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Examining the Impact of Land Development and Urban Sprawl on the Edwards Aquifer, and Exploring Prospective Solutions

The Edwards Aquifer sources the wellsprings that supply drinking water to over two million people, support numerous endemic, endangered species and niche ecosystems, and bolster industries in Central Texas; these wellsprings have also have supported human activities for thousands of years before European colonization and serve as a substrate of the character of Central Texas at large. Springs in Central Texas supplied by the Edwards Aquifer (without forgetting the importance of smaller springs sourced from aquifers such as the Trinity) give life and meaning to an entire region of organisms and species, including humans, and are unquestionably irreplaceable resources. Regardless of the perceptions and opinions of its nature, land development is occurring at rapid rates in areas of sensitivity for the Edwards Aquifer, specifically along the Balcones Escarpment and I-35 corridor. To best safeguard the wellsprings essential to life in this region, it is vital to understand the impacts, both direct and indirect, that land development and urban sprawl have on the health of the Edwards Aquifer, in addition to their trickle down complexities, while exploring solutions based on improving upon current technologies, knowledge, and infrastructure, as well as those rooted in new innovative methods.

When looking at the Edwards Aquifer as a system, we must first understand how it works, then examine what inputs or stimuli are changing and how this impacts the system based on its original function. A starting point would be to define the Edwards Aquifer as a whole, which is "an underground layer of porous, honeycombed, water-bearing rock that is between 300-700 feet thick," according to Gregg Eckhardt (Eckhardt, 1995). For the Edwards Aquifer to maintain levels that allow for stable and constant spring flows, the aquifer must recharge to replenish losses from pumping, said spring flows, etc. The structure of the Edwards Aquifer is broken up into three zones (technically four, but the transition zone will not be discussed due to available space), which are not to be confused with the segments or pools of the aquifer (Eckhardt, 1995). The contributing zone is in the Texas Hill Country and is higher in elevation than the other two zones; in this "catchment area," streams and creeks originate from "water table aquifer(s)" to give rise to the basins that eventually fuel recharge (Eckhardt, 1995). These waterways then descend to the fractured Edwards limestone that make up the recharge zone, where streams are "frequently ephemeral in nature" despite playing a significant role in aquifer recharge (Thuesen, K. 2013, p. 406). Water enters the aquifer in one of two ways, being through allogenic or autogenic recharge; allogenic recharge occurs when the water recharging the aquifer comes from locations not directly within the recharge zone, whereas autogenic recharge is characterized by water falling on and entering from areas directly atop the recharge zone, as studied from Figure 4 of World Heritage Caves and karst: a thematic study (Williams, 2008). From the perspective of the Edwards Aquifer, allogenic recharge takes place in areas such as the fractured Edwards limestones of Cibolo and Helotes streambeds as they reach the recharge zones (Eckhardt, 1995). In contrast, autogenic recharge would be present at a site such as the Seco Creek Sinkhole, where water enters only from areas within the recharge zone, as opposed to the entire drainage basins that compromise the allogenic recharge of the two waterways mentioned above (Eckhardt, 1995). Also, note that the ratio of total recharge for the Edwards Aquifer is about 80% allogeneic and 20% autogenic recharge (Eckhardt, 1995). Lastly, the artesian zone represents the confined, underground area of the aquifer where water is stored under pressure and eventually forms artesian wells such as Comal Springs and Barton Springs (Eckhardt, 1995). Outlining the systems by which the Edwards Aquifer Works gives us an excellent springboard into understanding how the stimulus or change to the system, in this case land development, will impact it.

Today, Central Texas is in flux regarding land development and urban sprawl. This region is growing rapidly, containing "three of the five fastest-growing counties in the United States" along the I-35 or I-10 corridors, with much of the land development coming in unincorporated areas (Eldredge, 2022). In an article examining this style of development, Ben Eldredge from the Cibolo Center for Conservation characterizes it well, stating that developers can "(exploit) existing infrastructure without paying for the impacts of new development" (Eldredge, 2022). Specifically, the state of Texas has altogether failed to enact legislation that "prevent(s) pollution from fouling aquifers or (preventing) recharge features from being destroyed," which would consequently harm aquifers in a drastic way (Eldredge, 2022). In addition to not preventing these blatant offenses, the housing developments constructed in the Hill Country use techniques to build homes that scrape the land of vegetation entirely, weakening the ability of drainage basins to capture, hold, and channel water toward the recharge zone. Furthermore, developers are increasingly requesting permits of rising magnitude to dump treated wastewater effluents into Central Texas streams, which is an "ill-advised practice" due to the limestone substrates of these streambeds, which can cause these waterways to become easily eutrophic (Wimberley Valley Watershed Organization, 2019). In addition to the impact this would have on aquifer recharge, we must consider the implications for endangered cave species such as the Barton Springs Salamander. Previously, this organism was only thought to live in Barton Springs and associated smaller springs but has recently been found in the Onion Creek watershed, within the contributing zone of the Edwards Aquifer, "in the vicinity of the proposed [wastewater] discharge [location]" that was planning to go ahead until Protect Our Water opposed it

