

 Metropolitan Council <i>Environmental Services</i>	SOP	Environmental Quality Assurance (EQA) Standard Operating Procedure
Standard Operating Procedure: Estimation of Annual River Pollutant Loads with Flux32		
Version	1.3 (Updated 12/01/2010; 12/09/2011; 1/20/2012; 9/13/2012)	
Author(s)	Karen Jensen, Adam Freihoefer, Emily Resseger	
Procedure Description	To calculate the annual pollutant loads for Twin Cities Metropolitan Area rivers using Flux32 software and water quality and flow data collected by the Metropolitan Council Environmental Services (MCES) EQA – Environmental Monitoring and Assessment Unit or other project partners (USGS).	
Materials	<ul style="list-style-type: none"> • Flux32 software (most recent version). Download at ftp://ftp.usace.army.mil/pub/erdc/EL/Simple_Tools/FLUX_Updates/ • Daily average flows (continuous record of measured and estimated daily flows) • Grab sample water quality concentrations 	
References	<ul style="list-style-type: none"> • Manual_IR-W-96_2.pdf: “Simplified Procedures for Eutrophication Assessment and Prediction: User Manual”. William W. Walker. Instruction Report W-96-2. September 1996. Updated April 1999. U.S. Army Corps of Engineers (USACE) • SOP_Flux32_Stream_Load_Estimates_V1.3.doc • MCES Steps for Flux Analysis_draft_200307.doc • MPCA_FLUX32_Process_Checklist.doc 	
Contents	<ul style="list-style-type: none"> • Summary • Tables • Systematic Operations • Attachment A 	

Summary:

This SOP outlines the MCES methodology for estimating annual pollutant loads of three major rivers (Mississippi, Minnesota, and St. Croix) from monitored daily average flow and grab sample chemistries using the U.S. Army Corps of Engineers’ software Flux32. Due to differences in input data processing and load estimation methodology, a separate SOP exists for estimating annual loads for monitoring stations located on the tributary streams within the Twin Cities Metropolitan Area.

Flux32 can easily be used mindlessly, resulting in inaccurate loads and statistics. It is crucial to use Flux32 mindfully with good technical judgment and familiarity with the stream or river dynamics, to ensure loads are accurate and defensible. This SOP is intended to provide typical procedures followed by MCES when calculating river pollutant loads. Some river sites or some years of data may be aberrant, and pollutant load calculation methodology must deviate from this SOP. All deviations from SOP procedures will be recorded in both the .TXT output file and in the results database “notes” field.

Since flow in the four major rivers responds relatively slowly to precipitation events, MCES and MPCA (Minnesota Pollution Control Agency) staff have determined, based on the MCES sampling frequency, that using a **one-year record of average daily flow and grab sample water chemistry** data is adequate

to estimate annual loads for the major rivers with acceptable uncertainty. The application of a one-year dataset to define an annual river load, rather than multiple years, is acceptable since river events are typically defined as a multi-day record (3 days or greater). The subtle nature of the river system hydrograph, along with consistent frequency of monitoring, allows for a strong statistical relationship when using regressions within Flux. In comparison, the streams possess relatively flashy event hydrographs, at times defining 2 days or less, requiring the stream load estimates to rely on a 3-year dataset.

Annual load estimates for the rivers will be used within the Metropolitan Council benchmark report, annual water quality summary reports, special studies, and shared with external stakeholders.

Basic steps for estimation of annual loads include (Figure 1):

- Creation of two Flux32 input files per site: average daily flow and water quality (Table 1)
- The estimation of loads using Flux32 software. This effort typically requires adjusting flow or seasonal stratification breaks to reduce the coefficient of variance (C.V.) to 0.2 or lower and reduce the slope in residual plots to ensure that the methods produce similar results
- Creation of output text files in specified format to document Flux32 results
- Transfer the results to master database of river load results
- Creation of Flux32 Session (.FSS) File.

Table 1: Historic MCES Metropolitan Area River Sites

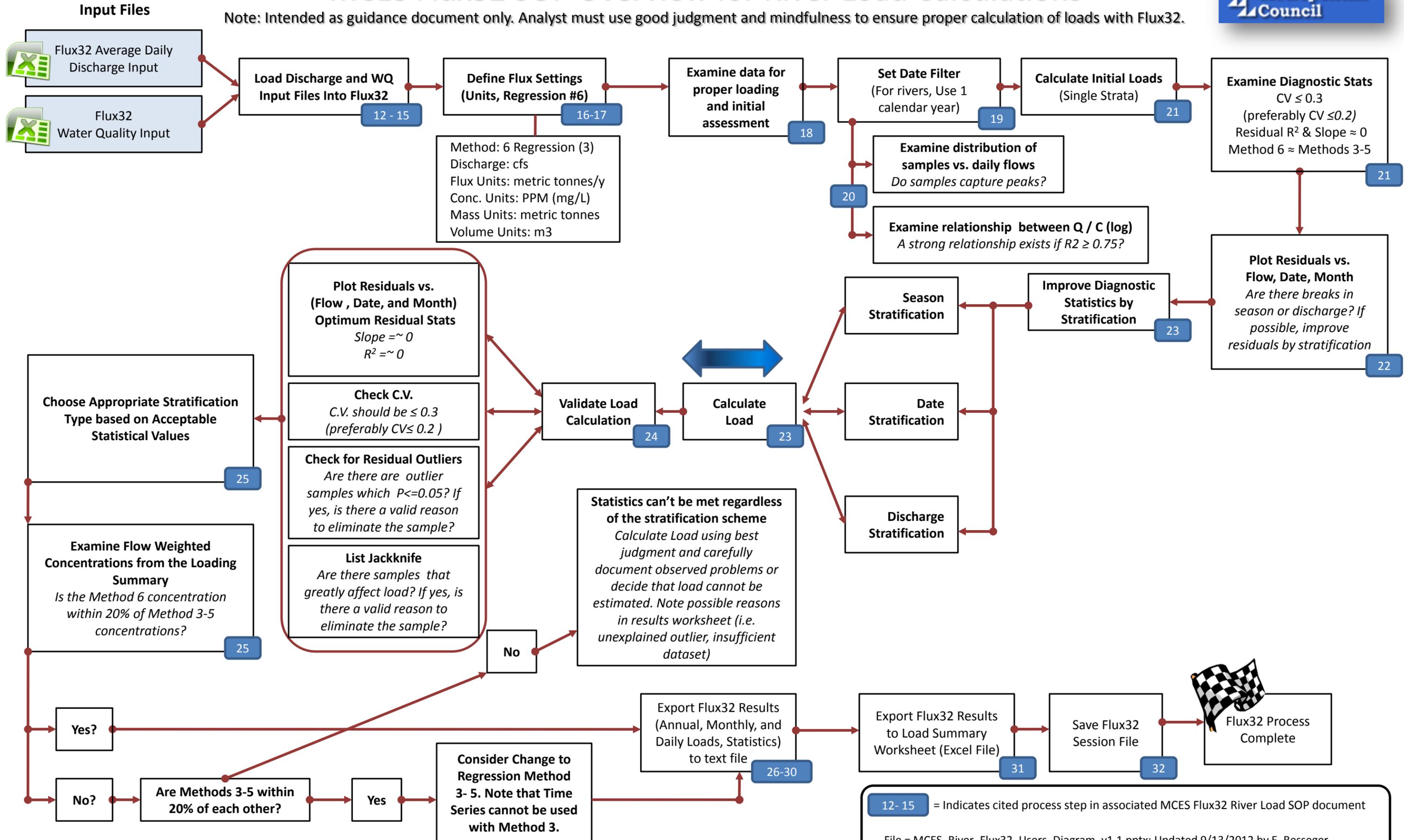
MCES Site Code	Site Name	Flux Abbreviation	Discharge	Discharge Monitoring Record ¹	Water Quality Monitoring Record
MI39.4	Minnesota River at Jordan	MNJORD	USGS 05330000	1934-Present	1979 - Present
MI3.5	Minnesota River at Fort Snelling	MNFSN	USGS 05330920	2004-Present	
UM871.6	Mississippi River at Anoka	UMANOKA	USGS 05288500 - Rum River - USGS 5287890	1931-Present	1976 - Present
UM847.7	Mississippi River above Lock and Dam No. 1	UMLD1	USACOE	1985-Present	
UM839.1	Mississippi River at St. Paul	MSSTP	USGS 05331000	1900-Present	
UM826.7	Mississippi River at Grey Cloud Island	UMGREY	USGS 05331000 + Metro WWTP	1971-Present ²	
UM815.6	Mississippi River above Lock and Dam No. 2	UMLD2	USGS 07010206	1995-Present	
VR20.6	Vermillion River at Farmington	VRFARM	USGS 05345000-Empire WWTP	1973-Present	
VR15.6	Vermillion River near Empire	VREMPIRE	USGS 05345000	1973-Present	
SC23.3	St. Croix River at Stillwater	STCRXSTILL	USGS 05340500 + USGS 05341500	1902-Present	1976 – Present
SC0.3	St. Croix River at Prescott	STCRXPRES	USGS 05344490	2007-Present	
UM796.9	Mississippi River above Lock and Dam No. 3	UMLD3	USGS 05344500	1959-Present	1976 - Present

¹If the primary discharge monitoring record does not extend the entire length of the water quality monitoring record, or there are gaps in the record, a secondary flow calculation method has been established. See Attachment A for complete documentation.

