Hothouse Flowers: Water, the West, and a New Approach to Urban Ecology

Dissertation

Presented in Partial Fulfillment of the Requirements for the Degree of Doctorate of Philosophy in the Graduate School of the Ohio State University

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2016

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Abstract

The Western United States contains not just one of the most arid regions in North America, but also the most urban region of the country. How to supply water to urban areas is one of the great questions of any society, and in the Southwest this was answered through a massive infrastructure centered around the Colorado River. It is my contention that the cities that received this water - such as Phoenix, Las Vegas, and San Diego - have been artificially subsidized in their population and land area growth, and have had to develop specialized economic functions in order to justify further subsidies of water from the river and, by extension, the rest of the country - that they are, in plain terms, hothouse flowers transplanted into an environment that they could never live in without massive inputs.

Multiple strands of urban and environmental theory are then presented and examined to gauge their ability to explain, let alone predict, the existence and development of such cities; while human ecology and urban political ecology have the tools and theoretical power to do so, I contend that the presence of technology and money - whether private or from government - is so new and combines so effectively in the form of these hyperspecialized cities that previous theories must be updated.
After establishing that there is a sufficient distinction between metropolitan areas in the Colorado River System (MSAs that receive water via the Bureau of Reclamation’s massive infrastructure) and those in the Rest of the Arid West, in addition to the rest of the United States, I then conduct time-series regressions with panel-corrected standard errors and conclude the following. Metro areas in the Colorado River System are larger and grew faster than their Arid counterparts in population and land area. The availability of Colorado River water induced land area growth in metropolitan areas such as Phoenix, Tucson, and Las Vegas. Metropolitan economies in the Colorado River System are somewhat hyperspecialized in that they rely upon certain tertiary & quartenary sector activities more than the rest of the country, but these economies are also not generating much benefit considering the environmental and national subsidy being provided. And lastly, the metro areas are heavily reliant upon a river that, according to the most likely scenarios of future projections and climate change forecasts, will only decrease in water output, putting further strain upon the entire region at the same time that it is expected to almost double in population.

In conclusion, I posit that these cities have overshot their natural resource base and represent a new form of modern risk due to their size and reliance on resources that may not exist in the future. I then contend that a new approach to urban ecology is needed to account for the complexity of the interlocking human and natural systems upon which these arid cities – holding tens of millions of people with billions of dollars in built infrastructure – have come to depend, as well as others like them in the future and around the world.
Dedication

First off, I would like to recognize and thank Robert Antonio for all of his guidance, advice, and inspiration since he helped set this all in motion on that August day in 2003 in Lawrence, Kansas. I would like to thank the faculty and staff of the Department of Sociology at the Ohio State University for their help, guidance, and support throughout my eight years here. My profound gratitude goes to Chris Otter, Hollie Nyseth-Brehm, and Edward Crenshaw. Chris’ seminar class in my first year helped orient not just what makes environmental studies so critical for our society, but also guided me in how to be a scholar at a time when I was just starting to learn what that really meant. Hollie has been nothing but supportive and helpful since the moment I first met her, and even when I was doubting myself (and that has been often), she asserted that I was, and still am, destined for greater things. And Ed has been my advisor since that Masters project so many years ago; we will never agree on everything, but I have come away from each and every one of our discussions having learned something new and with a revised perspective on the world, and can honestly say that I am a better man today because of him. Whatever career path I end up on, it will be Ed’s advice and guidance that helps me succeed in it.
I would like to thank my students over the past seven years that I have taught at this university; it was a pleasure and an honor to have met and helped educate so many bright young people – over a thousand – who will shape the world for decades to come. I would have never made it this far without the love and friendship of my fellow grad students; their kindness, help, beer, and laughter lightened what at times seemed like an intolerable load. Tate Steidley, Alicia Croft, Emily Shrider, Matt Schoene, Marty Kosla, Jennifer Mendoza, Dave Ramey, Brian Soller, Erica Phillips; you all made the past eight years both bearable and worthwhile, and I can only hope I returned the favor in kind.

I cannot express how much my family have played an immense part in this whole experience. My parents, Sharon and Virgil, instilled in me the values of selflessness, hard work, honesty, empathy, and not quitting until the job is done. Without them and their example, this dissertation quite simply does not exist. My sister Sheree always knew when to check in on me, and help me remember what is truly important in life.

And of course, Lindsay. I don’t know what I did to deserve and receive your boundless optimism, enduring love, and infinite reserve of patience, but I hope this shows that it was not wasted. Let’s go save the world, or at least some small little corner of it.
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Chapter 1: Hothouse Flowers

It is possible that the collapse of Chacoan society was partially a consequence of its success. By increasing subsistence security and reducing natural checks on population, the Chacoan system allowed regional population to rise to a level that would otherwise have never been attained.


A. ‘All Used Up’

The Native American tribes who lived in the region currently occupied by the Phoenix metropolitan area are now known as the Hohokam; they did not call themselves that, but were given the name – meaning “all used up” – by the tribes that succeeded them in the arid Arizona basin stretching from Flagstaff to Tucson (Powell 2008: 32). The Hohokam and their even more ancient counterparts, it is estimated, first inhabited this broad region approximately three thousand years ago, and while their numbers and reach varied over the next few millennia, they were a mainstay in the area thanks to the presence of water from the Salt and Gila Rivers (Logan 2006; Powell 2008). The most direct and lasting knowledge of their society comes from the eight hundred year stretch, between the 7th and the 15th centuries, when the Hohokam occupied the valley along the Salt River where present day Phoenix exists (Debuys 2011).

During this time the Hohokam were at their height, with an archaeological consensus that the population reached at least forty thousand people by the 1400s – in fact some estimates suggest as high as fifty thousand,
and this despite a setback in the mid-1100s when a fifty-year drought pushed the society to the brink of survival in regards to resources for a still-growing population (Diamond 2005; Ross 2011). To provide for such numbers in an area that gets approximately seven inches of precipitation annually, the Hohokam built a vast irrigation system of hundreds of miles of canals to harness the spring flows from the Salt and Gila Rivers, providing enough water for an agriculture that would provide the vast majority of the society’s caloric needs, as they evidently ate very little meat (Powell 2008). Over three hundred miles of canals have been discovered, though it’s likely that not all of them were used at once, as today’s water engineers have realized that the Hohokam figured out how to use geography and the water table to their advantage and would have used the canals only when needed and when water was available, long before the invention of modern infrastructure (Logan 2006). In the middle of one of the most arid places in North America, the Hohokam built a flourishing society complete with four-story buildings, trade networks and even sports, as they harvested crops from tens of thousands of acres of land serviced by canals as wide as 30 feet across and 10 feet deep, illustrating a massive undertaking and division of labor within a complex and rooted society (Diamond 2005; Logan 2006; Powell 2008; Debuys 2011; Ross 2011). And yet, according to archaeologists, there is no trace of the Hohokam of central Arizona after the year 1450.

The Hohokam were not the first to suddenly disappear from an area without any immediate repopulation, as the Anasazi in Chaco Canyon in the 1100s and the Puebloans at Mesa Verde in the 1200s share similar stories of rise
and fall in a harsh and unrelenting landscape. The San Juan Basin in New Mexico saw off-and-on human habitation over several millennia, culminating in the Chacoan culture that was developed by the 800s; Chaco Canyon was filled with stone complexes of multi-room dwellings, along with an agricultural system that facilitated the creation and trade of valuable goods from further afield (Diamond 2005). The architecture of the Chacoans belied its austere surroundings – with vast buildings of several hundred rooms surrounded by hundreds of smaller pueblos which held the bulk of the population – as did the resource consumption of a society that at its peak held between 4,000 and 10,000 people (Tainter 1988; Diamond 2005). But in the mid-1100s, the same fifty-year drought that affected the Hohokam in Arizona began destabilizing Chaco Canyon; more droughts and instability over the next several decades led to resource depletion, deforestation, declining economic and agricultural productivity, and depopulation. By the 1200s, Chacoan culture had effectively collapsed.

During those last couple of centuries, some of the residents of Chaco Canyon migrated to Mesa Verde, in present-day southwestern Colorado. There, Puebloans had built cliff dwellings over the previous several hundred years (the Puebloans were considered part of the larger Chacoan system, but remained distinct in their geography and culture) and forged a rather sustainable lifestyle using the water and land of the surrounding valleys, taking advantage of the temperature and precipitation differences between the top and middle of the mesa (itself thousands of feet above the floor of the larger Mancos Canyon). At its peak, Mesa Verde is believed to have been inhabited by as many as 22,000 people,
twice that of Chaco Canyon. Despite their location and resource systems, however, the Puebloans were not immune to the climatic instability of the region. A nearly seventy-year drought in the 1200s was followed by other weather anomalies, and the same extremes that finished off Chaco Canyon began the process of destabilization and outmigration at Mesa Verde, eventually bringing hundreds of years of habitation to an end (Tainter 1988).

As goes the Chacoans and Puebloans, most likely went the Hohokam, who had hundreds of miles of canals but may have very suddenly found both too little and too much water to go through them, as there is evidence of decades-long drought followed by severe flooding (the extremes of a desert ecosystem make both outcomes possible in an incongruous but ever-present manner) (Debuys 2011). There is also evidence that like the societies before them, the Hohokam absorbed migrants into their population during good times that strained their existing resources without increasing the marginal productivity of their economy to even try to balance out the costs (Tainter 1988; Debuys 2011). The Hohokam demonstrated, in the words of Powell, “that a desert society that expands to the limit of the carrying capacity of the land and water balances on the thin edge of survival” (2008: 33). It is possible for life to thrive in a land of aridity and extremes; indeed, the deserts of the American Southwest are some of the most biodiverse areas on the continent (Logan 2006; Nicholls 2009). But the margin of error is much narrower, thus demanding one of two responses: a more intrinsically robust species adapted for life in all of its various circumstances in
such a place, or the creation of systems for augmenting resources in that place in order to stave off disaster for the fragile systems and species therein.

**B. The Question of Water**

Rome, capital of a burgeoning republic, had outstripped its own local water supplies by 300 BC, and began construction of an aqueduct called the Aqua Appia, which reached ten miles from a natural spring and was calculated to have brought in 75,000 cubic meters, or approximately nineteen million gallons, per day (Ashby & Platner 1929). Additional aqueducts, bringing even larger amounts of water, followed in the future in order to facilitate an ever-growing urban population that had grown from, and vastly exceeded, the resources of its immediate hinterlands. Over several hundred years, the Roman Republic and Empire built eleven aqueducts to overcome the water problem that threatened to not only prevent the city from meeting its expanding demands, but also posed a public health hazard. Such building projects were not confined to the capital, as aqueducts were spread throughout Roman civilization to augment existing local water supplies for agriculture, industry and urban usage; a single aqueduct in Carthage was nearly 60 miles in length, while a continuous system of aqueducts and canals spread out over 155 miles to bring water to Constantinople (Mamboury 1953). But the system serving Rome itself was a technological marvel for its time, eventually totaling almost 500 miles to, around and across the city, supplying vast amounts of water that exceed what some modern cities of
millions use today. Using concrete, ceramic, and lead pipe, there are numerous existing sections of aqueducts still standing and some even still in use.

A couple of millennia later, another emerging center of the known world also faced the question of water, as New York City would find itself rapidly expanding over a period of mere decades and repeatedly overshooting its local water supplies (with the attendant problems of sewage and disease). The first of three main aqueducts was built in the mid-1800s, with a capacity of ninety million gallons per day; it was replaced and supplemented with other aqueducts to bring in water from various rivers and storage reservoirs around the city and its environs over the next several decades (Gandy 2002). The lynchpin of the modern New York City water system, though, was the decision to acquire and set aside a large portion of the Catskills Mountains and its watershed that supplies the vast majority of the drinking water to the city. Combined with other policy decisions throughout the 20th century, including restricting development and pollution in the watershed in order to avoid having to build expensive water treatment plants downstream, the watershed not only provides the city with abundant, clean water, but also ensures that approximately 95% of the water New York City uses is gravity-fed, requiring no additional pumping to bring the water to its users and thus dramatically reducing costs. The city still faces problems of water quality and stormwater displacement which is par for any urban setting, but has solved its water question through both modern infrastructure and a respect for natural processes.
These examples of sites and cities represent different aspects of the water question that plagues urban societies whether they are in the middle of a watershed or in the middle of a desert. But these examples also show the importance of geography, resources, context, and of the umbrella concept that governs all of those aspects of society and more: ecology. To have a full and complete understanding of a place – that is, to understand it ecologically – is to understand the various interactions that occur within it, allowing for life to exist, flourish and thrive. The indigenous societies of the Southwest tried to balance on the knife edge of their local resource base, utilizing the scarce water as best they could but never knowing, due to the inherent uncertainty of an arid environment, when they would be pushed over that edge. Rome and New York City were located in regions that had enough initial water supplies to create what would become a self-actualized urban area; upon outstripping their local water resources, they then sought to augment those resources to meet existing demand. In so doing, they were able to utilize economic and engineering means that were unavailable to the Chacoans, Puebloans and Hohokam. Such means have now made themselves available to descendants of those native societies – the people and governments of the American West – and the spirit and moral of these societies combine to form the foundation and inspiration of this dissertation: the creation, existence, and future of Phoenix, Arizona.
C. Phoenix

The city we know as Phoenix started more or less as a U.S. army installation, foreshadowing Phoenix’s later growth due to military spending and federal infrastructure dollars (VanderMeer 2010). VanderMeer describes Phoenix as not being a typical ‘western’ town despite its location, nor a ‘cow town’ despite nearby ranching. Agriculture – thanks to the irrigation canals, the year-round warm temperatures, and the cheap land made possible through various developers and speculators – was the basis for Phoenix and, it was believed, would establish some natural growth barriers to the town (2010: 16). Despite having only a couple of hundred people in 1870, Phoenix would grow 240-fold by 1930; although this still gave it a population of just under 50,000 (cf. Denver’s 288,000), it was an extraordinary growth rate that set the stage for even more growth in the decades to come (VanderMeer 2010).

Phoenix would double in size during the Depression and World War II, with a 1950 population of approximately 107,000 people that made it the urban center that central Arizona hoped for to compete against Tucson farther south. The war brought not just Army and Air Force bases to the Phoenix region, but later on defense contractors and other industries aligned with the military would come to the area, bringing in hundreds of millions of dollars just in aviation contracts alone (Logan 2006; VanderMeer 2010). Tourism also began to bring in its own hundreds of millions in the years following World War II, as motels and trailer parks benefited from the temperate climate and the growth of
a modern tourism industry for middle class families and retirees, who also started to migrate to the area in search of warm winters and cheaper living costs (Logan 2006: VanderMeer 2010). While there was obviously a large portion of the population who lived in the city year-round through the oppressively hot summers, the growth of Phoenix wouldn’t take off in earnest until a technological breakthrough: air conditioning. Logan describes it as such: “As boosters proudly proclaimed in 1940, ‘Phoenicians do not move to new localities when they desire a climatic change. They change the climate!’ ... Technology seemed to have finally conquered the desert environment, allowing human society to force its own concepts of time and space onto a pliant nature” (2006: 145).

This innovation allowed for Phoenix to attract not just tourists and retirees, but also additional industries such as manufacturing and service-sector corporations to try and help diversify a regional economy still largely dependent upon mining and agriculture (Logan 2006). But while manufacturing does play a significant role in the Phoenix economy entering the 21st century, that sector of the economy remains far behind wholesale and retail trade in terms of GDP, and employs far fewer people than administrative services or health care (Census 2016). Despite efforts to create a diversified economy rooted in manufacturing and productive industries in order to achieve sustained (that is, non-boom and bust) development, in many ways, the prime economic engine in the city has been its own growth as residential and commercial construction, and the
workers who built those houses and buildings, propelled a regional economy being buffeted by rising housing prices (Ross 2011).

It is almost impossible to look at a city that grew from approximately 107,000 people in 1950 to nearly four million in today’s metropolitan area and not see that such explosive population growth was the key function for the entire region (VanderMeer 2010). As Grady Gammage, former president of the board of directors for the Central Arizona Project and one of Arizona’s premier water & land use experts, told me in a personal interview in 2013, the city planners have continually drawn a line on a map and infilled up to that line with single-family houses and box stores on a massive grid pattern, in contrast to how the ‘traditional’ eastern city may grow outwards (Gammage 2013b). (Indeed, upon visiting Phoenix in 2013, I was struck by how quickly one goes from desert to being surrounded by full housing divisions, shopping centers, and parking lots, with almost no transitional zone at all.) The 170% increase in population from 1980 onwards served as a catalyst for Phoenix’s economic growth, but it also became indispensable for continued prosperity. Much like a shark that must keep moving or die, the economy of the city became dependent on consumption over all else: housing prices, construction jobs for new housing starts, and the retirees and families who would fill those houses (Heim 2001; VanderMeer 2010; Ross 2011).

The vast majority of Phoenix’s metropolitan population of four million people lives in the suburbs within Maricopa County, and while the county is one of the groundwater management areas set up under a groundbreaking 1980 law
to regulate groundwater drilling (one of the first, and still one of the few, such policies in the West), even per capita reductions in water use have not offset the demands upon the larger water system which relies more and more upon the Colorado River via the Central Arizona Project (Holland & Moore 2003). The CAP is the apex of public infrastructure projects in the American West and the culmination of centuries of water engineering; as such, it represents Arizona’s attempt to solve the water question, and serves as one of the premier modern examples of cities attempting to surpass and exist beyond their immediate hinterlands (Hanemann 2002; Holland & Moore 2003; Ross 2011; Debuys 2011).

While this dissertation, broadly construed, is meant to investigate the development of urban areas in ways that ignore their physical environments, and uses those cities as the unit of analysis (and the entire Colorado River watershed as the area of operations), it is the story of cities like Phoenix and projects like the CAP that serves as both inspiration and warning for what I believe is the next critical phase in environmental and urban sociology, and serves as the guiding purpose of this dissertation. In the movie *V for Vendetta*, the titular character says “You already have the information. What you want, what you really need, is a story.” As such, the narrative – of the place, of its formation, and of its future – becomes as integral to the study as theories, pieces of data, and statistical analysis, and serves to ground the very real implications of what we will find in the water and the sand of the American Southwest.
D. The Question of Control

The quintessential issue of ecological studies is the question of control – how much power do we have (or think we have) over nature, and how long we can hold on to that power before it reverses. Think, for instance, about a flower in a hothouse (also known as a greenhouse); while flowers exist in the wild and can grow and spread with seemingly no necessary action on the part of other species, a plant inside of a hothouse is very much dependent upon the people who planted it there. It will be planted as a seedling in its own container so that it does not have to compete for resources; those resources will need to be supplied to it as it is not connected to the larger ecosystem outside; and its existence is managed for the purpose of growing a specimen worthy of sale or prize. Every stage of life for that flower is managed for an outside purpose, and while it is a natural and physical reality, its very presence in this world is, in many ways, an artificial phenomenon.

The hothouse flower, then, is one extreme of the question of control over nature, but even then, such flowers raise their own issues; they are grown in very specific conditions, for very specific purposes, with no interaction required with a larger ecosystem and the requisite environmental changes that exist within such a system. In contrast to species that developed and evolved in the wild and thus had to become more robust in order to thrive in competition for resources, the hothouse flower has had no such competition; even its own evolution is guided not by the quest for resilience in the face of competition and extinction, but by a separate process for a specialized function that may not fit even the
nature of its own existence. While such flowers may very well survive just fine when transplanted to a different, more dynamic environment, it remains the case that the flower’s existence is in many ways an artificial one, and its interaction with the larger, unsubsidized environment is not by any means guaranteed to be successful.

The interplay and impacts of humans upon their environment, and of the environment in shaping human society, is fundamentally a study of how much agency and control exists within a given ecosystem. Bernard asserted that social science must account for the role of nature in understanding the existence, type and growth of societies, as technological and organizational innovations were based on adapting the environment to suit the needs of man; as great and wonderful as the resulting culture may be in enhancing human quality of life, though, he warned that culture must also adapt itself to its surroundings or else “pay the penalty of its ignorance or arrogance by being destroyed” (1930b: 42). As will be described and examined in this dissertation, Congress, the Bureau of Reclamation, and the States of the Southwest envisioned a Colorado River – one of the great rivers of the North American continent, if not the Western Hemisphere – that would be not just be tamed, but managed; and not just managed, but even mechanized to not only serve the needs of a growing population that didn’t even exist in the area yet, but to turn the nearly uninhabitable Great American Basin into an economic powerhouse. In such a vision, the issue of control was already settled: theirs was a dominion that was unquestioned, with the certain belief that the Colorado River would supply so
much guaranteed water that for decades the only real question to be considered was how to use it all before it was ‘wasted’ by flowing into the Gulf of California (Reisner 1993).

With such an ironclad belief that the river would always supply the necessary & expected water, the Southwest boomed over the second half of the 20th century at an unprecedented rate; many cities saw their population and land area grow several times over in a matter of decades, built on a post-industrial morphology of radial zoning, suburban development, highways and interstates, and perhaps as important as anything else, the idea of a lush green lawn for every person who bought a house in the most arid region of the United States. Cities like Los Angeles, Phoenix, and Las Vegas are the obvious beneficiaries of concerted efforts by the Bureau of Reclamation to dam, store and pipe the rivers of the desert Southwest to anywhere that asked for it, but the Colorado River has also, in some form or fashion, made its presence felt in San Diego, Palm Springs, Albuquerque, Tucson, Denver, and Salt Lake City (Dawdy 1989; Bureau of Reclamation 2015). These urban areas, themselves containing the majority of the region’s entire population, saw most of their growth occur at the exact same time that the Bureau built megadams and large-scale aqueduct and irrigation projects the likes of which the world had never seen before. Indeed, the size, complexity and expense of many of these projects – ultimately responsible for damming, diverting, and reclaiming some three trillion gallons of water a year just for the lower Colorado Basin alone – dwarfs that of any society up to the present, with only the Chinese government as a potential
challenger. The technological achievement of these projects, and the willingness of the Federal Government to fund them, was a game changer for the American West, allowing millions of people to live in areas that had never before supported more than a fraction of that number (Debuys 2011). Phoenix, Las Vegas, and San Diego (to name just a few cities) are no more dependent upon water than any other urban area in the U.S.; they are, however, far more dependent upon a complex, region-wide infrastructure in a more precarious ecosystem – that happens to span almost a fifth of America’s continental land area – than most other urban areas. Having obtained the full flow (and then some) of the Colorado River to supplement local rivers and groundwater sources, these cities have now grown so much that they cannot possibly provide for themselves without the subsidized water that flows through the subsidized aqueducts and intake pipes from a river that is managed with subsidized dams down to its last drop by a Federal bureau whose existence is defined and perpetuated by those projects, and by extension, those cities (Reisner 1993; Glennon 1995; Sabo et al 2010). These cities, I will contend, are the human and systemic equivalent of hothouse flowers; the ‘seedlings’ of economic interests and urban morphology were transplanted into a foreign environment, grown and managed for a very specialized purpose, artificially supplied with outside resources that the cities could not obtain or afford on their own, allowed to grow (in both population and land area) at a nearly uncontrolled rate in order to increase economic prosperity, and now face the shock of encountering ecological constraints that cannot be easily or forever overcome.
The most obvious constraint is that of the extreme dependency upon this complex water delivery system. It might seem unfair that I used New York City as an example in comparison to Phoenix, since NYC exists on the East Coast, is serviced by multiple rivers in a watershed with abundant precipitation, and is in fact surrounded by water. But to talk about Phoenix as if it is in a vacuum, and not part of a larger society which contains cities with just as many people but without the vast expense of obtaining and using water, would be to overlook the very issue of environmental determinants in social systems. And to talk about Phoenix as if it exists as an isolated metropolitan area, rather than as the locus of an entire socio-ecological construct, placed and bounded within a defined environmental setting and governed by multiple interlocking economic, political, and natural systems, would be to deny how cities exist in the first place. Both of these issues form the underlying foundation of not just the chapters you are going to read but the current state of the West itself.

E. The New Normal

At the time this dissertation project was begin in earnest, California had been stricken with a drought that became so historically severe that by 2014 the State Water Project – serving California’s agriculture-rich central valley with water from the northern part of the state – decided to cut off water deliveries for agricultural users for the first time in its over 50-year history, while every water district in the state was ordered to meet a mandated 25% total reduction in state usage due to the extremely dry wet season that led to the snowpack being just 5%
of normal by April 2015 (Ball 2014; Nagourney 2015). Some water districts in the state found themselves trying to reduce usage by as much as 36%, while the regulatory regime to help create and enforce such reductions remained archaic at best and nonexistent at worst – leading to the literal public ‘shaming’ of exorbitant water users for whom the fines were always less than the cost of the water itself – in trying to meet the current crisis, which in the eyes of many experts is on the verge of becoming a superdrought the likes of which hasn’t been seen in the region in over a millennia (Cook et al 2015; Egan 2015).

In August 2013, I took a research trip to Phoenix, Arizona, where I spoke to a land- and water-use expert named Grady Gammage who guided me through the history of Arizona’s policies in regards to its water projects and how it consumes its Colorado River allotment. In the course of that conversation, Gammage said that the prevailing belief in Phoenix, and the state at large, is that the cities control the water supply, that the water will continue to flow, and that the urban fabric and the four-million residents of the Phoenix metropolitan area will be buffered from any changes in the supply from the river (Gammage 2013b). Immediately upon my return from that trip in mid-August, the Bureau of Reclamation announced that for the first time since building the Glen Canyon Dam and creating Lake Powell (a massive reservoir on the Arizona/Utah border) it would start to plan for reducing the outflow for the lower Colorado River by 9% under the amount that is traditionally stipulated in the Law of the River. That interstate compact, originally written in 1922, divided the Colorado River between the seven States that share its basin (as well as Mexico, which is
guaranteed a minimum amount of the Colorado’s outflow under a binational treaty); under the most recent update to the Law of the River, an official shortage on the river would trigger a 4.3% reduction in water appropriations for Nevada and 11.4% for Arizona, but, surprisingly to outside observers, none for California (Kenworthy 2013; MacDonald 2015). This is due to a prescient and potentially catastrophic compromise regarding the Central Arizona Project, through which the vast majority of Arizona’s allotment flows, with all of it used by farmers, businesses, and approximately five million out of the six and half million people in the entire state.

Continued mild winters over the past several years have further reduced water outflows for the Colorado River, leading to lower water levels in Lake Mead (which was formed behind Hoover Dam on the border of Nevada and Arizona). As of the summer of 2016, the lake is at its lowest level ever, and officials are hoping that releases from upriver at Lake Powell will help avoid that automatic shortage on Lake Mead (James 2016). This forecast led the Southern Nevada Water Authority (which services the Las Vegas metropolitan area) to spend the better part of a billion dollars in an emergency project to build a third intake tunnel into Lake Mead, as the water levels in the lake are rapidly approaching the point below where the two existing intakes may be rendered useless in carrying water to the city. Las Vegas gets 90% of its water from this one supply built decades ago on the misguided assumption that the amount of water carried by the Colorado was millions of acre-feet more than is the historical norm (Powell 2008; Brean 2014). Continuing to wring every drop of water out of existing
supplies (along with bringing more supplies online from further afield) will require more and more money from regional cities and States, and potentially the federal government, as the millions of urban residents become both the impetus and guinea pigs for the law of diminishing returns in regards to the desert’s most valuable resource.

The American West is our most urban region, in that a greater proportion of its residents live in urban areas compared to the other regions of the United States, and what we consider to be the Southwest (southern California, Nevada & Utah, Arizona, western New Mexico, southwestern Colorado) is no exception. Of the 56 million people who live in the entire region, some 93% live in towns and cities, many of which, despite being relatively new and seeing more explosive growth compared to their eastern counterparts, have proven to be economically successful and socially adaptable (Garfin et al 2014). But these cities also exist within an ecosystem that is subject to extreme climatic, geological and hydrological variations, where environmental instability is in many ways a constant for the land and its inhabitants. The combination of the water question and the control question creates a formidable challenge for any city, but a new dynamic is about to enter the picture for human society: climate change, and its attendant impacts on the ecosystems that humans have spent hundreds of years, and countless amounts of money, energy, and lives, adapting and shaping to their own ends. New York’s recent history with hurricanes and superstorms has led to the awareness of how rising sea levels and powerful weather events will be a more frequent occurrence, necessitating efforts to built a more resilient
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tyscape that can withstand this ‘new normal’ (Shorto 2014). The same is now
ture for the American West, which will endure higher temperatures, increased
risk of wildfires, more extreme and longer lasting droughts, at the same time that
the Southwest itself is expected to almost double in population to a hundred
million people by the middle of this century (Garfin et al 2014). Climatologists
have been warning for years now that human society will have to adapt to the
‘new normal’ of higher than average temperatures for the rest of this century, but
that new normal, in a desert ecosystem, further sharpens that knife’s edge of
survival, and makes finding the right balance of ecological co-existence that
much more difficult (perhaps impossible) for a sustained period of time.

F. Black Swans & Moral Hazards

Two brief theoretical points of order should be made about how to approach the
arguments and analyses that will follow. Both, it turns out, became prominent
during the financial crisis of 2008.

The first point is in regard to how to think about cities in the Southwest.
In the aftermath of the 2008 crisis, Nassim Taleb became famous for his 2007
book Black Swan: The Impact of the Highly Improbable, in which he made the case
against standardized assumptions about the world we live in, arguing that
evidence against something (i.e. it has never happened before) is not evidence for
something (i.e. ergo it cannot or will never happen). Taking on much of the
financial industry and doing so before the crisis, Taleb was considered a prophet
of sorts, though he stresses that he was not predicting the specific crisis, but
simply stating that the assumptions and statistical models that were being used – because they did not account for the possibility of a crisis – were almost inherently inducing that very situation; in other words, when you think nothing bad will happen to you, more often than not you set the stage for your own downfall.

Urban areas require an intimate knowledge of their surrounding environment and the systems, both natural and social, that sustain them with resources. That knowledge, however, can never be perfect or complete, and thus requires making certain assumptions about such things as the frequency of natural disasters and potential disruptions in resource supplies. The Federal government, the states of the American West, and the cities of the Colorado River Basin acted upon incomplete information about just how much water comes down that lifeline of a river every year, and overbuilt the capacity and stimulated too many demands upon that river based on assumptions that the natural system simply could not meet for a sustained period of time. Millions of people, and billions of dollars of built environment, now lay in the direct path of ‘black swans,’ and by ignoring the potential risk that there might a shortage of water, it actually increases the odds of that such a shortage will occur and do even greater damage. Furthermore, the argument can and should be made here and in environmental sociology in general that while droughts are a natural occurrence in arid regions (and other ecosystems as well) and will undoubtedly be referred to as such by governments, institutions, and the media, it’s not a pure
natural disaster when we knowingly put people in the firing line of such circumstances in the first place.

The second factor relates to how we should think about water in the Southwest. In 2008 the term *moral hazard* became a common phrase when the Federal government responded to the financial crisis by ‘bailing out’ the Wall Street institutions that were exposed to the liquidity trap of their own creation, in order to prevent those institutions from going under and through their sheer weight bringing the rest of the economy down as well. In so doing, however, the government may have unwittingly sent a signal that banks and other financial institutions will be bailed out in the future by being ‘too big to fail’; by bearing the burden for Wall Street’s behavior, there is no disincentive for those institutions to avoid repeating it in the future, as they can take risks without the certainty of having to pay a penalty (Luyendijk 2015).

The Colorado River Compact was negotiated to ensure that the trillions of gallons of the Colorado River be put to productive use, and the Bureau of Reclamation was created to use Federal dollars towards that end, in the hopes that by guaranteeing water and electricity to the Southwest, this arid section of the country would become populated and prosperous. This growth has indeed happened, but because the Federal government, using taxpayer money and on our behalf, has subsidized and promised water to facilitate an urbanizing and ‘useful’ Southwest, now the government is in the position that it will have to keep delivering water that may not even exist, at whatever fiscal, ecological, or political cost that may entail, in order to prevent hundreds of billions of dollars
in economic investment from literally drying up in the desert and millions of people from migrating away. These billions represent sunk costs in the form of concrete and iron, houses and businesses, roads and stadiums; a built environment on top of a natural environment that, through its inherently uncertain and fragile nature, has already rendered previously existing societies in the region “archaeologically invisible” (Ross 2011: 25). The taxpayers of the United States, represented by Congress and the executive branch and with power and money appropriated through the Interior Department, Bureau of Reclamation, and Army Corps of Engineers, may be effectively guaranteeing that the people of the Southwest can continue to divvy up the Colorado River until every last drop has been pumped out, regardless of how economically inefficient or environmentally unsound those actions may be (Worster 1985; Reisner 1993).

G. Outline of this Dissertation

Chapter 2 will address the insufficiency of current theories on urban ecologies; while much work has been done on the role and importance of urban location, many of these theories suffer from being either too narrow in their descriptions of how cities develop, or were too early to account for the fundamental technological and economic changes in the post-war era that could allow for new kinds of cities to grow in regions where such growth wasn’t possible even decades before. Chapter 3 will then examine the nature of the Urban Southwest and how the enormous population and economic growth of the last six decades was fueled by a direct effort on the part of the Federal government to augment
and subsidize water supplies, spurred on by the contradictory economics of scarce resources, and resulted in an engineered region-wide urban system that has tried to surpass its immediate hinterlands.

Chapter 4 introduces the analysis sections of the dissertation, laying out the data and methods, as well as the challenges, of studying this critical but all too often overlooked issue of national and global importance. Chapter 5 unveils the results of these statistical tests to determine whether and how much of the growth – physical, demographic, and economic – that has occurred in the cities of the American West are in fact the result of efforts to control and deliver the Colorado River, rather than the other way around. This chapter will also utilize case studies of some of these cities as well as future projections of the Colorado River to gauge the potential problems of a declining watershed in an era of increasing demands.

Chapter 6 then concludes the dissertation with a call for a new theory of urban environments; drawing upon Beck’s concept of the ‘risk society’ and Catton’s warnings of ‘overshoot’ to understand the challenge that these cities present to both society and nature, I then propose that urban areas must be understood as the locus of chains of interactions between coupled natural and social environments which result in systems that draw their resilience, or fragility, from the number and types of interactions that support them. Too many theoretical perspectives either focus on the direction of the forces acting upon cities or concentrate on the origins of those forces, rather than seeing that the structures and systems that cities exist within lead to interlocking steps that
either open or close the flows of resources, capital, people, etc., in and out of the city; it is the interactions that are the key barometer of whether and how a city functions. In other words, four million people now live in an area of the Sonoran desert where 40,000 people, six centuries ago, proved too numerous to bear. We may have found more water, but we also made more assumptions about that water; we may have built extensive aqueducts, but we also induced more demand; we may have gleaming cities in a desert, but without external resources, they may just be really expensive and specialized hothouse flowers unsuitable for an environment that they have simultaneously tried to ignore, and we are now invariably committed as a society to fight off the ecological and economic consequences in order to keep them alive. This dissertation is an examination of how we got to this point, and why urban ecology must learn the lessons for our new era of complexity on the knife’s edge of survival.
Chapter 2: Theories Of Cities & Environments

The forces of the urban economy are not disengaged from the physical reality of the urban place; its topography, climate, biogeochemical cycles. These forces necessarily act along vectors that function as conduits for the delivery and consumption of urban resources. ... Every city embodies complexity. From ancient Aleppo to contemporary Dubai, the urban context always plays a primary role as host for the diversity of transactions that characterize human experience.


