Final

TMDLs for Bear Lake

Ohio County, West Virginia

U.S. Environmental Protection Agency
Region 3
1650 Arch Street
Philadelphia, PA 19103

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EXECUTIVE SUMMARY

The objective of this study was to summarize the background information, analyze load reductions, and document Total Maximum Daily Loads (TMDLs) for nutrients, dissolved oxygen, and siltation. The West Virginia Division of Environmental Protection (WVDEP) has identified Bear Lake (designated code WV_O(L)-88-D-2-F-1) for aquatic life as being impacted by these pollutants, as reported in the 1998 303(d) list of water-quality-limited waters (WVDEP 1998). WVDEP has determined that the aquatic life use designation (Class B1 for warm water fishery) has been impaired by nutrients, dissolved oxygen, and siltation.

The West Virginia standards and listing practices were reviewed to develop numeric targets which will meet water quality standards.

- West Virginia uses a trophic state index when considering lakes for listing due to nutrient impairment. Lakes with a total phosphorus or chlorophyl *a* trophic state index greater than or equal to 65 were considered to be impacted by nutrients. For Bear Lake the target selected was a total phosphorus and chlorophyll *a* trophic state index of less than 65.

- Siltation has no specific water quality criteria; however, elevated inputs of sediment has been demonstrated to cause impairment of the support of aquatic life and recreational uses of the lake. The endpoint for the development of a TMDL for siltation of Bear Lake is based on the evaluation of the total sediment load delivered to the lake, as indicated by the average accumulation rate of sediment in selected critical locations, allowing for a 40 year life span for the lake.

- As obtained from the West Virginia Requirements Governing Water Quality Standards (Title 46), the relevant numeric criteria for low dissolved oxygen is 5.0 mg/l. In evaluating low dissolved oxygen in lake, West Virginia considers the difference in dissolved oxygen between the surface and six foot depth, and the dissolved oxygen concentration in the top four feet of the lake. The low dissolved oxygen was attributed to elevated loads of nutrients and was managed by the nutrient TMDL.

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 Bear 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 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. The period from 1978 to 1997 was used to evaluate the source loading under a range of climatic conditions. The resulting allocation for the listed pollutants includes a 50 percent reduction of nutrients (expressed as total phosphorus) to address the dissolved oxygen and nutrient listing and a 30 percent reduction of sediment load to address siltation problems. The reduction of nutrient load is expected to improve the tropic condition resulting in less severe stratification and increased surface oxygen levels.

The loads are described as average annual load reductions, which is typically appropriate for reservoirs and impoundments. The margin of safety has been addressed through an explicit portion of the TMDL load. The load reductions can be achieved through a combination of land use and restoration practices such as erosion and sediment control practices, forest management, and stream restoration.

1 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 Bear Lake for aquatic life has been impaired by nutrients, dissolved oxygen, 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 Bear Lake for the uses designated by West Virginia.

This report presents the background information, analyses, and TMDLs that address the designated use impairments of Bear Lake. The report is organized as follows:

- Section 2 - A description of the waterbody and the impairments listed by West Virginia as required under Section 303(d) of the Clean Water Act
- Section 3 - A presentation of the essential information that characterizes the impaired waterbody and watershed
- Section 4 - A description of the applicable water quality standards and the selection of TMDL endpoints to achieve the standards and to meet the designated uses
- Section 5 - An assessment of the water quality data and information pertinent to developing TMDLs
- Section 6 - An assessment of the sources of pollutants pertinent TMDL allocation
- Section 7 - A description of the modeling process used to develop TMDLs
- Section 8 - Allocation of the load reductions to sources
- Section 9 - A description of the process used to monitor the effectiveness of the proposed TMDLs and compliance

This 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. Describe waterbody, pollutant of concern, pollutant sources, and priority ranking (Section 2)
2. Describe applicable water quality standards and numeric water quality targets (Section 4)
3. Loading capacity- linking water quality and pollutant sources (Section 8)
4. Load allocations (LAs) (Section 8)
5. Wasteload allocations (WLAs) (Section 8)
6. Margin of safety (MOS) (Section 8)
7. Seasonal variation (Section 8)
8. Reasonable assurance for implementation (Section 9)

2 PROBLEM STATEMENT

A general description of the impaired waterbody, Bear Lake, and the causes for its listing on the 303(d) list are presented in this section.

The Bear Lake watershed is located within the Upper Ohio River hydrologic cataloging unit (05030106), as shown in Figure 2.1. The land area of the watershed is approximately 185.8 hectares (457 acres) contained solely within Ohio County. Runoff from the watershed flows into Bear Lake from Todd Run. Water discharged from the lake continues in Todd Run to Middle Wheeling Creek and then to the Ohio River. The lake is used for recreational activities such as fishing and picnicking. Boating and electric motors only are permitted on the lake. The lake's watershed is primarily rural, and the main land uses are forest and hay/pasture.

WVDEP listed Bear Lake on the 1998 303(d) list for not meeting its designated uses. The waterbody is given a high priority for TMDL development. The lake (designated code O(L)-88-D-2-F-1) was listed for nutrients, low dissolved oxygen, and siltation (WVDEP, 1998). The impairments, from the West Virginia Primary Waterbody List, are presented in Table 2.1.

The water quality use that is impaired is aquatic life. The primary source column provides the "general source descriptions, if confirmed" (WVDEP, 1998). WVDEP assumed that the lake impairments are due to a variety of sources including agriculture and construction activities.

West Virginia classifies a waterbody as impaired for the listed pollutants based on the following considerations:

- Nutrients: Impairment due to nutrients "means enrichment from phosphorus and nitrogen compounds, both of which lead to eutrophic conditions. Eutrophic conditions can occur without a numeric water quality standard violation. In fact, West Virginia has no phosphorus standard, and the nitrate standard is centered around public health concerns" (WVDEP, 1998). West Virginia uses a trophic state index when considering lakes for listing due to nutrient impairment. Lakes with a total phosphorus or chlorophyl *a* trophic state index greater than or equal to 65 were considered to be impacted by nutrients (WVDEP, 1998).

- Siltation: West Virginia considers lakes to be impaired by siltation if sediments are visually observed to accumulate to a depth approaching the lake normal pool elevation.

- Low dissolved oxygen: Lakes with severe stratification or dissolved oxygen (DO) less than 5 mg/l for any reading between the surface and the four-foot depth are listed as impaired.

The development of TMDLs for Bear Lake includes a review of the potential causes of impairment and the establishment of the TMDL loading capacity, load allocation, wasteload allocation, and margin of safety.

