Synthetic Rating Curves Factsheet (Public Domain)

FIM uses synthetically derived rating curves to relate an input flow value to its corresponding HAND stage value for a given reach. A Synthetic Rating Curve [SRC] is calculated using Manning's Equation, which is an empirical, one-dimensional [1D], steady-state hydraulic formulation that assumes uniform flow conditions. It is applied to compute a relationship between discharge and average HAND depth for each reach-catchment pair using the following:

01. Reach-Averaged Variables

02. Channel Bed Slope Approximation

03. Variable Roughness Coefficient

Manning's Equation

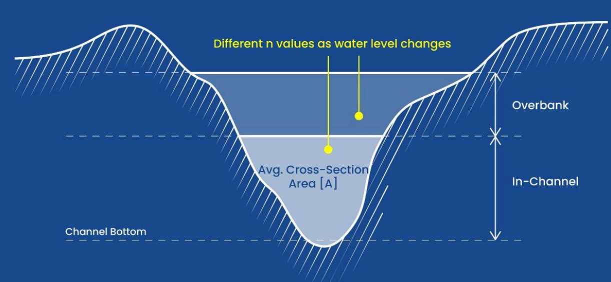
$$Q = \left(\frac{1}{n}\right) A R^{\frac{2}{3}} \sqrt{S}$$

n = Roughness Coefficient

A = Avg. Cross-Section Area

R = Hydraulic Radius

S_0 = Slope Bed

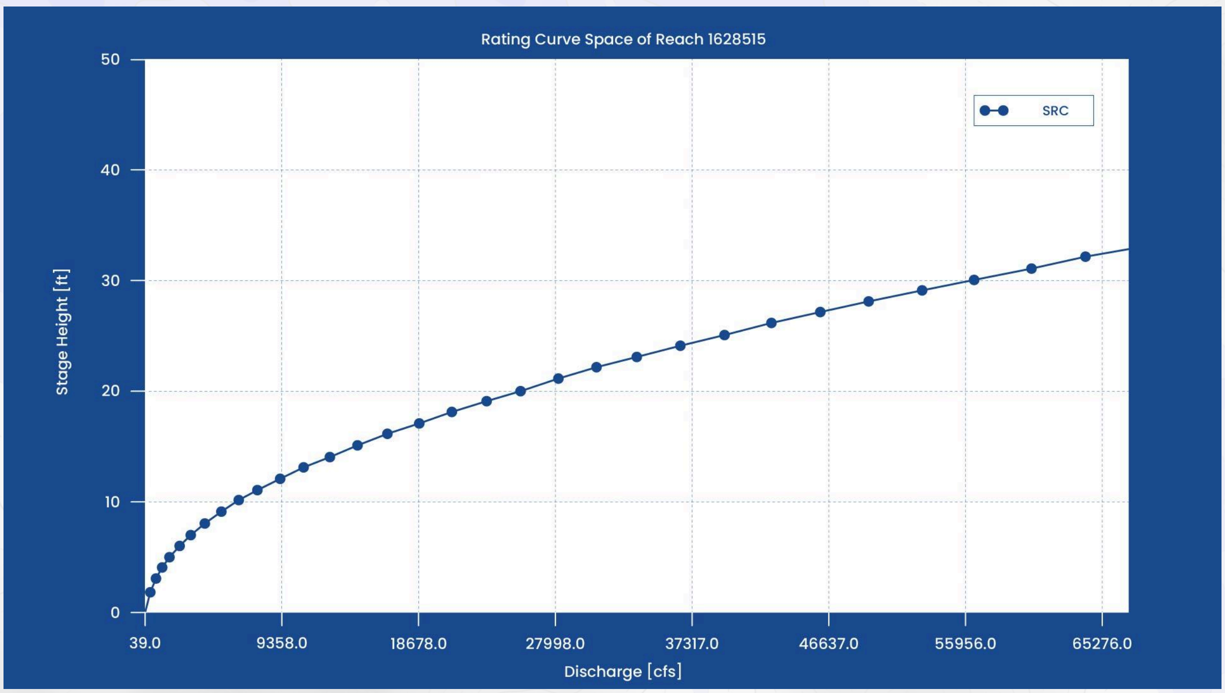


Manning's Equation

The HAND grid data is used to compute channel/floodplain geometry including the following reach-averaged variables:

1. Channel Top Width [T] is derived by dividing the Inundated Surface Area [As] by the Reach Length [L]
2. Cross Section Area [A] is derived by dividing the Volume of the Inundated Area [V] by the Reach Length [L]
3. Wetted Perimeter [P] is derived by dividing the Inundated Bed Area [Ab] by the Reach Length [L]
4. Hydraulic Radius [R] is derived by dividing the Cross Section Area [A] by the Wetted Perimeter [P]
5. Using the hydrologically-conditioned DEM, a Channel Bed Slope [S0] value is computed for each reach

Manning's Equation is calculated at 0.5ft stage intervals to derive a reach-averaged SRC for every unique flowline using reach, a channel bed slope approximation and a variable roughness coefficient for each reach in the hydrographic network. Two separate roughness coefficients are used in a new “subdivision” approach which was introduced in FIM V.4: one value is used for “in-channel” areas and the other for “overbank” areas. See below for an SRC example.



Limitations

SRCs are consistently being calibrated and improved. As such, updates are common, and the limitations listed below are accurate as of the publication of this summary sheet in October, 2024.

1. Synthetic Nature of Rating Curves
2. Channel Slope Value Accuracy
3. Does Not Account for Backwater Effects
4. Universal vs. Variable Roughness Coefficient in Manning

When working with SRCs, it's important to consider these limitations while bearing in mind that efforts to mitigate them are underway. The FIM development team is actively incorporating enhancements to address or compensate for these SRC limitations. For example, SRC calibration routines are configured in the FIM workflow to adjust/correct the default SRC. By ingesting observed or benchmark datasets, the calibration algorithms are able to recompute stage-discharge values that produce inundation extents that more closely match the "truth" data.

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01. Nature of Synthetic Rating Curves

Synthetic rating curves are not developed based on observed stage and flow measurements. There are known biases when computing reach-averaged geometry variables from the HAND outputs. When computing the inundated geometry at each stage interval, the geometry for all inundated pixels are factored into the calculations. This means that inundated areas outside of the primary flow conveyance path (e.g., off-channel pits, oxbow lakes, tributary channels) are included in the volume and bed area calculations along with the typical channel and floodplain domain. These "extra" areas can artificially inflate some of the geometry variables that are used by Manning's Equation.

02. Channel Slope Value Accuracy

There are uncertainties surrounding the accuracy of the channel slope value that the current workflow computes from the terrain defined channel thalweg. The existing algorithm used by the NWC to compute the rise over run values for each unique stream segment uses the hydroconditioned DEM along the channel, but there is an artificial limit on the minimum slope value to ensure that unrealistic slope values do not corrupt the discharge calculation. More investigation is needed to understand the sensitivity of these assumptions and limitations.

03. Does Not Account for Backwater Effects

Backwater effects occur along river segments where the velocity of water decreases or changes direction, due to changes in the hydraulic gradient, obstructions in the stream channel, or interaction with additional water bodies. This limitation is often pronounced at river confluences, the intersection of streams and infrastructure (e.g., bridges and culverts), as well as in regions of minimal relief (flat topography). Backwater effects can also occur when water flowing from multiple directions converges at one location, such as in coastal regions where coastal currents merge with river flows. The SRCs currently use a one-to-one relationship between the stage and discharge values. SRCs do not currently allow for multidimensional stage-discharge relationships.

04. Universal vs. Variable Roughness Coefficient in Manning's Equation

Historically, NWC FIM has relied on a single Manning's n [roughness] value that is applied to all stage values within an SRC. This configuration forces the user to select a single roughness value that will perform best for a specific type of flood event. Enhancements to the SRC workflow now allow for two Manning's n values for each SRC in an effort to better represent in-channel vs. overbank roughness characterizations. The goal of this enhancement is to bolster the model skill for a wider range of flood magnitudes [e.g., Action, Minor, Moderate, & Major flood stage thresholds] rather than optimize for a single flood magnitude. A shortcoming with this approach is the use of a global in-channel and overbank roughness value rather than physically based and spatially explicit characterizations [e.g., using a land class database to compute a variable roughness at each stage interval]. Initial tests using more spatially explicit roughness calculations were unable to outperform the global variable roughness approach with the evaluation framework currently available.