Updating Catskill Mountain bankfull discharge and hydraulic geometry regional relationships

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Introduction

- Regionalized regression relationships (regional curves) that predict bankfull discharge (Q_{bf}) and associated channel hydraulic geometry (W_{bf}, D_{bf}, A_{bf}) as a function of drainage area (DA) are widely used in applied fluvial geomorphology.
- Miller and Davis (2003) utilized 18 USGS gaged reaches to create initial regional curves for the Catskill Mountain region. In addition to an unstratified curve for the Catskills, hydraulic geometry and Q_{bf} data were stratified by hydrologic region (Lumia 1991), and mean annual runoff. By 2015, 21 additional USGS stream gages were eligible for potential inclusion in the regional curves.
- This study adds seven sites (6 new and 1 surveyed in 2004) to the existing regional curves, revisits potential stratifying covariables, and evaluates the merit of periodic updating of regional curves.

Methods

1. **USGS gage record assessment:** Log Pearson Type III flood frequency statistics were computed for all existing and eligible USGS stream gages in the regional curve data set to: (a) evaluate whether the 2003 Q_{bf} recurrence intervals changed; and (b) evaluate how flood frequency changed over time and with record duration.
2. **USGS gage site selection:** All eligible gaged reaches needed to (a) have periods of record >10 years; (b) have reasonably stable alluvial boundaries over a length at least 20(W_{bf}); (c) not be impacted by upstream flow regulation; and (d) exhibit obvious bankfull stage indicators. Preference was for sites representing needed DA values.
3. **Site reconnaissance:** Initial site visits confirmed or rejected sites from further assessment. Reconnaissance analysis included flagging bankfull morphology indicators and high water marks, test cross sections, and photo documentation. Sites were scored based on initial selection criteria and quality of bankfull morphology.
4. **Bankfull discharge calibration surveys:** Longitudinal profile and cross section surveys were conducted according to 2004 USGS Open File Report 03-92 protocol. Stream bed particle-size distribution was estimated using pebble counts.
5. **Data analysis and quality assurance:** Hydraulic geometry data were analyzed in Rivermorph software. Q_{bf} values were chosen by plotting best-fit lines in longitudinal profiles through stream gage locations and using stage-discharge rating tables to obtain discharge. Calibrated Q_{bf} values were checked using Manning's equation at surveyed cross sections.