²The daily Metro WWTP flow record begins is June 1981. Monthly flows are available in paper form back at least as far as 1971.

MCES Flux32 SOP Overview for River Load Calculations

Note: Intended as guidance document only. Analyst must use good judgment and mindfulness to ensure proper calculation of loads with Flux32.



12-15 = Indicates cited process step in associated MCES Flux32 River Load SOP document

Action 1: Create Flux32 Input File: Daily Average Flow

- ☑ (STEP 1) Download discharge data. The process for calculating discharge at each site is unique and will depend on the completeness of the record for that year. For sites with a short primary flow record, many data gaps, or difficulty acquiring data from the USGS for October-December of the prior year (because USGS calculates flow on a water year basis), an alternative flow calculation method has been provided. See Attachment A for a detailed description of determining flows at each site.
 - Daily average daily flows are downloaded from the USGS or USACE Website.
 - Minnesota USGS sites: http://waterdata.usgs.gov/MN/nwis/current/?type=dailydischarge&group_key=basin_cd
 - Army Corps of Engineers sites: <http://www.mvp-wc.usace.army.mil/projects/>
- ☑ (STEP 2) If not already developed, create an Excel spreadsheet with separate worksheets for each site location as well as a worksheet for notes related to changes and updates made to each dataset. The excel file will serve as the Flux32 Discharge Input File.



- ☑ (STEP 3) Each Excel worksheet should use the following format or append new data to existing input file and update notes page. The notes worksheet should be updated as new data is added each year.
 - Cell A1 has no effect on Flux and should contain site description and any other relevant information.
 - Cell B1 should define the flow units used (i.e. ft³/sec)
 - *Site Discharge (MN JORDAN) Worksheet Format:*

	A	B	C	D
1	Site description	ft ³ /sec		
2	DATE	FLOW	QUALIFIER	
3	01/01/80	10		
4	01/02/80	15	e	

- *Notes Worksheet Format.*

	A	B	C	D
1	Site description			
2	DATE	NOTE	AUTHOR	
3	05/26/09	Added 2008 data	KMJ	
4	05/28/10	Added 2009 data	ATF	

- ☑ (STEP 4) Name flow input file according to following naming convention:
Example: River_Discharge_75_09.xls

Note: If updating an existing Flux32 input file, update the *Notes* page and resave file in appropriate file folder with new file name appropriate for the most recent data added (i.e. River_Discharge_75_10.xls). **Do not alter existing files**, as they will be used to recreate loads if questions arise in future. MCES internal file structure for the storage of Flux32 files is outlined in the Annual WQ Assessment SOP.

File Location: \NATRES\Assessments \Documents\SOP\SOP_WaterQuality_Assessment_V1.doc

Action 2: Create Flux32 Input File: Water Quality

- ☑ (STEP 5) Download verified water quality data from the Water Quality Database. Each site's data report should include a date, sample identification number, and a water quality concentration per constituent per sample.
 - There have been times when a replacement site has been used for sampling when the primary site is inaccessible due to weather or access issues. These sites should always be included in the download to make sure no samples are missed. These sites are:
 - UM836.8- Used regularly when UM839.1 is inaccessible during the winter.
 - SC 23.4- Used when the bridge was being repaired in place of SC 23.3.
 - VR 21.9- used in place of VR 20.6 during construction work.
- ☑ (STEP 6) To avoid calculation error in Flux32, make sure there is only one sample per date.
 - For two (or more) grab samples per date: average concentration
- ☑ (STEP 7) Create an Excel spreadsheet with separate worksheets for each site location as well as a worksheet for notes related to changes and updates made to each dataset. The excel file will serve as the Flux32 Water Quality Input File.



- ☑ (STEP 8) Each site specific Excel worksheet should use the following format or append new data to existing input file.
 - Cell A1 has no effect on Flux and should contain site description and any other relevant information.
 - Cell B1 should define the concentration units used (i.e. mg/L)
 - Cell C1 defines the sample flow units, but should be left blank for river load calculations
 - Format each site worksheet as follows:

Site Water Quality (MN Jordan) Worksheet Format:

	A	B	C	D	E	F
1	Site description	mg/L				
2	STATION	DATE	Field_Data_ID	TP	TSS	NO3
3	MI39.4	01/01/80	345678	0.105	549	4.5
4	MI39.4	01/14/80	356780	0.255	1549	1.2

- ☑ (STEP 9) If modifications are made to the water quality dataset, the changes should be reflected within the **Notes** worksheet. The format of the Notes worksheet is as follows:

Notes Worksheet Format:

	A	B	C	D	E
1	Site description				
2	DATE	NOTE	DATE DOWNLOAD	DATA FILE NAME	AUTHOR
3	05/26/09	Added 2008 data	05/13/09	River_WQ_76_08.xls	KMJ
4	05/28/10	Added 2009 data	05/20/10	River_WQ_76_09.xls	ATF

- ☑ (STEP 10) Name flow input file according to following naming convention:

Example: River_WQ_76_09.xls

Note: If updating an existing Flux32 input file, update the *Notes* page and resave file in appropriate file folder with new file name appropriate for the most recent data added (i.e. River_WQ_75_10.xls). **Do not alter existing files**, as they will be used to recreate loads if questions arise in future. MCES internal file structure for the storage of Flux32 files is outlined in the Annual WQ Assessment SOP.

File Location: \NATRES\Assessments \Documents\SOP\SOP_WaterQuality_Assessment_V1.doc

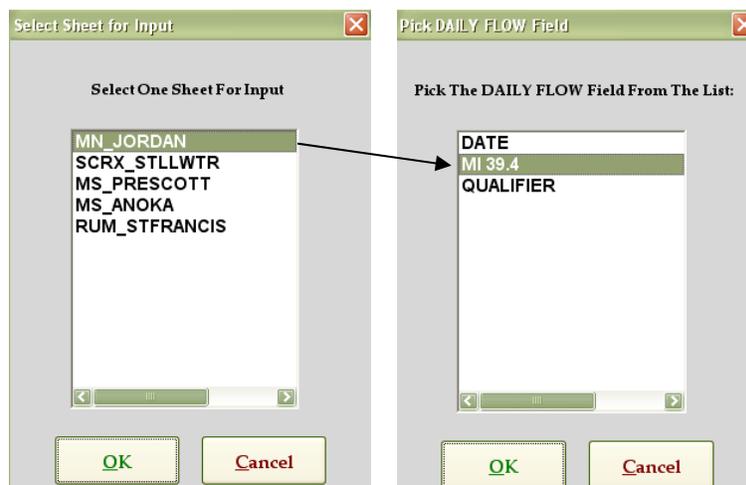
Action 3: Load Flux32 Input Files for New Project

- ☑ (STEP 11) Open Flux32 executable



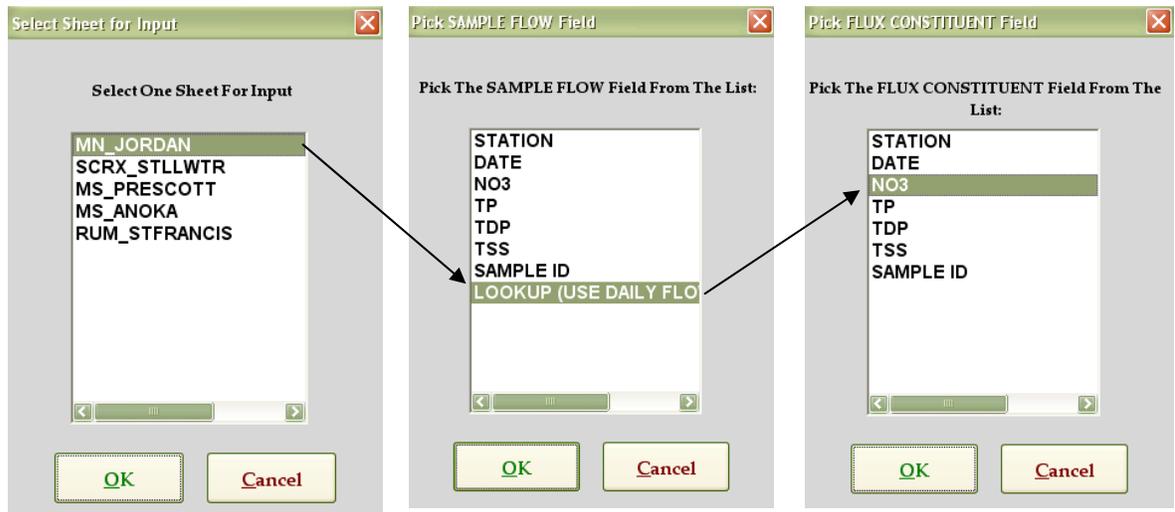
If starting a New Project: **Data** → **Read** → **New Sample and Flow Data** → **New Stratification**
If opening an existing project: **Session** → **Resumed Saved Session** (.FSS File)

- ☑ (STEP 12) After selecting New Stratification, Flux32 will prompt the user to locate the file directory of the discharge (River_Discharge_75_09.xls) and water quality samples (River_WQ_76_09.xls).
- ☑ (STEP 13) Flux32 will first read in the discharge worksheet. If the daily flow file contains multiple worksheets, the user must indicate what worksheet (i.e. monitoring site) is going to be used and column identifier that the flow data is located in.

