Appendix A

TMDL Analyses for Phosphorus for Reservoirs in the Yellow and Little Yellow Creek Watersheds

BATHTUB/GWLF Modeling

Introduction

The Yellow Creek TSD concluded that three stream reaches downstream of reservoirs were biologically impaired possibly due to the effects of lakes just upstream of these sites. The lakes and stream segments involved in this study were Jefferson Lake on Town Fork as well as Highlandtown Reservoir and Wellsville Reservoir on Little Yellow Creek. These sites appeared, during the biological sampling, to be either affected by excess algae obstructing substrate habitat macropores or by flow alteration. The cause and source findings of impairments of these sites are presented in Table A1 below.

To determine if the impairments were created by nuisance algae discharging to the downstream stream segments, site specific information was collected and long-term modeling was performed. Limnology and water quality data from the lakes as well as influent and effluent water quality data and flows were collected from each of the study areas in this report. Review of chlorophyll *a* data was completed to determine the potential for non-attainment.

A phosphorus TMDL was completed for Jefferson Lake, Highlandtown Reservoir, and Wellsville Reservoir utilizing the Generalized Watershed Loading Functions (GWLF) model (Haith et al., 1992) coupled with BATHTUB (Walker, 1987) as a watershed/receiving water model combination. Hydrology and nutrients for each lake watershed were then modeled for each of the basins with GWLF. The eutrophication state of each lake was subsequently modeled with BATHTUB. The non-point source model, GWLF, was utilized to predict nutrient loads and hydraulic flows received by the reservoirs. To calibrate the hydrology and nutrients for the lake watersheds, GWLF modeling was initially calibrated for the Yellow Creek watershed up to the Hammondsville USGS gage site. Calibration to this location was necessary because significant water quality and discharge data was available for this site. The variables of calibration from the gage site were utilized in the lake watersheds. This is an acceptable practice because of the closeness and similarity including land use, geology, and meteorological conditions when comparing all the modeled watersheds. The purpose of the modeling effort was to determine the nutrient loads from each significant source category (specifically agricultural runoff and septic systems). From the results of this effort a calibrated nutrient model for the eutrophic state lake modeling was also utilized to assist in determining the potential excess nutrient sources to focus mitigation efforts.

The calibrated nutrient loadings as well as site specific data were then input into the BATHTUB lake model to assess predictions of the eutrophication state of each lake with respect to chlorophyll *a* concentrations. The U.S. Army Corps of Engineers' BATHTUB model was selected to simulate eutrophication in the three selected lakes. BATHTUB predicts eutrophication-related water quality conditions (e.g., phosphorus, nitrogen, chlorophyll *a*, and transparency) using empirical relationships previously developed and tested for reservoir applications (Walker, 2004). BATHTUB is a steady-state model. It incorporates several empirical equations of nutrient settling and algal growth to predict steady-state nutrient and

chlorophyll *a* concentrations based on waterbody characteristics, hydraulic characteristics, and nutrient loadings. Total phosphorus and chlorophyll *a* were the primary indicators of eutrophication and nutrient source presented in the TMDL; however, nitrogen and secchi disk readings were utilized in the modeling effort as well. The BATHTUB model was selected because it does not have extensive data requirements and can therefore be used in conjunction with the non-point source loads calculated by GWLF. Chlorophyll *a* is known to be proportionate to the mass of productive algal biomass within a waterbody.

The GWLF model was chosen because of its widespread use in TMDLs and its ability to simulate the important processes of concern, specifically hydrology and nutrients. Actual 10 year USGS record gage flow and two seasons of chemistry results from the Yellow Creek basin survey were utilized to calibrate and compare model results. GWLF input parameters were assigned based on available monitoring data, default parameters suggested in the GWLF User's Manual (Haith et al., 1992), and the meteorological record. Default values were used for many parameters due to a lack of local data and to ensure the modeling results are consistent with previously validated studies. Sediment was not considered a factor in the water quality modeling of nutrients because the vast majority of each drainage was forested and not considered to be significantly erodible.

Similar to GWLF, BATHTUB was chosen based on the ability to simulate the reservoir conditions without significant historic data requirements. Site specific morphometric, meteorological, hydrologic, and water quality data of the lakes as well as influent/effluent streams were used to calibrate the coupled modeling effort. Simulated watershed loads and flows from GWLF as well as eutrophication modeling with BATHTUB was completed for the 10 years up to and including the water quality survey years. With these model results, percent reductions of nutrient load to the lakes are proposed to reduce eutrophication to a level that is generally accepted as just below that of nuisance algae conditions. Within the non-nuisance level of in-basin chlorophyll *a*, the effluent is not expected to create nuisance algae conditions. Therefore, this trophic state level should eliminate the habitat reduction from the algal fines sedimentation found during the watershed survey.

Table A1. Attainment table subset for streams of Yellow Creek and Ohio River Tributary Assessment Units that are suspected for lake impairment, June to October, 2005 and August to September, 2006

Lower Yellow Creek Basin HUC 05030101 190 (Upstream Town Fork to mouth, *Western Allegheny Plateau Ecoregion*)

Town Fork 06-920 WWH* (existing) Fork *EWH - Jefferson Lake to mouth (recommended)*

Stream/Code RM Fish/Macro.	**Attainment**	**IBI**	**MIwb**	**QHEI**	**ICI[a]**	**Location**	**DA**	**Cause**	**Source**
8.0/8.1	PARTIAL	52	NA	77.0	MG*	Dst Jefferson Lake (intermittent)	7.9	Flow Alt. -H	Upstream Impoundment -H
Comments: Intermittent late summer flow conditions immediately downstream from Jefferson Lake were the primary cause of Partial attainment of the recommended EWH use. Outside of this localized area, biological communities were consistently in the exceptional range between Jefferson Lake and the mouth.									

Ohio River Tributaries HUC 05030101 100 (Downstream Little Beaver Creek to upstream Yellow Creek, *Western Allegheny Plateau Ecoregion*)

Little Yellow Creek 06-079 WWH* (existing) *WWH (recommended)*

Stream/Code RM Fish/Macro.	**Attainment**	**IBI**	**MIwb**	**QHEI**	**ICI[a]**	**Location**	**DA**	**Cause**	**Source**
6.7/6.6	NON	32*	NA	63.5	F*	McCormick Run Rd.	8.2	Flow Alt. - H Nutrients - M	Impoundment - H Excess Algae - M Ag. - S
Comments: Fair fish and macroinvertebrates were found downstream from Highlandtown Res. and upstream from Wellsville Res. Fish may be influenced by limited potential for fish movement and recovery due to upstream and downstream impoundments while macroinvertebrates appeared enriched. Observations of excessive "organic fines" by fish crews and an unusual, "dark brown silt" obs. during macro. sampling may be associated with dead algal mats or biomass from the upstream reservoir. An odor of manure from nearby farms was also noted.									
3.5/3.3	PARTIAL	38*	NA	61.0	G	Forbes Rd.	17.1	Flow Alt. – H	Impoundment – H
Comments: Like sites upstream, flow alteration associated with the limited flow from Wellsville Res. coupled with limited potential for fish movement and recovery between the reservoir and the impounded Ohio River were considered the most likely reasons for the fair quality fish community. Outside of an increasing trend in sulfate, chemical results indicate no obvious water quality problems.									

a A narrative evaluation is used in lieu of the ICI from sites with Qualitative data only (E=Excellent,VG=Very Good, G=Good, MG=Marginally Good, F=Fair; P=Poor, VP=Very Poor).

*** Significant departure from ecoregional biocriteria; poor and very poor results are underlined.**

Study Area and Preliminary Data Evaluation

Within the Yellow Creek watershed, the three basins modeled were located within two distinct drainages. The influent and effluent streams as well as the impoundments themselves were analyzed by geospatial, physical and chemical analysis. Figure A1 indicates the flow schematics of the drainage areas and water quality sampling collection sites completed in the survey season of 2006. Instream flow sites, chemical sampling locations, and limnology profiling/sampling locations are indicated on this schematic with red dots. The reservoirs were bracketed during the field studies. Drainage specific information, model specific morphometric characteristics, water quality input data, and model calibration data were collected from these sites.

Little Yellow Creek

Little Yellow Creek is a relatively small basin (total length 11.3 miles; drainage area 22.22 mi^2) that flows directly into the Ohio River near Wellsville, Ohio. The basin is completely within the Western Allegheny Plateau ecoregion of Columbiana County. It is assigned the 11-digit United States Geological Survey (USGS) assessment unit code HUC-05030101-100. Land use is mostly agricultural and forest, with scattered areas of mostly historical and some active strip mining for coal. No current or historical USGS flow monitoring stations are present in the Little Yellow Creek basin.

Wellsville Reservoir

Two reservoirs impound the Little Yellow Creek mainstem. The most downstream is the Wellsville Reservoir with a dam structure at RM 4.20 (dam constructed in 1926). Bailey Run also flows into this reservoir from the north at about RM 4.40. Morphometric data for this reservoir can be viewed in the BATHTUB Model section of this report. During the 2005 and 2006 survey this reservoir was utilized by the Buckeye Water District as a primary source of public drinking water. About 0.768 mgd of reservoir water was diverted to the Buckeye Water District-Wellsville plant for treatment (Source Water Assessment Plan (2003) for the Wellsville Reservoir). The intake structure located near the dam and the orifices were located at multiple depths. Wellsville Reservoir and the intake structure can be viewed in Figure A2.

Although the reservoir is drawn from for drinking water at various depths, the receiving stream flow occurs by overtopping of the spillway. Therefore, the receiving stream obtains water from the epilimnion only. Other discharges to Little Yellow Creek downstream of the dam observed during the September, 2006 field visits were dam seepage as well as water treatment plant backflush washwater batch discharge. Samples of lake discharge, flow data, and data sonde investigations were completed in Little Yellow Creek upstream of the WTP discharge outfall.

From the limnology work completed in 2006, this reservoir was found to be thermally stratified. Figure A3 provides data at depth for the lake on September 25. This graph indicates a drastic temperature and dissolved oxygen decline starting at 2 meters in depth. Because of this stratification, the BATHTUB model input data requirements are

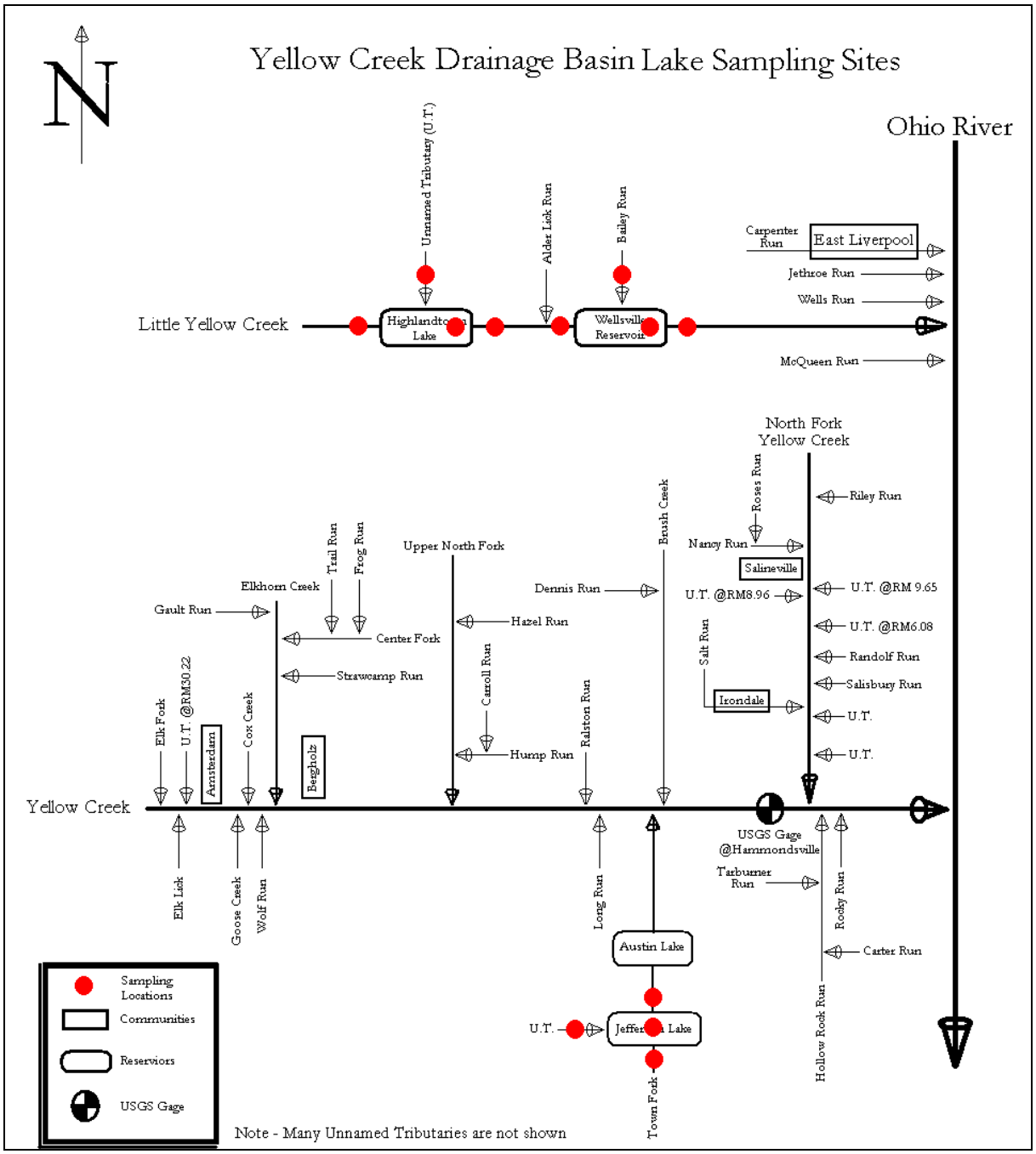


Figure A1. Yellow Creek drainage schematic and lake survey sampling locations

Figure A2. Wellsville Reservoir and Buckeye Water District intake photo taken from spillway 9/6/06

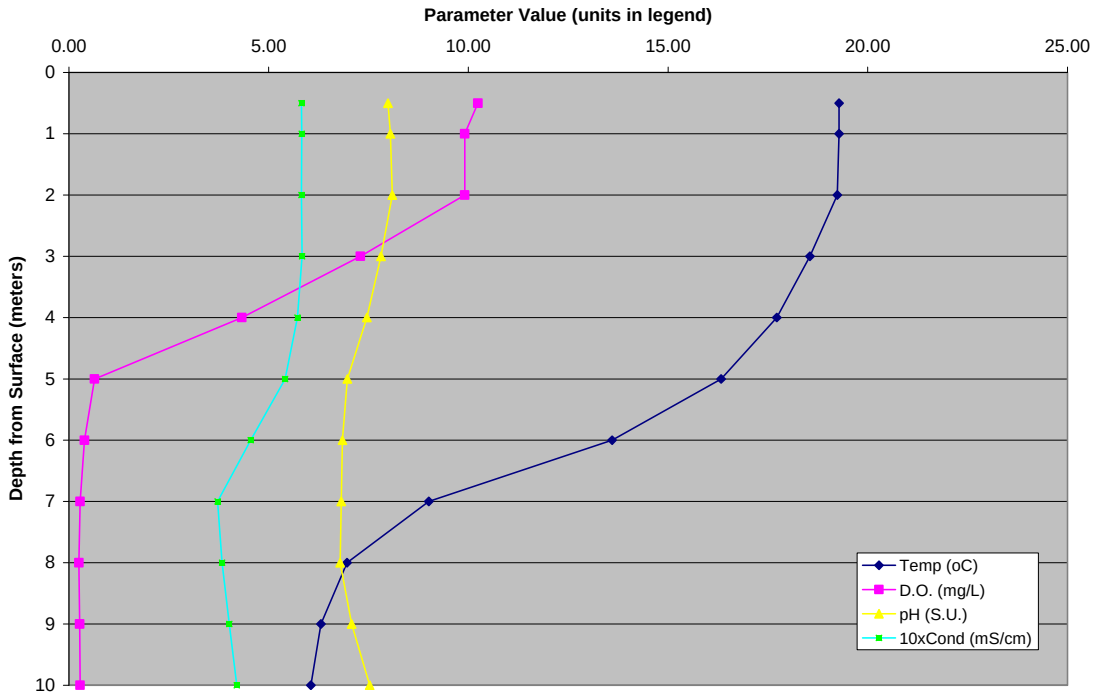


Figure A3. Wellsville Lake 9/25/06 Profile Data

increased. Discussion of the additional requirements are discussed in the BATHTUB modeling section of this report. Bracketed sampling of chlorophyll *a* from influent, reservoir, and effluent data is presented in Figure A4. Each of these samples were filtered and analyzed in triplicate to assure proper quality assurance.

Laboratory analysis provided three chlorophyll *a* results for each sample location; hence, the bar chart indicates three results per site. As can be seen by the small inter-quartile range of each data set, the quality assurance was acceptable for the preparation and performance of the chlorophyll *a* test for all sites of Wellsville Reservoir.

Figure 4 indicates that algae biomass was significantly elevated within the epilimnion and the increase in chlorophyll *a* was carried over into Little Yellow Creek by discharge over the spillway and into the stream channel below. Dilution of the chlorophyll *a* in Little Yellow Creek could have occurred from lower strata lake water discharging downstream through dam seepage observed at the mid-dam height as well as the discharge at the base of the dam from the dam drainage system.

