Total Maximum Daily Load
Upper Blackwater River
West Virginia

Established by the U.S. Environmental Protection Agency Region III

Developed in cooperation with the West Virginia Division of Environmental Protection

February 20, 1998

Established by:

for W. Michael McCabe
Regional Administrator
EPA Region III

2/20/98
Date

Acknowledgments

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Executive Summary

This document contains the total maximum daily loads (TMDL) for the Upper Blackwater River, West Virginia. (waterbody identification # MC-60-D). These TMDLs are necessary to achieve the water quality standard for dissolved oxygen and use as a trout fishery. EPA and the West Virginia Division of Environmental Protection (DEP) published and requested comments on a proposed TMDL on October 22, 1997. EPA and the DEP also held a public hearing on November 18, 1997 to hear comments on the proposal. The agencies received comments from thirty two individuals. Based on these comments, EPA and the State made a number of changes to the proposed TMDLs, most notably to the allocation of pollutants to existing point sources in the watershed.

Under Section 303 (d) of the Clean Water Act, each state must list the waters that don't meet water quality standards even after required pollution controls are in place. For listed waters, the State must develop TMDLs which, in the most general sense--

- calculate how much pollutant can go into the water each day without violating water quality standards. This is the water's total maximum daily load of that pollutant.
- distribute the total daily load to all significant sources which include point sources (such as sewage treatment plants and factories), nonpoint sources (such as runoff from fields and roads), tributaries, and adjacent water segments.

Among West Virginia's listed waters for 1996 is the Upper Blackwater River whose dissolved oxygen has been measured below the state standard of a minimum of 6.0 mg/l, and thus is not meeting its designated use as a trout fishery. The low dissolved oxygen is a result of too much organic carbon and ammonia nitrogen and organic nitrogen during low flow periods. West Virginia attributed the problem to municipal point sources. There are also natural conditions including beaver dams and wetlands that impact the dissolved oxygen.

The organic and ammonia nitrogen and organic carbon contribute to the dissolved oxygen problem as bacteria convert them to different chemical forms, consuming oxygen in the process. The amount of oxygen used in the breakdown of carbon is represented by the five-day carbonaceous biochemical oxygen demand (CBOD5). The amount of oxygen used by the nitrogen is represented by nitrogenous biochemical oxygen demand (NBOD).

Pollutants can or will enter the Upper Blackwater River from--

- Fifteen small sewage treatment plants on the Blackwater and its tributaries,
- Waste load allocations issued by the WV DEP but not yet used by dischargers, and
- Nonpoint sources draining directly to the river and to the tributaries.

Modeling pollutants to establish TMDLs

To develop these TMDLs for the Upper Blackwater River, EPA and the West Virginia DEP used QUAL2E, a computer program supported by the U.S. Environmental Protection Agency to simulate how chemicals move and change in water. The program's mathematical equations simulated the Upper Blackwater's dissolved oxygen level given inputs of pollutants from point sources, nonpoint sources, and tributaries. Comparing the model's predictions with data sets measured in the field on three separate days, it was found that the simulated predictions reasonably matched the measured field data.

Allocations, TMDLs, and needed reductions

EPA and DEP simulated a number of pollutant loading scenarios that would keep the dissolved oxygen above the water quality standard of 6.0 mg/l. Based on a number of factors discussed in the report, EPA, in consultation with DEP, chose an allocation that requires removing all unused wasteload allocations. The existing dischargers can continue discharging at their permitted levels. The following table shows the allowable loads of CBOD5 and NBOD from all sources of pollutants to the mainstem of the Upper Blackwater River. The loads from each source are broken into the wasteload allocation (WLA) from point sources and the load allocation (LA) from nonpoint sources. The TMDL is the sum of the WLA and the LA.

Executive Summary Table Allocations and TMDLs

Source	**CBOD5 (lb/day)**			**NBOD (lb/day)**		
	WLA	**LA**	**TMDL**	**WLA**	**LA**	**TMDL**
Background on Blackwater Mainstem	n/a	2.69	2.69	n/a	2.13	2.13
Dischargers on Blackwater Mainstem	4.80	n/a	4.80	17.55	n/a	17.55
Club Run	0.21	0.19	0.40	0.76	1.73	2.49
Mill Run	0.67	0.19	0.86	2.45	1.73	4.18
Coon Run	0.29	0.04	0.33	1.07	0.35	1.42
Freeland Run	1.00	0.12	1.12	3.66	1.08	4.74
Yoakum Run	2.75	0.11	2.86	10.07	1.04	11.11
Sand Run	0.00	0.21	0.21	0.00	1.87	1.87
North Branch Blackwater River	9.42	0.47	9.89	32.80	4.29	37.09
Little Blackwater River	0.00	0.81	0.81	0.00	7.40	7.40
TMDLs	19.14	4.83	23.97	68.36	21.62	89.98

1.0 INTRODUCTION

1.1 Purpose of this Study

The objective of this study was to develop the TMDL and associated wasteload allocations (WLAs) and load allocations (LAs)[1] for the pollutants impacting the Blackwater River as identified on West Virginia's 1996 section 303(d) list of waters. The West Virginia Division of Environmental Protection (DEP) has identified the top 23.4 miles of the Upper Blackwater River as being impacted by low Dissolved Oxygen (DO) as reported in the 1996 303(d) list of water quality limited waters (West Virginia, 1996). The Blackwater River is ranked number 50 on the 303(d) list and municipal point sources are identified as a possible source of the low DO. DEP listed the water on the 303(d) list based on a water quality survey and associated modeling performed by the U.S. Geological Survey (USGS) in 1990-92, with the results published in 1996. The results of that survey indicated that five measurements of DO levels were below the applicable state standard of a minimum of 6 mg/l at the first monitoring site on the Blackwater mainstem, Canaan Valley State Park about 0.8 miles upstream for the Route 32 bridge.

The TMDLs and resulting WLAs and LAs will serve as planning tools in the Blackwater River watershed. The WLAs developed in this study will be used as the basis for any National Pollutant Discharge Elimination System (NPDES) permit issued or reissued to a point source included in the study. Any recommendations made concerning the control of nonpoint sources can be used to consider the location and type of nonpoint source controls, such as best management practices (BMPs), that would be necessary to attain the applicable water quality standards.

1.2 Regulatory Requirements

The Clean Water Act requires that TMDLs be developed for waters that will not meet water quality standards after the application of secondary or best practical treatment. The water quality standards are state regulations that are applicable to the surface waters of the state. All TMDLs developed in the state of West Virginia must be designed to achieve the existing state water quality standards.

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[1] WLAs are allowable loadings assigned to point sources and LAs are allowable loads to nonpoint sources. Together with a margin of safety, the WLAs and LAs equal the TMDL.

1.2.1 Federal TMDL Clean Water Act Requirements

Section 303(d) of the Clean Water Act and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130) require states to develop Total Maximum Daily Loads (TMDLs) for waterbodies identified on the CWA section 303(d) list of waters that do not or are not expected to meet water quality standards after the application of technology-based controls. The TMDL process establishes the allowable loadings of pollutants or other quantifiable parameters for a waterbody based on the relationship between pollution sources and in-stream water quality conditions. By following the TMDL process, States can establish water quality-based controls to reduce pollution from both point and non point sources and restore and maintain the quality of the water resources.

EPA approved West Virginia's 1996 section 303(d) list of waters on December 13, 1996. This list includes the Blackwater River as the 50th priority waterbody out of a total of 51 waters. Although ranked 50th, settlement to a suit against EPA by a number of environmental groups in West Virginia identified the Blackwater River as a major concern for the groups. It was therefore selected as one of the first major TMDLs to be completed in West Virginia.

In listing the water, West Virginia identified low dissolved oxygen levels as the major water quality problem. The existing State water quality standards for dissolved oxygen for the Blackwater River is a minimum of 6 mg/l. West Virginia has data to show that this water quality standard is being violated during low flow critical conditions. The State has further identified point source discharges as the major controllable sources of oxygen demanding substances. Based on the existing water quality data, the low flow was identified as the critical stream flow condition for which the TMDL would be developed. Based on the identified sources of pollution, the TMDL was developed for carbonaceous biochemical oxygen demand (CBOD5) and nitrogenous biochemical oxygen demand (NBOD).

There are basic regulatory requirements for the development of an approvable TMDL. Each TMDL approved by EPA must meet these requirements. The basic needs of a TMDL are as follows:

1. The TMDL must be developed for the critical stream conditions.
2. The TMDL must be developed to meet water quality standards.
3. The TMDL must consider seasonal variations.
4. The TMDL must include the wasteload allocations and load allocations.
5. The TMDL must include a margin of safety.
6. The TMDL must consider the impacts of background contributions.
7. The TMDL must be subject to public participation.

Although an approvable TMDL does not need to include an implementation plan, there must be a reasonable expectation that the TMDL can be implemented.

1.2.2 West Virginia Water Quality Standards

West Virginia has established water quality standards for all of the surface waters within the state. The water quality standards consist of one or more designated uses for each water and criteria (numeric or narrative) to protect those uses. West Virginia has designated the Blackwater River as a trout stream. With this comes a numeric criteria for DO of a minimum of 6 mg/l. The West Virginia DO standard for the Blackwater River is as follows:

> The in-stream dissolved oxygen concentration must not be less than 7.0 mg/l in spawning areas and in no case less than 6.0 mg/l at any time.

1.3 Study Area Description

The study area is the Blackwater River in the Canaan Valley in northeastern Tucker County. The Canaan Valley is an elongated, oval-shaped valley located in the Allegheny Mountains of northern West Virginia. It is the highest valley of its size east of the Rocky mountains, with an average elevation of 3,200 feet above sea level. This TMDL applies to a section of the Blackwater river extending from the headwaters to a point approximately 2.8 miles upstream of Davis, West Virginia. There are eight main tributaries to the Blackwater in the study area.

The Canaan Valley area has experienced rapid development over the past several years. Much of this development is associated with recreation and tourism, particularly skiing and golfing. Real estate development has followed. The wastewater from the recreational and other developed areas is treated with extended aeration plants, aerated lagoons, and individual septic tanks. There is no centralized wastewater-treatment facility in the valley. These small, individual plants discharge directly to the Blackwater River or one of its tributaries.

There are three wastewater treatment facilities that discharge directly to the Blackwater River. There are 12 additional facilities that discharge to tributaries. In addition, there are five unused wasteload allocations (WLA)[2]. Three of the five are located on the Blackwater mainstem. The remaining two unused WLAs are located on tributaries. One of the unused WLAs represents an increase over a currently active facility. Table 1.1 lists the tributaries and

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[2] An unused WLA, in this context, is a document, issued by West Virginia DEP, which states certain wasteload values which are allowable for a particular discharge. It is issued before a facility is built and before a permit is issued. It is used to plan and design wastewater treatment plants.

the number of facilities or unused WLAs located on each. See Section 3.1 for a thorough discussion of these facilities and unused WLAs.

Table 1.1 Tributaries to the Blackwater River and number of permitted discharges and unused WLAs on each.

Mainstem or Tributary Name	# of dischargers	# of unused WLAs
Blackwater Mainstem	3	3
Club Run	1	0
Mill Run	2	0
Coon Run	1	1[3]
Freeland Run	1	0
Yoakum Run	1	0
Sand Run	0	0
North Branch Blackwater River	6	1
Little Blackwater River	0	0
Total	15	5

1.4 Previous Studies

In 1996 the USGS completed a study of the Blackwater watershed from its headwaters to just above Davis, West Virginia. The resulting report, *Water Quality and Processes Affecting Dissolved Oxygen Concentrations in the Blackwater River, Canaan Valley, West Virginia*, discusses the water quality of the Blackwater and its major tributaries and identifies environmental processes that can affect DO concentrations in the river during periods of low flow. Data was collected by the USGS during a 30-month period at eight Canaan Valley stations. Each site was sampled manually at intervals of 1 to 2 months for 29 water quality properties and constituents.

In addition to the eight-station monitoring network, synoptic streamflow and water quality data were collected during low flow periods of 2 to 4 days in mid-summer, at 35 sites on the mainstem and major tributaries of the Blackwater River. The synoptic survey data were used to calibrate and verify a steady state, one dimensional water quality model that represented the physical, chemical and biological processes affecting the DO concentrations in the river at low flows.

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[3] This unused WLA represents an increase over the permitted discharge for a currently existing facility.

During the development of this TMDL, EPA and the West Virginia DEP relied heavily on the USGS water quality monitoring and modeling activities presented in report noted above. The USGS provided EPA and West Virginia with the data files for the calibration and verification water quality model runs, which were then used to determine the TMDL.

1.5 Stream Characteristics

1.5.1 Physical Characteristics[4]

The Blackwater River and its major tributaries, the North Branch and the Little Blackwater River, are low-gradient streams. Other tributaries, such as Yoakum Run and Freeland Run, originate on mountain sides and fall rapidly to the valley floor before joining the Blackwater River. Beavers have constructed dams on many Canaan Valley streams, flooding stream margins and forming deep pools and wet meadow-marshes. In other areas, particularly in the northern end of the valley, peat bogs have developed where a shallow confining layer of weathered limestone restricts drainage. Stream channels in these areas have cut down below the level of the bog, and at low flow there is little surface contact between the wetlands and the streams.

During the period that was used for calibration and verification of the water quality model, beaver dams in the upper reaches of the Blackwater River significantly impacted the water quality. The West Virginia Division of Environmental Protection reports that those dams are no longer present. See Section 4.1.4 for a discussion of the impacts of the dams and how they were considered in developing this TMDL.

1.5.2 Existing Water Quality Characteristics

The 1996 USGS study produced the most complete set of recent data for the Blackwater River. Values obtained by the USGS for most water quality properties were within the State water quality limits. The maximum measured concentration of dissolved nitrate plus nitrite was 0.6 mg/l, well below the West Virginia water quality standards of 10 mg/l for dissolved nitrate-nitrogen and 0.6 mg/l for dissolved nitrite-nitrogen. The maximum unionized ammonia concentration was 0.01 mg/l, again below the West Virginia water quality standard of 0.05 mg/l. Concentrations of orthophosphorous were low as well with median values of 0.01 mg/l compared to regional values of 0.1 mg/l for the Ohio River. West Virginia has no water quality standard for orthophosphorous.

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[4] Much of the following discussion is taken from the USGS report, *Water Quality and Processes Affecting Dissolved Oxygen Concentrations in the Blackwater River, Canaan Valley, West Virginia*, 1996, page 5.

Analysis of precipitation at the Fernow Experimental Forest in Parsons, West Virginia indicates nitrate-nitrogen concentrations of 1.6 mg/l and dissolved ammonia-nitrogen levels of 0.2 mg/l. These data indicate that precipitation was a major source of inorganic nitrogen in the Canaan Valley during the study period. Seasonal analysis of dissolved nitrogen compared to changes in stream flow show that dissolved nitrogen levels were highest during periods of high stream flow, indicating that the main source of nitrate-nitrogen was surface runoff. A similar pattern was noted for dissolved orthophosphorous.

The West Virginia water quality standard for DO in the Canaan Valley streams is a minimum of 6.0 mg/l. Two sites indicated DO concentrations less than the State standard during the two-year USGS study. A value of 5.5 mg/l was measured on one occasion at the Club Run monitoring site, and concentrations of 5.3 and 5.8 mg/l were measured on five occasions at the Canaan Valley State Park site on the mainstem of the Blackwater River. No other monitoring sites had DO concentrations lower than the West Virginia water quality standard.

USGS also monitored diel changes in DO at three sites on the Blackwater River (Canaan Valley State Park, Cortland, and near Davis) during one of the synoptic surveys. The biggest diurnal swing in DO was observed in the upper reaches of the Blackwater River, where differences between early morning and afternoon DO concentrations of 1.5 to 2.0 mg/l were recorded. The early morning and afternoon differences in DO at the station located near the lower end of the study area were generally less than 1.0 mg/l.

2.0 POLLUTANTS, ENDPOINTS, AND CRITICAL CONDITIONS FOR TMDL DEVELOPMENT

2.1 Pollutants for TMDL Development

TMDLs are to be developed for those waters and pollutants that the State has identified on their most recent section 303(d) list of waters as exceeding or have the potential to exceed existing state water quality standards. West Virginia's 1996 section 303(d) list of waters identifies low dissolved oxygen as the parameter for the Blackwater River that does not attain water quality standards. The State has not included any of the tributaries to the Blackwater River on the most recent list of waters. Therefore, necessary TMDLs have been developed for DO in the Blackwater River mainstem. The TMDL for DO, however, does not include actual limits for DO. Instead, it includes limits for those pollutants that impact the in-stream DO concentrations, namely carbonaceous biochemical oxygen demand (CBOD) and nitrogenous biochemical oxygen demand (NBOD).

2.2 Endpoints for the TMDL

One of the major components of a TMDL is the establishment of in-stream numeric endpoints that are used to evaluate the attainment of acceptable water quality. In-stream numeric endpoints represent the water quality goals that are to be achieved by implementing the load reductions specified in the TMDL. The endpoints allow for a comparison between predicted in-stream conditions and conditions that are expected to restore beneficial uses. The endpoints are usually based on either the narrative or a numeric criteria in the states water quality standard.

For the Blackwater River TMDL, the applicable endpoints can be determined directly from West Virginia's Series 1 Requirements Governing Water Quality Standards Appendix A, for waters designated as category B2, trout waters. The applicable standard for Dissolved Oxygen is not less than 6 mg/l at any time. The allocated loads of CBOD and NBOD will be distributed such that DO levels in the Blackwater River will not be less than 6 mg/l at any time at any point in the study area.

2.3 Critical Conditions for TMDL Development

The critical conditions–the time when violations of water quality standards are most likely to occur–were determined to occur during periods of low flow and high temperatures. These conditions were selected because monitoring data and modeling indicates that the dissolved oxygen in the Blackwater River is lowest during these times. Further, West Virginia's 1996 303 (d) list identified point sources as the primary controllable cause of the low dissolved oxygen, and it is during low flow periods when there may not be adequate water in the channel to dilute these point source loads. Low flow conditions were represented by the 7Q10 flow–the low stream flow that occurs for seven consecutive days once in ten years. The low flows were accompanied by high temperatures during the critical conditions because high temperatures can exacerbate dissolved oxygen problems by increasing the rate of oxygen-consuming chemical transformations in the water.

Federal regulations require that seasonal variation be considered in determining TMDLs. There is no data showing dissolved oxygen problems during any conditions other than low flow and high temperatures found during the summer months. Therefore, conditions found during other seasons were not considered analyzed.

3.0 MODELING PROCEDURE

3.1 Model Selection

The QUAL2E water quality model (version 3.21, 1995) was selected to simulate the hydraulics and water quality of the Blackwater River. QUAL2E is a one dimensional, steady state stream water quality model that can simulate up to 15 water-quality constituents and properties and allows for multiple waste discharges, withdraws, and tributary flows along individual reaches. It has a 15-year history of application and is a proven, effective analysis tool (US EPA 1997). QUAL2E is well suited for the Blackwater River and the analysis necessary to develop a TMDL. The model is designed for rivers like the Blackwater that have no vertical or horizontal stratification, and it simulates the multiple waste dischargers, withdraws, and tributary inflows found in this river.

3.2 Model Set-up, Calibration, and Verification

3.2.1 Overview

EPA relied on the USGS model calibration and verification for this TMDL development study.[5] USGS provided EPA and West Virginia DEP with copies of the model calibration and verification data files for use in this study. EPA believes that the product provided by the USGS is appropriate for use in the development of TMDLs.

The following sections describe the calibration and verification efforts of the USGS. Readers who wish more detailed information are directed to the USGS report *Water Quality and Processes Affecting Dissolved Oxygen Concentrations in the Blackwater River, Canaan Valley, West Virginia*, Marcus C. Waldron and Jeffrey B. Wiley, USGS, Water Resources Investigations Report 95-4142, 1996.

Data used for model calibration and verification were collected by USGS during low-flow synoptic surveys conducted during the following periods:

Calibration:	August 18-19, 1992
First Verification:	July 14-17, 1992
Second Verification:	July 30-August 1, 1991

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[5] Model calibration is the testing or tuning of a model to make it fit a set of field data. Model verification is the testing of the calibrated model against a second set of field data.

During each synoptic survey, 11 mainstem sites, 7 tributary inflows, 16 point sources and 1 withdrawal were sampled at least once. EPA obtained data for eight Blackwater River sampling stations, and used these data to depict the USGS calibration and verification of the water quality model. The calibration and verification curves appear in Appendix A.

The model was calibrated using boundary conditions (flows and constituent concentrations for headwaters, tributaries, point sources, and the single withdrawal) as measured during the August 1992 survey. Model coefficients and rate constants were measured whenever possible, and those that were not measured were set to median values obtained from published ranges. These coefficients were adjusted as necessary, within published ranges, so that the model predictions would closely resemble the August 1992 survey measurements. The calibration curves appear in Appendix A.

The calibrated model was then verified using water-quality data collected from the other two synoptic surveys (July 1992 and July-August 1991). Rate constants and system coefficients were the same as for the calibrated model. Boundary conditions and local meteorological variables were taken from the appropriate survey data set. Model predicted values were compared to measured values for the constituent concentrations to verify that the model adequately simulates environmental processes for the Blackwater River during low flows. The verification curves appear in Appendix A.

3.2.2 General Model Set-up

The modeled section of the Blackwater River is from river mile 32.0, at the headwaters, to river mile 13.6, approximately 2.8 miles above Davis, West Virginia. This distance of 18.4 miles was divided into eleven reaches. Each of these reaches was selected to assure uniform hydraulic and local environmental characteristics within each reach. QUAL2E further divided the eleven reaches into 0.1 mile computational elements that formed the basis for the model's one-dimensional, advection-dispersion calculations. All computational elements in a reach, as required by QUAL2E, were considered to have the same hydrogeometric properties (stream slope, roughness, width and depth, for example) and ecological rate constants (reaeration rate, pollutant decay rate and sediment oxygen demand rate, for example). The tributaries to the Upper Blackwater River were treated in the model as point source loads.

The following constituents were modeled in this study:

1. stream temperature
2. total organic nitrogen
3. total ammonia nitrogen
4. total nitrite nitrogen
5. total nitrate nitrogen

6. dissolved oxygen
7. carbonaceous biochemical oxygen demand

3.2.3 Hydraulics and Discharge

Hydraulic characteristics for the Blackwater River were determined and modeled using equations developed by Leopold and Maddock. In the USGS study, one set of dye measurements was made and time of travel data for upstream and downstream reaches were combined and treated as if they represented measurements made at multiple discharges for the entire study reach. Discharge measurements made during the time of travel study indicated that flow durations were equivalent throughout the basin and travel time data collected on tributaries were combined with data from the mainstem to develop regional hydraulic characteristics relations.

Mainstem hydraulics were affected by the presence of a beaver dam about 0.5 miles upstream from the confluence with Freeland Run. Velocity through this reach under the flow conditions of the dye study was 0.018 feet per second (fps) compared to a velocity of 0.08 fps in the free flowing section downstream. Maximum depth of the pool was about 5 feet compared with depths of 1 foot or less in parts of the river that were not impacted by the dam. Because these data were unique to this particular section of the river, these data were used only to establish the characteristics for the reach impacted by the dam and were not used to determine the regional hydraulic characteristics.

The following equations were used for velocity, width and depth projections:

$V = kQ^m$ - where velocity (V) is in fps

$W = aQ^b$ - where width (W) is in feet, and

$D = cQ^f$ - where depth (D) is in feet

The three equations are related to each other such that the product of the hydraulic geometry coefficients (a*c*k) is one, and the sum of the hydraulic geometry exponents (b+f+m) is also one. These relations and the data from the dye study formed the basis for calculation of hydraulic coefficients used to model the mainstem Blackwater River. The hydraulic coefficients and exponents used in the model are presented in Table 3.1 below.

Table 3.1 Hydraulic Geometry Exponents and Coefficients

Model Reach	Hydraulic geometry coefficient for . .		Hydraulic geometry exponent for . .	
	Velocity (ft/s)	Depth (ft)	Velocity (ft/s)	Depth (ft)
1	0.059	2.050	0.338	0.309
2	0.017	4.316	0.338	0.309
3	0.059	1.014	0.338	0.309
4	0.059	1.014	0.338	0.309
5	0.059	1.014	0.338	0.309
6	0.059	1.014	0.338	0.309
7	0.059	1.014	0.338	0.309
8	0.059	0.723	0.338	0.309
9	0.059	0.723	0.338	0.309
10	0.059	0.723	0.338	0.309
11	0.059	0.723	0.338	0.309

The calibration and verification curves showing stream velocity and flow are presented in Appendix A.

3.2.4 Nitrogenous Biochemical Oxygen Demand

QUAL2E calculates the decay of organic nitrogen to ammonia nitrogen, to nitrite nitrogen, and finally to nitrate nitrogen. It does not include denitrification. USGS set the algae biomass to zero since they observed few phytoplankton algae in the study reach. This did not allow for the uptake of nitrate or ammonia nitrogen by phytoplankton algae. The USGS did observe dense beds of eel grasses and benthic green algae in reach one at the top of the study area. Lessor beds were observed in the middle reaches.

Uptake of ammonia and sloughing of organic nitrogen by benthic algae beds were represented by setting some coefficients for nitrogen transformations to negative values. Reaches 1, 3, 4, 5, and 6 were assigned negative coefficients for organic settling to represent production and sloughing of organic nitrogen by algal beds. Reaches 1, 3, and 4 also were assigned negative values for release of dissolved ammonia thereby representing uptake by benthic algae and aquatic plants in these reaches. USGS assumed that the rates of oxidation of ammonia and nitrite were slower in the reach with the beaver dam because of the reduced turbulence and longer travel times.

Coefficients and rate constants used to simulate nitrogen in the Blackwater River are presented in Table 3.2.

Table 3.2 Coefficients and Rate Constants for Nitrogen

Model Reach	Organic Nitrogen Hydrolysis (1/day)	Organic Nitrogen Settling (1/day)	Ammonia Nitrogen Oxidation (1/day)	Benthic Ammonia Flux (mg/ft2/d)	Nitrite Nitrogen Oxidation (1/day)
1	0.01	-0.20	0.20	-0.10	1.0
2	0.01	0.0	0.10	0.10	0.5
3	0.01	-0.10	0.20	-0.05	1.0
4	0.01	-0.10	0.20	-0.05	1.0
5	0.01	-0.05	0.20	0.0	1.0
6	0.01	-0.05	0.20	0.0	1.0
7	0.01	0.0	0.20	0.0	1.0
8	0.01	0.0	0.20	0.0	1.0
9	0.01	0.0	0.20	0.0	1.0
10	0.01	0.0	0.20	0.0	1.0
11	0.01	0.0	0.20	0.0	1.0

Calibration and verification curves showing the nitrogen series are presented in Appendix A. Agreement between measured and predicted values for ammonia and organic nitrogen was reasonably close given the extremely low values of these constituents. Predicted ammonia concentrations were somewhat lower than measured concentrations for the August 1992 data set, and predicted concentrations were higher than measured for the other two data sets. USGS thought that these differences could be indicative of changes in the distribution or activity of the benthic algae beds.

