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MEMORANDUM

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Re:	Colorado River Environmental Models Phase 4 Scenarios-FINAL		

INTRODUCTION

The objective of the Colorado River Environmental Models (CREMs) project is to develop comprehensive, linked watershed and water quality modeling tools for the Highland Lakes. Phases 1 and 2 focused on Lake Travis (completed in 2009); Phase 3 on Lake Marble Falls, Lake Lyndon Baines Johnson, and Inks Lake (completed in 2011); and Phase 4 on Lake Buchanan (completed in 2013). The CREMs project is designed to help diagnose existing water quality issues, discern water quality trends, and predict the consequences of various management decisions on the water quality of the Highland Lakes. This memorandum summarizes the scenarios evaluated using the watershed and lake water quality models developed for Lake Buchanan. The goal was to investigate the response of water quality in Lake Buchanan to potential changes in its watershed. Specifically, seven scenarios focused on two variables and combinations of these variables as follows:

- Changes in wastewater flows and concentrations
- An increase of urbanization in subbasins that may experience development within Lake Buchanan's watershed, with and without the Highland Lakes Watershed Ordinance (HLWO) in place

The CREMs models comprise linked watershed and lake water quality models. Details on the model development, calibration, and sensitivity analyses for Lake Buchanan can be found

in the *Colorado River Environmental Models Phase 4: Lake Buchanan* report (Anchor QEA and Parsons 2013).

SCENARIO DEVELOPMENT

The scenarios considered changes in each of the variables described above, as well as cumulative impacts from a combination of different changes occurring simultaneously over the watershed. The seven scenarios selected for simulation are detailed in Table 1. Of the seven scenarios, three (Scenarios1, 2, and 3) involved changes in concentrations and flows of Texas Land Application Permit (TLAP)[1] and Texas Pollution Discharge Elimination System (TPDES; i.e., point source) permit holders; two (Scenarios 4 and 5) were solely a function of urbanization; and two (Scenarios 6 and 7) involved increases in both TLAP and point source discharges as well as urbanization.

For all of the scenarios simulated, the impact was assessed relative to the base case model result, which represents historical (1984 to 2011) meteorological conditions and sediment characteristics superimposed with land cover data from 2006 (Anchor QEA and Parsons 2013). The hydrologic condition that was simulated for the scenarios was the same period as the calibration (1984 to 2011). This 28-year period represents a range of low, high, and average precipitation conditions (Figure 1). By running the future scenarios using the same hydrology as the calibration, it is possible to observe relative impacts in Lake Buchanan to changes in the watershed during both wet and dry periods.

REPRESENTATION OF THE SCENARIOS WITHIN THE MODEL FRAMEWORK

Increases in Point Source Discharges

Of the seven scenarios, five involved changes in either or both point source discharge flows and concentrations. For these five future scenarios, it was assumed that current TLAP permit holders would be allowed to discharge at their permitted flows into streams within the watershed.

[1] For purposes of this document, facilities that do not discharge wastewater to streams or lakes under normal operating conditions were considered as TLAP dischargers, regardless of whether the wastewater is applied to land or another method or evaporated.

The Lake Buchanan watershed contains 16 permit holders[2], (Table 2 and Figure 2) consisting of both TLAP and TPDES permit holders:

- City of Bangs – TPDES
- City of Blanket – TPDES
- City of Brady – TPDES and TLAP
- City of Brownwood – TPDES
- City of Coleman – TPDES
- City of Eden – TPDES
- City of Goldthwaite – TPDES (two facilities)
- City of Menard – TPDES (two facilities)
- City of Mullin – TPDES
- City of Richland Springs – TPDES
- City of San Saba – TPDES and TLAP
- City of Santa Anna – TLAP
- City of Lometa – TPDES (two facilities)
- New Horizons Ranch and Center – TLAP
- Roddie Wool Scouring – TLAP
- Unimin Corporation – TPDES

For all discharge scenarios, effluent pollutant concentrations were based on measured levels (from discharge monitoring reports [DMR]), current TPDES permit limits, estimates based on effluent measurements during the Lower Colorado River Authority-San Antonio Water Systems Project Colorado River low-flow surveys (QEA 2004, 2005), and professional judgment. Table 2 lists the assumptions for point source discharge concentrations for the base case, fully permitted, and advanced treatment simulations, respectively.

[2] Kohler Company had two TPDES permits and was discharging occasionally until its permits were cancelled in 2009. These discharges are in the calibration run but not in the base case future scenario run because the permits are no longer in effect.

Silver Creek Lodge, Marina, and Yacht Club holds a TPDES permit to discharge directly to Lake Buchanan. However, it was not included in the base case or scenarios because its wastewater treatment facility was recently dismantled. Furthermore, loads would have been minor due to the low allowable flow in the permit.

In Scenario 1, TLAP discharges were converted to direct discharges, and both TLAP and TPDES dischargers were assumed to be at fully permitted flows and concentrations[3]. Where permitted concentrations were not available, concentrations from the base case were used.

Scenario 2 investigated potential impacts of current TLAPs discharging during wet weather conditions to streams in the watershed. The wet weather conditions were defined through a review of measured flows for the Colorado River near San Saba (U.S. Geological Survey gage 08147000) for the period of January 1, 1980, through December 31, 2011. Similar to the modeling approach for determining wet weather flows during other phases of the CREMs project, a probability plot was developed, and the flow at approximately the 88th percentile was chosen to represent wet weather conditions (Figure 3). The 88th percentile flow was approximately 800 cubic feet per second. Scenario 2 allowed land application permittees to discharge at fully permitted flows and concentrations on days when this flow threshold was met or exceeded; all other discharges were maintained at the values used in the base case. Where permitted concentrations were not available, concentrations from the base case were used.

For Scenario 3, TPDES dischargers were assumed to be at base case flows and advanced treatment concentrations (see Table 2 for assumed concentrations; it should be noted that advanced treatment concentrations for some permittees and constituents were higher than base case concentrations).

Increases in Urbanization

Four scenarios evaluated the impact on receiving water quality due to an increase in urbanization in the watershed 20 years into the future (see Appendix A for details about assumptions made regarding urbanization). Two of the scenarios (Scenarios 4 and 6) represented future urbanization without the HLWO in place, and two (Scenarios 5 and 7) assumed the HLWO to be in place. Urbanization was assumed to occur in the most common land uses that bordered currently urbanized land: brushy rangeland, evergreen forest, and grass rangeland. Development was assumed to increase homogeneously among all the existing developed land uses. As a result, urbanization in the Lake Buchanan watershed

[3] In a few instances, Scenario 1 concentrations were lower than base case concentrations, likely because they are from the most recent permits, whereas base case concentrations are based on average DMR data that occasionally date back to 2001.

increased from 4.0% under base case conditions to 5.5% in the future scenario runs (see Appendix A). Because the calibration of the watershed model used data from subbasins where most of the land was not urbanized or whose urbanization was grandfathered (thus, not affected by the HLWO), the model parameters established during the calibration of the watershed model reflect conditions without the HLWO in place. Therefore, urban land changes in the model for Scenarios 4 and 6 represent urbanization occurring without the HLWO in place. An adjustment to the amount of load based on best professional judgment was required to simulate the impact of the HLWO on reducing pollutant loading to Lake Buchanan for Scenarios 5 and 7.

The scenarios representing future urbanization with the HLWO in place (Scenarios 5 and 7) were created in several steps. For Scenario 5, the differences in watershed loads between the base case run and the future urbanization run (Scenario 4) were presumed to be due to urbanization without the HLWO; these differences are referred to as "incremental urban loads." Subbasins with at least 25% of their area within the boundary of the HLWO were identified (Figure 4); all subbasins whose results were directly used in the lake model were found to be within the HLWO boundary. Best management practices (BMPs), in accordance with the HLWO, were assumed to be 70% efficient, meaning that 30% of the incremental urban loads enter Lake Buchanan.[4] Accordingly, future loads with urbanization and the HLWO in place were calculated as the sum of the base case load from the watershed model plus 30% of the incremental urban loads. The BMPs were applied to each daily load for each subbasin included in the lake model. On days when the incremental urban loads were negative (i.e., future urbanization loads were lower than those for the base case), the future urbanization loads (i.e., Scenario 4 loads) were used. The same steps were followed for Scenario 7, but because point sources were included in the watershed model, the increase in load due to urbanization was calculated as the difference between the run with future urbanization and point sources at permitted values (Scenario 6) and the run with current urbanization and point sources at permitted values (Scenario 1). On days when the future urbanization with point source loads at permitted values (i.e., Scenario 6) were lower than those for the base case, the future urbanization with permitted point source loads were used.

[4] In all future urbanization scenarios, HLWO BMPs treat runoff only in the newly urbanized areas; BMP retrofits in existing urban areas are not modeled.

Changes in Loadings Relative to Base Case

Each of the scenarios described above was developed to investigate the potential impact of water management within the Lake Buchanan watershed. The changes in loadings for each scenario are shown in a series of bar charts illustrating the percent change relative to the base case (e.g., calibration run[2]) in Figure 5.

Nutrient Loadings from On-site Sewage Facilities

On-site sewage facilities, including septic tank systems and aerobic systems, were not simulated in the watershed model for several reasons, including the following:

- Although these facilities may be a source of nutrients to surface waters when malfunctioning, their impacts were considered to be negligible because of the low population density in the Lake Buchanan watershed. Out of the more than 21,800 septic systems on the Highland Lakes within 2,200 feet of the shoreline, 3,300 of those are around Lake Buchanan. There is no indication that these systems contribute significant nutrients to surface waters (LCRA On-site Sewage Facilities Department 2012).
- A review of 1,130 septic system inspection reports for 2007 and 2008 for areas around the Highland Lakes showed that the septic system failure rate (as indicated by surfacing effluent) was approximately 1% (Carter 2009).
- In the area around the Highland Lakes, the following two factors provide greater environmental protection: 1) aerobic treatment units, which produce secondary quality effluent; and 2) disposal of effluent into shallow, low-pressure dosed drainfields and drip irrigation drainfields.

Consequently, nutrient loadings from septic systems are anticipated to be negligible and, thus, were not included in the watershed model.

SCENARIO RESULTS

Impacts of the changes in the watershed on water quality in Lake Buchanan were assessed at the following six locations (Figure 6):

- Near Beaver Creek Cove (Segment 6)
- Approximately 3/4 miles south of Garret Island (Segment 7)
- At Rocky Point (Segment 9)

- Near Buchanan Dam (Segment 13)
- At the confluence of Council and Morgan Creeks (Segment 18)
- At Golden Beach (Segment 26)

The assessment compared the average and maximum of predicted daily average chlorophyll-*a* concentrations in the top 2 meters of the water column for each scenario during the entire year to the model output from the base case. Chlorophyll-*a* concentrations were used to determine impact because algal blooms are potentially more important to stakeholders and because the parameter is linked to changes in nutrient loadings. The model was configured to print daily average results to an output file for the 28-year simulation period; for ease of comparison, however, the average and maximum of the daily average chlorophyll-*a* concentrations over the course of the year for the entire run[5] were used in the presentation of the model results below. Overall (i.e., long-term) average and maxima were computed from average and maximum daily mean concentrations for each year.

Model results are shown as percent changes in chlorophyll-*a* concentrations from the base case concentrations over the entire 28-year simulation period. These percent changes can be considered relative to the absolute surface water chlorophyll-*a* concentrations for the base case.[6] Table 3 presents the daily average and maximum surface water chlorophyll-*a* concentrations for the 28-year base case simulation, along with the proposed Texas Commission on Environmental Quality nutrient criteria (as chlorophyll-*a*; 30 TAC §307.10(6)). Tables 4 through 27 contain scenario results. Because all model simulations use historical (instead of future) sediment nutrient release rates,[7] the chlorophyll-*a*

[5] For thoroughness, averages are also presented for 1984 to 1997 and 1998 to 2011. During the hydrologic calibration of the watershed model, it was possible to obtain a satisfactory model fit to the measured flows for these two periods but not to both periods together; the calibration focused on the latter period, although model results from all years were reviewed (Anchor QEA and Parsons 2013).

[6] The model results were evaluated by pairing the scenario concentration and base case concentration for each simulated year, dividing the difference between the scenario concentration and base case concentration by the base case concentration and multiplying by 100, and averaging the percent changes for each year over the entire 28-year simulation. In this manner, the average percent change captures the variability in scenario results during the entire run, which includes different hydrologic conditions. The percent change is not the change in the overall average (i.e., not the percent change between the average scenario and average base case results) and should not, therefore, be used directly to compute an absolute surface water chlorophyll-*a* concentration but instead be used in a manner relative to other scenario results.

[7] The Lake Buchanan lake model included modification of the CE-QUAL-W2 code to specify a linearly-increasing maximum sediment release rate in place of the temporally constant zero-order maximal rates for PO4 (orthophosphate, as phosphorus) and NH4 (ammonium, as nitrogen) in the original model code

concentrations reported herein are suitable for inter-scenario comparison but should not be interpreted as actual predictions of future chlorophyll-*a* concentrations in Lake Buchanan.

Impact of Increases to Point Source Discharges (Scenarios 1 through 3)

Scenario 1 involved setting the pollutant loads from continuous point source discharges (TPDES) to their permit limits and allowing TLAP holders to continuously discharge fully permitted loads. This scenario predicted that the long-term average chlorophyll-*a* concentrations would increase from 9% (near Buchanan Dam) to 17% (near Beaver Creek Cove). The long-term average of the annual maximum chlorophyll-*a* concentrations increased by 11% to 18% under Scenario 1 compared to the base case.

Scenario 2 simulated additional point source loading from TLAPs at permitted levels during wet weather conditions only. This increased loading resulted in less than a 1% change in long-term average chlorophyll-*a* concentrations. The long-term average of the annual maximum chlorophyll-*a* concentrations ranged from a 1% decrease to a 1% increase.

Scenario 3 simulated the nutrient loading from continuous point source discharges (TPDES) due to advanced wastewater treatment. In this scenario, long-term average chlorophyll-*a* concentrations declined by 5% to 11%. Annual maximum chlorophyll-*a* concentrations declined by 6% to 9%, on average.

Impact of Increases in Urbanization (Scenarios 4 and 5)

Increases in urbanization without the HLWO in effect resulted in increases in long-term average chlorophyll-*a* concentrations of 7% to 8%, with a 7% increase in the segment nearest Buchanan Dam. Also under this scenario, the long-term average annual maximum chlorophyll-*a* concentration increased by 7% (in upstream segments) to 11% (at the segment nearest Buchanan Dam and at Golden Beach).

(Anchor QEA and Parsons 2013). This change was necessary to match the increasing trend in hypolimnetic nutrient data observed over time. Release rates of PO4 and NH4 during the first year of simulation (i.e., 1984, year 1) were set to fit PO4 and NH4 data measured in 1984. Likewise, rates during the last year of simulation (i.e., 2011, year 28) were set to fit data measured in 2011. For years 2 through 27, the rates were increased incrementally by an equal amount per year. The future trajectory of sediment releases cannot be confidently predicted with CE-QUAL-W2. While it is unlikely that future sediment releases will decrease from current levels, it is unclear if future sediment releases will approximate current levels or continue to increase (and, if they increase, what the rate of increase might be). For these reasons, the impacts of the various scenarios are assessed relative to the base case model; results are not intended to be viewed on an absolute basis.