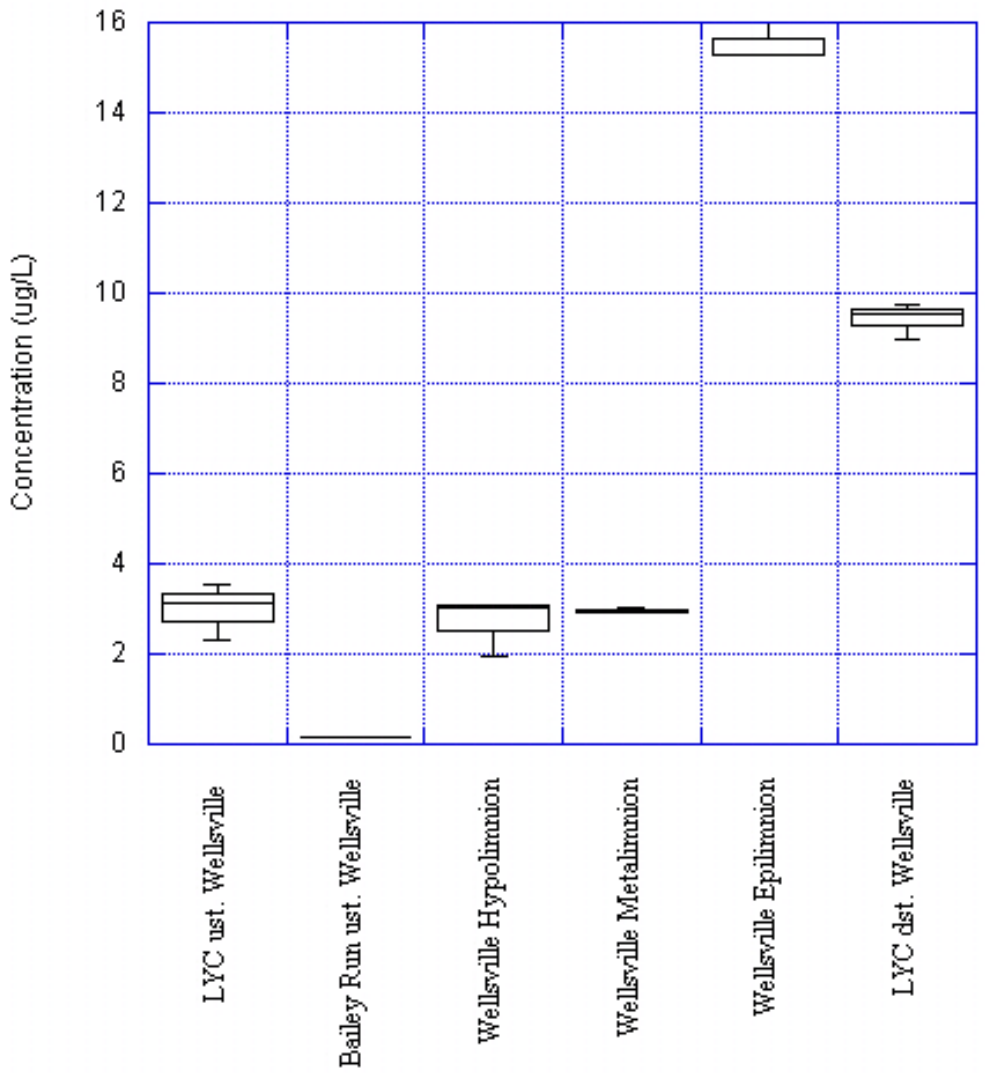


Figure A4. Wellsville Reservoir - influent, reservoir and effluent chlorophyll *a* concentrations, 9/25/06

Highlandtown Reservoir

The upstream impoundment on Little Yellow Creek is Highlandtown Reservoir (dam constructed in 1968) maintained by the Ohio Department of Natural Resources for public boating and fishing. An un-named tributary enters from the north into this lake at RM 10.15. The dam structure is located at RM 8.10 on Little Yellow Creek. Morphometric data for this reservoir can be viewed in the BATHTUB model section of this report. Figure A5 is a photograph of Highlandtown Reservoir taken from the spillway and looking upstream toward the Little Yellow Creek inlet.

Figure A5. Highlandtown Reservoir photo taken from dam on 9/6/06

From limnology work completed in 2006, this reservoir was found to be thermally stratified. Figure A6 provides data at depth for the lake on September 20. This graph indicates a drastic temperature and dissolved oxygen decline at 6 meters in depth. Because of this stratification, the BATHTUB model input data requirements are increased. The additional requirements are discussed in the BATHTUB modeling section of this report.

Bracket sampling of chlorophyll *a* from influent, reservoir, and effluent data is presented in Figure A7. Each of these samples was filtered and analyzed in triplicate to assure proper quality assurance. Laboratory analysis provided three chlorophyll *a* results for each sample; therefore, the bar chart indicates three results per site. All but the Highlandtown Reservoir metalimnion have small inter-quartile ranges indicating appropriate quality assurance and quality control. The metalimnion data is suspect,

possibly because of sample mixing inadequacies. The metalimnion results were not utilized in the BATHTUB modeling input for this reservoir.

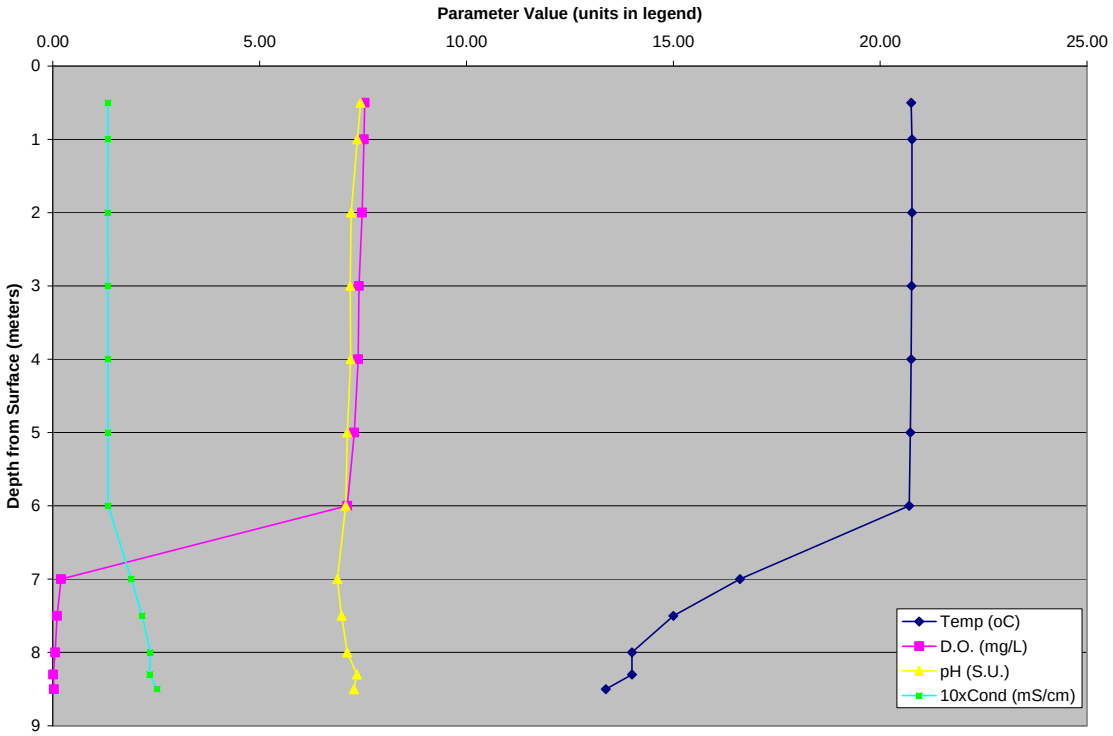


Figure A6. Highlandtown Lake 9/20/06 Profile Data

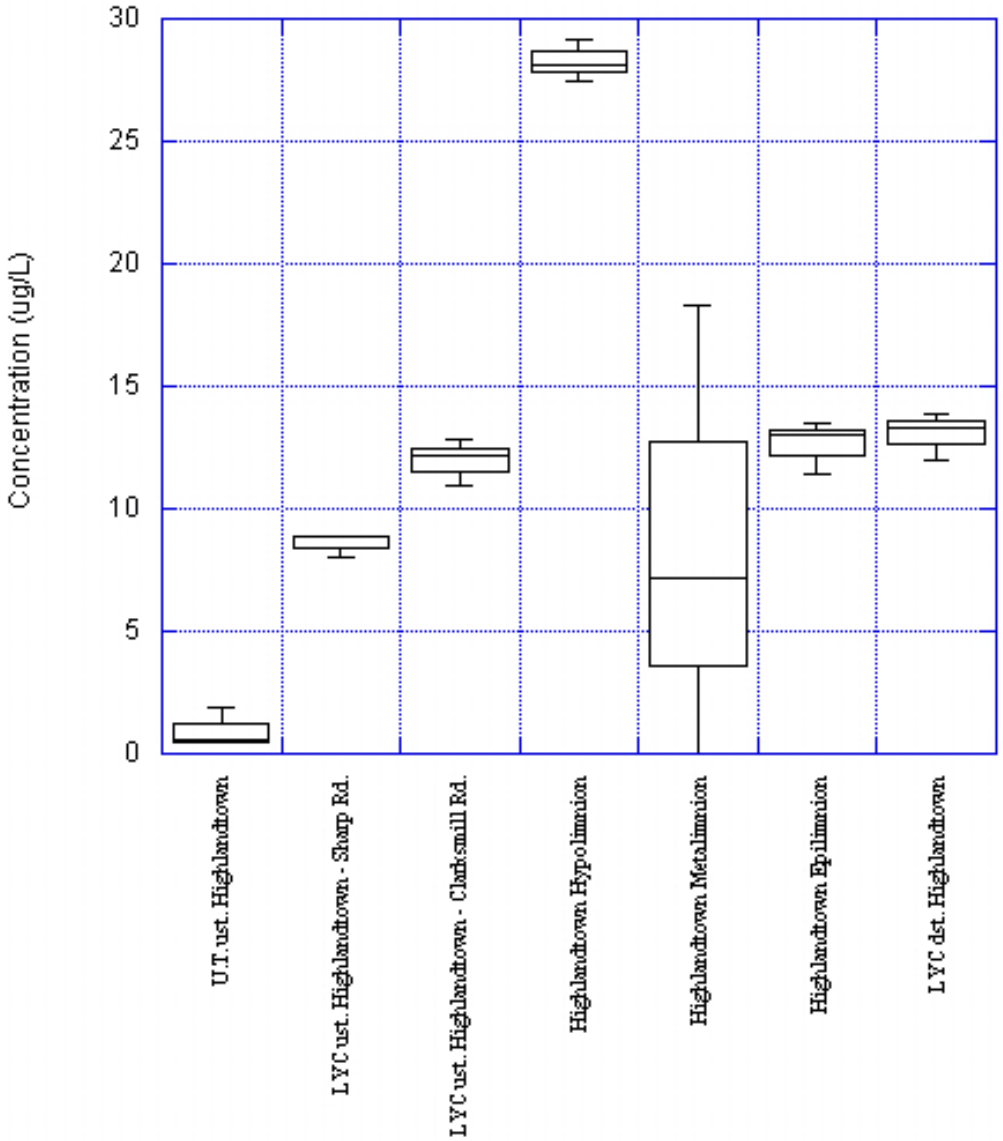


Figure A7. Highlandtown Reservoir - influent, reservoir and effluent chlorophyll *a* concentrations, 9/20/06

A water quality survey of Highlandtown Reservoir was also conducted in 2005 at a single sampling location near the dam. The results of the initial survey are discussed in the TSD report.

Town Fork

Town Fork is a small stream (total length 12.4 miles; drainage area 26 mi^2, average fall of 43.7 feet per mile) that flows into the mainstem of Yellow Creek at RM 8.75 near New Somerset, Ohio. The basin is completely within the Western Allegheny Plateau ecoregion of Jefferson County. It is assigned the 14-digit U.S.G.S. assessment unit

code HUC-05030101-190-010. Land use is mostly agricultural and forested. No current or historical USGS flow monitoring stations are present in the Little Yellow Creek basin.

Jefferson Lake

The discharge from Jefferson Lake is epilimnetic over a concrete ogee type spillway. Figure A8 is a photograph taken on September 1, 2006 of Jefferson Lake from the location of the spillway. Subsurface drainage of the dam structure is discharged at the base of the dam to Town Fork.

From limnology work completed in 2006, this reservoir was found not to be thermally stratified. Figure A9 provides data at depth for the lake on September 20. This graph indicates a uniform temperature throughout depth with a near-bottom sag in dissolved oxygen. Because of the lack of thermal stratification, the BATHTUB model input data requirements are reduced. Discussion of the actual input data needed for BATHTUB modeling is included in the modeling section of this report.

Bracket sampling of chlorophyll *a* from influent, reservoir, and effluent data is presented in Figure A10. Because of the lack of stratification, only epilimnion data was collected and presented. The lake did have a discharge to Town Fork during the sampling event. Each of these samples were filtered in triplicate to assure proper quality assurance. Laboratory analysis provided three chlorophyll *a* results for each sample; therefore, the bar chart indicates three results per site. As can be seen from the small inter-quartile range of each data set, the quality assurance was acceptable for the preparation and performance of the chlorophyll *a* test.

Figure A10 indicates the algae biomass was significantly elevated within the mixed layer of Jefferson Lake and the increase in chlorophyll a was carried over into Town Fork by discharge over the spillway and into the stream channel below. Dilution of the chlorophyll *a* in Town Fork could have occurred from lower strata lake water flowing downstream through dam seepage discharges observed at the base of the dam from the dam drainage system.

Figure A8. Jefferson Lake photo taken from spillway 9/1/06 (beach in background)

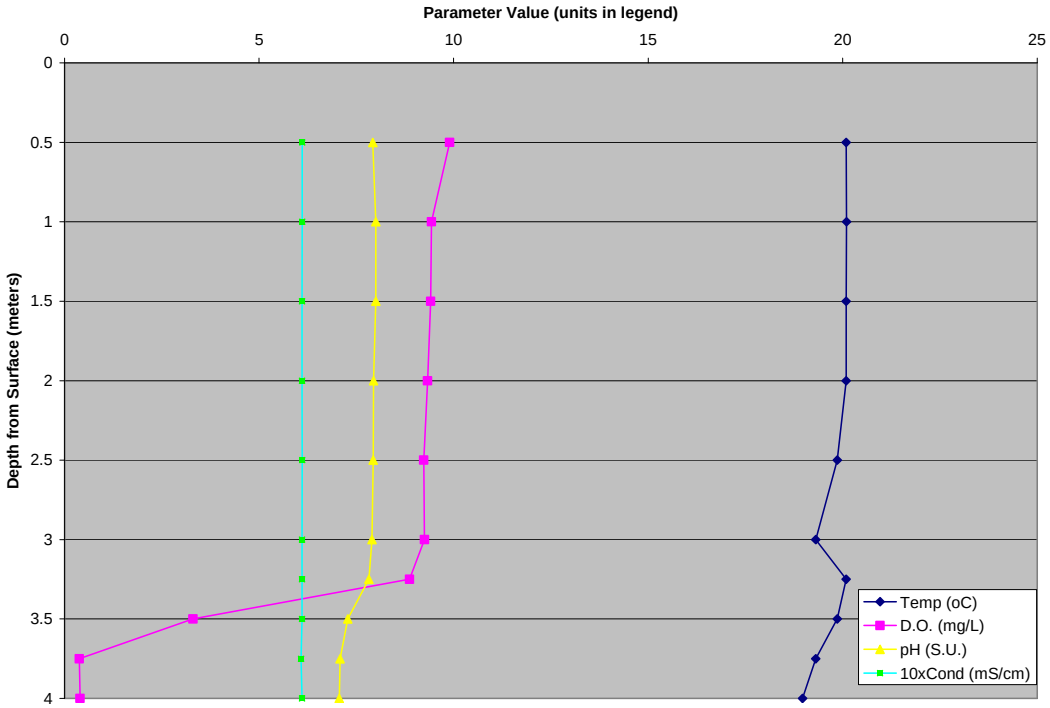


Figure A9. Jefferson Lake 9/20/06 Profile Data

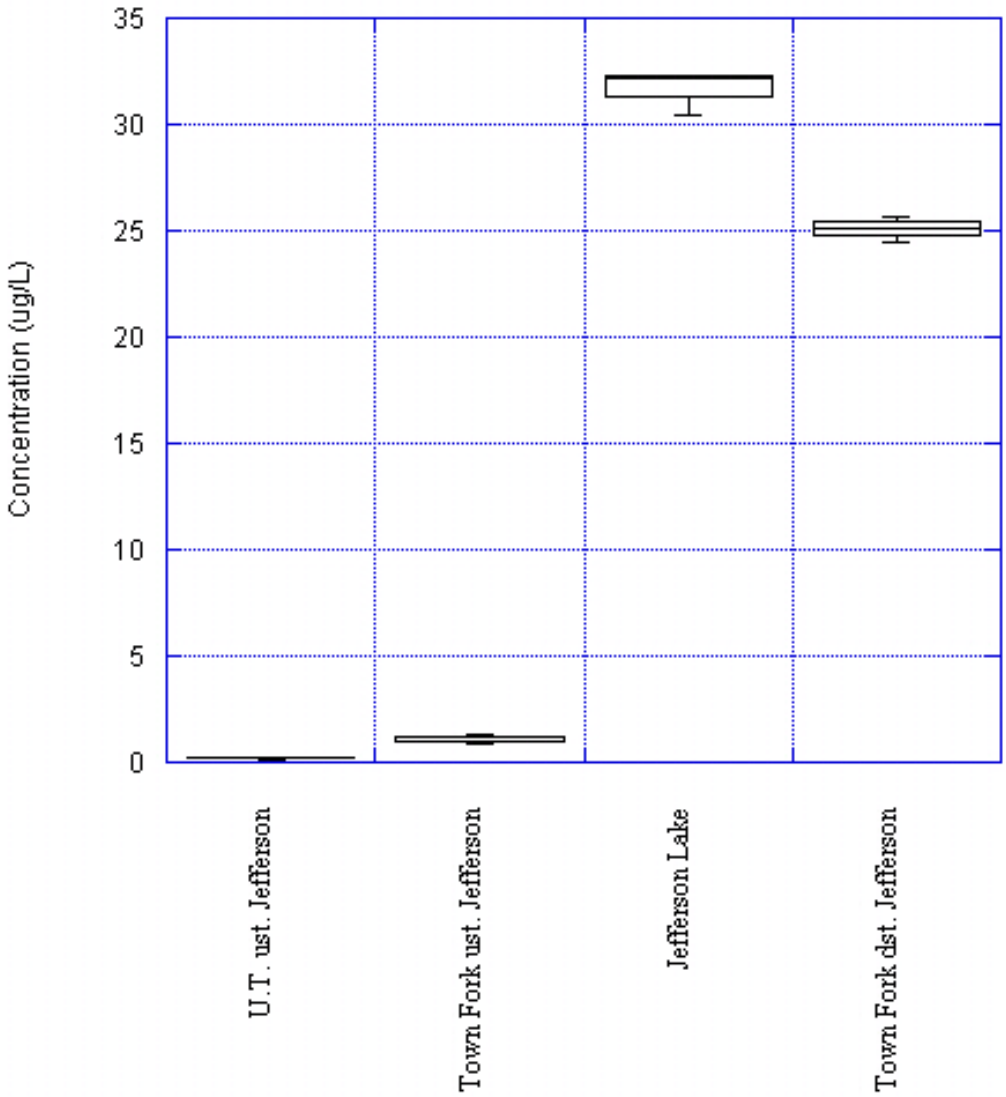


Figure A10. Jefferson Lake – influent, reservoir and effluent chlorophyll *a* concentrations, 9/20/06

Coupled Model Development

GWLF Model Development

GWLF provides a simulation of precipitation-driven runoff and sediment delivery. Solids load, runoff, and ground water seepage are used to estimate particulate and dissolved phase pollutant delivery to a stream, based on pollutant concentrations in soil, runoff, and ground water (USEPA, 2006).

