Land-Applied Wastewater Effluent Impacts on the Edwards Aquifer

Prepared for:
Greater Edwards Aquifer Alliance
and
Save Our Springs Alliance

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Executive Summary

This report examines existing evidence that wastewater effluent discharged in the Barton Springs and San Antonio Edwards Aquifer contributing zones under Texas Land Application Permits (TLAPs), issued by the Texas Commission on Environmental Quality, have failed to protect springs, creeks, rivers, and groundwater. Significant findings of the study include:

- The total TLAP-permitted daily flow in the Barton Springs Edwards Aquifer contributing zone is 5.75 million gallons per day, compared with only 3.18 million gallons per day in the San Antonio Edwards contributing zone. On a per acre basis, the permitted effluent in the Barton Springs Edwards Aquifer contributing zone is 24 times the amount in the San Antonio Edwards Aquifer contributing zone.
- Across the Barton Springs and San Antonio Edwards Aquifer recharge zones from Austin to Brackettville, there are currently no TLAPs. A recently proposed TLAP system over the Barton Springs Edwards Aquifer recharge zone presents a significant new threat to aquifer water quality.
- TLAPs are wildly inconsistent in terms of requirements for wastewater treatment, offline effluent storage volume, irrigation area size, or downgradient monitoring. The result of these inconsistencies is widely different levels of protection for downgradient springs, streams, rivers, and wells.
- Sparsely available monitoring data from streams and/or springs downstream from TLAPs indicate significant degradation of the high quality water that would naturally occur at those locations.
- Regulations governing TLAPs should be overhauled to provide a consistent and high level of water quality protection across the Edwards Aquifer.

In the context of the thin soils, numerous springs, and delicately sensitive Texas Hill Country streams, rivers, and aquifers, any wastewater effluent system represents the threat of permanent and significant degradation. Only by soundly based and strictly enforced regulations can we balance provision of wastewater infrastructure to suburban residences with protection of the natural streams and springs that draw people to these areas.

Introduction

In the drought-prone, arid area of the Texas Hill Country, springs, creeks, rivers, and groundwater are valued for their clarity and purity. These pristine water characteristics arise out of a unique natural setting of geology, soils, and vegetation. Partly ***because*** of their limited water supply, watersheds that sustain Texas Hill Country streams and aquifers have remained primarily rural ranch land.

With the combined pressures of increasing population and water importation, however, rural ranch land is rapidly being converted to suburban development. Along with more people and more water comes more wastewater. Because of their unique sensitivity to pollution, the Texas Commission on Environmental Quality (TCEQ) and its predecessor agencies have traditionally refused to grant wastewater effluent discharge permits within the San Antonio Edwards and Barton Springs recharge and contributing zones. An alternative permit, the Texas Land Application Permit (TLAP), has been granted instead. A TLAP requires that all wastewater effluent be irrigated onto fields or wooded areas, rather than being piped directly into a river or stream.

Until recently the number of TLAPs within the Texas Hill Country watersheds has been small. In 2003, for example, the volume of effluent disposal through TLAP permitted systems for the Barton Springs contributing zone was 1.7 million gallons per day.[1] As more people choose to live outside of the central urban areas, however, the volume of wastewater effluent being disposed of through TLAPs is burgeoning. By 2010, 7.2 million gallons per day of effluent irrigation had been permitted in the Barton Springs Edwards Aquifer contributing zone.

This report examines available evidence that current TLAP standards have failed to protect springs, creeks, rivers, and groundwater. It identifies significant permit inconsistencies; and short-comings of the current regulations governing TLAP permits terms. It recommends necessary regulatory changes to protect the character and quality of pristine Texas Hill Country streams and springs against an onslaught of expanding development and larger wastewater effluent volumes that come with increased human habitation.

[1] Herrington, Chris, Matthew Menchaca and Matthew Westbrook, *Wastewater Disposal Practices and Change in Development in the Barton Springs Edwards Aquifer Recharge Zone,* City of Austin Watershed Protection Department, 2010, and personal communication.

Setting

This study addresses effects of wastewater effluent disposal in the San Antonio and Barton Springs Edwards Aquifer contributing zones shown in Figure 1. This study region was selected because of its uniquely beautiful landscape; the importance of springs and stream flow in an otherwise water-short setting; and because the characteristics of these springs and streams make them naturally vulnerable to degradation from wastewater effluent. The following sections provide additional information on the streams and aquifers in the study region.

Natural Stream Conditions

There are ten major streams or rivers that originate in the contributing or recharge zones and carry water across the recharging limestone to sustain flow in the Edwards Aquifer. From west to east, these are the West Nueces, the Nueces, the Frio, the Sabinal, Hondo Creek, the Medina, the Guadalupe, the Blanco Rivers, Onion Creek and Barton Creek. In addition to these major rivers and creeks, there are numerous smaller creeks with unique biological habitat and beauty that contribute flow to the aquifer and springs. The pristine conditions of these creeks are also shared by other creeks and rivers near to, but outside of the Edwards Aquifer area, like the Pedernales River and its tributary Lick Creek.

Photograph 1. East Lick Creek in Travis County, Prior to Effluent Irrigation Impacts

Flow in these streams and rivers are characterized by two distinct regimes: a high flow regime shortly following storm rainfall; and a long duration low or baseflow regime. The long duration of the low-flow baseflow regime provides little to no dilution of any pollutants from wastewater effluent.

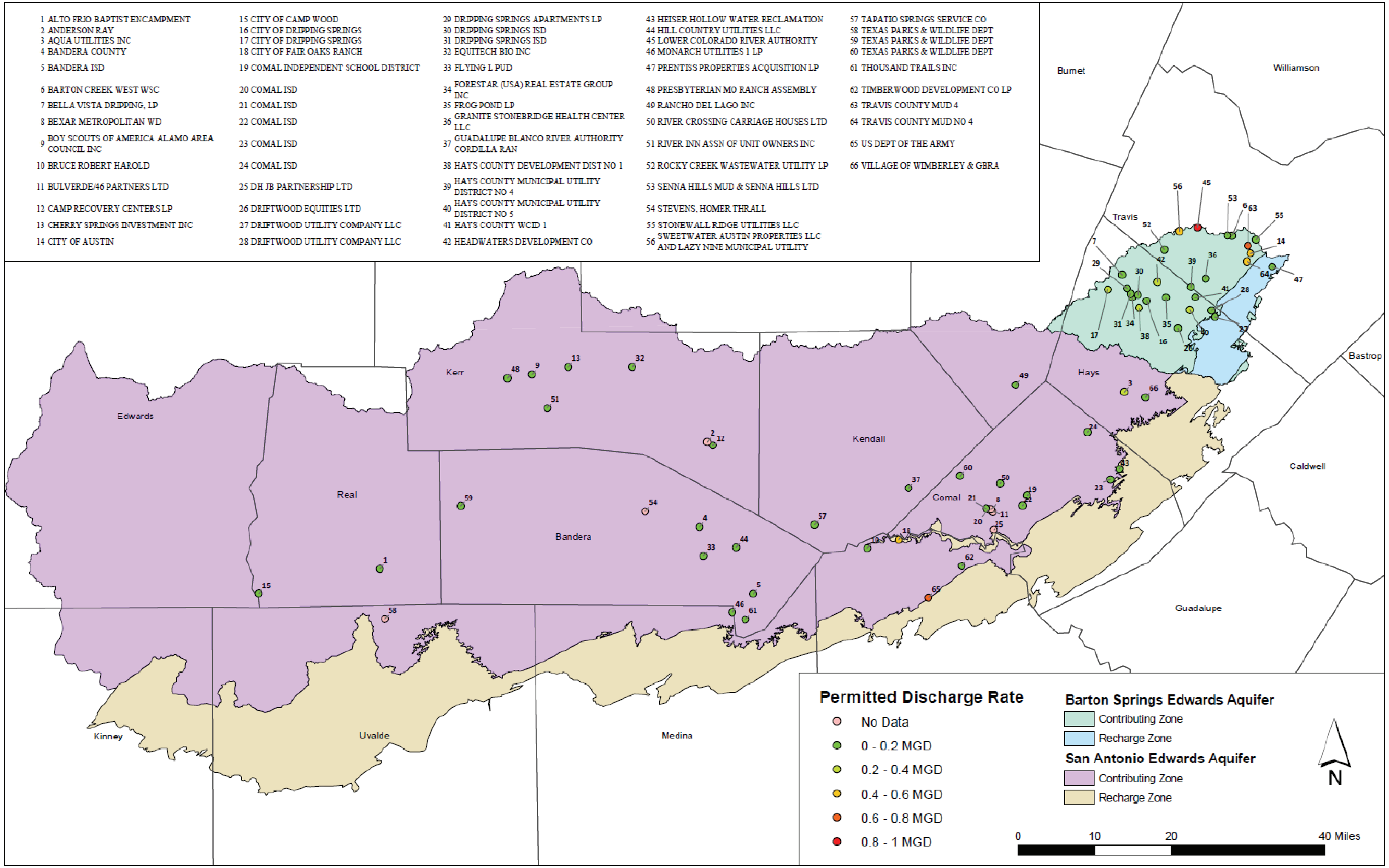

Figure 1. TLAPs Permitted within the San Antonio and Barton Springs Recharge and Contributing Zones

