UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF ON-FARM STRUCTURES AND WATER DELIVERY MANAGEMENT MODEL FOR IMPROVED RICE IRRIGATION PRACTICES, TANJUNG KARANG, MALAYSIA

MOHD YAZID BIN ABDULLAH

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By

MOHD YAZID BIN ABDULLAH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Doctor of Philosophy

April 2016

DEDICATION

This work is dedicated to my beloved parents, wife, children and siblings.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirement for the Degree of Doctor of Philosophy.

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Chairman : Professor Mohd Amin Mohd Soom; PhD, P.Eng.
Faculty : Engineering

This pilot project study was conducted in Tanjung Karang Rice Irrigation Scheme, Selangor. The problems of the tertiary canal and on-farm water management in the scheme are related to the design of the tertiary canal; structures employed and water delivery management system for different modes of irrigation requirement. Other problems were related to the design and distribution of the existing structures along the tertiary canal and length of concrete canal measured up to seven kilometer serving up to 230 paddy lots caused the difficulties in delivering water timely, equitably and adequately to the whole canal length for different water delivery modes. As to overcome these problems, this study proposed development of three new on-farm structures and water delivery management models. Three structures in the tertiary irrigation canal and on-farm levels which were developed and evaluated in this study are: (1) flexible field offtake and automated float type flow control valve structure; (2) tertiary canal water level regulator or check structure and (3) field drainage outlet control structure. This water delivery management model was developed for four modes of irrigation supply for rice irrigation requirements, namely presaturation, second flooding, supplementary and termination of irrigation supply. The developed structures were tested in the laboratory and at the pilot project site for performance in terms of suitability and functionality in water delivery to obtain their accuracy, sensitivity and flexibility in different water delivery modes. The on-site evaluation were conducted to evaluate their performance in water delivery for different delivery modes, effectiveness in improving farm related activities in rice production and overall crop planting duration. The tests of these structures showed encouraging results for their respective functions in improving water delivery management in tertiary canal and on farm rice irrigation system. The most outstanding result of the laboratory tests was the stable and close to linear nature of flow through the flexible field offtake, for flow rate up to 10 liter/sec and maximum delivering capacity of up to 22 liter/sec. The results indicated its suitability to function as a flow measurement and flow control structures to provide a stable and accurate water delivery for supplementary irrigation and meet the flexibility of faster delivery for presaturation and second flooding other irrigation practices for rice cultivation.

Sensitivity analysis of the offtake indicated that there was about 175 mm allowable water level fluctuation that provide flexibility and advantage to deal with the possible different in gate submergence in the canal operation or other reasons. Improved presaturation water delivery with the utilization of the newly developed flexible field offtake was based on the fact that faster water delivery in a shorter duration has reduced the amount of water required for presaturation. Through the utilization of the developed delivery management model for supplementary irrigation, the advantages of minimizing perturbation in tertiary canal flow, reducing farmers' task in managing on farm irrigation practice, harvesting and capturing rainfall in paddy fields as well as controlling the run off flow from irrigation and rainfall to the drainage system could all be realized. It was successfully proven that the developed model with the support of efficient farm machinery service provider and responsive farmers result in shorter presaturation duration, saving a significant amount of water, and also shortened the overall duration of seasonal rice production significantly.

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

PEMBANGUNAN STRUKTUR-STRUKTUR PERINGKAT LADANG DAN MODEL PENGURUSAN PENYAMPAIAN AIR BAGI PENAMBAHBAIKAN AMALAN PENGAIRAN PADI,TANJUNG KARANG, MALAYSIA

