

A Comparison of the Salar de
Atacama and Clayton Valley
Lithium Ore Deposits:
Groundwater Mining in the some of
the Driest Places on Earth

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Introduction

- Water Laws in Chile
- Water situation in Chile
- Groundwater mining and lithium
- Comparison of Clayton Valley (CV) and Salar de Atacama (SDA) lithium brine mines
 - Surface water, groundwater and geology
 - Wells and Infrastructure
 - Inflows & ground water management
- Conclusion



Water Authority

- General Water Board (DGA) (DWR-US Equivalent)
 - Plan for the development of water resources and make recommendations for better management
 - Assign rights of water use, and research and measure water resources
 - Co-ordinate public sector research programs and partially publicly funded private initiatives
 - Supervise the use of public waters
 - Supervise the work of local regulatory bodies



Water laws in Chile

Water Law of 1981

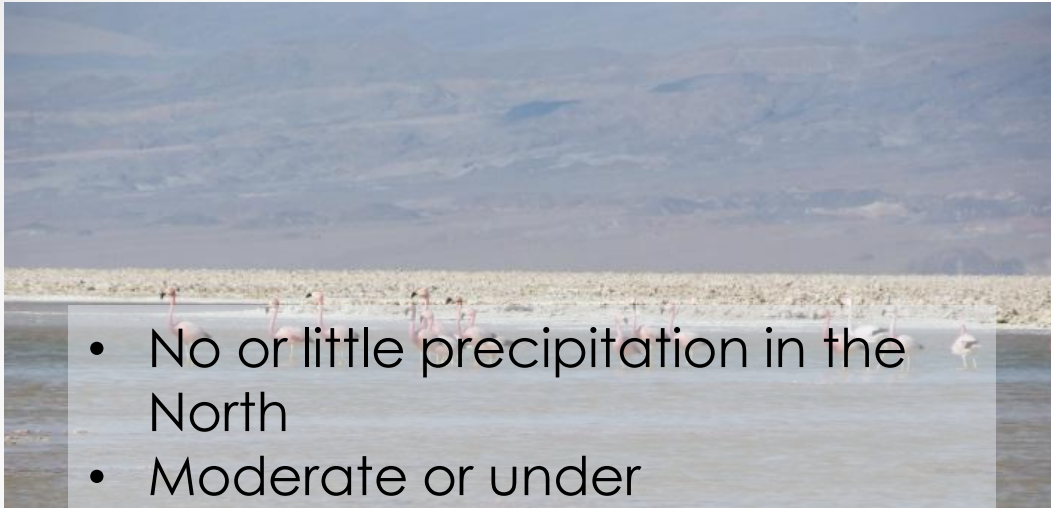
- Administered by DGA
- Established water resources as public assets
- Created a water market
- Water rights may be granted to individuals, companies
- Water rights can be sold, traded, inherited, etc...
- Limits power of State to intervene on management of the resource
- Applies to surface or groundwater

