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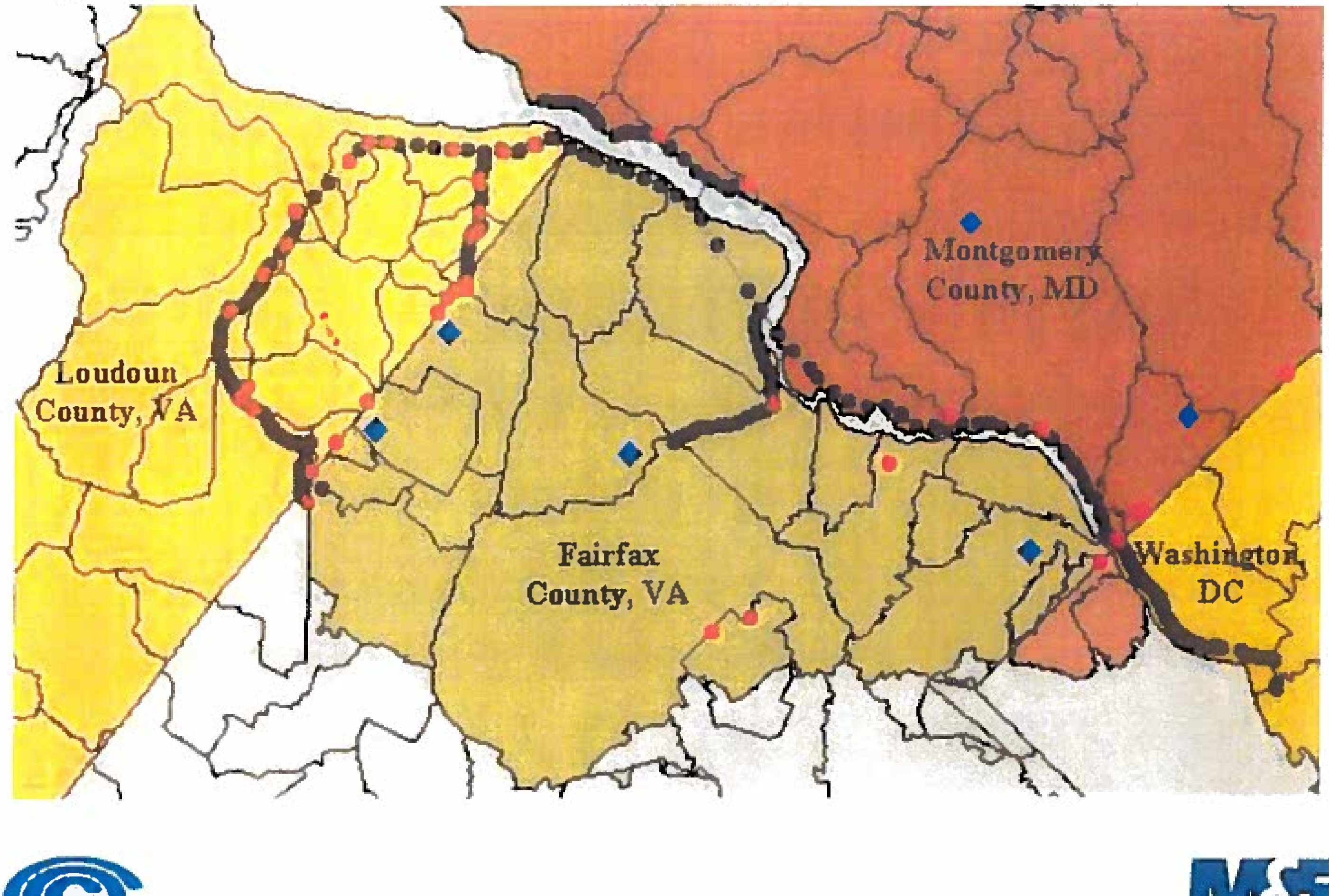
POTOMAC INTERCEPTOR HYDRAULIC MODELING REPORT

July 17, 2003

FINAL

Prepared under:
Metropolitan Washington Council of Governments
Contract 99-037
The Potomac Interceptor Conditions Survey
Modeling and Meter Study, Task 6/7



Metcalf & Eddy

METROPOLITAN WASHINGTON COUNCIL OF GOVERNMENTS
POTOMAC INTERCEPTOR HYDRAULIC MODELING

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EXECUTIVE SUMMARY

This report provides the methodology used for Task 6 (Development of Inflow Loadings from Sewershed Areas) and the results of Task 7 (Engineering Assessment of the Potomac Interceptor Capacity) for the Potomac Interceptor Conditions Survey, Modeling and Meter Study. Task 6 consisted of wastewater flow data analysis to develop model input parameters for the Task 7 hydraulic model of the Potomac Interceptor (PI) system. The simulation of inflow in the PI separate sewer system was based on flow meter data collected during the study period. The overall approach that M&E utilized to simulate the rainfall response inflow in the PI system was to use the SWMM RUNOFF block as a synthetic storm hydrograph generator. Input parameters to RUNOFF were selected to simulate inflow and yield flows that matched the peak flows, as determined from flow monitoring data. M&E conducted model development and calibration of the dry and wet weather flows in the PI system through meter data analysis. Once the model was calibrated to metered flow data, it was used as a tool to evaluate the PI system's capacity in the future under different flow scenarios.

Based on the model simulations conducted for this project, the PI system has capacity to convey the 5-year, 24-hour design storm for the Year 2025 flow projections based on the conditions described by the contributing jurisdictions. However, based on model simulations, the PI system cannot convey peak flows simulated for the 10-year, 24-hour design storm without flooding or surcharging in the downstream area of the PI system. The model developed under this project can be used as a regional planning tool to simulate the impacts of future physical infrastructure changes or demographic changes on the Potomac Interceptor's wastewater conveyance capacity.

1.0 INTRODUCTION

As part of Contract 99-037, The Potomac Interceptor Conditions Survey, Modeling and Meter Study, Metcalf & Eddy (M&E) developed and implemented a dynamic hydraulic model of the Potomac Interceptor (PI) system using PCSWMM. This modeling effort was based on extensive analysis of metered flow data. The goal of this project task was to assess wastewater flow capacity throughout the PI for existing and future conditions during both dry weather and wet weather conditions. The existing conditions were based on field data collected under other project tasks, and the future conditions were based on future population projections provided by the Metropolitan Washington Council of Governments (MWCOG) and input from the PI Users Group.

The PI Users are defined as those jurisdictions that rely on the PI to convey their wastewater flows to the Blue Plains WWTP. This Group provides input and serves as a subcommittee to address technical issues related to the PI system. The PI Users Group consists of the Blue Plains Users Group in addition to Loudoun County Sanitation Authority (LCSA). The Blue Plains Users Group consists of District of Columbia Water and Sewer Authority (DCWASA), Washington Suburban Sanitary Commission (WSSC), Montgomery County, Prince Georges County and Fairfax County. MWCOG serves as the overall coordinator and project manager of this multi-jurisdictional Potomac Interceptor project, which addressed regional wastewater conveyance issues.

As part of this evaluation, M&E collected and analyzed existing jurisdictional wastewater flow meter data and jurisdictional rain gauge data to develop model input parameters to simulate base flows and wet weather response inflows to the PI system. The flow evaluations included derivations of all components of the wastewater flow from meter data including sanitary baseflow, diurnal fluctuations, groundwater infiltration, and rainfall-dependant inflow. By analyzing the behavior of the existing system and using this information to calibrate a dynamic sewer model, the impacts of future changes to the system can be predicted.

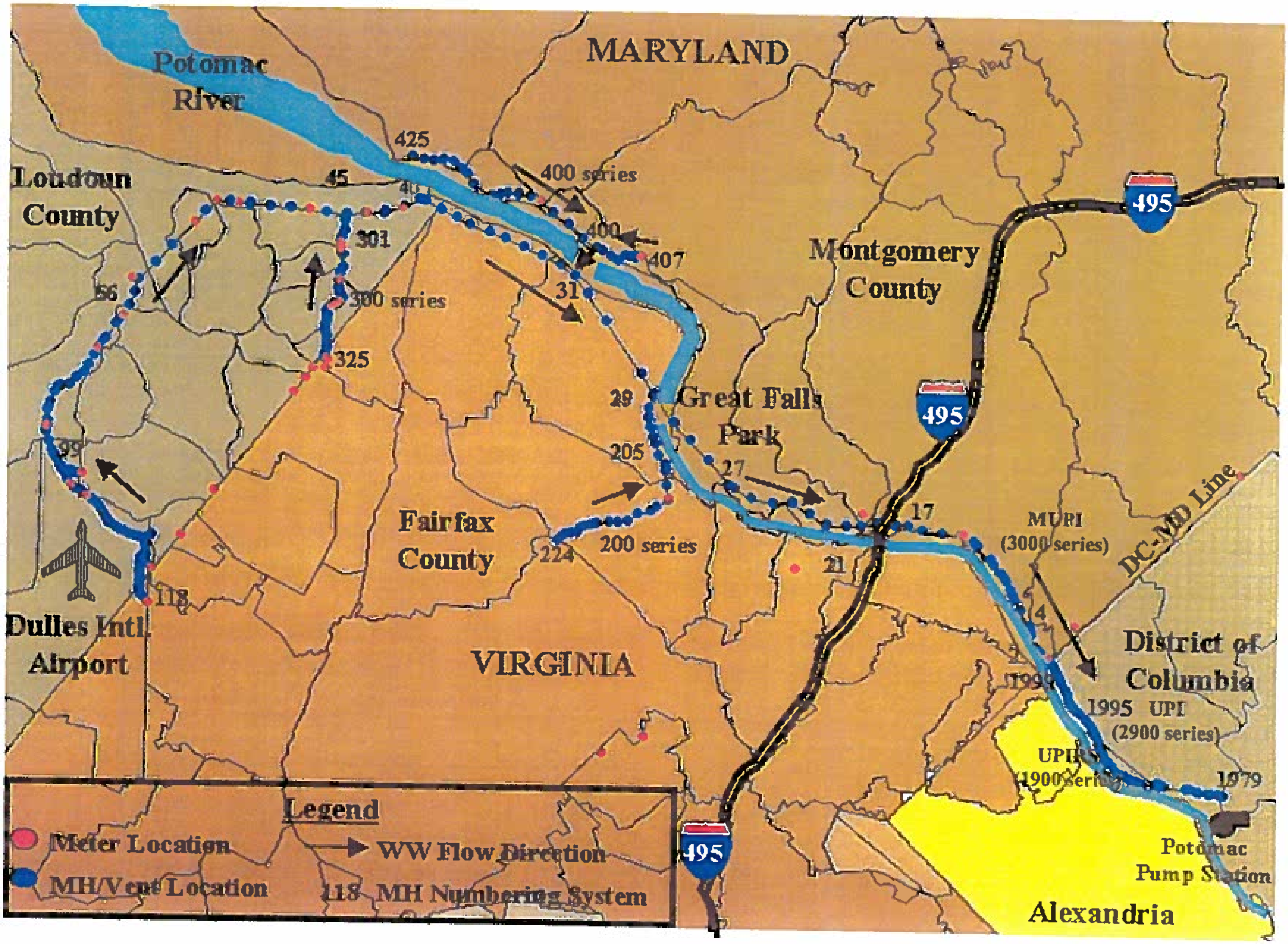
The PI is a separate sanitary sewer system that conveys wastewater from portions of Loudoun County and Fairfax County in Virginia and portions of Montgomery County in Maryland to the border of the

District of Columbia. From the border, the flows are conveyed via the Upper Potomac Interceptor Relief Sewer (UPIRS) to the Potomac Pump Station in Washington, DC. The wastewater flows are then pumped to Blue Plains Advanced Wastewater Treatment Plant (AWTP) in Washington, DC. Several jurisdictions discharge into the PI system, including LCSA, Fairfax County, the Town of Vienna, the Town of Herndon, Dulles Airport, and WSSC. Figure 1 provides the location of the PI and the contributing jurisdictions.

The PI system consists of the main trunk of the PI (Structures 118-1), the Sugarland Run Extension (Structures 325-300), the Difficult Run Extension (Structures 224-200), and the Upper Maryland Spur (Structures 425-400). At the DC/Maryland border, the UPIRS begins at Structure 1999 and continues to the Potomac Pump Station (PS). The Maryland Upper Potomac Interceptor (MUPI) (Structures 3019-3000) is a separate WSSC sewer line that originates at the Cabin John meters (CJ1 and CJ2) and terminates at the Maryland/DC border. At the border, the flows from the MUPI are conveyed via the Upper Potomac Interceptor (UPI) (Structure 2999- 2950) within the District of Columbia, and the UPI currently discharges flow into the UPIRS upstream of the Potomac Pump Station. The UPI and UPIRS run parallel throughout a portion of the District of Columbia.

The PI system has a tributary area of approximately 246,500 acres covering portions of Loudoun County, Fairfax County and Montgomery County. The PI was constructed in 1962 under a Congressional mandate, which authorized the District of Columbia to plan, construct, operate and maintain a sanitary sewer to connect Washington Dulles International Airport with the District of Columbia (Public Law 86-515). The PI system is currently operated and maintained by DCWASA.

Figure 1. Potomac Interceptor (PI) System



2.0 WASTWATER FLOW ANALYSIS

M&E conducted an extensive meter analysis program to develop and calibrate the PI model. Thirty-six jurisdictional wastewater flow meters are located throughout the PI sewershed basin, to meter wastewater flows entering the PI. These meters are owned and operated by the contributing user jurisdictions, and flow data are reported to DCWASA on a monthly basis for billing purposes. Field inspections of the meters were conducted as part of the PI study, and included other meters in the Blue Plains Service Area (BPSA) in addition to those meters in the PI sewershed (for a total of 54 meters). The meter assessments were summarized in the Task 5A – Wastewater Flow Meter Installation, Calibration, and Maintenance Report.

M&E requested metered flow data from the user jurisdictions from January 1998 through December 1999. M&E used the flow data from 30 jurisdictional meters for development of input parameters and flows for the model. The flows from the remaining six meters in the PI sewershed were not directly input to the model since those flows are also metered at other service connections upstream of the PI system. Treeside is a Herndon meter that measures flows entering the PI via the Indian Creek meter; Woodstone, Bridges Branch and Hughes Branch meters measure LCSA flows that enter the PI via the Sugarland Run meter; and Creek Crossing and Northside are Vienna meters that measure flows entering the PI via the Great Falls meter. The locations of the jurisdictional flow meters are shown on Figure 1. Table 1 summarizes the type of flow data obtained from the jurisdictions for flow analysis. A summary of the meters used in the model and the jurisdictional flows metered are provided in Table 2.

Table 1 - Jurisdictional Flow Data Used for Model Development

Jurisdiction	**Type of Meter Data**	**Time Series**
Fairfax County	Electronic	15-minute
LCSA	Electronic	15-minute
WSSC	Circular charts and electronic (for CJ)	Hourly (15-minute only for CJ)
Dulles	Circular charts	Hourly

Table 2– Jurisdictional Meters Used in PI Flow Analysis

Meter Name	Jurisdiction	Used in the Model
Sugarland Run	Fairfax	√
Great Falls	Fairfax	√
Sully Road #1	Fairfax	√
Sully Road #2	Fairfax	√
Rock Hill Road	Fairfax	√
Scotts Run	Fairfax	√
Pimmit Run	Fairfax	√
AT&T	Fairfax	√
Creek Crossing	Vienna	X
Northside	Vienna	X
Cabin Branch	LCSA	√
Indian Creek	LCSA	√
Boise Cascade	LCSA	√
Triple 7	LCSA	√
Seneca	LCSA	√
Russell Branch	LCSA	√
PIP – ZEROX	LCSA	√
Countryside #2	LCSA	√
Great Falls Forest #1	LCSA	√
Great Falls Forest #2	LCSA	√
Countryside #1	LCSA	√
Cascades Western	LCSA	√
Cascades Northern	LCSA	√
Broad Run	LCSA	√
Northwestern	LCSA	√
Northeastern	LCSA	√
Beaumeade #1	LCSA	√
Woodstone	LCSA	X
Bridges Branch	LCSA	X
Hughes Branch	LCSA	X
Treeside	Herndon	X
Dulles Airport	Dulles	√
Muddy Branch	WSSC	√
Watts Branch	WSSC	√
Cabin John Dulles	WSSC	√
Rock Run	WSSC	√

The wastewater flows entering the PI system were evaluated during dry and wet weather conditions to determine the system's responses under varying conditions and to develop model input parameters for inflow. M&E evaluated the flow entering the PI system by analyzing the metered wastewater flow data in correlation with rainfall data collected from several jurisdictional rain gauges. Table 3 provides a list of the rain gauges used in the study, as well as the owner/jurisdiction, gauge location, and data time series recorded by the gauges. Rain gauge data were used to identify and characterize dry and wet weather periods for the PI system. Storm events with varying depth, duration and intensity were analyzed to assess the PI flow response under varying storm conditions. The wet weather wastewater flows were characterized by the amount of rainfall that entered the PI system through the connecting tributary sewers in the form of inflow during these varying storm events. The methods used for dry and wet weather analyses are described in the following sections.

Table 3 - Rain Gauge Data Used for Flow Analysis

Rain Gauge	Jurisdiction	Location	Data Time Series
Sugarland	Fairfax County	Rt 7 and Dranesville Road, near Sugarland Run wastewater flow meter.	15-minute
Rock Hill Road	Fairfax County	Rt 28, near Dulles, near Rock Hill Road wastewater flow meter.	15-minute
CIA	Fairfax County	CIA facility in Langley.	15-minute
Colvin Run	Fairfax County	Colvin Run Road and Leesburg Pike, east of Herndon.	15-minute
RGCC	Montgomery County	Congressional Club, 8500 River Road, Bethesda.	15-minute
RGLT	Montgomery County	2501 Lyttonsville Road, Silver Spring.	15-minute

2.1 Dry Weather Flow

The dry weather flow analysis included evaluation of the average dry weather flow (ADWF), the average groundwater infiltration rate, and the typical diurnal pattern for each analyzed meter. The values of these parameters were estimated using flow data collected during an extended consecutive seven-day dry period (June 1 – 7, 1999) to determine the PI system flow response under dry weather conditions.

The dry weather flows for the 30 jurisdictional meters are included graphically in Appendix A-1. The figures provide the wastewater flow diurnal curves, ADWFs, average daily minimum flow and average infiltration for the dry weather period. The flows were averaged over a 3-hour low flow period (typically in the early morning hours) to calculate the minimum dry weather flows for the meters. Average infiltration rates were estimated for each meter by calculating 88% of the average daily minimum flows, consistent with standard engineering practice.

A typical weekday diurnal curve was developed for each of the evaluated jurisdictional meters using the Monday through Friday flow data for the dry period. The diurnal curves varied between weekdays and weekends due to differing water consumption patterns. The diurnal curves for each meter were developed by averaging the flow meter readings recorded at each time increment over the five day period (Monday – Friday), subtracting the estimated infiltration, and then dividing this value by the difference between the average dry weather flow and the infiltration. This resulted in dimensionless values that represent the diurnal pattern for sanitary flow. The average diurnal curves that were used in the model are discussed further in Section 3.2.

2.2 Wet Weather Flow Analysis

The wet weather flow analysis provided a correlation between rainfall events and wet weather inflow to determine the PI wet weather flow response, and to develop the model input inflow parameters. Inflow is highly variable and was estimated based on data collected throughout the project. Inflow enters sanitary sewers through unintentional openings such as gapped joints, manhole cover openings, leaks in frame seals, roof leaders, yard drains or cellar sump pumps. Since these inflow pathway connections are usually unidentified and difficult to document, inflow was not modeled explicitly. Instead, the amount of inflow entering the PI was estimated based on measured flow meter data during wet weather events.

To characterize wet weather events, M&E evaluated the rainfall data collected throughout the study period and chose a number of storms of varying depth, duration and intensity. In order to evaluate the wet weather response measured for each meter, M&E obtained and correlated rainfall data from the rainfall gauge located in closest proximity to each wastewater flow meter. The rain gauges used for wet weather flow analyses for the wastewater flow meters are provided in a summary table (Table B-1) in Appendix B. The rainfall events selected for the analyses are shown in Table 4. Table 4 indicates the total depth of rain recorded at each rain gauge, in addition to the average duration and intensity of each storm. Differences were noted in the data collected from the various gauges during the same storm, which were attributed to the variability of storms, storm travel characteristics, and the size of the PI sewershed.

Table 4 - Summary of Rain Events Analyzed

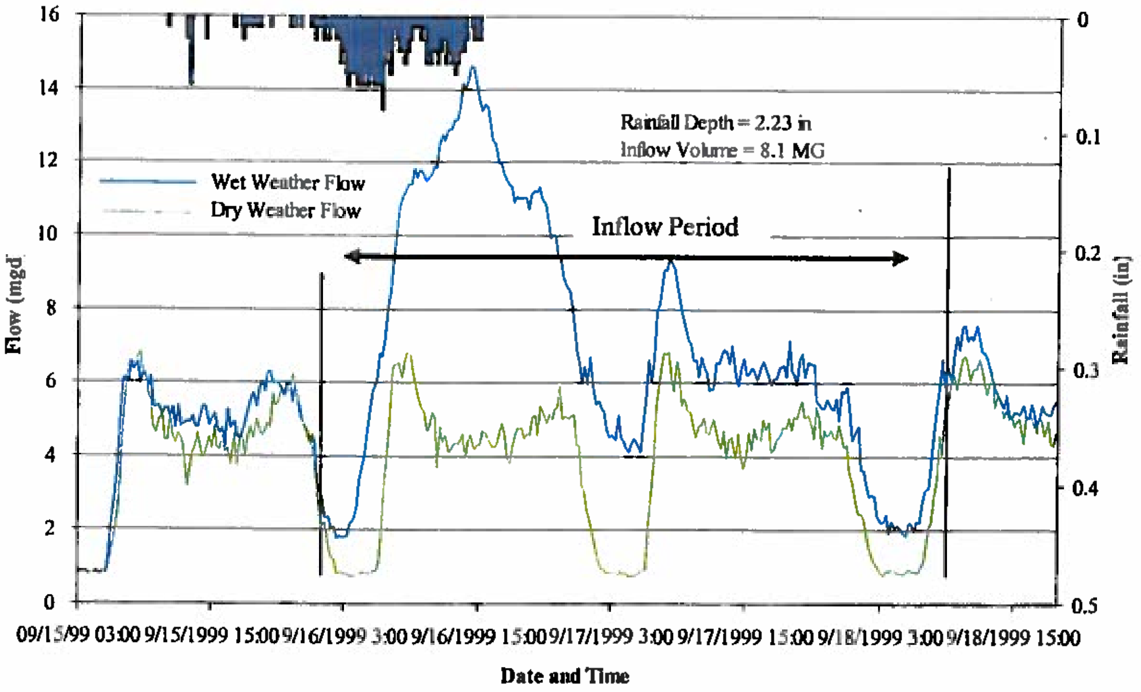
		Total Depth Rain (in)						Average Duration	Average Intensity
Storm #	Date	Sugarland	Rock Hill	CIA	Colvin Run	RGCC	RGLT	(hour)	(in/hr)
1	3/20/98	2.01	2.24	1.85	1.97	1.95	1.72	10.00	0.21
2	4/1/99	0.45	0.41	0.3	0.33	NA	0.45	7.50	0.06
3	5/7/99	1.47	0.86	0.12	0.32	NA	1.47	3.25	0.42
4	5/22/99	0.75	0.49	0.54	0.39	NA	0.51	10.00	0.08
5	5/24/99	0.38	0.42	0.34	0.64	NA	0.66	6.75	0.06
6	7/25/99	0.27	1.02	0.08	1.05	NA	0.15	0.75	0.27
7	8/25/99	1.6	2.7	1.49	1.27	NA	1.1	6.25	0.25
8	9/4/99	0.6	1.21	0.6	0.99	NA	0.87	5.50	0.1
9	9/5/99	0.29	0.48	0.26	0.57	NA	0.75	1.25	0.18
10	9/9/99	0.72	0.68	1.51	2.47	1.18	1.3	3.00	0.22
11	9/15/99	2.23	2.55	4.4	3.41	3.45	3.8	26.25	0.1
12	9/29/99	1.4	1.4	1.37	1.31	-	1.12	15.50	0.09
13	12/13/99	0.98	0.96	0.98	0.96	0.87	0.92	8.50	0.12

NA = data not available or not used.

The primary component of the wet weather flow data analysis was the isolation of the inflow to separate it from the total wastewater flow measured during the wet weather event. M&E isolated and quantified the inflow that occurred during the various storm events by removing the estimated dry weather flow component from the total wastewater flows measured at each metered connection. The dry weather flow pattern that occurred during the 24-hour period immediately preceding the rain event was typically used to remove the dry weather component. If the data in the preceding 24-hour period was not available, then data from an alternate dry weather period were used to represent typical dry weather flow. An extended period during and following the rain event was analyzed until the sewer system flows characteristics returned to dry weather conditions.

The wet weather flows were expressed as a percentage of the dry weather flows to represent the system response to wet weather events. This percentage was calculated by dividing the wet weather flows by the corresponding dry weather flow. The period of time when the wet weather flow was significantly greater than the typical dry weather data was identified as the period during which inflow was impacting the system. This time period generally occurred when the wet weather flow percentage of dry weather flow was greater than 110%. The volume of inflow was estimated for each storm event by subtracting the dry weather flow from the wet weather flows during the period when inflow was impacting the system. This difference was multiplied by the inflow total time period to yield a total inflow volume in millions of gallons (MG). Figure 2 provides an example of the isolation of wet weather inflow in the PI for the Sugarland Run meter site.

Figure 2 Sugarland Run Meter I/I Isolation



The total inflow volume in MG was then converted to acre-inch (MG x 36.83 = acre-inch). Inflow volumes in units of acre-inches for each storm (Table 4) were plotted versus the corresponding rainfall depth in inches. A linear regression was performed for the points, and the resulting equation of the line was used to relate the volume of inflow to the depth of rainfall. The slope of the line was used to represent the area of the basin multiplied by the capture ratio/inflow coefficient. Regression plots are included in Appendix A-2 to represent the wet weather flow analysis for 18 of the wastewater flow meters, including the equation of the regression line and the R^2 value. The R^2 values provide a statistical indication of how well the rain and inflow volume form a linear relationship and can range from 0.0 to 1.0, with higher values indicating a stronger regression relationship. In some cases, storms were identified as outliers and not used in the regression analysis.

The regression analyses described above were performed using the data obtained from the 18 meters that meter the connections contributing the highest average flows to the PI. Regression analyses were not conducted for the 12 wastewater meters that meter small flows to the PI (AT&T, Countryside #2, Broad Run, Northeastern, Northwestern, Beaumeade #1, Seneca, Countryside #1, Cascades Western, Cascades North, Great Falls Forest #1, Great Falls Forest #2). For these flows, model input parameters were developed based on an evaluation of inflow and rainfall data from fewer storms.

The capture ratio identifies the fraction of the rainfall occurring in the metered basin that entered the sewer system as inflow. The point at which the regression line crosses the x-axis (x-intercept) represents the depression storage. This value indicates how much rain must fall before the sewer system shows an inflow response. The wet weather flow data analysis resulted in model input parameters to simulate inflow. These parameters are further discussed in Section 3.2.

3.0 MODEL DEVELOPMENT

3.1 Model Description

PCSWMM 2000 was used for modeling and assessment to simulate the hydrodynamic conditions throughout the PI system. PCSWMM was developed from the Environmental Protection Agency (EPA) Stormwater Management Model (SWMM) engine, and combined with a Windows-based shell and graphical user interface by Computer Hydraulics International (CHI) in Ontario, Canada. PCSWMM provides a user-friendly version of the public domain SWMM program. SWMM version 4.4gu was used for this project. The TRANSPORT, RUNOFF and EXTRAN blocks of SWMM were used to model the flows in the PI system. Each SWMM block models one aspect of the overall system and the results from a block can stand-alone or be used as input into another block. The RUNOFF block simulates the rainfall and the hydrology of the PI basins in the form of inflow hydrographs. RUNOFF was used as a synthetic storm hydrograph generator to simulate rainfall-induced inflow for the PI metered connections. The TRANSPORT block simulates sanitary flows entering the sanitary system at each connection based on an average diurnal curve. The average groundwater infiltration was input to each connection in the EXTRAN block. The EXTRAN block routes the flows generated in RUNOFF and TRANSPORT through the collection system. The EXTRAN block was used to model the hydraulics of the PI pipe network. EXTRAN solves the complete dynamic flow routing equations (St. Venant equations) for an accurate simulation of backwater, looped connections, surcharging, and pressure flow. Model input and output flow values are given in units of cubic feet per second (cfs), however flows documented in this report are in units million gallons per day (mgd) (1.0 cfs = 1.54723 mgd).

3.2 Model Input File

As described in Section 3.1, the model input file developed for the PI model consists of three SWMM blocks: TRANSPORT, RUNOFF and EXTRAN. Dry weather flows were modeled using the TRANSPORT and EXTRAN blocks. Average sanitary flows enter the system at each node representing a metering site in TRANSPORT. Average diurnal curves were developed based upon wastewater flow analysis for each flow meter, as described in Section 2.1. One diurnal curve may be entered for each TRANSPORT block, however eight TRANSPORT blocks were used in the model to simulate different diurnal patterns observed at the meter sites throughout the PI. The average diurnal curves are shown in Appendix A-1. The average diurnal curve entitled Diurnal #1 represents the average of Sully Road #1, Sully Road #2, Rock Hill Road, Sugarland Run, Scotts Run, AT&T (Fairfax meters), Cabin John, Watts Branch, Rock Run, (WSSC meters), Cabin Branch, Countryside #2, Broad Run, Northeastern, Northwestern and Beaumeade #1 (LCSA meters). The average diurnal curve entitled Diurnal #2 represents the average of Boise Cascade, Seneca, Countryside #1, Cascades Western, Cascades North, Great Falls Forest #1, Great Falls Forest #2, Triple 7 (LCSA meters). Unique diurnal curves (and hence different TRANSPORT blocks) were simulated for Great Falls (Fairfax), Russell Branch, Indian Creek, PIP-Zerox (LCSA meters), Muddy Branch (WSSC meter) and Dulles. The summary table in Appendix B provides the diurnal pattern used in the model for each metered flow connection (1, 2 or "u"). The average diurnal pattern identified as "u" in the table indicates that a unique diurnal curve is used in the model pertaining to these flows. The average flows were entered on the Q1 (Subarea) card and the diurnal pattern was entered on the M1 (Hourly Flow Correction) card in the TRANSPORT block.

The physical data describing the PI system, including manholes (junctions) and pipes (conduits) was entered in the EXTRAN Block. This information was imported into EXTRAN using the PCSWMM GIS Import Wizard from a spreadsheet. The information was collected under other tasks of the PI Conditions Survey, Modeling and Meter Study-the node and junction information were obtained by the conditions assessment and physical survey (Task 3), and stored in the PI Relational Database Management System (Task 4). Additional information was obtained through review of the PI record drawings provided by DCWASA. Pipe (conduit) information entered on the C1 (Conduits/ Channels) card includes the following: conduit ID, upstream junction ID, downstream junction ID, type of conduit material, conduit depth (diameter), length, ZP1, ZP2 and roughness. ZP indicates the height of the invert of connecting conduits above the junction floor (ZP1 represents the upstream value and ZP2 the downstream value). Information included on the D1 (Junction Data) cards for junction (node) data includes the junction ID, rim elevation, invert elevation and base infiltration flow. Average groundwater infiltration values were entered at each node representing a metering site. The model conduit and junction numerical identifiers (IDs) are similar to the IDs used for manholes and pipes in the PI Database (Task 4), with some exceptions. Due to model limitations with alphanumeric identifiers and decimal points, some of the IDs used in the model input files for conduits and junctions are different from the pipe and manhole IDs in the database (DB). Table C-1 in Appendix C provides a legend for comparison between database IDs and the model IDs for manholes/ junctions, and Table C-2 provides a legend for comparison between database IDs and the model IDs for pipes/ conduits. Typically, when a decimal is used for a DB ID, the corresponding model ID starts with a 7 and has no decimal place (for example, 103.83 in the DB is 710383 in the model). The meter IDs used in the model are the same 4000-series as identified in the database, and are provided in Appendix C. Table C-3 in Appendix C summarizes the upstream and downstream nodes and "dummy" pipes for each metered connection used in the model to simulate the flow entering the PI from the metered connections. These pipes are referred to as "dummy" since they do not represent the actual physical conditions of the upstream jurisdictional sewer lines that feed into the PI, as these upstream conditions have not been modeled.

M&E used RUNOFF as a synthetic storm hydrograph generator to simulate rainfall-induced inflow in the PI sanitary sewer system. This approach differs from the more conventional use of the RUNOFF block to simulate the physical characteristics of the overland flow for storm sewers or combined sewer systems. The wet weather relationships between rainfall and inflow were modeled using the RUNOFF block. The RUNOFF block requires input values for percent impervious, basin area, overland slope and basin width parameters. Calculation of the percent inflow, or capture ratio was previously discussed in Section 2.2. The percent inflow was used as the percent impervious (of the basin) model input value by setting the infiltration rate to a high value in the model (100 in/hr). This action prevents the pervious areas from contributing to the inflow in the separate sewer system and establishes the inflow to be derived from the impervious percent of the basin.

Drainage areas associated with each flow meter were estimated based on the geographical information system (GIS) subsewershed shapefile provided by MWCOG, and are included in the summary table in Appendix B. A constant overland slope of 0.01% was used throughout the basins. An empirical basin width, rather than the actual physical width of the basin, was used in the model. The empirical basin width represents the time of concentration of the basin. RUNOFF input parameters consist of: the meter ID, the associated rain gauge ID, basin width, area of the basin, percent impervious, ground slope, impervious area Manning's *n* value, pervious area Manning's *n* value, depression storage and infiltration rate. These parameters were entered in the H1 (Subcatchment Data) card. Rainfall data was entered into the model in the E3 (Precipitation Input) card. The input parameters were selected, then adjusted during calibration if necessary, to yield flows that match the inflows determined from the metered data.

4.0 MODEL CALIBRATION

4.1 PI Calibration

The hydraulic model of the PI system through MH-2 (upstream of the District of Columbia border) were calibrated and verified using inline meter data collected during the project period. The downstream flows of the PI system were estimated as described in Section 4.2. A continuous model simulation for the month of September 1999 was selected for both the dry and wet weather calibration period. A number of varying storm events occurred in September 1999, including Storm # 8, 9, 10, 11, 12 (see Table 4). The hydraulic model simulates dry weather flows as a product of the average dry weather flow and the diurnal curve. The calibration of dry weather flows included base groundwater and sanitary diurnal flows. Wet weather events were calibrated for peak flow and duration (inflow) using 15-minute rainfall data. Calibration of the jurisdictional meters was conducted first to verify that the modeled flows entering the PI system matched the jurisdictional meter data. The in-line meters were then used to compare the flows and depths of wastewater in the PI system to the modeled wastewater flows and depths. The inline meters were located at MH-56, MH-45, MH-40, MH-301, MH-205, MH-29, MH-21, and MH-2, which provided a geographical distribution throughout the PI for flow calibration locations. Flow data from these eight inline meters were used to calibrate the PI model pipe network. The inline wastewater flow meters used were area-velocity meters (American Sigma, Model 950) that used both depth and velocity sensors. During the study period, the meters were inspected and verified biweekly to confirm that they were operating properly. These meters were also calibrated routinely for depth and velocity measurements (under Task 5A).

The dry weather flows simulated in the hydraulic model corresponded well with actual metered flow data. Calibration of wet weather flows required minor adjustment of some model parameters including the basin width and percent impervious values. The percent impervious model input value was determined as described in Section 3.2; however during calibration the C value was adjusted slightly to get a better match between peak modeled flows and peak metered flows. The delay between the rain and the corresponding wet weather inflow response in the sewer was simulated using the basin width parameter. The basin length determines the corresponding time of concentration of rainfall in the basin between the time it is raining and the time when the rain reaches the system. Selection of the basin width parameter allowed for the timing of peak flows to match between the modeled and metered flows. The model was calibrated by adjusting the basin width and percent inflow. Calibration for flow depth included slight adjustment of Manning's *n* value from 0.015 to 0.013, which is in the expected range for reinforced concrete pipe (RCP) roughness values.

Wet weather and dry weather events in September 1999 were used to calibrate and verify the model. The modeled flows correlated well with the metered flow data. Calibration plots that show the model results matched to the jurisdictional metered data are included in Appendix D-1. Calibration plots that show the flow and depth model results matched against the flow and depth metered data for the eight inline meters along the PI are included in Appendix D-2. The summary table in Appendix B provides the calibrated modeled peak flows. These peak flows include the sanitary, infiltration and inflow that entered the PI during the September 1999 calibration period.

4.2 Boundary Conditions

The limits of the model were defined as the same limits for Task 3 field survey and assessment of the PI. The upstream limit consisted of the main PI pipes and spurs as described in Section 1.0. The downstream boundary condition of the model consisted of the UPIRS and the Potomac Pumping Station. The Potomac PS receives flow from the UPIRS (108-inch connection), the 66-inch East Rock Creek Diversion Sewer and the 60-inch Easby Point Trunk Sewer. Both the 66-inch and the 60-inch sewers convey combined sewer (CS) flows from DC. Both of these lines have associated combined sewer overflow structures with inflatable dams (Structure 35 and 34, respectively). The Potomac PS discharges through a 96-inch and a 72-inch force main that routes the flow to the Blue Plains AWTP.

In order to establish the downstream boundary condition and to confirm that the downstream flow conditions do not affect the upstream capacity in the PI, the pipe network from the DC/MD border to the Potomac PS was incorporated into the model and flow inputs were estimated for that segment. The Potomac PS was modeled with a constant flow capacity of 432 mgd design flow. M&E

developed and implemented a plan for estimating dry and wet weather flows in the lower PI sewer system between the MD/DC border and the Potomac Pump Station. The lower PI system consists of flows in the UPIRS received from the PI, UPI, and various other service connections in DC. Figure E-1 provides a schematic with meter locations. The methodology M&E used for estimating dry and wet weather flows in the lower PI system is outlined below, with meters identified and the flow determination points (e.g., Location A) provided in Figure E-1 in Appendix E.

Three of the inline meters described in Section 4.1 (MH-21, MH-45, and MH 205) were removed from service and installed in selected DC locations in August and September 2000. These three meters were installed in DC to assist in determining flows in the downstream area of the PI system. The remaining five inline meters (MH-2, MH-29, MH-40, MH-56 and MH 301) were unavailable for relocation and installation in DC since they were required for flow monitoring verification and billing data collection. There were a number of limitations for meter installations within DC due to access restrictions and hydraulic conditions at many locations. The DC meters were located in MH-2955, MH-2800 and MH-1979, as indicated in Figure E-1 (Appendix E). MH-2955 is part of the UPI, and is located upstream of where the UPI temporarily connects to the UPIRS due to an abandoned and damaged portion of the UPI. The meter located in MH-2800 measures flow in a 48-inch line connecting to the UPI, downstream of the meter at MH-2955. MH-1979 is on the UPIRS and is located in the vault structure on the upstream side of the Rock Creek siphon. Analysis of metered data from existing meters in conjunction with the additional flow meters provided a means to quantify estimated flow inputs in DC. Dry weather flow, followed by estimates for wet weather flow during September 2000 were analyzed at four locations (Locations A- D). Location A was determined using flow data from MH-1979 and subtracting flows from MH-2955 and MH-2800. M&E compared this flow with the flow metered at MH-2 and Pimmit Run meter, and did not find a considerable difference. Based on this flow comparison for September 2000 (see Figure E-2), flows in the 18-inch service/overflow connection on the UPIRS were considered negligible and not included in the model. There are a number of unmetered service connections (as determined from the UPI and UPIRS contract drawings) that connect to the UPI. Total UPI flows were estimated by subtracting the flows at Cabin John #2 meter, which meters flow entering the MUPI from MH-2800 and then adding MH-2955 flows. Unmetered UPI flow connections were input to the model at MH-

2997 and MH-2977, and the metered flow connection at MH-2800 was input in the model. Location B, which is downstream of the location where UPI flows connect to the UPIRS, was determined by adding Location A flows back to MH-2955 and MH-2800 flows. Location B was compared with the flow data at MH-1979 and compared well during September 2000, however, during wet weather, combined sewer flows may enter the UPIRS just upstream of MH-1979 through a 6-inch high stop-plank chamber prior to flowing into the CSO (see Figure E-3 for Structure 38a, 30th Street south of K Street). A wet weather CSO contribution at this location was not identified during September 2000 flow comparison (see Figure E-4).

Location C, which represents UPIRS flows entering the Potomac PS, was more difficult to estimate because of the unmetered combined sewer flows entering the UPIRS at Structure 35a. Structure 35a is located in the Kennedy Center garage in District of Columbia. Due to access restrictions and hydraulic conditions, it was not possible to install temporary meters in this location or directly upstream of the Potomac PS. The flows entering the UPIRS from the 78-inch combined sewer were difficult to determine due to a wye diversion in the line, where a portion of the flow enters the UPIRS and a portion continues into the B-Street/New Jersey Avenue Trunk Sewer. Drawings of this diversion structure indicate that flows can be controlled with two aluminum slide gates, but a note from an inspection on April 23, 1992 indicated that both gates were open (Figure E-5). Considering that the invert elevation of the UPIRS diversion structure is 1.67 feet lower than the B-Street/New Jersey Avenue Trunk Sewer extension, a large percentage of dry and wet weather flow is expected to enter into the UPIRS (Figure E-5).

M&E estimated the flows entering the UPIRS at Structure 35a using metered flow data from MH-1979 and the Potomac PS discharge line meters for the 72-inch and 96-inch force mains. M&E obtained SCADA flow data from DCWASA for the effluent force mains at the Potomac PS. However, since the Potomac PS also receives flows from the 66-inch and 60-inch combined sewer lines, these flows also had to be considered. M&E obtained flow data for a meter that was installed in the 66-inch East Rock Creek Diversion Sewer combined line downstream of Structure 35 and upstream of the Potomac PS from October 1999 to July 2000 to determine the flows entering the Potomac PS. Based on evaluation of the data, average flows for that time period were estimated to be 32 mgd. Upon reviewing the average flow data for MH-1979 and DCWASA flow data for the Potomac PS discharge lines for September 2000, there was a 52 mgd flow difference. This flow difference was determined to be a combination of the flow contributions from the 60-inch Easby Point Trunk Sewer line and the flow entering the UPIRS at Structure 35a. Based on the size of the lines, a 65/35 ratio was applied to the 52 mgd flow difference. Although M&E attempted to model flows entering the UPIRS based on the available meter data, these flows could not be calibrated because of the unconfirmed flow estimates. The model does not simulate the combined sewer lines that enter the Potomac PS (60-inch and 66-inch). Based upon the flow estimates described above, operation of the Potomac PS as designed (460 mgd design flow) and the hydraulic grade line of the UPIRS, flows entering the PI system in the District of Columbia do not appear to affect the capacity of the PI system upstream of the MD/DC border (MH-2).

5.0 FUTURE FLOW SCENARIO

Upon calibration of the model, M&E simulated future flows for the year 2025 in order to identify potential capacity restrictions and identify planning level relief alternatives for the future. The PI Users Group defined the "No Further Action Scenario" as those future changes that have already been planned throughout the jurisdictions that contribute flow to or offload flow from the PI. The "No Further Action Scenario" conditions are further described in the following section.

5.1 Future Wastewater Flows

The Regional Wastewater Flow Forecast Model (RWFFM) provides future wastewater base flow projections (sanitary and infiltration) for the Blue Plains Service Area (BPSA) in 5-year increments from Year 2000 to Year 2025. The RWFFM Update for the BPSA Final Report, dated August 14, 2001 (prepared by M&E under Task 8 of the PI Study) provides information pertaining to unit flow factors (UFFs), infiltration and other planning parameters for the jurisdictions contributing flow to Blue Plains WWTP. The results of the RWFFM were input to the PI model for year 2025 base sanitary and infiltration flows. The wet weather inflow parameters, that were discussed in previous sections were used to simulate the 2025 inflow response to storm events.

5.2 Modeling Assumptions

The physical features in the model (junctions and conduits) were updated to reflect system changes based on the planned 2025 "No Further Action Scenario" physical modifications, as described by the PI Users Group. These condition changes included:

- Offloading Seneca subsewershed flows from the PI due to the Seneca WWTP expansion;
- Offloading LCSA average flows in the PI greater than 13.8 mgd to the Broad Run Water Reclamation Facility (WRF) at MH-56 based on the agreement between LCSA and DCWASA;
- Offloading Fairfax average flows in the PI greater than 31.0 mgd to the Broad Run Water Reclamation Facility (WRF) at MH-56 based on the Intermunicipal Agreement (IMA);
- Modeling the Cabin John meter system as per the WSSC Standard Operating Procedure (ie, flows less than 16 mgd to the MUPI; flows greater than 16 mgd diverted to the PI via the CJ valve);

- UPI flows currently routed to the UPIRS in Georgetown near the Capitol Crescent Trail will no longer flow to the UPIRS in the future because the currently abandoned UPI will resume service and UPI flows will flow to the Rock Creek Pump Station. These future flows and pipe networks are not modeled.

5.3 Design Storm

The calibrated model was used to simulate design storms by replacing the measured rainfall used for model calibration with the design storm rainfall. The model response for the design storms were then observed. The model was simulated using the 5-year, 24-hour and 10-year, 24-hour design storms. The rainfall distribution is based on the Soil Conservation Survey (SCS) Type II rainfall distribution curves for the Washington metropolitan area. The design storm hyetographs are attached in Appendix F.

The model was simulated such that the peak inflow occurred simultaneously with the peak diurnal sanitary flow (morning). In addition, the design storm was simulated to occur throughout the entire PI sewershed simultaneously. This assumed that the rain event occurred uniformly throughout the areas connected to the PI in LCSA, Fairfax and WSSC jurisdictions.

5.4 Model Results

The PI system wet weather response was evaluated for the 5-year and 10-year design storms to assess PI capacity under the conditions described above. Criteria for analysis included the amount of surcharge that was deemed allowable. Based on discussions with representatives of DCWASA and MWCOG, the criteria for acceptable levels of surcharge within much of the PI was determined to be not less than 2 feet below the manhole rim. However, further surcharging was allowed in the downstream area of the PI along the C&O Canal based upon review of the PI record drawings. The record drawings indicated that the peak hydraulic grade line (HGL) of the lower section of the PI was designed to be pressurized and that the HGL is greater than grade for the downstream manholes.

The peak flows determined from the 5-year, 24-hour design storm simulation resulted in surcharging in a number of areas in the upstream section of the PI (MH-118 – MH 103, MH-94 – MH-83, MH-

73L – MH-57) as well as the downstream area (MH-19 – MH-1990). This surcharging was determined to be acceptable based on the above definitions. Based on these model runs, the capacity of the downstream section of the PI (near MH-2) is 144.6 mgd.

In addition, the 10-year, 24-hour design storm simulation of peak flows resulted in further surcharging in a number of areas in the upstream section of the PI (MH-118 – MH-57) at peak flows. However, the model simulated flooding in the lower section of the PI (MH-18, MH-13 and MH-9). Based on the model results further flow management is required to prevent flooding due to a 10-year storm, which may include reduction of inflow, storage, relief sewer construction or other measures. The tabular results of the 5-year and 10-year, 24-hour design storm simulations are provided in Appendix G. In addition, the peak HGL model results for the specific areas where surcharging and/or flooding occurred are included in Appendix G.

6.0 ADDITIONAL MODEL RUNS

Based upon the results of the 5-year, 24-hour and 10-year, 24-hour design storm simulations for Year 2025, other model simulations were conducted. As defined by the PI Users Group, additional model runs were simulated to assess the capacity of the PI under two additional future scenarios, which were:

- A 10-year, 24-hour "traveling storm" (not occurring throughout the entire PI basin at one time).
  - A simulation of an aggressive I/I program throughout the PI sewershed. Sub-basins with high inflow were identified, and the inflow for those connections was limited.

These two modeling scenarios are further described below.

6.1 Traveling Storm Sensitivity Analysis

Additional model scenarios were simulated to perform a traveling storm sensitivity analysis. Varying the model input parameters for rainfall provided a more realistic representation of the PI's response to wet weather under varying storm conditions. Table 5 below summarizes the six storms that were simulated in addition to the original 10-year storm scenario (Section 5), and the table provides direction, speed and model simulation results for each storm.

Table 5 - Summary of 10-Year, 24-Hour Traveling Storm Analysis

Storm #	Direction	Description	Results
10-year storm	-	Occurring throughout the region	Flooding at MH-9, 13 and 18
		Traveling Storms	
1	W to E	2 mi/hr	Flooding at MH-9, 12, 13 and DC
2	W to E	2 mi/hr	Surcharging, no flooding
3	E to W	2 mi/hr	Surcharging, no flooding
4	E to W	2 mi/hr	Surcharging, no flooding
5	W to E	VA/ MD one hour time lag rain	Flooding at MH-9, 13, 18 and DC
6	E to W	VA/ MD one hour time lag rain	Flooding at MH-9, 13, 18 and DC

The various storms in Table 5 resulted in varying model results due to the location where the simulated peak inflow coincided with the peak diurnal curve. Storms #1, #3 and #5 simulated peak inflow to occur simultaneously with average peak diurnal flows occurring in the upstream region of the PI, whereas Storms # 2, #4 and #6 simulated peak inflow to occur simultaneously with average peak diurnal flows occurring in the downstream region of the PI. Depending upon the timing of the rain event with the diurnal flow, and the overall direction the storm was moving, the model simulations resulted in flooding of the system in the lower section of the PI (MH-9, MH-12, MH-13, MH-18, and throughout the UPIRS in DC) or surcharging in the lower section of the PI.

These six storms were selected to represent variability of storm events and to simulate the variability in the PI response to varying storm events. However, rain direction, intensity and frequency are affected by a number of parameters, and there are many other types of storm events that might occur throughout the Washington DC metropolitan area. As indicated in Table 5, the model results for each of the storm simulations varied with respect to the location and degree of flooding or surcharging. These simulations support the concept that the PI response varies depending upon the type of storm. The key parameters that impact the PI response include the time the peak rain occurs in relation to the peak diurnal flow, and the direction of the rainfall with respect to the PI sewershed.

6.2 I/I Reduction Program Simulation

Additional model scenarios were initiated to simulate an aggressive I/I reduction program with the objective of preventing the flooding that was observed in the 10-year storm models runs (as described in Section 5.4). Six connections throughout the PI were selected due to the high inflow from those connections as seen in the model simulations:

- Muddy Branch – WSSC
- Cabin Branch – LCSA
- Russell Branch – LCSA
- Rock Hill Road – Fairfax
- Sugarland Run – Fairfax
- Pimmit Run – Fairfax

Under this scenario the inflow was reduced for these connections in an iterative process until the PI system no longer flooded which corresponds to a peak flow in the downstream section of the PI of 144 mgd. (See Appendix H). The results of this scenario indicate that with a reduction in the amount of inflow at certain connections, the PI system could operate under surcharged condition rather than flooded conditions. Table 6 below summarizes the simulated peak flow reduction that was obtained for the six selected meter connections in this modeling scenario. Further results (summary of flows and HGL model output) of this modeling scenario are also included in Appendix H.

Table 6 - Summary of I/I Reduction Program

Meter Name	**Peak Flow Reduction (mgd)**
Muddy Branch	7.43
Cabin Branch	5.16
Russell Branch	3.03
Rock Hill Road	1.36
Sugarland Run	4.10
Pimmit Run	4.92

7.0 CONCLUSIONS

The PI model may be used as a tool to run additional scenarios to evaluate the results of future PI system changes and to evaluate alternatives to reduce potential capacity restrictions, including I/I reduction programs, rehabilitation programs, and/or structural modifications.

Continued monitoring of the PI flows through the current metering program is recommended. Additional data collection of flows entering the PI (average and peak flows) would provide a means to confirm the flow projections and the conditions used in the model simulation.

The model was developed using currently available meter data (1998/99) and information obtained from the jurisdictions at the time of the project. If changes occur that would affect the PI system, the model should be updated in the future to include any additional structural or other changes that occur (in addition to those included in the model runs described herein for future scenarios). The inflow response for the 2025 flows were based on the wet weather flow response observed during the calibration period, but metered connections may exhibit different responses in the future due to age or changes upstream in the system. These changes should be periodically incorporated into model updates in the future. Additional flow data collection would provide data to support any required model changes due to future changed conditions.

Based on the specific operating assumptions and model simulations conducted for this project, the PI system has capacity to convey the 5-year, 24-hour design storm for the Year 2025 flow projections based on the conditions provided by the contributing jurisdictions. However, based on model simulations, the PI system cannot convey peak flows simulated for the 10-year, 24-hour design storm (occurring throughout the system simultaneously), without flooding in the downstream area of the PI system.

To reduce the risk or frequency of flooding flow management actions are required such as the I/I reduction measures simulated in the model (described in Section 6-2).

The model developed under this project can be used as a regional planning tool (rather than as a detailed investigation model for specific flooding problems) to simulate the impacts of future physical infrastructure changes or demographic changes on the Potomac Interceptor's wastewater conveyance capacity. The model is only approximate downstream of MH-2 due to limitations in the available data and possible effects from CSOs (as described in section 4.2). These would need to be investigated further and more precisely modeled to allow the model to be used for more detailed analysis of the PI system downstream of MH-1, within the District of Columbia.

Based on the model runs carried out, the capacity of the downstream section of the PI (near MH-2) is 144 mgd. This is based on the capacity of the surcharged PI.

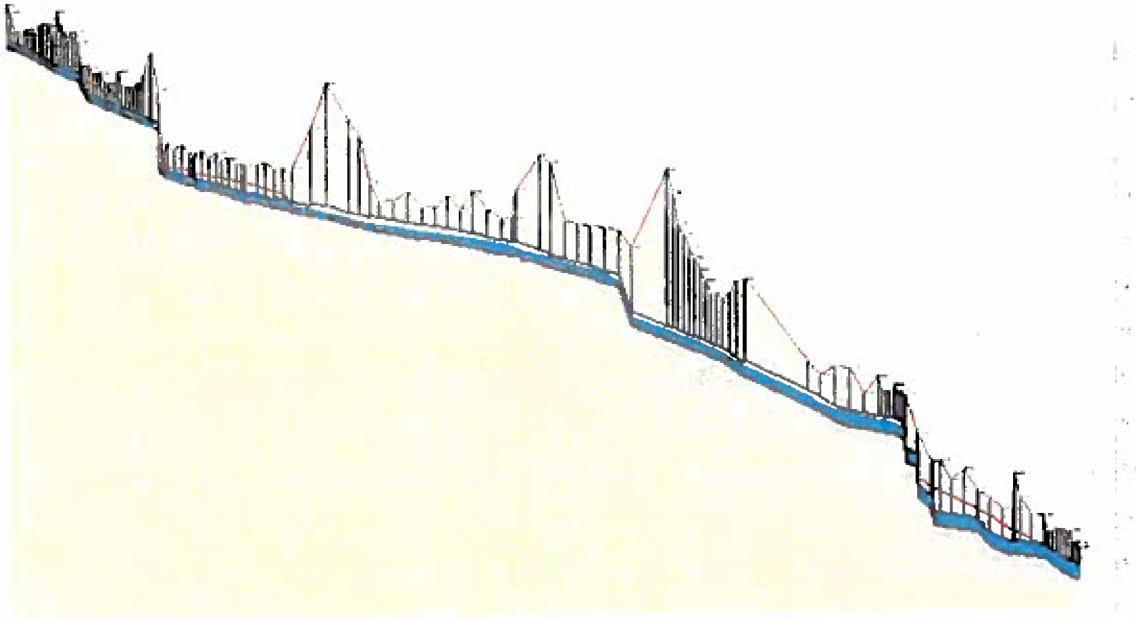
Details of the PI capacity based on the peak flows for the 10 year, 24 hour storm for year 2025 with I/I reduction (as described in Section 6.2) are included in Table 7. A profile of the PI for this flow condition is shown in Figure 3. More detailed profiles for each of the sections referred to in Table 7 are included in Appendix I.

Table 7 - **Estimated PI Capacity**

PI Section MH to MH	Location	County	State	Estimated PI Capacity (MGD)	Notes
118 - 107	Dulles	Loudoun	VA	10	
107 - 103	Dulles	Loudoun	VA	15	
103 - 83	Dulles	Loudoun	VA	17	
83 - 62	Dulles / Broad Run	Loudoun	VA	25	
62 - 58	Broad Run	Loudoun	VA	27	
58 - 56	Broad Run	Loudoun	VA	33	
56 - 49	Broad Run / Algonkian	Loudoun	VA	31	*
49 - 44	Algonkian to Sugarland Run	Loudoun / Fairfax	VA	36	*
44 - 31	Sugarland Run to River Bend	Fairfax	VA	61	*
31 - 29	River Bend to Difficult Run	Fairfax	VA	93	*
29 - 23	Difficult Run to Carderock	Montgomery	MD	121	*
23 – 20	Carderock	Montgomery	MD	127	*
20 - 11	Carderock to Cabin John	Montgomery	MD	132	
11 - 1	Cabin John to DC Line	Montgomery	MD	144	

Rows marked with * refer to sections that were not surcharged under the modeled conditions. There is therefore theoretically additional capacity in the pipe in these sections although use of this spare capacity would result in overloading the PI further downstream.

Figure 3 – PI Capacity Profile



8.0 ADDITIONAL FLOODING INVESTIGATION

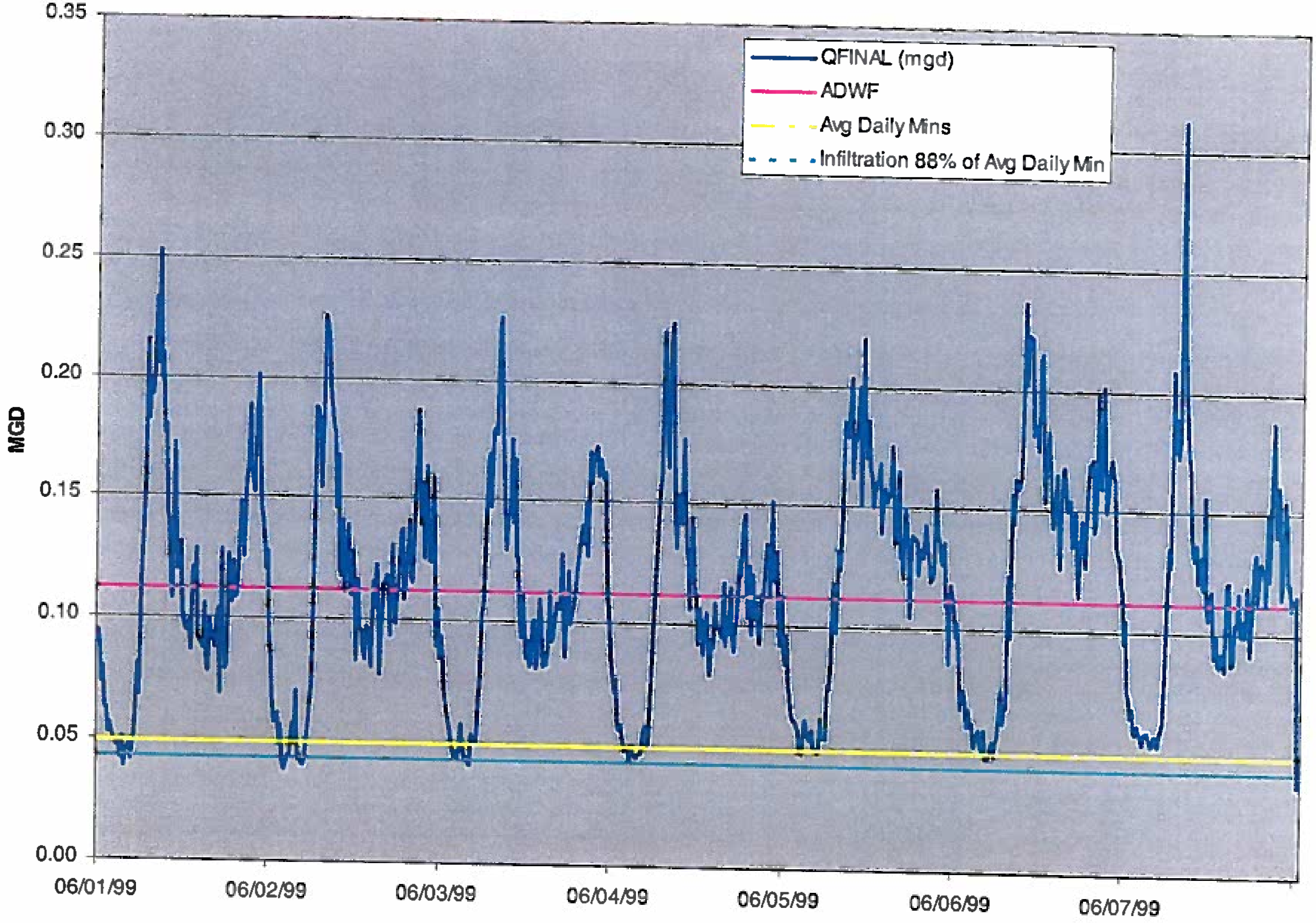
Following completion of the original modeling exercise an additional modeling task was undertaken. This was carried out in early 2003 to investigate flooding that occurred on the PI system during a rain event in February 2003. During this event several manholes on the PI flooded. The flooding occurred in locations that were not predicted by the original model and the rain event was less severe than the return period predicted to cause flooding from the PI system. A report on the flooding is included in Appendix J. The following comments are made based on the results of the investigation of the flooding event.

- The model was calibrated based on a set of specific storms that occurred in the Washington DC area during the project period. Storms of different characteristics may produce different response characteristics. The event conditions in the February 2003 were unusual and not a scenario that is commonly modeled in the analysis of design events. Specifically the rain event in February was combined with snowmelt from recent very heavy snowfall. The snow melt may have filled available depression storage in the catchment which would create higher runoff rates and faster response to the rainfall. The snow melt may also have contributed to higher than normal base flows in the system.
- The model has not been fully calibrated in detail downstream of MH-1. Therefore the depths in this section are not calibrated. If depths are higher than predicted by the model (MH-1979) then the flooding (MH-1991) may be more severe than predicted by the model along the UPIRS (downstream of MH-1).

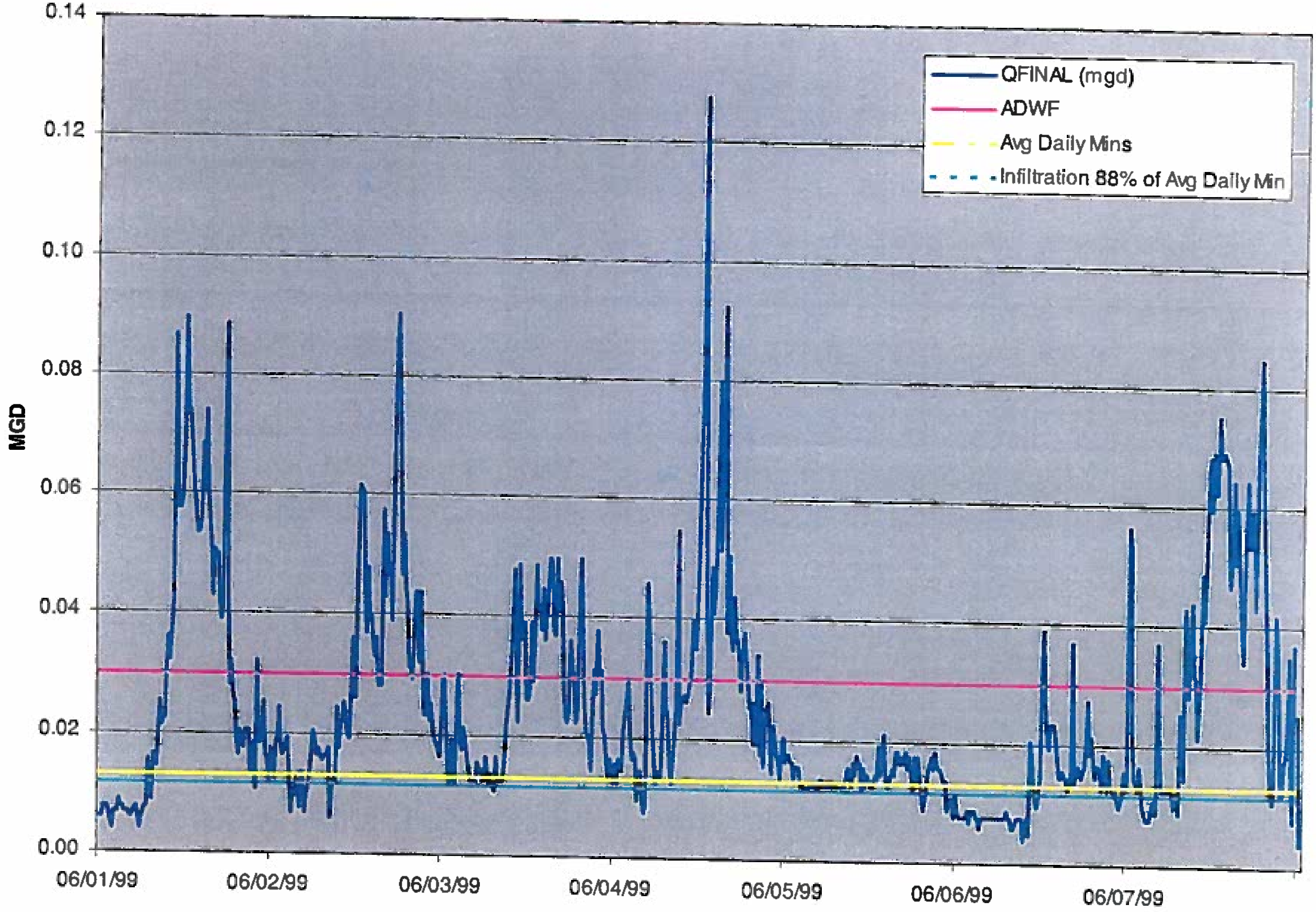
Appendix A
Wastewater Flow Data Analysis Results

Appendix A-1
Dry Weather Flow Analysis Results

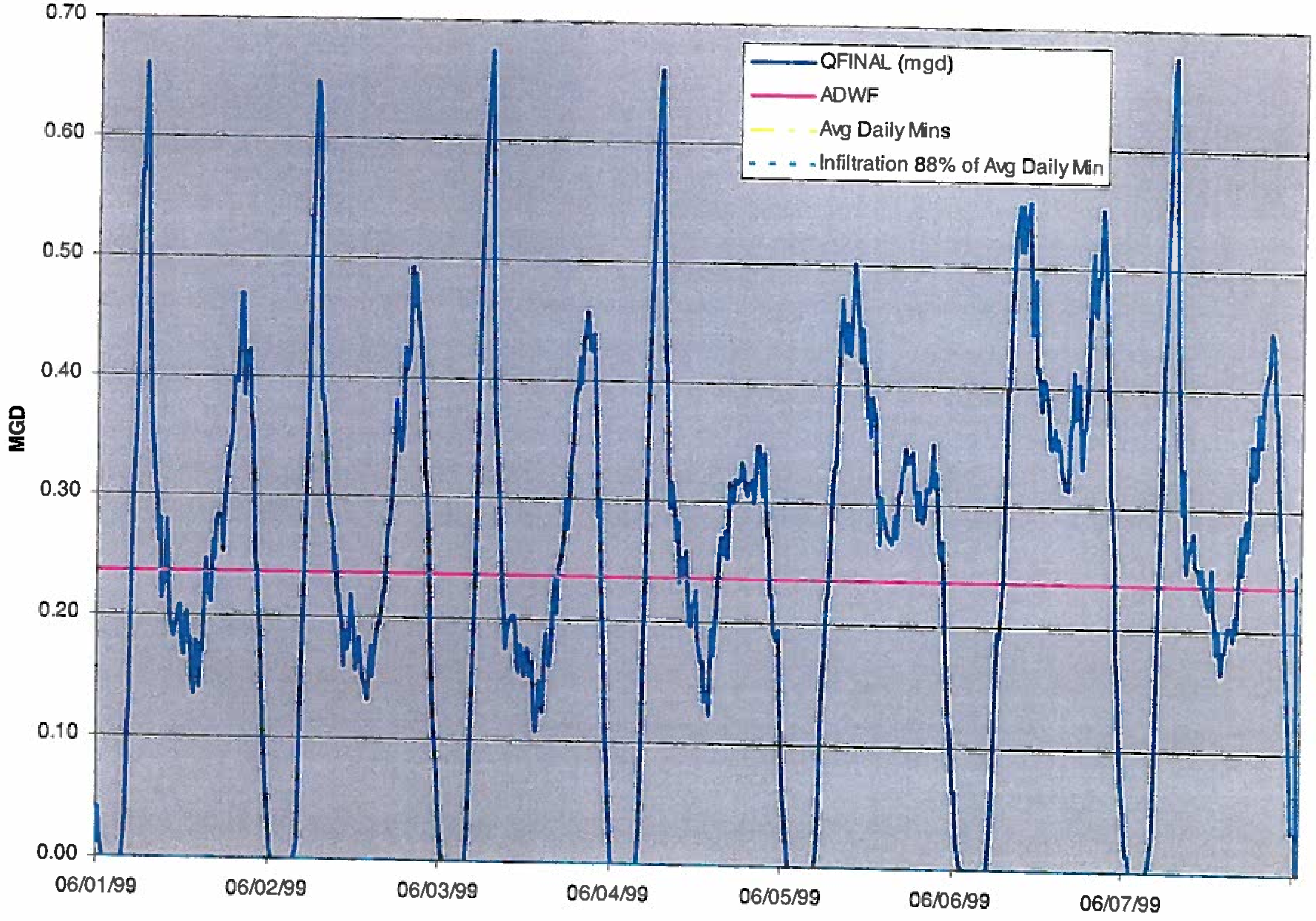
Dry Weather Flow Analysis for AT&T Meter



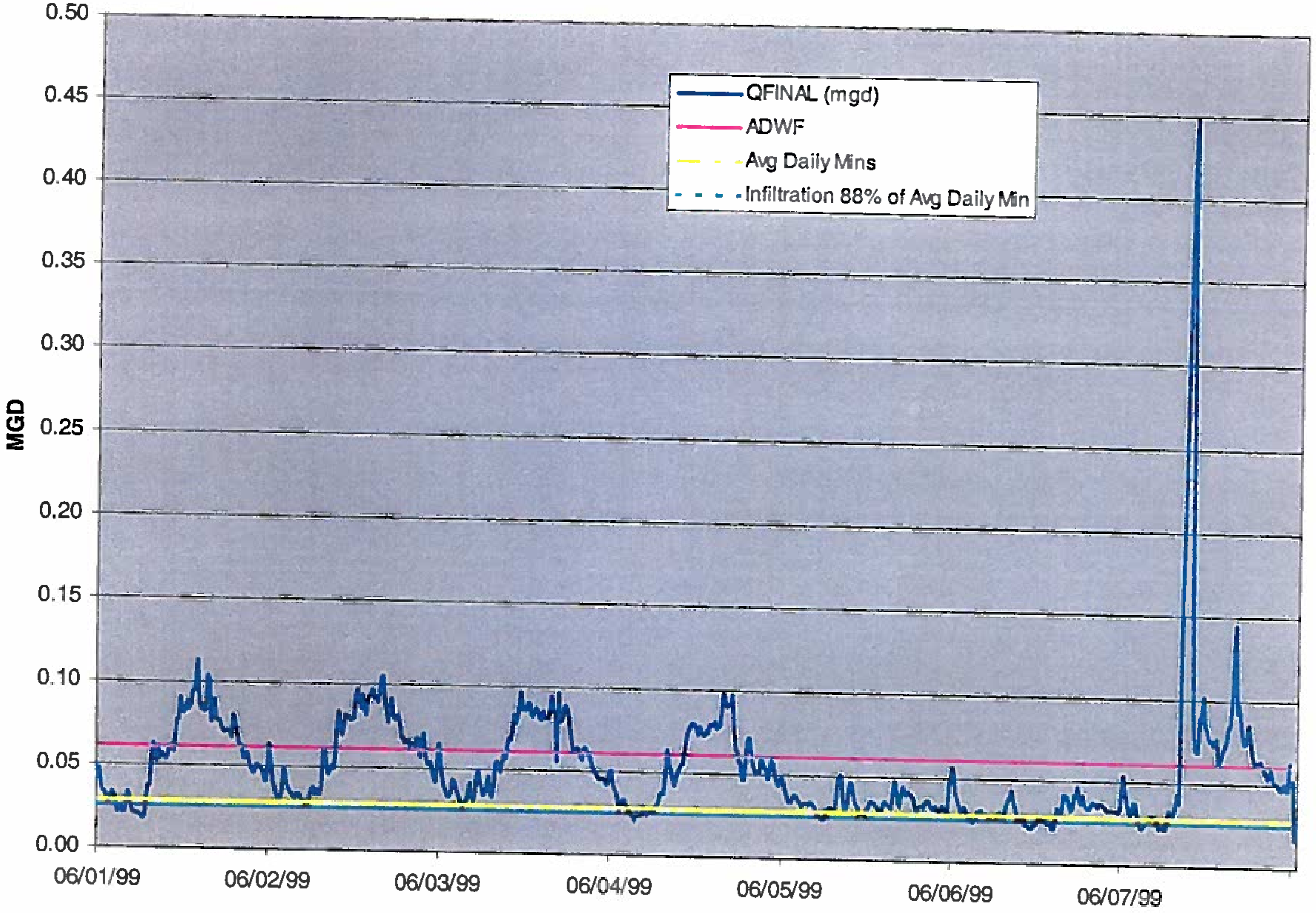
Dry Weather Flow Analysis for Beaumeade Meter



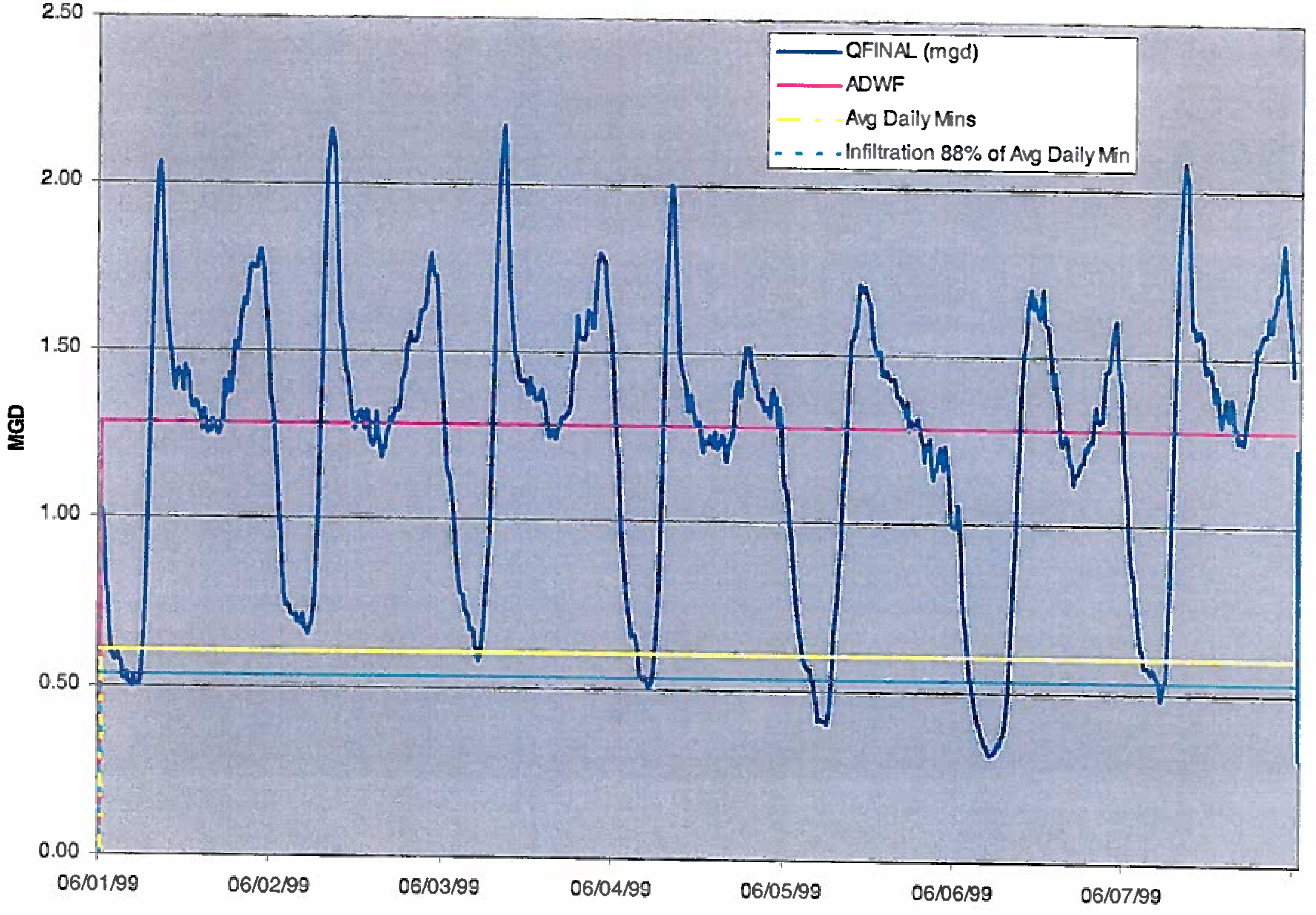
Dry Weather Flow Analysis for Boise Cascade Meter