GWLF simulates runoff and stream flow by a water-balance method, based on measurements of daily precipitation and average temperature. Precipitation is partitioned into direct runoff and infiltration using a form of the Natural Resources Conservation Service's (previously Soil Conservation Service [SCS]) Curve Number method (SCS, 1986). The Curve Number determines the amount of precipitation that flows off directly from various land uses and soil types, adjusted for antecedent soil moisture based on total precipitation in the preceding 5 days.

In stream flows may originate from surface runoff from precipitation events or from ground water pathways. The amount of water available to the shallow ground water zone is strongly affected by evapotranspiration, which GWLF estimates from available moisture in the unsaturated zone, potential evapotranspiration, and a cover coefficient. Potential evapotranspiration is estimated from a relationship to mean daily temperature and the number of daylight hours.

The user of the GWLF model must divide land uses into "rural" and "urban" categories, which determines how the model calculates loading of sediment and nutrients. For the purposes of modeling, "rural" land uses are those with predominantly pervious surfaces, while "urban" land uses are those with predominantly impervious surfaces. Monthly sediment delivery from each "rural" land use is computed from erosion and the transport capacity of runoff, whereas total erosion is based on the universal soil loss equation (USLE) (Wischmeier and Smith, 1978), with a modified rainfall erosivity coefficient that accounts for the precipitation energy available to detach soil particles (Haith and Merrill, 1987; USEPA, 2006). For "urban" land uses, soil erosion is not calculated, and delivery of nutrients to the water bodies is based on an exponential accumulation and washoff formulation. All nutrients loaded from urban land uses are assumed to move in association with solids. Nutrient loads from rural land uses may be dissolved (in runoff) or solid-phase (attached to sediment loading as calculated by the USLE).

The Yellow Creek watershed is predominantly rural with predominantly forested land use. Only very small fractions of the watershed are cropland. Therefore, erosion is considered to be an insignificant source of total phosphorus loading. As such, this source of nutrients was not considered in the nutrient model.

GWLF requires three input files to simulate runoff and pollutant loads from each subwatershed. The weather file contains daily values of precipitation and average temperature. The nutrient file contains nitrogen and phosphorus concentrations of

groundwater and runoff as well as build-up/wash off rates from urban areas. The transport file contains land use areas and parameters for estimating runoff, erosion, and evapotranspiration. This section of the report describes the modeling assumptions used to develop these three files for existing and natural conditions.

Transport Data

Land use, soil and weather data are critical components of hydrology functions of GWLF. The National Land Cover Dataset is used as the land cover resource for this study and is described more fully in the Land Use section of this report. Evapotranspiration values from the GWLF manual were utilized for this data since no actual data source was available.

Subwatershed Delineation

The first step in developing the transport files was to delineate sub-watersheds corresponding to the listed segments and major stream confluences. Each lake sub-watershed was outlined utilizing visual determination of topographic map drainage patterns and GIS spatial analysis. The new watershed was developed by clipping a 30-meter digital elevation model of the watershed and the National Hydrography Dataset stream coverage. The results of this effort are presented in Figure A11. This figure presents the drainage areas and the reservoir locations within the Yellow Creek Watershed. The Wellsville Reservoir includes the drainage from Highlandtown Reservoir as well as additional watershed area. In Figure A11, these areas are shaded differently; however, the Wellsville drainage is comprised of both areas.

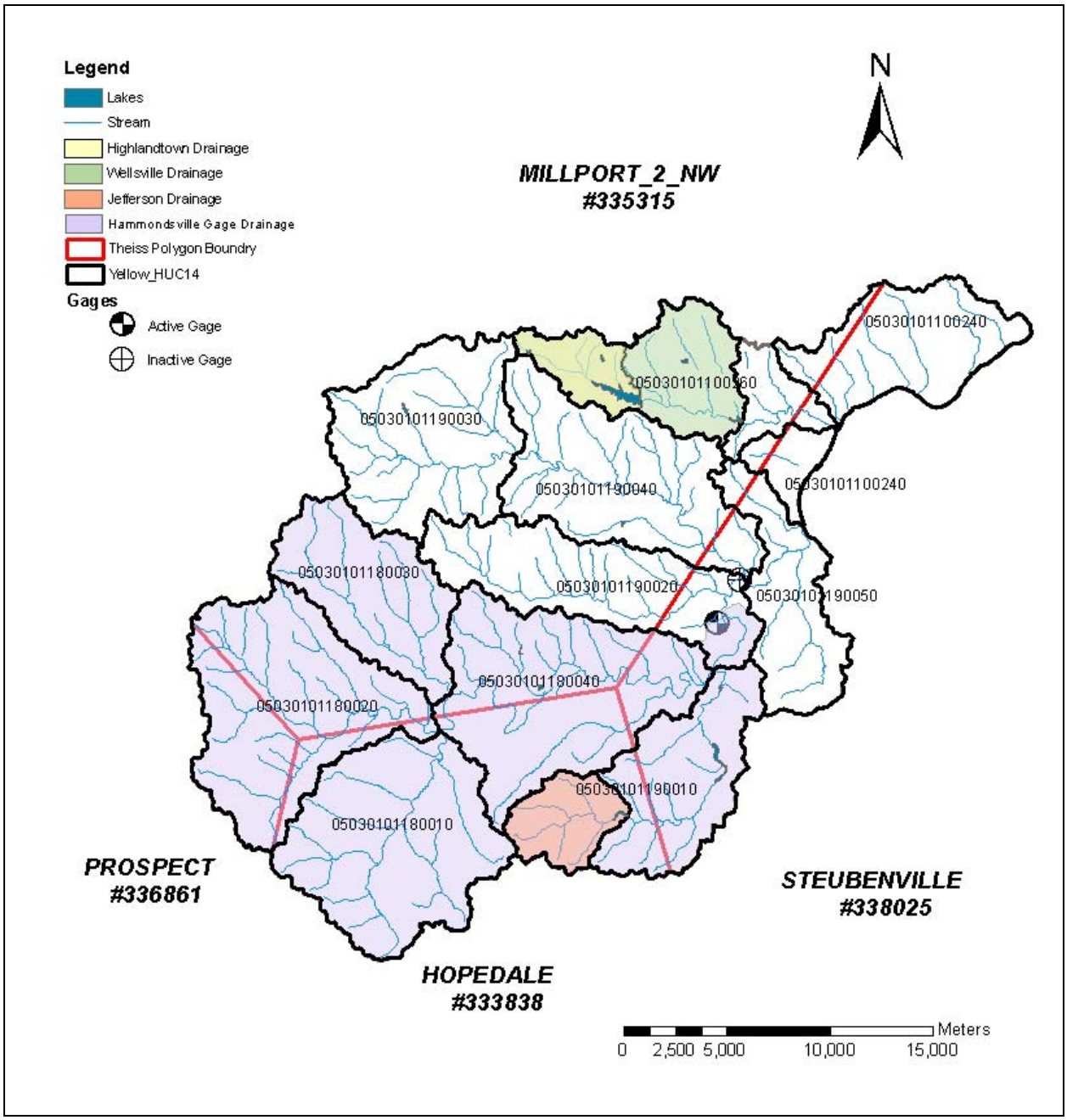


Figure A11. Yellow Creek watershed emphasizing Hammondsville gage and lake drainages

Land Use in the Yellow Creek Watershed

Existing land use and land cover in Highlandtown Reservoir, Jefferson Lake, and Wellsville Reservoir were determined from satellite imagery, digital aerial photography, and geographic information system (GIS) layers. Digital land use/land cover data were obtained from the National Land Cover Dataset (NLCD). The NLCD is compiled from Landsat ™ satellite imagery acquired between 1991 and 1993. The NLCD is a consistent representation of land cover for the conterminous United States

generated from classified 30-meter resolution Landsat thematic mapper satellite imagery data.

The NLCD is classified into urban, agricultural, forested, water, and transitional land cover subclasses. NLCD information is reclassified to agree with the land use categories of GWLF. No significant changes in land use in these watersheds have occurred since the land use data was collected; therefore, no adjustment to this GIS coverage was attempted. Figure A12 indicates the final land use coverage and the data is summarized in Table A2.

Runoff Curve Numbers

The GWLF model uses the curve number method to estimate runoff from each land use area. Area weighted curve numbers were developed for each subwatershed and land use based on the reported NRCS soil hydrologic groups. Soil hydrologic groups were used to account for the different infiltration rates of different soil types (e.g., higher infiltration for sands compared to clays).

The direct runoff fraction of precipitation in GWLF is calculated using the SCS Technical Release 55 (TR55) method literature based on land-use and soil hydrologic group (SCS, 1986). This method utilizes curve numbers for various land uses and soil characteristics which vary from 25 for undisturbed woodland with permeable soils, to, 100, for essentially impervious surfaces. Land uses with higher curve numbers are assumed to have more surface runoff than those with lower curve numbers. The hydrologic soil group was determined from available soils data and curve numbers were calculated for each land use category/soil hydrologic group. Area weighted curve numbers assigned for the lakes watersheds are summarized in Table A2.

Evapotranspiration Cover Coefficients

The portion of rainfall returned to the atmosphere is determined by GWLF based on temperature and the amount of vegetative cover. For urban land uses, the cover coefficient was calculated as (1 - impervious fraction). For all other land uses it was assumed that land had vegetative cover during the growing season (cover coefficient = 1) and limited vegetative cover during the dormant season (cover coefficient = 0.3). The cover coefficients were area-averaged to result in one coefficient value for the growing season (March-October) and one for the dormant season (November-February) as advised by the GWLF manual.

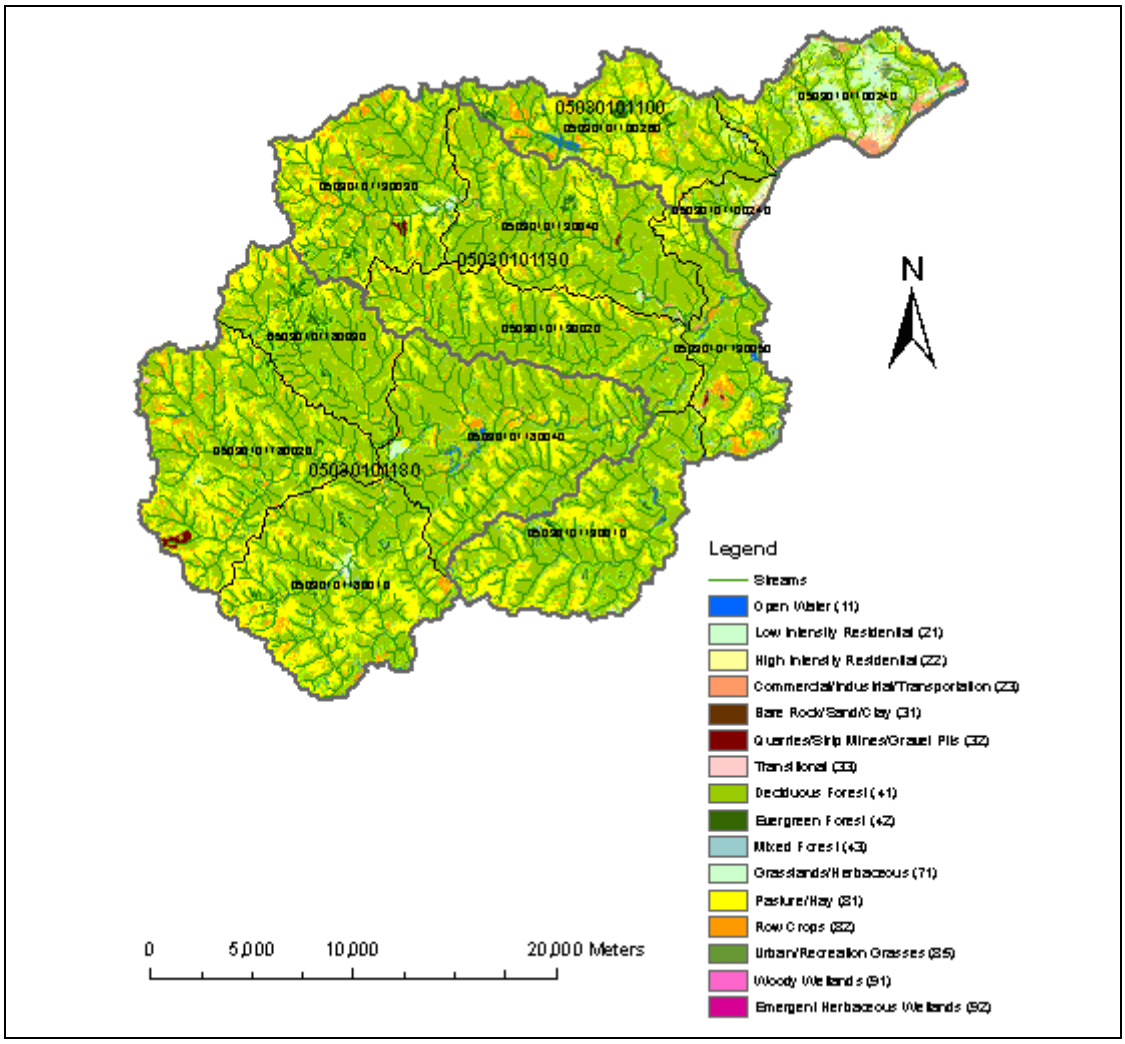


Figure A12. Land uses in the Yellow Creek and Little Yellow Creek Basins

Table A2. Area and SCS curve number method CN values of basin drainages

	Highlandtown Reservoir		Jefferson Lake		Wellsville Reservoir		Above Hammondsville Gage	
	Area (hectares)	Weighted CN	Area (hectares)	Weighted CN	Area (hectares)	Weighted CN	Area (hectares)	Weighted CN
Water	7.3	100.0	0.6	100.0	8.7	100.0	425.6	100.0
Built-up	8.4	90.0	14.3	79.3	26.7	90.5	265.5	89.9
Forest	98.9	70.0	122.0	97.5	247.1	70.3	26526.8	70.8
Pasture	21.8	76.1	31.7	73.8	99.6	82.8	8758.4	75.7
Row Crop	2.1	84.0	11.0	71.5	24.9	76.4	2228.7	82.7
Total	138.4		179.7		407.0		38205.0	

Soil Water Capacity and River Recession

Water stored in soil may evaporate, be transpired by plants, or infiltrate to ground water through the root zone. The amount of water that can be stored in soil (the soil water capacity) varies by soil type and rooting depth. Based on soil water capacities reported in the STATSGO database, soil types present in the watershed, and GWLF user's manual recommendations, a GWLF soil water capacity of 10 cm was used.

The GWLF model has three subsurface zones: a shallow unsaturated zone, a shallow saturated zone, and a deep aquifer zone. Behavior of the second two stores is controlled by a ground water recession and a deep seepage coefficient. The recession coefficient was set to 0.01 per day and the deep seepage coefficient to 0.

Weather Data

The GWLF model uses daily values of precipitation and average temperature to estimate water inputs to the system as well as potential evapotranspiration rates. A ten year record of weather data from the National Midwest Regional Climate Center stations named Millport_2_NW (#335315), Steubenville (#338025), Hopedale (#333838), and Prospect (#336861) were used as GWLF input. Figure A11 indicates the lake and gage drainage areas as well as the weather station Theissen polygons. The average temperature of the daily average temperature readings were used as well as a weighted average rainfall utilizing the Theissen polygon method. Additional data from these stations was utilized for the BATHTUB model and will be discussed in subsequent sections of this report.

Nutrient Data

The GWLF model simulates nutrient runoff from rural land uses and washoff from urban land uses. In addition, soil is assumed to carry sorbed nutrients; groundwater also serves as a component of the total load. Because site-specific data were not available, soil nutrient concentrations are based on spatial distributions provided in the GWLF manual. Both the soil nitrogen and soil phosphorus concentrations were set to the average of the suggested range for the geographic area during model calibration. The soil nitrogen concentration is estimated to be 1400 mg/kg and the soil phosphorus concentration is estimated to be 1320 mg/kg. Nutrient modeling methods for the nutrient load allocations are provided in Table A3.

