sector

CFE

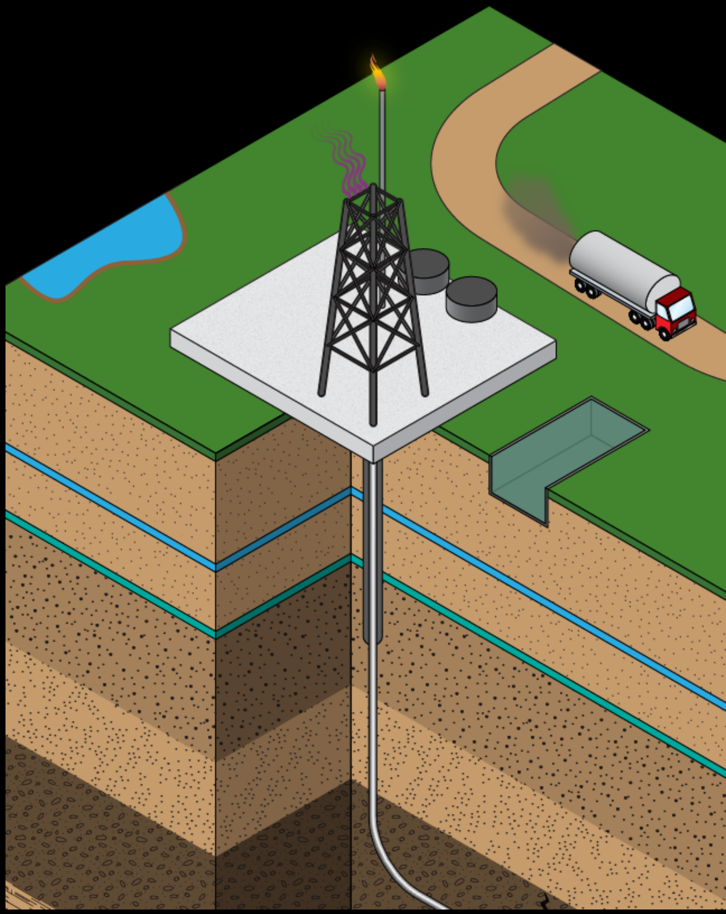
Horizontal drilling coupled with hydraulic fracturing (HF) enabled extraction from shale reserves previously deemed uneconomic

- 1 – 10 Mgal of water are injected after drilling the wells.
- Estimated ultimate recovery (EUR) is the quantity of shale resource recovered in the 20-30 year lifetime of a well.
- HF is a small water user compared with irrigation, but a water-intensive user at a local level in some counties in Texas.



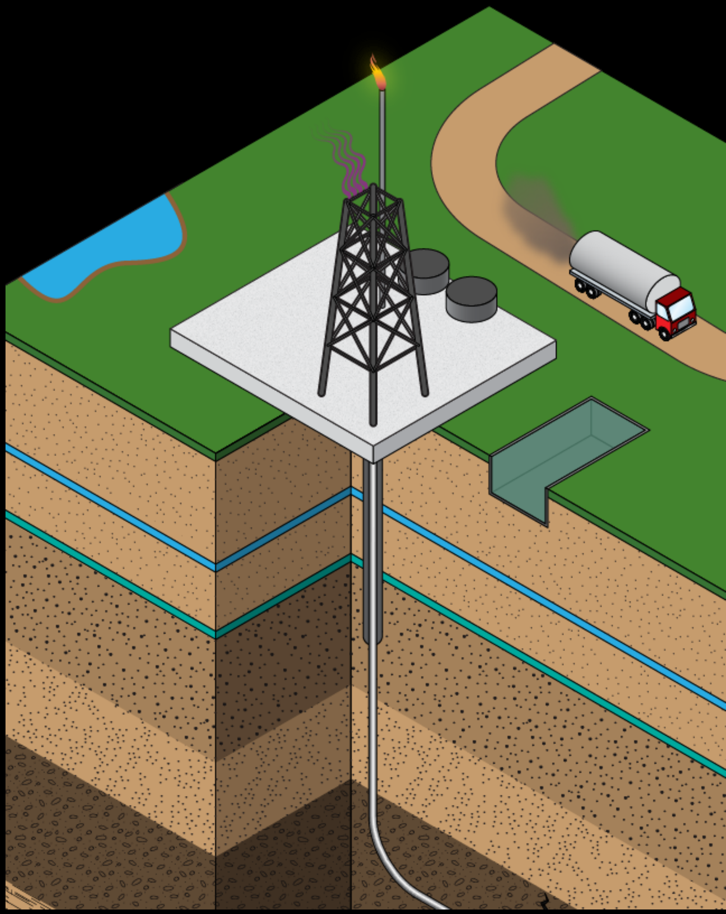
Horizontal drilling coupled with hydraulic fracturing (HF) enabled extraction from shale reserves previously deemed uneconomic

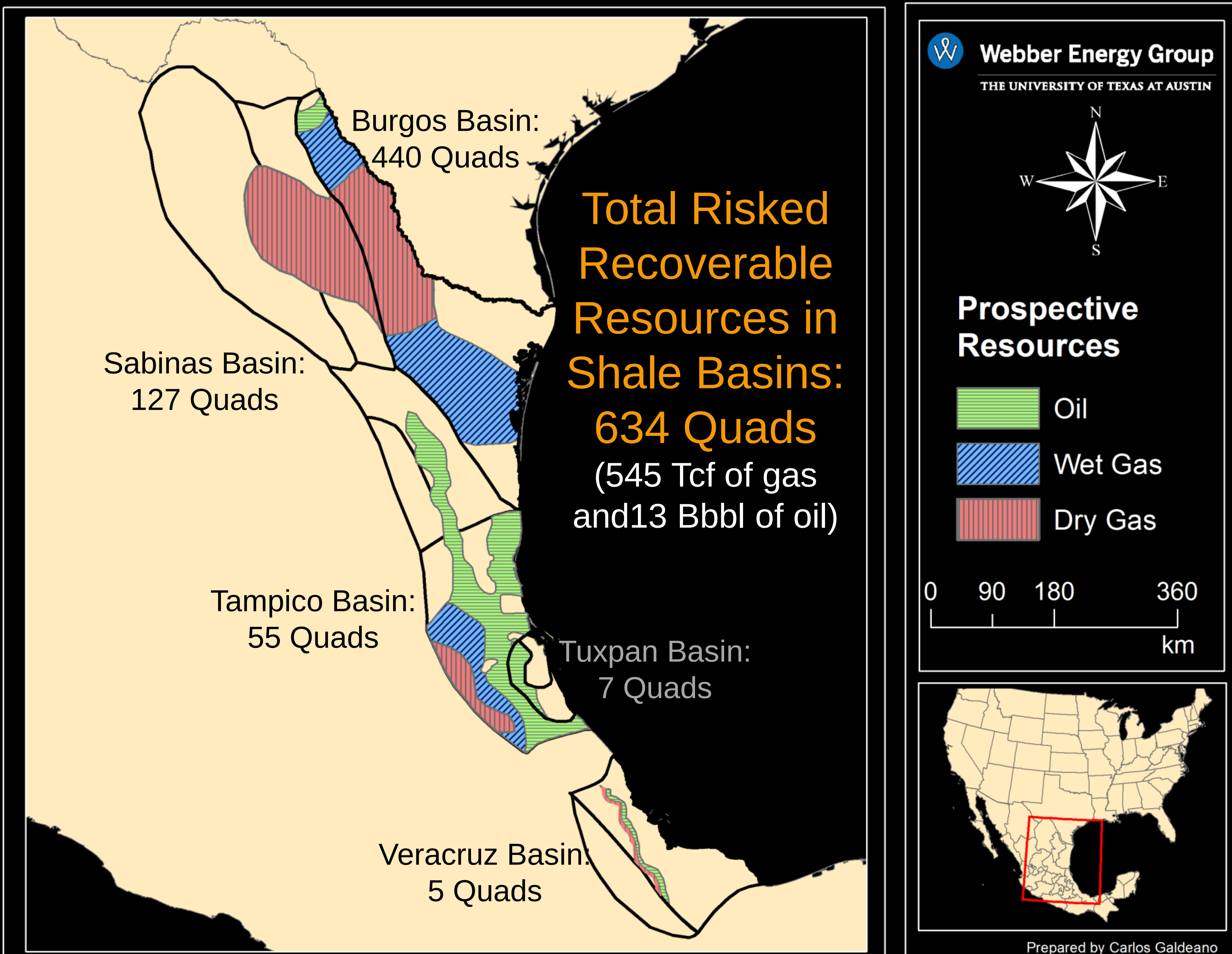
- 1 – 10 Mgal of water are injected after drilling the wells.
- Estimated ultimate recovery (EUR) is the quantity of shale resource recovered in the 20-30 year lifetime of a well.
- HF is a small water user compared with irrigation, but a water-intensive user at a local level in some counties in Texas.



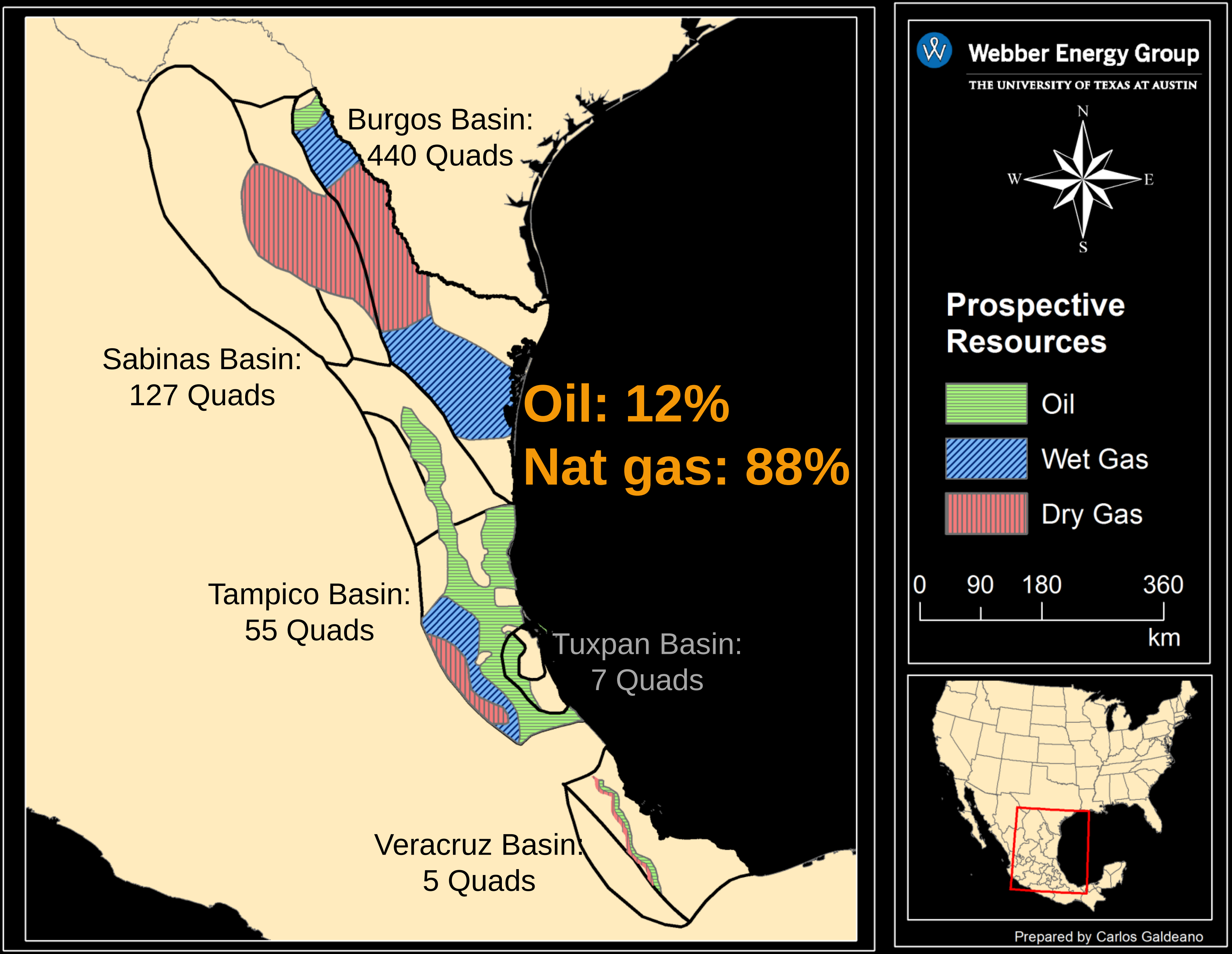
Horizontal drilling coupled with hydraulic fracturing (HF) enabled extraction from shale reserves previously deemed uneconomic

- 1 – 10 Mgal of water are injected after drilling the wells.
- Estimated ultimate recovery (EUR) is the quantity of shale resource recovered in the 20-30 year lifetime of a well.
- HF is a small water user compared with irrigation, but a water-intensive user at a local level in some counties in Texas.

