Final Report

Metals TMDL for Little Kanawha River Watershed, West Virginia

US Environmental Protection Agency Region 3
1650 Arch Street
Philadelphia, PA

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Decision Rationale

**Total Maximum Daily Load for
Total Aluminum and Total Iron for the Little Kanwaha River Watershed**

I. Introduction

This document will set forth the Environmental Protection Agency's (EPA) rationale for establishing the Total Maximum Daily Load (TMDL) for Total Iron and Total Aluminum for the Little Kanawha River and five of its tributaries (Reedy Creek, Spring Creek, Sand Fork, Oil Creek, and Saltlick Creek). The TMDL was sent out for public comment on July 15, 2000. Our rationale is based on the determination that the TMDL meets the following 8 regulatory conditions pursuant to 40 CFR §130. According to the 1997 Consent Decree EPA was responsible to fulfill West Virginia's obligations under the Consent Decree if the State was unable to do so. EPA established the TMDL for the Little Kanawha River Watershed because the State was unable to fulfill its Consent Decree commitments.

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 have been subject to public participation.
8. There is reasonable assurance that the TMDLs can be met.

II. Background

Located in central West Virginia, the Little Kanawha River watershed [1] is approximately 2,307 square miles (1.5 million square acres). The TMDL addresses 47 river miles of the Little Kanawha River from the Burnsville Dam to its confluence with the Ohio River. Reedy Creek, Spring Creek, Sand Fork, Oil Creek, and Saltlick Creek have impaired lengths of 22.63 miles, 25.27 miles, 18.66 miles, 9.81 miles, and 17.71 miles respectively.

In response to Section 303 (d) of the Clean Water Act (CWA), the West Virginia Division of Environmental Protection (WVDEP) listed 47 river miles of the Little Kanawha as being impaired by elevated levels of Total Aluminum and Total Iron on West Virginia's 1998 303 (d) list. Spring Creek,

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[1]The Little Kanawha River watershed is hydrologic unit No. 05030203

Reedy Creek, Oil Creek, Saltlick Creek, and Sand Fork were all listed on the 1998 303 (d) list for violating the Total Aluminum and Total Iron standard as well. The Little Kanawha River and five of its tributaries were listed for violations of West Virginia's Total Aluminum and Total Iron standard for aquatic life and human health. Aluminum is a naturally occurring metal, and the most common metal found in the earth's crust. Although it is common in the environment, it is not found in pure form and is extracted from bauxite and cryolite ore. Aluminum has a wide range of industrial applications. The metal is not readily soluble in a neutral solution, however, it may readily dissolve in an acidic or alkaline solution. In the 1988 EPA report Ambient Water Quality Criteria for - Aluminum, several studies are documented that demonstrate the toxicity of Total Aluminum to freshwater organisms. Studies conducted in the 1970s and 1980s document the toxicity of this metal to Trout and Carp. The LC-50 (concentration at which the substance is lethal to 50% of the organisms exposed) for Carp after a 48-hour exposure and Brook Trout after a 98-hour exposure was 4,000 and 3,600 ug/L respectively. The freshwater Final Acute Value for Aluminum at a pH between 6.5 and 9.0 was calculated to be 1,496 ug/L[2]. The Aluminum standard of 750 ug/L, was derived by multiplying the acute value of the most sensitive organism by 0.5.

Section 303 (d) of the Clean Water Act and its implementing regulations require a TMDL to be developed for those waterbodies identified as impaired by the State where technology-based and other controls do not provide for the attainment of Water Quality Standards. The TMDL prepared by EPA is designed to determine the acceptable load of Total Aluminum and Total Iron which can be delivered to the Little Kanawha and the five tributaries, as demonstrated by the Storm Water Modeling Method (SWMM)[3], in order to ensure that the water quality standard is attained and maintained. These levels of Total Aluminum and Total Iron will ensure that the Aquatic Life and Human Health usage are supported. SWMM is considered an appropriate model to analyze this watershed because of its dynamic ability to represent loading to a mixed land use watershed during observed meteorological conditions.

The TMDL for the Little Kanawha River watershed was established for Total Aluminum and Total Iron. Acid mine drainage is often considered the primary source of instream Aluminum and Iron. As mentioned earlier, the solubility of Aluminum will increase with changes to the waters pH. The lower pH typically seen in waters effected by acid mine drainage makes the Aluminum more soluble. However, there is a limited amount of mining activities or abandoned mines within this watershed and most of these activities are isolated to specific subwatersheds, such as the Sand Fork. Therefore, it was determined that there must be another source of metals (Total Aluminum and Total Iron). There were no industrial or commercial centers identified within the watershed.

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[2]USEPA. 1998. *Ambient Water Quality Criteria for - Aluminum 1988*. EPA 440/5-86-008. U.S. Environmental Protection Agency, Office of Water.

[3]Huber, W.C., Dickinson, R.E., Barnwell, T.O. 1992. The USEPA SWMM4 Stormwater Management Model: Version 4 Users Manual. EPA/600/3-88/001a. U.S. Environmental Protection Agency, Environmental Research Laboratory, Athens, Georgia.

Forested lands and agriculture make up 77% and 16% of the land usage within the watershed, respectively. The remainder of the watershed is compromised of water, urban built-up land, and transportation land (streets and roads). The traditional sources of metals were thus ruled out, because they were not detected in sufficient numbers. During the literature review process, sediment was identified as another possible source of Aluminum and Iron contamination. Further research documented that the bedrock in the Little Kanawha River and watershed is rich in metals and oxidizing sulfides that can cause elevated concentrations of Aluminum. In addition, correlation coefficients indicate that iron is associated with Aluminum as a result of precipitated iron oxyhydroxides in the streambed.[4]

Five monitoring stations were located within the watershed. Water quality data from these stations was evaluated to determine if there was a link between the elevated metals and Total Suspended Solids (TSS). The Total Aluminum and Total Iron concentrations correlated with the concentrations of TSS. As the TSS increased, so did the levels of Aluminum and Iron. High flow events are often associated with elevated levels of TSS. The rainfall and runoff that cause these high flow events also have the power to washoff sediments from the land segments and feed this sediment load to the stream. Sediment on the stream bed is also resuspended during these turbulent flows. This can be illustrated in Spring Creek where the concentration of Total Aluminum and Total Iron increased by four folds for flow events ranking in the highest 10% of observed sediment concentrations. Regression analysis indicated that a good linear relationship exists for between Total Aluminum and Total Iron and sediment concentrations[5]. It was determined that this relationship did not hold true for Dissolved Aluminum and Dissolved Iron.

A relation was drawn between the maintenance and attainment of the Total Aluminum and Total Iron standard and the concentration of TSS. Therefore, one could insure that the Little Kanawha River Watershed would attain standards if limitations and controls were placed on the amount of sediment reaching the river.

III. Discussion of Regulatory Conditions

EPA finds that sufficient information has been provided to meet all of the 8 basic regulatory requirements for establishing a metals TMDL on the Little Kanawha River watershed.

1) The TMDL is designed to meet the applicable water quality standards.

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[4]Watts, K.C., Hinkle, M.E., and Griffits, W.R. 1994. *Isopleth Maps of Titanium, Aluminum, and Associated Elements in Stream Sediments of West Virginia.* U.S. Department of the Interior, U.S. Geologic Survey.

[5]USEPA. 2000. *Metals TMDL for Little Kanawha River Watershed, West Virginia*. U.S. Environmental Protection Agency, Region III.

Modeling and data interpretation by EPA and its contractor has indicated that excessive levels of Total Aluminum and Total Iron can be linked to the amount of suspended solids in the watershed. The West Virginia water quality criterion for Total Aluminum is 0.75 mg/L. The Aluminum standard was derived by multiplying the acute value of the most sensitive organism by 0.5. As mentioned earlier, the acute value of the most sensitive organism was 1,496 ug/L, therefore the Final Acute Value is 0.75 mg/L (750 ug/L). This standard is for Total Aluminum (dissolved and suspended) for the protection of Aquatic Life. This standard is not to be exceeded on average more than once every three years. The standard is applied to all B1 (warm water fisheries), B2 (trout waters), and B4 (wetlands) waters.

The Total Iron standard is applied to B1, B2, and B4 waters as a Chronic (four-day average concentration not to be exceeded more than once every three years on average) value. The Total Iron standard is applied to the use designation A as well. The designation is applied to public water supplies, whose criteria must not be exceeded to protect human health from the toxic effects through drinking water and fish consumption[6]. The Human Health standard for Total Iron is not to exceed 1.5 mg/L.

The West Virginia Environmental Quality Board has proposed to change the aluminum water quality criteria from a total standard to a dissolved standard. This modification has not yet been finalized, and EPA has expressed some concern that the Board has not presented sufficient information to indicate that dissolved aluminum will be protective of aquatic life in the State. According to the Federal regulation at 40 CFR 131.21 (c)(2), even if the modification is finalized, it is not considered effective for Clean Water Act purposes (that includes the development of TMDLs) until EPA approves. Similar to the aluminum standard, the proposed change to the iron criteria has not been finalized or approved by EPA and therefore is not viewed as effective.

The SWMM model was used to evaluate the instream concentrations of TSS, Total Aluminum, and Total Iron. The Little Kanawha River watershed was broken up into several hydrologically connected watersheds for the model. The modelers' goals were to develop a model for the Little Kanawha River that would represent the dominant characteristics of the watershed, represent the point and nonpoint source loadings to the Little Kanawha watershed during various flows and storm events, and estimate instream pollutant concentrations and loading under different hydrologic conditions.

The Little Kanawha River has 19 major tributaries, these subwatersheds were further broken down into 85 subwatersheds to provide more detail in the pollutant loading to each of the Little Kanawha's tributaries. There were 26 land uses defined in the watershed, these 26 were then categorized into 11 land use types. Therefore, every land use in the watershed was grouped into one of these 11 categories. The eleven land uses are forest 1, forest 2, forest 3, agriculture 1, agriculture 2, urban, road 1, road 2, barren, wetland, and water.

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[6]USEPA. 2000. *Metals TMDL for Little Kanwaha River Watershed, West Virginia*. U.S. Environmental Protection Agency, Region III.

Rainfall and meteorological conditions drive hydrologic modeling by providing a transport mechanism for nonpoint sources of pollutants and providing flow to the stream via surface runoff, interflow, and groundwater. Temperature and weather patterns also determine the type of precipitation (snow or rain), snowmelt and subsequent runoff, and evapotransportation. Six hourly participation monitoring stations were evaluated for potential use in this TMDL. It was determined that the Liverpool (WV5323) and Gassaway (WV3361) stations were representative of the meteorological conditions in the Little Kanawha River watershed. The Liverpool station which is located in the southwestern border of the watershed was selected for use in this model. The mean monthly rainfall at the Liverpool station ranged from 2.41 inches to 4.32 inches for the 1948 through 1998 time period. From 1988 to 1997, the mean annual rainfall at the Liverpool station was 44.21 inches, with a maximum annual rainfall of 52 inches and a minimum of 35 inches.

SWMM runoff block simulated the runoff and buildup of pollutants in each of the subwatersheds. As mentioned earlier, the Little Kanawha River Watershed was divided into several (85) subwatersheds. By dividing the watershed into several smaller basins, the simulations of runoff, water quality, and pollutant loading became more manageable. Several factors were evaluated in determining the boundaries of the subwatersheds, such as: local geology and drainage patterns, 303 (d) listed segments, primary conveyance streams, land based loadings, and location of instream monitoring stations. For example, the Reedy Creek tributary to the Little Kanawha River was modeled as nine subwatersheds.

The 26 designated land uses identified in the GAP 2000 Land Use Coverage data, were reclassified into 11 land uses. These designated land use categories were classified by an estimation of their sediment, Total Aluminum, and Total Iron yields and loading behavior. The objective of this reclassification was to simplify the modeling process. For a description of the GAP and SWMM designated landuses please refer to Table 5-2 of the Metals TMDL for Little Kanawha River Watershed, West Virginia, USEPA, 2000. The percent impervious area was estimated for each land use category prior to the SWMM simulation. Imperviousness directly affects the runoff and infiltration capacity of the land segments. Generally, segments with a higher percentage of impervious land have lower infiltration rates and higher runoff values, as rainfall is unable to percolate through the land surface. The percent impervious for a subwatershed can be determined by multiplying the percent impervious for each land use by its acreage. This process is repeated for each landuse within the watershed and summed.

The water quality modeling was simulated for the meteorological conditions at the Liverpool station from 1988-1997 using the 11 categories identified from the GAP 2000 land use conditions. The model was developed for the Total Iron, Total Aluminum, and TSS. The processes of buildup and washoff were analyzed to determine pollutant loading to a stream. Buildup is the accumulation of the pollutant upon the land surface during dry weather conditions. Washoff is the process of transporting the pollutant to the stream during wet weather (rainfall) events.

Erosion from pervious land segments is a source of Aluminum and Iron to the Little Kanawha River Watershed. Erosion from the different land sources is a function of soil type, rainfall characteristics (intensity, etc.), slopes of the land surface, and land use. The runoff block of the SWMM model estimates the erosion and sediment loading to the stream. A sediment loading for each of the land uses was determined using literature values and public input.

2) The TMDL includes a total allowable load as well as individual waste load allocations and load allocations.

Total Allowable Loads

A three staged approach has been developed for achieving water quality standards on the Little Kanawha River Watershed. The first stage of the TMDL focuses on reducing the frequency of violations so that the standards are being met 75% of the time. Stage 1 targets smaller to medium sized storm events and sediment control practices in specific portions of the watershed. Stage 2 of this plan, which can be run concurrently to Stage 1, consists of compiling additional water quality information on the watershed to monitor the water quality conditions and the efficiency of the management practices installed on the watershed. Stage 3 of this TMDL will use the information generated in Stage 2 to evaluate water quality in the watershed and work toward insuring that the standards are fully (for all storm events) achieved. Stage 3 will look at which of the State's management practices work best in the reduction of metals loading.

There are several advantages to the three-stage program. By phasing reductions in loading, the TMDL limits the severity of the load reductions being sought. It also allows the State to monitor water quality in the watershed to insure that the model's assumptions are correct and determine if the standards will be achieved with smaller load reductions. Strategies for the attainment of the standard can be changed based on information gathered during stages 1 and 2. Lastly, the TMDL may be amended and reevaluated based on new information and/or an adoption of new State standards.

The TMDLs for the Little Kanawha Watershed were developed on a subwatershed basis. There are 19 tributaries to the Little Kanawha River, one of the tributaries was further divided into 3 subwatersheds. Allocation plans were therefore established for 21 subwatersheds. These 21 allocation plans represent the allocation plan needed for the total watershed. These plans are meant to be protective of the main stem of the Little Kanawha River and its tributaries.

Three allocation scenarios were originally proposed by EPA, a fourth scenario was developed after the public comment period. The fourth scenario was developed in response to the comments and recommendations of local stakeholders. Scenario #4 was chosen for the Little Kanawha River TMDL. Scenario #1, called for an identical load reduction from all watersheds except watersheds 50 and 55, these watersheds would need greater load reductions.

Scenario #2, used a three-tier reduction approach. A loading magnitude was determined for each watershed, those watersheds with the highest loadings per unit area were assigned with the highest load reductions. The watersheds with the lowest loadings per unit area were assigned with the lowest load reductions.

Scenario #3, was similar to Scenario #1, all watersheds were assigned with an identical load reduction with the exception of watershed #65. The Hughes reservoir is being developed in this watershed and will impact the sediment and metals load to points downstream. Therefore, Scenario #3 called for a higher load reduction in watershed #65.

Scenario #4 is a combination of Scenarios 2 and 3. Scenario #4, used a three-tier reduction approach identical to the approach used in Scenario #2. A loading magnitude was determined for each watershed, those watersheds with the highest loadings per unit area were assigned with the highest load reductions. The watersheds with the lowest loadings per unit area were assigned with the lowest load reductions. Similar to Scenario #3, this Scenario also addressed the impact of the Hughes Dam being developed on watershed #65. The reduction in this watershed was based on a calculation of sediment and trap efficiency specific to the reservoir.

Waste Load Allocations

The TMDL for the Little Kanawha River Watershed identified several point sources. Point sources were identified through EPA's Permit Compliance System (PCS). Thirty-four Permitted facilities were identified by PCS. Roughly, fifty percent of these permits were for sewage treatment plants. There were only three facilities with Iron limits. There were no permits with Aluminum limits. Loading from these facilities was determined through flow and concentration values documented in the facilities Discharge Monitoring Record (DMR). Facilities without limits for Iron or Aluminum were not seen as contributing these pollutants to the watershed. No waste load allocations were established in this TMDL. Gross allocations were determined for the tributaries which receive the effluent from the facilities permitted for Iron or Aluminum. These streams were also listed as impaired due to acid mine drainage (AMD). The WLAs for these facilities will be addressed in the AMD TMDLs.

Load Allocations

According to federal regulations at 40 CFR 130.2 (g), load allocations are best estimates of the loading, which may range form reasonably accurate estimates to gross allotments, depending on the availability of data and appropriate techniques for predicting loading. Wherever possible natural and nonpoint source loads should be distinguished.

As mentioned earlier loads were determined for each land use based on literature values. These loads were placed in the model which was calibrated to observed data. Loads were determined for agricultural land, urban built-up land, roadways, forestry activities, undisturbed, forested land, barren lands, construction sites, mining operations, and oil and gas operations.

Table 1 Selected Stage 1 Allocation - Scenario 4 [a]

	% Reduction	TSS	Al	Fe
Subwatershed		**ton/yr**		
153	22.0%	1345	65	48
540[b]	46.5%	1392	110	121
555[b]	37.7%	2396	189	210
3	30.0%	918	42	40
8	30.0%	464	22	16
5	30.0%	2110	100	59
10	14.0%	1725	80	70
15	22.0%	1856	90	66
20	22.0%	3352	156	135
25	30.0%	1508	68	61
30	30.0%	856	30	49
35	30.0%	3101	145	118
40	30.0%	798	28	44
45	30.0%	4281	143	238
50[c]	45.1%	1518	120	748
55[c]	35.9%	2760	218	1126
60	22.0%	602	45	51
65[d]	13.0%	9598	679	783
70	5.0%	764	61	68
75	5.0%	1026	85	92
80	5.0%	806	64	71
85	5.0%	1727	119	139
90	5.0%	1696	105	128
95	13.0%	455	23	32

[a] Limiting pollutant is aluminum. TSS and associated iron reductions are based on meeting aluminum target
[b] Load reduction based on meeting tributary target
[c] Load reduction includes reduction for listed tributary
[d] Presumes construction of Hughes Reservoir

Table 2 Stage 3 Final Load Reduction Targets for the Little Kanawha Metals TMDLs

Segment	***Aluminum***	**Existing Loads**	**Stage 3**	**Percent Reduction from 25% exceedence to 0%**
	Segment Name	**tons/yr**	**tons/yr**	
555	Reedy Creek	303.00	24.00	54.6%
540	Spring Crek	206.00	17.00	45.6%
153	Sand Fork Creek	83.00	14.00	60.9%

8	Oil Creek	32.00	5.00	53.6%
3	Salt Lick Creek	59.00	8.00	56.7%
60	Little Kanawha River	1,760.00	238.00	64.5%
95	Little Kanawha River	3,153.00	384.67	67.8%
	Iron			
	Segment Name			
555	Reedy Creek	336.00	60.00	44.7%
540	Spring Crek	227.00	41.00	35.3%
153	Sand Fork Creek	62.00	35.00	21.3%
8	Oil Creek	23.00	14.00	8.7%
3	Salt Lick Creek	57.00	22.00	31.6%
60	Little Kanawha River	1,833.00	629.00	43.7%
95	Little Kanawha River	3,464.00	918.00	52.5%

3) The TMDL considers the impacts of background pollution.

A constant discharge representing base flow was incorporated at the inlet points in the modeled stream network to represent contributions from groundwater seepage[7]. A sediment loading was established for undisturbed forest land conditions, which would be considered a background loading, as well.

4) The TMDL considers critical environmental conditions.

EPA regulations at 40 CFR 130.7 (c)(1) require TMDLs to take into account critical conditions for stream flow, loading, and water quality parameters. The intent of this requirement is to ensure that the water quality of the Little Kanawha River Watershed is protected during times when it is most vulnerable.

Critical conditions are important because they describe the factors that combine to cause a violation of water quality standards and will help in identifying the actions that may have to be undertaken to meet water quality standards[8]. In specifying critical conditions in the waterbody, an attempt is made to use a reasonable "worst-case" scenario condition. For example, stream analysis often uses a low-flow (7Q10) design condition because the ability of the waterbody to assimilate pollutants without exhibiting adverse impacts is at a minimum.

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[7]USEPA. 2000. *Metals TMDLs for Little Kanawha River Watershed, West Virginia.* U.S. Environmental Protection Agency, Region III.

[8]EPA memorandum regarding EPA Actions to Support High Quality TMDLs from Robert H. Wayland III, Director, Office of Wetlands, Oceans, and Watersheds to the Regional Management Division Directors, August 9, 1999.

Monitoring data shows that the most severe violations in the water quality standard primarily occur during the time period from July to November. By modeling to insure that water quality standards are attained and maintained for this time period it is believed that the standards will be attained through all periods.

5) The TMDLs consider seasonal environmental variations.

Seasonal variations involve changes in stream flow as a result of hydrologic and climatological patterns. In the continental United States, seasonally high flow normally occurs during the colder period of winter and in early spring from snow melt and spring rain, while seasonally low flow typically occurs during the warmer summer and early fall drought periods. Consistent with our discussion regarding critical conditions, the SWMM model and TMDL analysis will effectively consider seasonal environmental variations. The TMDL was developed to attain standards during the time period from July through November, over which the most severe violations took place. It is believed that episodic thunderstorms caused the large violations observed during this period.

6) The TMDLs include a margin of safety.

This requirement is intended to add a level of safety to the modeling process to account for any uncertainty. Margins of Safety (MOS) may be implicit, built into the modeling process by using conservative modeling assumptions, or explicit, taken as a percentage of the wasteload allocation, load allocation, or TMDL.

EPA has used an implicit margin of safety in establishing the TMDL for the Little Kanawha River Watershed. The MOS has been incorporated implicitly by using a dynamic model to simulate daily loading over a wide range of conditions and modeling more conservatively then standards (the standards would allow a violation once every three years the TMDL has been modeled for no exceedances over the ten year modeling period).

7) The TMDLs have been subject to public participation.

From the beginning of the TMDL process in the Little Kanawha, there has been significant public participation and stakeholder involvement. When the Little Kanawha River was announced in November 1999 as a potential stream for TMDL development in 2000, the DEP received a significant number of public comments.

After the Little Kanawha River was formally selected for TMDL development in early 2000, the DEP opted to have an informational meeting in the watershed to answer questions of stakeholders and provide a timeline for the process through Sept. 30. The meeting, held in March, was attended by over 100 people. Participants included concerned farmers, Farm Bureau members, local residents, representatives from the oil and gas industry, foresters, and state agencies.

A number of comments up to that point suggested that DEP and EPA look at additional data in the development of the TMDL for the Little Kanawha. Based on those comments, the agencies provided for additional public involvement through a stakeholder group comprised of agencies and groups involved in nonpoint source management. Participants included the DEP and several of its program offices, West Virginia Soil Conservation Agency, Division of Highways, Division of Forestry, Department of Agriculture and the Division of Natural Resources. The group was encouraged to provide additional land use and water quality data to EPA contractors, who would be incorporating all data into the TMDL model. An independent stakeholder group made up of industry and agriculture representatives active in the Little Kanawha watershed was also formed and worked to provide additional information to the DEP and EPA for the TMDL development.

Based on the data collected by DEP, data provided via public comment and informational meetings, and data shared between state nonpoint source management agencies and industry groups, the TMDL was written and the model was executed.

The public had additional venues for comment and data submission, including the 45-day comment period provided by the EPA after the draft TMDL was released in August 2000.

8) There is a reasonable assurance that the TMDL can be met.

EPA requires that there be a reasonable assurance that the TMDL can be implemented. WLAs will be implemented through the NPDES permit process. According to 40 CFR 122.44(d)(1)(vii)(B), the effluent limitations for an NPDES permit must be consistent with the assumptions and requirements of any available WLA for the discharge prepared by the state and approved by EPA. Furthermore, EPA has authority to object to issuance of an NPDES permit that is inconsistent with WLAs established for that point source.

EPA anticipates the DEP's Office of Water Resources will use the report to reenergize the activities of various agencies with appropriate authorities to address the water quality impacts. For example in Stage 1, reductions targets of 5 to 46.5% are proposed in select streams. Partner agencies will be asked to review those watersheds for the presence of their respective land uses and determine if additional maintenance by the industries and/or land users is needed. Eroding farmland may be addressed through landowners accessing cost-share funding from the Conservation Partnership. Maintenance of existing unpaved county roads falling under jurisdiction of the Division of Highways will be encouraged. Oil and gas and logging road maintenance and reclamation can, in many cases, be required of industries which built them.

It is anticipated that focusing increased attention on the implementation of existing nonpoint source program mechanisms, as well as enforcement of existing statutory and regulatory authorities, will result in sediment reductions to the various streams. Stage 2 indicates that follow-up monitoring will be conducted to ascertain the effectiveness of that process and to enable modifications if necessary to ultimately achieve standards.

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1. Problem Understanding

The Little Kanawha River is centrally located in the State of West Virginia (Figure 1.1), and its 2,307 square mile (1.5 million acres) drainage area is represented by the Little Kanawha River Watershed (HUC: 05030203). Parkersburg (Wood County) is the closest metropolitan area in this region, lying on the western border of the watershed at the confluence of the Ohio and Little Kanawha rivers. The land use distribution is dominated by forest and agricultural lands.

The mainstem of Little Kanawha River below Burnsville Dam and five of its tributaries are on the West Virginia 1998 303(d) list due to total aluminum and/or total iron impairments. The listed segments are described below and Figure 1.2 is a map of the Little Kanawha River Watershed showing their locations.

- Little Kanawha River (O-47), mainstem between Burnsville Dam and the confluence with the Ohio River, is listed for both total aluminum and total iron, has a total impaired length of 124.2 miles and falls inside the counties of Wood, Wirt, Calhoun, Roane, Gilmer, Braxton, Lewis and Webster.
- Reedy Creek (LK-25), is listed for both total aluminum and total iron, has a total impaired length of 22.63 miles, and is the first impaired segment located upstream of the mouth of the Little Kanawha in Wirt and Roane Counties.
- Spring Creek (LK-31), is listed for both total aluminum and total iron, has a length of 25.27 miles, and is located just upstream of Reedy Creek, also in Wirt and Roane Counties.
- Sand Fork (LK-86), is listed for both total aluminum and total iron, has a total impaired length of 18.66 miles, is located above Indian Fork, which is just downstream of Burnsville Dam, and lies in Lewis and Gilmer Counties.
- Oil Creek (LK-94), which is listed for total aluminum, has a total impaired length of 9.81 miles and is located at Burnsville Dam, within the counties of Lewis and Braxton.
- Saltlick Creek (LK-95), is listed for both total aluminum and total iron, has a total impaired length of 17.71 miles, is also located at Burnsville Dam, and lies within Braxton County.

This report describes TMDL development for the five listed segments and their mainstem, the Little Kanawha River. Since the six listed segments are within the same watershed, a comprehensive watershed assessment (Little Kanawha Watershed) was used to develop the TMDLs for the listed waters.

The Little Kanawha River has a priority ranking of medium, and its five listed tributaries have a priority ranking of low. According to West Virginia's schedule, the six TMDLs for the Little Kanawha Watershed are due for completion October 1, 2000.