These Hill Country streams are also characterized by very low nutrient concentrations. Typical total phosphorous concentrations during baseflow conditions in a pristine Hill Country stream range from about 0.003 to 0.010 milligrams per liter and total nitrogen ranges from about 0.1 to 0.7 milligrams per liter.[2] Streams with these nutrient concentrations are classified as "oligotrophic." Oligotrophic waters are clear, with little algae. They have consistently high dissolved oxygen levels that support fish and other aquatic life.

Edwards Aquifer

Both the San Antonio and the Barton Springs Edwards Aquifers are karst systems. Groundwater flows through voids dissolved from the limestone. These voids range in size from pencil-width or smaller, to "big enough to drive a truck through." Water can move through a karst aquifer from recharge to discharge points in a matter of hours. The large passageways and rapid movement offer little opportunity for filtration or natural attenuation. Pollution that enters this aquifer shows up quickly in springs or wells. Karst aquifers are uniquely vulnerable to damage from pollution, including wastewater effluent.

Photograph 2. Underground Flow of Water in Blowing Sink Cave, Travis County, Texas

Pollution enters the Edwards Aquifer with the flow of recharging water. Understanding the source of water into the Edwards, both under natural conditions and in the presence of effluent irrigation conditions, is important to protecting the aquifer from pollution. Water can enter the Edwards Aquifer from four sources:

1. from upstream watersheds through recharge

[2] Herrington, Chris, *Impacts of the Proposed HCWCID 1 Wastewater Discharge to Bear Creek on Nutrient and DO Concentrations at Barton Springs,* City of Austin Watershed Protection Department, 2008; and Mabe, J.A., "Nutrient and biological conditions of selected small streams in the Edwards Plateau, Central Texas, 2005–06, and implications for development of nutrient criteria." *U.S. Geological Survey Scientific Investigations Report 2007–5195*, 2007.

features in creek channels;
2. through soil and fractured rock;
3. through internal drainage into sinkholes; and
4. from overlying or adjacent aquifers.

A recent study by Hauwert[3] estimated that 27% to 36% of the Barton Springs discharge might be sourced from upland areas rather than from stream bottoms. That study also determined that the proportion of rainfall recharging through soil-covered areas increased from 3% of rainfall during average rainfall conditions to 26% of rainfall during wet conditions.

This experimental finding is significant in two ways for understanding the potential effect of TLAPs on Edwards Aquifer water quality. First, the findings indicate direct connection between upland areas, where effluent irrigation occurs, and the underlying aquifer. There is no requirement that effluent first migrate to a channel bottom for aquifer degradation to occur. Second, aquifer recharge through soils regularly irrigated with effluent will be significantly higher than through soils saturated only by rainfall.

Wastewater treatment plants built for Shady Hollow and Travis Country residential developments in the 1980s irrigated wastewater effluent onto the recharge zone. Both plants were closed in the early 1990s to protect the Barton Springs Edwards Aquifer water quality. Currently there are no TLAPs for either the San Antonio or Barton Springs Edwards Aquifer recharge zones. There is, however, currently a permit application before the Texas Commission on Environmental Quality for such a system.[4]

A significant portion of the Edwards groundwater enters the aquifer through openings in the bottom of streams. Water to these stream bottoms is provided from their entire watersheds, which may stretch as far as 50 miles beyond the recharge zone boundary. These relatively large contributing watersheds gather rainfall runoff and then funnel it across stream bottom recharge features where the Edwards Limestone crops out. Wastewater effluent disposal within both the recharge and contributing areas would potentially affect the aquifer water quality.

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[3] Hauwert, Nico. *Groundwater Flow and Recharge within the Barton Springs Segment of the Edwards Aquifer, Southern Travis and Northern Hays Counties, Texas.* Dissertation, University of Texas at Austin, 2009, page 213.
[4] Jeremiah Venture, L.P., February 1, 2007.

Wastewater Effluent

Of the wastewater generated and disposed of within the study area, the majority is municipal or domestic wastewater. Domestic wastewater is a mix of human urine and feces, soaps, detergents, cleaning products, body care products, and pharmaceuticals. The Federal Clean Water Act, originally passed in 1972 and subsequently amended, requires communities to treat wastewater before releasing it into streams or rivers.

Wastewater treatment however, usually addresses only a couple of wastewater characteristics. Oxygen demand is treated by inoculating wastewater with a concentrated liquor of biological microorganisms; and then supporting their growth by bubbling air into the mixture. After a certain amount of time, this mixture is transferred to a clarifying basin where suspended solids settle to the bottom of the basin. The clearer water flows over the top edge of the basin into the next basin. Chlorine is added to sterilize pathogens, and the wastewater effluent is then discharged to streams or rivers.

Wastewater effluent permits do ***not*** require treatment to remove metals, pharmaceutical chemicals, or the wide range of chemicals found in body care products, soaps, detergents, pesticides, or other cleaning products. These chemicals remaining in treated effluent are undesirable additions to pristine streams or aquifers. They reduce oxygen levels, kill fish, and stimulate algae blooms. These chemicals contribute to the occurrence of cancer, birth defects and impaired health. Even at very low concentrations, nutrients, toxic metals, pesticides, and pharmaceuticals disrupt aquatic life. Some of these chemicals may accumulate in fatty tissue, impair ability to reproduce, escape predation, maintain proper metabolism, and/or lead to premature death.

Municipal wastewater typically contains 20 to 85 milligrams per liter of total nitrogen. Approximately 60% of the nitrogen will be in the form of ammonia; and 40% bound up in plant and animal tissue. Activated sludge and similar treatment processes typically reduce effluent total nitrogen concentrations to 15 to 35 milligrams per liter. Advanced biological nitrification/denitrification processes can achieve total nitrogen concentrations of 2 to 10 milligrams per liter.[5]

[5] Solomon, Clement, et al. *Trickling Filters: Achieving Nitrification*. National Small Flows Clearinghouse. http://www.nesc.wvu.edu/pdf/WW/publications/eti/TF_tech.pdf, September 25, 2011.

Elevated nutrients in drinking water can also significantly affect human health. Elevated nitrate concentrations have been linked to methemoglobinemia (blue baby syndrome), bladder and ovarian cancers in older women, and brain cancer in children of women using private well water during pregnancy. When combined with factors like low vitamin C or high meat intake, more than 10 years of exposure to water with more than 5 milligrams per liter of nitrate has been associated with a significant increase in the risk of colon cancer. Studies have also found positive associations between higher levels of nitrate intake during pregnancy and infant neural tube and congenital heart defects.[6]

Although nutrients are essential for a healthy ecosystem, natural ecosystems are precisely tuned to historical nutrient timing and concentrations. Nutrients higher than historical levels disrupt habitat. Increased plant growth pulls more oxygen out of the water when the dead plant matter decomposes. Excessive plant material also reduces stream velocities and increases sediment bottom deposition.

Current Texas Land Application Permits (TLAPs) in the Barton Springs and San Antonio Edwards Contributing Zones

Texas has historically recognized the sensitivity of the Edwards Aquifer by refusing to permit wastewater effluent discharges directly into creek and rivers within the San Antonio and Barton Springs Edwards Aquifer recharge and contributing zones. Wastewater treatment systems within these areas have been required to obtain a Texas Land Application Permit (TLAP), rather than a Texas Pollution Discharge Elimination System (TPDES) permits. In February 2009 TCEQ granted a direct discharge permit to Hays County Municipal Utility District No.1 (Belterra Subdivision), overturning decades of precedent requiring a more protective permit standard. To date there have been no TLAPs issued for either the San Antonio or Barton Spring Edwards Aquifer recharge zones.

