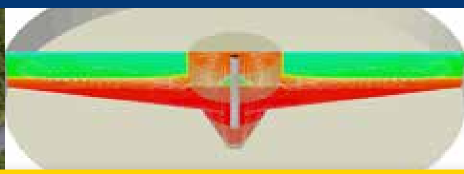
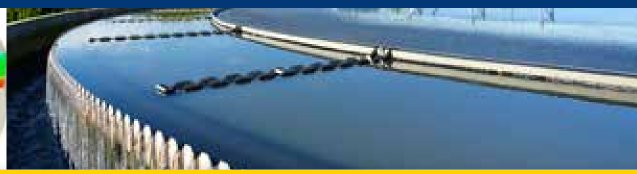
MMI
engineers • scientists • innovators

Optimization of Water Treatment

www.mmiengineering.com

MMI Engineering in the Water Industry

MMI Engineering provides specialist analysis expertise in the design of water treatment equipment and systems using bespoke Computational Fluid Dynamics methods.

Our services include:

1. Clean Water Applications

- Reservoirs
- Contact Tanks
- Service Reservoirs
- Ozone Tanks
- Ultraviolet Disinfection
- Pump Sumps
- Surge Analysis
- Network Modeling / Flow Distribution

2. Wastewater Applications

- CSOs / Storm Tanks
- Primary Tanks
- Anaerobic Digesters
- Flow Load Balancing
- Aeration Lanes
- Final Settlement Tanks
- Phosphorous Removal
- DSEAR (Dangerous Substances & Explosive Atmospheres) Assessments
- Surge Analysis

Our Water Clients

We enable clients to optimize their assets with minimal disruption and expenditure.

Some of our Clients:

- A&J Fabtech
- Aquafin (Belgium)
- Atkins
- Black & Veatch
- Chemineer
- Grontmij
- Hyder
- Imtech
- Meica Process
- MWH Global
- MWH Treatment / Biwater
- NMC Nomenca
- OVIVO / Tamesis
- Pick Everards
- Purac
- Severn Trent Water
- Southern (4D)
- South West Water
- Thames Water
- United Utilities
- Veolia Water (Scotland & NI)
- Welsh Water (Dwyr Cwmru, Kelda)
- Wessex Water
- Yorkshire Water

Reservoirs

Many reservoirs and Water Treatment Works (WTW) within the UK are adjacent to farmland.

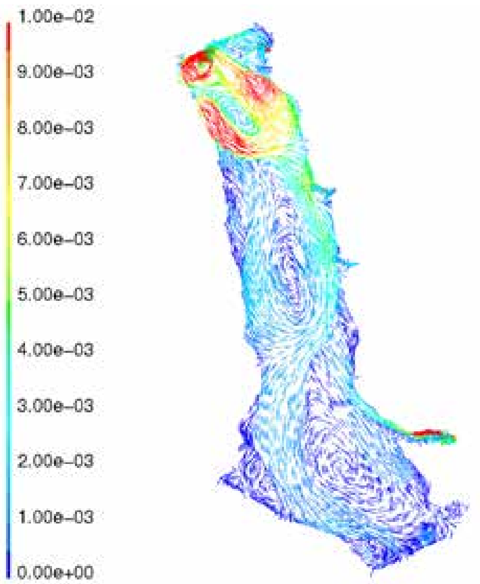
This means there is a possible risk of cryptosporidium or other pollution within these water supplies during periods of heavy rainfall.

MMI has many years' experience in the successful application of flow modeling techniques across a range of process industries. In particular, MMI has applied Computational Fluid Dynamics to model the dispersion and convection of contaminants in reservoirs. In this way, important flow features such as recirculation zones, short-circuiting and flow stagnations can be highlighted.

Fresh Water Reservoirs

Our Engineers have developed a risk assessment method for quantifying the impact of a cryptosporidium release event. Response curves at the reservoir off takes can be monitored in the model with respect to potential releases from coastal sources. The model can provide the Water Treatment Works (WTW) plant operators with detailed information such as peak arrival time, peak concentration, dilution factors and mixing effectiveness. Analysis of this information can then highlight which release points pose the greatest risk and the relative magnitude of this risk.

