Appendix I - Development of stream flow alteration–ecology relationships

Contents

This appendix provides detailed documentation on how the flow alteration – ecology (FA-E) relationships between the flow metrics and macroinvertebrate metrics were developed, and lists the files provided in separate directories on the attached disc.

Disc Contents
Document (PDF file)

- AppendixI_FA-E.pdf (234 KB) – this file
- FA-E_ CondProb_plots.pdf (398 KB)
- FA-E_QuantileRegr_plots.pdf (433 KB)

Data file (Excel 2007 spreadsheet)

- QuantileRegr_Data_R-scripts.xlsx (27 KB)
- CondProb_Data_R-scripts.xlsx (1,412 KB)
- PearsonCorrelations.xlsx (1,628 KB)

Flow alteration – ecology (FA-E) relationships

Three analysis methods were used to identify possible relationships between flow alteration and biological health: Pearson correlations, quantile regressions, and conditional probability plots. An initial set of 256 flow metrics and 51 biometrics were reduced to a semi-final list of eight flow metrics (Table 1) and seven biometrics (Table 2) that represent key components of the hydrology and macroinvertebrate community, respectively. The final step in the scientific process of determining flow alteration – ecology relationships is developing plots to show those representative relationships. As discussed in report section 5.2, each of the three analysis methods can be used to quantify FA-E relationships under certain circumstances. The strengths and weaknesses of each method are summarized in report Table 8. Features of the quantile regression and conditional probability methods are described in more detail in this appendix.

Quantile regression method

Figure 1 is an example scatter plot of biometric value as a function of flow alteration. The plotted points represent biometric values calculated for more than 1,200 observed samples collected at various times during a nine year period, 2000 – 2008, plotted against percent flow alteration

Table 1. Semi-final list of flow metrics sorted into characteristics of the flow regime.

Flow Range	Magnitude	Duration	Frequency	Rate of Change
High	3-day maximum	High flow duration DH17 High flow volume index MH21	High pulse count	
Mid	Median			Flashiness
Low	3-day minimum	Low pulse duration	Low pulse count Extreme low flow frequency	

Table 2. Final selected biometrics with ecological characteristics.

Biometrics	Ecological characteristic
Chesapeake Benthic Index of Biotic Integrity (BIBI)	Multi-metric composite Index
Shannon-Weiner Index (SW)	Taxonomic diversity
Pct_EPT	Composition; generally pollution sensitive
Pct_Scraper	Feeding group
Hilsenhoff Family Level Biotic Index (FBI)	Pollution tolerance
Pct_Chironomidae	Composition; generally pollution tolerant
Pct_Clingers	Habit group

calculated from simulated flow time series for the water years 1984 - 2005. Flow alteration is calculated as:

(Current scenario value - Baseline scenario value) / Baseline scenario value

A flow alteration value of 0 percent means no difference between the current and baseline scenarios. Positive values mean that the flow statistic has a higher value in the current scenario, while negative values mean that the flow statistic is higher for the baseline scenario. Additional observations about this scatter plot:

- The concentration of points at 0 percent flow alteration represents biometric values for watersheds where the baseline flow statistic and current conditions flow statistic are the same. In other words, the watershed characteristics for the current conditions scenario are essentially the same as for the Baseline scenario: >78 percent forest; < 0.35 percent impervious surface, and no discharges, withdrawals, or impoundments.
- The broad distribution of biometric values at a given flow alteration value indicates the biometric (i.e. ecological health) is impacted by many factors other than flow alteration (see Figure 5 in report). Even in watersheds where current flow conditions are essentially the

