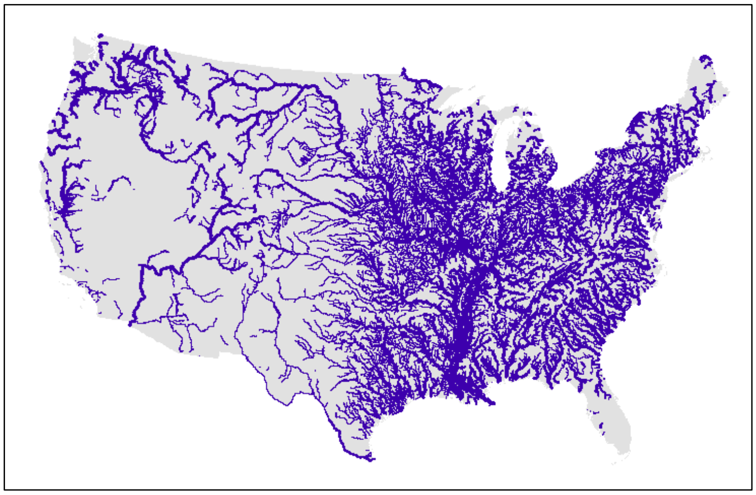
Development of 7Q10 Flows for the iSTREEM® 2.0 Model



iSTREEM® 7Q10 Flows; Map by Tim Bondelid

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Introduction to 7Q10 Flows for iSTREEM® 2.0

iSTREEM® is an in-stream environmental exposure model which is web-based and made freely available to the public by the American Cleaning Institute (ACI). The model provides a means to estimate concentrations of "down-the-drain" chemicals in effluent, receiving waters, and drinking water intakes across national and regional scales under mean annual and low-flow conditions for the continental United States and several watersheds in Canada.

The underlying model algorithm and data were recently upgraded and released as iSTREEM® 2.0 which incorporates the most current information available on wastewater treatment facilities from the 2012 Clean Watersheds Needs Survey by US EPA and national river network to the higher spatial resolution National Hydrography Dataset Plus (NHDPlus) version 2, which was jointly developed by the USGS and US EPA. The NHDPlus inherently provides the mean annual flow data for rivers across the United States, but low-flow (7Q10) data were not readily available.

ACI contracted the development of 7Q10 flow estimates for the NHDPlus river network to a team of Horizon Systems, Inc. and Tim Bondelid, Engineering Consultant. This report provides a background on the methodologies used for developing the 7Q10 flow estimates for iSTREEM® 2.0, documents the known issues and explores potential future enhancements.

The 7Q10 flow data thus generated for the NHDPlus river network is currently part of the iSTREEM® 2.0 model which is available for public use at www.iSTREEM.org.

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Development of 7Q10 Flows for the iSTREEM® 2.0 Model

I. Overview of iSTREEM® 7Q10 Flow Development

The 7Q10 flow estimates for the NHDPlus-based iSTREEM® 2.0 System were developed in 2015 by a team of Horizon Systems Corporation (HSC) and Tim Bondelid, Engineering Consultant. Lucinda McKay of HSC developed the iSTREEM® 2.0 thinned NHDPlus network and the 7Q10 flow estimates for USGS stream gages. The thinned NHDPlus is the portion of the full NHDPlus network that is on or downstream of the iSTREEM® pollutant dischargers (i.e., waste water treatment plant). The iSTREEM® 2.0 thinned network 7Q10 flow estimates were developed by Tim Bondelid, author of this report. The scope of the NHDPlus and associated data is the medium-resolution NHDPlus for the Continental United States.

The objectives of this report are to provide basic background on the methodologies used for developing the iSTREEM® 2.0 7Q10 flow estimates, to document known issues and to explore potential future enhancements to the iSTREEM® 2.0 7Q10 flow estimates.

This document will describe the development of 7Q10 flow estimates at stream gages, provide an overview of the two iSTREEM® Pilot Studies, the national iSTREEM® 2.0 7Q10 production process, and discuss known issues and caveats. The first iSTREEM® 7Q10 Pilot Study is covered in greater detail because that study developed the processes ultimately used for the iSTREEM® national production. The second pilot study refined and validated the approach developed in the first pilot study.

The starting point for the development of the iSTREEM® 7Q10 flow estimates was a project done during 2013 by Horizon Systems Corporation and Tim Bondelid for USEPA with the goal of computing 7Q10 flows for all of the networked flowlines in NHDPlus. This USEPA project, named "Estimating 7Q10 Flows Using NHDPlus Version 2 and the Enhanced Runoff Method (EROM)", tested a multiple regression approach. While the approach did not produce statistically acceptable results, it did provide a rich set of baseline regression variables and many important lessons were learned. The 7Q10 gage flows used the 1971-2000 time period, so this should be considered the timeframe for the iSTREEM® 2.0 7Q10 flows.

