Impacts of the proposed HCWCID 1 wastewater discharge to Bear Creek on nutrient and DO concentrations at Barton Springs

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The impacts of the proposed Belterra (HCWCID 1) discharge, located in the contributing zone of the Barton Springs portion of the Edwards Aquifer, on concentrations of nutrients in Barton Springs were evaluated using a karst aquifer model (Barrett and Charbeneau 1996, Turner 2006). Additionally, the change in Barton Springs dissolved oxygen was estimated based on change in biochemical oxygen demand in creek recharge to the aquifer generally following previous City of Austin method (COA 2006). Both analyses utilized predicted daily Bear Creek concentrations with and without the proposed discharge generated from a series of LA-QUAL models (Herrington 2008) as an input data source. As drafted, the proposed discharge is predicted to increase concentrations of nitrogen and phosphorus in Barton Springs and decrease Barton Springs dissolved oxygen. These estimates could be improved with a more spatially detailed karst aquifer model; however, they are the best possible using accepted methods currently available.

Introduction

Hays County Water Control and Improvement District No. 1 (HCWCID1) serving the Belterra Subdivision has applied to the Texas Commission on Environmental Quality (TCEQ) for a permit (Table 1) to discharge up to 500,000 gal/day (0.774 ft^3/s) of treated wastewater directly to the headwaters of Bear Creek, Hays County, Texas. If approved by TCEQ, the discharge would be the first in the contributing zone of the Barton Springs segment of the Edwards Aquifer.

Table 1. Final phase draft permit limitations for proposed HCWCID1 discharge (WQ0014293-001).

Effluent Characteristic	Daily Average	7-day Average	Daily Maximum	Single Grab Maximum
Flow, MGD	500,000	n/a	n/a	n/a
Carbonaceous BOD (5-day), mg/L	5	10	20	30
Ammonia Nitrogen, mg/L	2	5	10	15
Total Phosphorus, mg/L	0.15*	0.3	0.6	0.9

*expressed as a daily median

The change in water quality of Bear Creek with the proposed discharge was previously predicted at the upstream recharge zone boundary of the Barton Springs segment of the Edwards Aquifer using the steady-state one-dimensional LA-QUAL (version 8.0) model under varying flow and temperature conditions (Herrington 2008). LA-QUAL models were evaluated for 30 different temperature/flow scenarios with and without the proposed discharge and then applied to real mean daily Bear Creek discharge and estimated water temperature to create a time-series prediction of changes in Bear Creek water quality at the upstream recharge zone boundary. Although this model has limitations in its application to algae growth dynamics in Bear Creek, it was used by TCEQ in evaluating both dissolved oxygen and nutrient decay in the creek, and used for consistency herein.

Predicting the impact of increased loading to the Edwards Aquifer at the primary point of discharge, Barton Springs, is of critical importance because Barton Springs is not only home to the federally-endangered Barton Springs salamander (*Eurycea sosorum*) but also is utilized as a contact recreation resource by more than 250,000 visitors annually. The water quality of Barton Springs may already be degrading with respect to dissolved oxygen (DO) and nitrogen (COA 2005). Periodic nuisance algae blooms objectionable to pool swimmers have been documented (Alan Plummer and Associates 2000), and Barton Springs salamanders have been shown to be adversely affected by decreases in DO concentrations (Poteet and Woods 2006, Turner 2004).

The impact of predicted changes in Bear Creek water quality on the water quality of Barton Springs was evaluated using two modeling approaches, both incorporating the time-series output from the LA-QUAL as an input data source. First, the change in concentration of nutrients in Barton Springs pool were evaluated using the lumped parameter karst aquifer model for nitrogen (Barrett and Charbeneau 1996, 1997) which has previously been adapted for simulation of phosphorus (Turner 2006). Second, the change in biochemical oxygen demand (BOD) concentration in total creek recharge was used to estimate the potential decrease in Barton Springs DO.