However, with HLWO in effect, these same increases in urbanization caused the long-term average chlorophyll-*a* concentrations to increase by 2% at all locations evaluated; the long-term annual maximum chlorophyll- *a* concentrations increased by 1% to 2%.

Impact of Point Source and Urbanization Scenario Combinations (Scenarios 6 and 7)

Scenario 6 simulated the combined increases of nutrient loading from point sources at fully permitted levels and increased urbanization without the HLWO in effect. Under this scenario, the long-term average chlorophyll-*a* concentrations were projected to increase by 16% (near Buchanan Dam) to 24% (near Beaver Creek Cove). Annual maximum chlorophyll-*a* concentrations were projected to increase by 22% to 25%, on average.

Scenario 7 included the combined increases of nutrient loading from point sources at fully permitted levels and increased urbanization with the HLWO in effect. The long-term average chlorophyll-*a* concentrations were projected to increase by 11% (near Buchanan Dam) to 19% (near Beaver Creek Cove). Annual maximum chlorophyll-*a* concentrations were projected to increase by 15% to 20%, on average.

Other Observations

In most cases, the impacts of the increases in loading under various individual scenarios (Scenarios 1 through 5) produced roughly additive impacts on average and maximum chlorophyll-*a* levels in the combined scenarios (Scenarios 6 and 7). Thus, it appears likely that the impacts of additional scenarios can be evaluated individually, with the cumulative effects on chlorophyll-*a* reasonably estimated by addition. This relationship may not hold when nutrient levels are increased drastically or if the water quality impacts are evaluated over a shorter time frame.

CONCLUSIONS

From the seven scenarios performed using the CREMs Phase 4 watershed and lake water quality models, the following conclusions were made:

- Model results indicate increases in point source discharges would have a large impact on lake water quality in Lake Buchanan. Under fully permitted conditions, average

chlorophyll-*a* concentrations increased 9% to 17%, on average, over the 28-year simulation period. Results are sensitive to assumptions made regarding effluent concentrations and nutrient availability.

- Allowing TLAP dischargers to discharge during wet weather only (i.e., calculated as approximately 12% of the time) had minor impacts on chlorophyll-*a* concentrations. Compared to base case conditions, long-term average chlorophyll-*a* concentrations changed less than 1% at all segments evaluated.
- Instituting advanced treatment for continuous dischargers in the Lake Buchanan watershed reduced chlorophyll-*a* concentrations in the lake (approximately 5% to 11% lower concentrations from base case, on average).
- The urbanization simulated in the watershed resulted in some impact on lake water quality (through increased runoff and loadings). Average chlorophyll-*a* concentrations increased (average annual increase over 28-year simulation of 7% to 8%); with the HLWO in place, the impact was lessened to a 2% average annual increase over the 28-year simulation. Future urbanization impacts can be controlled to some degree with the HLWO.

REFERENCES

Anchor QEA and Parsons, 2013. Colorado River Environmental Models Phase 4: Lake Buchanan. January 2013.

Carter, B., 2009. Personal communication with M. Suarez. Austin, Texas, August 26, 2009.

LCRA (Lower Colorado River Authority) On-site Sewage Facilities Department, 2012. Personal communication with L. Hatzenbuehler. Austin, Texas, November 29, 2012.

QEA, 2004. Summary of Low Flow Survey, November 9 to 12, 2004. Memorandum; Austin, Texas: Lower Colorado River Authority, December 2004.

QEA, 2005. Calibration of QUAL-TX. Austin, Texas: Lower Colorado River Authority, August 2005.

TABLES

Table 1
Scenario Overview

Scenario	Point Sources				Urbanization		
	TPDES		TLAP				
	Flows	Concentrations	Flows	Concentrations	Current Land Use	Increased Urbanization HLWO not in-place	Increased Urbanization HLWO in-place
0. Base Case	DMR	DMR	0	0	x		
1. Point sources (constant discharge, including WWTPs and current/pending land applications) fully permitted	FP	FP when available, otherwise DMR	FP	FP when available, otherwise DMR	x		
2. Point sources (wet-weather discharge) only	DMR	DMR	in WW: FP	in WW: FP when available, otherwise DMR	x		
3. Point sources with advanced treatment	DMR	AT	0	0	x		
4. Increased urbanization without HLWO in place	DMR	DMR	0	0		x	
5. Increased urbanization with HLWO in place	DMR	DMR	0	0			x
6. All point sources & increased urbanization without HLWO in place (Scenarios 1 + 4)	FP	FP when available, otherwise DMR	FP	FP when available, otherwise DMR		x	
7. All point sources & increased urbanization with HLWO in place (Scenarios 1 + 5)	FP	FP when available, otherwise DMR	FP	FP when available, otherwise DMR			x

Notes:

AT - advanced treatment; see Table 2

DMR - reported flows and concentrations from discharge monitoring reports or Colorado River LSWP low-flow survey (QEA 2004, 2005); see Table 2

FP - at full permit limits; see Table 2

HLWO - Highland Lakes Watershed Ordinance

TLAP - Texas Land Application Permit

TPDES - Texas Pollutant Discharge Elimination System

WW - wet weather conditions only

WWTP - wastewater treatment plant

Wet weather flow trigger for Lake Buchanan watershed = 800 cfs in Colorado River near San Saba (USGS 08147000)

Table 2
Assumed Concentrations and Flows for Point Sources

Base Case												
Model	Type	Permit Number	Permittee	Flow (MGD)	CBOD (mg/L)	TSS (mg/L)	NH3 (mg/L)	TP (mg/L)	DO (mg/L)	PO4 (mg/L)	NOX (mg/L)	OrgN (mg/L)	OrgP (mg/L)
SWAT	TPDES	0011982-001	LCRA (Kirby Creek WWTF)	0.065	3.77	6.81	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0014296-001	LCRA (Lometa WTP)	0.040	5	4.3	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0010122-001	City of Bangs	0.100	2.62	2.68	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0010150-003	City of Coleman (Hords Creek WTP)	0.024	5	9.11	2	3.2	4	3	20	0.5	0.2
SWAT	TLAP	0010274-001	City of Santa Anna	0.046	5	10	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0010459-001	City of Goldthwaite	0.100	3.6	8.1	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0010459-003	City of Goldthwaite (WTP)	0.013	5	4.29	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES Indust No-D/C (Evap)	0001297-000	Roddie Wool Scouring	0.000	5	10	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0003911-000	Unimin Corp	0.000	5	18.5	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES Indust D/C + Evap	0004712-000	City of Brady (WTP)	0.000	5	10	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0010081-001	City of Eden	0.209	19	38	6	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0010132-001	City of Brady	0.359	2.8	3.1	0.36	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0010345-001	City of Menard	0.048	10	30	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0010345-002	City of Menard (WTP)	0.003	5	2.7	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0010665-001	City of Richland Springs	0.000	5	10	2	3.2	4	3	20	0.5	0.2
SWAT	Dual TLAP-TPDES	0010687-001	City of San Saba	0.000	5	71	2	3.2	4	3	20	0.5	0.2
SWAT	TLAP	0012759-001	New Horizons Ranch and Center	0.009	20	10	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0013758-001	City of Mullin	0.004	9.7	15.8	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0014618-001	City of Blanket	0.009	5	7	0.2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0010565-001	City of Brownwood	2.425	2.2	1.1	0.37	3.2	4	3	20	0.5	0.2

Fully Permitted												
Model	Type	Permit Number	Permittee	Flow (MGD)	CBOD (mg/L)	TSS (mg/L)	NH3 (mg/L)	TP (mg/L)	DO (mg/L)	PO4 (mg/L)	NOX (mg/L)	OrgN (mg/L)	OrgP (mg/L)
SWAT	TPDES	0011982-001	LCRA (Kirby Creek WWTF)	0.100	20	20	2	3.2	3	3	20	0.5	0.2
SWAT	TPDES	0014296-001	LCRA (Lometa WTP)	0.230	5	25	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0010122-001	City of Bangs	0.300	10	10	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0010150-003	City of Coleman (Hords Creek WTP)	0.050	5	25	2	3.2	4	3	20	0.5	0.2
SWAT	TLAP	0010274-001	City of Santa Anna	0.141	5	10	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0010459-001	City of Goldthwaite	0.254	10	15	2	3.2	5	3	20	0.5	0.2
SWAT	TPDES	0010459-003	City of Goldthwaite (WTP)	0.022	5	25	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES Indust No-D/C (Evap)	0001297-000	Roddie Wool Scouring	0.143	5	10	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0003911-000	Unimin Corp	intermittent/ flow variable	5	25	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES Indust D/C + Evap	0004712-000	City of Brady (WTP)	0.075	10	10	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0010081-001	City of Eden	0.440	10	15	3	3.2	5	3	20	0.5	0.2
SWAT	TPDES	0010132-001	City of Brady	1.103	7	5	2	3.2	6	3	20	0.5	0.2

Table 2
Assumed Concentrations and Flows for Point Sources

Fully Permitted												
Model	Type	Permit Number	Permittee	Flow (MGD)	CBOD (mg/L)	TSS (mg/L)	NH3 (mg/L)	TP (mg/L)	DO (mg/L)	PO4 (mg/L)	NOX (mg/L)	OrgN (mg/L)	OrgP (mg/L)
SWAT	TPDES	0010345-001	City of Menard	0.220	20	20	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0010345-002	City of Menard (WTP)	0.094	5	25	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0010665-001	City of Richland Springs	0.050	30	90	2	3.2	4	3	20	0.5	0.2
SWAT	Dual TLAP-TPDES	0010687-001	City of San Saba	0.310	30	90	2	3.2	4	3	20	0.5	0.2
SWAT	TLAP	0012759-001	New Horizons Ranch and Center	0.018	20	15	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0013758-001	City of Mullin	0.040	20	20	2	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0014618-001	City of Blanket	0.035	10	15	3	3.2	4	3	20	0.5	0.2
SWAT	TPDES	0010565-001	City of Brownwood	4.540	10	15	3/4 [a]	3.2	6.0/5.0 [a]	3	20	0.5	0.2

Advanced Treatment												
Model	Type	Permit Number	Permittee	Flow (MGD)	CBOD (mg/L)	TSS (mg/L)	NH3 (mg/L)	TP (mg/L)	DO (mg/L)	PO4 (mg/L)	NOX (mg/L)	OrgN (mg/L)	OrgP (mg/L)
SWAT	TPDES	0011982-001	LCRA (Kirby Creek WWTF)	0.065	5	5	2	0.15	4	0.15	4	0	0
SWAT	TPDES	0014296-001	LCRA (Lometa WTP)	0.040	5	5	2	0.15	4	0.15	4	0	0
SWAT	TPDES	0010122-001	City of Bangs	0.100	5	5	2	0.15	4	0.15	4	0	0
SWAT	TPDES	0010150-003	City of Coleman (Hords Creek WTP)	0.024	5	5	2	0.15	4	0.15	4	0	0
SWAT	TLAP	0010274-001	City of Santa Anna	0.046	5	5	2	0.15	4	0.15	4	0	0
SWAT	TPDES	0010459-001	City of Goldthwaite	0.100	5	5	2	0.15	4	0.15	4	0	0
SWAT	TPDES	0010459-003	City of Goldthwaite (WTP)	0.013	5	5	2	0.15	4	0.15	4	0	0
SWAT	TPDES Indust No-D/C (Evap)	0001297-000	Roddie Wool Scouring	0.000	5	5	2	0.15	4	0.15	4	0	0
SWAT	TPDES	0003911-000	Unimin Corp	0.000	5	5	2	0.15	4	0.15	4	0	0
SWAT	TPDES Indust D/C + Evap	0004712-000	City of Brady (WTP)	0.000	5	5	2	0.15	4	0.15	4	0	0
SWAT	TPDES	0010081-001	City of Eden	0.209	5	5	2	0.15	4	0.15	4	0	0
SWAT	TPDES	0010132-001	City of Brady	0.359	5	5	2	0.15	4	0.15	4	0	0
SWAT	TPDES	0010345-001	City of Menard	0.048	5	5	2	0.15	4	0.15	4	0	0
SWAT	TPDES	0010345-002	City of Menard (WTP)	0.003	5	5	2	0.15	4	0.15	4	0	0
SWAT	TPDES	0010665-001	City of Richland Springs	0.000	5	5	2	0.15	4	0.15	4	0	0
SWAT	Dual TLAP-TPDES	0010687-001	City of San Saba	0.000	5	5	2	0.15	4	0.15	4	0	0
SWAT	TLAP	0012759-001	New Horizons Ranch and Center	0.009	5	5	2	0.15	4	0.15	4	0	0
SWAT	TPDES	0013758-001	City of Mullin	0.004	5	5	2	0.15	4	0.15	4	0	0
SWAT	TPDES	0014618-001	City of Blanket	0.009	5	5	2	0.15	4	0.15	4	0	0
SWAT	TPDES	0010565-001	City of Brownwood	2.425	5	5	2	0.15	4	0.15	4	0	0

	permit limits (as of September 2012)
	average of self-reported monthly average flows or concentrations
	advanced treatment concentration assumptions
	Colorado River LSWP low-flow survey data (QEA 2004, 2005)

Table 2
Assumed Concentrations and Flows for Point Sources

Notes:
a - Two seasonal permit limits provided for: April through October / November through March
CBOD – carbonaceous biological oxygen demand
DO – dissolved oxygen
EVAP - evaporation
INDUST - industrial
MGD – million gallons per day
mg/L – milligrams per liter
NH3 – ammonia
NOX – nitrate + nitrite, as nitrogen
OrgN – organic nitrogen, as nitrogen
OrgP – organic phosphorus, as phosphorus
PO4 – orthophosphate, as phosphorus
TLAP – Texas Land Application Permit (no-discharge)
TP – total phosphorus
TPDES - Texas Pollutant Discharge Elimination System
TSS – total suspended solids
WTP – water treatment plant
WWTF – wastewater treatment facility

QEA, 2004. Summary of low flow survey, November 9 to 12, 2004. Memorandum; Austin, Texas: Lower Colorado River Authority, December 2004.
QEA, 2005. Calibration of QUAL-TX. Austin, Texas: Lower Colorado River Authority, August 2005.

