Elklick Run and Holcomb Run

Trout Water Iron Modeling Project

FINAL

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1.0 INTRODUCTION

This report summarizes the development and testing of a surface water model for two trout streams:Elklick Run and Holcomb Run. Tetra Tech developed this model at the request of the West Virginia Department of Environmental Protection (WVDEP) to assist in its evaluation of potential future changes to the trout water total iron criteria.

TMDL modeling in the Gauley and New River basins has indicated that West Virginia's chronic aquatic life protection water quality criterion for total iron in trout waters, which is 0.5 mg/L, 4-day average, with a once per three years average exceedance frequency, cannot be practically attained in certain streams. Modeled scenarios that incorporated the following allocation provisions did not completely attain the criterion:

- All continuous flow sources established at the value of the criterion
- All streambank stability ratings equal to the best measured condition in the watershed
- All land disturbing nonpoint sources reduced to the forest background loading
- No allowance for new activity under the Construction Stormwater General Permit

As such, criterion attainment would require pollutant reductions from existing sources that are well beyond practical levels, coupled with reductions of undisturbed upland and streambank background loadings, and no future growth allowances.

The TMDL modeling indicated that the relatively high iron content of the soils in the Gauley and New River watersheds is a significant factor in criterion non-attainment. Closely related to clay deposits, iron in soils can become mobilized through precipitation-induced runoff and eventually be delivered to streams. Iron can also become entrained in stream waters via erosion processes that worsen as stream energy (discharge) increases. Therefore, modeled extreme precipitation events or a series of significant storms resulted in elevated instream TSS and non-attaining iron concentrations, in minimally disturbed areas.

Due to the unreasonable source allocations that would have been required to meet the trout water criterion for TMDL development, an adaptive phased implementation of the TMDLs was proposed, under which the source allocations necessary to universally achieve the iron criterion for warmwater fisheries (1.5 mg/L, 4-day average, once per three years average exceedance frequency) are implemented concurrently with additional study of the situation. This report presents the results of the study, which determined the range(s) of total iron concentrations that occurred in the subject trout waters and evaluated the previous model representation of the precipitation induced loading of iron from upland and streambank erosion sources.

The selected trout waters represent both a disturbed and an undisturbed watershed. Data collection included intense water quality monitoring targeted to a range of stream flows, storm event monitoring, high-resolution stream channel configuration and bank vegetative condition assessments, soil sampling for iron content and particle size distribution and detailed landuse characterization. Fieldwork was initiated in calendar year 2008 and continued through May 2009. Electrofishing was conducted to document the continued presence of trout. Monitoring and assessment results were used in the configuration and calibration of the model, which focuses on the physical movement and the geochemical relationship between iron and sediment. Once calibrated, the model was run for longer periods to represent iron concentrations to which trout were exposed.

1.1 Watershed Selection

Streams in the targeted watersheds with known populations of brook trout (*Salvelinus fontinalis*) or brown trout (*Salmo trutta*) were considered as candidates for the study. The ideal setting was proposed as a stream inhabited by a reproducing or sustaining trout population, as evidenced by a minimum of three different age classes. Because trout disperse as they age, the presence of individuals of multiple sizes indicates that a stream is both productively capable of sustaining growing in younger individuals and is suitable for the spawning activities of adults. Because brook trout are generally considered more pollution sensitive than brown trout, this study took place in streams inhabited by native brook trout. The presence of brook trout in the selected streams was evidenced through electrofishing by WVDEP biologists. The electrofishing study results are presented in Appendix E.

Another element important to consider in stream selection was the level of land disturbance present in the watershed. Ideally, an undisturbed watershed would be selected in order to determine the iron concentrations resulting from natural background levels, and a watershed with some land disturbance activities would be selected in order to determine the concentrations resulting from such activities.

Two streams were selected for this study, both located within the Gauley River watershed: Holcomb Run and Elklick Run.

Holcomb Run is in the Cherry River watershed, located approximately four miles northwest of Richwood in Nicholas County (Figure 1-1). The Holcomb Run watershed is 1,416.8 acres, and the Holcomb Run mainstem flows approximately 2.7 miles from its headwaters to the confluence with Morris Creek. Holcomb Run has three perennial tributaries, each just over half of a mile long. With the exception of a few acres of recently harvested forest, several completely re-vegetated clearcuts, and some hayfields and utility right of ways in the headwaters, the Holcomb Run watershed is almost completely undisturbed.

Elklick Run is a tributary of the South Fork of Cherry River and is located in northern Greenbrier County, approximately six miles southeast of Richwood, WV (Figure 1-1). The Elklick Run watershed is 813.2 acres, with a total stream length of approximately 1.8 miles from its headwaters to the confluence with the South Fork of the Cherry River. Timber harvest was occurring in the Elklick Run watershed at the time of the study, and many acres of harvested forest in various stages of re-growth were also observed.

Sediment-producing logging roads and unreclaimed skid trails were found throughout the steep-sloped watershed.

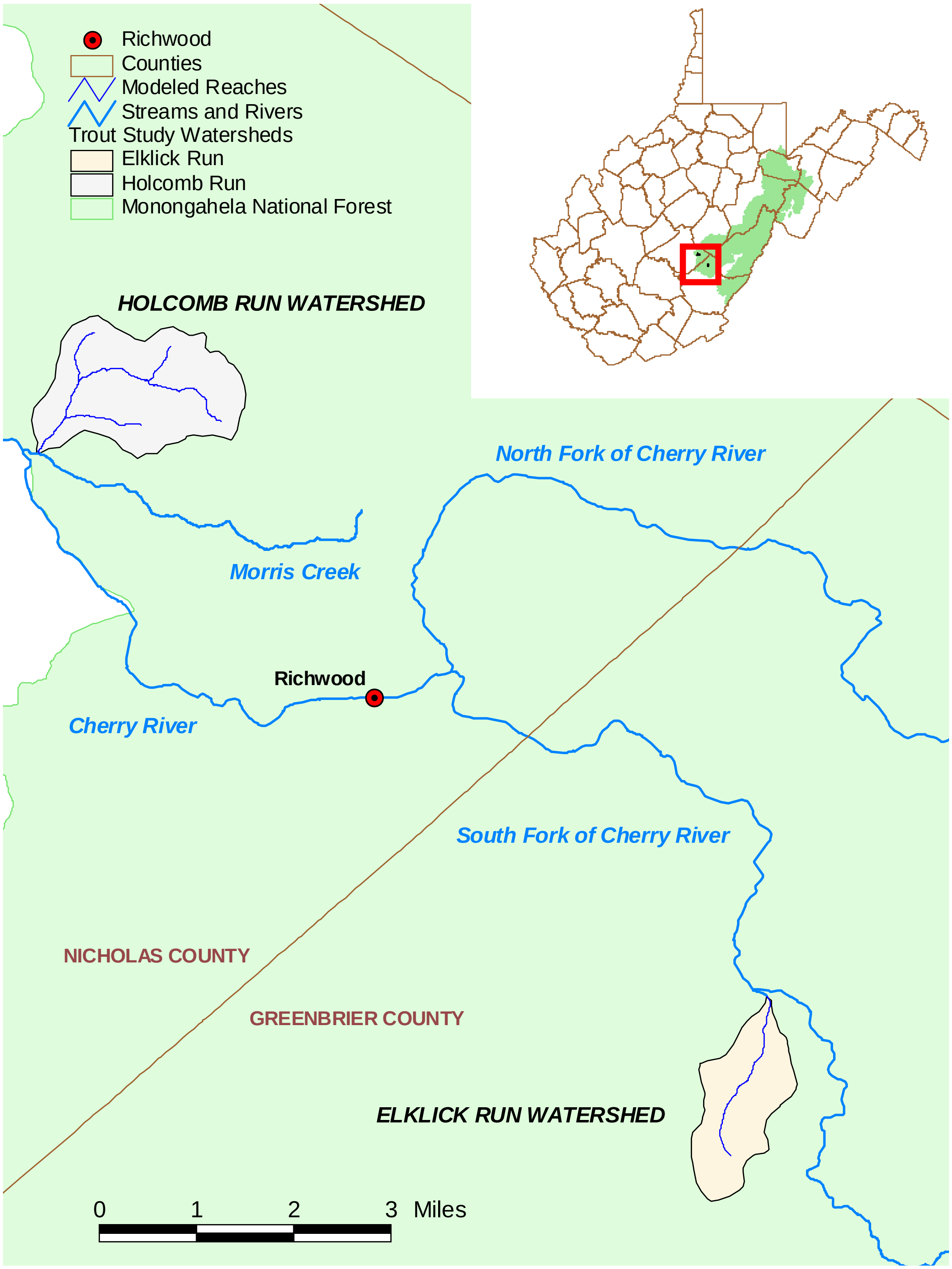


Figure 1-1. Locations of the study watersheds

1.2 Source Description and Background

Soil erosion at logging sites is recognized as the largest source of sediment and total iron in the watersheds. Logging and the land disturbance associated with the creation and use of haul roads to serve logging sites can dramatically increase sediment loading to streams through both surface erosion and as a delivery mechanism. Forest harvest information related to sites within the study area including harvest date, disturbed area, and logging method were obtained from landowners.

Streambank erosion is another potential sediment source in the watersheds. Field assessments were conducted to assess the bank erosion potential along the entire reach length of both Holcomb Run and Elklick Run using the bank erosion hazard index (BEHI). BEHI variables include bankfull height, bankfull angle, vegetation and root density, bank stratification, and particle size of bank materials (ADEQ, 2004). The sample reach is assigned a qualitative value between 1 and 3 for each BEHI variable, with higher scores representing less stable streambanks and higher sediment bank erosion rates.

