Australian Government

Cotton Research and Development Corporation

SUMMER SCHOLARSHIP REPORT: 2015-2016 SEASON

1. Project Title : Using a sprinkler infiltrometer and GAML model to predict moving sprinkler performance in the field.

2. Proposed Start Date : 16 March 2015
Proposed Cease Date : 29 October 2015

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SUMMER SCHOLARSHIP REPORT

1. Executive Summary:

This project sought to verify whether the Mein-Larson variant of the Green-Ampt infiltration equation could work for time-varying application rates using real-world moving sprinkler systems. This required laboratory testing of sprinkler equipment, computer modelling and field trials to verify the modelling. Field measurements of surface runoff were problematic, however, and ultimately no conclusive position could be arrived at.

2. Background:

The Green-Ampt (1911) equation has been regarded as one of the foremost infiltration models. Mein and Larson's (1971) work extended its use to modelling infiltration under rainfall conditions, known as the GAML model, and Chu (1987) further extended its use to time-varying application rates such as occurs under moving sprinkler systems. However, Chu only demonstrated the efficacy of his work using simple, idealised application patterns that are not seen in the real world. This project, then, sought to extend Chu's work by testing it in the field using real sprinkler performance data.

3. Aims and Objectives:

The aim of this project was to apply the Green-Ampt-Mein-Larson (GAML) model to time-varying sprinkler application patterns in a field environment to predict the runoff (if any) that was generated. The primary objective was to create a computer model, based on the methods of Chu, which used the performance data of real sprinkler components to predict runoff. A series of field tests were then scheduled to verify the model.

A secondary objective that arose in the course of the project was to develop and assess an alternative design concept that the author had for a sprinkler infiltrometer. A sprinkler infiltrometer was essential for applying the GAML model and it was hoped that the proposed alternative design concept could overcome some of the limitations typically associated with regular sprinkler infiltrometer designs.

4. Materials and Methods:

Sprinkler performance data, using Nelson brand centre-pivot S3000 sprinkler heads, was collected for the project in the hydraulics laboratory at USQ, Toowoomba. A sprinkler infiltrometer was used in the field to determine modified GAML parameters, per Chu (1986). A computer program written in Matlab, based on the graphical methods of Chu (1987), used the laboratory sprinkler data and the modified GAML parameters to make a prediction of the runoff that would be generated from a specified time-varying application rate. A mobile sprinkler rig was constructed to deliver the time-varying application rate of water in the field.

The project was conducted in three stages.

1. Laboratory testing stage. During this stage the testing of the centre-pivot sprinkler components was carried out under highly controlled conditions. The intent was to gather high quality data on the performance of the sprinkler systems which could be used later in the computer model. A timber frame and protective screen was constructed to support the sprinkler heads and associated piping, plus a suite of Wika mechanical and ABB Magmaster electromagnetic pressure and flow monitoring equipment. Catch-cans were set out at 0.25m intervals, starting from immediately below the sprinkler head.

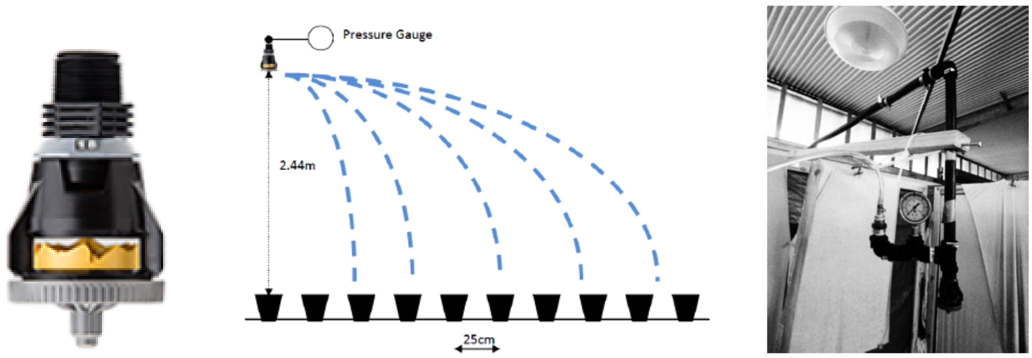

Figure 1: Laboratory testing components and setup

2. Computer modelling stage. During this stage the computer model, written in Matlab, would determine an infiltration characteristic function for the field, and then apply the laboratory catch-can data in conjunction with the user-specified speed of travel of the moving sprinkler system and the spacing between sprinkler heads (so that the sprinkler application patterns were overlapping) to ultimately produce estimates of infiltration and runoff that would result from the system.

