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		Project:	SRRTTF9
To:	Spokane River Regional Toxics Task Force	**CC:**	

SUBJECT: DRAFT: Follow-up Investigations from Spokane River Multi-media Data Collection

Summary

The Spokane River Regional Toxics Task Force has conducted and/or supported several data collection studies in the Spokane River, covering a range of environmental media (water column, biofilm, and sediment.) LimnoTech reviewed these data in order to:

- Identify river reaches where data indicate impacts from non-point sources are occurring
- Develop a matrix that estimates mass loading contribution for each identified reach, as well as a best estimate of the aerial extent and concentration of the area identified
- Prioritize the reaches for further investigation.

The reach between Plante's Ferry and Upriver Dam (and more specifically, the segment between E. Mission Ave. and Gonzaga University, referred to as the "Mission Reach") was selected as the priority reach, due to consistently elevated PCB concentrations in biofilm. The reach between Barker Rd. and Plante's Ferry also receives significant non-point source PCB loads, but was not designated as a priority reach because existing cleanup efforts are already in place to address the source of that load.

Initial forensic analyses were conducted to evaluate potential sources of PCBs causing the Mission Reach contamination. The available data are not sufficient to identify a specific source, and a range of options are provided for conducting future studies to better determine the source of this contamination. These findings and options for future studies were presented at the July 21, 2020 Technical Track Work Group meeting, and the decision was made to defer selection of any future studies until results of the upcoming SPMD and fish tissue PCB monitoring studies (and potentially PCB samples of bottom fill material) are available.

This memorandum describes the above analyses, and is divided into sections of:

- Data Sources Considered
- Mass Loading and Extent of Contamination by Reach
- Prioritization of Reaches for Further Study
- Forensic Analysis of Potential Sources in Mission Reach
- Options for Future Studies

Data Sources Considered

The sources of data considered during this study fall into two categories:

- Water Quality Monitoring Conducted by the Task Force
- Biofilm/Sediment Studies Conducted by Ecology's Environmental Assessment Program

Water Column Studies Conducted by the Task Force

The Spokane River Regional Toxics Task Force has conducted four separate monitoring studies assessing water column PCB concentrations:

- August 2014 Synoptic Survey (LimnoTech, 2015)
- August 2015 Synoptic Survey (LimnoTech, 2016)
- Monthly 2016 Water Quality Monitoring (LimnoTech, 2017)
- August 2018 Synoptic Survey (LimnoTech, 2019)

The synoptic surveys were designed to estimate non-point source loading of PCBs via application of a mass balance approach. Non-point source load estimates were generated for a series of reaches as follows:

Non=point source load = Observed instream load at downstream boundary of reach
- Observed instream load at upstream boundary of reach
- Observed point source loading to the reach

The 2014 synoptic survey estimated loads for reaches between the Lake Coeur d'Alene outlet and the USGS gage in Spokane. The 2015 synoptic survey estimated loads for reaches between Barker Rd and the USGS gage in Spokane. The 2018 synoptic survey estimated loads for reaches between Barker Rd and Nine Mile Dam. The 2016 monthly monitoring was not designed to support a mass balance assessment, and was intended to provide information on the seasonal variability of instream PCB concentrations.

Biofilm/Sediment Studies Conducted by Ecology's Environmental Assessment Program

Ecology's Environmental Assessment Program conducted measurements of PCBs in biofilm during two sampling events, with partial financial assistance from the Task Force in August, 2018 and August, 2019 (Wong and Era-Miller, 2019)

The 2018 survey collected biofilm samples at 19 locations and sediment samples at three locations in the Spokane River. Sediment PCB concentration were measured at two sites in 2018, Plante's Ferry and near Gonzaga University. The 2019 survey added several additional biofilm sampling locations in the Mission Park area, with a total of 33 sites being sampled. Although the data from the 2019 study has not been officially released, it has undergone quality control review and deemed to be of sufficient quality to support the investigative analyses conducted for this work.