There is one mining related NPDES permit (WV0096971) in the Elklick watershed. WVDEP’s Division of Mining and Reclamation (DMR) provided a spatial coverage of the outlets related to this permit. The discharge characteristics, related permit limits, and discharge data for these NPDES outlets were acquired from West Virginia’s Environmental Resources Information System (*ERIS)* database system. The outlets 015-019 were closed circa 1996 and 1998. Outlets 007, 020, 021, 022 and 023 have been subject to post-mining limits (effluent type H) since 2/27/2003. Although technically still open, land draining to the outlets is completely reclaimed and monitoring has demonstrated negligible water quality impacts. Therefore, the outlets were not explicitly represented as continuous sources. The reclaimed land was represented as a mining landuse characterized similar to grassland.

2.0 WATER QUALITY AND SOILS DATA

2.1 Water Quality Storm Sampling

Water quality sampling was conducted by WVDEP personnel during five storm events on Elklick Run and three storm events on Holcomb Run between March 2008 and May 2009. The details of these sampling events are shown in Table 2-1. Sampling was conducted over the duration of the hydrograph and captured base flow conditions prior to the rainfall event and the return to base flow after storm flow recession. Figures 2-1 and 2-2 show where field samples for water quality, streambank condition, and soils were collected in Elklick Run and Holcomb Run, respectively. A complete table of observed water quality results is presented in Appendix A.

Table 2-1. June 2008 water quality storm sampling locations and events

Stream	Date	Total Event Precipitation	Water Quality Parameters
Elklick Run	19-20 March 2008	0.70 inches	pH, DO, Conductivity, Fe, TSS
Elklick Run	8 May 2008	0.68 inches	pH, DO, Conductivity, Acidity, Alkalinity, Fe, SO4-, TSS
Elklick Run	4 June 2008	0.42 inches	pH, DO, Conductivity, Acidity, Alkalinity, Fe, TSS, SO4-, TSS
Elklick Run	9-13 December 2008	2.70 inches	Fe, TSS
Elklick Run	3-5 May 2009	1.04 inches	pH, Conductivity, Fe, TSS
Holcomb Run	19 March 2008	0.72 inches	pH, Conductivity, Fe, TSS
Holcomb Run	9-13 December 2008	3.35 inches	Fe, TSS
Holcomb Run	2-3 May 2009	0.72 inches	pH, Conductivity, Fe, TSS

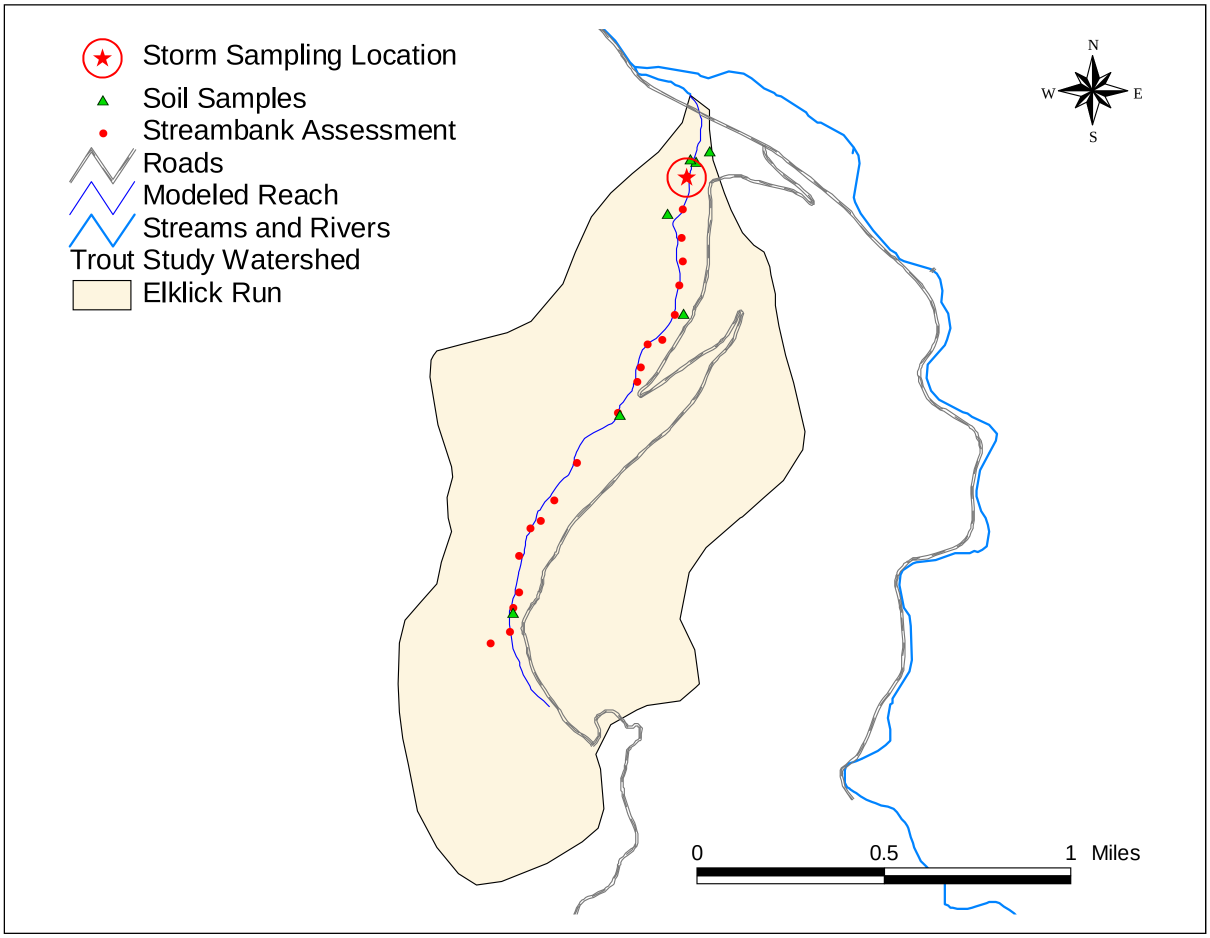


Figure 2-1. Elklick Run sampling locations

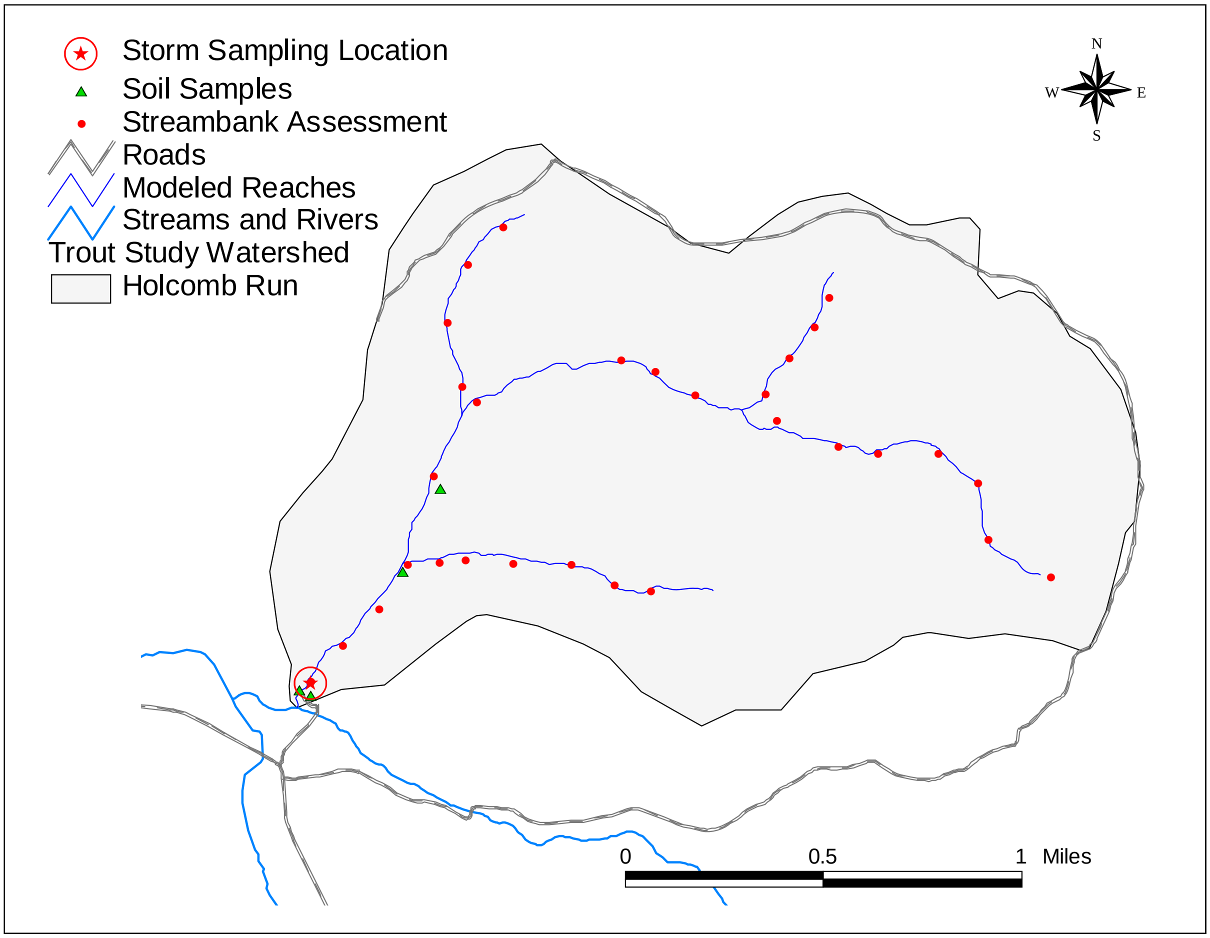


Figure 2-2. Holcomb Run sampling locations

2.2 Streambank Erosion and Hydrogeomorphology Assessment

Tetra Tech performed field assessments along the entire length of both streams in April 2009. There were 20 assessment sites on Elklick Run, and 29 sites in the Holcomb Run watershed; both on the Holcomb Run mainstem and its perennial tributaries (Figures 2-1 and 2-2). Because streambank erosion is a potential sediment source throughout the watersheds, the bank erosion potential was recorded using a bank erosion hazard index (BEHI) at each assessment site. BEHI variables included bankfull height, bankfull angle, vegetation and root density, bank stratification, and particle size of bank materials (ADEQ, 2004). Bankfull width and a Manning's Roughness value were also recorded at each site. The field team also took photos of significant hydrologic features and noted any observed potential sediment sources. The BEHI sample was assigned a qualitative value between 1 and 3 for each variable, with higher scores representing less stable streambanks and higher sediment bank erosion rates. Detailed results for this effort are presented in Appendix B.