Table A3: Summary of nutrient TMDL development

Development step	Source	Method
Existing load	surface runoff	GWLF nutrient modeling and field data comparison
	ground-water	GWLF nutrient modeling
	point source	Discharger permit limit used as phosphorus loading
	HSTS	Population served by failing HSTS estimated via GIS and county Health Departments. Phosphorus load based upon population estimate and a per capita loading rate.
Calculation of loading capacity	-	Product of the annual discharge volume from each sub-basin (GWLF hydrology) and the phosphorus target concentration.
Allocation	surface runoff	LA is equal to the sum of all WLAs and the MOS subtracted from the assimilative capacity.
	Point Sources	Product of design flow rate and technology based effluent limitation of 1.0 mg TP/ml (or less depending on plant type).
	natural runoff	The expected background phosphorus load is determined based on running GWLF considering all lands to be unmanaged.
	HSTS	Septic systems are allocated a phosphorus load of zero.
	MS4	MS4s are allocated a portion of the total LA. MS4s allocations are the product of the percentage of the sub-basin area occupied by MS4s and the sub-basin surface runoff allocation.
	MOS	Five percent of the assimilative capacity is reserved for the margin of safety.

Nutrient Concentrations for Rural Land Uses

GWLF requires a dissolved phase concentration for surface runoff from rural land uses. Particulate concentrations are taken as a general characteristic of area soils, determined by bulk soil concentration and an enrichment ratio indicating preferential association of nutrients with the more erodible soil fraction and not varied by land use. Dissolved and solid phase nutrient concentrations in runoff from each land use were set to GWLF default values and are summarized in Table A4. Because site-specific data were not available, default values were chosen to estimate relative contributions from the pollutant sources.

Table A4. Default values used in the GWLF model for dissolved and solid phase nutrient concentrations for rural land uses

GWLF Land Use Group	Nitrogen		Phosphorus	
	Dissolved Phase (mg/L)	Solids Phase (mg/kg)	Dissolved Phase (mg/L)	Solids Phase (mg/kg)
Forest	0.25	3000	0.01	1276
Pasture	3.00	3000	0.25	1276
Row Crop	2.90	3000	0.26	1276
Barren/Transitional/Mines	0.65	3000	0.06	1276
Wetland	0.25	3000	0.01	1276

Buildup Washoff Rates from Urban Land Uses

GWLF simulates nutrient loads from developed land uses through a buildup/washoff formulation. Buildup rates for nitrogen and phosphorus are based on weighted averages of pervious and impervious default values suggested in the GWLF manual (Table A5).

Table A5. Pollutant buildup rates for urban land uses

Land use	Nitrogen build up (kg/ha-d)	Phosphorus build up (kg/ha-d)
Commercial/Industrial/Transportation	0.083	0.009
Low density residential	0.030	0.003

Groundwater Nutrient Concentrations

Groundwater nutrient concentrations were based on baseflow measurements reported in the GWLF manual for various levels of forested and agriculturally developed watersheds. Completely forested watersheds have values of 0.07 mg-N/L and 0.012 mg-P/L. Primarily agricultural watersheds have values of 0.71 mg-N/L and 0.104 mg-P/L. Intermediary values are also reported. Because the overwhelming majority of the land use for the watersheds studied were forest, concentrations for primarily forested areas were used as 0.34 mg-N/L and 0.013 mg-P/L.

Septic System Loading Data

The GWLF model requires an estimation of population served by septic systems to generate septic system nutrient loading rates. The number of home sewage treatment systems (HSTS) were determined via GIS analysis of census data. The number of HSTS in each 14-digit HUC is estimated based upon 1990 and 2000 census demographic information and adjusted to conditions expected in 2006 from population trends provided by the Ohio Department of Development. The Jefferson County Health Department estimated approximately 80 percent of the total number of systems in the Yellow Creek watershed were failing. A failing system is assumed to short circuit the adsorption field and plant uptake zones and discharge directly to surface waters. The population served by normal and failing systems is summarized by subwatershed in Table A6. HSTS pollutant loads are estimated as the product of the number of persons

served by failing systems in each subwatershed, a per capita wastewater flow-rate and representative wastewater-quality information.

Table A6. Population of lake drainage basins from GIS analysis and Ohio Department of Development population trend predictions

	Population of Year		
Lake Drainage	2005	2006	Houses
Highlandtown	227.6	226.9	92
Jefferson	487.8	458.9	206
Wellsville	1260.1	1256.3	508
@Gage	2382.1	2373.3	1005

Daily per capita mass loading rates and plant uptake rates for normal and failing systems were set to GWLF default values and are summarized in Table A7. Using the default parameters suggested by the manual allows for an estimation of pollutant loading relative to other sources in the watershed. An overall failure rate of 80% is estimated by the Jefferson County Health Department. This value was used to simulate the failed and normally functioning systems within the watersheds.

Table A7. Septic system loading rates and plant uptake rates

Parameter	Nitrogen	Phosphorus
Loading Rate from Septic Tank Prior to Drainfield Treatment and Plant Uptake (grams/capita/day)	12	1.5
Growing Season Plant Uptake Rate (grams/capita/day)	1.6	0.4
Dormant Season Plant Uptake Rate (grams/capita/day)	0	0
Percent Additional Treatment in Soil Adsorption Field of Normal System (%)	0	100
Percent Additional Treatment in Soil Adsorption Field of Failing System (%)	0	0

Note that normal and failing systems are assumed to have the same tank effluent loading rates. In a normally functioning system, tank effluent is distributed over a soil adsorption field. Phosphorus is assumed to have the capability to be completely adsorbed to the soil particles and some nitrogen is taken up by plant roots during the growing season. The failing system bypasses both of these treatment mechanisms and is assumed to discharge pollutants at rates equivalent to the tank effluent values. This appears to be a valid assumption for the watershed studied because the overwhelming majority of homes are in very close proximity to receiving streams.

Point Sources

The Ohio EPA point source database was used to determine the permitted point source discharges existing in the Highlandtown Reservoir, Jefferson Lake, and the Hammondsville USGS gage drainages. The Sunrise Mobile Home Park discharges under NPDES permit #3PV00094*AD to a tributary of Yellow Creek below the Highlandtown Reservoir but above the Wellsville Reservoir. The design flow of this small WWTP is 10,000 gpd; however, since 2002, the flow data indicates they discharge 5050 gpd on average. Treatment processes include extended aeration, sand filter, trash trap, and chlorination/dechloration. No phosphorus limit is imposed on the plant and as such no data was available to characterize the loading of this discharge. Since the flow is relatively low and the plant operates as exteneded aeration with sand

filtration, no total phosphorus loading is allocated to this WWTP discharge. No other centralized wastewater treatment systems discharge was found upstream of the three reservoirs or the Hammondsville gage.

GWLF Calibration

Calibration refers to the adjustment or fine-tuning of modeling parameters to reproduce observations. Hydrologic calibration precedes water quality calibration because runoff is the transport mechanism by which nonpoint pollution occurs. In an ideal situation, calibration is an iterative procedure of parameter evaluation and refinement as a result of comparing simulated and observed values of interest and is based on several years of simulation to evaluate parameters under a variety of climatic conditions.

Limited flow and water quality data were available on the lake watershed drainages. Therefore, calibration of modeled hydrology and nutrients were completed at the USGS gage in Hammondsville or Little Yellow Creek. Daily stage record was available for this site and very useful in calibration. Default values were used in GWLF for modeling parameters in which no site specific information was available. A comparison of the simulated and observed data is presented below.

Hydrologic Calibration

The GWLF model predicts flow volumes from runoff at monthly intervals. Simulated flows were compared to observed discharge at the USGS Hammondsville Gage during model calibration. Daily flows reported from April 1, 1998, through March 31, 2007, were summed by month for comparison with the GWLF simulation. Figure A13 provides the trend of monthly total flow in centimeters for the watershed area.

This figure also compares the known monthly flow volumes observed at the gage to the calibrated GWLF estimates. GWLF was calibrated by adjusting the evapotranspiration in an iterative approach until the covariance was maximized and the predicted/observed statistic was most nearly the value of one. Twenty eight calibration runs were completed to obtain an r^2 value of 0.7128 and predicted/observed of 1.000153. As can be observed by Figure A13 and from the values of the comparison statistics, the model simulates the hydrology very well.

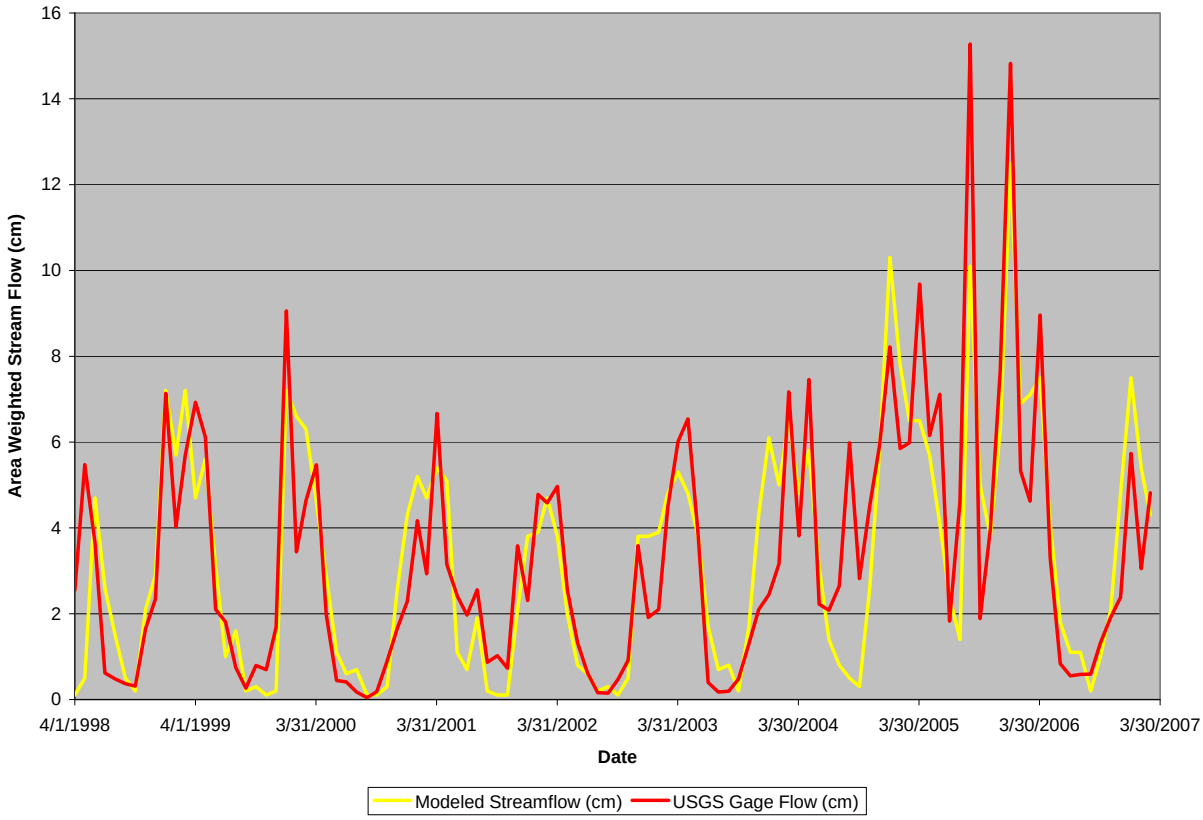


Figure A13. Yellow Creek @Hammondsville gage GWLF hydrology simulation result after calibration (Gross Monthly Flow, 28 calibration runs, r^2 = 0.7128, Predicted/Observed = 1.000153)

Nutrient Verification

During the 2005 and 2006 survey season of the Yellow Creek watershed, Ohio EPA obtained seven samples from Yellow Creek at the Hammondsville Gage. This data was utilized to compare the GWLF ten year model run results to actual nutrient data. GWLF simulates the average monthly concentration for the modeled timeframe. Field data is collected as daily grab samples. Therefore, calibration could not be completed, but comparison of the average monthly concentrations and the daily values could be accomplished.

The most recent simulated average monthly concentrations are compared to daily observed concentrations are shown in Figure A14 for total nitrogen and Figure A15 for total phosphorus. In both cases the average simulated monthly concentrations are similar in value with the observed concentrations. Variability does arise from observed to modeled values for a variety of reasons including assumptions in land use sources of nutrients and other modeling assumptions used to simulate the Yellow Creek drainage area. In addition, a relatively small number of daily samples used to compare monthly modeled concentrations can create variability when attempting to compare these data sets.

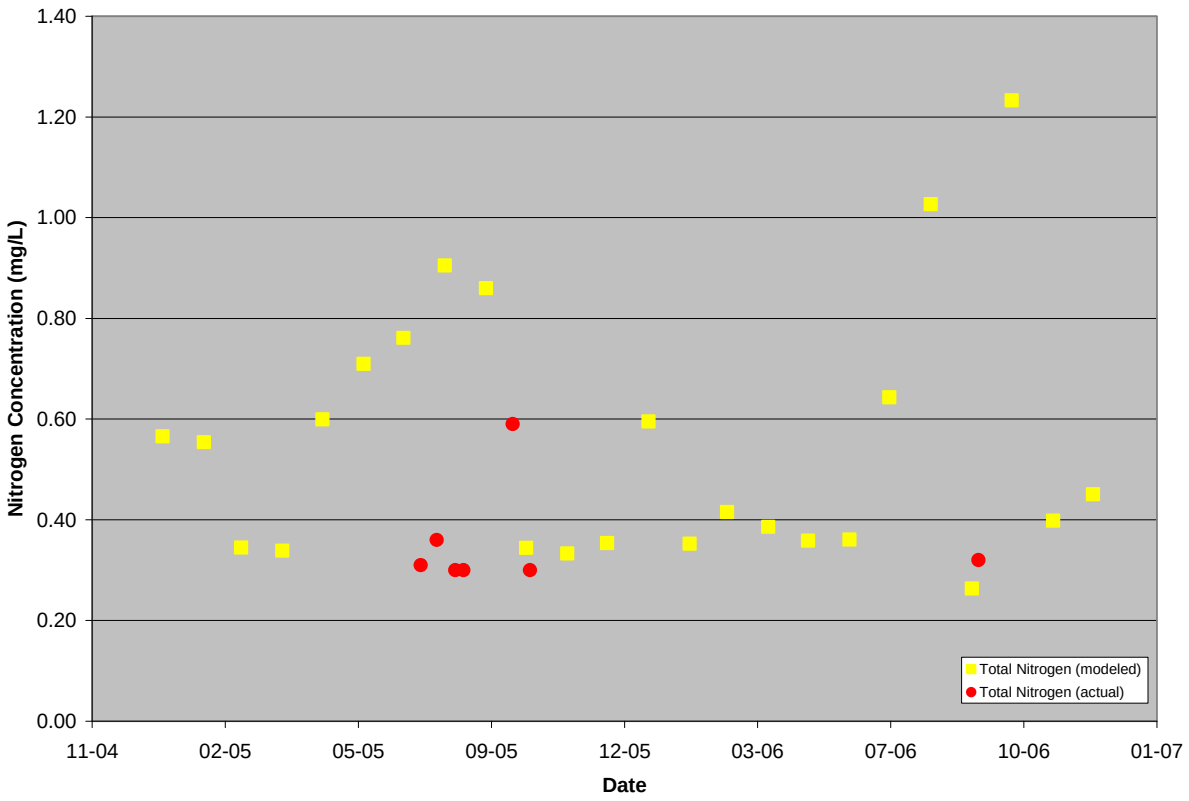


Figure A14. Yellow Creek @ Hammondsville USGS gage GWLF nitrogen modeling result comparison to true data after model calibration

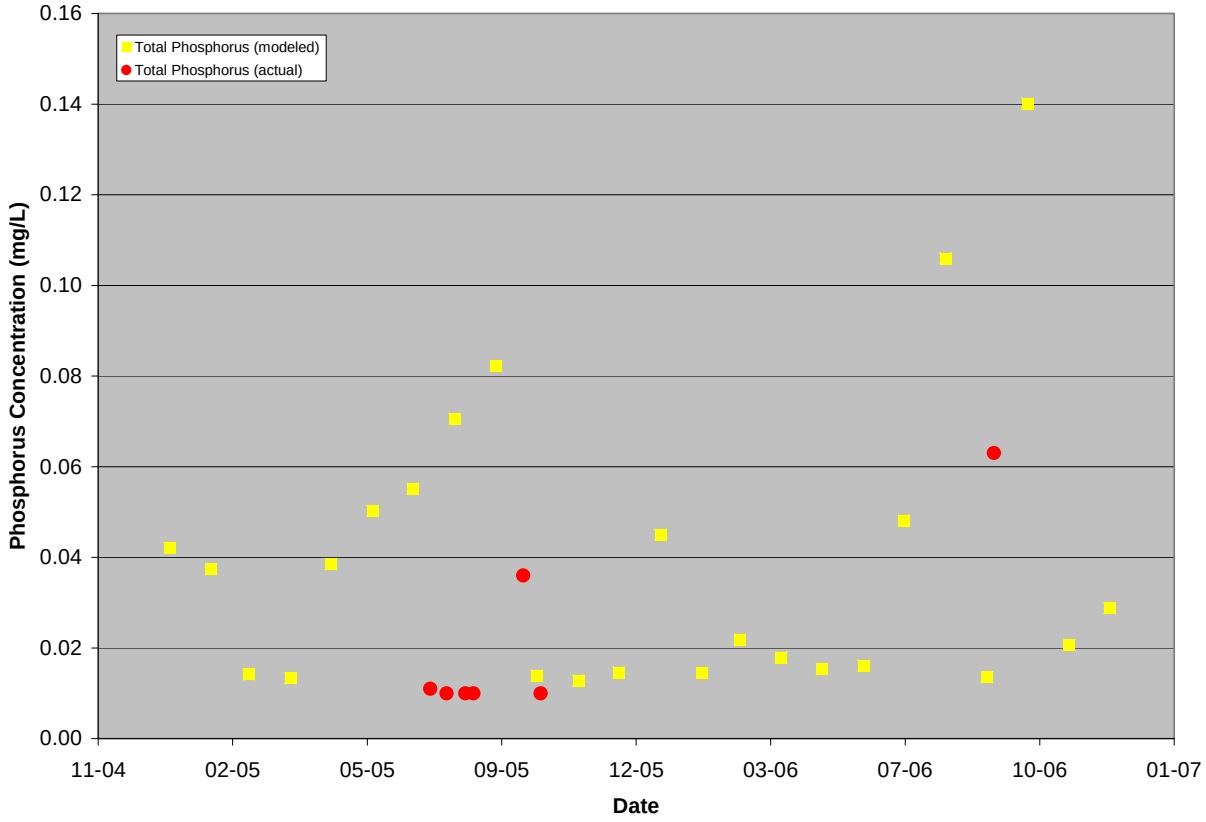


Figure A15. Yellow Creek @ Hammondsville Gage GWLF total phosphorus result comparison after calibration

BATHTUB Model

The USACE BATHTUB model (Walker, 2004) was utilized to simulate nutrient response in Jefferson Lake, Highlandtown Reservoir, and Wellsville Reservoir based on input from the GWLF model for the various scenarios. BATHTUB performs steady-state water and nutrient balance calculations in a spatially segmented hydraulic network, which accounts for pollutant transport and sedimentation (USEPA, 2006). Eutrophication-related water quality conditions (e.g., phosphorus, nitrogen, chlorophyll *a*, and transparency) are predicted using empirical relationships previously developed and tested for reservoir applications (Walker, 1987).

