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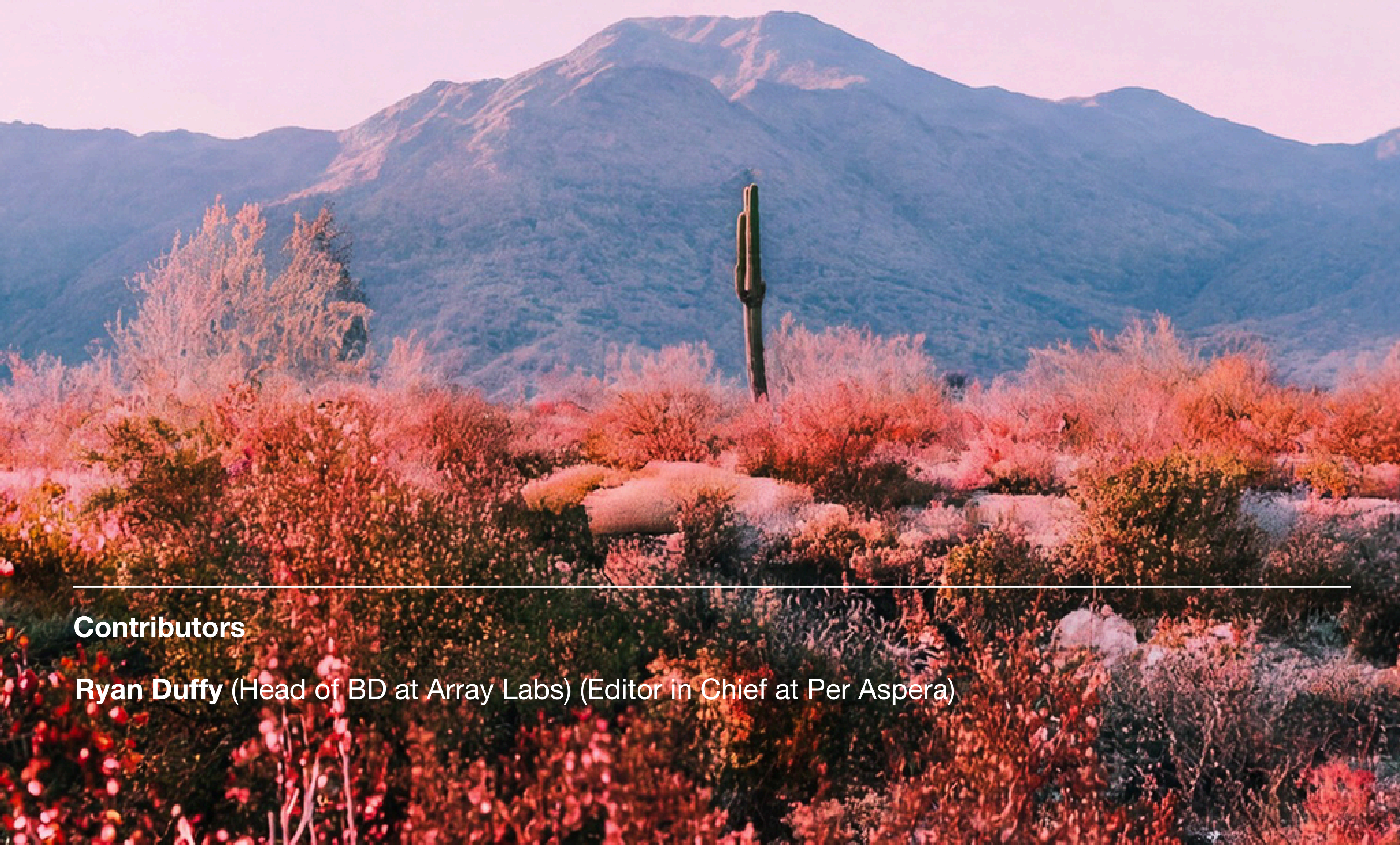
**Per Aspera — Antimemo**

# THE END OF THIRST TRAPS

*The Southwest Is Running Dry. Conservation Won't Fix It. Engineering Can.*



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INTRODUCTION

# REHYDRATING THE AMERICAN SOUTHWEST

There's been no shortage of op-eds framing the Southwest's crisis as a morality tale: conserve more, grow less, accept decline. What's been missing is a serious proposal to flip the script — not by shuffling scarcity, but by engineering abundance. This antimemo isn't a sermon or a slogan. It's a blueprint. For what it would take, physically and financially, to swap sunlight and seawater for a future that can keep growing.

The old pact of the West — endless growth, endless water, endless power — is unraveling beneath an unforgiving sky.

The American Southwest stands on the brink of a full-blown water crisis, as decades of overdrawn rivers and aquifers and explosive urban growth expose the limits of a century-old system built for a wetter, smaller world. Flows from the almighty Colorado River have dropped by about 20% since the turn of the century, and across the river basin, reservoirs register historic lows. Case in point: America's two largest reservoirs are barely clinging to a third of their capacity...

Yet this is not an elegy for a dying desert. It is a call to arms, and a reminder that scarcity, defeatism, and managed decline are a choice. If we refuse to settle for rationing and retreat, we can deploy the very forces that built Hoover Dam — and deploy a solution that matches the scale of the American Southwest's needs.

This antimemo lays out the only path forward: a desert-scale machine that trades photons for fresh water, degrowth for surplus, and half a century of drought fatalism for a future that honors the West's legacy of abundance, reinvention, and rugged resiliency. This new 21st-century megaproject channels the same pioneering spirit that blasted railroad tunnels through granite peaks, spanned canyons with steel-cabled bridges, and turned arid frontier into thriving cities against all odds.