Reformation of 2005

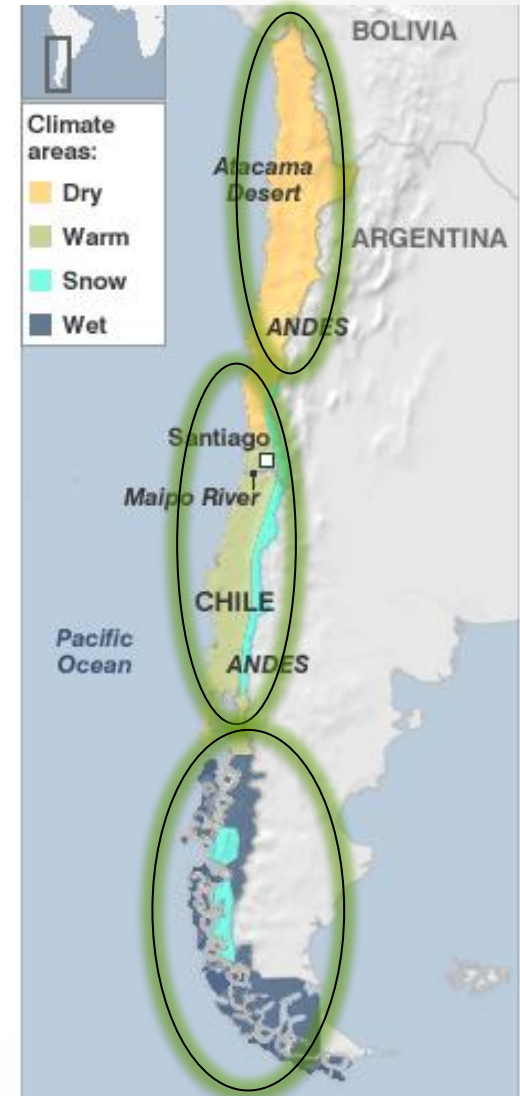
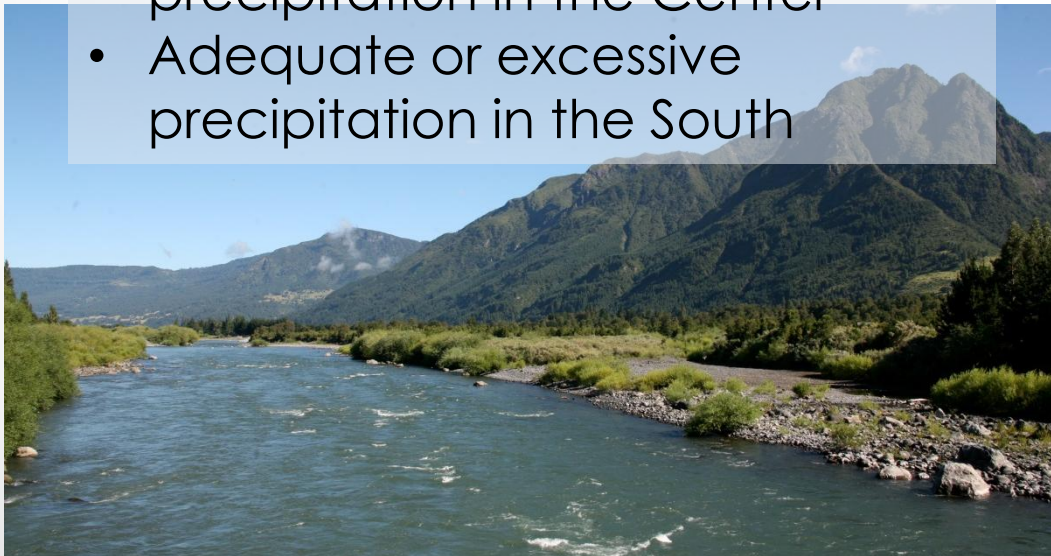
- Focused on establishing flow restrictions to an ecological minimum
- Allowed for creating a reserve, respecting need, and established a fee for non-use, and obligational reporting



Chile Water Situation



- No or little precipitation in the North
- Moderate or under precipitation in the Center
- Adequate or excessive precipitation in the South



