# Recommended Regional Models to Predict Chloride Concentrations from Specific Conductance

## Table of Contents



## Primary Recommendation:

It is recommended that we use a regional Mid-Atlantic piecewise model developed by Joel Moore and USGS colleagues to predict chloride concentrations for watersheds without paired specific conductance and chloride data and that do not drain primarily Triassic Basin soils. The piecewise regional model is:

y = 0.171x - 0.580 below 321 µS/cm
y = 0.291x - 44.5 above 321 µS/cm

In addition to the published journal article, all data used to produce the Mid-Atlantic regional model along with the model results also can be found in a USGS data release by Fanelli and colleagues: https://www.sciencebase.gov/catalog/item/5d2c98e8e4b038fabe22ce86.

**Justification for recommendation:**

- The SaMS project area models are skewed to the Accotink Creek watershed (especially on the high end).
- The Mid-Atlantic model has a dataset that is over 2 times larger than the dataset for the SaMS area and drains watersheds comprised of similar soils to the SaMS project area, with the exception of Triassic Basin soils.
- The piecewise approach will allow for better prediction of chloride at lower specific conductance values.
- The slightly lower slope of the piecewise regional model as compared to the Accotink will result in lower (or more conservative) estimates of chloride concentrations near the chronic chloride criterion of 230 mg/L. For example, with the SaMS study area single regression model, 230 mg Cl/L is predicted when SC equals 813 µS/cm, whereas with the Mid-Atlantic regional piecewise regression model, 230 mg Cl/L is predicted when SC equals 943 µS/cm. This difference in predicted Cl is unlikely to make much difference in estimating chronic chloride criterion exceedances since Moore and USGS colleagues found that maximum chloride concentrations during exceedance events commonly exceed 1000 mg Cl/L.
- The methods are being peer reviewed and can be referenced.

**Conditions for recommendation:** Since the Triassic Basin model's dataset was limited and since the influence of the Accotink Creek watershed data on the regression equation was strong, it is additionally recommended that:

- The Mid-Atlantic piecewise model only be used for watersheds draining primarily non-Triassic Basin soils, and
- The Mid-Atlantic piecewise model only be used in the absence of catchment specific models. The ultimate goal when studying any watershed should be to develop catchment specific models.

## Background:

At the second Water Quality Monitoring & Research (WQMR) workgroup meeting, the workgroup agreed that "developing specific conductance and chloride relationships can help to develop an area-specific regression model to allow for chloride concentration estimates." Considering that data collected by Fairfax County suggests that watersheds draining primarily Triassic Basin soils have elevated Specific Conductance, the workgroup agreed to "identify geographic gaps in chloride-conductivity relationships for the different physiographic provinces in the SaMS project area." This action item was step 1 towards the ultimate goal of developing models to predict chloride concentrations from specific conductance.

The analysis for gaps in paired chloride and specific conductance was conducted on USGS stations. This analysis was presented at the third WQMR workgroup meeting and concluded the following:

- The major physiographic provinces in the SaMS area include Northern Piedmont (37.1%), Triassic Basin (25.0%), Piedmont (23.9%), Coastal Plain (10.0%), and Blue Ridge (3.9%) provinces.
- There are no monitoring stations in the Coastal Plain with the paired data.
- Much of the paired data is comprised of lower concentrations where regression relationships are more variable/less confident.

When the workgroup discussed the content of this analysis, they agreed on the following:

- The relationships did not need to be watershed-specific, but there should be 2 regional models developed. One model should be developed for watersheds draining primarily Triassic Basin soils and one model should be for watersheds draining majority other physiographic provinces.
- Because of the lack of data in Virginia draining primarily Triassic Basin soils, the workgroup also agreed that that model could be supplemented by data from outside the SaMS project area.

So to prepare for the fourth and final WQMR workgroup meeting, an attempt was made to develop these 2 regional models.

