SRAT Model Calibration

SRAT functionality is based upon pollutant loads estimated from use of the *MapShed* modeling application (see www.mapshed.psu.edu). In this case, loads were developed for 426 HUC-12 basins within the larger Delaware River Basin (DRB). With the SRAT, loads are essentially re-distributed to smaller NHD catchments, which number about 15,000 within the DRB. With this tool, loads can also be aggregated downstream. As loads move downstream, an "attenuation factor" is typically applied to account for natural reductions that occur as a result of such processes as de-nitrification, plant uptake and sedimentation.

To assure that pollutant load estimates being calculated by SRAT are reasonably accurate, a limited amount of calibration was performed using observed stream flow and water quality sample data available at a number of existing USGS sampling stations located throughout the DRB. For this purpose, stream flow and water quality data were compiled for twelve stations (see Figure 1) for a 10-year period from 2006-2015. Each of these stations has daily flow, as well as a sufficiently long-term record of sampling observations for nitrogen, phosphorus and sediment (TSS). A listing of these stations is provided in Table 1.

Table 1. List of USGS stations to be used for calibration purposes.

Stream Reach Name	USGS Station No.	Area Drained (Sq. Miles)	Stream Reach Name	USGS Station No.	Area Drained (Sq. Miles)
Brandywine R./Del.	01481000	287	E.Br. Delaware/Fish Ed.	01421000	784
Schuylkill R./Phila.	01474500	1893	Flat Brook/Flatbrookville	01440000	64
Lehigh R./Glendon	01454700	1359	Paulins Kill/Blairstown	01443500	126
Brodhead Cr./Minisink	01442500	259	Delaware R./Trenton	01463500	6780
Bushkill Cr./Shoemakers	01439500	117	Maurice River	01411500	112
Delaware R./Pt. Jervis	01434000	3070	Neshaminy River/Lang.	01465500	210

Using the monitored water quality data, statistical load versus flow relationships were first developed for each of the calibration stations. Daily stream flow data were then obtained from USGS at www.waterdata.usgs.gov/nwis , and daily pollutant loads for the calibration period were subsequently computed for each corresponding drainage area using the statistical relationships (rating curves) previously developed. Loads computed in this fashion were then used as the "observed" loads against which SRAT-simulated loads were compared.

Figure 1. Location of pollutant loading calibration points within the Delaware River Basin.

Using the observed daily load data described above, mean annual loads were computed for each of the twelve stations and compared against the corresponding estimates from SRAT. Based upon a preliminary assessment of the loads, it was believed that they were already close to those predicted by USGS using their SPARROW model (Moore et al., 2011), and that the differences between the observed and SRAT-produced loads could be attributed to slight differences in the attenuation factors used. Therefore, a primary focus of this particular activity was to “fine-tune” the attenuation factors in order to achieve a “best-fit” between the observed and predicted loads across the twelve sampling station locations.

Model Results

As described above, SRAT was used to calculate nutrient and sediment loads for each of the NHD catchments as well as the entire DRB. As part of the calibration process, the loads delivered to the outlet of the drainage areas represented by the twelve calibration points shown in Table 1 were calculated by summing the values for the corresponding NHD catchments. These were then compared to the observed loads at each point. Table 2 shows the simulated and observed loads (expressed as loading rates in kg/ha) for each of the calibration sites.

Figures 2 through 4 graphically show the comparisons between the observed and simulated loads for the calibration points using the mean annual loading rate (in kg/ha) as a standardized unit of measure. As can be seen from these figures, the SRAT approach provided a reasonably good estimate of the nutrient and sediment loads on a mean annual basis, with the total phosphorus (TP) estimates being the most accurate (R^2 = 0.95), and the total suspended sediment (TSS) estimates being the least accurate (R^2 = 0.61).

As can be seen for TN, estimates from SRAT were under-predicting loads by about 14% on average. In this case, it is suspected that the under-prediction may primarily be due to the general unavailability of good data on nitrogen discharges from wastewater treatment plants in the DRB where only ammonia concentrations (which are general a very small fraction of TN) are typically required by regulatory agencies. In many cases, TN concentrations from such facilities had to be estimated based on other data on typical TN concentration values available from DRBC as well as best professional judgment.

Attenuation rates were applied to the TP loads to account for losses that typically occur as the load travels from a given source to a point downstream due to such processes as sedimentation and plant uptake. For phosphorus, a loss rate (first-order decay rate) of 22.6% per day was applied, which is slightly less than that used for recent SPARROW modeling done in the same region. In the case of TN, it was found that the best estimates for simulated loads were obtained without a loss rate being applied. This suggests that either the point source loads (see above discussion), non-point source loads, or both were being slightly under-estimated by the model.

Table 2. Comparison of observed and simulated loads for the calibration sites.