SECTION 001

# THE SOUTHWEST'S WATER RECKONING

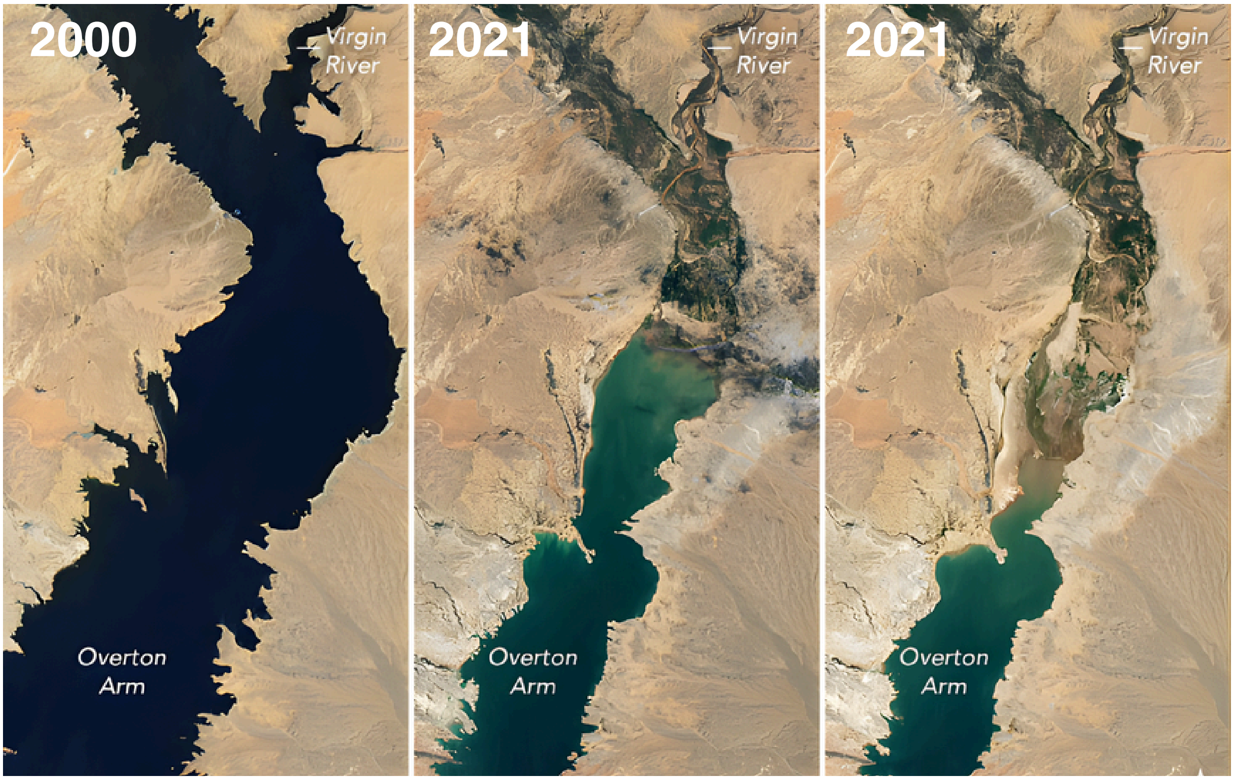
A blistering Sonoran sun warps the All-American Canal's concrete bed outside Yuma, its channels gouged by plummeting flows. In Phoenix, planners scrub through forecasts that warn of a 35% cut in Central Arizona Project allocations by 2035 — and water bills that have doubled to $2,000 per acre-foot. Public parks lie brown, homeowners and ranchers watch shallow wells go silent, and land trades hands for water rights. Along the Salton Sea's receding shore, toxic dust storms send health costs soaring past $1B a year.

This isn't a distant scenario — it's the near-future Southwest. Faced with this reckoning, the region has a choice:

1. One path continues down the well-worn path of inertia, letting inaction and a patchwork of half-measures serve as its default response. This is a future defined by rationing, incremental fixes, and learning to live with less (degrowth).

2. The other musters agency and technological ambition in pursuit of abundance. Along this path, a set of bold investments and forward-thinking programs promise fresh flows from the sun, sea, and subsurface. Here, scale isn't the obstacle — it's the point.

To understand why half-measures won't suffice, consider the region's savings account: Lake Mead and Lake Powell. These giants were engineered to hold a year's worth of U.S. household supply at full pool. Today, Mead clings to just 35% of capacity — 170 feet below full pool — and Powell sits at 38%, its bathtub rings etched into canyon walls. If Powell's outflow shrinks beyond a certain level, Mead cannot refill, threatening a cascading failure that imperils both reservoirs and users downstream.




In July 2022, Mead plunged to its lowest level since 1937; brief conservation gains and federal intervention have nudged it up only marginally.

The hydropower lifeline is fraying too. The Hoover and Glen Canyon dams, which hold back Mead and Powell, once generated 4,000+ MW on a good day — lighting up Las Vegas, irrigating the Imperial Valley, and promising that the desert could bloom forever. Now they produce barely half that, forcing utilities to buy replacement power at premium rates and exposing the grid to summer price spikes. Should Mead fall another 100 feet, Hoover's turbines will hit "minimum power pool," going silent as gravity fails to drive water through the generators. This unthinkable scenario would silence the turbines and cut water deliveries for tens of millions downstream.

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Beneath the surface, the story repeats itself. California's Central Valley aquifer has lost tens of millions of acre-feet since 2000, sinking farmland and cracking canals. In rural Arizona, wells that once tapped shallow water now require drilling hundreds of feet deeper, driving pumping costs through the roof. And the Salton Sea — once a simmering oasis sustained by agricultural runoff — has receded more than 20 feet since 2000, its exposed playa belching toxic dust that chokes Imperial County communities.

Together, these pressures — parched canals, faltering power, sinking ground, and dust storms — underscore a stark truth: even heroic conservation efforts (1.5 million acre-feet saved across AZ, CA, and NV since 2023) only slows the crisis; it doesn't reverse it. A structural deficit persists, with annual demand outstripping supply by millions of acre-feet — a gap likely to only widen with time.

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## THE SALTON SEA, A CAUTIONARY TALE...

The Salton Sea is California's largest inland lake. Born in 1905 from a canal breach and kept alive by farm runoff, it has receded more than 20 feet since 2000. As water inflows dwindle, salinity has spiked and shorelines have receded. Exposed playa now belches toxic dust, reminding us how irrigation and shrinking allocations can amplify scarcity and health hazards.

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The Southwest's water system, built for a climate and a population that no longer exists, is a warning shot for the entire region. As we mentioned up top, the old bargain no longer holds. If we do not create a new bargain — one that necessitates building solutions at the scale of the problem — on our watch, the lights will dim, the fields will wither, and the American desert will slip into a new kind of darkness.

If we hope to reverse the tide and engineer a solution at the scale of the problem, we must first reconcile the river's books. Part II will take up that ledger reconciliation, laying the contextual groundwork for the desert-scale response this moment demands.

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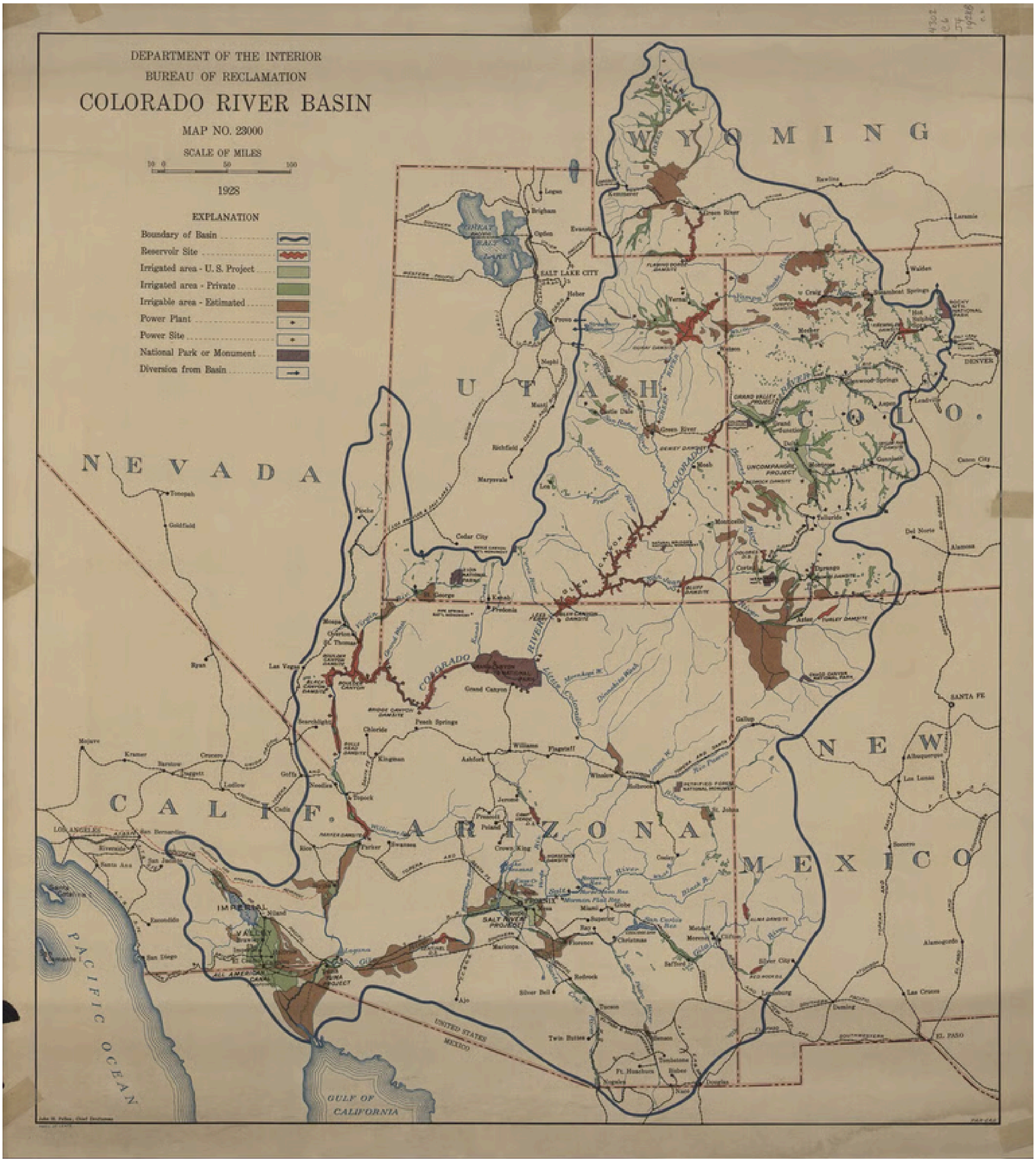
**SECTION 002**