Mass Loading and Extent of Contamination by Reach

LimnoTech (2015, 2016, and 2019) calculated non-point source PCB loading rates and subsequently summarized them as part of a 2019 Data Synthesis workshop (http://srrttf.org/?page_id=10370). The largest non-point source load, averaging 130 mg/day, occurred between Barker Road and Plante's Ferry. The non-point source load estimated for the reach between the USGS Gage and Nine Mile Dam was on the order of 50 mg/day, based solely on results from the 2018 synoptic survey. Non-point source load estimates between Plante's Ferry and the USGS Gage were generally negative, although the 2018 survey indicated a non-point source load of 47 mg/day between Greene St. and the USGS gage. Nonpoint source loads upstream of Barker Rd. were consistently calculated as being negligible.

Biofilm PCB concentrations measured by Ecology were analyzed to address the project objective of determining the aerial extent of impact. The assessment began with statistical analysis of the frequency distribution of all biofilm data, to distinguish areas impacted by the hot spot from those areas reflecting more typical Spokane River PCB concentrations. Figure 1 shows the frequency of occurrence of different ranges of biofilm concentrations. The distribution exhibits a long tail, with the majority of observed concentrations less than 1000 pg/g (ppt), but with a significant percentage of concentrations greater than 5000 ppt.

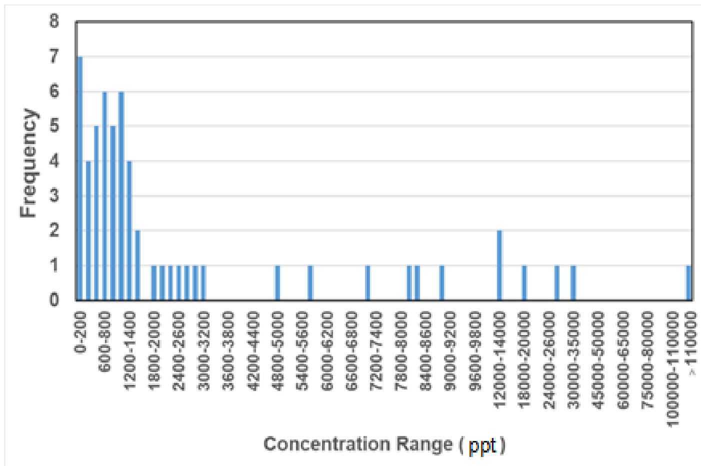

Figure 1. Frequency Distribution of 2018-2109 Biofilm Data

In order to assess whether the variation in observed data followed a log-normal distribution, data were log-transformed and plotted as a cumulative normal probability graph. If the variability in the entire data set followed a log-normal distribution, the individual data points would all fall along a straight line. Figure 2 shows that log concentrations below 3.5 (translating to concentrations below 3200 ppt) all fall roughly along a straight line and can be considered part of a single log-normally distributed population. Concentration greater than log 3.8 (translating to concentrations above 4800 ppt) all fall well to the right of the log-normal line, which can be taken as an indication that these concentrations are much greater than would be expected if all samples came from the same distribution. For this reason, biofilm concentrations greater than 4800 ppt serve as the indicator of the presence of atypically elevated concentrations.

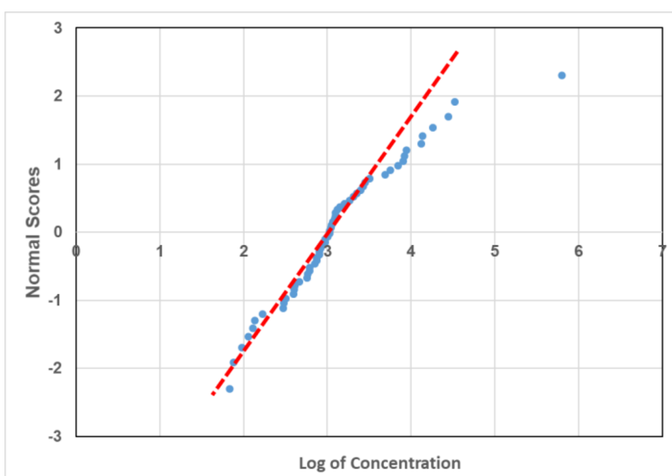

Figure 2. Probability Plot of Biofilm Concentration Distribution, with Dashed Line Showing Idealized Log Normal Distribution

Figure 3 shows the observed concentrations at different river location, and indicates that the presence of atypically elevated PCBs concentrations overwhelming occurs between Mission Bridge (identified as Station MIB in Figure 3) and Spokane Falls Boulevard (identified as Station SFB).