All measured and predicted nitrite concentrations were lower than the minimum reporting level of 0.01 mg/l. Nitrate concentrations could not be accurately calculated because the river contains little phytoplankton and the model does not provide for benthic nitrate fluxes. Consequently nitrate concentrations continued to increase.

3.2.5 Carbonaceous Biochemical Oxygen Demand and Sediment Oxygen Demand

QUAL2E calculates carbonaceous biochemical oxygen demand (CBOD) from the breakdown of organic carbon using a first order decay rate. USGS used graphical and least squares methods to estimate the decay rate for CBOD. There was close agreement between the two methods which resulted in decay rates that were within published ranges for similar type waters. Table 3.3 shows the CBOD decay and settling coefficients used in the model calibration and verification.

USGS adjusted the sediment oxygen demand (SOD), the rate of oxygen consumption by material decaying on the river bottom, as part of the calibration of the model. Negative values were used to represent photosynthetic DO production by benthic algae and eelgrasses. The dense beds of benthic algae and aquatic plants in many of the upstream reaches were hypothesized by USGS to be the main source of DO in the absence of phytoplankton. Both SOD and photosynthesis would be proceeding simultaneously since the model simulation is limited to mid-day conditions. The SOD rate determined for each reach represents the net result of these two processes.

The SOD rates determined for the calibration and verification data sets are listed in Table 3.3. Reach 1 was adjusted to the largest negative value representing the largest release of oxygen to the stream from the benthic algae and aquatic plants. Reach 2 was adjusted to a positive value representing a reduced light penetration caused by the deeper water behind the beaver dam. Reaches 3 through 11 were adjusted to progressively less negative values until a positive value was used in reach 11.

Table 3.3 CBOD Decay and Settling Rates and SOD Rates

Model Reach	Carbonaceous Biochemical Oxygen Demand		SOD Rate gm/ft2/d
	Decay Coefficient (1/day)	Settling Coefficient (1/day)	
1	0.04	0.0	-0.15
2	0.04	0.0	0.05
3	0.02	0.0	-0.1
4	0.02	0.0	-0.1
5	0.01	0.0	-0.5
6	0.01	0.0	-0.025
7	0.01	0.0	-0.01
8	0.01	0.0	-0.01
9	0.01	0.0	0.0
10	0.01	0.0	0.01
11	0.01	0.0	0.05

CBOD was accurately predicted for the calibration and the two verification data sets. The calibration and verification curves showing CBOD are presented in Appendix A.

3.2.6 Dissolved Oxygen

Reaeration rates were estimated by the USGS based on mean stream velocity and depth using the O'Connor and Dobbins equation. The value of reaeration increases with stream velocity and decreases with increasing mean stream depth. Values computed for the August 1992 calibration data set ranged from 0.10 per day for the reach with the beaver dam to 2.0 per day in other reaches. Values for the July 1992 verification data set were similar. The rates computed for the July 1991 verification data set, however, were somewhat higher. These differences resulted because discharges were lower and the river more shallow during this verification period. The reaeration rates are presented in Table 3.4.

Table 3.4 Range of Calculated Reaeration Rate Coefficients (1/day) using the O'Connor - Dobbins Equation

Model Reach	August 1992	July 1992	July-August 1991
1	0.55 - 0.9	0.59 - 0.84	0.86 - 1.18
2	0.10 - 0.32	0.10 - 0.34	0.15 - 0.51
3	0.86 - 1.51	0.88 - 1.58	1.30 - 2.36
4	1.49 - 1.54	1.58 - 1.60	2.36 - 2.38
5	1.41 - 1.53	1.56 - 1.60	2.29 - 2.40
6	1.40 - 1.41	1.57 - 1.58	2.37 - 2.40
7	1.29 - 1.40	1.40 - 1.57	2.11 - 2.38
8	1.71 - 1.99	1.87 - 2.11	3.06 - 2.79
9	1.88 - 2.00	2.12 - 2.17	3.09 - 3.27
10	1.77 - 2.00	1.89 - 2.16	2.79 - 3.26
11	1.75 - 1.78	1.89 - 1.89	2.887 - 2.97

The calibration and verification curves showing dissolved oxygen are presented in Appendix A.

4.0 ALLOCATION

EPA used the water quality model developed by the USGS to calculate the TMDL and load allocations for the significant pollutant sources in the watershed.

4.1 Model Configuration

The QUAL2E model is designed to represent multiple branches and headwaters in a drainage basin. However, the USGS model was constructed only for the mainstem Blackwater River and did not branch into any of the tributaries. EPA elected not to expand the model into the tributaries because of the time frame for which the Blackwater River TMDL was required to be completed and since only the mainstem river was listed on the section 303(d) list.

4.2 Point Source Considerations

There are fifteen wastewater treatment plants (WWTPs) operating in Canaan Valley. These are regulated by the State of West Virginia through the National Pollutant Discharge Elimination System (NPDES), which is administered by West Virginia DEP's Office of Water Resources. Five of these are regulated by one permit which is issued to Canaan Valley State Park. The remaining eleven individual plants have either individual NPDES permits or are covered under the General Permit.

All but one of the WWTPs in the valley utilize package plants. These are small, prefabricated sewage treatment plants which use the extended aeration process and provide treatment at the secondary level. In the past, DEP recognized a need for further treatment and required all the dischargers in the valley to install additional treatment. The preferred unit for additional treatment has been the sand filter. The other unit common in the valley is a polishing pond. There is one aerated lagoon which achieves the necessary level of treatment without an additional treatment unit.

In addition to the fifteen WWTPs, there are five unused wasteload allocations (WLA) in the valley for which no facility or treatment plant yet exists. In this context, an unused WLA is a document, issued by West Virginia DEP, which states certain wasteload values which are allowable for a particular discharge. It is issued before a facility is built and before a permit is issued. It is used to plan and design wastewater treatment plants. One of the five unused WLAs is issued to a permit holder for an increase over what they are currently permitted to discharge.

In addition to the WWTPs and unused WLAs, there is a water withdrawal in the Canaan Valley State Park. Table 4.1 shows the receiving waters and permit limits for each withdrawal, discharge, and unused WLA.

Table 4.1 Discharges and Unused WLAs in the Blackwater River

Facility Name	Receiving Stream	Unused WLA	Q mgd	DO mg/l	BOD5* mg/l	NH3-N* mg/l
CVSP Cabins	Club Run		0.005	6	5	3
CVSP ski area	Mill Run		0.010	6	5	3
CVSP Campground	Mill Run		0.006	6	5	3
CVSP Withdrawal	Blackwater		0.068			
Oriskany Inn	Coon Run		0.007	6	5	3
Oriskany Inn**	Coon Run	√	0.023	6	5	3
CVSP Lodge and Clubhouse	Blackwater		0.105	6	5	3
Glen Fiddich	Blackwater		0.004	6	5	3
Blackwater Center	Blackwater		0.006	6	5	3
Canaan Vistas	Freeland Run		0.024	7	5	3
Hertz & Reikle	Blackwater	√	0.175	6	5	3
Beal Properties	Blackwater	√	0.1029	7	5	3
Timberline Resort	Yoakum Run		0.066	7	5	3
REC Associates	Blackwater	√	0.1029	6	5	3
Black Bear Resort	N. Branch		0.02	6	5	3
North Point	N. Branch		0.04	6	5	3
Beaver Ridge	N. Branch		0.03	6	5	3
Martin Jefferson	N. Branch	√	0.036	6	5	3
Winwood Fly In Resort	N. Branch		0.055	6	6	3
Deerfield Village	N. Branch		0.03	6	5	3
Canaan Village	N. Branch		0.04	6	5	3

* These permit limits are monthly averages.

** This facility has an unused WLA to increase their discharge above their current limits.

Since the water quality model was not extended in to the tributaries, the WWTPs discharging to the tributaries were not directly accounted for in the model. Instead, these sources were included by using a separate mix calculation of the point source with the receiving tributary. EPA used the conservative approach of calculating the mix concentrations of the point sources and the receiving tributaries at the mouth of the tributaries. These values were then input to the model as a single point source. An allocation was determined for each tributary, which in turn must be reallocated to both the background and point source loading. For example, the discharges on the North Branch were mixed with the background flow and concentration of the tributary. The resulting flow and concentrations were entered into the model as a single point source. Section 4.3 discusses the source of the background concentration data.

4.3 Nonpoint Source Considerations

At the critical conditions of the 7 day 10 year low flow, it was assumed that nonpoint source pollutant contributions were minimal with respect to impacts on the DO of the River. Data available for the Blackwater tend to show that nonpoint sources contribute to pollutant loads found in the River under other conditions. For instance, analysis of precipitation data for the period of the USGS sampling program indicate that precipitation may very well be a major source of inorganic nitrogen in the Canaan Valley. Seasonal analysis of dissolved nitrogen compared to changes to stream flow show that dissolved nitrogen levels were highest during periods of high stream flow, indicating that the main source of nitrate nitrogen was surface runoff. A similar pattern was noted for dissolved orthophosphorous.

For the calibration and verification model runs, the tributary flows and pollutant concentrations were taken from the data collected during the synoptic surveys. This data represented both the point source contributions from the wastewater treatment plants on the tributaries as well as any naturally occurring background loadings. The incremental flows were set to zero meaning that all of the nonpoint source flow and pollutants entering the mainstem of the Blackwater River is by way of the tributaries.

For the development of this TMDL, nonpoint source contributions were considered by assigning background concentrations to the Blackwater River headwaters and the tributary inflows. For the TMDL model runs, the tributaries were considered as point sources on the mainstem and the incremental flows were kept at zero, as was the case for model calibration and verification. As discussed in Section 4.2, the loads from point sources on the tributaries was mixed with the background flow and load and then entered into the model as single point sources.

To estimate the background flows from each tributary, EPA used the ratio of drainage area and 7Q10 flow at the Davis, West Virginia gage and applied it to the drainage area of each tributary. The background pollutant loads for each tributary were assumed to be the same as those reported by the USGS for the headwaters of the Blackwater (above any WWTPs) during the August 1992 calibration period. Table 4.2 presents the background, or nonpoint source loads (including natural loadings), used for the headwaters and the tributaries.

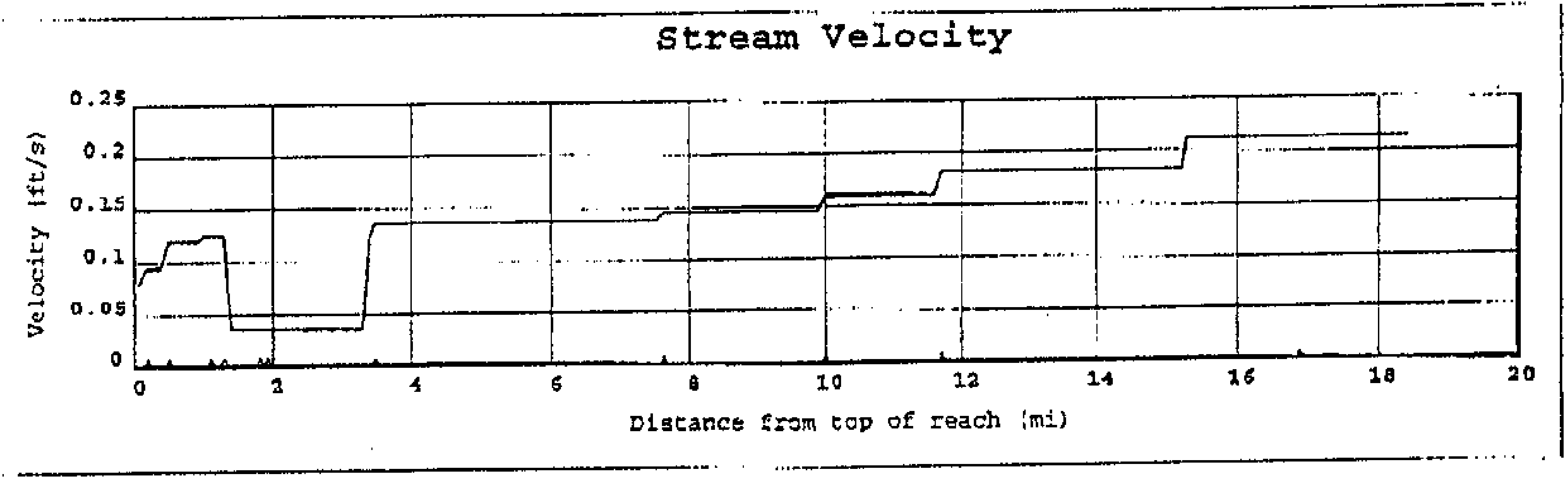
Table 4.2 Nonpoint Source Contributions Used in the Model

Tributary	Q (mgd)	DO (mg/l)	BOD (mg/l)	Org-N (mg/l)	NH3-N (mg/l)
Blackwater Headwater	0.14	6.0	2.3	0.37	0.03
Club Run	0.226	7.6	0.1	0.18	0.02
Mill Run	0.226	7.6	0.1	0.18	0.02
Coon Run	0.0452	7.6	0.1	0.18	0.02
Freeland Run	0.142	7.6	0.1	0.18	0.02
Yoakum Run	0.136	7.6	0.1	0.18	0.02
Sand Run	0.246	7.6	0.1	0.18	0.02
North Branch	0.562	7.6	0.1	0.18	0.02
Little Blackwater	0.970	7.6	0.1	0.18	0.02

4.4 Assumptions and Impacts of Beaver Dams

The water quality data collected by the USGS for the calibration and verification of the QUAL2E model were collected at a time when a beaver dam existed in reach 2 of the Blackwater River. This dam dramatically reduced the velocity of the Blackwater River by widening and deepening the river's channel. Stream velocities in sections of the river not impacted by the dam were recorded at approximately 0.08 feet per second while stream velocities in impounded areas were approximately 0.018 feet per second (USGS, 1996). Nearly an order of magnitude difference, this 77.5% reduction in flow velocity greatly reduces the system oxygen transfer efficiency. Figure 4.1 shows the effect of the beaver dams on stream velocity during the first model verification. With respect to the deepening of the water in the river, many of the actual decay processes occur at the bottom of the system. This decay has an associated oxygen demand and replenishment of the oxygen consumed by the decay is inhibited by the increased depth and compounded by the decreased velocity.

Figure 4.1 Effects of the Beaver Dam on Stream Velocity



Beaver also increase organic matter and elevate stream temperatures, two fundamental control factors in determining dissolved oxygen concentration. They increase the organic matter in the river by virtue of their feeding habits. The organic matter has an associated increase in the waters oxygen demand as the material decays. The beaver feeding habits also contribute to the elevated stream temperatures by removing riparian vegetation, thus decreases stream shading.

Because the model was calibrated and verified using the data collected when the beaver dam existed, the various stream characteristics used in the model are based on the dam being present. According to the West Virginia DEP, this dam does not exist today and these stream characteristics have most likely changed, though EPA has no data to confirm the magnitude of the changes. Without the dams, the water quality conditions in reach 2 are expected to be better than the USGS calibrated and verified model predicts.

Each model run was made both with and without the beaver dams present. In removing the beaver dams from the model, EPA made the assumption that the characteristics of the stream found immediately below the dam would apply in the reach previously impacted by the dam. The hydraulic coefficients, SOD rate, nitrogen and phosphorous rate coefficients, and initial BOD concentrations were adjusted in reach 2 to match those downstream in reach 3.[6]

4.5 Margin of Safety

Federal regulations at 40 CFR 130.7 require that TMDLs include a margin of safety (MOS) which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality. EPA guidance suggests two approaches to meet the MOS requirement. First, the MOS can be met implicitly by using conservative model assumptions to develop allocations. Alternately, it can be met by allocating a portion of the allowable daily load to the MOS.

The margin of safety for this TMDL is implicitly incorporated by using conservative assumptions in the modeling process. The 7 day 10 year low flow stream flow was used to calculate the waste load allocations. This is the minimum flow at which the state water quality standards apply. This flow, statistically, has less than one tenth of one percent chance of occurring for seven consecutive days. Instantaneous flows at the 7Q10 level are more common–on the order of once or twice each year–but still rare. The small possibility of this low flow coinciding with the high temperatures further bolsters the MOS.

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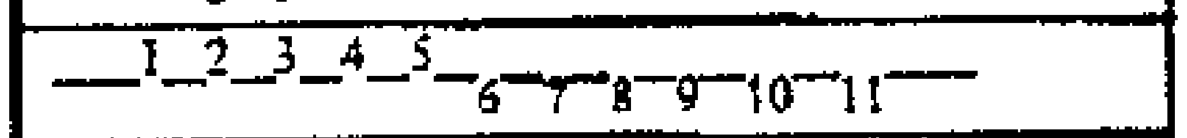
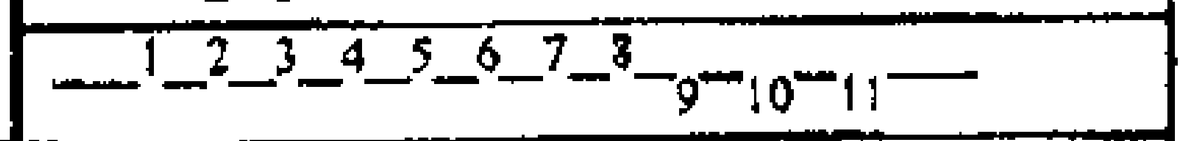
[6] In the *proposed* TMDL, only the hydraulic coefficients were changes when the dams were removed from the model. Based on comments provided by the USGS, who developed the Blackwater model, EPA made the additional adjustments to more accurately reflect conditions when the dams are removed.

4.6 Alternative Management Scenarios

A number of different loading scenarios were simulated in order to assess the relative impact of a variety of management options. Table 4.3 shows the simulation runs. Each possible allocation was run first with the beaver dam present (i.e. #1) and then without the beaver dams (i.e. #1a). Note that when the unused WLAs are "IN", they are treated as existing point sources and are subject to the same reductions as the existing point sources. The last column in the table shows whether the minimum DO predicted in each of the eleven reaches is above or below the water quality standard. For example, an entry reading "$-^{1}-^{2}-_{3}-_{4}-_{5}-_{6}-_{7}-^{8}-_{9}-_{10}-_{11}-$" means that the minimum predicted DO in reaches 1, 2, and 8 is above the standard while the minimum DO in the remaining reaches is below the standard. The goal of the allocation process is to ensure that the DO is above the standard in all eleven reaches, a result which would have the following entry in the table: "$-^{1}-^{2}-^{3}-^{4}-^{5}-^{6}-^{7}-^{8}-^{9}-^{10}-^{11}-$".

Table 4.3 Alternative Loading Scenarios and Predicted DO

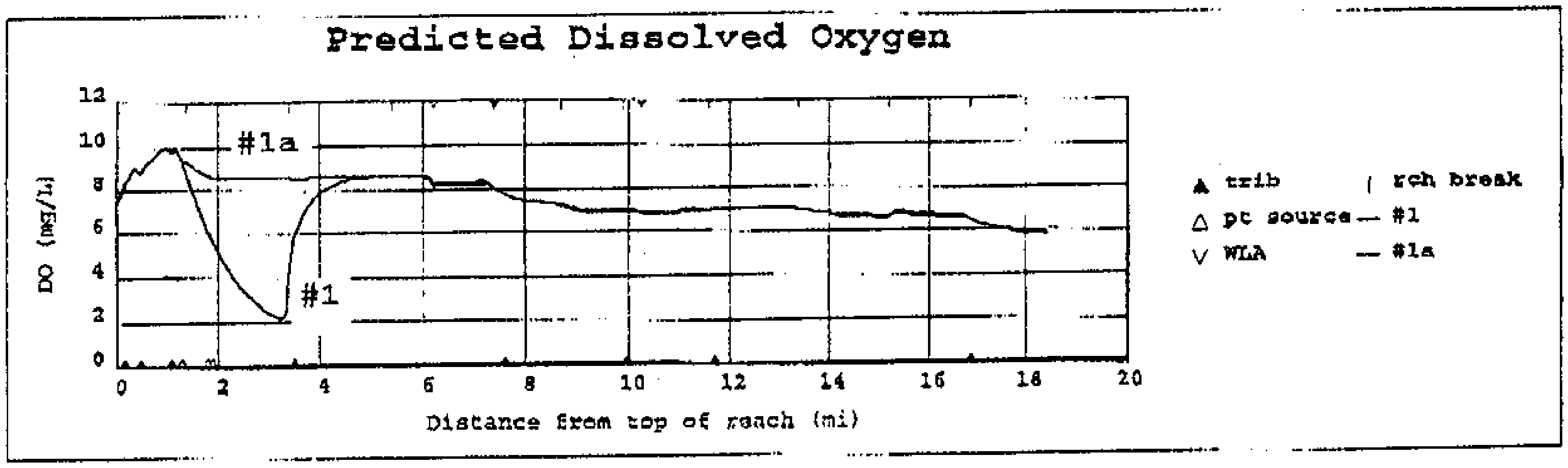
#	Dams	Flow	Point Source % Reduction			Unused WLAs	Predicted DO: above or below standard for the eleven model reaches
			R1-R2	R3-R11	CVSP Lodge		
1	Y	7Q10	0%	0%	0%	IN	$-^{1}-_{2}-_{3}-^{4}-^{5}-_{6}-_{7}-_{8}-_{9}-_{10}-_{11}-$
1a	N						$-^{1}-^{2}-^{3}-^{4}-^{5}-_{6}-_{7}-_{8}-_{9}-_{10}-_{11}-$
2	Y	7Q10	100%	100%	100%	OUT	$-^{1}-_{2}-_{3}-^{4}-^{5}-^{6}-^{7}-^{8}-_{9}-_{10}-_{11}-$
2a	N						$-^{1}-^{2}-^{3}-^{4}-^{5}-^{6}-^{7}-^{8}-_{9}-_{10}-_{11}-$
3	Y	7Q10	0%	0%	0%	OUT	$-^{1}-_{2}-_{3}-^{4}-^{5}-^{6}-^{7}-^{8}-_{9}-_{10}-_{11}-$
3a	N						$-^{1}-^{2}-^{3}-^{4}-^{5}-^{6}-^{7}-^{8}-_{9}-_{10}-_{11}-$
4	Y	7Q10	50%	50%	50%	IN	$-^{1}-_{2}-_{3}-^{4}-^{5}-^{6}-^{7}-^{8}-_{9}-_{10}-_{11}-$
4a	N						$-^{1}-^{2}-^{3}-^{4}-^{5}-^{6}-_{7}-^{8}-_{9}-_{10}-_{11}-$
5	Y	7Q10	50%	50%	50%	OUT	$-^{1}-_{2}-_{3}-^{4}-^{5}-^{6}-^{7}-^{8}-_{9}-_{10}-_{11}-$
5a	N						$-^{1}-^{2}-^{3}-^{4}-^{5}-^{6}-^{7}-^{8}-_{9}-_{10}-_{11}-$
6	Y	7Q10	0%	0%	75%	IN	$-^{1}-_{2}-_{3}-^{4}-^{5}-_{6}-_{7}-_{8}-_{9}-_{10}-_{11}-$
6a	N						$-^{1}-^{2}-^{3}-^{4}-^{5}-_{6}-_{7}-_{8}-_{9}-_{10}-_{11}-$
7	Y	4 x 7Q10	0%	0%	0%	IN	$-^{1}-_{2}-_{3}-^{4}-^{5}-^{6}-^{7}-^{8}-_{9}-_{10}-_{11}-$
7a	N						$-^{1}-^{2}-^{3}-^{4}-^{5}-^{6}-^{7}-^{8}-_{9}-_{10}-_{11}-$
8	Y	5 x 7Q10	0%	0%	0%	IN	$-^{1}-_{2}-_{3}-^{4}-^{5}-^{6}-^{7}-^{8}-_{9}-_{10}-_{11}-$
8a	N						$-^{1}-^{2}-^{3}-^{4}-^{5}-^{6}-^{7}-^{8}-_{9}-_{10}-_{11}-$
9	Y	7Q10	50%	50%	75%	IN	$-^{1}-_{2}-_{3}-^{4}-^{5}-^{6}-^{7}-^{8}-_{9}-_{10}-_{11}-$
9a	N						$-^{1}-^{2}-^{3}-^{4}-^{5}-^{6}-_{7}-^{8}-_{9}-_{10}-_{11}-$

#	Dams	Flow	Point Source % Reduction			Unused WLAs	Predicted DO: above or below standard for the eleven model reaches
			R1-R2	R3-R11	CVSP Lodge		
10	Y	7Q10	50%	0%	75%	IN	
10a	N						
11	Y	7Q10	50%	50%	75%	OUT	
11a	N						
13	Y	7Q10	50% DO=7	50% DO=7	75% DO=7	IN	
13a	N						
15	Y	7Q10	50%	0%	75%	OUT	
15a	N						
16	Y	7Q10	50% DO=7	0% DO=7	75% DO=7	IN	
16a	N						
17	Y	7Q10	0%	50%	0%	IN	
17a	N						
18	Y	7Q10	50%	0%	50%	IN	
18a	N						

4.6.1 Base Run–Existing Conditions

Run #1 and #1a represent the base or existing conditions. The results of the other potential loading scenarios will be compared to these runs. To generate the base run, the stream flow was assumed to be at the 7Q10 level. All point source dischargers (in Reaches 1-2, 3-11, and the CVSP Lodge) and unused WLAs were assumed to be discharging at their permit limits. Figure 4.2 shows the predicted DO under these conditions both with and without the beaver dams present.

