Urban Development in Deserts: Does Water Matter?

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Abstract

Deserts are characteristically low in resources, and due to this, the environment itself does not allow for widespread habitation. The most lacking, essential resource in this case is water. Nevertheless, humans inhabit deserts, and in some cases they contain huge, rapidly growing cities such as Phoenix, Arizona and Riyadh, Saudi Arabia. These cities defy classic environmental thought, especially Limits to Growth, which emphasizes the limits that finite resources supposedly place on growth. They far surpass perceived carrying capacities with the aid of technologies and massive financial inputs. In the United States, military spending during WWII brought industry to Phoenix, which had previously been a remote farming and tourism community. It created an image of economic opportunity which, sustained by the military industrial complex, attracted citizen and businesses in a growth trend that continues to this day. Limits to Growth underestimates the ability for human ingenuity and financial investment, in response to overwhelming demand, to contrive development in even the most inhospitable environments.

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Introduction

When looking at a map of most developed countries, you notice that most of the major cities are located along rivers, lakes, or coastlines. This makes sense. Situating a city near a body of water offers clear benefits in terms of fishing, waste disposal, and transportation of people and goods. It also provides a major source of freshwater for urban water supply, since even coastal cities are usually located near the mouth of local rivers.

Given the above, it is no surprise that all of the major cities in Australia are located on its coast. More than 90% of the population lives in coastal areas, constituting about 30% of the country's landmass. This is attributable to the fact that the other 70% of the country is a vast desert area known as the Outback. The Outback sees minimal amounts of annual rainfall, and has no major rivers running through it. In turn, the biggest city is Alice Springs, with a population of less than 30,000.

In a sense, this is how one would think the situation "should be." Given the scarcity of water in the Australian Outback, large-scale urban development has only occurred around the coast, where there are major sources of freshwater. There are hundreds of cities in the Outback, but the biggest one is only 30,000 people because these cities have been forced to develop within the limits imposed by their environment. There is not enough freshwater readily available to support a city of a million people. In other words, it seems as though these small cities have hit the *limits to their growth*. Indeed, the extent of human development in the Australian Outback supports the theories famously presented by Meadows et al. in 1972. The cities in the outback have been unable to grow past a certain size due to the constraints placed on them by their environment, by the scarcity of essential resources.

However, other parts of the world present drastically different situations. Saudi Arabia is one of the most notable, a country of 30 million people on a landmass that is 95% desert. Average annual rainfall is 3 inches, and only 2% of the country's landmass is considered arable (Darfaoui and Assiri 2010). Its capital city, Riyadh, has a population of nearly 6 million people, despite the fact that it's located nearly 300 miles from the nearest body of surface water (the Persian Gulf). It's located over a large supply of groundwater, but even given that, it is undoubtedly far exceeding the capacity of its available freshwater resources. It's a city of millions of people in the middle of a desert environment. Yet despite the fact that it doesn't seem like it "should exist," it has been growing rapidly since the 1940's, using desalinated water from the Persian Gulf, and is still growing today.

The United States also has major cities in the middle of desert areas, despite the fact that only about 5% of the land is considered desert (Cordey 2013). These cities include Phoenix, Tucson, and Las Vegas, all with populations over 500,000 people. Phoenix, the capital of

Arizona, is the biggest. It has a population of 1.5 million people, and is currently one of the fastest growing cities in the country, despite the fact that it is located in an isolated area that only receives an average of 7 inches of rainfall a year. It does have substantial groundwater and nearby surface water that flows from the Salt and Gila Rivers, but again, these resources alone are not nearly enough to support or explain the huge population that exists there.

These desert metropolises present a peculiar scenario, wherein the most growth is happening in the least habitable regions. In Saudi Arabia, the growth of huge cities in the middle of the desert was undoubtedly out of necessity, since the country is almost entirely desert. The United States, on the other hand, has plentiful rivers, lakes, and fertile land, yet for

some reason populations and industries are being drawn to areas that seem to be the least suitable to support them. Considering that this sort of development isn't occurring in similar developed nations (Australia), there must be certain, extraneous forces unique to the United States that are fostering such growth. In this thesis I find that massive federal investment, beginning with military spending during WWII, is what sparked the growth of Phoenix and provided the foundation for it to grow into the burgeoning metropolis that it is today. Water, a characteristically scarce part of the environment, did not limit its growth. Rather, water scarcity was a challenge that only needed to be addressed periodically throughout Phoenix's development, by means of technological advances and further federal investment.

Limits to Growth

Since it was published in 1972, *Limits to Growth* has been a foundation of classical environmentalism. It claims that, due to the finite nature of essential resources such as water, arable land, and precious metals, there is a carrying capacity for our planet. That is to say, there's a certain size of population and industry that we cannot grow past. If we pass that carrying capacity, our society will collapse.

The authors use a series of models to predict when we will hit the limits to our growth. They consider varying degrees of population growth, pollution, resource depletion, and industrialization. And they even consider the role that technology plays in overcoming limits to population and economic growth. However, they claim that "…even the most optimistic estimates of the benefits of technology in the model did not prevent the ultimate decline of

population and industry, and in fact did not in any case postpone the collapse beyond the year 2200" (Meadows et al. 1972).

