EROM Monthly Flows

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The Enhanced Runoff Method (EROM) provides Mean Annual stream flow and velocity estimates for all networked flowlines (stream segments) in NHDPlus V21. EROM also has the capability for performing mean monthly (MM) flow and velocity estimates. The MM flows were not released because of QA issues. These QA issues have been addressed and now the MM flows are available for distribution. The following describes the steps that have been taken to address these QA issues. The sections on EROM and EROMQA in Appendix A of the NHDPlusV21 User Guide have also been updated, and users are encouraged to review these updated sections.

Since the release of the MA and MM flows in 2014 there have been several other updates done to EROM. These updates are summarized at the end of this document and in the NHDPlusV21 User Guide.

EROM estimates are done on a "Vector Processing Unit" (VPU) basis. The VPUs are generally the same as the HUC-2's (Hydroregions) except for the Missouri Basin (Region 10) and the Southeast (Region 03) which are divided into multiple units because of their size. Figure 1 shows a map of the 21 VPUs in NHDPlusV21:

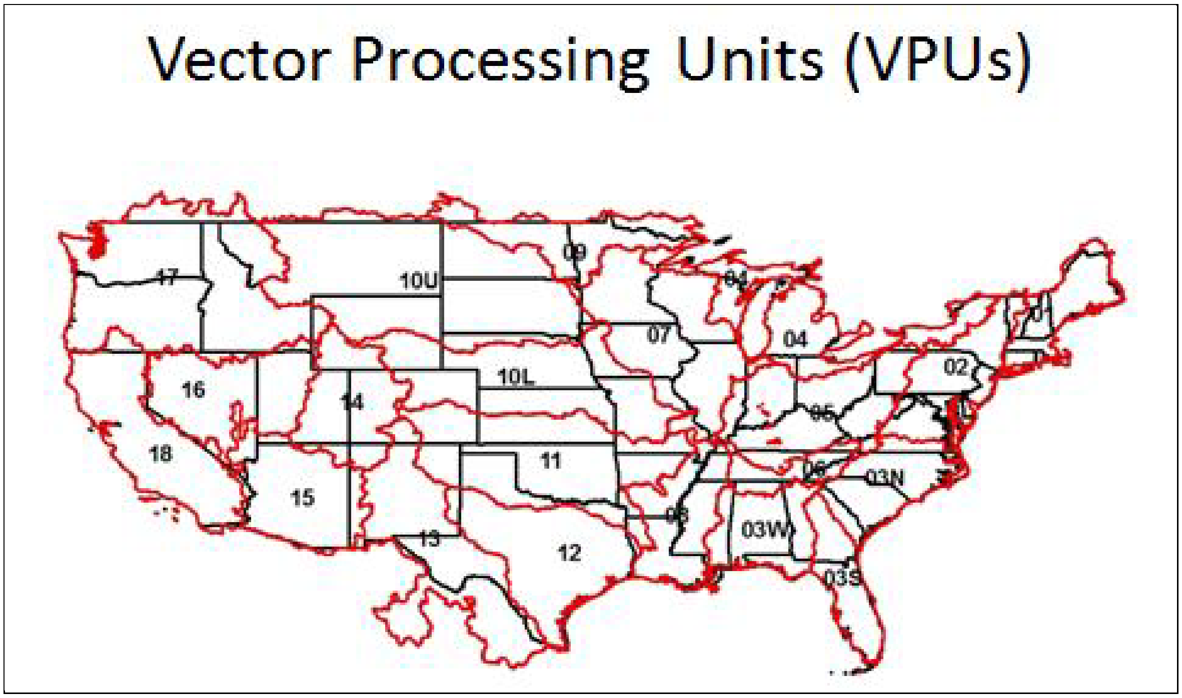

Figure 1: Vector Processing Units (VPUs)

EROM also has a QA module the compares the flow estimates to gage flows. The two statistics used for comparison are the Log10 mean values and the Standard Error of the Estimate (SEE). The SEE is a percentile; one can expect 2/3 of the EROM flow estimates to be within +/- one SEE. For instance, if the SEE = 50%, then one can expect 2/3 of the EROM flow estimates to be within +/- 50% of the gage flows.

In various months/VPUs, there are different QA issues. The objective of this work is to identify and correct as many MM flow QA issues as feasible. The outcome is full set of MA and MM flow and velocity estimates for all networked flowlines in NHDPlus V21.

