

# **The West Plains Sewage Lagoon Drama, 1978: A Lesson on Infrastructure Failure in a Karst Landscape**

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## *Abstract*

This paper chronicles the 1978 collapse of the sewage lagoon that served the city of West Plains, Missouri—a disaster that polluted local wells and sickened hundreds. The event reinforced lessons about building infrastructure in regions known to be vulnerable to sinkhole formation. The geologic term for the local terrain is “karst,” which is characterized not only by sinkholes, but also by caves, springs, and losing streams. The ground in karst areas can be susceptible to collapse, and the groundwater below is vulnerable to contamination from the surface. In West Plains, a natural earth process was triggered by land development. As population and development increase, the potential for future similar disasters could increase.

## *Introduction*

In the late afternoon on Friday, May 5, 1978, a city employee routinely checked the 37-acre sewage lagoon that served some 7,500 residents of West Plains, seat of Howell County in south central Missouri. He saw that a small sinkhole had developed. The water level in the lagoon had dropped about one foot, which translates to about 25 million gallons of sewage that had disappeared underground.<sup>1</sup> Due to the weekend and a state holiday on Monday, the situation was not reported to environmental authorities until Tuesday, and by the time a state geologist inspected on Wednesday, the lagoon appeared to have resealed itself.<sup>2</sup> Neither the city nor state officials involved issued any statements or warnings.

Also on Wednesday, the local health department found itself tracking a sudden epidemic whose victims suffered flu-like symptoms and intestinal disorders, but the health department was not aware of sewage in the groundwater. Not until Friday—a full week after the sewage loss—did the puzzle pieces fit together. The state director of health promptly issued a boil water order for a section of south central

Missouri.<sup>3</sup> By then 50 people were reported sick, and finger-pointing began as to why the public had not been notified earlier.

By Tuesday of the following week, May 16, the illness tally was at 275.<sup>4</sup> Late that evening, two new sinkholes opened in the floor of the lagoon. Whirlpools formed, sucking down foul green liquid as if draining a bathtub. Most of the lagoon's remaining contents, an estimated 25-50 million gallons, disappeared by Wednesday evening.<sup>5</sup> During the following days, a host of government bureaucrats converged upon the city. The National Guard trucked in drinking water, the EPA ran water tests on hundreds of private wells, and reporters covered tense meetings that ensued between city, state, and federal officials. Media coverage thrust the city into a national spotlight.

City water remained safe; sick people had drunk from private rural wells, and those victims became angry with city officials. By the end of May, health authorities had collected reports of about 800 people ill with symptoms.<sup>6</sup> But within a few weeks, those who were ill had recovered, local wells cleared up and the publicity blew over. Several results endure. West Plains received emergency federal funding and by late 1979 completed a state-of-the-art sewage treatment plant to replace the faulty lagoon.<sup>7</sup> The Missouri Department of Natural Resources (DNR) evaluated other towns' sewage lagoons for collapse risk; several nearby towns subsequently also obtained federal funding to build new sewage treatment plants. Due to comprehensive site evaluations implemented by DNR, no sewage lagoons built in Missouri since 1978 have collapsed.<sup>8</sup>

This paper focuses on events in May and June, 1978, leading up to and during the media and agency flap that followed the collapse. Certain questions stand out. How was geology involved in the collapse? Why did the city build a sewage lagoon in a poor location? Why did word not get out to the public until a week after groundwater was contaminated? Did city officials cover up? A high percentage that became ill had eaten at the local Dairy Queen. Questions arose over whether that restaurant's private well was contaminated by the lagoon effluent or another source. Where did the lost sewage go? How did the public react?

These questions are addressed herein, but two threads run through. One thread addresses how relationships between govern-

ment entities and the public played into the epidemic. The other discusses the relationship between geology—the land under West Plains residents' feet—and the structures that people had built there, such as wells and lagoons. This land's underside hasn't changed, and understanding its character is still important today as new structures are built upon it.

In 1978, the local daily newspaper extensively covered the collapse and resulting epidemic. Government agencies involved produced at least six day-by-day reports. These primary sources provide a thorough examination of events; they serve as foundation for this report, supplemented by personal interviews, maps, engineering reports, geological reports, and a survey of residents.

While a few recent publications briefly mention this dramatic 1978 event,<sup>9</sup> no comprehensive account of it has been published, thus the story herein fills a void in the historical record.

### *Karst Topography is Vulnerable in Two Ways*

Land in karst areas—which is characterized by caves, springs, sinkholes and losing streams—is susceptible to catastrophic collapse and to groundwater pollution;<sup>10 11</sup> the West Plains sewage disaster dramatically demonstrated both, but many more instances have been documented.

As populations grow and as land development spreads nationwide, the construction of buildings, roads, lakes, and lagoons is likely to take place on land at risk of sinkhole formation. Karst regions similar to those in south central Missouri exist in Arkansas, Kentucky, Tennessee, Virginia, West Virginia, Florida, and many other places around the world (see Figure 1).

This topographic feature is common in areas once covered by seas, where sediment deposits were compressed into carbonate rock such as limestone or dolomite. After seas subsided, the exposed sedimentary rock was subjected to surface erosion and also to weathering beneath the surface. Rainwater found its way into cracks, dissolved the surrounding rock, and formed underground conduits. Some channels enlarged into massive caves that house vast underground water reservoirs; some are sources for springs.<sup>12</sup>

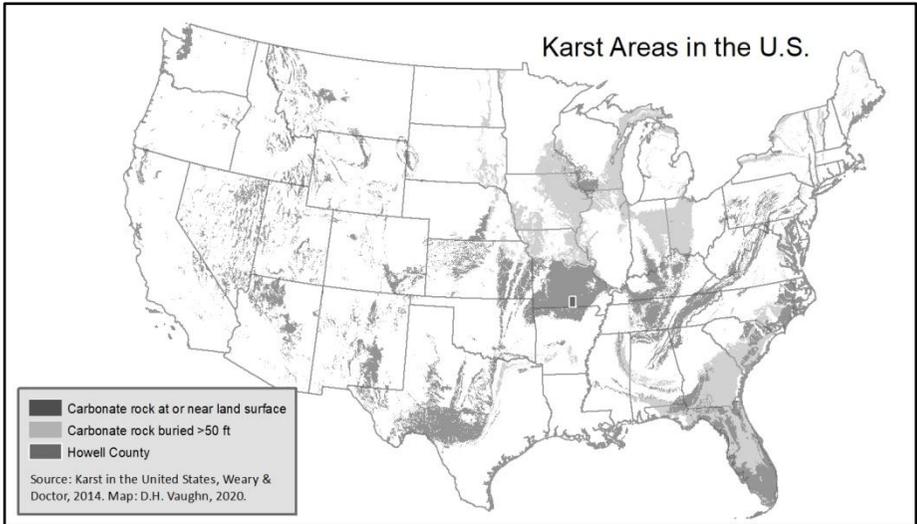


Figure 1. The Ozarks are among the largest and most heavily concentrated karst areas in the U.S.

In well-developed karst areas, the ground beneath a surface stream can become so laced with conduits feeding into the subterranean system that the stream won't hold water at all except when flooding fills the underground voids. A number of dry losing streams such as this are in Howell and surrounding counties (see Figure 2).<sup>13</sup> Their water is drawn underground and channeled to Mammoth Spring, 28 miles to the southeast, which is the source of Arkansas' Spring River.<sup>14</sup>

In a karst area networked with underground tunnels large and small, matter from the surface inevitably washes downward into dark passageways, usually during storms. For rural residents who rely on this for their well water, murky water after storms is a fact of life. Normally this infrequent natural flush—typically soil, leaves and gravel—merely clouds groundwater temporarily, then settles, and water quality returns within a day or two. But when contaminants associated with development—like farm chemicals, sewage or other pollutants—enter from the surface, the defenseless condition of this open groundwater system becomes quickly apparent.<sup>15</sup>



Meandering through West Plains and then south past the city's wastewater treatment plant is Howell Creek, a classic losing stream. (Photo: D. H. Vaughn)

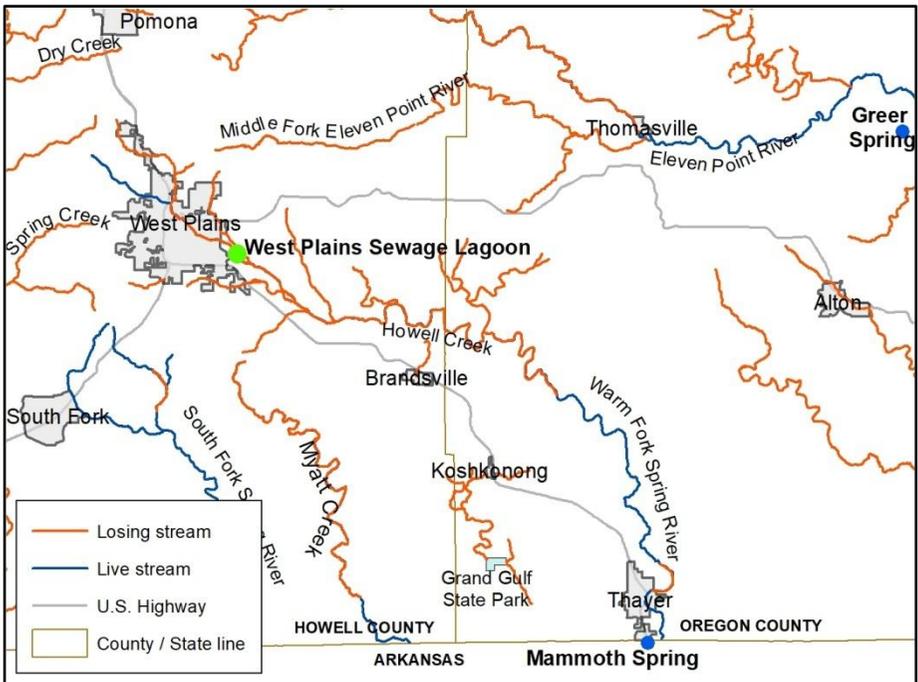


Figure 2. Losing streams dominate much of Howell and Oregon counties. The rain-water that disappears underground in these streams reappears in large springs, such as Mammoth Spring and Greer Spring. (Map: D. H. Vaughn)

### *Sinkhole Formation is Usually Slow and Subtle*

As soil erodes and is deposited subsurface, the land surface lowers. Usually this occurs insidiously, and can go almost unnoticed in sparsely populated forest land, or be a mere annoyance to a farmer trying to maintain pasture. But when human development intersects with a highly developed karst landscape, even small sinkholes become important. In a school district not far from West Plains, a small sinkhole opened under a school's foundation in 2007, leading to construction of a new school building.<sup>16</sup>

For the past half-century, the city of Farmington, about 70 miles southwest of St. Louis, has been plagued with some 48 sinkhole collapses, some seriously destructive to buildings and city infrastructure.<sup>17</sup> Forty miles east of Farmington, in Perryville, sinkholes also form frequently. That city actively manages some 300 sinkholes within city limits, many of which are close to houses.<sup>18</sup>

Catastrophic collapses, although rare, make news, especially when expensive construction is involved. A newly formed sinkhole—ultimately 75 feet deep—was caught on video in Nixa, Missouri, in 2006. TV viewers saw part of a suburban house collapsing into the hole. The garage fell in and the car inside was never recovered.<sup>19 20</sup>

### *Sinkhole Collapse Risk Increases when Impoundments Built*

Dammed water can be particularly troublesome in karst areas because the weight of water bears down on the land that supports it. The West Plains sewage lagoon was neither the first nor the last Missouri impoundment built on karst to spill its contents into underground channels.