# BALANCING THE WATER LEDGER

The American Southwest's water system creaked into crisis long before wells ran dry. Decades of growth, over-allocation, and wishful thinking are now colliding with the hard math of scarcity. The Southwest's prosperity and identity have been defined by the belief that water could be engineered, banked, and delivered on demand — a faith that is being tested as never before.

## THE SUPPLY SIDE: GO EAST, TO WHERE THE WATER STARTS

The Colorado begins as mountain snow in the Rockies. Come spring, the snowpack melts and trickles into tributaries, gathering force and feeding the 1,450-mile Colorado River. This delicate hydrology means a warm winter or dry spring can reverberate hundreds of miles downstream.




1928 Bureau of Reclamation map of the Colorado River Basin: early reservoir sites, irrigation projects, and diversion points that laid the foundation for the modern West.

But the river's bounty was always more myth than measurement. The Colorado River Compact of 1922 — the legal cornerstone of the Basin — defined the bounty as 15 million acre feet (MAF). The Compact, built on this assumption of a 15 MAF river, divided the flow among seven states, later adding 1.5 MAF for Mexico. These "paper water" legal rights, enshrined in the Compact, subsequent treaties, and court decrees, rarely line up neatly with reality.

Today, paper water rights total nearly 18 MAF once you factor in treaty obligations, tribal rights, and system losses — a number that typically far exceeds what the Colorado can physically deliver in any given year. Throughout much of the 20th century, actual flows averaged closer to 12–13 MAF. Since 2000, annual flows have averaged just 10 MAF, even dipping below 8 MAF in the driest years.

So, by and large, the Colorado's flow has been quietly but relentlessly shrinking. And the physics of a changing planet are unforgiving. For every 1°C of regional warming, the river's flow is projected to drop by nearly 10%. By 2050, models project another 14–31% reduction, even if precipitation holds steady.

Mead and Powell, once symbols of abundance, now display markers of drought and overuse — manifested as "bathtub rings" visible from space. California's Central Valley aquifer — once a 100 MAF underground ocean — has lost 36 MAF since 2003, causing land to sink up to two feet a year, cracking canals and forcing ever-deeper wells. Across rural Arizona, water tables have fallen ten feet in two decades, pushing ranchers and small towns to truck in water or watch their livelihoods vanish.

## THE DEMAND SIDE: GO WEST, TO CITIES, FARMS, AND A NEW DIGITAL FRONTIER

The scale of the Southwest's thirst is grand: nearly 45M people and 5M acres of farmland depend on the Colorado River system.

Sunbelt migration — millions drawn by jobs, warmth, and affordable living — supercharged demand for water, land, and energy. You can see this manifest destiny viscerally in the cities. Phoenix, once a dusty outpost, now sprawls across the desert like a mirage, its population surging from a few hundred thousand to nearly five million in a few short decades. Las Vegas, which once depended on a single spring, now glows neon in the night, drawing water from hundreds of miles away. The Inland Empire, once citrus groves and chaparral, is now a checkerboard of rooftops and golf courses.

All told, between 1990 and 2025, the population of the Colorado River Basin states swelled from 30m to nearly 45M, with the fastest growth in the Lower Basin: Arizona, Nevada, and Southern California. Because these regions are relentless in their growth, and because each new subdivision and golf course demands more water, it's easy to blame booming metros as the most obvious culprit in the Southwest's water crisis. But collectively, the major cities in the Basin — Phoenix, Vegas, LA, Denver, Salt Lake City — draw just under 2 MAF of Colorado River water each year, less than a quarter of the Colorado River's total managed withdrawals and a fraction of the river's original promise. Yet these same cities generate 85–90% of the Basin's total GDP, squeezing extraordinary value from every drop.

### The real story of the river's fate is not written in the cities, but in the fields.

Agriculture is the Basin's dominant aquatic force, consuming 70–80% of all Colorado River water diverted for human use — 3X more than all cities and industries combined. The Imperial Irrigation District alone draws 2.6 MAF per year — more than all of Nevada — with 97% going to ~450,000 irrigated acres of alfalfa, vegetables, and other crops. In California's Central Valley, almond orchards have expanded dramatically, and alfalfa, hay, and other cattle-feed crops together soak up nearly half of all water consumed from the river.

These patterns reflect longstanding choices — what we grow, where we grow it — shaped by market demand, policy, and the promise of abundant water. For generations, people, cattle, and crops have depended on this resource. Any conversation about the Basin's future must balance the realities of scarcity with the essential role that ag plays in food security, rural economies, and the region's identity.

As the Basin's economy evolves, a new(er) set of water users has joined this age-old competition for the river's flow.

### Advanced facilities, fabs, and factories...much ado about nothing?

The modern Southwest is fast becoming an American crucible for a new class of water-intensive enterprises, as leading-edge chip fabs and "AI factories" (datacenters) rise across the desert. Take TSMC's Phoenix megafab, a $165B+ bet that will house multiple advanced chip lines (4nm in production, 3nm planned, and 2nm in subsequent phases) for anchor customers like Apple and NVIDIA. Drawn by cheap land, low energy prices, and generous incentives, hyperscalers have embraced Arizona and Nevada as a launchpad to bring new servers online. Today, the two states rival Northern Virginia for new datacenter capacity

Cue the headlines: "AI is drinking the desert dry!" As we're often told, the new and insidious villain in our nation's resource consumption saga isn't the almond orchard or the golf course — it's ChatGPT and its fellow frontier models, guzzling untold gallons every time someone asks for a Studio Ghibli picture. Yes, a single advanced fab or hyperscaler's datacenter can gulp millions of gallons a year, and yes, the AI revolution adds a new, year-round, non-negotiable layer of demand to our water ledgers...but add up all of the data center footprint in the region, and the combined result still amounts to less than 1% of the Basin's total demand. Basically a drop in the bucket compared to what's poured into alfalfa or almonds in a single day.

