



8140 Walnut Hill Lane, Suite 1000
Dallas, Texas 75231
tel: 214 346-2800
fax: 214 987-2017

January 16, 2006

City of Dallas
Trinity River Corridor Project
1500 Marilla Street, Room 6BS
Dallas, TX 75201

Attention: Greg Ajemian, P.E. - Project Manager

Subject: Preliminary Water Quality Analyses for Dallas Floodway Draft Environmental Impact Statement (DEIS)

Regarding: Transmittal of Final Technical Memorandum Depicting the Results of Subject Water Quality Analyses

Dear Mr. Ajemian:

Please find accompanying five copies of the Final Version Technical Memorandum depicting the results of the preliminary water quality analyses performed by Camp Dresser & McKee Inc. (CDM) for the Dallas Floodway Draft Environmental Impact Statement. One electronic version of the Technical Memorandum has also been included and transmitted.

With this transmission, CDM believes it has completed all remaining elements of our agreed scope of work with the Trinity River Corridor Project office at this time. Please let us know if this is not your understanding, and thank you for allowing CDM to serve you on this very interesting project.

Very truly yours,

Randy R. Rogers, P.E., DEE
Senior Vice President
Camp Dresser & McKee Inc.

RRR/wjh

cc: Tim Cox Roger Schenk
 Ginger Croom Scott Stone
 Patrice Melancon Al Sun
 Nicole Rowan

File: RT/1400



Technical Memorandum

To: Greg Ajemian, City of Dallas

From: Ginger Croom, CDM / Randy Rogers, CDM

Date: October 28, 2005

Revision 1: November 30, 2005

Revision 2: January 9, 2006

Subject: Preliminary Water Quality Analyses for Dallas Floodway Draft
Environmental Impact Statement (DEIS)



Introduction and Purpose

The information in this technical memorandum is organized and presented in the manner requested by the U.S. Army Corps of Engineers (USACE) in their communication with the City of Dallas (June 2005).

This technical memorandum summarizes the assessment of the water quality characteristics of the proposed Balanced Vision Plan (City of Dallas 2003) for the Dallas Floodway in downtown Dallas, Texas. The Balanced Vision Plan represents the Locally Preferred Plan (LPP) as it relates to the USACE assessment of feasibility and environmental impact. The LPP proposes to reconfigure the current Dallas Floodway by adding a roadway within the floodway (outside of the 100-year flood level) and excavating within the floodway to create new river meanders and two new off-channel lakes with recycled water as the principal water source for these lakes.

Since the off-channel lakes would be located within the floodway, they would be considered waters of the State of Texas (State) and therefore will need to meet applicable State water quality standards. Additionally, the urban design plan associated with the Balanced Vision Plan identifies maintenance of the water aesthetics and quality of the Trinity River as critical to the successful implementation of the Dallas Floodway improvements. Water quality characteristics of the proposed lakes were previously analyzed as part of the 1999 master plan for the Dallas Floodway (CH2M Hill 1999) and also as part of the development of the Balanced Vision Plan. Analyses presented in this memorandum represent a refinement of these assessments.



Technical Memorandum

To: Greg Ajemian, City of Dallas

From: Ginger Croom, CDM / Randy Rogers, CDM

Date: October 28, 2005

Revision 1: November 30, 2005

Revision 2: January 9, 2006

*Subject: Preliminary Water Quality Analyses for Dallas Floodway Draft
Environmental Impact Statement (DEIS)*

Introduction and Purpose

The information in this technical memorandum is organized and presented in the manner requested by the U.S. Army Corps of Engineers (USACE) in their communication with the City of Dallas (June 2005).

This technical memorandum summarizes the assessment of the water quality characteristics of the proposed Balanced Vision Plan (City of Dallas 2003) for the Dallas Floodway in downtown Dallas, Texas. The Balanced Vision Plan represents the Locally Preferred Plan (LPP) as it relates to the USACE assessment of feasibility and environmental impact. The LPP proposes to reconfigure the current Dallas Floodway by adding a roadway within the floodway (outside of the 100-year flood level) and excavating within the floodway to create new river meanders and two new off-channel lakes with recycled water as the principal water source for these lakes.

Since the off-channel lakes would be located within the floodway, they would be considered waters of the State of Texas (State) and therefore will need to meet applicable State water quality standards. Additionally, the urban design plan associated with the Balanced Vision Plan identifies maintenance of the water aesthetics and quality of the Trinity River as critical to the successful implementation of the Dallas Floodway improvements. Water quality characteristics of the proposed lakes were previously analyzed as part of the 1999 master plan for the Dallas Floodway (CH2M Hill 1999) and also as part of the development of the Balanced Vision Plan. Analyses presented in this memorandum represent a refinement of these assessments.

This assessment evaluated whether the waterways associated with the project currently meet State standards for designated uses and assessed how the waterway resulting from the proposed project would affect compliance with State standards.

1.0 Existing Conditions

1.1 Comparison of Surface Water Standards and Applicable Stream Data for Designated Uses

The Dallas Floodway exists within State stream segment 0805, the Upper Trinity River. Segment 0805 extends from a point immediately upstream of the confluence of the Cedar Creek Reservoir discharge canal in Henderson/Navarro County to a point immediately upstream of the confluence of the Elm Fork of the Trinity River in Dallas County. The State-designated uses for this stream segment are: aquatic life use, contact recreation use, and general use. The State establishes water quality standards based on these uses and continually measures waterways to determine whether or not they meet these standards.

In addition to these designated uses, **Table 1** provides information regarding surface water standards not met in the Texas Commission on Environmental Quality's (TCEQ) 2004 water quality inventory (TCEQ 2004).

Table 1: 2004 Surface Water Inventory and 303(d) List Summary for the Upper Trinity River

Segment	Aquatic Life Use	General Use	Recreation Use	Fish Consumption
0805_01 25 mile reach near FM 85	Fully supporting	Fully supporting	Fully supporting	Fully supporting
0805_02 25 mile reach near SH 34	Fully supporting	Fully supporting	Fully supporting	Not Assessed
0805_03 11 mile reach near S. Loop 12	Fully supporting	Fully supporting	Not supporting	Not supporting
0805_04 Upper 8 miles	Fully supporting	Fully supporting	Not supporting	Not supporting
0805_05 Remainder of segment	Not Assessed	Fully supporting	Not Assessed	Not Assessed

1.1.1 Fish Consumption

Due to the presence of chlordane and polychlorinated biphenyls (PCBs) in fish tissues, the Texas State Department of Health Services (TSDHS) issued a ban on the consumption (possession) of fish from the Trinity River from the 7th Street Bridge in Fort Worth downstream to the Texas State Highway 34 Bridge in Kaufman and Ellis Counties southeast of Dallas. The bans were issued on January 4, 1990 and September 27, 2002 (TSDHS 2005). The chemicals of concern associated with the bans are PCBs, chlordane, and DDE. Persons are prohibited from possessing any species of fish from this area. TCEQ has an approved total maximum daily load (TMDL) for this segment of the Trinity River to reduce the concentrations of these pollutants.

1.1.2 Contact Recreation

TCEQ defines contact recreation as recreational activities involving a significant risk of ingestion of water, including wading by children, swimming, water skiing, diving, and surfing. The associated water quality criteria to protect this designated use are a geometric mean *E. coli* criterion of 126 per 100 mL and a single sample maximum *E. coli* criterion of 394 per 100 mL.

1.1.3 Aquatic Life Use

TCEQ defines four subcategories of significant aquatic life use – limited, intermediate, high, or exceptional. These subcategories are based on habitat characteristics, species assemblage, sensitive species, diversity, species richness, and trophic structure. Significant aquatic life use is a broad characterization of aquatic life that includes the subcategories listed above and the Trinity River near the proposed lakes is designated for High aquatic life use. The water quality criterion that is established to protect High aquatic life use is a dissolved oxygen (DO) concentration of 5.0 mg/L. In addition to this criterion, during low flows in the Trinity River (less than 80 cubic feet per second [cfs] at an upstream reference point) the DO criterion is 3.5 mg/L.

1.1.4 General Use (Water Aesthetics)

Water aesthetics are narrative general criteria that apply to all surface waters of the State and specifically apply to substances attributed to waste discharges or the activities of man. These narrative criteria limit taste and odor producing substances, floating debris, settleable solids, aesthetic attractiveness, turbidity, foam, and oil sheens. There are no numeric criteria to assess compliance with these general criteria.

1.2 Existing Non-Point Sources of Pollution

Existing sources of pollutants contributing to the waterways in the project area result from runoff from urban and rural (undeveloped and agriculture) lands. Pollutant load characteristics of runoff from contributing land uses are available from a regional stormwater monitoring program through the North Central Texas Council of Governments (NCTCOG). Developed to assist local governments in complying with the federal Clean Water Act requirements for stormwater discharges, the program has been collecting data for over a decade from watersheds across the Dallas/Fort Worth Metroplex (NCTCOG 2002).

1.3 Existing Point Source Discharges

During dry summer weather the base flow of the Trinity River is over 95 percent treated wastewater downstream of the Dallas and Fort Worth metropolitan area. The Upper Trinity Water Quality Compact, created in 1975, plays a key role in wastewater treatment in the area. Membership includes the Trinity River Authority, the City of Fort Worth, the City of Dallas, and the North Texas Municipal Water District. These entities operate a series of regional

wastewater treatment systems. Together these entities have worked with TCEQ on developing a water quality model regulating all wastewater plants along the river. Any addition or movement of wastewater discharges ultimately must be examined within this model.

2.0 Water Quality Analyses of Proposed Plan

2.1 Methodology

Numerical water quality models were used to simulate the proposed lakes and Trinity River realignment with respect to DO and algae. DO and algae are key parameters associated with the support of aquatic life, general use, and aesthetics in the proposed lakes and adjacent river.

The U.S. Environmental Protection Agency (EPA) Water Quality Analysis Simulation Program (WASP) version 6.0.0.12 (EPA 2004) was used to simulate DO and floating algae (phytoplankton) in the proposed lakes. WASP is well suited to modeling both river segments and lakes and has been used extensively on upstream segments and reservoirs of the Trinity River.

A simplified spreadsheet model was used to simulate the effects of river realignment and lakes discharge on the Trinity River with respect to DO. Both the WASP model and the spreadsheet model are described further in subsequent sections.

2.2 Lakes Assessment

2.2.1 Model Input and Parameters

WASP was used to simulate DO, nutrients, carbonaceous biological oxygen demand (CBOD), and phytoplankton (as measured by chlorophyll *a*) as functions of lake hydrology and hydraulics, upstream loadings, instream kinetics, and environmental conditions (temperature, light levels, and wind speed). WASP is a surface water quality model maintained by EPA, capable of dynamically simulating the fate and transport of solutes in up to three dimensions. The model calculates solute concentrations in specified computational elements or "segments" throughout the water body of interest and at each time step in the simulation period. WASP simulates advection, dispersion, diffusion and point mass loading, and boundary exchange. Flows are calculated in WASP for each point in space and time based on user-specified headwater and tributary inflows. Lake or stream hydraulics (velocity, depth, and width) can either be calculated with a separate dynamic flow package (e.g., HEC-RAS), and then input to WASP, or can be calculated within WASP through user-defined power equations.

The WASP model developed for these analyses is steady-state (flows and loadings do not change with time) and one-dimensional. Vertical stratification in the model was not simulated due to a lack of supporting data. Specifically, exchange rates between layers would not be

able to be quantified or calibrated with the available data. Furthermore, a single layer is deemed adequate for providing the screening-level analysis needed to support the Draft Environmental Impact Statement (EIS).

The modeled system includes the two proposed lakes with approximately 1,000 feet segmentation and is shown in **Figure 1**. The total length of the system is approximately 2 miles (11,000 feet).

Inflow to the lakes is assumed to be composed entirely of effluent from the Central Wastewater Treatment Plant (CWWTP). An expected average flow rate through the lakes of 75 cfs (50 million gallons per day [mgd]) was assumed in the model based on current CWWTP discharges. Lake hydraulic characteristics for the given flow rate were calculated with a HEC-RAS model recently developed to assist in evaluation of the proposed project. HEC-RAS calculates reach hydraulics (velocities, depths, widths, and volumes) for given flow rates at cross-sections located throughout the lakes. Additionally, WASP model scenarios took into consideration an elevation drop of five feet for the CWWTP effluent discharge into the upper lake.

Lake longitudinal dispersion is simulated in WASP to capture the exchange of solute particles between segments due to turbulence, random movement, or other non-advective forms of transport. Total effective dispersion in WASP is a combination of user-input hydrodynamic dispersion and model numerical dispersion. The total effective dispersion coefficient ranges from 1 to 2 m²/s in the modeled lakes system. This range is appropriate for this type of water body (Chapra 1998). Cross-sectional areas through which the dispersive exchanges take place were set using HEC-RAS output.

Mass loadings to the model at the point of CWWTP effluent discharge were set based on recently measured summer CWWTP effluent concentrations for DO, CBOD, organic nitrogen, ammonium nitrogen, nitrate nitrogen, orthophosphate, and organic phosphorus. To maintain conservatism in the model, the maximum levels of oxidizing pollutants and nutrients and the minimum level of DO level were used. These values are summarized in Table 2.

The following water quality variables were included in the model: DO, CBOD, organic nitrogen, ammonium, nitrate, orthophosphate, organic phosphorus, and phytoplankton. The key processes associated with these variables are reaeration, organic nitrogen mineralization, nitrification, and phytoplankton growth and respiration/decay.

