WASTEWATER SYSTEM MASTER PLAN

Submitted To

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Submitted By

BIRKHOFF, HENDRICKS & CARTER, L.L.P.
PROFESSIONAL ENGINEERS

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DEREK B. CHANEY
107199

Texas Firm F526

CITY OF MCKINNEY
WASTEWATER SYSTEM MASTER PLAN

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EXECUTIVE SUMMARY

The City of McKinney, located on the northeastern edge of the Dallas-Fort Worth Metroplex, is one of the fastest growing cities in the country. The United States Census Bureau reports that McKinney is the 5th fastest growing City in the United States since the 2010 Census. Consistently named in publications as one the best places to live in the United States, McKinney has remained dedicated to maintaining master plans for various elements of infrastructure to support the existing population and future growth anticipated to occur. In continuing this systematic approach, the City of McKinney retained Birkhoff, Hendricks & Carter, L.L.P. to update the Wastewater System Master Plan.

This analysis and report presents a comprehensive plan for the development of the Wastewater System to serve the City of McKinney at build-out land use conditions. This plan is based on the best available information on existing and future land uses and projections provided by the City of McKinney Planning Department. Although the proposed system is designed to accommodate the ultimate development of the City's planning boundary, it should be examined at regular intervals and revised to conform to changing conditions that may arise as the City continues to grow. Likewise, prior to undertaking a major expenditure an examination should be made to sufficiently verify the design criteria used in developing the overall plan is still valid.

The City embarked on a flow monitoring program to record and analyze dry and wet weather sanitary flows in key basins throughout the existing collection system. Twenty-four (24) temporary flow meters and four (4) rain gauges were deployed from March 23, 2013 to May 31, 2013. In addition, data for seven (7) flow meters was provided by the North Texas Municipal Water District (NTMWD) where interconnections exist between McKinney's wastewater collection system and NTMWD's regional wastewater system. The observed data was analyzed to develop dry weather and wet weather design flows for each basin. A unique diurnal flow pattern was developed for both weekday and weekend sanitary flows. The City's commitment to flow monitoring allowed the hydraulic model of the existing wastewater collection system to be updated and calibrated based on actual data. While the existing condition model was calibrated to match observed flows, the buildout and year 2022 scenarios were applied a factor of safety to allow for potential variances in rising groundwater levels, aging infrastructure and changes in land use characteristics.

The previous wastewater collection system model was brought forward to current modeling software allowing hydraulic analysis to be performed utilizing InfoSewer Professional Suite, Version 7.6. Extended Period Simulation (EPS) hydraulic models were created for the build-out, 2022 (10-Year Projection) and 2012 (Existing) conditions and tailored to determine peak hourly sanitary flow demands simulated with 48-hour diurnal curves. The use of this dynamic modeling software aided in developing an overall system of wastewater collection lines, lift stations and force mains required to efficiently serve the area within the planning boundary. The 48-hour diurnal curves utilized in the hydraulic model are shown in Appendix "A" of this report. The updated model will allow "what-if" scenarios to be analyzed quickly and effectively at the City's direction based on potential new developments or re-development.

A Capital Improvements Plan (CIP) was developed based on evaluation of existing conditions of the system and the required capacity to convey projected flows over the 10-year planning horizon. The 10 –year CIP is presented in Section F of this report.

At the end of this report, a Master Plan Map is enclosed identifying the planning boundary and the various elements of the existing and proposed wastewater system, including collection lines, lift stations and force mains. The master plan map is a living document that will serve as a valuable tool in addressing infrastructure improvements required to serve potential developments.

A. INTRODUCTION

A.1. Purpose

The purpose of this report and planning document is to identify elements of the wastewater collection system that will be required to serve the City of McKinney under ultimate (buildout) land use conditions. With the availability of buildout sanitary sewer line size information, sanitary sewer lines can be installed in many cases to serve the full development of the drainage basin and minimize the costly duplication of construction activities that might otherwise occur. In large drainage basins it may not be feasible, initially, to install lines of adequate capacity to serve buildout conditions. Although a practice generally avoided by the City of McKinney, in such cases, incremental service can be provided to match capacity requirements and corresponding financial constraints, as the City grows to buildout.

This report also focuses on determination of and recommendations to relieve deficiencies of the existing wastewater collection system to convey peak wet weather sanitary flows.

Based on existing and 10-year projected growth, a Capital Improvement Plan (CIP) was developed to assist the City in planning for the anticipated cost of improvements to the Wastewater Collection System over the span of the planning horizon.

A.2. Scope

To accomplish the above mentioned objectives, the scope of this study included:

- Conversion and update of Hydraulic Model of Wastewater Collection System
- Completion of a sanitary sewer flow monitoring study
- Development of dry and wet weather wastewater design flows
- Calibration of hydraulic model to closely match observed flow data
- Conduct a capacity analysis to determine wastewater collection system requirements of existing and future flows
- Develop Budgetary Opinions of Project Cost for each improvements project determined necessary to meet the existing and 10-year wastewater demands projected

A.3. Planning Boundary

The planning area for the 2012 Wastewater System Master Plan is consistent with McKinney's anticipated ultimate city limits and ETJ. The Planning Boundary is identified by the dashed purple line on the Master Plan Map, included at the end of this report. The land within the City's proposed ultimate Wastewater System service area consists of approximately 75,016-acres or 117-square miles. The City's existing Certificate of Convenience and Necessity Sewer (CCN) service area extends to the projected ultimate planning boundaries, but is currently surrounding the New Hope Sewer CCN. For the purpose of the 2012 Master Plan and as directed by the City, it is assumed that the McKinney CCN will consume the New Hope CCN at ultimate development New Hope's Population and wastewater demand were estimated and included in the Build-out hydraulic model for the possibility of future wastewater service to the City of New Hope.

B. STUDY APPROACH

B.1. Land Use Assumptions (LUAs)

The Land Use Assumptions (LUAs) utilized in this update were prepared by the City of McKinney's Planning Department and are presented in a separate document titled, Land Use Assumptions Report – 2012 Impact Fee Update. Within the Planning Boundary, one hundred six (106) sub-service areas were developed for demands to be distributed. Figure No. B.1 illustrates the planning sub-service area locations. Wastewater demand for the hydraulic models were calculated and distributed to model manholes based on these sub-service areas. The LUA's projected an ultimate residential population of approximately 357,967 in the City of McKinney's ultimate planning boundary. This is a lower ultimate population than projected in the City's previous 2007 Master Plan Update, which estimated a residential population of 387,964, a decrease of 29,997 people. The residential and non-residential LUAs provided by the City for the years 2012, 2022 and buildout are summarized in Table No. B.1.

TABLE NO. B.1
RESIDENTIAL AND NON-RESIDENTIAL LAND USE ASSUMPTIONS

Year	Residential Population*	Non-Residential Uses**	
		Type	**Developed Area (SF)**
2012	136,813	Basic	11,453,254
		Service	9,804,571
		Retail	9,900,940
		Total:	**31,158,274**
2022	199,003	Basic	12,780,084
		Service	14,260,185
		Retail	14,401,196
		Total:	**41,441,465**
Build-out	357,967	Basic	59,212,145
		Service	42,347,198
		Retail	57,933,959
		Total	**159,493,302**

** Residential Population – Represent Estate, Low Density, Medium Density & High Density Residential Categories*
*** Basic – Industrial Land Uses*
*** Service – Office & Institutional Land Uses*
*** Retail – Commercial Land Uses*

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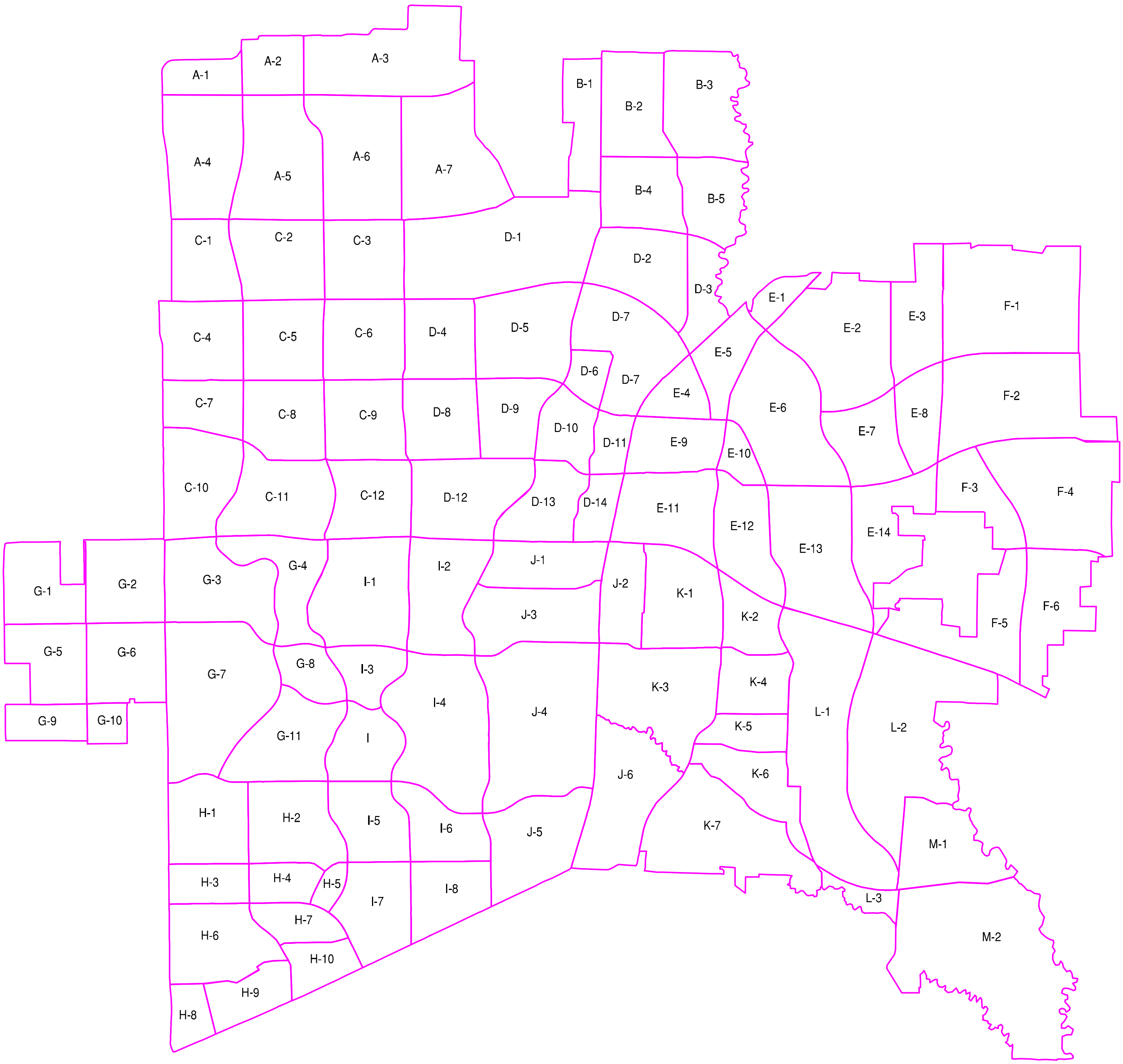

RESIDENTIAL & NON-RESIDENTIAL PLANNING SUB-SERVICE AREA MAP

FIGURE B.1

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As shown in Table No. B.1, increases in the residential population and non-residential uses will occur between 2012 and 2022. The wastewater demand from the residential and non-residential uses dictate the ultimate size of facilities, while the rate of growth is important to determine the timing of system capital improvements to meet the City's growing needs.

The developed area for non-residential land uses summarized in Table No. B.1 includes developed square footage of structures within gross areas of land. Wastewater demands in the models for non-residential uses are based on total gross acreage of land in Gallons per Acre per Day (gpad). The developed square footage of non-residential uses was converted to gross acreage by land use to calculate the projected non-residential wastewater demands.

Steady residential growth is anticipated. Commercial and industrial development is expected to be more sporadic and is predicted to lag behind the residential buildout.

Table No. B.2 provides a summary of the historical and projected residential population from 1900 to 2012, 2022 and Build-out.

TABLE NO. B.2
RESIDENTIAL POPULATION PROJECTIONS

Year	Status	Population
1900	Reported	4,342
1910	Reported	4,714
1920	Reported	6,677
1930	Reported	7,307
1940	Reported	8,555
1950	Reported	10,560
1960	Reported	13,763
1970	Reported	15,193
1980	Reported	16,256
1990	Reported	21,283
2000	Census	54,369
2010	Census	131,117
2012	Reported	136,813
2022	Projected	199,003
Build-out	Projected	357,967

B.2. Existing Hydraulic Wastewater Model

The initial step in obtaining an updated hydraulic wastewater model was conversion of the existing model to the software selected for this project, InfoSewer Professional Suite, Version 7.6. InfoSewer is powerful ArcGIS-based modeling software utilized for planning, design, and analysis of sanitary sewer collection systems. Innovyze, the developers of the InfoSewer modeling software, was retained to perform the model conversion from the previous software. As was anticipated, the converted model was not a polished product. Significant preliminary efforts were expended on establishing a methodical identification system for model elements, most notably sanitary sewer manhole and pipes. The identification system developed allowed each major basin (discussed in Section B.3) to coordinate with a particular set of numbers. Table No. B.3 displays the numbering system developed for both existing and proposed facilities in the model. With limited exceptions, the numbering system was devised to move in a upstream direction of each basin in numerical order.

The City provided a well-organized database of GIS files of various elements of the City's infrastructure. The GIS data provided allowed record drawings of most existing wastewater system projects to be easily identified and examined in PDF format, an invaluable feature which allowed existing elements of the wastewater system to be checked for accuracy on the fly.

The existing model was updated to reflect addition and revisions since the previous Master Plan Update in 2007 completed by RJN Group. For this purpose of this study, pipes generally 10-inch in diameter and larger were added, while smaller pipes were added on a case-by-case basis. The newly added projects were populated with hydraulic information gathered from construction record drawings, typically obtained from the GIS database provided by the City. As can be expected, many of the modern construction plans utilized had different vertical datum's than that of the existing wastewater collection system. In many instances, this required a common datum to be developed for modeling purposes.

TABLE NO. B.3
WASTEWATER MODEL NUMBERING SYSTEM

Major Sewer Basin or Major Trunk Sewer Name	Model Numbering for Existing System	Model Numbering for Proposed System
Wilson Creek Trunk Sewers	10,000	WC100
Lower Wilson Creek	10,500	LW100
Southeast Downtown	11,000	SE100
West Downtown	12,000	WD100
Comegys Creek	13,000	CM100
Jeans Creek	14,000	JC100
Herndon Branch	15,000	HB100
Franklin Branch	16,000	FB100
Gray Branch	17,000	GB100
Stover Creek	18,000	SC100
Upper Wilson Creek	19,000	UW100
Rutherford Branch	20,000	RB100
Lower East Fork	21,000	LE100
Big Branch	N/A	BB100
Northeast Downtown	22,000	NE100
Clemons Creek	N/A	CC100
Bray Central	24,000	BR100
Upper East Fork	25,000	UE100
Honey Creek	26,000	HB100
Rowlett Creek	30,000	RC100
Watters Branch	40,000	WB100
Cottonwood Creek	50,000	CT100

Upon identifying and updating the model with recent projects, the existing model was thoroughly examined for accuracy. As a basis for ensuring a high level of model accuracy, construction records drawings were accumulated, catalogued and compiled, a process which required cross referencing of various plans dating back to the early 1960's. Most notably, a significant portion of the vertical alignment of the Wilson Creek Trunk Sewer System was revised due to unsynchronized datum's. In parallel trunk sewers such as the Wilson Creek System, improperly synchronized datum's often cause imbalances in sanitary flows through the system, typically creating an artificial surcharged condition in one of the parallel pipelines.

Lift station data was also incorporated into the model. When available, the pump data was retrieved from construction record drawings and the model was populated with the pump(s) design flow and head, simulating the pump curve. Where available, the pump levels were also input into the model.

Throughout the process of updating the existing model, coordination was regularly maintained with City's Engineering and Public Works staff. The City promptly assisted as necessary in addressing connectivity issues and general inquiries regarding the existing collection system.

It should be noted that the existing system as it is described herein is not indicative of the system that exists at the time of this reports publication. There are projects of significance currently under construction or in detailed design such as the sanitary sewer (18-inch though 24-inch diameter) line project along U.S. Highway 380 (University Drive) from Custer Road to Rutherford Branch. Such projects have been indicated on the Master Plan Map included at the end of this report as "proposed". These projects have been excluded from the existing model for the purpose of calibrating the existing model at the time of the wastewater flow monitoring study.

B.3. Wastewater Service Areas

Concurrently as the existing wastewater collection system was assembled and updated the major basins were delineated and defined within the Planning Boundary. The major basin divides generally follow the natural divides of major rivers, creeks and tributaries while simultaneously accounting for the man-made divides created by the existing wastewater collection system. There were a total of twenty-two (22) major basins within the City's ultimate planning boundary.

Figure No. B.2 identifies the major basins defined within the planning boundary of this study. Upon establishment of the Major Basins, sanitary sewer service areas (subcatchments) were defined. The boundaries of the service areas were determined using the defined collection system in developed areas while divides were more heavily weighted towards the natural topography, future land use and major thoroughfares in the future development areas. The service areas defined ranged from less than 20 acres in densely populated areas to greater than 300 acres in predominantly undeveloped areas. A total of 480 wastewater service areas were defined within the planning area. Efforts were made to maintain homogenous land usage within service areas but this was not always a feasible approach. As many as four sanitary sewer manholes were designated as loading points within each service area, allowing a means for introducing the wastewater flow generated into the model.

Both the planning and parcel data provided by the City was integrated with the wastewater service areas utilizing the intersect functionality of ArcGIS software. This process allowed the total residential units and non-residential areas of various types within each service area to be determined efficiently and accurately. During this process, minor adjustments to the wastewater service areas were made to ensure occurrences with overlap between the comparative areas were as negligible as practical. This information was catalogued for use in developing the wastewater design flows discussed in Section C.

B.4. Future Model Development

As wastewater service areas were developed, the existing hydraulic model was extended into future growth areas to serve all areas within the planning boundary for this study. The pipe and manhole input information was based on the United States Geological Survey (USGS) maps and contour GIS files provided by the City. At this stage, the pipes sizes were estimated. Proposed Lift Stations were also created were necessary to provide service to future service areas, the pump size and force main information was also roughly estimated. This future model input information is revisited and refined in Section E.

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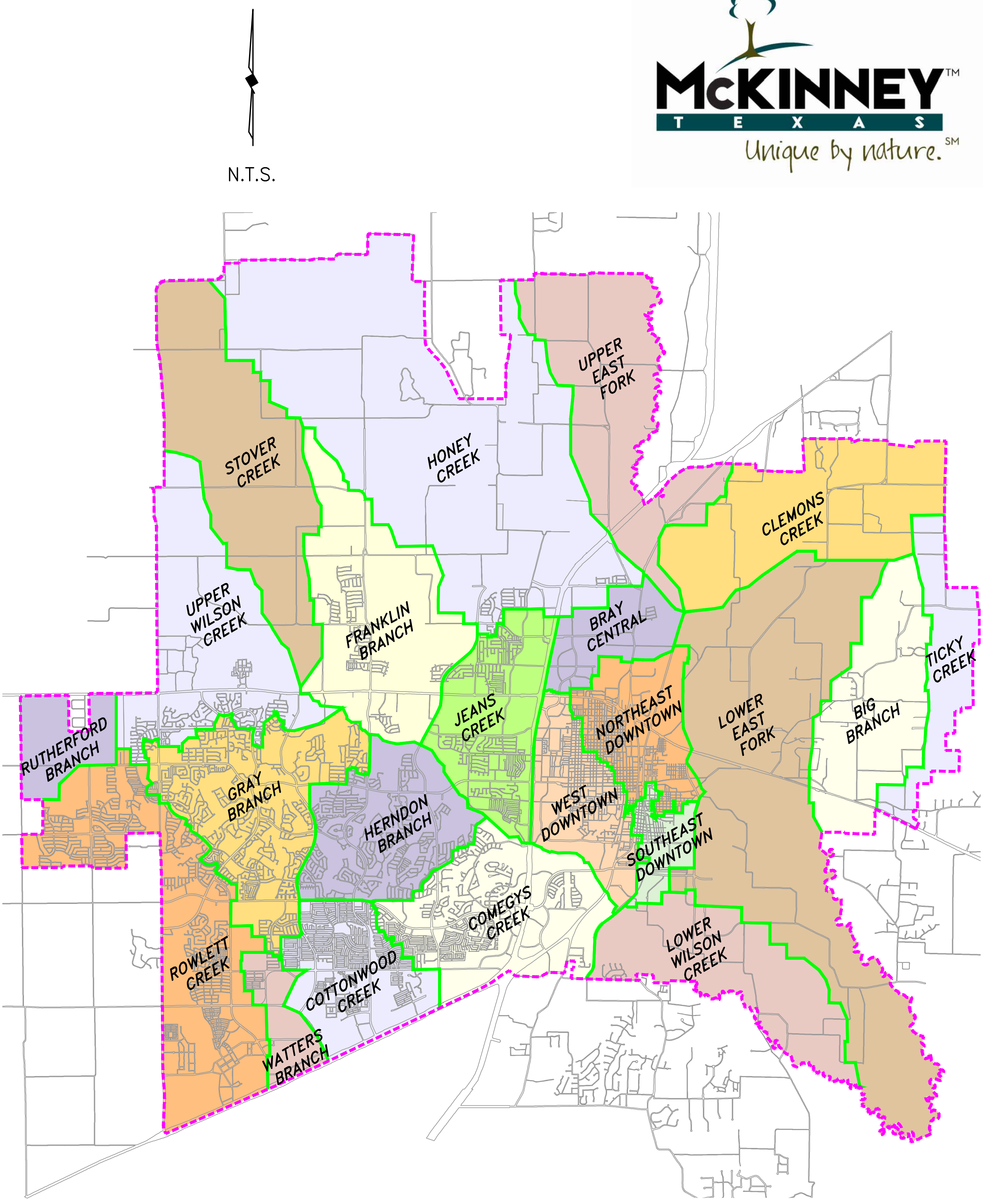

PLANNING AREA BOUNDARY

MAJOR BASIN DIVIDE

MAJOR WASTEWATER BASINS

FIGURE B.2

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C. DEVELOPMENT OF WASTEWATER DESIGN FLOWS

The procedures for developing wastewater flow demands for input into the wastewater model are described in this section. For this study, results of the flow monitoring study indicated that several areas of the City were generating less than expected amounts of wastewater. These areas were mostly pertaining to modern construction located north of U.S. Highway 380 (University Drive) and west of U.S. Highway 75 (Central Expressway). These lower wastewater generating areas were applied their observed per capita rates for the existing system model, but were applied with a factor of safety for future land use scenarios to account for aging of the sewer system, changing groundwater levels and deviations to the current and future land use characteristics. The details of the design flow variations are described in Section C.2 and C.3 respectively.

C.1. Flow Monitoring

Based on initial discussions with the City regarding the potential of wet weather occurring in the spring, March, 2013 was targeted as the deployment date for the wastewater flow meters. The flow meter boundaries were defined, typically coinciding with the wastewater service areas, to determine optimal locations for gathering dry and wet weather sanitary flow data. A total of twenty-four (24) flow monitoring basins were identified for this study. Stream Water Group (SWG) was selected to conduct the flow monitoring portion of this study.

Prior to deployment of the flow monitoring equipment, preliminary site investigations were conducted to determine the condition of the manholes, incoming pipe characteristics (bends, drops, etc.) and to determine any potential issues that could arise with accessing the sites. Sample photos taken during the investigations are provided in Figure C.1.

FIGURE C.1

Preliminary Flow Monitoring Field Investigation Photos

The flow meters selected for use on this project were FLO-DAR Radar Area/Velocity Flow Meters as manufactured by Hach. SWG coordinated with Hach to ensure the meters were properly installed, calibrated and maintained throughout the flow monitoring period. SWG also performed the engineering evaluation of the collected data. A report of their findings is included in Appendix "C". After refining the flow meter locations to suite the results of the field investigation, the flow monitors were deployed on March 23, 2013. The meters were installed in manholes with pipes sizes ranging from 12-inch to 48-inch in diameter.

Four (4) tipping bucket rain gauges were also deployed to ensure accurate rainfall intensity and distribution data would be available for analysis. Accurate rainfall information is a critical element in determining the relationship between rainfall and inflow and infiltration (I/I) within each basin. Figure C.2 identifies the final location of each rain gauge, flow meter and its accompanying flow monitoring basin. The flow meter site number, location and pipe size are listed in Table No. C.1. Figure C.3 is a schematic flow diagram of each monitoring station.

In addition the flow meters deployed for this study, the NTMWD operates and maintains dedicated flow meters for three (3) of the Major Basins within the planning boundary, and an additional four (4) meters which monitor wastewater flows being intercepted into the Rowlett Creek and Wilson Creek Trunk Sewers respectively. Regular coordination with NTMWD staff was a critical portion of this study. The NTWMD flow meter data was provided for the same time frame as that of the flow monitoring study. The wastewater flow monitoring study concluded on May 31, 2013.

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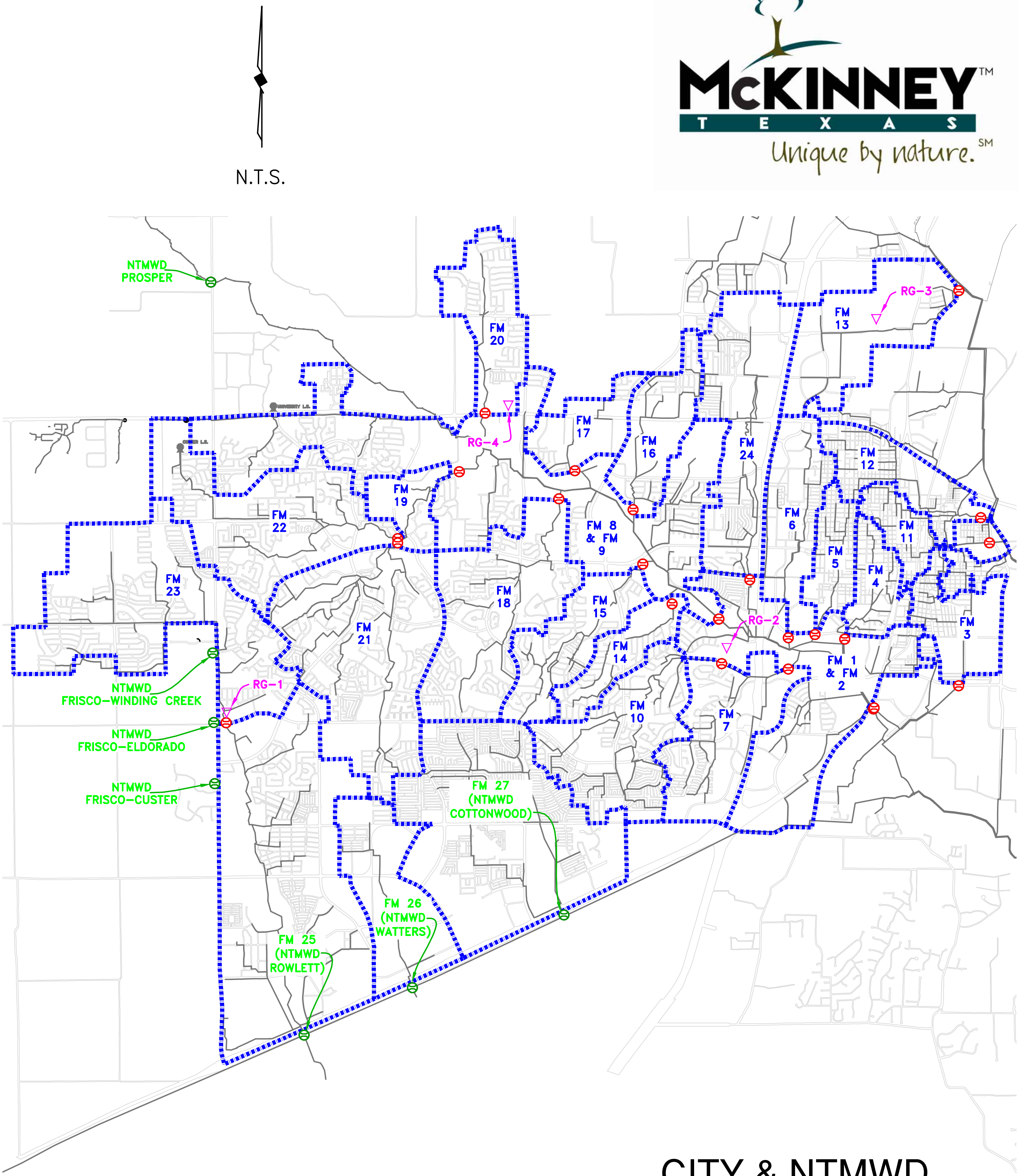

LEGEND

┈┈┈ *CITY METER BASIN*
⊜ *CITY METER SITE*
⊜ *NTMWD METER SITE*
▽ *CITY RAIN GAUGE SITE*
── *EXISTING SANITARY SEWER LINE*

CITY & NTMWD FLOW MONITORING BASIN MAP

FIGURE C.2

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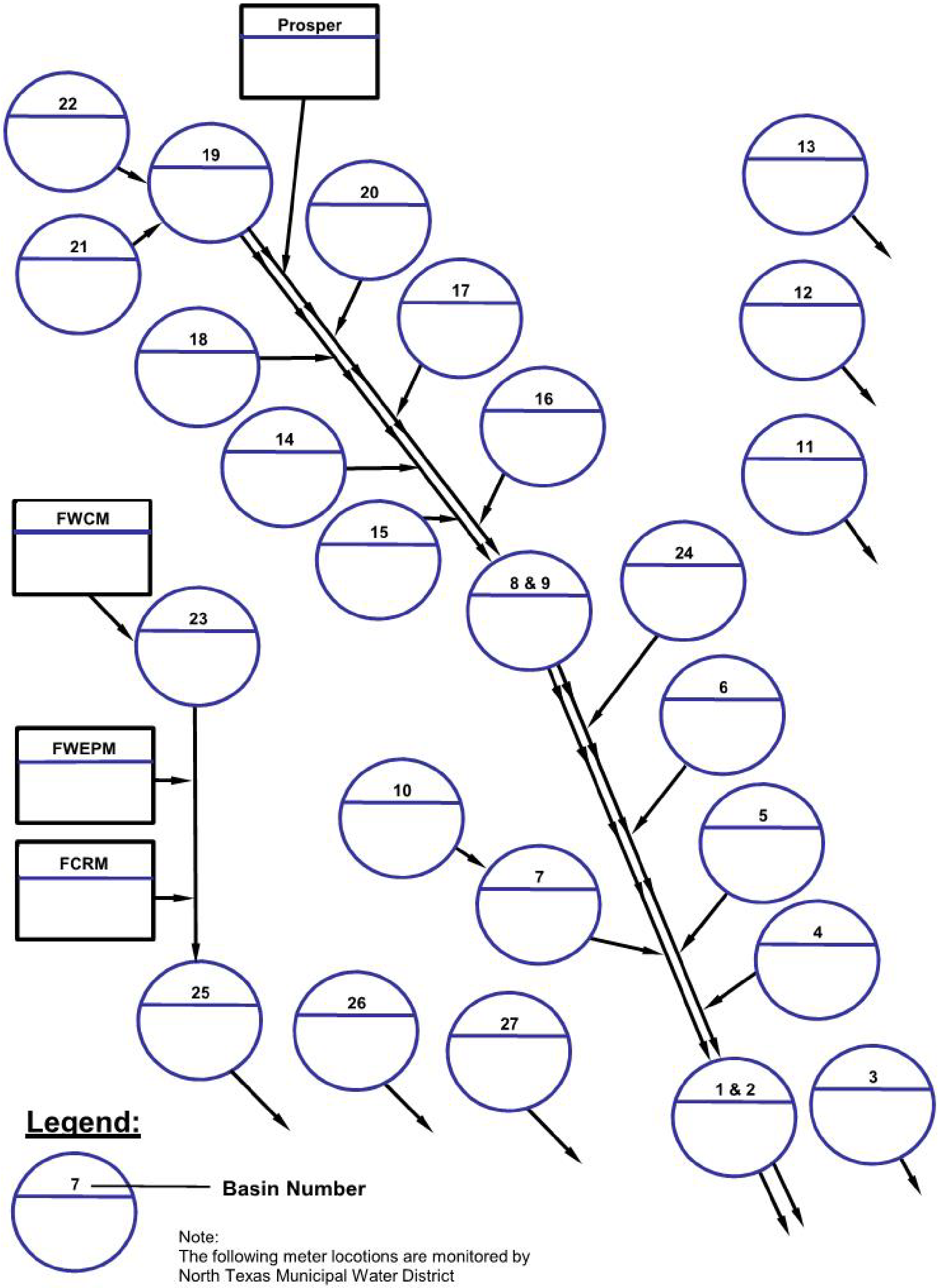
FIGURE C.3
Monitoring Basin Flow Diagram



Note:
The following meter locotions are monitored by North Texas Municipal Water District
Prosper: Prosper Meter
FWCM: Frisco Winding Creek Meter
FWEPM: Frisco West Eldorado Parkway Meter
FCRM: Frisco Custer Road Meter
Basin 25: McKinney Rowlett Creek Meter
Basin 26: McKinney Waters Branch Meter
Basin 27: McKinney Cottonwood Creek Meter

Prepared by:

SW Group

TABLE NO. C.1

WASTEWATER FLOW METER LOCATIONS

Flow Monitoring Basin	Address/Location	Internal Pipe Diameter (inches)
FM01	Highway 5 and Miller Rd.	48.12
FM02	Highway 5 and Miller Rd.	30.38
FM03	1710 Couch Dr.	18.00
FM04	Next to Jeans Creek	14.00
FM05	Towne Lake Park/ Park Entrance	14.37
FM06	Towne Lake Park/ Next to the concession stand	21.06
FM07	1100 Eldorado Pky/ Towne Lake Park North of Elem.	25.38
FM08	Wilson Creek Park/ SW of restrooms	35.25
FM09	Wilson Creek Park/ SW of restrooms	23.25
FM10	1820 Lakeshore Ct/ Eldorado Country Club	23.50
FM11	1201 Virginia St.	17.69
FM12	1205 Roosevelt St/ Field north of Roosevelt St.	17.22
FM13	East of sub-division in cornfield	17.88
FM14	2300 Provine Rd/ In the cul-de-sac	11.88
FM15	3331 Virginia Pkwy/ Next to the walking trail. S. of Virginia	11.63
FM16	601 Bois D Arc Rd/ McKinney Christian Academy	14.81
FM17	1100 Eastbrook Dr./ Next to the bike path and pond	26.73
FM18	600 North Lake Forest Dr/ Hay field east of High School	20.41
FM19	1232 Gray Branch Rd/ Hay field off of Gray Branch Rd.	29.88
FM20	5440 Hwy 380/ North of 380 in the easement	17.50
FM21	6210 Virginia Pkwy/ Behind bldg next to creek	27.00
FM22	300 Longhorn Dr/ End of cul-de-sac on bike path	18.00
FM23	Eldorado Pkwy & Custer Rd.	21.00
FM24	2105 Rockhill Rd/ In the sidewalk	15.25
FM25	NTMWD-McKinney Rowlett Creek Meter	Approximately 36
FM26	NTMWD-McKinney Waters Branch Meter	Approximately 24
FM27	NTMWD-McKinney Cottonwood Creek Meter	Approximately 24
FWCM	NTMWD-Frisco Winding Creek Meter	*
FWEPM	NTMWD-Frisco West Eldorado Parkway Meter	*
FCRM	NTMWD-Frisco Custer Road Meter	*
Prosper	NTMWD-Prosper Meter	Approximately 24

** The NTMWD Frisco Meter data was provided without reference to the Pipe Diameter*

C.2. Existing Wastewater Flows

The components of existing wastewater flow developed for the wastewater collection system are described in this section. Generally, these components are Base Wastewater Flow (BWF), Groundwater Infiltration (GWI), and Rainfall Derived Inflow and Infiltration (RDI/I). For this project, all three components were developed from the flow monitoring data retrieved. Simply stated, BWF is produced by people or employees, the GWI is groundwater entering the system through defects in pipes or manholes, and RDI/I enters the system as a direct result of a storm event. For the purpose of this study, the GWI component is combined with BWF to form the basis for Dry Weather Flow, while RDI/I combined with Dry Weather flow is the basis for Wet Weather Flow. In summary, the following formulas hold true for the purpose of this study:

- Dry Weather Flow = BWF + GWI
- Wet Weather Flow = BWF + GWI + RDI/I

a) Existing Population Based Dry Weather Flow

In Section B.3, the method of intersecting the wastewater service areas with the planning sub-service areas provided by the City was described. The data retrieved from this step was the basis for developing population based flows for wastewater collection system. Populations within each flow monitoring basin were calculated utilizing the previously calculated population data for each service area. Within each monitoring basin, the population of the service areas was accumulated, allowing a population per monitoring basin to be derived as displayed in Table No. C.2. The populations shown in Table C.2 are representative of the City of McKinney only. Consequently, the monitored flows were adjusted accordingly to account for City of Frisco and Prosper wastewater flows being intercepted by the Rowlett Creek and Wilson Creek Trunk Sewers respectively based on the Flow Meter data provided for NTMWD flow meters.

To develop average daily dry weather flows, a dry weather period was identified during the flow monitoring study. This dry weather period selected was from April 30, 2013 to May 6, 2013. The monitored flows were analyzed to develop average daily dry weather flows for each monitored basin. The total average daily dry weather flow for the totality of the monitoring basins was calculated to be approximately 14.8 million gallons per day (MGD).

Unique average daily wastewater flows were then developed from the observed flow monitoring data utilizing an average of weekday and weekend flows. To calculate the residential per capita portion of this average daily flow, the observed meter data was then adjusted to account for non-residential usage within the meter basin. The methods used for adjustment are discussed in Section C.3.b. Table No. C.2 also presents the calculated per capita flows for each flow monitoring basin. The per capita flow determined for each basin was subsequently applied to all wastewater service areas within their respective meter basins. The system wide average of the per capita flows was calculated to be approximately 80 gallons per capita per day (gpcd). This average per capita flow was applied to wastewater service areas not located within a meter basin, a relatively infrequent occurrence.

TABLE NO. C.2
EXISTING POPULATION AND PER CAPITA FLOWS PER MONITORING BASIN

Flow Monitoring Basin	Existing Basin Population (McKinney Only)	Dry Weather Residential Per Capita Flow (gpcd)
FM01&02	11,229	76
FM03	1,965	90
FM04	2,130	116
FM05	2,261	67
FM06	2,832	117
FM07	4,846	72
FM08&09	7,735	72
FM10	8,764	111
FM11	1,015	110
FM12	4,285	63
FM13	1,057	74
FM14	3,428	58
FM15	2,276	56
FM16	3,209	75
FM17	460	56
FM18	8,619	55
FM19	982	100
FM20	3,522	57
FM21	9,684	76
FM22	9,313	58
FM23	14,834	103
FM24	4,513	61
FM25 (NTWMD Watters)	1,231	74
FM26 (NTMWD Rowlett)	7,848	85
FM27 (NTMWD Cottonwood)	14,191	69

* *Flow Meter FM01 & FM 02 and Meter FM08 & FM09 were combined as a result of their installation in the parallel Wilson Creek Trunk Sewer System.*
gpcd –gallons per capita per day

b) Existing Non-Residential Dry Weather Flow

The intersected wastewater service and planning sub-service areas discussed earlier in section B.3 of this report were utilized once again in calculation of non-residential flows within each flow monitoring basin. The intersected areas were utilized to determine the area of non-residential flows in each service area. Non-residential flows are primarily comprised of Commercial, Office and Industrial land use or variances thereof. The existing non-residential wastewater flow was typically calculated based on the demands shown in Table C.3.

TABLE NO. C.3
EXISTING NON-RESIDENTIAL WASTEWATER DEMANDS BY LAND USE

Land Use	Average Daily Flow (gpad)
Local Commercial / Office	600
Public / Semi-Public	600
Retail / Service	1,000
Light Industrial	600
Heavy Industrial	5,000
Regional Commercial	1,500
Regional Employment	1,500
Office Park	3,000
Parks	50
Golf	50
Airport	500

gpad –gallons per acre per day

The City provided data for the commercial and industrial water usage accounts based on billing records. This data was examined to identify substantial users by isolating usage to winter months (to minimize irrigation use) and sorted in descending order. Some specialized non-residential users did not fit the mold of the demands provided in Table C.3. One example is Food Source, LP, located within the Bray Central Major Basin. Once identified, these heavy wastewater yielding businesses were applied unique wastewater demands.

It should be noted that the non-residential demands shown in Table No. C.3 differ (in most cases are lower) from those in the City of McKinney's Water and Wastewater Design Manual. Wastewater flow rates provided in Design Manuals are often conservative to account for the wide variety of potential non-residential uses and corresponding wastewater demands. A prime example is Food Source, L.P., the commercial user we have identified during this study. Retaining conservative design standards provides the City with a level of comfort that can only be achieved with in-depth analysis of each potential non-residential development otherwise.

The average daily demands for non-residential flow were applied to the corresponding land use from the intersected areas created with ArcGIS and quantified within each wastewater service area. The calculated average daily dry weather non-residential flows within each flow monitoring basin were deducted from the total observed average dry weather flows to obtain the average daily dry weather flows that can be attributed to residential use, the basis for the per capita flows shown in Table C.2.

c) Existing Wet Weather Flow (RDI/I)

The wet weather component (RDI/I) of wastewater flow can generally be attributed to two factors resulting from a rainfall event; Inflow entering the collection system through illicit stormwater connection or defects on or near the surface and Infiltration through defects below the surface caused by saturated soils and/or elevated groundwater levels. Inflow related surges are often the cause of surcharged sewers and sanitary sewer overflows.

The wet weather flows were derived from the flow monitoring study discussed in detail in Section C.1 of this report. During the flow monitoring period, several rain events occurred, only one of which triggered a response from the system considered adequate for development of wet weather design flows. This storm event occurred on March 31, 2013, which followed a storm event occurring on March 30, 2013. Interestingly, this was not the most significant rain event, in terms of rainfall amount. However, the other more significant events occurred with such dry soil conditions that stormwater runoff was lessened substantially, therefore resulting in reduced impact on the wastewater system.

The inflow component of the peak wastewater flow is often the controlling factor in determination of required system capacities. Consequently, the selection of a design storm is a key element for capacity analysis. For the purpose of this study, both 1-year / 60-minute and 5-year / 60-minute duration design storms were considered, and the more conservative 5-year design storm was selected as the design parameter based on consultation with the City. The source of IDF (intensity-duration-frequency) data for the City of McKinney and this study was the "Rainfall Frequency Atlas of the United States", Technical Paper No. 40. The 1-year design storm has a total volume of 1.58-inches, while the 5-year design storm has a total volume of 2.50-inches. For comparison, the observed rainfall volume on March 31, 2013 event varied by location but was generally in the range of 0.70-inches. The observed flow data was consequently adjusted for each monitoring basin to develop synthetic data indicative of what the system would experience during the more severe design storm events.

