TOTAL MAXIMUM DAILY LOADS
FOR
CASTLEMAN RUN LAKE, WEST VIRGINIA

Introduction

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies that are not meeting designated uses under technology-based controls. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, states can establish water quality-based controls to reduce pollution from both point and nonpoint sources and to restore and maintain the quality of their water resources (USEPA, 1991).

The West Virginia Division of Environmental Protection (WVDEP) has determined that the use designation of Castleman Run Lake for aquatic life has been impaired by nutrients and siltation. The United States Environmental Protection Agency (USEPA) conducted this study to analyze the loadings to the lake and to establish TMDLs that will restore and maintain the quality of Castleman Run Lake for the uses designated by West Virginia.

This report (including the attached technical report) also provides a description of the waterbody and associated pollution sources, provides a summary of water quality monitoring data, and describes the analytical approach used to develop the TMDL. The report specifically addresses each of the elements of a TMDL, including the following:

1. The TMDLs are designed to implement applicable water quality standards.
2. The TMDLs include a total allowable load as well as individual waste load allocations and load allocations.
3. The TMDLs consider the impacts of background pollutant contributions.
4. The TMDLs consider critical environmental conditions.
5. The TMDLs consider seasonal environmental variations.
6. The TMDLs include a margin of safety.
7. The TMDLs has been subject to public participation.
8. There is reasonable assurance that the TMDLs can be met.

II. Background

The Castleman Run Lake watershed is located within the Upper Ohio River 2 hydrologic cataloging unit (05030106), as shown in Figure 2.1. The land area of the watershed is approximately 2,128 hectares (5,256 acres) located in Brooke County, WV and Ohio County, WV, and Washington County, PA. Runoff from the watershed flows into Castleman Run Lake from Castleman Run. Castleman Run receives flow from Crupe Run, Rices Run, Murray Run, Blayney Run, Curtis Run, Garrison Run, and unnamed creeks. Water discharged from the lake to Castleman Run and then to the Buffalo Creek. The lake is used for recreational activities such as fishing and picnicking. Private boats with electric motors are permitted on the lake. The lake's watershed is primarily rural, and the main land uses are forest and hay/pasture. Castleman Run Lake is a 8.9-hectare impoundment located 5 miles east of West Liberty, WV.

WVDEP listed Castleman Run Lake on the 1998 303(d) list for not meeting its designated uses, as described below in section III. The waterbody is given a high priority for TMDL development. The lake (designated code WV_O(L)-92-L-1) was listed for nutrients and siltation (WVDEP, 1998).

To evaluate the relationship between the sources, their loading characteristics, and the resulting conditions in the lake, a combination of analytical tools were used. Assessments of the nonpoint source loading into the lake were developed for Castleman Run Lake watershed using the Generalized Watershed Loading Function (GWLF) computer program. GWLF provided estimates of nutrients and sediments transported to the lake for individual land use categories. The lake was evaluated using the BATHTUB water quality simulation computer model to estimate the concentrations of nutrients and chlorophyll *a*. The lake was segmented into two cells to better represent the system. The results of the watershed and reservoir models were compared with observed water quality data, literature values, previous studies, and reservoir conditions to evaluate the models' performance.

TMDLs are composed of the sum of individual waste load allocations (WLAs) for point sources, load allocations (LAs) for nonpoint sources, and natural background levels. A representative hydrologic simulation year was used for testing and development of the TMDL by averaging the hydrologic conditions for the period from 1978 to 1997. The resulting allocation for the two listed pollutants includes a 30 percent reduction of nutrients (expressed as total phosphorus) and a 40 percent reduction of sediment load.

III. Discussion of Regulatory Conditions

EPA developed these TMDLs consistent with statutory and regulatory requirements and EPA policy and guidance. The Castleman Run Lake TMDLs address the following eight regulatory requirements.

1) The TMDLs are designed to implement applicable water quality standards.