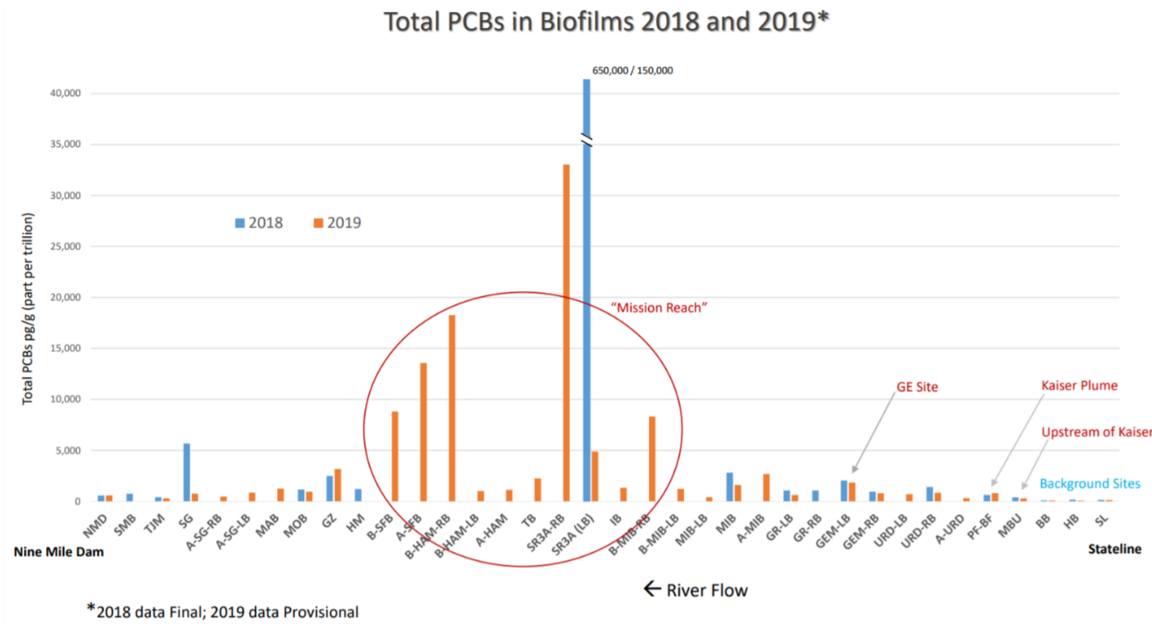

Figure 3. 2018 and 2019 Total PCBs in Spokane River Biofilms by Location (from Era-Miller, 2020a)

Sediment PCB concentrations measured in 2018 consist of 14 ppb measured at Plante's Ferry and two samples at Gonzaga of 90 and 127 ppb.

Prioritization of Reaches for Further Study

Table 1 summarizes the biofilm and sediment PCB concentrations and nonpoint source loading estimates and uses a quantitative categorization scheme to rank each parameter as low, medium, or high priority. For biofilm, average PCB concentration less than 200 ppt represent low priority, between 200 and 1500 ppt medium priority, and above 1500 ppt high priority. For sediment, average PCB concentration less than 10 ppb represent low priority, between 10 and 100 ppb medium priority, and above 100 ppb high priority. For nonpoint source PCB loads, of average loading of zero or less represents low priority, between zero and 75 mg/day medium priority, and above 75 mg/day high priority.

Table 1.