The work for the iSTREEM® model, which culminated in a thinned NHDPlus network and 7Q10 flow estimates on all networked flowlines, is an outgrowth of the hard and thoughtful work of many people over the past 30+ years. For more information, please see the NHDPlus Web links in the References Section.

II. 7Q10 flows at Gages: The Basis for the iSTREEM® 7Q10 Flows

The first part of the 2013 USEPA project ("Estimating 7Q10 Flows Using NHDPlus Version 2 and the Enhanced Runoff Method (EROM)") was to compute 7Q10 flows at stream gages across the Continental United States. There are two "standard" programs used for low flow statistics calculations: the USEPA DFLOW program and the USGS SWSTAT program. In consultation with USGS hydrologists, it was decided to use the DFLOW program to compute the 7Q10 gage flows.

The 7Q10 Gage flows used the USGS NWIS daily flow values from the 1971-2000 time period. A minimum of 10 complete years of record was required for consideration in these 7Q10 flow computations. This time period corresponds to the EROM system that is used for estimating mean annual and mean monthly flows. The genesis of the DFLOW 7Q10 flows is from the 2013 project for EPA that required the 7Q10 flow time period to match the EROM time period.

The DFLOW program was used in an "unsupervised" mode, which means that these flow computations were not reviewed and adjusted on a gage-by-gage basis. USGS standards require this gage-by-gage review in their work, however it was well beyond the scope of this project to perform the manual review.

There were significant difficulties with applying the DFLOW program. HSC overcame these problems with custom software and a mostly manual production process. The result is a dataset of 5,850 gages across the Continental United States with 7Q10 flow estimates. This dataset is the basis for the iSTREEM® 2.0 7Q10 flows.

III. Development of the iSTREEM® 2.0 7Q10 Flow Estimation Methodology

A. Rationale for Selection of the Pilot Areas

Given the problems with the USEPA 7Q10 flow estimation project, it was important to select two pilot areas that reflected the diversity of flow conditions in the United States. In general, the areas east of the Mississippi River are water-rich, while most areas in the West are arid. Two pilot study areas were selected in order to develop methods that could be effectively used for these very different hydrologic conditions. These two pilot areas are the Wabash River Basin and the Lower Colorado Basin as shown in Figure 1. The Wabash River Basin, Hydrologic Unit 0512, is water-rich, while the Lower Colorado River Basin, Hydrologic Unit 15, is mostly arid.

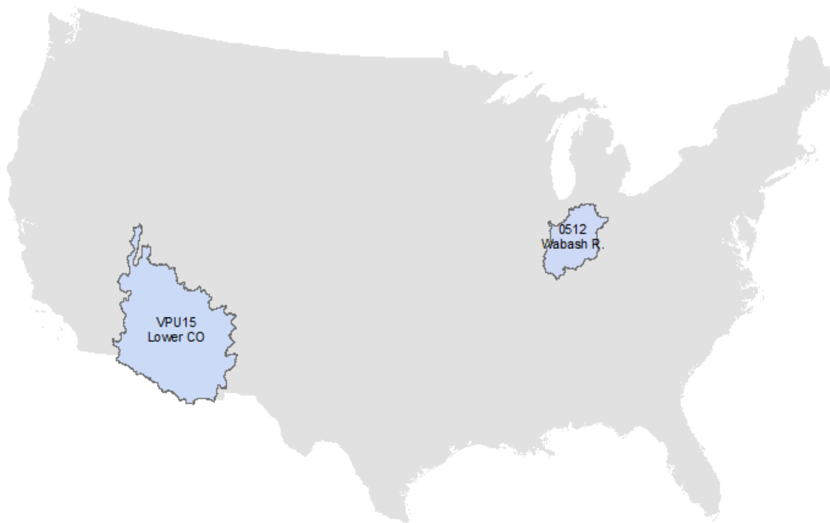

Fig. 1: Pilot Areas for iSTREEM® 7Q10 Flow Development

B. Pilot Area 1: Wabash River Basin

The Wabash River Basin, hydrologic sub-basin 0512, is a populated, non-arid area in the Midwest that contains several hundred pollutant dischargers. It was initially selected as a area pilot to test the multiple regression methodology. The concept was that the multiple regression approach would work better in smaller, more homogeneous areas than in a larger hydrologic unit. The USEPA regression study had found that drainage area, mean annual or mean monthly flow, and Base Flow Index were the most significant predictors for 7Q10 flows.