A number of sinkhole-induced lake failures were documented in counties near West Plains during the 1960s.<sup>21</sup> One spectacular collapse occurred in the early 1960s only 15 miles north of West Plains, at the Dean W. Davis Reservoir. The lake's dam, built in a losing stream valley, held water for only a short period after construction. A sinkhole drained the lake overnight.<sup>22</sup>

In 2004, a 23-acre recreational lake—the centerpiece for an affluent residential development on the outskirts of St. Louis—drained

suddenly via a sinkhole in a karst area. Homeowners paid about \$650,000 for repairs to regain their waterfront properties.<sup>23</sup>

### *Band of Deeply Developed Karst Creates Unusual Conditions*

While much of the Ozarks sits on karst terrain, one area stands out. The ill-fated Dean Davis lake rests near the north end of “a band of intense karst development, several miles wide” that covers segments of Howell and Oregon counties. It begins a few miles south of Willow Springs and runs to Thayer. West Plains lies in the middle.<sup>24</sup>

This is a land of many sinkholes, home to sink basins up to several thousand acres in size (see Figure 3). In these basins, rainwater has no stream in which to flow. Consequently, storm water drops below the surface and flows southeast through deep conduits toward Mammoth Spring.<sup>25 26</sup>

Geologists and hydrologists understood the vulnerability of this highly developed karst terrain prior to the lagoon collapse in 1978. Nearby lakes had collapsed in the 1960s. Then in the early 1970s, the pollution risk had been demonstrated through dye traces, which had proven a direct connection between sinkholes and discharge to area springs.<sup>27</sup>

### *During 1960s, Laws Less Stringent, Financing Less Available*

But less of this was understood in 1964, when the West Plains sewage lagoon was built. Then, city wastewater systems were overseen by the Missouri Division of Health, and restrictions were less stringent than today.

The Federal Clean Water Act and environmental enforcement agencies did not exist. Geologists with the Missouri Geological Survey, Rolla, were available for consultation, but those receiving their expert advice were free to accept or reject it. Also at that time federal and state financing for infrastructure, such as municipal wells or sewage treatment plants, was not readily available.<sup>28</sup> The Ozarks, with its generally limited natural resource base, has historically been sparsely populated and economically depressed, which has a negative impact on local tax bases.

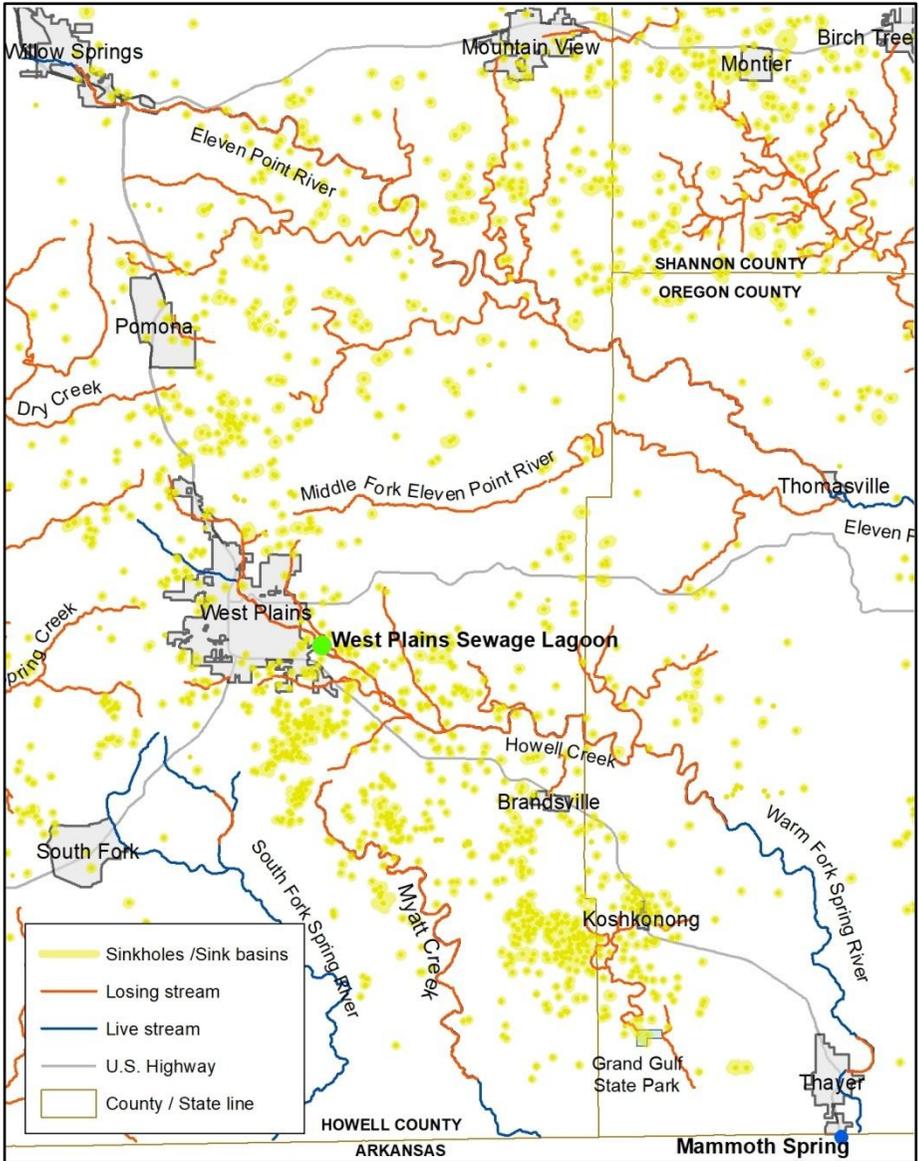


Figure 3. Sinkholes and sink basin are heavily concentrated in a band of intense karst development several miles wide that runs from Pomona to Thayer. Karst features are also concentrated in the upper Eleven Point River watershed. (Map: D. H. Vaughn)

### *City Leaders Examine Options*

Against this backdrop, West Plains city officials were faced with a tough decision when the flow from the town's growing number of toilets outpaced capacity at their small sewage treatment plant on Bratton Avenue. Residents numbered just under 6,000 in 1960, but this number increased by almost 1000 by 1970.<sup>29 30</sup>

They needed something better than the type of plant they had, which was an "old trickle filter system" consisting of merely "a big tank of rocks and filters, with some biological growth."<sup>31</sup> But the better system cost a lot more. It involved a central concrete basin, which allowed solids to settle, and expensive mechanical equipment and chlorinators.<sup>32</sup>

City leaders decided on a third option, a sewage lagoon, a common choice in the 1960s. These shallow artificial lakes were inexpensive in both construction and maintenance. Lagoons take advantage of gravity to settle solids and of sunlight to grow algae and microorganisms that will kill bacteria and decompose organic matter.<sup>33</sup>

Finding a good site was more difficult than choosing the system. A state geologist looked at three potential sites. Apparently the karst terrain was not a primary concern, because his report did not focus on such risks, although he mentioned that "cavernous bedrock" could contaminate groundwater. But collapse risk was not mentioned at all.<sup>34</sup>

Two of the sites were much too small. City leaders selected the largest site, about 60 acres in a broad, open plain next to Howell Creek, a classic losing stream. "The valley floor has been noticeably sculptured by sinks," wrote a geologist in 1972.<sup>35</sup>

Even though the site later led to a major drama, in the city's defense, options were limited. Both of the other choices were also in a losing stream valley. State geologist Jim Hadley Williams defended the city's 1964 decision, saying every nearby site was at risk of leaking or collapsing.<sup>36</sup>

### *A Lagoon is Built*

West Plains voters passed a municipal bond issue, and the lagoon was built at a cost of \$358,000.<sup>37</sup> During construction, earthen berms were built up above ground level to form a rectangular barrier around the lagoon's perimeter. The small lake was divided into two cells.

Untreated effluent entered the primary cell, 37 acres on the upstream side. Later the wastewater passed into the 12.5 acre polishing cell at the downstream end. The finished effluent was eventually discharged into Howell Creek.

The hidden treacheries of the subterranean karst topography caused problems from the start. The first collapse occurred in 1964 during construction, resulting in a hole in the polishing cell about 17 feet in diameter and 10-20 feet deep. Workers filled the hole with cement, clay and bentonite, a material that absorbs water and expands, commonly used to seal ponds.<sup>38</sup>

When a 34-foot sinkhole opened in the primary cell during 1966, it “created a vortex of such size” that a city worker “was unwilling to get close to it with a boat.” The 37-acre cell drained in 52 hours. A peninsula was built into the lagoon to access the hole, which was repaired with clay and bentonite.<sup>39</sup> The peninsula remained in place, protecting the capped sinkhole.

The EPA reports “another minor collapse,” believed to have occurred in the polishing lagoon in 1974.<sup>40</sup> None of these instances resulted in evidence of sewage downstream, or any reported illnesses. Nor was any agency, the media or the public notified; this set a precedent for 1978.<sup>41</sup>

### *New Laws Instigate Plan for New Sewage Plant*

Increased environmental awareness nationally led to the creation of the EPA in 1970, the Federal Clean Water Act in 1972, and the formation of the Missouri Department of Natural Resources (DNR) in 1974. The Missouri Geological Survey merged with DNR. By 1975, the city had been told that the sewage lagoon’s effluent being discharged into Howell Creek did not meet new water quality standards, especially since the receiving creek was a losing stream. Too much bacteria and suspended solids were descending into the groundwater.<sup>42</sup>

Thus, by 1978 when the lagoon floor gave out for the last time, the city had already hired engineers to design a new sewage treatment plant, and the city had applied for a federal construction grant. Karst terrain was still not being seriously considered; engineers produced a design that used a portion of the existing earthen lagoon as a wastewater holding area. As the new system was being designed, these

engineers were warned by a state geologist who evaluated the site in 1975. His report predicted “a distinct likelihood of a catastrophic sink-hole collapse occurring beneath the proposed lagoon.” The geologist recommended selecting a different type of sewage plant.<sup>43</sup> However, engineers proceeded with their original plan. A second geological report, issued in April 1978, only one month before the disaster, said “integrity of the existing lagoons is very questionable. Further collapses could occur at any time.”<sup>44</sup>

### *DNR Tests a Problematic Private Well*

One more separate scenario set the stage for the disaster. At that time, the Dairy Queen, located south of town on U.S. highway 63, was the only fast food restaurant along the highway, so many passers-by stopped there. Sitting just outside of city limits, the establishment was not served by city water; instead, a private well provided water for about a dozen businesses and residences in that area. DQ was a water customer and not the responsible party for this well.

