Memorandum

September 27, 2017

To: John Palmer, USEPA and Dru Keenan, USEPA

From: Peter Leinenbach, USEPA

Subject: Supplement to estimated CWR volume in Herman Creek Cove

Background - A previous USEPA memorandum (Estimating the volume of Cold Water Refugia (CWR) within the Herman Creek Cove – 6/1/2017) presented temperatures estimates at the confluence of Herman Creek and the Columbia River. It was determined that more information within the Herman Creek "Cove" was needed to more accurately estimate the volume of CWR volume at this confluence and as a result additional field data was collected on August 16, 2017. This memorandum presents these new efforts to estimate water temperatures within the Herman Creek "Cove".

Results - Bathometric maps were originally used to estimate the average depths within three zones at the Herman Creek and Columbia River Confluence (top image in **Figure 1**). Field Data collected within the cove regions of this confluence zone on August 16, 2017 was used to develop bathometric estimates and temperatures estimates within the "cove" zone of this confluence area (i.e., red areas in the bottom image in **Figure 1**).

It was previously determined in the June 1, 2017 USEPA memo that water temperatures within the confluence zone were more than 2*C cooler than the Columbia River mainstem and therefore could serve as cold water refuge. The CWR volume of the "non-cove" zone areas (i.e., green areas in the bottom image in **Figure 1**) are presented in **Table 1**.

Table 1. Calculated Surface Areas and Volumes outside of the Herman Creek Cove.

Cove Depth Group	Surface Area (m^2)	Volume (m^3)
1.5m	8,018	12,219
2.4m	8,533	20,479
Total Herman Creek CWR Volume (m^3) outside of the cove		**32,698**

Methods used to model water depths and temperatures within the Herman Creek Cove (i.e., the red areas in the bottom image of **Figure 1**) are presented in Appendix A and B of this memorandum.

Results of this analysis indicated that cold water from Herman Creek subsided into the lower depth of the Herman Creek Cove (**Table 2** and **Figure 2**).

Figure 1. Original assessment zone (top image) and modified assessment zones (bottom image).

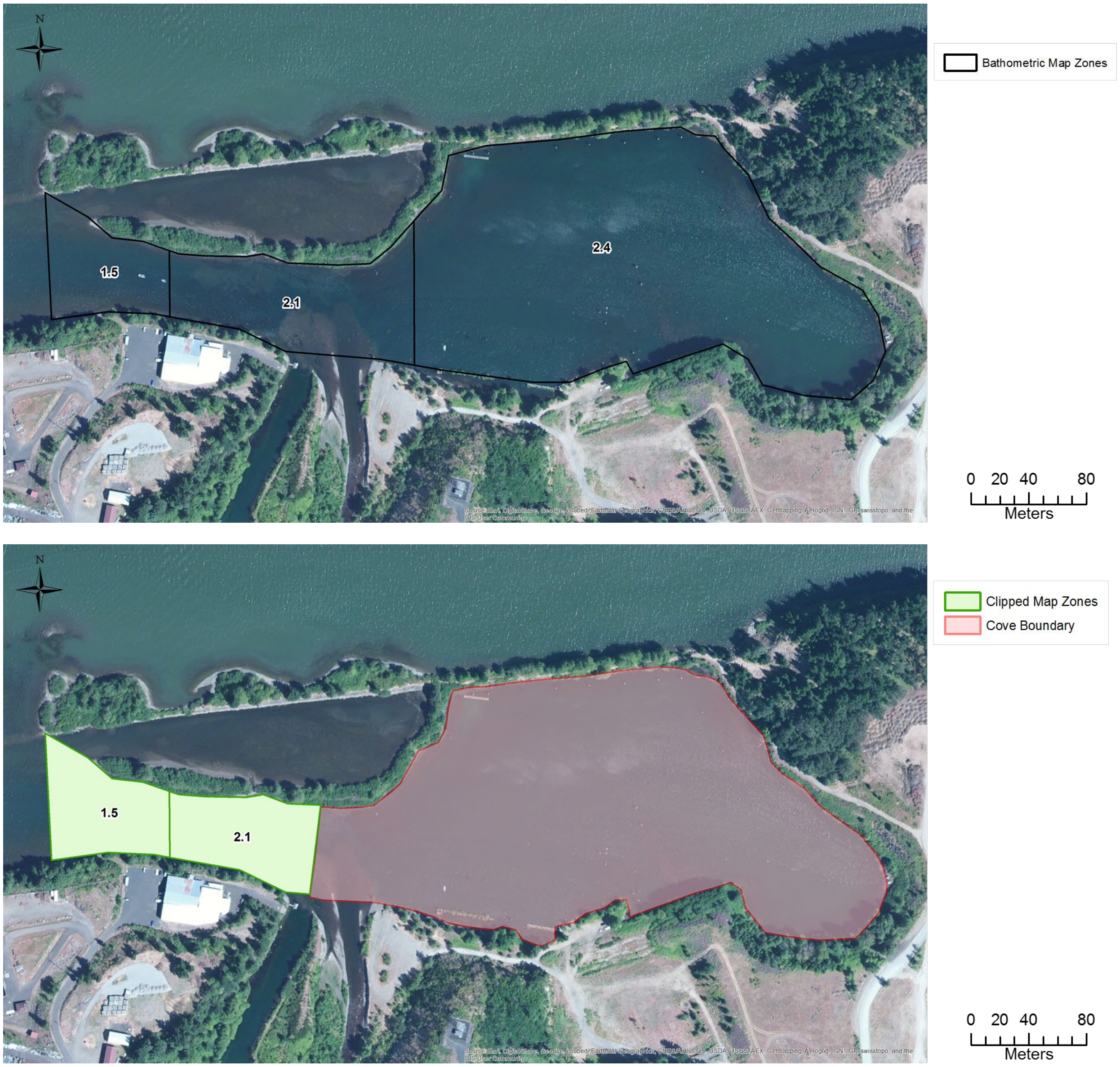
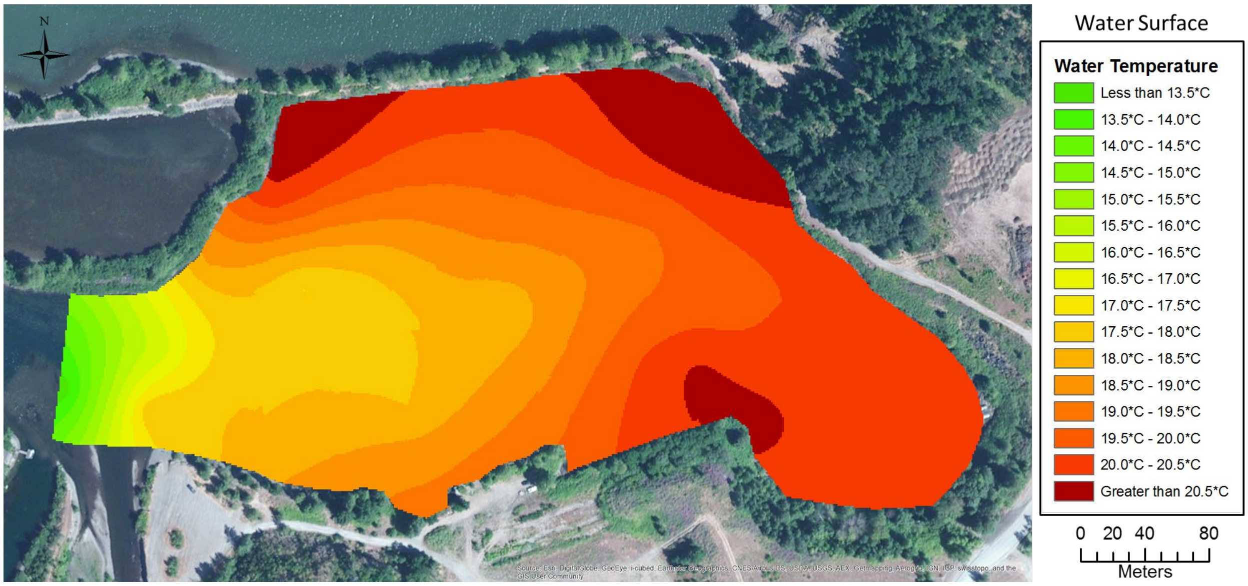