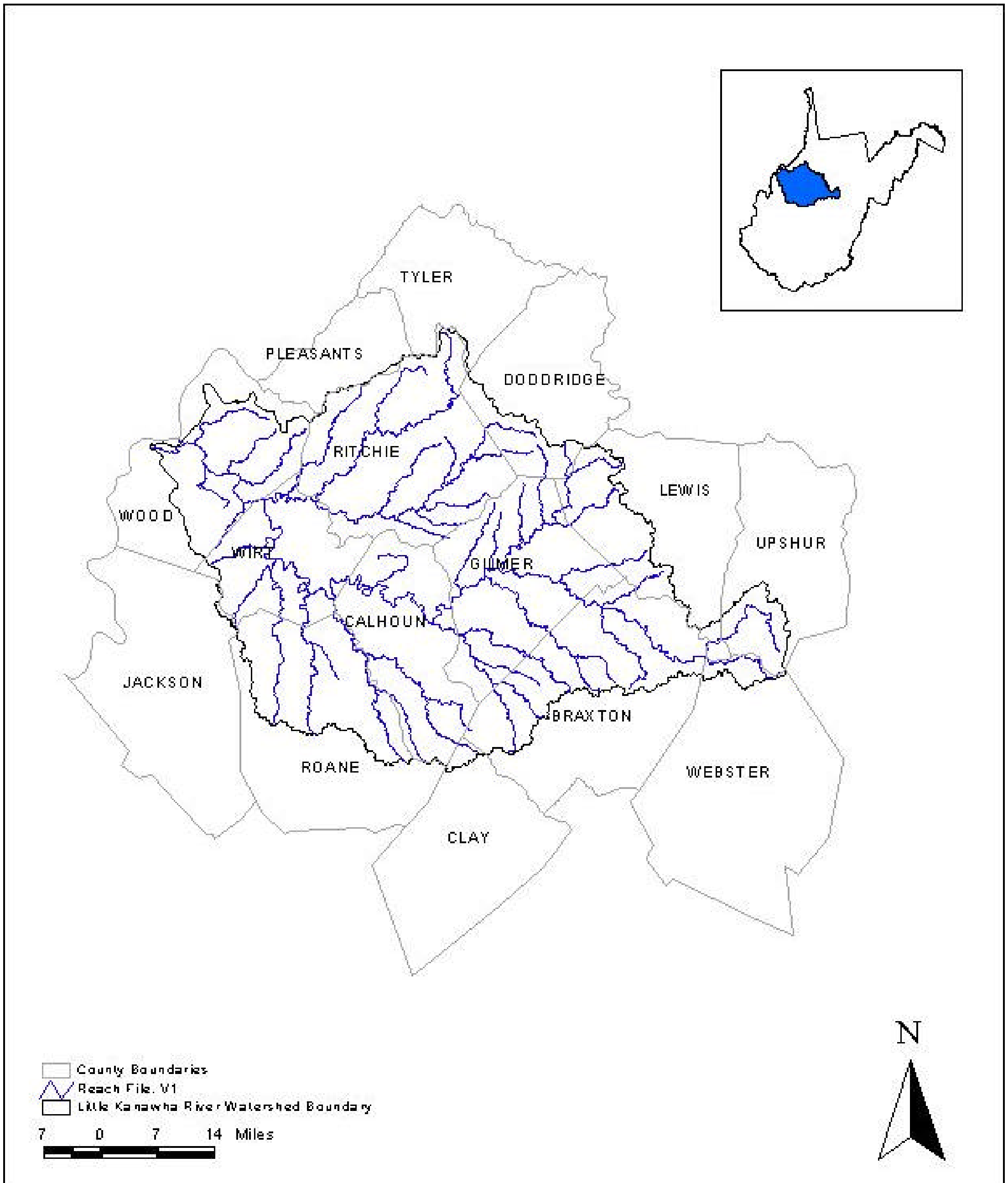

Figure 1.1
The Little Kanawha River Watershed

Data Sources: U.S.EPA BASINS, USGS,WVDEP

Map Projection: Albers Equal Area, GRS 80

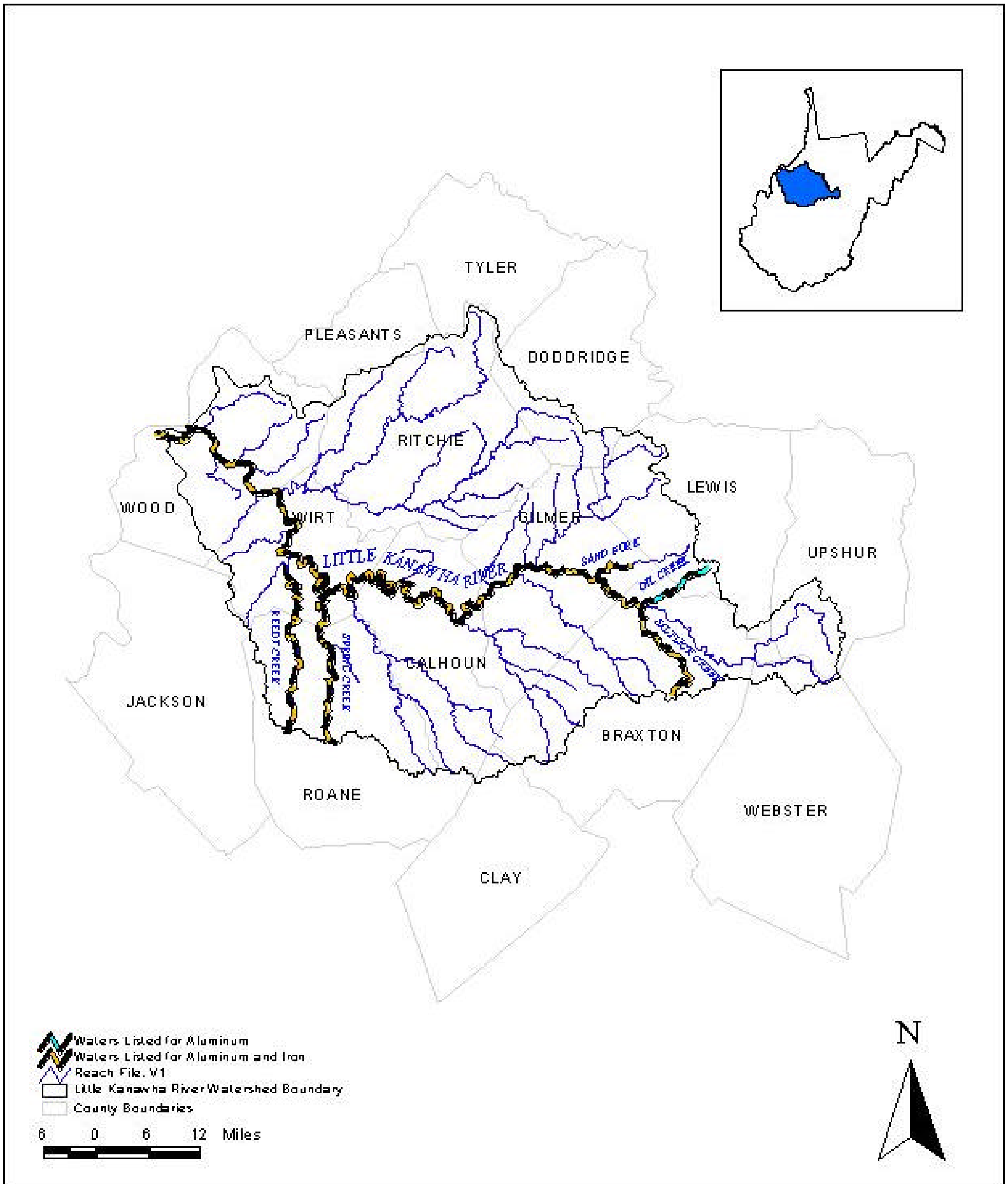

Figure 1.2
303(d) Listed Segments in the Little Kanawha Watershed

Data Sources: U.S.EPA BASINS, USGS, WV 303(d) List, WVDEP

Map Projection: Albers Equal Area, GRS 80

2. Applicable Water Quality Standards

West Virginia's *Requirements Governing Water Quality Standards* (WVSOS, 1999) have defined water quality criteria for surface waters as a numeric constituent concentration or narrative statement representing a quality of water that supports a designated use or uses of the waterbody. Total aluminum and total iron are given numeric criteria under the Aquatic Life and the Human Health use designation categories. The following is a summary of the applicable water quality criteria.

- The total aluminum standard is applied to the use designations B1(warm water fishery streams), B2 (trout waters) and B4 (wetlands), as Acute (one hour average concentration not to be exceeded more than once every three years on the average).

- Total iron is applied to the use designations B1, B2 and B4 as Chronic (four-day average concentration not to be exceeded more than once every three years on the average).

- Total iron is applied to the use designation A (public water supply, whose criteria must not be exceeded to protect human health from toxic effects through drinking water and fish consumption).

Table 2-1 lists the West Virginia's water quality standards for total aluminum and total iron..

Table 2-1. West Virginia water quality standards for All Uses

Pollutant	Use Designation					
	AQUATIC LIFE				HUMAN HEALTH	ALL OTHER USES
	B1, B4		B2		A	
	ACUTE	CHRONIC	ACUTE	CHRONIC		
Aluminum, Total Not to Exceed (µg/L)	750		750			
Iron, Total Not to Exceed (mg/L)		1.5		0.5	1.5	

Source: WVSOS, 1999

The impaired segments of the Little Kanawha River and its tributaries have been classified as A (public water supply) and B1 (warm water fishery) streams. For these TMDLs, the target limits used are 750 µg/L (0.75 mg/L) for aluminum and 1.5 mg/L for iron.

3. Impairment Analysis

This section focuses on the identification and analysis of ambient water quality data to characterize the type, frequency and the severity of violations of the water quality standards for total aluminum and total iron. The analysis was also designed to evaluate potential critical conditions where violations are most likely to occur. It is assumed that if violations do not occur under these critical flow conditions, then violations will not occur under other flow conditions. Another objective of the analysis is to link the instream total aluminum and total iron concentrations to potential point and nonpoint sources in the watershed.

3.1 Data and Information Inventory

A wide range of data and information were used in the development of this TMDL. The categories of data used include physiographic data that describe the physical conditions of the watershed, potential pollutant source data that identifies potential pollutant sources and their contribution, and instream water quality monitoring data. Table 3.1 shows the various data types and data sources used in this TMDL.

Table 3-1. Inventory of data and information used in the development of the Little Kanawha River TMDL

Data category	Description	Data Source(s)
Watershed Physiographic Data	Land use/land cover data	WVDEP, USDA NRCS, USGS, WVU
	Soil data (SSURGO, STATSGO)	USDA, NRCS
	Stream reach coverage	USGS, WVDEP
	Topographic characteristics: USGS-30 meter DEM, USGS Quad	WVDEP
	Weather information	National Climatic Data Center
Watershed activities and uses data and information	NPDES permitted facilities	WVDEP
	Timber harvest data, experimental station data	WV Forestry US Forest Service
	WV roadways characteristics Forest access road information	WVDOT Westvaco, US Forest Service
	BMPs implementation-Agriculture	Farm Bureau
	BMPs implementation-Oil and Gas	Flannery, 2000
	Storm water construction permits	WVDEP
	Land disturbances over 3 acres	SCA
	319 Program projects, land use data, installation of BMPs, identification of additional sampling sites	SCA
	AML database, stream restoration	WVDEP AML
	Abandoned oil and gas well information, active wells	WVDEP OOG
Environmental Monitoring Data	Ambient instream monitoring data	WVDEP
	Water quality Monitoring data for 19 sampling stations	WVDOA
	Water quality data on impoundment on North Fork of Hughes River	NRCS

	Fish surveys, limited water quality data	WVDNR
	Permitted facilities date	WVDEP

3.1.1 Stream Flow Data

The flow data from USGS gages located within the Little Kanawha River Watershed were used in the analysis of frequency and severity of the water quality standard violation. Table 3-2 shows the twelve flow gaging stations and the corresponding period of record for each. Figure 3.1 is a map showing the locations of the twelve flow gaging stations located within the Little Kanawha River Watershed.

Table 3-2. USGS flow gages located in the Little Kanawha River Watershed

Gage Id	Gage Name and Location	Years	From	To
3151600	Little Kanawha River at Burnsville, WV	4	4/23/74	12/7/78
3152000	Little Kanawha River at Glenville, WV	78	6/4/15	9/30/93
3152200	Buck Run near Leopold, WV	8	10/6/69	9/30/77
3152500	Leading Creek near Glenville, WV	14	10/6/37	12/31/51
3153000	Steer Creek near Grantsville, WV	38	10/6/37	10/7/75
3153500	Little Kanawha River at Grantsville, WV	50	10/6/28	12/13/78
3154000	West Fork Little Kanawha River at Rocksdale, WV	47	10/5/28	10/7/75
3154250	Tanner Run at Spencer, WV	8	4/6/69	9/30/77
3154500	Reedy Creek near Reedy, WV	27	10/6/51	9/30/78
3155000	Little Kanawha River at Palestine, WV	54	10/6/39	9/30/93
3155200	South Fork Hughes River at Macfarlan, WV	36	6/5/15	12/31/51
3155410	North Bend Run near Cairo, WV	2	6/19/85	9/30/87
3155500	Hughes River at Cisco, WV	65	10/5/28	9/30/93
3151500	Little Kanawha River Near Burnsville, WV	37	10/6/37	10/1/74
3155520	Robinson Run near Petroleum, WV	2	6/19/85	9/30/08

Gage Id	Gage Name and Location	Years	From	To
3151520	Little Kanawha River below Burnsville Dam, WV	17	7/19/76	9/30/93

3.1.2 Instream Water Quality Data

Instream water quality monitoring data for the Little Kanawha River Watershed were obtained from WVDEP and retrieved from STORET. Table 3-3 shows the five stations for which data were used in the analysis of frequency and severity of the water quality standard violation. Figure 3.2 is a map showing the locations of the ambient water quality stations located within the Little Kanawha watershed.

Table 3-3. Water quality stations located in the Little Kanawha River

ID	Location	Type
550482	Little Kanawha River at Elizabeth, WV	Ambient/Stream
551052	Sand Fork in Layopolis, WV	Ambient/Stream
551053	Saltlick Creek in Burnsville, WV	Ambient/Stream
551055	Reedy Creek east of Palestine, WV	Ambient/Stream
551056	Spring Creek below Sanoma, WV	Ambient/Stream

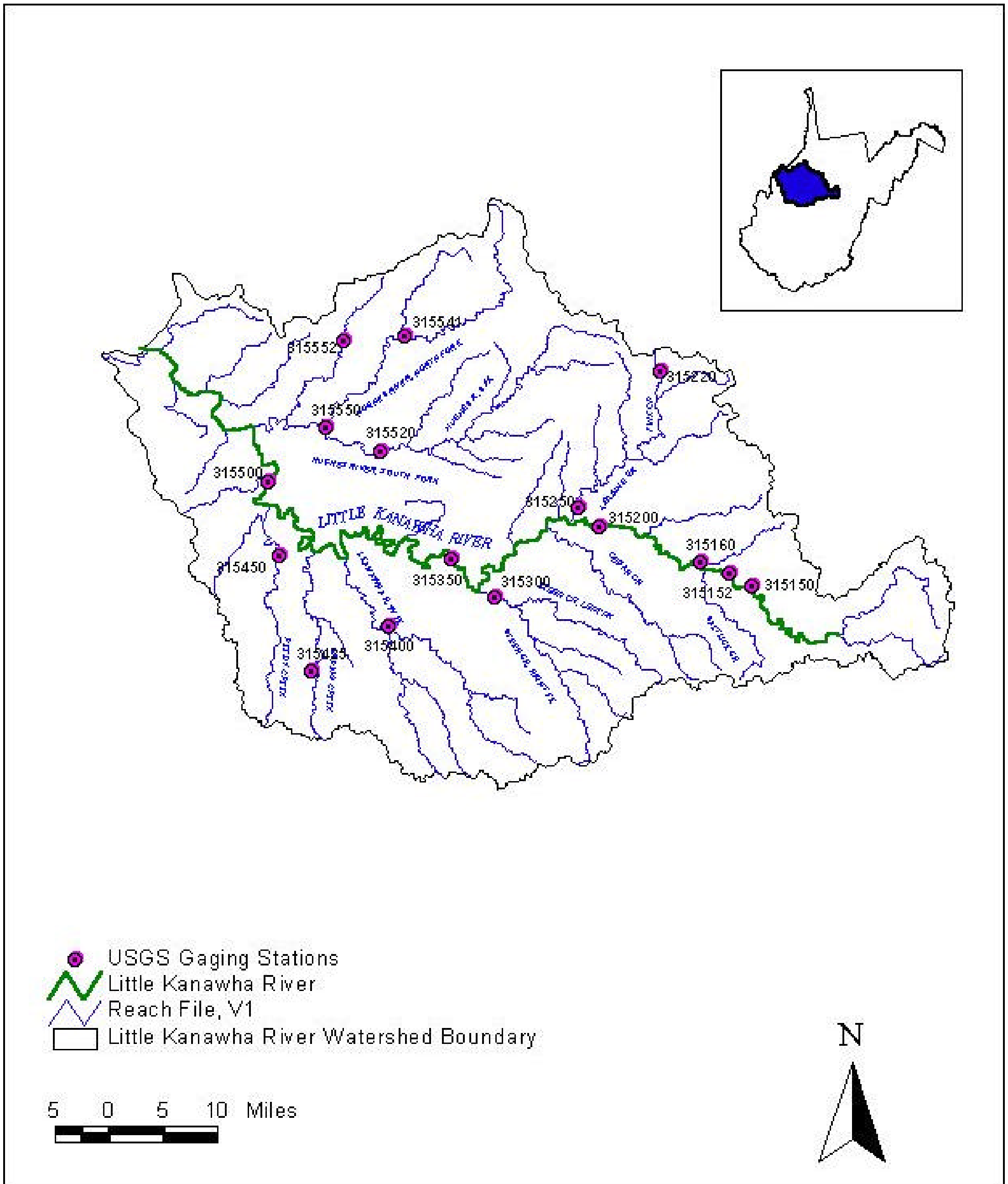

Figure 3.1
USGS Flow Gaging Stations in the Little Kanawha River Watershed

Data Sources:	U.S.EPA BASINS, USGS, WVDEP
Map Projection:	Albers Equal Area, GRS 80

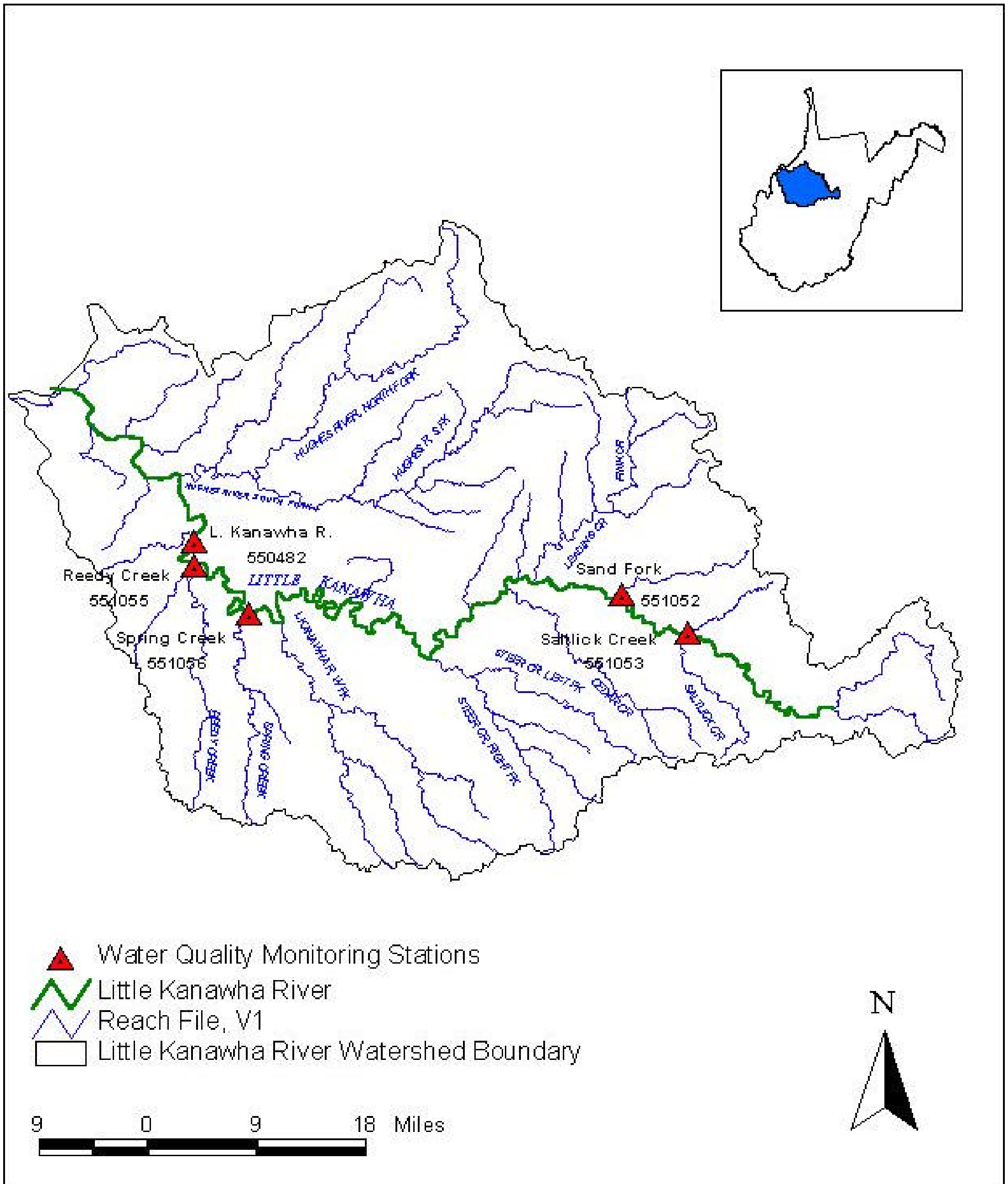

Figure 3.2

Water Quality Monitoring Stations in the Little Kanawha River Watershed

Data Sources: U.S.EPA BASINS, USGS, U.S. EPA STORET, WVDEP

Map Projection: Albers Equal Area, GRS 80

3.2 Listing Confirmation

The five tributaries and the Little Kanawha River mainstem water quality impairment and inclusion on the West Virginia 303(d) list is based on WVDEP monitoring data. Twelve water quality samples were taken throughout the 1994 hydrologic year (October 1993 to September 1994) from each of the Little Kanawha tributaries and fifteen samples were taken from the Little Kanawha River from March 1996 to August 1999. Sampling identified violations for total aluminum, exceeding state water quality standards levels more than 50 percent of the time for the listed tributaries, and 40 percent of the time for the Little Kanawha River. Total iron violations occurred in 35 percent of the tributary samples and 26 percent of the Little Kanawha River samples. Sampling during drought conditions at Spring Creek showed one violation in three samples for both total aluminum and total iron.

Thresholds used for analyzing water quality violations are 0.75 mg/L for aluminum and 1.5 mg/L for iron are based on the specific waterbody designated use or uses as shown in Table A-1 of Appendix A. To confirm the 303(d) listing of the mainstem of the Little Kanawha below Burnsville Dam and the five tributaries, instream water quality conditions were retrieved from STORET and analyzed. Table 3-4 is a summary of the analysis and the table confirms that the total aluminum and total iron threshold was exceeded in all six listed segments.

Table 3-4. Instream water quality for the Little Kanawha River Watershed (Data Source: STORET;
WVDEP)

Location	Period	Total Aluminum			Total Iron		
		# Obs.	# Viol.[1]	%	# Obs.	# Viol.[2]	%
Little Kanawha at Elizabeth, WV	1970-1998	133	51	38	117	42	36
Sand Fork in Layopolis, WV	1993-1994	12	6	50	12	5	50
Saltlick Creek in Burnsville, WV	1993-1994	12	4	33	12	3	25
Reedy Creek east of Palestine, WV	1993-1994	12	7	58	12	7	58

Spring Creek below Sanoma, WV	1993-1994	12	9	75	12	8	67
Oil Creek	1979-1994	25	6	24	NA	NA	NA

1- 0.75 mg/L was used to assess violations for aluminum
2- 1.5 mg/L was used to assess violations for iron

3.3 Water Quality Conditions Analysis

3.3.1Critical Flows

Available flow and instream total aluminum and iron concentration data was used to determine the critical conditions for the five stations. Statistical analysis was performed on the available data and the results are shown in Appendix A. For all stations, higher total aluminum and iron concentrations occur during high flow conditions. For example, for the Little Kanawha River at Elizabeth (Figures A-1 and A-2), over half of the total aluminum and total iron threshold violations occurred during the flow conditions that rank among the highest 20% of the observed flow.

This critical flow condition, defined as water quality impairment during high flow, occurs during storm events. Therefore, aluminum and iron loadings from point and nonpoint sources are considered significant in development of this TMDL.

3.3.2 Analysis of Water Quality Impairment for Aluminum and Iron

In the mining areas of West Virginia, acid mine drainage is often considered the primary source of instream aluminum and iron. In the Little Kanawha River Watershed, limited mining activities and abandoned mine lands exist and they are exclusively located within the Sand Fork watershed. In addition, evaluation of the land use and land cover data indicated that Little Kanawha land use is dominated by forestland and agricultural land. No major urban built up areas, industrial, or commercial were identified in the watershed. Therefore, the traditional sources of aluminum and iron were eliminated based on the preliminary data evaluation. Further investigation was required to identify other potential sources of aluminum and iron. Based on literature review and analysis of available data, sediment is a potential source of high metal contamination. The Little Kanawha River bedrock contains metals and oxidizing sulfides that cause high aluminum concentrations in the stream sediment. In addition, correlation coefficients indicate that iron is associated with aluminum as a result of precipitated iron oxides and oxyhydroxides in the streambeds (Watts *et al.*, 1994).

Water quality data from five stations within the Little Kanawha River Watershed were evaluated to further investigate whether a relationship between total metals and suspended sediment concentrations exists. Comparison of the water quality data for total aluminum and total iron concentrations appeared to closely follow sediment concentrations, increasing as sediment concentrations increase. Average total aluminum and iron concentrations for Spring Creek increased nearly four times during conditions that rank among the highest 10% of the observed sediment concentrations as shown in Figures A-3 and A-4 of Appendix A. Furthermore, regression analysis indicated that a good linear relationship exists between the total aluminum and total iron and sediment concentrations. Figures A-5 and A-6 of Appendix A show the results of the correlation analysis between the observed total aluminum and total iron concentration of Little Kanawha at the Elizabeth monitoring station. The correlation coefficients were 0.72 for aluminum and 0.76 for iron. Similar results were obtained at Spring Creek below the Sanoma monitoring station. The correlation coefficients were 0.74 for aluminum and 0.73 for iron as shown in Figures A-7 and A-8 of Appendix A.

Similar results were also obtained at Saltlick Creek and Sand Fork. The correlation coefficients were 0.88 for aluminum and 0.83 for iron at the Saltlick monitoring station and for Sand Fork the correlation coefficients were 0.86 for aluminum and 0.79 for iron. This clearly indicates that spatial variation in the sediment total metal relationship does not exist in the Little Kanawha River watershed.

Furthermore, correlations between the available dissolved aluminum and iron, and sediment concentration data indicated that there is no relationship between the dissolved aluminum and iron concentrations and sediment concentrations. Figures A-9 and A-10 of Appendix A show the results of the correlation analysis between the observed dissolved aluminum and dissolved iron concentrations downstream of the Burnsville Dam (Station 1BUSW0101). The correlation coefficients were 0.002 for dissolved aluminum and 0.007 for dissolved iron.

Sediment loading and transport occurs during high flow conditions, Figure A-11 of Appendix A shows the variation in sediment concentration with flow at the Little Kanawha at Elizabeth monitoring station. In conclusion, sediment is considered a significant contributor to the high metals concentration in the Little Kanawha River

Watershed, therefore analysis of potential sources of sediment must be considered in the development of this TMDL.

4. Source Assessment

In Section 3, sediment was identified as a major source of instream high total metals concentration. The objective of this section is to identify potential sources of sediment including point and nonpoint sources.

4.1 Nonpoint Source Identification

The predominant land uses in the Little Kanawha River watershed were initially identified based on the 1997 land used data provided by the USDA, NRCS. Forest land is the dominant land use since it makes up 77% of the Kanawha watershed area followed by agricultural land uses which make up 16% of the watershed area. The remaining 7% is made up of Urban buildup and transportation land and water (USDA, NRCS 2000). The GAP 2000 land use data was also used in the characterization of the existing land uses in the Little Kanawha watershed. It confirmed that forest lands and agricultural land uses are dominant.

In addition to forest land and agricultural land uses, other nonpoint sources such as runoff from abandoned and active mine areas, forestry operations, oil and gas operations, and roads can contribute significant amounts of sediment to the receiving streams. Since it has been established that sediment is the primary source of high instream metals concentrations, then the reduction of sediment loadings to the Little Kanawha watershed is vital to the reduction of the total aluminum and iron concentrations.

A conceptual representation of sediment loading from the various sources relative to natural or undisturbed forest condition is presented in Table 4-1 based on evaluation of literature. Also included in the table is the time scale of impact on the receiving waterbody. Some sources recover after short period of time, others are continuously active over time. The objective is to characterize sediment sources based on sediment contribution amounts and time scale of impact. Based on Table 4-1, sediment loads and impacts can be summarized as follows:

- Undisturbed forested condition has the least sediment yield and has no impact on the receiving waterbody

- Forest operations has a high sediment yield and the impact on the receiving water body is short, typically diminishes within the first two years.

- Access roads in forest areas contribute substantial amounts of sediment to the receiving water body and the impact is usually long term and can be reduced through better designs, continuos maintenance, and implementation of control practices.

- Forest operations use the existing roads and may require use of additional roads during forest harvest operations.

- Agriculture contribution of sediment is classified as medium, the impact is long term and can be reduced through implementation of various control practices.

- Oil and gas drilling delivers a medium sediment loading to the receiving water body and the impacts are short term with recovery time within one year.

- Oil and gas operations use existing roads and may require building additional access roads to newly constructed wells. New access roads can deliver a substantial loading of sediment to the waterbody and the impacts last as long as the well is active. Sediment loading can be reduced through better designs, continuos maintenance, and implementation of control practices.

- Abandoned mine lands deliver a medium sediment load to the stream and the impact is long term.

- Permitted active mining delivers a low sediment load to the receiving waterbody and the impacts are short term (life of the mine) as long as erosion control practices are installed and maintained.

- Construction sites deliver a large sediment load to the receiving waterbody and the impacts are short term. Including the impoundment in the Hughes River basin within the little Kanawha watershed, construction areas are minimal compared to the other land uses.

- Roadway construction delivers a large sediment load to the receiving waterbody and the impacts are short term. Sediment loading can be reduced through better designs, continuos maintenance, and implementation of control practices.

- Paved roads and highways deliver a low sediment load to the receiving waterbody and the impacts are long term.

- Unpaved roads deliver a large sediment load to the receiving waterbody and the impacts are long term. Sediment loading can be reduced through better designs, continuos maintenance, and implementation of control practices.

- Permitted facilities deliver a low sediment load to the receiving waterbody and the impacts are continuos based on the life of the discharging source.

Table 4-1. Conceptual representation of Potential Sediment Sources and their Impacts

	Sediment Contribution			Time Scale of impact on receiving water body	
Sources	**High**	**Medium**	**Low**	**Long**	**Short**
Forest (Undisturbed)[1]			X	NA	NA
Forest Operations	X				X
Access Roads in Forest	X			X	
Agriculture		X		X	
Oil and Gas Drilling		X			X
Oil and Gas Access Road	X			X	
Mining (abandoned)		X		X	
Mining (active)			X	X	
Construction	X				X
Roadway construction	X				X
Paved roads and Highways			X	X	
Unpaved Roads	X			X	
Point Sources (permitted)			X	X	
1 Undisturbed forest condition is the reference level condition					

To spatially analyze the sediment loadings from nonpoint sources, the Little Kanawha watershed was divided into 84 subwatersheds. The land uses in each of the subwatersheds was determined using data from the GAP 2000 Land Use provided by WVDEP. More details on the delineation process and the land use classification is presented in Section 5.

4.2 Point Source Identification

Permitted point source facilities located within the Little Kanawha River watershed were identified using the EPA's Permit Compliance System (PCS), Office of Mining and Reclamation (OMR) and WVDEP data. Table 4-2 shows thirty-four permitted facilities that were identified by type, NPDES number and the number of discharge pipes. Fifty percent of the point sources located in the Little Kanawha watershed are sewage treatment systems, only three facilities have a permit limit for iron and no facilities have a discharge permit limit for aluminum in the Little Kanawha watershed.

Table 4-2. Number of Point Source discharges in the Little Kanawha River Watershed

NPDES ID	Facility Name	Type	Number of Pipes
WV0058696*	Baldwin Mining Co.	Coal Mine	3
WV0119121*	Waco Oil and Gas	Sandstone Quarry	3
WV1003259*	Gilmer Energy Corp.	Coal Loadout	2
WVG022520	Boggs Natural Gas	Quarry	1
WV0058696	Baldwin Mining Co.	Coal Mine	3
WV0003204	Plant #1	Hand and Edge Tools	1
WV0024945	Burnsville Public Utilities	Sewerage System	1
WV0027308	City of Pennsboro	Sewerage System	1
WV0032590	Lubeck Psd	Sewerage System	1
WV0037389	Calhoun Cnty Bd of Ed	Elem. & Secondary School	1
WV0041181	Grantsville, Town of	Sewerage System	1
WV0041505	Elizabeth, Town of	Sewerage System	1
WV0042692	Reedy, Town of	Sewerage System	1
WV0043991	Community Acres Subdivision	Sewerage System	1
WV0071323	Water Treatment Plant	Water Supply	1
WV0084212	Cairo, Town of	Sewerage System	1
WV0101702	Mt Zion Psd	Sewerage System	1
WV0103586	Sand Fork, Town of	Sewerage System	1
WV0110515	Arrow Concrete Co	Concrete Products	1
WV0111911	Alfab Inc.	Motor Vehicles	1
WV0002518	Parkersburg Facility	Glass Production	1
WV0111813	Burke-Parsons-Bowlby Corp	Wood Products	1
WV0104116	Normantown Elementary School	Elem. & Secondary School	1
WV0078166	Interstate 77,Section 1	Sewerage System	1
WV0081141	Mineral Wells Psd	Sewerage System	1
WV0020095	Spencer, City of	Sewerage System	1
WV0074799	Mason Cnty Psd	Water Supply	1
WV0076872	Dredging Operation	Water Transportation	1
WV0045616	Mountwood Park	Sewerage System	1
WV0040401	Glenville,Town of	Sewerage System	1
WV0077615	Water Treatment Plant	Water Supply	1

NPDES ID	Facility Name	Type	Number of Pipes
WV0022357	Harrisville, Town of	Sewerage System	1
WV0025739	Pennsboro, City of	Sewerage System	1
* Iron Discharge Permits			
Data Source: WVDEP, WVOMR, EPA PCS			

Loading from these NPDES facilities was estimated based on flow and concentration values obtained from the Discharge Monitoring Record (DMR). Loading allocations for this TMDL rely on developing various discharge scenarios. For the initial allocation, all permitted facilities are assumed to be discharging at their permit limits. Contribution of aluminum load from these point sources to the overall watershed aluminum load was not considered because permit limits do not exist. The load for iron for NPDES facilities for which a permit limit is available (WV0058696, WV0119121,WV1003259) were considered in the modeling.