2.3 Soil Sampling

Information regarding the iron content of watershed soils is vital to developing an accurate water quality model for iron. Soil samples were taken from streambanks and adjacent riparian areas at the selected study site locations. These samples were analyzed for iron content and particle size distribution. Samples were representative of upstream and downstream locations as well as significant tributaries. Soil samples obtained from other areas in the watershed were similarly analyzed for the characterization of the various soil types that are present and potentially entrained in runoff.

A total of 11 soil samples were collected in representative locations in both watersheds. Seven samples were collected in Elklick Run and four were collected in Holcomb Run. Table 2-2 shows a summary of the results and locations of the soil samples collected for the study. Detailed results are presented in Appendix C.

Table 2-2. Soil sampling locations

Stream	Site ID	Description
Elklick Run	DEP001	Elklick Run at mouth, RDB bank sediment
Elklick Run	DEP002	Elklick Run at mouth, LDB bank sediment
Elklick Run	DEP003	Elklick Run at mouth, riparian forest sediment
Elklick Run	DEP004	Elklick Run, logging road sediment (LDB)
Elklick Run	EL-3	Elklick Run at EL-3 headwaters
Elklick Run	EL-RD	Elklick Run at road drainage gully
Elklick Run	EL-10	Elklick Run at EL-10 mid watershed
Holcomb Run	DEP005	Holcomb Run at mouth, RDB bank sediment
Holcomb Run	DEP006	Holcomb Run at mouth, riparian forest sediment
Holcomb Run	HC-33	Holcomb Run near confluence of 1st UNT
Holcomb Run	HC-SEEP	Iron Seep sediment

A particle size distribution analysis was conducted on soils samples by wet sieving. Oven dry sediment samples for each size fraction were subsequently analyzed for iron content. Figure 2-3 shows the average iron content in each particle size fraction (sand, silt, clay) for the samples collected in the Elklick Run and Holcomb Run watersheds.

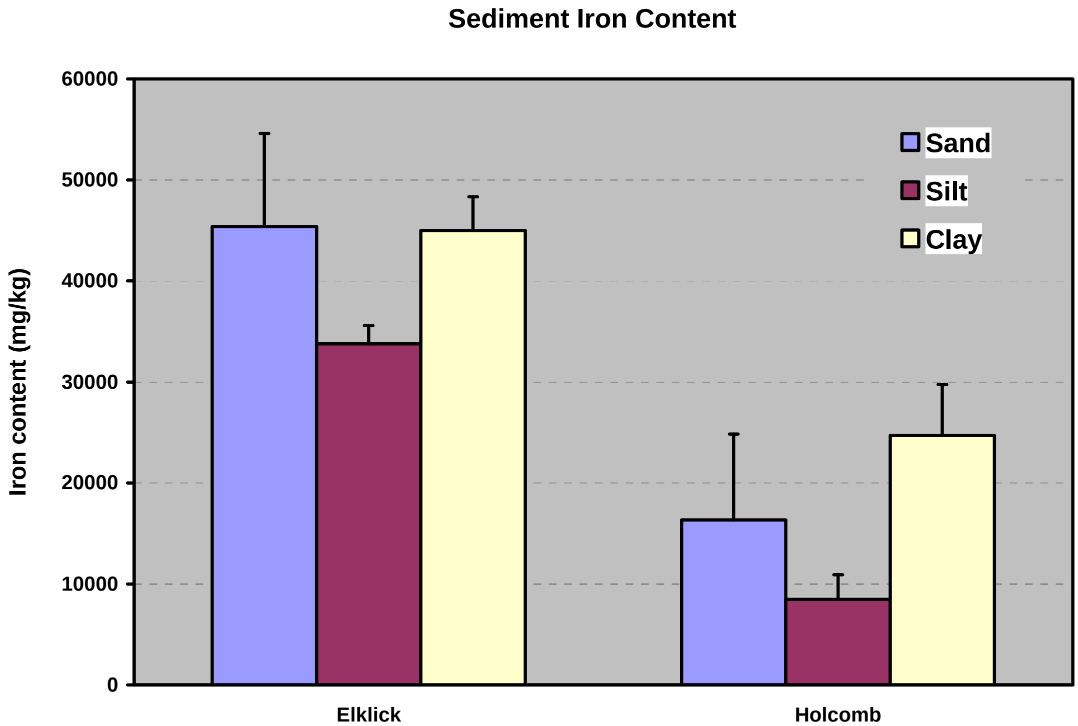


Figure 2-3. Average iron content of various particle size fractions (sand, silt, and clay) for sediment samples in Elklick Run and Holcomb Run watersheds**.**

2.4 Trout Electrofishing and Macroinvertebrate Sampling

On February 20, 2008, WVDEP biologists electroshocked Elklick Run and quickly collected brook trout, *Salvelinus fontinalis*, from three distinct age classes: 7.6 cm, 14.0 cm and 20.3 cm. That initial observation of fish of various developmental stages provided a strong indication of the presence of a naturally sustaining fishery. On March 13, 2008, WVDEP biologists again electroshocked Elklick Run and observed eight brook trout, ranging in length from 8.89 cm to 20.32 cm. An additional electrofishing survey on August 12, 2009 also found brook trout of multiple age classes in Elklick Run; therefore, WVDEP biologists concluded that the stream was a naturally sustaining brook trout fishery.

WVDEP biologists electroshocked Holcomb Run on March 13, 2008 and observed 13 brook trout, ranging in length from 7.62 cm to 17.78 cm. A follow-up electrofishing survey on August 12, 2009 also found brook trout in Holcomb Run. Based on these observations, the biologists also considered the stream to be a naturally sustaining brook trout fishery.

The electrofishing surveys clearly demonstrate that Elklick Run and Holcomb Run are trout waters pursuant to the definition provided in West Virginia water quality standards

(47 CSR 2 – 2.19). The surveys do not indicate a decline in reproduction or abundance over the study period.

WVDEP biologists performed macroinvertebrate sampling on August 12, 2009 in both Elklick Run and Holcomb Run. Identification results showed a diverse macroinvertebrate community in both streams. The West Virginia Stream Condition Index (WVSCI) scores for Elklick Run and Holcomb Run were 81.36 and 95.92, respectively. These results would classify both benthic communities as excellent do not indicate any existing adverse impact to the biological integrity of those streams.

Results of the electrofishing and macroinvertebrate surveys are included in Appendix E.

2.5 Precipitation

Precipitation during storm sampling events was recorded concurrently with field sampling using on-site rain gauges. Long-term hourly precipitation for longer model runs was developed from the National Oceanic and Atmospheric Administration, National Climatic Data Center (NOAA-NCDC) data for weather stations in Beckley and Valley Head, WV.

2.6 Forestry

The forest logging history in the relatively undisturbed watershed, Holcomb Run, was obtained from USFS. There were two time periods with recent logging activity. First, 254 acres were logged from about 1995 to 1997 using the conventional skidding method. Approximately 40 acres were logged by helicopter from September 10, 2008 to November 28, 2008. The primary landowner in Elklick Run provided forest harvesting history in the watershed. This information included the location, the area of land harvested, and the subset of land disturbed by haul roads and landings over the past twelve years. Figure 2-4 shows the year of logging and logging activity (clear cut or select cut) in Elklick Run from 1997 to 2009. In addition, the acreage and date of forest harvesting were further verified during field surveys. Figure 2-5 illustrates logging activities in northwest Elklick Run watershed photographed in March 2009. Appendix F contains more photographs of the watershed, as well as photographs taken during fieldwork and sampling, and biological surveying.

