The Water Problem: The Luna Colony and More

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Abstract

With modern civilization providing near limitless clean, fresh water at the turn of a knob, it's easy to overlook the difficulties of supplying water to a population. The output of sources varies, sometimes erratically, depending on weather and season. Natural and human activities can quickly contaminate a source and water is heavy and difficult to transport. Perhaps the most difficult aspect of the water problem is the quantity needed to sustain a population. This article looks at how early documented U.S. colonies solved, or failed to solve, their water problem. The article also presents insight into how people of the Luna Colony might have solved their water problems.

Introduction

When I was a child, my father and I would frequently float the Blackwater River in his old aluminum canoe, camping on the river's many soft, white sandbars. This was back when you could float the river and not see another person for two days. One of my jobs was to fill a bucket in the river and lug it back to camp. The fifty-foot trip, carrying that heavy bucket of sloshing, tannic river-water, seemed like a mile. We used the water for cooking, refilling canteens, and Dad would heat a large pot of it to wash our dishes. Not including bathing in the river, the two of us together used about four gallons of river-water a day. Of course, we had the benefit of canned and bottled drinks too.

When designing modern water systems for residential use, engineers typically size the system based on an estimated usage of one hundred gallons of water per day per person. In 2010, the national average domestic potable water use was eighty-nine gallons per person per day (Maupin *et al*., 2014, p. 23). This accounts for household consumption, leaks, lawn irrigation, and other residential uses. Water requirements get much higher when you factor in industrial, commercial, and agricultural demands.

By today's standard, a colony with a population of 1,500 residents would consume about 133,500 gallons of water per day. Clearly, per-capita usage in early settlements would have been far below modern demand. For example, Luna Colony's minimum daily water requirement for its 1,500 settlers, 230 mariners and 150 horses is estimated to be about 4,000 gallons (Dobson, 2016). This calculates out to less than two and a half gallons per person per day or between two and three percent of modern usage. With no record of potable water being in short supply, it's reasonable to believe that Luna

Colony solved its water problem early and with a quantity substantially exceeding the minimum survival requirements.

Luna, however, had a bigger water problem than finding a continuous source of 4,000 gallons per day. Modern engineers design potable systems with the capacity to supply approximately four times the average daily demand. This is referred to as Peaking Factor in that peak usage in a small system is about four times the average usage (Fair and Geyer, 1954, p. 136). The reason for this is because modern people use much more water in the mornings and evenings than in the middle of the night. Modern water systems use storage devices such as water towers to attenuate the difference between peak and average demand. Otherwise, utility companies would have to install pumps capable of matching peak demands rather than average demands, which would be mechanically inefficient and prohibitively expensive. Although 16^{th}-century settlers obviously would not have all taken a thirty-minute hot shower each morning at the same time, they would not have used water at a constant rate. Their water demands would have had daily and seasonal rhythms.

Water loss, the unaccounted difference between water flowing into a system and the amount withdrawn, from leaks, illegal taps, faulty meters and other causes, in a modern closed system averages about 15 percent (Kenny, 1999). Obviously, modern closed water systems are protected from evaporation, soil infiltration, and continuous discharge into a larger water body. If a colony's main water source was an open channel such as a stream, it is not reasonable to believe settlers could collect more than a small percentage of what was flowing through channel. What water was not collected would have been quickly lost. When considering the Peaking Factor, losses from spills and leakage, and inefficiency of collection, the actual flow needed to meet a colony's basic requirements from a flowing source would need to be in the hundreds of thousands, if not more, of gallons per day. Dodson's minimum 4,000 gallons a day model might apply for shipboard passage of the original sail from Vera Cruz to Pensacola but, clearly, the actual needs of the colony on land required a very substantial water source.

Looking at water sources of early documented U.S. settlements provides insight into the water problem pioneers faced and the importance they placed on their water source.

Santa Elena: The Mendez Occupation

The surface water surrounding Parris Island is brackish and undrinkable. Potable groundwater, however, is readily available inches below the surface. The soils at Santa Elena prevented the settlers from simply digging a small shallow shaft into the water table. Granular material such as wet sand will not remain vertical due to the soil's "angle of repose." This maximum angle at which a soil slope is stable means that as the settlers attempted to dig deeper, their hole would get wider. The builders' only choice was to excavate large-diameter holes or pits to get down even a few feet. Once keyed into the groundwater, they would create a barrel well by placing a bottomless or perforated wooden barrel, or stacking two or three barrels, into the pit and backfilling around them. These wells may have been shallow enough for horses and other animals to drink from directly. Archeologists have excavated and documented numerous barrel wells at Santa Elena (South *et al*., 1988).