An overview of EROM

EROM is a multi-step process with each step designed to incrementally improve the flow estimates. The MM flow QA can be affected, and improved, by factors related to any of these steps. The five steps used in EROM are:

1. Accumulated runoff based on the flow balance grids; this will be referred to as **Q_A**. Note: all EROM flows are based on the 30-year period from 1971-2000.
2. “Excess Evaporation”, (EET) which is applied to Q_A and takes into account stream channel losses as the flow moves downstream; this is referred to as **Q_B**.
3. A Reference Gage Regression (RGR) that has been found to be helpful in taking certain factors into account, such as a fairly consistent groundwater influence (first observed in the Great Lakes), but it helps in other situations as well. This is referred to as **Q_C**. Q_C can be considered to be the best estimate of natural flows, i.e., no manmade flow alterations.
4. A PlusFlowAR step that can be used for flow augmentation, withdrawal, transfer, etc. At this point, it is not heavily used in most Regions. It is used in the Pacific Northwest (Region 17) and in the Upper Colorado (Region 14). This is referred to as **Q_D**.
5. Gage flow adjustments, which correct flows a distance upstream and downstream of observed gage flows. This is referred to as **Q_E** and should be considered the best EROM flow estimate. This is most useful in correcting flows on larger rivers and accounts for any factors not taken into account in the prior steps, for instance reservoirs, withdrawals (not accounted for in Q_D), errors in flow estimation that occur in the previous steps, etc. This adjustment is done at all gages that meet the gage selection criteria: the reported drainage area in NWIS is within +/- 20% of the NHDPlus calculated drainage area and there are at least 20 complete years of record within the 30 years covered by EROM. This set of gage criteria is also applied in selecting the Reference Gages used in Q_C calculations. All gages meeting the criteria are used in this step.

Summary of QA issues by VPU

The first step in developing MM flows was to run EROM and the EROM QA for MA and MM flows in all 21 VPUs. A first cut overview of the QA issues by VPU for MM flows is shown in Table 1.

VPU	VPUID	Runoff	All Gages	Reference Gages	Notes
NE	01	Jan, Feb, Mar	Mar, Apr	Mar	
MA	02	Feb, Sep	Feb, Mar	Feb, Mar	
S1	03N	Oct, Nov	Oct, Nov	ok	
S2	03S	Oct	ok	ok	
S3	03W	Aug, Sep, Oct	ok	ok	
GL	04	Oct, Jan, Feb, Mar	Mar	Mar	RGR Works well
M2	05	Feb	ok	ok	not bad
M1	06	Oct	Oct	Oct	not bad
M5	07	Nov-Mar	Nov-Mar	Nov-Mar	
M7	08	Oct	ok	ok	need more gages
SR	09	Nov-Mar	Nov-Mar	Nov-Mar	VERY poor results
M4	10L	Dec-Feb	Dec-Feb	Dec-Feb	VERY poor results
M3	10U	Nov-Mar	Nov-Mar	Nov-Mar	VERY poor results
M6	11	Jan	Jan	Jan	VERY poor results
TX	12	ok	ok	ok	ok compared to MA
RG	13				need more gages
C1	14				EET does not work well
C2	15				EET does not work well
GB	16	Feb	Dec-Mar	Jan, Feb	
PN	17	Jan, Feb	Jan, Feb	ok	
CA	18	Jun-Aug	Jun-Aug		EET does not work well

Table 1. Summary of Mean Monthly Flow Issues by VPU, Runoff Step, All Gages, and Reference Gages

The most serious QA issue occurs in Great Plains VPUs in winter months. The “VERY poor results” means that SEE’s for these VPUs/months are on the order of hundreds of thousands, versus typical SEE’s of between 10% and ~100%. There are also issues in different VPUs/months in which the EET and/or RGR steps make the results worse.

Improving Mean Monthly Flows

Based on the review of MM flow issues, following steps were taken:

1. Increase the number of gages used in EROM by changing the gage selection criteria. An immediate effect of more gages will be that the Q_E adjustments will be done on more rivers which will improve the final EROM results. This is done by reducing the minimum number of years of record from 20 to 10 years. The effects of increasing the number of gages also increases the number of flowlines that are adjusted to match the gage flows.