BATHTUB has three primary input interfaces: global inputs, lake morphology, and watershed loading. Compared to other reservoir models, the BATHTUB model requires a moderate amount of site-specific data to configure and calibrate. Input data includes atmospheric loads of nutrients, tributary flows and concentrations, and global parameters such as evaporation rates and annual average precipitation. For lakes with low phosphorus residence times, the recommended critical condition is the period of increased sunlight, temperature and algal growth from May through September. Due to the effects of settling, the phosphorus residence time is often somewhat longer than hydraulic residence times.

The BATHTUB model was determined to be appropriate for use in this modeling effort because it addresses the parameters of concern and has been used previously for reservoir TMDL applications. The use of more sophisticated lake models was not warranted based on the very limited water quality data with which they could be calibrated.

Global and Lake Morphometric Data

The global inputs for each lake represent water balance contributions of precipitation and evaporation and phosphorus input from atmospheric deposition. Rainfall data was obtained from Midwest Regional Climatic Center weather stations in the local area of each waterbody. The area weighted Theissen polygon method was used to obtain average precipitation for each lake drainage. Figure A11 indicates the lake drainages, weather stations, and the Thiessen polygon boundaries. Solar radiation and barometric pressure were obtained from the Ohio Agricultural Research Development Center (OARDC) station in Wooster, Ohio. Seasonal lake evaporation was calculated using Penman's equation with a standard pan coefficient of 0.78, in conjunction with OARDC data. The default atmospheric phosphorus deposition rate suggested in the BATHTUB model (30 $kg/km^2/yr$) was used in the absence of site-specific data.

The BATHTUB model requires basic lake morphometric data to assess residence time, net flow rate, and potential euphotic depth. Morphometric data, as presented in Table A8, was collected on-site, retrieved from GIS analysis, and obtained from the Ohio Department of Natural Resources dam safety inventory database. Because the lakes are fairly uniform and no ponding occurs along the downstream reaches of the tributaries,

segmentation for modeling was not completed. The model was run assuming normal pool elevation.

Atmospheric Deposition to Lakes

Atmospheric deposition can contribute a significant proportion of nutrient loads directly to a lake surface, particularly when the ratio of watershed area to lake surface area is low. The watershed to lake area ratios for Highlandtown Reservoir (1:2), Jefferson Lake (1:23), and Wellsville Reservoir (1:51) vary significantly. Highlandtown reservoir is most likely affected by direct atmospheric deposition of phosphorus. For Jefferson Lake and Wellsville Reservoir, the surface area to drainage area ratio is relatively high; therefore, atmospheric deposition is not likely a major source of phosphorus loading. BATHTUB default values in units of $^{mg}/_{m^2 * yr}$ for total nitrogen (1000), inorganic nitrogen (500), total phosphorus (30) and ortho-phosphate (15) were used in the model simulation for each watershed.

Table A8. Highlandtown Reservoir, Jefferson Lake, and Wellsville Reservoir Morphometric Data

Lake Parameter	Highlandtown Reservoir	Jefferson Lake	Wellsville Reservoir	Units
Drainage Area	138.4	179.7	407.0	hectares[1]
Lake Area	70.1	7.97	8.00	hectares[2,3]
Volume	333.0	23.3	33.3	hectare-meter[2,3]
	2700	189	270	acre-feet[2,3]
Maximum Depth	9.0	4.4	11.0	meters
Average Depth	4.8	2.9	4.2	meters
Relative Depth*	0.010	0.014	0.034	dimensionless
Development of Volume	1.59	1.98	1.14	dimensionless
Fetch	2556	527.1	480.2	meters[4]
Maximum Width,Perpendicular to Fetch	586.7	141.9	180.5	meters[4]
Shoreline Length	6794.67	1961.8	1816.69	meters[5]
Development of Shoreline	2.29	1.96	1.81	dimensionless[5]
Mean Annual Flow	55.5	92.1	160.9	hectare-meter[6]
	450.29	746.81	1304.15	acre-ft[6]
Mean Modeling Season Flow**	55.5	39.9	44.0	hectare-meter[6]
	450.3	323.6	356.8	acre-ft[6]
Average Hydraulic Residence Time	71.9	1.34	2.48	months[3,6]
Average Seasonal Surface Overflow Rate**	0.79	2.09	2.29	m/year[3,6]
Phosphorus Residence Time	10.6	0.93	0.80	months
BATHTUB Modeling Season	12	5	5	months
Phosphorus Turnover Ratio	1.1	5.4	6.3	#/season

*maximum depth / lake diameter, if the lake area was a circle. Most lakes < 0.02.
** Season for Highlandtown is 12 month year, Jefferson and Wellsville season is May through Sept.
[1] ArcGIS result
[2] ODNR Inventory Sheets
[3] Normal pool (principal spillway)
[4] ArcGIS using USGS 1:24000 topographic map
[5] National Hydrography Dataset (ArcGIS) values
[6] GWLF results

Inorganic Nutrient Fractions
BATHTUB requires an estimate of inorganic nutrient fractions for all loads to the lake. The inorganic nutrient fractions for the watershed loads were approximated from the ratios of dissolved nutrient load to total nutrient load determined during the sampling events in 2006. Atmospheric and groundwater recharge loads were assumed 100 percent inorganic.

Light Penetration in Lakes
The BATHTUB model requires average Secchi depth to determine the nonalgal turbidity in the lake. A Secchi depth reading was collected by Ohio EPA during the limnology visit to the respective lake in 2006. The readings collected were 1.45, 1.80, and 1.41 meters for Highlandtown Reservoir, Jefferson Lake, and Wellsville Reservoir, respectively. These actual readings were utilized to calibrate BATHTUB for Secchi visibility. The calibrated model was utilized to model the Secchi visibility for each lake from 1997 to 2006.

BATHTUB Calibration and Setup

The BATHTUB model for each lake was calibrated utilizing data collected during the sampling event at each water body in 2006. The model allows calibration by total phosphorus and/or chlorophyll *a*. Both parameters were utilized for calibration of each lake model. BATHTUB offers the user several choices for nutrient sedimentation modeling which affects the predicted in-lake concentrations from loading rates and residence time.

For all three lake watersheds, the single basins modeled in GWLF represented the tributary inputs. BATHTUB requires that lakes with a phosphorus turnover ratio of less than two per year must be modeled throughout an entire calendar year. Lakes with greater turnover ratios must only be modeled from May to September of each year. Turnover rations for the modeled lakes can be found in Table A9. For Jefferson Lake and Wellsville Reservoir, the monthly loads were summed over the May to September period, and average monthly flows were also taken from the GWLF output for this time period. For Highlandtown Reservoir, a complete calendar year loads were summed. Average phosphorus concentrations were determined by dividing the gross nutrient mass by the gross volume of flow during this modeling season. Table A10 indicates the selected BATHTUB options chosen during the BATHTUB modeling. Individually for each lake, the results of the GWLF model for each modeling season period from 1997 to 2006 were applied to BATHTUB to evaluate water quality/trophic conditions. BATHTUB was run ten times, using non-point source loads from each of the years. The BATHTUB model was then used as a diagnostic tool in order to estimate the phosphorus load reductions required to achieve an annual average chlorophyll *a* target of about 20 ug/L (equivalent to a Carlson's TSI of 60). The calculated seasonal loads reflect the effects of varying climatic conditions observed during these years. Therefore, an average value of these years was set as the target loading to meet the in-lake water quality standards of about 20 ug/L chlorophyll *a*.

Table A9. Algorithms used within BATHTUB to simulate water quality in modeled lakes

Process	Algorithm number	Algorithm description
Phosphorus balance	1	Second order, available phosphorus
Nitrogen balance	1	Second Order, available N
Chlorophyll *a* concentration	4	Linear function of phosphorus
Secchi depth	3	Function of total phosphorus
Phosphorus calibration	1	Decay rates
Nitrogen calibration	1	Decay Rates

Description of Target Endpoint

A frequently used biomass-related trophic state index is that of Carlson (1977). It is relatively simple to use, requires a minimum of data, and is generally easy to understand, both in theory and use. Carlson's trophic state index uses algal biomass as the basis for trophic state classification. Three variables, chlorophyll pigments, Secchi depth, and total phosphorus, independently estimate algal biomass. The trophic index is a base two logarithmic transformation of Secchi depth; each 10-unit division of the index represents a halving or doubling of Secchi depth.

Because total phosphorus is often correlated with transparency, a doubling of the total phosphorus often corresponds to a halving of Secchi depth. Chlorophyll pigments double every 7 units rather than every 10 units (Carlson, 1977). The relationship between Carlson's TSI and relative algal abundance is given in Table A9. For all three lakes modeled, the target trophic state index was set at 60, because of the need to reduce algal levels below nuisance conditions.

Table A9. Carlson Trophic State Index (Carlson, 1977)

TSI	Chl *a* (µg/L)	SD (m)	TP (µg/L)	Attributes	Water Supply	Fisheries & Recreation
<30	<0.95	>8	<6	**Oligotrophy:** Clear water, oxygen throughout the year in the hypolimnion	Water may be suitable for an unfiltered water supply	Salmonid fisheries dominate
30-40	0.95-2.6	8-4	6-12	Hypolimnia of shallower lakes may become anoxic		Salmonid fisheries in deep lakes only

40-50	2.6-7.3	4-2	12-24	**Mesotrophy:** Water moderately clear; increasing probability of hypolimnetic anoxia during summer	Iron, manganese, taste, and odor problems worsen. Raw water turbidity requires filtration	Hypolimnetic anoxia results in loss of salmonids. Walleye may predominate
50-60	7.3-20	2-1	24-48	**Eutrophy:** Anoxic hypolimnia, macrophyte problems possible		Warm-water fisheries only. Bass may dominate
60-70	20-56	1-0.5	48-96	Blue-green algae dominate, algal scums and macrophyte problems	Episodes of severe taste and odor possible	Nuisance macrophytes, algal scums, and low transparency may discourage swimming and boating
70-80	56-155	0.5-0.25	96-192	**Hypereutrophy:** (light limited productivity). Dense algae and macrophytes		
>80	>155	<0.25	192-384	Algal scums, few macrophytes		Rough fish dominate; summer fish kills possible

Modeling results, loading capacity, and allocations

The results of the analyses are summarized in tables and figures in this section. The coupled BATHTUB/GWLF model results for in-lake chlorophyll *a*, total phosphorus, Secchi depth visibility, and Carlson's trophic state index are presented for ten years. On these graphs, the actual data obtained by lake survey are presented for 2006. This data was also utilized for calibration as discussed previously in this report.

With the calibrated BATHTUB model, percent reduction of nutrients was modeled for each reservoir. Graphs presented in this section indicate the Carlson's trophic state index for each percent reduction modeled. Nutrient allocations were determined by determining the nutrient load allowable to accomplish a trophic state index of 60. Allocations are presented in table format.

Modeling Results

Results for each lake GWLF/BATHTUB modeling are presented in the following discussion and graphics.

Highlandtown Reservoir
For Highlandtown Reservoir, the existing average yearly loading for total phosphorus was calculated at 77.04 kg. The majority of this loading is from failing septic systems (61.3 kg) with small fractions from runoff (10.2 kg).

Results of BATHTUB modeling and actual 2006 data for in-lake chlorophyll *a*, total phosphorus, Secchi depth visibility, and Carlson's trophic state index are presented in Figures A16 to A19, respectively. For each of these data sets, the real data compares well with modeled data. Some actual data overlies the modeled data as a result of calibration.

As shown, BATHTUB predicted a range of seasonal in-lake chlorophyll *a* concentrations from 13 to 52 ug/L (Figure A16). Eight of the ten modeled years, the chlorophyll *a* was above the 20 ug/L target. This result was duplicated in the BATHTUB modeling of the Carlson's trophic state index. Eight years were found to be greater then the target of 60, with a range **of 63 to 68** (Figure A19). Reduction of total influent phosphorus is needed to attain the non-nuisance conditions.

Jefferson Lake
For Jefferson Lake, the existing average seasonal (May-September) loading for total phosphorus was calculated at 164.9 kg. The majority of this loading is from failing septic systems (142.2 kg) with small fractions from runoff (20.7 kg).

Results of BATHTUB modeling and actual 2006 data for in-lake chlorophyll a, total phosphorus, Secchi depth visibility, and Carlson's trophic state index are presented in Figures A20 to A23, respectively. For each of these data sets, the real data compares well with modeled data. Some actual data overlies the modeled data as a result of calibration.

As shown, BATHTUB predicted a range of seasonal in-lake chlorophyll *a* concentrations from 26 to 105 ug/L (Figure A20). All of the ten modeled years, the chlorophyll *a* was well above the target of 20 ug/L. This result was duplicated in the BATHTUB modeled Carlson's trophic state index. All ten years were found to be greater then the target of 60, with a range of 64.5 to 76.5 (Figure A23). Reduction of total influent phosphorus is needed to attain the non-nuisance conditions.

Wellsville Reservoir
For Wellsville Reservoir, the existing average seasonal (May-September) loading for total phosphorus was calculated at 418.7 kg. The majority of this loading is from failing septic systems (350.7 kg) with small fractions from runoff (78.0 kg).

Results of BATHTUB modeling and actual 2006 data for in-lake chlorophyll *a*, total phosphorus, Secchi depth visibility, and Carlson's trophic state index are presented in Figures A24 to A27, respectively. For each of these data sets, the real data compares well with modeled data except Secchi depth visibility (Figure A26). Some actual data overlies the modeled data as a result of calibration.

As shown, BATHTUB predicted a range of seasonal in-lake chlorophyll *a* concentrations from 18 to 142 ug/L (Figure A24). Nine of the ten modeled years, the chlorophyll *a* was well above the target of 20 ug/L. This result was duplicated in the BATHTUB modeled Carlson's trophic state index. Nine years were found to be greater then the target of 60, with a range of 71.0 to 79.0 (Figure A27). Reduction of total influent phosphorus is needed to attain the non-nuisance conditions.

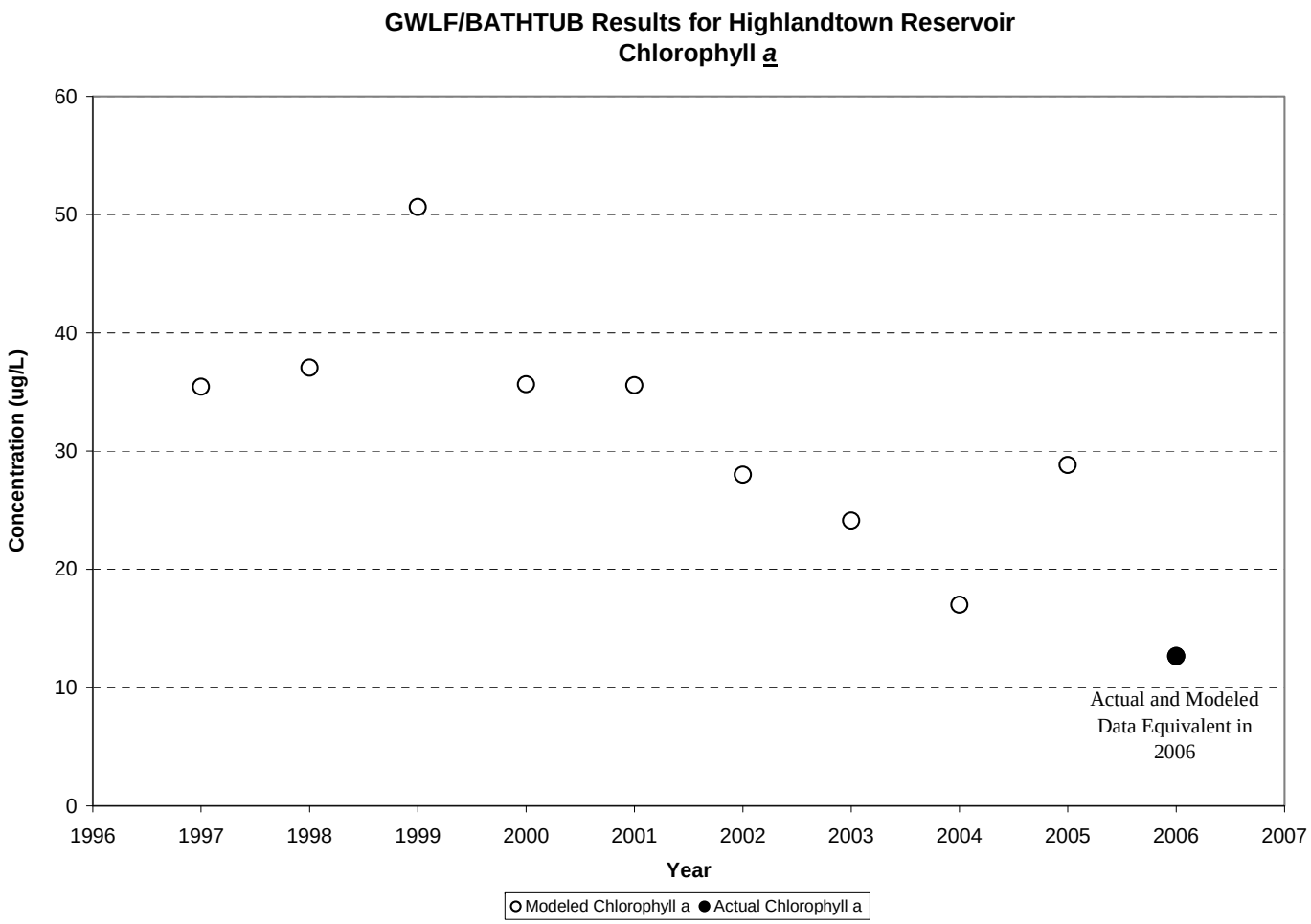


Figure A16. Highlandtown Reservoir chlorophyll *a* from GWLF/BATHTUB results, 1997 to 2006