Again, these predictions are based on the finiteness of resources, the prospect of 'running out' of something that is essential to our society. Take oil, for example. Most developed countries rely on oil for transportation and industry. So if we were to run out of oil, our current economies wouldn't be able to function. This is why the prospect of "peak oil" was so worrisome and seemed to confirm the Limits to Growth predictions when it was popularized in the 1970's. "Peak oil" was the correct prediction (at the time) that US extraction of oil would peak in the 1970's and begin a steady decline. And since oil is a finite resource, with most available deposits thought to have been discovered, this did seem to mark a limit to our society's ability to continue functioning.

However, with the recent invention and proliferation of fracking, oil production has actually increased again. With the introduction of new technologies, we have actually increased the supply of what was thought to be a dwindling, finite resource. Peak oil, in its original form, can hardly be discussed anymore. This is a testament for the ability of technology and financial investment to overcome perceived resource limits. Once a problem arises (in this case, dwindling oil supplies), it creates the need for people to innovate and create new technologies to address it.

Metropolitan cities in desert environments are also a testament to the fallibility of Limits to Growth. Limits to Growth would argue that the scarcity of water, an essential and finite resource, would set a certain population capacity for a desert region. Even with technological inputs that effectively harness local supplies of water, it seems inconceivable that

a metropolitan city could grow in such a region. Yet, as evidenced, they exist and continue to grow. The factor that Limits to Growth doesn't consider is the ability for new innovations and massive financial investments to increase the supply of water far past what was thought to be the 'available, finite supply.'

Of course, governments don't randomly commit huge amounts of funding to allow industrial growth in water-scarce areas. They do it in response to certain demands. Nowadays, urban development in deserts is largely a result of citizen demand. As will be discussed later, desert cities are continuing to grow because they are attractive to citizens and companies, who migrate there and increase its size. The government then must invest in massive infrastructure projects (desalination plants in Saudi Arabia, elaborate canal systems in the United States) to support these growing populations. But historically, at least in the United States, urban development in deserts was a product of the demand for wartime industries and military bases.

Military Spending and the Early History of Phoenix, Arizona

One of the defining characteristics of the United States in the 20th and 21st Centuries is its presence as a military superpower. Currently, the United States spends more on defense than the next eight countries combined, totaling $640 billion and accounting for 20% of federal spending (PGPF 2014). US military spending during past decades came in peaks and troughs, but starting with WWII, the US has been characterized by a supreme, well-funded military. WWII was a period of unprecedented military spending, wherein 41% of the federal spending was towards the war. To invigorate the sorts of manufacturing that were essential for the war

(such as steel and aircraft manufacturing), the government funded the construction of hundreds of factories and paid for the training of the diverse, specialized personnel associated with them (Hinshaw and Stearns 2013). The government then allowed large corporations to manage the facilities, and purchased the output that they produced. This pattern of production was indicative of the increasing presence of the military-industrial complex in the United States.

The "military industrial complex" is a term popularized by President Eisenhower during his farewell address in 1961. It describes the mutually-beneficial relationship between legislators, the Department of Defense, and private military-industrial firms, in which money and policy are circulated for the betterment of each other's positions. For example, military corporations make campaign donations to government officials, who in return vote for proposals that would extend military presence in a region, thus granting more contracts to the corporations. This phenomenon rose to prominence in the US during WWII, when weapons production shifted from publically owned companies to private firms.

The massive increase in US military spending and manufacturing during WWII drastically transformed the distribution of population and industry across the country. Even though the United States didn't formally enter WWII until 1942, the government began a push to expand and modernize the military at the onset of the war in 1939 in the name of preparedness (Logan 2006). This brought government-financed industry to many cities across the country, providing huge boosts in employment and living standards during what was still the Great Depression (Harper 2007). The economic promise brought on by this increase in government spending caused cities to compete against one another to receive these new contracts and installations. It also brought on a migration from rural areas to urban areas (Harper 2007). And even though

a large portion of the contracts and installations ended up being given to the already-established industrial centers of the Northeast and Midwest, previously remote and un-industrial places like Tucson and Phoenix, Arizona were also successful in securing military bases and industry.

Up until WWII, Phoenix's economy was dominated by agriculture. As mentioned, even though it is located in the middle of a desert valley, it receives substantial surface water flow from the surrounding mountains. The Salt and Gila Rivers spill out into the flat valley, providing surprisingly favorable conditions for agriculture (Hirt, Gustafson, Larson 2008). Long before the city of Phoenix was established by Americans in the mid-19th Century, it had been cultivated by the Hohokam, a Native American Tribe that lived in the valley between 300BC and 1450 AD. In fact, the overall system of irrigation canals used by early farmers in Phoenix followed the exact same paths as the Hohokam's (Nies 2012).

Phoenix was founded in 1867 when an out-of-work miner excavated some of the old Hohokam canals and found that the system was still functional. He began leasing farmland, and soon, with the ancient irrigation system working once again, the valley reemerged as an agricultural center (the name "Phoenix" is a play on this rebirth: a frontier city rising from the ruins of a past civilization). Up until WWII, the production of cotton and citrus was were the main industries that supported Phoenix's economy (Logan 2006). At the same time, the clean air and mild winters made Phoenix an early attraction for tourists and medical patients (Logan 2006). Its population grew steadily, from 240 in 1870 to 65,000 in 1940, but it remained an agricultural and tourist center. It had little resemblance to the city that it is today.