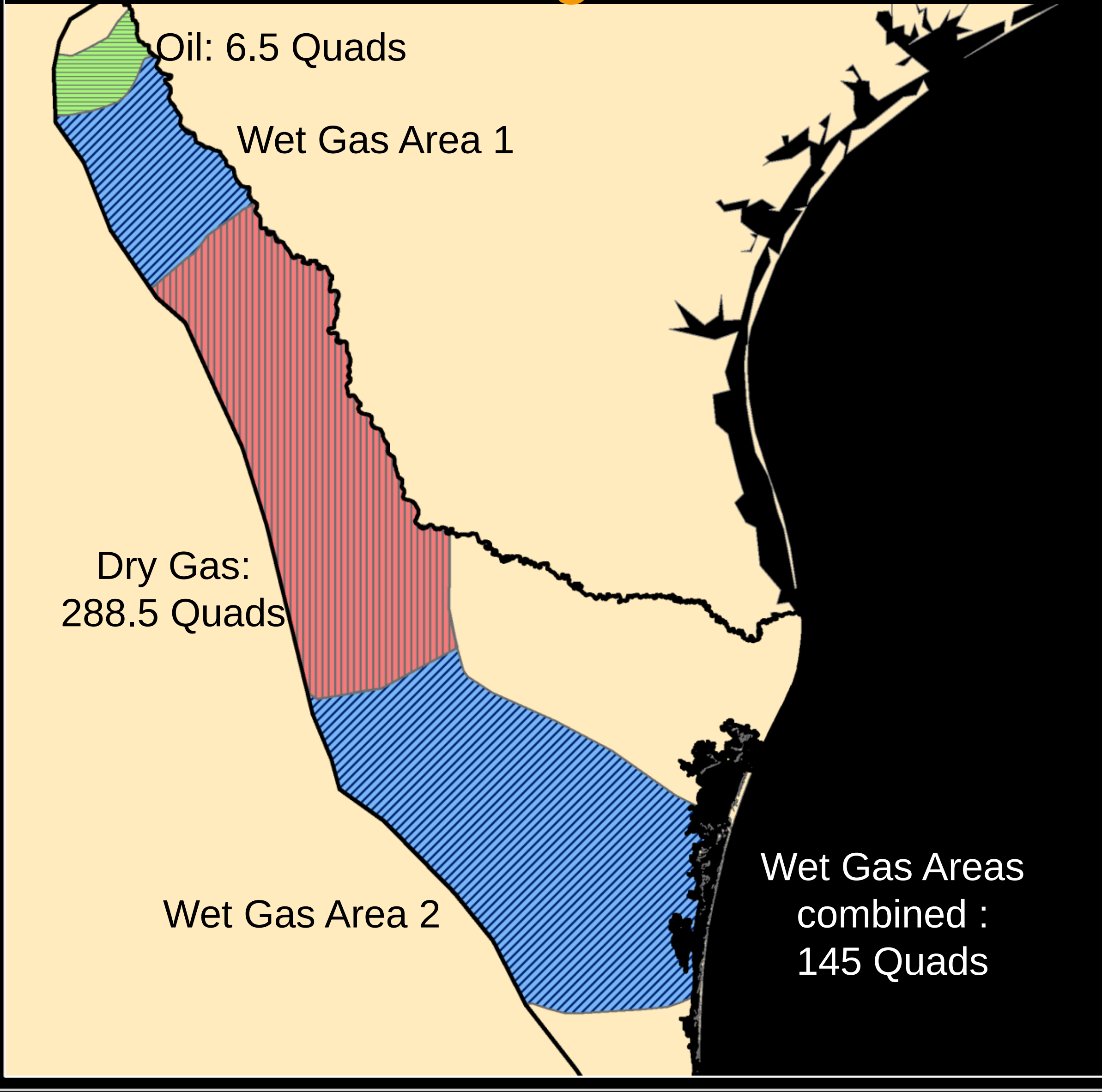




Burgos Basin:
440 Quads
Sabinas Basin:
127 Quads
Tampico Basin:
55 Quads
Tuxpan Basin:
7 Quads
Veracruz Basin:
5 Quads
Total Risked Recoverable Resources in Shale Basins:
634 Quads
(545 Tcf of gas and13 Bbbl of oil)
Webber Energy Group
THE UNIVERSITY OF TEXAS AT AUSTIN
N
W
E
S
Prospective Resources
Oil
Wet Gas
Dry Gas
0
90
180
360
km
Prepared by Carlos Galdeano

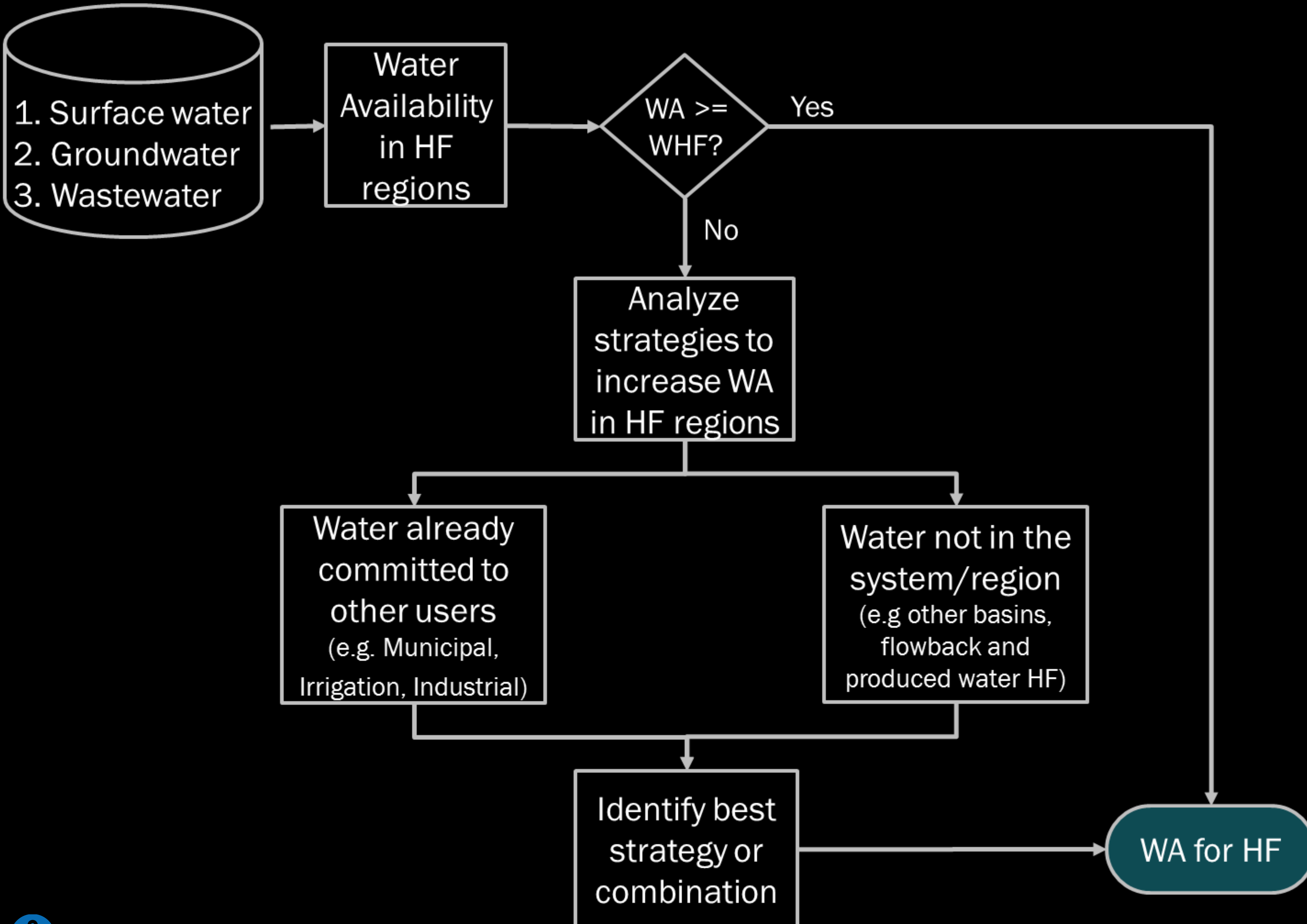

Burgos Basin:
440 Quads
Sabinas Basin:
127 Quads
Oil: 12%
Nat gas: 88%
Tampico Basin:
55 Quads
Tuxpan Basin:
7 Quads
Veracruz Basin:
5 Quads
Webber Energy Group
THE UNIVERSITY OF TEXAS AT AUSTIN
N
W
E
S
Prospective Resources
Oil
Wet Gas
Dry Gas
0
90
180
360
km
Prepared by Carlos Galdeano