Figure 4.2 Predicted DO for base run with and without beaver dams (Runs #1 and #1a)

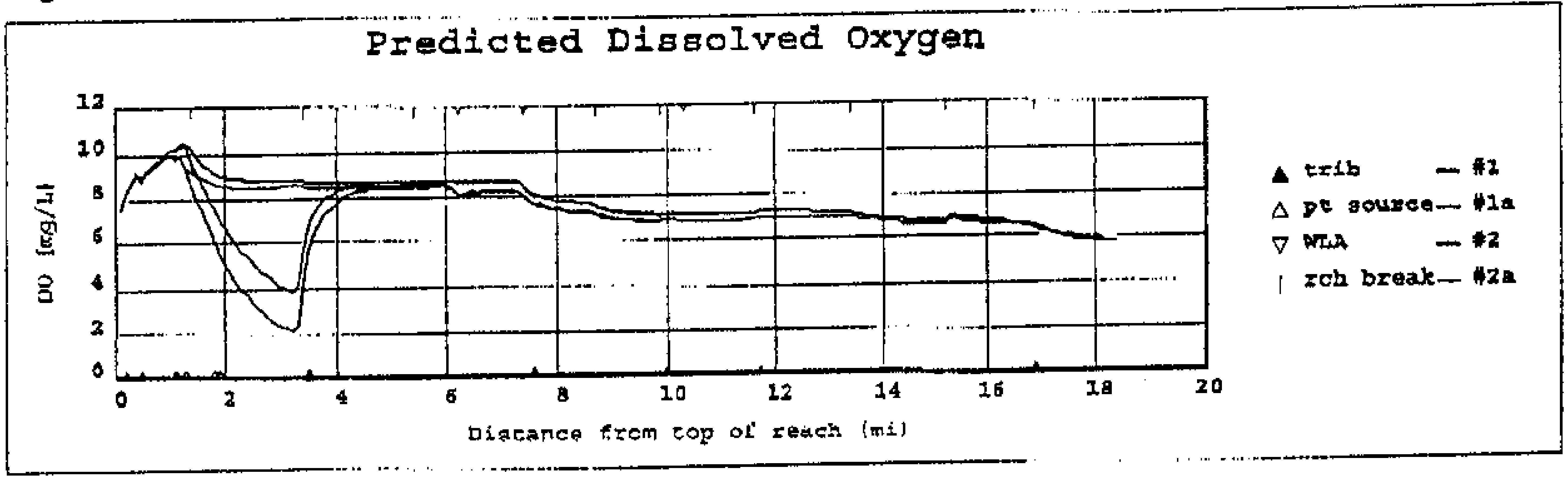


The model predicts the average daily DO in the river rather than the instantaneous minimum. Monitoring data show the diurnal variation in DO is approximately 1 mg/l about the mean. Therefore, model results must show a dissolved oxygen of at least 7.0 mg/l to ensure that the standard, an instantaneous minimum of 6.0 mg/l, is met. As Figure 4.2 shows, with dams present, under existing loading conditions, the DO standard is not met in model reaches 2 - 3 and 6 - 11. Without the beaver dams, the DO increases above the standard in the upper reaches but is still too low in reaches 6 - 11.

4.6.2 Removing All Point Sources and Wasteload Allocations

In Runs #2 and #2a, all point source discharges and unused WLAs are removed from the system. The only pollutant load that remains is the natural background contribution from the headwaters and the tributaries. Figure 4.3 shows the resulting DO and, for comparison, the predicted DO when the dischargers and unused WLAs are at permitted loads (Run #1 and #1a).

Figure 4.3 Impact of Removing all Points Sources and unused WLAs



With all discharges and unused WLAs removed and the dams removed, the DO remains above the standard in all but the lowest three reaches (reaches 9-11, approximately five miles of the study area). With or without these sources, the DO concentration falls below 7.0 mg/l in these lower reaches, thus violating the standard.[7] Figure 4.3 also shows that in these downstream reaches the dischargers have a negligible impact. That is, the dischargers are not making a bad situation worse. It can be concluded that the effluent from the point sources has been largely assimilated prior to reaching the downstream area, and background natural conditions are causing the violation of the DO standard in those lower reaches. It is believed that the dissolved oxygen violations are a result of several natural processes including oxygen demand from the bog plant and algae species, elevated temperatures due to the (natural) lack of stream shading, and low stream gradient. Because of this negligible impact by the point sources in the lower reaches, further discussion of the TMDL alternatives will focus on the upper (1-2) and middle (3-8) reaches of the Blackwater River.

4.6.3 Impacts of Beaver Dams

Figure 4.2 shows that when the point sources are at full strength and the beaver dam is present, the DO drops to approximately 2.2 mg/l in reach 2, well below the water quality standard. However, when the dam is removed, the minimum DO in that section is approximately 8.5 mg/l. Had removing the dams still not brought the DO above the standard it would have been necessary to pursue a loading scenario that would bring the DO up to the standard in this section. Since the beaver dams are no longer present and the model shows the DO standard is met in the upper reaches (where the dams were), there is no need to pursue load reductions to improve the upper two reaches.[8]

Nonetheless, each loading scenario was run both with and without the dams, primarily for illustrative purposes. The runs with the dams illustrate the dramatic effect that naturally occurring conditions in the Canaan Valley can have on the water quality of the Blackwater River. These model runs also illustrate that under some loading scenarios, removing the dams results in the upstream dischargers having an impact at points downstream that they did not impact when

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[7] Recall that the model predicts the average daily DO in the river rather than the instantaneous minimum. Monitoring data show the diurnal variation in DO is approximately 1 mg/l about the mean. Therefore, model results must show a dissolved oxygen of at least 7.0 mg/l to ensure that the standard, an instantaneous minimum of 6.0 mg/l, is met.

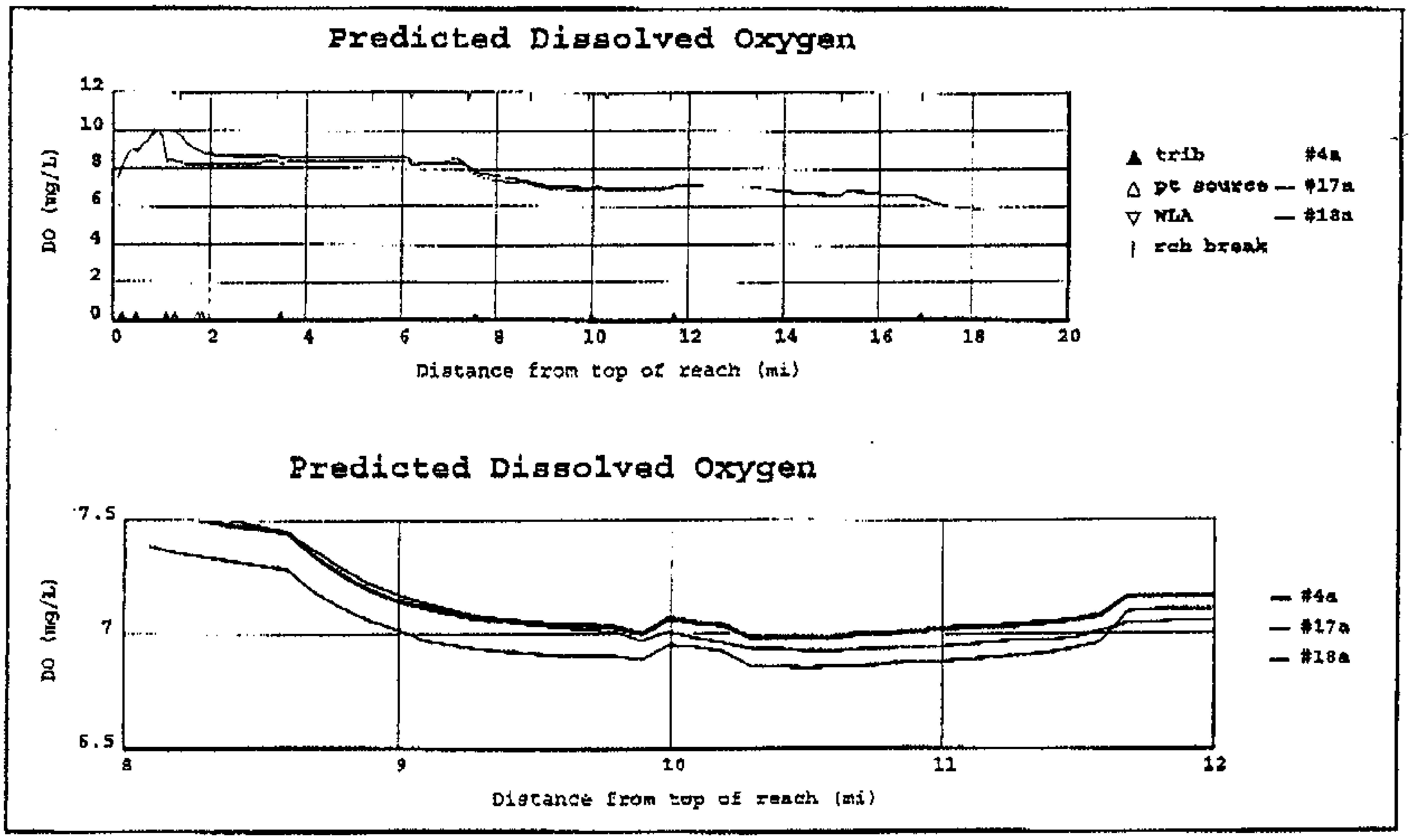
[8] In the modeling done for the *proposed* TMDL, removing the dams resulted in a DO that was still below the standard. Therefore, it was necessary to pursue load reductions to raise the DO in the upper reaches. The USGS provided comments suggesting a more accurate method of modeling the river with the beaver dams removed. EPA incorporated the USGS comments in the modeling for this *final* TMDL. Using this different approach (see Section 4.4), the model predicts that removing the beaver dams improves conditions in the river more than was predicted in the proposed TMDL.

the dams were present. This is a result of increased stream velocity and decreased settling rates that cause the effluent from the upstream dischargers to be carried further downstream before it is fully assimilated.

4.6.4 Point Source Reductions

A number of additional simulation runs were conducted to assess the impact of reducing point source loads. With the exception of model runs #13 and #14, the loads from the point sources were reduced by changing the *volume* of discharge. The *concentration* of pollutants in the effluent was kept at the permit limits. Preliminary analysis showed that flow reductions had a significantly greater impact on DO levels than did reductions in effluent concentrations. Figure 4.4 shows the results (without dams) of model run #4a (all point sources reduced 50%), #18a (only point sources in reaches 1 - 2 reduced 50%), and #17a (only point sources in reaches 3 - 11 reduced 50%).

Figure 4.4 Impact of Reducing Point Source Loads on DO



Predicted Dissolved Oxygen

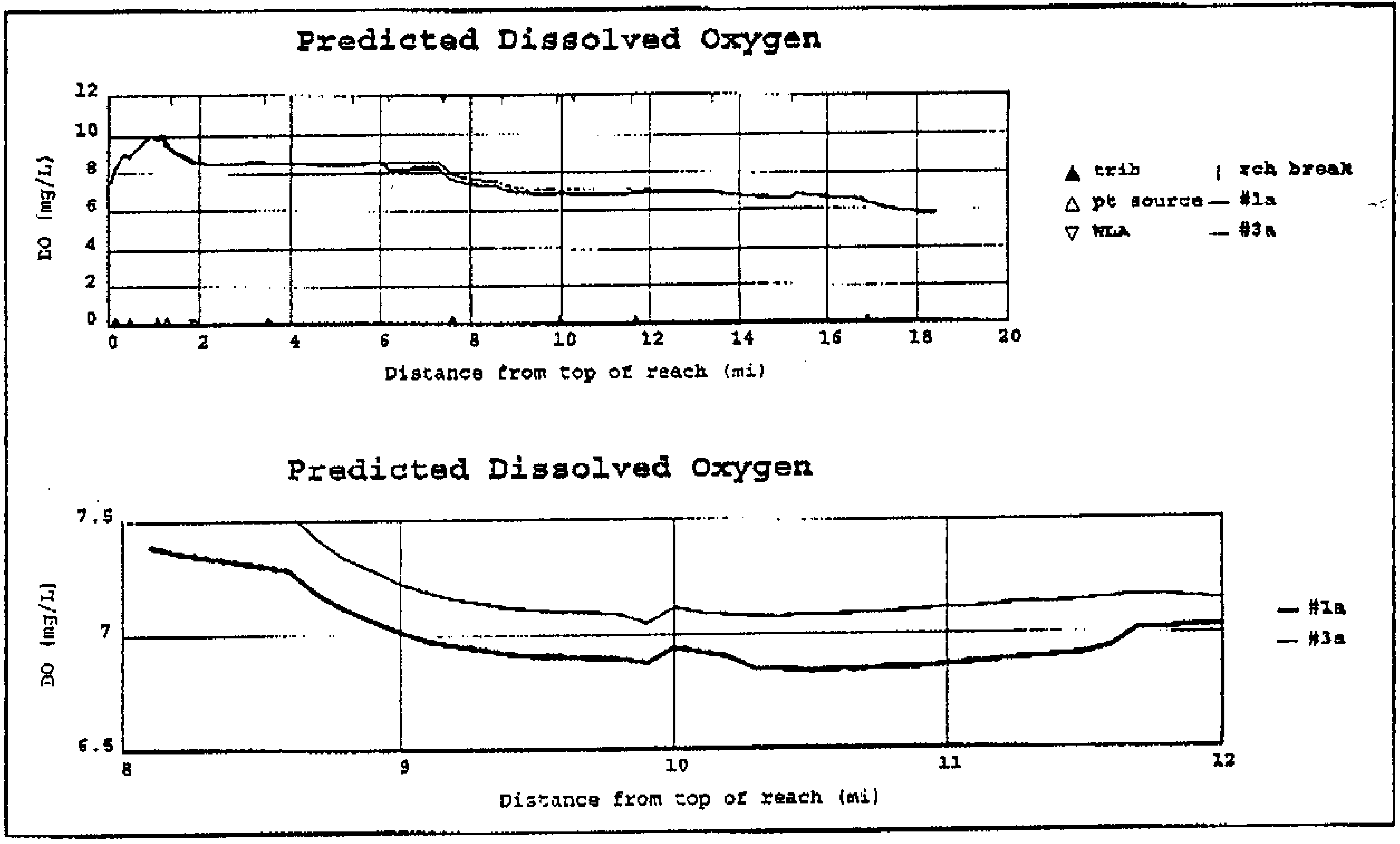
Predicted Dissolved Oxygen

Neither reducing the point source discharges by fifty percent in reaches 1 and 2 (run #18) nor reaches 3 - 11 (run #17) will raise the DO above the standard. However if all dischargers in all reaches (including the currently unused WLAs) are reduced fifty percent, the DO standard is met.

4.6.5 Unused Waste Load Allocations

West Virginia DEP has issued waste load allocations (WLA) to future point sources. These WLAs are, as of now, unused. It was desired to observe the impact on the River's DO resources if these unused allocations were removed. Figure 4.5 compares the results of run #3a, in which the unused WLAs are removed, and the base run (run #1a). With the unused WLAs removed, the DO increases above the standard in reaches 6 through 8. As discussed in Section 4.3.2, the DO in reaches 9 through 11 is below the standard even when all point sources and unused WLAs are removed. In other words, removing the unused WLAs brings the DO above the standard in all reaches where point source loads contribute to low DO.

Figure 4.5 Impact of unused WLAs on the Dissolved Oxygen



4.7 Summary of DO Impacts from Allocation Options

We refer the reader back to Table 4.3 which lists the model runs and shows in which of the eleven model reaches the DO remains above the standard. None of the scenarios result in the DO being above the standard in all eleven reaches. As discussed previously, even complete removal of all human-induced pollutant loads will not raise the DO above the standard in the lower reaches of the river (reaches 9 through 11). The DO deficit there is attributed to natural conditions, and our efforts will focus on improving the DO elsewhere where point source loads have an impact.

With the beaver dams removed, the river meets the DO standard reaches 1 and 2. The DO in reaches 6 through 8 is below the standard under existing conditions but can be raised through a number of different loading scenarios. These scenarios call for reductions from point source loads, elimination of unused WLAs, and combinations of both.

4.8 Final Loading Scenario

Model run #3a was selected as the final loading scenario for this TMDL. In this scenario, all five unused WLAs in the watershed are removed. The existing point source dischargers remain with no reduction in their permitted loads.

The predicted DO for the selected scenario (run #3a) was shown previously in Figure 4.5. To summarize, removing the unused WLAs from the river results in the DO remaining above the standard for the entire river except the three most downstream reaches. As has been discussed, that downstream drop in DO is the result of natural conditions; no change in human-induced pollutant loads will raise the DO there.

TMDLs are to be developed so that water quality standards will be met after implementation of the TMDL. The selected scenario meets this requirement. The TMDLs must also have a reasonable chance of being implemented. The West Virginia DEP issues WLAs for six months periods at which time they must be used or renewed. All five unused WLAs have expired, and applications for renewal have been put on hold pending the outcome of this TMDL.

Interested parties may elect to reevaluate the existing water quality standard for DO on sections of the Upper Blackwater River. The water is classified as trout water with a minimum DO standard of 6 mg/l. However, it is believed that dissolved oxygen violations that have been observed are a result not only of point source loads but also several natural processes including oxygen demand from the bog plant and algae species, elevated temperatures due to the (natural) lack of stream shading, low stream gradient, and beaver ponds. The model projections show that point sources have a negligible impact on DO in the lower reaches; the modeling shows that natural occurring conditions in these lower reaches contribute to DO concentrations below the minimum of 6 mg/l. Interested parties might consider reevaluating the DO criteria for this section of the Blackwater River through a Use Attainability Analysis and make modifications, if necessary, to the numeric criteria and designated uses.

4.9 Calculating the TMDL

The TMDLs for the Blackwater River are for CBOD5 and NBOD.[9] The TMDLs were derived by multiplying the flow by the pollutant concentration for each tributary or point source on the Blackwater River during the selected loading scenario. The loads originating from point sources make up the waste load allocation (WLA). The load associated with natural background concentrations make up the load allocation (LA). Table 4.5 shows the WLAs, LAs, and TMDLs for CBOD5 and NBOD.

Table 4.4 WLAs, LAs, and the TMDLs for BOD5 and NBOD

Source	CBOD5 (lb/day)			NBOD (lb/day)		
	WLA	LA	TMDL	WLA	LA	TMDL
WLAs, LAs, and TMDLs	19.14	4.83	23.97	68.36	21.62	89.98

Table 4.5 shows the individual sources of pollutants that compose the overall WLAs, LAs, and TMDLs shown in the previous table. The numbers that were used to calculate the values in Table 4.5 are presented in Appendix C.

Table 4.5 WLAs and LAs for the significant Pollutant Sources

Source	CBOD5 (lb/day)			NBOD (lb/day)		
	WLA	LA	TMDL	WLA	LA	TMDL
Background on Blackwater Mainstem	n/a	2.69	2.69	n/a	2.13	2.13
Dischargers on Blackwater Mainstem	4.80	n/a	4.80	17.55	n/a	17.55
Club Run	0.21	0.19	0.40	0.76	1.73	2.49
Mill Run	0.67	0.19	0.86	2.45	1.73	4.18
Coon Run	0.29	0.04	0.33	1.07	0.35	1.42
Freeland Run	1.00	0.12	1.12	3.66	1.08	4.74
Yoakum Run	2.75	0.11	2.86	10.07	1.04	11.11
Sand Run	0.00	0.21	0.21	0.00	1.87	1.87
North Branch Blackwater River	9.42	0.47	9.89	32.80	4.29	37.09
Little Blackwater River	0.00	0.81	0.81	0.00	7.40	7.40
TOTAL	19.14	4.83	23.97	68.36	21.62	89.98

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[9] CBOD5 is a measure of the quantity of oxygen consumed during the first five days during the biological breakdown of carbonaceous material. NBOD is a measure of the quantity of oxygen consumed by the conversion of organic nitrogen to ammonia, then to nitrite, and finally to nitrate.

The spatial distribution of the TMDLs is as important as the quantities themselves. That is, the TMDL will only protect water quality if the locations at which the allowable loads are input to the system is taken into account. For instance, if the entire allowable load of NBOD is discharged at a single point on the stream, the DO standard could be violated. Therefore, these TMDLs are valid only if the location of the loads remains relatively constant. For example, the TMDLs may not be protective of water quality if a discharger on the Blackwater mainstem moves his operation to a different point on the river; the daily load to the stream would remain the same but the change of location may negatively impact the river.

If in the future, dischargers in the Canaan Valley propose to add or to relocated loads on the mainstem of the Blackwater River, the model would need to be rerun to assess the impact. In addition, if dischargers are interested in trading wasteload allocations between existing sources, the West Virginia DEP can rerun the model to assess the impact.

The situation is different for loads originating from the tributaries. As discussed in Section 4.2, all dischargers on a tributary were assumed to be discharging at that tributaries mouth. The resulting load was calculated and then input into the model as a single point source. The location (as we have represented it in this analysis) of the point source loads sited on the tributaries has no bearing on the water quality in the Blackwater. The WLA assigned to each tributary can be divided between the existing point sources in any manner as long as the WLA for that tributary is not exceeded. Additionally, new WLAs could be granted on a tributary but the new allocation would have to be deducted from the existing source. Again, the WLA for the tributary cannot be exceeded, but the location on the tributary is not important for the water quality in the Blackwater River.

5.0 MODEL LIMITATIONS AND RECOMMENDATIONS

There are a number of uncertainties in the development of this TMDL. The most significant are discussed below. The margin of safety (Section 4.2) is meant to account for these uncertainties.

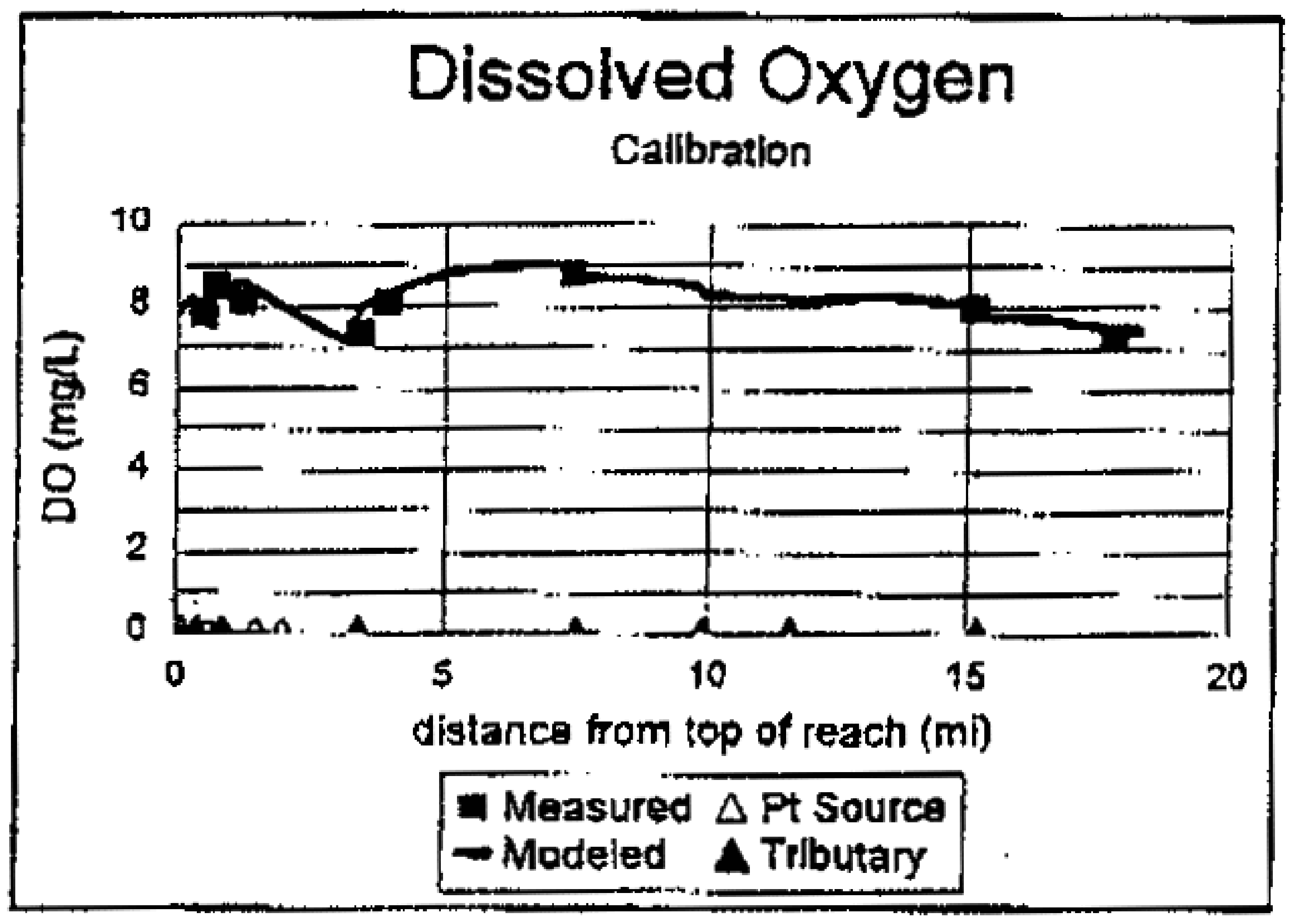
No sediment oxygen demand (SOD) measurements were taken by USGS when they developed the QUAL2E model of the Blackwater. Instead, SOD was used as a tuning parameter to obtain proper model-observed dissolved oxygen agreement. The USGS report states that "the SOD rate coefficients were adjusted to reflect the expected balance between benthic oxygen production and benthic oxygen consumption." The modelers used SOD to account for the impact of benthic algae. A better approach, though out of the scope of the USGS's efforts, would have been to incorporate a benthic algae sub-model into QUAL2E to account for the impacts of nutrient concentration and solar radiation on benthic algae oxygen production and consumption.

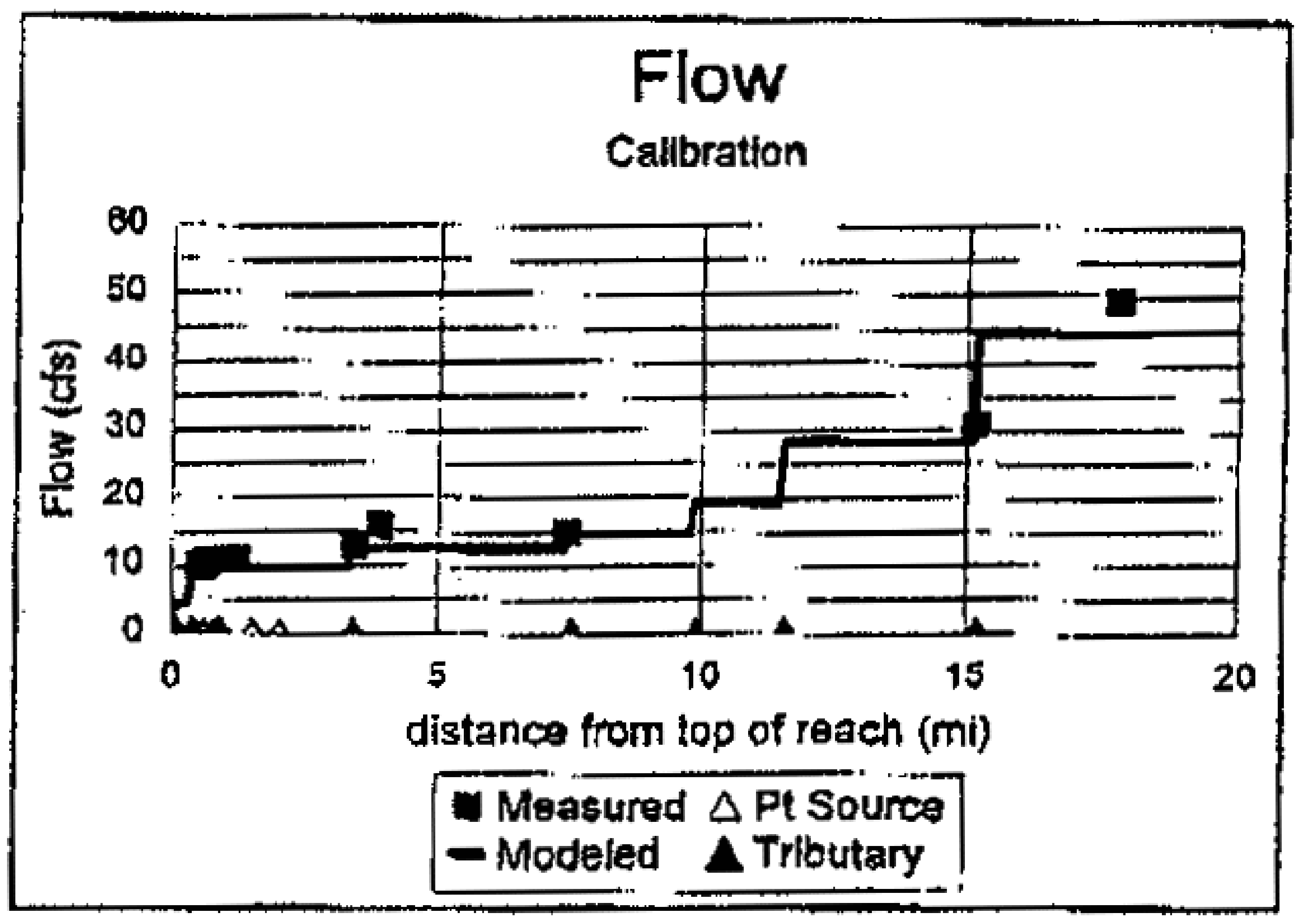
The synoptic surveys were conducted during a period when beaver dams were prevalent in reach 2 of the Blackwater River and having a dramatic impact on that portion of the river. In removing the dams from the model to simulate the conditions that exist today, EPA assumed the characteristics of the previously dammed reach were the same as those of the adjacent downstream reach that was not dammed. While EPA believes this approach is appropriate, we acknowledge that it adds some uncertainty to the model.