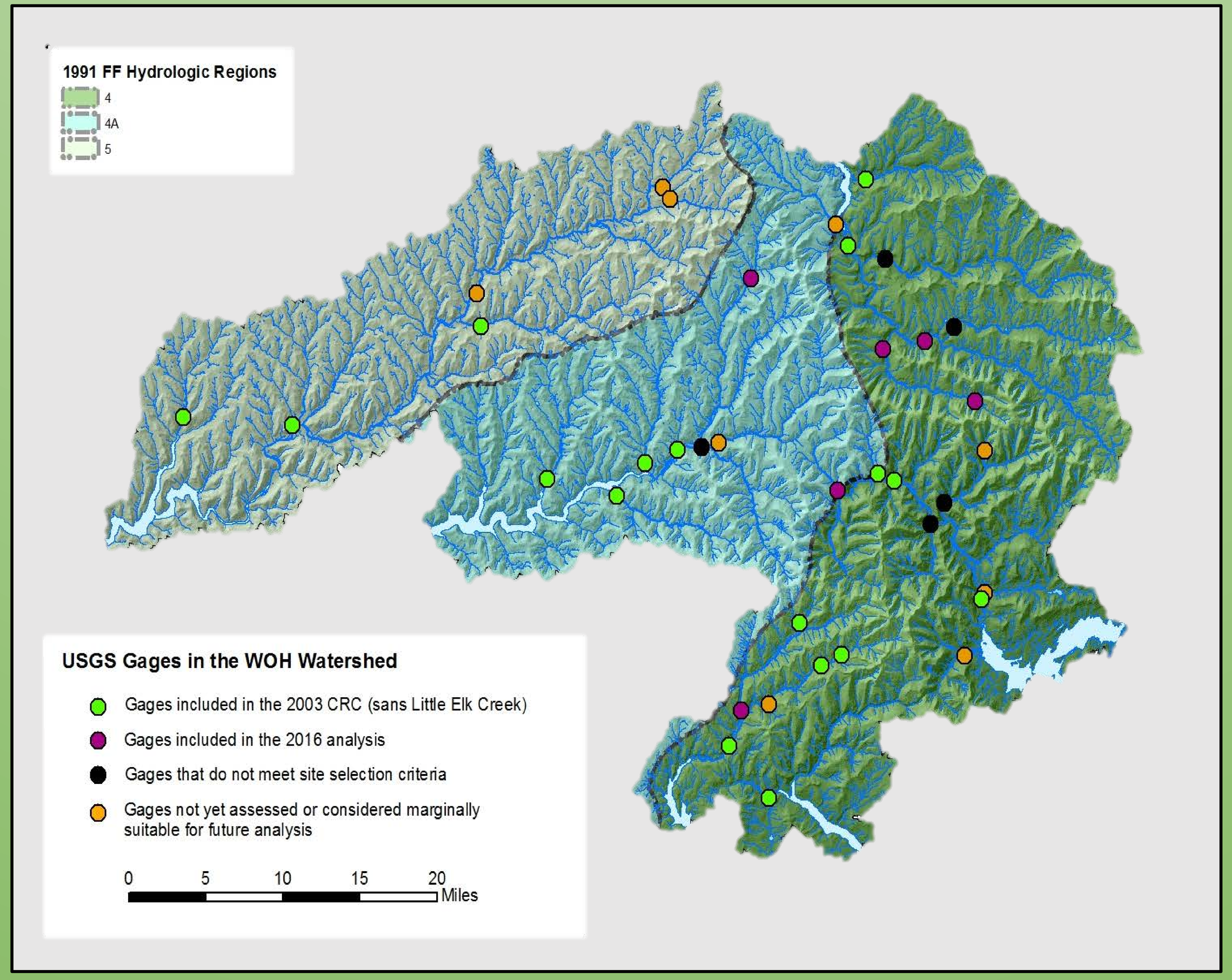