A. A Sense of Place

Sociology, for all intents and purposes, tended to ignore environmental determinants of societal development during its first formative decades, that is, until Bernard started examining how various geographical and biological forces shape human civilization (Bernard 1925). Adaptation to one’s surroundings, Bernard asserted, is the primary force in the building of not only what kind of physical society will develop there (with all of the material and institutional constructs that entails), but also what kind of culture that society creates in order to justify or reinforce its existence (1930a; 1930b). These material and cultural constructions represent an attempt to dominate, or at the very least manage, the physical space that a society inhabits; it almost goes without saying that Arabic and Nordic societies will have different approaches not only to how to build the means to survive in hostile climes, but also in how they organize their societies in order to facilitate long-term habitation. But for too long, sociology tried to focus on the differences and development in those societies as
being entirely within the mind – whether individual or collective – with only
passing references to the environmental and ecological roots of all human
society.

Bernard’s solitary salvo was, in time, joined by Mumford, but it wasn’t
until the post-war period that such ideas were embraced and expanded upon by
such sociologists as Lenski and Catton, and geographers like Diamond and
Crosby, by which point ecological studies were rapidly becoming not only an
organizing force within multiple disciplines, but a force in itself extending from
academia outward into a world that was beginning to realize the consequences
of modern industrial life, regardless of whether that industry was capitalist or
socialist in nature (Mumford 1934; Catton 1980; Crosby 1986; Diamond 2005;
Lenski & Nolan 1984; Radkau 2009). Incorporating geographic and
environmentalist themes into their work sometimes led to these scholars being
dismissed as ‘determinists’, which overlooked the fact that they were far more
balanced in addressing both physical and social forces than those who dismissed
them, as well as the fact that by bringing determinist arguments into the fray
they were helping balance social science in general as it embarked on a new
ecological age. The end result of this geographic turn – which in many ways can
be traced in a direct, though dormant, line from both Spencer’s examination of
natural and social differentiation and from Marx’s analysis of how capitalism
was transforming the very conception of space and time itself – is to help restore
within sociology a concept that is necessary if we hope to even understand the
physical, psychological, and social context of the urban areas we live in, let alone
address the ongoing economic, political, and technological changes that make our cities much like the proverbial river into which no man ever steps in the same one twice.

This chapter sifts through the existing theories of urban environments, highlights how they locate cities in the context of their physical geography and ecological resource base, and helps place those theories into a template from which to view how sociology has tried to make the ‘turn’ in bringing a sense of place to our predominant social theories. But those theories also fail, each in their own way, to fully account for not just the physical differences between cities and ecosystems, but also the temporal differences in how cities have tried, since the ages of the Romans and the Hohokam, to overcome their hinterlands. Those differences, growing larger at the same time that humanity is itself growing larger and more urban, could not be more important for urban and environmental sociology in our modern, ‘post-nature’ world, and set up the inflection point that this dissertation hopes to address.

B. Central Place Theory

Assuming, as Christaller did, that cities are boundless, isotropic and evenly distributed human systems, then their development and placement in physical spaces follows a relatively predictable model of maximizing efficiency on a

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1 This has become a popular phrase in recent years as both environmentalists and philosophers have grappled with the meaning and definition of nature itself, let alone how to understand our role within and outside of it. Vogel’s recent work arguing that the traditional concept of nature is actually a social construction that doesn’t serve us well since humanity has always altered nature in fundamental ways, and that our built environment should be considered just as ‘natural’ as a grove of old-growth redwoods, since both are part and parcel of how we think of the world around us and have been incorporated into the daily life of humanity in irreversible ways, is one of the standouts of this literature (2015).
equidistant scale (1933). Such assumptions, among others, allow for determining and even modeling where settlements will take root and how they will scale up (i.e. which settlements will become central nodes and develop higher order services, and which settlements will become part of the hierarchical order that is then placed into the larger system). These systems are based, in Christaller’s reasoning, on the minimum threshold of population that can support given services and functions, and the maximum range that people and information will travel to obtain those services and functions (1933). The beauty of the theory is that it provides a predictable approach for seeing where cities will naturally place and organize themselves on multiple levels, using and foreshadowing other principles of urban theory that have been developed by economists, geographers and sociologists.

One of the primary principles represented within theories of cities is that of agglomeration, that people, businesses, institutions, etc., will congregate near each other in order to take advantage of greater productivity and economies of scale (Abel et al 2012). This is how entire industries have generally been explained – the auto manufacturers around Detroit, the financial sectors in New York and London, the movie and TV production studios in Hollywood – and can even describe such seemingly incongruous phenomenon from the urban ‘creative classes’ of Richard Florida’s analyses to the clusters of jewelry stores in shopping malls, which capitalize on both the competition and cooperation inherent in being close together (Florida 2002 & 2008).
How this serves the purposes of central place theory is in that cities serve as critical nodes for not just populations but the disparate yet still intertwined systems within those populations: economic functions, governmental administration, societal norms, and cultural forces, among others. Central place theories stress the primacy of social structures and populations over the physical space, based on those underlying assumptions of distance, density and distributions. Populations that were spread out over geographical space will eventually coalesce in ways that reach the critical thresholds and ranges mentioned above, generating settlements, towns, and cities that abide by certain general rules regarding their size and frequency in a region (i.e. cities of the same size may tend to be equidistant from each other, while settlements surrounding them will be similarly sorted along a more or less fixed transportation system). The guiding idea behind such hierarchical urban settings is that of reducing overlap and inefficiency, with the idea that human systems will almost organically create higher and lower order cities and settlements in areas based on, again, the underlying assumptions about resources, population and physical space. Such systems exist as emergent properties, building out of fundamental physical forms and then reinforcing themselves because of social dynamics. Economic efficiency, then, is the selection agent in the placement, arrangement and development of urban areas: transportation networks, news and information systems, corporate market shares, even sports teams can be plotted in a reliably predictable manner. Overlap would not just apply to functions within cities, but also between cities, as agglomerated masses of economic power
and human capital would serve as magnets, pulling in individuals while pushing away other masses (Spates & Macionis 1987).

What central place theories are describing, then, is the urban-hinterland divide, and the fact that even in a boundless plane with resources and people evenly distributed such a divide will inevitably form itself as the physical geography of interactions take precedence over nearly everything else. Some of the most powerful criticisms of central place theories assert that, for one thing, the systems which govern how cities form are not in and of themselves natural (in that markets and governments are not themselves ‘natural’) and thus there is no reason to believe that the hierarchies of urban formation are exempt from the economic, political and social forces that shape other facets of human experience (one needs only look at zoning battles in residential areas as a prime example of this) (Spates & Macionis 1987; Davis 1992). Hand in and hand with this criticism is that not every city is formed for the same reason or with the same idea (minimizing overlap of functions) in mind, especially when considering cities in pre-industrial eras; religious and political centers grew into urban areas in their own right, and multiple cities could occupy the same region or function due to path dependencies that, once set in motion, became impossible to alter.

To these I believe we can and should add another criticism: that central place theory does not explicitly account for the physical environment on which its based. Central place theory may be implicitly describing the urban-hinterland divide, but it takes that divide as a given and does not delve into both the historical basis for why that city might be placed there, and the implications
of that city within its environmental footprint. Theories of place, let alone of human settlements with all of the interactions that are intrinsic to such settlement, must account for the foundational characteristics of that place. An urban geography that fails to let the physical environment inform, let alone guide, the understanding of the various systems that are then laid atop it will itself understand nothing. Central place theories can describe many aspects within and among cities, but underlying assumptions that assume away the environmental (both physical and social) aspects of those cities cannot allow for a complete analysis of the most important aspect of urban places: the divide between cities and their hinterlands.

C. Resource Bases and the Urban-Hinterland Divide

Central place theories do address the functions of urban areas and the primacy of cities that carry out higher order services over those that do not have the threshold to sustain such services, but Christaller and others talked about cities as seemingly static systems in which geographical units, once formed, were effectively closed by the transportation and information costs involved in traversing them (Berry & Kasarda 1977; Spates & Macionis 1987; Ferrão & Fernández 2013). This is an untenable approach to urban and environmental theory, starting first with understanding the resource bases of various societies and cities.

As mentioned above, geography exists because places exist, and those places are made real by the interactions of humans with the physical space they
occupy. It is the interactions that are critical issue for our purposes here and throughout this dissertation, as urban (and increasingly, environmental) theories are intrinsically focused on how people create and then transport themselves, their ideas and their goods over distances. When central place theory grounds its findings in the closed system of an urban grid, it is describing one set of interactions, but ignoring other vast sets of interactions based on the physical and human geography of place. Some of the most critical understandings of environment and society come from historical moments such as the dawn of agriculture (the creation of a fixed food supply to sustain at least semi-permanent settlement in one place), the creation of irrigation systems (which not only symbolize a transformation of nature but also the development of a new type of social organization), and the deforestation of a city’s surroundings due to overpopulation and consumption, to mention just a few events (Diamond 2005; Radkau 2009; Ferrão & Fernández 2013).

What this connotes is that a city’s base is, for all intents and purposes, its resource base: the amount of food, water, and other material that it can utilize for the purpose of habitation, sustenance, and perhaps eventual exportation. Whatever the inhabitants can gather for shelter and survival will determine the overall likelihood of the settlement’s existence, and the fact that resources are not evenly distributed (even within a settlement) means that the physical geography of a city and its hinterlands are the *sine qua non* of any urban theory and analysis.
That the resource base of a settlement determines its, and its inhabitants’, lifecourse can be seen in the history of any settlement on earth, none more so than in the societies who introduced this dissertation, such as the Chacoans of New Mexico. The Chacoans relied upon a form of agriculture that utilized whichever canyon floodplains happened to get precipitation, thus leading to wet years which accelerated population growth as well as increasing the overall size and power of the central settlement: “Chaco Canyon became a black hole into which goods were imported but from which nothing tangible was exported” (Diamond 2005: 149). Diamond details the extensive bio-historical research that has been done to reconstruct the record of the pinyon and juniper forests that the residents of Chaco Canyon relied upon for the timber of their structures, a critical ingredient of the physical and social development of the culture (2005). But their agriculture failed, suddenly and totally, at precisely the time period when the hinterlands became deforested, leaving the residents even more susceptible to changes in climate (which itself had also exacerbated deforestation, as dry climates are harsher for growth rates of forests) (Diamond 2005). The reason the Puebloan inhabitants settled in Chaco Canyon was because its resources and setting provided the best chance at survival, thus allowing for a burgeoning city that verged on what Diamond termed a ‘mini-empire’, with a clear hierarchy of higher and lower order sectors and an extensive transportation network which satisfies much of central place theory’s expectations of social organization and human space. Yet Chaco Canyon collapsed on its itself due to the inherent contradictions of the physical space
those inhabitants occupied. Cities may be be the epitome of human culture, but as Bernard would say, nature will always demand and compel the adjustment of culture to ecological ends (1930b: 42).

Cities are human adaptations to the environment; pre-modern cities were built to modify and shape the physical ecosystem to increase chances of survival, while post-industrial urban areas are governed primarily by their social environment and the quest to enhance quality of life. In addition to the food and materials needed for survival, the resource base of a city will also shape the economic industries and sectors that develop within it, thus having an outsized effect on the various types of capital (physical, human, cultural) that it can command. Pittsburgh, Houston, Kansas City, San Francisco, and New York, to name just a few such places, utilized considerable natural resources or geographic features within their immediate surroundings in order to expand their reach further out and become centers of entire industries or trade networks. In other words, they leveraged their physical gifts into a social environment in order to develop into regional, national and even world urban centers. Unlike Chaco Canyon, modern cities are able to develop export industries that capitalize on their nearby resources, thus bringing in money to build and expand infrastructure as well as alleviate any shortages in necessary goods and prevent the sort of disasters that befell their pre-industrial counterparts. Physical geography plays a major role in the human geography of cities in ways that can alter or even compromise the expected urban design from central place and ‘rational choice’ theories, such as wealthy residents living on
hills and/or upwind in order to escape pollution of various types, as was the case in ancient Rome, industrial age Manchester and Chicago, and modern day Los Angeles (Davis 1992; Radkau 2005; Platt 2005). This human geography leads to the creation or depletion of human capital, which has proven to be just as critical of a resource for modern cities as physical goods that can be packaged and sold, and is yet another facet of the resource base of cities that must be included in theories of place. The mere presence of these deviations from central place theory show that social and environmental factors have always been at play in urban development, even if social, environmental, and urban theorists failed to account for them all of the time.

Underlying any analysis of urban resources and geography, including the previous pages, then is the issue of the urban-hinterland divide. Accounting for the hinterlands has become a serious component of scholarly work on urban & environmental studies in recent years, whether it is from industrial ecologists simply trying to calculate material flows in and out of urban areas from their rural surroundings, to critical theorists using world-systems approaches to talk about the ‘global hinterlands’ that supply resources to wealthy developed nations (Czeskleba-Dupont 2003; Kennedy et al 2007). The hinterlands of any urban area can be difficult to define and map, especially as low-density development and outlying communities can, and often do, claim to be both part of a metropolitan area and separate from the central city at the same time; hinterlands have lately come to manifest themselves socially as well as physically, in a distinct shift along with the rest of our understanding of social
and physical environments, which further leads to confusion over the
demarcation and even the definition of the hinterlands themselves.

But they exist nonetheless, and whereas cities in the past were far more
reliant and dependent upon the resources that their immediate hinterlands
provided (and in many cases still are, as the aforementioned Catskills watershed
are obviously an essential part of the hinterlands of New York City), it can now
be argued that hinterlands – whether in the form of suburbs, exurbs or even
‘edge cities’ – also find themselves symbiotically attached to the goods and
services made available only through cities (Garreau 1992; Gandy 2004; Ferrão &
Fernández 2013). The connection of urban areas to their hinterlands can often be
overlooked in academic discourse which often speaks of cities, and only cities, as
points in an etherized space, rather than as the nexus by which flows of materials
(including water) from actual physical places both near and far from the city are
metabolized and transformed (Swyngedouw 2006; Ehrenfeld 2008; Wachsmuth
2012). The urban-hinterland divide challenges theories of urban environments to
envision the city in all of its forms, dimensions and connections, and through the
interactions of its inhabitants with the physical and social space that will
invariably impact the material resources of the entire place; it must envision
active cities, not static ones. These theories must start to think ecologically.

D. Human Ecology and the Legacy of Duncan & Hawley

Human ecology, in the tradition of Amos Hawley, asserts that the key functions
of ecosystems can be seen within societies as well; that essentially, we should
think of cities as having multiple and hierarchical layers of activity based on both density and functionality (Hawley 1950, 1971). Just as a natural ecosystem has various species that exist in an interdependent set of roles, with some species serving in an ‘apex’ role that helps govern how the rest of the system works, urban areas can be studied in a similar manner of interdependence between parts & regions and key functions of an urban area that drive much of how the urban area will govern and shape itself (Holling 1971).

Hawley explained such reasoning in critical mid-century publications on human and urban ecology that, along with Otis Duncan, brought the theory forward as a way of studying social change (Hawley 1950, 1968, 1971; Duncan 1959 & 1964). Both theorists adapted the language and concepts of the environmental sciences – of nature and its species – to apply to the communities of human beings; such concepts were meant to allow for a methodical and intuitive study of how individuals interact with each other within a given environment (Duncan 1964; Hawley 1968). The goal of human ecology became, most of all, to explain social organization through biological concepts and logic (La Gory 1979).

For his part, Hawley was very much committed to using this ecological perspective not as an end in itself, but as a framework upon which urban society could be studied in an expanded manner. In essence, an ecosystem is a self-contained unit in which the connections between various species can be understood. To study how populations, speciation, and thresholds operate in nature was simply to apply the same concepts for how human systems develop over time. As population grows in a given area, organization develops in order to
increase the chance of survival for both the individuals and for the larger
population; in Hawley’s conception, organization refers to the entire system of
interdependencies that govern interactions between individuals, institutions,
and resources (1971).

Perhaps Hawley’s most important conceptual achievement was to bring
over the notion of ‘key functions’ from ecosystem studies. A key function is, in
essence, the primary interaction from which other interactions follow; in a
natural ecosystem, the transformation of energy governs the development of the
ecosystem and its inhabitants, i.e. the plants and algae that convert the sun’s
energy into edible nutrients for the other species in a pond, thus allowing for
differentiation of species, functions and interactions. It is that initial conversion,
that defining function, which makes the ecosystem possible in the first place and
provides the foundation for not just growth but also specialization within the
rest of the system.

This is not an unusual line of thought, but much of human ecology and
indeed urban theory was produced and built to explain the predominant forms
of the urban areas in a modernizing age, which was geared towards industry-
fueled, export-oriented growth and models. The key function of a city is that in
which the urban system is essentially ‘optimized’ for that industry (ie: finance in
New York, automobiles in Detroit, broadcast entertainment in Los Angeles, etc.)
to take inputs from outside – whether from its immediate hinterlands or
through trade networks – and convert those inputs into a product that can be
sold as output. The other ancillary areas of the local economy – such as housing,
services, and recreation – follow then from that key function in terms of the capital available to them and the socio-economic system that springs up around that function. Community is made possible through the differentiation that is enabled by these functions, and key functions lead to complex division of labor which unlocks and facilitates urban development as we know it.

Keep in mind that this strain of urban theory was created in the middle part of the century (Hawley’s first major work on the topic came out in 1950). It is not to say that specialized trade, entertainment, or administrative cities (such as Miami, Washington D.C., or Salt Lake City) did not exist when social theorists were turning their sights on the types and differences in urban areas, but that at the time of Hawley and other human ecologists within the realm of urban theory, these cities did not achieve the same scale and size as those in which a major productive industry exported a product; simply put, these were cities with no industrial-type engine of growth where inputs clearly transform into outputs with economies of scale and clear spatial delineations in land use. In so many words, Hawley, human ecology, and social science itself during this major mid-century period never envisioned that human society might become so wealthy and complex that truly specialized post-industrial cities could not only exist but thrive, and that social environment and organization could very well replace physical environment as the primary determinant of human living and urban development in cities that would exceed the scale of anything that came before.
A potentially understated point in human ecology, since it has traditionally focused almost solely on human systems, is that key functions link the environment to the community (Schnore 1958; Hamilton et al 2012). The urban area is inextricably a part of the surrounding ecosystem, even if its resources are imported and goods are exported; one can think of Pittsburgh’s key function relating to steel production using minerals mined nearby, while New York’s trading history is due to its harbor and geographic location within a larger system of navigational routes and world cities. The linkages to other places do not hide or bely the fact that the city itself had to be rooted somewhere. To identify a key function is to see how the community is embedded within its particular environment; otherwise, that community could indeed be anywhere else.

Just as a natural ecosystem has various species that exist in an interdependent set of roles, urban areas (with their attendant social, economic and political structures) can be studied in a similar manner of interdependence between and within industries and regions, and the key functions of the city that drive much of how the larger urban system will govern and shape itself. Traditional human and urban ecology, however, focused almost exclusively on the interdependence within the social systems, with very little attention paid to environmental systems and physical resource flows upon which all human society rests upon. This omission leaves human ecology with the task of addressing new key functions and technological developments that never existed before, resulting in cities larger than the local ecosystem could
traditionally handle, due to the ability of social systems to alter and augment those resource flows in a cost-effective manner. For most of human history, cities rarely exceeded their local hinterlands for very long if at all (cf. Rome & Athens), as the consequences of overshoot were often immediate and unforgiving; modern technology and wealth often masks the reliance, and consequences, upon local ecosystems to the point where it seems as if cities and societies have been ‘decoupled’ from the environment, at which point nature always and invariably reasserts itself.

Thus the need to address the social relations of such things as cities, capital, development, and technology, and how they link together and within the ecological relations that surround them. Duncan’s POET model, part of the renewed wave of human ecology in the post-war era, was the beginning of a process within a fledgling environmental studies movement to systematize and quantify those interactions. In Duncan’s conception, POET stands for population, organization, environment, and technology (1959). These social forces have impacts upon the ecosystem in which they take place, and vice versa: “By mere occupancy of an environment, as well as by the exploitation of its resources, a human population modifies its environment to a greater or lesser degree” (Duncan 1959: 681). The POET model uses groups of variables in order to best determine the nature of the interaction, allowing for a variety of approaches (whether regression, multiplicative, or metabolic) and a wide range of methods, variables, and time-series data (Scarrow & Crenshaw 2015). But at its core, the POET model takes it as a given that these forces will not only impact one another,
but create further interactions that then create feedback loops. Rather than existing as a fixed, linear equation for measuring the ecological impacts of social variables – like the IPAT and STIRPAT models that became popular within environmental sociology in the 1970s and beyond – the POET model is simply, but powerfully, an organizing principle for how to think about, categorize, and analyze how the social and ecological environments affect each other (Scarrow & Crenshaw 2015). The POET model demands that we look at the transactional chains that lead into these impacts, the nature of those relationships and their type and scale, and then account for the fact that once the impacts have occurred, the system will invariably react back upon those original variables and relationships. In this way, ecological thinking not only came into the study of environmental sociology, but influenced multiple disciplines and encouraged their interaction as well, allowing for an expansion of our perceptions and analyses of natural and built environments, as well as the argument that those environments are becoming one and the same through interdependence (Vogel 2015).

E. Political Economy and the Influence of Stakeholders

Interdependence of large scale physical and human phenomena has profound effects on the creation and existence of urban areas, let alone entire societies, but as with central place theories, we cannot leave the discussion of places to the study of macro-level indicators without accounting for the various influences that can impact urban settlements within those ecological forces mentioned
above. Ignoring the many micro- and meso-scale influences that exist on the level of individuals and institutions within the development of cities and the structures that sustain them would be not only a woefully incomplete picture of our cities, but also a terrible approach to policy making. In our world of global industrial and financial capitalism, stemming from the dawn of the first world cities over two hundred years ago, the first primary influence acting within and upon cities is that of capital, which generates and reinforces the power of existing stakeholders in many areas of urban life and development.

Marx asserts that capital should be understood as ‘value in motion’, meaning that capital is not useful if it is not flowing through an economy, being invested and reinvested in order to gain an ongoing profit (Loftus 2006). I referred to urban areas above as centers of flows of materials, ideas, people, but we should also add the flow of money to the mix as well, as cities reflect the power of capital in facilitating the transformation of those active flows into built and social environment (Friedmann & Wolff 2006; Loftus 2006). Political economy gives us a framework for seeing the various transformations that take place within a city due to the power and influence of capital on the part of various stakeholders.

Rather than speak in generalizations, it can help to see such transformations and interests on the ground in cities where they are acting in ways that affect the day to day life of residents and help shape the long-term future of urban areas. The theories above may help explain urban location and provide broad outlines of how a city may develop, but they cannot speak to the
full story of why cities develop in the ways they do. For example, the harbors of New York, Boston, and Charleston were ideal for deep water shipping and allowed those cities to become the primary nodes for an Atlantic and intercontinental trade network, reflecting the importance of physical geography and natural resources (Paine 2013). But the development of a shipping industry tied to specific industrial or agricultural needs and on a coast with many other maritime cities, of trade networks that connected these cities into an early precursor of worldwide commodity flows, and of the financial institutions required to make the machinery of capitalism work on an ever-growing scale, were born out of and simultaneously led to the formation of not just economic sectors and functions whose prosperity was crucial to the city, but also of individual elites and business interests with outsized influence over how the city was governed and how its human geography would be shaped.

In addition to filling in some of the gaps, so to speak, in how human ecology would explain the emergent forms of social organization in urban life, political economy can also provide a mechanism by which to understand precisely how cities develop and change over time. Population, technology, institutions, and environment all act upon the formation of elite power structures in a society, which then has outsized power to determine the course which that society takes. However, there is also a model of urban development in which those social elites can select and alter those fundamental components, i.e. instituting population control programs, or substituting certain technologies, or, in cases stretching from St. Petersburg to Mexico City to Phoenix, trying to
change the physical environment itself. In these ways, political economy provides a causal mechanism by which to look at the context and historical form of social power that the previously described theories cannot account for.

That kind of power and influence not only affects urban life in the present time, but also can set in motion path dependencies that exist for decades; one need only look at the construction of interstate highways through and between neighborhoods in inner cities across the United States to see how the will of certain politicians, business interests, and planners can be made real through concrete and steel. Jane Jacobs not only described this in her books, but also gave rise to a prime example of how individual action can affect large-scale forces in the fight that occurred when she rallied a grassroots campaign against Robert Moses’ plan to obliterate Greenwich Village for the Lower Manhattan Expressway at the very time when the overwhelming consensus of business and political structures across the country was that cities needed to be shaped and adapted to automobiles, not the other way around (one can also look at the destruction of Los Angeles’ streetcars by General Motors in the same vein). More recently cities like Los Angeles, San Francisco and New York are at odds with companies like Uber and AirBnB, which threaten to upend the traditional taxi and hotel industries in those cities; what may be seen as simply a fight over profits and rent-seeking is also a fight over livelihoods and worker protections, and recently cities have started to side with their more traditional industries, showing the inertia of stakeholders and their ability to keep and build on already existing power. When conflicts erupt between individuals and interest groups
over zoning ordinances, housing density, tax abatements, and transit networks, let alone macro-level infrastructure spending and economic development, one is seeing battles played out on the field of political economy for control of the city, control that undoubtedly has impacts upon the physical environment, as can be seen in the contempt with which most people utter the word ‘sprawl’.

Later sections and chapters will discuss Phoenix, Las Vegas and Southern California in more detail, but it is worth noting here that the dynamics just described – while present in every city that has ever existed – have been witnessed on a vastly compressed time scale over the past several decades. Built on seemingly boundless planes allowing for low-density development and facilitated by a massive road transportation network, these cities would fit the description of central place models and the nature of historical path dependencies when it comes to their urban morphology, and yet all of the theories discussed up to now would still fail to fully explain the development of these cities. Namely, the combination of cheap land, publicly funded highways and subsidized water provided the right conditions for housing developers and construction companies to gain influence in the local governments. In Phoenix, even as some residents feared that their city was following the same path as Los Angeles, the only real change this led to was that developers tried to make subdivisions slightly less monotonous in their layout and design (VanderMeer 2010; Ross 2011). Residents of gated communities of Las Vegas are almost $20,000 richer in median annual income compared to their fellow citizens who do not live in gated communities, a powerful signifier and incentive for developers to
build even more exclusive housing compounds catering to higher incomes in one of the fastest growing metropolitan areas of the last 30 years, rather than addressing the geographical and economic imbalances of the city (Vesselinov 2012). And Davis devotes a significant portion of his landmark work City of Quartz to discussing how homeowners and developers were able to not only influence local governments in Los Angeles, but even take over various offices and elected boards in order to protect the predominant model of low-density, automobile-centric, single-family housing in vast swaths of Southern California (1992). It could even be said that in many of these communities and cities, a major part of the economy was “building houses for people who are building houses” (Ross 2011: 55). When growth for growth’s sake becomes a key function for a city, all of the vested stakeholders – from the politicians seeking reelection to the developers planning their next subdivision to the existing homeowners trying to increase their property values – have an incentive to keep that growth going by any means necessary (Logan & Moloch 1987).

Political economy is not a theory per se as much as it as a perspective for addressing the different contexts and forces acting upon human society. In many ways, it is a necessary complement to the other theories presented thus far; as political economy provides tools to fill in the blind spots in central place theory, it expands upon the historical trajectory of resource bases, and it gives us the means by which to adjust the components of the POET model when we want to update it and make human ecology more accurate and reflective, as well as contributing narrative power to all of those internal forces and individuals who
may get lost in the larger scales of social science. Without political economy, much of social and urban analysis would be lost in the forest of our own confusion about the various activities and ideas acting upon our day to day life. Social organizations do not create themselves in a vacuum, and when those organizations stratify into power structures that can not only exert pressure on the rest of the social system, but also on the environment itself. Ecology becomes not just a location or an input for a city, but an outcome to be shaped as well. But while political economy can explain much of the social interactions in cities, there is still a great need for theories that can try to add power to those interactions, as well as into the math behind the material flows and the urban-hinterland divide that makes cities work or fail.

**F. Urban Political Ecology & Critical Human Ecology**

To study a social system in a structural framework, as Mayhew tells us, is to examine the forms of organization between the units within that system (1980). This means examining the type of network that connects the units, the functions of those units, the logic of the overall system, and most importantly, the means of relationships between the units within a given structure. A theoretical standpoint for how those relationships organize themselves – politically, economically, and culturally – and how those resulting structures affects other relationships, at multiple levels and scales, is a necessary step for ecological studies which are fundamentally predicated upon the interplay between humans and their environment.
Urban political ecology and critical human ecology can give us that theoretical base from which to understand the underpinnings of modern economic development in an environmental context (Marvin et al. 1994; Keil 2003 & 2005; Moffatt & Kohler 2008; York & Mancus 2009). Notable works of UPE have focused on the very issues of water scarcity and urban drought from the perspective of capital production, ‘ownership’ of water, and the political institutions that fall on the side of private ownership over public control (Coccossis & Nijkamp 2002; Kallis & Coccossis 2002; Kallis & de Groot 2002; Swyngedouw et al. 2002; Cohen 2012). For example, in the late 1980s, legislative, bureaucratic, and utility leaders in Athens, Greece openly proclaimed that they had filled the city’s main reservoirs and would have abundant water supplies for the city’s needs for years; two years later a sudden drought coincided with a crisis that threatened to undo the urban fabric while also providing political and economic elites with a chance to benefit from a crisis that they themselves instigated (Kaika 2003 & 2006). Kaika explains that efforts to try to alleviate the drought were analyzed through concurrent, and contradictory, mindsets: that according to political leaders, the drought was entirely a natural disaster rather than a man-made disaster caused by the effort to ‘optimize’ water resources for human use, and that according to the water utilities, water is inherently a ‘scarce’ resource even though the years prior to the drought had led them to express complete confidence in the abundance of water for years to come (2003). The crisis was used to pass ‘emergency measures’ such as increases in water rates, but the rates were set so that those who used more water would achieve greater
savings; this led to an outcome whereby the majority of reductions in water use came from those using the lowest individual volumes, ultimately leaving the richest 3% of the urban population to account for 40% of total usage because they could afford it (Kaika 2006). This event forms the basis of the study of scarcity in the next chapter, but it is noteworthy here to see that without taking into account not just the various power brokers involved in the water question (as political economy does), but the nature and means of their relationships to each other and to the other residents of the city and the overall structure in which they operate, we would fail to see the true picture of how scarcity can be used as an ecological weapon.

Similar accounts can be found in Yorkshire, as a drought there in 1995 following the privatization of water utilities can be viewed through the lens of how scarcity is ‘produced’ as the outcome of a regulatory regime focused solely on human activity rather than the “constraints of the hydrosocial cycle”; in Mumbai, where the perpetual crisis of inadequate supplies of clean drinking water finds its historical roots in the dysfunctional merging of state regulation and market capitalism; and in Spain, where power over water went hand in hand with power over an emerging nation-state (Bakker 2000: 20; Gandy 2008; Swyngedouw 2015). Critical human ecology blends the human ecology tradition mentioned above with the narrative and analytic power of historical materialism; in essence, it seeks to add the dimension of time into the framework of socio-environmental interactions, and takes the material relationships of social life as a starting point in any understanding of
environmental impacts (York & Mancus 2009). What these works, and others that generalize the issue of water supplies in urban areas, point to is the necessity of placing a city’s resource base and consumption within a confluence of contexts: the political (how resources are distributed and regulated in the first place), the economic (how scarcity of a resource increases profits), the social (the assumption and expectation of uninterrupted supplies to a settled area), and the ecological (the physical constraints of a given watershed) (Greer 2011; Edwards 2013; Verhoeff & Nijkamp 2008; Jacobs 2011).

Where UPE and CHE differ from the other theoretical frameworks provided, beyond taking critical and conflict-based perspectives, is that they focus more specifically on the transformations of capital and nature that occur with urban environments; in fact, Swyngedouw asserts that we are currently witnessing the transformation of water into money in many cities around the world (2004). These theories share a potential criticism that has often been leveled at conflict and critical theories, that they start with a ready-made target and narrative of economic and power imbalances and then fit details of urban and environmental development into that pre-existing framework. But when done correctly, these perspectives add a needed dimension to traditional political economy and human ecology, by seeing power dynamics that are often missed by both social scientists and ecologists when it comes to the material realities and consumption of urban life.
G. Urban Metabolism

Urban metabolism has evolved over the past several decades from its roots in human ecology, through industrial ecology, and lately with the introduction of sustainability studies and urban political ecology (Wachsmuth 2012). Urban metabolism examines the interplay of humans and their surroundings by taking as its base the study of resource flows; in many ways this can be a simple accounting of inputs and outputs of materials, but the framework of urban metabolism lends itself to any model that takes as its premise that cities are not self-contained systems, but are instead the focal points of vast transformations of resources.

Over a century ago the chemist Justus von Liebig investigated the declining crop yields of England’s agricultural industry and realized that the soil was suffering from a lack of nutrients; the human waste that would have gone back into the soil when most people were subsistence farmers was now being denied to the soil since the vast majority of food was going to cities, with the wastes being disposed of via water closets or sewers instead of being brought back to the original farmland (Foster et al 2010). This represented a new problem of cities beyond deforestation or other problems caused simply from overuse; this was social organization causing a change in the way the ecosystem could actually respond to human activity. Cities, by altering the environment in a profound way, were now affecting the demographic and economic structure of society, and vice versa, leading to a disconnect between human activities and the surrounding environment. Marx, building upon the work of Liebig, used the
analogy of a body’s metabolism which generates the energy that keeps the rest of the system functioning and coined this socio-ecological disconnect as a ‘metabolic rift’, as it threatened the ability of the environment to sustain itself and, by extension, us (Foster et al 2010).

Urban metabolism in its current form owes much to industrial ecology in that it provides normative (that is, non-jargon and non-theoretical) context for how ecological systems work, stressing that connections and cooperation are essential to understanding natural systems; industrial ecology can also shift paradigms of thinking about those systems and how we model our own forms of social, economic, and material life (Ferrão & Fernández 2013). That type of thinking then morphed into urban metabolism which sought to create methodological frameworks for accounting material flows in and out of cities. In essence, look around your office and consider each of the objects you see: now, hone in on one object, and think about the embodied materials and processes that went into bringing that object to your office, to your city, to your nation, and then think about the materials that went into the factories to manufacture the object, and the processes that brought them there in the first place. Marx’s labor theory of value follows a similar thought process in terms of capturing the inherent value of any manufactured object, but urban metabolism looks upon the material impacts of that object and the many others that we use on a daily basis (Bailey et al 2004; Harman 2010). For that object contains within it the embodied efforts of an entire chain of interactions; how we measure that effort,
and gauge the material flows that cumulatively take the form of a city, is the rationale behind urban metabolism.