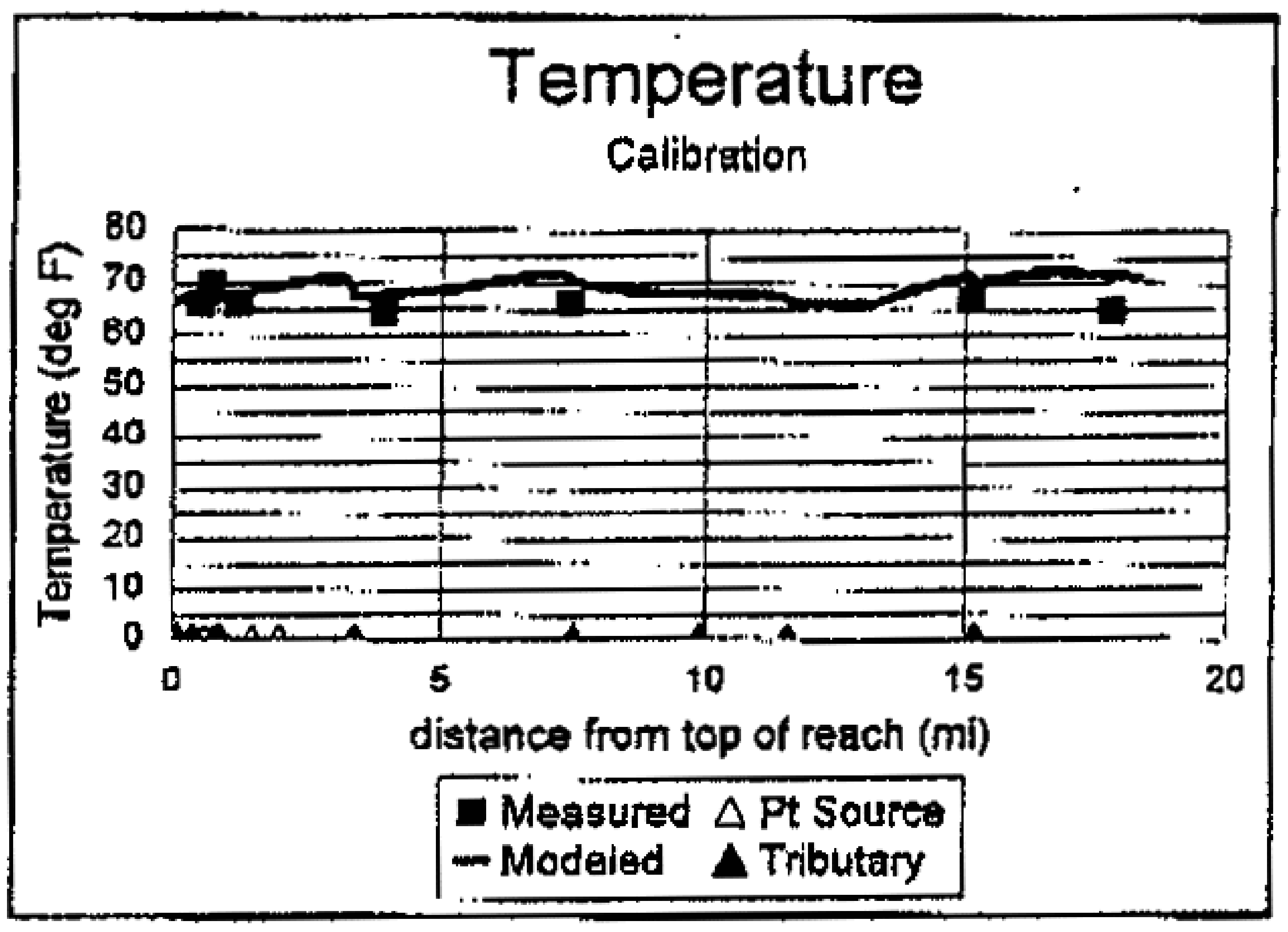
The model was developed as a main stem configuration only. A number of point sources discharge to the tributaries of the Blackwater River. In order to include these facilities in the calculations, EPA had to calculate loadings based on a mass balance of the background tributary load plus the point source load. Direct allocations to the point sources were not possible.

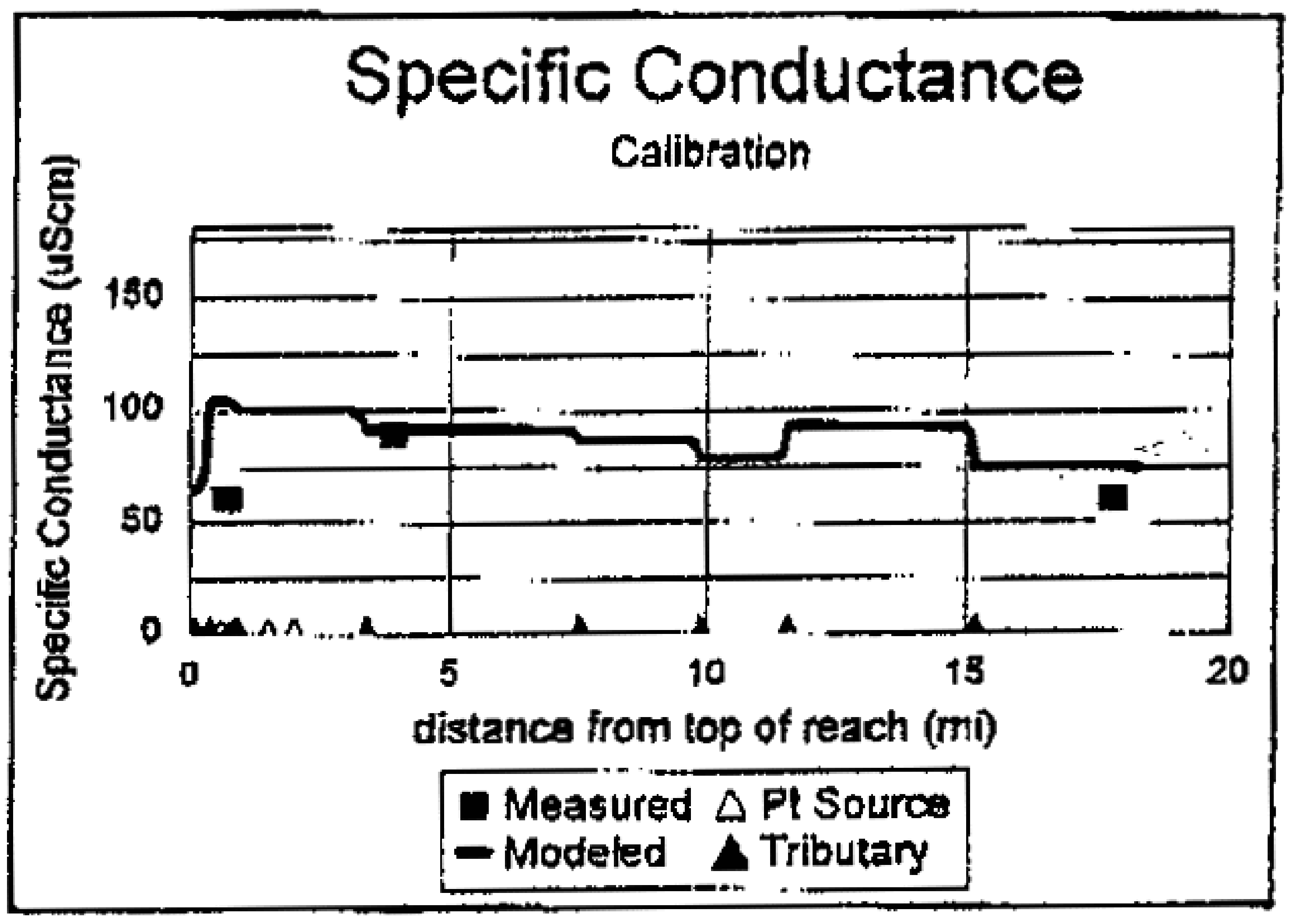
Appendix A Calibration and Verification Curves

Calibration Curves with data collected 8/18-19/1992

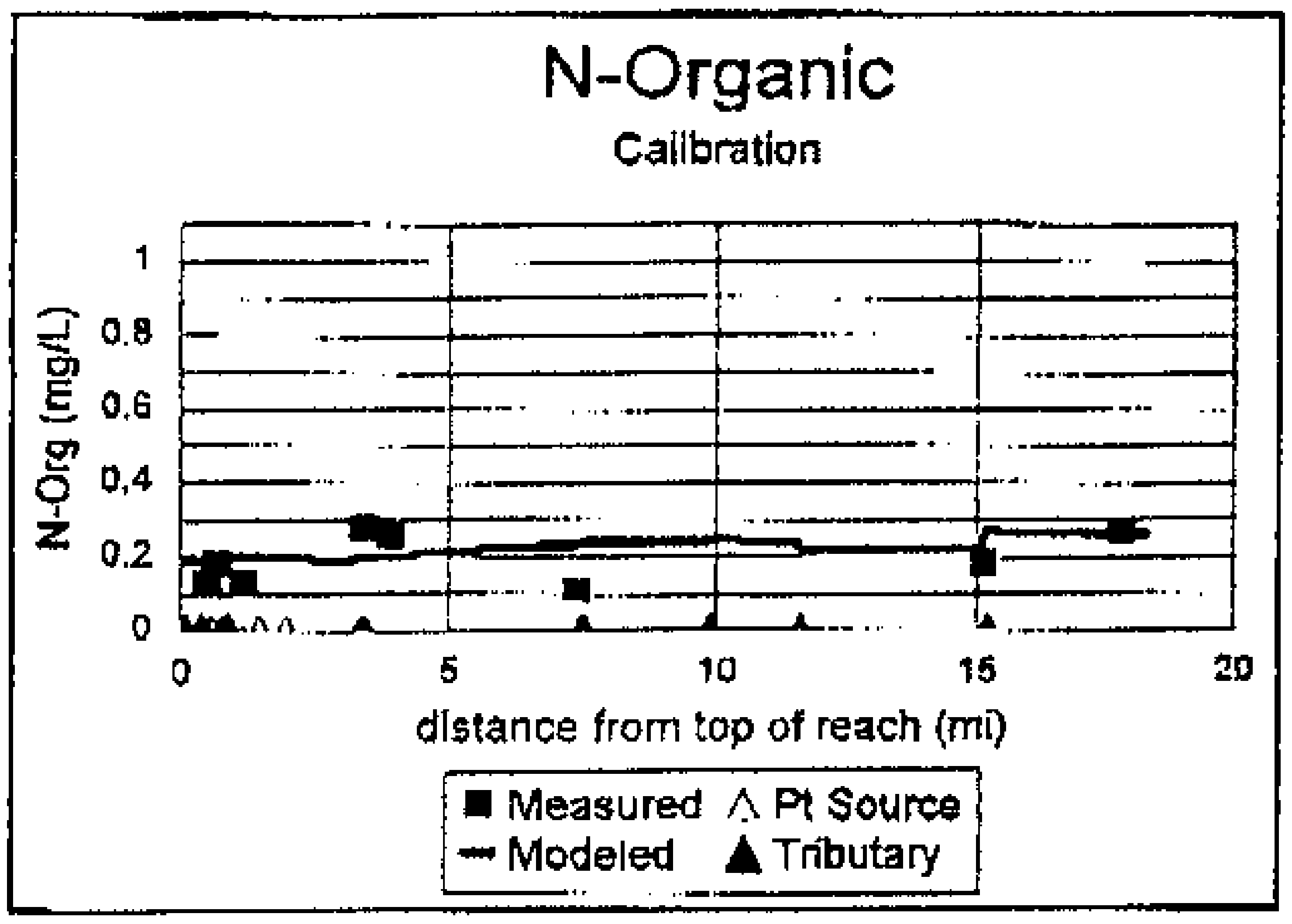


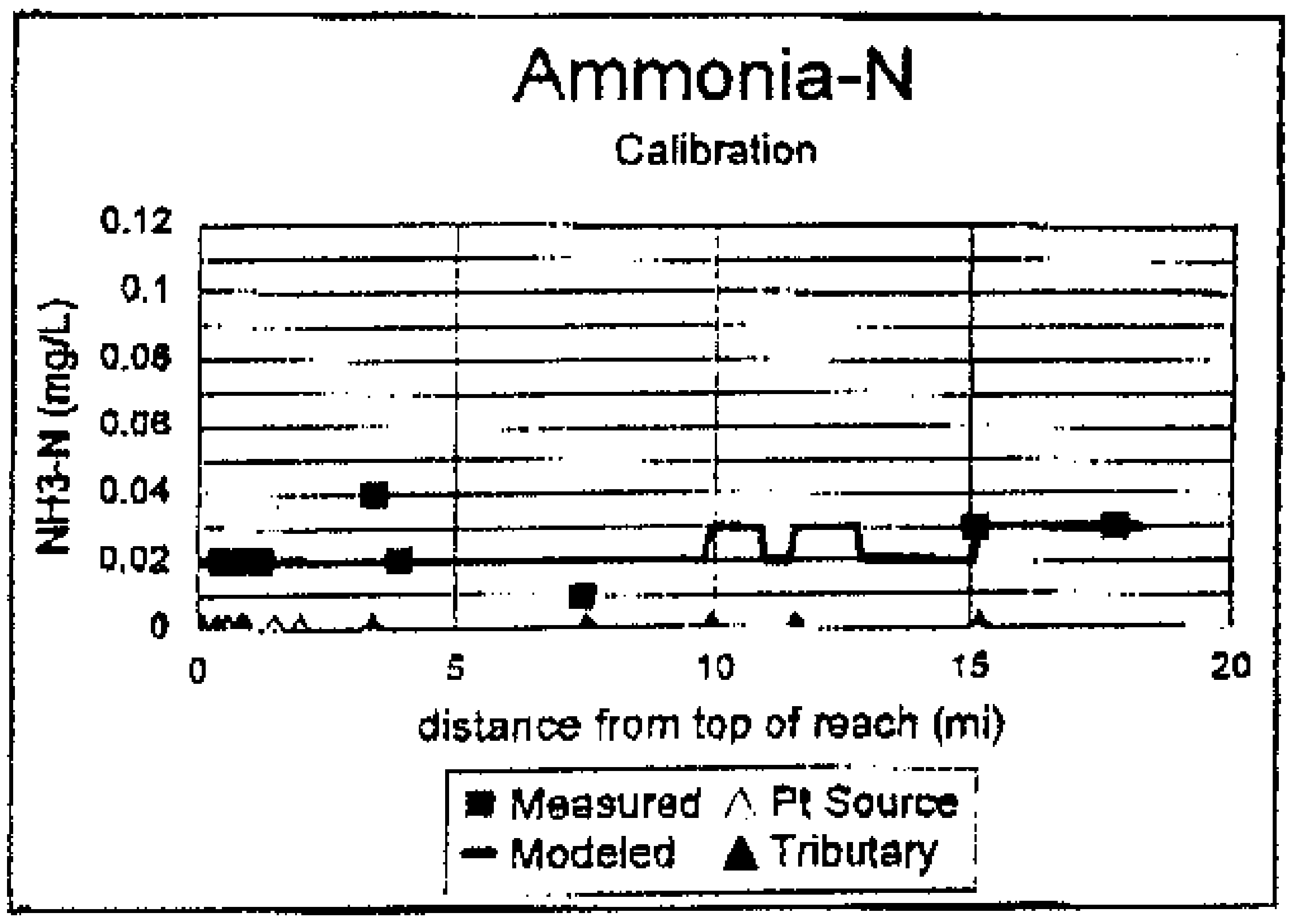


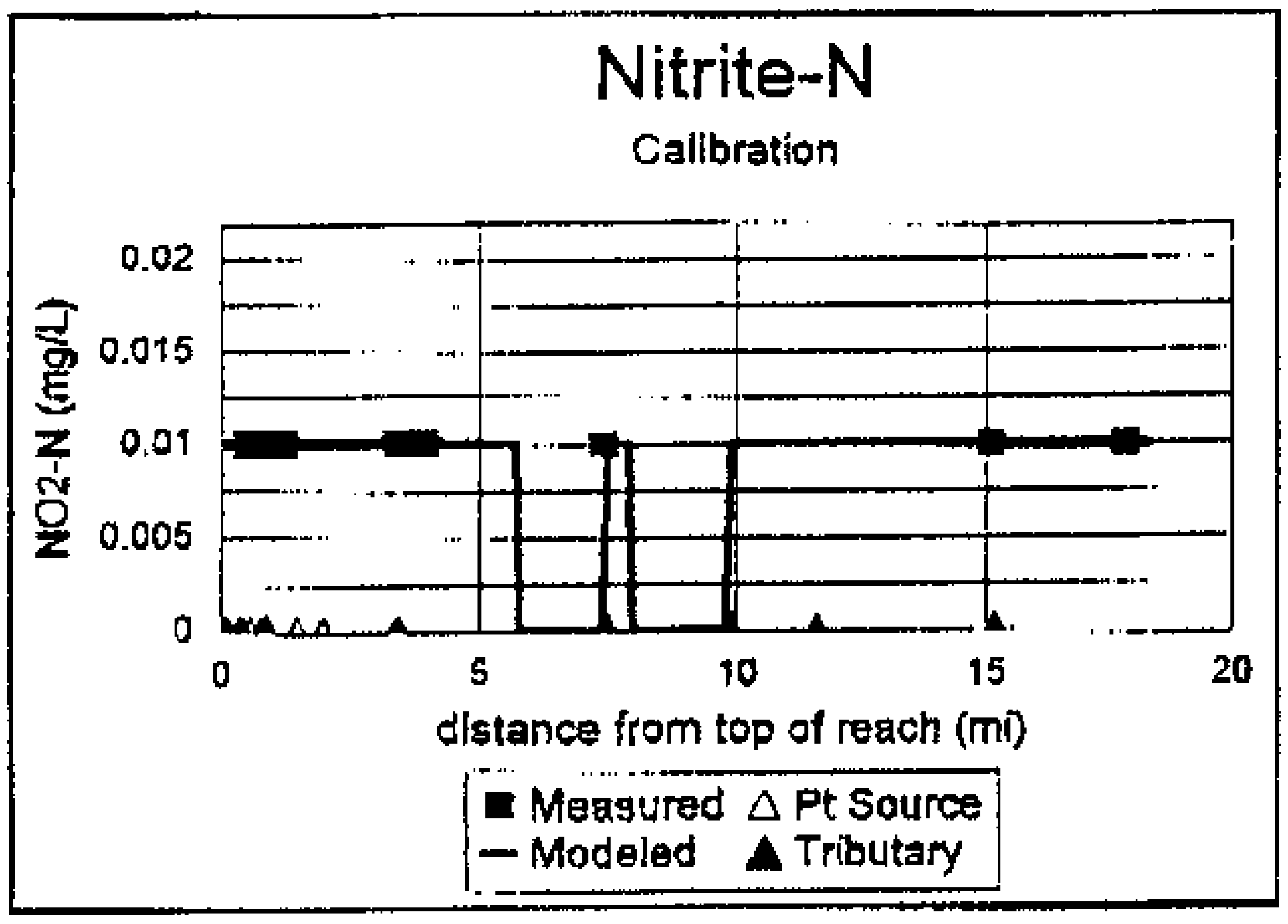


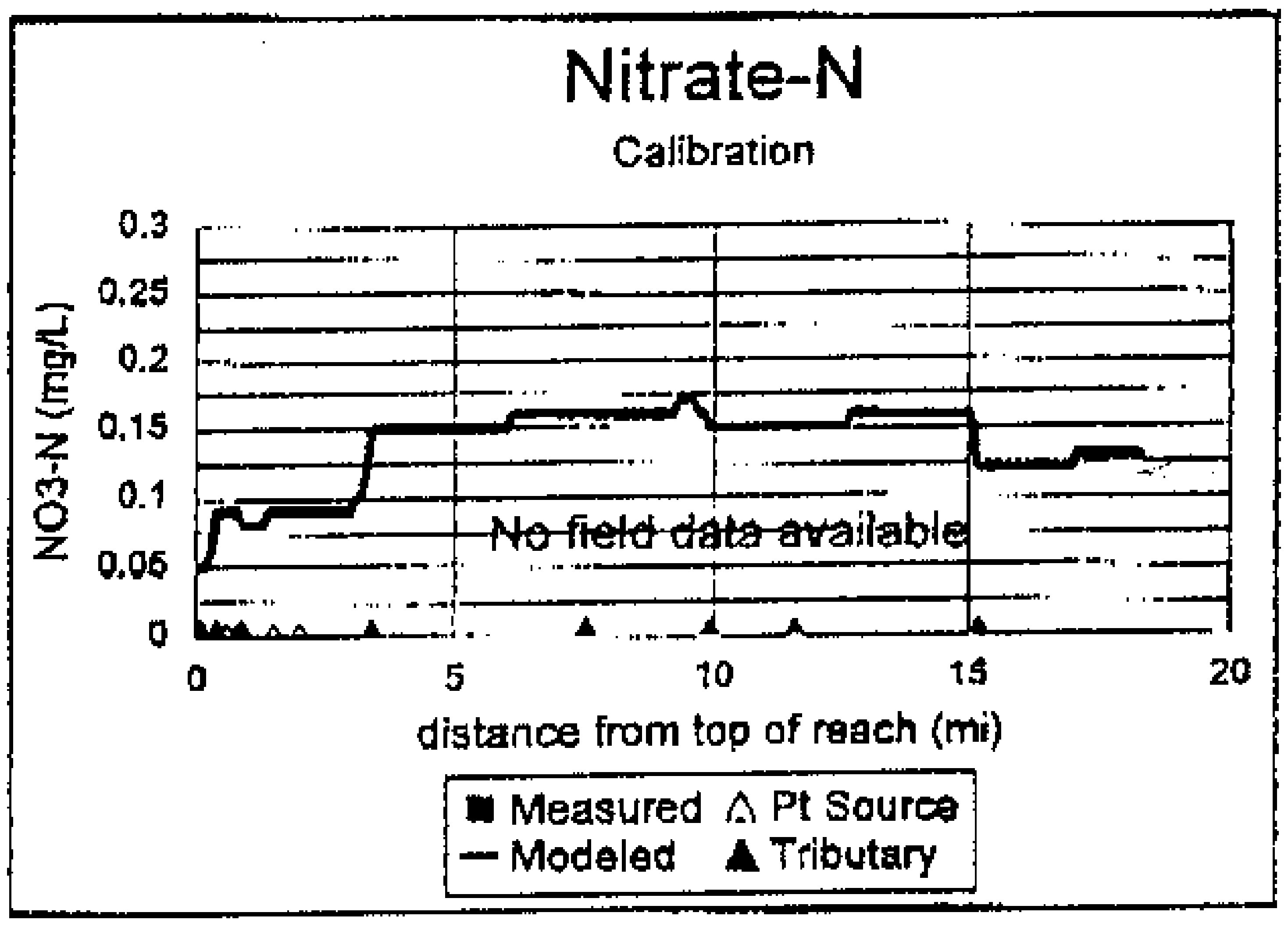


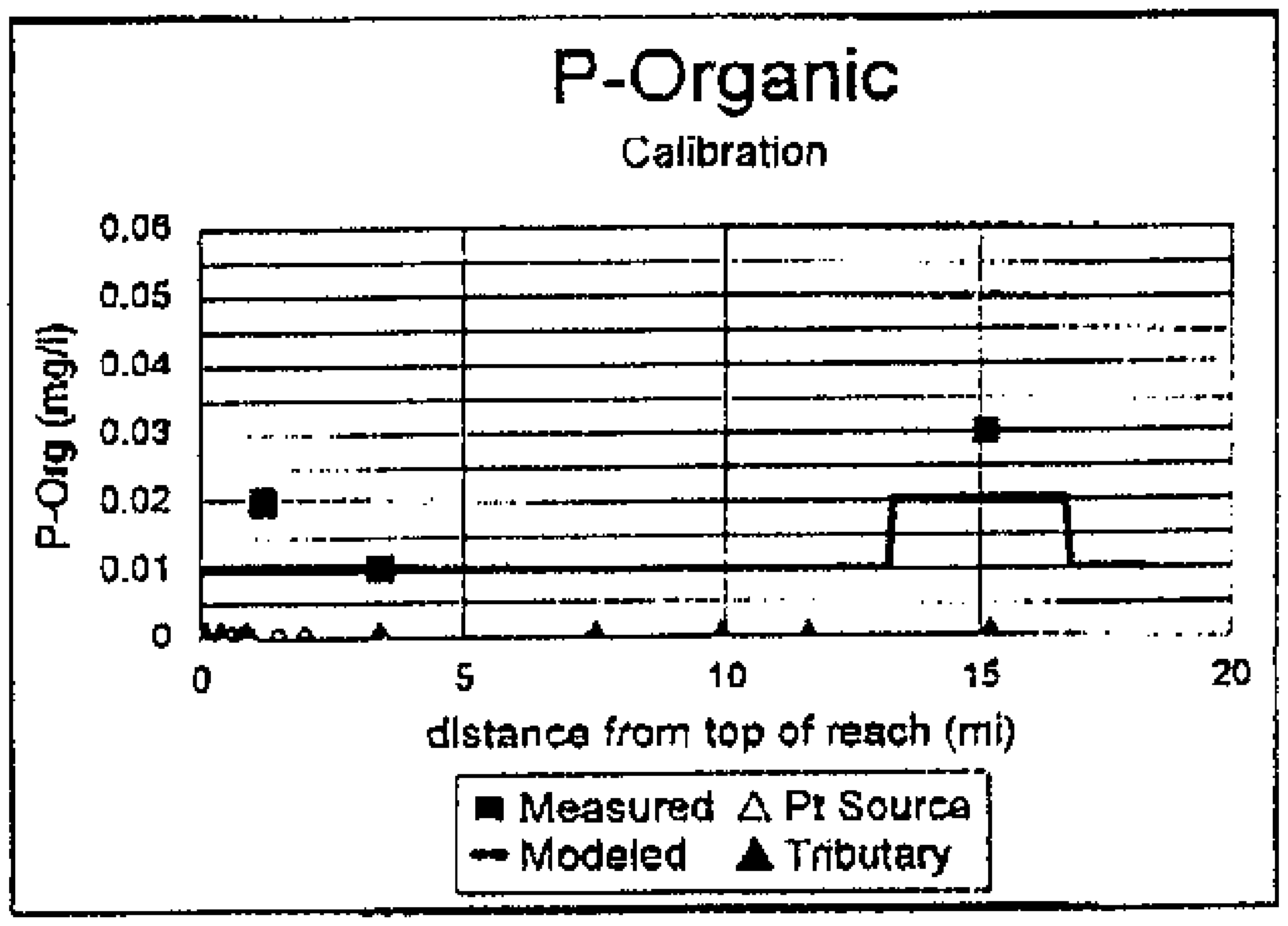
Calibration Curves with data collected 8/18-19/1992