$\frac{Flow(mgd)}{50}$	$\frac{D.O.(mg/L)}{6.0}$	$\frac{CBOD_{ult}(mg/L)}{7.0}$
$\frac{ON(mg/L)}{0.5}$	$\frac{NH_4(mg/L)}{0.5}$	$\frac{NO_3(mg/L)}{17}$
$\frac{Ortho-P}{5.0}$	$\frac{OP(mg/L)}{1.0}$	

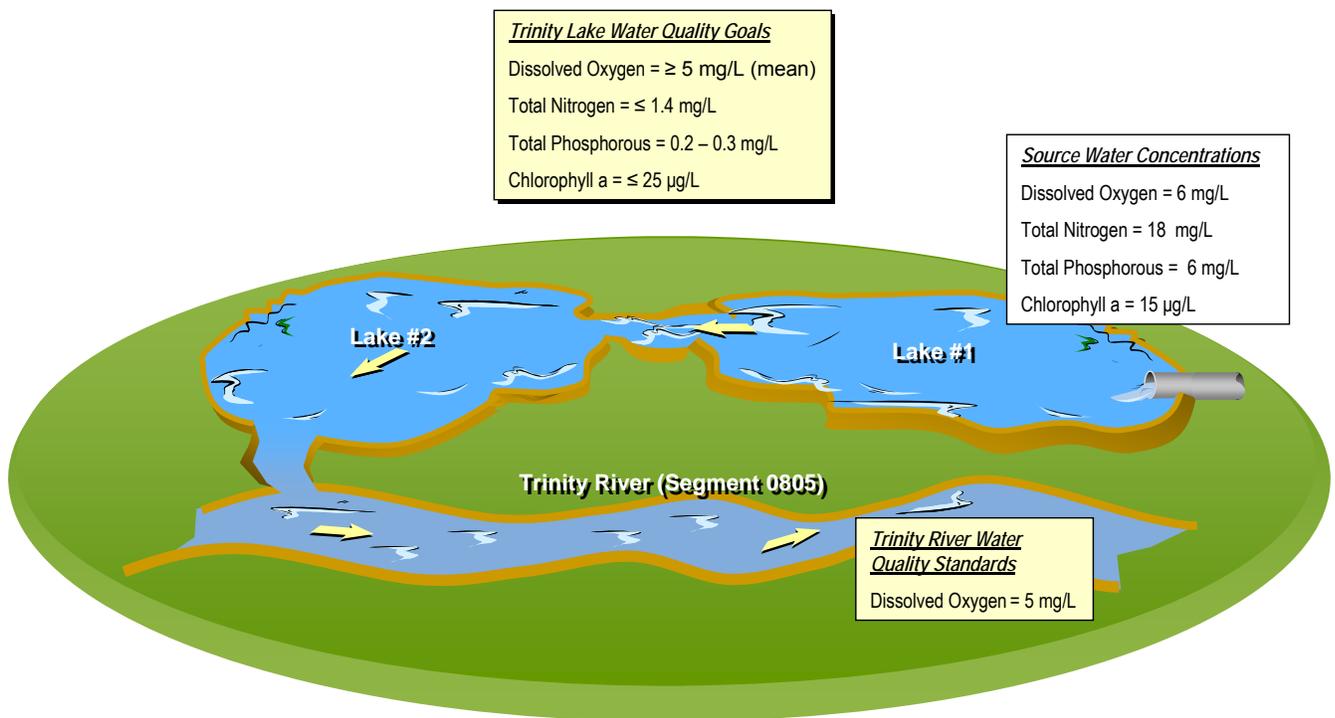


Figure 1
Modeled System Schematic

2.2.2 Model Simulations and Results

Two sets of simulations were performed with the constructed WASP model. One set of simulations targeted DO, while varying wind speeds and holding phytoplankton levels in the lake constant (at 15 µg/L). The second set of simulations targeted phytoplankton and simulated potential blooms in the lakes over a range of associated kinetic and environmental factors designed to bracket a minimum and maximum expected level. The range of conditions and parameters used for the phytoplankton simulations were taken from WASP recommended ranges and calibrated parameters from previous WASP modeling upstream in the Trinity River. The phytoplankton simulations are considered screening level only and represent a large range of potential conditions. Without supporting data, WASP cannot be used with confidence to simulate a single expected algal condition in a lake. This limitation is due to the complexity and number of parameters associated with these types of simulations.

Model kinetic parameters were set based on previous calibrated model simulations performed by the State (TCEQ) for the Trinity River near Dallas using the QUALTX water quality model. Reaeration rates were calculated in the model as a function of stream hydraulics and wind speed. For the DO simulations, wind speed was varied from 1.7 m/s (summer 2-day minimum wind speed) to 4.3 m/s (mean summer speed). These wind speeds were derived from historical data measured at the Dallas-Fort Worth Airport. A water temperature of 30 degrees C was assumed in the lakes based on expected typical summer values.

Model parameter values are summarized in **Table 2**. The range of phytoplankton parameter values used for the algae simulations are provided in parenthesis where applicable.

Results of the lake water quality model simulations are shown in **Figures 2 through 12**. Relevant water quality goals are provided on the figures for reference. **Results show that, due to the oxidation of carbon and nitrogen, small excursions below the Trinity River DO standard of 5 mg/L are possible under low wind conditions.** **Figure 2** shows the DO standard of 5 mg/L and resulting DO concentrations as one moves from upstream to downstream in the proposed lake system. This figure indicates that during worst-case conditions, excursions below the water quality standard are possible. **Figures 3 and 4** show the impact of temperature on DO levels in the lake system and indicate that as temperature in the lake system decreases, DO levels increase.

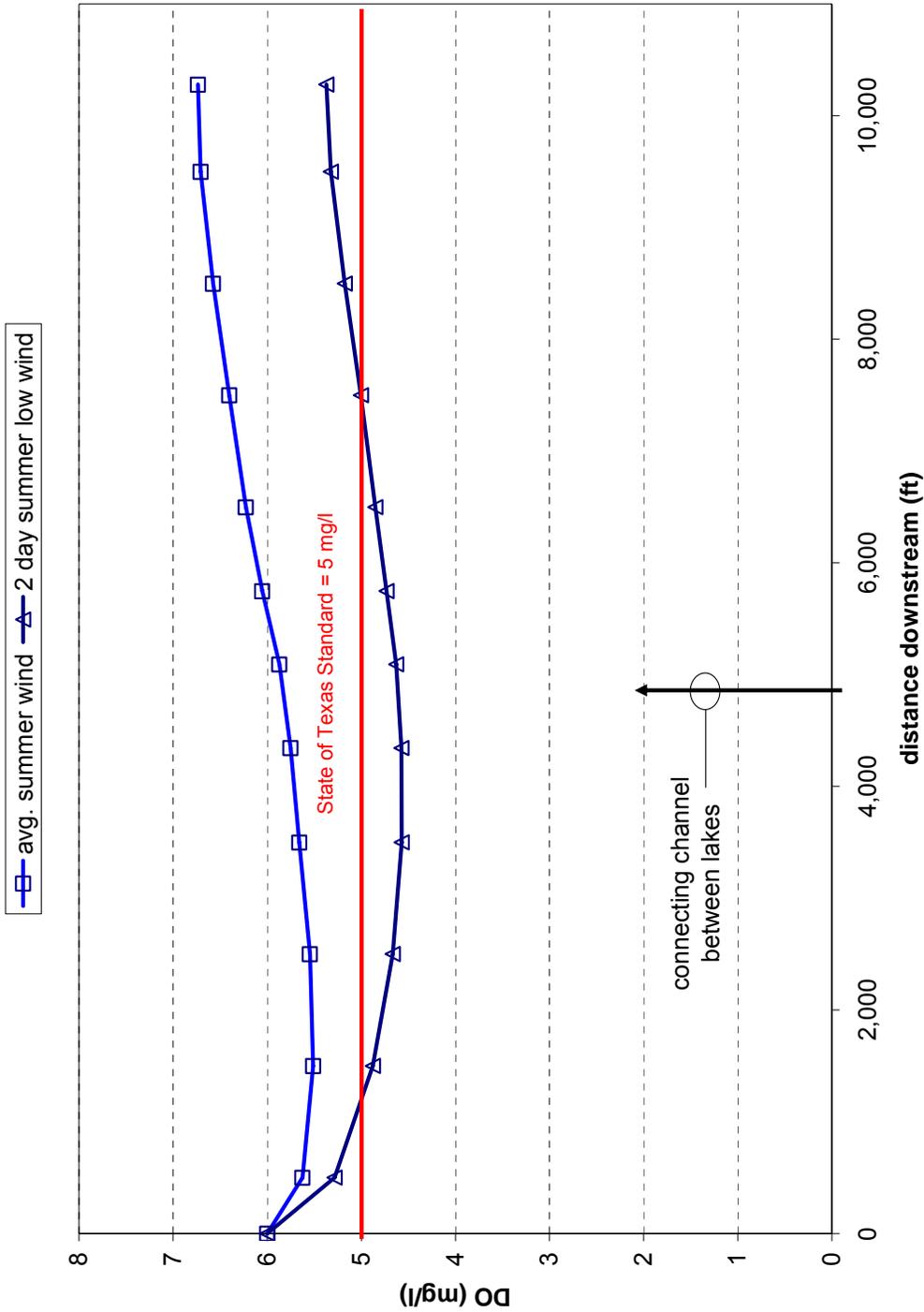


Figure 2
 Dallas Lakes Dissolved Oxygen under
 Average and Low Wind Conditions

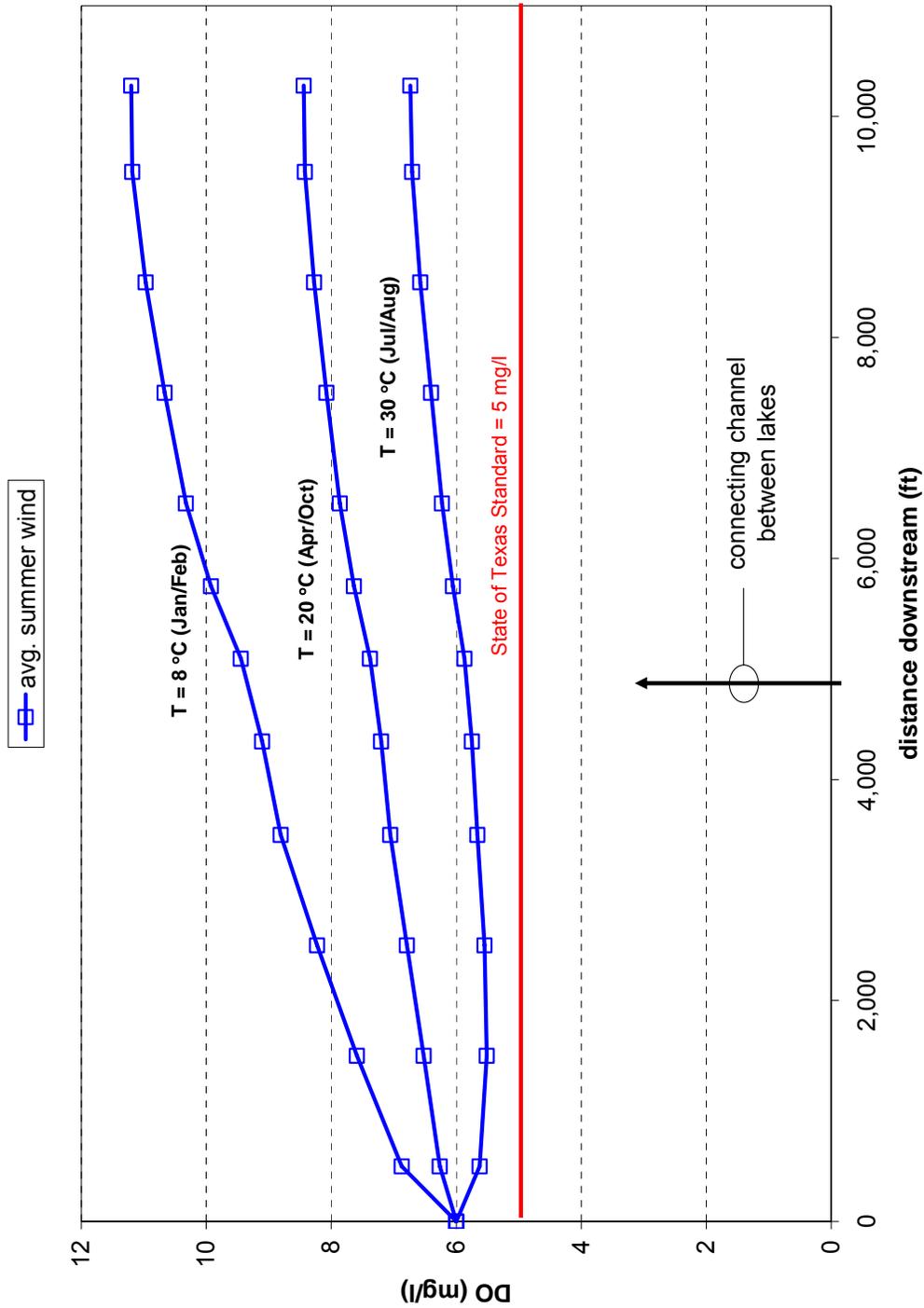


Figure 3
 Dallas Lakes Dissolved Oxygen Temperature
 Sensitivity under Average Wind Conditions

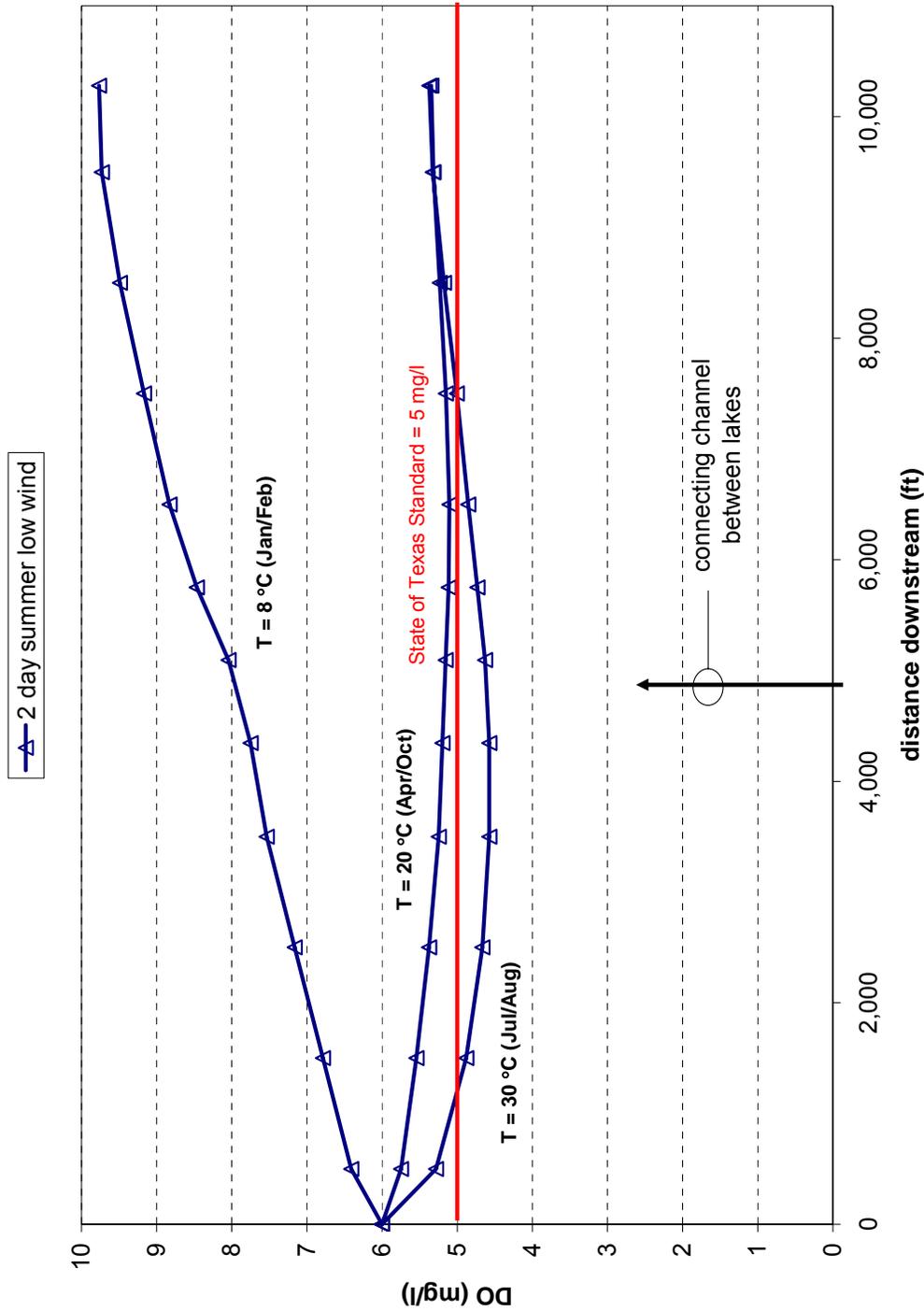


Figure 4
 Dallas Lakes Dissolved Oxygen Temperature
 Sensitivity under Low Wind Conditions