An advantage that it did have, though, was an early investment of federal funds to build the Theodore Dam. Funded by the Bureau of Reclamation, the Roosevelt Dam was a masonry dam that harnessed the Salt River in in the mountains 70 miles away from Phoenix. Roosevelt Dam and the other nearby reclamation projects provided a stable supply of water that was distributed by the Salt River Project, a public water utility that managed agricultural water. This meant that the city of Phoenix didn't have to worry about agriculture, which is hugely water-intensive, soaking up their water supply (which at the time came from the Verde River, a cleaner but smaller river). Dam technology and early federal investment, even before WWII, had made a surprising amount of water available in a desert region.

This abnormally plentiful amount of water allowed Phoenix to be a burgeoning agricultural city of 120,000 at the onset of WWII. Of interest to the US military, though, was its dry climate, expanses of unoccupied land, and clear and open skies (Melton and Smith 2003). It was also attractive because it was safely inland (from possible air attacks on the West Coast), but still near California, a major manufacturing and distribution region (Logan 2006). So, between 1940 and 1941, the government sponsored the construction of three air force bases and training facilities, as well as multiple defense plants related to airplane manufacturing (Logan 2006).

After WWII, Phoenix boomed in population and industry. The military bases and defense industries built during WWII had already established Phoenix as a powerful industrial center, and at the same time, they brought a large supply of capable workers to the city, many of whom remained after the war. This resulted in a valuable labor pool which began to attract more industries to the city. Civic leaders recognized Phoenix's economic potential and sought

ways to encourage it. They adopted a business-friendly attitude, reducing taxes for manufacturing industries, and made it a priority to attract clean, high-tech industries in order to preserve the image of clean, open air that had originally made Phoenix desirable (Logan 2006). Motorola became the first major corporation to relocate to Phoenix, while the existing defense industries, feeding off of the military industrial complex and early Cold War fears, expanded their production.

Up until this point, a major factor constraining growth in Phoenix was the intolerably hot summertime. However, during the 1940's and 1950's, air conditioning systems were introduced and became wildly available to the public. This single technological improvement transformed Phoenix to the point that it became "the air conditioned capital of the world" (Reisner 1993). During the blistering summer heat, residents could live comfortably in air-conditioned homes, drive to work in air-conditioned cars, and spend their work or school days in air-conditioned buildings. Phoenix was now habitable year-around. Residents could enjoy the benefits of the winter and avoid the heat of the summer. The summer heat, a defining characteristic of the environment they lived in, was now merely a nuisance. Air conditioning allowed residents to ignore their desert surroundings.

Even though the temperature was no longer a problem, the booming city faced an issue of water shortage in its first postwar years. City leaders in Phoenix had been unprepared for the postwar boom, and for the remainder of the 1940's, there were issues with water supply. Most notably, consumers noticed drops in water pressure during peak afternoon periods. Water running out of taps would turn to a trickle, due to a lack of sufficient water in the system (Logan 2006). As a temporary solution, the city formed a contract with the Salt River Project (SRP), the

agricultural water supplier. The city would be allowed to use agricultural water during emergency periods, in return for helping fund certain SRP projects. This contact ended up being fruitful and was immediately renewed upon expiration. In the following years, the two parties sought a more permanent solution, and in 1952, they reached an agreement.

The agreement between Phoenix and the SRP was mutually beneficial and secured an abundant supply of water for further growth in Phoenix. The contract addressed the issue of suburban sprawl, which was characteristic of Phoenix's development during its postwar boom (Logan 2006). Phoenix is located in a flat valley, meaning that there's ample land and little geographic barriers to constrain growth. Accordingly, development projects were usually low-density, along the outskirts of the city in areas that had previously been used for agriculture. This means that new subdivisions were being built on land that was owned and serviced by the SRP. Under their agreement, Phoenix would pay all fees associated with SRP land (which had previously gone unpaid, due to the pre-computer inability to assess and calculate the particular amount owed by each of the thousands of new homeowners) and in return, the city would receive all the water that has previously gone towards agricultural uses on the land. Since agriculture uses vastly more water than even the most wasteful homeowners, the city received a surplus of water from each new portion of developed SRP land (Hirt, Gustafson, Larson 2008).

Between 1950 and 1960, Phoenix grew faster than any other city in the country. Its population shot from 106,000 to 440,000, a 311% increase. Yet even despite this, the massive amount of water available through the city's contract with the SRP allowed water to remain cheap and abundant. Phoenix adopted the image of an oasis, becoming known for its extensive

golf courses and lavish lawns (Stearns 2005). Additionally, the city welcomed further growth. Manufacturing employment tripled as corporations continued to move to Phoenix (Logan 2006). Wages were competitive. Manufacturing surpassed agriculture as the dominant form of income for the city.

The transfer of agricultural water to municipal uses caused farmers to resort to groundwater to meet their agricultural needs. At the time, groundwater was a common-pool resource with no restrictions on pumping (Reisner 1993). So even though the recharge rate is dramatically low, farmers could pump as much water as they wanted. Moreover, the recent invention of the centrifugal pump greatly increased the capacity of farmers to withdraw groundwater (Hirt, Gustafson, Larson 2008). This technology and lack of regulation began a period when farmers were able to easily and effectively pump as much water as they wanted, a period of major groundwater overdraft, which wouldn't be addressed until the 1970's.

Between 1960 and 1980, Phoenix continued to grow rapidly, increasing from 440,000 people in 1960 to 790,000 in 1980. The city continued to show economic promise and comfort for residents, and companies continued to be attracted by its business-friendly mentality. Also contributing to Phoenix's growth during this time was the decline of the Rust Belt (the former industrial region around the Great Lakes) and the increasing costs of conducting business in Southern California (Logan 2006). Los Angeles especially was becoming increasingly congested, polluted, and costly, making Phoenix an increasingly desirable alternative. As a result, there was an industrial migration from Los Angeles to Phoenix that lasted into the 1980's.