Various multiple regressions using log-log forms were tested. All of the regressions produced uniformly poor results. The basic reason for these poor results was that the 7Q10 flow characteristics varied greatly across the basin to such an extent that the independent variables available for regressions were not able to fully explain this cross-basin variation. The next section describes how the 7Q10 flows varied across the Basin.

i. Areal Variation in 7Q10 Flow Characteristics

Drainage area is consistently the most significant independent variable for estimating 7Q10 flows. One very useful way to look at the 7Q10 flows is the unit flow, which is the ratio of the 7Q10 flow divided by the drainage area. Fig. 2 shows the 7Q10 unit flows across the Wabash Basin. The gages are shown as green circles, sized by the unit flow (7Q10/Drainage Area). The thinned NHDPlus is shown in blue, with the Wabash River mainstem highlighted in red. Note in particular the Southwest area in the basin, with much lower unit flows than the northern part of the basin. The major problem for the regressions is that the regression variables were not able to explain this magnitude of variation.

Fig. 2: Wabash River Basin with iSTREEM® 2.0 NHDPlus, 7Q10 Gages and Wabash River Mainstem

The conclusion from these analyses was that the regression methods would be difficult if not impossible to streamline, even for smaller basins such as the Wabash. Therefore, a routing technique was developed and tested in this Basin.

ii. Development of NHDPlus-Based Routing Method

An examination of the unit flows in Fig. 2 shows that there can be significant variation in unit flows on tributaries as opposed to mainstems of rivers. The routing method for computing 7Q10 flows takes this variation into account. Note that for each gage on Fig. 2, the 7Q10 flow and drainage area are known. Also, the drainage area is known for each flowline in the NHDPlus network. This includes both the iSTREEM® subset network and the full NHDPlus network.

The routing method takes advantage of NHDPlus Value Added Attributes (VAAs), especially stream level (STREAMLEVE), level path identifier (LEVELPATHID), and hydrologic sequence (HYDROSEQ). Stream levels start at a value of 1; the tributaries to the level 1 stream are a level 2, etc. For example, the Mississippi River is level 1; the Ohio River is a tributary to the Mississippi River and is a level 2; the Wabash River is a tributary to the Ohio River and is a level 3 stream. For each of these streams the unique identifier is the LEVELPATHID. The LEVELPATHID makes it easy, for instance, to subset out one river. Fig. 2 takes advantage of this VAA to highlight the Wabash River mainstem. Finally, the HYDROSEQ can navigate a given LEVELPATHID from downstream to upstream, or upstream to downstream.

The basic routing method, as applied in the Wabash Basin, is to work from lowest level to highest level streams. The Wabash mainstem is processed first, by interpolating unit flows on the Wabash River between gages and extrapolating below the most downstream gage and above the most upstream gage. Given the unit flows for each flowline, the 7Q10 flow is readily computed as unit flow times the drainage area. The immediate tributaries are then processed, using a tributary-based unit flow. To illustrate this, the immediate tributaries to the Wabash mainstem are highlighted red in Fig. 3.

Figure 3. Wabash River with Mainstem and First-level Tributaries Highlighted.

After the mainstem is processed, the next level tributaries are processed from downstream to upstream. The LEVELPATHs are used to compute the changes in tributary unit flows and then they are used as the unit flows on tributaries. Note in Fig. 2 how the unit flows on the Southern part of the Wabash River are much smaller than the unit flows on the mainstem. This process is continued by level and level path until all flowlines are processed.

There are several advantages to this routing method. First, it dynamically takes 7Q10 flow variability into account as reflected by the 7Q10 flows at gages. Second, it can be applied nationwide. Third, it can deal with coastal areas where there are tributaries that enter the coast but do not have 7Q10 gages on them. This third capability exists because the NHDPlus includes the coastlines. The routing process will actually travel up the coastline, retaining the unit flow ratios from streams with gages as it goes.

iii. QA of the Routing Method

Three QA approaches were used in this Pilot area. Initially, a check of the flows at and around the gages was done to ensure that the routing method was working properly at the gages. Second, the 7Q10 flows were mapped using line thicknesses proportional to the 7Q10 flows to ensure that the fundamental 7Q10 spatial "pattern" was being replicated. Third, a comparison between the Pilot 7Q10 flows and the Reach File Version 1 (RF1) 7Q10 flow patterns was done.

As part of the QA process, a "sequestration" process was tested, in which a random subset of 20% of the gages was removed from the routing computations, and then the calculated flows were compared to the sequestered gage 7Q10 flows. The sequestration process proved to be too computationally intensive for consideration beyond a pilot effort. However, one important conclusion came out in this testing: It is important to use all of the available gages.

