Drilling Down, Pumping Up: A History of Center-Pivot Irrigation and Hydraulic Fracturing in Kansas

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Introduction: Origins

Frank Zybach conceived of center-pivot irrigation in 1947. The 53-year-old Nebraska native had had fallen on hard times. Unable to afford his own land, he rented a small plot on the undulating Rocky Mountain piedmont outside Strasburg, Colorado, forty miles east of Denver. The rolling topography made ditch-flow gravity irrigation impossible, forcing Zybach to abandon water-intensive alfalfa and sugar beets in favor of dryland wheat. Even so, his efforts found little success (Morgan, 1993).

Frustrated and desperate, Zybach attended a demonstration of a new, movable sprinkler irrigation system. Unlike furrow irrigation, the system operated on uneven, sloped terrain; and, instead of drowning fields with periodic torrents, the sprinklers applied a light, steady rain. However, the contraption itself, thought Zybach, left much to be desired. Most crucially, it relied on manpower. Each time a farmer wanted to water a different spot, he had to trudge through the muck, disconnect a series of hoses, fittings, and heads, schlepp all the components to the new location, then reassemble the thing. Zybach left the demonstration invigorated by the promise of sprinkler irrigators and determined to mechanize them (Ashworth, 2006).

By 1949 Zybach had fabricated a working prototype. It consisted of a central wellhead that supplied water to a horizontal hose fitted with nozzles every few feet. Two mobile towers held this lateral sprinkler line eighteen inches above the ground. Water flushing through the suspended pipe actuated a series of pistons which powered a rotating arm mounted to one of the tower's wheels. In this way, the sprinkler system crept along on its own, dropping a controlled amount of water as it circumnavigated a field. Zybach applied to patent this "Self-Propelled Sprinkling Irrigating Apparatus" in June 1949 (Zybach, 1952, Green 1992).

Zybach modified his unit over the next few years. He adjusted the positioning of the lateral pipe, improved the drive mechanism, and lengthened the sprinkler line by adding three towers. These changes enabled the system to water a full forty acres. In 1952, Zybach sold his first irrigating apparatus to a Strasburg alfalfa farmer; two years later he sold the manufacturing rights to Valley Manufacturing of Nebraska. Valley reworked the concept, raising the sprinkler pipe to eight feet and adding more towers. With these alterations, Valley systems could clear tall row crops—like corn—and water up to 133 acres of a standard 160-acre quarter-section. By the 1970s, center-pivot irrigators, as they came to be known, had brought into production millions of acres of submarginal land previously deemed too hilly and dry to cultivate.

The same year (1947) Frank Zybach envisioned center-pivot irrigation in Strasburg, Colorado, 250 miles to the southeast, in Grant County, Kansas, the Stanolind Oil and Gas Corporation performed the first-ever hydraulic fracture (commonly known as 'fracking') of an oil or gas well. During the mid-1940s, Stanolind engineers had reasoned that squeezing a jellied fluid into a wellbore might cleave adjacent rock formations, improving the system of drainage channels encouraging oil or gas to flow into the well. They hoped the technique could enhance the productivity of slowing, aging, or deteriorating wells (Howard and Fast, 1970; Gow, 2005).[1]

Eager to test the technique, in November 1946 Stanolind sent a team to Klepper Gas Unit No. 1—a 2,580 foot natural gas well sunk into the Hugoton Embayment. The crew fired a slurry

[1] Several methods already existed to increase a well's drainage area, including 'shooting' the bore with explosives and injecting acid to make rock formations more permeable. Hydraulic fracturing offered a more economical, efficient, and safe way to increase a well's deliverability. Until the late-2000s, nearly all hydraulic fracturing on the High Plains was performed on vertical wellbores; most of the present-day controversy revolves around hydraulic fracturing of horizontal wellbores.

containing 1,000 gallons of napalm-thickened gasoline and Arkansas River sand into the well followed by an amine gel breaker, which lowered the viscosity of the jellied gasoline enabling it to evacuate the crack it opened while depositing the sand to keep that crack propped open. Although Klepper No. 1's deliverability increased only minimally, the glimmer of promise convinced Stanolind to pursue an experimental fracturing program. Over the next two years, the company treated five additional gas wells in Southwest Kansas and eighteen others across Oklahoma, Texas, and Louisiana. The five jobs in Kansas "resulted in sustained and significant increases in productivity"; the deliverability of one of those wells jumped 508%, from 53,000 cubic feet per day to 322,000 (Clark, 1949; Howard and Fast, 1970; Montgomery and Smith, 2010; KGS, 2013a).

Stanolind applied to patent their "Hydrafrac treatment" in 1949. Later that year, hydraulic fracturing was made commercially available, and the Halliburton Oil Well and Cementing Company (Howco) secured exclusive rights to perform the process through 1953. During this four-year period, 7,800 of the 10,500 wells fractured in Kansas, Oklahoma, Texas, and Louisiana were judged "successful in increasing well productivity" (Clark, Fast and Howard, 1952). In the mid-1950s, two innovations emerged: low-cost, water-based fluids replaced hydrocarbon-based solutions, and a multiple fracturing technique returned exponentially higher yields of oil and gas. By the 1970s, the industry employed hydraulic fracturing not only to stimulate lethargic wells but also to access oil-and-gas-saturated zones lying beneath previously impenetrable rock formations (Reistle, 1951; Farris, 1952; Clark, 1952; Gow, 2005).