These TMDLs ensure that Castleman Run Lake will meet applicable water quality criteria for nutrients and sediment, thus ensuring that the water supports its designated use. West Virginia has only narrative criteria related to nutrients and sediment.

The state water quality standards include water use categories, antidegradation criteria, numeric criteria, and narrative descriptions of conditions in waters of the state.

The relevant water use categories for Castleman Run Lake include the following:

> Propagation and Maintenance of Fish and Other Aquatic Life (Category B-1)
> Water Contact Recreation (Category C)

No special exceptions or use designations are identified for Castleman Run Lake.

1.1 Nutrients

No numeric criteria are available in the West Virginia water quality standards relevant to the 303(d) listing of this waterbody for nutrient impairment. The relevant narrative description of condition includes the following:

> §46-1.3 Conditions Not Allowable in State Waters.
> 3.2 No sewage, industrial wastes or other wastes present in any of the water of the State shall cause therein or materially contribute to any of the following conditions thereof:
> a. Distinctly visible floating or settleable solids, suspended solids, scum, foam or oily slicks;
> b. Deposits or sludge banks on the bottom;
> ...
> i. Any other condition ... which adversely alters the integrity of the waters of the State including wetlands; no significant adverse impact to the chemical, physical, hydrologic, or biological components of aquatic ecosystems shall be allowed. (Title 46, Series 1, Requirements Governing Water Quality Standards, 1999)

WVDEP identifies lakes as impaired due to nutrients on the state's 303(d) list

> "...if summer total phosphorus or chlorophyll *a* levels in surface waters resulted in a trophic state index value of $ 65 (highly eutrophic) or summer algal blooms or excessive aquatic vegetation were noted." (WVDEP, 1998).

The concept of trophic states was developed by Einar Naumann to characterize the condition of lakes (Naumann 1919). The principle behind trophic states is that physical and chemical factors control the production of algae which in turn affects the biological structure of the lake. The amount of algal production plays an important role in lake conditions such as color, visible light penetration, dissolved oxygen concentrations, and odor. Common trophic state classifications include oligotrophic (low production, low nitrogen and phosphorus, oxygenated hypolimnion), mesotrophic (moderate production, moderate nitrogen and phosphorus), and eutrophic (high production, high nitrogen and phosphorus, anoxic hypolimnion).

The Carlson Trophic State Index (TSI) (Carlson 1977) was developed to estimate the algal production and determine trophic state based upon chlorophyll pigments, secchi depth, and total phosphorus. The TSI is a logarithmic scale that ranges from approximately 0 to 100. The three index variables chlorophyll pigments (CHL), Secchi depth (SD), and total phosphorus (TP) use regression equations to estimate the index value and algal production. These three index variables are interrelated and should produce the same index value for a given combination of variables values. The regression equations used to calculate the TSI are shown in equations 1.1 to 1.3.

$$TSI(SD) = 60 - 14.41 \ln (SD) \quad (1.1)$$
$$TSI(CHL) = 9.81 \ln (CHL) + 30.6 \quad (1.2)$$
$$TSI(TP) = 14.42 \ln (TP) + 4.15 \quad (1.3)$$

The trophic state can be related to the trophic state index and lakes conditions as shown in Table 3.

Table 3 Trophic state, trophic state index and lakes conditions

TSI	**Trophic State**	**Attributes**	**Aquatic Life**
< 30	Oligotrophic	Clear water, low production, oxygenated hypolimnion.	Trout possible in deep lakes.
30-50	Mesotrophic	Moderately clear water, possible anoxia in summer.	Warm Water Fishery
50-70	Eutrophic	Low transparency, anoxic hypolimnion in summer.	Warm Water Fishery
>70	Hypereutrophic	Dense algae and macrophytes, noticeable odor, fish kills possible.	