Methods

Barton Springs mean daily discharge was predicted using the karst aquifer model (Barrett and Charbeneau 1996) with and without the proposed HCWCID 1 discharge for the time period 1984-1995. The 1984-1995 time period includes periods of both low (19 ft^3/s) and high (128 ft^3/s) spring discharge. Because the karst aquifer model implicitly doubles the flow from Bear Creek to represent both Bear Creek and Little Bear Creek recharge (insufficient Little Bear Creek discharge gage data was available at the time the model was developed, only 50% of the HCWCID 1 discharge amount (0.385 ft^3/s) was added to ambient Bear Creek discharge for the scenario with the proposed discharge.

Nutrients

Input concentrations to the karst aquifer model of total nitrogen and total phosphorus for all recharge creeks except Bear were based on estimated average values during storm and non-storm conditions (Table 2). The determination of whether baseflow or stormflow concentrations should be applied was evaluated individually for each recharging creek based on change in current mean daily discharge (Q_i) from the previous day's discharge (Q_{i-1}):

$$\text{if } (Q_i/Q_{i-1})>1.5 = \text{storm day, else baseflow}$$

Table 2. Average concentrations of total nitrogen (from Barrett and Charbeneau 1996) and phosphorus (from Turner 2006).

Creek	Total Phosphorus (mg/L)		Total Nitrogen (mg/L)	
	Baseflow	Stormflow	Baseflow	Stormflow
Barton	0.009	0.085	0.50	1.29
Williamson	0.110	0.220	0.88	2.79
Slaughter	0.007	0.036	0.59	1.39
Little Bear	0.009	0.022	0.61	0.92
Onion	0.011	0.071	0.55	0.68

Bear Creek nutrient input concentrations were determined from LA-QUAL model output (Herrington 2008) with and without the proposed discharge. Bear Creek input concentrations were adjusted by flow-weighted average with Little Bear Creek to account for the doubling of Bear Creek flow in the karst aquifer model to insure the correct mass of nutrient addition. In previous application of the BSEA model to phosphorus, it was determined that a relatively constant fraction of total phosphorus (particulate and adsorbed forms) that enters the aquifer is not released at Barton Springs, therefore, this was accounted for in the model (Turner 2006).

BOD and DO

A linked parameter model of DO has not been developed for BOD/NH_3-N/DO kinetics within the Barton Springs Edwards Aquifer (Turner 2006). However, a method was developed previously to estimate an equilibrium state, or worst case condition, at Barton Springs utilizing the predicted change in BOD in creek recharge (Turner 2006). This method utilizes the karst aquifer model *only* to estimate the change Barton Springs flow with the proposed discharge.

DO concentrations were predicted from Barton Springs discharge using a regression equation previously developed by Turner (2004) with daily Barton Springs discharge output from the karst aquifer model:

$$\text{DO in mg/L} = -2.18 + 1.98 \log_e(\text{flow in ft}^3/\text{s})$$

Barton Springs DO was predicted with and without the HCWCID 1 discharge on a daily basis for the time period 1984-1995. BOD in recharging creeks was estimated based on flow condition (storm, base) using averages calculated from COA and United States Geological Survey (USGS) data (COA 2006) (Table 3). Ambient (background) Bear Creek BOD concentrations were revised to reflect input concentrations for recent LA-QUAL modeling (Herrington 2008). Base/Storm conditions were determined individually for each recharging creek based on change in current mean daily discharge from the previous day as described for nutrient modeling input.

Table 3. Concentrations of mean BOD (1984-1996) in creek recharge.

Creek	**Mean Baseflow BOD (mg/L)**	**Mean Stormflow BOD (mg/L)**
Barton	0.36	3.45
Williamson	0.58	7.60
Slaughter	0.71	2.43
Little Bear	0.57	1.50
Onion	0.58	1.71
Bear*	0.53	1.58

*revised based on Herrington (2008).