Table 3

Mean and Maximum Surface Water Chlorophyll-*a* Concentrations Predicted for Base Case Conditions for Lake Buchanan

Location (Model Longitudinal Segment)	Proposed TCEQ Nutrient Criteria	Overall Average Chlorophyll-*a* (µg/L)	
		Mean	Maximum
Near Beaver Creek Cove (Segment 6)	N/A	11.8	28.6
~3/4 mile South of Garret Island (Segment 7)	N/A	11.0	26.4
At Rocky Point (Segment 9)	N/A	10.1	23.5
Near Buchanan Dam (Segment 13)	9.82*	9.1	22.1
At Confluence of Council and Morgan Creeks (Segment 18)	N/A	10.5	24.0
At Golden Beach (Segment 26)	N/A	10.2	23.9

Notes:

µg/L - microgram per Liter

N/A - not applicable

TCEQ - Texas Commission on Environmental Quality

* Measured at dam

Overall average concentrations computed from annual means and maxima of daily averaged model output

Table 4

Average Predicted Chlorophyll-a Concentrations (µg/L) at Segment 13 (near Buchanan Dam)

Year	Base Case	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	3.4	3.7	3.4	3.2	3.8	3.5	4.0	3.8
1985	9.7	10.5	9.7	9.1	10.9	10.0	11.7	10.9
1986	7.7	7.9	7.8	7.6	8.2	7.9	8.4	8.1
1987	7.2	7.8	7.2	6.7	7.6	7.3	8.2	8.0
1988	6.8	7.9	6.8	6.3	7.4	7.0	8.4	8.1
1989	7.8	8.6	7.8	7.3	8.5	8.0	9.3	8.9
1990	7.5	8.0	7.5	7.2	7.9	7.6	8.4	8.1
1991	6.3	7.1	6.3	5.8	6.7	6.4	7.4	7.2
1992	9.3	9.8	9.3	8.9	9.8	9.4	10.4	9.9
1993	3.8	4.1	3.8	3.6	4.0	3.8	4.5	4.2
1994	5.5	5.7	5.5	5.3	5.7	5.6	6.0	5.8
1995	6.8	7.3	6.7	6.4	7.1	6.9	7.6	7.4
1996	7.0	7.5	7.0	6.7	7.2	7.1	7.6	7.5
1997	11.9	12.5	11.9	11.6	12.4	12.0	12.9	12.5
1998	11.9	12.6	11.9	11.7	13.1	12.1	14.1	13.3
1999	12.7	14.3	12.6	11.5	14.5	13.1	15.8	14.9
2000	8.9	10.5	8.9	8.0	10.0	9.1	11.4	10.8
2001	10.7	11.6	10.7	10.0	11.4	10.8	12.3	11.8
2002	10.3	11.5	10.4	10.1	11.4	10.4	13.0	12.0
2003	8.1	9.3	8.1	7.7	8.8	8.2	10.1	9.6
2004	10.5	11.1	10.5	10.2	10.9	10.6	11.7	11.3
2005	12.0	12.5	12.0	11.5	12.2	12.0	12.7	12.5
2006	10.1	11.2	10.2	9.5	10.7	10.4	11.5	11.4
2007	13.4	14.2	13.5	13.0	14.1	13.7	14.8	14.4
2008	8.5	9.5	8.5	7.5	9.0	8.6	9.9	9.6
2009	10.0	11.2	10.1	9.4	10.9	10.3	11.9	11.4
2010	13.8	14.6	13.8	13.1	14.6	14.0	15.4	14.9
2011	12.5	13.4	12.4	11.9	13.3	12.6	14.2	13.8
Average	9.1	9.9	9.1	8.6	9.7	9.2	10.5	10.1

Notes:

µg/L - microgram per Liter

HLWO - Highland Lakes Watershed Ordinance

Values are averages of daily concentrations in the lake surface (top 2 meters) for the entire year.

Table 5

% Change in Average Predicted Chlorophyll-a Concentrations at Segment 13 (near Buchanan Dam)

January through December, 0 to 2 meters of water column

Year	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	9	0	-6	10	3	18	12
1985	8	0	-7	12	3	20	12
1986	3	0	-2	6	2	9	5
1987	9	1	-6	6	2	15	11
1988	16	0	-7	8	3	22	18
1989	11	0	-6	9	3	19	14
1990	6	0	-4	5	1	11	8
1991	13	0	-8	7	2	18	15
1992	5	1	-4	6	2	12	7
1993	9	0	-5	5	2	18	11
1994	4	0	-3	4	1	9	6
1995	8	0	-6	6	1	13	9
1996	7	0	-4	3	1	9	8
1997	5	0	-3	4	1	9	5
1998	6	0	-2	10	1	18	11
1999	13	-1	-10	14	3	24	17
2000	18	0	-10	12	3	28	21
2001	9	0	-6	7	2	15	11
2002	11	0	-3	10	1	26	16
2003	14	0	-6	8	1	24	18
2004	6	0	-3	4	1	11	8
2005	4	0	-4	2	0	6	5
2006	11	0	-6	6	2	14	12
2007	6	1	-4	5	2	10	7
2008	12	0	-12	6	2	16	13
2009	12	0	-6	8	2	19	14
2010	6	0	-6	5	1	12	8
2011	7	-1	-5	6	1	14	11
Average (1984-2011)	9	0	-5	7	2	16	11
Average (1984-1997)	8	0	-5	6	2	14	10
Average (1998-2011)	10	0	-6	7	2	17	12

Compared to Base Case

- increase >=50%
- increase >=10% and <50%
- increase >=1% and <10%
- no change <1% and >-1%
- decrease >=1% and <10%
- decrease >=10% and <50%
- decrease >=50%

Note:
HLWO - Highland Lakes Watershed Ordinance

Table 6

Maximum Predicted Chlorophyll-a Concentrations (µg/L) at Segment 13 (near Buchanan Dam)

Year	Base Case	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	8.0	8.8	7.9	7.3	8.8	8.3	9.7	9.0
1985	19.7	22.0	19.7	18.1	24.4	20.7	26.6	23.5
1986	17.4	18.4	17.4	17.0	18.9	18.0	19.9	18.8
1987	17.5	22.1	17.5	14.3	20.1	18.4	24.3	22.6
1988	16.5	20.3	16.7	14.8	19.0	17.8	22.0	21.0
1989	15.7	16.4	15.6	15.3	17.4	16.3	17.8	16.9
1990	19.3	20.6	20.3	19.9	21.5	19.8	22.5	21.2
1991	10.5	12.5	10.3	9.5	11.2	10.6	13.7	12.8
1992	27.4	30.6	27.8	25.0	30.9	28.2	34.3	31.6
1993	6.1	7.2	6.1	5.7	6.9	6.3	8.2	7.5
1994	17.8	18.8	17.6	16.8	19.5	18.4	20.6	19.4
1995	11.1	12.1	11.0	10.8	12.1	11.0	13.7	12.5
1996	15.3	16.7	15.1	14.4	16.0	15.7	18.0	17.3
1997	35.1	36.2	34.3	34.6	35.8	34.9	35.5	35.0
1998	30.6	33.6	30.6	29.7	36.2	31.6	39.5	35.9
1999	31.0	40.0	30.2	23.8	41.0	32.5	48.1	43.2
2000	22.6	29.4	22.4	18.8	27.0	23.3	33.8	31.3
2001	27.1	26.8	27.0	25.8	27.8	26.8	26.8	27.4
2002	32.5	36.1	33.5	34.7	37.0	32.3	45.5	39.6
2003	14.7	18.9	14.3	15.0	16.5	14.7	21.8	20.1
2004	25.6	26.1	25.0	24.1	26.0	25.3	26.9	26.5
2005	33.7	33.6	34.2	33.8	33.7	33.7	34.2	34.2
2006	16.4	19.2	16.6	16.4	18.1	17.1	20.2	19.5
2007	40.9	42.0	41.3	39.6	44.3	42.0	45.3	43.2
2008	23.3	27.1	23.6	16.7	25.7	23.5	28.3	27.7
2009	17.4	19.9	17.5	16.3	19.3	18.2	21.2	20.4
2010	38.3	38.7	38.3	36.3	38.3	37.4	37.6	37.9
2011	28.6	32.9	28.2	24.3	30.5	28.9	35.8	34.6
Average	22.1	24.5	22.1	20.7	24.4	22.6	26.8	25.4

Notes:

µg/L - microgram per Liter

HLWO - Highland Lakes Watershed Ordinance

Values are averages of daily concentrations in the lake surface (top 2 meters) for the entire year.

Table 7

% Change in Maximum Predicted Chlorophyll-a Concentrations at Segment 13 (near Buchanan Dam)

January through December, 0 to 2 meters of water column

Year	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	11	-1	-9	11	3	22	13
1985	12	0	-8	24	5	35	19
1986	6	0	-2	9	3	14	8
1987	27	0	-18	15	6	39	29
1988	23	1	-10	15	8	33	27
1989	4	-1	-3	11	4	13	7
1990	6	5	3	11	3	16	10
1991	19	-2	-9	7	1	31	22
1992	11	1	-9	13	3	25	15
1993	18	1	-6	14	4	35	23
1994	6	-1	-6	9	4	16	9
1995	10	-1	-3	10	0	24	13
1996	9	-1	-6	4	2	17	13
1997	3	-2	-1	2	-1	1	0
1998	10	0	-3	18	3	29	17
1999	29	-2	-23	32	5	55	40
2000	30	0	-17	20	4	50	39
2001	-1	0	-5	3	-1	-1	1
2002	11	3	7	14	-1	40	22
2003	29	-3	2	12	0	48	37
2004	2	-2	-6	1	-1	5	3
2005	0	1	0	0	0	1	2
2006	17	1	0	10	4	23	19
2007	3	1	-3	8	3	11	6
2008	16	1	-28	10	1	22	19
2009	14	0	-7	11	4	22	17
2010	1	0	-5	0	-3	-2	-1
2011	15	-1	-15	6	1	25	21
Average (1984-2011)	12	0	-7	11	2	23	16
Average (1984-1997)	12	0	-6	11	3	23	15
Average (1998-2011)	13	0	-7	11	1	23	17

Compared to Base Case

- increase >=50%
- increase >=10% and <50%
- increase >=1% and <10%
- no change <1% and >-1%
- decrease >=1% and <10%
- decrease >=10% and <50%
- decrease >=50%

Note:
HLWO - Highland Lakes Watershed Ordinance

Table 8

Average Predicted Chlorophyll-a Concentrations (µg/L) at Segment 6 (near Beaver Creek Cove)

Year	Base Case	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	5.2	6.4	5.2	4.3	5.7	5.3	6.9	6.6
1985	11.8	13.5	11.8	10.6	13.1	12.1	14.8	13.9
1986	10.4	11.3	10.5	9.7	10.9	10.5	11.8	11.5
1987	10.1	11.6	10.2	9.1	10.5	10.2	11.9	11.6
1988	8.9	11.1	8.9	7.9	9.5	9.1	11.5	11.2
1989	9.8	11.7	9.8	8.7	10.7	10.0	12.5	12.0
1990	9.9	11.1	9.9	9.0	10.4	10.0	11.6	11.3
1991	7.8	9.4	7.8	6.8	8.3	7.9	9.8	9.5
1992	12.4	13.8	12.6	11.5	13.2	12.6	14.7	14.0
1993	5.1	6.0	5.1	4.5	5.3	5.2	6.4	6.1
1994	7.5	8.2	7.5	6.9	7.7	7.4	8.6	8.3
1995	9.1	10.5	9.1	8.1	9.6	9.2	11.0	10.7
1996	9.9	11.2	9.9	9.1	10.3	10.0	11.4	11.3
1997	17.6	19.6	17.7	16.0	18.2	17.7	20.1	19.6
1998	15.5	17.1	15.5	14.6	17.0	15.7	19.5	17.9
1999	15.4	19.0	15.3	13.2	18.2	16.2	21.7	19.9
2000	11.0	14.5	11.0	9.5	12.3	11.3	15.7	14.9
2001	12.8	14.8	12.8	11.6	13.8	13.1	15.8	15.1
2002	12.9	15.1	13.0	12.2	14.4	13.2	17.5	16.0
2003	10.4	12.7	10.5	9.2	11.2	10.5	13.7	13.0
2004	14.2	15.9	14.2	13.1	14.8	14.3	16.7	16.2
2005	14.7	16.0	14.7	13.4	15.0	14.7	16.2	16.0
2006	12.3	14.7	12.3	10.8	13.1	12.6	15.3	15.0
2007	19.2	20.5	19.2	16.6	19.9	19.3	21.2	20.7
2008	12.0	14.4	12.0	10.1	12.9	12.1	15.1	14.5
2009	14.3	17.9	14.3	12.4	15.3	14.5	18.7	18.1
2010	15.7	17.6	15.7	14.1	16.6	15.9	18.4	17.8
2011	14.6	17.8	14.5	13.2	16.1	14.9	19.4	18.5
Average	11.8	13.7	11.8	10.6	12.6	12.0	14.6	14.0

Notes:

µg/L - microgram per Liter

HLWO - Highland Lakes Watershed Ordinance

Values are averages of daily concentrations in the lake surface (top 2 meters) for the entire year.

Table 9

% Change in Average Predicted Chlorophyll-a Concentrations at Segment 6 (near Beaver Creek Cove)

January through December, 0 to 2 meters of water column

Year	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	25	0	-16	10	3	34	27
1985	15	0	-10	12	3	26	18
1986	8	0	-7	5	1	13	10
1987	14	0	-10	4	1	18	15
1988	25	0	-11	7	2	30	27
1989	20	0	-11	9	2	27	22
1990	13	0	-9	6	2	18	15
1991	21	0	-13	6	1	25	22
1992	11	1	-7	6	1	18	13
1993	18	0	-12	5	1	26	20
1994	10	0	-8	3	-1	15	12
1995	16	0	-12	5	1	20	17
1996	13	0	-8	3	1	15	13
1997	11	0	-9	3	0	14	12
1998	11	0	-6	10	1	26	16
1999	23	0	-14	18	5	41	29
2000	32	0	-14	12	3	43	35
2001	15	0	-10	8	2	23	17
2002	17	1	-6	11	2	36	24
2003	22	1	-12	7	1	32	25
2004	12	0	-8	5	1	18	14
2005	9	0	-8	2	0	11	9
2006	20	1	-12	7	2	25	22
2007	7	0	-13	4	1	11	8
2008	20	0	-16	7	1	26	21
2009	25	0	-13	7	2	31	27
2010	12	0	-10	6	1	18	14
2011	21	-1	-10	10	2	33	26
Average (1984-2011)	17	0	-11	7	2	24	19
Average (1984-1997)	16	0	-10	6	1	21	17
Average (1998-2011)	18	0	-11	8	2	26	21

Compared to Base Case

- increase >=50%
- increase >=10% and <50%
- increase >=1% and <10%
- no change <1% and >-1%
- decrease >=1% and <10%
- decrease >=10% and <50%
- decrease >=50%

Note:
HLWO - Highland Lakes Watershed Ordinance

Table 10

Maximum Predicted Chlorophyll-a Concentrations (µg/L) at Segment 6 (near Beaver Creek Cove)

Year	Base Case	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	17.8	20.8	17.9	14.1	19.6	18.2	22.2	21.2
1985	21.6	33.6	21.9	20.5	23.9	21.8	34.5	34.2
1986	33.8	34.6	34.3	32.5	36.2	34.0	35.0	36.3
1987	27.6	31.4	27.6	26.7	27.1	28.0	32.8	31.4
1988	22.9	25.4	22.6	21.4	23.2	23.7	27.2	26.0
1989	18.7	22.5	18.9	17.5	20.7	19.3	23.2	22.4
1990	26.9	29.8	27.6	24.9	28.8	27.4	31.8	30.6
1991	12.9	16.0	13.1	11.8	13.8	13.2	16.8	16.2
1992	29.6	34.0	29.8	27.2	31.3	30.0	36.1	34.4
1993	12.9	19.1	13.1	9.0	13.2	13.0	19.8	19.1
1994	37.2	38.0	37.3	34.2	37.1	35.0	38.2	39.1
1995	22.1	24.5	22.4	20.2	23.6	22.6	25.8	25.2
1996	23.5	25.4	22.7	21.6	24.3	23.3	26.4	25.3
1997	34.5	36.6	34.4	32.6	34.6	33.9	36.5	36.6
1998	40.7	43.1	39.5	38.8	43.0	41.1	44.8	44.1
1999	22.4	30.2	22.0	20.2	30.2	23.9	38.9	33.0
2000	32.4	38.6	32.7	29.4	34.9	32.7	40.8	38.9
2001	36.2	42.6	37.9	32.5	39.1	36.9	42.6	43.2
2002	26.3	32.3	26.8	25.4	29.6	26.0	39.4	35.9
2003	28.5	35.0	33.5	26.3	33.1	32.1	36.7	35.3
2004	33.0	33.9	32.8	32.3	33.1	32.8	35.2	34.3
2005	39.4	40.0	39.6	38.2	39.4	39.1	40.3	40.1
2006	20.3	25.4	20.6	18.0	22.5	21.3	27.1	26.2
2007	56.0	57.4	57.7	51.6	59.5	57.8	59.9	57.9
2008	23.2	29.3	23.4	20.3	25.7	23.5	31.0	29.7
2009	29.5	35.8	29.5	28.2	29.7	29.0	37.9	36.5
2010	43.8	51.0	44.6	35.7	48.6	45.5	50.2	50.0
2011	27.2	36.7	26.7	22.9	30.2	27.5	40.7	38.9
Average	28.6	33.0	29.0	26.2	30.6	29.0	34.7	33.6

Notes:

µg/L - microgram per Liter

HLWO - Highland Lakes Watershed Ordinance

Values are averages of daily concentrations in the lake surface (top 2 meters) for the entire year.