C.3. Projected Wastewater Flows (2022 and Buildout Conditions)

The components of the projected (2022 and buildout) wastewater flow developed for the wastewater collection system are described in this section. The components are not unlike those identified in Section C.2 and are again Base Wastewater Flow (BWF), Groundwater Infiltration (GWI), and rainfall derived inflow and infiltration (RDI/I). The principal difference in the determination of the wastewater design flows for projected or future flows is the element of the unknown as the City moves from today into the future. Efforts to predict future wastewater usage and rate of deterioration of the wastewater system would likely result in poor outcomes. Therefore as a conservative measure, the projected wastewater demands are (while still developed based on flow monitoring results) applied a factor of safety to counterbalance future uncertainties

a) Projected Population Based Dry Weather Flow

In Section C.1 of this report, the populations within each flow monitoring basin were calculated and the accompanying unique per capita average daily wastewater flows were developed from the observed flow monitoring data utilizing an average of weekday and weekend flows. As noted earlier, several of the monitoring basins were determined to have per capita wastewater usage rates well below the historical 100 gpcd commonly used in design practice. The lower per capita rates can likely be attributed to two factors, minimal groundwater infiltration (GWI) amounts due to the drought conditions in North Central Texas, and water conservation practices, including higher efficiency fixtures and appliances. Many basins with older and likely less efficient household elements experienced per capita flows more in line with the commonly used 100 gpcd. Based on discussions with the City, the most sensible approach was to place a floor of 90 gpcd on the per capita flows for existing facilities within monitored basins future (2022 and Buildout) scenarios. The City also provided input regarding the per capita for future facilities, and a conservative approach was taken by setting the per capita wastewater demand at 100 gpcd for all future facilities. Table No. C.4 presents the adjusted per capita flows for projected (2022 and buildout) wastewater demands. The previously discussed existing per capita demands are also included in Table C.4 for comparison. The per capita flows determined were subsequently applied to the population calculated within their appropriated wastewater service area.

TABLE NO. C.4

PROJECTED PER CAPITA FLOWS PER MONITORING BASIN

Flow Monitoring Basin	**Projected Residential Per Capita Flow (gpcd)**	**Existing Residential Per Capita Flow (gpcd)**
FM01&02	90	76
FM03	90	90
FM04	116	116
FM05	90	67
FM06	117	117
FM07	90	72
FM08&09	90	72
FM10	111	111
FM11	110	110
FM12	90	63
FM13	90	74
FM14	90	58
FM15	90	56
FM16	90	75
FM17	90	56
FM18	90	55
FM19	100	100
FM20	90	57
FM21	90	76
FM22	90	58
FM23	103	103
FM24	90	61
FM25 (NTWMD Watters)	90	74
FM26 (NTMWD Rowlett)	90	85
FM27 (NTMWD Cottonwood)	90	69
Future	100	-

* *Flow Meter FM01 & FM 02 and Meter FM08 & FM09 were combined as a result of their installation in the parallel Wilson Creek Trunk Sewer System.*
gpcd –gallons per capita per day

b) Projected Non-Residential Based Dry Weather Flow

The intersected wastewater service and planning sub-service areas discussed earlier in section B.3 of this report were utilized once again in calculation of non-residential flows extending into undeveloped areas of the ultimate planning area. The intersected areas were utilized to determine the area of non-residential flows in each service area. The projected non-residential wastewater flow was typically calculated in accordance with the demands shown in Table C.5. Not unlike the increases to the per capita flows discussed in Section C.3.a, the non-residential flow demands have been increased to account for variances that may occur with future flows.

TABLE NO. C.5

PROJECTED NON-RESIDENTIAL WASTEWATER DEMANDS BY LAND USE

Land Use	Average Daily Flow (gpad)
Local Commercial / Office	1,000
Public / Semi-Public	800
Retail / Service	1,200
Light Industrial	1,000
Heavy Industrial	5,000
Regional Commercial	1,500
Regional Employment	1,500
Office Park	3,000
Parks	50
Golf	50
Airport	500

gpad –gallons per acre per day

The average daily demands for non-residential flow were applied to the corresponding land use from the intersected areas created with ArcGIS and quantified within each wastewater service area.

c) Projected Wet Weather Flow

The existing wet weather flows discussed in Section C.2.c of this report are applicable to projected wastewater flows in the developed areas of the City. As recalled from Section C.2.c, the 5-year / 60-minute design storm was selected for developing the existing wet weather design flows. However, in undeveloped areas, a factor of 500 gallons per acre per day (gpad) was developed based on analysis of the Rainfall Derived Inflow and Infiltration (RDI/I) calculated from the observed data in a selection of monitoring basins containing wastewater facilities of varying age. For the analysis, four (4) flow monitoring basins containing relatively modern infrastructure and two (2) flow monitoring basins containing relatively dated infrastructure were identified and their corresponding RDI/I were tabulated in gpad format. The objective was to obtain an average RDI/I factor representative of what a future basin might experience. The results of this analysis are displayed in Table C.6.

TABLE NO. C.6

ANALYSIS OF AVERAGE RDI/I FOR PROJECTED WET WEATHER FLOW

Relative Age of Wastewater Facilities	Flow Monitoring Basin	Average RDI/I (gpad)
New	FM14	367
	FM15	280
	FM17	373
	FM20	197
Old	FM06	944
	FM10	930
	Average	**500**

gpad –gallons per acre per day

The basis for projecting wet weather flows in future elements of the collection system is calculated by applying the established demand of 500 gpad to each service area.

D. MODEL CALIBRATION

Upon completion of the hydraulic model update and calculation of the design flows, the calculated design flows, both dry weather and wet weather, are distributed to the model at the loading points (sanitary sewer manholes) identified for each wastewater service area. For this particular model, there are just under 1,000 loading points within the model at buildout. The premise of calibration is to match flow monitoring results at each meter location. This process is achieved by adjusting model parameters, including but not limited to lift station pump operation, pipe conditions (controlled by Manning's "n" factor) and the identified loading points. Further explanation of the calibration process is described in this section.

D.1. Dry Weather Flow Calibration

The initial step in developing dry weather flows was covered in Section C, by developing design flows. Following this procedure, a dry weather flow period was identified from the flow monitoring data. To be considered dry weather, a period of time, a week in this case, is chosen in which no rainfall occurs and therefore minimal effects from RDI/I are observed. The dry weather week selected began April 30, 2013 and ended May 6, 2013.

For this study, a diurnal curve for each of the flow monitoring basins was derived from the dry week data identified to simulate the temporal variations that occur over a weekday and weekend. Traditionally, a diurnal curve is by definition is a 24-hour cycle. However, to ensure true peaks were retrieved from model results, the weekday and weekend patterns were developed separately and spliced together, thereby mimicking a typical weekday, followed by a typical weekend day wastewater flow pattern. The patterns created are stored in the model and applied to their designated loading points. The diurnal flow patterns created for this study are dimensionless 1-hour interval curves, each of which are included in Appendix "A". The diurnal curves are applied to the appropriate dry weather flows established in Section C, thus providing the basis for calculation of peak dry weather flow in the hydraulic model.

During the model calibration process, each monitoring basin was analyzed from upstream to downstream and adjustments were made as necessary. Multiple iterations were performed until the model results closely matched the observed results at each flow meter location.

The comparison of modeled dry weather flows versus observed dry weather flows at each monitoring site are provided in graphic format in Appendix "B".

It should be noted that the observed results from one flow meter, specifically FM19, were unable to be applied to the model while maintaining true levels of calibration in the downstream segments of the model. The calibration graph, located in Appendix "B", for Meter Basin FM19 is a true representative of the modeled results. Referring to the calibration graph for FM19, the peaks recorded by the flow meter are significantly higher (more than 1.5 MGD) than those produced in model results. Forcing the model at this location to produce the peaks observed would have required an average day dry weather loading of over 700 gallons per capita per day (gpcd). An adjustment was made during calibration to force the per capita in flow monitoring basin FM19 to 100 gpcd.

While the wastewater line conveying the sanitary flows in basin FM19 has adequate capacity to convey the peak flows, we recommend additional analysis be performed to isolate this area due to the sporadic results of the flow monitoring data. While no difficulty will be shown by model results as it relates to deficiencies, the data suggests that excessive Inflow and Infiltration (I/I) may exist in this area. A variety of approaches can be taken to further investigate the condition of this pipe, including but not limited to the following:

- Additional flow monitoring can be conducted to isolate and prioritize problematic areas.

- Smoke testing can by conducted by pumping a harmless colored vapor into sanitary sewer manholes. Locations were smoke escapes would indicate defects in the sewer collection system. This method most frequently identifies segments of broken pipe or improper private connections (roof or foundation drains).

- Dyed testing can be conducted by placing a non-toxic dye in an upstream suspected storm water source. The presence of the dye in a downstream manhole would indicate a cross-connection between sanitary and storm sewer, a direct source of I&I.

- Closed circuit television (CCTV) investigations can be conducted to determine internal sanitary sewer conditions. The video footage can lead to discovery of cracks, intrusions and leaks.

D.2. Wet Weather Flow Calibration

Subsequent to dry weather calibration, wet weather calibration is performed to predict RDI/I influenced flow responses in the model to mimic the response of the collection system to the observed flow meter data. As covered in Section C.2.c, the rainfall event occurring on March 31, 2013 was identified as producing an acceptable response in the collection system to be utilized for development of wet weather design flows. The rainfall amounts recorded in the four (4) rain gauges were distributed to each flow meter.

Similar to dry weather calibration, a unit hydrograph for each of the flow monitoring basins was derived from the wet weather data developed based on the 5-year / 60 minute design storm selected. The projected wet weather data was applied strategically based on peaks experienced during dry weather for each basin. In other words, the wet weather data was overlaid onto the dry weather patterns developed in Section D.1 to simulate the occurrence of a design storm timed up to match the peaks of both a week day and weekend day. Most frequently, this was achieved by beginning the design storm at 7 a.m. during the weekday patterns and 10 a.m. during the weekend patterns.

Again similarly to the process of dry weather calibration process, each monitoring basin was analyzed from upstream to downstream and adjustments were made as necessary to ensure the model results closely matched the observed results at each flow meter location.

E. MODEL RESULTS AND CAPACITY ANALYSIS

The results and corresponding deficiencies identified from the modeling results of the three (3) planning horizons created as part of this master plan effort are summarized in this section. The model scenarios analyzed are 2012 (existing), 2022 (10-year projection) and buildout. Hydraulic modeling evaluates the effectiveness and timing of projects and provides the basis for necessary improvements to the wastewater collection system and additional Capital Improvements Plan (CIP) projects as discussed in Section II.

The model results were analyzed for surcharged pipes and sanitary sewer overflows (SSOs). The City requested existing collection system areas identified to have insufficient capacities to convey the peak wet weather flows be examined on a case-by-case basis to make determinations regarding the need for system improvements, if any. To accommodate this constraint, an initial query was established in the model to identify surcharged pipes. This query was further refined to identify those pipes with heavy surcharging, a condition determined for this study as locations where the hydraulic grade line (HGL) was more than 2-feet above the soffit of the pipe. This condition is defined for this report as a “Stage 2 Surcharge”. This initial method of identifying system deficiencies often proves to be more reliable than a criterion allowing pipes to surcharge to a certain distance below the manhole rim elevations.

The following design criteria was utilized for elements of the proposed collection system”

- Based on discussions with the City all future pipes were sized to accommodate a “free-flow” condition, with no surcharging.

- Gravity sewer lines were sized to maintain a minimum velocity of 2 feet per second, and a maximum velocity of 8 feet per second.

- Lift stations were sized to provide capacity to meet peak wet weather design flows with the largest pump out of service (firm capacity).

- Force Mains were sized to convey the lift station pumping capacity at a minimum velocity of 2 feet per second for Triplex Stations and 3 feet per second for Duplex Stations and maximum velocity of 8 feet per second (all cases) utilizing a Hazen Williams Coefficient (C-factor) of 120.

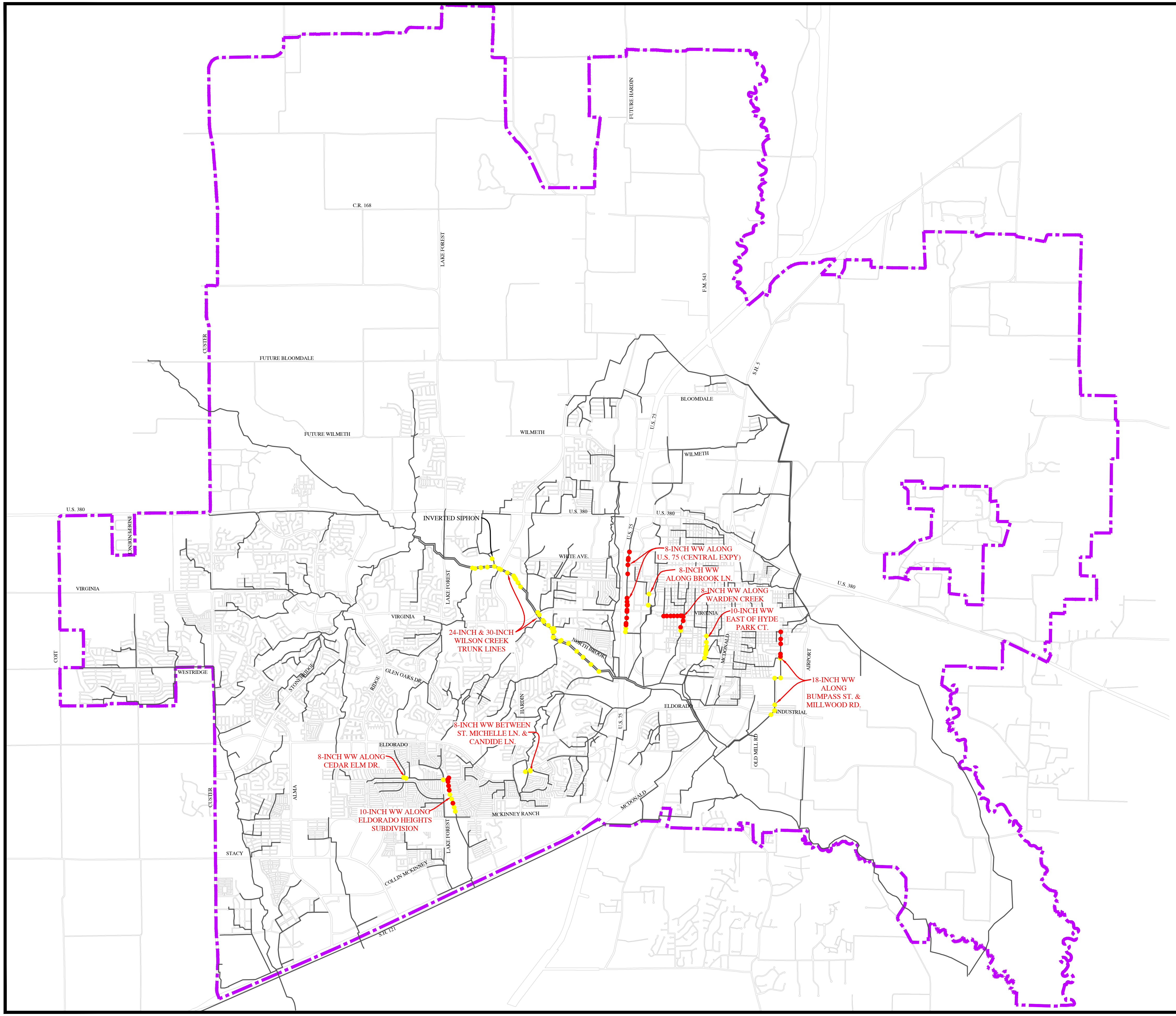
E.1. Existing System Model

As indicated earlier in this report, the "existing system" is the system in place at the time of the flow monitoring study period (March-May, 2013). The existing system was used to perform model calibration with the observed flow monitoring results. Initially the model was calibrated with dry weather flows only. The existing collection system experienced no capacity issues of note conveying the peak dry weather flows.

The model was then calibrated for wet weather flows and a capacity analysis was performed on the existing system to identify problematic areas. Based on the model results, the existing collection system experienced Stage 2 Surcharging in 90 locations (manholes), 35 of which experienced an overflow. It should be noted that no overflows have been reported by the City to date and the overflows presented in this report are based on the response of the hydraulic model to the 5-year design storm. Figure E.1 highlights manholes with a Stage 2 Surcharged or overflow condition as a result of the existing system response to the 5-year / 60-minute design storm and corresponding peak wet weather flows.

The areas experiencing difficulties conveying the wet weather design flows can generally be confined to the following nine (9) segments of the collection system:

- Several segments of the 24-inch and 36-inch parallel Wilson Creek Trunk Sewer System from Lake Forest Drive to U.S. Highway 75 (Central Expressway).
- The 8-inch wastewater line in the vicinity of Candide Lane and Eldorado Pkwy.
- The 8-inch wastewater line along the northbound service lanes of U.S. Highway 75 (Central Expressway) from Rock Hill Road to White Avenue.
- The 8-inch wastewater line along Brook Lane from Hunt Street to Greenwood Road.
- The 8-inch wastewater line along Warden Creek from Cole Street to Louisiana Street.
- The 10-inch wastewater line east of Hyde Park Court to Willie Street.
- The 10-inch wastewater line along the western boundary of the Eldorado Heights, Phase 1 Subdivision, from McKinney Ranch Parkway to Bellcrest Drive
- The 8-inch wastewater line along Cedar Elm Drive.
- An 18-inch wastewater line along Bumpass Street, south of Murray Street.



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EXISTING SANITARY SEWER LINE	—
EXISTING SANITARY SEWER MANHOLE UNDER STAGE 2 SURCHARGED CONDITION (HGL 2' ABOVE ADJOINING PIPE SOFFIT)	◉
EXISTING SANITARY SEWER MANHOLE OVERFLOW (SSO)	◉
PLANNING BOUNDARY	–·–

EXISTING MODEL DESIGN STORM RESPONSE

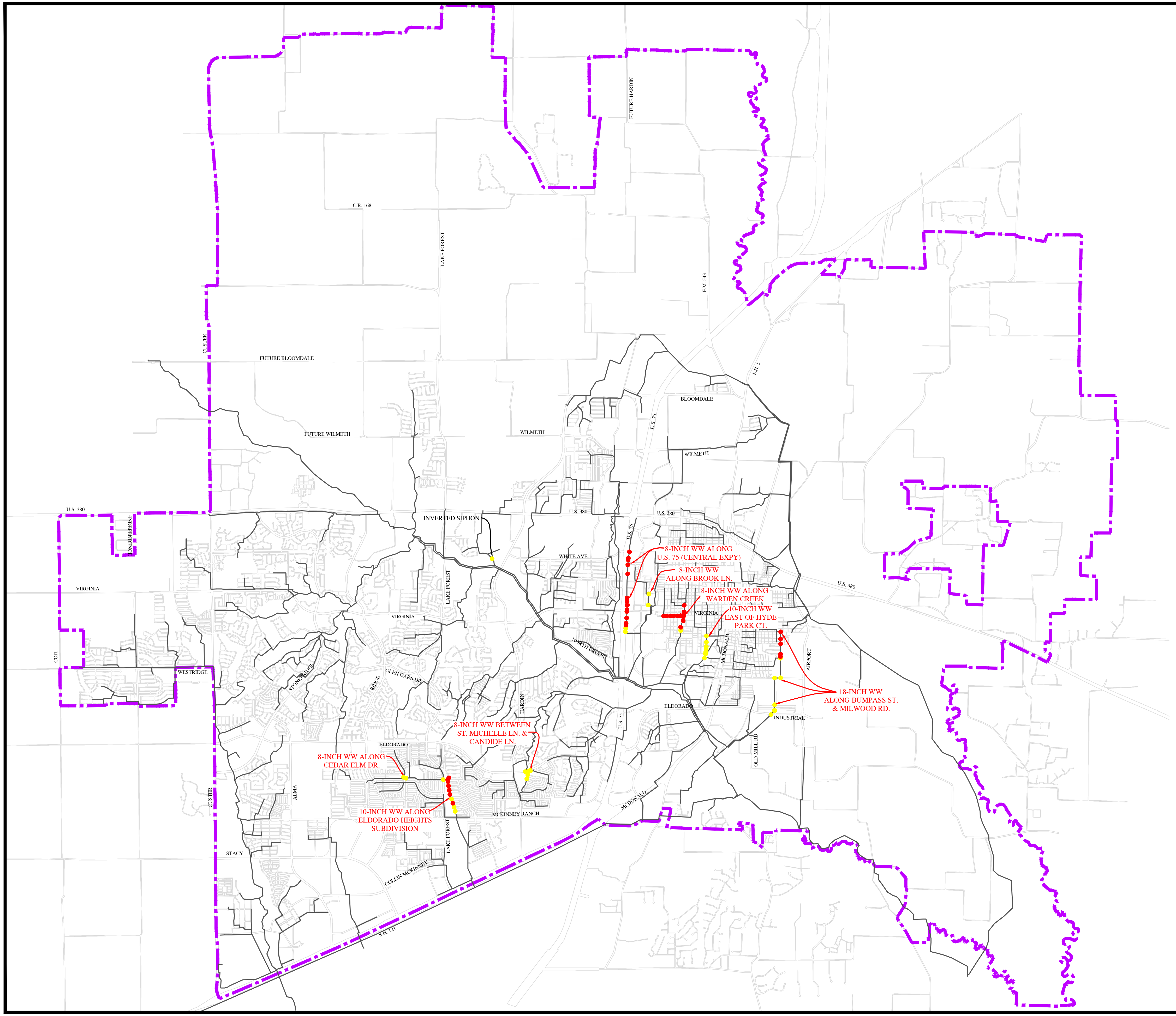
FIGURE E.1

E.2. 2022 System Model

The 2022 system model was adjusted to reflect all improvement project identified by the current Capital Improvement Plan (CIP). Additionally, the 2022 system model was applied with the projected growth in population and employment data in accordance with Table B.1 and the planning sub-surface areas discussed in Section B. The method for calculating projected flows for this scenario is described in Section C. The model was run to simulate the response of the system to the increased population and employment projection and the 5-year / 60-minute design storm.

Generally, the problem areas were consistent with that of the 2012 (existing) system model with exception to the Wilson Creek Trunk Sewer System, which was improved under the 2022 scenario to provide additional capacity in accordance with the current CIP plan. Based on the model results, the existing collection system experienced Stage 2 Surcharging at 57 locations (manholes), 39 of which experienced a SSO. The numbers of surcharged pipes decreased due to the Wilson Creek Improvements, however the number of SSO increase as a result of the increased demands placed on the system from growth anticipated to occur over the 10 year planning period.

Figure E.2 highlights manholes with a Stage 2 Surcharged or overflow condition as a result of the 2022 system response to the 5-year / 60-minute design storm and corresponding peak wet weather flows.



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EXISTING SANITARY SEWER LINE	—
EXISTING SANITARY SEWER MANHOLE UNDER STAGE 2 SURCHARGED CONDITION (HGL 2' ABOVE ADJOINING PIPE SOFFIT)	●
EXISTING SANITARY SEWER MANHOLE OVERFLOW (SSO)	◎
PLANNING BOUNDARY	— · —

2022 MODEL DESIGN STORM RESPONSE

FIGURE E.2

E.3. Build-Out System Model

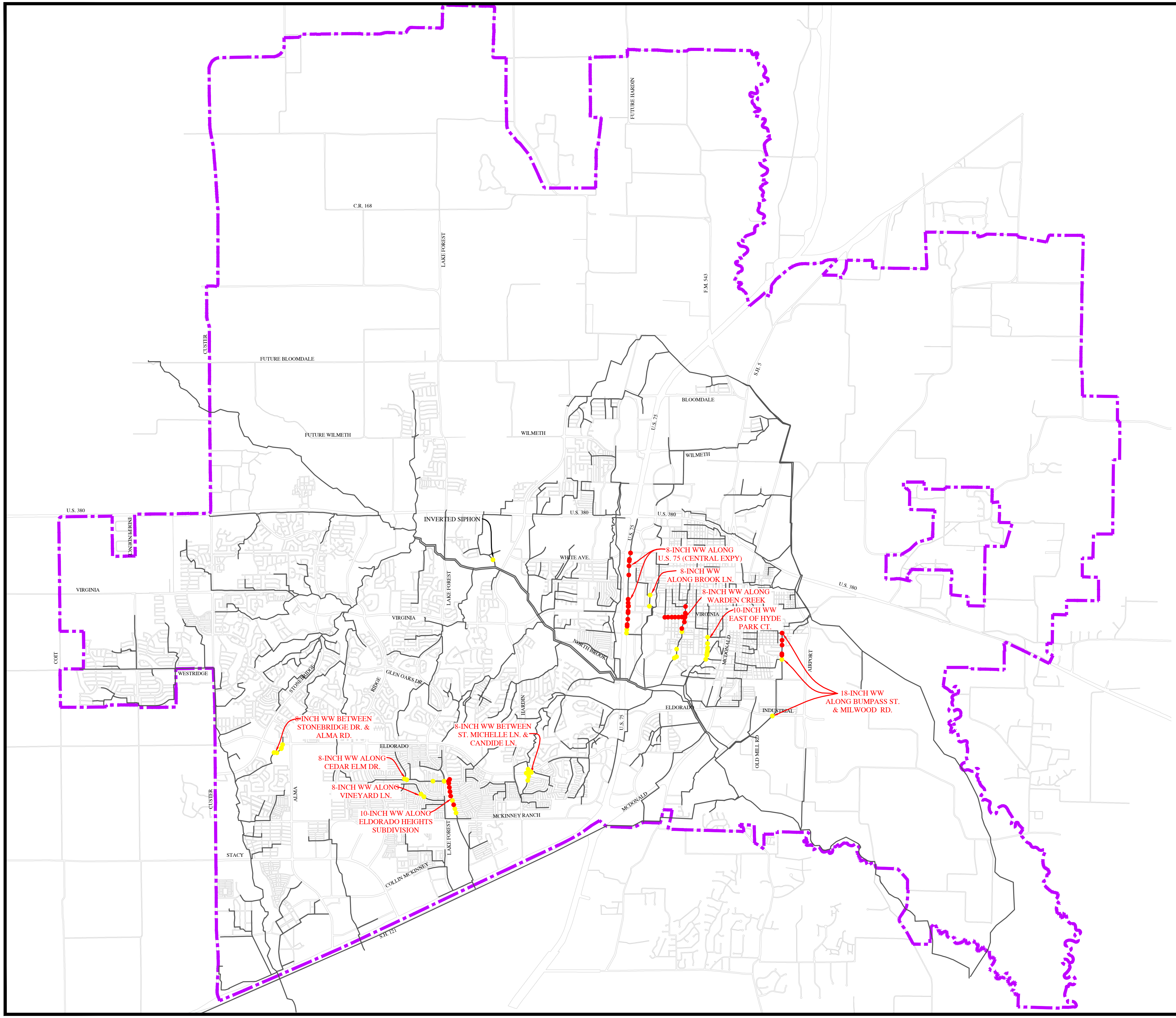
The buildout system model was developed with the City of McKinney's ultimate goals in mind. The model was applied buildout population and non-residential flows demands in accordance with Table B.1and the planning sub-surface areas discussed in Section B. The method for calculating projected flows for this scenario is described in Section C. The model was run to simulate the response of the system to the increased population and employment projections and the 5-year / 60-minute design storm. The wastewater pipes and lift stations preliminarily sized during model development were adjusted to suite the design criteria established earlier in the section. When practical, lift stations were identified to be abandoned and essentially converted to junction structures.

Again, the problem areas were consistent with those identified by the preceding scenarios. Based on the model results, the existing collection system experienced Stage 2 Surcharging in 70 locations (manholes), 39 of which experienced an overflow (SSO). While the same general areas were problematic, the demands associated with the ultimate development of land within the planning boundary caused the surcharging and consequent overflows to be extended further upstream.

One additional segment of the collection system was identified as having capacity issue due to the increase in population and employment projected for buildout conditions.

- The 8-inch wastewater line located between Stonebridge Drive and Alma Road, from Eldorado Parkway to approximately 1,000 feet south or Eldorado Parkway.

Figure E.3 highlights manholes with a Stage 2 Surcharged or overflow condition as a result of the buildout system response to the 5-year / 60-minute design storm and corresponding peak wet weather flows.



N.T.S.

LEGEND

EXISTING SANITARY SEWER LINE —

EXISTING SANITARY SEWER MANHOLE UNDER STAGE 2 SURCHARGED CONDITION (HGL 2' ABOVE ADJOINING PIPE SOFFIT) ●

EXISTING SANITARY SEWER MANHOLE OVERFLOW (SSO) ●

PLANNING BOUNDARY — · —

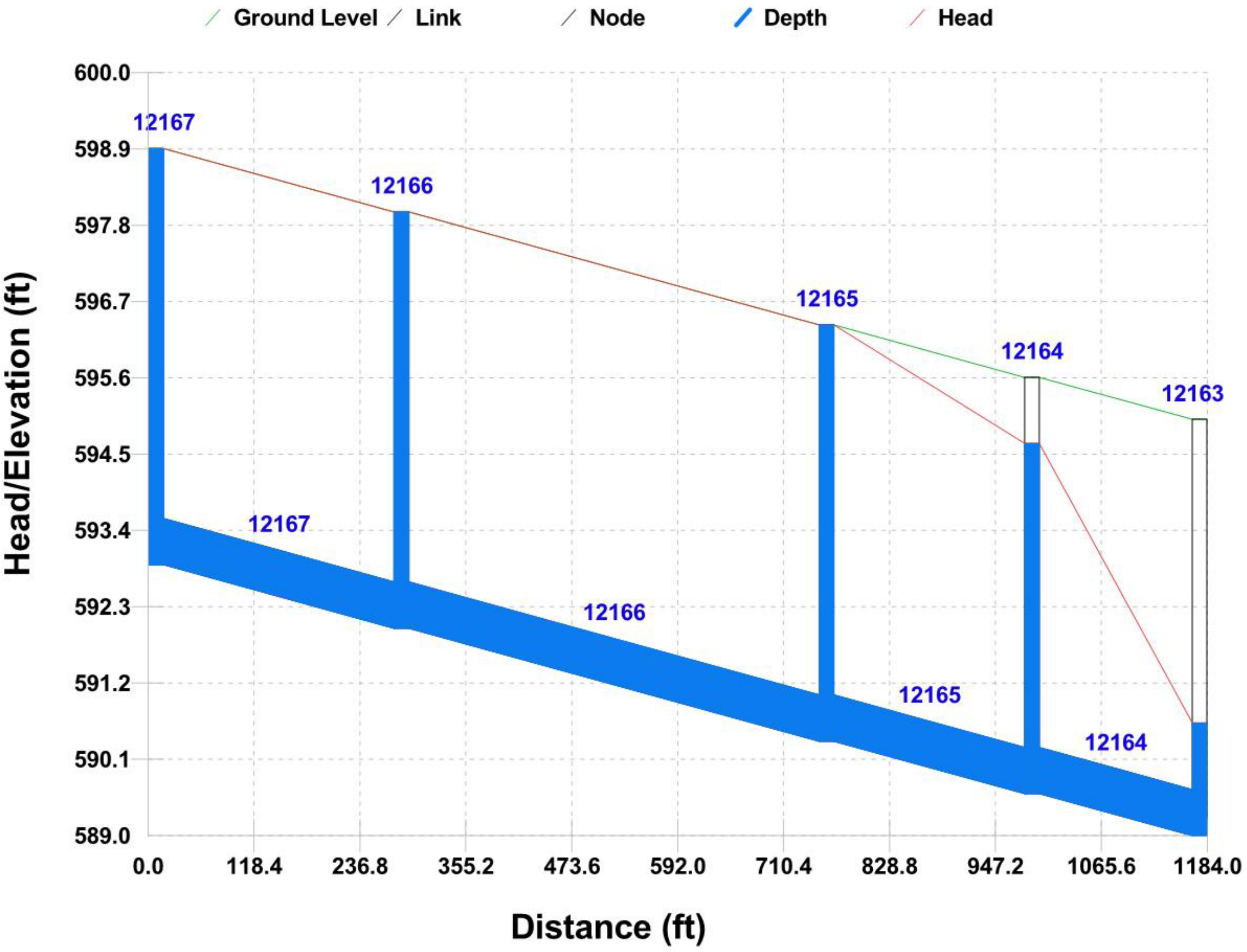
BUILDOUT MODEL DESIGN STORM RESPONSE

FIGURE E.3

E.4. Improvements Analysis

At the City's request to review existing system deficiencies on a case-by-case basis, the details of the projects identified as deficient were provided to the City for consideration regarding determinations of potential system improvements necessary to provide relief to the surcharged or overflowing segments of the collection system. This interim review process was facilitated by providing profile graphs generated by the existing scenario hydraulic model at a snapshot in time identified to represent at or near the maximum HGL in the selected segment of the system. Figure E.4 illustrates an example of the profiles provided, in this case of the 8-inch wastewater line along Warden Creek from Cole Street to Louisiana Street.

FIGURE E.4
SAMPLE HYDRAULIC MODEL PROFILE



Profiles similar to that presented in Figure E.4 were provided for each project identified in Section E.1 through E.3. This particular profile was quickly identified as a segment of the system not capable of conveying peak design flows, therefore providing the basis for replacement with an up-sized pipe, however not all projects were as straight forward due to differing levels of deficiency. The City provided input on each profile and collectively, a determination was made on whether to up-size (replace) or leave the line in service allowing surcharging to occur under peak wet weather conditions. While the improvement analysis was performed based on existing system demands, the proposed improvements identified were sized to convey peak wet weather flows from the buildout scenario. Although the majority of the system deficiencies are in fully developed portions of the City, significant re-development is envisioned in the City's buildout land use plan. Sizing the replacement facilities for buildout flows ensures re-development, if any occurs, will be accounted for in the conveyance capacities of the improvements.

After consulting with the City, the criteria for necessitating improvements of a deficient wastewater line were established. While the initial method of identifying system improvements deficiencies was defined earlier as a Stage 2 surcharge, a new criteria was established to allow those deficient pipes with HGL's (wastewater level) more than 3-feet below the elevation of the rim to remain in service and surcharge under peak wet weather conditions. Conversely, those facilities with HGL's less than 3-feet below the elevation of the manhole rim were replaced with pipes sized to convey the peak wet weather flows with no surcharging. Utilizing this new criteria, the following projects were identified:

- The 8-inch wastewater line along Warden Creek from Cole Street to Louisiana Street is replaced with a 10-inch wastewater line.

- The 8-inch wastewater line along the northbound service lanes of U.S. Highway 75 (Central Expressway) from Rock Hill Road to White Avenue is replaced with a 12-inch wastewater line.

- The 10-inch wastewater line east of Hyde Park Court to Willie Street is replaced with a 12-inch wastewater line.

- The 10-inch wastewater line along the western boundary of the Eldorado Heights, Phase 1 Subdivision, from McKinney Ranch Parkway to Bellcrest Drive is replaced with a 12inch wastewater line

Details of the proposed improvements to the wastewater collection system and their estimated project cost are outlined in the City's Wastewater CIP in Section F.

F. 10-YEAR CAPITAL IMPROVEMENT PLAN (2012 THROUGH 2022)

F.1. General

2012 and 2022 Hydraulic Models were created to simulate the immediate growth and 10-year growth anticipated within the planning boundary. It is envisioned that as new development occurs within the Planning Boundary, the City will annex the proposed developments into the City and acquire the CCN to serve the area. The existing Wastewater Collection system will require significant improvements over the next ten years to meet the projected wastewater demands resulting from the anticipated growth.

F.2. Wastewater Collection Lines & Facilities

The natural creeks, whose basins will collect wastewater through the installed system of collection lines that flow into the geographic area serviced by the North Texas Municipal Water District (NTMWD). The wastewater collection system analysis covered all of the drainage basins within the Service Area planning boundary. The collection system was generally analyzed for pipe sizes 12-inches in diameter and larger, while hydraulically significant pipes 8-inch and 10-inch in diameter were included as necessary. Eliminating line sizes smaller than 12-inches in diameter from the study leaves only the interceptor and trunk lines included in the study. The wastewater project cost includes necessary appurtenances (manholes, lift stations, aerial crossings and the like), purchase of easements, utility relocation, pavement removal and replacement, and engineering costs.

Proposed wastewater lines scheduled to be constructed between 2012 and 2022 are summarized in Table No. F.1 and illustrated on Figure No. F.1. The projects listed with a "1" before the proposed project description in Table No. F.1 are wastewater collection system improvements that will be initiated by development and the City will participate (if funds are available) in the cost oversize between the size of collection line required to support the development and the buildout size. These improvements are colored green on Figure No. F.1. The balance of projects in Table No. F.1 are system wide projects the City will construct. These lines are colored as indicated in the legend on Figure No. F.1.

Table No. F.2 summarizes recommended improvements to the existing collection system. These projects were identified in Section E and are required to provide relief to deficient wastewater lines identified by model results. These projects have been included on Figure No. F.1.

F.3. Treatment

The NTMWD provides the City of McKinney with a significant portion of its wastewater collection. NTMWD also owns and operates the Wilson Creek Treatment Plant and provides the entirety of McKinney's wastewater treatment. McKinney pays NTMWD for the cost of this service based on the City's present contribution of wastewater flows in each of the regional facilities in any given year.

This study excludes the cost of NTMWD regional collection facilities located within the City's Service Area planning boundary that were paid for by NTMWD. Existing treatment plant and future treatment plant expansion costs of NTMWD were specifically excluded from this study.