Groundwater Mining & Lithium



Lithium

Li

6.941

Lithium

hydrogen 1 H 1.0079																	helium 2 He 4.0026														
lithium 3 Li 6.941	beryllium 4 Be 9.0122																	boron 5 B 10.811	carbon 6 C 12.011	nitrogen 7 N 14.007	oxygen 8 O 15.999	fluorine 9 F 18.998	neon 10 Ne 20.180								
sodium 11 Na 22.990	magnesium 12 Mg 24.305																	aluminum 13 Al 26.982	silicon 14 Si 28.086	phosphorus 15 P 30.974	sulfur 16 S 32.065	chlorine 17 Cl 35.453	argon 18 Ar 39.948								
potassium 19 K 39.098	calcium 20 Ca 40.078	scandium 21 Sc 44.956	titanium 22 Ti 47.867	vanadium 23 V 50.942	chromium 24 Cr 51.996	manganese 25 Mn 54.938	iron 26 Fe 55.845	cobalt 27 Co 58.933	nickel 28 Ni 58.693	copper 29 Cu 63.546	zinc 30 Zn 65.39	gallium 31 Ga 69.723	germanium 32 Ge 72.61	arsenic 33 As 74.922	selenium 34 Se 78.96	bromine 35 Br 79.904	krypton 36 Kr 83.80														
rubidium 37 Rb 85.468	strontium 38 Sr 87.62	yttrium 39 Y 88.906	zirconium 40 Zr 91.224	niobium 41 Nb 92.906	molybdenum 42 Mo 95.94	technetium 43 Tc [98]	ruthenium 44 Ru 101.07	rhodium 45 Rh 102.91	palladium 46 Pd 106.42	silver 47 Ag 107.87	cadmium 48 Cd 112.41	indium 49 In 114.82	tin 50 Sn 118.71	antimony 51 Sb 121.76	tellurium 52 Te 127.60	iodine 53 I 126.90	xenon 54 Xe 131.29														
cesium 55 Cs 132.91	barium 56 Ba 137.33	lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04	lutetium 71 Lu 174.967	hafnium 72 Hf 178.49	tantalum 73 Ta 180.95	tungsten 74 W 183.84	rhenium 75 Re 186.21	osmium 76 Os 190.23	iridium 77 Ir 192.22	platinum 78 Pt 195.08	gold 79 Au 196.97	mercury 80 Hg 200.59	thallium 81 Tl 204.38	lead 82 Pb 207.2	bismuth 83 Bi 208.98	polonium 84 Po [209]	astatine 85 At [210]	radon 86 Rn [222]
francium 87 Fr [223]	radium 88 Ra [226]	actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]	unnilium 110 Uun [271]	ununium 111 Uuu [272]	unbinium 112 Uub [273]	ununseptium 114 Uuq [289]												

*Lanthanide series

lanthanum 57 La 138.91	cerium 58 Ce 140.12	praseodymium 59 Pr 140.91	neodymium 60 Nd 144.24	promethium 61 Pm [145]	samarium 62 Sm 150.36	europium 63 Eu 151.96	gadolinium 64 Gd 157.25	terbium 65 Tb 158.93	dysprosium 66 Dy 162.50	holmium 67 Ho 164.93	erbium 68 Er 167.26	thulium 69 Tm 168.93	ytterbium 70 Yb 173.04
actinium 89 Ac [227]	thorium 90 Th 232.04	protactinium 91 Pa 231.04	uranium 92 U 238.03	neptunium 93 Np [237]	plutonium 94 Pu [244]	americium 95 Am [243]	curium 96 Cm [247]	berkelium 97 Bk [247]	californium 98 Cf [251]	einsteinium 99 Es [252]	fermium 100 Fm [257]	mendelevium 101 Md [258]	nobelium 102 No [259]

** Actinide series

What is lithium?

- Lithium is a soft, pale, white metal that belongs to the alkali metal group of chemical elements
- Lithium metal does not occur naturally in the environment
- Lithium is found as lithium chloride in aquifers of the Clayton Valley and halite aquifers of the Salar de Atacama

Clayton Valley Lithium brine mining

- Lithium in groundwater first discovered in 1950s by Leprechaun Mining
- Foote Mineral purchased land
- 1967 First Li_2CO_3 produced
- Rockwood Lithium Inc. operates the Clayton Valley lithium brine extraction facility at Silver Peak, NV