Table 11

% Change in Maximum Predicted Chlorophyll-a Concentrations at Segment 6 (near Beaver Creek Cove)

January through December, 0 to 2 meters of water column

Year	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	17	1	-21	10	2	25	19
1985	55	1	-5	11	1	59	58
1986	2	2	-4	7	1	4	7
1987	14	0	-3	-2	1	19	14
1988	11	-1	-6	2	4	19	14
1989	21	1	-6	11	4	24	20
1990	11	3	-7	7	2	18	14
1991	24	1	-9	7	2	30	26
1992	15	1	-8	6	1	22	16
1993	48	1	-30	3	1	53	48
1994	2	0	-8	0	-6	3	5
1995	11	1	-9	7	2	17	14
1996	8	-4	-8	3	-1	12	8
1997	6	0	-6	0	-2	6	6
1998	6	-3	-5	6	1	10	8
1999	35	-2	-10	35	7	74	48
2000	19	1	-9	8	1	26	20
2001	18	4	-10	8	2	18	19
2002	23	2	-3	12	-1	50	36
2003	23	18	-7	16	13	29	24
2004	3	0	-2	0	0	7	4
2005	2	1	-3	0	-1	2	2
2006	25	1	-11	11	5	33	29
2007	3	3	-8	6	3	7	3
2008	26	1	-12	11	1	34	28
2009	21	0	-4	1	-2	28	24
2010	16	2	-18	11	4	15	14
2011	35	-2	-16	11	1	50	43
Average (1984-2011)	18	1	-9	7	2	25	20
Average (1984-1997)	17	0	-9	5	1	22	19
Average (1998-2011)	18	2	-9	10	2	27	22

Compared to Base Case

- increase >=50%
- increase >=10% and <50%
- increase >=1% and <10%
- no change <1% and >-1%
- decrease >=1% and <10%
- decrease >=10% and <50%
- decrease >=50%

Note:
HLWO - Highland Lakes Watershed Ordinance

Table 12

Average Predicted Chlorophyll-a Concentrations (µg/L) at Segment 7 (~3/4 miles South of Garret Island)

Year	Base Case	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	4.5	5.2	4.5	4.0	5.0	4.6	5.7	5.4
1985	11.0	12.4	11.1	10.1	12.4	11.4	13.7	12.8
1986	9.8	10.4	9.8	9.2	10.3	9.9	10.9	10.6
1987	9.3	10.5	9.3	8.5	9.7	9.4	10.8	10.6
1988	8.2	10.0	8.2	7.4	8.8	8.4	10.4	10.2
1989	9.1	10.5	9.1	8.4	10.0	9.4	11.3	10.8
1990	9.1	10.0	9.1	8.5	9.6	9.3	10.5	10.2
1991	7.2	8.6	7.3	6.4	7.7	7.3	8.9	8.7
1992	11.7	12.8	11.8	11.0	12.5	11.9	13.6	13.0
1993	4.5	5.2	4.6	4.2	4.8	4.6	5.6	5.3
1994	7.0	7.5	7.0	6.6	7.3	7.0	7.9	7.7
1995	8.3	9.4	8.3	7.6	8.8	8.5	9.8	9.6
1996	9.0	9.9	9.0	8.4	9.3	9.0	10.1	10.0
1997	16.0	17.4	16.1	14.9	16.6	16.1	17.9	17.4
1998	14.6	15.9	14.6	14.0	16.1	14.8	18.1	16.6
1999	14.6	17.5	14.5	12.8	17.2	15.3	20.0	18.3
2000	10.5	13.2	10.5	9.2	11.8	10.8	14.4	13.6
2001	12.3	13.9	12.3	11.3	13.2	12.5	14.8	14.1
2002	12.2	14.0	12.3	11.7	13.6	12.4	16.3	14.9
2003	9.5	11.3	9.6	8.6	10.2	9.6	12.3	11.7
2004	13.1	14.5	13.1	12.3	13.8	13.3	15.2	14.8
2005	13.8	14.7	13.8	12.8	14.1	13.8	15.0	14.8
2006	11.3	13.0	11.4	10.3	12.0	11.6	13.5	13.2
2007	17.7	18.9	17.8	16.0	18.5	17.9	19.6	19.1
2008	10.9	12.7	10.9	9.2	11.6	11.0	13.3	12.8
2009	13.1	15.6	13.1	11.9	14.1	13.4	16.4	15.8
2010	15.0	16.5	15.0	13.7	15.8	15.2	17.4	16.7
2011	14.4	16.6	14.3	13.3	15.7	14.6	18.1	17.3
Average	11.0	12.4	11.0	10.1	11.8	11.2	13.3	12.7

Notes:

µg/L - microgram per Liter

HLWO - Highland Lakes Watershed Ordinance

Values are averages of daily concentrations in the lake surface (top 2 meters) for the entire year.

Table 13

% Change in Average Predicted Chl-a Concentrations at Segment 7 (~3/4 miles South of Garret Island)

January through December, 0 to 2 meters of water column

Year	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	17	0	-11	11	3	27	20
1985	12	0	-8	12	3	24	16
1986	6	0	-6	5	1	11	8
1987	13	0	-9	4	1	17	14
1988	22	0	-10	7	3	27	24
1989	15	0	-8	9	3	23	18
1990	10	0	-7	5	2	15	12
1991	18	0	-11	6	1	23	20
1992	9	1	-6	6	2	16	11
1993	14	0	-8	5	1	23	16
1994	8	0	-6	4	-1	13	9
1995	13	0	-9	6	1	18	15
1996	11	0	-6	4	1	13	11
1997	9	0	-7	4	1	12	9
1998	9	0	-4	10	1	24	14
1999	20	-1	-12	18	5	37	26
2000	26	0	-12	13	3	37	29
2001	13	0	-8	8	2	21	15
2002	15	1	-4	12	2	34	22
2003	19	0	-9	8	1	30	23
2004	10	0	-6	5	1	16	12
2005	7	0	-7	2	0	9	7
2006	15	1	-9	6	2	20	17
2007	7	1	-10	4	1	10	8
2008	17	0	-15	7	1	22	18
2009	19	0	-9	8	2	25	20
2010	10	0	-8	6	1	16	12
2011	15	-1	-8	9	1	25	20
Average (1984-2011)	13	0	-8	7	2	21	16
Average (1984-1997)	13	0	-8	6	2	19	14
Average (1998-2011)	14	0	-9	8	2	23	17

Compared to Base Case

- increase >=50%
- increase >=10% and <50%
- increase >=1% and <10%
- no change <1% and >-1%
- decrease >=1% and <10%
- decrease >=10% and <50%
- decrease >=50%

Notes:

Chl-a - Chlorophyll-a

HLWO - Highland Lakes Watershed Ordinance

Table 14

Maximum Predicted Chlorophyll-a Concentrations (µg/L) at Segment 7 (~3/4 miles South of Garret Island)

Year	Base Case	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	13.7	15.1	13.7	12.4	15.3	14.2	16.5	15.5
1985	19.1	26.5	19.1	18.4	21.3	19.2	28.4	27.3
1986	30.7	30.2	31.1	27.3	33.0	30.7	30.1	33.0
1987	27.2	27.3	24.5	24.6	24.2	26.7	29.5	27.0
1988	18.7	23.5	19.1	16.4	21.0	20.0	25.0	24.0
1989	18.7	20.3	18.3	17.6	20.1	18.8	21.6	21.1
1990	27.3	31.3	27.9	24.9	29.6	27.8	31.4	31.8
1991	11.1	14.5	11.3	10.3	12.1	11.5	15.1	14.4
1992	27.8	31.8	28.1	25.0	30.3	28.3	34.2	32.3
1993	7.7	9.5	7.7	7.5	8.1	7.8	9.8	9.6
1994	36.8	38.3	36.9	33.4	37.0	34.0	39.8	39.5
1995	18.5	19.9	18.4	17.8	20.0	19.2	20.7	20.5
1996	21.8	23.4	21.9	20.7	23.4	22.4	25.0	24.2
1997	35.0	37.0	34.2	33.6	35.5	33.7	36.3	35.0
1998	38.7	40.4	37.5	36.3	39.6	38.9	42.2	42.1
1999	21.8	30.1	21.6	18.5	31.0	24.1	39.3	32.8
2000	29.6	35.3	29.6	26.8	31.8	29.8	37.4	36.2
2001	34.2	40.6	35.9	31.3	36.2	34.8	40.9	41.1
2002	26.0	31.1	26.5	24.8	30.6	26.3	38.4	35.2
2003	20.5	22.9	21.6	19.4	21.9	20.8	24.6	23.4
2004	30.2	30.8	30.1	29.7	30.4	30.1	32.1	31.2
2005	39.0	39.5	39.3	37.9	38.9	38.6	39.8	39.5
2006	19.1	22.9	19.3	17.4	21.1	20.0	24.4	23.5
2007	51.5	53.7	52.7	48.6	53.6	52.1	55.3	53.8
2008	22.4	28.0	22.6	17.1	24.4	22.8	30.2	28.5
2009	24.4	26.2	24.6	23.9	24.8	24.2	28.7	27.2
2010	40.1	43.5	40.8	34.0	42.6	40.9	44.3	43.3
2011	27.7	36.4	27.2	22.4	30.3	27.7	38.4	38.1
Average	26.4	29.6	26.5	24.2	28.1	26.6	31.4	30.4

Notes:

µg/L - microgram per Liter

HLWO - Highland Lakes Watershed Ordinance

Values are averages of daily concentrations in the lake surface (top 2 meters) for the entire year.

Table 15

% Change in Maximum Predicted Chl-a Concentrations at Segment 7 (~3/4 miles South of Garret Island)

January through December, 0 to 2 meters of water column

Year	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	10	0	-10	11	3	20	13
1985	39	0	-4	11	1	48	43
1986	-2	1	-11	7	0	-2	7
1987	1	-10	-10	-11	-2	8	-1
1988	26	2	-12	12	7	34	29
1989	9	-2	-6	8	1	15	13
1990	14	2	-9	9	2	15	16
1991	30	1	-7	8	3	36	30
1992	15	1	-10	9	2	23	16
1993	22	0	-4	5	1	26	24
1994	4	0	-9	0	-7	8	7
1995	7	0	-4	8	3	11	11
1996	7	1	-5	7	3	15	11
1997	6	-2	-4	1	-3	4	0
1998	4	-3	-6	2	1	9	9
1999	38	-1	-15	42	11	80	50
2000	19	0	-9	7	1	26	23
2001	19	5	-8	6	2	20	20
2002	20	2	-5	18	1	48	35
2003	11	5	-6	7	1	20	14
2004	2	0	-2	1	0	6	3
2005	1	1	-3	0	-1	2	1
2006	20	1	-9	10	5	28	23
2007	4	2	-6	4	1	7	5
2008	25	1	-24	9	2	35	27
2009	7	1	-2	2	-1	17	12
2010	9	2	-15	6	2	11	8
2011	32	-2	-19	10	0	39	38
Average (1984-2011)	14	0	-8	7	1	22	17
Average (1984-1997)	13	0	-7	6	1	19	16
Average (1998-2011)	15	1	-9	9	2	25	19

Compared to Base Case

- increase >=50%
- increase >=10% and <50%
- increase >=1% and <10%
- no change <1% and >-1%
- decrease >=1% and <10%
- decrease >=10% and <50%
- decrease >=50%

Notes:

Chl-a - Chlorophyll-a

HLWO - Highland Lakes Watershed Ordinance

Table 16

Average Predicted Chlorophyll-a Concentrations (µg/L) at Segment 9 (at Rocky Point)

Year	Base Case	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	3.9	4.4	3.9	3.6	4.3	4.0	4.7	4.5
1985	10.3	11.3	10.4	9.6	11.6	10.7	12.6	11.7
1986	8.9	9.3	8.9	8.6	9.4	9.0	9.8	9.5
1987	8.2	9.2	8.3	7.6	8.7	8.4	9.6	9.3
1988	7.4	8.8	7.4	6.8	8.0	7.6	9.3	9.0
1989	8.5	9.5	8.5	7.9	9.3	8.7	10.2	9.8
1990	8.5	9.1	8.4	8.0	8.9	8.6	9.6	9.3
1991	6.7	7.7	6.7	6.1	7.1	6.8	8.0	7.8
1992	10.8	11.6	10.9	10.3	11.5	11.0	12.4	11.8
1993	4.2	4.6	4.2	3.9	4.4	4.2	5.0	4.7
1994	6.4	6.7	6.4	6.1	6.6	6.4	7.1	6.8
1995	7.5	8.3	7.5	7.0	7.9	7.6	8.7	8.4
1996	8.0	8.7	8.0	7.6	8.3	8.1	8.8	8.7
1997	14.1	15.0	14.2	13.4	14.7	14.2	15.5	15.0
1998	13.4	14.4	13.3	13.0	14.8	13.6	16.4	15.1
1999	13.7	16.0	13.6	12.2	16.1	14.3	18.1	16.7
2000	9.8	11.9	9.9	8.8	11.1	10.1	13.0	12.3
2001	11.5	12.7	11.5	10.7	12.4	11.7	13.6	12.9
2002	11.2	12.7	11.3	10.9	12.5	11.4	14.5	13.4
2003	8.8	10.2	8.8	8.1	9.5	8.8	11.2	10.5
2004	11.8	12.7	11.8	11.2	12.3	11.9	13.3	12.9
2005	12.6	13.2	12.6	11.9	12.8	12.6	13.5	13.3
2006	10.6	11.9	10.7	9.8	11.3	10.9	12.4	12.1
2007	15.5	16.5	15.7	14.5	16.3	15.7	17.2	16.7
2008	9.7	11.1	9.7	8.4	10.4	9.8	11.5	11.2
2009	11.4	13.0	11.4	10.5	12.3	11.6	13.8	13.2
2010	14.2	15.4	14.3	13.2	15.1	14.4	16.2	15.6
2011	13.8	15.3	13.7	12.9	14.9	14.0	16.6	15.9
Average	10.1	11.1	10.1	9.4	10.8	10.2	11.9	11.4

Notes:

µg/L - microgram per Liter

HLWO - Highland Lakes Watershed Ordinance

Values are averages of daily concentrations in the lake surface (top 2 meters) for the entire year.