Change in Bear Creek BOD was estimated on a daily basis using the LA-QUAL model output (Herrington 2008). Change in Bear Creek BOD was determined by comparing model results with and without HCWCID 1 discharge at the upstream boundary of the recharge zone. Additionally, any change in predicted Bear Creek DO concentrations at the recharge zone boundary with the proposed discharge were added to calculated change in BOD concentrations to yield an estimate of the change in "effective" BOD generally following previous COA methods (COA 2006):

$$\Delta BOD_{effective} = (BOD_{with} - BOD_{without}) - (DO_{with} - DO_{without})$$

The change in the concentration of "effective" BOD in total creek recharge with HCWCID 1 was calculated on a daily-basis by flow-weighted average of all recharge creeks for 1984-1995. The average DO in Barton Springs was estimated on a daily basis using predicted recharge flows with and without HCWCID 1. The change in the concentration of "effective" BOD with HCWCID 1 was subtracted from the predicted DO concentration based on recharge flows with HCWCID 1 to yield a predicted Barton Springs DO concentration with HCWCID 1. This assumes that under worst case conditions all of the additional BOD in total creek recharge from HCWCID 1 would be consumed by microbial respiration in the aquifer resulting in an equivalent drop in DO at Barton Springs. The growth, death and decay of algae and macrophytes are not simulated in LA-QUAL. The decay of biomass would represent a secondary load of BOD to system, and thus the estimates for change in BOD for total creek recharge represent a lower bound on the BOD entering the aquifer.

Results

Nutrients

Both nitrogen and phosphorus are predicted to increase in Barton Springs with the proposed discharge (Figure 1, Figure 2) based on the karst aquifer model simulations. The maximum increase in total nitrogen for the simulation period is predicted to be 0.018 mg/L. The maximum increase in total phosphorus for the simulation period is predicted to be 0.001 mg/L.

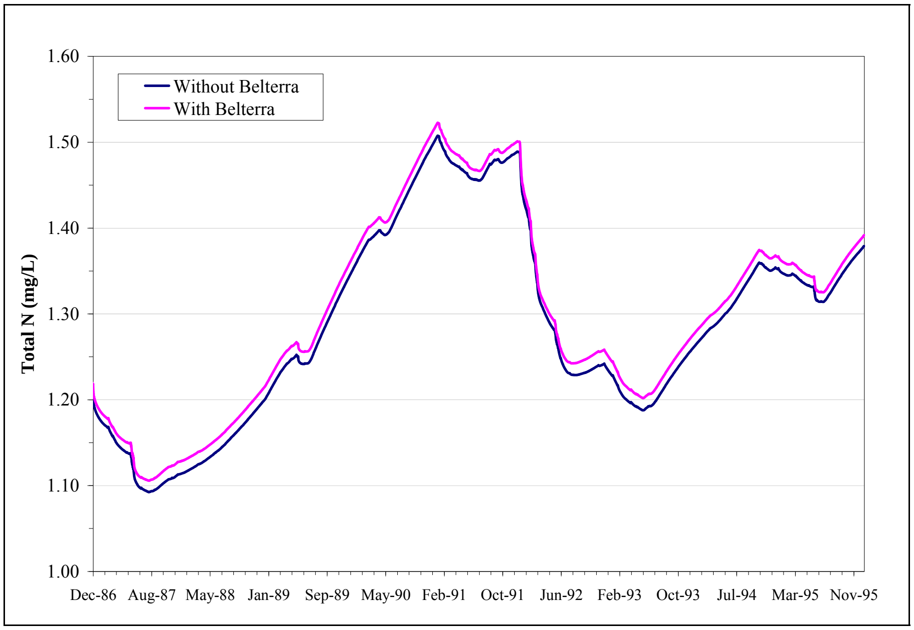

Figure 1. Total nitrogen predicted by karst aquifer model simulation with (pink) and without (blue) the proposed discharge.