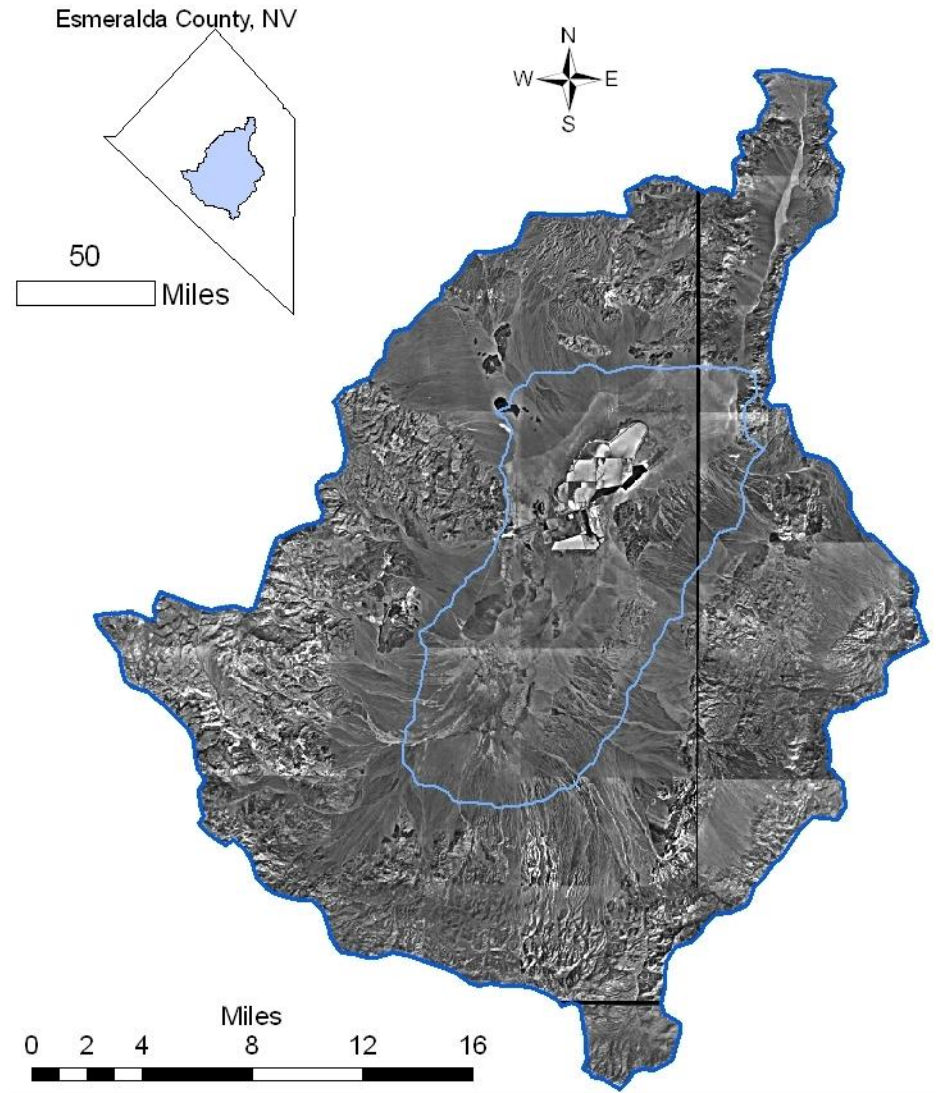


Water in Clayton Valley



Groundwater at Clayton Valley

- Closed basin
- Basin area 1342 km²
(518 sq mi)
- Playa area 78 km²
(30 sq mi)
- Playa elevation 1300 m
- Arid region in rain shadow of Sierra Nevada
- Precipitation 3.6-17.5 cm
Average 8.9 cm(3.5")
- Evaporation 45-161 cm
Average 147 cm(58")
- Mean average temperature 10.5C (51F)



Geology & Groundwater

- Partial graben structure
- Fault bounded-controls recharge to basin
 - Paymaster Fault
 - Cross Central Fault
 - Angel Island Fault
- Main recharge from Smoky Valley - north
- Ash, gravel, halite aquifers host lithium deposit
- Evaporation and EVT at borders