Table 17

% Change in Average Predicted Chlorophyll-a Concentrations at Segment 9 (at Rocky Point)

January through December, 0 to 2 meters of water column

Year	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	12	0	-7	10	3	21	15
1985	10	0	-7	13	3	22	14
1986	4	0	-4	6	1	10	6
1987	11	0	-8	5	2	16	13
1988	18	0	-9	8	3	24	21
1989	12	0	-7	9	3	20	15
1990	8	0	-5	5	1	13	10
1991	15	0	-9	6	1	20	17
1992	7	1	-5	6	2	14	9
1993	11	0	-6	5	2	20	13
1994	5	0	-4	4	0	11	7
1995	10	0	-7	6	1	16	12
1996	9	0	-5	3	1	11	9
1997	6	0	-5	4	1	10	6
1998	7	0	-3	11	1	22	13
1999	17	-1	-11	17	4	32	22
2000	21	0	-11	13	3	32	25
2001	10	0	-7	7	2	18	12
2002	13	0	-3	11	1	29	19
2003	17	0	-7	8	1	27	20
2004	8	0	-5	5	1	13	10
2005	5	0	-5	2	0	7	5
2006	13	1	-7	6	2	17	14
2007	6	1	-6	5	1	11	8
2008	14	1	-13	7	2	19	16
2009	14	0	-8	8	2	21	16
2010	8	0	-7	6	1	14	10
2011	11	-1	-7	8	1	20	15
Average (1984-2011)	11	0	-7	7	2	18	13
Average (1984-1997)	10	0	-6	7	2	16	12
Average (1998-2011)	12	0	-7	8	2	20	15

Compared to Base Case

- increase >=50%
- increase >=10% and <50%
- increase >=1% and <10%
- no change <1% and >-1%
- decrease >=1% and <10%
- decrease >=10% and <50%
- decrease >=50%

Note:
HLWO - Highland Lakes Watershed Ordinance

Table 18

Maximum Predicted Chlorophyll-a Concentrations (µg/L) at Segment 9 (at Rocky Point)

Year	Base Case	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	10.3	11.2	10.2	9.5	11.4	10.6	12.2	11.5
1985	17.5	21.0	17.3	17.0	19.4	17.6	22.5	21.4
1986	25.2	26.0	25.3	24.5	26.0	25.3	26.7	26.3
1987	25.7	25.6	19.9	22.0	21.8	24.9	28.1	26.9
1988	16.4	19.7	16.4	14.5	18.4	17.1	21.4	20.9
1989	17.0	18.8	17.2	15.8	18.4	17.3	20.3	19.4
1990	23.2	24.8	23.4	23.1	24.3	23.8	26.3	25.1
1991	10.1	12.3	9.9	9.2	10.9	10.2	13.4	12.6
1992	26.9	29.4	26.8	24.2	28.7	27.1	31.7	30.4
1993	6.7	7.3	6.7	6.5	7.1	6.8	7.9	7.4
1994	29.8	33.3	31.3	28.9	31.4	29.1	33.8	32.9
1995	12.7	14.1	12.8	12.3	14.2	13.4	15.0	14.6
1996	18.8	20.1	18.7	17.9	19.8	19.2	21.7	21.0
1997	35.9	36.7	35.4	34.9	36.0	35.1	35.7	35.3
1998	33.5	35.2	32.4	32.8	36.9	34.2	39.5	36.5
1999	22.5	29.9	22.3	18.5	32.1	25.7	40.4	33.5
2000	25.9	31.7	26.2	23.4	28.6	26.4	34.1	32.6
2001	34.5	36.2	36.0	30.0	36.6	35.0	36.8	36.9
2002	26.6	31.3	26.2	26.8	31.1	26.5	40.1	34.0
2003	14.1	19.5	14.2	15.5	16.8	14.4	23.9	21.5
2004	28.0	28.7	26.8	27.8	28.5	28.1	28.9	28.9
2005	34.9	34.9	34.4	33.2	35.0	34.1	35.6	34.5
2006	15.0	17.5	15.4	16.4	16.7	15.9	19.6	18.2
2007	44.1	46.7	45.3	38.8	47.3	45.6	48.4	46.9
2008	21.9	27.5	22.0	15.7	24.5	22.1	28.9	27.9
2009	17.8	21.0	17.9	17.2	19.7	18.2	23.3	21.9
2010	35.5	39.5	35.9	32.9	37.2	36.0	40.1	39.4
2011	28.7	35.8	28.2	23.3	31.3	29.1	39.6	37.8
Average	23.5	26.3	23.4	21.9	25.3	23.9	28.4	27.0

Notes:

µg/L - microgram per Liter

HLWO - Highland Lakes Watershed Ordinance

Values are averages of daily concentrations in the lake surface (top 2 meters) for the entire year.

Table 19

% Change in Maximum Predicted Chlorophyll-a Concentrations at Segment 9 (at Rocky Point)

January through December, 0 to 2 meters of water column

Year	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	9	-1	-8	11	3	19	12
1985	20	-1	-3	11	1	29	23
1986	3	0	-3	3	1	6	5
1987	0	-23	-14	-15	-3	9	5
1988	20	0	-12	12	4	30	27
1989	11	2	-7	8	2	20	14
1990	7	1	-1	5	2	14	8
1991	22	-1	-9	8	1	33	25
1992	9	0	-10	7	1	18	13
1993	9	0	-3	5	1	18	11
1994	12	5	-3	5	-2	13	10
1995	11	0	-4	12	6	18	15
1996	7	-1	-5	5	2	16	12
1997	2	-1	-3	0	-2	0	-1
1998	5	-3	-2	10	2	18	9
1999	33	-1	-18	43	14	79	49
2000	22	1	-10	10	2	32	26
2001	5	4	-13	6	1	7	7
2002	18	-1	1	17	0	51	28
2003	38	0	10	19	2	69	52
2004	2	-4	-1	2	0	3	3
2005	0	-1	-5	0	-2	2	-1
2006	17	3	9	11	6	31	21
2007	6	3	-12	7	3	10	6
2008	25	0	-29	12	1	31	27
2009	18	1	-3	11	2	31	23
2010	11	1	-8	5	1	13	11
2011	25	-2	-19	9	1	38	32
Average (1984-2011)	13	-1	-6	8	2	23	17
Average (1984-1997)	10	-1	-6	5	1	17	13
Average (1998-2011)	16	0	-7	12	2	30	21

Compared to Base Case

- increase >=50%
- increase >=10% and <50%
- increase >=1% and <10%
- no change <1% and >-1%
- decrease >=1% and <10%
- decrease >=10% and <50%
- decrease >=50%

Note:
HLWO - Highland Lakes Watershed Ordinance

Table 20

Average Predicted Chlorophyll-a Concentrations (µg/L) at Segment 18 (at the Confluence of Council and Morgan Creeks)

Year	Base Case	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	4.2	4.7	4.2	3.8	4.6	4.3	5.2	4.9
1985	10.6	11.7	10.6	9.8	11.9	10.9	13.0	12.1
1986	9.5	10.0	9.6	9.1	10.1	9.7	10.5	10.2
1987	8.7	9.8	8.7	8.0	9.1	8.8	10.2	9.9
1988	7.8	9.4	7.8	7.1	8.4	8.0	9.8	9.5
1989	8.7	9.9	8.7	8.1	9.5	9.0	10.6	10.2
1990	8.7	9.5	8.7	8.2	9.2	8.9	10.0	9.7
1991	6.9	8.0	6.9	6.2	7.4	7.0	8.3	8.1
1992	11.3	12.2	11.4	10.7	12.1	11.5	13.1	12.4
1993	4.3	4.8	4.3	4.0	4.5	4.4	5.2	4.9
1994	6.6	7.0	6.6	6.3	6.8	6.5	7.4	7.1
1995	7.8	8.7	7.8	7.2	8.2	7.9	9.1	8.8
1996	8.5	9.3	8.5	8.0	8.8	8.6	9.5	9.4
1997	15.0	16.0	15.0	14.1	15.5	15.0	16.4	16.0
1998	13.9	14.9	13.8	13.4	15.3	14.0	17.0	15.6
1999	14.1	16.6	14.0	12.4	16.5	14.7	18.8	17.3
2000	10.1	12.4	10.1	9.0	11.4	10.4	13.5	12.7
2001	11.7	13.0	11.7	10.9	12.6	11.9	13.9	13.3
2002	11.7	13.2	11.7	11.3	13.0	11.9	15.3	14.0
2003	9.1	10.7	9.1	8.4	9.8	9.2	11.6	11.0
2004	12.4	13.5	12.4	11.7	13.0	12.5	14.2	13.7
2005	12.9	13.6	13.0	12.2	13.2	13.0	13.9	13.7
2006	10.9	12.4	11.0	10.0	11.6	11.1	12.8	12.6
2007	16.6	17.6	16.7	15.3	17.2	16.7	18.2	17.7
2008	10.2	11.7	10.2	8.8	10.9	10.3	12.3	11.9
2009	12.2	14.1	12.2	11.2	13.1	12.4	14.9	14.3
2010	14.4	15.8	14.5	13.3	15.3	14.6	16.6	16.0
2011	14.2	15.9	14.0	13.1	15.3	14.3	17.2	16.5
Average	10.5	11.7	10.5	9.7	11.2	10.6	12.4	11.9

Notes:

µg/L - microgram per Liter

HLWO - Highland Lakes Watershed Ordinance

Values are averages of daily concentrations in the lake surface (top 2 meters) for the entire year.

Table 21
% Change in Average Predicted Chlorophyll-a Concentrations at Segment 18
(at the Confluence of Council and Morgan Creeks)
January through December, 0 to 2 meters of water column

Year	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	13	0	-9	11	3	24	16
1985	10	0	-7	12	3	23	14
1986	5	0	-5	6	1	10	7
1987	12	0	-8	5	1	17	14
1988	20	0	-9	7	3	25	22
1989	13	0	-7	9	3	21	16
1990	9	0	-6	6	2	14	11
1991	16	0	-10	6	1	21	18
1992	8	1	-5	7	2	16	10
1993	12	0	-7	5	2	21	14
1994	6	0	-5	4	0	12	8
1995	11	0	-8	6	2	17	13
1996	9	0	-5	3	1	12	10
1997	7	0	-6	4	0	10	7
1998	8	0	-3	10	1	23	13
1999	18	-1	-12	17	5	34	23
2000	23	0	-11	13	3	33	26
2001	11	0	-7	7	2	18	13
2002	13	1	-3	11	2	31	20
2003	17	0	-8	8	1	28	21
2004	9	0	-5	5	1	14	11
2005	6	0	-6	2	0	8	6
2006	14	1	-8	6	2	18	16
2007	6	1	-7	4	1	10	7
2008	15	1	-14	7	2	21	17
2009	16	0	-8	8	2	22	17
2010	9	0	-8	6	1	15	11
2011	12	-1	-7	8	1	22	17
Average (1984-2011)	12	0	-7	7	2	19	14
Average (1984-1997)	11	0	-7	6	2	17	13
Average (1998-2011)	13	0	-8	8	2	21	16

Compared to Base Case

- increase >=50%
- increase >=10% and <50%
- increase >=1% and <10%
- no change <1% and >-1%
- decrease >=1% and <10%
- decrease >=10% and <50%
- decrease >=50%

Note:
HLWO - Highland Lakes Watershed Ordinance

Table 22

Maximum Predicted Chlorophyll-a Concentrations (µg/L) at Segment 18 (at the Confluence of Council and Morgan Creeks)

Year	Base Case	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	12.4	13.5	12.3	11.4	13.8	12.8	14.8	13.8
1985	17.5	21.6	17.4	17.1	19.2	17.6	23.4	22.1
1986	29.1	28.8	29.3	26.9	31.0	29.5	29.3	31.5
1987	25.3	25.4	22.2	22.6	22.2	24.3	28.5	26.7
1988	17.9	21.9	17.8	15.6	20.0	18.5	23.3	23.0
1989	17.0	18.3	17.2	15.9	18.0	17.5	19.8	19.0
1990	21.9	22.8	22.1	21.4	23.3	22.3	24.4	23.7
1991	10.4	12.5	10.4	9.6	11.4	10.6	13.3	12.7
1992	28.1	31.4	28.4	26.1	30.7	28.7	33.5	31.9
1993	7.0	7.9	7.0	6.8	7.4	7.1	8.2	8.1
1994	28.8	29.5	29.2	27.2	30.2	27.3	32.4	31.0
1995	14.6	15.9	14.8	14.0	16.1	15.1	17.3	16.5
1996	20.1	21.4	20.1	19.1	21.4	20.6	23.2	22.4
1997	31.4	32.1	31.0	30.3	31.4	30.6	32.4	31.3
1998	34.5	36.3	32.2	32.8	36.6	33.7	39.5	37.1
1999	21.6	29.7	21.7	19.3	30.5	24.3	38.0	31.9
2000	26.2	31.7	26.4	23.2	28.7	26.6	34.1	32.7
2001	34.1	34.4	35.7	31.2	35.0	34.6	34.9	35.1
2002	24.1	27.5	23.5	23.7	28.2	24.8	37.3	31.6
2003	14.6	19.5	14.5	14.9	17.3	14.6	23.5	20.4
2004	27.1	27.5	27.0	26.8	27.4	27.1	28.6	27.8
2005	34.9	34.9	34.4	32.9	35.0	33.9	35.8	34.3
2006	15.6	18.0	15.8	16.8	17.1	16.3	19.1	18.6
2007	45.8	47.3	46.4	39.9	48.8	45.9	50.1	47.9
2008	23.0	27.3	23.2	16.0	25.1	23.4	28.6	27.7
2009	21.4	22.7	21.5	21.0	21.7	21.3	25.0	23.5
2010	40.4	42.8	40.6	31.4	40.8	40.1	45.2	43.5
2011	28.3	34.2	28.0	23.9	29.9	28.2	37.6	35.5
Average	24.0	26.3	23.9	22.1	25.6	24.2	28.6	27.2

Notes:

µg/L - microgram per Liter

HLWO - Highland Lakes Watershed Ordinance

Values are averages of daily concentrations in the lake surface (top 2 meters) for the entire year.