This private well failed a water quality test in mid-April, 1978, and again in early May.<sup>45</sup> On May 3, a DNR staffer told well owner, Don Brown, that he would need to install disinfectant equipment. Brown said he would rather quit using the problematic well and hook onto nearby city water lines. Two days later he requested city water service for his water customers.<sup>46</sup>

### *Preludes to an Unfolding Disaster*

On the evening of Friday, May 5, the same day that Brown requested city water hookup, Street Department Supervisor Jerry Lung conducted a routine inspection at the city sewage lagoon. The lake, normally four-foot deep, had dropped over a foot.<sup>47</sup> A small sinkhole had formed in the peninsula built in 1966 to cover the sinkhole that year.<sup>48</sup>

That day, Dairy Queen owner Lowell Shrable first noticed discolored water.<sup>49</sup>

The next day Lung told his boss, City Engineer Lowell Patterson, about the wastewater loss.<sup>50</sup> They opened pipes, allowing water from the primary cell to drain into the polishing cell, lowering the water level and easing the pressure on the new sinkhole.<sup>51</sup>

At DQ, water quality was worse. Schrable brought in tanks of city water; he used them until the city water lines were hooked up five days later. Saturday was the last day DQ used the private well.<sup>52</sup>

On Monday, Patterson tried to notify officials of the lagoon leak, but discovered that state offices were closed due to Truman Day, a state holiday. City Hall received two calls from people “concerned about water quality at Dairy Queen.” They were referred to the health department.<sup>53</sup>

Both Patterson and another city employee on Tuesday called the DNR regional office in Poplar Bluff; their report of wastewater loss was relayed to supervisors in Jefferson City. The regional DNR director advised Patterson to get recommendations for repairs from DNR’s geology division. Patterson told DNR that health authorities had also been notified.<sup>54</sup>

Wednesday morning, local health department director Eddie Wooldridge found two notes on his desk about people who claimed to be ill from eating at the Dairy Queen.<sup>55</sup> He notified the state epidemiologist in Jefferson City. “Investigate,” directed Wooldridge’s superiors. Later, a woman came into the office with several sick kids, saying they had all become ill after eating at DQ. She mentioned that some track meet competitors from out-of-town high schools were also ill.

Later on Wednesday, as Wooldridge was tracking down leads for the DQ illnesses, he and Patterson discussed the bad water samples from Brown’s well. Patterson said the well owner wanted city hookup and was “trying to place blame (for their bad samples) on the lagoon.” But at no time did Patterson “indicate a major leak,” Wooldridge maintains.<sup>56</sup>

That day, the city council met with Don Brown and his attorney; the city agreed to provide temporary water service for his well users.<sup>57</sup>

Also on Wednesday, state geologist Jim Hadley Williams dropped by to inspect the city lagoon, detouring from other field work to West Plains. The sinkhole was no longer draining, Williams observed. Transferring effluent from the primary cell into the polishing cell apparently had proved effective, and the sinkhole had “sealed itself.” No city workers were at the lagoon site, and Williams left town without contacting anyone.

On Thursday, city workers completed construction and disinfection of temporary water lines to Brown's well customers, including Dairy Queen.

Patterson learned of Williams' lagoon inspection conducted the previous day. He again asked for technical recommendations for lagoon repairs. The lagoon showed no signs of leaking.<sup>58</sup>

That day Wooldridge and a nurse traveled to Mountain Grove and Houston, investigating illnesses among girls track team members. They began by assuming a food-borne illness, but "some of those made ill mentioned the bad taste of the water," and the trend of the interviews "tended to implicate water as the source of illness."<sup>59</sup>

### *Health Department Pieces the Puzzle Together*

By Friday, May 12, a full week had passed since Lung first noticed water loss in the lagoon. That day, Wooldridge, while zeroing in on water as the probable cause of the DQ illnesses, remembered Patterson mentioning the city lagoon. He asked Patterson if there was "some major problem with the lagoon that should be considered." Patterson would only speak to him with the city clerk present. "To the best of my memory, that was when I learned that a major leak had occurred," Wooldridge later reported. He called his boss.<sup>60</sup>

The boss, Poplar Bluff sanitarian A. F. Crownover, had inadvertently just found out the same thing. Dairy Queen's water supply was under DNR jurisdiction, and Crownover had called DNR to say that the health department was considering closing the restaurant. The DNR regional director told Crownover that he "could understand the problem because the bottom had dropped out the West Plains sewage lagoon." Suddenly, the mysterious rash of illnesses made sense.

Like a lit fuse, the news sizzled up the chain of command. The health department chief in Jefferson City issued a boil water order within five minutes of hearing the news. Forces mobilized. The state epidemiologist was dispatched to the scene. A state geologist was consulted to delineate an area likely to be affected, and Arkansas health authorities were notified about possible effects on their water supplies. Press releases were hurriedly disseminated.<sup>61</sup>

The story finally broke into print news in the Friday issue of *The West Plains Daily Quill*, one full week after the sewage loss. The story

said at least 50 people were suffering nausea, vomiting, and diarrhea, and it directed anyone not on a chlorinated water system to boil water to cook and drink.<sup>62</sup> But the news came too late for hundreds who were ultimately sickened.



*In the foreground of this May 15, 1978, photo is the small sinkhole that formed in the peninsula within the city's lagoon. (Photo courtesy West Plains Daily Quill)*

### *Reflections on the Public Notice Delay*

Who-told-who-what-and-when was the subject of at least seven reports—written after the event—when staffers with nearly every government entity involved enumerated their day-by-day actions; apparently all were trying to diffuse blame for the delay in notifying the public.

Taken together, the reports resemble a string of dominos that just won't fall down.

Part of the delay was just unfortunate timing. Lung didn't tell Patterson until Saturday. State offices were closed Monday, so DNR wasn't notified until Tuesday.

Key clues in conversations were misinterpreted. During a discussion Wednesday, Wooldridge thought Patterson was referring to the “landfill” when he actually said “lagoon.”<sup>63</sup>

Some reports are contradictory. The most significant inconsistency revolves around a claim about when or if the city notified the local health department about the lagoon loss. On Tuesday, Patterson told DNR that the wastewater plant operator had notified the division of health. The secretary in that office emphatically denies receiving any such phone call.<sup>64 65</sup>

Some individuals may have underestimated the situation’s urgency. Several days after geologist Williams dropped by to inspect the leaking lagoon, the city was still waiting for word on how to proceed with repairs. Williams, when prodded for a report, apparently misunderstood the request and sent background data, rather than repair recommendations.<sup>66</sup>

Contributing to the delay was the tendency for government officials to stick with their own agency. Staffers apparently did not feel responsible to notify anyone beyond their boss. Each agency has clear documentation of the word going up the chain of command, but crossover was minimal. DNR officials did not contact the health department or the EPA. That agency was not informed until even later, May 17; they found out when a reporter asked their role in the crisis.<sup>67</sup>

Clearly, intentional obfuscation also played a role. On Monday, a *Quill* editor thought city commissioner Joe Pyles must be joking when he heard Pyles tell a city employee not to make any statements to anyone about a leak in the city “reservoir.”<sup>68</sup> When that same editor sent a reporter to question Pyles about the “reservoir,” Pyles said “there was nothing to it.”<sup>69</sup> When Wooldridge asked Patterson about complaints of bad water at the local Dairy Queen, Patterson replied that he “would answer questions but could not volunteer information by order of the city officials.”<sup>70</sup>

Former *Quill* Publisher Frank L. Martin III has no doubt the city covered up. “We first heard about the leak when someone driving by on the highway noticed the water level was low,” he said. That person called *The Quill* to ask why. A reporter checked and determined the lagoon was leaking. When asked about it, Patterson was evasive at first, but then came into the *Quill* office to explain. “He said he was

supposed to have kept it quiet but filled us in since the cat was out of the bag,” Martin said. “I think he feared for his job. Everyone did go to prodigious efforts to keep things quiet.”<sup>71</sup>

Ultimately, illnesses resulted from the delay. In a May 16 *Quill* story, the state health director would not comment on the actions of “persons outside the Division of Health” other than to say the passage of time before the sewage loss was reported “speaks for itself.”<sup>72</sup>

### *The Crisis Snowballs*

Over the May 13-14 weekend, health authorities checked out more than 100 illness reports. The boil order was extended. School was cancelled in Alton for lack of chlorinated water. Several area meat-packing plants temporarily closed. DNR and health officials tried to rustle up temporary chlorination units for unprotected water supplies in rural schools and nearby towns.<sup>73</sup>

Meanwhile, Patterson again asked state geologists for lagoon repair recommendations.<sup>74</sup>

By late Monday, the health department reported 275 people sick.<sup>75</sup>

The Tuesday edition of the *Quill* called the illness “at epidemic levels.” The state epidemiologist said that although the first illness reports came from people patronizing “a local restaurant,” newly ill people had not eaten there, indicating contamination of other private wells. Since chlorinated city water remained safe, this poisoning of only rural residents’ water source set the stage for antagonistic relations to develop between town officials and rural dwellers. Sales of distilled water and soft drinks were up. The local Coca-Cola bottling plant said the company uses only purified water.<sup>76</sup>

### *Lagoon Totally Drained*

Late Tuesday afternoon, May 16, “signs of further deterioration” appeared at the lagoon in the form of “two swirls” about “75 feet north of the first sinkhole.”<sup>77</sup>

On Wednesday, the serious situation suddenly worsened. “Millions more gallons of untreated or partially treated sewage were lost into the ground overnight” read *The Quill’s* story. A reporter described “two distinct whirlpools” where “large quantities of green-colored effluent were rushing into the two holes.”<sup>78</sup>

# West Plains Daily Quill

WEST PLAINS, HOWELL COUNTY WEDNESDAY EVENING, MAY 17, 1978

NO. 97

## News in brief

### The World

**14 killed in ambush**  
 (AP)—Fourteen Soviet military personnel were killed in an ambush and many more wounded, the Los Angeles Times reported today. The ambush occurred on the Thai-Lao border region. Official Lao news reports have not mentioned the attack. The ambush was the first of a three-vehicle column about 12 miles east of Vientiane on the highway, which runs along the border between Thailand and Laos. The report by heavy machine-gun fire, the estimate that between 500 and 1,000 military advisers are stationed in Laos, and the presence of helicopters. The estimate also estimates that between 100 and 200 Soviet advisers are in Laos, which have been operating in Laos since early in late 1975. According to military sources, the rebels include both regular and irregular forces, and are active in an area of the border.

**Body recovered**  
 (AP)—The body of a man who was killed in a robbery on the night of March 3 has been identified today. The man, who was killed in a robbery on the night of March 3, was identified today. The man, who was killed in a robbery on the night of March 3, was identified today. The man, who was killed in a robbery on the night of March 3, was identified today.

### The Nation

**Collision in Illinois**  
 (AP)—Two freight trains collided head-on on the night of May 17, 1978, in the Jackson County sheriff's office. The collision occurred on the night of May 17, 1978, in the Jackson County sheriff's office. The collision occurred on the night of May 17, 1978, in the Jackson County sheriff's office.



**MORE SEWAGE GOES UNDERGROUND**—Dr. Pat Phillips, state epidemiologist, from Poplar Bluff, photographed a second collapse in the floor of the West Plains sewage lagoon that occurred overnight, causing an estimated amount of the remaining sewage to drain into underground caverns. The city began draining as much of lagoon's contents into another nearby cell when the second break was discovered late Tuesday. The first break on May 3 appeared to seal itself after the initial loss of 300,000 gallons. The hole on the left was about six feet in diameter. The hole on the right was about eight feet across and sewage was taken about 1 1/2 in. deep. Both were 600 feet in length in the cells contained within the collapsed lagoon. The hole on the left was the primary concern in the May 3 leak occurred.