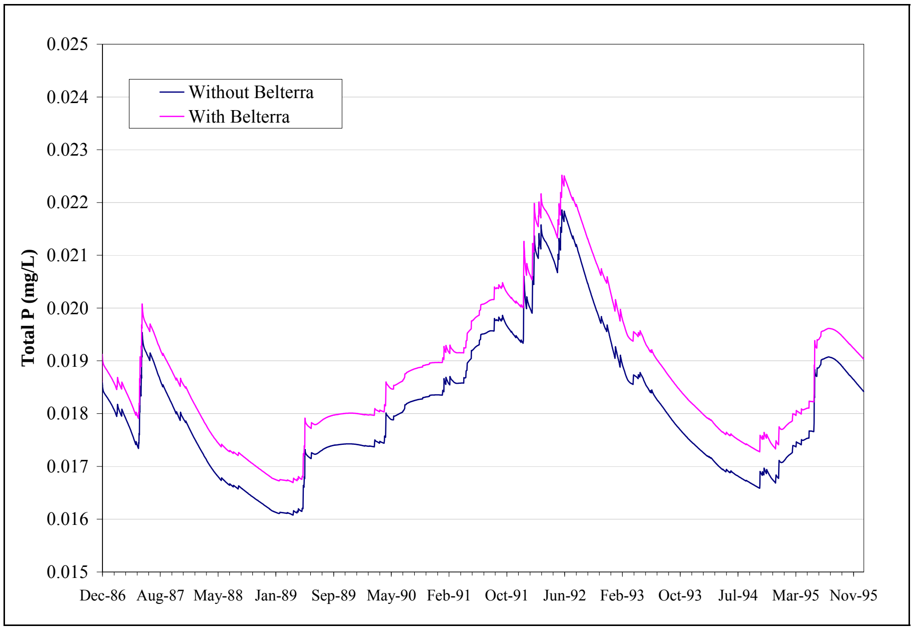

Figure 2. Total phosphorus predicted by karst aquifer model simulation with (pink) and without (blue) the proposed discharge.

To facilitate a general evaluation of the magnitude of the predicted increase in total nitrogen and phosphorus, a simple frequency analysis was performed (Figure 3, Figure 4). The predicted increase in total nitrogen is at least 0.014 mg/L approximately 50% of the simulation. The predicted increase in total phosphorus is at least 0.00065 mg/L approximately 50% of the simulation period.

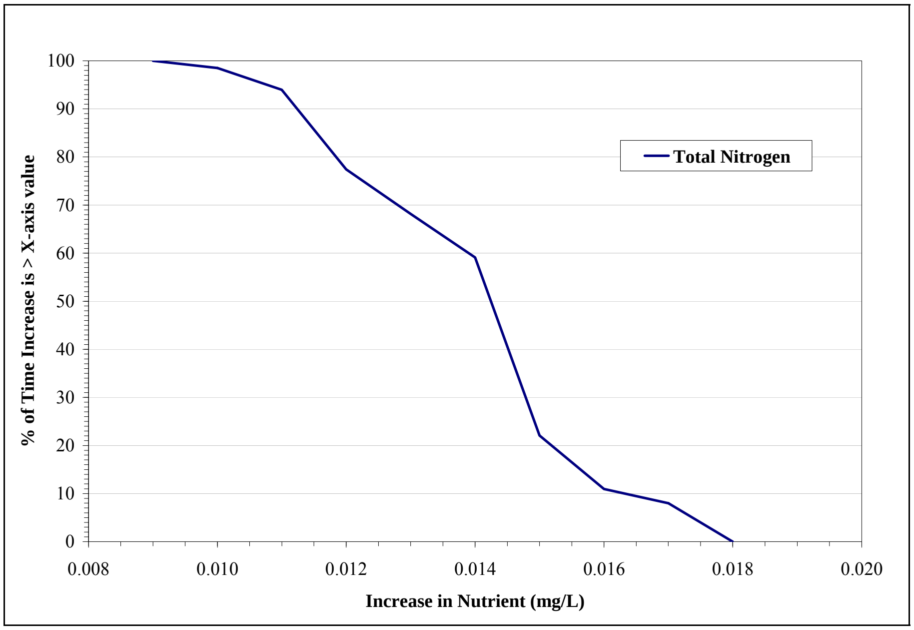

Figure 3. Frequency analysis for predicted increase in total nitrogen at Barton Springs. Vertical axis values represent % of time that increase in total nitrogen with the proposed discharge would be greater than corresponding amount shown on x-axis.