Table 23
% Change in Maximum Predicted Chlorophyll-a Concentrations at Segment 18
(at the Confluence of Council and Morgan Creeks)
January through December, 0 to 2 meters of water column

Year	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	9	0	-8	11	3	19	12
1985	24	0	-2	10	1	34	26
1986	-1	0	-8	6	1	0	8
1987	1	-12	-11	-12	-4	13	6
1988	22	0	-13	12	3	30	29
1989	8	1	-6	6	3	17	12
1990	4	1	-3	6	2	11	8
1991	20	1	-8	10	2	29	23
1992	12	1	-7	9	2	19	14
1993	13	0	-3	6	1	17	15
1994	2	1	-6	5	-5	12	8
1995	9	1	-4	10	4	19	13
1996	7	0	-5	7	3	16	12
1997	2	-1	-4	0	-2	3	0
1998	5	-7	-5	6	-2	14	8
1999	37	0	-11	41	13	76	47
2000	21	1	-11	10	1	30	25
2001	1	5	-9	3	1	2	3
2002	14	-2	-2	17	3	55	31
2003	34	-1	2	18	0	60	40
2004	2	0	-1	1	0	5	3
2005	0	-1	-6	0	-3	3	-2
2006	15	1	7	10	4	23	19
2007	3	1	-13	6	0	9	4
2008	18	1	-30	9	2	24	20
2009	6	1	-2	1	0	17	10
2010	6	0	-22	1	-1	12	8
2011	21	-1	-16	6	0	33	25
Average (1984-2011)	11	0	-7	8	1	22	15
Average (1984-1997)	9	-1	-6	6	1	17	13
Average (1998-2011)	13	0	-8	9	1	26	17

Compared to Base Case

- increase >=50%
- increase >=10% and <50%
- increase >=1% and <10%
- no change <1% and >-1%
- decrease >=1% and <10%
- decrease >=10% and <50%
- decrease >=50%

Note:
HLWO - Highland Lakes Watershed Ordinance

Table 24

Average Predicted Chlorophyll-a Concentrations (µg/L) at Segment 26 (at Golden Beach)

Year	Base Case	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	3.6	4.0	3.7	3.4	4.0	3.8	4.4	4.1
1985	10.5	11.4	10.5	9.8	11.9	10.8	12.8	11.8
1986	8.6	8.8	8.6	8.4	9.1	8.7	9.4	9.0
1987	7.9	8.8	8.0	7.3	8.4	8.1	9.3	8.9
1988	7.2	8.4	7.2	6.6	7.8	7.4	8.9	8.6
1989	8.4	9.3	8.4	7.9	9.2	8.6	10.1	9.6
1990	8.6	9.2	8.6	8.2	9.1	8.7	9.7	9.4
1991	6.6	7.5	6.6	6.0	7.1	6.7	7.9	7.6
1992	11.4	12.1	11.5	10.8	12.2	11.6	13.0	12.4
1993	4.0	4.4	4.1	3.8	4.3	4.1	4.8	4.5
1994	6.5	6.8	6.5	6.2	6.8	6.5	7.2	6.9
1995	7.4	8.0	7.4	6.9	7.9	7.5	8.5	8.2
1996	7.6	8.2	7.6	7.3	7.9	7.7	8.4	8.3
1997	14.7	15.4	14.7	14.2	15.3	14.7	15.9	15.5
1998	13.7	14.6	13.7	13.4	15.4	13.9	16.9	15.6
1999	14.1	16.5	14.0	12.5	16.8	14.8	19.0	17.3
2000	9.9	12.0	9.9	8.8	11.2	10.2	13.1	12.3
2001	11.9	13.2	12.0	11.1	12.9	12.2	14.2	13.4
2002	11.7	13.2	11.7	11.4	13.1	11.8	15.4	14.0
2003	8.7	10.1	8.7	8.2	9.5	8.8	11.1	10.5
2004	12.3	13.1	12.3	11.8	12.9	12.4	13.8	13.4
2005	13.0	13.6	13.0	12.4	13.3	13.0	13.9	13.6
2006	10.6	11.8	10.6	9.9	11.3	10.8	12.2	12.0
2007	17.6	18.6	17.7	16.7	18.7	17.8	19.5	18.8
2008	9.9	11.4	9.9	8.5	10.6	10.1	11.9	11.5
2009	10.7	12.1	10.7	10.0	11.7	11.0	12.9	12.3
2010	14.8	15.9	14.8	13.8	15.8	15.0	16.9	16.2
2011	13.9	15.3	13.8	13.0	15.0	14.1	16.6	16.0
Average	10.2	11.2	10.2	9.6	11.0	10.4	12.1	11.5

Notes:

µg/L - microgram per Liter

HLWO - Highland Lakes Watershed Ordinance

Values are averages of daily concentrations in the lake surface (top 2 meters) for the entire year.

Table 25

% Change in Average Predicted Chlorophyll-a Concentrations at Segment 26 (at Golden Beach)

January through December, 0 to 2 meters of water column

Year	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	10	0	-6	11	3	20	13
1985	8	0	-7	13	3	22	13
1986	3	0	-2	7	2	10	6
1987	11	1	-7	7	2	17	13
1988	17	0	-8	9	3	24	20
1989	11	0	-6	10	3	20	15
1990	7	0	-5	6	2	13	9
1991	14	0	-8	7	2	19	15
1992	7	1	-5	7	2	15	9
1993	9	0	-5	6	2	20	12
1994	5	0	-3	5	1	11	7
1995	9	0	-6	7	2	15	11
1996	8	0	-4	4	1	10	9
1997	5	0	-3	4	0	9	5
1998	7	0	-2	13	2	24	14
1999	17	-1	-12	18	5	34	22
2000	21	0	-11	14	3	33	25
2001	10	0	-7	8	2	19	12
2002	12	0	-2	12	1	31	20
2003	16	0	-6	9	1	27	20
2004	7	0	-4	5	1	12	9
2005	4	0	-4	2	0	7	5
2006	12	1	-7	7	3	16	14
2007	6	1	-5	6	2	11	7
2008	15	1	-14	8	2	21	16
2009	13	0	-7	9	2	21	15
2010	7	0	-6	7	1	14	10
2011	10	-1	-6	8	1	19	15
Average (1984-2011)	10	0	-6	8	2	18	13
Average (1984-1997)	9	0	-5	7	2	16	11
Average (1998-2011)	11	0	-7	9	2	21	14

Compared to Base Case

- increase >=50%
- increase >=10% and <50%
- increase >=1% and <10%
- no change <1% and >-1%
- decrease >=1% and <10%
- decrease >=10% and <50%
- decrease >=50%

Note:
HLWO - Highland Lakes Watershed Ordinance

Table 26
Maximum Predicted Chlorophyll-a Concentrations (µg/L) at Segment 26 (at Golden Beach)

Year	Base Case	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	9.5	10.6	9.4	8.8	10.6	9.9	11.6	10.9
1985	20.0	22.3	19.9	18.6	24.6	21.2	27.0	23.3
1986	17.3	18.3	17.2	16.4	19.1	17.6	20.2	18.9
1987	19.5	25.3	19.6	15.8	22.4	20.2	27.8	26.2
1988	17.7	22.1	17.6	15.5	20.1	18.6	24.4	22.9
1989	15.6	16.5	15.4	15.0	17.1	15.9	17.6	16.9
1990	24.7	25.9	24.6	24.1	26.2	25.4	28.1	26.8
1991	11.0	12.6	10.9	9.8	12.0	11.2	13.6	12.9
1992	29.3	31.3	29.4	27.5	30.9	29.6	34.5	31.8
1993	6.3	7.1	6.4	6.2	6.7	6.4	7.8	7.2
1994	20.3	21.2	20.6	19.7	21.8	20.3	22.6	21.9
1995	12.5	13.2	12.4	12.0	13.1	12.6	13.9	13.4
1996	17.1	18.5	16.9	16.2	18.4	17.2	19.8	19.1
1997	40.0	41.1	39.9	39.5	40.3	39.4	41.4	40.8
1998	36.4	39.3	35.4	35.9	42.2	37.5	43.7	41.5
1999	29.8	39.7	29.5	23.0	41.3	32.7	50.6	43.0
2000	22.2	29.9	22.3	18.6	26.8	23.0	35.3	31.6
2001	31.3	35.8	32.4	28.7	34.5	32.1	35.7	36.1
2002	31.1	35.6	31.3	33.2	36.9	30.9	45.3	38.5
2003	15.4	20.7	15.4	16.4	18.2	15.6	24.1	22.2
2004	31.8	33.1	31.9	31.8	32.3	31.9	33.9	33.5
2005	35.5	36.0	35.0	35.5	35.4	35.2	36.2	36.1
2006	17.6	20.6	17.6	16.6	19.6	18.2	21.7	20.9
2007	45.2	45.9	45.6	44.1	46.1	45.1	46.4	46.0
2008	24.9	30.9	24.9	17.3	28.0	25.1	33.0	31.5
2009	17.1	20.2	17.0	15.9	19.2	17.8	22.0	20.8
2010	39.1	38.4	38.7	36.2	38.6	37.5	39.1	38.3
2011	31.5	38.5	31.0	26.2	34.5	32.0	42.9	40.6
Average	23.9	26.8	23.9	22.3	26.3	24.3	29.3	27.6

Notes:

µg/L - microgram per Liter

HLWO - Highland Lakes Watershed Ordinance

Values are averages of daily concentrations in the lake surface (top 2 meters) for the entire year.

Table 27

% Change in Maximum Predicted Chlorophyll-a Concentrations at Segment 26 (at Golden Beach)

January through December, 0 to 2 meters of water column

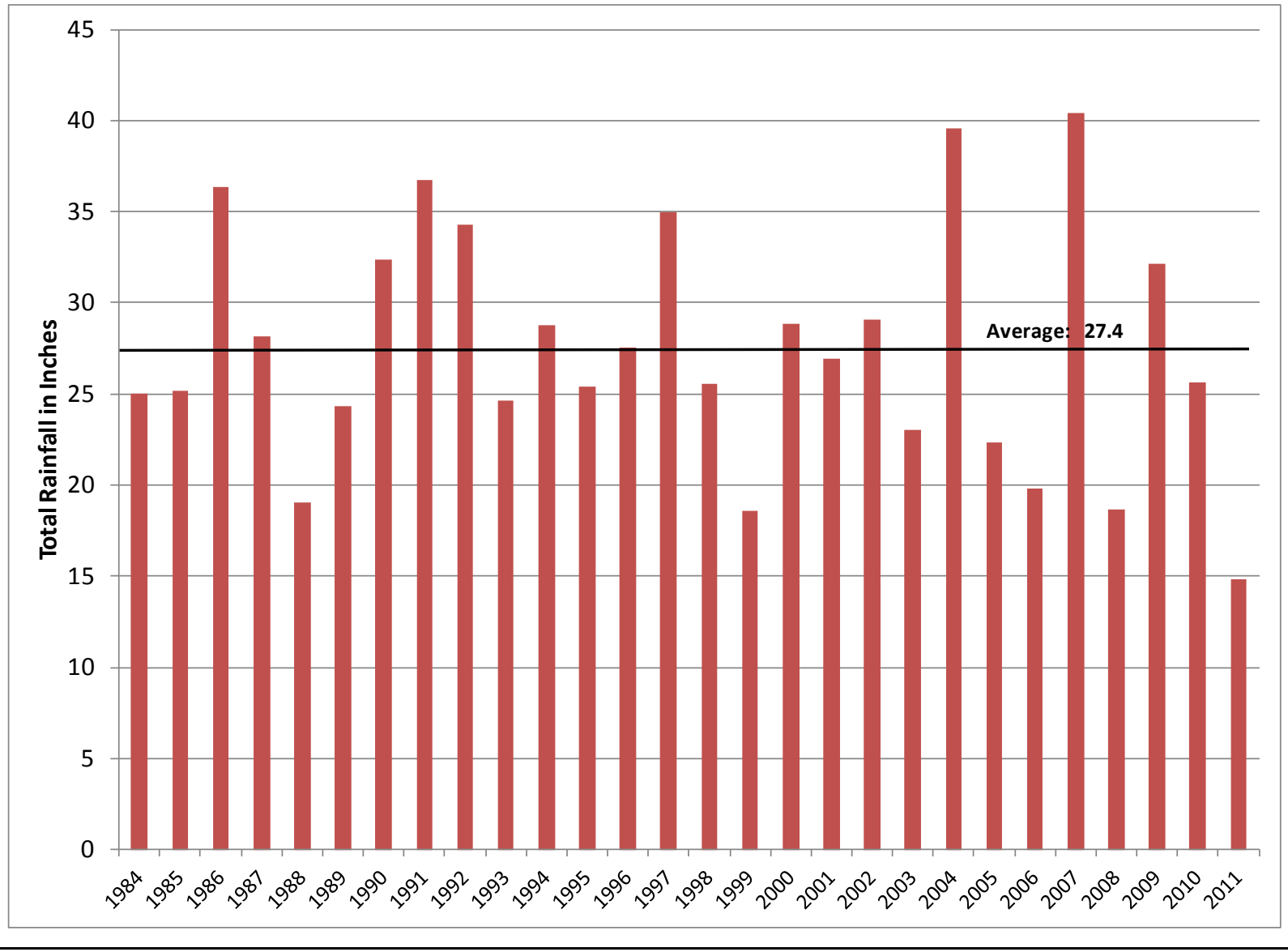
Year	Scenario 1 Point Sources, Fully Permitted	Scenario 2 Point Sources, Wet Weather	Scenario 3 Point Sources, Advanced Treatment	Scenario 4 Future Urbanization without HLWO	Scenario 5 Future Urbanization with HLWO	Scenario 6 #1 + #4	Scenario 7 #1 + #5
1984	12	-1	-8	12	4	22	14
1985	12	-1	-7	23	6	35	17
1986	6	-1	-5	10	2	17	9
1987	30	1	-19	15	4	43	34
1988	24	-1	-13	14	5	37	29
1989	6	-1	-3	10	2	13	9
1990	5	0	-2	6	3	14	8
1991	15	-1	-11	9	2	23	17
1992	7	0	-6	6	1	18	8
1993	12	0	-2	6	1	23	14
1994	5	2	-3	7	0	12	8
1995	5	-1	-4	5	1	11	7
1996	8	-1	-5	8	1	16	12
1997	3	0	-1	1	-1	4	2
1998	8	-3	-1	16	3	20	14
1999	33	-1	-23	39	10	70	44
2000	35	0	-16	21	4	59	42
2001	14	3	-8	10	2	14	15
2002	14	0	7	19	-1	45	23
2003	34	0	6	18	1	56	44
2004	4	0	0	1	0	6	5
2005	2	-1	0	0	-1	2	2
2006	17	0	-6	12	4	24	19
2007	1	1	-3	2	0	3	2
2008	24	0	-31	12	1	33	26
2009	18	0	-7	12	4	29	22
2010	-2	-1	-8	-1	-4	0	-2
2011	22	-2	-17	10	2	36	29
Average (1984-2011)	13	0	-7	11	2	24	17
Average (1984-1997)	11	0	-6	9	2	20	13
Average (1998-2011)	16	0	-8	12	2	28	20

Compared to Base Case

- increase >=50%
- increase >=10% and <50%
- increase >=1% and <10%
- no change <1% and >-1%
- decrease >=1% and <10%
- decrease >=10% and <50%
- decrease >=50%