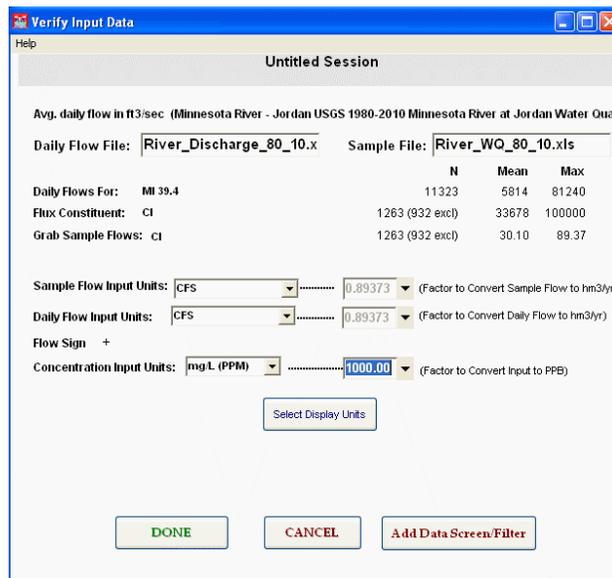


- ☑ (STEP 14) Flux32 will then read the water quality worksheet. Similar to the discharge input, if the water quality file contains multiple worksheets, Flux32 will prompt user to select the worksheet that contains the appropriate site information (i.e. monitoring site) to be used. Flux32 will next prompt user to select **SAMPLE FLOW Field** from a list of fields. For river load estimation, the user should select the **LOOKUP (Use Daily Flow)** since the MCES water quality samples do not have an associated sample flow. MCES typically uses the daily average flow to represent the sample flow when calculating major river loads. Most major river samples are collected as grab samples and the major river flows change relatively slowly – thus use of daily average flow as an approximation of sample flow is appropriate.

Note: This differs from stream load estimation as tributary streams are typically flashy and therefore daily average flow is not a good surrogate for event flow. The tributary streams have either a grab or composite flow associated with sample chemistry, and daily average flows are used only to estimate loads for those days without a sample flow.

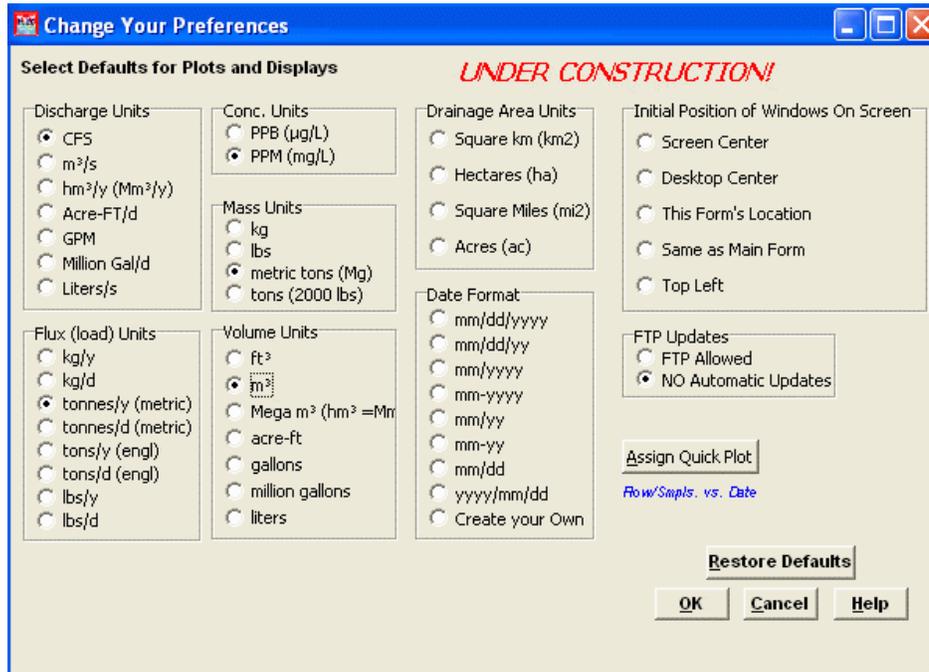


- ☑ (STEP 15) Flux32 will next prompt user to select the **FLUX CONSTITUENT Field** from a list of fields. Select field name of parameter to be estimated.
- ☑ (STEP 16) Flux32 will then prompt user to complete the following:
 - Enter/Modify Site Name: Enter appropriate site name and location.
 - Confirm input data. Examine the page to make sure number of daily flows and number of samples seems appropriate
 - Confirm appropriate values for unit conversion. Ensure the conversion factors are correct: 0.894 if using cfs; 1,000 if using mg/l. Use dropdown menus to change values, if necessary.



- Click on the ‘Select Display Units’ button. Select the default units for estimating stream loads (these are different than river loads).
 - Discharge Units: *CFS*
 - Flux (load) Units: *tonnes/y (metric)*
 - Conc. Units: *PPM (mg/L)*
 - Mass Units: *metric tons (Mg)*
 - Volume Units: *m³*

The right two columns of the dialog box can be left blank.



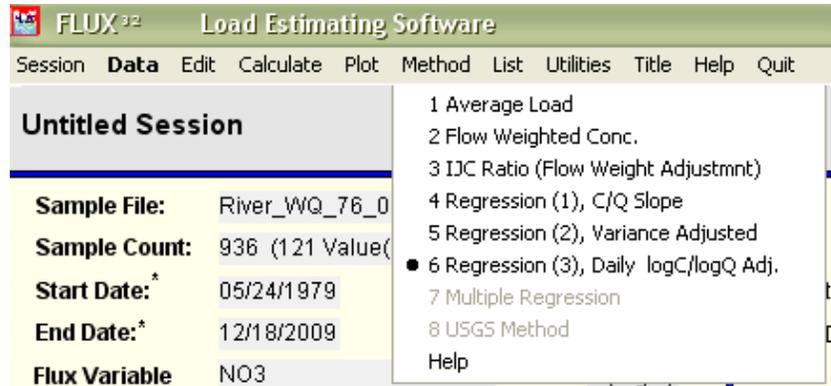
Note: If Flux32 detects duplicate samples, open the water quality input file and manually delete duplicates as described previously in this SOP. Reload data into Flux32. Do not use the Flux32 prompts to delete duplicate samples.

Action 4: Estimate Loads with Flux32

☑ (STEP 17) Define Initial Settings

- Select Method #6: **Method** → **6 Regression (3): Daily log c/log q, adj**

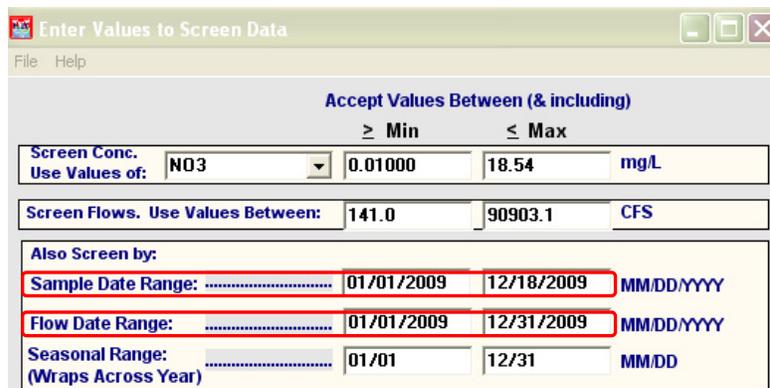
Note: Method 6 is the preferred calculation method as it designed for use with the time series function, which will be used later in this SOP to save data output for yearly, monthly, and daily time steps. (If a load is unable to be calculated using Method 6, the user may use an alternate method and refrain from citing sub-annual time series information. A complete explanation of the Method 6 departure criteria is outlined in Step 27.)



- ### ☑ (STEP 18) Examine entire dataset to ensure proper loading and assess potential stratification schemes. Confirm that flow data are complete without breaks and that number of samples indicated seems appropriate. Examine plots for concentration vs. flow or concentration vs. season relationships.

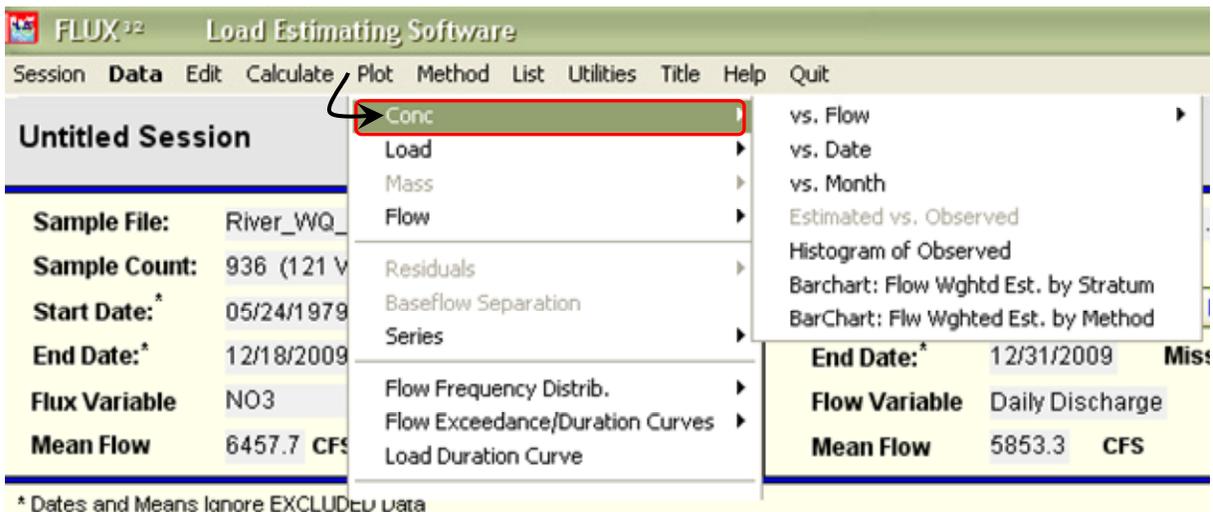
☑ (STEP 19) Set Data filter/screen to include only data period of interest.