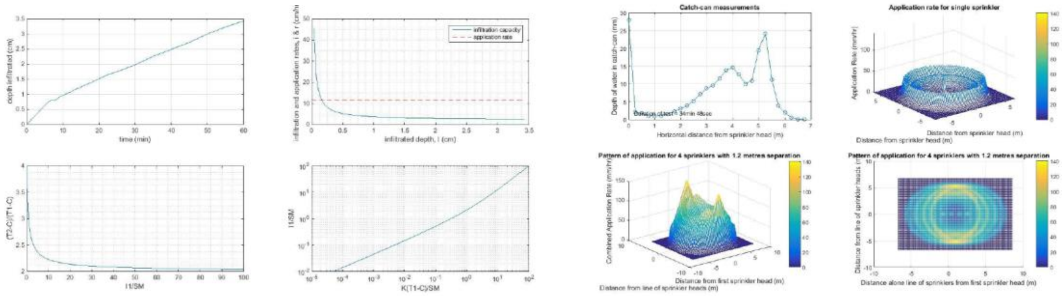
Figure 2: Examples of computer model outputs

3. Field verification stage. A mobile sprinkler rig was constructed for the purpose of this project. Its purpose was to provide a time-varying application rate where the pressures and flowrates could be closely monitored and controlled. The runoff that was generated from underneath this mobile sprinkler rig was collected, measured and compared to that predicted by the computer model.

Figure 3: Mobile sprinkler rig constructed for the project

5. Results:

67 laboratory catch-can tests, each lasting approximately 35 to 60 minutes were conducted over two months using a variety of sprinkler nozzle sizes (14/128th inch ie. #14 nozzle, through to 48/128th inch #48 nozzle), pressures (6psi to 30psi) and spinner plate types (yellow plate and red plate). The data were recorded and plotted in Excel. These data were further analysed to determine values for Christiansen's Uniformity coefficient (CU), 2-dimensional distribution patterns and for ideal nozzle+pressure+plate combinations for use in the sprinkler infiltrometer. The Nelson S3000 with a red spinner plate and a #44 nozzle operating at 25psi was identified as most suited for the forthcoming field phase of the project.

The results of the computer model, that used the laboratory data, agreed well with published results in the literature for the simplified scenarios. However, some difficulties with convergence were encountered when using complex, real-life sprinkler data.

		Silt Loam	Loamy Sand
Equations of curves used for modelling		$i = 1.15t^{-0.587}$ $I = 2.79t^{0.413}$ $r = 1500t$ $R = 750t^2$	$i = 15.8t^{-0.336}$ $I = 23.8t^{0.664}$ $r = 1500t$ $R = 750t^2$
Predicted time to ponding	Numerical solution to Richards equation	0.018 days	0.043 days
	Chu's graphical method	0.018 days	0.043 days
	Part 2 of computer model	**0.020 days**	**0.049 days**

Figure 4: Comparison between computer model's output and published results.

Based on Chu's methods, infiltration characteristic curves were generated for 9 separate field tests.