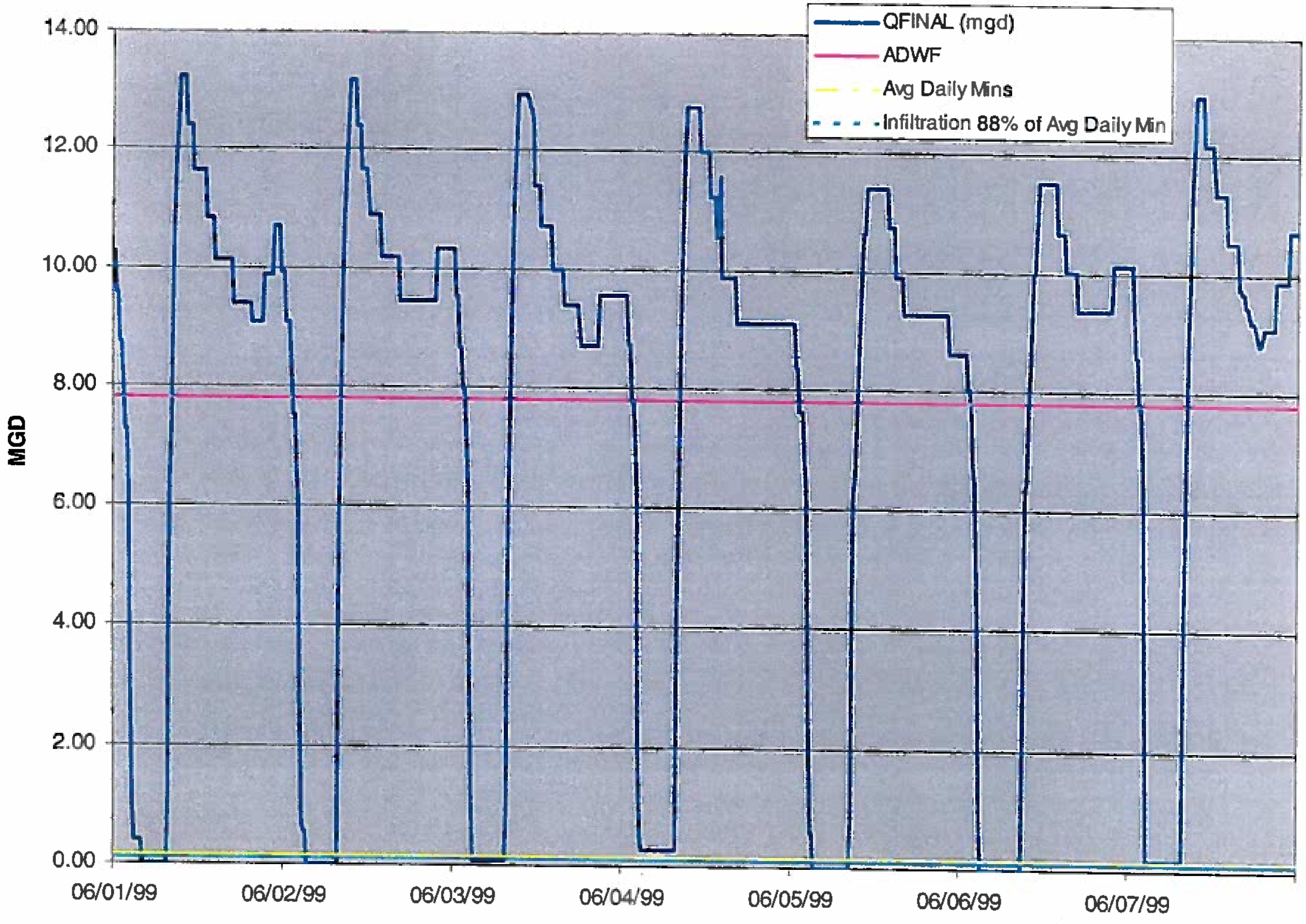
Dry Weather Flow Analysis for Broad Run Meter



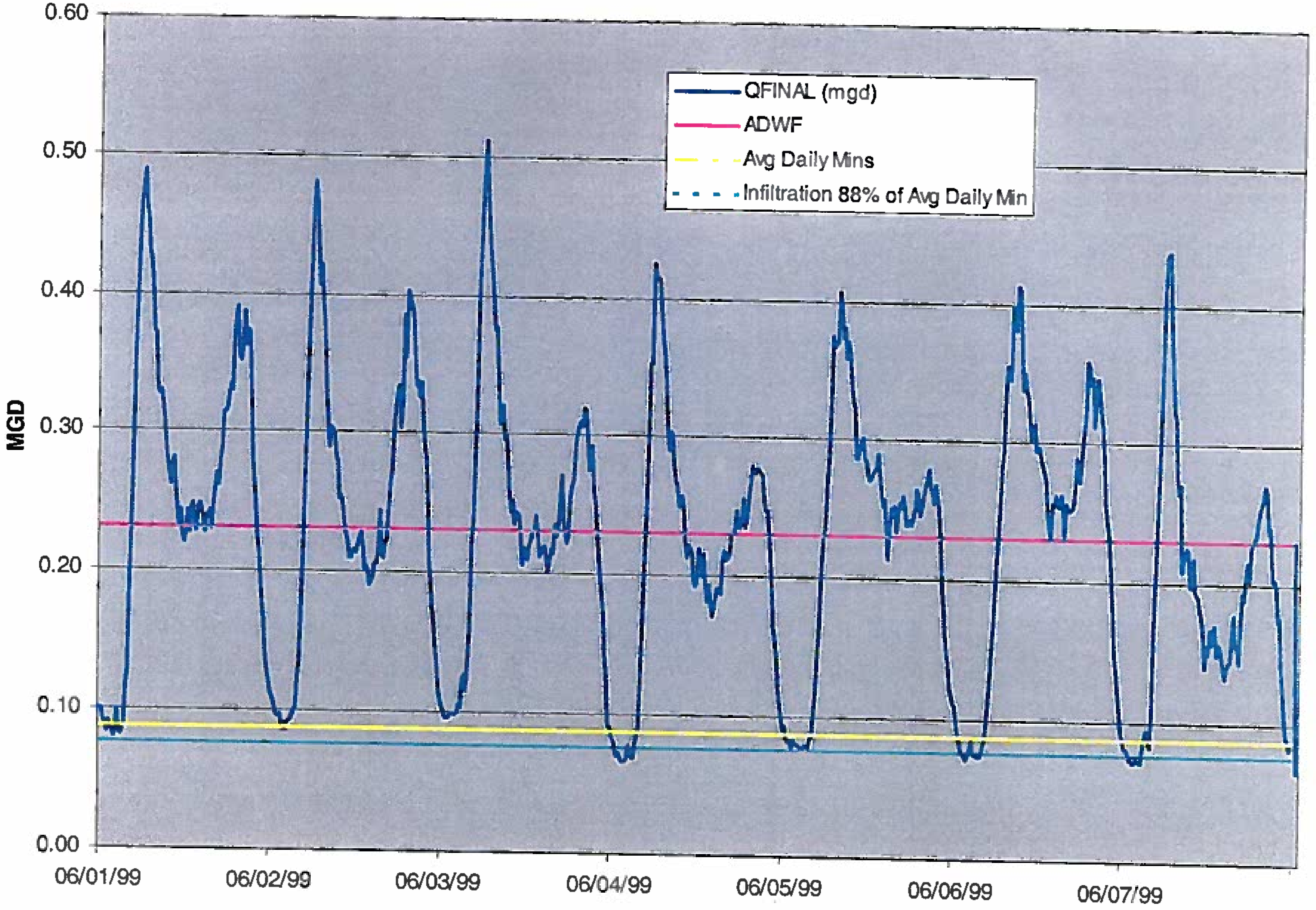
Dry Weather Flow Analysis for Cabin Branch Meter



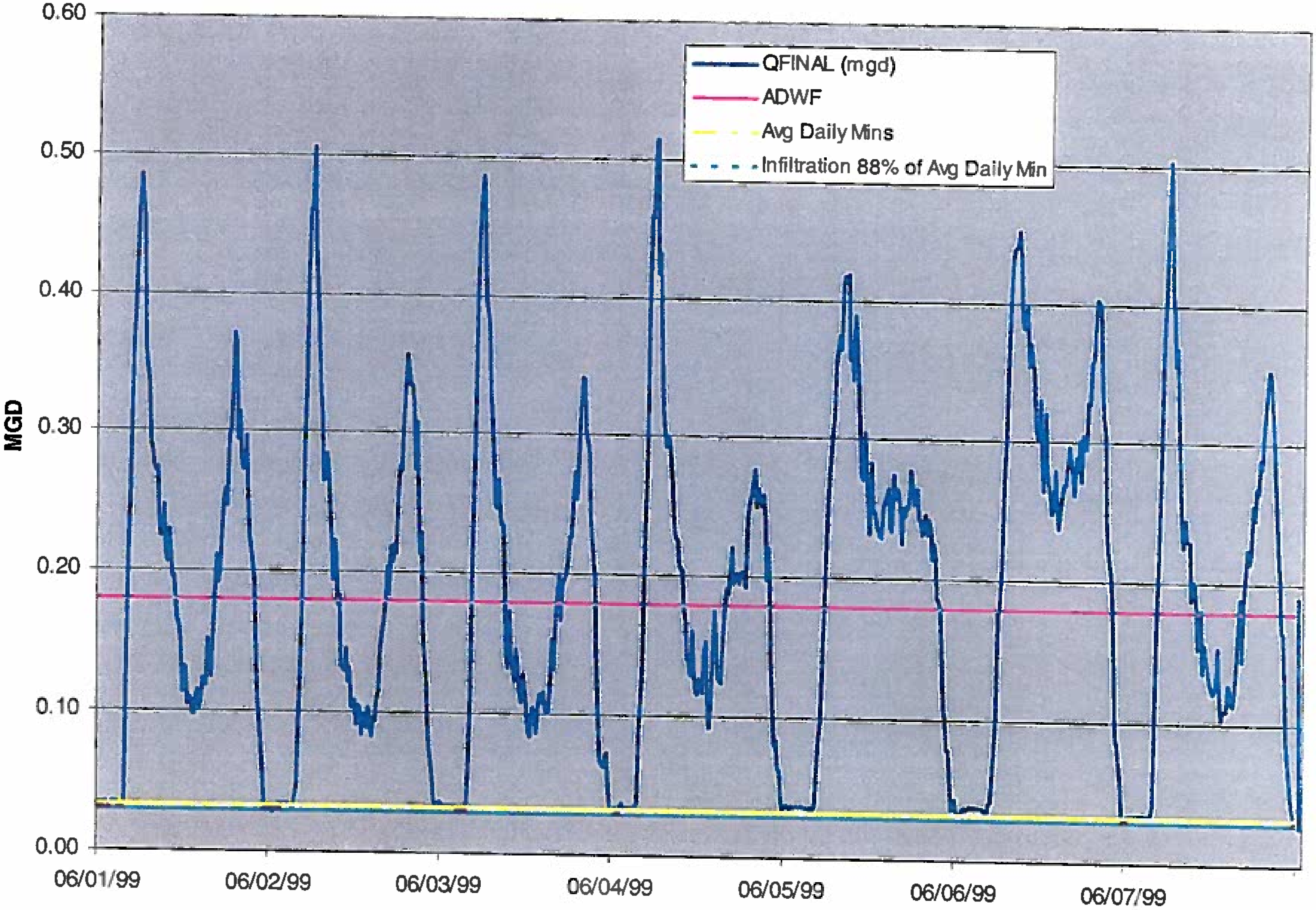
Dry Weather Flow Analysis for Cabin John Meter



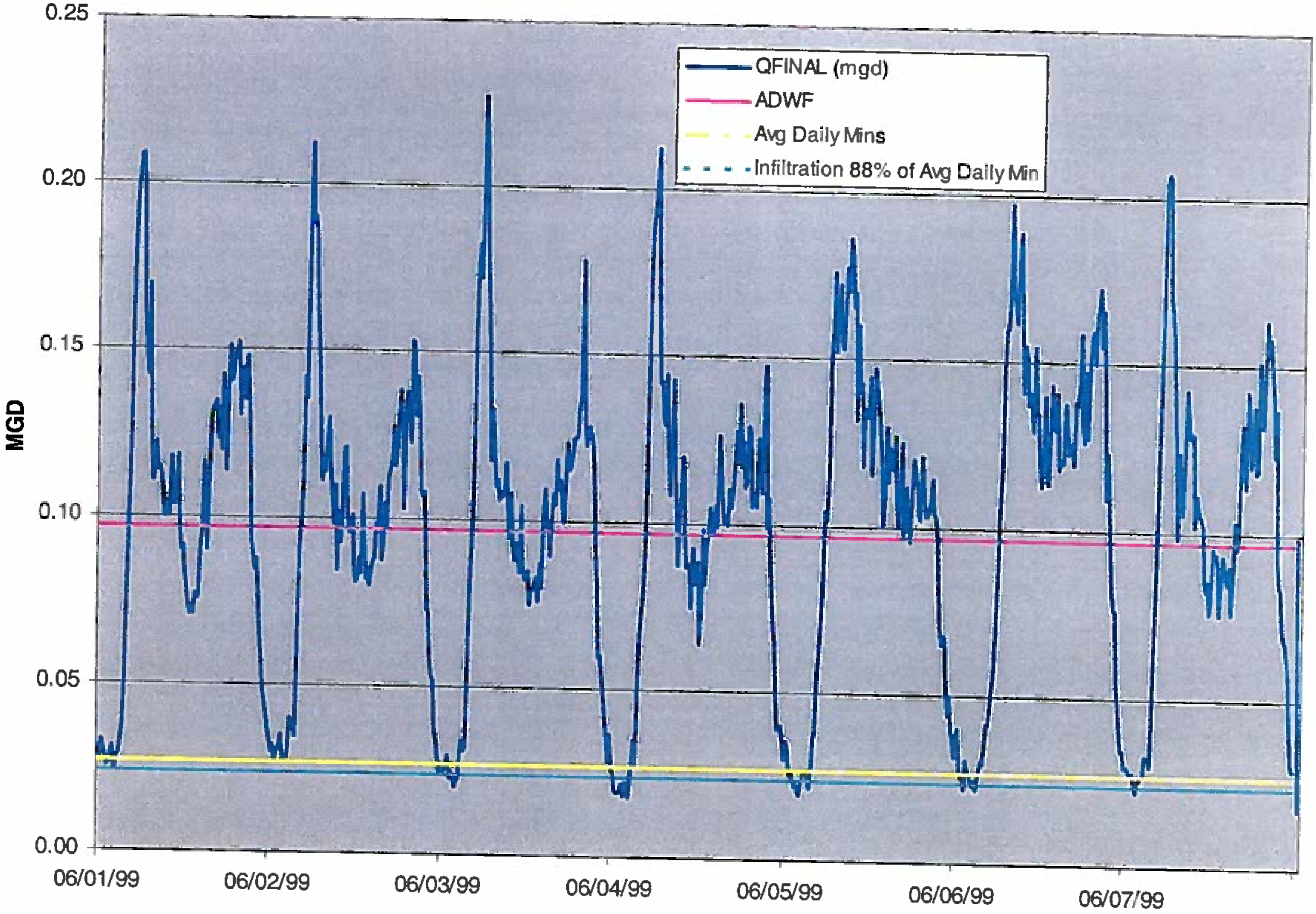
Dry Weather Flow Analysis for Cascades North Meter



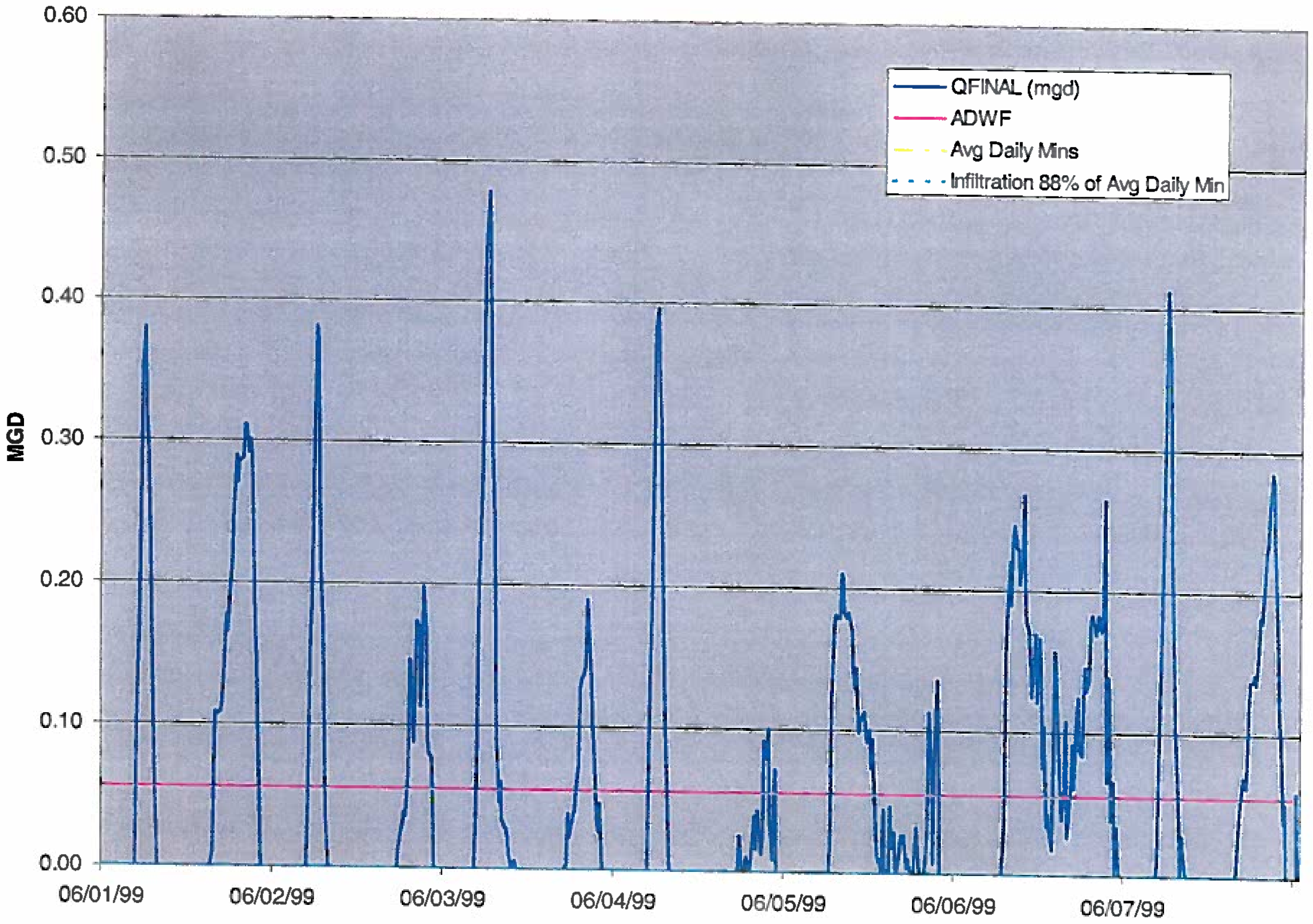
Dry Weather Flow Analysis for Cascades Western Meter



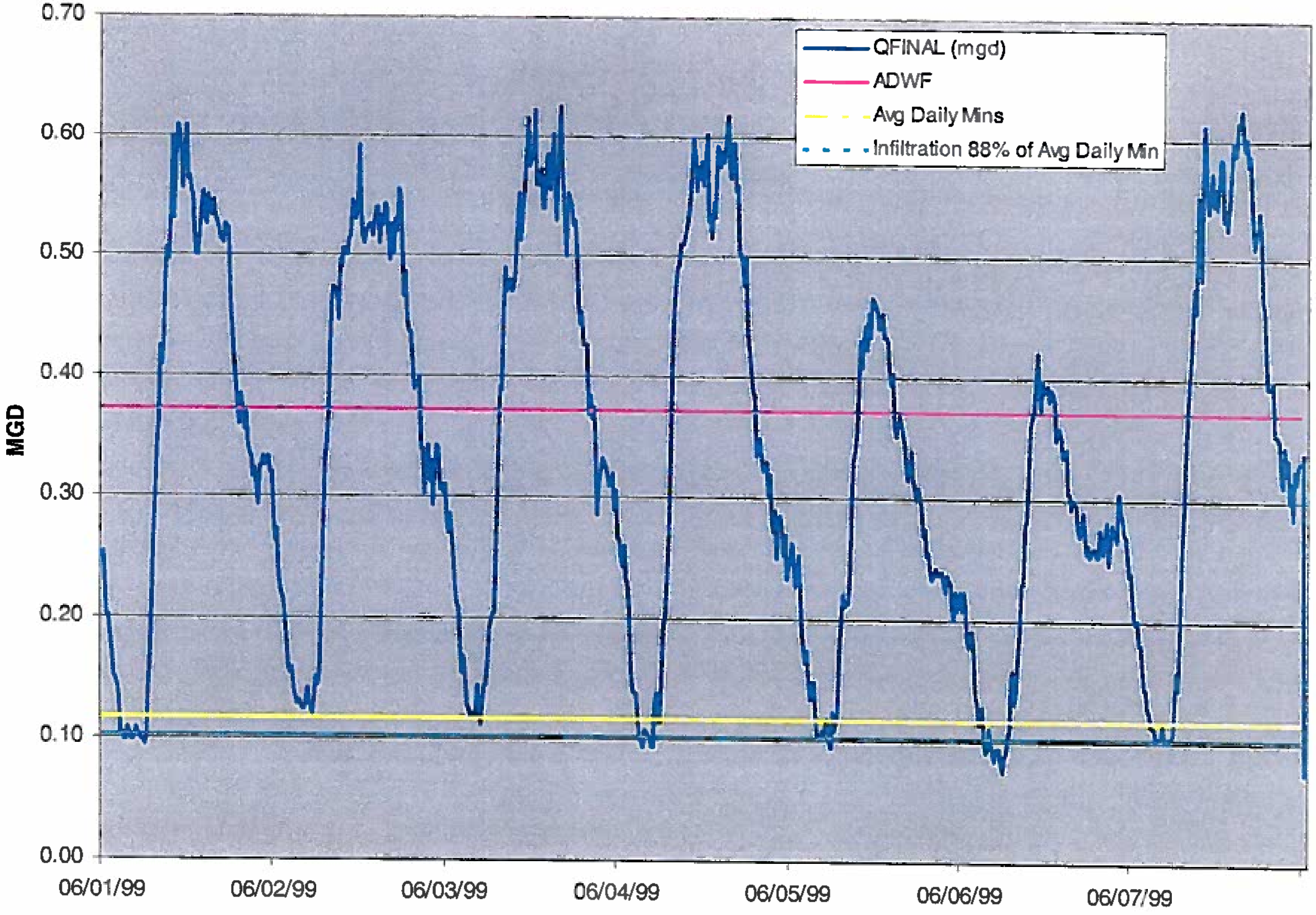
Dry Weather Flow Analysis for Countryside #1 Meter



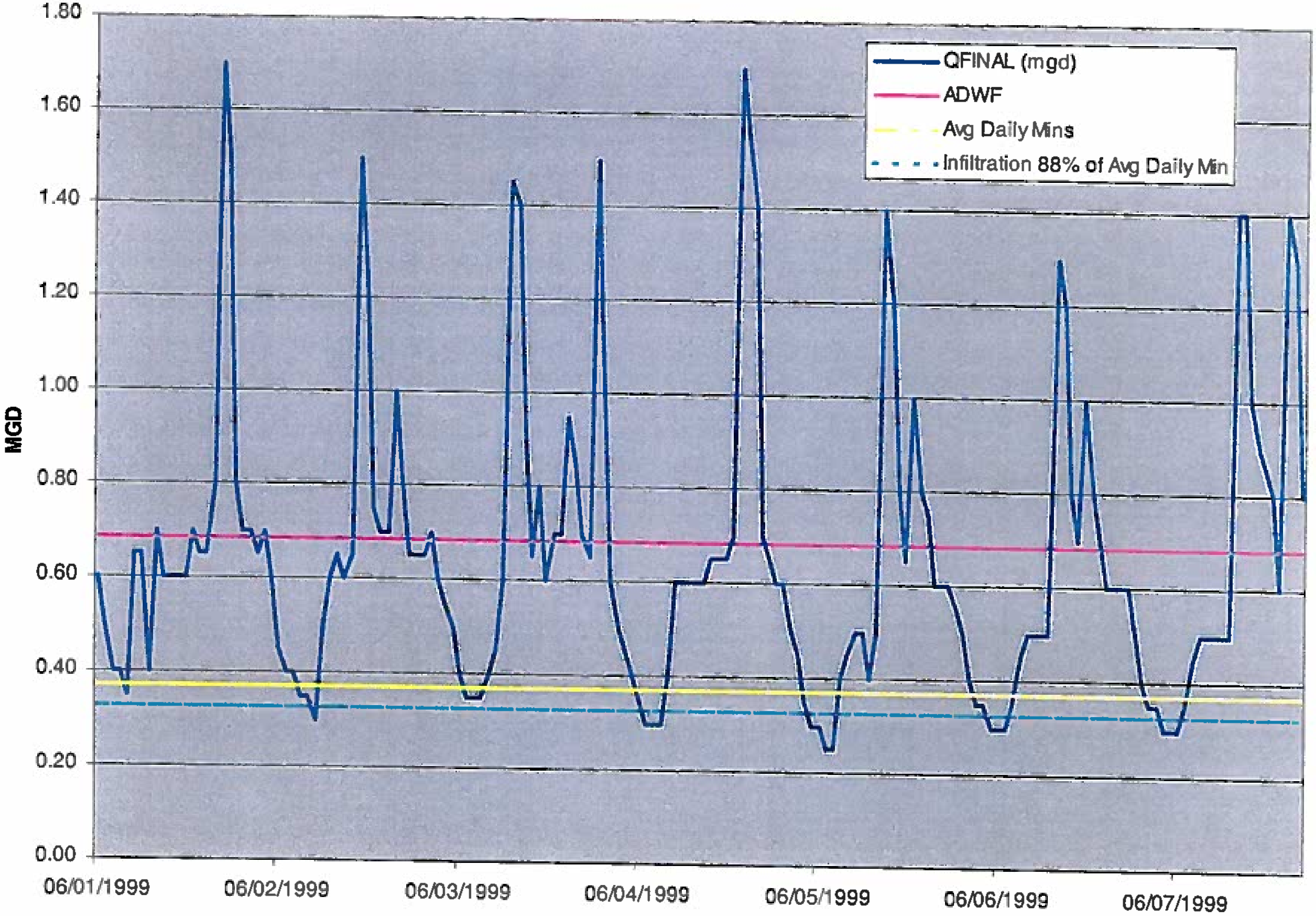
Dry Weather Flow Analysis for Countryside #2 Meter



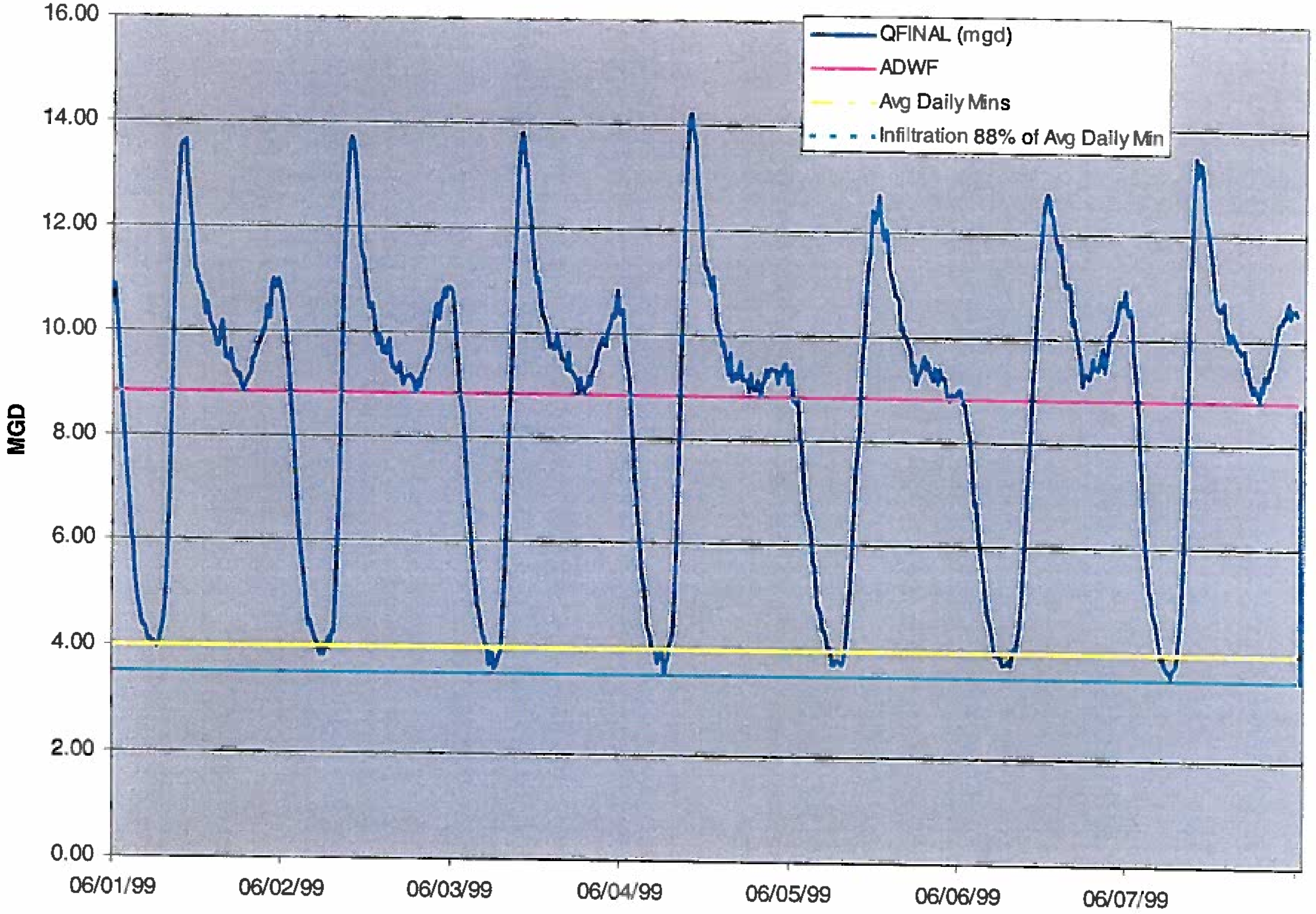
Dry Weather Flow Analysis for Indian Creek Meter



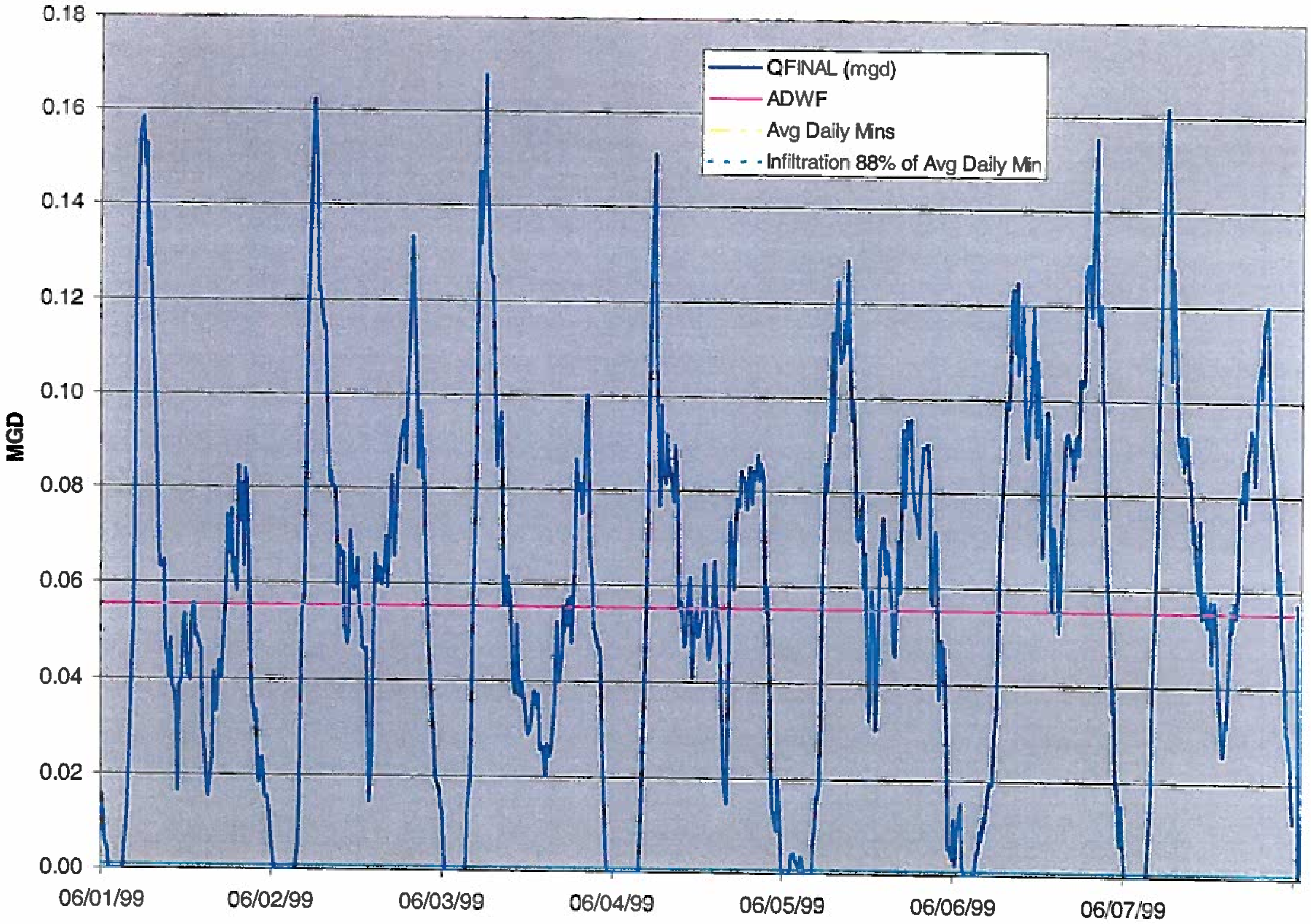
Dry Weather Flow Analysis for Dulles Meter



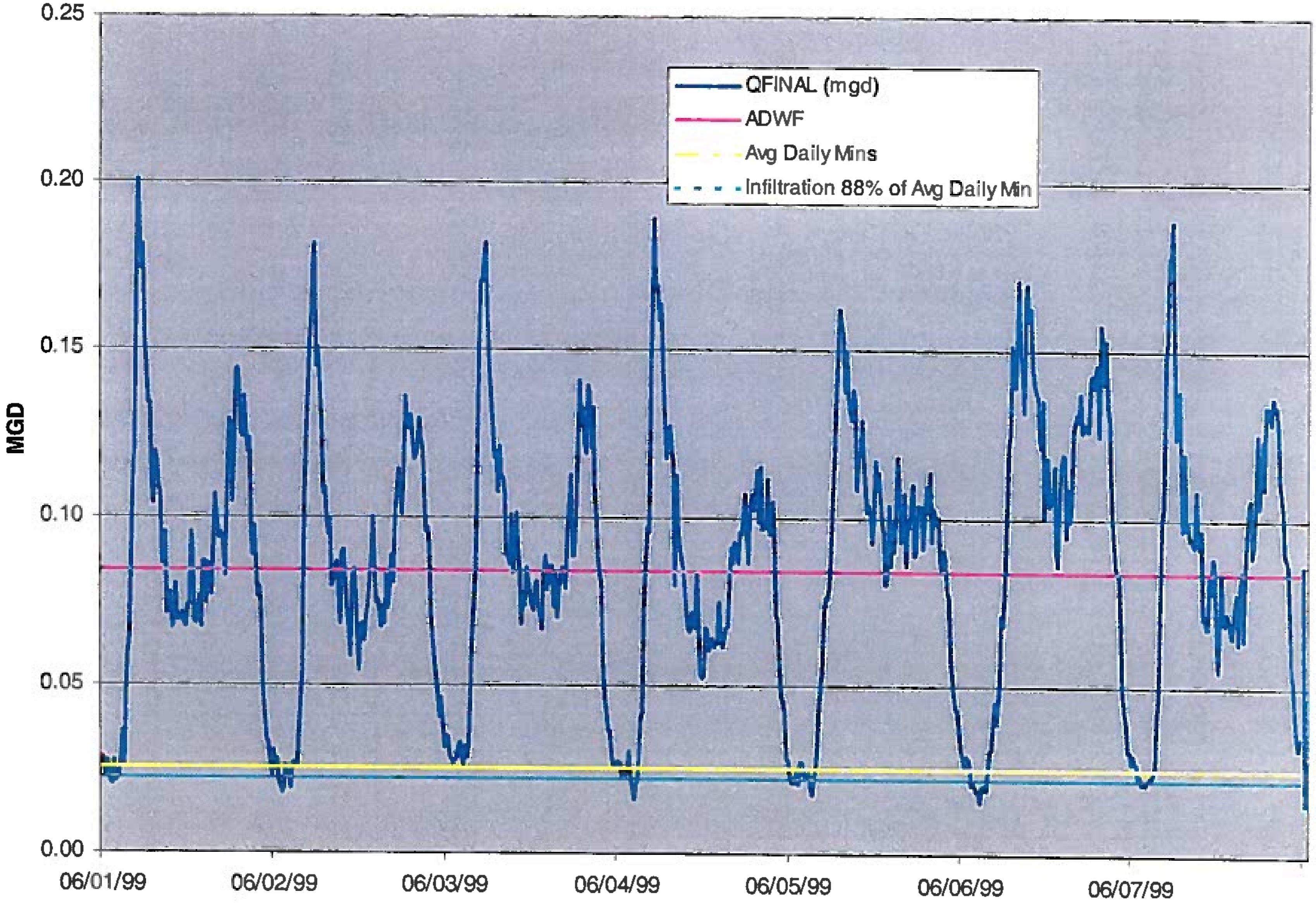
Dry Weather Flow Analysis for Great Falls Meter



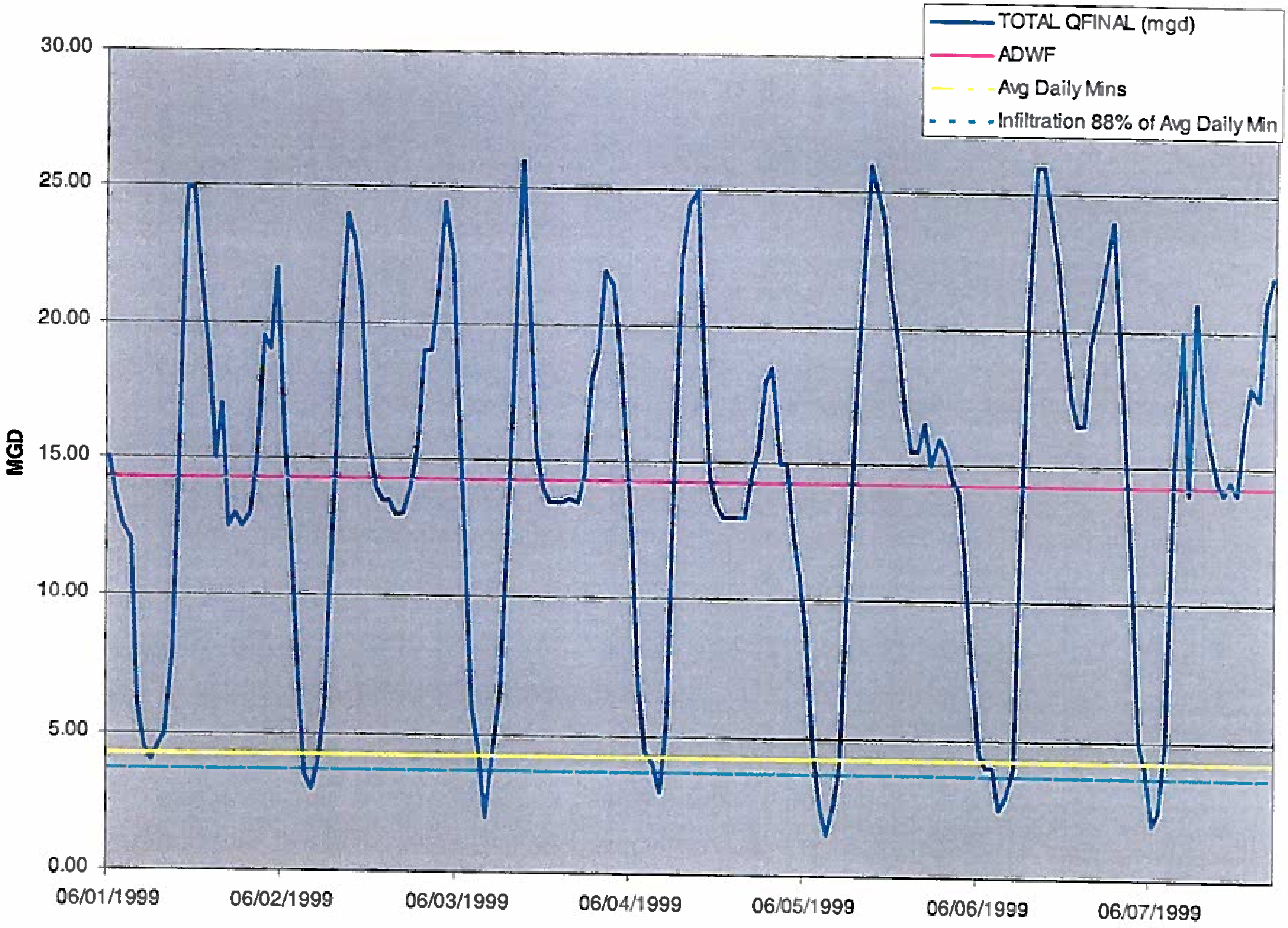
Dry Weather Flow Analysis for Great Falls Forest #1 Meter



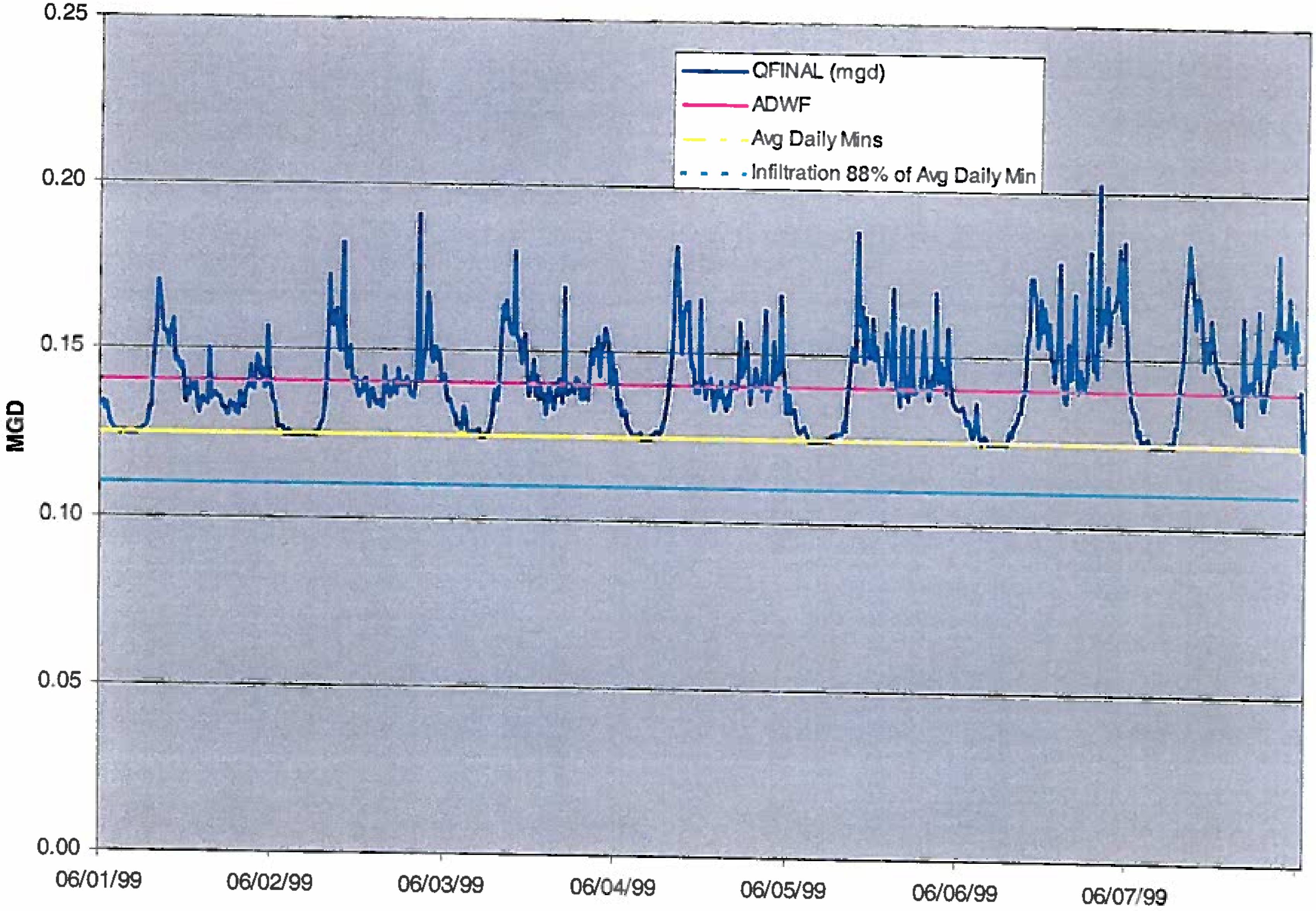
Dry Weather Flow Analysis for Great Falls Forest #2 Meter



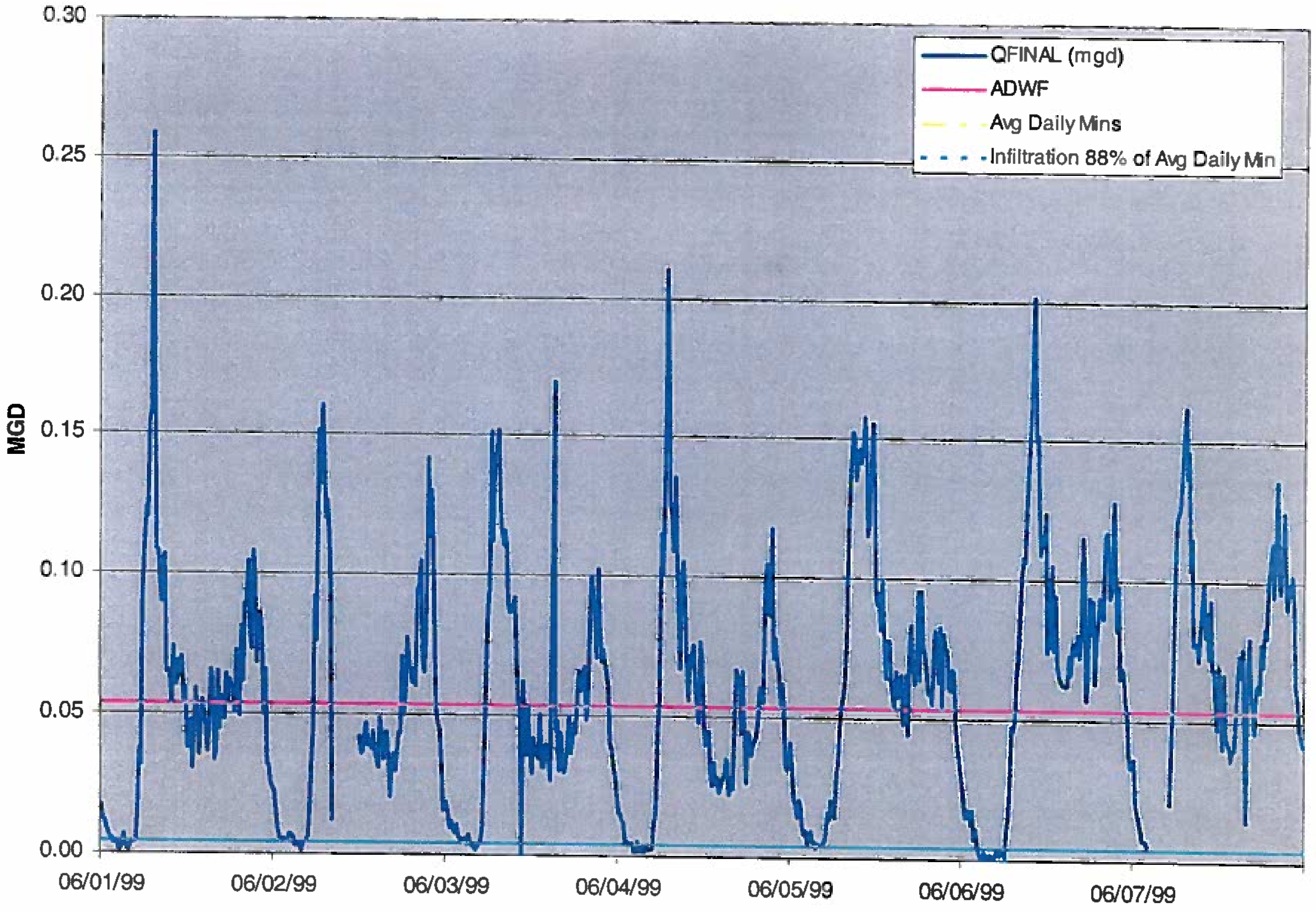
Dry Weather Flow Analysis for Muddy Branch Meter

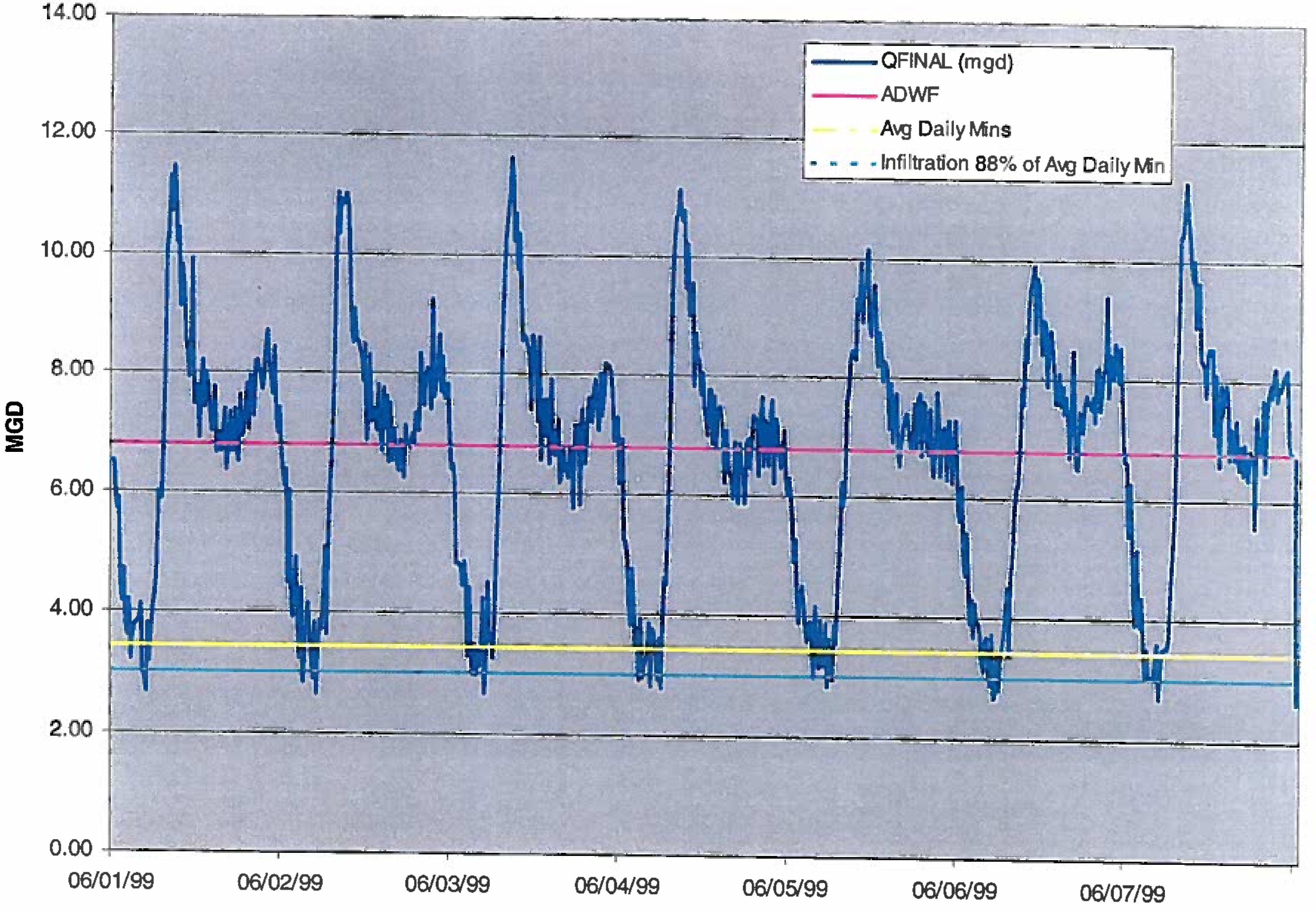


Dry Weather Flow Analysis for Northeastern Meter



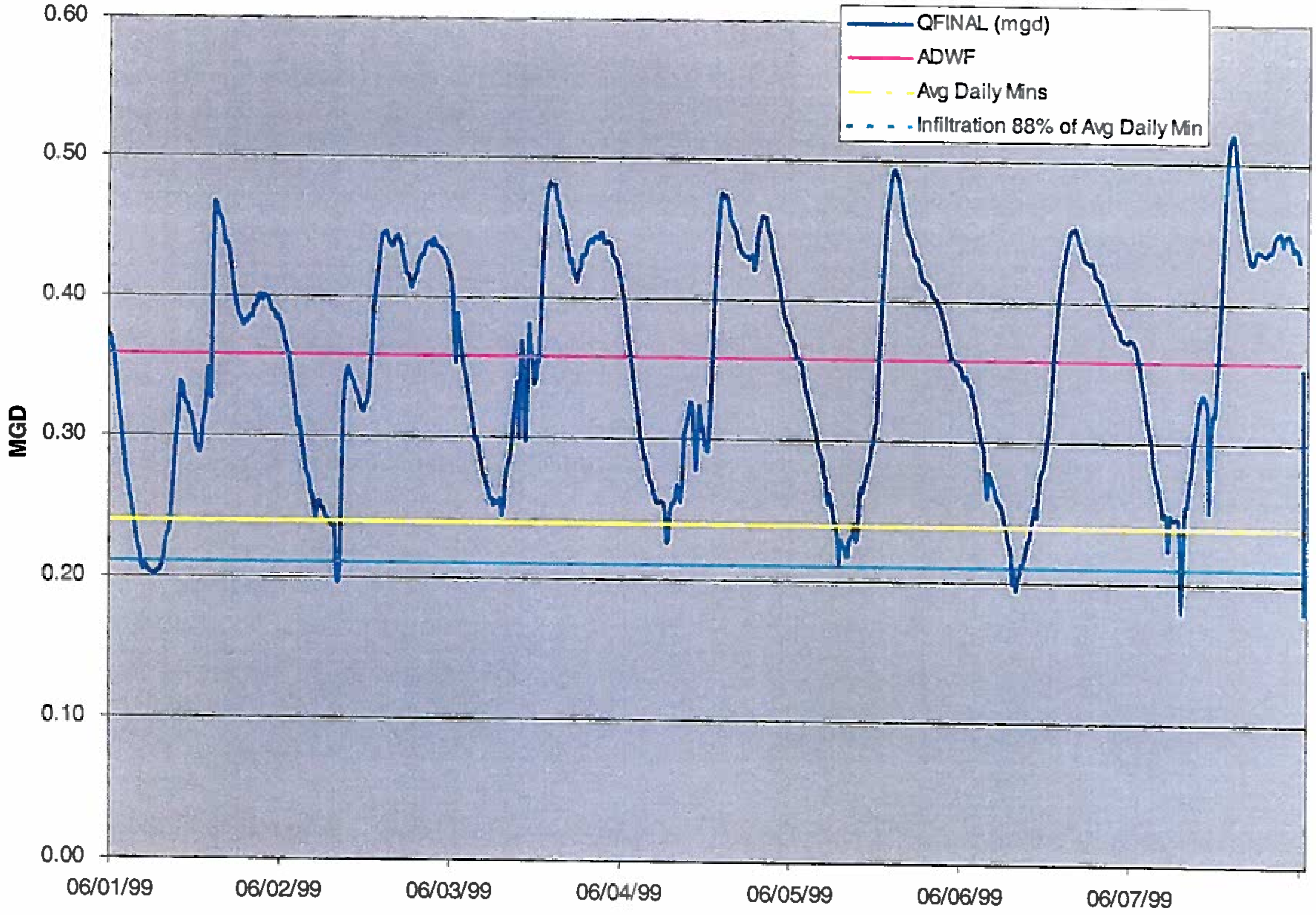
Dry Weather Flow Analysis for Northwestern Meter



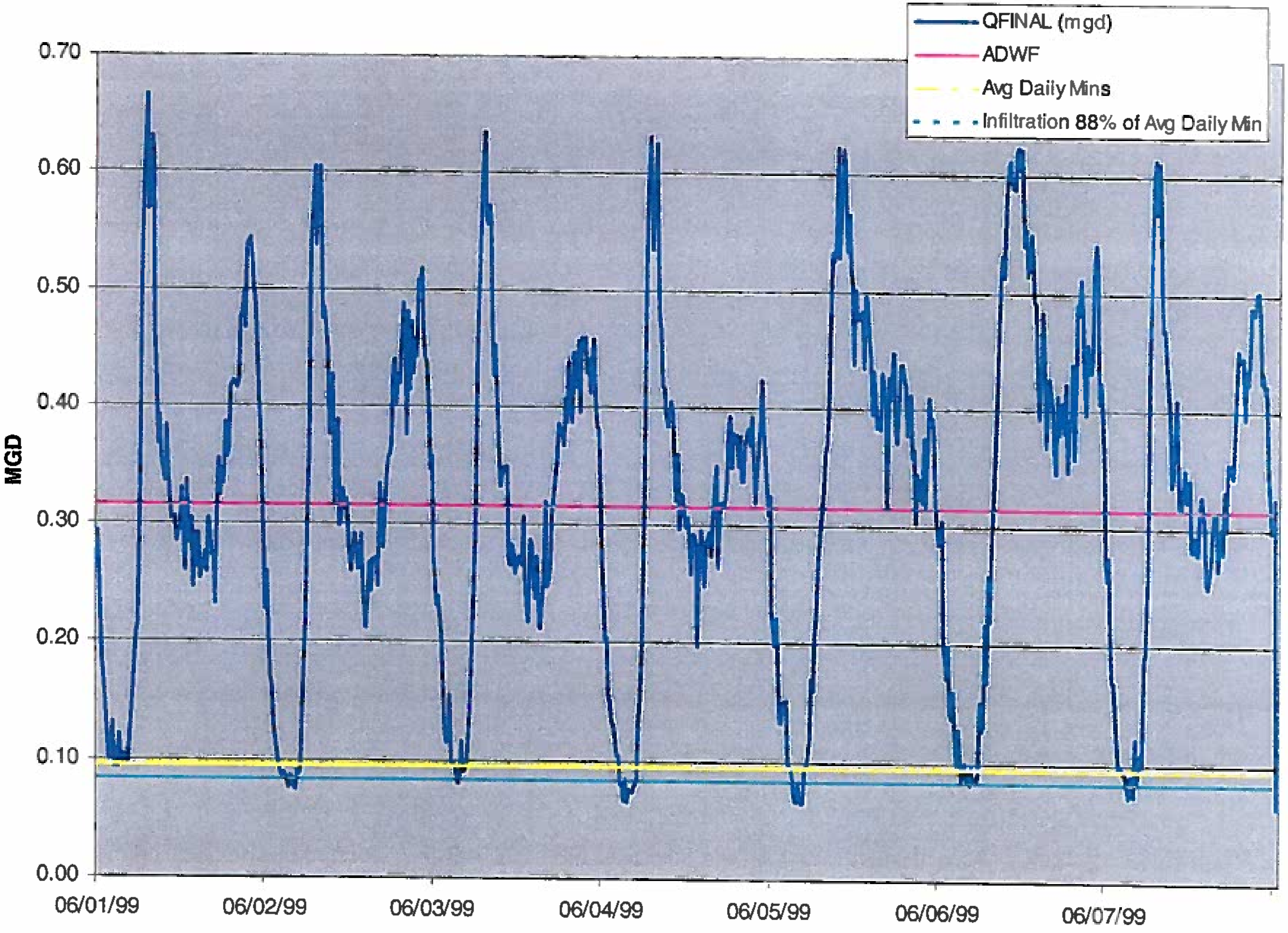


Dry Weather Flow Analysis for Pimmit Run Meter

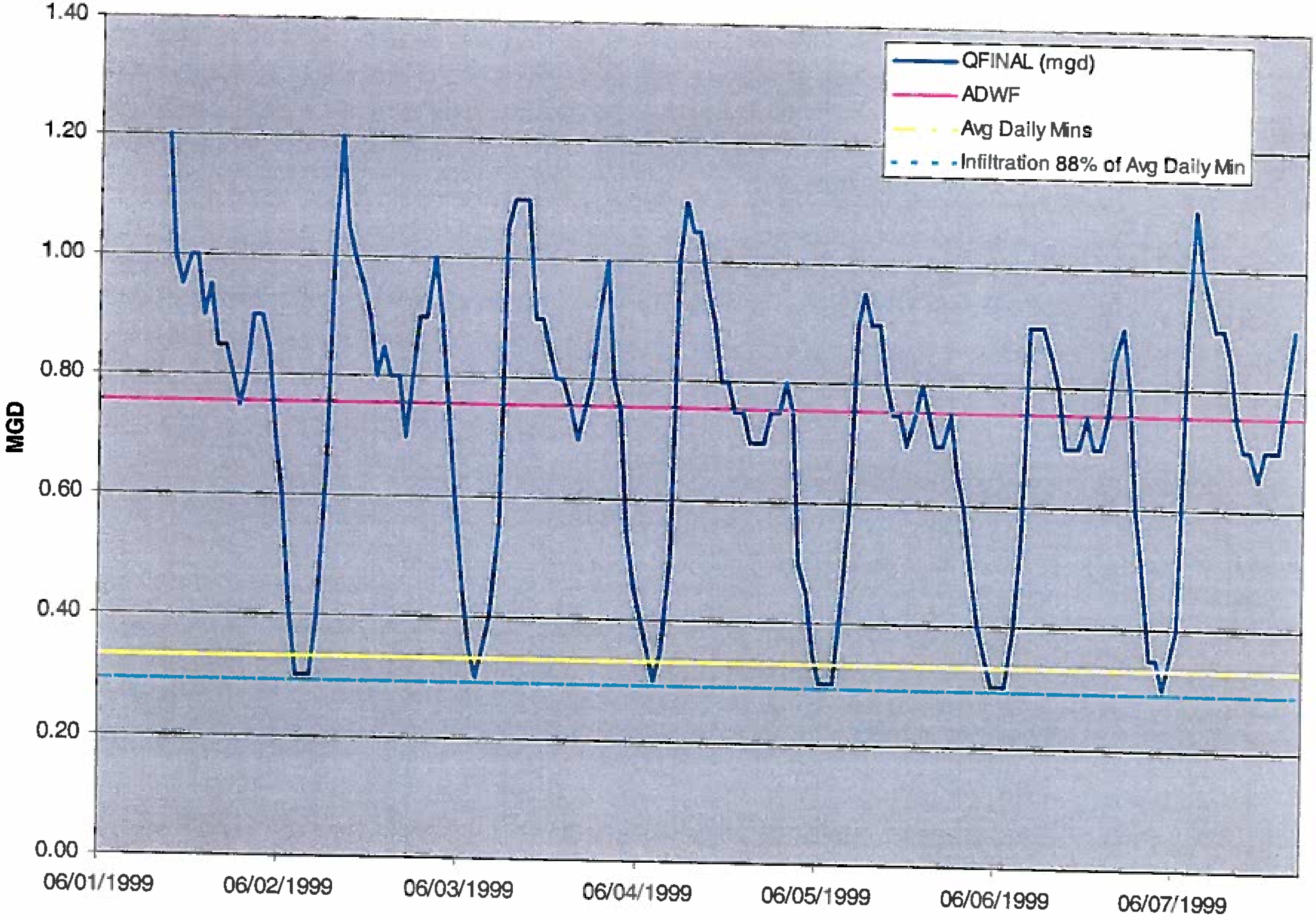
Dry Weather Flow Analysis for PIP-ZEROX Meter



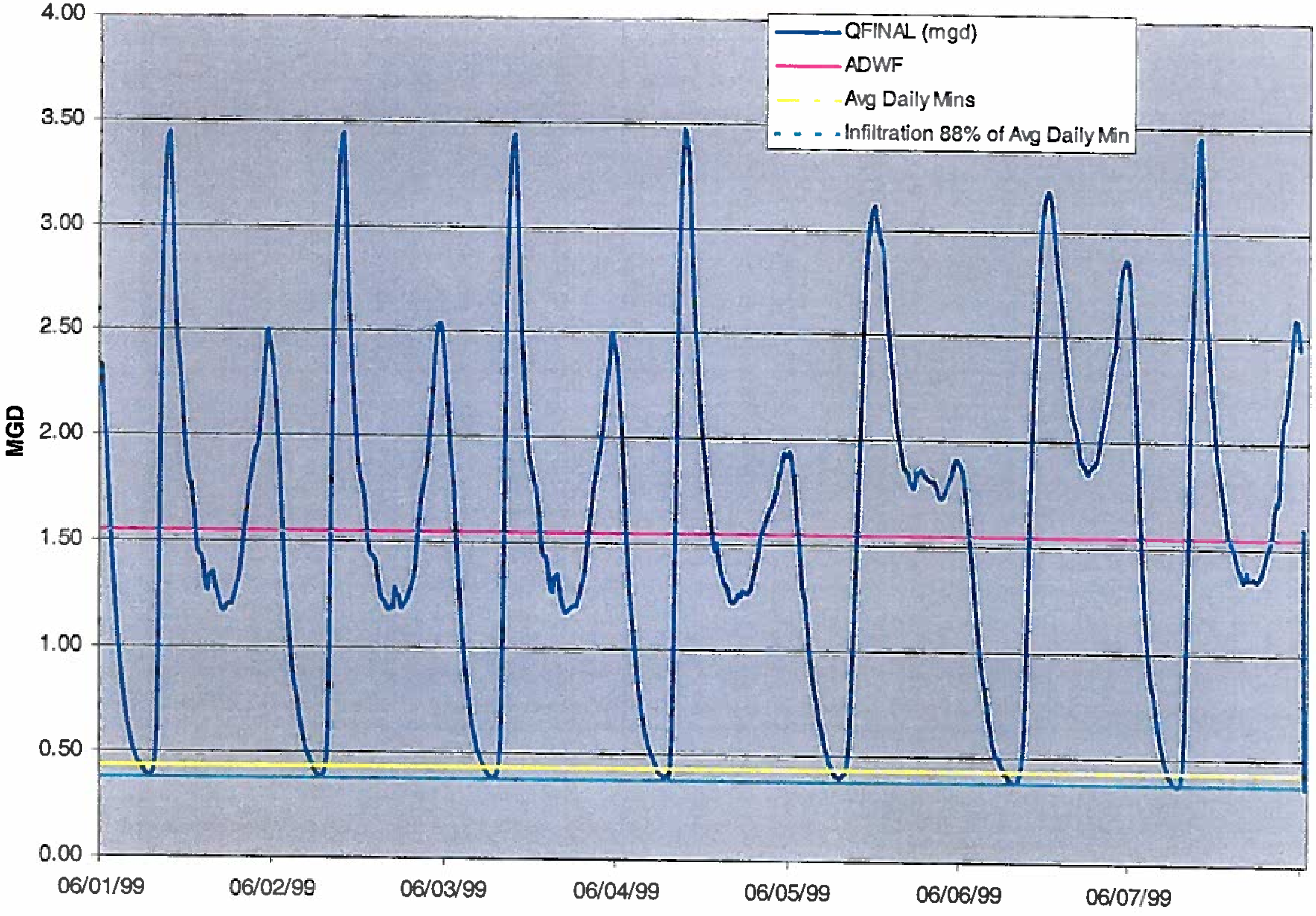
Dry Weather Flow Analysis for Rock Hill Road Meter



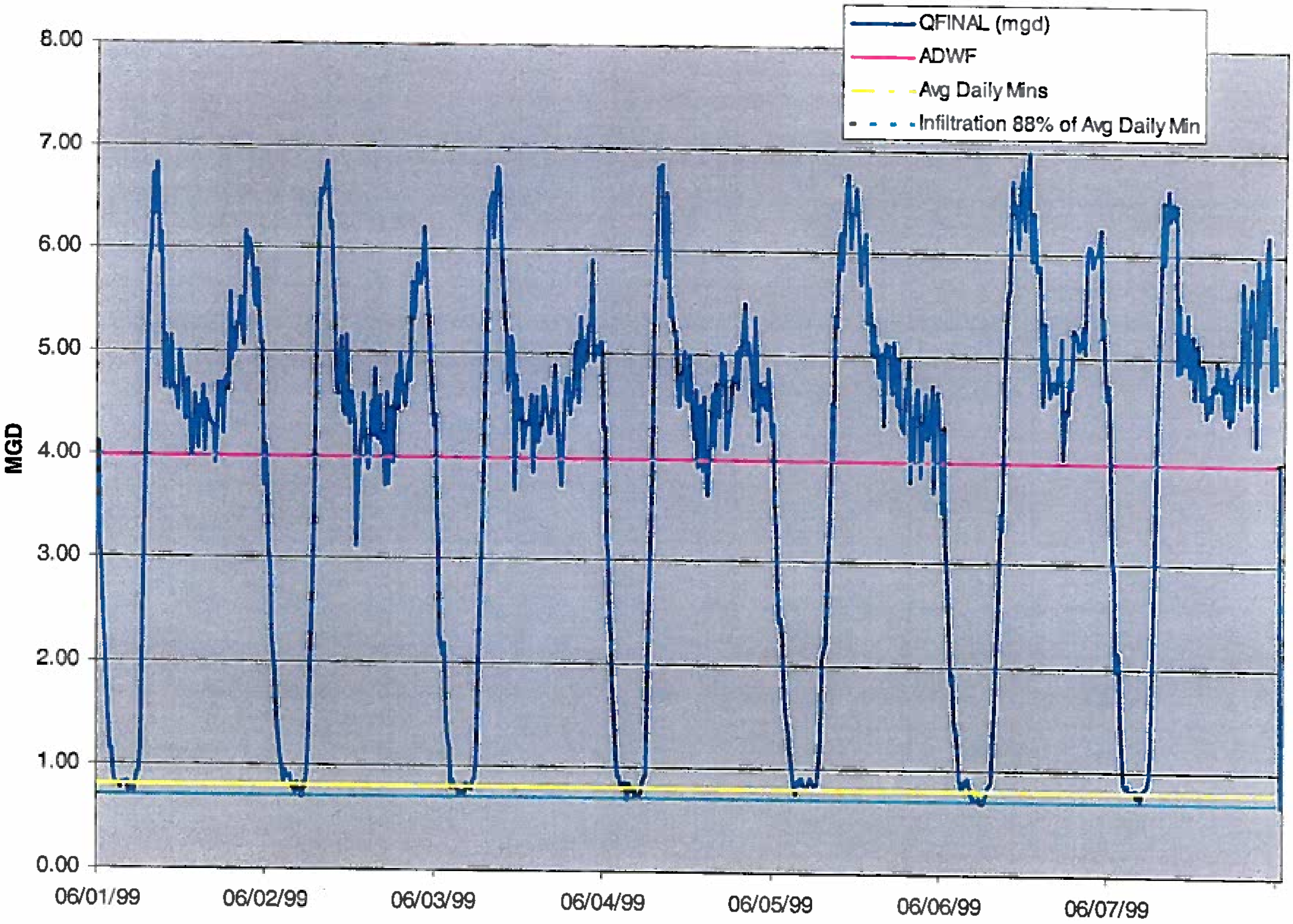
Dry Weather Flow Analysis for Rock Run Meter



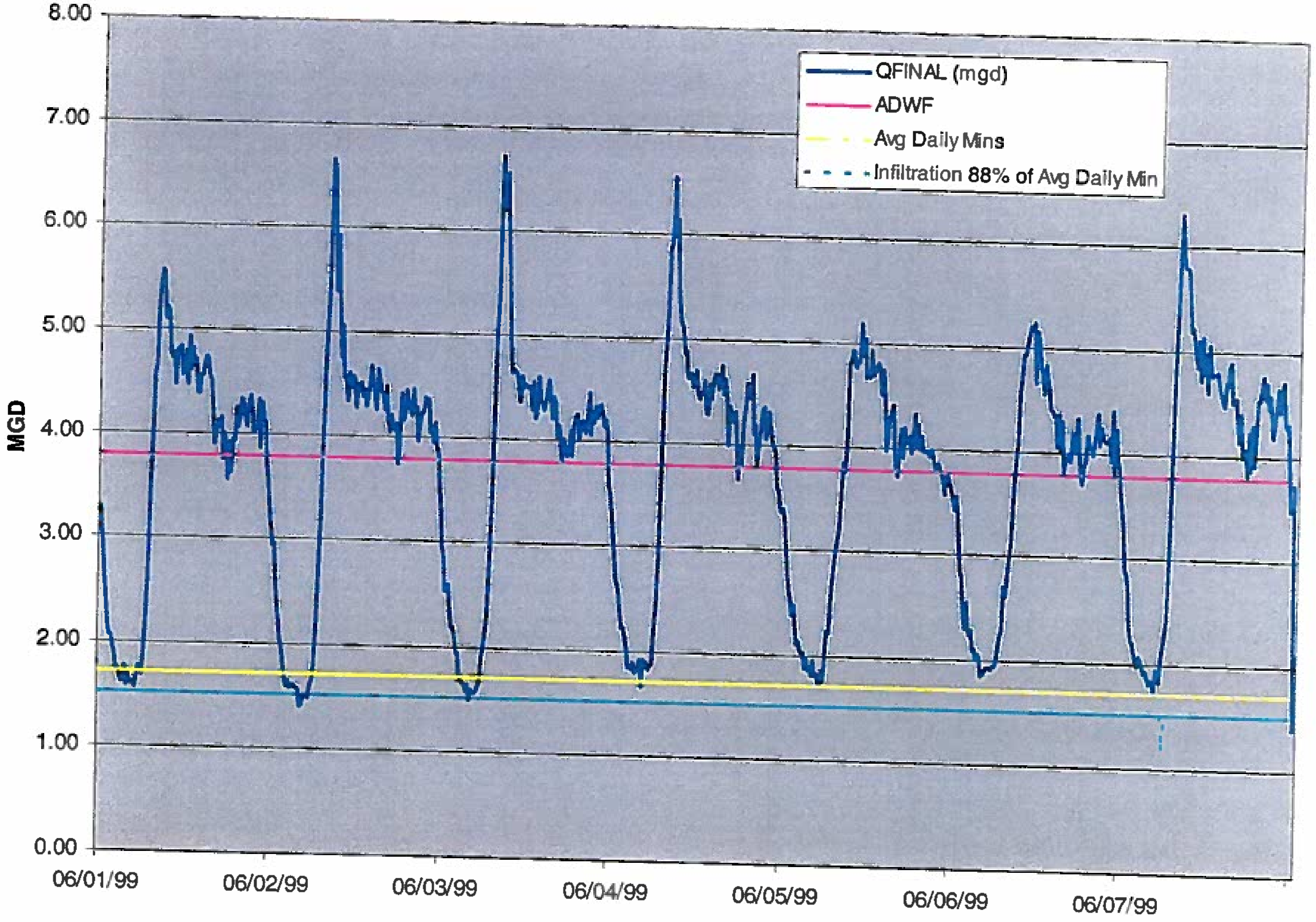
Dry Weather Flow Analysis for Russell Branch Meter