- **Data** → **Screen/filter data** → **Apply Date & Value screens** → **Sample Date Range:**
For river sites, one calendar year of data are used to develop regression equations used in estimating loads. The max date should be set to the last day of the year of interest (12/31/2009 when estimating 2009 loads). The min date should be set to the first day of year (for estimating 2009 loads, the min date would be 01/01/2009).
- **Data** → **Screen/filter data** → **Apply Date & Value screens** → **Flow Date Range:**
For river sites, one calendar year of data are used. The max date should be set to the last day of the year of interest (eg. 12/31/2009 when estimating 2009 loads). The min date should be set to the first day of year (for estimating 2009 loads, the min date would be 01/01/2009).



Note: Once dates are changed using data screen, do not simply change the dates again to re-filter data, as an error occurs and data will not be loaded properly. To reset dates:
Data → **Screen/filter data** → **Apply Date & Value screens** → **Reset** and then repeat date filter process described above.

- ☑ (STEP 20) Examine filtered dataset to ensure proper loading and assess potential stratification schemes. Make sure flow data is complete without breaks and that number of samples indicated seems appropriate. Examine plots for concentration vs. flow or concentration vs. season relationships. Look for logical breaks in relationship where stratification breaks could be made.
 - **Plot** → **Conc** → **vs. Flow** → **linear**
 - **Plot** → **Conc** → **vs. Flow** → **log**
 - **Plot** → **Conc** → **vs. Date**
 - **Plot** → **Conc** → **vs. Month**

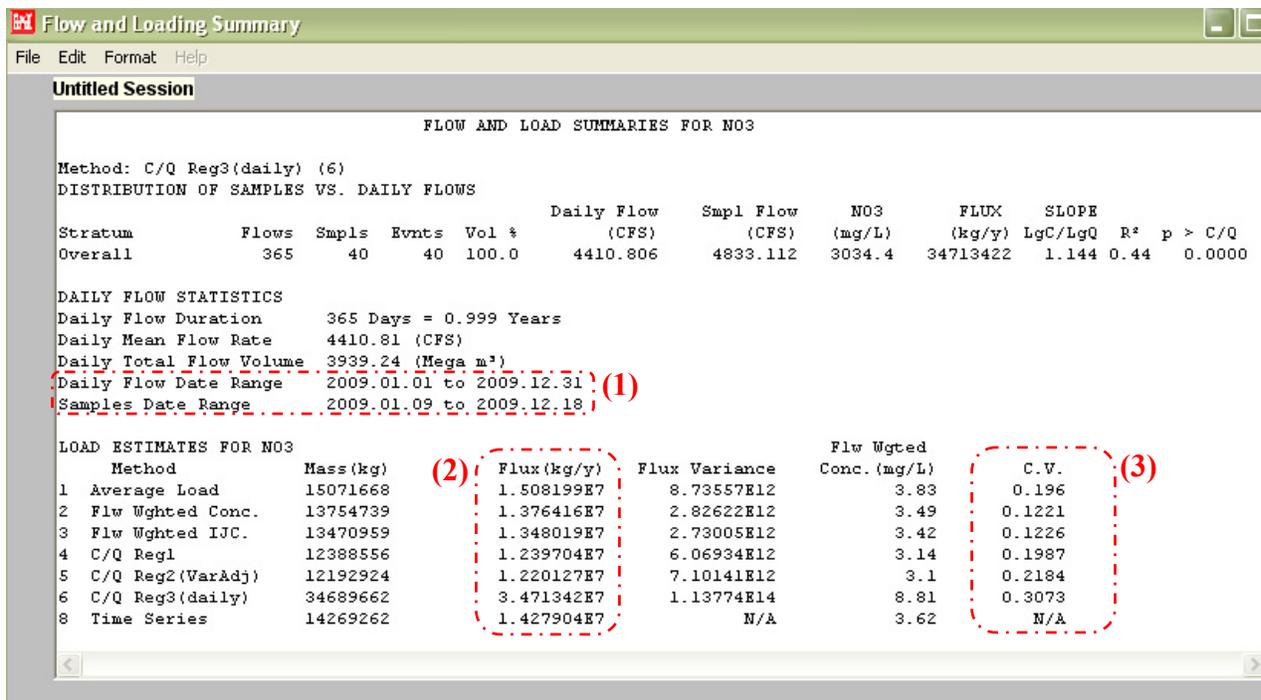


- Verify the distribution of samples versus daily flows to ensure that the samples capture the peaks. This information can be obtained using the Quick Plot tool on the main screen of Flux32.



While there are no specific criteria for appropriate flow vs. concentration or the distribution of samples to daily flows, weak relationships can hinder the users ability to calculate loads and can be used to justify the inability to calculate a load (Step 27).

- ☑ (STEP 21) Calculate initial loads using one stratum
 - **Calculate** → **Loads**
 - Examine *Flow and Load Summary* output. In particular:
 - Do the daily flow statistics agree with the dates selected in the data filtering process (#1)?
 - Is the Flux (kg/y) similar between the various statistical methods (1-6) (#2)? Is the Method 6 C.V. < 0.2? How do the Method 6 results compare to the other methods (#3)?
 - The inability to meet the following criteria does not necessarily mean a load cannot be calculated; however, additional modifications to the data as outlined in subsequent steps (i.e. stratification, method change) may be needed.



☑ (STEP 22) Examine initial qualitative (graph) and quantitative (statistics) diagnostics.

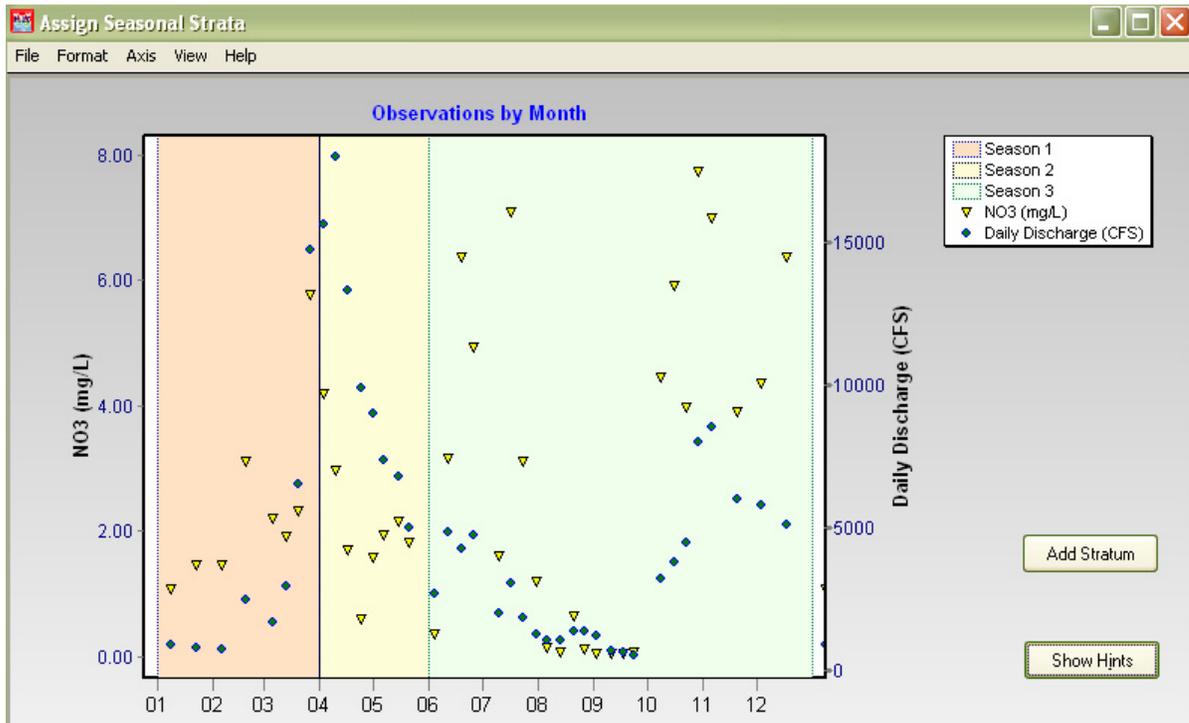
- Plot → Residuals → vs. Flow → Show Stats
- Plot → Residuals → vs. Date → Show Stats
- Plot → Residuals → vs. Month → Show Stats

Note: Input data and associated loads for a river may be influenced by flow and by date/season, in which case the flow residual plot may look acceptable (no slope, high slope significance, low R²) while the date or month residual plots may be sloped, indicating a date or seasonal bias. Flux32 does not include both date and flow relationships in the load estimates; however, the USGS load estimation tool (LOADEST) does have that capability. With Flux32, the user must choose to either minimize flow residuals or minimize date/seasonal residuals using stratification.