In the six decades since the invention and commercial introduction of center-pivot irrigators and hydraulically fractured gas wells, both have become ubiquitous in Kansas. In 2012, over 15,000 center-pivots operated in the state and over 57,000 wells had been hydraulically fractured (Pfeiffer and Lin, 2009; Suchy and Newell, 2012). This essay investigates that growth. I argue that the simultaneous rise of center-pivot irrigation and hydraulic fracturing was not entirely coincidental; rather, the widespread adoption of these two technologies in the same place at the same time owes to a web of environmental, scientific, technological, socioeconomic, and cultural factors. A quick rundown: both technologies owe their genesis to a series of natural discoveries made around the turn of the twentieth century; both benefitted from mechanical breakthroughs of the early twentieth century; both emerged commercially amidst the post-WWII economic boom; and both applications experienced tremendous growth as agriculture became increasingly industrialized from the 1960s into the 2000s. Most importantly, the similarities and connections between center-pivot irrigation and hydraulic fracturing illustrate a twofold inclination of modern America: (1) the desire to access natural resources and (2) the ongoing, ever-intensifying quest to both sustain and improve that access. Thus, this dual history aims to reveal how American's have produced a certain standard of living by pushing against (and beyond) environmental limits.

Speaking of limitations, I admit to three. First, I do not suggest a strict co-dependence between center-pivot irrigation and hydraulic fracturing. I will merely highlight the instances when, and sites where, the two technologies influenced one another's development. Neither is this a balanced study. Hydraulic fracturing contributed far more to center-pivot irrigation than vice-versa. As such, the majority of this essay focuses on the astounding increase in irrigated acreage over the past sixty years and how natural gas extraction literally fueled that increase. Nor do I offer provocative conclusions. After all, center-pivot irrigation may well have become as omnipresent as it is today without the aid of hydraulic fracturing.

I set my story in Southwest Kansas,[2] and I am especially concerned with seven counties in the region: Morton, Kearny, Grant, Stevens, Finney, Haskell, and Seward. These seven counties sit atop the most saturated portion of the Ogallala aquifer in the state (Fig. 1). Underneath this water sprawls the largest complex of natural gas fields in North America and the second-largest in the world—the Hugoton Natural Gas Area (Fig. 2). In the early 1940s, Southwest Kansas turned to new technologies to finally access these deep deposits of water and hydrocarbons. That moment signals the emergence of what I call a 'mining mentality,' epitomized by an intertwined demand: drilling down for the very energy needed to pump up fossil water.

This mining mentality has, perhaps, been most pronounced and energetic around Garden City, a town of 27,000 people near the center of Finney County. Perched on an arid steppe, the area receives between fifteen and twenty inches of rain each year. Just to the southwest of Garden City, lay the Sandhills—or Sandsage Prairie. Little besides sagebrush and soapweed once grew on this predominantly loose, sandy loam; but, thanks to 1,000 deep wells currently tapping fossil water, lush circles of wheat, sorghum, and corn have replaced those hardy prairie grasses. Much of this grain and grass fattens the region's 1.5 million cattle destined for the slaughter market.[3] Many landowners supplement their agricultural earnings by leasing land to petrochemical companies. They receive, in return, free access to any natural gas extracted and often use it to fuel the water pumps supplying their center-pivot irrigators. As of 2013, 1,343

[2] This region has been defined and demarcated differently at different times by different people with different interests. In the 1930s, the counties of Hamilton, Stanton, Morton, Stevens, Grant, Kearny, Wichita, Finney, Haskell, Seward, Meade, Gray, Ness, Hodgeman, Ford, and Clark marked the heart of the Dust Bowl in Kansas. In 1948, landowners in Finney, Grant, Hamilton, Haskell, Kearny, Morton, Seward, and Stanton counties formed the Southwest Kansas Royalty Owners Association in an effort to protect their mineral ownership rights. And in 1976, the state organized Hamilton, Stanton, Morton, Kearny, Grant, Stevens, Finney, Haskell, Seward, Gray, Meade, and Ford counties as Groundwater Management District No. 3.

[3] In 2012, Kansas held 2.37 million head of cattle for the slaughter market; nearly 2/3 of those cattle resided on feedlots scattered across Southwest Kansas.

natural gas wells had been sunk in Finney County. Thus, Southwest Kansas, and Finney County's Sandhills, in particular, seems an ideal place to examine the century-long coevolution of center-pivot irrigation and hydraulic fracturing (KDA 2012; KGS, 2013a; KGS, 2013b).

In Search of Water

Finding and securing water has long been *the* central preoccupation in Southwest Kansas. In 1540, Spanish conquistador Francisco Vásquez de Coronado ventured onto the High Plains looking for a wealthy civilization called Quivira. After months tramping through a vast grassland with "no more landmarks than as if we had been swallowed up in the sea," the expedition stumbled on "well-settled...river bottoms" near what is now Lyons, Kansas (Winship, 1904). Coronado's men combed the cluster of Native American villages for weeks but found no sign of the fabled riches. Disappointed, they returned to Mexico with little more than the memory of having felt stranded "in great need of water" on "limitless plains" (Winship, 1904).