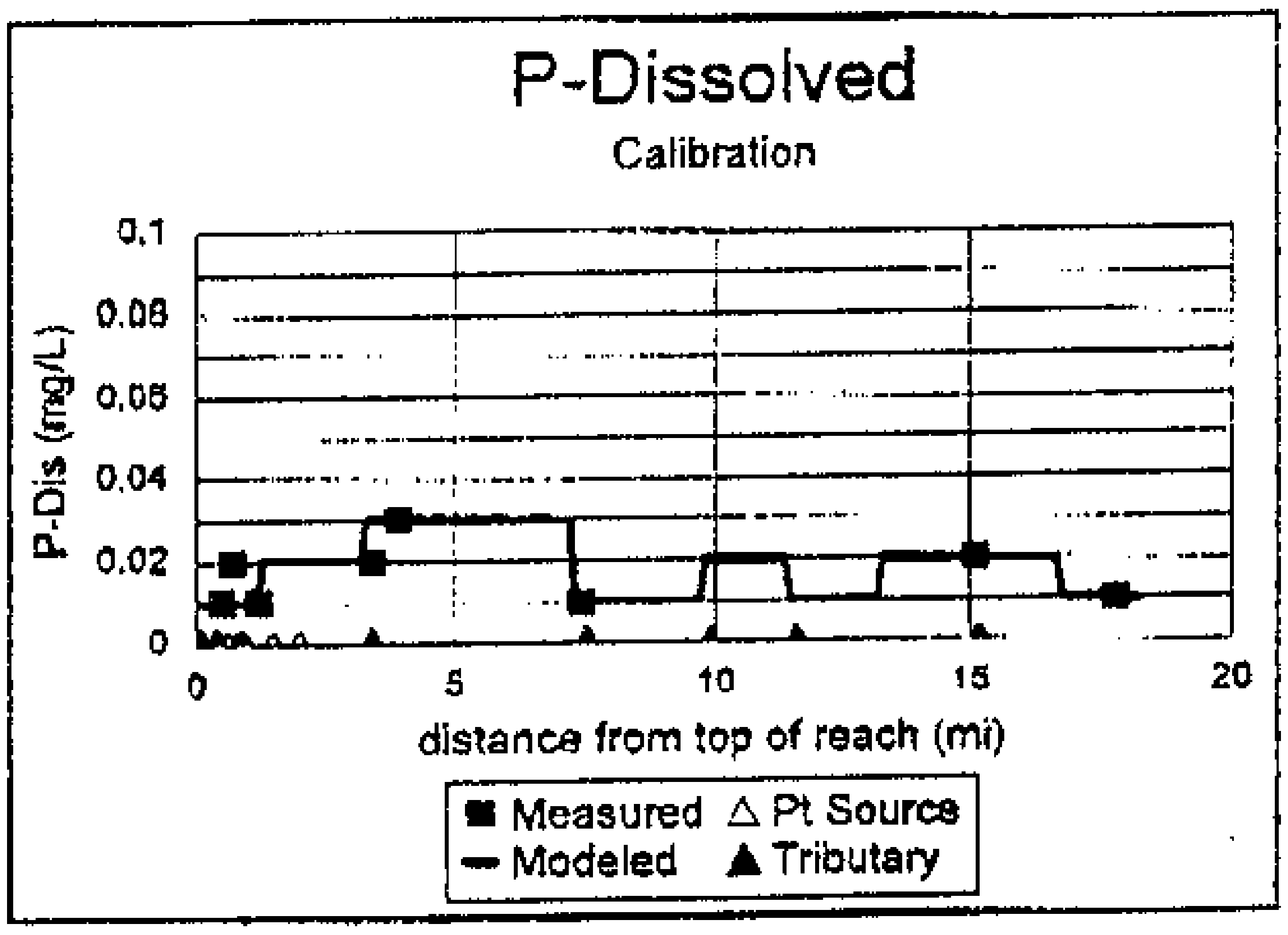




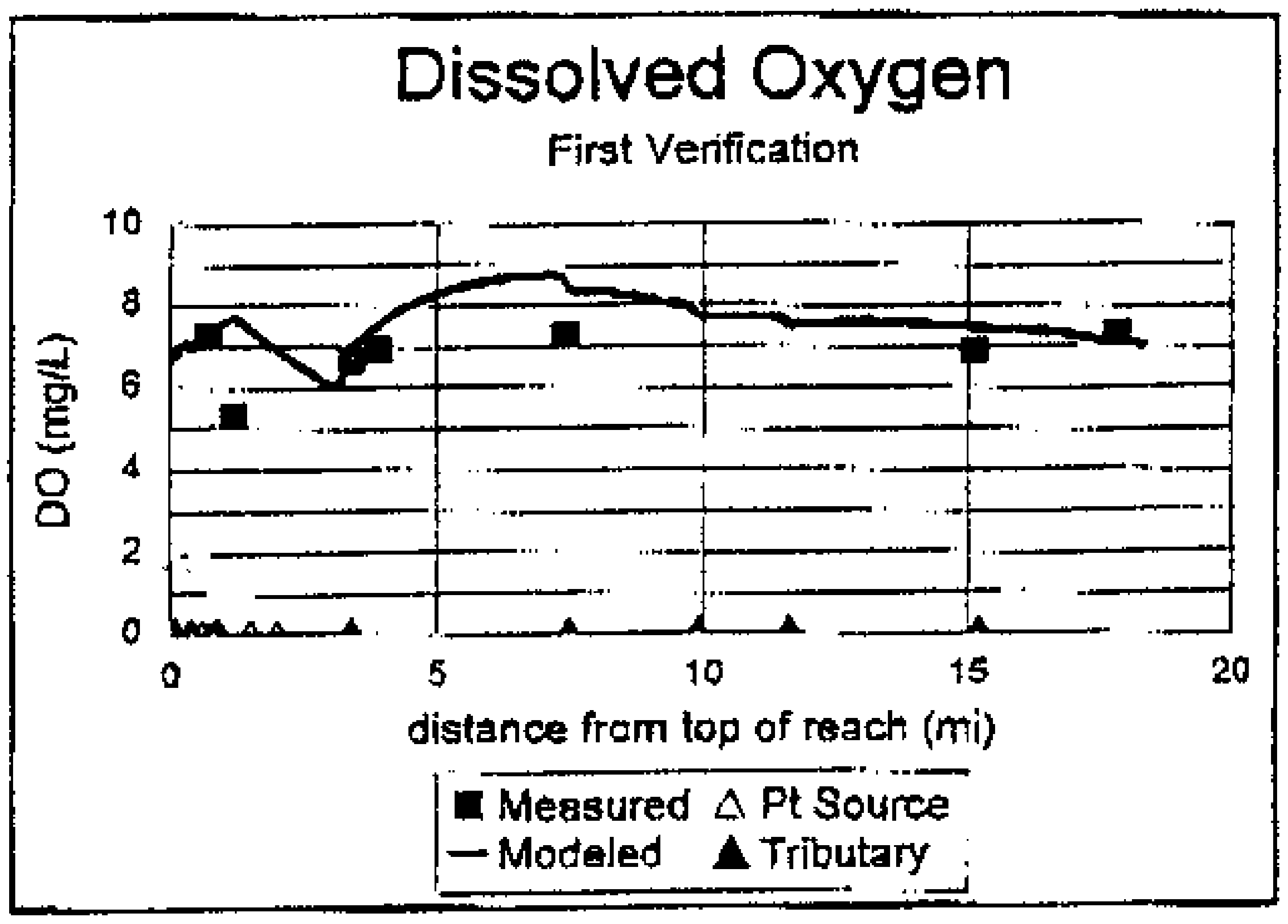


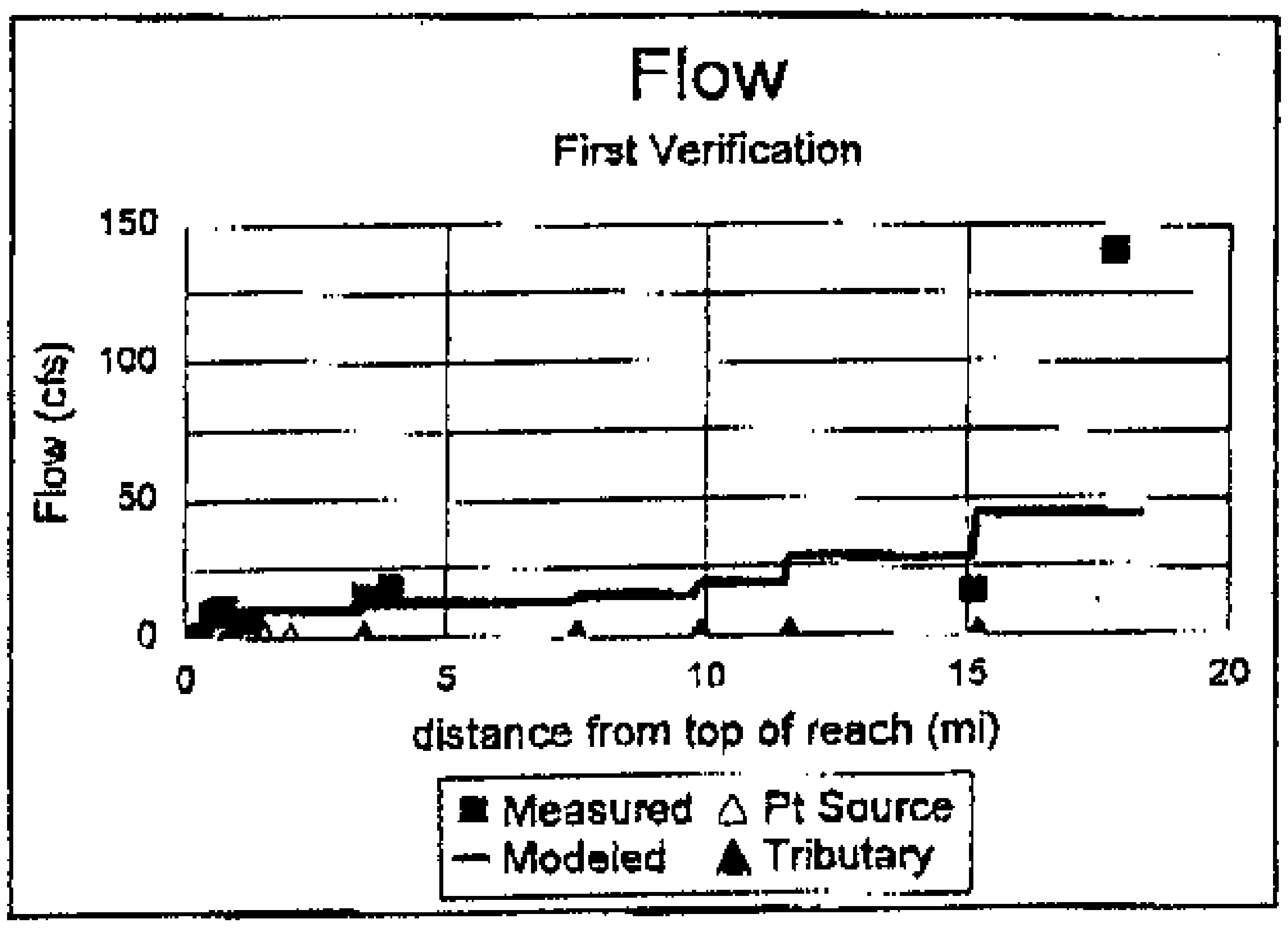


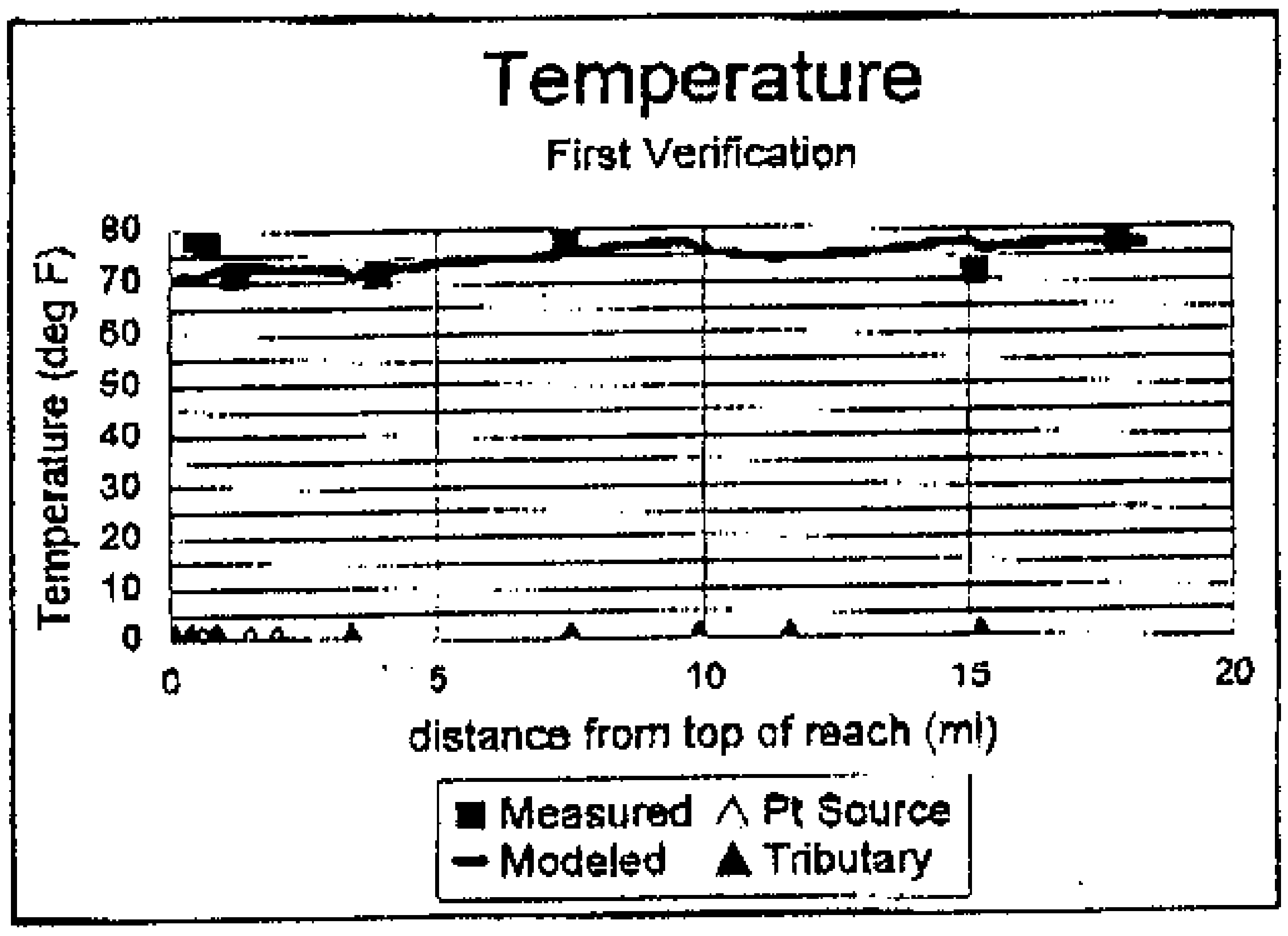


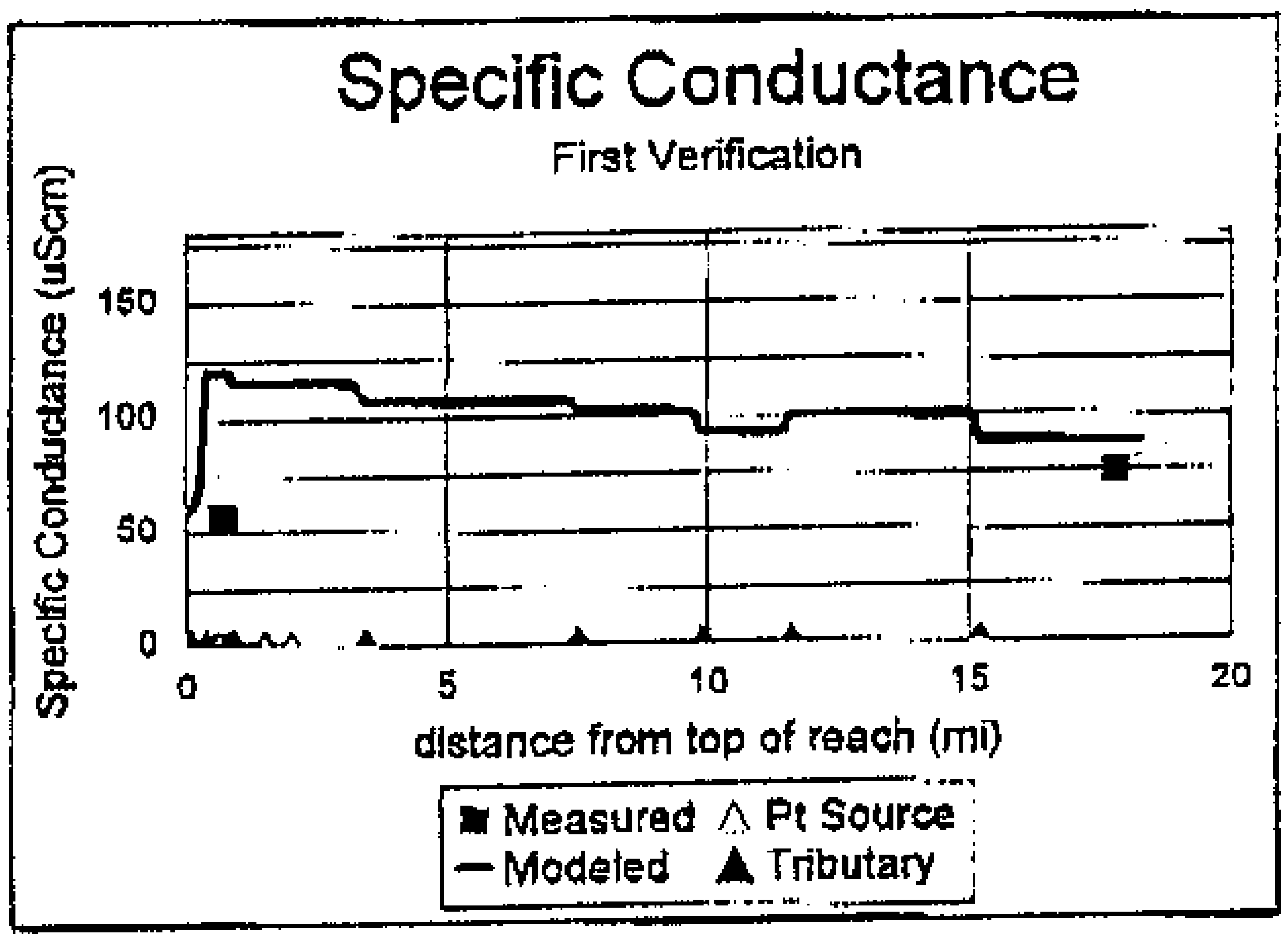


First set of Verification Curves with data collected 7/14-16/1992

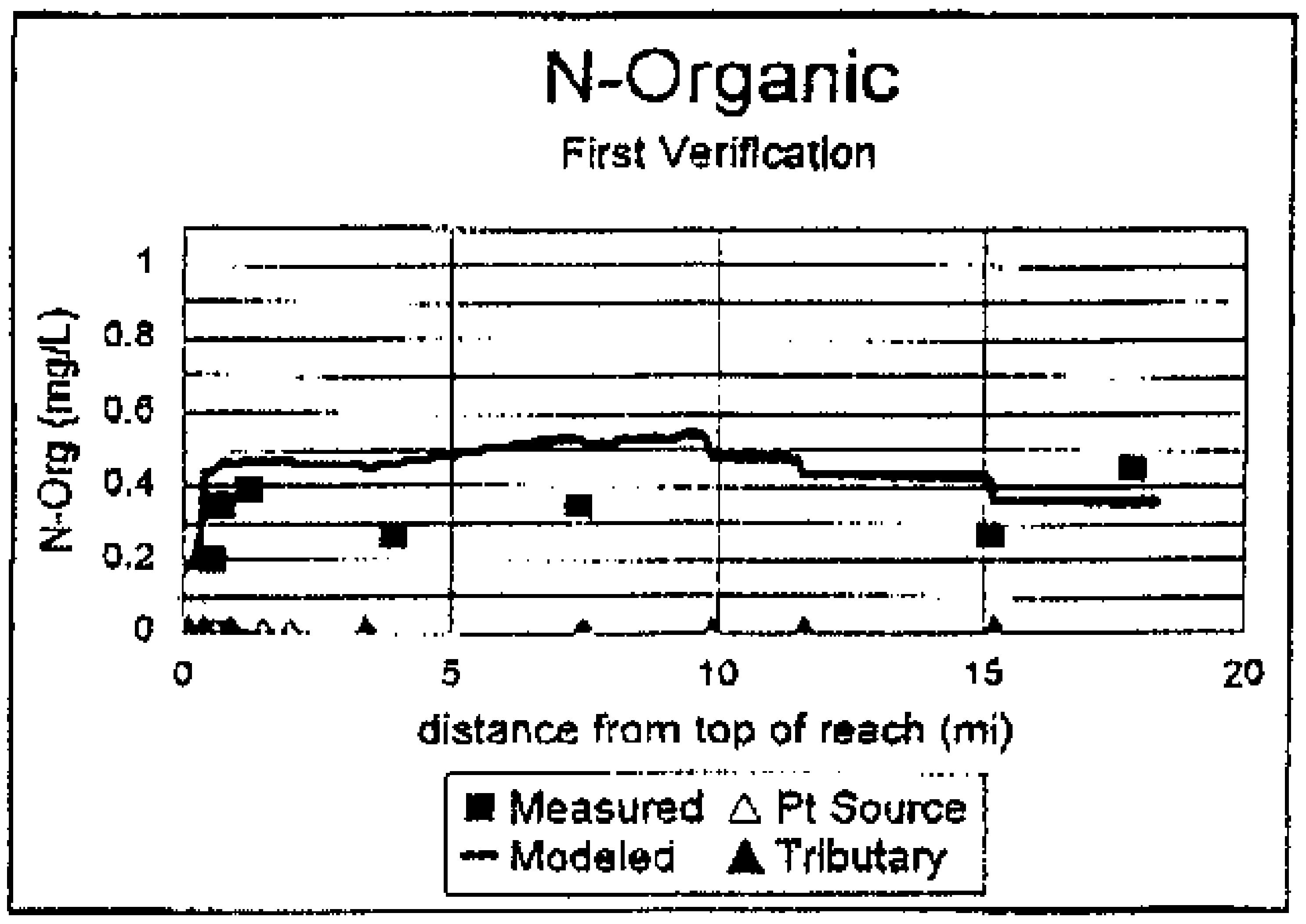


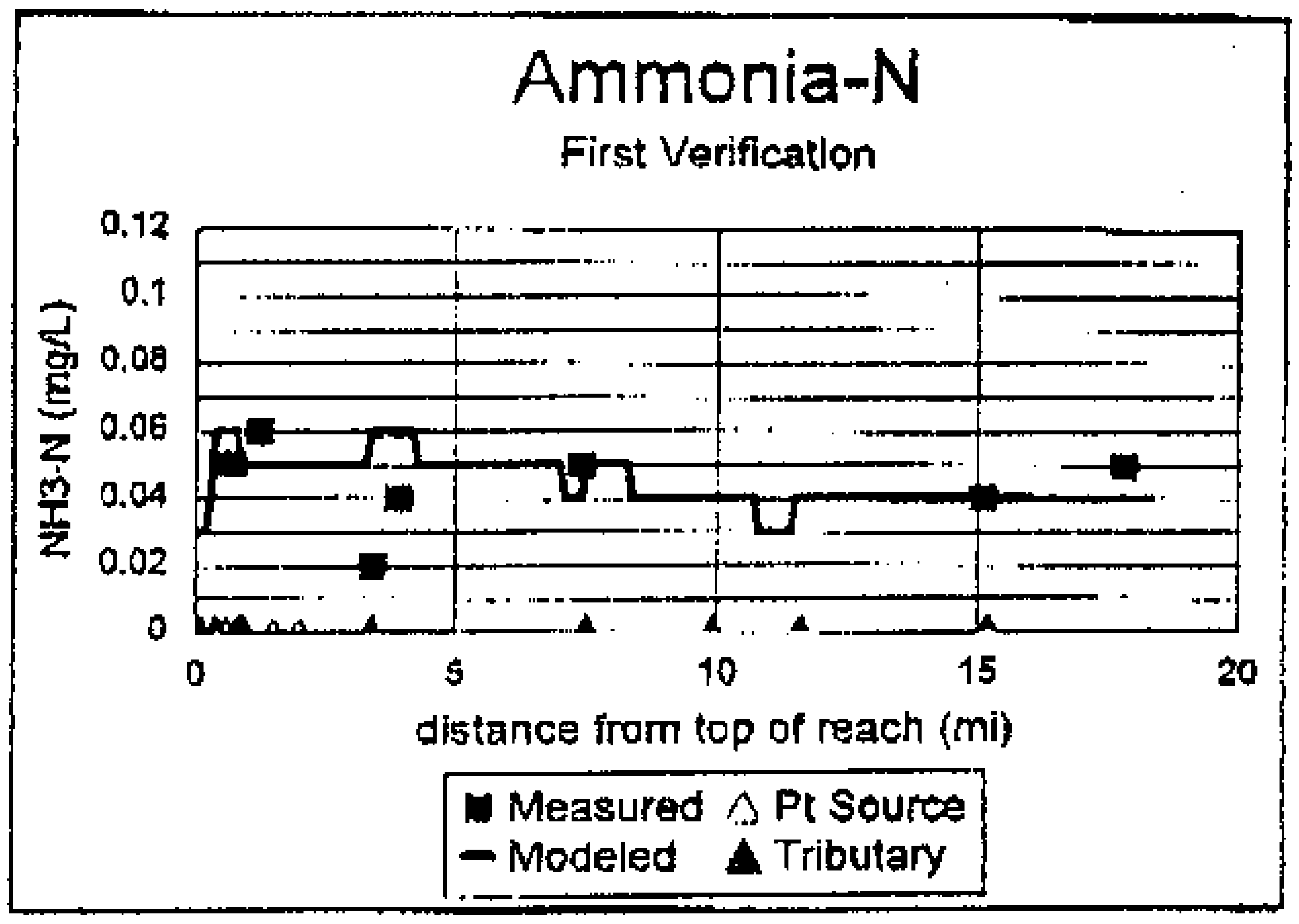


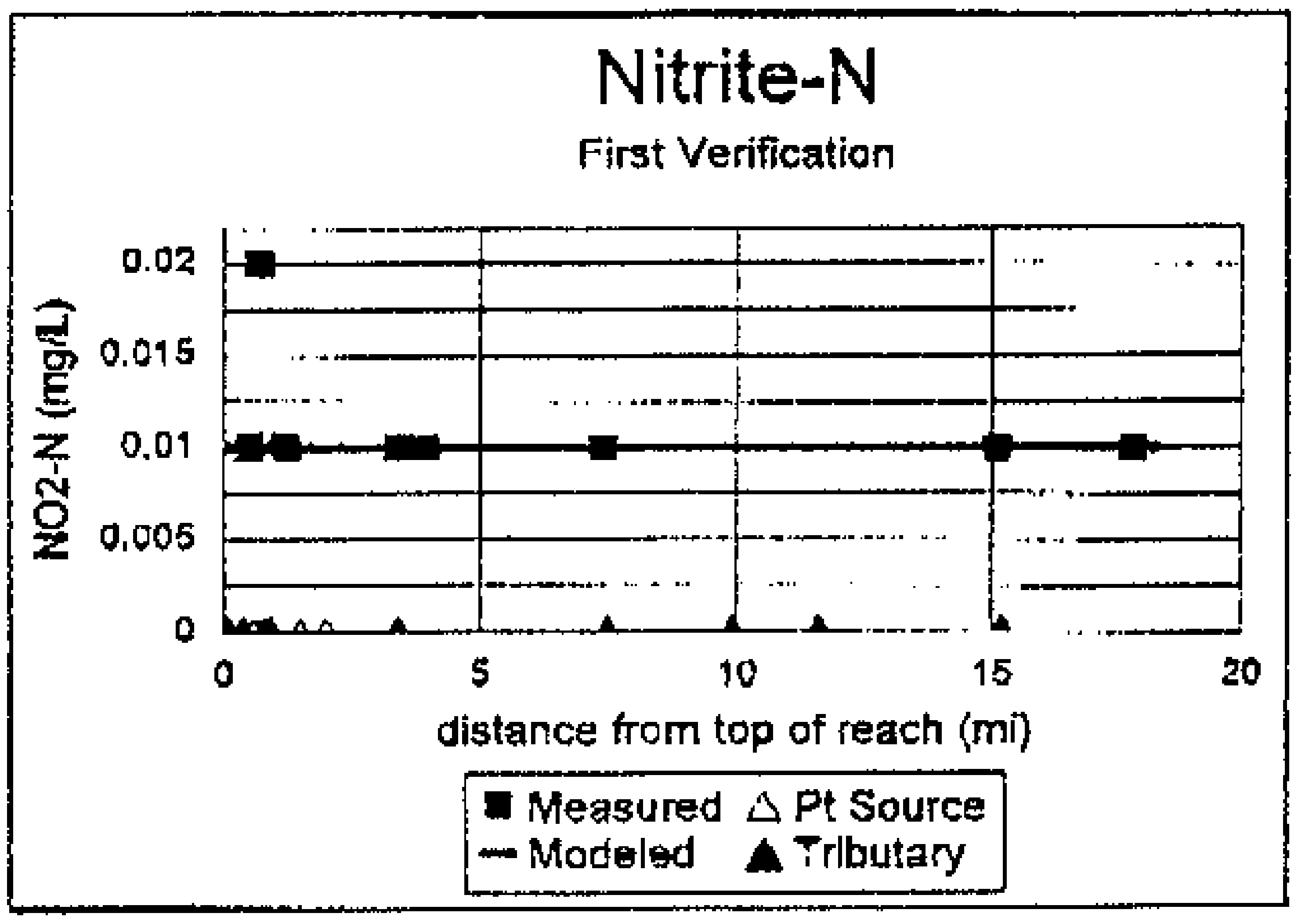


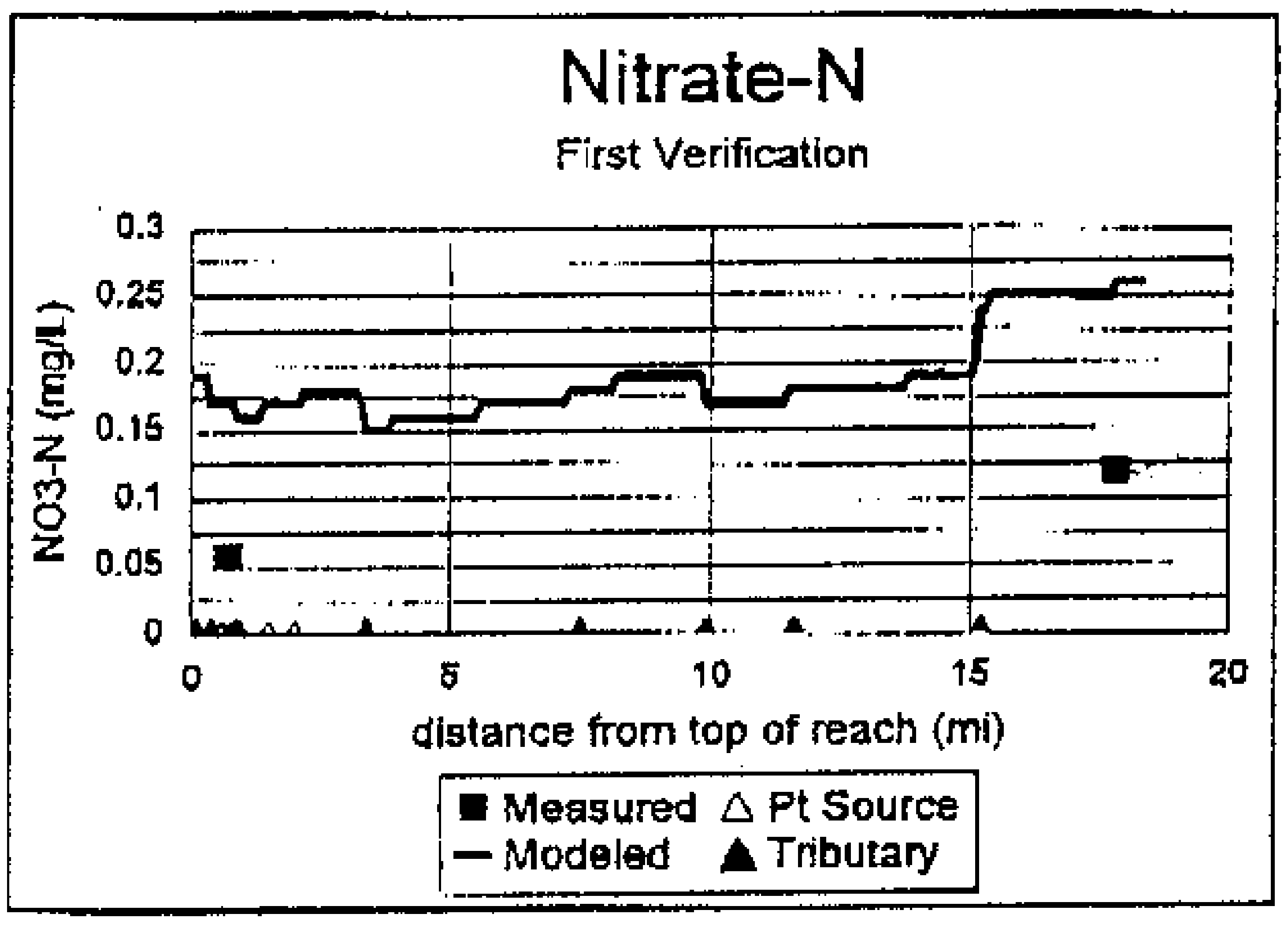


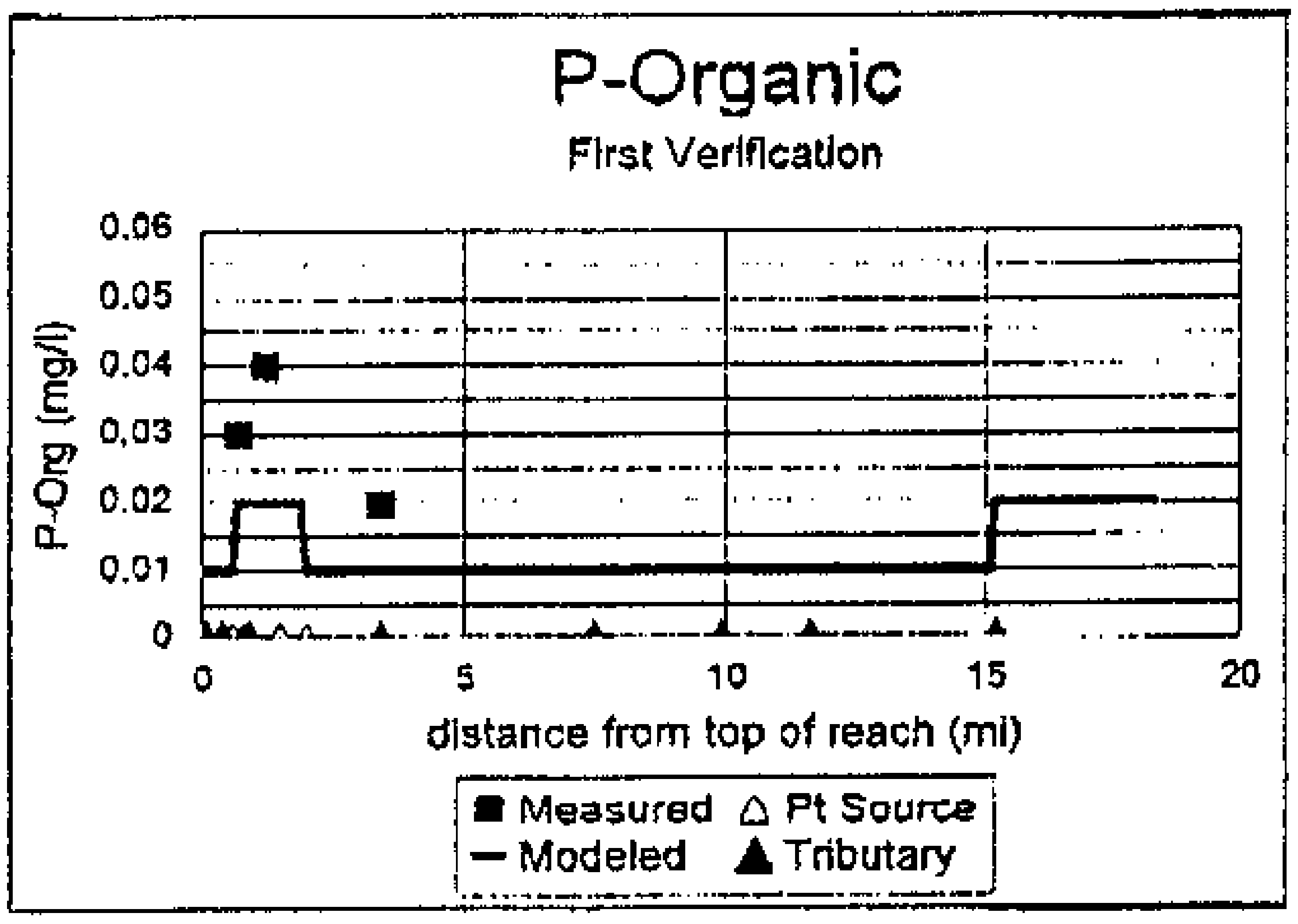
First set of Verification Curves with data collected 7/14-16/1992

