Chapter 2

Calibration of SWMM-EXTRAN Using Short-Term Continuous Simulation

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As part of the City of Jacksonville Master Stormwater Management Plan (MSMP), a short-term continuous water quantity model calibration was performed for three primary stormwater management systems (PSWMSs) to verify that design storm models accurately simulated a wide range of hydrologic and hydraulic characteristics. This chapter presents a summary of the water quantity methodology used for the Little Sixmile Creek calibration, the calibration results at the stream gage on Little Sixmile Creek, and the impact on the MSMP results. The nine basin plans in the MSMP were completed from 1991 to 1993. This calibration was performed for the month of January 1991. Prior to calibrating the model parameters used in the MSMP to the Little Sixmile Creek gage, the peak stages computed by Camp Dresser & McKee Inc.'s (CDM's) Version of the United States Environmental Protection Agency (EPA) Storm Water Management Model (SWMM) MSMP RUNOFF and EXTRAN blocks were within 0.5 ft (150 mm) of the measured peak stages for all of the events during the calibration period, and most peak stages were within 0.2 ft (60 mm). The calibration was used to make small adjustments in runoff volume, timing, and peak. Changes from the MSMP results based on the calibrated parameters were less than 0.5 ft (150 mm) at all locations along the PSWMS.

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2.1 Introduction

The City of Jacksonville MSMP is a comprehensive program that was developed in phases to address flooding problems, properly manage new development, address nonpoint pollutant loading, and establish an equitable means of financing recommended stormwater improvements. For the purposes of the study, the City was subdivided into nine basins based on the respective receiving waterbody. Each basin was further subdivided into sub-basins based on major streams within the basin. Each major stream and its associated tributaries were considered to be PSWMSs and were studied in detail in terms of hydraulics and hydrology.

Little Sixmile Creek is a major tributary in the Ribault River Sub-Basin, which is a part of the Trout River Basin (Figure 2.1). Since 1990 the United States Geological Survey (USGS) has operated a stream gage (gage number 02246700) on Little Sixmile Creek approximately 0.6 miles (1 km) upstream of its confluence with Ribault River. The gage records stage at 15-minute intervals. The area upstream of the gage is approximately 4.5 square miles (12 km²). Land use of the contributing area is predominately a mixture of open land, medium density residential development, commercial development, and light industrial development. Soils in the contributing area are largely D or dual hydrologic soil class in an undrained condition. Hydrologic boundaries and EXTRAN network PSWMS are shown in Figure 2.2.

Modified versions of the RUNOFF and EXTRAN blocks of SWMM were used to model the hydrology and hydraulics, respectively. Computationally, these modified versions are nearly identical to Version 4.3 of the SWMM. Although it did not have a significant impact in this calibration, the modification with potentially the most significance to continuous simulations is the maximum infiltration volume option. With this option enabled, all rainfall on the pervious surface becomes runoff after a specified volume has infiltrated (e.g. saturation of a perched water table). Regeneration of this term is computed similarly to regeneration of the Horton infiltration rate. For this calibration, the maximum infiltration volume was not reached in any of the hydrologic units.

Two of the applications of SWMM for the MSMP were to establish and verify flood elevations. As with any model, it is desirable to calibrate SWMM in order to increase the accuracy of the results and the level of confidence in those results. The calibration discussed in this chapter was performed for the purpose of comparing computed stage-time hydrographs to observed values for a 1-month wet period. Calibration of RUNOFF and EXTRAN for a 1-month period allows use of several successive events and computation of antecedent moisture conditions while maintaining manageable run times and amounts of data.

Figure 2.1 Ribault River hydrologic units and PSWMS.

2.2 Methodology

Calibration of the RUNOFF and EXTRAN input data sets for the Little Sixmile Creek portion of the Ribault River Sub-Basin included:

- selecting a suitable calibration period and identifying rainfall,
- adjusting for antecedent moisture conditions,
- adjusting hydrologic parameters,
- separating baseflow from direct surface runoff,
- establishing boundary and initial conditions for the specific time period,
- adjusting conduit roughnesses to match observed stages and stage-discharge relationships, and
- refining the bridge representation at the gage location for better definition of low-flow characteristics.

These topics are discussed in detail below.