Site	Observed TN Load (kg/ha)	Observed TP Load (kg/ha)	Observed TSS Load (kg/year)	Simulated TN Load (kg/ha)	Simulated TP Load (kg/ha)	Simulated TSS Load (kg/ha)
Brandywine River	18.33	0.91	344.5	13.99	0.81	222.2
Schuylkill River	18.72	1.33	NA[2]	15.90	1.37	NA[1]
Lehigh River	14.16	0.73	133.9	10.62	0.86	113.0
Brodhead Creek	4.69	0.37	34.9	3.53	0.24	78.8
Bushkill Creek	2.51	0.15	34.0	1.69	0.10	1.6
Delaware/Port Jervis	3.06	0.21	NA[1]	3.38	0.14	NA[1]
E. Branch Delaware	2.66	0.13	NA[1]	2.34	0.12	NA[1]
Flat Brook	2.73	0.16	85.0	3.25	0.14	20.6
Paulins Kill	5.72	0.20	37.7	7.08	0.30	120.1
Delaware/Trenton	7.35	0.43	172.9	5.64	0.34	72.8
Maurice River	10.69	0.23	20.2	11.92	0.34	112.43
Neshaminy River	11.37	0.78	953.3	11.30	0.67	360.0

[1] Stream data not available

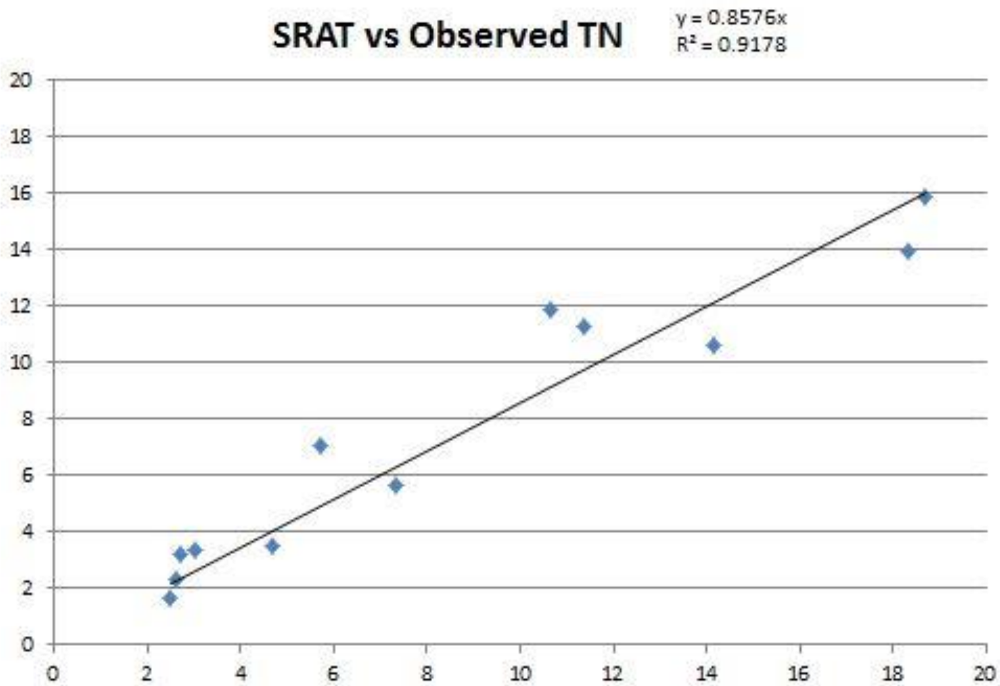

Figure 2. Comparison of observed vs. simulated TN loads (in kg/ha).