5. Summary of Technical Approach

5.1 Introduction

The objective of this section is to document and to summarize the hydrologic and water quality modeling approaches applied to estimate instream pollutant concentrations and loadings in the Little Kanawha River watershed. The major elements provided in this section are:

- A review of the modeling approach, including overall system characterization.
- A description of the modeling input, including precipitation and evaporation, hydrologic simulation, water quality modeling, erosion and sedimentation, background and base flow conditions, and runoff routing routines.
- A discussion of the hydrologic calibration.
- A discussion of the water quality calibration.

5.2 Modeling Approach

5.2.1 Overall System Characterization

Hydrologic and water quality simulations of the watershed were performed for Little Kanawha River system. This included the listed segment of the main stem of Little Kanawha River, streams on the West Virginia 303(d) list, other major tributaries and areas that drain directly to the Little Kanawha River. The model development presented here includes continuous simulation of precipitation, runoff and simulates instream total aluminum and iron concentrations and overland erosion and instream sediment scour and deposition. Flow and instream total aluminum and iron concentrations and loadings were simulated as time series or summarized based on the subwatershed annual loadings. The estimates of instream concentrations and pollutant loadings to West Virginia 303(d) listed segment of the mainstem and the five tributaries of the Little Kanawha River are used to develop allocation scenario that meets the West Virginia water quality standards and minimizes the frequency of standard violations.

<u>Modeling Goals</u>
The storm water management model (SWMM) was selected for developing the TMDLs for the Little Kanawha River watershed. The SWMM model allows for the representation of mixed land use watersheds using continuous simulation based on observed meteorologic conditions. At the subwatershed scale, SWMM model provides for evaluation of instream conditions allowing for direct comparison with

the relevant water quality standards. The model represents the Little Kanawha as a series of hydrologically connected subwatersheds.

The goal of the modeling approach is to develop a predictive tool for the Little Kanawha that can:

- represent the watershed characteristics
- represent the point and nonpoint sources and their respective contribution using input time series data (precipitation, and flow) and kinetic data
- estimate the instream pollutant concentrations and loadings under various hydrologic conditions

Modeling Units

The Little Kanawha River has 19 major tributaries, shown in Figure 5.1. The 1.5 million acre Little Kanawha River watershed was subdivided into 85 subwatersheds to provide a high degree of detail and accuracy of the spatial distribution of the pollutant loading from the various tributaries. The main stem of the Little Kanawha River was subdivided into 18 segments using 19 nodes. The nodes represent the inflow locations of the major tributaries to the Little Kanawha River.

Input Parameters

Previous modeling studies conducted in West Virginia watersheds, along with written and verbal communications with various public and private agencies and institutions contributed to defining the model parameters.

Several model technical issues were addressed including:

- Sources of precipitation data
- Identification of point and nonpoint sources
- Pollutant source representation in the model
- Pollutant loading rates

5.3 Modeling Options

5.3.1 Precipitation and Evaporation

For the Little Kanawha River TMDL, six hourly precipitation stations were evaluated for potential use in the model. Figure 5.2 is a map showing the locations of the stations. Statistical analysis and evaluation of the precipitation data for missing records indicated that Liverpool (WV5323) and Gassaway (WV3361) stations are considered representative of the precipitation conditions in the Little Kanawha River watershed. Monthly precipitation volumes for the 1948-1998 and 1951-1998 periods of record for Liverpool and Gassaway are presented in Appendix B, Tables B-1 and B-2, respectively. The mean monthly precipitation volume at Liverpool ranged from 2.44 in. to 4.32 in. and at Gassaway, the range was from 2.70 in. to 4.74 in. Liverpool precipitation data was selected for this analysis.

For the most recent 10 years of data, 1988 to 1997, a statistical summary of Liverpool (WV5323) precipitation data indicate that the mean precipitation is 48.84 inches with a maximum of 52 inches, a minimum of 35 inches, and a standard deviation of 6.69 inches. At the Gassaway (WV3361) precipitation station, the mean precipitation for the simulation period was 44.21 inches with a maximum of 70 inches, a minimum of 35 inches, and a standard deviation of 9.68 inches. The simulation period was considered to be representative of the annual and seasonal variability of precipitation in the watershed because of the similarity of the standard deviation of the simulation period and the period of record.

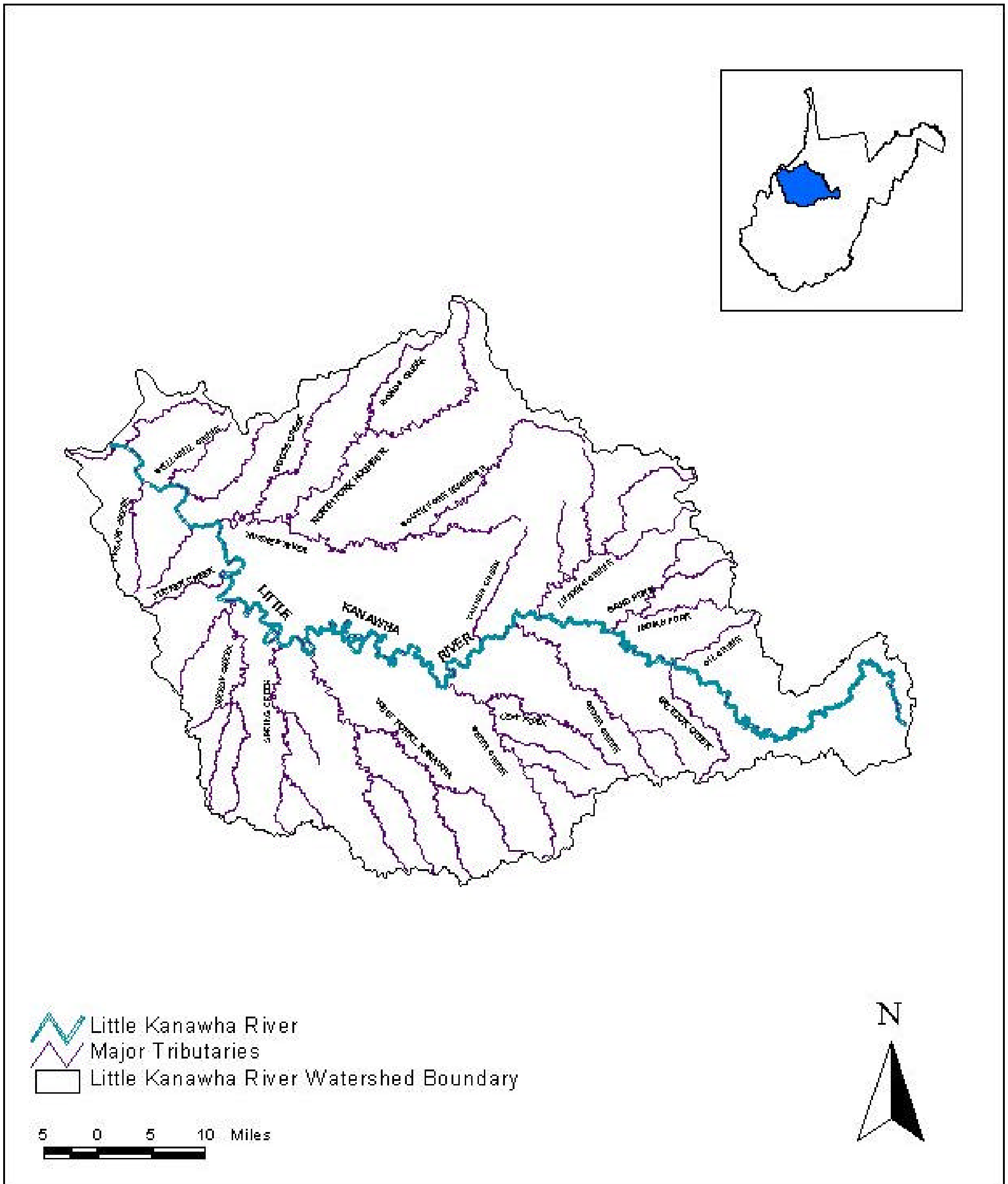

Figure 5.1
Major Tributaries of the
Little Kanawha River Watershed

Data Sources: U.S.EPA BASINS, USGS, WVDEP

Map Projection: Albers Equal Area, GRS 80

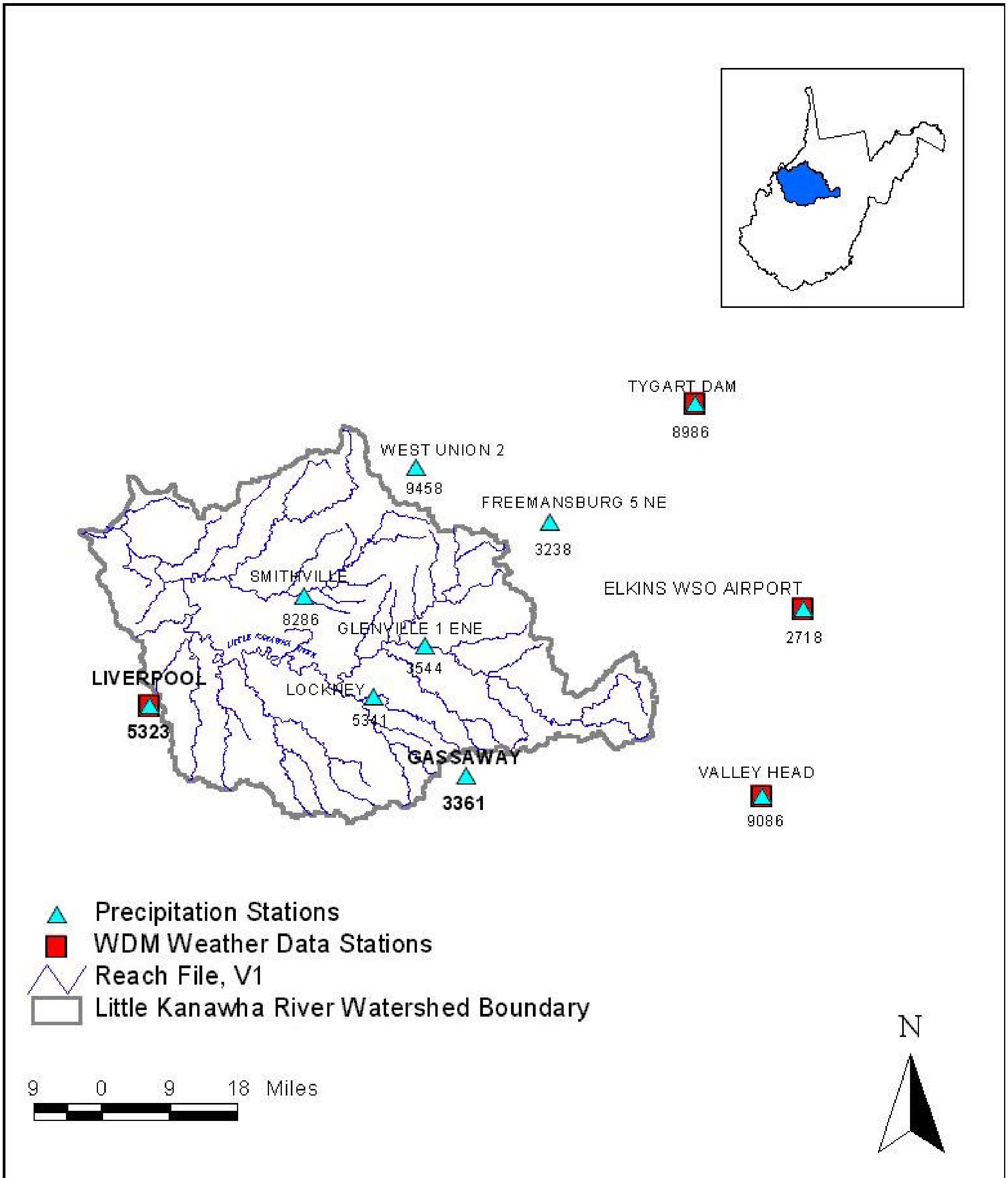

Figure 5.2
Precipitation Stations
Little Kanawha River Watershed

Data Sources:	U.S.EPA BASINS, USGS, National Climate Data Center, WVDEP
Map Projection:	Albers Equal Area, GRS 80

SWMM allows for the designation of wet weather and inter-event time steps. For this analysis the wet weather time step was set to 1 hour. The inter-event time step between storm events was based on a 4-hour period of dry weather.

The mean monthly evaporation data were based on data from Liverpool (WV5323) and Valley Head (WV9086). Tables B-3 and B-4 of Appendix B show the average monthly evaporation data used in the SWMM application.

5.3.2 Hydrologic Simulation

Runoff and pollutant concentrations for each subwatershed were simulated using the SWMM runoff block. The input parameters required by the runoff block are described in the sections that follow.

5.3.2.1 Subwatersheds Delineation and Characterization

As mentioned earlier, the Little Kanawha River watershed was delineated into several basins smaller in size to simplify the simulation of runoff, analysis of water quality and pollutant loadings. The U.S. Geological Survey (USGS) quad sheets, 7.5 quad DEM, stream reach file version 3 (RF3), and geological information system (GIS) coverage data obtained from WVDEP were used in delineating the subwatersheds. Factors taken into consideration in determining the boundaries of the subwatersheds included:

- 303(d) listed segments
- Primary conveyance streams
- Location of instream monitoring stations
- Spatial distribution of pollutant loadings.

Based on boundary limits, the Little Kanawha major tributary watersheds were divided into a number of subwatersheds with smaller areas. The 26 major tributary watersheds were divided into 84 subwatersheds. For example, Reedy Creek is a tributary of the Little Kanawha River with a drainage of 85,389 acres. This watershed was delineated into 9 subwatersheds. Table B-5 of Appendix B shows the subwatershed identification number, location and area for the 84 subwatersheds. A map of the delineated subwatersheds is presented in Figure 5-3.

5.3.2.2 Land Use/Land Cover Classification

The Little Kanawha River watershed land use/land cover conditions were based on the Gap 2000 Land Use coverage data. The 26 land use/land cover classifications contained in the Gap 2000 data are presented in Table 5-1 and a detailed description is presented in Appendix B.

The supplied land use coverages were reclassified to 11 land segments that best describe the watershed conditions and dominant source categories. The objective of reclassification of land use is to meet the modeling goals and to simplify the simulation process. In this case, it is the estimation of sediment yield and associated total aluminum and iron concentrations. Therefore the reclassification focus was on potential sources of sediment, aluminum and iron.

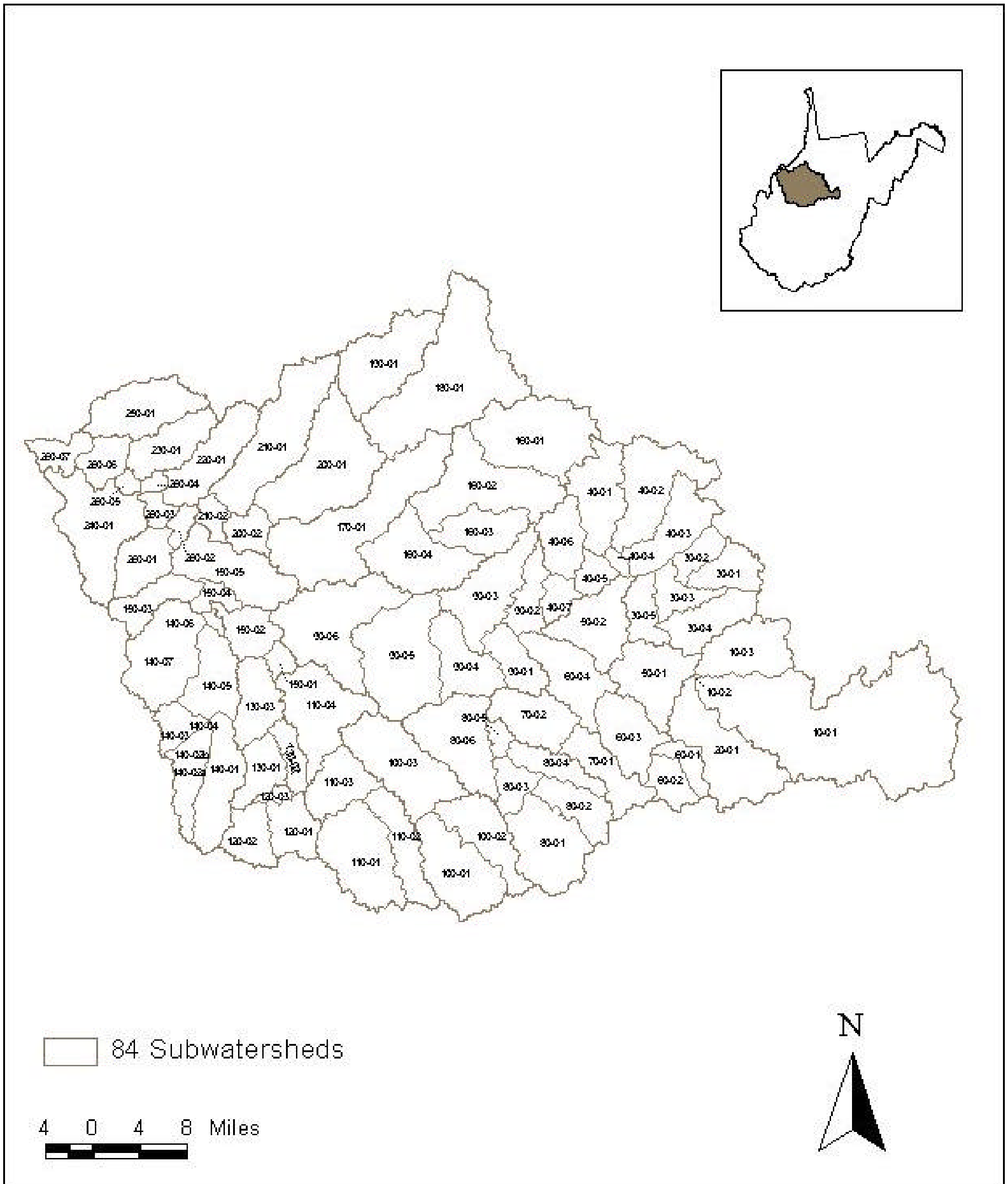

Figure 5.3

Little Kanawha Delineated Subwatersheds

Data Sources: U.S.EPA BASINS, USGS

Map Projection: Albers Equal Area, GRS 80

Table 5-1 WV GAP2000 land use/land cover

GAP Land Use Id	Label[1]
1	Shrubland
2	Woodland
3	Surface water
4	Major highways
5	Major powerlines
6	Populated area – mixed land cover
7	Low intensity urban
8	Moderate intensity urban
9	Intensive urban
10	Row crop agriculture
11	Pasture/grassland
12	Barren land – mining, construction
13	Planted grassland
14	Conifer plantation
15	Floodplain forest
16	Forested wetland
17	Shrub wetland
18	Herbaceous wetland
19	Surface water (combine with class #3)
20	Cove hardwood forest
21	Diverse/mesophytic hardwood forest
22	Hardwood/conifer forest
23	Oak dominant forest
24	Mountain hardwood forest
25	Mountain hardwood/conifer forest
26	Mountain conifer forest
1: A complete description of the land use labels is included in Appendix B	

The reclassified GAP 2000 land use/land cover is presented in Table 5-2. The first column of this table shows the general land use categories such as forest, agriculture and urban built up. The second column shows GAP 2000 land uses that fall under these general categories. For example, cropland and pastureland fall under agriculture, therefore, it was divided into two subcatogories as shown in the third column of the table.

In summary, based on reclassification of the WV GAP 2000 land use, forestland was subdivided into 3 categories, agricultural land uses were subdivided into 2 categories, roads were subdivided into two categories, and urban built up areas, barren land, wetlands, and water areas were not subdivided, each on was kept as a separate category.

Figure 5-4 is a map showing the distribution of the reclassified Little Kanawha River watershed land segment distribution. It can be seen that forest and agriculture land use and coverages dominates the watershed. Land segment distribution for each of the 84 delineated subwatersheds is presented in Table B-6 of Appendix B. The distribution of the 11 land segments by subwatershed was considered as a basis for the modeling.

Table 5-2 Representative land use classes applied in SWMM Simulation

General Land Use Category	Gap land use	Description [1]	SWMM land Use designation
Forest	Mountain conifer forest Mountain hardwood/conifer forest Mountain hardwood forest Oak dominant forest Hardwood/conifer forest Diverse/mesohytic hardwood forest Cove hardwood forest	Well Established forest areas	Forest_1
	Woodland	Intermediate forest areas-wooded areas without mature canopy forest cover	Forest_2
	Shrubland Major powerlines	Natural highland scrubland or reverting agricultural fields with woody vegetation. Powerline right-of-ways	Forest_3
Agriculture	Row crop agriculture	Includes row crops such as corn and soybeans	Ag_1
	Planted grassland	Includes pastureland, hay fields, old fields, abandoned farms, and other herbaceous land cover areas (excluding wetlands).	Ag_2
Urban Builtup	Low intensity urban Moderate intensity urban Intensive urban Populated area – mixed land cover	Rural developed areas Concentrated residential, commercial, industrial, and institutional areas in which a significant portion of the land area may be undeveloped. Dense residential, commercial, industrial, and city core areas in which the majority of the land is developed Rural or lightly developed areas	Urban
Roads	Major highways	Paved	Road_1
		Unpaved	Road_2
Barren land	Barren land – mining, construction	unvegetated lands resulting from construction, timbering, mining, or other activities.	Br

Wetlands	Forested wetland Shrub wetland Herbaceous wetland Floodplain forest	Forested, shrub, and hebaceous land cover derived from National Wetlands Inventory (NWI) Bottom land forest	Wet
Water	Surface water	Open water, including lakes large ponds and rivers	Wat
1 Adapted from WV GAP 2000 land use description			

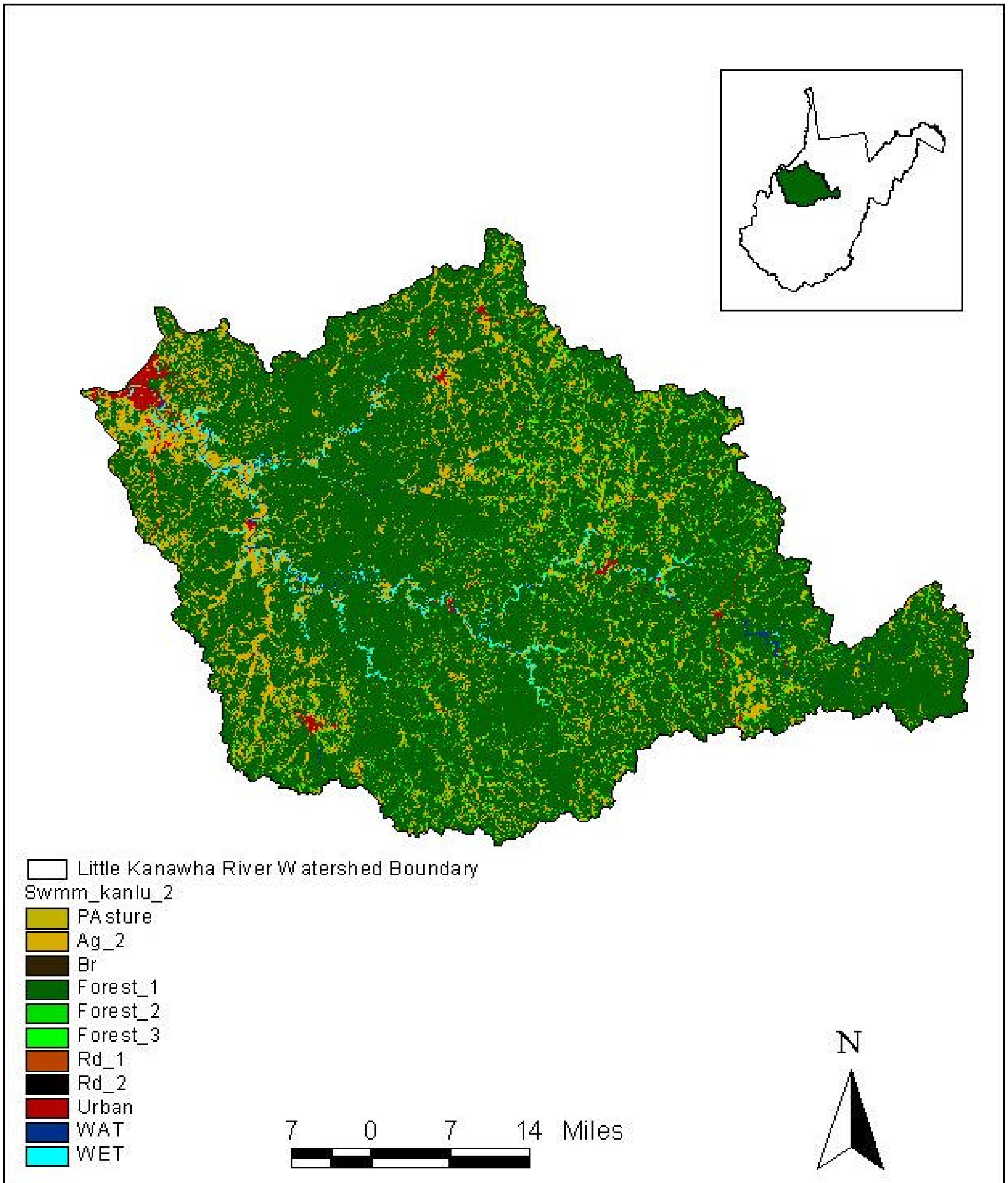

Figure 5.4
Reclassified Little Kanawha River Watershed land segment distribution

Data Sources: U.S.EPA BASINS, U.S. EPA GAP 2000 Land Use, USGS

Map Projection: Albers Equal Area, GRS 80

5.3.2.3 Subwatershed Perviousness/Imperviousness

The percent impervious area must be estimated for each subwatershed prior to SWMM simulation. Subwatershed percent imperviousness was estimated by assigning an effective impervious value to each land use, then using the land use distribution to estimate the percent effective imperviousness for the entire subwatershed. Typical values of percent imperviousness by land use are presented in Table B-7 of Appendix B. Based on these values, the land use effective impervious used in the SWMM model is presented in Table 5-3.

Table 5.3 Land use effective percent impervious values used in the SWMM model

SWMM LU #	LU Designation	Description	Impervious%
1	Forest_1	Forest land-Established	0 - 1.0
2	Forest_2	Forest land-Intermediate	1.0 - 1.5
3	Forest_3	Forest land-	1.5 - 2.5
4	Ag_1	Cropland	2.0 - 3.0
5	Ag-2	Pastureland	2.0 - 5.0
6	Urban	Urban Buildup	25 - 40
7	Road_1	Paved roads	80 - 90
8	Road_2	Unpaved Roads	40 - 60
9	Brn	Barren land	2.0 - 5.0
10	Wet	Wetlands	0 - 1
11	Wat	Surface water	0

5.4 Water Quality Modeling

SWMM was used to estimate storm water runoff and pollutant washoff for the time period 1988-1997 under GAP 2000 land use conditions and various pollutant loading scenarios. For this study, the model was developed for following specific parameters:

- Dissolved Aluminum
- Total Aluminum
- Dissolved Iron
- Total Iron
- Total suspended solids (TSS)

To estimate pollutant loading in storm water runoff using SWMM, the pollutant buildup and washoff processes are calculated based on drainage area and land use type. Buildup refers to the complex processes occurring during dry weather periods that lead to the accumulation of the pollutant on the surface. Washoff is the process in which the accumulated particles are removed from the surface by -generated runoff. The power linear constituent buildup equation was used to simulate the surface deposition and the exponential relationship was used to simulate washoff processes . These equations are presented in the SWMM manual (USEPA, 1992).

5.5 Erosion and Sedimentation

Pervious areas such as agricultural (cropland and pastureland), forestland (undisturbed and forest operations, access roads), construction sites, oil and gas (drilling and access roads), highways, mining (active sites and abandoned mine lands) are potential sources of erosion and sediment. Erosion from these various sources is function of several factors including the soil type, characteristics, steepness of the area, and the type of activities taking place. Erosion and sediment loading from these sources are estimated using the runoff block of the SWMM model.

5.5.1 Erosion and Sediment Sources

In Section 4, a conceptual representation of sediment loading from the various sources relative to natural or undisturbed forest condition was presented in Table 4-1. The objective was to identify potential sediment sources and to characterize them based on sediment contribution amounts and time scale of impact on the receiving water body. Following the identification step, is model parameterization, which involves assigning values to the parameters of the runoff block that can represent the watershed conditions, and the relative contribution of each potential sediment source to the overall watershed loading. A description of NPS source categories follows:

<u>Undisturbed Forest Land</u>
This land use represents the natural or the undisturbed conditions. Based on the GAP 2000 land use data, forest areas were characterized and summarized by subwatershed in Table B-6 of Appendix B. Sediment loading from undisturbed forest land is expected to be low. Typical sediment loading from undisturbed forest land is presented in Table B-11 of Appendix B. It ranges from 30 lb/ac-y to

100 lb/ac-y.. The variation in sediment loading is expected since it is highly dependent on the site specific conditions and the physical characteristics of the watershed. Sediment loading for undisturbed forested land was estimated at 31 lb/ac-year based on a locally conducted study by Kochenderfer et al. in 1984. This loading is considered representative of loadings from undisturbed forestland conditions.

Sediment loading from the second category of forest land used in SWMM, intermediate forest, is expected to be higher than the background condition. The sediment loading reported by Wannielista and Yousef,1993, 75 lb/ac-yr, is considered representative of this intermediate land use condition (Table B-11 of Appendix B).

Forestry Activities

The 1989 forest inventory of West Virginia indicated the following (US Forest Service, 2000):

- Seventy nine percent of West Virginia 12.1 million acres are forested, and 98% of the forest land is classified as timberland.
- The growing stock volume is 19 billion cubic feet, with an average of 1598 cubic feet per acre. The average annual net growth of growing-stock volume is 2.6% and the average net cubic foot removals is less that 1% of the inventory.

In addition to the information presented above, the average annual removal of growing stock on timberland by county data (compiled by Forest Inventory and Analysis (FIA) research units) was retrieved using the National Data Base Retrieval System (DBRS). Table B-13 of Appendix B is a summary of timber removal for all counties in West Virginia. These data and information were used to convert the average annual removal of growing stock to acres of timberland harvested annually by county.

The types of forestry activities that can potentially increase erosion and the rate sediment yield from forested area include timber harvesting, access road construction and use, and mechanical equipment operations. The skid roads and log landing areas are sites with the highest erosion potential. On average, these sites account only for 10.3% of the harvest area (Kochenderfer, 1977). Estimates of the percent of timber harvest area in skid roads varies greatly in the literature. Hornbeck (1964) reported that the percent of timber area in skid roads range from 2.1% to 3.6% of the watershed area. For ground based logging, US Forest Service reported that roads can make up to 5% of the area being logged (US Forest Service, 2000).

For this TMDL development, skid roads areas were assumed to make an average of 2.5% of the area being timbered. Typical sediment loading from forest operations and roads are presented in Table B-14 of Appendix B. The table shows that sediment loads from logging areas and skid roads substantially decrease within the first year of completion of logging activities in the watershed. Sediment yield decreased from the area being logged by 92% and sediment yield from skid roads decreased by 99%.

Agriculture

Cropland and pastureland, the fourth and fifth land use categories are considered primary areas prone to erosion and can potentially contribute to the watershed sediment loads. These areas were characterized based on the GAP 2000 land use data. Typical sediment yield from these sources are 300 lb/ac-yr for pastureland and 405 lb/ac-yr for cropland, shown in Table B-15 of Appendix B. Additional information on these sources is provided in Tables B-9 and B-16 of Appendix B.

Urban Buildup

Urban buildup is the sixth land use category simulated in the model. The GAP land use was used to estimate the urban buildup areas. Additional information on this source category is provided in Table B-9 of Appendix B.