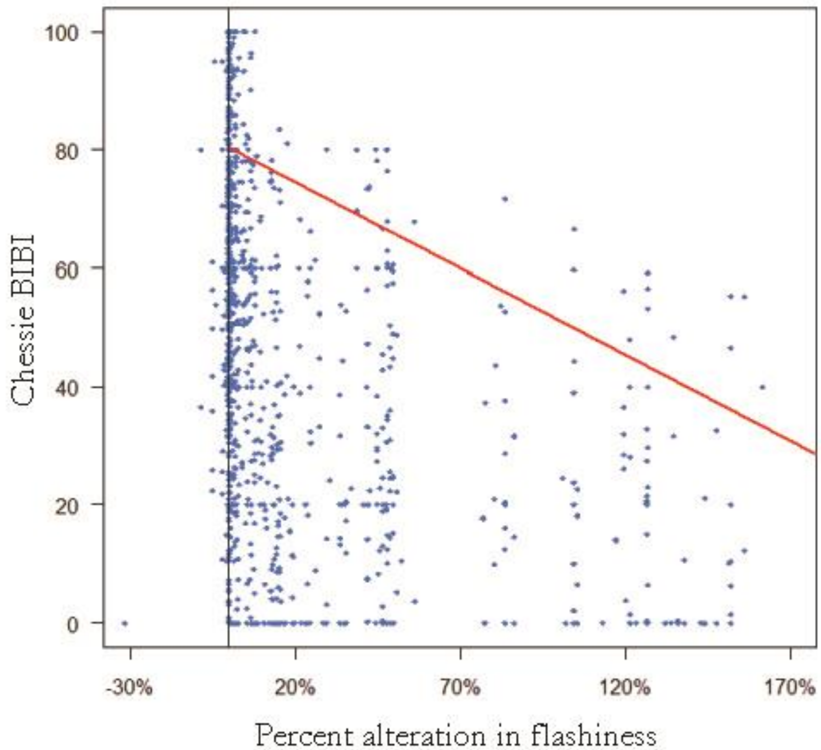

Figure 1. Example of a quantile regression relating a biometric (Chessie BIBI) to percent flow alteration in a flow metric (flashiness).

same as for undisturbed baseline, biometric values (ecological health) ranges from 0 (worst possible) to 100 (best possible).

- Quantile regressions are one method for eliciting the flow alteration impact on biological status. A 90th percentile quantile regression line (red line in Figure 1) shows that, despite the wide vertical distribution of values, there is a decline in the best biometric values as flow alteration increases. This shows that for those locations with the best biometric values and thus least impacted by other factors, as flow alteration increases away from zero there is a decrease in the best achieved biometric value. One way of interpreting this pattern is that increasing flow alteration limits the best possible biologic status that can be achieved, in addition to the impacts of other factors on biological health.
- In this plot most of the points show zero or positive flow alteration. It is characteristic of most flow metrics to have either positive or negative flow alteration but not an equal distribution between positive and negative alteration.

Scatter plots of biometric versus flow metric alteration do not always show the pattern illustrated in Figure 1 of decreasing “best” biometric values as flow alteration increases but in every case of a statistically significant quantile regression the relationship is one of decreasing “best” values as flow alteration increases. The spreadsheet QuantileRegr_Data_R-scripts.xlsx includes data and R scripts for generating plots, as well as a summary table of quantile regression statistics for all biometric – flow metric combinations (for those metrics listed in Table 1 and Table 2). The file FA-

E_QuantileRegr_plots.pdf contains plots for all biometric – flow metric combinations with statistically significant quantile regressions.

Conditional probability method

The quantile regression plots discussed above show that for multiple biometrics and flow metrics increasing flow alteration has a negative impact on biological health. These plots nevertheless have some drawbacks that complicate their interpretation.

- The calculated quantile regressions are linear and yet the observed distribution of points does not always appear to be linear.
- Each biometric has its own scale and for some biometrics an increasing value indicates better health while for other biometrics it is the reverse.
- Criteria for assigning "Poor", "Fair", or "Good" status for given biometric values varies by bioregion.

Buchanan et al (2011) assigned "Good", "Fair", and "Poor" quality categories to ranges of values for each of the biometrics used in this project. By converting the biometric values into these quality scores, all of the biometrics are in a consistent frame of reference, i.e. same scale, that relates to biological quality. This conversion has the added benefit that ranges for the quality categories take into account bioregion differences – eliminating a potential need to subset the data. As shown in the plot in appendix Figure 1, for any short interval along the X-axis (flow alteration) there can be multiple biological samples: some that are "Good", some "Fair", and some "Poor". By looking at the proportion of samples that are Good, Fair, and Poor at each increment along the X-axis, the FA-E relationship can be described as a conditional probability that a benthic marcroinvertebrate sample is "fair or better" for a given amount of flow alteration. Appendix Figure 2 shows an example conditional probability plot. The X-axis for this plot is similar to the one in appendix Figure 1 but the Y-axis is now the conditional probability of the biological status, as indicated by a biometric (in this example, the BIBI), at any location is fair or better for a given amount of alteration in stream flashiness. To create the plot, the biological data are binned along the X-axis, each bin representing 20 samples, and probabilities are calculated for each bin. The solid blue line is a LOESS smoothed regression through the binned probabilities. The dashed lines are a 0.05 confidence interval around the regression line. On the vertical line at 0 percent alteration there is a dark red filled circle which is the probability of fair or better status for just the set of watersheds that meet reference criteria.