Phoenix's growth remained characterized by suburban sprawl, due in part to the increased use of automobiles around this time, as well as the continued availability of flat, surrounding land. The population, while massive, was spread thinly across the valley. Given this, Phoenix was undoubtedly a decentralized city. And at the same time, there wasn't any sort of central planning to the way the city was being laid out. Most development to this point was controlled by individual companies, who solely sought to maximize profits (Hirt, Gustafson, Larson 2008). This meant that massive populations began emerging in areas where the roads were unable to handle the exponential increase in traffic. Phoenix had avoided building a freeway system during previous decades out of a desire to preserve its image as a clean, desert city (Logan 2006). But at the same time, streets were overwhelmed by Phoenix's increasing population, demonstrating a need new transportation infrastructure that would make at last make residents and civic leaders question the pro-growth mentality that had driven Phoenix up until this point. In fact, a freeway proposal was rejected by voters in the 1970's, out of fear of turning Phoenix into a congested, polluted, metropolitan city like Los Angeles (Logan 2006). But by 1975, it was increasingly clear that the city required a freeway system to handle its increasing size, and a new proposal was approved by voters.

Phoenix's development between 1960 and 1980 continued to follow another trend from previous decades, in which agricultural land is converted to suburban neighborhoods. As Phoenix sprawled outward, surrounding farmers found that the value of their land increased to the point that it would be more profitable to sell it than to continue to cultivate it (Logan 2006). Most of these farmers chose to sell their land and move their agricultural operations farther out into the desert, where they could continue to draw on the region's unregulated groundwater

(Logan 2006). In turn, Phoenix continued to increase its water supply (by obtaining SRP water from farms), while farmers continued to overdraft water from the aquifer. That is to say, additional water was obtained during this period by increasing groundwater withdrawals.

The negative consequences of groundwater overdraft became increasingly apparent, and by the 1970's, it was a prominent issue. During this time, Arizona was using groundwater at a rate that would drain its aquifers in less than one hundred years (Jerome 1991). The water table began to drop noticeably, as much as 400 feet in some areas, while instances of subsidence became increasingly common (Hirt, Gustafson, Larson 2008). It became increasingly clear that groundwater overdraft was a major issue that needed to be addressed. But at the same time, the region's agriculture depended on groundwater overdraft, due to the fact that all the other nearby water sources (mainly the Verde and Salt Rivers) had already been harnessed for municipal use. Without overdrawing groundwater, they wouldn't have nearly enough water for their crops. Phoenix again faced a water crisis.

In the background of these developments was the proposed Central Arizona Project (CAP). The CAP was a canal system, first proposed in 1947, that would carry water over 335 miles from the Colorado River to Phoenix and Tucson. This would enable the cities to receive their share of water from the Colorado River, which had been divided among seven states (Colorado, Utah, Wyoming, New Mexico, Arizona, California, Nevada) in the Colorado River Compact of 1922. California, a rival for Colorado River water, initially blocked the legislation in Congress, but after a lawsuit brought forth by Arizona, Congress authorized the project in 1968. It was to be largely funded by the federal government (Bureau of Reclamation), and was

intended to be a “rescue mission” to save Arizona from the problem of groundwater overdraft (Hanemann 2002).

Construction started on the CAP in 1973, but it remained a controversial project. The 1970’s was a period of skepticism around large water projects (Hirt, Gustafson, Larson 2008). In addition to the budding environmental movement (which increasingly opposed large reclamation projects), the Vietnam War had left the government with massive budget deficits. In response to both these factors, President Jimmy Carter formed a “Hit List” of ten water projects that he wanted canceled. Unsurprisingly, the CAP was on this list. In addition to current financial and cultural difficulties, the federal government was concerned about the declining groundwater levels in the region. They wanted the state of Arizona to take its water supplies seriously, rather than relying on the federal government to bail them out (by funding large reclamation projects whenever they experience water difficulties) (Larson, Gustafson, and Hirt 2009). In response to this, Arizona introduced the Groundwater Management Act (GMA) in 1980, which to this day remains one of the most comprehensive pieces of groundwater regulation in the country (Logan 2006). According to the GMA, Arizona would return to safe-yield withdrawal levels by 2025, in which the annual amount of water withdrawn equals the natural and artificial recharge of the aquifer.

Construction on the CAP continued, reaching a cost of over 4 billion dollars by the 1980’s, making it the most expensive aqueduct system ever constructed in the United States. The first agricultural delivery of CAP water occurred in 1985, and by 1986, the canal had reached Phoenix. Phoenix now had abundant surface water, but at the same time, was

confronted with the issue of reducing their groundwater usage. This meant that for the first time in Phoenix's history, citizens and civic leaders would have to start considering conservation measures.