TABLE NO. F.1
10-YEAR CAPITAL IMPROVEMENT PLAN
WASTEWATER COLLECTION SYSTEM

PROPOSED WASTEWATER COLLECTION LINES

Year	1=City Participation in Cost Oversize 2=City Initiated and Funded	Project	Size	Opinion of Construction Cost (1)
2013	1	Westerra Stonebridge - Sanitary Sewer Trunk Line Line "H-3"	15-24"	$ 628,692
2013	1	Trinity Falls Off-site Wastewater Line	36"	$ 2,503,778
2014	1	Clemons Creek Trunk Sewer	21"-27"	$ 834,039
2016	1	Honey Creek Trunk Sewer	15"-36"	$ 1,177,041
2017	1	NTMWD Prosper / McKinney Parallel Interceptor	42" - 48"	$ 2,310,393
2018	1	Big Branch Trunk Sewer	21"-27"	$ 468,264
2018	1	Upper East Fork Trunk Sewer	15"-30"	$ 855,365
2020	1	Franklin Branch Trunk Sewer	15"-18"	$ 297,066
2022	2	Stonebridge Lift Station No. 1 Abandonment Sanitary Sewer	24"	$ 1,022,400
2022	1	Stover Creek Trunk Sewer	24"-27"	$ 1,114,487
2022	1	Upper Wilson Creek Trunk Sewer	15"	$ 157,933
		Subtotal: Proposed Wastewater Lines		**$ 11,369,457**

PROPOSED WASTEWATER FACILITIES

Year	1=City Participation in Cost Oversize 2=City Initiated and Funded	Project	Capacity (MGD)	Opinion of Construction Cost (1)
2013	1	Westerra Stonebridge - Lift Station No. 2 & Forcemain	4.9	$ 345,674
2013	1	Westerra Stonebridge - Lift Station No. 3 & Forcemain	4.4	$ 380,098
		Subtotal: Proposed Wastewater Facilities		**$ 725,772**
		Grand Total: Proposed Wastewater Improvements		**$ 12,095,229**

** Construction Cost Reduced by 50% On Lift Station No. 3 and 60% On Lift Station 2*

for Excess Capacity Available to City for Future Development

(1) Opinion of Cost includes:

a) Engineer's Opinion of Construction Cost

b) Professional Services Fees (Survey, Engineering, Testing, Legal)

c) Cost of Easement or Land Acquisitions

TABLE NO. F.2
MISCELLANEOUS CAPITAL IMPROVEMENTS
EXISTING COLLECTION SYSTEM IMPROVEMENTS

Project	Project Length (feet)	Pipe Diameter (inches)	Opinion of Construction Cost (1)
Replacement of 8-inch sanitary sewer along Warden Creek From Cole Street to Louisiana Street with a 10-inch sanitary sewer line	1,250	10 & 12	$ 222,400
Replacement of 8-inch sanitary sewer along northbound service lanes of U.S. Highway 75 (Central Expressway) from Rock Hill Road to White Avenue	2,400	12	$ 460,800
Replacement of 10-inch sanitary sewer line east of Hyde Park Court to Willie Street with a 12-inch sanitary sewer line	900	12	$ 172,800
Replacement of 10-inch sanitary sewer line along the western boundary of the Eldorado Heights, Phase 1 Subdivision, from McKinney Ranch Parkway to Bellcrest Drive is replaced with a 12-inch sanitary sewer line	2,850	12	$ 547,200
Replacement of 18-inch sanitary sewer line along Couch Drive and Millwood Road from Old Mill Road to Approximately 1,000 feet north of Elm Street with a 24-inch sanitary sewer line	8,500	24	$ 2,448,000
Subtotal: Existing WastewaterLine Improvements			**$ 3,851,200**

(1) Opinion of Cost includes:

a) Engineer's Opinion of Construction Cost

b) Professional Services Fees (Survey, Engineering, Testing, Legal

c) Cost of Easement or Land Acquisitions

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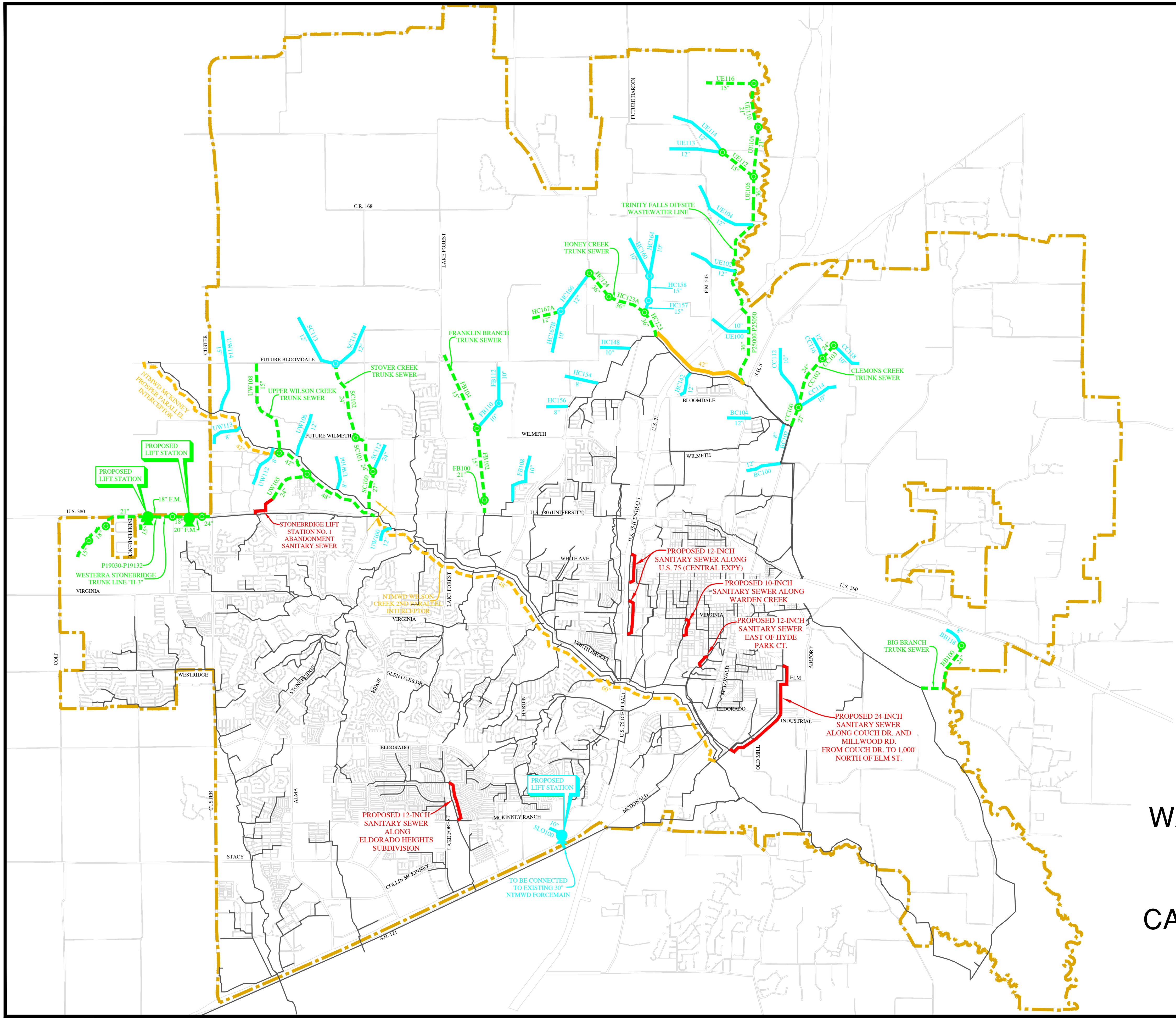

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LEGEND

EXIST. SANITARY SEWER LINE	―
PROP. WASTEWATER COLLECTION LINE (DEVELOPER INITIATED - CITY OVERSIZE)	🟩 🟩 🟩
PROP. WASTEWATER COLLECTION LINE (DEVELOPER CONSTRUCTED)	―
PROP. WASTEWATER COLLECTION LINE (CITY CONSTRUCTED)	🟥
FUTURE MASTER PLAN PIPE (NOT IN THIS 10-YEAR C.I.P.)	🟨
FUTURE NTMWD SANITARY SEWER LINE (IN THIS 10-YEAR C.I.P.)	🟨 🟨 🟨
PLANNING BOUNDARY	▬ ▪ ▬

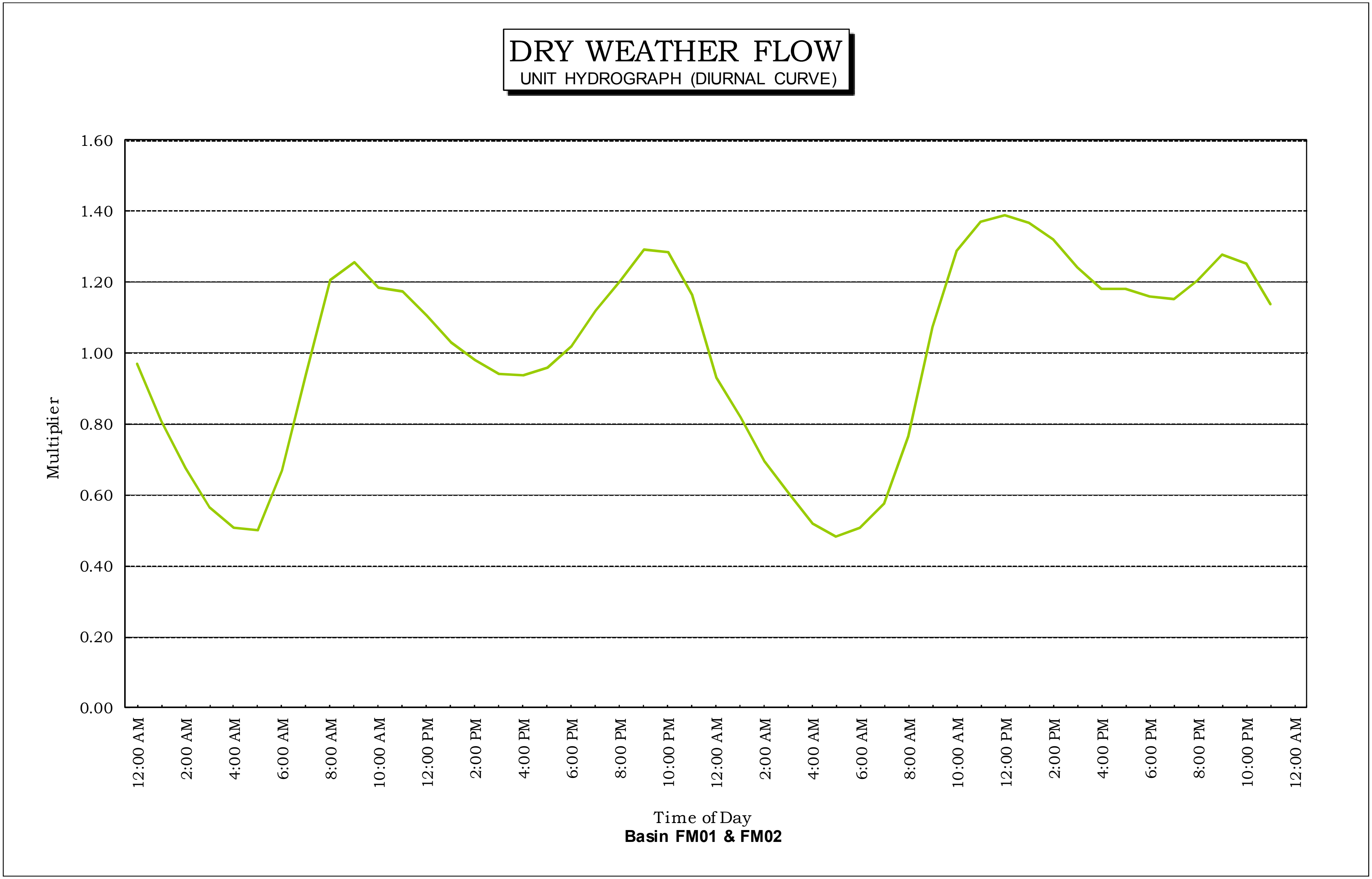
2012 - 2022 WASTEWATER SYSTEM MASTER PLAN 10-YEAR CAPITAL IMPROVEMENT PLAN

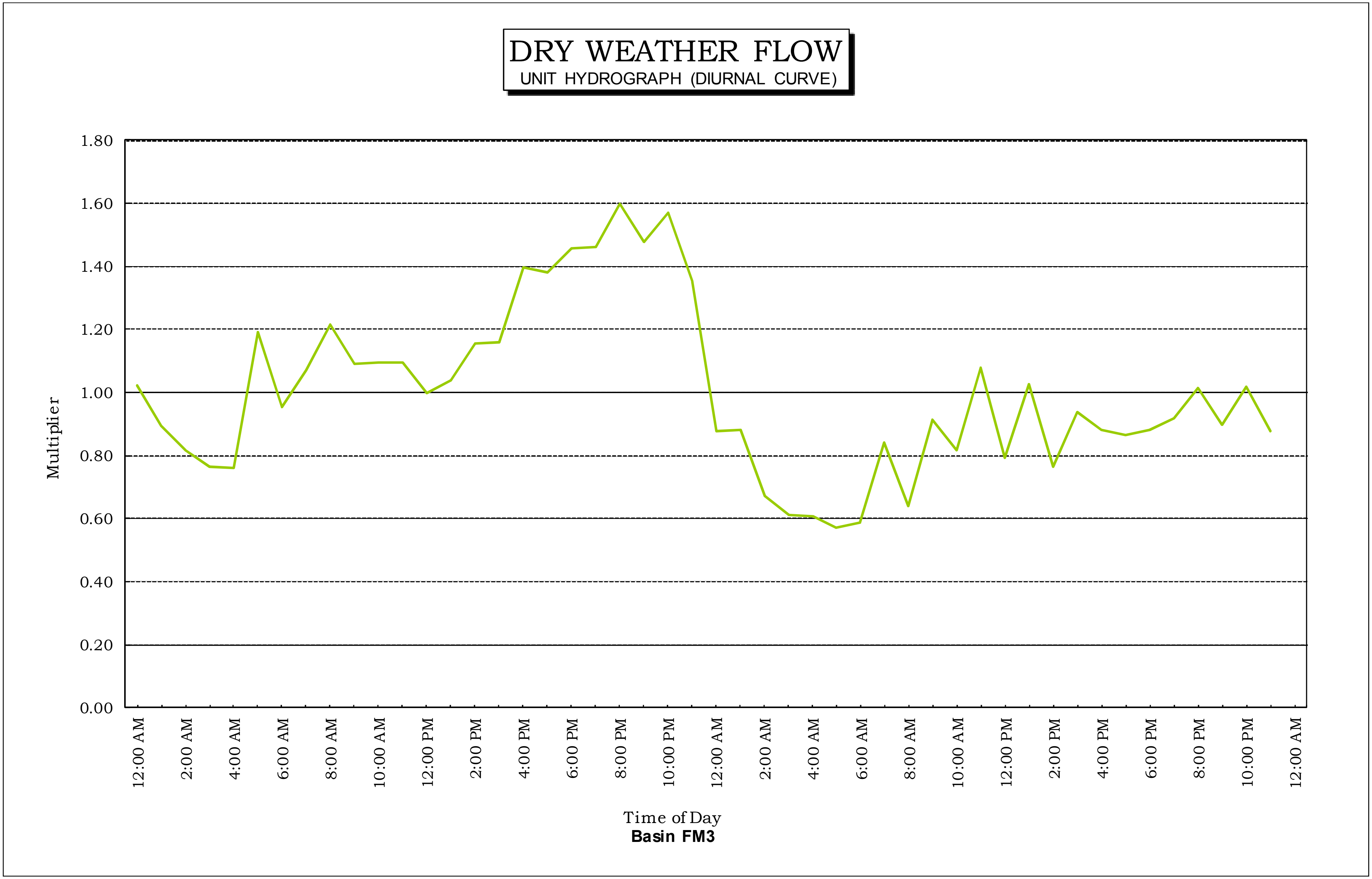
FIGURE F.1

McKINNEY™
T E X A S
Unique by nature.℠

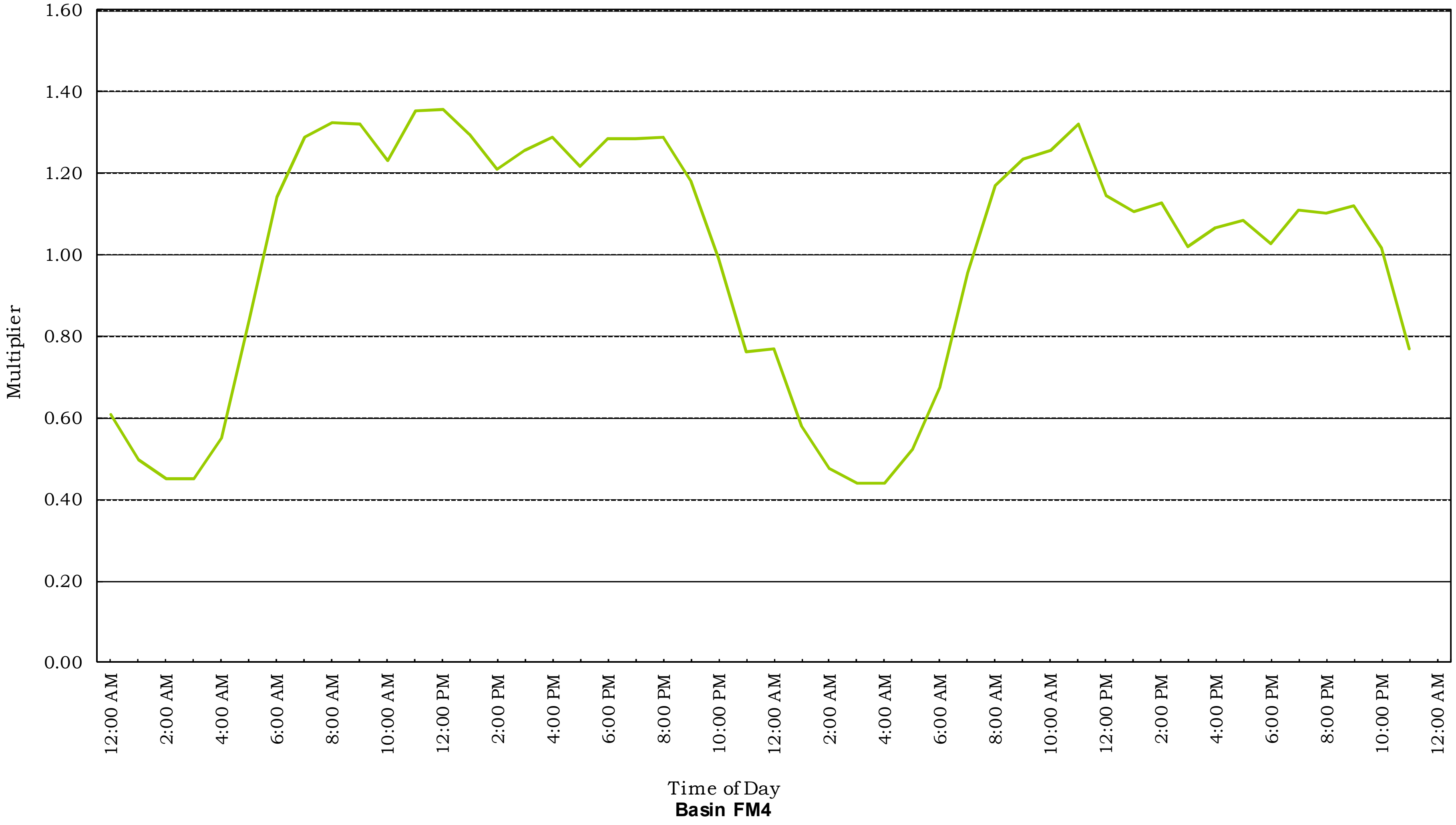
APPENDIX "A"

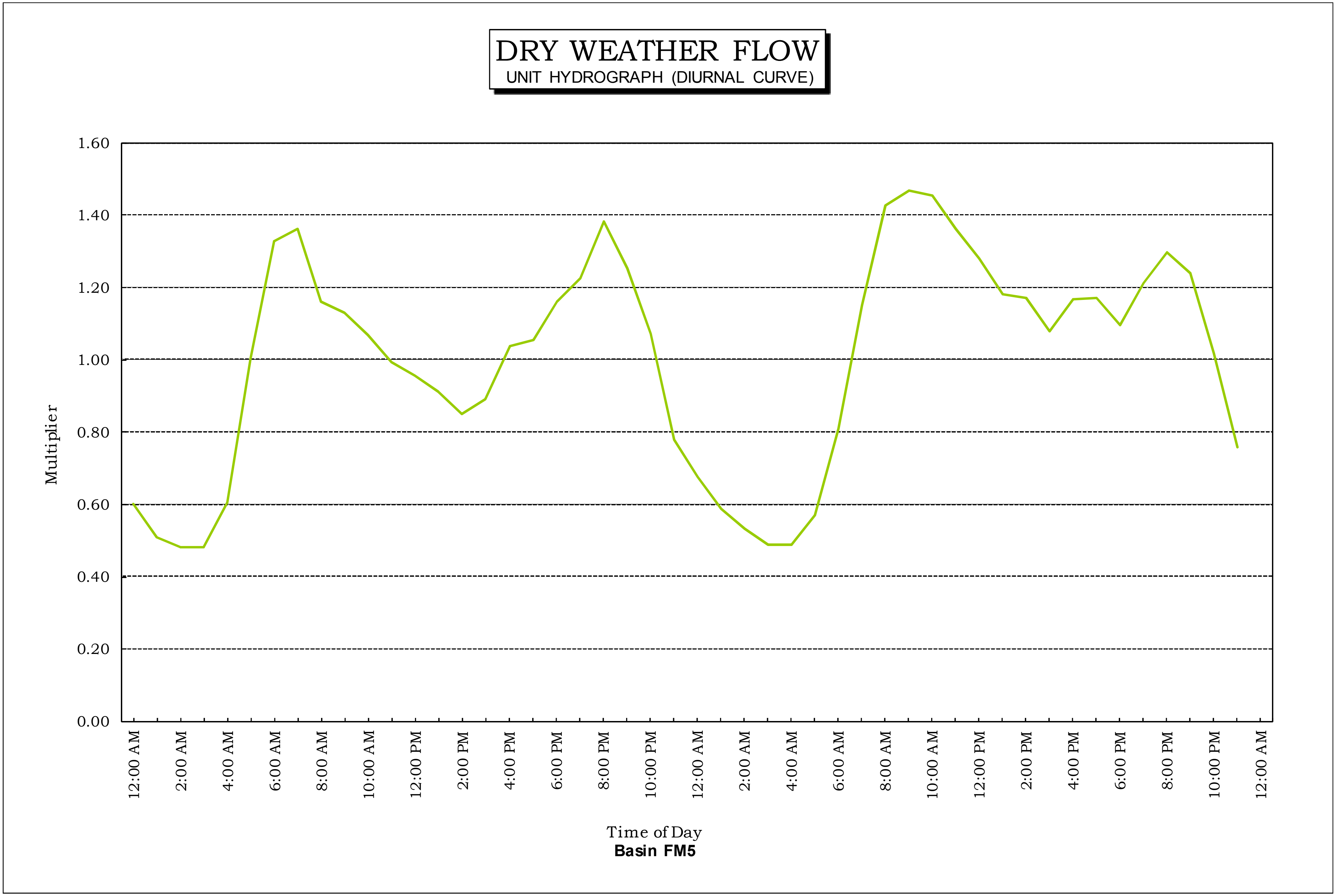
Diurnal Curves For Dry Weather Wastewater Flow


DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)
Multiplier
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day
Basin FM01 & FM02


DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Multiplier
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day
Basin FM3

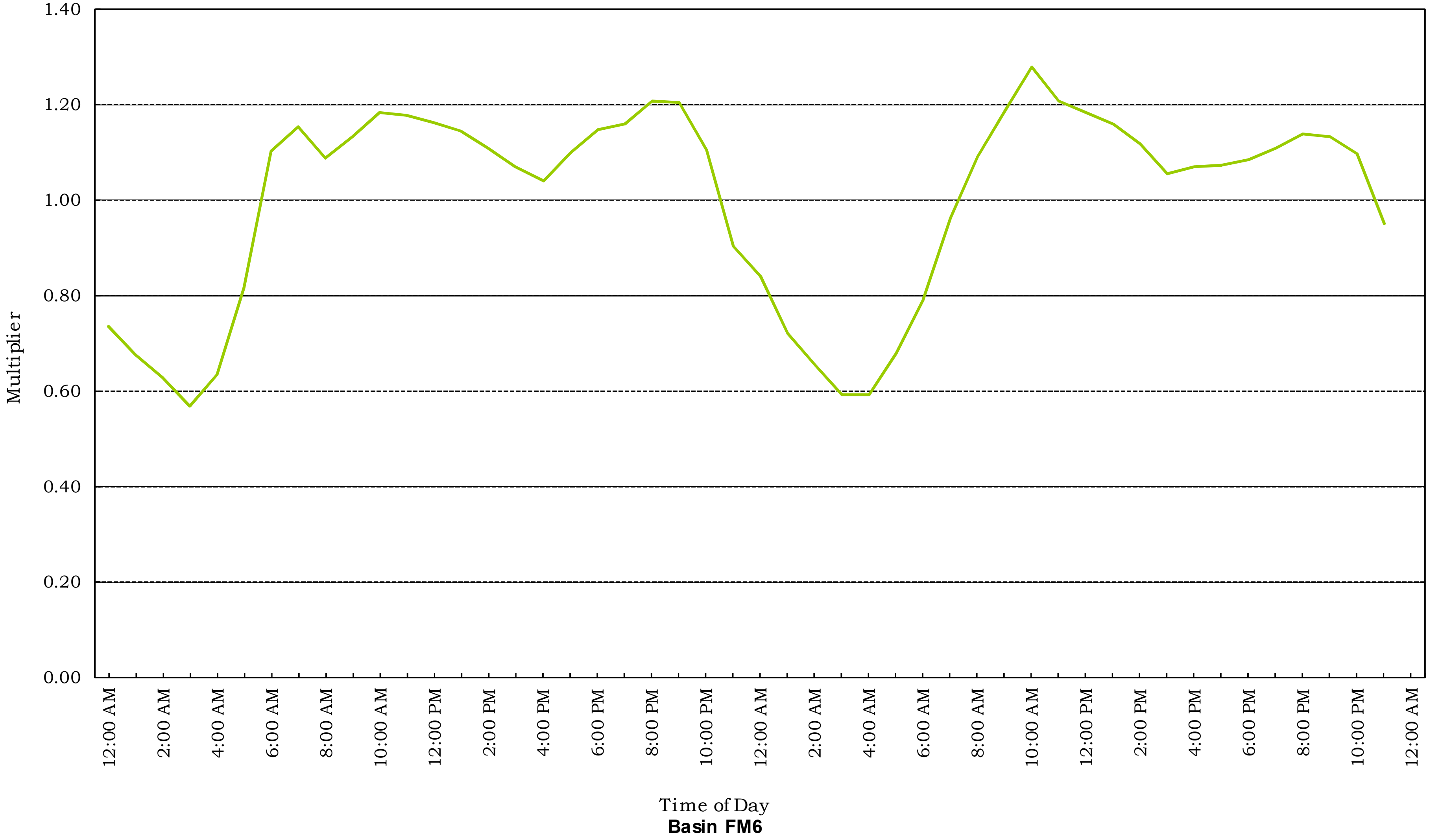
DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)

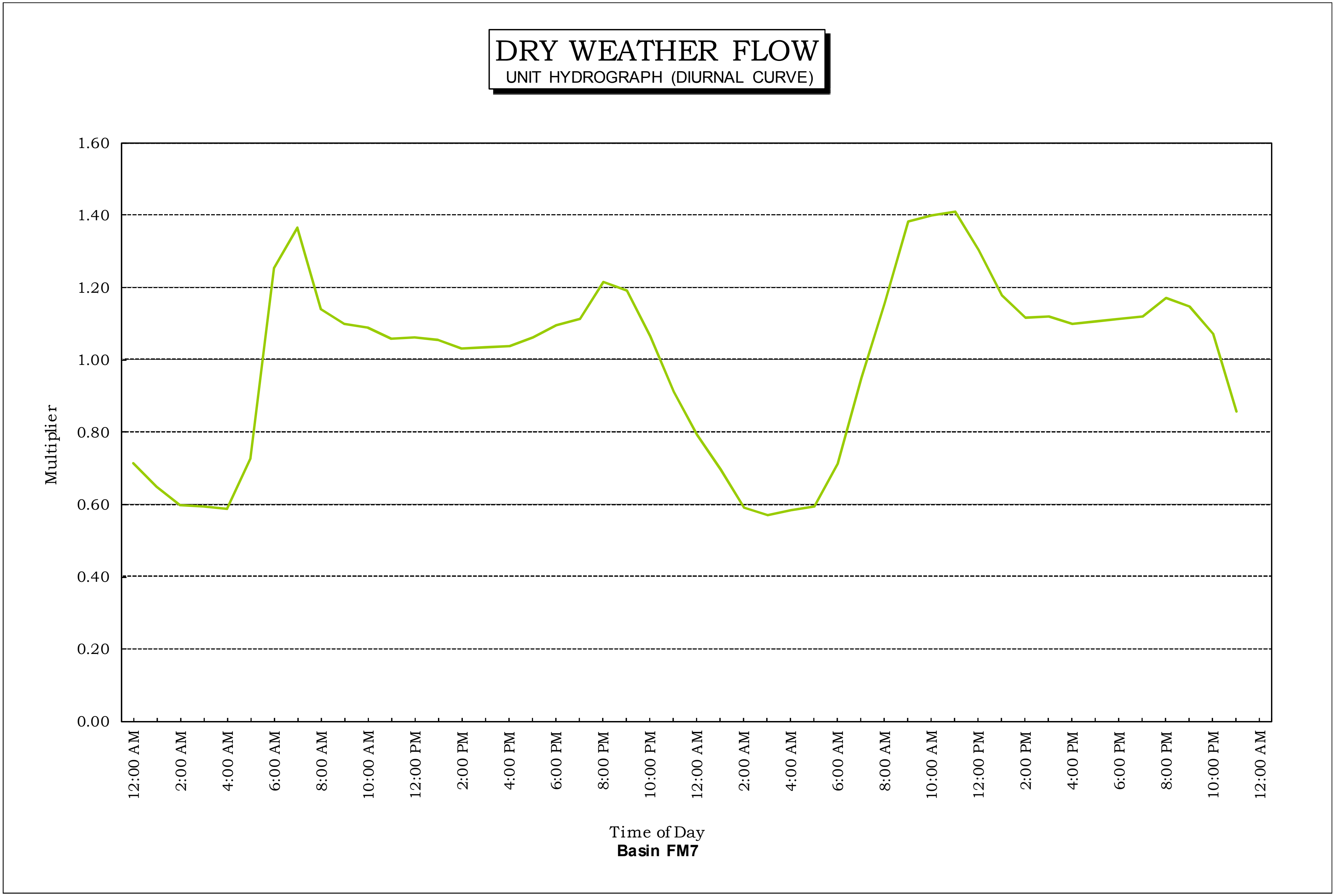


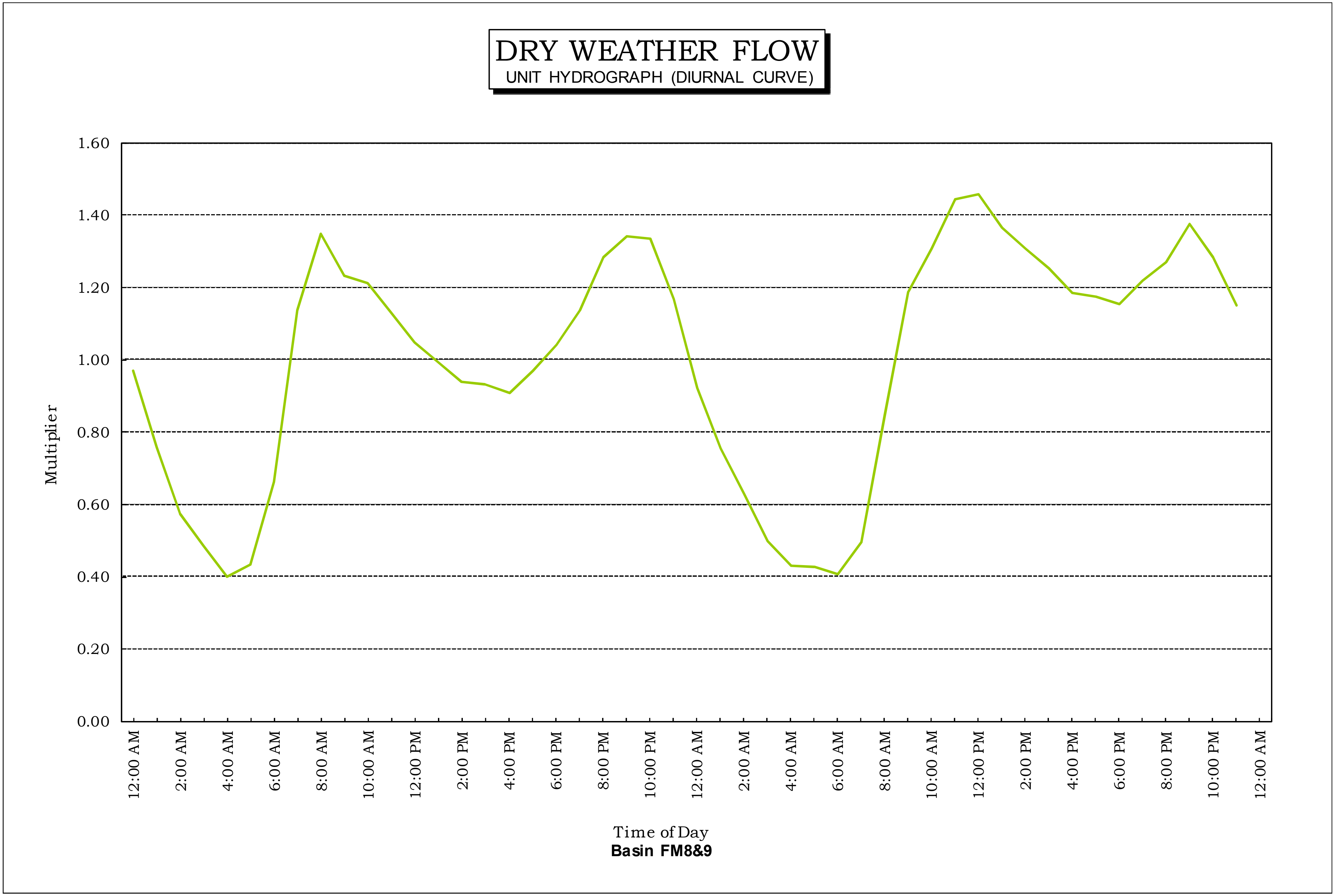

DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Multiplier
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day
Basin FM5

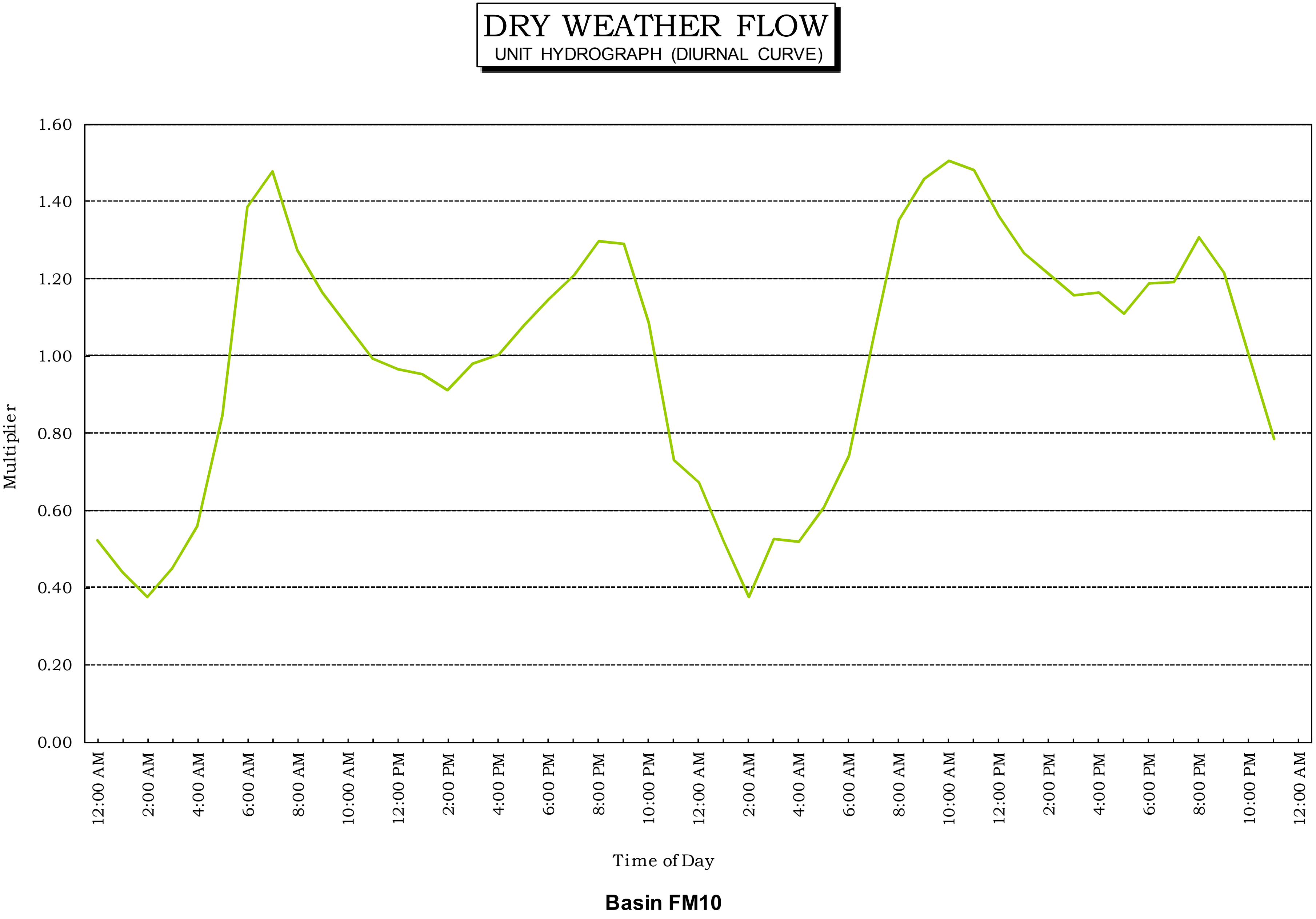
DRY WEATHER FLOW

UNIT HYDROGRAPH (DIURNAL CURVE)



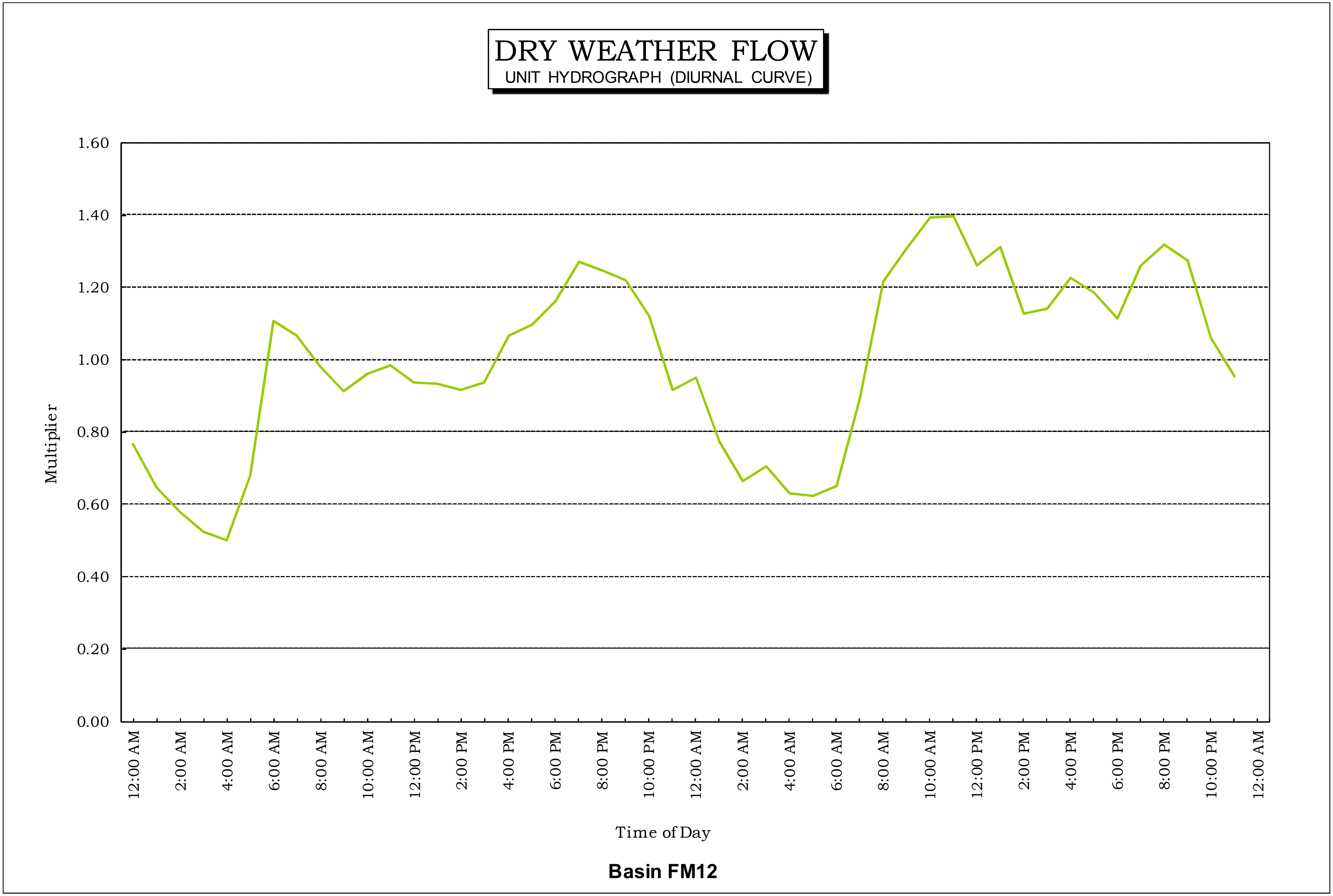

DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Multiplier
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day
Basin FM7

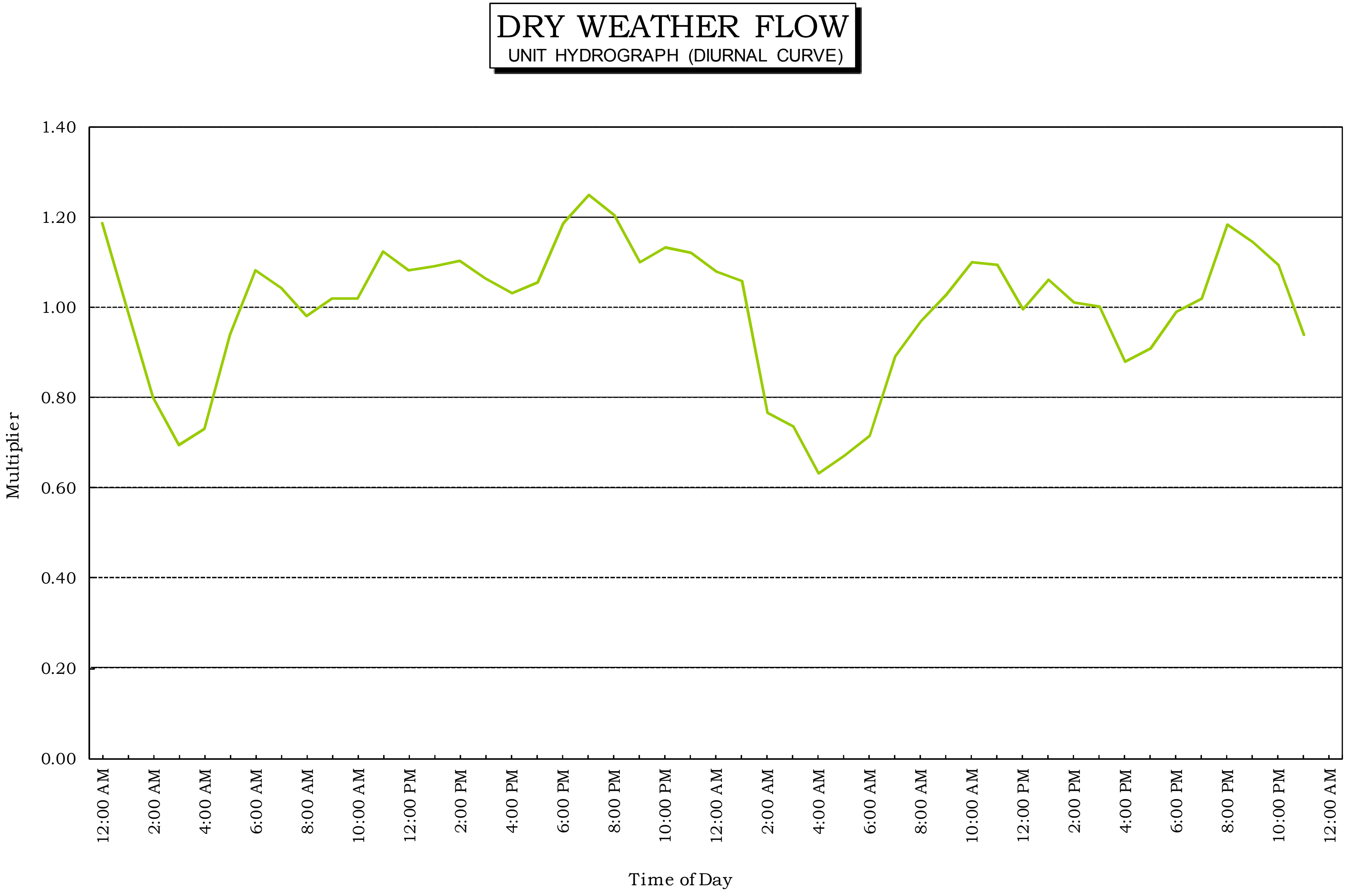

DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Multiplier
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day
Basin FM8&9


DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)
Multiplier
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day
Basin FM10

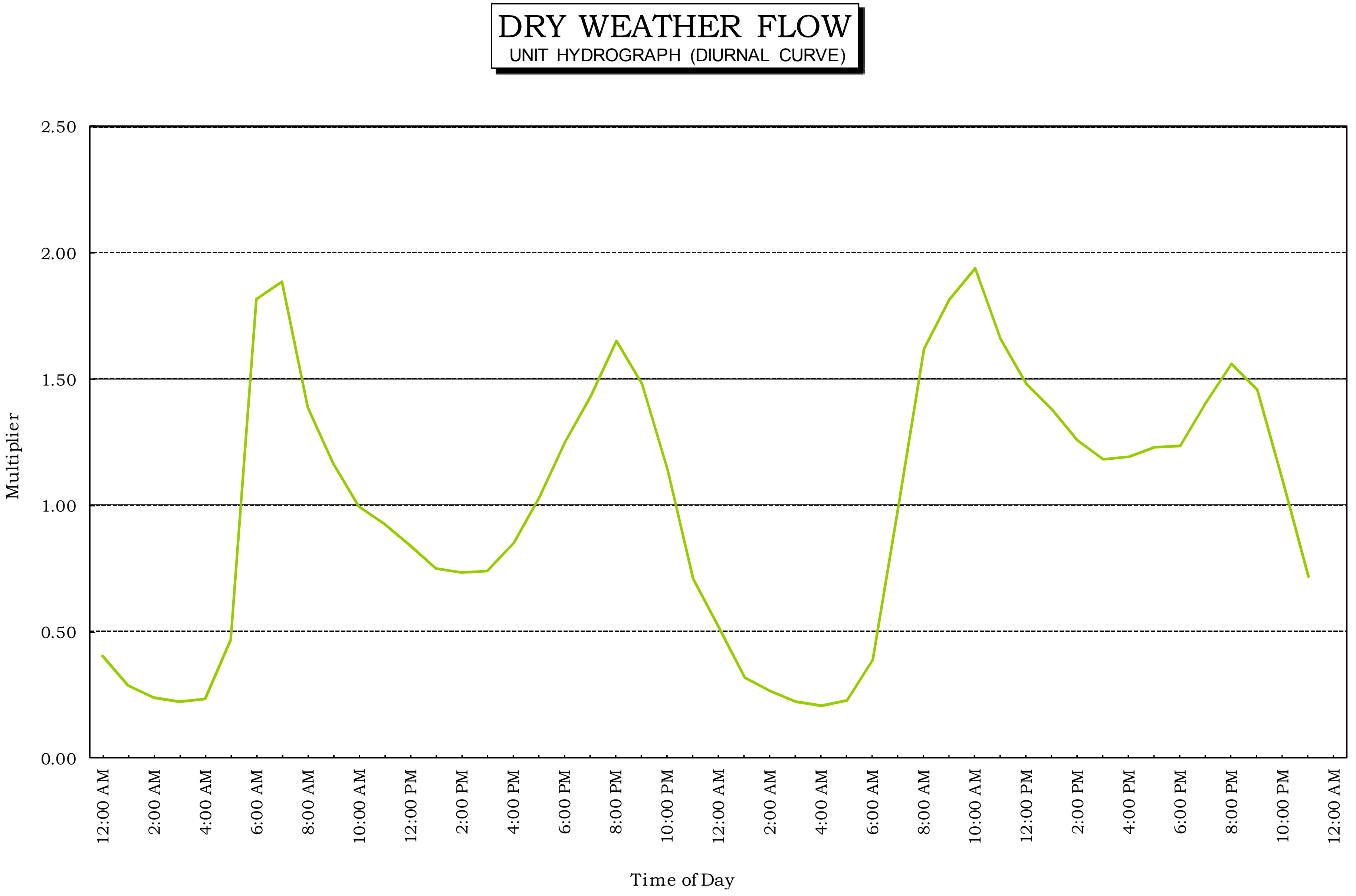
DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)