Review of the available water quality monitoring information from 1993 to 1996 and 1998 indicates the likely source of impairment is periodic nuisance algal blooms. Based on monitoring (15 samples), observed chlorophyll *a*, an indicator of algae, is periodically elevated during the growing season, ranging from 6 to 130 ug/l with a mean of 59.5 ug/l (see section 5.2 of the attached report). For Castleman Run Lake, the total phosphorus and chlorophyll *a* TSI were calculated from the available sampling information. Insufficient monitoring data was available to calculate the secchi depth TSI. The phosphorus TSI is 70.7 and the chlorophyll TSI is 63.2. The phosphorus TSI clearly exceeds the West Virginia listing guideline of 65.

In the absence of a relevant numeric criterion, a numeric endpoint is selected consistent with the use description, the narrative condition, and West Virginia listing guidelines.
Based on the evaluation of the lake monitoring and modeling analysis and evaluation of the nitrogen-phosphorus ratio (see section 5.2 of the attached report), phosphorus was determined to be the limiting nutrient for the reservoir. It is assumed that the forebay is used to provide the control of the recreational portion of the lake. The endpoint is evaluated as the TSI calculated from predicted phosphorus and chlorophyll *a* in the deep pool

The lake is characterized by a shallow depth and a high watershed to surface area ratio. On the basis of the site specific characteristics of the lake a target is selected which is consistent with the best water quality that this lake can be expected to achieve. The identified target is less than the state listing guidelines of a TSI of 65. In this case the selected target is a TSI index of 63.2, with an associated chlorophyll *a* concentration of 62.5 ug/l. The TMDLs are described as average annual loads, which is typically appropriate for reservoirs and impoundments.

1.2 Sediment

Castleman Run Lake is listed as impaired due to siltation on the 303(d) list. Siltation is the excessive accumulation of sediment in the reservoir. The accumulation of sediment can impair the water uses of Fish and Other Aquatic Life and Recreation. The excessive accumulation of sediment can adversely affect aquatic life by creating thick mud deposits, filling habitat, and increasing turbidity. The excessive accumulation of sediment impairs recreational use by reducing access and degrading the aesthetic character of the lake.

The state has no numeric criteria related to the impairment of siltation in lakes. The relevant narrative conditions specify the following:

> §46-1-3.3.2 No sewage, industrial wastes or other wastes present in any of the water of the State shall cause therein or materially contribute to any of the following conditions thereof:
> ...
> c. Deposits or sludge banks on the bottom.
> ...
> i. Any other condition ... which adversely alters the integrity of the waters of the State including wetlands; no significant adverse impact to the chemical, physical, hydrologic, or biological components of aquatic ecosystems shall be allowed. (Title 46, Series 1, Requirements Governing Water Quality Standards)

In the absence of numeric criteria for lake siltation in West Virginia, EPA derives as follows a numeric limit for the development of the Castleman Run Lake siltation TMDL. This numeric limit is selected to be protective of the lake uses and serves as a target for identifying achievement of water quality standards associated with the lake listing. The selection of this numeric limit was based on several considerations:

> The selected endpoint, expressed as a long-term sedimentation rate for Castleman Run Lake, is consistent with the causes of the Castleman Run Lake listing. Excessive siltation is reported by the state as the main cause of the lake impairment.
>
> The long-term annual siltation rate should not be excessive and should allow for a reasonable life span of the lake before deposits become evident at normal pool elevations or create barrier to recreational uses. For small impoundments such as Castleman Run Lake with large drainage areas, and in the absence of the design specifications of the lake, a minimum 40-year life span is selected as a target and is used in derivation of siltation rate limit for this TMDL.

Siltation does not occur uniformly over the entire lake bottom. Selected locations within the lake experience high siltation rates compared to other locations within the lake. The selected locations are the areas most likely to create barrier for recreational uses. Specifically for Castleman Run Lake, characterized by a small area (9 hectares) and a shallow depth (1.5 meters mean depth), the high siltation locations are assumed to correspond to 55,970 cubic meters.