## THE ARITHMETIC OF THIRST

We've traced the river's journey from snowpack to city tap, and mapped the relentless tug-of-war among farms, cities, and new digital giants. Now, let's look state by state, basin by basin, for a more granular view of how water use, population, and economic output stack up across the region: Upstream of Lee Ferry in northern Arizona, the Upper Basin (Colorado, New Mexico, Utah, and Wyoming) is responsible for providing the majority of the river's natural flow. Downstream, the Lower Basin (Arizona, Nevada, California) receives water allocations after the Colorado flows through the Upper Basin.

| State | Water Use (AF) | Population | Per Capita (AF) | GDP (SB) | AF per $1M GDP |
|---|---|---|---|---|---|
| California | ~3,700,000 | 39,663,800 | 0.093 | 4,132 | 0.9 |
| Arizona | ~2,100,000 | 7,582,384 | 0.277 | 556 | 3.78 |
| Nevada | ~500,000 | 3,320,570 | 0.151 | 201 | 2.49 |
| Colorado | ~2,500,000 | 5,957,493 | 0.42 | 557 | 4.49 |
| Utah | ~1,000,000 | 3,564,000 | 0.281 | 303 | 3.3 |
| Wyoming | ~600,000 | 590,169 | 1.017 | 53 | 11.32 |
| New Mexico | ~500,000 | 2,139,350 | 0.234 | 111 | 4.5 |

**The colossus of the Basin:** California draws roughly 3.7 MAF a year — enough to flood the entire state of Delaware knee-deep. This titanic draw makes California the river's single largest customer. Yet, when measured against its population and an economy that ranks #5 globally, California's water use is almost miraculously efficient: 0.1 AF per capita, and 0.9 AF per incremental $1M in Golden State GDP. The Lower Basin, broadly speaking, has built dense urban economies that squeeze more value from every drop (with California in particular investing heavily in infrastructure and efficiency).

**The equation flips upstream**… Look at Wyoming or New Mexico, where populations are sparse and economies smaller, and the ratio of water to wealth inverts. In Wyoming, 600,000 AF (⅓ of LA's allotment) propels a $53B economy. A WY resident, on average, consumes 1+ AF per annum, and each $1M of economic output by the state requires 11+ AF (~12X that of California). The Upper Basin's higher water utilization rates make sense: the states have smaller populations and more water-intensive economies (agriculture, livestock, and so forth). In these states, water is not just a resource but a birthright, woven into the fabric of ranching, mining, and open space.

## Disparity shapes the politics of scarcity

The Upper Basin, sitting atop the headwaters, controls the supply. Its water use is largely dictated by what nature provides each year: snowpack, spring melt, and the vagaries of mountain weather. Accordingly, allocations are percentages of what's available, not fixed volumes. In dry years, consumption naturally contracts. In contrast, the Lower Basin has built economies and communities on the promise of predictable, year-round supply, drawing deeply from the river (and aquifers) even as flow diminishes (and water tables recede). The result is a profound asymmetry in both leverage and responsibility. The Upper Basin, by virtue of geography and legal structure, can argue that it is already "living within its means," taking what the river gives and no more. Their economies, though less water-productive, are not structurally overdrawn.

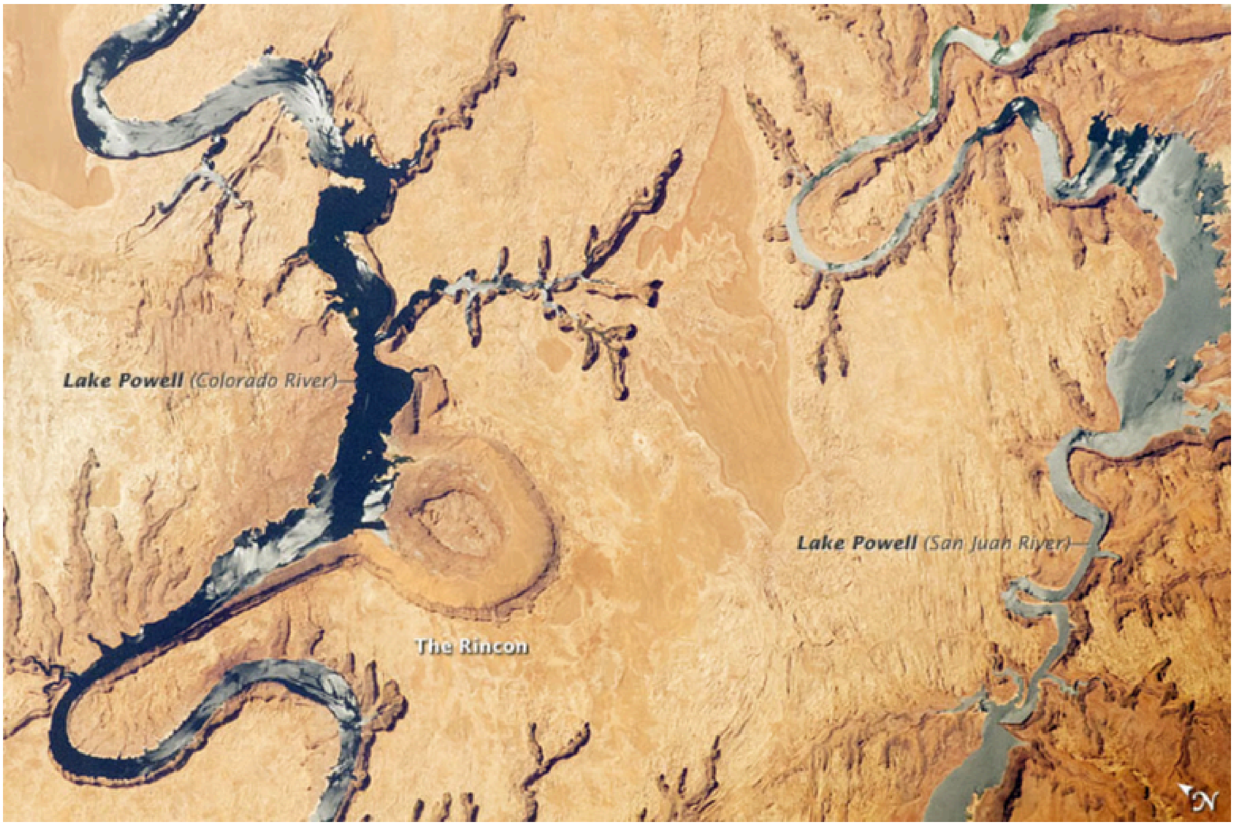
This shapes their negotiating posture: Upper Basin states push for voluntary, incremental conservation and resist calls for mandatory, across-the-board cuts. From their vantage point, the Lower Basin—especially California, with its sprawling agricultural empires and dense urban centers—should bear the brunt of rationing and efficiency investments.

**For good measure**… layered atop all of this is a legal and political thicket: tribal water rights (~3.2 MAF) remain largely "paper water," undelivered for lack of pipes and pumps. Environmental-flow mandates and endangered species protections can further pile on the pressure. And beyond these headline hurdles, a trio of entrenched doctrines tend to drive over-use and stall reform:

1. **Use it, or lose it:** Under prior appropriation law, in some states, water rights are forfeited if not "put to beneficial use" each year, so holders must divert their allocation or risk losing priority. This perverse incentive forces water to flow through canals or fields — even when conserved water may be more valuable — undermining any real savings.

2. **First-in-time, first-in-right:** The oldest water rights — often held by century-old irrigation districts — enjoy absolute seniority during shortages, while junior rights are the first cut. That pecking order can thwart flexible sharing, penalize growth areas, and entrench lower-value usage even as the Basin dries.