Anxiety about the High Plains environment persisted for next three centuries. A Spanish expedition stalled in 1598 after soldiers deserted, unwilling to enter the empty, arid expanse. In 1787, James Monroe informed Thomas Jefferson that the land west of the Appalachian Mountains was "miserably poor, consist[ing] of extensive plains which have not had from appearances, and will not have, a single bush upon them for ages" (Sauer, 1967). In 1810 Zebulon Pike substantiated Monroe's suspicions. Pike crossed what would become Kansas, describing the landscape he traversed as "barren soil, parched and dried up for eight months in the year." He reckoned the "vast plains of the western hemisphere may become, in time, equally celebrated as the sandy deserts of Africa" (Pike, 1811). A decade later, Stephen Herriman Long crossed the continent's midsection, promptly declaring that Great American Desert "almost wholly unfit for cultivation and, of course, uninhabitable by a people depending upon agriculture for their subsistence" (James, 1823). John Wesley Powell agreed, confirming in 1878 that "the climate [of the High Plains] is so arid that agriculture is not successful" (Opie, 1993).

This portrait of a dehydrated wasteland did much to keep farmers out of Southwest Kansas into the late nineteenth century. In addition to worrying about where they might find water, potential settlers feared baking hot summers and piercingly cold winters. They recoiled at the thought of formidable winds blowing dust and fanning wildfires. And they fretted over the lack of wood for building homes, fences, and furniture.

Things changed around 1880. A wet decade between 1878 and 1887 attracted a hoard of eager, optimistic agriculturalists to Southwest Kansas. Not only did the rain seem to follow the plow, as Joseph Henry of the Smithsonian Institute professed it would, many farmers found ways of securing water more regularly. Initially, they sucked it from obvious, if rare, sources: springs, ponds, rivers, and creeks. They stored their liquid harvest in buckets and barrels. In the absence of such low-hanging fruit, some farmers got more creative, draining wet-weather draws, playa lakes, and even buffalo wallows. The most desperate dug gaping, stone-or brick-lined holes twenty-to thirty-feet-deep to reach the water table. Still, these primitive wells hardly guaranteed agricultural success. Into the early-1900s, most well water had to be hoisted by the bucketful. In addition to the arduous nature of this task, even the best wells could only supply enough water for the family, a small kitchen garden, and a few barnyard animals. Even if a farmer could afford to purchase or piece together a windmill, it promised to slurp up only enough to reliably water a five to ten acre crop (Worster, 1979).

Irrigation canals also emerged around this time in Southwest Kansas. In 1878, two farmers—one from Colorado the other from California—relocated to the newly platted Garden

City. They brought with them extensive knowledge of the irrigation ditches being feverishly cut in their home states. Following the dry summer of 1879, the pair set to work diverting water from the Arkansas River into their fields. They enlisted a team of farmers to hand trench the four-mile-long, eight-foot-wide, two-foot-deep canal. Along the route, the crew gouged laterals to carry allotted amounts of water to crops. The ditch proved a great success: in the year after its completion, one farmer harvested five alfalfa crops! Over the next decade, the ditch was extended twenty miles. By 1892, a total of 336 miles of canals—in addition to the Garden City Ditch, the Kansas Ditch, the Amazon Ditch, the Southwestern Ditch, and the South Side Ditch all diverted water from the Arkansas River—irrigated 70,000 acres of the Arkansas River basin surrounding Garden City (Opie, 1993).

However, irrigation ditches failed to solve the underlying problem in the region: water scarcity. A prolonged drought between 1890 and 1900, combined with diversions upstream in Colorado, effectively turned off the Arkansas River. The once-vaunted Garden City ditches ran dry by 1900. Not long after, the 70,000 irrigated acres around the town withered to a paltry 409. Lacking water, farmers fled the region by the thousands. Between 1890 and 1900, the number of farms in Southwest Kansas declined from 14,300 to 8,900. It would take the discovery of a far vaster supply of water and the invention of a means to extract it to bring them back (Opie, 1993).

Underground Riches

Residents of Southwest Kansas long believed that a subterranean river thundered below their feet. Farmers figured if they could only tap this underground 'sheet water'—replenished, according to some, by Rocky Mountain run-off, according to others, by Arctic glacial melt—they would no longer have to depend on either the fickle High Plains weather or the vagaries of the

Arkansas River (Opie, 1993). Science fired the belief in such an underflow. In 1891, the United States Geological Survey (USGS) confirmed that some Rocky Mountain streamwater bled through the soil into an underground cascade. In 1904, geologist Charles M. Slichter drilled several wells in a straight line near Garden City. Slichter argued that because the returns dwindled from west to east, a torrent must run from the Rockies toward the Mississippi.

Alas, no river raged beneath the High Plains. Instead, a thick layer of sand, gravel, silt, and clay had trapped millions of years of percolating rainwater. In 1899, Nelson Horatio Darnton, a USGS geologist working in Nebraska, named and described this Ogallala Formation (Darnton, 1899). Over subsequent years, geologists discovered the aquifer underlays some 174,000 square miles, from the Texas panhandle to South Dakota. In a few places, the water burbles to the surface, in others it remains nearly 1,000 below; in most, the table lies a couple hundred feet down.