Note:
HLWO - Highland Lakes Watershed Ordinance

FIGURES



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ANCHOR QEA PARSONS

Figure 1
Total Average Annual Rainfall
CREMs Phase 4 Scenarios
Lower Colorado River Authority

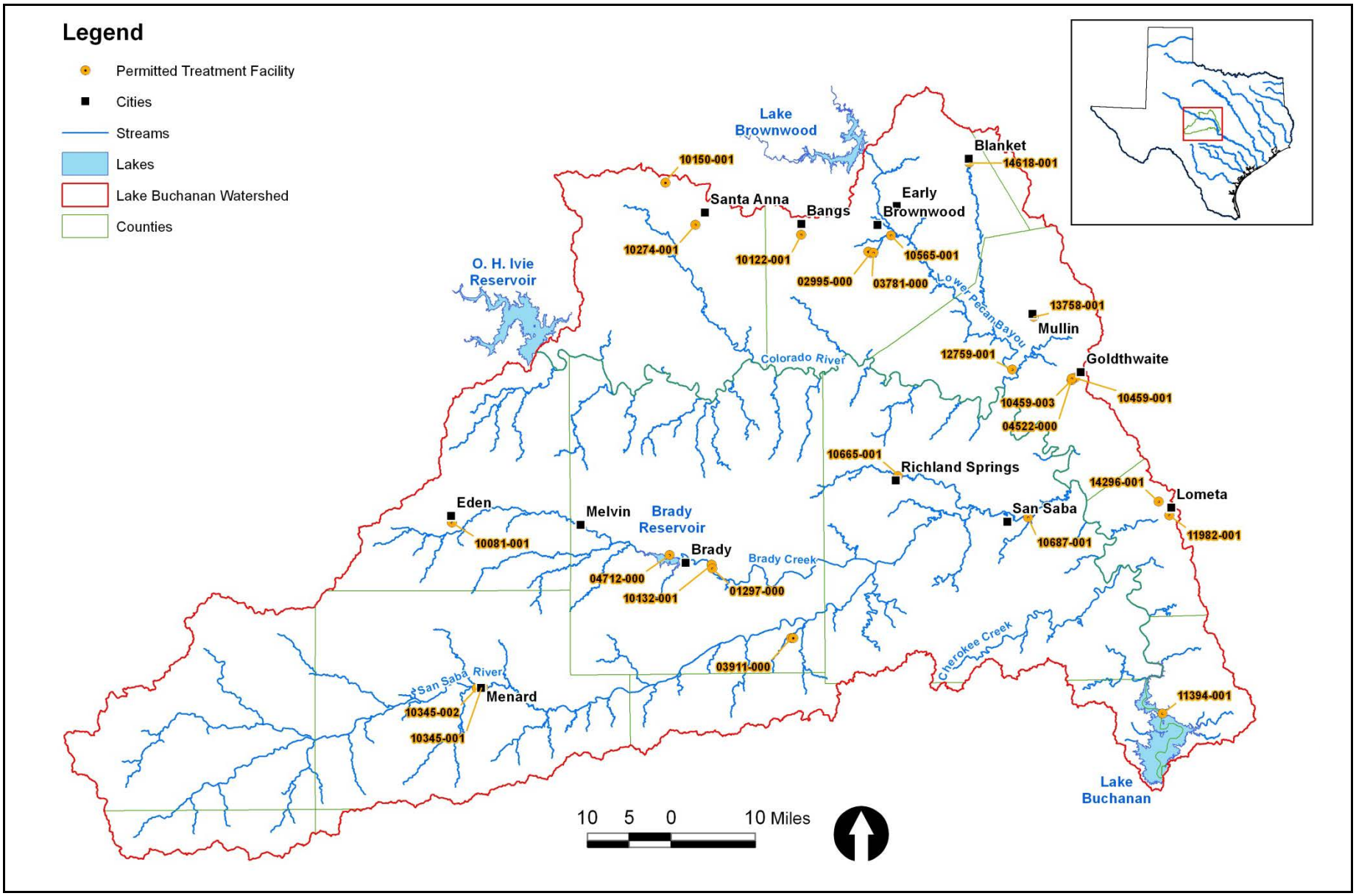

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Figure 2
Lake Buchanan Watershed Permitted Wastewater and Stormwater Treatment Facilities
CREMs Phase 4 Scenarios
Lower Colorado River Authority

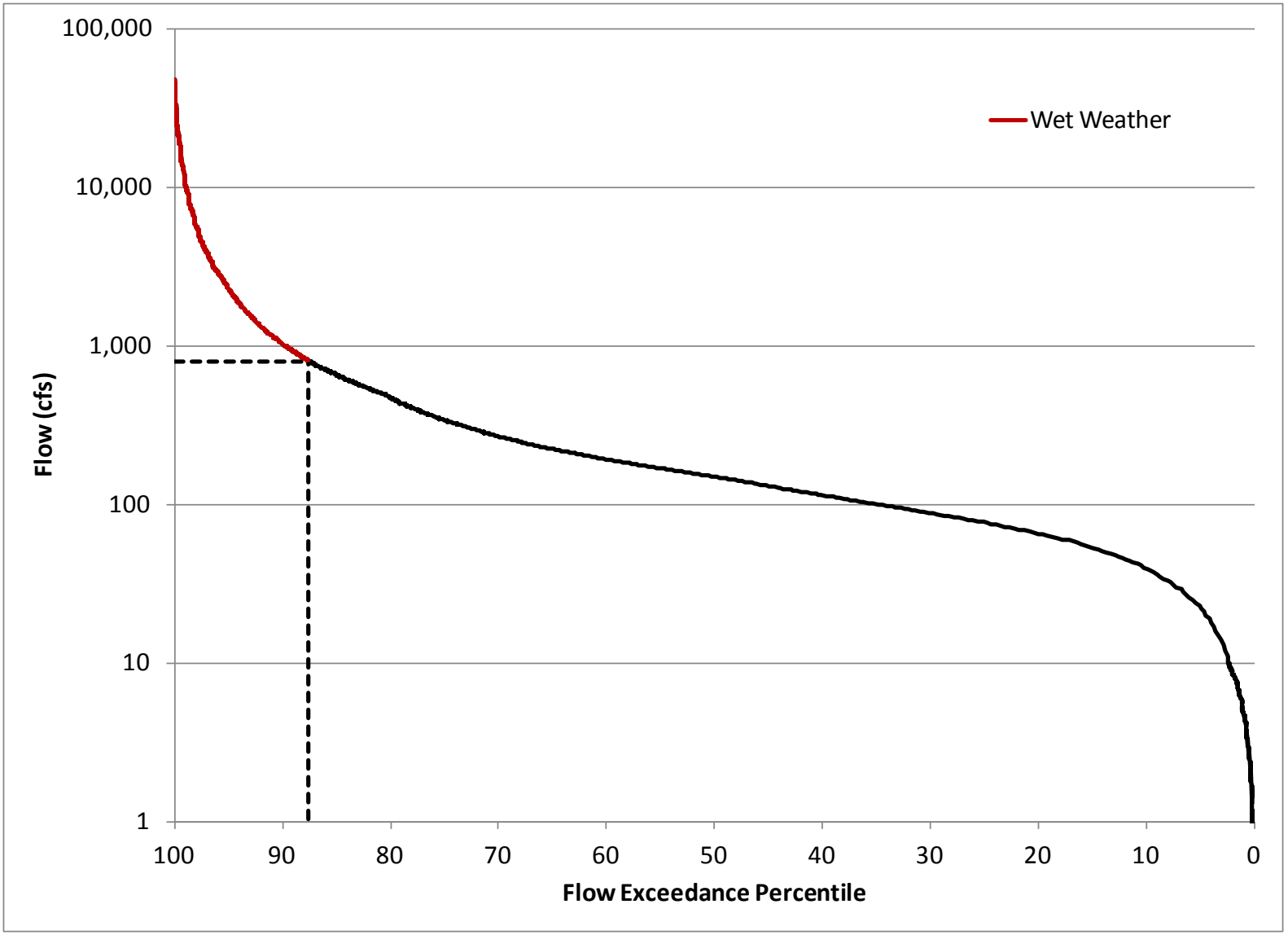

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Figure 3
Flow Exceedance Plot of Measured Flows at Colorado River near San Saba
CREMs Phase 4 Scenarios
Lower Colorado River Authority

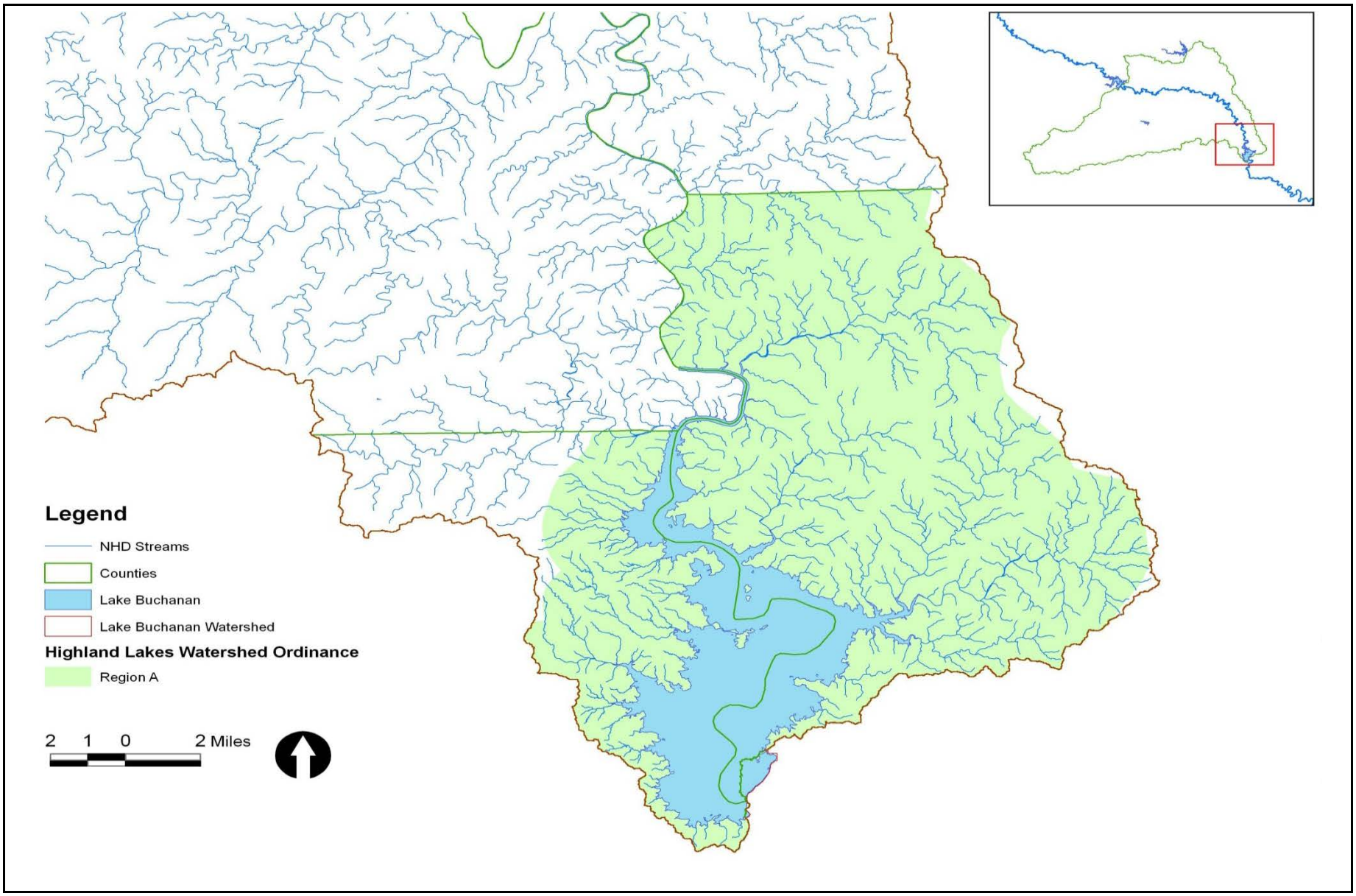

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Figure 4
Lake Buchanan Watershed Within the Highland Lakes Watershed Ordinance
CREMs Phase 4 Scenarios
Lower Colorado River Authority

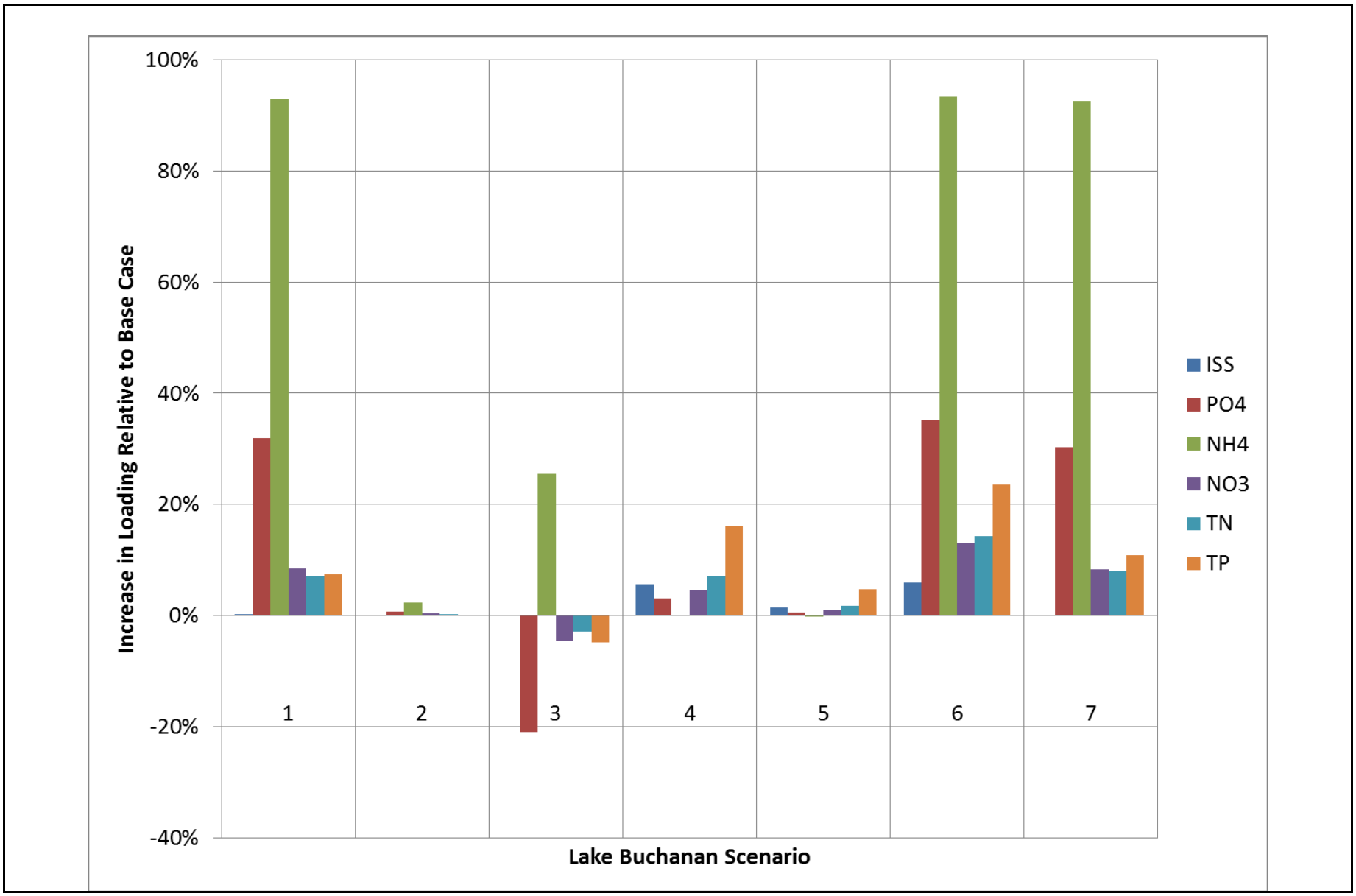

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Figure 5
Changes in Loadings to Lake Buchanan by Scenario Relative to Base Case
CREMs Phase 4 Scenarios
Lower Colorado River Authority