Table 2. Volume of water (m^3) within specific temperature ranges for the cove at the Herman Creek and Columbia River Confluence on August 16, 2017			
Depth	Less than 16*C	Between 16*C and 18*C	Between 18*C and 20*C
Surface	726	2,748	30,044
0.5 m	1,164	6,037	17,581
1.0 m	2,129	8,257	14,988
1.5 m	7,069	10,645	5,971
2.0 m	8,311	8,871	0
2.5 m	9,704	0	0
3.0 m	1,397	0	0
Sum	30,499	36,558	68,583

Figure 2. The cove at the Herman Creek and Columbia River Confluence – Model Water Temperature at Various Depths for August, 16, 2017.

<u>Depth - Surface</u>



<u>Depth – 0.5 m</u>

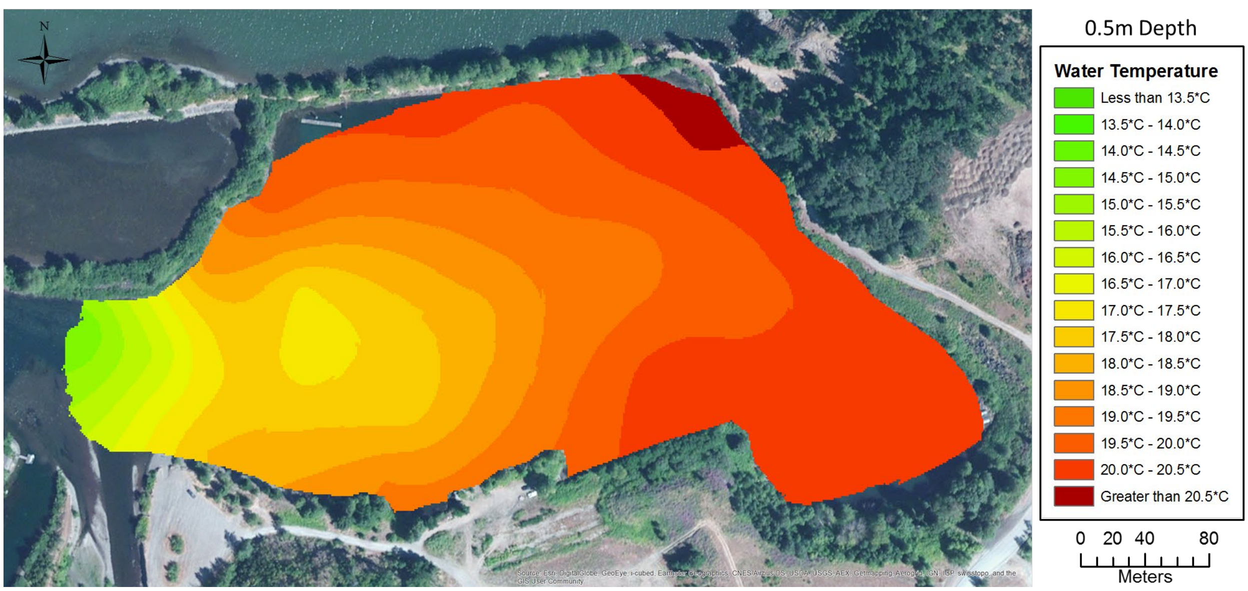
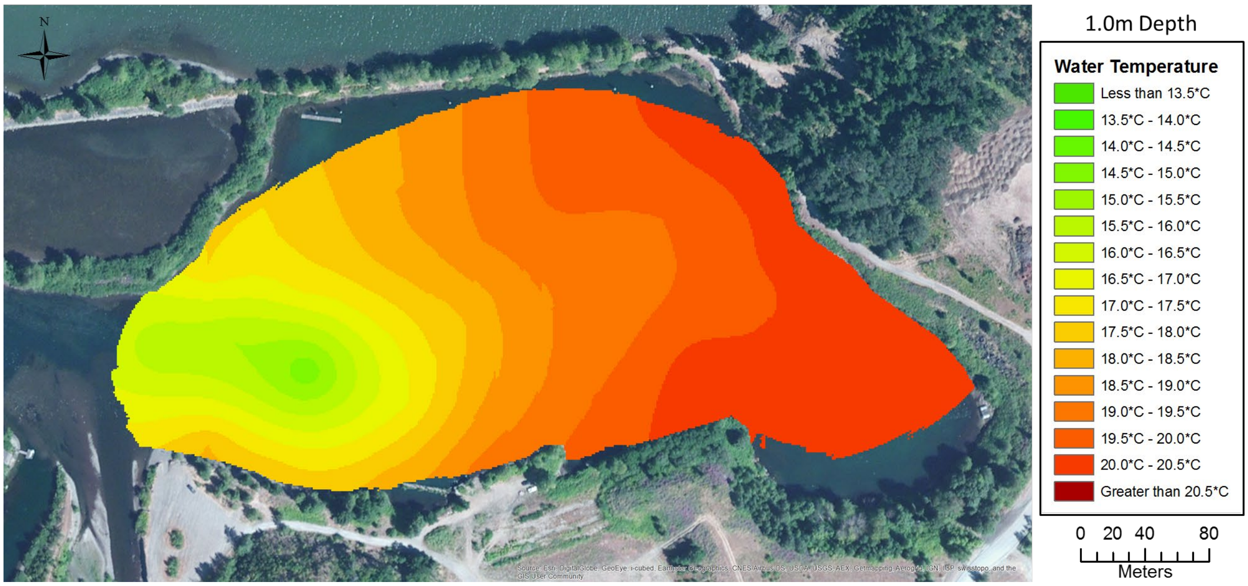


Figure 2 (Continued). The cove at the Herman Creek and Columbia River Confluence – Model Water Temperature at Various Depths for August, 16, 2017.