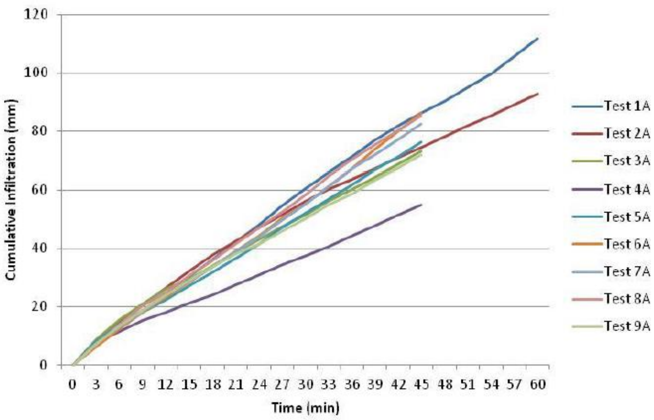

Figure 5: Cumulative infiltration curves for 9 separate tests.

The mobile sprinkler rig worked remarkably well and was able to reliably deliver the time-varying application rate of water to the test plots as required. It travelled at a speed of 36m/hour and had a system throughput of 2.1L/s, or 7.6m³/hr. The peak application rate was 140mm/hr, and the mean application rate was 48mm/hr.

The predicted runoff from the computer model was generally higher that what was measured in the field tests. However, there were significant difficulties with ensuring that all of the runoff from the soil test plots was collected and this likely impacted upon the final results.

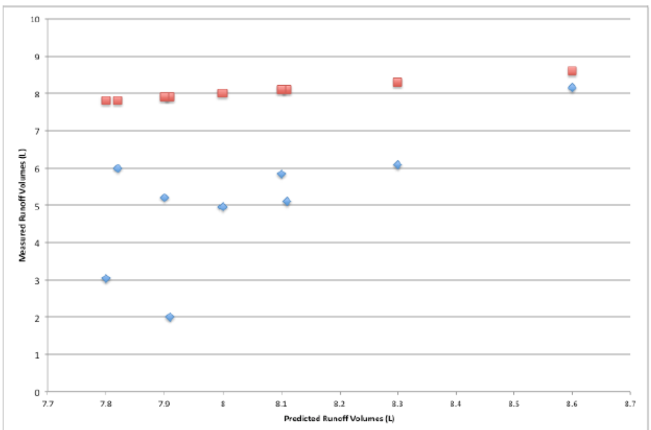

Figure 6: Comparison of predicted (red squares) vs measured (blue dots) values for runoff.

6. Discussion and Conclusions:

The field tests were unable to confirm that Chu's method of applying the GAML model to time-varying application rates would work with real sprinkler systems in a field situation. There were significant practical difficulties with collecting all of the runoff (which the literature was surprisingly quiet on). Thus it cannot be concluded with confidence that the GAML is suited, or not, to modelling real-world moving sprinkler systems.

7. Highlights:

Highlights included successful design, construction and deployment of the custom-build mobile sprinkler rig that reliably provided the time-varying application rates required. Another highlight was successfully collecting high quality laboratory sprinkler data that was of value to this project and, possibly, will be of value to future sprinkler irrigation research efforts.

8. Future Research:

The ability of Chu's method for applying the GAML model in real situations still has not been convincingly confirmed or ruled out. If the model is shown to be valid then it could be informative to irrigation designers and operators. Better quality field equipment to measure field runoff would be required to achieve this end.

9. Presentations and Public Relations:

I made a presentation of this project at the 2015 USQ Project Conference before fellow students, academics and interested persons from local industry. My presentation was awarded Second Place by the judges. (CRDC sponsored projects took out First and Second Place at the Project Conference.) A copy of my presentation has been attached with this report.

10. Reference List:

87 referenced papers or data sources were included in the dissertation. The 4 key papers were:

Green W.H. & Ampt G.A. 1911, 'Study on soil physics', Journal of Agricultural Science, Vol. 4, pp.1-24.

Mein R.G. & Larson C.L. 1971, 'Modelling the rainfall component of the rainfall-runoff process', Water Resources Research Center, University of Minnesota, Bulletin 43.

Chu S. 1986, 'Determination of Green-Ampt parameters using a sprinkler infiltrometer', Transactions of the ASAE, Vol. 29, No. 2, pp. 501-4.

Chu S. 1987, 'Generalised Mein-Larson infiltration model', Journal of Irrigation and Drainage Engineering, Vol. 113, No. 2.