Table 3: WASP Model Kinetics and Environmental Parameters

<i>Nitrification rate constant (1/day)</i>	<i>Nitrogen processing rate temperature correction coeff. (unitless)</i>	<i>Nitrification ½ saturation constant for DO limitation (mg/L)</i>	<i>Denitrification rate constant (1/day)</i>	<i>Denitrification ½ saturation constant for DO limitation (mg/L)</i>
0.3	1.08	0	0	-
<i>Organic nitrogen (ON) mineralization rate constant (1/day)</i>	<i>Calculated reaeration rate constants (1/day)</i>	<i>Fraction of phytoplankton (phyto) death recycled to nitrogen</i>	<i>Phyto max growth rate constant (1/day)</i>	<i>Phyto growth temperature correction coeff. (unitless)</i>
0.05	0.1 - 0.5	1	0.3 (0.3 - 2)	1.06
<i>Phyto Carbon: chlorophyll a ratio (unitless)</i>	<i>Phyto optimal light saturation (langleys/day)</i>	<i>Phyto ½ saturation constant for nitrogen (mg/L)</i>	<i>Phyto ½ saturation constant for phosphorus (mg/L)</i>	<i>Phyto respiration rate constant (1/day)</i>
50	200	0.025	0.001	0.125 (0.05 - 0.125)
<i>Phyto death rate constant, predation (1/day)</i>	<i>Phyto nitrogen to carbon ratio (unitless)</i>	<i>Phyto phosphorus to carbon ratio (unitless)</i>	<i>Sediment oxygen demand (g/m2/d)</i>	<i>Net settling rates (for all particulates, m/d)</i>
0	0.25	0.025	0.1	0.3
<i>Stream temperature (°C)</i>	<i>Daily solar radiation (langleys/day)</i>	<i>Non-algal light extinction coefficient (1/m)</i>	<i>Wind speed (m/s)</i>	<i>CBOD decay rate constant (1/d)</i>
30	300 (200 - 600)	5 (0.2 - 8.9)	1.7, 4.3	0.1

Note: Values in parentheses indicate ranges used for phytoplankton simulations.

Reaeration concepts identified to date for the proposed lakes include the use of cascade creating dams in the connecting channel between the two lakes and at the outfall of the lakes (discharge point to the Trinity River). Specifics for the design of either the lakes or the cascade structures, with respect to structure characteristics, size, and shape, have yet to be determined. However, early discussions indicate a drop of approximately 5 feet at the beginning of the lake system, 3 feet between the lakes and approximately 17 feet at the lakes discharge point to the Trinity River. In order to approximate the anticipated effects these structures may have on lake water quality, modeling was performed using the following empirical equation (Butts and Evans 1983):

$$r = 1 + 0.38abH(1 - 0.11H)(1 + 0.046T) \quad (3)$$

where:

- r = ratio of the DO deficit above and below the dam, H = change in water elevation (m)
- T = water temperature (°C)
- a and b = coefficients that correct for water quality and dam type, respectively

This equation was incorporated into a spreadsheet model of the proposed lakes following the approach used for modeling the Trinity River, as described in Section 2.3.1. The low wind

scenario (refer to **Figure 2**) was simulated with this model. Flat, broad crested, curved face dam structures were assumed ($b = 0.45$). Simulated results incorporating dam structures are shown in **Figure 5**. **Modeling results indicate significant jumps in DO can be achieved with the dam structures. However, a very slight excursion below the target level of 5 mg/l within the lakes is still present.**

Results showing that oxidizing pollutants decrease as one moves from upstream to downstream in the lake system are shown in **Figure 6**.

Figures 7 through 12 show the results of screening level analysis for phytoplankton biomass in the proposed lake system. **Results suggest that, without proper management, algal blooms could be a problem in the lakes due to slow water movement and the high nutrient loadings from CWWTP (particularly nitrate and phosphorus).** **Figures 7, 8, 9 and 10** show the results of the screening level analysis for phytoplankton biomass in the lakes. A large range of potential algal levels are predicted for the range of parameters used, with excursions well above the reference water quality goal of 25 $\mu\text{g/L}$ (CH2MHill 1999) under worst case conditions. Under best case conditions, algal levels were shown to be less than the water quality goal. Best and worst case conditions were simulated by modifying kinetic parameters which were presented as a range in **Table 2**.

Figure 7 shows the difference between varying the kinetic parameters from best case to worst case. **Figure 8** shows a sensitivity analysis based on flow through the lake system. By increasing the flow, the residence time of the system is decreased and small reductions in predicted chlorophyll *a* concentrations are realized. Chlorophyll *a* concentration sensitivity to temperature is shown in **Figures 9 and 10**.

To further investigate the relationship between predicted phytoplankton and nutrient loadings, model sensitivity analyses were performed. **Figure 11** shows predicted chlorophyll *a* concentrations as a function of influent total phosphorus concentration, using the "worst case" model parameter set. As can be seen, under this set of parameters, influent total phosphorus concentrations require a reduction well below 0.1 mg/L to achieve the 25 $\mu\text{g/L}$ chlorophyll *a* target. **Reductions in TP from the currently assumed influent value of 6 mg/L down to approximately 1 mg/L result in no significant changes in chlorophyll *a* concentrations due to the fact that the system is nitrogen-limited in this range of nutrient levels.** **Figure 12** shows predicted nitrogen to phosphorus ratios for the lake as a function of influent TP. Results support the conclusion that, for the given nitrogen loading, influent TP levels above approximately 3 mg/L result in a nitrogen-limited system. The shown demarcation between nitrogen and phosphorus limitation comes from the generally accepted algal internal N:P ratio of 7.2 (Chapra 1998). These results are significant with respect to lake management strategies.

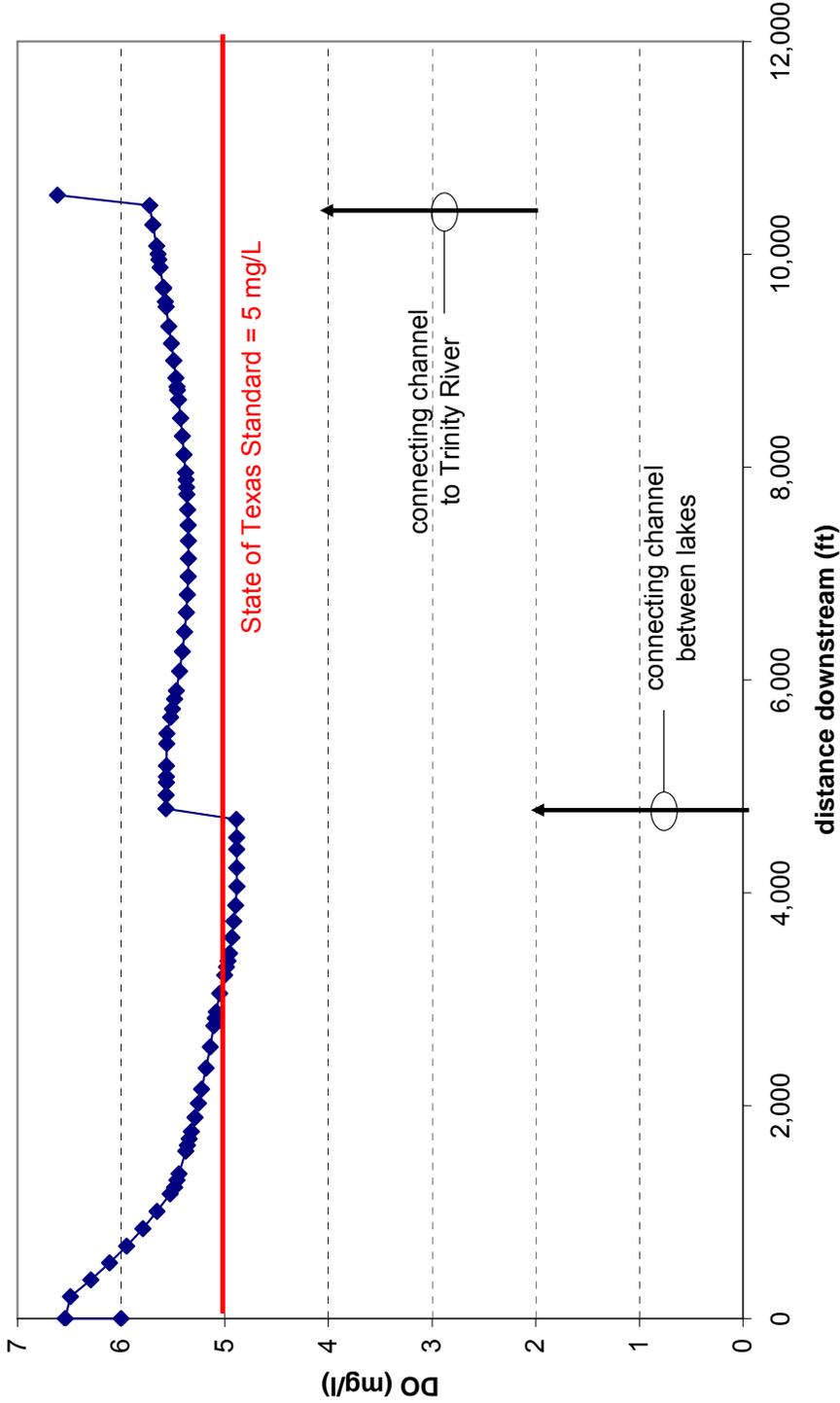


Figure 5
Dallas Lakes Dissolved Oxygen Impact of Aeration
Dams under Low Wind Conditions