<u>Depth - 1.0 m</u>



<u>Depth -1.5 m</u>

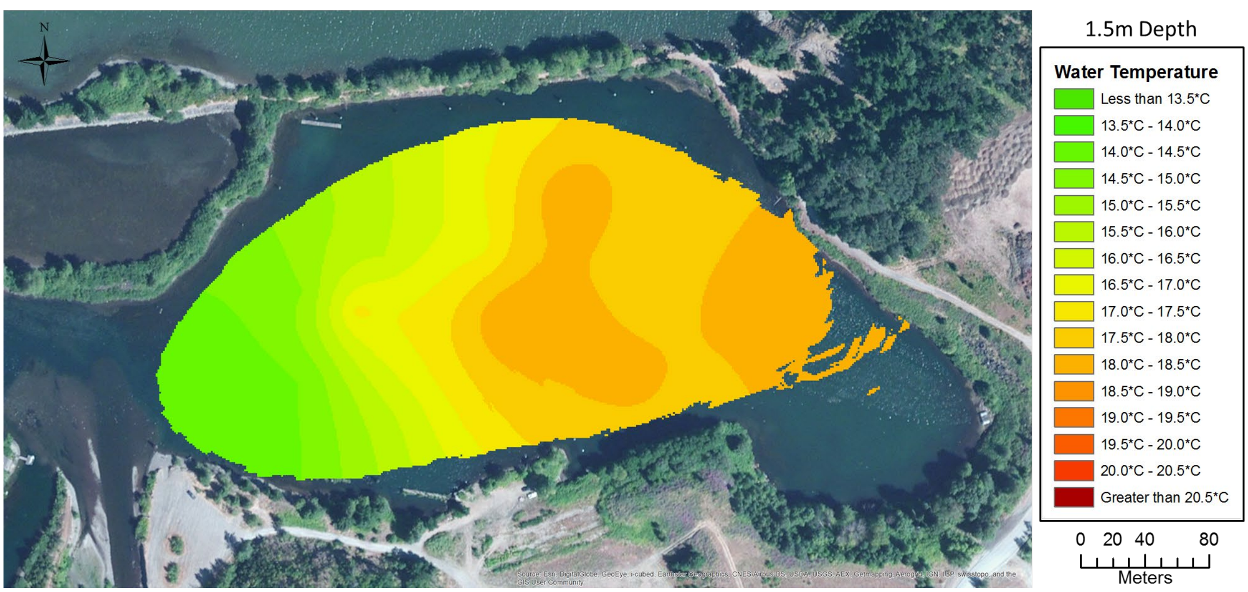
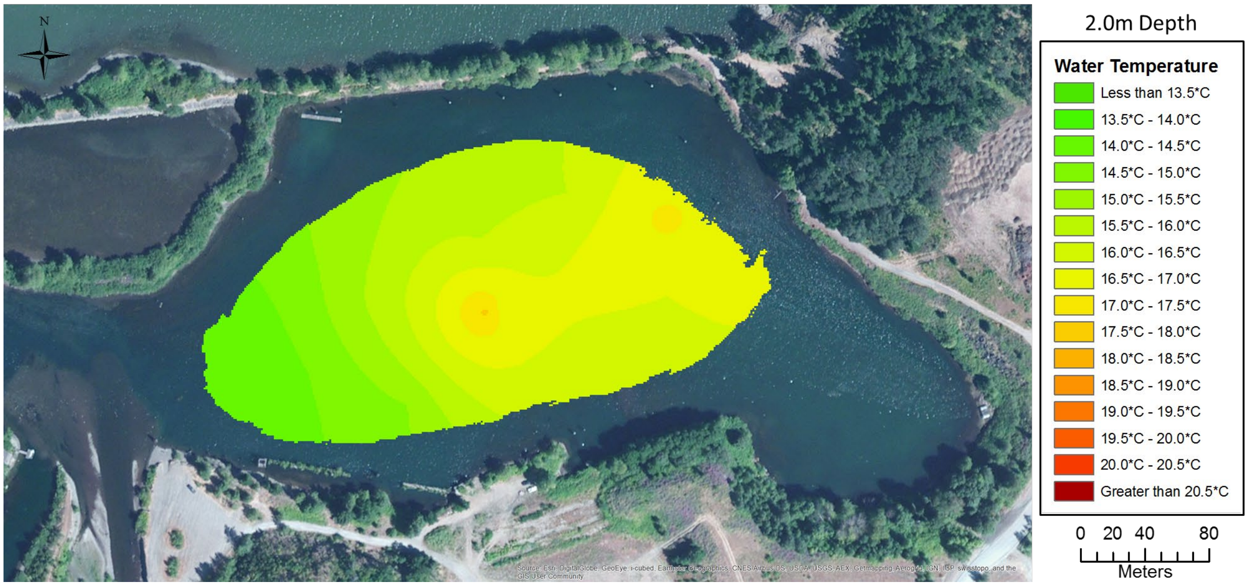


Figure 2 (Continued). The cove at the Herman Creek and Columbia River Confluence – Model Water Temperature at Various Depths for August, 16, 2017.