70% of Shale Resources in Mexico are in Burgos Basin

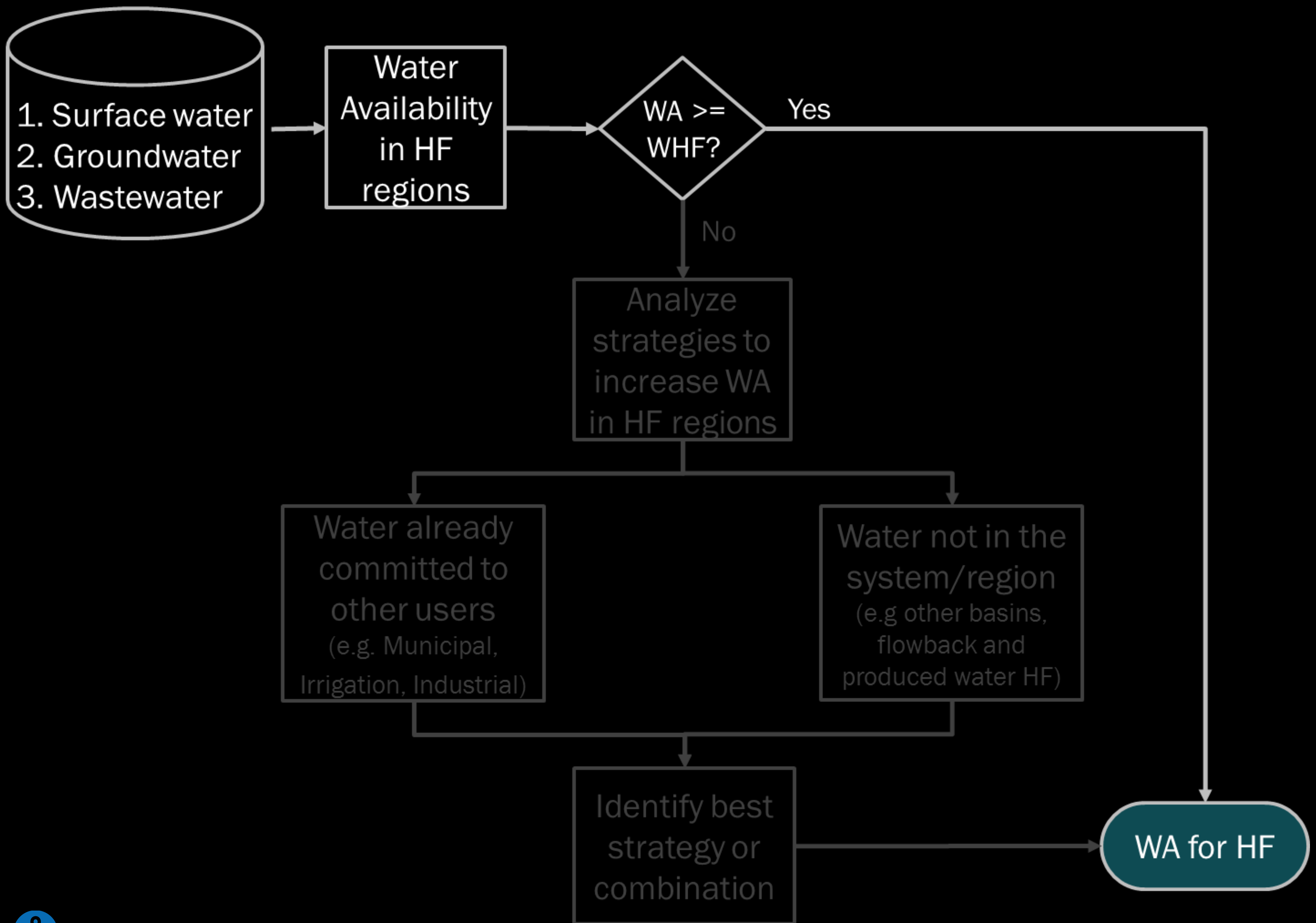


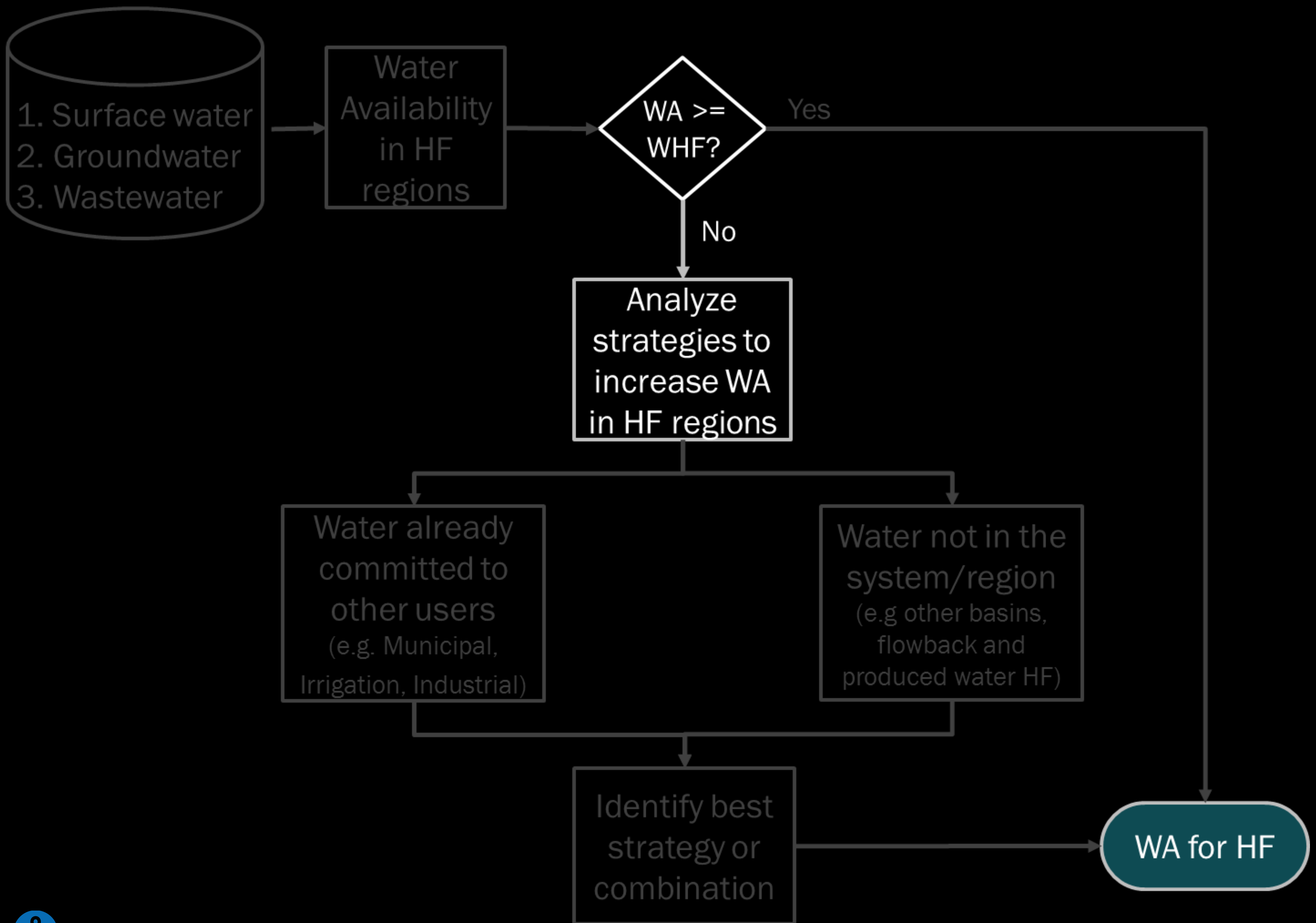
Prepared by Carlos Galdeano

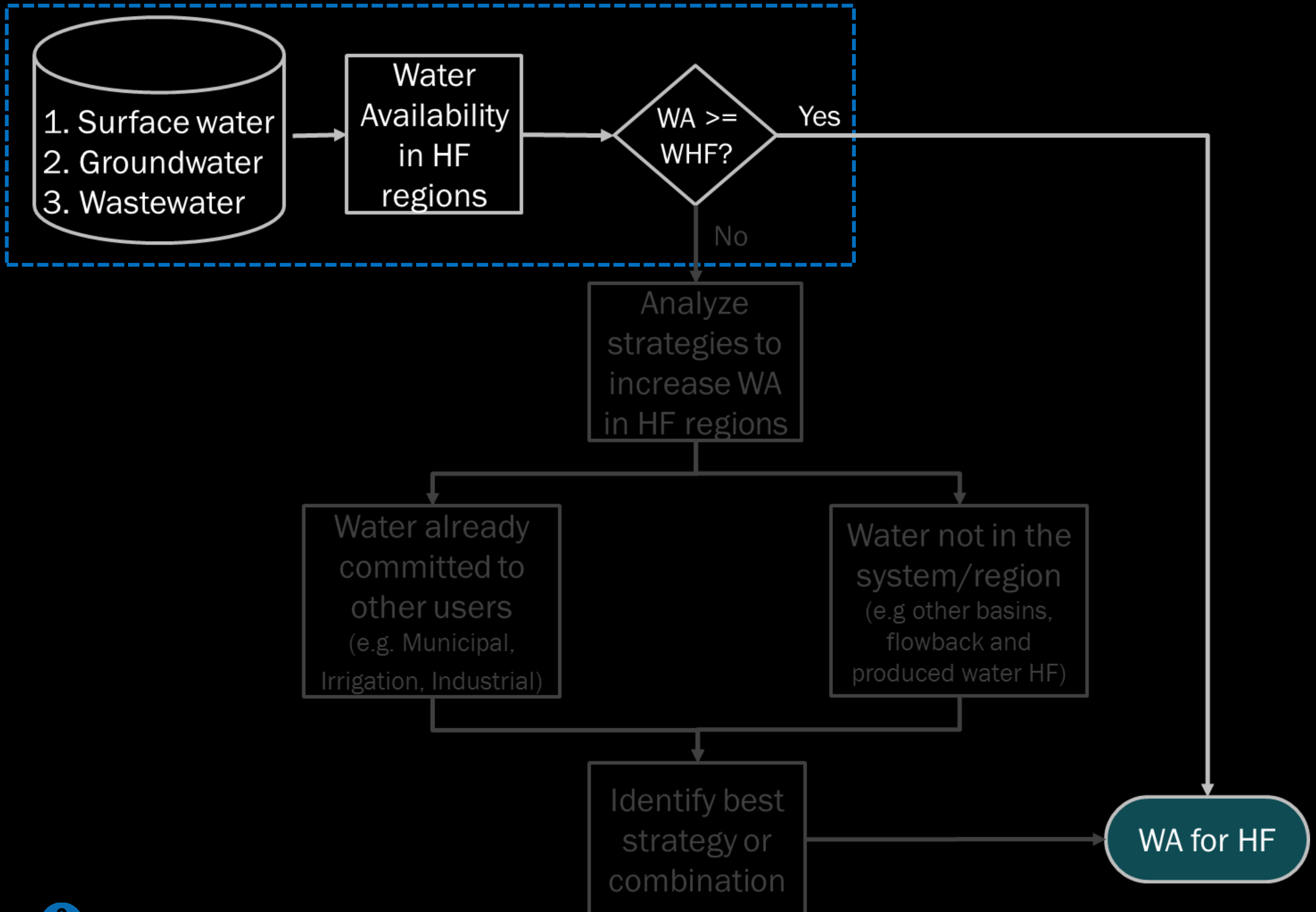
Where are the hydraulic fracturing sites going to get their water from?

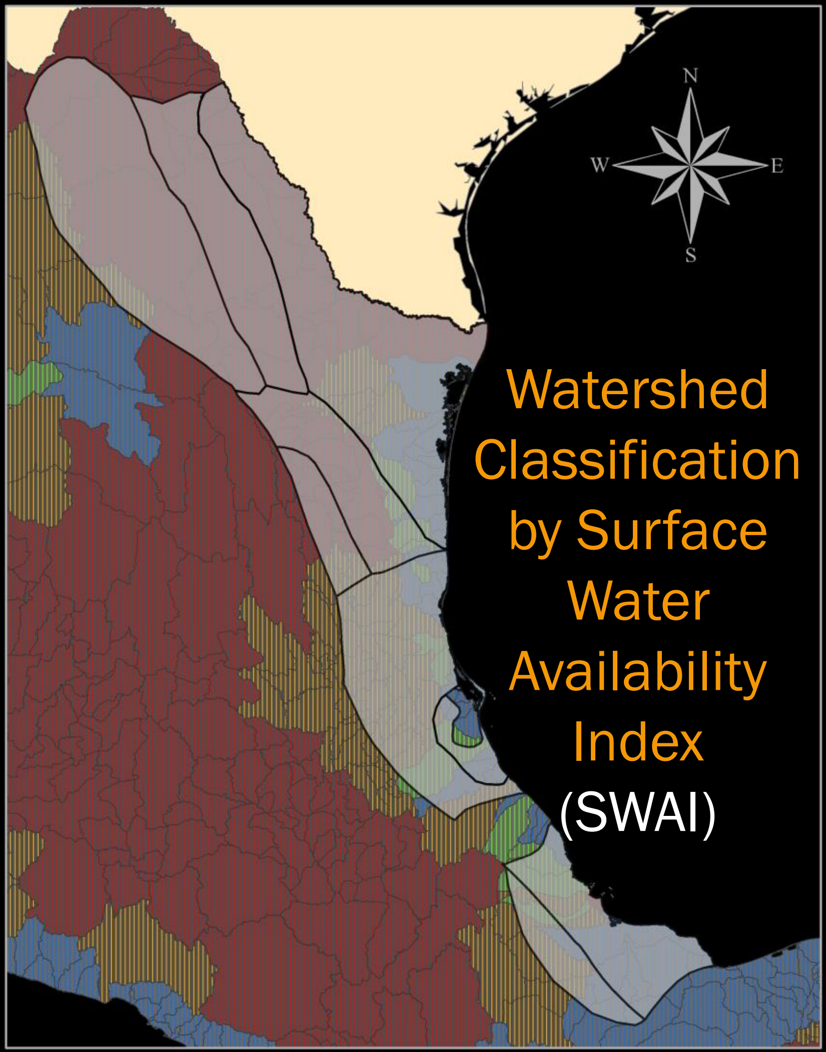


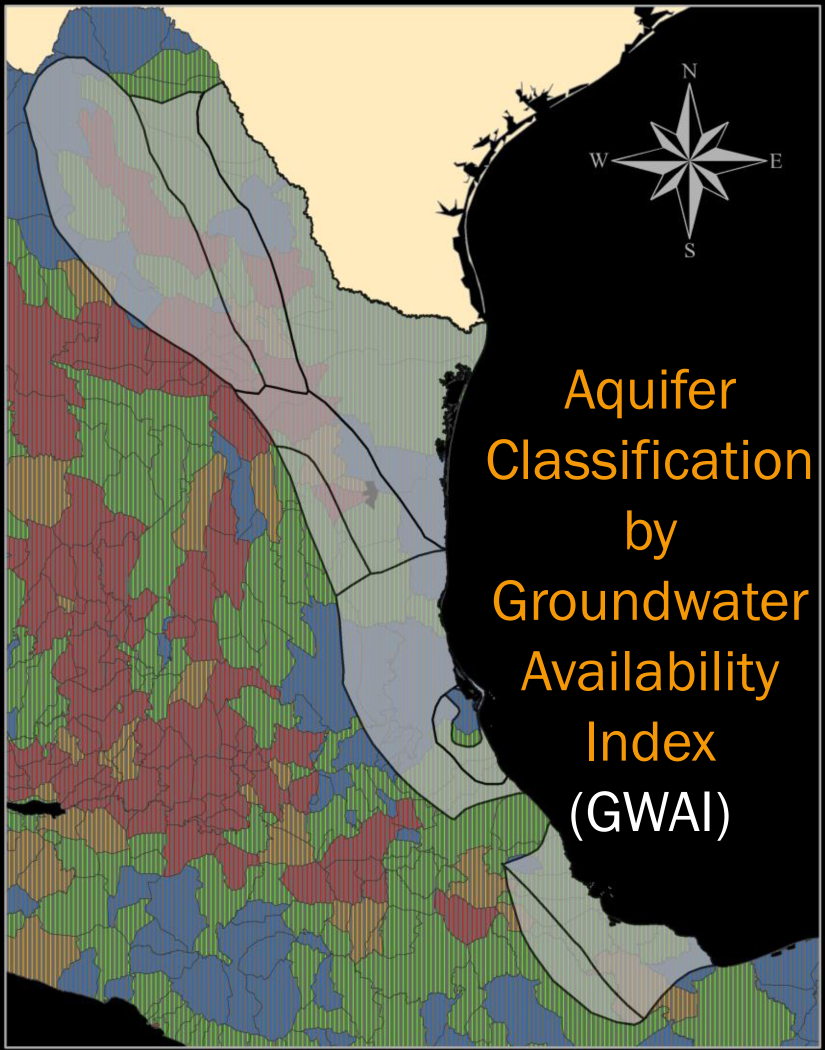
1. Surface water
2. Groundwater
3. Wastewater
Water Availability in HF regions
WA >= WHF?
Yes
No
Analyze strategies to increase WA in HF regions
Water already committed to other users (e.g. Municipal, Irrigation, Industrial)
Water not in the system/region (e.g other basins, flowback and produced water HF)
Identify best strategy or combination
WA for HF