Basin FM11

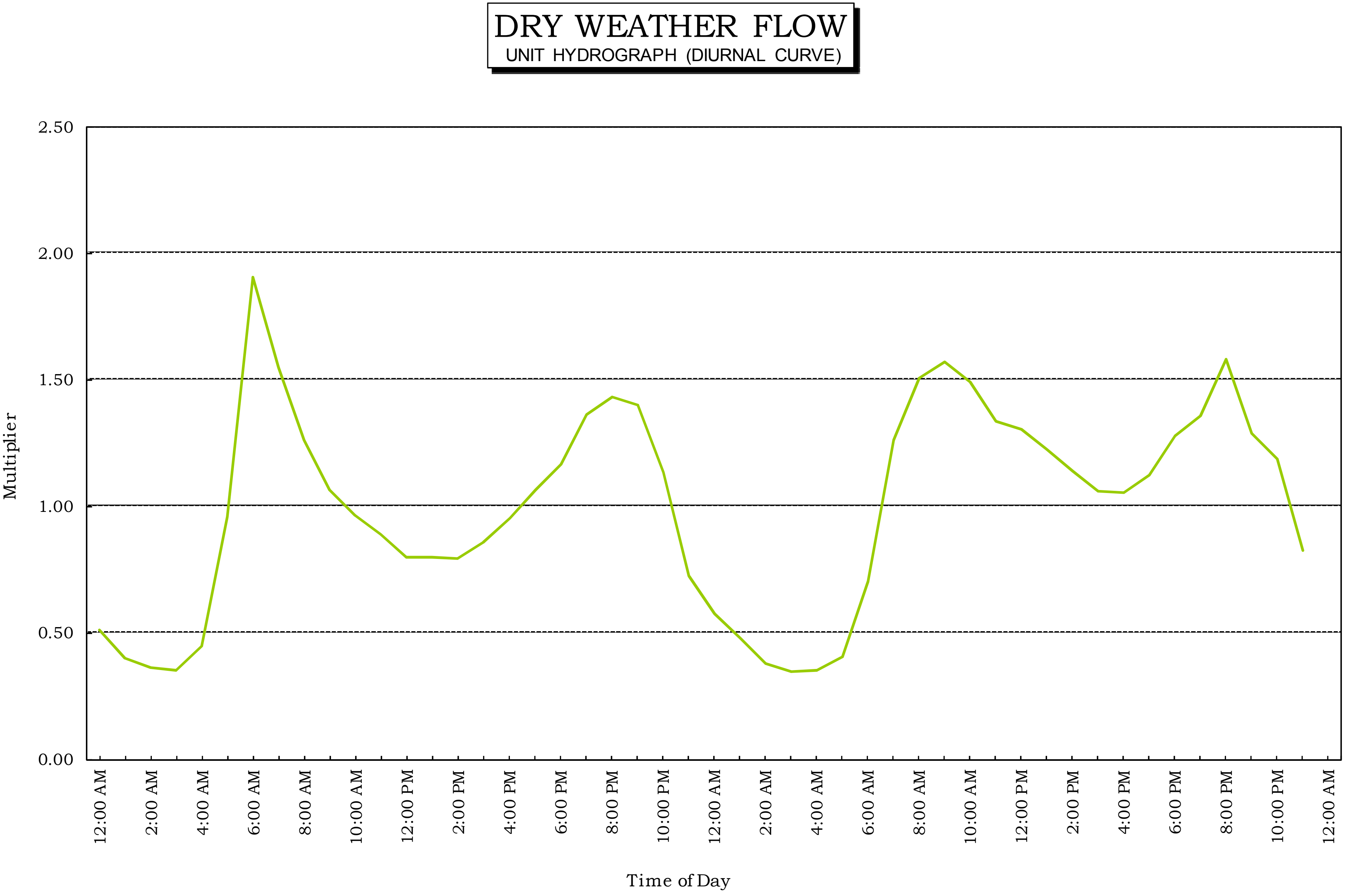

DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Multiplier
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day
Basin FM12


DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Multiplier
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day

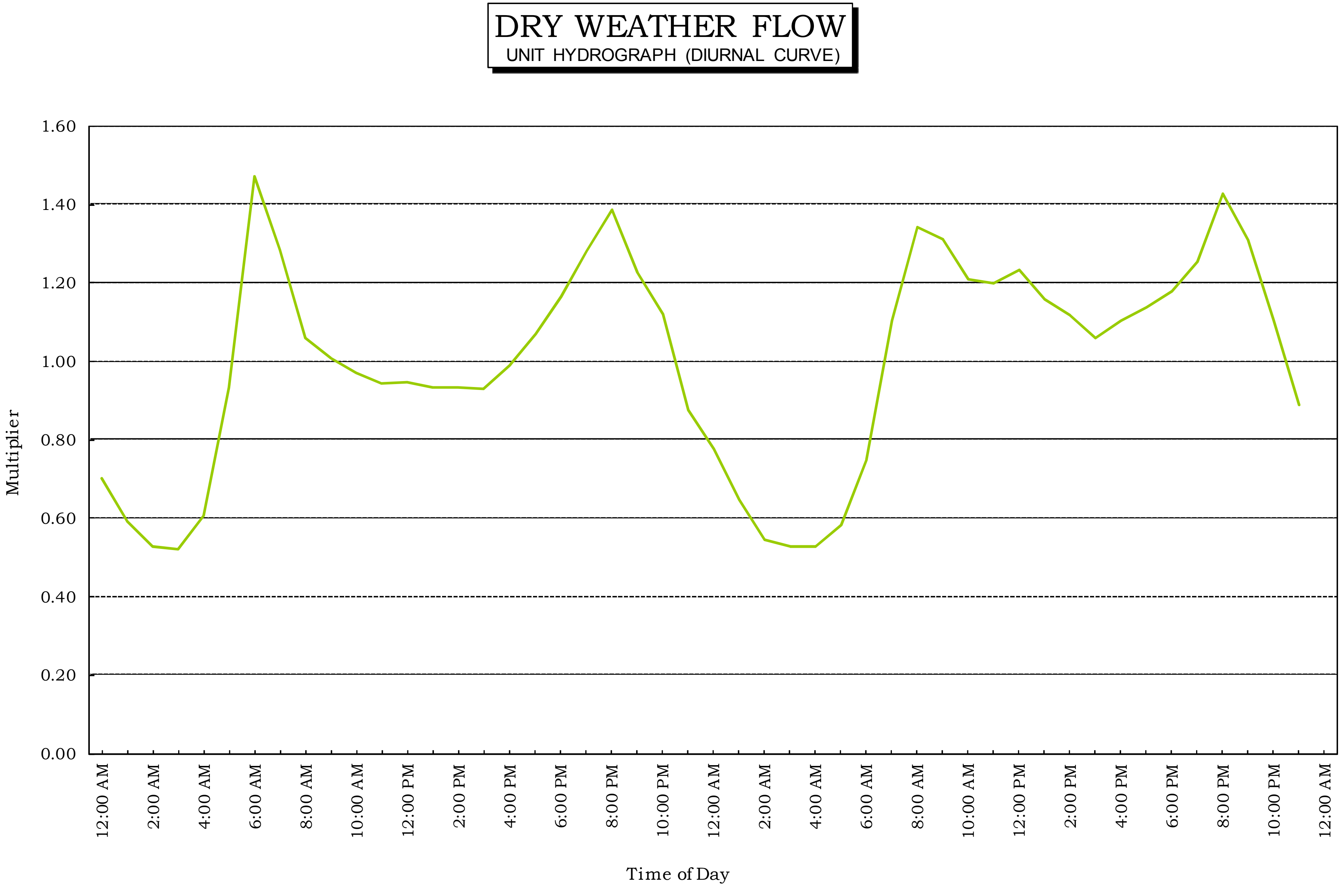
Basin FM13


DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)
Multiplier
2.50
2.00
1.50
1.00
0.50
0.00
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day

Basin FM14


DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)
Multiplier
2.50
2.00
1.50
1.00
0.50
0.00
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day

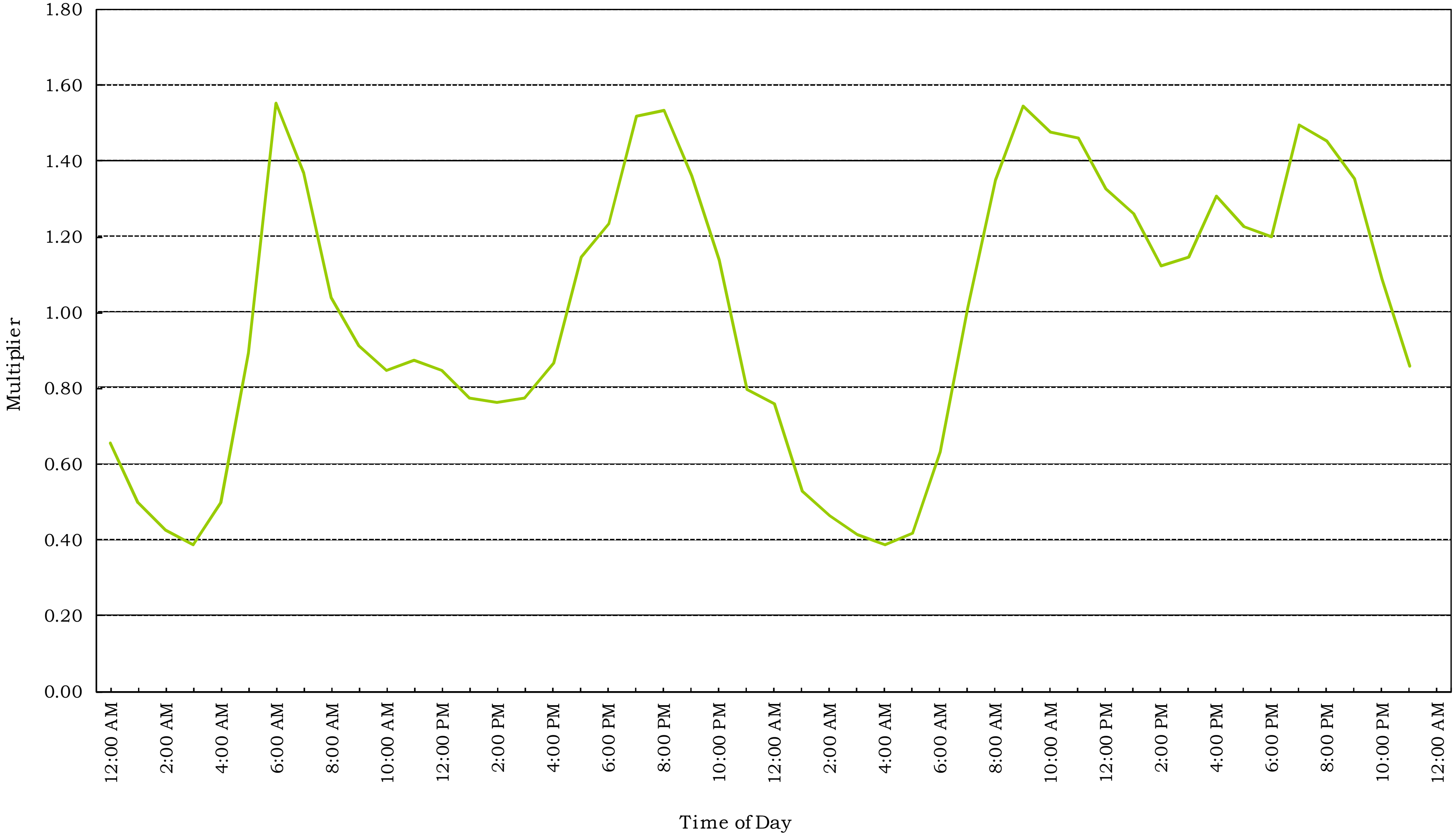
Basin FM15


DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Multiplier
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day

Basin FM16

DRY WEATHER FLOW

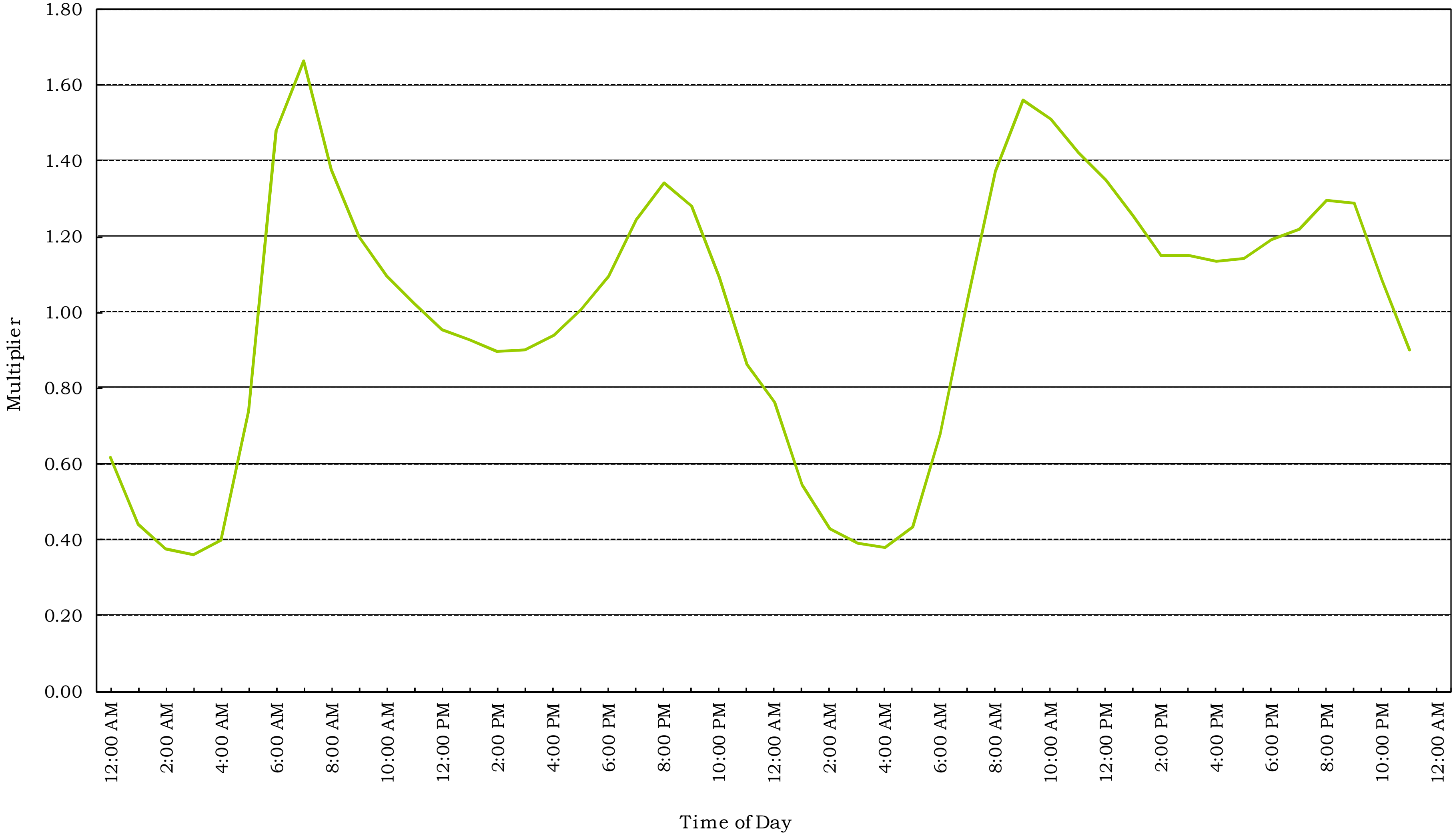
UNIT HYDROGRAPH (DIURNAL CURVE)



Basin FM17

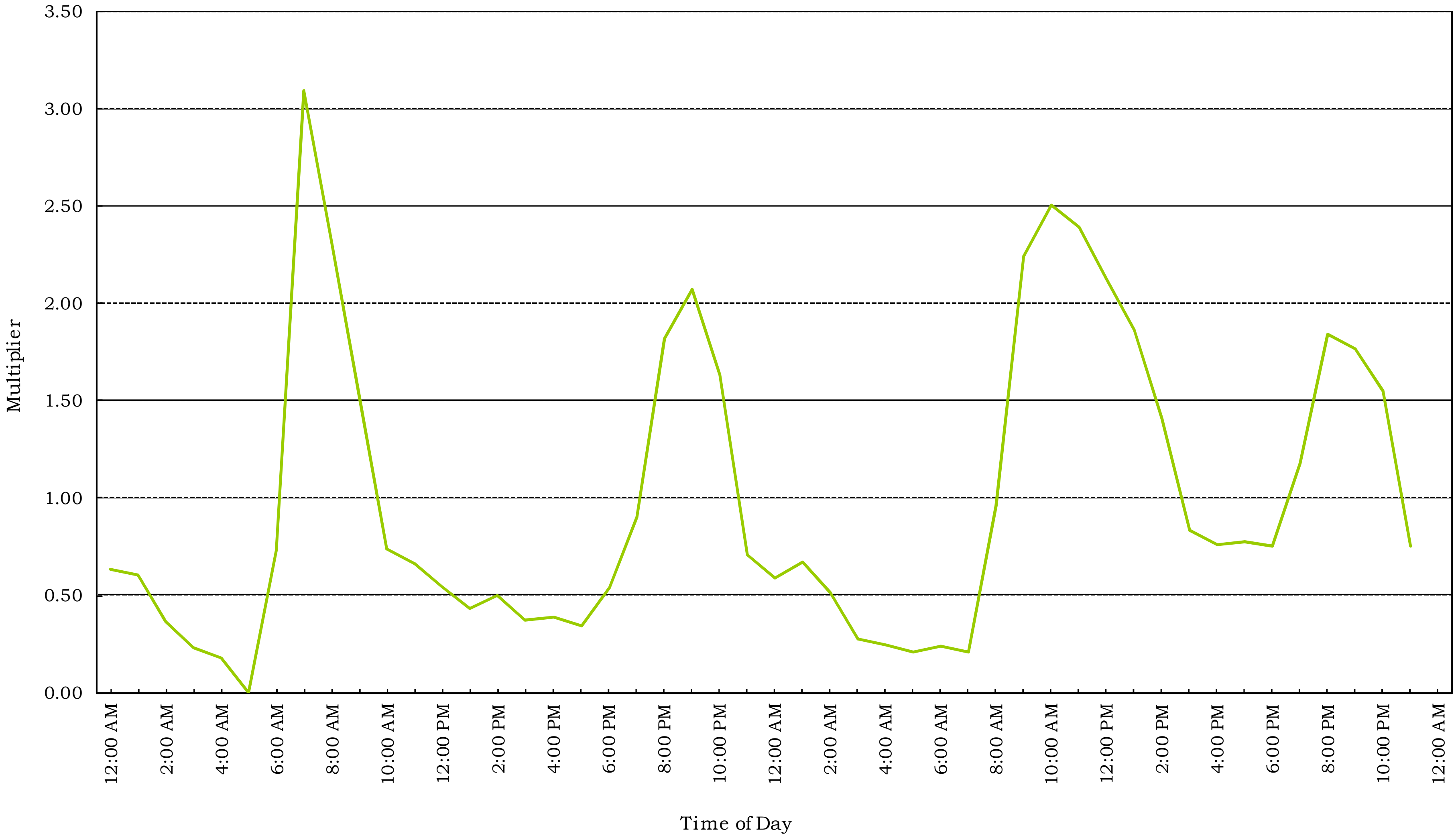
DRY WEATHER FLOW

UNIT HYDROGRAPH (DIURNAL CURVE)



Basin FM18

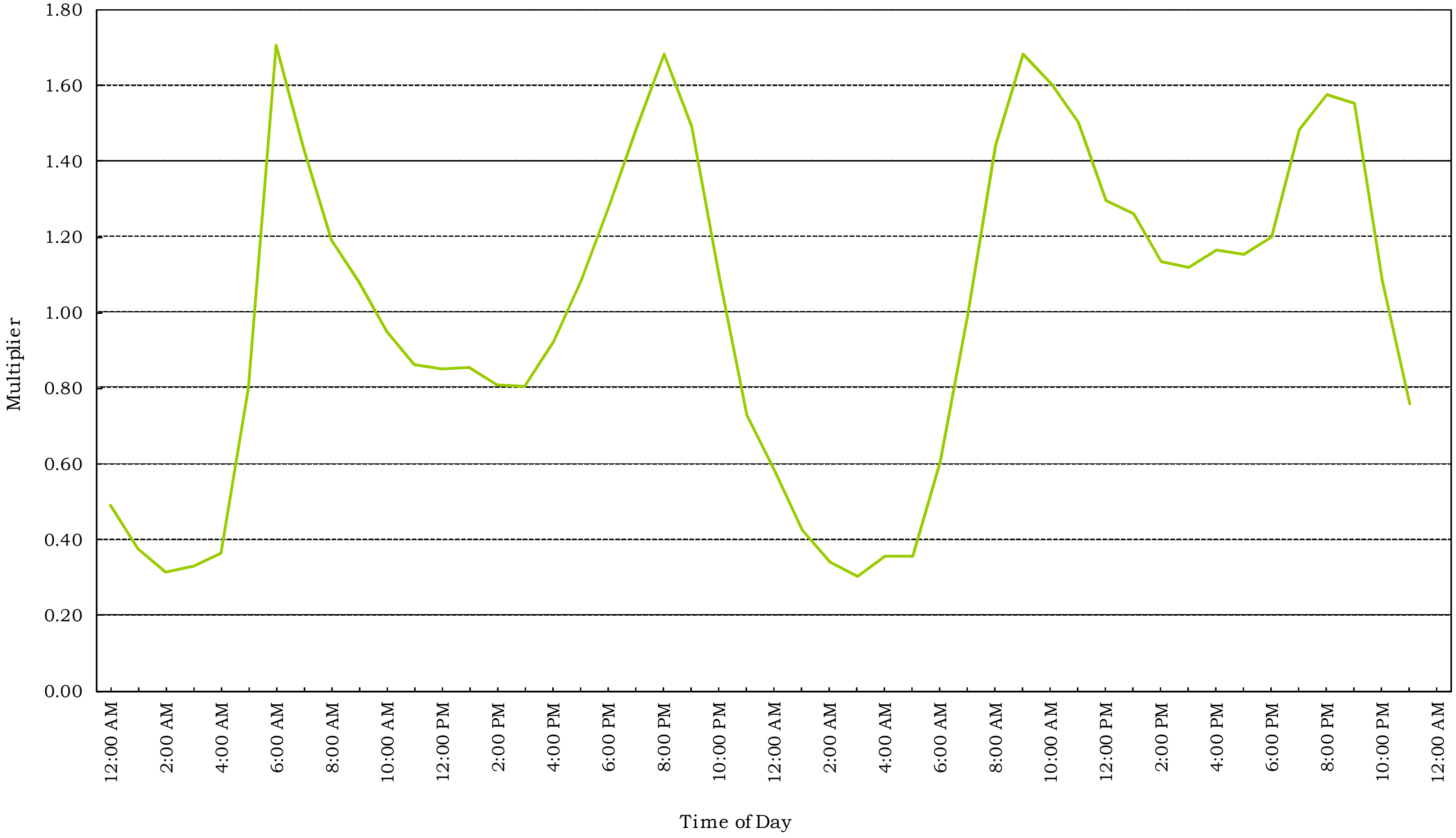
DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)



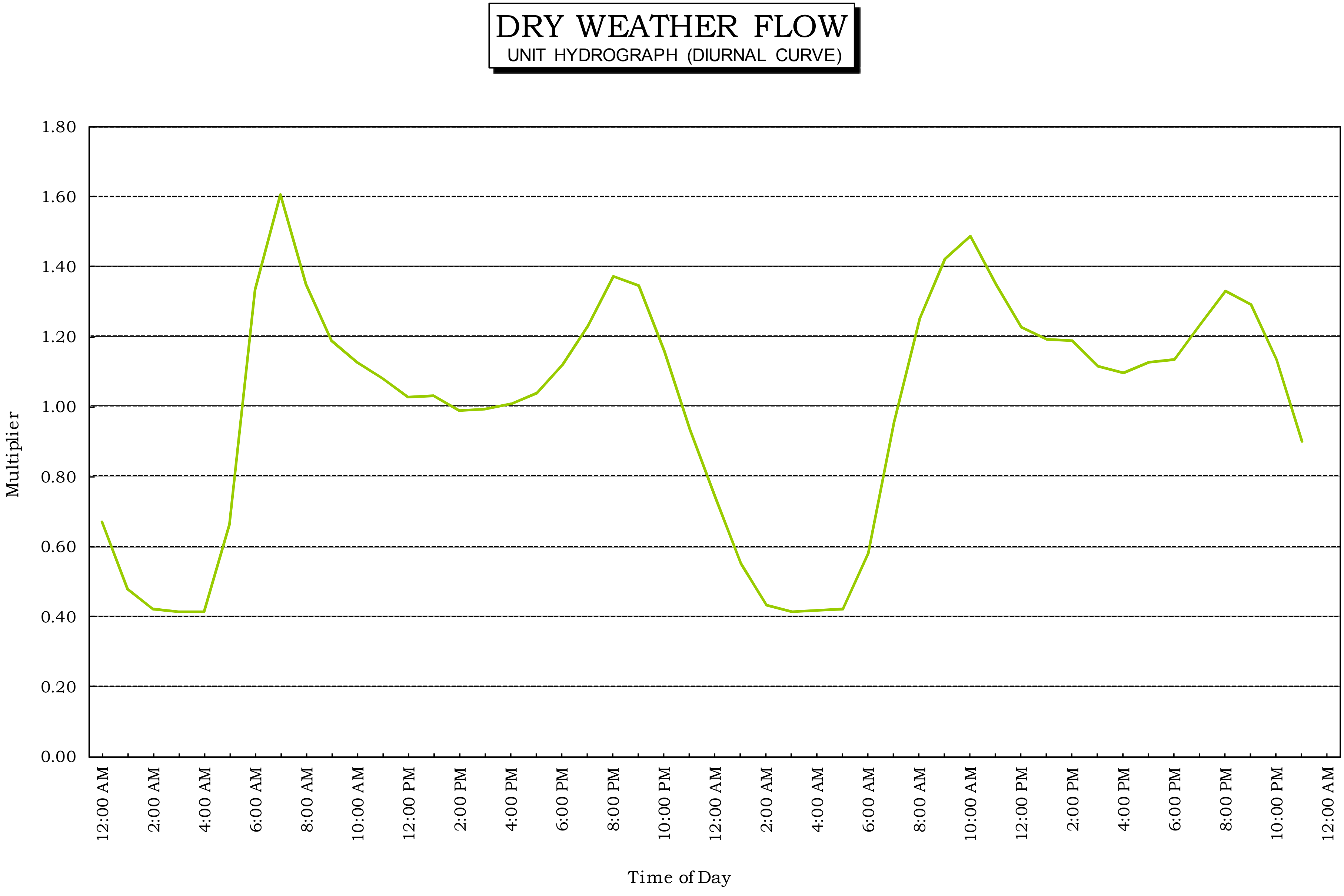
Basin FM19

DRY WEATHER FLOW

UNIT HYDROGRAPH (DIURNAL CURVE)

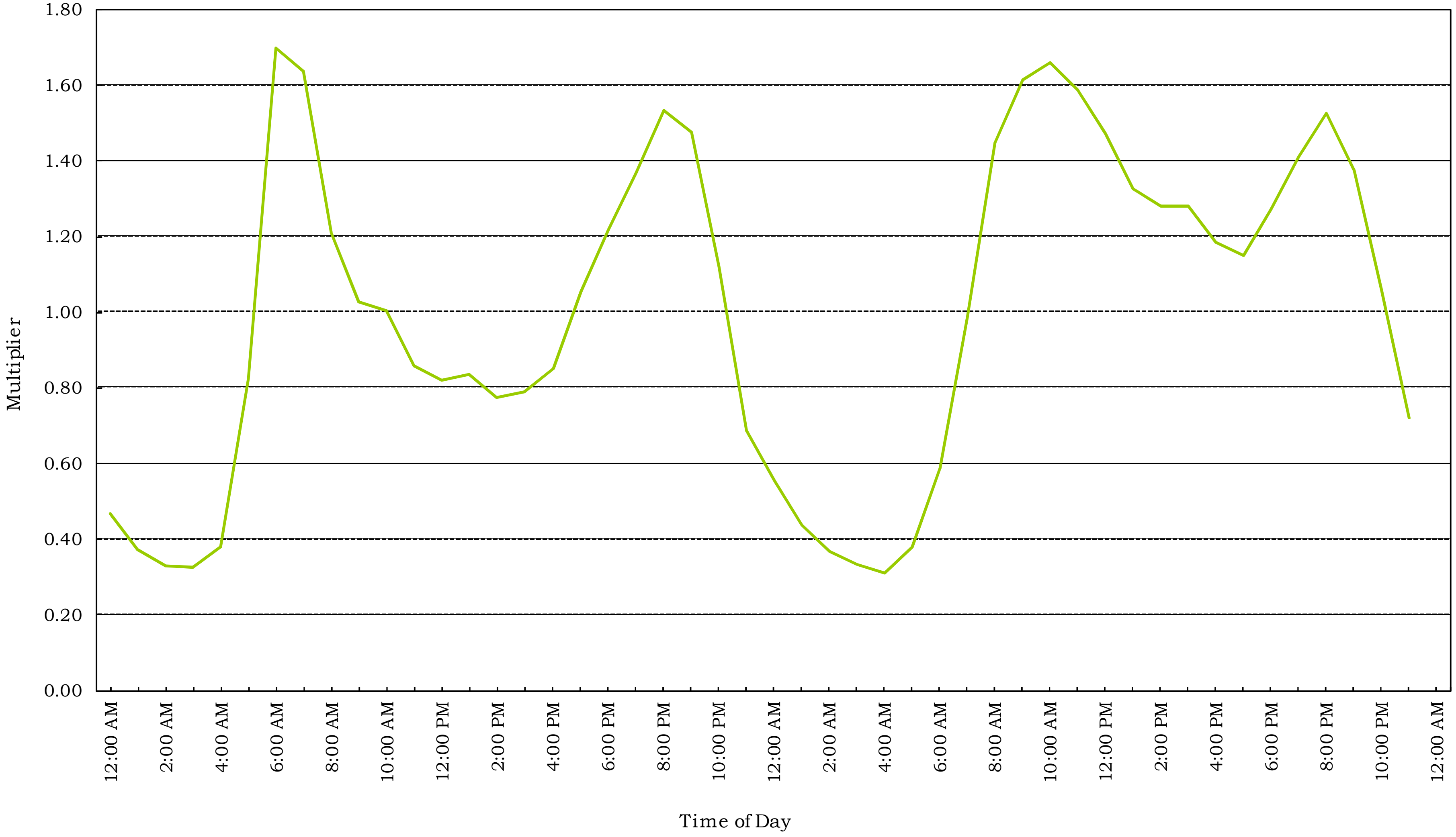


Basin FM20


DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)
Multiplier
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day

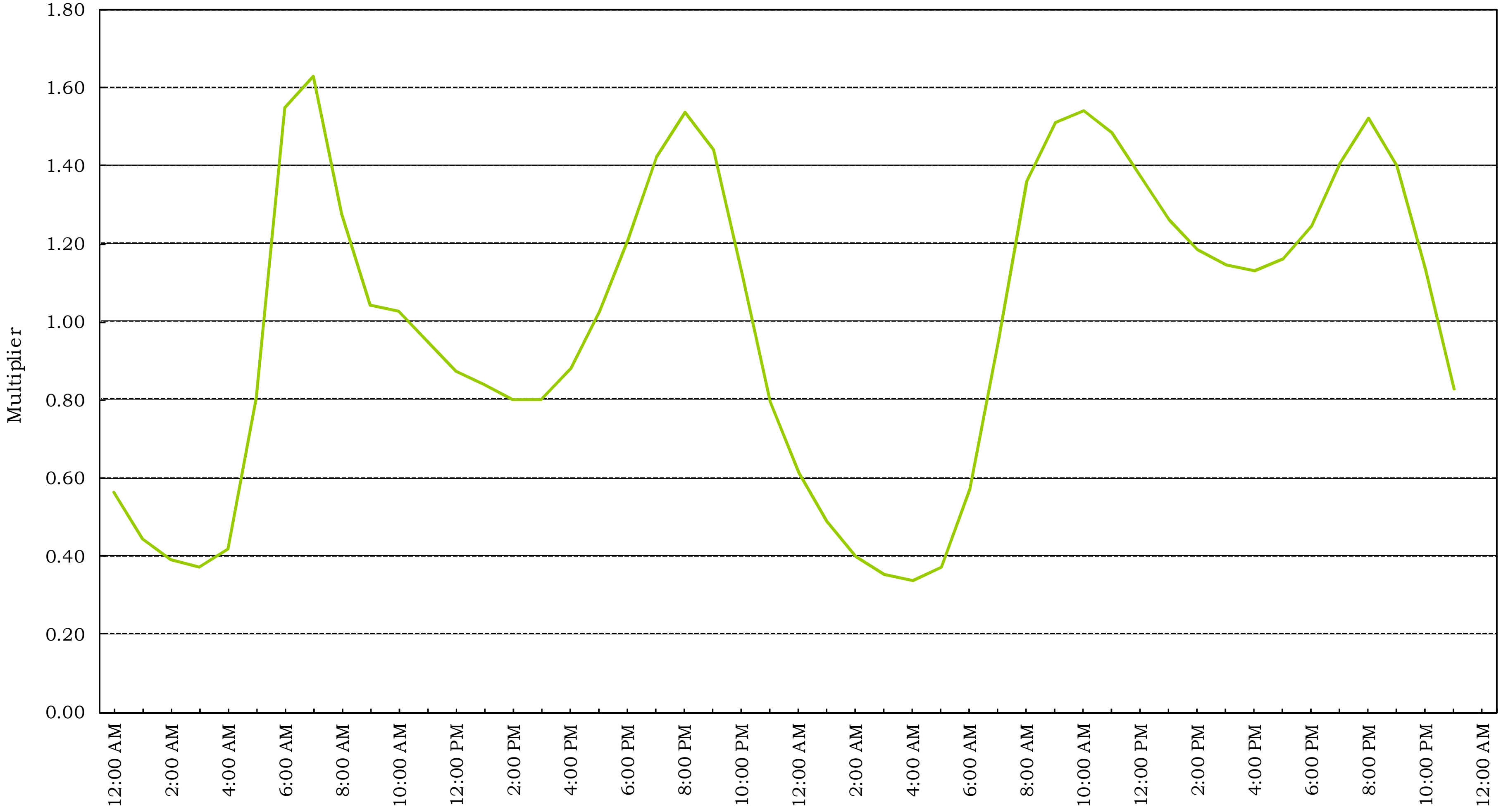
Basin FM21

DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)

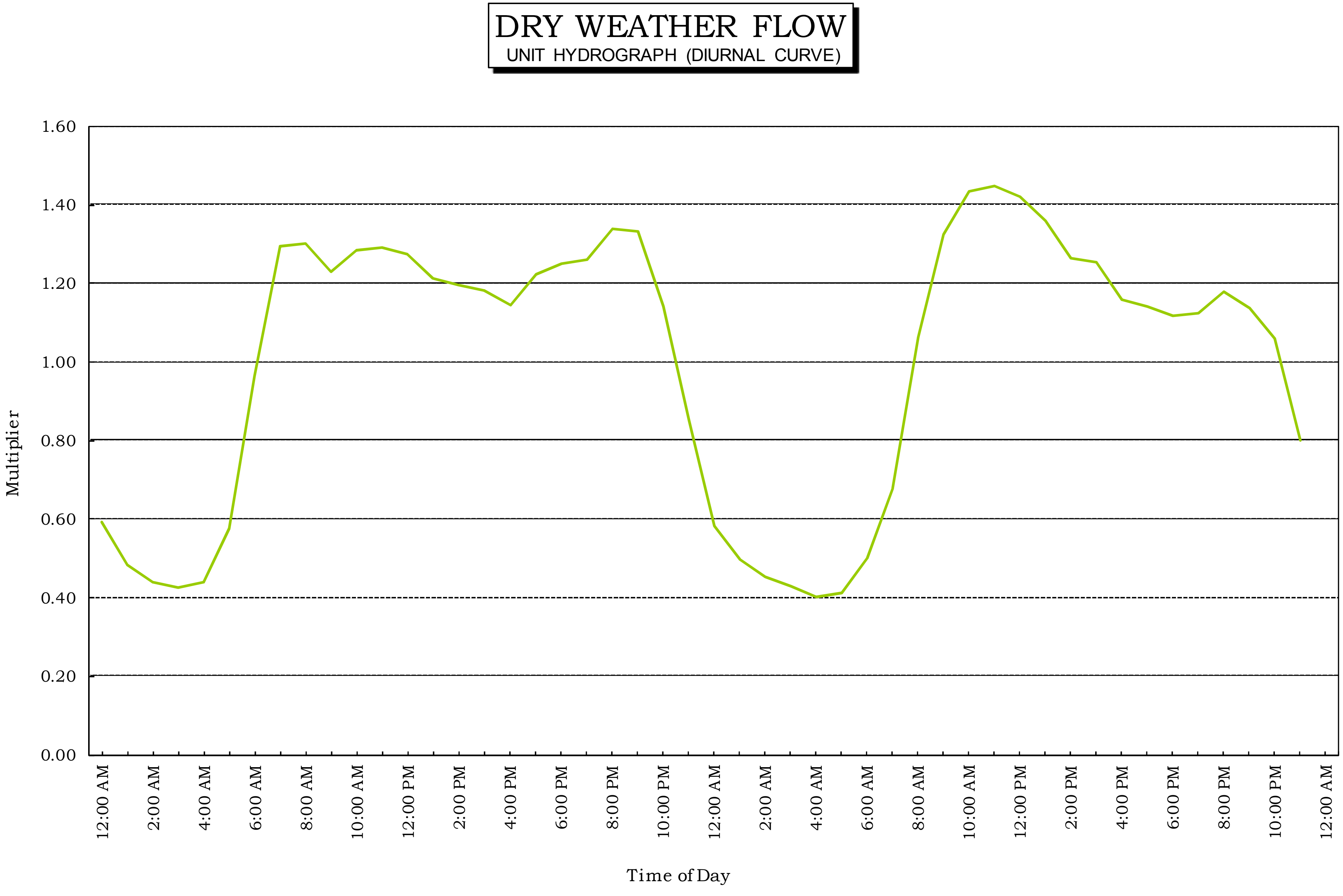


Basin FM22

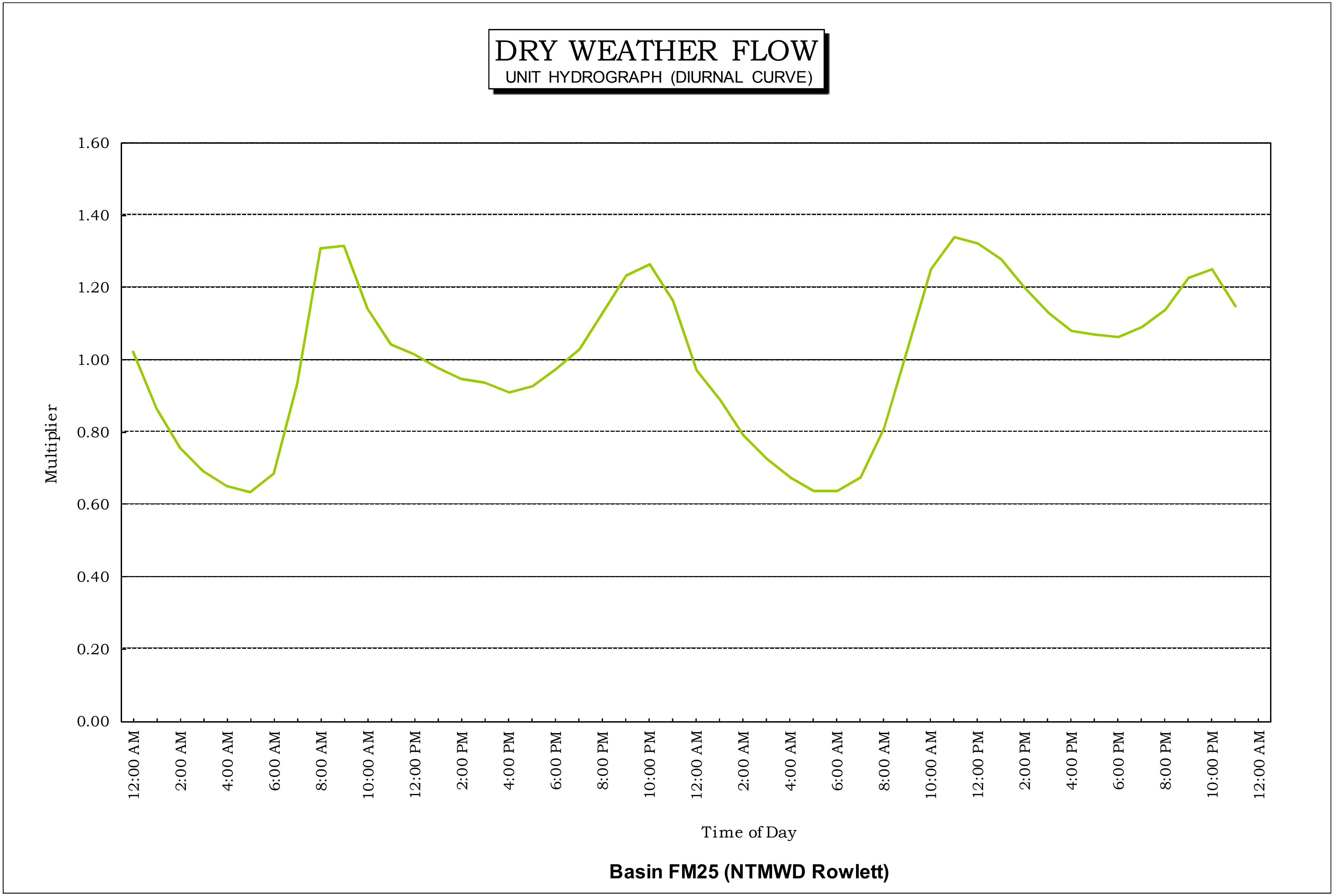
DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)