SDA Lithium Brine Mining



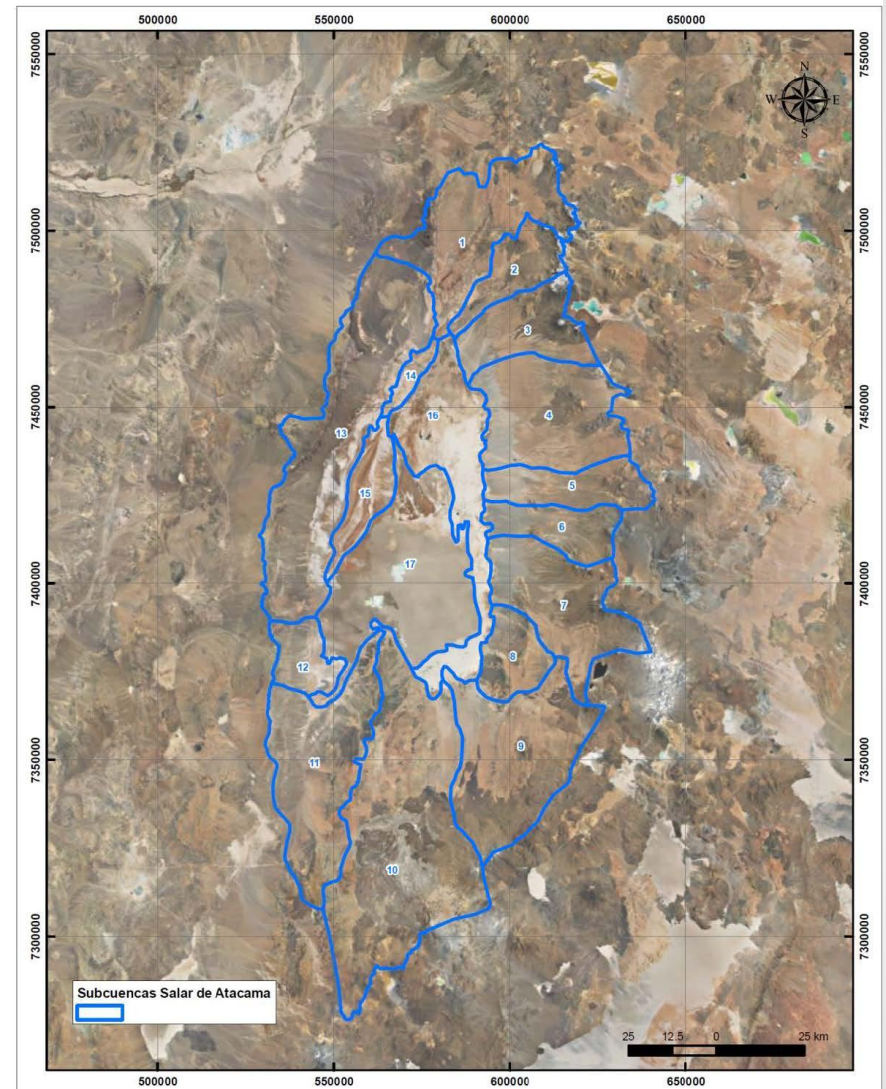
- Lithium discovered in 1970s
- Sociedad Chilena de Litio company was constituted 1980
- The first concentrated brine production was in 1984
- La Negra production facility first produced lithium carbonate in