1. Surface water
2. Groundwater
3. Wastewater
Water Availability in HF regions
WA >= WHF?
Yes
No
Analyze strategies to increase WA in HF regions
Water already committed to other users
(e.g. Municipal, Irrigation, Industrial)
Water not in the system/region
(e.g other basins, flowback and produced water HF)
Identify best strategy or combination
WA for HF


1. Surface water
2. Groundwater
3. Wastewater
Water Availability in HF regions
WA >= WHF?
Yes
No
Analyze strategies to increase WA in HF regions
Water already committed to other users
(e.g. Municipal, Irrigation, Industrial)
Water not in the system/region
(e.g other basins, flowback and produced water HF)
Identify best strategy or combination
WA for HF


1. Surface water
2. Groundwater
3. Wastewater
Water Availability in HF regions
WA >= WHF?
Yes
No
Analyze strategies to increase WA in HF regions
Water already committed to other users
(e.g. Municipal, Irrigation, Industrial)
Water not in the system/region
(e.g other basins, flowback and produced water HF)
Identify best strategy or combination
WA for HF





Webber Energy Group
THE UNIVERSITY OF TEXAS AT AUSTIN

Shale Basins

0 112.5 225 337.5 450 km

Watersheds

- Zone 1: SWAI < 1.4
- Zone 2: 1.4 > SWAI < 3
- Zone 3: 3 > SWAI < 9
- Zone 4: SWAI > 9

Aquifers

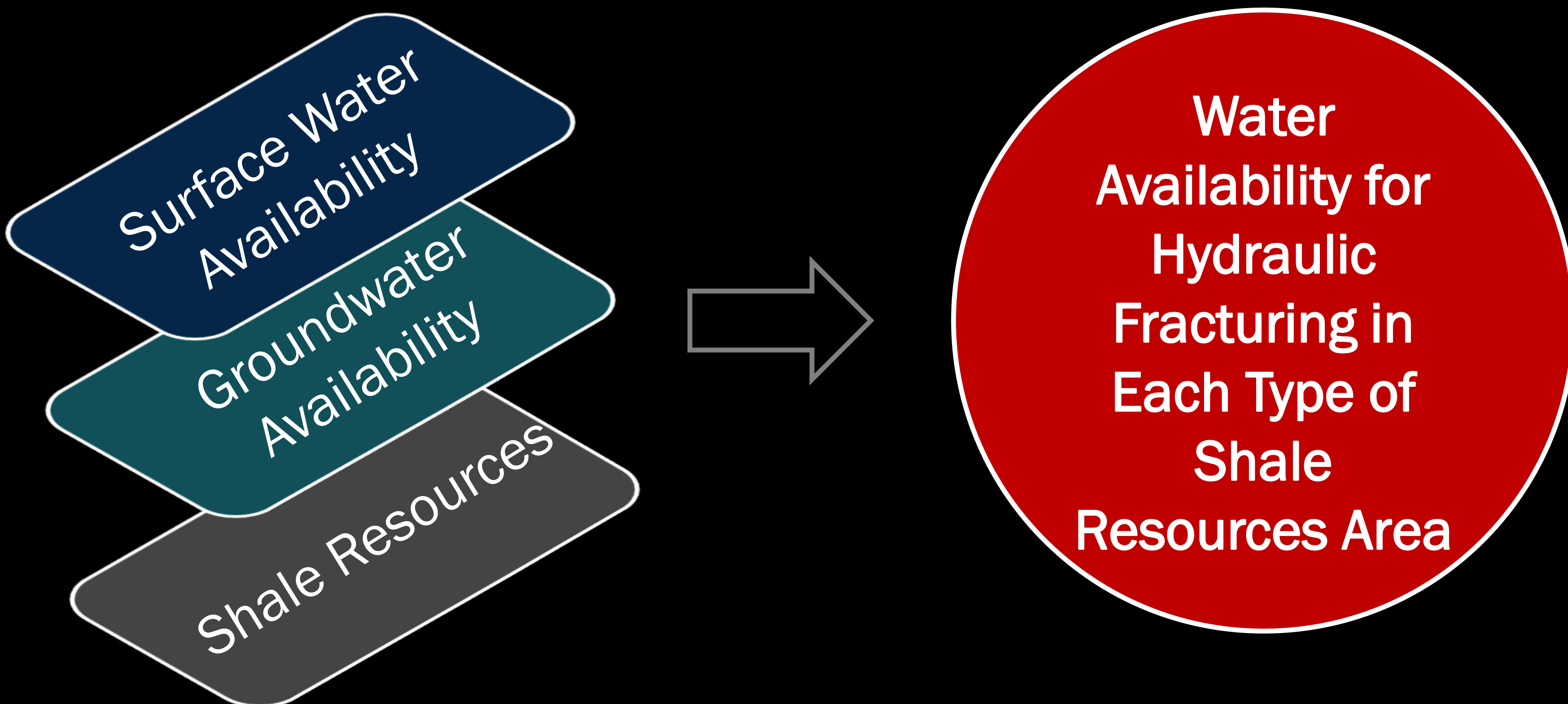
- Zone 1: GWAI < -0.1
- Zone 2: - 0.1 > GWAI > 0.1
- Zone 3: 0.1 > GWAI > 0.8
- Zone 4: GWAI > 0.8

Data from Conagua

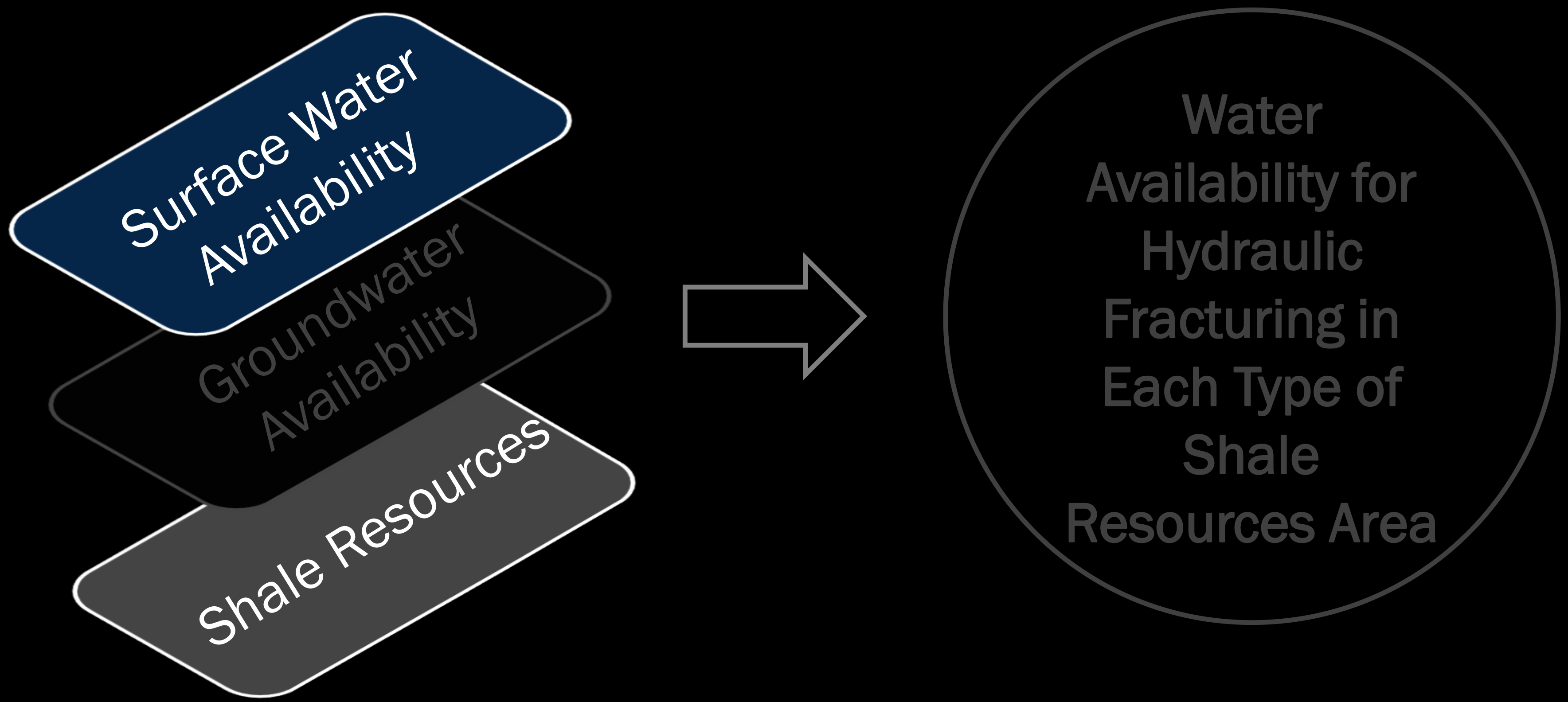
The zones are estimated based on water availability and are used to define water prices.

Zone	Increase in water price with respect to Zone 4	
	Watersheds	Aquifers
Zone 1	766%	921%
Zone 2	299%	295%
Zone 3	31%	38%
Zone 4	-	-

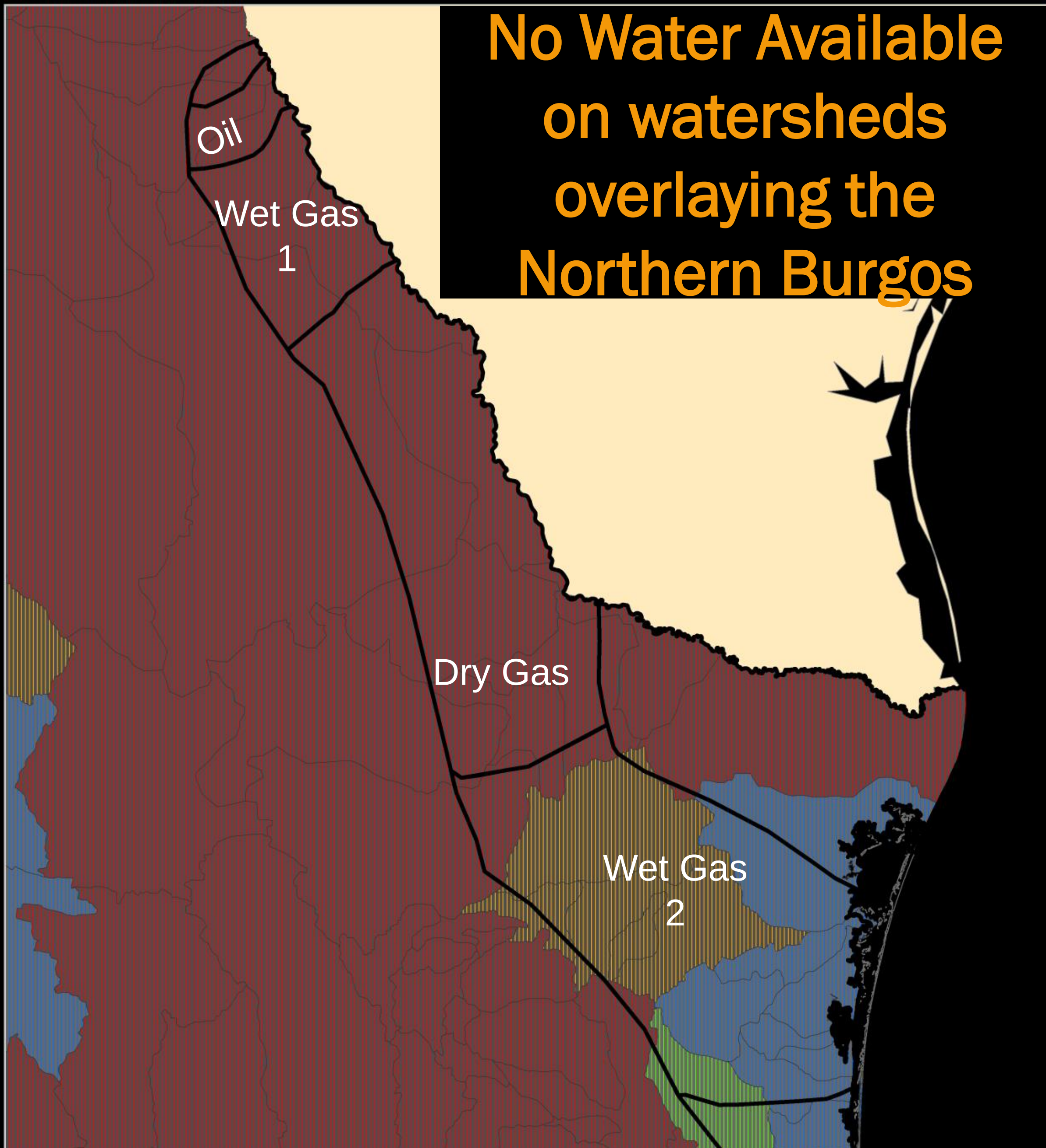
Water available in the system was estimated by overlaying the watersheds and aquifers with the shale resources

