Results Summary Update for the Integrated Regional Risk Assessment for the South River and Upper Shenandoah, Virginia

September 2014

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(Photo courtesy of W.G. Landis, 2013)

Project Summary

The briefing paper summarizes objectives, status, major outcomes / conclusions, and any recommendations going forward.

Objective 1: Updated ecological risk assessment for South River Study Area

1. Implement Phase IV of the South River regional scale ecological risk assessment to integrate the ecological with the human health risk assessment.

   Status: We have conducted a regional scale risk assessment using Bayesian networks (Ayre and Landis 2012) structured on the relative risk model (RRM) as described by Landis and Weigers (2005). The Bayesian networks relative risk model (BN-RRM) calculations were performed in three parts (**Figure 1**):

   1. We conducted the risk assessment using two fish species and two bird species as biotic endpoints (Summers 2012).

   2. Concurrently, a BN-RRM was constructed and applied to four water quality parameters that are specifically tied to ecosystem services delivered by the South River.

   3. The outputs of the two BN-RRM models were then combined using Monte Carlo analysis to provide an overall characterization of relative risk within the South River watershed.

   Outcome: An increasing gradient of risk was identified that extends from Region 1 north until the merger of the South River with the South Fork of the Shenandoah River (**Table 1**). The smallmouth bass had the highest risk scores, with regions 4 and 5 being the areas of highest risk to them. Carolina Wren were also at high risk in these regions, but had lower risk scores than the smallmouth bass. White sucker and Belted Kingfisher had the highest risk scores in region 2. All biotic endpoints except white sucker had lower risk in region 6 (the South Fork of the Shenandoah) compared to region 5.

Table 1. Risk Scores for the different endpoints by risk region. SMB-smallmouth bass, WS-white sucker, BK-Belted Kingfisher, CW-Carolina Wren, WQ-water quality standards, WF-fishing standards, WS2-swimming standards, WB-Boating standards. To provide perspective for the total risk scores a maximum risk score would be 48 (24 from each the biotic and WQ).

Biotic Endpoints					**Water Quality**				**Totals**		
Region	SMB	WS	BK	CW	WQ	WF	WS2	WB	Biotic	Water	Overall
2	2.4	3.6	2.5	1.1	4.9	1.6	4.5	4.4	9.6	15.4	25
3	2.7	3.1	1.5	1.9	4.5	1.5	4.6	4.6	9.2	15.2	24.4
4	4.3	2.4	2.1	3	4.5	2.1	4.3	4.2	11.8	15.1	26.9
5	4.5	1.3	2.2	2.9	4.8	1.9	4.8	4.7	10.9	16.2	27.1
6	3.3	1.7	1.5	2.5	4.3	1.2	4.6	4.5	9	14.6	23.6