Oleh

MOHD YAZID BIN ABDULLAH

April 2016

Pengerusi : Profesor Mohd Amin Mohd Soom; PhD, P.Eng.
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Kajian projek perintis ini telah dilaksanakan di Skim Pengairan Padi Tanjung Karang, Selangor. Masaalah utama bagi sistem tersier dan ladang di skim ini adalah berkaitan dengan rekabentuk taliair tersier, struktur-struktur yang digunapakai dan sistem pengurusan penyampaian air bagi memenuhi keperluan pengairan air untuk tanaman padi yang berubah. Masaalah lain adalah berkailan dengan rekabentuk dan taburan struktur-struktur sepanjang taliair, panjang taliair tersier yang mencapai tujuh kilometer panjang dengan bilangan lot padi mencapai 230 lot menimbulkan kerumitan untuk menyampaikan air mengikut jadual, saksama dan mencukupi ke seluruh kawasan mengikut bentuk penyampaian yang berbeza berdasarkan keperluan air bagi amalan penanaman padi masa kini. Untuk menyelesaikan masaalah tersebut, kajian ini mencadangkan pembangunan tiga struktur baru dan pembangunan model pengurusan penyampaian air. Tiga jenis struktur peringkat tersier dan ladang yang telah dibangunkan dan dinilai dalam kajian ini: (i) Offtake sawah fleksibel beserta sistem injap kawalan aliran automatik jenis pelampong; (ii) struktur kawalan paras air jenis rata dan (iii) struktur kawalan saliran keluar air sawah. Model-model ini telah dibangunkan bagi empat bentuk pembekalan air pratepuan (presaturation), banjiran kedua, bekalan pencukupan semasa pertumbuhan padi dan penamatan bekalan dan kawalan saliran sebelum penuaian padi. Penilaian terhadap model dengan struktur yang telah diubahsuai kemudiannya dilakukan di tapak projek perintis bagi menilai prestasi penyampaian air untuk keperluan bekalan air yang berlainan, dalam meningkatkan keberkesanan aktiviti berkaitan pengeluaran padi serta tempoh keseluruhan bagi pengeluaran padi semusim. Pengujian-pengujian tersebut telah memperlihatkan keputusan yang memberangsangkan mengikut fungsi masing-masing dalam meningkatkan mutu penyampaian air. Keputusan yang paling terserlah dari pengujian di makmal hidrolik adalah kadar aliran menghampiri linear bagi aliran melalui flexible field offtake bagi kadar aliran sehingga 10 liter sesaat dan kapasiti penyampaian maksima 22 liter sesaat. Keputusan ini dan pengiraan sensitiviti yang dibuat menunjukkan bahawa struktur ini sesuai untuk berfungsi sebagai struktur pengukuran kadaralir dan kawalan air bagi penyampaian air bagi tujuan bekalan air untuk bekalan pencukupan. Pengujian sensitiviti mendapati terdapat 175 mm ruang perubahan turun naik paras air untuk

mengekalkan kesesuaian struktur ini yang boleh memberikan fleksibiliti dan mengatasi kemungkinan perbezaan paras penenggelaman pintu air semasa pengoperasian taliair diakibatkan oleh perubahan paras air dalam taliair tersier, jarak relatif dari pengatur paras air, pemendapan taliair atau sebab-sebab lain. Oleh itu, penambahbaikan bekalan air pratepuan dengan menggunakan flexible field offtake dibuat berdasarkan fakta bahawa penyampaian air yang cepat dalam tempoh yang pendek telah mengurangkan jumlah air yang diperlukan untuk bekalan pratepuan. Saranan untuk mengamalkan pembekalan air untuk bekalan pencukupan melalui penyampaian secara berterusan mengikut keperluan harian telah membolehkan kelebihan meminimakan pertubasi paras air dalam taliair tersier, mengurangkan tugasan petani dalam menguruskan praktis pengairan peringkat ladang, penuaian dan penakungan air hujan dan pengawalan aliran keluar air hujan dan air pengairan dapat direalisasikan. Keputusan ujian juga telah mengesahkan bahawa model yang dibangunkan dengan disokong oleh pembekalan jentera pertanian yang cekap serta petani yang responsif; telah berjaya memendekkan tempoh pratepuan, menjimatkan air dengan banyak, justeru memendekkan tempoh keseluruhan pengeluaran padi dengan signifikan.