Which is not to say that urban metabolism is simply an accounting model for adding up material flows; while it has roots in the engineering and planning fields, scholars in urban metabolism have pushed their field to go farther into the how and why of cities, especially with regards to the systems they exist within. Urban metabolism sees cities as their own environments, interdependent with their surroundings and species, and thus needing updated approaches for studying resource consumption (Botkin & Beverage 1997; Brunner 2007; Kennedy et al 2011; Kennedy & Hoornweg 2012). It has been used to examine historical trajectories of cities such as Pittsburgh, and the current impacts of world cities from Toronto to Lisbon to Hong Kong (Tarr 2002; Kennedy et al 2007; Niza et al 2009). And it has become the framework for sustainability scholars to build upon in their quest for a theoretical and paradigmatic model of urban environments that can examine cities as they are (in their location, geography, resources, and social organization) and, using that data, also bring in new perspectives of what urban sustainability could and should look like (Baccini 1997; Newman 1999; Barles 2010; Baccini & Brunner 2012; Golubiewski 2012; Wachsmuth 2012). This is not easy by any means; as I will discuss in more detail in Chapter 4, one of the biggest issues in studying water in the United States is the lack of reliable, extensive, or even yearly data on one of our most important natural resources, and the same problem can affect the study of urban metabolism in almost any city that does not measure their material and resource
flows (Kennedy & Hoornweg 2012). Nor does urban metabolism easily lend itself to models beyond accounting or input-output equations; regressions have, to my knowledge, not made its way into the literature on urban metabolism. There are recent efforts to create models for shaping public policy on the basis of metabolic frameworks that try to link the entire chain from the drivers of ecological change to the urban responses, in order to help bridge this theoretical and quantitative gap (Ferrão & Fernández 2013). But the underlying concept of urban metabolism opens a new window for not just how to study cities from the political economy perspective (i.e. of flows of resources), but also place them properly into the fabric of ecological thinking (i.e. of those interdependent forces that interact with each other on a constant basis).

H. The Challenge of Postindustrial & Postnatural Cities

Each of the theoretical perspectives, frameworks and paradigms presented here do a great job in describing, examining and explaining the cities and environments of human life. Even when they each have gaps and subjective failings that keep them from fully covering the problems and promises of urban location, collectively they have been able to build urban and environmental sociology over several decades. However, much of the foundational theoretical work presented here was developed and generated in the shadow of the industrial city, with some of the core concepts going even earlier than that (such as many of the principles of political economy). Thus they can have blind spots when it comes to new models of urban life, particularly the development of post-
industrial cities that challenge the predominant model of city building and economic roles. Human ecology did at least account for the potential for cities that may break out of the commonly accepted functions of earlier eras, but even it could not foresee the possibility of technological and economic changes that would, for example, enable millions of people to live in arid environments, vastly outstripping local water supplies and requiring massive infrastructures that are not only built but taken for granted. Post-industrial cities in uniquely difficult physical environments must form specialized key functions, linked to social environments, in order to survive; in fact, I contend that the combined nature of these economic and ecological contexts lead to a ‘hyperspecialization’ of urban areas that exist due to very complex, interlayered systems. These systems, on the surface, may seem to solve the hinterland problem, and increase the flows of resources and capital, but in reality, they just further deepen the dependence of the cities upon underlying assumptions about both nature and technology that, inevitably, cannot hold.

At this point, then, we return to the American West, and the realization that for all of the theoretical and normative power that urban and environmental sociology has developed over the past several decades, there still does not exist a cohesive framework that addresses the particular dynamics, and broader structural forces, that led to fifty million people effectively colonizing²

² I realize this is a loaded word, but I use it in the sense of Crosby’s Ecological Imperialism in which it’s not simply showing up with people to politically impose a society’s will upon a place, but also trying to effectively terraform a place by bringing flora and fauna and introduce ‘old’ environmental forms upon the ‘new’ environment; for instance, throughout the Southwest there was, at least until the recent droughts, extensive use of water-intensive grass lawns around homes and businesses, a cultural and ecological construct imported from the wetter East, as well as the fact that the primary crops grown in large parts of the Southwest also require vast amounts of water, despite the extreme cost of that water compared to the areas of the country where many of the farmers may have moved from! (Worster 1985; Crosby 1986)
the biggest arid region on the continent. The cities of the Southwest – such as Phoenix, Las Vegas, Tucson, and San Diego, among others – represent a new type of city in which the key functions are as specialized as the ecosystem they live in – so that the cities would have a reason to exist and grow in the first place – and in which the social environment is seen to have surpassed or even replaced the physical environment. Their development is the end result of decades of economic and political decision making that acted upon the natural environment to harness water in order to make the ‘Great Basin’ useful, but that mentality itself is based upon both an unspoken philosophy of how to think about resource-driven growth as well as flawed assumptions about just how sustainable those resources were and were ever going to be. And the continued growth and existence of these cities reflects very real path dependencies and sunk costs of individuals, businesses, and governments which have led to divergent outcomes not just between the cities that are fortunate enough to get this water and those that weren’t, but also between the cities and their hinterlands.

Cities that exist in niche environments and ecosystems – whether in the swamps of St. Petersburg, the lagoons of Venice, or the high desert of Las Vegas – are intrinsically more vulnerable to even routine changes in their natural environment, let alone the onset of the periodic shifts that can disrupt that ecosystem for years if not decades at a time. Meanwhile, cities that are developed and dependent upon specialized economic functions – such as administrative, religious, service, or entertainment functions – find themselves
less resilient to economic downturns that can choke off the funds that were previously flowing into a city that, for all intents and purposes, was not really converting that into an export product. It is the combination of these two statuses that can make it difficult, if not prohibitive, to fend off a dramatic change in either its ecological or economic setting; in fact, a change in one can often lead to a change in the other, for all social environments rest upon the physical environment. Many cities may take their environment for granted, but hyperspecialized cities take their social organization to be a replacement for their surroundings. No matter how post-modern, post-industrial, and post-natural these cities may portray and believe themselves to be, they are still rooted in a physical space; any theory of urban ecology worthy of the name must address the dynamics, structures, and flows that created the blind spot of hyperspecialized cities, and bring a new perspective to the sense of place that underlies all of our urban settings.
Chapter 3: Too Much and Not Enough at the Same Time

“They’ll skin the cat twenty ways if they have to, but they’re going to make the water affordable. Congress will go along, because it will be goddamned embarrassing for Congress to have authorized a multibillion-dollar water project when there’s no demand for the water because no one can afford it. The CAP belongs to a holy order of inevitability. ... The sensible thing would have been for the farmers to move,” Steiger said. “There are hundreds of thousands of acres of good farmland along the Colorado River where you’d only have to build short diversion canals and maybe pump the water uphill a few hundred feet. But the farmers got established in the central part of the state because of the Salt River Project. The cities grew up in the middle of the farmland. The real estate interests, the money people—they’re all in Phoenix, Scottsdale and Tucson. They didn’t want to move. So we’re going to move the whole river to them. At any cost. We think.”

– Mark Reisner (1993: 304-305)

A. The Hundredth Meridian

While every region of the United States likes to think of itself as unique in comparison to the others, many of those distinctions come down to cultural, economic, or political differences. For all intents and purposes, much of the east and midwest portions of the country were settled and developed in largely the same process of gradually spreading out and adapting the land to what had worked for others in the east. Out of this came a vision of manifest destiny that meant to extend that established way of life – industry and agriculture, towns and farms, side by side – all the way to the Pacific Coast.

Then comes the hundredth meridian. West of that imaginary but still all too real line demarcating the physical geography of much of North America, the land literally changes from anything that exists from the Great Plains back to the
Atlantic. Mountain ranges that reach for the sky, scorching deserts, canyons that reach for miles, and a massive continental basin all forming a region that took months for even well trained cavalry to traverse (Sides 2006). While to the north and along the coast the land was greener and more hospitable, the fact remains that a significant portion of the landscape of the American West receives so little rainfall that it is considered arid or semi-arid: less than 20 inches a year falls in much of the area between the coastal ranges and the midwestern plains, an area that came to be known as the Great Basin. For decades following John Wesley Powell’s initial reports on the unique ecosystem of the southwest, farmers, ranchers, and speculators continued to believe that they could adapt the land to their uses back east, that they could coax rain out of the sky and that toil would ‘improve’ the landscape to something akin to what their predecessors had worked with for hundreds of years. When that didn’t work, they moved to terraform vast tracts of the high desert through irrigation and groundwater in order to force the Great Basin to be as productive as wetter regions of the country. While this had some effect in creating the types of intensely subsidized ranching and agricultural operations that have fundamentally changed large portions of the western landscape, it still did not succeed in making the West, and the Southwest in particular, look like the rest of America. This issue of aridity will be discussed in more detail in the next chapter, but for now it is essential to delve into how the arid and semi-arid ecosystem of some 40% of America’s land area shaped its urban development; for the West is both the most
sparsely populated, and also its most intensely urban, region in the country precisely because of this unique ecology.

This simultaneous nature of the West – of urban outposts scattered across a vast and sometimes unforgiving landscape – combined with the historically late development of the region and the boom and bust dynamic of the area’s economy to create a unique economic and social structure that would embed itself within the cities themselves (Scarrow 2014). Home to some of the fastest growing cities in the U.S. over the past 70 years, the Southwest epitomizes an urban fabric that created itself in a seemingly clear break from the traditional cities of the East and industrial Midwest. A region that was really only developed in the modern sense after the creation of the automobile, it is no wonder that its cities would be centered around cars; wide expanses of land gave way to suburban homes in cities that didn’t have the typically defined ‘eastern’ urban uses and growth patterns in the first place. Post-industrial economies and post-modern urban identities formed the basis of the Sun Belt and launched a thousand sociology titles, but they would not be possible without conquering the water question. As stated previously, desert ecosystems are home to extraordinary biodiversity, with a large array of different species, if not large populations of those species; in essence, to exist each species must find a niche in which it can survive and thrive in order to avoid competition for scarce resources. In an arid region, access to water is the key to growth for any species that exists; the cities that had plentiful water would be at the top of the regional food chain, but providing that water on the scale that was necessary to terraform
the Great Basin would be a greater task than any individual or business could hope to accomplish.

B. A Brief History of the Colorado River

During the 1800s, the Federal government undertook expeditions and organized agencies for the exploration of the vast area west of the hundredth meridian; the information gathered was critical for the various homestead acts that enticed would-be pioneers and settlers with nearly free land on the promise that they ‘improve’ that land for cultivation (Reisner 1993; Powell 2008). However, the inconvenient truth for both settlers and politicians was that in the nearly 40% of the country between the Pacific Coast and the Great Plains, the amount of water that fell as precipitation was not nearly enough for 160 acres of farmland (Reisner 1993). The first man to realize this, John Wesley Powell, was the director of the US Geological Survey, and in 1878 submitted a report to Congress on the arid lands of the Southwest; the report detailed the amount of water available, and stated in no uncertain terms that the idea of agriculture that had prevailed in the much wetter East could not work in this region of mountains and high desert (Powell 2008).

Powell asserted that any system regarding the distribution of water in the American West would have to revolve around two main precepts: the understanding that water was scarce enough to require extensive projects carried out by the federal government, and the idea that policy should be steered and governed by people in the watersheds, not by states whose borders
did not match the actual physical and ecological landscape of the West (Reisner 1993). Throughout his surveys, Powell grounded his observations in the hard science of precipitation and land use, calculating that the sections of farmland for farming would be absolutely dependent upon proximity to a river (namely, that 160 acres, properly irrigated, was too much for a family), and the amount of land required for ranching would have to be several times larger than the 160-acre homesteads that were being given away by the federal government for ‘improvement’ due to the minuscule rainfall and vegetation that could not support a single herd (Reisner 1993; Powell 2008). Such observations led to the conclusion that water policy must be shaped from a holistic perspective, rather than done piecemeal and engineered by various interest groups who would seek to impose a way of life upon an ecosystem that would never sustain it. Invariably, this conclusion was roundly rejected.

Almost immediately Powell was sidelined in Washington in terms of influence over how the government would pursue Western settlement and water operations (Reisner 1993). By the early 1900s hundreds of thousands of settlers would be drawn by promises not just of land but of arable land, enticed by the popular but false maxim that ‘rain follows the plow’, that is, that the simple act of farming could change the weather patterns and reward those who are productive. When the rain failed to materialize, two general trends emerged: first, many of the homestead claims were sold at a discount to speculators or developers who counted on the second trend, that the federal government
would not abide by having an entire region of the country lay arid when a perfectly good river ran right through it.

In regards to the former trend, the main reason as to why speculators would buy up vast tracts of failed homesteads was due to a new form of water rights that emerged in the West. Whereas Eastern states predicated water rights on ‘reasonable usage’ (i.e. you took from the river only as much as you actually needed, and all landholders along the river had equal access to that watershed), Western states based water claims on ‘first in time, first in right’ (Wehmhoefer 1989; Beard 2015). What that meant was that the first to stake a claim to water along a river had the right to however much water they were using in perpetuity as long as they continued to use it; senior rights to the Colorado River have existed for over a hundred years and are in many ways more valuable than gold, since in the event of a shortage on the river, junior rights holders (regardless of how much, how effectively or what they use the water for) have to restrict or even turn off their water flow in deference to those whose rights precede theirs (Reisner 1993; Beard 2015). The development of this type of law encouraged monopolization of land in order to monopolize water, and encouraged the continued use of water in order to keep one’s claim, even if it was for unnecessary production or consumption (such as water-intensive agriculture in the desert or new housing developments).

As pertains to the latter trend, the Bureau of Reclamation has gone through several names and iterations, but in many regards its major reason for being starts in the 1930s with the construction of the largest dam the world had
ever seen: Hoover Dam, near the then-village of Las Vegas, Nevada (Robinson 1979; Andrews & Sansone 1983; Dawdy 1989). The Bureau had begun the century focusing on the construction of small dams for irrigation and reclamation projects along the Missouri River, but with the approval and building of Hoover Dam, the Bureau turned its sights to the Colorado and its monstrous outflow in which it was not just the amount of water that was prized but also the force it generated as it plunged down from the Rockies (Robinson 1979; Reisner 1993). Hoover Dam was intended to help store water for the lower basin states of Arizona, California and Nevada through the creation of Lake Mead, as well as generate cheap hydroelectric power for Southern California. The government put up the money upfront for the construction, with the idea that electricity sales would recoup the costs of building the massive structure (the dam was finally paid off in 1984 with the expiration of the original 50-year electricity contracts) (Reisner 1993). The project was a massive success in the eyes of the American public; the residents of the Southwest who now had guaranteed water and energy resources; their representatives and Senators who found a new avenue for federal spending on their constituents; and of course the Bureau of Reclamation which would thrive as long as they had rivers to dam and water to deliver, and according to the the Bureau’s initial calculations, they did.

In the early 1900s the first systematic attempts to measure the outflow of the Colorado River began at Lee’s Ferry, Arizona. These measurements would become the basis of the Colorado River Compact (also known as the Law of the
River\(^3\) that would eventually divide the water of the river amongst the states of the Colorado River basin and Mexico. Negotiations for the Compact began in 1922 and were based on two decades worth of numbers that tried to quantify the flow of the Colorado River as it went past Lee’s Ferry. Those measurements established that the annual average outflow of the Colorado River was 17.5 million acre-feet (MAF)\(^4\), and this became the starting point for both all of the negotiations and agreements stemming from the Law of the River, and for all of the projects that would be dreamed up and built by the Bureau of Reclamation over the next several decades (Hundley 1975; Parsons 1990; Reisner 1993). However, there were some critical problems with that number, namely that it was not even remotely close to being right.

According to geologists, those first two decades of the 1900s during which the measurements were taken just happened to be the wettest two decades of the past millennia, an exceptional spell of snowfall and increased outflow that brought enormous amounts of water down the river even before it started being dammed and diverted on a huge scale (Powell 2008; DeBuys 2011; Ingrid & Malamud-Roam 2013). The actual average flow of the Colorado River during the previous millennia, and since those first decades of the 20th century, was between 13.5 and 15 MAF, dramatically less than the 17.5 MAF figure used for the Law of the River compact (Ingrid & Malamud-Roam 2013). Rumblings of the

\(^3\)More specifically, the Compact is the term for the actual allocation of the water; the Law of the River refers to all of the attendant regulations, policies, and procedures that extend from and enforce the Compact.

\(^4\)One acre-foot being the amount of water that covers one acre of land, one foot deep; one acre-foot equals roughly 326,000 gallons, and is generally considered to be the amount of water used by two average middle-class American households in a single year (Powell 2008).
disparity were known by the 1950s; Reisner notes that a hydrologic engineer pointed out in 1953 that in the decades since the Compact was approved in 1928, the annual average flow of the Colorado was actually less than 12 MAF, foreshadowing a massive gap between what the Bureau of Reclamation was planning for and what the river could actually deliver (1993: 263). Undeterred, the Bureau of Reclamation not only pursued reclamation projects on the upper Colorado River (where such projects would never recoup their costs due to the subsidized nature of the loans and farming that produced crops worth hundreds of dollars with water worth thousands of dollars, once the construction costs of the projects were accounted for), with the centerpiece being the Glen Canyon Dam in northern Arizona which at full capacity could hold 7.5 MAF, the entire allotment for the Upper basin states under the Law of the River (Robinson 1979; Reisner 1993; Powell 2008; Debuys 2011).

Glen Canyon Dam was a cash-register dam, meaning that along with creating a reservoir (Lake Powell) to help enhance water storage along the river, it would generate electricity to help pay for the cost of irrigation projects in the upper basin, implicitly admitting that such projects would never pay for themselves despite Bureau promises and farmer’s contracts (Reisner 1993; Farmer 1999; Powell 2008; Beard 2015). Lake Powell (named after the man who warned against such massive interference with the Colorado River) and Lake Mead were created to boost the accessible water capacity of the river by millions of acre-feet over the annual outflow levels; when full, both reservoirs essentially doubled the annual flow of the Colorado. By allowing for the states in the Upper
Colorado basin to ‘store’ water while still delivering their required 9.0 MAF to the Lower Basin (plus Mexico), and to receive their allotments even in years in which the river did not attain the projected 17.5 MAF, these federal projects not only allowed each state to get their full share of Colorado River water, but also sent a signal that the Bureau of Reclamation would always provide supply to meet any demand (Reisner 1993; Powell 2008). This is especially important when it came to the projects to build the Central Arizona Project and the outflow pipes drilled into Lake Mead, the lifelines providing the millions of subsidized gallons necessary each year for the extraordinary population and economic growth in Phoenix and Las Vegas based on the belief of never-ending water.

Though the Law of the River was negotiated by the seven states of the Colorado River basin, they did not negotiate on equal terms. Allocations of river water were based not just on the size of the state’s population at that time, or by how much water the state contributed to the overall watershed, but also by how much water each state had been using up to that point through first in time laws (Katz & Moore 2011). Thus, California, despite contributing no water to the Colorado River watershed, was able to claim prior appropriation to millions of acre-feet that it had been using for years and was in fact awarded 4.4 MAF (plus whatever water remained unused by the other states), while Nevada with its small population at that time has had to make do with a measly 300,000 acre-feet per year since the Compact was negotiated (Hundley 1975; Wehmwoefer 1989; Parsons 1990; Reisner 1993). Arizona was allocated 2.8 MAF, but they rejected the disparity with California, and refused to sign the Compact for so long that
Interior Secretary Hoover changed the bylaws and allowed the other six states to make the Compact into a binding agreement (Hundley 1975; Reisner 1993). Over several decades, in the halls of Congress, and via lawsuits that went to the Supreme Court, Arizona tried to both challenge their allocation from the Compact and to get approval for an aqueduct that would allow them to claim their full allocation from the Colorado River, lest ‘their’ unused water continue to go to California in perpetuity (August 1999). Funding for the CAP was blocked by California’s House delegation for years, until California extracted an unusual but prescient demand: Arizona would get its aqueduct allowing it to use its full allocation of 2.8 MAF per year (up to that point, the state had only been using less than half of its allotment because so many of its farms and cities were in the middle and southern portions of the state), but, in exchange, California’s water allocation under the Compact would become senior to Arizona’s. In the event that a shortage is declared on the Colorado River (as measured at Lake Mead) and the Lower Basin is unable to get its full 7.5 MAF from the Upper Basin states (after accounting for Mexico’s guaranteed share), California is entitled to receive its full allocation under the Compact before Arizona can get its allotment. In practical terms, Arizona must reduce its water allocation in proportion to the shortage, but California does not have to, hence the previous mention of a potential 11% reduction in water consumption from Arizona should Lake Mead’s water levels fall below 1,075 feet in coming years (the reductions increase even more dramatically if the lake falls below further thresholds including ‘dead pool’ at 895 feet, the point at which the Colorado River effectively ends because the
water will not reach high enough to go over Hoover Dam’s outtakes and flow downriver\(^5\) (Hundley 1975; Reisner 1993; Hanemann 2002; Powell 2008; Debuys 2011). Arizona agreed to such a demand because according to the Bureau of Reclamation’s projections, despite warnings that the data and projections may be faulty, state & Federal leaders assumed that such a shortage would never happen and that their water allotment would never have to be reduced.

In addition to servicing several million residents in central and southern Arizona, the Colorado River finds its way into and impacts the water supplies of multiple other metropolitan areas in the Southwest, even outside of its watershed boundaries. San Diego gets the majority of its water from the Colorado River through the Metropolitan Water District\(^6\), which built aqueducts over hundreds of miles to augment local and upstate resources in Southern California and uses a substantial portion of California’s 4.4 MAF allotment under the Law of the River. Las Vegas, as previously mentioned, gets 90% of its water from Lake Mead (which comprises virtually all of Nevada’s 300,000 acre-feet allocation from the Colorado River) via two intake pipes drilled into the lake at varying levels, with the third to be drilled from below the lake to access water even when Hoover Dam reaches ‘dead pool’. Meanwhile, Salt Lake City, Albuquerque, and Boulder all receive some portion of their water supplies

\(^5\)Of course, the Colorado River almost never flows all the way to the Gulf of California anymore anyway; only one year in the last twenty-five has there been enough water to follow the entire existing riverbed, and that was only after a ‘pulse flow’ was negotiated so that the US and Mexico would both agree to not use up the entire river and allow thousands of acre-feet to flow, unhindered (Jacobsen 2014).

\(^6\)The MWD has been popularized in culture via the movie Chinatown and the battle over Owens Valley. Chief engineer William Mulholland famously (or infamously) bought up the water rights to the Owens River valley, built what was then the longest and most complex aqueduct in America to bring that water to Los Angeles, and capped off the project by saying simply, as what used to be the Owens River cascaded towards the 40,000 people assembled to see Southern California’s newest source of water, “There it is. Take it.” (Reisner 1993: 86.)
from the larger Colorado River watershed that the Bureau of Reclamation manages, illustrating that once built, the infrastructure that watered the Southwest has not only stretched out to cities even beyond the ecological boundary lines of the watershed, but helped an entire region grow beyond anybody’s wildest expectations. That these cities require the Colorado River’s water in order to function in their present morphology is obvious, but less obvious is how that water influenced the morphology over decades, starting with the most basic fact of water in a desert: there is not enough of it, and that (ironically) leads to its overconsumption.

C. The Political Economy of Scarcity

It may be seen as remarkable that cities in arid environments like the American Southwest could have not only grown but thrived despite their seeming ecological challenges and contradictions (Poyner 1998; Logan 2006; Meir et al 2013). But what if that growth and wealth happened because of the potential scarcity of water, and the subsequent ability of these cities to acquire cheap water from federal sources? This would enable a unique political and economic structure to benefit from, and reinforce, the specialization of a city’s key functions even as they are even further detached from the surrounding physical environment.

Such a structure, though, is dependent upon assumptions about the surrounding environment; just as car-dominant, low-density metro areas were primarily built in an era of relatively cheap gasoline, the cities of the Southwest
were created in an era when the Colorado River was running high and the Federal government funneled that water to cities, businesses and farmers who rushed into the profitable vacuum of land development. In so many ways, the use of water in the West reflects an alternative dynamic than how we generally understand resource use: rather than engineers only building and expanding supply to meet an existing demand, they instead created massive supply which future residents would then use up with their demands (such as crops, pools, and air conditioning, among others), demands that only existed because of the oversupply in the first place (Powell 2008). Seen from this perspective, the very concept of risk starts to take on much more expansive meanings for an urban center that is placed inside a harsh environment (made hospitable only through massive, but fallible, technological systems) and whose wealth and existence is based upon a specific type of economic performance (Futrell 2001; Bolin et al 2002; Worster 2014). Alter or remove the underlying environmental condition, and the characteristics (social, economic, political) of the city are fundamentally changed, perhaps in an irreversible manner. This is what the meanings of fragility and resilience speak to: the fundamental assumptions and vulnerability of cities, and their ability to adapt or dissipate in the face of ever-changing circumstances (Taleb 2012).

In this way, we acknowledge that cities, like the societies that produce them, are dynamic systems of human and natural production. Human knowledge and processes will have impacts, whether intended or unintended, upon the systems they touch, and this is the case whether such knowledge and
thought processes are rational or not. Many writers of the West have described and dissected the end results of how various stakeholders – farmers, speculators, bureaucrats, etc. – have approached the region from both philosophical and practical standpoints. The philosophical discussions have more or less relied upon anthropological notions of ‘making nature subservient’ to explain how humans approached such an untamed wilderness in the American Southwest (Nash 1965; Worster 1985; Reisner 1993). The philosophy of nature and environmental use, as I’ve alluded to above, is certainly important and underlies much of the research upon which this dissertation is based, but for our purposes I will be focusing more on the practical matters of how the Southwest was tamed, shaped, and built for the needs of man, and to do so I must discuss a heretofore understated dimension of the water question: the political economy of scarcity.

After all, it has been known since those initial surveys by Powell that the American Southwest was an extremely arid region, both in absolute and relative terms compared to other parts of the United States. The amount of precipitation that falls in the non-mountainous areas of Arizona, Nevada, and California is just marginally enough for livestock provided with large grazing areas, let alone agriculture on any level. Without irrigation, complex fixed society is nearly impossible in the region once known as the Great American Desert (Powell 2008). The hope of ‘rain follows the plow’ was disproven by Powell’s reports, yet a constant in-migration of people and money effectively overruled any of Powell’s plans for establishing a new form of watershed-based democracies, with water rights owned directly by those who would seek to simply use what the land and
water allowed. What the Southwest got instead was, as Donald Worster has described it, a hydraulic regime the likes of which had never existed on earth before (1985).

The water question is a matter that has confronted nearly every society in human existence, and those societies responded in a variety of ways to meet the almost inescapable disparity of not enough water in the places where you need it most (Libecap 2005). In the face of resource scarcity, there are two potential responses: to use less (either through conservation or efficiency) in order to not overreach physical capacities, or to find new sources of that resource. A number of other social factors will play into such decisions, but the exclusive and predominant relationship here is between the physical environment and how humans respond to that environment: as a limit to be accepted, or as a challenge to be overcome (Kallis & Coccossis 2002). The Hohokam, like the Chacoans and Puebloans before them, lived within the physical capacity of their local watersheds while trying to expand what was possible with those resources as much as possible. Worster labels this the ‘local subsistence’ mode of water regimes, in which a society uses whatever resources it has on hand and builds some irrigation features, but the decentralized power structure leaves it unable to build large-scale projects (1985). Though Malthusian arguments regarding ‘limits to growth’ may be dismissed in much of social science, ecological limits and carrying capacity are still fundamental physical laws of nature, and this all the more so when it comes to a non-replaceable resource like water. Though these cultures relied heavily upon heavily variable precipitation that was out of
their control, their irrigation and agricultural systems were incredibly successful, and as established in Chapter 1, ultimately too successful, as the social system ultimately exceeded what the physical system could sustain. The response worked until it didn’t.

The other response to the scarcity problem is to find new sources to augment existing resources from further afield, even outside the local ecosystem. This was the response of Rome, New York, and the American Southwest, and is made possible by two factors that only exist with large-scale bureaucratic social organizations: technological means, and economic capital. Again, Worster informs us that after the development of such organizations, more water regimes formed along the lines of Wittfogel’s hydraulic states; the Romans, along with other civilizations such as the Egyptians and Chinese, illustrate the ‘agrarian state’ regime in which centralized power structures create projects that control and shape hydrology on a regional or even national scale (1985). Even these regimes, though, were still geared towards water usage for the broadest public good: the production of as much food as possible in order to feed growing populations in an era when agricultural technology was still at risk of being outpaced by demographic changes, thus the term ‘agrarian state’. New York City falls into this type of regime, in which the massive water infrastructure was built over a period of decades by an increasingly consolidated and centralized urban public utility for the express purpose of providing water for millions of residents (Gandy 2002).
It is in the modern Southwest that we find Worster’s third regime: the ‘capitalist state’. Two key distinctions can be made in comparing the capitalist water regime to its predecessors: the development of a power structure that is geared towards profit rather than simply production of water, and the belief that water “has no intrinsic value, no integrity that must be maintained” (Worster 1985: 52). In other words, what marks the capitalist state is the combination of politics and the profit motive. Water becomes commoditized, its value measured by what can be sold thanks to it, and social organization – particularly the bureaucracies of state and corporations – becomes geared towards obtaining ever more supplies of it, even in the most arid regions:

“Where nature seemingly puts limits on human wealth, engineering presumes to bring unlimited plenty. Even in the desert, where men and women confront scarcity in its oldest form – not the deprivation of a particular industrial resource, which is always a cultural contrivance, but the lack of a basic biological necessity – every form of growth is considered possible. Undaunted by any deficiency, unwilling to concede any landscape as unprofitable, planners and schemers assure that there is water in the driest rocks, requiring only a few spoken commands to make it gush forth without end.” (Worster 1985: 52-53)

The end result of such a regime, Worster continues, is that the state becomes particularly embedded within, and a party to, the production of water for private uses. Governments are not only the largest, most centralized power within a society and thus able to mobilize the resources necessary for water
infrastructure on the scale required for such projects, with such power increasing at higher levels of government, they are also vulnerable to the combined influence of both private interests – such as agribusiness, land owners, and corporations – and their own technical specialists, each of whom has separate but converging goals towards building such infrastructures which are, invariably, built with publicly-funded resources (Andrews & Sansone 1983; Blomley 2008). Just as the state provides money to universities for basic research which is then used by private companies – effectively constituting a public subsidy of business as governments pay for critical research that companies do not have to count against their profits – the state also becomes involved in construction, maintenance and operation of infrastructure projects whose costs are almost never fully paid for by those who profit most directly from the availability of that water (LeVeen & King 1985; Worster 1985). It often isn’t even a situation of so-called ‘blended’ partnerships, such as in that Athens drought, where the government is the sole or primary owner of an ostensibly private utility company (Kaika 2006). Governments of various forms and ideologies have always been involved in water utilities, but the capitalist state – due to this combination of government power and corporate money – sees a particular outcome that results in socializing the costs of water production and scarcity for taxpayers and citizens, while privatizing the benefits of both for owners and shareholders (Swyngedouw 2002 & 2015).

In essence, the American West is a hydraulic regime that represents the combination of private capital and bureaucratic power, constituting an effective
and unique response to the problem of scarcity (whether such scarcity is natural or manufactured). Confronted with an arid region surrounding a major river, and with few companies or cooperatives willing to undertake the work for irrigation projects (the Metropolitan Water District being one exception), the federal Bureau of Reclamation facilitated the interests of both capital and the political establishment through intensive projects that were cost-ineffective from a public standpoint, but provided a large benefit to the farmers, developers, and residents of the Southwest who received an influx of water precisely because there was very little of it (Worster 1985; Reisner 1993; Glennon 2009; Powell 2008; Debuys 2011).

This is a point that should not be overlooked. Despite the lack of precipitation in vast area between the Sierra Nevadas and the Rocky Mountains, and the fact that the Colorado River has relatively few easy access points, a sustainable agricultural system could have been built in the Southwest, as the quote from Reisner that began this chapter alludes to. The watershed-based democratic communities that Powell envisioned in the Southwest were meant to form not just communal economies but also locally-based authorities to build reclamation projects on their own or with minimal outside financing, meaning that the projects would have stayed on a scale befitting the resources of the watershed and needs of that community (Reisner 1993). However, the logic of capitalism is incompatible with restraint; growth and profit are not just encouraged but demanded, and all the better if the risk is on somebody else’s dime. Reclamation, with the full weight of the nation behind it, became
inevitable in the West as soon as Powell came back with his surveys illustrating just how arid the West was. Scarcity made water in the West so valuable that the Federal government would spend billions of dollars and pour millions of tons of concrete to guarantee supplies so that nobody wanting to farm or live in the region would ever doubt that there was enough water. But the political economy of the West made it easy for the various stakeholders in the water regime to justify not recouping the public investment in the infrastructure; the water was and still is sold at such rates that an urban homeowner in Phoenix (and Las Vegas, and San Diego) pays only a third as much per month for water than their counterpart in Seattle, and the farmers along the Central Arizona Project pay even less than that (Walton 2015). In fact, not only is the water sold at such low rates in the places where ostensibly it should cost the most, various government agencies have been unwilling or incapable of even accurately measuring just how the water is used and keep long-term records of how much it costs over time. Rather than the ecology shaping the developing of social organization in the Southwest, it has been the other way around, with money and power (in its myriad of forms) driving massive alterations to the physical environment without regard to the true socio-ecological costs of those actions. As Reisner put it: “The government first created a miraculous abundance of water, then sold it so cheaply that the mirage filled the horizon” (1993: 480).

In contrast to most other urban areas, where water infrastructure was built in accordance to meet rising demand, in the Southwest it appears that the supply came first, and spurred a demand so great that the water of one of our
great rivers has now been overleveraged and overpromised. None of this is to say that the Southwest would’ve been depopulated or bereft of urban areas – the history of Tucson, which grew sustainably in line with existing surface and groundwater resources along with extensive conservation programs for many decades, is a testament to this fact – but the history of the region is highly suggestive of the fact that the great boom period of such cities in the post-war era coincides with not just the harnessing of water supplies, but also the knowledge of government intervention to guarantee those water supplies. That is to say, much of the population and economic growth in the Southwest likely occurred because the Federal government assured, through its actions, that it would not allow the Colorado River to flow unused, and an entire region to remain arid (Reisner 1993; Malloy 2013b). This is exactly the conditions for bubbles – economic, social, and environmental – and their resulting, though avoidable, moral hazards.

The other components of the political economy of scarcity, along with the power structure that builds and maintains the hydraulic regime just described, are faith in technology to ‘conquer’ nature, and the commodification of water. As pertains to the former, it is true that technological transformation is an integral component of human systems, in that the development of tools, machines, and processes to augment and improve quality of life, even at the expense of nature, is not only a cultural universal and a constant throughout history, but it is even a necessary part of human environments (Kaika 2006; Vogel 2015). It is not the technology itself that is at issue here, however, but the belief that technology
automatically and intrinsically solves any problem; when the belief is applied without even fundamentally understanding the problem, such as the highly variable outflows of the Colorado River, it sets up problematic situations for systems built on the assumptions of technological superiority and predictability (Worster 1985; Kaika 2006; Taleb 2012; Morozov 2013). Instead of being seen as a means to a better society, technology itself is instead mistaken as the incarnation of that better society, accelerating the disconnection as environments are seen by their inhabitants as separate from both natural and social processes (Morozov 2013). For example, all too often in today’s technological discourse, arguments about the use and role of the internet in economic, political, and social structures are grounded on the premise that ‘the internet’ is some extraordinary force of nature that must simply be accepted as is and as the way things will just be from now on, as if it were not built by those same economic, political, and social structures and itself subject to change in the same way that it has changed our daily lives (Morozov 2013). Similar discourses treat built environments as simply there, the constructs of a technological determinism that is not up for social debate and which sets path dependencies from which we either fail to see alternate paths or are told repeatedly that it’s simultaneously too late, too expensive, or too inefficient to change now (Gandy 2005; Kaika 2006; Verhoef & Nijkamp 2008; Morozov 2013). In this, one can see that the history of reclamation in the American West has been one of constant building of dams, reservoirs, and irrigation ditches to the point where the Bureau of Reclamation and the Corps of Engineers both struggled to find more rivers and projects by
even the 1960s, as all of the easy sites had been used already, yet the belief in the technology (and existence of government bureaucracies) drove the ongoing quest for more water, rather than ask hard questions about how much water actually existed and how it could be most effectively used (Reisner 1993; Jenkins 2009). The answer to the water question was always, in essence, concrete; in good times, there were calls for more dams, and in droughts, more dams were called for (Glennon 1995 & 2009; Nevarez 1996; Debuys 2011; Beard 2015). Reclamation could not fail, it could only be failed.