☑ (STEP 23) Upon examining the initial load results using a single stratum, the user has the option of assigning multiple strata based on discharge or seasonal / date. The objective is to reduce the C.V., minimize residual slopes, and achieve convergence between flux and concentration for Methods 3-6.

- Stratify data: **Data** → **Stratify** → **On Flow**
On Hydrograph
On Season
On Date
- **On Flow Stratification:** Typically relies on two strata (split at Qmean) or three strata (split at ½ Qmean and split at 2x Qmean). Upon choosing one of the flow strata, the user can then manually edit the strata boundaries through numeric or graphical means. If the user would prefer to manually enter all of the strata breaks, use **Data** → **Stratify** → **On Flow** → **Other**.

- On Season Stratification: Stratification breaks often correlate with winter (mid-October – January), spring (February – mid May), summer (mid-May – mid-August), and fall (mid-August – mid-October). Examining the graphical interface will assist the user in appropriately identifying strata breaks.
- On Date Stratification: Using the date function allows the user to break up strata while viewing the hydrograph. Similar to the season stratification, it is recommended that the user identify and define strata breaks with the graphical interface.



- (STEP 24) Check diagnostic plots and statistics: Once strata breaks are set, go through the following process to check diagnostic plots and statistics. Table 2 outlines diagnostic tests and goals.

Table 2: Flux32 Diagnostics for Load Calculation Acceptability

Flux32 Diagnostic Plot or Statistic	Description	Optimum Goal
Plot → Residuals → vs. Flow, vs. Date, vs. Month	Examine residual plots for bias; Click “Show Stats” on plot. Often bias can be eliminated for Flow or Date, but not both	No slope (slope ≈ 0) Minimize R ² (R ² ≈ 0) Maximize Slope Significance (≈1)
Calculate → Loads	Creates summary table of load by method; also gives C.V. by method	Flow weighted concentration estimate for Method 6 should be within 20% of Methods 3-5. <u>C.V. range</u> 0 - 0.1 (Good) 0.1 - 0.2 (Fair) > 0.2 (Poor) > 0.3 (Unacceptable)

Calculate → Compare Sample Flow with Total Flow Distribution	Provides a variety of statistics comparing sample flow with total flow distribution	Provides information about distribution that may help with data interpretation
List → Residuals → Outliers	Provides lists of statistical outliers (P<=0.050)	Outliers should only be deleted with some evidence of problem with sample. Deletion of outliers can greatly affect load estimates. If outlier is deleted, be sure to note in output text file.
List → Jackknife Table	Jackknife procedure systematically deletes individual samples and recalculates load without that sample, then presents % change in load estimate.	Look through table and identify individual samples that greatly influence load estimate. May add in interpretation or aid in elimination of outliers.
List → Breakdown by Stratum and Optimum Sampling	Can provide information about optimizing sample collection during future efforts.	Can aid in data interpretation.

(STEP 25) If diagnostics are acceptable (based on calculation method and statistical relationships), proceed to Step 26. If diagnostics are unacceptable, first attempt to adjust stratification breaks or change stratification scheme (for example, change from flow stratification to seasonal stratification). Evaluate outliers and jackknife to identify aberrant samples. **Outliers should be deleted cautiously and only with reason; always make note of deleted outliers in output file.**

- *As a general guideline*, if the Method 6 flow weighted concentration is greater than +/- 20% of Methods 3-5 concentrations/loads, then use of Method 6 may be abandoned for an alternative methods (Methods 3 – 5, preferably Method 4 or 5). It is advised not to use the time series function with Methods 2 or 3. The user will therefore only be able to cite annual modeled loads (rather than monthly or daily). Dave Soballe of ACOE reports that Method 6 time series (calendar year, monthly, and daily results) are most accurate as long as the C/Q relationship has a high r^2 (~0.75) or if Methods 2-6 converge on a similar result. Analyst notes on method selection should be included in both .TXT output file and output database “notes” field.
- If the none of the methods produce a statistically significant load (C.V. > 0.3 and loads do not converge on similar value) and indicators exist such as weak representation of samples to the daily flow regime and poor residual statistics regardless of stratification scheme, you may not be able to calculate a load for the specified calendar year. If there is some variability between the flow weighted concentrations of Methods 3-5, but all indicators suggest an appropriate dataset, proceed will load calculation and make note of variability.

(STEP 26) Once diagnostics are evaluated and optimized, calculate final loads and create output file as defined in Action 5.

Action 5: Create Output File

☑ (STEP 27) Open text editor like “Notepad” or “Notetab Light”

☑ (STEP 28) Enter introductory information as follows:

Line 1: Site name, parameter, year of interest

Line 2: Date of analysis and analyst name

Line 3: Version of Flux32

Line 4: Input file names

Line 5: Stratification breaks

Line 6: Outliers deleted

Line 7: Notes

Example

Minnesota River at Jordan NO3 loads for 2010

Date/analyst: 05/26/10; Emily Resseger

Flux 32 Version: 2.97 (3/23/10)

Flux32 input files: River_Discharge_80_10.xls; River_WQ_80_10_wq.xls

Stratification breaks: Seasonal (4 strata) (1/1, 4/7, 7/26, 10/1)

Outliers deleted: None.

Notes: While flow residuals look good, monthly residuals are biased (sloped)

☑ (STEP 29) Once above information has been added, then cut and paste the following into the text file, in this order:

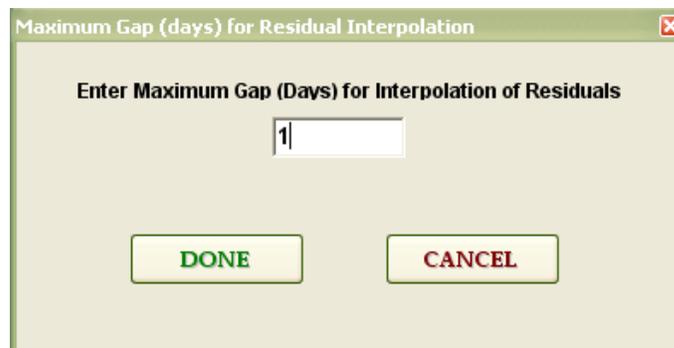
○ **Calculate** → **Loads**

○ To calculate time series loads (daily, monthly, calendar) Use 1 Day as Maximum Gap for Interpolation

→ **Calculate** → **Series** → **Calendar Year** (1 Day as Maximum Gap for Interpolation)

→ **Calculate** → **Series** → **Monthly** (1 Day as Maximum Gap for Interpolation)

→ **Calculate** → **Series** → **Daily** (1 Day as Maximum Gap for Interpolation)



☑ (STEP 30) Save output file using the following naming convention:

Sitenameabbreviation_parameter_year.txt

Example: MNJORD_NO3_2009.txt

in the folder:

NATRES\ Assessments\WQ_Load_Calculations\Output_Files\Rivers\Text_Files

- (STEP 31) Load values and statistics are manually extracted and summarized within a historic river loads worksheet. The location of the MCES River Loads dataset is:
NATRES\Assessments\WQ_Load_Calculations\Output_Files\Rivers\Rivers_WQ_Load_Dataset.xlsx

If additional load data is added to the 2009_River_WQ_Load_Dataset.xlsx the user should update the *Notes* worksheet.

Information that needs to be added to the Rivers_WQ_Load_Dataset.xlsx file is:

- Site Code
- Site Type
- Parameter
- Version (if input data is updated and the model is rerun, the output text file should be saved as *Sitenameabbreviation_Parameter_year_V#.txt*, where # is run of the model. # should be indicated here)
- Database Query Date
- Analysis Period
- Load Year
- Stratification Scheme
- Stratification Divisions
- Calculation Method
- Samples Excluded
- Samples Used
- Annual volume (either in cfs or m³)
- Model-Mass (Mg)
- Model-Conc (mg/L)
- Interp-Mass (Mg)
- Interp-Conc (mg/L)
- CV (Coefficient of Variation)
- Updated By
- Updated On
- Comments (should match notes in text file)

Columns shaded in blue are should calculate automatically. These calculations include:

- Site Name
- Flux Abbreviation
- Multiple Versions? (yes or no)
- Output Text File Name
- Output Flux32 Session File Name
- Annual Volume (cfs) (calculated based on whether you enter volume in cfs or m³)
- 95% CI Upper Limit (Mg)
- 95% CI Lower Limit (Mg)
- Quality Check: Back-Calculate concentration (mg/L)
- Quality Check: Highlight if >3% diff

The upper and lower confidence limits of the 95% confidence interval are calculated using the method cited within the Flux user's manual entitled *Simplified Procedures for Eutrophication Assessment and Prediction: User Manual* (William Walker, 1999) as follows:

$$\text{Lower Limit value} = Y_m * e^{(-2 * CV)}$$

$$\text{Upper Limit value} = Y_m * e^{(2 * CV)}$$

where Y_m is the predicted mean value and CV is the error mean coefficient of variation.

(STEP 32) Save Flux32 Session File using similar naming scheme as used in Step 30.

- **Session → Save This Session**

- Save output file using the following naming convention:

Sitenameabbreviation_parameter_year.txt. The file should be saved in

NATRES\Assessments\WQ_Load_Calculations\Output_Files\Rivers\Session_Files.

Note that session file names cannot include “.” or “-“. Use only alpha-numeric characters and underscores in session file names.