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I certify that a Thesis Examination Committee has met on 15 April 2016 to conduct the final examination of Mohd Yazid bin Abdullah on his thesis entitled "Development of On-Farm Structures and Water Delivery Management Model for Improved Rice Irrigation Practices, Tanjung Karang, Malaysia" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Doctor of Philosophy.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Doctor of Philosophy.The members of the Supervisory Committee were as follows:

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- the research conducted and the writing of this thesis was under our supervision;
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LIST OF ABBREVIATIONS

BPSP	Bahagian Pengairan & Saliran Pertanian (Irrigation and Agricultural Drainage Division, MOA)
DID	Department of Irrigation and Drainage
DOA	Department of Agriculture
DR	Drainage Requirement
ET	Evapotranspiration
ETc	The crop evapotranspiration is the evapotranspiration from a disease-free, well-fertilized and under optimal soil-water and agronomic conditions growing crop (ETc = ETo * Kc).
ETo	Reference crop evapotranspiration (or reference evapotranspiration is defined as the evapotranspiration rate (for example mm day-1) from a reference surface which is hypothetically a well-watered grass crop with specific characteristics.
ETc	The crop coefficient (Kc) is an experimentally determined coefficient relating ETc to ETo (ETc = ETo * Kc)
ETP	Economic Transformation Program
FSL	Full Supply Level
FAO	Food and Agriculture Organization
IADA	Integrated Agricultural Development Area
JICA	Japan International Cooperation Agency
MASSCOTE	Mapping System and Services for Canal Operation Techniques
MOA	Ministry of Agriculture and Agro-base Industry, Malaysia
RAP	Rapid Appraisal Procedure
SWC	Soil water content
SWT	Soil water tension
TASS	Taliair Sawah Sempadan (Tertiary Canal in Sawah Sempadan Compartment)

CHAPTER ONE

INTRODUCTION

1.1 Background

Water is a scarce resource all over the world and irrigation consumes more than 70% of the fresh water resources, hence management of the agricultural water resources has become an important issue. As water resources are stretched between competing demands, irrigation efficiency must be increased at all levels of irrigation system (Guera et al., 1998). A key component of improving irrigation efficiency is the accurate measurement and control of water flow rate as well as water level control in the main canal, secondary canal, and tertiary canal. Increasing irrigation efficiency through water conservation, management of field for high water productivity, management of non-point source pollutants, rainwater havesting and storing all would require efficient management at the tertiary canal and on-farm level. The water losses in irrigation channels are large, but it is recognized that these losses can be substantially reduced by employing improved and efficient modern control systems.

A major part of the 250 million hectares irrigated land worldwide is served by surface canal systems where 142 million hectares is cultivated with rice (UN, 2007). In surface canal systems, performance is generally low and improvements are critically needed to improve water resource management, service to irrigated agriculture and cost-effectiveness of infrastructure management for efficient irrigation water schedule.

Allocation, distribution and control of water is the core process of water management in irrigation system. It is the process by which the available water is divided and equitably distributed to the smaller command units or irrigation blocks within the system, which in turn is distributed further down to the individual water user (farmers) who will control and direct to the crop root zones in particular fields. Chambers (1980) stated that 'who gets what, where and when', is the point as far as irrigation is concerned. Surrounding this issues, human actions and interactions take place resulting in the re-design, re-construction, and re-shaping of the physical and organizational arrangements (Pradhan, 1996). The process of water control in canal irrigation and on-farm using modern technology therefore becomes the main thrust of this study.

Canal irrigation has been traditionally practised in Malaysia for many decades. However the development of modern canal irrigation systems that can ensure flexibility is yet to be adopted. The increasing investment by the government in the development of modern canal irrigation systems, especially after realization of the need to manage water as a scarce resources. Despite this effort, however, there is a general contention that most of the government-built modern canal irrigation systems do not function optimally and therefore more water is being wasted daily. The reason for this is not clear since there are almost no scientific studies into what actually happens in these systems as regards to their design and water allocation and distribution. Hence there is a need to examine and explore irrigation water allocation and distribution, the technical design and the operational features of the existing tertiary canals with the aim to innovate some of its facilities. It should be possible to develop appropriate methods for improving water control in public canal irrigation systems.

