HYDRAULICS DIVISION

TECHNICAL NOTE

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AUTHORS: J. Marsalek

TITLE: Summary Report on Kennedy-Burnett Modelling Study

REASONS FOR REPORT:

To respond to request from Mr. H. S. Loijens, Coordinator, Rideau River Stormwater Management Study.

CORRESPONDENCE FILE NO:

5105 (Study 332)

1.0 INTRODUCTION

Under the Rideau River Stormwater Management program, a modelling study of the Kennedy-Burnett Pond was undertaken. The study was conducted under a contract awarded to Marshall Macklin Monaghan, Ltd. and the University of Ottawa. The report that follows is a critical summary of the contractor's final report. Recommendations for further course of action are also offered.

2.0 STUDY OBJECTIVES

The study objective was to determine the pollution control effectiveness of the existing Kennedy-Burnett (K-B) stormwater pond under both the present and anticipated fully developed catchment conditions, and under various operational modes. As stated in the contract, this objective was to be achieved through modelling both the catchment runoff and pond operation. An appropriate runoff model was to be selected, calibrated, and used to generate runoff flow and pollutant flux records (loading records) for a period of twenty years. Such records were to be produced for both the existing and anticipated catchment conditions. Using these loading records, the long term pollutant removal effectiveness of the pond was to be assessed for various modes of operation. The associated pollutant removal costs were also to be determined.

Thus the study consisted of two major tasks - the development of loading data and analysis of the pond performance. It should be stressed that while the first task represents a fairly common procedure, the second task called for some developmental work. Both tasks are discussed below.

3.0 RUNOFF LOADING SIMULATIONS

The SWMM model (Version II) was selected for runoff loading simulations. Extensive efforts were made to calibrate and verify the model for the area studied. This work encountered considerable difficulties, mostly because of the type and limitations of the data available, at that time, for calibration and verification. Further details follow.

The volumetric calibration was initially accomplished by adjusting the catchment imperviousness to a value which was significantly lower than that reported by the Regional Municipality of Ottawa-Carleton (RMOC). During model verifications, it became necessary to continue with model calibration, because one heavy storm, which was used for verification, produced too much runoff. To match this large runoff volume, the infiltration rates in the model were lowered and a small final adjustment of the catchment imperviousness was made. Thus the volumetric calibration/verification results should be viewed in the light of the following limitations:

(i) The calibrated infiltration rates were derived from one event only. These rates were not verified against those which would correspond to the soil type in the catchment.

(ii) The directly connected impervious area in the test catchment has not been accurately determined. The estimates of imperviousness were based on the total impervious area, of which some fraction drains on pervious areas.

With additional field data, both limitations could be removed, or at least reduced.

The runoff quality calibration focused on event loadings. For such loadings, a fairly good calibration was achieved for the data which corresponded to a particular stage of the catchment development. This stage was characterized by extensive construction activities and the corresponding high production of suspended solids. No model verification against field data was carried out, because the whole data set was used in calibration.

The work on the runoff loading model did not proceed further, because of budget constraints and contractor's concerns about the feasibility of estimating the parameters of the fully developed catchment. These concerns were related to both runoff quantity and runoff quality simulations. From the quantity point of view, it would be required to determine the directly connected impervious area of the fully developed catchment. The problem of determining the directly connected impervious area in the K-B catchment has never been fully resolved. Although the initially high estimates of the imperviousness were corrected, the possibility of impervious areas draining onto pervious areas (e.g. roof leaders discharging on lawns, or roads without curbs mentioned in the contractor's report) was not thoroughly investigated in the field. Another source of losses may be an increased surface storage on roads because of slightly raised catch-basins. Thus, considering the uncertainty in the current estimate of the effective catchment imperviousness, one can appreciate the difficulties with projecting this value to the fully developed catchment. For that purpose, the contractor recommended a value of 15%.

In terms of runoff quality, the contractor was concerned about the transfer of model parameters from the catchment under development to the fully developed catchment. Attempts to resolve this problem by comparative sampling in two subcatchments, one underdeveloped and one fully developed, were not fully successful. Nevertheless, these observations (1) showed that the subcatchment under development produced much higher loads of suspended solids, but the fully developed subcatchment produced higher bacteria counts.