## Lagoon collapses again; Arkansas residents get warning

There was both bad news and good news, according to a rural public water district that has been found safe in recent weeks—sewage has returned to regular operation after two individual water supplies were some "waiting" in the third month that was closing more quickly than expected. The larger lagoon cell, however, is under construction. Large quantities

Above: State epidemiologist Pat Phillips photographed the two whirlpools that drained the West Plains sewage lagoon on May 17, 1978.

The EPA found out about the collapse, and a response team was dispatched that day.<sup>79</sup> West Plains residents were asked to “cut back on the volume of wastes going into city sewers.”<sup>80</sup>

Mayor Glenn Roe “was anxious to initiate repair.” He and the regional DNR director inspected the lagoon. State geologists were called, who cautioned that heavy equipment could cause more collapses, “engulfing operator and equipment in a swirl of rushing sewage.”<sup>81</sup> A firm repair plan was still undecided, but Roe got on the phone and mobilized an army of dump trucks to haul limestone from a nearby quarry.<sup>82</sup> Construction of access roads capable of carrying heavy equipment began that day.<sup>83</sup>

Illnesses now totaled more than 400.<sup>84</sup>

Thursday, three members of the EPA team arrived; more were expected from Cincinnati, Louisiana, Denver, and Washington, D.C. The EPA agreed to help by testing private wells<sup>85</sup> “to reveal the extent and duration” of the spreading underground pollution.<sup>86</sup>

The lagoon’s primary cell was virtually drained by Thursday afternoon, revealing two gaping holes plus a small one<sup>87</sup> and thick stinking sludge, littered with hundreds of condoms.<sup>88</sup> The former whirlpools, now exposed, appeared to be 15 and 20 feet in diameter.<sup>89</sup>

City wastewater continued to arrive in the supply pipe, only to go down these new holes. Thus, on Thursday, DNR agreed to allow the city to temporarily bypass the lagoon and release the sewage directly into the dry bed of Howell Creek, provided they treat it with chlorine.<sup>90</sup> This discharge disappeared into the ground 40 feet downstream.<sup>91</sup>

City officials were still waiting for instructions from state geologists. *Quill* Publisher Frank Martin remembers Mayor Glenn Roe as headstrong, who “was not going to let experts tell him what to do.” Martin recalls that while out-of-town agency staffers were away, Roe ordered up gravel and “dumped truckload after truckload into the hole.”<sup>92</sup> These truck drivers filled up the first sinkhole, formed May 5, because it could be safely accessed by way of the peninsula.<sup>93</sup> The various EPA and DNR reports do not substantiate any willful violation of their instructions, but a May 18 *Quill* article, “Mayor Starts His Own Repairs,” says Roe “made the decision on his own . . . after growing tired of waiting for state authorities to issue specific recommendations.”<sup>94</sup>

Later that day, DNR finally agreed to a repair plan for the two big sinkholes, and workers made rapid progress building a dike to isolate these recently formed craters. This approach was deemed safer than filling them. Former city wastewater supervisor Jim Woodworth was a dump truck driver in 1978. “We hauled for days and days,” working for 10-12 hours a day, he said. “Everybody in driving distance was contracted. . . . The rock bill would have been tremendous.”<sup>95</sup>



Above: Haulers dump rock to build a dike to isolate sinkholes on left. (Photo courtesy West Plains Daily Quill)

Illness reports were at 425, but tapering off. Few had required hospitalization.<sup>96</sup>

#### *Media Circus Descends on a Small Town*

By Thursday, reporters from several broadcast and print news media had visited the empty lagoon.<sup>97</sup> A gas station owner said he gave “a lot of directions to out-of-staters” who wanted to see the lagoon.<sup>98</sup> The story went out on news wires and was featured on national network news.<sup>99</sup> News clippings in DNR files document publication of the story in at least 20 cities in Missouri alone.

On the day marking two weeks since the first sewage loss, Friday, May 19, a meeting at the Ramada Inn was attended by some 50 public officials—state, federal, and local—and was covered by reporters from “as far away as Chicago.”<sup>100</sup>

The mayor was angry at the news media for suggesting that he and other city officials were “somehow to blame.” Roe said, “It’s just something that happened. It couldn’t be helped.” When the lagoon lost its contents in 1966, Roe said, no one was notified. “We just fixed it.”<sup>101</sup>

#### *Hiland Dairy and National Guard Deliver Drinking Water and Pamphlets*

That day, Friday, illnesses tallied 520. Of those, 219 were directly associated with Dairy Queen.<sup>102</sup> National Guard troops added to the

drama by traveling to West Plains with tanker trucks full of potable water for rural residents south and east of West Plains.<sup>103</sup> By May 30, the Guard had provided more than 10,000 gallons in 13 locations.<sup>104</sup> Hiland Dairy trucked in 4,000 gallons of fresh Springfield tap water in plastic jugs, which were distributed at cost to stores that sold that dairy's products.<sup>105</sup> Several thousand pamphlets printed by the state health department were flown by helicopter to West Plains and then hand-distributed by Guard members and also mailed to all postal boxes on rural routes. The flyers instructed well users how to sterilize drinking and cooking water.<sup>106 107</sup>



During the following work week, between May 22 and 26, the crisis was winding down. Dike construction was far enough along that the mayor gave orders to divert incoming wastewater away from the creek bed and put it back into the unaffected part of the lagoon, now separated from the sinkholes. The EPA was uncomfortable with any interim plan that made use of the existing lagoon, fearing another collapse. But the decision was approved because chlorinating the raw sewage as it was being released into the creek had “proved ineffective.”<sup>108</sup>

Next, the sinkholes themselves were filled with rock and clay. But before they were sealed, a geologist dumped in 10 pounds of fluorescent dye, in an effort to trace the lost effluent's path.<sup>109</sup>





*Preceding two photos: Heavy equipment operators fill the two holes that drained the lagoon. (Photos courtesy West Plains Daily Quill)*

### *Money Issues Surface; Funding Friction Begins*

Even as one element settled down, discussion on what to do next revved up. State and federal authorities were willing to help with funding. The regional administrator of the EPA went to Washington D.C. and hand-delivered a request for \$600,000 in emergency funds for West Plains.<sup>110</sup> During a meeting between city, EPA and DNR officials, the EPA advised temporary use of a portable package mechanical treatment plant, and offered to pay 90 percent of its cost. However, the mayor objected to spending any city money on an interim solution.<sup>111</sup> Despite the EPA's displeasure, city leaders prevailed, refusing to invest in any kind of temporary fix, opting for the cheaper route—to take the risk of another lagoon collapse while a new sewage plant was under construction.<sup>112</sup> The gamble paid off, as the lagoon held up as long as it was needed.

### *Rural Residents Resentful*

As the crisis unfolded, residents living south of town in the pollution's path were upset. The mayor of Thayer said "people out in eastern Oregon County are furious, scared, and mad."<sup>113</sup> When health officials held a public information meeting in Mammoth Spring, Arkansas, about 200 attended. Some "expressed dismay and hostility" toward government officials, primarily complaining about slow notification.<sup>114</sup>

Painfully obvious was the fact that city people caused the problem, but they weren't suffering the effects. When Mayor Roe said he didn't think he could get voter approval for a bond issue to pay for a new sewage plant when money was still owed on the present lagoon, Thayer's mayor pointedly reminded Roe that West Plains residents have a safe, chlorinated water supply, unlike the rural residents most affected by the spill.<sup>115</sup>

Tensions escalated between rural and city residents, particularly after Roe said "another collapse is the least of my worries" while arguing in a public meeting against spending money on a temporary sewage plant.<sup>116</sup> That attitude antagonized rural well users, many of whom had suffered gut-wrenching illness and incurred large medical bills. *Quill* letters to the editor were resentful. A Mammoth Spring business owner complained of lost business and of spending \$500 for a private water treatment system.<sup>117</sup> A rural West Plains woman said she had been boiling water and caring for ill family members for weeks.<sup>118</sup> Both criticized the city council for resistance to spending money to protect those downstream.

### *Survey: Public Reaction Ranged from Anger to Indifference*

"Why Flush," a newly-formed local environmental group, conducted a survey, randomly calling West Plains area residents. About 125 people filled out questionnaires or answered phone surveyors' questions. Some interviewees faulted the city for choosing such a vulnerable sewage treatment system. Many criticized the government for trying to cover up; they felt that "if the public had known about the collapse immediately, and the probability of widespread contamination, that much of the sickness, anxiety, and expense could have been avoided."<sup>119</sup>

Survey respondents said they learned of the collapse by newspaper, radio, and gossip. One person's water turned green. Nine reported they had become ill, and another 26 knew people who did. Eleven reported doctor bills. One person claimed to have heard over the scanner "city crews . . . checking [the] lagoon and they were avoiding the state inspectors." Some were angry and criticized the city. "[They] should have acted sooner," "The mayor made an ass of himself," "the experts screwed up again," "[I'm] disgusted at officials, mainly the mayor for not informing public."

About two-thirds surveyed were on city water, but some of them boiled water anyway. Of the 36 who tested their well water, 10 had polluted water. Two said it smelled bad.

Respondents' opinions were split on how officials handled the problem. Those satisfied thought the city hadn't been negligent and "were doing the best they can," and "it's just one of those things that happen." One person thought the situation was blown out of proportion. About one-third said they were satisfied with the proposed solution, which was to build a new mechanical treatment plant. Of those dissatisfied, one pointed to how city actions hurt rural people. "They weren't going to say anything until people got sick, so they had to [then]." Another said "the situation stinks worse than the lagoon." One was glad to be "up-wind of it, because folks downstream got a raw deal." Two said the people south of town should sue the city. "I think the city's cover-up was disgraceful, negligent, and that they are liable for everyone's sickness and expense." And finally, one person had "bad dreams of our house sinking into such a hole."<sup>120</sup>

### *Epidemic Numbers Finalized; CDC Proclaims Cause*

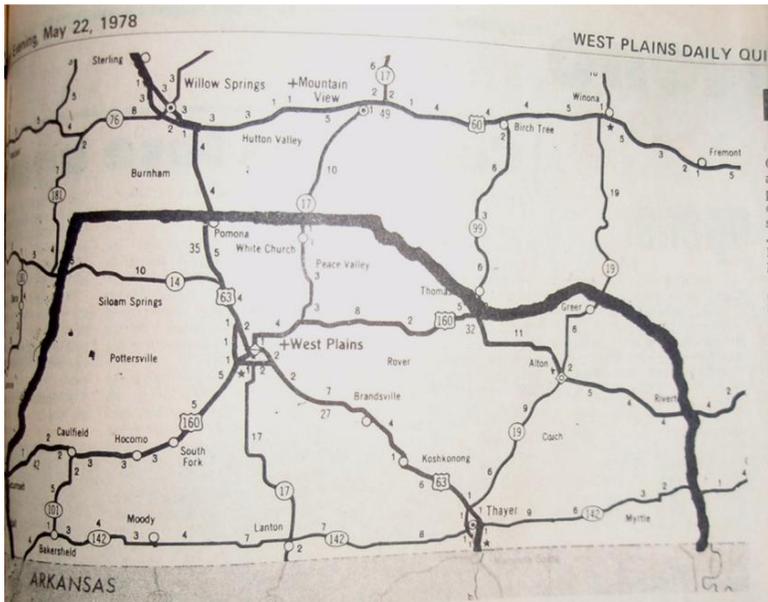
In late May, even as local illness reports tapered off, the total tally continued to climb, in part because "travelers who were passing through . . . [had] later read about the epidemic" and reported in to the health department.<sup>121</sup> As of May 24, about 309 of 759 reported illnesses were directly related to DQ.<sup>122</sup> The last published daily tally was on May 26, at 780.<sup>123</sup> All subsequent reports put the final number at 800.