[6] Mary H. Ward, Division of Cancer Epidemiology and Genetics, National Cancer Institute, National Institutes of Health, Department of Health and Human Services, Bethesda, MD, Jean D. Brender, Department of Epidemiology and Biostatistics, Texas A&M Health Science Center, School of Rural Public Health, College Station, TX, Nitrate in Drinking Water: Potential Health Effects in Dubrovsky, N.M., Burow, K.R., Clark, G.M., Gronberg, J.M., Hamilton P.A., Hitt, K.J., Mueller, D.K., Munn, M.D., Nolan, B.T., Puckett, L.J., Rupert, M.G., Short, T.M., Spahr, N.E., Sprague, L.A., and Wilber, W.G., 2010, The quality of our Nation's waters—Nutrients in the Nation's streams and groundwater, 1992–2004: U.S. Geological Survey Circular 1350, 174 p. http://water.usgs.gov/nawqa/nutrients/pubs/circ1350.

Effluent disposal under TLAP is generally more protective of creeks, rivers, springs, and the aquifer, compared with a TPDES disposal permit. Effluent receives additional treatment within plant roots and soil in several ways. Water is removed by plant roots and evapotranspiration, reducing the hydraulic pressure to carry contaminants beyond the disposal field. Soil organisms and plants convert nutrients into living cells. Toxic chemicals are transformed into safer substances. Chemicals are bound to organic matter and clay. Metals precipitate and are bound into the soil by iron and clay.

Whether or not these processes work effectively, however, depend on several aspects of the TLAP system:

- the chemical quality of treated effluent;
- the effluent application rate;
- soil depth;
- offline effluent storage capacity, used when the soil is saturated or frozen;
- excess vegetation removal; and
- monitoring and adjusting effluent irrigation in response to weather and rain.

Permit copies were obtained for this report from the TCEQ for 64 out of a total of 70 TLAPs issued for systems operating within the contributing zones of the San Antonio and Barton Springs Edwards Aquifer. Basic characteristics regarding the permitted flow, effluent quality, application rates, and storage volume were extracted from the TLAPs and are presented in Appendix A.[7]

The degree to which TLAPs degrade rivers, streams, and springs depends partly on the volume of wastewater that is treated and disposed of within a given area. Figure 1 illustrates the high density of TLAP systems in the Barton Springs Edwards Aquifer contributing zone compared with the San Antonio Edwards Aquifer contributing zone. An analysis of the data supports the visual impression. Table 1 compares TLAPs in the San Antonio and Barton Springs Edwards contributing zones. The permitted effluent volume in the Barton Springs Edwards Aquifer contributing zone is almost twice the volume permitted in the San Antonio contributing zones, even though the San Antonio contributing area is 17 times larger. On a per-area basis, there is 24 times as much wastewater effluent permitted for

[7] Permits for six systems in the San Antonio Edwards contributing zone were not located. These permits are listed in Appendix B.

irrigation in the Barton Springs Edwards Aquifer contributing zone compared with the San Antonio Edwards.

Table 1. Permitted TLAP Effluent in the Barton Springs Edwards Aquifer Contributing Zone Compared with the San Antonio Edwards

Aquifer	Total Flow (MGD)	Total Irrigated Area (acres)	Zone Area (acres)	GPD per Acre
Barton Springs	5.75	2,063	238,557	24
San Antonio Edwards	3.18	1,461	4,177,172	1

River, stream, well and spring degradation also depends on the degree of effluent treatment before it is irrigated onto the soil. There is a wide variety of effluent treatment methods, effluent quality standards, effluent storage capacity, and irrigation area size requirements in TLAPs issued within the study area. Table 2 lists the different types of treatment technologies and the number of permits associated with each. Of the 64 TLAPS, 44 use the activated sludge treatment method described above. Twelve of the TLAPs either fail to specify any required treatment method, or specify a treatment method less effective than activated sludge.

Table 2. Treatment Technologies for TLAPs in the Study Area

Treatment Methods	
Treatment Method	**Number of TLAPs**
activated sludge	44
septic tank	6
single stage nitrification	2
not specified	2
membrane bioreactor	2
septic and textile filter	1
S&L Fast K 1086 T	1
facultative lagoon	1
disk filtration	1
Cycle-let	1
aerobic treatment	1
aeration basin	1

Out of the 64 TLAPs, only 10 specify limits on nutrient discharges. Of these 10 that specify nutrient limits, eight limit only ammonia nitrogen. An ammonia limitation does ***not***, however, reduce available nitrogen in the discharge. In the activated sludge system used in each of these eight systems ammonia nitrogen is converted to nitrate nitrogen.[8] Nutrient nitrogen is not removed; it is simply converted to a different form.

In addition to differences in treatment methods and nutrient standards, TLAPs in the San Antonio Edwards and Barton Springs contributing zones differ widely in terms of the allowed application rates and the required effluent storage volume. An examination of the information in Appendix A indicates that the permit-allowed application rates range from 0.08 to 12.20 acre-feet per acre per year. The most common application rate is 4.88 acre-feet per acre per year, equivalent to the subsurface drip irrigation rate of 0.1 gallons per day per square foot. Twenty seven of the 64 current permits specify this application rate. Note, however, that the next section describes three systems with this application rate that exhibit indications of downstream degradation.

Out of 64 TLAPs, only 43 specify an effluent storage volume requirement. Twenty-one TLAPs have no effluent storage requirements. All permit-required volumes have been converted to “days of storage.” See Appendix A. This measure is the number of days for which the entire permitted flow could be contained in the storage volume. Since the value of effluent storage is the ability to postpone irrigation during saturated or frozen soil conditions, this measure in days is comparable between facilities across the range of permitted flows.

Of those that require effluent storage, required volumes range across five orders of magnitude, from 0.08 to 308 days. Effluent storage required for subsurface irrigation systems ranges from 0.08 to 70 days; and the average is 5.8 days. For surface irrigation systems the range is 12 to 308 days and the average is 70 days. The wide difference in average storage reflects differences in TCEQ regulations for subsurface and surface irrigation TLAPs. This wide difference in average storage requirements does not, however, reflect any difference in the sorptive capacity of the soils. In general, systems with less storage will be less protective of rivers, streams, wells, and springs than those with more storage. For

[8] Solomon, Clement, et al., *Trickling Filters: Achieving Nitrification*; National Small Flows Clearinghouse, http://www.nesc.wvu.edu/pdf/WW/publications/eti/TF_tech.pdf, September 25, 2011.

this and other reasons, subsurface irrigation systems represent a greater risk of degradation compared to surface irrigation.

Evidence of Degradation from TLAP Wastewater Systems

Monitoring to determine whether TLAPs have damaged streams, creeks, springs, and wells is not required by Texas environmental regulations; nor is it a requirement of most permits. Nevertheless, water monitoring programs by other agencies indicate stream and aquifer degradation in streams and springs associated with TLAPs. This section summarizes some of the available water quality measurements indicating TLAP systems have resulted in degraded water quality.

Hays County Water Control Improvement District No. 1

Hays County Water Control Improvement District No. 1, for the Belterra Subdivision, holds a subsurface irrigation permit for 150,000 gallons per day. The irrigation area is 35 acres in the Bear Creek watershed, tributary to Onion Creek, and located about seven stream miles upstream of the Barton Springs Edwards Aquifer recharge zone. The authorized application rate for this drip irrigation system is 4.88 acre-feet per acre per year. The system has 2.2 days of effluent storage, and the treatment limits, on a daily average, are 20 milligrams per liter biochemical oxygen demand and 20 milligrams per liter total suspended solids. There are no nitrogen or phosphorous effluent limits.

The City of Austin collected water quality samples from Bear Creek at seven locations to determine whether wastewater effluent irrigation associated with the Belterra Subdivision may have caused creek degradation.[9] The City's program includes monitoring from a spring at Aspen Drive upstream of possible TLAP irrigation field influences, downstream to a riffle at Bear Creek Pass. The City has also monitored four tributary locations to assess the impact of their inflows on Bear Creek water quality.

