Technical paper

Gatwick Airport: Use of Urban drainage modelling techniques to develop a pollution control system

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Synposis

Passenger and aircraft safety are primary concerns for airports and airlines worldwide. Some of the materials and processes used for managing safety can cause environmental damage if used or managed incorrectly. For example, aircraft and runway deicers are essential for safe take-off and landing, but are also highly polluting if they are discharged directly into the river environment without adequate treatment.

Understanding the transport and fate of deicer in the drainage system and environment has historically been very difficult to predict and manage. Recent advances in modelling, and the innovative application of modelling techniques developed in the urban drainage sector, mean that we can successfully predict the transport, fate and impact of deicer contaminated runoff on the water environment.

This paper focusses on work recently undertaken For Gatwick Airport Limited; the modelling and improvement of the pollution control system at Gatwick Airport.

The drainage system in and around the airfield is very heavily controlled in real time by a series of monitors, pumps, actuated penstocks, weirs, large storage ponds, and other control devices, all of which have the twin aims of:

- discharging uncontaminated storm water to the River Mole as quickly as possible without causing downstream flood risk; and
- preventing contaminated storm water from entering the River Mole by storing and treating the contaminated storm water, ultimately discharging to Thames Water's Crawley Sewage Treatment Works

Previous attempts to model the Gatwick pollution control system had not met Gatwick Airport and the Environment Agency's requirements, and CH2M HILL were employed to review the previous modelling work and make recommendations about the most appropriate modelling techniques and software.

Our solution was an Infoworks ICM model of the airport drainage catchment. This was validated against continuous rainfall, flow and water quality data, and successfully replicates the hydraulics and pollutant loads, the real time control switches, discharges to the environment and environmental water quality. The model has also been used to assess the impact of surface water flooding on the airfield, and the risk of combined fluvial and surface water flooding.

The modelling process has not been straightforward, and close partnership working between Gatwick Airport, the Environment Agency and CH2M HILL has been essential to agree assumptions and modelling workarounds when software capabilities and data uncertainty have reduced model performance.

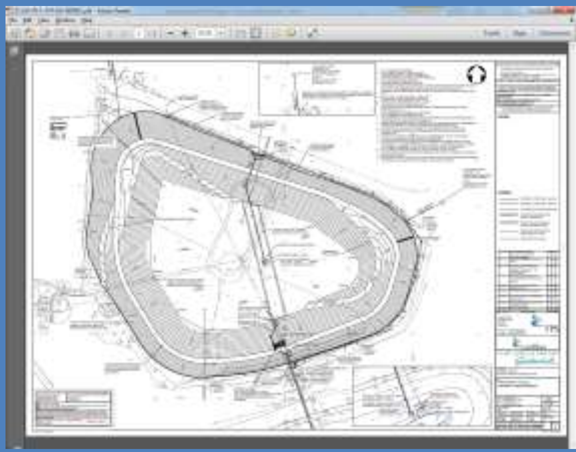
The modelling process and model outputs have been essential in giving the Environment Agency and Gatwick Airport the confidence they need to come to a pragmatic decision about the permitting of the operational system. Rather than relying on end of pipe discharge controls, in principle agreement has been reached that the revised permit will reflect operational procedures. The model has also been used to model and plan capital solutions to further reduce the impact of discharges on the water environment. These include additional storage capacity and additional treatment capacity.

Technical paper

2.1 Context

Passenger and aircraft safety are primary concerns for airports and airlines worldwide. Some of the materials and processes used for managing safety can cause environmental damage if used or managed incorrectly. For example, aircraft and runway deicers are essential for safe take-off and landing, but are also highly polluting if they are discharged directly into the river environment without adequate treatment.

The transport and fate of deicer in the drainage system and environment has historically been very difficult to predict and manage, normally resulting in either the tacit acceptance of reduced water quality standards, or strict end of pipe controls with little flexibility for the airport operator to best manage airport and environmental risks. Recent advances in modelling, and the innovative application of modelling techniques developed in the urban drainage sector means that we can successfully predict the transport, fate and impact of deicer contaminated runoff on the water environment.