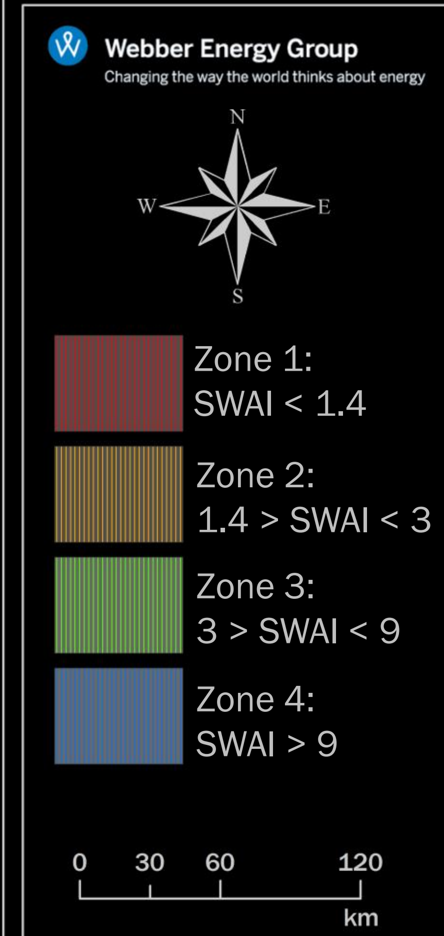


First, the water available from the intersection between watersheds and shale areas is estimated



No Water Available on watersheds overlaying the Northern Burgos





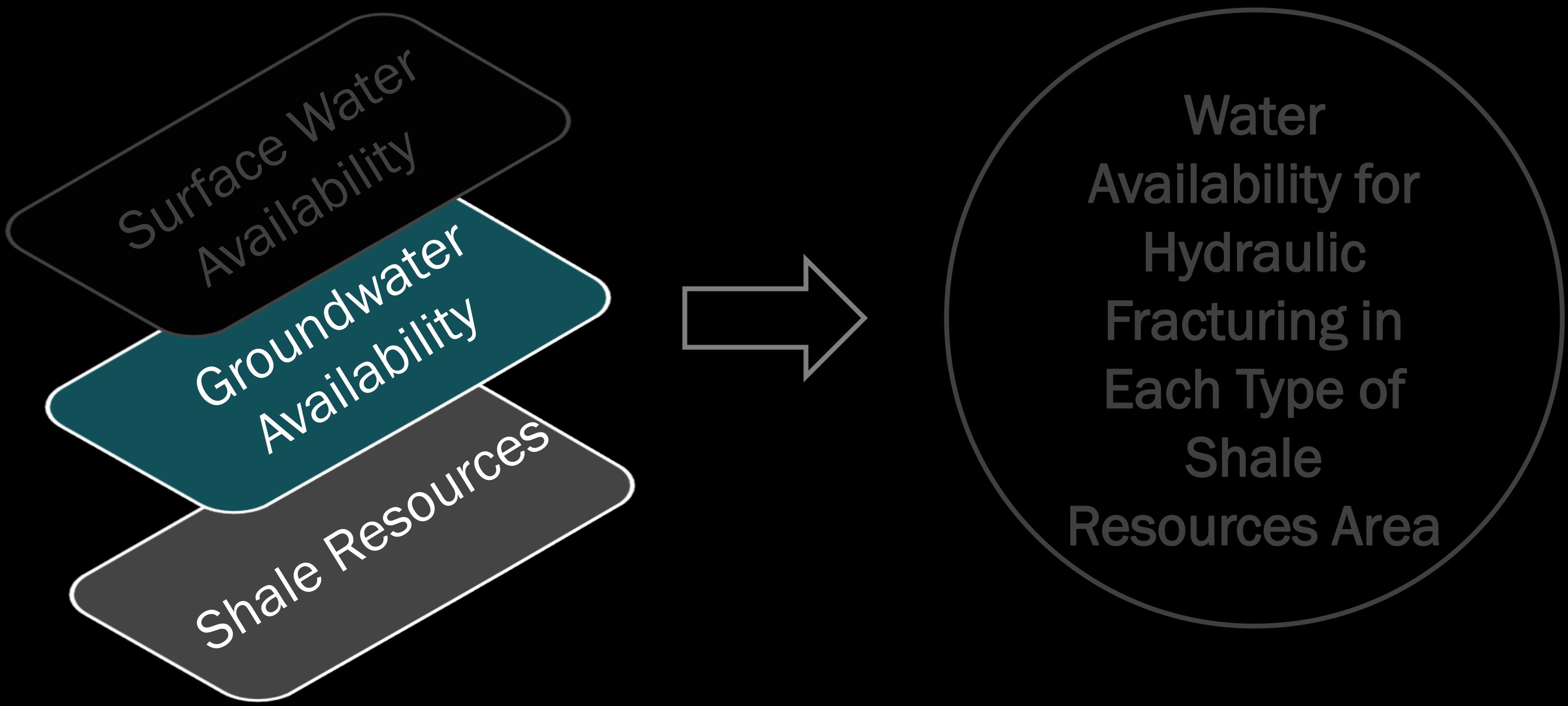
Data from Conagua

The SWAI in each watershed is estimated by dividing its inputs and outputs

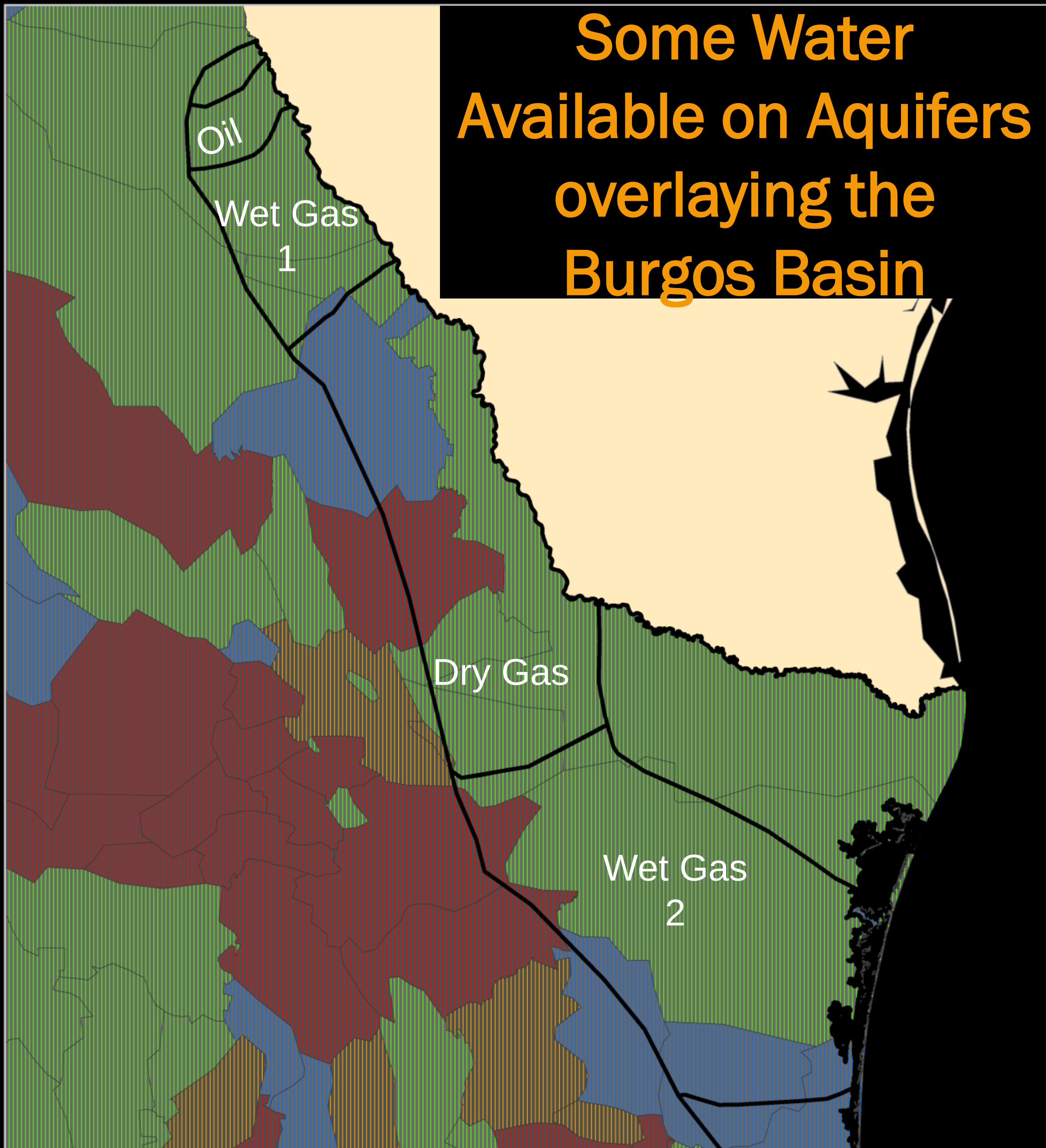
$$SWAI = \frac{Inputs}{Outputs}$$

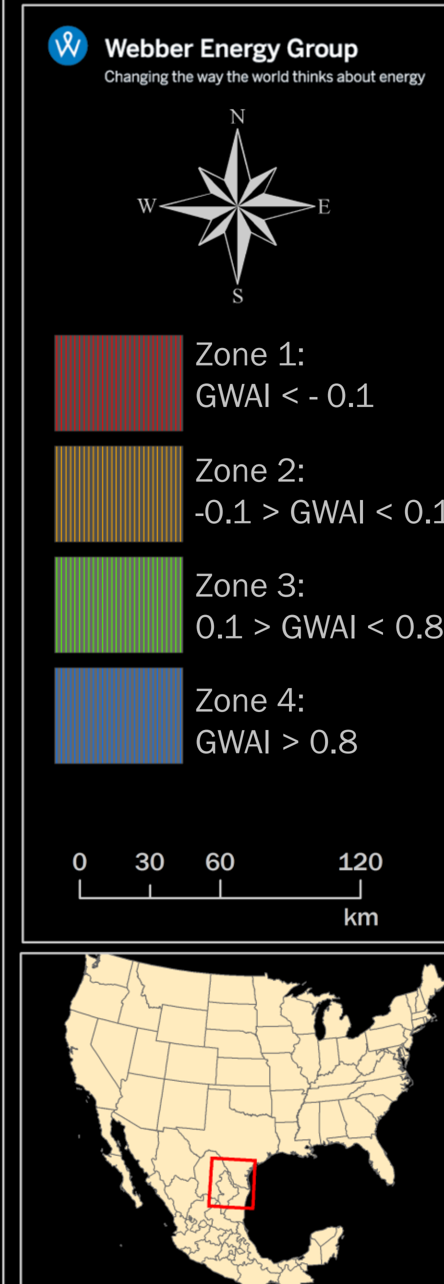
Inputs	Outputs
Natural runoff	Surface water extraction
Runoff from upstream watershed	Exports
Imports	Evaporation
Returns	Water committed to downstream watershed

Second, the water available from the intersection between aquifers and shale areas is estimated



Some Water Available on Aquifers overlaying the Burgos Basin





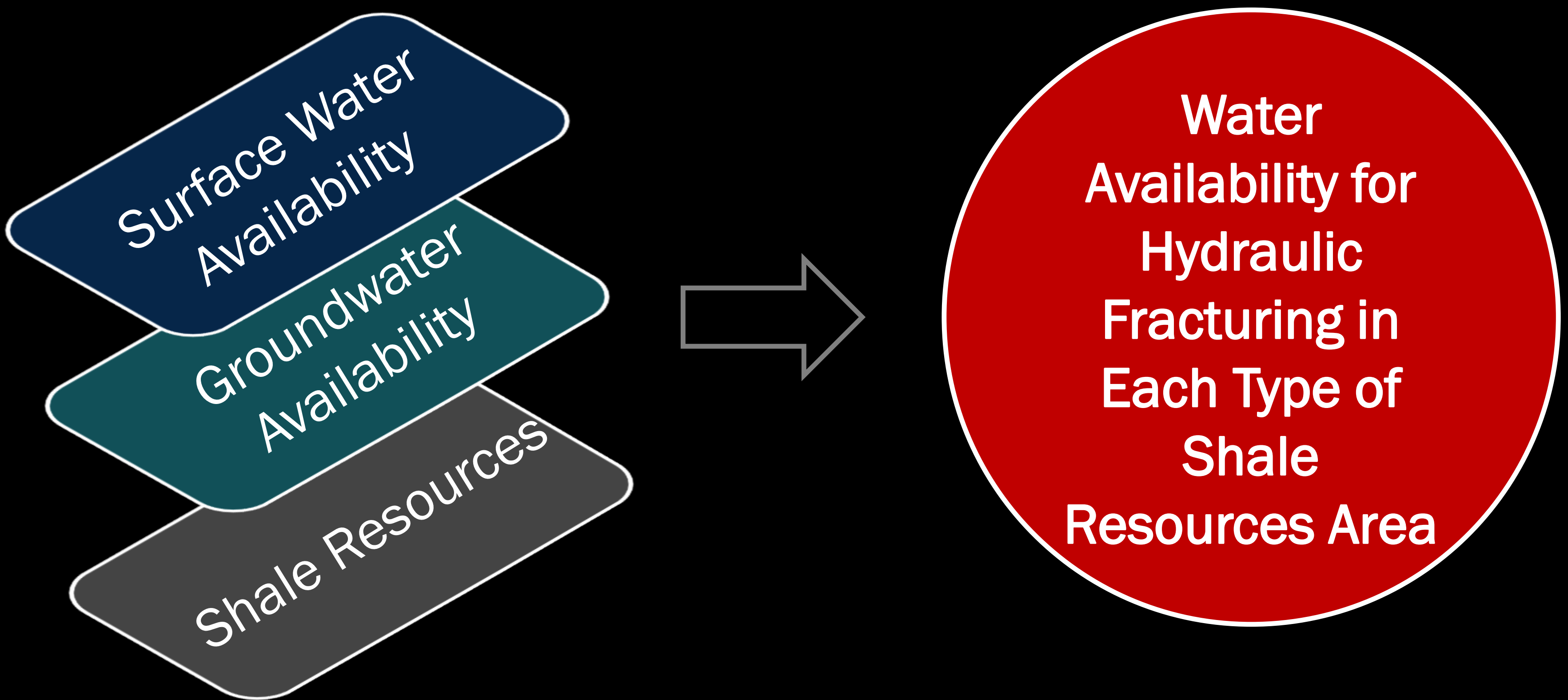
The GWAI in each aquifer is estimated using the GWA, aquifer recharge, and natural committed discharge

$$GWAI = \frac{GWA}{(R - NCD)}$$

Where:
GWAI: Groundwater Availability Index
NCD: Natural Committed Discharge
R: Annual Recharge
GWA: Average Annual Groundwater Available

$$GWA = R - NCD - GW_{permits\,for\,other\,uses}$$

Water availability for HF in each shale area was estimated by overlaying SWA and GWA