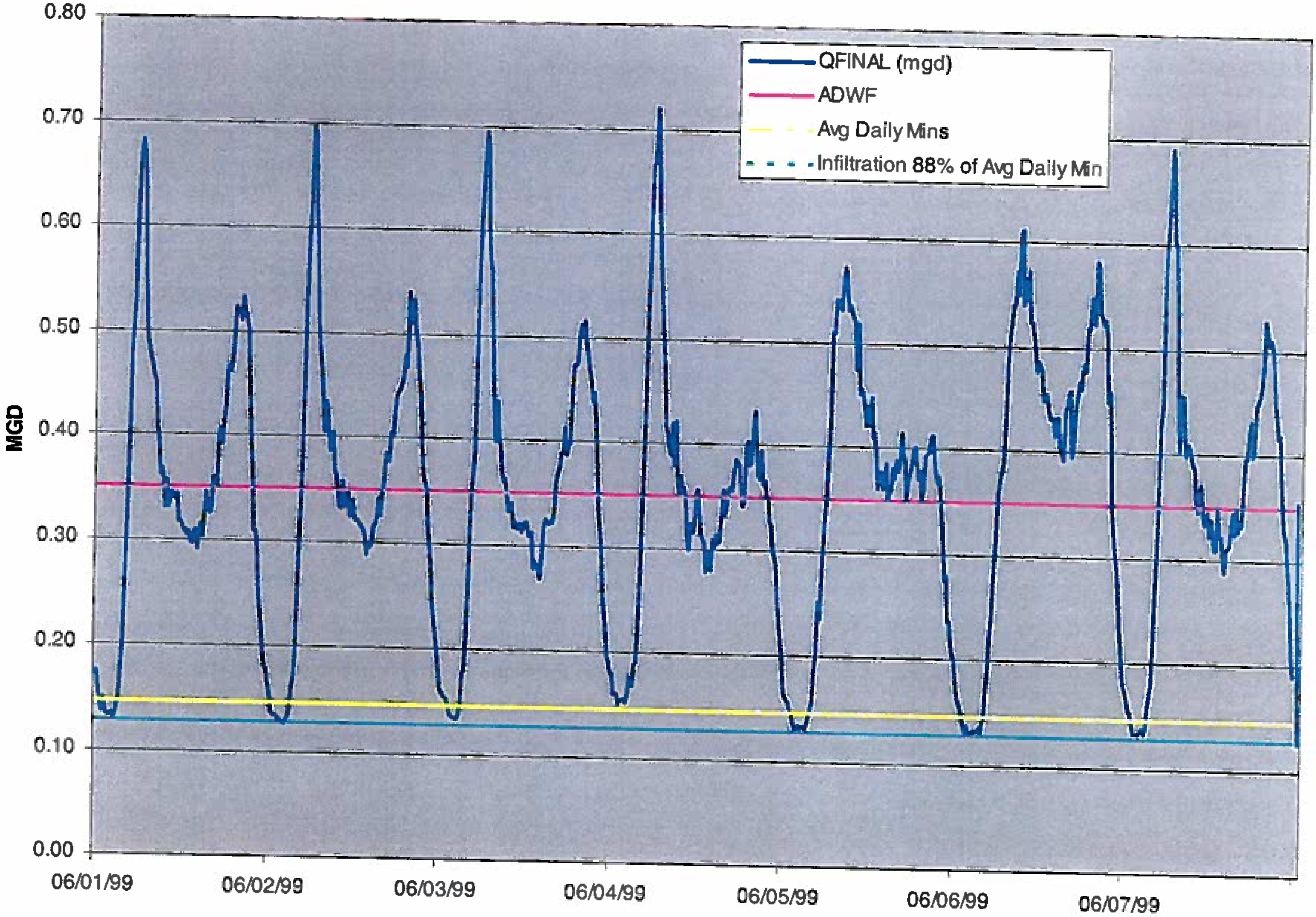


Dry Weather Flow Analysis Results for Sugarland Run Meter

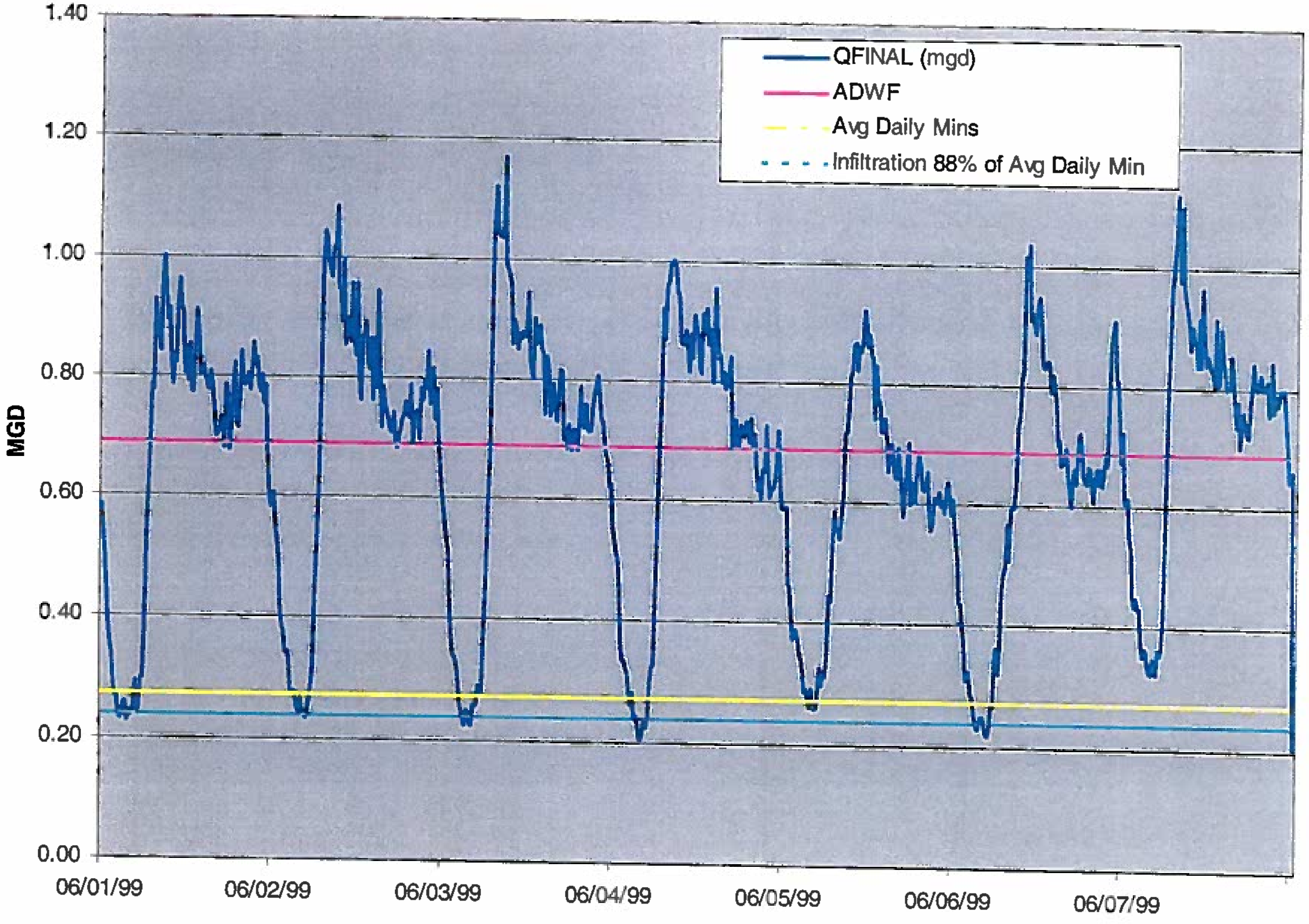


Dry Weather Flow Analysis for Scotts Run Meter

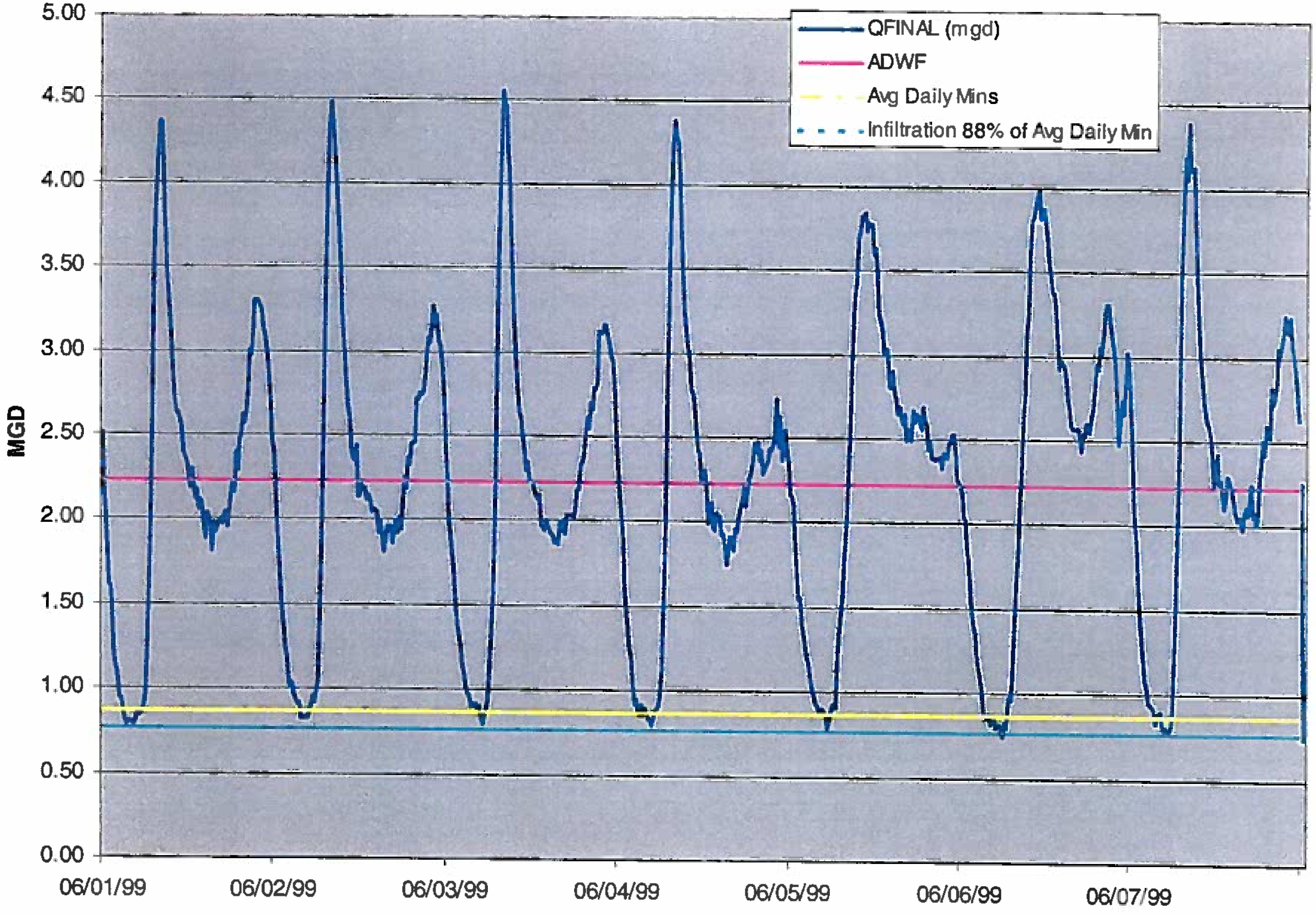




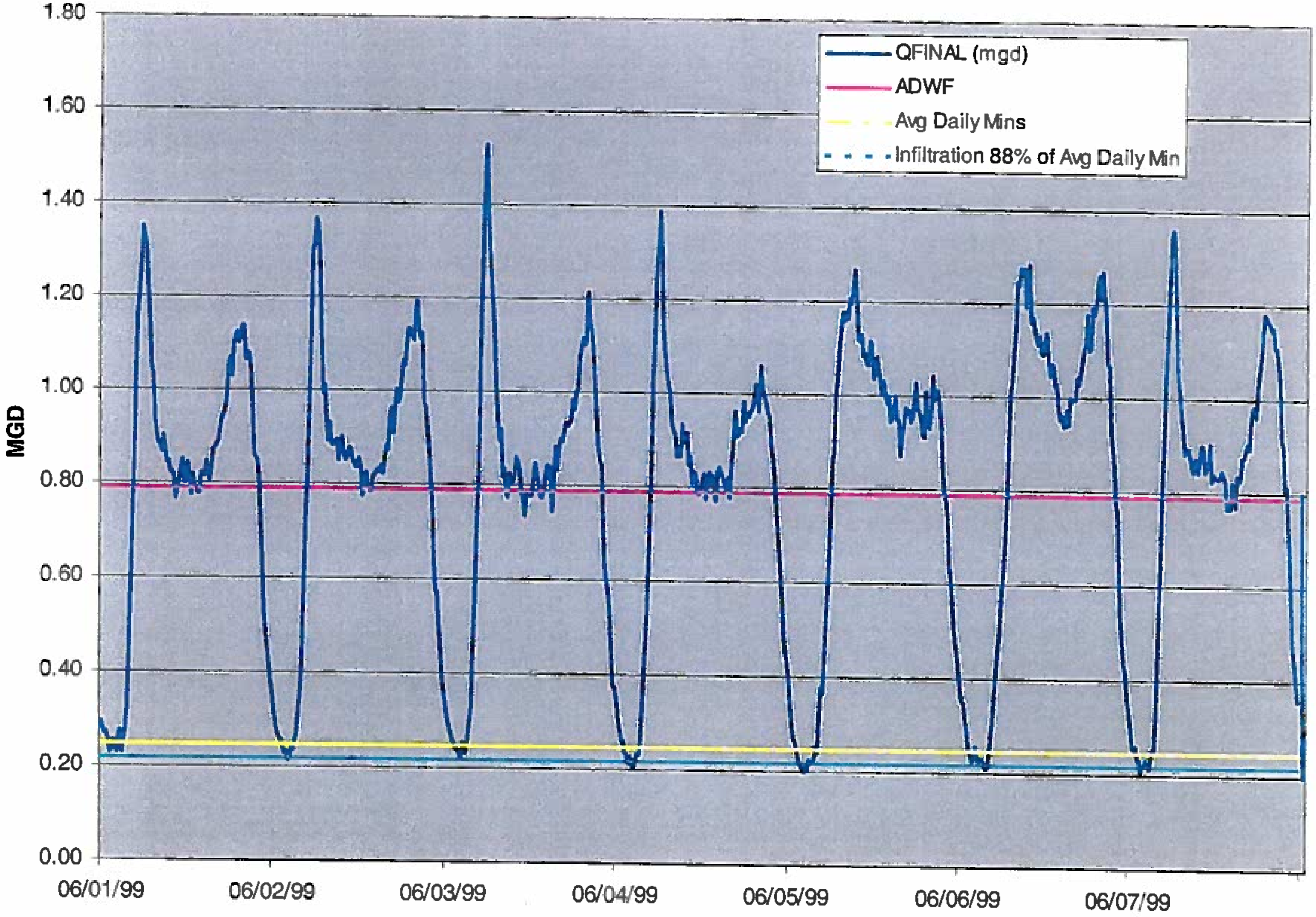
Dry Weather Flow Analysis for Sully Road #2 Meter



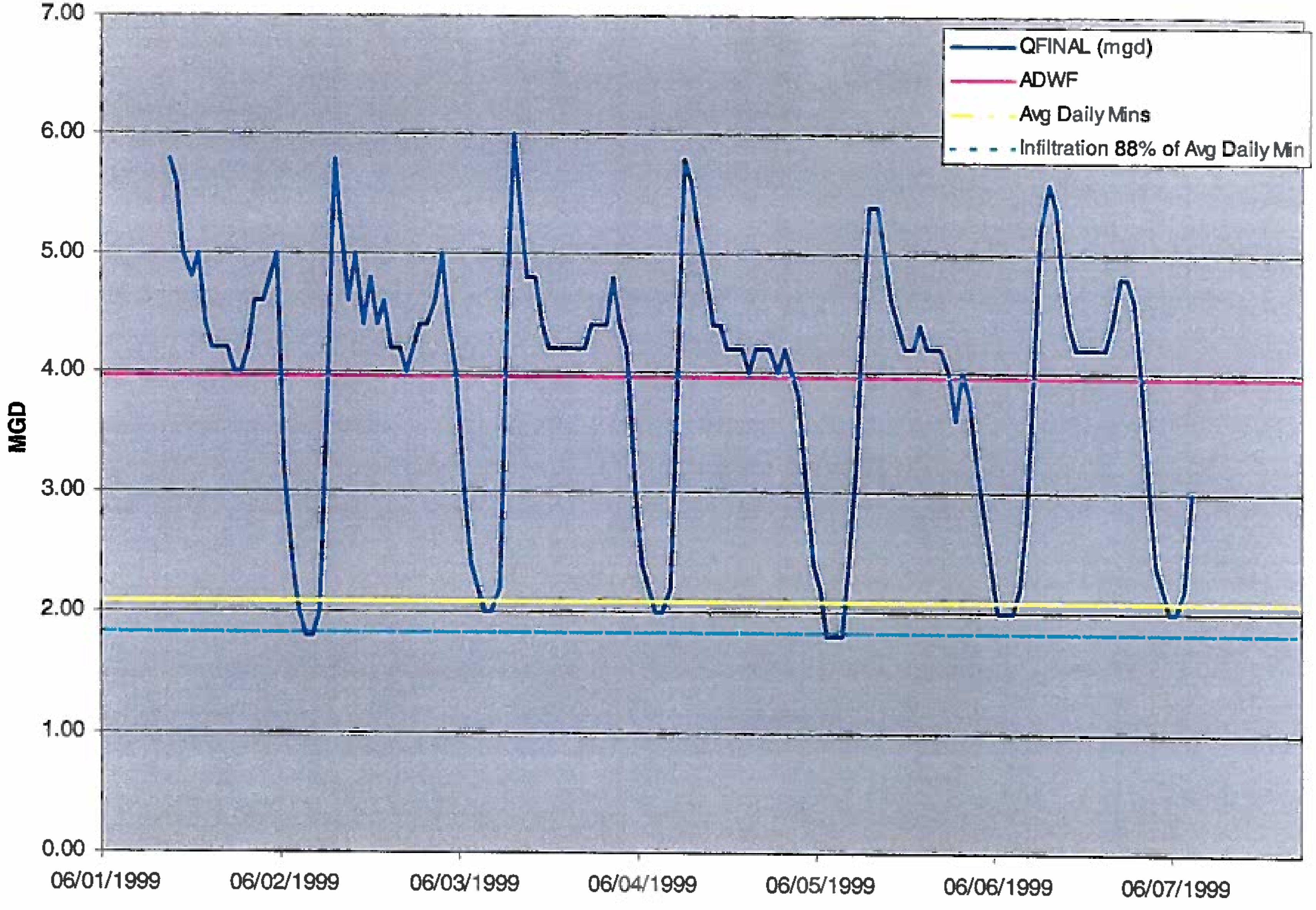
Dry Weather Flow Analysis for Sully Road #1 Meter



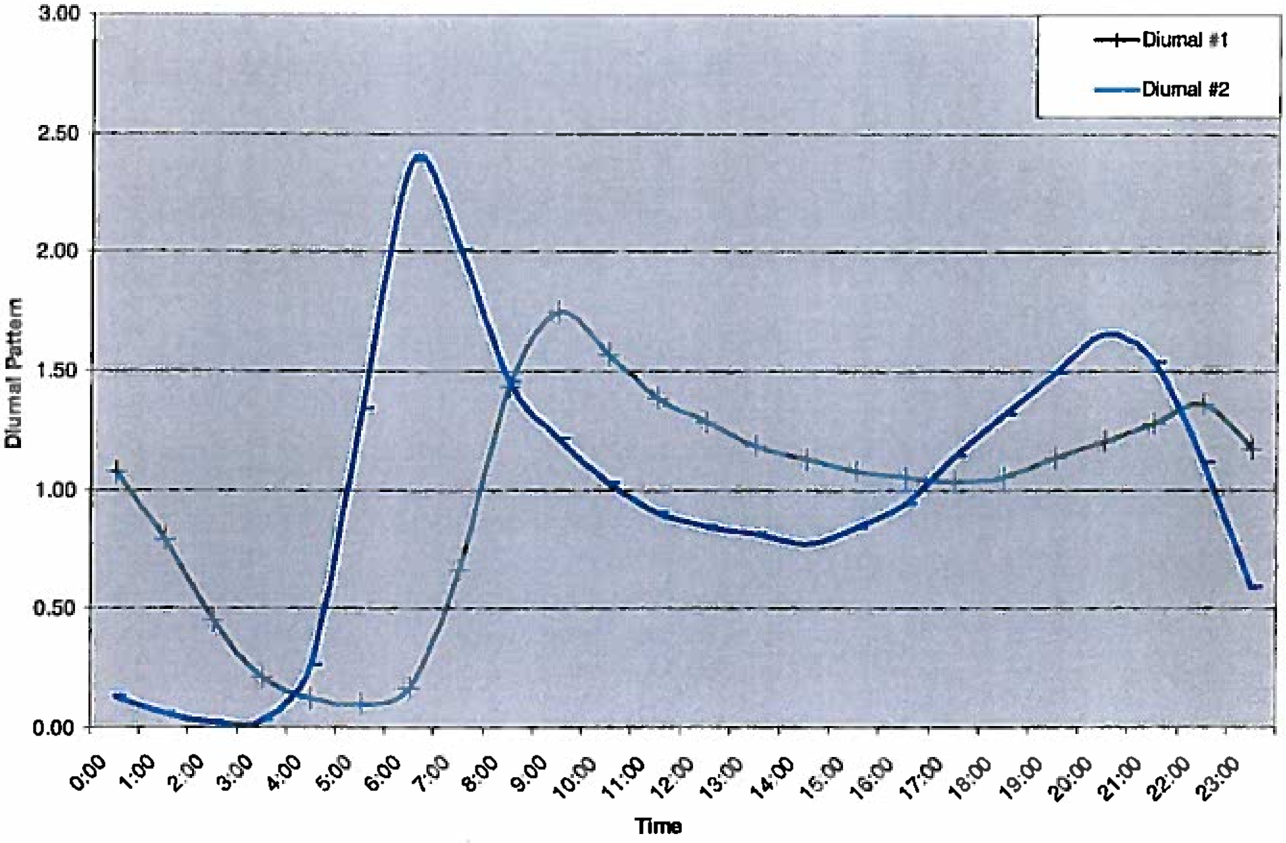
Dry Weather Flow Analysis for Triple 7 Meter



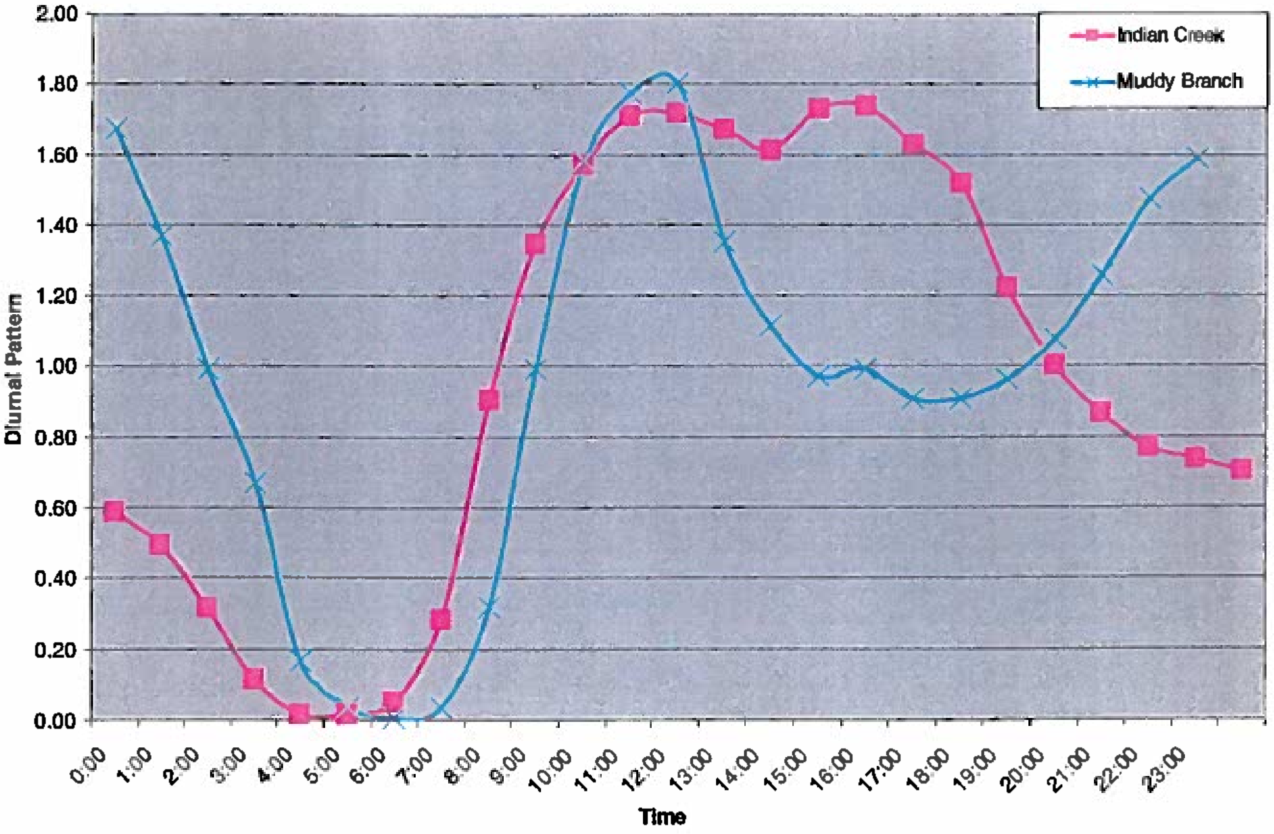
Dry Weather Flow Analysis for Watts Branch Meter

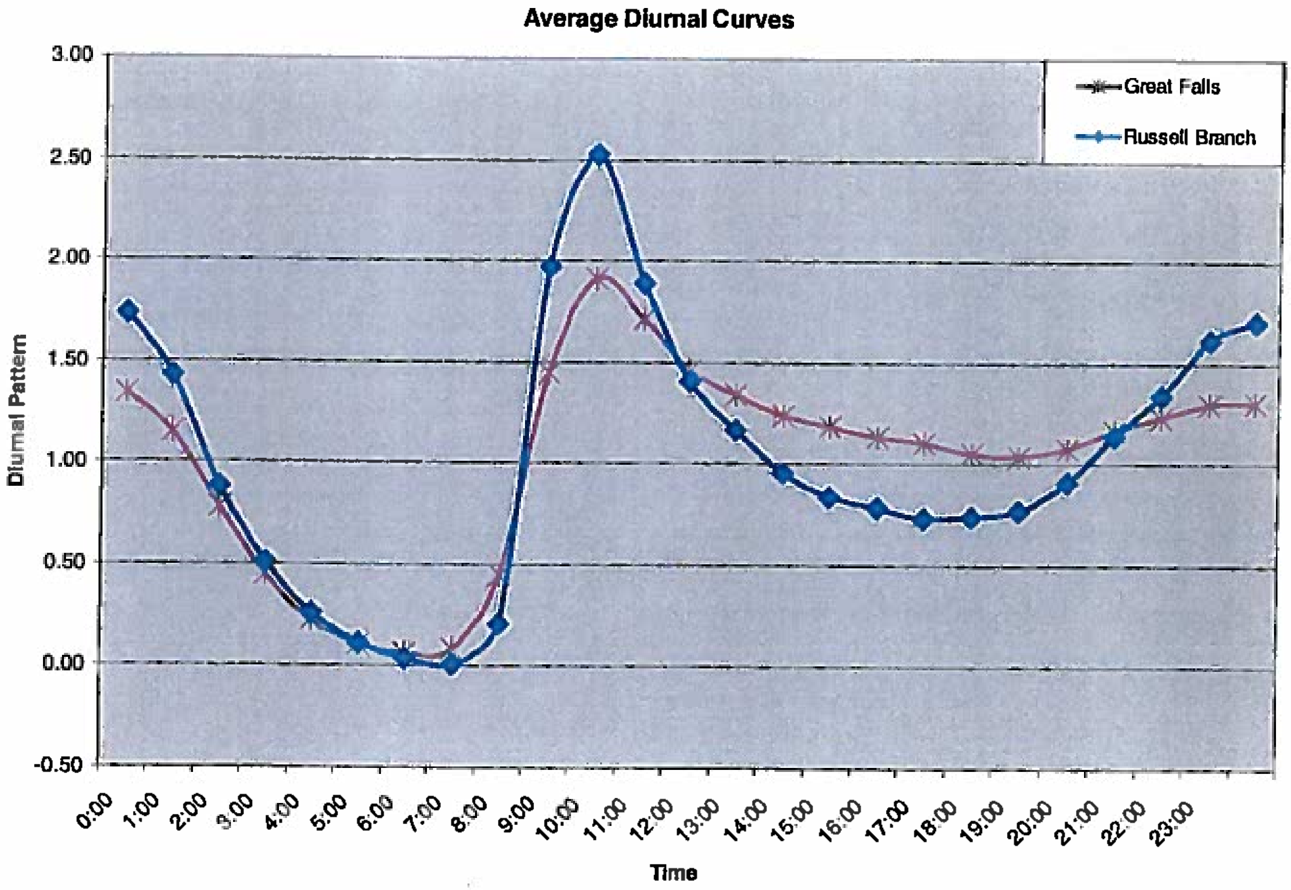


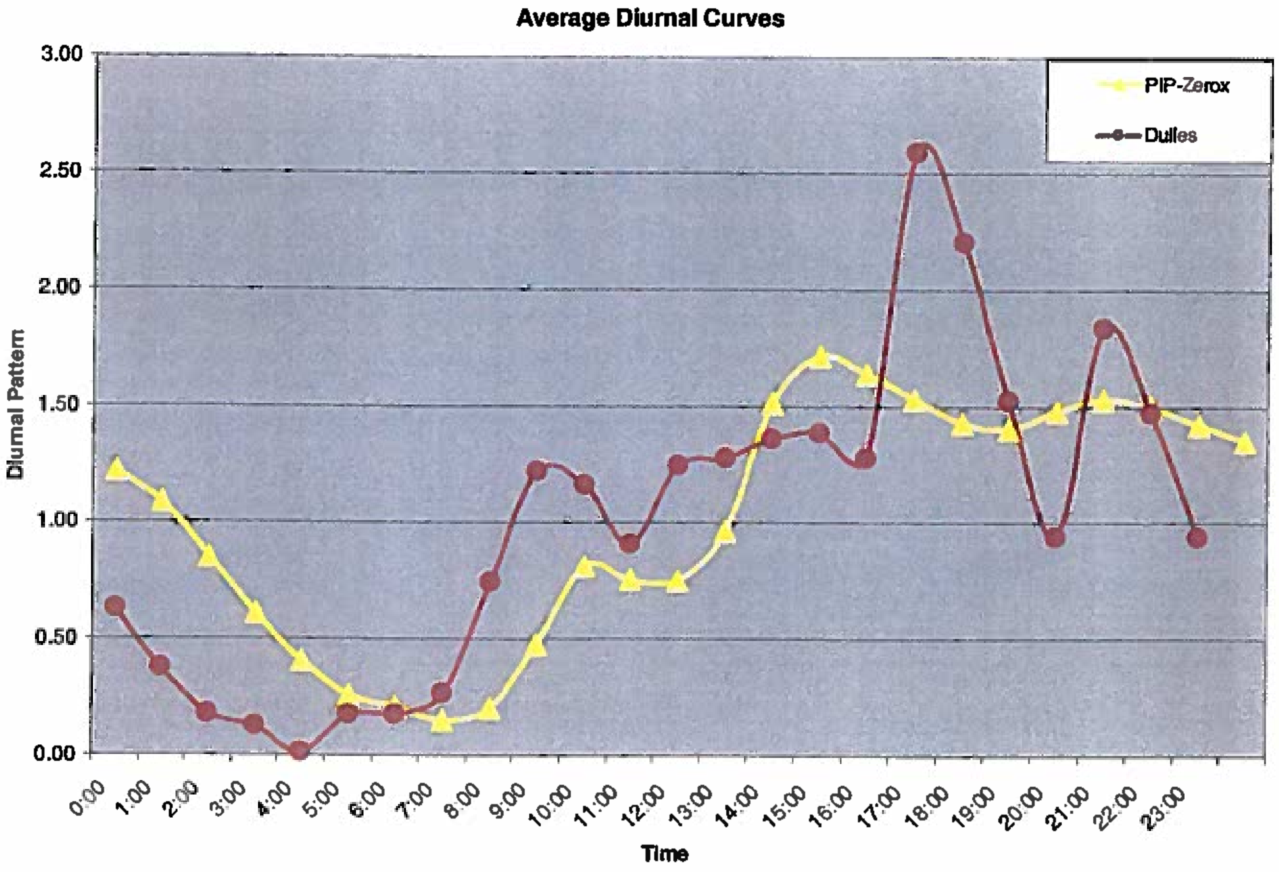
Average Diurnal Curves



Average Diurnal Curves



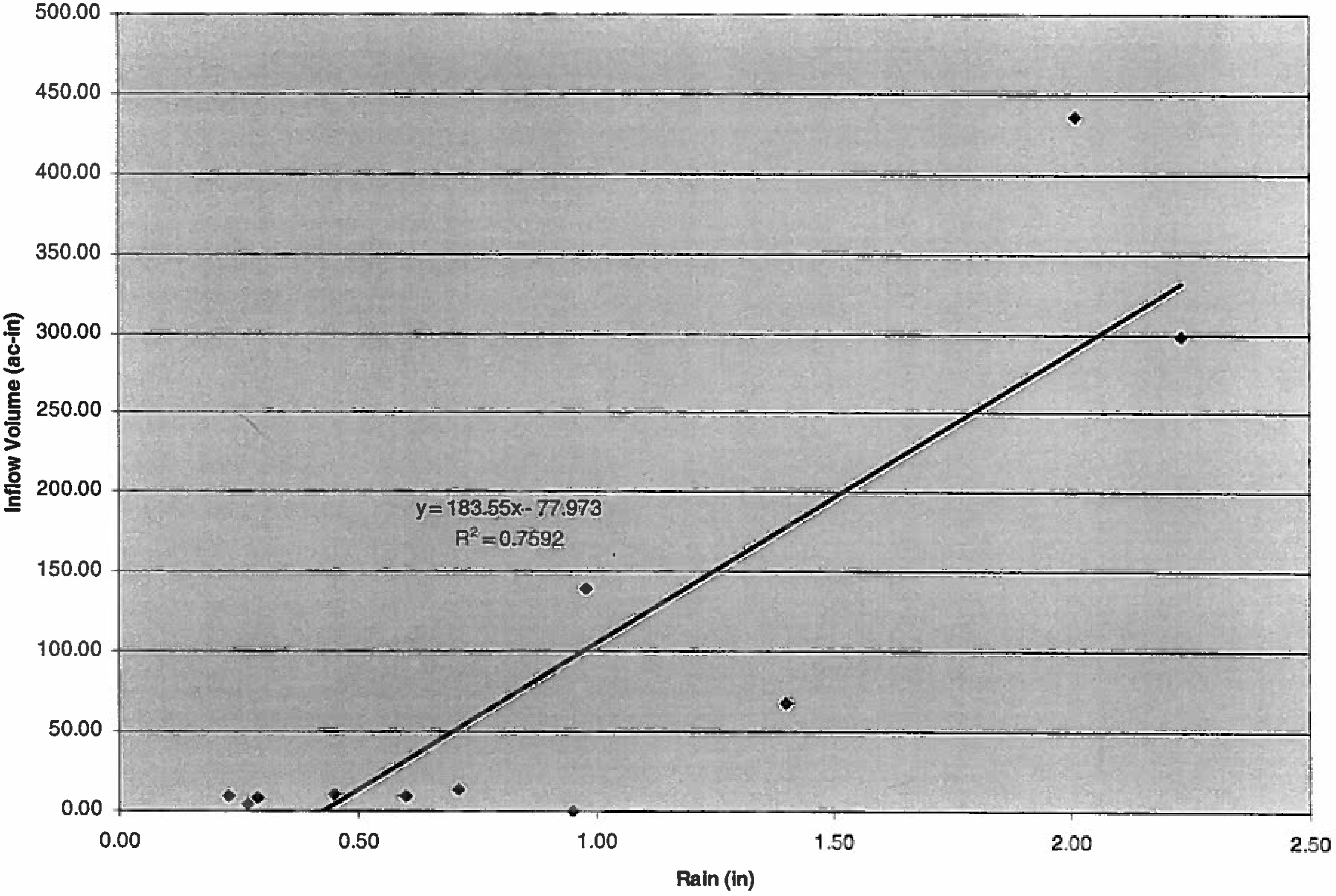

Average Diurnal Curves
Great Falls
Russell Branch
Diurnal Pattern
3.00
2.50
2.00
1.50
1.00
0.50
0.00
-0.50
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time


Average Diurnal Curves
PIP-Zerox
Dulles
Diurnal Pattern
3.00
2.50
2.00
1.50
1.00
0.50
0.00
0:00
1:00
2:00
3:00
4:00
5:00
6:00
7:00
8:00
9:00
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
19:00
20:00
21:00
22:00
23:00
Time