Based on the above considerations regarding the life span of the impoundment and the siltation volume (or critical volume), a long-term average annual siltation rate limit of 0.63 cm was calculated and established as the numeric criteria for this siltation TMDL.

2. **The TMDLs include a total allowable load as well as individual waste load allocations and load allocations.**

A) Wasteload Allocation

No point sources were identified within the drainage area of the listed water after review of several databases from WVDEP and EPA . Therefore the wasteload allocation is set to zero.

B) Load Allocation

2.1 Nutrients

Nonpoint sources of pollutants within the watershed can generally be associated with the different types of land uses and land activities within the watershed. For example, sediment loadings can originate from silvicultural activities and road construction. Expansion of residential and commercial/industrial areas can also cause an increase in storm water flows and sediment loads through soil erosion and sediment transport. In addition, the erosion rate can potentially increase phosphorus loads since phosphorus is readily adsorbed onto soil particles. For nutrient enrichment, animal waste handling, manure and fertilizer application, and septic systems are the key potential sources.

Nutrient loading capacity was evaluated using the BATHTUB water quality simulation model to simulated phosphorus and chlorophyll *a* concentrations and resulting estimates of the Trophic State Index (TSI) for phosphorus and chlorophyll *a*.

The primary land uses within the Castleman Run Lake watershed are agriculture and forest with minor components of residential uses. The load estimation model and the lake model were used to derive the TMDLs for Castleman Run Lake. The table below contain the results of the TMDL analysis for each of the listed pollutants. Table 4 summarizes the existing loading, the loading capacity, the projected load reductions, and the load allocation for the nutrient TMDL

Table 4. Castleman Run Lake nutrient TMDL (in kilograms per year)

Source	**Existing Loading Total Phosphorus (kg)**	**Estimated Percent Reduction**	**Load Allocation (kg)**	**Comments**
Forest	116.9	20	93.5	
Agriculture	653.5	40	392.1	
Urban	0.1	0	0.1	
Transitional Barren	2.2	50	1.1	
Septic Systems	3.7	80	0.7	
Groundwater	113.6	0	113.6	
Total Load	**890.0**	**3 Load Allocation**	**601.1**	
Load Reduction	**266.3 (30%)**	**Waste Load Allocation**	**0**	**No point sources**
		Margin of Safety	**22.6**	**3.5 % of the loading capacity**
TMDL = Loading Capacity =			**623.7**	

2.2 Sediment

The sediment allocation was based on the long-term average siltation rate as an endpoint and a numeric limit of 0.63 cm per year. Table 5 provides the computed mean siltation rate of the lake for three different conditions: (1) existing condition; (2) predevelopment condition (assuming the watershed is totally forested); and (3) a loading scenario that meet the numeric limit of 0.63 cm per year as the long-term average siltation rate. The table also compares the life span of the lake under these 3 conditions.

Table 6 summarizes the sediment load allocation scheme corresponding to an overall reduction of 40% and extending the useful life of the lake from 24 to 40 years.

Table 5 Siltation Analysis for Castleman Run Lake

	Existing Conditions	**Predevelopment Conditions**	**Loading Scenario**
Mean annual load (kg)	1,152,211	444,632	691,327
Siltation rate (cm)	1.05	0.41	0.63
Fill time (years)[a]	24	62	40
Loading scenario for 40 year time span corresponds to a 40% load reduction			

[a]Based on a siltation volume of 55,9700 m^3

Table 6 Castleman Run Lake sediment TMDL (in metric tons per year)

Source	Existing Loading Sediment (metric tons/yr)	Percent Reduction	Load Allocation (metric tons/yr)	Comment
Forest	320.2	25%	240.2	
Agriculture	826.9	50%	413.4	
Urban	0			
Transitional Barren	5.1	50%	2.55	
Septic Systems	0			
Groundwater	0			
Total Load	**1152.2**	**3 Load Allocation**	**656.2**	
Load Reduction	**460 (40%)**	**Waste Load Allocation**	**0**	**No point sources**
		Margin of Safety	**36**	**5.2% of Load Capacity**
TMDL = Loading Capacity =			**692.2 metric tons/yr**	

