SUSTAINABLE WATER MANAGEMENT IN THE MINERALS INDUSTRY

(Centre for Water in the Minerals Industry)

Industry representative:
Mr Horatio Davis, Centre for Water in the Minerals Industry, Queensland, Australia

Moderators:
Professor Bill Whiten, University of Queensland, Australia
Assoc. Professor Mark McGuinness, Victoria University of Wellington, NZ

Student Moderator
Mr Sayed Hoseini, University of Wollongong, NSW, Australia

The MISG was asked to examine the problem of water storage at Queensland coal mines. The water dams (or reservoirs) at the coal mines need to hold sufficient water to maintain a supply to the mine and need to be large enough to avoid overflow of water that does not meet environmental specifications. The water supply comes from rain and a pipeline from a public water source. The water is used for washing coal, and for dust suppression on roads and in underground mines. There is also an amount of water lost to evaporation and seepage.

Two major questions were of interest: What size does the dam need to be to reduce the probability of running empty and of overflowing to acceptable levels, and how should the use of pipeline water be scheduled. An additional question on the control of salt content in the dam was of interest.

Variation in the rain fall provides the major variation in the water balance. Rain falls in summer and in winter there is typically a net loss of water due to evaporation. The amount of summer rain varies considerably from year to year. Forty years of monthly rainfall data was available.

A Fourier analysis of the rainfall data showed, as expected, a strong annual period and also a six monthly period. There was no sign of longer periods. The total summer rain was found to closely follow a log normal distribution.

The problem was found to be similar to inventory problems that have been studied extensively. These included dam capacity problems. However, it was found that these used unrealistic rainfall assumptions and neglected the problem of dam overflow.

Order of magnitude estimates were made for the major flows for a typical mine. There clearly was a need for more accurate data for these estimates, and in the absence of these the subsequent work used assumed values that could be updated when more accurate data came available.

It was realised that to avoid overflow and emptying of the dam, feedback control is needed. Without feedback from the dam level, if the net mean flow into the dam is above zero the dam will eventually overflow, and if it is below zero the dam eventually empties. Even when the net mean flow is exactly zero, the dam level behaves as a random walk eventually emptying at times and also at other times overflowing.

The level in the dam could be approximated by a Wiener process and thus a Fokker-Planck equation. This however resulted in zero probabilities for the dam being empty or full. A definition of empty as being below a given level is needed for this type of formulation. Some care is needed in interpreting the probability that the dam is eventually emptied or overflows, or in finding the expectation of the time for the dam to empty.

A discrete formulation based on monthly steps gave greater flexibility for using different rainfall assumptions and adding feedback control. Using this formulation an optimal control problem can be formulated as per Bellman.

Simulations using bootstrap data for 1000 years were run to test and evaluate different control policies. As the appropriate weighting between overflow and emptying was not known a Pareto diagram which plotted overflow probability verses underflow probability was used to evaluate the policies. Each control policy was run 100 times to determine the expected variation in performance. It was found that a control policy of using pipeline water only when the dam level is below a set level gave good results.

A simplified simulation that divided the year into wet and dry parts was used to determine the size of dam required to reduce probability of overflow and empty conditions below given maximum values. Parametric bootstrap data based on a log normal distribution for the summer rain was used for this simulation.

For the case of a fresh water dam and a separate used-water (i.e. recycled
water) dam, a simple simulation of the salt content was undertaken. It was found that the salt concentration in the used-water dam would build up to some natural mean level consistent with the concentration of the recycled water, if there were no control actions taken to reduce the salt content.

The project has provided the methods that could be used to determine dam size and evaluate feedback control for the maintenance of dam levels. There remain several extensions that could be implemented using the techniques demonstrated. The first area that needs attention is to determine typical values of flows into and out of the dam. Investigating the benefits of extending the control policies to be season dependent as well as using feedback from the dam level is an obvious next step. Incorporating the feedback control effects into the determination of dam size would also be useful.

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