- Example: MNJORD_NO3_2009.FSS

Attachment A

River Flow Estimation Method

NATRES\Assessments\Documents\Memos\River_Loads\River Flow Estimation Method.docx

Internal Memorandum

DATE: 05/29/2012, updated 06/07/2012, 06/19/2012, 6/25/12, 9/14/12
TO: Water Resources Assessment Section; File
FROM: Emily Resseger
SUBJECT: Daily river flow estimation

This memorandum provides the methodology for estimating average daily flow at MCES river monitoring sites for use in data reports or Flux modeling. The sites included in this memo are those selected for Flux load calculation as of 05/29/2012. The description for each site includes the following: MCES site code and river mile, site name, water quality sampling point, primary and secondary methods for estimating flow, and watershed area. The secondary flow calculation method is used where it is not possible to use the primary method (prior to installation of equipment for the primary method, or for October-December of a year when USGS flows are not yet available).

The next page contains a table summary of the primary and secondary method for each site. A more complete description of each site with regression plots where appropriate follows, with each site beginning on a new page.

Metropolitan Council River Site Flow Calculation Method Summary

SITE CODE	SITE NAME	PRIMARY FLOW CALCULATION METHOD	SECONDARY FLOW CALCULATION METHOD
MI39.4	Minnesota River at Jordan	USGS 05330000 MINNESOTA RIVER NEAR JORDAN, MN	Raw USACOE data
MI3.5	Minnesota River at Fort Snelling	USGS 05330920 MINNESOTA RIVER NEAR FORT SNELLING STATE PARK, MN	MI39.4 flow lagged one day with area adjustment factor
SC23.3	St. Croix River at Stillwater	(USGS 05340500 ST. CROIX RIVER AT ST. CROIX FALLS, WI) + (USGS 05341500 APPLE RIVER AT SOMERSET, WI)	USGS 05341550 ST. CROIX RIVER AT STILLWATER, MN
SC0.3	St. Croix River at Prescott	USGS 05344490 ST. CROIX RIVER AT PRESCOTT, WI	Regression with (USGS 05340500 ST. CROIX RIVER AT ST. CROIX FALLS, WI) + (USGS 05341500 APPLE RIVER AT SOMERSET, WI) lagged one day
UM871.6	Mississippi River at Anoka	(USGS 05288500 MISSISSIPPI RIVER NEAR ANOKA, MN) –(Rum River (MCES RUM 0.7))-(USGS 5287890 ELM CREEK NR CHAMPLIN)	
UM847.7	Mississippi River above Lock and Dam No. 1	Mississippi River at L&D #1 (USACOE)	Regression with USGS 05288500 MISSISSIPPI RIVER NEAR ANOKA, MN
UM839.1	Mississippi River at St. Paul	USGS Station 05331000 MISSISSIPPI RIVER AT ST. PAUL, MN	MI3.5 flow+UM847.7 flow
UM826.7	Mississippi River at Grey Cloud Island	(USGS Station 05331000 MISSISSIPPI RIVER AT ST. PAUL, MN) + (Metro WWTP influent)	
UM815.6	Mississippi River above Lock and Dam No. 2	USGS 07010206 MISSISSIPPI RIVER BELOW L&D #2 AT HASTINGS, MN	Regression with Mississippi River at L&D #2 (USACOE)
UM796.9	Mississippi River above Lock and Dam No. 3	USGS 05344500 MISSISSIPPI RIVER AT PRESCOTT, WI	Regression with Mississippi River at L&D #3 (USACOE)
VR20.6	Vermillion River at Farmington	(USGS Station 05345000 VERMILLION RIVER NEAR EMPIRE, MN) –(Empire WWTP influent)	
VR15.6	Vermillion River near Empire	USGS Station 05345000 VERMILLION RIVER NEAR EMPIRE, MN	

MI39.4- Minnesota River at Jordan

Water Quality Data

Grab samples are collected by MCES staff at MI39.4, from the Carver Cty Hwy 45 and Scott Cty Hwy 9 Bridge. Sampling began 08/12/1976.

Primary Flow Calculation Method

Daily average flow data is collected by the USGS at station 05330000 MINNESOTA RIVER NEAR JORDAN, MN. Data is available starting 10/01/1934.

Secondary Flow Calculation Method

If data is not available from the USGS, raw flows at the same site may be obtained from the US Army Corps of Engineers (USACOE) website. These flows are calculated using raw stage and may use an outdated rating curve. Flows should be spot checked to make sure they are reasonable.

Contributing Drainage Area

16,300 sq. mi. (10,430,000 ac) as calculated using USGS StreamStats.

MI3.5- Minnesota River at Fort Snelling

Water Quality Data

Grab samples are collected by MCES staff at MI3.5 near Fort Snelling State Park. Sampling began 01/07/1976.

Primary Flow Calculation Method

Daily average flow data is collected by the USGS at station 05330920 MINNESOTA RIVER NEAR FORT SNELLING STATE PARK, MN. Data is available starting 02/18/2004.

Secondary Flow Calculation Method

If data is not available from the USGS or prior to the installation of the USGS gage, daily average flow is estimated by lagging the data by one day and multiplying by an area adjustment factor:

$$\text{Minnesota River at Fort Snelling} = (\text{Minnesota River at Jordan lagged by one day}) \times 1.05$$

Where *Minnesota River at Jordan* is daily flow developed for MCES MI39.4 (see previous section).

This lag+area adjustment factor procedure was previously derived by Steve Kloiber. The method is likely based on the USGS procedure for routing flow to USGS station 05331000 MISSISSIPPI RIVER AT ST. PAUL, MN which is to adjust Jordan flows by adding 5% or 200 cfs, whichever is greater, and lagged by a number of days that depends on flow. This procedure was derived from a 1976 dye study by the USGS.

Contributing Drainage Area

17,000 sq. mi (10,880,000 ac) as calculated using USGS StreamStats.

SC23.3- St. Croix River at Stillwater

Water Quality Data

Grab samples are collected by MCES staff at SC23.3 from the Stillwater Lift Bridge (upstream of the Stillwater WWTP). During construction at the Stillwater Lift Bridge, samples were collected by MCES staff at SC23.4. Sampling began 01/07/1976.

Primary Flow Calculation Method

Daily average flow is calculated as follows:

$$\text{St. Croix River at Stillwater} = (\text{St. Croix River at St. Croix Falls}) + (\text{Apple River at Somerset})$$

Where *St. Croix River at St. Croix Falls* is daily average flow collected by the USGS at station 05340500 ST. CROIX RIVER AT ST. CROIX FALLS, WI and *Apple River at Somerset* is the daily average flow collected by the USGS at station 05341500 APPLE RIVER AT SOMERSET.

St. Croix River at St. Croix Falls data is available starting 01/01/1902. Apple River data is available starting 07/12/1914.

Secondary Flow Calculation Method

Currently none. Provisional St. Croix Falls flows are usually available with little delay. If Apple River flows are unavailable, the daily median statistic over the period of record should be used.

The USGS has installed a gage at the Stillwater lift bridge (USGS 05341550 ST. CROIX RIVER AT STILLWATER, MN) and began collecting data 09/09/2011. When a stream record is developed for this site it will be compared to that generated using the above equation, and we will determine whether to shift the primary flow data method to the Stillwater gage or keep our existing method and use the Stillwater gage as backup.

Contributing Drainage Area

7,060 sq. mi. (4,518,000 acres) as calculated using USGS StreamStats.

SC0.3- St. Croix River at Prescott

Water Quality Data

Grab samples are collected by MCES staff at SC0.3 from the Highway 10 lift bridge. Sampling began 01/06/1976.

Primary Flow Calculation Method

Daily average flow data is collected by the USGS at station 05344490 ST. CROIX RIVER AT PRESCOTT, WI. Data is available starting 08/20/2007.

Secondary Flow Calculation Method

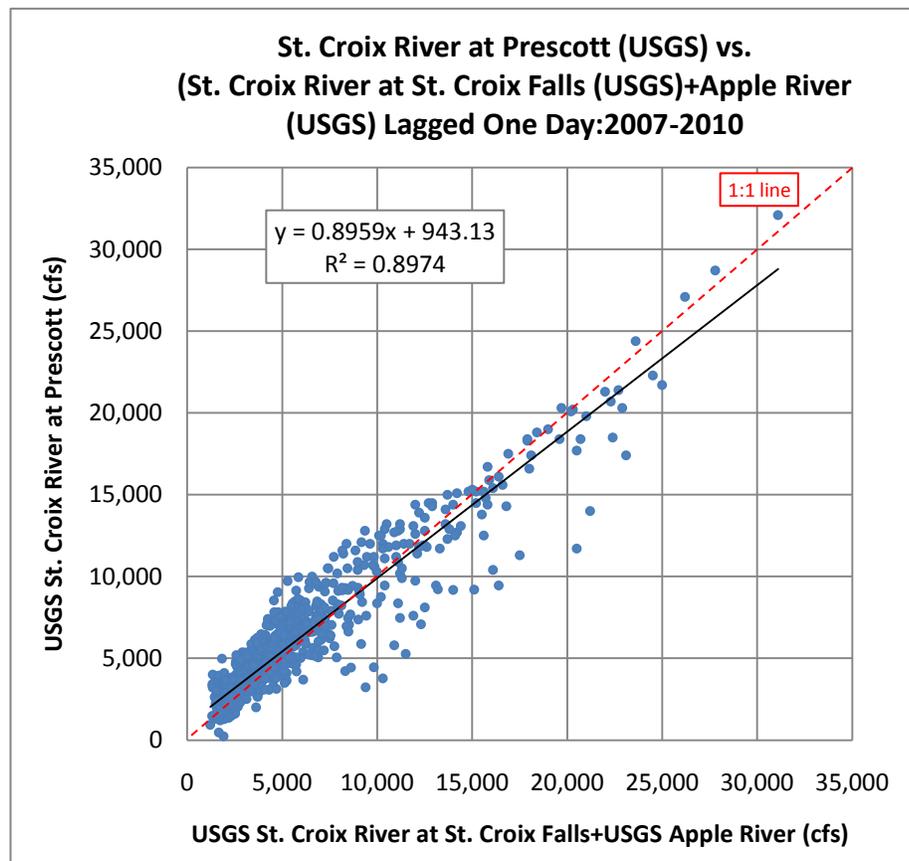
If data is not available from the USGS or prior to the installation of the USGS gage, daily average flow is estimated using the following regression equation:

St. Croix River at Prescott = $0.0.8959 * (St. Croix River at St. Croix Falls + Apple River at Somerset both lagged one day) + 943.13$

Where *St. Croix River at St. Croix Falls* is daily average flow collected by the USGS at station 05340500 ST. CROIX RIVER AT ST. CROIX FALLS, WI and *Apple River at Somerset* is the daily average flow collected by the USGS at station 05341500 APPLE RIVER AT SOMERSET.

Contributing Drainage Area

7,710 sq. mi. (4,934,000 acres) as calculated using USGS StreamStats.



UM871.6- Mississippi River at Anoka

Water Quality Data

Grab samples are collected by MCES staff at UM871.6 at the US Highway 52-169 Bridge. Sampling began 01/07/1976.

Primary Flow Calculation Method

Daily average flow data is calculated as follows:

$$\text{Mississippi River at Anoka} = (\text{Mississippi River near Anoka}) - (\text{Rum River}) - (\text{Elm Creek at Champlin})$$

Where *Mississippi River near Anoka* is daily flow collected by the USGS at station 05288500 MISSISSIPPI RIVER NEAR ANOKA, MN, *Rum River* is daily flow at MCES RUM 0.7, a stream site in the MCES WOMP 1 program, and *Elm Creek at Champlin* is daily flow collected by the USGS at station 5287890 ELM CREEK NR CHAMPLIN. Data at Anoka starts 05/01/1905, while Elm Creek starts 10/01/1978.

Prior to 2011, Rum River flows were acquired from USGS station 5286000 RUM RIVER AT ST. FRANCIS which has data starting on 05/01/1929. The site was changed because the MCES site is at the Rum River dam and only 0.7 miles upstream of the river mouth, while the USGS site is significantly farther upstream, above the dam. The dam is occasionally drawn down so flow above the dam at the USGS site does not reflect flow at the mouth of the river where it enters the Mississippi.

Secondary Flow Calculation Method

None. Provisional USGS data at Mississippi River near Anoka and Elm Creek at Champlin are usually available with little delay, and if there are sporadic missing daily flows they can be linearly interpolated. The MCES stream program is supposed to finalize all data from the previous year by March 31 of the following year, which should not cause a significant delay in calculating flows.

Contributing Drainage Area

Approximately 17,500 sq.mi. (11,220,000 ac) as calculated by MCES.

UM847.7- Mississippi River above Lock and Dam No. 1

Water Quality Data

Grab samples are collected by MCES staff at UM847.7 above Lock and Dam No. 1 (L&D #1). Sampling began 01/07/1976.

Primary Flow Calculation Method

Daily average flow data is collected at L&D #1 by the USACOE. Flow data begins 01/01/1985.

Secondary Flow Calculation Method

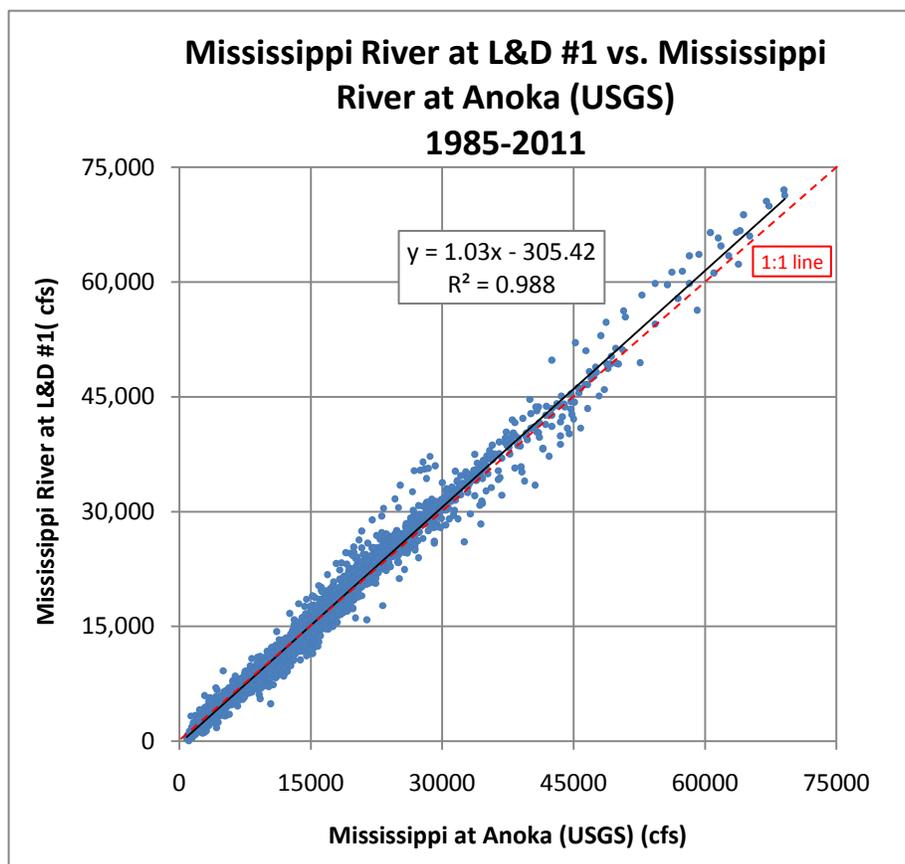
If data is not available from the USACOE, daily average flow is estimated using the following regression equation:

$$\text{Mississippi River above L\&D \#1} = 1.03 * (\text{Mississippi River near Anoka}) - 305.42$$

Where Mississippi River near Anoka is daily average flow collected by the USGS at station 05288500 MISSISSIPPI RIVER NEAR ANOKA, MN.

Contributing Drainage Area

Approximately 19,700 sq.mi. (12,590,000 ac) as calculated by MCES.



UM839.1- Mississippi River at St. Paul

Water Quality Data

Grab samples collected by MCES staff at UM839.1 near St. Paul. When ice conditions or other factors make collection at 839.1 impossible, samples are alternately collected at 836.8. Sampling began 01/07/1976.

Primary Flow Calculation Method

Daily average flow data is collected by the USGS at station 05331000 MISSISSIPPI RIVER AT ST. PAUL, MN. Data is available starting 4/1/1900.

Secondary Flow Calculation Method

If data is not available from the USGS, daily average flow is calculated as follows:

$$\text{Mississippi River at St. Paul} = (\text{Minnesota River at Fort Snelling}) + (\text{Mississippi River above L\&D \#1})$$

Where *Minnesota River at Fort Snelling* is daily flow developed for MCES MI3.5 and *Mississippi River above L&D #1* is daily flow developed for MCES UM847.7 (see previous sections).

Contributing Drainage Area

36,800 sq. mi. (23,550,000 ac) according to the USGS website.

UM826.7- Mississippi River at Grey Cloud Island

Water Quality Data

Grab samples are collected by MCES staff at UM826.7 at the Camus Gravel Pit on Grey Cloud Island. Sampling began 01/06/1976.

Primary Flow Calculation Method

Daily average flow data is calculated as follows:

$$\text{Mississippi River at Grey Cloud Island} = (\text{Mississippi River at St. Paul}) + (\text{Metro WWTP influent})$$

Where *Mississippi River at St. Paul* is daily flow developed for MCES UM839.1 (see previous section) and *Metro WWTP influent* is daily average inflow to the Metropolitan Wastewater Treatment Plant (effluent is not monitored). Daily Metro WWTP flow is available back to 06/01/1981 in the EIMS database. Monthly Metro WWTP flows are available in hardcopy reports back until at least 1971.

Secondary Flow Calculation Method

None. Daily flow for Mississippi River at St. Paul should be calculated previously using either the recommended primary or secondary method; Metro daily WWTP flows are required to be submitted to MPCA on a monthly basis so are readily available.

Contributing Drainage Area

Approximately 37,000 sq. mi. (23,650,000 ac) as calculated by MCES.

UM815.6- Mississippi River above Lock and Dam No. 2

Water Quality Data

Grab samples are collected by MCES staff at UM815.6 above Lock and Dam No. 2 (L&D #2), on the upstream side of the roller gate. Sampling began 01/06/1976.

Primary Flow Calculation Method

Daily average flow data is collected by the USGS at station 07010206 MISSISSIPPI RIVER BELOW L&D #2 AT HASTINGS, MN. Data is available starting 10/01/1995.

Note: MCES staff have found the USGS flows collected below L&D #2 at Hastings to be more accurate than the USACOE flow reported at L&D #2, even though samples are collected above the dam. USACOE flows appear to be under reported.