The technology existed to move Ogallala water. Invented in the 1870s, the centrifugal pump pulled water up and into a chamber, where an impeller forced it toward the outside walls, pushing it out through a discharge pipe (Green, 1992). The pump, however, required a massive amount of energy. Given the absence of a reliable source—electric plants, like the central plant erected by the United States Sugar and Land Company in Garden City in 1909, often flickered out due to the high cost of generating power so far from the Appalachian coal beds—few Southwest Kansans adopted the new technology. The introduction of the internal combustion engine in the 1870s and, more importantly, its adaptation to run on oil in the 1890s did help the centrifugal pump gain more widespread use (Opie, 1993). However, the high cost of the pump, engine, and fuel source, combined with the complicated nature of maintaining the equipment, meant that only the wealthiest High Plains agriculturalists could afford to install and run hydraulic pumps in their water wells. Besides, an even more pressing problem plagued turn-of-the-century pumping efforts in Southwest Kansas: the quantity of water necessary to irrigate a standard, 160-acre homestead lay deep below the surface. The water's depth rendered existing technologies incapable of tapping it (Green, 1973).

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In 1926, a wildcatter named Walter L. Sidwell came to Southwest Kansas in search of oil. Upon arriving, Sidwell learned that four years earlier roughnecks had drilled around Seward County with no luck. Ever optimistic, he forged ahead, prospecting four miles southwest of Hugoton, in Stevens County. In 1927, Sidwell found natural gas about 2,600 feet below the surface. Two years later, Kansas Governor Clyde M. Reed lit a gas flame atop a temporary rig erected on the Hugoton High School football field and symbolically proclaimed Southwest Kansas the natural gas capital of the entire US Southwest (KHC, 2012).

The natural gas Sidwell struck came from the Hugoton Natural Gas Area, a conglomeration of four gas fields, including the Hugoton, Panoma, Bradshaw, and Byerly, that stretches some 6,500 square miles under Southwest Kansas, the Oklahoma Panhandle, and Northern Texas. Although geologists had presumed the fields' existence since the early 1900s, its precise depth and extent remained unknown until the years following Sidwell's discovery in 1927. By 1930, several pipelines carried gas to markets across Southwest Kansas and Eastern Colorado. Eventually, extension lines carried Hugoton gas west to the Front Range and as far east as Minneapolis and Detroit (WPA, 1939). With a ready market for their natural gas, drillers sunk 150 wells in the Kansas portion of the Hugoton in the 1930s; by 1944, that number topped 400 (Ver Wiebe, 1945).

Drilling for natural gas in Southwest Kansas did two things for farmers wanting water. One: the rotary augers used to reach natural gas deposits bored far deeper than the shovels and 'spudders' (units that repeatedly raised and dropped a steel bit) commonly used to dig domestic water wells. The prevalence of these modern drill rigs in Southwest Kansas during the 1930s and 1940s provided farmers easy access to technology capable of reaching once unreachable fossil water. Two: farmers who leased their land for oil and gas development often received free natural gas in return. This agreement gave them an abundant fuel source with which to power their hydraulic water pumps. In this way, mineral drilling operations provided Southwest Kansas farmers with the means to efficiently and economically move Ogallala water.

In 1937, a deep-water well (typically classified as 100+ feet) outside of Liberal became one of the first in Southwest Kansas. Coming close on the heels of the Dust Bowl disaster, the occasion attracted considerable fanfare, including a celebratory parade that "wound its way to the well, where hundreds of people and cars gathered to watch the spudding ceremony" (Opie, 1993). By 1944, Finney County alone boasted forty-five deep wells watering roughly 7,500 acres (Latta, 1944). While this event certainly symbolized change, the real mining bonanza would start twenty years later.

A Mining Mentality

Following a decade of favorable weather, drought returned to Southwest Kansas in the 1950s. The Filthy Fifties had all the hallmarks of the Dirty Thirties: scorching heat, unrelenting wind, and savage dust storms. Indeed, in some ways, the 1950s drought, though shorter, proved more severe than its infamous predecessor—it eroded twice the acreage of the 1930s drought and produced even more black blizzards. However, when rain returned in 1957, rather than re-think the logic of extensive, intensive agriculture on the High Plains, Southwest Kansans plowed ahead. By 1965, farmers in Finney County relied on some 550 irrigation wells to water 100,000 acres; by 1982, 2,267 wells watered over 244,000 acres (SCS, 1965; Opie, 1998). They carved much of this new farmland out of the extremely fragile, erosion prone Sandhills southwest of Garden City. The introduction of two new technologies made this possible: center-pivot irrigation and hydraulic fracturing.

In the years after Valley Manufacturing bought the rights to Frank Zybach's center-pivot irrigator, it changed the system substantially. By the mid-1960s, a unit spanned three-quarters of a mile. The lateral sprinkler pipe stood eight feet off the ground, supported by seven or eight wheeled towers. These center-pivots typically watered between 120 and 133 acres of a 160-acre plot. It could make that rotation in as little as twelve hours—although most completed one circuit in three to five days, depending on the crop being watered, the soil conditions, and the weather. Operating on a deep-water well guzzling an average of 900 gallons each minute, a center-pivot covered a field with one inch of water on a single rotation. Over the course of a summer, a single center-pivot dropped up to two feet of water on a field, enough to supply a town of one thousand people for an entire year (Splinter, 1976).