Roadways

Roadways can be a major source of erosion and sediment yield, depending on the roadway surface. Based on data provided by WVDEP and WVDOT, the roadways were characterized based on type of surface cover and length in miles. The break down of roadway type was used to estimate the paved and non-paved miles of road in each county and subsequently in every subwatershed in the study area. The roadway length was converted to areas based on data provided by WVDOT and shown in Table B-19 of Appendix B . Typical sediment loading rates from various road types are presented in Table B-20 of Appendix B.

Paved roadways is the seventh land use category simulated in the model. Sediment loads from paved road ways is expected to decrease once the construction and soil stabilization is completed.
Unpaved roadways is the eighth land use category simulated in the model. Higher sediment loads from unpaved than paved roadways are expected.

Barren Lands

Barren lands are any areas where the soil has no protection from the forces of and runoff. Consequently, soils under these conditions are subject to variable levels of erosion and sediment yield.   Loads from this type of area can be substantial. Barren conditions may exist at abandoned mine lands, and construction sites without any erosion controls installed on site. Estimates sediment loads from barren land vary substantially because erosion under these conditions is site specific. Loading can be as high as 60,000 lb/ac-yr, reported by Horner, 1994 for a construction site which can be considered barren land if erosion control measures are not properly installed and maintained.

Construction Sites

Construction sites can potentially be a major source of erosion and sediment depending on the size and the type of erosion control measures installed on site. Construction sites are simulated as part of the barren lands category where the soil has no protection from the . The Gap 2000 land use area is used to estimate the areas of construction sites located within the Little Kanawha watershed. Sediment yield from construction sites is presented in Table B-17 of appendix A.

Mining Operations

Mining operations that can contribute to erosion and sediment yield include permitted active mining sites and abandoned mine lands. The permitted active mine site are modeled as point sources. However, abandoned mine land areas were identified using the GAP 2000 Land Use land cover data and PADs data provided by WVDEP. In simulating erosion and sediment yield, the abandoned mine lands are treated as barren lands. Additional information on erosion associated with abandoned mine lands are presented in Table B-18 and Table B-10 of appendix B.

Oil and Gas Operations

The types of oil and gas operations that can potentially contribute to erosion and sediment loading include construction of new wells and access roads. Oil and gas wells located in the Little Kanawha watershed were identified based on GIS data provided by the WVDEP. These wells were characterized into the following categories. Active drilling operations, active production operations, abandoned sites and Plugged wells (Flannery, 2000). An active well drilling operation requires site clearing and preparation and can require building or clearing access roadways. Sediment loading form active drilling operation sites diminishes after construction operations cease and the site is stabilized. During the construction phase, sediment loads can be reduced through better designs, maintenance, and implementation of erosion control practices. However, the access roads can potentially be a large contributor to the sediment loading in the watershed when improperly designed and maintained erosion controls are installed. Sediment load contribution from abandoned and plugged well sites is considered low if these sites are restored and vegetation is reestablished.

Sediment loading from active drilling operations and active well production can be from the drilling site and the access road. Factors taken into account in the model representation of active well sites include the identification of the number of active drilling operations and the active production operations in the little Kanawha. This step was based data obtained from WVDEP and Flannery, 2000. It is assumed that new well sites are located near the closest access road, whenever possible, to avoid any additional land disturbance (WVDEP Office of Gas, 1992). BMP compliance is high, based on a survey of well sites conducted by WV DEP within the Little Kanawha watershed which indicated that 50 sites out of 509 sites were in violation.

Wetland Areas

Wetland areas is the tenth category simulated in the model. This category can include forestland, shrubland or any land that is on the National Wetland Inventoy. The GAP land use was used to estimate the wetland areas.

Water

Water is the eleventh category considered. This category describes surface water (rivers, streams, and lakes). The GAP land use was used to estimate the surface water areas. A cropping management factor of 0.0, and a control practice factor of 1.0 are considered representative of water conditions and were used in the model, see Table B-9 of Appendix B.

5.6 Base Flow and Background Concentrations Conditions

5.6.1 Base Flow conditions

A constant discharge representing base flow rate was incorporated at inlet points in the modeled stream network to represent contributions from groundwater seepage . Base flow information from 16 USGS gages located within the Little Kanawha River watershed, shown in Table B-22, were considered in estimating the base flow conditions at each node in the study area. For locations in the watershed where flow gages are not available, base flows were estimated using the area-weighted method. Figure 5-4 is a map showing the locations of flow gaging stations in the Little Kanawha watershed.

5.6.2 Low Flow Concentrations

Total aluminum and total iron background concentrations were based on a survey of the water quality sampling stations located within the watershed study area and based on data provided by WVDEP and WV Department of Agriculture. For the specific stations shown in Table B-23, the instream total suspended solids, total aluminum and total iron concentrations were evaluated under low flow conditions. Table B-24 of Appendix B is a summary of the instream concentrations for each of these parameter.

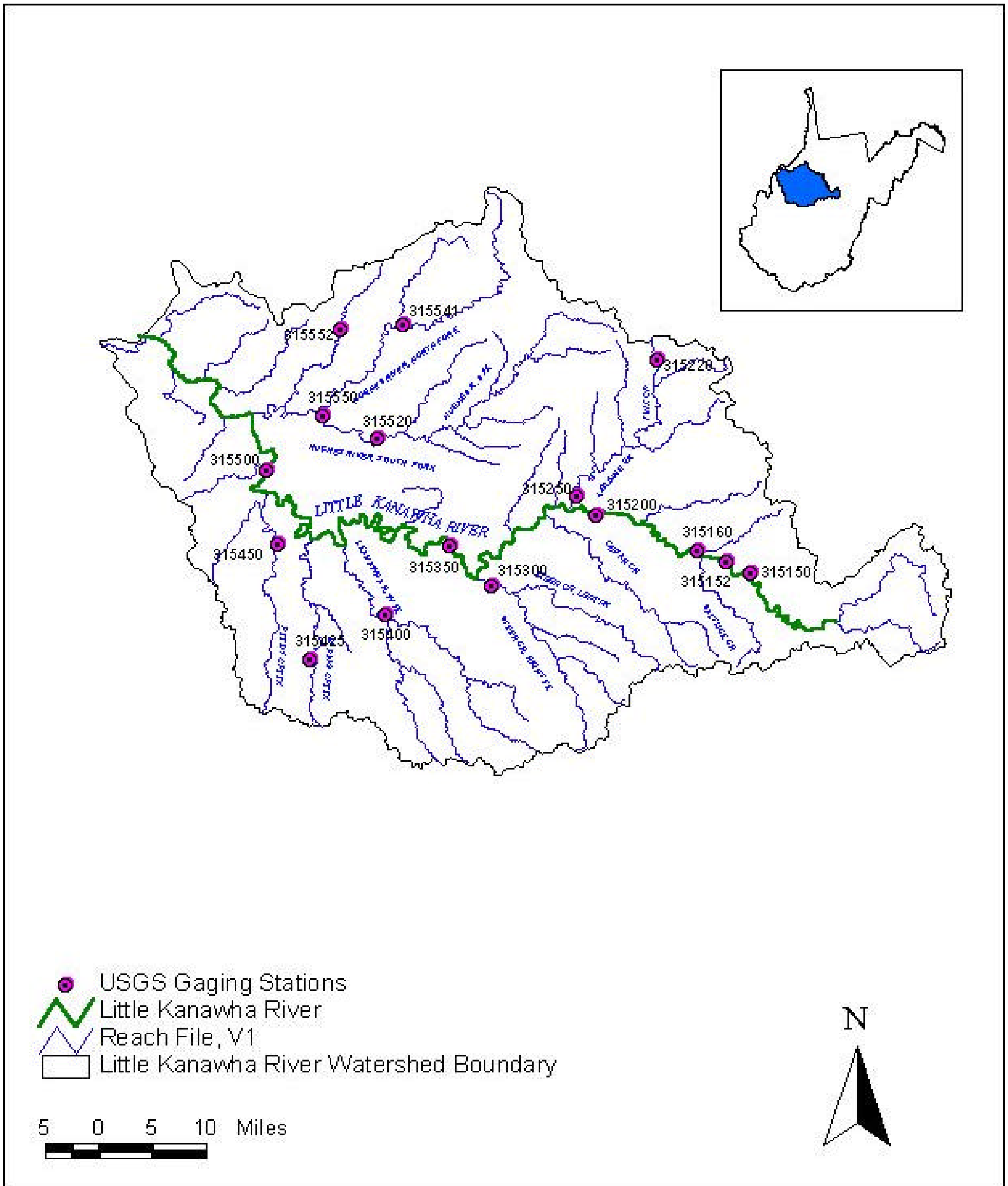

Figure 5.5

USGS Flow Stations used in SWMM Modeling

Data Sources: U.S.EPA BASINS, USGS, WVDEP

Map Projection: Albers Equal Area, GRS 80

5.7 Flow Routing

Hydrographs and pollutographs generated using the runoff block of the SWMM model are routed through the stream network using the transport block. The inlet numbers shown in Table B-25 of Appendix B represent the inflow locations of the 19 major tributaries of the Little Kanawha River. Also shown in Table B-25 of Appendix B are the numbers of the subwatersheds.

The use of the transport block in SWMM requires determination of channel types and estimation of length, slope, depth, width, and Manning's coefficients for each channel. For this study, all the streams were modeled as rectangular channels. A summary of the data sources used in the estimation of these parameters is shown in Table B-26 of Appendix B.

6. TMDLs

Analysis of water quality data, presented in Section 3, showed frequent violations of existing water quality standards in the Little Kanawha. Several of the listed reaches show greater than 50 percent exceedence of the available samples. The magnitude of the impairment is also significant: several observations show values more than ten times higher than applicable standards. The frequency and magnitude of the impact require careful consideration of the implementation strategy in the determination of the TMDL allocations.

The implementation strategy for the TMDL allocations is designed to incrementally work toward achieving water quality standards. The strategy is designed to meet the needs of the stakeholders, work within the context of existing programs and management opportunities, be oriented to technically feasible practices, provide the flexibility needed to incorporate continued monitoring and tracking, and provide a mechanism to initiate update or revision of the TMDL when needed.

The TMDL allocation strategy consists of a three-stage approach to achieving water quality standards. Stage 1 focuses on reducing the frequency of violations to meet water quality standards at least 75 percent of the time. This stage emphasizes management that targets smaller to medium-sized storm events and sediment control practices in specific portions of the watershed. Stage 2, which can be initiated concurrently to stage 1, focuses on compiling information, tracking, and monitoring to support continued evaluation of the existing water quality conditions and the efficacy of the management practices identified for remediation of the Little Kanawha. During stage three the progress toward compliance and restoration will be evaluated and implementation will be initiated to fully achieve water quality standards within the Little Kanawha.

The strategy is designed to be responsive to ongoing data collection and analysis, and to new standards that might be promulgated in West Virginia. The TMDL may be revised, at the discretion of the State of West Virginia and EPA Region 3, if new information or standards indicate that the allocation will change.

This section describes the evaluation of the degree of impairment and the characteristics of the existing loading, the allocation stages for the listed segments, and the associated TMDL elements of seasonality and margin of safety.

6.1 Geographic Extent of the TMDL

The TMDLs for the Little Kanawha watershed are derived and presented on a subwatershed basis. The subwatersheds used for allocation purposes are based on the West Virginia coverage of 19 major tributaries presented in Table B-25. One of the major tributaries (5) was represented as three individual subwatersheds to more closely match the drainage areas of the listed reaches, resulting in the use of 21 major tributaries for allocation purposes. Figure 6.1 shows the configuration of the 21 subwatersheds used for allocation purposes and the associated listed reaches within the watershed. The more detailed subwatershed delineations used for modeling purposes, shown in Table B-5 and Figure 6.2, were grouped to derive the loading information for the 21 allocation subwatersheds. Table 6.1 shows the listed reaches and their watershed ID numbers.

Five of the listed reaches are associated with individual subwatersheds (555, 540, 153, 8, and 3). The listing of the Little Kanawha River main stem also requires control of the entire larger watershed. The allocation for the main stem is therefore presented for the total watershed representing all 21 subwatersheds (including the 5 smaller subwatersheds associated with the listed tributary reaches). The load allocations identified are designed to be protective of *both* the tributary listings and the mainstem listing.

These TMDLs affect three point sources. These point sources are located in the Little Kanawha River watershed and discharge pollutants affected by the TMDL. One point source is located in subwatershed 15, which drains to the impaired reach for Sand Fork Creek and downstream to the impaired portion of the Little Kanawha. The remaining point sources are located in subwatershed 20 and are affected by only the TMDL for the main stem of the Little Kanawha.

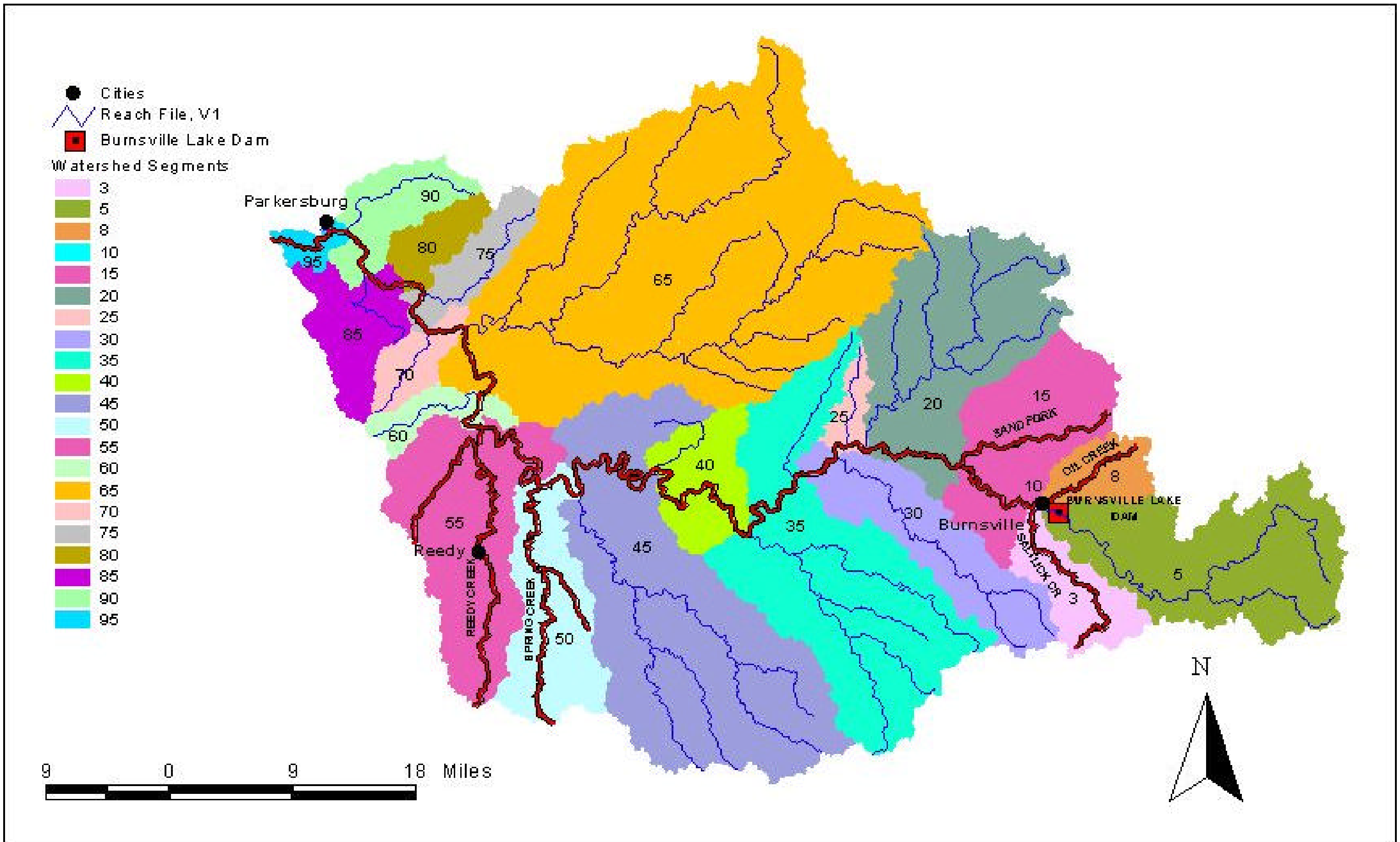

Figure 6.1 Little Kanawha Watershed Segmentation (for Allocation)	Data Sources: WV 303(d) List, WVDEP Map Projection: Albers Equal Area, GRS 80

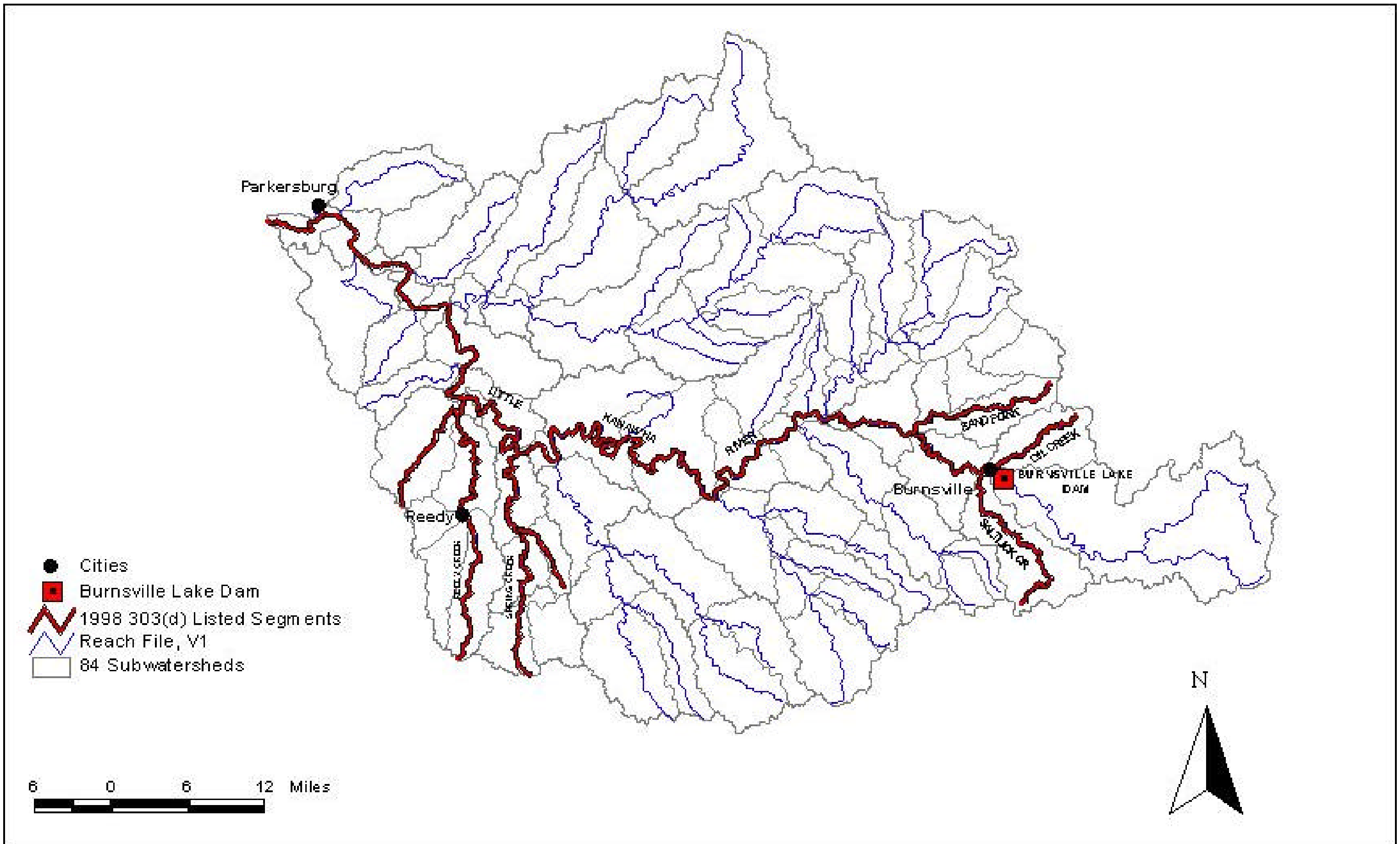

Figure 6.2
Little Kanawha Watershed Segmentation
(for Loading Evaluation)

Data Sources: WV 303(d) List, WVDEP

Map Projection: Albers Equal Area, GRS 80

Table 6.1 Listed segments and associated subwatersheds for TMDL development

	Segment Name	Number of subwatersheds in drainage area	Subwatershed ID Number
Listed Segment	Reedy Creek	1	55
	Spring Creek	1	50
	Sand Fork Creek	1	15
	Oil Creek	1	8
	Salt Lick Creek	1	3
	Little Kanawha River	21[a]	5-95
Point Sources	**NPDES ID Number**	**Subwatershed ID Number**	
	WV0058696	20	
	WV0119121	20	
	WV1003259	15	

[a] Little Kanawha River listing includes five listed subwatersheds.

6.2 Evaluation of Monitoring Data for Selection of TMDL Allocation

The available monitoring data were evaluated to support selection of the appropriate critical time period for TMDL evaluation. The data were also examined further to determine the severity and frequency of violations to provide guidance in the selection of appropriate allocations.

6.2.1 Selection of Critical Time Period

The available monitoring information on Saltlick Creek in Burnsville, Sand Fork in Layapolis, Reedy Creek east of Palestine, and the Little Kanawha in Elizabeth was evaluated for the time period of violations and occurrence of violations. Figures 6.3 and 6.4 illustrate the distributions of occurrences of iron and aluminum concentrations in Saltlick Creek. In both plots the pattern that emerges shows the most severe violations occurring in the time period from July through November. This pattern was also observed at other locations within the listed reaches of the watershed where data were available. Based on this examination, a determination was made to use the July through November time frame as the critical period for

TMDL analysis and development. The control of loading sufficient to meet standards during the critical time period will result in meeting water quality standards throughout the year.

Location: Spring Creek below Sanoma
Pollutant: Aluminum, Total (mg/L as Al)
Data from: 10/20/1993 to 9/27/1994 (12 Observations)

Time Period	# Obs	Residue (mg/L)			Pollutant (mg/L)		
Month	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
January	1	26.0	26.0	26.0	1.0	1.0	1.0
February	1	59.0	59.0	59.0	2.7	2.7	2.7
March	1	74.0	74.0	74.0	2.4	2.4	2.4
April	1	55.0	55.0	55.0	3.0	3.0	3.0
May	1	11.0	11.0	11.0	0.3	0.3	0.3
June	1	22.0	22.0	22.0	0.3	0.3	0.3
July	1	101.0	101.0	101.0	5.9	5.9	5.9
August	1	17.0	17.0	17.0	0.3	0.3	0.3
September	1	36.0	36.0	36.0	1.0	1.0	1.0
October	1	46.0	46.0	46.0	1.4	1.4	1.4
November	1	478.0	478.0	478.0	13.9	13.9	13.9
December	1	45.0	45.0	45.0	1.9	1.9	1.9

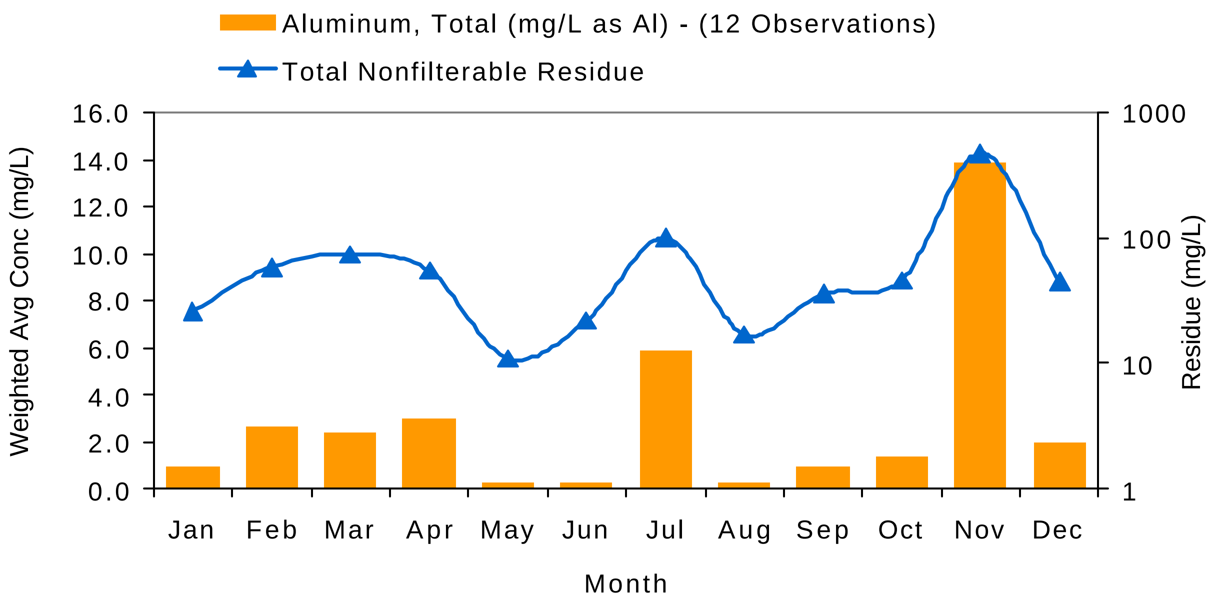

Figure 6.3 Aluminum concentrations in Saltlick Creek in Burnsville

Location: Saltlick Creek In Burnsville
Pollutant: Iron, Total (mg/L as Fe)
Data from: 10/20/1993 to 9/29/1994 (12 Observations)

Time Period	# Obs	Residue (mg/L)			Pollutant (mg/L)		
Month	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
January	1	7.0	7.0	7.0	0.2	0.2	0.2
February	1	1.0	1.0	1.0	0.5	0.5	0.5
March	1	16.0	16.0	16.0	0.8	0.8	0.8
April	1	11.0	11.0	11.0	0.7	0.7	0.7
May	1	5.0	5.0	5.0	0.8	0.8	0.8
June	1	14.0	14.0	14.0	0.4	0.4	0.4
July	1	31.0	31.0	31.0	1.9	1.9	1.9
August	1	7.0	7.0	7.0	0.9	0.9	0.9
September	1	2.0	2.0	2.0	0.6	0.6	0.6
October	1	48.0	48.0	48.0	1.8	1.8	1.8
November	1	52.0	52.0	52.0	2.6	2.6	2.6
December	1	1.0	1.0	1.0	0.6	0.6	0.6

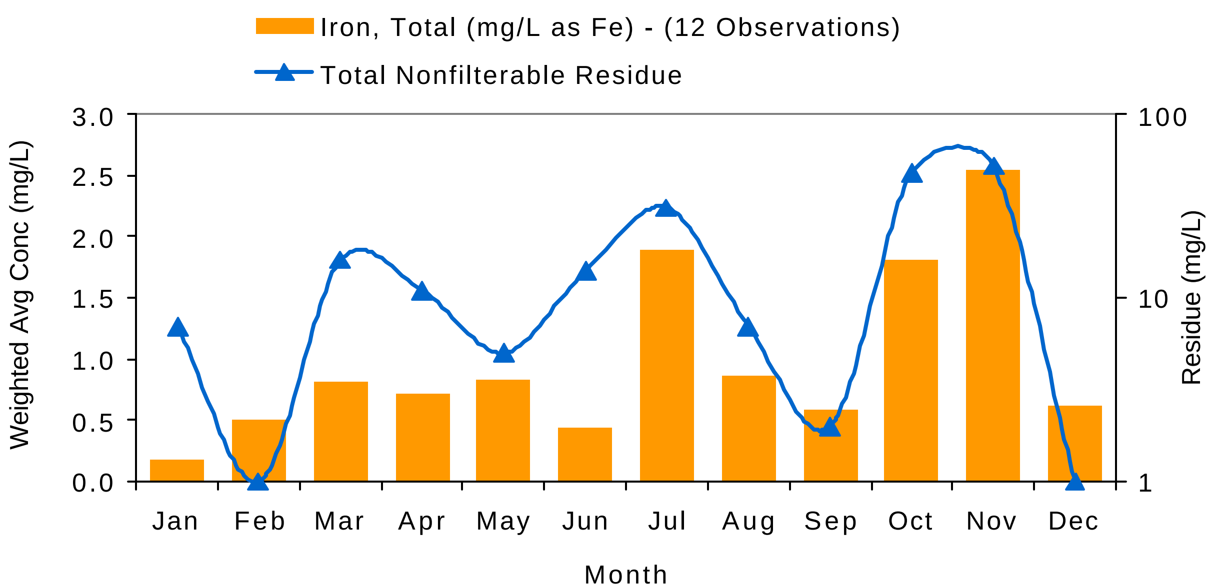

Figure 6.4 Iron concentrations in Saltlick Creek in Burnsville

6.2.2 Frequency and Magnitude of Water Quality Impairment

The frequency and magnitude of violations of water quality standards were also examined further for the purposes of defining the degrees of management required to meet water quality standards in the listed streams. Table 6.4 shows a summary of the maximum observed values and the percent of sample that exceeded thresholds based on the existing water quality standards. Insufficient samples were available to calculate a 4-day average for the chronic criteria for iron, so samples

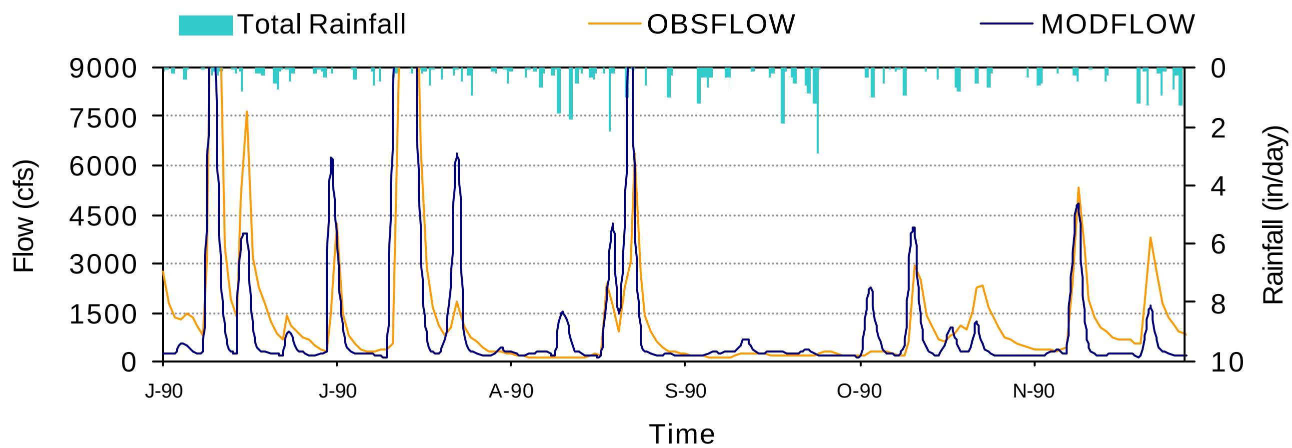

Figure 6.5 Time series of simulated and observed daily streamflows for the Little Kanawha at N60

were compared directly to the 1.5 mg/L threshold. Figures A-12 to A-18 show the ranked observed concentrations for each of the monitoring stations on the listed streams. Each figure shows a distinct pattern when elevated aluminum or iron concentrations occur. Table 6.2 and the figures show periodically very high concentrations, especially in Reedy Creek, Spring Creek, and the Little Kanawha River at Elizabeth. These three locations are located in the central portion of the Little Kanawha watershed. Monitoring stations located in the upstream portions of the watershed show moderate maximum values when compared with water quality standards.