Saint Augustine

There were multiple artesian springs located on and within yards of the Menéndez occupation site at Saint Augustine (Deagen, 2004). The terms 'artesian well' and 'artesian spring' are often used interchangeably, but a well is technically manmade and a spring is natural. An artesian condition occurs when the hydraulic-grade-line (water pressure) of an aquifer is higher than the ground elevation, but confined from above by an impervious layer such as rock or clay. In places where there are natural breaks or fissures (or manmade holes) in the confining layer, groundwater flows up and rises above the surface, often in significant quantities. The confining layer below Saint Augustine is the Hawthorn Formation, primarily clays and marls, and is what separates the surficial aquifer from the Floridian Aquifer. The surficial aquifer is the shallower water that is on top of the Hawthorn Formation and is not under pressure and therefore does not flow up to the surface. The Floridian Aquafer in the Saint Augustine area is, at least at times, under artesian condition, allowing for both artesian springs and manmade artesian wells (Spechler and Hampton, 1984). Artesian conditions, particularly old abandoned wells, in and around the Saint Augustine area, are a concern for engineers and builders as they can cause flooding and create issues with streets and foundations. These wells would have been fitted with a valve so they would not flow when not in use. Over time, old valves and plugs of abandoned wells can fail. In 2011, the plug from and old well failed, flooding an area around Grant Street in Saint Augustine. A well expert estimated the flow from this single artesian well at 300 gallons per minute or 432,000 gallons per day (Amaro, 2011).

Excavations at the Menéndez occupation site also uncovered a barrel well, similar to those used at Santa Elena (Deagen, 2004, p. 28). With abundant artesian springs in proximity of the barrel well, it is unclear why the settlers needed the shallow well. Deagan (2004) indicates that the barrel well may have been installed at a defensive location to secure a water source, perhaps in the event access to the artesian springs became challenged.

Jamestown

Jamestown colonists placed their settlement adjacent to the James River, 40 miles upstream from the Chesapeake Bay. The pioneers probably assumed they had solved their water problem as rain and snowmelt draining into the river's basin kept its flowrate high enough to keep the Chesapeake Bay's brackish water downstream from the colony. A drought, beginning in 1606, and seasonal flow and tidal variations eventually allowed unsafe levels of salt to migrate up the James River, thereby degrading the colony's water supply (NASA, 2017). The low river flows likely stagnated around the colony, preventing the colonist from removing their wastewater. In the fall of 1609, ships brought a new wave of settlers, putting more pressure on the colony's water source. Tensions between colonists and local natives over food and water resources led to a siege that confined the settlers to their fort. Shallow wells dug in the second year of the settlement turned brackish in a process referred to as saltwater intrusion (NASA, 2017). Since brackish water from the river permeated the shallow wells, it's probable that the settlers' own wastewater was no longer being flushed by the James River and entered their wells (Cohen, 2011). Between the fall of 1609 and June of 1610, Jamestown's population declined from several hundred to sixty. It's reasonable to believe that poor water quality played a part in the colony's extremely high death rate.

Plymouth Colony

Although the Mayflower initially landed on Cape Cod, the Pilgrims realized there was little fresh water on the sandy peninsula. It was for this reason that they moved to the mainland and settled Plymouth Colony adjacent to Town Brook (Abigail, 2010). Based on its approximate twenty-foot width, this spring-fed brook would have an outflow in the tens of millions of gallons per day. Not only did it provide continuous year-round clean water, its flow created a channel and salt marsh into Plymouth Bay allowing ships to anchor at its mouth and closer to the shore than would have otherwise been possible (Abigail, 2010).

Presidio Santa María de Galve

The settlement's initial population of 400 in 1698 varied from a low of about 180 in 1700 to a high of about 700 in 1705 (Bense, 2004, 48). Inside the site's fortification, Fort San Carlos de Austria, there appears to be one or two deep brick-lined wells and cisterns (Bense, 2004, 57) but French drawings of the fort in 1719 indicate the main water source was probably the many barrel wells situated along the shoreline (personal communication Dodson to Bense 2004; Dodson 2017). While Pensacola's climate is well suited to the use of cisterns where rainfall from an area is collected and contained, the archeological record within the fortification did not indicate that these cisterns were wells tapped into the surficial groundwater. Either way, the difficulty with this method at this location is that water stored in an unlined pit or pond would quickly infiltrate into the permeable sands. As mentioned above, there is some evidence that Santa María de Galve solved this water problem by importing bricks and lining their wells and cisterns, an option most likely unavailable to the earlier Luna Colony. However, the historical record does not indicate that any bricks were ever manufactured at Pensacola for Santa María de Galve.

The María de Galve site is relatively high, approximately thirty feet above the elevation of the bay. The sandy slope is steeper closer to the settlement and flattens out closer to the bay. This topography lends itself to spring-fed creeks and thus the barrel wells located at the lower elevation outside the fort, as the French recorded. Currently, there are drainage features such as lined ditches and pipes in several places along the slopes in this area. Although the vicinity has been highly modified through development, economic limitations of moving large volumes of soil probably means that modern drainage features are not too far from original streams. With springs and streams nearby, the installation of cisterns within the settlement's fortification is an indicator that the settlers may have anticipated limited access to their primary water source—barrel wells nearer the shoreline of the bay. Santa María de Galve existed in complex political times with French colony rivals in nearby Mobile and sieges—sometimes lasting years—from Native Americans mainly supported by English agitators.

