

**INTEGRATED WATER RESOURCE
ASSESSMENT OF IRRIGATION SYSTEM
OF HARYANA**

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**DEPARTMENT OF CIVIL ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY DELHI
MAY 2018**

INTEGRATED WATER RESOURCE ASSESSMENT OF IRRIGATION SYSTEM OF HARYANA

by

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Submitted In fulfillment of the requirements for the degree of Doctor of Philosophy

to the



INDIAN INSTITUTE OF TECHNOLOGY DELHI

MAY 2018

In loving memory of

“My parents”

who inspired me to fight against all odds.

CERTIFICATE

This is to certify that the thesis, entitled “**Integrated Water Resource Assessment of Irrigation System of Haryana**”, being submitted by **Mr. Shiv Singh Rawat** to the Indian Institute of Technology, Delhi for the award of **Doctor of Philosophy** is a record of bonafide research work carried out by him under my supervision. He has worked under my guidance and supervision and has fulfilled the requirements for the submission of his thesis, which has attained the standard required for a Ph.D. degree from the Indian Institute of Technology, Delhi. The results presented in this thesis have not been submitted, in part or in full, to any other University or Institute, for the award of any degree or diploma.

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ACKNOWLEDGEMENTS

I would like to express my deepest sense of gratitude to my supervisor, Dr. A.K. Gosain, Department of Civil Engineering, Indian Institute of Technology, Delhi for his continuous guidance, encouragement, motivation and efficient supervision during the course of this research work. I really thank him for guiding me to conduct my Ph.D. research in a challenging field of integrating the man made canal system modeling with the natural system hydrological modeling of the natural system in the catchment of the Yamuna river.

A special thanks goes to Prof. Rakesh Khosa and Mr. Sankalp Lahiri, a research fellow at IIT Delhi for their valuable suggestions, comments and discussions to improve the quality of my research work. I wish to extend my sincere thanks to all faculty members and the staff of the Civil Engineering Department, IIT, Delhi, especially Mr. Rajeev Aggarwal for their all types of support, cooperation and encouragement.

I am also thankful to eWater of Australia for giving me an opportunity to work on their Source Platform for hydrological modeling and crop modeling. I am also thankful to the officers and officials of Irrigation and Water Resources Department, Haryana for their continuous support and cooperation.

This acknowledgement shall remain incomplete unless I thank my wife and my twin sons for their patience, love, care and constant encouragement. My Wife has spent the best and the worst time with me but her love, moral support and care has made it possible to complete my Ph.D. work.

Last, but not the least, I am thankful to my friends, colleagues and everyone who helped me directly or indirectly in completing my research work.

(Shiv Singh Rawat)

ABSTRACT

Haryana is agriculture based State and majority of water resources are consumed by the agriculture sector. There is limited water availability as compared to the crop water demand in the state. There is large gap between demand and supply of water resources of Haryana. There is non-judicious, indiscriminate and excess utilization of surface water for irrigation which causes water logging, seepage and soil salinity. On the other hand, there is over exploitation of ground water that causes depletion of water table and deterioration of quality of water. More than sixty percent of the blocks of Haryana have been declared as dark zone. Further, the water use efficiency of canal system of the state is low. Also, the state does not have any perennial river. Haryana receives water mainly from Yamuna River and also from Bhakra system. But, there are low flows in the Yamuna during non rainy season and it is matter of concern for aquatic life.

As irrigated agriculture is the major activity in the study area and large volume of water is required to meet the irrigation demands of the crops grown in the study area. Hence, it is imperative to assess the water resources of the state. The present research has been taken to look into the problem and to focus on integrated assessment of the water resources for the study area to tackle the demand side issues as well.

Snow melt, glaciers melt and rainfall mainly contribute water in the catchment of Yamuna River which in turn supplies water to the study area of Haryana. Therefore, hydrological modeling (snow and rainfall runoff) approach has been used to assess sources of water in the Yamuna river catchment. GR4JSG, a snow model and GR4J, a rainfall runoff model have been conceptualized and then set up. The models have been run to assess the flows. These models have been properly calibrated and

validated. The calibration period is from year 1995-2005 including warm up period of one year and validation period is from year 2006-2013. The modeled flows at Hathnikund Barrage, the diversion point on Yamuna, have been supplied to the manmade canal system of Haryana. The diverted water is used to meet the crop water demands generated by Irrigator canal model for the study area. The Irrigator canal model of Source platform has been used for each district to assess the district wise crop demands in the study area. The water balance and Irrigation system efficiency have been worked out for each district of Haryana.

The results of modeled flow at Tuini (P), Yashwant Nagar, Bausan, Haripur, Poanta and HKB sites were compared with the observed flows at these six CWC sites. The objective functions of NSE Daily and log Flow duration was found between 0.69 to 0.85 for calibration period and between 0.60 to 0.73 for validation period. Finally, the model has been validated at Mathura, the outlet of the study area. The value of the objective function NSE Daily and log Flow duration comes out to be 0.54 at Mathura. The values of the objective function of NSE Daily and log Flow duration obtained are fairly good values. It proves that both the snow model GR4JSG and rainfall runoff model GR4J have been successfully set up and also performed well in the Yamuna catchment of the study area.