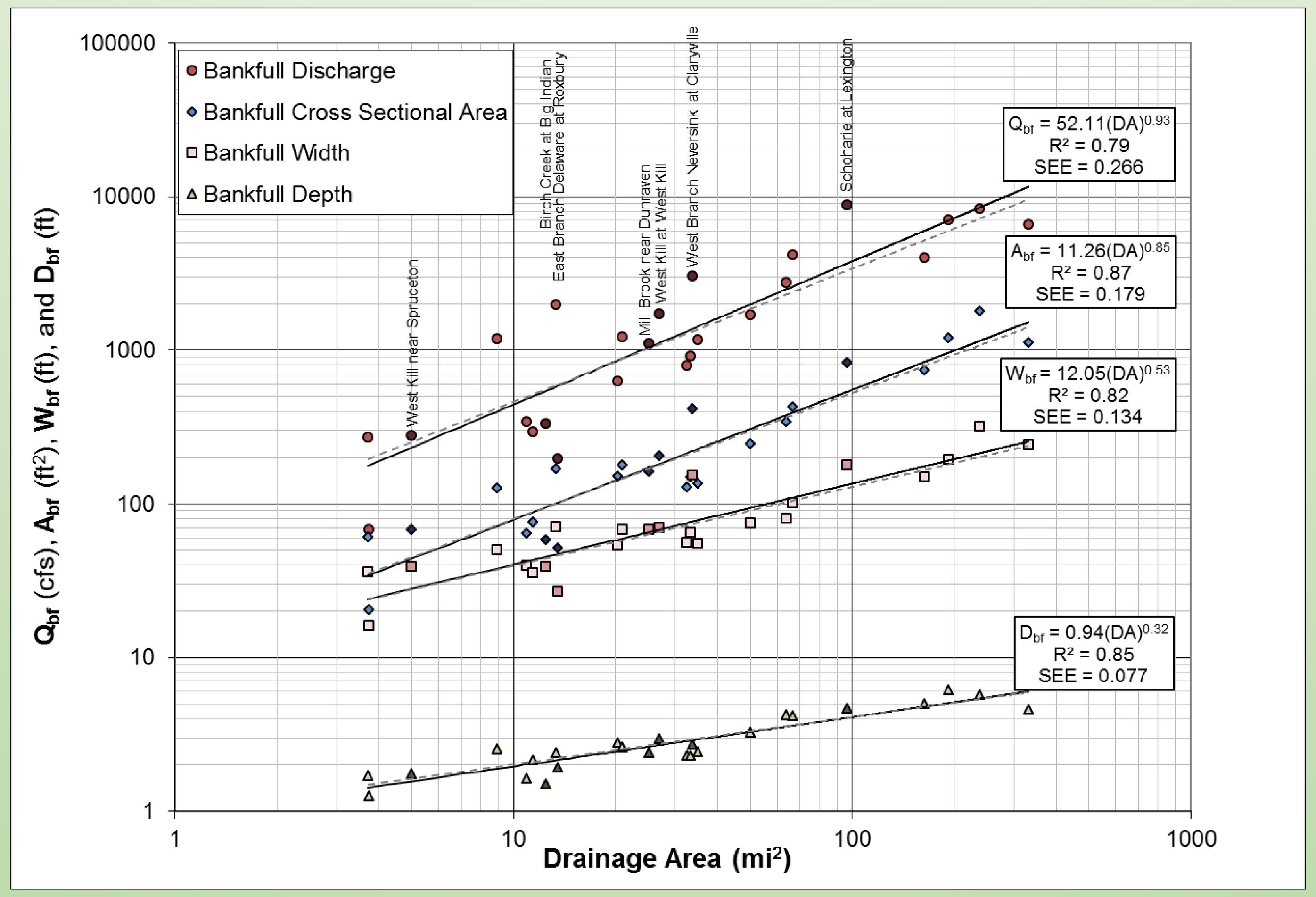