One basic issue considered was whether to use the iSTREEM® NHDPlus thinned network or the full NHDPlus network to compute the 7Q10 flows. This decision is very important from a production standpoint. The full NHDPlus contains 2.7 million networked flowlines, while the iSTREEM® NHDPlus thinned network contains 331,000 flowlines. The NHDPlus thinned network was further refined to remove divergences from the network and the final network used by iSTREEM® 2.0 contains 228,000 flowlines. Tests were performed using both networks in the Wabash Basin. The tests using the full network were then subset to the iSTREEM® network for analysis. Using the full NHDPlus network was found to be superior because it provided additional "information" in terms of more gages and the denser network. In other words, the more information the better.

Graphical comparisons of the iSTREEM® 7Q10 Flows to the RF1 7Q10 Flows were done, primarily to check for "patterns" of 7Q10 flows being similar, and to look for possible outlier issues in the iSTREEM® 7Q10 flows. This is a very useful general QA step. The RF1 7Q10 flows are the only known equivalent in geographic scope to the iSTREEM® 7Q10 flows. Also, the RF1 flows went through significant QA and peer review. The RF1 7Q10 flows at gages were manually analyzed by hydrologists to look for possible skewness in the flow distributions and then the 7Q10 flows were adjusted accordingly. Such a manual step was beyond the available resources for the 7Q10 gage flows used for iSTREEM. Issues with gage 7Q10 flows could possibly be flagged in a geographical comparison approach.

Fig. 4 shows the iSTREEM® NHDPlus network with the flowline thickness proportional to 7Q10 flow. Fig. 5 shows the RF1 equivalent network with reach thicknesses using the same proportional thickness as the iSTREEM®7Q10 flows. To appreciate the difference between the iSTREEM® NHDPlus and the full NHDPlus, Fig. 6 shows the entire NHDPlus network in the Wabash Basin. Figures 4 and 5 illustrate that the iSTREEM® NHDPlus and the RF1 7Q10 flows have the same basic pattern. There will be differences, attributable to differences in networks, gages used, and 7Q10 computation timeframes.

One comment on Figure 6: Note that there are stream density shifts, for example in the Southwest and the Northeast. These are map density-based shifts that are an artifact of the original maps used for NHDPlus. Also note that these map density shifts do not show up in the iSTREEM® network. This is because the thinning methodology is based on the location of dischargers, which are uniformly distributed across the basin.