As to the commodification of water, the disconnection appears here as well, for the use and exchange value of water becomes warped by the question of scarcity. Early societies in the Southwest knew all too well the worth of water, and while the Chacoans and Hohokam built economies within their local subsistence regimes, those economies were not driven by the exchange value of water; it had intrinsic value that was not and could not be measured quantitatively (Worster 1985). Even when the first modern towns started popping up throughout the region, water was not expensive; because there was enough for those who needed it, it was free for the taking. Only when a resource becomes scarce does its exchange value rise; the same bottle of water that is given freely to attendees at a public event could fetch a ransom from somebody parched in a desert. Glennon notes that Adam Smith called this ‘the diamond-water paradox’, remarking on the relative usefulness and yet diverging prices commanded by each of those resources (2009: 224). Yet even in agrarian states, water was not a commodity; that could only happen in the capitalist mode of water regimes, as
water is transformed from a natural resource to a socially constructed product, through the use of technology that 'delivers' water not from a river but from a pipe and faucet and the increasing insistence that only markets can properly manage water and water rights in a given system (Landry 1998; Kaika 2006; Culp et al 2014; Swyngedouw 2015).

When water is commodified, as in a capitalist state, and scarce, as in the Southwest, it then follows that such a resource will be considered so valuable that not only will local supplies be collected and used, but more will be imported from as far away as is feasible. The limited amount of precious water compels society to pursue whatever means is necessary to obtain more, but the commodity fetish means that once the water is obtained, its actual use is not a matter of social debate (Kaika 2006). Congress, through the Bureau of Reclamation and its appropriations to Western states, took on the burden of building infrastructure to solve the water question in the Colorado River basin in order to transform the region for economic and population growth, spending billions of Federal tax dollars to augment water supplies in many urban and agricultural areas that the local residents, business owners and farmers could not have possibly afforded themselves (Reisner 1993). Those billions effectively form a subsidy on the part of the taxpayers of the rest of the country to the residents of the Southwest that created an abundance of water that has then been used for low-value crops, swimming pools, air conditioners, and the like; even the economic growth that has occurred in the region was very likely not much more than replacement value from the rest of the country, i.e. farmers,
workers, jobs, and money being imported from other regions of the United States due to the cheap land and water made possible through subsidized reclamation, itself made real by the physical scarcity of water in the not-too-distant past (Worster 1985; Reisner 1993; Glennon 2009; Debuys 2011).

This is not an American-only phenomenon. As previously mentioned, in 1989 Athens, Greece began experiencing a severe drought just a few years after Greek water officials announced that their main reservoir was full and that they had mastered the hydrological system bringing water to the country’s main urban area, effectively saying that they had conquered nature and guaranteeing water supplies in a region where such supplies regularly went scarce (Karavitis 1998; Kaika 2003, 2006). The Greek Parliament, in 1987, had declared that water was a ‘natural gift’ and ‘an undeniable right’ to every person, thus declaring that residents of Athens would never have to worry about availability of water; water usage consequently, and in line with a growing population, increased throughout the decade leading into the 1989 drought. The response to that drought on the part of Greek officials was two fold: first, there was the policy response of building new dams and aqueducts to store and transport more water towards the city (though such projects would take years to complete) and a retroactive rate increase on water usage that gave bigger discounts to the people who used the most water, who, it turns out, hardly decreased their consumption despite the potential savings (Kaika 2006).

Second, and even more conducive for our discussion here, is the rhetorical response of the officials during this period in which they proclaimed their
triumph over the environment and asserted that Athens’ water question was solved, and then had to respond almost chaotically to a drought that rendered their assumptions and projections worthless. The massive infrastructure and investment funded by the Greek government in the decades leading up to the drought fueled the same elements of population growth that occurred in the Southwest: “the urban sprawl that occurred between 1950 and 1970 could not have happened without the expansion of the water supply network, and of the resource base, both of which were either funded or heavily subsidized by the state” (Kaika 2006: 165). In turn, land developers, real estate speculators, and construction companies and workers, all of whose jobs were heavily linked to the housing and building boom from said sprawl, supported these infrastructure investments premised on conquering the water question, again illustrating the political economy of water as a commodity whose value is only reflected in its ability to be monetized. However, this infrastructure and the utilities who provide water to users means that water is not merely a natural resource anymore, but is instead the product of a socially managed process; various officials tried to argue that they should not be blamed for the injurious effects of the drought because water is ‘not produced’ like electricity, and because its scarcity is a natural condition, but this ignores the mediated systems built by the utilities themselves which attempt to manage rivers as an assembly line and deliver water with guaranteed service schedules (Kaika 2006). Efforts to try and alleviate the drought were done through two concurrent, and contradictory, mindsets: that the drought was entirely a natural disaster rather than
potentially a man-made fiasco caused by the effort to ‘optimize’ water resources for human use, and that water is inherently a ‘scarce’ resource even though the years prior to the drought had led to the widespread belief that there would be abundant water for years to come. By building projects to eliminate scarcity and create abundance, Greek officials unwittingly created the conditions for an even worse situation should a drought come along in the future as even more people would be affected by scarce water resources, and the path dependency of relying upon technology, infrastructure, and commodification meant that their hands would be tied in trying to alleviate the effects of the very drought they believed would never happen (Nevarez 1996; Karavitis 1998; Swyngedouw et al 2002). Make no mistake: what happened in Athens was a failure on the part of central planning and government bureaucracies trying to ‘optimize’ a scarce resource that they did not understand, let alone control. Governments and markets can often check each other in this regard, and even help each other to manage resources for the greatest mutual benefit; however, and especially in crisis situations involving necessary, life-giving resources – cf. Irish and Indian famines of the 1800s in which grain was still being exported from those countries while entire regions starved – they can also exacerbate each other’s worst tendencies (Davis 2001).

This leads into another aspect of the scarcity issue in regards to natural resources that have gone through the commodification process. Predictions of scarcity can lead to overproduction of that resource, warping any systems and markets that were set up to efficiently and fairly manage remaining quantities of
it. Four decades of predictions of ‘peak oil’ have been regular features of the energy discussion in this country and around the world, while oil production has still maintained its upward trend line, driven by both new technology to extract oil from places previously thought unreachable, and the economic realities that make oil extraction that was previously too expensive more palatable to both companies and society at large (Roberts 2005; Mann 2015). Meanwhile, wild fishing stocks in the world’s oceans are being overfished on a massive scale, with some estimates suggesting that 90% of the world’s most popular seafood species have been harvested (Clark & Clausen 2008). Efforts to combat further overfishing run up against the economics of such an outcome, namely, that scarce seafood is more valuable, providing a bigger incentive for fishermen, companies and distributors to continue or even ramp up production in order to capitalize on a potential windfall from the last remaining members of a previously thriving fishery. In essence, believing that a resource is scarce leads to the development of ever more schemes and projects by which to extract or harness as much of that resource as possible in the time remaining. And for a time this can have great success, but nature, as they say, bats last. Reclamation projects in the West have operated on the same principle, and there has been economic prosperity stemming from this technological achievement in solving the water problem, but remember the lesson of the Chacoans and Hohokam: it worked until it didn’t (Tainter 1988; Reisner 1993). At this point, I believe we can start to add a new lesson: the more it works, there is a disproportionately greater
the fall when it doesn’t, to the point that that society may have been better off not pursuing its grand project in the first place.

Large scale projects for water infrastructure, like the aforementioned Roman and New York aqueducts, generally formed the basis of bringing water to already existing urban areas; even William Mulholland’s Los Angeles was about to start bursting at the seams when it seized the Owens River valley. Phoenix, Las Vegas, and San Diego did not come close to meeting this criteria at the time that the Bureau of Reclamation began its multi-billion dollar terraforming of the Colorado River, especially as they were still able to exist within the constraints of their local watersheds, and yet those cities benefitted immensely from a confluence of government officials, industry leaders, and civic boosters (Jenkins 2009). The availability of water in an arid landscape leads to a cognitive dissonance about what is possible – socially, economically, and politically – precisely due to its scarcity, which is exploited as much as it is feared. Even in the past few years, California has debated whether or not to build new dams to help alleviate its drought-induced water shortages, even though dams would not increase the supply of water, open-air reservoirs may even increase evaporation, and dams regularly go over-budget and over-schedule (Ansar et al. 2014; Leslie 2015). This new manufactured supply of water, however, would not have been available without the ever-present threat of drought and scarcity; in other words, it is the very location of these desert cities that compelled federal projects to ‘reclaim’ every available river, even those that were hundreds of miles away, and move those rivers to the cities. If water flows uphill towards money, as the
traditional Western dictum holds, it will also flow across a desert towards money. That is, until the unbreakable physical laws of nature demand that the water inevitably and invariably dries up.

D. A Brief Description of the Central Arizona Project

In the 1980s the state of Arizona opened the sluice gates on the longest aqueduct in the world: the Central Arizona Project, a project idealized for decades as the state’s attempt to achieve the economic growth they felt was their destiny by being able to harness the water they believed they were entitled to, but couldn’t acquire without the efforts and money of the Federal government. The CAP transports 1.6 million acre-feet (MAF) of water, which is the majority of the 2.8 MAF that Arizona is allotted under the Law of the River agreement. A three hundred and thirty mile aqueduct and canal stretching from the Colorado River on the western border of Arizona, heading east towards Phoenix with its eventual terminus in Tucson in the southeast corner of the state, the CAP requires fourteen pumping stations, using millions of megawatt-hours of energy from the coal-fired Navajo Generating Station near Page on the northern border, to lift billions of gallons of water up 2900 vertical feet over three mountain ranges before allowing gravity to bring the water down to its agricultural and urban users (Debuys 2011; Nies 2014). The history of the CAP is one that can and has filled books on the politics of water in the West, but one fact rises above all the others: Arizona must have the CAP in order to use its allocation of water from the Colorado River, and for the CAP to exist, the Federal government had to
essentially guarantee billions of gallons of water to pour into a desert metropolis that may have not grown without it.

It is important here to illustrate just how much Phoenix and central Arizona benefits from this massive, Federally-approved and -financed aqueduct which was only authorized by the Colorado River Basin Project Act of 1968 after decades of arguing with California over how much water Arizona was allowed, and more importantly, how it could get it (Reisner 1993; August 1999; Hanemann 2002). The two primary purposes of the CAP were that it would allow Arizona to finally claim its full share of the Colorado River (since the vast majority of the state’s economic activity occurs in the middle part of the state), and that it would allow the state to reduce its groundwater extraction, which was overdrawing the existing aquifers in the populated and agricultural centers of the state (Reisner 1993; Hanemann 2002). By more than doubling what Arizona was previously able to use from the Colorado, the CAP effectively guaranteed that residents of the state would not have to worry about water again; unfortunately the economics of the CAP also set in motion a shell game in which the nation’s taxpayers would subsidize Arizona’s water, while urban residents would subsidize the water rates for farmers, so that the farmers would use enough water to justify the CAP in first place, so that the project would not just be an $8 billion gash in the landscape (Reisner 1993; Hanemann 2002; Glennon 2009; Nies 2014; Beard 2015).

The CAP, then, is not just a concrete-lined canal that draws water across the desert (which leads to not-insignificant evaporation since neither the aqueduct or the reservoirs are covered); it is a microcosm of the water question
and the political economy of scarcity in the American Southwest, as the project was the final piece in the conquest of the Colorado River and the firm establishment of not just the urban metropolises of Arizona but also the system by which various governments (federal, state and local) used their power to expand the resource base and facilitate economic growth in very specialized ways, even if it was subsidized and imported on behalf of a seeming oasis (Worster 1985; Reisner 1993; Debuys 2011). Such growth has been self-evident over the past two decades, but it also hides the potentially devastating effects of a shortage on the Colorado River, because the CAP, and by extension Phoenix as we know it, is only made possible due to a highly complex socio-ecological system built and based upon, we now know, the faulty premises of just how much water actually exists in the Colorado River basin.

There is inherent instability in regards to water availability in the Southwest due not just to the natural hydrological cycles but also to the economic underpinnings of an bureaucratic and technological system that delivers water throughout a region whose population is projected to almost double to one hundred million people by mid-century (Garfin et al 2014). The scale of the water infrastructure in the Southwest represents not just money but a new form of social organization that urban and environmental theorists must wrap their heads around in order to understand how the built environment and physical environment of cities have become both intertwined and decoupled at the same time.
Phoenix is not the only example, but it is a prime one: in order to get the water to support four million people in an area in which 40,000 Hohokam eventually proved too many, Phoenix relies upon the $8 billion CAP (which was originally budgeted at just over a billion dollars). In order to get the aqueduct in the first place, Arizona had to agree to disadvantageous terms within a multi-state compact that governs every last drop of water of the Colorado River and has turned what used to be one of the most powerful rivers in North America into a waterway that does not even reach the Gulf of California anymore (Jacobsen 2014). In order to power the pumps at Lake Havasu City that put water into the aqueduct, electricity must be generated hundreds of miles to the north at the Navajo Generating Station (owned by the Bureau of Reclamation and multiple water utilities) near the Utah border, burning coal from Indian reservations and currently operating as the second largest individual source of carbon dioxide emissions in the United States (Nies 2014). In order to have a water allotment from the Colorado River in the first place, Arizona and the other states rely upon the Bureau of Reclamation, and its hundreds of billions in federal funding, to build the dams and run the management systems that measure and regulate the river’s water for distribution, based on outdated calculations and, as will be explained later, absurdly unrealistic projections about the Colorado River’s output. Each link is an interaction in a complex economic and political structure built over a century, and an ecosystem that extends across thousands of miles of a watershed balanced precariously upon mere inches of precipitation.
What this brief historical and ecological snapshot displays is that the footprint of Phoenix’s water resource base – that is, of just one Southwestern city – is much bigger than perhaps commonly perceived, and that its ecology is therefore far more complex, and thus far more fragile, than is likely admitted to and hoped for by residents, boosters, and politicians alike. The laws, infrastructure, and development represented here are an attempt by the residents of Phoenix (and Las Vegas, and Los Angeles, and San Diego, and Tucson, and every other urban center of the entire vast region) to expand upon what the Romans and New Yorkers did in using economic and technological means to avoid the fate of the Southwest’s indigenous ancestors who, despite knowing the ecosystem far better than the average modern suburban resident of central Arizona, still disappeared into the sand.

E. Social Determinants of Physical Environments

Worster’s explication of the capitalist mode of water regime and Kaika’s explanation of the commodification of water run concurrently with the theories of place presented in Chapter 2 to form a new and essential construct of modern urban ecology: that social environments have and are replacing physical environments as the primary determinants of city morphology (Worster 1985; Kaika 2006; Swyngedouw 2006; Monstadt 2009). The historical examples of societies and cities noted so far in this dissertation – from Rome to Chaco Canyon to New York – were urban civilizations very much rooted in their ecosystems, depending upon their hinterlands while at the same time reaching
beyond them for more resources. What differentiates them from the cities which will be the focus of the rest of this dissertation is that Southwestern cities such as Phoenix, Las Vegas, and San Diego have a far more fraught relationship with their hinterlands: acquiring their abundant water resources due to their arid locations and complex infrastructures, while at the same time developing key functions that are not rooted in any unique geographical advantages and presenting themselves as independent from nature. These cities ignore their physical surroundings and simultaneously demand to be rescued from them.

Perhaps the key development in the shift from physical to social determinants of urban environments has been the creation and refinement of networks. Rome built aqueducts for its water needs alongside its extensive road networks which connected the various realms of its burgeoning republic; the power of its city lay in the power of its connections to both its hinterlands and other cities, reflecting ecological and economic interdependence. Meanwhile, Chaco Canyon, as explained earlier, had a trade network which allowed for products to be imported from a regional basis including timber and other materials, while still relying upon its immediate ecosystem for water and food; thus, they were able to achieve elements of economic complexity that eluded other similar indigenous societies of the region (Diamond 2005). This complexity led to not just prosperity but also differentiation, in which various settlements and functions radiated outwards from Chaco Canyon, reinforcing and expanding existing networks. However, such social organization also found itself to be inherently unstable as it could not support the growing population
pressures that had been attracted to and forged by such organization in the first place. The social environment of Chaco Canyon had become decoupled from its physical environment, and without extensive infrastructure and networks in place – such as in Rome – the inhabitants had no resources to fall back upon (whether through direct acquisition or by trading export-worthy products for imports which could stave off social collapse).

Networks not only allow for the social production of life-sustaining resources into commodities as Kaika asserted, they allow for the very idea of social production to begin with; after all, the creation of needs and goods for a given population, and the processes by which we share ideas, produce resources, and govern their distribution are only rendered within a construct of social organization. Without networks, urban life is a non-starter; agglomeration requires the movement of people, information, and materials in a dynamic system. The concept of network effects explains this perfectly, as the value of the network lies in the value of every node that is connected into that network; you join Facebook because your friends are on it, and they join because you’re on it (McChesney 2013). Similarly, you move to an urban area because you value the amenities that exist because other people also moved there, and those amenities only exist due to a critical mass of people (and are generally expected to be enhanced by the inclusion of more people). While amenities such as schools, theaters, and parks may get much of the attention when it comes to urban quality of life, the foundational aspects of city morphology – economic functions, public utilities, and physical geography – are the necessary and
guiding components of quality of life, and also exist due to the agglomeration of people and formation of internal and external networks (Klinge 2007). In this way we can conceptualize a social production of urban life: the creation of the infrastructures and institutions that generate the necessary resources for towns, cities, and regions, and their development and evolution in response to the demands, pressures, and norms of the society that those infrastructures help sustain (Heynen et al 2006; Monstadt 2009; Ferrão & Fernández 2013).

Water is not just a natural resource, and it is not in every instance a commodity, but it is always, in the context of human systems, a socially produced good due to the mediated networks that act upon it and deliver it from, to, and within the infrastructures of urban life. Those infrastructures, from ancient Rome to the present, are driven by two factors above all else: social organization and technology. The physical geography that a society is formed in will undoubtedly have a large influence on its form of social organization, but complexity, differentiation, and specialization on the part of societies and cities seem to be a temporal universal. Given enough time, urban areas and the networks that facilitate and sustain them will develop in a way that becomes delinked from its physical environment (Swyngedouw 2006; Axinn & Ghimire 2011). The capital and bureaucracy necessary for building massive water projects – whether irrigation, dams, reclamation or aqueducts – requires a mode of production with surplus labor as well as a political system that can govern all of the disparate laws and norms regarding distribution and allocations in a watershed. This is not to say that only certain forms of social organization will
build water infrastructures – communist governments and command economies were and are just as fond of massive reclamation projects as capitalist, democratic societies, as the Aral Sea disaster in the Soviet Union and the Three Gorges Dam in China sadly illustrate – but that generally such societies are generally more advanced, dense, and have a high division of labor, marking their turn into the types of societies with the qualities stated above.

The second factor, technology, marks the distinction between the local water projects of the indigenous peoples of the Southwest (impressive though their dams and canals may be) and the megaworks of Rome, New York, and the modern Southwest, which stretch for hundreds of miles, span valleys and mountains, and carry enormous volumes of water. These concrete and steel reinforced structures, along with the electric pumps, power stations, filtration plants which service them, allow cities to augment local water supplies from a much larger regional ecosystem, which, while giving urban areas the ability to draw upon a greater quantity of water and tying them even more into the physical landscape, also counterintuitively allows the users of that water (such as urban residents, and in the case of the CAP, rural farmers as well) to think that they are no longer dependent upon the physical landscape. Sheltering individuals from the extremes of nature is precisely what cities were built to do, as even Bernard would argue (1930a & 1930b). In Phoenix, however, homeowners can look outside and see desert off in the distance, but green grass and a full swimming pool around their home, further reinforcing a social environment (which as much a function of norms and values as it is economic and political
structures) that is, at least in the short term and in a limited way, disconnected from the physical environment (Malloy 2013).

In addition to conquering space, new technologies (and more capital) allows for these projects to be carried on even grander scales, including projects that exceed the expected demand at the present time. The aqueducts of Rome and New York were built as the city needed them; while this surely added time and monetary expenses to the cities and their residents, it also meant that the urban infrastructure was built in lockstep with the urban morphology itself. The vast majority of reclamation projects in the West were built not because of proven necessity or to satisfy existing demand, but instead based on projections of both future water supplies and how that water would be used (i.e. assumptions that farmers would switch from groundwater to irrigated water, the expected value of that water and crops grown with it, how fast urban areas would grow in coming decades) (LaVeen & King 1985; Brown et al 1990; Reisner 1993; CBO 1997; Hanemann 2002; Brelsford 2014). As such, the Colorado River reclamation projects, taken as a whole, were vastly overbuilt compared to their existing needs and to the actual ends of such a system in terms of the water that can be delivered (Reisner 1993). Think of a 10-lane highway built through a city, designed to handle the projected traffic of rush hour, but underused all of the other hours of the day; similarly, the Los Angeles River was transformed, by the Corps of Engineers with millions of tons of concrete, into a 40-mile stormwater channel to handle the rains that wash down through Southern California for a few weeks
each winter, while the rest of the year it sits as a mostly empty gash through the landscape (Deverell & Hine 2005).

This overcapacity for water further exacerbates the disconnection from the physical environment as the built infrastructure represents a sunk cost that must be then used in order to justify itself, even at the expense of the local hydrology and if the political economy skews the social organization of the urban area and its hinterlands. The quote to start this chapter refers to the varying costs projections and financial and hydrological realities of the CAP, in which the project promised to deliver water cheaper than farmers could pump out of the ground on their own land. When that became impossible due to the rising costs of the CAP (which was already being built), in order to keep the farmers from tearing up contracts for CAP water, urban residents had to pay higher rates and subsidize water for the farmers through an aqueduct already subsidized by state and federal funds (Reisner 1993; Glennon 1995; Fuller 1998; Hanemann 2002). In fact, the economics of the CAP were so skewed by these expectations and assumptions of future usage and costs that the state of Arizona may have actually been better off by not even building the CAP for the next eighty years and forcing itself to use its groundwater more conservatively rather than open the taps of the Colorado River (Hanemann 2002; Holland & Moore 2003). Meanwhile, new NASA studies of the Colorado River basin as a whole estimate that when groundwater pumping is factored into analyses of how much water the Southwest uses, the region is using 1.5 times more water than the Colorado River can provide in a given year – and a surprising amount of that
groundwater is not separate from the hydrological cycle of the river, so the disparity may be even worse and will only exacerbate the inevitable shortages in the future (Glennon 2009; Beard 2015; Lustgarten 2015c). State-sponsored development, in which the government provides both the impetus for settling an area and underwrites some of the most expensive and necessary infrastructure, can remove social, economic, and ecological checks upon the growth imperative of both the state and of capital; the problem is not necessarily that of either government or corporations, but of a failure or unwillingness on the part of both to see what was right in front of their eyes, and thereby leading to accelerating overshoot of available resources. The American Southwest is in many ways an artificial ecosystem; social forces have acted in such a way that cities have had access to guaranteed amounts of water an ecosystem where such a thing was never meant to exist. There is, at the same time, both too much water, as a function of the infrastructure, and not nearly enough, as a function of the arid nature that this infrastructure can’t ignore. Social environments, encompassing the political, economic, and cultural forces of a given system, increasingly seek to manufacture their own physical reality, even if that reality is not just derived from, but also simultaneously divorced from the environment that underlies and supports it.

A defining outcome of these intersecting processes of networks, social organization and technology intersecting is that of the path dependencies that are set in motion in urban settings (Atkinson & Oleson 1996; Moffatt & Kohler 2008; Hyltrek & Márquez 2013). Once the infrastructure is laid down, the network
connections are set, and the institutions are in place for urban life, they will reinforce and expand upon themselves barring some massive external shock or internal disruption (as we have seen in Chaco Canyon and elsewhere across ancient societies who existed on the knife edge of what their ecosystem could sustain) (Diamond 2005). Sunk costs play a determinative role in the formation and expansion of both cities and the complex systems that sustain them; a fascinating history of America’s urban areas could be told through its massive transportation projects whose existence is due to the fact that once begun, they are almost impossible to stop regardless of cost overruns or delays; vested interests often use the agencies or mechanisms of government to keep both public and private projects going, come what may. In the same way, water megaprojects, as the 20th century has shown us, will be finished even if there was evidence beforehand of little economic or environmental benefit; the Central Arizona Project, originally budgeted for a billion dollar construction cost during its 20-year planning phase, ballooned to over $8 billion by the time it was finished, forcing various governments and agencies to move shells around to mask the costs because once built, the water must flow and it must not be allowed to be too expensive (Reisner 1993; Powell 2008; Glennon 2009; Beard 2015). Path dependencies and sunk costs, predicated on short-term incentives and social psychology, can greatly influence the long-term future of a city and constrain its ability to adapt to changing conditions, in whatever form those conditions take. This inflexibility becomes a prime concern in the event of a change in the social or natural environment – one need only look at the
population decline in Detroit as an illustration of the short- and long-term ripple effects of overcapacity combined with dramatic population loss. The morphology and physical environment of the urban Southwest has and is still being driven by social determinants which have taken precedence over the ecological reality of an arid region that is facing even greater environmental pressures in the future.

These social determinants run counter to Bernard’s warning regarding culture paying the “penalty of its ignorance or arrogance by being destroyed” when it fails to adjust itself to nature (1930b: 42). The primacy of social environment in urban areas can be very profitable and encourage population, economic, and cultural growth for cities and regions, but ignoring physical constraints opens the doors to environmental blowback; scarce resources may be more valuable, but there remains a finite limit on their quantity; and just as physical ecosystems have thresholds and tipping points at which non-linear feedback loops kick into effect in terms of negative impacts on inhabiting species, cities can exhibit similar trends if they are not cognizant of their place in nature. This is not to say that social, political, and economic determinants of urban form should be dismissed or ignored, but that the physical environment must be recognized and respected in the life of cities. When a drought, hurricane, or flood strikes an urban area, we call it a natural disaster or an act of God, but is that truly the best descriptor when millions of people and billions of dollars were purposely placed and invested in an area where those phenomenon are not just possible, but a regular feature of the ecosystem itself?
F. Introducing the Hyperspecialized City

The combination of a unique hydrological and socio-political history of the West, the political economy of water in arid regions, and the modern rise of social environment as the primary determinant of urban ecologies comes together in the formation of a distinct typology of city in the Southwest: the hyperspecialized city. These cities will be examined in more detail in the analysis chapters, but I would like to discuss the theoretical underpinnings of these urban areas and what they may represent for socio-ecological study.

Much of urban theory and the notions of key functions represented above focus on cities with a dominant industry or economic sector which the rest of the urban ecosystem built itself around. While cities may be known for a particular function or economy, up into the post-World War 2 era it was still somewhat rare for a major American metropolitan area to be heavily specialized on a non- or post-industrial key function; the notion of cities being able to achieve profitability and population growth without industry or major trade was perhaps theoretically possible, but even the proponents of human ecology did not imagine that a society or city could be wealthy enough to grow into a metropolis without a clear export economy. Furthermore, nearly every large city in America was on or near a freshwater source that could supply enough quantities of water for urban residents and economic uses; certainly towns and small cities could exist and function just fine in arid and desert regions, but only by using the water resources that they could conceivably harness and living
within those constraints. Human ecology did not foresee the kind of technological and economic developments that would make possible the massive reclamation projects seen in the western United States that overcame the physical environment and allowed cities to live not just beyond their hinterlands, but even grow almost entirely on the basis of constructed hinterlands that they previously didn’t have access to. It is the intersection of these two forces – economic specialization and ecological disconnect – that make the hyperspecialized city.

It is my contention that the desert environment in which urban areas such as Phoenix, Las Vegas, San Diego, and others have grown and thrived over the past several decades has had a profound influence on these cities in two ways. First, the physical environment, providing very little in the way of export-oriented industry (central Arizona’s subsidized agriculture notwithstanding), pushed these cities to develop a specialized economic function, such as entertainment and gambling, military bases and government contracts, and retirement and tourism services. These functions can and have been very profitable for the cities and regions involved, but they are also a one-way street; the money comes in from the rest of the country, but there does not seem to be much going back out in the form of products or services that take place outside of the city. In many ways, this type of specialization and key functions enables the city to effectively replace their resource base; no longer dependent on their immediate hinterlands for resources in order to be economically competitive, they can utilize their social environment as well as extensive networks with
other cities and regions in order to bring in resources and capital. This means that the cities are vulnerable to two things: competition from other cities that could just as easily offer similar functions (since the key function stems from the social, not the physical environment), and changes in the availability or cost of inputs (i.e., an economic recession that reduces discretionary income for tourism, or a government decision to close bases or cancel contracts). This, to continue the metaphor, is not unlike our hothouse flower, which is grown in an environment without competition and with all necessary inputs provided to it on a regular and consistent basis. Secondly, the environment also compels the cities, and their residents, to behave in ways that ignore their physical constraints at the same time that, as established in previous sections, the cities would not exist in the current form without the political and economic gain of being in that ecological situation. Until recently, Phoenix had virtually no restrictions on housing development and water usage; Las Vegas’ water commissioner tried to restrict development during a drought in the early 1990s and was told by casino and hotel owners to never do so again; and Southern California exists as a region defined by chronic wildfires and water shortages yet also has some of the most expensive real estate in the entire nation (Starr 2004; VanderMeer 2010; Lustgarten 2015a).

These two factors shape the very core of the cities in question. It is not that hyperspecialized cities do something inherently better than other urban areas or that those other cities cannot do, it is that they do it more profitably. The profit comes, as always, from the surplus wealth left over after the expenses are
accounted for; in the case of desert cities, those expenses are primarily land and water. Once society builds the infrastructure for transporting people and resources to a city, then growth is simply a function of having land to develop and water to service it. The low-density sprawl that can be witnessed in Phoenix, Las Vegas and Southern California demonstrates that land has been cheap enough to make more dense living cost-prohibitive – when it isn’t outright prohibited, that is (Davis 1992; Futrell 2001; VanderMeer 2013). Meanwhile, when there is no ‘price’ on water – for example, California water agencies have been prohibited from charging more for water than the cost of physically supplying it to a user, so that only nominal fines are available as a tool to reduce consumption – or when its price is subsidized at a rate below its true economic and environmental cost, then its use generates pure profit. The key problem for these cities in the future may not even be whether water is available (though that is obviously a huge problem), it’s what will happen when there is an actual cost associated with water that was previously taken for granted.

Furthermore, these cities rely upon more extensive infrastructures for their functioning than most other cities in the country; outside of the Colorado River basin, no other urban area relies upon a system of dams, pumps, intake tunnels, aqueducts, and canals that stretch for as long as those servicing the major cities of this region. These water infrastructures represent sunk costs that, at the cost of tens of billions of dollars by the government, stimulated the investment of many more billions by private business and individuals in a path dependency that by necessity involves the federal government in the continued
management of water in the interstate compact and the entire basin. The
government, at many levels, sets the rules of the game for how water supplies the
west, even when that water flows through and into private hands. However,
water can only be managed, not created, and while the Law of the River
stipulates certain cutbacks and reductions, there is likely no plan in place that
accounts for the non-linear economic impacts of when water service is no longer
guaranteed; even studies that assume the Colorado River was completely dry for
a year make assumptions regarding GDP and jobs lost simply based on arbitrary
definitions of ‘direct’ and ‘indirect’ economic activity due to the availability of
water, with no provision in the model for the fear of water rationing leading
companies or workers to leave even if they weren’t ‘directly’ getting water from
the Colorado (James et al 2014a & 2014b). As stated above, none of this is stating
that the Colorado River has to run dry for there to be problematic outcomes for
cities that rely upon it and the complex system that delivers the water to where it
is needed. The housing bubble of 2008 did not burst because housing prices went
down, it burst because housing prices (fueled by subsidized home loans) simply
stopped going up at the rate that Wall Street’s financial models projected
(Salmon 2009). In the Southwest, water doesn’t need to stop flowing to cause a
problem; it just needs to not be as infinite and as cheap as everybody has always
assumed it to be.

As established in this chapter, the major metropolitan areas of the
Southwest have established a unique place in theoretical conceptions of urban
environments: they are decoupled from their hinterlands and immediate
physical environment, using technology and wealth to augment and even replace their resource base while creating post-industrial specialized key functions, and yet simultaneously, without the geography of place, the necessary infrastructure and resources for building the cities into their current form may have never been provided. The narrow economic sectors of the cities are derivative and dependent upon importing capital from the rest of the country, albeit in a rather successful manner over the past few decades. The urban growth machines are tied, however, to a highly complex life support infrastructure also built and maintained by outside capital, providing vastly more water than exists anywhere nearby and whose functioning is based on assumptions about the natural environment that, if incorrect (and the hydrological record suggests that they are), are not easily fixable. I label these cities as hyperspecialized because they exist at the nexus of a particular economic and ecological circumstance; because those economic and ecological circumstances are fundamentally intertwined in a way that the cities have to this point tried to dismiss or even deny; and because those circumstances leave the cities open to the potential for non-linear, 'fat tail'\textsuperscript{7} type impacts of the kind that occur when the underlying assumptions of the social and physical environment no longer accurately describe the world that the cities exist within.

\textsuperscript{7}‘Fat tails’ are the outcomes that are skewed to one side of a distribution; as Taleb describes it, such outcomes are the result of assuming that a situation follows a normal distribution when in fact it does not (2012). What makes them non-linear is that one or a few events can invariably outweigh any or all potential outcomes on the other side of the distribution, i.e. the expected gains on Wall Street during the financial bubble were not nearly as much as what they stood to lose when the bubble burst. The infrastructure of water distribution in the West, built over many decades, could be rendered useless by just a few years of drought; such an event could put the Southwest in a more precarious economic state than before the infrastructure existed.
G. Chains of Interactions

Considering the theoretical and historical discussions up to this point, I would like to briefly posit a new approach to urban ecology that will inform the rest of this dissertation. As stated in the first chapter, it is my contention that urban ecology must start to look beyond the city, and think beyond the direction of social and environmental forces, and focus instead at the intersections of these great systems that determine so much of the physical and human morphology of the city. Chapter 2 explains many of the necessary and invaluable perspectives and tools that urban and environmental theorists have used throughout the decades, and this is in no way meant to be a dismissal of those approaches. However, while human ecology provides a fully-functioning framework by which to analyze the interplay of cities and environments, it can lack the narrative and normative power to explain why a city exists in its current form or predict what may happen to it; while political economy and critical theories provide that narrative power to explain why, they all too often focus on the direction by which social forces are dominating the city, whether through conflict or functionalist lenses; and while urban metabolism provides a methodology that focuses uniquely on the flows of resources through cities, it still tends to treat cities as the only link by which those flows cycle through. What is needed is an approach to urban ecology which combines the aims and tools of these three dominant paradigms, understanding that cities don’t create themselves, that they exist within an interdependent feedback loop of multiple structures and systems, and that the city, though it is, for our purposes, the most
important link in the flows of resources that sustain them, is but one link in a far longer and more interesting chain of interactions. And this approach is based on one key premise: the more isolated the chain of interactions, the more complex the ‘life support’ system upon which a city depends, and thus the more fragile it is to a disruption in its underlying resource base.