Irrigation water scheduling at farm level constitutes the most critical part in on-farm water management, a plan and most suitable situations, a decision on when, how long and with what flow rate, expressed in absolute value or as a sharing proportion, water should be delivered at the off-take gate to meet crop water requirement. It would be nice if every farm could be supplied with enough irrigation water from the canal. The farmers would then be in a position to fully master their irrigation schedules and to best manage irrigation for their crops and gain from farming business, an indicator to the on-farm constraints which could be constraints from economics and/or the environment.

Current issues of food shortage and significant increase of food prices post a challenge to many countries including Malaysia, to increase food production. In order to meet future food demand, increase farmers' income and the contribution to Gross National Income (GNI), The Government of Malaysia, through the Economic Transformation Program (ETP), plan to construct new and upgrading the existing infrastructures including the tertiary canals to facilitate the economic growth in rice production. The main constraints to increase rice production include limited land and water resources, competition for available water resources with the other sectors, low efficiency in irrigation water use, poor management of the irrigation systems, non-availability of appropriate infrastructure for modern irrigation management and environmental degradation.

The success of any irrigation project in meeting water requirements depends to a large extent on the proper functioning of its water conveyance and distribution system. Proper functioning is essentially identified with proper operation of the system so that equitable and reliable apportionment of water among users and the conveyance of water with minimum losses are ensured. While operation of an irrigation system is dependent on good organizational and institutional backing, its effectiveness is basically dependent on a well-planned, designed, constructed and maintained network from the source of the water supply down to farmers' fields.

Optimum irrigation management and control has different meanings to different stakeholders. Levine (1980) pointed out that 'what is optimum from an irrigation system point of view is not necessarily optimum from the farmers' point of view; these optima must be reasonably close for efficient use of the resources available to both irrigation system and farmers alike.

Supply system flexibility is the main factor in modern irrigation structures to increase water productivity and increase crop yield. Flexibility means ability to adjust the frequency, rate and duration of flow to suit crop water requirement, requirement of land preparation and need to serve recommended field activities and agricultural practices to optimize water, input or labor. The practices are required to increase yield (quality and quantity) or to reduce production costs.

Bhumiyan et al. (1998) recognized the excessive amount of water often used for land soaking and providing required standing water for land preparation during presaturation supply in rice cultivation. Reducing the period of land preparation would lead to substantial saving in water including water lost because of evaporation, seepage and percolation and surface run off. Then, reducing the presaturation duration will definitely reduce the water application, increase irrigation efficiency and consequently reduce the overall rice planting duration. The time needed for distributing water in the field can be shortened significantly by using more field channels instead of the plot-to-plot method. In the case of water delivery is conveyed through the tertiary canal, the delivery period can be reduced through the delivery of larger amount of water to each lot. Changing the presaturation duration requires the flexibility in the canal system to change flows through offtakes.

To have a flexible system, the offtakes should be able to control flows, have the size larger than normal rates and able to measure flows. The tertiary canal also should be large enough to convey the required discharge for the system to be flexible. The question is in order to have a flexible system for rice cultivation, what is the flow rate to be provided for individual paddy lot, as compared to the continuous flow normally practiced in Malaysia, or in other parts of the world. In irrigation districts, water management is becoming more challenging as irrigators realize that crop yields can be maximized if sufficient amounts of water can be delivered at the proper time. As irrigation districts try to be more responsive to water users, they are finding that water losses are increasing and the canal systems are becoming harder to manage (Stringam et al., 2003).

1.2 Importance of Study

This pilot project study was conducted in Tanjung Karang Rice Irrigation Scheme, Selangor. Previous studies on the performance of irrigation schemes in Malaysia and other parts of the world indicated that water delivery service quality at tertiary canal and on farm levels operated by farmers and paid employees is comparatively low as compared to the main and secondary canal levels.

