RES 17-06

M E M O R A N D U M

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DATE: June 18, 2002

SUBJECT: Western Boundary Flows at the L-1 and the L-3 Canals for Simulation of the ECP Base (BASERR2R, SFWMM V3.8.2), ECP Future Base (2050wPROJ, SFWMM V4.4r6) and CERP Update (SFWMM V5.0).

In May of 2001, the Environmental Engineering Section (EES) of the Everglades Restoration Office requested additional regional modeling support to improve on the Everglades Construction Project (ECP) Base simulation. This simulation was used to provide base line flows for the Basin Specific Feasibility Studies (BSFS) (Schweigart, 2001). One of the specific items in this request was to incorporate into the South Florida Water Management Model (SFWMM) a more complete and accurate set of boundary conditions based on the flow data representing runoff from the C-139 basin. This flow data set was the same used in the C-139 Basin Rulemaking process. Later, in September 2001, the EES requested the development of a new Future Base simulation for the implementation of ECP and for the BSFS (Bushey, 2001). The ECP Future Base simulation is defined as the ECP Base with incorporation of the Comprehensive Everglades Restoration Plan (CERP) components, in addition to the most up to date information (conceptual and detailed design) for the reservoirs in the Everglades Agricultural Area (EAA) and the impoundments in the Water Preserve Areas (WPA) Tentative Selected Plan (TSP). The new data set for the C-139 basin was to be used also in the ECP Future Base simulation. It was decided that the same time series of flows should be used as boundary flows for the simulation of the CERP 2000 Base and 2050 Base. The only difference in terms of the C-139 data is that the ECP simulations cover the period 1965-1995, while CERP updates will cover 1965-2000. The ECP simulations are documented in a technical memorandum produced by the Hydrologic Systems Modeling Division (HSM) (Brion and Ali, 2002).

This memorandum describes the criteria and procedures followed to obtain Western Boundary flows at the L-1 and L-3 canals for the SFWMM simulations. These flows are not intended to reflect historical values, but rather flows that would be obtained if climatological conditions for the period 1965-2000 (1965-1995 for the ECP simulations) were repeated, given infrastructure and operations of the system that were in place circa 2000. Flow time series needed as boundary inflows to the SFWMM are given at two different locations (see Figure 1):

- G-136, representing flows from the L-1 canal and the C-139 basin. These flows will be directed to the EAA and will not enter STA-5.
- G-406, representing flows from the C-139 basin. These flows will be potentially diverted into STA-5.

Other flow monitoring locations playing an important role in this analysis are G-88, G-155, G-89 and the L3DF and L3BRS UVM (Ultrasonic Velocity Meter) locations. L3DF is located on the L-3 canal slightly downstream of the current G-406 location, and L3BRS is also located on the L-3 canal just upstream of the G-88, G-155 and G-89 structures.

The flow data set used in the C-139 Basin Rulemaking process is comprised of flows at the G-136 and G-406 locations for the period October 1978 through April 2000 (Walker, 2000a). The input data set for the CERP-related SFWMM simulation is comprised of flows at the locations described above for a longer period of time: January 1965 through December 2000 (December 1995 for the ECP simulations). The construction of flow time series for the SFWMM follows closely the procedures applied for assembling the flow data set for the C-139 Basin Rule (Walker, 2000a, 2000b). The reader is encouraged to review Walker's reports for a complete understanding of the procedures utilized here.

The last section of this memorandum presents a brief comparison between the new boundary flow data set derived as part of this effort and the boundary flows used previously in the SFWMM.

1. Flows at the G-136 Location

The G-136 structure in the L-1 canal was completed in November of 1982, following the June 1982 storm event. This structure was to provide relief from future large storm events. Flow recording at the structure did not start until June of 1983. The preparation and collection of the data set for G-136 flows required the consideration of three different time periods. The rationale, materials and procedures used in each case are described below.

January 1, 1965 to July 3, 1982: The lack of flow monitoring and indirect flow estimation at the G-136 location, for the period January 1965 through June 1982, required the use of statistical techniques to produce a flow trace for this period, similar to historical flows recorded after May 1983. The methodology adopted to achieve this result follows closely the weekly rainfall runoff model developed by Walker (2000a) for flows at the L3DF location. The variation implemented here correlates weekly rainfall against the sum of mean weekly flows at the L3DF and the G-136 locations, as compared to Walker's approach, wherein only L3DF flows were considered. Model parameters were derived from historical flow data collected for the period 01/07/1996 to 04/30/2000, during which flows at

G136 and L3DF were concurrently measured. Historical rainfall for the same period was obtained from the Devils, Alico and Paige stations (SFWMD Corporate Hydrologic Data Base DBKEYS IV150, 15197 and IV151, respectively). The resulting model is shown in Figure 2.

The regression model was applied for the period January 1965 to July 1982 to estimate the non-existent data. Rainfall data for application of the model was extracted from the binary rainfall file used in the SFWMM (nsm_rain_v1.2.bin), for grid cells where the stations used for calibration of the weekly regression model are located. The SFWMM coordinates (Row Column) used for rainfall stations to estimate weekly rainfall in the C-139 basin are as follows: Paige (51,12); Devils (51,7); Alico (48,11).

The regression model gives average weekly flows, which are constant for periods of 7 days, and represent the sum of the L3DF and G136 flows. Once the regression model is applied the total flow must be disaggregated between the two components. To accomplish this, the relationship between total flow and the G-136 flow was investigated, as illustrated in Figure 3. A piece-wise linear relationship between G-136 and the L-3 + G-136 flows was chosen to disaggregate the flows.

July 4, 1982 to May 31, 1983: Given the significance of the flows at the G-136 location during the wet season of 1982, the SFWMD and Walker (2000b) provide indirect flow estimation at the G-136 structure for the period July 1982 to May 1983. The estimation was based on staff gage readings and rating curves developed at a later period, auxiliary pumps used during July 1982 and estimated capacity for the open connection between the L-1 and the Miami Canal. Data for this period was extracted directly from the deliverables provided by Walker (2000b).

June 1, 1983 to December 31, 2000: For the period June 1983 through December 2000, historical flow data collected at the G-136 location was selected as the input data for the SFWMM. For consistency purposes with the C-139 Basin Rulemaking process, data for this period was extracted directly from the deliverables provided by Walker. The same data can be extracted from DBKEY 15195 in the SFWMD Corporate Hydrologic Data Base.

Figure 4 displays the time series of daily flows for the period 1965-2000 for G-136, both estimated and recorded. Figure 5 is a comparison of the monthly means derived from the recorded history for the station and from data obtained using the regression approach. The following observations are obtained from examining Figures 4 and 5:

- The regression approach shows a very persistent seasonal cycle and it appears to produce a higher mean monthly flow for July.
- The regression approach does not capture the flow variability observed in the 1983-2000 historical period, in terms of the frequency by which high flows tend to occur.
- The largest flows took place during August 1982, basically a little over a month after the June 1982 storm event. However, the information gathered and procedures followed as part of this effort do not link the magnitude of these two events neither do they portray the extreme character of the June 1982 event.
- The extreme character of the period July 1982 – May 1983 is also observed in Figure 5, where monthly flows are compared to the means for the other periods.

2. Potential C-139 Basin Runoff into STA 5

The second time series in the L-3 canal provided as boundary inflows into the SFWMM represents the total potential runoff from the C-139 basin into STA-5. In the case when STA-5 is not part of the system, this time series would represent flows measured at the G-406 location (Figure 1). As before, the work performed by Walker (2000a) to provide flows for the C-139 Basin Rulemaking process is extensively used here. In fact, out of the required period of simulation, January 1965 to December 2000, flows for the period October 1978 to May 2000 were taken directly from the work by Walker (2000a).

It is important to point out that in other previous SFWMM simulations, the traditional approach has been to provide boundary flows at the “Confusion Corner” point, i.e. at the location of the G-88, G-155 and G-89 structures. However, due to the requirement to maintain consistency with the C-139 Basin Rule data, the assumption that boundary flows are provided at a more upstream location (G-406), instead of the “Confusion Corner” location, has been introduced.

It is necessary to distinguish among different periods due to historical data availability and the different methods and materials used to produce the flows. The procedures followed to obtain the flows for each case are described below in chronological order.

January 1, 1965 to September 30, 1969: The weekly rainfall-runoff model developed to obtain the flows for G-136 for the period January 1965 to June 1982 (Section 1) is used for this period. After the total L-3 + G-136 and the individual G-136 flows are obtained separately, the flows at the G-406 location are obtained by subtracting these two quantities.

October 1, 1969 to September 30, 1978: The USGS flow data recorded at the L-3 station (USGS ID 02289030) was used for this period. The data was extracted directly from the SFWMD Corporate Hydrologic Data Base (DBKEY 00613). As noted by Walker (2000a), flows recorded by the USGS during this period did not account for contributions from the

Deerfence Canal, and therefore, the original USGS flows needed to be increased by 25%. The increased flows are then filtered through “Method 2” in Walker’s Report (2000a), in order to convert them to current conditions values at the G-406 site. Information about “Method 2”, as presented in Walker’s report, is reproduced in Figure 6.