What would this mean in real life? Consider, just for now, the previous examples of New York City and Phoenix. The majority of New York’s water supply comes from the Catskill Mountains which collects water and snowmelt from the central part of the state; several aqueducts bring that water from various rivers to multiple reservoirs, all within a hundred miles of the city, which deliver the necessary water for the 15 million residents of the city’s five boroughs, and the vast majority of this water is brought to the city without the need for pumping or extensive water treatment. If any one of the aqueducts were to fail, there would be a disruption in water service certainly, but the system has enough redundancy to help alleviate the impact, and New York could in all likelihood augment its water supplies from other nearby watersheds and water utilities. Meanwhile, Phoenix relies exclusively upon a single aqueduct, the CAP, for most of the water to serve four million residents; the CAP stretches three hundred miles through the desert, and relies upon a massive pumping station to get water out of the Colorado River up and over a mountain; the electricity for that station comes from a power plant several hundred miles to the north, which itself is powered by coal that comes from an Indian reservation seventy miles to the east; and the water itself is collected from a watershed that covers almost a
fifth of America’s land area and is highly variable due to yearly changes in rain and snowfall, while the river has multiple other claims upon it dividing the outflow down to the gallon. Any link in this chain of interactions that provides water to the residents of Phoenix could change or fail and there would be little to no fallback for the city except emergency and/or long-term water restrictions, which would fundamentally alter the historical dynamic of the city itself. These are two completely different urban ecologies, two completely different foundations upon which the cities are able to base their economic outputs and demographic destiny, and two completely different potential outcomes based on the chains of interactions that allow them to exist and function in the first place. I will delve into further detail in the concluding paragraph, but it is important to keep in mind just how extensive, how isolated, and how potentially fragile this system is that turns the Colorado River into tap water for tens of millions of people who take it for granted every day.

**H. Hypotheses on the Water Question in the Southwest**

On the basis of the preceding theoretical and historical arguments regarding urban development and the scarcity of water in the Southwest, I would like to posit the following hypotheses for analysis in the following chapters.

1) **The availability and guarantee of augmented water supplies in an arid environment led to urban growth in these cities, not the other way around.** The political economy of scarcity shows that the development of water in the Southwest became the driver of urban and economic development; without sustained
water supplies, and the promise of future availability of water, it is unlikely that millions of people and billions of dollars in economic investment would have come into urban areas. Federal reclamation projects not only delivered newly abundant supplies of water, they sent a signal that those cities would be guaranteed water indefinitely, thus spurring increased development and growth, as represented by the land area and population of these cities.

2) *Cities in narrow ecological niches must develop narrow economic niches.*

Phoenix, Las Vegas, and San Diego are classic desert cities in which their hinterlands provide sustainable but limited water supplies, among other natural resources necessary for life; because they do not have a clear ecological function, they found themselves needing a key economic function, namely in a specialized or service sector. This economic niche allows for the urban area to focus on the social environment to generate profitability rather than the physical environment. Heavily narrow sectors such as gambling, entertainment, retirement services, tourism and military-defense spending lead to hyperspecialized economic outcomes of dependence and over-reliance on that function and a lack of diverse economic interests to keep the urban environment balanced.

3) *The Colorado River may not provide the amount of water that can support the Southwest as it currently exists, let alone any future population and economic growth.* The assumptions over the past hundred years regarding the flows of the Colorado River have been overstated from the outset, yet those are the assumptions that are ‘baked in’ to the built infrastructure of the entire Colorado basin, including
its urban areas. There are already more demands placed on the Colorado than there is outflow in any given year, plus the ongoing drought which is placing further stress on the reservoirs that hold the water necessary to keep the lower basin from automatic delivery cuts, and there is evidence that even without the spectre of climate change the Colorado was reverting back to a historical norm that would leave an extraordinary gap in how much water will be available during the remainder of this century. The ‘overshoot’ of the Colorado River basin is not only a reflection of how much the social environment of the region made false assertions about what the physical environment could provide, but may also endanger various aspects of the urban Southwest as we know it.
Chapter 4: Data & Methodology

When all the rivers are used, when all the creeks in the ravines, when all the brooks, when all the springs are used, when all the reservoirs along the streams are used, when all the canyon waters are taken up, when all the artesian waters are taken up, when all the wells are sunk or dug that can be dug in all this arid region, there is still not sufficient water to irrigate all this arid region.

– John Wesley Powell (1893: 109)

A. Groupings of Cities as the Focus of the Analysis

To begin to answer the questions raised by these hypotheses, I have compiled data regarding the demographics, land area, and economic performance of cities in the West and elsewhere, using the Census Bureau’s definitions and delineations of U.S. metropolitan areas. First let me lay out the regions that will be used in the rest of this dissertation for hypothesis testing and analysis.

Region 1 includes every metropolitan statistical area (MSA) that is in an arid or semi-arid ecosystem – meaning that the urban area receives, on average,

<table>
<thead>
<tr>
<th>Albuquerque, NM</th>
<th>Boulder, CO</th>
<th>Cheyenne, WY</th>
<th>Colorado Springs, CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Denver, CO</td>
<td>El Centro, CA</td>
<td>Farmington, NM</td>
<td>Fort Collins, CO</td>
</tr>
<tr>
<td>Grand Junction, CO</td>
<td>Lake Havasu City, AZ</td>
<td>Las Vegas, NV</td>
<td>Los Angeles, CA</td>
</tr>
<tr>
<td>Oxnard, CA</td>
<td>Phoenix, AZ</td>
<td>Prescott, AZ</td>
<td>Provo, UT</td>
</tr>
<tr>
<td>Pueblo, CO</td>
<td>Riverside, CA</td>
<td>St. George, UT</td>
<td>Salt Lake City, UT</td>
</tr>
<tr>
<td>San Diego, CA</td>
<td>Santa Fe, NM</td>
<td>Tucson, AZ</td>
<td>Yuma, AZ</td>
</tr>
</tbody>
</table>

Table 1 – Region 1: Metropolitan Statistical Areas, Colorado River System
less than 20 inches of rain per year – and gets water from the Colorado River system as listed in Table 1.

These MSAs form the foundation of the analysis in this dissertation, as this list includes not only areas that get water directly from the Colorado, but also urban areas that receive water from tributaries or even water storage systems that are managed by the Bureau of Reclamation as part of the larger Colorado River basin; as such, they benefit from the Federal government’s largest reclamation project even if they don’t receive regular water deliveries but are part of the Bureau’s infrastructure and can be assured of water in the event of a shortage. Their urban growth reflects the underlying basis of guaranteed, and subsidized, water supplies that allowed for ongoing development even though these cities all exist in an arid or semi-arid climactic region, as defined by the Köppen climate classification system (McKnight & Hess 2000).

Region 2 consists of nearly all of the other metropolitan areas west of the hundredth meridian that are in an arid or semi-arid climate zone, but which do

<table>
<thead>
<tr>
<th>Amarillo, TX</th>
<th>Bend, OR</th>
<th>Bismarck, ND</th>
<th>Boise City, ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carson City, NV</td>
<td>Casper, WY</td>
<td>El Paso, TX</td>
<td>Great Falls, MT</td>
</tr>
<tr>
<td>Greely, CO</td>
<td>Idaho Falls, ID</td>
<td>Kennewick, WA</td>
<td>Las Cruces, NM</td>
</tr>
<tr>
<td>Lewiston, ID</td>
<td>Logan, UT</td>
<td>Lubbock, TX</td>
<td>Medford, OR</td>
</tr>
<tr>
<td>Midland, TX</td>
<td>Missoula, MT</td>
<td>Odessa, TX</td>
<td>Pocatello, ID</td>
</tr>
<tr>
<td>Rapid City, SD</td>
<td>Reno, NV</td>
<td>San Angelo, TX</td>
<td>Sierra Vista, AZ</td>
</tr>
<tr>
<td>Spokane, WA</td>
<td>Walla Walla, WA</td>
<td>Wenatchee, WA</td>
<td></td>
</tr>
</tbody>
</table>

Table 2 – Region 2: Metropolitan Statistical Areas, Rest of the Arid West
not receive water from the Colorado River system. These MSAs may and likely do have their own infrastructures for local water supplies and augmenting those supplies with nearby rivers or groundwater sources, but to the best of my knowledge, the metros in this list are not recipients of any large-scale Federal reclamation project, and are left, so to speak, to fend for themselves in terms of guaranteeing their own water supplies. Those MSAs are listed in Table 2.

For transparency purposes, I felt compelled to separate a group of MSAs from these regions that exist in a very arid ecosystem – California’s Central Valley – but also benefit from a Federally-built and subsidized and State-managed irrigation system, the Central Valley Project. A Congressional report on this project remains one of the few concrete records I have been able to find regarding the level of subsidized financial support that the government has provided to water users in the West through these systems, with a major finding that some 90% of the total cost of the system and its water is borne not by the consumers of the water, but by taxpayers at large (CBO 1997). However, the existence of this separate infrastructure, and the overwhelming dependency of these areas on irrigated agriculture as their key function, does make these metro areas – Bakersfield, Fresno, Hanford, Madera, Merced, Modesto, Stockton, and Visalia – a group something of an outlier for the purposes of analysis here, and they are categorized as Region 3.

After grouping the MSAs, I then included all other Census-defined metropolitan statistical areas in the rest of the United States as Region 4, which will provide a sort of ‘control’ group by which to gauge the population and
physical growth and economic performance of these Western regions, and
determine whether these groups of metro areas have developed different key
functions and sectors in order to survive and grow in their unique ecosystem
(the full list of metropolitan areas is in Appendix A).

What follows in this chapter is a selection of analyses of economic and
population growth in both the regions and the cities listed above, which serves
two purposes: the first is that while the MSA is the object of interest in terms of
being the locus of these various flows (i.e. water, capital, people), it is actually the
system that is the determining factor in how these cities develop overall. The
West may appear to be dotted with metro areas hundreds of miles away from one
another, but they are inextricably linked in a larger regional physical and social
ecosystem that evolves in different ways depending on the types of inputs that it
can utilize. It just so happens that the West may provide us with a real-life
experiment of how urban areas can evolve based on a differential in a critical
input: half of the MSAs in the arid West are beneficiaries of the Colorado River’s
output, and the other half are not. As such, both the MSAs and their regional
context serve the function as laid out from the beginning of this dissertation: to
consider cities as the result of a series of interactions that exist beyond the city,
but also simultaneously as the reason for those interactions in the first place.

B. Data Sources & Variables
The population data used in this analysis covers the years 1990-2014 inclusive,
and comes from the Census Bureau’s data for Metropolitan and Micropolitan
Statistical Areas (Census Bureau 2016). The 2000 and 2010 Decennial Census established the population levels in 1990, 2000, and 2010, and linear interpolation was used to provide yearly numbers for time series analysis; the numbers for 2011 through 2014 come from the Census Bureau’s population estimates for those years. Despite my best efforts, it has proved impossible to find or reconstruct comparable metropolitan population data before 1990, both due to the changing nature of the Census Bureau’s definitions and delineations of geographical boundaries for metropolitan areas, and because so many of the towns and suburbs that were later incorporated into metro areas were themselves absent from earlier iterations of Census data, or in the City and County Datebooks. In addition to raw population totals, I also created variables for a one-year lag and for the level of population growth from year to year, in order to account for how population would change over time on account of water availability.

The land area data comes from Issi Romem’s work on urban expansion (Romem 2016). Romem compiled a database of land area expansion, in square miles, for metropolitan, micropolitan, and Census statistical areas across the country, by decade, since the 1940s up to 2010. Since the data came in the form of how many square miles the cities grew by in each decade, I worked backwards with land area in 2010, and subtracted the land area expansion for the available metro areas in the groupings for Regions 1 and 2, since those are the primary focus for the hypothesis test of whether access to the Colorado River system led to a differential in growth. This provides for data on land area, in square miles, for each decadal year from 1950 to 2010, and then linear interpolation was applied.
to provide yearly numbers for time series analysis to cover those sixty years inclusive. In addition to raw land area totals, I also created variables for a two-year lag and for the rate of land area growth from year to year, in order to account for how the size of urban areas would change over time on account of water availability (a two-year lag seemed more appropriate here than one year due to the increased cost and time scale for zoning and construction compared to the more fluid process of population moving in and out of a MSA).

The economic data comes from the Bureau of Labor Statistics, and consists of gross domestic product statistics for metropolitan areas, hereafter referred to as gross metro product or GMP, as defined by the Census Bureau, from 2001 to 2014 inclusive (BLS 2016). The statistics used in this analysis were compiled into economic sectors, to form broad economic indicators which would measure the basis of the metropolitan economies (a full listing of how the economic sectors were delineated is in Appendix B). In short, the primary sector applies to those industries which engage in extracting or harvesting raw materials; the secondary sector consists of utilities, construction and manufacturing industries in a MSA; the tertiary sector are services broadly rendered, from trade to real estate to the arts; and the quartenary sector is a subset of the tertiary economy, in which information services and government funding are not only separated out for analysis as their own group, but also further separated on their own in order to measure the specialization of key
functions in urban economies\textsuperscript{8}. These sectors were converted to percentages of total GMP, and the analysis also includes a one-year lag for each sectoral variable to account for change in industrial output. Furthermore, the data includes GMP per capita (also with a one year lag), also compiled by the Bureau of Labor Statistics.

The water data comes in two forms. The first analysis looks at the water deliveries in the Lower Colorado River (which, as established above, is split between Arizona, Nevada, and California) for the major cities in the region. The data comes from the Bureau of Reclamation’s Water Accounting Reports, and lists the specific entities or people who took water out of the Lower Colorado for each year from 1964 on up to the year 2014 (Bureau of Reclamation 2016). I compiled the water deliveries in each year, as applicable, for the public water utilities that took water out of the river. Some of these utilities changed names and forms over the years, and I updated accordingly, but they take the following forms: the City of Yuma, AZ; the Central Arizona Project, which services the Phoenix and Tucson metropolitan areas; the Metropolitan Water District, which services more than two dozen water utilities in Southern California, primarily the Los Angeles and San Diego metro areas; and the Southern Nevada Water Authority, which arose out of the Las Vegas Valley Water District and services the

\textsuperscript{8} In so many words, the quartenary sector measures functions of an urban economy that exist beyond the physical place of the city, i.e. information services could effectively be rooted anywhere, as telecommunications and allow for content to be, if not completely without a material base of operations, then untethered from specific places. Meanwhile, government funding, whether in the form of federal assistance, military spending, or state and local bureaucracies, serve two functions: the first is that such funding must exist if the city itself exists, so that this type of economic sector is ever-present in a way that few other sectors of the urban economy are; the other function is that government funding provides a measure by which various levels of government can subsidize or stabilize local economies, such as through military bases or regional headquarters for federal agencies. The unusual nature of these economic functions necessitates analysis, as cities that are not dependent on their physical economies must find some other means for economic importance, invariably through social economies.
entire Las Vegas metro area. The latter three entities saw their water deliveries change over time, while Yuma, AZ, has stayed relatively consistent in the amount of water it takes from the Colorado, and can provide a sort of control entry to measure against the far more populated and dominant metro areas of the region. The water deliveries are regressed against the land area variables already described above and included in the data set; for Yuma, the MWD, and the SNWA, the water delivery years covered are 1964-2010 inclusive, while for the CAP, the years covered in the regression are 1985-2010, as the CAP itself did not come ‘online’ until 1984. Summary statistics are presented in Table 3.

The second set of water data comes in the form of the Colorado River Open Source Simulator, or CROSS (CROSS 2016). This database with statistical macros was established to be an open-source tool for researchers who wanted to not just analyze the Bureau of Reclamation’s water outflow data for the Colorado River (the data in the simulator comes from the Bureau’s own documented reports), but also make their own projections of future outflows with model parameters and assumptions that the Bureau either fails or chooses not to make in regards to such variables as the amount of precipitation in the Colorado Basin, the level of evaporation, and the demands placed by users on the system. The simulator uses almost a hundred years worth of Colorado River data and then makes projections for the next hundred years using the historical patterns, while also adjusting for the knowledge that the river was well above its historical and

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9 Though to be fair, the Bureau has lately started to make up for its previous unwillingness to consider the likelihood of future gaps in outflows and demands, especially by commissioning and releasing the Colorado River Basin Water Supply and Demand Study in 2013 which details the state- and basin-level usage of water as well as projections of demands from rising population levels and economic growth, and the effects of climate change upon future water supplies in the Colorado Basin.
| Region 1 - Colorado River System (dummy variable) | 1320 |
| Region 2 - Rest of the Arid West (dummy variable) | 1475 |
| Region 3 - California Central Valley (dummy variable) | 200 |
| Region 4 - Rest of the United States (dummy variable) | 8050 |
| Population | 9504 | 630283.2 | 1477296 | 31577 | 20092883 |
| Lag Population (1 year) | 9123 | 626717.6 | 1470233 | 31577 | 20002086 |
| Population Growth | 9123 | 7414.271 | 22193.15 | -662099.1 | 188718 |
| Lag Population Growth (1 year) | 8742 | 7462.853 | 22393.35 | -662099.1 | 188718 |
| Land Area | 2318 | 164.6956 | 534.5274 | 0 | 4407.55 |
| Lag Land Area (1 year) | 2318 | 164.6956 | 534.5274 | 0 | 4407.55 |
| Land Area Growth | 2280 | 3.616745 | 8.82652 | -0.000000687 | 72.673 |
| Lag Land Area Growth (1 year) | 2280 | 3.616745 | 8.82652 | -0.000000687 | 72.673 |
| Gross Metro Product Primary Sector (% of Total GMP) | 5090 | 0.0277235 | 0.0546301 | 0.00000678 | 0.6716712 |
| Lag GMP Primary Sector (% of Total GMP) (1 year) | 4847 | 0.0273515 | 0.0546195 | 0.00000678 | 0.6716712 |
| GMP Secondary Sector (% of Total GMP) | 5090 | 0.2126399 | 0.103303 | 0.0017526 | 0.7325445 |
| Lag GMP Secondary Sector (% of Total GMP) (1 year) | 4847 | 0.2135032 | 0.1035623 | 0.0017526 | 0.7325445 |
| GMP Tertiary Sector (% of Total GMP) | 5090 | 0.759636 | 0.108366 | 0.2504182 | 0.9591526 |
| Lag GMP Tertiary Sector (% of Total GMP) (1 year) | 4847 | 0.7591452 | 0.1085003 | 0.2504182 | 0.9591526 |
| GMP Tertiary Sector - w/o Government (% of Total GMP) | 5064 | 0.5761042 | 0.114098 | 0.1338874 | 0.8738163 |
| Lag GMP Tertiary Sector - w/o Government (% of Total GMP) (1 year) | 4821 | 0.574997 | 0.1141369 | 0.1338874 | 0.8738163 |
| GMP Quaternary Sector (% of Total GMP) | 5090 | 0.2109198 | 0.0969081 | 0.0512516 | 0.7814682 |
| Lag GMP Quaternary Sector (% of Total GMP) (1 year) | 4847 | 0.2113638 | 0.0973055 | 0.0512516 | 0.7814682 |
| GMP Quaternary Sector - Information (% of Total GMP) | 5077 | 0.0276559 | 0.0648549 | 0 | 1.329387 |
| Lag GMP Quaternary Sector - Information (% of Total GMP) (1 year) | 4834 | 0.024421 | 0.0198403 | 0 | 0.176006 |
| GMP Quaternary Sector - Government (% of Total GMP) | 5077 | 0.187611 | 0.100879 | 0.0499542 | 0.7714682 |
| Lag GMP Quaternary Sector - Government (% of Total GMP) (1 year) | 4834 | 0.1868797 | 0.0988294 | 0.0499542 | 0.7714682 |
| Gross Metro Product Per Capita | 5320 | 40682.68 | 11525.91 | 15370 | 162786 |
| Lag GMP Per Capita (1 year) | 4940 | 40612.14 | 11347.66 | 15370 | 134934 |
| Yuma Land Area | 47 | 27.32945 | 11.03143 | 9.814 | 44.43 |
| Lag Yuma Land Area (2 year) | 47 | 27.32945 | 11.03143 | 9.814 | 44.43 |
| City of Yuma Water Deliveries | 51 | 18777.06 | 6589.382 | 6493 | 32363 |
| Phoenix Land Area | 47 | 577.3748 | 277.4146 | 186.594 | 1119.53 |
| Lag Phoenix Land Area (2 year) | 47 | 577.3748 | 277.4146 | 186.594 | 1119.53 |
| Tucson Land Area | 47 | 202.7305 | 78.82982 | 73.86 | 329.83 |
| Lag Tucson Land Area (2 year) | 47 | 202.7305 | 78.82982 | 73.86 | 329.83 |
| Phoenix + Tucson Land Area | 47 | 780.1053 | 355.4862 | 260.454 | 1449.36 |
| Lag Phoenix + Tucson Land Area (2 year) | 47 | 780.1053 | 355.4862 | 260.454 | 1449.36 |
| Central Arizona Project Water Deliveries | 30 | 117273.6 | 52351.3 | 33502 | 1685190 |
| Los Angeles Land Area | 47 | 3562.256 | 587.7035 | 2434.362 | 4407.55 |
| Lag Los Angeles Land Area (2 year) | 47 | 3562.256 | 587.7035 | 2434.362 | 4407.55 |
| San Diego Land Area | 47 | 446.1415 | 121.1408 | 221.68 | 618.5 |
| Lag San Diego Land Area (2 year) | 47 | 446.1415 | 121.1408 | 221.68 | 618.5 |
| Los Angeles + San Diego Land Area | 47 | 4008.398 | 708.567 | 2656.042 | 5026.05 |
| Lag Los Angeles + San Diego Land Area (2 year) | 47 | 4008.398 | 708.567 | 2656.042 | 5026.05 |
| Metropolitan Water District Water Deliveries | 51 | 1060706 | 210640.3 | 632424 | 1303276 |
| Las Vegas Land Area | 47 | 224.7206 | 132.5044 | 48.678 | 478.09 |
| Lag Las Vegas Land Area (2 year) | 47 | 224.7206 | 132.5044 | 48.678 | 478.09 |
| Southern Nevada Water Authority Water Deliveries | 51 | 232103 | 169574.1 | 3596 | 484304 |

Table 3: Simple Statistics of All Variables Included in Regression Analysis

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ecological average for many of those first hundred years; the CROSS simulator allows for researchers to make educated projections for how much water the Colorado River may have over the rest of the century.

C. Issues With Data Collection

Before moving on to the methodology used in the following analysis section, I must point out a couple of items regarding the data itself. Even three years of research has left me unable to find complete and accessible records on just how much money the Federal government has spent constructing and maintaining the water infrastructure upon which the tens of millions of people and acres of farmland of the Southwest depend, let alone the full amounts and true costs of the water that flows through that infrastructure to those end users. Appropriations for dams and aqueducts are hidden or split between various agencies and governments; expenses have ballooned and skyrocketed for many projects during their decade or multi-decade construction span; and cost projections and water & electricity contracts are almost always wildly out of proportion to each other (Reisner 1993; Glennon 1995; Hanneman 2002).

The few specific sources I have been able to find have stated that the cost of water in the Southwest may be subsidized by the Federal government by as much as 90%, and in some cases the various bureaus and agencies may actually be losing money providing water to farmers who then sell crops worth less than the water being poured on them (LeVeen & King 1985; Worster 1985; Reisner 1993; CBO 1997; Beard 2015). Furthermore, the United States government does not
devote nearly as many resources to tracking and calculating water usage and keeping that data in a timely fashion as compared to energy, agriculture and other industrial statistics; the only comprehensive national water data comes from the United States Geological Survey in five-year increments, which are often late (the 2010 survey, for example, was not released until late autumn 2014) and provide little detail outside of state or county delineations. Researchers in a recent Arizona State study reached this same conclusion:

“The lack of consistency displayed by Federal agencies in the collection of water use data, and the frequency with which they publish findings, is a real concern for researchers. ... The USGS and USBR [Bureau of Reclamation] have privately stated that their respective datasets cannot be compared or used in conjunction with one another due to a variety of differences in measurement methodology and categorical definitions.” (James et al 2014b: 38)

In addition, the numerous water utilities I contacted directly in order to obtain any data they had on water usage (and its costs along the chain from where they acquire the water to when it comes out of a user’s tap) all invariably told me that they either did not have large parts of that data, or that if they did have it, it did not exist beyond the previous several years, rendering impossible my hopes of conducting analyses of the costs and subsidies of the water being used and sold in the urban Southwest, and making long-term time series analysis of other variables tremendously difficult. Furthermore, even the data regarding water deliveries are at best proxies; for example, the Metropolitan Water District, as
noted above, supplies water to dozens of water utilities, not just Los Angeles and San Diego, and still does not account for the majority of California’s allotment of Colorado River water (the rest goes towards agriculture). Meanwhile, most of the water that goes through the CAP is still used for agriculture, and yet it was impossible to get public access to any long-term data regarding the exact breakdown and amounts that go to farms or cities, let alone industrial or municipal usage. These issues further prove the point that water data is woefully inadequate in the United States, especially in the 21st century, even when it comes to water we know we’re using.

Beyond the data collection issues, the rights to the Colorado River are so overallocated that there is not nearly enough water to meet all of the demands in the foreseeable future; even without the current drought, groundwater pumping was extensive throughout the region – it is estimated that 43% of water consumed in Arizona is from groundwater (James et al 2014a). Recent NASA data that suggests that when groundwater pumping is factored in – with a surprising amount of that groundwater, it turns out, being part of the river’s hydrological cycle – the region’s residents are using a 1.5 times more water than the river can provide in any given year (Glennon 2009; Beard 2015; Lustgarten 2015c). The presence of, and heavy reliance upon, groundwater pumping in the Southwest plays havoc with efforts to statistically measure how much water cities, businesses, and farmers are using throughout the Southwest compared to how much water is available or is taken from the Colorado River, due to the aforementioned hydrological cycle, and also because there are relatively few
laws regulating or even measuring groundwater pumping. Even in the midst of California’s recent drought, new laws requiring measurements of groundwater usage – while ground subsidence in the Central Valley and elsewhere has become a nationally-recognized issue – will not be fully enforced until the next decade at the earliest, while in Arizona, laws passed in 1980 (in exchange for final CAP approval from the Federal government) to phase out or reduce groundwater pumping in urban areas still allow such pumping through the year 2025 (Ross 2011; Lustgarten 2015c). As such, even the best data and projections from the Bureau of Reclamation make it incredibly difficult to provide scientifically robust analyses or predictions of urban water supplies and usage, simply because the data, and laws, are failing to keep up with the ecosystem and how humans are actually interacting with it.

Furthermore, as stated above, the population and economic data for the metropolitan areas run into their own constraint: the ability of the Census Bureau to keep up with the changing nature of the MSAs themselves. Though I’m hoping to make a case regarding the growth of these urban areas in the postwar period, the data for demographic and economic shifts only covers the last couple of decades at best. However, there are still a tremendous number of metro-years in the dataset – some 9500 in the population variable alone – that provides a comprehensive snapshot of how these cities have performed over the past twenty years, and to my knowledge, no one has yet compared metropolitan areas in the United States in this manner before, in order to determine whether there has been a clear divergence in this many cities due to their ecological
foundation, i.e. their access to water in an arid region. I believe the data, along with a brief but powerful history of these places and the established theoretical construct of their socio-ecological basis, will bear out these questions.

\textit{D. Methodology for Statistical Analysis}

For the regression analysis I use pooled time-series cross-section regression for panel-corrected standard errors with pairwise selection covering the metro areas during the time periods for the variables included: 1990-2014 for population, 2001-2014 for economic sectors, 1950-2010 for land area, and 1964-2014 for water deliveries (unless otherwise noted). The main advantage of this method is that the cross-sectional and time-series nature of the database, establishing ‘metro-years’ for each data point, creates a larger sample size for analyzing changes over time in the dependent variables. Such analysis allows for observation of variation over time and space at the same time; however, the error structure can be complicated by cases that have non-random variation in those dimensions. Pooling data with an improper model specification can also lead to the conclusion that error terms are heteroscedastic and autocorrelated when they are not. To correct for these potential problems, I use an ordinary least squares regression with panel-corrected standard errors; PCSEs are considered the most accurate set of standard errors from ordinary least squares regression as they will correct for correlation in repeated errors, the kind that would be found in time-series cross-sectional data (Beck & Katz 1995).
Chapter 5: Growth, Hyperspecialization, & an Overburdened River

The guest today was a visiting Marxist economist from one of the Warsaw Pact nations, who appeared to be in the middle of a nervous breakdown. “Las Vegas,” he tried to explain, “it sits out here in the middle of desert, produces no tangible goods, money flows in, money flows out, nothing is produced. This place should not, according to theory, even exist, let alone prosper as it does. I feel my whole life has been based on illusory premises. I have lost reality. Can you tell me, please, where is reality?” The interviewer looked uncomfortable and tried to change the subject to Elvis Presley.

– Thomas Pynchon (2009: 231)

A. Water & Growth Beyond the Hundredth Meridian

The first regression results presented in this chapter concern the population and land area growth seen in the American West. It is important to note that the unit of analysis here is that of metropolitan areas within these four regions – the MSAs of the Colorado River System, the Rest of the Arid West, the California Central Valley, and the Rest of the United States – and thus reflects the predicted metropolitan average within those regions.

Using the pooled time series regressions with panel corrected standard errors, Table 4 shows the results for how the population of MSAs is affected by the regions established in the previous chapter to account for the differences in water availability and subsidy. The first model, regressing population size for metropolitan areas, shows that the population size for metro areas in Region 1 – those that are dependent upon the Colorado River water & infrastructure – is substantially larger than the average metro populations in the non-arid regions;
on average, MSAs in the Colorado River system are larger than the average for the rest of the United States (the reference category) by 719,000 people, while metro areas in the rest of the Arid West are substantially smaller than those cities in the reference category, results that are statistically significant at the .001 level. However, region status alone only explains a small part of the variance in population size, something that the lag for population size helps account for ($R^2 = .9999$) in model 2, where the Colorado River MSAs are again significantly (both in size and in their statistical likelihood) larger than their counterparts in the rest of the country. While the coefficient for the lag ($b = 1.009, P<.001$) suggests that the size of those MSAs appears to build on itself over time – i.e. metro areas create a feedback loop in which size induces and predicts ever larger size –

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged Population</td>
<td></td>
<td>1.009***</td>
</tr>
<tr>
<td></td>
<td>(3002.73)</td>
<td></td>
</tr>
<tr>
<td>Region 1 – Colorado River System</td>
<td>719431.8***</td>
<td>7571.66***</td>
</tr>
<tr>
<td></td>
<td>(34.45)</td>
<td>(5.28)</td>
</tr>
<tr>
<td>Region 2 – Rest of the Arid West</td>
<td>-438622.3***</td>
<td>387.185</td>
</tr>
<tr>
<td></td>
<td>(-86.65)</td>
<td>(1.55)</td>
</tr>
<tr>
<td>Region 3 – California Central Valley</td>
<td>-188957.4***</td>
<td>2106.972***</td>
</tr>
<tr>
<td></td>
<td>(-149.34)</td>
<td>(7.03)</td>
</tr>
<tr>
<td>Intercept</td>
<td>619993.1***</td>
<td>1177.831***</td>
</tr>
<tr>
<td></td>
<td>(63.67)</td>
<td>(4.83)</td>
</tr>
<tr>
<td>$N$</td>
<td>9504</td>
<td>9123</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.022</td>
<td>0.9999</td>
</tr>
</tbody>
</table>

*** $p < .001$, two-tailed test  ** $p < .01$, two-tailed test  * $p < .1$, one-tailed test

Table 4: Pooled Time Series Regressions (PCSE), Metropolitan Statistical Area Population 1990-2014 Regressed On Selected Variables (Region 4 Reference Category) (Z Scores in Parentheses)
controlling for that, the results show that the CRS metro areas, on average, are vastly more populated than is typical in the rest of the country.

Population size is an important criteria of urban primacy, but an equally compelling and critical measure is population growth, the year to year measure of how much MSAs may grow or shrink in size. Table 5 indicates that metropolitan areas in the CRS experienced, on average, about twice the population growth of the reference category (that is, non-Arid West and non-Central Valley MSAs in the rest of the United States). Although the MSAs in that category (containing so many more metropolitan areas than these regions) added more people in total, their pace of growth was not as rapid as the CRS metro areas. This table also shows that even as the Arid West metro areas added people, they did so slower than the rest of the nation (which is comparably wetter), let alone the metro areas in the Colorado River System. Again, the variance explained by this regional status alone is small, but the statistical significance of such growth is highly unlikely to be due to chance alone.

The second model of Table 5 incorporating lagged change in population reinforces these findings. Population growth tends to boost future population growth by a substantial margin ($b = .596, P < .001$), which is typical for lagged variables (as is the substantial boost in explained variance from .026 to .372), suggesting that on average a 1000-person increase in size leads to about 596-person expansion the following year. Yet even holding the change in population constant, the intercept shifters (regional variables) still demonstrate that the Colorado River-dependent metropolitan areas have had a large advantage in
adding population (the intercept indicates that the mean population growth for CRS metro areas is about twice that of metro areas in the reference category and more than that compared to metro areas in the rest of the Arid West which don’t draw from the Colorado River). To be more specific CRS metro areas have expanded at 5530 persons per year ($b = 5530, P < .001$) on top of of the 2709 persons in the reference category ($b = 2709, P < .001$). Also, unlike in the results for population size, the Rest of the Arid West remains significant in that while it still had positive growth over time, it was substantially lower than the MSAs that were able to benefit from the Colorado River System ($b = -1427, P < .001$).