Bubble barriers are commonly used to disperse algal blooms but they can also be positioned to effectively screen the treatment works and provide dilution and dispersion of the Cryptosporidium oocysts.



Surface flow patterns for reservoir in normal flow conditions

Contact Tanks

The design of a good contact tank depends on its ability to promote plug flow.

Plug flow will provide water of uniform treatment quality to a domestic water supply. Computational Fluid Dynamics techniques can be used to generate detailed information about flows, Residence Time Distribution (RTD) and chlorine degradation in water treatment systems.

Modeling the Flow & RTD

The basic hydrodynamics are generated from a three dimensional model of the geometry, with boundary conditions applied to represent inflows, outflows and the presence of internal baffles. A simple age scalar can be used to emphasize the presence of flow recirculation and quiescent regions.

Dye trace studies can be replicated in a Computational Fluid Dynamics calculation and used to compare different designs via different indices that characterize the mixing characteristics such as t10 and the number of tanks in series.

The transport of a disinfectant such as chlorine can be included in the calculation including a decay model in order to determine for example the residual chlorine at the discharge from the contact tank.

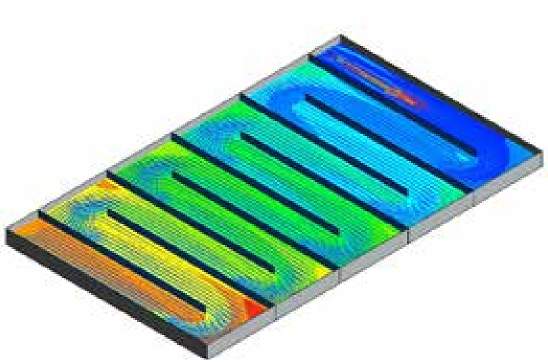


Figure 1: A rectangular contact tank with baffles explicitly modeled. An age scalar is used to show the distribution of the youngest water (in blue) and the oldest water (in red)

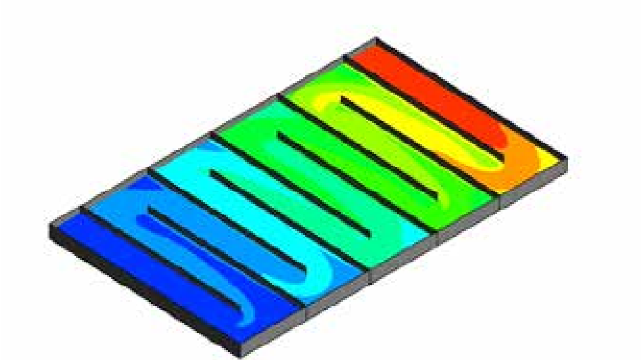


Figure 2: Chlorine concentration. Note how the oldest water (see Figure 1) corresponds with the region of lowest chlorine concentration

Ultraviolet (UV) Water Treatment

UV sources are increasingly being used for the inactivation of pathogens in drinking water, including cryptosporidium oocysts.

Although target dose rates can be specified, it is difficult to design configurations of UV tubes that guarantee it.

MMI Engineering has worked with UV equipment manufacturers and the water companies to improve dosing performance. Due to the rapid throughput and short residence time, any reduction in hydraulic performance away from plug flow (dead zones or poor distribution) has a significant influence on overall performance. We have developed a modeling technique based upon Computational Fluid Dynamics that can assess the dose given to a water stream and to compare and optimize UV treatment.

Modeling the Flow

The 3D geometry is built or imported from CAD and the flow conditions and fluid properties are supplied so that the Navier Stokes fluid flow equations can be solved to give the flow distribution. A further equation is solved to evaluate the UV radiation field distribution. Fluid stream lines are then tracked through the flow and cumulative UV radiation dose to the stream is computed.