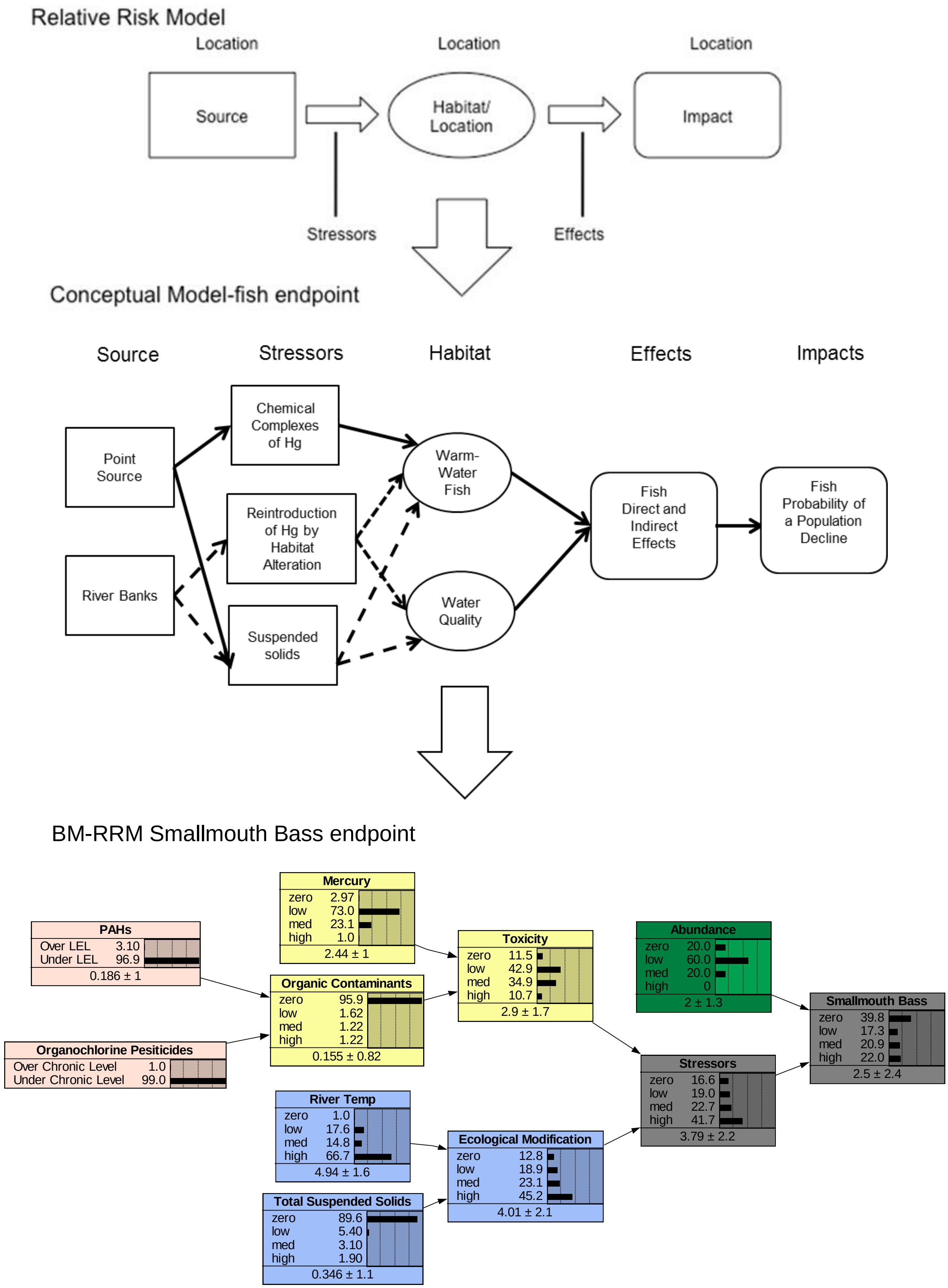

Figure 1. Derivation of a Bayesian Networks RRM. The basic form of the RRM (top) is converted into a conceptual model that describes the cause-effect linkages that will be used to estimate risk (middle). Finally a Bayesian Network is built that describes these pathways and incorporates the likelihood distributions for each variable (bottom).

2. **Uncertainty Reduction**: To reduce uncertainty, additional analyses were conducted to better describe the toxicity of Hg to fish and temperature tolerances of smallmouth bass.

    A. Hg Toxicity to Fish: An analysis of the exposure-response data, summarized in Dillon et al. (2010), by curve fitting allowed a better description of the toxicity at lower levels of Hg exposure. Raw Hg concentration data and model predicted mercury fillet concentration values for the smallmouth bass, white sucker and fishing river use endpoints were used (**Figure 2**).

    Outcome: The BN-RRM output showed only a slight change in the probability of risk to smallmouth bass. Overall, this output resulted in an increase in the total risk score for all risk regions.

    B. Temperature Tolerances of Smallmouth Bass: A detailed analysis of the temperature tolerances of smallmouth was constructed by referring to data from the scientific literature. The analysis of these data for both high and low temperature ranges allowed the construction of an exposure-response curve that included both extremes (**Figure 3**).

    Outcome: After applying the alternative temperature ranking schemes to the BNs, very little change was observed to the smallmouth bass risk scores in any risk region, however, overall there was a slight decrease in risk.

