CFD Modelling of WEARS Australia ResMix™ 400 System - 95ML Reservoir

1.0 Introduction

The Wears Australia ResMix™ 400 source water management system was engineered and designed for installation into municipal water reservoirs. The system, which can incorporate dosing reagent mixing and dispersant is a purpose-designed, high flow, low powered, easy to install and addresses reservoir and circulation and stratification related issues. The ResMix™ 400 can reduce the impact of chlorine residual reductions by as much as 45 percent, eliminate stratification and reduce surface temperature, remove dead zones in the reservoir and minimise floor sedimentation and biological build-up on internal surface.

In order to better comprehend as well as visualise the effects a ResMix™ 400 has when installed into a typical municipal reservoir WEARS Australia engaged e3k to conduct a Computational Fluid Dynamics (CFD) analysis of the system.

2.0 Initial Parameters

2.1 CAD Model

A three dimensional Computer Aided Design (CAD) model, based on drawings of a typical 95ML municipal reservoir, of a single chamber of the reservoir was created using SolidWorks software.

The reservoir is divided into two symmetrical, rectangular chambers. A single chamber was modelled as the fluid system for CFD simulation. Figure 1 shows the CAD model of the reservoir chamber, which measures approximately 65 metres in width and 162 metres in length.

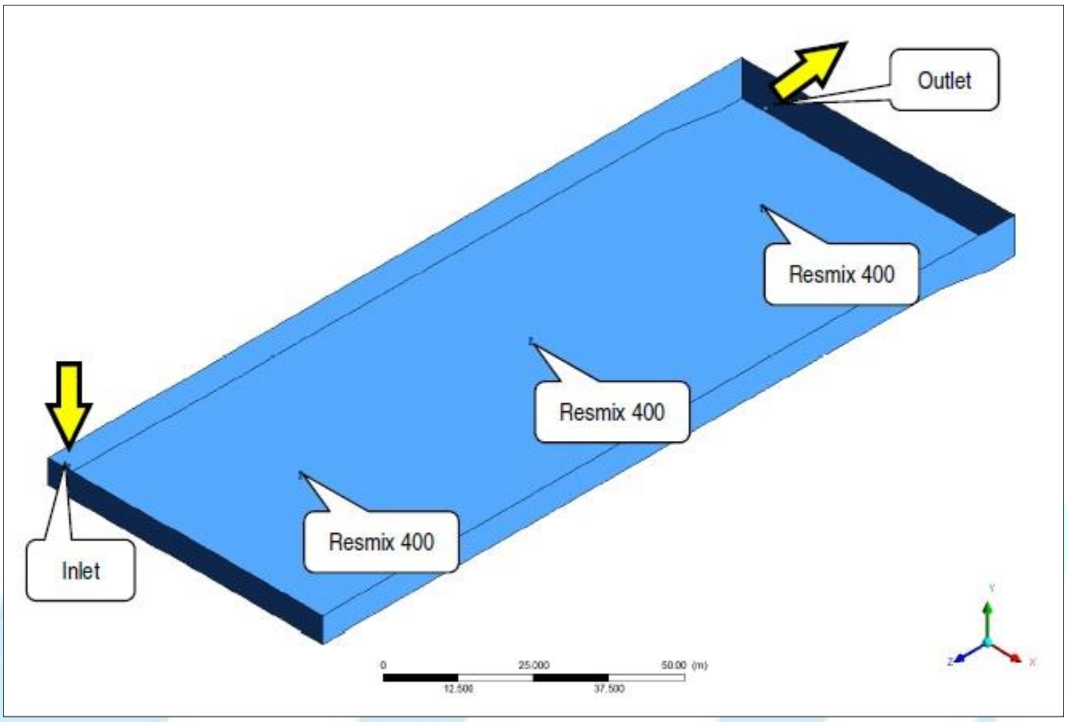

Figure 1: CAD model of the reservoir chamber

A single inlet is located at one corner in a downwards direction. At the opposite end of the reservoir chamber is a single outlet (discharge). The inlet and outlet were modelled as circular pipes.

The reservoir floor declines at a constant grade of 0.5 percent lengthways from the inlet, with increasing gradient of 16.32 percent within 17.3m of the outlet and constant level within 5.5 metres of the outlet. The reservoir height ranges from 6.5m at the inlet end to 9.1m at the discharge end. Within the reservoir chamber are vertical columns, in a 16 x 6 arrangement. However, for simplification of the CFD simulations, the columns were not included in the model.

Figure 2 is an image of the CAD model with two baffle curtains, as was requested for two of the three CFD simulations. The baffle curtains are located approximately one third and two thirds along the reservoir length and extend from the floor to above the water surface. The two baffle curtains permit fluid flow through a 10 metre gap on alternating sides of the reservoir.

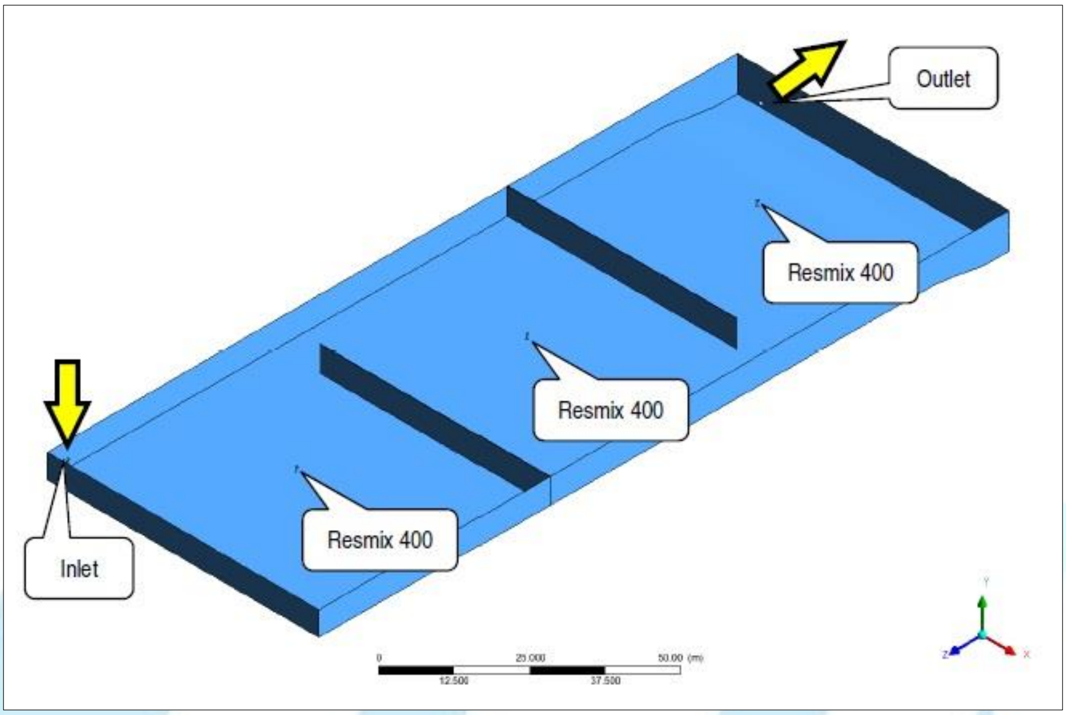

Figure 2: CAD model of reservoir chamber, with two baffle curtains.