3. The TMDLs consider the impacts of background pollutant contributions.

Background Conditions for Nutrients

The TMDL load allocation should include, when possible as a separate allocation, the natural background loading of the pollutant. In this analysis natural background is included as an allocation to groundwater or baseflow loadings, and the forest loadings. Note that the forest category also includes some additional loads due to forestry activities, which are in addition to the naturally occurring runoff and erosion from forested areas. The monitoring data were insufficient to separate natural forest loadings from other forest sources.

Background Conditions for Sediment

The TMDL load allocation should include, when possible as a separate allocation, the natural background loading of the pollutant. For sediment natural background is included as an allocation to the forest loadings. Note that the forest category also includes some loads due to forestry activities, which are in addition to the naturally occurring runoff and erosion from forested areas. The monitoring data were insufficient to separate natural forest loadings from other forest sources.

4. The TMDLs consider critical environmental conditions.

Critical Conditions for Nutrients

The critical conditions for the nutrient TMDL are selected to evaluate the type of impairment (eutrophication) and the type of waterbody (reservoir). Protection of the lake condition requires the control of long term loadings and accumulation of phosphorus. The lake condition is evaluated based on trophic state indices in response to long-term annual loading of nutrients (phosphorus).

Critical Conditions for Sediment

The critical conditions for the sediment TMDL are selected to evaluate the type of impairment (siltation) and the type of waterbody (reservoir). Protection of the lake condition requires the control of long term loadings and accumulation of sediment. The lake condition is evaluated based on mean siltation rates, in selected locations, in response to long-term annual loading and trapping of sediments in the reservoir.

5. The TMDLs consider seasonal environmental variations.

Seasonality for Nutrients

The nutrient analysis considered seasonality in the loading through the simulation of monthly watershed loadings based on historic precipitation records. The evaluation of nutrient impacts in the reservoir was considered for the average annual conditions representing the response to long term, cumulative nutrient loading. The TMDL and load allocation are presented as annual average loading consistent with the type of impairment (eutrophication) and waterbody type (reservoir). Reduction of the average annual load is expected to result in achievement of water quality standards.

Seasonality for Sediment

The sediment analysis considered seasonality in the loading through the simulation of monthly watershed loadings based on historic precipitation records. The evaluation of sediment impacts in the reservoir was considered for the average annual conditions representing the response to long term, cumulative siltation. The TMDL and load allocation are presented as annual average loading consistent with the type of impairment (siltation) and waterbody type (reservoir). Reduction of the average annual load is expected to result in achievement of water quality standards.

6. The TMDLs include a margin of safety.

Margin of Safety for Nutrients

The MOS one of the required elements of a TMDL. There are two basic methods for incorporating the MOS (USEPA 1991):

Implicitly incorporate the MOS using conservative model assumptions to develop allocations.
Explicitly specify a portion of the total TMDL as the MOS; use the remainder for allocations.

The margin of safety for this TMDL was expressed as an explicit number, calculated as a percentage of the total loading capacity. A 3.5 percent margin of safety was selected to reflect the uncertainty in the modeling analysis and the selection of the TMDL endpoint. Other implicit conservative assumptions provide an additional margin of safety. Specific assumptions which are conservative include:

> The endpoint for the reservoir is defined as a TSI less than 65. The selected load reduction is below 65 providing an additional margin of safety.
>
> The loadings calculated by the nonpoint source model (GWLF) were derived using conservative assumptions in the selection of nutrient potency factors. The use of conservative assumptions in developing the loading model results in relatively highly loads and slightly larger required load reductions.