Table 1. All gage sites included in 2003 and 2016 studies. Sites added in 2016 shown in bold red.

Stream/Gage	Drainage Area (mi^2)	Hydrologic Region	Mean Annual Runoff (cfsm)[3]	Bankfull Discharge (cfs)	Return Period (yrs)	Mean D_{bf} (ft)	Mean W_{bf} (ft)	Mean A_{bf} (ft^2)
Biscuit Brook abv Pigeon Brk @ Frost Valley, NY	3.72	4	2.89	270.9	1.50	1.7	36.0	61.3
Little Elk Creek nr Westford, NY	3.73	5	1.70	68	1.24	1.3	16.1	20.5
West Kill near Spruceton	**5**	**4**	**3.04**	**276**	**1.33**	**1.8**	**38.8**	**68.0**
East Branch Neversink River ne Denning, NY	8.93	4	3.80	1187	1.25	2.6	50.1	127.0
Platter Kill @ Gilboa, NY	10.9	4	1.34	342	2.70	1.6	39.7	64.3
Bushnellsville Creek @ Shandaken, NY	11.4	4a	2.50	294	1.50	2.1	35.7	76.6
Birch Creek at Big Indian	**12.5**	**4a**	**2.31**	**331**	**1.55**	**1.5**	**39.1**	**58.3**
East Branch Neversink River @ Denning, NY	13.3	4	3.10	1982	1.65	2.4	71.2	169.2
East Branch Delaware River at Roxbury	**13.5**	**4a**	**1.91**	**196**	**1.26**	**1.9**	**26.8**	**51.2**
Trout Creek nr Trout Creek, NY	20.2	5	1.79	630	1.25	2.8	54.1	151.7
Chestnut Creek at Grahamsville, NY	20.9	4	1.96	1228	2.15	2.6	68.5	178.7
Mill Brook near Dunraven, NY	**25.2**	**4a**	**2.24**	**1100**	**1.70**	**2.4**	**67.8**	**161.0**
West Kill near West Kill	**27**	**4**	**2.69**	**1712**	**1.42**	**3.0**	**69.6**	**205.9**
Manor Kill @ W. Conesville nr Gilboa, NY	32.4	4	1.59	803.3	1.20	2.3	56.0	129.5
Tremper Kill near Andes, NY	33.2	4a	1.81	913.9	1.40	2.3	65.5	151.0
West Branch Neversink River at Claryville	**33.8**	**4**	**3.37**	**3027**	**1.55**	**2.7**	**152.5**	**412.4**
Platte Kill near Dunraven, NY	34.9	4a	1.98	1172	1.45	2.5	55.7	135.7
Little Delaware River nr Delhi, NY	49.8	5	1.9	1700	1.48	3.3	75.3	246.2
Esopus Creek @ Allaben, NY	63.7	4	2.39	2772	1.65	4.3	80.5	342.9
Neversink River nr Claryville	66.6	4	2.96	4182	1.30	4.2	102.2	426.5
Schoharie Creek at Lexington	**96.8**	**4**	**2.68**	**8759**	**1.42**	**4.6**	**178.8**	**829.9**
East Branch Delaware River @ Margaretville, NY	163	4a	1.94	4047	1.32	5.0	149.6	747.1
Esopus Creek @ Cold Brook, NY	192	4	2.4	7069	1.20	6.2	194.7	1201.0
Schoharie Creek @ Prattsville, NY	237	4	2.02	8344	1.25	5.8	320.1	1814.6
West Branch Delaware River at Walton, NY	332	5	1.83	6644	1.33	4.6	243.6	1121.2