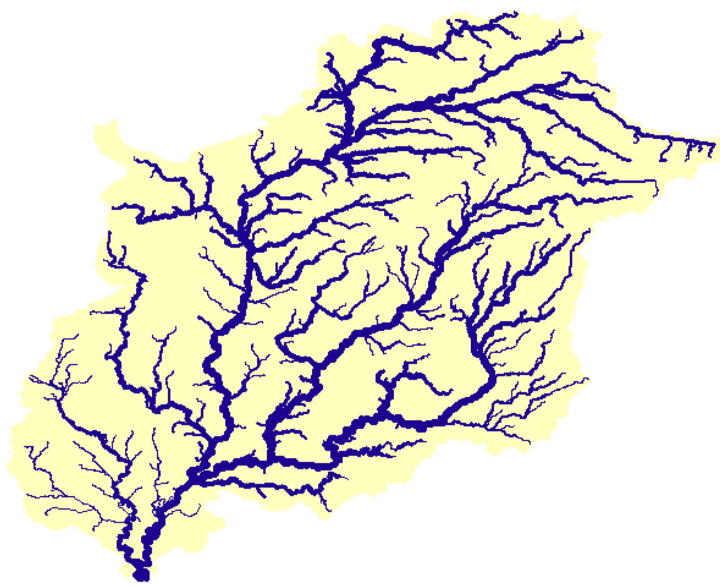

Fig. 4. Wabash Basin NHDPlus iSTREEM® 7Q10 Flows

Fig. 5. Wabash Basin RF1 7Q10 Flows

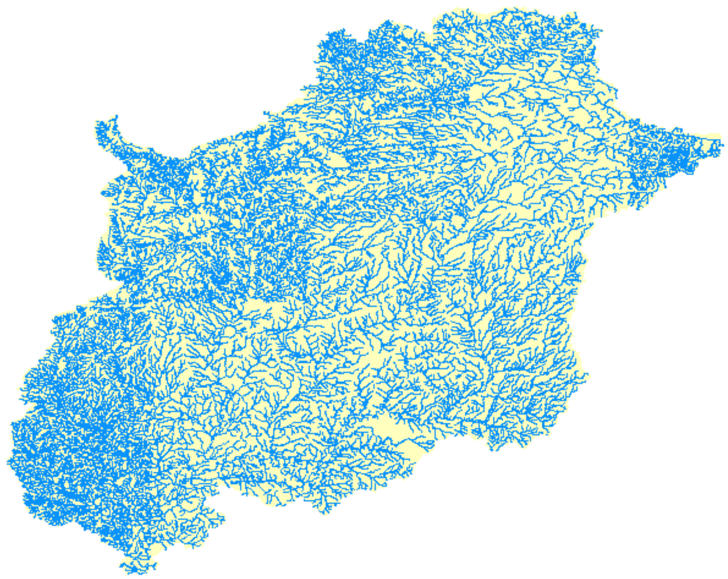

Fig. 6. Wabash Basin Full NHDPlus Network

C. Pilot Area 2: Lower Colorado River Basin

The methodology for Pilot Area 2 is fundamentally the same as for Pilot Area 1. The primary difference between Pilot Area 1 and Pilot Area 2 is related to which 7Q10 flow gages were used. First, in Pilot Area 2, two gages were manually removed because they were major outliers along the Colorado River. Also, it was found that there were some 7Q10 gages that were not used in the EROM gage adjustment. These gages were not used in EROM because the NHDPlus and USGS NWIS drainage areas are significantly different. This is an important criterion for drainage area-based analyses. Because the 7Q10 methodology is highly dependent on good drainage area estimates, 7Q10 gages that are not part of the EROM analyses are removed. Other than those minor adjustments, the same basic procedures developed for the Wabash Basin were successfully applied in the Lower Colorado Basin.

During Pilot Area 2, various tests were performed on the feasibility of continuing to use the "gage sequestration" technique to be able to develop QA measures. These tests were inconclusive and have not been pursued further.

The Lower Colorado Basin is a very dry area with a large part of it in desert. Figure 7 shows the iSTREEM® 2.0 thinned NHDPlus for this basin. The stream thicknesses are scaled by the magnitude of the iSTREEM® 7Q10 flows. Note that the Colorado mainstem is shown with highest 7Q10 flows. This is reasonable because the Colorado mainstem drains the Upper Colorado River, an area of 280,000 Sq. Km. Also note how few streams are in the iSTREEM® NHDPlus network. For comparison, the RF1 7Q10 flows are shown in Fig. 8, using the same line thickness scaling values that are used in Fig. 7. The iSTREEM® 7Q10 flows and the RF1 7Q10 flows show very much the same pattern. There are some differences, which is to be expected given all of the differences in the baseline data used: a different set of gages with different periods of record and different stream networks.

One important advantage of the iSTREEM® 7Q10 flows over the RF1 flows is that the thinned NHDPlus network includes the total drainage areas above the thinned network headwaters. This helps to improve the headwater 7Q10 flow estimates. The RF1 7Q10 flows have a major caveat in that the headwater 7Q10 flows are considered unreliable. In this respect, the iSTREEM® 7Q10 flows are an important advance over the RF1 flows.

The conclusion drawn from Pilot Area 2 is that the routing method developed in the Wabash Pilot is applicable to larger areas with very different hydrologic conditions. Therefore, this method is used for national production.