Margin of Safety for Sediment

The margin of safety for this TMDL was expressed as an explicit number, calculated as a percentage of the total loading capacity. A 5.2 percent margin of safety was selected to reflect the uncertainty in the modeling analysis and the selection of the TMDL endpoint. Other implicit conservative assumptions provide an additional margin of safety. Specific assumptions which are conservative include:

> The endpoint for the reservoir is defined based on a 40 year lifespan for a selected volume of the lake.
>
> The loadings calculated by the nonpoint source model (GWLF) were derived using conservative assumptions in the selection of soil erosion factors. The use of conservative assumptions in developing the loading model results in relatively high loads and slightly larger required load reductions.

7. The TMDLs has been subject to public participation.

EPA published and requested comments on the proposed TMDLs on July 1, 1999 in the Charleston Gazette , which has statewide distribution. In addition, a press release was sent to most of the newspapers in West Virginia. The public comment period closed on August 16, 1999, and EPA did not receive comments from any individual or organization for the Castleman Run Lake TMDL.

8. There is reasonable assurance that the TMDLs can be met.

Management Practices

There are number of best management practices that can be adopted to minimize the nutrient, sediment and metals loadings in accordance with the identified TMDLs and load reduction targets.

Nutrient

The nutrient TMDL identifies load allocations and reductions from forested land, agricultural operations, urban, transition/ barren areas, construction areas, and septic systems. Some of the management practices that can be used to achieve the identified load reductions include:

Current regulations of the WV Dept of Health require correction of all straight pipes and failed septic systems, and it is recommended in the TMDL allocation that all such sources be brought into compliance. Because it is difficult to obtain accurate numbers for these sources during development of a TMDL, ground proofing may be needed as part of the implementation.

Forestry management: forestry practices including preharvest planning, streamside area management and buffers, road construction/reconstruction/management, timber harvest management, site preparation, erosion and sediment control, and forest regeneration. Wildlife and water fowl control can also be used to manage nutrient loads.

Agricultural management: Agricultural management practices can reduce sediment and associated nutrient loads. Typical practices include conservation tillage, terraces, crop rotations, and stream buffers. A nutrient management plan can be adopted for individual farms. The plan addresses the methods to utilize manure nutrient and to apply manure and fertilizers at agronomic rates. Fencing or alternative water supplies can assist in reducing the time where livestock are in or near streams.

Urban areas: Sediment and associated nutrient loads can be reduced through management of new developments, site planning, pollution prevention, and stormwater management.

Maintenance and inspection of septic systems: By properly maintaining septic systems, the failure rate and associated nutrients loadings could be greatly reduced.

Sediment

The sediment TMDL identifies load allocations and reductions from forest land, agricultural operations, and construction areas. Some of the management practices that can be used to achieve the identified load reductions include:

Forestry management: forestry practices including preharvest planning, streamside area management and buffers, road construction/reconstruction/management, timber harvest management, site preparation, erosion and sediment control, and forest regeneration.

Agricultural management: Agricultural management practices can reduce erosion and sediment delivery. Typical practices include conservation tillage, terraces, crop rotations, and stream buffers. Fencing or alternative water supplies can assist in reducing the time when livestock are in or near streams. Trampling of stream corridors can increase erosion and turbidity.

Construction: Sediment loads can be reduced through management of new developments, erosion and sediment control practices, site planning, and stormwater management.

The West Virginia Division of Environmental Protection-Office of Water Resources, as the lead agency for West Virginia's nonpoint source program, coordinates with other cooperating state agencies to address nonpoint source impacts, develop and implement best management practices reducing pollutant loads for agricultural, silvicultural, oil and gas, abandoned mines and construction activities. Activities in the various categories include education, technical assistance, financial assistance, research, regulatory and enforcement. WV DEP, through the Nonpoint Management Program hs been successful in initiating land use controls of BMP's for controlling NPS pollution and protecting the designated uses of the states waterbodies.