3. **Buy-and-dry externalities:** When cities buy senior agricultural rights outright, fields are fallowed and rural economies hollow out, yet the deal delivers no net new water to the Basin — only a shift from farm to tap. This market outcome protects urban supply at the expense of communities and fails to expand overall availability.



## The Structural Deficit

At its peak, and when the Compact was formed, the Colorado River was thought to yield 15 MAF/year. Today, legal claims, treaties, and system losses demand nearly 18 MAF. Yet...the river reliably delivers only about 10 MAF, and less in drought. That leaves a yawning 3-5 MAF gap today, one that will only widen with growth and a warming Basin. Much of the water being litigated and leased isn't even in the channel—it's "paper water" banking on rains that may never arrive.

## Do the MAF: Future scenarios...

*Scientific interpretation and some interpolation lead to the following possible future scenarios:*

- By 2035: Even with aggressive conservation, flows dip to 9–9.5 MAF/yr as demand climbs to 17 MAF. This leaves an 8 MAF gap — enough to leave millions of acres fallow and force urban rationing.
- By 2045: Under high-emissions scenarios, flows plummet to 7.7–9.1 MAF. If demand hits 20 MAF, we face a 10–12 MAF shortfall — twice Mead's full capacity.
- By 2050: Worst-case models suggest flows around 7 MAF/yr vs. 22–25 MAF demand — a deficit equal to Arizona + Nevada's entire budgets.

The mismatch between paper water and wet reality is the Southwest's defining challenge. There is no room for half-measures: pinpricks of conservation and a patchwork of rebates and bans won't close a multi-MAF gap.

The key question: do we reshuffle an ever-shrinking water supply, or do we grow the supply itself? What follows is not a grab-bag of miracle cures but a clear-eyed survey of responses. Some concepts simplify shuffle dwindling drops at steep social or economic cost while others eke out marginal gains with heavy tradeoffs. One bold path that brings truly new water into play. In Part 3, we'll consider each approach, then zero in on the solution that we think can truly turn the tide.

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SECTION 003

# FROM THE DRIP LINES TO DESALINATION, HOW TO SAVE THE SOUTHWEST

Over the last century, the West amassed a toolkit ranging from the straightforward (conservation, recycling, smarter farming) to the audacious (massive reservoirs, long-distance pipelines, even proposals to tow icebergs).

Each path — and our portfolio of collective responses (or inaction) — signals a belief: will we engineer our way out of crisis, or resign ourselves to "doing more with less?"

The challenge isn't a shortage of ideas, but choosing which to pursue, scale, or leave behind. Below, we map out proposed responses before unleashing our chosen strategy. No surprise, it's the boldest, most transformative potential lever that could rewrite the Southwest's hydrology.

## 001 / CONVERSATION & DEMAND MANAGEMENT

This represents the most immediate, and politically expedient, lever: tightening the screws on how existing water is used.

- What it looks like: Tiered pricing (the more you use, the higher your $/AF); low-flow mandates; rainwater-capture incentives; and lawn-removal rebates (e.g., Phoenix piloted a program that paid homeowners $2 per ft$^2$ to swap lawns for rock/native shrubs).

- Potential: Scaled region-wide, these measures could trim 200,000–250,000 AF/year from demand — enough to delay the worst cuts by a few seasons.

- Tradeoffs: Taken to its extreme, conservation forces a grim choice: trade showers for sprinklers, shade trees for boulders, and neighborhood oases for urban heat traps. Command-and-control mandates strip homeowners of choice and undoes decades of valuable work "greening" the desert's near-surface water cycle (see below for more).

**Verdict:** Conservation is a double-edged sword. It can buy time for supply and demand to re-cross paths, and more ambitious projects to clear the queue. But the more efficient cities and farms become, the harder and costlier it is to squeeze out further savings. Once the low-hanging fruit is gone, each incremental mandate yields diminishing returns and invites political backlash. This paradigm demands that homeowners rip out their lawn and farmers fallow their fields. And…we've buried the lead here..but there's another gaping issue with this concept: it doesn't grow supply!

> "Conservation and demand management are temporary stop gaps in the face of a declining resource and growing population. We must engineer more scalable and economic solutions or the American Southwest will continue to burn away."
>
> Jeff Crusey, Deep Tech Investor (Per Aspera Co-Creator)

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### 002 / PRECISION AGRICULTURE

If conservation is the lever of first resort, smarter irrigation — sometimes called precision agriculture — is the next lever. This is a tantalizing vision: farms that use data, not guesswork, rough intuition, or "just in case" overwatering tendencies, to deliver exactly the water each crop needs.

- **What it looks like:** Low-cost soil moisture sensors, satellite imagery and derived analytics, smarter predictive models, and AI-driven irrigation controllers that optimize crop per drop (taking into account water needs, weather, and even market swings).

- **Potential:** Fine-tuning irrigation in real-time can cut water use by up to 30% and boost yields 10-20%, all while reducing fertilizer and energy waste. If scaled across even half the Basin's irrigated acreage, smarter irrigation could in theory free up 1 MAF a year.

- **The catch?** Barriers to adoption are a real thing here. Growers' margins are razor-thin and commodity prices swing wildly. The integration complexity and upfront cost of sensors, connectivity, and analytics is daunting — especially for small and mid-sized operations. And the incentives are misaligned: if one farmer invests in efficiency, the "saved" water often just gets used by a neighbor or absorbed by the system, creating a classic prisoner's dilemma. Why shoulder the cost if others don't? Worse, by wringing every last gallon from reclaimed groundwater, precision irrigation accelerates the Salton Sea's decline — more runoff diverted for crops means less inflow to the shrinking lake.

- **Verdict:** Subsidies and grants could help farmers with adoption, but they're still being asked to do more with less. Meanwhile, mandates or compulsive measures risk backlash. Farmers may be weary of top-down rules, especially when their livelihoods are already in a precarious state. Without shared incentives, direct payments, or reliable market mechanisms, asking agriculture to unilaterally solve the Basin's water deficit is both politically and economically fraught.

### 003 / HARVESTING THE ATMOSPHERE & FOG

For decades, the Southwest has flirted with the idea of "making it rain." Cloud seeding — once the stuff of folklore — represents a tactical tool to coax rain where and when it's needed (now, or in the near future).

- **What it looks like:** Startups like Rainmaker Technologies are developing and dispatching drones that carry biodegradable salt flares into passing storm cells; in Arizona and California tests, that's translated to a 5–8% boost in rainfall (about 1,000 AF extra per winter month, 500 AF per monsoon storm).

- **Potential:** Scaled across the Rockies to the Sierra, coordinated fleets could deliver 10,000–15,000 AF a year, at $500–$700 per AF — if there's moisture to harvest. Globally, China's provinces have sprayed thousands of flights annually to bolster snowpack, and the UAE's cloud-seeding program runs year-round over the Hajar Mountains.

- **The catch:** Atmospheric harvesting depends entirely on the presence of suitable clouds and ambient moisture — during dry spells, there's often nothing to seed. Legal and regulatory questions also linger, from downstream "rain theft" claims to evolving permitting complications (case in point).

- **Verdict:** Atmospheric harvesting is an interesting and valuable tool offering a rapid, point-of-need supplement—especially for headwaters, strategic lands, and remote ranches when rivers and wells run dry. At true scale, a capability like Rainmaker's could even shift atmospheric rivers themselves and provide a more reliable flow into the continent's interior.