The maximum value of modeled flow at HKB is 11660 cumecs and the minimum modeled value is 40 cumecs for the period 1995 to 2013. The peak flows have been underestimated particularly at Poanta and HKB stations which are on lower elevations. The maximum snow cover predicted by the model is 2054 Km² (18%) during February, 2002 for calibration period and 1142 Km² (10%) during January 2011 for validation period against the corresponding values of MODIS snow area of

6078 Km² and 5512 Km². However, the model underestimates the snow cover in comparison to MODIS snow cover.

The results of Irrigator canal demand model have proved that all the Districts in Haryana have proper water balance. The model results have shown that all the inflows, outflows and the utilizations of water have been properly balanced for each district. The results have shown that the Irrigation system efficiency of districts varies from 27 to 59 %. The overall Irrigation system efficiency for Haryana canal system has been calculated as 39%. This is low value and it indicates that excess water is being extracted to meet the water demands. From these findings many conclusions have been drawn and recommendations have been made for further research in the study area.

KEY WORDS: Hydrological modeling, GR4JSG model, GR4J model, MODIS snow cover, Irrigator canal model, eWater Source, water balance, water use efficiency and Irrigation system efficiency.

सार

हरियाणा कृषि आधारित राज्य है और कृषि क्षेत्र द्वारा जल संसाधनों का उपयोग किया जाता है। राज्य में फसल जल की मांग के मुकाबले पानी की उपलब्धता सीमित है। हरियाणा में जल संसाधनों की मांग और आपूर्ति के बीच बड़ा अंतर है। सिंचाई के लिए सतही जल के गैर-न्यायिक, अंधाधुंध और अधिक उपयोग से जल जमाव, सीपेज और मिट्टी की लवणता होती है। दूसरी तरफ, भूजल का अधिक शोषण होने से जल स्तर में कमी आती है और पानी की गुणवत्ता में गिरावट होती है। हरियाणा के 60 प्रतिशत से अधिक ब्लॉक अंधेरे क्षेत्र के रूप में घोषित किए गए हैं। इसके अलावा राज्य की नहर प्रणाली की जल उपयोग दक्षता कम है। इसके अलावा, राज्य में कोई बारहमासी नदी नहीं है। हरियाणा मुख्य रूप से यमुना नदी से और भाखड़ा प्रणाली से पानी प्राप्त करता है। लेकिन, शुष्क ऋतु में यमुना में कम प्रवाह होता है और यह जलीय जीवन के लिए चिंता का विषय है।

जैसा कि सिंचित कृषि अध्ययन क्षेत्र में प्रमुख गतिविधि है और अध्ययन क्षेत्र में उगाई गई फसलों की सिंचाई मांगों को पूरा करने के लिए पानी की बड़ी मात्रा की आवश्यकता होती है। इसलिए, राज्य के जल संसाधनों का आकलन करना जरूरी है। वर्तमान शोध को समस्या को समझने के लिए लिया गया है और मांग पक्ष के मुद्दों से निपटने के लिए अध्ययन क्षेत्र के लिए जल संसाधनों के एकीकृत मूल्यांकन पर ध्यान केंद्रित किया गया है।

बर्फ पिघलाव, हिमनदी पिघलाव और बारिश मुख्य रूप से यमुना नदी के जलागम क्षेत्र में पानी का योगदान करती है जो बदले में हरियाणा के अध्ययन क्षेत्र में पानी की आपूर्ति करती है। इसलिए यमुना नदी जलागम क्षेत्र में पानी के स्रोतों का आकलन करने के लिए जलविज्ञान मॉडलिंग (बर्फ और बारिश के बहाव) का उपयोग किया गया है। जीआर 4 जेएसजी, एक बर्फ मॉडल और जीआर 4 जे, एक वर्षा रनऑफ मॉडल को संकल्पनाबद्ध किया गया है और फिर स्थापित किया गया है। प्रवाह का आकलन करने के लिए मॉडल चलाए गए हैं। इन मॉडलों की उचित ढंग से अंशांकन (कैलिब्रेट) और पुष्टि (वैलिडेट) की गई है। अंशांकन अवधि वर्ष 1995-2005 है जिससे एक वर्ष की गर्म अवधि (वार्मअप) है। और वर्ष 2006-2013 से सत्यापन अवधि है। मॉडल से प्राप्त प्रवाह को हथनीकुंड बैराज से, जो कि यमुना पर मोड बिन्दु है, हरियाणा की मानव निर्मित नहर प्रणाली की आपूर्ति की गई है। इस पानी का उपयोग अध्ययन क्षेत्र में इरिगेटर नहर मॉडल द्वारा उत्पन्न फसल जल मांगों को पूरा करने के लिए किया जाता है। सोर्स प्लेटफार्म के इरिगेटर नहर मॉडल का उपयोग अध्ययन क्षेत्र में