Table 6.2. Water Quality Monitoring Exceedence Summary (1993-1994 monitoring data)

	Aluminum		Iron	
Location	**Max (mg/L)**	**% of Time Exceeding Threshold[a]**	**Max (mg/L)**	**% of Time Exceeding Threshold [b]**
Little Kanawha River at Elizabeth, WV	28.00	47.6	12.00	24.2
Reedy Creek	18.45	55.4	9.70	52.0
Spring Creek	13.92	60.2	18.31	49.9
Salt Lick	2.17	27.4	2.55	19.7
Sand Fork	2.06	48.6	1.90	28.3
Oil Creek	1.40	18.5	1.40	0.0

[a] 0.75 mg/l threshold based on acute criteria.

[b] 1.5 mg/l threshold based on chronic criteria (4-day averaging period not considered).

6.3 Model Testing

The model was applied to the critical time period and evaluated for performance relative to observed flow gaging and water quality monitoring data. Model simulation and flow gaging were compared using a combination of statistical analyses and visual observation. Figure 6.5 shows a comparison of simulated and observed time series data for the gaging station on the Little Kanawha at N60 near Elizabeth. Table 6.3 summarizes the performance of the model for

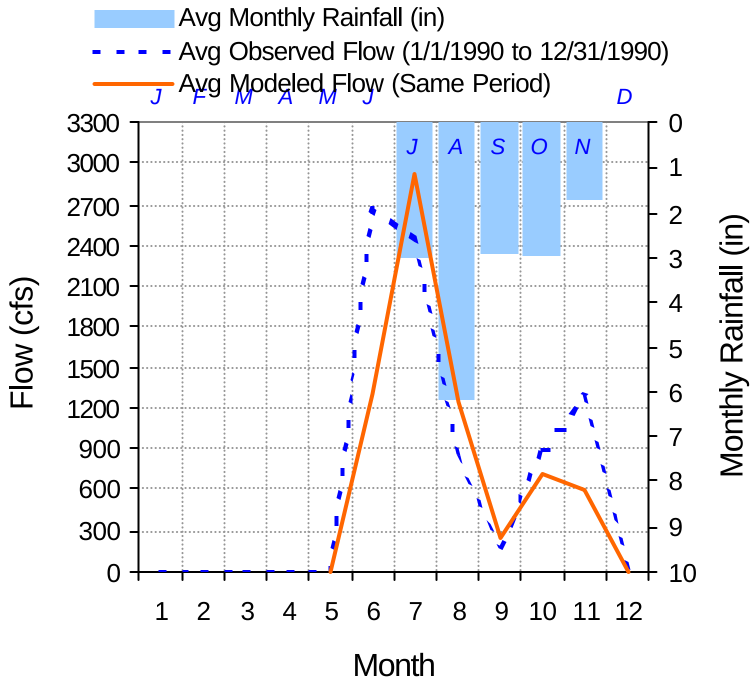

Figure 6.6 Average monthly rainfall and simulated and observed flows for the Little Kanawha at N60

various components of the flow regime, including low flow and peak flow conditions during the critical time period evaluated. A comparison of observed and simulated flows for July through November is shown in Figure 6.6. Observed versus simulated flows are plotted in Figure 6.7. The hydrologic simulation was determined to be within calibration specifications for use in the analysis of the TMDLs for the Little Kanawha River watershed.

Table 6.3 Comparison of simulated and observed flows in the Little Kanawha River at N60
(June - November 1990)

	Simulated (cfs)	Observed (cfs)
In-stream Flow	5.43	6.01
Total of highest 10% flows	4.38	4.11
Summer flow volume	3.44	2.54
Fall Flow Volume	1.00	1.56

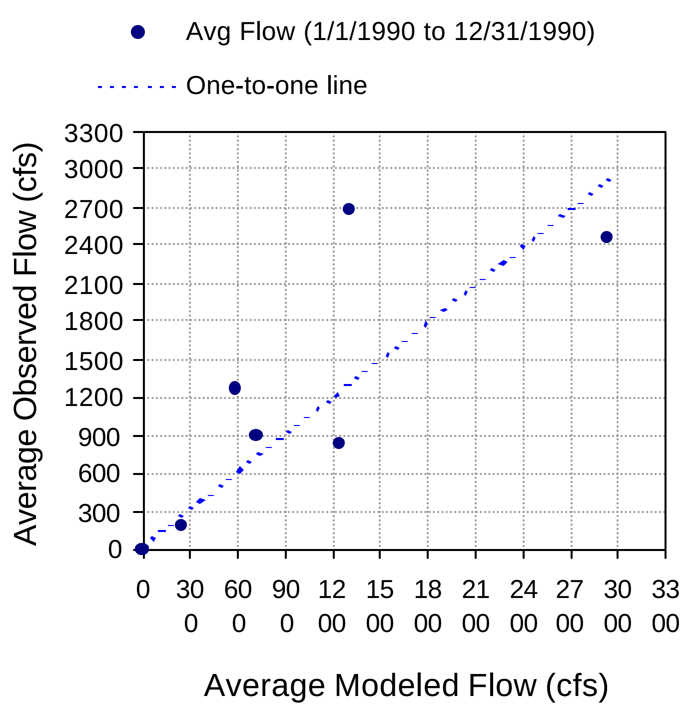

Figure 6.7 Observed versus predicted flow for the Little Kanawha River watershed.

The model performance was also tested at selected checkpoints in the watershed where sufficient water quality information was available. The predicted metals concentrations compared well with the observed data. Figures 6.8 through 6.12 show the predicted concentrations and the observed concentrations for TSS, aluminum, and iron for five locations.

6.4 Existing Condition

This section presents the results of the analysis of existing conditions in the Little Kanawha watershed and comparison with applicable water quality standards. Figures 6.13 shows the modeled existing conditions and applicable water quality standards for aluminum and iron for a sample reach. The existing conditions were evaluated using the Little Kanawha modeling system. Based on examination of plots such as this, and supporting data sets for the listed reaches, the number of days standards are exceeded can be determined. For the iron standard this analysis considered the 4-day averaging period. Table 6.6 summarizes the number of days that the standard is exceeded in each of the listed reaches based on evaluation of the modeling simulation and the applicable water quality standard.

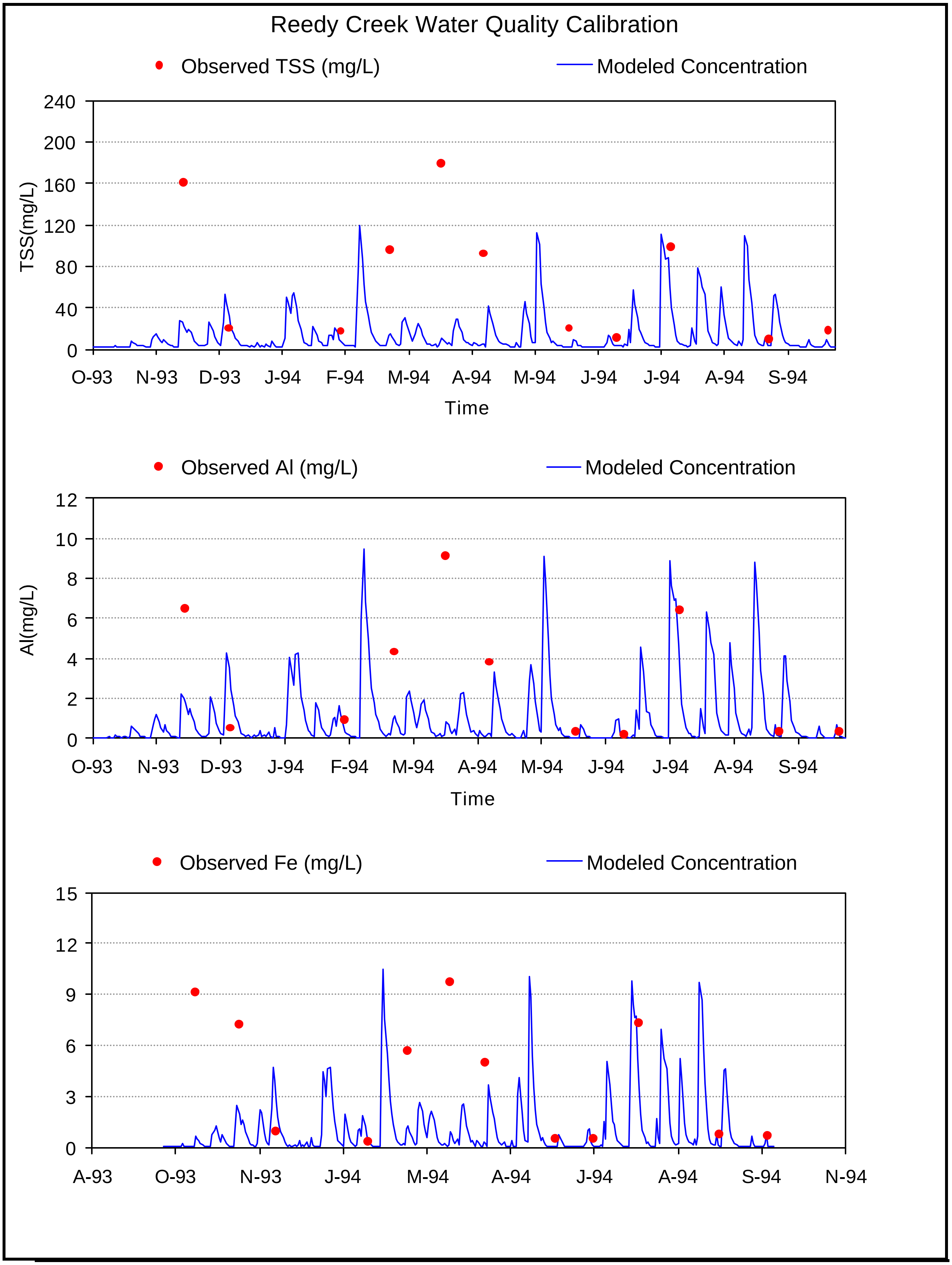

Figure 6-80 Observed and modeled conditions at Reedy Creek

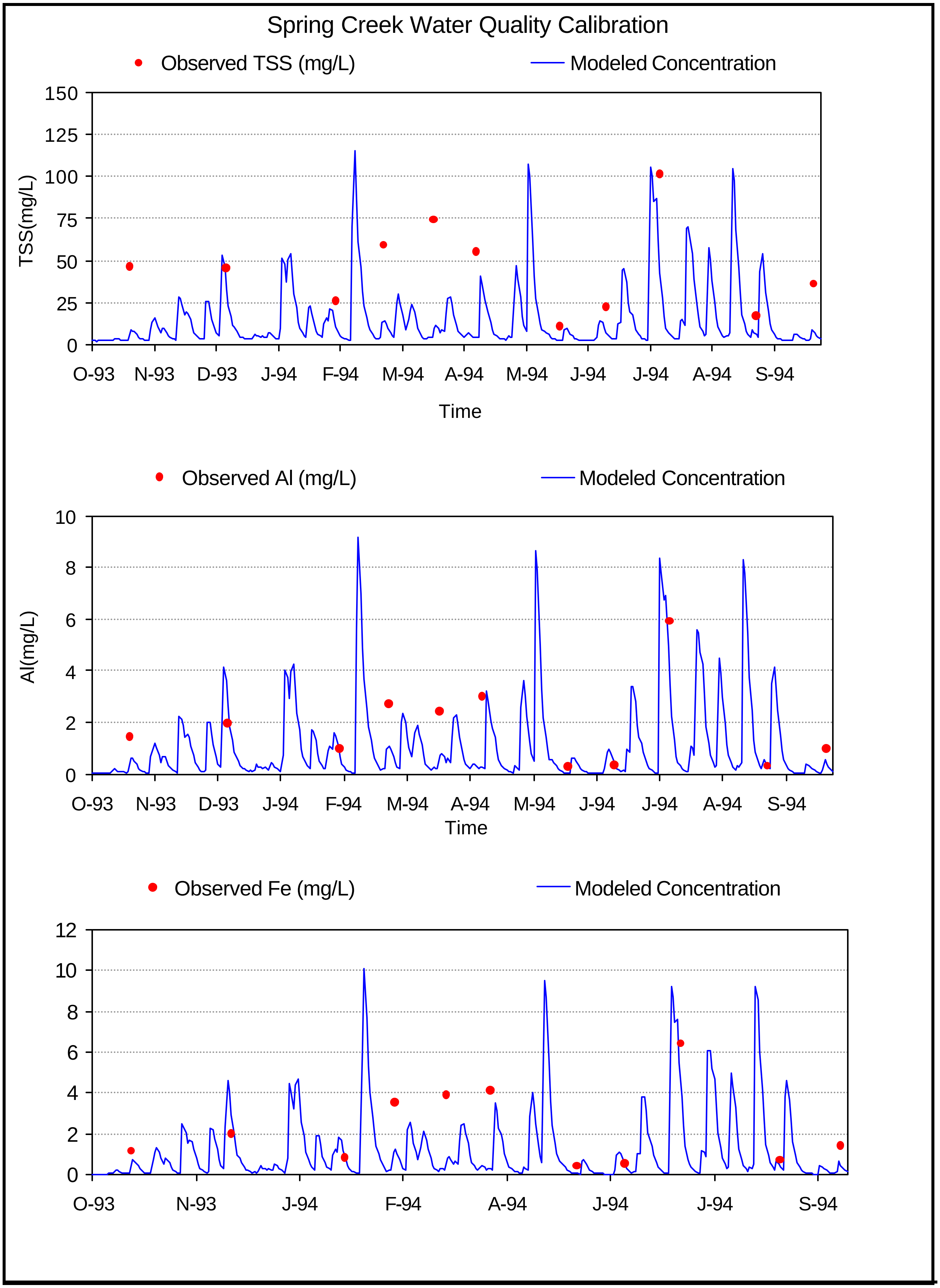

Figure 6.9 Observed and modeled conditions at Spring Creek

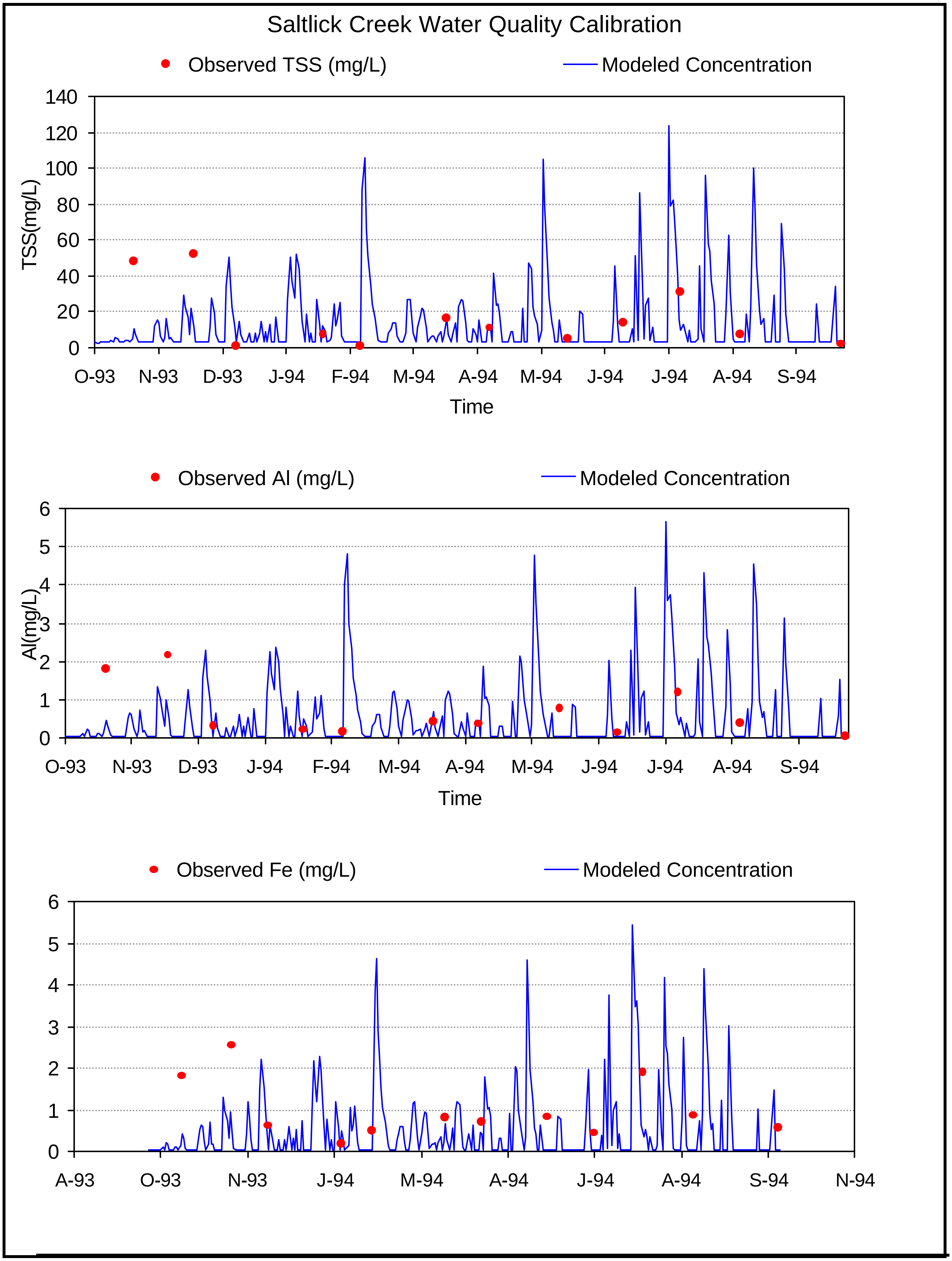

Figure 6.10 Observed and modeled conditions at Saltlick Creek

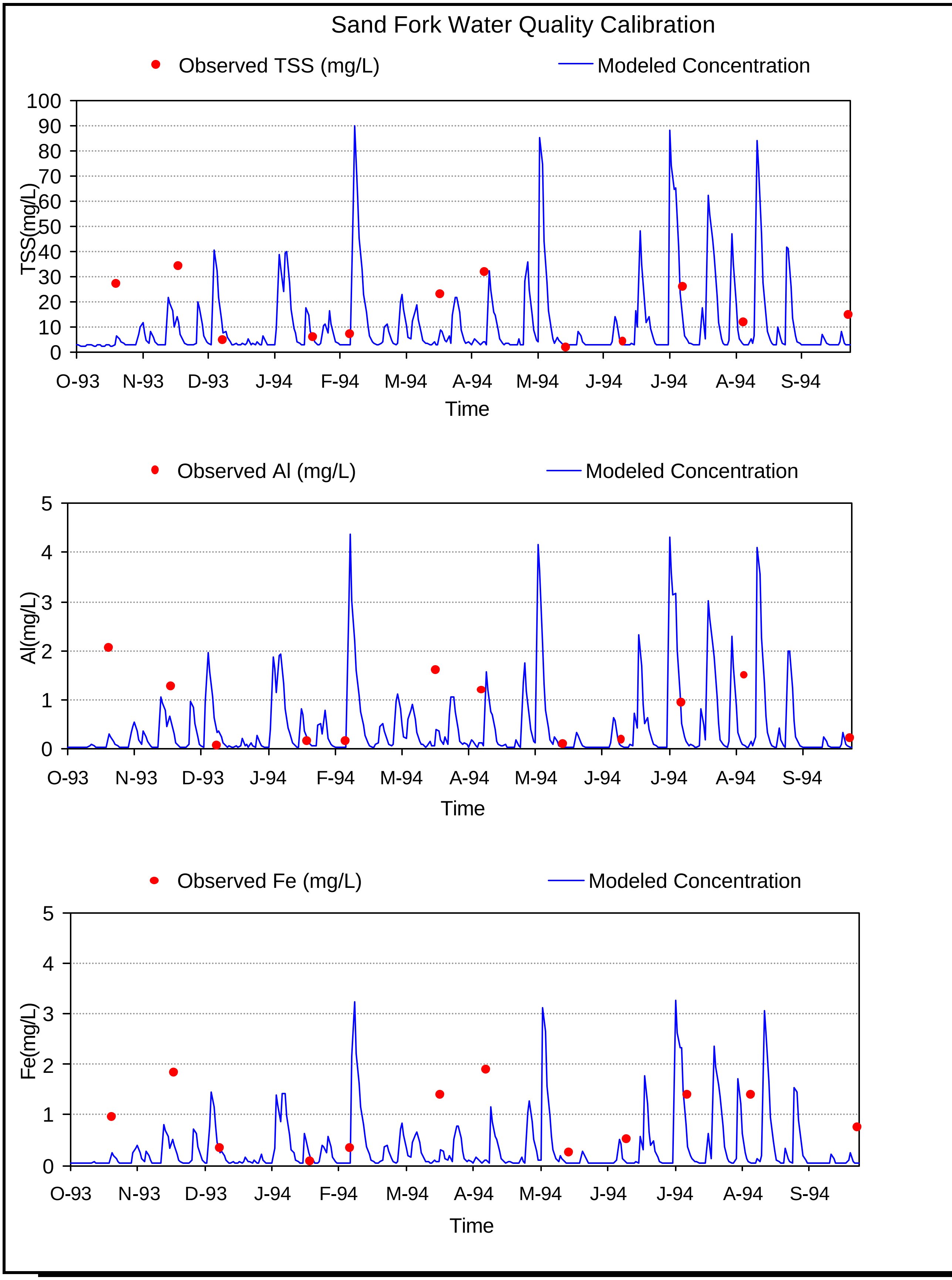

Figure 6.11 Observed and modeled conditions at Sand Fork

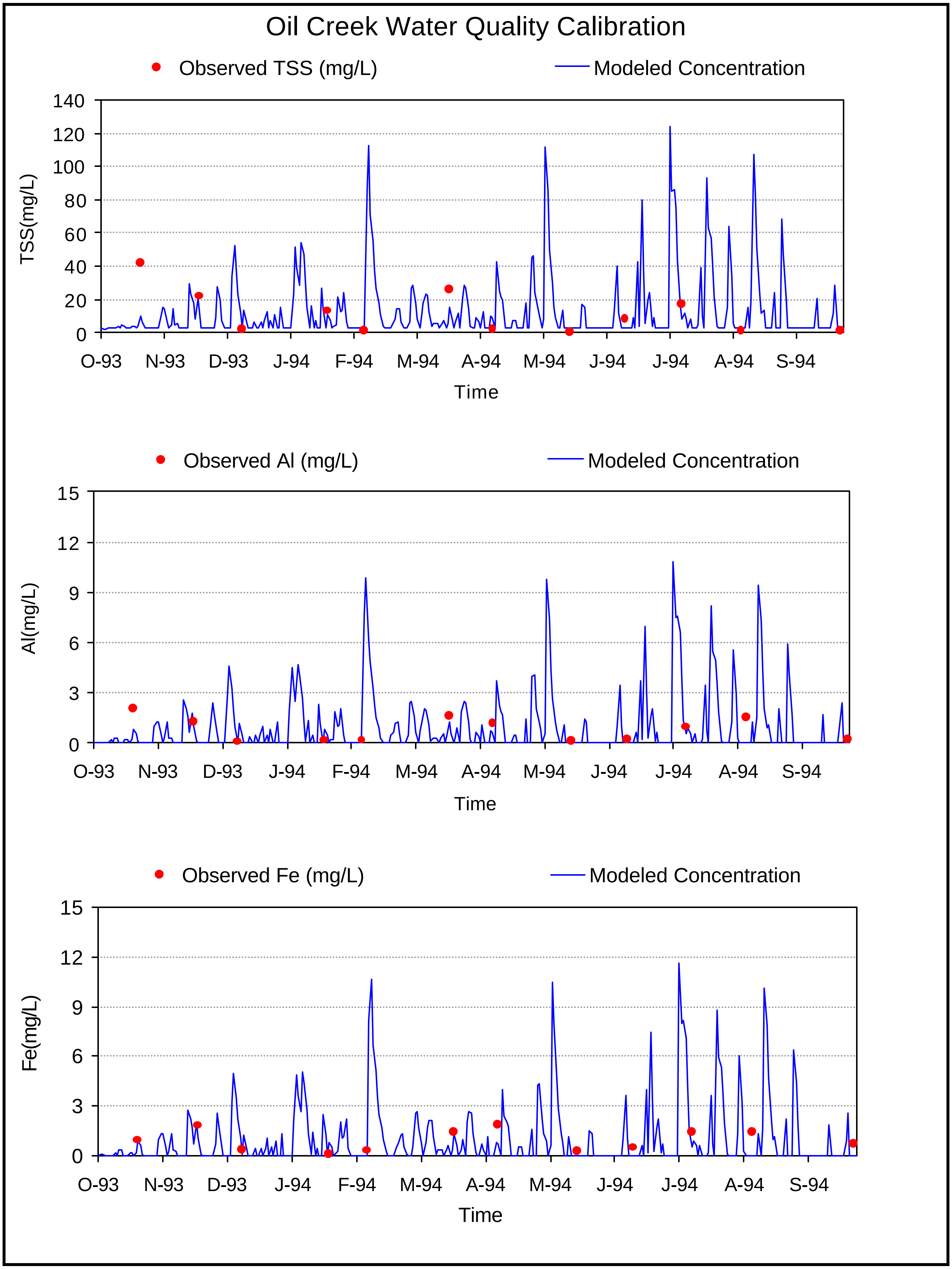

Figure 6.12 Observed and modeled conditions at Oil Creek

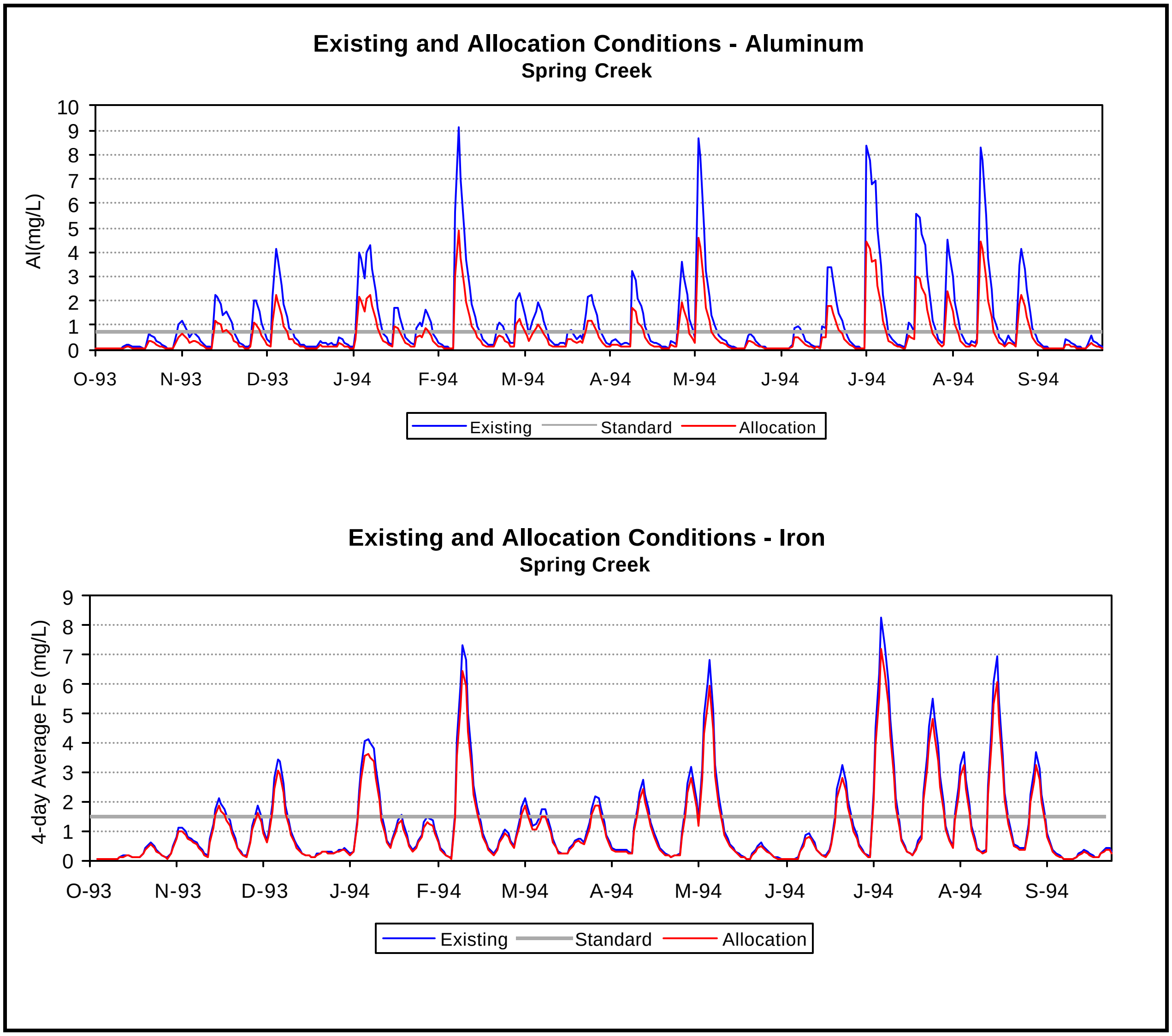

Figure 6.13 Spring Creek existing conditions and stage 1 allocation

Table 6.4 Number of exceedences predicted under existing conditions for impaired reaches

Listed Segment	% Violation Aluminum	% Violation Iron
Reedy Creek	32.6	25.4
Spring Creek	37.5	27.4
Sand Fork Creek	18.6	3.9
Oil Creek	18.4	3.0
Salt Lick Creek	23.4	3.0
Little Kanawha River @ Elizabeth, WV	27.7	9.0
Little Kanawha River @ Mouth	32.3	18.2

The loadings for existing conditions for sediment, aluminum, and iron also can be summarized as average annual loadings. Table 6.5 summarizes the average annual loading for all tributary and Little Kanawha subwatersheds that contribute to the overall impairment of the main stem of the Little Kanawha.

Table 6.5 Predicted average annual loading for 1993-1994 hydrologic condition for Little Kanawha major subwatersheds

Node	Name	TSS ton/yr	Aluminum ton/yr	Iron ton/yr
153	**Sand Fork Creek**	1,725	83	62
540	**Spring Creek**	2,604	206	227
555	**Reedy Creek**	3,845	303	336
3	**Salt Lick Creek**	1,311	59	57
8	**Oil Creek**	662	32	23
5	**Upper Little Kanawha River (includes Salt Lick (3) and Oil Creek (8))***	3,015	142	84
10	Upper Little Kanawha	2,006	93	81
15	Sand Fork Creek, Little Kanawha River	2,379	115	84
20	Leading Creek, Little Kanawha River	4,298	201	174
25	Cedar Creek, Little Kanawha River	2,154	98	87
30	Little Kanawha River	1,223	42	70
35	Left Fork Steer Creek, Little Kanawha River	4,430	208	168
40	Little Kanawha River	1,141	40	63
45	Little Kanawha River, Upper N. Fk.. L.KR, Upper W. Fk LKR	6,116	204	341
50	**Upper Spring Creek, Left Spring Creek, Little Kanawha River**	2,766	218	1,363
55	**Reedy Creek, Little Kanawha River**	4,309	341	1,757
60	Little Kanawha River	771	58	65
65	Hughes River, Little Kanawha R., Goose Crk, Indian Ck, Bonds Ck	13,604	909	1,071
70	Little Kanawha River	804	64	72
75	Little Kanawha River, Walker Creek	1,080	89	96
80	Stillwell Creek, Little Kanawha River	849	67	75
85	Tygart Creek, Little Kanawha River	1,818	126	146
90	Worthington Creek, Little Kanawha River	1,785	111	135
95	Little Kanawha River	523	27	36

* Note: Boldface type denotes subwatershed that also include listed tributary segment.