Three WEARS ResMix™ 400 Mixers are located as indicated in Figure 2 and each unit was modelled as a simple vertical cylinder with tapered inlet and dimensions were based on a CAD model of a ResMix™ 400. Figure 3 shows the CAD model of the ResMix™ 400 and the simplified CAD model for the simulation.

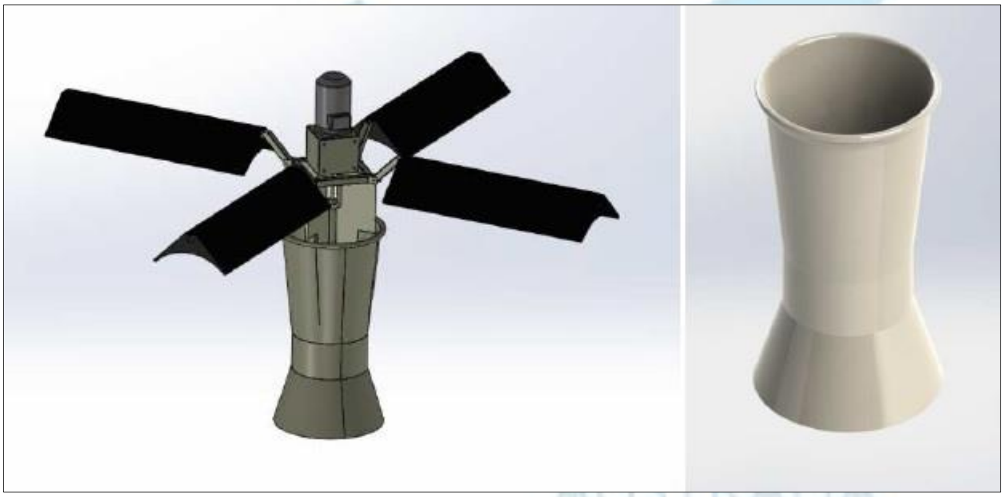

Figure 3: CAD model of the WEARS Australia ResMix™ 400 (left) and simplified model for the simulation (right).

The ResMix™ 400 Mixers were modelled in the reservoir at a depth of 370 mm below the water surface. Figure 4 shows the location of the WEARS ResMix™ 400 Mixer relative to the water surface.

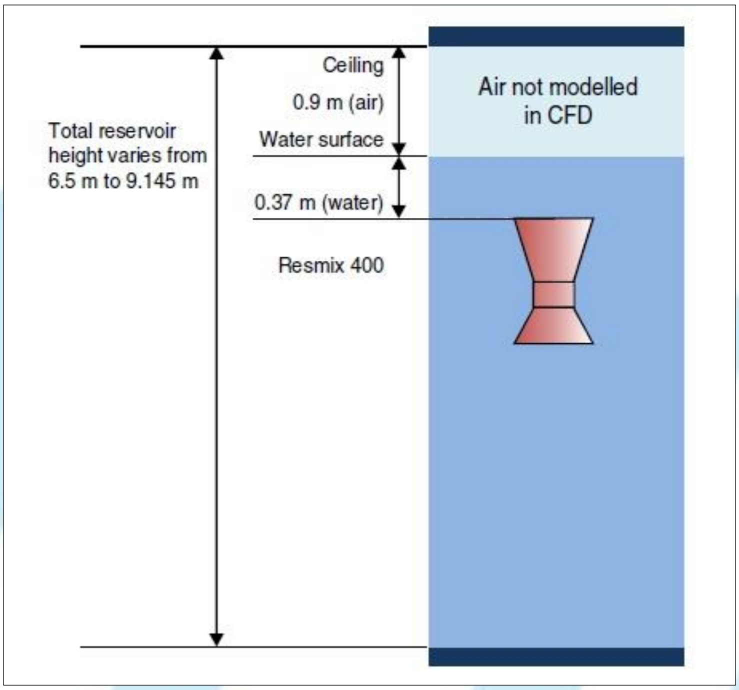

Figure 4: Location of the WEARS ResMix™ 400 relative to water surface.

2.2 Simulation variables

The simulation variables used in the modelling were as follows:

Inlet flow rate (entering a single chamber of the reservoir)	1526 litres per second
Inlet flow temperature	30°C
Outlet (discharge) pressure	Relative to water level in reservoir
ResMix™ 400 pump flow rate	75 litres per second (each unit)

Assumptions:

- Fluid is fresh water, filled to within 0.9 metre of the ceiling. The air layer was not modelled and the top water surface was defined as a free slip wall.
- Ceiling, walls and floor of the reservoir are insulated (adiabatic simulation)
- The columns were omitted.

3.0 CFD Modelling

CFD simulation of the WEARS ResMix™ 400 system was conducted to explore how the three ResMix™ 400 units, one in each chamber of the 95ML reservoir, were able to mix the water in the reservoir as well as the approximate time duration of the mixing process.

3.1 Previous Simulation Results

In previous simulations it was shown the three units, without baffle curtains, were able to effectively mix the initial stratified temperature distribution to reach an equilibrium temperature of approximately 40- 43°C, within six hours. It was anticipated a transient CFD simulation would show similar temperature mixing.

3.2 Setup

During the CFD simulations, the fluid system boundaries were defined as follows:

- Top water surface: free slip, adiabatic wall
- Baffle curtains and reservoir floor: no slip, adiabatic walls
- Inlet: inlet boundary with bulk mass flow rate 1560L/s, constant temperature of 30°C
- Outlet: opening at hydrostatic pressure
- Three ResMix™ 400 Mixers: constant velocity inlets and outlets of 75L/s
- Initial temperature profile within the chamber: 55°C at the top water surface, decreasing linearly to 30°C at a depth of 6.5 metres below the water surface. Water deeper than 6.5 metres below the water surface was 30°C.

The shear stress transport turbulence model was used, with thermal energy. This is suitable for low speed flow such as that in the reservoir.

3.3 Simulations

Two steady-state CFD simulations were performed.

Simulation 1: Demonstrated the effect of three ResMix™ 400 units with two baffle curtains. The inflow was not active.

Simulation 2: Demonstrated the effect of 3 ResMix™ 400 units, with the baffle curtains excluded and the inflow not active.