The abundant supply of water in Phoenix up until 1980 allowed leaders to avoid instituting conservation measures, and at the same time, allowed residents to feel like there were no downsides to living in the desert. In 1980, the total water consumption for the city of Phoenix was 267 gallons per capita per day (GPCD), which was one of the highest rates of consumption in the country at the time (Solley, Pierce, Perlman 1993). One would think then, that the GMA would serve as a sobering reminder for civic leaders and residents alike, since Phoenix's abundance of water up until that point was partially a product of groundwater overdraft (Larson, Gustafson, and Hirt 2009). With new regulation that set out to reduce overdraft, civic leaders would be faced with the prospect of reducing water consumption while still allowing for further population growth. However, the arrival of CAP water weakened the resolve of all parties involved. The GMA required "reasonable reductions in per capita use," but considering the abundance of water from the Colorado River, as well as the continued conversion of cropland to suburban development (adding a surplus of water supply), Phoenix's water utility providers had little sense of urgency or necessity for conservation measures.

On a state-wide level, each major utility provider was required to reduce their usage by a mere 6% between 1980-1987, but by 1987 about 2/3 of them had failed to meet their goals. Moreover, the agency formed to monitor the GMA, the Arizona Department of Water Resources (ADWR) decided against imposing fees. The language surrounding the regulations was vague, making it hard to identify "noncompliance," as well as the sort of fees that would be

imposed in cases of noncompliance (ADWR 1984). Instead, it entered into written agreements with utility providers, identifying best practices and other ways to encourage their users to reduce water consumption. But again, by the mid 1990's, about 2/3 of the parties had failed to even achieve the goals set out in their written agreements.

Rather than strengthen their resolve, state regulators in the ADWR instead chose to create an alternative conservation program. They implemented the Non-Per Capita Conservation Program (NPCCP) in 1995, which, as suggested by the name, did not require certain reductions in per capita water consumption. Instead, it merely mandated the implementation of twelve "Reasonable Conservation Measures," including consumer outreach, and efficient technologies and landscaping in new houses. Instead of requiring actual reductions in water consumption, the GMA now merely required efforts at water conservation (Larson, Gustafson, and Hirt 2009). Success was measured in brochures distributed, rather than water conserved. All in all, the GMA had been significantly weakened by the 21st Century.

Between 1980 and 2000, groundwater overdraft in Phoenix declined by about half, not through conservation efforts, but through the continued process of converting farmland into residential subdivisions. So even though Phoenix grew by an additional 550,000 people over the span of those two decades, the reduction of water-intensive agriculture (plus the addition of CAP water) had actually reduced their groundwater usage (Hirt, Gustafson, Larson 2008). There were minor efforts at conservation, especially through brochures and codes on new developments (including water-efficient appliances and landscapes), but overall, the city still didn't take water conservation seriously (Larson, Gustafson, Hirt 2009). Up until that point, they had no need to.

From 2000 to the present day, the situation in Phoenix has changed little. Considering the persistent abundance of water available through the CAP and SRP (by means of farmland conversion), there have been no major efforts at water conservation in Phoenix. There have certainly been minor improvements, such as water efficiency requirements in new buildings, and a ban on private lakes. And as of 2013, Phoenix reuses 82% of its wastewater, for landscape irrigation, groundwater recharge, and agriculture (ASU, 2013). But all in all, the water supply system remains supply-driven, rather than demand-driven (Larson, Gustafson, Hirt 2009). That is to say, city leaders and utility providers chose to focus on improving water supply, rather than reducing water demand.

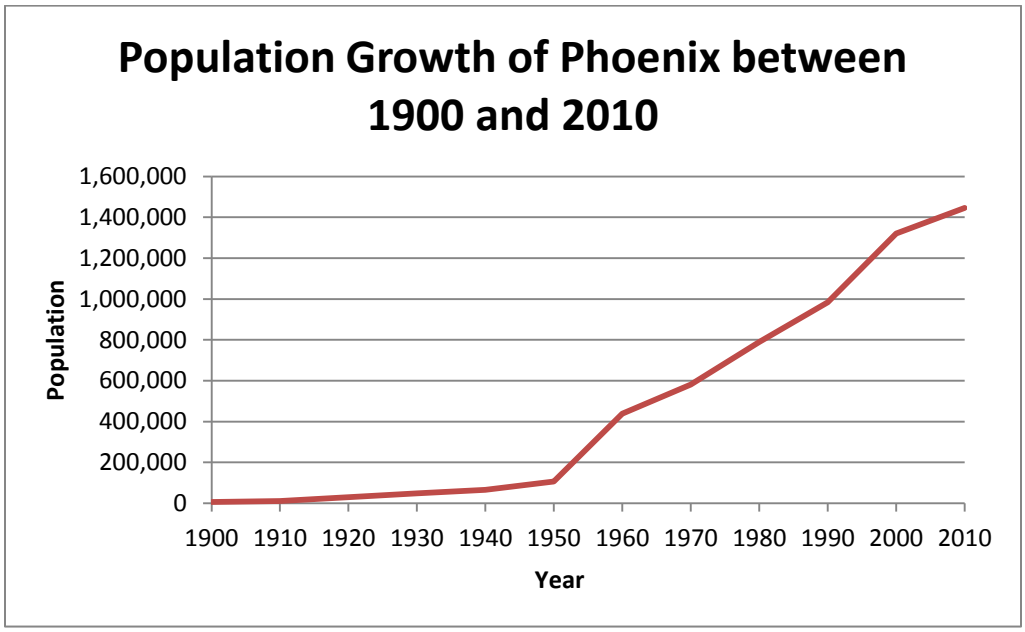
Analysis of Urban Water Supply in Phoenix

As shown through this extensive history of Phoenix, the biggest desert city in the United States, available water was a secondary factor for its growth. It grew because of other factors, one of which was the availability of technology. Technology such as air conditioning made Phoenix habitable year-round, allowing residents to live without the discomfort of summertime temperatures. This made Phoenix desirable for families and companies alike, allowing it to grow into a highly-populated industrial center. The centrifugal pump, on the other hand, is what supported Phoenix's prominent agricultural industry. Indeed, the centrifugal pump allowed a rate of withdrawal that was far greater than what farmers were capable of in the 1800's, making it so that farmers could start growing wherever they could drill a well and access groundwater (Fiege 1999). As SRP water increasingly went towards municipal uses, the

centrifugal water allowed farmers to withdraw as much groundwater as they needed (up until the 1980's).