Table 2.1. Water quality impairments of Bear Lake pursuant to section 303(d) of the Clean Water Act

Stream Name	Stream Code	Use Affected	Pollutant	Primary Source	Size Affected (acres)
Bear Lake	O(L)-88-D-2-F-1	Aquatic Life	Nutrients, siltation, low dissolved oxygen	Agriculture, construction	8

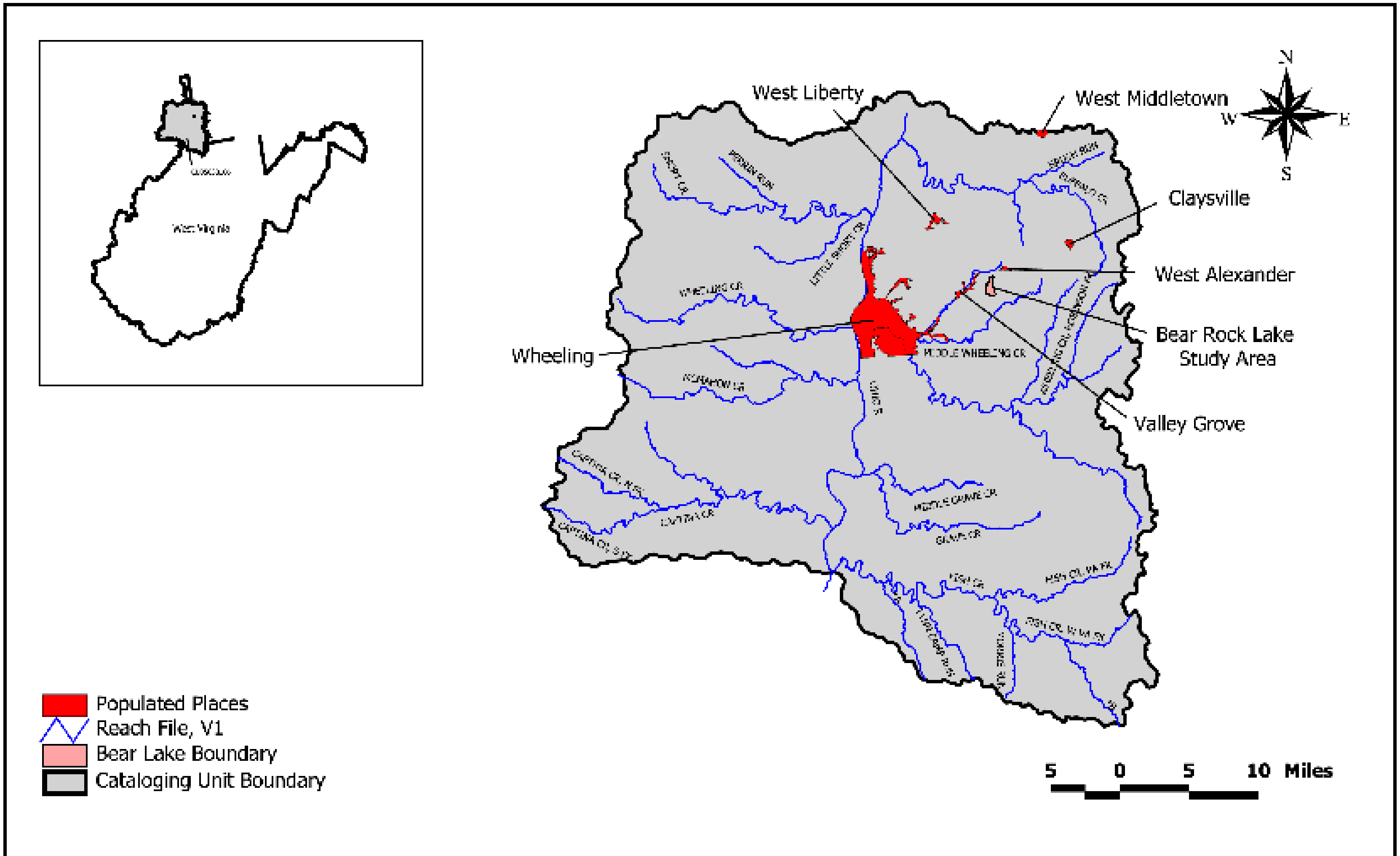


Figure 2.1. Site and Location Map
Bear Lake Watershed, Ohio County, West Virginia

Map Projection: Albers Equal Area, GRS 80

Data Sources: USGS (RF1), ESRI 1995

3 ENVIRONMENTAL SETTINGS

The environmental settings that contribute to the impairment of Bear Lake include those of the lake itself, the watershed, and the atmosphere. This section presents the environmental information that will be used in subsequent sections.

3.1 Lake Characteristics

3.1.1 Physical Characteristics

Based on discussions with WVDEP personnel, historical information regarding the Bear Lake was collected. The lake was constructed at an elevation of 1,080 feet during 1949 by the former West Virginia Conservation Commission.

The lake consists of the flooded Todd Run stream valley. Records available from the WVDNR show that Bear Lake is part of a four-lake complex, all within less than a mile of stream length. Three of the lakes are on Todd Run and are, in series from upstream to downstream, Baker Lake, Bear Lake and Rock Lake (WVDNR, 1983). A fourth lake, Wood Pond, drains to Todd Run between Baker and Bear Lakes. Table 3.1 presents the size and mean depth of the lakes as presented by WVDNR (1983). It should be noted that Rock Lake is downstream of Bear Lake and, therefore, not part of this study area.

Because Todd Run flows through Baker Lake before entering Bear Lake, Baker Lake will remove some sediments in the Todd Run bedload before it flows into Bear Lake. The capacity of Baker Lake and hydrologic and hydraulic characteristics of the watershed determine the volume of sediment that will be captured and the efficiency of Baker Lake to continue to capture sediments over time.

Table 3.1. Bear Rocks Lake Public Hunting and Fishing Area lake dimensions (WVDNR, 1983)

	Surface Area		Mean Lake Depth (m)		Maximum Lake Depth	
Lake Name	(hectares)	(acres)	(meters)	(feet)	(meters)	(feet)
Baker Lake	1.4	3.4	1.2	4	2.1	7
Bear Lake	3.2	8.0	1.8	6	6.1	20
Rock Lake	1.7	4.1	1.8	6	4.3	14
Wood Pond	0.2	0.5	NA	NA	NA	NA

Based on the available bathymetric and physical characteristics data obtained from the 1980 survey (WVDNR, 1983), several physical characteristics of Bear Lake have been derived and are presented in Table 3.2. The lake surface area extends over approximately 3.2 hectares (8.0 acres). The lake is shallow with a maximum depth of 6.1 meters (20 feet) and a mean depth of 1.8 meters (6 feet). The overall storage volume of the lake at normal pool is about 59,300 cubic meters (0.48 acre-feet) and drains a watershed area totaling 185.8 hectares (459 acres).