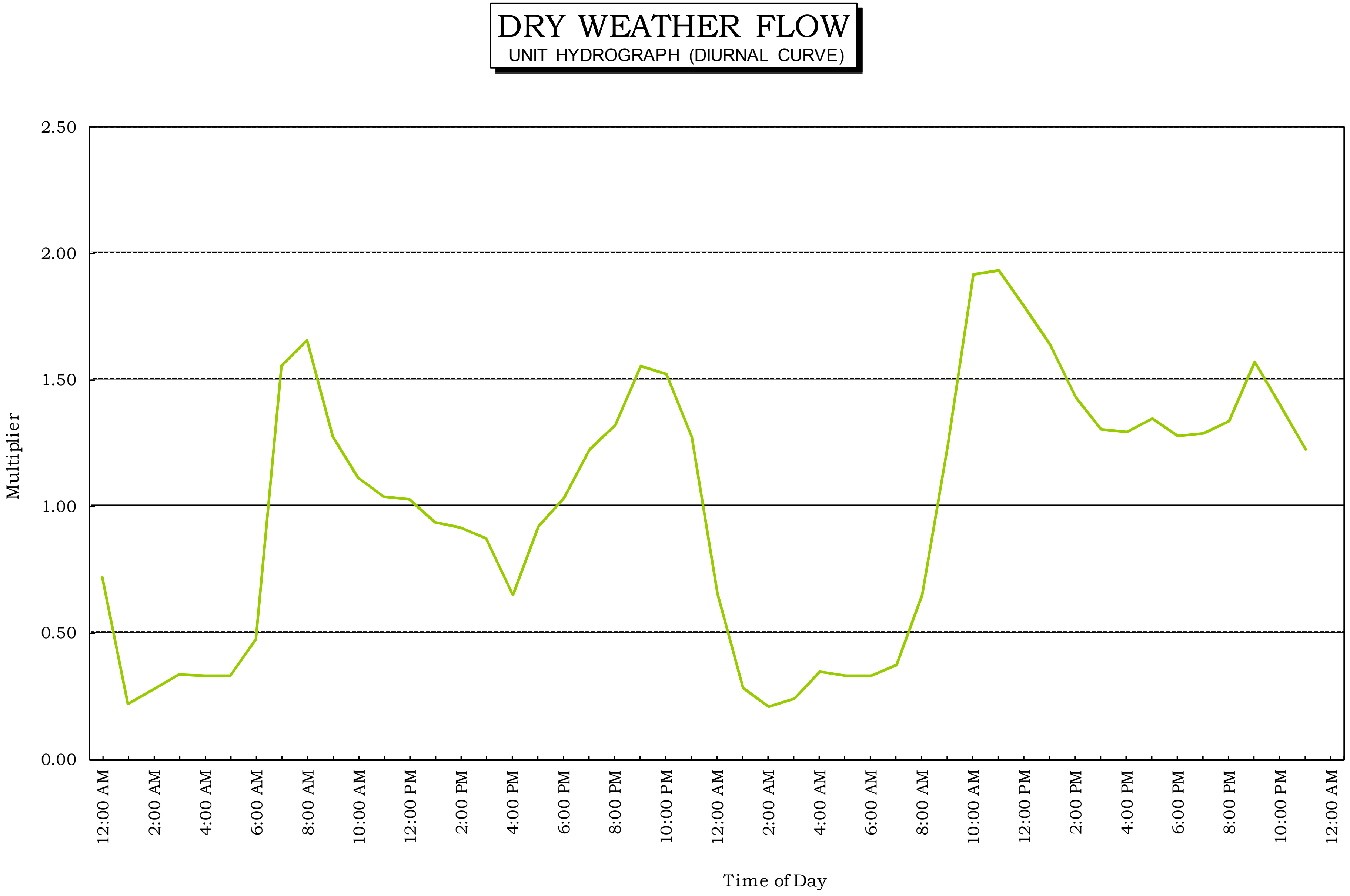
Basin FM23


DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
Multiplier
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day

Basin FM24

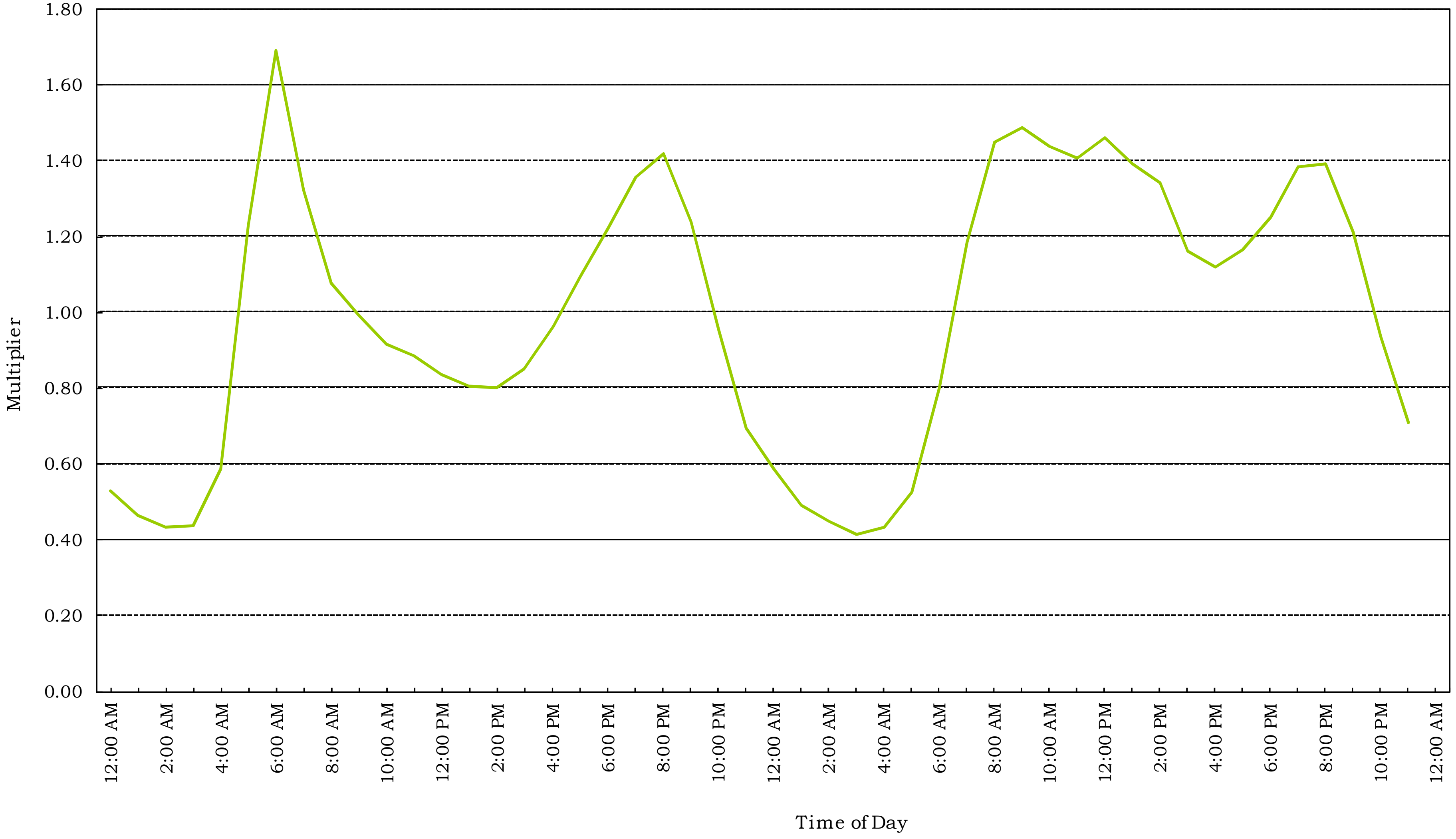


Basin FM25 (NTMWD Rowlett)



Basin FM26 (NTMWD Watters)

DRY WEATHER FLOW
UNIT HYDROGRAPH (DIURNAL CURVE)



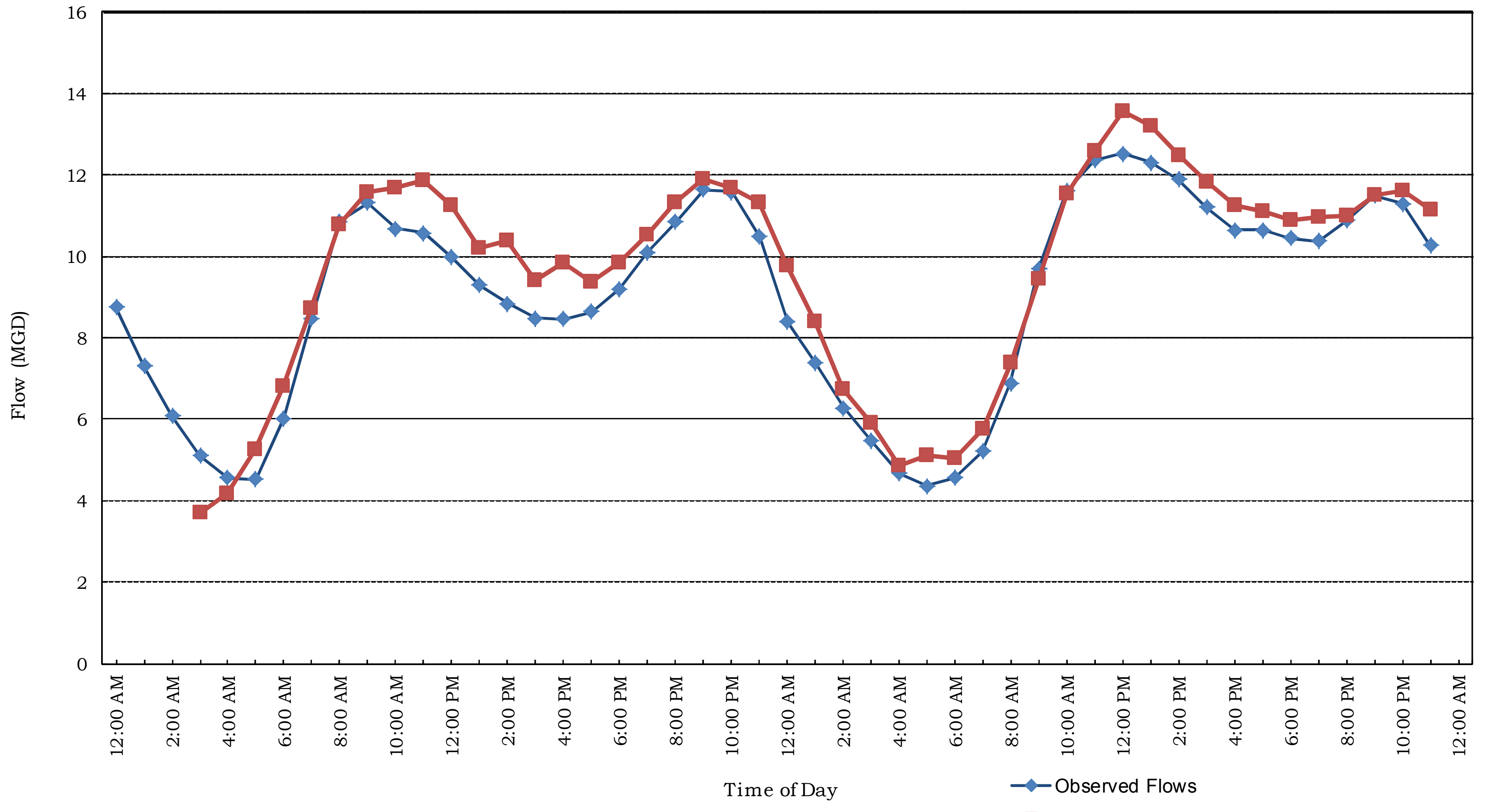
Basin FM27 (NTMWD Cottonwood)

McKINNEY™
TEXAS
Unique by nature.℠

APPENDIX "B"

Model Calibration

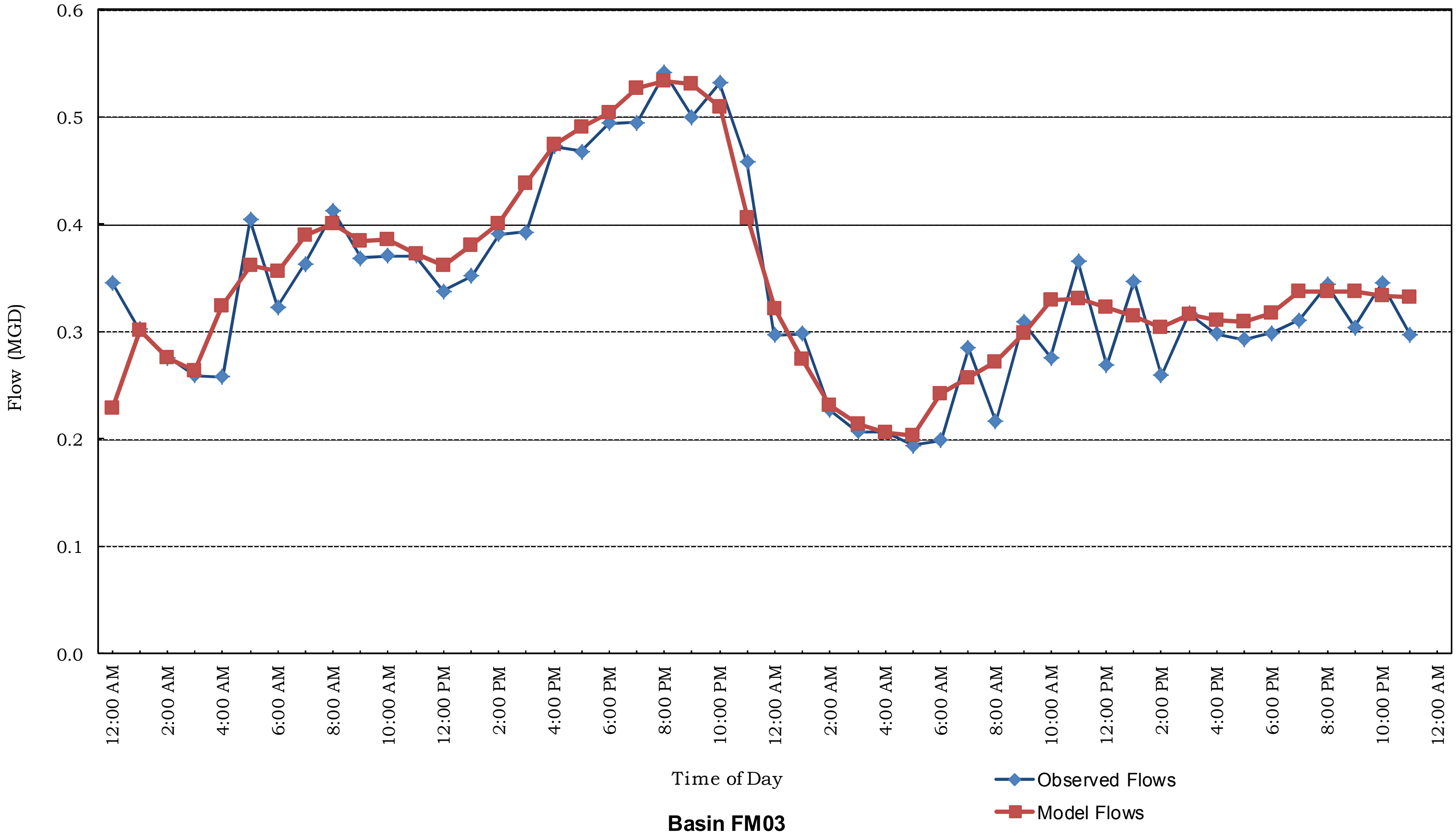
MODEL CALIBRATION - DRY WEATHER FLOW
FLOW METER DATA VS. MODELED RESULTS

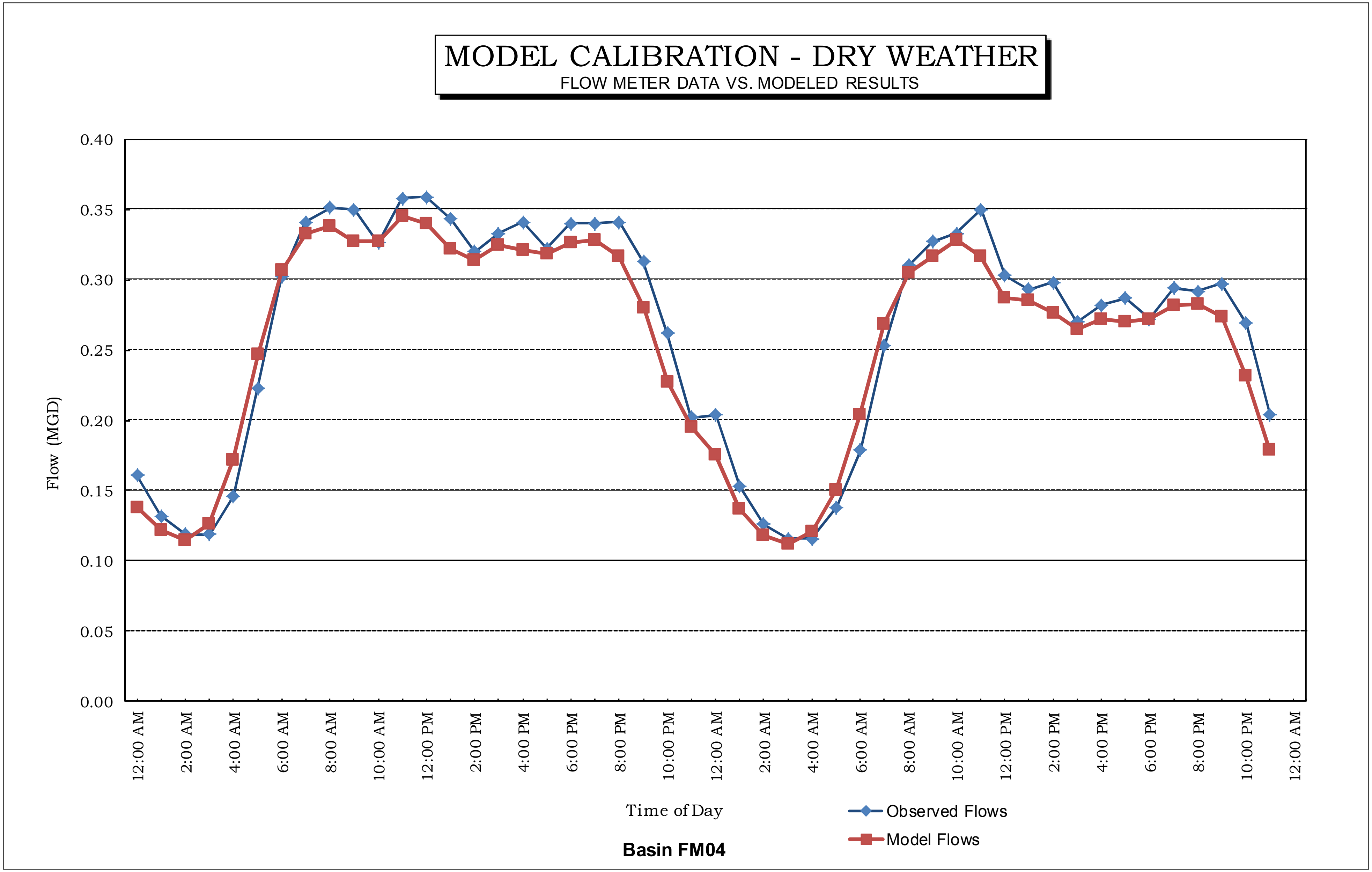


Basin FM01 & FM02

MODEL CALIBRATION - DRY WEATHER

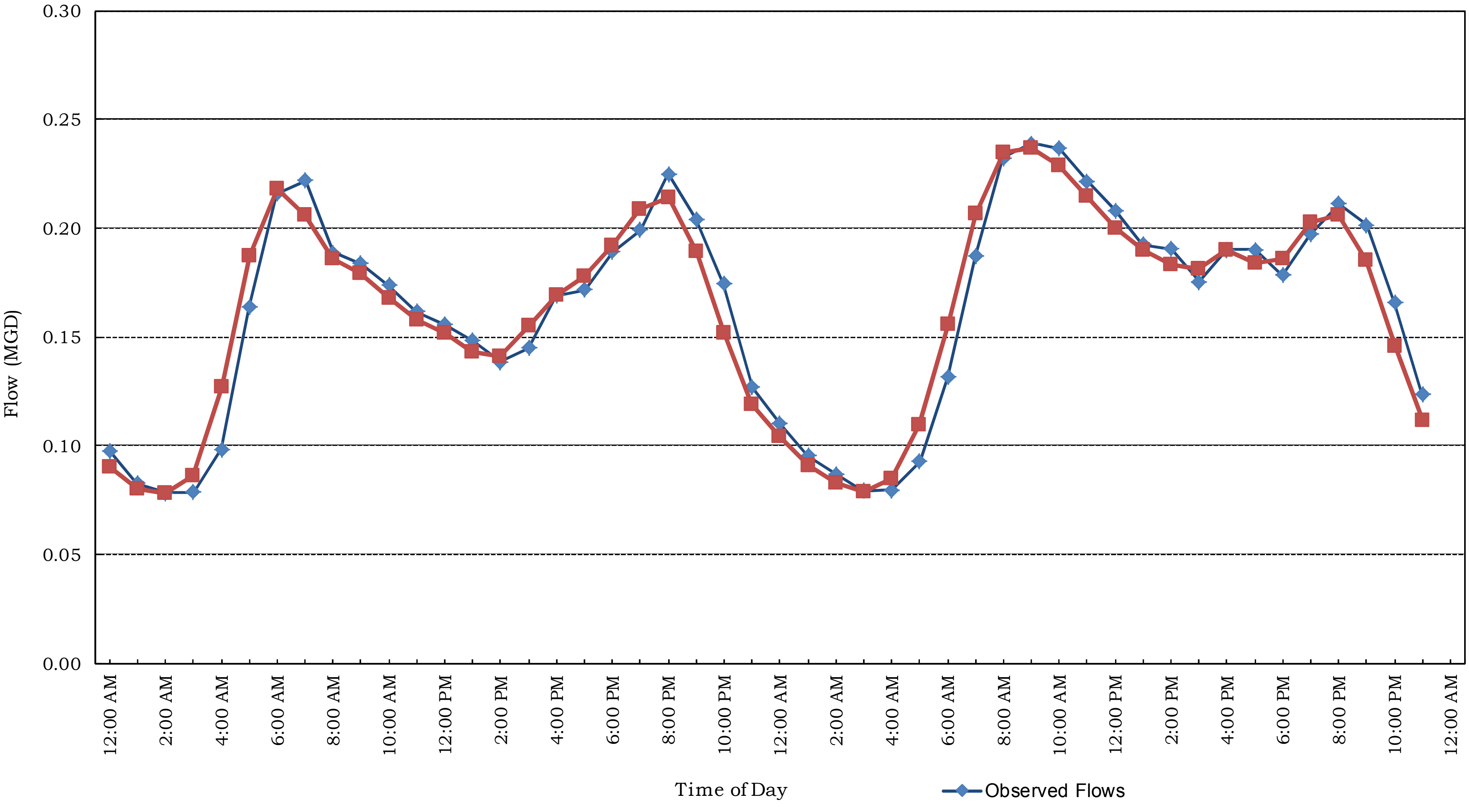
FLOW METER DATA VS. MODELED RESULTS




MODEL CALIBRATION - DRY WEATHER
FLOW METER DATA VS. MODELED RESULTS
Flow (MGD)
0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0.00
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day
Observed Flows
Model Flows
Basin FM04

MODEL CALIBRATION - DRY WEATHER

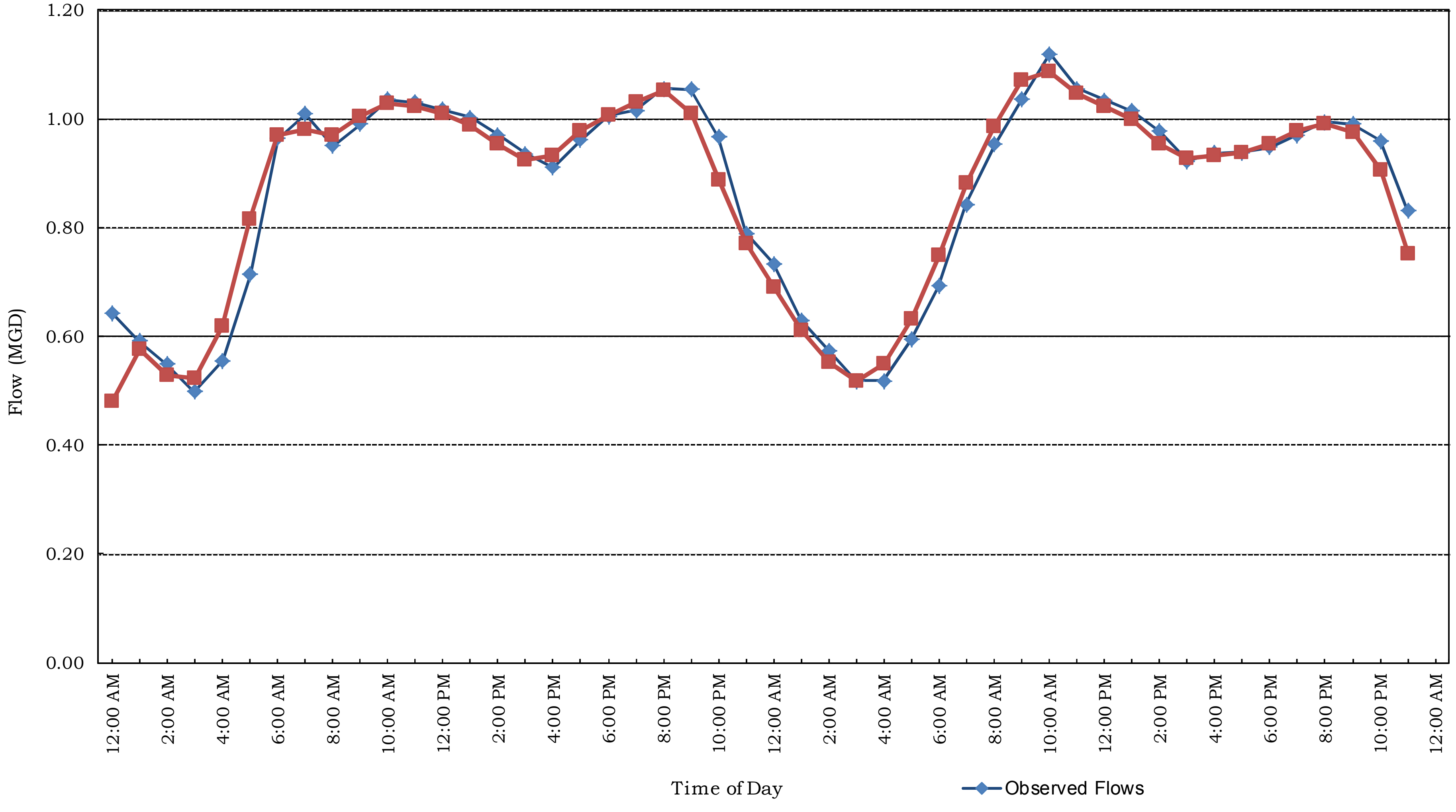
FLOW METER DATA VS. MODELED RESULTS



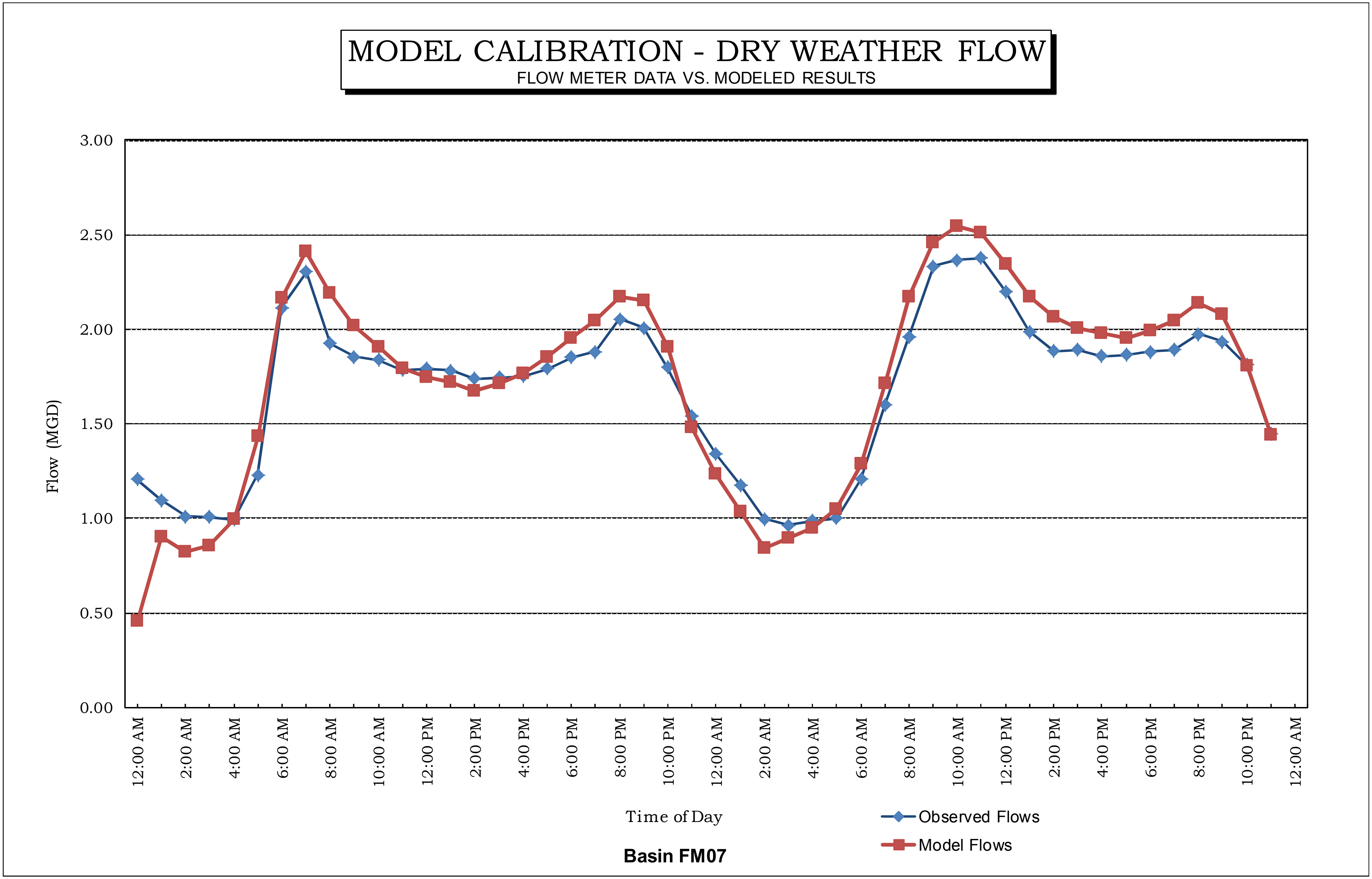
Basin FM05

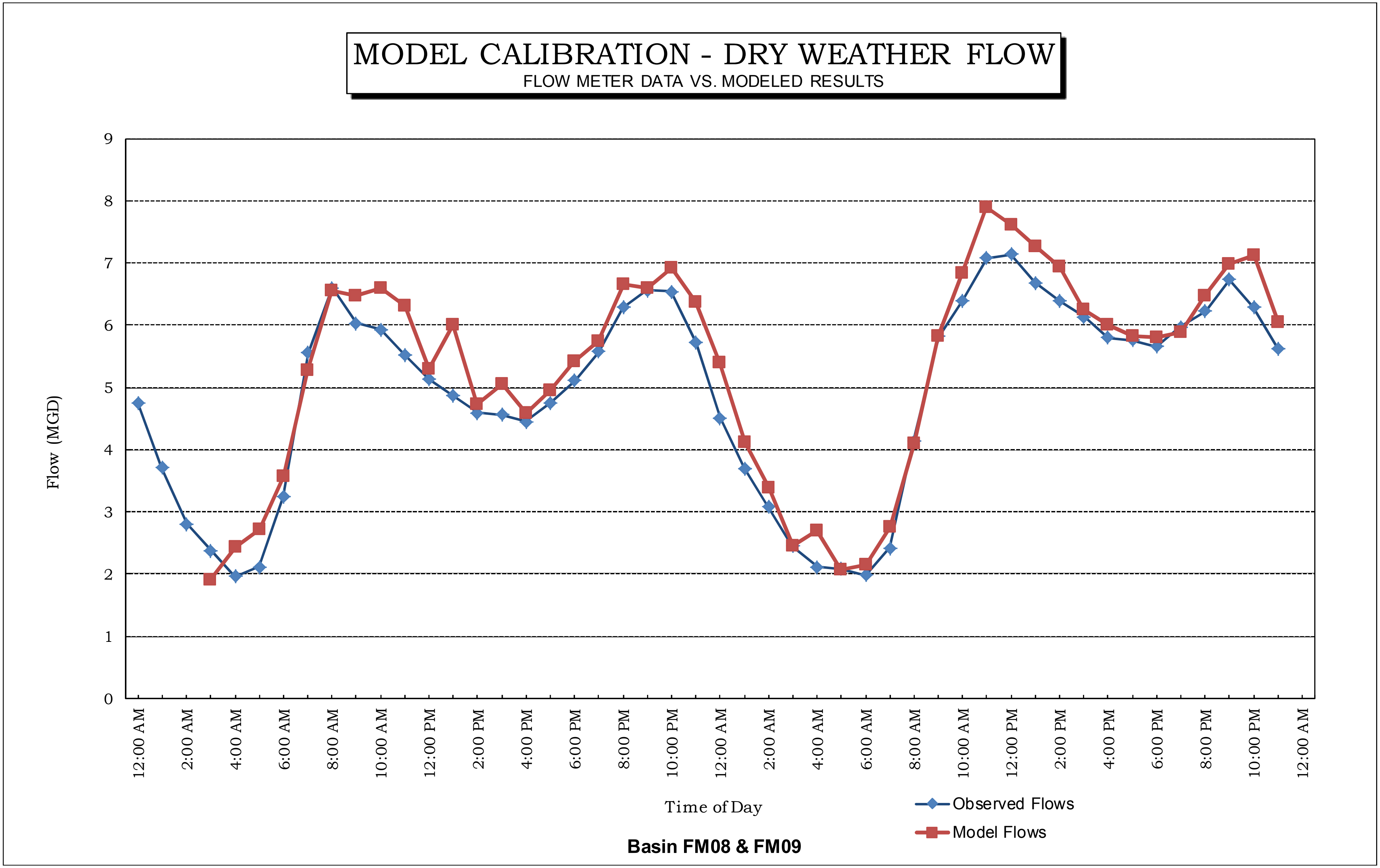
MODEL CALIBRATION - DRY WEATHER FLOW

FLOW METER DATA VS. MODELED RESULTS



Basin FM06


MODEL CALIBRATION - DRY WEATHER FLOW
FLOW METER DATA VS. MODELED RESULTS
Flow (MGD)
3.00
2.50
2.00
1.50
1.00
0.50
0.00
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day
Observed Flows
Model Flows
Basin FM07

