

**MODELLING WATER ALLOCATION FOR A RUN-OF-THE-RIVER RICE
IRRIGATION SCHEME USING GIS**

By

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**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirement for the Degree of Doctor of Philosophy**

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Dedication

To the author's heartfelt loving daughter, wife and parents

Abstract of thesis presented to the Senate of the Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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Water is becoming increasingly scarce and it is important to find methods to reduce water consumption. It is a well-known fact that in most run-of-the-river irrigation projects, the water demands seldom satisfactorily match the erratic flows in the river. In large-scale irrigation schemes like the Tanjung Karang Rice Irrigation Scheme, allocation of water resources is more difficult due to the variability of water use, typical irrigation supply and the pattern of water availability. Due to unreliable water supply in the absence of storage reservoir for the scheme, there is a need for daily prediction and allocation of the available water resources equitably and efficiently to improve the system management. A study was attempted to develop Geographical Information System (GIS) integrated with water allocation model for ensuring equitable supply and efficient use of available water resources.

A mathematical model was developed for the equitable and allowable water delivery through tertiary canals. The relationship was also developed for determining the available daily discharge for irrigation supply at Tengi River Headworks (TRH) in the main canal with respect to the upstream discharge at the Bernam River

Headworks (BRH). The discharge variation regression equation was used to compute discharges downstream using known discharge records at the upstream point. It was found to be reliable for estimating daily available discharges for irrigation supply at the downstream point. New performance indicators were also developed to evaluate the irrigation delivery performance. The crop-water relationship model was developed based on different water allocation rules under field condition.

A water balance model was studied. The model is able to determine the crop water requirements of rice at specific periods. The Penman-Monteith method was applied for estimating daily reference crop evapotranspiration. Autoregressive model was applied to forecast reference crop evapotranspiration and water diverted to the irrigation system at the upstream of the scheme since daily records were not available. A First-order Markov chain model was used to simulate the occurrence of rainfall, and a skewed normal distribution was applied to fit the amount of rainfall for a rainy day. Results obtained showed that these stochastic models could satisfactorily be used to generate daily records for the area.

A comprehensive modelling framework was developed for equitable water allocation in tertiary units considering the optimal utilisation of limited water resources as the season advances. It was embedded into the user-friendly interactive tool known as Rice Irrigation Management Information System (RIMIS). ArcObjects and Visual Basic for Application (VBA) programming languages were used to develop RIMIS inside the powerful ArcGIS 8.3 software. RIMIS is comprised of six modules, several sub-modules and functions. The “Detailed Scheme Information” module describes a new framework for creating generic graphical user interfaces with ArcObjects and VBA for database access of spatial and non-spatial data recorded in a

geodatabase. It provides appropriate information interactively for irrigation engineers or water managers towards solving the irrigation water management issues as the season advances. The “Equitable Irrigation Deliveries” module simulates irrigation deliveries incorporated with allowable and design irrigation supply based on the tertiary canal’s command areas, stochastic daily rainfall and evapotranspiration and available water resources for irrigation supply. It allows the manager to enhance the decision-making for delivering the right amount of water to the fields for the upcoming irrigation period. The “Optimisation of Irrigation System” module is intended for optimal utilisation of available water resources through proportional allocation to all irrigable areas. The simulation model was tried with different parameters and criteria using optimal allocation policy. The “Monitoring Irrigation Deliveries” module gives information on the uniformity of water distribution and the shortfall or excess; and what decisions to adopt for the next day. The “Post-Season Analysis” module uses daily or periodic information to evaluate the season’s irrigation management performance. The “Hydro-climatologic Simulation Module” integrates several sub-modules for hydrological simulation models.

The RIMIS is a new development in Malaysia. It was evaluated for its decision-making capability on equitable water allocation along with trade-offs in water use by the scheme for two irrigation seasons in 2003 and 2004. The RIMIS was found to be practically acceptable and an effective tool for providing a more equitable distribution of available water resources for irrigation supply or more crops with less water.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

**PEMODELAN PENGAGIHAN AIR
UNTUK SKIM PENGAIRAN PADI BERSUMBER AIR SUNGAI
MENGUNAKAN GIS**

Oleh

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Air semakin berkurangan dan adalah penting untuk mencari kaedah bagi mengurangkan penggunaan air. Adalah menjadi pengetahuan umum bahawa dalam projek pengairan bersumber air larian sungai, keperluan pengairan jarang dapat dipenuhi oleh aliran tak menentu air sungai. Dalam sistem pengairan yang berskala besar seperti skim Pengairan Padi Tanjong Karang, pengagihan sumber air adalah lebih susah kerana perbezaan penggunaan air, kebiasaan bekalan air pengairan, dan corak kebolehdapatan bekalan air. Oleh kerana bekalan yang tidak menentu dengan tiadanya takungan simpanan air untuk rancangan pengairan, ada keperluan untuk ramalan dan pengagihan air yang sediaada secara saksama dan cekap untuk meningkatkan sistem pengurusan. Satu kajian telah dilakukan untuk membangunkan satu sistem maklumat geografi yang diintegrasikan dengan model pengagihan air untuk memastikan bekalan yang saksama dan penggunaan cekap sumber air yang ada.