Depth – 2.0 m



Depth – 2.5 m

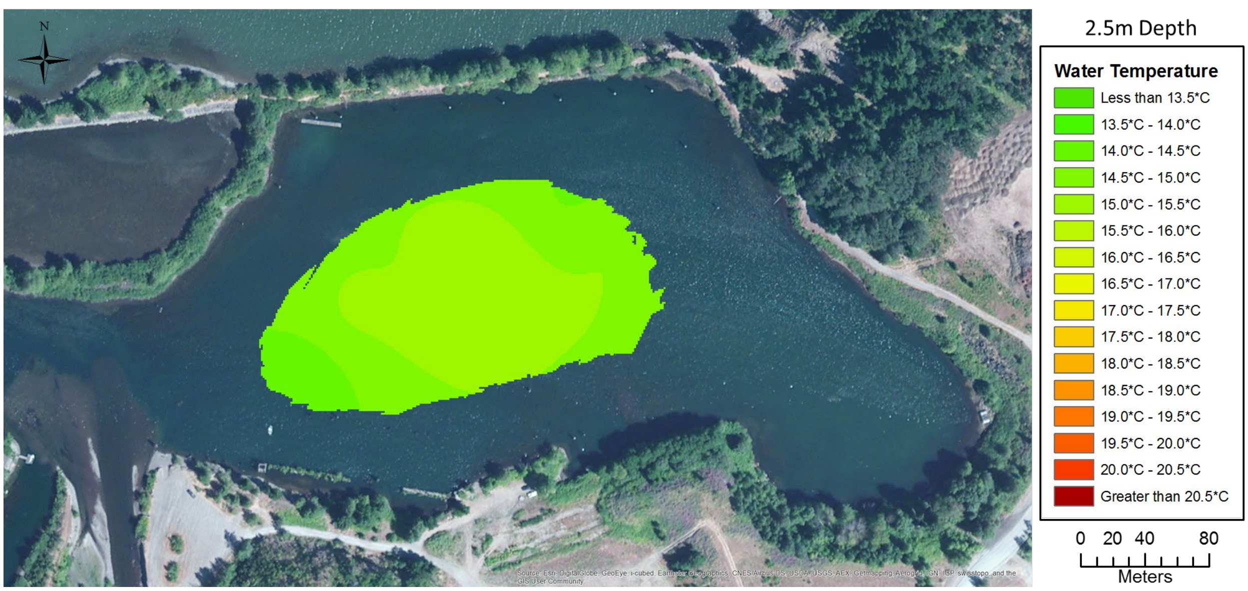
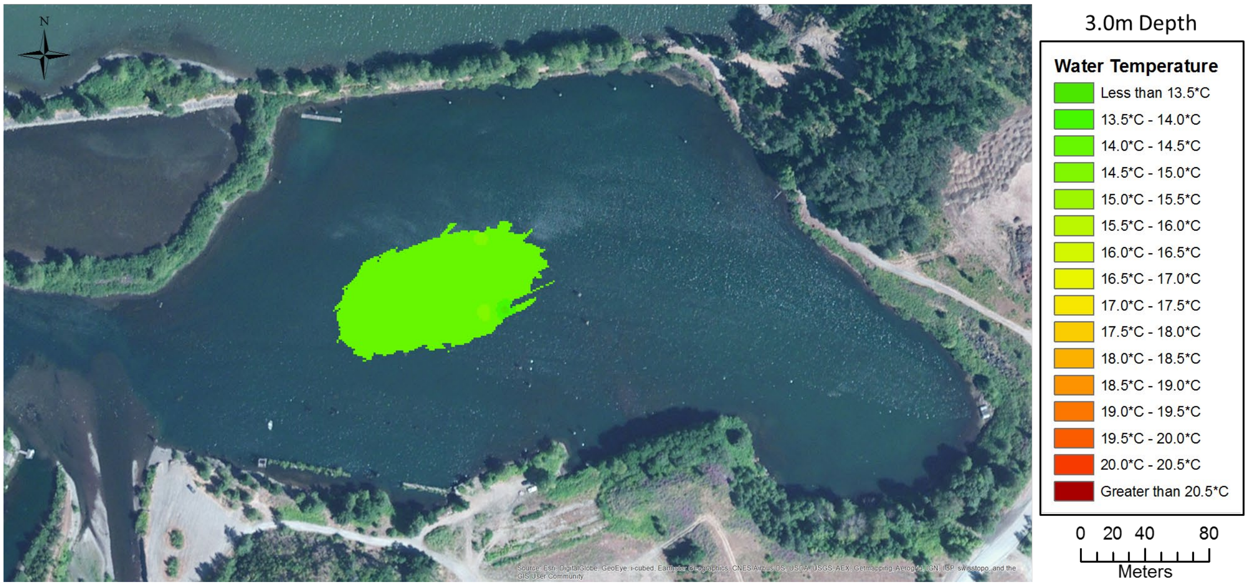


Figure 2 (Continued). The cove at the Herman Creek and Columbia River Confluence – Model Water Temperature at Various Depths for August, 16, 2017.