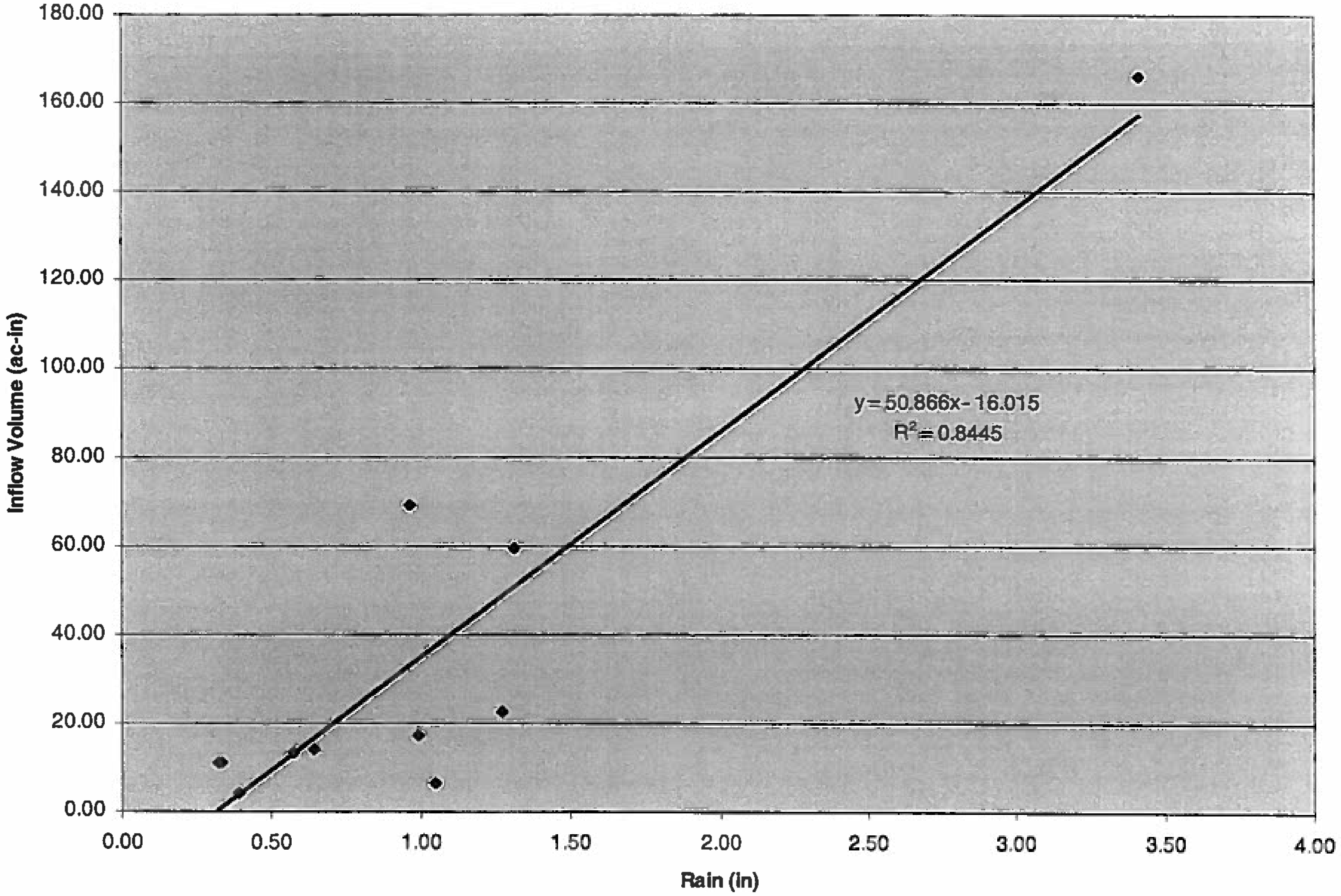
Appendix A-2

Wet Weather Flow Analysis Results

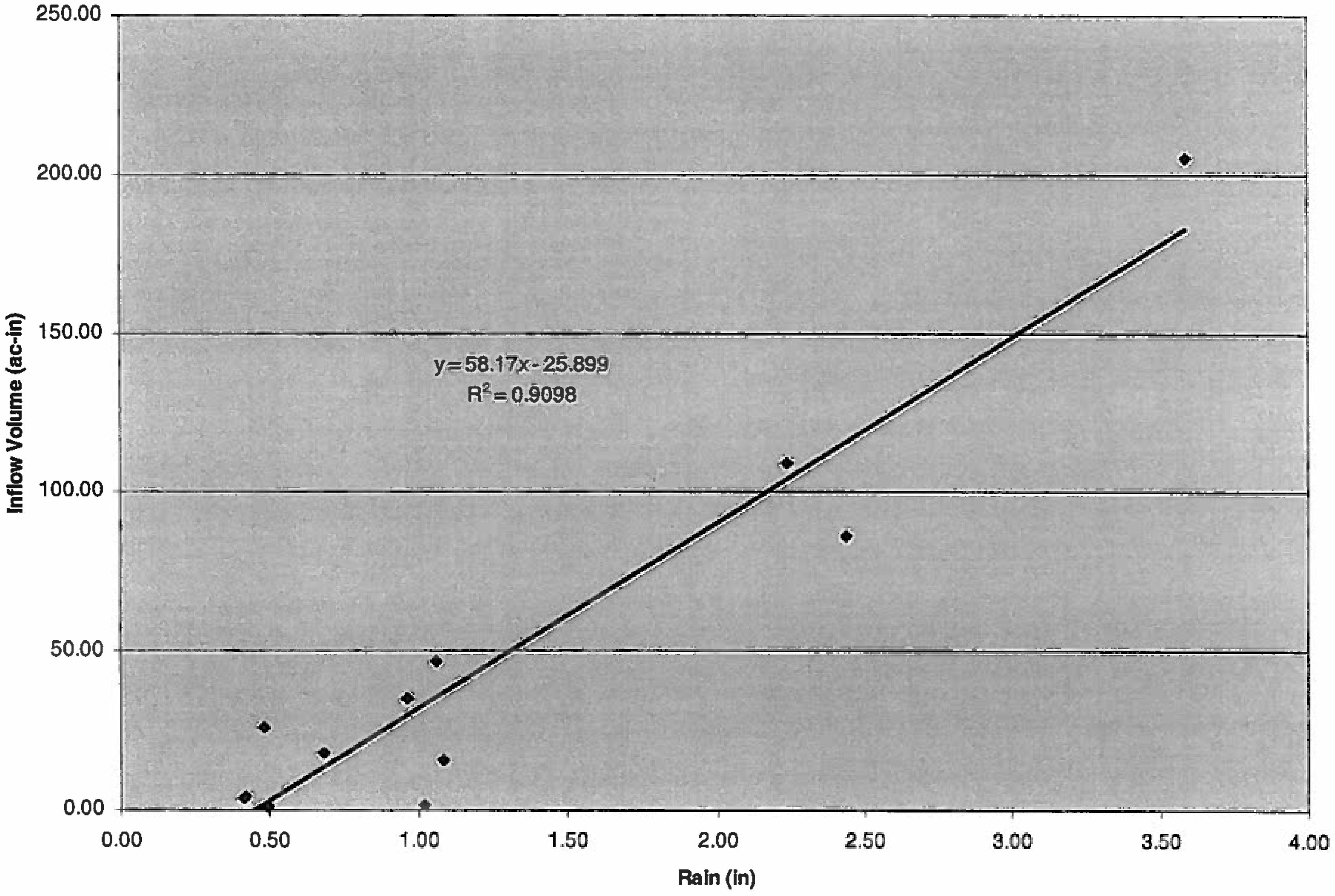
Sugarland Run Regression



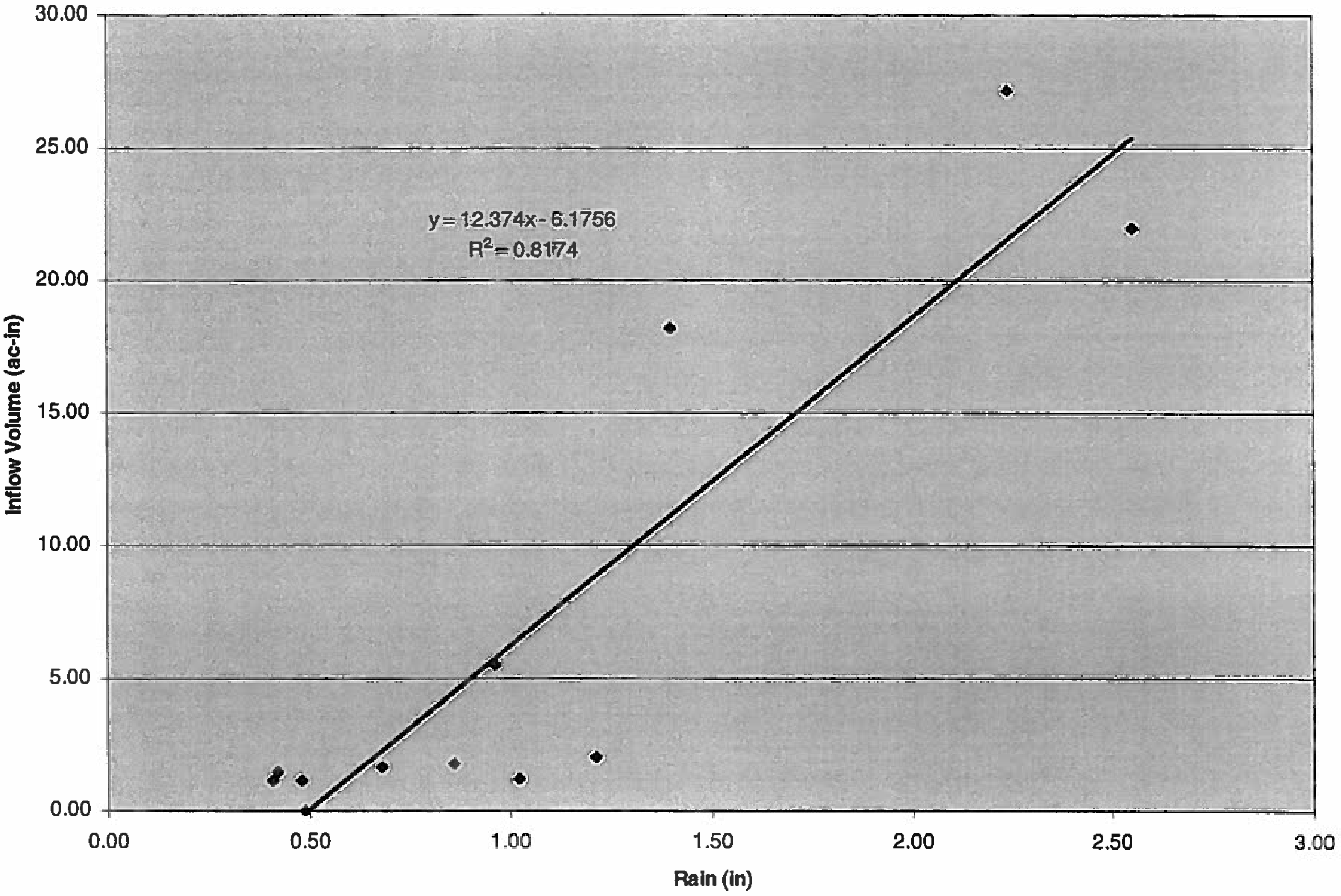
Great Falls Regression



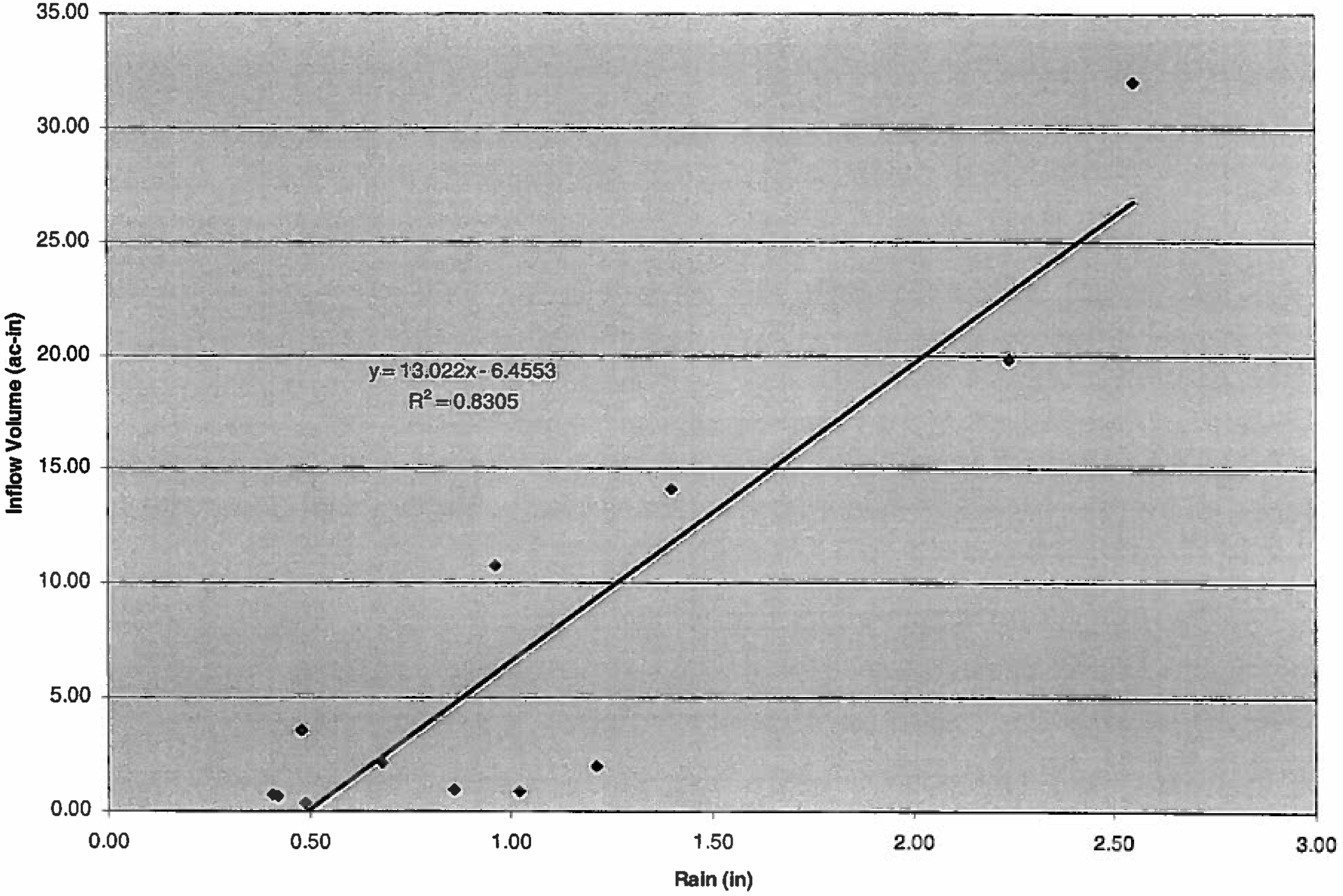
Sully Road #1 Regression



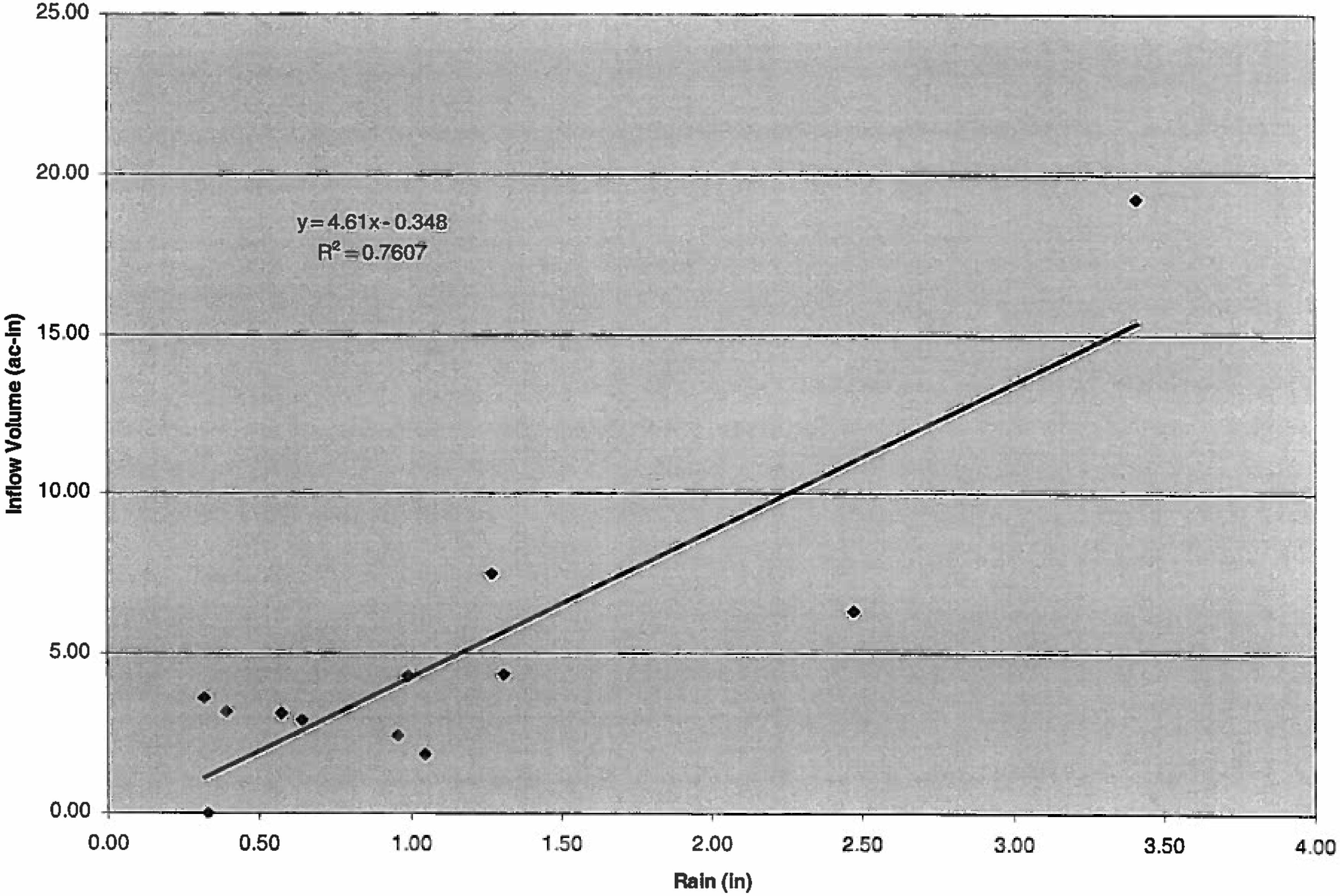
Sully Road #2 Regression



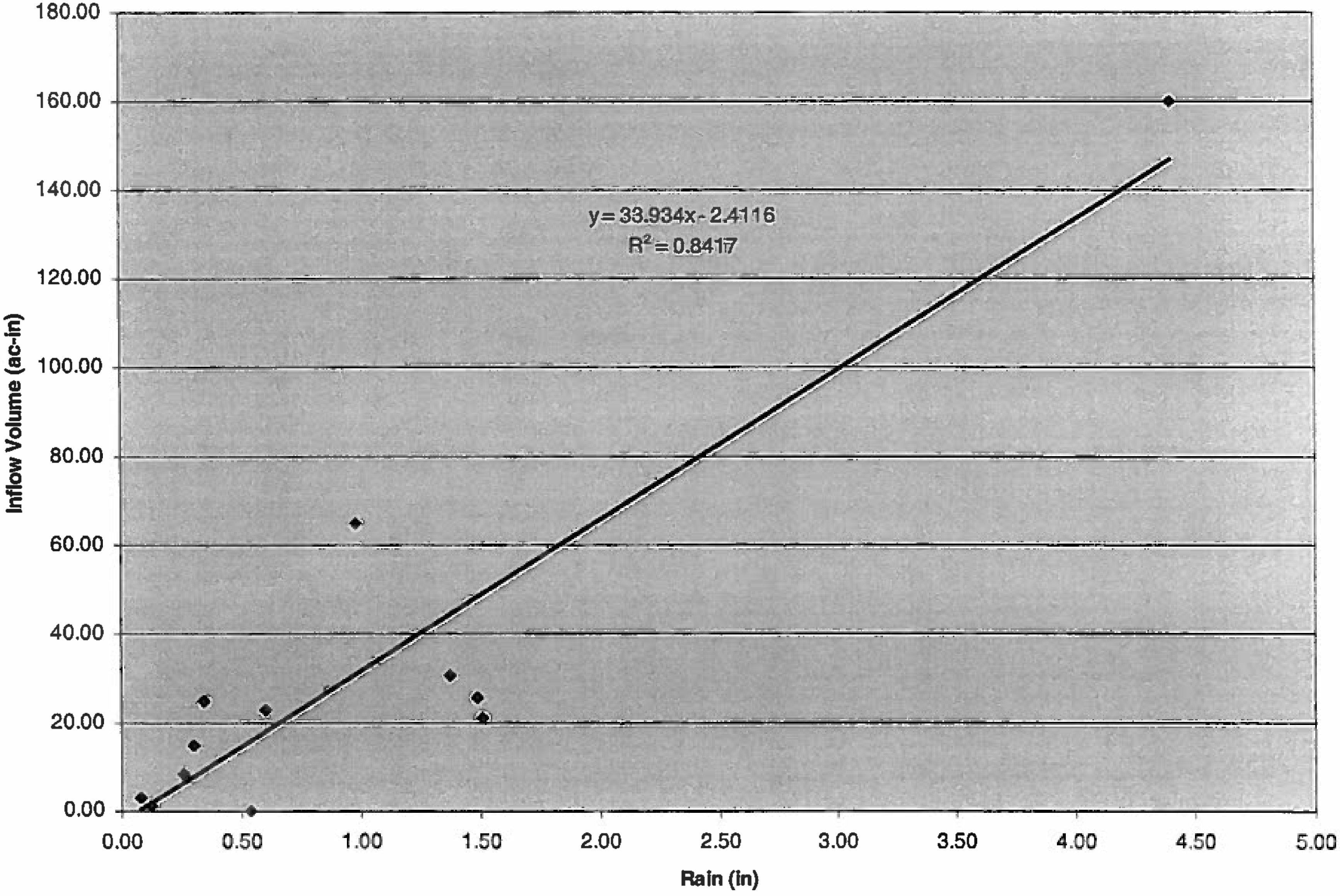
Rock Hill Road Regression



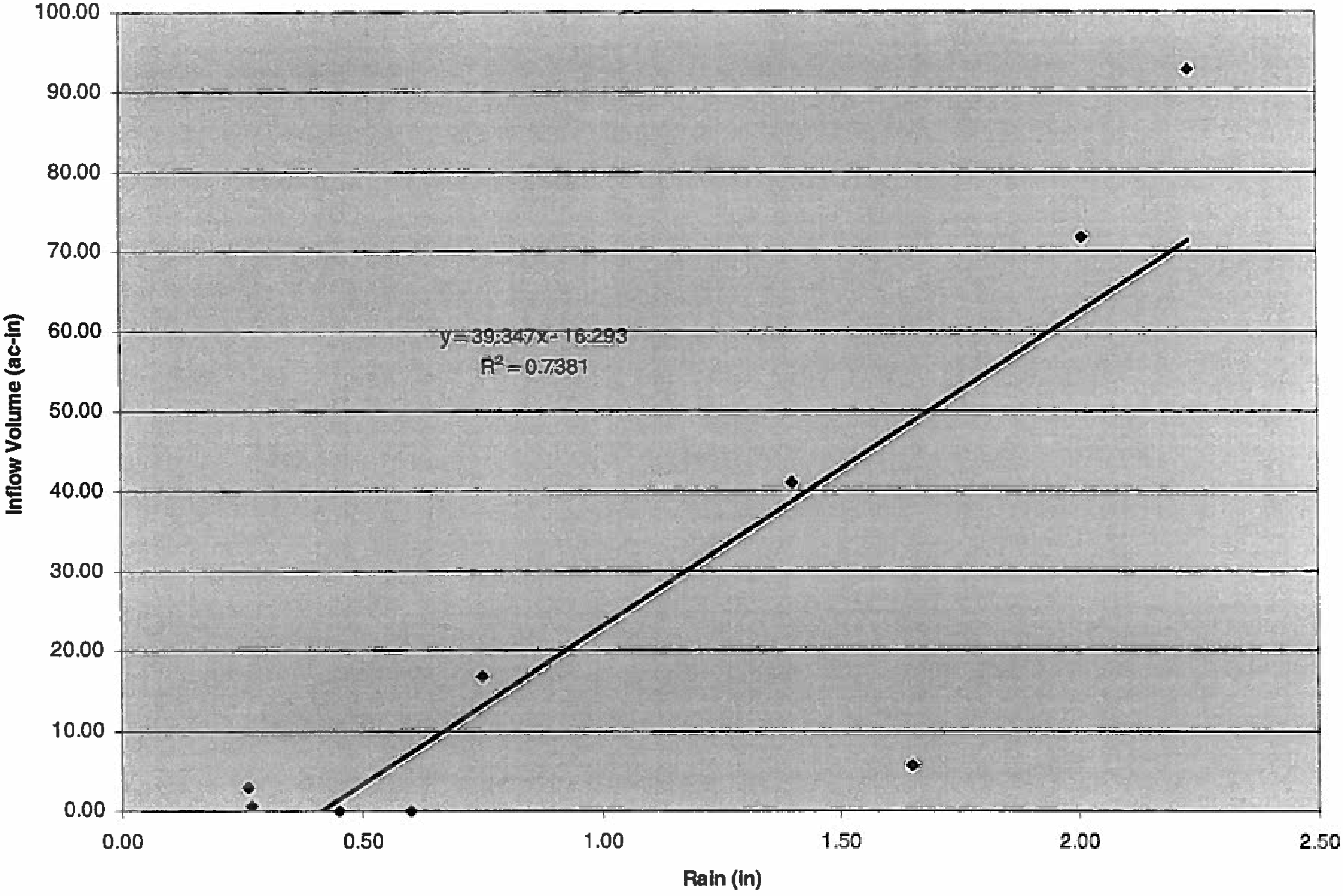
Scotts Run Regression



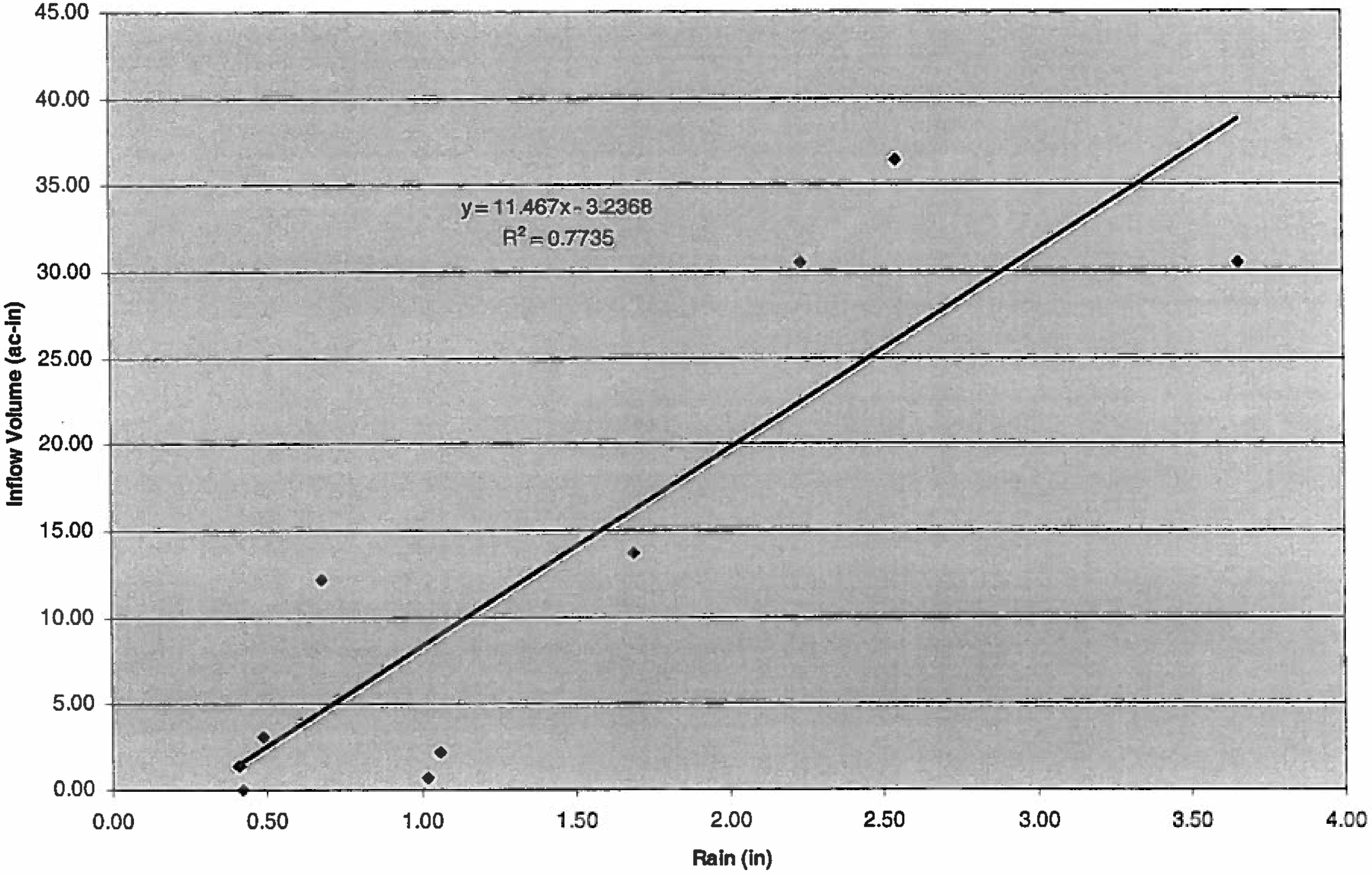
Pimmit Run Regression



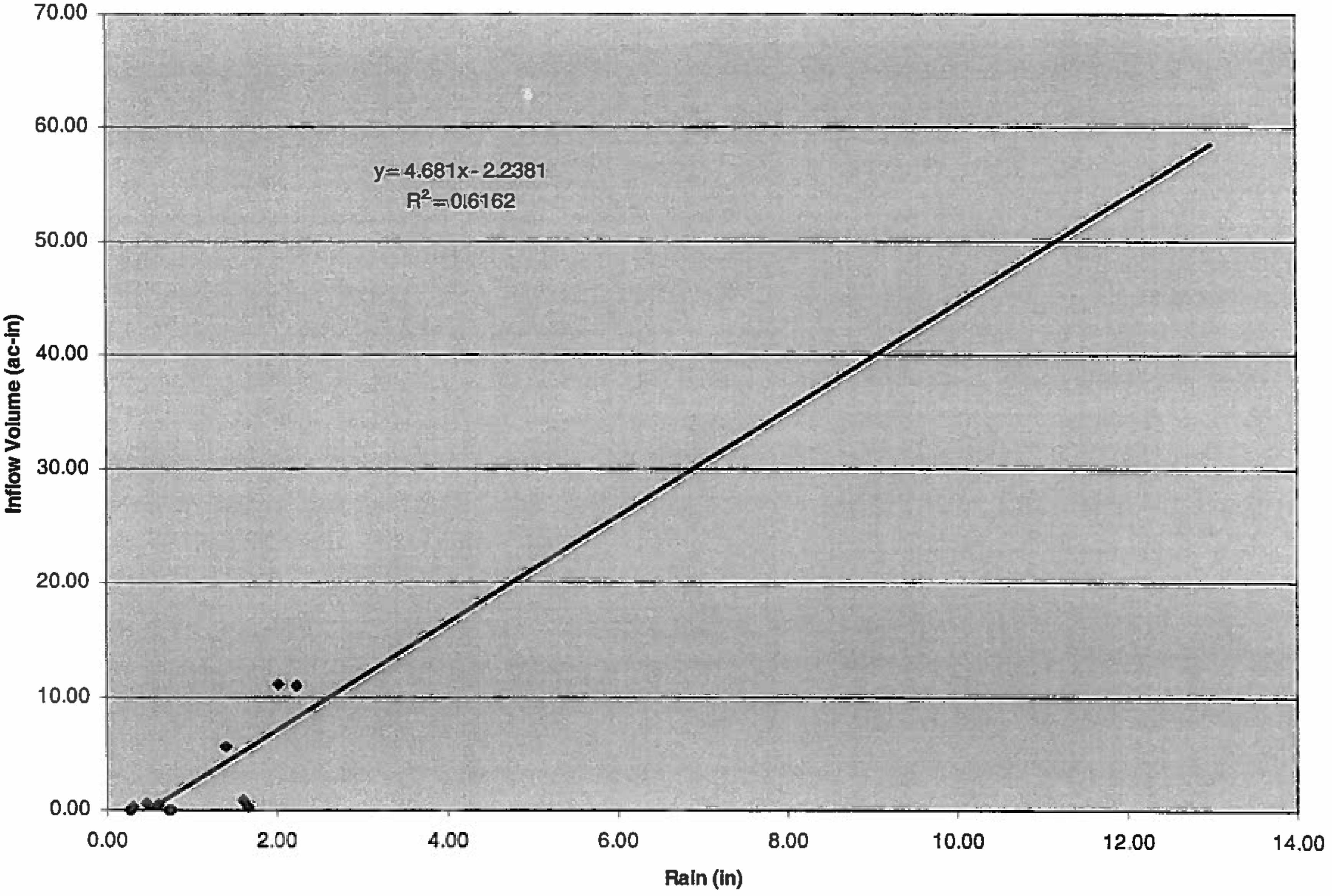
Cabin Branch Regression



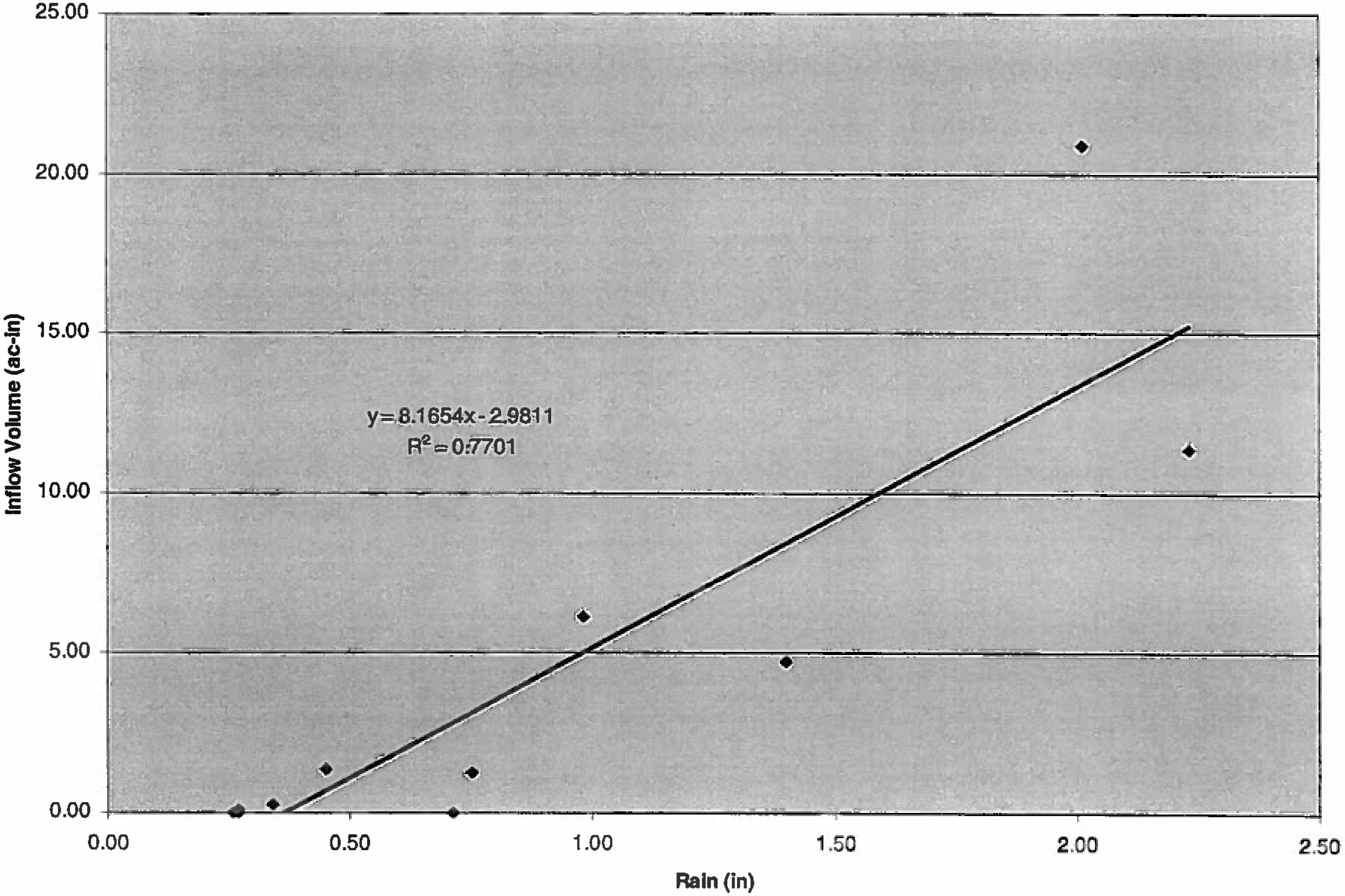
Indian Creek Regression



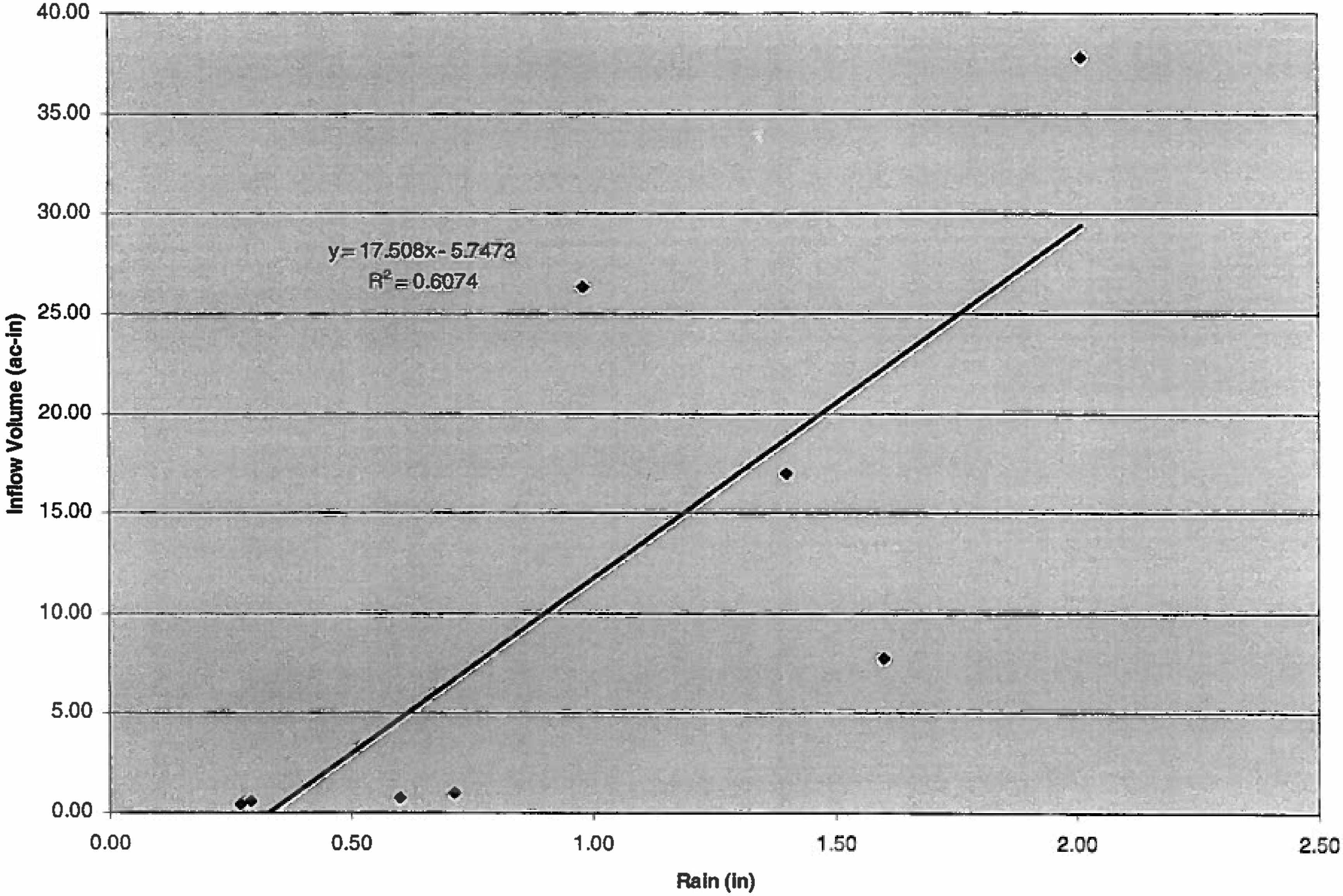
Boise Cascade Regression



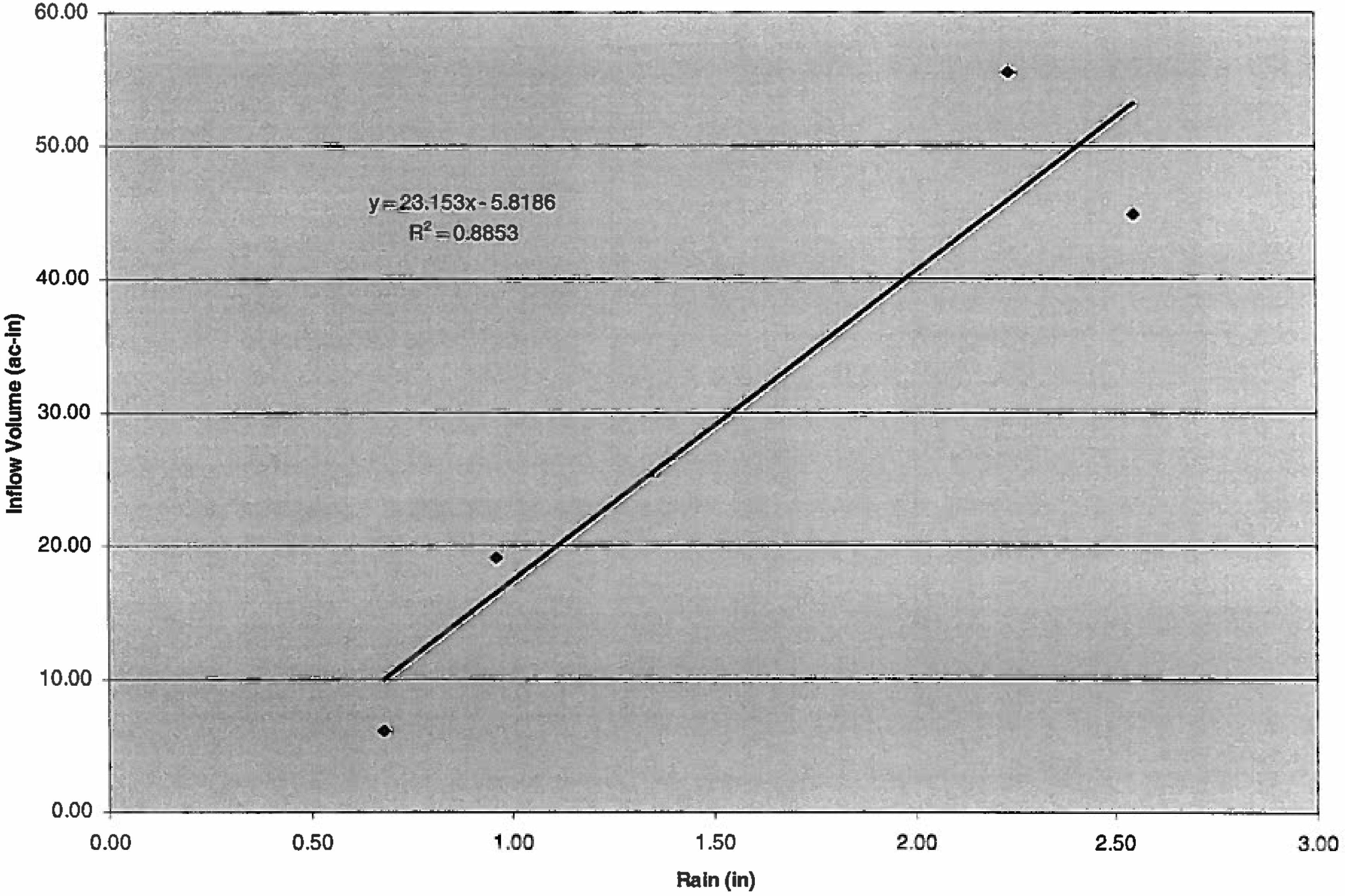
Triple 7 Regression



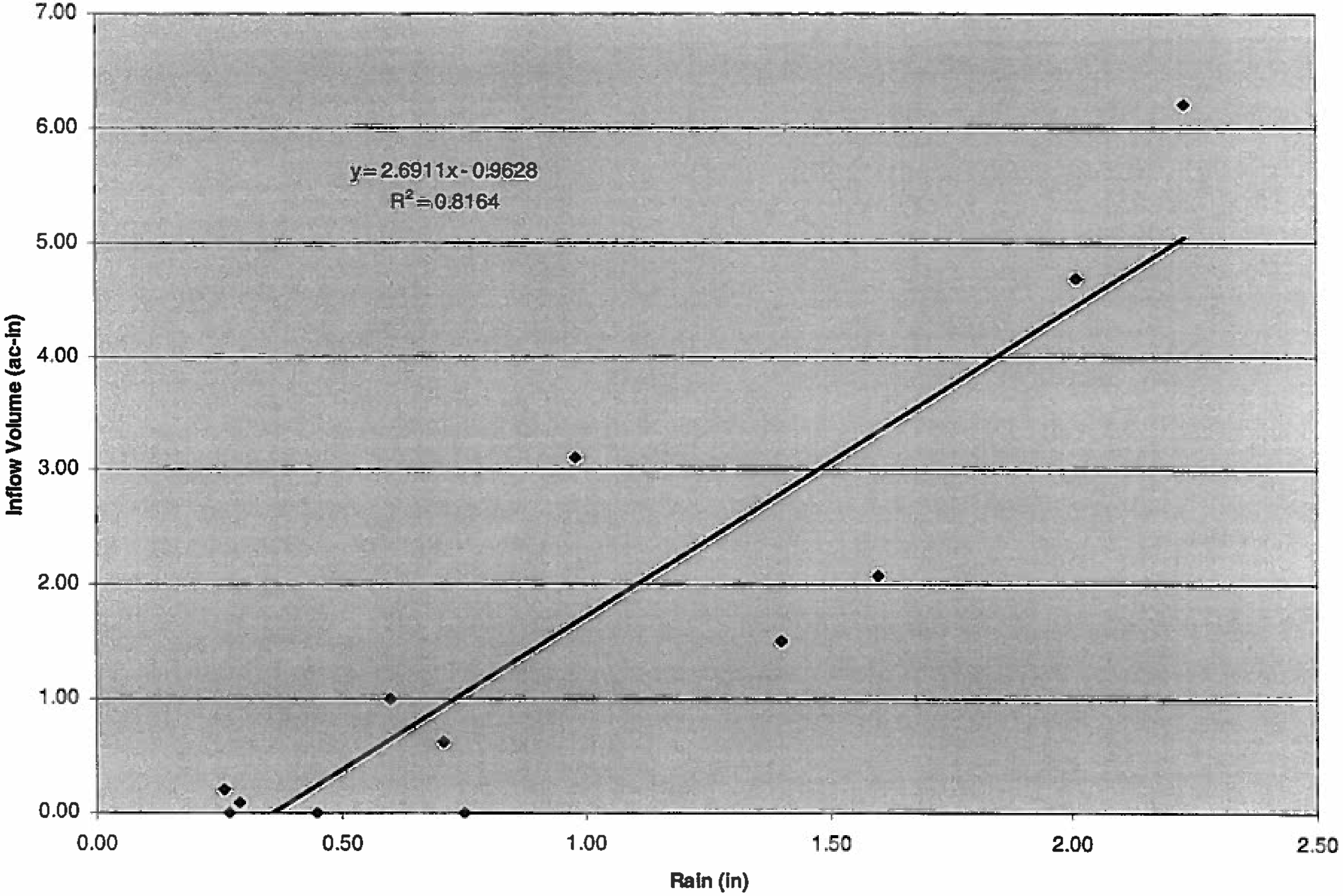
Russell Branch Regression



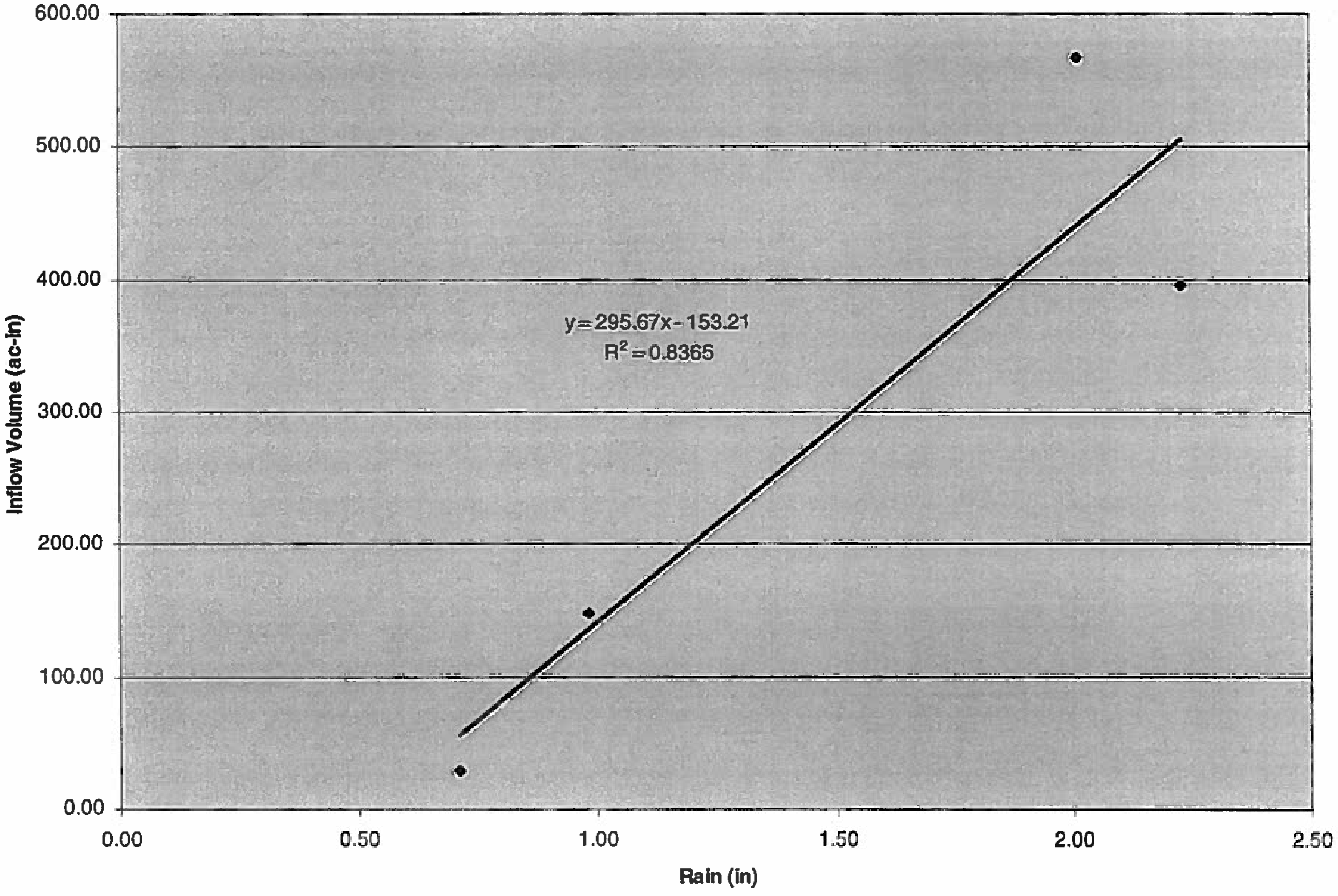
Dulles Regression

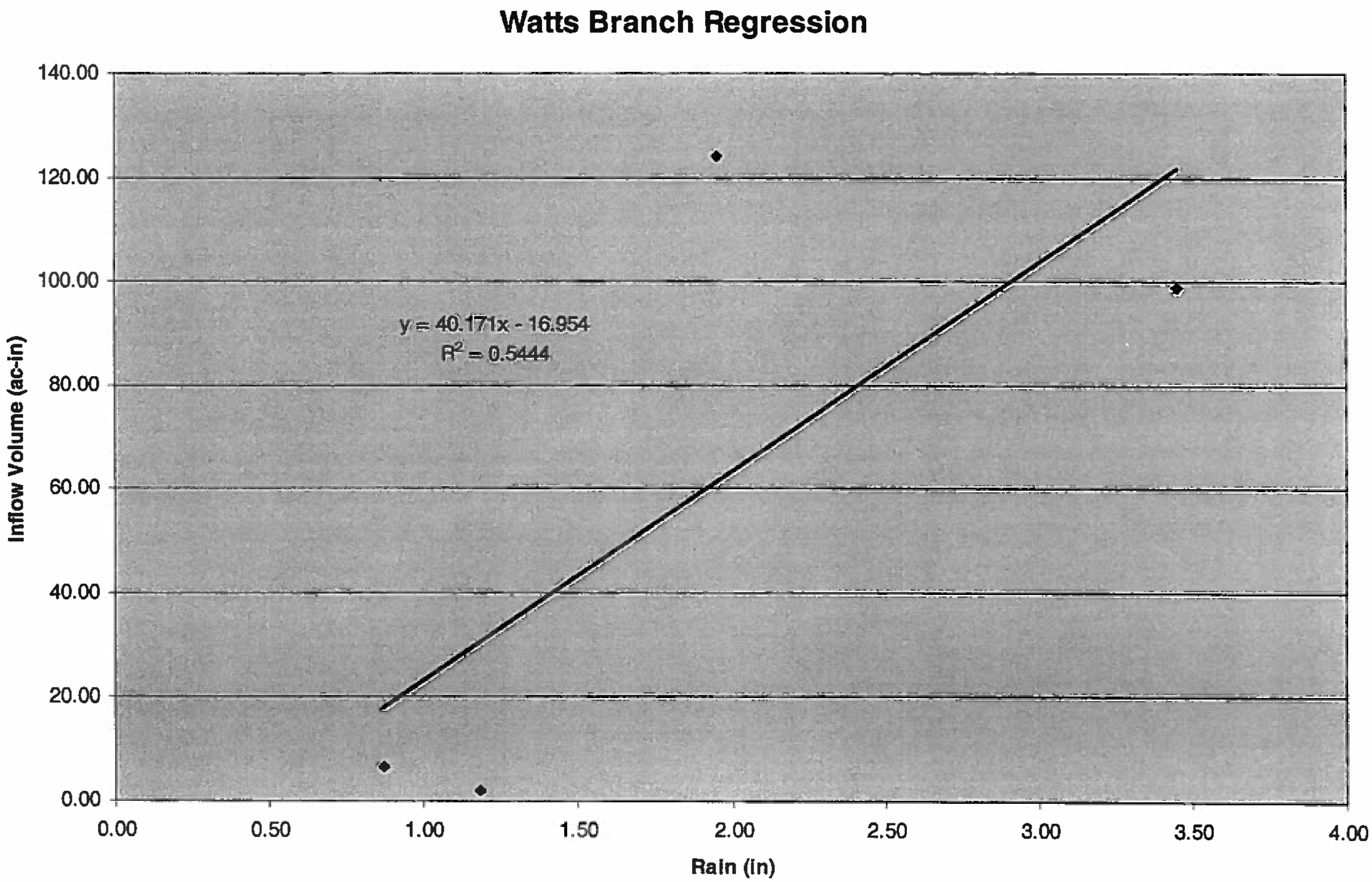


PIP Zerox Regression



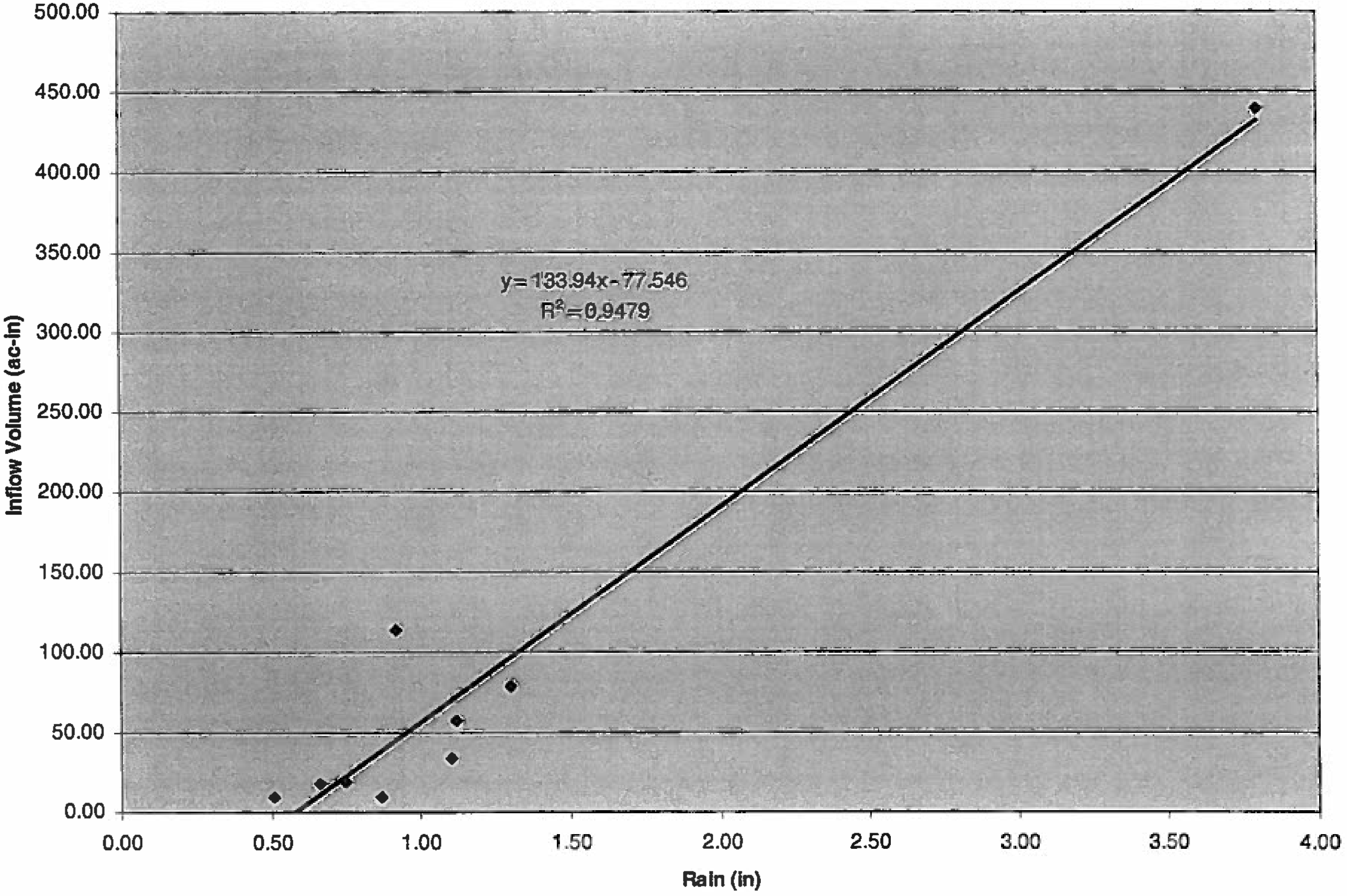
Muddy Branch Regression



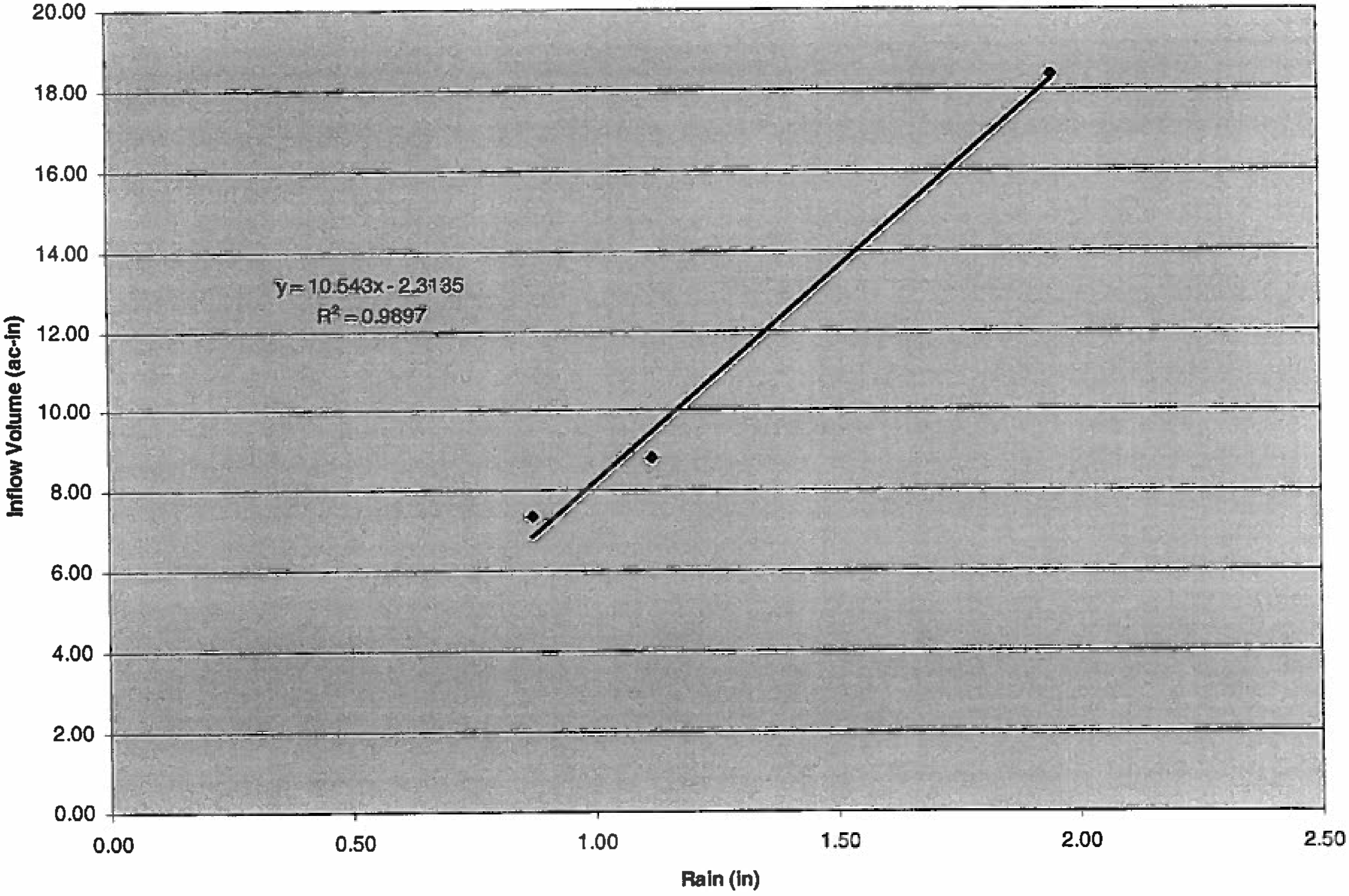


Watts Branch Regression

Cabin John Regression



Rock Run Regression



Appendix B

Summary of Model Input Parameters & Calibrated Peak Flows

Table B-1
Summary of Model Input Parameters and Calibrated Peak Flows

Meter Name	Meter ID		1999 Model Base Flows		Information Used in Model Analysis		Task 6 Results		Calibrated Model Input Parameters		Calibrated Model Peak Flows
		Averge Diurnal Pattern	Sanitary Flow (mgd)	Infiltration (mgd)	Rain Gauge	Basin Area (acres)	Capture Ratio (%)	Depression Storage (in)	Basin Width (ft)	% Impervious	Sept. 15-16, 1999 Flow (mgd)
Fairfax											
Sugarland Run	4039	1	3.26	0.84	Sugarland	8,820	2.08	0.43	879	1.75	14.67
Great Falls	4040	u	4.76	2.89	Colvin Run	35,529	0.14	0.35	200	0.18	16.70
Sully Road #1	4036	1	1.60	0.80	Rock Hill	5,065	1.15	0.47	231	2.50	8.49
Sully Road #2	4037	1	0.60	0.20	Rock Hill	950	1.30	0.50	36	1.10	1.73
Rock Hill Road	4038	1	0.25	0.08	Rock Hill	313	4.16	0.35	54	4.40	1.31
Scotts Run	4041	1	2.46	1.30	Colvin Run	3,945	0.12	0.24	1100	0.25	6.65
Pimmit Run	4042	1	3.77	3.02	CIA	12,515	0.27	0.12	7883	0.34	21.14
AT&T	4043	1	0.07	0.02	Sugarland	1,741	0.36	0.35	27	0.53	0.55
LCSA											
Cabin Branch	4016	1	0.75	0.80	Sugarland	2,143	1.84	0.41	139	1.50	3.56
Indian Creek	4027	u	0.26	0.12	Rock Hill	1,780	0.64	0.28	25	1.00	1.27
Boise Cascade	4019	2	0.24	0.02	Sugarland	466	1.04	0.46	25	1.00	0.80
Triple 7	4028	2	0.41	0.08	Sugarland	1,716	0.48	0.37	40	2.00	1.64
Seneca	4020	2	0.22	0.13	Sugarland	640	0.38	0.41	3	0.20	0.69
Russell Branch	4021	u	1.56	0.34	Sugarland	10,620	0.16	0.47	134	0.60	6.35
PIP – ZEROX	4029	1	0.15	0.26	Sugarland	956	0.28	0.36	15	0.35	0.69
Countryside #2	4023	1	0.20	0.02	Sugarland	463	0.00	0.41	378	0.73	0.59
Great Falls Forest #1	4025	2	0.05	0.00	Sugarland	117	0.00	0.41	300	0.00	0.13
Great Falls Forest #2	4026	2	0.06	0.02	Sugarland	300	0.06	0.41	1	0.06	0.17
Countryside #1	4022	2	0.04	0.12	Sugarland	400	0.06	0.41	786	0.06	0.24
Cascades Western	4024	2	0.15	0.03	Sugarland	566	0.18	0.41	1516	0.05	0.48
Cascades Northern	4031	2	0.22	0.08	Sugarland	522	0.23	0.41	3134	0.23	0.70
Broad Run	4032	1	0.04	0.02	Rock Hill	561	0.05	0.41	8	0.05	0.11
Northwestern	4033	1	0.05	0.00	Sugarland	165	0.40	0.41	1831	0.40	0.29
Northeastern	4034	1	0.03	0.11	Sugarland	320	0.07	0.41	709	0.07	0.21
Beaumeade #1	4035	1	0.02	0.01	Sugarland	318	0.01	0.41	46	0.02	0.05
Dulles											
Dulles Airport	4045	u	0.36	0.60	Rock Hill	7,057	0.33	0.25	250	0.13	2.15
WSSC											
Muddy Branch	4013	u	10.92	1.94	Sugarland	66,348	0.45	0.52	300	0.10	28.27
Watts Branch	4014	1	2.08	1.80	RGCC	13,841	0.29	0.42	120	0.22	7.80
Cabin John Dulles	4011	1	7.80	0.12	RGLT	4,860	2.76	0.59	585	1.00	29.78
Rock Run	4015	1	0.46	0.23	RGCC	3,149	0.33	0.22	284	0.40	2.93

Appendix C

Legend for Database and Model Identifiers

Table C-1

MODEL ID	DB ID
1	1.6
2	2
3	3
4	4
5	5
6	6
7	7
8	8
9	9
10	10
11	11
12	12
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15	15
16	16
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25	25
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32	32
33	33
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35	35
36	36
37	37
38	38
39	39
40	40
41	41
42	42
43	43
44	44
45	45

Table C-1

MODEL ID	DB ID
46	46
47	47
48	48
49	49
50	50
51	51
52	52
53	53
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83	83
84	84
85	85
86	86
87	87
88	88
89	89
90	90

Table C-1

MODEL ID	DB ID
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93	93
94	94
95	95
96	96
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98	98
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100	100
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102	102
103	103
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211	211
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213	213
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216	216
217	217

Table C-1

MODEL ID	DB ID
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302	302
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304	304
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323	323
324	324
325	325
400	400
401	401
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405	405
406	406
407	407
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409	409
410	410
411	411

Table C-1

MODEL ID	DB ID
412	412
413	413
414	414
415	415
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421	421
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1993	1993
1994	1994
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1996	1997.93
1997	1997
1998	1998
1999	1999
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2953	2953
2954	2954

Table C-1

MODEL ID	DB ID
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2991	2991
2993	2993
2994	2994
2995	2995
2996	2996
2997	2997
2998	2998
2999	2999
3000	3000
3001	3001

Table C-1

MODEL ID	DB ID
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3006	3006
3007	3007
3008	3008
3009	3009
3010	3010
3013	3013
3014	3014
3015	3015
3016	3016
3018	3018
3019	3019
4027	80.2
4032	103.2
4036	118.2
4037	107.2
4040	208.2
7538	53.8
7688	68.8
7738	73.8
7808	80.8
19911	1991.81
19912	1991.8
29891	2989.8
29892	2989.81
71038	103.8
71078	107.8
76881	68.81
78081	80.81
78082	80.82
78083	80.83
710381	103.81
710782	107.82
710783	107.83

Table C-2
Legend for DB and Model Ids

MODEL ID Pipes	DB Pipe ID	Comments
5000, 50016, 50017, 50018, 50019	5000	pipe split into multiple segments in model
50010, 50011, 50012, 50013, 50014	5001	pipe split into multiple segments in model
50020, 50021, 50022, 50023, 50024	5002	pipe split into multiple segments in model
5003	5003	
5004	5004	
5005	5005	
5006	5006	
5007	5007	
5008	5008	
5009	5009	
5010	5010	
5011	5011	
5012	5012	
5013	5013	
5014	5014	
5015	5015	
5016	5016	
5017	5017	
5018	5018	
50190, 50191, 50192, 50193, 50194	5019	pipe split into multiple segments in model
50200, 50201, 50202, 50203, 50204	5020	pipe split into multiple segments in model
5021	5021	
5022	5022	
5023	5023	
5024	5024	
5025	5025	
5026	5026	
50274, 50273, 50272, 50271, 50270	5027	pipe split into multiple segments in model
282, 50283, 50284, 50285, 50286, 50	5028	pipe split into multiple segments in model
5029	5029	
5030	5030	
5031	5031	
5032	5032	
5033	5033	
5034	5034	
5035	5035	
5036	5036	
5037	5037	
5038	5038	
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5043	5043	
5044	5044	
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5046	5046	
5047	5047	

Table C-2
Legend for DB and Model Ids

MODEL ID Pipes	DB Pipe ID	Comments
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5089	5089	
5090	5090	
5091	5091	
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5093	5093	
5094	5094	
5095	5095	

Table C-2
Legend for DB and Model Ids

MODEL ID Pipes	DB Pipe ID	Comments
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5098	5098	
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5107	5107	
5108	5108	
5109	5109	
5110	5110	
95111	5111	
5112	5112	
5113	5113	
5114	5114	
5115	5115	
5116	5116	
6117	5117	
95118	5118	
5119	5119	
5120	5120	
5121	5121	
5122	5122	
5123	5123	
5124	5124	
5125	5125	
5126	5126	
5127	5127	
5128	5128	
5129	5129	
5130	5130	
5131	5131	
95132	5132	
5133	5133	
51340, 51341	5134	pipe split into multiple segments in model
5135	5135	
5136	5136	
5137	5137	
5138	5138	
5139	5139	
5140	5140	
5141	5141	
95142	5142	
5143	5143	

Table C-2
Legend for DB and Model Ids

MODEL ID Pipes	DB Pipe ID	Comments
5144	5144	
5145	5145	
5146	5146	
5147	5147	
5148	5148	
5149	5149	
5150	5150	
5151	5151	
5152	5152	
5153	5153	
5154	5154	
5155	5155	
5156	5156	
5157	5157	
5158	5158	
5159	5159	
5160	5160	
5161	5161	
5162	5162	
5163	5163	
5164	5164	
5165	5165	
5166	5166	
5167	5167	
5168	5168	
5169	5169	
5170	5170	
5171	5171	
5172	5172	
5173	5173	
5174	5174	
5175	5175	
5176	5176	
5177	5177	
5178	5178	
5179	5179	
5180	5180	
5181	5181	
5182	5182	
5183	5183	
5184	5184	
5185	5185	
5186	5186	
5187	5187	
5188	5188	
5189	5189	
5190	5190	
5191	5191	

Table C-2
Legend for DB and Model Ids

MODEL ID Pipes	DB Pipe ID	Comments
5192	5192	
5193	5193	
5194	5194	
5195	5195	
5196	5196	
60000, 60001, 60002	6000	pipe split into multiple segments in model
6001	6001	
6002	6002	
6003	6003	
6004	6004	
6005	6005	
6006	6006	
6007	6007	
6008	6008	
6009	6009	
6010	6010	
6011	6011	
6012	6012	
6013	6013	
6014	6014	
6015	6015	
6016	6016	
6017	6017	
6018	6018	
6019	6019	
6020	6020	
7000	7000	
7001	7001	
7002	7002	
7003	7003	
7004	7004	
7005	7005	
7006	7006	
7007	7007	
7008	7008	
7009	7009	
7010	7010	
7011	7011	
7012	7012	
8000	8000	
8001	8001	
8002	8002	
8003	8003	
8004	8004	
8005	8005	
8006	8006	
8007	8007	
8008	8008	

Table C-2
Legend for DB and Model Ids

MODEL ID Pipes	DB Pipe ID	Comments
8009	8009	
8010	8010	
8011	8011	
8012	8012	
8013	8013	
8014	8014	
8015	8015	
8016	8016	
8017	8017	
8018	8018	
8019	8019	
8020	8020	
8021	8021	
8022	8022	
8023	8023	
8024	8024	
8025	8025	
8026	8026	
8027	8027	
8028	8028	
8029	8029	
8030	8030	
8031	8031	
8032	8032	
8033	8033	
8034	8034	
8035	8035	
8036	8036	
8037	8037	
8038	8038	
8039	8039	
8040	8040	
8041	8041	
8042	8042	
8043	8043	
8044	8044	
8045	8045	
8046	8046	
8047	8047	
8048	8048	

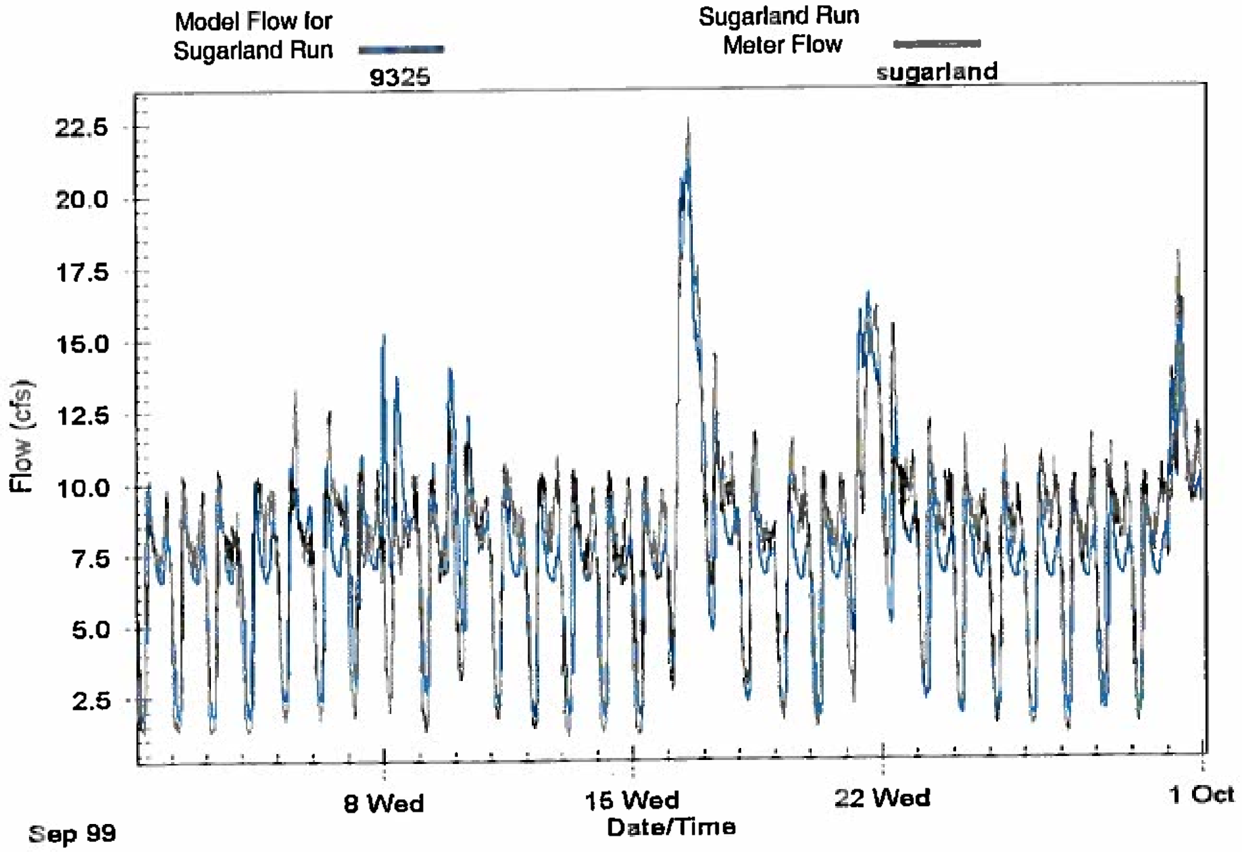
Table C-3 Metered Connections and "Dummy Pipe" Model IDs

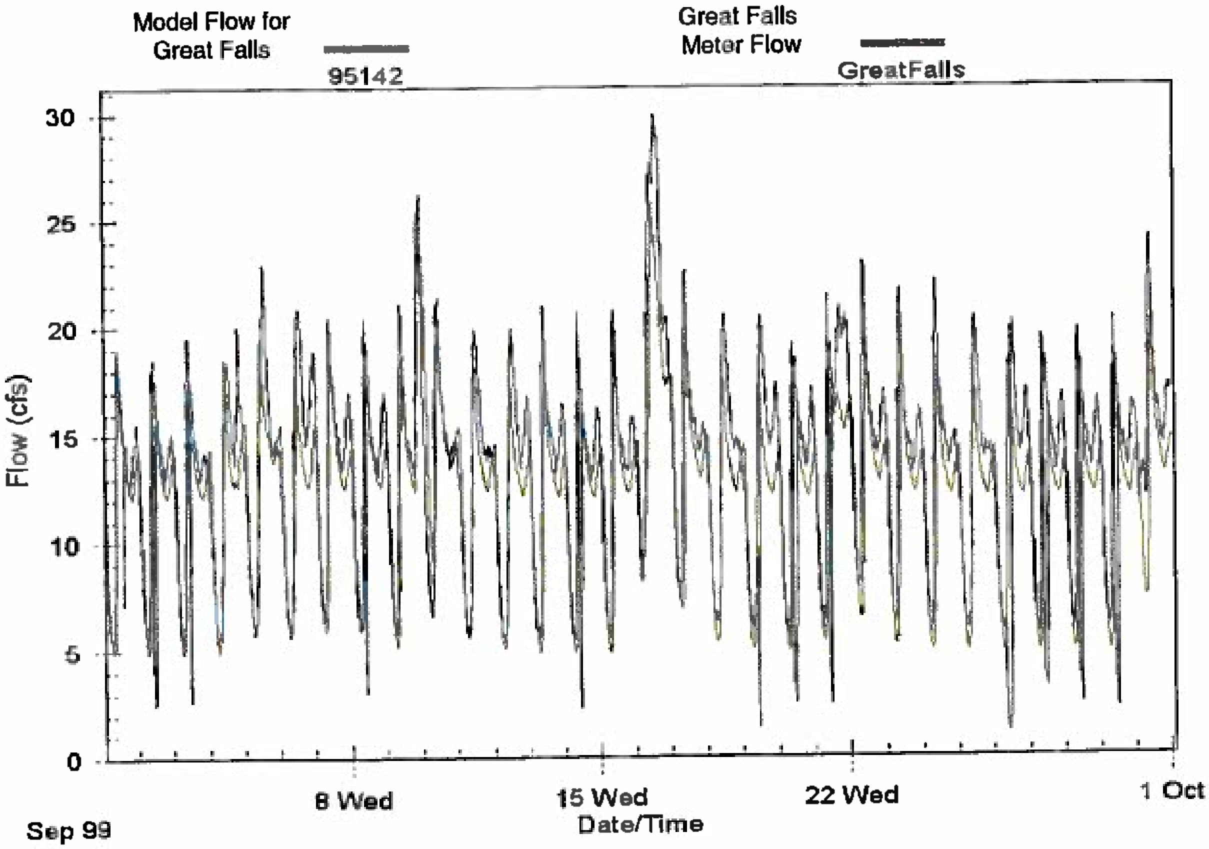
Pipe ID	Upstream Node	Meter Name	Downstream Node
94011	4011	CJ1	4012
94012	4012	CJ2	3020
910	4012	CJ2	10-11
9411	4013	Muddy Branch	411
9407	4014	Watts Branch-MC	407
920	4015	Rock Run	20
958	4016	Cabin Branch	58
9304	4019	Boise Cascade	304
9313	4020	Seneca	313
955	4021	Russell Branch-S-17	55
953	4022	Countryside #1	53
9303	4024	Cascades Western	303
9315	4025	Great Falls Forest #1	315
9309	4026	Great Falls Forest #2	309
95083	4027	Indian Creek-S-6	78083
949	4028	Triple 7-S-20	49
951	4029	PIP - ZEROX	51
9951	4023	Countryside #2	51
946	4031	Cascades North	46
96881	4032	Broad Run	76881
943	4033	Northwestern	43
941	4034	Northeastern	41
962	4035	Beaumeade #1	62
95132	4036	Sully Road #1	117
95118	4037	Sully Road #2	710783
95111	4038	Rock Hill Road	710381
9325	4039	Sugarland Run	325
95142	4040	Great Falls	208
923	4041	Scotts Run	23
9324	4043	AT&T B3046	324
983	4045	Dulles Airport	83
94042	4042	Pimmit Run	1996

Appendix D
Calibration Plots

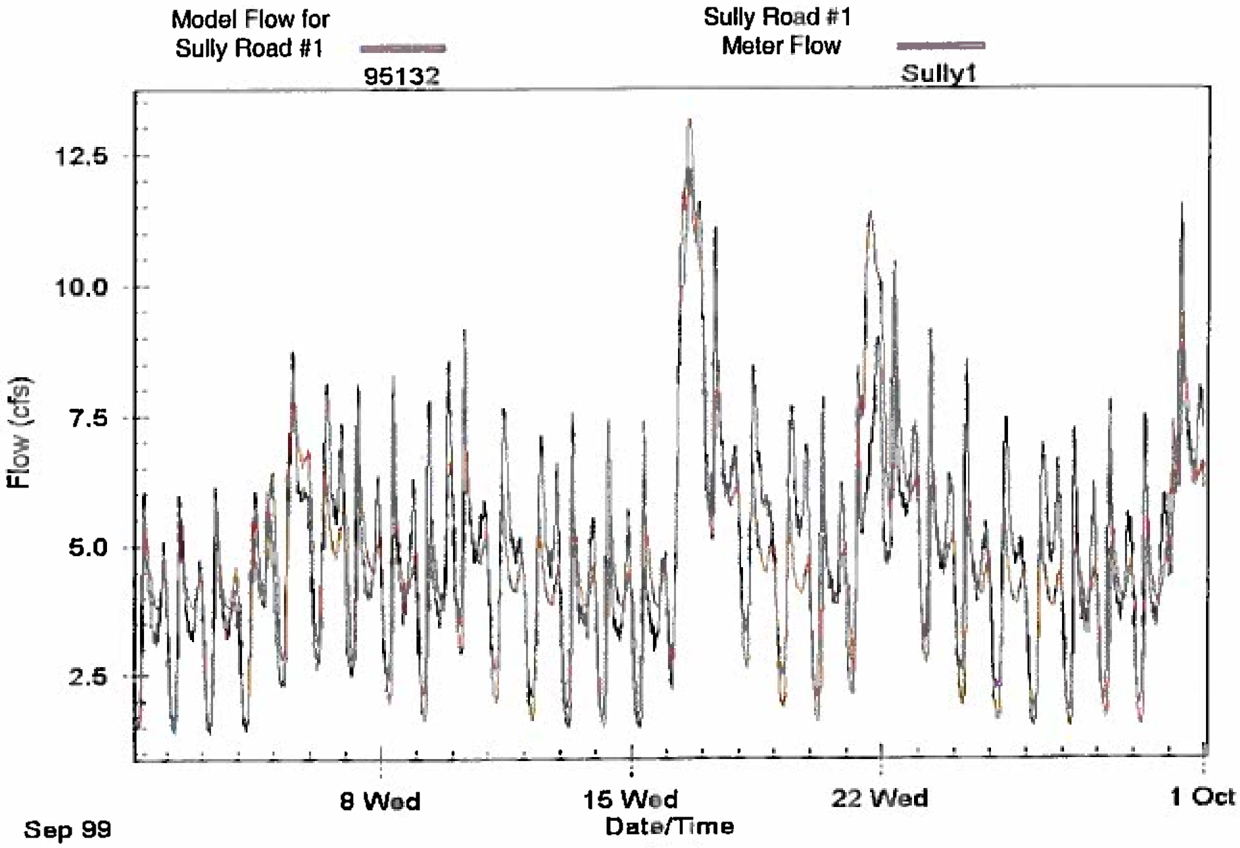
Appendix D-1
Jurisdictional Calibration Plots