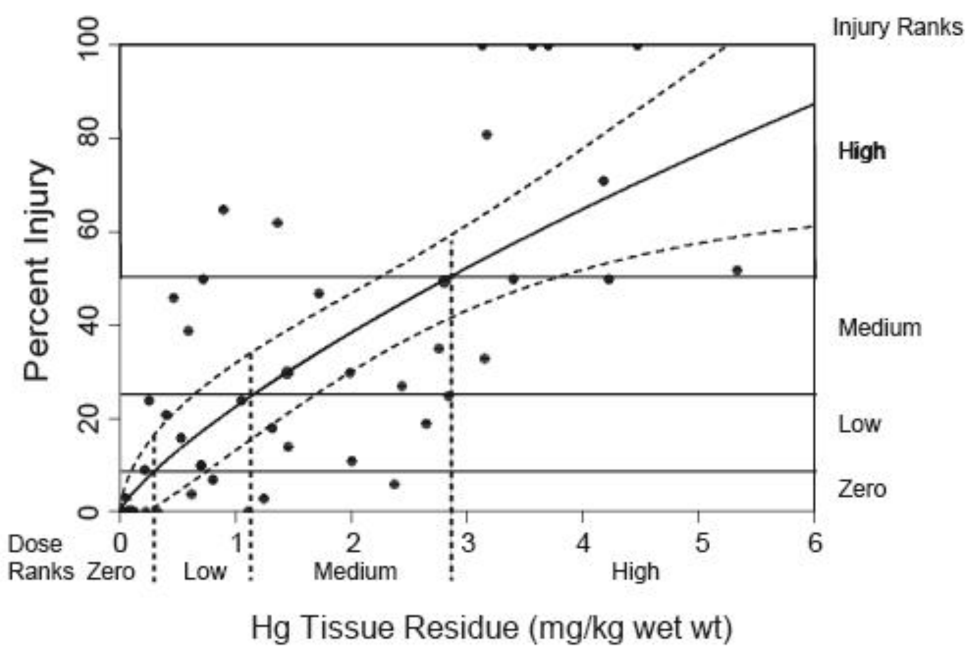

Figure 2. Exposure-response curve for determining exposure ranks based on tissue residue in fish to Hg.

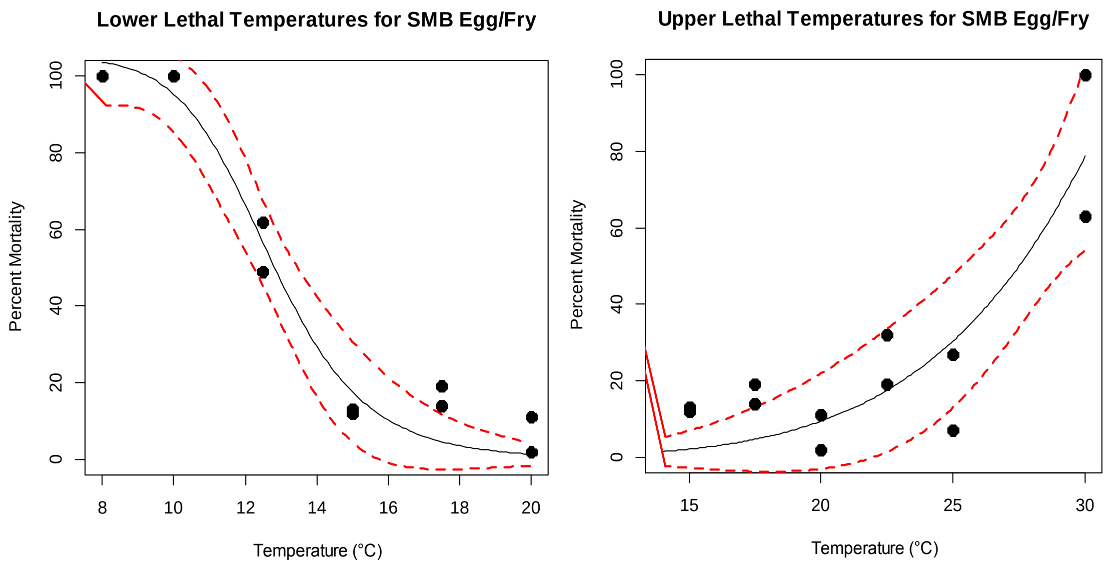

Figure 3. Temperature and percent mortality data for smallmouth bass egg and larval stages. This is a log-logistic model; dashed lines indicate 95% confidence intervals (CI). The 63% mortality point at 30°C represents eggs that hatched, but larvae died soon after hatching. Data source: Kerr 1966, also see Shuter et al. 1980.