Prioritization Matrix of River Reaches (Green=Low, Yellow=Medium, Red=High)

Reach	Biofilm PCB	Sediment PCB	Nonpoint Source PCB Load
Upstream of Barker		No data	
Barker to Trent			
Trent to Upriver Dam			
Upriver Dam to Greene		No data	
Greene St. to USGS Gage			
USGS Gage to Nine Mile		No data	

The Barker to Trent reach and Greene to USGS Gage reaches stand out as the highest priority reaches, scoring medium or high in all categories. We recommend that the reach from Greene St. to the USGS Gage (and specifically, the portion of that reach between Mission Bridge and Gonzaga) be given highest priority for future study, because remediation activities are already occurring to address the nonpoint source loading from the Kaiser facility that is driving the prioritization of the Barker to Trent reach.

Forensic Analysis of Potential Sources in Mission Reach

This section provides forensic analysis of available data to help identify a possible source of the observed contamination in the Mission Reach, divided into discussions of:

- Potential source categories
- Spatial distribution of contamination
- Transport mechanisms between potential source and river
- Assessment of sources

Potential Source Categories

The forensic analysis began with identification of categories of sources that could be potentially responsible for the observed contamination in the Mission Reach. We identified the following four categories

- Contaminated river fill material
- Contaminated bottom sediments
- Landside surface contamination
- Landside subsurface contamination

The river bottom in the Mission Reach contains large quantities of artificial fill material, both broken concrete and brick. This fill material could be the source of elevated biofilm PCB concentrations, if the material was contaminated with PCBs prior to being put in the river.

The second source category identified was contaminated bottom sediments. Historical PCB loading upstream of Mission Reach was much higher than in the present day, and elevated legacy PCB concentrations were found and remediated above Upriver Dam. It is possible that some legacy sediment contamination exists within the Mission Reach. There is also the possibility that PCB containing objects (drums, transformers) could be buried in the river bottom.

The third source category identified was landside surface contamination. The Mission Reach receives both stormwater and combined sewer overflow loading from the City of Spokane drainage network. Contaminated surface soils, if they existed in the area draining to the Mission Reach network, could be delivered to the river during wet weather events.

The final source category is landside subsurface contamination, i.e. contamination that is buried beneath the land surface in locations where it could be delivered to the Spokane River via groundwater.

Spatial Distribution of Contamination

Review of the spatial distribution of observed PCB concentrations can provide insight into the source of the contamination. This was accomplished by reviewing the biofilm and water column data; sediment PCB sampling was too sparse (two Spokane River locations) to provide any insight.

Biofilm

The spatial distribution of biofilm data was assessed both on a broad scale and via more detailed analysis of the Mission Reach. From a broad spatial perspective, biofilm PCB concentrations rise to atypically high levels near E. Mission Avenue Bridge, remain elevated downstream to near Gonzaga University, and then return to typical levels further downstream (Figure 3). This provides two pieces of relevant information in terms of assessing a source:

1. The source first occurs somewhere near E. Mission Avenue Bridge, and
2. The signal of the source is lost downstream of Gonzaga.

Geostatistical analyses were conducted on the biofilm PCB data from the Mission Reach to assess spatial autocorrelation, i.e. the dependence between two observations as a function of the distance between them. This was conducted via development and assessment of a semivariogram, which graphs the variance of the difference in concentrations at two locations over the range of locations sampled. The resulting data points are then assessed for how correlation between samples changes as a function of distance between them.

Figure 4 shows a longitudinal semivariogram for log-transformed Spokane River biofilm data. The results indicate that spatial correlation exists over a range of approximately 500 feet. In order to accurately interpolate concentrations in un-sampled areas (and potentially locate a source), samples are required at ¼ to 1/5 of this range. This translates to the need for samples 100 to 125 feet apart in the flow direction. Sample density in the across-stream direction cannot be assessed, since the current sampling density is too sparse across the width of the river.