6.5 Allocation Scenarios

6.5.1 Objective of the Allocation

A series of allocations are defined to ultimately achieve existing water quality standards for aluminum and iron in the six listed reaches of the Little Kanawha River watershed. Loads are expressed as total annual loads for each subwatershed within the Little Kanawha. The loading targets are defined to ultimately meet water quality standards in both the listed subwatershed as well as the cumulative impacts from all subwatersheds on the impacted portion of the Little Kanawha main stem. The stage 1 and stage 3 TMDL scenarios identify a load allocation (for nonpoint sources) and waste load allocation. The stage 3 TMDL also addresses the seasonal considerations and critical conditions of the final allocation.

6.5.2 Stage 1 Interim Loading Targets

For the Little Kanawha TMDL the load allocation and waste load allocation are summarized as average annual loadings for each of the listed subwatersheds of the Little Kanawha River. Several scenarios were considered in the draft TMDL analysis for the stage 1 allocation. The three scenarios originally considered included uniform reductions for each subwatershed, loading ranges defined by magnitude of unit area loading, and reduction from the Hughs reservoir watershed and uniform reductions from the remaining watersheds.

Load Allocation

Based on public comments, the final selected scenario (Scenario 4) is a combination of the Scenarios 2 and 3. Additional analysis was performed to evaluate the sediment and metals removal to be expected from the construction of the Hughs Reservoir. The Little Kanawha SWMM application was used to propagate the reduction of TSS downstream of the proposed North Fork Dam structure in subwatershed 65. Sediment trapping efficiency was calculated to be 78 percent. This was determined by relating trap efficiency and the ratio between reservoir capacity and mean annual water inflow (Brune 1953). Area-weighted flow data from USGS00315550 at Cisco, WV was used to determine reservoir inflows. The reservoir data was obtained from the Draft North Fork Hughes River Watershed Project Work Plan - EIS (1994).

The selected scenario for the stage 1 allocation is shown in Table 6.6 below. For this scenario Aluminum is the limiting agent. TSS and iron reductions are based on meeting the more stringent reduction requirements for aluminum. The required reductions for watersheds Reedy Creek (555) and Spring Creek (540) were achieved based on meeting the tributary loading target for the individual listed tributary. Further loading reductions, beyond the individual tributary target, were required for other listed tributary waters Sand Fork (153), Oil Creek (8), Salt Lick Creek (3) in order to meet the loading targets for the main stem of the Little Kanawha River. Note also that loading reductions for subwatershed 50 and 55 include portions of listed reaches (and their allocations) for Spring Creek (540) and Reedy Creek (555) More detailed description of the land use related distribution of the loading is shown for selected scenario in Appendix C.

The assumption of sediment and metals removal by the Hughes Reservoir is evaluated for the purposes of protection of the downstream Little Kanawha River. Although no specific load reduction is identified for this TMDL upstream of the Hughes Reservoir, management of sediment and associated metals is encouraged for the protection of the reservoir capacity and aquatic life resources.

Table 6.6 Selected Stage 1 Allocation - Scenario 4 [a]

	% Reduction	TSS	Al	Fe
Subwatershed		ton/yr		
153	22.0%	1345	65	48
540[b]	46.5%	1392	110	121
555[b]	37.7%	2396	189	210
3	30.0%	918	42	40
8	30.0%	464	22	16
5	30.0%	2110	100	59
10	14.0%	1725	80	70
15	22.0%	1856	90	66
20	22.0%	3352	156	135
25	30.0%	1508	68	61
30	30.0%	856	30	49
35	30.0%	3101	145	118
40	30.0%	798	28	44
45	30.0%	4281	143	238
50[c]	45.1%	1518	120	748
55[c]	35.9%	2760	218	1126
60	22.0%	602	45	51
65[d]	13.0%	9598	679	783
70	5.0%	732	61	67
75	5.0%	939	85	89
80	5.0%	759	64	70
85	5.0%	1628	119	136
90	5.0%	1591	105	125
95	13.0%	426	23	31

[a] Limiting pollutant is aluminum. TSS and associated iron reductions are based on meeting aluminum target
[b] Load reduction based on meeting tributary target
[c] Load reduction includes reduction for listed tributary
[d] Presumes construction of Hughes Reservoir, percent reduction based on additional management in watershed

Waste Load Allocations

The TMDL for the Little Kanawha River Watershed identified several point sources. Point sources were identified through EPA's Permit Compliance System (PCS). Thirty-four Permitted facilities were identified by PCS. Roughly, fifty percent of these permits were for sewage treatment plants. There were only three facilities with Iron limits. There were no permits with Aluminum limits. Loading from these facilities was determined through flow and concentration values documented in the facilities Discharge Monitoring Record (DMR). Facilities without limits for Iron or Aluminum were not seen as contributing these pollutants to the watershed. No waste load allocations were established in this TMDL. Gross allocations were determined for the tributaries which receive the effluent from the facilities permitted for Iron or Aluminum. These streams were also listed as impaired due to acid mine drainage (AMD). The WLAs for these facilities will be addressed in the AMD TMDLs.

6.5.3 Stage 2 Interim Targets

Stage 2 may be initiated concurrently with stage 1. The emphasis of stage 2 is on collecting and analyzing information on the impairment status and management practices available for the Little Kanawha River watershed. During stage two information will be compiled and analyzed to further evaluate the condition of the waterbody and the degree to which impairment will be successfully managed using best management practices (BMPs). During this stage the state may also choose to reevaluate the site specific standard or perform evaluations related to the potential revisions of the state water quality standard for aluminum and/or metals.

6.5.4 Stage 3 Final Loading Targets: TMDL

For the Little Kanawha River TMDL the load allocation and waste load allocation are summarized as average annual loadings for the each of the listed subwatersheds of the Little Kanawha. These loading targets are designed to fully meet the existing water quality standards. Table 6.7 summarizes the load allocations for the listed waters of the Little Kanawha.

Table 6.7 Stage 3 Final Load Reduction Targets for the Little Kanawha Metals TMDLs

Segment	*Aluminum*	Existing Loads	Stage 3	Percent Reduction from 25% exceedence to 0%
	Segment Name	tons/yr	tons/yr	
555	Reedy Creek	303.00	24.00	54.6%
540	Spring Crek	206.00	17.00	45.6%
153	Sand Fork Creek	83.00	14.00	60.9%
8	Oil Creek	32.00	5.00	53.6%
3	Salt Lick Creek	59.00	8.00	56.7%
60	Little Kanawha River	1,760.00	238.00	64.5%
95	Little Kanawha River	3,153.00	384.67	67.8%
	Iron			
	Segment Name			
555	Reedy Creek	336.00	60.00	44.7%
540	Spring Crek	227.00	41.00	35.3%
153	Sand Fork Creek	62.00	35.00	21.3%
8	Oil Creek	23.00	14.00	8.7%
3	Salt Lick Creek	57.00	22.00	31.6%
60	Little Kanawha River	1,833.00	629.00	43.7%
95	Little Kanawha River	3,464.00	918.00	52.5%

Margin of Safety. The margin of safety (MOS) is part of the TMDL development process. There are two basic methods for incorporating the MOS (USEPA, 1991):

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

The MOS was considered implicitly in the Little Kanawha stage 3 TMDL allocation. An implicit margin of safety was provided by conservative modeling assumptions including:

- A dynamic model was used to simulate daily loading (flow, concentrations) over a wide range of hydrologic and environmental conditions.

- The stage 3 allocation was derived based on a slightly more stringent or conservative interpretation of the applicable water quality standards. The standards allow for a once in three year exceedence of the criteria. In evaluating the TMDL no exceedences were allowed within the representative simulation period.

Seasonal Variation. A TMDL must consider seasonal variations in the derivation of the allocation. For stage 3 the Little Kanawha metals TMDLs seasonal variation was considered in the formulation of the modeling analysis. By using continuous simulation, over a period of several years, seasonal hydrologic and source loading variability is considered. The dominant factor in seasonal variation is hydrologic variability and seasonal land disturbance associated primarily with agriculture. The various loading conditions simulated on a daily time step by the modeling system were compared with water quality standards to derive an allocation which meets water quality standards throughout the year. The standard for both aluminum and iron does not vary seasonally but must be met throughout the year.

Background Conditions. Natural background conditions are considered through the evaluation of established and undisturbed forest land and natural baseflow or low flow conditions in the watershed. Since most of the watershed has historic land use activities such as forestry, agricultural, and residential development, the natural background condition cannot be clearly distinguished from the existing conditions throughout the watershed..

7. Monitoring Plan

Follow-up monitoring of the Little Kanawha watershed is recommended. Future monitoring can be used to evaluate water quality conditions, changes or trends in water quality conditions, and contribute to an improved understanding of the source loading behavior. The following monitoring activities are recommended for this TMDL.

- West Virginia DEP should continue monitoring the impaired segments of the Little Kanawha River (mainstem and tributaries) according to its routine monitoring efforts.

- West Virginia DEP should consider additional stations and more frequent sampling of water quality in the impaired reaches.

- West Virginia DEP should emphasize the use of proper Quality Assurance Quality Control (QA/QC) protocols to avoid potential sample contamination during water sample collection and transfer.

- West Virginia DEP should consider additional sampling of dissolved metals using more rigorous clean chemistry methods of sample analysis for metals (aluminum and iron) to avoid potential sample contamination during laboratory analysis. If the standard for iron and/or aluminum is changed an expanded database of dissolved metals and hardness sampling will be needed to revise the TMDL appropriately.

In addition to chemical sampling, periodic tracking of BMP adoption can assist in determining the status of the TMDL implementation as well as the potential for water quality benefits. Periodic tracking of agricultural and forestry related management activities, under existing programs, will provide information to support evaluation of the implementation and effectiveness of the TMDL.

8. Implementation and Reasonable Assurance

This TMDL will be implemented in three steps. Stage 1 implementation will focus on management intended to achieve greater than 75% of the time. Stage 2 will focus on ongoing monitoring and tracking to determine success of program activities, degree of impairment, and the appropriateness of the existing water quality standards. Stage 3 will reevaluate the TMDL, if necessary, and proceed with further implementation of BMP and management as appropriate to fully meet water quality standards.

Stage 1 implementation will include revision of discharge permits according to the TMDL allocation through the WV NPDES permitting process. As a part of this process WV DEP will ensure that point source permits are establish to meet localized water quality and that discharge monitoring requirements as defined for each major point source. In stage 1 nonpoint source BMPs will be implemented through existing programmatic mechanisms for agriculture, forested, and urban areas throughout the watershed. The allocations are identified on a subwatershed basis as gross allotments or a single loading target for the commutative loading from each subwatershed. The specific implementation should consider the load reduction targets in allocating resources to the individual land use categories within the watershed. This analysis addressed the TMDL at the Little Kanawha watershed and its tributaries using a watershed scale approach. WVDEP is working with various offices, agencies, commissions, and departments at the local and state level as well as the federal levels to foster the implementation of best management practices to address nonpoint sources. In addition, public education efforts will be targeted to individual stakeholders to provide information regarding the use of best management practices to protect water quality.

Stage 2 implementation will focus on data collection and analysis on a watershed wide basis.

Stage 3 implementation will require more comprehensive data analysis as well as more aggressive implementation of management to achieve the identified load reduction targets for the final TMDL allocation. WV acknowledges that water quality standards that affect the Little Kanawha may change. The potential for development of site specific criteria that are sensitive to local conditions and naturally occurring metals in the soils may also be verified with further data analysis.

During Stage 3 implementation the State of WV or EPA Region 3 may choose to revise the TMDL should the following conditions occur:

1.25 If monitoring over the next 5 years shows water quality improvement that results in meeting the water quality standard
1.26 If the expression of the water quality standards for aluminum and iron are changed
1.27 Further data analysis supports development of site specific criteria
1.28 Further data analysis indicate revision of the model analysis is necessary
1.29 Significant additional growth occurs

9. Public Participation

Stakeholder meetings were held on March 22, 2000 and May 11, 2000 to review existing data and collect any additional information the stakeholders could provide in for the analyses of the TMDL. During the stakeholder meetings, the technical approach for the development of the little Kanawha TMDLS was presented and discussed.

A thirty day public notice will be provided for this TMDL. During this time period the public is invited to provide comments on the TMDL.

10. Administrative Record

An administrative record for this TMDL is compiled and stored by USEPA Region 3.

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Appendix A
Little Kanawha River TMDL: Water Quality Data Analysis

Table A-1 Designated uses of impaired streams in the Little Kanawha Watershed

Name	WV ID	WV Use Code	Use Name
Reedy Creek	WLK-25	24	Primary Contact Recreation
Reedy Creek	WLK-25	42	Bait Minnow Fishery
Spring Creek	WLK-31	24	Bait Minnow Fishery
Spring Creek	WLK-31	42	Primary Contact Recreation
Sand Fork/L. Kanawha R.	WLK-86	24	Bait Minnow Fishery
Sand Fork/L. Kanawha R.	WLK-86	42	Primary Contact Recreation
Oil Creek	WLK-94	24	Primary Contact Recreation
Oil Creek	WLK-94	42	Bait Minnow Fishery
Little Kanawha River	WO-47	22	Bait Minnow Fishery
Little Kanawha River	WO-47	24	Primary Contact Recreation
Little Kanawha River	WO-47	42	Bait Minnow Fishery
Little Kanawha River	WO-47	50	Primary Contact Recreation
Saltlick Creek	WLK-95	24	Bait Minnow Fishery
Saltlick Creek	WLK-95	42	Primary Contact Recreation

Source: WVDEP, 1999

Location: 550482
Pollutant: Aluminum, Total (ug/L as Al)
Data from: 1/29/1974 to 9/15/1993 (117 Observations)
Number of Violations: 51

Flow Range	# Obs	Flow (cfs)			Concentration (ug/L)			# Viol
Percentile	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*	*Count*
0-10	12	46.8	20.0	62.0	620.3	50.0	2393.0	3
10-20	12	131.9	72.0	177.0	696.3	120.0	1600.0	3
20-30	11	242.7	186.0	290.0	793.1	140.0	2300.0	6
30-40	12	449.3	290.0	629.0	695.8	50.0	2360.0	4
40-50	12	774.6	635.0	868.0	580.1	140.0	1500.0	4
50-60	11	1124.5	896.0	1330.0	590.4	99.0	2700.0	2
60-70	12	1773.3	1530.0	2040.0	871.8	223.0	2900.0	3
70-80	11	2347.3	2090.0	2550.0	1652.0	50.0	9800.0	3
80-90	12	3424.2	2660.0	4390.0	1559.9	440.0	3400.0	11
90-100	12	12232.5	4520.0	38100.0	9558.2	840.0	28000.0	12

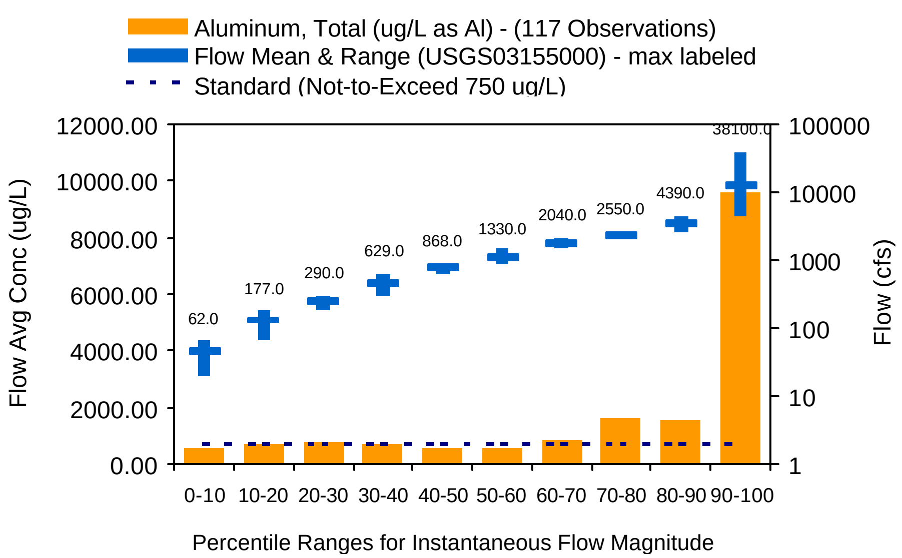

Figure A-1. Flow/Total Aluminum Relationship – Little Kanawha River at Elizabeth **(Station #550482)**

Location: 550482
Pollutant: Iron, Total (ug/L as Fe)
Data from: 2/2/1970 to 9/15/1993 (133 Observations)
Number of Violations: 42

Flow Range	# Obs	Flow (cfs)			Concentration (ug/L)			# Viol
Percentile	Count	Mean	Min	Max	Mean	Min	Max	Count
0-10	14	48.6	20.0	72.0	469.1	65.0	1280.0	1
10-20	13	134.4	78.0	177.0	477.9	70.0	1120.0	1
20-30	13	240.4	186.0	290.0	848.5	120.0	1820.0	5
30-40	13	427.8	290.0	588.0	818.6	160.0	3200.0	3
40-50	14	735.6	620.0	829.0	660.1	30.0	1640.0	4
50-60	13	1095.9	850.0	1330.0	778.8	65.0	2770.0	1
60-70	13	1734.6	1390.0	2040.0	657.4	25.0	1900.0	1
70-80	13	2406.2	2090.0	2800.0	1818.8	70.0	13000.0	6
80-90	13	3587.7	2970.0	4520.0	1666.3	370.0	4700.0	9
90-100	14	11612.9	4640.0	38100.0	7574.0	510.0	14000.0	11

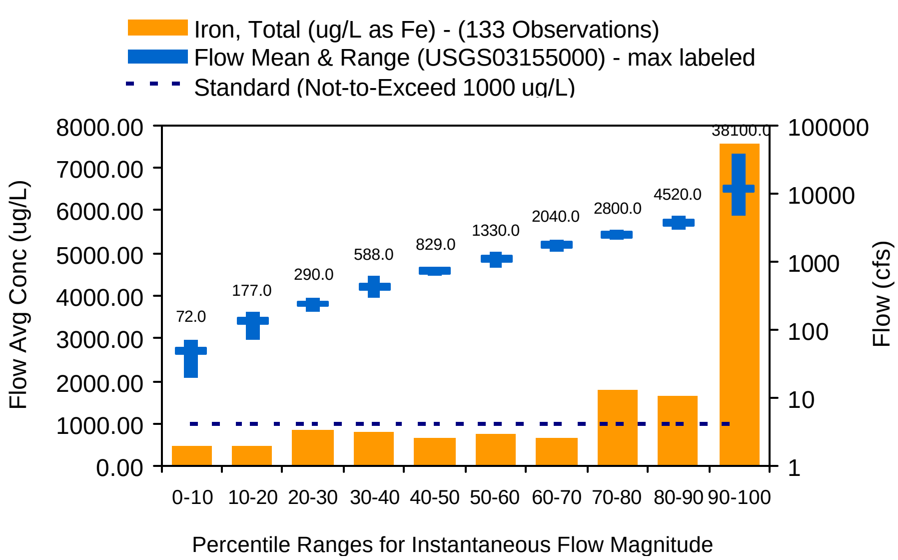

Figure A-2. Flow/Total Iron Relationship – Little Kanawha River at Elizabeth (Station #550482)

Location: Spring Creek below Sanoma
Pollutant: Aluminum, Total (mg/L as Al)
Data from: 10/20/1993 to 9/27/1994 (12 Observations)

Residue	# Obs	Residue (mg/L)			Pollutant (mg/L)		
Percentile	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
0-10	2	14.0	11.0	17.0	0.3	0.3	0.3
10-20	1	22.0	22.0	22.0	0.3	0.3	0.3
20-30	1	26.0	26.0	26.0	1.0	1.0	1.0
30-40	1	36.0	36.0	36.0	1.0	1.0	1.0
40-50	1	45.0	45.0	45.0	1.9	1.9	1.9
50-60	1	46.0	46.0	46.0	1.4	1.4	1.4
60-70	1	55.0	55.0	55.0	3.0	3.0	3.0
70-80	1	59.0	59.0	59.0	2.7	2.7	2.7
80-90	1	74.0	74.0	74.0	2.4	2.4	2.4
90-100	2	289.5	101.0	478.0	12.5	5.9	13.9

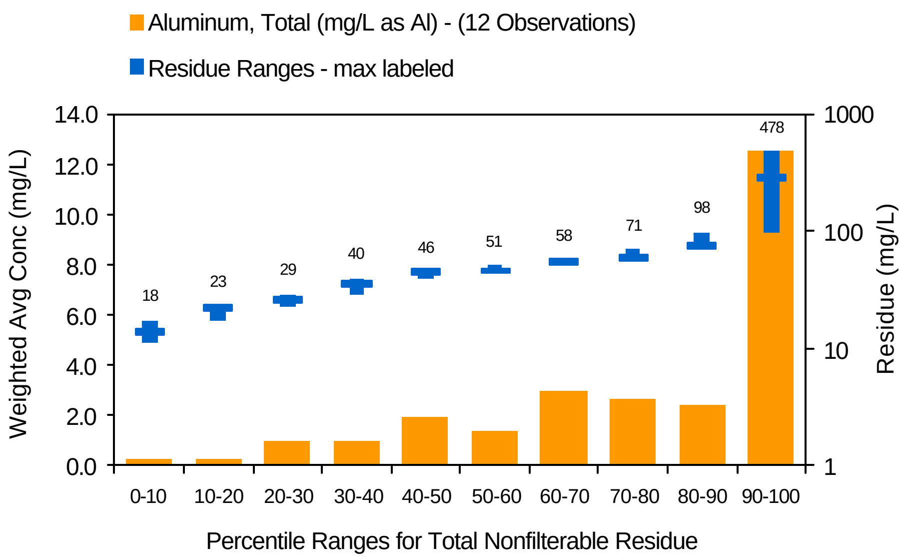

Figure A-3. Flow/Total Aluminum Relationship – Spring Creek below Sanoma (Station #551056)

Location: Spring Creek below Sanoma
Pollutant: Iron, Total (mg/L as Fe)
Data from: 10/20/1993 to 9/27/1994 (12 Observations)

Residue	# Obs	Residue (mg/L)			Pollutant (mg/L)		
Percentile	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
0-10	2	14.0	11.0	17.0	0.6	0.4	0.7
10-20	1	22.0	22.0	22.0	0.5	0.5	0.5
20-30	1	26.0	26.0	26.0	0.8	0.8	0.8
30-40	1	36.0	36.0	36.0	1.4	1.4	1.4
40-50	1	45.0	45.0	45.0	2.0	2.0	2.0
50-60	1	46.0	46.0	46.0	1.1	1.1	1.1
60-70	1	55.0	55.0	55.0	4.1	4.1	4.1
70-80	1	59.0	59.0	59.0	3.5	3.5	3.5
80-90	1	74.0	74.0	74.0	3.9	3.9	3.9
90-100	2	289.5	101.0	478.0	16.2	6.4	18.3

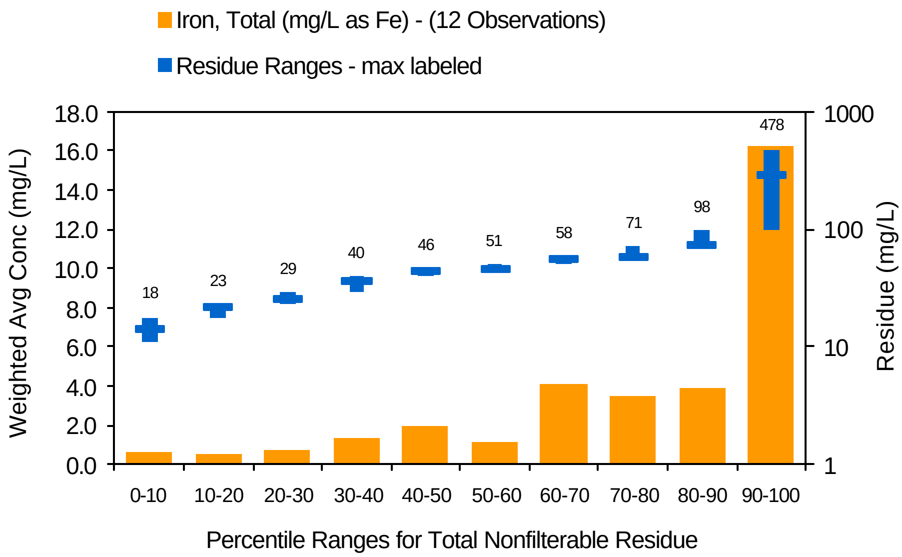

Figure A-4. Flow/Total Iron Relationship – Spring Creek below Sanoma (Station #551056)

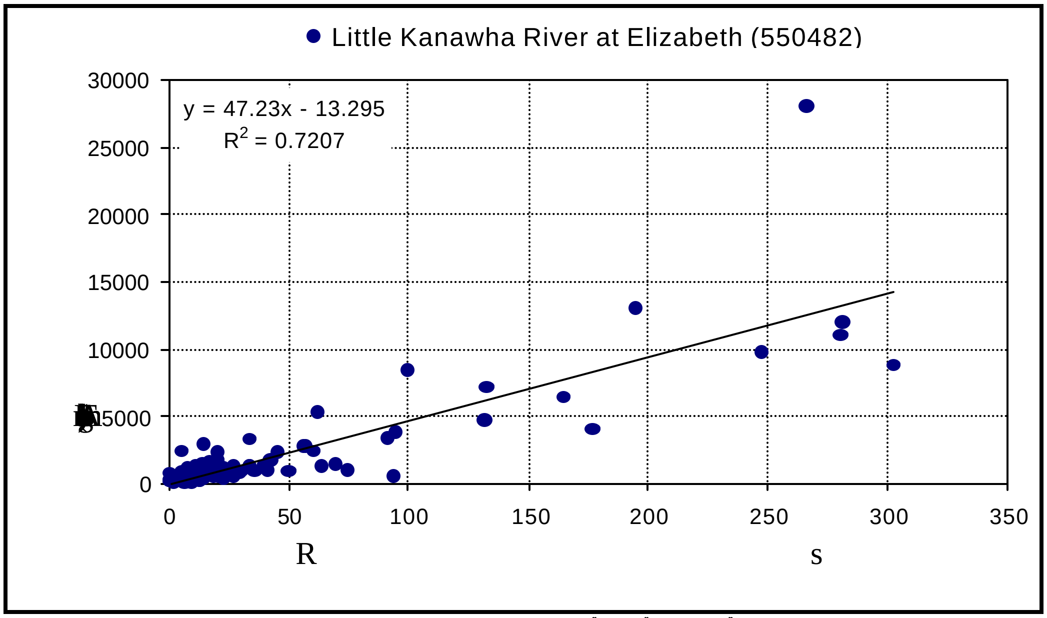

Figure A-5 . Total Aluminum-Solids Correlation (mg/L as Al) – Little Kanawha River at Elizabeth (Station #550482)

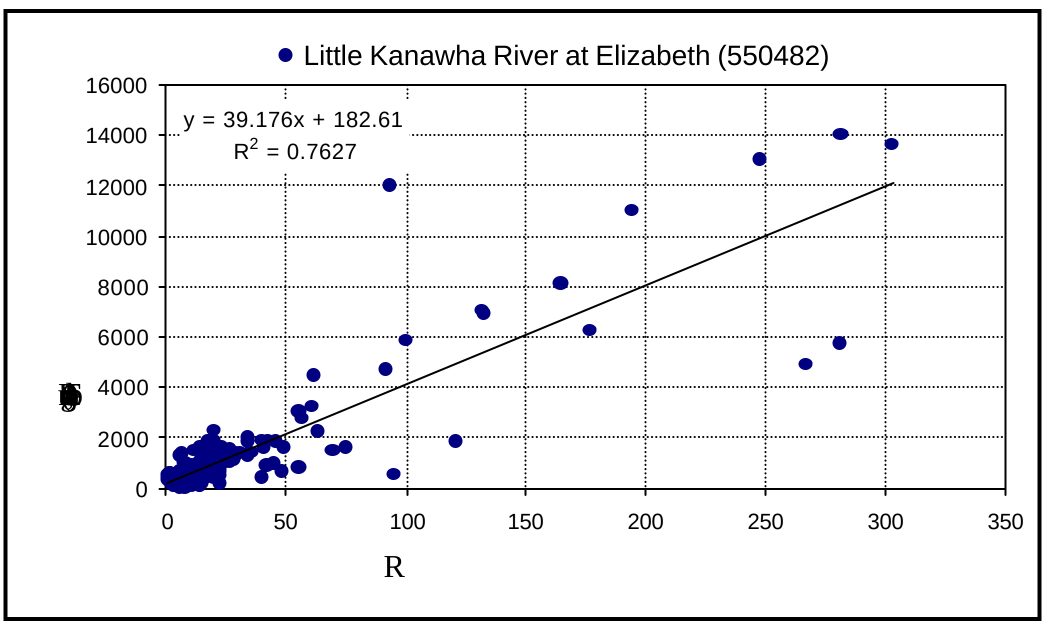

Figure A-6. Total Iron-Solids Correlation (mg/L as Fe): Little Kanawha River at Elizabeth (Station #550482)

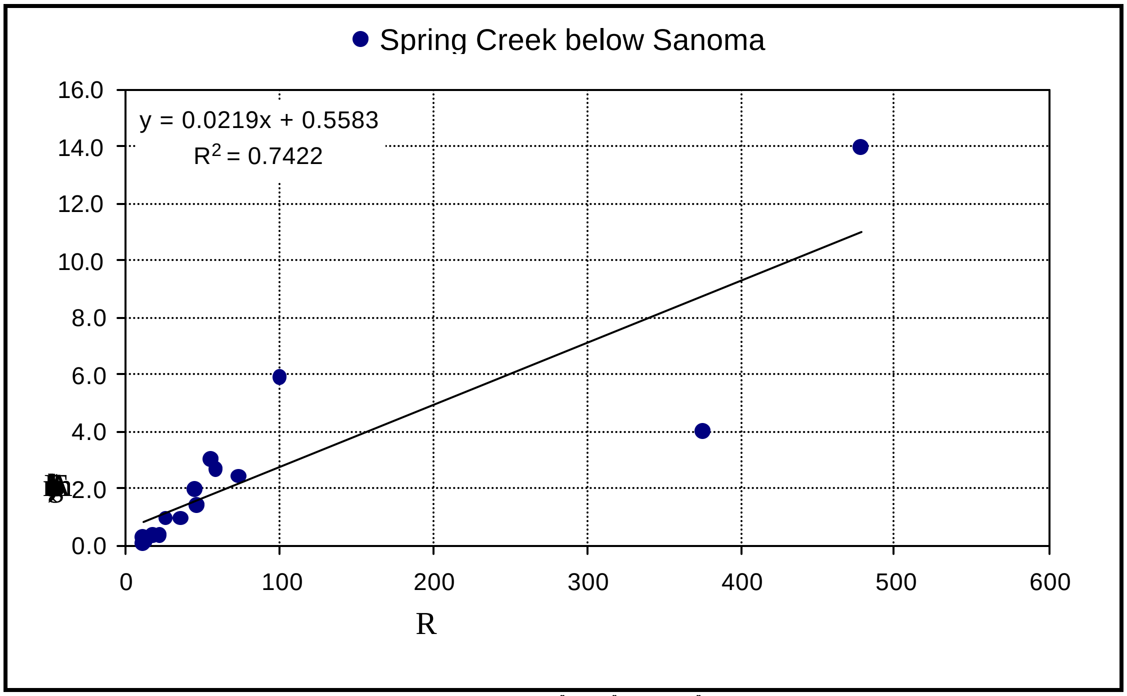

Figure A-7. Total Aluminum-Solids Correlation (mg/L as Al) – Spring Creek below Sanoma (Station #551056)