Federal reclamation projects are also important factors that fostered Phoenix's growth, and are primarily responsible for the abundance of water currently available for municipal use. As outlined in Phoenix's pre-urban history, Roosevelt Dam was what permitted Phoenix's large-scale agriculture to emerge in the first half of the 20th Century, while the CAP was what set the stage for Phoenix to start reducing its dependence on groundwater overdraft (while continuing to support a growing population). The role of the Bureau of Reclamation is clear in this sense. It made more water available to a growing metropolis, which supported further growth. This is argued and documented effectively in Mark Reisner's famous 1993 book, *Cadillac Desert*.

Yet, less-considered are the forces that actually drove the metropolitan growth of Phoenix. Improvements in technology and water supply are what fostered its growth, but what was driving it in the first place? To review, below is a graph of Phoenix's population growth.



Source: US Census Bureau

Roosevelt Dam, the first major Bureau of Reclamation Project, was finished in 1911, yet Phoenix didn't explode in population until the 1950's, after WWII. If Reclamation Projects were driving metropolitan growth, one would think that Phoenix would have exploded in size and industry around 1911. However, as discussed, it wasn't until WWII that large-scale industry emerged in Phoenix. Military spending, in the form of Air Force bases and defense companies, brought industry to an area that had previously been a farming community. Then, after the war, residents moved to Phoenix primarily because of the economic opportunities created by this federal spending. Indeed, although the desirability of a suburban lifestyle and desert climate were reasons that residents and companies moved to Phoenix, people wouldn't have moved there in the first place if industry didn't already exist. Federal defense spending thus created a basis for economic opportunity, which was then supported by civic leaders, technological improvements, and reclamation projects, forming Phoenix into a metropolitan center of 1.5 million people. US Defense spending during WWII seems to be the primary factor responsible for Phoenix's metropolitan growth.

On this note, I do not want to underscore the importance of reclamation projects in Phoenix's history. Phoenix wouldn't have been able to grow at the rate it did without the abundance of water from reclamation projects on the Salt and Colorado Rivers (SRP and CAP). However, I think the real importance of these reclamation projects is linked to economic desirability, rather than the physical supply of water they brought. Since these huge, elaborate projects were largely funded by the federal government, citizens of Phoenix benefit from them without having to pay the full price. For example, residents are only responsible for paying 45%

of the CAP's 4$ billion cost (Walton 2015). The rest is entirely paid for by the federal government. This provides Phoenix with water that is not only abundant, but cheap.

Cheap water is part of the image of economic opportunity that continues to drive Phoenix's growth. Even though Phoenix receives less than 20cm of precipitation annually, it has some of the cheapest water in the country, as well as one of the highest rates of consumption (Walton 2015). That is to say, massive federal spending on reclamation projects allows residents and industries to disregard the aridity of their environment. And in addition to the low price of water, there is also a lack of major conservation programs in Phoenix. Phoenix's water supply system is notoriously supply-driven, meaning that little attention is placed on discouraging water demand (in contrast to neighboring Las Vegas and Tucson, which have prominent demand-side restrictions). This seems to be part of the city's attempt to be an economic hub. Water use restrictions or high water prices would undoubtedly begin to erode the city's oasis image, which would threaten the desirability for people and companies to move there.

All in all, Phoenix's metropolitan growth has been driven by its image of economic opportunity. This opportunity, first created through military spending during WWII, has since been supported by technology, the military industrial complex, and further federal spending in the form of reclamation projects. Phoenix has crafted an image for itself as a burgeoning desert oasis, with all the positives (comfortable winters, open air) and none of the negatives (summertime heat and water scarcity) of the environment that it's located in.

The Situation in Australia and Saudi Arabia

Australia spends much less than the United States on its military. Aside from a spike in spending the early 1960's (in response to Indonesia's rapid military buildup), Australian defense spending since WWII has been around 2% of GDP and characterized by a downward trend (Novak 2013). This is even despite the fact that in the past they have pledged to maintain a decent number of peacetime troops in order to help allies (Vandenbosch 2015). But then again, it's no surprise that Australia has let its defense forces decline. It knows that its powerful allies, like the US, will protect it in the case of any major conflict, so it really has no need to maintain a large standing military of its own. They have instead chosen to focus on developing their internal economy, which they claim is still an effective way of helping their allies (Vandenbosch 2015).

The Australian economy is largely based on exports, which largely go to Southeast Asian countries like Japan, Korea, and China. (Hinshaw and Stearns 2013). The primary exports are food and minerals. The country experienced a spike in domestic manufacturing during the 1960's, but this has also declined since then, to the point that it is currently only about 10% of their GDP (Vandenbosch 2015). The industry that emerged during WWII, along with the remaining industry today, concentrated around Australia's major coastal cities. There were no blossoming industry-friendly cities in the middle of the Outback to entice them. Perhaps the situation would have been different if they had a bigger military program. If they spent an amount compared to the United States on their defense industry, they may look to the Outback to build massive air force bases and airplane-related manufacturing industries. And if these cities began increasing in population and attracting other businesses, the Australian

government may also be inclined to fund reclamation projects or desalinization plants to support the cities. However, since Australia has much smaller military spending and government, they have not supplied the immense amount of funds needed to allow urban development in an arid region.