Table 3.2. Description of the physical characteristic of Bear Lake

Characteristics	Original (1970)	1980[a]	Present (1999)[b]
Lake volume (cubic meters)	NA	59,300	NA
Surface area (hectares)	NA	3.2	NA
Drainage area (hectares)	NA	185.8	185.8
Mean depth (meters)	NA	1.8	NA
Maximum depth (meters)	NA	6.1	5.6
Length (meters)	NA	420	NA
Mean width (meters)	NA	78	NA

[a]WVDNR, 1983.
[b]WVDEP 1999 bathymetric survey

3.1.2 Morphometric Characteristics

The 1980 bathymetric analysis (summarized in Table 3.3) shows that the ratio of mean to maximum depth is close to 0.3, indicating moderately steep side slopes. As the lake continues to lose capacity to siltation, sediment deposits around the inflow points reduce the slopes at lake entrance areas.

The ratio of the drainage area to lake surface area is about 58, which indicates that the watershed loading, including both sediment and nutrient, could have a significant impact on the lake water quality. The drainage watershed is relatively large in comparison to the impoundment area, making the lake very sensitive to increased loading, especially in the areas surrounding the lake.

The ratio of the length of Bear Lake to its mean width (5.4) indicates that the length of the lake is moderately the dominant process. The lake tends to act more like a wide river than a deep lake.

Table 3.3. Morphometric parameters of Bear Lake

Characteristics	Original (1970)	1980[a]	Present[b]
Mean to max depth ratio	NA	0.3	NA
Drainage area to surface area ratio	NA	58	NA
Length to mean width ratio	NA	5.4	NA

[a]WVDNR, 1983.
[b]1999 Screening bathymetry.

3.1.3 Hydrologic Characteristics of the Lake

Two key hydrologic parameters of Bear Lake were determined based on estimates of streamflow rates and volumetric characteristics of the impoundment. The lake residence time, calculated as lake volume over the annual flow rate is shown in Table 3.4. This short residence time is typical for lakes with a large drainage area-to-lake surface area ratio. In lakes with short residence times, a significant portion of the sediment and nutrient loads is transported farther into the impoundment beyond the transition to deeper water.

Table 3.4. Hydraulic residence time estimates for Bear Lake

Annual Precipitation (cm)	Date of Occurrence	Magnitude	Annual Discharge (m^3/yr)	Hydraulic Residence Time (days)
110	1978 to 1996	Average	9.3×10^5	23.3
126	1978	Maximum	1.1×10^6	20.3
79	1987	Minimum	6.7×10^5	32.4

Rainfall data source: Morgantown, West Virginia.

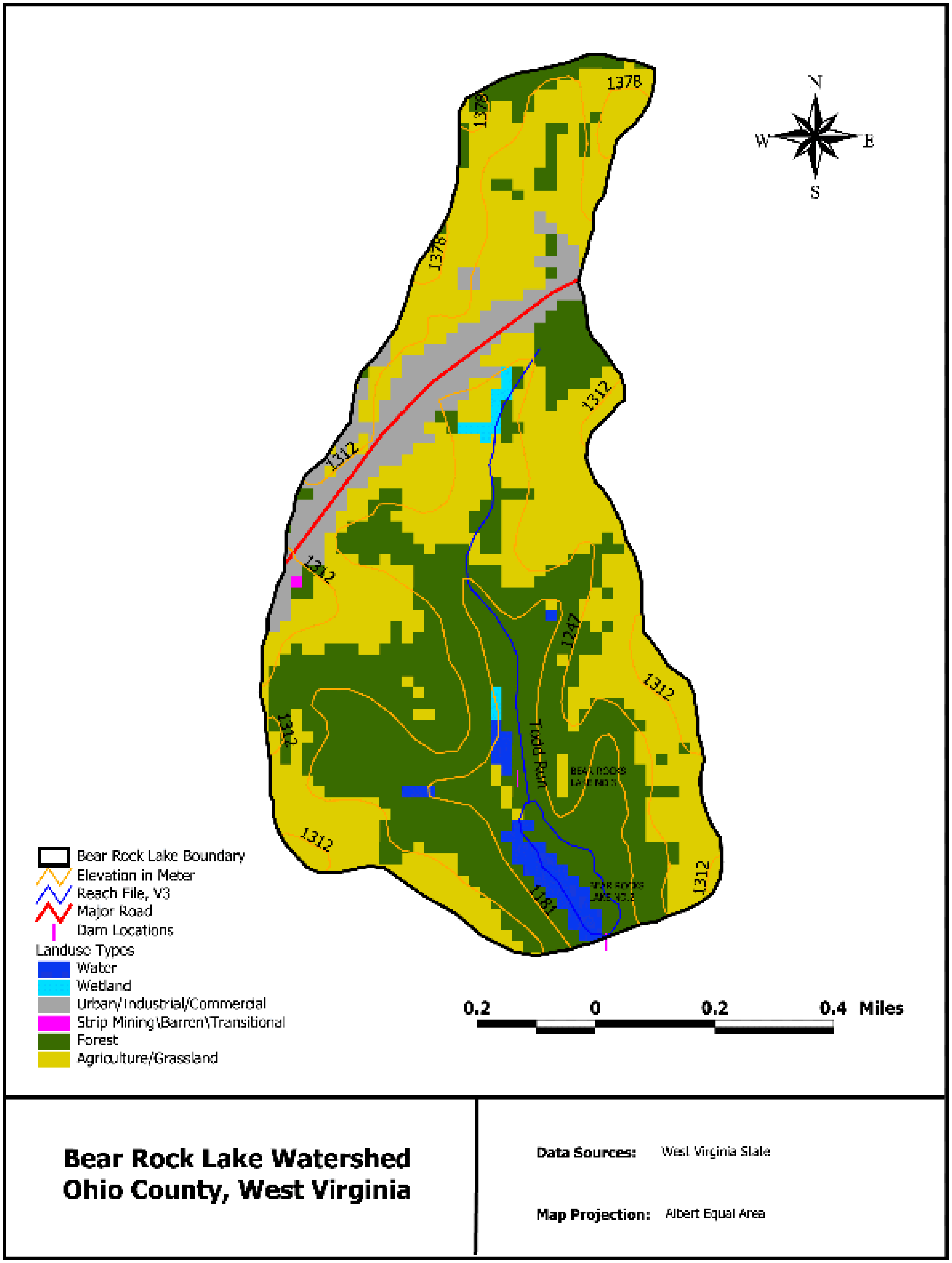
3.2 Watershed Characteristics

The Bear Lake watershed is a small drainage basin of 185.8 hectares (457 acres). All of the watershed consists of hydrologic soil group C (USDA, 1993). The major soil series include Dormont, Culleoka and Westmoreland. The watershed size yields an estimated sediment delivery ratio of 0.31, that is 31 percent of the eroded soil reaches the lake based on long-term average annual loading analysis (Vanoni, 1975).

