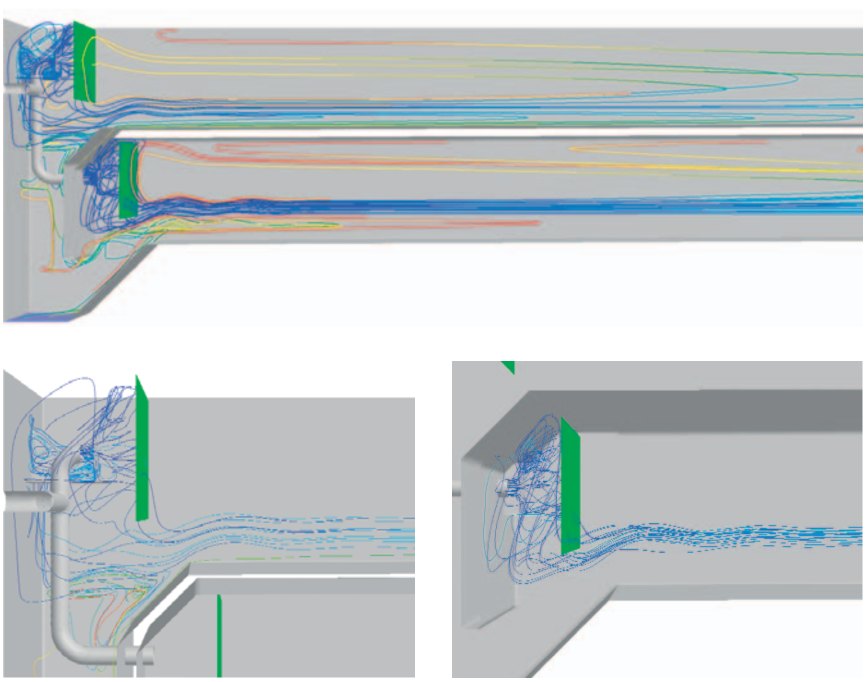
Settling Wastewater Tank Modeling Issues

By Barry W. Roff, Empresa Metropolitana de Sanejament SA (EMSSA), Barcelona, Spain, and Roberto Garcia, Didier Bessette, and Benoit Post, Fluent France SA

The new wastewater treatment plant

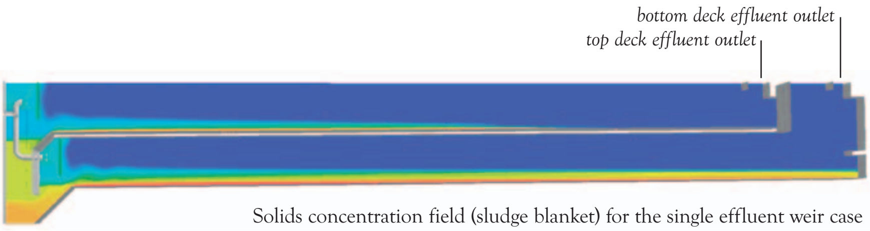


Pathlines illustrate the flow in the rectangular settling tank (top), with enlarged detail near the inlets of the upper (lower left) and lower (lower right) decks

A CRITICAL STEP in wastewater treatment is the clarification step, where solids produced in the biological reactors are separated from the treated water to provide a clean, treated effluent. In the Wastewater Treatment Plant of Besòs (Barcelona, Spain) the sedimentation step is accomplished using space-saving, double-decker rectangular settling tanks. Although not new, there is limited experience with these tanks, so CFD was used in the design process to verify certain details before the tanks were constructed.

Due to their particular features, the design of the clarifier tanks was a challenging task. The tank introduces flow, at both inlet levels, using a double baffle arrangement consisting of perforated plates to absorb energy and distribute the flow evenly across the full width of the tank. The resulting flow pattern should be well-aligned in the sedimentation zone, where solids settle towards the floor of the tank. The floor slope in the settling region is less pronounced than that used in the more common circular settling tanks, so the scraper system at the base of the tank, used to transport and later remove the settled solids, needs to be carefully designed. Beyond the settling region, there were additional design challenges where the effluent is discharged. Outlet baffle walls and two different effluent outlet arrangements (that make use of single and double effluent weirs) were studied as part of the project.

In addition to the geometrical complexities, several process issues needed to be addressed during the design of this particular tank configuration. For example, the hydraulics of the process should guide the flow from the inlet, through the sedimentation zone, and towards the effluent outlet



Solids concentration field (sludge blanket) for the single effluent weir case

without short-circuiting. The design should achieve a minimum, uniform longitudinal flow velocity everywhere; and efficiently transport and remove the solids.

Many physical phenomena exert a strong influence on the hydrodynamic performance of the settling tank and these were considered in the CFD analysis. They include the sludge settling velocity and viscosity, both dependent on concentration, turbulence effects, and buoyancy. The CFD analysis was also used to assess the performance of the sedimentation unit by means of residence time distribution (RTD) using a "tank in series" model. A series of operating conditions and flow rates were considered.