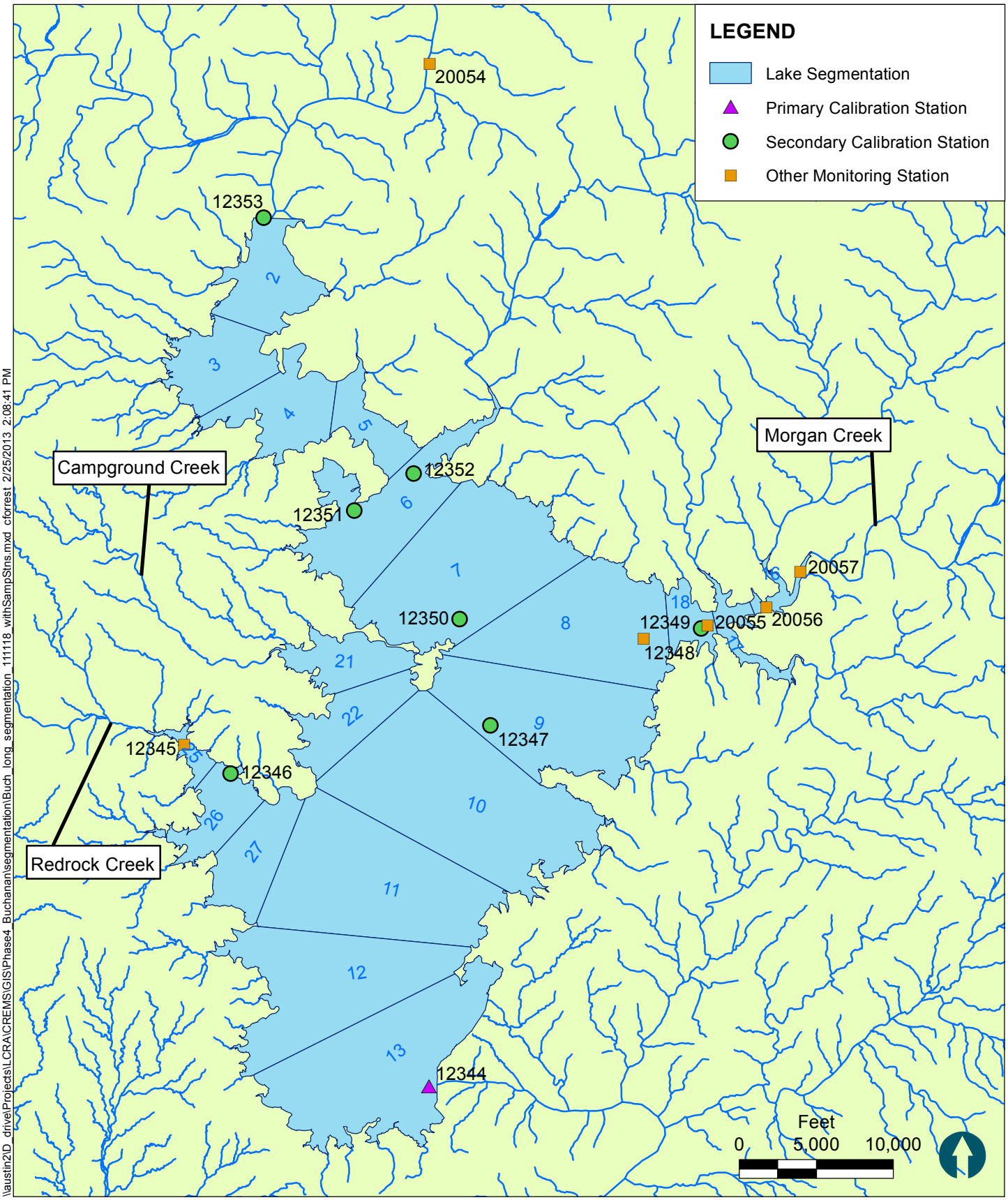

Figure 6
Lake Buchanan Longitudinal Segmentation
CREMs Phase 4 Scenarios
Lower Colorado River Authority

APPENDIX A

CREMs Phase 4
Watershed Urbanization Assumptions
January 2, 2013
Prepared by LCRA Watershed Engineering & Planning

Objective

Estimate future urbanization conditions in the Lake Buchanan Watershed in approximately 20 years.

Methodology

Subbasins from each watershed component were overlaid with aerial photography to assess the potential for future urbanization. Future urbanization assumptions took into account the existing urbanization level,[1] proximity to transportation networks and utilities as well as constraints such as quarry/mine operations and dedicated open space (e.g., parks, golf courses). A number of factors will affect these assumptions, including economic growth patterns and regulatory environment. Repurposing of quarries and open space may open up additional land for development.

The following categories and corresponding urbanization levels were developed to establish consistency in estimating future conditions:[2]

- Rural: Areas with less than 1% urbanization in the current condition were assigned a 1% future urbanization level.
- Semi-Rural: Areas with low levels of urbanization but which had proximity to transportation networks or river frontage were assigned a 3% to 5% future urbanization level.
- Urbanized: Areas with moderate urbanization in the current condition were assigned a 15% to 20% future urbanization level.

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[1] Data used to estimate current urbanization is from the National Land Cover Database (NLCD) 2006 release. This database is a product created by the Multi-Resolution Land Characteristics (MRLC) Consortium, a partnership of federal agencies led by the U.S. Geological Survey. The NLCD 2006 release is the most recent release; NLCD 2011 is scheduled for public release in December 2013 (USGS 2013).

[2] Despite each urbanization category having a range of urbanization levels, modest increases in expected future conditions would be reflected in scenario runs even if the increase would not change the category classification. For example, if a watershed subbasin had an existing impervious cover of 3.2% and is assumed to grow to 4.6%, it would still be classified as Semi-Rural, but the increased impervious cover would be reflected in the scenario runs.

- Heavily Urbanized: Currently urbanized areas with suitable transportation and utility infrastructure for continued growth were assigned a 30% to 35% future urbanization level.
- Super Urbanized: Areas with significant existing urbanization or with adjacent existing urbanized or heavily urbanized areas with suitable transportation and utility infrastructure for continued growth were assigned a 50% to 90% urbanization level.

Most of the Lake Buchanan watershed is rural with very low levels of development. The primary urbanized areas include a heavily urbanized core in Brownwood and several developed areas along Lake Buchanan's lakefront. Other smaller communities in the watershed are expected to have moderate growth, but in relation to the size of the subbasins used in the modeling, the increased development is not expected to be extensive enough to change classifications to Urbanized, Heavily Urbanized, or Super Urbanized. The current level of development included in the watershed model indicates 162,698 acres out of 4,036,753 acres are currently urbanized (4.03%); this development level was based on the 2006 MRLC Consortium NLCD data. Our 20 year prediction has an additional 57,813 acres urbanizing for a total of 220,511 urbanized acres in 2031 (5.46%), which corresponds to 2,891acres of new urbanization per year (Table A-1).

References

USGS (U.S. Geological Survey). The National Land Cover Database Fact Sheet. Updated: February 2012. Cited: January 28, 2013. Available from: http://pubs.usgs.gov/fs/2012/3020/fs2012-3020.pdf

Table A-1

Lake Buchanan Watershed Urbanization Assumptions

Subwatershed	Subwatershed Development Type	Total Area (acres)	Existing Urban Area (acres)	Existing % Urban	Future % Urban	Future Urban Area (acres)	Future Urbanization Notes	% increase
1	Semi-Rural	56,789	4,693	8.26%	10.00%	5,679		1.74%
2	Heavily Urbanized	74,159	13,435	18.12%	30.00%	22,248	Potential development in and around Brownwood	11.88%
3	Semi-Rural	100,979	8,113	8.03%	10.00%	10,098		1.97%
4	Semi-Rural	75,847	5,023	6.62%	10.00%	7,585		3.38%
5	Semi-Rural	54,966	1,122	2.04%	3.00%	1,649		0.96%
6	Semi-Rural	75,420	5,355	7.10%	10.00%	7,542		2.90%
7	Semi-Rural	63,667	1,977	3.11%	5.00%	3,183		1.89%
8	Semi-Rural	14,081	526	3.73%	5.00%	704		1.27%
9	Semi-Rural	42,253	1,935	4.58%	5.00%	2,113		0.42%
10	Semi-Rural	78,268	5,962	7.62%	10.00%	7,827		2.38%
11	Semi-Rural	67,595	3,618	5.35%	10.00%	6,759		4.65%
12	Semi-Rural	41,534	2,575	6.20%	10.00%	4,153		3.80%
13	Semi-Rural	85,219	3,661	4.30%	5.00%	4,261		0.70%
14	Semi-Rural	118,976	5,224	4.39%	5.00%	5,949		0.61%
15	Semi-Rural	61,971	2,627	4.24%	5.00%	3,099		0.76%
16	Semi-Rural	43,370	2,599	5.99%	8.00%	3,470		2.01%
17	Semi-Rural	143,825	7,380	5.13%	8.00%	11,506		2.87%
18	Semi-Rural	84,028	5,316	6.33%	10.00%	8,403		3.67%
19	Semi-Rural	121,002	6,053	5.00%	5.00%	6,050		0.00%
20	Semi-Rural	78,685	3,025	3.84%	5.00%	3,934		1.16%
21	Semi-Rural	35,432	2,323	6.56%	8.00%	2,835		1.44%
22	Semi-Rural	70,725	3,515	4.97%	5.00%	3,536		0.03%
23	Semi-Rural	35,320	2,946	8.34%	10.00%	3,532		1.66%
24	Semi-Rural	100,900	5,193	5.15%	6.00%	6,054		0.85%
25	Semi-Rural	30,428	2,335	7.67%	8.00%	2,434		0.33%
26	Semi-Rural	64,735	2,079	3.21%	5.00%	3,237		1.79%
27	Semi-Rural	65,280	1,904	2.92%	3.00%	1,958		0.08%
28	Semi-Rural	24,768	810	3.27%	5.00%	1,238		1.73%
29	Semi-Rural	29,984	1,551	5.17%	8.00%	2,399		2.83%
30	Semi-Rural	31,550	493	1.56%	3.00%	946		1.44%
31	Rural	33,832	328	0.97%	1.00%	338		0.03%
32	Semi-Rural	132,715	4,459	3.36%	5.00%	6,636		1.64%
33	Semi-Rural	36,778	1,884	5.12%	8.00%	2,942		2.88%
34	Semi-Rural	41,384	3,187	7.70%	8.00%	3,311		0.30%
35	Semi-Rural	64,845	949	1.46%	3.00%	1,945		1.54%
36	Semi-Rural	70,216	4,607	6.56%	8.00%	5,617		1.44%
37	Rural	85,153	928	1.09%	2.00%	1,703		0.91%
38	Semi-Rural	87,474	2,876	3.29%	5.00%	4,374		1.71%
39	Semi-Rural	110,235	6,420	5.82%	6.00%	6,614		0.18%
40	Semi-Rural	102,214	2,191	2.14%	3.00%	3,066		0.86%
41	Rural	19,541	47	0.24%	1.00%	195		0.76%
42	Semi-Rural	61,762	1,803	2.92%	3.00%	1,853		0.08%

Table A-1

Lake Buchanan Watershed Urbanization Assumptions

Subwatershed	Subwatershed Development Type	Total Area (acres)	Existing Urban Area (acres)	Existing % Urban	Future % Urban	Future Urban Area (acres)	Future Urbanization Notes	% increase
43	Rural	77,612	1,066	1.37%	2.00%	1,552		0.63%
44	Rural	127,724	1,575	1.23%	2.00%	2,554		0.77%
45	Rural	66,946	1	0.00%	1.00%	669		1.00%
46	Semi-Rural	121,679	3,284	2.70%	3.00%	3,650		0.30%
47	Rural	18,960	31	0.17%	1.00%	190		0.83%
48	Rural	2,067	25	1.22%	2.00%	41		0.78%
49	Rural	69,169	6	0.01%	1.00%	692		0.99%
50	Rural	97,769	1,375	1.41%	2.00%	1,955		0.59%
51	Rural	34,595	117	0.34%	1.00%	346		0.66%
52	Semi-Rural	74,065	3,559	4.80%	5.00%	3,703		0.20%
53	Rural	62,376	457	0.73%	1.00%	624		0.27%
54	Rural	26,601	28	0.10%	1.00%	266		0.90%
55	Rural	46,587	674	1.45%	2.00%	932		0.55%
56	Rural	113,774	868	0.76%	1.00%	1,138		0.24%
57	Rural	29,592	48	0.16%	1.00%	296		0.84%
58	Semi-Rural	4,700	151	3.21%	5.00%	235		1.79%
59	Semi-Rural	6,090	340	5.58%	8.00%	487		2.42%
60	Rural	65,242	627	0.96%	1.00%	652		0.04%
61	Semi-Rural	11,216	142	1.27%	3.00%	336		1.73%
62	Heavily Urbanized	1,621	455	28.03%	30.00%	486	Potential lakefront development	1.97%
63	Rural	13,080	49	0.37%	2.00%	262		1.63%
64	Semi-Rural	13,193	222	1.69%	3.00%	396		1.31%
65	Semi-Rural	1,504	89	5.91%	8.00%	120		2.09%
66	Semi-Rural	5,579	447	8.02%	10.00%	558		1.98%
67	Semi-Rural	3,363	141	4.18%	6.00%	202		1.82%
68	Rural	91,742	1,477	1.61%	2.00%	1,835		0.39%
69	Semi-Rural	3,651	163	4.47%	6.00%	219		1.53%
70	Semi-Rural	4,559	273	5.98%	10.00%	456	Potential lakefront development	4.02%
71	Semi-Rural	12,801	938	7.33%	10.00%	1,280		2.67%
72	Semi-Rural	4,941	412	8.35%	10.00%	494		1.65%
73	Urbanized	6,047	614	10.16%	15.00%	907	Potential lakefront development	4.84%
Total		**4,036,753**	**162,698**	**4.03%**	**5.46%**	**220,511**		

Note:

Assuming a 20-year period for urbanization, 2,891 acres are projected to be urbanized per year.