Center-pivots promised several advantages over ditch irrigation or other sprinkler devices. First and foremost, they offered a savings in labor. Once installed, the system literally drove itself. But three more important benefits compelled Finney County's Sandhills farmers. First, the unit operated on undulating terrain. Whereas other irrigation methods had been restricted to flat or leveled land, the flexibility of a center-pivot's lateral pipe and its self-propelled drive mechanism made it capable of climbing and descending gradients up to 30%. Second, center-pivots converted sunburned grasslands into fertile farmfields. Because they applied water in a light, frequent, and uniform fashion, center-pivots allowed adoption of water-intensive crops like corn, alfalfa, and sorghum on Sandhill soils known for their rapid absorption and poor retention of water. Finally, center-pivots could deliver fertilizer. This meant that farmers working scrubland could easily replenish their nutrient-poor soils (McKnight, 1979).

Yet, center-pivots did have drawbacks. Most simply, the units puzzled and frustrated farmers accustomed to farming rectangular fields. For many, center-pivots "wasted" the corners of a standard quarter-section (McKnight, 1979). Proponents responded to this critique by noting that the increase in productivity on the 133 acres more than compensated for the loss of twenty-seven acres. Others reminded doubters that most center-pivots brought into production land that had never before been irrigated or even cultivated. Any crop, they reasoned, represented improvement. An especially enterprising few even filled those pesky missed corners with non-irrigated crops, planted it to pasture, or clustered in trees and farm buildings to serve as windbreaks.

A more serious concern became the cost of owning and operating a center-pivot. When commercially introduced in the mid-1950s, a system could be purchased for between $5,000 and $10,000; in the early-1970s, a center-pivot cost $25,000; and, by the 1980s, one ran around $70,000 (Opie, 1993).[4] This price tag, of course, did not factor in the cost of land, drilling a deep well, or, most importantly, acquiring energy to run the hydraulic pump that fed the center-pivot. Hydraulic pumps are thirsty machines: those supplying a center-pivot consumed upwards of fifty gallons of fuel per acre per year—by some estimations, this was ten times the fuel needed to till, plant, cultivate, and harvest a crop without one. By the mid-1970s, the energy used to operate the pumps that made center-pivot irrigation possible accounted for nearly one-half the total amount of energy used by the agricultural industry on the High Plains (Splinter, 1976).

[4] A turnkey center-pivot now costs around $140,000.

Farmers in Finney County—and across Southwest Kansas—largely evaded high fuel costs by relying on free access granted them to the natural gas tapped on or transmitted across their land. Soon after the commercial introduction of hydraulic fracturing in the early 1950s, gas development skyrocketed across the Hugoton Embayment. Whereas Finney County had zero gas wells in 1950, by 1955 it had 416 wells; by 1965 another 233 wells had been drilled, and in 1980 there were 764 natural gas wells across the county. Of course, not all of these were hydraulically fractured.[5] But, according to industry experts, "by the early 1960s, the primary method of stimulation [of gas wells in the Kansas portion of the Hugoton Natural Gas Area] was hydraulic fracturing using large volumes of low-cost, water-based fluid pumped at high rates with 1 pound per gallon of river sand." In addition to the hydraulic fracturing of new wells in the Hugoton Embayment, the procedure was also used to "restimulate" many wells drilled prior to 1950 (McCoy, et. al., 1990).

With a ready supply of cheap fuel running hydraulic pumps pulling Ogallala water up from a growing network of deep wells, Finney County agriculturalists embraced center-pivot irrigation. In 1965, 11 units watered nearly 1,800 acres in Finney County; by 1971, the total had risen to 252. That total kept growing in subsequent years: 338 units in 1972, 459 units in 1973, 590 units in 1974, and 700 units in 1975 (Sexson, 1983) (Fig. 3). The exponential growth of center-pivot irrigation across Southwest Kansas—and the High Plains more generally[6]—during the 1970s prompted one observer to call it "the most significant mechanical innovation in agriculture since the replacement of draft animals by the tractor" (Splinter, 1976).

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[5] Well diggers submitted drilling logs, many of which reveal whether or not they hydraulically fractured the well. A few of these paper logs have been digitized by the Kansas Geological Survey (KGS), most remain in paper form. The KGS charges a fee to access each file. Therefore, due to cost constraints, I was unable to tabulate the number of wells hydraulically fractured in Southwest Kansas since 1950.

[6] Between 1972 and 1978, the number of center-pivots in the state of Nebraska spiked from an estimated 3,000 to more than 17,000.