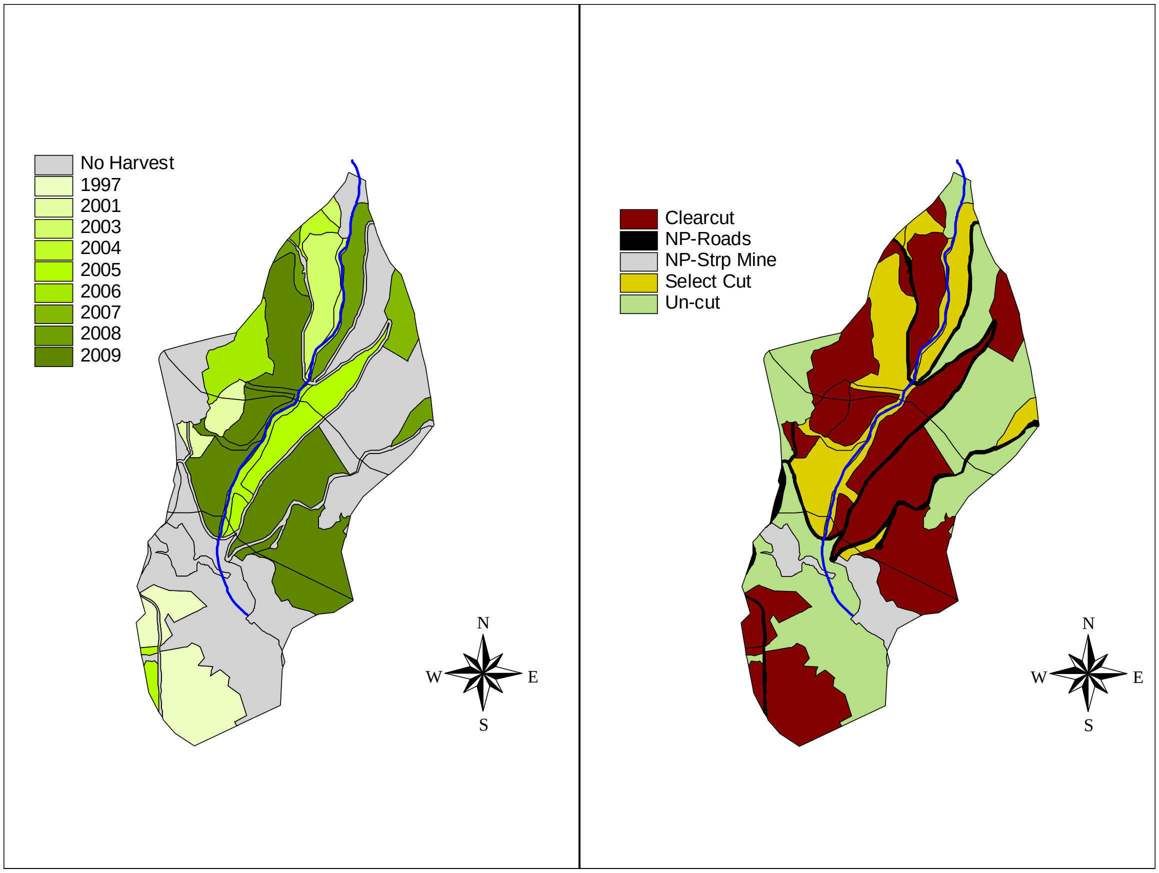


Figure 2-4. Forest harvest history in Elklick Run watershed

Figure 2-5. Logging activity in Elklick Run watershed (March 2009)

3.0 MODEL DEVELOPMENT AND CALIBRATION

Establishing a relationship between the instream water quality targets and source loading is a critical component of the source loading assessment and contaminant transport modeling. Identifying the cause and effect relationship between pollutant loads and water quality response is necessary in order to evaluate the loading capacity of the receiving waterbodies. The loading capacity is the amount of pollutant that can be assimilated by the waterbody while still attaining and maintaining water quality standards. This section discusses the model development for evaluating total iron concentrations in the Elklick Run and Holcomb Run watersheds.

3.1 Model Selection

The Mining Data Analysis System (MDAS) was the model selected to simulate iron concentrations in the two trout streams. The MDAS was developed specifically for TMDL application in West Virginia to facilitate watershed modeling applications. The MDAS is particularly applicable to areas affected by both point and nonpoint pollution sources, as well as instream processes such as streambank erosion. The system integrates a dynamic watershed model with a post-processing system for data analysis. The Loading Simulation Program–C++ (LSPC) model is the MDAS component that provides the linkage between source contributions and instream response (Shen et al., 2002). LSPC is a comprehensive watershed model used to simulate watershed hydrology and pollutant transport, as well as stream hydraulics and instream water quality. It is capable of simulating flow and the behavior of sediment, metals, temperature, pH, and many other organic and inorganic constituents. LSPC is essentially a recoded C++ version of selected Hydrologic Simulation Program–FORTRAN (HSPF), upon which it is based. LSPC's algorithms are identical to HSPF's. Refer to the Hydrologic Simulation Program–FORTRAN User's Manual for Release 11 (Bicknell et al., 1996) for a more detailed discussion of simulated processes and model parameters.

3.2 Model Development

The MDAS was configured for the two trout stream watersheds, and LSPC was used to simulate each stream as a series of hydrologically connected subwatersheds. These subwatersheds were delineated based on stream reach network, topography, and sampling locations. Connectivity between subwatersheds was determined by confluences of specific stream segments. Configuration of the model involved subdividing each watershed into modeling units and performing a continuous simulation of flow and water quality for these units using meteorological, landuse, source loading, and stream data.

Meteorological data are a critical component of the watershed model. Appropriate representation of precipitation, wind speed, potential evapotranspiration, cloud cover, temperature, and dewpoint is required to develop a valid model. While specific precipitation data were limited to observations collected during storm sampling, long-term meteorological data were obtained from the closest NOAA weather stations in an effort to develop the most representative dataset for the study.

Modeling subwatersheds and calibrating hydrologic and water quality model components require routing streamflow, iron, and sediment through streams and then comparing the modeled flows and concentrations with available data. Required stream data include slope, Manning's roughness coefficient, and stream dimensions, including mean depths and channel widths. Stream dimensions and Manning's roughness coefficients were derived from field observations. Slopes were calculated based on Digital Elevation Model (DEM) data. Stream lengths were measured with GIS using the USGS's National Hydrography Dataset (NHD) stream coverage. GIS-derived stream morphology was verified by field observations. The subwatershed delineations are shown in Figure 3-1.

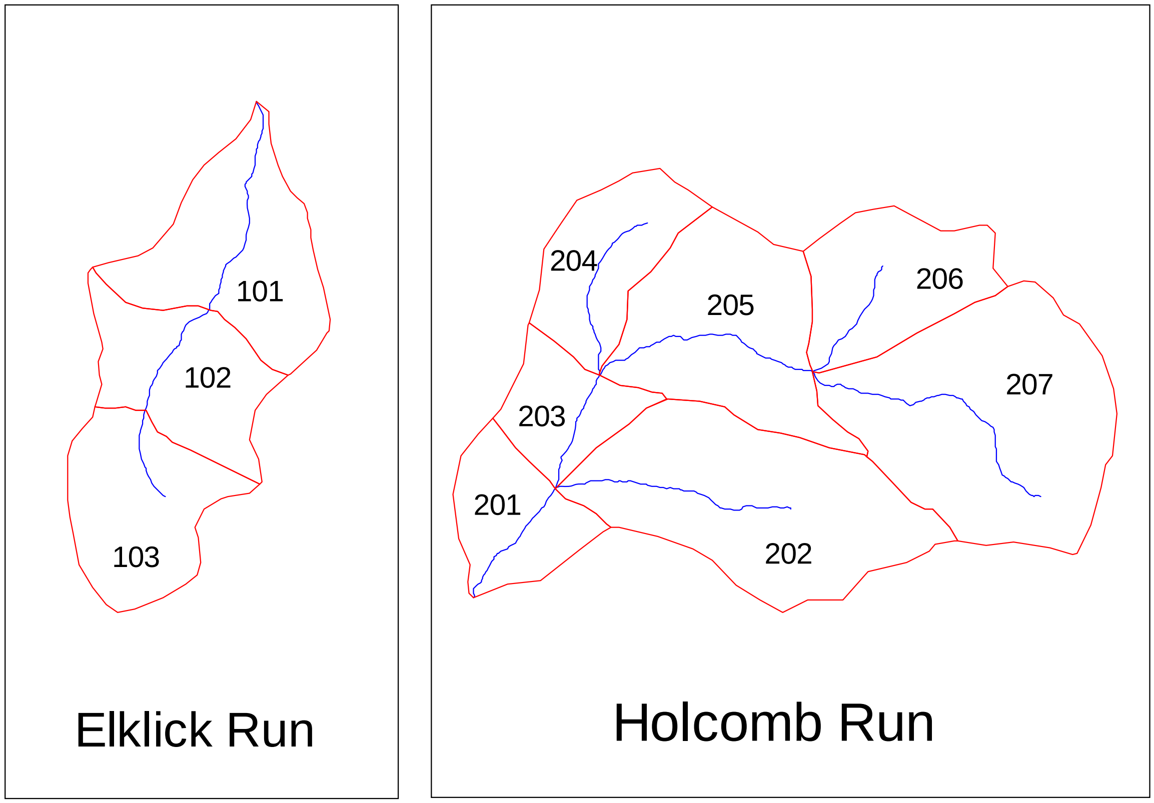


Figure 3-1. Subwatershed delineations

Hydrologic processes were represented in the MDAS using algorithms from two HSPF modules: PWATER (water budget simulation for pervious land segments) and IWATER (water budget simulation for impervious land segments) (Bicknell et al., 1996). Parameters associated with infiltration, groundwater flow, and overland flow were designated during model calibration. The loading contributions of iron from different nonpoint sources were represented in MDAS using the PQUAL (simulation of quality constituents for pervious land segments) and IQUAL (simulation of quality constituents for impervious land segments) modules of HSPF (Bicknell et al., 1996). Pollutant transport was represented in the streams using the GQUAL (simulation of behavior of a generalized quality constituent) module.

Streambank erosion was modeled as a unique sediment source independent of other upland-associated erosion sources. The MDAS bank erosion model takes into account stream flow and bank stability. The relevant parameters in the bank erosion algorithms are the threshold flow at which bank erosion starts to occur, and a coefficient for scour of the bank matrix soil for the reach. The threshold flow at which bank erosion starts to occur was estimated as the flow that occurs at bankfull depth. This flow threshold was user-specified for each reach. The bank scouring process is a power function dependent on high-flow events (those exceeding the flow threshold). The coefficient of scour for the bank soil was related to the bank erosion hazard index (BEHI).