Multi-Resolution Land Classification (MRLC) coverage was used to develop the land use distributions within the Bear Lake watershed (USEPA, 1998), which are presented in Table 3.5 and Figure 3.1.

Table 3.5. Watershed land use distributions

TMDL Land Use Classes	Pervious/Impervious (Percent)	MRLC Land Use Class (Class No.)	Land Use Distribution in Watershed (hectares)
Residential	Pervious (50%) Impervious (50%)	Low-Intensity Developed (21)	15.5
Transportation	Impervious (100%)	High Intensity Industrial/Commercial/ Transportation (23)	0.4
Forest	Pervious (100%)	Deciduous Forest (41) Evergreen Forest (42) Mixed Forest (43)	79.3
Hay/pasture	Pervious (100%)	Hay and Pasture (81)	84.8
Barren (includes grading or construction)	Pervious (100%)	Quarries/Strip Mines/Gravel Pits (32)	0.4
Water	Impervious (100%)	Lakes and Streams	4.1
Herbaceous wetland	Impervious (100%)	Woody Wetland (91) Emergent Herbaceous Wetland (92)	1.3
Total			**185.8**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Tridd Run
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S
Bear Rock Lake Boundary
Elevation in Meter
Reach File, V3
Major Road
Dam Locations
Landuse Types
Water
Wetland
Urban/Industrial/Commercial
Strip Mining\Barren\Transitional
Forest
Agriculture/Grassland
0.2
0
0.2
0.4 Miles
Bear Rock Lake Watershed
Ohio County, West Virginia
Data Sources: West Virginia State
Map Projection: Albert Equal Area

4 WATER QUALITY STANDARDS AND TMDL ENDPOINT

4.1 Water Quality Standards

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 Bear 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 Bear Lake.

4.2 Nutrients

No numeric criteria are available in the West Virginia water quality standards relevant to the 303(d) listing. 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 4.1 to 4.3.

$$TSI(SD) = 60 - 14.41 \ln (SD) \qquad (4.1)$$
$$TSI(CHL) = 9.81 \ln (CHL) + 30.6 \qquad (4.2)$$
$$TSI(TP) = 14.42 \ln (TP) + 4.15 \qquad (4.3)$$

The trophic state can be related to the trophic state index and lakes conditions as shown in Table 4.1.

Table 4.1. 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 <3.8 ug/l to 226 ug/l, with a mean of 52.8 ug/l (see section 5.2). For Bear 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 76.4 and the chlorophyll *a* TSI is 69.5. Both TSI clearly exceed 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. The numeric endpoint is based on consideration of the trophic state index (TSI). Consistent with the West Virginia listing procedures, the TSI threshold of 65 (chlorophyll *a* and total phosphorus) was used as the upper limit for reservoir condition. This lake is characterized by a shallow depth and a high watershed to surface area ratio. These characteristics make the lake highly sensitive to nutrient loading even under managed conditions. 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 values used to designate the acceptable limit in Bear Lake are a total phosphorus TSI of 63.2 and a chlorophyll *a* TSI of 64.1.

4.3 Sediment

Bear 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, a numeric limit is selected for the development of Bear 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 Bear Lake, is consistent with the causes of the 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 Bear Lake, 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 barriers for recreational uses. Specifically for Bear Lake, characterized by a small area (3.2 hectares) and a shallow depth (1.8 meters mean depth), the high siltation locations are assumed to correspond to 9,600 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 0.3 cm was calculated and established as the numeric criteria for this siltation TMDL.

4.4 Dissolved Oxygen

Bear Lake is listed as impaired due to low dissolved oxygen on the 303(d) list. As obtained from the West Virginia Requirements Governing Water Quality Standards (Title 46), the relevant numeric criteria for low dissolved oxygen is 5.0 mg/l. West Virginia has specific procedures to determine if lakes should be listed for dissolved oxygen impairments (WVDEP 1998).

> Lakes were considered impaired by dissolved oxygen if: 1) a decrease of >10 mg/l occurred between the surface and six-foot depth (indicating severe stratification) or 2) the D.O. concentration was less than 5.0 mg/l for any reading taken between the surface and four-foot depth.

Low dissolved oxygen is typically a result of eutrophication of lakes. High nutrient concentrations during the growing season can cause increased algae and vegetation growth. The settling of detritus from these activities consumes oxygen which lowers dissolved oxygen concentrations near lake bottoms. As the trophic state index increases from eutrophic to hyper-eutrophic, the stratification of the reservoir becomes more pronounced and the occurrence of low DO in the surface layers of the lake increases (Carlson and Simpson, 1996).

Management of the DO impairment is achieved by improvement of the trophic state of the reservoir. In order to change the trophic state reduction of nutrient loads is required. Lowering the nutrient inputs (i.e. phosphorus) is expected to achieve TSI of <65. Reducing the TSI results in moving the trophic state from a hypereutrophic to eutrophic state and consequently will result in following:

- Increased oxygen in the surface portion of the lake
- Reduction of the severe stratification
- Reduced frequency of algal blooms and associated oxygen depletion
- Improved habitat for the warm water fishery.

The DO TMDL will therefore be addressed by meeting the trophic state index and reducing nutrient loads as defined under the nutrient TMDL.

5 WATER QUALITY ASSESSMENT

This section provides an inventory and analysis of the available water quality data for Bear Lake, its tributary (Todd Run), and the watershed.

5.1 Inventory of Available Water Quality Monitoring Data

Limited water quality monitoring activities have been conducted for Bear Lake and its inflows. Water quality data reviewed as part of this report were collected as follows: WVDEP seasonal sampling of Bear Lake and its inflow (Todd Run) from spring to fall during 1993, 1994, 1995, and 1996 (a total of 10 sampling events) and from spring to fall 1998 (a total of 3 sampling events). Data include the monitoring of nutrients, metals, temperature, suspended solids, and other water quality parameters.

5.2 Analysis of Water Quality Monitoring Data for Bear Lake

Summaries of the minimum, maximum, and average values for the monitored water quality parameters are presented on Tables 5.1 and 5.2 for the lake and tributary, respectively. The summaries were derived using the following practices:

- Analytical results of less than the detection limit were assigned a value of one-half the detection limit when calculating the average value.
- Numerous samples collected on a single date were averaged and treated as one sample when calculating an average value.
- Mean values for in-lake nutrients only were weighted as 70% of surface values and 30% of bottom values.

The conclusions from the review of the data are as follows:

- Although a few parameters showed a range of nearly two orders of magnitude (for example, dissolved oxygen, total suspended solids, and ammonia), the wide range was generally due to an extreme value detected from a single sampling date.
- D.O. standard was violated in the surface samping on 9/19/99 (D.O. of 3.6 mg/l)/
- Nutrient and suspended sediment average concentrations are generally higher in the lake than in the tributary.
- The long-term average chlorophyll *a* concentration is 52.77 ug/l with a high reading of 226 ug/l.

