Increasing Contact Time and Reducing Short-Circuiting In a Clearwell Tank

White Paper

Updated January 2009

Background

In 2005 the City of Bend, Oregon's Water Division commissioned a new reservoir, known as Outback Reservoir #2, which functions as a clear well. The reservoir is welded steel above ground tank, which is 120 feet in diameter and has a maximum depth of 35.4 feet. The reservoir has a capacity of 2.9 million gallons (MG), however typical operating depth is about 26.6 feet or approximately 2.23 MG. The well was designed with separate inlet and outlet pipes, which are located directly opposite each other at the bottom of the tank. There are no baffles and the disinfectant used is chlorine.

In summer conditions, the maximum inflow from surface water sources is about 7,000 gallons per minute (gpm). Water is chlorinated just prior to inflow to the clear well. At this flow rate, the water in the tank would optimally turn over more than four (4) times per day. However, disinfection efficiency was unacceptably low. Thermal stratification and high flow rates were causing short-circuiting of the flow directly from inlet across the tank to the outlet. Contact times (CT) were about 30 minutes.

Several steps were undertaken to address the concerns. These were:

1. Installed a SolarBee mixer in the center of the tank inline between the inlet and outlet to increase CT and break up thermal stratification;
2. Undertook a tracer study to verify the contact time with the mixer operational to ensure regulatory compliance;
3. Conducted a computational fluid dynamics (CFD) model of the flow conditions with and without the SolarBee

SolarBee Installation Objectives

The SolarBee SB10000v12PW was installed in October 2006. This NSF 61-certified unit has a direct flow of 3,000 gpm and a total direct and induced flow of 10,000 gpm. The unit is a low-head, high-volume pump that is solar-powered by photovoltaic panels on the roof of the tank, and runs by battery around the clock.

The intake hose for the SolarBee was placed on the floor near the center of the tank directly inline with the inlet and outlet pipes. The intent of the SolarBee is to increase contact time and efficiency by intercepting the plume of water transiting across the bottom of the tank and pull it to the surface, thereby mixing the incoming flow, breaking thermal stratification in the water column and eliminating stagnation.

Tracer Study Verification

In January 2007, Water Division staff undertook a tracer study in order to evaluate how effective the SolarBee circulation was in improving the contact time. Prior to the SolarBee, the Water Division was seeing contact time in the 30-minute range; the regulatory requirement was 30 minutes and the SolarBee model and placement was designed to increase CT.

The tracer study consisted of injecting a tracer of food-grade calcium chloride with a metered pump, and monitoring water temperature and specific conductance at the inlet and outlet of the clear well tank. Figure 1 shows the tracer study results, which conclusively determined that CT was 80 minutes, or a comfortable 150% greater than the regulatory target value.