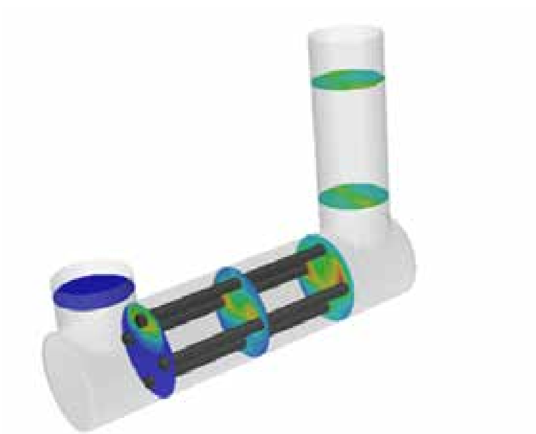
Processing & Comparison

The base flow information is augmented with UV dose data to give the designer a pictorial view of problem areas. UV dosage can also be quantified in a histogram of the total flow, useful for comparing design alternatives.

Design Studies

MMI have conducted modeling investigations for clients on flow and dose rate, including modifications to:

- Chamber geometry
- UV tube layout & power
- Upstream & downstream geometry
- Inflowing water properties



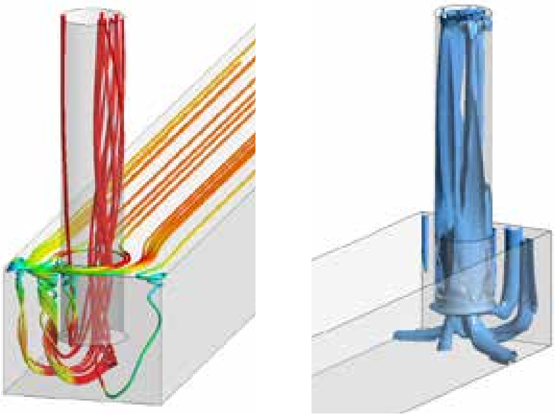
A contour plot of cumulative UV dose on the water

Pump Sumps

The efficiency of a pump is affected by the hydrodynamics of the flow approaching it.

This is due to the pump's impellers, which are designed with the assumption that the flow will approach axially. Examples of non-ideal flow conditions include:

- Pre-swirl of the flow
- Free surface vortex formation
- Submerged vortex formation
- Spatial asymmetry of the flow
- Temporal fluctuations (turbulence) in the flow approaching the pump impeller



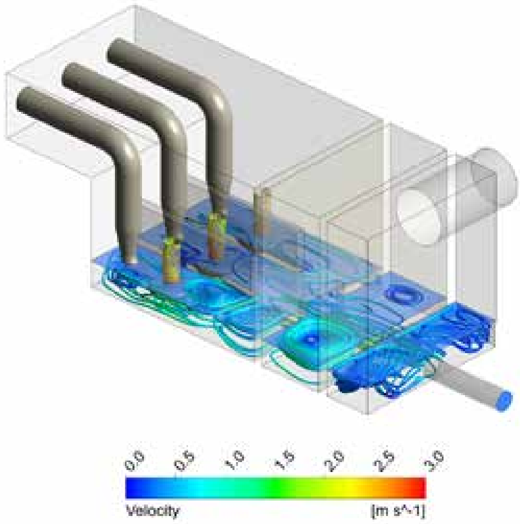
Identification of free-surface & submerged vortex structures

Optimization of Pump Sumps

When designing pump sumps, it is generally required to demonstrate that:

- No organized free surface and / or subsurface vortices of greater magnitude than Type 2 shall enter the pump
- The level of pre-swirl should be steady and less than 5° from the axial direction
- Time-averaged velocities measured at eight locations in the pump throat should be within ± 10% of the spatial mean of time-averaged velocities
- The temporal fluctuations of velocities measured at each of the eight locations should be less than 10% of the average velocity measured at that location

MMI uses Computational Fluid Dynamics to confirm a new design or optimize an existing pump sump.

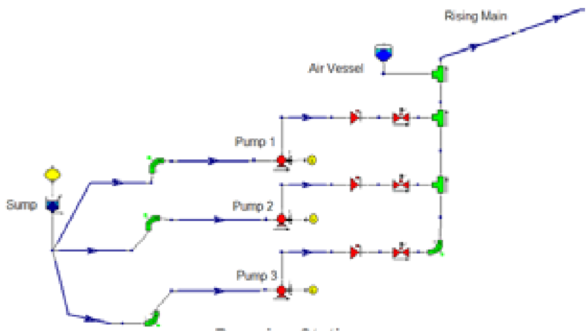


Streamlines showing non-uniform approach flow in a series of pump bays

Surge Analysis

MMI Engineering uses computational pipe network models to undertake surge analysis to determine transient pipeline pressure.