New pollution control infrastrucure at Gatwick Airport

CH2M HILL are Gatwick Airport's Master Civil Engineer, and through a framework arrangement have been helping to characterise the key water environment risks from current and future airport operations, and have assisted in modelling and designing new operational procedures and capital schemes to reduce both water quality and flooding risks, and support ongoing and future airport development

This paper focusses on one aspect of the improvement works delivered through the Master Civil engineering framework; the modelling and improvement of the pollution control system at Gatwick Airport.

The drainage system in and around the airfield is very heavily controlled in real time by a series of monitors (rainfall, water quality, pump state, level and flow) pumps, actuated penstocks, weirs, large storage ponds, and other control devices, all of which have the twin aims of:

- discharging uncontaminated storm water to the River Mole as quickly as possible without causing downstream flood risk; and
- preventing contaminated storm water from entering the River Mole by storing and treating the contaminated storm water, ultimately discharging to Thames Water's Crawley Sewage Treatment Works

2.2 The challenge

Gatwick Airport have a strong relationship with the environmental regulator, the Environment Agency, developed over many years as Gatwick airport implement actions to continually improve their operations to reduce water quality and flood risk.

In 2012 as part of their ongoing improvement cycle, Gatwick Airport and the Environment Agency agreed that a study would be undertaken to assess the impact on Water Framework Directive compliance from rainfall related deicer contaminated discharges to the River Mole. It was also agreed that options to reduce the number of discharges to the river environment would be explored at the same time.

Previous attempts to model the Gatwick pollution control system using a simplified model had been unrealistic and not secured the confidence of Gatwick Airport or the Environment Agency; the model was not sufficiently reliable to accurately predict the quality and timing of spills to the River Mole, or to accurately predict environmental water quality. Because of the modelling inadequacies discussions about the future permitting arrangements for the airport were running into difficulties. To resolve this CH2M HILL were asked to review the previous modelling work and make recommendations about the most appropriate modelling techniques and software.

Previous modelling

An earlier attempt to model intermittent discharges from the pollution control system used an event based stochastic model (similar to SIMPOL2) to model the water quality impact of discharges to the River Mole. This model could not reliably replicate either the spill frequency, volume or quality, because of the limitations of the software;

- Initial conditions in the storage ponds from which discharges are made has an antecedent period of up to 4 months. Therefore event based modelling was unable to predict initial conditions sufficiently robustly
- Real time controls determining whether a spill occurs is based on data being recorded in real time at numerous monitors. Without this real time control being modelled explicitly, the model was unable to accurately predict when a spill would occur.

Plane de-icing in action

Runway ploughing and de-icing

2.3 The solution

CH2M HILL recommended and implemented the development of an Infoworks ICM model of the airport drainage catchment. A schematic of the system is shown below in Figure 1.