2.2.1 Selection of Calibration Period and Rainfall

In order to calibrate the RUNOFF and EXTRAN models, stream stage and nearby rainfall data were needed for the calibration period. Stage data from the Little Sixmile Creek gage (USGS number 02246700) were supplied by the St. Johns River Water Management District (SJRWMD). As shown in Figure 2.3, there are two 5-minute interval raingages maintained by the USGS (R7 and R10) that are within 1 mile (1.6 km) of the Little Sixmile Creek study area. Records from these two gages were used in the simulations. Rainfall from a third nearby gage (R5) was used for additional screening purposes.

Upon reviewing the available stream and rainfall data, the month of January 1991 was selected for the calibration period. The selection was based on:

- uniformity and availability of rainfall from the nearest three gages, or the ability to measure both temporal and spatial rainfall variations,
- presence of at least one event greater than 2 inches (50 mm) to allow runoff from both directly connected impervious area (DCIA) and pervious area,
- reasonable correlation of rainfall and stream gage response, and
- a relatively dry antecedent period (to a lesser degree).

A comparison of event depths from the three nearest rainfall gages is shown in Table 2.1 for the period of January 1991. The uniformity of storm event depths between the three raingages is reasonably strong for seven events within January. Additionally, there are two events in January with a total rainfall depth of greater than 2 inches (50 mm). It is important to have either relatively uniform rainfall or the ability to measure temporal and spatial variation of rainfall within the study area since rainfall is the most dominant factor in generating stormwater runoff.

Table 2.1 Comparison of storm event depths.

Comparison of storm event depths. Depth of storm event, inches.			
Date	Gage R7	Gage R10	Gage R5
01/10/91	0.61	0.61	0.70
01/11/91	2.37	2.26	2.28
01/18/91	3.10	3.13	2.65
01/23/91	1.11	1.10	1.10
01/27/91	0.92	1.14	1.19
01/28/91	0.62	0.77	0.56
01/30/91	0.21	0.28	0.27

2.2.2 Antecedent Moisture Conditions (AMC) Adjustment

When using RUNOFF in continuous mode, it is necessary to initially use AMC I (dry condition) infiltration parameters since the model is only capable of regenerating the parameters back to their original input value. Ideally, the actual antecedent moisture conditions at the start of a continuous simulation should also be dry. As an alternative, several days of rainfall prior to the start of the actual simulation can be used to allow the model to adjust to actual antecedent conditions if they are not dry. Since the actual antecedent conditions at the start of January 1991 were dry, no adjustments beyond setting infiltration parameters to dry conditions were necessary to account for antecedent moisture conditions.

Infiltration parameters that were adjusted were the maximum Horton infiltration rate and the maximum infiltration volume or soil storage value. The soil storage was adjusted from AMC II (average conditions, which were used in the MSMP) to AMC I based on a curve number approach as outlined by SJRWMD (1985). Maximum infiltration rates were increased by 50% over AMC II values based on an extension of the Horton infiltration curve and experience gained from similar calibrations in the study area.

2.2.3 Hydrologic Parameter Adjustment

Model results using the MSMP hydrologic parameters were compared to measured stream data. These hydrologic parameters included rainfall, imperviousness, width, slope, Manning n values for overland flow, initial abstractions, and soil infiltration parameters. The trend over the several events recorded during the calibration period was that the predicted hydrographs were slightly higher in volumes and produced slightly higher peak stages than the measured

hydrographs (the maximum overprediction of stage was less than 0.5 ft (152 mm)). In order to reduce the predicted volume and peak stages, the DCIA of the contributing area was reduced from approximately 35% to 31%. This was reasonable, based on verification using aerial photographs.

2.2.4 Baseflow Separation

Baseflow may be modeled using RUNOFF or separated from the total flow and entered as an input to the model. For this calibration, the baseflow hydrograph was separated from the total flow hydrograph (based on visual inspection of hydrographs and rainfall data) and entered into the EXTRAN model as a hydrograph (flow versus time data set). Baseflow rates were developed using recorded stage data and the USGS rating curve for the gage. In general, the baseflow did not significantly affect peak stages, since total peak flows were usually more than an order of magnitude greater than baseflows.

2.2.5 Establishment of Boundary and Initial Conditions

For the MSMP, a 1-year tidal stillwater elevation of 2.9 feet (880 mm) referenced to National Geodetic Vertical Datum of 1929 (ft-NGVD) for the St. Johns River was used as the boundary condition and to help establish initial conditions in the downstream portion of the model. Based on the results from sensitivity runs, the boundary condition does not have a significant effect at the Little Sixmile Creek gage location, because the calibration study area is several miles upstream of the tidal boundary and is therefore unaffected. Measured baseflow was used to establish initial conditions in Little Sixmile Creek. For the calibration period, the boundary condition was set to 0.0 ft-NGVD in the EXTRAN model.