[9] Turner, Martha, *Bear Creek Receiving Water Assessment – January 2009 – March 2010,* City of Austin Watershed Protection Department, SR-10-10, September 2010.

The City's monitoring and data analysis found higher nitrate concentrations at sites immediately below the Belterra TLAP irrigation fields compared with nitrate in the spring above the irrigation fields.[10] The average nitrate concentration increased from 0.47 milligrams per liter upstream, to 1.31 milligrams per liter downstream of the TLAP irrigation area. See Figure 2. This nitrogen concentration increase shifts Bear Creek across the classification boundary between an oligotrophic and a mesotrophic stream at 0.7 milligrams per liter.

Chlorophyll-a concentrations, a measure of algae, were also higher in the Davis Pond immediately downstream from the irrigation fields, compared with the pond at Bear Creek Pass. Similarly, there are significantly higher occurrences of plants and algae above the Davis Pond, compared with the sampling site at Bear Creek Pass.[11]

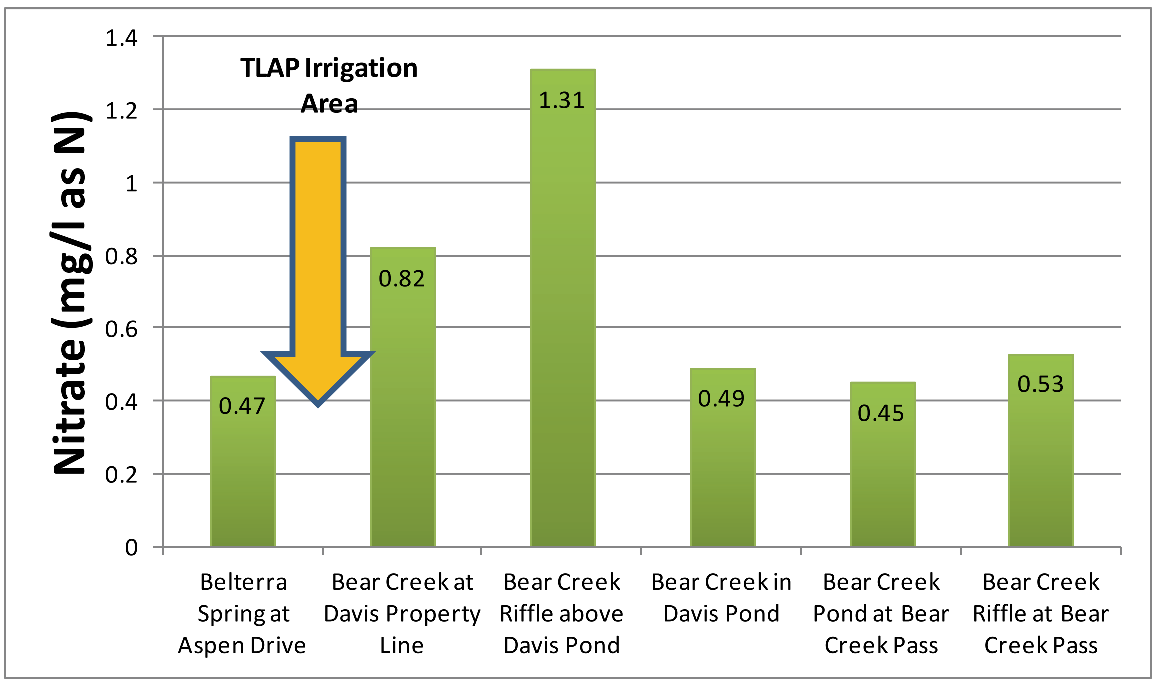

Figure 2. Increased Average Nitrate Concentration Downstream from Belterra TLAP Irrigation Area

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[10] Turner, Martha, *Bear Creek Receiving Water Assessment – January 2009 – March 2010,* City of Austin Watershed Protection Department, SR-10-10, September 2010, page 10.
[11] Turner, Martha, *Bear Creek Receiving Water Assessment – January 2009 – March 2010,* City of Austin Watershed Protection Department, SR-10-10, September 2010.

Sources other than effluent irrigation could produce higher nitrate concentrations and algae indicators downstream from the TLAP irrigation fields. These sources include subdivision fertilization, cattle ranching, and suburban stormwater runoff. There are several factors, however, that suggest that the observed water quality degradation is associated with the TLAP system, rather than any of these alternative sources:

- Nitrate concentrations are similar in Bear Creek at the Davis property line and in the Davis Pond. The property line site is above the influence of any cattle on the Davis property.
- Nitrate concentrations are highest during low flow situations. If the source were storm runoff, high concentrations would be observed during high flow, storm runoff conditions.
- Nitrate concentrations are highest during winter months. This pattern is consistent with TLAP effluent application when plant uptake is reduced.
- Algae occurrence increased during baseflow following heavy rains, suggesting that nutrients in the irrigation field may be flushed during these events.

In addition to sampling in the main stem of Bear Creek, the City of Austin also sampled two tributaries. One tributary north of the pond has relatively better quality than Bear Creek. Contributions from this tributary dilute nutrients and improve Bear Creek water quality.

Measurements on samples collected by the City of Austin from the western tributary to Bear Creek are similar to those of the main stem below the Belterra irrigation fields. This western tributary is downstream from the Highpointe subdivision, which is located on its headwaters. Like Belterra, Highpointe is served by a TLAP effluent irrigation system. This system is permitted for 300,000 gallons per day, subsurface irrigated on 68.87 acres. The application rate, 4.88 acre-feet per acre per year, is the same as Belterra's. Effluent treatment standards for Highpointe are the same as for Belterra.

Similarly to the situation in Bear Creek above and below the Belterra effluent irrigation fields, nitrates were relatively low (less than 0.004 milligrams per liter) in the western tributary above the Highpointe TLAP fields; and increase below the TLAPS irrigation fields to about 0.64 milligrams per liter.[12]

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[12] Turner, Martha, *Bear Creek Receiving Water Assessment – January 2009 – March 2010,* City of Austin Watershed Protection Department, SR-10-10. September 2010, Figure 11.

Barton Creek West

Barton Creek West is a residential subdivision in the Barton Creek watershed. The subdivision is located about 8 miles west of downtown Austin on Bee Caves Road. The Barton Creek West Homeowners Association, Inc. was registered in April 1985; and the subdivision currently consists of 398 homes.[13] The TLAP authorizes treatment and surface irrigation of 126,000 gallons of effluent per day on 53.3 acres of native grass. The allowed application rate is 2.7 acre-feet per acre per year. The system includes 62.7 acre-feet of storage to store 162 days of effluent. Treatment limits, on a daily average, are 10 milligrams per liter biochemical oxygen demand and 15 milligrams per liter total suspended solids. The permit does not restrict nitrogen or phosphorous in the treated effluent.

The City of Austin has monitored water quality in Scenic Bluff Spring, downstream of the irrigation fields since 1997. Average nitrate concentrations in this pool are 1.3 milligrams per liter[14]; and the maximum observed concentration is 5.9 milligrams per liter. Nitrate concentrations in uncontaminated wells and springs from the Glen Rose formation, from which this spring emerges, are about 10 to 50 times lower than these concentrations; on the order of 0.1 milligrams per liter.