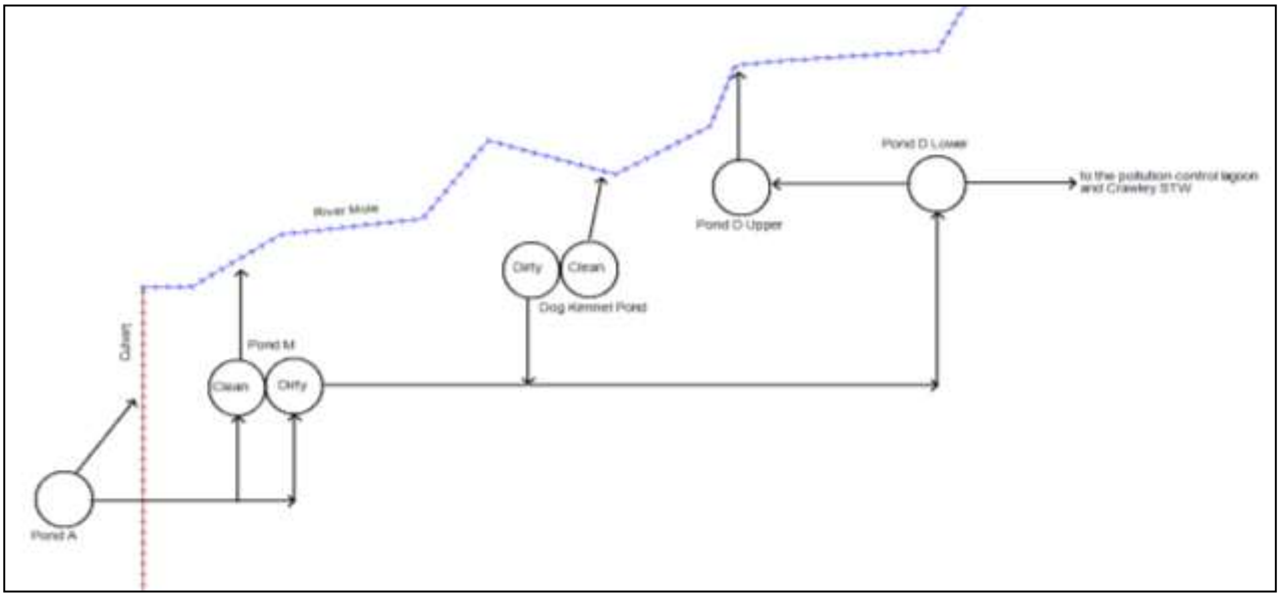


Figure 1 - Model Schematic

This model, now validated against real time rainfall, flow and water quality data collected by Gatwick across the Airport (as shown by results in and **Error! Reference source not found.**), successfully replicates the model hydraulics and pollutant loads, by implementing a real time control logic that accurately predicts when the model is operating in contaminated mode and when it is operating in clean mode.

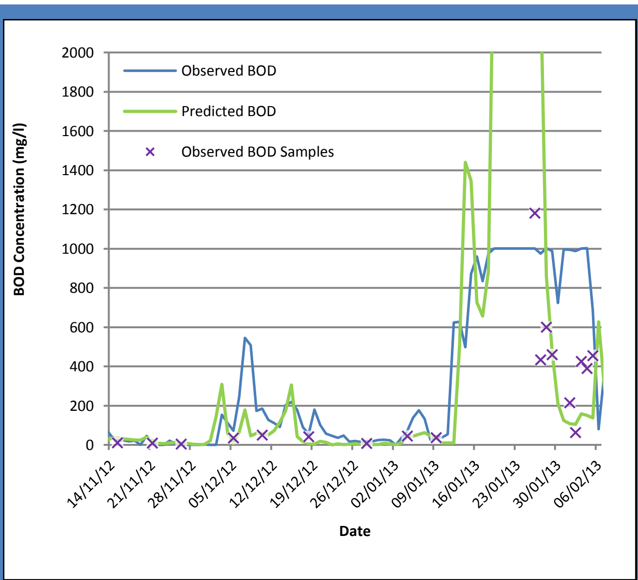


Figure 2 – Water quality verification plot

Figure 2 shows comparison results for biological oxygen demand within Pond D Lower which controls transfer of flows from the Gatwick site.

The continual observation made by the monitor were reviewed alongside spot sample data due to concerns over monitor accuracy and limitation (e.g. the maximum concentration recorded by the monitor is 1,000mg/l).

Where the model was found to diverge from the continual monitor results it was generally found to be close to data obtained from spot samples.

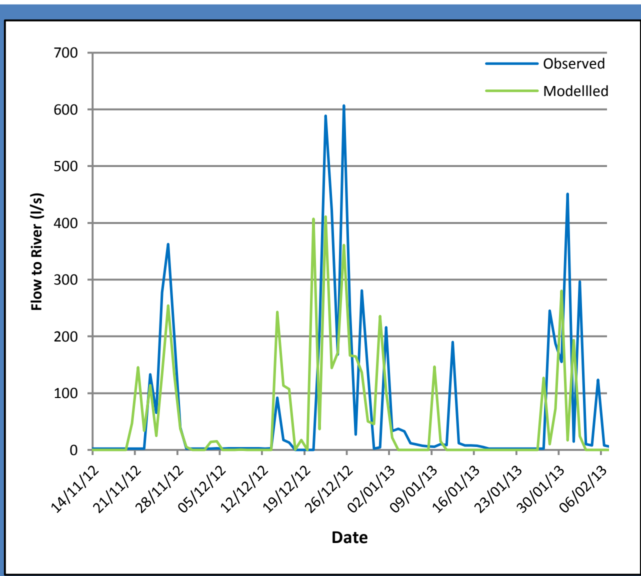


Figure 3 – hydraulic calibration plot

Figure 3 shows comparison results of flow passing to the river during the verification period.