Water in Atacama



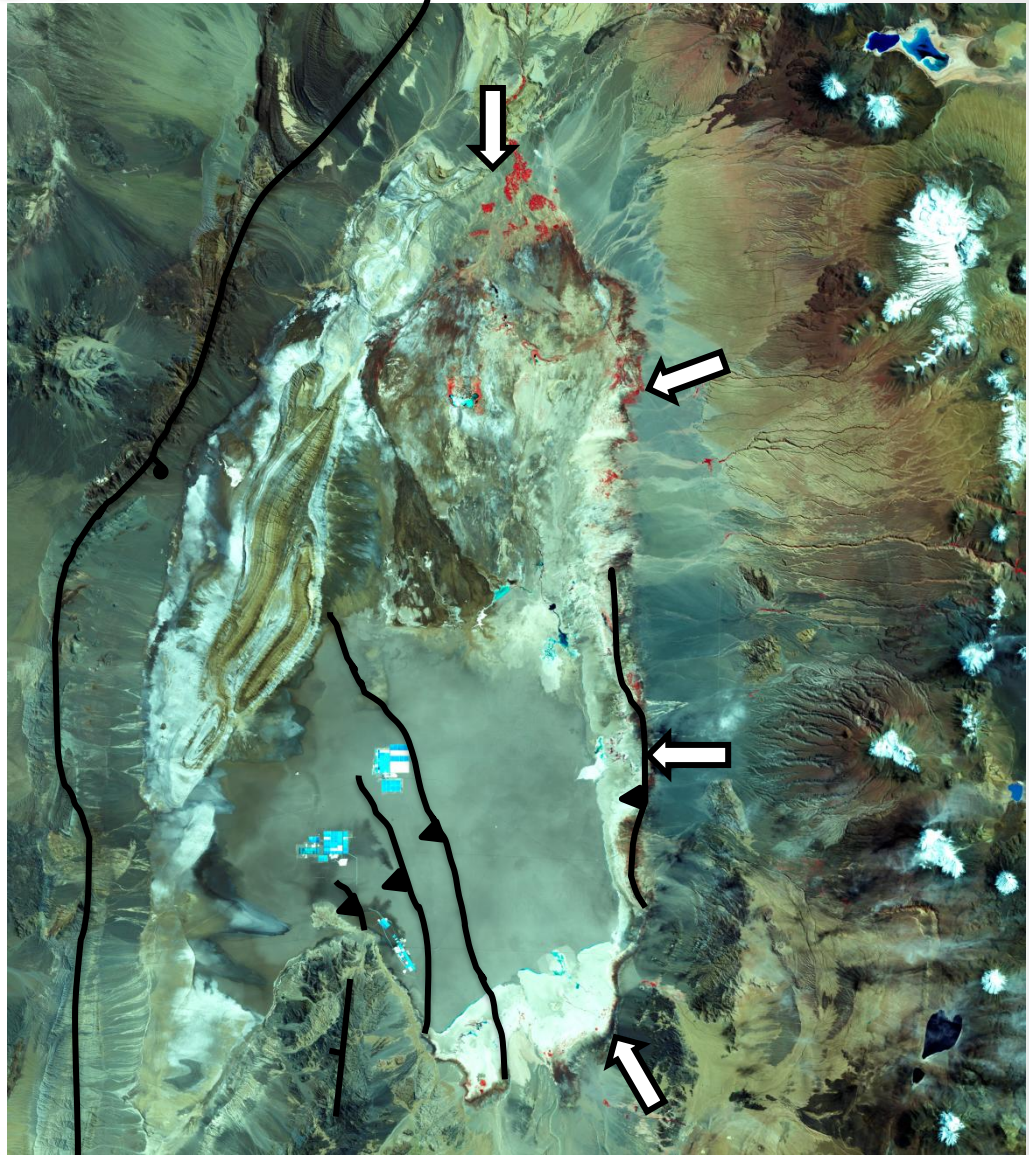
Groundwater at SDA

- Closed basin with multiple sub basins
- Basin area 18,100 km²
(7000 sq mi)
- Playa area 2,017 km²
(779 sq mi)
- Salar elevation 2300 m
- Hyper arid region
- Precipitation 0 to 20 mm/y
- Evaporation 70-200 cm/y
- Mean temperature 14C
(57F)
- Recharge rate 125,000AF/y
- Groundwater pumping
- Water rights over-extended



SDA Geology & Groundwater

- Active faulting
- Compressional basin
- Rio San Pedro to North
- Main inputs on east side
- Halite aquifer hosts lithium deposit
- Climate controlled recharge
- Recharge reaches periphery and dissolves halite
- Evaporation and EVT at borders