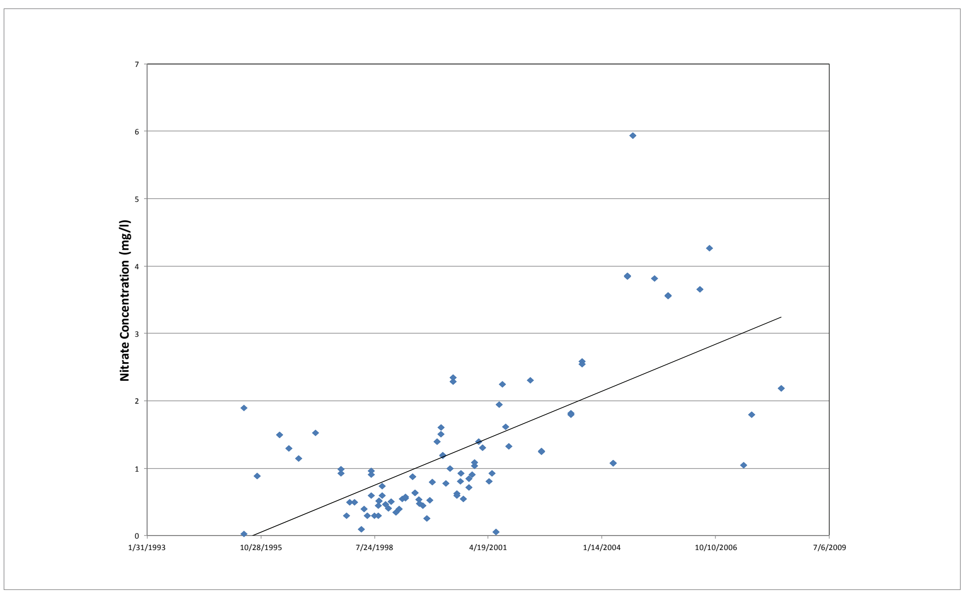

Figure 3. Increasing Nitrate Concentrations in Scenic Bluff Springs Over Time

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[13] Barton Creek West HOA. https://community.associawebsites.com/sites/BartonCreekWestHOA/Pages/AcwDefault.aspx, September 25, 2011.
[14] Nitrate concentration as nitrogen.

Figure 3 is a graph of nitrate concentrations in Scenic Bluff Spring as a function of time. The graph shows a clear trend of increasing concentrations. Grotto Spring, also apparently downgradient from the irrigation fields shows a similar trend of increasing nitrate concentrations with time.

Hebbingston Hollow, downstream from Bluff Springs, has been dammed to form a small pond. The presence of a thick algae layer across the entire surface of the pool on June 11, 2009 demonstrates the consequences of the high nitrate concentrations measured in the spring.

Photograph 3. Algae-Covered Pool Downstream from Barton Creek West Irrigation Fields

Residential lawn fertilization may be another source for the observed nitrate concentration increases over time in the two springs downstream from the Barton Creek West effluent irrigation fields. Monitoring by the City of Austin, however, suggests that stream nitrogen concentrations downstream from suburban residential areas on septic systems are relatively low compared with similar areas irrigated with effluent. See Figure 4. This difference suggests that irrigated effluent is at least partly the source of the elevated nitrate concentrations observed in Bluff Springs.

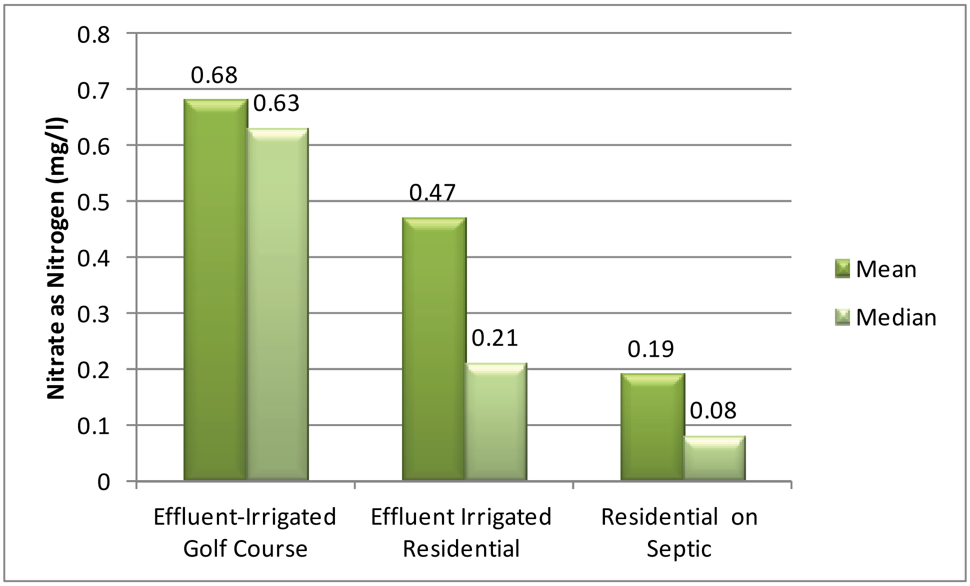

Figure 4. Nitrate Concentration in Barton Creek Canyons Baseflow

West Cypress Hills

West Cypress Hills is a residential subdivision located about 16 miles west of central Austin. Although the system is located just outside of the contributing zone to the Barton Springs Edwards Aquifer, it is included here because soils, geology, climate, and regulatory requirements for wastewater effluent are similar to many of the systems within the subject area of this study. This is another TLAP system for which water quality measurements in East Lick Creek above and below the TLAP irrigation fields are available. There is also another branch of Lick Creek, West Lick Creek without wastewater effluent irrigation, for which water quality measurements provide a comparable reference.

West Cypress Hills is proposed to be constructed in three phases. The first phase, begun in 2003, encompassed construction of 88 residences.[15] The second and third phases of the development contemplate construction of an additional 244 and 895 residences, respectively. The final phase of this permit would allow 31,000 gallons per day to be applied through a subsurface drip irrigation system to 72.08 acres. Allowed application rates are 4.88 acre-feet per acre per year. At least three days of effluent storage are required. Effluent permit limits are 20 milligrams per liter biochemical oxygen

[15] The Moore Group, *Cypress Ranch Phase One*, Section One. Engineer's Report. April 6, 2003.

demand and 20 milligrams per liter total suspended solids, on a daily average basis. There are no nutrient limit requirements.

The owner's representative collected water quality samples from springs and streams upstream and downstream from the West Cypress Hills TLAP irrigation area in June and September 2007. Nitrate concentrations in these data, presented in Figure 5 show a pattern similar to the one observed downstream from the TLAP irrigation areas for Belterra and Barton Creek West.

Photograph 4. West Lick Creek Downstream from Pedernales Canyon Trail

Nitrate concentrations are low upstream from the irrigation fields. These concentrations rise sharply just downstream from the irrigation fields. Further downstream concentrations are once again lower. More extensive algae coverage of the creek, and the presence of algae types like *Cladophora,* however, indicate that the trophic state of the stream has been altered even where nutrient measurements in the water column are relatively low. Photograph 4 and Photograph 5 depict the difference in algae coverage in East Lick Creek downstream for the currently irrigated areas, compared with clear flow in West Lick Creek, where there are currently no effluent-irrigated fields in the watershed.

Photograph 5. Algae in East Lick Creek Downstream from Pedernales Canyon Trail

As with any suburban development, there are other potential nutrient sources. The West Cypress Hills developer originally believed that the source of the nitrogen might be a commercial plant nursery, a horse barn, or storm runoff from Highway 71. Nitrate concentrations from stream locations downgradient from these sites, however, are lower than at sites below the effluent irrigation areas.