FLUENT was used to calculate the flow field. An additional scalar transport equation was solved to track the concentration of sludge [1], where the convection term was dependent on the sludge settling velocity. The settling velocity was modeled using the exponential settling function of Takács [2], whose parameters were defined for a target stirred sludge volume index (SSVI) of 100 ml/g. The SSVI is calculated based on the volume occupied by 1 liter of sludge after 30 minutes of settling in a gently stirred settling column. A Boussinesq-type approach was considered to account for the effect of gravity on the sludge, using source terms in the momentum equations. The concentration gradient, which reaches maximum values at the interface between the clear fluid and sludge, dampens the turbulence. To account for this effect, source terms were introduced in the turbulence equations.

The effect of the scraper blades was estimated with a sub-model in which the drag force exerted by the moving blades is calculated for both laminar and turbulent regimes. During the actual simulation, the velocity is calculated locally and the force of the scraper is adjusted based on the flow regime and relative blade-to-fluid velocity. It is then introduced by means of a momentum source.

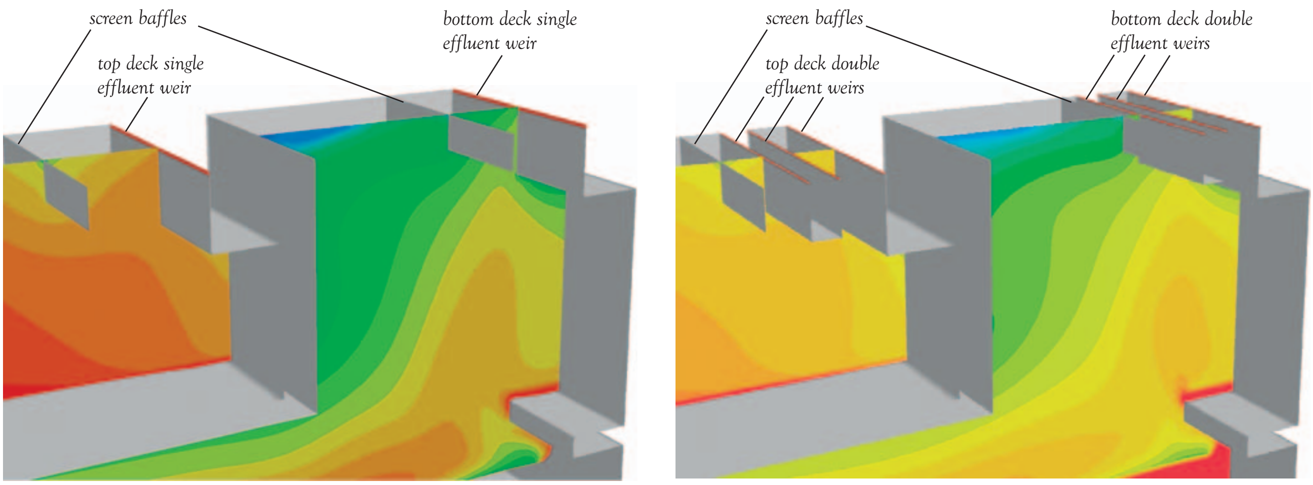
A time-marching scheme was used to conduct the calculation until a pseudo steady-state solution was achieved. Using a flow equivalent to normal operating conditions, an additional RTD calculation was performed to further characterize the behavior of the sedimentation tank.

The results show that effective solid removal efficiencies were achieved for the range of operating conditions considered. The inlet baffling arrangement succeeded in controlling the decay of kinetic energy and producing uniform directional velocity profiles in the sedimentation area of the clarifier. The flow patterns and RTD analysis confirm that short-circuiting is negligible and no dead zones are present. Finally, a detailed statistical analysis based on a tank-in-series model was employed to model the RTD data. For each of the three outlets (top deck effluent, bottom deck effluent, and return activated sludge), a best fit curve was calculated using three elements in parallel, each one consisting of several CSTRs (continuous stirred tank reactors) in series. From the results, it can be concluded that, for the purpose of sedimentation and based on forward flow, the behavior of the unit is close to plug flow in nature. In fact, the mean residence time (MRT) for the forward flow taken as a whole is above the hydraulic residence time (HRT), which should improve settling. ■

References

1 Lakehal, D.; Krebs, P.; Krijgsman, J.; and Rodi, W.: Computing shear flow and sludge blanket in secondary clarifiers. Journal of Hydraulic Engineering, 125(3), 253-262, 1999.

2 Takács, I.; Patry, G.; Nolasco, D.: A dynamic model of the clarification-thickening process. Water Research, 25, 1263-1271, 1991.



Solids concentration in the vicinity of the outlet with the single- (left) and double- (right) weir designs; no major improvement was observed when adding a second weir. For two throughputs (2190 m^3/h and 2865 m^3/h), high solids retention was attained