It has been acknowledged today worldwide that the demands for fresh water resources is on the rise and are stretched between competing demands; irrigation efficiency needs to be increased especially at farm level. Tertiary canal and on farm level are the most critical part of the irrigation system as these levels take up most of efforts and money spent for water management and loss most of water that is lost from the whole scheme.

A key component of improving irrigation efficiency is accurate control of off-take gates for water flow into the farm area. The off-take gate function is for getting the right amount of water into the farm. There is a lack of accurate information and lack of precision in the setting of these structures. In non-automated off-take systems, management requires the mobilization of human resources to set and check structures (Renault & Hemakumara, 1999). Many researchers have delved into the gate control system and have made remarkable achievements worthy of mentioning here related to this research.

Field off-take is an important structure in tertiary canal provided as the turn-out structure from tertiary or quaternary level canal to the field. This structure plays important roles in providing the required water to the farm to suit crop water requirement and controlling the flow rate of water into the field. There are many complaints by many parties on the availability of simple flow measuring devices to measure flow rate in the case of small scale surface irrigation systems (Gopalakrishnan, 2009).

For an efficient water distribution, distant-downstream control, i.e. use the upstream gate to control the downstream water-level of each pool, is paramount (Li and Schutter, 2010). Results obtained from the previous studies showed that the off-take discharge deviations as a results of the errors in cross-regulator settings are significant consequently a new sensitivity indicator can be defined for those off-takes that are influenced by the cross regulators (Shahrokhnia & Javan, 2008). This sensitivity not only defines better indicator but also prove that cross-regulator settings are prone to errors. Ghazali et al. (2006) undertook a study with the ultimate aim of evaluating the performance of an automated CHO off-take structure in terms of discharge, orifice gate and turnout gate openings and operational time requirements.

Measurement and control of flows are another important aspect of water management in tertiary canal. Measurement of flows is required to ensure exact amount of water is supplied to every lot according to the demand of the lot based on predetermined rate as agreed or planned. Knowing the rate of flow, the duration and frequency can be easily manipulated accordingly to manage supply and demand. The opening of the intake gate can then be operated to suit the various planned or unplanned requirement to save water. The uncertainty may occur due to changes in flow of the river, pumps operation, rainfall, spill, flood control in paddy fields, etc. Hence, flow control and measurement of the field intake are very important for on-farm water management.

Through the Economic Transformation Program (ETP), the Malaysian government has launched a massive campaign to transform rice production so as to become a commercial business for farmers, to increase rice production as well as farmers' income while ensuring environmental sustainability. One of the important aspects in rice production is the ability of the existing irrigation system to provide required water supply to the paddy fields. For this purpose the tertiary canal and on farm structures and water delivery and management system obviously play very important role in providing water supply to the paddy fields.

1.3 Statement of Problem

The problems encountered in the scheme with regard to existing tertiary canal and field infrastructure are related to original design of structures inclusive of concrete conduit canals, field offtakes, check structures and field drainage outlet control structures to meet new water delivery requirement for different modes of irrigation supply as demanded by farmers.

The conveyance capacity of the concrete conduit is not large enough to meet faster presaturation for direct seeding practices that require faster presaturation period and farmers' demand for presaturation for individual paddy lot of less than three days. If presaturation is made simultaneously, the whole tertiary canal, the canals need to be reconstructed and enlarge to meet the requirement.

Reconstruction and enlargement of the existing canal will require a heavy investment cost from the government. Other problems of the existing tertiary concrete conduit canals are related to the settlement of canal stump that caused the uneven level of the conduit and the leaking of the conduit. Long tertiary canal up to seven kilometre covering number paddy lots up to 230 lots caused the difficulty in delivering water timely, equitably and adequately to the whole canal length for different modes delivery.

The existing field offtake pipe is made of uncontrolled 50 mm diameter steel pipes to each farm lot. This field offtake pipe gives different discharge due to the available head fluctuations and various discrepancies. On top of that, settlement of canal stump caused the other discrepancy to field offtake delivery rate. As the flow capacity of the offtake pipes is insufficient to meet peak presaturation water requirement, the use of siphon was later suggested and practiced by the farmers. The problems are related to the utilization of plastic siphons for field off-take, without proper flow control and accurate flow measurement. Indiscriminate use of siphon caused the over taping of water by farmers resulting in inequitable, inadequate and unreliable of water delivery to the individual farmers, especially to tail end users.