Luna Colony

Although Luna Colony's water source has not been identified, logic indicates it would have been located convenient to the settlement. This is confirmed through both necessity and the locations of other documented settlements' water sources. But what likely solutions did Luna Colony employ to solve its water problem?

Barrel Well Solution

As shown at Saint Augustine and Santa Elena, Luna Colony's builders would have been familiar with barrel wells. Likewise, Luna's fleet would have had many empty barrels upon arriving at Pensacola. The colony is documented on sandy soils on a high point of land that slopes down to the bay (Priestley, 1929). The combination of sandy soils and high elevation, meaning it was higher than surrounding ground, indicates that surficial groundwater was not close to the surface. Without knowing the settlement's precise location, its elevation can only be assumed. Based on topography along Pensacola Bay's western shoreline, an elevation of twenty or more feet above sea level with a depth to surficial groundwater of ten to fifteen feet below the ground is a reasonable estimation. In order to key into the groundwater, the setters would have had to dig a hole to a depth of about fifteen feet, or more. The angle of repose of sandy soils varies, but would be in the range of thirty- to forty-five degrees (Cain, 1916, p. 9). Therefore, a fifteen-foot deep well would require a hole at the surface with a diameter upwards of thirty feet. The well would be multiple barrels high and the excavation would be thousands of cubic feet. If a person were to lower a three-gallon bucket down a fifteen-foot hole, wait for it to fill, retrieve it, and dump it, an average cycle time of ten minutes is reasonable. If this occurred continuously for twenty-four hours, this person or persons would have retrieved 432 gallons. If deep barrel wells were the colony's only source, the settlement would have had multiple wells and dozens of people dedicated to water supply, which seems impractical when there would have been nearby springs.

If the colony's builders had placed wells closer to the bay where less excavation was required, similar to the barrel wells at Presidio Santa María de Galve, those wells would have risked inundation from hurricane storm surges. If shoreline barrel wells were the colony's main potable water source, evidence of them may be well preserved.

River Solution

Documentation places the Luna Colony on the bay and not into the freshwater zone up the Escambia or other local rivers (Priestley, 1929). If the river were the intended supply, settlers would have sailed up the river, collected large volumes of water, unloaded, and carted tons of water up the slope to camp. The fleet's shipboard water-holding capacity is estimated at approximately 20,000 gallons (Dobson, 2016). Even if a third of Luna's boats were dedicated to water supply, a water run would have to be completed about every day and a half just to meet basic needs. It seems impractical that a settlement struggling to get a toe-hold on the continent would dedicate that level of resources when much more efficient sources were readily available.

Springs

If a spring is considered anywhere fresh water bubbles out of the ground, an artesian spring is a more pronounced type of spring where water flows up from the ground at a single point. Regardless of the nomenclature, both springs and artesian springs bring clean groundwater to the surface that discharges via stream to a larger water body. San Miguel Creek was an example of a spring-fed creek and was the likely primary water source for later Spanish and British settlements at Pensacola during the 1700s. Rainwater, absorbed into the soil north of present-day downtown Pensacola, migrated underground until emerging near the base of North Hill. The water probably did not outflow in a manner similar to Saint Augustine's artesian springs, rather it likely dribbled out in many locations along the slope, collecting in a common basin and overflowing into a small creek. This spring water was also the likely water source for early and mid-nineteenth-century Pensacola. As the city had no aqueducts or artesian wells, homeowners had a personal water barrel. A slave or servant would attach himself to a tow chain and roll the barrel to a spring, fill it, and roll it back to the home (Pickett, 1985, p. 27).

Conclusion

The methods used to solve the water problem by early U.S. settlements varied in technique, but in each of the referenced cases, the water source was located adjacent to or within the settlement. Settlers selected their sites with the water problem in mind and they employed the most efficient solutions that their selected sites allowed. Jamestown, Plymouth, Santa María de Galve, and St. Augustine had direct access to near limitless free-flowing fresh water. Although Santa Elena had adequate water, accessing it was labor intensive. It is possible that other factors, such as the need for a highly defendable position, was more important than convenient access to water.

After weeks of shipboard rationing, the Luna Expedition would have certainly been focused on solving their water problem quickly and efficiently. Constructing deep wells and cisterns, though plausible, would have been energy and time intensive and would have required large quantities of imported materials such as bricks. A natural spring or spring-fed creek appears to be the most logical solution to Luna Colony's water problem. A spring with a strong flow rate would provide a continuous supply of clean fresh water in excess of basic needs without heavy investment of labor and materials. The colony, as positioned on a high point, may have had streams on both sides of it. The topography of Pensacola Bay's shoreline, from Naval Air Station Pensacola to the Escambia River, lends itself to small spring-fed creeks emerging from near the base of hills and discharging into the bay or bayous. It should also be noted that settlements, particularly those anticipating confinement, diversified their water sources, but in each case the primary source was conveniently located and greatly exceeded basic water requirements. This would have been the case of the site of the Luna Colony, wherever it is located.

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