In order to gain an understanding of the effectiveness of reservoir mixing, circulation and prevention of the stored water turning bad, the variable of interest monitored during the simulations was temperature. Transient simulation results record changes in the distribution of temperature over time. Effective mixing and circulation should swiftly cause the initially stratified temperatures within the reservoir to reach equilibrium and become uniform.

As shown in previous simulations, water adjacent to moving fluid is also circulated, i.e. water does not have to pass directly through each ResMix™ unit in order to gain motion and therefore circulate. The velocity and streamline results from the simulations were used to identify the extent of water circulation.

4.0 Results

4.1 Simulation 1 - 3 Mixers, 2 Baffles, No Inflow

Simulation 1 demonstrated the effect of three ResMix™ 400 units with two baffle curtains. The inflow was not active. An “outlet” was defined at the top of each mixer, to simulate water entry, and an “inlet” boundary was defined at the bottom of each mixer to simulate water discharged, at a velocity equivalent to volumetric flow rate of 75L/s.

Figure 5 depicts the location of animation views for Simulation 1 as two longitudinal cross-sectional views of the reservoir, at 5 metres and 32 metres from the long wall of the reservoir.

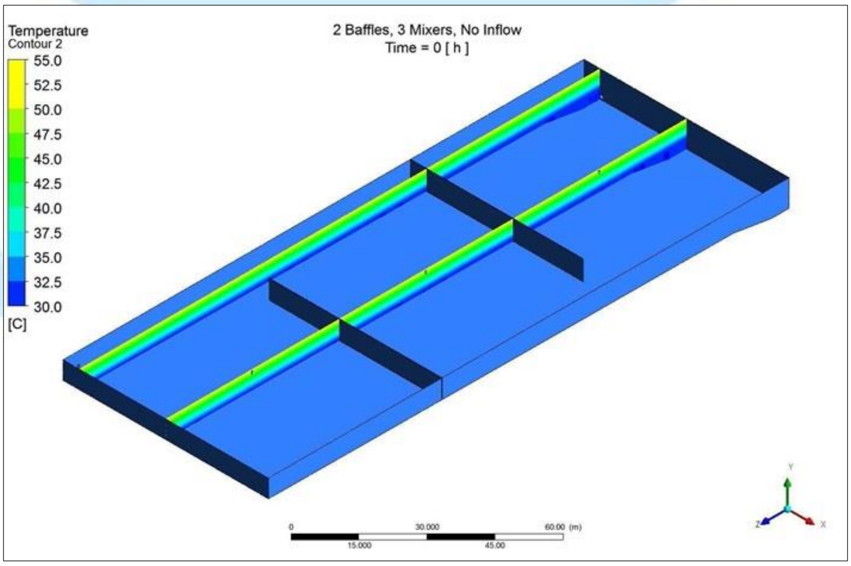

Figure 5: Location of animation views for Simulation 1: 2 baffles, 3 Mixers, no inflow.

Figure 6 shows the reservoir's initial stratified temperature, appearing as horizontal bands ranging from 30°C on the floor to 55°C at the water surface. As the simulation progressed, the outlets of the three Mixers expelled higher-temperature water to the floor of the reservoir whilst drawing in fluid from the upper layer of the reservoir, as shown in Figure 7 at 1 hour of simulated time.

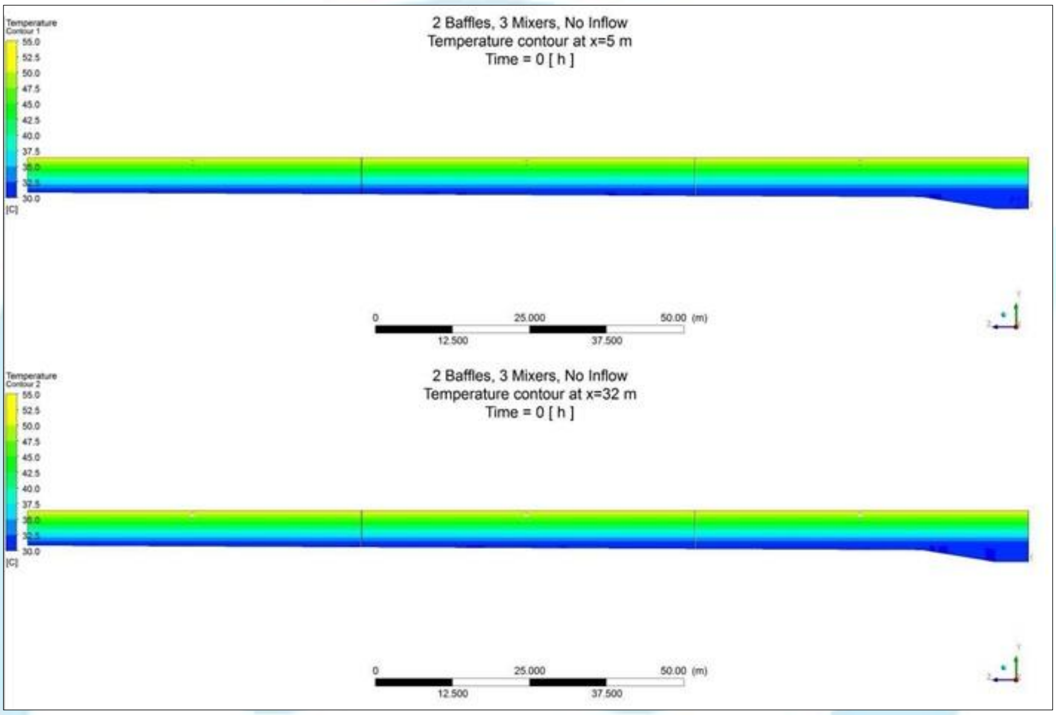

Figure 6: Simulation 1 reservoir temperature contours at 0 hours.