October 1, 1978 to September 30, 1979: Flows for this period were prepared following the same procedure as outlined above for the October 1969 to September 1978 period. However, a couple of factors are different. First, USGS flows for the period October 1978 to September 1990 (see the **October 1, 1979 to September 30, 1990** section) at the L-3 station (USGS ID 02289030) were revisited under a work order contracted out by the SFWMD (Curtis, 1997), as part of the data preparation for the C-139 basin Rulemaking process. The period October 1978 to September 1979 was part of this reevaluation effort. Secondly, Walker (2000a) performed the computations for this period, while the process for the October 1969 to September 1978 period was carried out by HSM staff. It is important to point out that flows for this period were also increased by 25% before they were filtered through “Method 2” in Walker’s Report to covert them to current flows at the G-406 location. Data for this period came directly from the deliverables provided by Walker (2000a).

October 1, 1979 to September 30, 1990: The raw data for this period is the USGS record at the L-3 station (USGS ID 02289030). Flow values were recomputed following the work undertaken by Curtis (1997). In January of 1996, the SFWMD installed new stage and flow instrumentation in the L-3 canal, along with sensors and recorders aimed at reproducing flow monitoring and computation procedures previously used by the USGS. This data collection effort continued until April 2000. Using these data, Walker (2000a) developed a regression model, referred to as “Method 2” in his report, to convert USGS flows to current condition flows recorded at the G-406 location. The reworked USGS flow data set for the period October 1979 to September 1990 was filtered using “Method 2”. Data for this period came directly from the deliverables provided by Walker (2000a).

October 1, 1990 to January 5, 1996: Data for this period came directly from the deliverables provided by Walker (2000a). For this period, Walker (2000a) established a relationship between the positive flows measured at the three downstream structures, G-88, G-155 and G-89, and the flows at the L3DF location. The independent variable for this regression model was selected as the sum of the positive flows at each one of the three structures. The relationship was derived using data recorded at the G-88, G-155, G89 and L3DF locations, during the 1996-2000 period, and the purpose is again to estimate current condition flows recorded at the G-406 location from other nearby flow stations. The regression model for this period (Walker, 2000a) is shown in Figure 7.

January 6, 1996 to June 26, 2000: The mean daily flow data in the L-3 Canal for this period was derived from flow monitoring at the L3DF UVM location. This data is stored in the SFWMD Corporate Hydrologic Data Base under DBKEY 16243. Walker (2000a) used most of this data (up to April 2000) in his analysis and derivation of statistical relationships. The data for the L-3 canal to use in the SFWMM for this period was extracted directly from Walker's deliverables (2000a).

June 27, 2000 to December 31, 2000: Data monitoring for the inflow structures into STA-5 (Figure 1), G-342A, G-342B, G-342C and G-342D, and the STA-5 by-pass structure in the L-3 canal, G-406, commenced in June 27, 2000. Data sets for these structures were obtained from the following SFWMD Corporate Hydrologic Data Base DBKEYS, respectively: J6406, J6398, J6407, J6405 and JU789. Consequently, for this period, the flow data in the L-3 Canal was computed as the summation of the flows at these five structures.

Figure 8 displays the complete time series of daily flows for the period 1965-2000 for the L-3 canal at the G-406 location. Figure 9 is a comparison of the monthly means derived from the different periods of estimation. Examination of Figures 8 and 9 produces the following observations:

- As expected, flows for the L-3 canal for the period January 1965 to September 1969 behave very similarly to the flows at the G-136 location for the period January 1965 to June 1982. The slow recession is easily observed in Figure 8.
- The period October 1969 to September 1978 exhibit the largest daily flows in the 1965-2000 period. Recessions are much faster and the frequency of low flows is reduced as compared to the sample for October 1978 to December 2000.

3. Comparison of Previous and New Flow Data Sets

This section provides a brief comparison of the G-136 and the L-3 flows used in previous SFWMM simulations and the newly developed data sets. Trimble (1995) derived the previous boundary flows and they have been used in practically every model simulation after October 1995. The comparisons presented here are in terms of monthly and annual flows, for the concurrent period for both sets, January 1965 to December 1995. Scatter plots and time series plots are examined.

Table 1 provides a comparison of the mean annual flows obtained over the corresponding simulation periods. Examination of Table 1 indicates that there are no major changes in the volumes entering the modeling domain for the period 1965-1995. Also, the addition of five years of data to the new data set does not appear to introduce sizeable modifications to the mean annual flows.

Table 1. Mean Annual Flows (1000 ac-ft)

	Previous (1965-1995)	**New (1965-1995)**	**New (1965-2000)**
G-136	16.2	17.5	17.2
L-3	131.0	135.0	134.5

Figures 10 through 17 use scatter plots and time series plots to compare monthly and annual flows at the G-136 location and the L-3 canal. Since the graphs provide additional resolution as compared to mean annual values, then different and more detailed conclusions are obtained from the figures:

- The new flow data set for G-136 provides higher monthly flows, as compared to the previous values. The seasonal cycles in the previous and new time series tend to agree, but the new time series shows larger variability in the sense that high flows are higher.
- The previous and new flow data sets for G-136 are basically different up to 1989, in terms of monthly flows (Figure 11). This difference is based on different methods used to obtain the flows. For the previous data set, Trimble (1995) derived a statistical relationship to obtain flows for the period 1965-1989, while in the new method a different statistical approach is applied only up to mid of 1982. Historical data is used after that point in time. Note that monthly flows are in good agreement for the period 1991-1995.
- Annual flows for G-136 derived from the new data set appear higher on the high end and lower on the low end (Figure 13). In conclusion, annual G-136 flows obtained from the new data set exhibit a higher variability than the annual flows derived from the previous data set.
- L-3 monthly flows derived from both data sets appear to cluster around a perfect agreement line (Figure 14). However, there is a slight tendency for the new monthly flows to be higher. As it was the case with G-136, seasonal cycles agree for both data sets, but high flows are higher in the new data set for the period up 1989. This situation reverses for 1990-1995, due to the use of the statistical relationship to transform G88+G155+G89 flows to G-406 current flows (Figure 7).
- Annual flows in the L-3 Canal derived from the new set tend to be larger and more variable than annual flows derived from the previous data set up to 1984.

4. Flows required by the SFWMM

During the execution of the SFWMM, the model expects to find flows at the three structures G-88, G-155 and G-89. Trimble (1995), established that these flows could be computed from the L-3 total flows by multiplying by factors of 0., 0. and 0.. Flows at structure G-136 are input separately.

5. Closing Remarks

This memorandum summarized the effort undertaken to update boundary flows for the SFWMM at the G-136 location and the L-3 canal, to be used for regional model simulations related to the ECP and the SFWMM 2000. As part of this effort the following general objectives were accomplished:

- The most up to date runoff data used in the C-139 Basin Rulemaking process was incorporated into the input data sets for the SFWMM simulations.
- The data was extended to cover periods that are not part of the C-139 original data. The methods and materials used to extend the data are consistent with those used during the data preparation for the Rulemaking process.
- The new data sets at the G-136 location and the L-3 canal were used in the ECP simulations (Brion and Ali, 2002), for the period of simulation 1965-1995.
- The new data sets at the G-136 location and the L-3 canal will used in the SFWMM 2000 simulations, for the period of simulation 1965-2000.

References

Brion, L. and A. Ali, 2002. ECP Base Simulation and 2050 with Project Simulation Using the South Florida Water Management Model, Internal Memorandum sent to G. Goforth and T. Piccone, April 15, 2002. Hydrologic Systems Modeling Division, South Florida Water Management District, West Palm Beach, FL.

Bushey, R. 2001. Hydrologic Systems Modeling (HSM) Support of the Everglades Restoration Resource Area Program Goals. Internal Memorandum sent to K. Ammon and J. Obeysekera dated September 27, 2001. Restoration Program Department, South Florida Water Management District, West Palm Beach, FL.

Curtis R. E. 1997. Final Report : Recomputation of Discharge Data for the L-3 Borrow Canal Near Clewiston, Florida – Water Years 1978-1990, March 4, 1997.

Schweigart, J. 2001. SFWMM Simulation Request for Basin-Specific Feasibility Studies to Achieve the Long-Term Water Quality Goals for the Everglades. Internal Memorandum sent to K. Ammon and J. Obeysekera dated May 11, 2001. Program and Project Management, South Florida Water Management District, West Palm Beach, FL.

Trimble, P. 1995. Structure Flow Near Western Boundary of South Florida Water Management Model, Internal Memorandum sent to Cal Neidrauer, October 26, 1995.

Walker, W. W. 2000a. Models for Tracking Runoff & Phosphorus Loads from the C-139 Basin, Draft Report Prepared for the South Florida Water Management District, July 11, 2000.

Walker, W. W. 2000b. Models for Tracking Runoff & Phosphorus Loads from the C-139 Basin, Final Report Prepared for the South Florida Water Management District, November 17, 2000.