One Finney County farmer, above any other, epitomizes the mining mentality. At the height of the Dust Bowl in the 1930s, Clarence J. Gigot began snatching up vacant land southwest of Garden City. By the mid-1960s, Gigot had amassed nearly 8,000 acres in Finney County's Sandhills. Hoping to bring this scrubland into agricultural production, Gigot and his sons—Dean and Terry—traveled to Nebraska and purchased a center-pivot. In the unit's first year of operation, they harvested 120 bushels of corn per acre off the quarter section it watered (Opie, 1993). Their wild success motivated the purchase of more Sandhill land and more center-pivots. Between 1972 and 1974, the Gigots applied for and drilled 100 new irrigation wells. And by 1980, the family operated 160 center-pivots, growing over 21,000 acres of corn on largely submarginal land (Fund and Clement, 1982). In addition to raising crops, the Gigots opened two feedlots, an equipment dealership, a fertilizer company, and a gasohol operation. These consummate capitalists also leased land for oil and gas exploration. Several of the natural gas wells drilled on Gigot property were hydraulically fractured (KGS, 2013a). These wells provided the Gigots a free fuel source with which to power their expanding center-pivot empire.

Conclusion: Beyond Limits

This essay has tried to illuminate some compelling links between the tapping of the Ogallala aquifer and the development of the Hugoton Embayment. I have suggested that the rise of hydraulic fracturing literally fueled the growth of center-pivot irrigation in Southwest Kansas, the two technologies roiling together into the emergence of a mining mentality. Up to now, my argument has hinged on environmental circumstance, technological innovation and overlap, and economic motivation. I hope I convincingly outlined some synergy between center-pivots and hydraulically fractured gas wells—be it geographical, chronological, or otherwise. I want to turn, finally, to perhaps the greatest connection between these two technologies. Both center-pivot irrigation and hydraulic fracturing reveal the tendency of Southwest Kansans (and Americans more generally) to push beyond environmental limitations.

By the early 1980s, scientists recognized that the pumping of Ogallala water for agricultural use was depleting the aquifer at a shocking rate. Between 1973 and 1981, the water table in Finney County dropped an average of 4.2 feet per year (Fund and Clement, 1982). By the late 1980s, the Ogallala's saturated thickness there had declined by a whopping 21%, representing a loss of over 100 feet since the introduction of deep-water wells around 1940 (Duncan, 1987). By 2007, the Kansas Geological Survey estimated that the aquifer's saturated thickness across much of the county had decreased by at least 30% and by up to 45% in some places (Buchanan, 2009).

This warning did no go entirely unheeded. Whereas in the 1960s, well applications in Finney County were seldom denied, in 1977 six out of ten failed. By 1987, the county rejected nearly 90% of applications (Opie, 1993). But this policy does not necessarily suggest a shift away from a mining mentality. Instead, it may owe largely to Kansas water law and the protection of water interests, especially during times of shortage, based on the adage of 'first in time, first in right.' Indeed, in some respects, things have changed surprisingly little in Finney County over the past twenty-five years. Agricultural water usage there has remained relatively steady, averaging around 340,000 acre-feet annually. Even more telling, in 2010, Finney County farmers irrigated 216,743 acres; they dedicated roughly two-thirds—146,316 acres—to water-intensive corn and alfalfa, much of which funnels directly into the region's many feedlots. And, although the exact number of center-pivot units in use remains unavailable, farmers did report using center-pivots systems to water roughly 190,000 acres, accounting for close to 90% of all irrigated acreage in Finney County (KDA, 2011).

The past three decades of gas exploitation in the Hugoton Embayment demonstrates a similar disregard for environmental limits. By the 1970s, roughly 650 gas wells in Finney County produced around 55,000,000 cubic feet annually (KGS, 2013a). When returns began to dip in the late 1970s, oil and gas companies once again began hydraulically fracturing old wells in the area hoping to increase their deliverability. But annual gas yields continued to decline into the mid-1980s, when 800 wells extracted less than 40,000,000 cubic feet each year. In 1986, the Kansas Corporation Commission (KCC), the agency responsible for regulating oil and gas exploration and production in the state, began allowing well operators to infill up to 25% of their leases annually. This measure effectively reduced well spacing from 640 acres to 320 acres (Hecker, et. al., 1996). In the fifteen years following, the number of gas wells in Finney County surged from 803 to over 1,300. Production followed suit, peaking around 54,500,000 cubic feet in 1996 (KGS, 2013a). However, output again declined in the early 2000s. By 2010, slumping natural gas production—to levels not seen since 1954—prompted the industry to introduce the controversial technique known as high-volume horizontal hydraulic fracturing.[7]

Perhaps even more effective evidence of Southwest Kansans' determination to (over)utilize natural resources comes not from statistics but from the mark eight decades of water and natural gas mining has left on the landscape. Driving through Finney County, it is impossible not to notice the pump jacks bobbing up and down along the horizon. The predominance of crop circles, especially when seen from an airplane, is even more powerful. On 1 October 2012, the United States Postal Service (USPS) issued a set of fifteen "Earthscape" Forever stamps. Taken high above the earth's surface by either photographers in aircraft or

[7] In 1954, 378 wells produced 28,048,734 cubic feet; in 2010, 1364 wells produced 20,943,503 cubic feet.

orbiting satellites, the collection gave the American public a bird's-eye view of three of the country's most dominant landscapes: natural, agricultural, and urban. The USPS cleverly arranged the booklet (three rows of five stamps) to mirror the geography of the United States. In the upper right corner sat a picture of Maryland's Blackwater National Wildlife Refuge; in the upper left a photograph of Alaska's Bear Glacier. The lower left stamp showed suburban Clark County, Nevada; the lower right a highway interchange in Miami, Florida. An image of center-pivot-irrigated fields outside of Garden City, Kansas, captured by the NASA/USGS Landsat 7 satellite, anchored the center of the collage (Fig. 4). The stamp served as a not-so-subtle suggestion of the geometric transformation that has taken place on the High Plains of Southwest Kansas.