The contractor accounted for high loads of suspended solids by means of soil erosion and recommended the use of other calibrated parameters (i.e. accumulation rates and composition of dust and dirt) for the fully developed catchment.

It can be concluded that the work on the loading records is well advanced and could be completed, with minimum costs, following the contractor's recommendations.

4.0 STORAGE/TREATMENT (S/T) MODELLING

The second study task dealt with the modelling of operation of the K-B stormwater pond. In principle, the contractor was supposed to produce a calibrated model for the pollutant removal in the pond and to apply this model to the loading records produced earlier and to estimate the associated costs of pollutant removal. Because the loading records were not produced, the simulation of the long term operation of the K-B pond was not undertaken either. The value of such simulations would be questionable in the light of the modelling results obtained so far.

The modelling activities focused on the S/T block (Release III) of the SWMM model. Extensive efforts were made to set up the model, to calibrate it, and to verify it for two most important constituents - suspended solids and bacteria. No results were reported for other constituents also listed in the terms of reference (2). A detailed discussion follows.

4.1 Model Selection

The contractor has chosen the S/T block of the SWMM model. This model seems to be the most comprehensive model available. It would readily accept the loading records which were supposed to be produced in the first task, and because of the deterministic nature of the model, it would be feasible to transfer modelling results to other catchments. It should be recognized however, that, in spite of recent improvements, the SWMM S/T (III) model is a first generation model first released in 1971. The recent improvements were directed towards increasing the model flexibility by emphasizing user input and knowledge of the processes to be modelled. The model flexibility is enormous and this of course complicates the model testing. It should be emphasized that, in spite of the contractor's extensive efforts, the major model options for pollutant removal have not been tested. For example, the removal equation adopted by the contractor was the older removal equation which specifies the removal rate as a function of the maximum removal rate and the detention time. Other model options make it possible to define removal rates as a function of up to 11 variables and the removal rates can vary with the particle size. Thus there is still some room for further testing of the SWMM S/T model for the K-B pond.

4.2 Basic Processes in Operation of the K-B Pond

It became more and more apparent during the study that the K-B pond is an unconventional facility. In retrospect, the modelling work should have been preceded by investigations of transport and water quality processes to indicate whether the facility can be successfuly modelled with the existing models.

From the storage point of view, the K-B pond storage volume is too large for the present state of development which was characterized by an effective imperviousness of 14%. Consequently, except for heavy storms, inflow volumes are relatively small compared to the stored volume. It is unlikely that either of the two routing options in the SWMM S/T model, complete mixing and plug flow, is fully applicable. It would be of interest to check transport processes in the pond by tracer observations. Density effects, surface waves and shortcircuiting may affect the transport processes in the pond.

During typical runoff events, only small volumes of the pond storage are displaced and, consequently, long detention times can be expected. It is questionable whether the water quality processes taking place during such long periods are adequately described by the model algorithm.

4.3 Evaluation of Modelling Results

The testing of the SWMM S/T model presented in the contractor's report appears to be inconclusive. The reproduction of observations "within an order of magnitude" is insignificant considering the slow response of the pond effluent quality to input variations and further "smoothing out" of such variations in the pond. One could only speculate, if better results could be obtained by selecting different removal functions in the S/T model.

It is possible that a better simulation of the K-B pond operation could be obtained using a statistical model, but the modelling results will not be transferable to other facilities.

5.0 OVERVIEW OF STUDY RESULTS

Budget restrictions and technical problems prevented the achievement of study objectives. The preparatory work for simulation of runoff loading records is almost complete. After a review of the calibrated model parameters and their adjustment for the fully developed catchment, the loading records can be readily produced. The completion of the pond modelling task would be more difficult. So far, only removal of suspended solids and bacteria was modelled. The accuracy of reproduction of observed data by simulation was described by the contractor as within an order of magnitude. Under these circumstances, it would be pointless to use the S/T model, in its present state of calibration, in conjunction with the loading records.