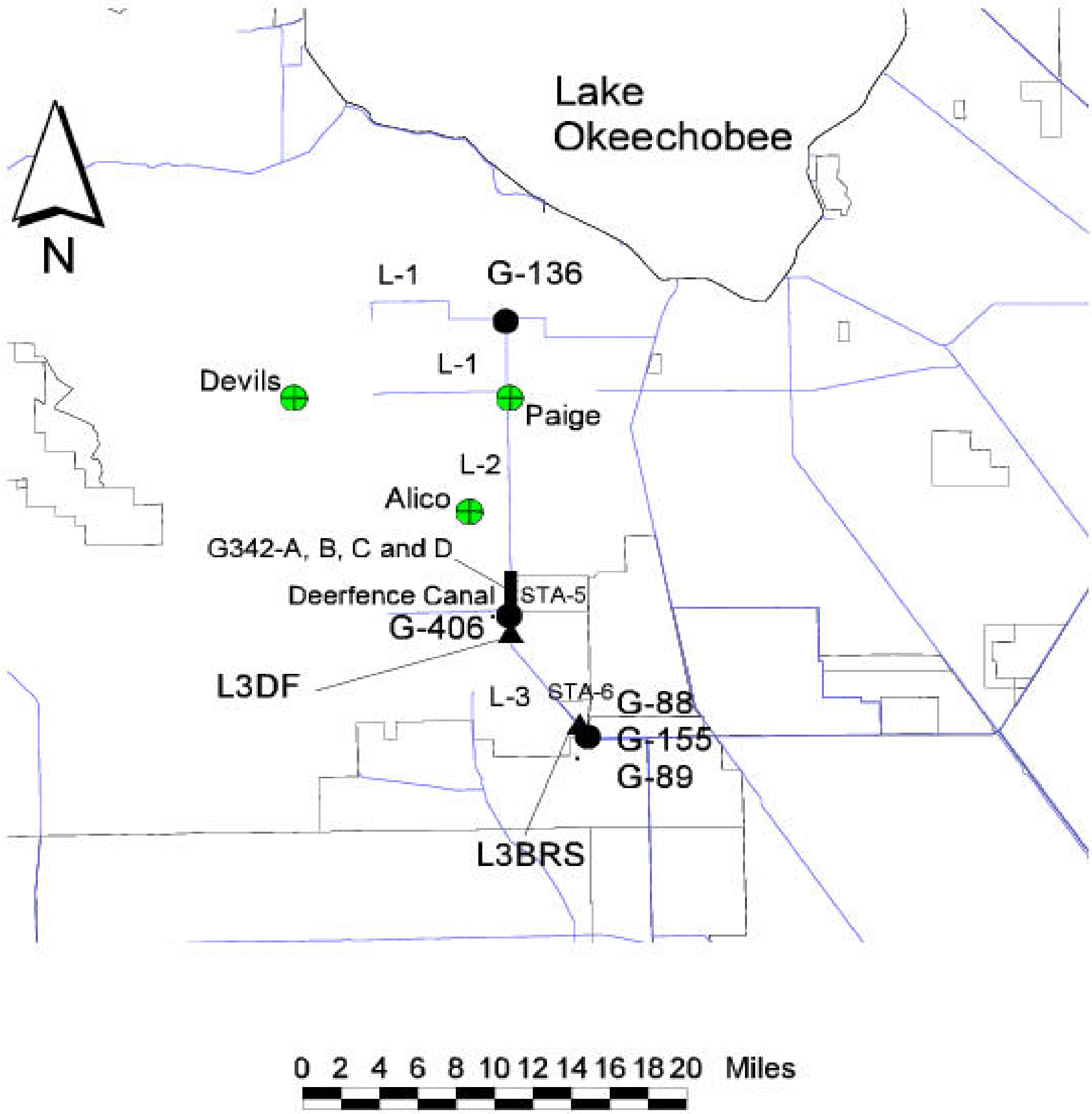
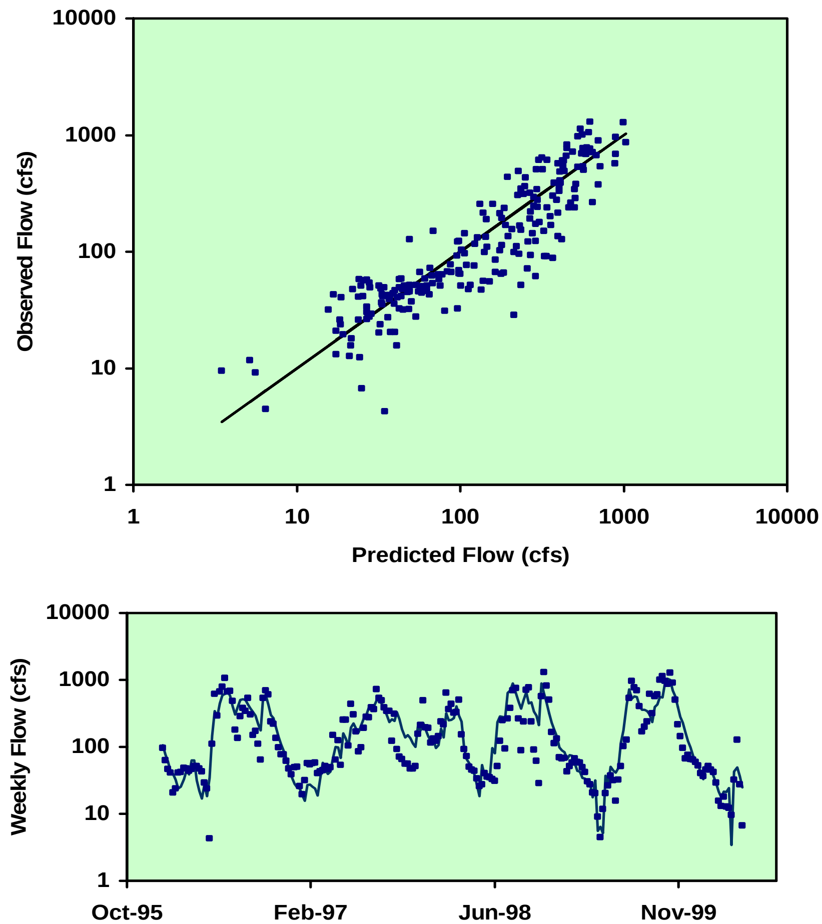


Figure 1. Schematic Representation of the L-3 Flow Locations



Model:

$Y = 1.085\ (1.7052 + 7.6669\ X - 1.6365\ S)^{E}$

$R^2 = 0.72$ SE = 141

Y = Weekly Average Flow L3DF+G136, cfs

X = $\Sigma P_j \exp(-K_j)$, j = 1, 20

S = Seasonal Dummy = 1 for April-Oct, =0 Nov-Mar

P_j = Weekly Average Rainfall, lagged j weeks

K_j = Calibrated Weight = 0.15 1/week

E = Calibrated Exponent = 2.5

Calibrated to Basin Rainfall & L3DF + G136 Flow Data
January 6, 1996 - April 30, 2000
Applied to 7-Day Rolling Average Rainfall Time Series, Oct 78 - Dec 95

Figure 2
Calibration of Rainfall / Runoff Model for L3DF+G136
After Walker (2000a)