Results

1. 2016 Unstratified Catskill Regional Curves

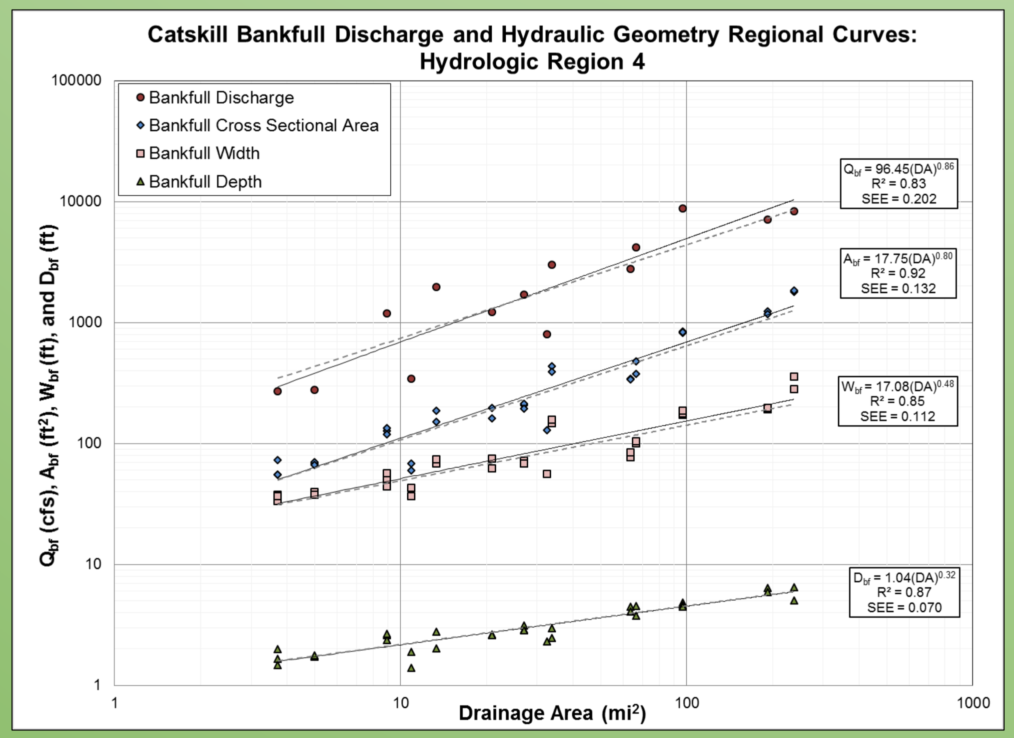


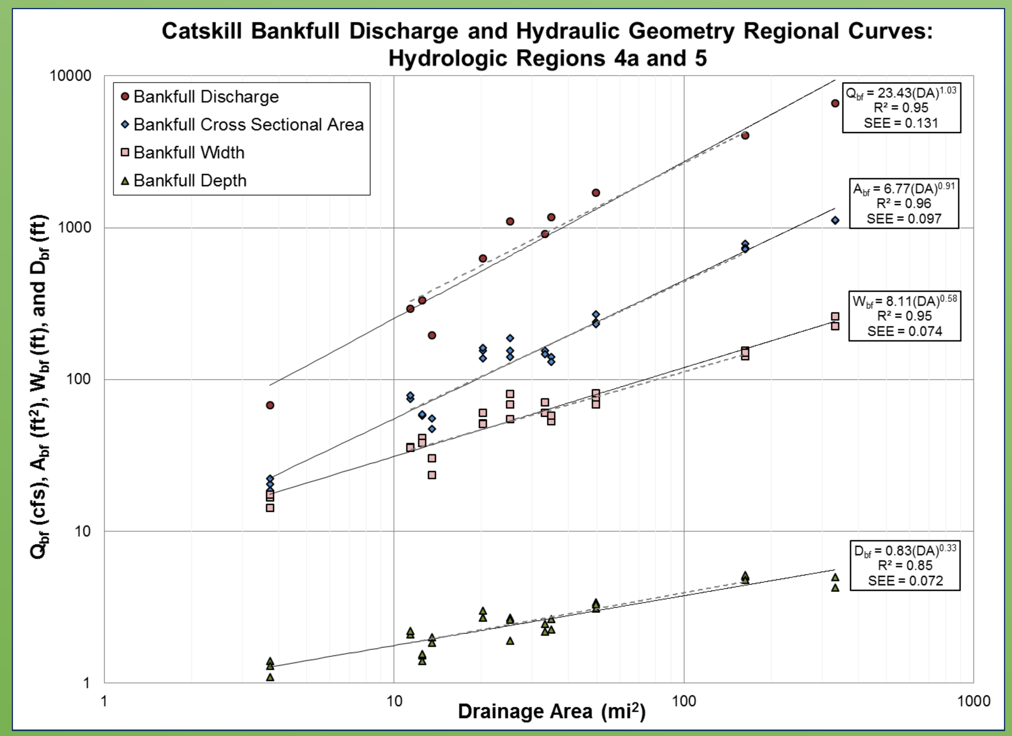
Dotted lines represent 2003 Catskill Regional Curve trends on all graphs.

Comparison to 2003 Study

Coefficients of determination (R^2 values) marginally decreased in all stratified regressions except for Hydrologic Region 4. Increasing sample size in Hydrologic Region 4 from 10 to 14 sites, covering underrepresented drainage areas, improved regression statistics. Slopes increased and slope intercepts decreased in each stratification with the exception of D_{bf} relationships in HR4 and MAR<2.3 which remained the same. Channel dimensions increase at a greater rate of change than previously predicted; however, channel dimensions for small drainage areas are less than previously predicted.