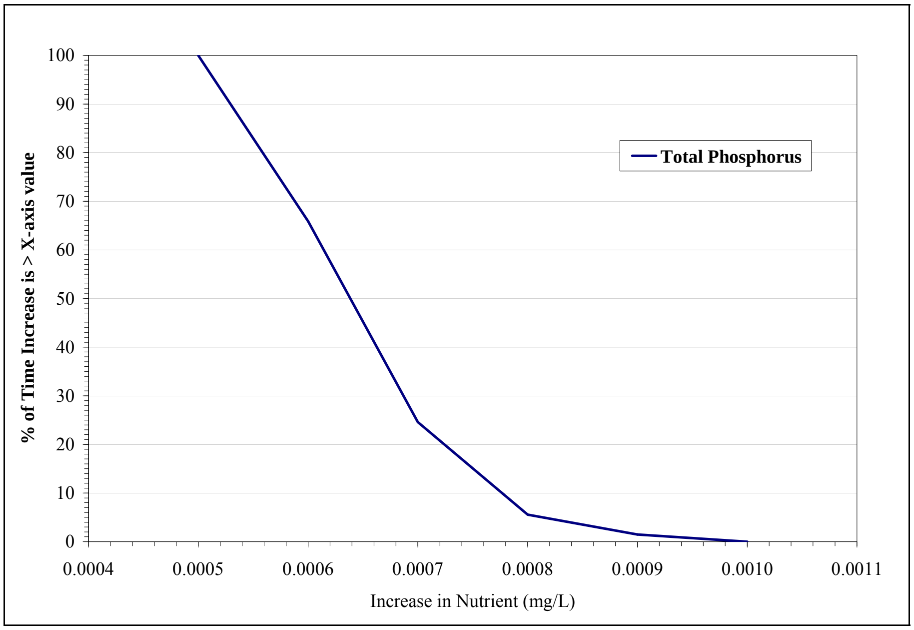

Figure 4. Frequency analysis for predicted increase in total phosphorus at Barton Springs. Vertical axis values represent % of time that increase in total phosphorus with the proposed discharge would be greater than corresponding amount shown on x-axis.

BOD and DO

BOD concentrations increase up to 0.97 mg/L in total creek recharge with the addition of the HCWCID 1 discharge during periods of low Barton Springs discharge (Figure 5). In some low flow time periods, the additional flow from the HCWCID 1 discharge acts to dilute BOD in total creek recharge. The variation in BOD at similar Barton Springs discharge flows is a factor of varying daily storm flow determinations between watersheds. BOD concentrations are representative only of total creek recharge, and do not consider any time-delay between recharge and discharge.