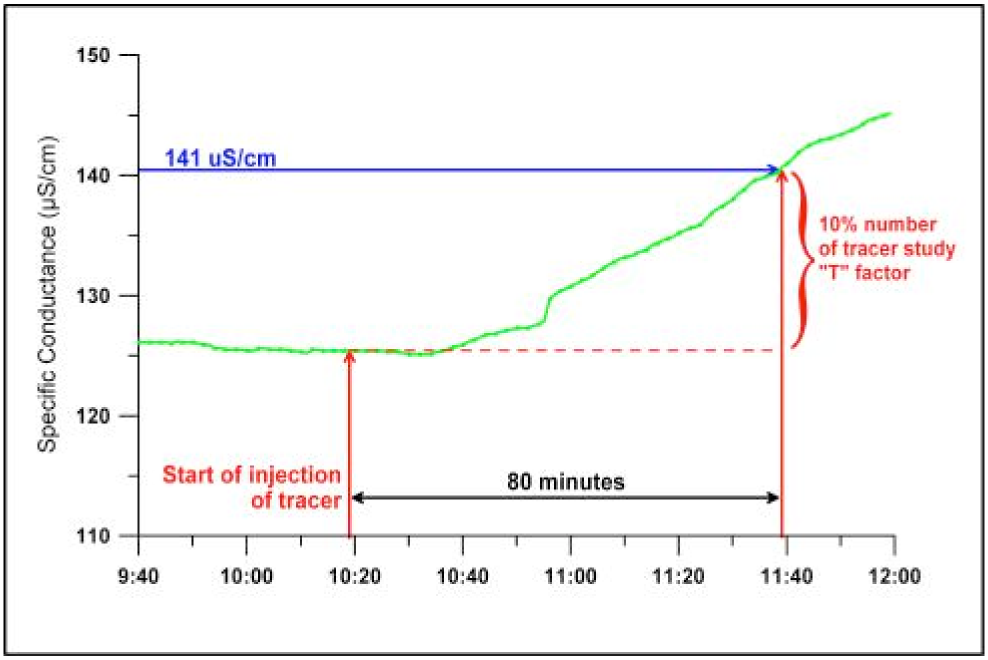

Figure 1 – Tracer Study Results

CFD Model Results

A computational fluid dynamics (CFD) model of the tank was subsequently developed by Tank Dynamics, Bend, OR. The model was developed to illustrate the hydrodynamic conditions as verified in the tracer study and to illustrate the short-circuiting phenomena without the SolarBee mixer in place. The results of the CFD modeling included the production of images based on the flow velocities as determined in the tracer study. Red indicates a high velocity of two feet per second (2.0 ft/s) or greater; dark blue indicates a low velocity of 0.2 ft/s or less.

Figure 2 shows the CFD modeling of the tank without a SolarBee mixer. Short-circuiting is clearly evident as the plume of cool, incoming water transits directly across the bottom of the tank. The modeling shows that the new water entering the tank stays low, near the bottom, and short-circuits right to the outlet structure. The tank diameter is 120 ft, with a velocity of 2 ft/s; the travel time through during peak periods for a portion of the flow is on the order of 2 minutes. Note that the upper levels of the tank, near the inlet structure, are at very low velocities and not mixing well with the new water coming into the tank. This condition is further aggravated with thermal stratification where these upper layers of the water column are warmer and less dense, and therefore do not easily mix with cooler denser water coming in.