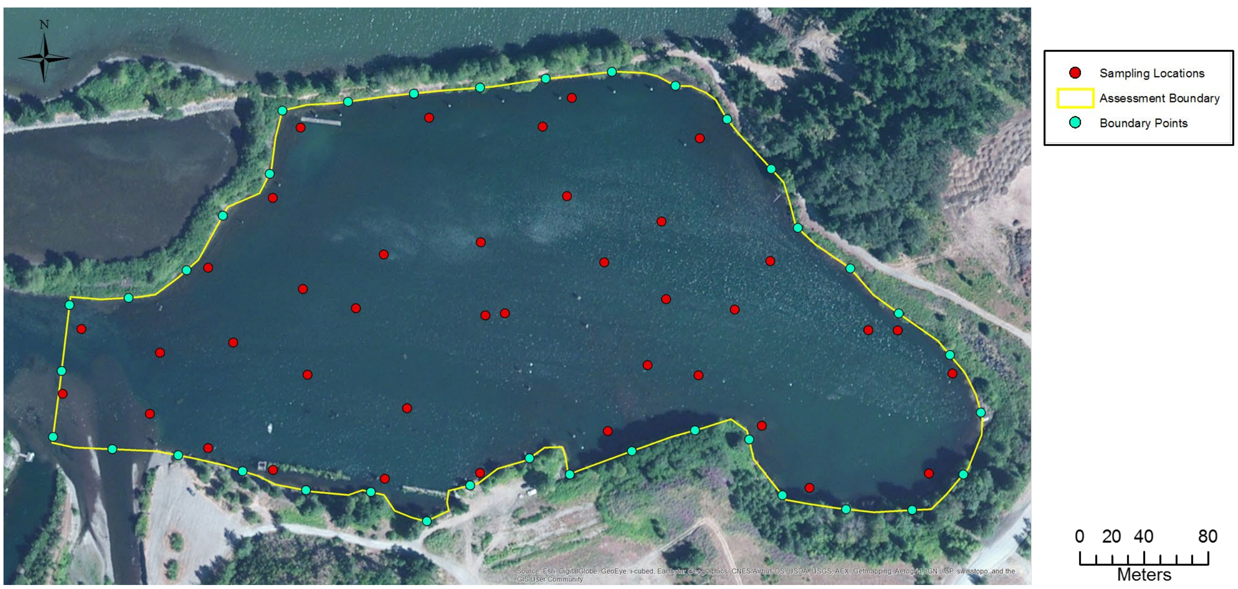
Depth – 3.0 m



Appendix A – Modeling Herman Creek Cove Bathometry

Developing Point Location Dataset

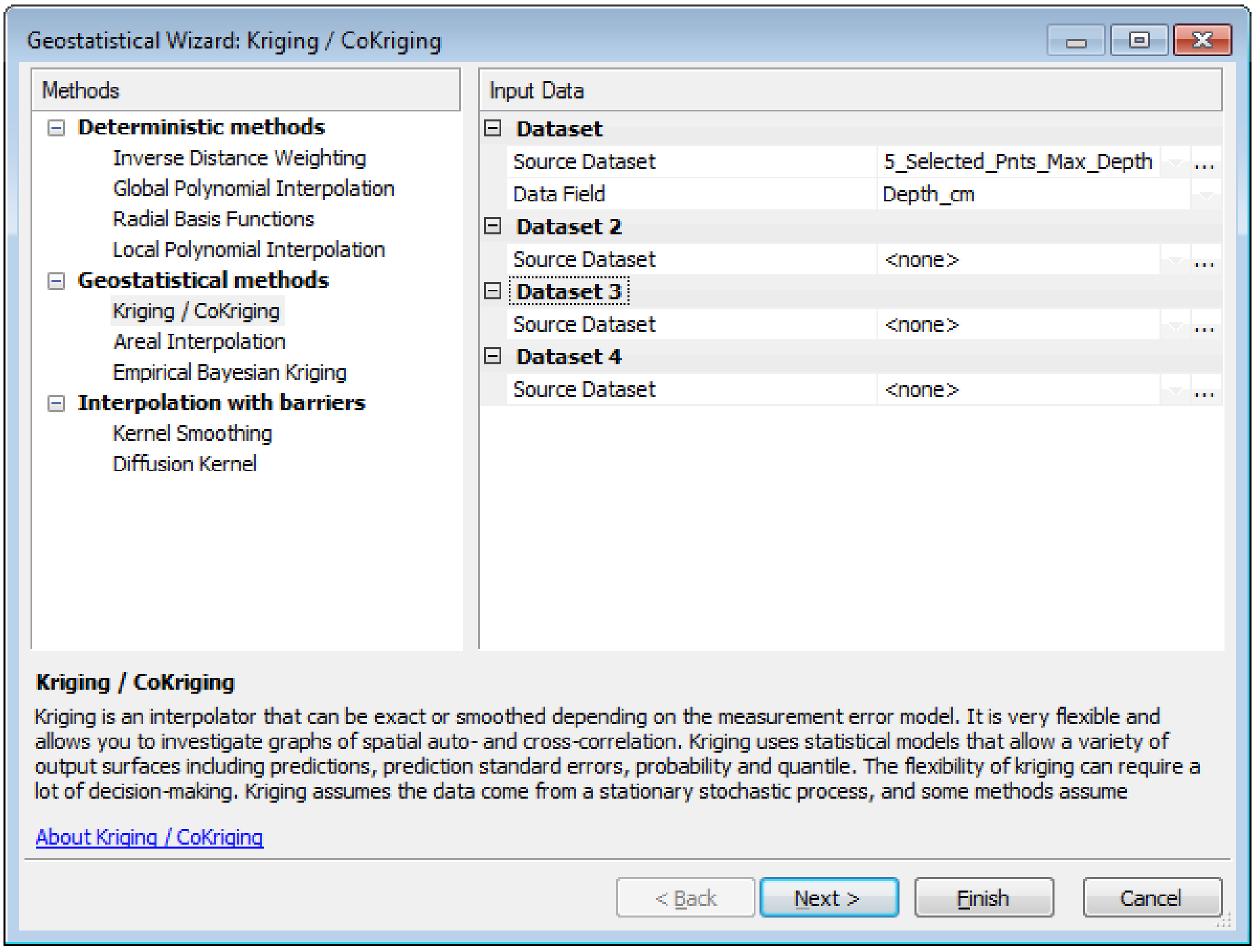
Depth measurements, and temperature measurements at depth, were collected within the cove at confluence of Herman Creek and the Columbia River on August 16, 2017 (Sampling locations are red dots in the image below). The average distance between each sampling location was 36 meters, calculated using the "Average Nearest Neighbor Summary" tool. This distance was used to calculate the distance of shore sampling nodes (i.e., zero depth) within this analysis area. The shore was digitized at a scale of 1:1000 scale from ortho-photos (Yellow line in image below). The digitized shore was converted to points (with a distance of 36 meters between each point) using X-tools (turquoise points in the image below). Subsequent processing will require that the depth values be in an integer format so it was necessary to convert depth from meters to centimeter in order to not loose information during subsequent Kriging analysis.