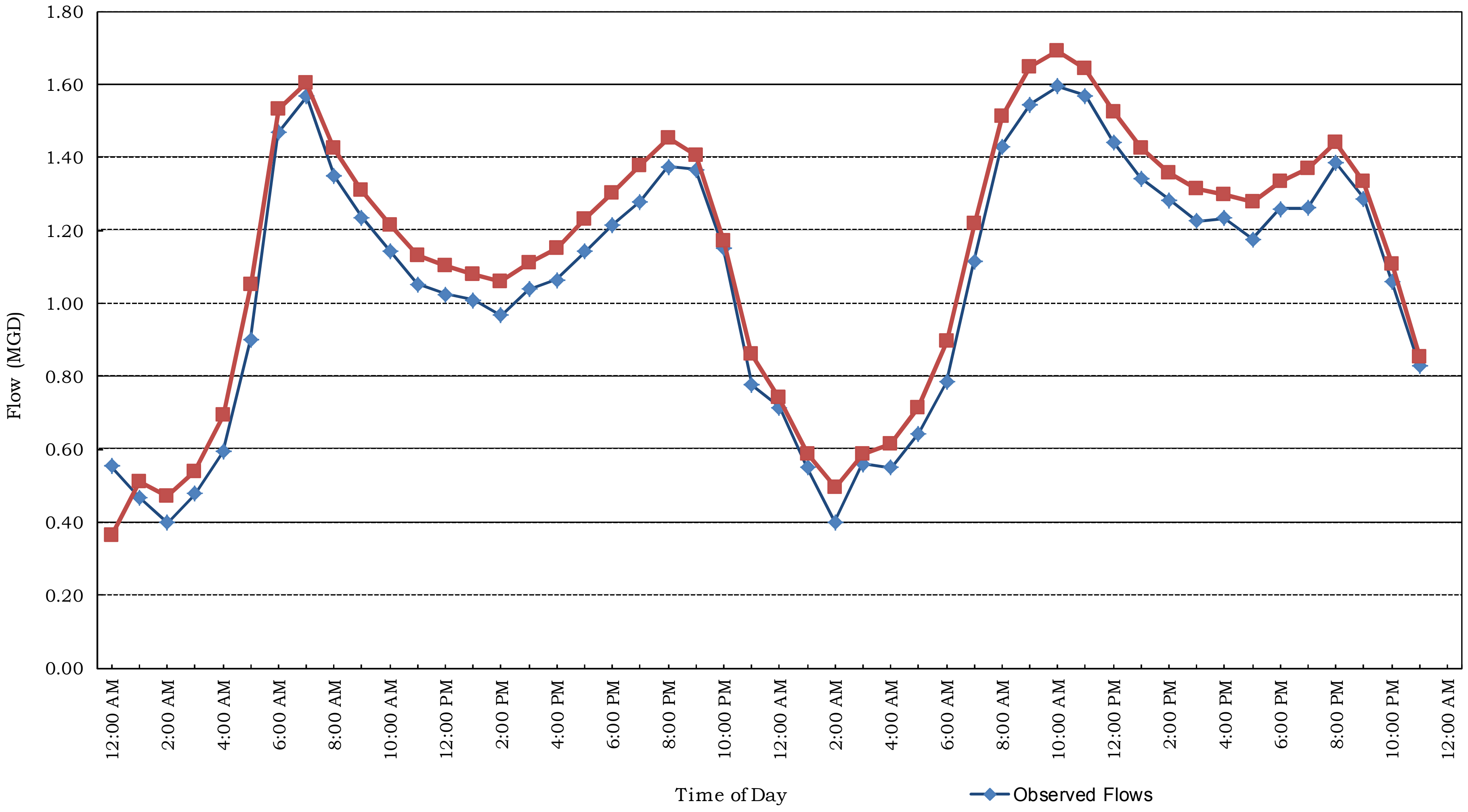

MODEL CALIBRATION - DRY WEATHER FLOW

FLOW METER DATA VS. MODELED RESULTS

Basin FM08 & FM09

MODEL CALIBRATION - DRY WEATHER FLOW

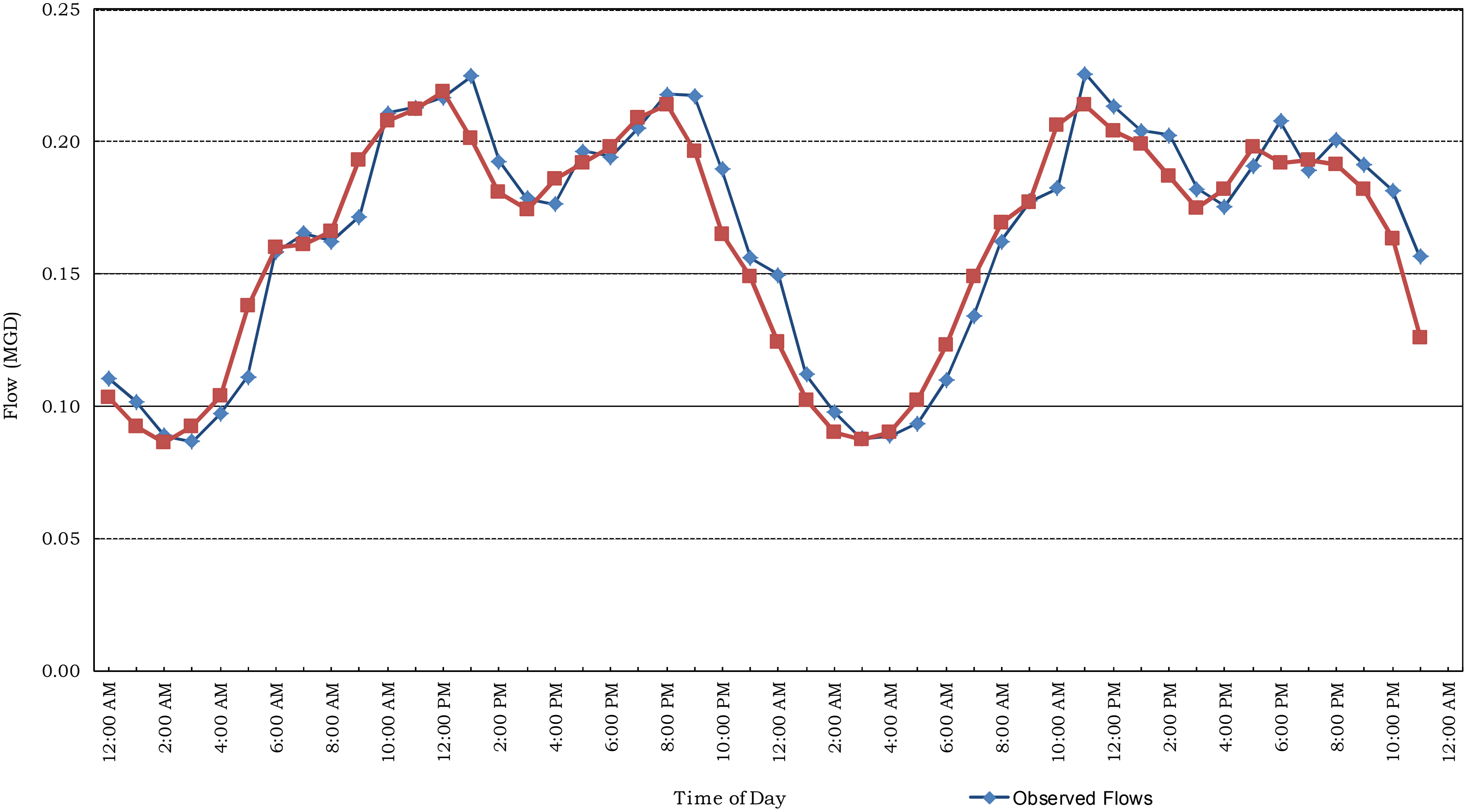
FLOW METER DATA VS. MODELED RESULTS



Basin FM10

MODEL CALIBRATION - DRY WEATHER FLOW

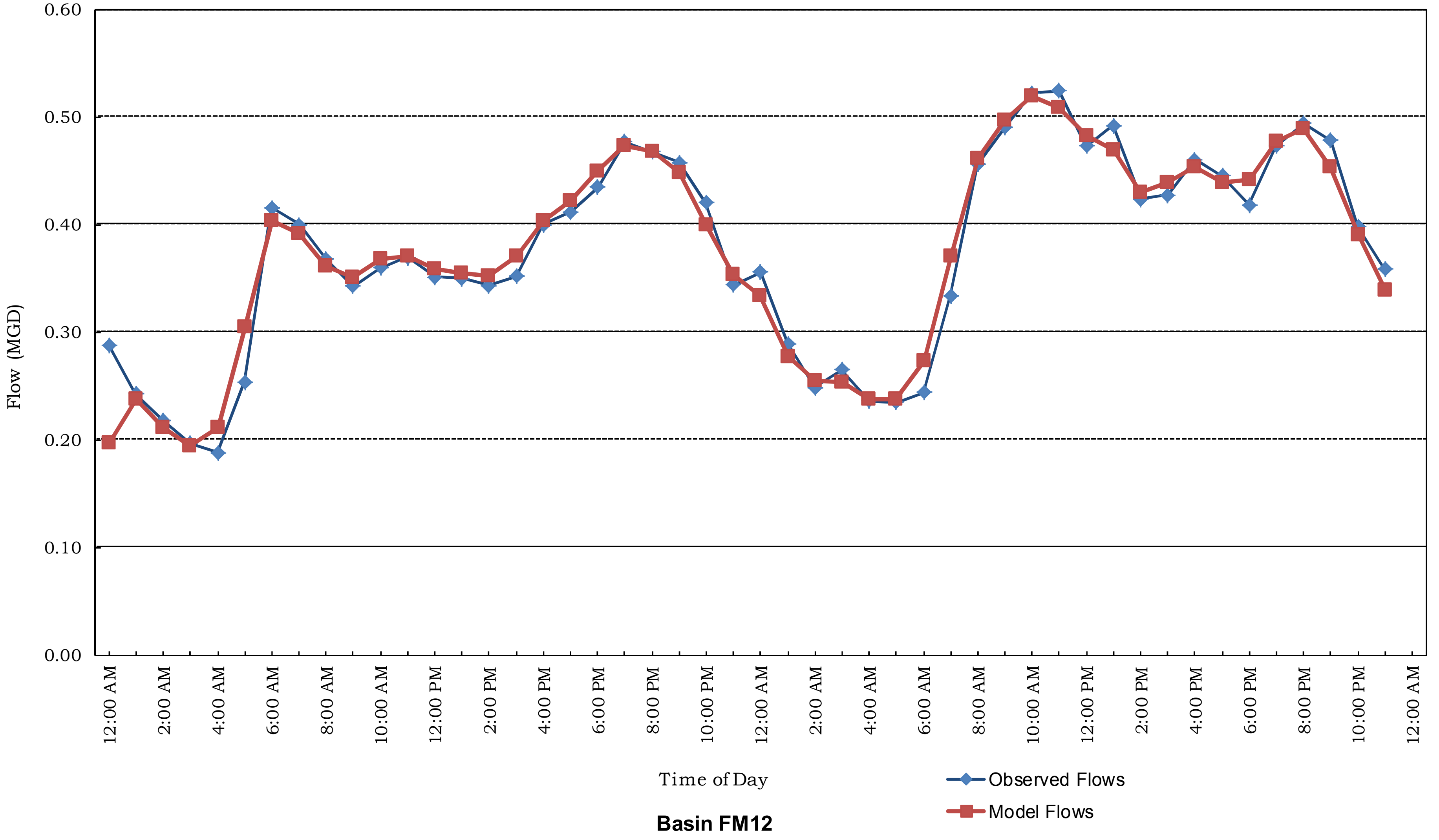
FLOW METER DATA VS. MODELED RESULTS



Basin FM11

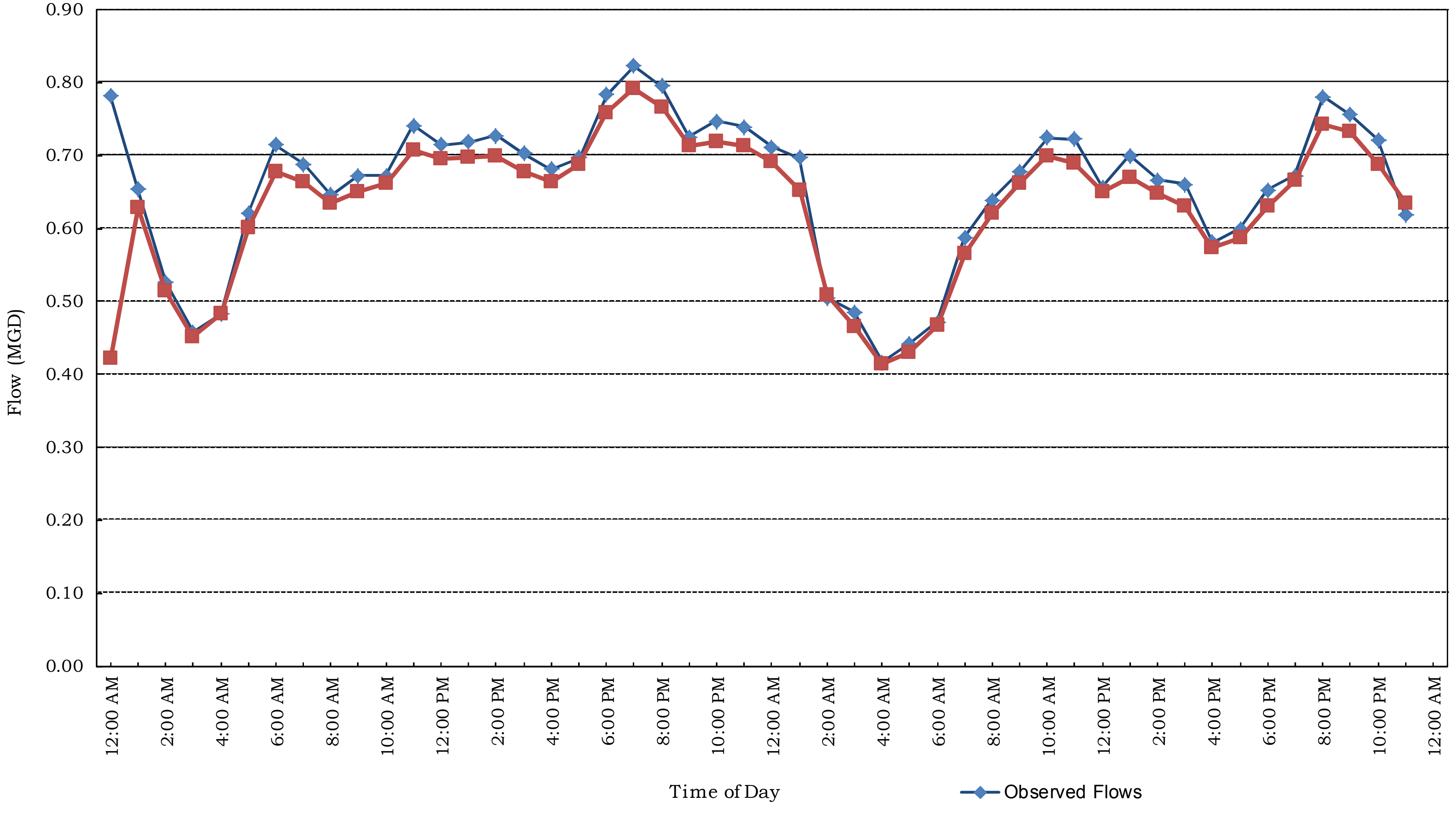
MODEL CALIBRATION - DRY WEATHER FLOW

FLOW METER DATA VS. MODELED RESULTS

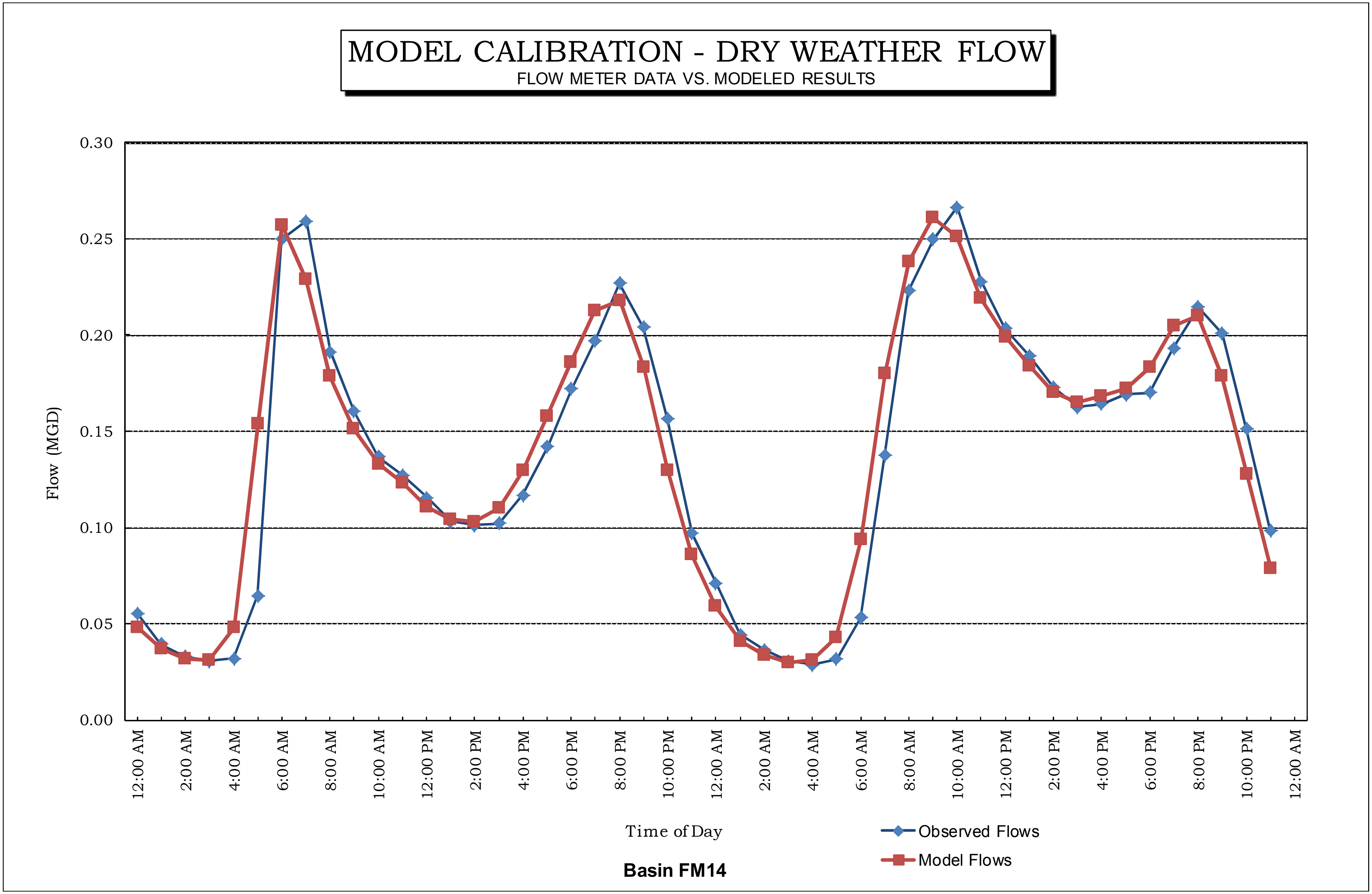


MODEL CALIBRATION - DRY WEATHER FLOW

FLOW METER DATA VS. MODELED RESULTS

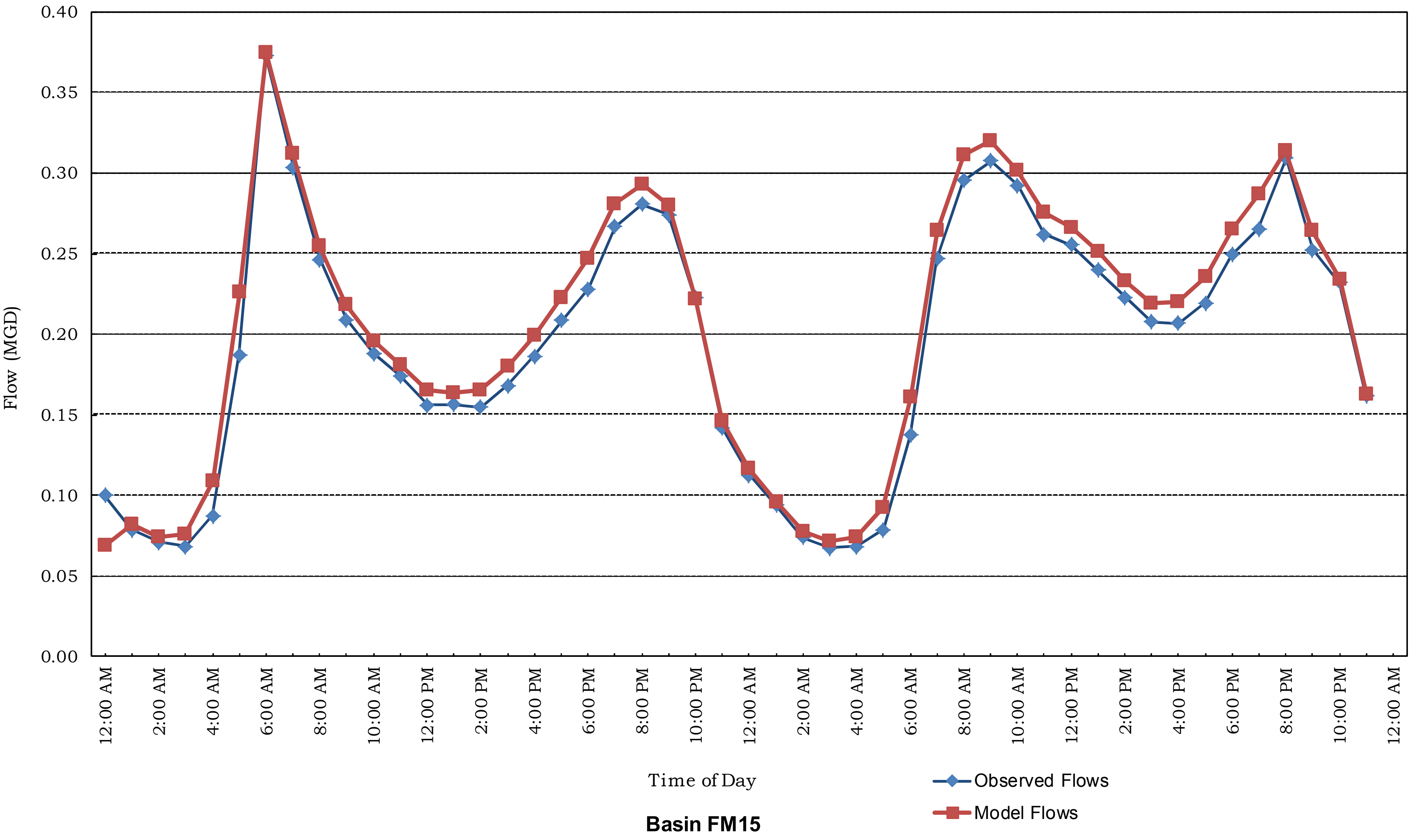


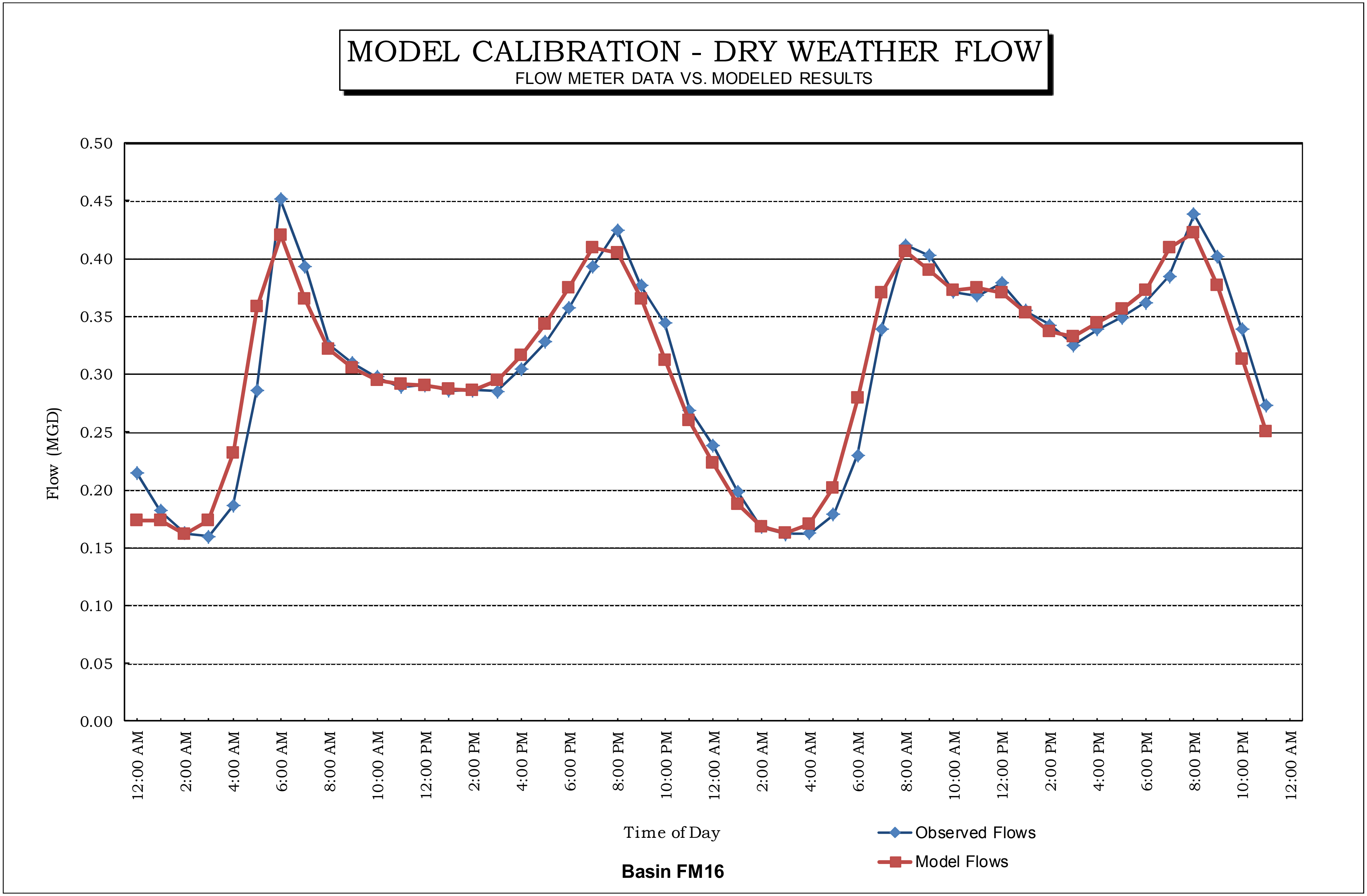
Basin FM13


MODEL CALIBRATION - DRY WEATHER FLOW
FLOW METER DATA VS. MODELED RESULTS
Flow (MGD)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day
Observed Flows
Model Flows
Basin FM14

MODEL CALIBRATION - DRY WEATHER FLOW

FLOW METER DATA VS. MODELED RESULTS

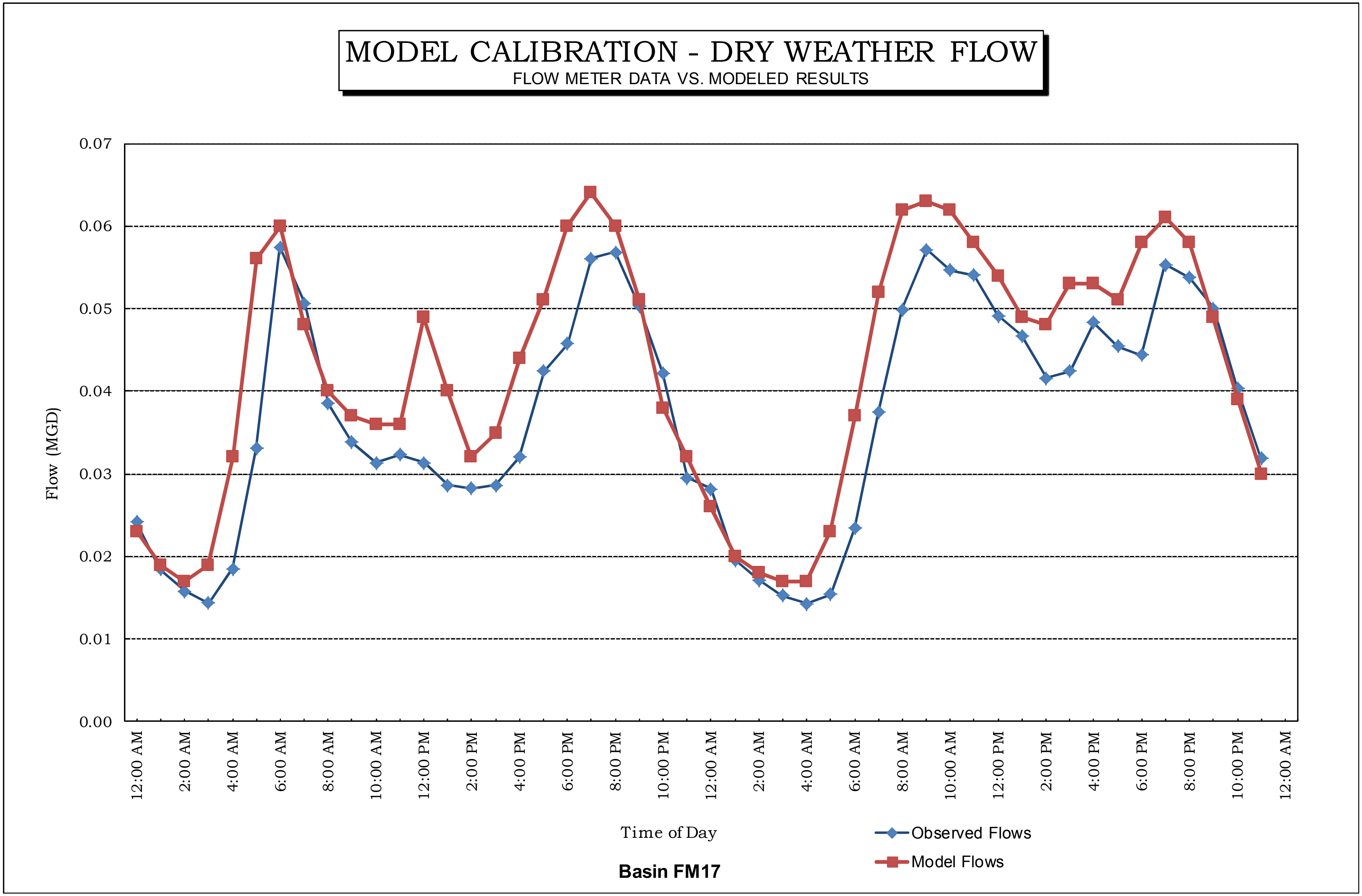




MODEL CALIBRATION - DRY WEATHER FLOW

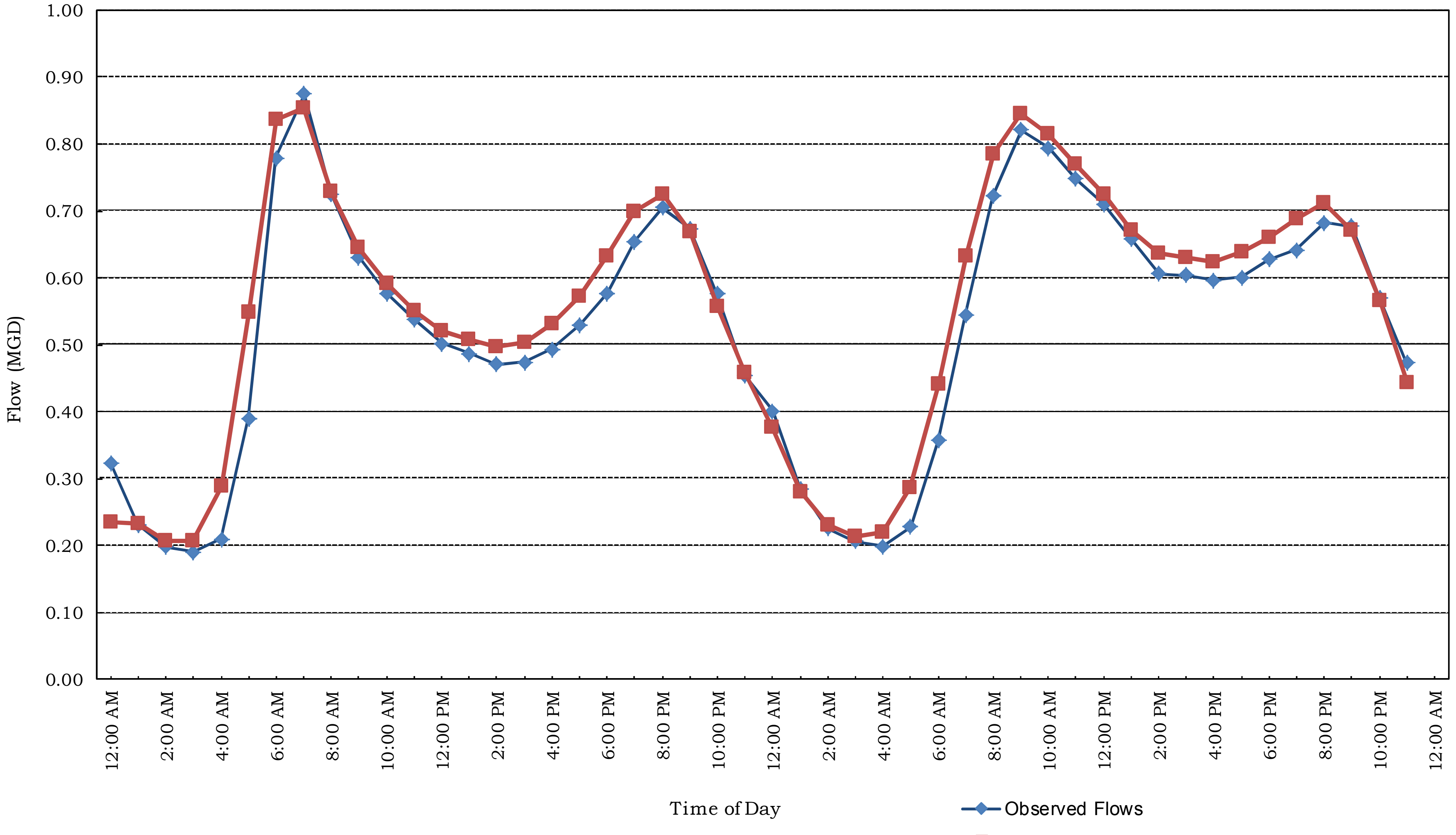
FLOW METER DATA VS. MODELED RESULTS

Basin FM16


MODEL CALIBRATION - DRY WEATHER FLOW
FLOW METER DATA VS. MODELED RESULTS
Flow (MGD)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0.00
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day
Basin FM17
Observed Flows
Model Flows