The flow discharged is controlled in real time, with controllers based on the concentration of BOD, level in Pond D and the flow within the river. Hydrobrakes, pump controllers and actuated penstocks are used to control the discharge which made replicating controls complex.

However, the total volume was found to be well replicated by the model.

This model now allows an accurate assessment of the timing and quality of discharges to the River Mole on a continuous basis and has been used to test a number of operational and capital improvements, some of which are now under construction. The model has also been used to assess surface water flood risk, and combined fluvial and surface water flood risk, supporting investment by the Environment Agency and Gatwick Airport in a new upstream flood alleviation reservoir and channel improvements.

2.4 Modelling challenges

The modelling process has not been straightforward, and close partnership working between Gatwick Airport, the Environment Agency and CH2M HILL has been essential to agree assumptions and modelling workarounds when software capabilities and data uncertainties have reduced model performance. Key modelling issues that have been managed are:

- Very high pollutant loads leading to mass balance and stability issues;
- Long run times due to water quality modelling and complex real time control;
- Runoff properties of Deicer being extremely difficult to replicate with simplified treatment of sediment and pollutant fate by IW ICM;
- Difficulty replicating treatment (aeration and biological pre-treatment) applied to storage ponds/lagoons.

A number of software improvements have been recommended in section 2.5.

Overcoming the challenges of modelling deicers

Deicers are a cohesive substance, therefore do not act as a soluble or particulate pollutant; characterising the washoff, deposition and re-erosion was challenging. To overcome this deicer had to be modelled as difference fractions, and the Velikanov sediment transport model was used. The fractions used were:

Dissolved BOD – fast runoff deicers (Aircraft deicers)
Sediment Fraction 1 – lighter, lower BOD deicers (aircraft deicers)
Sediment Fraction 2 – heavier, higher BOD deicers (pavement deicers)

Key success factors:

- Understanding the purpose and composition of different products used.
- Good deicer application and recovery data
- Excellent data collection, recording and management by Gatwick Airport
- Good representation of antecedent and initial conditions
- Representation of spatial variance of types of deicer application
- An understanding of deicer losses (windspray losses and deicer recovery) is essential when characterizing pollutograph

Real time control modelling success features

- Simplify as much as possible. If you can combine multiple regulators and controllers into a single control and structure, do so. One of the key causes of instabilities generated early in the project was regulators and controllers in series causing feedback
- Trial and error!

2.5 Outputs

The modelling process and model outputs have been essential in giving the Environment Agency and Gatwick Airport the confidence they need to come to a pragmatic decision about the permitting of the operational system. Rather than relying on end of pipe discharge controls, in principle agreement has been reached that the revised permit will reflect operational procedures. This more flexible approach that will allow Gatwick and Thames Water to best manage risk to environmental water quality and secure Water Framework Directive compliance, without needing to build capital solutions that would be used infrequently.

However, even this more flexible solution doesn't come cheap. A new pollution storage lagoon of approximately 100,000m3 is currently under construction, a new surplus activated sludge transfer system is in planning (to permanently implement a trial scheme to inject SAS into the a pollution storage lagoon to provide biological pre-treatment), and negotiations are underway for new primary treatment and aeration capacity at Crawley STW.

Potential improvements to ICM

There were a number of software limitations, some of which were known limitations when we started, and some of which were 'discovered' during the project. The following improvements to ICM would make future Airport modelling projects more efficient

1. Hard coded delay to Real Time Control controllers. Currently, the controllers operate at the model simulation timestep. Most in reality will only poll the data at fixed intervals. The polling of data every timestep is simulation and memory intensive, increases run time and increases the risk of instabilities as regulators switch mode frequently.
2. Integrated 1D and 2D quality modelling. It was surprising to find out that pollutants generated on the 2D domain cannot enter the 1D domain.
3. Spreadsheet import/export for easier manipulation of pollutograph files.
4. The ability to apply pollutant load to the catchment surface. Pollutant had to be added directly to the node, which means that the washoff performance had to be simulated in the network itself, rather than on the surface. The ability to apply pollutant load to the surface, and for this to be subject to the surface washoff parameters would have allowed more direct control of pollutant washoff rates.