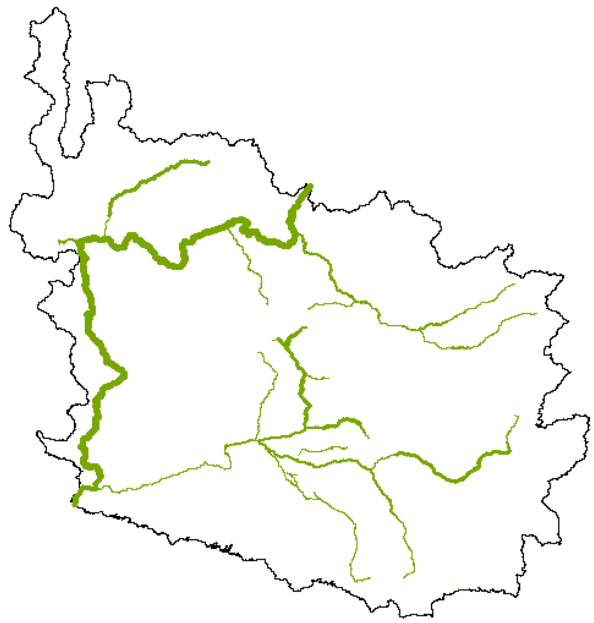

Fig. 7. iSTREEM® 7Q10 Flows in the Lower Colorado River Basin

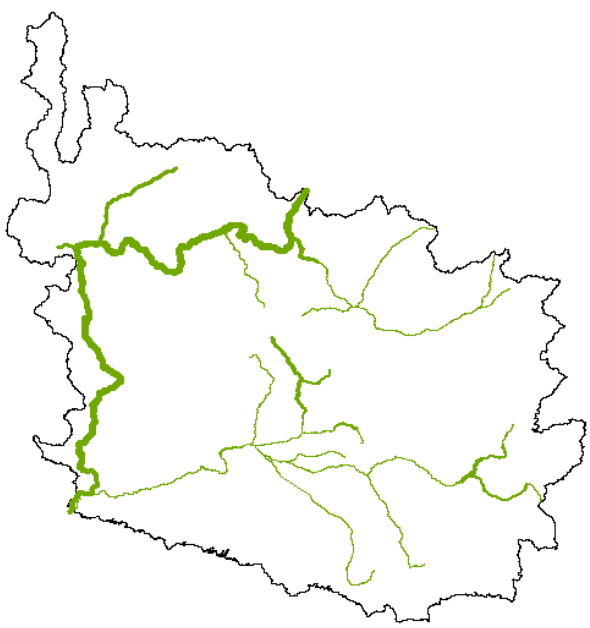

Fig. 8. RF1 Flows in the Lower Colorado River Basin

IV. National Production

The Pilot Area software required modification prior to the national production process. The software used for the Pilots and production is implemented in VB.NET and SQLServer. The Pilots showed that the best way to estimate the 7Q10 flows was to calculate them for the entire NHDPlus network and then subset out the results for the NHDPlus thinned network. National production could not be performed as one computer run for the entire U.S. due to the 2.7 million networked flowlines in NHDPlus. NHDPlus is built and consists of 21 Vector Processing Units (VPUs). VPUs were therefore the best breakout of the production processing units. The software was also modified to allow specification of a single VPU for processing. Finally, the production software was enhanced to produce the 7Q10 flow estimates for the complete NHDPlus network in a given VPU and to automatically subset out the thinned network flowlines and add them to a separate table.

A. NHDPlus Vector Processing Units (VPUs)

The VPUs generally line up with Hydrologic Regions, with a small number of exceptions. These exceptions occur where a given Hydrologic Region is too large for the NHDPlus production and development processes. Fig. 9 shows a map of the NHDPlus VPUs. Hydrologic Region 10, the Missouri River Basin, is divided into 2 VPUs, “10U” (upper) and “10L” (lower). The Southeast VPU 03 is divided into three VPUs.

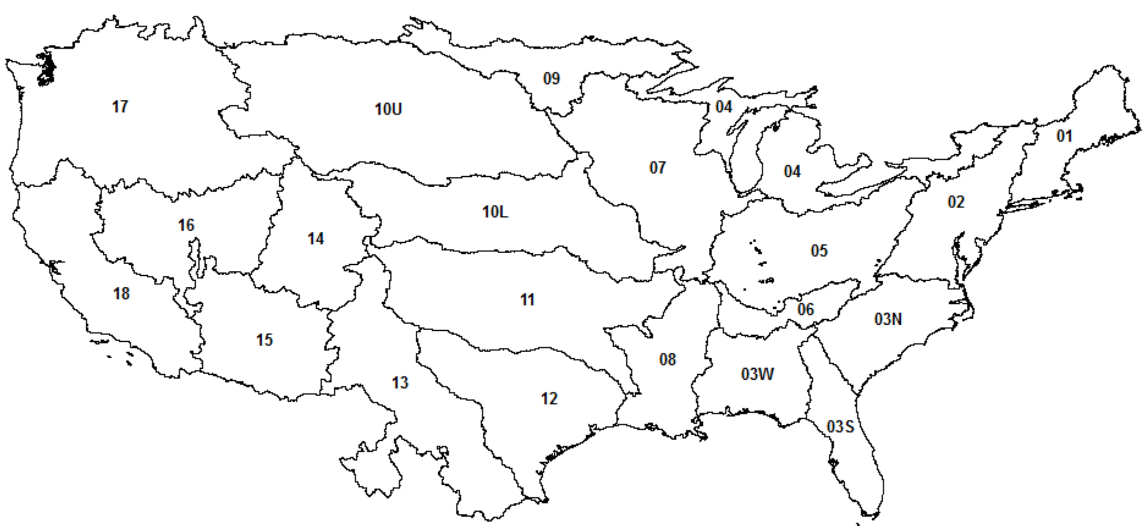

Fig. 9. NHDPlus Vector Processing Units (VPUs)

i. VPU-based Sequencing of Production

The 7Q10 flow estimations traverse the network from downstream to upstream. In many cases, the VPUs are independent units; thus they could be processed independently of other VPUs. This is the case for VPUs 01, 02, 03N, 03S, 03W, 04, 09, 12, 13, 16, 17 and 18.

The other VPUs needed to be processed in downstream-to-upstream order. It was necessary to incorporate a method to transfer the boundary value 7Q10 flows to the immediate upstream VPUs. This provided consistency and continuity in 7Q10 flow estimates. This boundary value method is described in the next section.