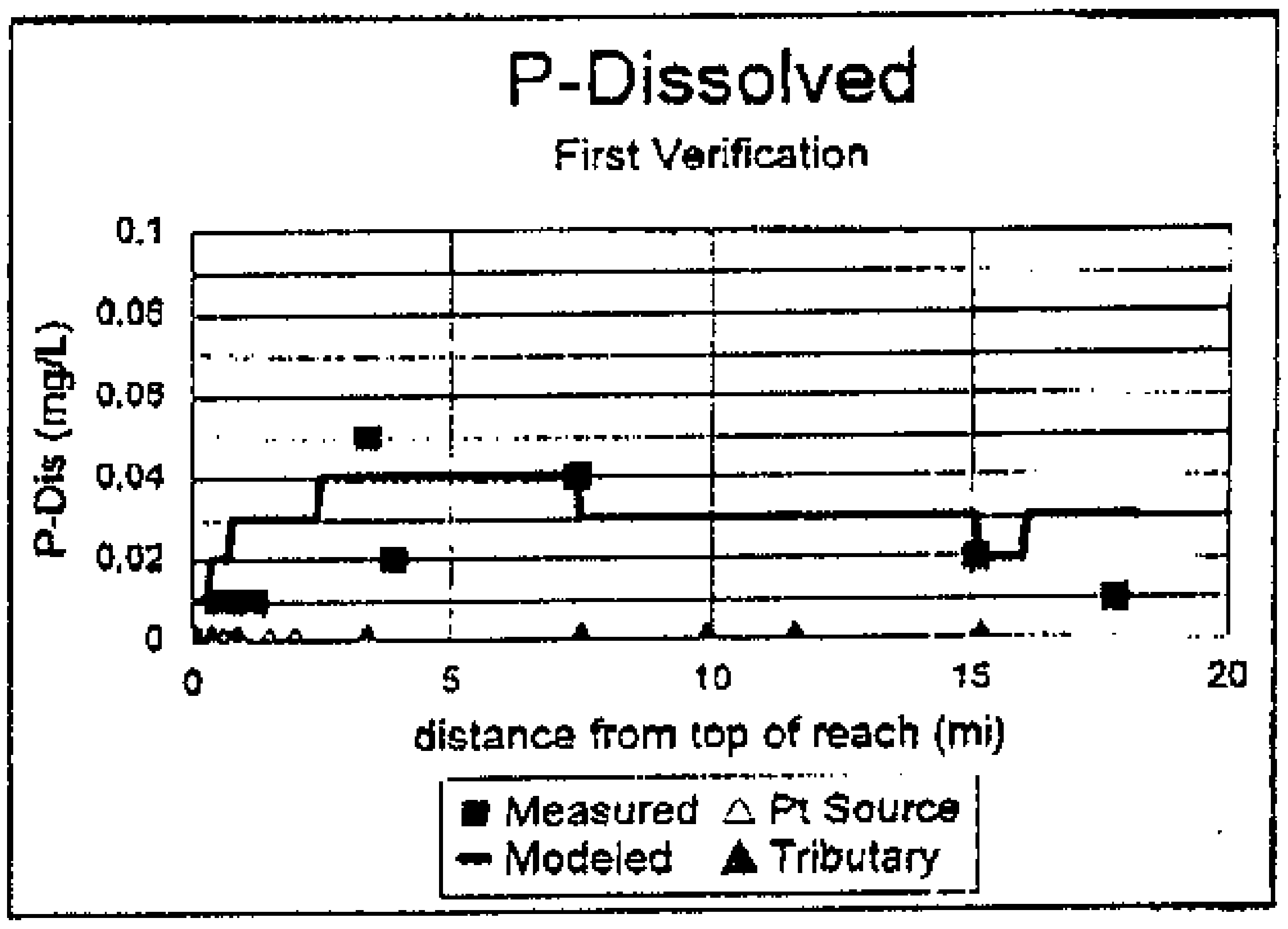




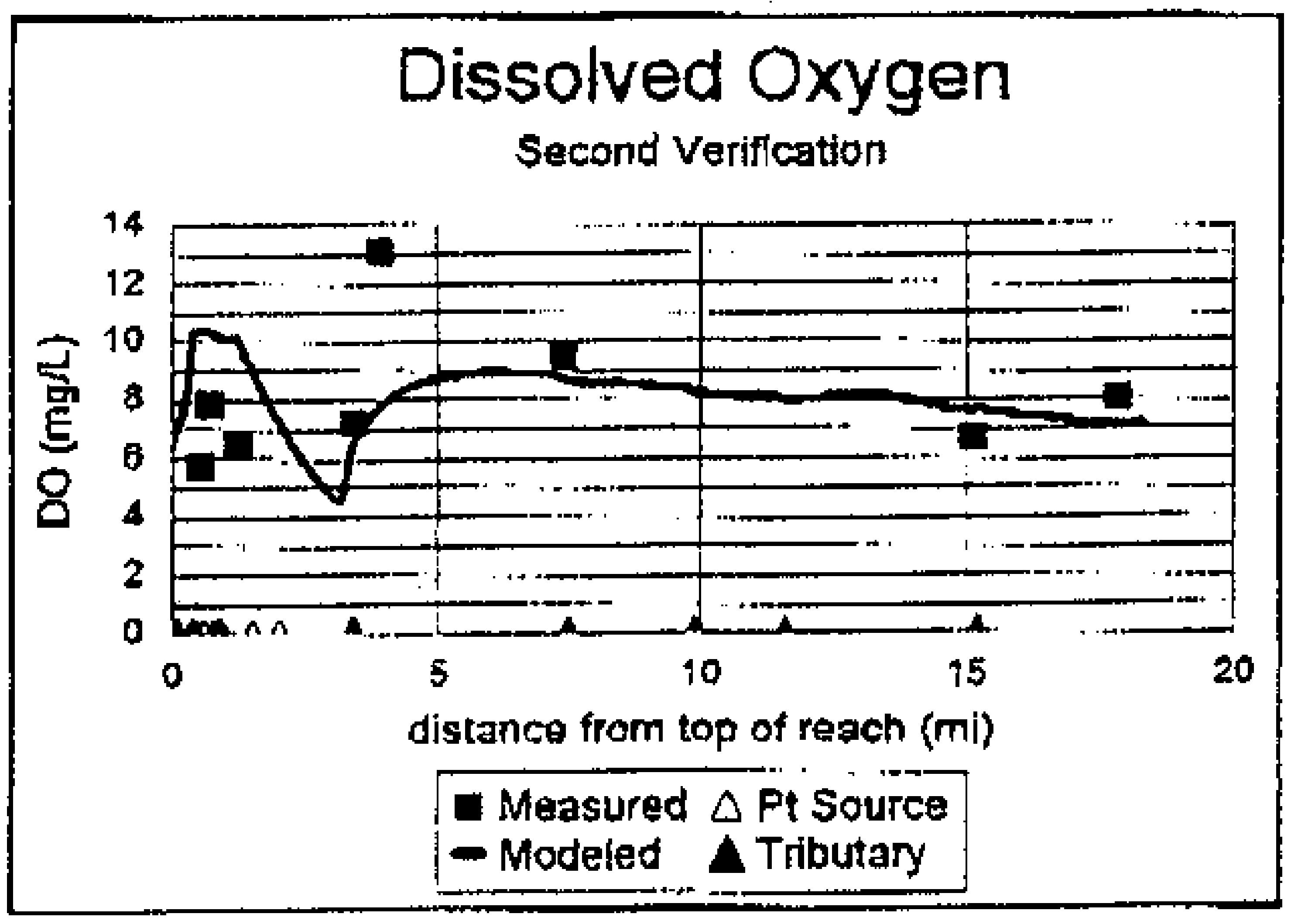


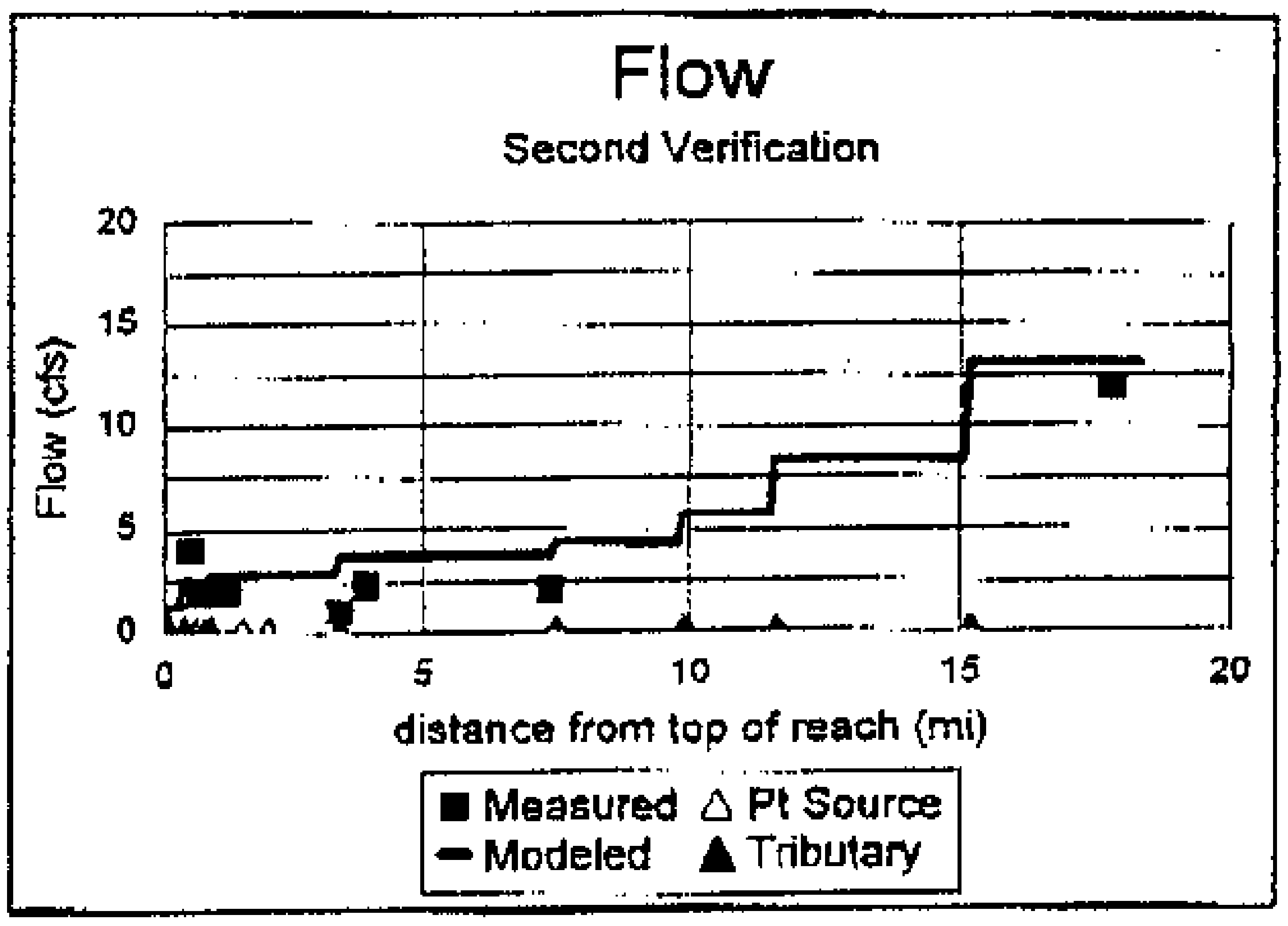


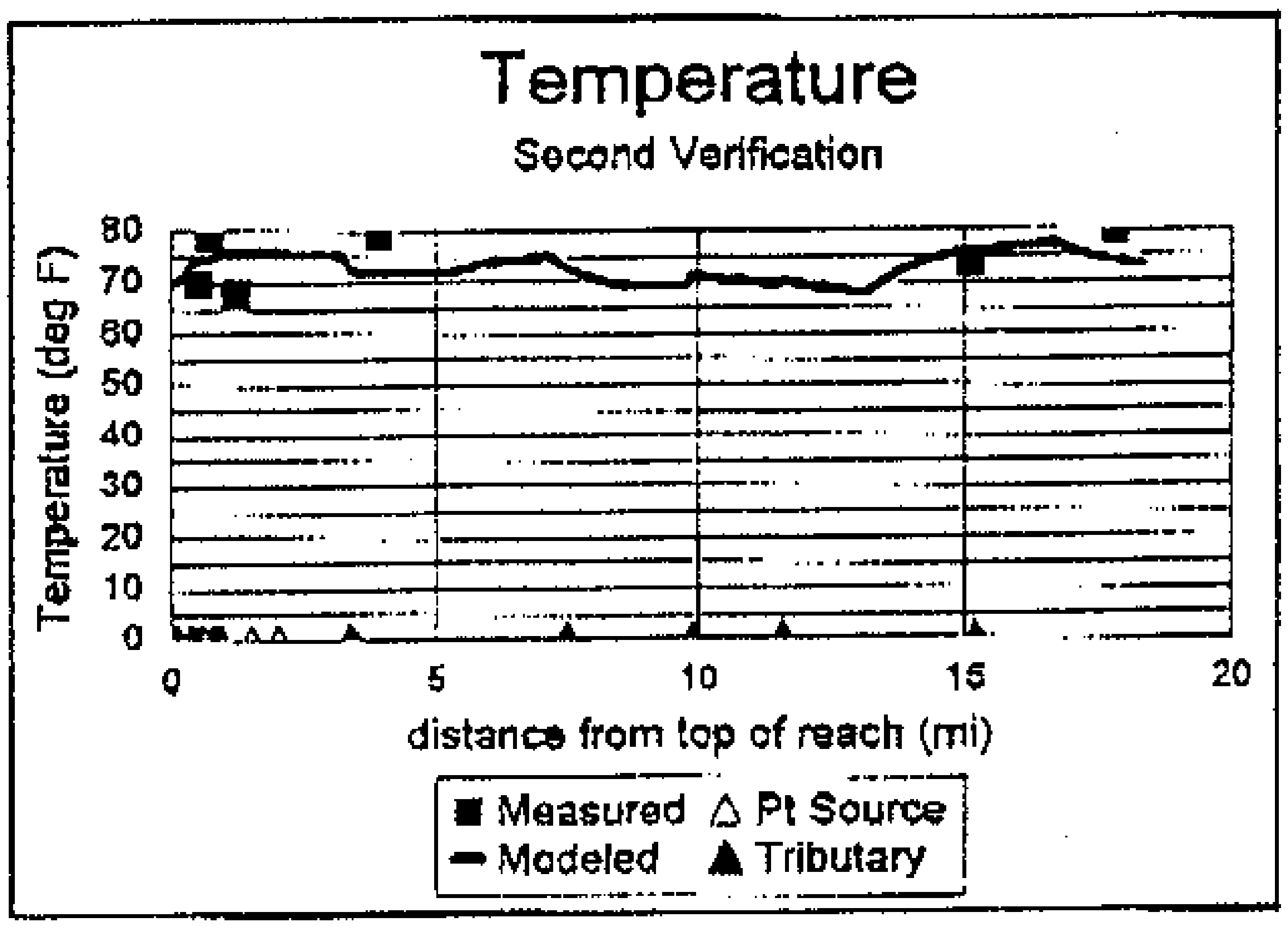


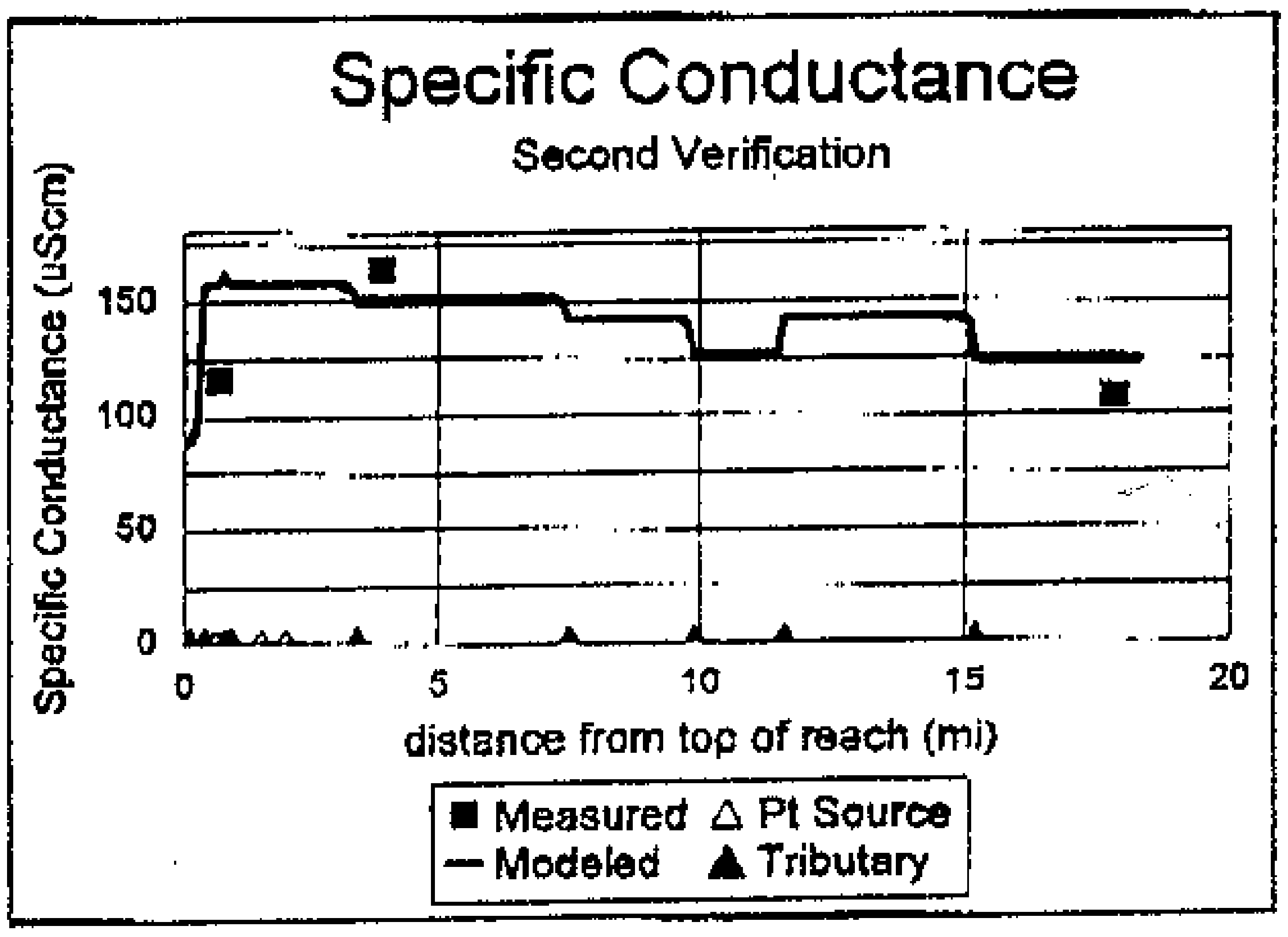


Second set of Verification Curves with data collected 7/30-8/1/1991









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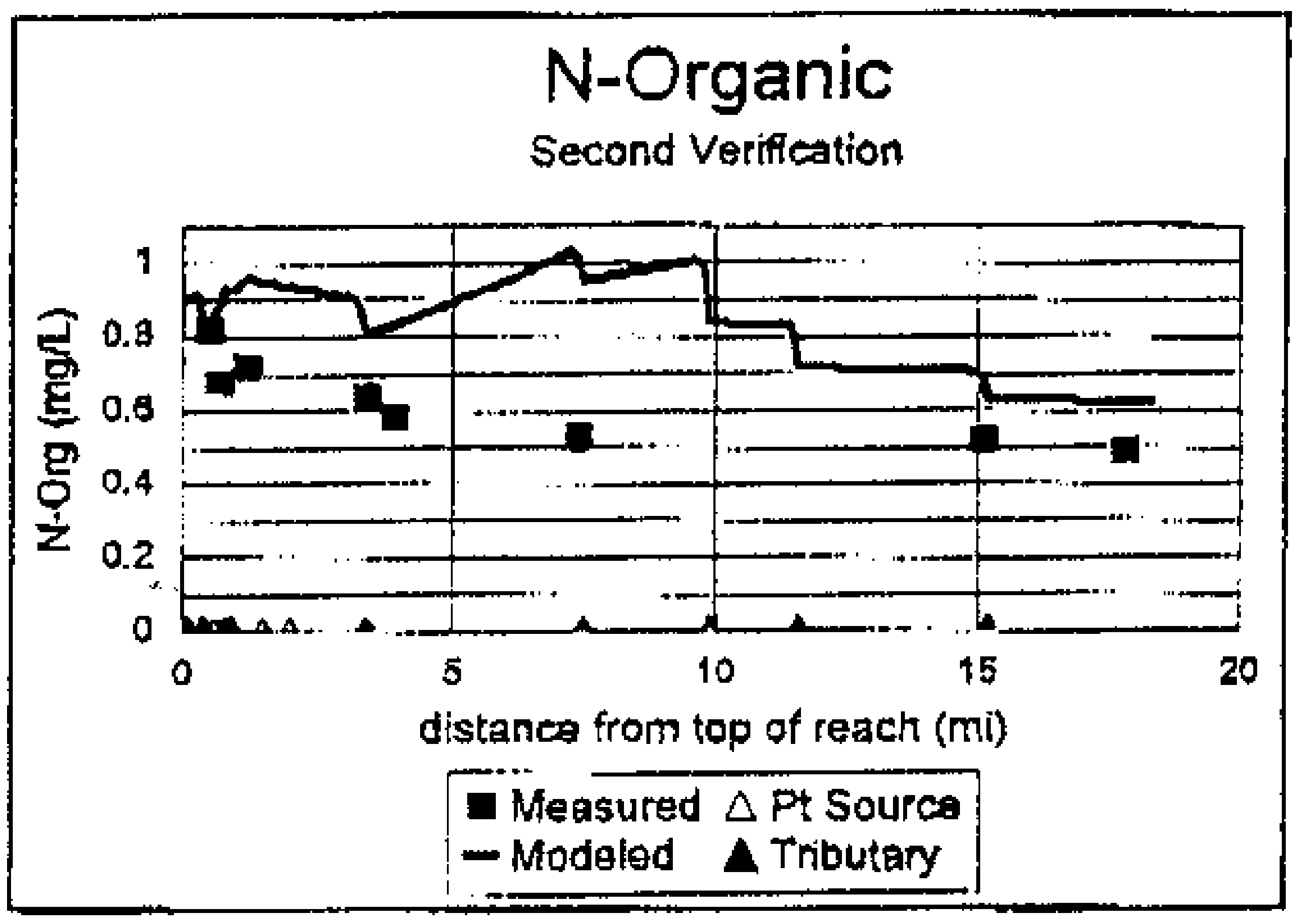