We also incorporated the latest data obtained earlier in the year from the South River Science Team as compiled by URS into our analysis. The data included the more current monitoring information for a number of variables included in the risk assessment.

3. Risk from Combining Alternative Mercury Concentration and Temperature Scenarios

Status: We explored combinations of the alternative temperature and methylmercury concentration scenarios to identify the highest and lowest probabilities of risk associated with each region.

Outcomes: Cold temperatures in combination with lower Hg concentrations (lower confidence intervals in Figure 2) resulted in a shift from high to lower risk, especially in the northernmost risk region, Region 6 where risk declined from 38% to 25.5%.

Objective 2: Integration to Adaptive Management and Monitoring

Status: The two current management alternatives for the South River have been evaluated. The management options included agricultural best management practices (BMPs) and bank stabilization. We adapted our initial BNs to include nodes specific to the effects that each will have within the watershed.

Outcomes: Agricultural BMPs did not increase risk to any assessment endpoint. The bank stabilization management option resulted in a shift to lower risk for some biotic endpoints (e.g. smallmouth bass), but at the potential cost of increasing risk to Belted Kingfisher by removing nesting habitat (**Figure 4**).

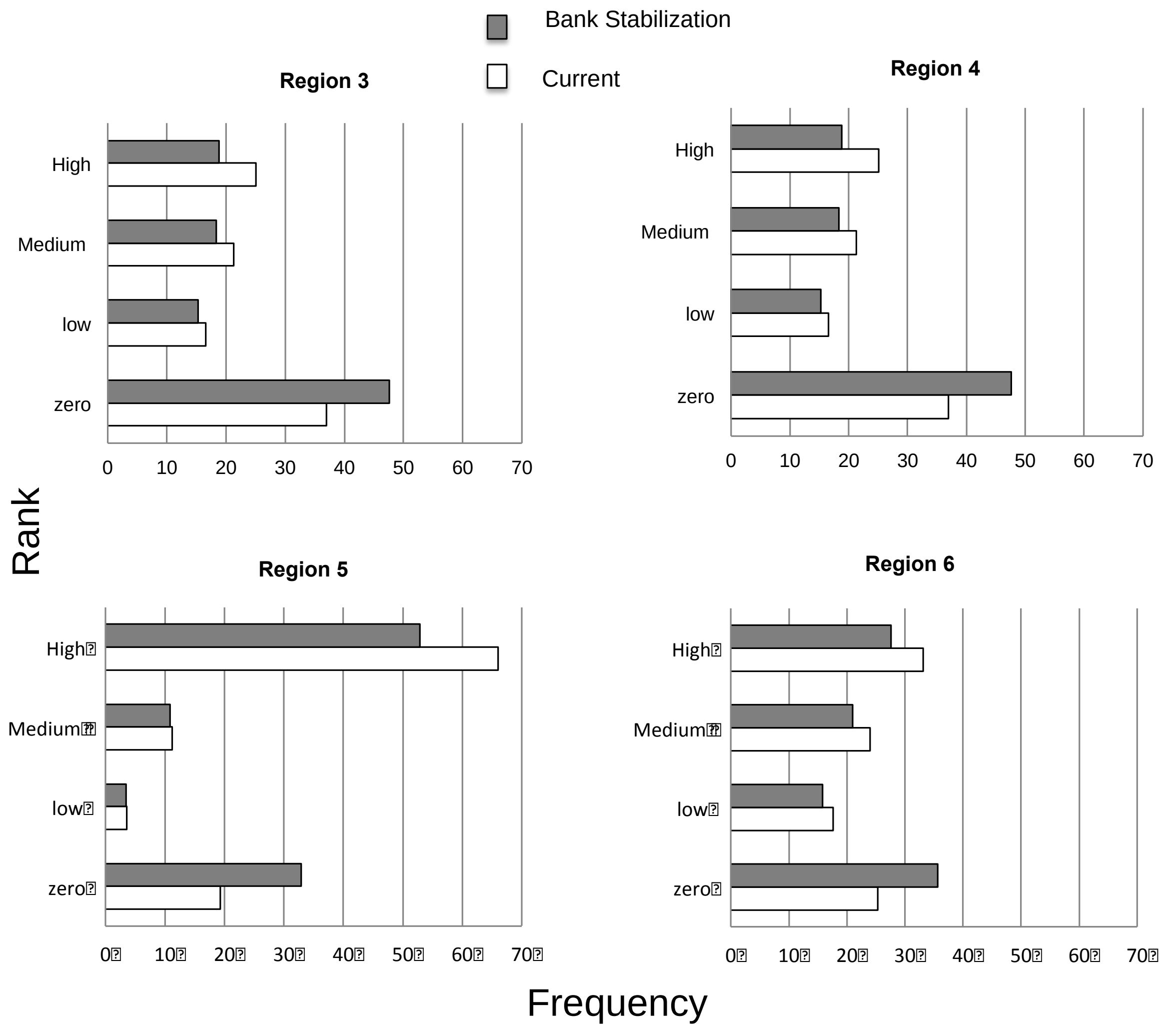

Figure 4. Effects of bank stabilization on risk to smallmouth bass. Graphical representations from Netica™ show the current risk distributions for smallmouth bass, and predicted risk distributions after bank stabilization management is employed in the South River. The frequency of the high and medium ranks decreased and the low and zero risk ranks increased compared to current risk.

The risk assessment process has also provided a list of variables associated with each assessment endpoint that should be measured as part of the long-term monitoring program of the South River Science Team (**Table 2**). The variables are listed for each endpoint and by the importance of each variable to be sampled. From the management alternatives assessment, a list of measurements was developed for both the BMP and the bank stabilization activities (**Table 3**).

Table 2. Monitoring to support the risk analysis. The monitoring parameters for each of the endpoints are based on the parameters that have the greatest influence on the risk to the fish, birds, and water quality endpoints. The parameters are listed from top priority down, and the numbers in parentheses indicate in how many regions the parameter was important. The parameters in **BOLD** font are the parameters that we would like SRST to monitor, the other data we obtained from outside sources.