VPU sequencing is as follows. The Colorado River is divided into 2 VPUs: VPU 15, the Lower Colorado and VPU 14, the Upper Colorado. There, production processing had to be done first for VPU 15, then VPU 14. The Mississippi Basin needed to be started with VPU 08, the Lower Mississippi. From there, VPUs 11 (Platte River), 05 (Ohio River), and 07 (Upper Mississippi) can be processed. Then, VPU 06 (Tennessee River) and 10L (Lower Missouri River) are done. Lastly, 10U (Upper Missouri River) is processed.

ii. The “GAGEADD” Table

An auxiliary table, “GAGEADD”, was added to the production processing. This table did not include actual gages. One important part of GAGEADD is the cross-VPU boundary value 7Q10 flows for use in the cross-VPU processing.

B. 7Q10 Gage Data Gaps

GAGEADD also contained “pseudo gage” flows for special cases where the 7Q10 gage database did not contain gages at key portions of the network. In these cases, 7Q10 flows from RF1 were extracted to provide these supplemental gage values. The following places were added to GAGEADD:

1. The outlet of Lake Champlain in VPU 02 did not have a 7Q10 gage. A “pseudo-gage” based on the RF1 7Q10 flow was added at that point to provide better results in the Lake Champlain drainage area.
2. The Souris River in VPU 09 did not have a 7Q10 gage. A “pseudo-gage” based on the RF1 7Q10 flow was added at the downstream end to provide better results in the Souris River drainage area.
3. The Lower Rio Grande River Basin in VPU 13 did not have any 7Q10 gages. “Pseudo-gages” based on the RF1 7Q10 flows were added to provide better results on the Lower Rio Grande River.

As noted previously, one advantage of the 7Q10 routing method is that 7Q10 gage flows in coastal areas are used on nearby coastal streams that do not have gages. QA checks were made in selected coastal areas to ensure that this did in fact take place.

C. QA of Results

Throughout the production processing, QA checks were made in comparison to the RF1 7Q10 flows. It was not expected, nor did it occur, that the iSTREEM® 7Q10 flows would exactly match the RF1 7Q10 flows. There was, however, general agreement between the two 7Q10 flows. In the course of this QA, some specific issues were identified, for example problems along the Rio Grande River, which were corrected.

D. Format of the 7Q10 Results File

The iSTREEM® 7Q10 results for the U.S. were provided in the file format shown in Figure 10 below. The variable "Q7Q10B4IP" was added to the original table to help address problems associated with divergent flow paths. This issue is discussed below in the section on "Divergences and Intermittent Streams".

Field	Format	Description
Comid	Long Integer	NHDPlus Flowline Unique Identifier
Q7Q10	Double	7Q10 Flow (cfs); if IPFLAG=1, then 7Q10=0.
V7Q10	Double	7Q10 Velocity (cfs)
IPFLAG	Integer	Intermittent Flag: 0 = not intermittent, 1 = intermittent
GAGEID	Text 16	The Gage Identifier, "0" if no gage on the flowline. This includes 26 "pseudo-gages" added during the production processing.
QGAGE	Double	The gage 7Q10 flow, -9999 if no gage
DASQKM	Double	The divergence-routed cumulative drainage area (Km^2)
VPU	Text 8	The NHDPlusV21 Vector Processing Unit
Q7Q10B4IP	Double	7Q10 Flow Before Applying Intermittent/Perennial Designation

Fig. 10: Layout of the 7Q10 results Table

V. Primary Issues and Considerations for Use of the iSTREEM® 7Q10 Flows

In general, stream flow estimates in the Great Plains and in the Southwest can be problematic. These areas have a very high percentage of intermittent flowlines but many of the remaining major rivers have gages so, for the purposes of iSTREEM®, many of the rivers of interest can still have decent 7Q10 flow estimates derived from their existing gages. This very situation contributed to the accuracy of 7Q10 flow estimates in Pilot Area 2.

Many perennial (more accurately “not intermittent”) streams will have 7Q10 flows equal to 0. The intermittent designation is for streams that **normally** will not be flowing during portions of the year, for example streams normally dry in the summer and flowing only during wetter conditions or during storm events. The 7Q10 flow reflects these intermittent flows as well as drought-related events (“once every 10 years”).

It is to be expected that the 7Q10 flows can decrease going downstream for many reasons including evapotranspiration, losses to groundwater, and flow withdrawals. For these same reasons, a 7Q10 of zero can occur along the stream network.

It is worth noting that all of these conditions do exist in the iSTREEM® RF1 7Q10 flows. There are few RF1 segments with a 7Q10 flow equal 0. Most of these zero 7Q10 flows occur on headwaters, but by no means all of them. There are also many cases where the RF1 7Q10 flow decreases going downstream.