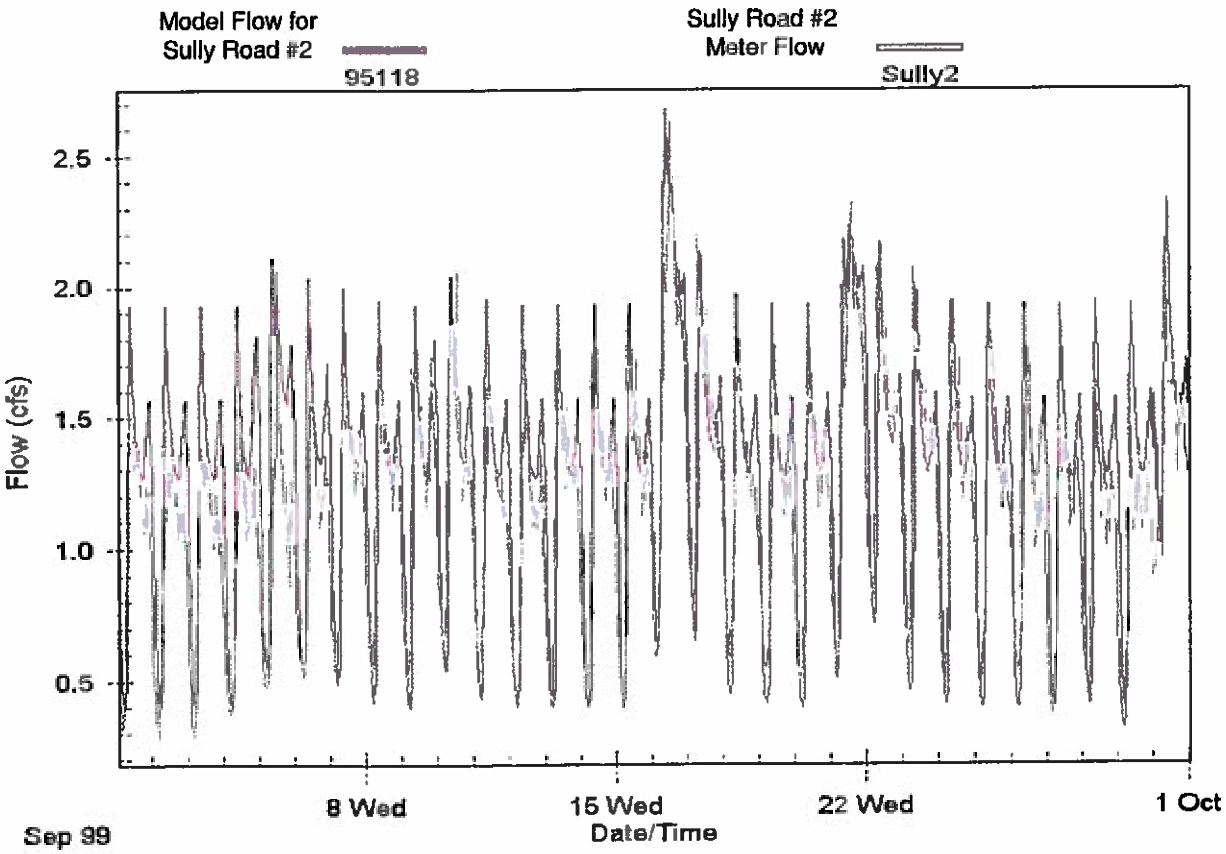
Fairfax Calibration Plots



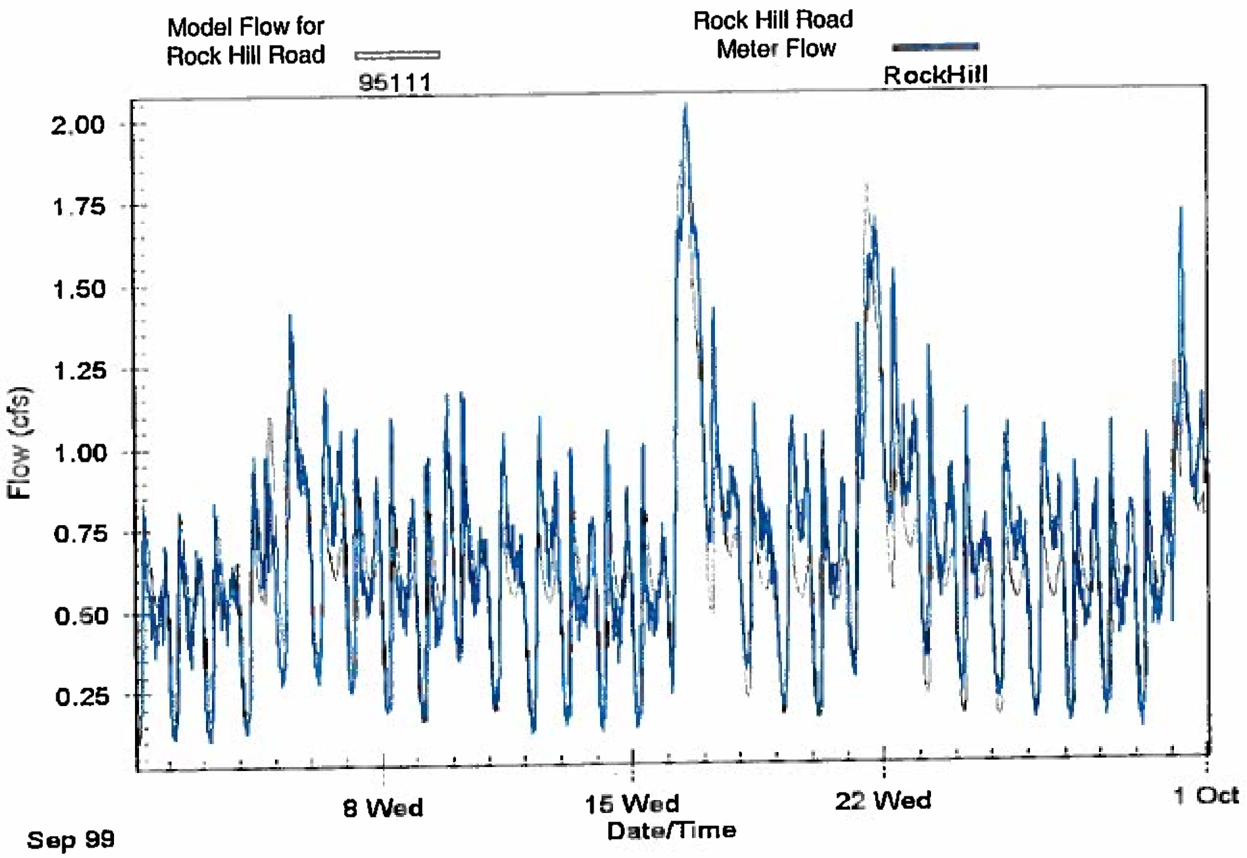


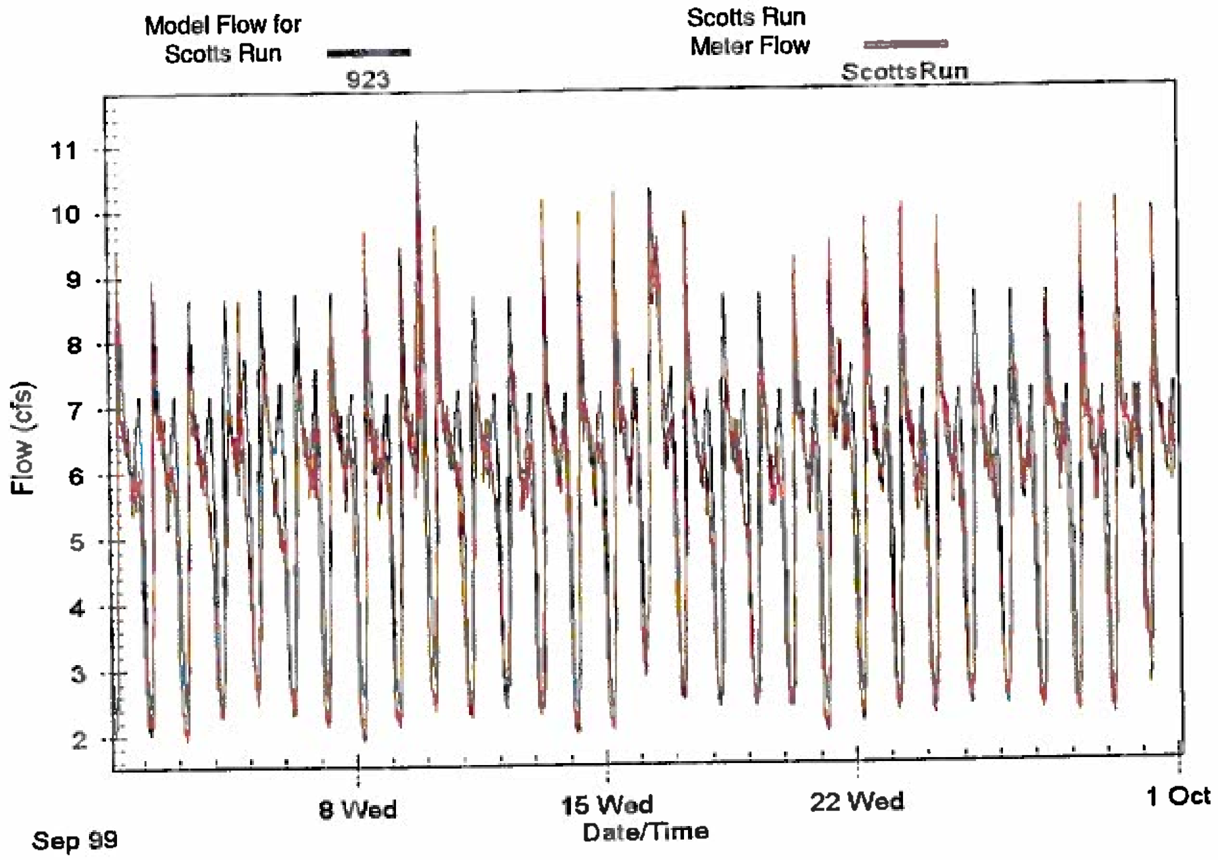
Fairfax Calibration Plots



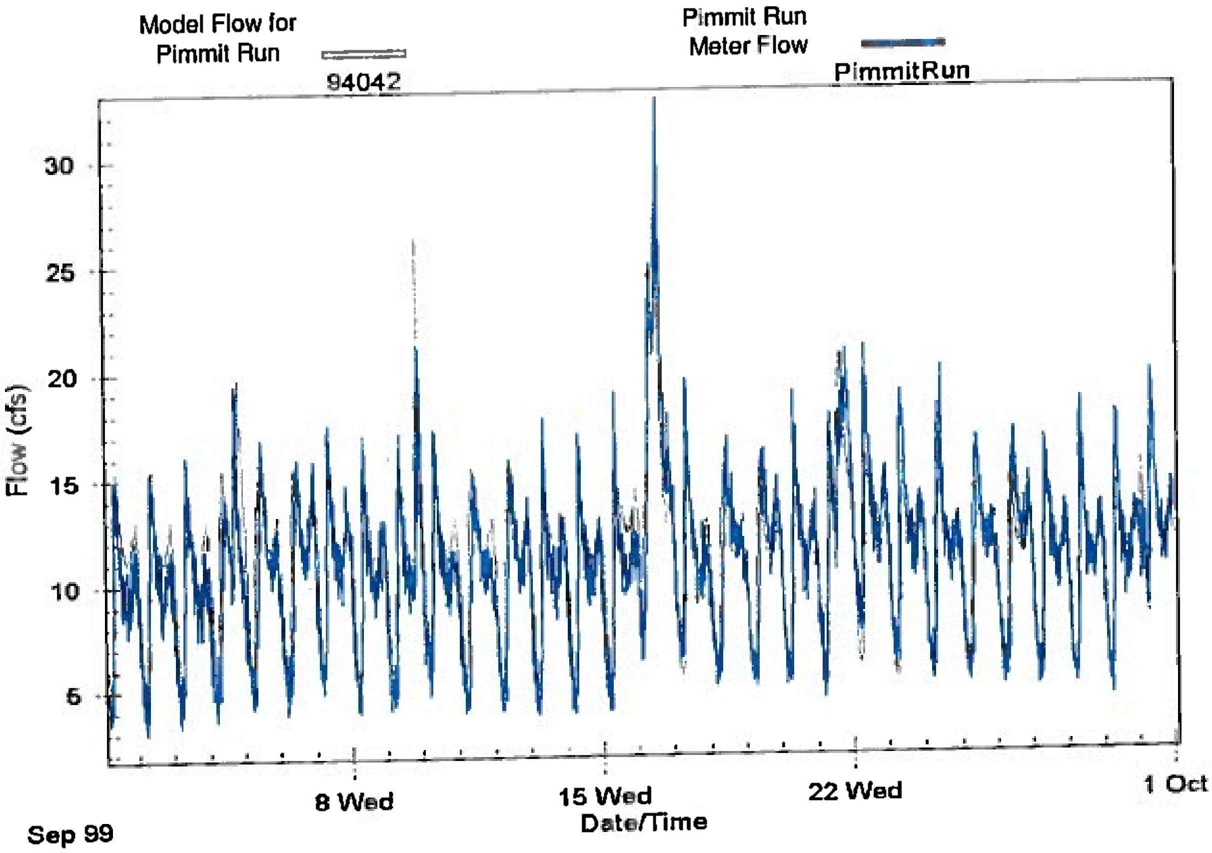


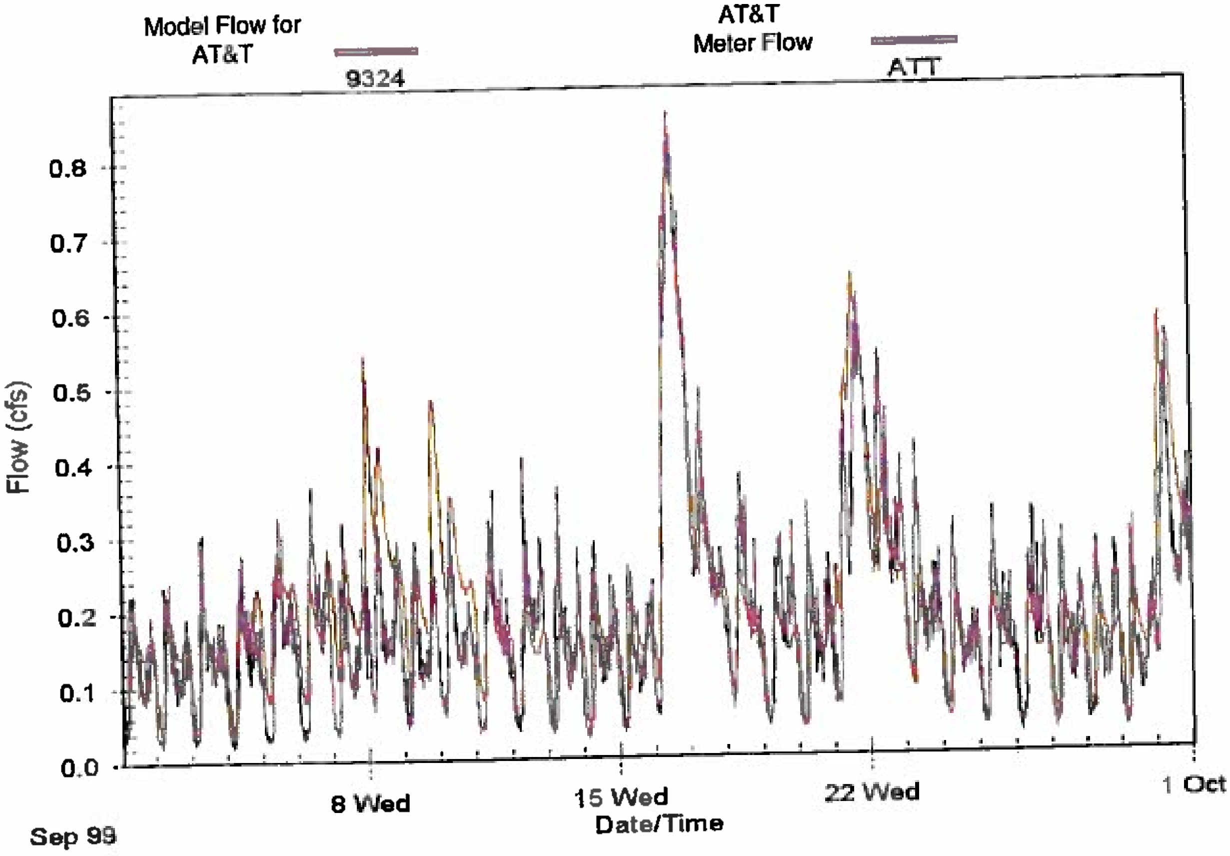
Fairfax Calibration Plots



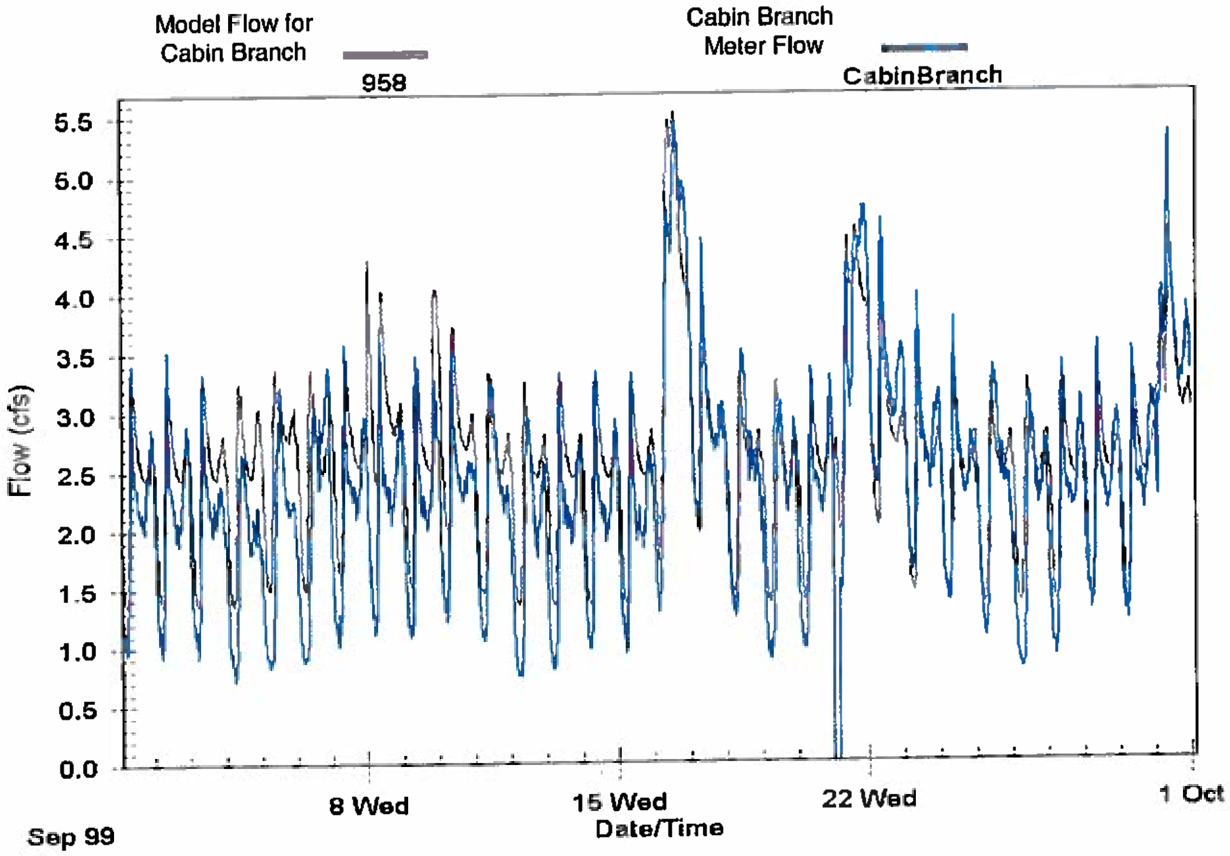


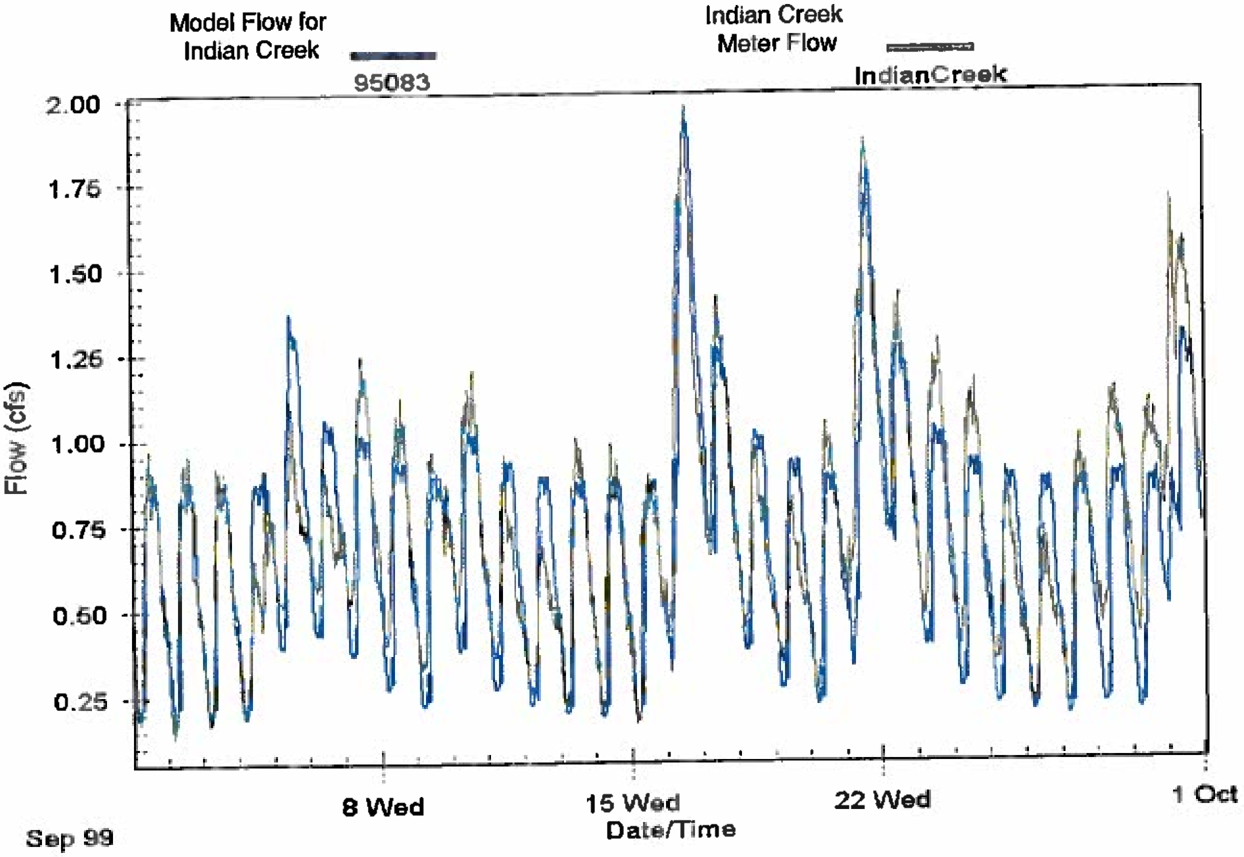
Fairfax Calibration Plots



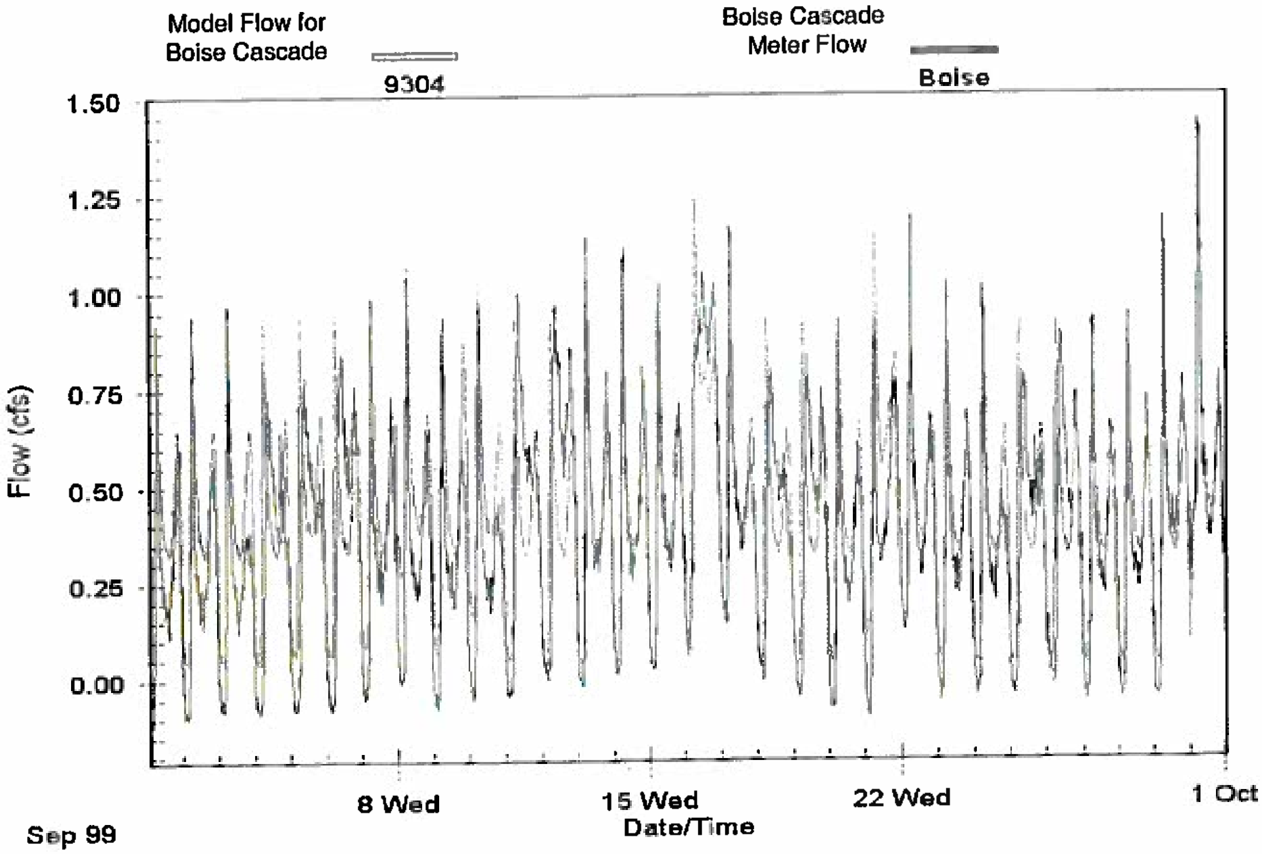


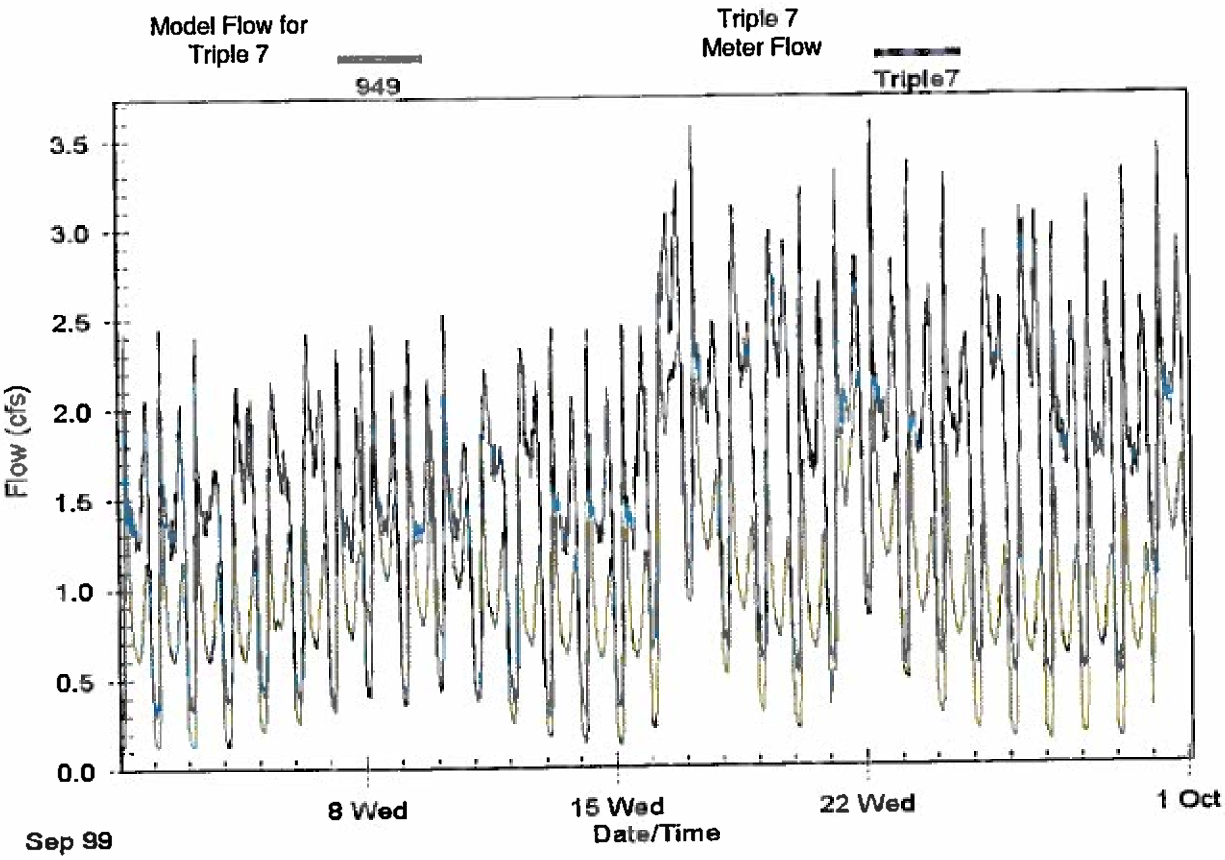
LCSA Calibration Plots



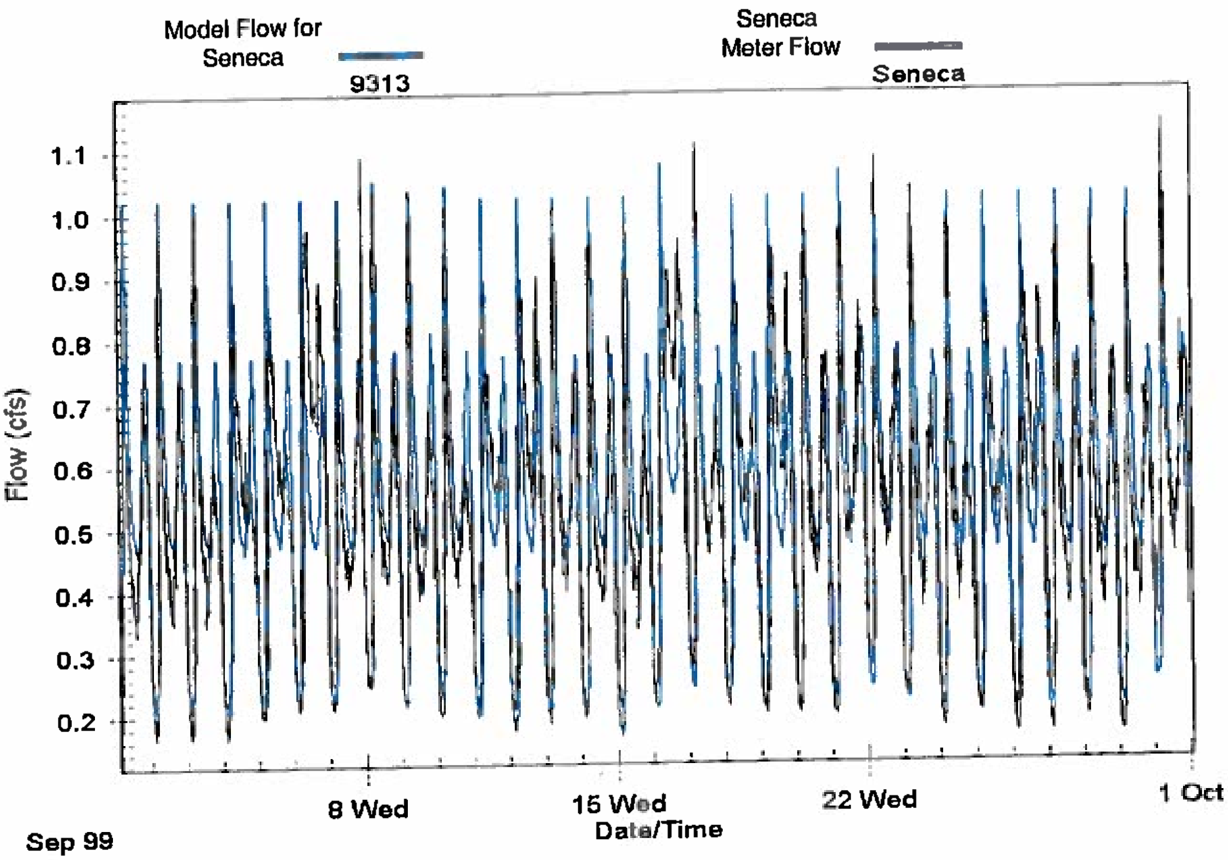


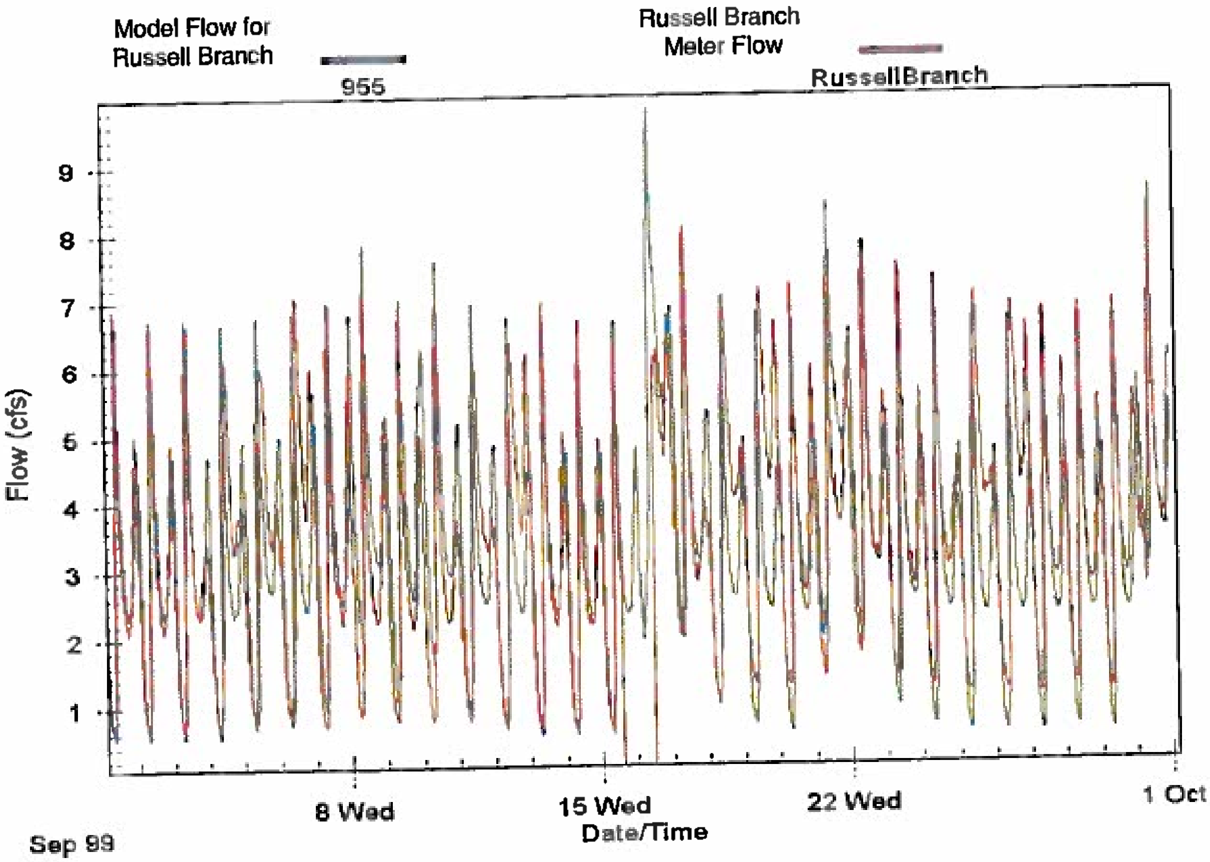
LCSA Calibration Plots



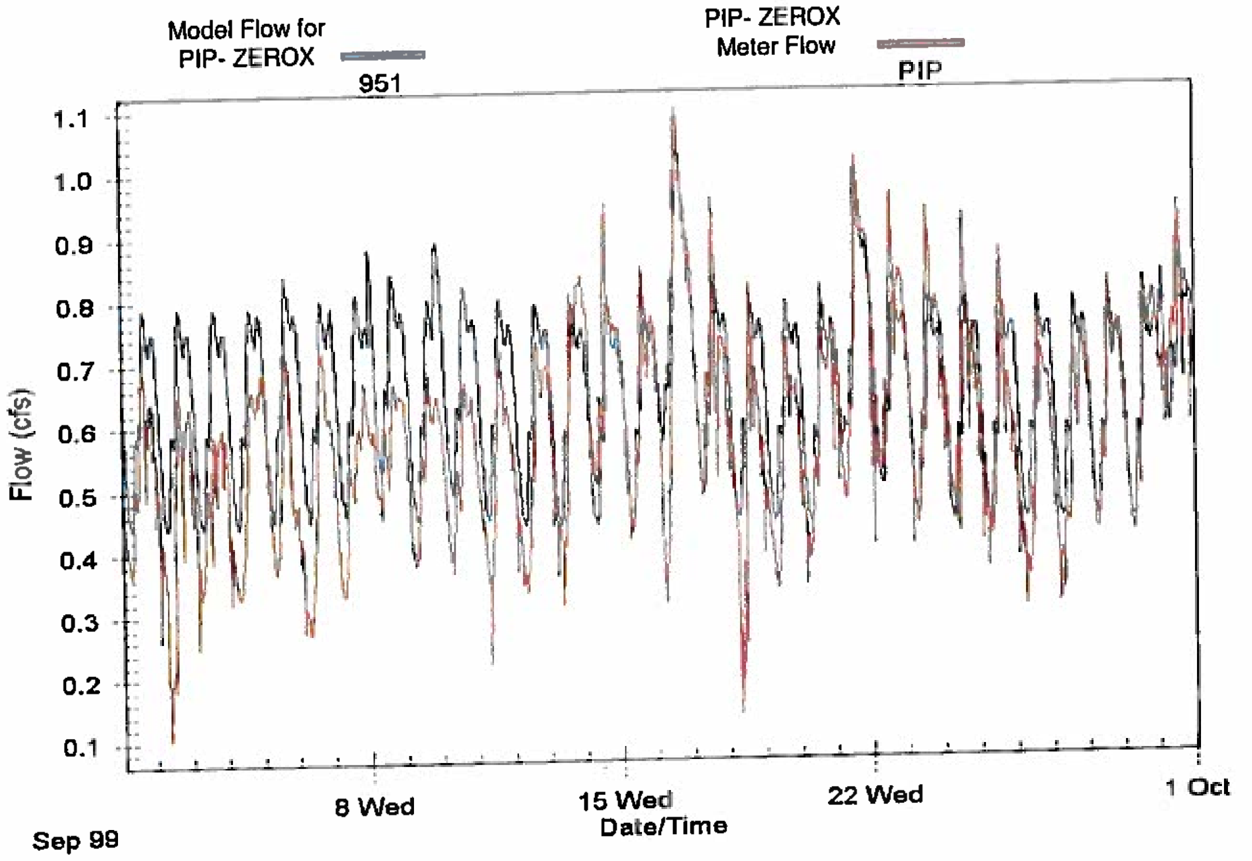


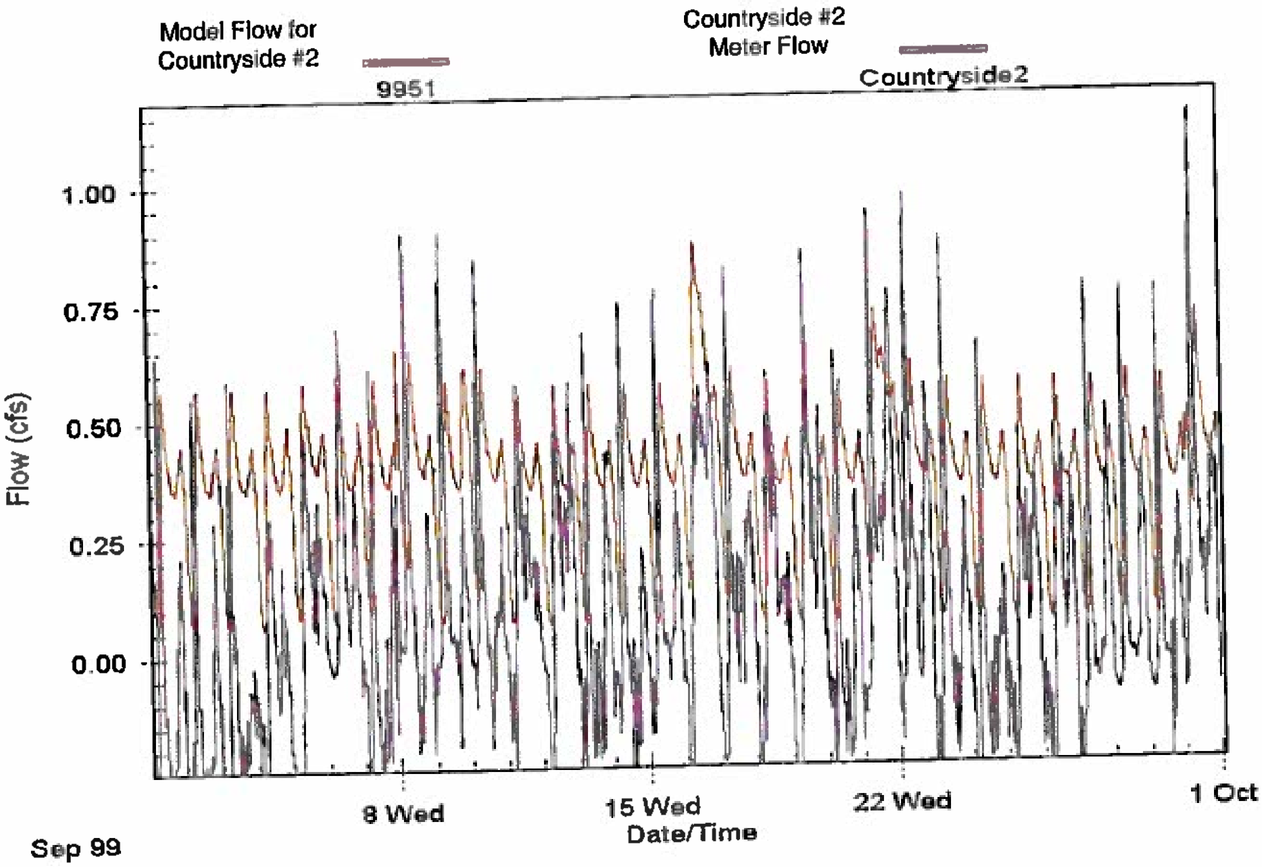
LCSA Calibration Plots



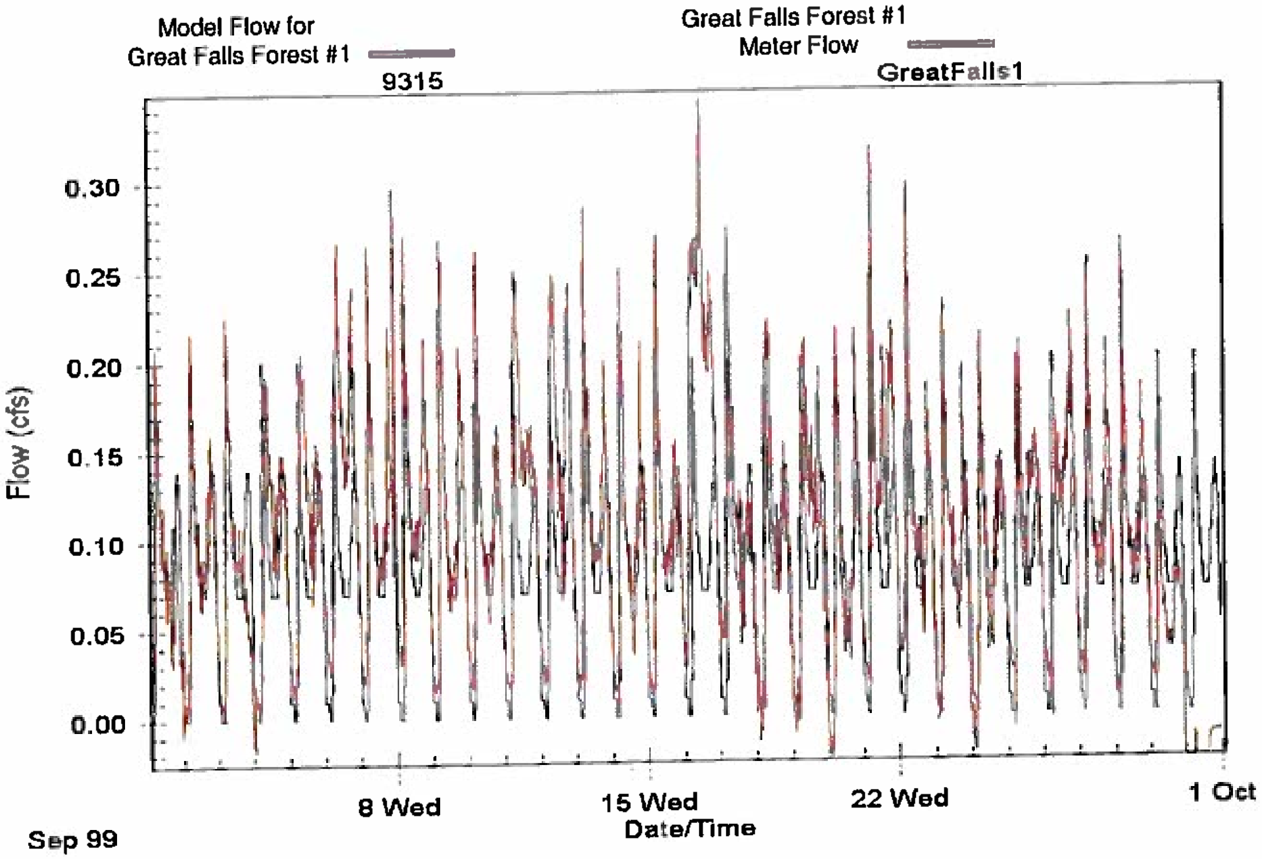


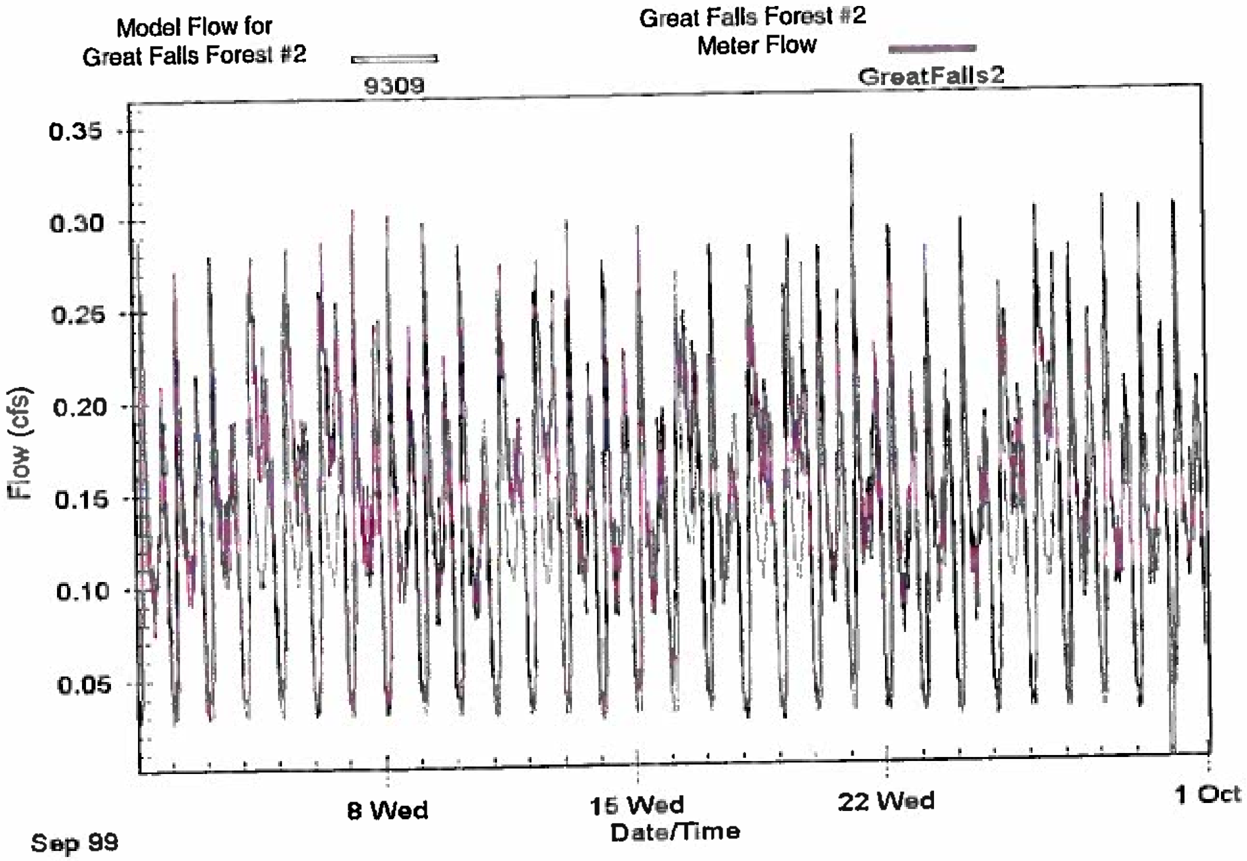
LCSA Calibration Plots



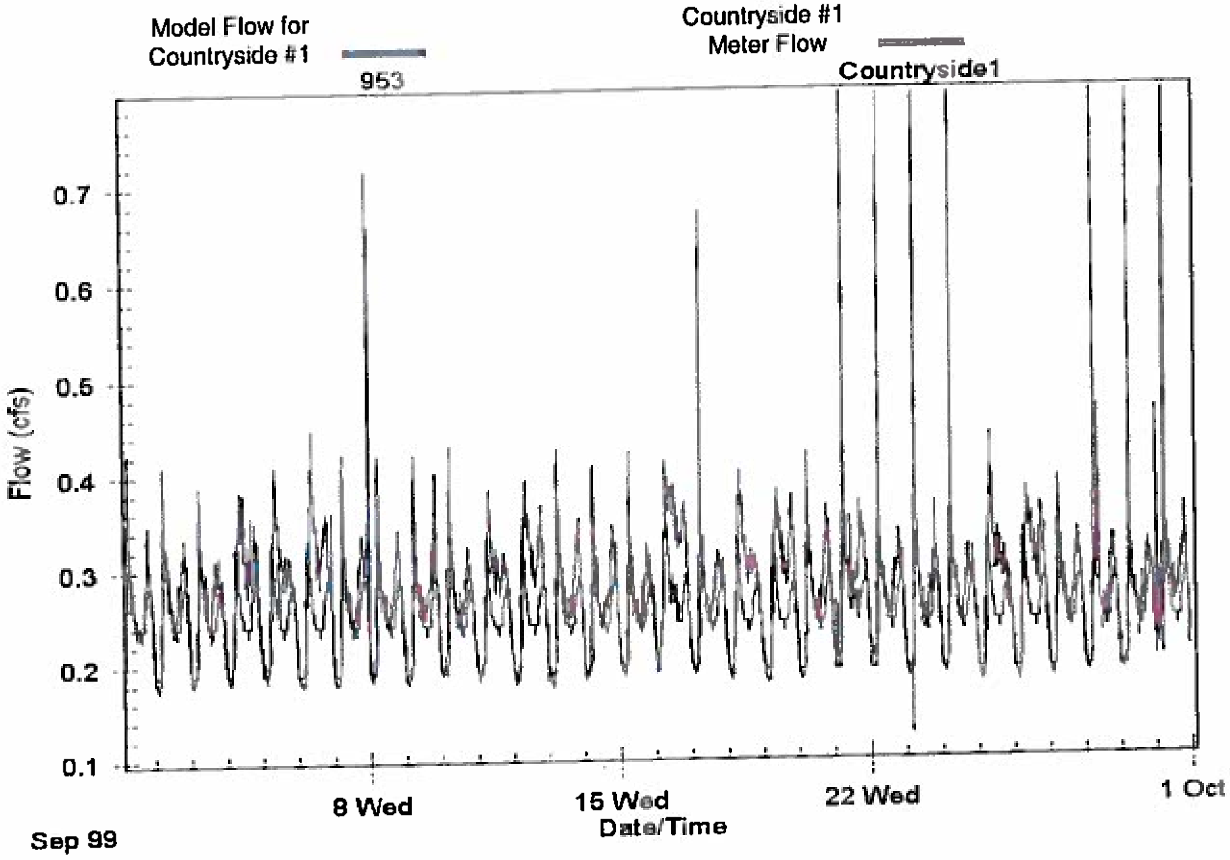


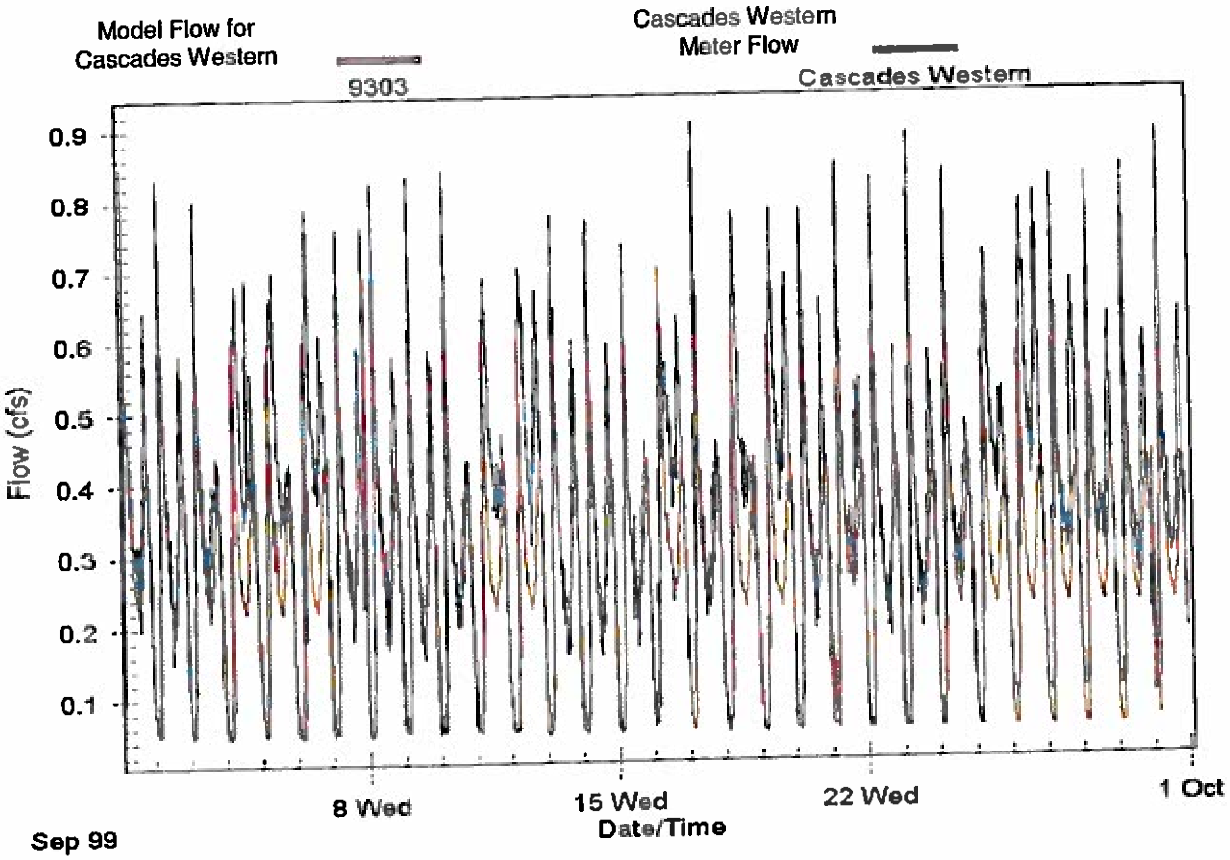
LCSA Calibration Plots



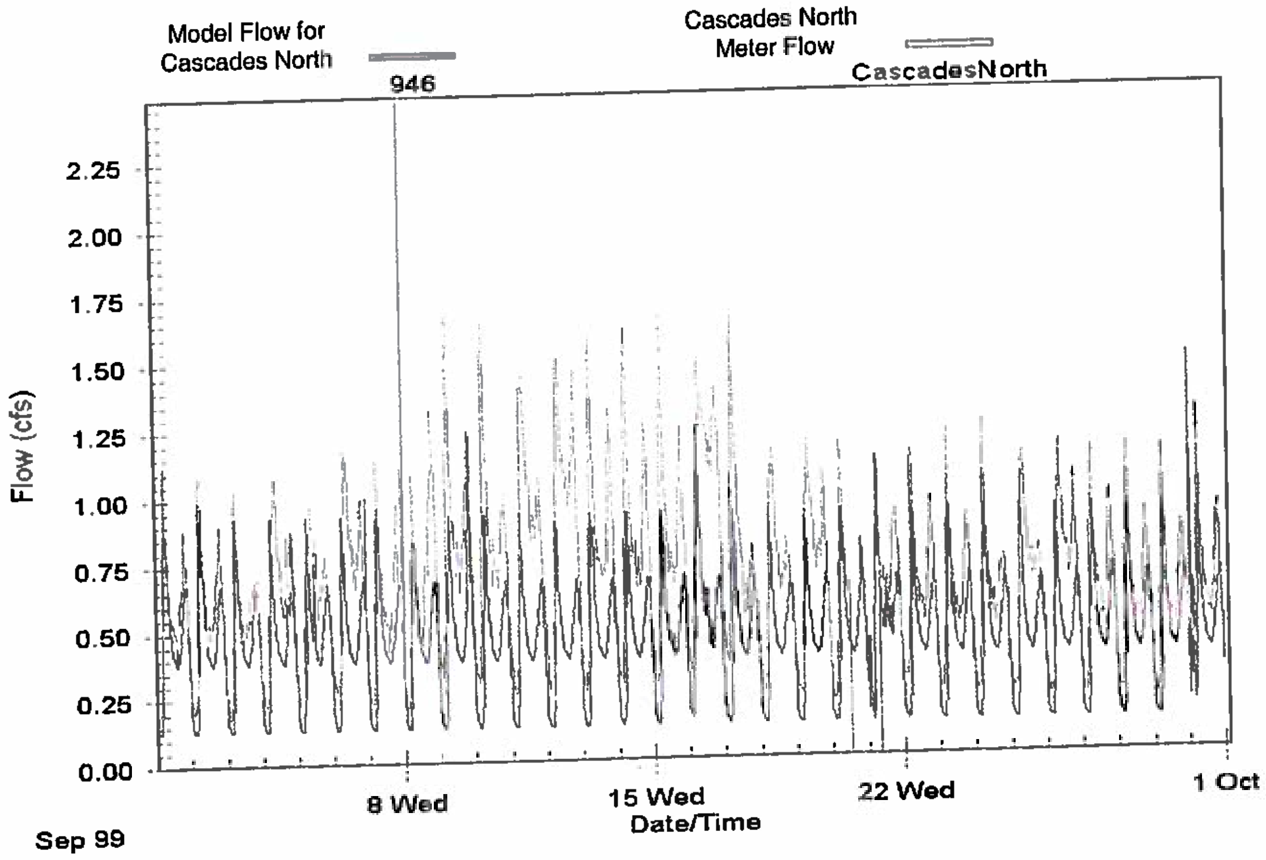


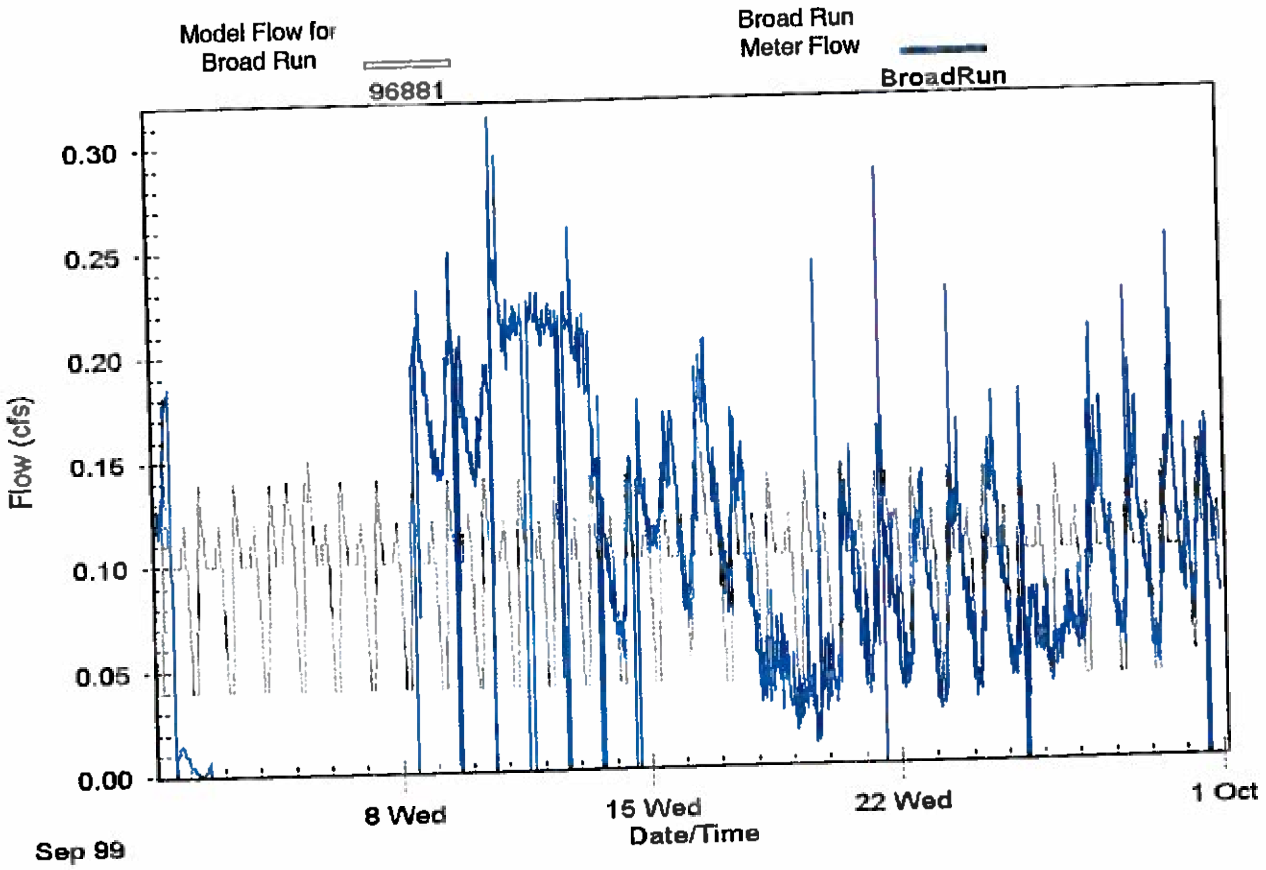
LCSA Calibration Plots



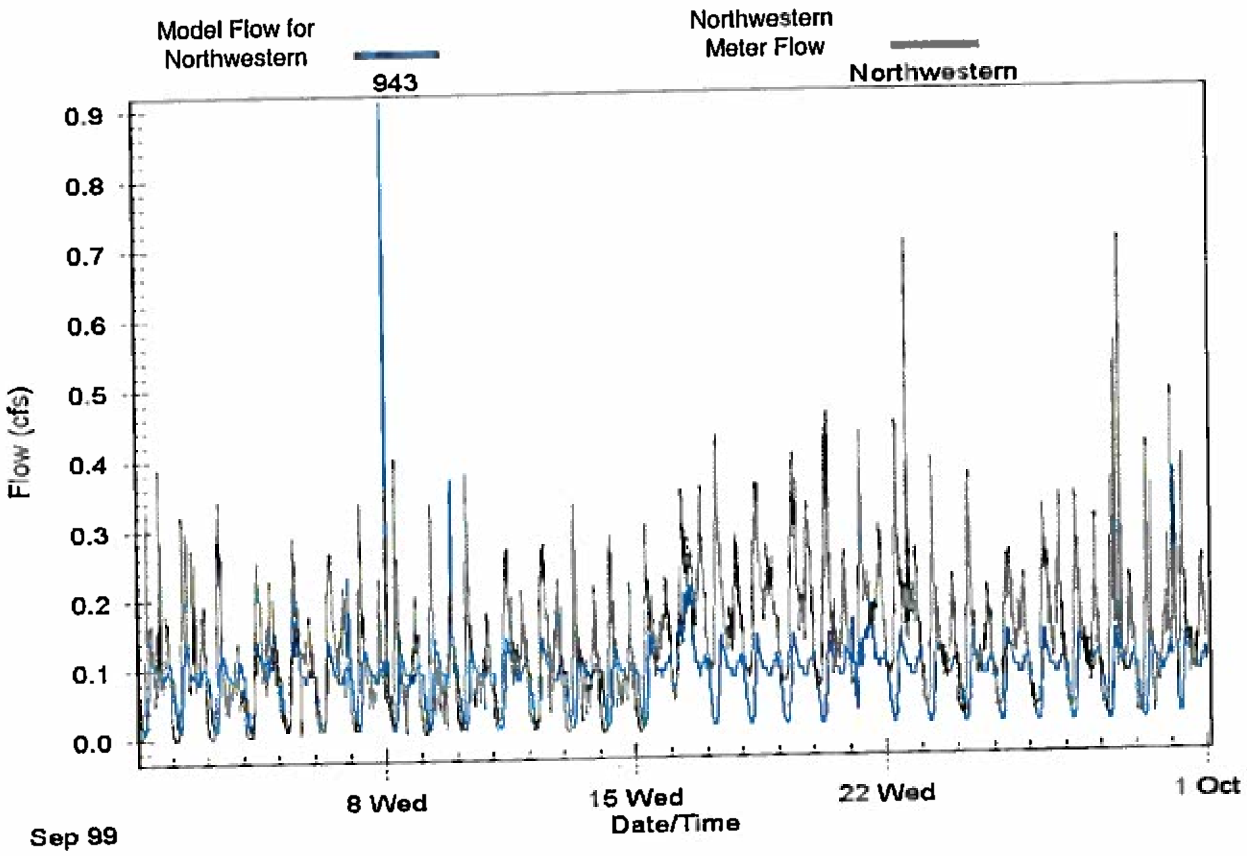


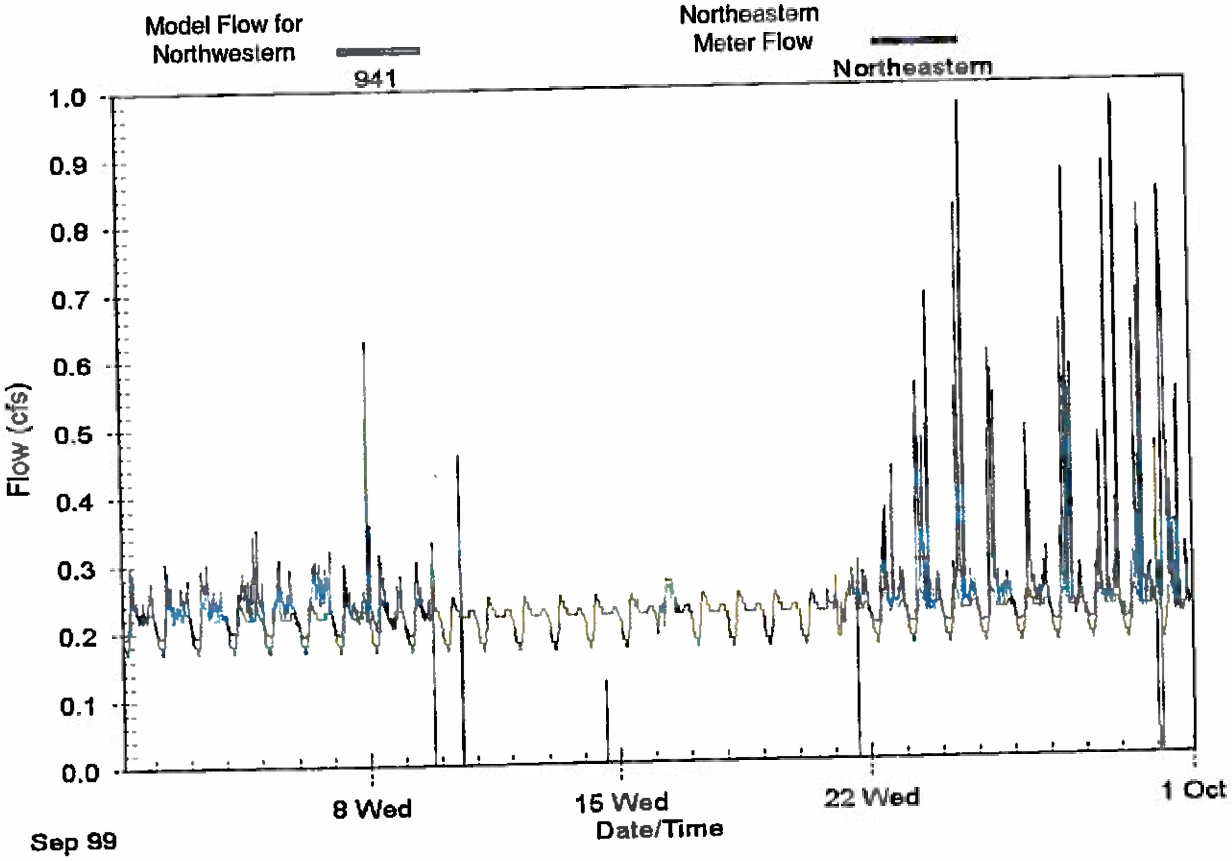
LCSA Calibration Plots



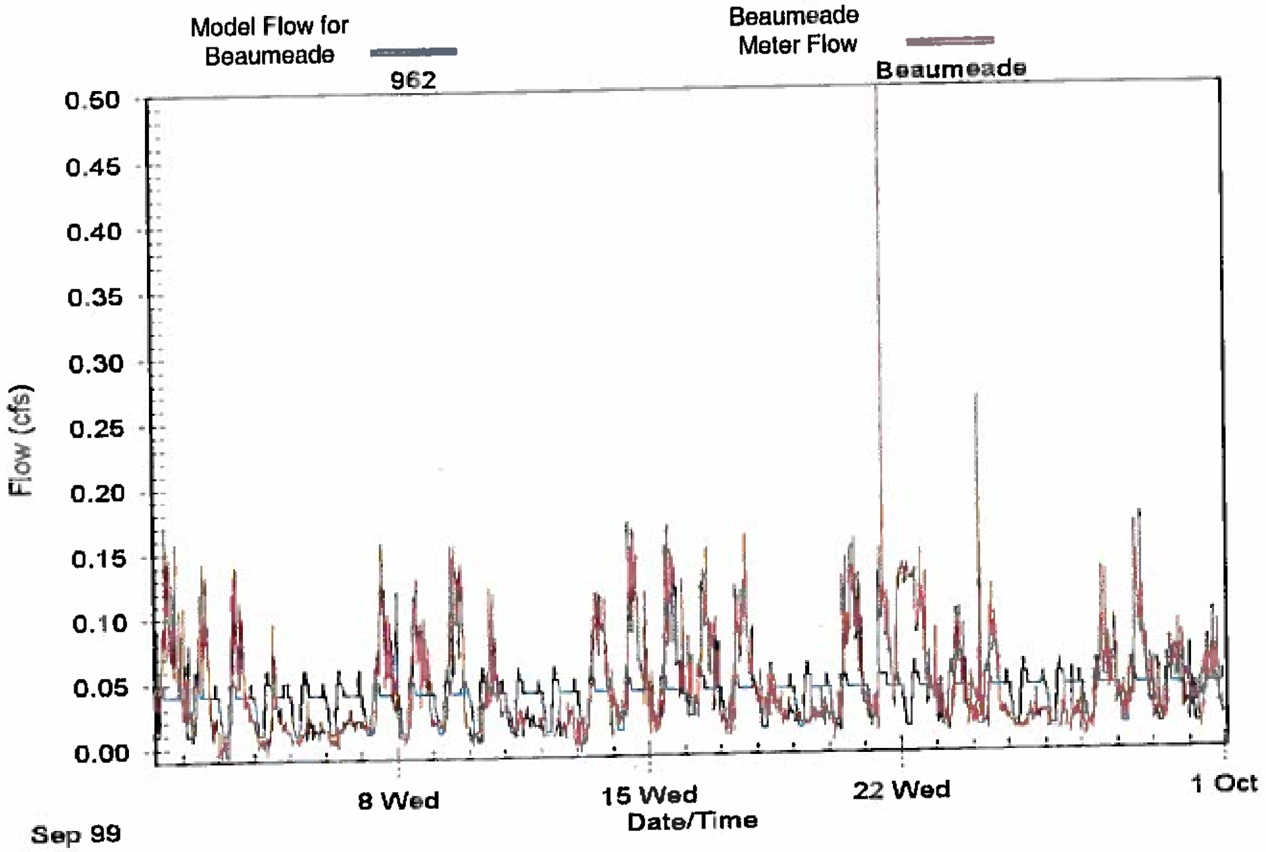


LCSA Calibration Plots

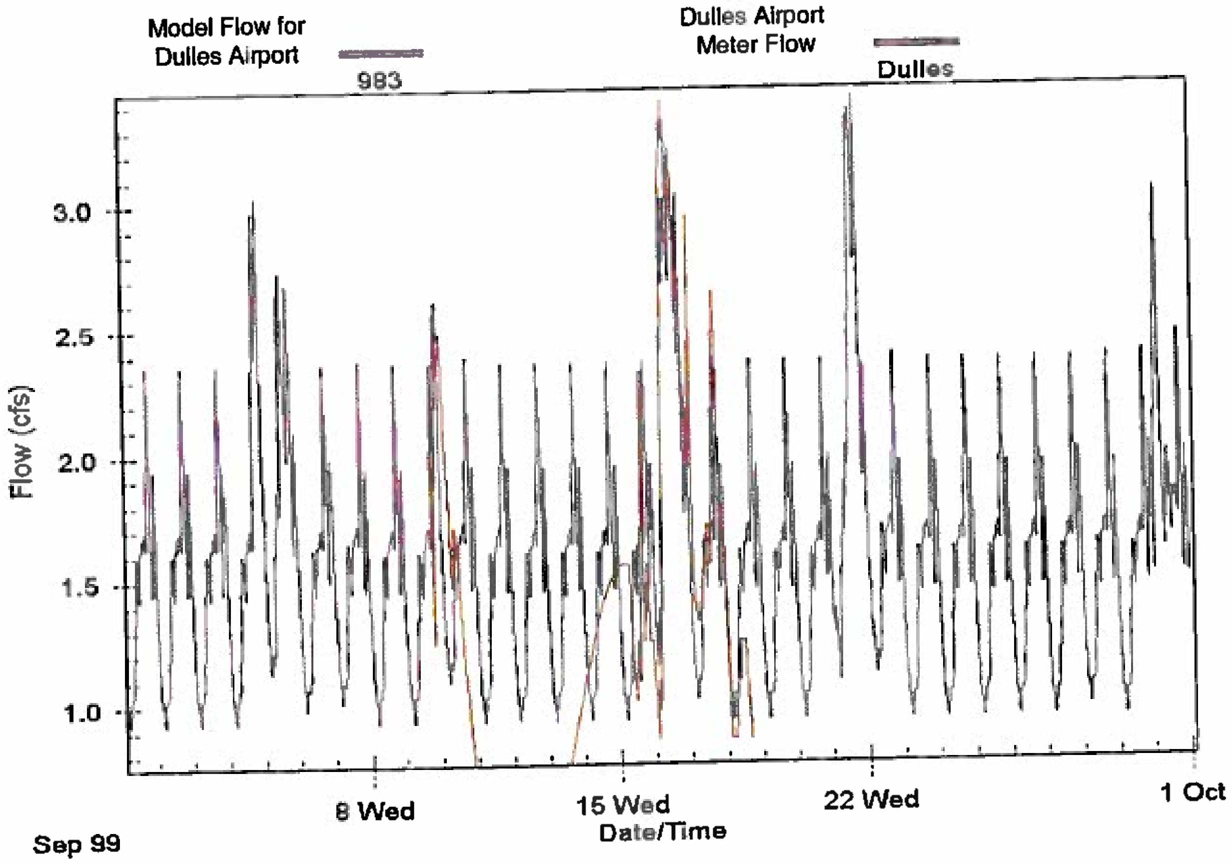




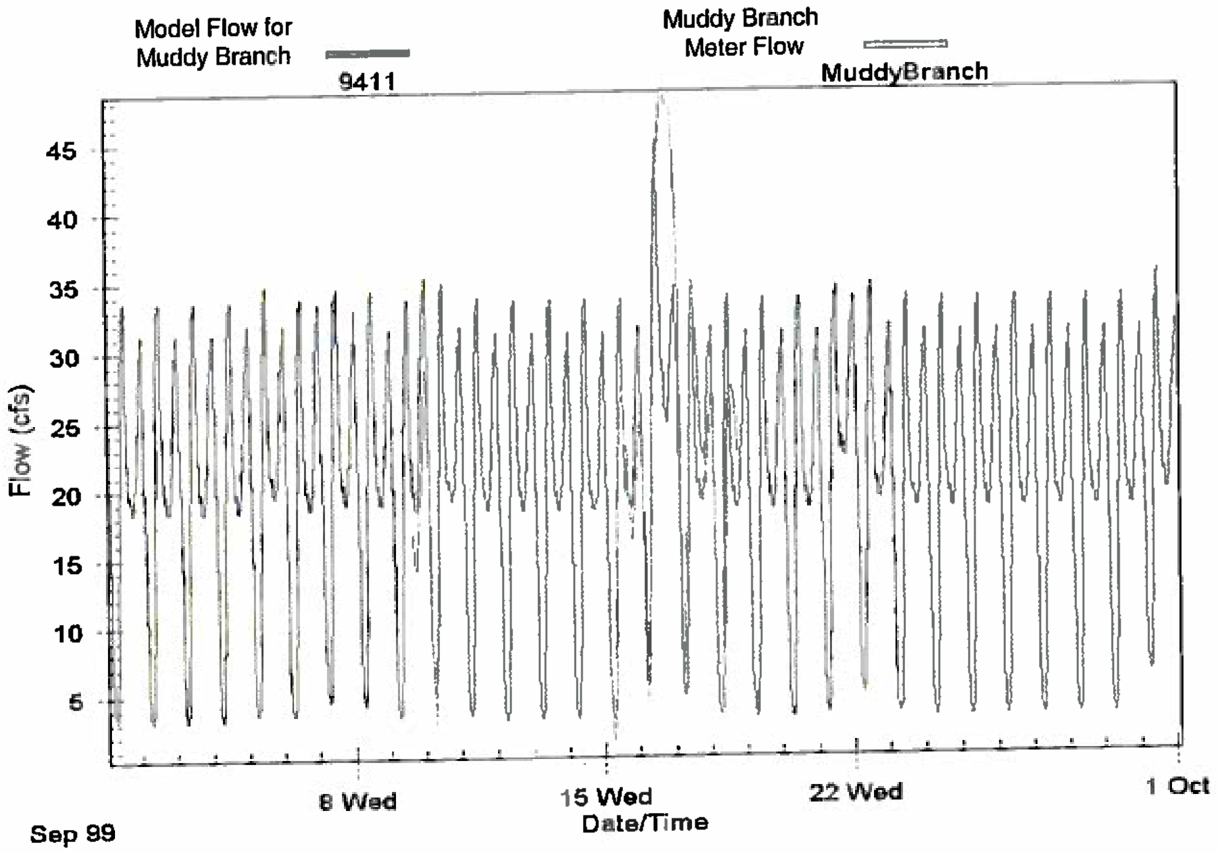
LCSA Calibration Plots

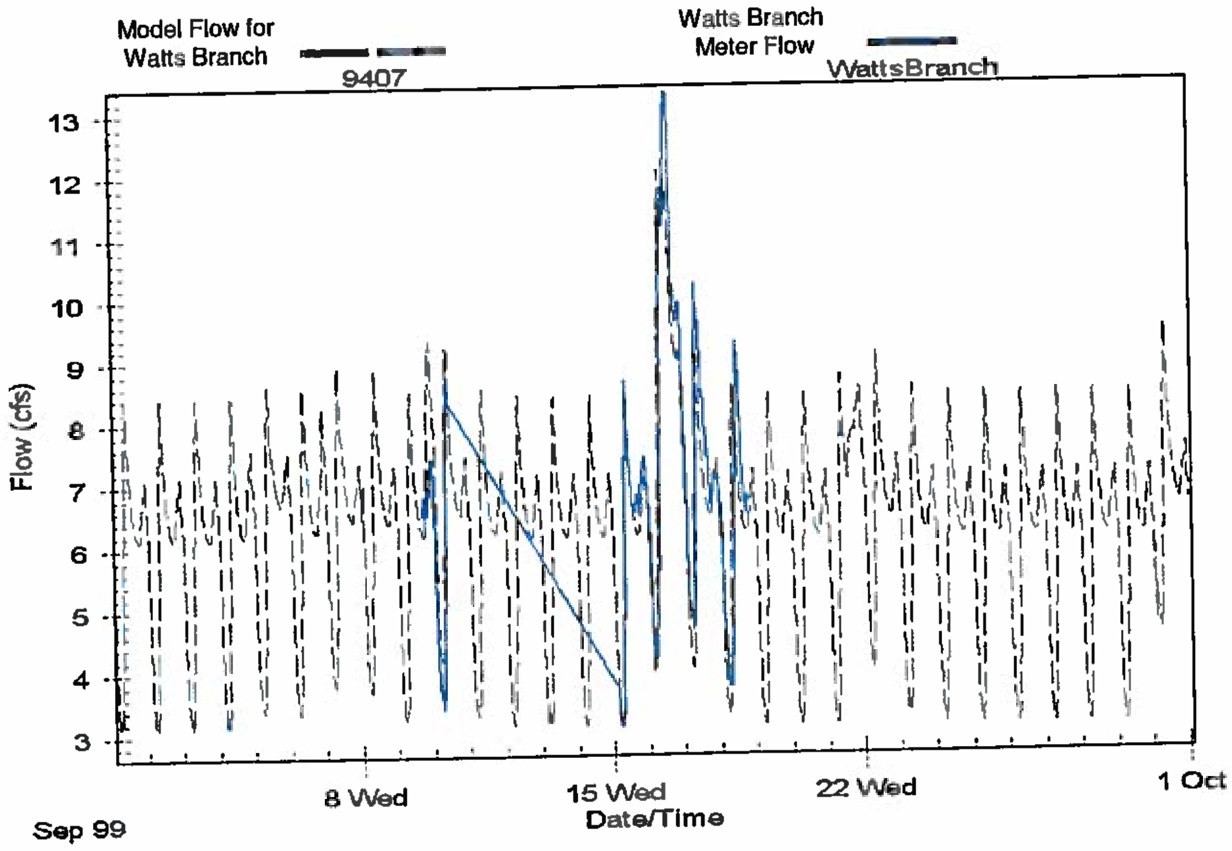


Dulles Airport Calibration Plot

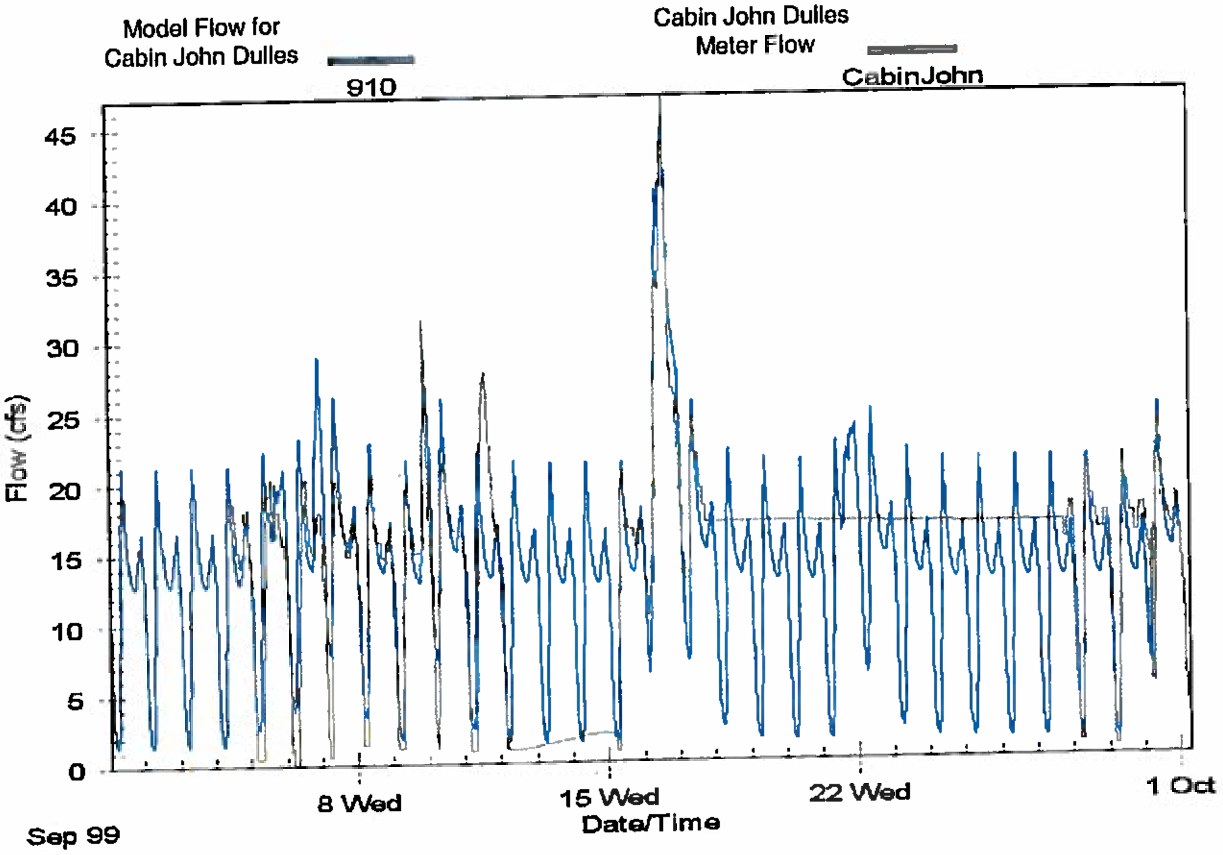


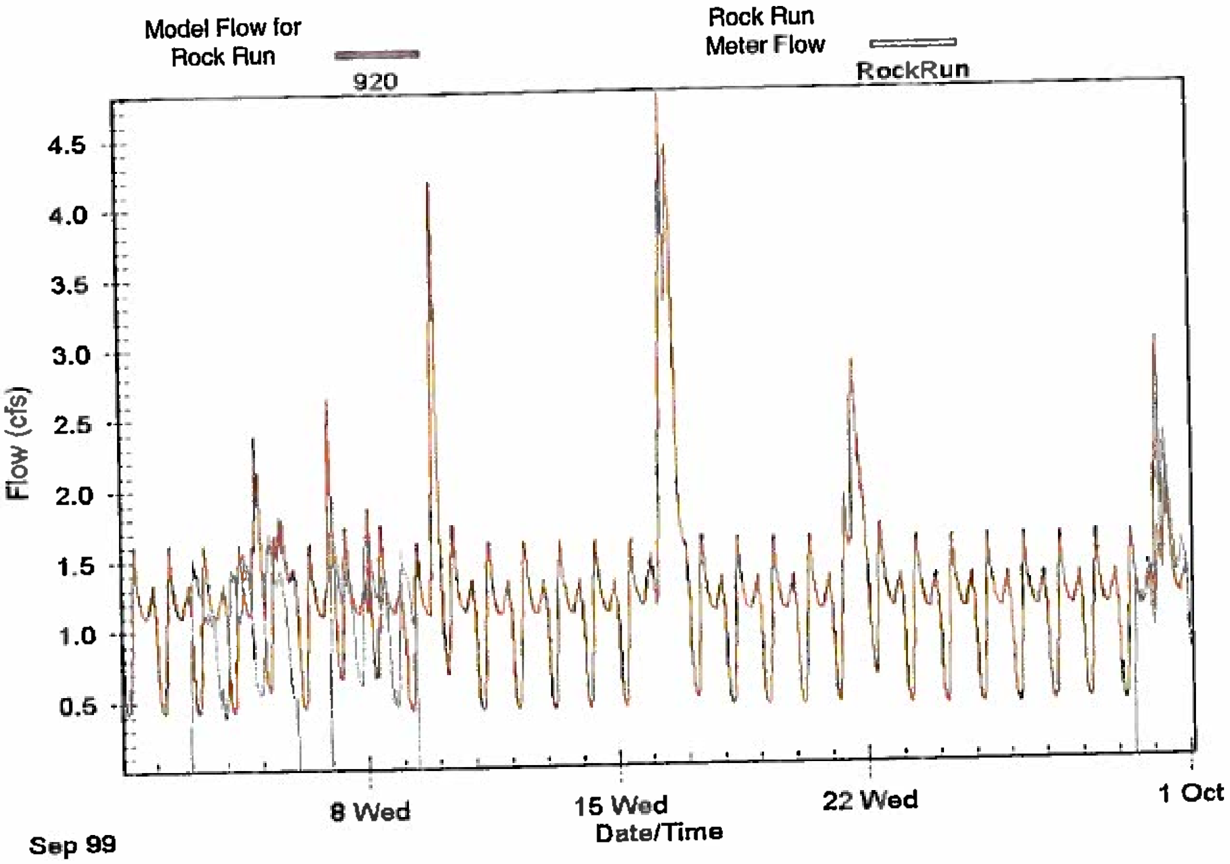
WSSC Calibration Plots





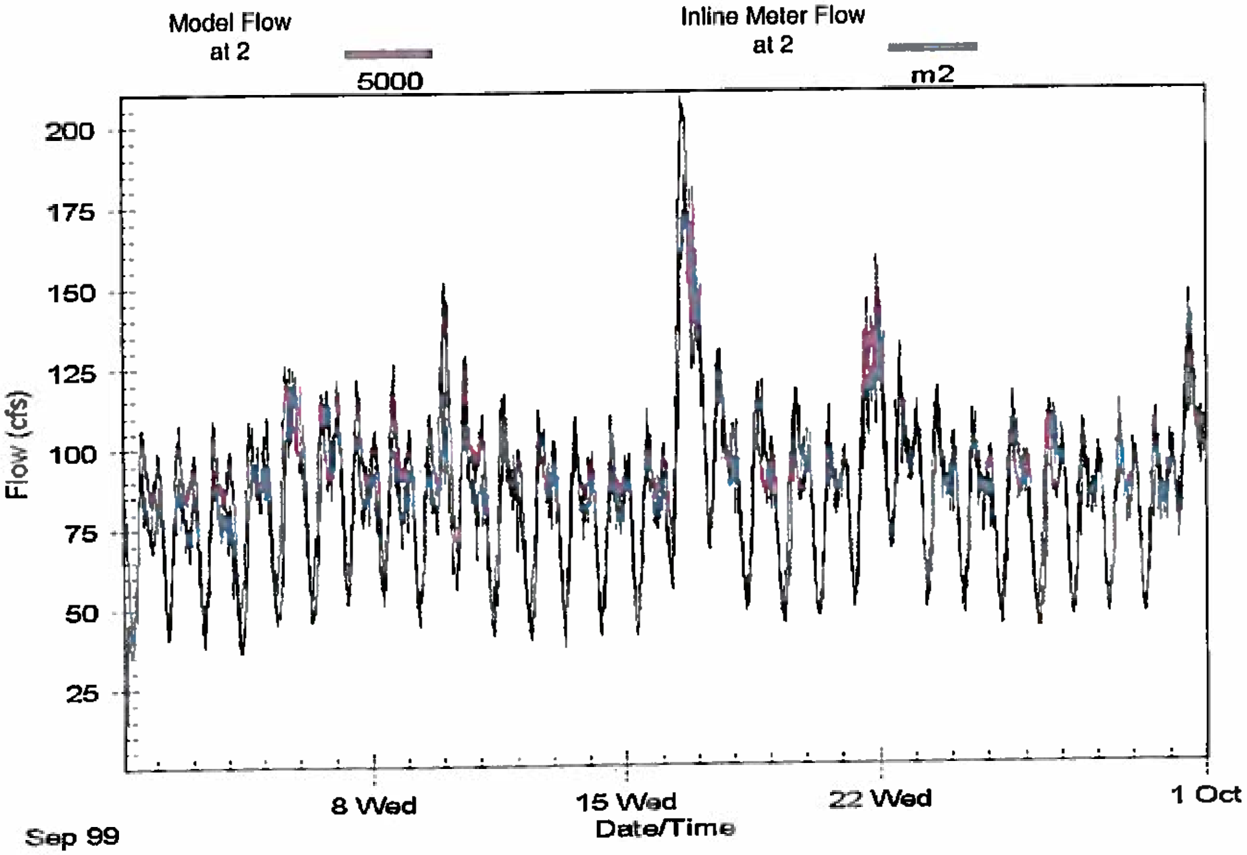
WSSC Calibration Plots



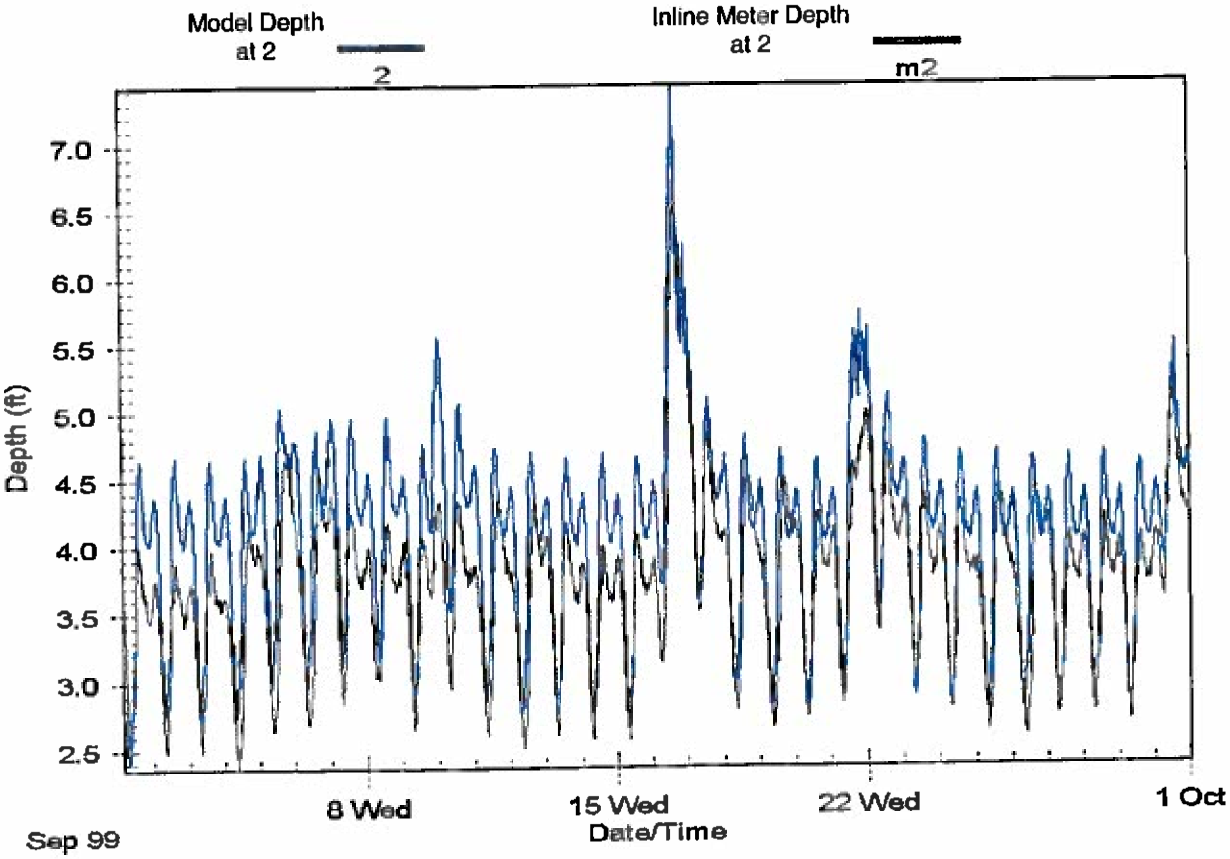


Appendix D-2
In-Line Calibration Plots

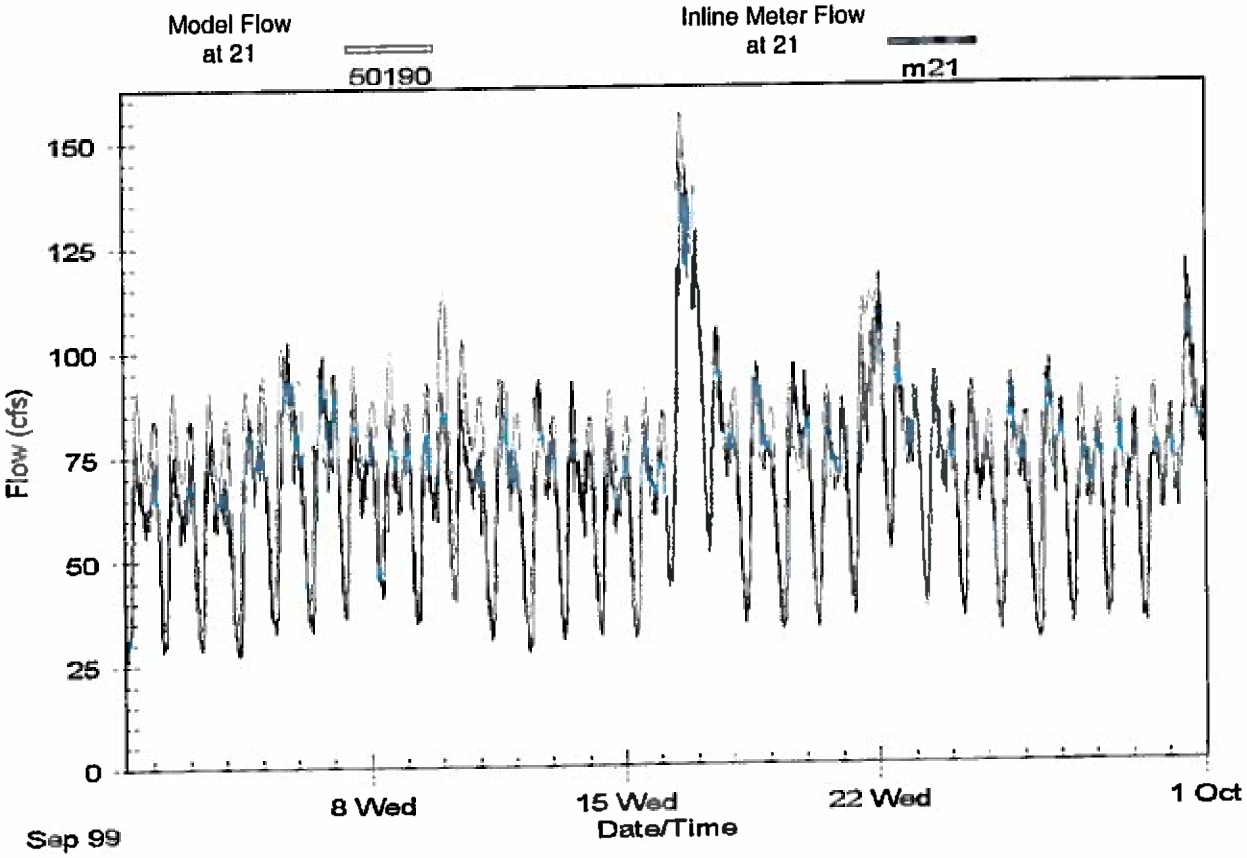
Flow Calibration Plot



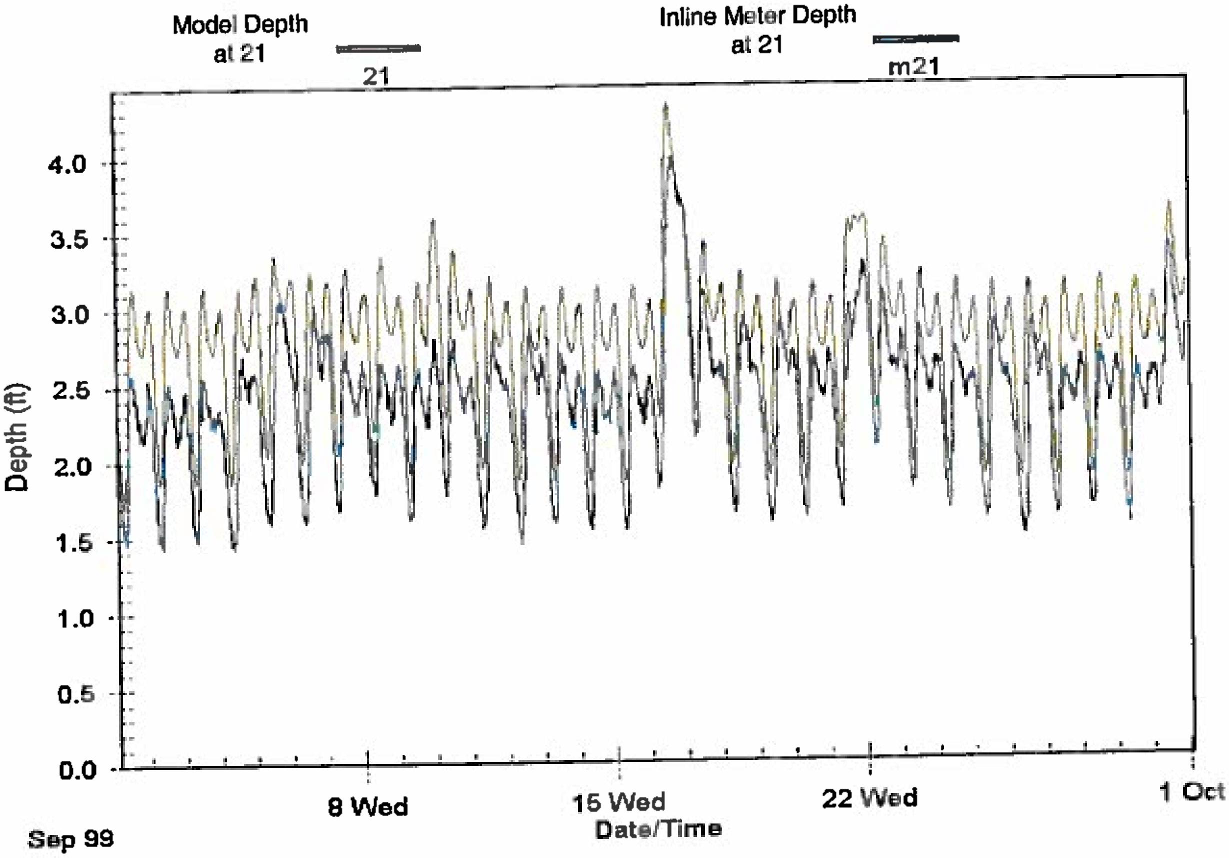
Depth Calibration Plot



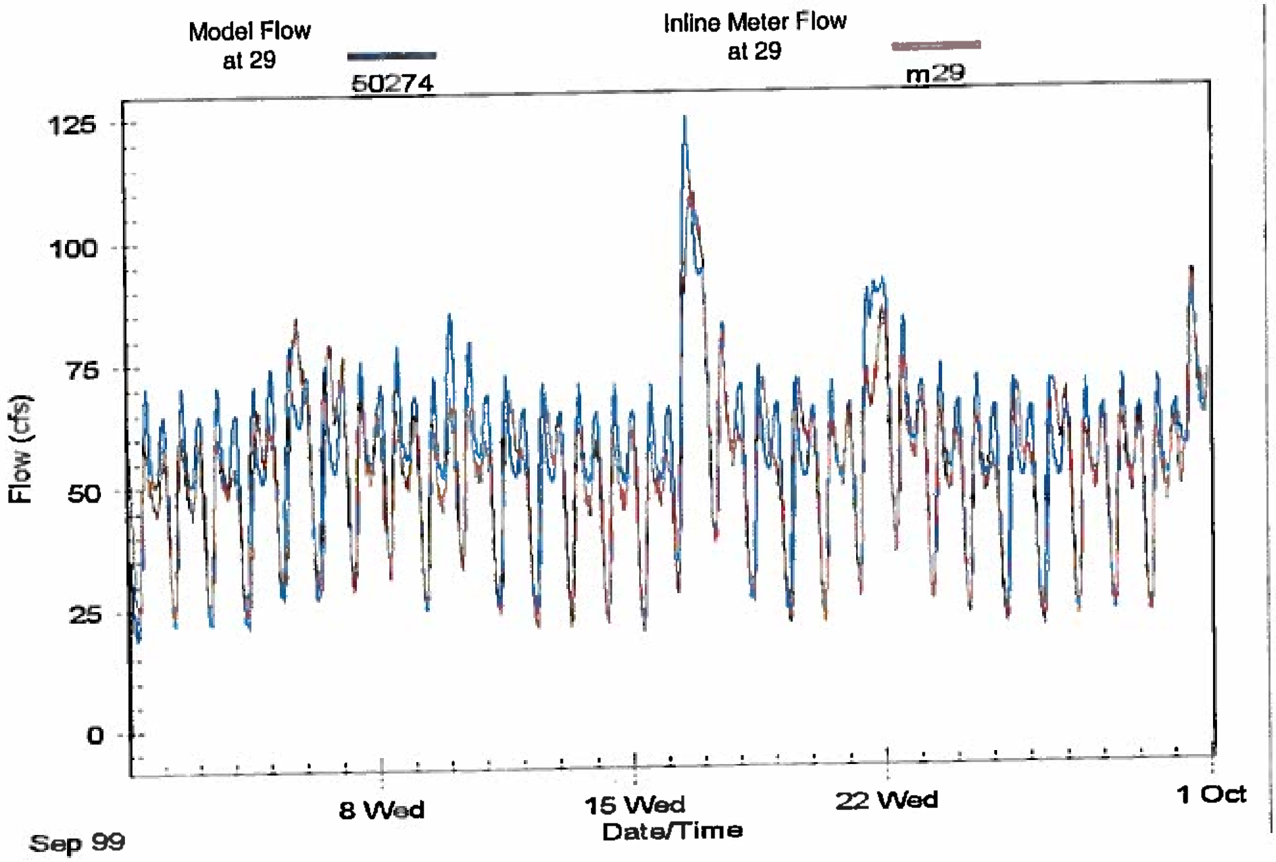
Flow Calibration Plot



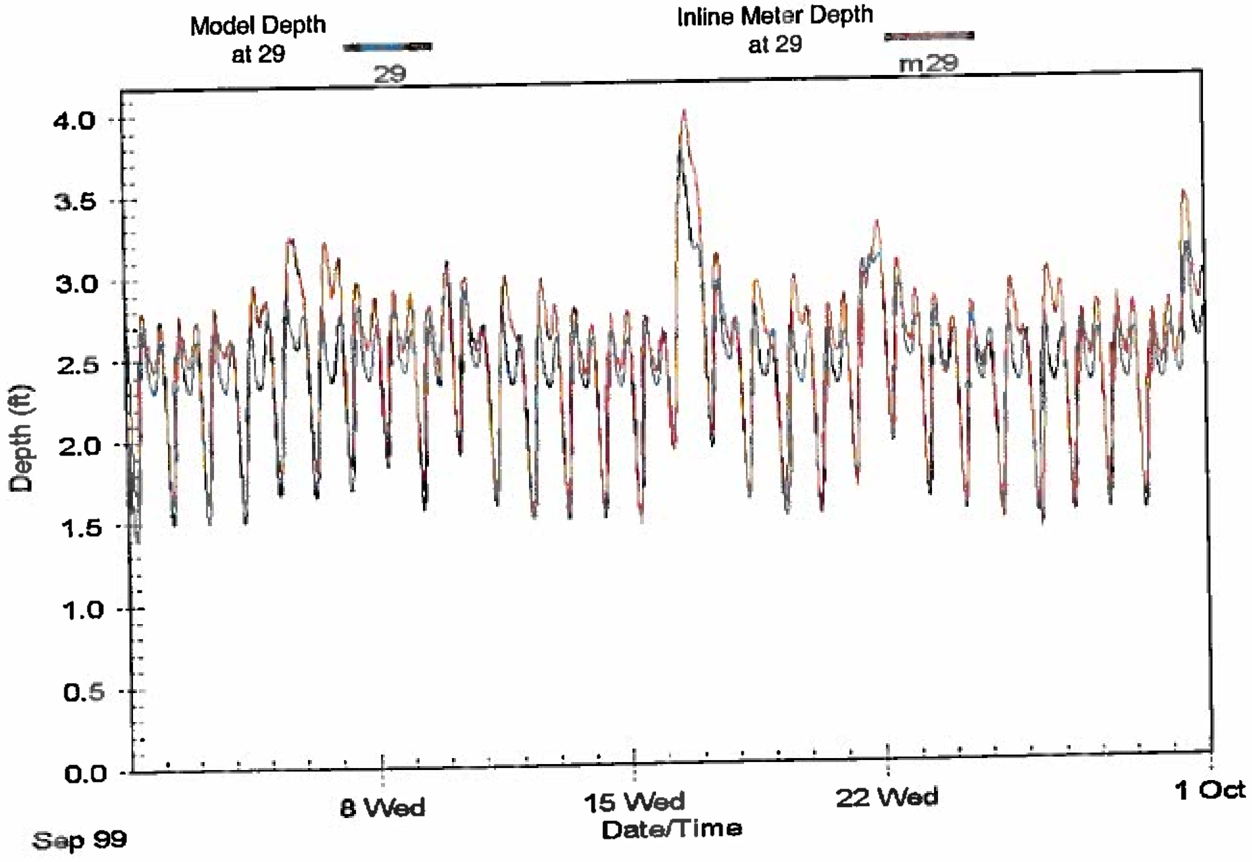
Depth Calibration Plot



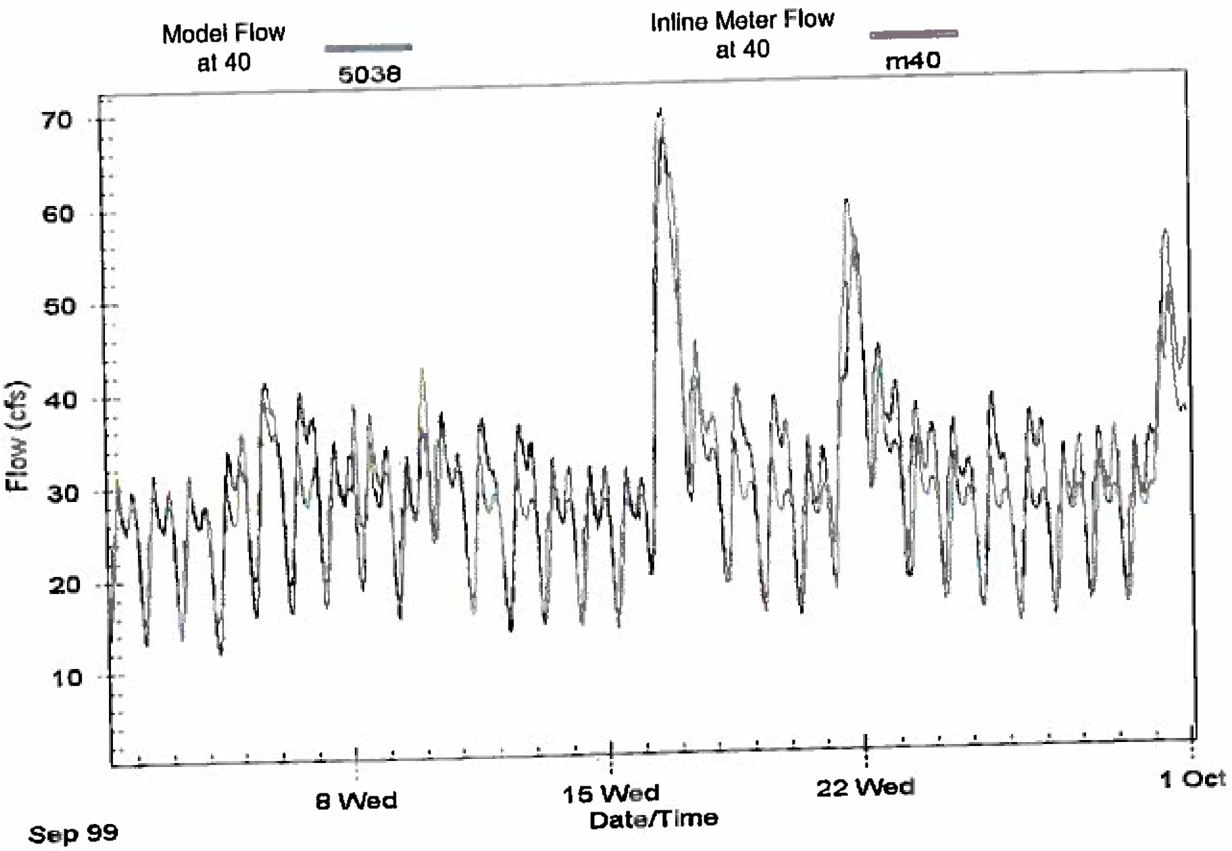
Flow Calibration Plot



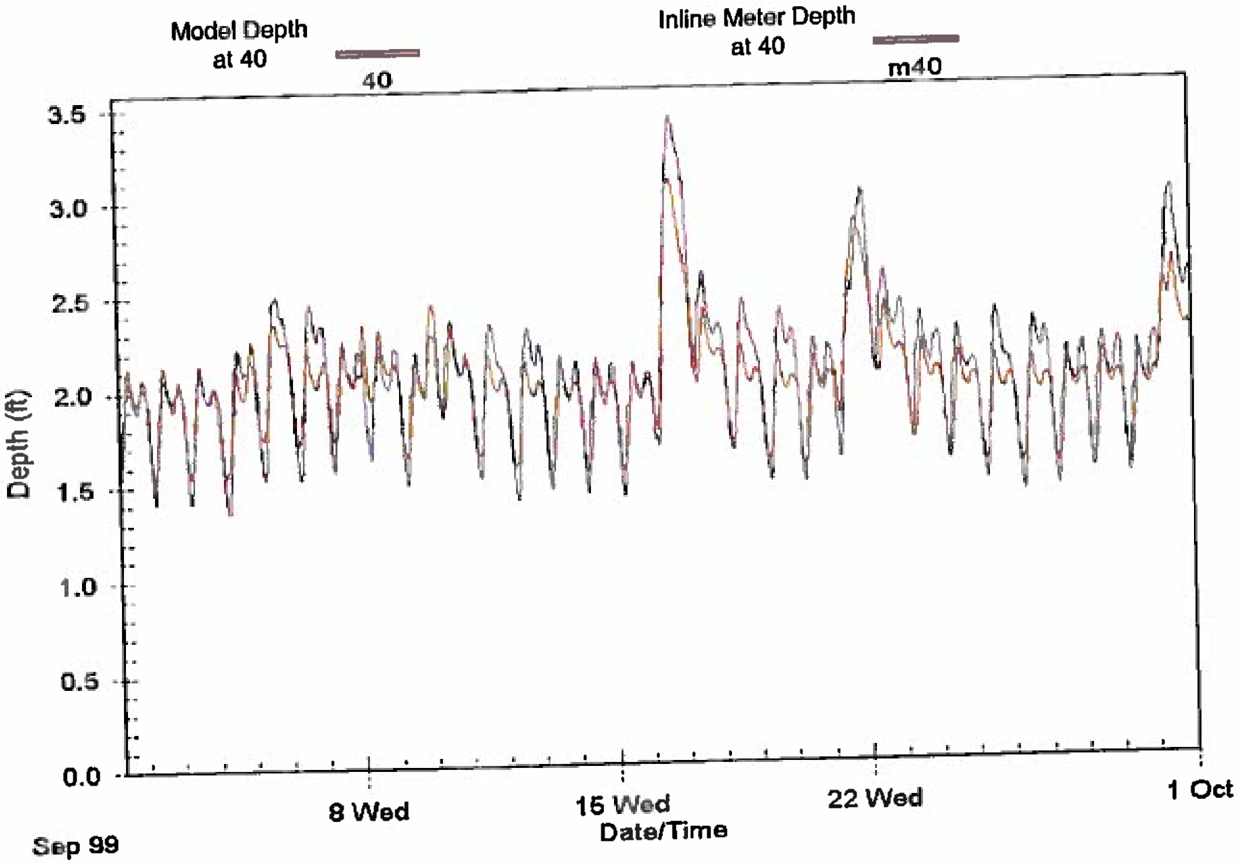
Depth Calibration Plot



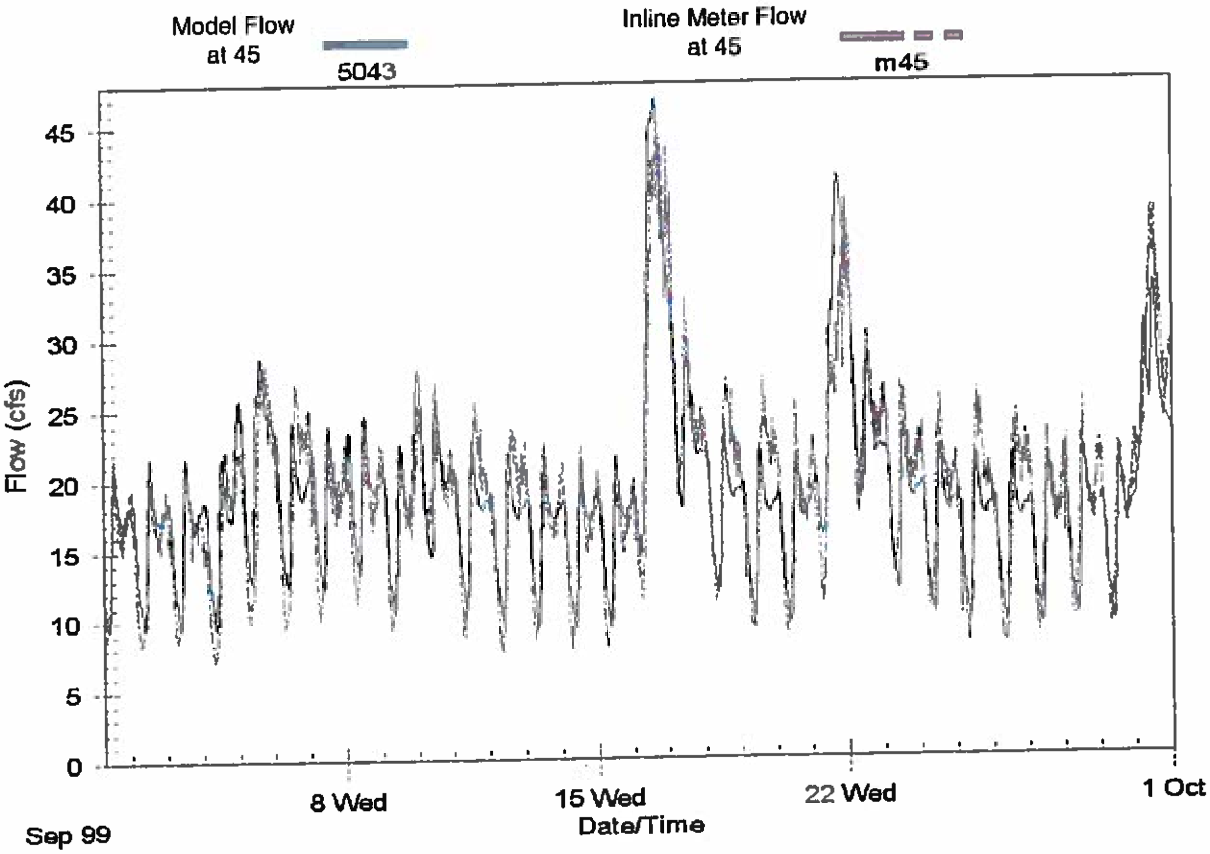
Flow Calibration Plot



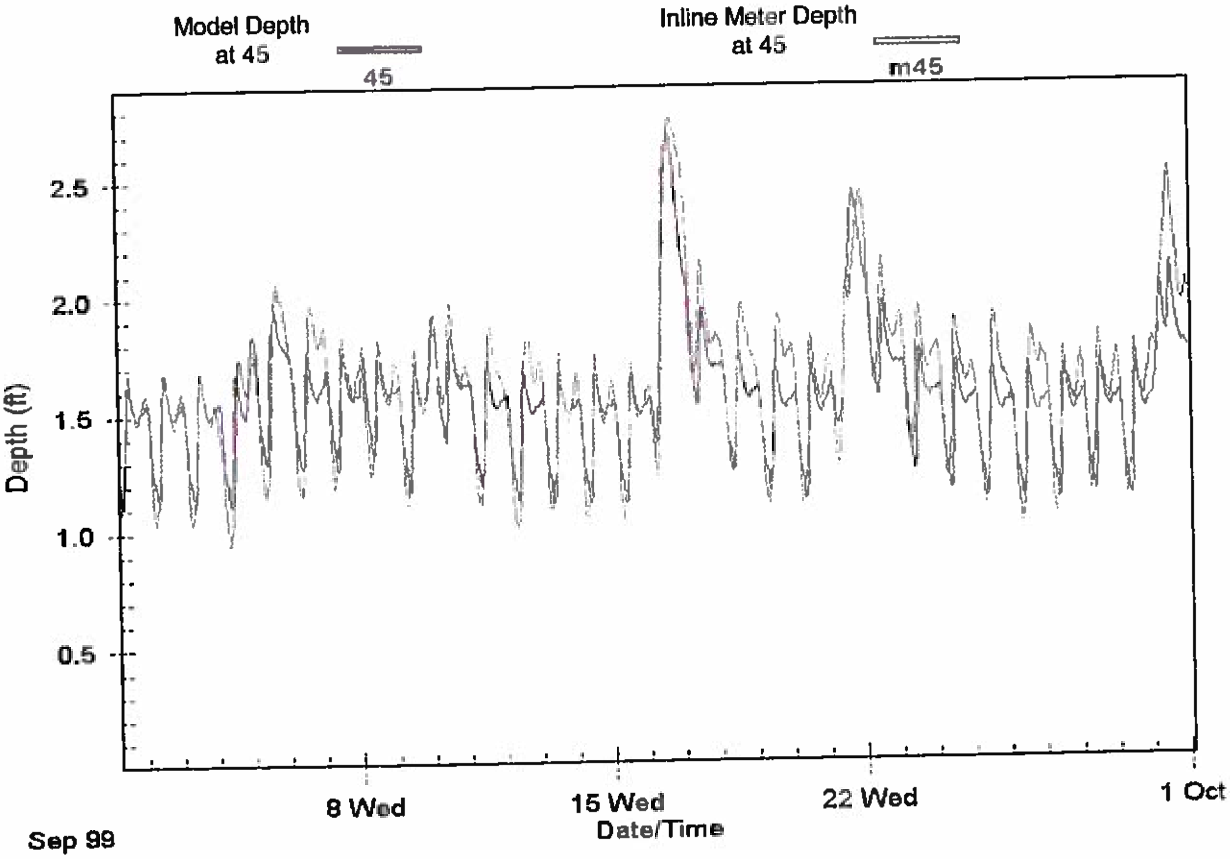
Depth Calibration Plot



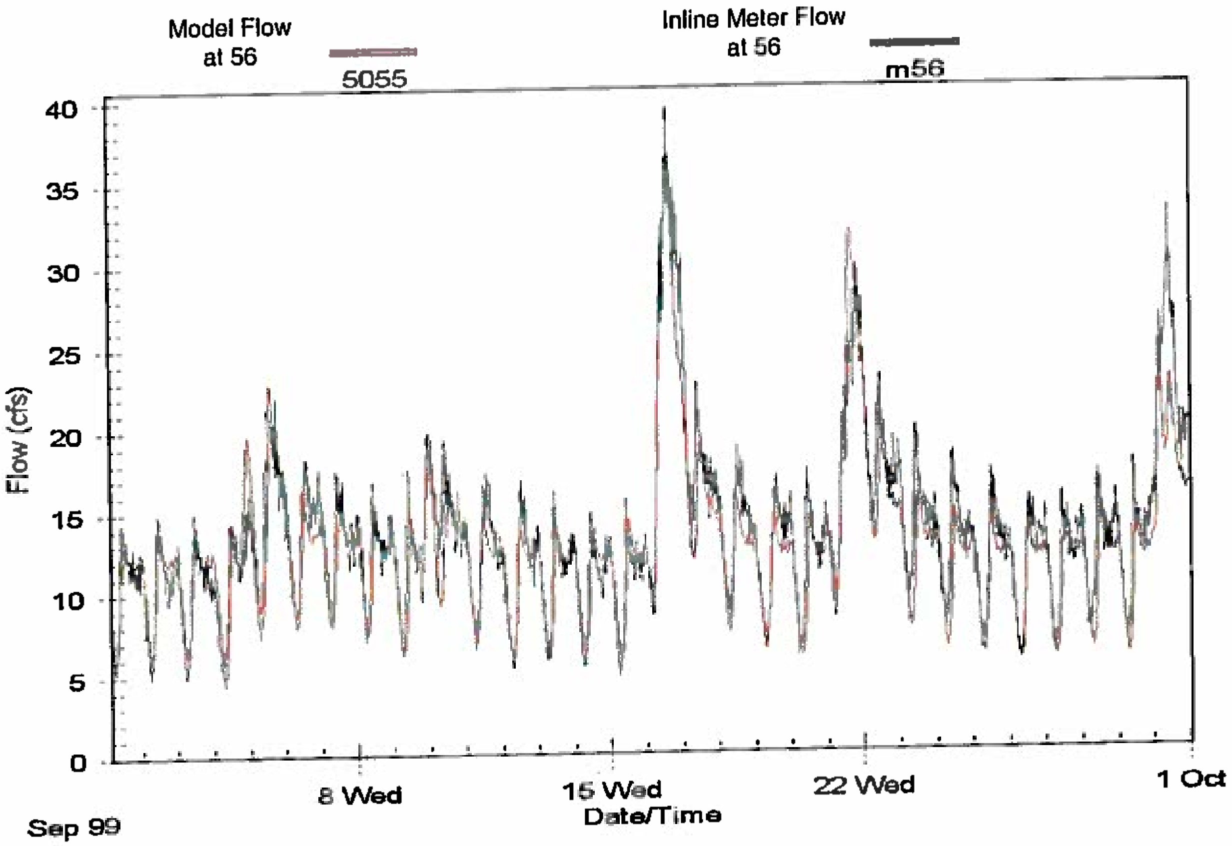
Flow Calibration Plot



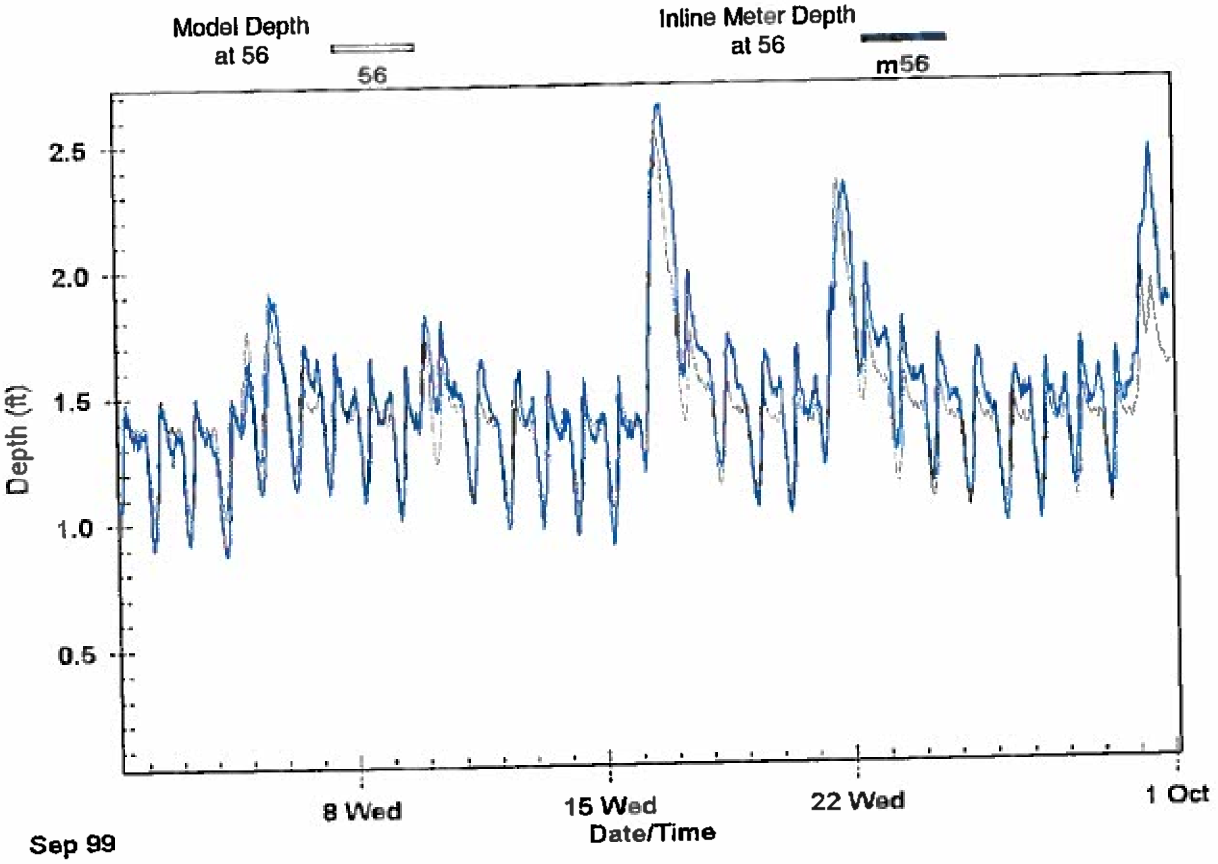
Depth Calibration Plot



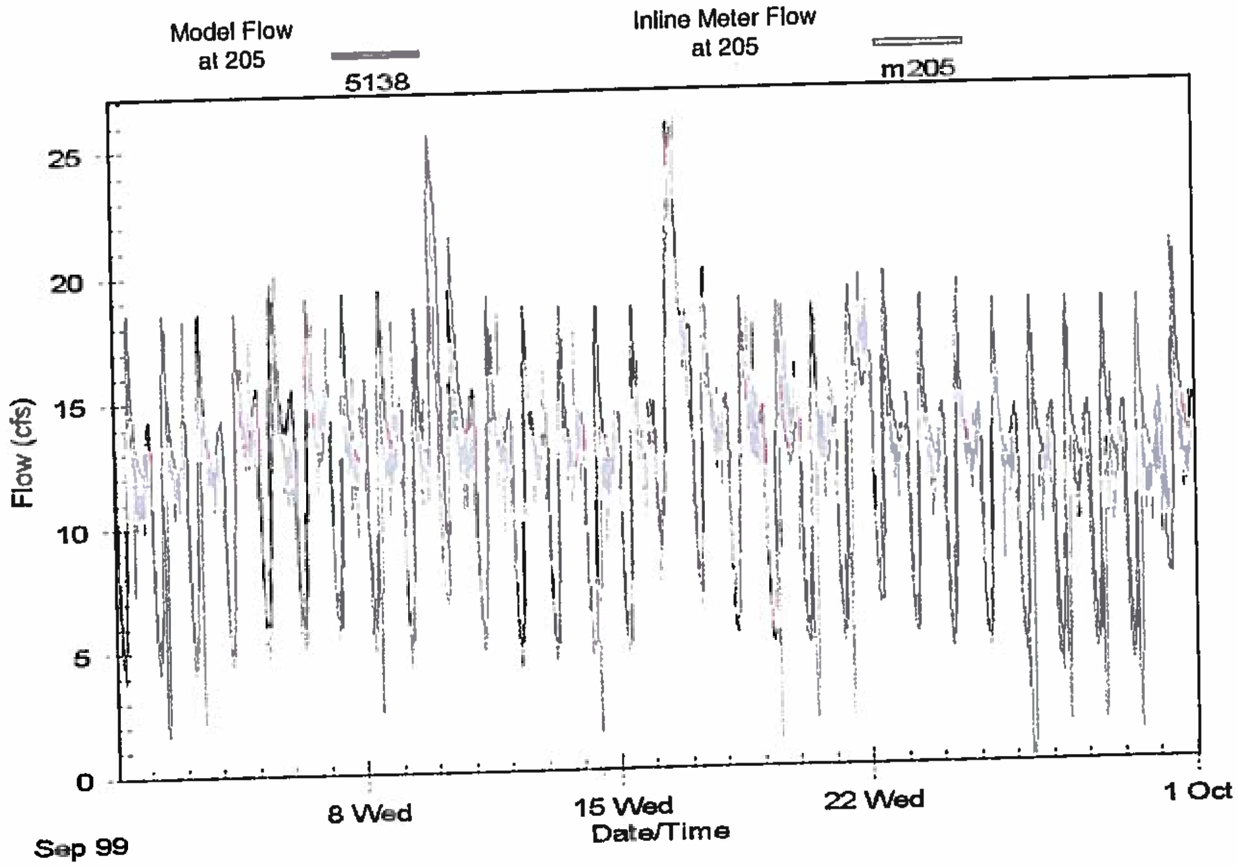
Flow Calibration Plot



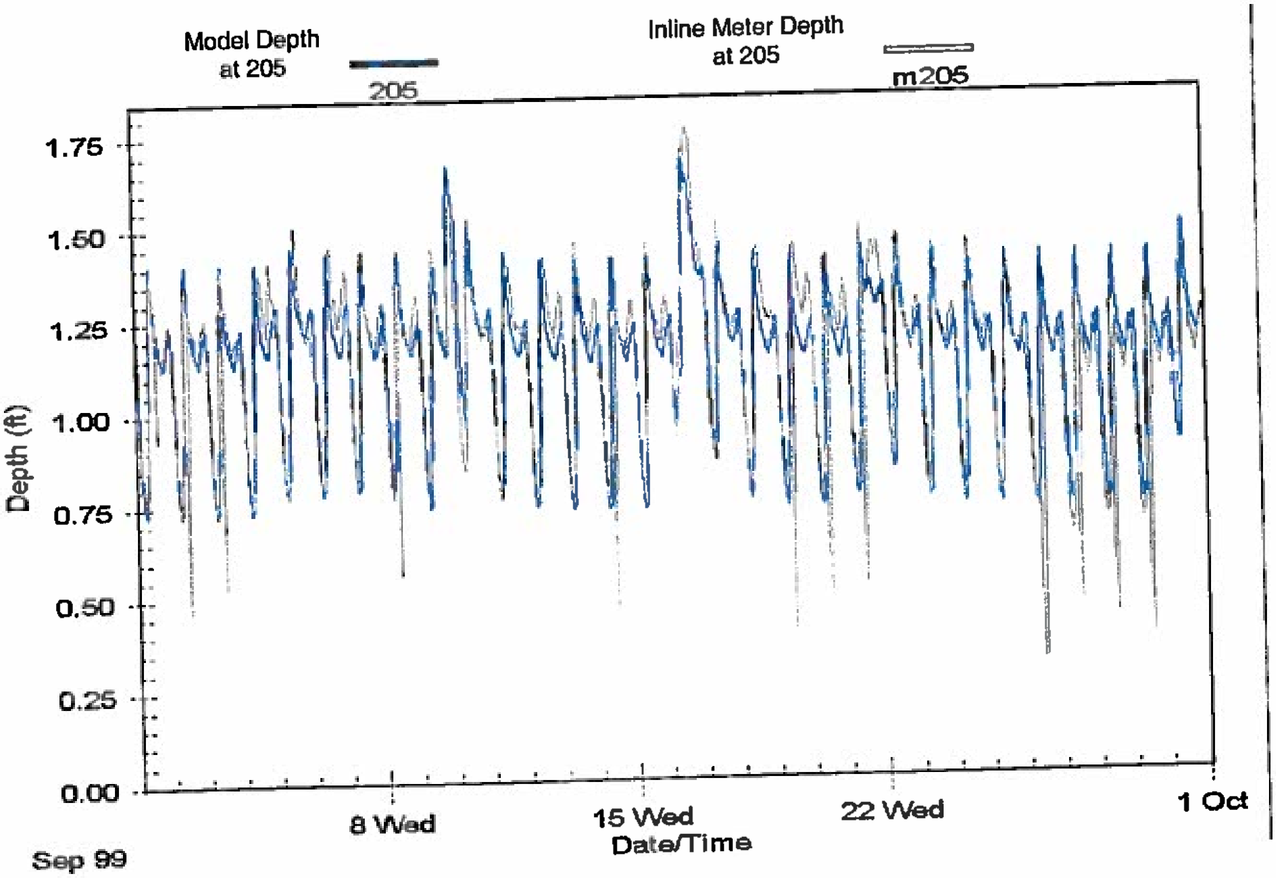
Depth Calibration Plot



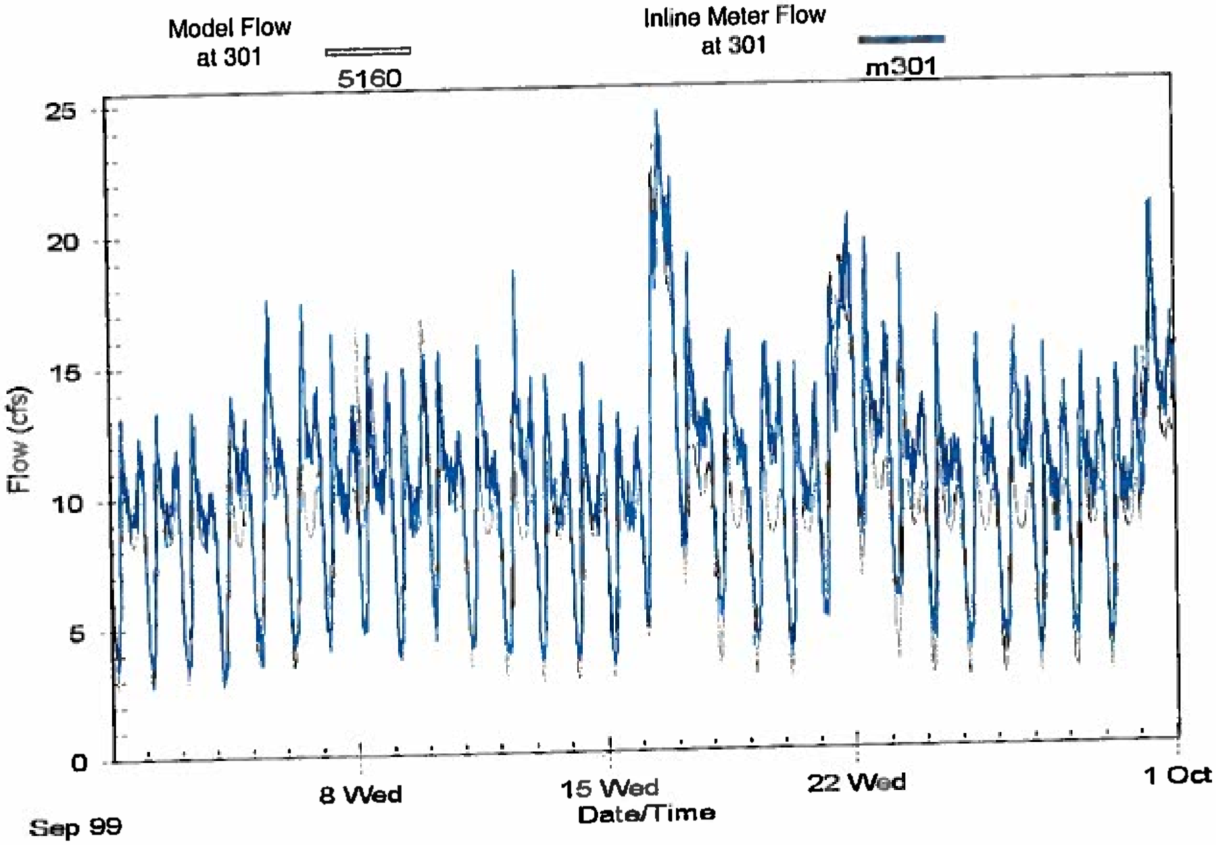
Flow Calibration Plot



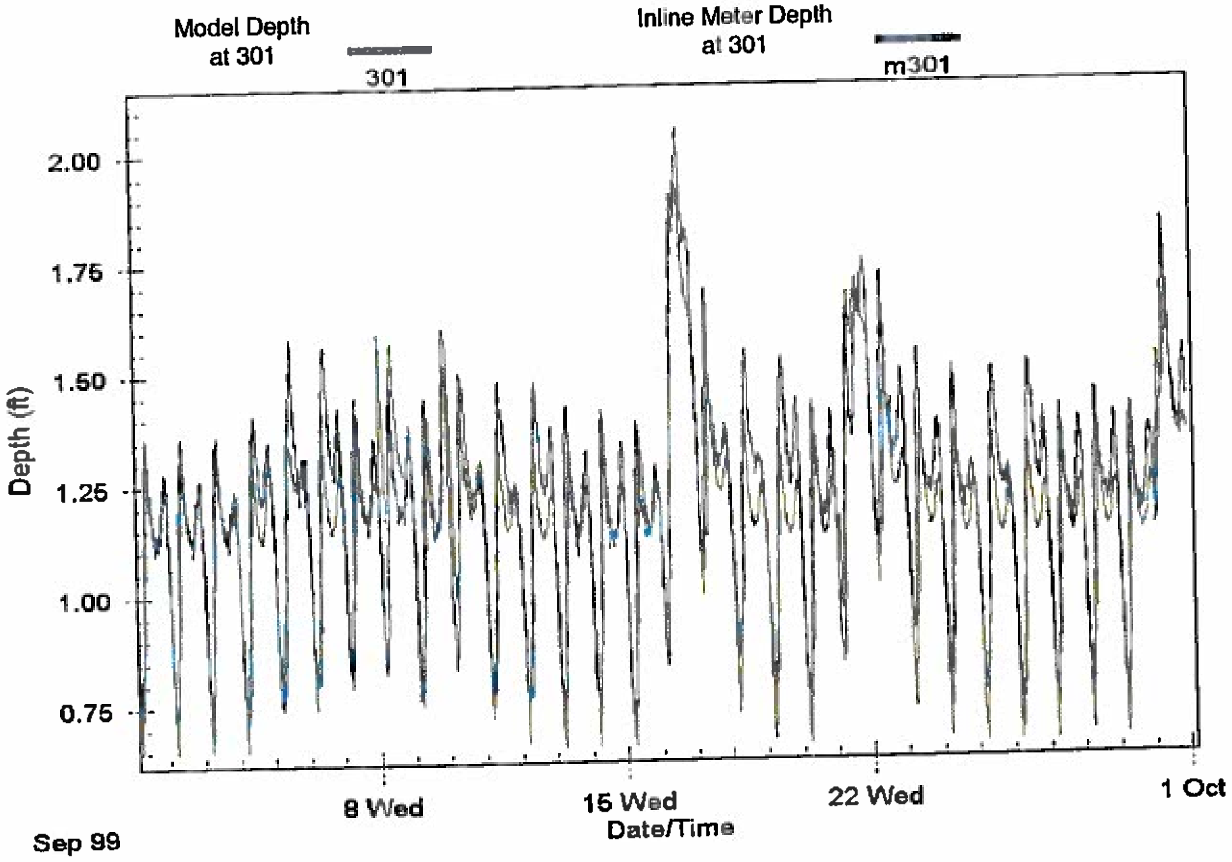
Depth Calibration Plot



Flow Calibration Plot



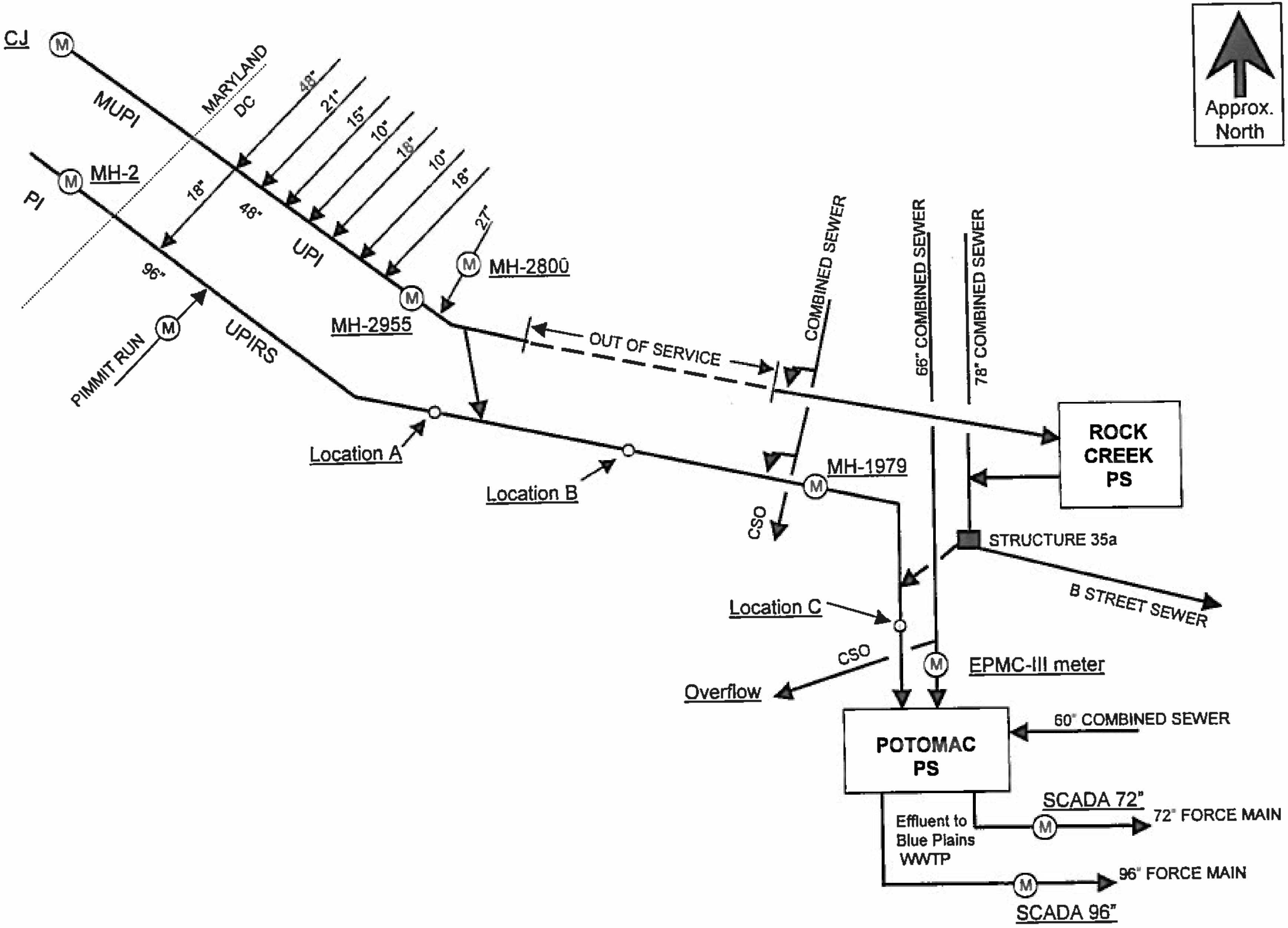
Depth Calibration Plot



Appendix E

Schematics for Downstream Boundary Condition Flow Estimates

FIGURE E-1
DC Flow Estimates for Downstream Boundary Condition



NOT TO SCALE

Figure E-2
Location A vs. MH-2 and Pimmit

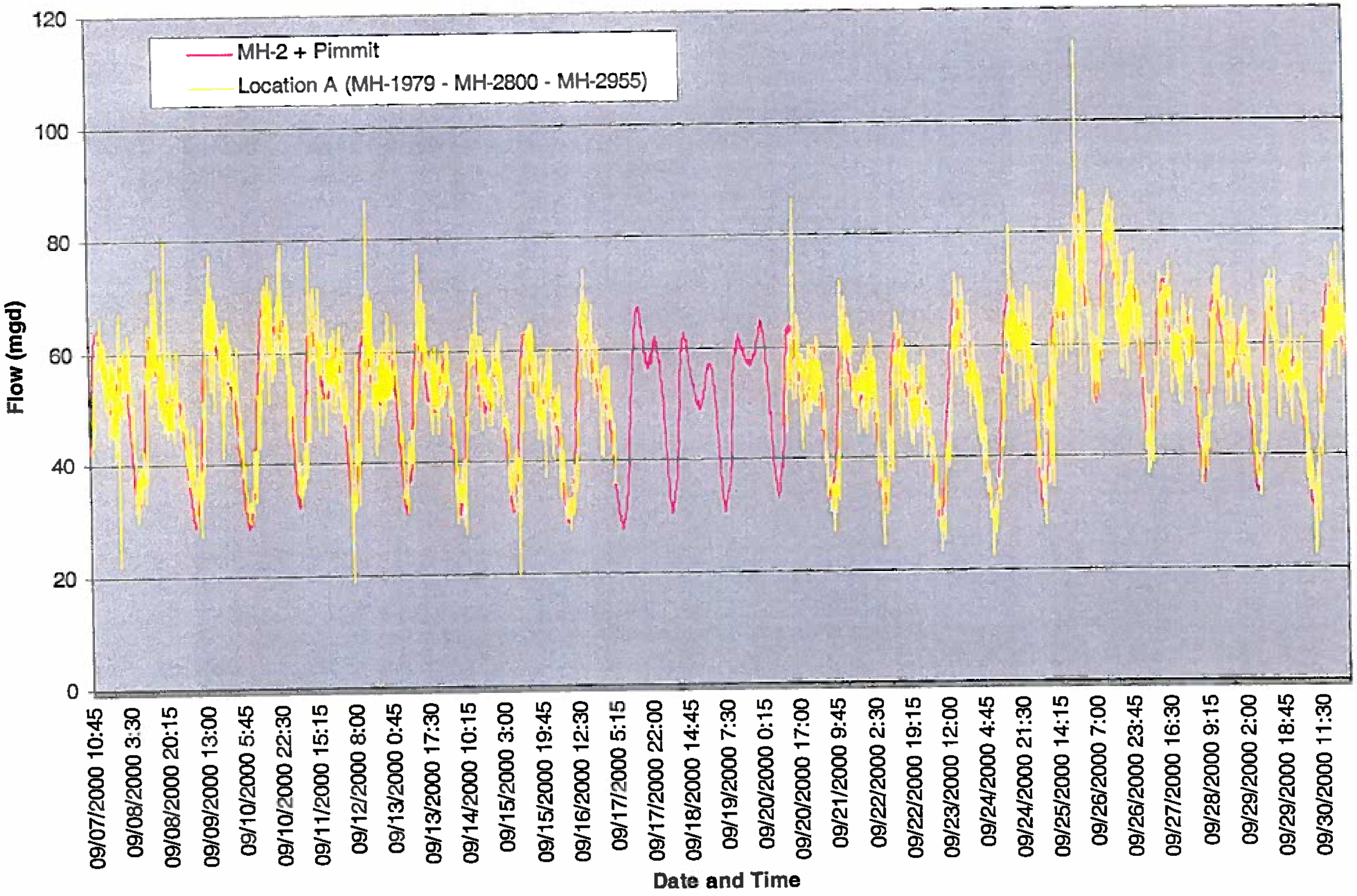
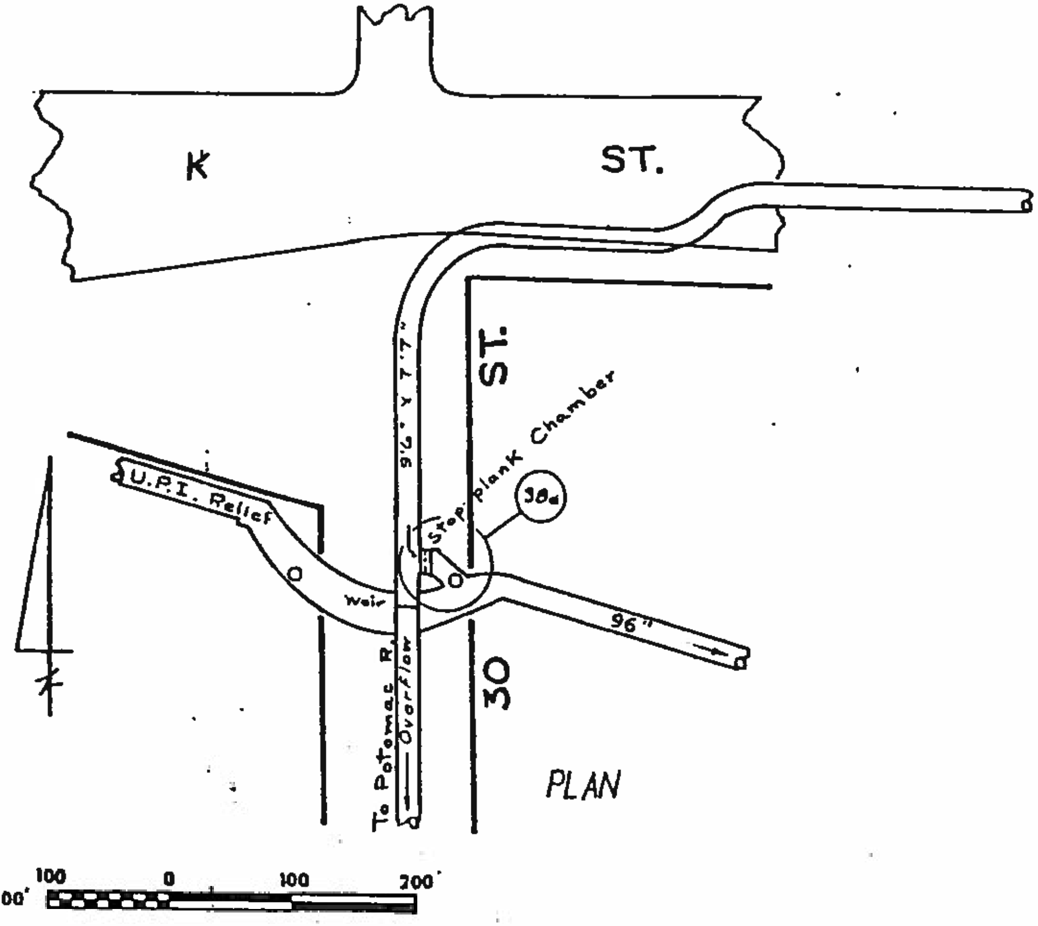


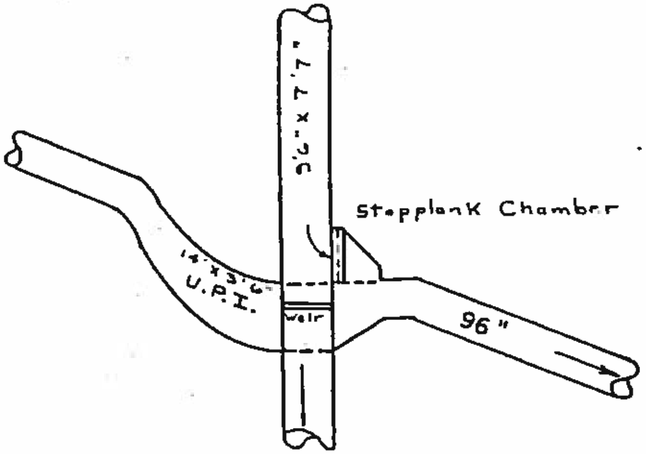
Figure E-3

__STRUCTURE NO. 38a, 30th St: south of K St., N.W.__ Flow in the 9'6" by 7'7" combined sewer discharges to Upper Potomac Interceptor Relief Sewer through a side stop-plank chamber. (Presently, there is a 6" high opening in the base of the stop-plank chamber to pass this flow.)

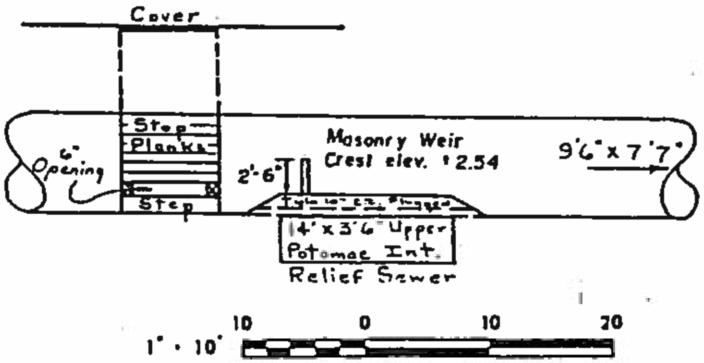
Overflow continues south to the Potomac River. (Downstream of the interception point on the overflow is a 2'6" high masonry weir to prevent tidal backflow.)



PLAN



DETAIL



38a

Figure E-4
Location B vs. MH-1979

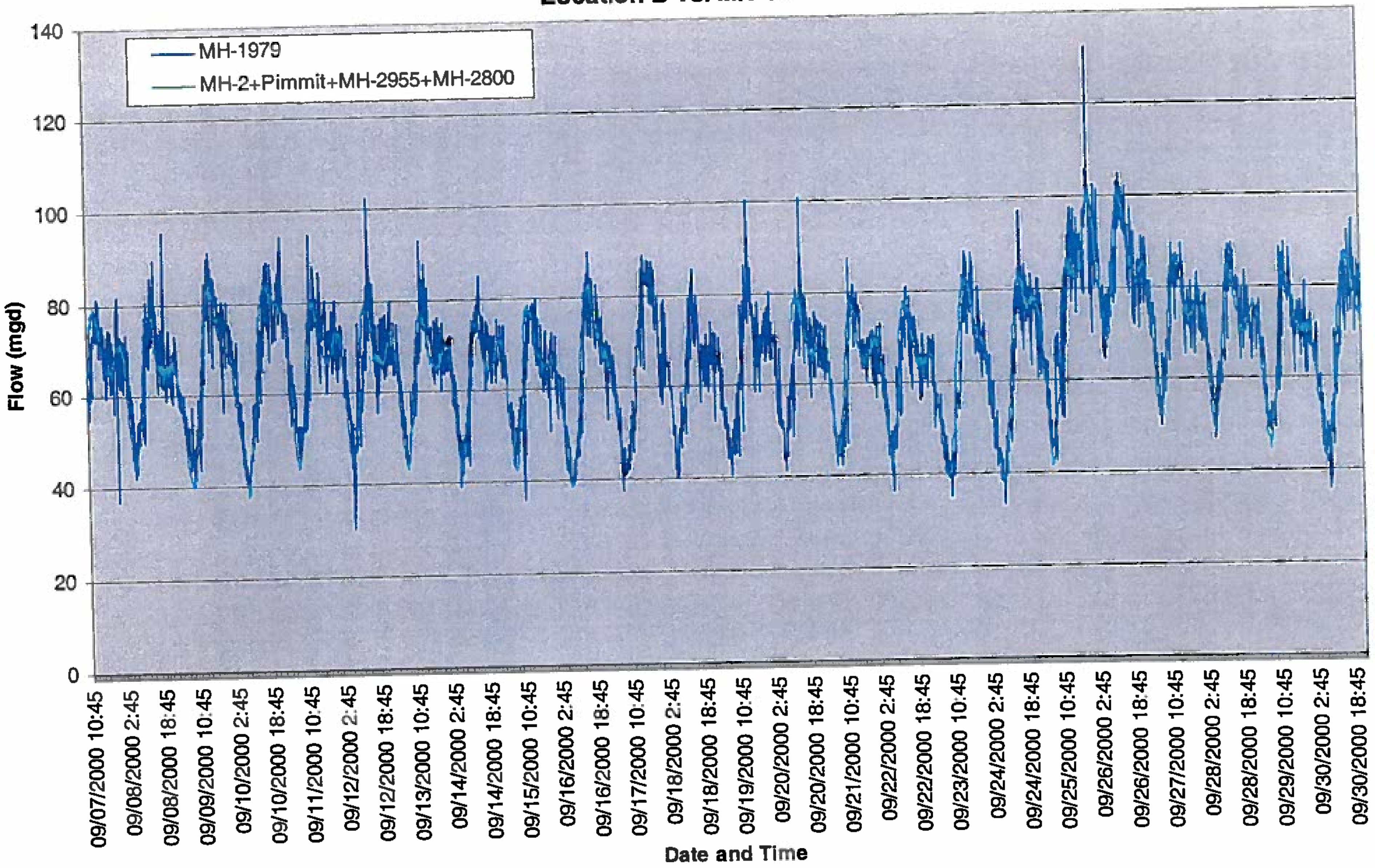
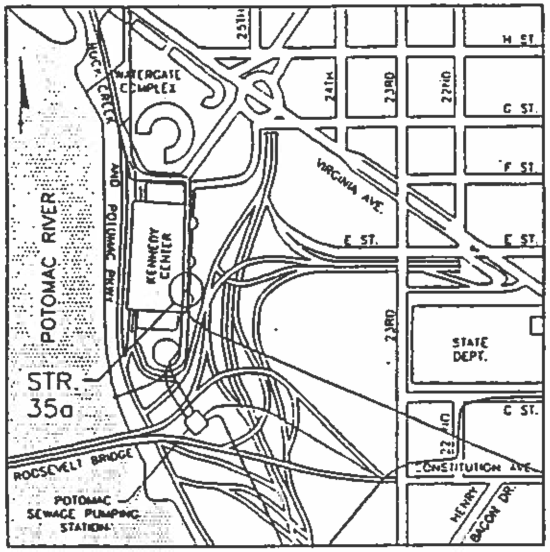


Figure E-5

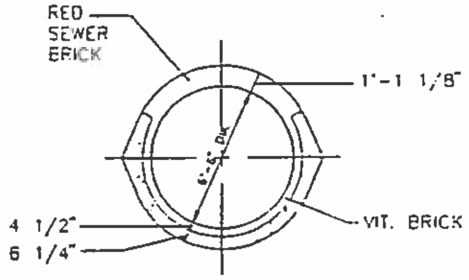