CV Wells & Infrastructure



SDA Wells & Infrastructure



Theoretical Basin Inflows

CLAYTON VALLEY INFLOWS AND OUTFLOW

Weepah Hills+Paymaster Ridge
1800 acre-ft/yr

Big Smoky Valley
13,000 acre-ft/yr

Alkali Valley
5000 acre-ft/yr

Green blocks
indicate interbasin
underflow

Blue blocks
indicate intrabasin
inflow

Palmetto Mountains
+Montezuma+Silver Peak
Range
35 acre-ft/yr

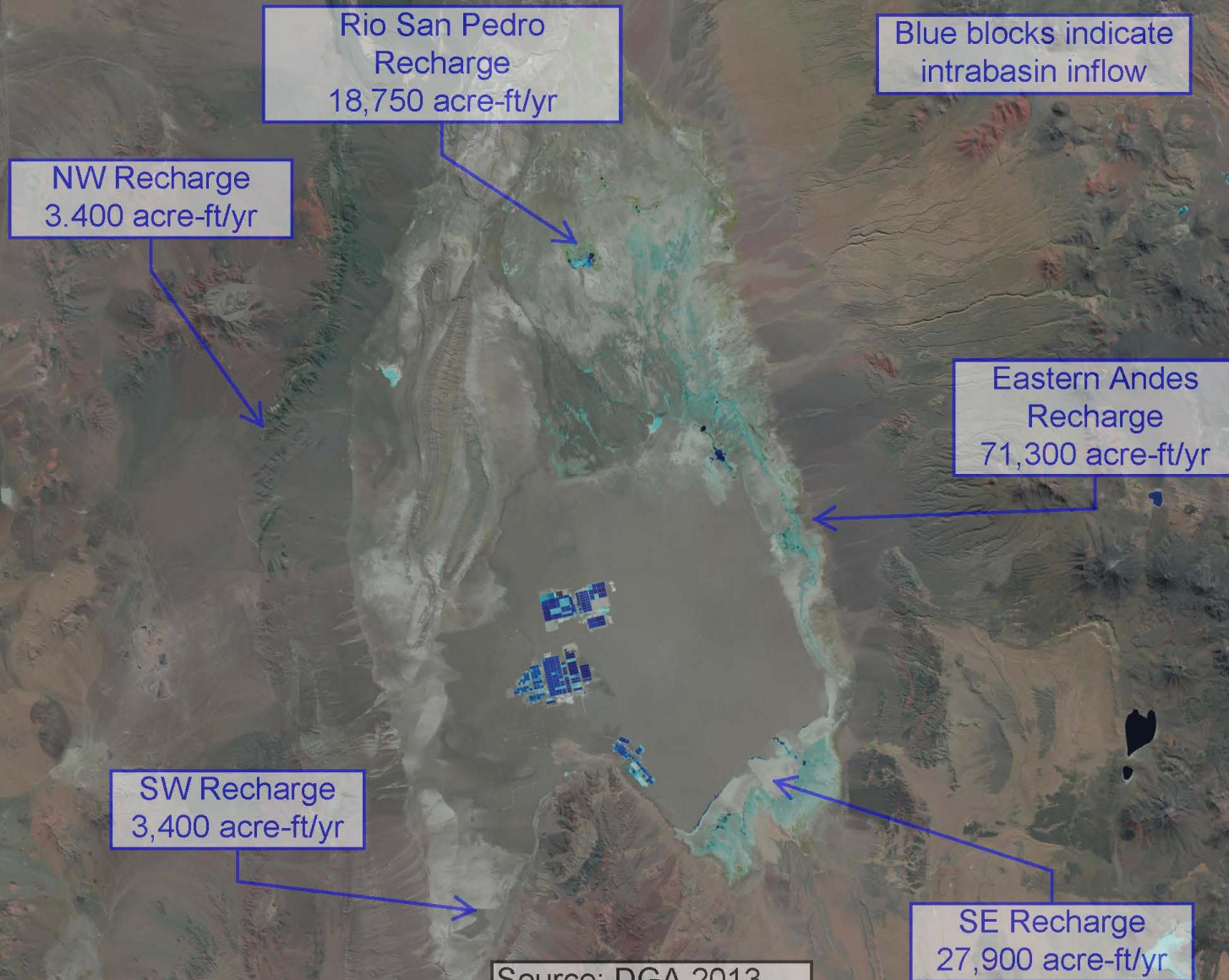
Taken from Rush, 1968

Image © 2010 DigitalGlobe
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Google

Theoretical Basin Inflows

SALAR DE ATACAMA INFLOWS



Conclusion

Comparison of Clayton Valley (CV) and Salar de Atacama (SDA)

- Similarities

- Closed basins, high altitude, non-potable water
- Low precipitation, high evaporation, moderate temperatures
- Methodology and process time

- Differences

- Size and scale
- Recharge rate rates
- Infrastructure and logistics
- Management strategies