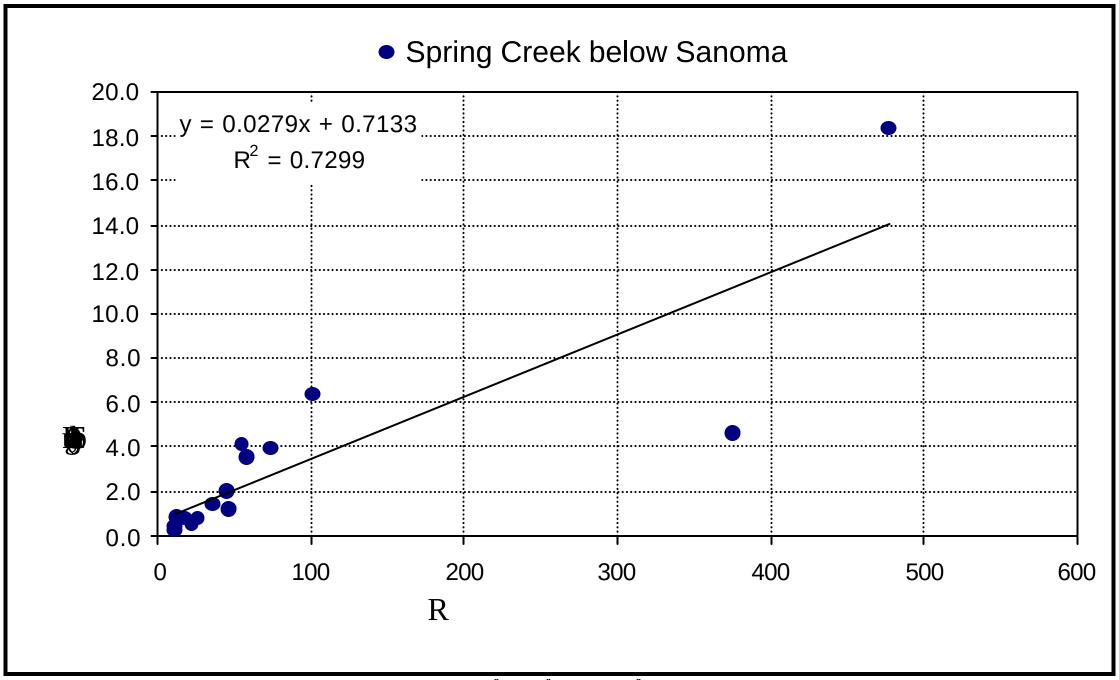

Figure A-8. Total Iron-Solids Correlation (mg/L as Fe): Spring Creek below Sanoma (Station #551056)

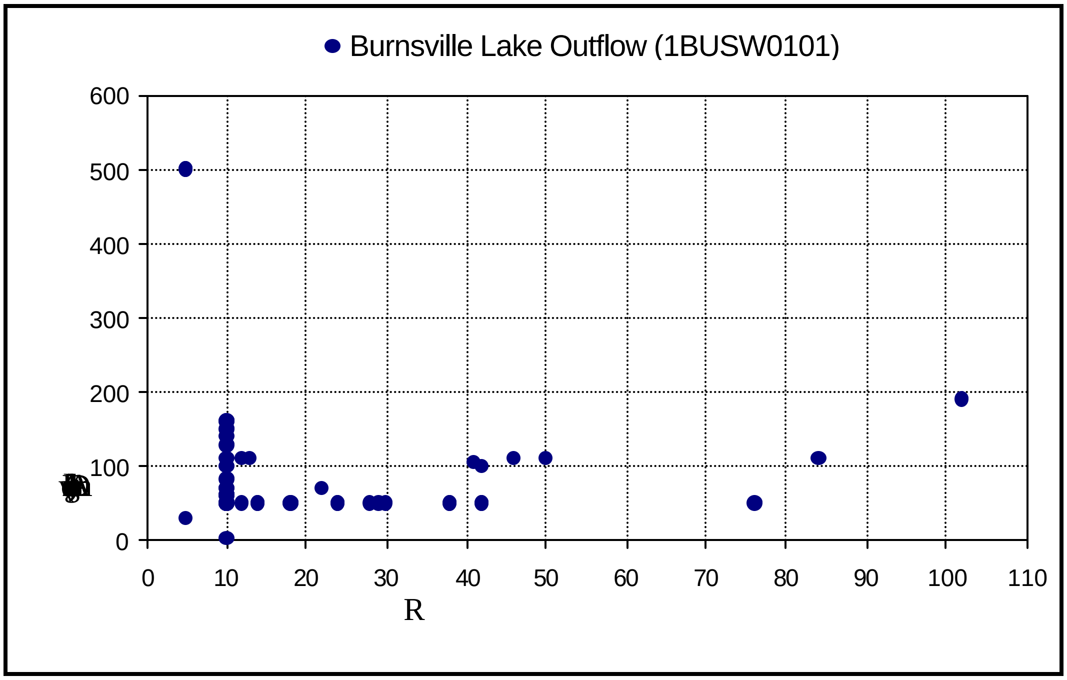

Figure A-9. Dissolved Aluminum concentrations at Burnsville Lake Outflow (Station #1BUS0101)

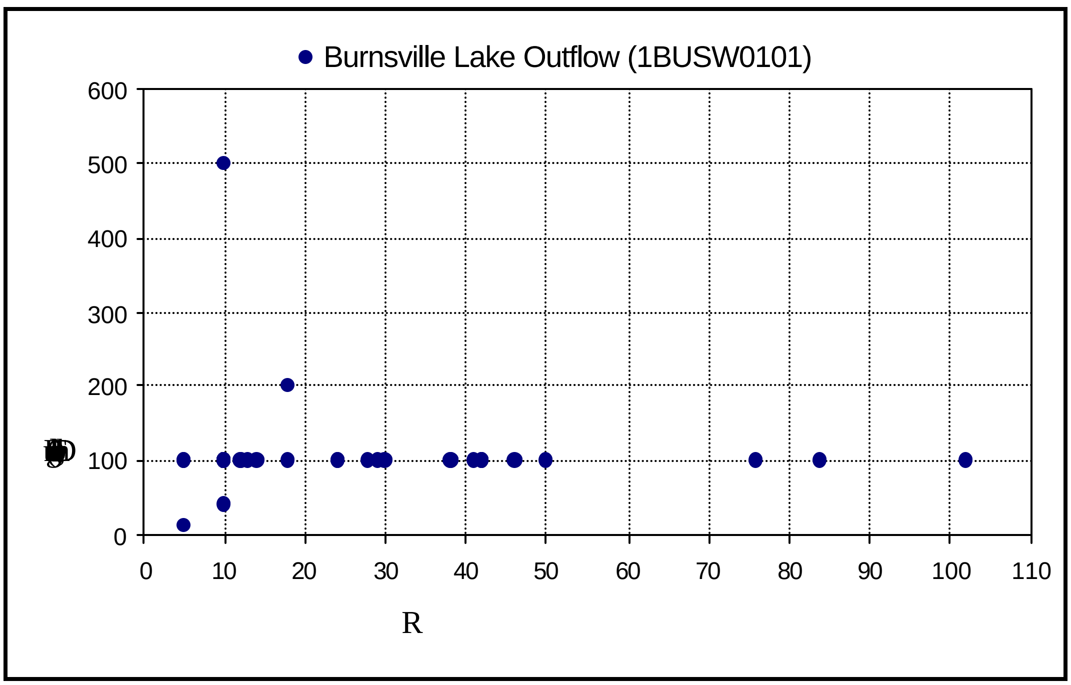

Figure A-10. Dissolved Iron concentrations at Burnsville Lake Outflow (Station #1BUS0101)

Location: 550482
Pollutant: Residue, Total Nonfilterable (mg/L)
Data from: 2/2/1970 to 9/15/1993 (139 Observations)

Flow Range	# Obs	Flow (cfs)			Concentration (mg/L)		
Percentile	*Count*	*Mean*	*Min*	*Max*	*Mean*	*Min*	*Max*
0-10	14	48.6	20.0	72.0	7.9	3.0	29.0
10-20	14	135.1	78.0	177.0	14.2	2.0	28.0
20-30	14	237.5	186.0	290.0	15.7	2.0	46.0
30-40	14	441.6	290.0	620.0	15.6	1.0	61.0
40-50	14	752.1	629.0	850.0	13.9	3.0	41.0
50-60	13	1113.6	868.0	1330.0	15.4	2.0	57.0
60-70	14	1714.3	1390.0	2040.0	14.0	3.0	46.0
70-80	14	2446.4	2090.0	2970.0	40.7	6.0	248.0
80-90	14	3675.0	3140.0	4640.0	39.7	11.0	92.0
90-100	14	11932.1	4670.0	38100.0	195.8	24.0	303.0

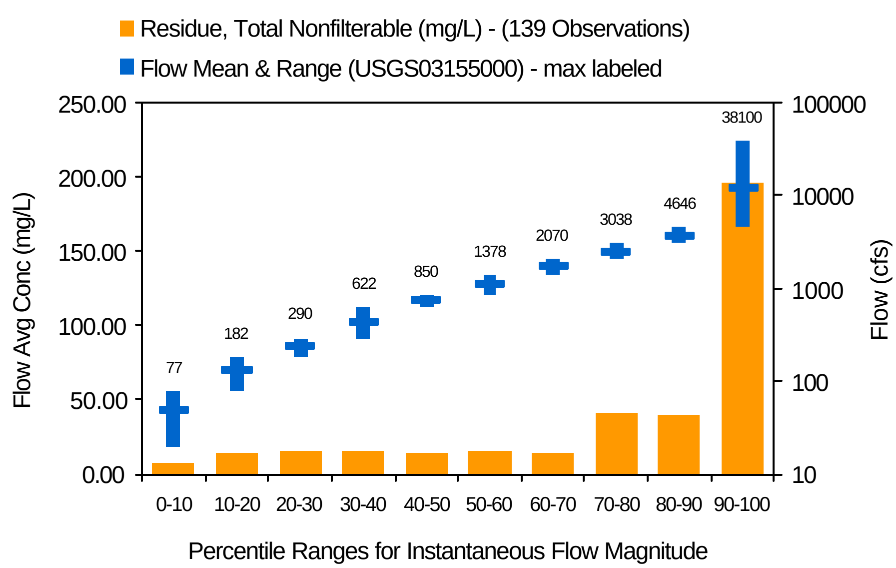

Figure A-11. Flow/Solids Relationship: Little Kanawha River at Elizabeth (Station #550482)

Appendix B

Little Kanawha Watershed TMDL: Data and Information Supporting the Technical Approach Development

Table B-1 Total Monthly Precipitation at Liverpool, WV (WV5323)

Analysis Period: 50 years (from August, 1948 to July, 1998)								
Month	**Count**	**Mean**	**Min**	**Max**	**St Dev**	**Median**	**25th**	**75th**
January	50	3.13	0.70	7.68	1.60	2.75	1.93	3.92
February	50	2.91	0.58	6.69	1.38	2.82	2.03	3.58
March	50	3.71	0.86	8.47	1.77	3.74	2.30	4.92
April	50	3.17	0.79	6.05	1.36	3.12	2.14	4.02
May	50	3.66	0.00	8.34	1.90	3.72	2.12	4.81
June	50	3.61	0.63	9.30	1.81	3.53	2.22	4.62
July	50	4.32	0.80	12.80	2.25	4.25	2.80	5.23
August	50	3.52	0.70	10.09	1.70	3.29	2.43	4.20
September	50	3.02	0.50	7.79	1.48	2.85	1.91	4.00
October	50	2.44	0.10	6.10	1.57	2.17	1.33	3.23
November	50	3.14	0.70	7.70	1.45	3.08	2.22	3.62
December	50	3.26	0.28	11.30	1.91	2.71	2.05	4.10

Table B-2 Total monthly Precipitation at Gassaway, WV (WV3361)

Analysis Period: 47 years (from April, 1951 to November, 1998)								
Month	**Count**	**Mean**	**Min**	**Max**	**St Dev**	**Median**	**25th**	**75th**
January	47	3.20	0.48	6.53	1.49	2.94	2.08	3.91
February	47	2.96	0.00	6.00	1.38	2.91	2.21	3.71
March	47	3.98	1.21	7.72	1.63	3.63	2.66	5.09
April	48	3.28	0.00	6.85	1.53	3.13	2.39	4.42
May	48	3.99	0.84	10.13	1.88	3.68	2.68	5.33
June	48	4.19	1.17	12.36	1.91	4.00	3.09	4.97
July	48	4.74	1.59	13.07	2.49	3.97	3.22	5.46
August	48	4.15	0.59	8.81	1.94	3.94	2.92	5.56
September	48	3.28	0.60	9.29	1.72	3.07	2.13	4.36
October	48	2.70	0.08	7.15	1.57	2.59	1.53	3.65
November	48	3.13	1.04	11.49	1.68	3.06	2.02	3.80
December	47	3.35	0.46	8.09	1.63	3.12	2.09	4.36

Table B-3 Mean monthly evaporation data for Liverpool (WV5323)

Month	In./Day	Month	In./Day
January	0.056340	July	0.249268
February	0.081923	August	0.216303
March	0.137618	September	0.165346
April	0.250128	October	0.118970
May	0.222134	November	0.088833
June	0.247577	December	0.062270

Table B-4 Mean monthly evaporation data for Valley Head (WV9086)

Month	In./Day	Month	In./Day
January	0.043784	July	0.199069
February	0.060934	August	0.174963
March	0.107680	September	0.125449
April	0.165846	October	0.095744
May	0.185050	November	0.067282
June	0.196551	December	0.046650

Table B-5 Little Kanawha River watershed basins input for SWMM

Basin ID	Tributary/Basin Name	Area (Ac)	Basin ID	Tributary/Basin Name	Area (Ac)
100-01	U. W. Fk. of Little Kanawha River	25,030.5	230-01	Stillwell Creek	15,522.3
100-02	U. W. Fk. of Little Kanawha River	18,250.9	240-01	Tygart Creek	32,361.5
100-03	U. W. Fk. of Little Kanawha River	29,314.2	250-01	Worthington Creek	22,167.8
10-01	U. Little Kanawha River	106,460.1	260-01	Little Kanawha River	13,413.7
10-02	U. Little Kanawha River	96.6	260-02	Little Kanawha River	3,749.9
10-03	U. Little Kanawha River	20,036.5	260-03	Little Kanawha River	4,127.5
110-01	L. W. Fk. of Little Kanawha River	27,935.5	260-04	Little Kanawha River	1,955.3
110-02	L. W. Fk. of Little Kanawha River	15,495.4	260-05	Little Kanawha River	2,116.8
110-03	L. W. Fk. of Little Kanawha River	14,666.5	260-06	Little Kanawha River	8,830.9
110-04	L. W. Fk. of Little Kanawha River	26,153.2	260-07	Little Kanawha River	7,584.5
120-01	U. Spring Creek	11,729.1	30-01	Sand Fork Creek	11,011.6
120-02	U. Spring Creek	11,284.5	30-02	Sand Fork Creek	6,743.9
120-03	U. Spring Creek	1,959.8	30-03	Sand Fork Creek	8,622.6
130-01	L. Spring Creek	10,836.0	30-04	Sand Fork Creek	15,387.5
130-02	L. Spring Creek	6,808.2	30-05	Sand Fork Creek	9,417.6
130-03	L. Spring Creek	14,526.3	40-01	Leading Creek	20,436.1
140-01	Reedy Creek	19,808.3	40-02	Leading Creek	26,760.7
140-02a	Reedy Creek	12,635.3	40-03	Leading Creek	18,927.0
140-02b	Reedy Creek	24.3	40-04	Leading Creek	1,951.7
140-03	Reedy Creek	7,012.5	40-05	Leading Creek	5,834.1
140-04	Reedy Creek	0.4	40-06	Leading Creek	13,045.4
140-05	Reedy Creek	16,882.3	40-07	Leading Creek	5,951.2
140-06	Reedy Creek	1,414.8	50-01	Little Kanawha River	21,084.8
140-07	Reedy Creek	27,235.2	50-02	Little Kanawha River	19,981.8
150-01	Little Kanawha River	3,526.4	60-01	Cedar Creek	6,247.9
150-02	Little Kanawha River	11,133.7	60-02	Cedar Creek	8,097.6
150-03	Little Kanawha River	11,821.1	60-03	Cedar Creek	17,451.0
150-04	Little Kanawha River	4,576.3	60-04	Cedar Creek	19,650.5
150-05	Little Kanawha River	24,533.5	70-01	Left Fk. of Steer Creek	14,723.9
160-01	S. Fork of Hughes River	34,270.7	70-02	Left Fk. of Steer Creek	17,237.9
160-02	S. Fk of Hughes R.	33,831.2	80-01	Steer Creek	25,142.3
160-03	S. Fork of Hughes River	14,974.6	80-02	Steer Creek	12,354.8
160-04	S. Fk. of Hughes River	26,544.1	80-03	Steer Creek	7,758.9
170-01	Indian Creek	49,513.1	80-04	Steer Creek	10,118.5
180-01	U. N. Fk. of Hughes River	60,409.4	80-05	Steer Creek	3,213.9
190-01	Bonds Creek	27,696.1	80-06	Steer Creek	26,750.3
200-01	L. N. Fk. of Hughes River	40,642.4	90-01	Little Kanawha River	11,303.7
200-02	L. N. Fk. of Hughes River	7,627.1	90-02	Little Kanawha River	10,470.2
20-01	Saltlick Creek	31,267.6	90-03	Little Kanawha River	23,299.2
210-01	Goose Creek	36,064.5	90-04	Little Kanawha River	16,946.5
210-02	Goose Creek	4,756.8	90-05	Little Kanawha River	36,456.4

220-01	Walker Creek	20,174.1		90-06	Little Kanawha River	37,101.5
N = North S = South U = Upper Fk. = Fork						

List B-6 West Virginia GAP 2000 Land Use/Land Cover descriptions

MAJOR ROADS. Includes only interstate highways from secondary data sources (USGS DLG 1:100,000). Other roads are not mapped or are classified as one of the developed/urban classes.

MAJOR POWERLINES. Powerline right-of-ways from secondary data sources (USGS DLG 1:100,000) and not satellite data classification.

Urban Buildup

POPULATED AREAS—MIXED LAND COVER. Rural or lightly developed areas with highly diverse and patchy land cover patterns, and population densities greater than 500 persons per square mile.

LIGHT INTENSITY URBAN. Rural developed areas including small towns and hamlets, roadway strip development, suburban areas, and other areas that are primarily residential in character.

MODERATE INTENSITY URBAN. Concentrated residential, commercial, industrial, and institutional areas with mixed land use town centers in which a significant portion of the land area may be undeveloped.

INTENSIVE URBAN. Dense residential, commercial, industrial, and city core areas in which the majority of the land is developed.

Agricultural Land

PLANTED GRASSLAND. Includes large grass areas such as parks, lawns, golf courses, cemeteries, and similar areas.

CONIFER PLANTATION. Single-species planted conifer stands. Can also potentially include Christmas tree farms.

ROW CROP AGRICULTURE. Includes row crops such as corn and soybeans. May also include sparsely vegetated pasture/grassland areas that are misclassified as row crops.

PASTURE/GRASSLAND. Includes pastureland, hay fields, old fields, abandoned farms, and other herbaceous land cover areas (excluding wetlands).

Shrubland/Woodland

SHRUBLAND. Natural highland scrubland or reverting agricultural fields with woody vegetation.

WOODLAND. Wooded areas, but not with mature closed canopy forest cover. Found on ridge tops, knobs, rocky areas, and other previously disturbed areas such as forest harvest areas, reclaimed coalmines, and the sites of forest fires.

Forested Land

FLOODPLAIN FOREST. Bottomland forest occurring in major river valley/riparian areas. Typical species include sycamore, red maple, silver maple, willow, and pin oak.

COVE HARDWOOD FOREST. Found in ravines, coves and along north-facing slopes. Species composition is generally very diverse with yellow poplar, red oak, pin and black cherry, paper and yellow birch, aspen, sugar and red maple, and Eastern hemlock. Local species dominance patterns are often small scale with significant species changes over relatively short distances.

DIVERSE MESOPHYTIC HARDWOOD FOREST. Predominant forest cover throughout much of the Allegheny Plateau region of West Virginia. The forests are characterized by high species diversity or species dominance patterns that are localized in very small areas. Typical species include: basswood, buckeye, beech, yellow poplar, black cherry, sugar maple, red maple, red oak, white oak, and Eastern hemlock.

HARDWOOD/CONIFER FOREST. Includes non high-elevation forest types such as oak–pine forest. Typically occur as dry forests along ridges and south-facing slopes in the less mountainous areas of the state.

OAK DOMINANT FOREST. Oak dominant forests occur throughout much of West Virginia. These areas generally occur on poorer/well-drained soils, ridges, or south and west facing slopes. Dominant species include white oak, black oak, chestnut oak, and red oak mixed with red maple, yellow poplar, beech, and sugar maple.

MOUNTAIN HARDWOOD FOREST. Northern hardwood forests that dominate the mountainous higher elevation areas in the state. Typical dominant species include sugar maple, beech, yellow birch, white ash, and basswood.

MOUNTAIN HARDWOOD/CONIFER FOREST. Found in the higher elevation areas of the state with red spruce, balsam fir, Eastern hemlock, Eastern white pine, sugar maple, beech, and yellow and paper birch.

MOUNTAIN CONIFER FOREST. Occurs in the highest elevations of the state. May include small pure stands of red spruce and red spruce with balsam fir with secondary amounts of yellow and paper birch.

Water

SURFACE WATER. Open water including lakes, large ponds, and rivers.

Wetland

FORESTED WETLAND. Palustrine forested land cover derived from National Wetlands Inventory (NWI) data. Data combined into classification to facilitate updating of NWI classifications from other data sources.

SHRUB WETLAND. Palustrine scrub / shrub wetland type derived similar to above.

HERBACEOUS WETLAND. Palustrine emergent wetland type derived and updated similar to above.

Barren Land

BARREN LAND – MINING, CONSTRUCTION. Barren, unvegetated lands resulting from construction, timbering, mining, or other activities.

Table B-6 Land use by subwatershed

Table B-7 Typical imperviousness values by land use

Land use	Description	% Imperviousness	Source
Residential	Single family lot size		
	1/8 acre	65	Corbit, 1990
	1/4 acre	35	Corbit, 1990
	1/3 acre	30	Corbit, 1990
	1/2 acre	25	Corbit, 1990
	1 acre	20	Corbit, 1990
	> 1 acre	15	Corbit, 1990
	Apartments and townhouses	75	Corbit, 1990
Schools		50	Corbit, 1990
Churches		50	Corbit, 1990
Business		85	Corbit, 1990
Commercial		85	Corbit, 1990
Industrial		70	Corbit, 1990
Parks		15	Corbit, 1990
Cemeteries		15	Corbit, 1990
Open/undeveloped		1	Corbit, 1990

Table B-8 Cropping management factors far various land uses

Land use	C values
Open water	0.0000
Perennial ice/snow	0.0000
Low intensity residential	0.0030
High intensity residential	0.0050
High intensity commercial/industrial/transportation	0.0030
Bare rock/sand/clay	0.0000
Quarries/strip mines/gravel pits	0.7500
Transitional	0.0200
Grassland/herbaceous	0.0030
Pasture/hay	0.0030
Row crops	0.1200
Small grains	0.0700
Bare soil	0.5000
Other grasses (urban/recreational; e.g. parks, lawns)	0.0030
Woody wetlands	0.0110
Emergent herbaceous wetlands	0.0030

Table B-9 Recommended C and P Factors for general land uses

Land Use	C Factor	P Factor
Cropland	0.08	0.50
Pastureland	0.01	1.0
Forestland	0.005	1.0
Urbanland	0.01	1.0

Source: (Wanielista and Yousef, 1993)

Table B-10 Selected BMP and P values

BMP type	P value
No BMP	1.00000
Silviculture: straw, crimp seed, fertilizer, transplant	0.95000
Silviculture: straw, crimp, net	0.93000
Silviculture: straw, polymer, seed, fertilizer, transplant	0.86000
Silviculture: straw, net, seed, fertilizer, transplant	0.83000
Silviculture: steep slope seeder, transplant	0.81000
Silviculture: hydro mulch, seed, fertilizer	0.71000
Silviculture: hydro mulch, seed, fertilizer, transplants	0.69000
Agriculture: reduced tillage systems	0.75000
Agriculture: diversion	0.35000
Agriculture: terrace	0.85000
Agriculture: filter strip	0.65000
Agriculture: contouring on slope 1.1 - 2.0%	0.60000
Agriculture: contouring on slope 2.1 - 7.0%	0.50000
Agriculture: contouring on slope 7.1 - 12%	0.60000
Agriculture: contouring on slope 12.1 - 18%	0.80000
Agriculture: contouring on slope 18.1 - 24%	0.90000
Agriculture: contouring on slope > 24%	1.00000
Strip cropping & terracing: alternate meadows on slope 1.1 -2.0%	0.30000
Strip cropping & terracing: alternate meadows on slope 2.1 -7.0%	0.25000
Strip cropping & terracing: alternate meadows on slope 7.1 -12%	0.30000
Strip cropping & terracing: alternate meadows on slope 12.1 -18%	0.40000
Strip cropping & terracing: alternate meadows on slope 18.1 -24%	0.45000
Strip cropping & terracing: close-grown crops on slope 1.1 -2.0%	0.45000
Strip cropping & terracing: close-grown crops on slope 2.1 -7.0%	0.40000
Strip cropping & terracing: close-grown crops on slope 7.1 -12%	0.45000
Strip cropping & terracing: close-grown crops on slope 12.1 -18%	0.60000
Strip cropping & terracing: close-grown crops on slope 18.1 -24%	0.70000
Confined animal facility: waste management system	0.60000
Confined animal facility: filter strip	0.60000
Confined animal facility: terrace	0.80000
Confined animal facility: waste storage	0.70000

Table B-11 Typical sediment yields from forest land

Sediment source	Description	Sediment load	Source
Undisturbed watershed	Fernow Experimental Forest, WV	0.05 to 0.10 ton/acre	Kochenderfer and Helvey, 1984
Undisturbed forested land	Near Parsons, WV	31 lbs/acre/yr	Kochenderfer *et al*, 1984
Forest		86 kg/ha	Horner *et al*, 1994
Woodland		85 kg/ha/yr	Wanielista and Yousef, 1993

Table B-12 Typical cropping management factor values for forestland

Land use	Value
Deciduous forest	0.0001
Evergreen forest	0.0001
Mixed forest	0.0001
Deciduous shrubland	0.0050
Evergreen shrubland	0.0050
Mixed shrubland	0.0050
Planted/cultivated (orchards, vineyards, groves)	0.0500

Table B-13 Average annual removals of growing stock on timberland by county and species group

County	Growing stock (million cubic feet)						
	Softwood				Hardwood		
	All species	Pine: planted	Pine: natural	Other	Soft	Hard	All species
Barbour	1.1	0	0	0	0.2	0.9	5.8
Berkeley	0.6	0	0.2	0	0.2	0.3	2.1
Boone	2.6	0	0	0	0.3	2.3	9.2
Braxton	1.6	0	0	0	0.2	1.4	7.1
Brooke	0.4	0	0	0	0.1	0.3	1.8
Cabell	2.9	0	0.1	0	0.6	2.2	7.3
Calhoun	2	0	0.2	0	0.2	1.6	7.6
Clay	1.3	0	0	0	0.5	0.8	5.2
Doddridge	0.2	0	0	0	0.1	0.1	0.3
Fayette	4.1	0	0	0.3	0.4	3.4	12.5
Gilmer	2.1	0	0	0	0.1	2	8.5
Grant	3.4	0	0	0.2	1.3	1.9	10.5
Greenbrier	10.4	0	0	0.1	3.4	6.9	39.7
Hampshire	0.7	0	0.2	0	0.1	0.4	2.6
Hancock	0	0	0	0	0	0	0
Hardy	3.3	0	1	0	0	2.3	7.6
Harrison	0.1	0	0	0	0	0.1	0.1
Jackson	1.7	0	0.4	0	0.9	0.5	3.2
Jefferson	1.1	0	0	0	0.2	0.8	3.5
Kanawha	6.9	0	0	0	1.1	5.8	20.7
Lewis	3.2	0	0	0	0.8	2.4	11.3
Lincoln	1.2	0	0.2	0	0.7	0.3	1
Logan	2.2	0	0	0	0.4	1.8	8.6
Marion	0.7	0	0	0	0.5	0.2	2.3
Marshall	1.7	0	0	0	0.8	0.9	7.1
Mason	2.9	0	0.3	0	0.3	2.3	10.9
Mc Dowell	1.1	0	0.2	0	0.4	0.5	3.7
Mercer	0.7	0	0	0	0.3	0.3	1.5
Mineral	2.2	0	0	0	0.8	1.4	5.1
Mingo	2.2	0	0	0	1.4	0.8	8.4
Monongalia	1.8	0	0	0	1.1	0.7	6.8
Monroe	1.4	0	0	0	0.1	1.3	4.5
Morgan	3.5	0	0	0	0.4	3.1	8.1
Nicholas	7.5	0	0	0.1	3.2	4.1	21
Ohio	0.7	0	0	0	0.4	0.4	2.1
Pendleton	2.4	0	0	0	0.3	2	9.3
Pleasant	2	0	0	0	0.8	1.2	8.2
Pocahontas	5.1	0	0	0.7	1.5	2.9	16.3
Preston	0.8	0	0	0	0.3	0.5	2.6
Putnam	2.8	0	1.6	0	0.3	0.9	7.9
Raleigh	5.6	0	0	0.1	3	2.5	18.1
Randolph	12.2	0	0	4	3.2	5	35.6
Ritchie	2.9	0	0	0	0.2	2.7	10.2
Roane	0.4	0	0	0	0.3	0.1	1.8
Summers	0.4	0	0	0	0.2	0.3	1.7
Taylor	0	0	0	0	0	0	0
Tucker	7.8	0	0.4	0.8	3.5	3.1	23.7
Tyler	2.2	0	0.1	0	0.8	1.3	9.1
Upshur	4.8	0	0	0	1.7	3.1	17.1
Wayne	1.5	0	0.1	0	0.5	0.9	3.6
Webster	7.3	0	0	0	4.3	3	29.2
Wetzel	1.4	0	0	0	0.3	1.1	5.5
Wirt	0.7	0	0	0	0	0.7	3

Wood	1.1	0	0.4	0	0.1	0.6	2.7
Wyoming	3.4	0	0	0.5	1.2	1.7	13.9
All counties	144.6	0	5.7	6.9	43.5	88.4	477.4

Table B-14 Typical sediment loading from forest operations

Sediment Source/Activity	Type	Comments	Sediment Load	Units	Source
Logging	Commercial clear cut	During logging	490	ppm, average turbidity	Hornbeck *et al*, 1964
		1st year after logging	38	ppm, average turbidity	
		2nd year after logging	1	ppm, average turbidity	
	Diameter-limit ed	During logging	897	ppm, average turbidity	
		1st year after logging	6	ppm, average turbidity	
		2nd year after logging	0	ppm, average turbidity	
Roads	Skid road	During logging	35	Tons/acre of skidroad	
		1st year after logging	0.5	Tons/acre of skidroad	
		Severely disturbed watershed	up to 0.5	Tons/acre	Kochenderfer and Helvey, 1984
		Undisturbed/carefully managed lands	0.05 to 0.10	Tons/acre	Kochenderfer and Helvey, 1984
		Erosion rate based on “phenomenal rain” event	5.0	Tons/acre	Patric and Kidd, 1982

Table B-15 Typical sediment yields from cropland and pastureland

Sediment source	Sediment Load	Source
Pasture	308 lb/ac -yr	Wanielista, 1993
Cultivated	405 lb/ac -yr	Wanielista, 1993
Grass	311 lb/ac -yr	Horner, 1994

Table B-16 Cropping management factors for agricultural land uses

Land use	C values
Grassland/herbaceous	0.0030
Pasture/hay	0.0030
Row crops	0.1200
Emergent herbaceous wetlands	0.0030
Unclassified	0.0010

Table B-17 Typical sediment yields from construction sites

Sediment source	Description	Sediment load	Source
Construction		60,000 lbs/ac-yr	Horner, 1994

Table B-18 Typical cropping factors for construction sites and mining

Land use	C values
Bare rock/sand/clay	0.0000
Quarries/strip mines/gravel pits	0.7500
Transitional	0.0200
Bare soil	0.5000

Table B-19 West Virginia roadway types and widths (WV DOT, 2000)

Roadway Type	Description	Width (ft)
Trail		5-8
Impassible	Older, unmaintained road	5-8
Primitive		5-8
Unimproved		5-8
Graded and drained	Surface has been graded	8-12
Soil surfaced		8-12

Gravel or stone		8-14
Bituminous—low type		10-14
Paved	At least two lanes	10-24
Divided highway	A four-lane system	48

Table B-20 Typical sediment loading rates from various road types

Road Type	Description	Sediment Load	Units	Source
Unpaved Surface	Bare soil	1.37	Tons/acre/inch rain	Swift, 1985
	2 inches crushed rock	1.45	Tons/acre/inch rain	
	Grass	0.73	Tons/acre/inch rain	
	6 inches crushed rock	0.1	Tons/acre/inch rain	
	8 inches large stone	0.03	Tons/acre/inch rain	
	Ungraveled	44.4	Tons/acre	Kochenderfer, 1984
	3-inch crusher-run gravel	11.4	Tons/acre	
	1-inch crusher-run gravel	5.5	Tons/acre	
	3-inch clean gravel	5.4	Tons/acre	
Paved Surface	Highway	45 - 798	mg/L	USDOT, 1996
	Highway	990	kg/ha	Wanielista, 1993
	Road	502	kg/ha	Horner, 1994
	Freeway	880	lbs/acre-y	
	Parking lot	400	lbs/acre-y	

Table B-21 Estimates of erosion parameters for various roadway conditions

C*P VALUE	ROAD DESCRIPTION
0.0000	Paved roadbed, grassed ditch line
0.0500	Road closed: stabilized, cover > 80%
0.1300	Light traffic: bare treads, cover 40-80%
0.5500	Closed: new, cover partly established, <40%
0.0500	Light traffic: fully graveled roadbed, grassed cut & fill.
0.2500	Light traffic: lightly graveled roadbed, grassed cut & fill.
0.6500	Light traffic: compacted, bare roadbed, cover 50-75%
0.8500	Heavy traffic: roadbed, <50% cover.
1.0000	New construction: disturbed soil, <20% cover
0.7500	Moderate traffic: rutted roadbed, grassed cut & fill.
Note: The combined C*P values are used for calculating road erosion only. For land erosion, C and P values are used separately for the calculation.	