35a KENNEDY CENTER GARAGE (FORMERLY 26TH & D ST. N.W.)

At this location there are two aluminum slide gates which enable control of flow in the "B" St. - New Jersey Avenue Trunk Sewer (which is a continuation of the Rock Creek Main Interceptor). Flow may continue in the trunk sewer or may be diverted to the Potomac River Interceptor Sewer (lower level of the "Piggy-back" Sewer). Access is via manholes in the Kennedy Center garage floor.



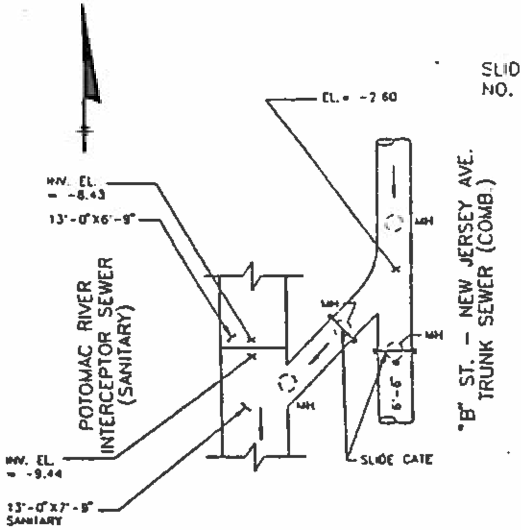
LOCATION PLAN

NOT TO SCALE

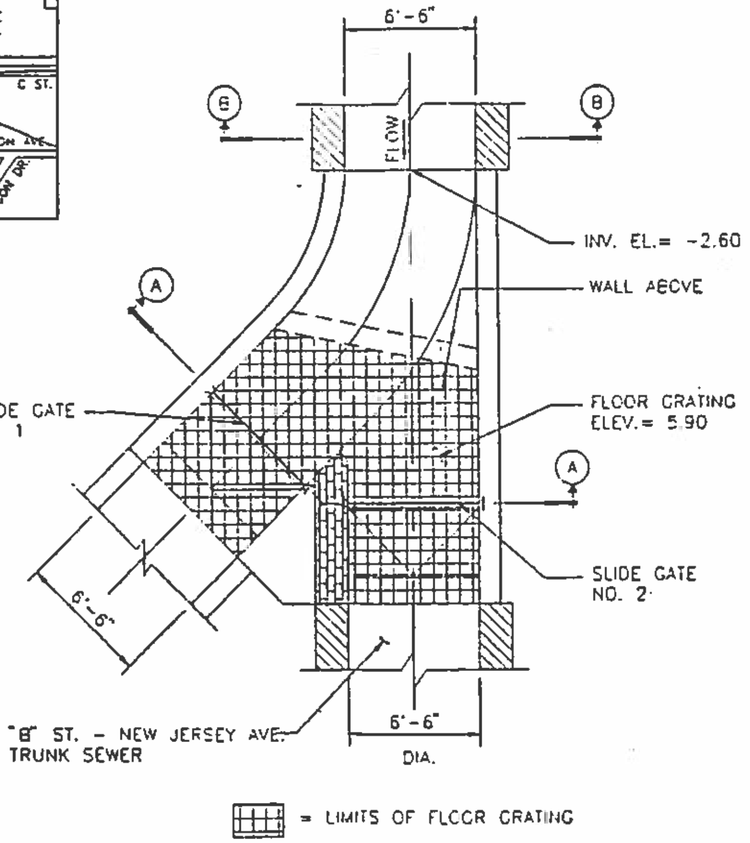


SECTION B-B

NOTE:
1. BOTH GATES FOUND TO BE OPEN APRIL 23, 1992
2. ACCESS TO SLIDE GATES IS VIA TWO MANHOLES IN THE KENNEDY CENTER GARAGE. THERE ARE TWO OVERHEAD EYEBOLTS IN THE GARAGE CEILING TO FACILITATE SLIDE GATE OPERATION.

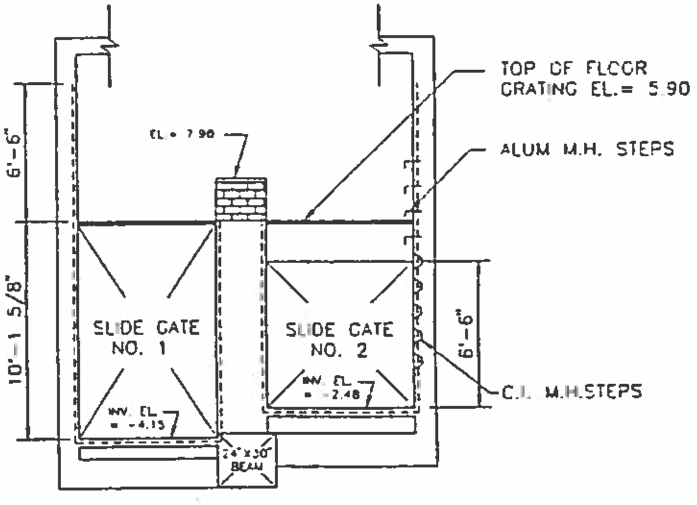


SCHEMATIC



▦ = LIMITS OF FLOOR GRATING

SECTIONAL PLAN



SECTION A-A

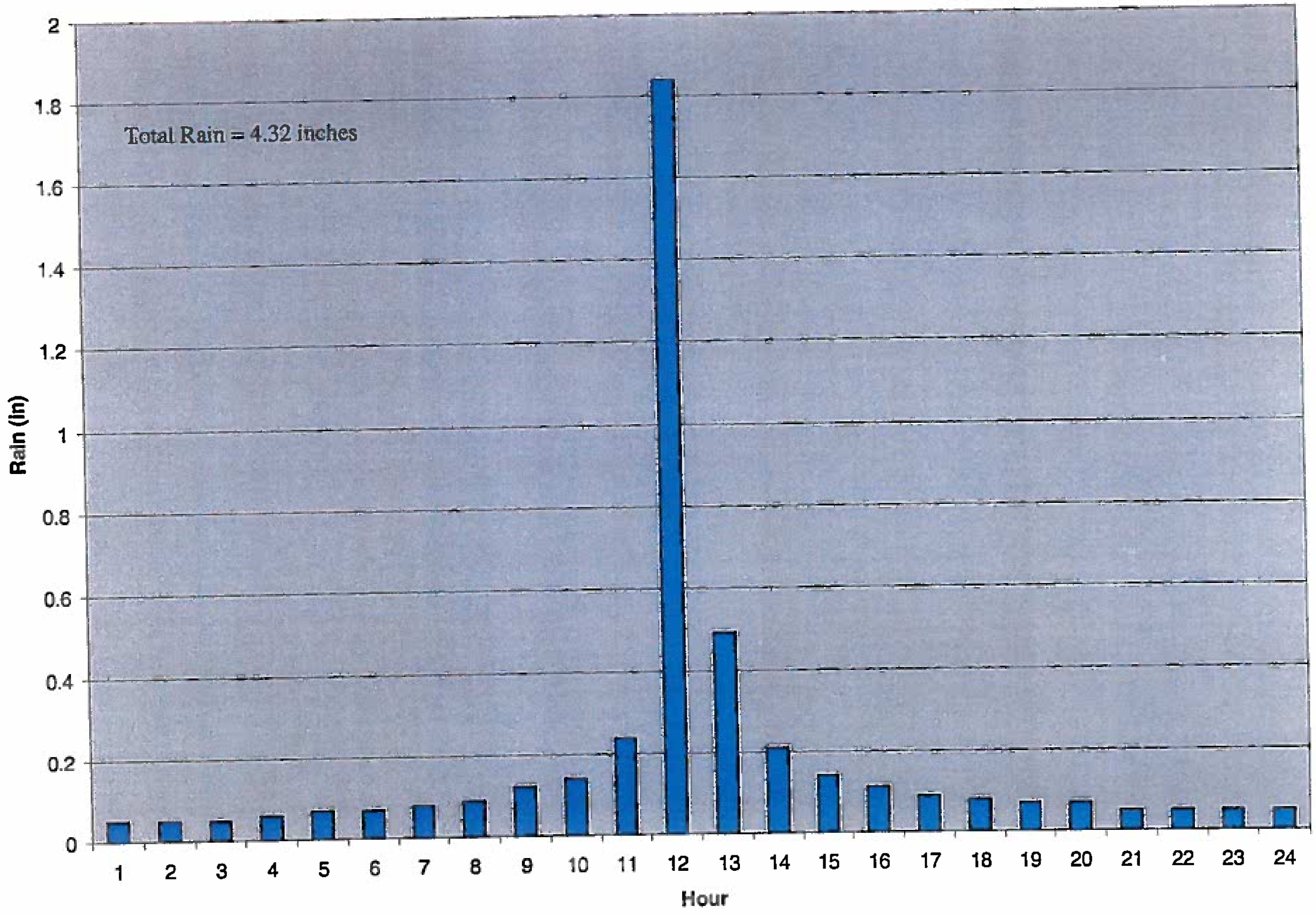
KENNEDY CENTER GARAGE

NOT TO SCALE

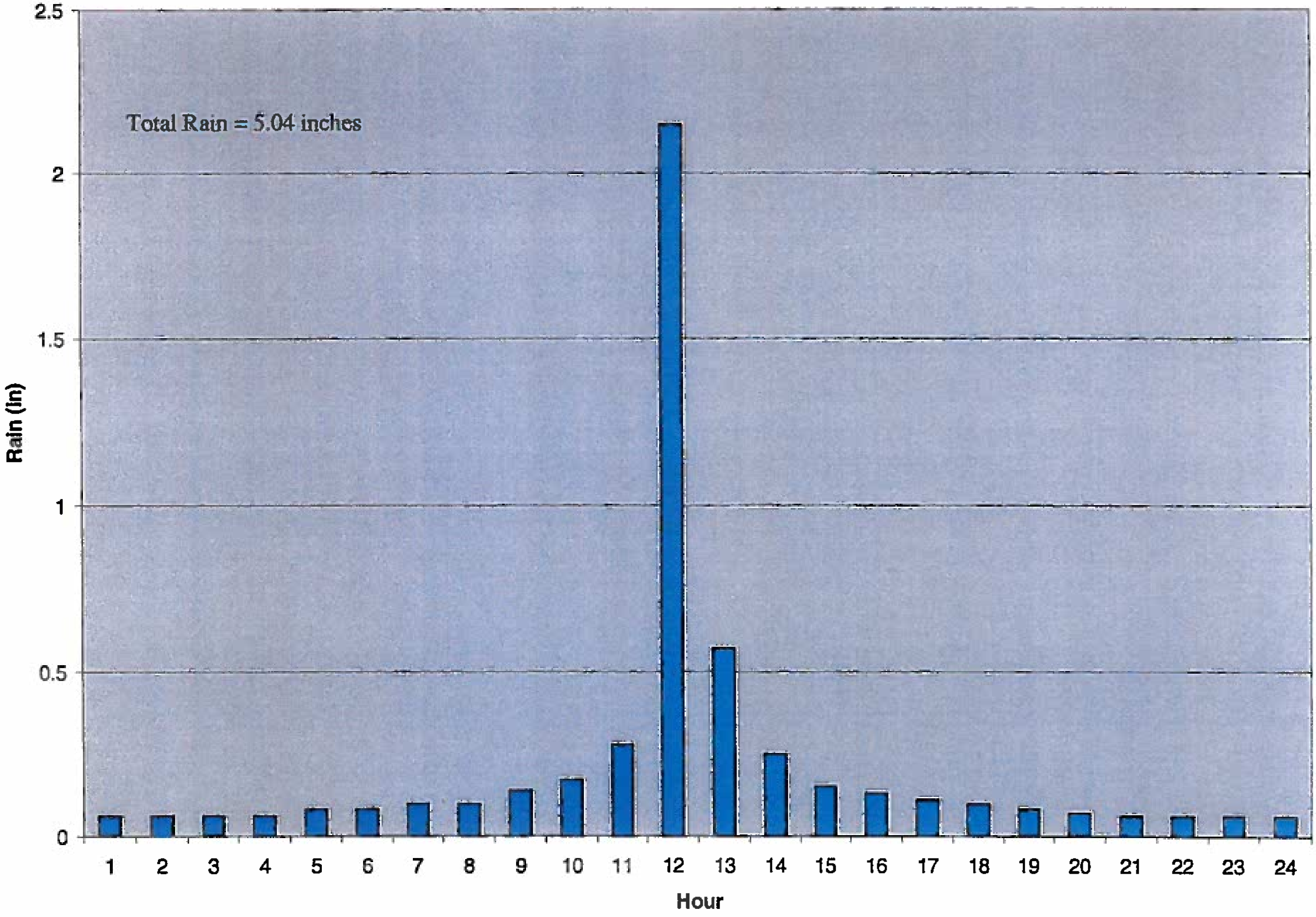
35a

Appendix F
Design Storm Hyetographs

5-Year, 24-Hour Design Storm



10-Year, 24-Hour Design Storm



Appendix G
PI Flows 2025
(Handout from August 14, 2001 Presentation)

Table G-1
PI Flows 2025

Meter Name	2025 RWFFM Projections (mgd)	Peak Flow (mgd)			IMA / LCSA Agreement Flow (mgd)	
	Annual Average Base Flow	5-yr, 24-hour Storm	10-yr, 24-hour Storm	Fairfax Peaking Factor	Annual Average	Peak
WSSC						
CJ1	12.76	33.33	33.33	31.90		
CJ2 (to MUPI)	12.76	16.00	16.00	31.90	10.3	23.3
CJ Dulles (to PI)	-	17.33	17.33	-	0.7	25.0
Muddy Branch	6.14	22.03	25.86	16.94	15.5	40.3
Watts Branch	6.49	14.92	16.83	17.66	4.5	14.2
Rock Run	0.96	3.00	3.00	4.05	0.9	3.7
Unmetered	0.47	-	-	-	-	-
WSSC Total	**14.05**	**57.27**	**63.02**	**38.65**	**21.6**	**83.2**
LCSA						
Unmetered	0.24	-	-	-		
Mercure	6.93	-	-	-		
Cabin Branch	2.02	9.39	11.22	7.20		
Boise Cascade	0.51	1.65	1.99	2.49		
Seneca	0.45	0.92	1.02	2.25		
Russell Branch-S-17	6.78	21.23	23.38	18.28		
Countryside #1	0.12	0.45	0.50	0.82		
Countryside #2	0.26	3.00	3.00	1.51		
Cascades Western	0.47	0.99	1.05	2.36		
Great Falls Forest #1	0.10	0.20	0.20	0.73		
Great Falls Forest #2	0.10	0.21	0.21	0.73		
Indian Creek-S-6	0.81	2.77	3.22	3.58		
Triple 7-S-20	1.10	3.70	4.34	4.51		
PIP - ZEROX	1.30	2.35	2.43	5.13		
Cascades North	0.56	2.17	2.41	2.69		
Broad Run	0.82	1.43	1.47	3.62		
Northwestern	0.27	1.20	1.34	1.51		
Northeastern	0.35	0.78	0.82	1.89		
Beaumeade #1	0.59	1.22	1.65	2.78		

Table G-1
PI Flows 2025

Meter Name	**2025 RWFFM Projections (mgd)**	**Peak Flow (mgd)**		
	Annual Average Base Flow	5-yr, 24-hour Storm	10-yr, 24-hour Storm	Fairfax Peaking Factor
LCSA Subtotal	25.03	53.67	60.25	62.08
(LCSA Offload)	*(11.23)*	*(12.89)*	*(12.89)*	*(12.89)*
LCSA Total	**13.80**	**40.78**	**47.36**	**49.19**

IMA / LCSA Agreement Flow (mgd)	
Annual Average	Peak
13.8	**31.9**

Table G-1
PI Flows 2025

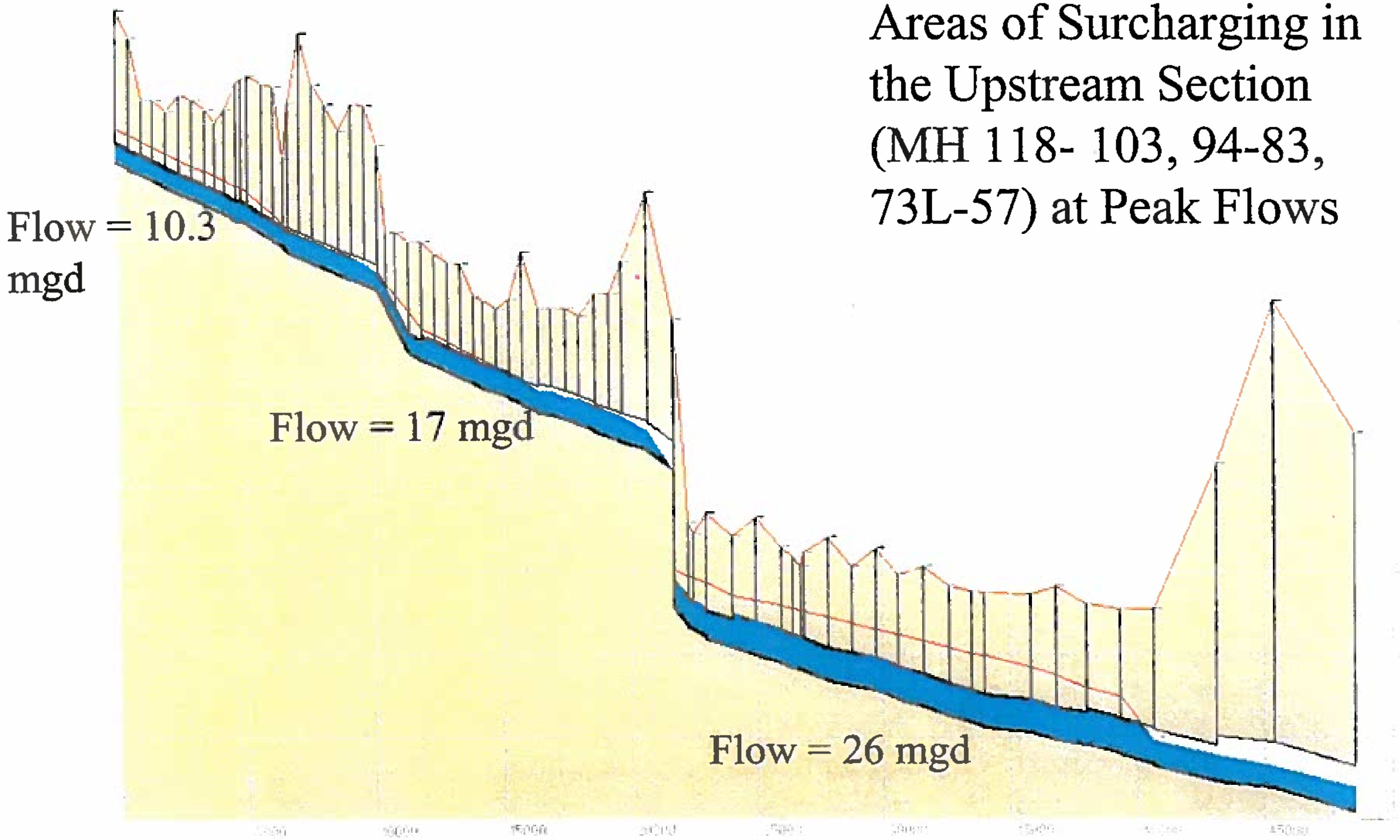
Meter Name	2025 RWFFM Projections (mgd)	Peak Flow (mgd)			IMA / LCSA Agreement Flow (mgd)	
	Annual Average Base Flow	5-yr, 24-hour Storm	10-yr, 24-hour Storm	Fairfax Peaking Factor	Annual Average	Peak
Fairfax						
Sully Road #1	4.02	10.30	10.30	12.22	4.0	9.2
Sully Road #2	1.44	3.86	4.37	5.57	1.1	2.1
Rock Hill Road	0.62	3.52	4.26	2.89	0.9	2.3
Sugarland Run *	6.81	22.60	22.60	18.34	4.0	12.0
Great Falls **	12.17	30.11	33.03	30.43	8.7	22.5
Scotts Run	4.74	10.50	10.50	13.88	2.9	9.4
Pimmit	8.36	30.00	30.00	21.47	9.4	23.6
AT&T B3046	0.19	1.67	2.09	1.17	-	-
Fairfax Subtotal	35.89	112.56	117.14	105.96		
(Fairfax Offload)	*(4.89)*	*(14.22)*	*(14.22)*	*(14.22)*		
Fairfax Total	**31.00**	**98.34**	**102.92**	**91.74**	**31.0**	**81.1**
Other						
Dulles Airport	1.62	5.82	5.82	6.07	1.0	-

* Includes 1.24 mgd LCSA flows.