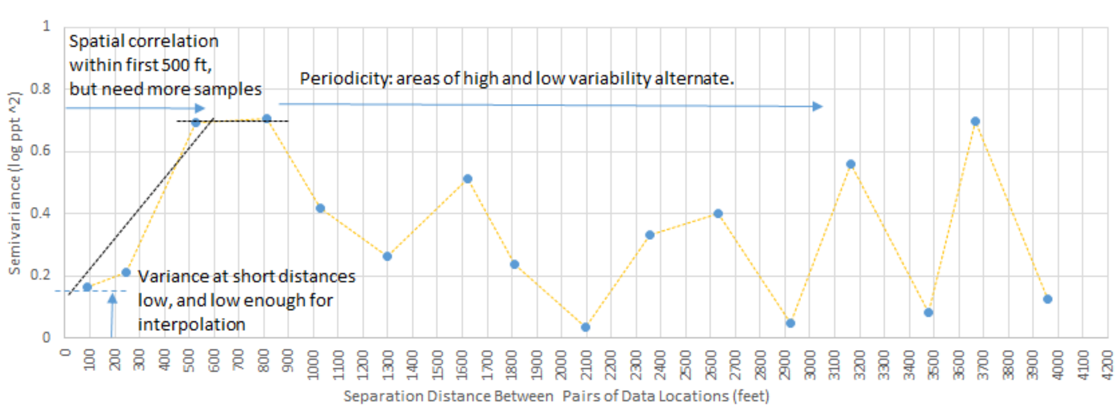

Figure 4. Longitudinal Semivariogram for Biofilm PCB Data

Water Column

Assessment of the spatial distribution of water column PCB can also provide insight into potential PCB sources. Figure 5 shows that observed Spokane River water column PCB concentrations averaged across the 2014-2018 surveys for a range f river locations. Concentrations are on the order of 20 pg/l for all stations upstream of Mirabeau Point, increase to approximately 100 pg/l at Plante's Ferry, then gradually increase further as the river passes through the City of Spokane. While concentrations increase slightly as the river passes through the Mission Reach (between Greene St. and the USGS Gage), the relative increase in water column concentration is much smaller than the increase in biofilm PCB concentrations.

From a source detection standpoint, these data indicate that the cause of the increased biofilm PCBs is not being reflected in the water column data. Potential explanations for this phenomenon include:

- The PCB source only manifests itself along the stream bottom and not in the water column (e.g. contaminated fill material)
- The PCBs entering the river are removed from the water column prior to reaching the USGS Gage Station
- The PCB source is episodic in nature (e.g. driven by wet weather events) and was not occurring during the times of the water column sampling.

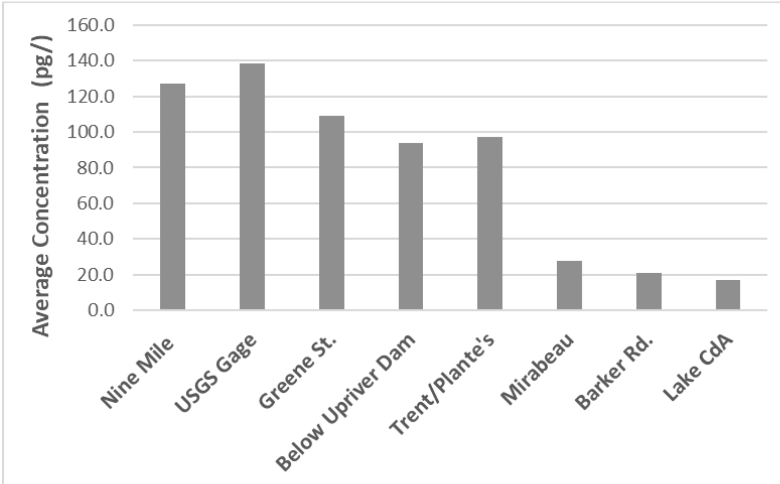

Figure 5.
Average Observed Spokane River Water Column PCB Concentration, 2014-2018.