As part of a surge analysis, MMI defines the requirements for surge protection. This is generally achieved with surge vessels on the suction and delivery side of pumps – MMI defines the volume, dimensions and connection details to the rising main. MMI also designs more bespoke systems using surge relief valves, pressure sustaining valves and utilizing existing equipment in a system. This ensures the transient pressures do not exceed the pipeline rating and do not drop below atmospheric pressure, which may result in ground water ingress.



Pumping station

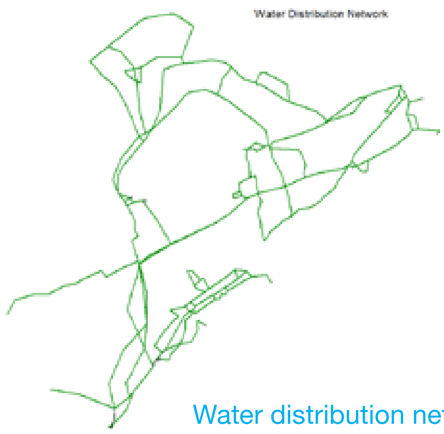
MMI's Surge Analysis team are highly experienced in the use of generalized surge analysis software packages, to solve problems associated with equipment operation, such as pump start-up/stop trip, valve actuations and pipe failures.

Network Flow Distribution

Computational analysis forms an essential part of the management of water distribution networks.

This can be used to identify operational issues, such as shortfalls in supply or depleting reservoir levels.

The same analysis techniques can be used to optimize operation (and cost) and the design of extensions to the network. MMI Engineering has the capability and expertize to provide this service.



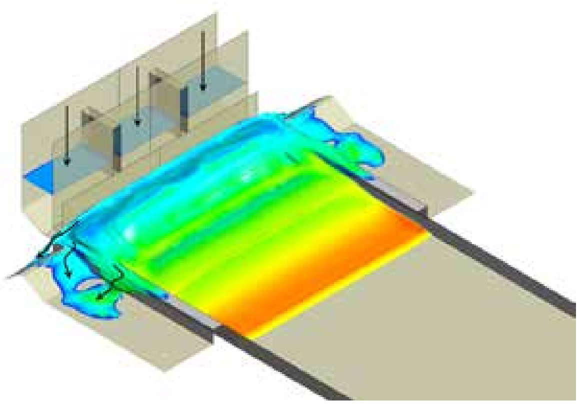
Water distribution network

Combined Sewer Overflows (CSO's)

CSO's are used to spill storm water during heavy rainfall. Storm Tanks act as a source of capacitance, providing storage of storm water until the storm load subsides.

It is desirable that both systems when necessary allow the flow to spill with minimal loss of solids.

MMI Engineering uses Computational Fluid Dynamics to assess the effectiveness of a CSO or Storm tank at retaining solids. Additionally, MMI Engineering also undertakes preliminary assessments of vac flush systems used for flushing solids from Storm Tanks and hydroejectors used for homogenizing the solids during drain down.



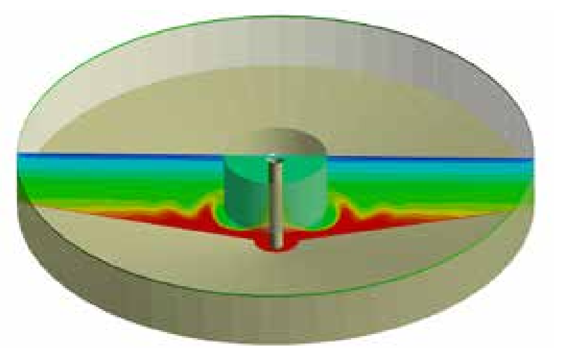
Combined sewer overflows

Primary Tanks

Primary tanks are used to remove the majority of settleable solids from raw and screened wastewater at a works. Solids sludge is usually passed forwards to digesters; the settled sewage goes on to secondary treatment.

MMI Engineering uses Computational Fluid Dynamics simulation techniques to assess the internal hydro-dynamic performance of settlement tanks.