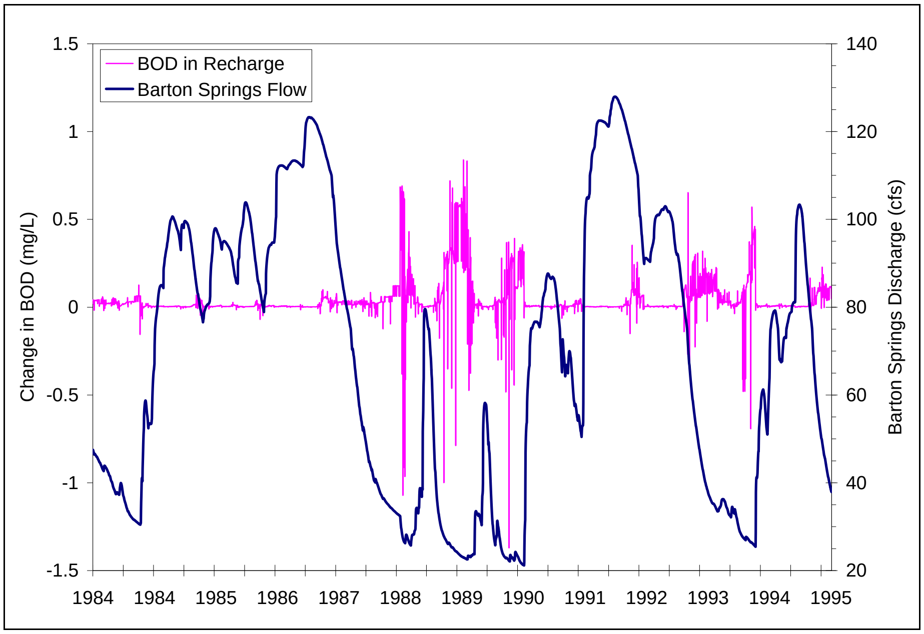

Figure 5. Change in BOD concentration in total creek recharge with predicted Barton Springs mean daily discharge (1984-1995).

Average DO concentrations in Barton Springs were calculated for varying integer Barton Springs discharge levels with and without HCWCID 1 (Figure 2). The difference between predicted average DO concentrations with HCWCID 1 and without the proposed discharge are on average greatest (i.e., maximum difference in average concentrations) at Barton Springs discharges less than 28 ft^3/s. The maximum DO deficit with the proposed discharge based on average values is 0.308 mg/L, although larger DO deficits with the proposed discharge are predicted on a daily basis. For any day in the simulation period 1984-1995, the maximum predicted DO deficit with the proposed discharge is 0.784 mg/L.

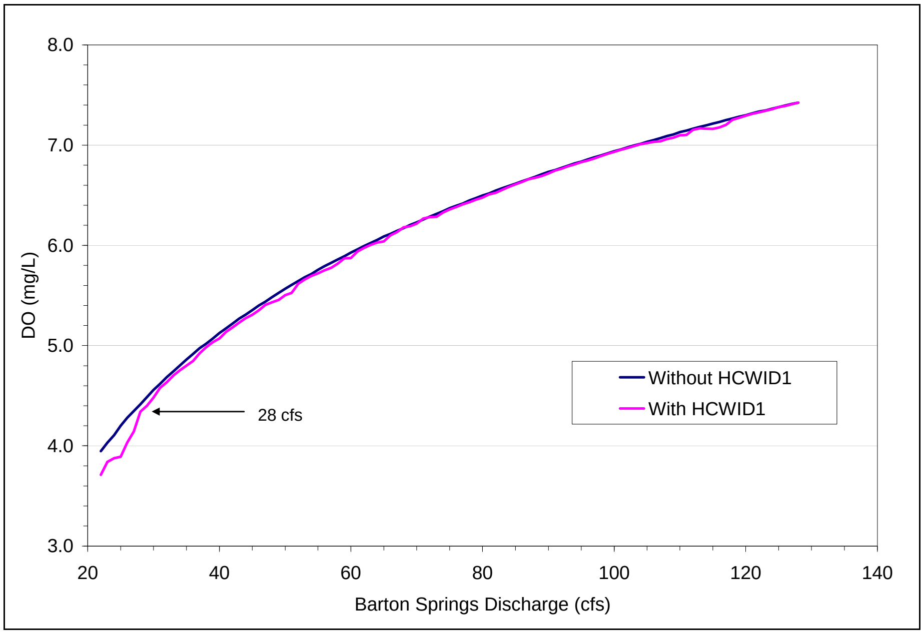

Figure 2. Average DO concentrations with and without HCWCID 1 by Barton Springs discharge (1984-1995).