Transport Mechanisms between Potential Sources and River

The third component of the forensic analysis consisted of analysis of transport mechanisms between potential sources and the river, in order to determine whether contamination located upland has a pathway that will deliver it to the river. Contaminated surface soils have a direct delivery method to the river, as both stormwater and combined sewer outfalls exist in the Mission Reach.

The existence of a transport pathway for upland subsurface contamination to reach the Mission Reach is less clear. This portion of the river is characterized as a losing reach, meaning that there is a net loss of water from the river to groundwater. If groundwater in this section moves uniformly away from the river, that would eliminate upland subsurface contamination as a source because there would be no mechanisms for transporting groundwater contamination to the river.

While the section of river containing the Mission Reach is characterized as losing, the characterization applies to average conditions over time and space. If portions of that section of the river were gaining during certain times, however, that would provide a potential transport mechanism for delivering contaminated groundwater to the river.

Data provided by Spokane County demonstrate that groundwater can be delivered to the Mission Reach, at least for certain times and locations. Figure 6 shows concurrent measurements of river stage and groundwater elevation taken from the south side of the Hamilton Street Bridge. River elevations are higher that groundwater elevations for the majority of measurements, indicating movement of water from the river to groundwater. Groundwater elevations are seen to be greater than river elevations during certain time periods, which represents movement of water from groundwater to the river. While insufficient data exist to determine how large of an area delivers groundwater to the river, it is clear that the river gains groundwater in a portion of the Mission Reach during certain times. This indicates that upland subsurface contamination does have a transport mechanism to deliver it to the river.

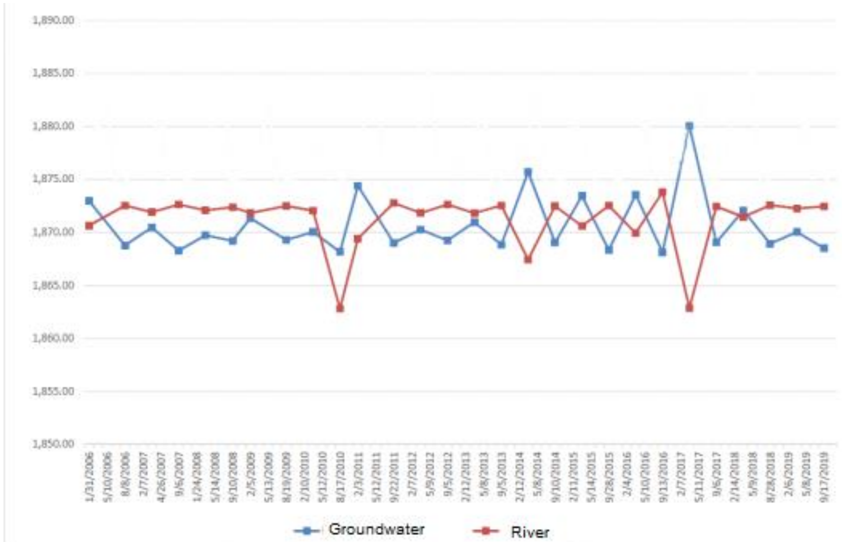

Figure 6. Spokane River Elevation and Groundwater Elevation below the South Side of Hamilton Street Bridge (adapted from Hermanson, 2020).

Analysis of Sources

The previous sections identified four potential categories of PCB sources to the Mission Reach, and concluded that transport mechanisms exists for all of them to be delivered to the river. This section considers available evidence and describes arguments in favor of (and against) each source category being responsible for the Mission Street contamination. The findings are summarized in Table 2 and discussed below.

