ECO-HYDROLOGICAL AND ECO-HYDRODYNAMIC STUDY FOR THE RESTORATION OF LOKTAK LAKE IN MANIPUR, NORTHEAST INDIA

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by

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Submitted

in fulfilment of the requirements of the degree of Doctor of Philosophy

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CERTIFICATE

This is to certify that the thesis entitled "**Eco-hydrological and eco-hydrodynamic study for the restoration of Loktak Lake in Manipur, Northeast India**" being submitted by **Ms. Khwairakpam Eliza** to the Indian Institute of Technology Delhi for the award of the degree of Doctor of Philosophy is a bonafide record of research work carried out by her under our supervision and guidance. The thesis work, in our opinion, has reached the requisite standard fulfilling the requirements for the degree of **Doctor of Philosophy**. The results contained in this thesis have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.

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Abstract

Loktak Lake is an internationally important, Ramsar designated, fresh water wetland system in the state of Manipur, India. The lake has also been listed under Montreux Record on account of the ecological modifications that the lake system has witnessed over time. During the recent decades, there have been various issues concerning the lake which include decrease in water holding capacity, deteriorating condition of Phumdis, prolific growth of Phumdis, deterioration of water quality, decrease in fish diversity and productivity, inundation of agricultural land and peripheral settlements, degradation of habitat for Sangai deer. The maintenance of high water level of the lake throughout the year after the construction of Loktak hydropower project has high impact on the ecology of the lake. This research presents a framework for restoring the ecological condition of the Loktak Lake. The framework is presented in two parts; the first part deals with habitat suitability analysis of a fish species. In this part, a target fish species was identified, and habitat suitability was analysed based on water quality. In the second part of the framework, a management approach for a floating vegetation mass, Keibul Lamjao National Park (KLNP) is presented based on water quantity. In this research, various physically based models such as Soil and Water Assessment Tool (SWAT), MIKE SHE, MIKE 11 HD, MIKE 11 ECO Lab, MIKE 21 HD and MIKE 21 ECO Lab modelling platforms were used. Habitat suitability of Pengba fish species in Loktak Lake and the nine rivers draining into the lake was analysed and it predicted different zones, namely least suitable, less suitable, moderately suitable, suitable and most suitable. For the second part, a comprehensive framework for management approach for KLNP has been framed. The management approach was designed by simulating mean monthly water balance of the Loktak Lake without compromising water level demand for hydropower generation. The management approach of KLNP considered the variation of water level suitable for Sangai deer and prevention of inundation of surrounding areas.