An example of this effect is shown later. Preliminary testing shows the increase in gages is on the order of 35% to 92%.

2. Implement a change in the RGR step that was identified as an issue in MA flow estimates. This change is to limit the RGR flow adjustments to the range of the Reference Gage flows used in developing the regression. Cases were found in the MA flow estimates where the RGR step "over-adjusted" the larger stream flows. This has been implemented.
3. Add "switches" to EROM so that running or not running the EET and RGR steps can be specified by VPU/month.
4. The "VERY poor results" are caused by the flow balance model not being able to simulate very low runoff values when the mean temperatures are all less than zero (Deg. C). In these cases there is a very low flow that is primarily from base flow that is not included in the runoff model. A research effort was undertaken to see if a regression methodology can be used as a replacement for the runoff grids in these cases. The first test case is 10U for January. The results of this work are presented below.

<u>Replacing the runoff grids with a runoff regression – 10U January</u>

VPU 10U in January was selected as the test case for replacing the runoff grid with a regression. The statistics for 10U in January are a good example of the problem. The runoff statistics from the QA module are:

Number of gages: 203
Gage Log10 mean flow: 1.6118
Runoff Log10 mean flow: 0.1465
SEE: 319,688%

EROM uses a flow balance so that the sum of the incremental catchment flows upstream are equal to the flow on the current catchment. Therefore, the regression needs to estimate a unit runoff (URO) in cfs/km^2 so that the individual catchment runoff values can be estimated. Independent variables included:

Drainage area (DA) in Km^2
January precipitation (P) in Cm
January Temperature (T) in Deg. C
January and mean annual Base Flow Index (BFI) – a proportional value from 0 to 1

A database was constructed to join the URO to the independent variables, and then exported to Excel spreadsheets for detailed examination of data relationships and running the regressions. Log-log regressions were tested, including standardizing the log10 independent variables. It was decided to use Reference gages for the regressions. Reference gages will provide regressions reflecting "natural" flow, which best matches the runoff model flow estimates.

The best regression is a log-log regression using P, T and January BFI. Regression using P, T, and mean annual BFI regression was also quite good. To implement the test values the independent variables are needed on all catchments. A mean annual BFI grid is available, and the allocation and accumulation has already been performed for a separate project. Therefore the testing is done using mean annual catchment-level values for BFI. DA is not a significant independent variable, which is not surprising because the regression is on URO in cfs/km2. The regression statistics were good, with an adjusted R^2 of 0.94 and a Standard Error of 0.43 ($\log_{10}$ space).

An ad-hoc version of EROM was implemented to test replacing the runoff grid values with the regression approach. The Unit Runoff (URO) equation for the 10U January test is:

$$URO\ (cfs/km^2) = 10^{-4.54} * DA^{0} * P^{1.601} * (T+15)^{1.65} * BFI^{0.53} * 1.38$$

Below are the results of using the regression-based runoff approach for 10U January.

QA results for All Gages:

Number of gages: 374 (increased because of the reduction from 20 to 10 years of record)
Gage Log_{10} mean flow: 1.2779
Runoff Log_{10} mean flow: 1.4913
SEE: 205% (reduced from 99,104%)

QA Statistics for Reference gages:

Number of gages: 77
Gage Log_{10} mean flow: 0.9224
Runoff Log_{10} mean flow: 1.0585
SEE: 134% (reduced from 597,929%)

Production Runs for MM Flows

Based on the January 10U QA results, the regression approach is considered to be successful. There are a total of 17 VPU/Months with "VERY poor results". The regressions were run on all of these 17 cases. To implement this in a production version of EROM a new input table named EROMOPTS.DBF was built and implemented as a driver table for EROM. This table also contains VPU/Month-specific "switches" to run/not run the EET and RGR steps. The first-cut analyses of the MM flow QA found situations in which the EET and/or RGR steps did not work well for particular VPU/Months. Also, EROM enhancements were implemented so that the RGR adjustments were limited to the flow range of the reference gages and the production runs were done with the minimum period of record for gages reduced from 20 to 10 years.

The EROMOPTS table layout is presented in Table 2.

Field Name	**Description**
VPU	The 3 character identifier for the VPU, e.g., "10L"
Timeperiod	"MA" = mean annual, "01" = January, "02" = February, etc.