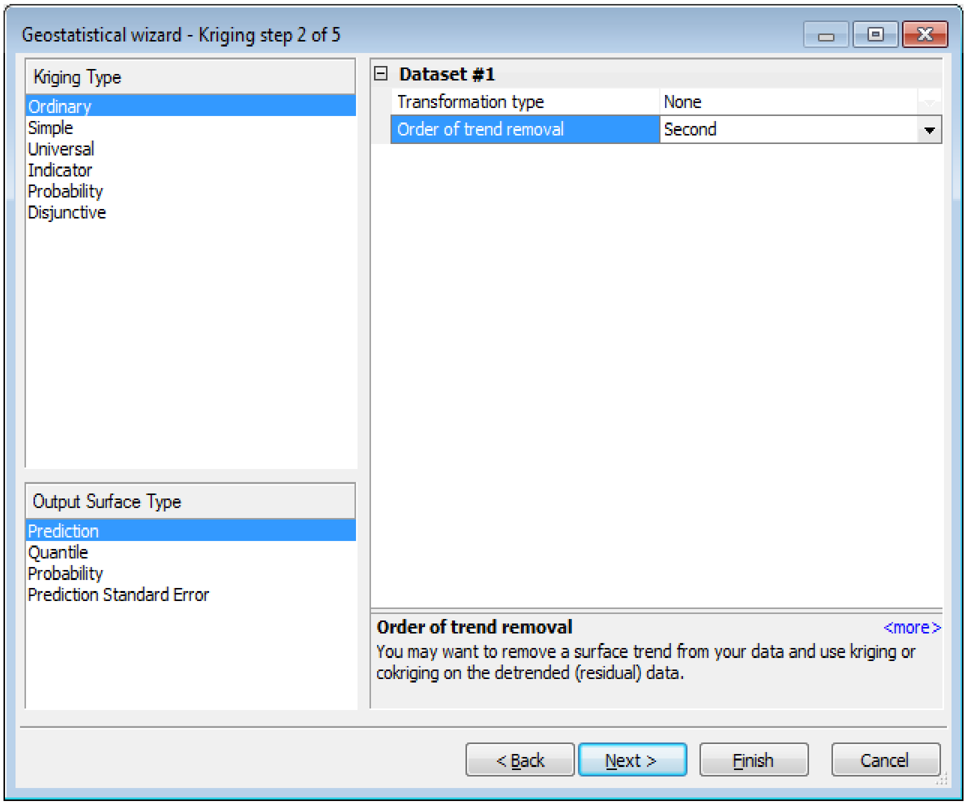
Spatial Kriging Modeling

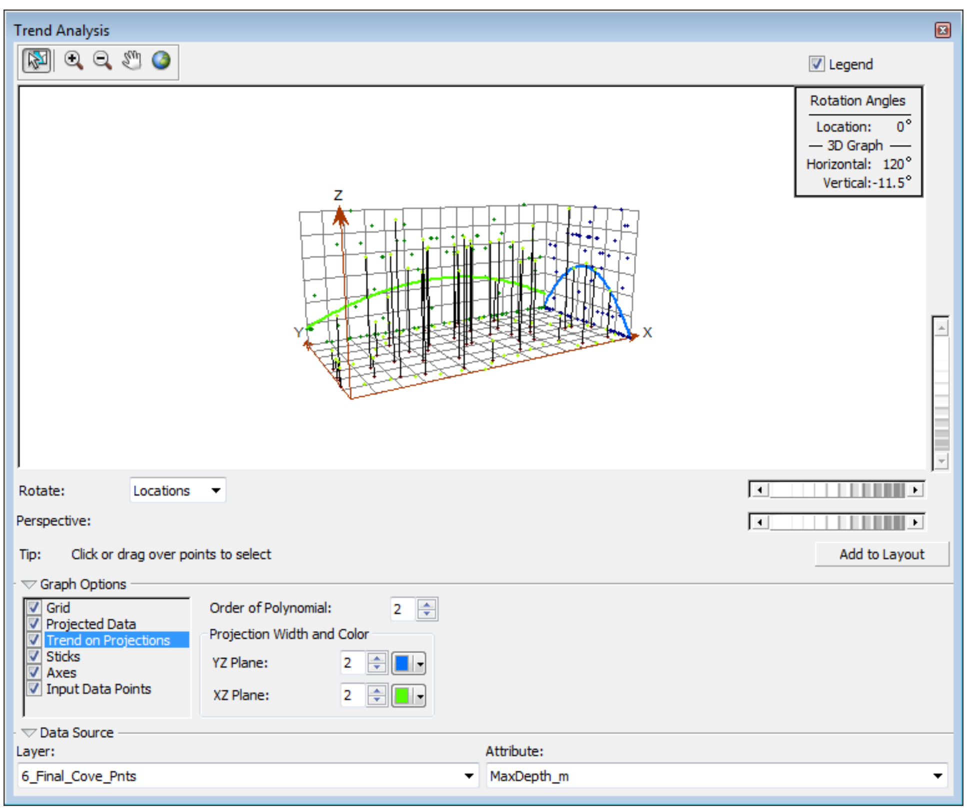
The bathometric elevation was calculated for the Herman Creek Cove through using the "Kriging" Geostatistical tool in ArcGIS. Methods used were similar as described in Tutorial 3 associated with this tool. Automatically optimized model variables calculated by the model were included in the analysis, except for the information provided on the following pages.

As can be seen below, the input dataset was set as the point coverage developed above (5_Selected_Pnts_Max_Depth and the "Data Field" was set to the depth in centimeters attribute (i.e., Depth_cm).

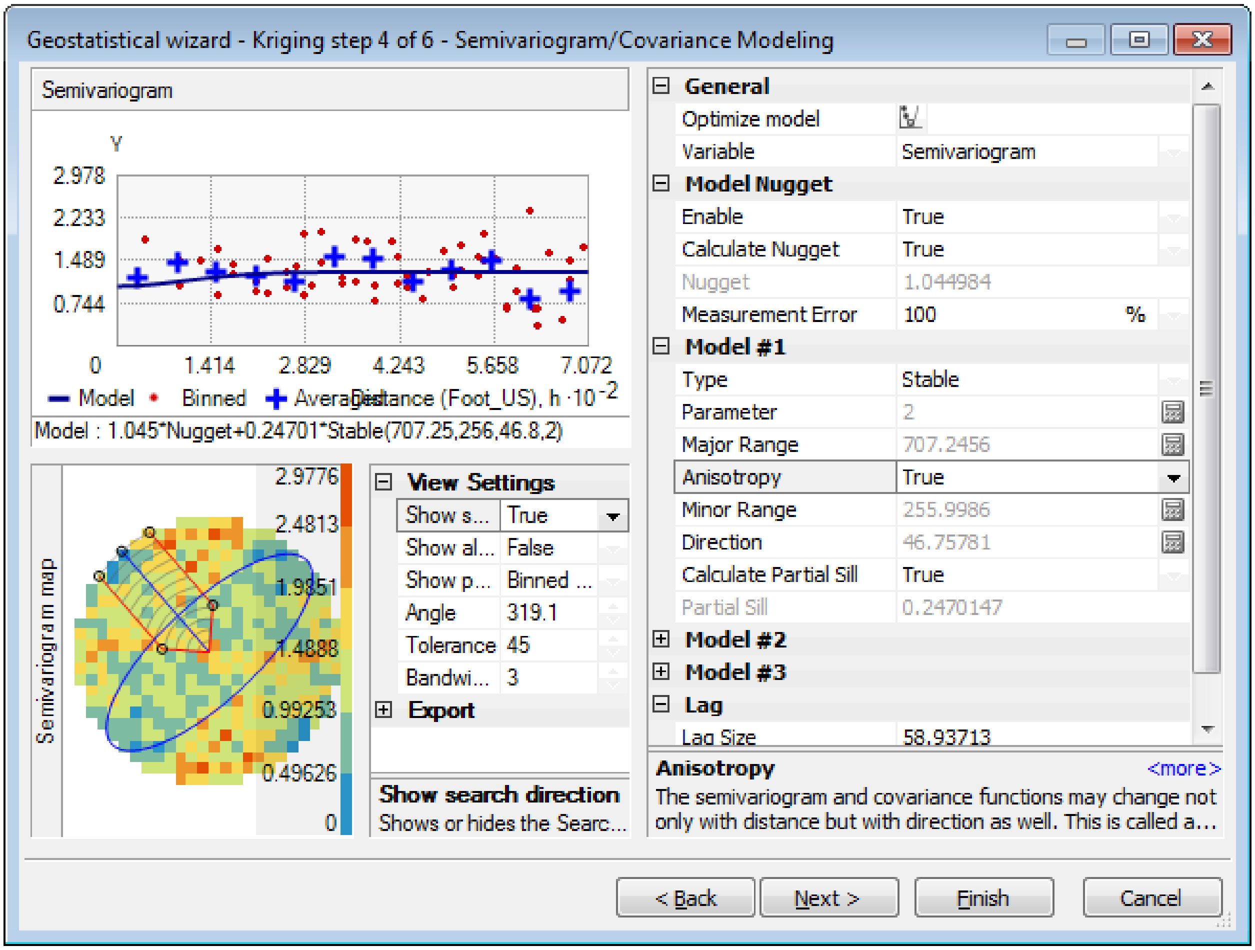


Ordinary Kriging method was chosen and the "Order of trend removal" was set at a Second, because there was a 2nd order polynomial trend observed in the data when using the "Tend Analysis" tool.