A. Areas with Known Problems or Issues

1. The 7Q10 flows for the Chicago Sanitary Ship Canal in VPU 07 are not reliable. No action was taken.
2. There are issues with the 7Q10 flows in the California Central Valley in VPU 18, particularly in some areas with divergent ditches and canals. No action was taken.
3. The isolated New River/Salton Sea in VPU 18 has poor results. No action was taken.
4. 7Q10 flows can and will decrease going downstream. This is to be expected as a characteristic of low flows.

B. Divergences and Intermittent Streams

An issue with 7Q10 flows at divergences has been noted when 7Q10 is greater than zero on minor paths of divergences, but is zero on the main stem. This is contrary to the major/minor divergent path designations in NHDPlus. The majority of the flow should in most cases be going down the major path. An investigation of this issue revealed that the problem goes back to the NHDPlus major/minor path designation methods. These methods follow named paths, and did not take the perennial/intermittent issue into account.

C. Lakes and Reservoirs

The iSTREEM® 7Q10 file has velocities which are calculated based on flowing rivers. These velocity calculations are not valid for lakes and reservoirs. The result is that the times of travel through lakes and reservoirs will be too fast. This issue is a possible problem for the iSTREEM® 2.0 first-order decay calculations. At the time the iSTREEM® 2.0 7Q10 flows were developed, there was no capability for computing volume-based times of travel through lakes and reservoirs. A recent update to NHDPlus however contains lake and reservoir volume information and procedures for computing times of travel in these waterbodies.

D. Estuaries

Similar to the lake and reservoir issue, flows through estuaries can be much longer than the velocity-based calculations will compute. As with lakes and reservoirs, when the iSTREEM® 2.0 7Q10 velocities were calculated, there was no existing estuary designation in NHDPlus. A recent update to NHDPlus provides a flag to designate estuarine flowlines, a designation that could potentially be used in future iSTREEM® modeling.

VI. Conclusions

A. Overall Success of the iSTREEM® 2.0 7Q10 Flows

The iSTREEM® 7Q10 flows represent a significant upgrade to the iSTREEM® system. Using NHDPlus rather than RF1 provides many advantages to the iSTREEM® community. Also, NHDPlus is heavily used for linking other data, and some of this additional data may be useful. One example of this could be State-defined Impaired Waters. For more information on additional data linked to NHDPlus see the references to NHDPlus.

B. Possible Refinements

A full production processing system has been built for computing the NHDPlus 7Q10 flows. This system could be used as needed or desired for refining certain aspects of the NHDPlus thinned network and the 7Q10 flow calculations. Refinements and upgrades could include:

1. Re-building the NHDPlus thinned network based on updates to the wastewater facility database.
2. Generating new gage 7Q10 flow estimates using a more current time period, e.g., 1981 to 2015.
3. Using the updated version of NHDPlus for the 7Q10 flow and velocity calculations. This process would primarily entail using more current versions of NHDPlus. This update could also include:
    a. Incorporation of the waterbody volume information for more realistic time-of-travel estimates through the waterbodies.
    b. Incorporation of the NHDPlus estuarine flags for modeling purposes.

C. Summary of Results

The routing methods used for the 7Q10 flows take advantage of NHDPlus characteristics that were not available for the RF1 7Q10 flows.

1. These flows are able to use many more stream gages because the NHDPlus network is much denser than RF1. This increase in density allows many more gages to be linked to the network.
2. There is a much richer set of data associated with NHDPlus as compared to RF1. In particular, drainage areas for NHDPlus are quite robust and help to improve on the 7Q10 flow estimates.
3. The thinned NHDPlus network is built to specifically include all of the WWTPs in the network.
4. This NHDPlus network is divided into much finer and more detailed segments than RF1. RF1 as used in iSTREEM® is divided into about 25,000 Reaches, while the thinned NHDPlus network contains 228,000 Reaches. In general, the average length of an RF1 reach is 10 miles, while an NHDPlus Reach is about 1 mile or less.

VII. References: Links to Relevant Data and Software

For more information about NHDPlus, including applications:

https://www.epa.gov/waterdata/nhdplus-national-hydrography-dataset-plus

https://www.epa.gov/waterdata

DFLOW Program:

https://www.epa.gov/waterdata/dflow

USGS SWSTAT Program:

https://water.usgs.gov/software/SWSTAT/

Reach File Version 1, Including RF1 Flows metadata:

Note: Web site no longer available on EPA Website; available at USGS:

https://water.usgs.gov/GIS/metadata/usgswrd/XML/erf1_2.xml

USGS NWIS Data:

https://waterdata.usgs.gov/nwis