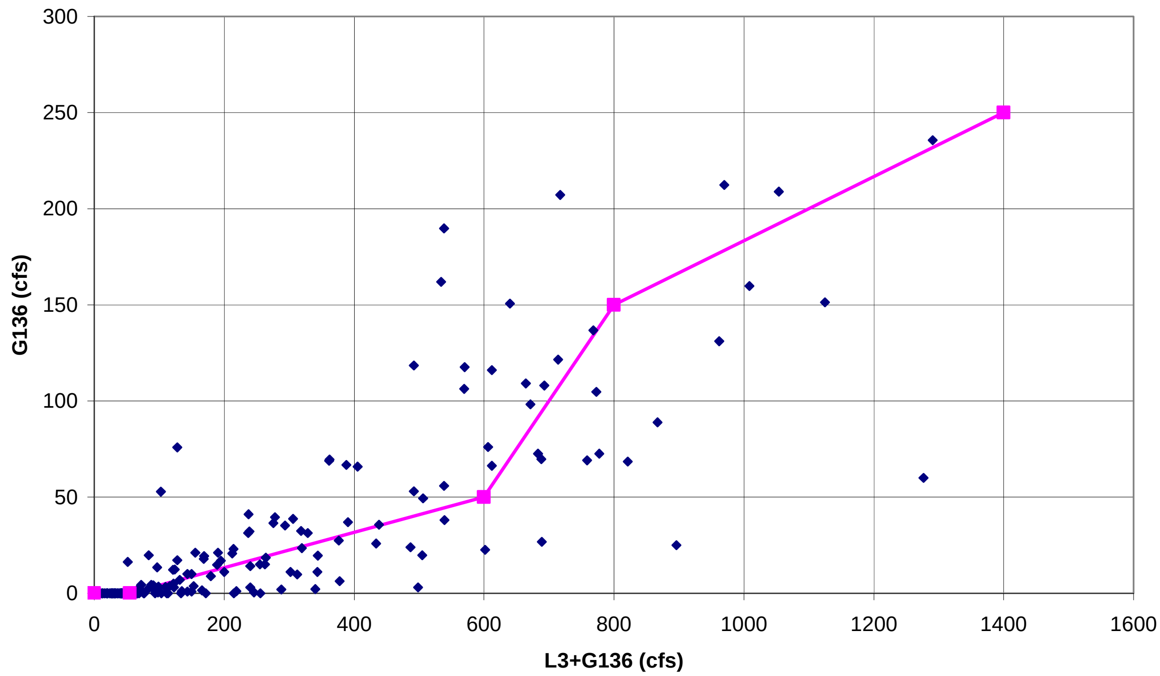


Figure 3. Mean Weekly Flows (cfs) 1996-2000
G-136 as Funtion of L3+G136

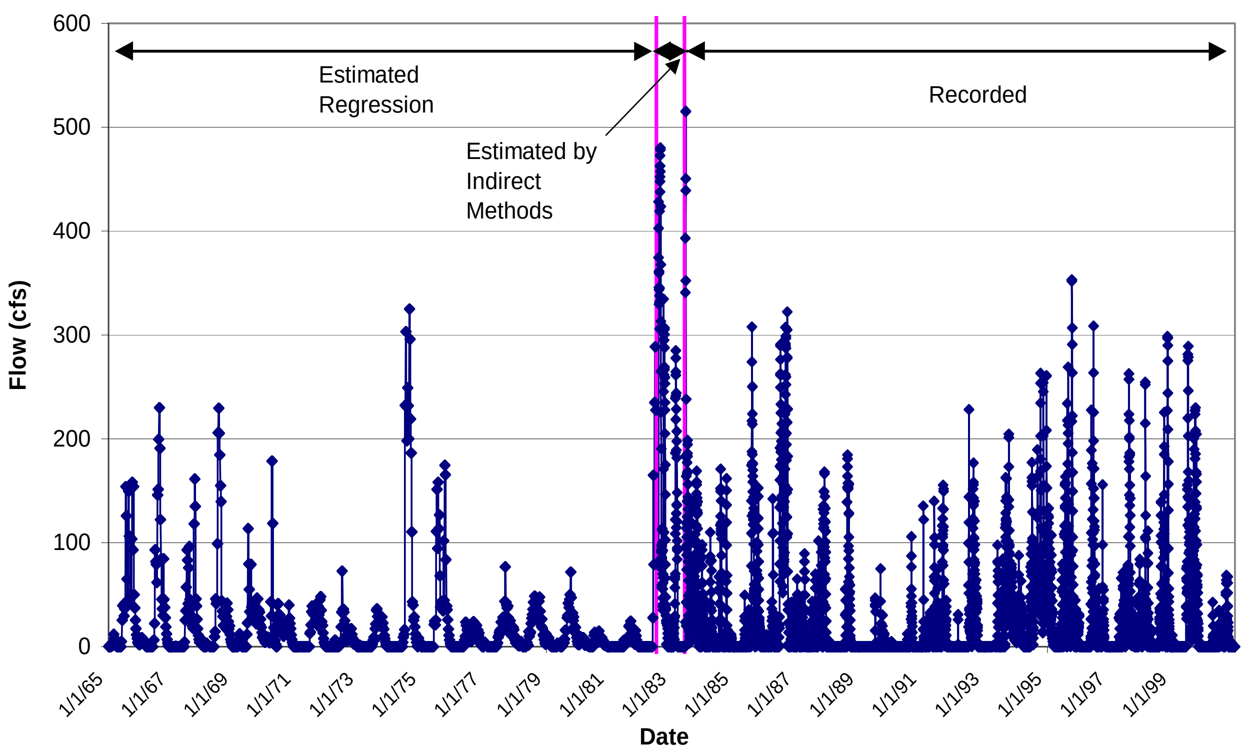


Figure 4. G-136 Mean Daily Flows

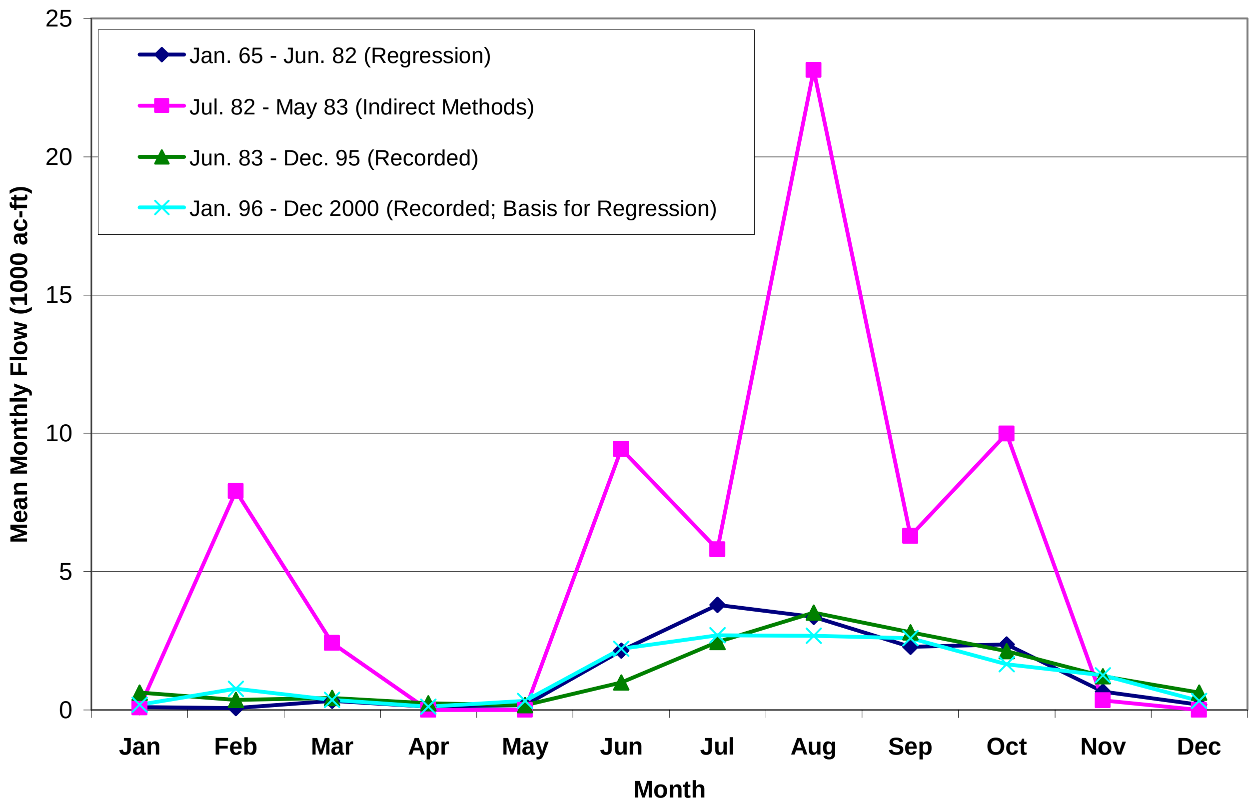
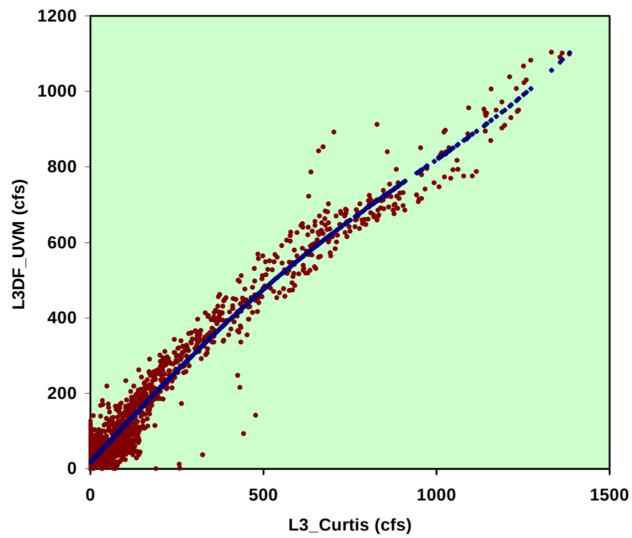