This allows MMI to assess the settling performance of an existing or new tank design and to optimize the effluent quality by optimization of the tank geometry or inlet arrangement.



Primary tank

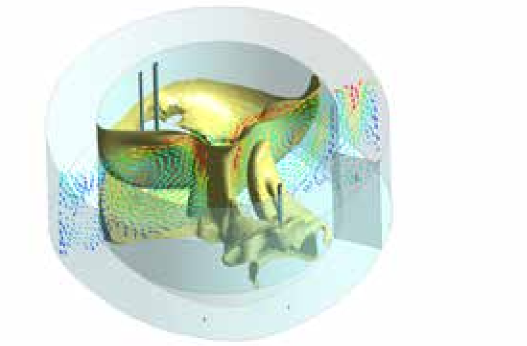
Anaerobic Digesters

Anaerobic digesters are increasingly used at Wastewater Treatment Works for a number of reasons...

... They reduce the need to remove solid waste from site, they reduce energy costs by means of on-site power generation from the biogas produced, and they reduce carbon emissions. Digester sludges are usually a blend of primary and surplus activated sludges and behave as a non-Newtonian fluid. MMI captures this behavior by modeling the sludge as a Heschel-Bulkley fluid.

In order to gain a homogenous blend of sludge and bacteria at a near constant temperature, the mixing system is important. To achieve this, a number of methods are available: gas mixing, mechanical mixing, and external pumping. For gas mixing, MMI uses a Eulerian-Eulerian approach - using drag models for the fluid-gas interaction.

To ensure the sludge has the desired residence time in the tank, a dye trace study can generate a Residence Time Distribution. MMI can confirm the effectiveness of an anaerobic digester design without the need for expensive testing.



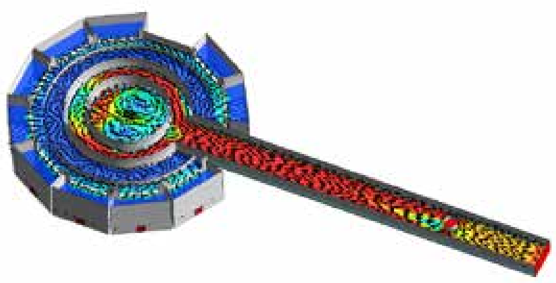
Feed sludge in the inner tank of an acid phase digester passing to the outer tank with a good degree of mixing

Flow / Load Balancing

Civil engineering structures are used to distribute the flow and solids load to multiple settling tanks or aeration lanes at a sewage treatment works.

Achieving a good fluid and solids distribution ensures equal loading on settlement tanks / aeration lanes and is fundamental to achieving optimal treatment performance.

MMI Engineering uses Computational Fluid Dynamics to assess the flow and solids distribution using appropriate multiphase models to resolve free surface effects, which influence fluid distribution and appropriate models for tracking the solids load.

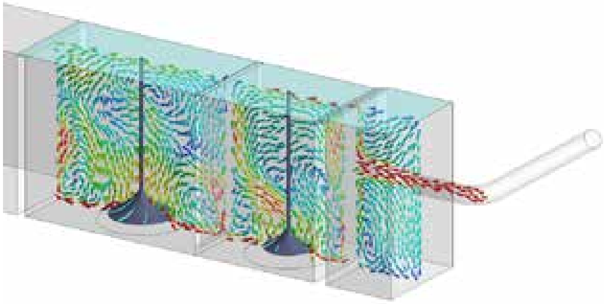


Flow / load balancing

Aeration Lanes

MMI Engineering uses Computational Fluid Dynamics to assess aspects of aeration lanes, such as anoxic zones, or the performance of aerators within the aeration lanes.

The use of Computational Fluid Dynamics allows the action of impellers on the flow and solids distribution to be resolved while dye trace studies may be undertaken using Computational Fluid Dynamics to determine the residence time and the degree of short circuiting.



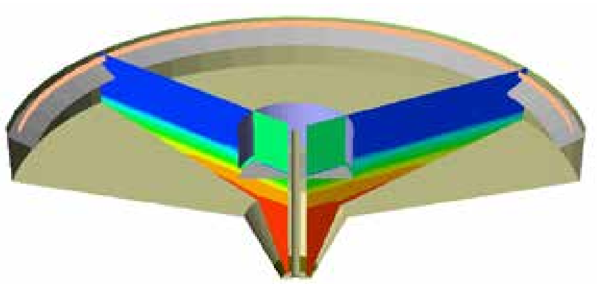
Aeration lanes

Final Settlement Tanks

Final settlement tanks clarify the final effluent at activated sludge plants.