Secondary Flow Calculation Method

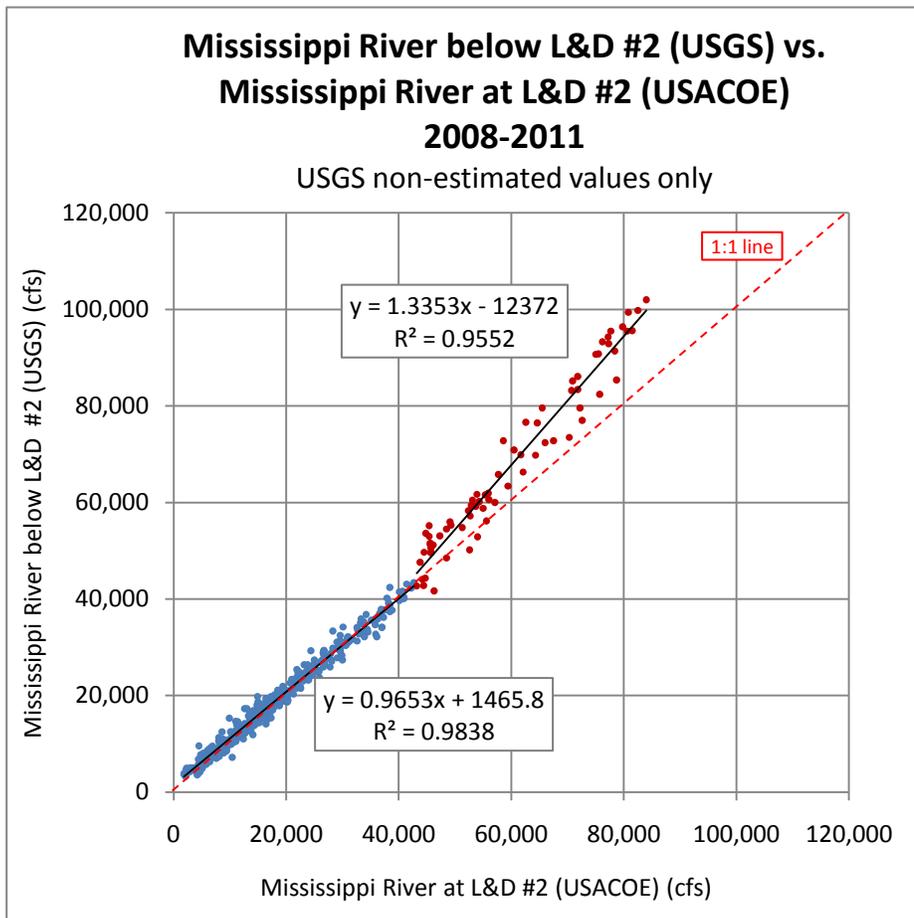
If data is not available from the USGS, or prior to the installation of the USGS gage, daily average flow is estimated using USACOE flow reported at L&D #2, but adjusted using the following split regression equation:

For Mississippi River at L&D #2 (USACOE) flow $\leq 43,000$ cfs:

$$\text{Mississippi River above L\&D \#2} = 0.9653 * (\text{Mississippi River at L\&D \#2 (USACOE)}) + 1465.8$$

For Mississippi River at L&D #2 (USACOE) flow $> 43,000$ cfs:

$$\text{Mississippi River above L\&D \#2} = 1.3353 * (\text{Mississippi River at L\&D \#2 (USACOE)}) + 12372$$



The regression was split at 43,000 cfs because of a natural break in the data. It is believed the change in relationship between the USGS and USACOE flows occurs when the gates are in operation at high flows. The operating curves downloaded from the USACOE website indicate the gates are in operation above 60,000 cfs. We anticipate a visit to L&D #2 at which point the operation of the lock and dam should be clarified and these equations may be modified.

Contributing Drainage Area

37,100 sq. mi. (23,740,000 acres) at USGS station 05331580 Mississippi River below L&D #2 according to USGS website.

UM796.9- Mississippi River above Lock and Dam No. 3

Water Quality Data

Grab samples are collected by MCES staff at UM796.9 above Lock and Dam No. 3 (L&D #3), on the upstream side of the roller gate. Sampling began 01/06/1976.

Primary Flow Calculation Method

Daily average flow data is collected by the USGS at station 05344500 MISSISSIPPI RIVER AT PRESCOTT, WI. Data is available starting 06/01/1928.

Note: MCES staff have found the USGS flows collected at Prescott upstream of L&D #3 to be more accurate long term than the USACE flows at L&D #3.

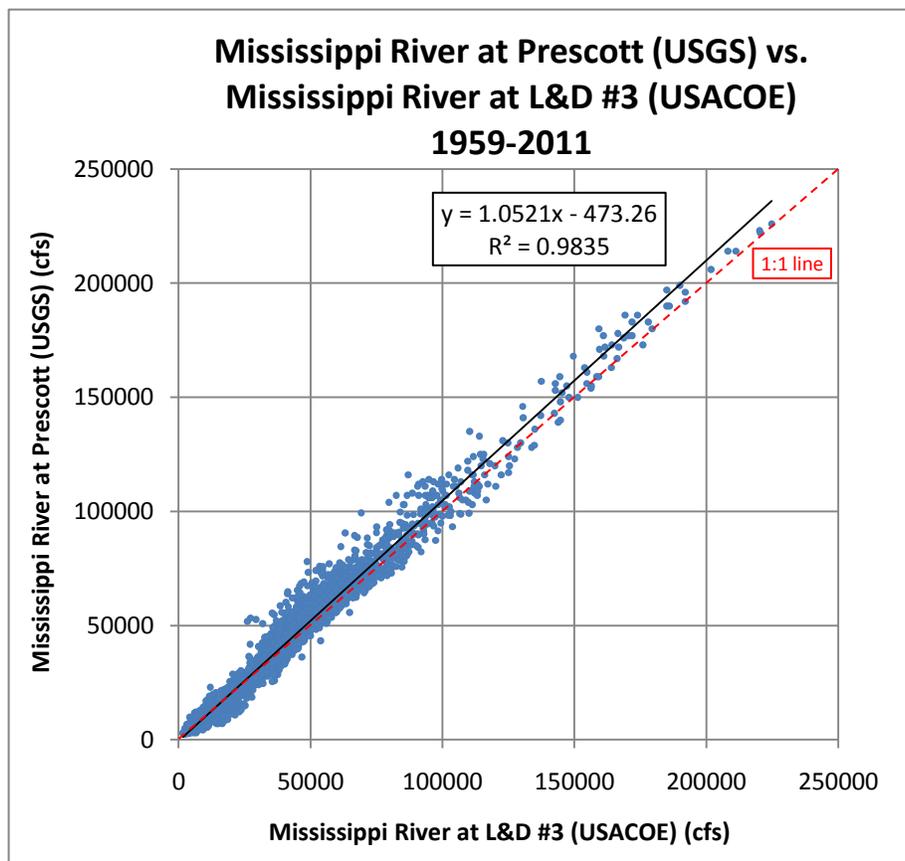
Secondary Flow Calculation Method

If data is not available from the USGS, daily average flow is estimated using USACOE flow reported at L&D #3, but adjusted using the following regression equation:

$$\text{Mississippi River above L\&D \#3} = 1.0521 * (\text{Mississippi River at L\&D \#3 (USACOE)}) - 473.26$$

Contributing Drainage Area

Approximately 44,800 sq.mi. (to USGS station 05344500 MISSISSIPPI RIVER AT PRESCOTT according to the USGS website).



VR20.6- Vermillion River at Farmington (upstream of WWTP)

Water Quality Data

Grab samples are collected by MCES staff at VR 20.6 off of Biscayne Avenue in Empire just downstream of Farmington. During construction work samples were collected at VR 21.9. Sampling began 04/18/77.

Primary Flow Calculation Method

Daily average flow data is calculated as follows:

$$\text{Vermillion River at Farmington} = (\text{Vermillion River near Empire}) - (\text{Empire WWTP influent})$$

Where *Vermillion River near Empire* is daily average flow collected by the USGS at station 05345000 VERMILLION RIVER NEAR EMPIRE, MN and *Empire WWTP influent* is daily average inflow to the Empire Wastewater Treatment Plant (effluent is not monitored). USGS data is available starting 04/12/1942, with a gap from 07/07/1945-10/01/1973. Empire WWTP went online 09/17/1979 and daily WWTP flows are available back to 06/01/1981. Monthly WWTP flows are available in hardcopy reports prior to 06/01/1981. Prior to Empire going online, wastewater flowed to the Apple Valley, Farmington, and Lakeville WWTPs which all discharged to the Vermillion River upstream of VR20.6.

Secondary Flow Calculation Method

None.

Contributing Drainage Area

109 sq. mi. (69,800 ac) as calculated using USGS StreamStats.

VR15.6- Vermillion River near Empire (downstream of WWTP)

Water Quality Data

Grab samples are collected by MCES staff at VR 15.6 off of Blaine Ave in Empire Township. Sampling began 08/02/1976.

Primary Flow Calculation Method

Daily average flow data is collected by the USGS at station 05345000 VERMILLION RIVER NEAR EMPIRE, MN. Data is available starting 04/12/1942.

Secondary Flow Calculation Method

None.

Contributing Drainage Area

129 sq. mi. (82,600 ac) according to the USGS website.