MODEL CALIBRATION - DRY WEATHER FLOW

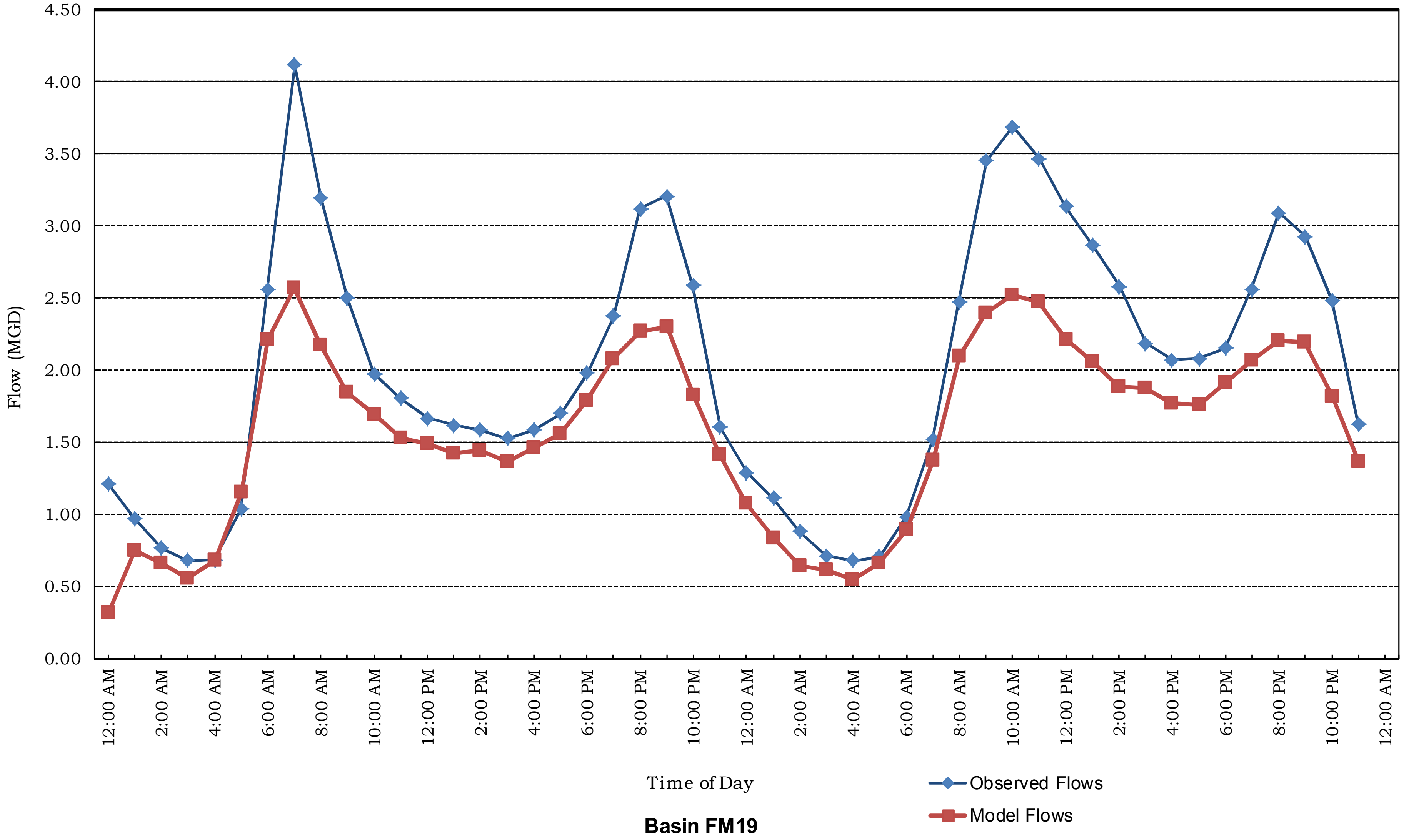
FLOW METER DATA VS. MODELED RESULTS



Basin FM18

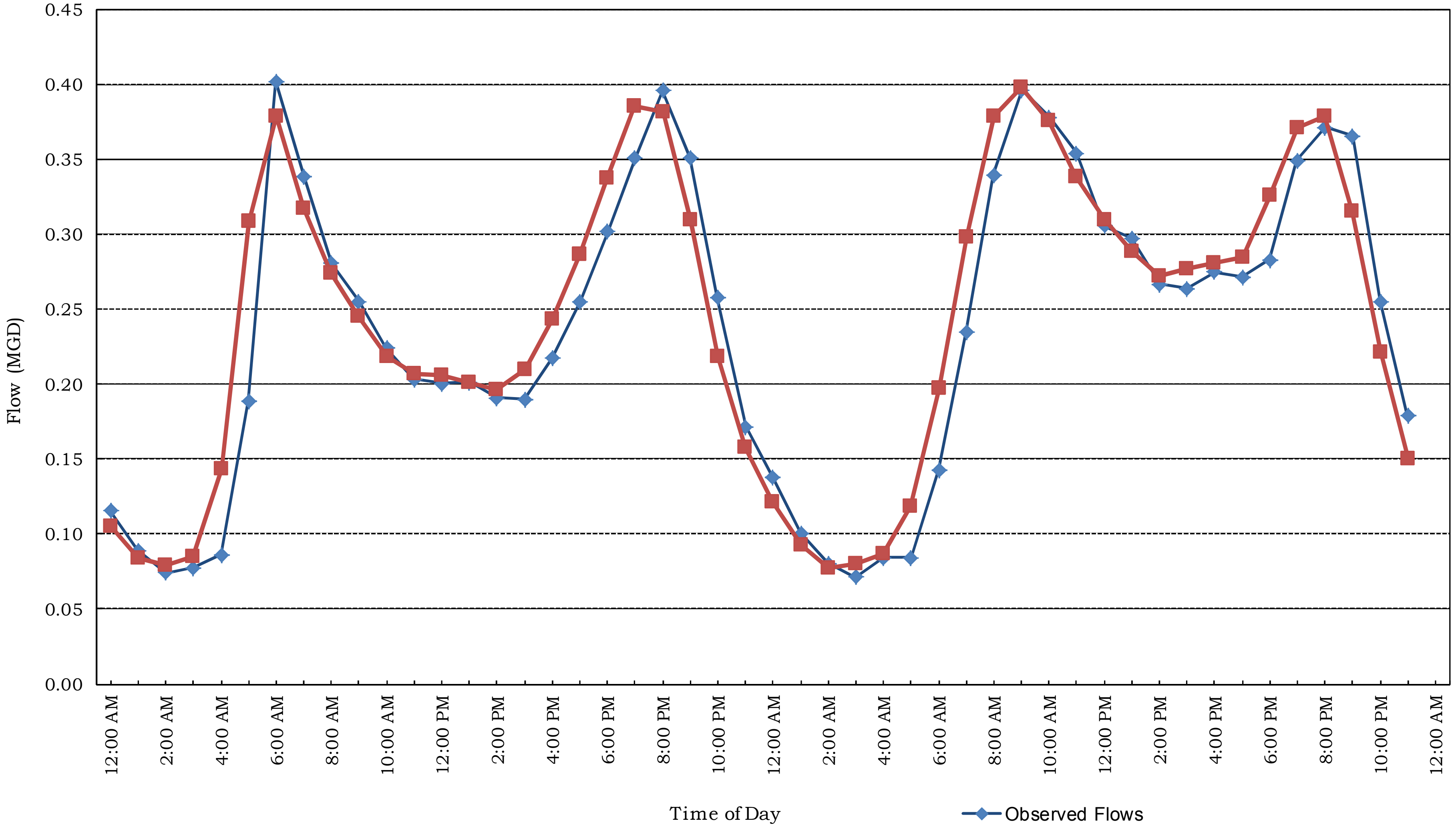
MODEL CALIBRATION - DRY WEATHER FLOW

FLOW METER DATA VS. MODELED RESULTS



MODEL CALIBRATION - DRY WEATHER FLOW

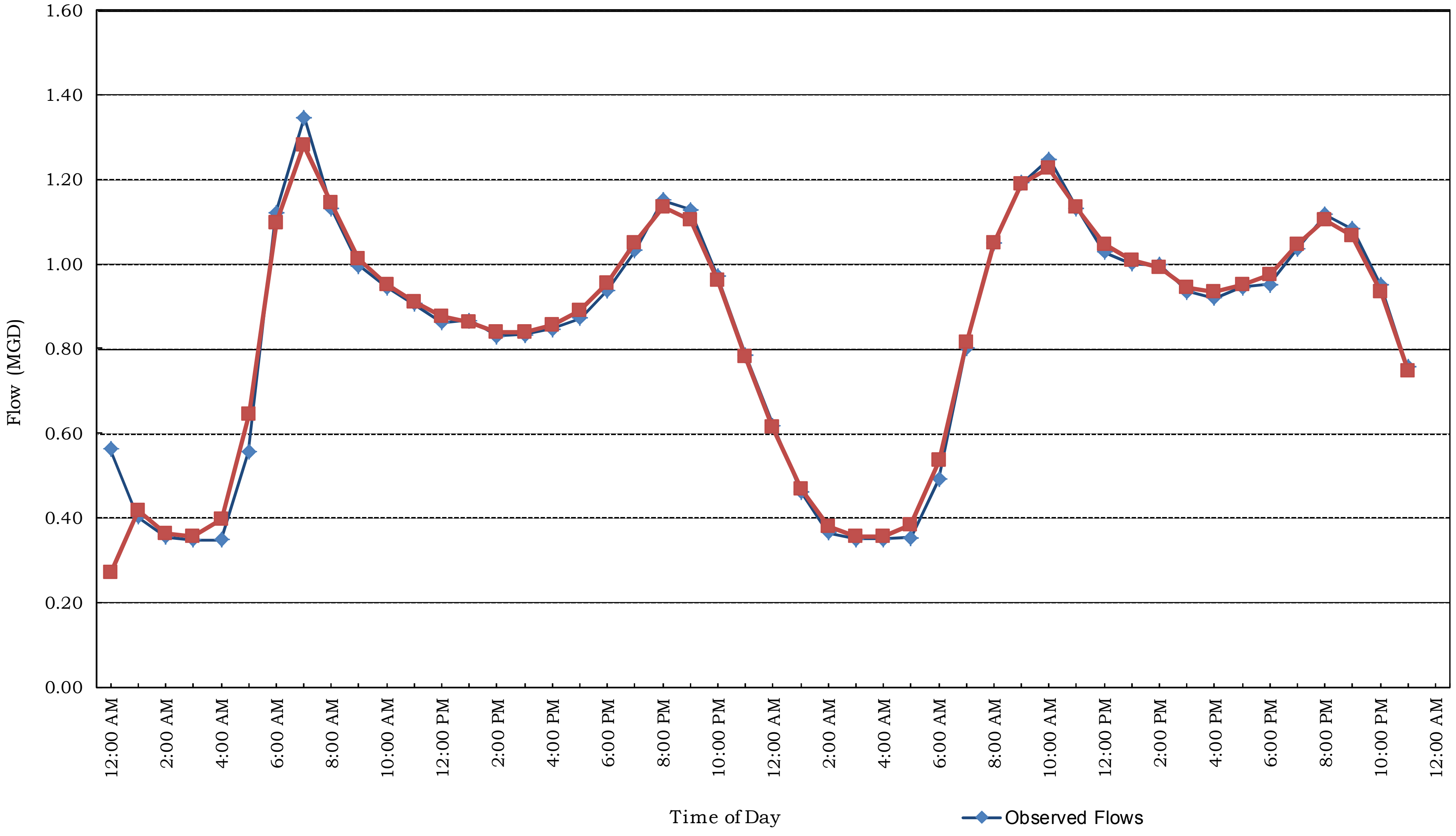
FLOW METER DATA VS. MODELED RESULTS



Basin FM20

MODEL CALIBRATION - DRY WEATHER FLOW

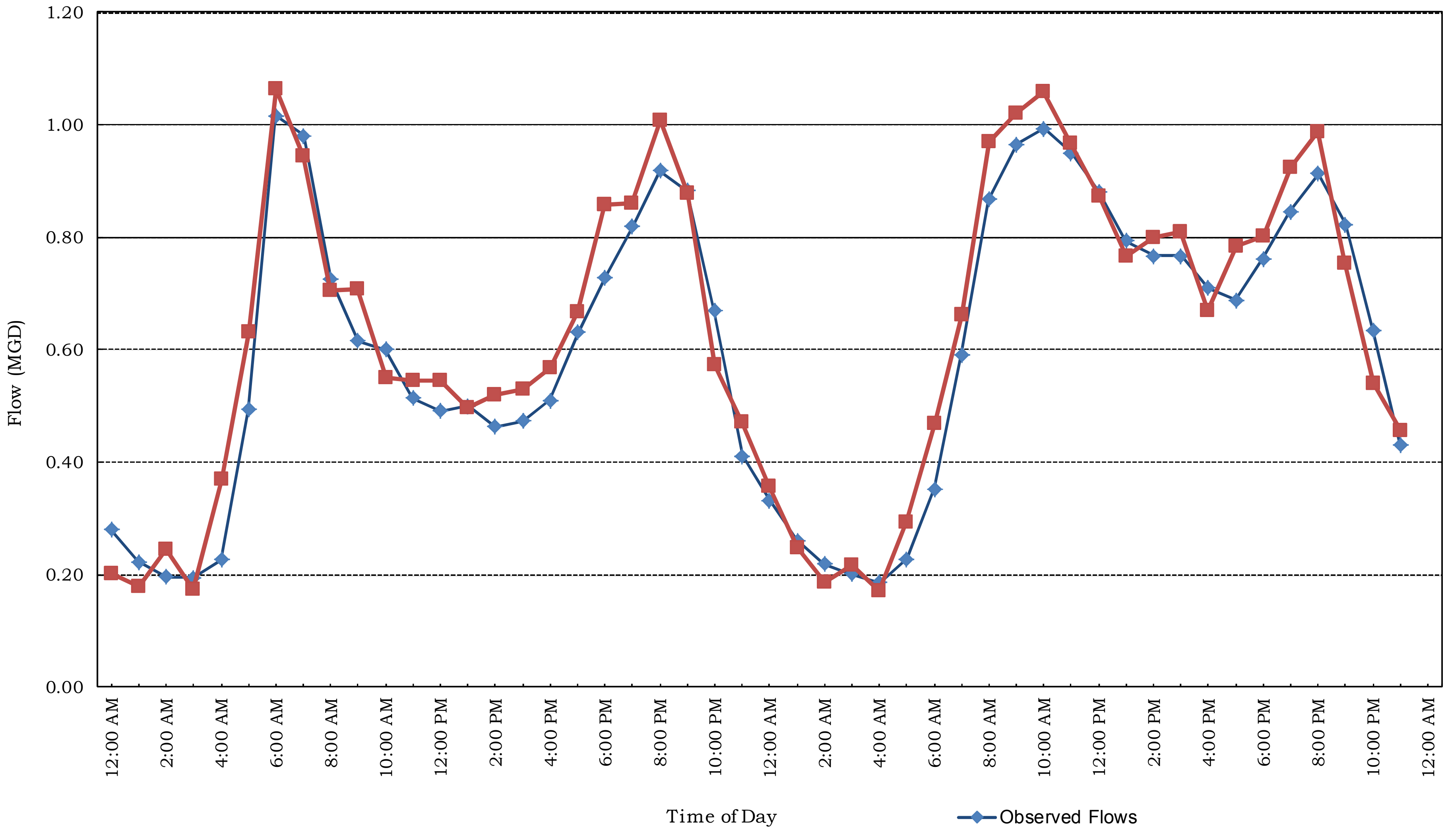
FLOW METER DATA VS. MODELED RESULTS



Basin FM21

MODEL CALIBRATION - DRY WEATHER FLOW

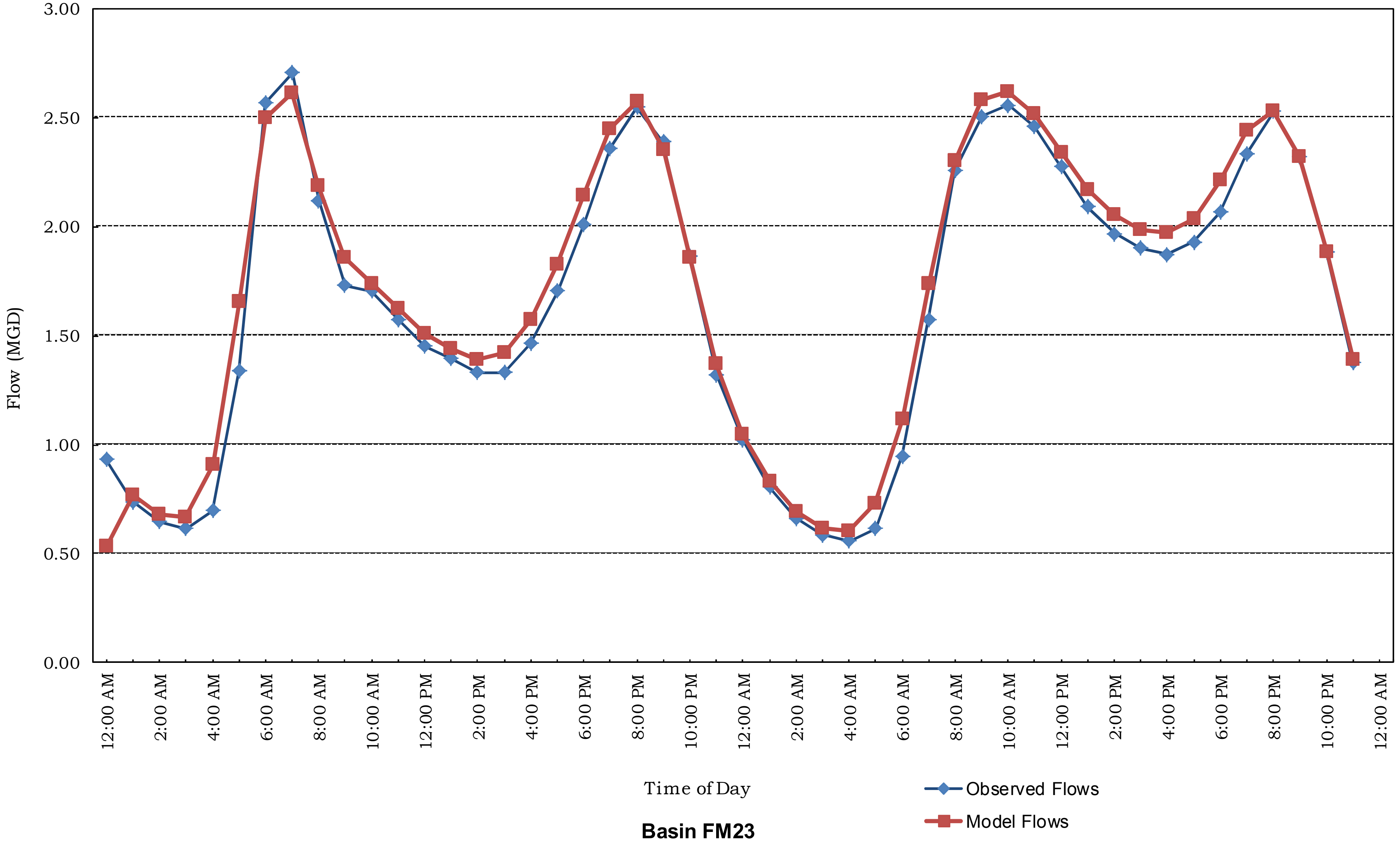
FLOW METER DATA VS. MODELED RESULTS



Basin FM22

MODEL CALIBRATION - DRY WEATHER FLOW

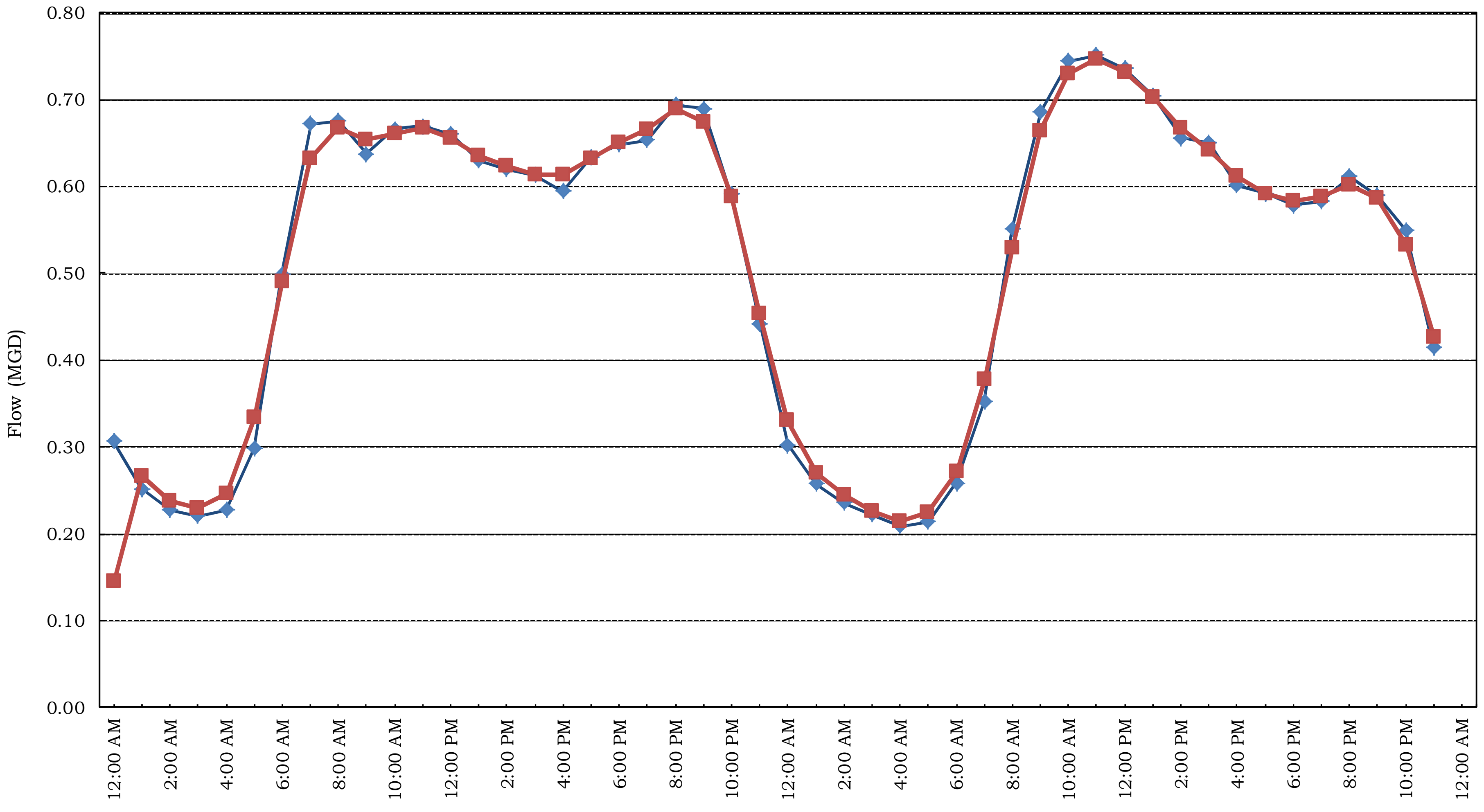
FLOW METER DATA VS. MODELED RESULTS



Basin FM23

MODEL CALIBRATION - DRY WEATHER FLOW

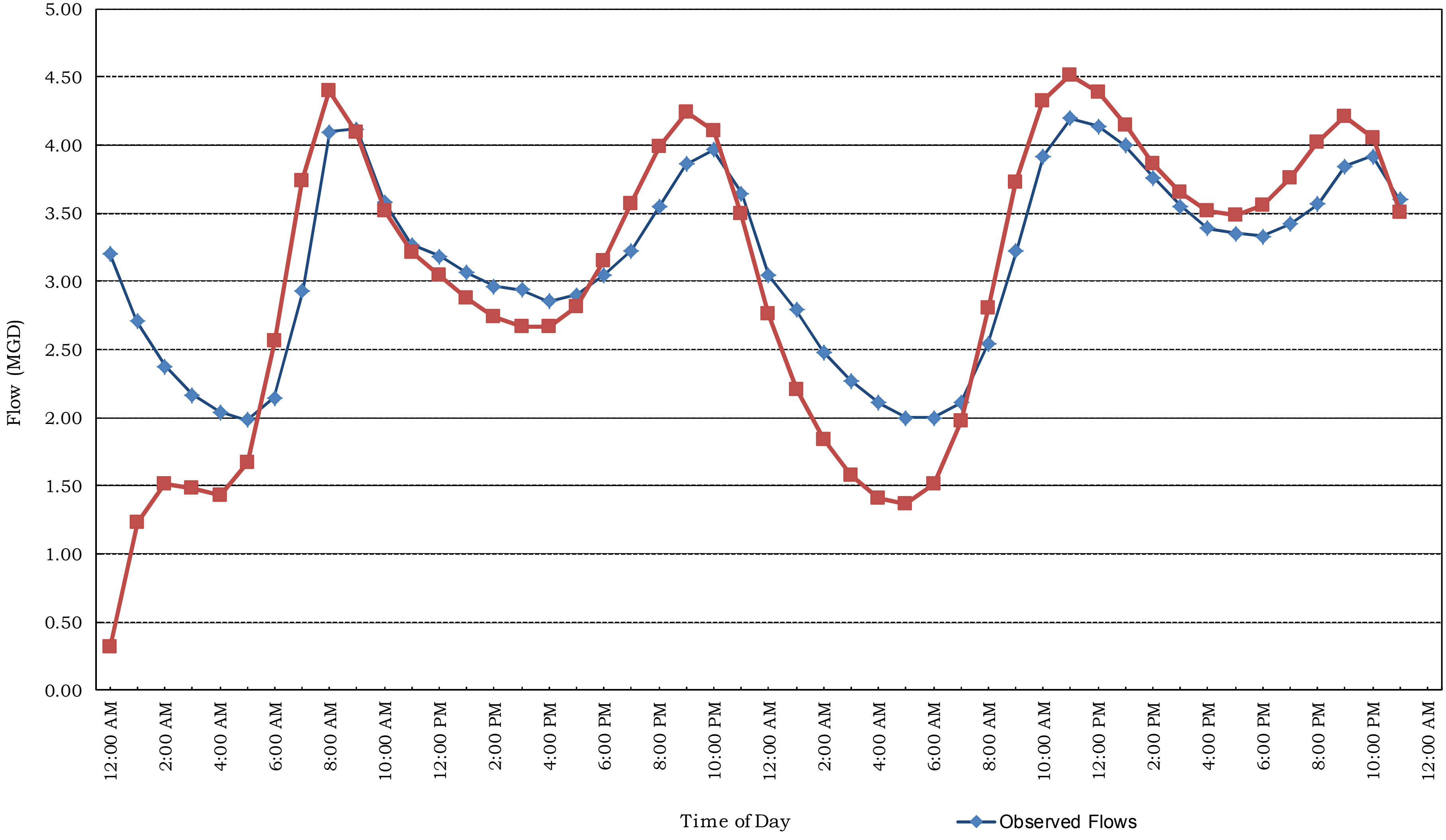
FLOW METER DATA VS. MODELED RESULTS



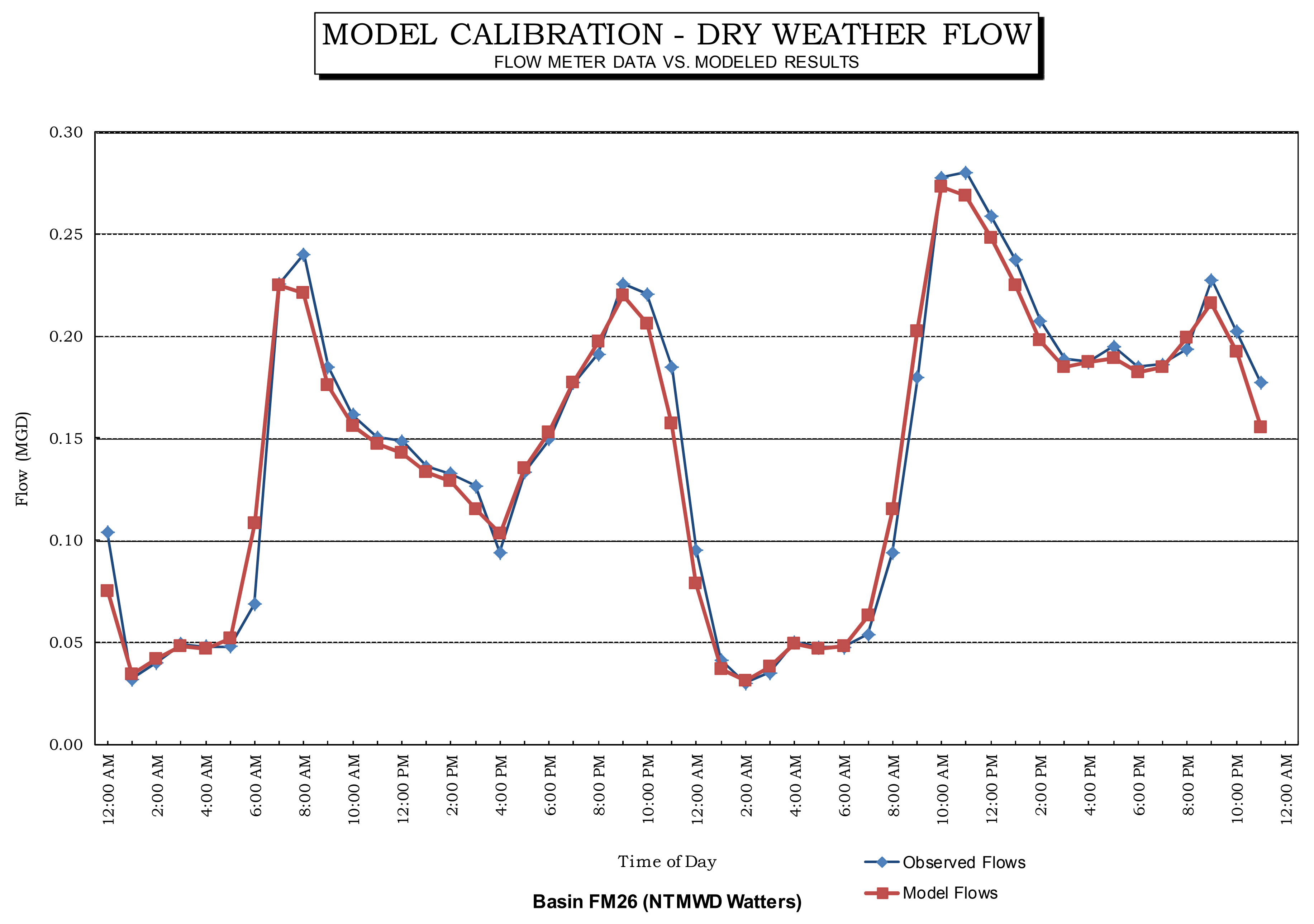
Basin FM24

MODEL CALIBRATION - DRY WEATHER FLOW

FLOW METER DATA VS. MODELED RESULTS

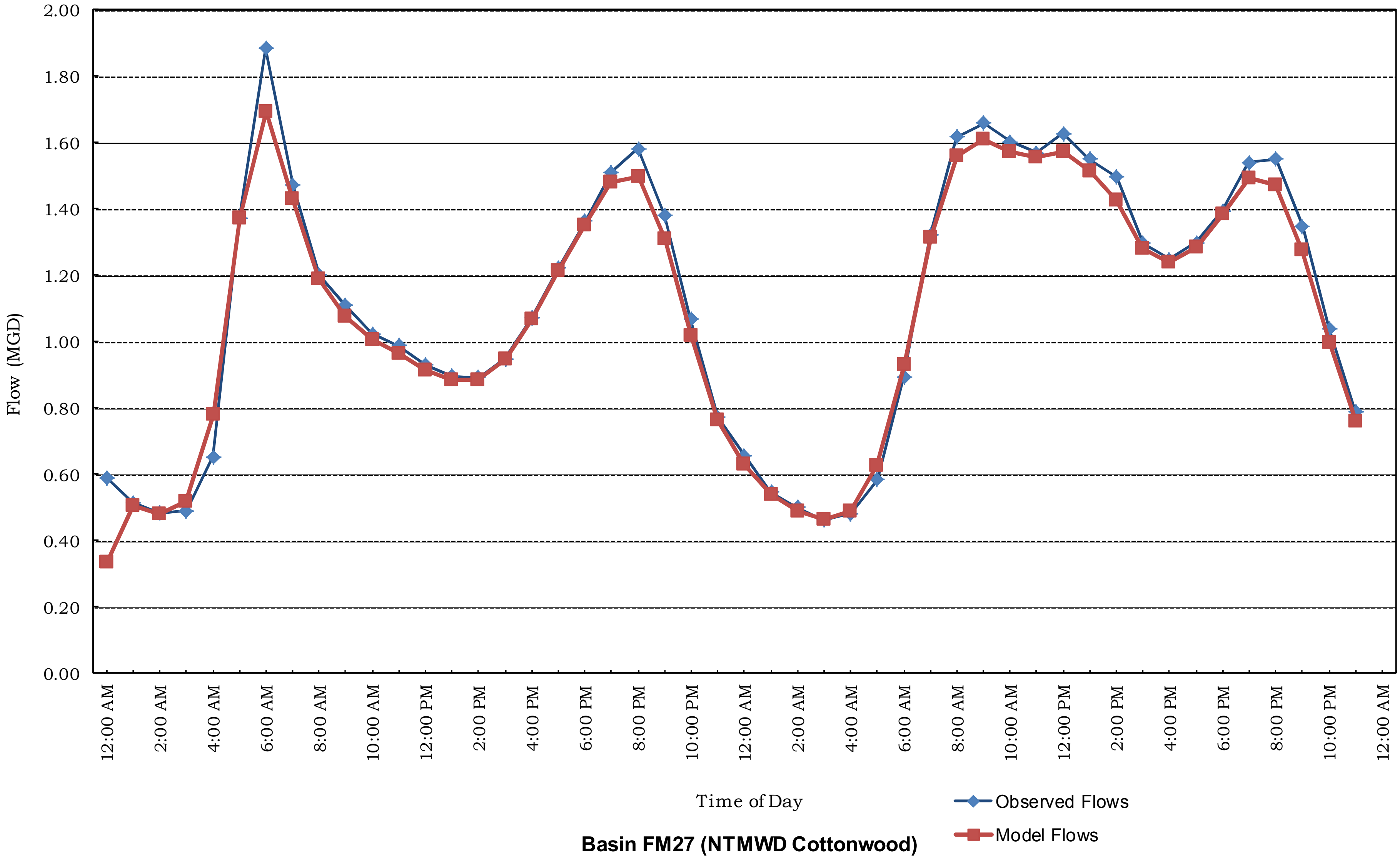


Basin FM25 (NTMWD Rowlett)


MODEL CALIBRATION - DRY WEATHER FLOW
FLOW METER DATA VS. MODELED RESULTS
0.30
0.25
0.20
0.15
0.10
0.05
0.00
Flow (MGD)
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
2:00 AM
4:00 AM
6:00 AM
8:00 AM
10:00 AM
12:00 PM
2:00 PM
4:00 PM
6:00 PM
8:00 PM
10:00 PM
12:00 AM
Time of Day
Observed Flows
Model Flows
Basin FM26 (NTMWD Watters)

MODEL CALIBRATION - DRY WEATHER FLOW

FLOW METER DATA VS. MODELED RESULTS



McKINNEY™
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APPENDIX "C"

Flow Monitoring Report

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1 GENERAL

1.1 Background

Birkhoff, Hendricks & Carter, L.L.P was retained by the City of McKinney, Texas to update their sanitary sewer master plan. In January 14, 2013, Stream Water Group, Inc. was retained by Birkhoff, Hendricks & Carter, L.L.P (BHCLLP) to assist in a flow monitoring study of the City's wastewater collection system to update the sanitary sewer model. The primary objectives of the study were to:

- Provide flow monitoring and
- Perform flow data analysis.

The City of McKinney has separate wastewater and storm water collection system.

2 FLOW MONITORING

After reviewing the map of the City of McKinney's wastewater collection system and record drawings provided by the City, Birkhoff, Hendricks & Carter, L.L.P (BHCLLP) developed the preliminary basin boundaries and also selected the flow monitoring locations for each basin with the assistance of Stream Water Group, Inc. The wastewater collection system within the City of McKinney was divided into twenty-seven (27) sewer drainage basins. A total of twenty-four (24) temporary flow monitoring locations were selected to monitor flow from each sewer basin and permanent meters monitored by "North Texas Municipal Water District" were utilized for three other basins. In addition to these twenty-seven (27) flow meters, four (4) additional permanent meters (Frisco Custer Rd Meter, Frisco West Eldorado Parkway Meter, Frisco Winding Creek Meter, and Prosper Meter) monitored by "North Texas Municipal Water District" were analyzed to determine the sewer flow entering the City of McKinney sewer system form outside of the City limit.

The twenty-four (24) meter locations were finalized after additional field investigations and discussion with the BHCLLP. A summary of the flow monitoring locations is provided in Table 2-A on the next page and a map showing the location of drainage basins, flow meters, and rain gauges is included in the back pocket of this report as Exhibit 1.

Table 2-A
Flow Monitoring Locations

Basin No.	Meter Number	Address/Location	Internal Pipe Diameter (inch)
1 & 2	FM-1	Highway 5 and Miller Rd.	48.12
	FM-2	Highway 5 and Miller Rd.	30.38
3	FM-3	1710 Couch Dr.	18.00
4	FM-4	Next to Jeans Creek.	14.00
5	FM-5	Towne Lake Park/ Park Entrance.	14.37
6	FM-6	Towne Lake Park/ Next to the concession stand.	21.06
7	FM-7	1100 Eldorado Pky/ Towne Lake Park North of Elem.	25.38
8 & 9	FM-8	Wilson Creek Park/ SW of restrooms.	35.25
	FM-9	Wilson Creek Park/ SW of restrooms.	23.25
10	FM-10	1820 Lakeshore Ct/ Eldorado Country Club.	23.50
11	FM-11	1201 Virginia St.	17.69
12	FM-12	1205 Roosevelt St/ Field north of Roosevelt St.	17.22
13	FM-13	East of sub-division in cornfield.	17.88
14	FM-14	2300 Provine Rd/ In the cul-de-sac.	11.88
15	FM-15	3331 Virginia Pkwy/ Next to the walking trail. S. of Virginia.	11.63
16	FM-16	601 Bois D Arc Rd/ McKinney Christian Academy.	14.81
17	FM-17	1100 Eastbrook Dr./ Next to the bike path and pond.	26.73
18	FM-18	600 North Lake Forest Dr/ Hay field east of High School.	20.41
19	FM-19	1232 Gray Branch Rd/ Hay field off of Gray Branch Rd.	29.88
20	FM-20	5440 Hwy 380/ North of 380 in the easement	17.50
21	FM-21	6210 Virginia Pkwy/ Behind bldg next to creek.	27.00
22	FM-22	300 Longhorn Dr/ End of cul-de-sac on bike path.	18.00
23	FM-23	Eldorado Pkwy & Custer Rd.	21.00
24	FM-24	2105 Rockhill Rd/ In the sidewalk.	15.25
25	1/	McKinney Rowlett Creek Meter	1/
26	1/	McKinney Waters Branch Meter	1/
27	1/	McKinney Cottonwood Creek Meter	1/
FWCM	1/	Frisco Winding Creek Meter	1/
FWEPM	1/	Frisco West Eldorado Parkway Meter	1/
FCRM	1/	Frisco Custer Road Meter	1/
Prosper	1/	Prosper Meter	1/

Note: 1/ Sewer Flow Monitored by "North Texas Municipal Water District".

Site reports, together with a detailed description of the location of each temporary flow meter, are included in Appendix A of this report.

Continuous flow monitoring was conducted from March 23, 2013 through May 31, 2013 for a period of 70 days. A total of twenty-four (24) FLO-DAR® Sensor with Hach FL904 Logger flow monitors were utilized throughout the monitoring period. Each flow monitor was mounted near the top of a manhole and connected to flow depth and velocity sensors positioned in an incoming sewer line. Each flow monitor is equipped with an ultrasonic depth sensor and a velocity sensor mounted at or near the invert of the sewer line. A pressure depth sensor is also mounted at or near the invert to measure surcharge depths.

The ultrasonic depth sensor operates by transmitting a high frequency signal perpendicular to the wastewater flow. This signal is reflected back to the sensor by the flow surface. The flow depth is directly proportional to the time required to receive the transmitted signal.

The velocity sensor operates by transmitting a high frequency signal through a cross section of the wastewater flow directly above and upstream of the sensor. This signal is reflected back to the sensor by particles moving through the wastewater flow. As described by the Doppler Effect, the velocity is directly proportional to the frequency modulation between the transmitted and received signals.

The pressure depth sensor operates by measuring the pressure difference between the weight of the wastewater flowing over the sensor and atmospheric pressure. The flow depth is directly proportional to the pressure difference.

SPECIFICATIONS OF FLOWMETER EQUIPMENT

FLO-DAR® Sensor with Hach FL904 Logger Specification

General

The Hach/Marsh-McBirney Flo-Dar® Sensor with Hach FL904 Logger consists of three components: an electronics unit, sensor, and interconnecting cable. The sensor combines advanced radar velocity sensing technology with ultrasonic pulse echo level sensing to remotely measure open channel flow. Flow shall be calculated based on the Continuity Equation (Q= V x A), where Q= Flow, V= Average Velocity and A= Area. The flow meter is of assured quality and provided by Hach Company, an ISO 9001:2000 Certified Manufacturer.

Sensor

The sensor consists of four transducers housed in a single polystyrene watertight enclosure. The sensors are mounted above the flow surface. The four transducers consist of a digital Doppler radar for surface velocity, an ultrasonic pulse echo for fluid level, a piezo-resistive pressure measurement for surcharge level and an electro-magnetic sensor for surcharge velocity measurement. The radar beam transmits signals, which interact with the fluid and reflect back at a different frequency. These reflected signals are compared with the transmitted frequency, resulting in a frequency shift. The frequency shift provides an accurate measurement of the flow velocity. Fluid levels are measured with an ultrasonic pulse echo transceiver by transmitting a sound wave to the fluid surface. The sensor accurately measures flows in circular and rectangular channels down to flow depths of ¼ inch. A Piezo-resistive pressure sensor is used to measure the level of fluid above the sensor if a surcharge condition occurs. An electro-magnetic sensor is used to measure surcharge velocity by measuring the change in the magnetic field caused by the velocity of the water flow.

Electronics

The electronics consist of the Hach FL904 Logger to receive, process, and transmit the data received from the FloDar Sensors. Each remote panel transmits level, velocity and flow signals via 1xRTT or GSM packet switched cellular wireless technology. The data is transmitted to the Customer via a password protected secure web application.

The Hach FL904 Logger has storage capacity of 325,000 data points; 1128 days for 3 channels at 15-minute log intervals. The electronics housing material is sealed, watertight PC/ABS structural foam and enclosures are NEMA 6P/IP68 rated. Electronics operating temperature range is between –18 to 60ºC (0 to 140ºF) at 95% RH. Storage temperature for electronics is –40 to 60ºC (–40 to 140ºF)

Sensor Cable

The standard sensor cable is abrasive resistant polyurethane jacket with waterproof connectors on each end. The connectors allow for each connection of the logger unit to the Flo-Dar® sensor. The FloDar Sensors are provided with 30 feet of cable. Additional sensor cable lengths are available.

Sensor Specifications

Flow Calculation

Method: Based on Continuity Equation, Q=V x A

Accuracy: ±5.0% of reading typical where flow is in a channel with uniform flow conditions and is not surcharged.

Velocity Measurement

Method: Radar

Range: 0.75 to 20 ft/s (0.23 m/s to 6.10 m/s)

Accuracy: ±0.5%; ±0.1 ft/s (±0.03 m/s)

Level Measurement
Method: Ultrasonic
Operating Range: 0.25 to 60 in. (0.634 to 152.4cm)
Optional Operating Range: 0 (0 cm) to 224" (5.7M) with 16" dead band)
Temperature Compensated
Accuracy: ±0.25 in. (±0.64 cm)

Surcharge Level Measurement
Method: Piezo-resistive pressure transducer
Maximum Range: 138 inches (3.5 meters)

Surcharge Velocity Measurement
Method: Electromagnetic
Range: -5 to +20 ft/s

Following final site selection, flow monitors were installed using a stainless steel band with the attached sensors (ultrasonic depth, velocity, and pressure depth). The meters were programmed to acquire and store depth of flow and velocity readings at 5-minute intervals. Computer was used to retrieve and store data from each temporary flow meter using wireless communication. Stream Water Group, Inc. utilized Hach Company's field personnel for the installation and maintenance of these meters.

During the monitoring period, field crews visited each monitored location to verify proper meter operation, and document field conditions. Manual depth and velocity readings were also taken to verify the meter data. Engineering review and input of additional calibration data was used to finalize the metered data. Utilizing the finalized data, the Continuity Equation (Q=V*A) was used to calculate the flow.

2.1 Rainfall Monitoring

An important part of an infiltration and inflow (I/I) study is the collection and analysis of rainfall data. The rainfall data is the basis for determining the rainfall induced inflow and infiltration (I/I) entering each basin being studied.

Rainfall data was collected at four (4) locations utilizing Sigma rain gauges in the study area throughout the flow-monitoring period. Site reports for each rainfall-monitored location are included in Appendix A of this report. The rain gauge location is indicated in Table 2-B below. Rainfall was recorded with a continuously recording rain gauge with an accuracy of 0.01 inches. Each recorded storm event was analyzed to determine the peak 60-minute rainfall intensity.

Rain Gauge Tipping Bucket

General
The Sigma rain gauge is a freestanding receptacle for measuring precipitation. It contains an open top, which allows rainfall to fall into the upper portion, which is called the collector. Collected water is funneled to a mechanical device (tipping bucket), which incrementally measures the rainfall accumulation and causes a momentary closure of a switch. As water is collected, the tipping bucket fills to the point where it tips over. This action empties the bucket in preparation for additional measurement. Water discharged by the tipping bucket passes out of the rain gauge with no need for emptying.

Specifications

Resolution:	0.01" rainfall per bucket tip
Accuracy:	0.5% at 0.5" per hour
Weight:	9.25 lbs., (4.2 kg)
Dimensions:	18" H x 12" W x 12" D, (45.7cm x 30.5 cm x 30.5 cm)
Operating Temp:	32 to135 degrees F (0 to 57 degrees F)

Table 2-B
Rainfall Monitoring Location

Rain Gauge No.	Location/Address
Rain Gauge 1	Intersection of Custer & Eldorado/ Lift station 8994.
Rain Gauge 2	2604 Country Club Dr/ Eldorado Country Club.
Rain Gauge 3	700A Wilmeth Rd/ Behind Bldg by antenna tower.
Rain Gauge 4	5252 W. University Dr/ Behind hospital in electrical area.

Historical rainfall data for the City of McKinney, Texas from the National Weather Bureau, Technical Paper 40, Rainfall Frequency of the United States is indicated in Table 2-C on the next page.

Table 2-C

Historical Rainfall Intensities

Storm Recurrence Interval (Year)	Total Rainfall 60-Minute Duration Storm (in)	Total Rainfall 24-Hour Duration Storm (in)
1	1.58	3.25
2	1.90	4.00
5	2.50	5.40
10	2.90	6.40
25	3.35	7.50
50	3.80	8.50
100	4.25	9.50

Peak 60-Minute rainfall intensities and daily rainfall totals recorded during the monitoring period from each rain gauge locations are given in Table 2-D on the next page.

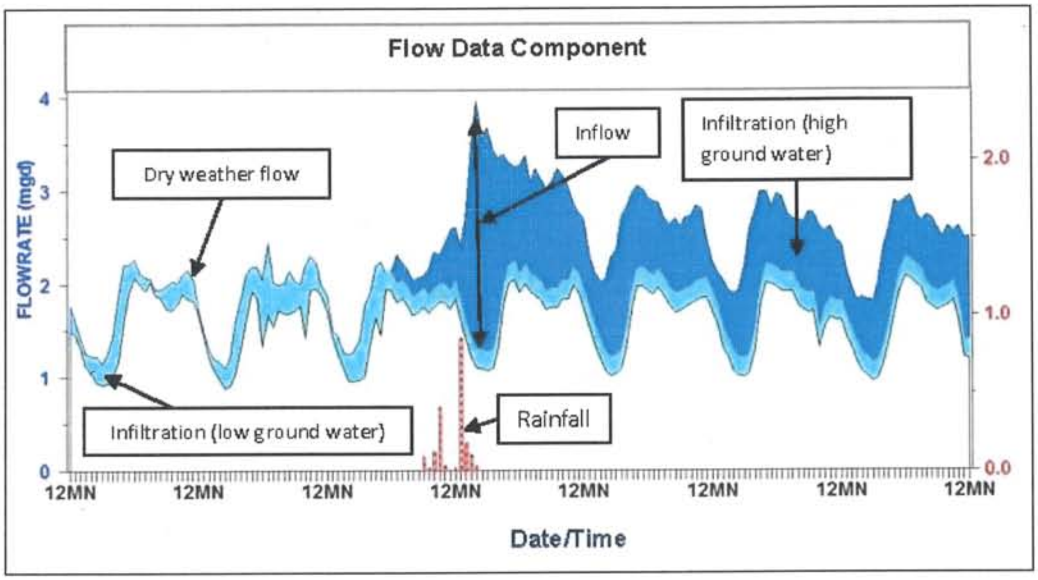
Table 2-D
Rainfall Summary

Rainfall Date		Rain Gage 1		Rain Gage 2		Rain Gage 3		Rain Gage 4	
		Daily Total Rainfall (inch)	Peak 60-Minute Rainfall Intensity (inch/hr)	Daily Total Rainfall (inch)	Peak 60-Minute Rainfall Intensity (inch/hr)	Daily Total Rainfall (inch)	Peak 60-Minute Rainfall Intensity (inch/hr)	Daily Total Rainfall (inch)	Peak 60-Minute Rainfall Intensity (inch/hr)
2013									
March	23	0.27	0.16	0.32	0.17	0.53	0.21	0.36	0.20
	27			0.04	0.02				
	28			0.03	0.02				
	29			0.01	0.01	0.61	0.61	0.86	0.86
	30	1.13	0.88	1.17	0.73	0.38	0.26	0.33	0.27
	31	0.56	0.56	0.68	0.66	0.9	0.89	0.98	0.98
April	2	0.14	0.11	0.12	0.06	0.18	0.06	0.16	0.06
	3	0.36	0.11	0.44	0.16	0.32	0.09	0.39	0.08
	4	0.04	0.02	0.06	0.02	0.01	0.01	0.04	0.04
	10	0.37	0.14	0.78	0.23	0.86	0.22	0.63	0.19
	18	1.36	1.17	0.83	0.63	1.03	0.82	1.6	1.39
	20			0.05	0.05				
	22			0.01	0.01			0.01	0.01
	23	0.04	0.04	0.04	0.04	0.08	0.07	0.07	0.04
	24	0.07	0.05	0.14	0.07				
	2	0.07	0.07	0.09	0.06	0.02	0.02	0.03	0.03
	3			0.08	0.07				
	4			0.04	0.04			0.01	0.01
	7			0.04	0.04				
	8			0.04	0.03				
	9	0.19	0.1	0.33	0.17	0.25	0.13	0.16	0.08
	10	0.04	0.05					0.01	0.01
	11			0.06	0.06				
	12			0.03	0.02				
	13							0.02	0.02
	15	0.46	0.24	0.49	0.23	0.37	0.15	0.37	0.19
	16	0.01	0.01	0.01	0.01	0.02	0.01	0.04	0.03
	17	0.01	0.01			0.01	0.01	0.02	0.01
	21	1.32	1.2	1.54	1.43	1/	1/	1.73	0.98
	23	0.02	0.01			1/	1/		
	24	0.94	0.75	0.79	0.46	1/	1/	0.71	0.44
	25	0.16	0.15	0.15	0.12	1/	1/	0.13	0.11
	26	0.51	0.29	0.47	0.35	1/	1/	0.23	0.12
	29	0.05	0.04	0.02	0.02	1/	1/	0.03	0.03
June	1	0.03	0.03	0.06	0.03	1/	1/	0.05	0.04
Total		8.15		8.96		5.57[2/]		8.97	

Note: [1/] Data not available
[2/] not a complete Total

3 FLOW DATA ANALYSIS

The flow data analysis consisted of determining the base flow, average daily dry weather flow, infiltration rates, and peak inflow rates for each monitored basin. A Graph showing the typical components of the flow is shown below.



A basin flow diagram illustrating flow direction from one basin to another is shown in Exhibit 2.

3.1 Base Flow

The base flow is the total quantity of wastewater flows including domestic, commercial, and industrial wastewater flows, but excluding all infiltration and inflow. Generally this is determined by reviewing the water billing records during the winter month when most of the water consumption returns to the wastewater collection systems. Typically 90% to 95% of water returns to the wastewater collection system.

3.2 Average Daily Dry Weather Flow

The basic definition of dry weather flow is all flow in a sewer except that caused directly by rainfall. Flow data collected during dry-weather/low groundwater periods was analyzed to determine the average daily dry weather flow for each metered-basin. The dry weather period selected for this analysis was from April 30, 2013 through May 6, 2013. The dry weather data analysis determined that the average flow under dry-weather/low groundwater conditions for the City of McKinney was 14.840 MGD.

It should be noted that depending on the actual groundwater condition the dry weather flow rate varies with season to season.

Average daily dry-weather flow by basin is shown graphically in Figure 3.1 below and indicated in Table 3-B on the next page.

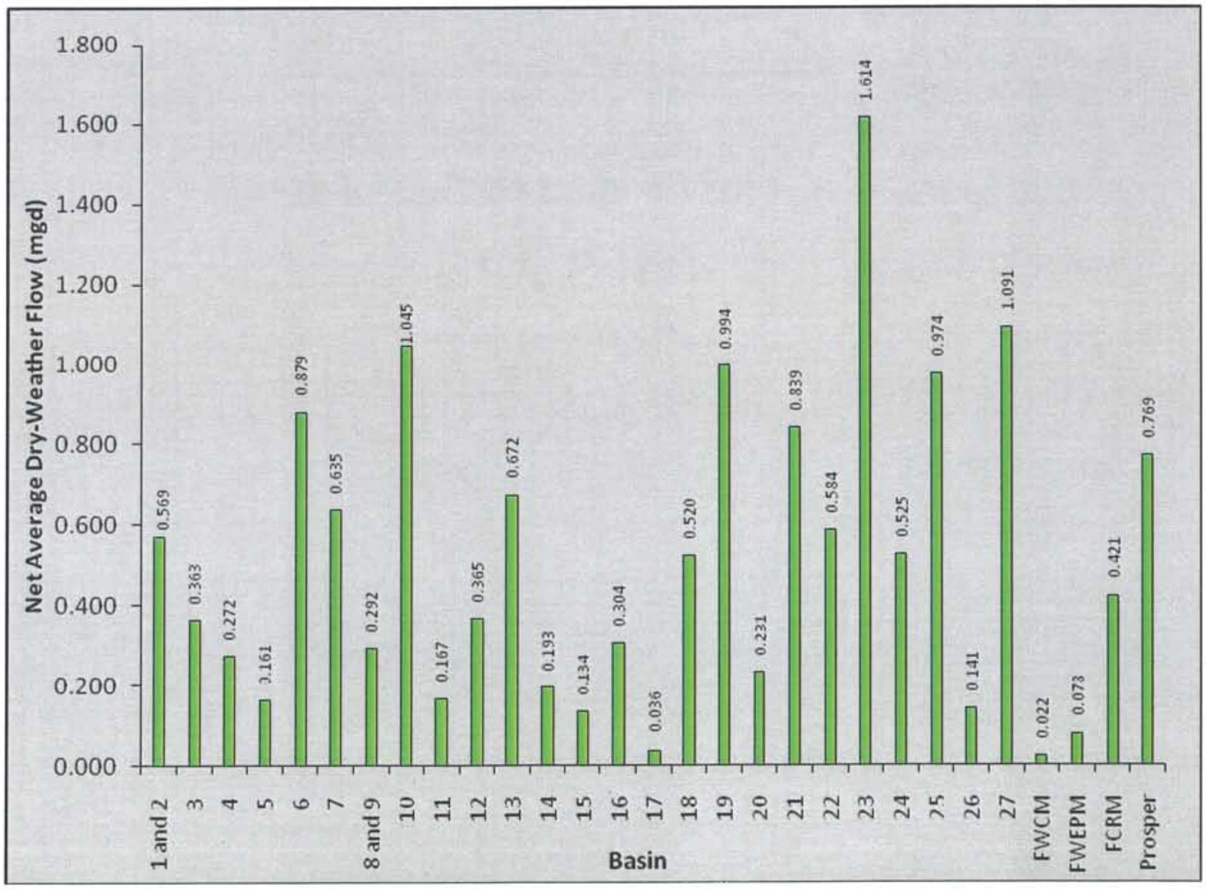


Figure 3.1 – Net Average Daily Dry Weather Flow

Table 3-A
Average Daily Dry Weather Flow

Basin No.	Meter Number	Gross Average Daily Dry Weather Flow (mgd)	Net Average Daily Dry Weather Flow (mgd)
1 & 2	FM-1	7.941	0.568
	FM-2	0.991	
3	FM-3	0.363	0.363
4	FM-4	0.272	0.272
5	FM-5	0.161	0.161
6	FM-6	0.879	0.879
7	FM-7	1.680	0.635
8 & 9	FM-8	4.566	0.687
	FM-9	0.280	
10	FM-10	1.045	1.045
11	FM-11	0.167	0.167
12	FM-12	0.365	0.365
13	FM-13	0.672	0.672
14	FM-14	0.193	0.193
15	FM-15	0.134	0.134
16	FM-16	0.304	0.304
17	FM-17	0.036	0.036
18	FM-18	0.520	0.520
19	FM-19	1.972	0.550
20	FM-20	0.231	0.231
21	FM-21	0.839	0.839
22	FM-22	0.584	0.584
23	FM-23	1.636	1.614
24	FM-24	0.525	0.525
25	FM-25	3.109	0.974
26	FM-26	0.141	0.141
27	FM-27	1.091	1.091
FWCM	1/	0.022	0.022
FWEPM	1/	0.078	0.078
FCRM	1/	0.421	0.421
Prosper	1/	0.769	0.769
		Total	**14.840**

Note: [1/] Flow Monitored by "North Texas Municipal Water District".

A basin flow diagram with average daily dry weather flow during a week is included in Exhibit 3. Dry weather hydrographs and flow data for each basin are included in Appendix B.

3.2.1 Peak Flow and Peaking Factor under Dry-Weather/Low Groundwater Conditions

The dry weather peaking factor is the ratio of the dry weather peak hourly flow rate and the average daily flow during dry weather. This ratio defines the stability or consistency of flow in a basin. The closer this factor is to 1.0, the less hour-to-hour flow variation exists. Larger dry weather peaking factors could imply relative high-volume, short-term users or in some instances the influence of pumping stations.

Dry weather peaking factors ranged from 1.30 to 4.62 for the monitoring sites. Peak hourly dry weather flows and dry weather peaking factors are given in Table 3-B on the next page.