As the flow through a final tank is not one -dimensional and will exhibit non-ideal flow behavior, such as flow recirculation and short circuiting, the actual settling performance will usually be less than predicted by Max Flux Theory (MFT).

MMI Engineering uses CFD to assess the internal hydrodynamic performance of existing or new tank designs. Improved effluent quality can be demonstrated by optimization of the tank geometry or inlet arrangement; by inclusion or adaptation of stilling wells, Energy Dissipation Influents or baffles e.g. McKinney baffle.



Final settlement tank,
visit ClariSim.net for more information

Phosphorous Removal

Since the Urban Wastewater Treatment Directive in 1991, UK water companies have had to manage phosphorus discharges. The target level for phosphate is below 0.1mg/L.

The growing interest in renewable sources of phosphorous and beneficial reuse applications has increased the range of phosphorous removal options available, making the evaluation process quite complex.

MMI's approach to phosphorous reduction involves the following steps:

- Evaluating the treatment process
- Listing phosphorous removal options
- Evaluating sludge handling & disposal practices
- Evaluating removal options using biological simulation software
- Preparing cost estimates

Options for phosphorous removal include:

- Biological phosphorous removal
- Controlled struvite formation & capture
- Chemical phosphorous removal
- A combination of the above

Solids separation can have a significant impact on the success of phosphorous removal technologies, since effluent limits are generally on a Total Phosphorous (TP) basis, rather than a soluble basis. Very low soluble phosphorous concentrations can be achieved through a combination of technologies, but the phosphorous associated with the solids means that the solids must be separated and captured.

MMI's expertise with improving solid-liquid separation using proprietary modeling and Computational Fluid Dynamics can be applied to optimize existing settlers and minimize capital investment.

DSEAR Capability

DSEAR require employers to specify the dangerous substances in their workplace.

As well as specifying dangerous substances, employers must assess the consequent fire and explosion risks. In the water industry, this might include chlorine gas, methane or hydrogen sulphide.

MMI has strong experience in DSEAR and can help employers with compliance. We can assess the hazardous properties of substances associated with on-site processes and analyse the risks.

Dispersion analysis can determine worst case gas cloud volumes following the release of a flammable substance and the regions affected by hazardous concentrations of gases. Explosion modeling assesses the potential consequences.

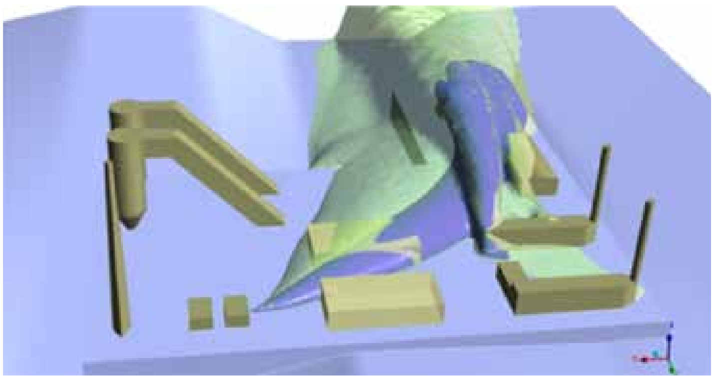
Hazardous area classification is the process of grading hazardous zones from a scale of worst case to least onerous. Protective equipment must be selected in accordance with the requirements contained in the Equipment and Protective Systems Intended for Use in Potentially Explosive Atmospheres Regulations, 1996.

MMI can assist with training if a dangerous substance is present. Employers are required to provide training to those at risk.

Example – Anaerobic Digestion

Biogas is generated during anaerobic digestion and there is the potential for methane and hydrogen sulphide to accumulate.

This poses a number of risks, as methane is flammable and hydrogen sulphide is both flammable and highly toxic, even at low concentration.



Multiple sources can combine to create significant hazardous areas

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