The Saudi Arabian government, on the other hand, has invested immense amounts of money into urban development in deserts. This is undoubtedly borne more out of necessity, since they live in a country that's 95% desert. They didn't need a massive war effort to spur industrial growth in desert regions. They had no choice but to do it.

When the present day Kingdom of Saudi Arabia was formed in 1932, Riyadh was chosen to be its capital. At the time, Saudi Arabia was one of the poorest countries in the world, and Riyadh was a town of only 27,000 people, who lived tribal lifestyles based around livestock and small-scale agriculture (Garba n.d.). However, oil was discovered near the Persian Gulf in 1938, which was started bringing massive wealth to the country by the 1940's. When King Saud came to power in 1953, he chose to use some of the government's new wealth to modernize Riyadh and make it a more admirable and functional center of government (Elsheshtawy 2008). He brought in American construction companies, who paved roads and built new, concrete administration buildings, which drastically contrasted the rest of the town. But at the same time, it signalized the intention for Riyadh to rise as a modern, metropolitan city.

Indeed, by the 1960's, people from all over the country were migrating to Riyadh, exploding its population to 500,000 by 1970. They came to Riyadh in response to the amount of money that the government was investing into it. Aside from the employment opportunities that stemmed from the federally-sponsored construction projects, the government also

invested significant sums of money into housing service provisions (e.g., land grants and interest-free loans) to make it easier for new residents to obtain houses (Garba n.d.). This made Riyadh especially attractive, considering that many other parts of the country were still relatively underdeveloped at the time (Elsheshtawy 2008). This began a migration that continues to this day, wherein immigrants from elsewhere in Saudi Arabia move to Riyadh seeking employment and a higher standard of living.

Riyadh has grown steadily since then, expanding in all directions with a population increase of about 8% a year. Over the course of this rapid development, urban planning and water supply have been the source of its problems (Elsheshtawy 2008). As the city ballooned in size, loose government policies and inefficient urban planning resulted in half of the city's land being unsuccessfully subdivided (Mubarak 2004). Roads were built around huge portions of land that didn't end up being developed, resulting in a patchwork of development that was similar to Phoenix's early development. In terms of supplying water to its increasing number of residents, Riyadh has had to turn to desalination, which currently provides more than half of the city's drinking water (Alabdula'aly 1997).

Desalination is a new technology that emerged commercially in the 1980's, and it is hugely expensive due to the amount of energy it requires. It is especially costly in Riyadh, since the water must be piped nearly 300 miles from multiple desalination plants on the Persian Gulf. But since Saudi Arabia is a major oil producer, they are able to operate these desalination plants at little cost to its residents (Fox 2013). However, even though residents don't have to worry about the cost of water, they have to worry about its reliability. In the past three decades, there have been repeated water shortages in Riyadh, with the most recent occurring

in the summers of 2011 and 2012. In the summer of 2012, water was available only once every 2.5 days (Fox 2013). In response to these shortages, and to keep up with population growth, the Saudi government continues to invest extraordinary amounts of money into building more desalination plants. In fact, they recently completed the Ras Al Khair plant in response to the 2011 and 2012 shortages. Ras Al Khair is the biggest desalination plant in the world, costing nearly $1.5 billion to build (Water Technology 2015).

At the same time, Riyadh officials have invested significant money into reducing urban water demand. They have championed water recycling, using wastewater for landscaping and industrial purposes (Garba n.d.). They also provide water-efficient appliances to households, free of charge. As a result of these efforts, they have reduced urban water demand by 25% in the past decade (Fox 2013).

King Saul's initial push to modernize his capital city made it stand out from the rest of the country, resulting in a large, unceasing migration of residents. They quickly outgrew the capacity of the groundwater supplies and turned to desalination as a supply-side solution. Given the availability of desalination technology and the massive wealth of the Saudi government, they have been able to continuously address the water supply, while at the same time, using money and technology to reduce demand. So in a way similar to Phoenix, an initial, massive government investment is what transformed a previously-agricultural center in the middle of the desert into an urban center with economic potential. The only difference is that Riyadh has seen even higher rates of growth, which are simultaneously addressed and encouraged by further government investment. That is to say, government investment in water supplies both addresses the problem of having a huge population in the middle of the desert,

and at the same time, increases the desirability of the city and attracts additional residents. It has grown larger than Phoenix because there is a bigger demand to live there, and a bigger input of government resources to make it possible. And so long as the government continues to be invest its resources into having an available supply of water for its residents, Riyadh will persist and continue to grow.

The Future of Urban Development in Deserts

The continuance of cities like Phoenix and Riyadh has been a dominant concern in recent years, especially with the predicted effects of climate change. The IPCC reports that "The contrast in precipitation between wet and dry regions and between wet and dry seasons will increase," essentially meaning that wet areas will get wetter and dry areas will get drier (Bates et al. 2008). For desert regions, this means that the occurrence and severity of drought will likely increase. Regional temperatures are also likely to increase, thus increasing evaporation and further decreasing supplies of surface water. Indeed, this seems to be a threat to the existence and continued growth of desert metropolises.