जिलावार फसल मांगों का आकलन करने के लिए किया गया है। हरियाणा के प्रत्येक जिले के लिए जल संतुलन और सिंचाई प्रणाली दक्षता की गणना की गई है।

ट्यूनी (पी), यशवंत नगर, बोसन, हरिपुर, पोंटा और एचकेबी साइटों पर मॉडलिंग से प्राप्त प्रवाह के परिणामों की इन साइटों पर अवलोकित प्रवाहों के साथ तुलना की गई है। एनएसई दैनिक और लॉग प्रवाह अवधि, जो कि उद्देश्य फलन है, वह अंशांकन अवधि के लिए 0.69 से 0.85 के बीच और सत्यापन अवधि के लिए 0.60 से 0.73 के बीच पाया गया है। अंत में, मॉडल को अध्ययन क्षेत्र के आउटलेट मथुरा पर सत्यापित किया गया है। मथुरा पर उद्देश्य फलन एनएसई दैनिक और लॉग प्रवाह अवधि का मूल्य 0.54 आया है। प्राप्त एनएसई दैनिक और लॉग प्रवाह अवधि के उद्देश्य फलन के मूल्य काफी अच्छे हैं। यह साबित करता है कि बर्फ मॉडल जीआर 4 जेएसजी और वर्षा रनऑफ मॉडल जीआर 4 जे दोनों सफलतापूर्वक स्थापित किए गए हैं और अध्ययन क्षेत्र के यमुना जलागम क्षेत्र में अच्छा प्रदर्शन किया है।

एचकेबी पर वर्ष 1995 से 2013 तक मॉडलिंग प्रवाह का अधिकतम मूल्य 11660 Cumecs है और न्यूनतम मूल्य 40 Cumecs पाया गया है। मॉडल द्वारा शिखर प्रवाह का कम आकलन किया गया है। खासकर पोंटा और एचकेबी स्टेशनों पर, जो कि कम ऊंचाई पर हैं, मॉडल द्वारा अधिकतम बर्फ कवर, फरवरी, 2002 के दौरान अंशांकन अवधि के लिए 2054 वर्ग किलोमीटर (18%) और सत्यापन अवधि के लिए जनवरी 2011 में 1142 वर्ग किलोमीटर (10%) आका गया है। जबकि इसी अवधि के लिए मोडिस कवर 6078 वर्ग किलोमीटर और 5512 वर्ग किलोमीटर है। हालांकि, मोडिस बर्फ कवर की तुलना में मॉडल ने बर्फ कवर को कम करके आंका है।

इरिगेटर नहर मांग मॉडल के नतीजों से साबित हुआ है कि हरियाणा के सभी जिलों में उचित जल संतुलन है। मॉडल के नतीजों से पता चला है कि प्रत्येक जिले के लिए सभी अंतर्वाह, बहिर्वाह और पानी के उपयोग ठीक से संतुलित किए गए हैं। नतीजे बताते हैं कि जिलों की सिंचाई प्रणाली दक्षता 27 से 59% तक है। हरियाणा नहर प्रणाली के लिए समग्र सिंचाई प्रणाली दक्षता की गणना 39% की गई है। यह कम मूल्य है और यह इंगित करता है कि पानी की मांगों को पूरा करने के लिए अतिरिक्त पानी निकाला जा रहा है। इन जांच परिणामों से कई निष्कर्ष निकाले गए हैं और अध्ययन क्षेत्र में आगे के शोध के लिए सिफारिशें की गई हैं।

मुख्य शब्द: जल विज्ञान मॉडलिंग, जीआर 4 जेएसजी मॉडल, जीआर 4 जे मॉडल, मोडिस बर्फ कवर, इरिगेटर नहर मॉडल, ईवाटर सोर्स, जल संतुलन, जल उपयोग दक्षता और सिंचाई प्रणाली दक्षता।

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ABBREVIATIONS

amsl	=	Above mean sea level
BCM	=	Billion cubic meter
CCA	=	Cultivable Command Area
cm	=	Centimeter
Cumecs	=	Cubic meter per second
Cusecs	=	Cubic feet per second
CWC	=	Central Water Commission
°C	=	Degree centigrade
E flow	=	Environmental flow
GW	=	Ground water
GIS	=	Geo information system
HKB	=	Hathnikund barrage
JLN	=	Jawahar Lal Nehru
Km	=	Kilometer
Km ²	=	Square kilometer
m	=	Meters
MAF	=	Million Acre feet
Mha	=	Million hectare
ML	=	Megalitres
mm	=	Millimeter
MODIS	=	Moderate Resolution Imaging Spectroradiometer
NWM	=	National water mission
RD	=	Reduced distance
WJC	=	Western Jamuna Canal
WUE	=	Water use efficiency