Table 5.1. Summary of WVDEP lake sampling observations of selected pollutants: Bear Lake, 1993-96, 1998[a]

Pollutant Type	Pollutant	Units	Total Obs.	Min	Max	Total Mean	Lake Bottom Mean	Lake Surface Mean
Nutrient	TKN	mg/l	26	0.31	7.55	1.14	2.43	0.87
	NO2-NO3-N[a]	mg/l	28	0.01	0.54	0.11	0.13	0.11
	TN	mg/l	28	0.37	8.10	1.25	2.36	0.91
	TP	mg/l	28	0.02	1.18	0.15	0.41	0.06
	Ammonia	mg/l	28	0.01	3.26	0.44	1.08	0.22
	Chlorophyll *a*	ug/l	15	<3.80	226.00	52.77	--	52.77
Siltation	Suspended Solids	mg/l	28	1.0	25.00	8.0	9.33	7.08
	Turbidity[b]	NTU	14	0.0	33.00	16.35	32.0	11.0
Low Dissolved Oxygen	Dissolved[c] Oxygen	mg/l	58	0.0	15.50	5.57	1.94	9.56

[a] Nitrate as nitrogen is not to exceed the 10 mg/l acute human health use designation.
[b] Turbidity cannot exceed 10 nephalometric turbidity units (NTU) when background is 50 NTU or less or have more than a 10 percent increase when background is 50 NTU or greater (plus 10 NTU minimum).
[c] Summary of all samples. WV guidelines evaluate D.O. for top 4 ft. of lake.

Table 5.2. Summary of WVDEP tributary sampling observations of selected pollutants, Bear Lake, 1993-96, 1998a.

Pollutant Type	Pollutant	Units	Total Obs.	Minimum	Maximum	Mean
Nutrient	TKN	mg/l	11	0.10	0.50	0.36
	NO2-NO3-N	mg/l	11	0.05	0.60	0.28
	TP	mg/l	12	0.02	0.08	0.05
	Ammonia	mg/l	12	0.01	<0.50	0.20
Siltation	Suspended Solids	mg/l	12	1.00	10.00	5.00
Low Dissolved Oxygen	Dissolved Oxygen	mg/l	12	6.30	12.10	8.54

Nitrogen:Phosphorus Ratio

The levels of nitrogen and phosphorus in the water column control the growth of aquatic plants. It is important to determine which nutrient is limiting in order to accurately model the system. A general guide used to determine the limiting nutrient is the Nitrogen:Phosphorus (N:P) ratio. Aquatic systems where the

N:P ratio is greater than 7.2 are considered to be phosphorus limited (Chapra, 1997). For Bear Lake, the N:P ratio of total mean values from Table 5.1 is calculated to be 8.3.

Trophic State

Trophic state indices have been developed to help define the usability of a lake for fishing and recreational uses. These indices are frequently based upon factors such as nutrient levels, temperature, light, and lake geometry (Carlson and Simpson, 1996). A common classification based on these factors includes the trophic states; oligotrophic (low production), mesotrophic (medium production), eutrophic (high production), and hypereutrophic (very high production). A quantitative description of these trophic states is seen in Table 5.3.

Table 5.3. Common trophic state characteristics [a]

Trophic State	Characteristics		Attributes
Oligotrophic	Low phosphorus Low nitrogen Low Chlorophyll *a* High secchi depth	(3.0 - 17.7 ug/L) (307 - 1630 ug/L) (0.3 - 4.5 ug/L) (5.4 - 28.3 m)	Oxygenated hypolimnion, clear water, suitable for cold water aquatic life in deeper lakes.
Mesotrophic	Moderate phosphorus Moderate nitrogen Moderate Chlorophyll *a* Moderate secchi depth	(10.9 - 95.6 ug/L) (361 - 1387 ug/L) (3 - 11 ug/L) (1.5 - 8.1 m)	Hypolimnetic anoxia possible, moderately clear water, suitable for warm water aquatic life.
Eutrophic	Moderate phosphorus Moderate nitrogen Moderate Chlorophyll *a* Moderate secchi depth	(16 - 386 ug/L) (393 - 6100 ug/L) (3 - 78 ug/L) (0.8 - 7.0 m)	Decreased transparency, noticeable odor and color, possible macrophyte problems, suitable for warm water aquatic life.
Hypereutrophic	High phosphorus High nitrogen High Chlorophyll *a* Low secchi depth	(750 -1200 ug/L) (Not available) (1 - 150 ug/L) (0.4 - 0.5 m)	Dense algae growth, nuisance weeds present, noticeable odor and color, low transparency, winter fish kills possible.

[a] Vollenweider and Kerekes, 1980.

These classifications may be used to determine whether waterbodies are meeting their “fishable” and “swimmable” designated uses. The trophic state index for Bear Lake is shown in Table 5.4 (Carlson and Simpson, 1996). Both TSI exceed the state listing guideline of 65.

Table 5.4. Trophic state index (TSI)

Pollutant	Observed Mean (ug/l)	TSI
Total Phosphorus	150	76.4
Chlorophyll *a*	52.8	69.5

6 SOURCE ASSESSMENT

6.1 Assessment of Point Sources

Several databases were reviewed to determine if permitted or regulated point source discharges were present within the watershed. The databases reviewed were obtained primarily from the USEPA mainframe system. In addition to review of available databases, local agencies, including WVDEP and USEPA Region 3 were contacted by telephone. The following database systems were searched:

- Permit Compliance System for permitted industrial or municipal facilities
- Hazardous and solid waste facilities
- Abandoned mines
- Oil and gas wells
- Toxic release inventory

No point sources were identified in the watershed (Donaghy, personal communication, May, 1999)

6.2 Assessment of Nonpoint Sources

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 agriculture, silvicultural, and road construction activities. Expansion of residential and commercial/industrial areas can also cause an increase in stormwater 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.

The primary land uses within the Bear Lake watershed are pasture and forest with minor components of residential and transportation land uses. The land uses within the watershed are presented on Table 6.1.

The broad categories of land uses have been separated into more detailed classes based on information obtained from the West Virginia Forestry Service (Warren, personal communication, May 1999). It was assumed that 2.4 percent of the forest land is selectively harvested every year (West Virginia Department of Forestry, 1999).

The potential contribution of nutrients from failing septic systems was also assessed. No sanitary sewer exists within the watershed. Data associated with the number of reported septic systems in Ohio County were obtained from 1990 U.S. Census data and the analysis of existing maps.

Urban development and associated construction activities were assumed to exist. This was based on an analysis of land use maps and census data that indicated a roughly 5.9 percent annual population growth in Ohio County. Construction activities for urban development was estimated at 0.3 hectare per year.

