

The Annual Surface and Ground Water Nutrient Budget of Spirit Lake, Mount Saint Helens, WA

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Introduction:

The eruption of Mount Saint Helens, May 18, 1980, initiated a massive redistribution of the physical properties of the surrounding areas, specifically Spirit Lake. "What had been a pristine, ultra-oligotrophic, relatively large alpine lake was reduced within minutes to a rolling, steaming body of water choked with logs and mud" (Larson, 1994). What had been Spirit Lake before the eruption is now buried under 60 meters of debris. The resulting lake basin is 80 percent larger, shallower, and has only 90 percent of the storage capacity (Larson, 1994). In addition to the physical changes, the newly formed log mat and geothermal activity of the eruption caused the temperature within Spirit Lake to suddenly rise by 20 degrees Celsius, along with other affects which include anoxic condition, and the elimination organisms that require oxygen (Larson et al. 2006).

Since the eruption, the ecosystem has been allowed to progress naturally without human restoration attempts. Currently Spirit Lake is experiencing significant primary productivity within the newly-created shallow region in the south end of the lake. This creates a unique research opportunity. The purpose of this study is to quantify the surface and ground water nutrient budget of Spirit Lake in an attempt to better understand the nutrient distribution and developing ecosystem of the watershed.

Over the summer of 2009 primary data was collected in order to create such a nutrient budget. In total eleven streams were sampled for nutrient concentrations and flow rates. Because of the floating migration of the log mat that exists of the lake, not all streams were accessible each

date of sampling. Seven streams were regularly sampled, which includes six streams on the south shoreline of the lake, and one on the north eastern shoreline. In addition to the surface water, inserted wells were also sampled on every occasion for nutrient concentrations and head-water depths. All six wells are located along the south shoreline of the lake.

Objectives:

To account for the nutrient budget of the entire watershed there needs to be a common related factor between the collected stream flow and nutrient data, and the watershed of the lake. In this case drainage area of each stream seems to be the logical answer. Using GIS, it is hoped that an area can be depicted that attributes to the flow of each witnessed stream. The area that was not sampled also needs to be accounted for. Since surface water in this watershed is fed by rain and snow melt, it is fair to assume that the source is evenly distributed and dependant on area and slope.

The tunnel is the only outflow for the lake and since it has a fixed shape, the flow is constant and can be calculated. Therefore ground water flow can be found as it is the only unknown in a three variable system by subtracting surface water flow from the tunnel flow.

Planning:

The course of planning this project spanned six months. The initially plan was to use physical characteristics of the watershed to propose alternative locations for sampling stream sites.

However after beginning to analyze the data and researching other data collected by such agencies as the USGS, it was realized that alternative flow areas flow during seasons other than that of sampling. Sampling can only take place when researchers can access the area. Due to the elevation and location the lake area, it becomes isolated by heavy snow accumulation during the other seasons of the year.

The next proposed use of GIS was to create sub-watershed areas. First, obtaining a base map of the area and using the clip tool to extract the watershed. Then importing it into ArcScene and overlaying it with an elevation raster to create a 3D model. Next it was planned to import the sample points and use the watershed tool in arc toolbox to create sub watersheds. Finally, nutrient data would be overlaid and an interpolation could be conducted to rank the sub watersheds in-terms of nutrient contribution.

With further thought into the project this plan became problematic. The watershed tool output areas did not account for all of the watershed area, and the interpolation was limiting because there are so few sample points.

Through exploring the hydrology set of tools in arc toolbox, the Basin tool was discovered as well as the Flow Accumulation and Flow Direction tool. It was then decided that these tools along with the clip tool, join feature, and field calculator, would be used to analyze the data.

Implementation:

First a surface raster was downloaded and imported from the USGS Seamless server. The raster was input in to Arcmap and the flow direction tool was used to create a raster of flow direction

from each cell to the steepest down slope neighbor. This raster was then input into the Flow Accumulation tool to create a raster of accumulated flow for each cell. The visual of the flow accumulation was very intriguing because it drew a picture of streams flowing toward the lake. These streams aligned with the sample points that were taken over the summer. Next the basins tool was used to create a raster to delineate basin boundaries. The basins created perfectly outlined the streams drawn by the flow accumulation tool. The basins accounted for the total area of the watershed. The basin raster was then converted to a polygon layer by using the raster to polygon tool. Sample points were imported and spatially joined to the basin layer. The attribute table of this layer was exported and opened in excel. In excel the relationship between basin area and stream flow was plotted to reveal a relevant relationship. Flow for the unsampled basins was then calculated and displayed on a map.

Nutrient data was next compared to basin area to see the relationship. The relationship for both nitrogen and phosphorus when compared to basin area was also relevant although with a lower r^2 value. So they concentration of nitrogen and phosphorus was calculated and mapped for the unsampled streams as well.

Then the question arose, what about the affects of plant coverage on the concentration of nutrients. To answer this question a plant coverage dataset was downloaded from the USGS Seamless server and imported into Arcmap. This raster layer was converted in to a polygon layer using the raster to the polygon layer. The layer was then given categories based on the metadata. The Plant Cover polygons were then spatially joined with the basins layer, and the average plant cover per basin was mapped.

Discussion:

The maps that were created are a visual representation of the flow and nutrient distribution of the Spirit Lake Watershed. To sum of the flow for all the basins is the estimated surface water flow for the watershed. The outflow from the tunnel was then calculated by flow rate data (USGS) multiplied by the area of the tunnel gate opening. The ground water flowing in to the lake was assumed to be the difference between the surface water inflow and the tunnel outflow.

There is a relationship between plant cover and nutrient load according to the maps that were created. This makes sense because plants absorb nutrients into their mass. However the plant cover data that was use is more specific than what is represented. The data included general types of plants not of only percent cover. Different types of plants absorb nutrients and water at differing rates. It would be interesting to include the absorption rate of each plant group and relate that to the nutrient budget.

Critiques:

To understand the nutrient budget in general for the Spirit Lake Watershed, this created model works but could be improved. The maps and nutrient budget created do not show an accurate nutrient distribution. Because the watershed is a heterogeneous collage of debris from the Mount Saint Helens eruption it is unlikely that the nutrients are distributed evenly over the total area. The assumptions that were used for this model need to be relooked at and refined for a better more comprehensive model to be created.

The south shoreline of the lake was the only portion that was regularly sampled. It was assumed that the samples from this portion of the lake would be representative of the occurrences of the total area. Also there are only six wells inserted and sampled regularly as of now, and they are all located on the south shoreline as well. It was assumed that these wells are a good representation of all ground water.

In order to improve the nutrient budget in the following years, a more complete dataset needs to be collected. This dataset needs to include regular sampling of every running stream on all sides of the lake. Also the number of wells inserted and sampled needs to be increased and located spaced around the entire shoreline to show variation of incoming nutrient loads.

The sampling occurred only in the summer months, it is assumed that the average of this time period is approximately the average surface water flow for the year. Although the height of the lake surface data supports this assumption, more data would be more accurate. Sampling months should be extended to the longest time possible.

One last possible error that needs to be addressed in the calculating of the tunnel flow, the gate is only assumed to be 50 percent open. Data could not be found to confirm the position of the gate. In order to limit error in both the outflow from the tunnel and the ground water flow the position of the gate needs to be verified.

Resources:

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