Figure 5. G-136 Mean Monthly Flows

Method2: L3Mid Gauge Increased by 0.11 feet



L3 Mid Offset = 0.11 feet

Y = L3DF_UVM flow (cfs)
X = L3_Curtis flow, from LBRN & adjusted L3Mid stages

$Y = b0 + b1\ X + b2\ X^3 + b3\ X^4$

b0 = 17.5167418
b1 = 0.98905242
b2 = -3.958E-07
b3 = 2.0862E-10

R^2 = 0.96
SE = 47

Period: Jan 6, 1996 to Apr 30, 2000

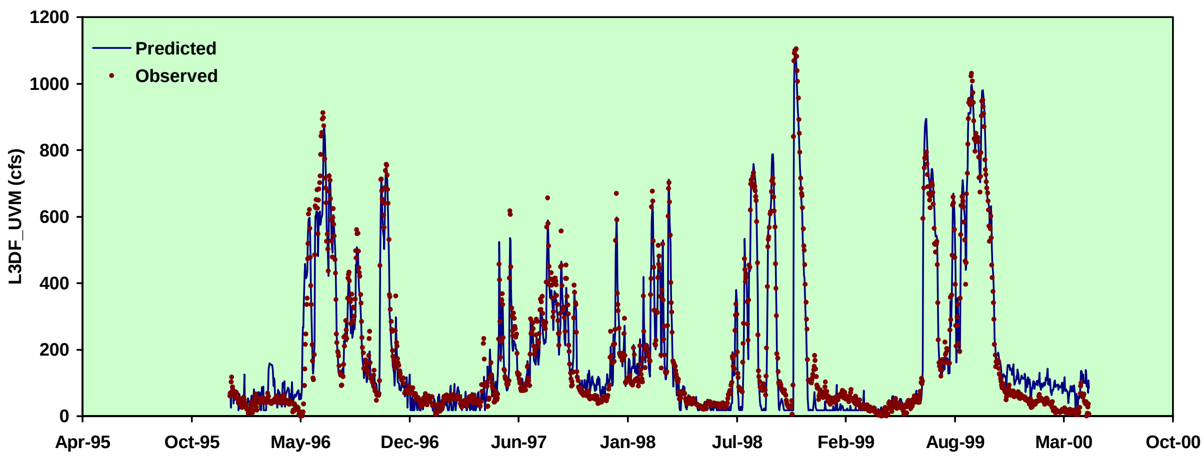
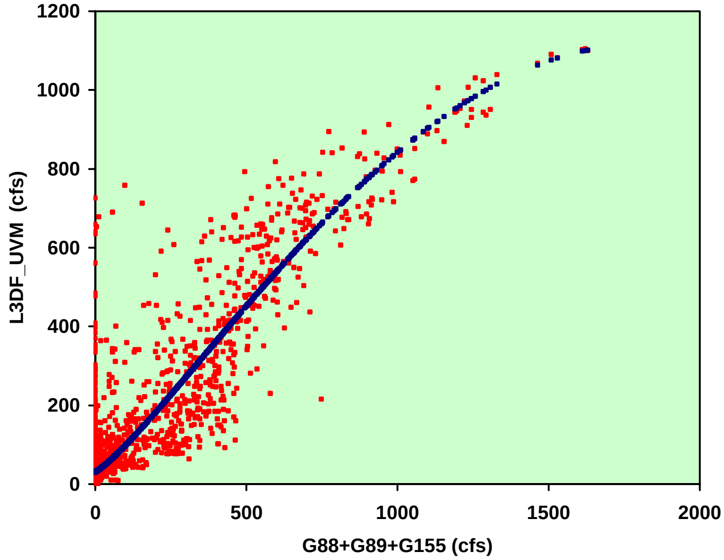


Figure 6
Calibration of L3_USGS Flows against L3_DFC UVM Flows - Method 2
From Walker (2000a)



Y = L3DFC_UVM Flow (cfs)
X = Max (0, G155+G88+G89) (cfs)

$Y = b0 + b1\,X + b2\,X^2 + b3\,X^{1.5}$

b0 =	30
b1 =	0.357264
b2 =	-0.00079
b3 =	0.03935
R^2 =	0.85
SE =	105

Period: Jan 6, 1996 to Apr 30, 2000

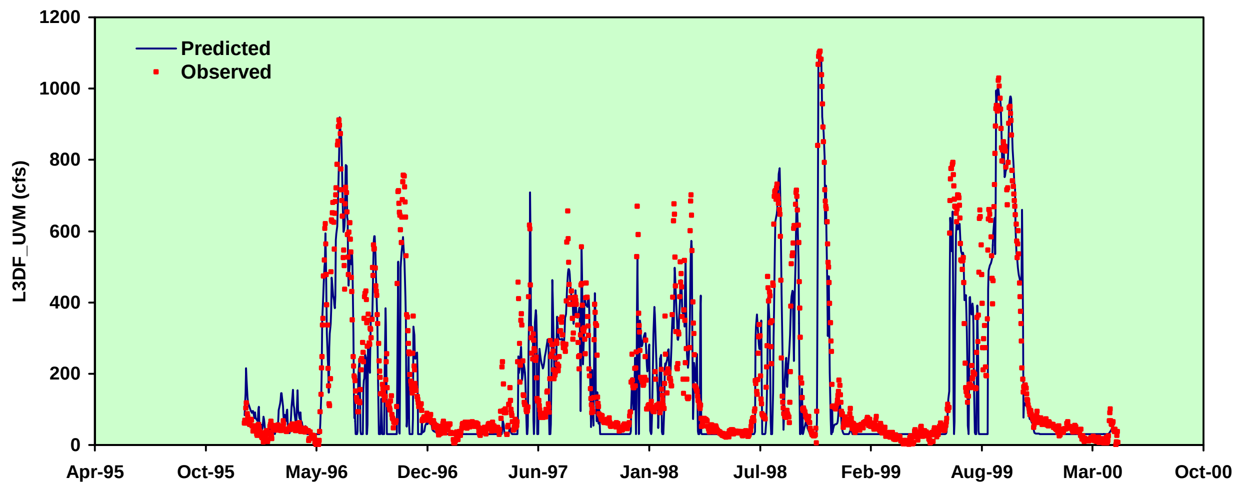


Figure 7
Calibration of G155+G89+G88 Flows against L3_DFC UVM Flows
From Walker (2000a)