Satu model matematik telah dibangunkan untuk penghantaran saksama air pengairan yang dibenarkan kepada kawasan dipengaruhi saluran taliair tersier. Hubungan telah

dibangunkan untuk menentukan aliran masuk harian yang ada bagi pengambilan di saluran utama bekalan pengairan di tempat kerjaturus Sungai Tenggi (STH) dengan mengambil kira aliran masuk harian di kerjaturus Sungai Bernam (BRH). Persamaan regresi variasi kadaralir telah digunakan untuk mengira kadaralir di hilir (TRH) dengan mengambil kira rekod kadaralir di hulu (BRH). Persamaan tersebut telah didapati boleh dipercayai untuk menganggar kadaralir sebagai bekalan air pengairan di hilir. Petunjuk prestasi yang baru juga telah diperkenalkan bersama dengan petunjuk yang lain untuk memantau pengagihan harian air pengairan. Model hubungan tanaman-air telah dibangunkan berdasarkan peraturan pengagihan air yang berbeza mengikut keadaan sawah.

Model imbalan air telah dikaji. Model tersebut dapat menentukan keperluan air tanaman padi pada jangkamasa tertentu. Kaedah Penman-Monteith telah digunakan untuk menganggar sejatpemeluhan tanaman rujukan harian. Model autoregresif telah digunakan untuk meramal sejatpemeluhan bagi tanaman rujukan dan aliran sungai boleh didapati yang dilencongkan ke sistem pengairan di bahagian hulu skim pengairan apabila rekod harian tidak boleh didapati. Model rantai Markov order pertama telah digunakan untuk simulasi kejadian hujan, dan taburan normal terpencong telah digunakan untuk menyesuaikan jumlah hujan bagi hari yang hujan. Hasil yang didapati menunjukkan bahawa model-stokastic ini boleh digunakan dengan memuaskan untuk menghasilkan rekod harian bagi kawasan kajian.

Satu rangka kerja pemodelan bersepadu telah dibangunkan bagi pengagihan air yang saksama dalam unit tersier melalui penggunaan optimum sumber air yang terhad untuk sepanjang musim. Ia diletak di dalam satu sistem maklumat mesra pengguna yang interaktif sebagai alat pengurusan yang dikenali sebagai Sistem Maklumat Pengurusan Pengairan Padi (RIMIS). Bahasa membuat program ArcObjects dan

Visual Basic bagi Aplikasi (VBA) telah diguna untuk membangunkan RIMIS di dalam perisian Sistem Maklumat Geografi ArcGIS versi 8.3. RIMIS mengandungi enam modul, beberapa sub-modul dan fungsi. Modul “Maklumat Skim Terperinci” menggambarkan rangka kerja yang baru untuk mencipta antaramuka grafik dengan ArcObjects dan VBA bagi capaian pangkalan data ruang dan tak ruang yang dirakamkan dalam pangkalan data bumi. Ia memberi maklumat bersesuaian secara interaktif kepada jurutera pengairan atau pengurus air untuk menyelesaikan isu pengurusan air pengairan disepanjang musim. Modul “PENGHANTARAN Air Pengairan Saksama” menyelaku penghantaran air pengairan yang termasuk bekalan rekabentuk dan yang diizinkan, berdasarkan kawasan pengarah saluran tersier, hujan dan sejat-pemeluhan harian stokastic dan sumber bekalan air yang ada. Ini membolehkan pengurus meningkatkan proses membuat keputusan untuk menghantar jumlah air yang tepat ke sawah untuk jangkamasa pengairan seterusnya. Modul “Pengoptimuman Sistem Pengairan” adalah untuk pengairan optimum sumber air yang ada melalui pengagihan berkadaran kepada semua kawasan pengairan. Model simulasi telah dicuba dengan parameter dan syarat-syarat yang berbeza menggunakan polisi pengagihan optimum. Modul “Pemantauan Penghantaran Pengairan” memberi maklumat berkenaan agihan air dan kekurangan atau lebihan, dan apa keputusan perlu dipilih untuk hari esoknya. Modul “Analisis Musim Lepas” menggunakan maklumat harian atau berkala untuk menilai perlakuan pengurusan pengairan bagi sesuatu musim. Modul “Simulasi Hidro-iklim” mengintegrasikan beberapa sub-modul bagi simulasi hidrologi.

RIMIS adalah suatu perisian yang baru dibangunkan di Malaysia. Ia telah dinilai bagi dua musim dalam tahun 2003 dan 2004 untuk menganggar keupayaannya sebagai alat untuk membuat keputusan. Berdasarkan penilaian, RIMIS telah didapati boleh diterima secara praktik dan suatu alat yang berkesan untuk mengagihkan air pengairan yang sedia ada secara saksama, atau meningkatkan pengeluaran tanaman padi dengan air yang kurang.

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I certify that an Examination Committee has met on the 10th March 2006 to conduct the final examination of Md. Rowshon Kamal on his Doctor of Philosophy thesis entitled “Modelling Water Allocation for a Run-of-the-River Rice Irrigation Scheme using GIS” in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at UPM or other institutions.

MD. ROWSHON KAMAL

Date: 20 April 2006

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