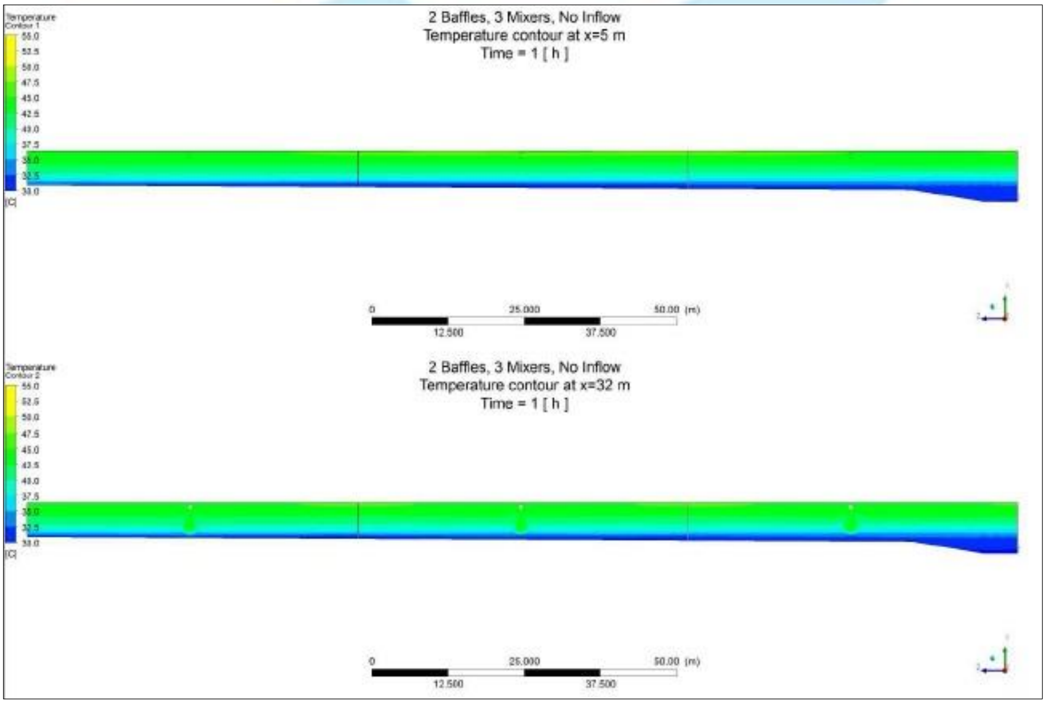

Figure 7: Simulation 1 reservoir temperature contours at 1 hour.

By approximately two and a half hours, the temperature layers have effectively mixed, with a calculated overall temperature range of just 4°C (36 to 40°C), as seen in Figure 8. The left-most chamber appears to have equalised to a slightly higher temperature than the central and right-most chambers. This was considered to have resulted from the greater depth of the reservoir in the central and right-most chambers, which initially contained a greater volume of low-temperature (30°C) water.

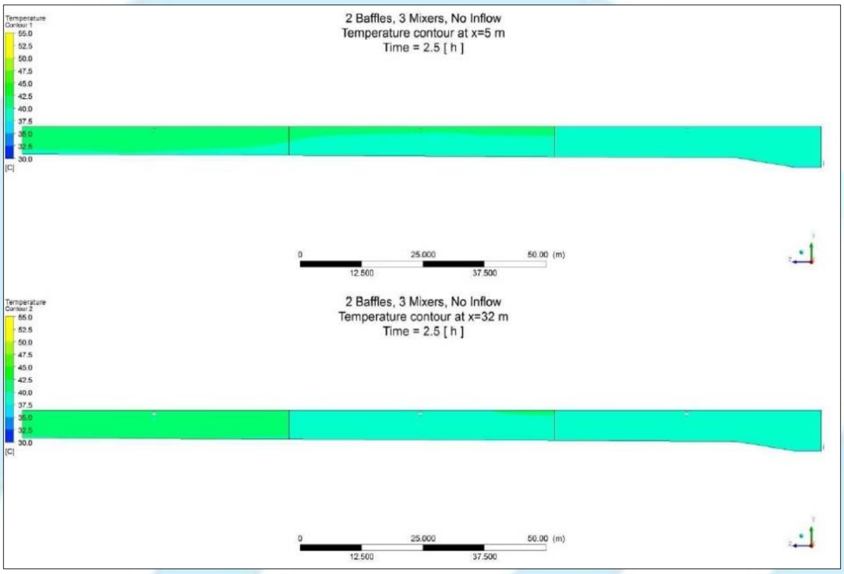

Figure 8: Simulation 1 reservoir temperature contours at 2.5 hours.

Simulation 1 was continued up to five hours. Temperature contours at five hours are shown in Figure 9. The simulation indicated an overall temperature range of just 1°C (39.3 to 40.2°C).

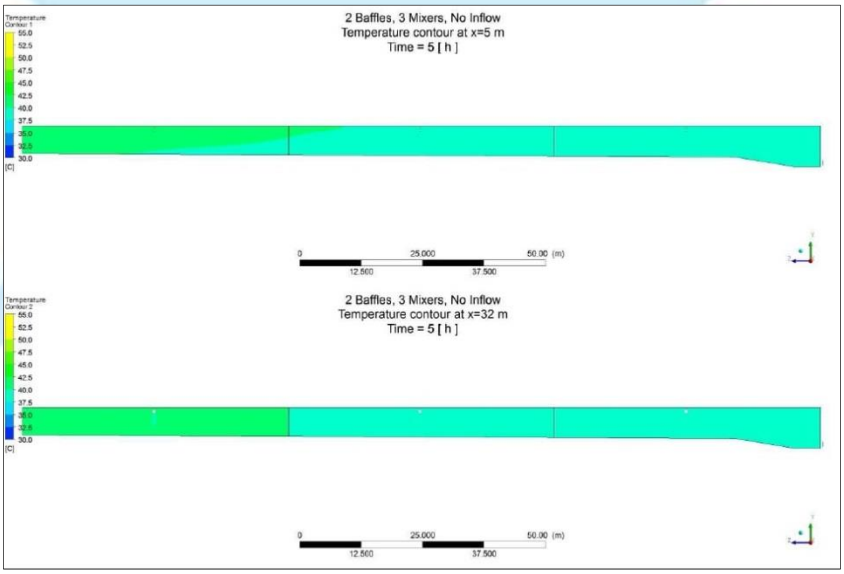

Figure 9: Simulation 1 reservoir temperature contours at 5 hours.

The velocity contour results indicate areas where water is in motion. The mixer outputs are evident, moving water down to the floor of the reservoir, spreading outwards, while moving fluid at the upper surface of the water appears to be driven by the Mixer intakes. The baffle walls do not appear to impair the operation of the Mixers, and fluid flow is evident in the baffle gap in the upper image of Figure 10.