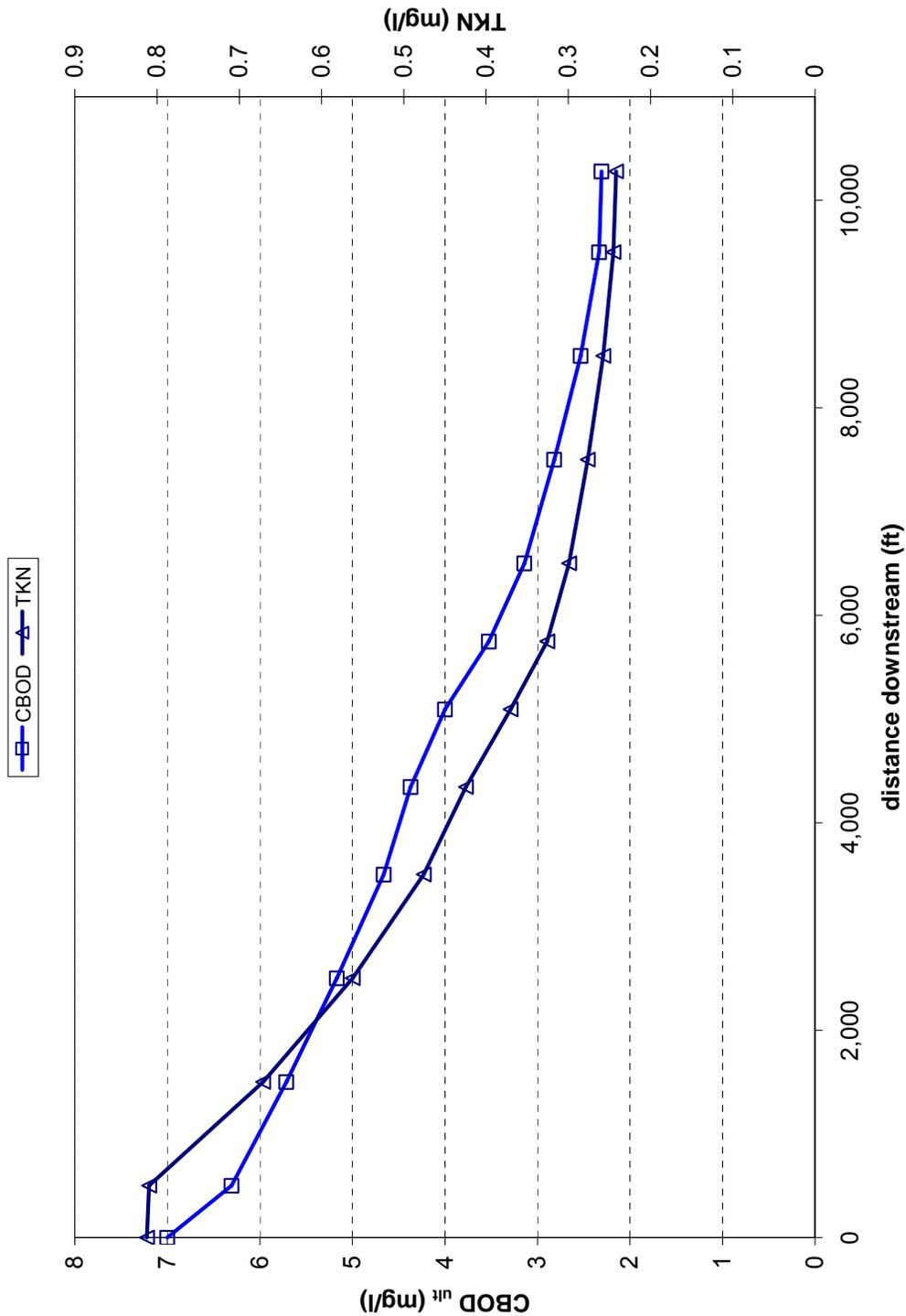


Figure 6
 Dallas Lakes Oxidizing Pollutants CBOD and TKN

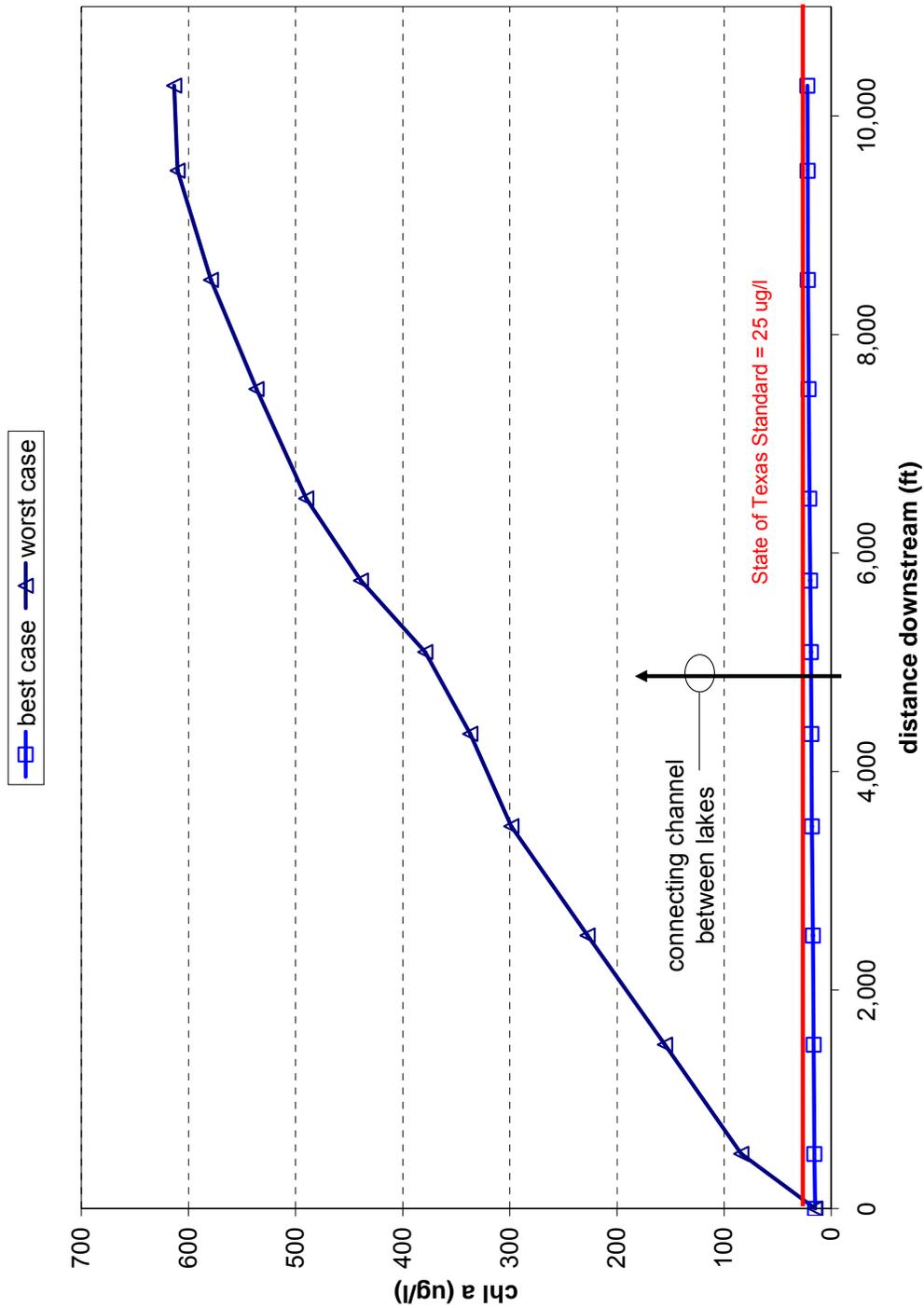


Figure 7
 Dallas Lakes Phytoplankton (as chlorophyll a)
 Best and Worst Case Kinetic Conditions

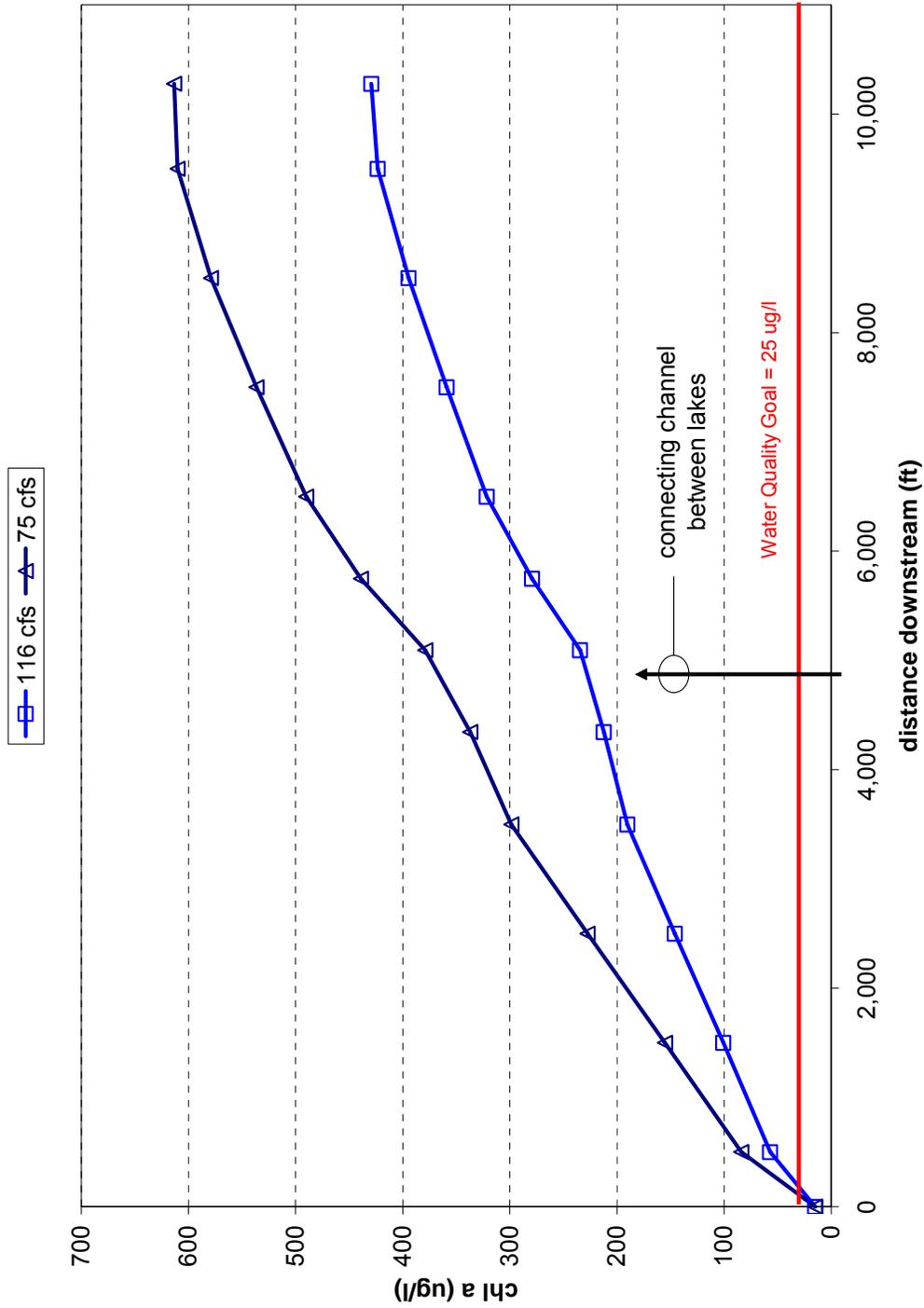


Figure 8
 Dallas Lakes Phytoplankton (as chlorophyll a) Flow
 Sensitivity under Worst Case Kinetic Conditions

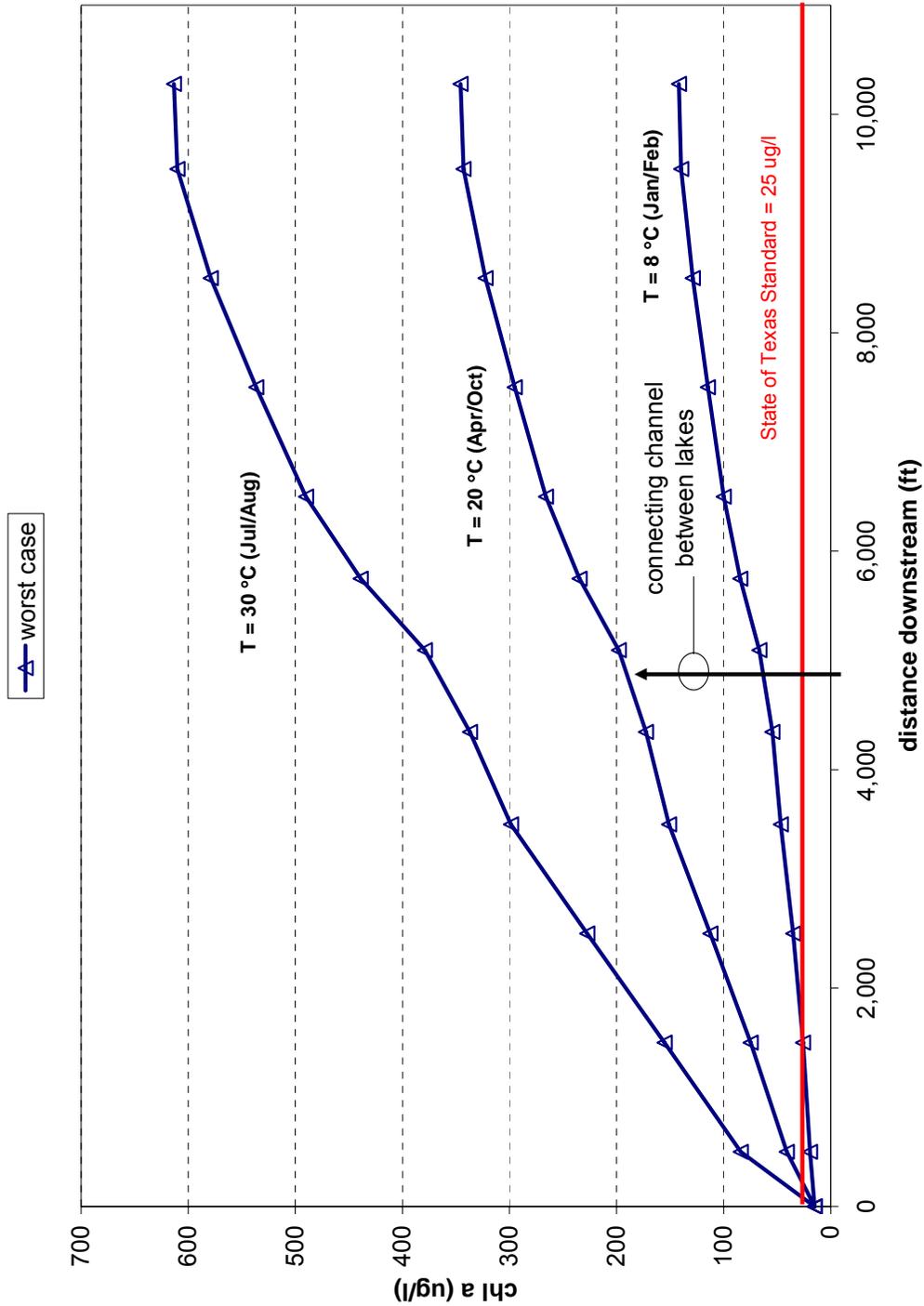


Figure 9
 Dallas Lakes Phytoplankton (as chlorophyll a) Temperature
 Sensitivity under Worst Case Kinetic Conditions

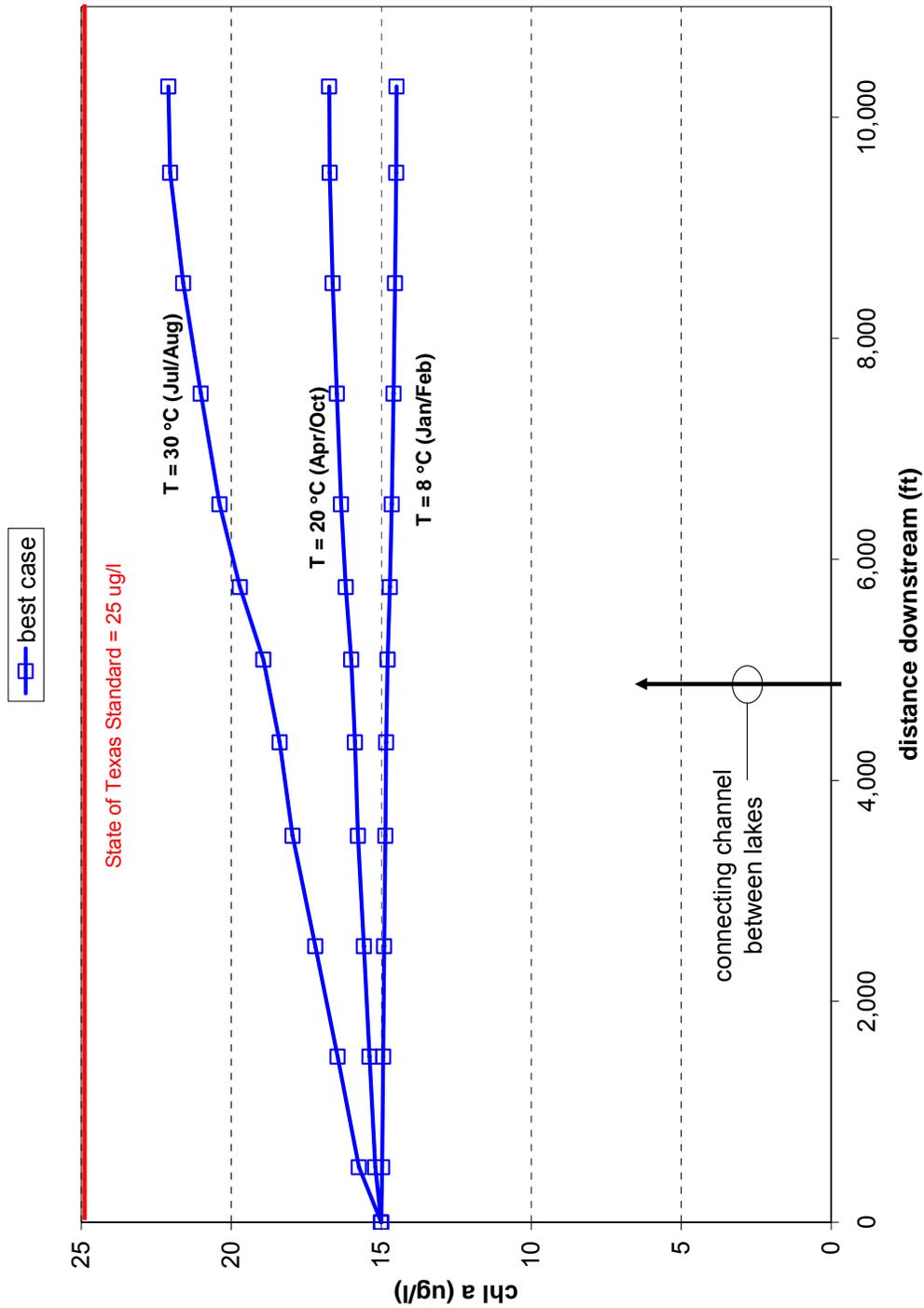


Figure 10
 Dallas Lakes Phytoplankton (as chlorophyll a) Temperature
 Sensitivity under Best Case Kinetic Conditions