The scenarios analyzed are 1) using all water available, and 2) leaving medium-high water availability on watersheds and aquifers

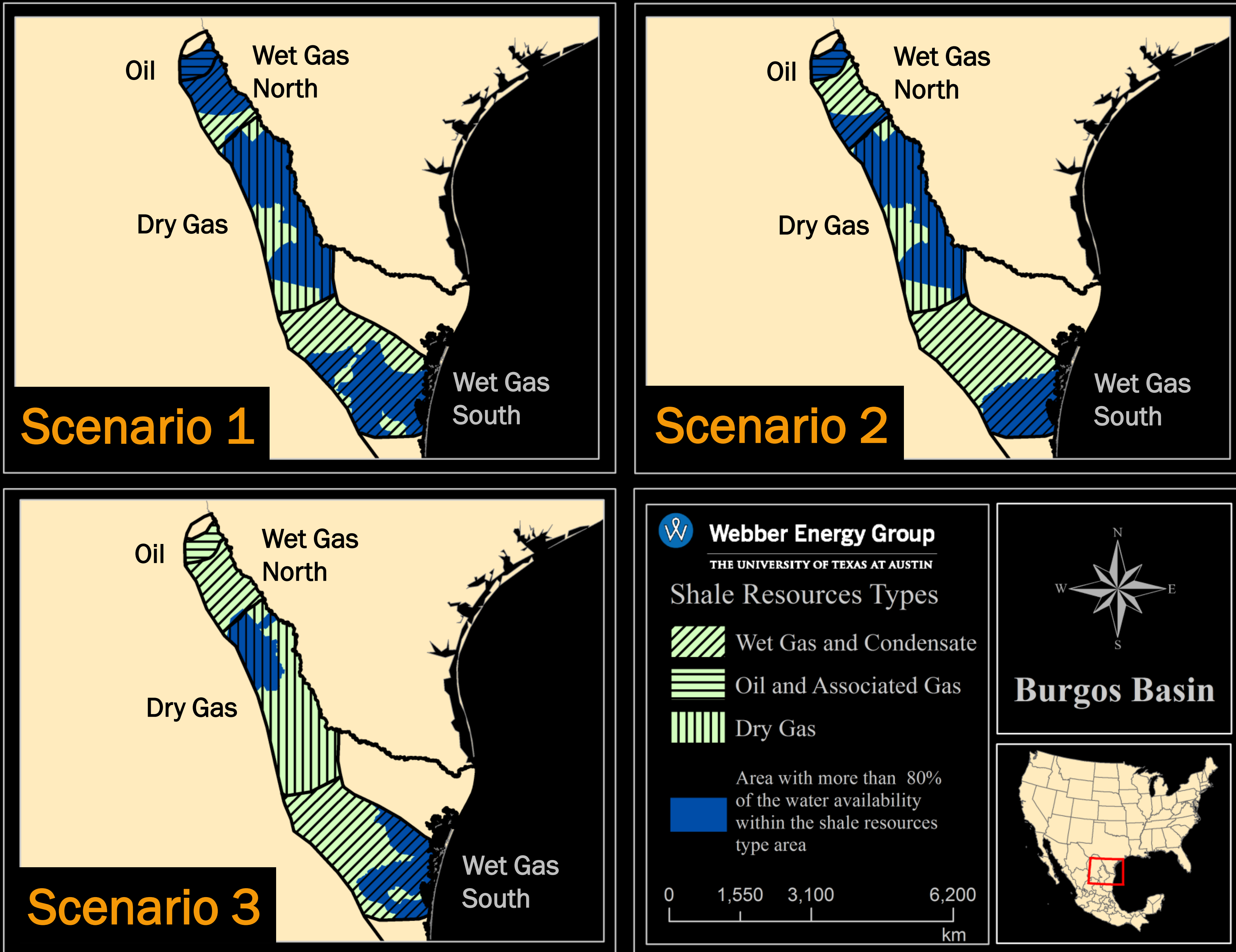
1. Using all water available

2. Leaving watersheds and aquifers in Zone 3

3. Leaving watersheds and aquifers in Zone 4

Results

Location of water available overlaying the shale resources areas

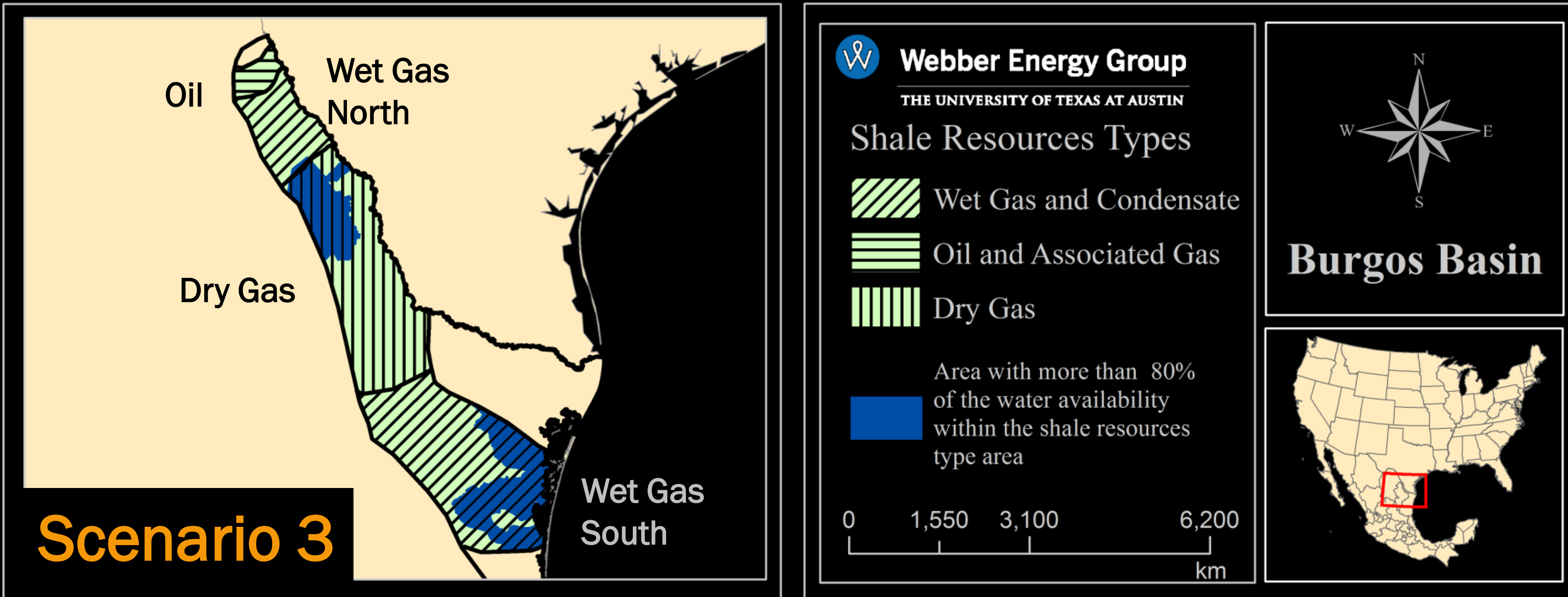

Oil
Wet Gas North
Dry Gas
Wet Gas South
Scenario 1
Oil
Wet Gas North
Dry Gas
Wet Gas South
Scenario 2
Oil
Wet Gas North
Dry Gas
Wet Gas South
Scenario 3
Webber Energy Group
THE UNIVERSITY OF TEXAS AT AUSTIN
Shale Resources Types
Wet Gas and Condensate
Oil and Associated Gas
Dry Gas
Area with more than 80% of the water availability within the shale resources type area
0
1,550
3,100
6,200
km
N
W
E
S
Burgos Basin

Results

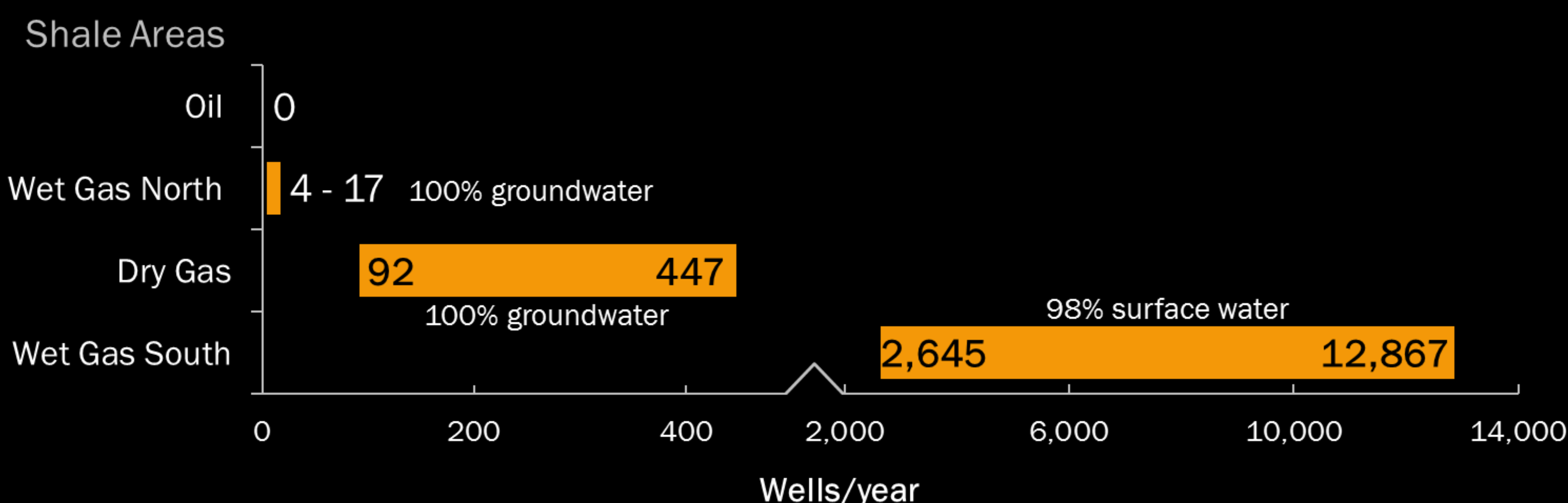
Potential number of wells that could be supplied with water available

Results assuming water used per well for HF in US:

Areas	Low Water Consumption (10^6 gal/well)	High Water Consumption (10^6 gal/well)
Oil	0.82	9
Gas	2.2	10.7



Oil
Wet Gas North
Dry Gas
Wet Gas South
Scenario 3
Webber Energy Group
THE UNIVERSITY OF TEXAS AT AUSTIN
Shale Resources Types
Wet Gas and Condensate
Oil and Associated Gas
Dry Gas
Area with more than 80% of the water availability within the shale resources type area
0
1,550
3,100
6,200
km
N
S
W
E
Burgos Basin



Shale Areas
Oil
0
Wet Gas North
4 - 17
100% groundwater
Dry Gas
92
447
100% groundwater
Wet Gas South
98% surface water
2,645
12,867
0
200
400
2,000
6,000
10,000
14,000
Wells/year