Table 2. Arguments in Favor and Against Each Potential Source Category Causing Mission Reach Contamination

Source Category	Arguments in Favor	Arguments Against
Contaminated Bottom Fill	• Consistent with localized biofilm contamination, absence of water column impact	• Fill has been there many decades, likely "spent"
Contaminated Bottom Sediments	• Consistent with localized biofilm contamination, absence of water column impact • Evidence of buried drum near Spokane Falls Blvd.	• High energy segment with little deposition makes historical sediment contamination unlikely
Upland Surface Contamination	• MS4 and CSO outfalls exist in area	• Existing outfall concentrations aren't compelling
Upland Subsurface Contamination	• Known areas of historical contamination exist • Localized times of gaining	• Net losing reach • No downstream signal in biofilm or water column

Contaminated Bottom Fill

The primary argument in favor of contaminated bottom fill being responsible for the Mission Reach contamination is that contamination from this source is consistent with localized biofilm contamination, and absence of water column impact. Presence of contamination in the fill material could elevate PCB concentrations in the attached biofilm without exhibiting enough of a signal to be observed in the water column. Investigation of the specific origin of the fill material was unsuccessful, beyond determining that the fill has been present in the river for many decades. This leads to the primary argument against contaminated fill being the cause, which is that the fill has been present in the river for so long that it is likely that the large majority of contamination that may have originally existed has diffused out of the fill.

Contaminated Bottom Sediment

The same argument in favor of contaminated bottom fill being responsible for the Mission Reach contamination also applies to contaminated bottom sediment, i.e. contamination originating from the stream bed is consistent with elevated biofilm contamination, and absence of water column impact. The primary argument against contaminated bottom sediment is the fact that the Mission Reach is a high energy segment with little sediment deposition. This makes it unlikely that legacy sediment contamination is a significant contributor. The possibility still exists that an external contamination source (e.g. drum containing PCBs, transformer) could be buried in the sediments. The Washington Department of Transportation found a 55 gallon drum buried five feet under the surface near E. Spokane Falls Boulevard in the early 2000s (Era-Miller, 2020b). While this drum was located downstream of the bulk of the Mission Reach contamination, is does lend credence to the theory that sources of external contamination exist buried in the river bottom.

Upland Surface Contamination

The primary arguments in favor of upland surface contamination being responsible for the Mission Reach contamination are: 1) Stormwater and combined sewers are known to have elevated concentrations of PCBs, and 2) Stormwater and combined sewers outfalls both exist in the Mission Reach. The primary counter argument is that these outfalls have been sampled for PCBs in the past and the estimated loading rate in the Mission Reach is much less than loads measured from stormwater and combined sewers outfalls from other sections of the river that do not exhibit highly contaminated biofilm,

Upland Subsurface Contamination

The primary argument in favor of upland subsurface contamination being responsible for the Mission Reach contamination is that known areas of historical soil contamination exist that could theoretically be delivered to the river via groundwater. The primary argument against this source is that, while evidence shows that groundwater can be delivered to the Mission Reach at certain times, the frequency of occurrence and contributing areas are largely unknown.

Options for Future Studies

Given that the source(s) of the Mission Reach biofilm contamination could not be positively determined, a range of studies were identified that could assisting in identifying the source(s). These studies fall into categories of:

- Refined assessment of groundwater contribution
- Additional data monitoring related to surface soil contamination
- Determine likelihood of stream bottom contribution
- Additional biofilm sampling

The section concludes with a discussion of the prioritization of these options at the July 21, 2020 Technical Track Work Group meeting,

Refined Assessment of Groundwater Contribution

The available data indicate that groundwater can enter the Mission Reach, but are insufficient to define either the spatial or temporal extent of this contribution. Two primary options exist to provide a more complete understanding. The first option consists of more robust monitoring of groundwater elevation data. This monitoring could either be conducted with continuous elevation measurements at existing wells (which would provide better temporal understanding) or through installation of piezometers at new locations (which would provide better spatial understanding).

The second option consists of near-bank water temperature monitoring along the length of the Mission Reach. This data can identify potential presence of groundwater contribution, because groundwater is colder than river water. This type of survey would provide a spatial description of where groundwater may be entering the river, but provide no temporal coverage as the survey results would indicate if/where groundwater was entering only during the time of the survey.