The existing check structures have failed to function appropriately to control water level in the tertiary canal. Tertiary canal system must ensure certain water level in the canal for the offtake gate to deliver the required amount into the field. The distance between checks is too far to provide the required water level in the canal. As the distance between checks is too far, the provision of slot was suggested to suitably control water level along the canal. The field drainage outlet control structure is made of concrete box opening with groove provided to insert wooden drop board to control water level in the paddy field. The problem with this structure is the leakage through the drop board and the step-wise control height depending on the width of the drop board, making it difficult to obtain precise water level as desired.

With regards to water delivery management for different irrigation requirement, several problems with the current land preparation practices require the presaturation for each individual lot to complete within 2 or 3 days. During the second flooding, a large amount of water is required in a short time, while during crop growth stages, smaller water delivery is required continuously or intermittently to meet crop consumption and water losses in paddy field. Hence, the field offtake certain degree of flexibility in it to deliver the required flow rate for different water delivery modes in rice irrigation supply and to function at different hydraulic conditions in tertiary canal.

Presently, in order to make best use of the present conduit, rotational irrigation was introduced together with the use of siphon to replace the existing field offtake pipe to meet peak presaturation water requirement caused over taping of water by farmers, fluctuation of water level in the conduit canal and run off flow of water from the drainage system. These problems caused waste of water, effect the water use efficiency, pollution of drainage system due to the flow of chemicals and water delivery service quality in term of reliability, adequacy and equity to the individual farmers.

Water level in the tertiary canal is also depending on the distance of the offtake upstream of the water level control structures as the structures function as a weir. The longer the canal, the more the number of off-takes, then more effort is required to properly manage the water flows and ensure in particular that the tail-enders is receiving a fair share. Provision of good flow control and measurement for off-takes and water level control structures of the tertiary canal will reduce the demand for canal operation related to perturbations.

Water level control in the paddy fields is important to provide uniform water depth in the paddy field, to capture and store water in the fields and to prevent run off flow of water and chemicals from the field to the drainage system. Current practice of controlling standing water depth in the paddy fields by the height control of drainage outlet caused low water use efficiency due to continuous flow of water. The problem with the tertiary canal supply is that the current structure is unable to provide the required flow control and precise flow measurement to meet field requirement accurately. Intermittent irrigation requires regular adjustment to open and close the field offtake by farmers and caused frequent water level fluctuation in tertiary canal water level.

As to overcome these problems, this study proposed development of three new on-farm structures and water delivery management model. Three structures in the tertiary irrigation canal and on-farm levels which were developed and evaluated in this study are: (1) field offtake to deliver water from tertiary canal to paddy fields; (2) tertiary canal water level regulator or check structure and (3) field drainage outlet control structure. Automated float type flow control valve structure is the attachment to the field offtake to provide automated water delivery control of the field offtake. Water delivery management model was developed for four modes of irrigation supply, viz. presaturation, second flooding, crop growth stage water delivery, and the termination of irrigation.

1.4 Research Questions

This research seeks to address the issue of improving water delivery management for tertiary canal and on farm for commercial rice production in canal irrigation system operated by individual farmers. The study has addressed these questions:

a. What is the most suitable water control management in tertiary canal and the paddy field and how to achieve it?

b. How to set, control and maintain the water level in the tertiary canal for different flow rates and different field requirements?

c. What are the physical and operational improvements required to the tertiary canal offtake to improve water delivery?

d. How to manage and operate tertiary canal offtake to control and measure flow rate for different flow rates to meet different rice water requirements and fluctuations of water level in the main and secondary canal?

e. How to manage tertiary canal water management and irrigation scheduling to deliver water to the paddy field for different stages of irrigation supply for rice cultivation?

f. What flexible water management model can ensure equitable water distribution in on-farm irrigation water management?

g. What is the suitable flow measurement flow control equipment for water delivery from tertiary canal to the field?

h. What are the structures required to improve water management and water delivery for tertiary canal and on farm for modern commercial rice cultivation?