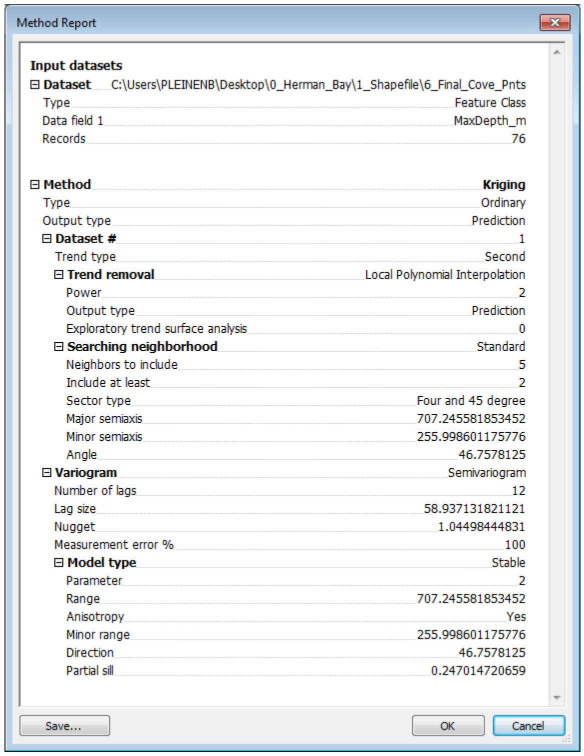




Adjusted for the local directional influence (anisotropy) in the semivariogram through changing the **Anisotropy** option from False to **True.** Geostatistical Analyst can account for directional influences, or anisotropy in the semivariogram model through this option. Anisotropy can be caused by wind, runoff, a geological structure, or a wide variety of other processes. The directional influence can be statistically quantified and accounted for when making your map through the use of this tool.



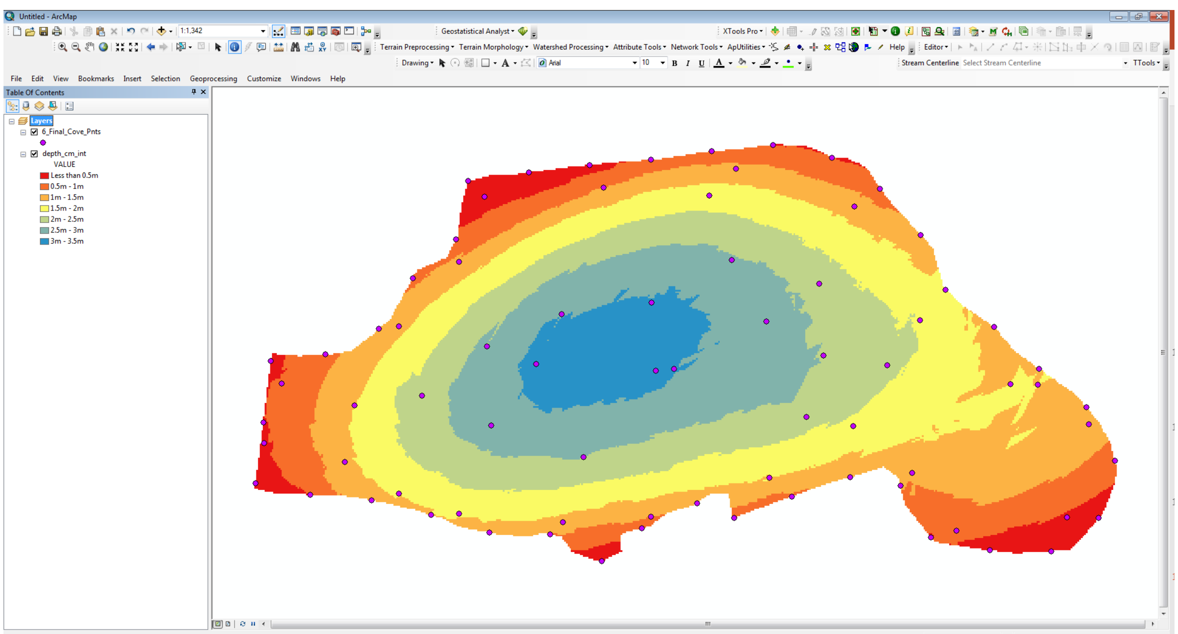
The input parameters are summarized and the output is illustrated below.



Method Report

Input datasets	
⊟ **Dataset**	C:\Users\PLEINENB\Desktop\0_Herman_Bay\1_Shapefile\6_Final_Cove_Pnts
Type	Feature Class
Data field 1	MaxDepth_m
Records	76
⊟ **Method**	**Kriging**
Type	Ordinary
Output type	Prediction
⊟ **Dataset #**	1
Trend type	Second
⊟ **Trend removal**	Local Polynomial Interpolation
Power	2
Output type	Prediction
Exploratory trend surface analysis	0
⊟ **Searching neighborhood**	Standard
Neighbors to include	5
Include at least	2
Sector type	Four and 45 degree
Major semiaxis	707.245581853452
Minor semiaxis	255.998601175776
Angle	46.7578125
⊟ **Variogram**	Semivariogram
Number of lags	12
Lag size	58.937131821121
Nugget	1.04498444831
Measurement error %	100
⊟ **Model type**	Stable
Parameter	2
Range	707.245581853452
Anisotropy	Yes
Minor range	255.998601175776
Direction	46.7578125
Partial sill	0.247014720659