सार

लोकटक झील, अंतर्राष्ट्रीय महत्त्व की रामसर नामित मीठे पानी वाली आर्द्रभूमि प्रणाली है। झील में समय के साथ हुए पारिस्थितिक परिवर्तनों के कारण इसे मॉन्ट्रो रिकॉर्ड के तहत सूचीबद्ध किया गया है। हाल के दशकों के दौरान झील के विषय में कई मुद्दे सामने आए हैं जिनमें जल धारण क्षमता में कमी, फुमदी की बिगड़ती स्थिति, फुमदी की अति- वृद्धि, जल की गुणवत्ता में गिरावट, मछली की विविधता में कमी और उत्पादकता, कृषि भूमि और परिधि क्षेत्रों में मानव बस्तियों में अति वृद्धि शामिल हैं जिसके कारण संगाई हिरन के पर्यावास में गिरावट आई है. लोकटक जल विद्युत परियोजना हेतु पूरे वर्ष झील के उच्च जल स्तर रखरखाव झील की पारिस्थितिकी पर व्यापक असर डालता है। यह शोध लोकटक झील की मूल पारिस्थितिक स्थिति को बहाल करने के लिए एक रूपरेखा प्रस्तुत करता है। यह शोध दो भागों में प्रस्तुत किया गया है । पहला भाग मछली प्रजातियों के पर्यावास उपयुक्तता विश्लेषण से संबंधित है जिसमें एक मछली प्रजाति को लक्षित करके पानी की गुणवत्ता के आधार पर आवास की उपयुक्तता का विश्लेषण किया गया था। दूसरे भाग में केइबुल लामजाओ नेशनल पार्क (केएलएनपी) में पानी की मात्रा के आधार पर चलायमान वनस्पति के द्रव्यमान के लिए एक प्रबंधन दृष्टिकोण प्रस्तुत किया गया है। इस शोध में विभिन्न भौतिकी आधारित मॉडल जैसे मृदा और जल मूल्यांकन उपकरण (SWAT), MIKE SHE, MIKE 11 HD, MIKE 11 ECO Lab, MIKE 21 HD और MIKE 21 ECO Lab आदि का उपयोग किया गया। लोकटक झील में पेंगबा मछली की पर्यावास उपयुक्तता और झील में गिरने वाली नौ नदियों का विश्लेषण किया गया और इसमें विभिन्न श्रेणियों जैसे कम से कम उपयुक्त, कम उपयुक्त, मध्यम उपयुक्त, उपयुक्त और उत्तम की भविष्यवाणी की गई है। दूसरे भाग के लिए केएलएनपी के लिए प्रबंधन दृष्टिकोण के लिए एक व्यापक रूपरेखा तैयार की गई है। जलविद्युत उत्पादन के लिए जल स्तर की मांग से समझौता किए बिना लोकतक झील के औसत मासिक जल संतुलन का प्रबंधन करके प्रबंधन दृष्टिकोण तैयार किया गया था। प्रबंधन दृष्टिकोण में केएलएनपी में संगाई हिरण हेतु उपयुक्त जल स्तर भिन्नता और आसपास के क्षेत्रों में जलप्लावन रोकथाम पर विचार किया गया।

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Nomenclature

BOD	Biochemical Oxygen Demand
BGL	Below Ground Level
COD	Chemical Oxygen Demand
CPCB	Central Pollution Control Board
CGWB	Central Ground Water Board
DEM	Digital Elevation Model
DO	Dissolved Oxygen
EFDC	Environmental Fluid Dynamics Code
ENVIS	Environmental Information System
FC	Fecal Coliform
FD	Forest Department, Government of Manipur
FSI	Forest Survey of India
FVCOM	Finite-Volume Community Ocean Model
GIS	Geographic Information System
GoI	Government of India
GoM	Government of Manipur
Hybrid SHE-SWAT	Combination of MIKE SHE and SWAT
HD	Hydrodynamic
HRU	Hydrological response units
ICAR	Indian Council of Agricultural Research
IB	Ithai Barrage
IBP	Imphal Barrage Project
IFCD	Irrigation and Flood Control Department
IMD	Indian Meteorological Department
KLNP	Keibul Lamjao National Park
LAI	Leaf Area Index
LDA	Loktak Development Authority
LLI	Loktak Lift Irrigation
M	Manning's Coefficient
MAE	Mean Absolute Error
MDL	Minimum Drawdown Level
MODIS	Moderate Resolution Imaging Spectroradiometer
NBSS and LUP	National Bureau of Soil Survey and Land Use Planning
NHPC	National Hydroelectric Power Corporation, Government of Manipur
NOAA	National Oceanic and Atmospheric Administration
NSE	Nash–Sutcliffe Coefficient

PWD	Public Work Department, Government of Manipur
QUASAR	Quality Simulation Along Rivers
R	Pearson coefficient
R^2	Coefficient of determination
RMSE	Root Mean Square Error
RKQC	Runge-Kutta with Quality Control
RMSE	Root mean square error
SPCB	State Pollution Control Board
SDWRML	Sustainable Development and Water Resources Management of Loktak Lake
SPCB	State Pollution Control Board, Government of Manipur
SRTM	Shuttle Radar Topography Mission
SWAT	Soil and Water Assessment Tool
TSS	Total Suspended Solid
USGS	United States Geological Survey
UNESCO	United Nations Educational, Scientific and Cultural Organization
UZ	Unsaturated Zone
WAPCOS	Water and Power Consultancy Services (India) Limited
WISA	Wetland International South Asia