2.2.6 Conduit Roughness Adjustment

In order to match more closely the observed stage-discharge relationship at the bridge where the gage is located, the EXTRAN Manning roughness of the bridge conduits and the open channel conduit downstream of the bridge were adjusted slightly from the roughnesses used in the MSMP. For the calibration period, these changes in roughness produced only slightly different peak stages from those produced by the MSMP values (peak stages changed by less than 0.2 ft (60 mm)).

2.2.7 Refinement of Bridge Representation

In the MSMP model configuration, the bridge at Little Sixmile Creek and Old Kings Road, which is where the stream gage is located, is represented by two equivalent rectangular conduits of similar geometry and conveyance. This

configuration was adequate for the larger return period events simulated in the MSMP, but the configuration was refined by subdividing the bridge into four equivalent rectangular conduits at different invert elevations during the calibration, in order to obtain better definition of the stage-discharge relationship during baseflow conditions. The method involves maintaining equivalent conveyance and geometry in EXTRAN as outlined by Schmidt and Cunningham (1993, 1994).

2.3 Results

The primary focus of the water quantity calibration was to match observed flood stage hydrographs at the Little Sixmile Creek gage for a 1-month period (January 1991). This period contains approximately seven storm events, depending on the definition of *storm event*. Figure 2.4 shows a comparison of measured and predicted water surface elevations at the Little Sixmile Creek gage for the calibration period. As can be seen in the figure, the predicted stage hydrographs compare very well with the measured stage hydrographs for the seven major storm events in the month. The maximum difference in peak water surface elevations between the measured and computed is approximately 0.1 ft (30 mm) with the calibration adjustments. Figure 2.5 shows a comparison of the measured versus computed peak stages for the seven major peaks in the calibration period.

Figure 2.4 Comparison of measured and computed stages of Little Sixmile Creek at USGS Gage 02246700

The diagonal line in Figure 2.5 represents the locations where computed and measured peak stages are equal. Figure 2.6 presents a comparison of the time to peak from the start of the simulation for computed and measured peak stages. As shown in Figure 2.6, the computed times to peak compare well with the measured times to peak, indicating that the mathematical model representation was realistic at the point of interest.

Figure 2.5 Comparison of measured and computed peak stages of Little Sixmile Creek gage.

An analysis of the computed rating curve showed that there was a considerable amount of hysteresis, particularly during the events with greater rainfall intensities (Figure 2.7). For example, some flows during the ascending portion of the hydrograph were over 20% greater than those during the descending portion of the hydrograph for the same stage. This level of hysteresis may be expected in an area with slopes as flat as those in Little Sixmile Creek, because the acceleration of the wave front becomes relatively more prominent and the tailwater conditions may vary. Flows at this gage are based on a rating curve, and since hysteresis is not accounted for, a comparison of flows to the USGS rating curve, and therefore volumes, was not considered to be appropriate.

2.3.1 Potential Impact on MSMP Results

The calibrated data sets were run for the 10-year and 100-year storm events under present land use conditions, and the results were compared to the previously published MSMP results to identify potential changes from the calibrated

Figure 2.6 Comparison of measured and computed times to peak at Little Sixmile Creek gage.

Figure 2.7 Comparison of rating curve and stage-time history.

model. Antecedent moisture conditions were returned to AMC II and the boundary condition was returned to 2.9 ft-NGVD in the calibrated data sets for the comparative design storm event runs. The flood levels predicted by the MSMP model and the calibrated model are within 0.5 ft (150 mm) at all locations along the PSWMS. In most cases where there is a difference, the results from the calibrated data set are slightly lower than the results from the MSMP. These slightly lower stages are likely due to the decrease in DCIA and adjustments to conduit roughnesses. Since this 0.5 ft (150 mm) is within the tolerance (1.0 ft (305 mm)) of a Federal Emergency Management Agency (FEMA) revision, it is recommended that the slightly higher levels be used.

2.4 Discussion

For this application of SWMM, the predictions based on parameter estimates made prior to calibration compared well to observations. Refinement of some of the hydrologic and hydraulic parameters produced an even closer match between computed and measured results.

Two of the advantages of using a short-term continuous simulation for calibration are

1. that multiple events can be examined, and
2. calculation of antecedent moisture conditions for each event is performed by the model.

By using a short-term period, information is obtained on the ability of the model to reliably simulate a range of storm events while output is still small enough to be reasonably manageable.

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