SkipEET	0 = Run the Excess Evapotranspiration (EET) step, 1 = do not run the EET step
SkipRGR	0 = Run the Reference Gage Regression (RGR) step, 1 = Do not run the RGR step
RUNOFFREG	0 = Do not use a Runoff (RO) Regression, 1 = Replace the Runoff grid values with the regression in the RO Step
ROA	RO Reg. Coefficient 1; intercept term
ROB	RO Reg. Coefficient 2; Drainage Area (DA) term (Sq Km)
ROC	RO Reg. Coefficient 3; Mean Monthly Precipitation term (cm/month)
ROD	RO Reg. Coefficient 4; Mean Monthly Temperature term (deg. C)
ROE	RO Reg. Coefficient 5; Mean Annual Base Flow Index (0 to 100)
ROBCF	RO Reg. Bias Correction Factor (BCF)
TPOS	Temperature (Deg. C) to be added to the Mean Monthly Temperature needed to produce positive temperature values for the log transform in the RO Reg.

Table 2. EROMOPTS Table

This new production version of EROM was run for MA and MM flows in all VPUs. In all cases the runoff regressions performed well. In many VPUs, it took a few full runs to “tune” the results to run/not run EET and/or RGR to achieve the best QA results. Also, to streamline production, the velocity calculation module was modified to automatically “loop” on all EROM runs in a VPU.

<u>The effect of increasing the number of gages on gage adjustments</u>

The gage adjustments are performed both upstream and carry downstream from the gage. Increasing the number of gages increases the number of flowlines that are gage-adjusted, improving the overall results. Figure 2 contains a map of VPU 18 (CA) showing this effect. The total number of flowlines with gage adjustments increases from 9,002 to 12,794. The dark purple lines on the map are the additional gage-adjusted flowlines.