## 004 / WATER REUSE & RECYCLING (AKA, FROM TOILET TO TAP)

- **What it is:** Treating municipal and industrial effluent through microfiltration, reverse osmosis, and advanced oxidation so it can be injected into aquifers or used directly. Wastewater recycling — turning effluent into potable or industrial-grade water — has already moved from pilot to mainstream in the Southwest. Orange County pioneered this on a large scale with GWRS. As "the world's largest water purification system for indirect potable reuse," GWRS treats 130M gallons per day (100,000 AF/year) of effluent to drinking-water standards, and injects it into coastal aquifers.

- **Potential:** Metro-scale reuse in Phoenix, LA, Tucson, and others could yield 1–1.5 MAF/yr of potable supply; blending into irrigation adds ~0.2 MAF/yr. Plus, at 2 $kWh/m^3$, recycling's carbon footprint is half that of seawater desalination.

- **The catch:** High upfront costs, inconsistent regulations, lingering "toilet-to-tap" stigma, and technical hurdles for smaller or inland communities. Reuse works best in large metro areas with the right infrastructure, but for much of the Basin, scaling advanced treatment remains difficult and expensive.

- **Verdict:** Recycling excels as a reliable drought buffer, but stops well short of being our silver bullet. Only ~26% of municipal wastewater is reused across the Colorado River Basin, and even with ambitious expansion targets, we top out at 1.7M/yr — less than a tenth of regional demand.

## 005 / MANAGED AQUIFER RECHARGE: BANKING WATER FOR A DRY DAY

An analogy for our electrified age: reservoirs and managed aquifer recharge (MAR) is like the battery to water's grid, storing floodwaters or treated flows underground and releasing them when the system faces a shortfall.

- **What it looks like:** MAR is the Southwest's oldest water hack, now greatly enabled by experience, data, and scale. Arizona has led the way in MAR, recharging over 4.4 MAF of Colorado River water into central Arizona aquifers (giving AZ 4.2+ MAF of long-term storage credits for future use). Next door, MAR is ramping up, too: California's 2023 Flood-MAR pilot banked 4 MAF across 24 Central Valley Basins, stabilizing groundwater for summer extraction.

- **Potential:** Ambitiously scaled, 10 recharge Basins across the Southwest — each banking 200,000 AF/year — could store 2 MAF annually. Combined with recycling, this creates a 3.5 MAF buffer against drought. At $100–$150/AF, it's the cheapest form of water storage, avoiding evaporation and securing supply for dry years.

- **Tradeoffs:** At $100–$150/AF, MAR is the cheapest storage, but it demands thousands of acres, complex easements, and favorable geology. Buildouts of treatment plants, recharge basins, and distribution pipelines also means securing access to thousands of acres, much of it privately owned or contested ground.

- **Verdict:** Even the most ambitious MAR efforts will hit real-world limits, as the Southwest can't simply build its way to resilience and scale one parcel at a time.

Even the best of the above tools, scaled to their plausible maximum scale, still leave the region unable to close a stubborn gap between what the river can provide and what the Southwest demands. So what if the answer isn't more optimizations to scarcity, but a bold reset on supply? What if the region could move beyond incremental fixes and half-measures, and instead make a leap on the scale of the Hoover Dam or Lake Mead — a project that doesn't just buy time, but fundamentally resets what's possible?

## 006 / MEGA-SCALE DESAL, SOLAR, AND STORAGE

No, our caps lock isn't broken — this is as bold as it sounds. When "doing more with less" won't close an 8–12 MAF gap, the most audacious strategists and thinkers have sketched out blueprints for engineered water abundance in the Southwest. For those who believe the only way out is through, these are the all-in, build-big, burn-the-boats types of proposals. We've picked our horse: a solar-powered, cross-border desalination megaproject large enough to reset the region's water ledger. In Part 4, we'll unpack that vision — its physics, its financing, and second-order implications — step by step, to show how desert sun, seawater, and storage can deliver the lifeline the Southwest needs.

SECTION 004

# BUILDING THE SUN-SEA-SALT MACHINE: HERE'S HOW IT WOULD GO…

This proposal conceives of one seamless machine stretching from the Gulf of California to the Sonoran high ground — a closed-loop ecosystem that swaps sunshine for potable water and, in the process, resets the drought math of the American West. At its heart are four Giants, each carrying a different load but marching in lock-step:

1. **Giant #001:** The Desert Solar Forest, an array of PV panels that turns relentless Sonoran light into the raw horsepower everything else depends on.
2. **Giant #002:** The Battery Backbone, a reserve of lithium-iron packs that smooths out clouds, dust storms, and nightfall so the pumps never miss a beat.
3. **Giant #003:** The Gulf Desal Cathedral, a next-generation SWRO campus that skims salt from seawater, tucks the brine safely back into the tide, and sends a river of fresh water north and east.
4. **Giant #004:** The Blue Arteries, a re-plumbed distribution network that steers new freshwater to Vegas, Phoenix, the Imperial Valley, and even a reborn Salton shoreline.

For decades, smart engineers and forward-thinking strategists have sketched out the contours of a desert-scale water solution, from CAP studies mapping out Gulf-to-Phoenix pipelines, to a 2015 MIT feasibility assessment of solar-powered SWRO without batteriest to IDE's Puerto Peñasco proposal for $5.5B, 1 MAF/year binational plant and pipeline. Just last year, Casey Handmer's deep dive on terraforming the desert with PV, solar, and RO crystalized the modern blueprint and served as a source of indirect inspiration for this effort.

Per Aspera's concept stands on the shoulders of these giants—not with a rehash of past ideas, but our own, integrated proposal. We're summoning our own Giants and in doing, laying out our own vision for a Sun-Sea-Salt Machine. Keep reading for the details.

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### Giant #001 // Trading Dust Devils for a Giant Desert Solar Array

We'll transform roughly 225 square miles of Sonoran scrubland — empty creosote flats baked to 110 °F — into a single, contiguous 48 GW fixed-tilt photovoltaic complex. From above, it will look like someone paved the desert with obsidian, with 48 GW worth of solar panels spaced at ~3 acres/MW.

To size it: the desert delivers about 7.5 kWh/$m^2$/day. Using 22%-efficient modules and a realistic 23% net capacity factor, a 48 GW field yields ~96.6 TWh/year. That output comfortably powers desal pumps, membranes, and battery charging entirely off-grid.

**Capex (all-in, roughed out):** at $0.09/W for panels plus $0.11/W for BoS and installation, the field costs $0.20/W → 48 GW × $200/kW = **$9.6B**, plus an 8% buffer (**~$800M**) for grading, wildlife corridors, and drainage → **$10.4B total**.

This is enough to run the entire water machine, feeding pumps, membranes, and batteries without touching the grid. The sun's daily rhythm becomes the plant's metronome, everything else marches to the beat.

- Optional Phase-2: Grid Integration & Revenue Upside?

- On Day 1 the solar forest and battery backbone run in a self-contained loop — powering only desalination and pumping — so you can bypass grid permits at startup. But by pre-installing conduit, cable trays, and switchgear pads, you could lock in an easy path to medium-voltage interconnection down the road. Once tied in, you could monetize up to ~36 TWh of surplus each year — selling into late-afternoon and evening peaks at $25–35/MWh.

### Giant #002 // Bottling Sunlight in Battery Megapacks

The Sonoran sun is steady, yet monsoon squalls can still dim a mid-afternoon sky. Rather than gamble, we'll right-size our battery backbone to 24 GWh of lithium-iron-phosphate (LFP) — enough for ~16 hours of the plant's full electrical load.