__**Belted Kingfisher**__
Mercury (5) – Blood samples
Fish Length (5)
Potential Habitat (2) – Land use type (%)
Territory (3) – Nests per length of river section (m)

__**Carolina Wren**__
Mercury (4) – Blood samples
Nest Predation (5)
Potential Habitat (2) – Land use type (%)
Winter Air Temperature (4)

__**Smallmouth Bass**__
River Temperature (5)
Mercury (5) – fish fillet mercury conc.

__**White Sucker**__
River Temperature (5)
Stream Cover (5) – Submerged aquatic vegetation cover (%)
Mercury (4) – Fish fillet mercury Conc.
Organic Contaminants (1)

__**Water Quality Standards**__
Dissolved Oxygen (5) - Summer DO
Bacteria (4) – Bacteria indicators (E. coli)
River Temperature (3) – Winter temp.
River Discharge (3) – Summer & winter discharge

__**Fishing River Use**__
Dissolved Oxygen (5) – Summer DO
Methyl Mercury (4) – Fish fillet MeHg conc.
River Temperature (5) – Summer & winter temp.

__**Swimming River Use**__
Bacteria (4) – Bacteria indicators (E. coli)
River Temperature (5) – Summer & winter temp.
River Discharge (1) – Summer Discharge

__**Boating River Use**__
River Temperature (5) – Summer & winter temp.
Bacteria (4) – Bacteria indicators (E. coli)
River Discharge (1) – Winter Discharge

Table 3. Adaptive Management Parameters: The lack of site-specific data added to the difficulty of parameterizing the management models. As adaptive management alternatives are implemented, monitoring the following parameters would decrease the uncertainty of our subsequent management assessments.

__**Agricultural best management practices**__
Total suspended solids
Total phosphorus
E. coli levels

__**Bank stabilization**__
Total suspended solids
Fish fillet mercury concentrations
Bird blood mercury concentrations
Stream cover
Habitat alteration (habitat loss for the Belted Kingfisher)
Dissolved oxygen
Discharge

Objective 3: Human Health and Integrated Risk Assessment

Status: The integration of human health risk assessment with the ecological risk assessment (HHRA-ERA) is underway and a conceptual model and preliminary Bayesian network are complete (**Figure 5**). This assessment will have two focuses: risk to human health from mercury exposure via dietary sources and risk to recreational activities in the South River watershed. The integration process began with endpoint selection and construction of the conceptual model, and will continue through risk analysis and risk communication.