Additional observations about this conditional probability plot:

- That the conditional probability of being in Fair or better biological status is less than 100% for reference condition watersheds, about 84 percent in this example, shows again that many factors other than flow alteration affect biological status, including such natural factors as recent weather preceding sample collection.
- There is considerable scatter in the other points, again showing the impact of many factors other than flow alteration. The regression line and its confidence interval nevertheless show there is a strong tendency for the probability of any location being in Fair or better biological status decreases as the amount of flow alteration increases. (Recall that the biological values are observations of current conditions while the flow alteration is a measure of change in flow condition between a baseline and current conditions.)

- The number of samples in each bin is nearly always 20, the exceptions being that all samples at 0 percent alteration are lumped into one bin and the bin furthest from 0 percent will typically have a count either slightly less than 20 or, more typically, a greater than 20 in order to capture all the remaining sample scores. In this example plot for Alteration in Flashiness, there appear to be many points at 0 percent alteration. Alteration in Flashiness has the characteristic that there are several hundred locations with alteration just slightly greater than 0 percent, resulting in many bins that at the scale of this plot appear to be on the 0 percent alteration line.

Some biometric – flow metric combinations show stronger relationships than others but there is a consistent pattern of decreasing probability of fair or better biological status as the amount of flow alteration increases. For many biometric – flow metric combinations, the decrease in the probability of Fair or better status is quite steep at low levels of flow alteration. It should be emphasized that the conditional probability plot does not predict a specific change in the biological status for any location for a given amount of flow alteration. Rather, it shows that the likelihood of being in the fair or better condition decreases as flow alteration increases. Conversely, the risk of not being in fair or better condition increases as flow alteration increases. The spreadsheet CondProb_Data_R-scripts.xlsx includes data and R scripts for generating conditional probability plots for those metrics listed in appendix Table 1 and Table 2 that have statistically significant quantile regressions for biometric value versus flow alteration scatter plots. The file Cond_Prob_plots.pdf contains plots for all biometric – flow metric combinations with statistically significant quantile regressions.

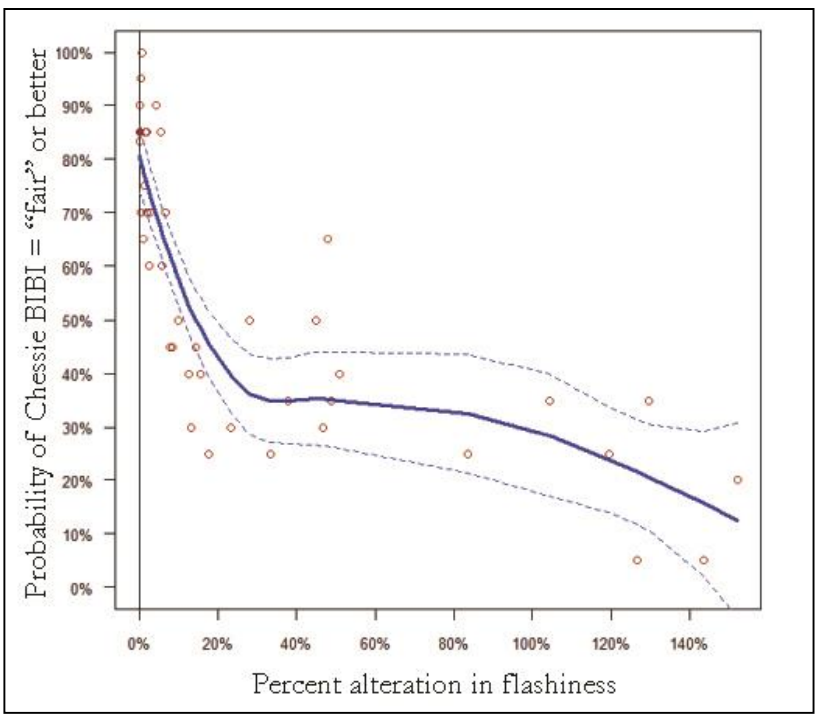

Figure 2. Example of a conditional probability flow alteration – ecology plot.