Table B-22 Summary of USGS gage flow data used in the calibration of the SWMM Model

Gage Id	Gage Name and Location	Years	From	To
3151600	Little Kanawha River at Burnsville, WV	4	4/23/74	12/7/78
3152000	Little Kanawha River at Glenville, WV	78	6/4/15	9/30/93
3152200	Buck Run near Leopold, WV	8	10/6/69	9/30/77
3152500	Leading Creek near Glenville, WV	14	10/6/37	12/31/51
3153000	Steer Creek near Grantsville, WV	38	10/6/37	10/7/75
3153500	Little Kanawha River at Grantsville, WV	50	10/6/28	12/13/78
3154000	West.Fork Little Kanawha River at Rocksdale, WV	47	10/5/28	10/7/75
3154250	Tanner Run at Spencer, WV	8	4/6/69	9/30/77
3154500	Reedy Creek near Reedy, WV	27	10/6/51	9/30/78
3155000	Little Kanawha River at Palestine, WV	54	10/6/39	9/30/93
3155200	South Fork Hughes River at Macfarlan, WV	36	6/5/15	12/31/51
3155410	North Bend Run near Cairo, WV	2	6/19/85	9/30/87
3155500	Hughes River at Cisco, WV	65	10/5/28	9/30/93
3151500	Little Kanawha River Near Burnsville, WV	37	10/6/37	10/1/74
3155520	Robinson Run near Petroleum, WV	2	6/19/85	9/30/87
3151520	Little Kanawha River below Burnsville Dam, WV	17	7/19/76	9/30/93

Table B-23 Water quality stations located in study area

ID	Location	Type
550482	Little Kanawha River at Elizabeth, W. Va.	Ambient/Stream
551052	Sand Fork in Layopolis, W. Va.	Ambient/Stream
551053	Saltlick Creek in Burnsville, W. Va.	Ambient/Stream
551055	Reedy Creek east of Palestine, WV	Ambient/Stream
551056	Spring Creek below Sanoma, W. Va.	Ambient/Stream
Dept of Ag 1	Burnsville at Town Hall	Instream Monitoring
Dept of Ag 2	Oil Creek at Town Hall Rd.	Instream Monitoring
Dept of Ag 3	Salt Lick Ck at Chruch Street	Instream Monitoring
Dept of Ag 4	Below Forks at Car Wash	Instream Monitoring
Dept of Ag 5	Sand Fork at Lick Run Rd.	Instream Monitoring
Dept of Ag 6	Sand Fork at Sand Fork	Instream Monitoring
Dept of Ag 7	Below Forks at State Police Office	Instream Monitoring
Dept of Ag 8	Rt 5 at Duck Spruce Rd Bridge	Instream Monitoring
Dept of Ag 9	Cedar Ck Rd.	Instream Monitoring
Dept of Ag 10	At Public Access Stream	Instream Monitoring
Dept of Ag 11	Above Forks	Instream Monitoring
Dept of Ag 12	Spring Creek at CR-36	Instream Monitoring
Dept of Ag 13	Below Forks at Dancing Meadow Farm Rd.	Instream Monitoring
Dept of Ag 14	Above Fork - Hatchery Cr. 14/8	Instream Monitoring
Dept of Ag 15	Reedy Creek NF Reedy Cr Bridge Rt 14	Instream Monitoring
Dept of Ag 16	Below Fork on Rt. 14 at Mile Mark 12	Instream Monitoring
Dept of Ag 17	7 Elizabeth Park Rt 14	Instream Monitoring
Dept of Ag 18	At CR 4 7/12	Instream Monitoring

Dept of Ag 19	At Parkersburg	Instream Monitoring

Table B-24 Background instream parameter concentrations

Parameter	Gage Id	Location	Median Concentration (mg/L)	Background Concentration (mg/L)
TSS	550482	Little Kanawha River at Elizabeth	14.0	8.5
Al(tot)	550482	Little Kanawha River at Elizabeth	0.560	0.324
Fe(tot)	550482	Little Kanawha River at Elizabeth	0.670	0.349
Al(dis)	1BUSW0101	Burnsville Dam Outflow	0.050	0.050
Fe(dis)	1BUSW0101	Burnsville Dam Outflow	0.100	0.100

Table B-25 Inflow locations for the major tributaries of the Little Kanawha River

Inlet Number	Basin Name	No. of Subcatchments	No. of Nodes
5	Upper Little Kanawha River, Salt Lick Creek	2	0
10	Upper Little Kanawha	2	0
15	Sand Fork Creek, Little Kanawha River	6	2
20	Leading Creek, Little Kanawha River	8	3
25	Cedar Creek, Little Kanawha River	5	2
30	Little Kanawha River	2	0
35	Left Fork Steer Creek, Little Kanawha River	8	4
40	Little Kanawha River	1	0
45	Little Kanawha River, Upper N. Fk.. L.KR, Upper W. Fk LKR	8	3
50	Upper Spring Creek, Left Spring Creek, Little Kanawha River	7	3
55	Reedy Creek, Little Kanawha River	9	4
60	Little Kanawha River	2	0
65	Hughes River, Little Kanawha R., Goose Crk, Indian Ck, Bonds Ck	12	6
70	Little Kanawha River	2	0
75	Little Kanawha River, Walker Creek	2	0
80	Stillwell Creek, Little Kanawha River	2	0
85	Tygart Creek, Little Kanawha River	2	0

90	Worthington Creek, Little Kanawha River	2	0
95	Little Kanawha River	1	0

Table B-26 Summary of data sources for estimating SWMM transport parameters

Parameter	Sources
Stream channel length	USGS quad sheets, RF3 stream coverage
Stream channel slope	USGS quad sheets, USGS 7.5 30m DEM
Stream morphology	Regional relationships
Manning's Coefficients	SWMM manual, Hydrology Text books

Appendix C

Little Kanawha Watershed TMDL: Summary of Allocation Results

Table C-1. Selected Stage 1 Allocation - Scenario 4 [a]

	% Reduction	TSS	Al	Fe
Subwatershed		ton/yr		
153	22.0%	1345	65	48
540[b]	46.5%	1392	110	121
555[b]	37.7%	2396	189	210
3	30.0%	918	42	40
8	30.0%	464	22	16
5	30.0%	2110	100	59
10	14.0%	1725	80	70
15	22.0%	1856	90	66
20	22.0%	3352	156	135
25	30.0%	1508	68	61
30	30.0%	856	30	49
35	30.0%	3101	145	118
40	30.0%	798	28	44
45	30.0%	4281	143	238
50[c]	45.1%	1518	120	748
55[c]	35.9%	2760	218	1126
60	22.0%	602	45	51
65[d]	13.0%	9598	679	783
70	5.0%	732	61	67
75	5.0%	939	85	89
80	5.0%	759	64	70
85	5.0%	1628	119	136
90	5.0%	1591	105	125
95	13.0%	426	23	31

[a] Limiting pollutant is aluminum. TSS and associated iron reductions are based on meeting aluminum target
[b] Load reduction based on meeting tributary target
[c] Load reduction includes reduction for listed tributary
[d] Presumes construction of Hughes Reservoir, percent reduction based on additional management in watershed

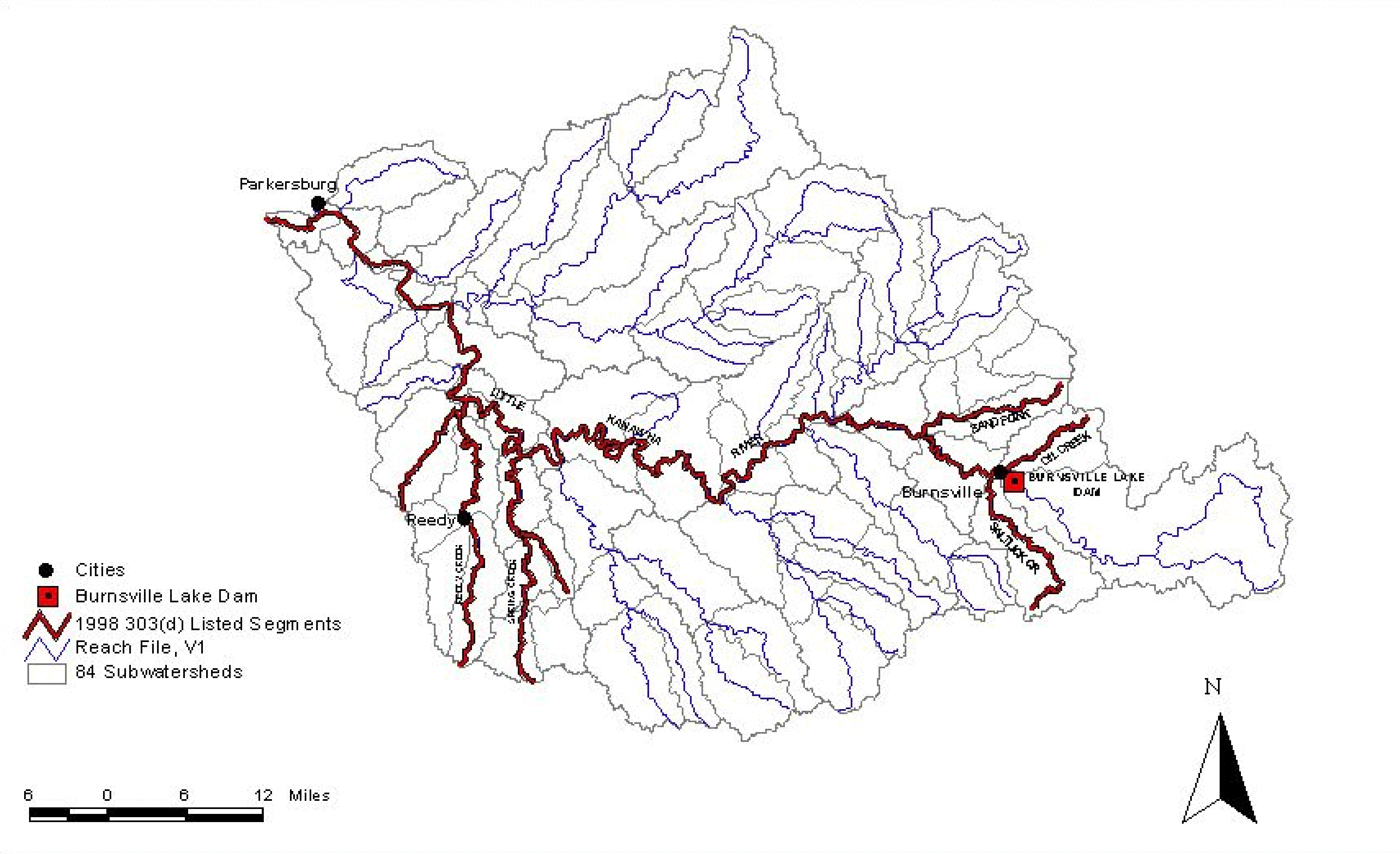

Figure 6.2
Little Kanawha Watershed Segmentation
(for Loading Evaluation)

Data Sources: WV 303(d) List, WVDEP

Map Projection: Albers Equal Area, GRS 80

Table C-2 Existing loading by subwatershed and land use category for TSS

TSS	FOR_1	FOR_2	FOR_3	AG	URBAN	RD	BRN	WET	TOTAL EXISTING
SUB	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr
153	949	299	206	234	9	14	14	0	1,725
540	1192	563	51	670	86	13	28	0	2,604
555	1781	689	55	1248	10	20	42	0	3,845
3	521	205	177	340	31	11	26	0	1,311
8	443	65	41	100	2	5	6	0	662
5	1727	528	307	351	48	37	15	0	3,015
10	471	308	13	51	919	141	103	0	2,006
15	1321	414	277	313	16	18	20	0	2,379
20	1973	727	510	918	61	22	87	0	4,298
25	1059	385	333	304	17	12	44	0	2,154
30	665	216	130	190	7	10	6	0	1,223
35	2428	796	422	720	11	27	25	0	4,430
40	664	259	28	143	18	8	21	0	1,141
45	3615	1306	265	828	8	40	54	0	6,116
50	1278	595	54	706	87	14	32	0	2,766
55	2004	775	60	1387	10	22	50	0	4,309
60	310	120	21	277	20	4	20	0	771
65	7290	2328	637	2873	104	82	289	0	13,604
70	378	128	21	251	1	4	21	0	804
75	553	177	19	266	8	6	51	0	1,080
80	373	134	9	270	24	4	34	0	849
85	610	258	15	758	65	19	93	0	1,818
90	473	240	22	585	373	15	77	0	1,785
95	63	63	2	163	212	1	20	0	523

Table C-3 Existing loading by subwatershed and land use category for Aluminum

AL	FOR_1	FOR_2	FOR_3	AG	URBAN	RD	BRN	WET	TOTAL EXISTING
SUB	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr
153	66	9	4	4	0	0	0	0	83
540	148	30	2	22	3	0	0	0	206
555	222	37	2	41	0	0	0	0	303
3	41	7	4	7	1	0	0	0	59
8	27	2	1	2	0	0	0	0	32
5	114	15	6	6	1	1	0	0	142
10	48	14	0	1	25	4	0	0	92
15	91	12	5	6	0	0	0	0	115
20	146	23	11	18	1	0	0	0	201
25	73	12	6	6	0	0	0	0	98
30	33	5	2	3	0	0	0	0	42
35	163	23	8	13	0	0	0	0	208
40	32	5	0	2	0	0	0	0	40
45	164	26	3	10	0	0	0	0	204
50	158	32	2	23	3	0	0	0	218
55	249	42	2	46	0	0	0	0	341
60	40	7	1	9	1	0	0	0	58
65	712	98	17	75	3	1	1	1	908
70	48	7	1	8	0	0	0	0	64
75	69	10	1	9	0	0	0	0	89
80	49	8	0	9	1	0	0	0	67
85	80	15	1	27	2	1	0	0	126
90	62	14	1	20	13	0	0	0	111
95	9	4	0	6	8	0	0	0	27

Table C-4 Existing loading by subwatershed and land use category for Iron

FE	FOR_1	FOR_2	FOR_3	AG	URBAN	RD	BRN	WET	TOTAL EXISTING
SUB	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr
153	43	7	5	6	0	0	0	0	62
540	140	34	3	42	5	1	0	0	227
555	210	42	3	78	1	1	1	1	336
3	32	7	6	11	1	0	0	0	57
8	18	1	1	2	0	0	0	0	23
5	61	10	6	7	1	1	0	0	84
10	31	10	0	2	32	5	1	0	81
15	59	10	7	7	0	0	0	0	84
20	108	21	15	27	2	1	1	0	173
25	57	11	10	9	0	0	0	0	87
30	48	8	5	7	0	0	0	0	70
35	117	20	11	18	0	1	0	0	168
40	46	9	1	5	1	0	0	0	63
45	250	47	10	30	0	1	0	1	340
50	849	205	19	247	31	5	3	4	1,363
55	1097	220	18	401	3	6	4	8	1,757
60	37	7	1	17	1	0	0	1	65
65	742	123	35	154	6	4	4	2	1,070
70	45	8	1	16	0	0	0	0	72
75	65	11	1	17	1	0	1	1	96
80	45	8	1	17	2	0	1	1	75
85	73	16	1	48	4	1	1	1	146
90	56	15	1	37	23	1	1	1	135
95	8	4	0	10	14	0	0	0	36

Table C-5 Percent load reduction for associated with each subwatershed and land use category for TSS based on aluminum as the limiting agent

TSS	FOR_1	FOR_2	FOR_3	AG	URBAN	RD	BRN	WET	TOTAL REDUCTION
SUB	percent	percent	percent	percent	percent	percent	percent	percent	percent
153	8.3%	6.9%	9.0%	5.4%	0.2%	0.5%	0.5%	0.0%	30.7%
540	20.5%	9.7%	1.5%	15.4%	1.0%	0.3%	0.6%	0.0%	49.1%
555	14.8%	8.1%	1.1%	19.5%	0.1%	0.3%	0.7%	0.0%	44.5%
3	8.7%	6.3%	10.1%	10.4%	0.7%	0.5%	1.2%	0.0%	37.9%
8	18.0%	3.9%	4.7%	7.2%	0.1%	0.4%	0.5%	0.0%	34.9%
5	14.6%	7.0%	7.6%	5.2%	0.5%	0.7%	0.3%	0.0%	36.0%
10	1.2%	4.2%	0.5%	0.6%	6.4%	4.2%	2.0%	0.0%	19.2%
15	8.3%	7.1%	8.7%	5.3%	0.2%	0.5%	0.5%	0.0%	30.6%
20	6.0%	6.8%	8.9%	8.3%	0.4%	0.3%	1.2%	0.0%	31.9%
25	11.3%	7.9%	11.6%	5.6%	0.2%	0.3%	1.2%	0.0%	38.2%
30	13.6%	7.4%	8.0%	6.2%	0.2%	0.5%	0.3%	0.0%	36.1%
35	13.7%	7.4%	7.1%	7.3%	0.1%	0.4%	0.3%	0.0%	36.3%
40	15.1%	9.8%	1.8%	6.0%	0.6%	0.4%	1.1%	0.0%	34.9%
45	15.4%	9.2%	3.3%	6.1%	0.0%	0.4%	0.5%	0.0%	34.9%
50	19.9%	9.7%	1.5%	15.1%	0.9%	0.3%	0.7%	0.0%	48.0%
55	13.9%	8.1%	1.0%	18.7%	0.1%	0.3%	0.7%	0.0%	42.8%
60	5.6%	6.7%	2.0%	12.6%	0.8%	0.3%	1.6%	0.0%	29.5%
65	5.4%	2.6%	3.5%	4.6%	0.2%	0.4%	1.3%	0.0%	17.9%
70	1.4%	0.6%	1.9%	3.1%	0.0%	0.3%	1.6%	0.0%	9.0%
75	0.5%	0.5%	1.3%	7.4%	0.2%	0.3%	2.8%	0.0%	13.1%
80	0.9%	0.6%	0.8%	4.8%	0.7%	0.3%	2.4%	0.0%	10.5%
85	0.7%	0.4%	0.6%	4.2%	0.9%	0.6%	3.1%	0.0%	10.5%
90	0.0%	0.0%	0.9%	1.6%	5.2%	0.5%	2.6%	0.0%	10.9%
95	0.2%	0.4%	0.3%	5.3%	10.1%	0.1%	2.2%	0.0%	18.7%

Table C-6 Percent load reduction for associated with each subwatershed and land use category for Aluminum based on aluminum as the limiting agent

AL	FOR_1	FOR_2	FOR_3	AG	URBAN	RD	BRN	WET	TOTAL REDUCTION
SUB	percent	percent	percent	percent	percent	percent	percent	percent	percent
153	11.8%	4.3%	3.6%	2.1%	0.1%	0.1%	0.0%	0.0%	22.0%
540	32.1%	6.6%	0.6%	6.5%	0.4%	0.1%	0.0%	0.0%	46.5%
555	23.4%	5.5%	0.5%	8.2%	0.0%	0.1%	0.0%	0.0%	37.7%
3	15.0%	4.7%	4.8%	4.8%	0.3%	0.2%	0.1%	0.0%	30.0%
8	23.3%	2.2%	1.7%	2.5%	0.0%	0.1%	0.0%	0.0%	29.9%
5	20.3%	4.2%	3.0%	2.0%	0.2%	0.2%	0.0%	0.0%	30.0%
10	2.6%	4.0%	0.3%	0.4%	3.8%	2.5%	0.2%	0.0%	13.7%
15	11.8%	4.4%	3.5%	2.0%	0.1%	0.1%	0.0%	0.0%	22.0%
20	9.5%	4.7%	3.9%	3.6%	0.2%	0.1%	0.1%	0.0%	22.0%
25	17.3%	5.2%	4.9%	2.3%	0.1%	0.1%	0.1%	0.0%	30.0%
30	19.5%	4.6%	3.2%	2.4%	0.1%	0.1%	0.0%	0.0%	30.0%
35	19.6%	4.6%	2.9%	2.8%	0.0%	0.1%	0.0%	0.0%	30.0%
40	20.7%	5.8%	0.7%	2.2%	0.2%	0.1%	0.1%	0.0%	29.9%
45	20.9%	5.4%	1.2%	2.2%	0.0%	0.1%	0.0%	0.0%	29.9%
50	31.1%	6.6%	0.6%	6.3%	0.4%	0.1%	0.0%	0.0%	45.1%
55	21.9%	5.5%	0.5%	7.8%	0.0%	0.1%	0.0%	0.0%	35.8%
60	9.7%	4.9%	1.0%	5.7%	0.4%	0.1%	0.1%	0.0%	21.8%
65	7.8%	1.6%	1.4%	1.8%	0.1%	0.1%	0.1%	0.0%	12.9%
70	2.2%	0.4%	0.9%	1.3%	0.0%	0.1%	0.1%	0.0%	5.0%
75	0.8%	0.3%	0.6%	3.0%	0.1%	0.1%	0.2%	0.0%	5.0%
80	1.4%	0.5%	0.4%	2.1%	0.3%	0.1%	0.1%	0.0%	4.9%
85	1.3%	0.4%	0.3%	2.1%	0.5%	0.3%	0.2%	0.0%	5.0%
90	0.0%	0.0%	0.5%	0.9%	3.0%	0.3%	0.2%	0.0%	4.9%
95	0.7%	0.4%	0.2%	3.8%	7.4%	0.0%	0.2%	0.0%	12.8%

Table C-7 Percent load reduction for associated with each subwatershed and land use category for Iron based on aluminum as the limiting agent

FE	FOR_1	FOR_2	FOR_3	AG	URBAN	RD	BRN	WET	TOTAL REDUCTION
SUB	percent	percent	percent	percent	percent	percent	percent	percent	percent
153	10.5%	4.6%	6.1%	3.6%	0.1%	0.3%	0.1%	0.0%	25.4%
540	27.7%	6.8%	1.1%	11.0%	0.7%	0.2%	0.1%	0.0%	47.6%
555	20.0%	5.6%	0.8%	13.9%	0.1%	0.2%	0.1%	0.0%	40.6%
3	12.4%	4.6%	7.6%	7.7%	0.5%	0.4%	0.2%	0.0%	33.5%
8	21.4%	2.4%	3.0%	4.5%	0.1%	0.3%	0.1%	0.0%	31.8%
5	18.3%	4.6%	5.2%	3.5%	0.3%	0.5%	0.1%	0.0%	32.3%
10	1.9%	3.5%	0.4%	0.5%	5.5%	3.6%	0.4%	0.0%	15.9%
15	10.6%	4.7%	5.9%	3.5%	0.1%	0.3%	0.1%	0.0%	25.3%
20	8.1%	4.8%	6.5%	6.0%	0.3%	0.2%	0.2%	0.0%	26.0%
25	15.0%	5.4%	8.2%	3.9%	0.2%	0.2%	0.2%	0.0%	33.2%
30	17.4%	4.9%	5.4%	4.2%	0.1%	0.3%	0.1%	0.0%	32.4%
35	17.4%	4.9%	4.9%	4.9%	0.1%	0.2%	0.1%	0.0%	32.4%
40	18.9%	6.3%	1.2%	4.0%	0.4%	0.3%	0.2%	0.0%	31.3%
45	19.1%	5.9%	2.2%	4.0%	0.0%	0.3%	0.1%	0.0%	31.6%
50	26.8%	6.8%	1.1%	10.7%	0.7%	0.2%	0.1%	0.0%	46.3%
55	18.7%	5.6%	0.8%	13.2%	0.1%	0.2%	0.1%	0.0%	38.7%
60	7.9%	4.8%	1.5%	9.3%	0.6%	0.2%	0.3%	0.0%	24.6%
65	6.9%	1.7%	2.4%	3.2%	0.1%	0.2%	0.2%	0.0%	14.9%
70	1.9%	0.4%	1.4%	2.2%	0.0%	0.2%	0.3%	0.0%	6.5%
75	0.7%	0.3%	0.9%	5.2%	0.1%	0.2%	0.5%	0.0%	8.0%
80	1.2%	0.5%	0.6%	3.5%	0.5%	0.2%	0.4%	0.0%	6.9%
85	1.0%	0.3%	0.5%	3.3%	0.7%	0.5%	0.6%	0.0%	6.9%
90	0.0%	0.0%	0.8%	1.4%	4.3%	0.4%	0.5%	0.0%	7.4%
95	0.4%	0.3%	0.3%	4.9%	9.3%	0.1%	0.5%	0.0%	15.8%

Table C-8 Loading under allocated conditions by subwatershed and land use category for TSS

TSS	FOR_1	FOR_2	FOR_3	AG	URBAN	RD	BRN	WET	TOTAL ALLOCATED
SUB	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr
153	806	179	52	140	6	6	5	0	1195
540	659	310	13	268	60	5	11	0	1327
555	1211	379	14	499	7	8	17	0	2135
3	406	123	44	204	21	5	10	0	814
8	324	39	10	52	2	2	2	0	431
5	1288	317	77	193	34	15	6	0	1930
10	447	223	3	38	790	57	62	0	1621
15	1123	244	69	188	11	7	8	0	1651
20	1716	436	127	560	43	9	35	0	2926
25	816	216	83	182	12	5	18	0	1331
30	499	125	32	114	5	4	3	0	781
35	1821	470	106	396	8	11	10	0	2821
40	491	148	7	74	11	3	9	0	742
45	2675	745	66	456	5	16	21	0	3984
50	729	327	13	289	61	6	13	0	1438
55	1405	426	15	582	7	9	20	0	2465
60	267	68	5	180	14	1	8	0	544
65	5640	1701	137	1926	67	28	100	0	9598
70	367	123	5	226	1	2	8	0	732
75	547	172	5	186	6	2	20	0	939
80	365	129	2	230	18	2	14	0	759
85	597	250	4	683	49	8	37	0	1628
90	473	240	6	555	280	6	31	0	1591
95	62	61	1	135	159	0	8	0	426

Table C-9 Loading under allocated conditions by subwatershed and land use category for Aluminum

AL	FOR_1	FOR_2	FOR_3	AG	URBAN	RD	BRN	WET	TOTAL ALLOCATED
SUB	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr
153	56	5	1	3	0	0	0	0	65
540	82	17	0	9	2	0	0	0	110
555	151	20	0	17	0	0	0	0	189
3	32	4	1	4	0	0	0	0	42
8	20	1	0	1	0	0	0	0	22
5	85	9	1	3	1	0	0	0	100
10	45	10	0	1	22	2	0	0	80
15	77	7	1	4	0	0	0	0	90
20	127	14	3	11	1	0	0	0	156
25	56	6	2	3	0	0	0	0	68
30	25	3	0	2	0	0	0	0	30
35	122	14	2	7	0	0	0	0	145
40	23	3	0	1	0	0	0	0	28
45	122	15	1	6	0	0	0	0	143
50	90	17	0	10	2	0	0	0	120
55	175	23	1	19	0	0	0	0	219
60	34	4	0	6	0	0	0	0	45
65	551	72	4	50	2	0	0	0	679
70	47	7	0	8	0	0	0	0	61
75	69	9	0	6	0	0	0	0	85
80	48	7	0	8	1	0	0	0	64
85	79	14	0	24	2	0	0	0	119
90	62	14	0	19	10	0	0	0	105
95	9	4	0	5	6	0	0	0	23

Table C-10. Loading under allocated conditions by subwatershed and land use category for FE

FE	FOR_1	FOR_2	FOR_3	AG	URBAN	RD	BRN	WET	TOTAL ALLOCATED
SUB	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr	ton/yr
153	37	4	1	3	0	0	0	0	46
540	78	19	1	17	4	0	0	0	119
555	143	23	1	31	0	0	0	1	200
3	25	4	1	7	1	0	0	0	38
8	13	1	0	1	0	0	0	0	15
5	45	6	1	4	1	0	0	0	57
10	29	8	0	1	27	2	1	0	68
15	50	6	2	4	0	0	0	0	63
20	94	12	4	16	1	0	0	0	128
25	44	6	2	5	0	0	0	0	58
30	36	5	1	4	0	0	0	0	47
35	88	12	3	10	0	0	0	0	114
40	34	5	0	3	0	0	0	0	43
45	185	27	2	17	0	1	0	1	233
50	484	113	5	101	21	2	1	4	731
55	769	121	4	168	2	3	1	8	1077
60	32	4	0	11	1	0	0	1	49
65	574	90	7	104	4	2	1	2	783
70	44	8	0	14	0	0	0	0	67
75	65	11	0	12	0	0	0	1	89
80	44	8	0	15	1	0	0	1	70
85	72	16	0	43	3	0	1	1	136
90	56	15	0	35	18	0	0	1	125
95	7	4	0	9	10	0	0	0	31