The bank erosion rate per unit area was defined as a function of bank flow volume above a specified threshold and the bank erodible area. The wetted perimeter and reach length represent ground area covered by water (Figure 3-2). The erodible wetted perimeter is equal to the difference between the actual wetted perimeter and the wetted perimeter during threshold flow conditions. The bank erosion rate per unit area was multiplied by the erodible perimeter and the reach length to obtain the estimate of sediment mass eroded corresponding to the stream segment.

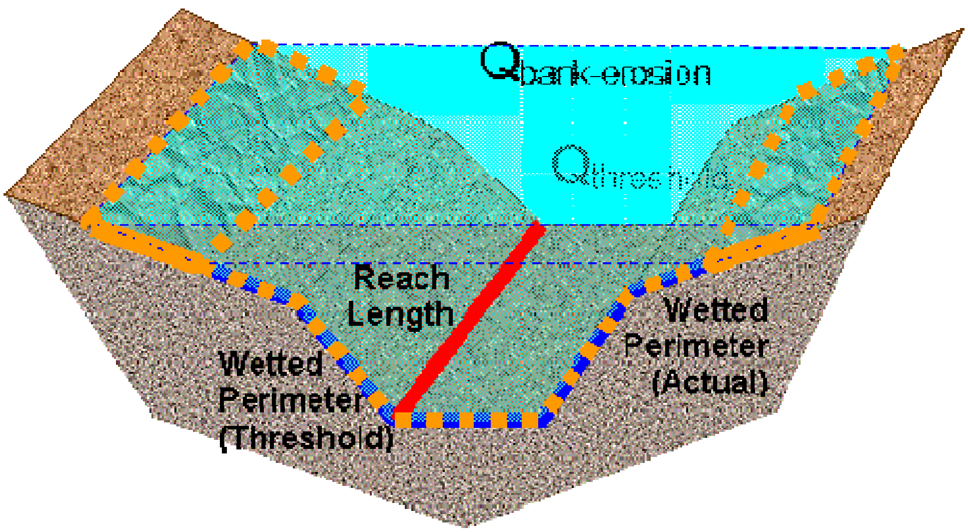


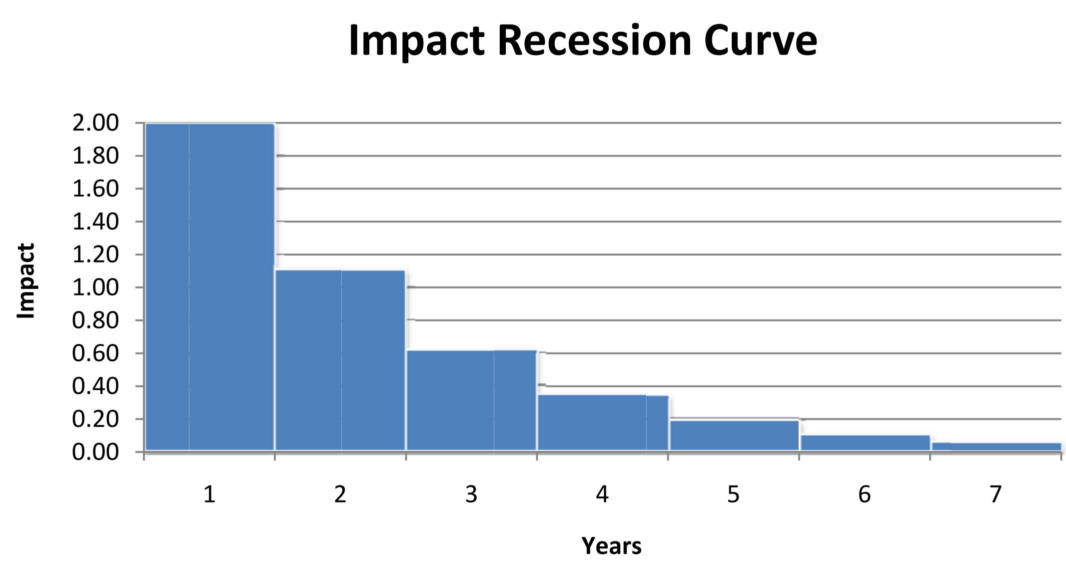
Figure 3-2. Conceptual diagram of stream channel components of bank erosion model

During the sediment calibration process, the suspended sediment time series were compared with available data. Adjustments were made to the initial parameterization, but the relative magnitude between the sources was kept constant.

Model representation of harvested forest lands was designed to capture the dynamic process of forest recovery after harvesting. The Forest Service and landowner compiled map layers for timber harvest regions for different events over time. These map layers also represented the degree of harvesting (clear cut and selected cut) in each affected area. For each harvested zone, an equivalent barren area was computed. The equivalent barren area represented the percentage of land in a particular area that was affected by that activity. For example, a harvest equivalent barren area of 0.1 indicated that 10 percent of the area within the associated boundary was disturbed due to timber harvesting. To account for the diminishing impact of forest harvesting over time, the recession curve shown in Figure 3-3 was used to represent the time-sensitive events in the model. The recession curve, which was obtained from the U.S. Forest Service

(WATSED, 1991), assumes that it takes seven years for the effect on water quality to be small enough to be considered negligible.

To simplify modeled landuse categories, the NLCD 2001 landuse categories were consolidated and disturbance activities including roads and barren areas were digitized using aerial photography from 2003 and 2007. The consolidated NLCD 2001 landuses were then modified to include the digitized areas. The clear cut and selected cut harvest areas were each represented separately based on the seven year recession curve described above. The modeled landuse groupings shown in Table 3-1 provided the basis for estimating and distributing sediment associated total iron from land-based precipitation-driven sources.



Note: Recession Curve from U.S. Forest Service. 1991 WATSED, water yield and sediment

Figure 3-3. Impact recession curve for simulating the diminishing impact of forest harvest

Table 3-1. Modeled landuse representation

Landuse ID	Landuse Name	Land Use Description	Elklick Run Area (acres)	Holcomb Run Area (acres)
0	Water	Water	1.2	0.0
1	Wetland	Wetland	0.0	0.0
2	Forest	Undisturbed Forest	370.5	1286.9
3	Barren	Barren	0.0	0.0
4	Grassland	Grassland	0.0	117.4
5	Up_road_1	One lane unpaved road	33.1	4.8
6	Up_road_2	Two lane unpaved road	0.0	7.8
7	Mining	Strip mining area	38.4	0.0
8	HF_CC_1	First year clear cut forest harvest	114.9	0.0
9	HF_CC_2	Second year clear cut forest harvest	5.0	0.0
10	HF_CC_3	Third year clear cut forest harvest	16.2	0.0
11	HF_CC_4	Fourth year clear cut forest harvest	29.4	0.0
12	HF_CC_5	Fifth year clear cut forest harvest	43.5	0.0
13	HF_CC_6	Sixth year clear cut forest harvest	0.0	0.0
14	HF_CC_7	Seventh year clear cut forest harvest	31.1	0.0
15	HF_SC_1	First year selective cut forest harvest	76.0	0.0
16	HF_SC_2	Second year selective cut forest harvest	29.9	0.0
17	HF_SC_3	Third year selective cut forest harvest	1.0	0.0
18	HF_SC_4	Fourth year selective cut forest harvest	0.0	0.0
19	HF_SC_5	Fifth year selective cut forest harvest	10.6	0.0
20	HF_SC_6	Sixth year selective cut forest harvest	5.8	0.0
21	HF_SC_7	Seventh year selective cut forest harvest	6.6	0.0
22	Unused	Unused	0.0	0.0
		Total Area	**813.2**	**1416.8**

3.3 Hydrology Calibration

Hydrology calibration was performed after configuring the model. For the MDAS, calibration is an iterative procedure of parameter evaluation and refinement as a result of comparing simulated and observed values of interest. It is required for parameters that cannot be deterministically and uniquely evaluated from topographic, climatic, physical, and chemical characteristics of the watershed. The calibration procedure resulted in parameter values that produce the best overall agreement between simulated and observed stream flow values throughout the calibration period. Calibration included a time series comparison of individual storm events.

The MDAS hydrology algorithm follows a strict conservation of mass, with various compartments available to represent different aspects of the hydrologic cycle. Sources of water are rainfall or snowmelt. Potential sinks from a land segment are total evapotranspiration, flow to deep groundwater aquifers, and outflow to a reach. From the reach perspective, sources include land outflow (runoff and baseflow), direct discharges, precipitation, or flow routed from upstream reaches. Sinks include surface evaporation or reach outflow.

The energy balance approach is used to simulate snow behavior. The MDAS SNOW module uses the meteorological forcing information to determine whether precipitation falls as rain or snow, how long the snowpack remains, and when snowpack melting occurs. Heat is transferred into or out of the snowpack through net radiation heat, convection of sensible heat from the air, latent heat transfer by moist air condensation on the snowpack, from rain, and through conduction from the ground beneath the snowpack. Melting occurs when the liquid portion of the snowpack exceeds its holding capacity; melted snow is added to the hydrologic cycle.

The source of water to the land is either direct precipitation or snowmelt. Some of this water is intercepted by vegetation or by other means. The interception is represented in the model by a “bucket” that must be filled before any excess water is allowed to reach the land surface. The size, in terms of inches per unit of area, of this “bucket” can be varied monthly to represent the level of each compartment (both above and below the land surface).

Water that is not intercepted is placed in surface detention storage. If the land segment is impervious, no subsurface processes are modeled, and the only pathway to the stream reach is through surface runoff. If the land segment is pervious, the water in the surface detention storage can infiltrate, be categorized as potential direct runoff, or be divided between the two depending on a function of the soil moisture and infiltration rate. The water that is categorized as potential direct runoff is partitioned into surface storage/runoff, interflow, or kept in the upper zone storage.