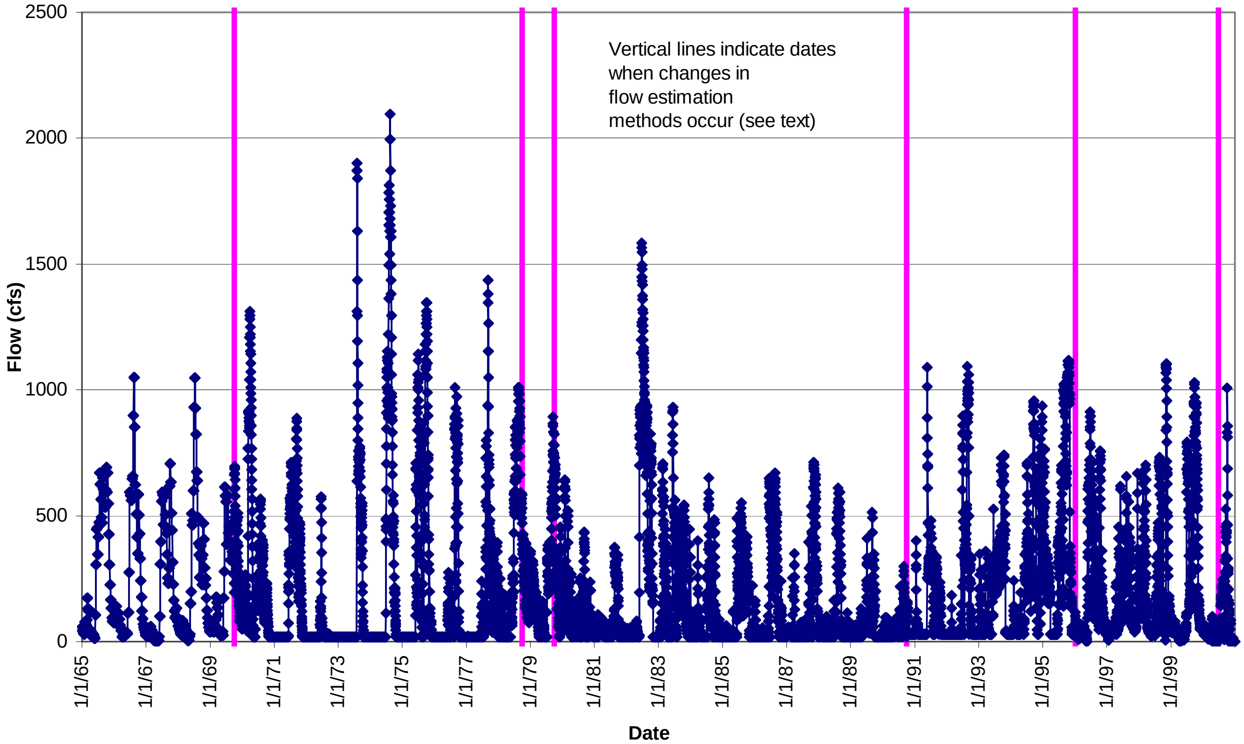


Figure 8. L-3 Mean daily Flows at the G-406 Location

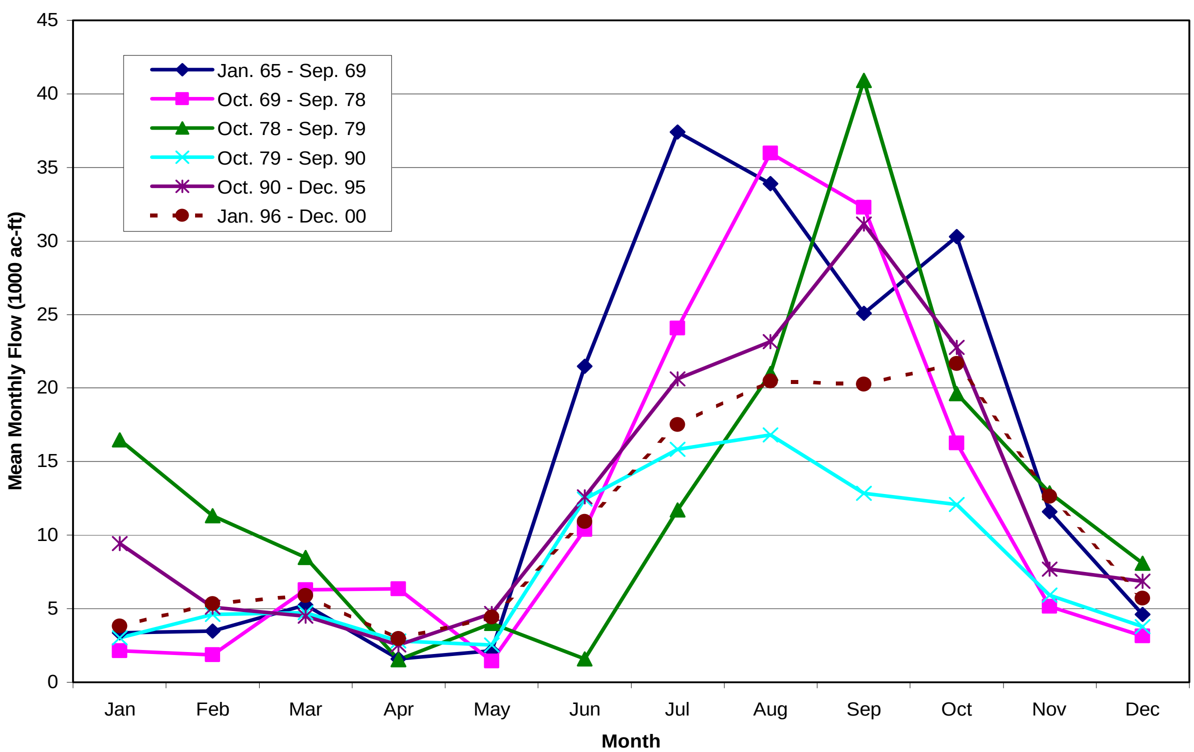


Figure 9. L3 Mean Monthly Flows at the G-406 Location

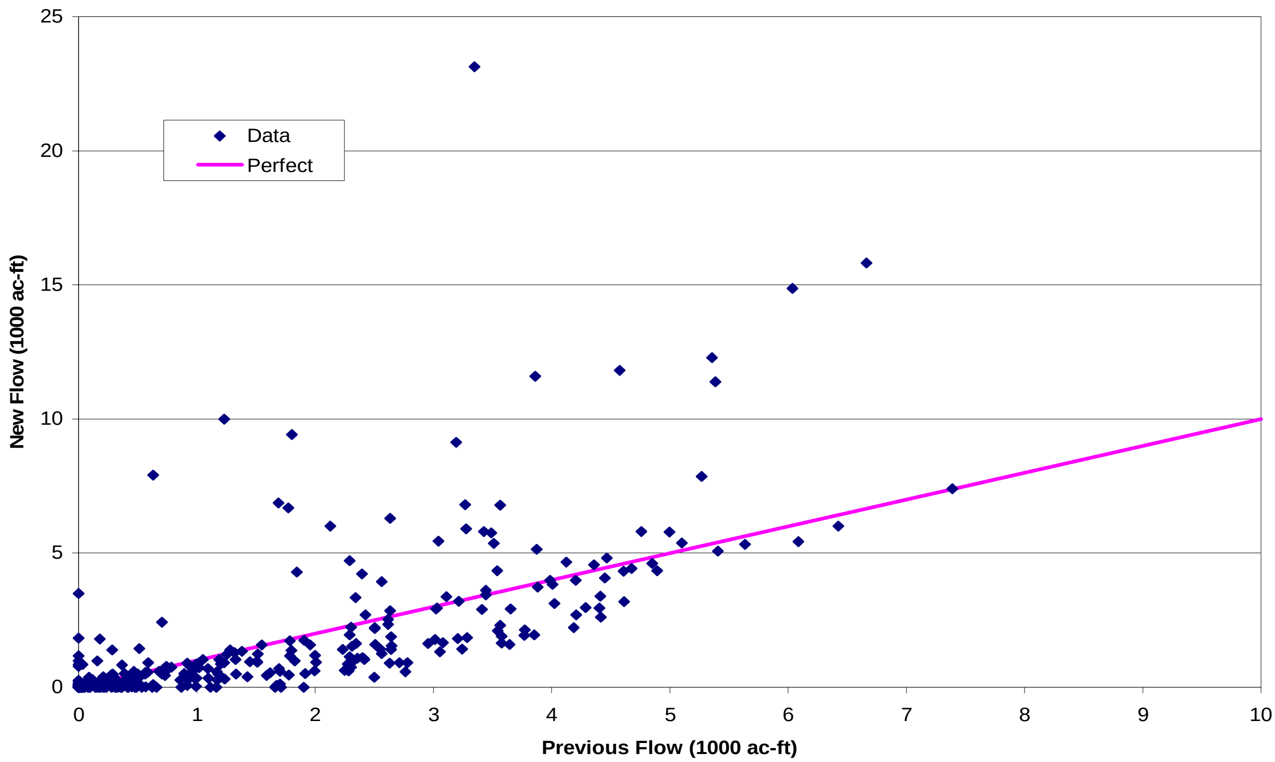


Figure 10. Comparison of Monthly Flows at the G-136 Location (1965-1995)

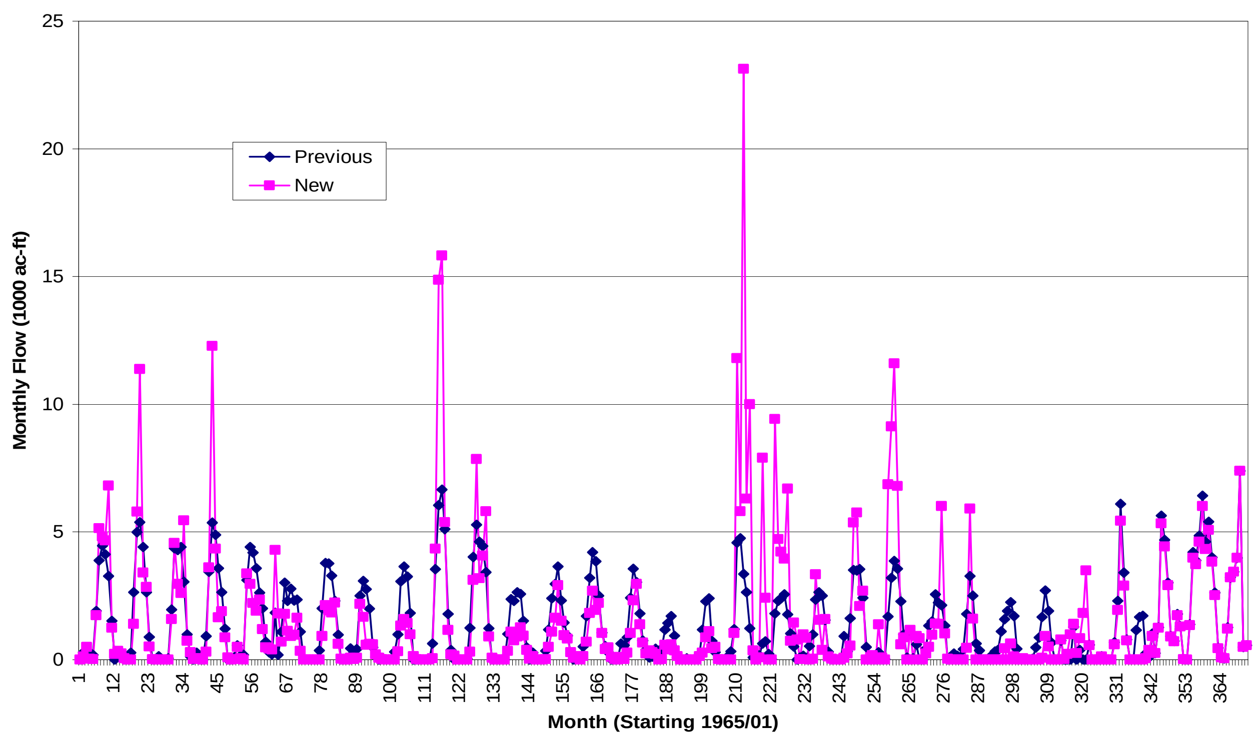


Figure 11. Comparison of Monthly Flows at the G-136 Location (1965-1995)