Just off the massive solar field — on a graded, flood-free bench — this backbone consists of four windowless, aircraft carrier-sized halls full of shipping container-esque packs. At a (optimistic) rate of $80/kWh installed, the 24 GWh reserve costs **$1.92B**, plus **$100M** for steel, HVAC, and sitework — so, **$2.02B all-in**.

The SWRO plant downstream draws about 38 GWh every 24 hours. Our packs soak up midday surplus from the 48 GW array, then discharge smoothly through dusk, dust storms, and the overnight lull — keeping pumps and membranes pressurized without ever tapping the grid.

### Giant #003 // Drinking the Ocean Without Killing It

Follow the transmission ditch south to the Gulf of California, where a seawater reverse-osmosis campus the size of a small refinery turns saltwater into sustenance for the Southwest. The Sea of Cortez earns the nod for three reasons: deep, cold inshore water that's gentle on membranes; naturally sparse marine life near its desert shorelines; and proximity to the Sonoran solar estate.

A buried 60-inch intake pipe snakes thirty miles offshore to clear, plankton-poor water. After screening and ultrafiltration, that feed surges into a stainless-steel hall housing 16 RO trains operating at ~900 psi. The plant then lifts 4.5 MAF of permeate each year and returns ~1 MAF of 140-ppt brine to the gulf through a multi-port diffuser.

- **Note:** The true environmental flashpoint is the reject stream, not the intake. Instead of chasing a zero-liquid-discharge vision, we return the brine through a multi-port diffuser three kilometers offshore, where it achieves an initial dilution of ~30× within minutes — well inside EPA salinity limits and common practice in the Gulf.

Energy requirements sit at 2.5 $kWh/m^3$, yielding roughly 13.9 TWh/yr ($5.55 \times 10^9$ $m^3$ × 2.5 $kWh/m^3$). All electrons are prepaid by the 48 GW solar array and 24 GWh battery backbone — no grid purchases needed.

Scaled for efficiency, the SWRO campus carries a capex of ~$11B (derived from a conservative ~$2,450/kW). Operating costs — including chemicals, membranes (with scheduled replacements), labor, and consumables — run about $500M/yr, with energy effectively free of charge.

- **Note:** Carlsbad desalination plant produces 0.05 MAF, and was built for $1B in 2015. Jubail 3A produces more than 3X the water and was commissioned last year for almost half the price ($650M). Israel's Sorek B has 0.2 MAF capacity and cost $600M.

- The estimated learning curve for this technology is thought to be around 15%. All of the above taken into account, $11B for 4.5 MAF feels very reasonable given the LC and globally observed drop in price.

### Giant #004 // Blue Arteries Back into the Desert

Once the Gulf plant is humming, 4.5 MAF of new water needs a home. Rather than carve fresh canals, we should try to reinforce what nature and the Bureau of Reclamation already give us.

To minimize new concrete and maximize immediate impact, we will try to split the flow across three blue arrows.

**001 // Imperial & Salton Renewal, 2.5 MAF/yr.** A strengthened California branch that keeps farms green and the Salton Sea blue.

- **Route:** Draw 1 MAF from the All-American Canal into a slightly widened Coachella Canal to nourish Imperial Valley farms, then lift 1.5 MAF via upgraded pumps into the Salton Sink.

- **Why it matters:** Stops toxic dust storms, revives critical wetlands, sustains local agriculture.

- **Speculative upside:** More boldly, a reclaimed Salton shoreline could be ringed by new "desert lakeside" communities, with condos, boardwalks, marinas, agriponics farms, even geothermal-heated spas. As Casey Handmer envisions, this could be the seedbed for dozens of mid-sized "lake cities" west of 100° W: land once thought uninhabitable, reborn as a 21st-century Riviera in the high desert, supporting a "trillion dollars of land value appreciation alone."

**002 // Colorado-Delta Exchange, 0.5 MAF/yr.** The second arrow uses a hydraulic swap that revives the delta and back-fills Las Vegas without a new canal.

- Route: Push a seasonal pulse through a 60-mile pipeline to re-flood cottonwood forests in the Colorado Delta, then let the overflow flow back into downstream reservoirs.

- Why it matters: Restores critical wildlife habitat, kick-starts fisheries, and locks up about 50 kt of $CO_2$ annually in marsh soils.

**003 // Arizona Reverse-CAP Lift – 1.5 MAF/yr.** The third arrow provides a strategic east-side push that lets gravity help with the long haul.

- **Route:** Use a small satellite desal unit on the Gulf's east side, send fresh water uphill once using daytime solar power, and let it gravity-feed down the Central Arizona Project canal to Phoenix and Tucson.
- **Why it matters:** Delivers a reliable, drought-proof supply that buys the metro corridor three decades of growth without scarcity-minded mandates, extra batteries, or a new long-distance canal.

Together, these three "blue arrows" channel 4.5 MAF per year into the Southwest almost entirely through upgraded canals, a single desal-to-pump lift, and minimal net-new civil works. For roughly $7–8B in canal relining, pump stations, and site upgrades, this conveyance package can be delivered in under a decade, with immense economic, societal, and ecological payback in short order. By leaning on what's already in the ground and investing less than 15% of overall Sun-Sea-Salt capex, the "blue arrows" reset a century of scarcity and usher in a new era of water abundance.

**Adding everything up…**When you zoom out from the pipes and panels, the entire machine looks less like an incremental infrastructural widget and more like a regional Marshall Plan: $41.7B in total capital cost. We have $10.4B for the Solar Forest, $2.02B for the Battery Backbone, $11B for the Gulf Desal Cathedral, and $7.5B for the Blue Arteries. So, how did we get to $42B? By adding two critical line items haven't yet appeared in the narrative:

- **BoS & Soft costs (est. 30% of hard costs):** We've allotted $9.3B to cover EPC margin, permitting, land leases, interconnection hardware, legal and financing fees, and an O&M reserve.

- **Authority setup and contingency:** We've set aside $1.5B covers legal agreements, initial reserves for schedule or cost risk, and the formation of the SWPA. (SWPA, you say? What's that? Keep reading for more…)

In addition to the above outlay, the Sun-Sea-Salt Machine carries ~$1.5B in annual opex costs ($720M for solar, $450M for SWRO, $120M for storage, and $200M for conveyance).

## How do you cover a tab that size? One Buyer, One Ledger

If we try to put together a capital stack with distinct accent colors (e.g., federal dollars, state & local funds, and private equity), the underwriting process could become more complex than the engineering task at hand. Mixing pension-fund equity, sovereign-wealth dollars, pre-sales, and long-term water-offtake contracts? A true prospectus would run thousands of pages and still leave room for hundreds of sleepless nights…

Rather than attempt to assemble a tangled capital stack, we regret to inform you that the cleanest solution may be legislative: Congress would charter the Southwest Water & Power Authority (SWPA) — a single federal-state utility empowered to:

- **Permit & Own:** Streamlined approvals and limited eminent-domain* along existing corridors.

- **Issue Bonds:** Long-dated revenue bonds backed by a uniform wholesale water tariff across CA, AZ, and NV.

*Eminent domain is on the books but tightly boxed in: new lines must follow existing federal corridors wherever possible; before any taking, the Authority must offer “fair market value + 25%”; and a portion of water is reserved for any country the pipeline crosses.

With predictable, inflation-linked cash flows and bond financing covering the lion’s share of capex — plus WIFIA/DOE loans and transferable tax credits to plug any gaps — SWPA can fund construction, cover O&M, service debt, build reserves, and even deliver future rate relief, all without elaborate financial gymnastics.