Surface runoff that flows out of the land segment depends on the land slope and roughness, and the distance it has to travel to a stream. Interflow outflow recedes based on a user-defined parameter. Water that does not become runoff, interflow, or lost to evaporation from the upper zone storage will infiltrate. This water will become part of the lower zone storage, active groundwater storage or be lost to the deep/inactive groundwater. The lower zone storage acts like a “container” of the subsurface. This “container” needs to be full in order for water to reach the groundwater storage. Groundwater is stored and released based on the specified groundwater recession, which can be made to vary non-linearly.

Water can exit the system in three ways: evapotranspiration, deep/inactive groundwater, or entering the stream channel. The water that enters the stream channel can come from direct overland runoff, interflow outflow, and groundwater outflow. The model attempts to meet the evapotranspiration demand by evaporation of water from baseflow (groundwater seepage into the stream channel), interception storage, upper zone storage, active groundwater, and lower zone storage. How much of the evapotranspiration demand is allowed to be met from the lower zone storage is determined by a monthly variable parameter.

During hydrology calibration, land segment hydrology parameters were adjusted to achieve agreement between simulated and observed stream flow at storm sampling locations in each trout stream. An example hydrology calibration plot is shown in Figure 3-4. All hydrology calibration plots are shown in Appendix D.

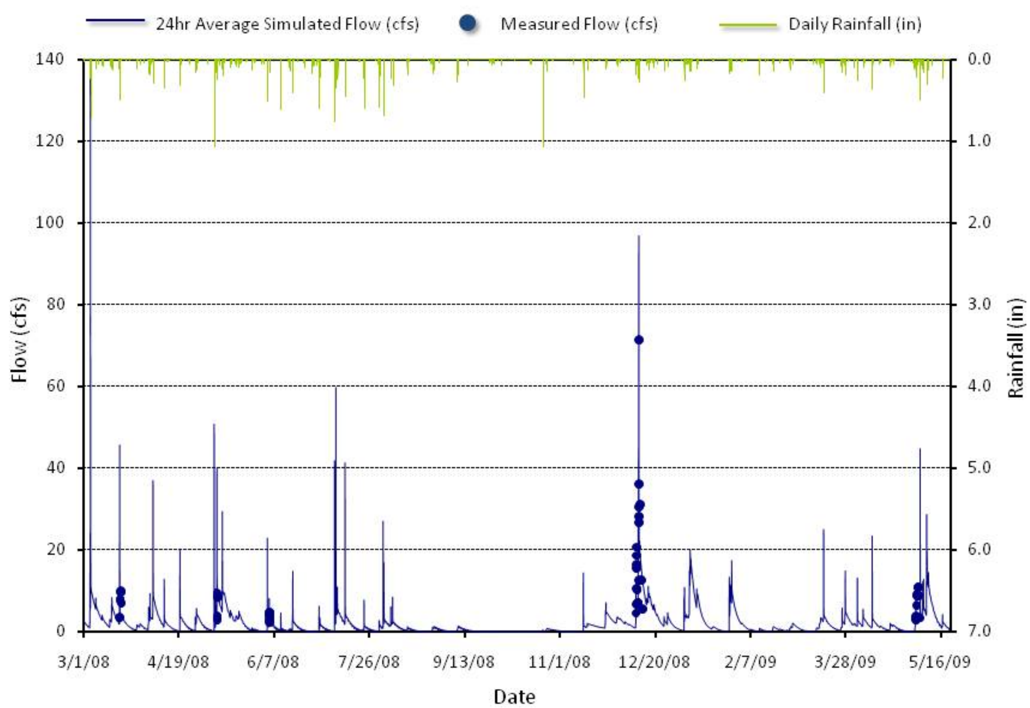


Figure 3-4. Holcomb Run hydrology calibration

3.4 Water Quality Calibration

3.4.1 Sediment Water Quality Calibration

Storm event monitoring data in the watershed were used for model water quality calibration (Appendix A). The MDAS water quality is largely a function of the hydrology and sediment production is directly related to the intensity of surface runoff. Sediment yield varies by landuse and the characteristics of the land segment. Sediment is delivered to the streams through surface runoff erosion, direct point sources, and instream bank erosion. Once sediment reaches the stream channel, it can be transported, deposited, and scoured, depending on the sediment size and flow energy. Figure 3-5 shows a schematic of the sediment pathways.

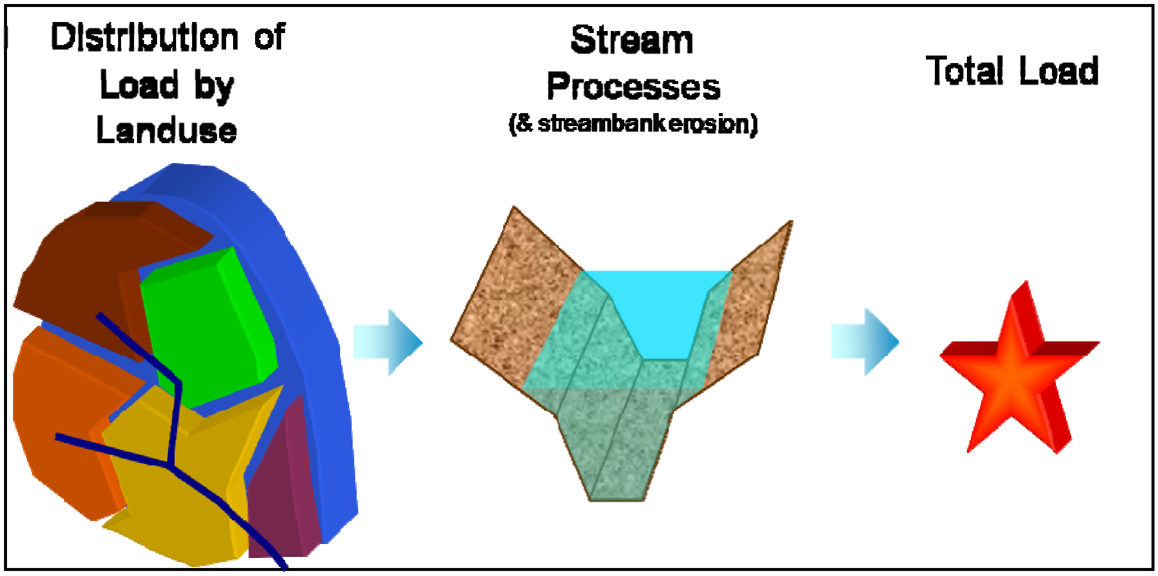


Figure 3-5. Schematic of sediment sources and transport pathways

The water quality parameters that were adjusted to obtain a calibrated model for sediment were the surface sediment concentrations (by landuse), and the magnitude of the coefficient of scour for bank-erosion. Relevant calibration parameters for the land-based sediment calibration were the sed-suro, sed-ifwo, and sed-agwo. These are average sediment concentrations (in mg/L) for runoff, interflow, and groundwater, respectively.

These concentrations were defined for each modeled landuse. The water that enters the stream channel can come from direct overland runoff, interflow outflow, and groundwater outflow by landuse. Initial values for these concentrations were based on available landuse-specific storm-sampling monitoring data and values established from the previous Gauley River TMDL modeling effort. Previously established parameters for background conditions (forest landuse) were applied while other landuse-specific values were refined through the calibration process.

Land-based sediment calibration consisted of adjusting the sed-suro, sed-ifwo, and sed-agwo concentrations for each landuse. The landuses were parameterized according to their sediment-producing capabilities. Soil samples collected from the trout stream watersheds were analyzed for percent sand, silt, and clay. These percent particle size values were used to parameterize the modeled sediment coming from surface runoff. An example sediment calibration plot is shown in Figure 3-6. Full results of the sediment calibration and validation are presented in Appendix D.

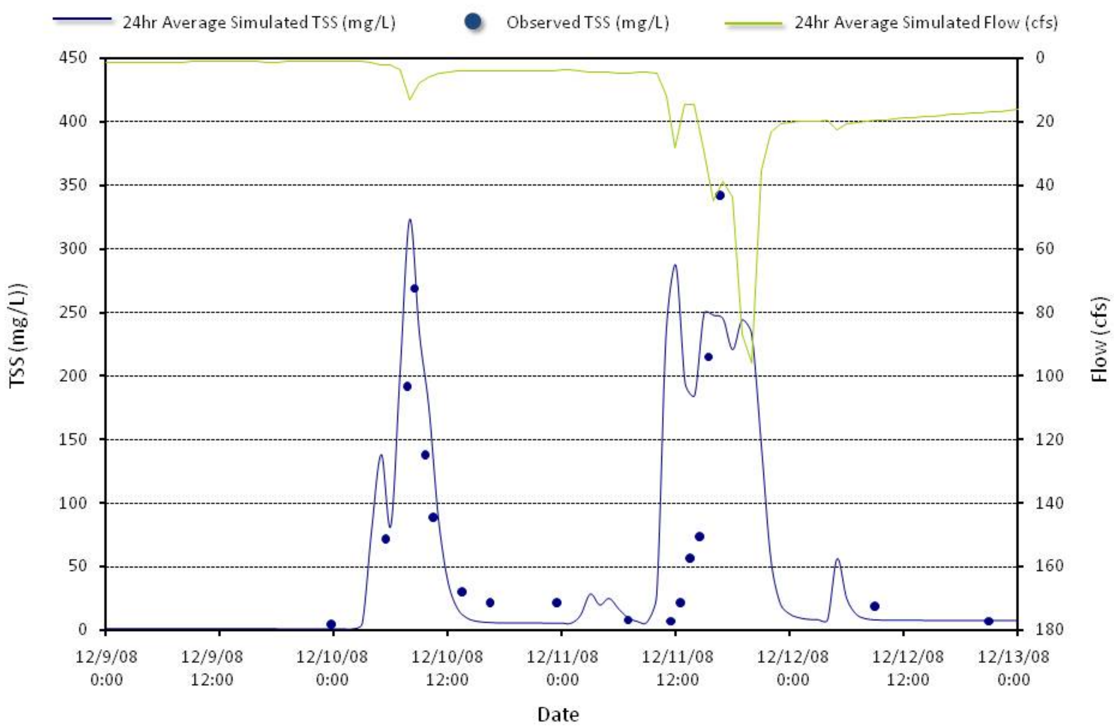


Figure 3-6. Elklick Run sediment calibration

3.4.2 Iron Water Quality Calibration

Iron loads are delivered to the tributaries with surface runoff, subsurface flows, and direct point sources. Sediment-producing landuses and bank erosion are also sources of iron because iron is associated with sediment. The MDAS provides mechanisms for representing all of these various pathways of pollutant delivery. A detailed water quality analysis was performed using statistically based load estimates with observed flow and instream monitoring data. The confidence in the calibration process increases with the quantity and quality of the monitoring data.