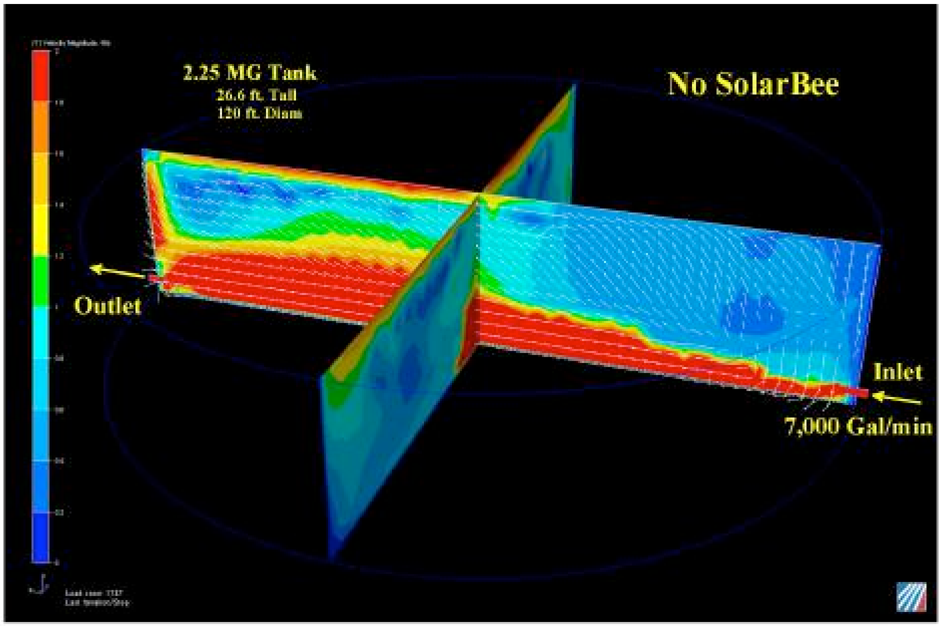

Figure 2 – No Mixing

Figure 3 shows the CFD modeling of the tank with the SolarBee mixer in place. The SolarBee is located in the middle of the tank, with the intake placed directly in the short-circuiting path between the inlet/outlet structures. The CFD modeling shows that much of the new water entering the tank is captured by the SolarBee in the middle and then dispersed to the surface of the tank radially, including back towards the inlet structure. The yellow color just past the SolarBee, in line with the outlet structure, shows some ‘blow by’ past the SolarBee, indicating that the short-circuiting is not completely eliminated, but rather significantly controlled.

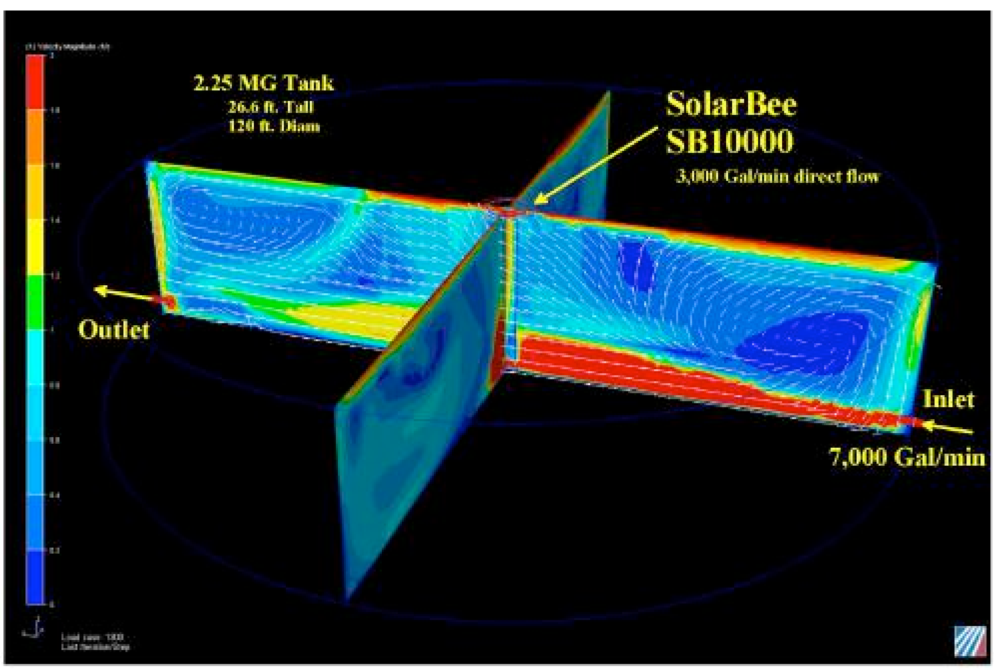

Figure 3 - With SolarBee Mixing

Conclusion

A tracer study has field-verified that CT has been increased from 30 minutes to 80 minutes in a 2.23 MG clear well. The clear well exceeds the regulatory requirement of 30 minutes by over 150%. CFD modeling has effectively replicated mathematically the results of the tracer study, and demonstrated the effectiveness of the SolarBee mixer. The CFD modeling has clearly illustrated the short-circuiting phenomenon that occurs without the SolarBee mixer in place. SolarBees can be effectively used to prevent short-circuiting by being placed directly in the short-circuiting path. The size and number of SolarBee required in other systems will be determined by geometry of the tank and flow rates.

Notes on CFD Modeling

Numerical CFD modeling represents an attempt to simulate highly complex processes in nature. Consequently, it is only an approximation of real-world conditions. The goal of numerical CFD modeling is to capture the dominant processes to present those results in a manner that is consistent with the physics associated with flow and hydraulics. As a rule, the greater the complexity of the conditions being simulated, the greater will be the uncertainty in the simulation of that system. Despite these limitations, CFD modeling is a highly valuable tool because it allows us to inexpensively conduct an unlimited number of "experiments" to observe changes on a system without the expense and time of field observations.