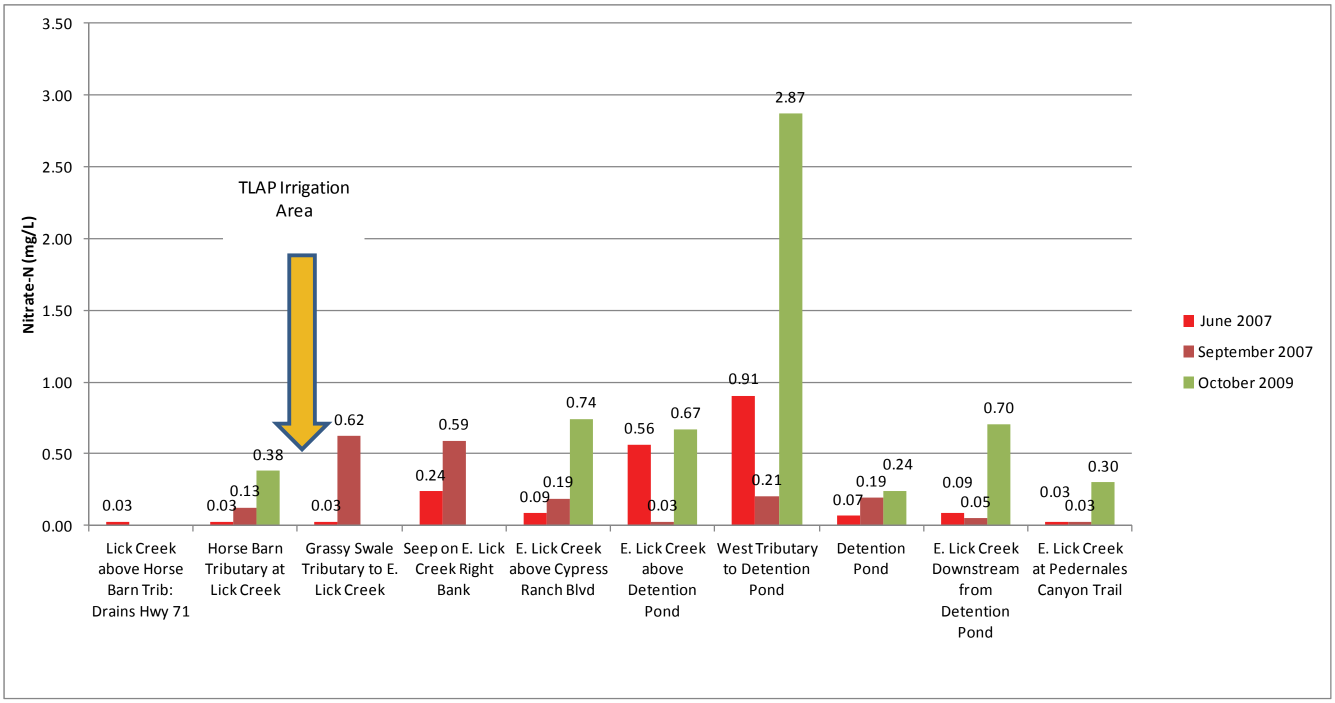

Figure 5. Nitrate Concentrations Above and Below West Cypress Hills TLAP Irrigation Fields

Other possible sources are residential lawn fertilization and compost used to revegetate the construction site.

Effluent Land Application in Other Areas

The soils, climate, and geology of the Edwards Aquifer are unique. There is evidence from other locations, however, that corroborate groundwater degradation from the land application of effluent in similar systems. A study of well and spring water quality in the karstic Wakulla Spring in northern Florida found nitrate-nitrogen concentrations increased from about 0.2 to 1.1 milligrams per liter downstream from a 17 million gallon per day wastewater spray field farming operation on 313 acres. The largest contribution to the nitrogen load, 55%, was attributed to municipal wastewater. Nitrate isotope signatures ($\delta^{15}N$ and $\delta^{18}O$) in groundwater match those of the effluent.

Boron and chloride concentrations were elevated. One pharmaceutical compound, carbamazepine (an anti-convulsant drug) was also detected in the groundwater. Spring-fed streams in Florida have experienced a proliferation of nuisance aquatic vegetation and algal growth.[16]

TLAP Noncompliance with Regulation Requirements

The following section discusses recommended improvements to current TLAP regulatory requirements. Before recommending regulatory improvements, however, it seems important to identify inadequate implementation of existing regulations.

Required Soil Monitoring

TCEQ regulations do not require stream, river, well, or spring monitoring downstream from effluent irrigation areas. 30 TAC §309.20 (b)(4) does, however, require pre-operational and annual soil testing of pH, total nitrogen, potassium, phosphorus, and conductivity. This requirement is included as part of each TLAP in Special Provision 10: "*The permittee shall submit the results of the soil sample analyses to the TCEQ Regional Office and Water Quality Compliance Monitoring Team of the Enforcement Division during September of each year.*"

A search of TCEQ records, however, indicates reported soil monitoring results for only two of the 64 TLAPs within the study area. Even for these limited reported data, only 2 out of the 18 include the required nitrogen measurements. Given indications of nutrient migration from the effluent irrigation fields resulting in significant water degradation, the failure by TCEQ to regulate and enforce what is clearly intended to be an early warning system on nutrient accumulation in the soil disposal zone is troubling.

Failure to Properly Review TLAP Applications

Numerous parties, including the City of Austin, Barton Springs Edwards Conservation District, the Lower Colorado River Authority, Hays County, and Save Our Springs Alliance are currently contesting a TLAP for Jeremiah Venture to treat and irrigate 330,000 gallons per day of wastewater effluent over

[16] Katz, Brian, Dale Griffin, J. Hal Davis, "Groundwater quality impacts from the land application of treated municipal wastewater in a large karstic spring basin: chemical and microbiological indicators." *Science of the Total Environment,* 407, 2872-2886, 2009.

the recharge area of the Barton Springs Edwards Aquifer. There are currently no surface or subsurface TLAP systems permitted within the San Antonio or Barton Springs Edwards Aquifer recharge zones.

Given the potential significance of this precedent-setting permit, and using the legal authority and resources of the contested hearing process, the City of Austin, Save Our Springs Alliance and Save Barton Creek Association undertook an in-depth review of the Jeremiah Venture TLAP application. The results of the review indicated that the TLAP application failed to represent the potential for significant degradation in the following ways:

- Effluent irrigation was proposed for areas where the soils were determined to be unsuitable for effluent irrigation because they were too rocky, thin, and clayey, and/or had more than 50% bedrock outcrop. Other irrigation areas were determined to be unsuitable because they were on gradients approaching 15% and soil water holding capacities were less than 2 inches.[17]
- The applicant's assessment identified four sinkholes, no caves, four solution cavities, and 14 closed non-karstic depressions. By comparison, a geologic assessment by the City of Austin,[18] conducted over eight days, identified nine cave features, 35 sinkholes, 27 karst depressions, 24 non-karst closed depressions, 23 solution enlarged fractures, 39 solution cavities, and 3 swallow holes. The applicant's assessment failed to characterize the potential for wastewater effluent migration through a sensitive karst region into the underlying Barton Springs Edwards Aquifer.
- Irrigation field sizing is based on a water balance of effluent irrigation, rainfall, runoff, evapotranspiration, and deep percolation. This water balance is particularly sensitive to the evapotranspiration estimates. The applicant's water balance was based on estimated evapotranspiration rates for dryer conditions west of the proposed Hays County location. The significance of this difference was that the applicant overestimated the volume of water that could be applied to the proposed irrigation area by 29%; and underestimated the required effluent storage volume by almost half.[19]

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[17] SOAH Docket No. 582-09-1617; TCEQ Docket No. 2008-1858-MWD. *Application of Jeremiah Venture, L.P. for a New TLAP, Permit No. WQ0014785001*, Direct Testimony of Dr. Lawrence (Larry) P. Wilding. July 31, 2009, pages 50-51.
[18] Hauwert, Nico, *Preliminary Phase I Assessment of the Jeremiah Ventures Site,* for the City of Austin, September 25, 2009.
[19] Ross, Lauren, *Engineering Analysis of Jeremiah Ventures L.P. Proposed Wastewater Irrigation Areas; Draft,* December 2009.

- As required by TCEQ regulations, the applicant provided a water balance for the wettest year of record: 2004. The wettest year of record does not, however, necessarily capture critical rainfall and evapotranspiration conditions. Weather conditions during 2007, a year with a lower rainfall total than 2004, are more restrictive in terms of both effluent irrigation area and storage volume. Nevertheless, the applicant was allowed to size these facilities based on a model using 2004 data.

The applicant proposed to provide wastewater service to 1450 residences. The number of residences that could be served using a water balance based on the appropriate evapotranspiration rates and providing buffers to the City of Austin-identified recharge features is 800. This significant financial incentive to the applicant to misrepresent actual site conditions can only be addressed by consistent and careful review by the authorizing agency, the Texas Commission on Environmental Quality.