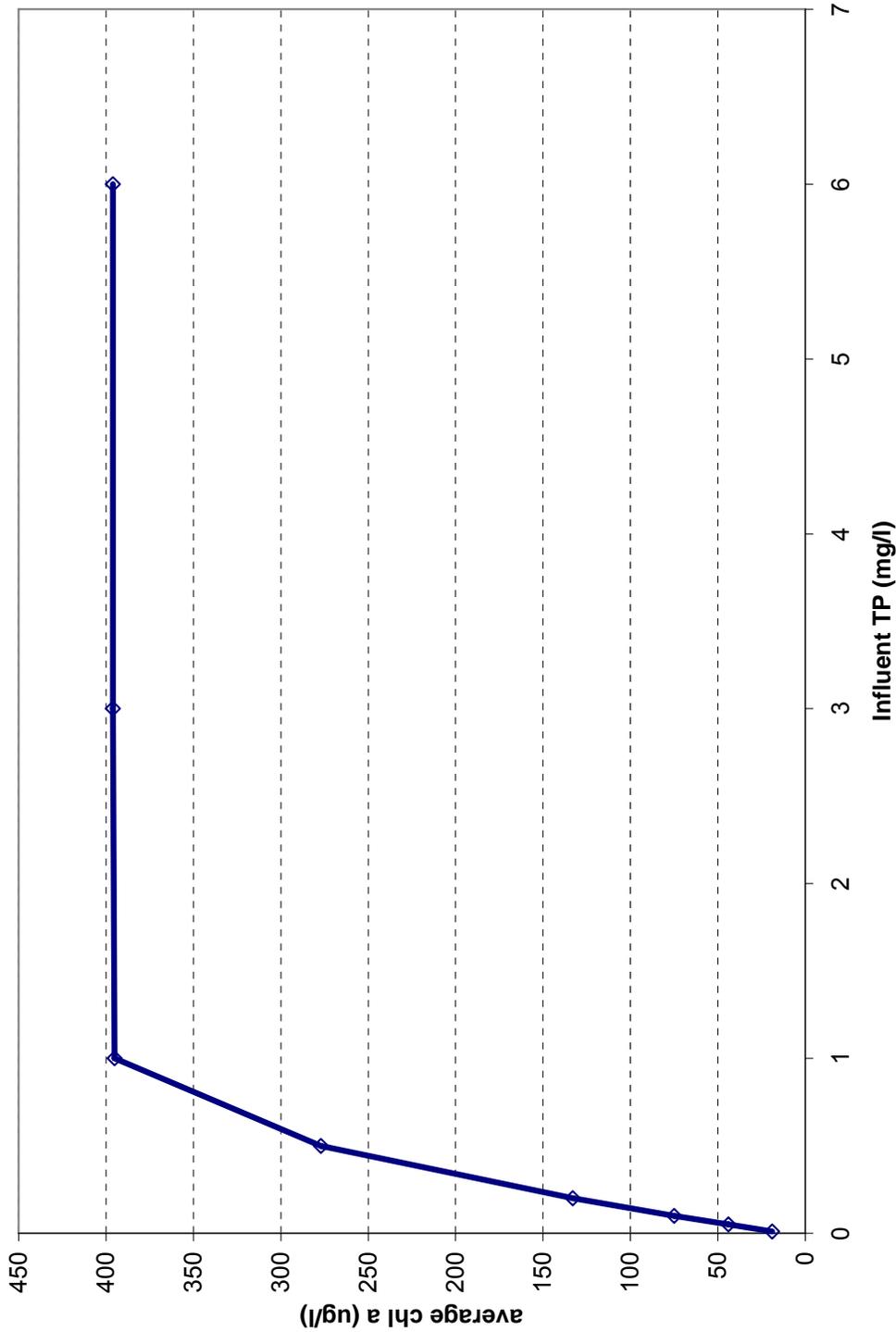


Figure 11
Dallas Lakes Predicted Algal Growth (chl a) versus Influent
Total Phosphorus under Worst Case Kinetic Conditions

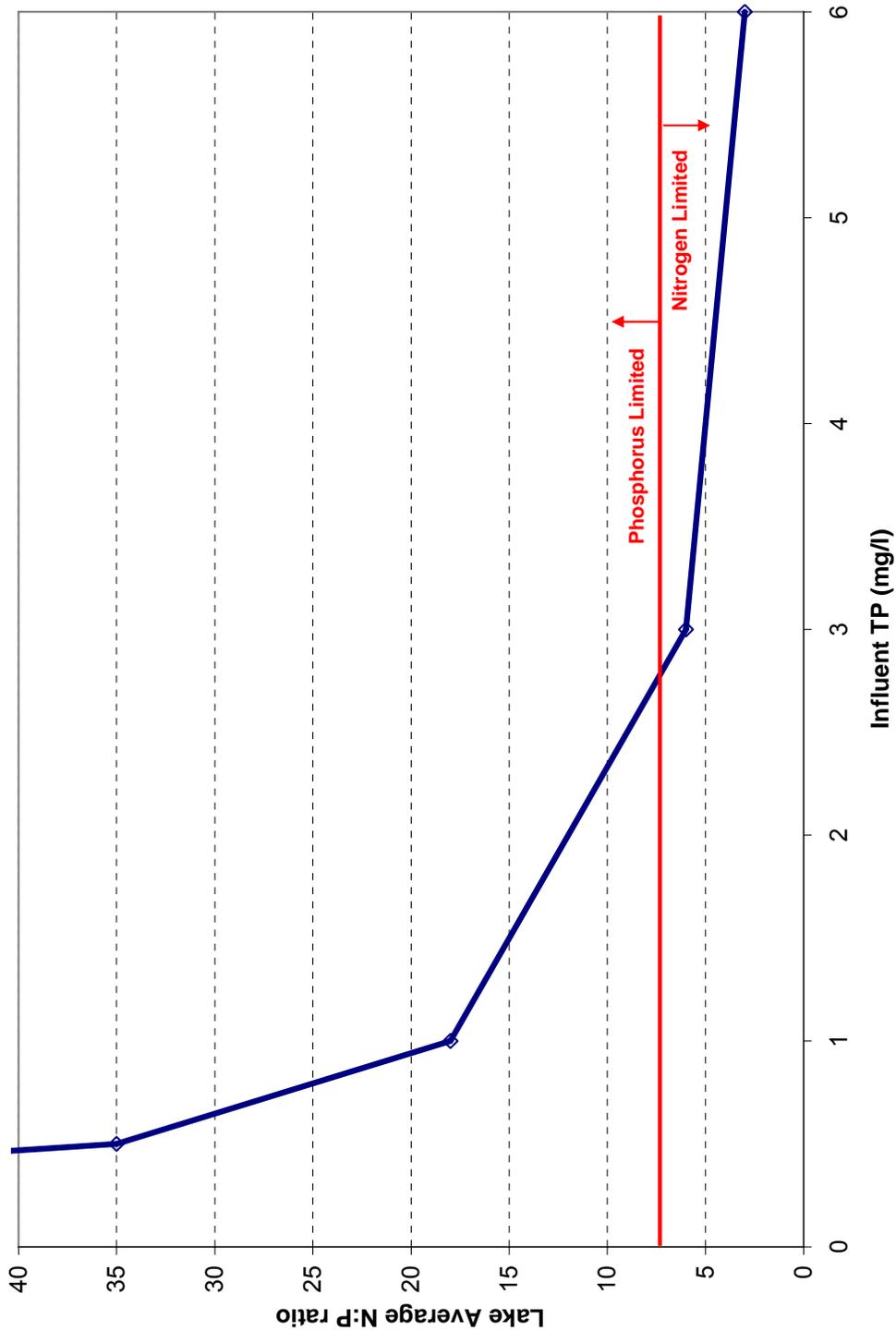


Figure 12
Dallas Lakes Nitrogen to Phosphorus Ratio versus Influent
Total Phosphorus under Worst Case Kinetic Conditions

2.3 Stream Assessment

2.3.1 Model Input and Parameters

A simplified stream water quality spreadsheet model was developed to analyze the impacts of the proposed realignment and lake discharge on the water quality in the Trinity River. The model was used to compare DO conditions in the proposed system versus those in the existing system to assess relative impacts of the proposed system. The modeled reach is shown in **Figure 13**.

The model simulates lumped nitrogenous and CBOD dynamics and oxygen reaeration using analytical solutions and assumed plug flow (longitudinal dispersion = 0). The steady-state analytical solutions used in the spreadsheets are given as (Chapra 1998):

$$L(x) = L_0 e^{-\frac{k_L}{U}x} \quad (1)$$

$$D = D_0 e^{-\frac{k_a}{U}x} + \frac{k_d L_0}{k_a - k_L} \left(e^{-\frac{k_L}{U}x} - e^{-\frac{k_a}{U}x} \right) \quad (2)$$

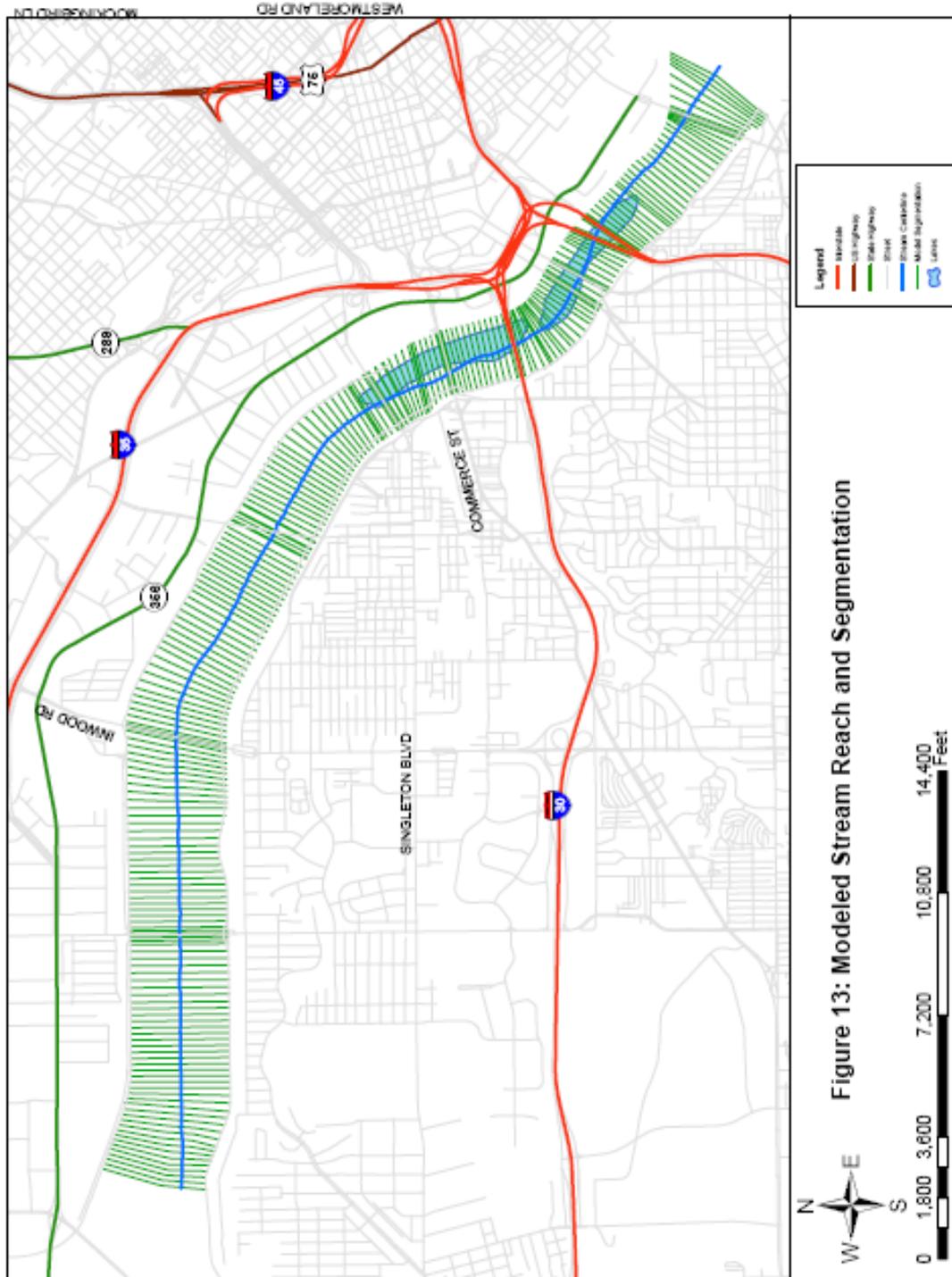
where:

L	=	lumped biochemical oxygen demand (mg/L)
D	=	DO deficit (relative to saturation in mg/L)
L ₀ and D ₀	=	starting L and D, respectively
k _d	=	BOD decay rate constant (1/day)
k _L	=	k _d + k _s ; k _s = BOD settling rate constant (1/day)
k _a	=	reaeration rate constant (1/day)
U	=	segment velocity (m/day); and x = distance downstream (m)

Two different flow rates were assumed for the simulations based on State permitting requirements. The first, 991 cfs, is representative of mean conditions in the river at Dallas as predicted by the State's QUALTX water quality model. This model is used by the State to support NPDES permitting and extends from the headwaters of the Trinity River to far downstream of the reach analyzed for this analysis. For this mean flow condition, the State's model assumes an upstream headwater flow of 80 cfs with significant downstream flow augmentation occurring from point source discharges and tributary inflows. Under this flow condition, the DO standard (average daily) is 5 mg/L.

The second simulated flow rate, 569 cfs, is representative of 7Q2 conditions in the targeted reach. This value is again taken from the State's QUALTX model and is used for discharge permitting. Under this flow condition, the DO standard is 3.5 mg/L.

Both hydraulics-induced and wind-induced reaeration rate constants are calculated in the model using published equations (Chapra 1998), with the final rate constant set equal to the



higher of the two. Reach segmentation and hydraulics used in the model were generated by a recently-developed HEC-RAS model for this section of the river.

Lumped first-order decay rate constants were set in the model based on the values used in the State's QUALTX model for this segment of the Trinity River. Pollutant loadings to the top of the reach and stream temperature were also taken from the QUALTX model. Wind speed was set equal to the mean summer wind speed referenced above (4.3 m/s).

2.3.2 Model Simulations and Results

The purpose of these analyses is to show relative changes in system DO and pollutant assimilative capacity as a function of proposed hydraulic alterations and discharge from the lakes. Only the "worst case" lake scenario is assumed for these simulations (i.e., the low wind condition described previously). A comparison of simulated DO in the existing system versus the proposed system under the 7Q2 and mean flow conditions is shown in **Figures 14 and 15**.

Neither the realignment of the river upstream of the lake discharge point nor the lake discharge are predicted to cause water quality impairment to the river for the given river flow and lake discharge. Neither modeled scenario results in excursions below the applicable State standard.

The results also show that the lake discharge and river realignment have negligible impact on nitrogen and CBOD concentrations, relative to the existing system. Simulated pollutant profiles for the two flow conditions are provided in **Figures 16 and 17**.

2.4 Effluent Conveyance to the Lakes

In addition to evaluating the water quality impacts of utilizing CWWTP effluent on the lakes, the feasibility of conveying between 50 and 75 mgd of CWWTP effluent to the lakes was analyzed. **Figures 18 and 19** depict a feasible conveyance scheme utilizing the existing, but modified, Effluent Pump Station at the CWWTP and an existing 60-inch raw sewage force main that is scheduled to be abandoned by 2010.