Figures

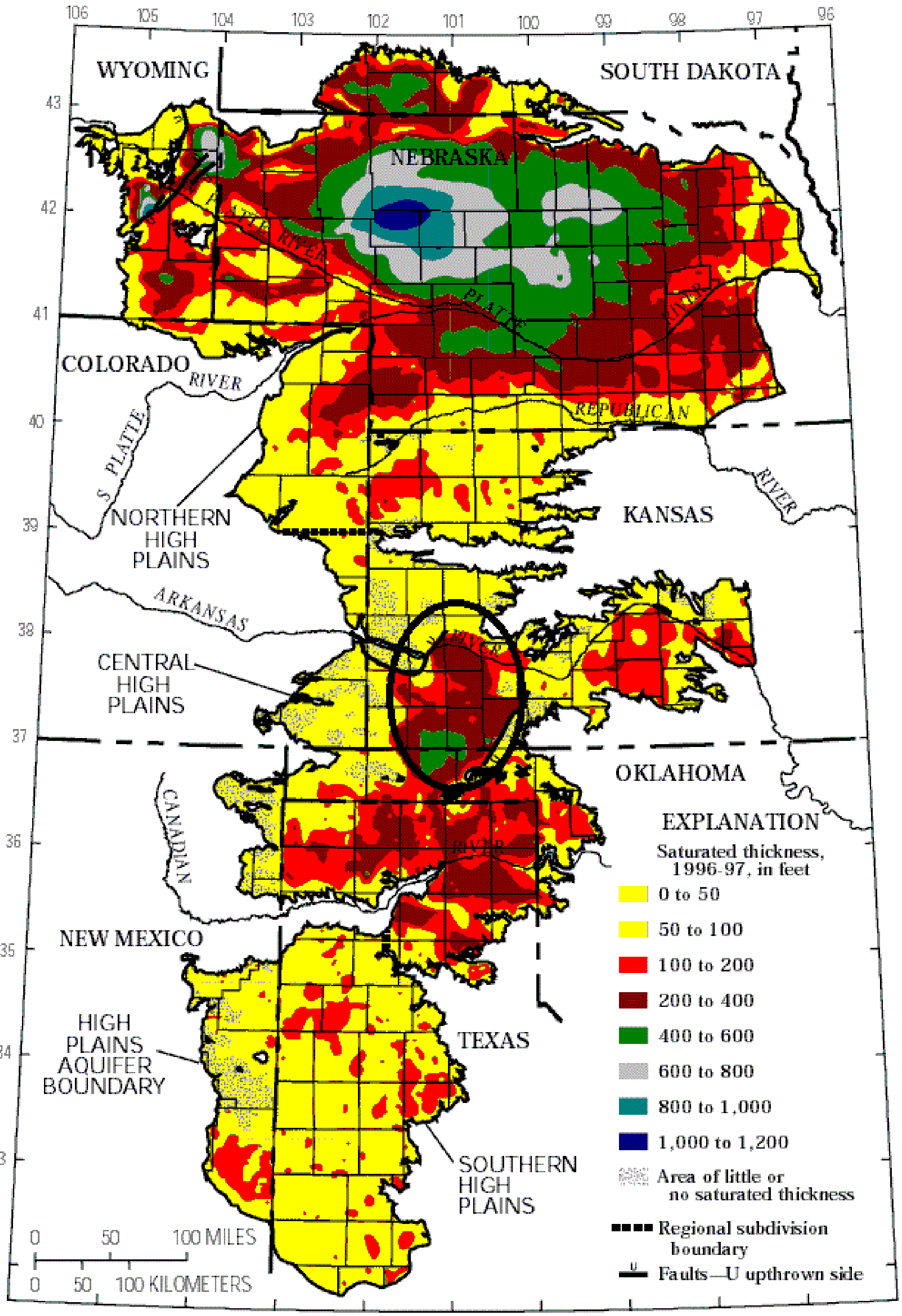

Fig. 1. The Ogallala Aquifer. Southwest Kansas saturation circled. Credit: www.data.gov.