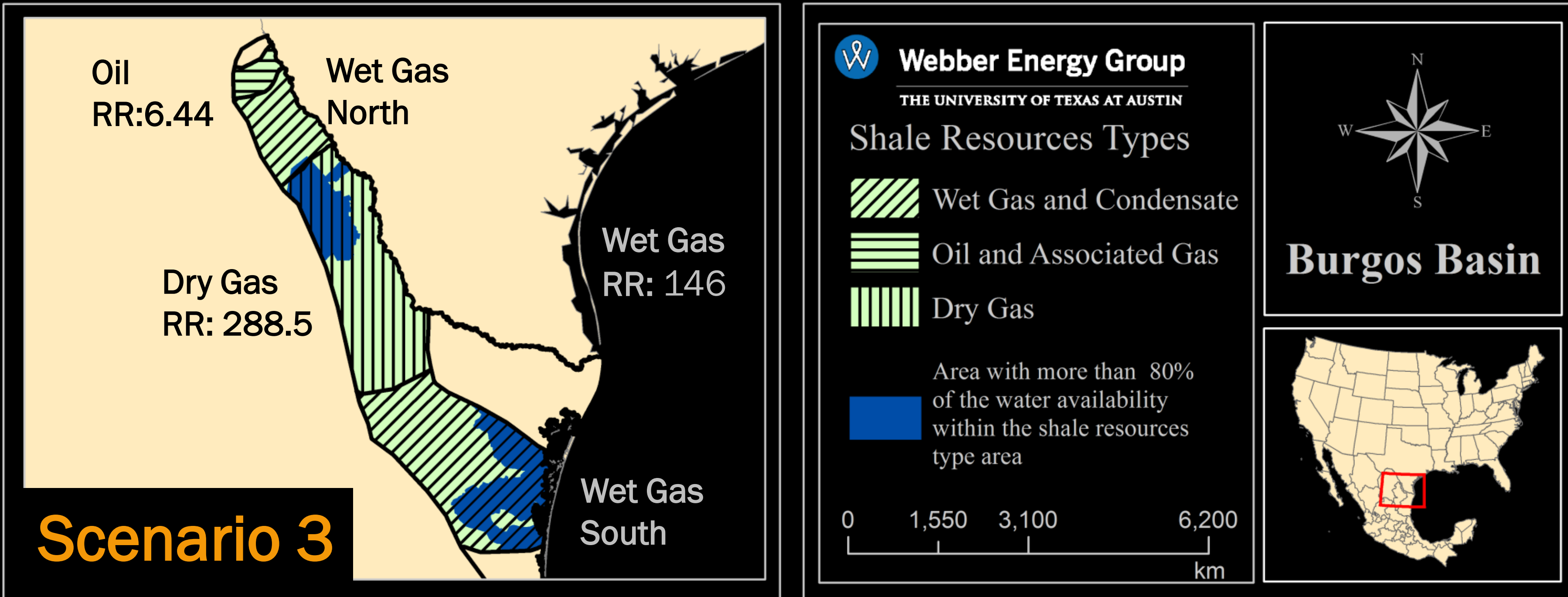
Results

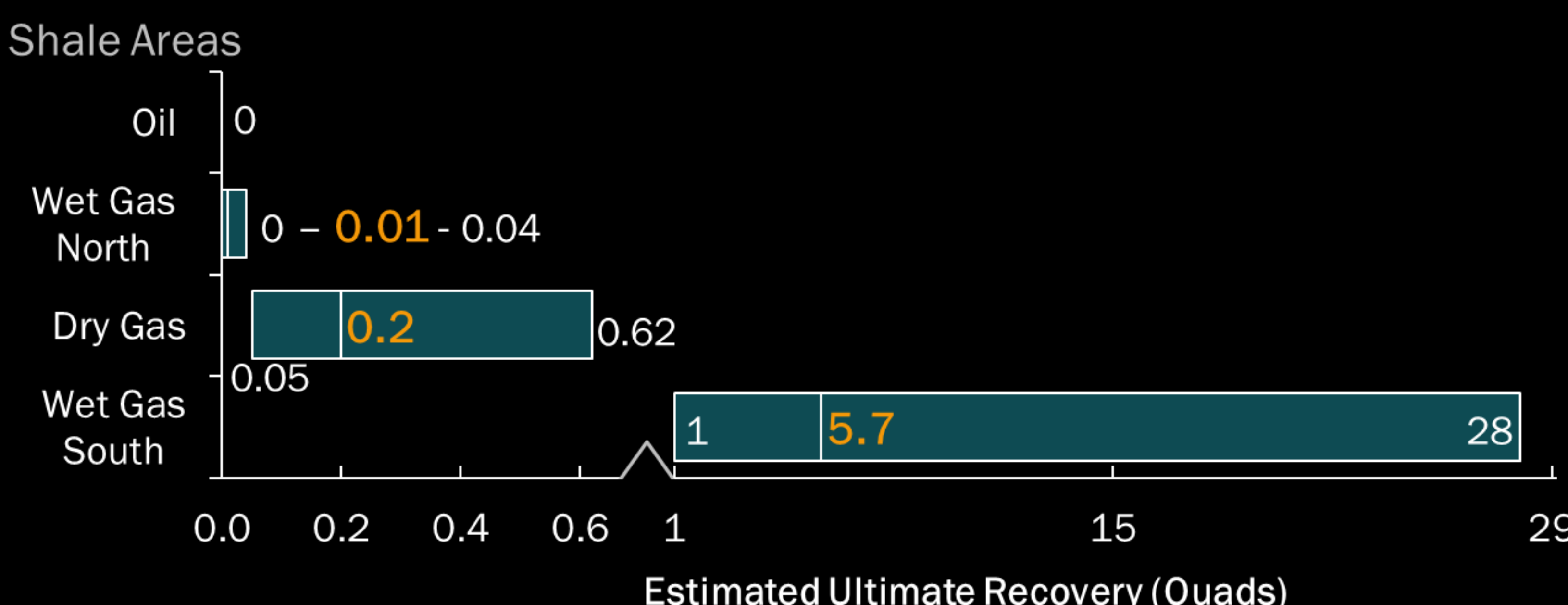
Potential energy to be extracted in the lifetime of wells with the average annual water available in watersheds and aquifers

Results assuming water consumption for HF in US:

Areas	Low (gal/MMBTU)	Average (gal/MMBTU)	High (gal/MMBTU)
Oil Areas	1.6	8.2	21.7
Gas Areas	1	5	28

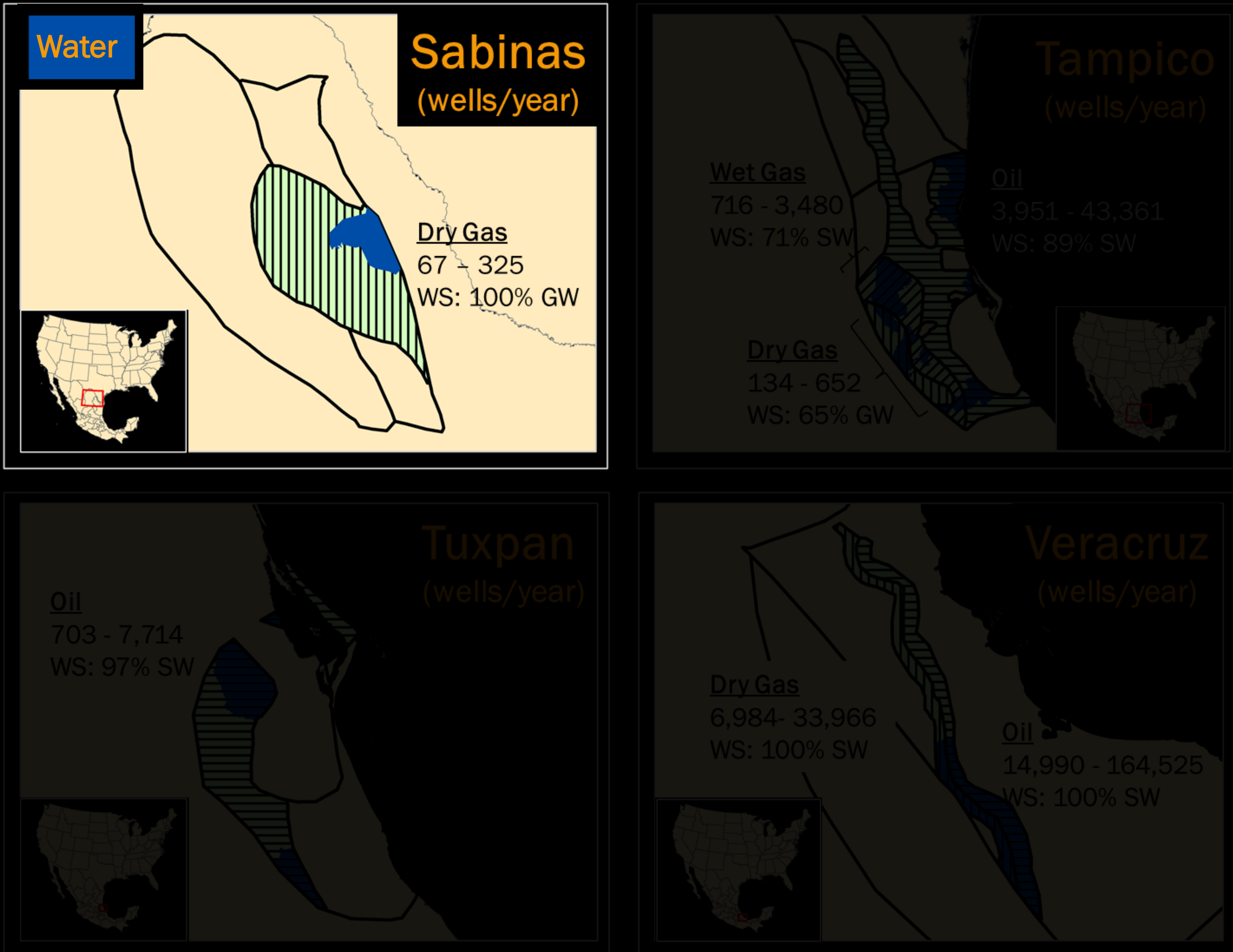
Source: Kuwayama et al. 2015

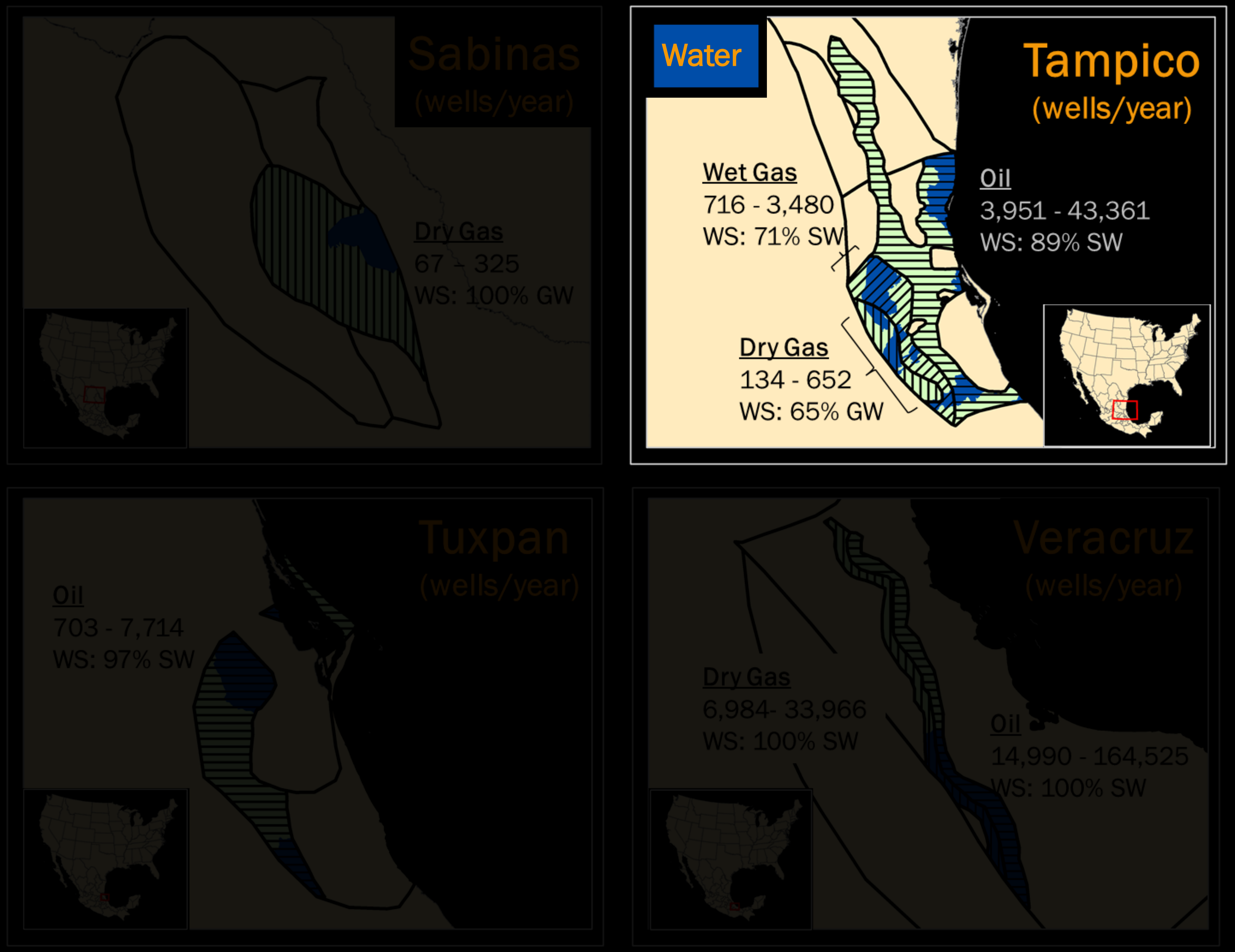

Oil
RR:6.44
Wet Gas
North
Dry Gas
RR: 288.5
Wet Gas
RR: 146
Wet Gas
South
Scenario 3
Webber Energy Group
THE UNIVERSITY OF TEXAS AT AUSTIN
Shale Resources Types
Wet Gas and Condensate
Oil and Associated Gas
Dry Gas
Area with more than 80% of the water availability within the shale resources type area
0
1,550
3,100
6,200
km
N
W
E
S
Burgos Basin