Currently, there are two 60-inch raw sewage force mains running between the Cadiz Street Pump Station and the Dallas Plant Headworks of the CWWTP. Planning is underway to eliminate the Cadiz Street Pump Station in its entirety by intercepting the raw sewage flows to the Pump Station and conveying the flows to the CWWTP via a new gravity flow interceptor system. Once eliminated, the two existing 60-inch raw sewage force mains will be retired and made available for future reclaimed water uses. The Dallas Water Utilities (DWU) has offered the older 60-inch raw sewage force main for use as an effluent conveyance pipeline between the CWWTP and the headwaters of the lakes (i.e., Lake Headwaters). The existing alignment of the offered 60-inch raw sewage force main allows much of the 13,500

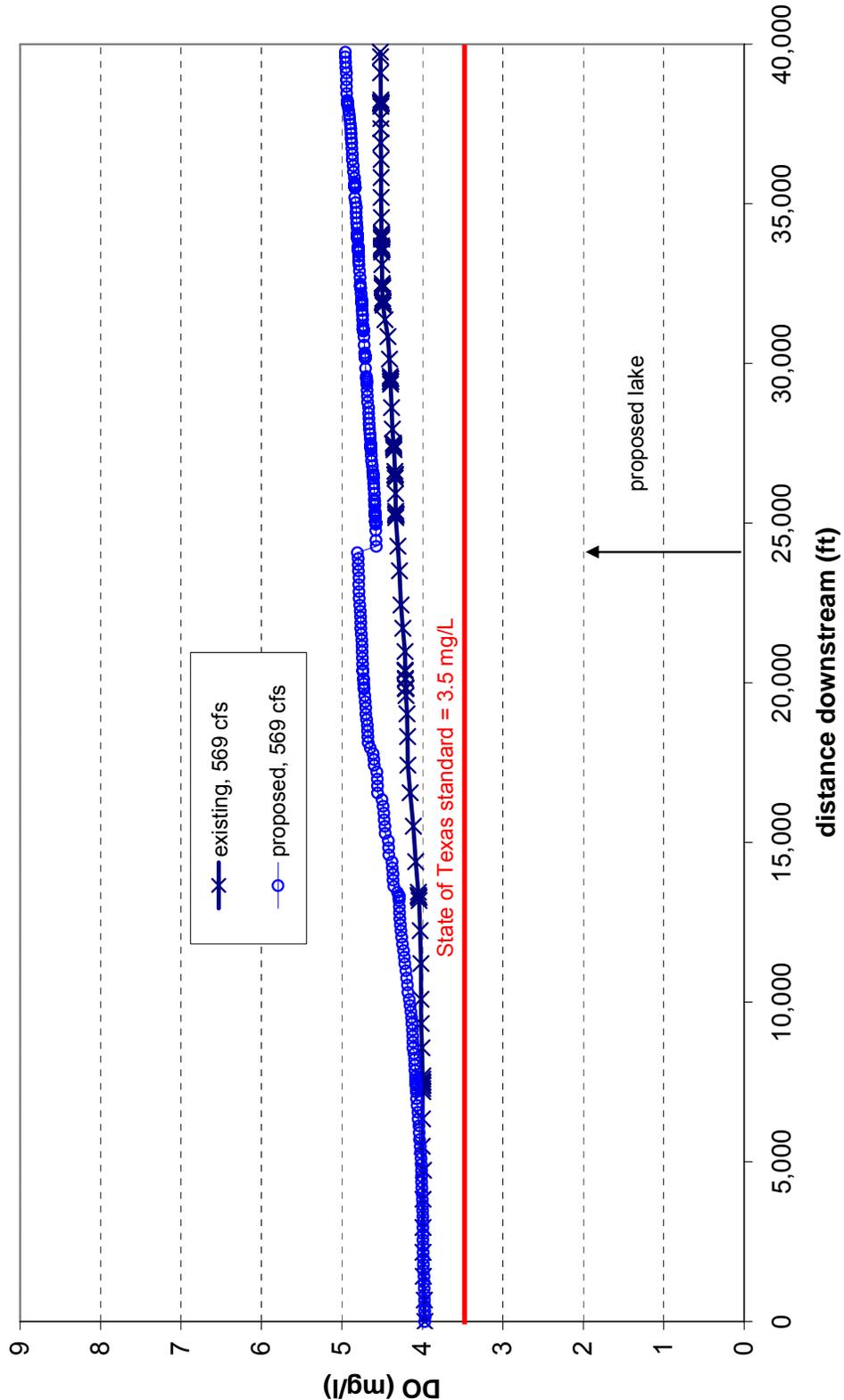


Figure 14
 Dissolved Oxygen in the Trinity River
 through Dallas (7Q2 Flow Condition)

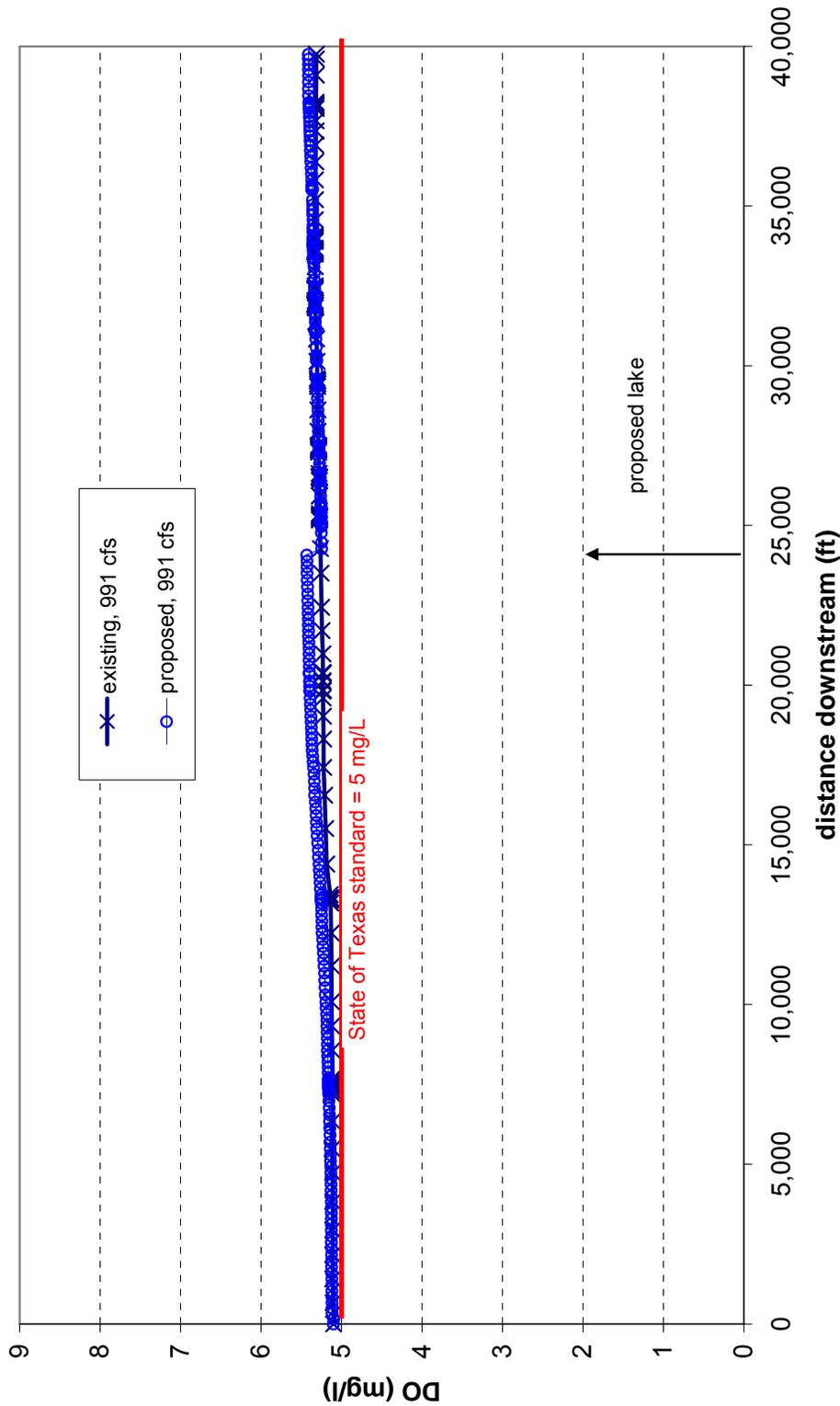


Figure 15
Dissolved Oxygen in the Trinity River
through Dallas (Average Flow Condition)

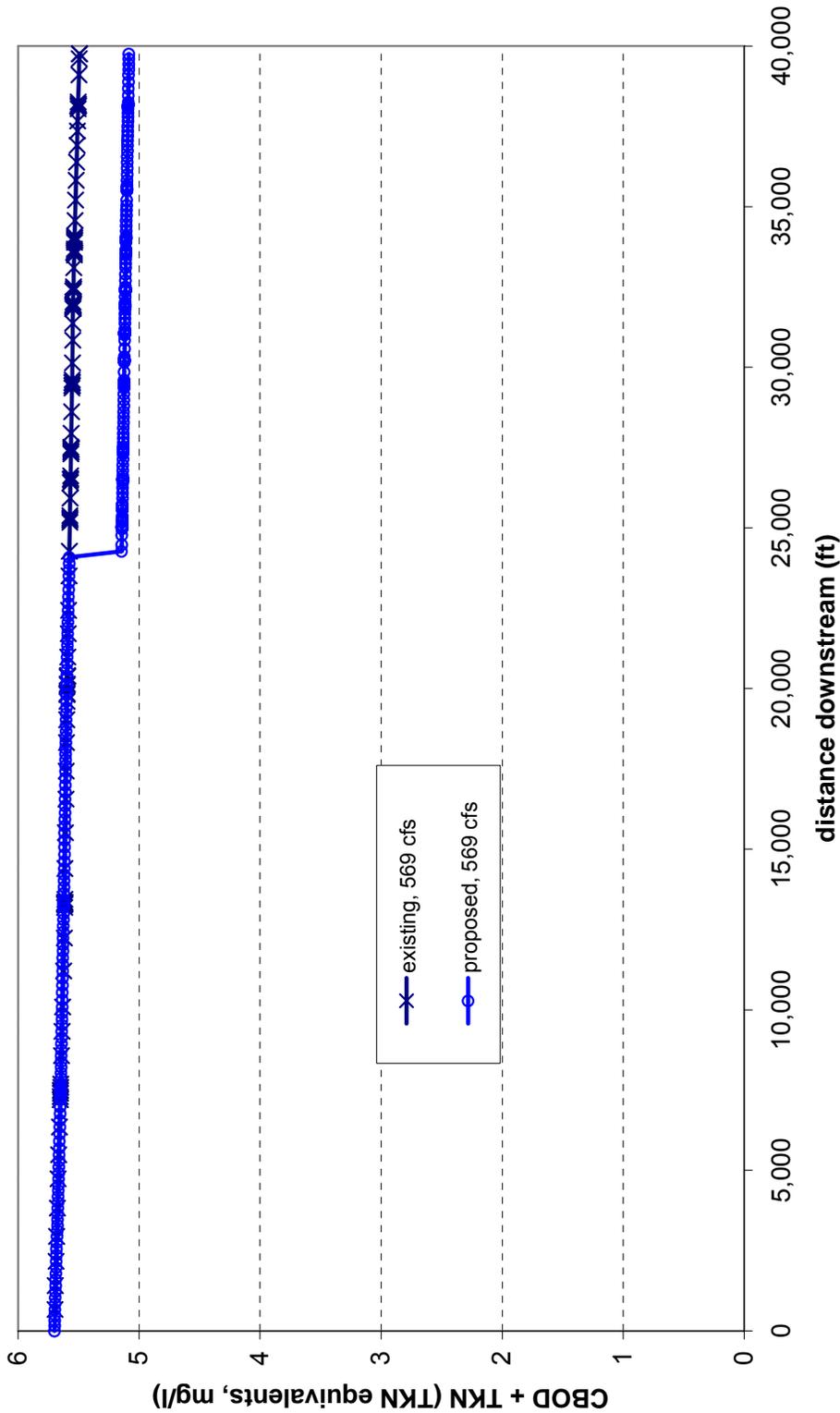


Figure 16
TKN versus Distance Downstream in the Trinity
River through Dallas (7Q2 Flow Condition)

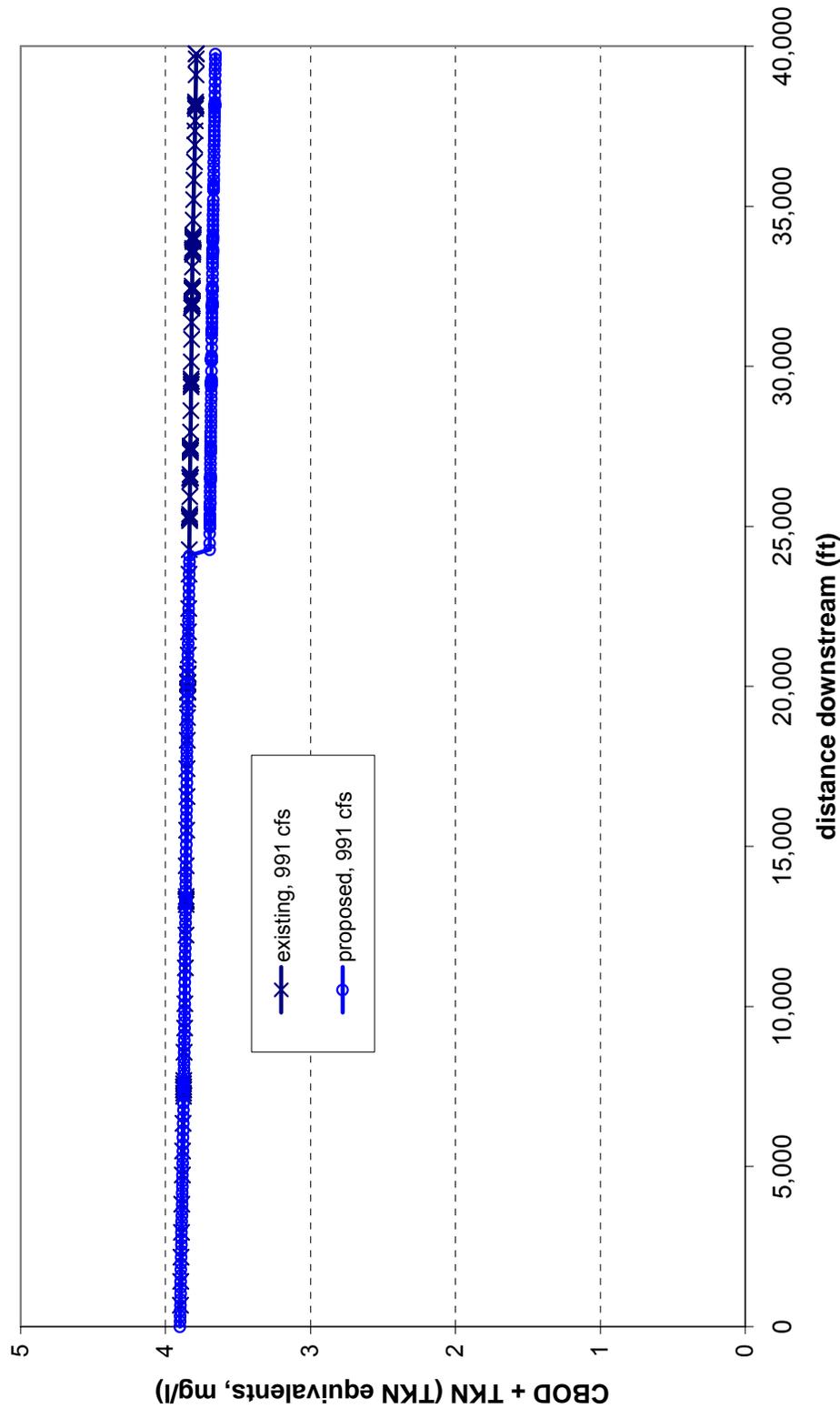


Figure 17
TKN versus Distance Downstream in the Trinity
River through Dallas (Average Flow Condition)

feet between the CWWTP Effluent Pump Station and the Lake Headwaters to be serviced by the force main. Approximately 3,250 feet of new 60-inch effluent conveyance pipeline will be necessary to facilitate the required point-to-point connections as shown on **Figure 18** (reference foldout figure in pocket at the end of this technical memorandum). **It is recommended that the condition of the offered 60-inch raw sewage force main be assessed as a next step in the feasibility process.** Although mitigated within a force main by full pipe flow, hydrogen sulfide corrosion could have damaged the interior walls of the pipeline over the years, effectively reducing the remaining useful life of the pipeline.