Recommendations

Given the number of currently permitted TLAP systems, particularly in the Barton Springs Edwards Aquifer contributing zone, and existing evidence of degraded streams and springs, several changes to TLAP regulations are warranted. These changes include:

- Given that karst features beneath irrigation areas cannot be completely identified, mapped or defined, spray effluent irrigation, as well as subsurface effluent irrigation, over recharge areas should be prohibited.
- Consistent effluent standards to limit concentrations of total nitrogen and phosphorous should be established. Any limitation based upon ammonia nitrogen alone provides no additional protection. Advanced wastewater treatment methods can consistently reduce total phosphorous concentrations to near or below 0.01 milligrams per liter.[20] Combined total nitrogen and total

[20] EPA Region 10, *Advanced Treatment to Achieve Low Concentration of Phosphorus,* April 2007, http://yosemite.epa.gov/r10/water.nsf/Water+Quality+Standards/AWT-Phosphorus/$FILE/AWT+Report.pdf, September 26, 2011.

phosphorous removal systems can achieve annual average concentrations less than 3 milligrams per liter and 0.1 milligrams per liter, respectively.[21]

- Subsurface effluent application does not increase soil storage or treatment capacity. In fact, because the potential evapotranspiration from the surface of tree and plant leaves is lost, the effluent storage and treatment capacity for subsurface effluent application is actually less than for surface applications. Furthermore, subsurface application bypasses the surface soil barrier to chemical and microbial migration.[22] Current rules should be changed to require the same effluent storage capacity for subsurface as for surface application systems.
- The same engineering basis should be used to determine effluent application rates and storage volume requirements for both surface and subsurface systems. That basis should be a daily time-step water balance using historic rainfall rates and evapotranspiration rates from representative weather stations within 25 miles of the proposed facility. The water balance modeling period should be the period of record.
- The leaching allowance in the current TLAP regulations is, essentially, an amount of effluent allowed to deep percolate into underlying aquifers. The leaching allowance should be eliminated.
- TLAPs should require downgradient monitoring, including nitrate, boron, chloride concentrations, nitrogen and oxygen isotope signatures and measures of the occurrence of algae, to identify any wastewater effluent contamination of springs, streams, and wells.[23]
- In addition to the current general prohibition, TLAPs should require soil monitoring to measure saturated or frozen conditions and prevent effluent application.
- Existing regulations requiring regular soil monitoring should be expanded to include a process for identifying soil monitoring results that would trigger a re-examination of the permit terms to prevent wastewater effluent chemical migration to streams, springs, and wells.

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[21] Kang, Shin, Kevin Olmstead, Krista Takacs, James Collins, *Municipal Nutrient Removal Technologies Reference Document,* EPA 832-R-08-006, September 2008, http://water.epa.gov/scitech/wastetech/upload/mnrt-volume1.pdf, September 26, 2011.
[22] Katz, Brian, Dale Griffin, J. Hal Davis, "Groundwater quality impacts from the land application of treated municipal wastewater in a large karstic spring basin: chemical and microbiological indicators." *Science of the Total Environment,* 407, page 2884, 2009.
[23] Katz, Brian, Dale Griffin, J. Hal Davis, "Groundwater quality impacts from the land application of treated municipal wastewater in a large karstic spring basin: chemical and microbiological indicators." *Science of the Total Environment,* 407, 2872-2886, 2009.

In the context of the thin soils, numerous springs, and delicately sensitive Texas Hill Country streams, rivers, and aquifers, any wastewater effluent system represents the threat of permanent and significant degradation. Only with soundly based and strictly enforced regulations can we balance provision of wastewater infrastructure to suburban residences with protection of the natural streams and springs that draw people to these areas.

Appendix A. TLAPs in the San Antonio and Barton Springs Edwards Contributing Zones

TLAP Permits in the San Antonio and Barton Springs Edwards Contributing Zones

Aquifer	Permit	Permittee	River Segment	Flow (MGD)	Irrig Area (acres)	Appli-cation Rate (ac-ft/ac/yr)	Effluent Storage (days)	Treatment Method	BOD Grab (mg/L)	Daily Average BOD (mg/L)	Daily Average TSS (mg/L)	Daily Average NH3 (mg/L)	Daily Average P (mg/L)
Barton Springs													
	11319-001	CITY OF AUSTIN, LOST CREEK	Barton Creek	0.52	308.42	1.89	43.36	activated sludge	35	10	15	-1	-1
	12786-001	BARTON CREEK WEST WSC	Barton Creek	0.13	53.30	2.65	162.15	activated sludge	35	10	15	-1	-1
	13206-001	TRAVIS COUNTY MUD 4	Barton Creek	0.72	298.70	2.70	75.13	activated sludge	30	5	5	2	-1
	13238-001	SENNA HILLS MUD & SENNA HILLS LTD	Barton Creek	0.16	70.30	2.50	112.08	activated sludge	30	5	5	2	-1
	13594-001	LOWER COLORADO RIVER AUTHORITY Lake	Barton Creek	1.00	350.00	3.20	32.59	activated sludge	35	5	5	2	-1
	13748-001	DRIPPING SPRINGS ISD	Onion Creek	0.02	3.44	4.88	0.00	septic tank	100	-1	-1	-1	-1
	13748-002	Dripping Springs ISD	Onion Creek	0.03	3.83	7.31	0.00	activated sludge	65	-1	-1	-1	-1
	13860-001	GRANITE STONEBRIDGE HEALTH CENTER LLC	Onion Creek	0.01	1.59	7.03	0.00	septic tank	100	30	30	-1	-1
	14077-001	PRENTISS PROPERTIES ACQUISITION LP	Barton Creek	0.00	0.00		70.45	Cycle-let	30	5	-1	-1	-1
	14146-001	DRIPPING SPRINGS APARTMENTS LP	Onion Creek	0.01	3.57	4.39	58.19	activated sludge	65	20	20	-1	-1
	14208-001	HAYS COUNTY DEVELOPMENT DIST NO 1	Onion Creek	0.30	120.00	2.80	72.31	activated sludge	30	5	5	-1	-1
	14235-001	DRIFTWOOD EQUITIES LTD Salt Lick	Onion Creek	0.01	2.30	4.87	2.53	activated sludge	35	10	15	-1	-1
	14293-001	HAYS COUNTY WCID 1 Beltera	Onion Creek	0.15	35.00	4.80	2.20	not specified	65	20	20	-1	-1

TLAP Permits in the San Antonio and Barton Springs Edwards Contributing Zones

Aquifer	Permit	Permittee	River Segment	Flow (MGD)	Irrig Area (acres)	Appli-cation Rate (ac-ft/ac/yr)	Effluent Storage (days)	Treatment Method	BOD Grab (mg/L)	Daily Average BOD (mg/L)	Daily Average TSS (mg/L)	Daily Average NH3 (mg/L)	Daily Average P (mg/L)
Barton Springs													
	14309-001	HAYS COUNTY MUNICIPAL UTILITY	Barton Creek	0.15	34.44	4.88	2.22	single stage nitrification	65	20	20	-1	-1
	14358-001	HAYS COUNTY MUD 5 Highpointe	Onion Creek	0.30	68.87	4.88	2.22	activated sludge	65	20	20	-1	-1
	14430-001	TRAVIS COUNTY MUD NO 4	Barton Creek	0.60	220.00	3.06	76.03	single stage nitrification	30	5	5	2	-1
	14435-001	STONEWALL RIDGE UTILITIES LLC	Barton Creek	0.01	1.15	4.87	0.00	activated sludge	65	20	20	-1	-1
	14480-001	DRIFTWOOD UTILITY COMPANY LLC Reunion	Onion Creek	0.05	11.50	4.87	3.98	activated sludge	65	20	20	-1	-1
	14480-002	DRIFTWOOD UTILITY COMPANY LLC Reunion	Onion Creek	0.10	22.10	4.88	4.88	activated sludge	65	20	20	-1	-1
	14488-001	CITY OF DRIPPING SPRINGS South Regional	Onion Creek	0.16	37.43	4.86	2.05	activated sludge	65	20	20	-1	-1
	14488-002	CITY OF DRIPPING SPRINGS Scenic Greens	Onion Creek	0.25	57.39	4.88	3.00	activated sludge	65	20	20	-1	-1
	14587-001	Austin Highway 290 (Headwaters	Barton Creek	0.33	76.00	4.79	7.00	activated sludge	30	5	5	2	1
	14629-001	SWEETWATER AND LAZY NINE MUD	Barton Creek	0.49	199.50	2.75	60.05	activated sludge	35	10	15	-1	-1
	14664-001	ROCKY CREEK WASTEWATER UTILITY LP	Barton Creek	0.13	50.00	2.81	61.67	activated sludge	30	5	5	2	-1
	14824-001	FORESTAR Arrowhead Ranch	Onion Creek	0.13	29.00	4.83	3.00	activated sludge	35	10	15	-1	-1
	14866-001	BELLA VISTA DRIPPING, LP	Barton Creek	0.02	5.28	4.88	3.00	activated sludge	35	10	10	-1	-1
San Antonio Edwards													