Using the daily predicted Barton Springs DO concentrations with and without the proposed discharge, the frequency of DO deficits of specified magnitudes were assessed from 1984-1995 (Table 4). DO deficits ≥ 0.50 mg/L at Barton Springs are predicted to occur 1.46% more frequently with the proposed discharge. DO deficits (of any magnitude) are predicted to increase 34% with the proposed discharge.

Table 4. Frequency of DO deficits in Barton Springs with the proposed HCWCID 1 discharge (1984-1995). For example, a DO deficit of 0.50 mg/L or more is predicted to occur 1.46% of the time from 1984-1995, or 61 days out of 4,383.

DO Deficit in Barton Springs (mg/L)	Increase in frequency of DO deficit numerically < amount shown if HCWCID1 is approved (% from 1984-1995)
-0.80	0.00
-0.75	0.05
-0.70	0.05
-0.65	0.09
-0.60	0.39
-0.55	0.52
-0.50	1.46
-0.45	1.60
-0.40	1.76
-0.35	2.10
-0.30	2.49
-0.25	3.72
-0.20	5.52
-0.15	6.89
-0.10	9.54
-0.05	14.94
0.00	34.47

Conclusions

If approved, the proposed HCWCID 1 discharge will result in a measurable increase in nutrients in Barton Springs and will decrease DO in Barton Springs to levels. Increases in nutrients at Barton Springs are likely to exacerbate existing periodic nuisance algae blooms in the impounded spring pool affecting contact recreation uses. Decreases in DO concentrations in critical low flow conditions may adversely affect the endangered Barton Springs salamander. More detailed interpretation of these results concerning the impact on the aquatic life and recreational resources of Barton Springs under worst case conditions are recommended. Consideration of these results in managing the resources of Barton Springs and permitting of wastewater discharges in the contributing zone is also of critical importance.

References

Barrett, M., and R. Charbeneau. 1996. A parsimonious model for simulation of flow and transport in a karst aquifer. The University of Texas at Austin Center for Research in Water Resources. Technical Report 269.

Barrett, M., and R. Charbeneau. 1997, Predicting the Effects of Urbanization on a Karst Aquifer. Proc. 24th Water Resour. Plann. Manage. Conf. Aesthetics in the Constructed Environment, Houston, Texas, Feb 6, 1997, pp. 358-363. American Society of Civil Engineers, Reston, Virginia.

City of Austin (COA). 2005. Update of Barton Springs water quality temporal trend analysis—2005. City of Austin Environmental Resource Management Division, Watershed Protection and Development Review Department. SR-05-09.

City of Austin (COA). 2006. Predicted impacts from the proposed Hays County Water Control and Improvement District 1 Discharge in Bear Creek and Barton Springs. City of Austin Environmental Resource Management Division, Watershed Protection and Development Review Department. SR-06-07.

Herrington, C. 2008. Extension of an LA-QUAL (version 8.0) model for the proposed HCWCID 1 wastewater discharge to realistic Bear Creek temperature and flow conditions. City of Austin Watershed Protection and Development Review Department. SR-08-04.

Alan Plummer and Associates. 2000. Barton Springs Pool Preliminary Algae Control Plan for City of Austin. Draft, September 2000.

Turner, M. 2004. Some water quality threats to Barton Springs Salamanders at Low Flows. City of Austin Watershed Protection and Development Review Department. SR-04-06.

Turner, M. 2006. Predicting phosphorus with the parsimonious model. City of Austin Watershed Protection and Development Review Department. SR-06-09.

Poteet, M. F., and H. A. Woods. 2006. Physiological and mortality responses of *E. nana* and *E. sosorum* to variation in conductivity and dissolved oxygen. Handout for 30 November 2006 meeting to discuss the synthesis of the preliminary biological risk assessment and the DO and conductivity toxicity study. *Prepared for* The Barton Springs Edwards Aquifer Conservation District.