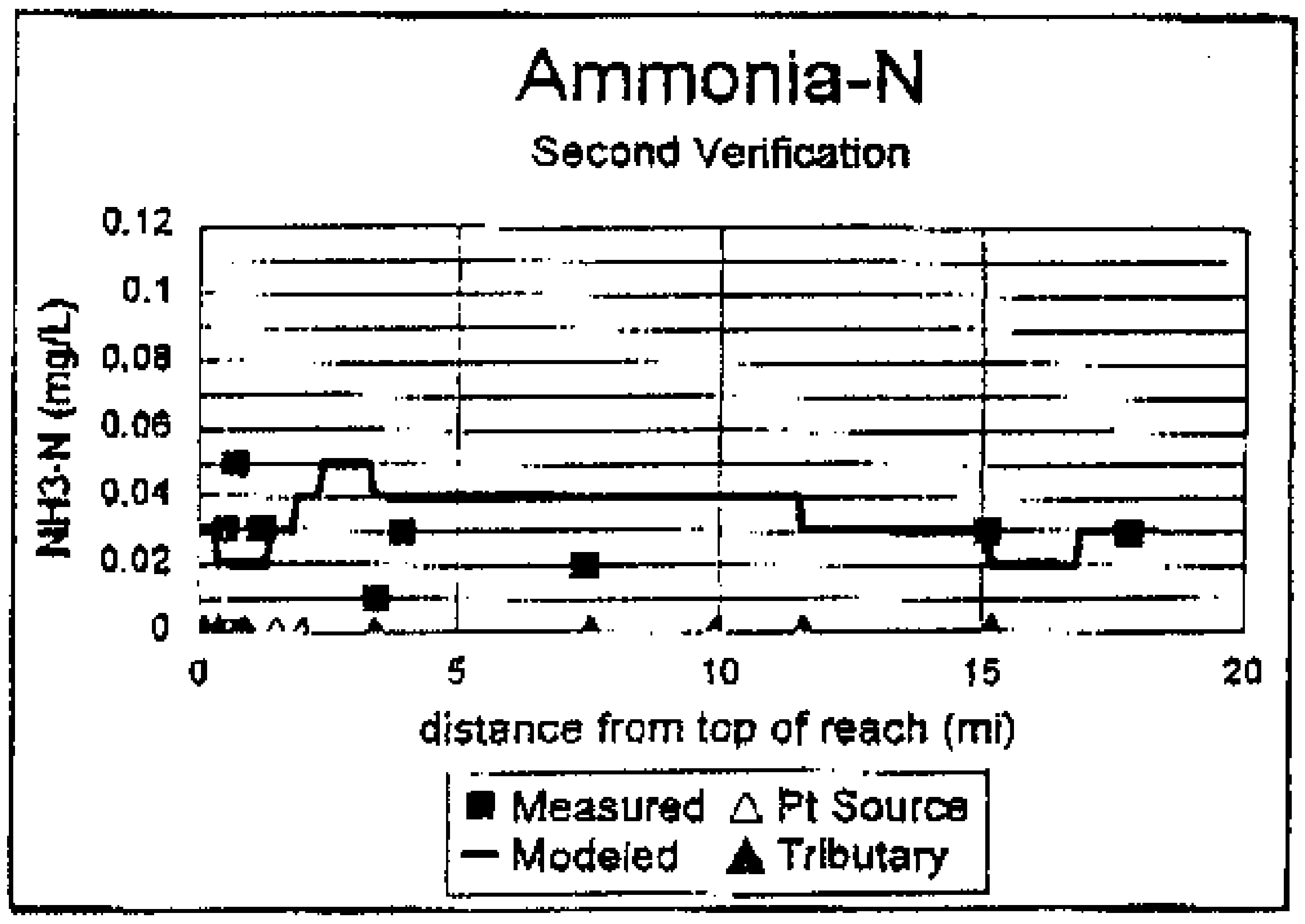

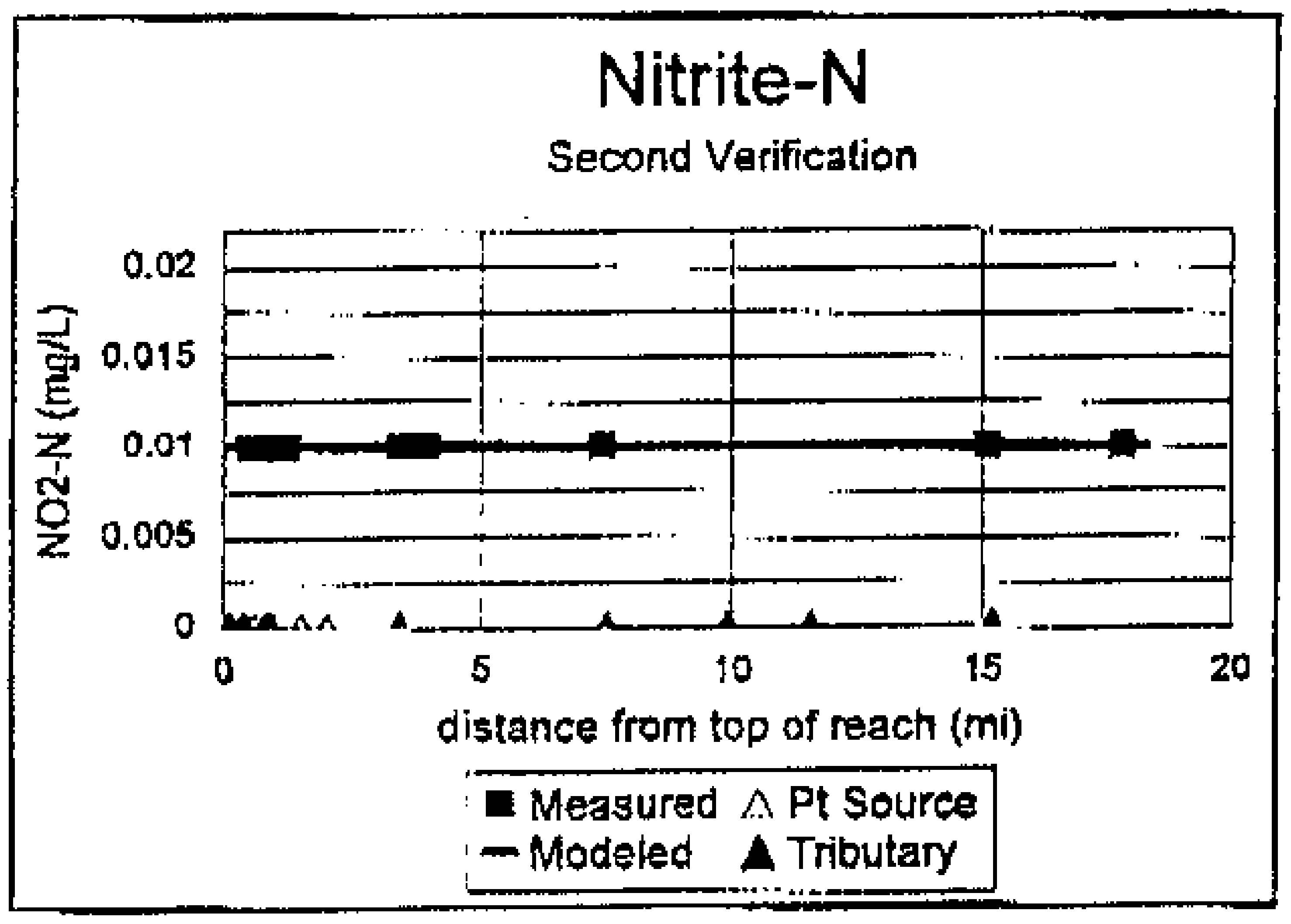

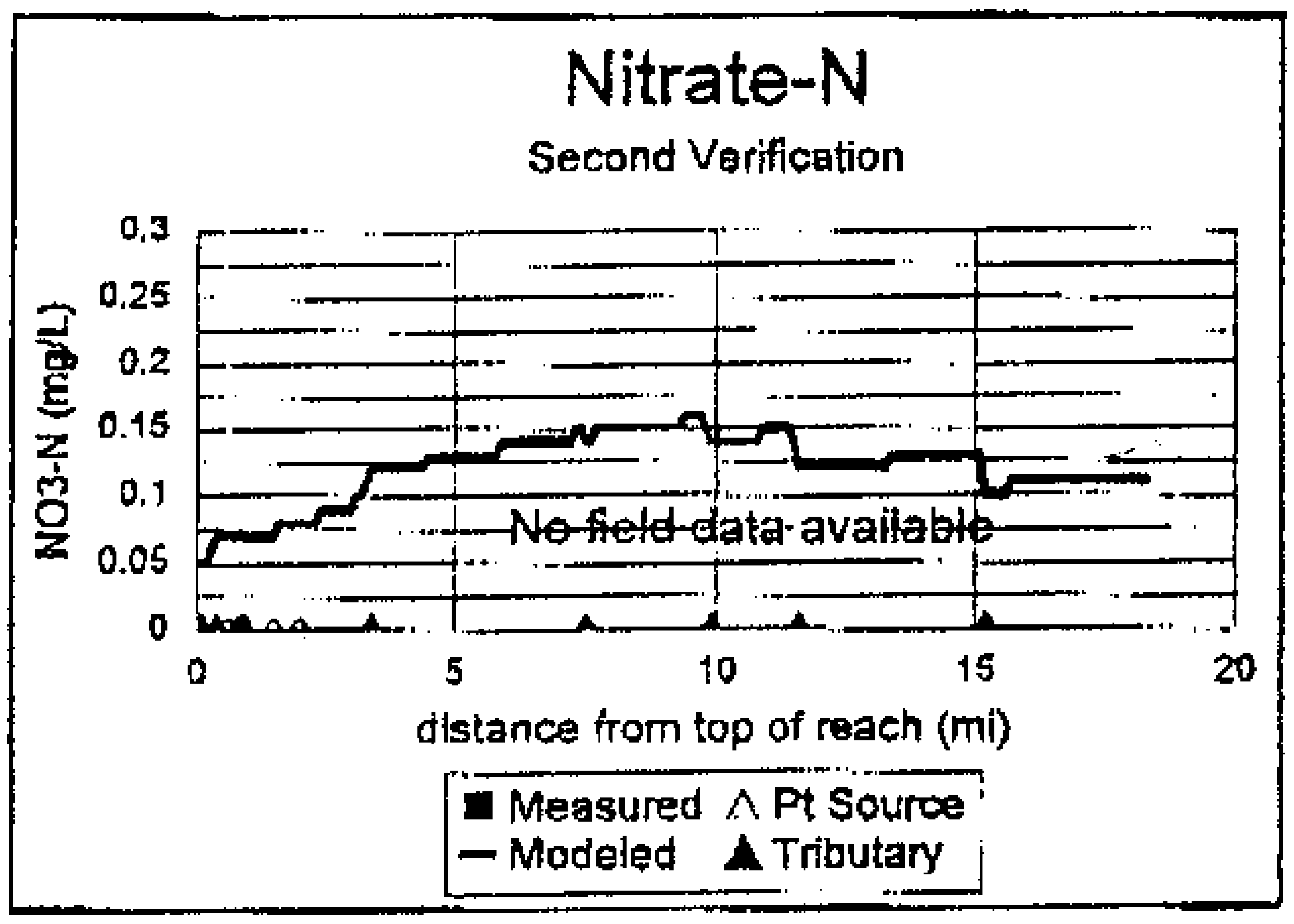

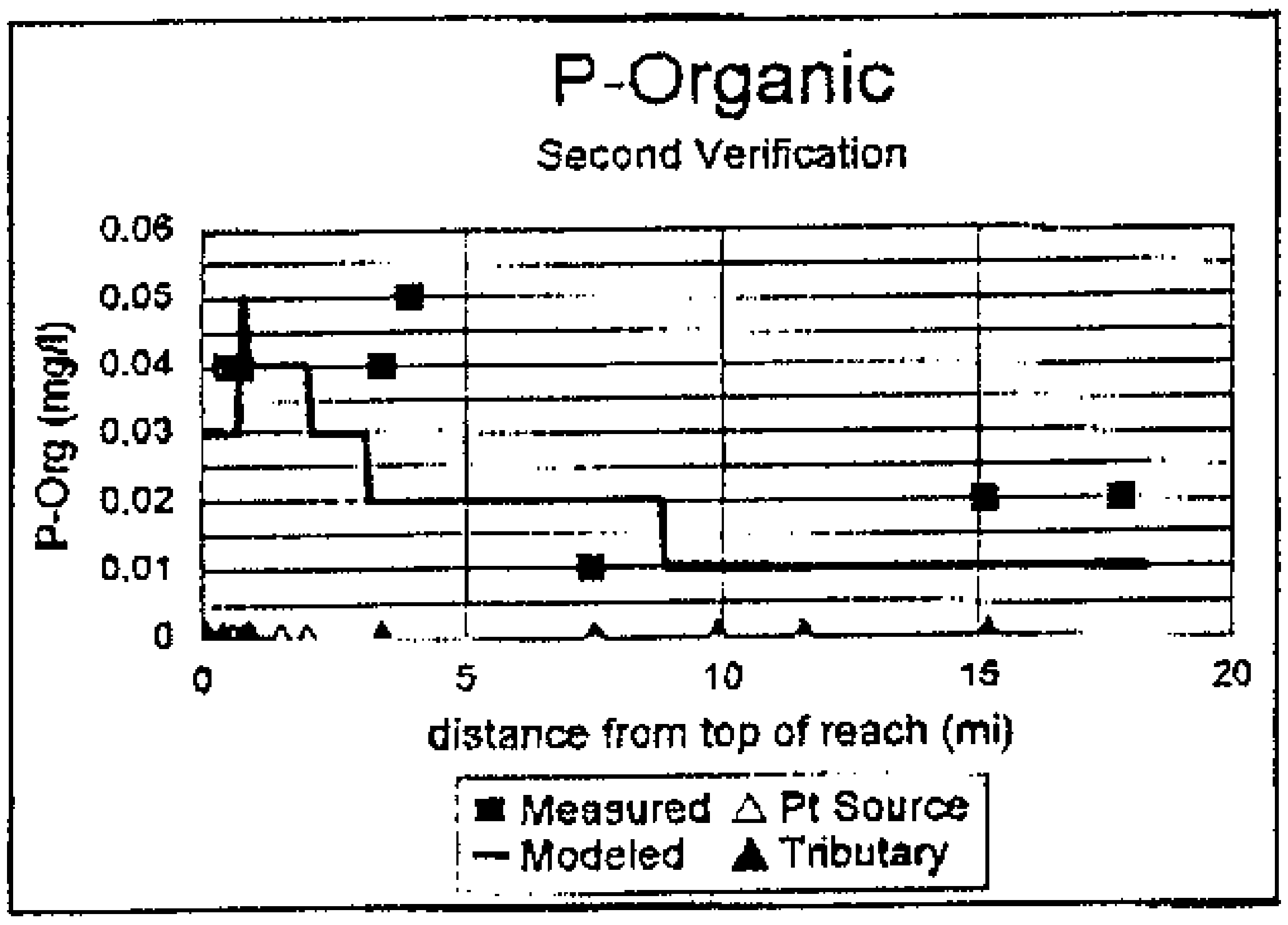

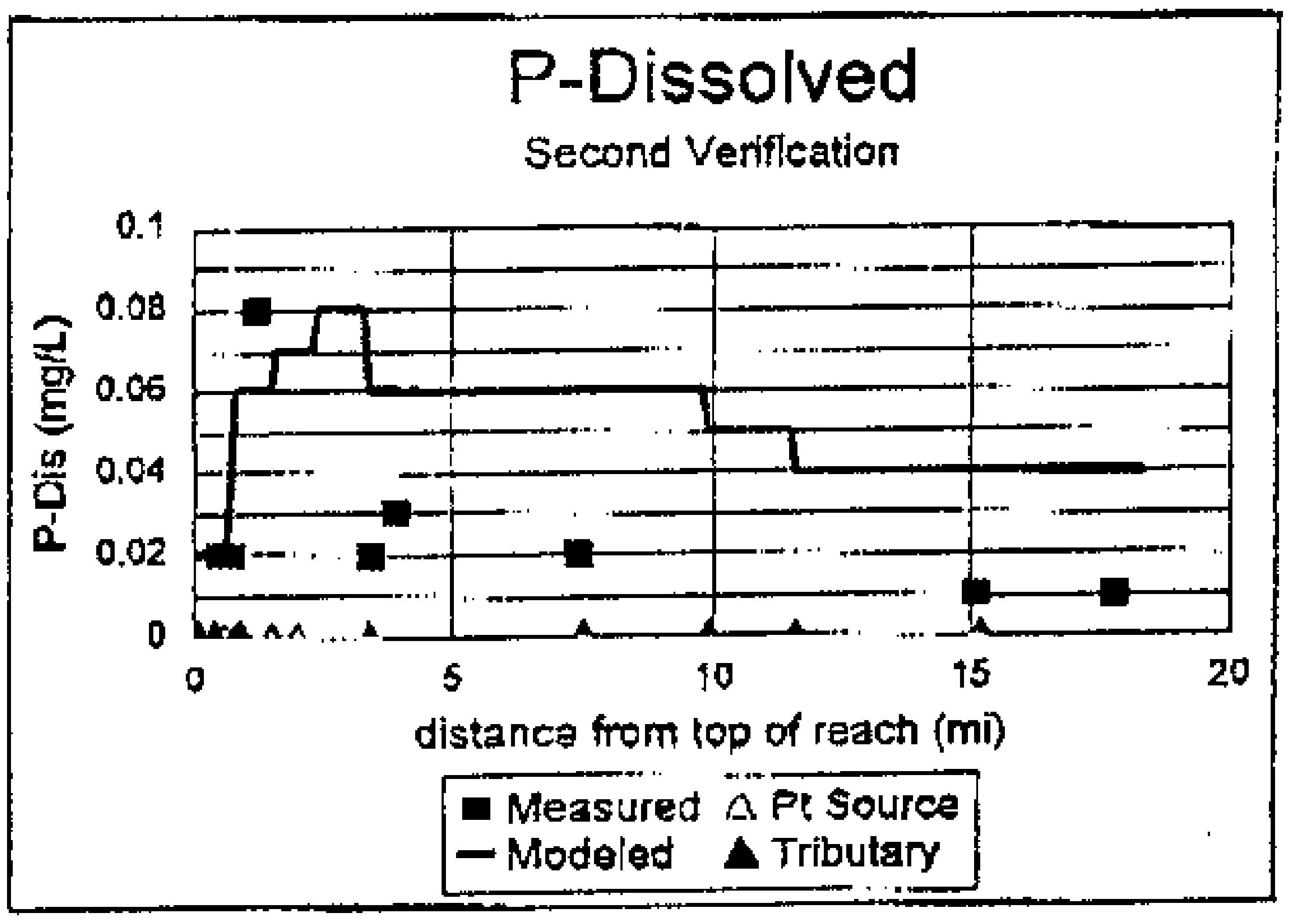

Appendix B QUAL2E Input File for the Final Allocation Scenario

```
TITLE01              #3a
TITLE02              UPPER BLACKWATER RIVER IN CANAAN VALLEY
TITLE03   NO         CONSERVATIVE MINERAL I      SK    IN uScm
TITLE04   NO         CONSERVATIVE MINERAL II     Cl    IN mg/L
TITLE05   NO         CONSERVATIVE MINERAL III    SiO2  IN mg/L
TITLE06  YES         TEMPERATURE
TITLE07  YES         5-DAY BIOCHEMICAL OXYGEN DEMAND
TITLE08  YES         ALGAE AS CHL-A IN UG/L
TITLE09  YES         PHOSPHORUS CYCLE AS P IN MG/L
TITLE10                (ORGANIC-P, DISSOLVED-P)
TITLE11  YES         NITROGEN CYCLE AS N IN MG/L
TITLE12                (ORGANIC-N, AMMONIA-N, NITRITE-N, NITRATE-N)
TITLE13  YES         DISSOLVED OXYGEN IN MG/L
TITLE14  YES         FECAL COLIFORMS IN NO./100 ML
TITLE15   NO         ARBITRARY NON-CONSERVATIVE
ENDTITLE
LIST DATA INPUT
WRITE OPTIONAL SUMMARY
NO FLOW AUGMENTATION
STEADY STATE
NO TRAPEZOIDAL X-SECTIONS
PRINT LCD/SOLAR DATA
PLOT DO AND BOD
FIXED DNSTM COND (YES=1)=       0.0         5D-ULT BOD CONV K COEF  =       0.04
INPUT METRIC (YES=1)    =       0.0         OUTPUT METRIC (YES=1)   =        0.0
NUMBER OF REACHES       =      11.0         NUMBER OF JUNCTIONS     =        0.0
NUM OF HEADWATERS       =       1.0         NUMBER OF POINT LOADS   =       15.0
TIME STEP (HOURS)       =       0.0         LNTH  COMP  ELEMENT (DX)=        0.1
MAXIMUM ITERATIONS      =      30.0         TIME INC. FOR RPT2 (HRS)=        0.0
LATITUDE OF BASIN (DEG) =     39.05         LONGITUDE OF BASIN (DEG)=       79.4
STANDARD MERIDIAN (DEG) =      75.0         DAY OF YEAR START TIME  =      211.0
EVAP. COEFF. (AE)       =   0.00103         EVAP. COEFF. (BE)       =    0.00016
ELEV. OF BASIN (ELEV)   =    3167.0         DUST ATTENUATION COEF.  =       0.06
ENDATA1
O UPTAKE BY NH3 OXID(MG O/MG N)=   3.43  O UPTAKE BY NO2 OXID(MG O/MG N)=    1.14
O PROD  BY ALGAE (MG O/MG A)   =    1.6  O UPTAKE BY ALGAE (MG O/MG A)  =     2.0
N CONTENT OF ALGAE (MG N/MG A) =  0.085  P CONTENT OF ALGAE (MG P/MG A) =   0.014
ALG MAX SPEC GROWTH RATE(1/DAY)=    2.5  ALGAE RESPIRATION RATE (1/DAY) =    0.05
N HALF SATURATION CONST (MG/L) =    0.2  P HALF SATURATION CONST  (MG/L)=    0.04
LIN ALG SHADE CO (1/H-UGCHA/L) = 0.0008  NLIN SHADE (1/H-(UGCHA/L)**2/3)=     0.0
LIGHT FUNCTION OPTION (LFNOPT) =    2.0  LIGHT SATURATION COEF (INT/MIN)=    0.09
DAILY AVERAGING OPTION (LAVOPT)=    1.0  TOTAL DAILY SOLAR RADTN (INT)  =    0.92
NUMBER OF DAYLIGHT HOURS (DLH) =   14.0  TOTAL DAILY SOLAR RADTN (INT)  =  1500.0
ALGY GROWTH CALC OPTION(LGROPT)=    2.0  ALGAL PREF FOR NH3-N (PREFN)   =     0.9
ALG/TEMP SOLR RAD FACTOR(TFACT)=   0.44  NITRIFICATION INHIBITION COEF  =    10.0
ENDATA1A
ENDATA1B
STREAM REACH     1.0RCH=RCH 01             FROM        18.4     TO          17.1
STREAM REACH     2.0RCH=RCH 02             FROM        17.1     TO          15.1
STREAM REACH     3.0RCH=RCH 03             FROM        15.1     TO          13.1
STREAM REACH     4.0RCH=RCH 04             FROM        13.1     TO          11.1
STREAM REACH     5.0RCH=RCH 05             FROM        11.1     TO           9.8
STREAM REACH     6.0RCH=RCH 06             FROM         9.8     TO           8.6
STREAM REACH     7.0RCH=RCH 07             FROM         8.6     TO           6.9
STREAM REACH     8.0RCH=RCH 08             FROM         6.9     TO           5.1
STREAM REACH     9.0RCH=RCH 09             FROM         5.1     TO           3.3
STREAM REACH    10.0RCH=RCH 10             FROM         3.3     TO           1.6
STREAM REACH    11.0RCH=RCH 11             FROM         1.6     TO           0.0
ENDATA2
ENDATA3
FLAG FIELD RCH=  1.0         13          1 6 2 2 6 2 7 2 2 2 6 2 6
FLAG FIELD RCH=  2.0         20          2 2 2 2 6 6 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  3.0         20          2 6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  4.0         20          2 2 2 2 2 2 2 2 6 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  5.0         13          6 2 6 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  6.0         12          2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  7.0         17          2 6 2 2 6 2 2 2 2 2 2 2 2 2 2 2 2
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FLAG FIELD RCH=  8.0        18            2 6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH=  9.0        18            2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH= 10.0        17            2 6 2 2 2 2 2 2 2 2 2 2 2 2 2 2 2
FLAG FIELD RCH= 11.0        16            2 2 2 2 2 2 2 2 2 2 2 2 2 2 2 5
ENDATA4
HYDRAULICS RCH=  1.0      500.0     0.059      0.338      2.05      0.309      0.034
HYDRAULICS RCH=  2.0      500.0     0.059      0.338     1.014      0.309      0.043
HYDRAULICS RCH=  3.0      500.0     0.059      0.338     1.014      0.309      0.043
HYDRAULICS RCH=  4.0      500.0     0.059      0.338     1.014      0.309      0.043
HYDRAULICS RCH=  5.0      500.0     0.059      0.338     1.014      0.309      0.043
HYDRAULICS RCH=  6.0      500.0     0.059      0.338     1.014      0.309      0.043
HYDRAULICS RCH=  7.0      500.0     0.059      0.338     1.014      0.309      0.043
HYDRAULICS RCH=  8.0      500.0     0.059      0.338     0.723      0.309      0.034
HYDRAULICS RCH=  9.0      500.0     0.059      0.338     0.723      0.309      0.034
HYDRAULICS RCH= 10.0      500.0     0.059      0.338     0.723      0.309      0.034
HYDRAULICS RCH= 11.0      500.0     0.059      0.338     0.723      0.309      0.037
ENDATA5
TEMP/LCD   RCH=  1.0     3218.0   0.06    0.1    74.3    59.0    27.0     8.8
TEMP/LCD   RCH=  2.0     3213.0   0.06    0.1    73.4    59.0    27.0     8.8
TEMP/LCD   RCH=  3.0     3205.0   0.06    0.1    78.8    62.6    27.0     8.8
TEMP/LCD   RCH=  4.0     3186.0   0.06    0.1    78.8    62.6    27.0     8.8
TEMP/LCD   RCH=  5.0     3161.0   0.06    0.1    86.0    68.0    27.0     8.8
TEMP/LCD   RCH=  6.0     3154.0   0.06    0.1    86.0    68.0    27.0     8.8
TEMP/LCD   RCH=  7.0     3148.0   0.06    0.1    77.0    61.7    27.0     8.8
TEMP/LCD   RCH=  8.0     3142.0   0.06    0.1    77.0    61.7    27.0     8.8
TEMP/LCD   RCH=  9.0     3139.0   0.06    0.1    86.0    68.0    27.0     8.8
TEMP/LCD   RCH= 10.0     3135.0   0.06    0.1    86.0    68.0    27.0     8.8
TEMP/LCD   RCH= 11.0     3131.0   0.06    0.1    89.6    71.6    27.0     8.8
ENDATA5A
REACT COEF RCH=  1.0    0.04     0.0   -0.15 3.0      3.0      0.0      0.0
REACT COEF RCH=  2.0    0.02     0.0    -0.1 3.0      3.0      0.0      0.0
REACT COEF RCH=  3.0    0.02     0.0    -0.1 3.0      3.0      0.0      0.0
REACT COEF RCH=  4.0    0.02     0.0    -0.1 3.0      3.0      0.0      0.0
REACT COEF RCH=  5.0    0.01     0.0   -0.05 3.0      3.0      0.0      0.0
REACT COEF RCH=  6.0    0.01     0.0  -0.025 3.0      3.0      0.0      0.0
REACT COEF RCH=  7.0    0.01     0.0   -0.01 3.0      3.0      0.0      0.0
REACT COEF RCH=  8.0    0.01     0.0   -0.01 3.0      3.0      0.0      0.0
REACT COEF RCH=  9.0    0.01     0.0     0.0 3.0      3.0      0.0      0.0
REACT COEF RCH= 10.0    0.01     0.0    0.01 3.0      3.0      0.0      0.0
REACT COEF RCH= 11.0    0.01     0.0    0.05 3.0      3.0      0.0      0.0
ENDATA6
N AND P COEF    RCH=  1.0   0.01   -0.2    0.2    -0.1     1.0     0.1   -0.1    -0.1
N AND P COEF    RCH=  2.0   0.01   -0.1    0.2   -0.05     1.0     0.1  -0.05    -0.1
N AND P COEF    RCH=  3.0   0.01   -0.1    0.2   -0.05     1.0     0.1  -0.05    -0.1
N AND P COEF    RCH=  4.0   0.01   -0.1    0.2   -0.05     1.0     0.1  -0.05    -0.1
N AND P COEF    RCH=  5.0   0.01  -0.05    0.2     0.0     1.0     0.1  -0.01   -0.05
N AND P COEF    RCH=  6.0   0.01  -0.05    0.2     0.0     1.0     0.1  -0.01   -0.05
N AND P COEF    RCH=  7.0   0.01    0.0    0.2     0.0     1.0     0.1    0.0     0.0
N AND P COEF    RCH=  8.0   0.01    0.0    0.2     0.0     1.0     0.1    0.0     0.0
N AND P COEF    RCH=  9.0   0.01    0.0    0.2     0.0     1.0     0.1    0.0     0.0
N AND P COEF    RCH= 10.0   0.01    0.0    0.2     0.0     1.0     0.1    0.0     0.0
N AND P COEF    RCH= 11.0   0.01    0.0    0.2     0.0     1.0     0.1    0.0     0.0
ENDATA6A
ALG/OTHER COEF RCH=  1.0   15.0    0.6   0.04     0.4     0.0     0.0    0.0
ALG/OTHER COEF RCH=  2.0   15.0    0.6   0.04     0.4     0.0     0.0    0.0
ALG/OTHER COEF RCH=  3.0   15.0    0.6   0.04     0.4     0.0     0.0    0.0
ALG/OTHER COEF RCH=  4.0   15.0    0.6   0.04     0.4     0.0     0.0    0.0
ALG/OTHER COEF RCH=  5.0   15.0    0.6   0.04     0.4     0.0     0.0    0.0
ALG/OTHER COEF RCH=  6.0   15.0    0.6   0.04     0.4     0.0     0.0    0.0
ALG/OTHER COEF RCH=  7.0   15.0    0.6   0.04     0.4     0.0     0.0    0.0
ALG/OTHER COEF RCH=  8.0   15.0    0.6   0.04     0.4     0.0     0.0    0.0
ALG/OTHER COEF RCH=  9.0   15.0    0.6   0.04     0.4     0.0     0.0    0.0
ALG/OTHER COEF RCH= 10.0   15.0    0.6   0.04     0.4     0.0     0.0    0.0
ALG/OTHER COEF RCH= 11.0   15.0    0.6   0.04     0.4     0.0     0.0    0.0
ENDATA6B