Cattle can contribute nutrient loadings and degrade vegetative buffers to streams. Wildlife, especially waterfowl, can contribute significant nutrient loadings directly to the lake. While waterfowl are expected to be present during the warmer months, no specific wildlife counts are available at this time.

Table 6.2 presents a summary of additional potential sources considered in this analysis.

Table 6.1. Land use categories

Land Use Classes	Area (hectares)
Residential	15.5
Transportation	0.4
Forest	79.3
Pasture	84.8
Barren (includes grading or construction)	0.4
Water[a]	4.1
Wetland	1.3
Total	**185.8**

[a]Water area may be slightly underestimated in the land use map due to the size of waterbodies and the resolution of spatial measurements.

Table 6.2. Additional consideration in representing potential sources

Potential Nonpoint Sources	Magnitude	Data Sources	Comments
Silvicultural activities (hectares/year)	1.9	WV Forestry Service	Selective tree logging methods assumed
Septic releases (population)	57	USGS quads; US Census data	Assumes 5.9% population growth per year
Urban development (hectares/year)	0.3	US Census data; USGS quads	Primarily low-density residential development
Wildlife and waterfowl (counts)	--	--	Included in Forest
Cattle/Livestock (counts)	--	--	Included in Agriculture

[a] Not available.

6.3. Representation of Potential Sources in the Development of Loading Estimation

The representation of the nonpoint sources in the loading model was determined based on the available data and considering the differences among the various categories of sources.

Nutrients

The sources simulated in the model include four land use categories representing surface loading, the septic system as an independent source, and the contribution of nutrient from ground water. Table 6.3 presents the nutrient sources simulated.

Table 6.3. The nutrient sources simulated in the loading model.

Sources Simulated	Characteristics
Forest	All the forest land, including forest harvesting and wildlife and waterfowl.
Agriculture	Pasture / hayland, and barnyards.
Urban	Residential areas.
Construction	Barren and construction areas
Groundwater	Nutrients from groundwater
Septic System	Septic release from human population

Sediment

The sediment sources represented in the model are shown in Table 6.4.

Table 6.4. The sediment sources simulated in the loading model.

Sources Simulated	Characteristics
Forest	All the forested land, including forest harvesting
Agriculture	Pasture/hayland and barnyards
Urban	Residential areas
Construction	Barren and construction areas.

7 MODELING AND ANALYSIS SUMMARY

Based on a review of the available data, listed pollutants, and lake characteristics the following approach was identified. The analysis is presented and described by pollutant—nutrients, sediment, and metals. In-lake modeling is compared with numeric criteria (for metals), trophic state indices (for nutrients), and available depth (for sediment).

7.1 Nutrient Model Setup

7.1.1 Nutrient Loading Analysis

The loading assessment requires evaluation of seasonal and annual loadings of nitrogen and phosphorus to the reservoir. The GWLF model was selected as consistent with the land use type, available information, and loading time scale. The GWLF model provides predictions of monthly total and dissolved nitrogen and phosphorus (Haith and Shoemaker, 1987; Haith, Mandel, and Wu, 1992). The model requires inputs of soil and land cover information. Daily precipitation and temperature are used for the selected simulation period. The GWLF model was applied as follows:

- Land use classification: MRLC (USEPA, 1998)
- Hydrologic soil group: C soils
- Simulation time period: 1978-97
- Meteorologic station: Morgantown, West Virginia

The flow to Bear Lake was estimated using the GWLF model. The flow consists of surface water runoff and groundwater contributions. The surface water runoff was simulated in GWLF using soil curve number information from Natural Resources Conservation Service (NRCS) Technical Release 55 (TR-55) (SCS, 1986). The mean stream flow to the lake was estimated to be approximately 45 percent of the total precipitation. This was within the range of estimates from five USGS gaging stations for small watersheds (less than 5 square miles) in West Virginia that have characteristics similar to those of the Bear Lake watershed (see Table 7.1). The precipitation records were obtained from Morgantown, West Virginia, for the period of 1978 to 1997.

Table 7.1. Long-term mean discharges reported by USGS gaging stations for small watersheds

USGS Station ID	Watershed Area (mi^2)	USGS Gaging Station Mean Discharge (cfs)	Estimated Watershed Precipitation Rate (cfs)	Streamflow as a Percentage of Precipitation
03193776	0.91	1.20	2.95	40.6%
03193778	1.44	1.96	4.66	42.0%
03198020	2.73	2.72	8.84	30.8%
03181200	3.06	5.20	9.91	52.5%
03114650	4.19	5.61	13.57	41.3%
03113700	4.95	6.48	16.03	40.4%
Average	2.88	3.86	9.33	41.3%
Minimum	0.91	1.20	2.95	30.8%
Maximum	4.95	6.48	16.03	52.5%

The GWLF Model was used to estimate nutrient loading for the sources described in Table 7.2.

Table 7.2. Information used to quantify source loadings [a]

Land Use	Existing Area (hectares)	Percent of Watershed	Description
Forest	79.3	43.3%	Forest harvesting, wildlife, and background erosion losses
Agriculture	84.8	46.3%	Includes crops, pasture, and hay
Urban	15.9	8.7%	Includes residential, commercial, industrial, and transportation
Soil Disturbances due to Construction	0.4	0.22%	Includes estimated mean annual construction area
Ground water			Assume background concentrations of 0.34 mg/l total nitrogen and 0.015 mg/l total phosphorous
Septic System			Conventional septic systems with 32% nitrogen removal efficiency; 2.5% septic failure rate
Total	183.3 [b]	100%[b]	

[a] Based on MRLC land use coverage representative of 1986-94 conditions (USEPA, 1998).
[b] Includes wetland and water area (2.9 ha) but excludes the lake

A summary of the phosphorus loading obtained from GWLF application is presented in Table 7.3.

Table 7.3. Nonpoint source loadings

Source	Phosphorus Loading (kg)
Forest	17.7
Agriculture	75.7
Urban	2.2
Soil Disturbance due to construction	3.1
Groundwater	9.5
Septic System	1.8
Total	110

The phosphorous loads converted to concentrations (in mg/l) were compared to observed lake concentrations. Comparisons between predicted and observed nutrient concentrations are presented in Table 7.4.

Table 7.4. Annual mean simulated and observed nutrients concentrations

Constituent	Simulation Results	In-Lake Observed Concentration[a]
Total Nitrogen (mg/L)	1.38	1.25
Total Phosphorus (mg/L)	0.12	0.15

[a]Based on 59 samples collected during the period from 1993-1998.