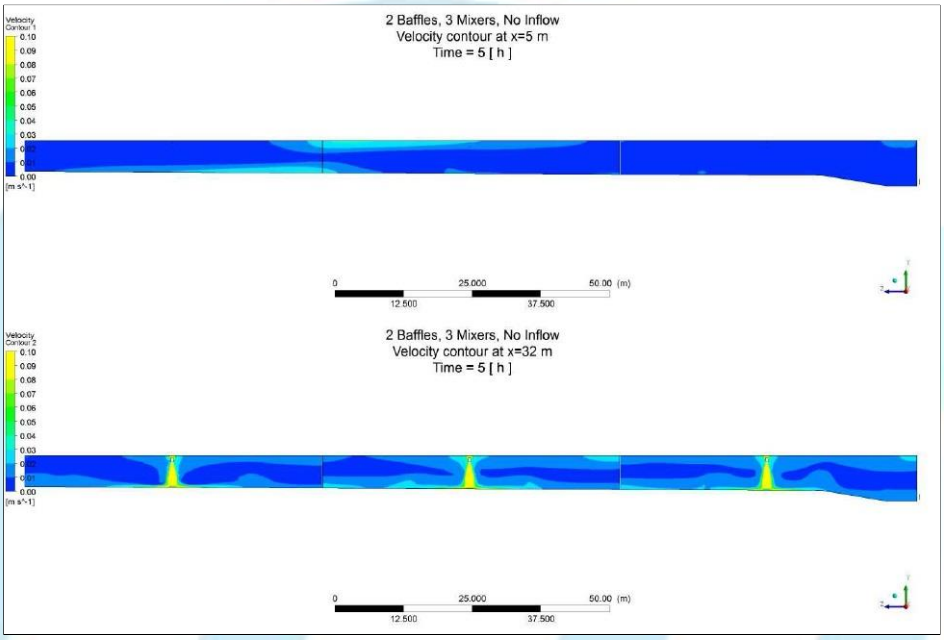

Figure 10: Simulation 1 velocity contours at 5 hours.

Streamline images confirm fluid motion throughout the reservoir, in Figure 11 to the Mixer inlets, and in Figure 12 expelled from the Mixer outlets.

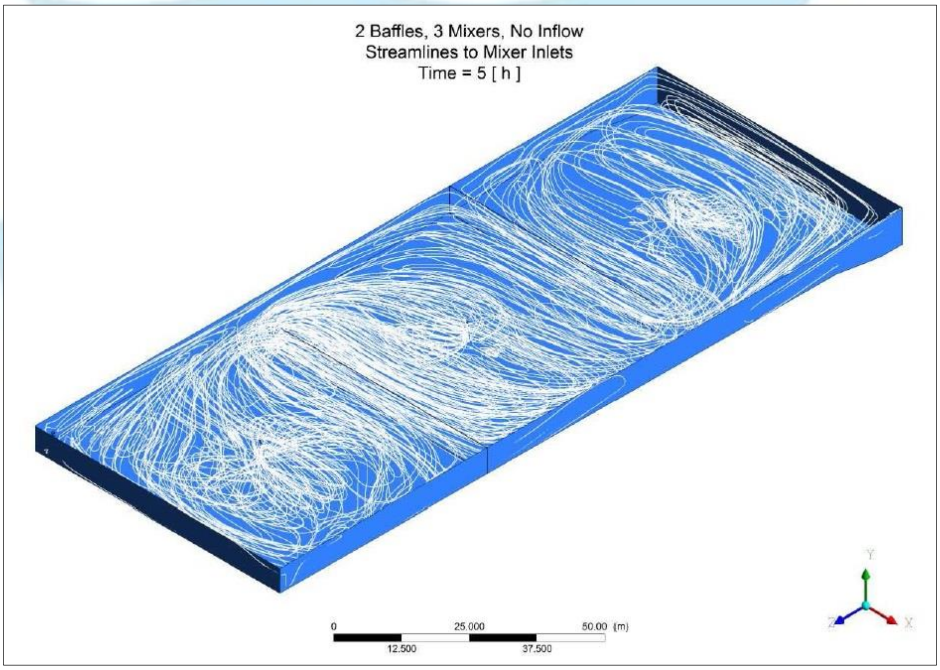

Figure 11: Simulation 1 streamlines to mixer inlets at 5 hours.

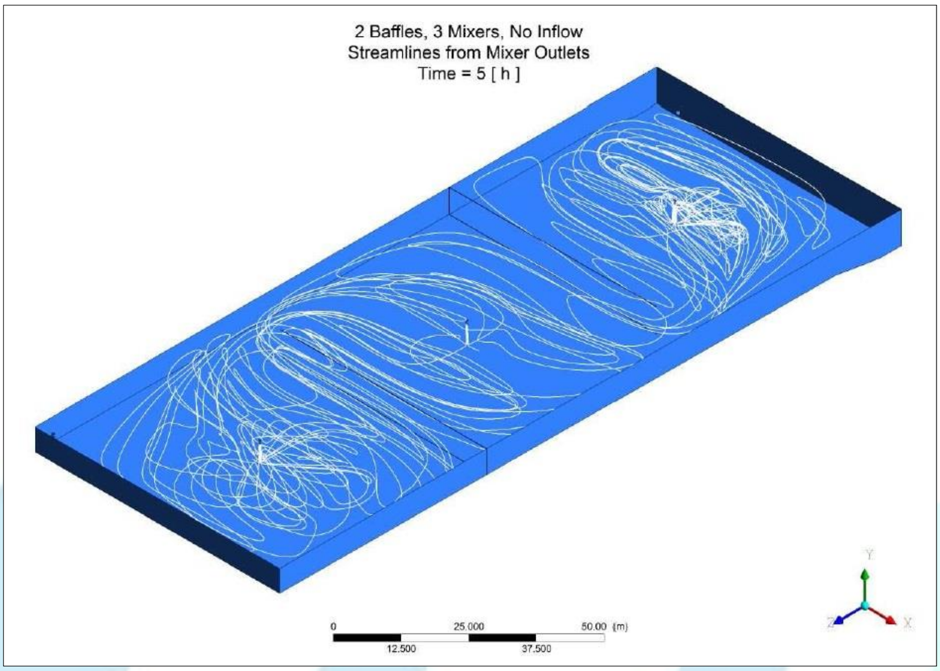

Figure 12: Simulation 1 streamlines from mixer outlets at 5 hours.

4.2 Simulation 2 - 3 Mixers, No Baffles, No inflow

Simulation 2 demonstrates the effect of three ResMix™ 400 units, with the two baffle curtains and inflow excluded. Water is drawn in from the top of the mixers, and is output from the bottom of the mixers, at a rate of 75L/s for each of the three mixers.

Figure 13 depicts the location of simulation at the two longitudinal cross- sectional views of the reservoir, 5 metres and 32 metres from the long wall of the reservoir. The inlet is on the left-hand side, and outlet on the right-hand side.