Given the perceived threat and level of concern around this issue, a multitude of case studies have been conducted for specific cities, especially Phoenix. The main concern for Phoenix would be the reduced flow of water in the Colorado, Salt, and Verde Rivers which, as discussed, are its major sources for urban water supply. A 2010 study by Bolin et al. notes that climate change will lead to smaller snow packs on the Colorado Plateau, thus resulting in lower water flow and disruption of delivery arrangements in the Colorado River (Bolin et al. 2010).

The higher regional temperatures would also affect the Salt and Verde Rivers, predicted to cause a 23% reduction in runoff by 2050 (Ellis et al. 2008).

Bolin et al. also discusses how a major stress on Phoenix's future water security will be further population growth. The authors note that, while past development has replaced agricultural land and provided a surplus of water for municipal uses, more recent development has not been on agricultural lands and is instead 100% reliant on groundwater (Bolin et al. 2010). This undermines the process of farmland conversion that has supported Phoenix up until this point, and at the same time, works against Phoenix's goal of reducing groundwater usage.

Another study by Gober and Kirkwood uses simulation modeling to explore future water-shortage conditions in Phoenix. They arrive at a conclusion similar to Bolin et al., stating that "…policy action will be needed to attain water sustainability in 2030, even without reductions in river flows caused by climate change." That is to say, they view further growth in population and water demand to be the main issues in Phoenix's near future (Gober and Kirkwood 2010). Reductions in river flow are a concern, but they aren't the most pressing issue.

The most pressing issue, then, is the same issue that Phoenix has been confronting in past decades: how to support a growing metropolitan city in an area characterized by aridity. As discussed, Phoenix has relied on reclamation projects and farmland conversation to increase municipal water supplies in the past. And in this way, it has been able to support a growing population.

The perceived threat is that they will soon be unable to continue increasing their available water supply in this way. This may be the case. But this perception also seems to

imply that Phoenix is doomed, that there simply won't be enough water and that the city will have to be abandoned. Critics call for massive actions that need to be taken immediately in order to avoid this catastrophe (Benson 2014, Ross 2011, deBuys 2011). Others think that the catastrophe is inevitable (Powell 2011, Adams 2014).

If Phoenix faces a water shortage, they won't be doomed. Instead, Phoenix will likely follow the trend of all other desert cities and start to take serious steps towards reducing water demand. This is the obvious solution proposed by many, including Gober and Kirkwood in their water-shortage study. They claim that changes in lifestyle, such as more native desert landscaping and fewer pools, would go a long way in terms of increasing future water security in Phoenix. And imagine if Phoenix provided tax incentives or subsidies to undertake these actions, or if they took the Saudi Arabian approach and provided water-efficient improvements to residents free of cost. These are all feasible solutions that have been used in the past to allow the growth of other desert cities, and there's no reason to think that they won't continue to be used in the future.

The role of technology is also overlooked in these criticisms. As discussed, technological innovations in past decades (such as air conditioning and desalination) are what made urban development in deserts possible up to this point. Air conditioning made living in Phoenix desirable year-round, and desalination provided enough water to support a population of 5 million people in the middle of the Saudi Arabian desert. Given that technology helped these cities get to where they are today, there's no reason to think that further technological innovations won't allow them to continue into the future.

This is in line with post-environmental thought, outlined in *Love Your Monsters* by Latour et al. Our technological ingenuity has enabled us to engineer comfortable metropolises in the middle of deserts, and rather than this as an abomination and back away from it, we should appreciate where it has gotten us today and embrace it into the future. Future growth depends on our ability to engineer further physical, biological, and social solutions (deFries et al. 2012).

In other words, these critics are overlooking the history of desert metropolises and underappreciating their significance. The fact that they exist now is a testament to their ability to exist into the future. These cities are already existing far beyond the supposed carrying capacity of the environments they're in. And so long as the governments can provide cheap water (through federal spending and technological innovation) and make these cities desirable to live in, their populations will continue to grow. Given the appropriate technology and financial inputs, there is no limit to their growth.

Conclusion

Deserts are commonly thought of as places devoid of life. And it makes sense why. Water is essential for life, and in deserts, rainfall is minimal and surface water is intermittent if existent at all. Based on the availability of water that is locally available, they certainly don't seem like the type of places that could support cities of millions of people.

Yet desert metropolises do exist. Urban development in the United States' deserts was spurred by federal military spending, and then sustained by the military-industrial complex

after the war, holding its image as an industrial center long enough for other non-military industries to settle there. Urban development in Saudi Arabia's deserts was also spurred by federal spending, except it was more deliberate in its intention to expand and modernize the city. In both cases, federal spending set the stage for migrations of millions of people, who found the cities comfortable (with new technologies like air conditioning) and economically opportune. Federal spending and new technologies are also what brought additional water to these areas, sometimes over hundreds of miles, in order to satisfy the growing populations and keep the cities desirable.

The historical growth of desert metropolises shows the fallibility of Classic Environmentalism and *Limits to Growth*. Cities of millions are growing in the most resource-scarce areas of the planet, places where one would think that *Limits to Growth* would apply the most. This shows that, with technological innovations, finite resources do not constrain human development. We have the ability to contrive any sort of development we want, given the demand to do so. And so long as people desire to live in these cities (and so long as the technology and financing is available), they will continue to grow, regardless of climate change or other predictions of decline. We have entered the Anthropocene, an era of human dominance over the environment, and the only limit to our growth is our own ingenuity.

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