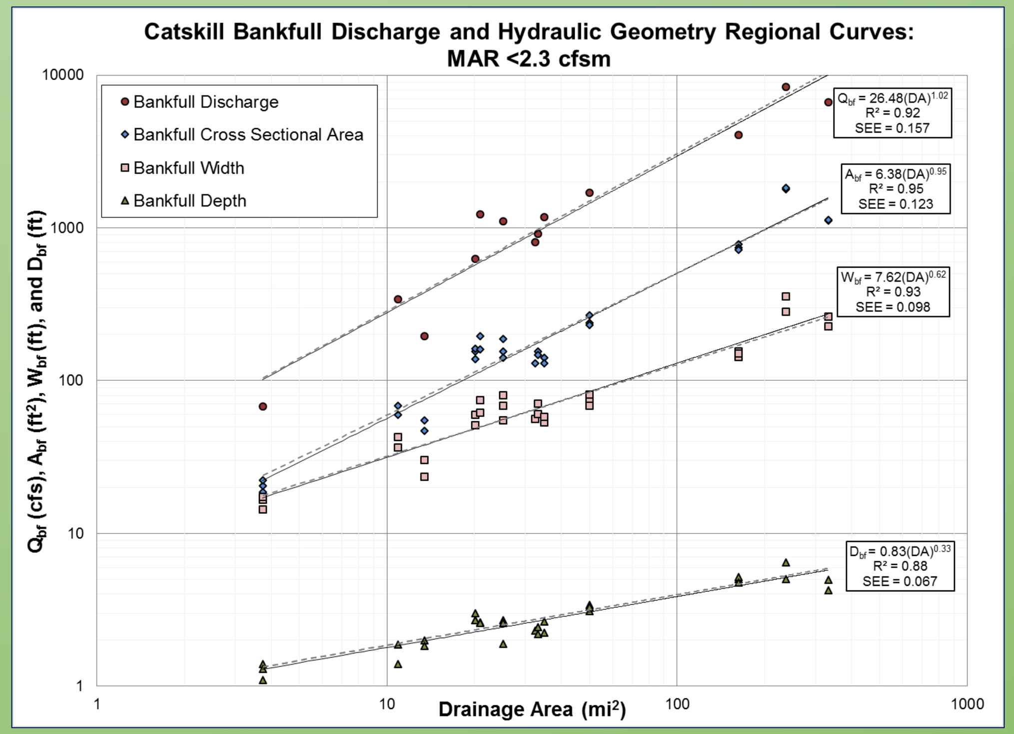
2. Stratified by Hydrologic Region

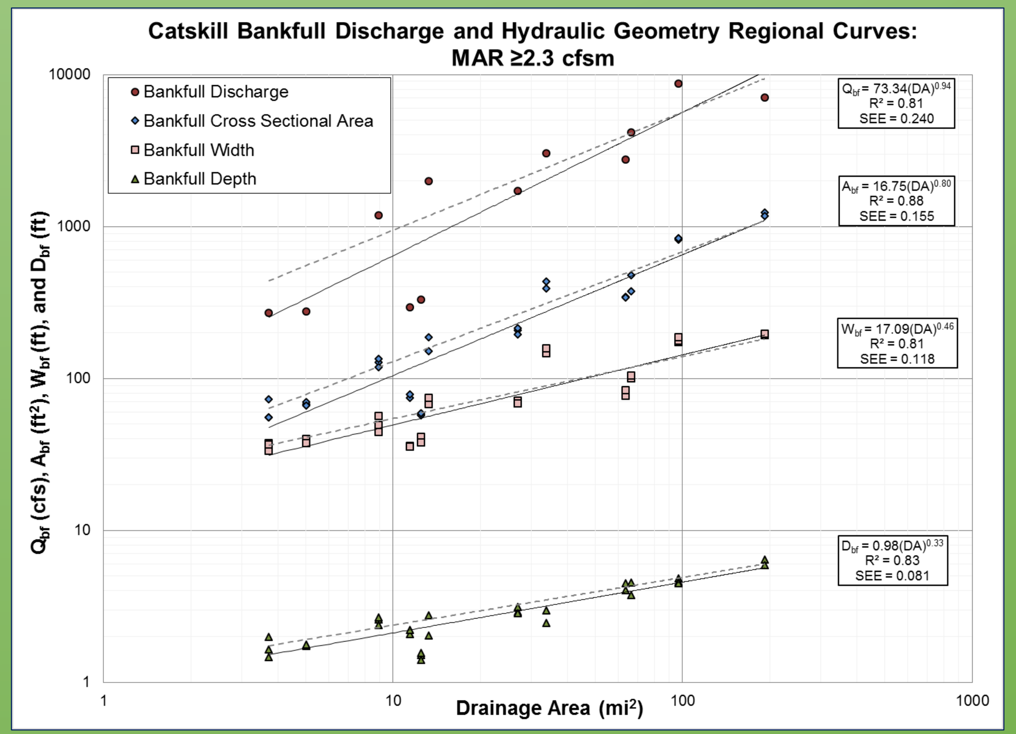




Regression for HR 4a and 5 produce very similar results (Miller and Davis 2003) and therefore were combined for the 2016 study. Dotted lines represent 2003 HR4a regional curves. Slope increased for HR4a data but vary for 4a and 5 combined.