(Lueckemeyer, 2018). This discovery emphasizes the importance of geochemistry to Edwards Aquifer and Edwards Plateau endemics. It also serves as a broader lesson to fully explore, map out, and understand natural systems before altering them in irreversible ways. This also supports Gregg Eckhardt's notion that the Contributing Zone does not receive enough protection compared to the recharge zone when it comes to regulations and practices (Eckhardt, 1995). Furthermore, as the population increases, so does the needed capacity of infrastructure, regardless of the lack of helpful support provided by developers. One such example is the Oak Hill Parkway, a massive freeway constructed over Williamson Creek, where the contributing zone meets the recharge zone. Such intensive construction in such an important area doesn't make sense from an environmental perspective, as the water going into the creek, now devoid of a riparian area, will momentarily enter the recharge zone. However, as Gregg Eckhardt Points out, as long as construction occurs in the contributing zone, "builders can do almost whatever they like on sensitive properties adjacent to the Recharge zone," he also points out that "once the water in the Aquifer becomes contaminated, it will be challenging and perhaps impossible to clean." (Eckhardt, 1995). The latter of the two pieces of evidence becomes increasingly important considering San Antonio's drinking water comes from disconnected wells; if polluted, "smaller treatment facilities… which would be more expensive to build and operate," would become necessary to build, causing a spike in infrastructure expenses (Eckhardt, 1995). There are apparent issues regarding the current development regulations, which need to change before irreversible damage is done.

Understanding how development impacts Edwards Aquifer recharge is an essential step to brainstorming solutions. Regarding the mitigation of pollutants, TCEQ acknowledges that "properly sited and designed soil dispersal systems," which is a zero-discharge method, represent a more effective alternative to wastewater discharge (Wimberley Valley Watershed Organization, 2019). Perhaps, a reallocation or potential increase of funds stemming from new developments could finance such projects. In addition, further, more environmentally sound, regulations regarding development restrictions and guidelines in the contributing zone, and those protecting endangered and endemic species such as the Barton Springs Salamander, should be put into place in the near future. Furthermore, we should look to enhance aquifer recharge through various methods, the first of which would be to increase the breadth and accuracy of mapping above and beneath the surface. For instance, according to their social media, the Lady Bird Johnson Wildflower Center, located above the recharge zone, recently found a previously undiscovered cave contributing to autogenic recharge on their grounds. Imagine the difference in recharge if every cave similar to this was discovered, protected, and managed as effectively as this one. Areas such as the Western Oaks Karst Preserve and William H. Russell Karst Preserve represent quintessential examples of how autogenic recharge can be significantly protected and enhanced through appropriate drainage, runoff, and grading design, even in developed areas. Aside from preventing wastewater discharges, allogenic recharge can be improved by restoring suitable riparian vegetation with the help of expert ecologists and hydrologists to "optimize the quality and quantity" and incorporating the use of "swallets" with grates to better filter out sediments before they enter the caves, openings, or fractures that contribute to aquifer recharge within streambeds in allogeneic waterways (Thuesen, K. 2013, p. 408). In addition, other devices used to filter out contaminants entering through either form of recharge should be an area where research resources are allocated, as well as fully exploring the potential of ASR technologies, which according to the Barton Springs Edwards Aquifer Conservation District, will become an "increasingly important tool for meeting future water demand" by managing water storage and recovery using existing aquifer frameworks and injection wells (Barton Springs Edwards Aquifer Conservation District, n.d.). Another potential recharge enhancement comes in the form of Type I and Type II dams, outlined by Gregg Eckhardt on The Edwards Aquifer website. Type I dams are constructed at higher elevations in the contributing zone, to capture and store water in order to eventually be released for recharge downstream, but have the downside of "(inundating) large areas during rainy times and (leaving) large mud-crusted areas during dry times" (Eckhardt, 1995). As a whole, this recharge method is geared more towards enhancing allogenic recharge, but it deprives long-term ecological value. On the other hand, Type II dams are "constructed on the Recharge zone itself, " playing more into the process of autogenic recharge, and having less of an ecological impact as opposed to a Type I dam (Eckhardt, 1995). An improved type two lake could be constructed if we improve the mapping of openings and caves within the recharge zone, along with tailoring the surrounding ecosystems to "yield the greatest quantity of water" through "(managing) brush and (encouraging) grass restoration, including mechanical thinning, prescribed fire and native grass seeding, " (Thuesen, K. 2013, p. 405). In this case, a shallow, wetland-style lake could be constructed that functions as a native grassland habitat in periods where recharge is not occurring. Many great recharge enhancement options exist, and, implemented in tandem, would work well to combat the effects of development on the Edwards Aquifer.

In response to rapid development in Central Texas, numerous and varied strategies can be put into place to mitigate its effects, especially until government regulations align with ecological and hydrological principles. Examining the Edwards Aquifer as a system is essential; identifying how it works, how changes negatively impact this system and exploring solutions to these changes based on function represents a clear path forward for the Edwards Aquifer.

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