At this point I sought to confirm the growth rate for these MSAs, so I calculated the rates for annual population growth from 1990 to 2014 upon the regional base for those metro areas in 1990. Colorado River System MSAs

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged Population Growth</td>
<td>.5959***</td>
<td>.5959***</td>
</tr>
<tr>
<td>(6.91)</td>
<td>(2.79)</td>
<td></td>
</tr>
<tr>
<td>Region 1 – Colorado River System</td>
<td>14041.36***</td>
<td>5530.434**</td>
</tr>
<tr>
<td>(10.07)</td>
<td>(2.79)</td>
<td></td>
</tr>
<tr>
<td>Region 2 – Rest of the Arid West</td>
<td>-3577.747***</td>
<td>-1427.286***</td>
</tr>
<tr>
<td>(-15.12)</td>
<td>(-3.61)</td>
<td></td>
</tr>
<tr>
<td>Region 3 – California Central Valley</td>
<td>390.5475</td>
<td>145.5853</td>
</tr>
<tr>
<td>(1.23)</td>
<td>(.49)</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>6773.645***</td>
<td>2709.735***</td>
</tr>
<tr>
<td>(29.73)</td>
<td>(4.43)</td>
<td></td>
</tr>
<tr>
<td>$N$</td>
<td>9123</td>
<td>8742</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.0263</td>
<td>0.3723</td>
</tr>
</tbody>
</table>

*** $p < .001$, two-tailed test  ** $p < .01$, two-tailed test  * $p < .1$, one-tailed test

Table 5: Pooled Time Series Regressions (PCSE), Metropolitan Statistical Area Population Growth 1990-2014 Regressed On Selected Variables (Region 4 Reference Category) (Z Scores in Parentheses)
expanded at a rate of 1.94%, compared to 2.22% for the Rest of the Arid West, 2.09% for the California Central Valley, and 1.27% for the Rest of the United States. While this may seem to contradict the regression findings, I would like to point out that the base population for the CRS metro areas in 1990 was 25.7 million people, compared to 3.88 million in the Rest of the Arid West; in any given year for over two decades, metropolitan areas in the Colorado River System were adding approximately half a million people, or roughly one-eighth of the total population of the Rest of the Arid West in 1990. Furthermore, such a rate was much higher than the Rest of the United States, even though the proportion of CRS total population to the Rest of the U.S. is exactly the same as the proportion of the Arid West to the CRS metro areas. While an analysis such as this cannot prove beyond doubt that the guarantee of and dependence upon Federally-subsidized Colorado River water encourages larger and more rapidly expanding metropolitan areas, the results are consistent with that conclusion.

The next sets of results look at urban land area, but data limitations constrained me to comparisons of Regions 1 & 2 only; as a further test of the hypothesis that the availability of a vast water infrastructure in an arid region leads to urban growth compared to the absence or at least reduced access to such water, such a test would establish either that there has been a divergence or not in growth trajectories. For it is important to keep in mind that urban areas throughout the West would not be able to exist if they did not have some supply of water in the first place, so the presence of these metro areas, stretching from Texas to eastern Washington, is not the question at hand, but rather it is whether
or not metro areas with ready access to Federally-guaranteed and -subsidized water, via the Colorado River, are larger than their counterparts throughout the rest of this arid ecosystem. Table 6 shows the results of regression analysis directly comparing the MSAS in the Rest of the Arid West to the CRS (which form the reference category in this regression) from 1950-2010. Looking at the land area itself, model 1 shows that CRS metro areas (again, the reference category), were, as a whole, 308 square miles larger than their counterparts in the Arid West (a result that is highly significant at the .001 level). Again, the variance here is small in terms of explanatory power for the physical size of the MSAs themselves, but when the lag for urban land area is brought into the model, we again have a significant effect for land area building upon itself ($b = 1.013, P<.001$). The divergence, however, remains in place in terms of land area between the two regions, and remains highly significant as CRS metro areas are substantially larger.

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged Land Area</td>
<td>-272.816***</td>
<td>1.013***</td>
</tr>
<tr>
<td></td>
<td>(-20.61)</td>
<td>(964.84)</td>
</tr>
<tr>
<td>Region 2 – Rest of the Arid West</td>
<td>-272.816***</td>
<td>-2.304***</td>
</tr>
<tr>
<td></td>
<td>(-20.61)</td>
<td>(-15.14)</td>
</tr>
<tr>
<td>Intercept</td>
<td>308.283***</td>
<td>2.706***</td>
</tr>
<tr>
<td></td>
<td>(15.215)</td>
<td>(14.77)</td>
</tr>
<tr>
<td>$N$</td>
<td>2318</td>
<td>2280</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.065</td>
<td>0.999</td>
</tr>
</tbody>
</table>

*** $p < .001$, two-tailed test   ** $p < .01$, two-tailed test   * $p < .1$, one-tailed test

Table 6: Pooled Time Series Regressions (PCSE), Urban Land Area 1950-2010 Regressed On Selected Variables (Region 1 Reference Category) (Z Scores in Parentheses)
Growth in urban land area, represented in Table 7, further reinforce these results, as the year-on-year expansion in urban land area confirms that while MSAs in the Rest of the Arid West are in fact growing over time, it is still at only a fraction of the expansion that metropolitan areas in the Colorado River System (the reference category) are experiencing ($b = 6.6817, P < .001$). The $R^2$ of .11 shows that regional status does account for a higher portion of the variance in urban land area growth, and again helps establish that while access to the Colorado River may not be the primary determinant of why CRS metro areas are bigger than their Arid counterparts, the intercept shifter here is highly suggestive that CRS metros have a substantial advantage in expanding over time. The lag coefficient of ($b = .986, P < .001$) in Model 2 confirms that growth builds upon itself in these metropolitan areas, and accounts for most of the rest of the variance in urban land growth; while expansion in CRS metros washes out of statistical significance, the Arid West MSAs are still growing extremely slowly in comparison to the reference category at a .1 level.

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged Land Area Growth</td>
<td>.986*** (180.54)</td>
<td></td>
</tr>
<tr>
<td>Region 2 – Rest of the Arid West</td>
<td>-5.8234*** (-98.04)</td>
<td>-.0769* (-1.9)</td>
</tr>
<tr>
<td>Intercept</td>
<td>6.6817*** (78.41)</td>
<td>.089 (1.6)</td>
</tr>
<tr>
<td>$N$</td>
<td>2280</td>
<td>2242</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.1087</td>
<td>0.9938</td>
</tr>
</tbody>
</table>

*** $p < .001$, two-tailed test   ** $p < .01$, two-tailed test   * $p < .1$, one-tailed test

Table 7: Pooled Time Series Regressions (PCSE), Urban Land Area Growth 1950-2010 Regressed On Selected Variables (Region 1 Reference Category) (Z Scores in Parentheses)
Figure 1: Urban Land Area (Average for MSAs Within Regions), 1950-2010

Figure 2: Urban Land Area (Total for MSAs Within Regions), 1950-2010
At this point I think it is worth seeing just how much these metropolitan areas have diverged in their land area expansion, for while the statistical analysis suggests that access to the Colorado River is not highly determinant of urban size or urban growth, it is clearly a significant and critical component of why the CRS metropolitan areas have been able to enjoy enormous gains compared to the metros that are not hooked into such a system. For it is worth reiterating that all of these MSAs in Region 1 and Region 2 are in the same type of physical environment, in that they receive less than 20 inches of precipitation each year; the primary environmental variable here is whether or not the metropolitan areas are able to access water from tens or even hundreds of miles away, and not have to pay enormous economic or ecological costs to access that water. Figures 1 & 2 show this divergence between the Colorado River System metro areas and the Rest of the Arid West. Meanwhile, an analysis of annualized rates of urban land area growth (similar to the population growth analysis), comparing the total square miles of land area in 2010 to that in 1950, finds that the Colorado River System MSAs grew at a rate of 6.27%, while the Rest of the Arid West grew at 8.33% annually. Again, it is necessary to keep in mind the sheer differential in land area, as the CRS metros were more than nine times larger in land area than their Arid West counterparts in 1950.

To follow up on the analysis of urban land area, the next several tables present regression results for whether and/or how the delivery of water from the Colorado River may have influenced the physical growth of various MSAs in the Colorado River System. I utilized the land area variables (both unlagged and
lagged) along with data regarding how much water was delivered directly by urban water utilities in the Lower Colorado River. Table 8 shows results for Yuma, Arizona, which is near the U.S.-Mexico border; the City of Yuma water utility has been delivering water to the metropolitan area since 1964, and the model 1 results show that while the size of the MSA is mostly independent of the water deliveries (though not statistically significant at any level), the water deliveries does have a slight positive effect on land area \( (b = .001, P<.001) \) and can explain most of the variance in land area over time compared to other factors. The 2-year lag in model 2, however, washes out the effect of water deliveries on the land area growth in the metro area, which is not surprising considering that the raw data of the water deliveries (from the Bureau of Reclamation) shows that there was not much variation over time in how much water Yuma took out of the river, so the link cannot be definitively proven here.

In Phoenix, Arizona, however, the effect of the water deliveries is clearly established on land area, as 81% of the variance in the physical footprint of the

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged Yuma Land</td>
<td>1.001***</td>
<td>1.001***</td>
</tr>
<tr>
<td></td>
<td>(250.03)</td>
<td>(250.03)</td>
</tr>
<tr>
<td>City of Yuma Water Deliveries</td>
<td>.001***</td>
<td>-.000004</td>
</tr>
<tr>
<td></td>
<td>(17.72)</td>
<td>(-.67)</td>
</tr>
<tr>
<td>Intercept</td>
<td>-.828</td>
<td>.802***</td>
</tr>
<tr>
<td></td>
<td>(-.57)</td>
<td>(6.84)</td>
</tr>
<tr>
<td>N</td>
<td>47</td>
<td>46</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.848</td>
<td>0.9987</td>
</tr>
</tbody>
</table>

*** \( p < .001 \), two-tailed test    ** \( p < .01 \), two-tailed test    * \( p < .1 \), one-tailed test

Table 8: Pooled Time Series Regressions (PCSE), Yuma Land Area 1964-2010, Regressed On Selected Variables (Z Scores in Parentheses)
metro area \((b = 423, P<.001)\) from 1985 to 2010 can be explained by the small but significant effect of water delivered via the Central Arizona Project \((b = .0003, P<.001)\). Keep in mind that while Phoenix was definitively established and growing by the 1980s, the CAP had been planned, discussed, and hoped for since the 1960s before approval to start building in the 1970s and being completed and delivering water in 1984, so much of the effect of the CAP may also be ‘baked in’ to the land expansion as developers and city officials anticipated the new water that previously had been inaccessible to those living in central Arizona. The two year lag shows a slight but not statistically significant effect, which may be a function of both the limited time-series available here and the possibility that Phoenix had already maxed out its potential footprint for growth.

Meanwhile, to put the growth in population, land area, and water deliveries in perspective, Figure 3 displays this urban development over time, and shows how the rapid rise in CAP water deliveries (as measured in thousands of acre-feet) may have helped spur the rise in both population and land area.
Again, the regression results do not definitively prove such a link, and CAP water fulfill many purposes including agriculture and municipal use for Tucson, Arizona, but without the CAP, Phoenix would not have access to nearly as much water as it uses and requires today.

At the far end of the Central Arizona Project lies Tucson, Arizona, which even resisted water deliveries from the CAP for years after it was finally connected in the 1990s, due to public outcry over how much the water tasted bad – being as it is delivered across over 300 hundred miles of open desert and subject to intense evaporation – as well as Tucson’s pride in water conservation and trying to remain a small city by accepting limitations on its local water supplies (Debuys 2011; Ross 2011). But eventually Tucson accepted CAP water, and
while this will invariably color the regression results in Table 10, one can still see a statistically significant result, however slight, of CAP deliveries upon land area in Tucson ($b = .00007, P < .001$) that explains 86.5% of the variance; the lag in model 2, however, washes the effect out of significance.

Table 11 presents results for the combination of Phoenix and Tucson land area, to present a model for how the CAP has changed the land area of the two major metropolitan areas that use it and have come to depend on it on a yearly basis. Model 1 shows that deliveries of water from the Colorado River via the Central Arizona Project have a highly significant effect upon the land area of these two metro areas ($b = .00004, P < .001$), accounting for 82% of the variance therein. The 2-year lag, knocking the still-positive effect of CAP water out of significance, can again perhaps be explained by the shorter time scale and the unique political economy & ecology of Tucson, thus statistically negating what by all accounts in the region has been a critical component of the development of Arizona in the past few decades.

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged Tucson Land</td>
<td>.997***</td>
<td>.997***</td>
</tr>
<tr>
<td></td>
<td>(905.41)</td>
<td>(-.45)</td>
</tr>
<tr>
<td>CAP Water Deliveries</td>
<td>.00007***</td>
<td>-.00000004</td>
</tr>
<tr>
<td></td>
<td>(14.97)</td>
<td>(.45)</td>
</tr>
<tr>
<td>Intercept</td>
<td>183.923***</td>
<td>6.251***</td>
</tr>
<tr>
<td></td>
<td>(36.92)</td>
<td>(30.54)</td>
</tr>
<tr>
<td>$N$</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.8650</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

*** $p < .001$, two-tailed test  ** $p < .01$, two-tailed test  * $p < .1$, one-tailed test

Table 10: Pooled Time Series Regressions (PCSE), Tucson Land Area 1985-2010, Regressed On Selected Variables (Z Scores in Parentheses)
The next set of tables look at the effect of water in Southern California. The Metropolitan Water District has not received as much attention in this dissertation as its utility counterparts in Arizona and Nevada, but it is perhaps the very model of how a large public utility sought to reshape an entire region by accessing water from hundreds of miles away (the MWD receives its allotment of Colorado River water via its own aqueduct which stretches for some two hundred miles from Lake Havasu, the same access point as the CAP). Unlike the CAP, the MWD has been making its water deliveries for many decades, and the results in Tables 12 through 14, for land area in Los Angeles, San Diego, and those two metro areas combined, reflect a few different forces. First of all, because those areas came to exist as urban areas in their own right well before Phoenix and Las Vegas, those metropolises were more even more built up by the time the land and water data pick up the trail; due to this, there is less variance that can be measured in this regression analysis, as seen in the $R^2$ of Tables 12, 13, and 14, in the land area due to the water deliveries that are included in this dataset.

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged Phoenix &amp; Tucson Land</td>
<td>1.017*** (255.66)</td>
<td>1.017***</td>
</tr>
<tr>
<td>CAP Water Deliveries</td>
<td>.0004*** (12.05)</td>
<td>.000002 (1.14)</td>
</tr>
<tr>
<td>Intercept</td>
<td>607.15*** (18.34)</td>
<td>10.19*** (3.88)</td>
</tr>
<tr>
<td>$N$</td>
<td>26</td>
<td>26</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.8228</td>
<td>0.9999</td>
</tr>
</tbody>
</table>

Table 11: Pooled Time Series Regressions (PCSE), Phoenix & Tucson Combined Land Area 1985-2010, Regressed On Selected Variables (Z Scores in Parentheses)

*** $p < .001$, two-tailed test  ** $p < .01$, two-tailed test  * $p < .1$, one-tailed test
Secondly, the MWD water deliveries may have some slight year-to-year variations due to the amount of water available in the Colorado River and demands by other entities within California that draw upon the Colorado, but due to the senior water rights that California enjoys under the Law of the River, the state’s allotment has never been seriously questioned or reduced, thus even in times of drought, developers and public officials in Southern California may

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged Los Angeles Land</td>
<td></td>
<td>.981***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(986.79)</td>
</tr>
<tr>
<td>MWD Water Deliveries</td>
<td>-.0003 (-1.02)</td>
<td>-.0000003 (-.2)</td>
</tr>
<tr>
<td>Intercept</td>
<td>3952.164*** (10.19)</td>
<td>110.5694*** (37.7)</td>
</tr>
<tr>
<td>( N )</td>
<td>47</td>
<td>46</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.0163</td>
<td>1.0000</td>
</tr>
</tbody>
</table>

*** \( p < .001 \), two-tailed test  ** \( p < .01 \), two-tailed test  * \( p < .1 \), one-tailed test

Table 12: Pooled Time Series Regressions (PCSE), Los Angeles Land Area 1964-2010, Regressed On Selected Variables (Z Scores in Parentheses)

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged San Diego Land</td>
<td></td>
<td>.963***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(149.96)</td>
</tr>
<tr>
<td>MWD Water Deliveries</td>
<td>-.00007 (-1.07)</td>
<td>-.000009*** (-3.82)</td>
</tr>
<tr>
<td>Intercept</td>
<td>527.974*** (6.91)</td>
<td>43.488*** (10.92)</td>
</tr>
<tr>
<td>( N )</td>
<td>47</td>
<td>45</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.0168</td>
<td>0.9986</td>
</tr>
</tbody>
</table>

*** \( p < .001 \), two-tailed test  ** \( p < .01 \), two-tailed test  * \( p < .1 \), one-tailed test

Table 13: Pooled Time Series Regressions (PCSE), San Diego Land Area 1964-2010, Regressed On Selected Variables (Z Scores in Parentheses)
have never felt constrained in expanding the land base of these urban areas. And
thirdly, the MWD, while it uses, on average, a million acre-feet of Colorado River
water, has multiple other sources of water; in fact, Los Angeles is less dependent
upon the Colorado River than San Diego, and both metro areas are less
dependent on the river than their urban counterparts in Arizona and Nevada
(though it would undoubtedly be a big blow to the California cities if their access
to the Colorado was cut off). This makes direct linkages between the MSAs and
the Colorado River harder to statistically establish, though, again, nobody
doubts the importance of the Colorado River for the initial and ongoing
development of urban California, as the MWD was created specifically to create
that aqueduct for Colorado River water to supply Los Angeles (Egan 2015;
Lustgarten 2015c; Owen 2015). The results in these tables, finding slightly negative
effects (when statistically significant) of MWD deliveries on land area, must be
read in the context of those forces, and are presented here to show the
interrelated and sometimes confounding nature of water in the West.
That being said, it is worth looking at a major metropolitan area like San Diego to see that even when controlling for the nature of its water deliveries and situation over time, there has still been enormous growth since 1950 in its population and land area, as illustrated in Figure 4.

The last table for this part of the regression analysis examines Las Vegas. Table 15 shows that the effect of the water deliveries from the various water utilities (here referred to by its latest iteration, the Southern Nevada Water Authority) throughout the history of the metro area not only has a highly significant effect upon the land area of the MSA \(b = .0007, P<.001\), but that such deliveries account for 96% of the variance in land area throughout the history of Las Vegas, showing just how much of Las Vegas’ physical footprint over time
comes from the availability of Colorado River water via Lake Mead, which is not surprising considering that 90% of the city’s water comes directly from that one source (Lustgarten 2015a). The two year lag reinforces the importance of this water for the city’s land area, with a still highly significant, though slightly decreased effect \((b = .00003, P<.001)\) which shows that after accounting for the yearly change in the dependent variable, the SNWA’s efforts have still been a prime determinant in the size of Las Vegas.

Figure 5 shows the population, land area, and water deliveries for Las Vegas from 1950-2010. What is interesting here is that the SNWA actually takes more water out of the Colorado River than Nevada is actually allotted under the Law of the River; allowed only 300,000 acre-feet a year, in recent decades the SNWA delivers more than 400,000 acre-feet per year to Las Vegas, getting credit for water that it treats and puts back into the river and thus able to take a larger portion than Nevada was given under the Compact (Lustgarten 2015a). So while Las Vegas exists in its current morphology largely because of the Colorado River,
it has also become very efficient in its use of Colorado River water through recycling and reuse programs, as well as recent efforts to encourage homeowners to replace green lawns with xeriscaping, thus increasing its water intensity as seen in the figure in which population numbers far outstrip both water and land area. This further illustrates that in the West, water may be a major determinant of the ability to survive and thrive, but it also exists within a interrelated and interdependent web of other forces.

What these results, rates, and figures help establish is that the presence of the Colorado River and the Federally-built and -subsidized infrastructure that helps deliver its water to metropolitan areas throughout the entire Southwest, has led to statistically significant greater and faster population and land area
growth both for individual MSAs and for the CRS metro areas as a regional system compared to their counterparts in the Arid West and the rest of the United States. This is not to say that these cities would not have existed or grown without the water or delivery systems, but it is possible, if not likely, that the CRS metro areas would be more like their Arid West brethren in that they would grow, but at a reduced rate over time, being more constrained by local water sources and physical hinterlands, rather than using the Colorado River to bypass those constraints, as illustrated by Figures 1 and 2. I contend that the first hypothesis – that Colorado River water led to urban growth – is accepted.

B. Economic Sectors Beyond the Hundredth Meridian

The next phase of the analysis regards the economic growth and sectors of the cities of the various regions. Most of the following tables present regression analyses for economic sectors in terms of the proportion of gross metro product (GMP) they are responsible for in urban areas from 2001-2014.

Table 16 presents the effect of regional status upon the gross metro product from primary economic sectors such as agriculture and extractive industries. Metro areas in the Colorado River System experience a higher primary sector GMP than MSAs in the rest of the United States (Region 4 again being the reference category for the remainder of these regression analyses) in a highly significant way ($b = .023, P<.001$), yet that effect is not nearly as strong as in those MSAs in the Rest of the Arid West ($b = .047, P<.001$) and California’s Central Valley ($b = .107, P<.001$); while the Central Valley is an obvious outlier here due to
its heavy reliance upon agriculture even within the urban context, it is likely that the Rest of the Arid West is also dependent upon agriculture and extractive industries due to the inability to access and leverage increased water supplies into a self-reinforcing social environment and specialized economic functions. In other words, they have to use what they can to get by, but this may also make the cities more self-sufficient and robust to downturns (dependent, of course, on prices of resources being exported). Also worth noting is that regional status alone explains almost 13% of the variance in the model for this sector. Most of these effects wash out, however, when a 1-year lag is applied in model 2, though the Central Valley retains a slight positive effect ($b = .003, P < .001$) above that of the rest of the United States metro areas.

Table 16: Pooled Time Series Regressions (PCSE), Gross Metro Product Primary Sector As a Proportion of Total GMP 2001-2014, Regressed On Selected Variables (Region 4 Reference Category) (Z Scores in Parentheses)

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged GMP Primary</td>
<td>.023***</td>
<td>.047***</td>
</tr>
<tr>
<td></td>
<td>(26.17)</td>
<td>(18.4)</td>
</tr>
<tr>
<td>Region 1 – Colorado River System</td>
<td>.023***</td>
<td>.003</td>
</tr>
<tr>
<td></td>
<td>(26.17)</td>
<td>(1.52)</td>
</tr>
<tr>
<td>Region 2 – Rest of the Arid West</td>
<td>.047***</td>
<td>.013*</td>
</tr>
<tr>
<td></td>
<td>(18.4)</td>
<td>(1.96)</td>
</tr>
<tr>
<td>Region 3 – California Central Valley</td>
<td>.107***</td>
<td>.003**</td>
</tr>
<tr>
<td></td>
<td>(25.12)</td>
<td>(2.8)</td>
</tr>
<tr>
<td>Intercept</td>
<td>.021***</td>
<td>.003**</td>
</tr>
<tr>
<td></td>
<td>(28.53)</td>
<td>(2.8)</td>
</tr>
<tr>
<td>$N$</td>
<td>5090</td>
<td>4669</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.1275</td>
<td>0.8517</td>
</tr>
</tbody>
</table>

*** $p < .001$, two-tailed test    ** $p < .01$, two-tailed test    * $p < .1$, one-tailed test
Results for the secondary sector, which consists of construction and manufacturing industries, are reported in Table 17. Each of the three regions of the West have a reduced proportion of their gross metro product coming from these industries than the urban areas in the rest of the United States, with all of those effects being highly significant at a .001 level (though regional status accounts for only 5% of the variance in secondary sector GMP across all urban areas). What is especially interesting is that when the 1-year lag is applied in model 2, the CRS metro areas remain significant in generating less of a proportion of their economic output ($b = -.004, P<.01$) from this sector than metro areas in the Rest of the United States outside of the West. This tells us that despite being supplied with millions of acre-feet of water from the Colorado River, the MSAs of this region have been unable to create the type of

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged GMP Secondary</td>
<td>.95***</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(50.87)</td>
<td></td>
</tr>
<tr>
<td>Region 1 – Colorado River System</td>
<td>-.055*** (-53.81)</td>
<td>-.004** (-2.86)</td>
</tr>
<tr>
<td>Region 2 – Rest of the Arid West</td>
<td>-.076*** (-17.66)</td>
<td>-.002 (-0.71)</td>
</tr>
<tr>
<td>Region 3 – California Central Valley</td>
<td>-.048*** (-25.36)</td>
<td>-.003 (-1.53)</td>
</tr>
<tr>
<td>Intercept</td>
<td>.223*** (74.1)</td>
<td>.01* (2.26)</td>
</tr>
<tr>
<td>$N$</td>
<td>5090</td>
<td>4669</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.0521</td>
<td>0.9043</td>
</tr>
</tbody>
</table>

*** $p < .001$, two-tailed test  ** $p < .01$, two-tailed test  * $p < .1$, one-tailed test

Table 17: Pooled Time Series Regressions (PCSE), Gross Metro Product Secondary Sector As a Proportion of Total GMP 2001-2014, Regressed On Selected Variables (Region 4 Reference Category) (Z Scores in Parentheses)
manufacturing and industrial capacity that formed the key functions of many of their Eastern counterparts, despite numerous and still ongoing attempts to build and sustain such capacity in throughout the urban Southwest (Glaeser et al 2001; Florida et al 2008; VanderMeer 2010).

Tables 18 and 19 present the results for both the tertiary sector and that sector without government funding included. The tertiary sector includes all non-industrial and non-extractive economic activity, from trade to real estate to entertainment to government at all levels (local, state, and Federal). It is the tertiary sector that provides the economic activity that separates the CRS metros from their counterparts in the other Western regions. The MSAs in the Rest of the U.S. get 76% of their GMP from tertiary sector activity, and the Colorado River System MSAs get about 3 percentage points more than that.

Table 18: Pooled Time Series Regressions (PCSE), Gross Metro Product Tertiary Sector As a Proportion of Total GMP 2001-2014, Regressed On Selected Variables (Region 4 Reference Category) (Z Scores in Parentheses)

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged GMP Tertiary</td>
<td></td>
<td>.942***</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(48.09)</td>
</tr>
<tr>
<td>Region 1 – Colorado River System</td>
<td>.032***</td>
<td>.002*</td>
</tr>
<tr>
<td></td>
<td>(26.23)</td>
<td>(1.92)</td>
</tr>
<tr>
<td>Region 2 – Rest of the Arid West</td>
<td>.03***</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>(7.1)</td>
<td>(.035)</td>
</tr>
<tr>
<td>Region 3 – California Central Valley</td>
<td>-.059***</td>
<td>-.005*</td>
</tr>
<tr>
<td></td>
<td>(-17.27)</td>
<td>(-2.2)</td>
</tr>
<tr>
<td>Intercept</td>
<td>.757***</td>
<td>.045**</td>
</tr>
<tr>
<td></td>
<td>(297.44)</td>
<td>(3.03)</td>
</tr>
<tr>
<td>N</td>
<td>5090</td>
<td>4669</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.0168</td>
<td>0.8906</td>
</tr>
</tbody>
</table>

*** $p < .001$, two-tailed test  ** $p < .01$, two-tailed test  * $p < .1$, one-tailed test
The Rest of the Arid West also has a highly significant effect that nearly matches the CRS metros ($b = .03, P < .001$). Although the variance for this sector is very small ($R^2 = .023$), results here and thus far suggest that even though the presence of the Colorado Water helps CRS metro areas be larger and grow bigger than the Rest of the Arid West, it is not actually helping them differentiate much in terms of economic functions or output, even though these metros have to make up for the lack of manufacturing and industry from Table 17, and the CRS as a region has tried to leverage the subsidy of water and money into an expanded social environment that ties them to other metro areas rather than to their physical hinterlands. CRS metros still have a slightly positive and significant improvement in tertiary GMP proportions with a 1-year lag in

\[ \text{Model 1} \begin{align*}
\text{Lagged GMP Tertiary w/o Government} & : .037^{***} \\
\text{Region 1 – Colorado River System} & : .005^* \\
\text{Region 2 – Rest of the Arid West} & : -.0002 \\
\text{Region 3 – California Central Valley} & : -.098^{***} \\
\text{Intercept} & : .575^{***}
\end{align*}
\text{Model 2} \begin{align*}
\text{Lagged GMP Tertiary w/o Government} & : .96^{***} \\
\text{Region 1 – Colorado River System} & : .002^* \\
\text{Region 2 – Rest of the Arid West} & : -0.002 \\
\text{Region 3 – California Central Valley} & : -0.004^* \\
\text{Intercept} & : 0.025^{**}
\end{align*}

\begin{align*}
\text{Model 1} & \begin{align*}
\text{Region 1 – Colorado River System} & : .005^* \\
\text{Region 2 – Rest of the Arid West} & : -.0002 \\
\text{Region 3 – California Central Valley} & : -.098^{***} \\
\text{Intercept} & : .575^{***}
\end{align*}
\text{Model 2} & \begin{align*}
\text{Region 1 – Colorado River System} & : .002^* \\
\text{Region 2 – Rest of the Arid West} & : -0.002 \\
\text{Region 3 – California Central Valley} & : -0.004^* \\
\text{Intercept} & : 0.025^{**}
\end{align*}
\end{align*}

$N = 5064, 4645$  
$R^2 = 0.0229, 0.9223$

*** $p < .001$, two-tailed test  ** $p < .01$, two-tailed test  * $p < .1$, one-tailed test

Table 19: Pooled Time Series Regressions (PCSE), Gross Metro Product Tertiary Sector (without Government) As a Proportion of Total GMP 2001-2014, Regressed On Selected Variables (Region 4 Reference Category) (Z Scores in Parentheses)
economic outputs, the effect of this regional status still acting upon the economy even accounting for the effect of the prior year’s tertiary sector \((b = .96, P < .001)\).

Meanwhile, in Table 19 presenting the tertiary sector without government funding included, there is some differentiation between CRS metro areas and the Rest of the Arid West, as the Colorado River MSAs have a highly significant improvement in the proportion of tertiary (non-governmental) sector economic activity \((b = .037, P < .001)\) on top of that in the reference cities in the Rest of the U.S. Meanwhile the Arid West metropolitan areas have a significant but much smaller 0.5% improvement \((b = .005, P < .1)\) over the non-government tertiary activity of the MSAs in the Rest of the U.S., perhaps indicating that a non-insubstantial portion of these Arid metros outside of the CRS do not have well developed service sectors, at least services that are not tied into or dependent

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged GMP Quartenary</td>
<td>.014*** (12.91)</td>
<td>.0004 (4)</td>
</tr>
<tr>
<td>Region 1 – Colorado River System</td>
<td>.016*** (7.23)</td>
<td>-.0005 (-.4)</td>
</tr>
<tr>
<td>Region 2 – Rest of the Arid West</td>
<td>.031*** (15.42)</td>
<td>-.001 (-.67)</td>
</tr>
<tr>
<td>Region 3 – California Central Valley</td>
<td>.208*** (201.14)</td>
<td>.002 (1.52)</td>
</tr>
<tr>
<td>Intercept</td>
<td>.208*** (201.14)</td>
<td>.002 (1.52)</td>
</tr>
<tr>
<td>(N)</td>
<td>5090</td>
<td>4669</td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.0047</td>
<td>0.9739</td>
</tr>
</tbody>
</table>

*** \(p < .001\), two-tailed test  ** \(p < .01\), two-tailed test  * \(p < .1\), one-tailed test

Table 20: Pooled Time Series Regressions (PCSE), Gross Metro Product Quartenary Sector As a Proportion of Total GMP 2001-2014, Regressed On Selected Variables (Region 4 Reference Category) (Z Scores in Parentheses)
upon government services, such as nearby national parks or public lands, federal agencies, or government investment and infrastructure. In the lagged model, however, that effect for the Arid West disappears and turns negative, though statistically insignificant; the CRS metro areas remain statistically positive \((b = .002, P < .1)\) above the proportion of economic activity for the rest of the U.S. \((b = .025, P < .01)\), but it is still a very slight effect, so these MSAs are not generating much more of their economic activity from these high-value service sectors beyond what you see in the Rest of the United States and the effect of already existing tertiary non-governmental activity.

Table 20 presents the results for quartenary sector GMP, which includes two economic activities selected due to their ‘outlier’ status as being service oriented but not really rooted in the physical place itself: information industries

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged GMP Quartenary (Information Only)</td>
<td>( .863^{***} ) (21.31)</td>
<td>( .002^* ) (2.09)</td>
</tr>
<tr>
<td>Region 1 – Colorado River System</td>
<td>( .008^{***} ) (13.97)</td>
<td>( .002^* ) (2.09)</td>
</tr>
<tr>
<td>Region 2 – Rest of the Arid West</td>
<td>(-.009^{***} ) (-16.65)</td>
<td>(-.0009 ) (-1.36)</td>
</tr>
<tr>
<td>Region 3 – California Central Valley</td>
<td>(-.01^{***} ) (-15.56)</td>
<td>(-.001^* ) (-2.06)</td>
</tr>
<tr>
<td>Intercept</td>
<td>(.03^{***} ) (37.71)</td>
<td>(.004^{***} ) (3.78)</td>
</tr>
<tr>
<td>(N)</td>
<td>5077</td>
<td>4657</td>
</tr>
<tr>
<td>(R^2)</td>
<td>0.003</td>
<td>0.7263</td>
</tr>
</tbody>
</table>

\(* * * p < .001, \) two-tailed test \( ** p < .01, \) two-tailed test \( * p < .1, \) one-tailed test

Table 21: Pooled Time Series Regressions (PCSE), Gross Metro Product Quartenary Sector (Information Only) As a Proportion of Total GMP 2001-2014, Regressed On Selected Variables (Region 4 Reference Category) (Z Scores in Parentheses)
(which due to its very nature can likely be done anywhere that is connected into telecommunications networks), and government activity (which, while it only exists because the metro area exists in that place, also would exist no matter where that urban area was placed, so it is not the environment that matters so much as presence of the metro area itself). The reference category shows that MSAs in the Rest of the U.S., as a region, derive almost 21% of their GMP from this sector \( (b = .208, P < .001) \), and each of the Western regions sees highly significant positive effects that increase this proportion (though the variance in this sector still remains very small). The 1-year lag, however, wipes out all of those effects, including that of the reference category itself.

It was then important to tease out which of the economic fields might be having these effects within the quartenary sector; Table 21 presents the regression for just the information industry, and on top of a 3% proportion for the rest of the U.S. as a region \( (b = .03, P < .001) \), the CRS metro areas see a highly significant positive effect of .8% on top of the proportion of economic activity generated by this sector in the Rest of the U.S. MSAs \( (b = .008, P < .001) \), while the Arid West and Central Valley cities have negative and significant effects below the proportion for the Rest of the U.S. With the one-year lag, the CRS cities remain positive and significant \( (b = .002, P < .1) \), and the Central Valley remains negative and significant \( (b = .001, P < .1) \) in conjunction with the reference category.

(it is also worth pointing out that the variance in this sector in this lagged model 2 is much lower than in all of the other sectors that have been studied in this analysis, reflecting the potential transitory nature of information economies).
The final sector analysis, that of just government activity only within the quartenary sector, is presented in Table 22. Compared to the information sector, government activity accounts for a large proportion of the GMP in the cities of the rest of the U.S. \( b = .185, P < .001 \), and perhaps confirming the results earlier in the tertiary without government table, the Rest of the Arid West has a highly significant positive effect for proportion of GMP from government funding (as does the Central Valley, which is not unusual considering the dependence upon agriculture and subsidies – there is even an argument that many farmers ‘double-dip’ by getting cheap government-provided water to grow crops which are also simultaneously subsidized by the government), while the CRS metro areas have no significant effects of government funding as a region (Beard 2015). The 1-year lag, however, wipes out everything.