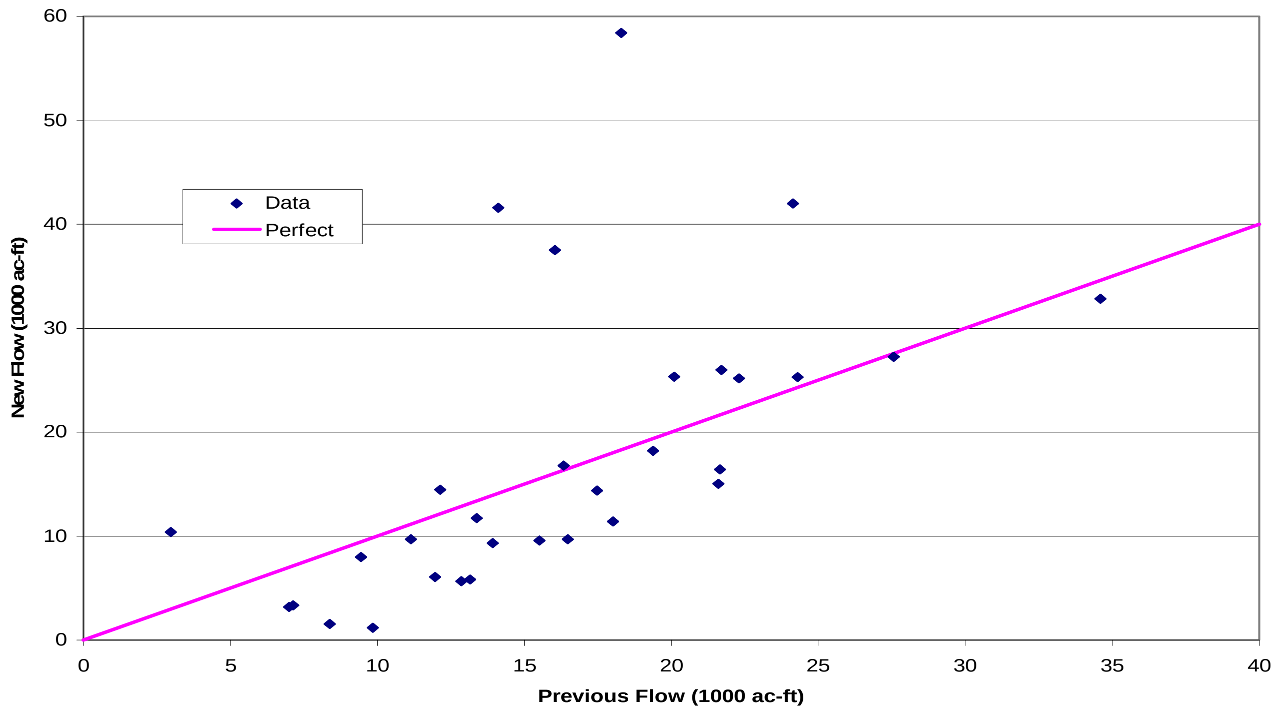


Figure 12. Comparison of Annual Flows at the G-136 Location (1965-1995)

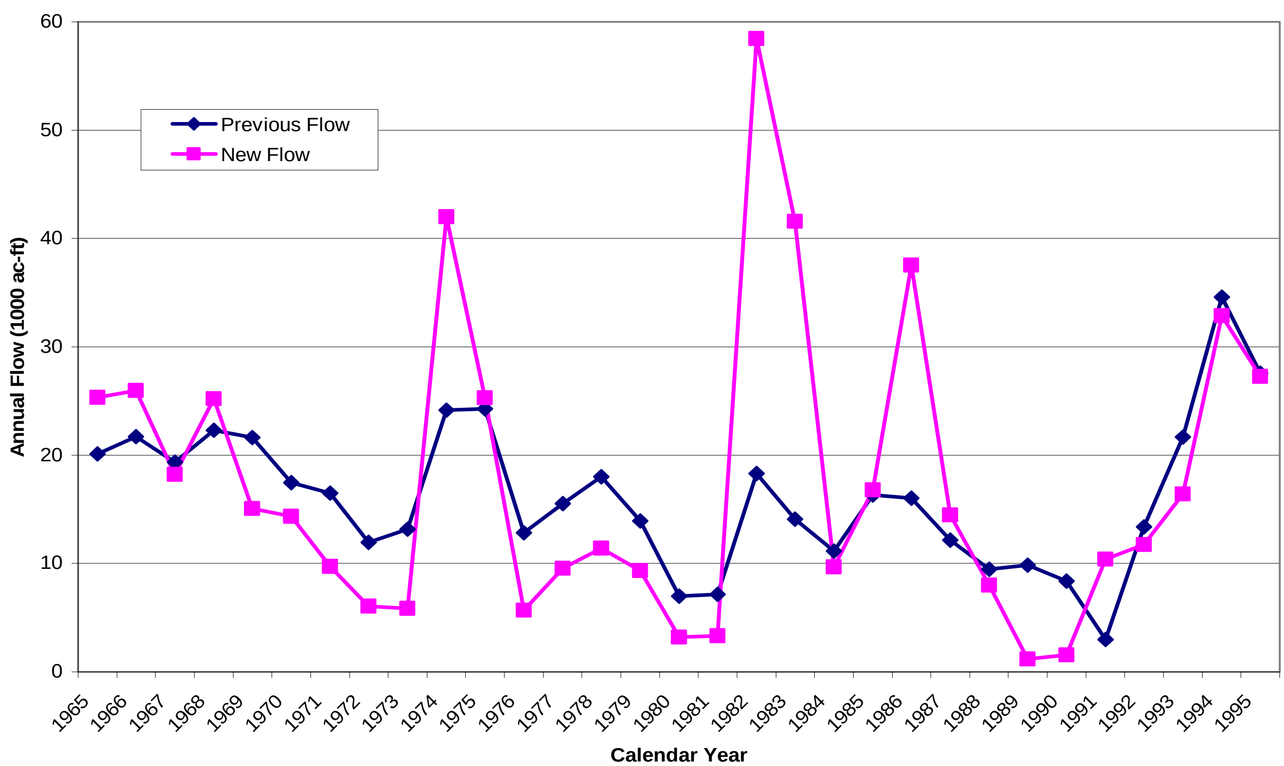


Figure 13. Comaprison of Annual Flows at the G-136 Location (1965-1995)

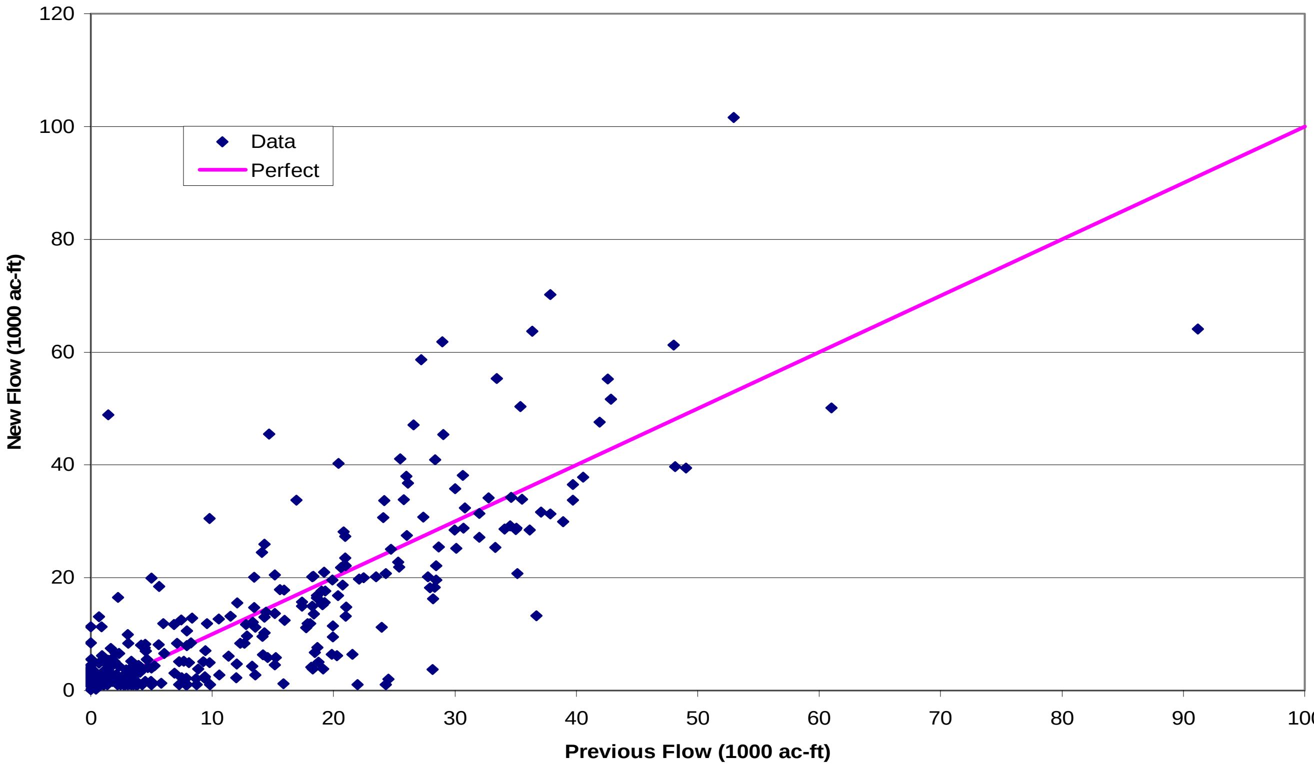


Figure 14. Comparison of Monthly Flows in the L-3 Canal at the G-406 Location (1965-1995)