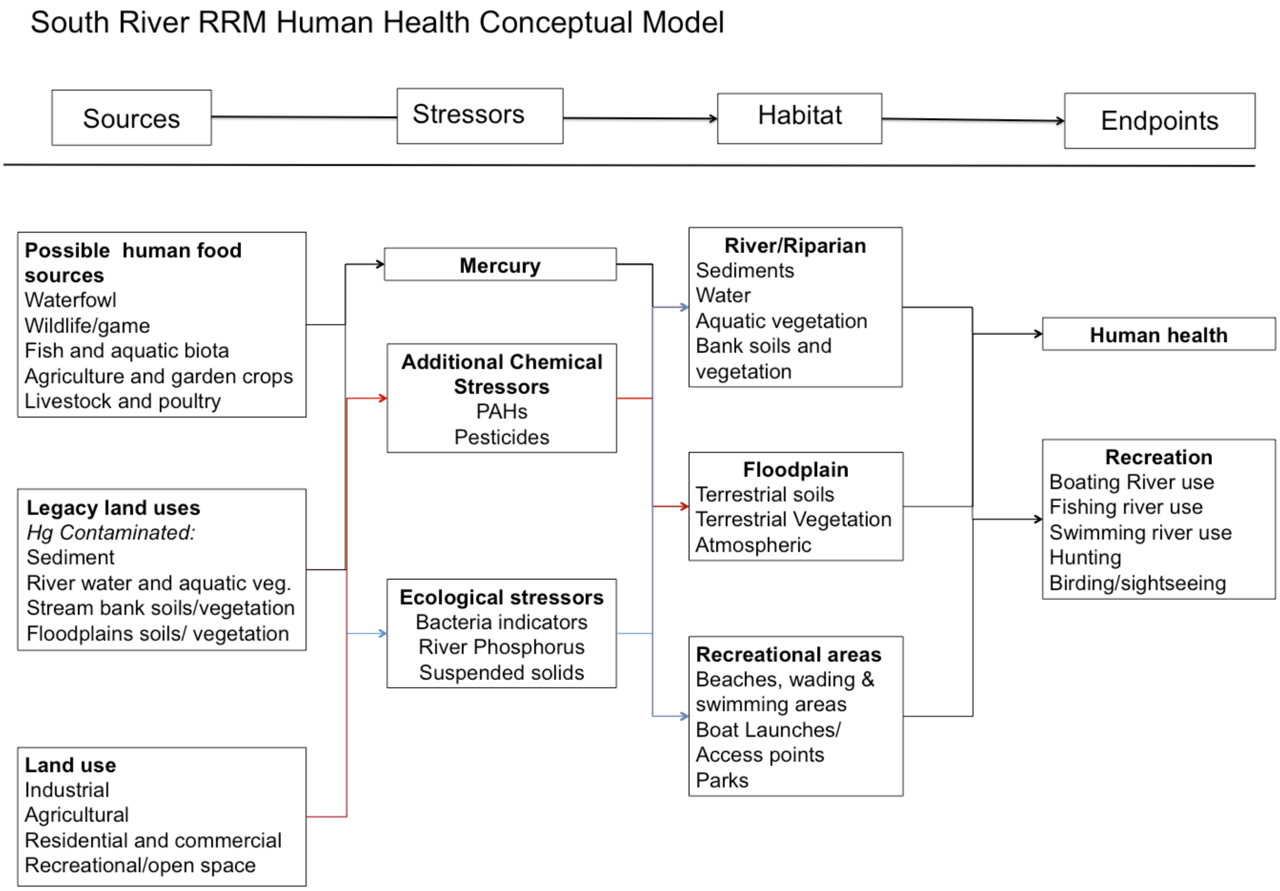

Figure 5. Conceptual model for the human health risk assessment. The model fits the overall structure of the relative risk model.