

Effects of Shortwave Radiation on Instream Temperatures Due to Increased Turbidity, Substrate Color Variation, and Reflection Changes

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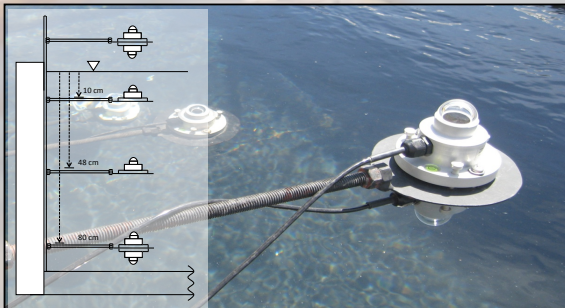
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Abstract

Limited water resources in Southern Utah with the competing interests of humans and native fishes require careful management. High instream temperatures resulting from low flows are a consideration in managing the Virgin River for two endangered fish species. Throughout these periods, fish behavior changes have been observed during times of high turbidity. One hypothesis was that high turbidity decreased the amount of solar radiation in the water column due to increased reflection at the water surface resulting in reduced instream temperatures. To quantify the extent of changes in incoming energy to the river, a water tank was constructed to measure the effects of turbidity on solar radiation reflection off the water surface and attenuation with depth. We found that increases in turbidity led to a linear increase in solar radiation reflection for specific turbidity ranges. We also found that attenuation of solar radiation increased linearly as turbidity increased for specific turbidity ranges. The effects of turbidity on solar radiation behavior were translated into changes in instream temperatures through the use of an instream temperature model. The results indicated during summer low flow conditions that turbidity increases from 30-500 NTU decreased instream temperatures 1°C on average with maximum increases of 2°C.

Experimental Overview

To study the changes of the solar radiation reflection and attenuation within the water column due to turbidity increases and apply it to conditions found in Southern Utah, a water tank was constructed and outfitted with a pump and manifold system to maintain uniformly mixed conditions. Sediments from white shale and red sandstone were obtained from St. George, Utah. For each sediment type, particles < 0.0021 in. diameter were introduced and turbidity was monitored with a DTS-12 turbidity meter. Additionally, solar radiation was measured at 6 locations in the system including incoming and reflected at the surface of the water and at the bottom of the tank. Incoming solar radiation was measured near the top, middle, and bottom of the water column.

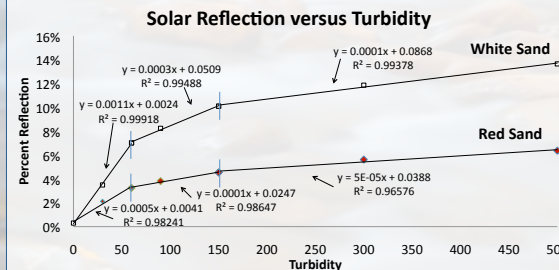


Turbidity Variation

While simultaneously measuring solar radiation above and within the water column, turbidity levels were increased initially from 0 to 500 within one day to establish dilution curves and assist in experimental design. Red and white sediment were then added daily over two weeks at intervals of 30, 60, 90, 150, 300, and 500 NTUs. Rapid addition of sand during four hours centered on solar noon was then completed at 10 – 30 NTU increments over ten minute periods. The resulting data provided relatively simple relationships between turbidity and reflection as well as turbidity and attenuation.



Water Surface Reflection Results



Radiation Attenuation

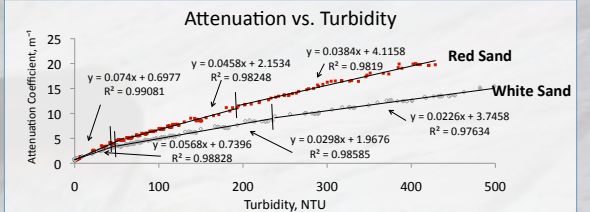
Broad spectrum light incident on the water column attenuates with an exponential decay relationship according to the following equation:

$$E_d(z) = E_d(0) e^{-K_d z}$$

where $E_d(z)$ is the incoming solar radiation at depth z , $E_d(0)$ is incoming solar radiation just below the water surface, and K_d is the estimated vertical attenuation coefficient.

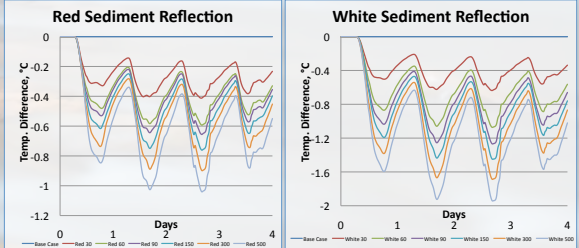
Attenuation coefficients were calculated for different water turbidity conditions and sand color variations.

Radiation Attenuation Results



Modeling Results

The results from the surface reflection data was used to adjust the amount of solar radiation entering the water column in an instream temperature model completed previously for the same area. The results show that for turbidities ranging from 30 to 500 NTUs, instream temperatures decrease on average 1 °C with maximum increases of 2 °C.



Conclusion

It was apparent that both radiation attenuation within the water column and surface reflection increased with increases in turbidity. Maximum instream temperatures are partly dependent on turbidity in the water. By understanding the relationship between turbidity increases and solar radiation, a better approximation of resulting changes in instream temperature can be established.

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