Iron and TSS concentrations from storm monitoring were used to develop a metals-sediment correlation. Statistical analyses using storm monitoring data collected in the subject watersheds were performed to establish the correlation between metals loads and sediment loads and to evaluate spatial variability. The results were then applied to the sediment-producing landuses during the water quality calibration phase of the MDAS. Laboratory chemical analysis of soils samples collected in the trout stream watersheds were used to validate the statistically derived metals-sediment correlation. The results of the correlation analysis are shown in Figure 3-7, with supporting water quality data available in Appendix A.

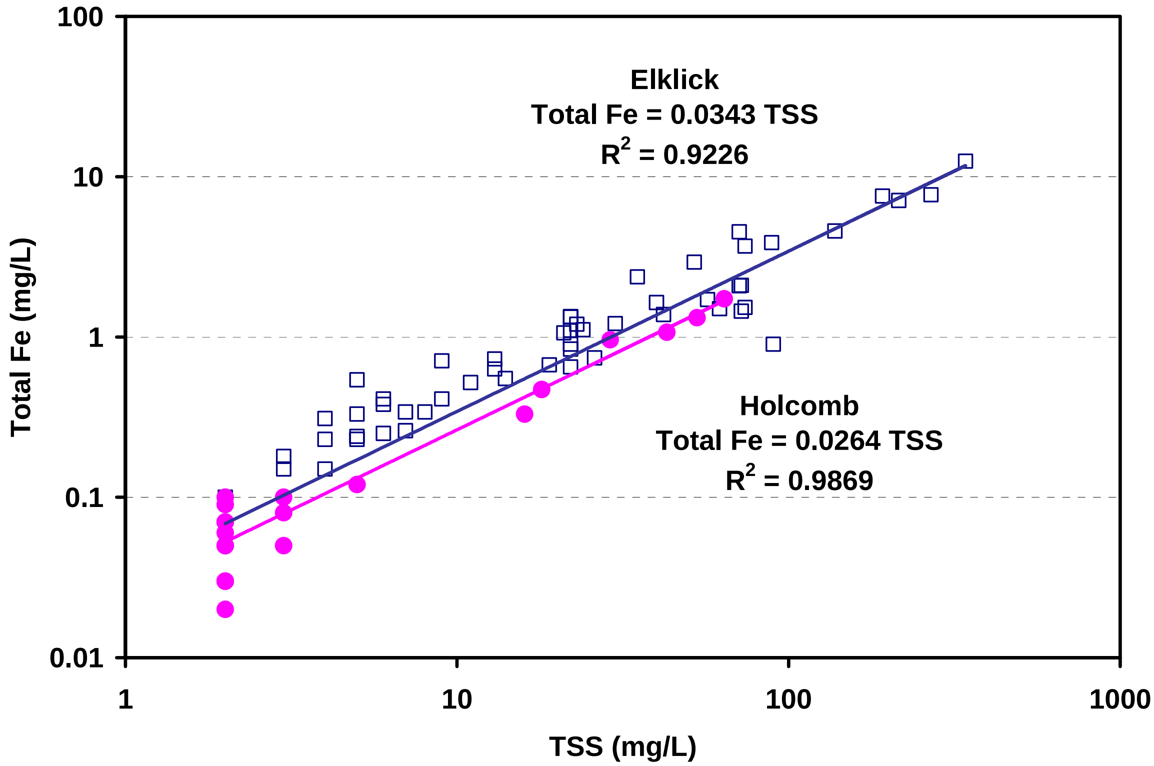


Figure 3-7. Metals-sediment correlation

In addition, non-sediment-related iron land-based sources were modeled using average concentrations for the surface, interflow and groundwater portions of the water budget. For these situations, discharges were represented in the model by adjusting parameters affecting pollutant concentrations in the PQUAL (simulation of quality constituents for pervious land segments) and IQUAL (simulation of quality constituents for impervious land segments) modules of the MDAS.

To validate the sediment/metals model, daily average instream concentrations from the model were compared directly with observed data at several locations throughout the watershed. The goal was to confirm that low flow, mean flow, and storm peaks at water quality monitoring stations draining mixed landuse areas were being represented. The representative stations were selected based on location (distributed throughout the TMDL watersheds) and loading source type. An example water quality calibration plot is shown in Figure 3-8. Full results of the iron water quality calibration and validation are presented in Appendix D.

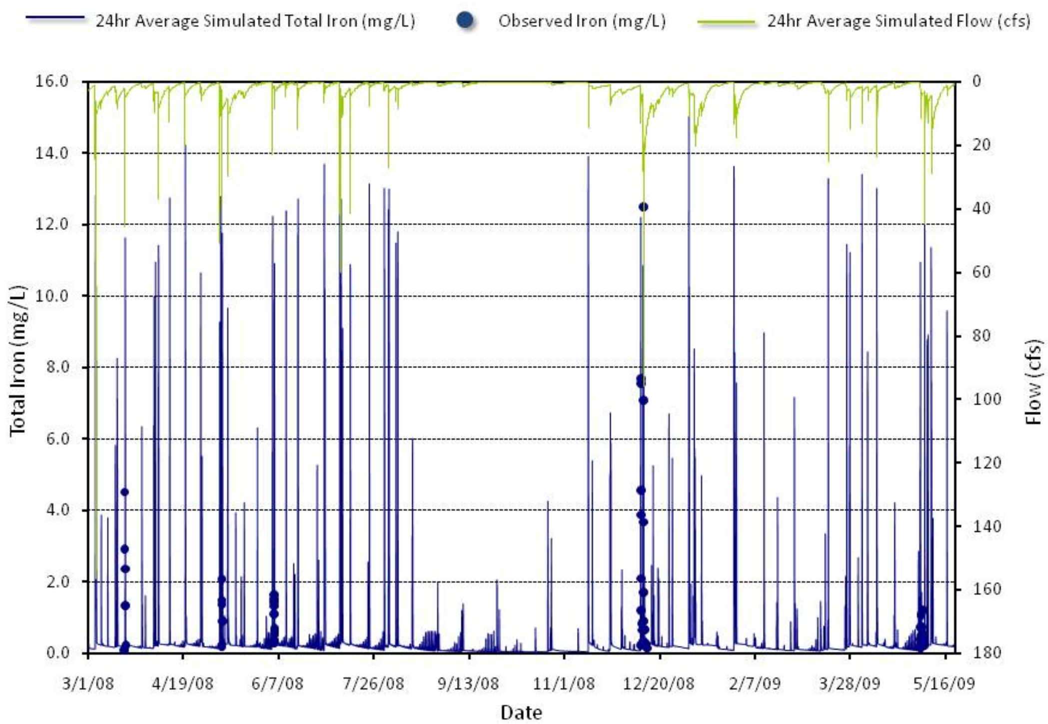


Figure 3-8. Calibration plots for total iron in Elklick Run

4.0 RESULTS

The calibrated model was executed for the period of 1/1/2007 through 5/20/2009 in order to determine the range(s) of total iron concentrations that occurred in Holcomb Run and Elklick Run as a result of precipitation induced runoff. Selection of this simulation period accounted for the model representation of the land disturbances from recent logging activities while considering the instream conditions to which the resident trout were subjected.

Violation analyses were performed using the simulated 24 hour average instream iron concentration model output. Targets selected for these analyses were based on the 4-day average iron concentrations of 0.5 mg/L,1.0 mg/L and 1.5 mg/L. The targets reflect the existing West Virginia trout water criterion, the EPA national recommended aquatic life water quality criterion, and the existing West Virginia warmwater fishery criterion, respectively. Figures 4-1 and 4-2 display the comparison of model output against these targets for Elklick Run and Holcomb Run, respectively.