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lagged GMP Quartenary (Government Only)</td>
<td>(.99***) (184.73)</td>
<td>(.99***) (184.73)</td>
</tr>
<tr>
<td>Region 1 – Colorado River System</td>
<td>-.0006 (.71)</td>
<td>.0002 (.28)</td>
</tr>
<tr>
<td>Region 2 – Rest of the Arid West</td>
<td>.02*** (10.65)</td>
<td>-.0004 (-.36)</td>
</tr>
<tr>
<td>Region 3 – California Central Valley</td>
<td>.035*** (20.9)</td>
<td>-.0008 (-.53)</td>
</tr>
<tr>
<td>Intercept</td>
<td>.185*** (125.44)</td>
<td>.00002 (.24)</td>
</tr>
</tbody>
</table>

\( R^2 = .005 \) 4657

*** \( p < .001 \), two-tailed test  ** \( p < .01 \), two-tailed test  * \( p < .1 \), one-tailed test

Table 22: Pooled Time Series Regressions (PCSE), Gross Metro Product Quartenary Sector (Government Only) As a Proportion of Total GMP 2001-2014, Regressed On Selected Variables (Region 4 Reference Category) (Z Scores in Parentheses)
The last regression analysis to determine economic activity by regional context is a study of gross metro product per capita in Table 23. In the MSAs in the Rest of the U.S., GMP/c is $40,989 ($b = 40988.56, P < .001); the Rest of the Arid West has a GMP/c of $1,250 less than that ($b = -1250, P < .001), while in the Central Valley it is more than $10,000 less ($b = -10558, P < .001). Meanwhile, in the CRS metros, it is a mere $82 more, but that result is not statistically significant at any level. In model 2, the effect of the lag – which indicates that for every $1,000 in GMP/c, the predicted effect for the next year is about $1,013 – wipes out nearly everything except that of a significant positive effect for the Arid West MSAs.

On balance, I contend that these results show that while there is some regional variation in the proportion of economic activity that metropolitan areas derive from the different sectors of the economy, the results do not seem to
indicate that metro areas in the Colorado River System are not that substantially different or substantially richer than their counterparts in the Rest of the U.S. There may be some differentiation between those MSAs and the Rest of the Arid West, which should go without saying considering the divergence in population and physical size, but for all of the water and money (which are often, in the West, one and the same) being poured into these metropolitan areas, there does not seem to be much return on investment being returned back to the rest of the country to justify the continued subsidization. Worster argued that many of the farmers who turned central Arizona into fields of alfalfa were not actually adding value to the nation’s economy, considering that they had likely moved to the Southwest from other regions where they were already farming anyway (Worster 1985). In essence, we may be seeing a simple displacement of economic activity in the American Southwest, rather than its development.

C. Key Functions in Hyperspecialized Cities

Phoenix, Las Vegas, and San Diego represent attempts to build urban metropolises in an arid ecosystem that, in the pre-World War 2 period. To do so would require developing and shaping an economic function that would help the metro areas thrive in this narrow ecological niche, activity that may not be a primary key function in the traditional and industrial sense, but in a post-modern metropolis that doesn’t depend on any one economic sector, it has outsized influence and is significantly different from other cities both nearby (within the region) and further afield (the Rest of the U.S.).
There is perhaps no better example in the American West than ‘America’s Playground’: Las Vegas. It is simultaneously one of the biggest tourist destinations in the United States and the focus of derision and theories regarding the hyper-atomized nature of a metropolis that is anchored in the middle of a desert and filled with casinos that are built to represent, among other places, the forums of Rome, the skyscrapers of New York, and the pyramids of Egypt. Las Vegas may have pre-dated Hoover Dam and the filling of Lake Mead, but it is that construction, and that water, that made the city truly exist in the nation’s consciousness; initially a site for illegal mob operations turned into legal gambling which then became corporatized with a focus on entertainment in all of its forms, the city itself draws upon its geographic condition and isolation as a reason to come – ‘What happens in Vegas stays in Vegas’ – while at the same time using fountains and golf courses to surround tourists with the belief that the city is somehow not rooted in its physical environment (Futrell 2001; Schmidt 2006; Nies 2007 & 2014). Existing within a very limited ecosystem, with only the literal
lifeline of the intake pipes in Lake Mead to rely upon for 90% of its water, Las Vegas had to find and maintain a niche in order to sustain its status as one of the fastest growing cities in American history, and it found it in the entertainment industry, which also includes arts, recreation, food, and accommodation. Using the gross metro product data from the Bureau of Labor Statistics, I constructed a table of the proportion of total GMP derived from the entertainment sector, for Las Vegas and the three other largest metro areas in the Colorado River System, as well as the proportion for the total of all Region 1 and all Region 4 MSAs as a function of the total GMP for those regions. As the table shows, entertainment accounts for 20-23% of the total gross metro product in Las Vegas between 2001-2014, which significantly larger than not only its regional counterparts – in fact, four or five times larger as a proportion of the metro economy compared to cities like Los Angeles, Phoenix, and San Diego – it maintains that incredible differential when compared to the regional averages for the entire Colorado River System and the Rest of the United States MSAs. Such activity then not only differentiates Las Vegas from most other urban areas\(^{10}\), but is very much the key function of the metropolitan area, and plays an outsized role in the urban economy so that when there is a downturn, such as the 2008 recession, Las Vegas was not only hit earlier and harder than most metro areas, but also took longer to recover from the downturn because of how dependent the metropolitan area was on a highly specific sector of the service economy which relies upon people

\(^{10}\) The only possible contender that comes to mind is Orlando, Florida, which is also a city that leveraged its physical environment into a social environment that utilizes agglomeration to attract tourists and businesses to a geographic location that didn’t really exist in public consciousness before the 1950s.
from other parts of the country coming in and spending money on rooms, food, gambling, and other forms of recreation (Pew 2013). In many ways, this is not unlike the reliance of Wall Street financial firms on the subprime mortgage and derivative market; when it was going well, there were seemingly endless profits, but at the slightest dip, the money dries up and the resulting lurch can hurt more than the good times helped in the first place, all the while Las Vegas grew to cover 48 times the physical land area in 2010 as it did in 1950 (Romem 2016).

Meanwhile, Phoenix as a metropolitan economy seems to defy categorization; as previously established in this dissertation, the key function, if there must be one, is likely the urban growth that defined not only the metropolitan area but also the state itself as Phoenix became one of the anchors of the emergent Sun Belt during the 1990s and 2000s. In such a post-modern urban economy, where primary and manufacturing industries exist but in more than a cursory role, and where services are ever-present but also diverse with no one industry steering the urban economy or providing a counterweight when

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PHX – Phoenix; LV – Las Vegas; LA – Los Angeles; SD – San Diego; R1 – Region 1; R4 – Region 4

Table 25 – Health Care/Total Gross Metro Product, Selected Region 1 Metro Areas and All Region 1 & Region 4 MSAs, 2001-2014
downturns come, it was hard to find a sector where Phoenix seemed to differentiate itself from the rest of the country, but health care, when used as a proxy for Phoenix’s long history and status as a place for ‘snowbirds’ and other retirees from the colder portions of the United States, showcases a bit of the dynamic at play here. As can be seen in Table 25, health care as a proportion of total GMP in Phoenix only accounts for about 6-8% of the urban economy over the past decade and a half, but this is a larger proportion of the economy than in other Sun Belt cities and in Regions 1 and 4 in total. I present this not to suggest that health care is the key function of Phoenix’s urban economy or plays even an outsized role in that economy, but that it is a signifier for the flow of money coming into the metropolitan region from the rest of the country. Much like the money that flows into Las Vegas, with little in the way of productivity or value-added processes going back out, the argument can be made that the same dynamic is happening in central Arizona, as the metro area brings in money, either from retirees themselves or from their families, and either private

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SD – San Diego; LV – Las Vegas; LA – Los Angeles; PHX – Phoenix; R1 – Region 1; R4 – Region 4

Table 26 – Government/Total Gross Metro Product, Selected Region 1 Metro Areas and All Region 1 & Region 4 MSAs, 2001-2014
retirement funds or government benefits, from the rest of the country to sustain itself. In essence, the subsidized water that allowed Phoenix to fill out, reach, and perhaps exceed its maximum state in the context of its hinterlands – Phoenix covers twenty times the land area in 2014 that it did in 1950 – is then used within a city that itself relies on subsidies from society in order to keep growing and to keep that water still flowing (Romem 2016).

The third city that I believe is worth taking a look at for the purpose of its unique economic indicators within a unique environmental region is San Diego. This city near the U.S.-Mexico border forms one of the more interesting economic and population units in America, as some government measurements combine San Diego with its Mexican counterpart Tijuana to capture the full extent of the metropolitan region. San Diego does have an extensive tourism sector, while trade due to its port status and border location is also a driver of the regional economy, showcasing how the city has capitalized on its physical location. But in Table 24, the proportion of San Diego’s total GMP that comes from government funding alone has hovered between 19-23% from 2001-2014, and this even after the drawdown of Cold War-era defense establishments and contractors (though military budgets did increase significantly after 11 Sept. 2001). This was significantly higher than any other MSA in the Region 1 list (and the total for all of Region 1), including Las Vegas, Los Angeles, and Phoenix, the three metros in the region that are larger by population than San Diego. In fact, those three metro areas were all each under the total GMP from government funding for the rest of the nation at large (Region 4) during the time period
covered, while San Diego was between 8-11 percentage points higher than the rest of the national average, indicating that a larger than usual proportion of San Diego’s urban economy is based on government funding for military and defense. While San Diego is a port city on the coast of California and has been the site of a Navy base since the 1920s, it is not the only such city on the Pacific Coast with a natural harbor, and one can only surmise that the path dependency that has led to San Diego becoming the home of so many military installations is due to some of the underlying characteristics that define the other desert cities described above. Firstly, there was plenty of land area for post-war urban expansion, as San Diego’s metropolitan footprint grew more than sevenfold between 1950 and 2010 (Romem 2016). Secondly, being connected to the Metropolitan Water District of Southern California gave San Diego a guaranteed supply for urban growth – in fact, the majority of San Diego’s water supplies come from the Colorado River, which is a higher proportion than Los Angeles (Reisner 1993; Murphy 2014).

The second hypothesis regards the development of niche economies within a niche ecology – asserting that cities within the unique physical environment of an arid ecosystem and unique social environment of subsidized water infrastructure and availability will and must form hyperspecialized key functions in order to grow and thrive. I find that the evidence for such hyperspecialization is mixed: it is clear that some of the largest metro areas in the Colorado River System have built and pushed for specific tertiary & quartenary industries that drive their economies, but the extent and
dependence upon those industries, as well as the total economic benefit that the cities get from those economies as well as the benefit that the country at large gets from those cities, reflects a more muddled picture of displacement and limited development of the urban centers that anchor the Southwest, power the regional economy, and alter the environmental characteristics – both social and physical – for the some fifty million people who live in this arid ecosystem, regardless of whether they drink from the Colorado River or not.

D. Future Projections of the Colorado River

The last section of this chapter will focus briefly on the future of the river itself, and whether or not the assumptions about the availability of Colorado River water will continue to hold true throughout the rest of the century. As noted earlier, the Bureau of Reclamation built the vast majority of the infrastructure capacity beyond the hundredth meridian based on measurements and projections that the Colorado River would carry some 15 MAF of water every year that would be used for American purposes, and built Lakes Mead and Powell in order to help boost the ‘storage’ of the river and guarantee that it could meet the obligations placed upon the river in years when outflows temporarily dipped below those historical projections. But already by the middle of the last century there were doubts about the historical viability of that 15 MAF number, and it is now estimated that the long-term (meaning, over the past 1000-1200 years) norm for the river is closer to 13-13.5 MAF, which would itself put the river into shortfall when there are already more obligations placed upon the river than it could
provide at 15 MAF (Barnett & Pierce 2008; Ingrid & Malamud-Roam 2013; Lustgarten 2015c).

With this context in mind, and having established how much the availability and guarantee of Colorado River water was a major determinant of the growth and economic development of metropolitan areas within the Colorado River basin compared to urban areas outside of the Bureau of Reclamation’s system, I wanted to make some simple projections of just how the river itself could continue to change over the rest of this century, and the implications of such changes over time. To do so, I used the Colorado River Open Source Simulator (CROSS), which uses Bureau of Reclamation data on water levels and capacity at multiple points along the Colorado River, as well as rates of outflow, evaporation, releases, and hydropower generation, from 1896 to 2006 to create a simulator in which one can make models altering parameters of the Colorado River and projecting just how much water one can expect.

I developed three scenarios for the future of the Colorado River. In the first, I input the latest (June 2016) reservoir elevation for Lakes Mead & Powell – 3620 and 1074 feet, respectively – and selected a historical average annual flow rate of 13.5 MAF instead of the default 15 MAF that the simulator uses, projected no decline in river outflow or increase in evaporation of reservoirs due to climate change, and projected a 3% annual increase in river storage through the year 2060 and 5% after that year due to conservation in the Upper or Lower basins of the Colorado River. This goes against every expectation from researchers, including the National Climate Assessment of 2014, which expects that the Colorado River
will be negatively affected for the foreseeable future, on top of the reversion of the river to that historical mean (Ingrid & Malamud-Roam 2013; Garfin et al 2014). But for this scenario I just wanted to see if there was a situation whereby the Colorado River could recover and go back to meeting its legal obligations now, let alone accounting for future growth which the Bureau of Reclamation itself expects to be substantial and which the National Climate Assessment estimates will be driven by projections of some 96 million people living in the Southwest by the middle of this century, up from its current 50 million (Census Bureau 2012; Garfin et al 2014). Using the Index Sequential Method in the CROSS simulator, which runs 111 ‘traces’ of historical projections – one from each of the starting years contained in its database, using the established trajectories of how the river has changed over time – and then combines those traces into a single projection for the rest of the century, Figure 6 shows the projection for combined storage in Lakes Mead and Powell (the CROSS simulator does not allow for

![Figure 6: Scenario 1, Combined Storage on Colorado River, 2008-2019.](image_url)
changing the physical output of the charts, thus the figures in this section look different from prior figures). The line for ‘Bureau’ is based on 2008 lake elevations and assumptions that there will be 15 MAF of outflow and no other changes affecting the output the river at all, while ‘Scenario 1’ shows that under current conditions, assuming a constant 13.5 MAF outflow, and hoping for increased conservation and storage that goes against expectations, the river will continue to drop but then stabilize in its total available storage capacity by the year 2045 for the rest of the century; this will still be more than five million acre-feet under the Bureau’s assumptions from a decade ago, and according to CROSS will lead to yearly shortages of just over a million acre-feet between what the river can provide and the expected demands and obligations placed on it.

Scenario 2 takes a moderate assumption about how much climate change could and likely will affect the Colorado River. Using the same setup as scenario 1, but assuming that there will be no added conservation of storage capacity, and
assuming a 1% annual decrease in the river's outflow for the rest of the century and a 1% increase in evaporation in the reservoirs (due to increased temperatures acting upon the surface area of Lakes Mead and Powell), Scenario 2 projects that the combined storage of the Colorado River will continue to decline into the last couple decades of the century before finally stabilizing, and that the yearly gap in storage between the Bureau's assumptions and this projection will be some 15 million acre-feet of water, which is more than the current yearly output of the river today. Also under this scenario, from outputs generated by CROSS, hydropower generation from the Colorado River would be cut by 50% due to the dramatically decreased reservoirs behind Glen Canyon and Hoover Dams.

Scenario 3, the final projection of this section, imagines that climate change not only affects the Colorado River, but accelerates in its impacts. It uses current lake levels and assumes that 13.5 MAF outflow, with no increase in conservation or storage, and instead a 3% reduction in outflows annually, reaching 5% by 2060, and 8% reduction by 2080, along with a 5% evaporation rate.

![Figure 8: Scenario 3, Combined Storage on Colorado River, 2008-2019.](image)
all of which may be extreme but well within the potential for the river, considering recent studies that snowfall in the Colorado River basin – which is a major component of not just how much water the river has but also its ability to sustain substantial year-long flows – may decline by as much 50% in this century (Wi et al 2012). Under this scenario, combined storage for the Colorado River, upon which so many urban areas and people depend, will decline and never stabilize through the rest of the century; the gap between Bureau expectations and this projection will reach approximately 20 million acre-feet. Shortages between outflows and demands will approach some 3 million acre-feet on an annual basis, the river will be unable to meet current obligations in the lower basin 93% of the time, and hydropower generation would be only 30% of what it would be under Bureau assumptions.

What these figures and results show is that even under the best case scenario, the Colorado River will not be able to meet its expected obligations for the rest of the century, let alone those obligations that rise with increased population and economic growth and demand as it currently exists. In fairness, the Bureau of Reclamation has started to adjust its expectations of river supplies and projected for multiple models of future demands (Bureau 2012), but its models, much like the projections above, are based on linear assumptions of what the river will do and how the ecosystem will operate. Based on the more likely scenarios of decreased outflows and increased evaporation, I contend that the third hypothesis – that the Colorado River may not be able to support future
growth in its expected form – is accepted, the implications of which will form the final chapter of this dissertation.
Chapter 6: Fifty Million People in a Desert

If we consider the relationship between cities and strategic policymaking, there is a significant time lag between catastrophic events and any kind of coordinated long-term response. A mix of technical disagreements, political expediency, administrative inertia, and economic uncertainty produces a common pattern of extended delay. The process of physical reconstruction is invariably also one of institutional reorganization, producing different constellations of power, finance, and technical expertise. An accelerated rather than incremental pattern of environmental change, impelled by the "abrupt" climate change scenario, could overwhelm the capacity of many cities to respond. At this point forecasts or models, as conventionally understood, begin to lose their practical utility, and we are left to contend with the ideological parameters of a science fiction imaginary in which worlds are turned upside down but remain strangely familiar.

– Matthew Gandy (2014: 220)

A. Overshoot

For all of the good that the environmental movement – as broadly constructed and understood despite its numerous and often contradictory forms – has done for the health and sustainability of natural and human systems over the decades, there are two aspects of the movement that stubbornly persist (Hawken 2007; Radkau 2014). The first is that there remains, for millions of activists and donors, a dominant guiding force and inspiration: the desire to ‘save the earth.’ From the Sierra Club – widely regarded as the first group built for explicitly environmental purposes – to more modern and radical groups like Greenpeace and 350.org, this driving impetus is at once both commendable and, for all intents and purposes, misguided. The earth, in many ways, will outlast and
outlive most, if not all, of our actions upon it; even the outbreak of nuclear war
would not kill all life on the planet, and while climate change will fundamentally
alter regional ecosystems and may even kill off some of the species who live in
them, nature as we think of it will survive.

The second attitude that persists within the environmental movement,
linked in many ways to the ‘save the earth’ premise, is an overriding belief that
the way things are now is the way that they’ve always been, and the way they
should always be; in other words, the environmental movement at times tends
to draw an ahistorical view of both the natural world and how humans fit within
it. This premise often leads both researchers and activists to mount their
criticisms within the framework of ‘saving the earth’ without truly
understanding that ecosystems are always and invariably dynamic and
everchanging (Duncan 1959). Population numbers are dependent upon available
resources, which will always be in flux due to the population feeding on or using
them, not to mention the other attendant impacts of both that population and
other natural, geological, climatological, and physical forces acting upon the
whole system; this interdependent system, feeding back upon itself in either
positive or negative directions, means that ecosystems are rarely ‘stable’ for very
long (Hawley 1950 & 1968; Duncan 1959). In many ways, this is a good thing; if the
atmosphere had the same concentrations of certain gasses as it did millions of
years ago, humans would not be able to survive, and the same goes for the retreat
of polar ice caps after the last ice age in which the island of Manhattan was
buried under a mile of ice just 12,000 years ago.
What has happened in recent years, however, is the dawn of what scientists have begun to term the ‘anthropocene’ period, in which human actions have begun having an outsized effect upon regional and global ecosystems and even overwhelming the combined effects of all other natural forces within those systems (Royal Society 2012; Vogel 2015). These man-made actions have increasingly drawn attention to the disparate impacts of climate change, resource consumption, ocean acidification, etc., upon the earth’s environment, and led some not insignificant portions of the environmental movement to blame civilization itself and assert that nature has an inherent value that is greater than that of human society (Jensen 2006). The overriding concern of these groups and their focus on man-made actions has been of our impacts upon the earth, but as stated above, the earth, and most of its species, will survive even as natural forces are dramatically altered by anthropogenic actions.

The more pressing concern for humans from an environmental perspective is not so much our impacts on earth, for those impacts, while perhaps different in type and scale from other species, will still be – for the most part – on par with that of asteroid collisions and volcanic eruptions. No, the more pressing concern is that of blowback, of how our impacts upon natural ecosystems will affect us; in a word, we’re talking about the problem that has been underlying this dissertation since the first chapter, and that is overshoot.

Essentially, humans, like all other species, will expand within the limits of their physical environment; all things being equal, human systems trend
towards the “maximum permitted by prevailing circumstances” (Hawley 1968: 331). Human societies also tend to have a spotty record at judging both their available resources and their ability to manage those resources (Diamond 2005; Radkau 2009; Foster 2009; Greer 2011). Human history is littered with stories of societies that didn’t make it through the collapse of their ecosystem or resource base, and sometimes it can seem as though blind luck determined the fate of civilizations, on top of any natural advantages or disadvantages and the choices made therein (Diamond 2005). The Incas were a mountainous civilization who fell to conquerers, not environmental collapse like the Chacoans and Anasazi; the Egyptians have survived for thousands of years along the banks of a single river in a desert, while the Hohokam became archeologically extinct after several centuries (Diamond 2005; Radkau 2009). Perhaps the single biggest determinant of whether a society will thrive or fail is its capacity for using its available resources without permanently endangering future resources; many societies can temporarily go beyond their immediate and present means (e.g., harvesting more logs or fish than naturally replenished that year, drawing down groundwater supplies that take thousands of years to recharge), but the ones that learn how to successfully control inputs and outputs on a long-term basis are the ones that have the better chance at survival, even with the random chance of external forces. My environmental history professor at the University of Kansas, Donald Worster, told my class a story about a village in Switzerland he visited and, in his words, fell in love with due to their centuries-old practices of farming, keeping livestock, and otherwise living sustainably in the Alps with no
need for inputs from outside. When he inquired about possibly buying a house to live in this village, he was told that he would have to wait for a current resident to die, as that was the only way they would allow new residents into their system. This may seem a bit extreme for our sensibilities, and in many ways it goes against the purposes of social organization and the development of technology and even civilization in the first place – to allow society to not only survive against natural extremes and shortages, but even thrive with improved quality of life – but for this village, existing in a niche environment high up in the mountains of central Europe, it was perhaps the only way to protect against overshoot, and even if it wasn’t the only way, it has been the socially agreed upon way for many centuries.

Bernard spoke to this concept of overshoot when he said that a “culture that does not make the adjustment of man to nature its primary objective, or even works in opposition to that end, pays the price of its ignorance or arrogance by being destroyed” (1930b: 42). Edward Abbey, one of the most famous writers on the subject of the American West, wrote in Desert Solitaire:

“There is no shortage of water in the desert but exactly the right amount, a perfect ratio of water to rock, water to sand, insuring that wide free open, generous spacing among plants and animals, homes and towns and cities, which makes the arid West so different from any other part of the nation. There is no lack of water here unless you try to establish a city where no city should be.” (1968: 126)
By the 1970s, the subject of overshoot was fast becoming a topic from multiple angles of research and society, from the Club of Rome’s report *Limits to Growth* to the various sci-fi films of the decade, such as *Soylent Green* and *Silent Running*, premised on dystopian futures caused, primarily, by overpopulation and overconsumption of resources. Bringing this environmental concept into sociology was the next necessary step, for what overshoot implies is not a problem of natural resources, but a problem of social organization; not an issue of management, but an issue of faulty initial premises about how society lives within its environment.

Catton’s titular work on *Overshoot* not only examines the social aspects of why overshoot occurs, but brings a desperately needed historical perspective back into the socio-environmental discussion of how civilization can find itself beyond the brink of its capacity to survive (1980). Introducing the concept of ‘phantom capacity’ into the sociological literature, Catton asserts that when society is able to draw upon these resources beyond their naturally replenished rates, then future growth becomes contingent on further access of those resources in even greater quantities (much like a weightlifter who, once started, needs continual and even stronger doses of steroids to keep building muscle). This concept, known within the ecosocialist literature as the treadmill of production, illustrates the ‘grow or die’ mentality that afflicts not just capitalism but also communist regimes such as China and the former Soviet Union; ideology is too often subservient to the managerial nature of modernity (Foster et al 2010).
In addition to that further reliance upon more and more resources, societies that have benefitted from such growth without experiencing immediate negative impacts also begin to act in such a way that avoids thinking about the future consequences of this overuse. This phantom carrying capacity not only leads to a diminished natural environment, but it greatly warps the social environment as well, as civilization becomes trapped in an age of ‘exuberance’; technology becomes a substitute for nature, and instead of circular systems governing the production and waste cycles of resources – i.e. solar and animal power, waste nutrients going back in the ground – we become reliant upon linear processes of burning fossil fuels or using artificial fertilizers to keep crop yields up, with no room for the byproducts (Catton 1980). Hawley was correct in writing that humans will expand to fill the limits of their ecosystems, but when those limits are artificially set beyond the natural limits, then there is now a gap in resources that may affect the natural environment (i.e. accelerated extraction and continued degradation) but affects the human society more, for that phantom carrying capacity means there is a now a phantom population that should not be there, and would not have been had society formed itself within those natural limits. Catton, writing in the midst of oil embargoes and concerns over waste, nuclear or otherwise, mentions water only a few times in his book, but there is no doubt that the same concepts apply to the development of desert cities which are dependent not just upon the water they get, but upon the systems that enable that water. Again, it’s not the resource itself that is the issue, but how much we leverage society and complex systems to get it.
This, perhaps, is the lesson from another ancient civilization in a desert river basin: the Egyptians. Farms and cities have existed along the banks of the Nile River for thousands of years, with countless generations and complex division of labor all using the same single river that stretches for hundreds of miles through northern Africa as a continuous oasis in an otherwise nondescript desert. And yet, despite being utterly reliant upon this one source of water, Egyptian society has withstood the normal ups and downs of annual floods and occasional droughts, mostly because of learning to live with and adapt to the resources the river provides them, but also because the society of Nile River was never more complex than it had to be (Radkau 2009). This is not to say that the river was always compliant, as megadroughts during the timespan of the ancient kingdoms did lead to a failure of state control and even cannibalism by the people; the resilience of both the natural system and the civilization, though, ensured that it could bounce back in a way that the Chacoans and Hohokam apparently couldn’t (Radkau 2009). The river could not be augmented or stored, canals didn’t stretch for tens or hundreds of miles continuously (indeed, most of Egyptian civilization existed within a twenty kilometer wide band of land straddling the Nile), and while trade existed within and outside of the Egyptian empire, it was both going in and out (in contrast to the inward nature of Chaco Canyon and modern day Phoenix and Las Vegas) and not necessary for the largely self-sufficient nature of the Egyptian economy (Worster 1985; Reisner 1993; Paine 2013). Indeed, it wasn’t until the construction of the Aswan Dam in the 1960s that Egypt sought to substantially change the river to suit their ends
instead of the other way around. Built to help ‘manage’ the yearly flooding the Nile and provide continuous flows of water, the dam has instead blocked much of the silt and nutrients that replenished the farmland along the river, along with reducing the lifespan of the dam due to the accumulated silt behind it (Reisner 1993; Nixon 2004; Shokr 2009). The dam was built on the advice of the Soviet Union, and was inspired by the dams of the Tennessee Valley Authority (which itself displaced thousands of residents) and the Bureau of Reclamation’s projects in the Southwest without regard to the ancillary consequences in those regions (Shokr 2009). The 20th Century is a testament to the almost contagious effect of ‘mega-projects’ – both within and across countries, and regardless of political or economic ideologies – that viewed nature as a resource to be controlled rather than as the source, and boundaries, of human activity.

What ecological overshoot demonstrates and asserts is that the parameters of the physical environment do not always act like other scientific laws; given enough money and technology, society can temporarily stave off drought, or extreme cold, or regional famine, thus leading to the ‘bending’ of how ecosystems might function. It can then be easy to overlook or even dismiss warnings about overconsumption of resources or degradation of ecosystems (Catton 1980; Greer 2011). However, biological systems also act on a non-linear principle, meaning that when they reach a tipping point, those systems can start to act in ways that are disproportional to the actions that led to that point; think of a body functioning without certain organs, but remove one more organ, and the end result is certain death. Embracing the concept of overshoot as a warning
for the continued functioning of human activities is not an anti-nature sentiment – though there are indeed segments of the environmental movement who would view it that way – but is instead a paradigm and perspective for putting the environment into the front and center of our human life. Bernard was not arguing against human culture itself, but instead arguing that culture must always remember its environmental foundation; Abbey was not calling for the razing of cities, but warning against putting cities where the physical environment could not sustain them. And Catton was not railing against a global economic system that has transformed human life, but railing against the misguided assumptions, arrogant ideologies, and resource overuse that made this particular system, eventually leading to outcomes in which both humans and the environment will be worse off. But one will always be more worse off than the other – natural ecosystems being more resilient than the human systems built atop and within them – and failing to acknowledge that distinction puts us no closer to the ecological future we need. Both human and natural systems are equally complex, but unlike Nature, which accepts massive dieoff and dieback as a matter of course, humans are far less accepting of civilizational collapse. Unlike Nature, we have the power of foresight, which is the guiding reason for this dissertation.

B. Risk Society

Modernization, as seen throughout the past century, entailed the belief that progress is inevitable, and that technology, which serves as both a driving force
and the side effect of that progress, can solve any and all problems that come along (Morozov 2013). The use of the atomic bomb, while shocking to many people here and abroad, also inspired an optimistic, even utopian vision of the future. Along with the idea of moon colonies and unlimited electricity, there was a government project titled Operation Plowshare, with theoretical musings on using atomic power to reshape the earth itself to create inland harbors and melting glaciers to irrigate deserts for farmland (Kirsch & Mitchell 1998). This belief, as well-intentioned as it may be, was a sign of false assumptions and a misunderstood sense of unintended consequences that permeated other forms of ‘progress’: the era of synthetic chemicals was the same era as DDT and *Silent Spring*, while the age of the automobile became the age of urban decline and suburban sprawl across developed and developing countries (Carson 1962; Scarrow & Crenshaw 2015).

Into this breach of a glowing future that never quite came to be arose not only the environmental movement, which initially and mostly sought to counter the effects of overconsumption and ecological degradation, but also an effort to identify what went wrong and led to these environmental problems, which were starting to take on a global scale. Beck’s *Risk Society* aimed squarely at the internal contradictions of modernity in the first place, by asserting that the framework and tools of progress were, left unchecked, creating just as many problems as they were solving, and that some of those problems were in fact bigger than they would have been otherwise (1992). Nuclear power, in this sense, may replace fossil fuel energy production and generate carbon-free electricity, but the risks
of meltdowns and explosions irradiating vast regions, and the problem of radioactive waste that lasts for millennia, can outweigh the gains. Moreover, the nature of such rapid development and deployment of technology can create unintended or hidden consequences down the line; the use of genetically modified crops can introduce interactions with natural strains of crops, and attendant interactions with other species of both flora and fauna, that exceed anything that scientists can currently model. In essence, according to this critique, modernity plays up the known knowns, plays down the known unknowns, and ignores the unknown unknowns (Beck 1995). It almost goes without saying that unintended consequences and emergent properties are difficult to anticipate, but some human systems – such as the Colorado River System – are notable for a failure to even engage in anticipatory safeguards.

In addition, the risks posed by such technologies and processes start to take on greater scales and become democratized (Beck 1995). Air pollution that used to be confined to downriver or downwind areas of a town now becomes smog that can encapsulate an entire city; nitrates that choked off a river accumulates into dead zones that can render entire coastlines incapable of supporting marine life. Rising seas from climate change will affect both the poor who live in river deltas and the rich who live in beachfront properties. It is this democratization of ecological risk – regardless of class, status, or even nationality – that encapsulates the modern and post-modern phase of social life, and renders the only lines of defense against degradation and resource depletion obsolete (Beck 1992 & 1995). As oil reserves are further diminished and gasoline
becomes more expensive and unpredictable, it may turn into a luxury good, but if the world’s supply of copper is depleted, then there may be no way to drill for oil in the first place (Roberts 2005). These negative externalities, as economists refer to them, are a function of a system that is incapable of putting a correct value on resources, or that socializes the costs of misuse/overuse of a resource while privatizing the benefits, so that society or the environment at large – which had no say in the matter – pays much of the price of such activity rather than the actors who caused the risk in the first place.

In this sense, the externalities of technological solutions can have outsized impacts beyond any potential gains. Modern society, run by technocrats, managers, and engineers trained in efficiency and optimization of resources, will then try to solve the problems caused by their approaches and tools by asserting that only such approaches and tools can do the job. Even the language will be couched in the vernacular of the technical fields that monopolize the discourse used to discuss the issues; there is nothing wrong, of course, with having reasoned and logical debate of social, political, and ecological issues, but very often the burden for proving that mega-projects have done harm is often set at a higher bar than projecting that they will have unalloyed benefits, and those in power require laypersons or activists to use methods and procedures that help obstruct or confuse the efforts to stop or reverse the projects (Beck 1995; Hawken 2007; Greer 2011).

While Beck spoke mostly of the causes and effects of pollution and waste in recent decades, I believe that the water question is but the next application of
the risk society in our world today. Reclamation projects throughout the West were posed as the savior for so many regions that were arid beyond the immediate boundaries of the rivers and tributaries flowing through them; irrigated agriculture and ranching was possible along those banks, as John Wesley Powell envisioned and just as it was along the Nile for so many millennia, but that would require rendering so many square miles of Great Basin land ‘useless’ for human activity (nevermind that such land served wildly varying and rich ecological purposes) (Nicholls 2009; Debuys 2011). Beyond the outsized costs of such projects which then made the resulting agriculture unproductive from a societal perspective – though not from the perspective of individual farmers who would never be asked to pay the full cost of the water being delivered to them – these projects set in motion a feedback loop in which the availability of the water led to increased usage of the water, thus necessitating that the projects either stay in place or even increase in number (Beard 2015). It is not a coincidence that nearly every branch of the upper Colorado River has been dammed and turned into a reservoir since the 1950s and that the number of acres being farmed may have increased, but not the value of the yields actually being produced (Reisner 1993; Powell 2008; Beard 2015).

This is an example of what engineers often call ‘induced demand’; think of the 10-lane highway referenced earlier in the dissertation, built to handle rush hour traffic in a metropolitan area. It was designed solely to accommodate traffic through a given stretch of the city in a given amount of time, but too often (if not always) the presence of such a massive superhighway induces more land
development, which creates more traffic, thus leading to even more congestion than existed in the first place. By trying to reduce the cost of driving (i.e. the time spent in rush hour traffic), the highway invariably leads to more cars spending ever more time on the highway, and now the urban area has more infrastructure to maintain and thousands of drivers who depend upon it to travel from their outlying neighborhoods that they may have moved to precisely because this highway was built.

This induced demand explains the results in Chapter 5 regarding the land area expansion of the Region 1 metro areas in the American Southwest. Because of the availability of the Colorado River, those cities expanded on a greater scale over a sixty-year period than their counterparts in the arid climate beyond the hundredth meridian than did not have their straws dipped into the Colorado, so to speak. Cities with only tens or hundreds of thousands of people in the 1950s, such as Phoenix, Las Vegas, and San Diego, became some of the fastest growing metropolises in the country and are some of the largest cities in the nation in their own right. Having leveraged the availability of Colorado River water into seemingly self-sustaining metropolitan areas, these cities were proof positive of the power of modernity to use technology in conquering nature (Debuys 2011; Ross 2011). However, now that these cities have outstripped their local water supplies and must have the water that is piped in from hundreds of miles away, they are dependent upon these massive systems which are themselves based on assumptions about the underlying environment; if there is a failure in either the human or ecological system, millions of people who otherwise would not have
lived in these cities become the victim of an environmental disaster that would not be entirely ‘natural.’