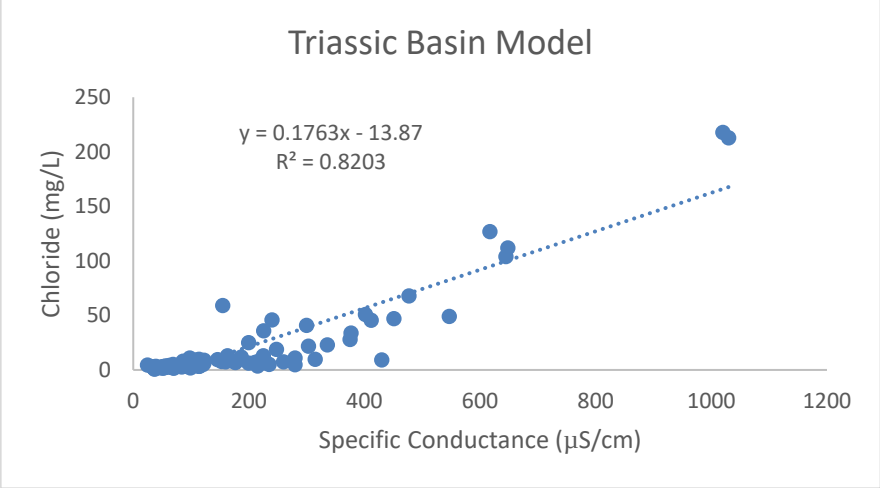
## Summary of Results:

**Triassic Basin Model:** For watersheds draining primarily Triassic Basin soils, the available data was limited to the SaMS project area. Investigating watersheds in Maryland identified one watershed (Monocacy River at Bridgeport, MD; 01639000) that drained 73.7% Triassic Basin soils. However, the remaining portion of the watershed was characterized by physiographic provinces not included in the SaMS project area and that may have different influences on specific conductance (e.g., Piedmont Limestone/Dolomite Lowlands). Therefore, the data supporting the development of a model for watersheds draining primarily Triassic Basin soils was limited to 3 gages in the SaMS project area. The total dataset (n = 97) comprised a range of chloride (max = 218 mg/L; min = 0.7 mg/L) and specific conductance (max = 1030 µS/cm; min = 25 µS/cm) values that were somewhat limited.

**Table 1.** USGS gages used in Triassic Basin model

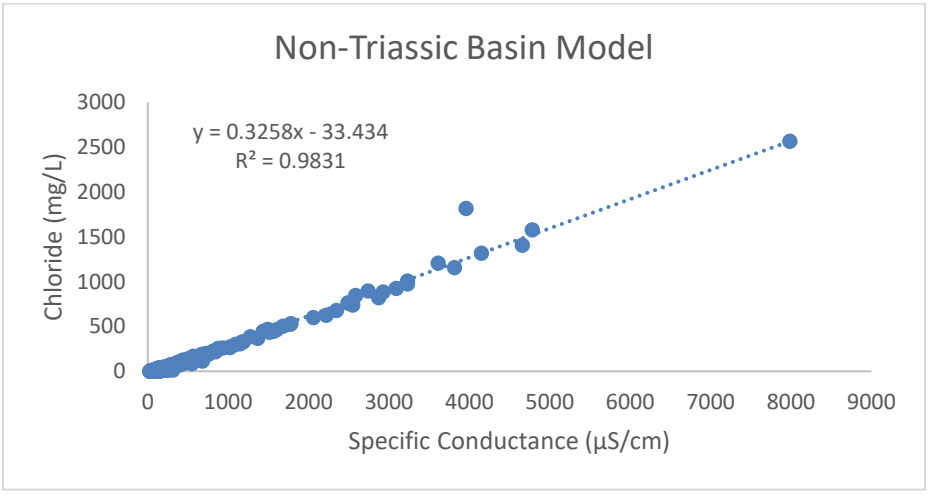
| Gage | % Triassic |
|---|---|
| 01644290 | 94.44% |
| 01644280 | 73.90% |
| 01644291 | 91.30% |

**Figure 1.** Relationship between specific conductance and chloride in watersheds located in the SaMS project area that drain primarily Triassic Basin soils.