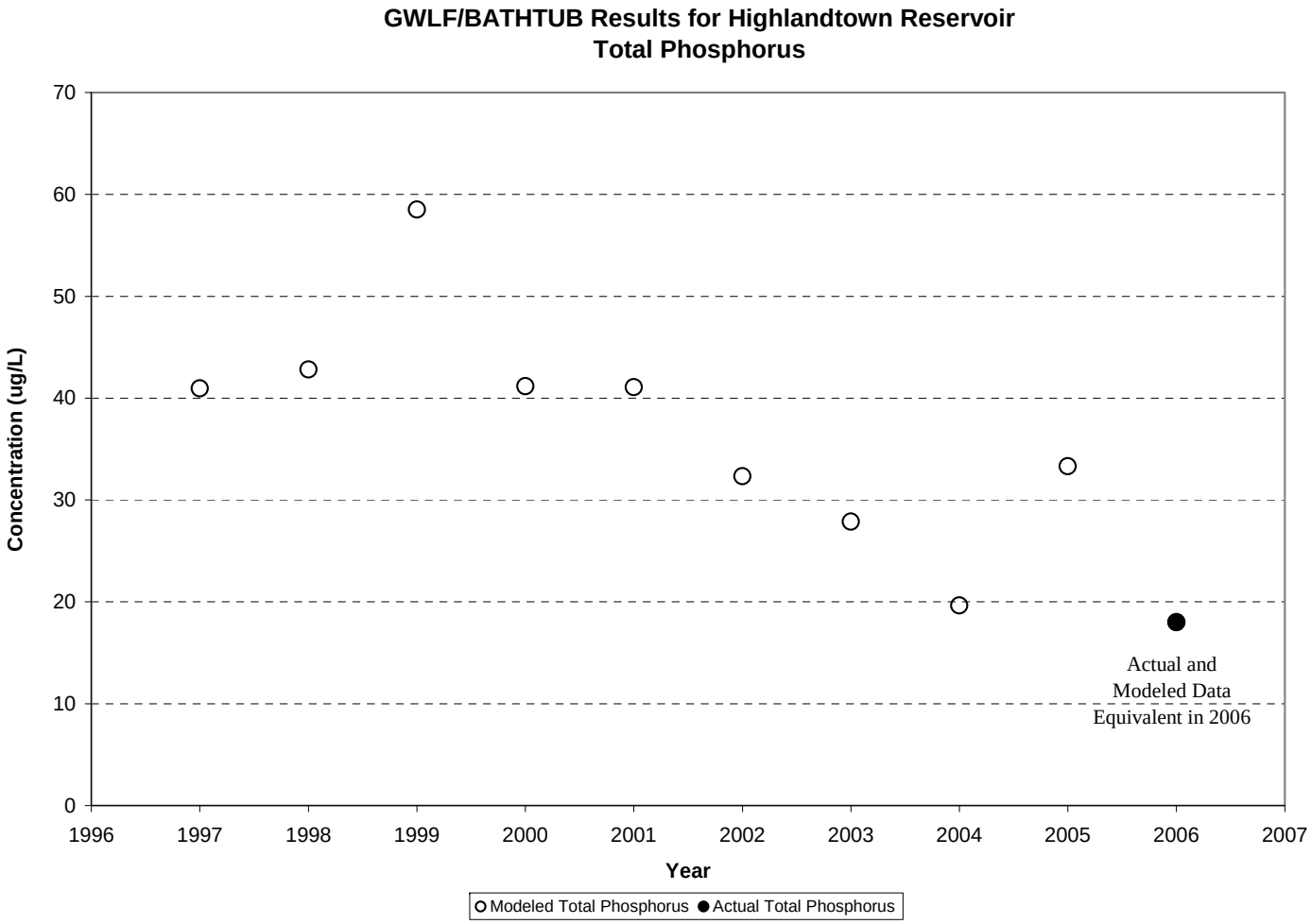


Figure A17. Highlandtown Reservoir total phosphorus from GWLF/BATHTUB results, 1997 to 2006

Figure A18. Highlandtown Reservoir Secchi depth visibility from GWLF/BATHTUB results, 1997 to 2006

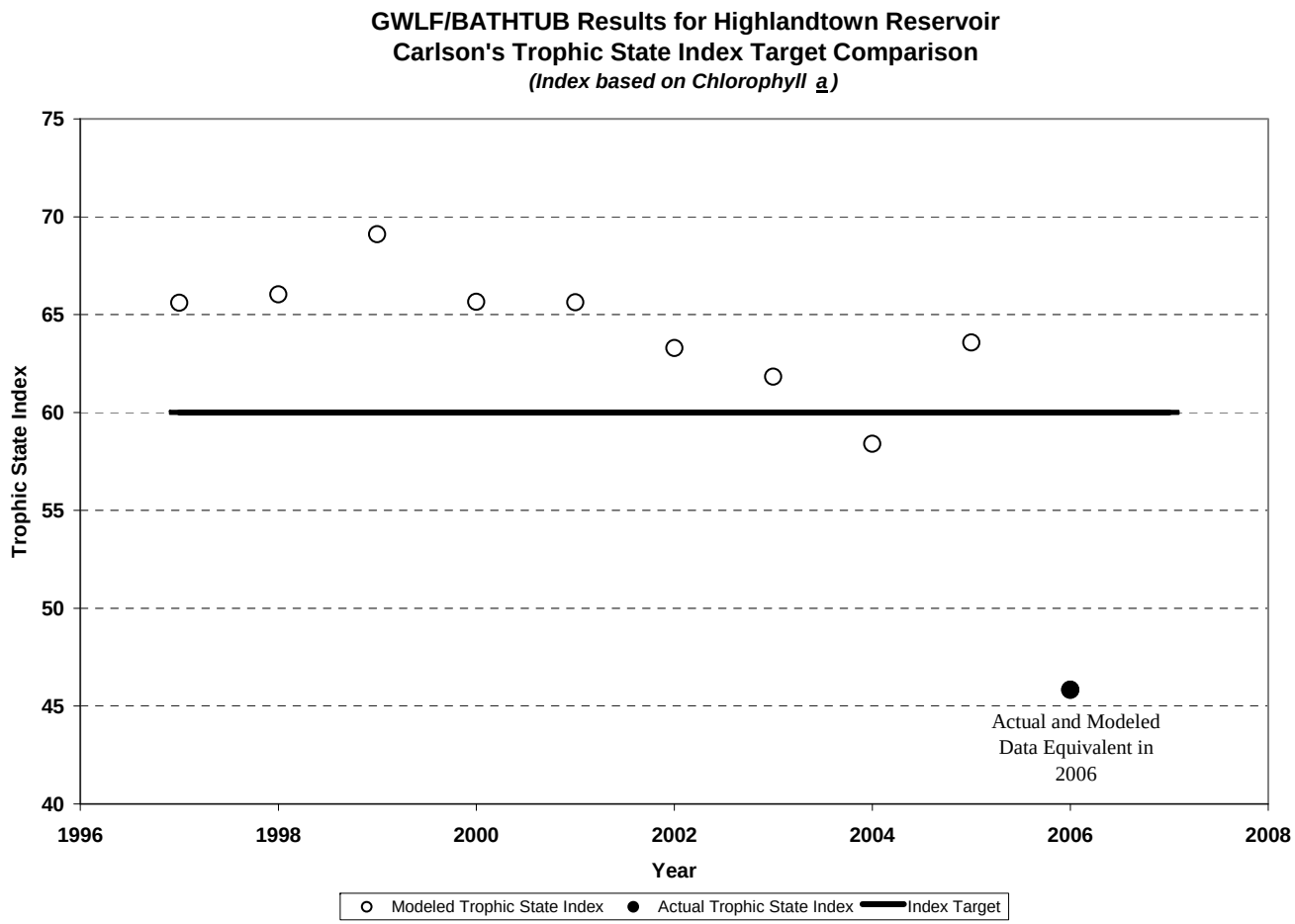


Figure A19. Highlandtown Reservoir Carlson's trophic state index from GWLF/BATHTUB results, 1997 to 2006 (bold line indicates target at TSI=60)

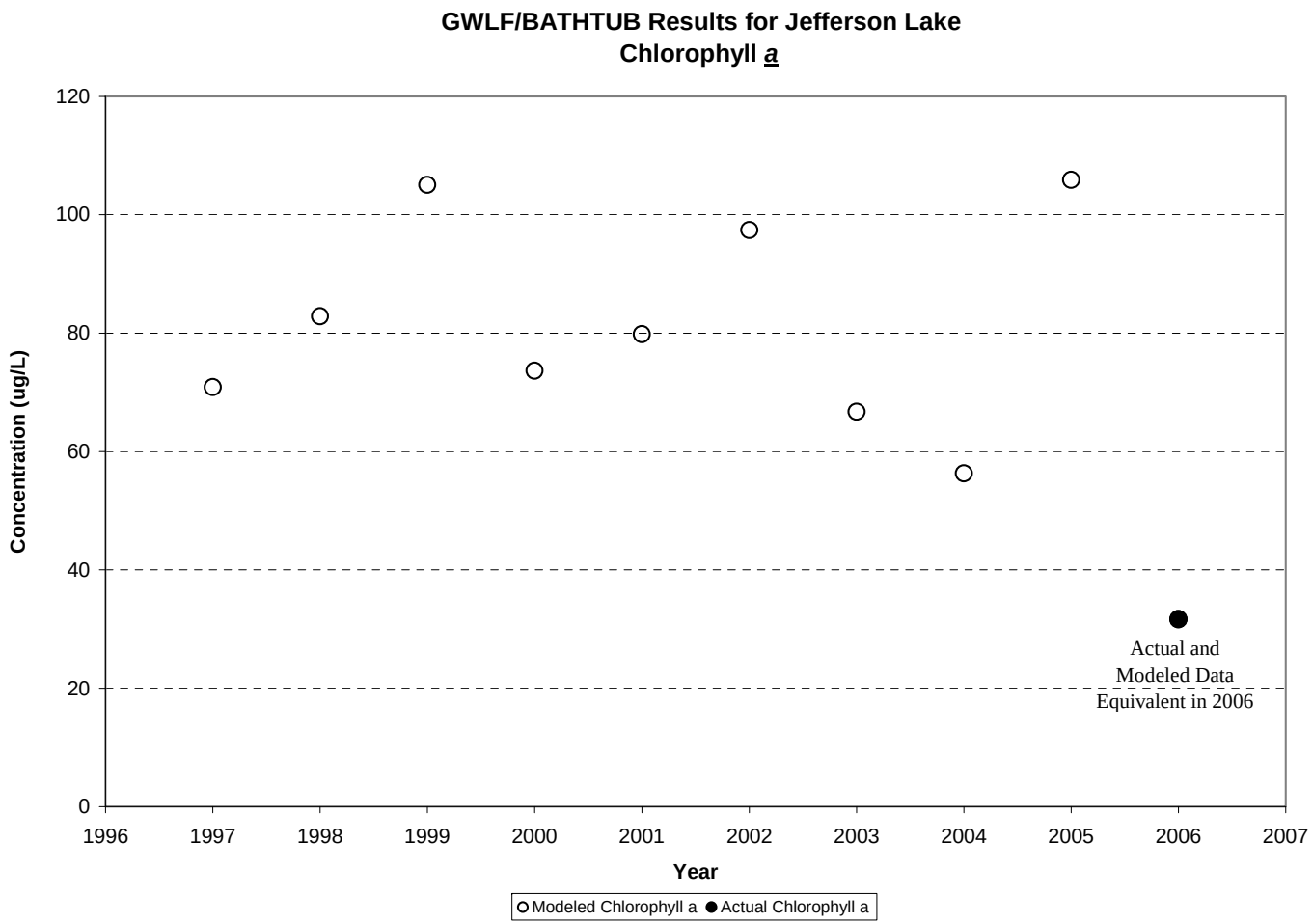


Figure A20. Jefferson Lake chlorophyll *a* from GWLF/BATHTUB results, 1997 to 2006

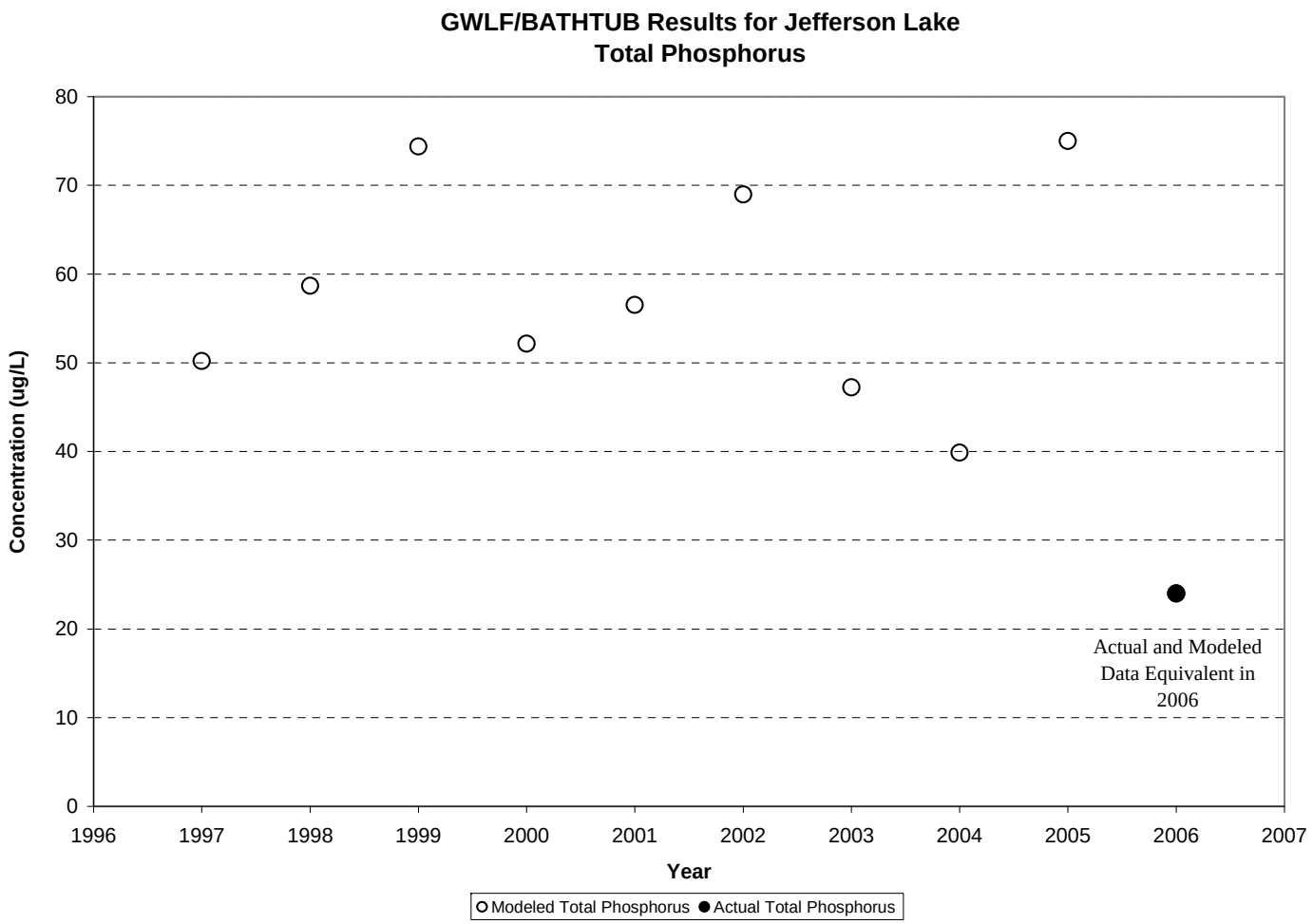


Figure A21. Jefferson Lake total phosphorus from GWLF/BATHTUB results, 1997 to 2006