## TO BE SURE, HARD QUESTIONS REMAIN.

Projects of this magnitude, ambition, and complexity necessarily encounter hard questions and serious critique. So, here, we want to air out, acknowledge, and proactively address the most pressing questions and critiques that any sharp-eyed reader, regulator, or investor may raise. Below are four anticipated lines of criticism of this proposal:

**001 // Geography & Conveyance:** A Baja-coast desal hub offers deep-water intake and sunlight, but delivering water hundreds of miles inland to Phoenix, Las Vegas, and other hubs requires careful routing. We’ve suggested gravity-fed and pumped options and examined potential satellite plants, but detailed cost-benefit modeling of each conveyance leg remains a priority.

**002 // Permitting & International Relations:** Navigating NEPA, CEQA, SEMARNAT, tribal consultations, and cross-border treaties is no small feat. A dedicated U.S.–Mexico task force could run parallel approval tracks, clear tribal engagement protocols, and built-in timeline buffers — but even the best efforts can’t entirely eliminate litigation or sovereignty concerns.

**003 // Energy Resilience:** Powering desalination at this scale purely with PV and storage will raise eyebrows — and yes, it demands rigorous reliability studies under clouds, storms, and heat waves. But the same design principles that can be seen with other global grid-scale deployments — solar overbuild, LFP batteries sized for daily carry, and healthy industry margins — scale naturally to this project. While detailed reliability modeling underlies any big build, the core technology is mature, the margins are well understood, and it can reliably power continuous desalination without reinventing the wheel.

**004 // Cost & Learning Curves:** No surprise: the final price tag would wobble as the world changes. The project's economics hinge on a handful of movable levers, each one capable of nudging water prices north or south but none fatal on its own. We anchor our pro-forma to 2025 realities, but history shows solar and battery costs will keep sliding. By the same token, construction inflation is a blunt threat, permitting costs are largely unaccounted for, and commodity swings cut both ways. By and large, we believe that learning curves with a project like this could quickly (and quietly) turn risk into upside. Key equipment tracks Wright's law: every global doubling of installed capacity knocks roughly ten percent off cost. Delay — usually the enemy — might actually buy us cheaper SWRO. Stack the worst-case assumptions — flat tech prices, high rates, etc. — and the project still stays solvent, if slower. Stack the best and the Sun-Sea-Salt machine becomes more than a drought hedge; it becomes a lucrative anchor asset for the Southwest.

## THE UPSHOT

The Southwest is staring at a 3-to-5 MAF annual shortfall, and only a Hoover-scale solution can close the gap outright. The Sun + Sea + Salt machine does exactly that: It pulls new water out of the ocean, buries Utah-sized dust storms, revives dead deltas, and helps power millions of homes.

The beauty of a project at this scale is that it doesn't ask every homeowner to rip out their lawn, every farmer to fallow their fields, or every city to fight over the last drops in a shrinking river. By generating new, reliable water at a scale that matches the region's ambition, the Southwest can sustain its legacy as a place where engineering, vision, and audacity make the impossible possible.

At forty-odd billion dollars, it isn't cheap — but the Hoover Dam, in today's dollars, cost ~$40B. If the region is willing to think big, act boldly, and invest at the scale of the problem, the Southwest doesn't have to resign itself to the politics of scarcity and accept a future defined by less. We can, and should, choose abundance.

SECTION 005

# AD AQUA, PER ASPERA

There is nothing noble in shrinking before the storm. To embrace decline — turf bans, lean farming, ration slips — is to resign our children to a parched future and perpetual zero-sum water warfare over dwindling drops. Instead, we must choose a harder path today: build at the scale of the challenge, engineer abundance, and resist the lull of false security offered by half-measures.

Here's why it can — and must — work:

1. **Ending the zero-sum game:** Under today's system, water management in arid regions is a zero-sum game: every new farm, factory, or subdivision carves away someone else's share of a shrinking pie. This breeds tension, lawsuits, gridlock, and interstate standoffs. Large-scale desal changes the equation, creating new supply rather than redividing a depleted resource. Suddenly, growth, security, and restoration are not in conflict; they can move forward together.

2. R**educing upstream-downstream tensions:** In a Basin defined by "first in time, first in right" and "use it or lose it," upstream states hold senior claims while downstream users get peppered with cutbacks. This proposal rewrites that dynamic: when water comes from the sea, it doesn't matter whether you're first or last. It dissolves the spark for interstate and tribal flashpoints that have dogged the Southwest — and any river system facing scarcity.

3. S**eeding new agreements:** Scarcity fosters fear, blame, and endless finger-pointing. An abundant, reliable source obviates this dynamic. With large-scale desal, states and tribes negotiate from strength, not desperation. In the Middle East, Israel's desal rollout underpinned water-sharing pacts. Here, too, desalination diplomacy could unlock joint ventures, revenue-sharing, and cooperation rather than competition.

4. **Terraform Lite, and rebooting desert ecosystems:** This isn't hardcore terraforming — nobody's turning sand into rainforest overnight — but it's a "terraform Lite" reboot. Pumping 1.5 MAF/year into the Salton Sea raises its level, caps salinity, and silences toxic dust. Breathing life back into 200 sq mi of wetlands, we kick-start migratory bird routes and restore brine shrimp. A 0.5 MAF pulse into the Colorado Delta re-greens 5 000 acres of riparian bosque. It's proof that, even in an arid land, engineering can spark ecological revival.

5. **Proving we can still build big, fast, and bold:** Hoover Dam, the Interstate Highway System, and Apollo didn't happen through small tweaks — they demanded audacious vision. A $50B desalination megaproject channels this spirit. It aligns federal, state, tribal, and private interests to move from permitting to ribbon-cutting in a decade or less. When it's complete, the world will see that America still delivers transformative projects — smart, ambitious, proudly built. It becomes a template for other drought-stricken regions. And large-scale infrastructure belongs in our toolbox.

When the Colorado loses 20% of its flow and aquifers lose tens of millions of acre-feet, "doing more with less" becomes surrender. Letting orchards die, laying off farmhands, and capping city sizes consigns the Southwest to shrinkage. It treats water like a token to hoard, not a resource to reclaim. Perpetual scarcity only guarantees conflict: seven Basin states scrambling for ever-smaller shares, tribes stuck with "paper water," and ecosystems teetering on collapse. That path isn't survival, but a spiral into resource-driven chaos.

Incremental conservation won't close the gap. Yes, pulling up lawns and reusing wastewater buys a year or two. Yes, cloud seeding can be applied tactically to bolster headwaters. But the math is relentless: a Basin that once delivered 20 MAF now produces 10 MAF against an anticipated future 25 MAF of demand. Every month spent debating half-measures deepens our debt.

Rekindling the old pact of endless growth, water, and power demands a desert-scale build. Yes, it will test federalism, interstate sovereignty, and more. It will demand regulators move with uncommon speed and ask communities to welcome pipelines down their backroads. But urgency must match the crisis, and delay only makes that future more impossible.

Per Aspera's creed: through hardship to the stars. Here, "hardship" is the desert-scale build that embraces bold trials rather than timid steps; transforms scarcity into abundance; and dignifies the Southwest's legacy. This is the moment to rewrite our water story and reignite the West's promise of boundless resources, power, and possibility. Our children will not marvel at what we hesitated to build; they will wonder what held us back. The time to choose hard is now.

*Ad Aqua, Per Aspera.*

**NOTHING FOLLOWS**

Per Aspera