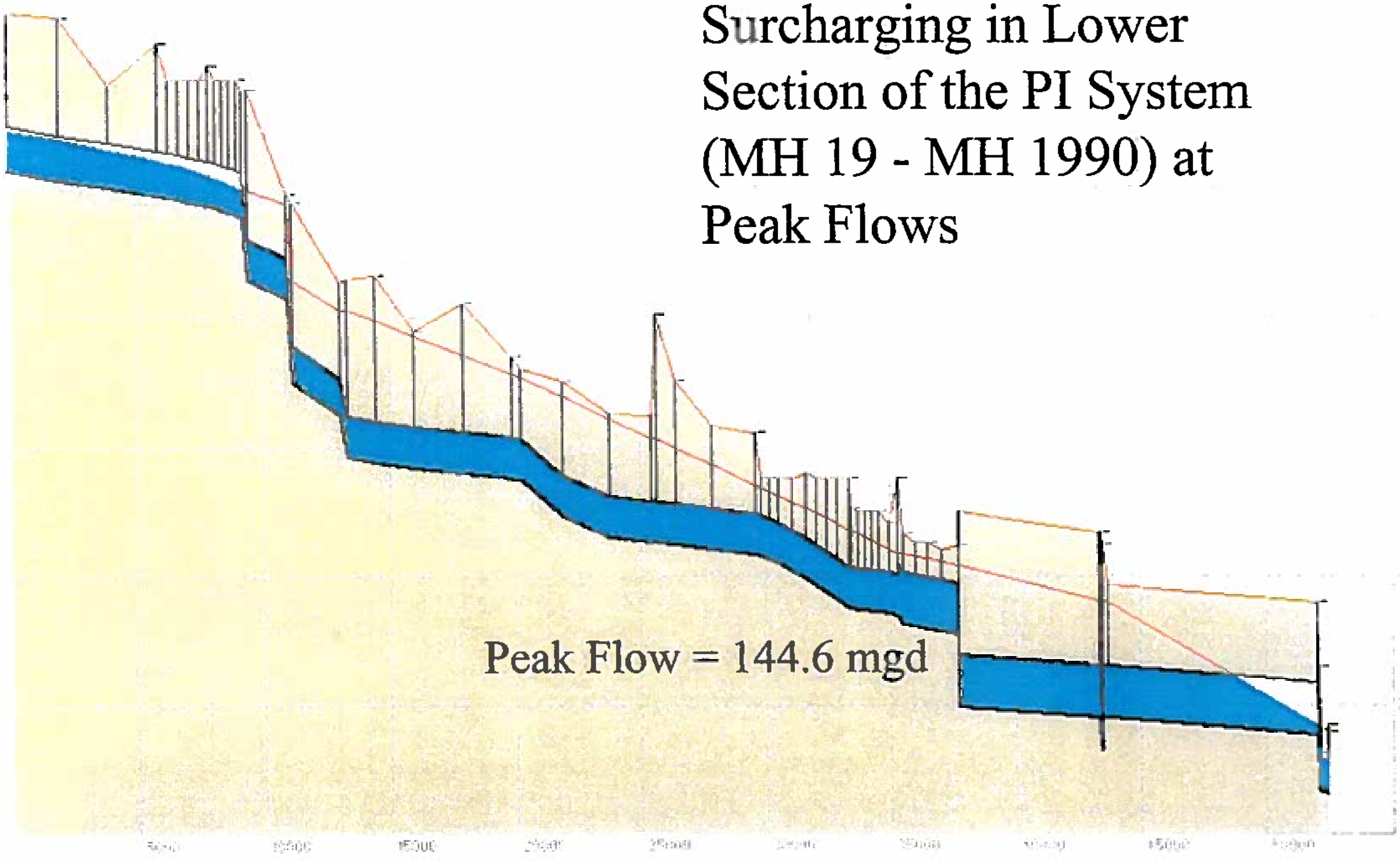
** Includes 1.23 mgd Vienna flows.

Results of 5-Year Storm

Areas of Surcharging in the Upstream Section (MH 118- 103, 94-83, 73L-57) at Peak Flows



Results of 5-Year Storm

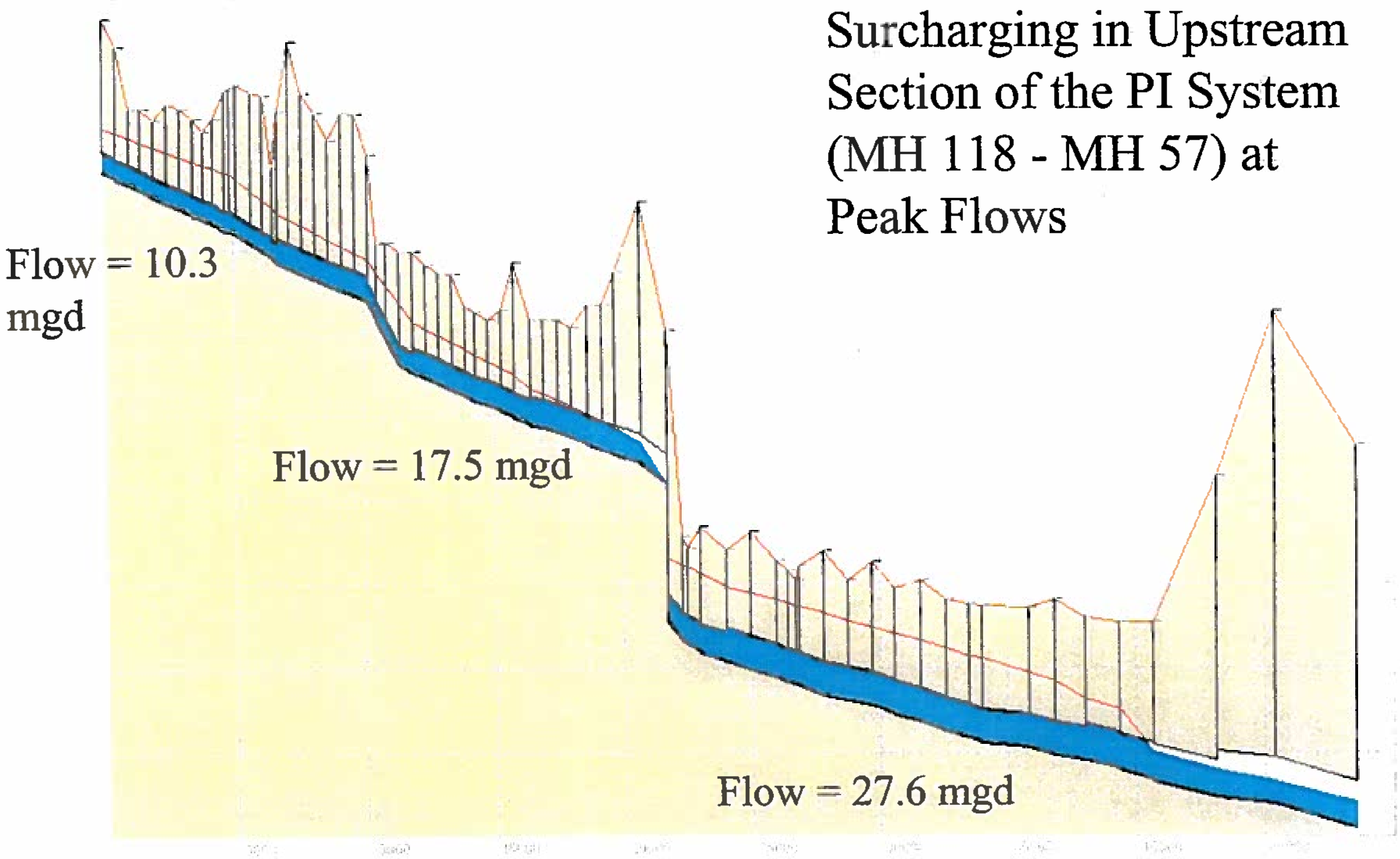


Surcharging in Lower
Section of the PI System
(MH 19 - MH 1990) at
Peak Flows

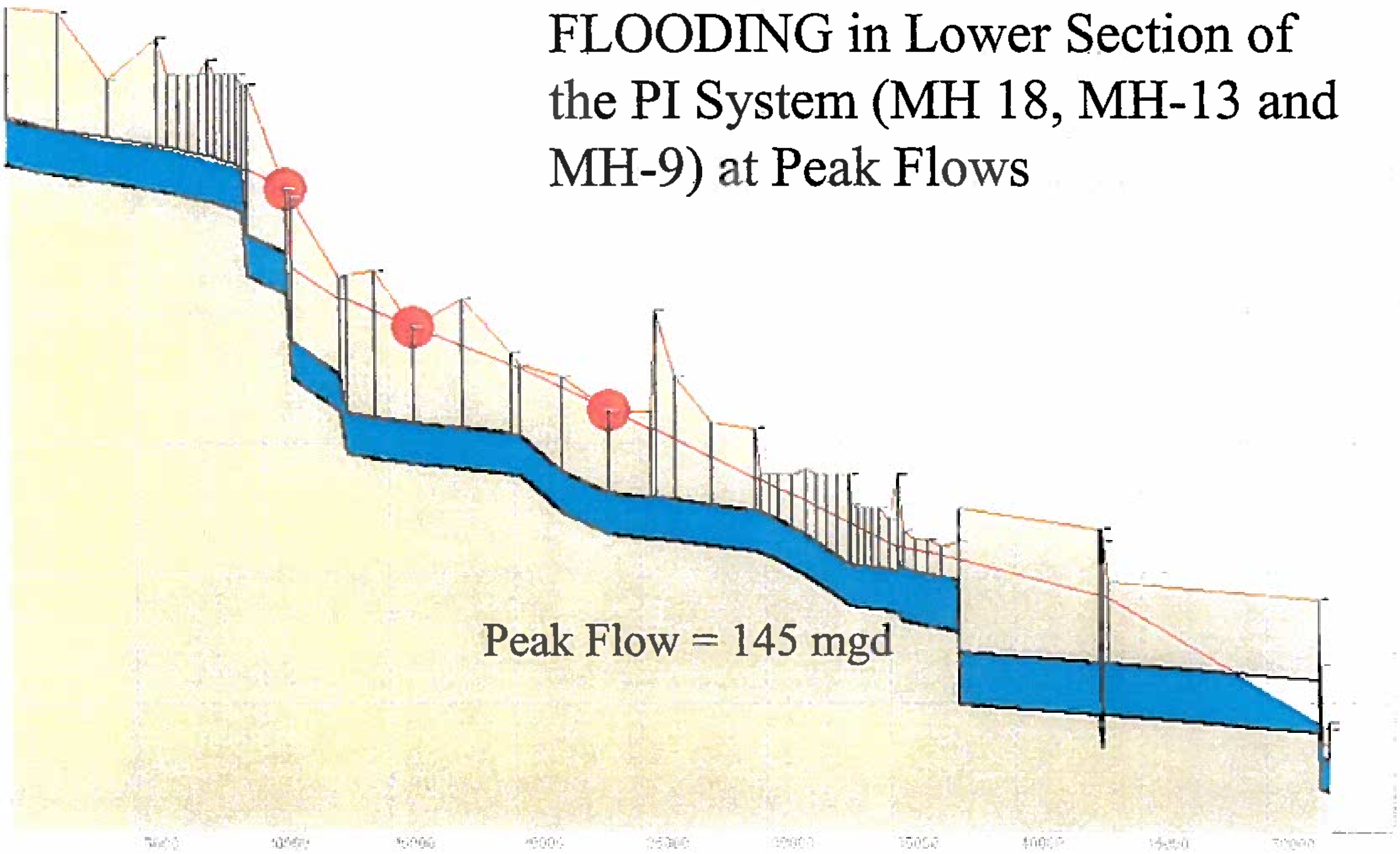
Peak Flow = 144.6 mgd

Results of 10-Year Storm

Surcharging in Upstream Section of the PI System (MH 118 - MH 57) at Peak Flows



Results of 10-Year Storm



FLOODING in Lower Section of the PI System (MH 18, MH-13 and MH-9) at Peak Flows

Peak Flow = 145 mgd

Appendix H
PI Flows
(Handout from November 13, 2001 Presentation)

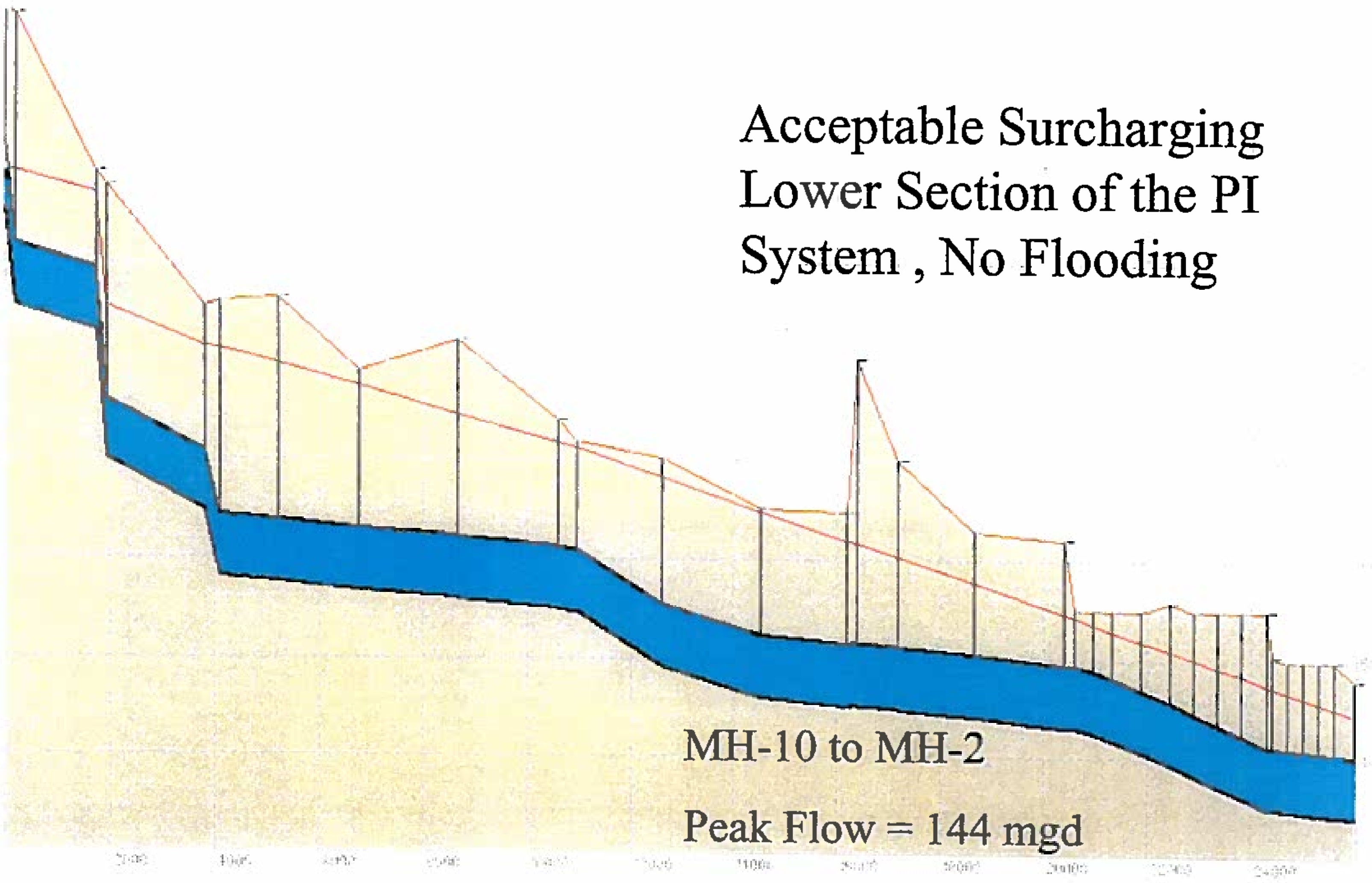
Table H-1
PI Flows

Meter Name	2025 RWFFM Projections (mgd)	10-yr, 24-hour Design Storm		I/I Reduction Simulation	
	Annual Average Base Flow	Peak Flows (mgd)	Peak to Avg Flows	Peak Flows (mgd)	Peak Flow Reduction (mgd)
WSSC					
CJ1	12.76	33.33	2.61		
CJ2 (to MUPI)	12.76	16.00	-		
CJ Dulles (to PI)	-	17.33	-		
Muddy Branch	6.14	25.86	4.21	18.43	7.43
Watts Branch	6.49	16.83	2.60		
Rock Run	0.96	3.00	3.14		
Unmetered	0.47	-	-		
WSSC Total	**14.05**	**63.02**	-		
LCSA					
Unmetered	0.24	-	-		
Mercure	6.93	-	-		
Cabin Branch	2.02	11.22	5.56	6.06	5.16
Boise Cascade	0.51	1.99	3.92		
Seneca	0.45	1.02	2.29		
Russell Branch-S-17	6.78	23.38	3.45	20.35	3.03
Countryside #1	0.12	0.50	4.15		
Countryside #2	0.26	3.00	11.36		
Cascades Western	0.47	1.05	2.23		
Great Falls Forest #1	0.10	0.20	1.95		
Great Falls Forest #2	0.10	0.21	2.01		
Indian Creek-S-6	0.81	3.22	3.96		
Triple 7-S-20	1.10	4.34	3.95		
PIP - ZEROX	1.30	2.43	1.87		
Cascades North	0.56	2.41	4.30		
Broad Run	0.82	1.47	1.79		
Northwestern	0.27	1.34	5.03		
Northeastern	0.35	0.82	2.32		
Beaumeade #1	0.59	1.65	2.82		
LCSA Subtotal	25.03	60.25	-		
(LCSA Offload)	*(11.23)*	*(12.89)*	-		
LCSA Total	**13.80**	**47.36**	-		
Fairfax					
Sully Road #1	4.02	10.30	2.56		
Sully Road #2	1.44	4.37	3.03		
Rock Hill Road	0.62	4.26	6.91	2.90	1.36
Sugarland Run *	6.81	22.60	3.32	18.50	4.10
Great Falls **	12.17	33.03	2.71		
Scotts Run	4.74	10.50	2.22		
Pimmit	8.36	30.00	3.59	25.08	4.92
AT&T B3046	0.19	2.09	11.01		
Fairfax Subtotal	35.89	117.14	-		
(Fairfax Offload)	*(4.89)*	*(14.22)*	-		
Fairfax Total	**31.00**	**102.92**			
Other					
Dulles Airport	1.62	5.82	3.60	5.82	

* Includes 1.24 mgd LCSA flows.

** Includes 1.23 mgd Vienna flows.

Results of I/I Reduction



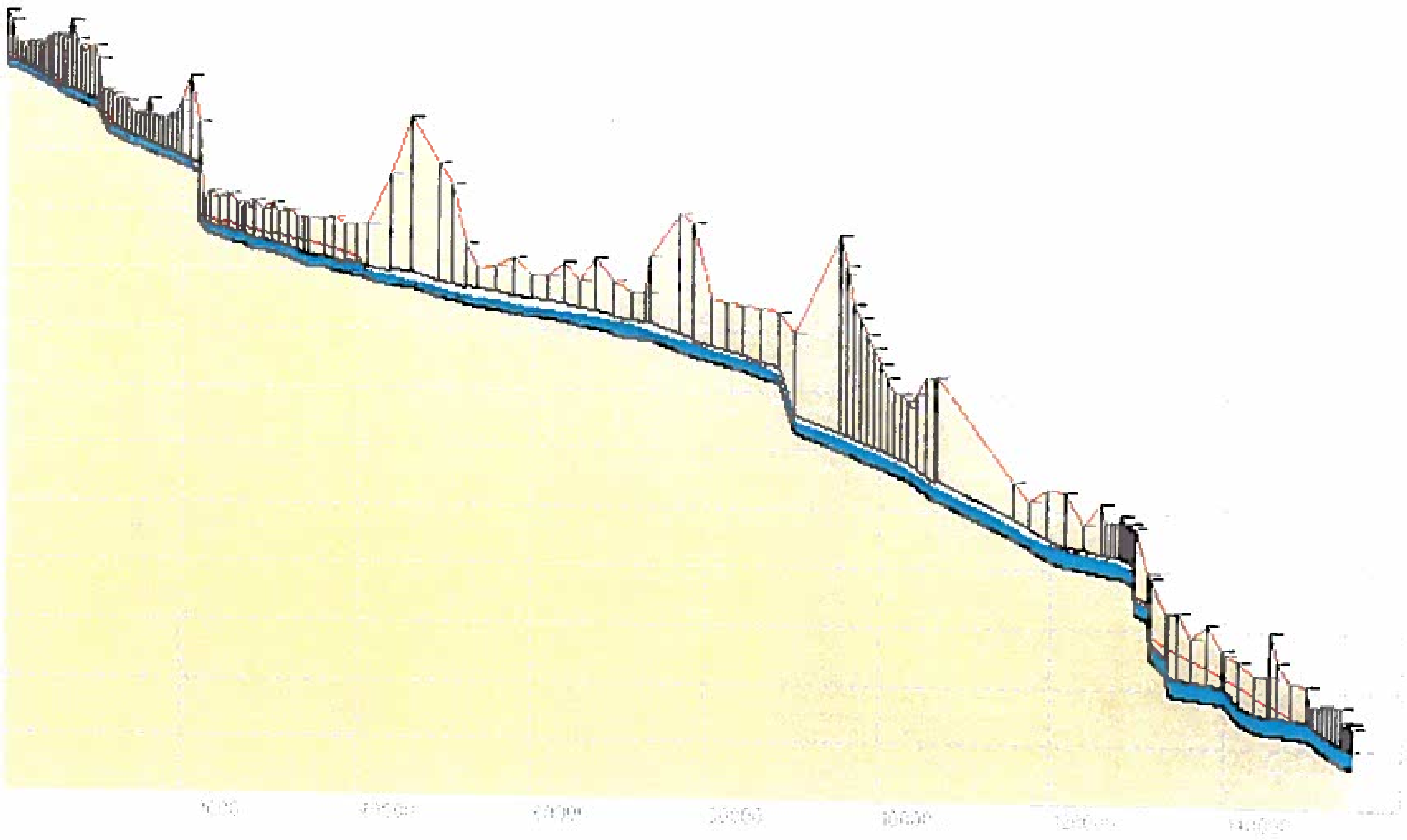
Acceptable Surcharging
Lower Section of the PI
System , No Flooding

MH-10 to MH-2

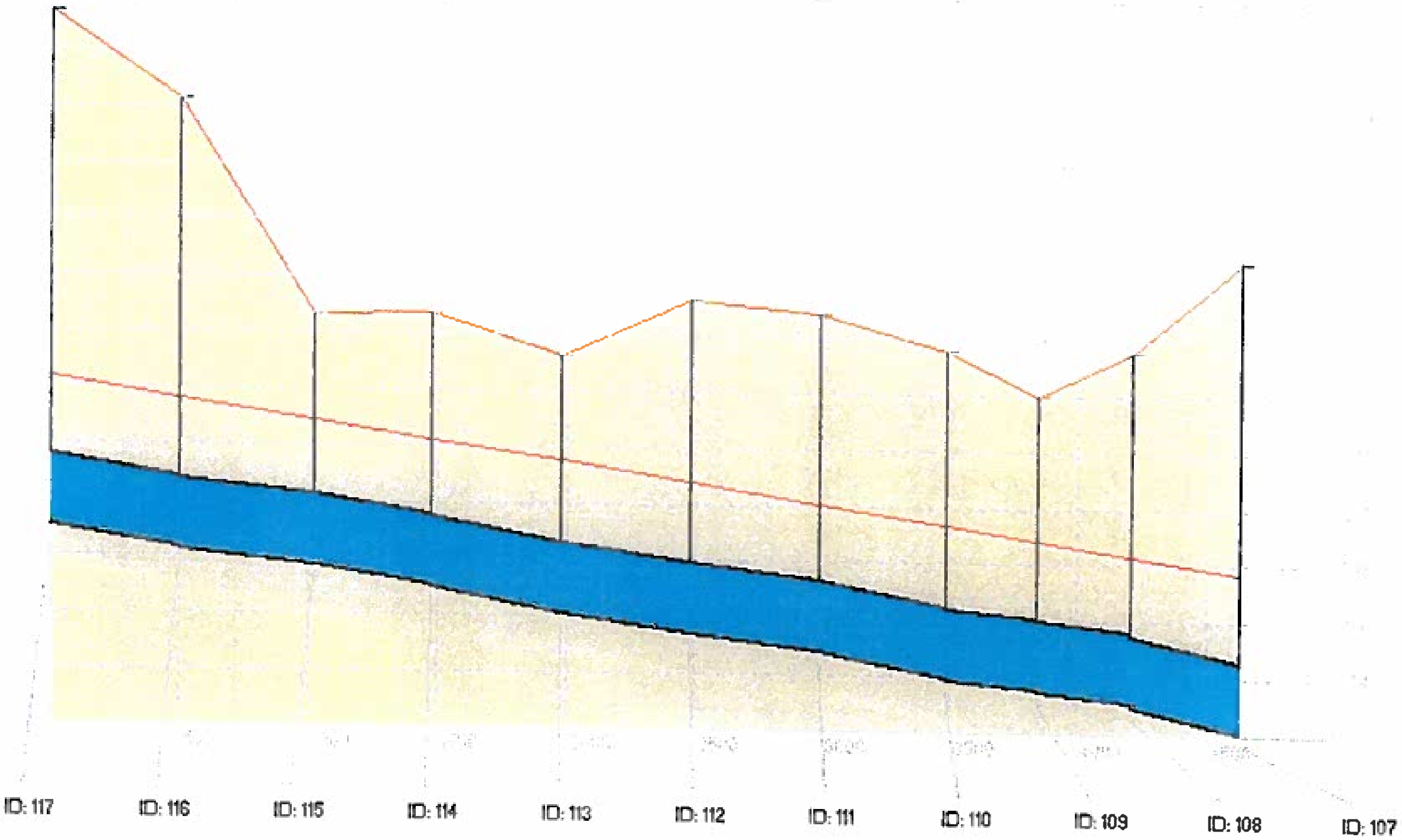
Peak Flow = 144 mgd

Appendix I
PI Capacity Profiles

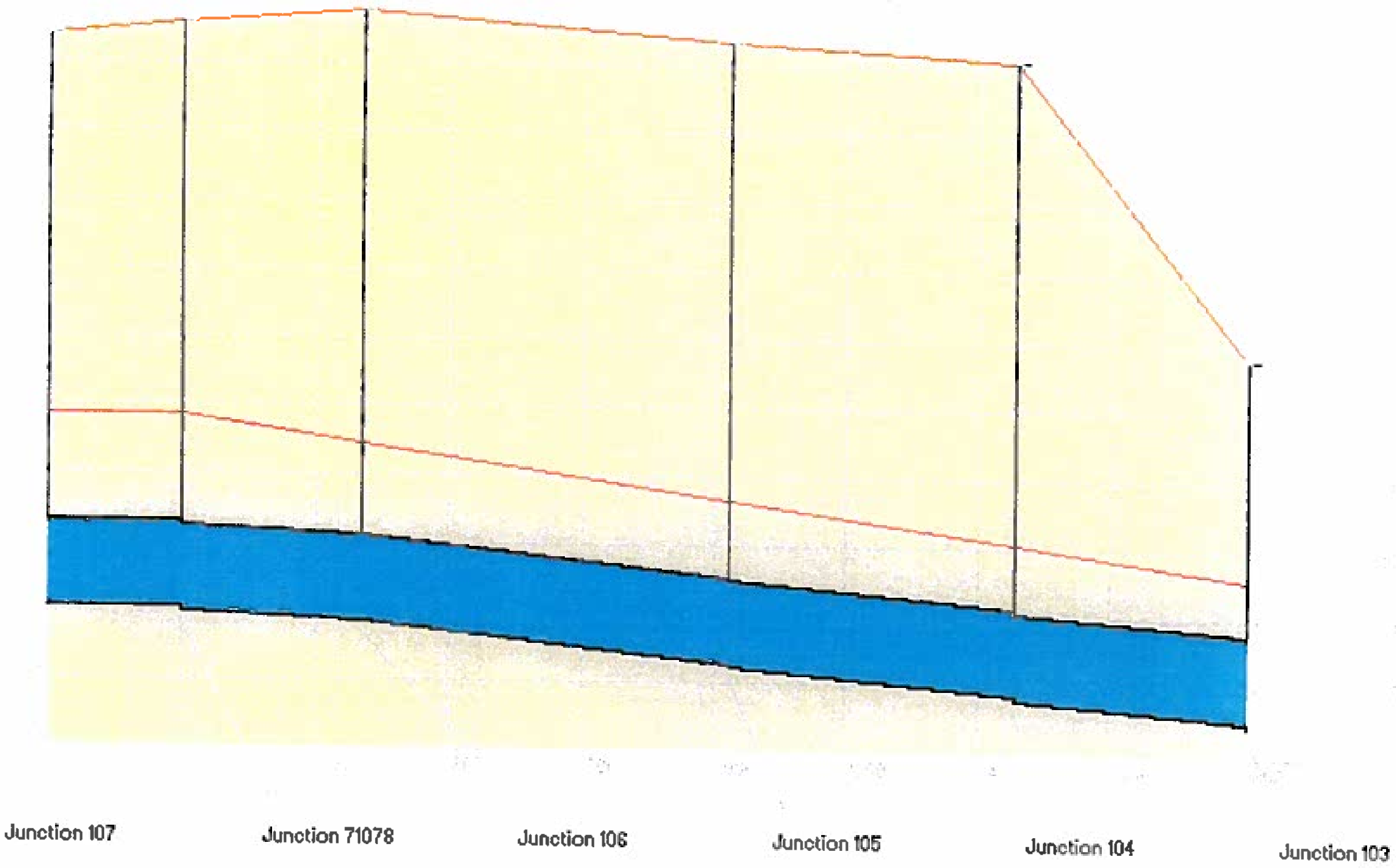
PI Profile MH 117 – MH 1



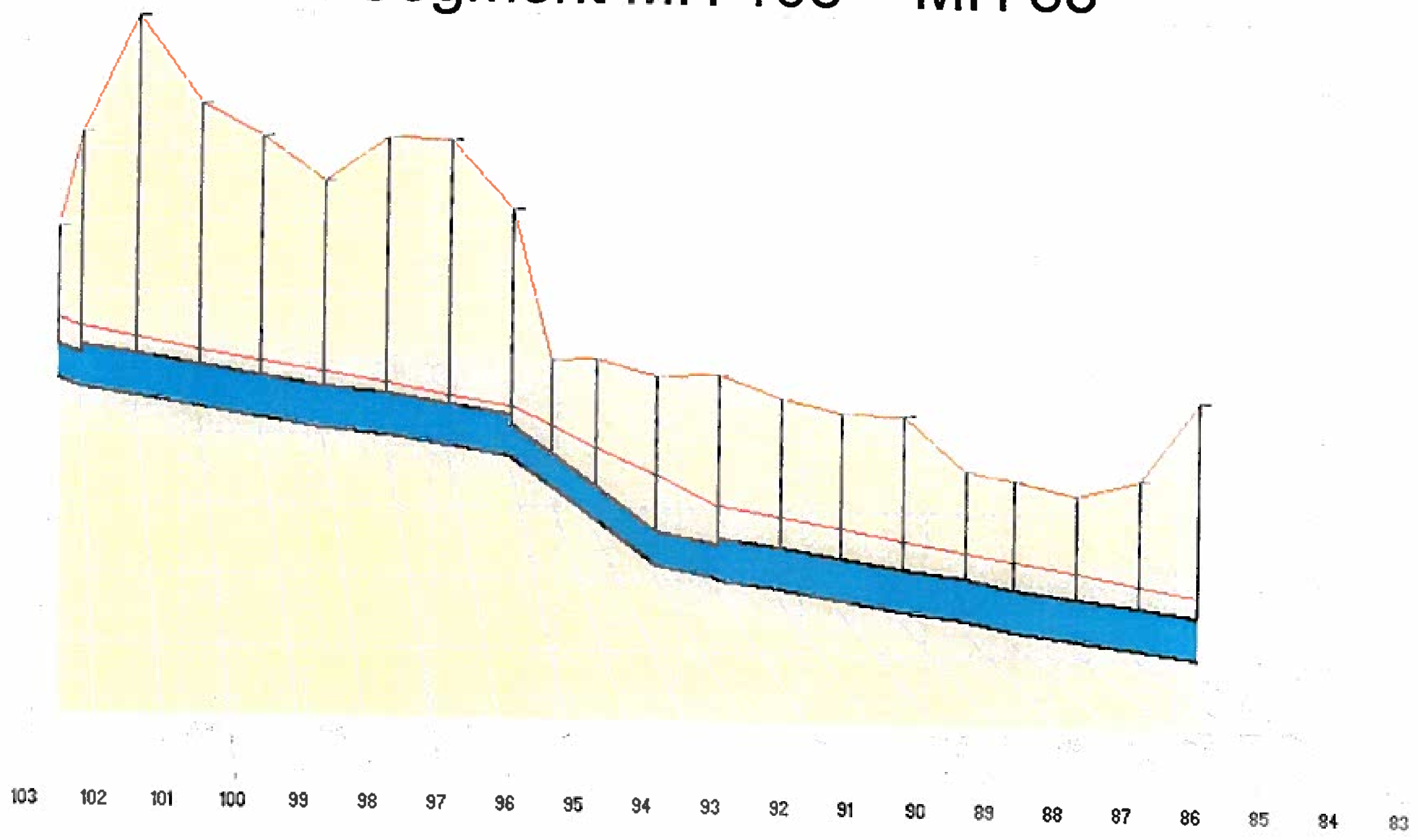
PI Segment MH 117 – MH 107



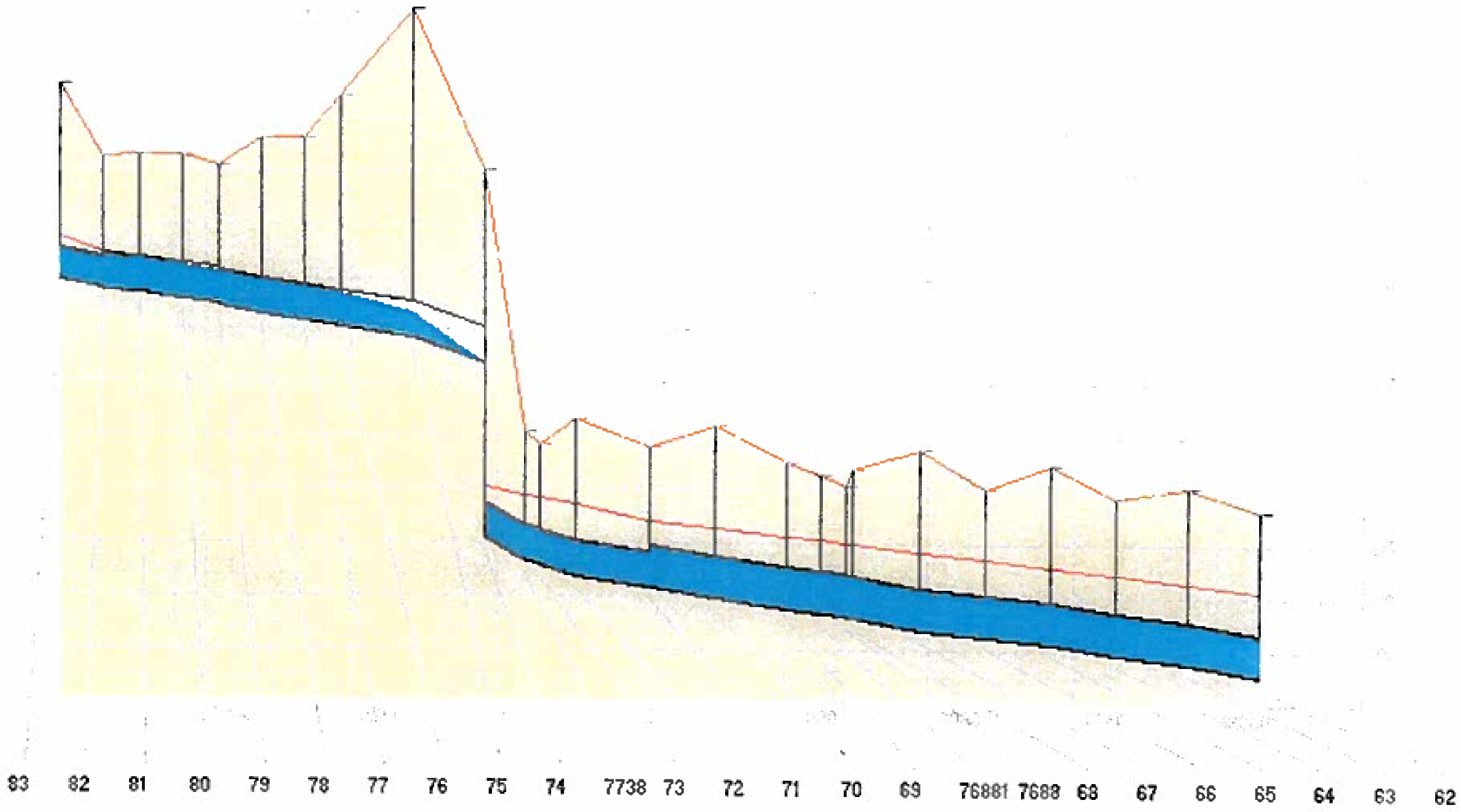
PI Segment MH 107 – MH 103



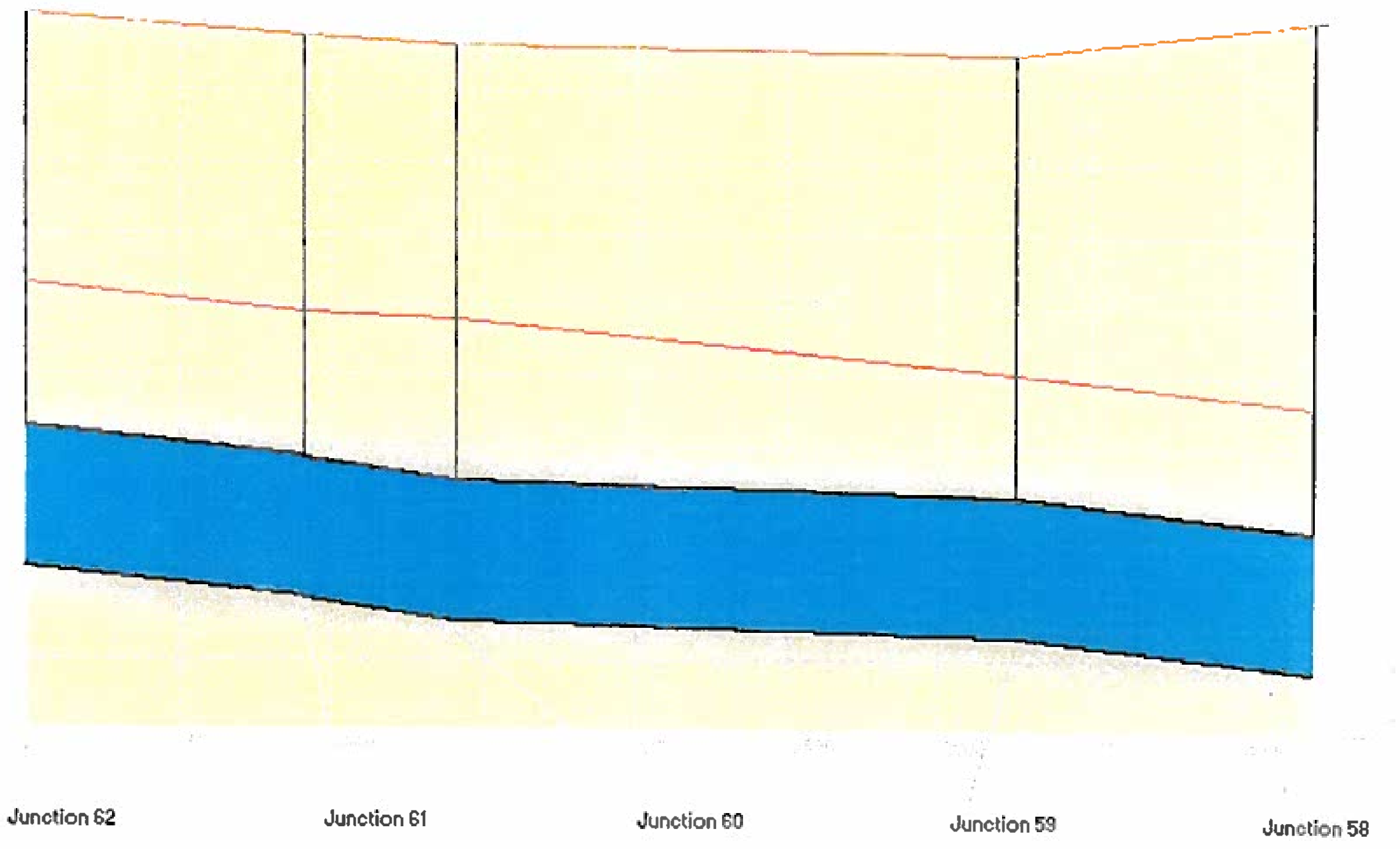
PI Segment MH 103 – MH 83



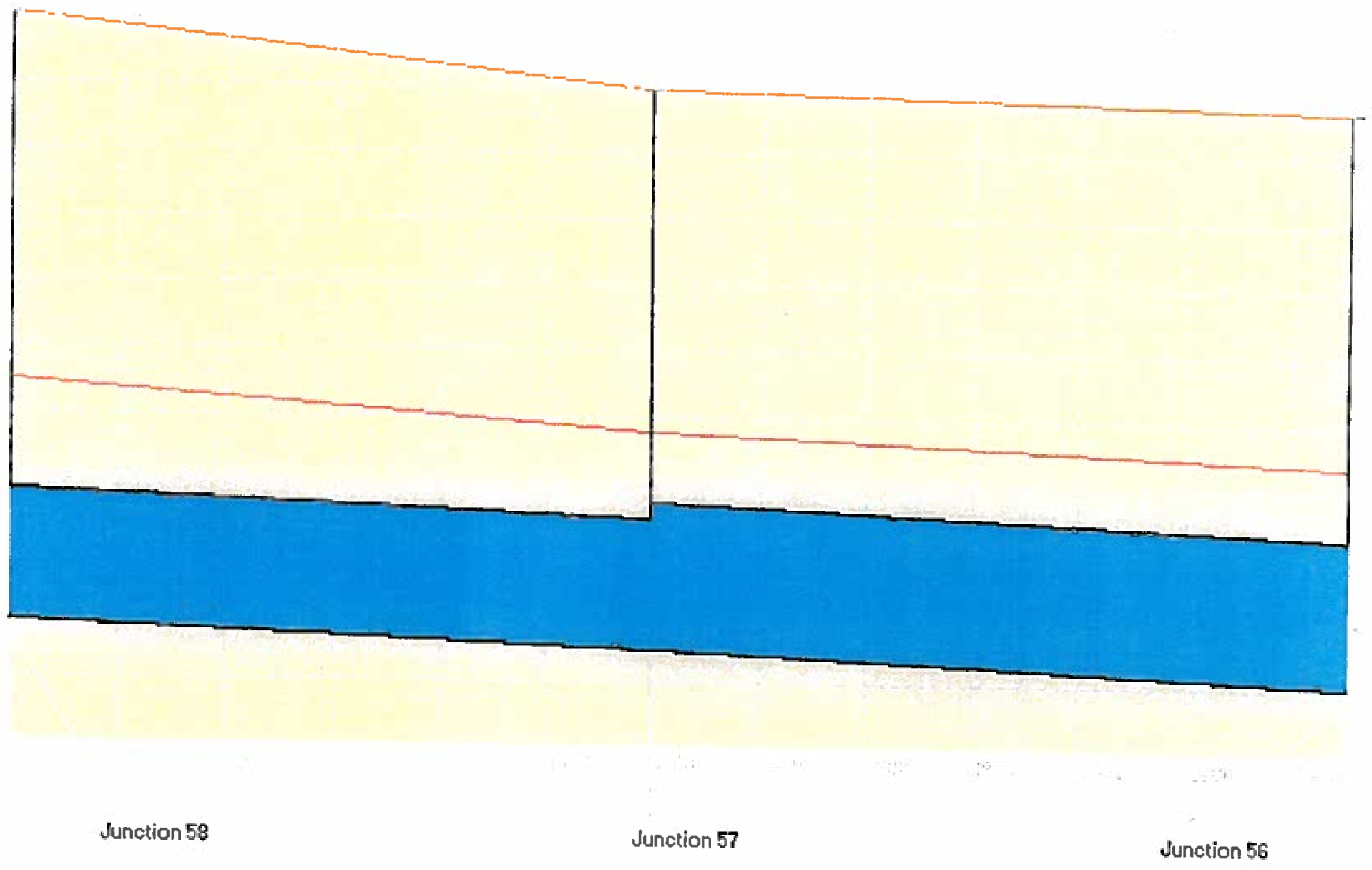
PI Segment MH 83 – MH 62



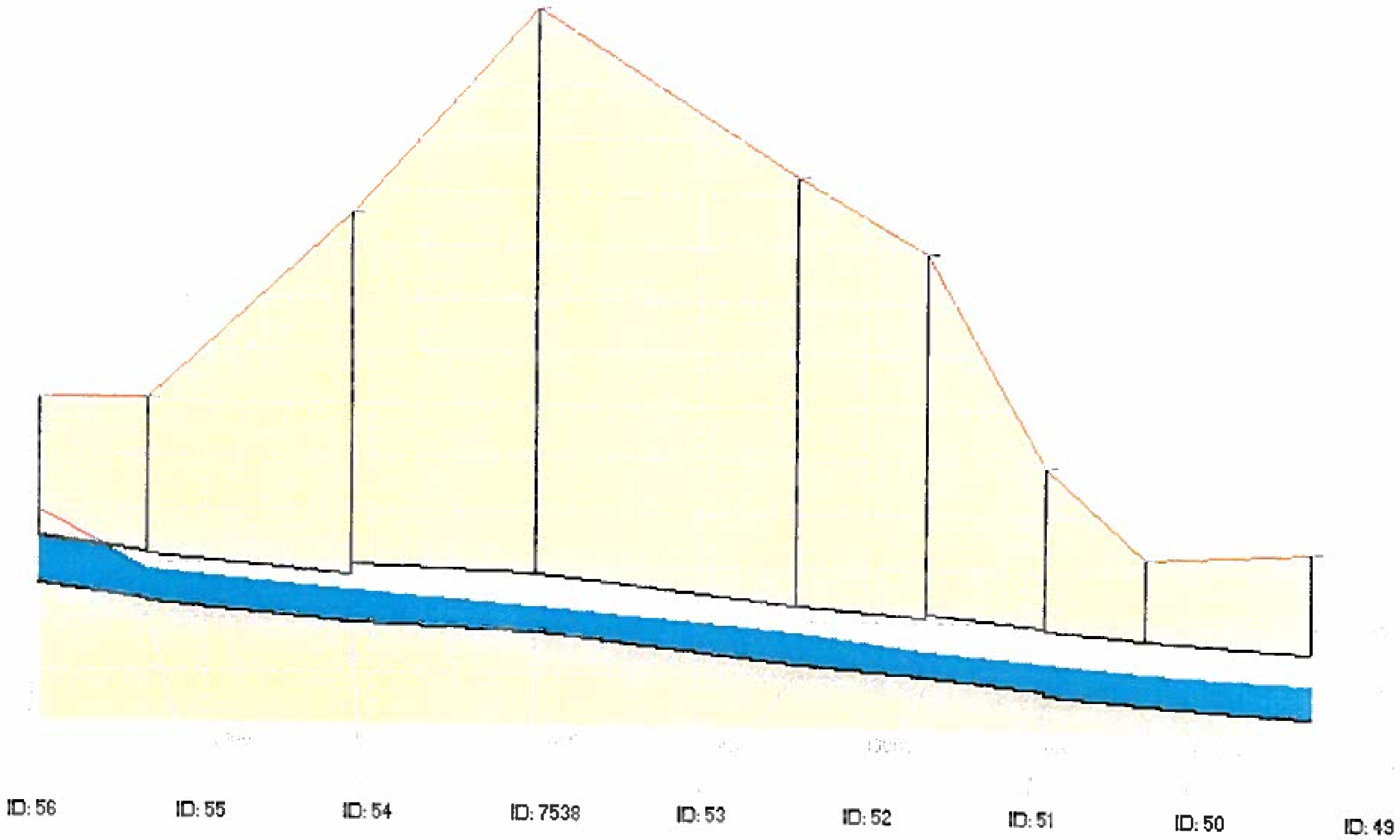
PI Segment MH 62 – MH 58



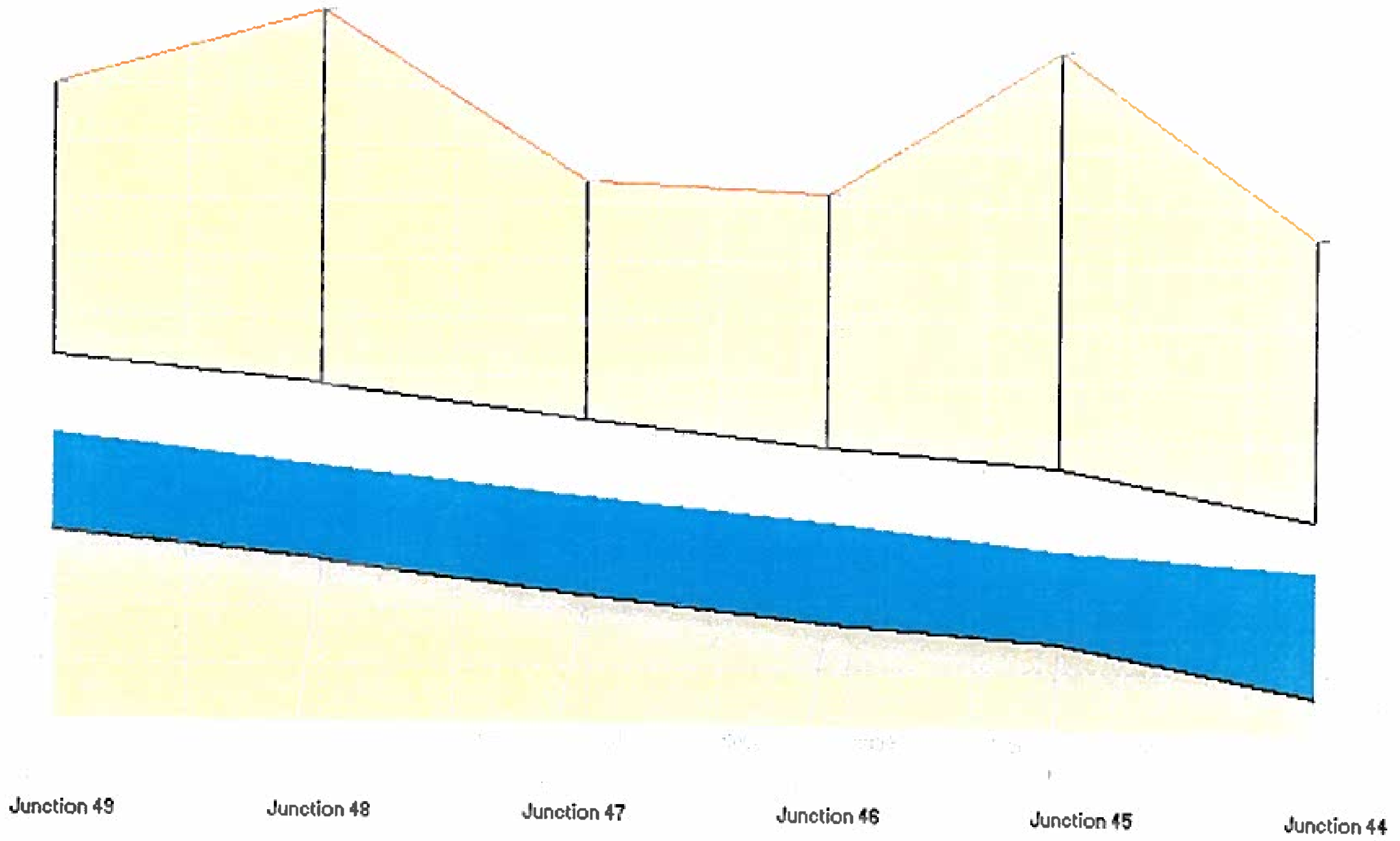
PI Segment MH 58 – MH 56



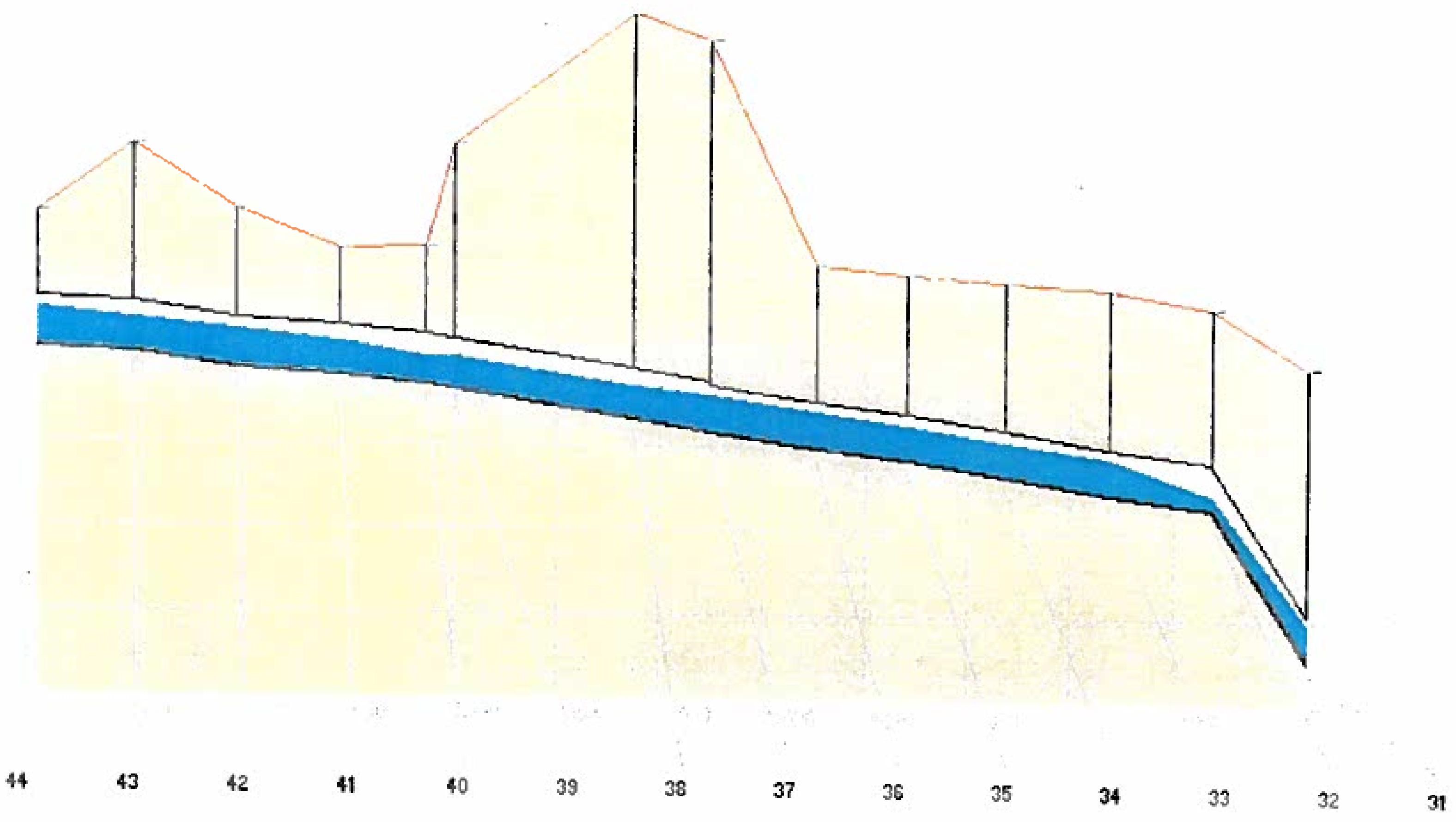
PI Segment MH 56 – MH 49



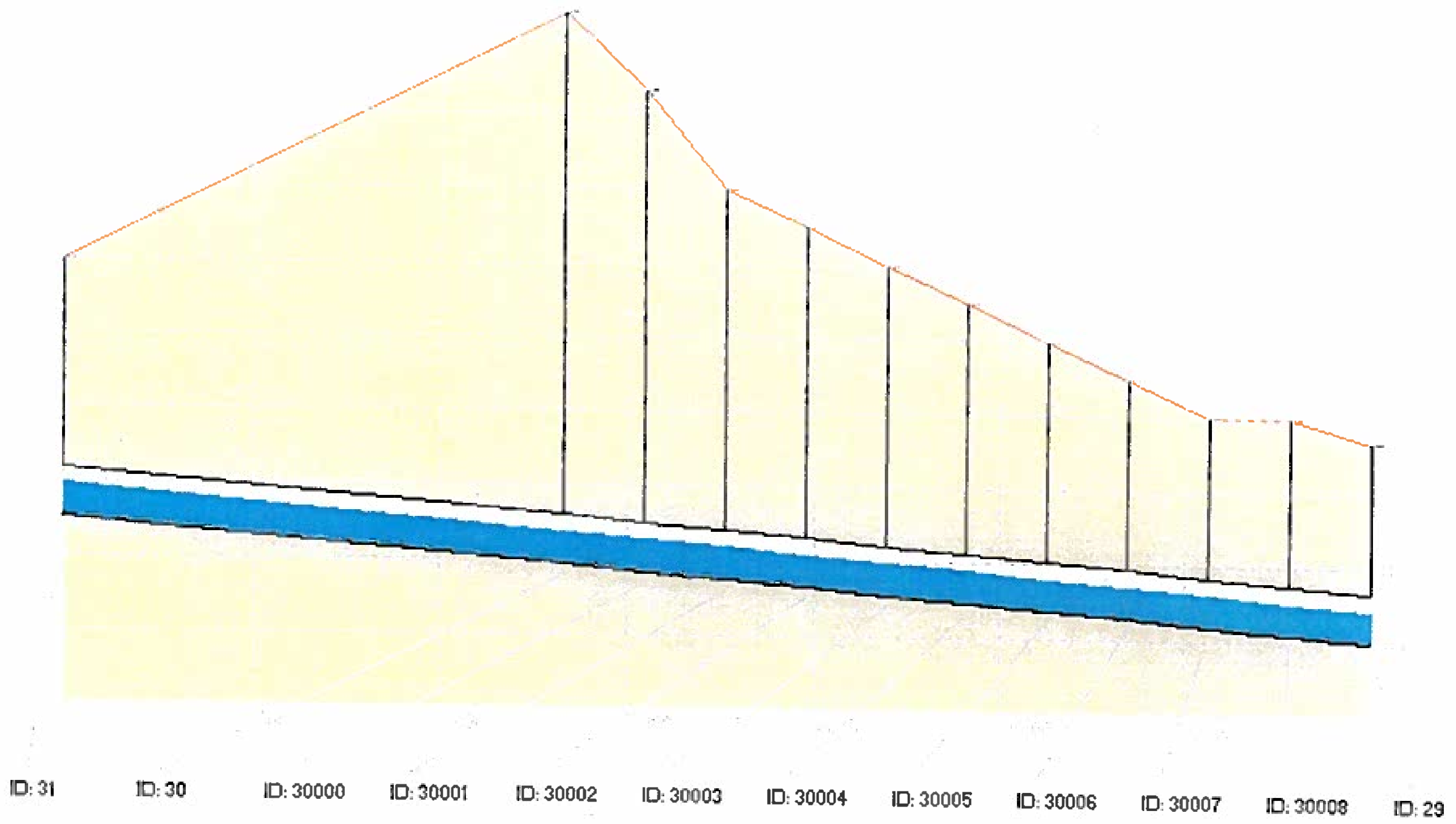
PI Segment MH 49 – MH 44



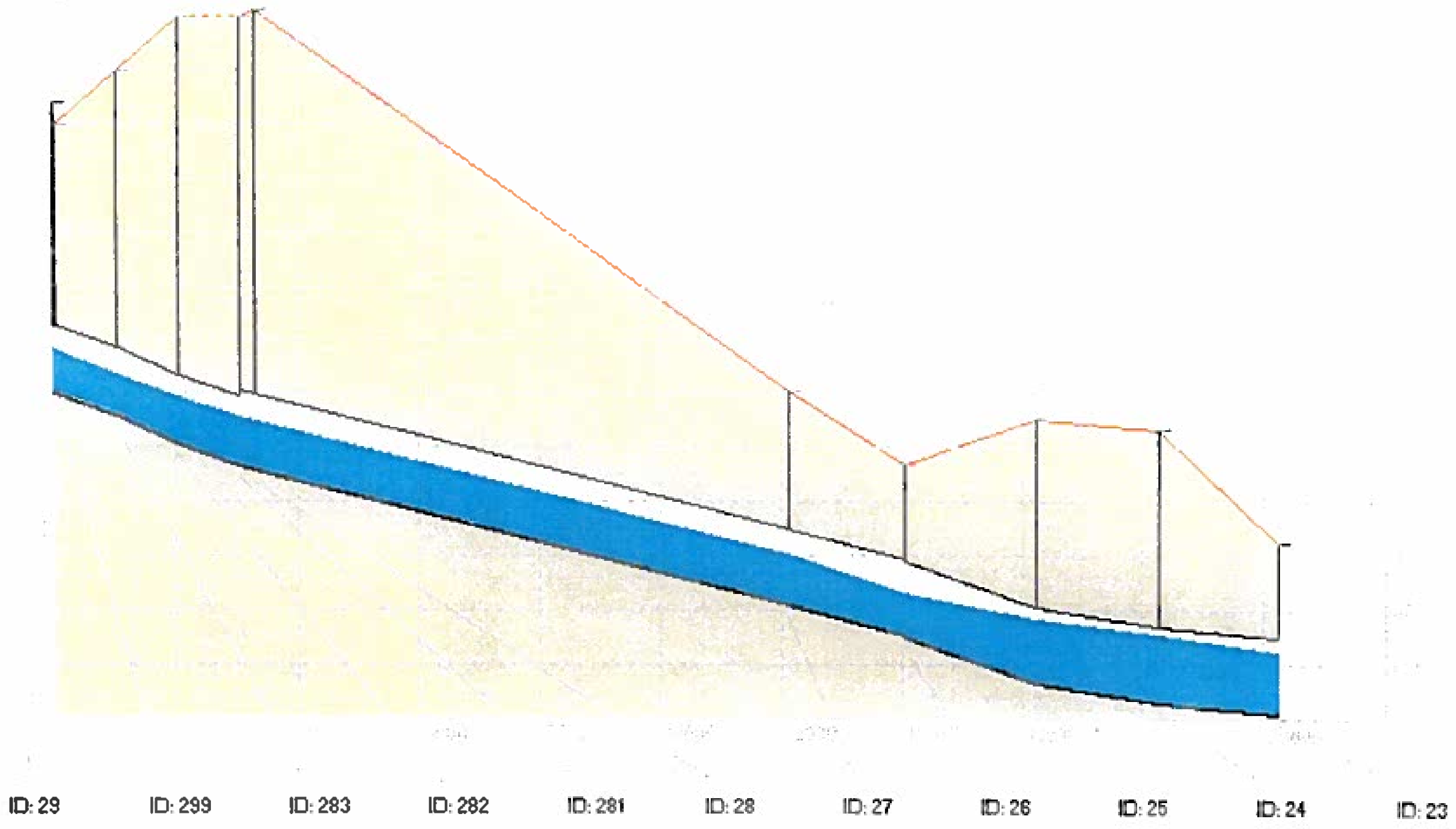
PI Segment MH 44 – MH 31



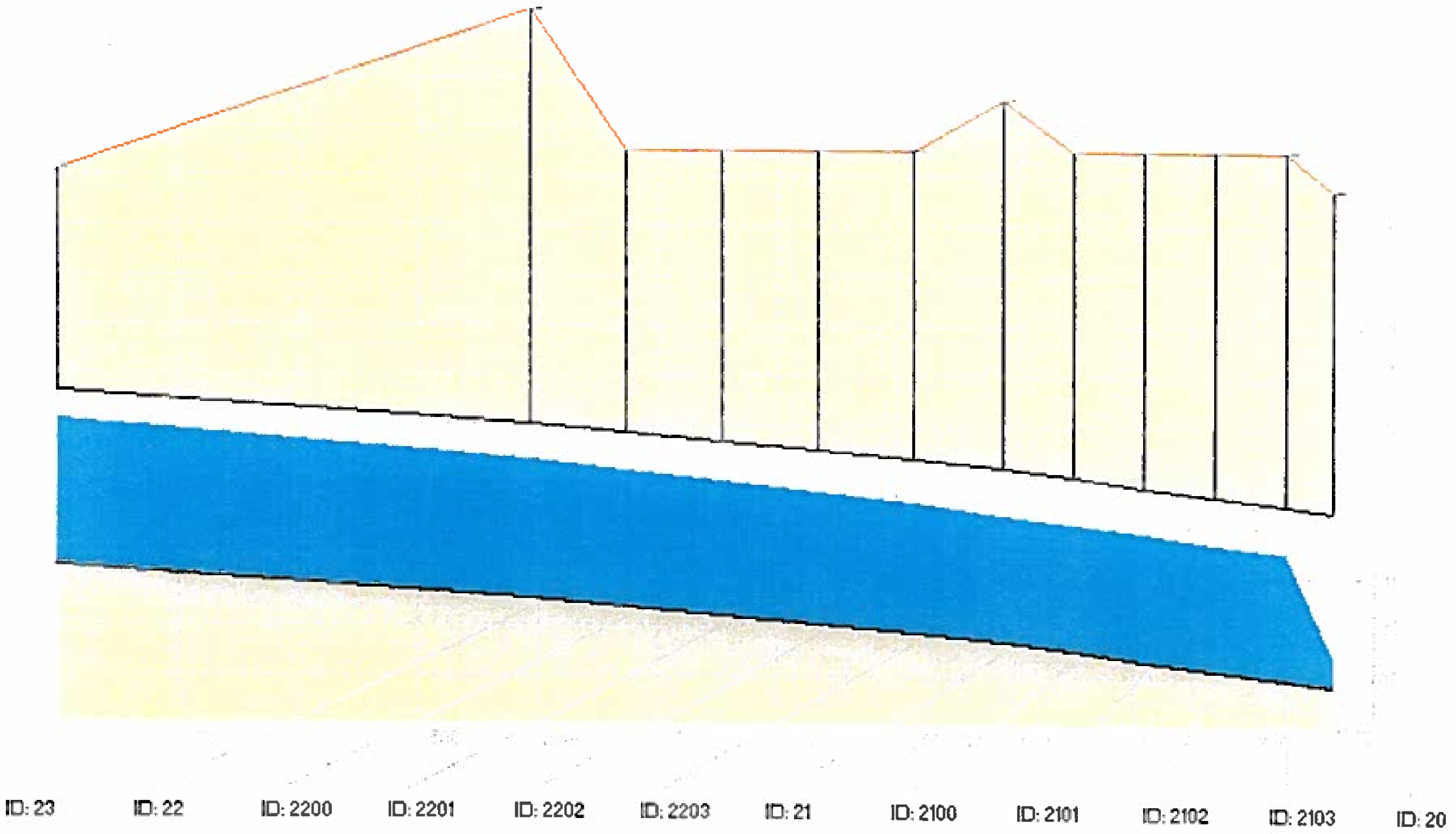
PI Segment MH 31 – MH 29



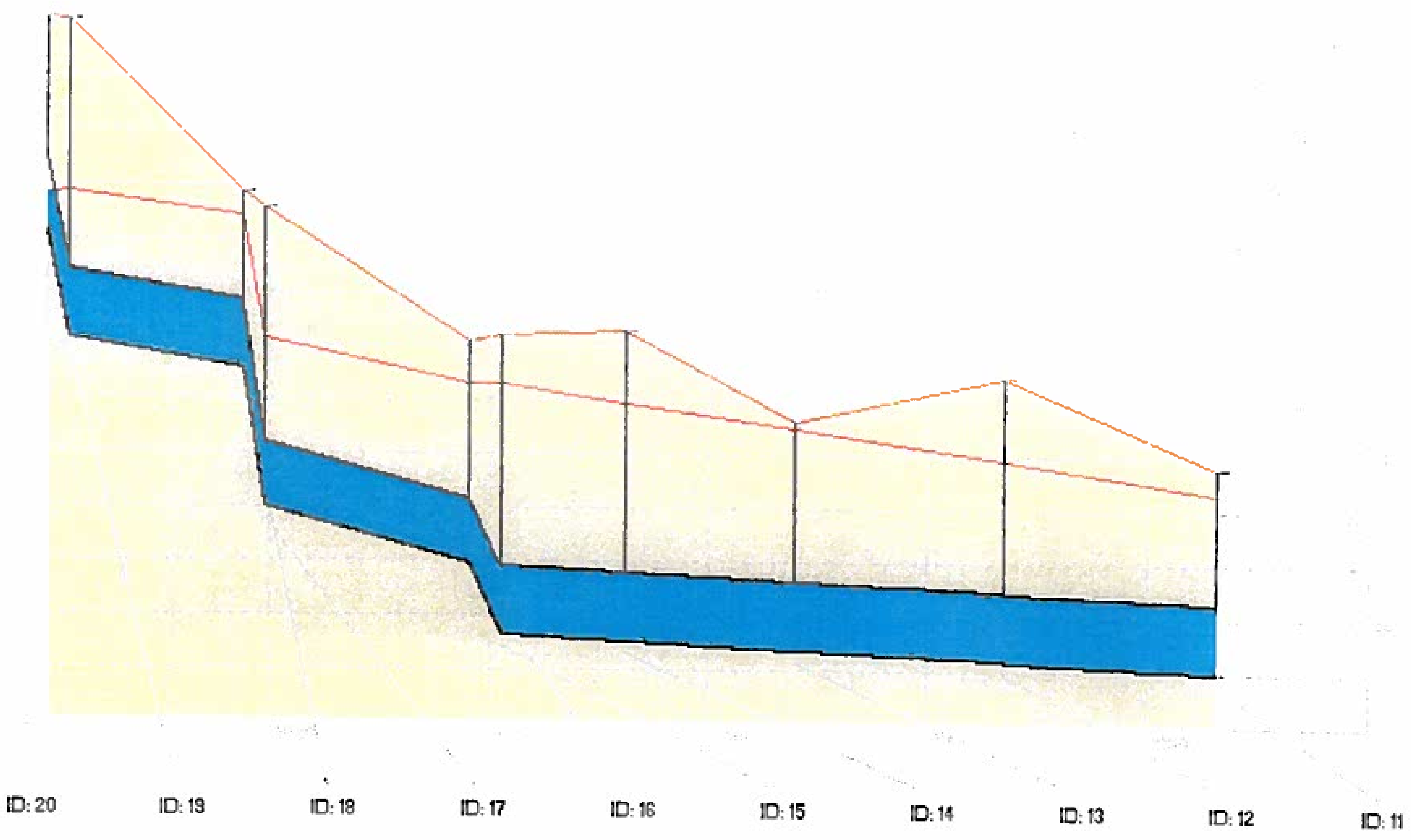
PI Segment MH 29 – MH 23



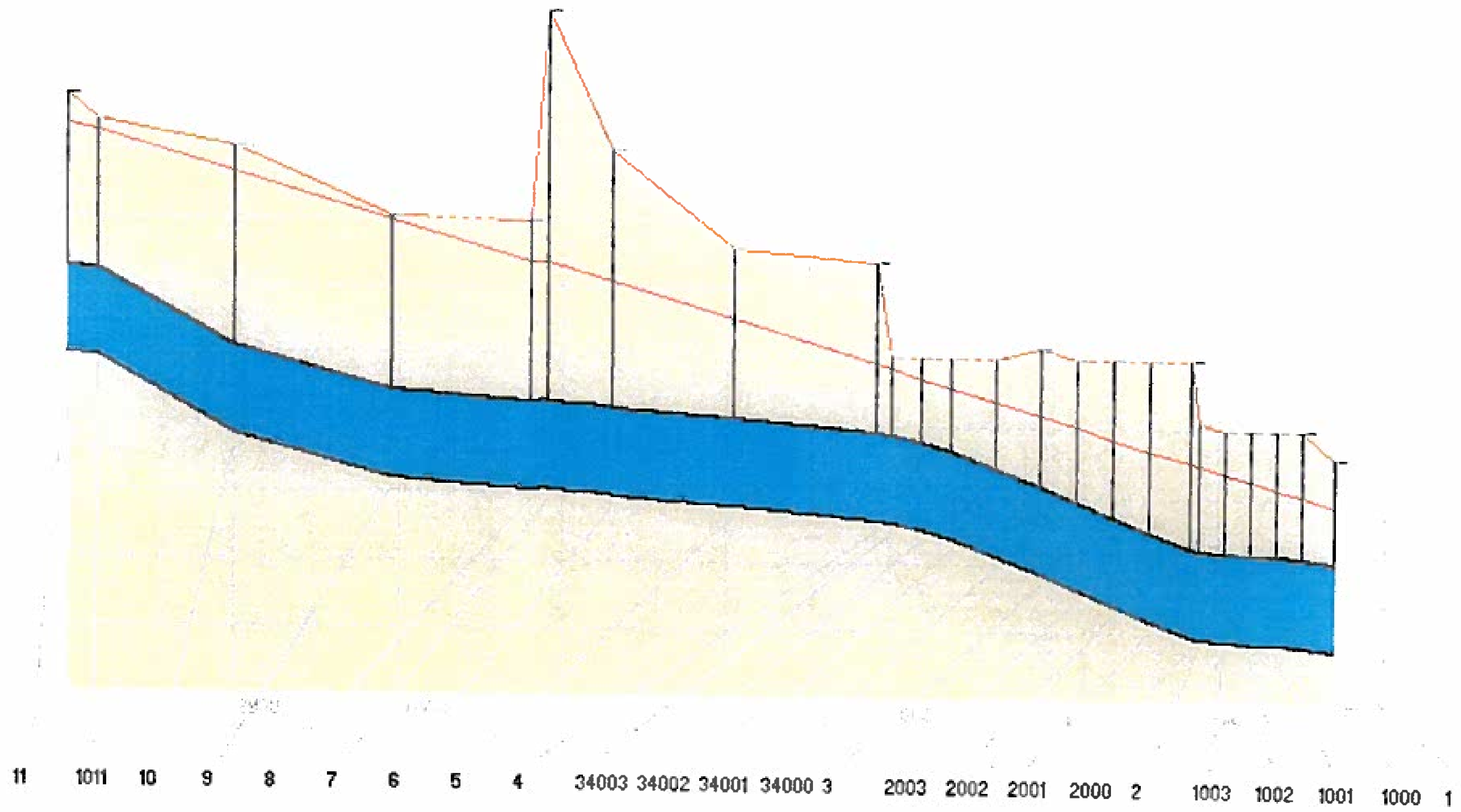
PI Segment MH 23 – MH 20



PI Segment MH 20 – MH 11



PI Segment MH 11 – MH 1



Appendix J

Hydraulic Analysis of February 22-23, 2003 Flooding Event

METROPOLITAN WASHINGTON COUNCIL OF GOVERNMENTS
POTOMAC INTERCEPTOR HYDRAULIC MODELING

Hydraulic Analysis of February 22-23, 2003 Flooding Event

REPORT

Prepared under
Metropolitan Washington Council of Governments
Contract 99-037: The Potomac Interceptor Conditions Survey, Modeling and Meter Study

APPENDICES

Appendix A	Unedited Hourly Precipitation Table
Appendix B	Reagan National Airport Station Climate Data February 2003; Washington Dulles Airport Station Climate Data for February 2003; Codes for the Climate Data.