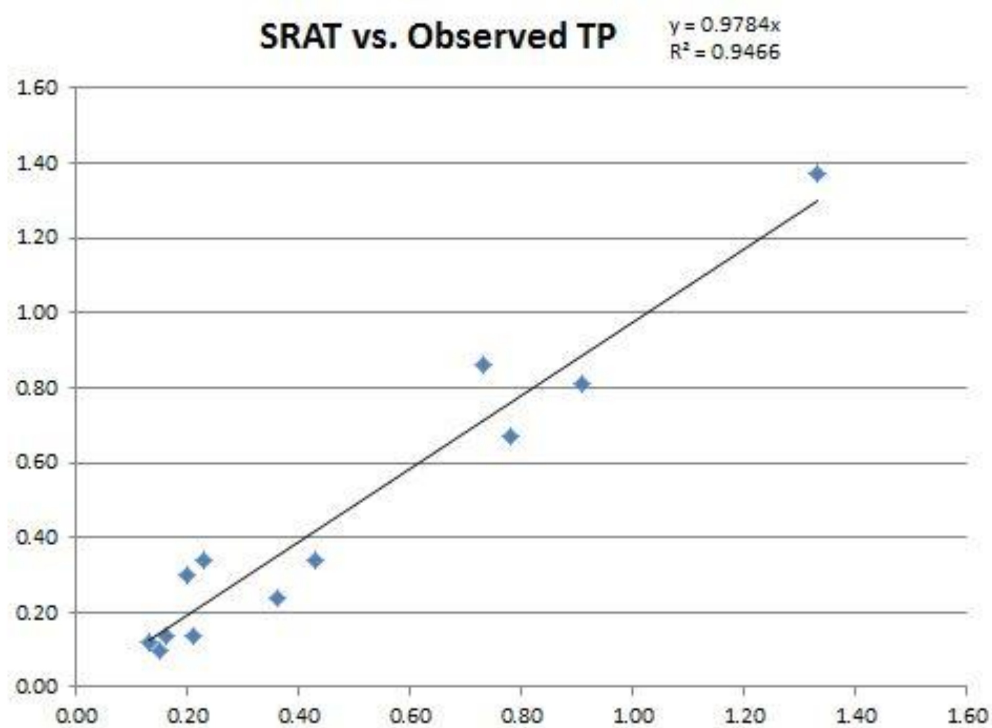

Figure 3. Comparison of observed vs. simulated TP loads (in kg/ha).

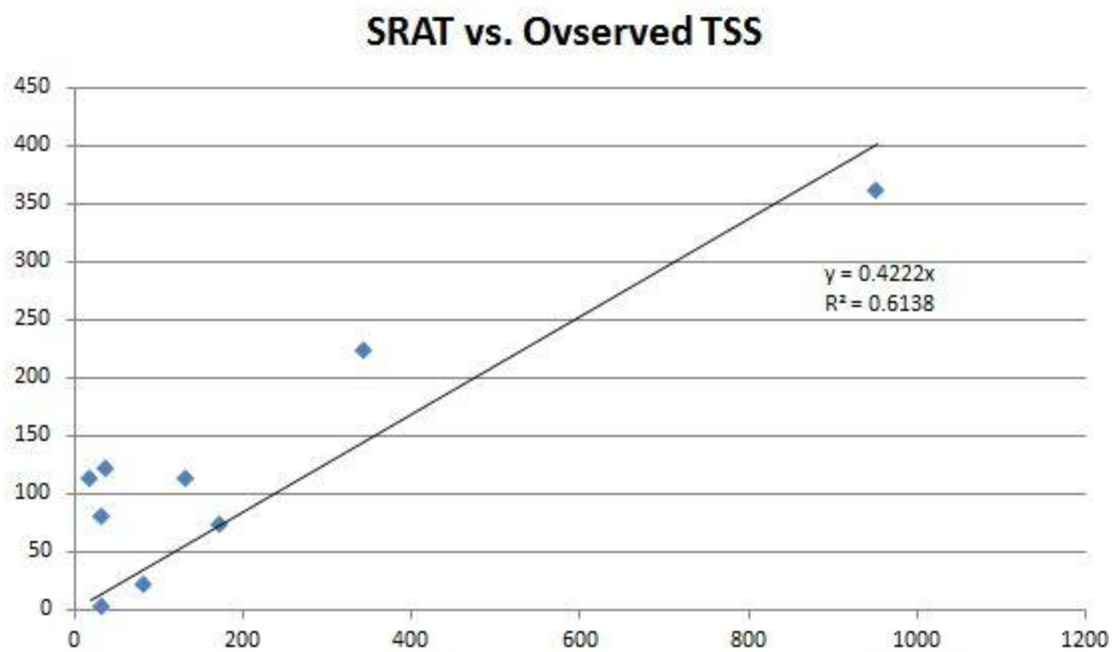

Figure 4. Comparison of observed vs. simulated TSS loads (in kg/ha).

With the sediment (TSS) loads, attenuation was estimated using both time of travel as well as the presence of “natural features” (e.g., wooded areas, wetlands, and ponds) within the riparian zone adjacent to stream segments. In this case, the fit between observed and simulated loads was not as good as with nitrogen and phosphorus. This is not surprising as in-stream samples of sediment are known to be very problematic. However, it is believed that the simulation results do capture the relative magnitudes of sediment loads in streams that are relatively “natural” versus those heavily influenced by agriculture and human development reasonably well.

For the Delaware River Basin, the SPARROW model estimated a mean annual TN load of 45,849 metric tons/year (see Table 3). In this current exercise, a mean annual TN load of 50,363 metric tons/year was calculated. For the SPARROW model, a watershed area of only 30,612 square km was simulated, which represents 10% less area than that simulated with SRAT. If a 10% adjustment of the SPARROW-produced load is made as shown in Table 3. It can be seen that the two loads are actually quite close, which provides a reasonable level of confidence about the simulations made with the STRAT approach.

Table 3. Comparison of SPARROW and SRAT TN loads for the Delaware River Basin.

	Time Period	Area (sq km)	TN (mt/yr)
SRAT/MapShed	2006-2015	34,144	50,363
SPARROW	ca. 2002	30,612	45,849
SPARROW (+10%)			50,434

Note: Only TN loads were estimated by SPARROW for the DRB

Reference

Moore, R.B., C.M. Johnston, R.A. Smith, and B. Milstead, 2011. Source and Delivery of Nutrients to Receiving Waters in the Northeastern and Mid-Atlantic Regions of the United States, J. Amer. Water Resources Assoc., Vol. 47, No. 5, pp. 965-990.