Not until June 5 was there an official proclamation that "confirmed what health authorities [had] suspected all along." The Centers for Disease Control (CDC) in Atlanta said "the gastroenteritis suffered

by rural residents after May 5 could be blamed on raw sewage contaminating groundwater.”<sup>124</sup>

*Well Water Tests Inconclusive, But Show a Southeast Trend*

Early on *The Quill* published a map provided by health authorities of a large “suspect area,” which included areas north of West Plains and much of Oregon County.<sup>125</sup> Later, the suspect area was expanded even farther to the north and west (see below). Both maps were unrealistically large, and unnecessarily added to residents’ fears.<sup>126</sup>

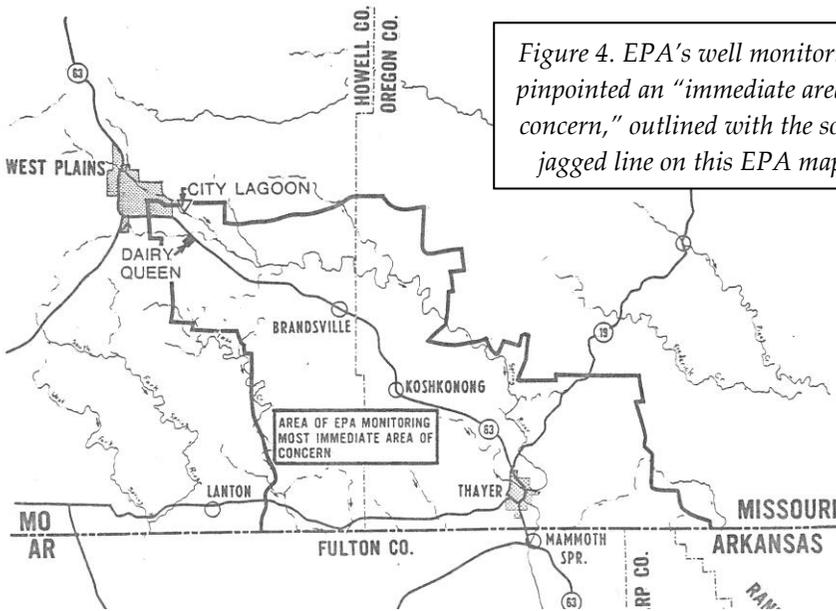


*This map, published May 22, 1978, shows a large area of concern. Well testing and dye traces later determined that this map far exceeded the area where polluted water actually traveled.*

The EPA tested about 1000 water samples from private and public wells in the affected areas south of town, plus a few wells farther away as a control group.<sup>127</sup> Tests showed 47 percent of private wells tested had unsafe bacteria levels.<sup>128</sup> The data were inconclusive, by EPA’s own admission. “No simple interpretation . . . will make sense out of all the sickness and water sample reports” said health authorities.<sup>129</sup> Bad wells showed up all over, even in the control area. This percentage

of polluted wells is not out of line with two other rural Missouri well studies, which were done during “normal” times.<sup>130</sup>

The EPA soon realized that so many variables affected well water quality that a proper scientific study was nearly impossible. Samples were collected on a voluntary basis, not randomly. Until 1974, Missouri had no well construction law for private wells.<sup>131 132</sup> The EPA’s Harry Gilmer said there was “no direct proof—other than the outbreak of illness following the sewage leak—that the high number of contaminated wells in the area resulted from the . . . lagoon.” The problem was “too many of the wells in the area are improperly constructed, improperly maintained, and improperly located, resulting in high contamination from other sources.”<sup>133</sup> Despite the “interferences and complex results,” the EPA concluded that their data showed “a trend” indicating that “the sewage followed a very narrow path from the lagoon to Mammoth Spring.” Around 71 percent of private wells in a triangle-shaped area southeast of West Plains (see Figure 4) were contaminated, as compared to only about 26 percent in a control area north of Pomona.<sup>134 135</sup> Testing also showed that “bacteria were not remaining trapped underground and continuing to breed,” which relieved people’s minds.<sup>136</sup>



### *Fate of the Vanished Sewage Suspected but Unproven*

The foul contents of the West Plains lagoon were never conclusively located, but strong evidence gave clues to their whereabouts. Charcoal filter packets had been strategically placed at several area springs in hopes of intercepting the dye injected May 18 into the lagoon sinkholes, before they were capped. Dye was recovered on May 30 at Mammoth Spring (see Figure 5). No dye was found anywhere else.<sup>137</sup> Fortunately, Mammoth Spring never appeared or smelled polluted. Daily tests for fecal bacteria showed only a slight rise; spring water stayed within the range considered safe for swimming during the time frame when the lagoon failure was expected to affect the spring.<sup>138</sup>

DNR investigators found another clue of the sewage's fate, a "resurgence" at Culp Ford on Howell Creek, about 16 miles downstream from the lagoon. "Evidence in the stream bed suggests a flood surge of short duration," with "a very odorous condition." The streambed was dry both upstream and downstream from this area, which suggests the surge came from underground and returned there.<sup>139</sup>

Very likely much of the effluent merely mixed with groundwater to the point that it became unidentifiable. Solids settle. They would have drifted downward and lined the conduit cracks and cavern floors as would any sediment washed into the system.

Reports are inconsistent as to the amount of sewage lost. The EPA report says 28-30 million gallons of sewage went down the first hole, and the second set of whirlpools upped the total to about 50 million gallons.<sup>140</sup> Missouri Engineering puts the total at 25-37 million gallons.<sup>141</sup> One DNR geologist used a 75 million gallon figure;<sup>142</sup> another used 38 million.<sup>143</sup>

Whatever the total sewage loss, its impact on Mammoth Spring would have been strung out over several days, thus pollution in any one day would be a small percentage of the spring's 227 million gallon per day flow. "Even though it's a serious environmental accident . . . in terms of overall hydrology, it's not that a big of an event," said DNR hydrologist Jim Vandike.<sup>144</sup>

### *Facets of Dairy Queen Contamination Source Still Mysterious*

The Dairy Queen is only one-half mile from the city's sewage lagoon, close to due south, within range of the general southeast path of underground water's flow. It may seem obvious that the city's lost sewage caused DQ's water pollution, particularly because Don Brown's well—serving twelve homes and businesses—would have pulled a lot of water. This “drawdown” could easily have lowered groundwater levels, creating a low spot to which the sewage could have flowed in and filled, creating a pocket of polluted water in that area. Certain other facts implicate the sewage spill. Previously failed water tests suggest the well was poorly constructed or otherwise vulnerable to penetration by contaminants, either from the surface or from shallow groundwater. But even though bacteria had been previously detected in the well, no foul taste or smell was reported prior to May 5, nor were any illnesses associated with the bad tests.

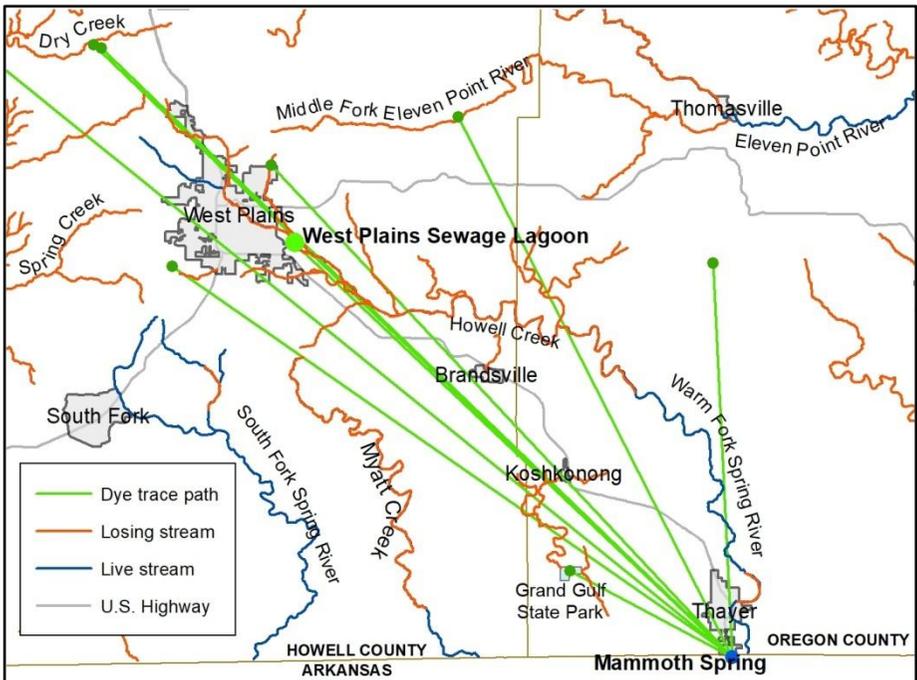


Figure 5. At least 11 dye traces in the West Plains area have been conducted between 1967 and 2016. Dye has consistently been traced to Mammoth Spring. (Map: D.H. Vaughn)

But this question is not totally resolved. Another factor tends to exonerate the city's sewage lagoon. DNR inspectors noticed a small private sewage lagoon behind the Dairy Queen; that lagoon received wastewater from DQ. It was quite close to Brown's multi-user well and it appeared to be leaking.<sup>145</sup> Further, the dye dumped into the craters in the city lagoon never showed up in Brown's well.<sup>146</sup> But months later, DNR ran a different dye trace, which established a clear connection between DQ's small lagoon and Brown's well.<sup>147</sup> DNR hydrologist Jim Vandike said the illnesses associated with DQ "could conceivably been from the West Plains lagoon but were probably from their own lagoon."<sup>148</sup>