INTRODUCTION

The Potomac Interceptor (PI) overflowed at manholes 9, 11, 12, 1991, and 3013 during the February 22-23, 2003 rainfall / snowmelt event. The return interval of the effective precipitation (rainfall and snowmelt) was analyzed and determined to be less than two years (see Attachment A). The combination of rainfall and snowmelt may have had a more severe effect on the PI than rainfall alone for the following reasons:

- Snowmelt before the February 22-23, 2003 rainfall may have caused higher than average groundwater infiltration.
- The snowmelt may have caused ponding around some of the manholes, which in turn could lead to excessive inflow at these locations.

A hydraulic model of the PI was previously developed and calibrated using rainfall from September 1999. The hydraulic model was also previously applied to determine the capacity of the PI for the year 2025 conditions. These results showed the PI would not flood for the 5-year storm in 2025. The assumptions used to model the year 2025 conditions are identified in the March 2002 Potomac Interceptor Hydraulic Modeling Report, and include offloading some WSSC, Loudoun County and Fairfax County flows based on the "No Further Action Scenario" identified by the PI Users Group. These assumptions were based upon identified future wastewater management plans (i.e. construction or expansion of wastewater treatment plants in the service area).

In order to provide insight into how the February 22-23, 2003 rainfall / snowmelt event compares with typical Soil Conservation Service (SCS) design storms, and assess what storm causes the PI to flood under existing conditions, the calibrated PI model was run for the SCS design storms. To provide a basis for comparison with the SCS design storms, the model was also run for the February 22-23, 2003 rainfall / snowmelt event. This report summarizes the model setup and the results of the analyses.

MODEL SETUP

The calibrated PI model was used as the base model for these evaluations. The model was adjusted to simulate bolted manholes and peak flow limitations.

Bolted Manholes. The PI is designed to operate with bolted manholes at some locations. The bolted manholes were simulated by raising the ground elevation by 10-feet. The following manholes were simulated as bolted for this analysis.

Table 1. Summary of Bolted Manholes for Existing Conditions

Manhole Designation	Ground Elev. (ft.) for Bolted Manhole
1	48
4	62
5	63
6	70
7	80
8	65
9	65
10	70
11	74
12	82
13	78
3008	62
3013	68
3014	70
3015	68
1994	44.8
1995	46.6
1996	50

Peak Flow Limitations. Based on the year 2025 evaluations, it was determined that the peak flow entering the PI for the design storms was unrealistically high. This occurs because of upstream flow restrictions that were not apparent for the model calibration storms. Peak flow limitations were specified at the following locations.

Table 2. Peak Flow Limitations Specified in Model for Existing Conditions

Description	Conduit ID	Flow Limitation (cfs)
CJ1	94011	49.35
CJ2	94012	24.75 *
Pimmit	94042	46.39
Sully #1	95132	15.93
Rocky Run	920	4.64
Countryside #2	9951	4.64
Sugarland	9325	34.96
Scotts Run	923	16.24
Dulles	983	9.00

*** Based upon the WSSC Standard Operating Procedure for CJ valve**

SCS Rainfall Data. SCS rainfall was provided by Mr. Timothy Murphy at MWCOG for the 2, 5, 10, 20, 25, 50, and 100 year 24-hour design storms. These data are summarized in Table 3.

Table 3. Summary of 24-hour SCS Design Storms

Hour	2-Year (inch)	5-Year (inch)	10-Year (inch)	15-Year (inch)	20-Year (inch)	25-Year (inch)	50-Year (inch)	100-Year (inch)
1	0.03	0.05	0.06	0.06	0.07	0.07	0.08	0.09
2	0.04	0.05	0.06	0.06	0.06	0.08	0.09	0.09
3	0.04	0.05	0.06	0.07	0.08	0.09	0.09	0.1
4	0.04	0.06	0.06	0.06	0.08	0.08	0.1	0.11
5	0.05	0.07	0.08	0.09	0.09	0.11	0.12	0.12
6	0.05	0.07	0.08	0.08	0.1	0.11	0.12	0.13
7	0.06	0.08	0.1	0.11	0.12	0.13	0.14	0.16
8	0.06	0.09	0.1	0.11	0.12	0.14	0.15	0.16
9	0.09	0.12	0.14	0.14	0.16	0.18	0.21	0.22
10	0.1	0.14	0.17	0.18	0.21	0.23	0.25	0.28
11	0.18	0.24	0.28	0.29	0.33	0.37	0.41	0.44
12	1.33	1.84	2.15	2.26	2.56	2.87	3.17	3.43
13	0.35	0.49	0.57	0.6	0.68	0.75	0.84	0.91
14	0.15	0.21	0.25	0.26	0.29	0.33	0.37	0.39
15	0.1	0.14	0.15	0.17	0.19	0.21	0.23	0.25
16	0.08	0.11	0.13	0.13	0.15	0.17	0.18	0.2
17	0.07	0.09	0.11	0.12	0.13	0.15	0.17	0.18
18	0.06	0.08	0.1	0.1	0.11	0.13	0.14	0.15
19	0.05	0.07	0.08	0.08	0.1	0.1	0.12	0.13
20	0.04	0.07	0.07	0.08	0.09	0.1	0.11	0.12
21	0.04	0.05	0.06	0.06	0.07	0.08	0.09	0.1
22	0.04	0.05	0.06	0.07	0.07	0.09	0.09	0.1
23	0.04	0.05	0.06	0.06	0.07	0.08	0.09	0.09
24	0.03	0.05	0.06	0.06	0.07	0.07	0.08	0.09
Total Rainfall (inch)	3.12	4.32	5.04	5.30	6.00	6.72	7.44	8.04

Flow Meter Data. Flow meter data were provided by Mr. John Trypus from DCWASA, and are summarized in Table 4. The maximum flow in the PI was 197.1 cfs at MH 2 during the February 22-23, storm event.

Table 4. Summary of Flow Meter Data for February 22-23, 2003 Storm

In-Line Meter (MH Location)	Pipe ID	Upstream Node	Downstream Node	Peak Flow (cfs)	Peak Depth (ft)
PI					
MH-2	5000	2	1	197.1	7.15
MH-29	50274	29	28	152.9	5.37
MH-40	5038	40	39	110.5	6.33
MH-45	5043	45	44	83	6.22
MH-56	5055	56	55	57.86	3.73
MH-301	5160	301	300	41.33	4.43
UPIRS					
MH-1979	6036	1978	1977	257.6	8.2
UPI					
MH-2955	8045	2955	2954	49.49	4.26

RESULTS

Comparison of SCS Storms to the February 22-23, 2003 Storm. The PI hydraulic model was run for the SCS design storms listed in Table 3 and then compared to the measured flows and depths (Table 4). These results are summarized in Table 5. Figure 1 is a plot of simulated flows versus measured flows at Manhole 29. Based on these comparisons, the February 22-23, 2003 rainfall / snowmelt event resulted in peak flows and depths in the PI that were between a 2-year and 5-year design storm.

Analysis of Flooding. Flooding volumes in the PI were computed for the design storms listed in Table 3. These results are summarized in Table 6. During the 5-year storm, the PI model predicted 0.39 MG of flooding occurred at MH-73. This location did not overflow during the year 2025 conditions. Further investigation indicates that under existing conditions this location receives flow from the Loudoun County Sanitation Authority (LCSA) and is recorded by the Mercure flow meter. The Mercure flow meter data were not available during the 1999 calibration. Therefore, this was an un-metered inflow point. The flow inputs at this location were estimated during model calibration based on comparison of the modeled jurisdictional flow inputs to the PI upstream of Manhole 56 with Meter 56, the downstream in-line flow meter. The inflow at this location was removed for the year 2025 conditions due to planned construction of a wastewater treatment plant in the LCSA service area. Since flooding was not reported at this location, it may be surmised that the model may be over-predicting the overflow at this location. The Mercure flow meter has a peak flow of 4.1 cfs during the February 22-23 storm, while the simulated inflow at this location for the 5-year storm under existing conditions was 25.5 cfs. Thus it is likely that recalibration of the model using the Mercure flow meter would eliminate the overflow at this location during the 5-year storm. It is noted that overflow did not occur at MH 9, 11, 12 and 3013 for the 5-year storm because the ground elevations at these locations were raised by 10-feet to simulate bolted manholes.

Table 5. Comparison of Simulated Flow and Depth for SCS Design Storms to Measured Flow and Depth for February 22-23 Storm

	Measured Flow and Depth at Meter							
	MH-2	MH-29	MH-40	MH-45	MH-56	MH-301	MH-1979	MH-2955
Peak Flow (cfs)	197.10	152.90	110.50	83.00	57.86	41.33	257.60	49.49
Peak Depth (ft)	7.15	5.37	6.33	6.22	3.73	4.43	8.20	4.26
Simulated Flow and Depth for Various Storms								
2-Year Storm								
Peak Flow (cfs)	183.40	140.90	101.70	65.58	51.24	37.71	253.50	40.81
Peak Depth (ft)	6.24	3.96	3.72	3.50	3.42	2.48	5.23	3.89
5-Year Storm								
Peak Flow (cfs)	225.80	168.30	130.70	85.09	63.40	40.40	289.00	45.26
Peak Depth (ft)	12.17	4.48	5.79	5.79	6.02	2.58	5.70	4.15
10-Year Storm								
Peak Flow (cfs)	228.60	177.40	135.20	91.79	65.70	41.99	302.20	45.37
Peak Depth (ft)	12.53	4.70	7.26	8.10	6.89	3.69	5.78	4.19
15-Year Storm								
Peak Flow (cfs)	226.20	180.50	135.20	94.03	65.35	41.86	324.00	45.54
Peak Depth (ft)	13.86	4.78	7.97	8.91	7.20	4.83	6.00	4.20
20-Year Storm								
Peak Flow (cfs)	226.40	194.50	138.30	98.97	67.23	43.29	327.70	46.04
Peak Depth (ft)	13.09	5.08	10.56	12.54	11.68	8.54	6.02	4.22
25-Year Storm								
Peak Flow (cfs)	226.50	203.40	139.30	96.60	68.22	44.81	316.90	46.44
Peak Depth (ft)	13.37	11.91	11.52	13.86	13.99	9.89	5.80	4.24
50-Year Storm								
Peak Flow (cfs)	226.60	224.90	136.30	99.23	70.50	46.50	300.10	46.80
Peak Depth (ft)	14.82	15.43	12.47	14.21	15.52	10.24	5.81	4.25
100-Year Storm								
Peak Flow (cfs)	226.80	222.00	137.70	107.00	71.44	47.34	295.60	47.24
Peak Depth (ft)	13.69	16.72	12.77	14.25	16.16	10.27	5.72	4.25

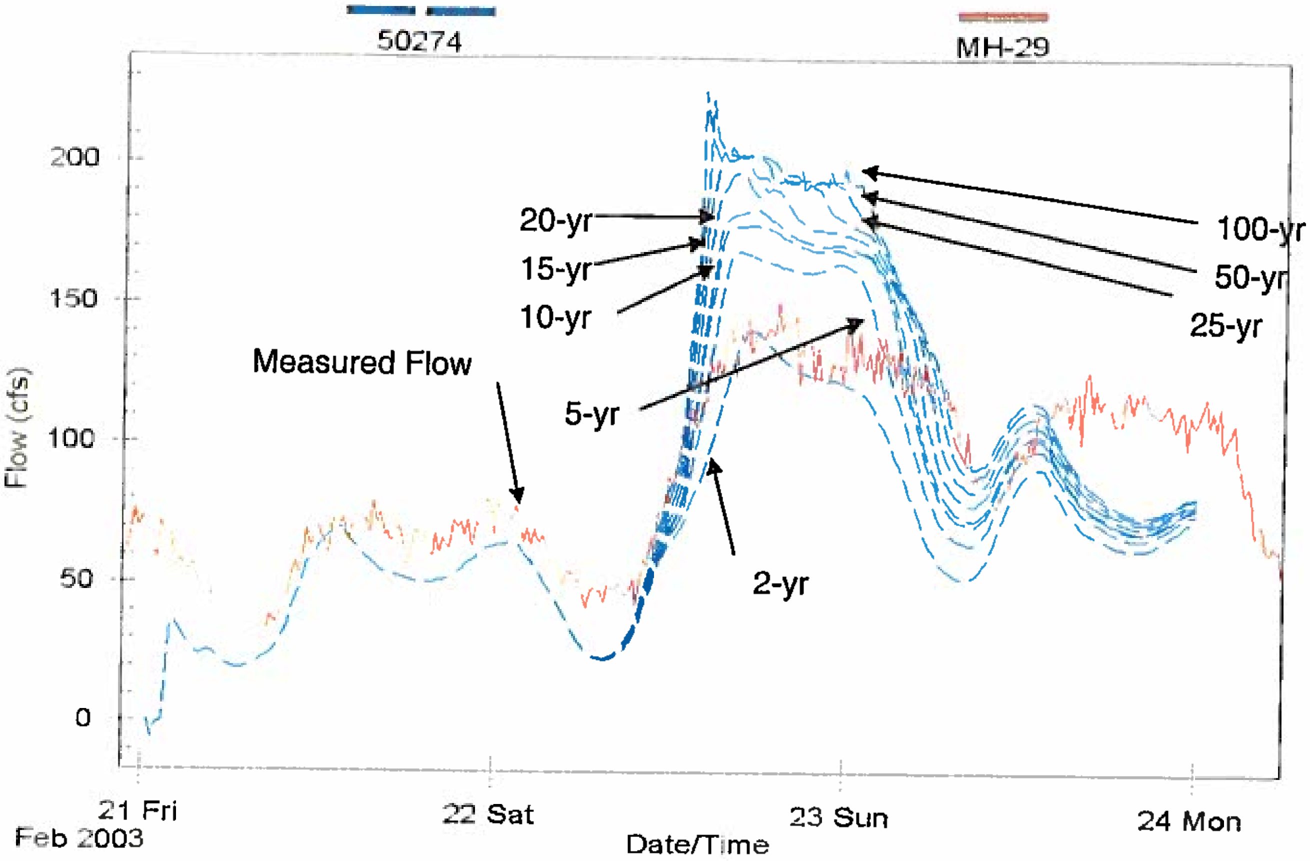


Figure 1. Comparison of Measured and Simulated Flows at Manhole 29

Table 6. Simulated Flooding Volumes for SCS Design Storms

Model Node	2-yr	5-yr	10-yr	15-yr	20-yr	25-yr	50-yr	100-yr
9	0.00	0.00	0.04	0.06	0.15	0.26	0.39	0.47
13	0.00	0.00	0.51	0.70	1.01	1.18	1.30	1.35
18	0.00	0.00	0.47	1.09	3.55	6.79	9.66	11.37
26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
47	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.05
50	0.00	0.00	0.00	0.00	0.00	0.08	0.76	1.46
60	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02
73	0.00	0.39	1.25	1.61	3.10	4.67	6.08	7.21
103	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.05
113	0.00	0.00	0.00	0.00	0.00	0.10	0.24	0.35
115	0.00	0.00	0.00	0.00	0.01	0.04	0.05	0.06
300	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.16
325	0.00	0.00	0.00	0.00	0.00	0.02	0.11	0.20
405	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.89
4038	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
7688	0.00	0.00	0.00	0.00	0.00	0.15	0.47	0.80
34003	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01
Sum	0.00	0.39	2.27	3.47	7.84	13.30	19.38	24.47

Table 7 is a summary of manholes in the PI in which the simulated hydraulic grade line (HGL) exceeded the ground elevation for one or more SCS design storms. It is noted that the flood elevation for bolted manholes was assumed to be 10-feet above the ground surface. The model results indicate that the HGL reached the flood elevation at manholes 13 and 73 during the 5-year storm. Although the HGL reached the flood elevation at manhole 13, the amount of flooding was very small (less than 5 gallons) and therefore was not included in Table 6. The model results indicate flooding would have occurred during the 2-year storm at manhole no. 1 and during the five year storm at manhole nos. 4, 5,6,8,9,10,11,12, and 13 if the bolted manholes were not functioning properly.

Comparison of Model to Measurements for February 22-23, 2003 Storm. The February 22-23, 2003 rainfall / snowmelt event was simulated to assess how well the PI model was able to reproduce measured flows. The rainfall from the February 22-23, 2003 storm, adjusted to account for snowmelt as described in Attachment A, was input to the model. The results were then compared in Figure 2 through 9. In general, the base flows were under-predicted by the model, indicating the groundwater infiltration in February, 2003 was higher than specified in the model. This may be the result of snowmelt before the storm. It is also noted that the receding limbs of the hydrographs are under-predicting. Again, this may be the result of snowmelt after the storm. Visual observation of the plots suggests that the peak flows would match fairly well if the base flows were adjusted to match the higher infiltration during February, 2003

Table 7. Summary of Manholes in Potomac Interceptor Where the Simulated Hydraulic Grade Exceeded the Ground Elevation for SCS Design Storms

Model Node	Ground (ft.)	Flood Elev. (ft.)[1]	2-Year (ft.)	5-Year (ft.)	10-Year (ft.)	15-Year (ft.)	20-Year (ft.)	25-Year (ft.)	50-Year (ft.)	100-Year (ft.)
1	38	48	38.96	44.49	45.23	45.69	45.84	46.36	46.18	46.18
4	52	62	47.82	54.5	55.34	55.33	55.36	55.34	55.33	55.33
5	53	63	50.02	57.68	58.43	58.38	58.53	58.36	58.52	58.52
6	60	70	50.51	62.16	62.9	62.78	63.33	65.34	65.6	65.6
8	55	65	50.43	61.9	62.48	62.33	62.56	63.45	63.82	63.82
9	55	65	52.3	64.95	65	65	65	65	65	65
10	60	70	54.27	68.47	68.55	68.5	68.58	68.6	68.54	68.54
11	64	74	59.27	72.04	72.15	72.07	72.17	72.21	72,13	72.13
12	72	82	61.67	75.04	80.38	80.08	81.21	75.12	75.1	75.1
13	68	78	63.48	78	78	78	78	78	78	78
18	99.39	99.39	86.93	98.47	99.39	99.39	99.39	99.39	99.39	99.39
23	116.29	116.29	105.69	106.29	106.59	106.62	115.77	115.57	116.29	116.29
26	123.46	123.46	111.25	111.74	112.75	112.84	123.46	123.46	123.46	123.46
40	193.24	193.24	180.49	191.75	191.56	192.2	192.41	191.55	193.24	193.24
41	192.9	192.9	182.12	183.97	185.63	186.2	189.18	190.31	192.9	192.9
42	197.39	197.39	183.37	191.53	194.56	195.04	197.21	194.82	197.39	197.39
44	197.06	197.06	185.8	190.39	190.66	193.84	194.98	196.29	197.06	197.06
46	198.39	198.39	187.31	189.07	192.6	193.64	198.39	198.39	198.39	198.39
47	198.79	198.79	188.2	189.32	193.38	193.49	197.72	198.77	198.79	198.79
49	202.01	202.01	190.23	191.22	195.1	195.18	200.37	202.01	202.01	202.01
50	201.21	201.21	191.17	191.78	195.82	196.98	201.21	201.21	201.21	201.21
55	215.52	215.52	200.5	204.18	204.64	204.5	211.64	215.03	215.52	215.52
56	215.44	215.44	201.41	204.99	205.71	205.55	212.7	215.44	215.44	215.44
57	215.96	215.96	202.35	206.2	208.51	207.69	213.72	215.96	215.96	215.96
59	217.09	217.09	204.08	208.52	211.42	211.17	215.43	217.09	217.09	217.09
60	217.35	217.35	205	213.3	217.35	214.16	216.86	217.35	217.35	217.35
66	220.35	220.35	209.39	218.7	220.35	220.35	220.35	220.35	220.35	220.35
73	224.29	224.29	215.77	224.29	224.29	224.29	224.29	224.29	224.29	224.29
103	269.55	269.55	260.73	261.07	261.2	261.31	267.55	268.79	269.55	269.55
113	275.29	275.29	268.15	268.24	268.24	268.24	275.29	275.29	275.29	275.29
115	276.65	276.65	269.66	269.72	269.72	269.72	276.65	276.65	276.65	276.65
300	197.28	197.28	188.55	189.01	191.89	192	195.96	197.28	197.28	197.28
324	230.5	230.5	219.48	221.18	221.63	222.77	229.15	230.5	230.5	230.5
325	231.54	231.54	220.82	222.7	223.16	224.29	230.67	231.54	231.54	231.54
405	172.67	172.67	163.55	163.8	163.95	164.01	164.16	172.16	172.67	172.67
4038	271.2	271.2	263.14	263.29	263.37	263.4	268.44	270.03	271.2	271.2
7688	220.49	220.49	211.16	218.96	219.14	219.18	220.49	220.49	220.49	220.49
34003	55	55	47.47	54.16	55	55	55	55	55	55

1. Flood elevation is assumed to be equal to ground elevation, except at bolted manholes; flood elevation at bolted manholes is assumed to be 10 feet above ground elevation

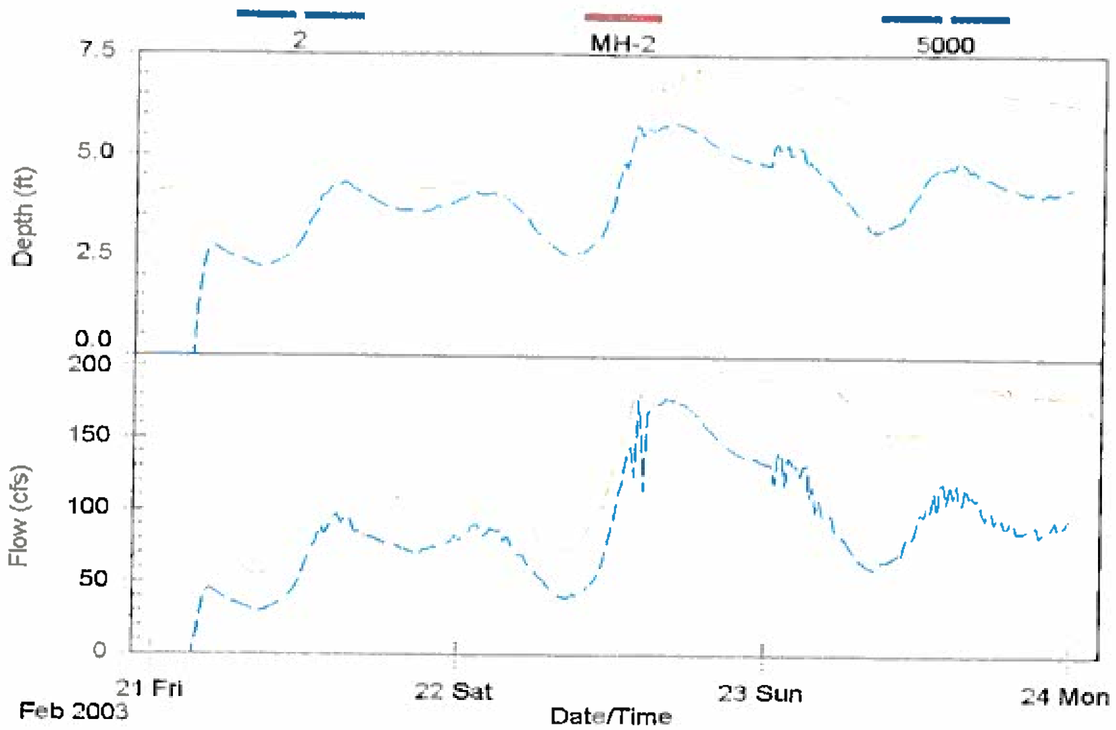
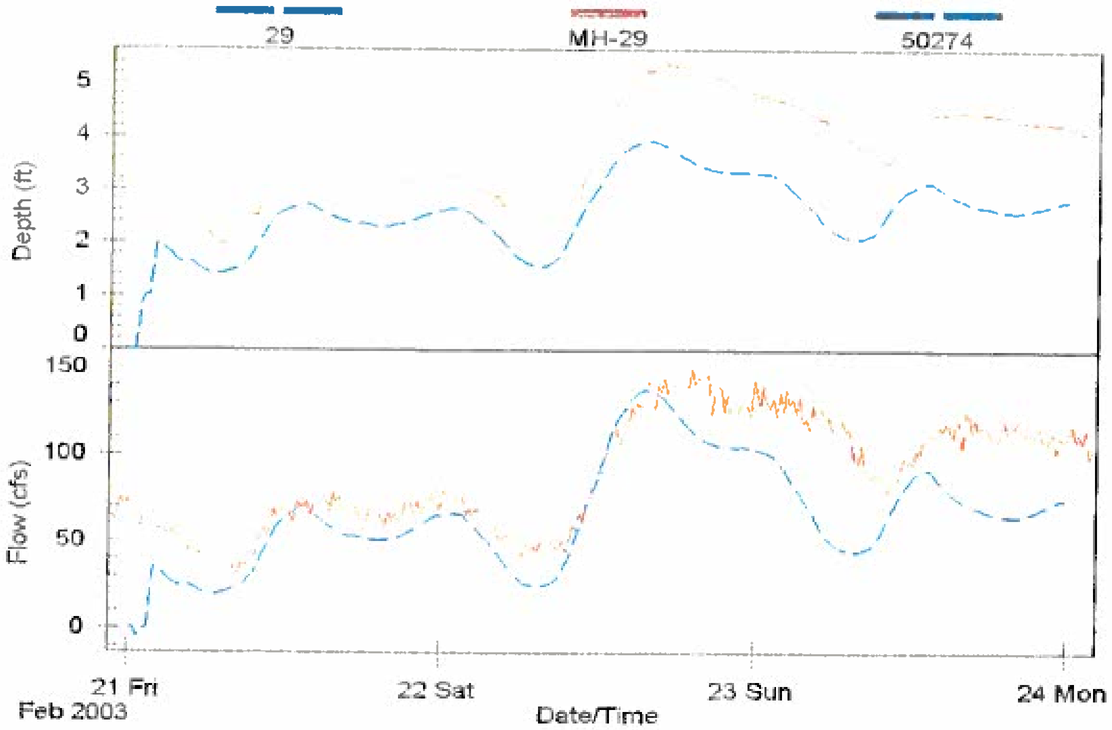
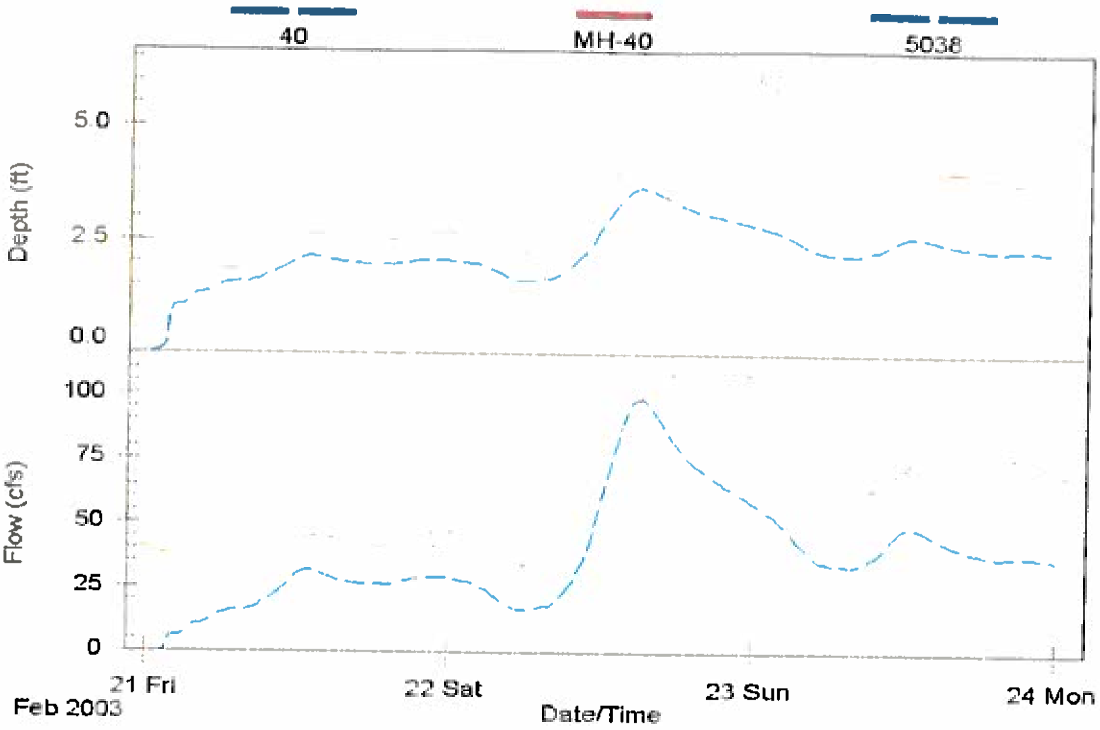


Figure 2. Comparison of Measured and Simulated Flow at MH-2 for February. 22-23, 2003 Storm





Storm

Figure 4. Comparison of Measured and Simulated Flow at MH-40 for February. 22-23, 2003 Storm

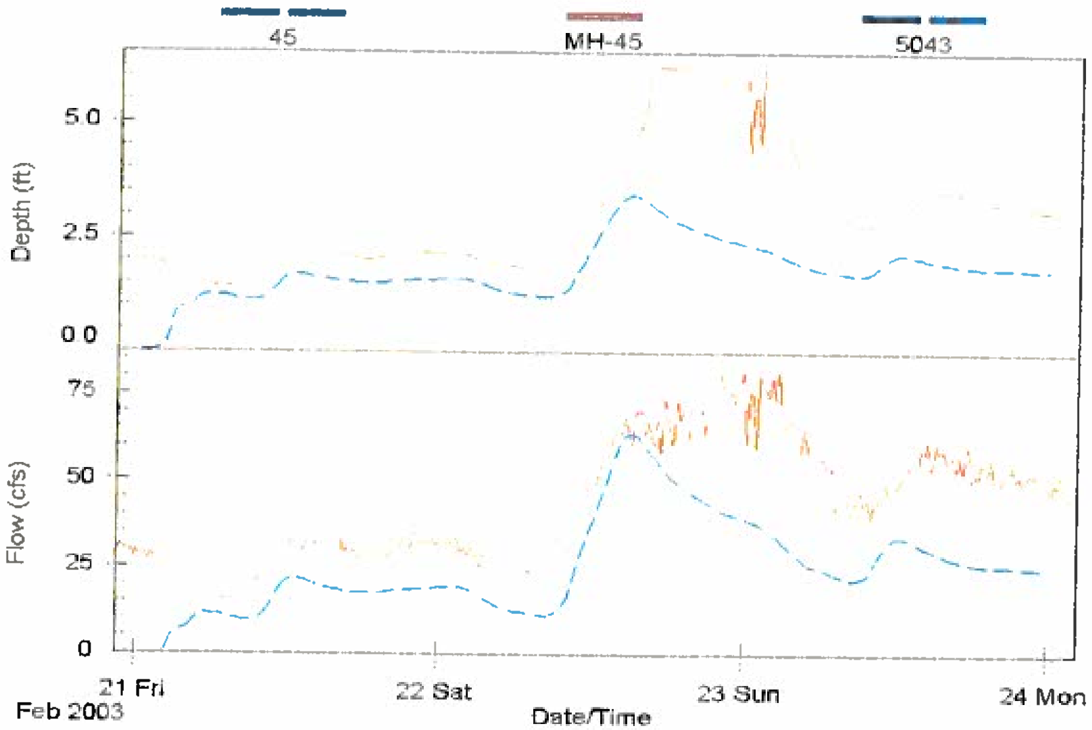


Figure 5. Comparison of Measured and Simulated Flow at MH-45 for February. 22-23, 2003 Storm

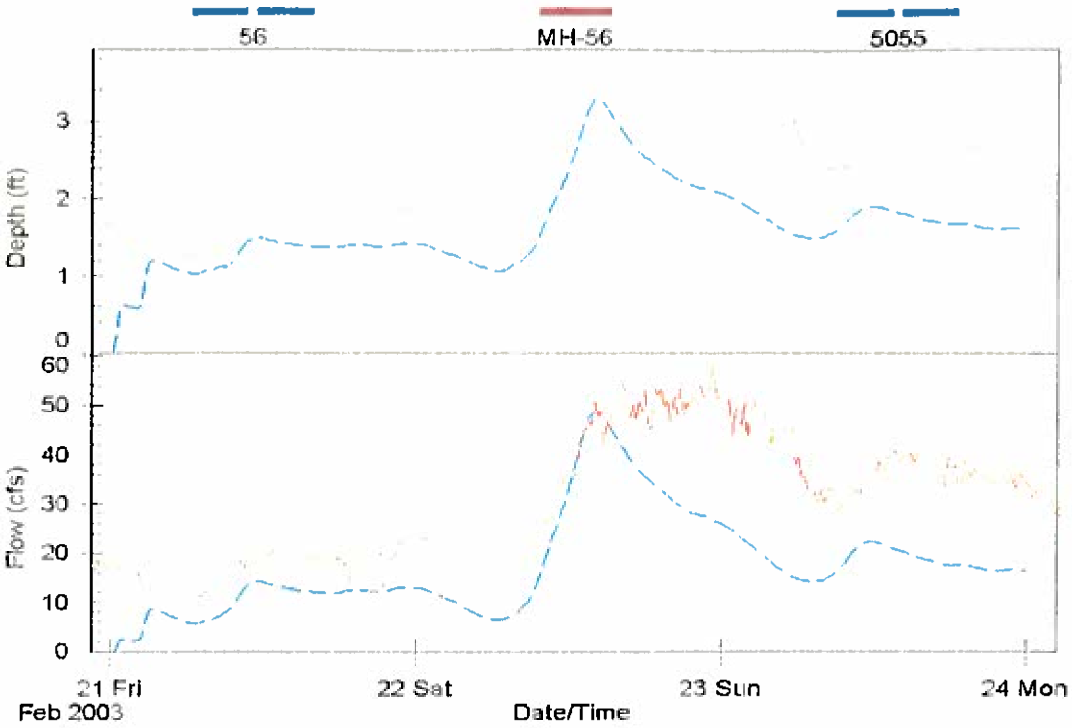


Figure 6. Comparison of Measured and Simulated Flow at MH-56 for February. 22-23, 2003 Storm

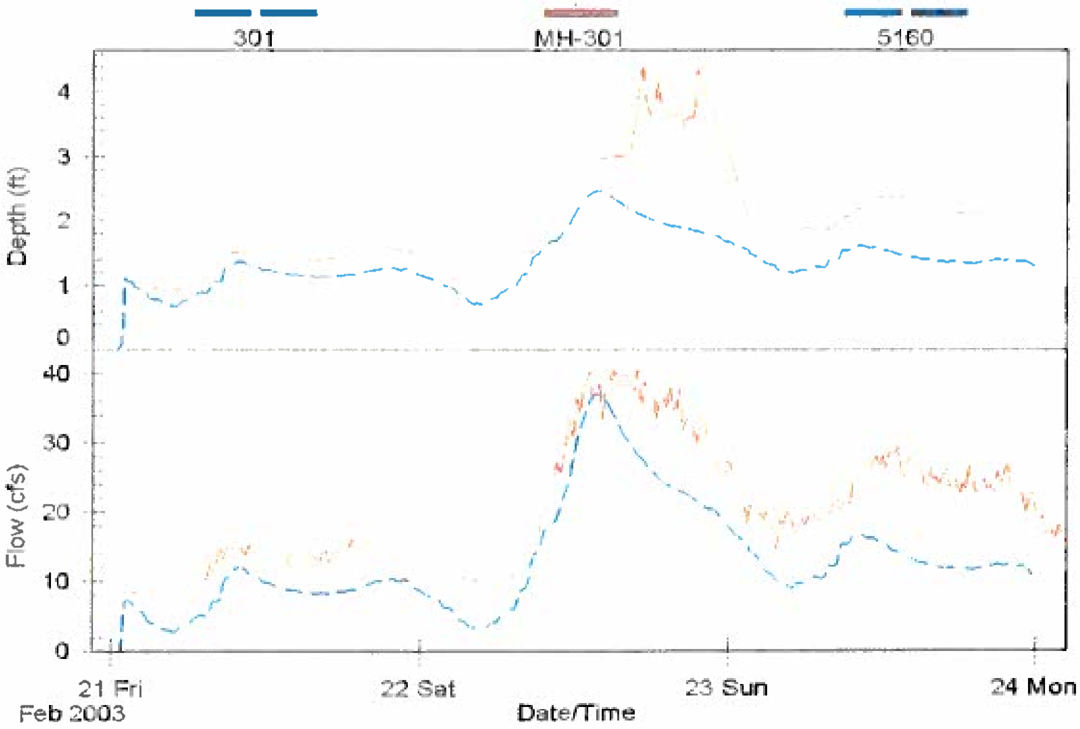


Figure 7. Comparison of Measured and Simulated Flow at MH-301 for February. 22-23, 2003 Storm

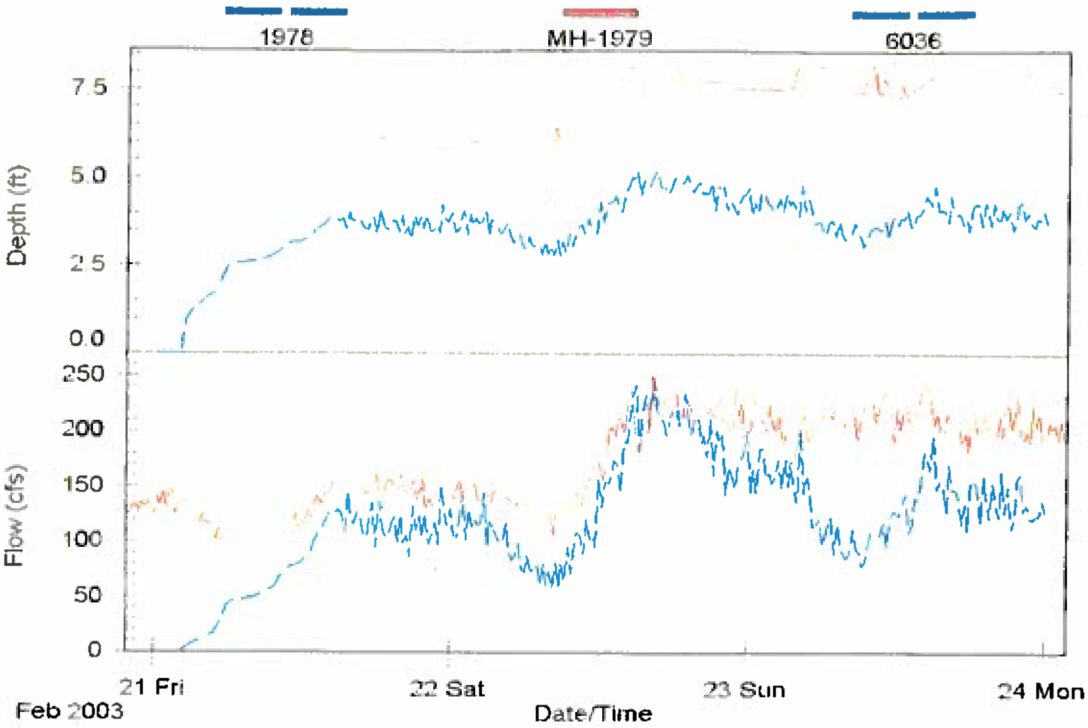


Figure 8. Comparison of Measured and Simulated Flow at MH-1979 for February. 22-23, 2003 Storm

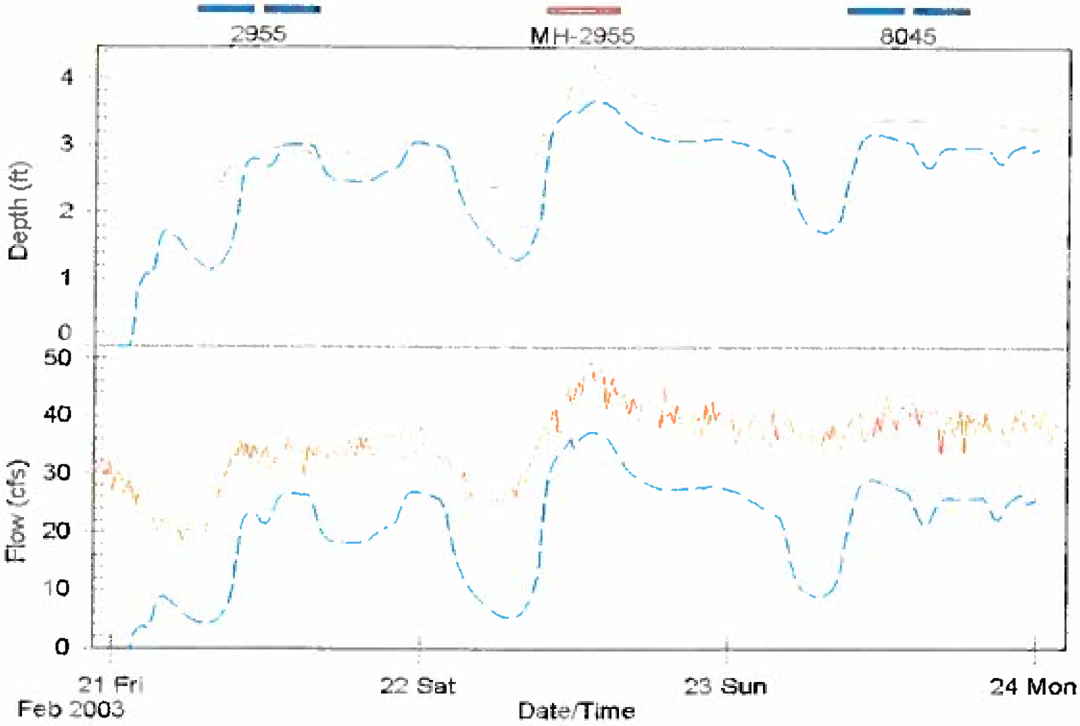


Figure 9. Comparison of Measured and Simulated Flow at MH-2955 for February. 22-23, 2003 Storm

CONCLUSIONS

A hydraulic evaluation of the Potomac Interceptor was conducted to assess how the February 22-23, 2003 rainfall / snowmelt event compares with typical Soil Conservation Service (SCS) design storms, and to assess what storm causes the PI to flood under existing conditions. The February 22-23, 2003 storm was also simulated and compared to flow meter data.

The model results indicate that the February 22-23, 2003 storm resulted in peak flows and water levels that were between a 2-year and 5-year design storm.

The PI model predicted flooding in the PI during the 5-year storm at Manhole 73, which is the location of flow input from Mecure. It was determined that the model may be over-predicting the inflow at this location because the meter data was not available when the model was calibrated. The model did not predict flooding at manholes nos. 9, 11, and 12 as these were simulated as bolted. Flooding would have occurred at these locations if the bolts were not operating properly.

Comparison of the measured and simulated flows for the February 22-23 storm indicates that the model is under-predicting the infiltration and receding limbs of the hydrographs. For these simulations, rainfall and snowmelt data from the Reagan Washington National and Washington Dulles Airports were applied across the basin. These values may have been less than actually occurred in the upstream portions of the watershed. Another factor is that the model was not calibrated for snowmelt conditions. As noted previously, snowmelt before the February 22-23, 2003 rainfall may have caused higher than average groundwater infiltration. In addition, the snowmelt may have caused ponding around some of the manholes, which in turn could lead to excessive inflow at these locations.

Although the PI model did not predict the flooding during simulation of the unusual February 22-23, 2003 rainfall / snowmelt event, the model should be a reliable tool for predicting flooding under more typical weather conditions. These results suggest that the PI would not flood for a 5-year storm if the bolted manholes are in good repair.

ATTACHMENT A.

Analysis of Return Period for the Potomac Interceptor Flooding Event on February 22-23, 2003

Prepared on March 31, 2003

Background: On February 22-23, 2003, flooding was observed in the Potomac Interceptor, located in Washington, DC metropolitan area. This flooding was partly caused by the rainfall on February 21-23, 2003, and partly by the snowmelt from the February 15-18, 2003 snowfall. The amount of snowfall, close to 20 inches at Washington National Airport and Washington Dulles Airport, was unusual for the area given its recent climate history.

This analysis was conducted to determine the return period of the effective rainfall for use in the hydraulic analyses of the Potomac Interceptor. The effective rainfall is the combination of the actual rainfall and the snowmelt from the preceding snowfall. The Intensity-Duration-Frequency (IDF) curves for Washington, DC area were used for comparison purposes and also to estimate the return period of the effective rainfall.

Data sources and the methodology used in obtaining the effective rainfall are discussed below.

Data Sources: Data from two stations, Reagan National Airport, and Washington Dulles Airport, were used for the analysis. Hourly precipitation data were obtained from the website of the National Climate Data Center (NCDC), and daily snowfall (water equivalent) and snow depth data were obtained from the National Weather Service (NWS). The snow depth data were given for measurements taken at 7 A.M. EST.

IDF curves for Washington, DC area were obtained from MWCOG.

Appendices A and B give the hourly and daily precipitation data, respectively.

Methodology: The amount of snowmelt (water equivalent) for each day past February 18 was estimated based on the snow depth data.

The following assumptions were used in the estimating the hourly snowmelt:

1) The daily snow pack depletion is represented by the 7 A.M. measurements.
2) The rate of the snow pack depletion is equivalent to the rate of snowmelt.
3) The rate of snowmelt is uniform throughout a day.

Figures 1 and 2 show the cumulative snowfall and snow depth for both the stations. The total amount of the water equivalent snowfall, 1.60 inch for the Reagan National Airport and 1.85 inch for the Washington Dulles Airport station were distributed based on the rate of depletion of the snow pack starting on February 18, 2003, the day the snow started to melt. As Figure 1 indicates, the accumulated snow started to melt before the rain began on February 21, 2003. Table 1 gives the amount of water equivalent snowmelt for the two stations after the commencement of the snowmelt. As the table indicates, there was a significant amount of snowmelt before the commencement of the rainfall. This was because of the high air temperature prevailing immediately after the end of the snowfall.

Table 1. Snowmelt Addition to Rainfall.

Date	Equivalent Water Snowmelt (in.)	
	Reagan National Airport	Washington Dulles Airport
2/18/2003	0.60	0.21
2/19/2003	0.10	0.41
2/20/2003	0.20	0.31
2/21/2003	0.10	0.31
2/22/2003	0.20	0.10
2/23/2002	0.20	0.10

The daily snowmelt from Table 1 was divided by 24 to obtain the hourly snowmelt. These values were then added to the hourly rainfall data in obtaining the effective rainfall for the area. The effective rainfall was further analyzed to obtain duration-intensity values. These values were then plotted on the IDF curves of Washington, DC area. Figure 3 shows the graphical result. As the figure indicates, the return period for the effective rainfall is less than two years, although a significant amount of snow, around 20 inches, was recorded at the stations.

Conclusion: A significant amount of snowfall occurred on February 14-18, 2003, followed by a rainfall on February 21-23, 2003. Snow pack depletion rate was used in estimating the amount of snowmelt that occurred during the rain event. The effective rainfall was obtained by adding the snowmelt and rainfall on hourly basis. The effective rainfall was further analyzed and plotted on the IDF curves for Washington, DC area. The effective rainfall was found to have a return period less than two years.

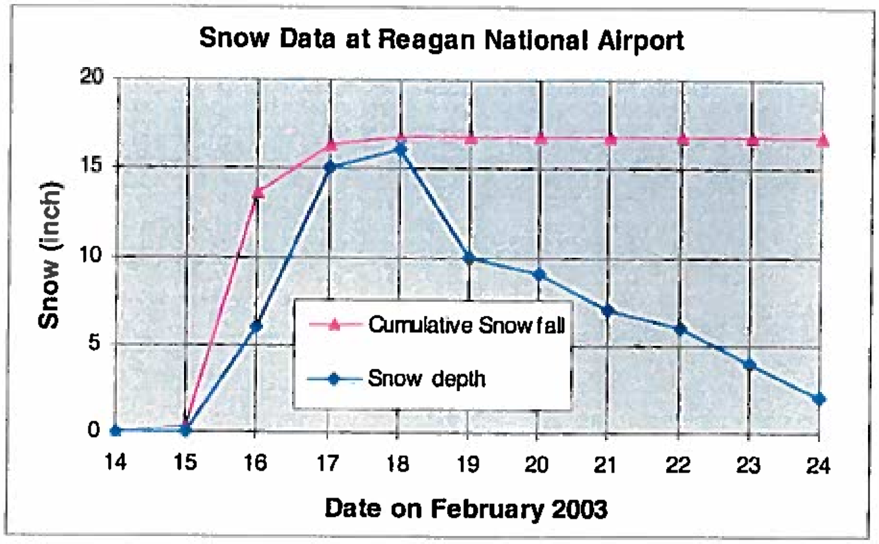


Figure 1. Cumulative Snowfall and Snow Depth at Reagan National Airport

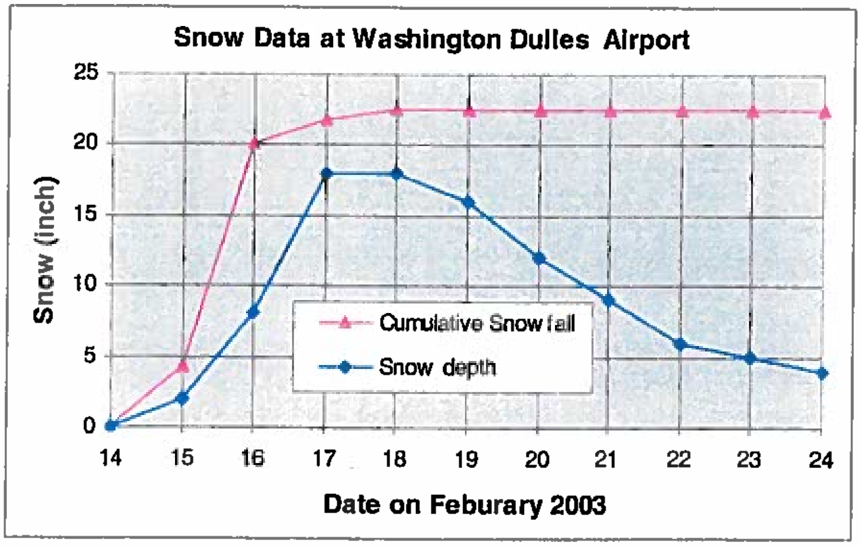


Figure 2. Cumulative Snowfall and Snow Depth at Washington Dulles Airport

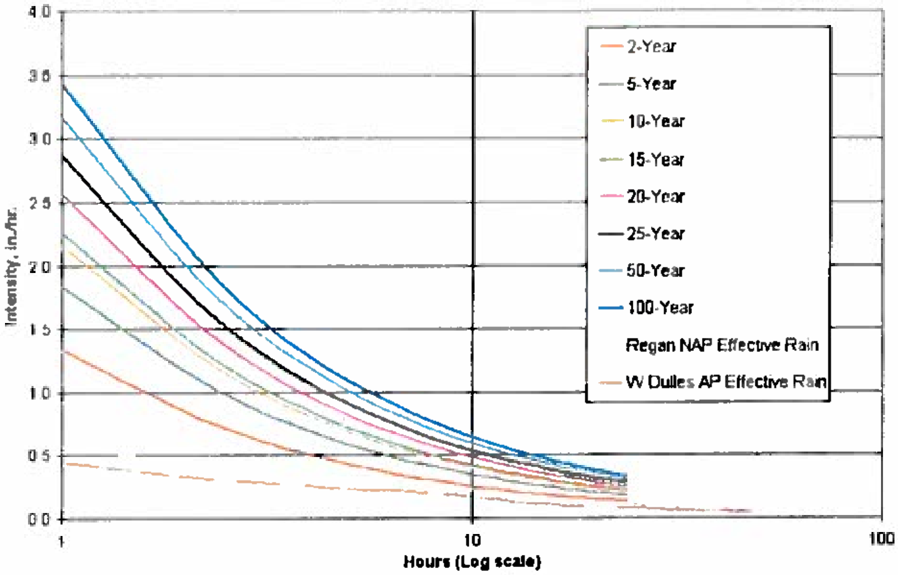


Figure 3. IDF Curves and February 21-23, 2003 Effective Rainfall Graph

Appendix A

UNEDITED HOURLY PRECIPITATION TABLE (Source: NCDC)

MONTH: 02/2003

WASHINGTON DC, DC

D T	A.M. HOUR (L.S.T) ENDING AT												D T	P.M. HOUR (L.S.T) ENDING AT												D T
	--- 1---	--- 2---	--- 3---	--- 4---	--- 5---	--- 6---	--- 7---	--- 8---	--- 9---	--- 10---	--- 11---	--- 12---		--- 1---	--- 2---	--- 3---	--- 4---	--- 5---	--- 6---	--- 7---	--- 8---	---9- ---	--- 10---	--- 11---	--- 12---	
01	.04	.02	.02	T	---	---	---	T	T	T	T	T	01	T	---	---	---	---	---	---	---	---	---	---	---	01
02	---	---	---	---	---	---	---	---	---	---	---	---	02	---	---	---	---	---	---	---	---	---	---	---	---	02
03	---	---	---	---	---	---	---	---	---	---	---	---	03	---	---	---	---	---	---	---	---	---	---	---	---	03
04	---	---	---	---	---	---	T	.08	.09	.03	.01	---	04	---	---	---	---	---	---	---	---	---	---	---	---	04
05	---	---	---	---	---	---	---	---	---	---	---	---	05	---	---	---	---	---	---	---	---	---	---	---	---	05
06	---	---	---	---	---	---	---	---	---	---	---	---	06	---	---	---	---	---	---	---	T	.02	.07	.06	.08	06
07	.06	.06	.06	.06	.06	.03	.01	T	T	T	---	---	07	T	---	---	---	---	---	---	---	---	---	---	---	07
08	---	---	---	---	---	---	---	---	---	---	---	---	08	---	---	---	---	---	---	---	---	---	---	---	---	08
09	---	---	---	---	---	---	---	---	---	---	---	---	09	---	---	---	---	---	---	---	---	---	---	---	---	09
10	---	---	---	---	T	T	T	T	T	T	.01	.01	10	T	T	.01	.01	T	T	---	---	---	---	---	---	10
11	T	---	---	---	---	---	---	---	---	---	---	---	11	---	---	---	---	---	---	---	T	---	---	---	---	11
12	---	---	---	---	---	---	---	---	---	---	---	---	12	---	---	---	---	---	---	---	---	---	---	---	---	12
13	---	---	---	---	---	---	---	---	---	---	---	---	13	---	---	---	---	---	---	---	---	---	---	---	---	13
14	---	---	---	---	---	---	---	---	---	---	---	---	14	---	---	---	---	---	---	---	---	---	T	T	.02	14
15	.03	.04	.06	.04	.04	.05	.02	.03	T	.01	T	T	15	T	T	T	T	T	T	T	T	---	---	---	---	15
16	---	---	.01	.04	.05	.07	.06	.05	.02	.02	.02	.02	16	.04	.02	T	.01	T	T	T	T	T	.19	.2	T	16
17	.08	.08	.04	.02	.02	.04	.06	.03	.03	.01	T	---	17	T	---	---	---	---	---	---	---	T	T	T	T	17
18	T	T	T	T	.01	.01	T	.01	T	---	---	---	18	---	---	---	---	---	---	---	---	---	---	---	---	18
19	---	---	---	---	---	---	---	---	---	---	---	---	19	---	---	---	---	---	T	T	T	---	---	---	---	19
20	---	---	---	---	---	---	---	---	---	---	---	---	20	---	---	---	---	---	---	---	---	---	---	---	---	20
21	---	---	---	---	---	---	---	---	---	---	T	T	21	T	.02	.04	.03	.04	.06	.05	.08	.01	---	T	.01	21
22	.01	T	---	T	.03	.12	.06	.15	.24	.18	.4	.54	22	.37	.14	.01	T	.01	T	---	---	---	T	.01	T	22
23	T	T	T	T	---	---	---	---	T	.07	.06	T	23	---	---	---	---	---	---	---	---	---	---	---	---	23
24	---	---	---	---	---	---	---	---	---	---	---	---	24	---	---	---	---	---	---	---	---	---	---	---	---	24
25	---	---	---	---	---	---	---	---	---	---	---	---	25	---	---	---	---	---	---	---	---	---	---	---	---	25
26	---	---	---	T	T	T	T	T	.01	T	T	.01	26	.01	T	.01	.01	T	T	.01	T	T	---	---	---	26
27	T	T	T	T	T	T	T	T	---	---	---	---	27	---	---	---	T	T	.03	.02	.03	.01	.03	.01	.01	27
28	T	T	T	---	---	---	T	T	T	.02	T	T	28	T	---	---	---	---	---	---	---	---	---	---	---	28
29													29													29
30													30													30
31													31													31

Appendix A, continued

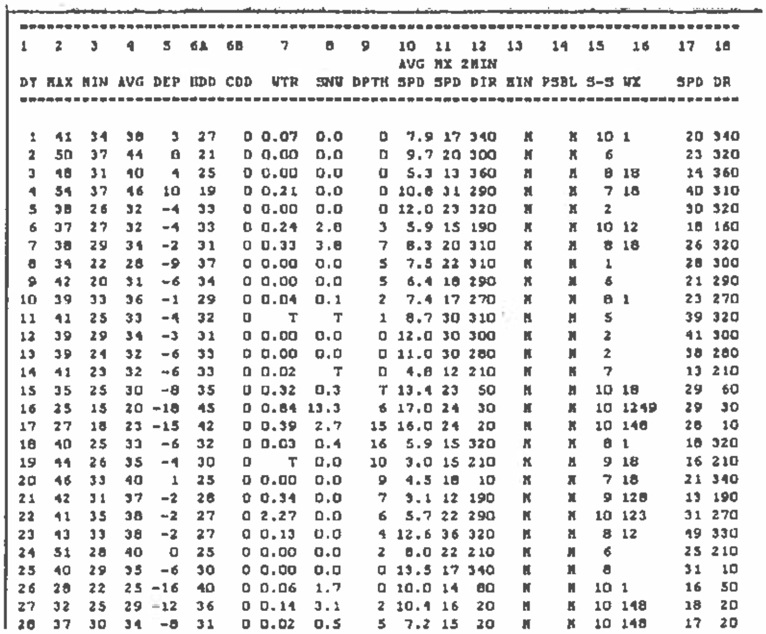
UNEDITED HOURLY PRECIPITATION TABLE (Source: NCDC)

MONTH: 02/2003

WASHINGTON DC/DULLES, DC

DT	A.M. HOUR (L.S.T) ENDING AT												DT	P.M. HOUR (L.S.T) ENDING AT												DT
	1	2	3	4	5	6	7	8	9	10	11	12		1	2	3	4	5	6	7	8	9	10	11	12	
01	.02	.05	.01	T	.02	T	----	.01	----	----	----	.01	01	T	----	----	----	----	----	----	----	----	----	----	----	01
02	----	----	----	----	----	----	----	----	----	----	----	----	02	----	----	----	----	----	----	----	----	----	----	----	----	02
03	----	----	----	----	----	----	----	----	----	----	----	----	03	----	----	----	----	----	----	----	----	----	----	----	----	03
04	T	----	----	----	T	T	.01	.1	.07	.01	----	----	04	----	----	----	----	----	----	----	----	----	----	----	----	04
05	----	----	----	----	----	----	----	----	----	----	----	----	05	----	----	----	----	----	----	----	----	----	----	----	----	05
06	----	----	----	----	----	----	----	----	----	----	----	----	06	----	----	----	----	----	----	T	T	.04	.06	.04	.08	06
07	.06	.05	.06	.05	.03	.01	T	T	T	T	.01	T	07	----	----	----	----	----	----	----	----	----	T	T	----	07
08	----	----	----	----	----	----	----	----	----	----	----	----	08	----	----	----	----	----	----	----	----	----	----	----	----	08
09	----	----	----	----	----	----	----	----	----	----	----	----	09	----	----	----	----	----	----	----	----	----	----	----	----	09
10	----	----	----	----	----	T	.01	T	.01	T	.01	T	10	----	T	.02	T	T	.01	----	----	----	----	----	----	10
11	T	----	----	----	----	----	----	----	----	----	----	----	11	----	----	----	----	----	----	----	----	----	----	----	----	11
12	----	----	----	----	----	----	----	----	----	----	----	----	12	----	----	----	----	----	----	----	----	----	----	----	----	12
13	----	----	----	----	----	----	----	----	----	----	----	----	13	----	----	----	----	----	----	----	----	----	----	----	----	13
14	----	----	----	----	----	----	----	----	----	----	----	----	14	----	----	----	----	----	----	----	----	----	----	----	.01	14
15	.04	.04	.05	.04	.05	.04	.03	.02	T	T	----	T	15	T	.01	T	.01	T	T	T	----	----	----	----	----	15
16	----	T	.04	.08	.09	.06	.06	.05	.05	.03	.04	.04	16	.05	.04	.07	.03	.03	.03	.07	.07	.06	.1	.13	.07	16
17	.02	.03	.05	.01	.05	T	T	.01	.02	T	T	T	17	----	----	----	----	----	----	----	T	.01	T	T	T	17
18	.01	T	----	T	.01	T	T	T	----	----	----	----	18	----	----	----	----	----	----	----	----	----	----	----	----	18
19	----	----	----	----	----	----	----	----	----	----	----	----	19	----	----	----	----	----	----	----	----	----	----	----	----	19
20	----	----	----	----	----	----	----	----	----	----	----	----	20	----	----	----	----	----	----	----	----	----	----	----	----	20
21	----	----	----	----	----	----	----	----	----	----	T	T	21	T	.02	.04	.04	.04	.06	.06	.02	.01	T	.01	T	21
22	.01	----	T	----	.01	.11	.06	.17	.14	.19	.44	.21	22	.17	.15	.01	T	T	T	----	----	----	.01	.01	T	22
23	T	T	----	----	----	----	.01	T	.02	.08	----	T	23	----	----	----	----	----	----	----	----	----	----	----	----	23
24	----	----	----	----	----	----	----	----	----	----	----	----	24	----	----	----	----	----	----	----	----	----	----	----	----	24
25	----	----	----	----	----	----	----	----	----	----	----	----	25	----	----	----	----	----	----	----	----	----	----	----	----	25
26	----	----	----	----	T	T	.01	.02	.01	T	T	.01	26	.02	T	.02	.01	T	T	.01	T	T	T	----	----	26
27	----	----	----	T	T	T	----	----	----	T	T	T	27	----	----	----	T	.01	.01	.01	.02	.02	.03	.02	.02	27
28	.01	T	----	----	----	----	T	T	.01	.01	T	T	28	----	----	----	----	----	----	----	----	----	----	----	----	28
29													29													29
30													30													30
31													31													31

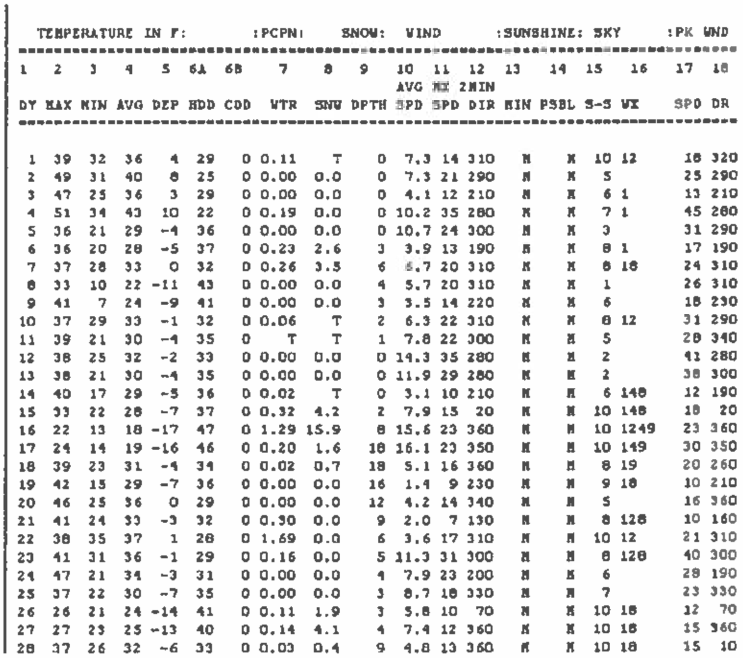
Appendix B



```
=================================================================================
1   2   3   4   5  6A  6B    7    8   9   10  11  12  13   14  15   16    17  18
                                          AVG MX 2MIN
DY MAX MIN AVG DEP HDD CDD  WTR  SNW DPTH SPD SPD DIR MIN PSBL S-S WX     SPD DR
=================================================================================


 1  41  34  38   3  27    0 0.07  0.0    0  7.9 17 340   M    M  10 1      20 340
 2  50  37  44   8  21    0 0.00  0.0    0  9.7 20 300   M    M   6        23 320
 3  48  31  40   4  25    0 0.00  0.0    0  5.3 13 360   M    M   8 18     14 360
 4  54  37  46  10  19    0 0.21  0.0    0 10.8 31 290   M    M   7 18     40 310
 5  38  26  32  -4  33    0 0.00  0.0    0 12.0 23 320   M    M   2        30 320
 6  37  27  32  -4  33    0 0.24  2.0    3  5.9 15 190   M    M  10 12     18 160
 7  38  29  34  -2  31    0 0.33  3.8    7  8.3 20 310   M    M   8 18     26 320
 8  34  22  28  -9  37    0 0.00  0.0    5  7.5 22 310   M    M   1        28 300
 9  42  20  31  -6  34    0 0.00  0.0    5  6.4 18 290   M    M   6        21 290
10  39  33  36  -1  29    0 0.04  0.1    2  7.4 17 270   M    M   8 1      23 270
11  41  25  33  -4  32    0    T    T    1  8.7 30 310   M    M   5        39 320
12  39  29  34  -3  31    0 0.00  0.0    0 12.0 30 300   M    M   2        41 300
13  39  24  32  -6  33    0 0.00  0.0    0 11.0 30 280   M    M   2        38 280
14  41  23  32  -6  33    0 0.02    T    0  4.8 12 210   M    M   7        13 210
15  35  25  30  -8  35    0 0.32  0.3    T 13.4 23  50   M    M  10 18     29  60
16  25  15  20 -18  45    0 0.84 13.3    6 17.0 24  30   M    M  10 1249   29  30
17  27  18  23 -15  42    0 0.39  2.7   15 16.0 24  20   M    M  10 148    28  10
18  40  25  33  -6  32    0 0.03  0.4   16  5.9 15 320   M    M   8 1      18 320
19  44  26  35  -4  30    0    T  0.0   10  3.0 15 210   M    M   9 18     16 210
20  46  33  40   1  25    0 0.00  0.0    9  4.5 18  10   M    M   7 18     21 340
21  42  31  37  -2  28    0 0.34  0.0    7  3.1 12 190   M    M   9 128    13 190
22  41  35  38  -2  27    0 2.27  0.0    6  5.7 22 290   M    M  10 123    31 270
23  43  33  38  -2  27    0 0.13  0.0    4 12.6 36 320   M    M   8 12     49 330
24  51  28  40   0  25    0 0.00  0.0    2  8.0 22 210   M    M   6        25 210
25  40  29  35  -6  30    0 0.00  0.0    0 13.5 17 340   M    M   8        31  10
26  28  22  25 -16  40    0 0.06  1.7    0 10.0 14  80   M    M  10 1      16  50
27  32  25  29 -12  36    0 0.14  3.1    2 10.4 16  20   M    M  10 148    18  20
28  37  30  34  -8  31    0 0.02  0.5    5  7.2 15  20   M    M  10 148    17  20
```

Reagan National Airport Station Climate Data February 2003
(Source: NWS)

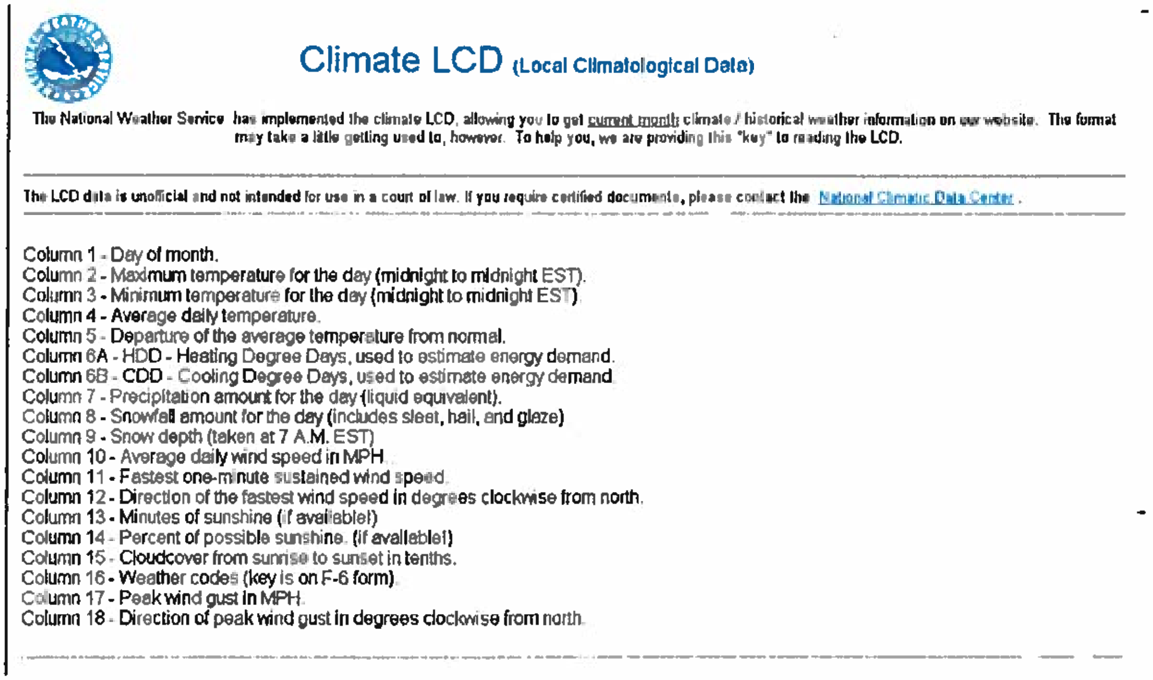


```
  TEMPERATURE IN F:         :PCPN:    SNOW:  WIND         :SUNSHINE: SKY      :PK WND
=================================================================================
1   2   3   4   5  6A  6B    7    8   9   10  11  12  13   14  15   16    17  18
                                          AVG MX 2MIN
DY MAX MIN AVG DEP HDD CDD  WTR  SNW DPTH SPD SPD DIR MIN PSBL S-S WX     SPD DR
=================================================================================


 1  39  32  36   4  29    0 0.11    T    0  7.3 14 310   M    M  10 12     18 320
 2  49  31  40   8  25    0 0.00  0.0    0  7.3 21 290   M    M   5        25 290
 3  47  25  36   3  29    0 0.00  0.0    0  4.1 12 210   M    M   6 1      13 210
 4  51  34  43  10  22    0 0.19  0.0    0 10.2 35 280   M    M   7 1      45 280
 5  36  21  29  -4  36    0 0.00  0.0    0 10.7 24 300   M    M   3        31 290
 6  36  20  28  -5  37    0 0.23  2.6    3  3.9 13 190   M    M   8 1      17 190
 7  37  28  33   0  32    0 0.26  3.5    6  6.7 20 310   M    M   8 18     24 310
 8  33  10  22 -11  43    0 0.00  0.0    4  5.7 20 310   M    M   1        26 310
 9  41   7  24  -9  41    0 0.00  0.0    3  3.5 14 220   M    M   6        18 230
10  37  29  33  -1  32    0 0.06    T    2  6.3 22 310   M    M   8 12     31 290
11  39  21  30  -4  35    0    T    T    1  7.8 22 300   M    M   5        28 340
12  38  25  32  -2  33    0 0.00  0.0    0 14.3 35 280   M    M   2        41 280
13  38  21  30  -4  35    0 0.00  0.0    0 11.9 29 280   M    M   2        38 300
14  40  17  29  -5  36    0 0.02    T    0  3.1 10 210   M    M   6 148    12 190
15  33  22  28  -7  37    0 0.32  4.2    2  7.9 15  20   M    M  10 148    18  20
16  22  13  18 -17  47    0 1.29 15.9    8 15.6 23 360   M    M  10 1249   23 360
17  24  14  19 -16  46    0 0.20  1.6   18 16.1 23 350   M    M  10 149    30 350
18  39  23  31  -4  34    0 0.02  0.7   18  5.1 16 360   M    M   8 19     20 260
19  42  15  29  -7  36    0 0.00  0.0   16  1.4  9 230   M    M   9 18     10 210
20  46  25  36   0  29    0 0.00  0.0   12  4.2 14 340   M    M   5        16 360
21  41  24  33  -3  32    0 0.30  0.0    9  2.0  7 130   M    M   8 128    10 160
22  38  35  37   1  28    0 1.69  0.0    6  3.6 17 310   M    M  10 12     21 310
23  41  31  36  -1  29    0 0.16  0.0    5 11.3 31 300   M    M   8 128    40 300
24  47  21  34  -3  31    0 0.00  0.0    4  7.9 23 200   M    M   6        28 190
25  37  22  30  -7  35    0 0.00  0.0    3  8.7 18 330   M    M   7        23 330
26  26  21  24 -14  41    0 0.11  1.9    3  5.8 10  70   M    M  10 18     12  70
27  27  23  25 -13  40    0 0.14  4.1    4  7.4 12 360   M    M  10 18     15 360
28  37  26  32  -6  33    0 0.03  0.4    9  4.8 13 360   M    M  10 18     15  10
```

Washington Dulles Airport Station Climate Data for February 2003
(Source: NWS)

Appendix B, continued



Climate LCD (Local Climatological Data)

The National Weather Service has implemented the climate LCD, allowing you to get current month climate / historical weather information on our website. The format may take a little getting used to, however. To help you, we are providing this "key" to reading the LCD.

The LCD data is unofficial and not intended for use in a court of law. If you require certified documents, please contact the National Climatic Data Center .

Column 1 - Day of month.
Column 2 - Maximum temperature for the day (midnight to midnight EST).
Column 3 - Minimum temperature for the day (midnight to midnight EST).
Column 4 - Average daily temperature.
Column 5 - Departure of the average temperature from normal.
Column 6A - HDD - Heating Degree Days, used to estimate energy demand.
Column 6B - CDD - Cooling Degree Days, used to estimate energy demand.
Column 7 - Precipitation amount for the day (liquid equivalent).
Column 8 - Snowfall amount for the day (includes sleet, hail, and glaze)
Column 9 - Snow depth (taken at 7 A.M. EST)
Column 10 - Average daily wind speed in MPH.
Column 11 - Fastest one-minute sustained wind speed.
Column 12 - Direction of the fastest wind speed in degrees clockwise from north.
Column 13 - Minutes of sunshine (if available!)
Column 14 - Percent of possible sunshine. (if available!)
Column 15 - Cloudcover from sunrise to sunset in tenths.
Column 16 - Weather codes (key is on F-6 form).
Column 17 - Peak wind gust in MPH.
Column 18 - Direction of peak wind gust in degrees clockwise from north.

Codes for the Climate Data (Source: NWS)

M&E
Metcalf & Eddy
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