Table 3-B
Peak Hourly Dry Weather Flow and Dry Weather Peaking Factor

Basin	Meter Number	Gross Peak Hourly Dry Weather Flow (mgd)	Gross Average Daily Dry Weather Flow (mgd)	Dry Weather Peaking Factor
1 & 2	FM-1	11.226	7.941	1.41
	FM-2	1.622	0.991	1.64
3	FM-3	0.745	0.363	2.05
4	FM-4	0.390	0.272	1.43
5	FM-5	0.249	0.161	1.55
6	FM-6	1.146	0.879	1.30
7	FM-7	2.539	1.680	1.51
8 & 9	FM-8	7.341	4.566	1.61
	FM-9	0.465	0.280	1.66
10	FM-10	1.660	1.045	1.59
11	FM-11	0.270	0.167	1.62
12	FM-12	0.547	0.365	1.50
13	FM-13	0.955	0.672	1.42
14	FM-14	0.393	0.193	2.04
15	FM-15	0.276	0.134	2.06
16	FM-16	0.514	0.304	1.69
17	FM-17	0.066	0.036	1.83
18	FM-18	0.895	0.520	1.72
19	FM-19	4.216	1.972	2.14
20	FM-20	0.447	0.231	1.93
21	FM-21	1.381	0.839	1.65
22	FM-22	1.088	0.584	1.86
23	FM-23	3.026	1.636	1.85
24	FM-24	0.795	0.525	1.51
25	FM-25	4.363	3.109	1.40
26	FM-26	0.303	0.141	2.14
27	FM-27	2.190	1.091	2.39
FWCM	1/	0.100	0.022	4.62
FWEPM	1/	0.143	0.078	1.84
FCRM	1/	0.755	0.421	1.79
Prosper	1/	1.355	0.769	1.76

Note: 1/ Flow Monitored by "North Texas Municipal Water District".

3.3 Infiltration Analysis

Infiltration can enter the sanitary sewer system through defective pipe joints, main sewer pipe defects and manhole defects including wall, pipe seal and bench defects.

Permanent infiltration is defined as the groundwater flow that enters the wastewater collection system during dry-weather/low groundwater periods. Generally permanent infiltration is determined by subtracting the base flows from the average daily dry weather flows.

Peak Infiltration is the maximum extraneous flow that enters the wastewater collection system during high ground water conditions. To determine the peak infiltration rate care must be exercised to exclude days that are too close to rainfall events to avoid overestimation of infiltration due to residual inflow when determining the infiltration rates under dry weather/high groundwater conditions. Generally periods of 24 hours following significant rainfall are used for analyzing the peak infiltration rates due to dry weather and high groundwater conditions.

3.3.1 Permanent Infiltration

As discussed earlier, the base flows for individual sewer basins could not be determined, and as a result the permanent infiltration also could not be determined for individual sewer basins.

It is to be noted that the permanent infiltration rate depends on the groundwater level and varies significantly from season to season.

3.3.2 Peak Infiltration (Rainfall induced infiltration)

The peak infiltration was determined by subtracting the average dry weather/low groundwater flow from the average dry weather/high groundwater flow. The peak infiltration under dry weather/high groundwater conditions for the City of McKinney was 3.640 MGD.

Peak infiltration by basin is indicated in Table 3-C and shown graphically in Figure 3.2 on page 16 and page 17 respectively.

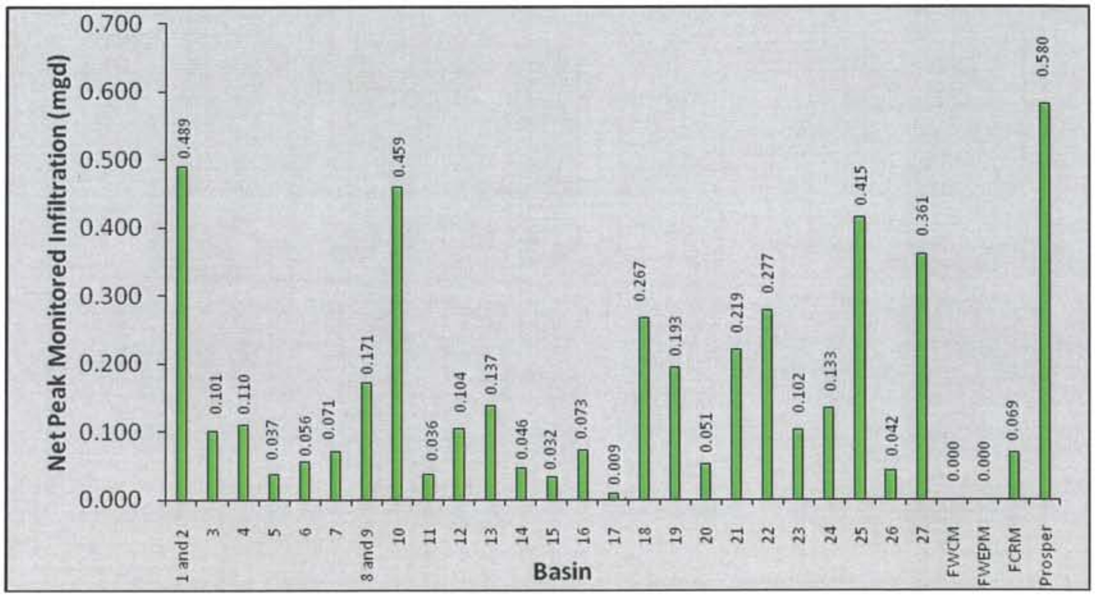


Figure 3.2 – Net Peak Monitored Infiltration

Table 3-C
Peak Monitored Infiltration

Basin	Meter Number	Gross Monitored Infiltration (mgd)	Net Peak Monitored Infiltration (mgd)
1 & 2	FM-1	3.276	0.489
	FM-2	0.891	
3	FM-2	0.101	0.101
4	FM-4	0.110	0.110
5	FM-5	0.037	0.037
6	FM-6	0.056	0.056
7	FM-7	0.530	0.071
8 & 9	FM-8	1.921	0.171
	FM-9	0.065	
10	FM-10	0.459	0.459
11	FM-11	0.036	0.036
12	FM-12	0.104	0.104
13	FM-13	0.137	0.137
14	FM-14	0.046	0.046
15	FM-15	0.032	0.032
16	FM-16	0.073	0.073
17	FM-17	0.009	0.009
18	FM-18	0.267	0.267
19	FM-19	0.689	0.193
20	FM-20	0.051	0.051
21	FM-21	0.219	0.219
22	FM-22	0.277	0.277
23	FM-23	0.102	0.102
24	FM-24	0.133	0.133
25	1/	0.586	0.415
26	1/	0.042	0.042
27	1/	0.361	0.361
FWCM	1/	2/	2/
FWEPM	1/	2/	2/
FCRM	1/	0.069	0.069
Prosper	1/	0.580	0.580
Total			**4.640**

Note: 1/ Flow Monitored by "North Texas Municipal Water District".

2/ Not significant

A basin flow diagram with peak-monitored infiltration is included in Exhibit 4. Wet weather hydrographs and flow data for selected rain event are included in Appendix B of this report. It should be noted that the infiltration rate depends on the amount of rainfall and the groundwater level; therefore, it can vary significantly from season to season.

3.4 Inflow Analysis

Wet weather flow monitoring data was analyzed to estimate the inflow rate associated with various rainfall events. In determining the peak inflow rate, the sum of base flow and infiltration was subtracted from the peak instantaneous flow rate observed following a rain event. Peak inflow was plotted against the peak 60-minute rainfall intensity for the corresponding rain event. Regression analysis was used to determine the best-fit relationship between the various data points.

According to the National Weather Bureau, Technical Paper No. 40, the 1-year/60-minute storm intensity for the City of McKinney is 1.58 inch/hour and the 5-year/60-minute storm intensity is 2.50 inch/hour.

The total 1-year/60-minute inflow for the City of McKinney is projected to be 23.686 MGD and the total 5-year/60-minute inflow is projected to be 35.759 MGD. A summary listing of the 1-year/60-minute inflow and 5-year/60-minute inflow, as projected from the data collected during the monitoring period for each basin, is given in Table 3-D on the next page. A basin flow diagram with 1-year/60-minute storm inflow and 5-year/60-minute storm inflow is shown in Exhibit 5 and Exhibit 6 respectively.

The log-log graphs of the rainfall intensity/inflow relationships for each basin are included in Appendix C. Net inflow by basin during a 1-year/60-minute storm event and 5-year/60-minute storm event, projected from data collected during the monitoring period, is shown in Figure 3.3 and Figure 3.4 respectively on page 15.

It should be noted five to six rain events with various rainfall intensities (minimum 0.15 inch/hr) are necessary for a reliable inflow projection. A total of nine (9) rainfall events were recorded with an intensity of between 0.15 inch/hr to 1.20 inch/hr; however, few of these rainfall events occurred and were followed by another rainfall. Additionally, during the larger rain events some of the meter sites were observed to be backed-up and surcharged. Care was taken to avoid the overestimation of inflow projection. Inflow analysis for the meter sites FM-1 and FM-2, FM-8 and FM-9 were combined together due to the upstream interconnected sewer lines. Inflow projections for the meter sites FM-1 & FM-2, FM-8 & FM-9, and FM-13 are most likely underestimated due to de-peaking of peak flow due to the long travel time between basins.

Table 3-D

Projected 1-Year/60-Minute & 5-Year/60-Minute Storm Inflow Rates

Basin	Meter Number	Gross Peak Projected 1-Year/60 Minute Storm Inflow (mgd)	Net Peak Projected 1-Year/60 Minute Storm Inflow (mgd)	Gross Peak Projected 5-Year/60-Minute Storm Inflow (mgd)	Net Peak Projected 5-Year/60-Minute Storm Inflow (mgd)
1 & 2	FM-1 & FM-2	15.438	0.694	23.997	2.542
3	FM-3	1.142	1.142	1.723	1.723
4	FM-4	0.842	0.842	1.097	1.097
5	FM-5	1.252	1.252	1.738	1.738
6	FM-6	2.889	2.889	4.452	4.452
7	FM-7	1.860	1.093	2.312	1.210
8 & 9	FM-8 & FM-9	6.792	0.943	10.406	2.084
10	FM-10	0.767	0.767	1.102	1.102
11	FM-11	1.466	1.466	1.947	1.947
12	FM-12	1.291	1.291	1.770	1.770
13	FM-13	0.712	0.712	0.991	0.991
14	FM-14	0.162	0.162	0.241	0.241
15	FM-15	0.218	0.218	0.284	0.284
16	FM-16	0.713	0.713	1.166	1.166
17	FM-17	0.071	0.071	0.109	0.109
18	FM-18	1.216	1.216	1.812	1.812
19	FM-19	1.913	0.299	2.648	0.369
20	FM-20	0.200	0.200	0.239	0.239
21	FM-21	0.862	0.862	1.240	1.240
22	FM-22	0.752	0.752	1.039	1.039
23	FM-23	1.341	1.327	1.849	1.833
24	FM-24	1.109	1.109	1.450	1.450
25	1/	1.831	0.129	2.517	0.151
26	1/	0.374	0.374	0.593	0.593
27	1/	1.432	1.432	2.221	2.221
FWCM	1/	0.014	0.014	0.016	0.016
FWEPM	1/	0.023	0.023	0.032	0.032
FCRM	1/	0.338	0.338	0.485	0.485
Prosper	1/	1.356	1.356	1.823	1.823
Total			**23.686**		**35.759**

Note: 1/ Flow Monitored by "North Texas Municipal Water District".

3.5 Capacity Analysis

A pipe capacity analysis was performed at each of the monitored locations to examine the existing hydraulic conditions. The analysis looked only at the conditions in the pipe where the monitors were located. Each monitored site has a calculated full pipe flow capacity. This is a projected full pipe capacity under uniform and free flow conditions. The flow capacity is a function of pipe size, slope and roughness coefficient. All twenty-four (24) meter sites monitored by SWG were examined for pipe capacity. The existing full pipe capacity was calculated based on the flow depths and velocities recorded during field investigation.

3.5.1 Dry Weather Capacity Analysis

Sewers commonly are designed to handle a maximum dry depth-of-flow over diameter-of-pipe (d/D) ratio of 0.5 for sewer lines less than 18 inches in diameter and 0.67 for sewer lines 18 inches or greater in diameter. From twenty-four (24) monitoring sites, twenty-two (22) monitoring sites have dry weather d/D ratios ranged from 0.11 to 0.51 and are typical values. Meter FM-3 and FM-4 has dry weather d/D ratio 0.70 and 0.60 respectively, which is over the design capacity criteria. No dry weather surcharging was observed during the normal operation of the monitoring period. However meter sites FM-1 and FM-2 were observed to be surcharged multiple times during the dry weather period due to unusual restriction along the downstream segments of the main sewer lines. A summary of d/D ratios and the percentage of capacity used under dry weather conditions are given, by monitoring site, in Table 3-E on the next page.

Table 3-E
Dry-Weather Flow Capacity Analysis

Meter Site	Full Pipe Capacity (mgd)	Existing Pipe Size D (inch)	Observed Maximum Depth of Flow, d (inch)	d/D Ratio	Observed Peak Hourly Flow (mgd)	Capacity Used (%)
FM-1	27.181	48.12	20.13	0.42	11.226	41.30
FM-2	7.553	30.38	10.36	0.34	1.622	21.47
FM-3	0.873	18.00	12.66	0.70	0.745	85.34
FM-4	0.476	14.00	8.46	0.60	0.390	81.93
FM-5	7.114	14.37	2.07	0.14	0.249	3.50
FM-6	13.684	21.06	4.43	0.21	1.146	8.37
FM-7	5.423	25.38	12.23	0.48	2.539	46.82
FM-8	13.315	35.25	17.92	0.51	7.341	55.13
FM-9	13.315	23.25	5.40	0.23	0.465	3.49
FM-10	1.969	23.50	10.71	0.46	1.660	84.31
FM-11	12.911	17.69	1.89	0.11	0.270	2.09
FM-12	9.970	17.22	2.62	0.15	0.547	5.49
FM-13	5.742	17.88	4.72	0.26	0.955	16.63
FM-14	7.498	11.88	1.78	0.15	0.393	5.24
FM-15	1.704	11.63	2.99	0.26	0.276	16.20
FM-16	1.242	14.81	6.42	0.43	0.514	41.38
FM-17	10.572	26.73	1.57	0.06	0.066	0.62
FM-18	8.310	20.41	4.53	0.22	0.895	10.77
FM-19	20.380	29.88	8.84	0.30	4.216	20.69
FM-20	7.807	17.50	3.08	0.18	0.231	2.96
FM-21	27.509	27.00	3.95	0.15	1.381	5.02
FM-22	3.086	18.00	7.25	0.40	1.088	35.26
FM-23	8.209	21.00	8.63	0.41	3.026	36.86
FM-24	1.917	15.25	6.11	0.40	0.795	41.47
FM-25	McKinney Rowlett Creek Meter				4.363	1/
FM-26	McKinney Waters Branch Meter				0.303	1/
FM-27	McKinney Cottonwood Creek Meter				1.963	1/
FWCM	Frisco Winding Creek Meter				0.050	1/
FWEPM	Frisco West Eldorado Parkway Meter				0.145	1/
FCRM	Frisco Custer Road Meter				0.755	1/
Prosper	Prosper Meter				1.355	1/

Note: 1/ Flow Monitored by “North Texas Municipal Water District”.

3.5.2 Wet Weather Capacity Analysis (Observed Flow)

Sewers commonly are designed to handle a d/D ratio of 0.75 during total peak flows. When 0.75 is exceeded, it may indicate that the pipeline has exceeded its design criteria. Wet-weather d/D ratios observed during the monitoring period ranged from 0.23 to 1.00 for the monitoring sites. From the twenty-four (24) monitored sites, there are eleven (11) monitoring sites that show to have exceeded the design criteria. Of these eleven (11) monitored sites, ten (10) of the meter sites have wet weather d/D ratios equal to 1 and a depth of flow higher than the actual pipe diameter. This means there is some surcharge occurring in these areas. A summary of d/D ratios and the percentage of capacity used under wet weather conditions are given, by monitoring site in Table 3-F on the next page.

Table 3-F
Wet-Weather Flow Capacity Analysis
(Observed Flow, various storm event)

Meter Site	Existing Manhole Depth (feet)	Projected Full Pipe Capacity (mgd)	Existing Pipe Size D (inch)	Observed Maximum Depth of Flow, d (inch)	d/D Ratio	Observed Peak Hourly Flow (mgd)	Capacity Used (%)
FM-1	12.80	27.181	48.12	68.69	1.00	15.329	56
FM-2	9.20	7.553	30.38	27.74	0.91	4.189	55
FM-3	13.40	0.873	18.00	26.47	1.00	1.110	127
FM-4	15.80	0.476	14.00	13.42	0.96	0.697	146
FM-5	12.50	7.114	14.37	4.97	0.35	0.702	10
FM-6	9.30	13.684	21.06	5.49	0.26	2.253	16
FM-7	10.10	5.423	25.38	12.76	0.50	3.434	63
FM-8	11.50	13.315	35.25	25.43	0.72	10.889	82
FM-9	10.90	13.315	23.25	7.06	0.30	1.015	8
FM-10	22.10	1.969	23.50	19.51	0.83	2.220	113
FM-11	7.10	12.911	17.69	9.22	0.52	0.637	5
FM-12	17.22	9.970	17.22	5.55	0.32	1.420	14
FM-13	17.30	5.742	17.88	5.18	0.29	1.090	19
FM-14	11.40	7.498	11.88	1.96	0.16	0.439	6
FM-15	7.20	1.704	11.63	3.59	0.31	0.371	22
FM-16	9.00	1.242	14.81	7.13	0.48	0.66	53
FM-17	8.40	10.572	26.73	3.13	0.12	0.115	1
FM-18	7.10	8.310	20.41	5.46	0.27	1.270	15
FM-19	10.40	20.380	29.88	10.04	0.34	5.465	27
FM-20	8.10	7.807	17.50	3.5	0.20	0.567	7
FM-21	14.20	27.509	27.00	4.24	0.16	1.645	6
FM-22	11.70	3.086	18.00	9.86	0.55	1.591	52
FM-23	16.80	8.209	21.00	9.26	0.44	3.361	41
FM-24	13.30	1.917	15.25	7.63	0.50	1.083	56
FM-25	McKinney Rowlett Creek Meter					5.400	1/
FM-26	McKinney Waters Branch Meter					0.340	1/
FM-27	McKinney Cottonwood Creek Meter					2.393	1/
FWCM	Frisco Winding Creek Meter					0.100	1/
FWEPM	Frisco West Eldorado Parkway Meter					0.143	1/
FWRM	Frisco Custer Road Meter					0.863	1/
Prosper	Prosper Meter					2.178	1/

Note: 1/ Flow Monitored by "North Texas Municipal Water District".

As indicated in the above Table 3-F, meter sites FM-1 and FM-2 were observed to be surcharged during wet weather periods.

3.5.3 Wet Weather Capacity Analysis (Projected 5 Year Peak Flow)

The total projected 5-year/60-minute peak hourly flow was determined in order to analyze the capacity of the City of McKinney's existing sanitary sewer line located around the City limit. A summary of the total projected 5-year/60-minute peak flow and the percentage of projected capacity used under wet weather conditions are given, by monitoring site, in Table 3-G on page 24.

Table 3-G

Wet-Weather Flow Capacity Analysis

(Projected 5-Year/60-minute Peak Flow)

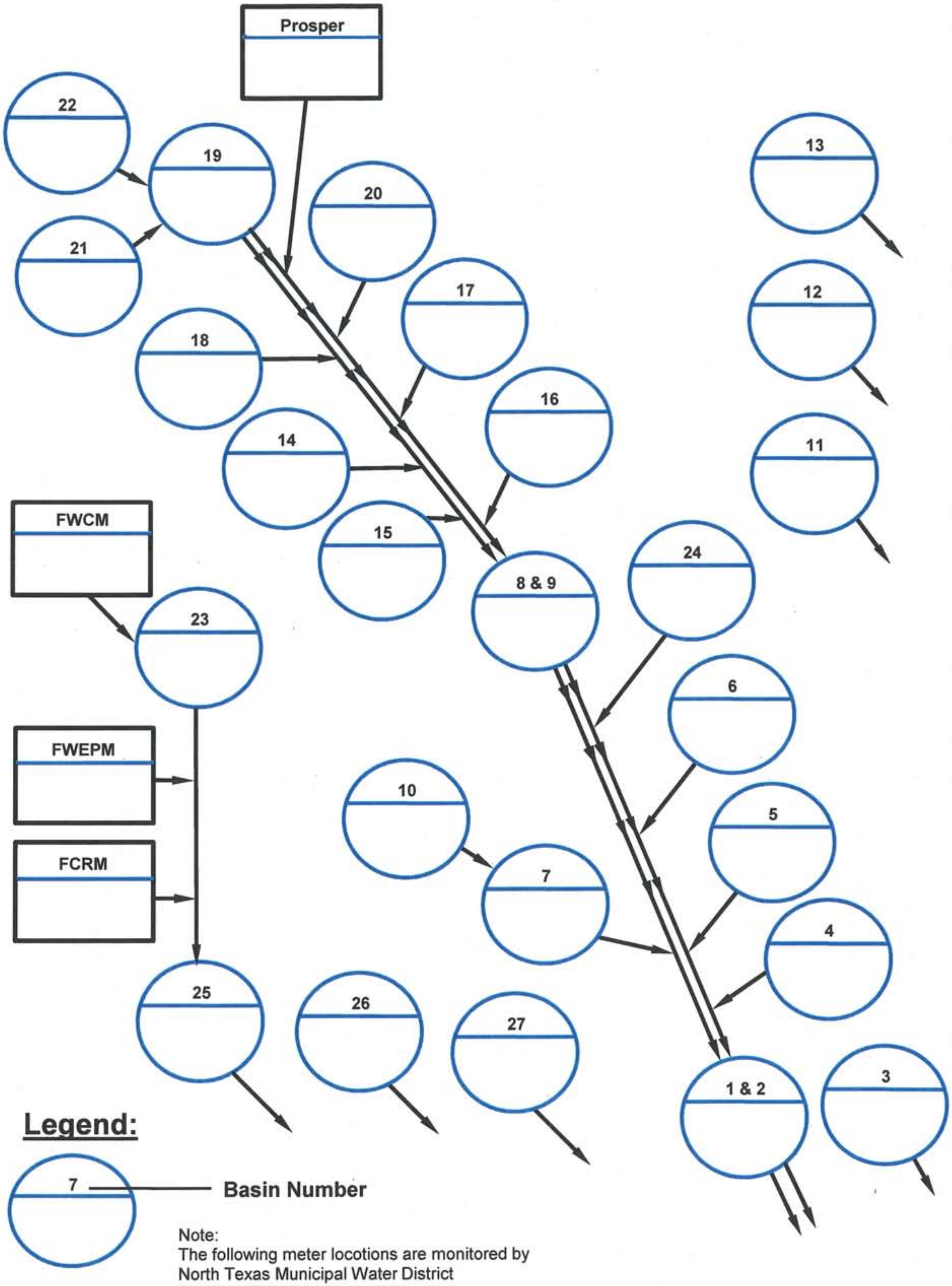
Basin	Meter Number	Full Pipe Capacity (mgd)	Gross Peak Hourly Dry-Weather Flow (mgd)	Gross Peak Monitored Infiltration (mgd)	Gross Projected Inflow Rates 5 Yr/60-Minute (mgd)	Total Projected Peak 5 Yr/60-Minute Flow (mgd)	Projected Capacity Used (%)
1 & 2	FM-1 & FM-2	34.734	12.848	3.276	23.997	40.121	116%
3	FM-3	0.873	0.745	0.101	1.723	2.569	294%
4	FM-4	0.476	0.390	0.110	1.097	1.597	336%
5	FM-5	7.114	0.249	0.037	1.738	2.024	28%
6	FM-6	13.684	1.146	0.056	4.452	5.654	41%
7	FM-7	5.423	2.539	0.530	2.312	5.381	99%
8 & 9	FM-8 & FM-9	13.315	7.806	1.921	10.406	20.133	151%
10	FM-10	1.969	1.660	0.459	1.102	3.221	164%
11	FM-11	12.911	0.270	0.036	1.947	2.253	17%
12	FM-12	9.970	0.547	0.104	1.770	2.421	24%
13	FM-13	5.742	0.955	0.137	0.991	2.083	36%
14	FM-14	7.498	0.393	0.046	0.241	0.680	9%
15	FM-15	1.704	0.276	0.032	0.284	0.592	35%
16	FM-16	1.242	0.514	0.073	1.166	1.753	141%
17	FM-17	10.572	0.066	0.009	0.109	0.184	2%
18	FM-18	8.310	0.895	0.267	1.812	2.974	36%
19	FM-19	20.380	4.216	0.689	2.648	7.553	37%
20	FM-20	7.807	0.447	0.051	0.239	0.737	9%
21	FM-21	27.509	1.381	0.219	1.240	2.840	10%
22	FM-22	3.086	1.088	0.277	1.039	2.404	78%
23	FM-23	8.209	3.026	0.102	1.849	4.977	61%
24	FM-24	1.917	0.795	0.133	1.450	2.378	124%
25	1/	1/	4.363	0.586	2.517	7.466	1/
26	1/	1/	0.303	0.042	0.593	0.938	1/
27	1/	1/	1.963	0.361	2.221	4.545	1/
FWCM	1/	1/	0.050	2/	0.016	0.066	1/
FWEPM	1/	1/	0.145	2/	0.032	0.177	1/
FCRM	1/	1/	0.755	0.069	0.485	1.309	1/
Prosper	1/	1/	1.355	0.580	1.823	3.758	1/

Note: 1/ Flow Monitored by "North Texas Municipal Water District".
2/ Not Significant

4 CONCLUSIONS

Flow monitoring was performed for the City of McKinney from March 23, 2013 through May 31, 2013 for a period of 70 days at twenty-four (24) key locations. In addition, data from seven (7) other permanent flow meter sites monitored by "North Texas Municipal Water District" were utilized for the study. Flow data analysis was performed to determine average daily dry weather flows, infiltration rates, and peak inflow rates. Additionally, capacity analysis was performed for each temporary monitoring site.

- The average daily dry-weather flow for the monitoring area was 14.840 MGD, which includes 1.290 MGD of dry-weather flow entering City's sewer system from the City of Frisco and Town of Prosper sewer system.
- The peak monitored infiltration rate for the monitoring area was 4.640 MGD and includes 0.649 MGD from the City of Frisco and Town of Prosper sewer system during the monitoring period.
- Flow rates increase significantly during wet weather periods. The total projected 1-Year/60-Minute inflow for the monitoring area was 23.686 MGD and the total projected 5-Year/60-Minute inflow was 35.759 MGD. The total inflow rates includes inflow from the City of Frisco and Town of Prosper sewer system. The project inflow entering City's sewer system from the outside of the City limits is 1.731 MGD and 2.356 MGD respectively during the 1-Year/60-Minute and 5-Year/60-Minute rain events.
- No dry-weather surcharging was observed during the normal activity of the monitoring period; however, wet weather surcharging occurred at meter sites FM-1 and FM-2. Also, it should be noted that FM-1 and FM-2 were observed to be surcharged multiple times during dry weather periods due to the unusual downstream flow restriction.



Note:
The following meter locotions are monitored by North Texas Municipal Water District

Prosper: Prosper Meter
FWCM: Frisco Winding Creek Meter
FWEPM: Frisco West Eldorado Parkway Meter
FCRM: Frisco Custer Road Meter
Basin 25: McKinney Rowlett Creek Meter
Basin 26: McKinney Waters Branch Meter
Basin 27: McKinney Cottonwood Creek Meter

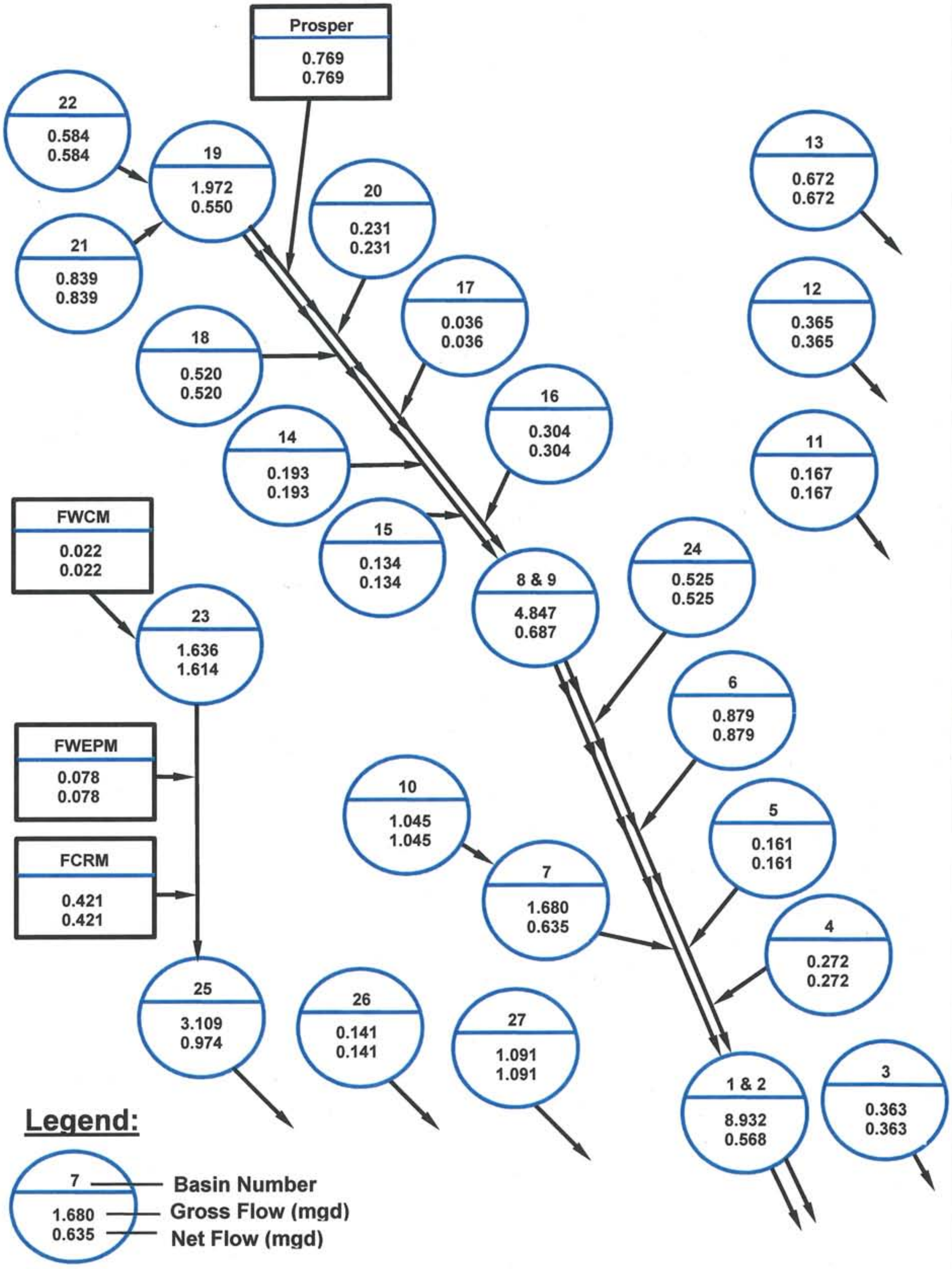
Prepared by:

SW Group

Basin Flow Diagram

Exhibit 2

City of McKinney, Texas



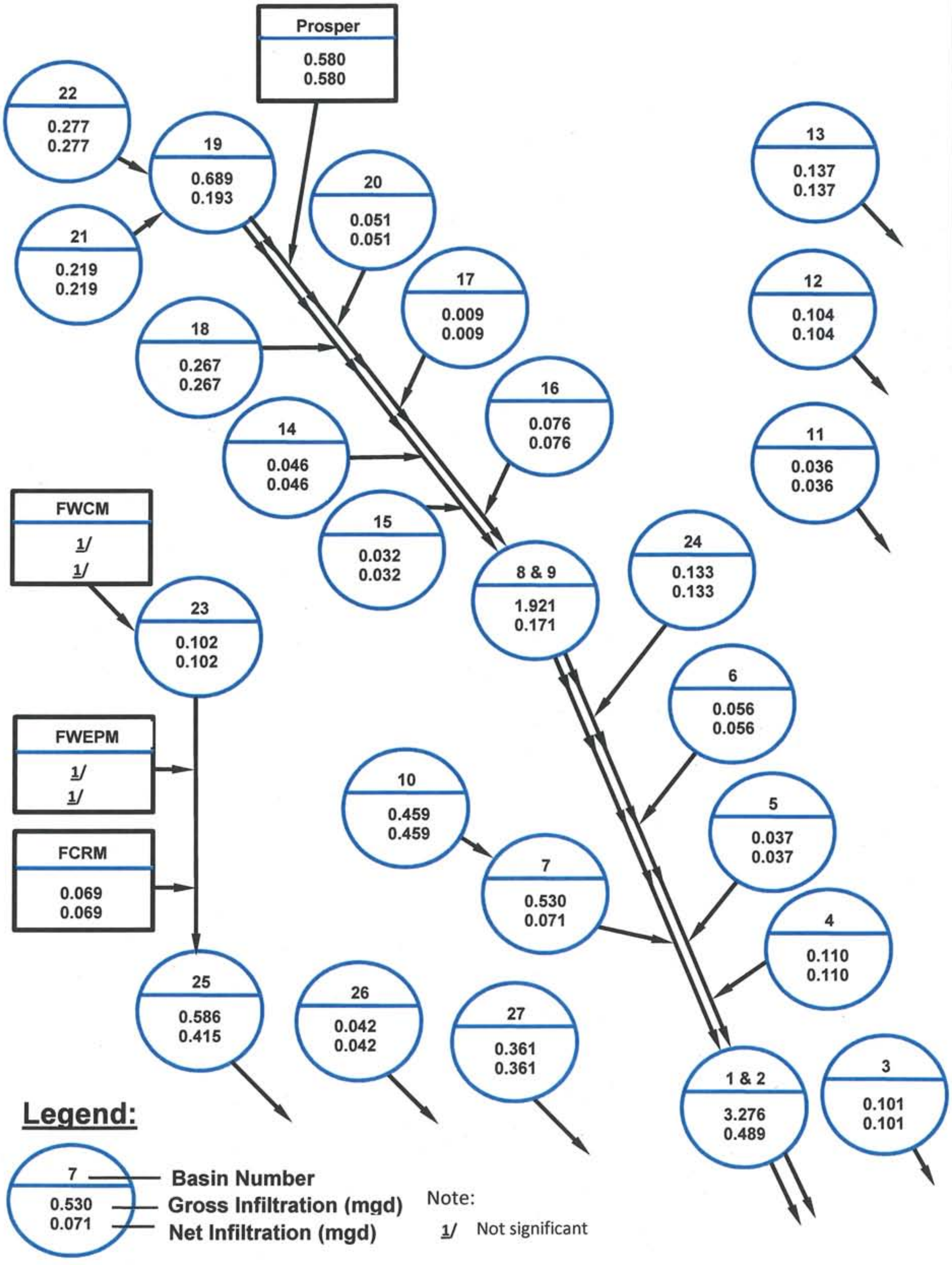
Prepared by:

SW Group

Basin Flow Diagram w/Dry-weather Flow

Exhibit 3

City of McKinney, Texas



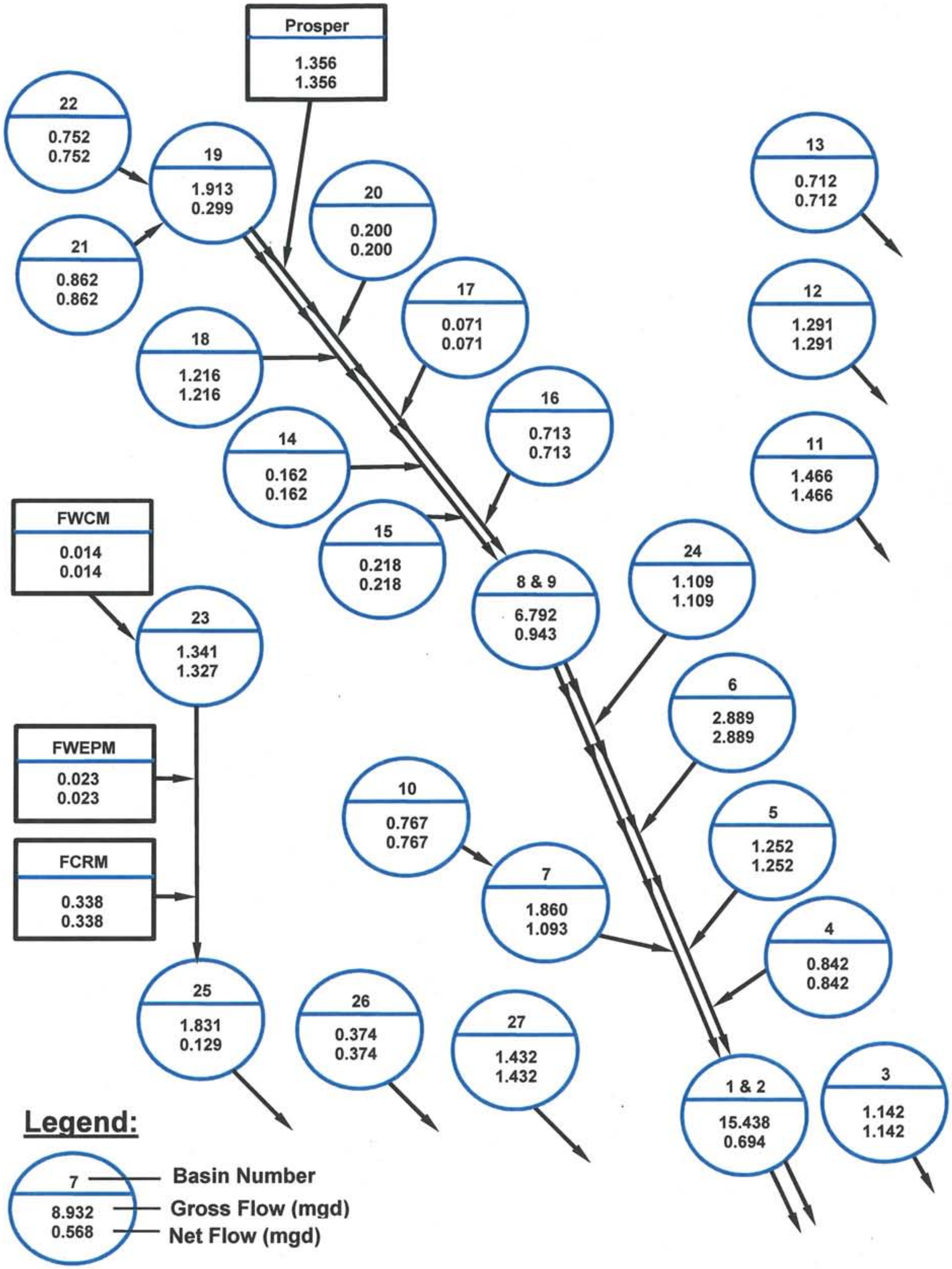
Prepared by:

SW Group

Basin Flow Diagram w/Peak Monitored Infiltration

Exhibit 4

City of McKinney, Texas



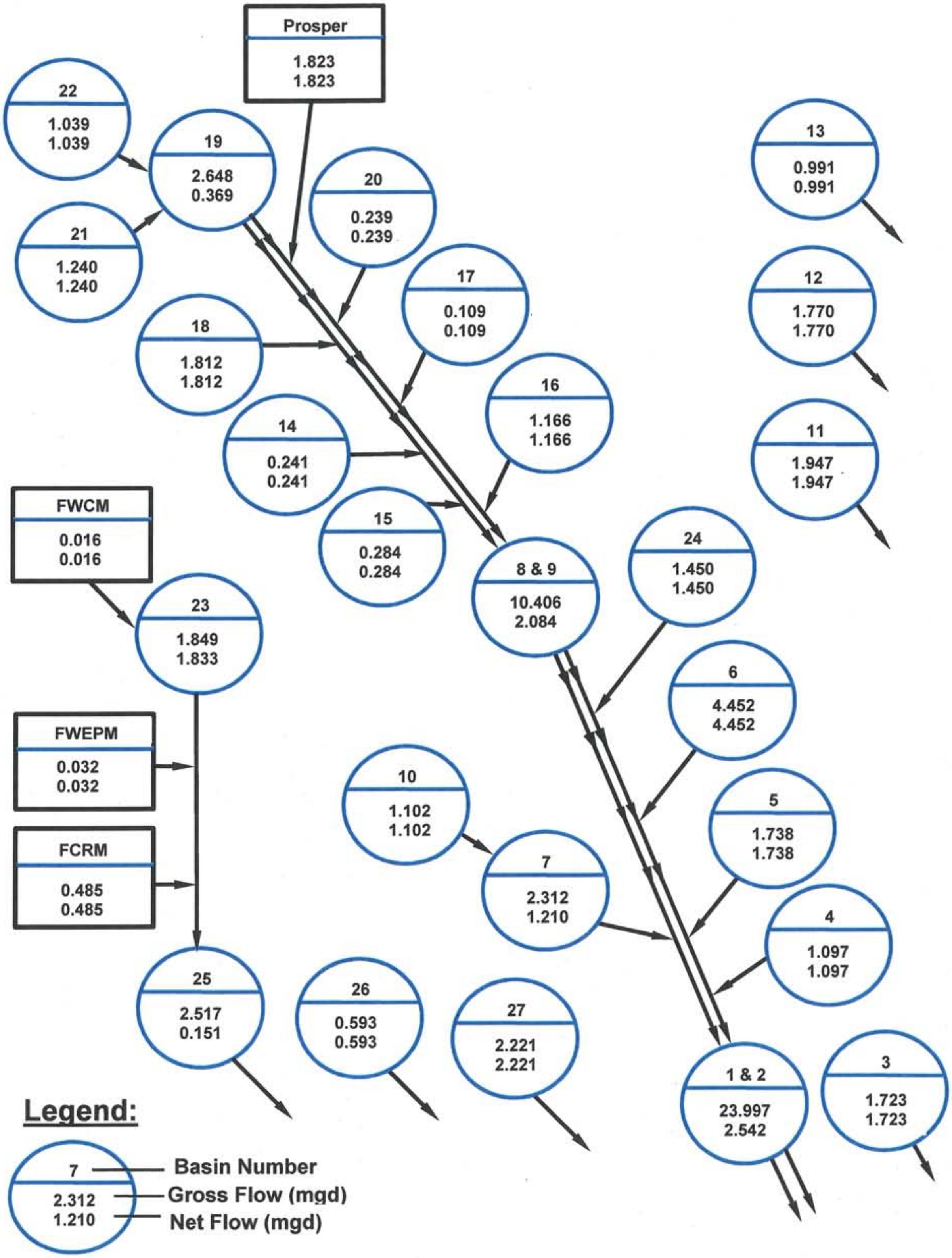
Prepared by:

SW Group

Basin Flow Diagram w/ Projected 1 year-60 minute Peak Inflow

Exhibit 5

City of McKinney, Texas



Prepared by:

SW Group

Basin Flow Diagram w/ Projected 5 year-60 minute Peak Inflow

Exhibit 6

City of McKinney, Texas

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WASTEWATER SYSTEM MASTER PLAN

BIRKHOFF, HENDRICKS & CARTER, L.L.P.
PROFESSIONAL ENGINEERS
DALLAS, TEXAS

August 2013