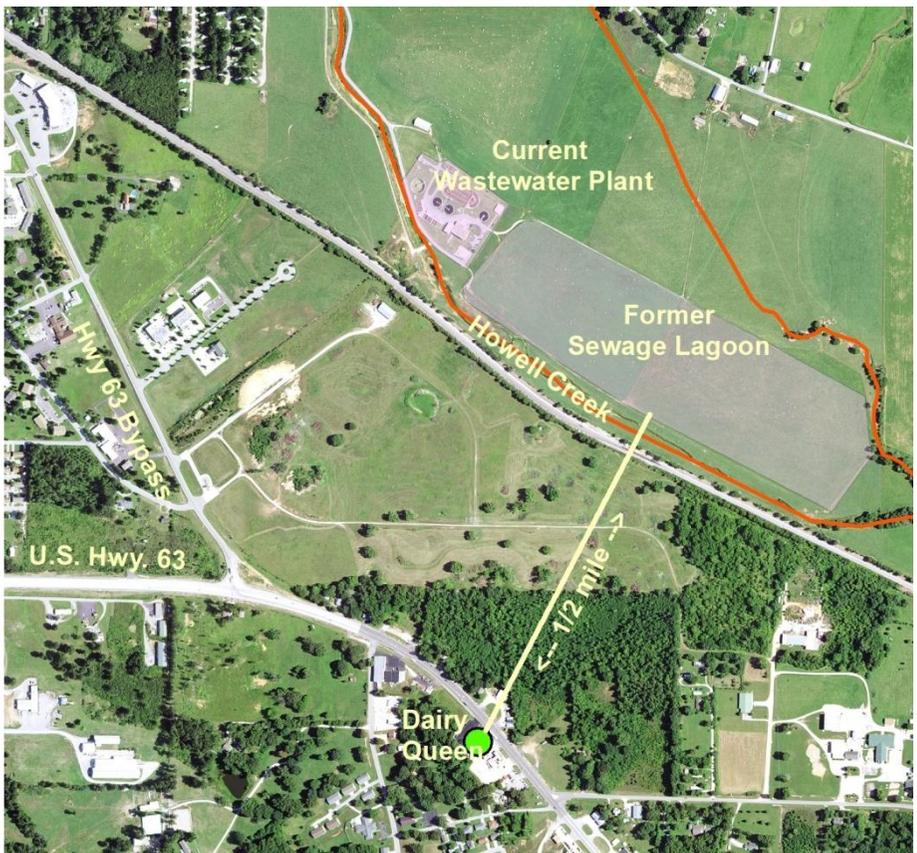


Figure 6. Aerial photo shows proximity of the sewage lagoon and Dairy Queen, which are approximately one-half mile apart as the crow flies. (Map: D. H. Vaughn)

But the lack of dye from the city lagoon entering Brown's well does not prove a corresponding lack of sewage.<sup>149</sup> If the DQ's own lagoon was the sole source of the illnesses, the symptoms should have

shown up before May 5, because that small lagoon is believed to have leaked constantly. This writer concludes that the city's lost sewage sickened DQ customers.

### *Sewage Treatment Plant Built in 1979 in Use Today*

The sewage treatment plant that now serves the city went online December 19, 1979. It had been built on time and "well within budget," at just under \$3.5 million.<sup>150</sup>

Prior to the lagoon collapse, engineers Crane and Fleming of Hannibal had completed a design for a new sewage plant that would have used a section of the existing lagoon. But after the disaster, EPA staff tossed out four years' worth of design and permitting work; they firmly nixed any use of an earthen structure to hold sewage.<sup>151</sup> With the pressure on to quickly decommission the lagoon, engineers completely redesigned the new plant, selecting an "oxidation ditch" system in which all sewage is contained within concrete pools.<sup>152</sup>

Located on the north end of the old lagoon, the new concrete plant was designed with collapse risk in mind. The site was selected based on seismic tests conducted prior to construction to search for underground voids.<sup>153</sup> The structure is built on 460 steel H-beams, driven down to bedrock in a checkerboard pattern.<sup>154</sup> Despite the seismic tests, crews driving the pilings found karst-induced holes. "In one instance the piling broke through a void and dropped almost 25 feet" before reaching solid rock.<sup>155</sup>

After the new oxidation ditch plant was in full operation, the lagoon was drained and the earthen berms were bulldozed inward to cover the remaining sludge on the lagoon surface. The area was seeded to grass. Today, cattle graze there, and the valley floor shows no obvious sign that it was once a lagoon site. City workers regularly spread sludge produced by the new treatment plant to fertilize this land; sludge is also trucked off site for land application elsewhere.

About two million gallons per day of clear, bacteria-free water exit the sewage treatment plant's effluent pipe and gush into Howell Creek, turning the dry watercourse into a flowing stream until it is lost underground some eight or nine miles downstream around the Oregon County line.<sup>156</sup>



*These photos taken in 2011 show: (top) former Wastewater Supervisor Jim Woodworth looking over a cattle pasture, the site of the old sewage lagoon, and (above) discharge from the sewage treatment plant flowing into Howell Creek.  
(Photos: D. H. Vaughn)*

### *Long-Term Effects: Improved Sewage Plants and Stricter Site Inspections*

Shortly after the collapse, the EPA identified “49 additional municipal lagoons and 212 private lagoons” in karst areas of the Ozarks which were vulnerable to sinkhole formation.<sup>157</sup> The DNR’s Geological Survey division visited and evaluated a number of them, and within a few years, the nearby towns of Alton, Mountain View, and Thayer received federal funding and replaced their earthen lagoons with concrete-bottomed treatment plants.<sup>158</sup>

In 2011, three long-time DNR geologists reflected on the long-term impact of the West Plains collapse. “Nothing about West Plains was new,” said Jim Hadley Williams. He compared it to a 1968 sewage lagoon collapse at Republic. This earlier collapse, not West Plains, instigated the practice of conducting risk assessments. What made West Plains stand out, said Williams, is “it brought publicity. I think that helped move things along.”<sup>159</sup>

Even so, said Jim Vandike, the West Plains collapse “had a big impact” and “shaped how we do things.”<sup>160</sup> Peter Price called the event “a big turning point for a lot of our processes.” DNR further developed its rating system used to evaluate any earthen wastewater storage in the state. The agency now insists on checking out all proposed lagoon sites that might be influenced by karst, looking for collapse potential. This approach appears to have avoided new problems. No lagoons built since 1978 have collapsed. “We learned from it,” said Price. “As far as I know, Missouri is the only state that does this kind of evaluation.”<sup>161</sup>

### *Conclusion*

For an epidemic, the 1978 West Plains sewage disaster was relatively benign. No one died, few were hospitalized, and no cases of typhoid, cholera, polio, hepatitis, or other serious diseases emerged.<sup>162</sup> Rural residents’ wells cleared up fairly quickly, and majestic Mammoth Spring barely blinked.

The drama played out in several stages. The first act occurred years ago when the city chose “the lesser of evils” in selecting their karst-susceptible location and lagoon-style sewage treatment. Even if city leaders did not understand the collapse risk in 1964, that risk had been revealed by 1978. But with finances tight, they gambled. The

second act opened when that gamble failed. The plot thickened when city officials declined to tell the public or the press of that failure, and dragged their feet in cooperating with other government agencies. They assumed such omissions were acceptable because the lagoon had drained before without fanfare. But the city bosses probably were not betting on the third act, staged at a very public venue: a Dairy Queen served by a poorly sealed private well and perfectly positioned to expose hundreds to gut-cramping sewage germs, which were relatively traceable by epidemiologists. This exposed both the city's gamble and cover-up, angering many, especially rural residents downstream. Despite this questionable behavior, in the final act the city was approved for federal funding; they built a new, better-designed treatment plant.

Looking back, understanding among south central Missourians about karst topography and its vulnerability to collapse and to groundwater pollution has greatly increased since the lagoon disaster, due in part to lessons learned during the painfully public 1978 drama.

As population growth and land development continues, more structures will be built. The likelihood of occasional karst collapse remains. Whether those unavoidable collapses are merely geologic spectacles or whether they are costly tragedies depends upon vigilant evaluation of sites before construction begins.

A letter published in the May 30, 1978, *Quill* serves as summary. "The lagoon disaster may be a blessing in disguise," wrote Kazie Perkins of Willow Springs. "Tis a fact of life that no one pays attention to any issue, any problem until it touches him personally. Perhaps, just perhaps, thousands in Howell County and the south central Ozarks will now open their eyes and minds to problems of growth, land use, and the ecological fragility of the land they live on."<sup>163</sup>

## Endnotes

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<sup>1</sup> "Health warning issued: Sewage lagoon leak being investigated," (1978, May 12) *West Plains Daily Quill*, 1.

<sup>2</sup> "Recap of the West Plains Incident, Howell County," attachment to letter, James Hadley Williams to Lowell Patterson, May 18, 1978.

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- <sup>3</sup> Memo, William F. Raithel to Herbert R. Domke, 14 June, 1978, 3, Missouri Division of Health.
- <sup>4</sup> "Illness at 'epidemic' levels," (1978, May 16), *West Plains Daily Quill*, 1.
- <sup>5</sup> "Lagoon collapses again; Arkansas residents get warning," (1978, May 17) *West Plains Daily Quill*, 1.
- <sup>6</sup> "Guard 'turning water off' Thursday," (1978, May 30) *West Plains Daily Quill*, 1.
- <sup>7</sup> "The Solution: A New Wastewater Treatment Plant for West Plains" (1981, November) *Missouri Engineer*, 16.
- <sup>8</sup> Peter Price, (2011, March 18) Personal interview. DNR Geology Section Chief.
- <sup>9</sup> The sewage disaster was briefly described by Gillman, et. al. (2008) "Soil-cover karst collapses: A geologic hazard in Missouri," *Proceedings of the 18<sup>th</sup> National Cave and Karst Management Symposium* and in *Living on Karst, a reference guide for Ozark Landowners* (The Nature Conservancy, 2003).
- <sup>10</sup> Thomas J. Aley, James H. Williams, and James W. Massello, *Groundwater contamination and sinkhole collapse induced by leaky impoundments in soluble rock terrain*. (Missouri Geological Survey and Water Resources, 1972).
- <sup>11</sup> James Vandike and Donald Miller, *Groundwater Resources of Missouri*, (Mo. Department of Natural Resources, 1998), 62.
- <sup>12</sup> *Living on Karst, a reference guide for Ozark Landowners* (The Nature Conservancy, 2003), 1.
- <sup>13</sup> Vandike and Miller, *Groundwater Resources of Missouri*, 67.
- <sup>14</sup> Vandike and Miller, *Groundwater Resources of Missouri*, 69.
- <sup>15</sup> *Living on Karst, a reference guide for Ozark Landowners* (The Nature Conservancy, 2003), 16.
- <sup>16</sup> In September 2007, in the Mountain View-Birch Tree RIII School District, some 35 miles northeast of West Plains, a six-foot wide by six-foot deep hole opened under the foundation of the middle school. School patrons became agitated; some kept their kids at home. Ultimately, the afflicted portion of the building was abandoned for student use, even though the foundation never moved. Voters passed bonds for construction of a new middle school.
- <sup>17</sup> Joe Gillman, et al, "Soil-cover karst collapses: A geologic hazard in Missouri." *Proceedings of the 18<sup>th</sup> National Cave and Karst Management Symposium*. (NCKMS Steering Committee, 2008), p. 178. These 48 sinkholes "have damaged residential building foundations and collapsed sections of city streets resulting in broken municipal water, sewage, and gas lines." One was about 80 feet deep and 60 feet wide, it "sever[ed] utilities and swallow[ed] pavement and sidewalk."

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<sup>18</sup> Denise Henderson Vaughn, *Karst in Perry County*, (Ozarks Resource Center, 2020).

<sup>19</sup> Joe Gillman, et al, "Soil-cover karst collapses: A geologic hazard in Missouri." *Proceedings of the 18<sup>th</sup> National Cave and Karst Management Symposium*. (NCKMS Steering Committee, 2008), p. 183.

<sup>20</sup> Underground Ozarks Blog, August 14, 2006.

<sup>21</sup> Aley, Williams, and Massello, *Groundwater contamination and sinkhole collapse induced by leaky impoundments in soluble rock terrain*.

<sup>22</sup> Aley, Williams, and Massello, *Groundwater contamination and sinkhole collapse induced by leaky impoundments in soluble rock terrain*, 16. According to local lore, the night that the doomed lake drained, the ground rumbled and shook in between the lake and the water's outlet, Greer Spring, more than 30 miles away.