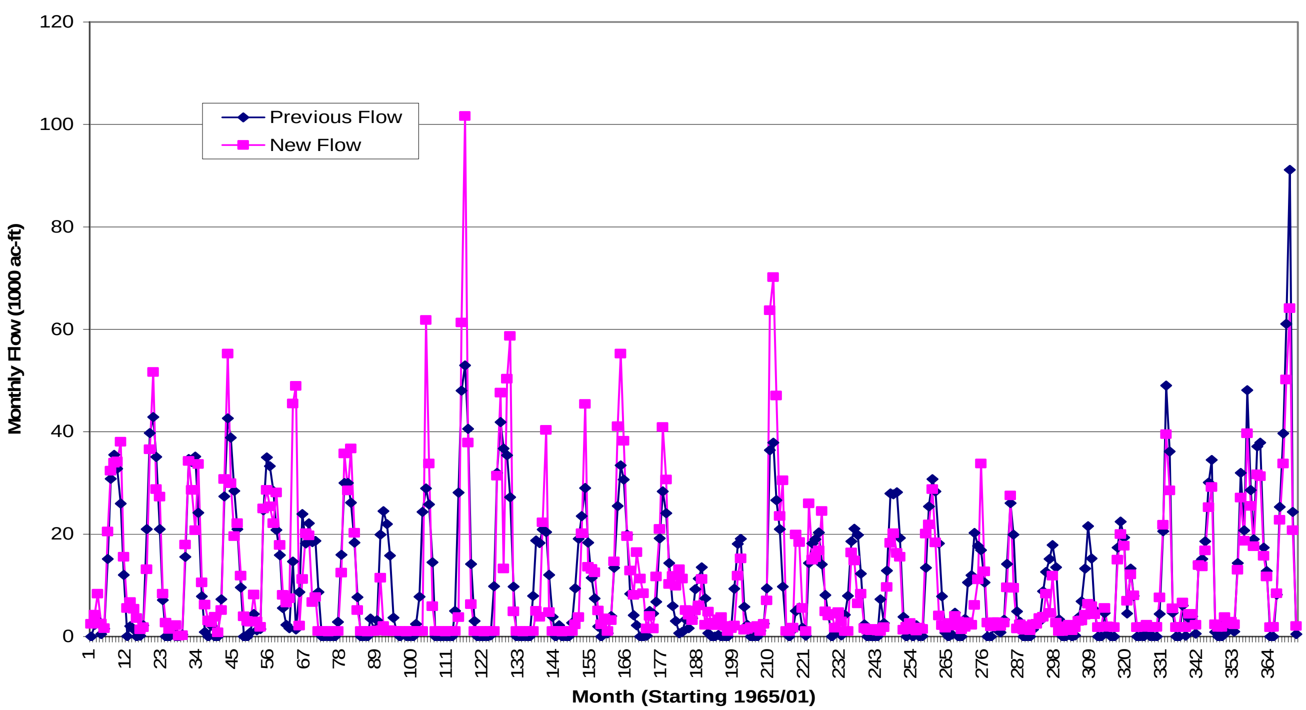


Figure 15. Comparison of Mean Monthly Flows in the L-3 Canal at the G-406 Location (1965-1995)

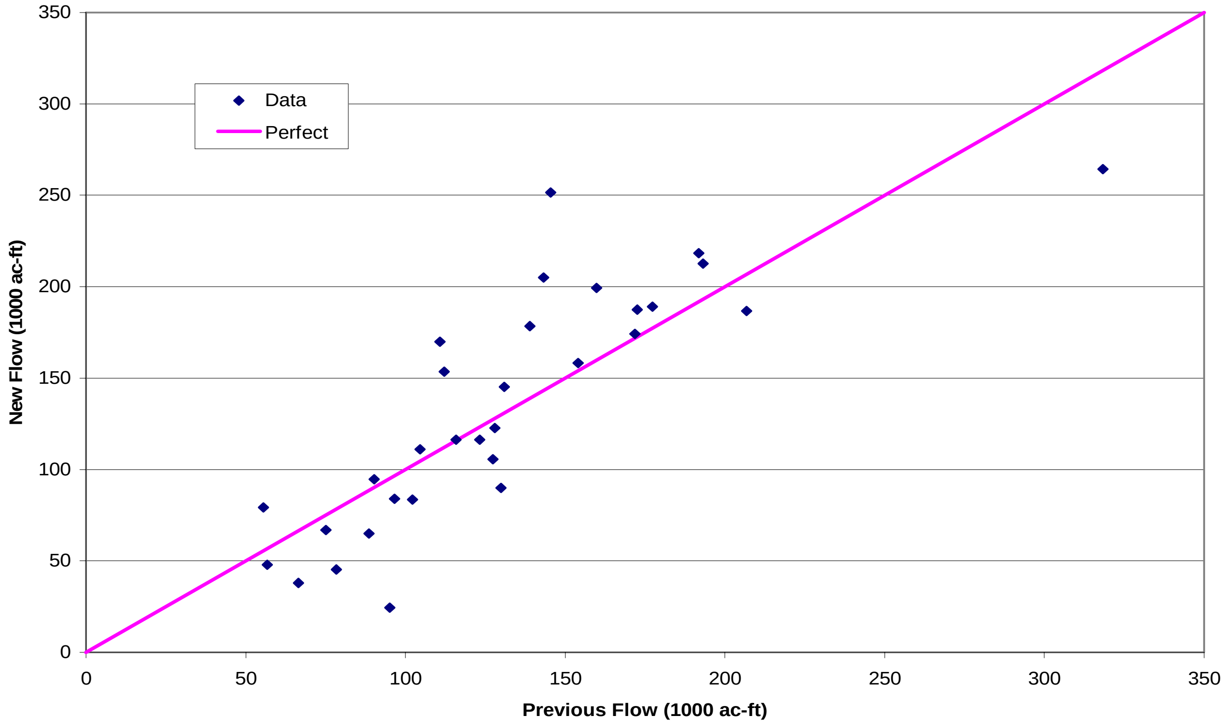


Figure 16. Comparison of Annual Flows in the L-3 Canal at the G-406 Location (1965-1995)

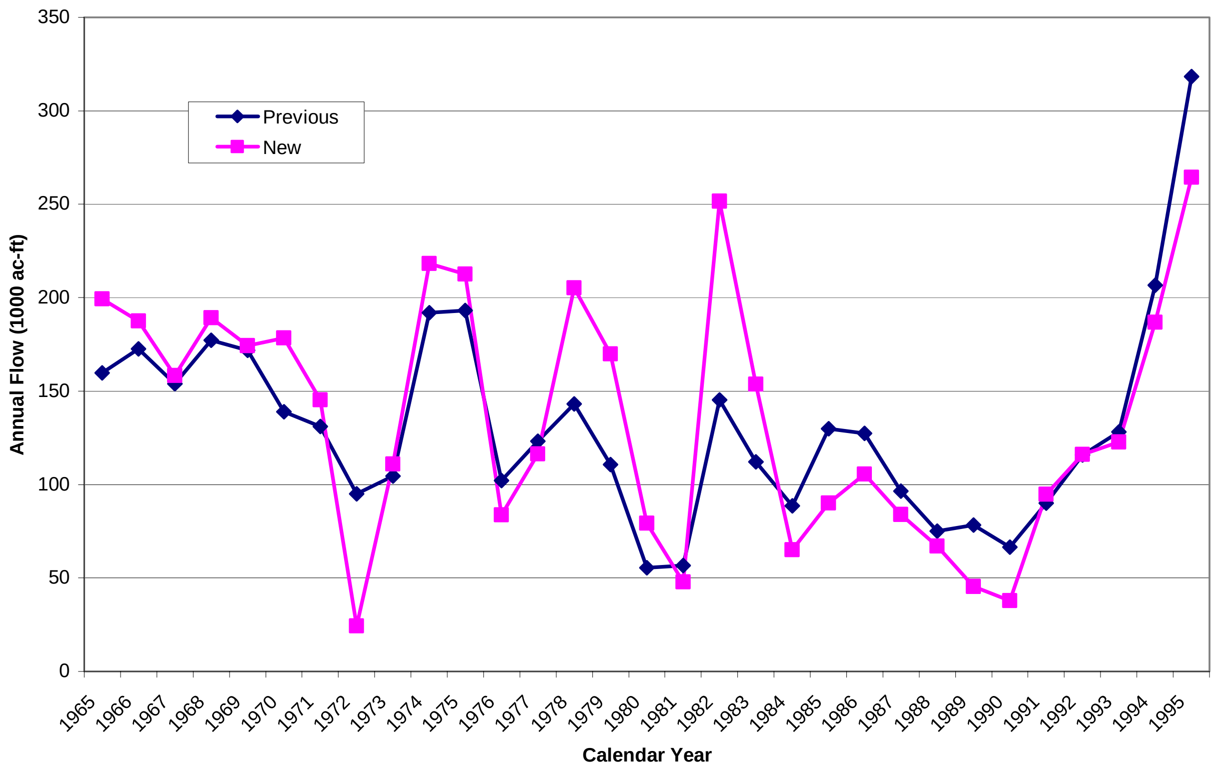


Figure 17. Comparison of Annual Flows in the L-3 Canal at the G-406 Location (1965-1995)