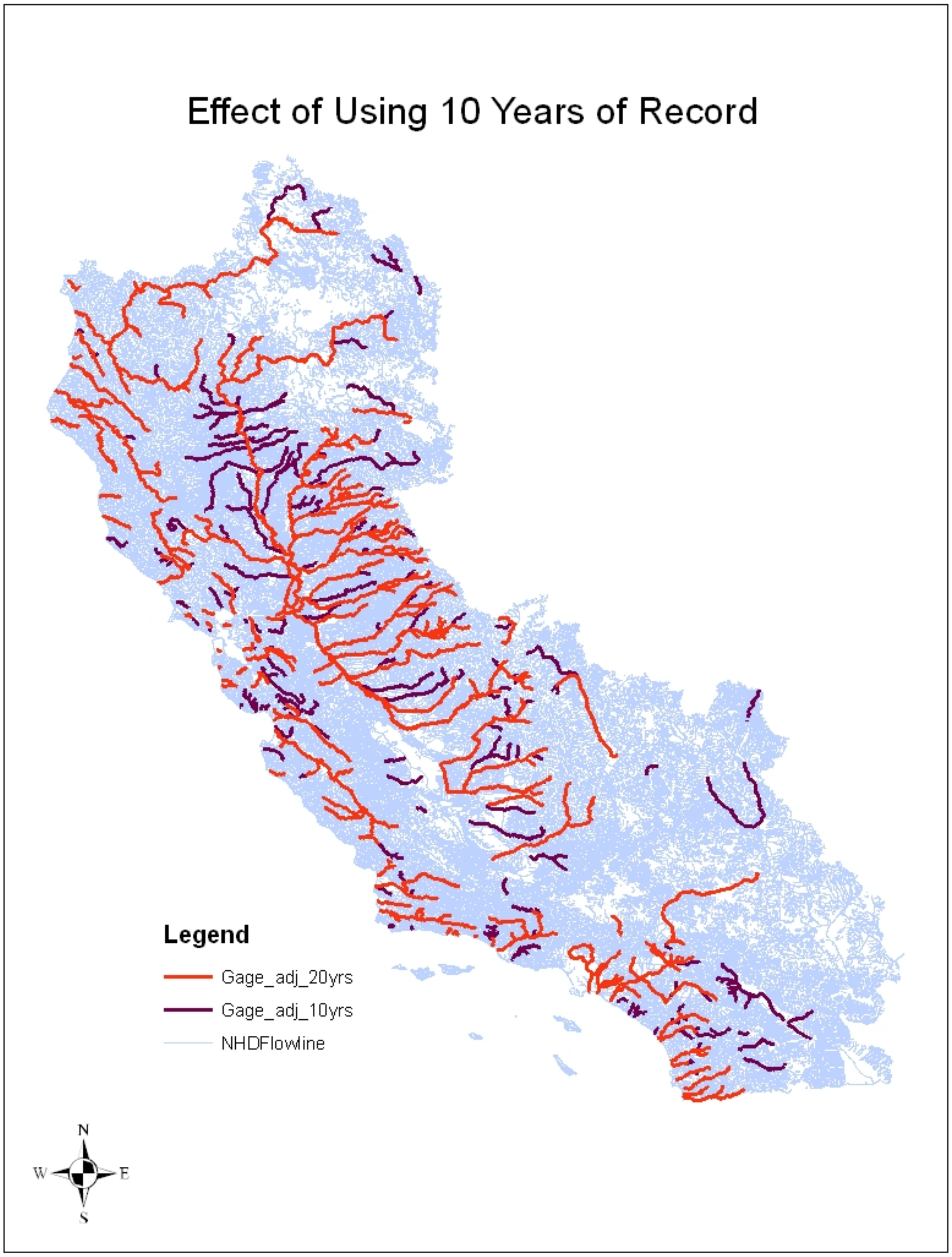

Figure 2: Effect of Using 10 Years of Record Versus 20 Years of Record

<u>Summary of the Steps Used for the Updated MA and MM Flows:</u>

1. Developed and ran the runoff regressions for the VPUs/months where the runoff SEE's are very large due to the winter runoff issue. There are 17 VPU/months where the regressions need to be performed.
2. Modified EROM to use a table of run options specified by VPU/month (EROMOPTS.DBF).

3. Re-ran EROM MA and MM flows for all VPUs and "tuned" the run parameters to achieve the best QA statistics. This required multiple runs of EROM in several VPUs.
4. Ran the velocity estimates.
5. Modified the EROM and EROMQA sections in Appendix A of the NHDPlusV21 User Guide.
6. Packaged the EROM files for distribution.

<u>Changes to EROM after the initial MA and MM release in 2014:</u>

There have been several changes and adjustments to the EROM flow and velocity computations. These changes are the result of user feedback and NHDPlus team analyses. The changes are summarized below:

1. The EET step is no longer run. There were problems with the step, including over-adjustments in certain headwater areas. The EET computation factors would need calibration, including coefficient changes within VPUs. This is beyond the scope of the national-scale EROM. The EROMOPTS table is used to "turn off" the EET step.
2. The RGR step has been modified as follows:
    a. The RGR is a log-log regression. The regressions are now computed using only flow values that are >0. Previously, an adjustment factor of 0.1 cfs was added to the flows to prevent the Log transformations from causing an error by trying to take the Log(0). An analysis of all of the Reference gage flows and corresponding EROM flows determined that there are very few cases with either flow being zero, so these cases are screened out of the regressions, the 0.1 factor is removed, and the RGR equations are adjusted accordingly.
    b. The RGR is applied to all EROM flows whether or not the flows are within the upper or lower bounds of the regression.
3. There was a problem with the incremental flows associated with EROM MA and MM flows. This problem occurred primarily for RGR and Gage Adjusted flows. To correct this problem, a new module was added that re-computed all incremental flows to ensure a flow balance. The flow balance enables the EROM flows to be re-computed using an accumulation of the incremental flows.
4. EROM velocities are now set to -9998 (missing value) in all water bodies except swamp/marsh. Also, EROM velocities are set to -9999 in estuaries. This is because the Jobson method used in EROM is valid only in flowing waters.
5. The NHDPlus VAA mean annual time of travel (TOTMA) has been updated based on the new EROM mean annual flows. Path time (PathTime) attribute has been added and populated based on the updated TOTMA values.
6. A QA step has been added that compares the EROM-computed divergence-routed cumulative drainage areas to the Value Added Attribute (VAA) based divergence-routed cumulative areas. This QA step is especially useful for detecting boundary value issues in EROM runs.

The NHDPlus Release Notes should be consulted for information on when these various changes were implemented. Also, consult Appendix A of the User Guide for more detail on EROM.