<sup>23</sup> Joe Gillman, et al, "Soil-cover karst collapses: A geologic hazard in Missouri." *Proceedings of the 18<sup>th</sup> National Cave and Karst Management Symposium*. (NCKMS Steering Committee, 2008), p.180. When Lake Chesterfield developers built the impoundment in a known karst area in 1987, they were not required to seek or heed DNR advice, because lake water is not a pollutant. But a 1978 engineering report from DNR's Division of Geology and Land Survey was available; it "noted a severe collapse potential for earthen wastewater storage facilities and lake sites constructed in this general area." "Extensive drilling and grouting" was required to plug the sinkhole.

<sup>24</sup> Vandike and Miller, *Groundwater Resources of Missouri*, 65.

<sup>25</sup> Besides factoring into demise of a 1960s lake and the 1978 sewage lagoon collapse, this deeply weathered karst band has caused other trouble. During the rainy spring of 1998, West Plains' city wells produced water so turbid that it darkened white laundry and made orange ice cubes. Well-drilling records showed pockets of karst weathering in several of these wells at depths over 900 feet. The new sediment suddenly appearing in decades-old wells is believed (but not proven) to have originated from ground laid temporarily bare during highway construction, located in the "upstream" portion of the recharge area for the city's water wells. Along with DNR prodding, the turbidity prompted the city to build a million-dollar purification plant to filter out sediment, completed in 2001.

<sup>26</sup> Vandike and Miller, *Groundwater Resources of Missouri*, 65. The water level in a DNR-monitored well in downtown West Plains has been known to "rise as much as 200 feet within a few hours after a major rainfall."

<sup>27</sup> "Groundwater Series Reprinted," *West Plains Daily Quill* (Special Section, Fall 1998), 2. The town of Alton, some 30 miles to the east, closed its dump, located in a sinkhole, after water originating from the dump was traced in

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1969 to Morgan Spring on the Eleven Point River. The use of a sinkhole dump serving Dora, 20 miles west of West Plains, was discontinued after water from it was dye traced in 1972 to popular Hodgson Mill Spring.

<sup>28</sup> James Hadley Williams, (2011, March 27) Personal interview. Geologist with Missouri Department of Natural Resources, Division of Geology and Land Survey, retired.

<sup>29</sup> U.S. Census – 1960 Census of Population, Preliminary Reports.

<sup>30</sup> 1970 Census of Population, Characteristics of Population, Missouri.

<sup>31</sup> James Woodworth, (2011, March 21), Personal interview. West Plains Water and Sewer Department Supervisor.

<sup>32</sup> Stuart Liederman, “Report on Public Reaction to the West Plains Sewage Disaster, 1978” (Drury, Missouri, Why Flush, 1978), 6.

<sup>33</sup> *Ibid*, 6-7.

<sup>34</sup> James Martin, “Proposed Sewage Lagoon Sites for the City of West Plains” (Missouri Geological Survey, October 29, 1963)

<sup>35</sup> Aley, Williams, and Massello, *Groundwater contamination and sinkhole collapse induced by leaky impoundments in soluble rock terrain*, 14.

<sup>36</sup> “Recap of the West Plains Incident, Howell County,” attachment to letter, James Hadley Williams to Lowell Patterson, May 18, 1978. To escape this threat, sewage would have to be piped under pressure five miles southwest, a prohibitively expensive option. Despite its dangers, Williams said the Howell Creek site was the “only possible location . . . given the economics.” The other option, building the type of mechanical treatment plant common in the mid-1960s, would have released poorly-treated effluent at all hours. “The least of the evils” was to “risk occasional collapses with slugs of pollution rather than continual pollution,” he said.

<sup>37</sup> *Report of the West Plains Lagoon Incident* (1978, June 30,). U.S. Environmental Protection Agency, 5.

<sup>38</sup> Aley, Williams, and Massello, *Groundwater contamination and sinkhole collapse induced by leaky impoundments in soluble rock terrain*, 14.

<sup>39</sup> *Ibid*.

<sup>40</sup> *Report of the West Plains Lagoon Incident*, 3.

<sup>41</sup> “Mayor starts his own repairs” (1978, May 18) *West Plains Daily Quill*, 1.

<sup>42</sup> *Report of the West Plains Lagoon Incident*, 5.

<sup>43</sup> Christopher J. Stohr, *Addendum: Preliminary Engineering Geologic Report on the West Plains Sewage Lagoon*. (1975, April 15, Missouri Geological Survey) attachment to letter, James Hadley Williams to Lowell Patterson, May 18, 1978.

<sup>44</sup> David Hoffman, “Liquid Waste Treatment Works – Engineering Geological Report.” (1978, April 18, Missouri Geological Survey) attachment to letter,

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James Hadley Williams to Lowell Patterson, May 18, 1978. Hoffman recommended building a foundation that could support a span 50 feet wide anywhere within the new treatment plant, to protect against effluent loss in the case of a collapse.

<sup>45</sup> Memo from James A Burris to Jim Odendahl, (1978, June 5) "West Plains Incident," 1. The May water sample contained algae, of the type commonly found in farm ponds and lagoons.

<sup>46</sup> Letter from Lowell B. Patterson to James Odendahl (1978, June 7), 1.

<sup>47</sup> "Health warning issued: Sewage lagoon leak being investigated," (1978, May 12) *West Plains Daily Quill*, 1.

<sup>48</sup> Memo from James A Burris to Jim Odendahl, (1978, June 5) "West Plains Incident," 1.

<sup>49</sup> "Health warning issued: Sewage lagoon leak being investigated," (1978, May 12) *West Plains Daily Quill*, 1.

<sup>50</sup> *Ibid.*

<sup>51</sup> Letter from Lowell B. Patterson to James Odendahl (1978, June 7), 1.

<sup>52</sup> "Health warning issued: Sewage lagoon leak being investigated," (1978, May 12) *West Plains Daily Quill*, 1.

<sup>53</sup> Letter from Lowell B. Patterson to James Odendahl (1978, June 7), 2.

<sup>54</sup> Memo from James A Burris to Jim Odendahl, (1978, June 5) "West Plains Incident," 2.

<sup>55</sup> Letter and report, James P. Odendahl to Carolyn Ashford, "Report on the Sewage Lagoon Failure at West Plains, Missouri." (1978, July 5), 5.

<sup>56</sup> Memo, William F. Raithel to Herbert R. Domke, "Events leading to the discovery of an epidemic of water-borne disease in West Plains, Missouri, 1978," (1978, June 14, The Division of Health of Missouri), 2.

<sup>57</sup> Letter from Lowell B. Patterson to James Odendahl (1978, June 7), 2.

<sup>58</sup> *Ibid.*, 3.

<sup>59</sup> Memo, William F. Raithel to Herbert R. Domke, "Events leading to the discovery of an epidemic of water-borne disease in West Plains, Missouri, 1978," (1978, June 14, The Division of Health of Missouri), 2.

<sup>60</sup> *Ibid.*, 3.

<sup>61</sup> *Ibid.*

<sup>62</sup> "Health warning issued: Sewage lagoon leak being investigated," (1978, May 12) *West Plains Daily Quill*, 1.

<sup>63</sup> Memo, William F. Raithel to Herbert R. Domke, "Events leading to the discovery of an epidemic of water-borne disease in West Plains, Missouri, 1978," (1978, June 14, The Division of Health of Missouri), 2.

<sup>64</sup> Memo from James A Burris to Jim Odendahl, (1978, June 5) "West Plains Incident," 2.

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<sup>65</sup> Memo, William F. Raithel to Herbert R. Domke, "Events leading to the discovery of an epidemic of water-borne disease in West Plains, Missouri, 1978," (1978, June 14, The Division of Health of Missouri), 1. Also contradictory: *The Quill* said a city worker noticed missing wastewater on Friday. Patterson's report said the city discovered the loss on Saturday.

<sup>66</sup> "Recap of the West Plains Incident, Howell County," attachment to letter, James Hadley Williams to Lowell Patterson, May 18, 1978.

<sup>67</sup> Stuart Liederman, "Report on Public Reaction to the West Plains Sewage Disaster, 1978" (Drury, Missouri, Why Flush, 1978), 24.

<sup>68</sup> "Health warning issued: Sewage lagoon leak being investigated," (1978, May 12) *West Plains Daily Quill*, 1.

<sup>69</sup> *Ibid.*

<sup>70</sup> Memo, William F. Raithel to Herbert R. Domke, "Events leading to the discovery of an epidemic of water-borne disease in West Plains, Missouri, 1978," (1978, June 14, The Division of Health of Missouri), 2. Wooldridge said he "thought this was strange but decided this was some new policy."

<sup>71</sup> Frank L. Martin III (2020, March 30) Personal correspondence with author. Owner and publisher, *West Plains Daily Quill*.

<sup>72</sup> "State Health chief says passage of time before leak reported 'speaks for itself,'" (1978, May 16), *West Plains Daily Quill*, 1.

<sup>73</sup> "Health warnings expanded; massive testing underway as illness reports top 100," (1978, May 15), *West Plains Daily Quill*, 1.

<sup>74</sup> Letter from Lowell B. Patterson to James Odendahl (1978, June 7), 3.

<sup>75</sup> Memo from Harold L. Patrick to James P. Odendahl, "Sequence of Events Regarding Lagoon Failure at West Plains (1978, June 6), 2.

<sup>76</sup> "Illness at 'epidemic' levels," (1978, May 16), *West Plains Daily Quill*, 1.

<sup>77</sup> Letter from Lowell B. Patterson to James Odendahl (1978, June 7), 3. Discrepancies cloud this date. Seven reports offer similar details, but three place the second lagoon failure's start on Monday, while three others plus *The Quill* say it occurred on Tuesday.

<sup>78</sup> "Lagoon collapses again; Arkansas residents get warning," (1978, May 17), *West Plains Daily Quill*, 1.

<sup>79</sup> *Report of the West Plains Lagoon Incident*, 13.

<sup>80</sup> James P. Odendahl, "Report on Sewage Treatment Lagoon Failure at West Plains, Missouri," (1978, July 5), Missouri Department of Natural Resources, 11.

<sup>81</sup> Memo from James A. Burris to Jim Odendahl, (1978, June 5) "West Plains Incident," 3-4.

<sup>82</sup> James Woodworth, (2011, March 21), Personal interview. West Plains Water and Sewer Department Supervisor.