INITIAL COND-1 RCH=  1.0   70.0    5.8    2.8    89.0     4.0     3.4    0.0  350.0
INITIAL COND-1 RCH=  2.0   67.0    7.2    2.4   177.0     6.8     3.3    0.0 1600.0
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INITIAL COND-1 RCH=  3.0    79.0    13.1     2.4  165.0     5.4     3.3     0.0  420.0
INITIAL COND-1 RCH=  4.0    79.0    11.3     2.3  165.0     5.4     3.3     0.0  420.0
INITIAL COND-1 RCH=  5.0    75.0     9.3     2.2  165.0     6.0     2.0     0.0   20.0
INITIAL COND-1 RCH=  6.0    75.0     8.6     1.7  165.0     6.0     2.0     0.0   20.0
INITIAL COND-1 RCH=  7.0    75.0     7.6     1.2  156.0     4.6     1.9     0.0   80.0
INITIAL COND-1 RCH=  8.0    72.0     7.1     1.1  123.0     3.1     1.2     0.0   97.0
INITIAL COND-1 RCH=  9.0    73.0     6.7     3.5  136.0     3.7     1.5     0.0  200.0
INITIAL COND-1 RCH= 10.0    73.0     6.7     3.5  136.0     3.7     1.5     0.0  200.0
INITIAL COND-1 RCH= 11.0    80.0     7.0     2.8  108.0     2.6     2.3     0.0    7.0
ENDATA7
INITIAL COND-2 RCH=  1.0     0.0    0.87    0.03   0.01    0.05    0.03    0.02
INITIAL COND-2 RCH=  2.0     0.0    0.58    0.02   0.01    0.05    0.03    0.02
INITIAL COND-2 RCH=  3.0     0.0    0.58    0.02   0.01    0.05    0.03    0.03
INITIAL COND-2 RCH=  4.0     0.0    0.58    0.02   0.01    0.06    0.03    0.03
INITIAL COND-2 RCH=  5.0     0.0    0.58    0.02   0.01    0.05     0.0    0.03
INITIAL COND-2 RCH=  6.0     0.0    0.58    0.02   0.01    0.05     0.0    0.02
INITIAL COND-2 RCH=  7.0     0.0    0.38    0.02   0.01    0.05    0.02    0.01
INITIAL COND-2 RCH=  8.0     0.0    0.48    0.01   0.01    0.05    0.02    0.01
INITIAL COND-2 RCH=  9.0     0.0    0.57    0.03   0.01    0.05    0.03    0.01
INITIAL COND-2 RCH= 10.0     0.0    0.57    0.03   0.01    0.05    0.03    0.01
INITIAL COND-2 RCH= 11.0     0.0    0.49    0.01   0.01    0.05    0.01    0.01
ENDATA7A
INCR INFLOW-1   RCH=  1.0     0.0    54.0     6.0    0.0   89.0     4.2     3.0    0.00.E+00
INCR INFLOW-1   RCH=  2.0     0.0    52.0     6.0    0.0   89.0     4.2     3.0    0.00.E+00
INCR INFLOW-1   RCH=  3.0     0.0    48.0     5.0    0.0  127.0     4.2     3.4    0.00.E+00
INCR INFLOW-1   RCH=  4.0     0.0    54.0     5.0    0.0  127.0     4.2     3.4    0.00.E+00
INCR INFLOW-1   RCH=  5.0     0.0    57.0     1.0    0.0  105.0     3.6     2.7    0.090.E+00
INCR INFLOW-1   RCH=  6.0     0.0    55.0     1.0    0.0  105.0     3.6     2.7    0.00.E+00
INCR INFLOW-1   RCH=  7.0     0.0    54.0     1.0    0.0  105.0     3.6     2.7    0.00.E+00
INCR INFLOW-1   RCH=  8.0     0.0    54.0     1.0    0.0  105.0     3.6     2.7    0.00.E+00
INCR INFLOW-1   RCH=  9.0     0.0    54.0     1.0    0.0  105.0     3.6     2.7    0.00.E+00
INCR INFLOW-1   RCH= 10.0     0.0    54.0     1.0    0.0  117.0     3.1     2.3    0.00.E+00
INCR INFLOW-1   RCH= 11.0     0.0    54.0     1.0    0.0  117.0     3.1     2.3    0.00.E+00
ENDATA8
INCR INFLOW-2   RCH=  1.0     0.0    0.48   0.035 0.0066   0.032   0.025   0.018
INCR INFLOW-2   RCH=  2.0     0.0    0.48   0.035 0.0066   0.032   0.025   0.018
INCR INFLOW-2   RCH=  3.0     0.0    0.38    0.02  0.005    0.13    0.02    0.02
INCR INFLOW-2   RCH=  4.0     0.0    0.38    0.02  0.005    0.13    0.02    0.02
INCR INFLOW-2   RCH=  5.0     0.0    0.29   0.018  0.006    0.11    0.02   0.008
INCR INFLOW-2   RCH=  6.0     0.0    0.29   0.018  0.006    0.11    0.02   0.008
INCR INFLOW-2   RCH=  7.0     0.0    0.29   0.018  0.006    0.11    0.02   0.008
INCR INFLOW-2   RCH=  8.0     0.0    0.29   0.018  0.006    0.11    0.02   0.008
INCR INFLOW-2   RCH=  9.0     0.0    0.29   0.018  0.006    0.11    0.02   0.008
INCR INFLOW-2   RCH= 10.0     0.0     0.3    0.01  0.003   0.024   0.003   0.013
INCR INFLOW-2   RCH= 11.0     0.0     0.3    0.01  0.003   0.024   0.003   0.013
ENDATA8A
ENDATA9
HEADWTR-1 HDW=  1.0BLKWTR (EST)          0.14   69.0    6.0    2.8   89.0    4.0    3.4
ENDATA10
HEADWTR-2 HDW=  1.0     0.03.E+02   0.0  0.87   0.03   0.01   0.05   0.03   0.02
ENDATA10A
POINTLD-1 PTL=  1.0CLUB RUN       0.0    0.358   69.0   7.57   0.21   89.0    4.0    3.4
POINTLD-1 PTL=  2.0MILL RUN       0.0    0.375   77.0   7.49   0.42  230.0   12.0    3.5
POINTLD-1 PTL=  3.0CVSP WTP W1    0.0   -0.105   70.0    7.6    0.1   89.0    4.0   0.34
POINTLD-1 PTL=  4.0COON RUN       0.0    0.081   79.0   7.39   0.76   99.2    4.9    3.3
POINTLD-1 PTL=  5.0CVSP LODGE     0.0    0.162   75.0    6.0    5.0  340.0   22.0    2.2
POINTLD-1 PTL=  6.0GLENFITTICH    0.0   0.0062   70.0    6.0    5.0  340.0   22.0    2.2
POINTLD-1 PTL=  7.0BLCKWTR CNTR   0.0   0.0093   70.0    6.0    5.0  340.0   22.0    2.2
POINTLD-1 PTL=  8.0FREELAND RUN   0.0    0.257   64.0   7.51   0.81  131.0    0.5    2.5
POINTLD-1 PTL=  9.0HARTZ&REI      0.0      0.0   70.0    6.0    5.0  340.0   22.0    2.2
POINTLD-1 PTL= 10.0BEAL PROP      0.0      0.0   70.0    7.0    5.0    0.0    0.0    0.0
POINTLD-1 PTL= 11.0YOAKUM RUN     0.0    0.312   72.0    7.4    1.7   93.0    2.5    3.5
POINTLD-1 PTL= 12.0SAND RUN       0.0     0.38   79.0    7.6    0.1   72.0    0.4    0.3
POINTLD-1 PTL= 13.0REC ASSOC      0.0      0.0   70.0    6.0    5.0    0.0    0.0    0.0
POINTLD-1 PTL= 14.0N BRANCH       0.0    1.203   73.0   7.16   1.53  178.0    6.0    2.3
POINTLD-1 PTL= 15.0L BLACKWATER   0.0      1.5   75.0    7.6    0.1   91.0    0.3    3.6
ENDATA11
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POINTLD-2 PTL=   1.0    0.02.E+01   0.0   0.2   0.08  0.07  0.18  0.07  0.12
POINTLD-2 PTL=   2.0    0.64.E+01   0.0  0.23   0.22  0.21  0.44  0.21  0.34
POINTLD-2 PTL=   3.0    0.03.E+02   0.0  0.18   0.02  0.01  0.05  0.01  0.01
POINTLD-2 PTL=   4.0    0.01.E+02   0.0  0.29   0.42  0.41  0.85  0.41  0.63
POINTLD-2 PTL=   5.0    0.04.E+02   0.0   1.0   3.0   3.0   6.0   3.0   5.0
POINTLD-2 PTL=   6.0    0.04.E+02   0.0   1.0   3.0   3.0   6.0   3.0   5.0
POINTLD-2 PTL=   7.0    0.04.E+02   0.0   1.0   3.0   3.0   6.0   3.0   5.0
POINTLD-2 PTL=   8.0    0.07.E+01   0.0   0.3   0.45  0.44  0.91  0.44  0.73
POINTLD-2 PTL=   9.0    0.04.E+02   0.0   1.0   3.0   3.0   6.0   3.0   5.0
POINTLD-2 PTL=  10.0    0.04.E+02   0.0   1.0   3.0   3.0   6.0   3.0   5.0
POINTLD-2 PTL=  11.0    0.02.E+02   0.0  0.45   0.99  0.99  2.0   0.99  1.64
POINTLD-2 PTL=  12.0    0.01.E+01   0.0  0.18   0.02  0.01  0.05  0.01  0.01
POINTLD-2 PTL=  13.0    0.04.E+02   0.0   1.0   3.0   3.0   6.0   3.0   5.0
POINTLD-2 PTL=  14.0    0.01.E+02   0.0  0.41   0.84  0.84  1.7   0.84  1.39
POINTLD-2 PTL=  15.0    0.01.E+01   0.0  0.18   0.02  0.01  0.05  0.01  0.01
ENDATA11A
ENDATA12
DOWNSTREAM BOUNDARY-1       70.0    7.3     0.4   61.0     1.6     3.1     0.01.3E+02
ENDATA13
ENDATA13A
BEGIN   RCH     1
PLOT    RCH     1     2     3     4     5     6     7     8     9    10    11
```

Appendix C Calculation of the WLAs and LAs for the tributaries to the Blackwater

Load allocations (LA) and wasteload allocations (WLA) of CBOD5 were calculated by multiplying the flow by the concentration of CBOD5 from each source. A similar approach was used to calculate the LAs and WLAs for NBOD. For NBOD, the flow was multiplied by the sum of the organic nitrogen and ammonia from each source. The product was then multiplied by 4.57 grams, the quantity of oxygen consumed by the conversion of one gram of organic nitrogen or ammonia to nitrite and then nitrate. Table C.1 shows the values used in the calculations. The resulting values were used in Table 4.5 in the report.

Table C.1 Calculation of WLAs and LAs for each source of pollutant to the Blackwater River

Source	Facility Name	Q	CBOD5		Org-N		NH3-N		NBOD
		mgd	mg/l	lb/d	mg/l	lb/d	mg/l	lb/d	lb/d
Background on Blackwater Mainstem	Background LA	0.140	2.30	2.69	0.37	0.43	0.03	0.04	2.13
Dischargers on Blackwater Mainstem	CVSP - Lodge and Clubhouse	0.105	5.00	4.38	1.00	0.88	3.00	2.63	16.02
	Glen Fiddich	0.004	5.00	0.17	1.00	0.03	3.00	0.10	0.61
	Blackwater Center	0.006	5.00	0.25	1.00	0.05	3.00	0.15	0.92
Club Run	Background LA	0.226	0.10	0.19	0.18	0.34	0.02	0.04	1.73
	CVSP - Cabins	0.005	5.00	0.21	1.00	0.04	3.00	0.13	0.76
Mill Run	Background LA	0.226	0.10	0.19	0.18	0.34	0.02	0.04	1.73
	CVSP - Ski area	0.010	5.00	0.42	1.00	0.08	3.00	0.25	1.53
	CVSP - Campground	0.006	5.00	0.25	1.00	0.05	3.00	0.15	0.92
Coon Run	Background LA	0.045	0.10	0.04	0.18	0.07	0.02	0.01	0.35
	Oriskany Inn	0.007	5.00	0.29	1.00	0.06	3.00	0.18	1.07
Freeland Run	Background LA	0.142	0.10	0.12	0.18	0.21	0.02	0.02	1.08
	Canaan Vistas	0.024	5.00	1.00	1.00	0.20	3.00	0.60	3.66
Yoakum Run	Background LA	0.136	0.10	0.11	0.18	0.20	0.02	0.02	1.04
	Timberline Four Seasons Resort	0.066	5.00	2.75	1.00	0.55	3.00	1.65	10.07
Sand Run	Background LA	0.246	0.10	0.21	0.18	0.37	0.02	0.04	1.87
North Branch Blackwater River	Background LA	0.562	0.10	0.47	0.18	0.84	0.02	0.09	4.29
	Black Bear Resort	0.020	5.00	0.83	1.00	0.17	3.00	0.50	3.05
	North Point	0.040	5.00	1.67	1.00	0.33	3.00	1.00	6.10
	Beaver Ridge - Lots and Lane	0.030	5.00	1.25	1.00	0.25	3.00	0.75	4.58
	Winwood Fly In Resort	0.055	6.00	2.75	1.00	0.46	3.00	1.38	8.39
	Deerfield Village	0.030	5.00	1.25	1.00	0.25	3.00	0.75	4.58
	Canaan Village	0.040	5.00	1.67	1.00	0.33	3.00	1.00	6.10
Little Blackwater River	Background LA	0.969	0.10	0.81	0.18	1.46	0.02	0.16	7.40