3. Stratified by Mean Annual Runoff





SEE Error

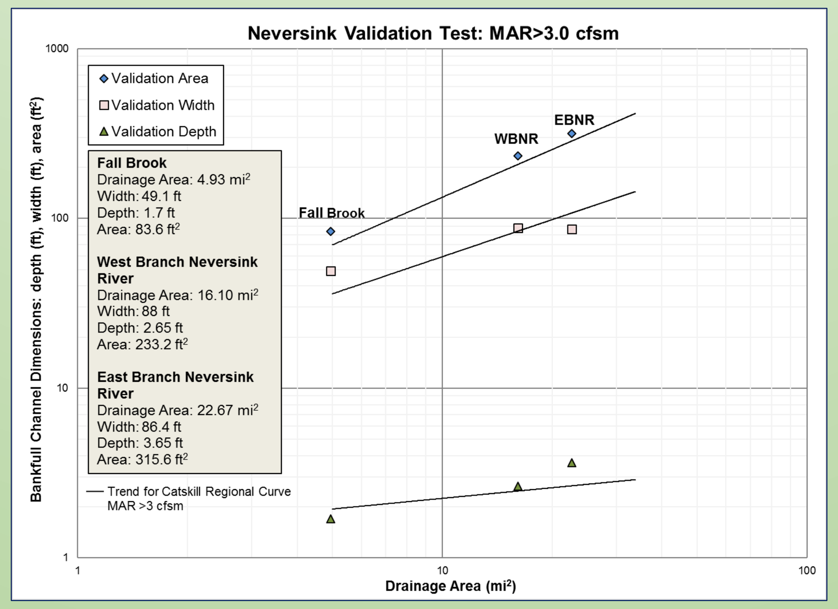
The 2016 CRC Update includes calculation of Standard Error of Estimate (SEE) to supplement R^2 values. SEE represents the average distance that observed values fall from the regression line.

Discussion

- Increased number of sample sites allowed evaluation of further refined MAR classes of <2cfsm, 2<MAR<3cfsm, and >3cfsm. Refinement of discrete MAR classes provides generally improved relationships.

MAR<2	**2<MAR<3**	**MAR>3**
$A_{bf} = 7.10(DA)^{0.90}$	$A_{bf} = 10.59(DA)^{0.89}$	$A_{bf} = 15.59(DA)^{0.93}$
$R^2 = 0.95$ n = 11	$R^2 = 0.92$ n = 10	$R^2 = 0.99$ n = 4

- Bankfull hydraulic geometry values from ungaged reaches in the Neversink watershed were plotted on the MAR>3.0 curve to test predictive validity. Points show a reasonable fit and are within the SEE. Validation tests for the other MAR stratified curves also produced a good match between observed and predicted values. The USGS StreamStats application can be used to obtain MAR values for use in applying the MAR stratified curves.



Conclusion: *Periodic revision of Catskill Mountain regional curves is useful for stream management applications.*

Recommendations for Future Study

1. Revisit sites with significant changes in return period flow statistics or sites with >2.5 year return periods that appear to be outliers in regional regression trends.
2. Prioritize future sites that represent drainage area gaps in existing predictive relationships.
3. Test hydrologic region values of Q2 as predictors of bankfull channel geometry in the Catskills (He and Wilkerson 2011). Preliminary test indicates this is an improvement over DA as a predictor variable.
4. Limit hydrologic region delineation to low return period flow statistics, and test for suitability for bankfull regional curve stratification.
5. Expand use of bankfull stage indicator ranking index for site suitability evaluation.
6. Further investigate combining hydrologic regions 4a and 5 for use in the Catskills.
7. Develop multivariate regression relationships to test available co-variables, e.g. mean annual precipitation and mean basin slope, in addition to drainage area.

References

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Acknowledgements

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