Additional Data Monitoring Related to Surface Soil Contamination

Although available monitoring data indicate that stormwater and combined sewer loads entering the Mission Reach are not larger than loads from these sources to other reaches, the data are limited in nature and many not fully represent actual loads. Additional stormwater and combined sewer outfall sampling would help confirm or refute the theory that surface soil is the cause of the contamination. Should contaminated surface soils be identified as a probable source. The use of dogs specifically trained to use their superior sense of smell to identify PCB hot spots (called Detection Dogs or PCB-Sniffing Dogs) could be used to identify specific areas from where the contamination is originating.

Determine Likelihood of Stream Bottom Contribution

Four activities were identified to help better assess the likelihood that the contamination is originating from the stream bottom:

- Deeper dive into the origin of fill material
- Visual survey of bottom characteristics
- PCB sampling of fill material
- Sub-bottom profiling for buried drums/transformers

Initial efforts to identify the nature of the fill material were unsuccessful, but more could be done in this regard. These efforts include: searches of historical material at the Spokane Library; surveying Task Force members and/or Ecology staff whether they have any information, or know of others with information, about the origin of the fill; and issuing a public call for information through the Spokane River Forum or via social media.

The second option consists of a more detailed visual survey of the river bottom characteristics. The bottom fill is comprised of different types of materials (e.g. bricks, large pieces of concrete) and a clearer understanding of where the various types of material are located would aid understanding of potential hot spot locations, if contamination is linked to a specific type of material.

The third option consists of monitoring the PCB content of the fill material itself, to see if elevated concentrations exist, and in which type(s) of material. Efforts are currently underway to have fill samples analyzed for PCBs as part of pier replacement work being conducted at Trent Bridge by the Washington Department of Transportation.

The final option consists of sub-bottom profiling, which uses acoustic technology to identify objects (e.g. drums, transformers) buried beneath the surface.

Additional Biofilm Sampling

Additional biofilm sampling, conducted at sufficiently high spatial resolution, could be used to better identify locations of hot spots and provide information that could be used to infer the nature of the source. Results of geostatistical analyses discussed above indicate that samples spaced approximately 100 feet apart would be required to pinpoint source location, making this option prohibitively expensive for analysis using Method 1668. This option may be more feasible if a less rigorous analytical method is used, as the superior detection limits and congener profiles provided by Method 168 would not be required if the intent of the monitoring was solely to identify hot spots.

Prioritization of Studies

The above options were discussed at the the July 21, 2020 Technical Track Work Group meeting, and the decision was made to defer selection of any future studies until results of the upcoming SPMD and fish tissue PCB monitoring studies (and potentially PCB samples of bottom fill material) are available.

References

Era-Miller, B., 2020a. Using Biofilms to Identify Sources of PCBs to the Spokane River: 2019 Preliminary Results. Presentation to SRRTTF. April 22, 2020. http://srrttf.org/wp-content/uploads/2020/04/4a-SRRTTF_Biofilm_4-22-20.pdf

Era-Miller, B., 2020a. Personal communication.

Hermanson, M. 2020. Personal communication.

LimnoTech, 2015. Spokane River Regional Toxics Task Force Phase 2 Technical Activities Report: Identification of Potential Unmonitored Dry Weather Sources of PCBs to the Spokane River. Prepared for Spokane River Regional Toxics Task Force.

LimnoTech, 2016. Spokane River Regional Toxics Task Force 2015 Technical Activities Report: Continued Identification of Potential Unmonitored Dry Weather Sources of PCBs to the Spokane River. Prepared for the Spokane River Regional Toxics Task Force.

LimnoTech, 2017. Spokane River Regional Toxics Task Force 2016 Monthly Monitoring Report. Prepared for the Spokane River Regional Toxics Task Force.

LimnoTech, 2019. Spokane River Regional Toxics Task Force 2018 Technical Activities Report: Continued Identification of Potential Unmonitored Dry Weather Sources of PCBs to the Spokane River. Prepared for the Spokane River Regional Toxics Task Force.

Wong, S. and B. Era-Miller. 2019. Quality Assurance Project Plan: Measuring PCBs in Biofilm, Sediment, and Invertebrates in the Spokane River: Screening Study. Publication No. 19-03-103. Washington State Department of Ecology, Olympia.