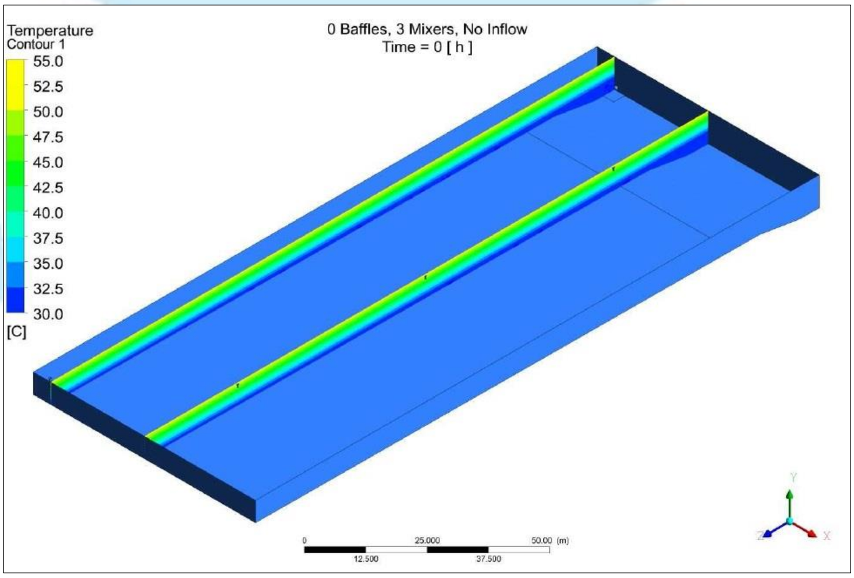

Figure 13: Location of animation views for Simulation 2 - 3 Mixers, No Baffles, No inflow.

The initial stratified temperature appears as horizontal bands, shown in Figure 14. Temperature contours over time show water drawn into and output from the three Mixers cause the temperature bands to gradually and consistently mix.

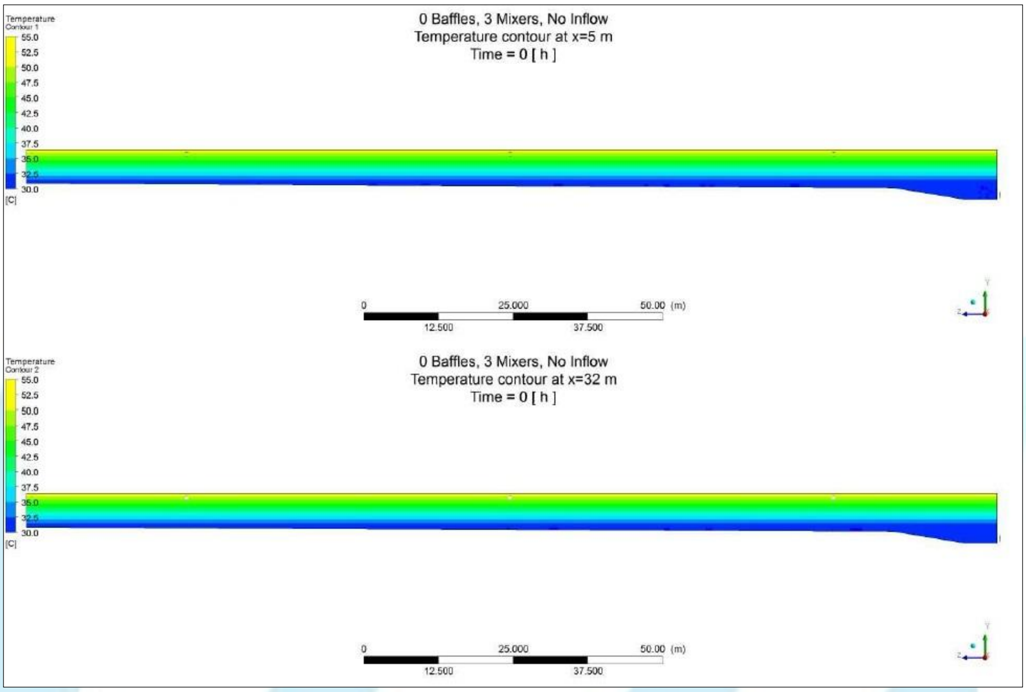

Figure 14: Simulation 2 reservoir temperature contours at 0 hours.

In Figure 15, output streams of higher temperature water are visible at the exits of the three mixers at a simulated time of 0.5 hours.

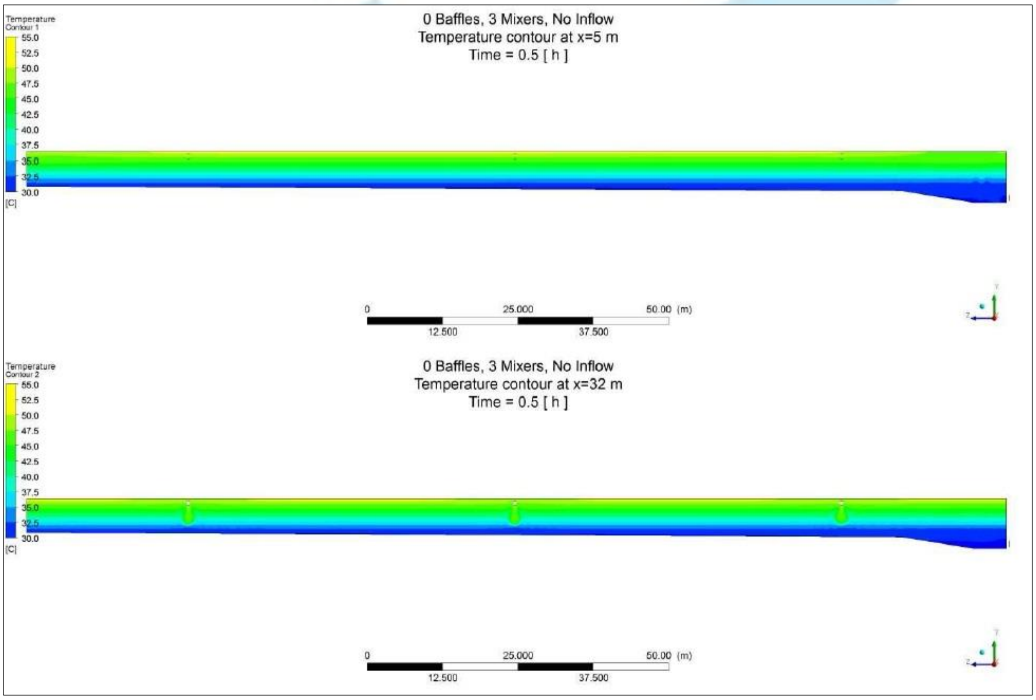

Figure 15: Simulation 2 reservoir temperature contours at 0.5 hours.

By simulation time 1 hour the range of temperature decreases, with areas of high temperature becoming cooler and low temperature areas growing warmer, as seen in Figure 16.