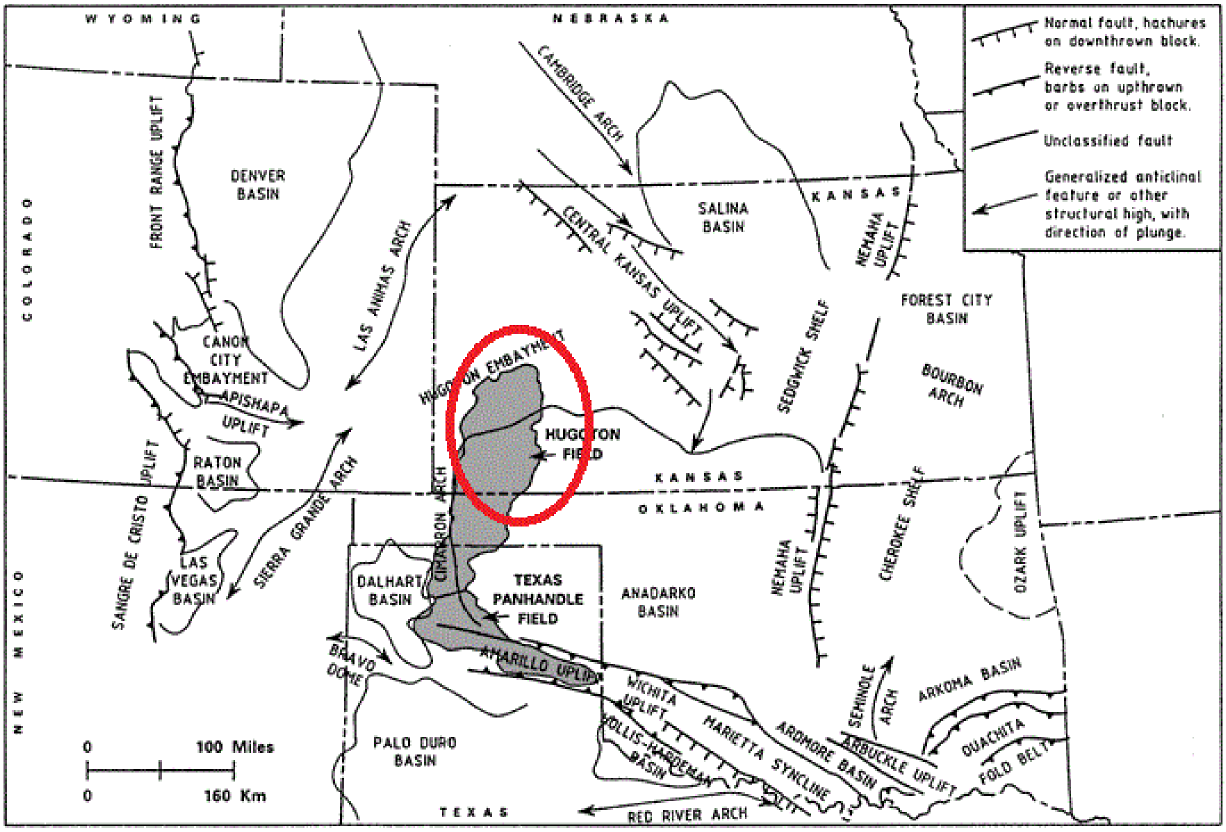

Fig. 2. Regional oil and gas stratigraphy. Hugoton Field circled. Credit: Kansas Geological Survey.

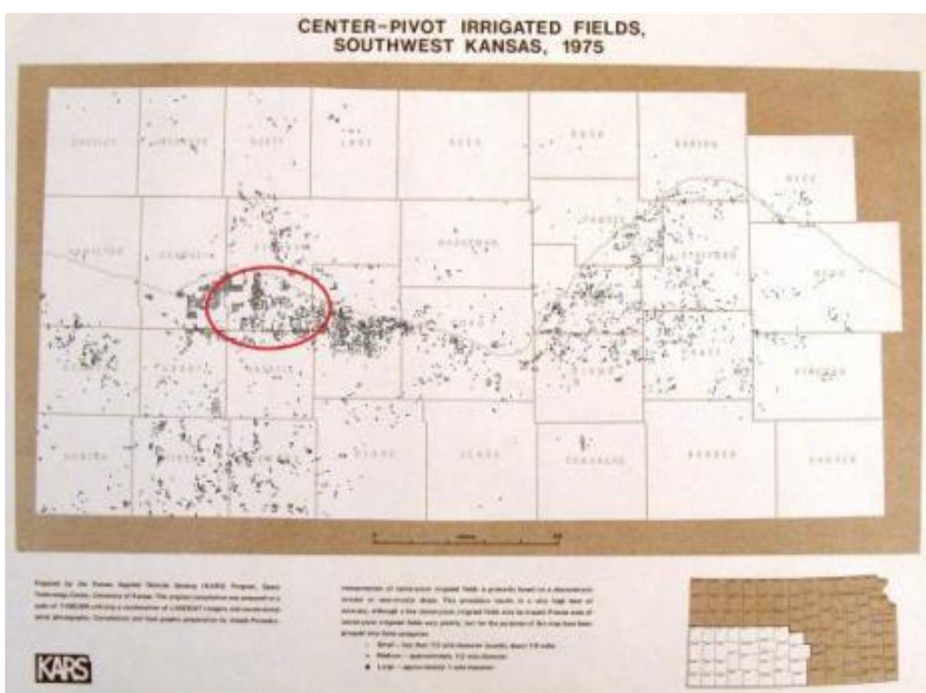

Fig. 3. A plot of center-pivot systems in use in Southwest Kansas in 1975. The red circle highlights the Sandhills southwest of Garden City, Kansas.

Fig. 4. "Earthscape" Forever Stamp featuring center-pivot circles outside of Garden City, Kansas.

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