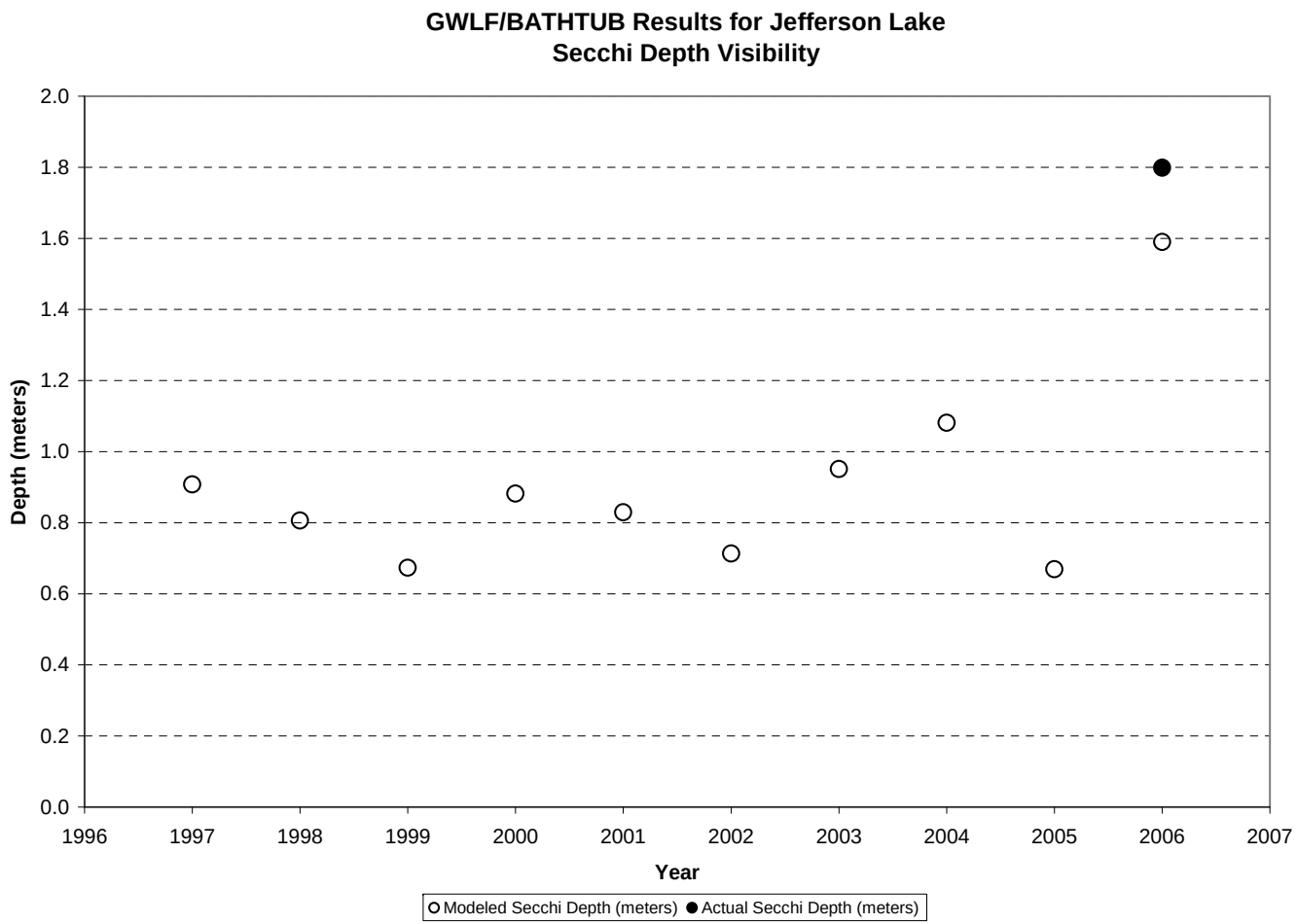


Figure A22. Jefferson Lake Secchi depth visibility from GWLF/BATHTUB results, 1997 to 2006

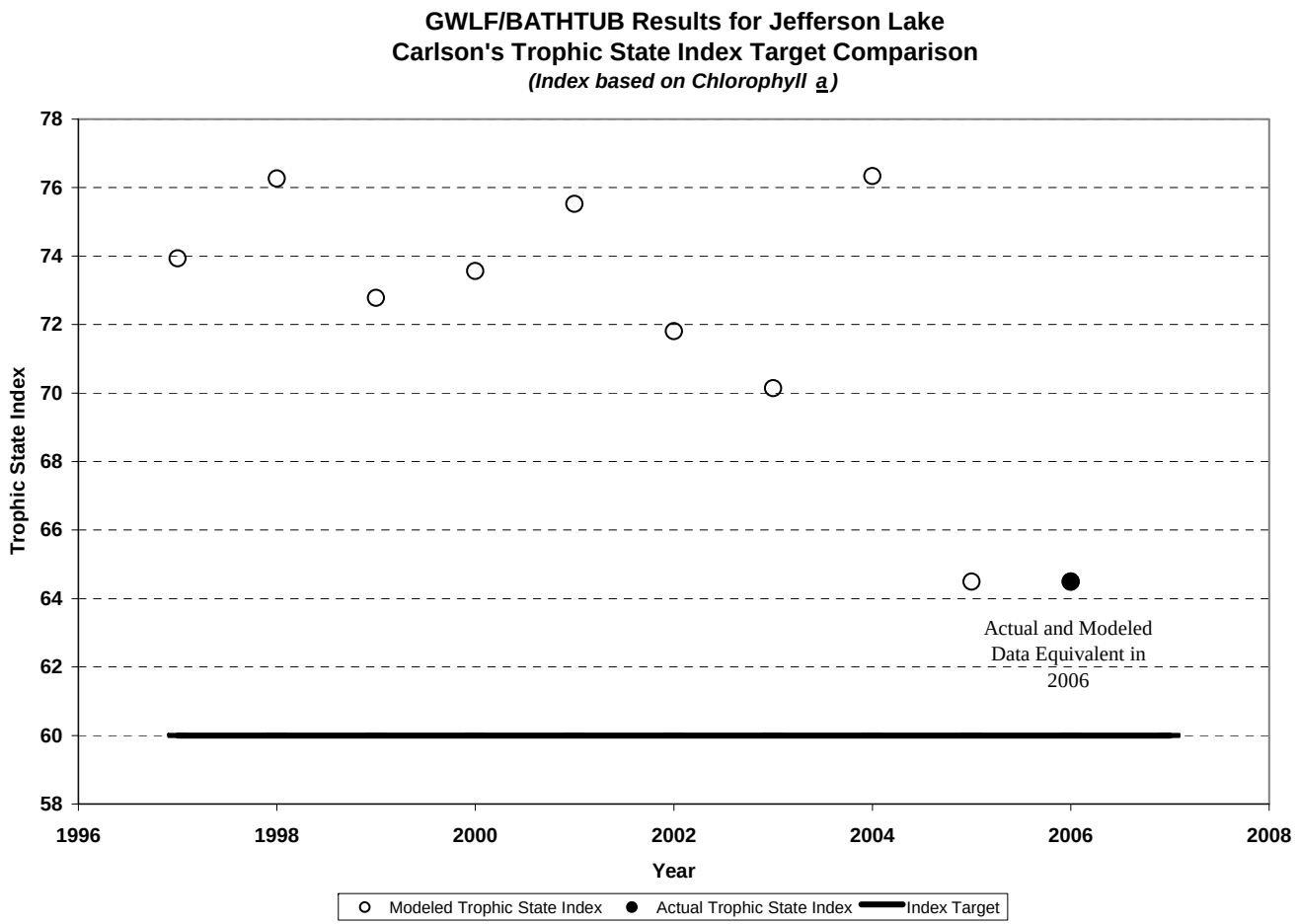


Figure A23. Jefferson Lake Carlson's trophic state index from GWLF/BATHTUB results, 1997 to 2006 (bold line indicates target at TSI=60)

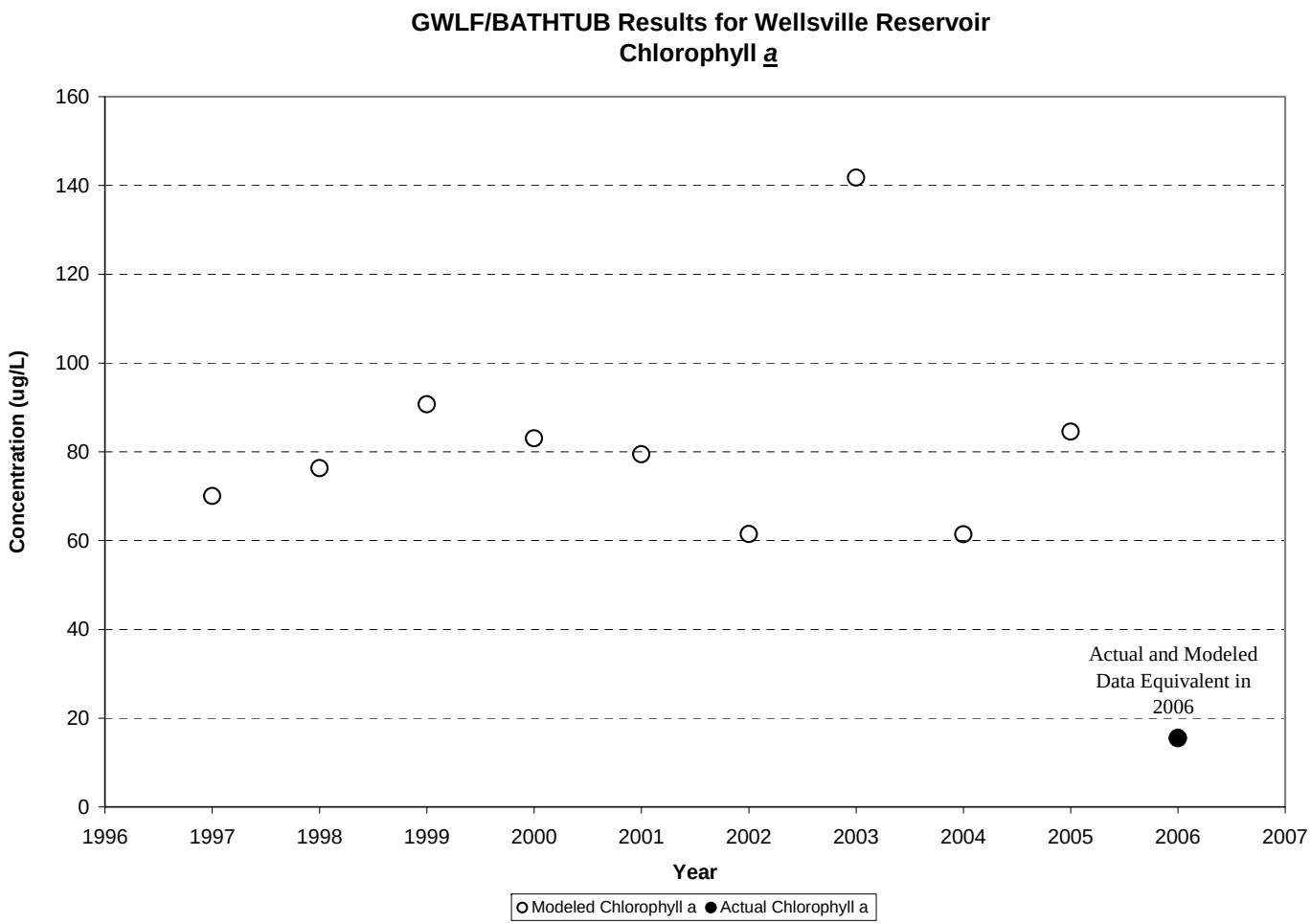


Figure A24. Wellsville Reservoir chlorophyll *a* from GWLF/BATHTUB results, 1997 to 2006

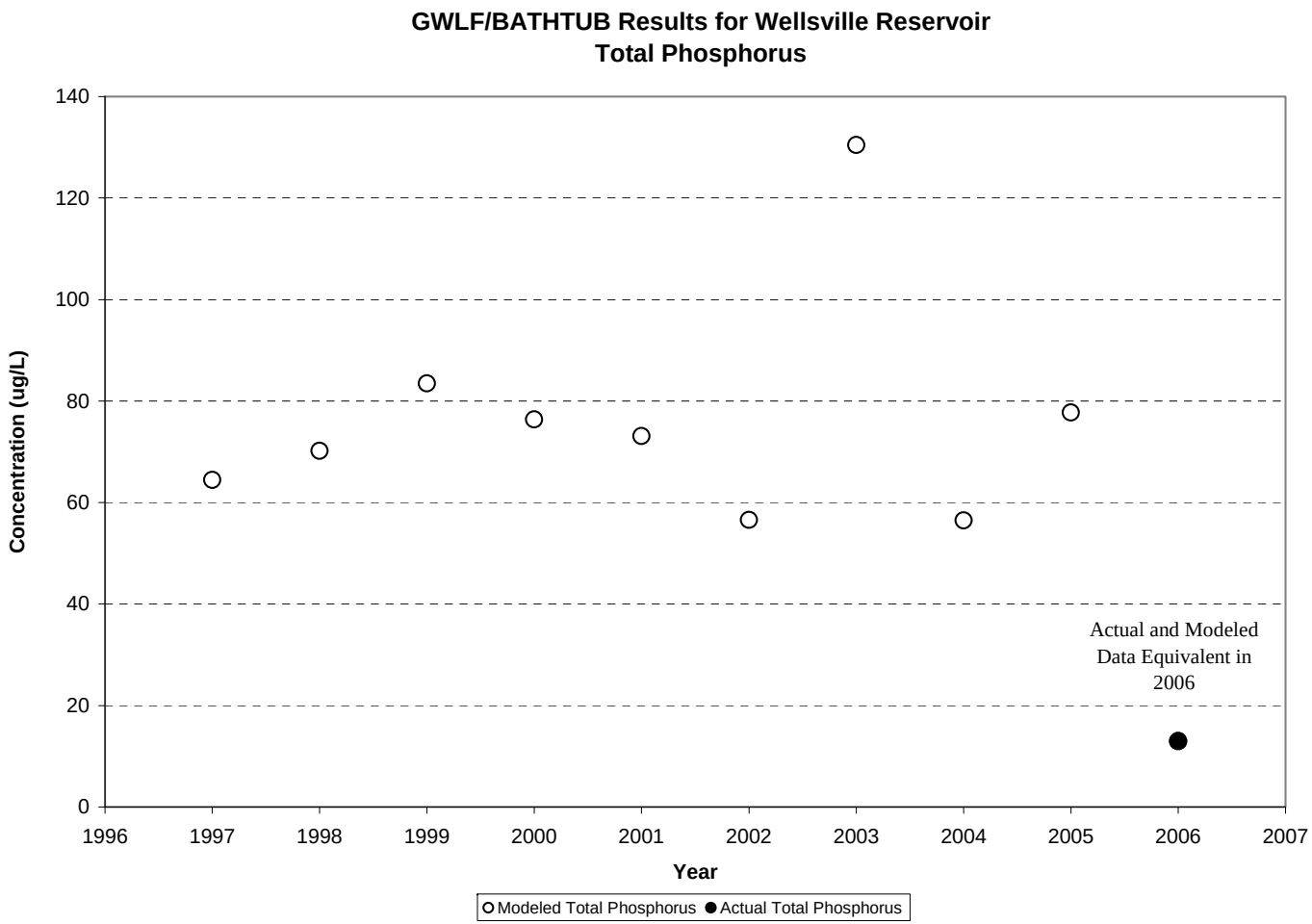


Figure A25. Wellsville Reservoir total phosphorus from GWLF/BATHTUB results, 1997 to 2006

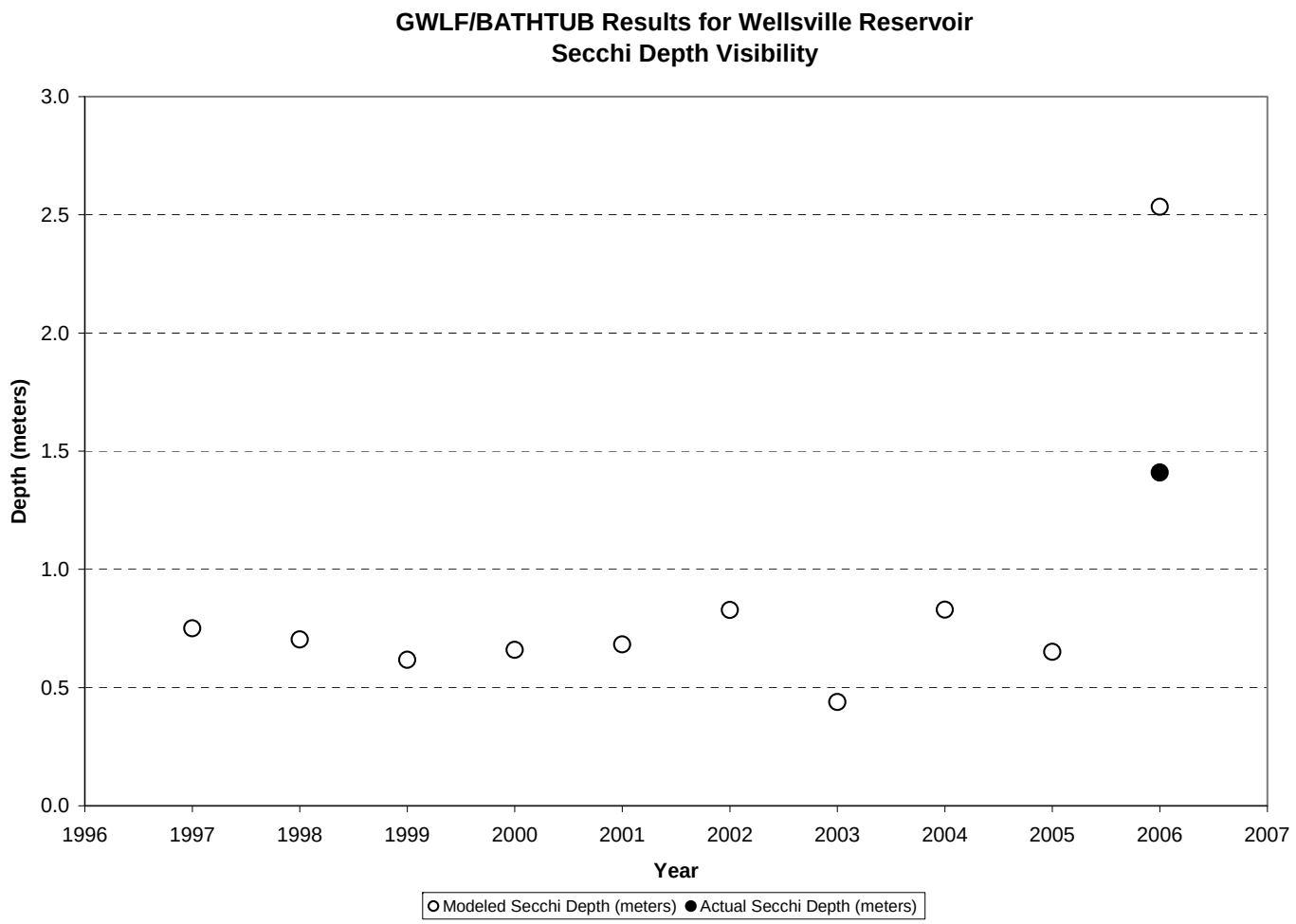


Figure A26. Wellsville Reservoir Secchi depth visibility from GWLF/BATHTUB results, 1997 to 2006