6.0 MAJOR PROBLEMS ENCOUNTERED DURING THE STUDY

Although the study yielded valuable information on runoff loadings, pond operation and the modelling of these phenomena, the original objectives have not been accomplished. Major causes for this are listed below. All these causes were identified by the contractor in the final report (2).

6.1 Budget Limitations

Almost all contractual research studies run into budget problems. To be competitive, contractors budget only for the first effort to complete a particular task. While this may be adequate for standard engineering studies, the conduct of research studies is quite different. Many tasks must be revised or redone, often for reasons beyond the contractor's control. Two examples from the study discussed - calibrations of the runoff loading model and calibrations and modifications of the S/T model.

6.2 Lack of Calibration Data

The field observations at the K-B pond yielded a large volume of unique data which provides a good insight into the pond operation. Nevertheless, these data were not collected for the purpose of calibration of the models used by the contractor. Consequently, the contractor requested some additional data for his work (e.g. subcatchment runoff quality, more data on pond operation in various modes) and this information could not be readily produced within the study period.

6.3 Limitations of the Current S/T Models

It became apparent from the contractor's progress reports that the K-B pond is excessively large for the catchment currently serviced. For most events, the inflow volume is fairly small compared to the volume stored, or storage capacity, and the resulting detention times are fairly long. Under such circumstances, the conventional approaches to the pollutant routing and removal in the pond may become questionable. From the routing point of view, no evidence was offered that either of the two model options, full mixing and plug flow, applies. Similarly, pollutant removal mechanisms in the pond may be more complicated than the sedimentation process conventionally assumed in similar cases. It would appear that the pond modelling work proceeded without a thorough understanding of the transport and water quality processes in the pond.

7.0 FINDINGS OF THE ENGINEERING FOUNDATION CONFERENCE ON STORMWATER DETENTION

To place the Kennedy-Burnett Study results into a proper perspective, pertinent findings of the Conference on Planning, Design, Operation and Maintenance of Stormwater Detention Facilities (SDFs), which was held in Henniker, N.H., August 1-6, 1982, are summarized below. The goal of the conference was to present the current state-of-the-art in the design and operation of SDFs.

1. The practice of designing and building SDFs is far ahead of the research on this subject. The current empirical design techniques for sizing and water quality operation of SDFs were criticized at the conference.
2. Although there are many "successful" detention facilities, there is probably an equal number of "unsuccessful" facilities. Concerns were voiced about the implementation of many small on-site facilities - their combined effect on the catchment hydrology is unknown and their maintenance becomes more and more difficult with the increasing age of facilities.
3. The modelling of water quantity and quality aspects of SDFs, using actual field data on pond performance, is almost non-existent. There was not a single paper presented on this subject. Some experts, including Drs. Randall and Whipple, felt that the modelling of water quality aspects of SDFs is infeasible at present and that a sedimentation theory will not provide the answer.
4. There is an urgent need for field evaluations of SDFs performance, so that their effectiveness can be evaluated and their design rationalized.

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8.0 RECOMMENDATIONS

(a) Considering the efforts expended on the K-B study so far and the general need for more field data on stormwater ponds, the analysis of the K-B data should be continued. This should be done even if the results obtained are specific to the K-B pond.

(b) Review all K-B pond data and investigate new approaches to the derivation of pollutant removal rates. Such approaches should include the general removal equation in the SWMM S/T model and statistical approaches. If an acceptable fit of observed removals is obtained, set up a calibrated removal model for the pond.

(c) If a pond operation model is successfully set up for the K-B pond, apply this model to a runoff loading record for the K-B catchment. This record would be produced according to the contractor's recommendations. The pond effluent record would then be analyzed for pollutant concentrations, loadings, frequencies of occurrence, and durations. Cost data would be also produced for various operational modes.

9.0 REFERENCES

1. Gietz, R. J., 1982. "Kennedy-Burnett Stormwater Runoff Treatment Study - Second Annual Report 1980-81". Pollution Control Division, Regional Municipality of Ottawa-Carleton, Ottawa, June.

2. Marshall Macklin Monaghan Ltd., 1982. "Kennedy-Burnett Modelling Study - Objective 1". Toronto, May.