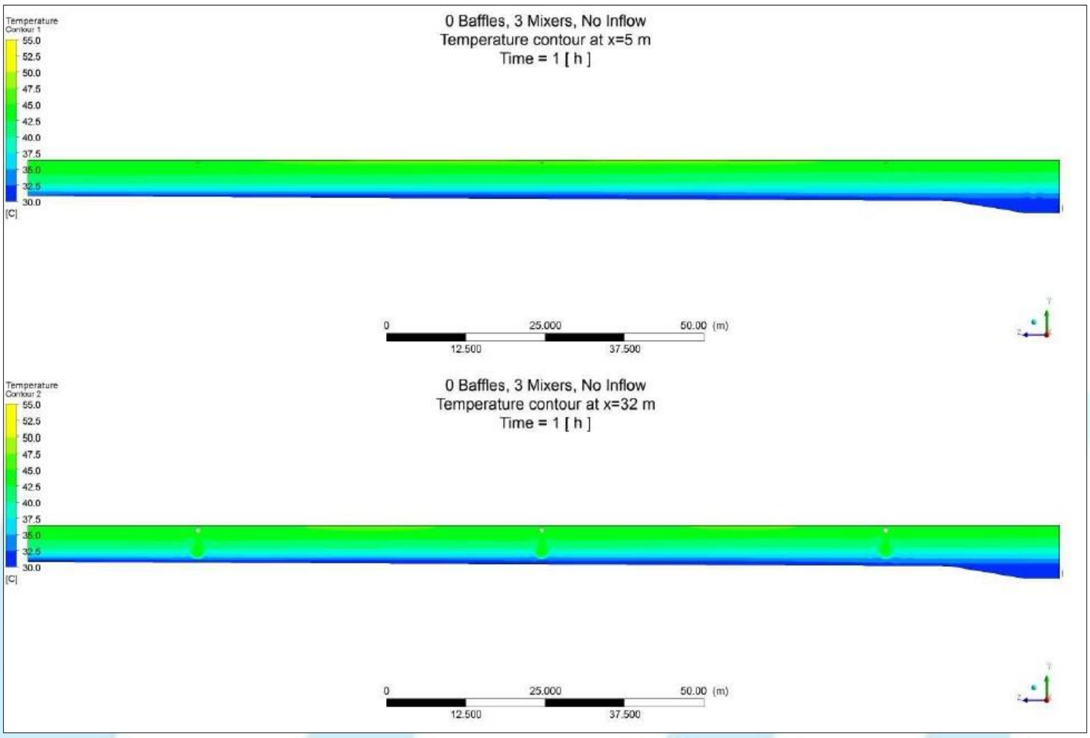

Figure 16: Simulation 2 reservoir temperature contours at 1 hour.

The simulation was ended after 3.5 hours passed, with an almost entirely consistent temperature contour displaying no stratification as shown in Figure 17.

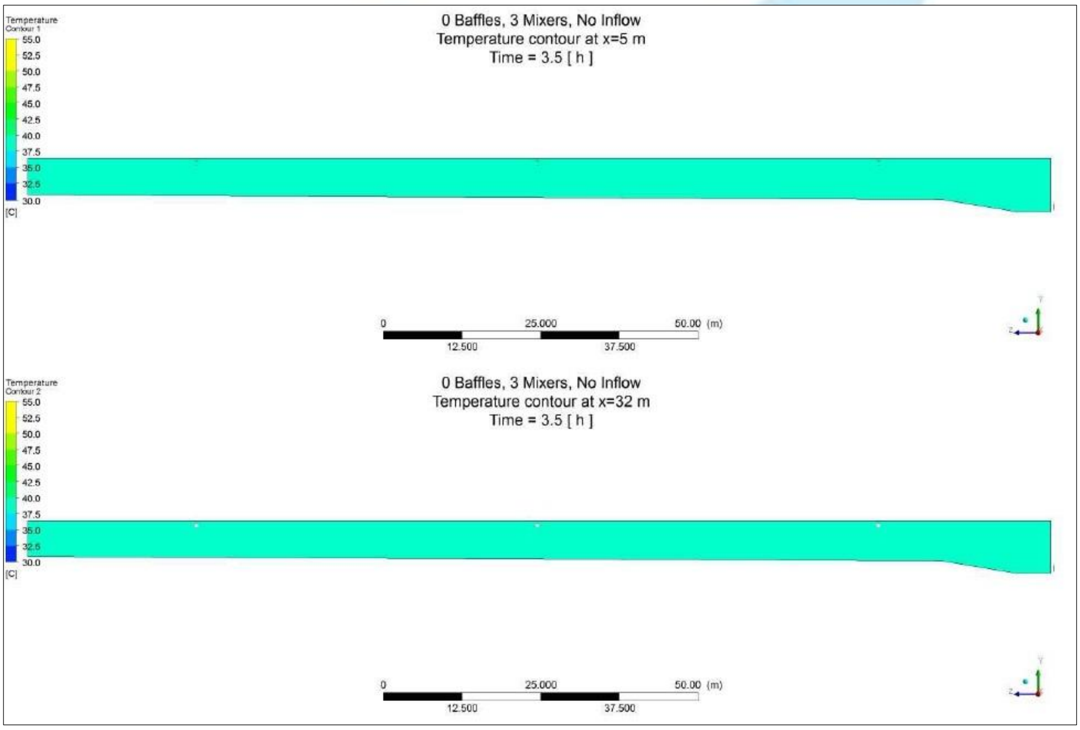

Figure 17: Simulation 2 reservoir temperature contours at 3.5 hour

Velocity results were also obtained and as seen in Figure 18, fluid flow from the three mixers is evidently reaching the floor of the reservoir. Movement in the fluid is visible near the upper water surface and the floor, indicating the Mixers are effectively drawing in upper fluid and expelling it to the lower reaches.

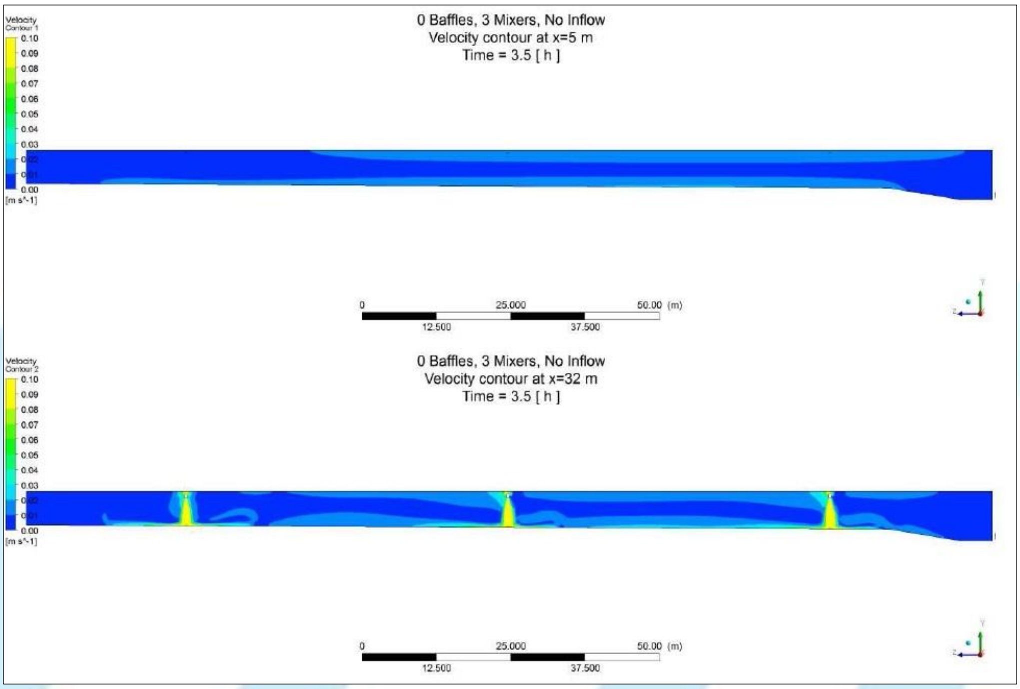

Figure 18: Simulation 2 velocity contours at 3.5 hours.