Such a disaster may not be entirely democratized at first - remember the lesson from Athens, where those with money were able to absorb the price hikes on water in the middle of a drought, and the current efforts in California to publicly shame ‘water hogs’ who continue to spend thousands of dollars per month on ornamental fountains and private orchards while working and middle class residents are recycling shower water and ripping out their lawns (Kaika 2006; Egan 2015). There are still lines of stratification in an unfolding environmental crisis, but no amount of money can pay for water that doesn’t come out of a faucet. Just as gravity acts upon all objects the same regardless of mass, the wealthy and poor alike suffer from the laws of physical ecosystems that fall into systemic failure.

The responses to such systemic crises further prove Beck’s point about the failure of modernity to look back on itself and recognize its own contradictions and lack of imagination. Efforts in California to build new dams and reservoirs are not the only attempts to ‘engineer’ a solution to the water question in the American West; the third intake pipe in Las Vegas is not only online and bringing Lake Mead water into the city, but it was explicitly drilled into the bottom of the lake at such a level that even when the lake falls below ‘deadpool’ and water cannot flow through the turbines of Hoover Dam, the Southern Nevada Water Authority will still continue to be able to draw upon its allotment and make its water deliveries (Egan 2015; Leslie 2015; Lustgarten 2015a & 2015c). In that latter
situation, the Colorado River will effectively end at Hoover Dam, and Las Vegas will drain what flows into the bathtub that is Lake Mead.

Meanwhile, Arizona has spent years ‘banking’ water by injecting perhaps millions of acre-feet of water into underground reservoirs and paying other water utilities in the Southwest to do the same in the hopes that when the declared shortages in the Colorado River do come (as the projections in Chapter 5 suggest they most certainly will), that ‘banked’ water will get them through the lean times (Debuys 2011; Ross 2011). This, obviously, presumes that the shortages will be temporary, that the other states and utilities will honor their agreements, and that such water will be used in efficient and effective ways for the greatest public good, which is unlikely given the dynamics of water law in the West and those senior rights holders.

Even those laws prove Beck’s thesis, as the tangle of water rights and the complexity of water operations forces people to talk about the issue in terms of ‘storage’ and ‘yields’ rather than in natural or biological language that reflects the life-value of the water and the ecosystem (1995). Such laws also ensure that lawyers and developers have a leg up on average citizens when discussing these rights, while the impossibility of changing those laws means that politicians promise more supply to their constituents rather than address the demand caused by those constituents who think of the water as both an entitlement and a natural right; a former commissioner of the Bureau of Reclamation now calls for the dismantling of both that agency and one of its biggest dams, believing it now to be easier to basically slice through the Gordian knot of the water, its
consumers, and these inbuilt political & legal systems, rather than try to untangle it (Beard 2015). Because the Colorado River, much like water itself, was thought of as nothing more and nothing less than a resource to be managed, the mentality of modernity – as expressed by government bureaucrats, engineers, capitalists, farmers, and homeowners, all acting in the most rational manner that they can – has found itself incapable of imagining the crisis that it itself set up, with some fifty million people (and potentially many many more) perched on the edge of systems that were never designed to alleviate, let alone solve, the unfolding disaster they unwittingly induced.

C. Black Swans & Non-Linear Impacts

In the aftermath of the 2008 financial crisis, many commentators in the worlds of finance and economics wondered how it could have happened without anybody seeing it coming. Blame was put on many agents, almost all of them deserving of it – Fannie Mae, mortgage clearinghouses, the banks, the ratings agencies, the homeowners themselves – though this was often thrown around without a proper understanding of how the crisis unfolded and was set in motion by the collective action of all of those actors for years leading up to the crisis (Lewis 2010). In the midst of this firing squad, Taleb’s 2007 book *The Black Swan* achieved a newfound popularity by seemingly ‘predicting’ the crisis a year before it happened. The book actually did no such thing, but it laid out a case for not only why such crises happen, but also why they take society by surprise.
Very simply, past performance is no guarantee of the future. Too many of the actors in the financial crisis – from the banks to the homeowners to the regulators who oversaw the whole system – bought into the notion that housing prices were on a constant upwards trajectory, and acted accordingly. Wall Street firms hired ‘quants’ who wrote algorithms and formulas that were engineered to take in market data on the credit default swaps and collateralized debt obligations and render whether or not they were a sure bet; however, those formulas only used very limited forms of data, such as housing prices, that were limited to the previous several years, precisely the years when there was a bubble in housing prices (Salmon 2009). The entire crisis was induced by the actions of people who looked at the landscape and assumed that no such crisis would happen. In fact, many of the formulas that Wall Street used were patterned on ‘historic volatility levels’ that never considered the possibility of massive losses because those losses had not happened before (Lewis 2010).

Because it was considered unlikely or even impossible for a downturn in housing prices to cause a systemic failure of nearly the entire global financial market, the various actors within that market behaved, traded, and acted as if it could not happen. In fact, such an event was probably very unlikely, but for the behavior of the markets that then made such an event nearly inevitable.

This is the black swan concept: that highly consequential events that are improbable or unlikely are often induced by the belief that unlikely events are not worth addressing, and usually have the effect of upending entire systems of thought based on their occurrence (Taleb 2007). The name comes from the
notion that if you have a rule that says ‘I’ve only ever seen white swans, therefore black swans don’t exist’, then the continued presence of white swans can never really ‘prove’ your rule, but the sight of a single black swan immediately disproves it. In essence, laws that are conditioned on the absence of an event or on assumptions about the nature of how a system functions are inherently vulnerable to even the slightest changes in those assumptions or the occurrence of that event.

As previously established, much if not all of the Bureau of Reclamation’s infrastructure in the Southwest United States was built on calculations of Colorado River outflows which, though accurate at the time, were not in line with the historical norms of the past thousand years (Powell 2008; Ingrid & Malamud-Roam 2013). On the basis of these calculations, massive dams, aqueducts, and irrigation projects were constructed throughout the entire Colorado River basin, which covers almost one-fifth of the land area of the continental United States; there isn’t a single drop of water in the basin that isn’t affected or accounted for by the Bureau’s system in some way, and whatever water does make it all the way to the border with Mexico has usually been recycled several times over (Powell 2008; Beard 2015; Lustgarten 2015c). And because of this infrastructure, developers, politicians, business owners, and homeowners built extensive metropolitan areas in the region, leveraging subsidized and ‘guaranteed’ water with cheap land into a more efficient standard of living than could be achieved in the East or North (Reisner 1993; Ross 2011; Bahr et al 2013). Essentially, the guaranteed availability and implied promise of water
made the land viable in the first place, and therefore valuable to those who would build, and live in, this arid region.

All of this is based on what turns out to be flawed assumptions, themselves based on a limited series of data, regarding the nature of the Colorado River and the larger arid ecosystem that these cities and their tens of millions of residents inhabit, acting on the belief that the Colorado River would always provide the water that they relied upon, or at the very least that the government would guarantee continued water availability. This situation fulfills all of the characteristics of a black swan scenario, in which the absence of a drought and decreased outflows of the river – in a desert where such droughts and decreased outflows have happened repeatedly, but outside of the measured lifespan of modern society – could never serve as proof that such an event wouldn’t happen (Nevarez 1996). By overbuilding and overengineering the built infrastructure for delivering Colorado River water to the farmers and residents living hundreds of miles away from the river, in the center of the most arid region in the United States, the Bureau induced the demand that used up the supply it delivered; that demand was premised on the notion that a shortage would likely never happen, or at least would be avoided by the Bureau with its storage capacity on the river. Thinking that Colorado River shortages was highly improbable, all of the actors in the basin – from the government on down to the homeowner filling their pool in the midst of a green lawn – acted as though it wouldn’t happen, and ended up making themselves ever more vulnerable to the
‘impossible,’ with potentially serious consequences and repercussions for not only the Southwest but the rest of the country at large.\footnote{One could look at the Great Lakes cities and how shifts in the larger social environment that they operated in – due to globalization, post-industrialization, etc. – took away their natural economic advantages due to their physical hinterlands and agglomeration of industries, and led to a decades long slide of depopulation, ongoing recession, and social doldrums. The economic and demographic slide experienced by Detroit, Cleveland, Rochester, Buffalo, among others, has required a massive effort by the cities, their states, and the nation to try to revitalize them. Even then, there is no guarantee that such efforts will succeed, both due to the scale of the problem (Detroit had 4 million people at its peak, much like Phoenix today, and is now a city of 800,000 with lots of developed land that will never be fully utilized again) and due to the issue of those natural advantages no longer being necessary, at least not like they were in the past. Even then, the cities on the Great Lakes have the benefit of local fresh water supplies, mild climate, and proximity to other metropolises that could stimulate new forms of economic activity, all of which are environmental advantages unavailable to the Southwest.}

On top of the lesson of black swans and their likelihood, there is also a necessary lesson regarding non-linear impacts of these events. Going back to the financial crisis, the amounts of money that were invested in the housing bubble, and the mortgages, and the derivatives on global financial markets, were so overleveraged that it was impossible for everybody to make the money they thought they would. Thinking that the probability of both results and expected losses and gains resembled a normal or Gaussian distribution, each of the actors in the system dramatically overestimated their potential gains and underestimated just how easy it would be to lose everything (Taleb 2007; Salmon 2009). Taleb calls these scenarios ‘fat tails’, in that rather than being a normal distribution with similar tails on each side, one side is much bigger, and thus has more downside (or upside) than the other; in the case of the housing bubble, the fat tail was on the downside, such that it didn’t even take a collapse in housing prices for the whole system to crumble; prices just had to stop going up at the expected rate, and this set off a systemic failure that was seemingly out of proportion to the event that triggered it (Taleb 2007; Salmon 2009).
These are non-linear impacts, and they are a fundamental concept in the biological sciences, as ecosystems often have a given range of impacts that they can absorb and adapt to, but that range is limited; exceed it, and one risks a cascading series of unstoppable changes within that ecosystem that fundamentally alters it in an irreversible or irreparable manner. Deserts are some of the more robust ecosystems in nature, in that they have a surprising bounty of biodiversity due to the niche character of the species that have adapted to live within it, each of whom are also rather robust to changes in the ecosystem (i.e. living without water for a given period of time). However, no species is immune to fundamental ecological changes, such as megadroughts or a river that is carrying only half of its normal outflows, and one can expect that to be all the more so when discussing transplanted species. In this sense, our hothouse flowers have been put into a desert ecosystem for which they were never truly suited in the first place, and now there are profound changes on the horizon – longer and hotter summers, increased wildfires, less precipitation, and of course, a reduced Colorado River (Garfin et al 2014). It may not take much of a decline in river outflows to induce economic and demographic impacts in the Southwest that seemingly bely the nature of those declines; it is possible that once a shortage is declared on the Colorado River for the first time, it could lead businesses and investment to dry up and stay away from the region, while residents may find it more difficult to sell their houses if potential transplants from other regions of the country decide not to move to a desert where the water isn’t guaranteed and getting more expensive. The entire Colorado Basin, and the
people who live in it precisely because of the assumptions that undergird the built infrastructure of the Colorado River System, are at risk of this black swan that by all accounts is coming down the river, and of the non-linear changes that almost inevitably entail when a complex system interacts with another complex system.

D. Post-Modern Hohokam?

Human ecology demands that we see the interconnected and interdependent functions of social and natural systems; political economy demands that we understand the historical and economic context of why societies function the way they do; and metabolism and political ecology puts the focus on the flows of resources and the direction in which they flow (Hawley 1950; Turner & Ibes 2011; Baccini & Brunner 2012). Each of these strands of urban ecological theory are necessary and each tells the story of the modern Southwest, in that the creation and future of these hyperspecialized cities are the function of many disparate forces that acted to form cities in a place where previous efforts had failed, and on a scale that had never before been attempted.

These forces also explain why the Southwest will continue to face immense pressures in the near future as the Colorado River declines in outflows (NRC 2007). It is true that municipal uses in urban areas take up less than half of the water allotments for each state in the Lower Colorado (with agriculture using most of the annual deliveries), and the Lower Colorado itself gets no more than half of the river’s output in any given year, thus politicians, business owners, and
others in the region lead themselves to believe that there is both room for
greater efficiency (i.e. with irrigation in farming) and a buffer for urban growth
(i.e. by shifting water deliveries from agriculture to the cities) (Bureau 2012; Leslie
2015). The recent drought in California has made many non-farmers in the state
knowledgeable about just how many gallons of water go into a package of
almonds, for example, and commentators in the state’s biggest cities routinely
state the amounts of water used on farms that could provide for entire year’s
worth of water in the more populated and prosperous urban areas (Egan 2015;
Leslie 2015).

However, a few structural forces stand in the way of this ‘more efficient’
use of water. The first is that farmers and agribusiness comprise a powerful
interest group in their own right, and will continue to fight for the water they
feel entitled to as a matter of both right and livelihood (Reisner 1993; Beard 2015).
The second is that there is no functional or legal platform for the transferring of
water rights in the Southwestern states; the water is tied to the land, meaning
that it can be handed down or over with whoever owns the land, but the water
rights cannot be sold or given, so that even if farmers could make more money by
selling their water to urban areas than by farming with it, legally there is no
framework for this to happen, reflecting a regulatory failure on more potentially

The third force is that of efficiency itself, which may have also contributed
to the current situation; recall that California was able to use whatever water
wasn’t used by all of the other states under the Law of the River, becoming so
dependent on this extra capacity that they fought for decades to prevent the Central Arizona Project in order to keep Arizona from using water that Arizona was actually entitled to but couldn’t use (August 1999). Water that isn’t used in the upper basin of the Colorado flows down and can be used by the lower basin, over and above their legal allotments, and water that is used and replaced into the river also counts as a credit towards further deliveries from the river; this can lead to a greater water intensity, in terms of value generated for each unit of water, but it can also lead to a greater reliance on ‘surplus’ water which cannot be guaranteed in the future (Lustgarten 2015a). As of June 2016, there were plans for a bottled water facility to be built in Phoenix, using spare capacity from the Central Arizona Project’s deliveries to bottle and export some 260 million half-liters of water a year (Loomis 2016). Arguments for the facility say that the city’s water supplies are secure for the foreseeable future (though there is no mention of potential declared shortages on the Colorado River), but also that if the water was not used for this plant – which would shut down as soon as the spare capacity disappears – it could be used by a land developer to build more houses, which would create a more permanent demand on that water that no longer exists (Loomis 2016). Furthermore, water that is ‘wasted’ through flood irrigation (when farms are covered in water) rather than drip irrigation (a system that makes sure the water only goes into the soil around the plants) may not be all that wasted, as the hydrological connection between groundwater and the Colorado River may be more extensive than previously thought, and the water from flood irrigation may actually make its way into recharging aquifers, while
any water that is saved from drip irrigation just goes down the river towards the next use, further diminishing groundwater sources and reinforcing existing demands (Castle et al 2014; Beard 2015; Lustgarten 2015c; MacDonald 2015; Owen 2015).

Because of the combination of this political economy and ecology, there are no seemingly ‘easy’ fixes to the water question in the urban Southwest. The cities have been built; the rivers have been dammed; the aqueducts crisscross the desert; and millions of farmers and residents, who came to this region in search of a better standard of living and quality of life, expect to be able to stay on the basis of that inherent promise of progress. To say that these structures and systems are bad or should not exist would be to deny both the reality of this place and to dismiss the very real reasons why the Southwest developed in the manner that it did. But we must study those reasons and forces, and examine the hidden and flawed assumptions that were inherent in the building of this particular place, for if urban ecology did not see this overshoot coming, it may not be able to predict the next occurrence either.

And none of this is to say that these systems are at risk of immediate and total collapse – Phoenix will not become a ghost city if there is a declared shortage on the Colorado River followed by years of declining deliveries in the CAP. The Hohokam overshot their local water resources and became archeologically extinct within a matter of decades; Phoenix, and Tucson, and Las Vegas, and Southern California, and all of the other metropolitan areas in the Colorado River basin have technological means available to them that the
Hohokam could have never dreamed of, means that will allow those cities to continue to draw water and use it as effectively as they can. Even if there are sustained and long-term shortages on the Colorado, to the point where it fails to be a primary and dependable source of water for many urban areas in the region, many of those areas do have other water sources that they can continue to use (Smith 1989). Southern California gets water from Northern California, and has already started building desalinization plants; Las Vegas has started buying land in the northern portions of the state with contingency plans for a pipeline crossing the state to supplement or replace ‘missing’ Colorado River water; and Phoenix has the Salt and Gila Rivers, along with groundwater aquifers that the CAP was built to help reduce reliance upon (Reisner 1993; Logan 2006; Bahr et al 2013; Egan 2015; Lustgarten 2015a). Phoenix, currently a metro area of some four million people, could conceivably support hundreds of thousands using current technology and local water sources; there are plenty of cities of that size that play an important role in regional and national economies, but a drawdown of that size and scale has only been seen, in the American experience, in Detroit (a slow change in economic and social organization) and New Orleans (a sudden change due to environmental disaster). Phoenix and the other cities of the Colorado River basin have spent the past several decades becoming hyperspecialized cities, leveraging technology and wealth into narrow economic functions that were only profitable because of, and in ignorance of, the narrow

\[\text{12 Such levels would be not unlike its sister city to the south, Tucson, which has a dynamic economy despite trying to contain its population growth so as to not overshoot its local resources, and only recently became a metro area of over a million people (Logan 2006).}\]
ecosystem that those cities grew within; they will, in all likelihood, spend the next several decades dealing with a slow moving (yet potentially suddenly rapid) ecological change that was caused by the same type of overshoot that ancient societies have experienced, will be managed by the same modern mentality that created this particular problem in the first place, and could introduce non-linear effects and impacts that we cannot predict simply because we have never seen them happen before on this scale. Looking at the rest of the world, it is also, in all likelihood, not the last time it will happen either.

E. Towards A New Urban Ecology

Though each of the strands of urban and environmental theory raised in this dissertation perform invaluable services for our understanding of cities and the physical systems that they exist within, they still fail at times to fully explain or predict the development, and potential failure, of social and natural systems.

With the development of social environments – thanks to specialized economic functions enabled by trade and resource networks and political institutions – it is possible for urban areas to bypass and even ignore their local hinterlands and geography in such ways that residents of major cities feel more connected to residents of other major cities than with those who live in suburbs or rural areas on the outskirts of the metro area (Sassen 1994).

With the creation of vast technological machines that are the products of modern engineering – themselves paid for with national wealth on a scale that did not exist even well into the industrial era – cities were able to grow and act, in
terms of their population and social organization, in ways that were not in line with their physical environment, exceeding the parameters of how human ecology would expect an urban system to function; human ecology may have predicted this could happen, but even then could not predict the scale (Duncan 1964).

With a political system that found it both easy and profitable to subsidize the settlement and expansion of a previously undeveloped region and an economic model that prioritized the communization of a scarce resource – and with all of this acting in conjunction with farmers, home owners, land speculators, and business owners who had all a vested stake in enlarging the status quo – the Southwest has built itself upon billions of dollars in built infrastructure, and a vast set of regulations and laws, both of which form path dependencies for the continued morphology of the region and which can be changed, if at all, only with additional political and legal battles and expenditures of public money (Reisner 1993; Beard 2015).

And perhaps most of all, with the development of region- and even nation-wide systems of bringing resources and capital from one place to another on demand due to the power or influence of political and economic elites – resource flows that make cities ever more dependent upon the physical environment while at the same time leading elites and residents to believe they are decoupled from it – cities have become dependent upon interactions that cannot be explained by simply looking at the types of flows or the direction in
which they travel, but by how many interactions there are and the interlocking nature of those interactions (Pincetl et al. 2012; Lustgarten 2015b).

An urban ecology worthy of its name must be able to incorporate each of these developments into a cohesive framework of how human society shapes and is shaped by its physical environment. The perspectives and theoretical power of urban ecology have done invaluable service for our study of human environments, but I contend that still not enough attention is paid (particularly within the fields of urban political ecology and critical human ecology) to the complexity of the systems that enable human systems to grow, expand, and exceed their natural limits. Meanwhile, urban metabolism does not always account for the political and economic forces that shape these systems; political economy does not do enough to address fundamental & underlying environmental forms that affect systemic morphology. Just consider the following passage, regarding the energy that is produced in order to run the power plants in northern Arizona and southern Nevada that augment the hydroelectric power of the megadams as well as run the pumps that deliver water each way to Phoenix, Las Vegas, and Southern California:

“As soon as the Mohave plant was completed, Bechtel moved its construction crews to the tiny town of Page, Arizona, overlooking the scenic Glen Canyon Dam, to begin construction on a second electrical generating station – another giant at 2,250 megawatts, the second largest utility station in the U.S. Somebody named it the Navajo Generating Station, a name rich in irony, since fewer than half of Navajo families have
electricity. The U.S. government was the single largest owner. The Department of the Interior needed the electricity to run a federal water project, the Central Arizona Project. ... In Los Angeles, air conditioners hummed. Las Vegas embarked on an enormous building spree to make gambling a family vacation. Phoenix and Tucson metastasized out into the desert – building golf courses and vast retirement developments with swimming pools and fountains. Few realize that much of the energy that makes the desert “bloom” comes from the Black Mesa strip mines on an Indian reservation. Even fewer know the true costs of such development.” (Nies 2007: 125)

At the risk of repeating yet again one of the core messages of this dissertation: it is not the dependence on water that is the core of the problem in the modern urban Southwest, it is the dependence upon a complex human infrastructure built on top of and within an equally (if not more) complex environmental system that was already finely balanced on the edge of survival. True, every society is complex, and every city embodies infrastructures that cover the fabric of space and time. What sets these cities, this region, and their functions apart is the interlocking nature of complexity on top of complexity, so that there are multiple failure points (whether its the pumping stations, or the dams, or the aqueducts, or the money to provide for all of those things to continue functioning) layered on top of the potential for tipping points and non-linear changes in the underlying ecosystem, any of which could introduce ripple effects that compromise or wipe out the ability of the human system to adapt
and respond, regardless of the wealth, technology, or intelligence of those humans. An urban ecology that looks at and addresses *systemic complexity as an inherent measure of fragility or resilience* is a theoretical framework that will be better equipped to examine the built environment of our modern and post-modern world; it focuses on humans, yes, but from the standpoint that humans are a part of the natural world, not distinct from it. Thus it is not anti-nature or anti-human, but approaches all interactions between humans and nature for what they are: nothing more, and nothing less, than ecological.
References


Brelsford, C. 2014. “Whiskey is for Drinking; Water is for Fighting Over: Population Growth, Infrastructure Change, and Conservation Policy as Drivers of Residential Water Demand.” PhD dissertation, School of Sustainability, Arizona State University, Tempe, AZ.


-----, 2013, 5 August. Personal interview at the Morrison Institute for Public Policy. Phoenix, Arizona.


James, T., A. Evans, E. Madly, & C. Kelly. 2014b. “The Economic Importance of the Colorado River to the Basin Region.” Report, W.P. Carey School of Business, Arizona State University, Tempe, AZ.


Appendix A: Metropolitan Statistical Areas defined by the Census Bureau, by Regional Groupings as Used in the Analysis

Region 1
Albuquerque, NM; Boulder, CO; Cheyenne, WY; Colorado Springs, CO; Denver-Aurora-Lakewood, CO; El Centro, CA; Farmington, NM; Fort Collins, CO; Grand Junction, CO; Lake Havasu City-Kingman, AZ; Las Vegas-Henderson-Paradise, NV; Los Angeles-Long Beach-Anaheim, CA; Oxnard-Thousand Oaks-Ventura, CA; Phoenix-Mesa-Scottsdale, AZ; Prescott, AZ; Provo-Orem, UT; Pueblo, CO; Riverside-San Bernardino-Ontario, CA; Salt Lake City, UT; San Diego-Carlsbad, CA; Santa Fe, NM; St. George, UT; Tucson, AZ; Yuma, AZ.

Region 2
Amarillo, TX; Bend-Redmond, OR; Bismarck, ND; Boise City, ID; Carson City, NV; Casper, WY; El Paso, TX; Great Falls, MT; Greeley, CO; Idaho Falls, ID; Kennewick-Richland, WA; Las Cruces, NM; Lewiston, ID-WA; Logan, UT-ID; Lubbock, TX; Medford, OR; Midland, TX; Missoula, MT; Odessa, TX; Pocatello, ID; Rapid City, SD; Reno, NV; San Angelo, TX; Sierra Vista-Douglas, AZ; Spokane-Spokane Valley, WA; Walla Walla, WA; Wenatchee, WA.

Region 3
Bakersfield, CA; Fresno, CA; Hanford-Corcoran, CA; Madera, CA; Merced, CA; Modesto, CA; Stockton-Lodi, CA; Visalia-Porterville, CA.

Region 4
Abilene, TX; Akron, OH; Albany, GA; Albany, OR; Albany-Schenectady-Troy, NY; Alexandria, LA; Allentown-Bethlehem-Easton, PA-NJ; Altoona, PA; Ames, IA; Anchorage, AK; Ann Arbor, MI; Anniston-Oxford-Jacksonville, AL; Appleton, WI; Asheville, NC; Athens-Clarke County, GA; Atlanta-Sandy Springs-Roswell, GA; Atlantic City-Hammonton, NJ; Auburn-Opelika, AL; Augusta-Richmond County, GA-SC; Austin-Round Rock, TX; Baltimore-Columbia-Towson, MD; Bangor, ME; Barnstable Town, MA; Baton Rouge, LA; Battle Creek, MI; Bay City, MI; Beaumont-Port Arthur, TX; Beckley, WV; Bellingham, WA; Billings, MT; Binghamton, NY; Birmingham-Hoover, AL; Blacksburg-Christiansburg-Radford, VA; Bloomington, IL; Bloomington, IN; Bloomsburg-Berwick, PA; Boston-Cambridge-Newton, MA-NH; Bowling Green, KY; Bremerton-Silverdale, WA; Bridgeport-Stamford-Norwalk, CT; Brownsville-Harlingen, TX; Brunswick, GA; Buffalo-Cheektowaga-Niagara Falls, NY; Brunswick, NC; Burlington-South Burlington, VT; California-Lexington Park, MD; Canton-Massillon, OH; Cape Coral-Fort Myers, FL; Cape Girardeau, MO-IL; Carbondale-Marion, IL; Cedar
Rapids, IA; Chambersburg-Waynesboro, PA; Champaign-Urbana, IL; Charleston, WV; Charleston-North Charleston, SC; Charlotte-Concord-Gastonia, NC-SC; Charlottesville, VA; Chattanooga, TN-GA; Chicago-Naperville-Elgin, IL-IN-WI; Chico, CA; Cincinnati, OH-KY-IN; Clarksville, TN-KY; Cleveland, TN; Cleveland-Elyria, OH; Coeur d’Alene, ID; College Station-Bryan, TX; Columbia, MO; Columbia, SC; Columbus, GA-AL; Columbus, IN; Columbus, OH; Corpus Christi, TX; Corvallis, OR; Crestview-Fort Walton Beach-Destin, FL; Cumberland, MD-WV; Dallas-Fort Worth-Arlington, TX; Dalton, GA; Danville, IL; Daphne-Fairhope-Foley, AL; Davenport-Moline-Rock Island, IA-IL; Dayton, OH; Decatur, AL; Decatur, IL; Deltona-Daytona Beach-Ormond Beach, FL; Des Moines-West Des Moines, IA; Detroit-Warren-Dearborn, MI; Dothan, AL; Dover, DE; Dubuque, IA; Duluth, MN-WI; Durham-Chapel Hill, NC; East Stroudsburg, PA; Eau Claire, WI; Elizabethtown-Fort Knox, KY; Elkhart-Goshen, IN; Elmira, NY; Erie, PA; Eugene, OR; Evansville, IN-KY; Fairbanks, AK; Fargo, ND-MN; Fayetteville, NC; Fayetteville-Springdale-Rogers, AR-MO; Flagstaff, AZ; Flint, MI; Florence, SC; Florence-Muscle Shoals, AL; Fond du Lac, WI; Fort Smith, AR-OK; Fort Wayne, IN; Fresno, CA; Gadsden, AL; Gainesville, FL; Gainesville, GA; Gettysburg, PA; Glens Falls, NY; Goldsboro, NC; Grand Forks, ND-MN; Grand Island, NE; Grand Rapids-Wyoming, MI; Grants Pass, OR; Green Bay, WI; Greensboro-High Point, NC; Greenville, NC; Greenville-Anderson-Mauldin, SC; Gulfport-Biloxi-Pascagoula, MS; Hagerstown-Martinsburg, MD-WV; Hammond, LA; Harrisburg-Carlisle, PA; Harrisonburg, VA; Hartford-West Hartford-East Hartford, CT; Hattiesburg, MS; Hickory-Lenoir-Morganton, NC; Hilton Head Island-Bluffton-Beaufort, SC; Hinesville, GA; Homosassa Springs, FL; Hot Springs, AR; Houma-Thibodaux, LA; Houston-The Woodlands-Sugar Land, TX; Huntington-Ashland, WV-KY-OH; Huntsville, AL; Indianapolis-Carmel-Anderson, IN; Iowa City, IA; Ithaca, NY; Jackson, MI; Jackson, MS; Jackson, TN; Jacksonville, FL; Jacksonville, NC; Janesville-Beloit, WI; Jefferson City, MO; Johnson City, TN; Johnstown, PA; Jonesboro, AR; Joplin, MO; Kahului-Wailuku-Lahaina, HI; Kalamazoo-Portage, MI; Kankakee, IL; Kansas City, MO-KS; Killeen-Temple, TX; Kingsport-Bristol-Bristol, TN-VA; Kingston, NY; Knoxville, TN; Kokomo, IN; La Crosse-Onalaska, WI-MN; Lafayette, LA; Lafayette-West Lafayette, IN; Lake Charles, LA; Lakeland-Winter Haven, FL; Lancaster, PA; Lansing-East Lansing, MI; Laredo, TX; Lawrence, KS; Lawton, OK; Lebanon, PA; Lewiston-Auburn, ME; Lexington-Fayette, KY; Lima, OH; Lincoln, NE; Little Rock-North Little Rock-Conway, AR; Longview, TX; Longview, WA; Louisville/Jefferson County, KY-IN; Lynchburg, VA; Macon, GA; Madison, WI; Manchester-Nashua, NH; Manhattan, KS; Mankato-North Mankato, MN; Mansfield, OH; McAllen-Edinburg-Mission, TX; Memphis, TN-MS-AR; Miami-Fort Lauderdale-West Palm Beach, FL; Michigan City-La Porte, IN; Midland, MI; Milwaukee-Waukesha-West Allis, WI; Minneapolis-St. Paul-Bloomington, MN-WI; Mobile, AL; Monroe, LA; Monroe, MI; Montgomery, AL; Morgantown, WV; Morristown, TN; Mount Vernon-Anacortes, WA; Muncie, IN; Muskegon, MI; Myrtle Beach-Conway-North Myrtle Beach, SC-NC; Napa, CA; Naples-Immokalee-Marco Island, FL; Nashville-Davidson-Murfreesboro-Franklin, TN; New Bern, NC; New Haven-Milford, CT;
New Orleans-Metairie, LA; New York-Newark-Jersey City, NY-NJ-PA; Niles-Benton Harbor, MI; North Port-Sarasota-Bradenton, FL; Norwich-New London, CT; Ocala, FL; Ocean City, NJ; Ogden-Clearfield, UT; Oklahoma City, OK; Olympia-Tumwater, WA; Omaha-Council Bluffs, NE-IA; Orlando-Kissimmee-Sanford, FL; Oshkosh-Neenah, WI; Owensboro, KY; Palm Bay-Melbourne-Titusville, FL; Panama City, FL; Parkersburg-Vienna, WV; Pensacola-Ferry Pass-Brent, FL; Peoria-IL; Philadelphia-Camden-Wilmington, PA-NJ-DE-MD; Pine Bluff, AR; Pittsburgh, PA; Pittsfield, MA; Portland-South Portland, ME; Portland-Vancouver-Hillsboro, OR-WA; Port St. Lucie, FL; Providence-Warwick, RI-MA; Punta Gorda, FL; Racine, WI; Raleigh, NC; Reading, PA; Redding, CA; Richmond, VA; Roanoke, VA; Rochester, MN; Rochester, NY; Rockford, IL; Rocky Mount, NC; Rome, GA; Sacramento-Roseville-Arden-Arcade, CA; Saginaw, MI; St. Cloud, MN; St. Joseph, MO-KS; St. Louis, MO-IL; Salem, OR; Salinas, CA; Salisbury, MD-DE; San Antonio-New Braunfels, TX; San Francisco-Oakland-Hayward, CA; San Jose-Sunnyvale-Santa Clara, CA; San Luis Obispo-Paso Robles-Arroyo Grande, CA; Santa Cruz-Watsonville, CA; Santa Maria-Santa Barbara, CA; Santa Rosa, CA; Savannah, GA; Scranton-Wilkes Barre-Hazleton, PA; Seattle-Tacoma-Bellevue, WA; Sebastian-Vero Beach, FL; Sebring, FL; Sheboygan, WI; Sherman-Denison, TX; Shreveport-Bossier City, LA; Sioux City, IA-NE-SD; Sioux Falls, SD; South Bend-Mishawaka, IN-MI; Spartanburg, SC; Springfield, IL; Springfield, MA; Springfield, MO; Springfield, OH; State College, PA; Staunton-Waynesboro, VA; Sumter, SC; Syracuse, NY; Tallahassee, FL; Tampa-St. Petersburg-Clearwater, FL; Terre Haute, IN; Texarkana, TX-AR; The Villages, FL; Toledo, OH; Topeka, KS; Trenton, NJ; Tulsa, OK; Tuscaloosa, AL; Tyler, TX; Urban Honolulu, HI; Utica-Rome, NY; Valdosta, GA; Vallejo-Fairfield, CA; Victoria, TX; Vineland-Bridgeton, NJ; Virginia Beach-Norfolk-Newport News, VA-NC; Waco, TX; Warner Robins, GA; Washington-Arlington-Alexandria, DC-VA-MD-WV; Waterloo-Cedar Falls, IA; Watertown-Fort Drum, NY; Wausau, WI; Weirton-Stebenville, WV-OH; Wheeling, WV-OH; Wichita, KS; Wichita Falls, TX; Williamsport, PA; Wilmington, NC; Winchester, VA-WV; Winston-Salem, NC; Worcester, MA-CT; Yakima, WA; York-Hanover, PA; Youngstown-Warren-Boardman, OH-PA; Yuba City, CA.
Appendix B: Economic Sectors, by Industrial Classification According to the Bureau of Labor Statistics

Primary Sector (Classification Code in Parentheses)
Agriculture (11); Mining (21)

Secondary Sector
Utilities (22); Construction (23); Manufacturing (31-33)

Tertiary Sector
Wholesale trade (42); Retail trade (44-45); Transportation and warehousing (48-49); Information (51); Finance and insurance (52); Real estate (53); Professional and business services (54-56); Educational services, health care, and social assistance (61-62); Arts, entertainment, and recreation (71); Accommodation and food services (72); Government (92)

Quartenary Sector
Information (51); Government (92)