7.1.2 Nutrient Lake Analysis

For in-lake assessment, the BATHTUB model (USACE, 1996) was selected to evaluate the chlorophyll *a* concentration resulting from nutrient inputs under existing and TMDL conditions. The BATHTUB model uses empirical relationships to evaluate lake conditions based on the physical characteristics of the lake, the nutrient inputs, and the meteorologic conditions. The BATHTUB model was set up as follows:

- Time period: Average annual loading
- Bathymetry: Existing conditions derived from 1980 bathymetry data and 1999 observations; allocations run assume lake is at pre-1980 conditions
- Configuration: Lake segmentation represented in the BATHTUB model (Table 7.5)

Table 7.5. Bear Lake morphology as represented in the BATHTUB model

Segment	1980 Lake Volume	1999 Lake Volume
Segment 1	34,000	27,400
Segment 2	27,200	24,960

Results of the BATHTUB analysis, under existing conditions, were compared with the observed lake data for the 1993-98 sampling seasons. The observed chlorophyll *a* concentrations were used to calibrate the model. The calibration results are shown in Table 7.6.

Table 7.6. In-lake chlorophyll *a* concentrations

Constituent	In-lake Simulation Results	In-lake Observed Concentration[a]
chlorophyll *a* (ug/L)	48.8	52.78

[a] based on 15 samples collected during the period from 1993-1998.

The nutrient and chlorophyll a predictions were used to derive trophic state indices for comparison with the TMDL endpoints defined in section 4.2.

7.2 Sediment

7.2.1 Sediment Loading Model

The loading evaluation requires the simulation of annual loading of sediment to the reservoir. The GWLF model was used to estimate sediment loading from the land. The model provides monthly and annual estimates of sediment yield to the reservoir, taking into consideration soil characteristics and land use information. Setup, analysis, and model testing were based on the same configuration as the nutrient loading model. Insufficient monitoring information is available to compare predictions to observed tributary loadings. Table 7.7 presents the sediment loading estimates for Bear Lake.

Table 7.7. Sediment loading estimates by source

Source	Existing Sediment Loading (metric tons)
Forest	37.3
Agriculture	93.1
Soil disturbance due to construction	6.1
Urban	1.4
Total	137.9

7.2.2 Sediment Lake Analysis

The sediment accumulation to the Bear lake is assessed using trap efficiency calculations. Trap efficiency refers to the ability of lakes and reservoirs to retain a portion of the sediment loading. This efficiency is expressed as the percent of sediment retained compared to total incoming sediment. The key factors that affect the efficiency of lakes/reservoirs to trap sediment include sediment particle size distribution, the lake hydraulic residence time, and the design and operation of the reservoir outlets. Brune's method for estimating lakes and reservoirs trap efficiency was developed based on analysis of numerous reservoir siltation studies (Chow, 1953). The method establishes a graphical relationship between the sediment trap efficiency and the ratio of the reservoir available storage capacity to the total annual inflow. This relationship has been extensively used to estimate siltation rates, reservoir life span, and other engineering parameters used in economic feasibility studies of reservoirs.

Using an approximate volume of 59,000 cubic meters and an estimated annual inflow from GWLF model, the trap efficiency of Bear lake is estimated to vary between 70 percent to 87 percent (80 percent median value). The siltation rate was estimated at 0.43 cm/year for Bear Lake (Table 7.8).

Table 7.8. Estimated sediment loadings to Bear Lake

Mean Sediment Loading (metric tons/yr)	Siltation (metric tons/yr)	Accumulation Rate (cm/yr)
137.9	110.3	0.43

8 TMDL

The load estimation model and the lake model were used to derive the TMDLs for Bear Lake. The results of the TMDL analysis for each of the listed pollutants are presented in this section.

8.1 Nutrients

The loading capacity was calculated as an average annual value, based on BATHTUB analysis of the chlorophyll *a* indicator. Table 8.1 describes the derivation of the required load reduction for nutrients and presents the selected level of control that meets the TMDL endpoint of a trophic state index (TSI) of less than 65.

Table 8.1. Allocation scenarios for Bear Lake

Scenario	TP	TSI(TP)	Chlorophyll *a*	TSI(CHL)
Observed Value	150	76.4	52.7	69.5
Dredged	120	73.2	48.3	68.6
10% nutrient reductions	108	71.7	46.3	68.2
20% nutrient reductions	96	70.0	43.9	67.7
30% nutrient reductions	84	68.1	41.2	67.0
40% nutrient reductions	72	65.8	36.4	65.8
50% nutrient reductions	60	63.2	30.4	64.1
60% nutrient reductions	48	60.0	23.1	61.4
A 50% reduction in nutrient loading meets the targeted endpoint of 65 for both TSI (TP) and TSI (CHL).				

The 1999 bathymetry data was used to setup the lake model under existing conditions. The designated use of the lake was specified using the as-built volumetric conditions. Original bathymetric data was not available to determine the as-built conditions of the lake. The allocation scenarios were simulated using the 1980 bathymetry data to represent the as-built conditions.

Based on evaluation of the lake monitoring and modeling analysis and evaluation of the nitrogen-phosphorus ratio (see section 5.2), phosphorus is determined to be the limiting nutrient for the reservoir. Table 8.2 summarizes the existing loading, the loading capacity, the projected load reductions, and the load allocation for the nutrient TMDL.

Table 8.2. Bear Lake nutrient TMDL

<table>
<tr><th>Source</th><th>Existing Loading Total Phosphorus (kg)</th><th>Estimated Percent Reduction</th><th>Load Allocation (kg)</th><th>Comments</th></tr>
<tr><td>Forest</td><td>17.7</td><td>10</td><td>15.9</td><td></td></tr>
<tr><td>Agriculture</td><td>75.7</td><td>70</td><td>22.7</td><td></td></tr>
<tr><td>Urban</td><td>2.2</td><td>0</td><td>2.2</td><td></td></tr>
<tr><td>Construction</td><td>3.1</td><td>50</td><td>1.55</td><td></td></tr>
<tr><td>Groundwater</td><td>9.5</td><td>0</td><td>9.5</td><td></td></tr>
<tr><td>Septic Systems</td><td>1.8</td><td>100</td><td>0</td><td></td></tr>
<tr><td>Total Load</td><td>110</td><td>3 Load Allocation</td><td>51.9</td><td></td></tr>
<tr><td colspan="2" rowspan="2">Loading Reduction = 54.7 (50%)</td><td>Waste Load Allocation</td><td>0</td><td>No point sources</td></tr>
<tr><td>Margin of Safety</td><td>2.8</td><td>5% of Loading Capacity[a]</td></tr>
<tr><td colspan="5">TMDL = Loading Capacity = 54.7</td></tr>
<tr><td colspan="5">[a]Margin of Safety. An explicit margin of safety was calculated as a percentage of the loading capacity (5%). The selected margin of safety is consistent with level of uncertainty identified in performance of the TMDL analysis.
Seasonality. The analysis considered seasonality in the loading through the simulation of monthly loadings. The evaluation of nutrient impacts in the reservoir was considered for the average annual conditions. The allocation is presented as an annual average loading consistent with the impairment of the reservoir and the expression of the load reduction required to achieve water quality standards.
Critical Condition. The critical conditions for the nutrient TMDL are selected to evaluate the impairments observed in the lake. The lake condition is evaluated based on mean chlorophyll a in response to long-term annual loading of nutrients (phosphorus).</td></tr>
</table>

Margin of Safety

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

C Implicitly incorporate the MOS using conservative model assumptions to develop allocations.
C 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 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 conservative assumptions 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.