Streamlines confirm this conclusion, shown below as Figure 19, streamlines to the mixer inlets, and Figure 20, streamlines from the mixer outlets.

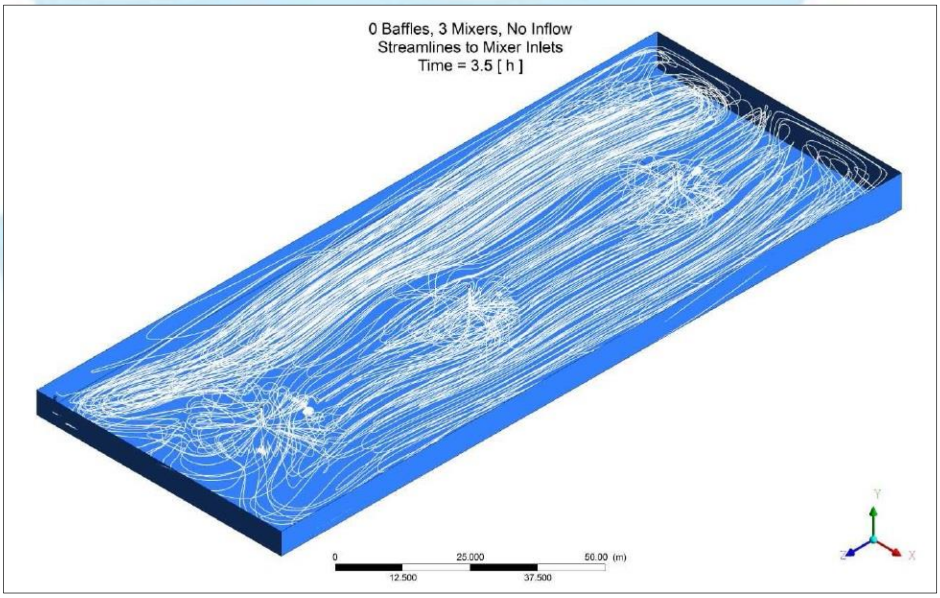

Figure 19: Simulation 2 velocity streamlines to mixer inlets at 3.5 hours.

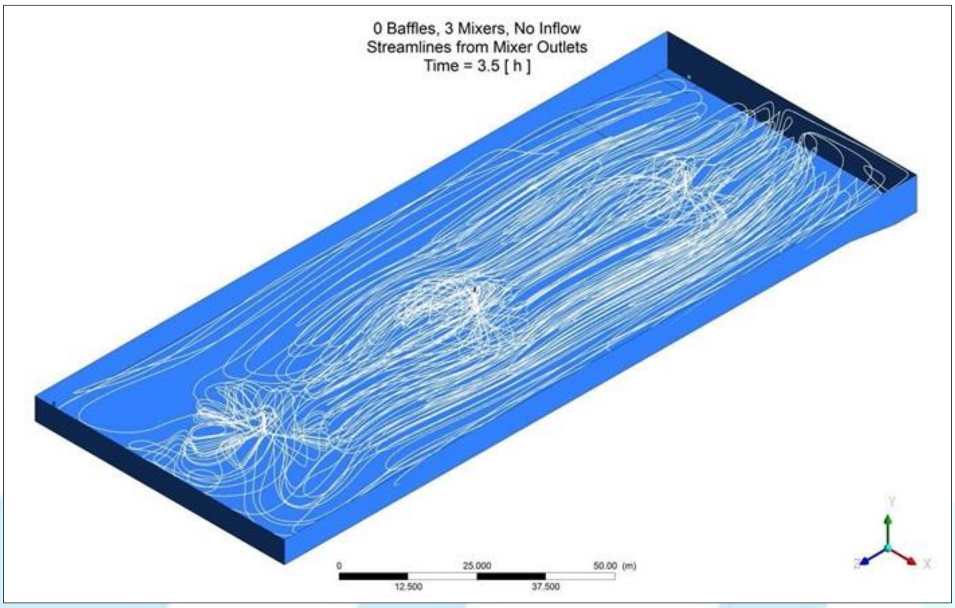

Figure 20: Simulation 2 velocity streamlines from mixer outlets at 3.5 hours.

5.0 General Conclusions

Based on the assumptions set out in this report, for the reservoir described, e3k are able to provide the following conclusion arising from this CFD study:

a) CFD simulations show the installation of three evenly-spaced WEARS Australia ResMix™ 400 Mixers in this 95ML reservoir, with or without baffles, produces reliable mixing and circulation of the water in the reservoir and removes temperature stratification within hours, with effective isothermal conditions predicted within 6-8 hours.

6.0 WEARS Australia Conclusions

WEARS Australia reviewed the CFD simulation results obtained by e3k and provided the following additional conclusions:

a) Whilst the ResMix™ 400 units are operational, at only 500 W per unit (1.5 kW for three mixer units in one reservoir chamber) the water in the reservoir is circulated and fully mixed to isothermal conditions and homogeneous chemistry. Therefore, the ResMix™ 400 units could be fitted with a disinfection dosing system designed to deliver an accurate top-up dose for extended water storage time.

b) CFD simulations indicate the ResMix™ system produces significant internal currents and effective circulation throughout the reservoir. Effective circulation throughout the reservoir could significantly extend the "life" of the water by maintaining water quality over time while reducing treatment and storage costs.

c) The simulations show a ResMix™ 400 system, using one or more units, can maintain fully mixed and isothermal conditions in municipal reservoirs of various capacity and the ResMix™ 400 provides a means for water managers and authorities to ensure:

- High water quality.
- Reduced disinfection rate with the option for a retrofit reagent dosing system.
- Evapouration reducing with a corresponding reduction in roof and other internal structural corrosion.
- Elimination of organic as well as inorganic buildup on internal structures.