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- <sup>83</sup> Memo from James A Burris to Jim Odendahl, (1978, June 5) "West Plains Incident," 4.
- <sup>84</sup> "Lagoon collapses again; Arkansas residents get warning," (1978, May 17), *West Plains Daily Quill*, 1.
- <sup>85</sup> Memo from James A Burris to Jim Odendahl, (1978, June 5) "West Plains Incident," 4.
- <sup>86</sup> Stuart Liederman, "Report on Public Reaction to the West Plains Sewage Disaster, 1978" (Drury, Missouri, Why Flush, 1978), 24.
- <sup>87</sup> Letter from Lowell B. Patterson to James Odendahl (1978, June 7), 4.
- <sup>88</sup> Dennis Crider, (2011, February 13) Personal interview. Photographer, *West Plains Daily Quill*.
- <sup>89</sup> Memo from James A. Burris to Jim Odendahl, (1978, June 5) "West Plains Incident," 4. The EPA reports the holes as being 18 feet and 24 feet in diameter, and a four-foot hole. *Report of the West Plains Lagoon Incident*, 14.
- <sup>90</sup> *Ibid*, 5.
- <sup>91</sup> *Report of the West Plains Lagoon Incident*, 14.
- <sup>92</sup> Frank L. Martin III (2011, March 18) Personal interview. Owner and publisher, *West Plains Daily Quill*. Martin remembers the cocky, Stetson-wearing mayor, Glenn Roe, who was "something else." During his tenure, he killed his neighbor's dogs, shot strays while he rode around with the police, and ran a union organizer out of town.
- <sup>93</sup> "Mayor starts his own repairs," (1978, May 18) *West Plains Daily Quill*, 1.
- <sup>94</sup> *Ibid*.
- <sup>95</sup> Jim Woodworth, (2011, March 21), Personal interview.
- <sup>96</sup> "Officials consider solutions," (1978, May 18), *West Plains Daily Quill*, 1.
- <sup>97</sup> "Officials consider solutions," (1978, May 18), *West Plains Daily Quill*, 1.
- <sup>98</sup> Stuart Liederman, "Report on Public Reaction to the West Plains Sewage Disaster, 1978" (Drury, Missouri, Why Flush, 1978), (no page number).
- <sup>99</sup> "Officials consider solutions," (1978, May 18), *West Plains Daily Quill*, 1.
- <sup>100</sup> "Local guard unit on duty: Governor dispatches water tanks," (1978, May 19), *West Plains Daily Quill*, 1.
- <sup>101</sup> "Mayor starts his own repairs," (1978, May 18) *West Plains Daily Quill*, 1.
- <sup>102</sup> Memo from Harold L. Patrick to James P. Odendahl, "Sequence of Events Regarding Lagoon Failure at West Plains (1978, June 6), 5. Unrelated cases were at 193 in Howell County, and 108 in Oregon County.
- <sup>103</sup> "Local guard unit on duty: Governor dispatches water tanks," (1978, May 19), *West Plains Daily Quill*, 1.
- <sup>104</sup> "Guard 'turning water off' Thursday," (1978, May 30), *West Plains Daily Quill*, 1.

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- <sup>105</sup> "Local guard unit on duty: Governor dispatches water tanks," (1978, May 19), *West Plains Daily Quill*, 1.
- <sup>106</sup> Ibid.
- <sup>107</sup> Memo from Odie Dickens to Jim Odendahl, (1978, May 26), "Informational pamphlet for West Plains area."
- <sup>108</sup> "Emergency funding sought; lagoon put back in service," (1978, May 23), *West Plains Daily Quill*, 1.
- <sup>109</sup> Thomas J. Dean, "Geologic Report of the West Plains Howell Valley Lagoon System," Missouri Geological Survey, (1978, July 11), 2.
- <sup>110</sup> "Emergency funding sought; lagoon put back in service," (1978, May 23), *West Plains Daily Quill*, 1.
- <sup>111</sup> "Present lagoon to be modified; plans call for new construction to begin soon," (1978, May 25), *West Plains Daily Quill*, 1.
- <sup>112</sup> "Council balks at building interim treatment facility," (1978, May 25), *West Plains Daily Quill*, 1.
- <sup>113</sup> "Local guard unit on duty: Governor dispatches water tanks," (1978, May 19), *West Plains Daily Quill*, 1.
- <sup>114</sup> "No evidence yet of contamination in Arkansas," (1978, May 23), *West Plains Daily Quill*, 1.
- <sup>115</sup> "Local guard unit on duty: Governor dispatches water tanks," (1978, May 19), *West Plains Daily Quill*, 1.
- <sup>116</sup> "Council balks at building interim treatment facility," (1978, May 25), *West Plains Daily Quill*, 1.
- <sup>117</sup> Woodrow Taylor, "Letter to the Editor," (1978, June 21), *West Plains Daily Quill*.
- <sup>118</sup> Ruth Wade, "Letter to the Editor," (1978, June 22), *West Plains Daily Quill*.
- <sup>119</sup> Stuart Liederman, "Report on Public Reaction to the West Plains Sewage Disaster, 1978," (Drury, Missouri, Why Flush, 1978), 36.
- <sup>120</sup> Ibid, (no page numbers).
- <sup>121</sup> "Warning area expanded; illness total up," (1978, May 22), *West Plains Daily Quill*, 1.
- <sup>122</sup> *Report of the West Plains Lagoon Incident*, 16.
- <sup>123</sup> "Lagoon investigation winding down, but don't stop boiling!" (1978, May 26), *West Plains Daily Quill*, 1.
- <sup>124</sup> "Health Officials say 'keep boiling water,'" (1978, June 5), *West Plains Daily Quill*, 1.
- <sup>125</sup> "Bold line shows extent of possible contamination," (1978, May 16), *West Plains Daily Quill*, 6. This map of Howell and Oregon counties shows the possible contamination area as extending northeast of West Plains to the Eleven Point River and including most of Oregon County.

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<sup>126</sup> Jim Vandike, (2011, March 18) Personal interview. DNR Hydrology section chief.

<sup>127</sup> "Lagoon investigation winding down, but don't stop boiling!" (1978, May 26), *West Plains Daily Quill*, 1.

<sup>128</sup> "Guard 'turning water off' Thursday," (1978, May 30), *West Plains Daily Quill*, 1.

<sup>129</sup> "Lagoon investigation winding down, but don't stop boiling!" (1978, May 26), *West Plains Daily Quill*, 1.

<sup>130</sup> A study of Springfield area rural wells in 1962 yielded 60 percent with bacteria, and a 2006 Howell County study found bacteria in 42 percent of rural wells.

<sup>131</sup> *Report of the West Plains Lagoon Incident*, 8.

<sup>132</sup> "Regulations Governing the Construction of Water Supply Wells," (1974, June, revised), The Division of Health of Missouri.

<sup>133</sup> "Guard 'turning water off' Thursday," (1978, May 30), *West Plains Daily Quill*, 1.

<sup>134</sup> "Guard 'turning water off' Thursday," (1978, May 30), *West Plains Daily Quill*, 1.

<sup>135</sup> Thomas J. Dean, "Geologic Report of the West Plains Howell Valley Lagoon System," Missouri Geological Survey, (1978, July 11).

<sup>136</sup> *Report of the West Plains Lagoon Incident*, 9.

<sup>137</sup> Thomas J. Dean, "Geologic Report of the West Plains Howell Valley Lagoon System," Missouri Geological Survey, (1978, July 11), 3.

<sup>138</sup> "Bacteria count in Mammoth Spring rises sharply, falls" (1978, June 27), *West Plains Daily Quill*. Oddly, during late June, fecal coliform bacteria levels at Mammoth Spring rose sharply, to about double that allowed for safe swimming. But this time period was considered to be much too late to be associated with the batch of sewage from either May 5 or May 17. The source of this bacteria burp was never explained, but it moved quickly through and safe swimming levels returned within a few days.

<sup>139</sup> Thomas J. Dean, "Geologic Report of the West Plains Howell Valley Lagoon System," Missouri Geological Survey, (1978, July 11), 3. No dye was found at Culp Ford, but the surge surfaced at an unknown time prior to May 22, so it may have predated the May 18 dye injection.

<sup>140</sup> *Report of the West Plains Lagoon Incident*, 2.

<sup>141</sup> "The Solution: A New Wastewater Treatment Plant for West Plains" (1981, November) *Missouri Engineer*, 12.

<sup>142</sup> Joe Gillman, et al, "Soil-cover karst collapses: A geologic hazard in Missouri." *Proceedings of the 18<sup>th</sup> National Cave and Karst Management Symposium* (NCKMS Steering Committee, 2008), 175.

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<sup>143</sup> Jim Vandike, (2011, March 18) Personal interview.

<sup>144</sup> Ibid.

<sup>145</sup> Thomas J. Dean, "Geologic Report of the West Plains Howell Valley Lagoon System," Missouri Geological Survey, (1978, July 11), 5. This small lagoon was built on the side slope of a 240-acre sink basin. An erosion gully had been plugged up to create the dam, and it was built in a manner that could collect "a considerable quantity of surface water." However, the spillway showed no sign that the water level had ever reached it; this lagoon did not hold much water and appeared to be leaking straight down through the bottom.

<sup>146</sup> Thomas J. Dean and Gary St. Ivany, "Summary of dye tracing results on Falcon Communications Well," (1978, October 23).

<sup>147</sup> Thomas J. Dean and Gary St. Ivany, "Summary of dye tracing results on Falcon Communications Well," (1978, October 23). After collecting several dye-negative water samples from Brown's well, which was no longer in use, the well pump was turned and allowed to run, creating a drawdown. Only then did DNR pull up dye-laden water, establishing "a strong positive connection" between the small lagoon and Brown's well.

<sup>148</sup> Jim Vandike, (2011, March 18) Personal interview.

<sup>149</sup> Brown's well was decommissioned May 11. Dye was poured into the city lagoon's sinkhole on May 18. If drawdown was a significant factor in originally pulling the sewage toward Brown's well, then that pull would have ceased before May 18, because the well was no longer in use. Therefore dye from the city lagoon would not have necessarily flowed in that direction.

<sup>150</sup> "The Solution: A New Wastewater Treatment Plant for West Plains" (1981, November), *Missouri Engineer*, 16.

<sup>151</sup> "Council balks at building interim treatment facility," (1978, May 30), *West Plains Daily Quill*, 1.

<sup>152</sup> "The Solution: A New Wastewater Treatment Plant for West Plains" (1981, November) *Missouri Engineer*, 12-16.

<sup>153</sup> "Council balks at building interim treatment facility," (1978, May 30), *West Plains Daily Quill*, 1.

<sup>154</sup> Jim Woodworth, (2011, March 21), Personal interview.

<sup>155</sup> "The Solution: A New Wastewater Treatment Plant for West Plains" (1981, November) *Missouri Engineer*, 15.

<sup>156</sup> Jim Woodworth, (2011, March 21), Personal interview.

<sup>157</sup> *Report of the West Plains Lagoon Incident*, 9-10.

<sup>158</sup> Jim Woodworth, (2011, March 21), Personal interview.

<sup>159</sup> Jim Hadley Williams, (2011, March 27), Personal interview.

<sup>160</sup> Jim Vandike, (2011, March 18), Personal interview.

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<sup>161</sup> Peter Price, (2011, March 18), Personal interview.

<sup>162</sup> *Report of the West Plains Lagoon Incident*, 25.

<sup>163</sup> Kazie Perkins, "Letter to the Editor" (1978, May 30), *West Plains Daily Quill*, 5.

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#### *About the author*

Denise Henderson Vaughn has been passionate about the Ozarks ever since she bought 40 acres near Ava, Mo., during her senior year of high school. She built a cabin there, gardened, and within a few years adopted a mission: environmental education in the Ozarks. During 20 years with the *West Plains Daily Quill*, her coverage of natural resource issues earned several awards for investigative reporting. She completed a master's degree in journalism and conservation biology from the University of Missouri (2014), has taught journalism there and at MSU-West Plains, has served as writer or media specialist for a half-dozen science and environmentally-focused non-profits, and has produced two documentaries available online, *Karst in the Ozarks* (2010) and *Karst in Perry County* (2020). Her work has also appeared in the *St. Louis Post-Dispatch* and *Forest History Today*.