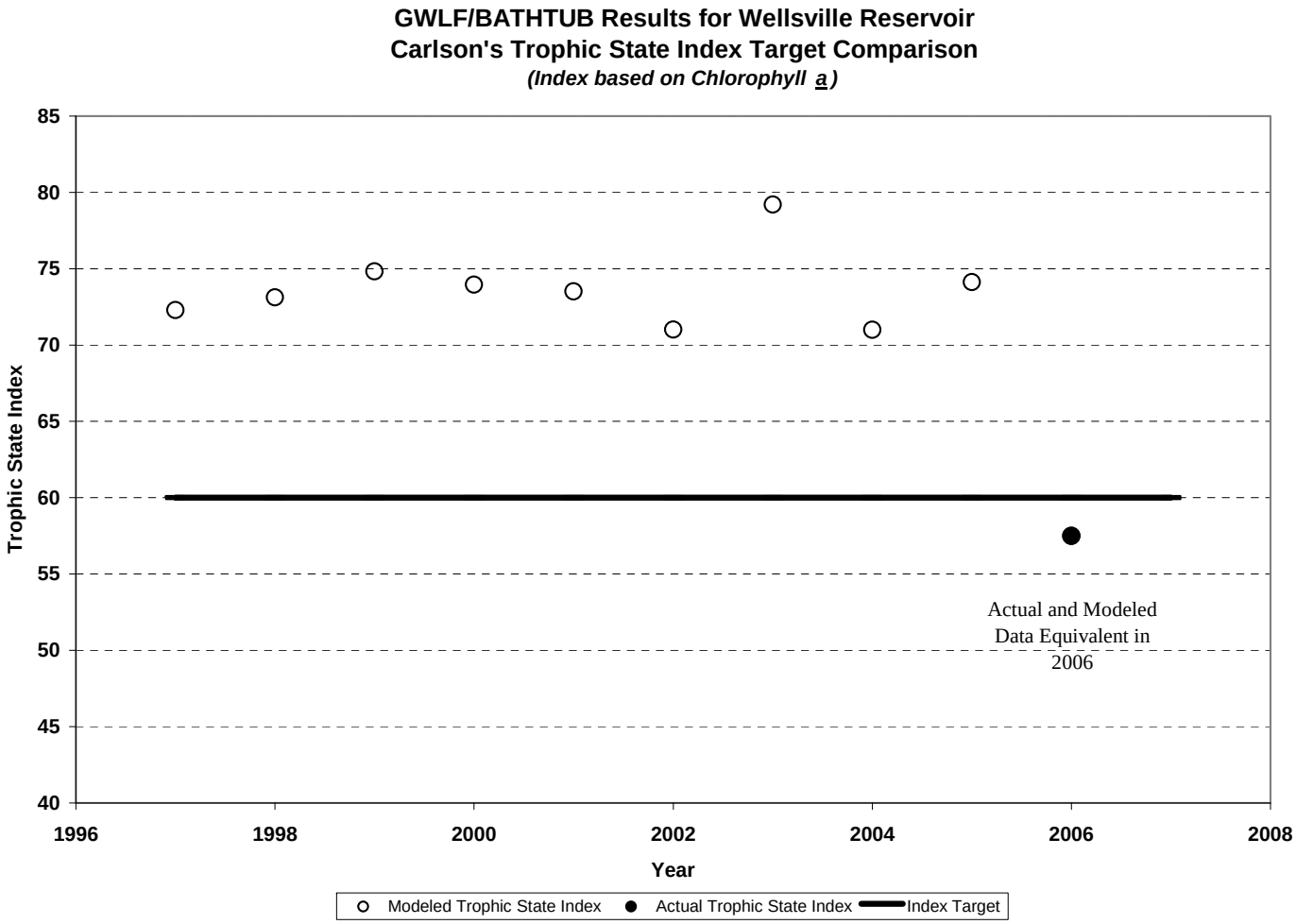


Figure A27. Wellsville Reservoir Carlson's trophic state index from GWLF/BATHTUB results, 1997 to 2006 (bold line indicates target at TSI=60)

Loading Capacity Determination

Loading capacity of total phosphorus was determined by adjusting the total influent phosphorus input into BATHTUB. Subsequently the BATHTUB model results were analyzed graphically (Figures A28 to A30) to determine the reduced influent loading required to obtain the seasonal Carlson's trophic state index value of 60.0. Nitrogen was not altered from the original GWLF output during these runs.

The average dissolved/total phosphorus ratio was assumed remain constantly the same as that found during filed sampling in 2006. In previous Ohio EPA TMDL modeling, it has been determined that BATHTUB is relatively insensitive to this ratio. The load reductions of nutrients needed to achieve the TMDL target concentrations are determined by comparing current loads to allowable loads. For example, if the current load in a segment is 10 tons/year and the allowable load is 4 tons/year, a 60 percent reduction in load is needed. The current load has not been ground-proofed in all segments due to a lack of significant water quality and/or flow data. However, modeling of nutrients influent to Jefferson Lake, Highlandtown Reservoir, and Wellsville Reservoir has been accomplished for a ten year period. Simulated nutrient loads are therefore used to estimate the required reductions with some refinement based on available water quality and flow data.

Highlandtown Reservoir

The total phosphorus loading to meet the target values is about 30.04 kg/season. With a 5% margin of safety (MOS), the total phosphorus loadings influent to Highlandtown Reservoir would need to be reduced by about 61% (Figure A28). To achieve this accomplishment, 78% of the failing septic systems within this watershed must be corrected. Allocations for all other land uses would not be required to meet the load capacity determination. The TMDL allocations are listed in Table A10.

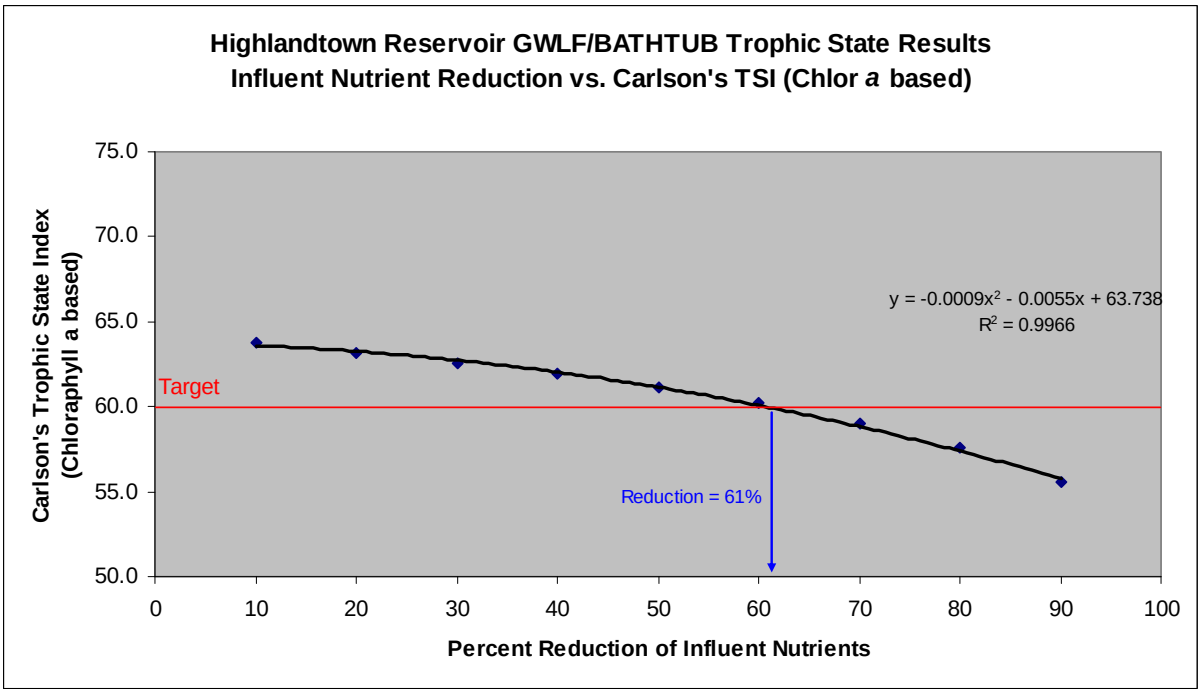
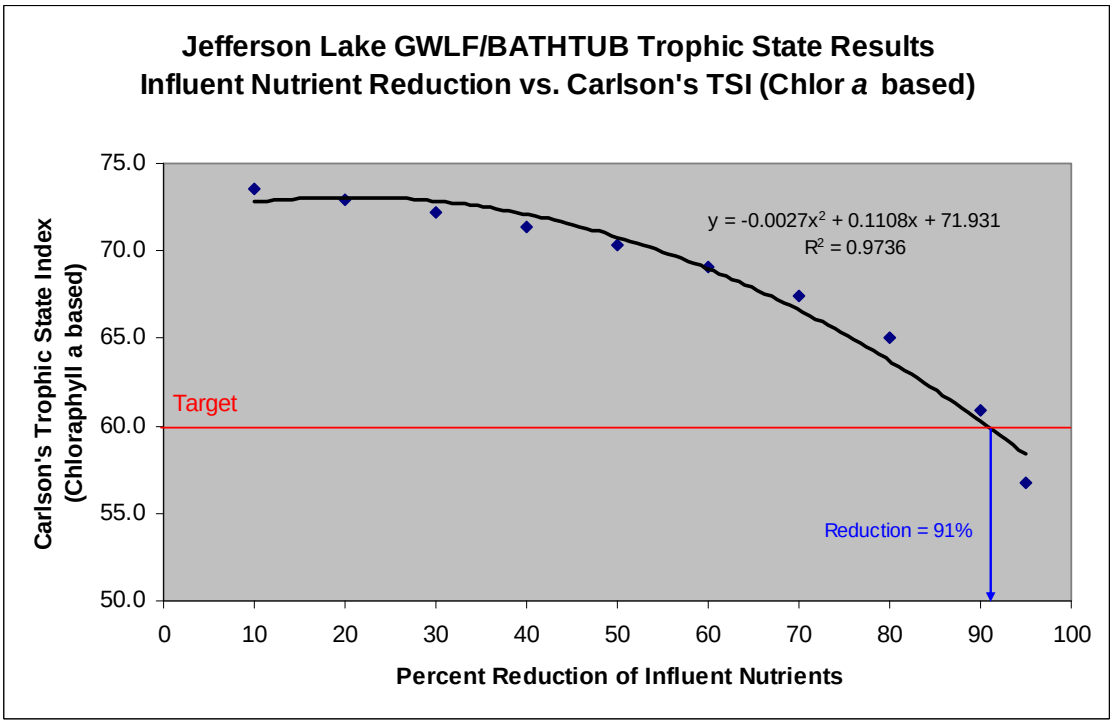


Figure A28. Highlandtown Reservoir total phosphorus loading capacity determination

Jefferson Lake

The total phosphorus loading to meet the target values is about 14.84 kg/season. With a 5% margin of safety (MOS), the total phosphorus loadings influent to Jefferson Lake would need to be reduced by about 91%. (Figure A29). To achieve this accomplishment, 100% of the failing septic systems within this watershed must be corrected. In addition, total phosphorus from runoff of cropland, pasture, and urban areas each must be reduced by 95%. It is expected all failing septic systems must be corrected. Runoff allocations were equally allocated between land uses. Reduction of total phosphorus from forested areas is assumed to be practical. The TMDL allocations are in Table A10.



Wellsville Reservoir

The total phosphorus loading to meet the target values is about 37.67 kg/season. With a 5% margin of safety (MOS), the total phosphorus loadings influent to Wellsville Reservoir would need to be reduced by about 91% (Figure A30). To achieve this accomplishment, 100% of the failing septic systems within this watershed must be corrected. In addition, reductions of total phosphorus from runoff of cropland, pasture, and urban areas must be each reduced by 70%. It is expected all failing septic systems must be corrected. Runoff allocations were equally allocated between land uses. Reduction of total phosphorus from forested areas is assumed to not be practical. The TMDL allocations are in Table A10.

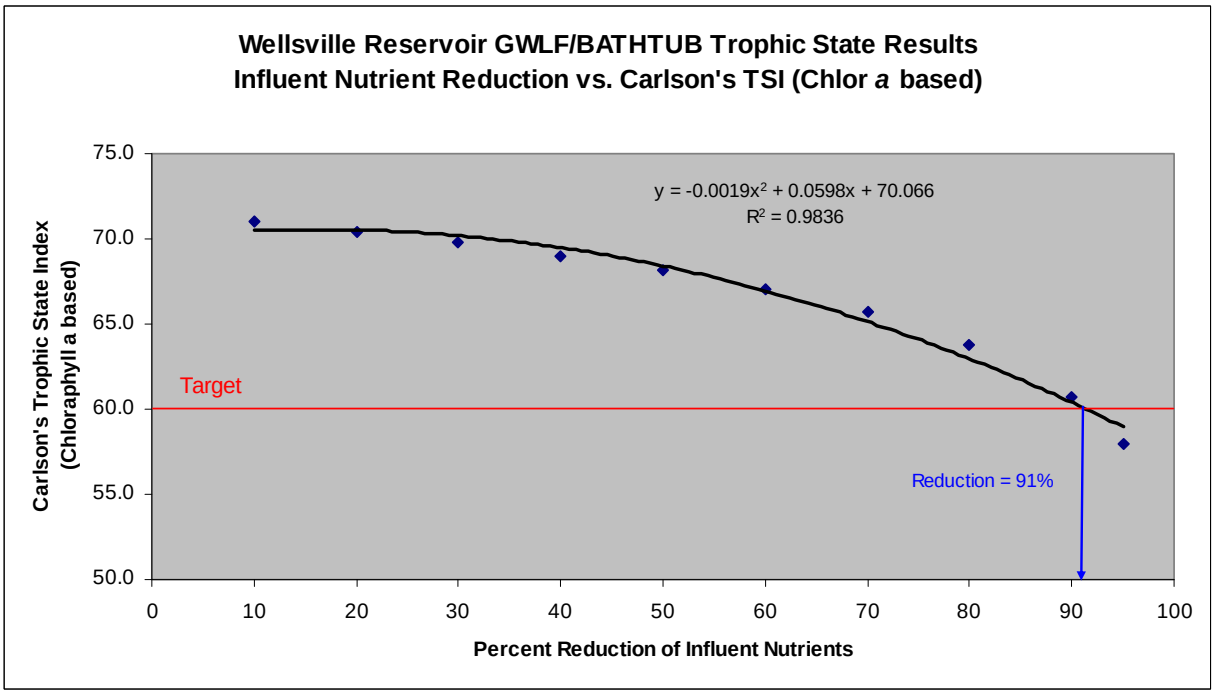


Figure A30. Wellsville Reservoir total phosphorus loading capacity determination

Allocations

Allocations for total phosphorus for Jefferson Lake, Highlandtown Reservoir, and Wellsville Reservoir are presented in Table A10. In general, reductions for total phosphorus are required for runoff and septic systems for Jefferson Lake and Wellsville Reservoir; whereas, Highlandtown Reservoir would need only septic system loading reduced. Forested area runoff loadings are not proposed to be reduced because it is not considered practical. No reduction of Nitrogen is proposed because BATHTUB modeling was completed without changes of original nitrogen loadings while completing the load allocation determinations. Without change to nitrogen, the goal of an in-lake Carlson's trophic state index of 60 was accomplished.

Current estimated septic system loading rates by major subwatershed are presented in Table 10. The table also indicates the proposed reduction percentages of total phosphorus load to the influent streams of each lake. These reductions include septic waste elimination or significant reduction. As can be seen in this table, the majority of total phosphorus in the lake study basins is a result of failing septic systems. Phosphorus loads from properly performing septic systems can be reduced to very near zero because the septic adsorption fields of normally functioning onsite systems are assumed to retain nearly all phosphorus. Therefore, one-hundred percent reduction is an achievable goal for total phosphorus septic waste load.

Table A10. Existing and TMDL total phosphorus loads to Jefferson Lake, Highlandtown Reservoir, and Wellsville Reservoir

Lake	14-Digit HUC	Sub-Watershed		Total Phosphorus Existing and TMDL Point and Non-Point Source Loads (kg/season)									
				Atmospheric	Cropland	Pasture	Forest	Urban	Groundwater	Point Source	Septic Systems	5% MOS	Total
Jefferson Lake	190-010	Town Fork	Existing	0.01	1.42	4.73	11.68	2.93	1.94	0	142.2	---	164.9
			Allocation	0.01	0.07	0.24	11.68	0.15	1.94	0	0.00	0.74	14.84
			% Reduction	0%	95%	95%	0%	95%	0%	0%	100%	---	91%
Highlandtown Reservoir	100-260	Little Yellow Creek	Existing	0.12	0.73	3.85	2.14	3.51	5.36	0	61.3	---	77.04
			Allocation	0.12	0.73	3.85	2.14	3.51	5.36	0	12.82	1.50	30.04
			% Reduction	0%	0%	0%	0%	0%	0%	0%	79%	---	61%
Wellsville Reservoir	100-260	Little Yellow Creek	Existing	0.15	4.68	29.86	5.39	11.57	16.28	0	350.7	---	418.7
			Allocation	0.15	1.42	9.05	5.39	3.50	16.28	0	0.00	1.88	37.67
			% Reduction	0%	70%	70%	0%	70%	0%	0%	100%	---	91%

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