TLAP Permits in the San Antonio and Barton Springs Edwards Contributing Zones

Aquifer	Permit	Permittee	River Segment	Flow (MGD)	Irrig Area (acres)	Appli-cation Rate (ac-ft/ac/yr)	Effluent Storage (days)	Treatment Method	BOD Grab (mg/L)	Daily Average BOD (mg/L)	Daily Average TSS (mg/L)	Daily Average NH3 (mg/L)	Daily Average P (mg/L)
San Antonio Edwards													
	04237-000	EQUITECH BIO INC	Guadalupe above	0.00	0.16	3.57	0.00	not specified	-1	-1	-1	-1	-1
	11291-001	FLYING L PUD	Medina River above	0.11	178.00	0.71	0.00	activated sludge	65	20	20	-1	-1
	11683-001	ALTO FRIO BAPTIST ENCAMPMENT	Upper Frio River	0.02	2.00	11.20	0.00	aerated lagoon	100	-1	-1	-1	-1
	11867-001	City of Fair Oaks Ranch	Upper Cibolo Creek	0.50	280.00	2.00	103.11	activated sludge	-1	-1	-1	-1	-1
	11976-001	Texas Lehigh Cement Company LP	Plum Creek	0.00	3.00	1.01	0.00	activated sludge	100	30	-1	-1	-1
	12014-001	TEXAS PARKS & WILDLIFE DEPT Guadalupe River	Guadalupe above	0.02	6.10	2.94	28.51	activated sludge	100	-1	-1	-1	-1
	12080-001	US DEPT OF THE ARMY Camp Bullis Miltary	Salado Creek	0.69	189.75	4.07	65.64	activated sludge	65	20	-1	-1	-1
	12334-001	CITY OF CAMP WOOD	Nueces River above	0.10	14.00	8.08	19.03	facultative lagoon	100	-1	-1	-1	-1
	12404-001	Kendall City UC	Upper Cibolo Creek	0.15	40.00	4.20	173.79	activated sludge	65	20	20	-1	-1
	13321-001	VILLAGE OF WIMBERLEY & GBRA	Upper Blanco River	0.05	19.00	2.95	142.07	activated sludge	35	-1	-1	-1	-1
	13449-001	CAMP RECOVERY CENTERS LP	Guadalupe above	0.02	4.00	4.76	12.27	activated sludge	65	-1	-1	-1	-1
	13449-001	CAMP RECOVERY CENTERS LP	Guadalupe above	0.02	0.34	55.30	12.27	activated sludge	65	-1	-1	-1	-1
	13755-001	RIVER INN ASSN OF UNIT OWNERS INC	S. Fork Guadalupe	0.01	0.92	8.30	0.00	activated sludge	65	20	-1	-1	-1

TLAP Permits in the San Antonio and Barton Springs Edwards Contributing Zones

Aquifer	Permit	Permittee	River Segment	Flow (MGD)	Irrig Area (acres)	Appli-cation Rate (ac-ft/ac/yr)	Effluent Storage (days)	Treatment Method	BOD Grab (mg/L)	Daily Average BOD (mg/L)	Daily Average TSS (mg/L)	Daily Average NH3 (mg/L)	Daily Average P (mg/L)
San Antonio Edwards													
	13783-001	BANDERA ISD Hill Country Elementary	Medina River	0.01	1.10	12.20	0.08	activated sludge	65	20	-1	-1	-1
	13812-002	COMAL ISD Arlon Seay Intermediate School	Upper Cibolo Creek	0.01	1.65	4.62	0.00	septic tank	100	-1	-1	-1	-1
	13812-003	COMAL ISD Spring Branch Middle School	Upper Cibolo Creek	0.01	2.98	4.88	0.00	activated sludge	65	20	20	-1	-1
	13812-004	COMAL ISD Smithson Valley Middle School	Guadalupe above	0.01	2.98	4.88	0.00	activated sludge	65	20	20	-1	-1
	13989-001	AQUA UTILITIES INC	Cypress Creek	0.38	175.00	2.40	83.40	activated sludge	65	20	20	-1	-1
	14157-001	BOY SCOUTS OF AMERICA ALAMO AREA	N. Fork Guadalupe	0.00	4.30	0.98	17.38	activated sludge	65	20	20	-1	-1
	14167-001	MONARCH UTILITIES 1 LP	Medina Lake	0.03	10.00	2.80	91.89	activated sludge	-1	-1	-1	-1	-1
	14280-001	THOUSAND TRAILS INC	Medina Lake	0.02	2.18	9.76	0.00	activated sludge	35	10	15	-1	-1
	14295-001	COMAL ISD Smithson Valley High School	Upper Cibolo Creek	0.03	6.20	4.88	0.00	septic tank	65	20	20	-1	-1
	14385-001	GUADALUPE BLANCO RIVER AUTHORITY	Guadalupe River above	0.19	102.00	2.11	0.00	membrane bioreactor	30	5	5	2	-1
	14485-001	BRUCE ROBERT HAROLD Boerne Stage Field	Lower Leon Creek	0.00	0.54	3.11	52.14	aerobic treatment	100	-1	-1	-1	-1
	14533-001	COMAL ISD Canyon Lake High School	Upper Blanco River	0.04	9.20	4.87	3.00	aeration basin	65	20	20	-1	-1
	14541-001	CHERRY SPRINGS INVESTMENT INC La	N. Fork Guadalupe	0.02	4.48	4.88	3.08	activated sludge	100	-1	-1	-1	-1

TLAP Permits in the San Antonio and Barton Springs Edwards Contributing Zones

Aquifer	Permit	Permittee	River Segment	Flow (MGD)	Irrig Area (acres)	Appli-cation Rate (ac-ft/ac/yr)	Effluent Storage (days)	Treatment Method	BOD Grab (mg/L)	Daily Average BOD (mg/L)	Daily Average TSS (mg/L)	Daily Average NH3 (mg/L)	Daily Average P (mg/L)
San Antonio Edwards													
	14603-001	PRESBYTERIAN MO RANCH ASSEMBLY	N. Fork Guadalupe	0.05	15.00	3.73	0.00	activated sludge	30	5	10	-1	-1
	14615-001	RANCHO DEL LAGO INC Rockin' J Ranch	Upper Blanco River	0.15	37.80	4.45	112.00	activated sludge	30	5	5	3	3
	14637-001	RIVER CROSSING CARRIAGE HOUSES LTD	Guadalupe River above	0.02	225.60	0.08	308.08	activated sludge	65	20	20	-1	-1
	14670-001	TIMBERWOOD DEVELOPMENT CO LP	Salado Creek	0.02	0.00		3.00	septic tank	65	-1	-1	-1	-1
	14760-001	HILL COUNTRY UTILITIES LLC	Medina River above	0.03	8.00	4.20	58.65	activated sludge	35	10	15	-1	-1
	14806-001	Whitewater Land, Heiser Hollow Water	Guadalupe below	0.20	46.00	4.87	0.00	septic and textile filter	65	20	20	-1	-1
	14839-001	BANDERA COUNTY Jail and Justice Center	Medina River above	0.01	2.63	4.88	3.00	disk filtration	100	-1	-1	-1	-1
	14959-001	Two Seventy Seven, GBRA, Park Village	Upper Cibolo Creek	0.20	49.24	4.44	3.00	membrane bioreactor	65	5	5	2	1
	14975-001	DH/JB Partnership, Johnson Ranch	Upper Cibolo Creek	0.08	17.22	4.88	0.00	activated sludge	65	20	20	-1	-1

Appendix B. TLAPs for which No Permits Were Located

The following permits were identified on a TCEQ-supplied Geographical Information System shape file. No corresponding permits were located, however, in TCEQ Central Records.

Permit Number	PERMITTEE	STATUS	Aquifer
11962-001	TEXAS PARKS & WILDLIFE DEPT	Current	San Antonio Edwards
14131-001	BEXAR METROPOLITAN WD	Current	San Antonio Edwards
14333-001	STEVENS, HOMER THRALL	Current	San Antonio Edwards
14397-001	ANDERSON RAY	Current	San Antonio Edwards
14733-001	DH JB PARTNERSHIP LTD	Current	San Antonio Edwards
14741-001	BULVERDE/46 PARTNERS LTD	Current	San Antonio Edwards