**Non-Triassic Basin Model:** Paired specific conductance and chloride data were pulled from 29 USGS gages (n = 674). All but one of the gages did not drain any Triassic Basin soils. The gage that did (01644000) was comprised of less than 4% Triassic Basin Soils. This data was supplemented with data from the Accotink Creek Stressor Analysis that included additional paired chloride and specific conductance data (n = 217). The total dataset (n = 891) represented a wide range of chloride (max = 2570 mg/L; min = 1.25 mg/L) and specific conductance (max = 7986 µS/cm; min = 26 µS/cm) values.

**Figure 2.** Relationship between specific conductance and chloride in watersheds located in the SaMS project area that drain watersheds with <4% Triassic Basin soils.




## Mid-Atlantic Regional Model Comparison:

Joel Moore (Towson University) and colleagues have been working on regional models for specific conductance and chloride, which includes a regional model for the Mid-Atlantic. These models are currently under peer review for publication. For this Mid-Atlantic dataset (n = 2401; all data collected by USGS) of watersheds that primarily drain Piedmont (and a few Coastal Plain) streams, the piecewise regression relationship (two-part linear regression) between chloride and specific conductance is:

$y = 0.171x - 0.580$ below 321 µS/cm
$y = 0.291x - 44.5$ above 321 µS/cm

Similar to the regressions above, the "x" is specific conductance and the "y" is chloride. The uncertainty on that breakpoint is 11.2 µS/cm. This piecewise regression was performed in R using the segmented library. Additionally, the $R^2$ for the Mid-Atlantic regression is 0.979 and $p < 0.001$. When considered as a single dataset (i.e., not piecewise), the single linear regression equation for the same dataset is:

$y = 0.283x - 32.2$, $R^2 = 0.976$

In an attempt to see if the data from within the SaMS study area (i.e., non-Triassic Basin watersheds + Triassic Basin watersheds; n = 1081) could be analyzed in a similar fashion, the same breakpoint of 321 µS/cm was used (**Figure 4)**. Since this was not computed using the same R software, individual regressions were developed based around that breakpoint. Based on this approach, the piecewise regression relationship between chloride and specific conductance in the SaMS dataset is:

$y = 0.2069x - 9.8144$ below 321 µS/cm, $R^2 = 0.8048$
$y = 0.3337x - 50.963$ above 321 µS/cm, $R^2 = 0.9811$

When considered as a single dataset (not piecewise), the single linear regression equation for the same dataset is:

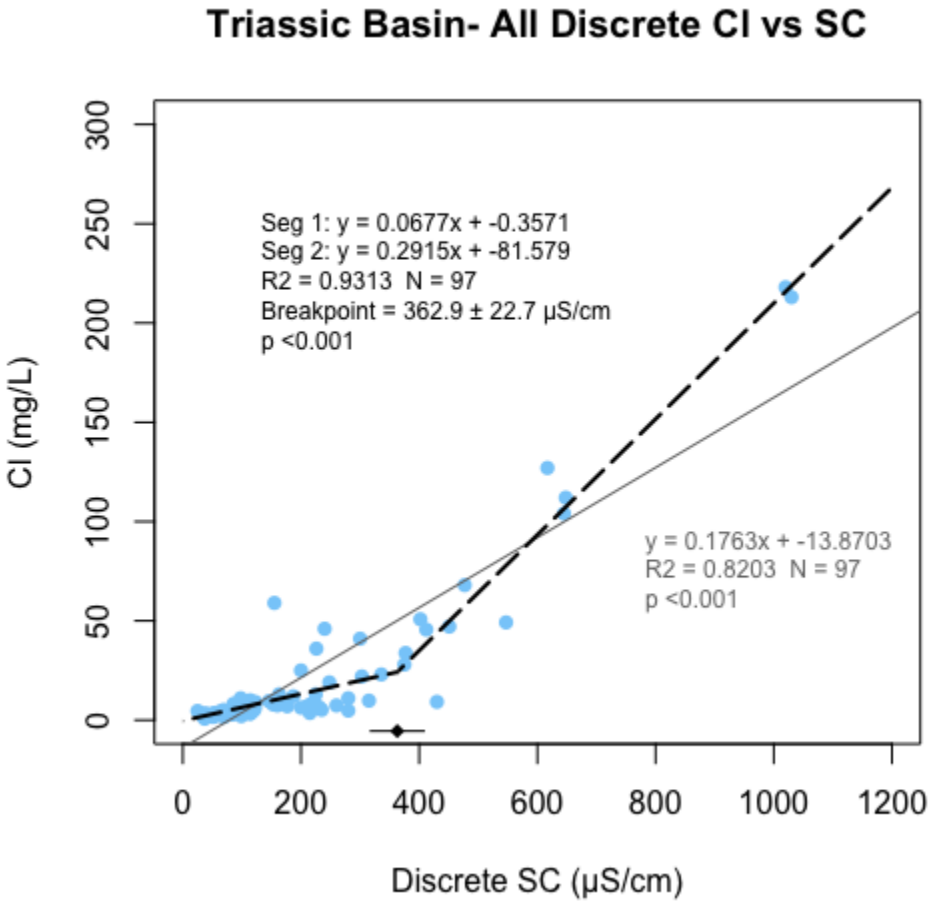
$y = 0.3231x - 32.541$, $R^2 = 0.9783$

Note, about 20% of the data in the combined dataset (n = 217) came from a single watershed, Accotink Creek. When looking exclusively at data from the Accotink Creek watershed, the single linear regression equation is:

$y = 0.3221x – 37.19$, $R^2 = 0.9975$

While the dataset is limited (n = 97), a piecewise regression was run using the same R software used in the Mid-Atlantic regional model developed by Joel Moore and USGS colleagues. This analysis was done since the slope for the higher values (i.e., above the breakpoint) appeared to be similar to those in non-Triassic Basin watersheds when comparing Figure 1 to Figure 2 and Figure 4. Predictably the first segment equation had a low slope due to the influence of other ions on specific conductance. However, although the dataset is small, the second segment equation is very similar to the second segment equation of the Mid-Atlantic regional piecewise model (**Figure 3**).

**Figure 3.** Piecewise relationship between specific conductance and chloride in 3 watersheds draining primarily Triassic Basin soils that are located in the SaMS project area.




Given the reasons below, it is recommended that we use the Mid-Atlantic piecewise model developed by Joel Moore and USGS colleagues for watersheds not draining primarily Triassic Basin soils:

- The SaMS project area models are skewed to the Accotink Creek watershed (especially on the high end).
- The Mid-Atlantic model has a dataset that is over 2 times larger than the SaMS area dataset and drains watersheds comprised of similar soils to the SaMS project area, with the exception of Triassic Basin soils.
- The piecewise approach will allow for better prediction of chloride at lower specific conductance values.
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- The methods will be peer reviewed and can be referenced.

Furthermore, given that the Triassic Basin model's dataset was limited and that the influence of the Accotink Creek watershed data on the regression equation was strong, it is additionally recommended that:

- The Mid-Atlantic piecewise model only be used for watersheds draining primarily non-Triassic Basin soils, and
- The Mid-Atlantic piecewise model only be used in the absence of catchment specific models. The ultimate goal when studying any watershed should be to develop catchment specific models.

**Figure 4.** Piecewise relationship between specific conductance and chloride in watersheds located in the SaMS project area where a breakpoint of 321 µS/cm was used.