Shale Areas
Oil
0
Wet Gas North
0 – 0.01 - 0.04
Dry Gas
0.2
0.62
0.05
Wet Gas South
1
5.7
28
0.0
0.2
0.4
0.6
1
15
29
Estimated Ultimate Recovery (Quads)

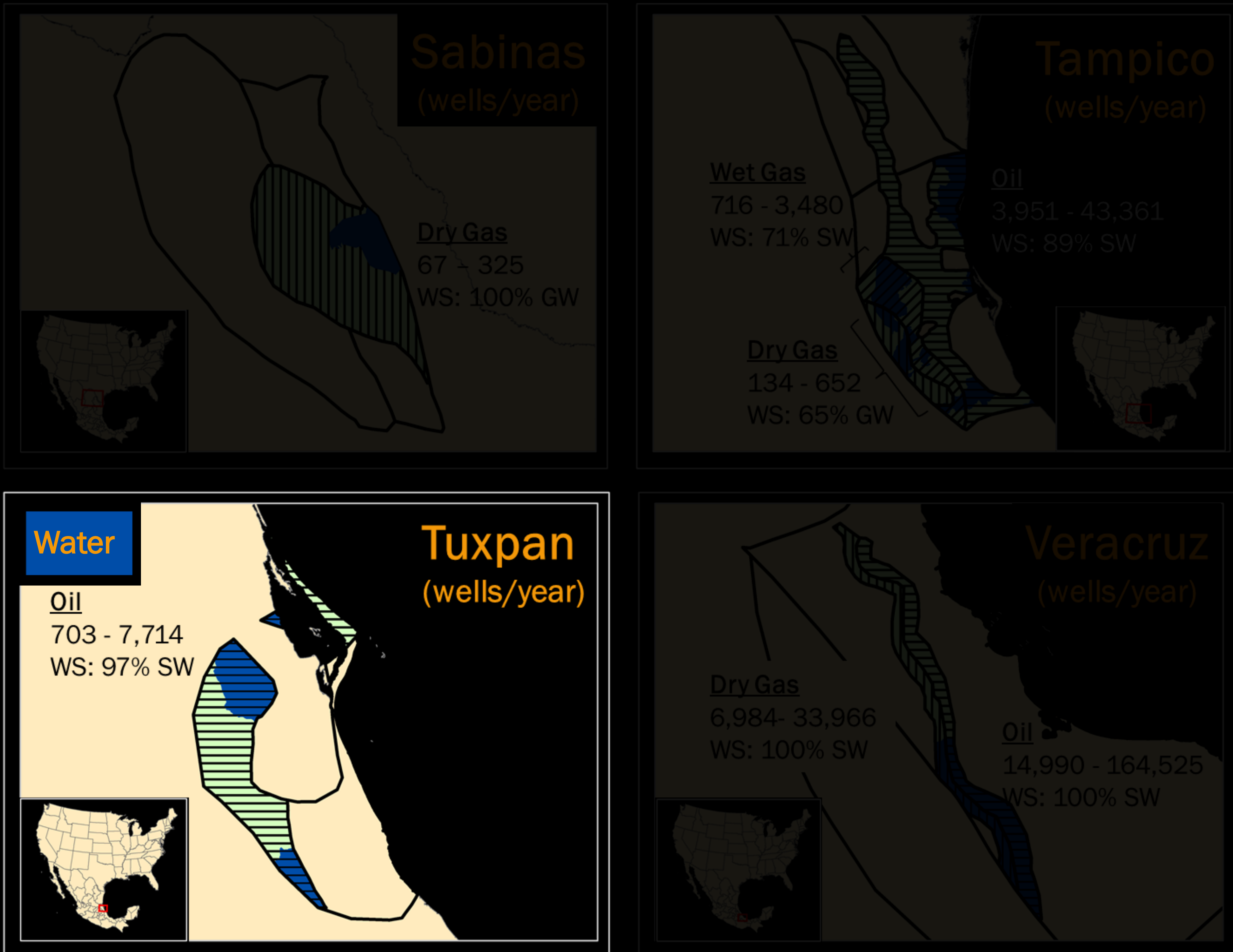
Results

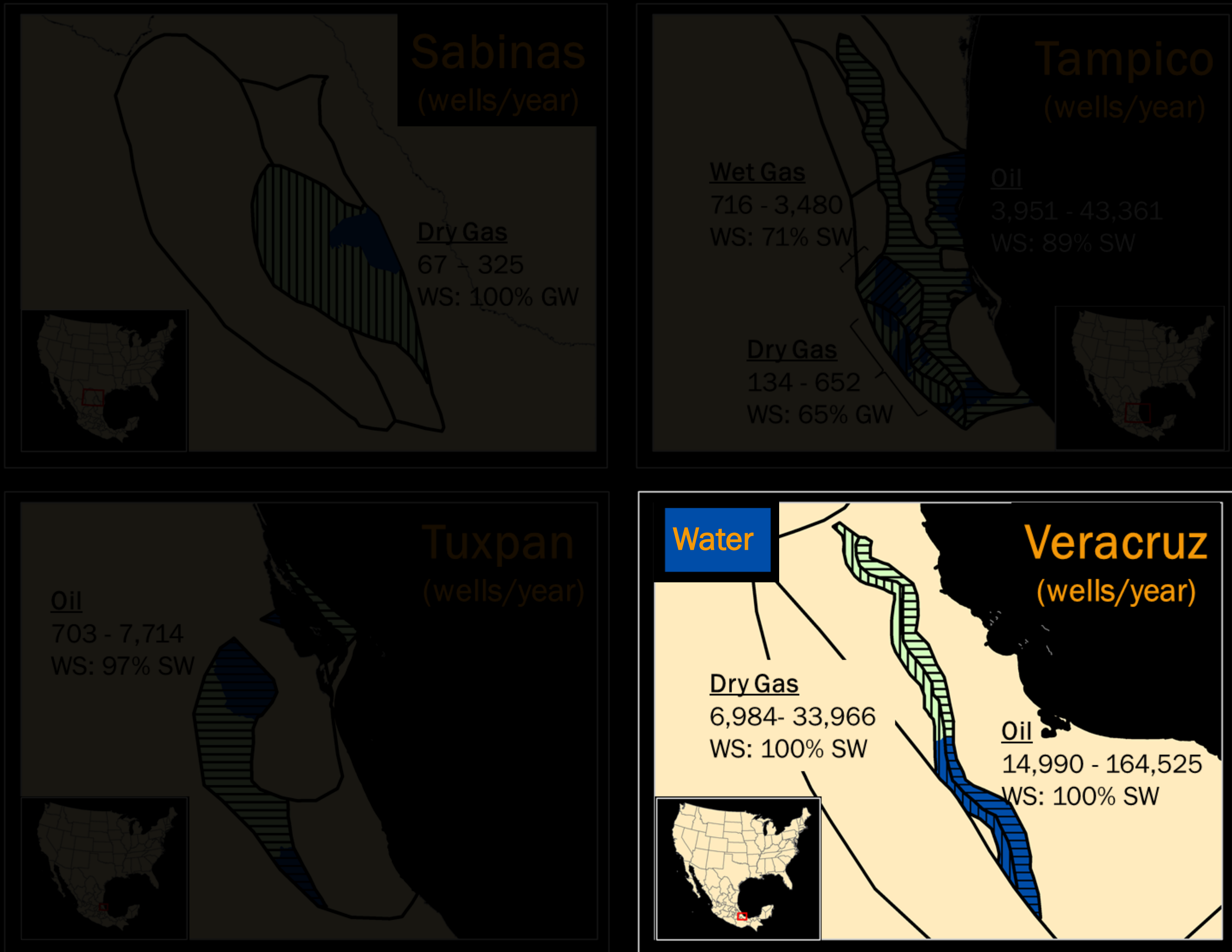
Scenario 3 for the other four shale basins in Mexico


Water
Sabinas
(wells/year)
Dry Gas
67 – 325
WS: 100% GW
Tampico
(wells/year)
Wet Gas
716 - 3,480
WS: 71% SW
Oil
3,951 - 43,361
WS: 89% SW
Dry Gas
134 - 652
WS: 65% GW
Tuxpan
(wells/year)
Oil
703 - 7,714
WS: 97% SW
Veracruz
(wells/year)
Dry Gas
6,984- 33,966
WS: 100% SW
Oil
14,990 - 164,525
WS: 100% SW



Sabinas
(wells/year)
Dry Gas
67 - 325
WS: 100% GW
Water
Tampico
(wells/year)
Wet Gas
716 - 3,480
WS: 71% SW
Oil
3,951 - 43,361
WS: 89% SW
Dry Gas
134 - 652
WS: 65% GW
Tuxpan
(wells/year)
Oil
703 - 7,714
WS: 97% SW
Veracruz
(wells/year)
Dry Gas
6,984- 33,966
WS: 100% SW
Oil
14,990 - 164,525
WS: 100% SW


Sabinas
(wells/year)
Dry Gas
67 - 325
WS: 100% GW
Tampico
(wells/year)
Wet Gas
716 - 3,480
WS: 71% SW
Oil
3,951 - 43,361
WS: 89% SW
Dry Gas
134 - 652
WS: 65% GW
Water
Tuxpan
(wells/year)
Oil
703 - 7,714
WS: 97% SW
Veracruz
(wells/year)
Dry Gas
6,984- 33,966
WS: 100% SW
Oil
14,990 - 164,525
WS: 100% SW



Sabinas
(wells/year)
Dry Gas
67 - 325
WS: 100% GW
Tampico
(wells/year)
Wet Gas
716 - 3,480
WS: 71% SW
Oil
3,951 - 43,361
WS: 89% SW
Dry Gas
134 - 652
WS: 65% GW
Tuxpan
(wells/year)
Oil
703 - 7,714
WS: 97% SW
Water
Veracruz
(wells/year)
Dry Gas
6,984- 33,966
WS: 100% SW
Oil
14,990 - 164,525
WS: 100% SW

On average, an EUR of 18 quads could be extracted (7% of Mexico's energy consumption in the next 30 years)

Three main takeaways from this analysis

1. Almost no water available in areas with more Shale Resources in Mexico
2. Areas closer to the Gulf of Mexico have more water available
3. Different strategies need to be analyzed to increase water availability in regions overlaying shale resources areas

Three main takeaways from this analysis

1. Almost no water available in areas with more Shale Resources in Mexico
2. Areas closer to the Gulf of Mexico have more water available
3. Different strategies need to be analyzed to increase water availability in regions overlaying shale resources areas

Three main takeaways from this analysis

1. Almost no water available in areas with more Shale Resources in Mexico
2. Areas closer to the Gulf of Mexico have more water available
3. Different strategies need to be analyzed to increase water availability in regions overlaying shale resources areas

Acknowledgments

- CONACyT, Banxico , The Cynthia & George Mitchell Foundation, and Osborne-Green endowment
- Dr. Webber and Margaret Cook
- Webber Energy Group
- Conagua

Carlos Galdeano

PhD Candidate

Civil Engineering

Cockrell School of Engineering

cgaldeano@utexas.edu

www.webberenergygroup.com

Webber Energy Group

THE UNIVERSITY OF TEXAS AT AUSTIN

Extra slides

Webber Energy Group

THE UNIVERSITY OF TEXAS AT AUSTIN

The alternatives analyzed are 1) using all water available, and 2) leaving high water availability on watersheds

1) Using all SWA

$$x = Inputs - Outputs$$

2) Using some SWA, leaving the SWAI > 3 (Zone 3)

$$SWAI = \frac{Inputs}{Outputs + x} \rightarrow x = \frac{Inputs}{SWAI = 3} - Outputs$$

3) Using some SWA, leaving the SWAI > 9 (Zone 4)

$$SWAI = \frac{Inputs}{Outputs + x} \rightarrow x = \frac{Inputs}{SWAI = 9} - Outputs$$

The alternatives analyzed are 1) using all water available, and 2) leaving high water availability on aquifers

1) Using all GWA

$$GWA = R - NCD - GW_{permits\,for\ other\ uses}$$

2) Using some GWA, leaving the GWAI > 0.1 (Zone 3)

$$x = GWA - 0.1\,(R - NCD)$$

3) Using some GWA, leaving the GWAI > 0.8 (Zone 4)

$$x = GWA - 0.8\,(R - NCD)$$