The existing Effluent Pump Station at the CWWTP has a firm pumping capacity of 325 mgd. The Pump Station currently consists of three, 55-mgd, variable speed pumping units and three, 80-mgd, constant speed pumping units. Planning is underway to increase the firm pumping capacity of the Pump Station to 350 mgd by upgrading one of the 55-mgd variable speed units to 80-mgd.

The Effluent Pump Station is predominantly unused, serving only to pump treated effluent out of the CWWTP when the Trinity River is high (i.e., under intense rain events that cause the river to rise out of its natural channel). Normally, CWWTP effluent flows to the Trinity River by gravity, effectively bypassing the Effluent Pump Station. Under high Trinity River conditions, it is essential that the Effluent Pump Station operate reliably and at its rated capacity to insure treatment levels and to keep the CWWTP itself from flooding.

With discharge piping modifications, it is possible to utilize one, two, or three of the installed pumping units to convey CWWTP effluent to the Lake Headwaters. The pumping units have a rated total dynamic head capacity of 31 feet. The total dynamic head requirement to convey CWWTP effluent to the Lake Headwaters is approximately 25 feet for 50 mgd and 35 feet for 75 mgd, assuming the use of the old 60-inch Cadiz Street force main, a Lake Headwaters elevation of 402, 13,500 feet of effluent conveyance pipeline, and a water surface elevation of 388 within the wetwell of the CWWTP Effluent Pump Station.

A feasible arrangement for utilizing the existing CWWTP Effluent Pump Station for conveying effluent to the Lake Headwaters is shown on **Figure 19**. The arrangement allows the Pump Station to be used in multiple modes of operation by opening and closing various combinations of proposed discharge valves. The arrangement facilitates the use of one, two, or three pumping units to convey effluent to the Lake Headwaters independent of whether the remaining pumping units are operating to convey effluent to the Trinity River outfall. Frictional headloss within the 60-inch effluent conveyance pipeline will limit the maximum amount of effluent conveyed to the Lake Headwaters to approximately 85 mgd with three pumping units operating in parallel.

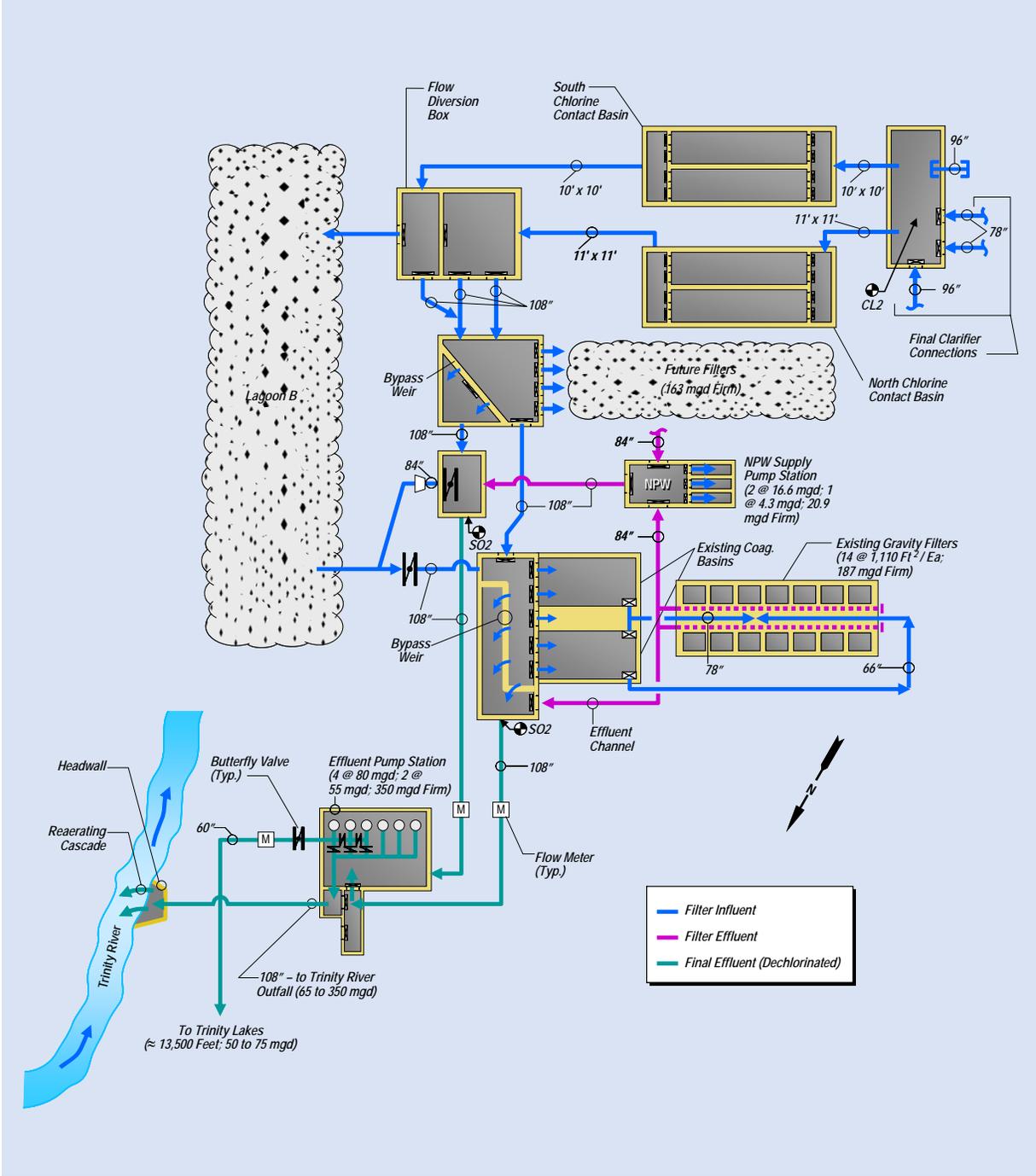


Figure 19
Feasible Arrangement for Conveying 50-75 MGD of Final Effluent from the Central WWTW to the Trinity Lakes

The estimated operation and maintenance costs associated with the continuous supply of effluent to the Lake Headwaters are shown in **Table 3** for both 50- and 75-mgd conditions.

Table 4: Estimated Operation & Maintenance Cost of Effluent Conveyance to Lake Headwaters

Conveyed Flow	Pumping Unit Electricity Costs	Pumping Unit Maintenance Costs	Total Annual O&M Costs
50 mgd	\$175,000/year ¹	\$16,000/year ²	\$191,000/year
75 mgd	\$260,000/year ³	\$30,000/year ⁴	\$290,000/year

The installation of a flow meter is also recommended on the discharge of the 60-inch effluent conveyance line to the Lake Headwaters. The TCEQ has determined the Lake Headwaters to be a secondary discharge point for the CWWTP effluent and, as such, will require this discharge to be flow metered.

3.0 Impacts of Proposed Plan

Based on results of preliminary analyses, anticipated impacts of the proposed plan relative to each currently designated use of the river segment are addressed in this section.

3.1 Contact Recreation

3.1.1 Stream Impacts

The proposed plan is not expected to change the bacterial loads currently experienced within the floodway and the remainder of the stream segment. The redirected effluent (approximately 50 mgd) from the CWWTP for the proposed off-channel lakes, which will discharge to the Trinity River from the proposed lakes, is expected to have bacterial concentrations lower than the Trinity River. TCEQ is currently developing a TMDL for bacteria for the Upper Trinity system and the proposed project would adhere to the requirements of such a TMDL once issued.

¹ $\left[\frac{(77 \text{ ft}^3 / \text{sec})(25 \text{ ft})(62.4 \text{ lbs} / \text{ft}^3)}{(550)(.75)} \right] \times \left(\frac{746 \text{ watts}}{\text{hp}} \right) \left(\frac{1 \text{ kw}}{1,000 \text{ watts}} \right) \left(\frac{24 \text{ hours}}{\text{day}} \right) \left(\frac{365 \text{ days}}{\text{year}} \right) \left(\frac{\$0.09}{\text{kWh}} \right) = \$171,000/\text{year}$; use

\$175,000/year for planning purposes.

² Assume 50 mgd pumping requirement is shared between two duty units and each duty unit has an installed cost of \$400,000. Assume “best in class” maintenance diligence at 2% of asset value per year; or (2)(\$400,000)(0.02) = \$16,000/year.

³ $\left[\frac{(116 \text{ ft}^3 / \text{sec})(25 \text{ ft})(62.4 \text{ lbs} / \text{ft}^3)}{(550)(.75)} \right] \times \left(\frac{746 \text{ watts}}{\text{hp}} \right) \left(\frac{1 \text{ kw}}{1,000 \text{ watts}} \right) \left(\frac{24 \text{ hours}}{\text{day}} \right) \left(\frac{365 \text{ days}}{\text{year}} \right) \left(\frac{\$0.09}{\text{kWh}} \right) = \$258,000/\text{year}$; use

\$260,000/year for planning purposes.

⁴ Assume 75 mgd pumping requirement is shared between two duty units and each duty unit has an installed cost of \$500,000. Assume “best in class” maintenance diligence at 2% of asset value per year; or (3)(\$500,000)(0.02) = \$30,000/year.

3.1.2 Lakes Impacts

The source of water for the proposed off-channel lakes would be derived from highly treated water from the CWWTP and, as such, will have bacterial concentrations that meet both water quality and effluent reuse standards. The CWWTP continually monitors the bacterial concentration of its effluent and would cease delivery of water to the lakes if an excursion occurred.

The only potential for bacterial excursions within the lakes would occur when the lakes were overtopped during a flood event (anticipated to occur approximately once every 2 years). In this situation, the City of Dallas would need to restrict recreation on the lakes until bacterial levels returned to acceptable levels.

3.2 Fish Consumption

3.2.1 Stream Impacts

The proposed plan is not anticipated to have a permanent impact, either positive or negative, on fish consumption within the floodway and the remainder of this stream segment. TCEQ has an EPA-approved TMDL for legacy pollutants for stream segment 0805 (TCEQ 2001) and the proposed project will adhere to the requirements of TMDL.

3.2.2 Lakes Impacts

The source of water for the proposed off-channel lakes would be derived from highly treated water from the CWWTP and, as such, will likely have lower concentrations of legacy pollutants than the Trinity River. Due to the existing fish consumption (possession) ban for this segment of the river and because the lakes can be overtopped with flood waters resulting in Trinity River fish populations inhabiting the lakes, the City of Dallas expects the fish consumption (possession) to extend to the lakes until such time as the current ban is lifted for the entire segment.

3.3 Aquatic Life Support

3.3.1 Stream Impacts

Preliminary analyses indicate no anticipated negative impacts of the proposed stream meander realignment or lakes discharge, with respect to supporting aquatic life, under the permitted flow rates.

3.3.2 Lakes Impacts

The preliminary analyses performed show the potential for DO impairment in the proposed lakes, below recommended levels for supporting aquatic life. This simulated impairment is due to the oxidation of carbon and nitrogen constituents present in the lakes source water. The risk of impairment is particularly high under low wind conditions, which limit reaeration. DO impairment could be mitigated through lake management strategies, such as

the implementation of aeration structures or increased removal of oxidizing pollutants from the source water.

4.0 Water Quality Mitigation Measures for the Proposed Plan

4.1 Stream Mitigation Measures

Preliminary analyses demonstrate that the proposed project should not negatively impact water quality in the Trinity River under permitted flow conditions. Lake mitigation measures, described further in subsequent sections, could further reduce the potential for negative impacts to the river from the proposed lake discharge, under all flow conditions.

Additionally, several of broader stormwater quality management initiatives (described in Sections 4.3) would also contribute to maintaining long-term water quality in the Trinity River through downtown Dallas.

4.2 Lakes Mitigation Measures

This section includes a discussion of potential mitigation measures for anticipated impacts to water quality in the proposed lakes.

4.2.1 Aquatic Life

Preliminary analyses indicate that water quality in the proposed lakes may not always meet State of Texas DO water quality standards, particularly during periods of low wind. A number of mitigation options are available to reduce the risk of DO excursions below the standard. Two options currently under consideration are reaeration dams and/or drop structures as presented in section 2.2.2.

In addition to dams and/or drop structures, induced circulation is also being considered as a potential mitigation measure for the proposed lakes. This type of measure would be particularly important during high temperature conditions or shortly after the lakes have been inundated with flood waters. Several options are available to accomplish this:

- *Inducing large scale circulation mechanically.* Several mechanical means could be used to induce circulation through the lakes. Subsurface pumps could be employed to force large volumes of water to move within the lakes. The proposed whitewater course pump station could be configured to accomplish this in addition to its primary function of conveying whitewater course flows.
- *Inducing localized circulation mechanically through aeration.* Surface aerators (commonly seen as fountains) could induce circulation in localized areas if needed. Pumps could be used to pull water from the waterway and allow it to return to the waterway over cascades or other aesthetic features on a localized basis. The size and location of the aerators would need to

be considered during the design of the lake. Based on preliminary analyses it is likely that aerators could be used to address the deficits below the DO standard during critical times.

Induced circulation will also greatly help with aesthetic concerns, as discussed below. Quantification of how aeration will impact dissolved oxygen levels in the lake will need to be determined during the design of the lake system.

4.2.2 Aesthetics

The urban design plan associated with the Balanced Vision Plan identifies maintenance of water aesthetics and quality of the Trinity River as critical to the successful implementation of the Dallas Floodway improvements. Primary aesthetic concerns are odors, algal growth, sedimentation, and floatable material.