1.5 Aims and Objectives

The aim of the study was to develop on-farm structures and water delivery management model to improve rice irrigation practices.

The specific objectives are as follows;

i. To design and evaluate laboratory performance of the flexible field offtake structure and float type automated flow control structure

ii. To evaluate field performance of the developed on farm structures in tertiary canal.

iii. To develop a new water delivery management model for rice tertiary irrigation canal utilizing the developed structures and evaluate the performance of the new model and structures in the pilot study area.

1.6 Scopes and Limitations

The Scopes of the study covered the following activities:

i. Laboratory testing in NAHRIM Hydraulics and Instrumentation Laboratory covered the calibration of 150 mm diameter orifice type field offtake for different water level, pipe length and pipe end and the functionality of automated float control flow valve system.

ii. Field applications of field offtake were conducted at lot no 3117 and 3137 in TASS 7 for 20 days duration from 1st September to 20th September 2013 during supplementary irrigation supply.

iii. Field applications of field offtake with automated float type flow control valve were conducted at lot no. 3121 and 3125 in Taliair Sawah Sempadan no 7 (TASS 7) for 20 days duration from 1st September to 20th September 2013 during supplementary irrigation supply.

iv. Field water delivery management for presaturation, second flooding and crop growth stage for the first 28 days of water delivery from 1st July to 28th July 2013 (Second Season 2013) for TASS 7 and TASS 8 Pilot Project Area.

v. Field water delivery monitoring for crop growth stage from week 10th to week 13th (Third month (September 2013) TASS 7 and TASS 8 of the Pilot Project Area, and TASS 9 and TASS 10 outside the Pilot Project Area for comparison.

vi. Tertiary canal flow calibration for the functionality and operational management procedures for flat gate regulator, flexible field offtake and tertiary canal offtake in first 1000 meter of the TASS 7 tertiary canal.

vii. Water level in the canal was observed by the use of electronic sensor. Flow rate was measured using PCM 4 flow rate and water depth measurement.

viii. Water level in canals referred to an assumed datum, properly surveyed by private surveyors.

Due to the financial, time and other resources constraints, there are several limitations associated with this study as described below:

i. As the tertiary canal levels and sizes in the scheme may differ from one another, the calibration made and the results obtained during the field testing may not be similar for other tertiary canals. Every tertiary needs to be assessed separately.

ii. Due to time and resources limitation, the data were only observed for the Second Season 2013 and during the limited time of the season, not throughout the whole season.

iii. Several data observed were based on the real time reading from the telemetry system. There was the possibility of the gate setting being disturbed by the land owner, although they were advised not to do so.

1.7 Thesis Organization

This thesis comprises of six chapters through which the reports of the study are compiled. Chapter one gives a broad background of the study and highlights (i) the importance of the study, (ii) the statement of problem, (iii) the research questions, (iv) Aim and objectives, and (v) the scope and limitations of the study (iv) thesis organization.

Chapter two explore the literature related to this study to determine what has been done so far in this problem area. The review unfold the problems that lead to this study, though there were not too many literature in this area until recently but the arguments are worthy of further study.

Chapter three discusses the design and fabrication of tertiary canal offtakes and on-farm structures. The design and fabrication of the offtake flexi-gate are described and evaluation of the structure is reported.

Chapter four is concerned with the testing for field applicability of the developed structures at the tertiary canal, Taliar Sawah Sempadan Number 7 (TASS 7), Sawah Sempadan Compartment, and Tanjung Karang irrigation scheme. The technique used and results obtained are described.

Chapter five deals with the development of water delivery management model followed with evaluation of its performance for field application in the pilot project. The technique used and results obtained are described in detail.

Chapter six provides the conclusions and recommendations for the future research related to this study.

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