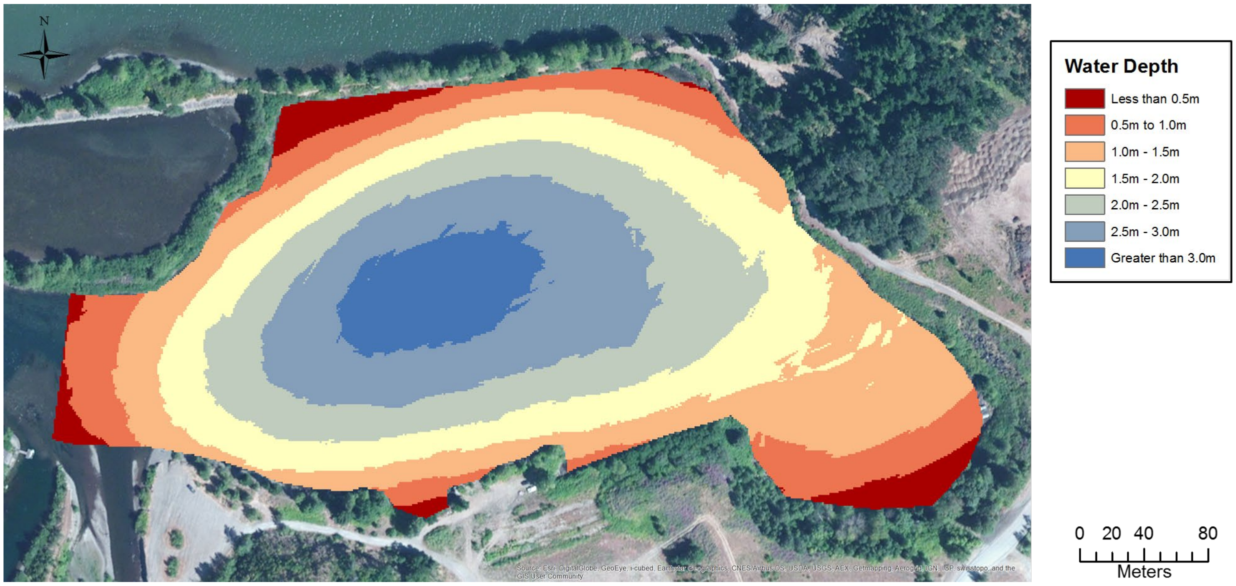
Save... OK Cancel



Kriging Model Output Processing - Export the output Kriging file as a grid file – making the cell size 1 meter. Convert the grid file into an integer using the “Int” tool – In the tools “Environmental Settings”, set the cell size as 1 meter, snap grid as the output grid described in the previous sentence and the boundary set to cove boundary.

Appendix B – Modeling Herman Creek Cove Temperature Profile Volumes

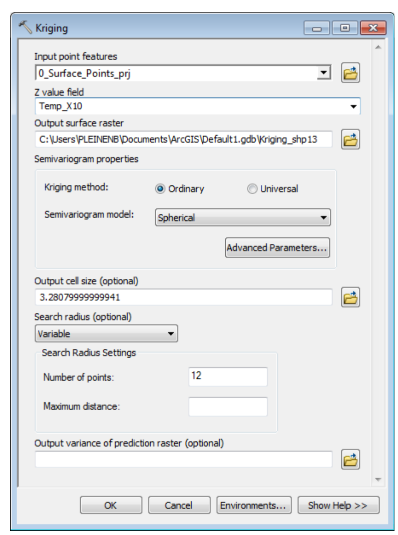
Water temperature profiles were collected at numerous locations within the Herman Creek Cove on August 16, 2017 (see image below). Water temperatures were modeled for different depths of this confluence zone based on this field data, and the bathometric data, through using the Spatial Kriging Geostatistical modeling tool in ArcGIS.



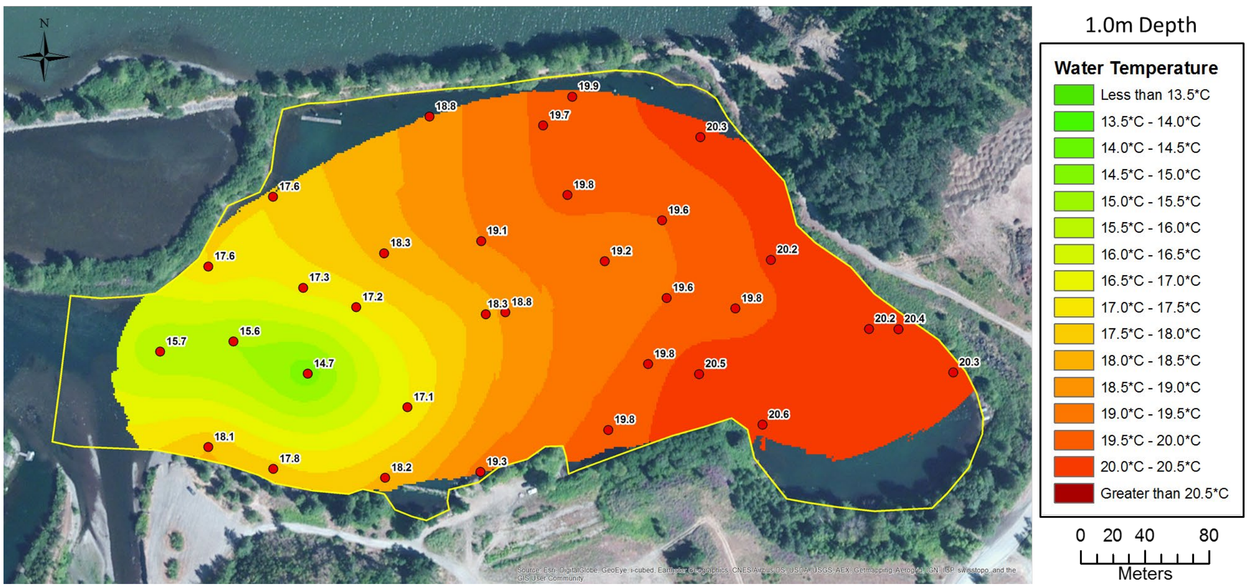
Stream temperatures was estimated for each 0.5-meter depth interval of the Herman Creek Cove through the kriging process in ArcGIS.

The first step was to create a boundary of each depth profile zone included in this analysis (i.e., determine the extent of each 0.5-meter depth profile within the sampling zone). These zones were selected through using the “Select by Attribute” tool in the Value Attribute Table (VAT). This selected zone was saved as a new grid file through using the “INT” tool in ArcGIS. It is very important that in the “Environmental Settings” with this tool that the “Processing Extent”, “Snap Raster”, “Cell Size” (i.e., 1m), and “Mask” were set to the original depth grid which depth zones are being “cut” from.

The next step was to estimate the water temperatures from the measured temperatures at that particular depth through using the Kriging tool in ArcGIS toolbox. Before running the tool, the measured temperatures were multiplied by 10 in order to not loose information during subsequent steps which required that the data be in an integer format. Default parameters were using with the Kriging tool. It is very important to that in the “Environmental Settings” with this tool that the “Processing Extent”, “Snap Raster”, “Cell Size”, and “Mask” were set to the sliced depth grid which the tool is estimating temperatures from.



The results of the Kriging process for the 1.0-meter depth profile in this confluence zone are illustrated in the image below (Monitoring locations, and the measured temperatures at these locations, used to estimate the water temperatures during the Kriging process are also illustrated in this image.) Similar analysis was processed for each 0.5-meter depth profile. The Kriging tool output does not have a VAT and therefor the results of this analysis were saved as a new grid file through using the "INT" tool in ArcGIS. It is very important that in the "Environmental Settings" with this tool that the "Processing Extent", "Snap Raster", "Cell Size", and "Mask" were set to the Kriged temperature grid that is being processed. The VAT associated with the INT grid was export as a Table and processed in MS Excel to calculate distribution of the temperatures in each zone (I.e., count the number of 1 meter cells).



A comparison analysis indicated that there is a close relationship between modeled and measured temperatures at the various depth conditions (see image below). This result would be expected due to the nature of the Kriging method. This analysis was implemented through using the "Sample" tool in ArcGIS.