4.2.2.1 Water Odors

Naturally-occurring, less desirable water odors typically develop when deeper, cooler water at the bottom of a water body reverses and rises to the top, bringing stagnant odors to the surface. This occurs as a result of seasonal temperature changes. In warm weather, cooler water sinks to the bottom and warmer water stays at the surface resulting in thermal stratification. Stratification is broken up by cooler weather which reduces the temperature of surface water to nearer that of the deeper water in the waterbody, allowing the two "layers" of water to mix.

One option to limit the potential for odor from the lakes is to limit the water depth to 8 to 10 feet, which will keep the water temperature nearly uniform and minimize temperature stratification. These depths are maintained in the current modeled system. Stratification is much more likely to occur at depths greater than 10 feet. Additionally, mechanical devices could be employed to pull water from deeper depths and bring it to the surface to eliminate stratification.

4.2.2.2 Algal Growth

Algae or phytoplankton are microscopic plants that contain chlorophyll and live floating or suspended in water. Like all plants, algae require nutrients (nitrogen and phosphorous) to grow. Excess algal growth can be a significant water quality concern as algae can greatly reduce DO at night, threatening other aquatic life. Algal growth in the proposed lakes system will be more of an aesthetic issue than genuine water quality issue.

During warmer periods of the year, algae growth could result in the water being less clear and somewhat green in color. Additionally, the potential for toxic (blue-green) algae blooms could exist under certain conditions, specifically high phosphorus loadings with nitrogen-limited algal growth. These risks could be minimized by increasing flow through the system, removing nutrients from the system by harvesting nutrients through periphyton gardens, or

by chemically treating the water to limit algae growth or to force algae to settle to the bottom to decompose. In addition, phosphorus precipitation and inactivation by additional of chemicals to the lake could also be used to control algal blooms. These measures should be addressed during the design of the lake system.

Preliminary modeling results indicate that, by itself, phosphorus removal would need to achieve total phosphorus levels of less than 3 mg/l to remove the risk for blue-green algal blooms and a level below 0.1 mg/l to force total phytoplankton levels below the State target (25 µg/l as chlorophyll a).

4.2.2.3 Sedimentation

During normal daily operations, water in the lakes will be highly treated reclaimed water with very low concentrations of suspended solids. As such, sedimentation in the lakes is not anticipated to be an issue.

However, as currently configured, the proposed lakes are expected to be overtopped with sediment-laden flood water approximately once every two years. Sediment will drop out in the lakes under such conditions. It is anticipated that the lakes will need to be dredged to remove this sediment.

4.2.2.4 Floatable Material

A universal impact to water aesthetics in urban areas is floatable material. Typically, litter that washes into drainageways with stormwater runoff, floatable material can aggregate on waterway banks and collect on structures creating unsightly clutters of trash. In conjunction with the additional hydraulic assessments associated with the further design of the project, floatable material mitigation should be further assessed. Design strategies should be developed to minimize floatable material entering the lakes and adjacent river. This may be in the form of refining how flow moves through the system or in the form of floatable control practices (e.g., netting, booms, etc.) designed to catch and remove floatables.

4.3 Stormwater Quality Management

4.3.1 Existing Programs and Policies

4.3.1.1 Stormwater Discharge Permit

In December 1996, EPA issued the initial NPDES Storm Water Discharge Permit for its municipal separate storm sewer systems to the City of Dallas and the Texas Department of Transportation (TXDOT) as co-permittees. The permit will be reissued as a TPDES permit through TCEQ, to whom EPA delegated the program. The permit requires the monitoring of stormwater quality and the development and implementation of a management plan to manage stormwater quality within the City of Dallas.

The City is responsible for managing stormwater from the majority of the City while TXDOT is responsible for coordinating with the City to manage stormwater quality from TXDOT owned and operated facilities - bridges, roads, and ancillary facilities.

Some major elements of the TPDES permit for stormwater runoff being implemented by the City of Dallas and TXDOT are listed below (City of Dallas 2003):

- Storm water collection system (operation and maintenance)
- Areas of new development and redevelopment (minimize pollutants)
- Roadways (minimize de-icing pollutants)
- Flood control projects (assess water quality improvements/retrofitting)
- Pesticide, herbicide and fertilizer application (educate staff/contractors)
- Improper discharges and disposal (enforce, collect, etc.)
- Spill prevention and response (prevent, contain, and respond to spills)
- Industrial and high risk runoff (conduct inspections and monitoring)
- Construction site runoff (ordinance, inspections/enforcement, and training)
- Public education (promote pollution prevention and public reporting)
- Monitoring programs (conduct six types of monitoring)
- Computer modeling (seasonal loadings in watersheds)
- Annual report to EPA/TCEQ

4.3.1.2 Regional Stormwater Quality Management Initiatives

Dallas is one community among over 225 entities in the NCTCOG planning area. Included among the many functions that NCTCOG provides is a forum for discussion of regional stormwater quality and quantity issues and needs. Through NCTCOG, area communities (including the City of Dallas) have coordinated regionally to address common stormwater management issues in the development of the integrated Storm Water Management (iSWM) program. The iSWM program provides guidance for all development and redevelopment-related storm water initiatives in North Central Texas (NCTCOG 2005). The purpose of this program is to provide comprehensive guidelines for integrated storm water quantity and quality management throughout each phase of development and redevelopment, including planning, design, construction, and maintenance.

The initial iSWM manuals consist of the:

- iSWM Policy Guidebook;
- iSWM Design Manual for Development/Redevelopment; and
- iSWM Design Manual for Construction.

The iSWM Policy Guidebook is designed to provide guidance for the local jurisdictions and developers on the basic principles of effective urban storm water management. The iSWM

Design Manual for Development/Redevelopment is a detailed design document to guide developers, consultants, and government agencies on the preparation of an integrated Storm Water Management Plan including design techniques for the control and management of storm water quality and quantity for new developments, redevelopments, or retrofitting developed areas. The iSWM Design Manual for Construction provides guidance on the control of sediment and other pollutants on construction sites. The guidance provided by the iSWM program is customized and adopted by participating entities based on local drainage characteristics.

4.3.1.3 Local Stormwater Quality Management Requirements

The nature of stormwater quantity and quality management from the areas draining to the Dallas Floodway will be governed by current City of Dallas drainage requirements and by the customization of the regional iSWM program and evolution of the stormwater quality management plan associated with the TPDES stormwater permit described previously.

4.3.2 Options for Stormwater Quality Management

4.3.2.1 During Construction

TCEQ requirements issued through the TPDES permitting program will require the management of stormwater quality for all construction associated with the Dallas Floodway project. TPDES requirements for construction activities necessitate the development and implementation of a stormwater pollution prevention plan. Enforcement of these requirements by TCEQ ensures that construction activities and construction wastes do not pollute waterways.

4.3.2.2 Post Construction

The City of Dallas is currently customizing guidance in the regional iSWM program for its use through a planning effort designed to significantly update the City's drainage ordinances and criteria (City of Dallas 2003). The iSWM guidance is being paired with information generated through a series of watersheds studies currently underway.

For the City of Dallas, customization and adoption of the regional iSWM guidance provides the principal means by which the City will comply with the TPDES permit requirement to manage the quality of runoff from areas of new and redevelopment in the City (including that associated with the Dallas Floodway project). Since the City is scheduled to finish customization and adoption of its updated stormwater program in the next few years, robust stormwater quality management requirements for new and redevelopment are anticipated to be in place by the time the land in the area of the Dallas Floodway begins to redevelop.

4.4 Recommendations

Based on the information contained in this memorandum, the following recommendations should be considered under the design phase of the Trinity Lakes development project:

- It is recommended that the condition of the offered 60-inch raw sewage force main be assessed as a next step in the feasibility process. Although mitigated within a force main by full pipe flow, hydrogen sulfide corrosion could have damaged the interior walls of the pipeline over the years, effectively reducing the remaining useful life of the pipeline.
- The installation of a flow meter is recommended on the discharge of the 60-inch effluent conveyance line to the Lake Headwaters. The TCEQ has determined the Lake Headwaters to be a secondary discharge point for the CWWTP effluent and, as such, will require this discharge to be flow metered.
- As part of the ultimate lake design, the Upper Trinity Water Quality Compact's model of the Trinity River should be completed to verify that impacts of the lake system are minimal on Trinity River.
- Potential lake mitigation measures discussed in this memorandum such as aeration, phosphorus removal, chemical treatment of the lakes, etc. should be further evaluated for applicability to final lake design.
- Consider depth of lake during design process to minimize stratification in lake system.

5.0 References

Butts, T.A. and R.L. Evans. 1983. Effects of Channel Dams on DO Concentrations in Northeastern Illinois Streams. Circular 132. State of Illinois, Dept. of Reg. and Educ. Illinois Water Survey, Urbana, Illinois.

CH2M Hill. 1999. Final Report on Trinity River Lake Water Quality to Accommodate Proposed Lake Design and Recreational Amenities; Part of the Trinity River Corridor Master Implementation Plan Report; Trinity River Corridor Project Office; City of Dallas, Texas.

Chapra, S. C. 1998. Surface Water-Quality Modeling. McGraw-Hill; New York.

City of Dallas. 2003. A Balanced Vision Plan for the Trinity River Corridor; Trinity River Corridor Project Office; City of Dallas, Texas. December.

City of Dallas. 2003. 2002 Annual Report: Municipal Separate Storm Water Sewer System Permit - Storm Water Management Program Implementation; Department of Public works; City of Dallas, Texas.

NCTCOG (North Central Texas Council of Governments). 2004. Integrated Storm Water Management Policy Guidebook, Review Draft. North Central Texas Council of Governments, Arlington, Texas. September.

Technical Memorandum
Preliminary Water Quality Analyses for Dallas Floodway DEIS
October 28, 2005
Revised January 9, 2006
Page 38

TAC (Texas Administrative Code). 2000. Low Flow Criteria; TAC; Title 30 - Environmental Quality; Part 1 - Texas Commission on Environmental Quality; Chapter 307 - Texas Surface Water Quality Standards; §307.10; Appendix B.

TAC (Texas Administrative Code). 2002. FINAL Annual Regional Storm Water Monitoring Report for North Central Texas: Monitoring Year 5, September 2000 - August 2001; North Central Texas Council of Governments; Arlington, Texas. February.

TCEQ (Texas Commission on Environmental Quality). 2004. Guidance for Assessing Texas Surface and Finished Drinking Water Quality Data; Texas Commission on Environmental Quality.

TCEQ (Texas Commission on Environmental Quality). 2004. Draft 2004 Texas Water Quality Inventory and 303(d) List; Texas Commission on Environmental Quality; Austin, Texas. November 23.

TCEQ (Texas Commission on Environmental Quality). 2001. Nine Total Maximum Daily Loads for Legacy Pollutants in Streams and a Reservoir in Dallas and Tarrant Counties - For Segments 0805, 0841, and 0841A. Austin, Texas.

TSDHS (Texas State Department of Health Services). 2005. Trinity River Ban <http://www.tdh.state.tx.us/bfds/ssd/map/pdf/trinityriverban.pdf>. Austin, Texas.

TXDOT (Texas Department of Transportation). 2002. Storm Water Management Guidelines for Construction Activities. TXDOT Environmental Affairs Division. July.

TWDB (Texas Water Development Board). 2004. Surface Water Data: Lake Evaporation and Precipitation Data, http://www.twdb.state.tx.us/data/surfacewater/surfacewater_toc.asp.

EPA (U.S. Environmental Protection Agency). 2004. WASP version 6.0.0.12 - Software Program for the USEPA Water Quality Analysis Simulation Program; Ecosystems Research Division of the National Exposure Research Laboratory; USEPA; Athens, Georgia.

EPA (U.S. Environmental Protection Agency). 1999. Polychlorinated Biphenyls (PCBs) - Update: Impact on Fish Advisories; EPA-823-F-99-019, Fact Sheet; USEPA; Office of Water; Washington, D.C.

EPA (U.S. Environmental Protection Agency). 1999. Update: National Listing of Fish and Wildlife Advisories. EPA-823-F-99-005, Fact Sheet; USEPA; Office of Water; Washington, D.C.

EPA (U.S. Environmental Protection Agency). 1992. Environmental Impacts of Storm Water Discharges: A National Profile; Publication No. EPA 841-R-92-001; USEPA; Washington, D.C. June.

USACE. (U.S. Army Corps of Engineers). 1998. Upper Trinity HEC-RAS Model, Upper Trinity Study - 22. May.

6.0 Attachments

6.1 Tables

- | | |
|---------|--|
| Table 1 | 2004 Surface Water Inventory and 303(d) List Summary for Upper Trinity River |
| Table 2 | Summary of WASP Model Loading Parameters (Central WWTP Effluent) |
| Table 3 | WASP model kinetics and environmental parameters |
| Table 4 | Estimated Operation & Maintenance Cost of Effluent Conveyance to Lake Headwaters |

6.2 Figures

- | | |
|----------|--|
| Figure 1 | Modeled System Schematic |
| Figure 2 | Dallas Lakes Dissolved Oxygen – Average and Low Wind Conditions |
| Figure 3 | Dallas Lakes Dissolved Oxygen – Temperature Sensitivity with Average Wind Conditions |
| Figure 4 | Dallas Lakes Dissolved Oxygen – Temperature Sensitivity with Low Wind Conditions |
| Figure 5 | Dallas Lakes Dissolved Oxygen – Impact of Aeration Dams with Low Wind Conditions |
| Figure 6 | Dallas Lake Oxidizing Pollutants – CBOD and TKN |
| Figure 7 | Dallas Lakes Phytoplankton (as chlorophyll <i>a</i>) – Best and Worst Case Conditions |
| Figure 8 | Dallas Lakes Phytoplankton (as chlorophyll <i>a</i>) – Flow Sensitivity with Worst Case Conditions |
| Figure 9 | Dallas Lakes Phytoplankton (as chlorophyll <i>a</i>) – Temperature Sensitivity with Worst Case Conditions |

- Figure 10 Dallas Lakes Phytoplankton (as chlorophyll *a*) - Temperature Sensitivity with Best Case Conditions
- Figure 11 Dallas Lakes Predicted Algal Growth (chl *a*) vs. Influent Total Phosphorus - Worst Case Conditions
- Figure 12 Dallas Lakes Lakes Nitrogen to Phosphorus Ratio vs. Influent Total Phosphorus - Worst Case Conditions
- Figure 13 Modeled Stream Reach and Segmentation
- Figure 14 Dissolved Oxygen - Trinity River through Dallas, 7Q2 Flow
- Figure 15 Dissolved Oxygen Trinity River through Dallas, Average Flow
- Figure 16 TKN vs. Distance Downstream - Trinity River through Dallas, 7Q2 Flow
- Figure 17 TKN vs. Distance Downstream - Trinity River through Dallas, Average Flow
- Figure 18 Feasible Arrangement for Conveying 50-75 MGD of Final Effluent from the Central WWTP to the Trinity Lakes (Aerial Image in Pocket)
- Figure 19 Feasible Arrangement for Conveying 50-75 MGD of Final Effluent from the Central WWTP to the Trinity Lakes

cc: Randy Rogers, CDM
Nicole Rowan, CDM
Tim Cox, CDM