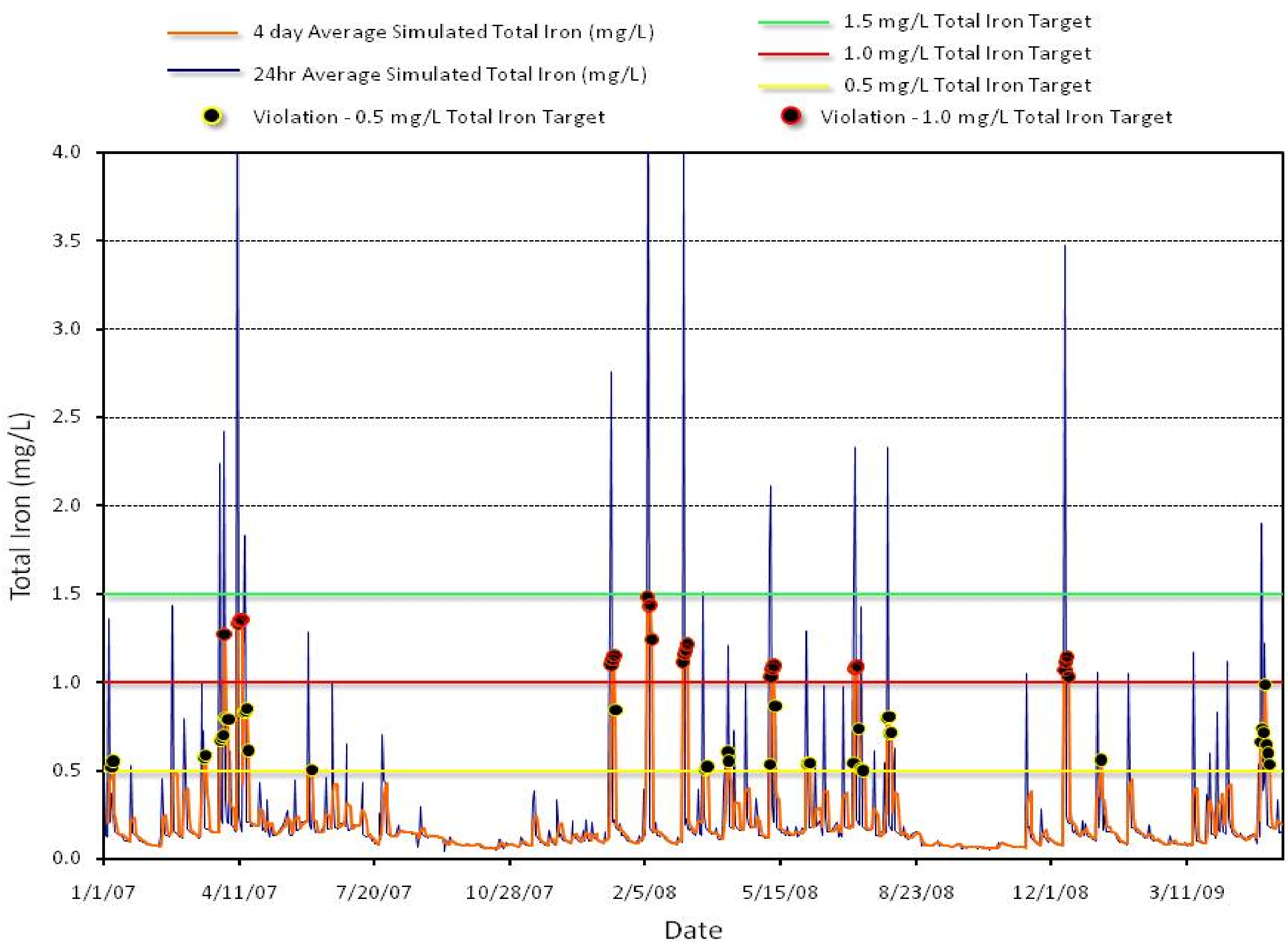


Figure 4-1. Modeled total iron concentrations in Elklick Run

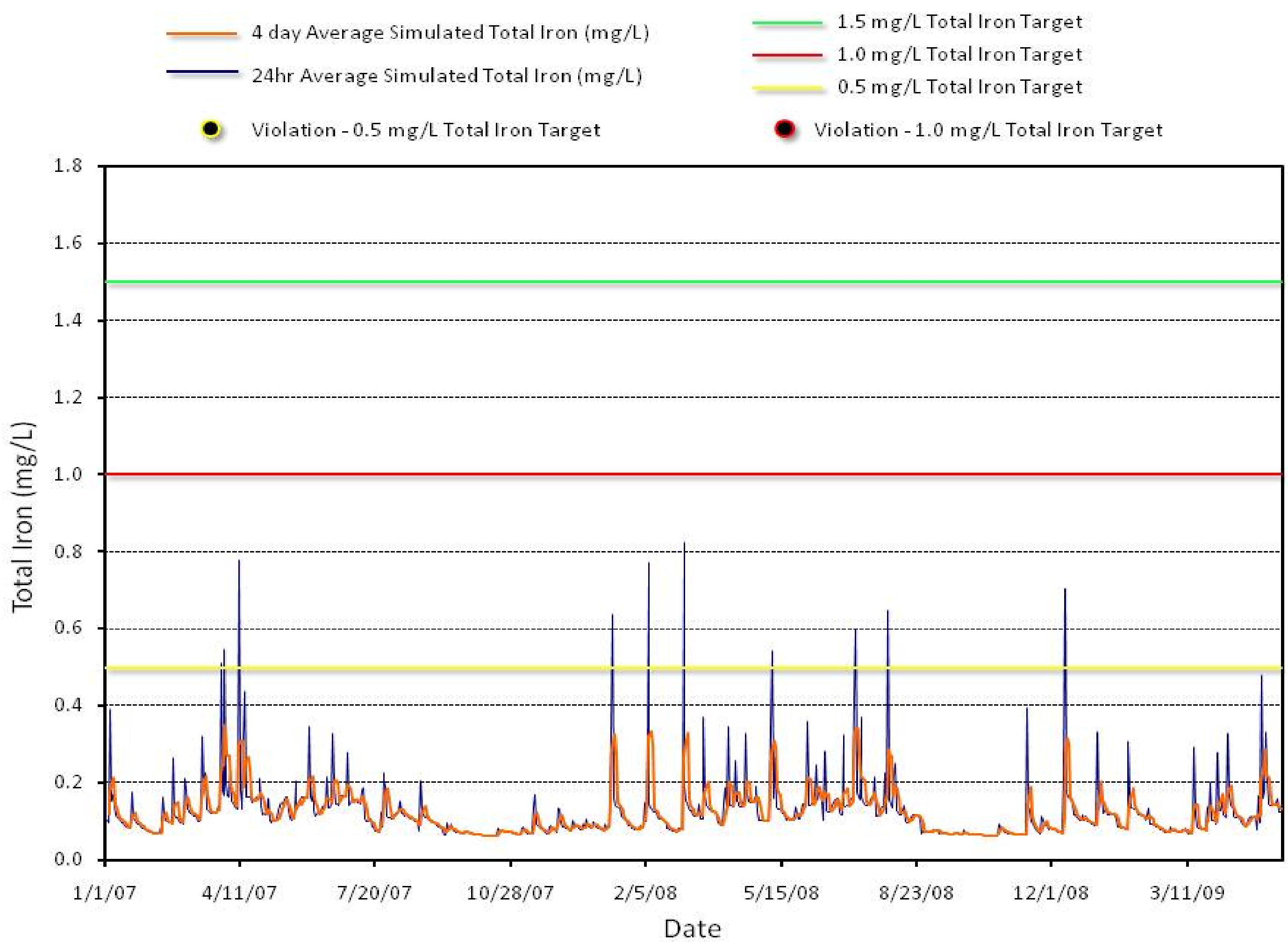


Figure 4-2. Modeled total iron concentrations in Holcomb Run

The violation analyses are summarized in Table 4-1. Simulation results (4-day average iron concentration) for Elklick Run resulted in 69 exceedances of the 0.5mg/L target, 26 exceedances of 1.0 mg/L target, and zero exceedances of the 1.5 mg/L target. The maximum predicted 4-day average concentration was 1.48 mg/L. The results for Holcomb Run did not exceed any of the targets, with yielding a maximum predicted 4-day average iron concentration of 0.35 mg/L. The surface disturbances in the Elklick Run watershed produced significantly more sediment associated iron through precipitation-induced runoff than in the undisturbed Holcomb Run watershed.

Table 4-1. Violation analysis results for Elklick Run and Holcomb Run

Elklick Run	**0.5 mg/L Target**	**1.0 mg/L Target**
Total Violations	69	26
% Violation	7.92%	2.99%
Maximum 4 day average	1.48 mg/L	
Holcomb Run	**0.5 mg/L Target**	**1.0 mg/L Target**
Total Violations	0	0
% Violation	0%	0%
Maximum 4 day average	0.35 mg/L	

In order to determine the magnitude of the precipitation events that typically produce water quality criteria exceedences, a precipitation analysis was also performed. The 4 day and 7 day rainfall totals that produced the execeedances in Elklick Run are summarized in Table 4-2. The average 4 day rainfall total that produced exceedances of the 0.5 mg/L and 1.0mg/L targets were 1.59 inches and 2.21 inches, respectively.

Table 4-2. Precipitation analysis summary for Elklick Run

Target Scenario	**Total Violations**	**4 day Precipitation (in)**			**7 day Precipitation (in)**		
		Ave	**Min**	**Max**	**Ave**	**Min**	**Max**
0.5 mg/L	69	1.59	0.69	2.72	2.32	0.72	4.01
1.0 mg/L	26	2.21	1.08	3.4	2.45	1.32	3.47

In summary, both Elklick Run and Holcomb Run have been documented by WVDEP to meet the definition of trout water in West Virginia water quality standards. The multiple observances of trout of various developmental stages also indicate that both are sustaining brook trout reproduction. A high resolution watershed model was developed and applied to estimate the range(s) of total iron concentrations that occur in these streams as a result of precipitation induced runoff. Modeling results indicate that the land disturbance activities in the Elklick Run watershed significantly increased the sediment associated iron produced during precipitation events and that the trout population experienced many excursions of the existing trout water criterion. This work also indicates that model overestimation of background, precipitation-induced iron loading was not a significant factor in previous nonattainment predictions associated with the Gauley and New River watershed TMDL projects.

5.0 REFERENCES

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Recession Curve from U.S. Forest Service. 1991 WATSED, water yield and sediment

Shen, Jian, M. Lahlou, L. Shoemaker, A. Parker, J. Ouyang, H.Yang, and Jon Ludwig. 2002. Mining Data Analysis System (MDAS). In *Water Environment Federation Watershed 2002 Proceedings*.