Seasonality

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.

Critical Condition

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 trophic state indices in response to long-term annual loading of nutrients (phosphorus).

Background Conditions

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 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.

8.2 Sediment

The sediment allocation was based on the long-term average siltation rate as an endpoint and a numeric limit of 0.3 cm per year. Table 8.3 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 0.3 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 8.4 summarizes the sediment load allocation scheme corresponding to an overall reduction of 30%, which will extend the timespan of the lake from 28 to 40 years.

Table 8.3. Siltation of Bear Lake

	Existing Conditions	Predevelopment Conditions	Loading Scenario
Mean Annual Load (kg)	137,934	64,861	96,554
Siltation Rate (cm)	0.43	0.20	0.30
Fill Time (years)[a]	28	59	40
Loading scenario for 40 year time span corresponds to a 30% load reduction (see Table 8.4).			

[a]based on a critical siltation volume of 9,621 m^3

Table 8.4. Bear Lake sediment TMDL

Source	Existing Loading Sediment (metric tons)	Percent Reduction	Load Allocation (metric tons)	Comments
Forest	37.3	20	29.8	
Agriculture	93.1	35	60.5	
Soil Disturbance due to construction	6.1	60	2.4	
Urban	1.4	0	1.4	
Total Load	**137.9**	**3 Load Allocation**	**94.1**	
Load Reduction = 41.4 (30%)		**Waste Load Allocation**	**0**	**No point sources**
		Margin of Safety	**2.4**	**2.5% of Load Allocation**
TMDL = Loading Capacity = 96.53				
Margin of Safety. An explicit margin of safety was calculated as a percentage of the loading capacity (2.5%). The selected margin of safety is consistent with level of uncertainty identified in performance of the TMDL analysis. **Seasonality.** The analysis considered seasonality in the loading through the simulation of monthly loadings. The evaluation of sediment impacts in the reservoir was considered for the long-term average annual conditions. The allocation is presented as an annual average loading consistent with the impairment of the reservoir and the expression of the load reduction required to achieve water quality standards. **Critical Condition.** The critical conditions for the sediment TMDL are selected to evaluate the long-term siltation impairments observed in the lake.				

Margin of Safety

The margin of safety for this TMDL was expressed as an explicit number, calculated as a percentage of the total loading capacity. A 2.5 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 conservative assumptions 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.

Seasonality

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.

Critical Condition

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.

Background Conditions

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.

8.3 Dissolved Oxygen

Low dissolved oxygen in the hypolimnium is associated with eutrophication processes including increased algal growth and severe stratification. Reduction of the phosphorus inputs has been identified as the treatment option for improving the trophic state and reducing the symptoms of eutrophication. By reducing the phosphorus inputs to the identified levels the required load reduction (i.e., TMDL) for dissolved oxygen control will be achieved as well. Control of dissolved oxygen will be achieved by meeting the allocation for phosphorus presented in Table 8.2.

9 REASONABLE ASSURANCE FOR IMPLEMENTATION

9.1 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:

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.

9.2 West Virginia Nonpoint Source Programs

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.

Silvicultural

The Division of Forestry administers several state and federally funded programs that relate to water quality protection and improvement. These include programs that provide technical and financial assistance, education and enforcement of state regulations. In coordination between the Office of Water Resources and the Division of Forestry, the Logging Sediment Control Act is enforced. Under the West Virginia Logging Sediment Control Act, all logging operations are required to be registered with the Division of Forestry and are to be in compliance with all regulations and laws of the state. Timber harvesting operators are required to protect the environment through the judicious use of silviculture best management practices adopted by the Division of Forestry to minimize soil erosion and sedimentation.

The West Virginia Division of Forestry may be reached at (304) 558-2788.

Agriculture

In cooperation with the West Virginia Soil Conservation Agency, agricultural nonpoint source problems are addressed through state and federal assistance programs to develop and apply best management practices. When water quality problems emanate from agricultural activity, the Division of Environmental Protection relies on the Soil Conservation Agency to contact and work with the landowner to correct problems. The two prominent areas of direct assistance provided to the agricultural community are technical and financial assistance that involves the following:

a. Nutrient Management/Pesticide Management planning with land users,
b. Agriculture erosion control conservation planning and BMP implementation with land users,
c. Manage NPS demonstration projects and coordinate with assisting agencies to carry out this management program.

For additional information on agricultural best management practices, you may contact the West Virginia Soil Conservation Agency at (304) 558-2204.

Oil and Gas Exploration

In West Virginia a well work permit from the Office of Oil and Gas of the West Virginia Division of Environmental Protection is required before any well work, including site preparation, can be performed. An erosion and sediment control plan must accompany each application for a well work permit, with the exception of permits to plug or replug a well. Each plan must contain methods of stabilization and drainage control that must meet the minimum requirements established in the Division of Environmental Protections "Erosion and Sediment Control Technical Manual," adopted by the Office of Oil and Gas. The erosion and sediment control plan becomes part of the terms and conditions of the well work permit which is issued. The erosion and sediment control plan also establishes the method of reclamation that will comply with the Oil and Gas regulations.

For additional information on oil and gas, you may contact the WVDEP - Office of Oil and Gas, (304) 759-0514

Construction

The West Virginia Nonpoint Source Program for construction activity involves coordination with the State Soil Conservation Agency and Office of Environmental Enforcement to provide education, technical assistance, compliance assistance and regulatory enforcement to minimize sediment and other pollutants impacts on surface and ground water resources.

For construction sites of less than 3 acres, voluntary Sediment Control Plans are prepared and submitted by the developer to one of the 14 Soil Conservation Districts in the State. They are reviewed by a Nonpoint Source Technician for adequacy to protect sediment runoff during the period of construction is ongoing. Construction sites of less than 3 acres are not subject to the Stormwater NPDES permitting process in West Virginia. Therefore, it is the responsibility of the developer to work with the local SCD to submit sediment and erosion control plans.   Approved erosion and sediment control plans are forwarded to the Nonpoint Source Program at the Office of Water Resources, where upon agency approval, provides protection in the event a violation of the turbidity water standard should occur while the plan is being properly implemented.

For additional information on construction sites which are less than three acres contact the WVDEP - Office of Water Resources, at (304) 558-2108.

Construction activities involving greater than 3 acres require a Stormwater NPDES Permit from the Office of Water Resources. The Permit Section may be contacted for additional information at (304) 558-4086.

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