

NUMERICAL MODELING OF RESERVOIR SEDIMENTATION AND DESILTATION TECHNIQUES

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NUMERICAL MODELING OF RESERVOIR SEDIMENTATION AND DESILTATION TECHNIQUES

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CERTIFICATE

This is to certify that the thesis entitled, “**NUMERICAL MODELING OF RESERVOIR SEDIMENTATION AND DESILTATION TECHNIQUES**” being submitted by **Suman Kilania** to the Indian Institute of Technology, Delhi, India, for the award of the degree of DOCTOR OF PHILOSOPHY, is a record of bona fide research work carried out by her under our supervision and guidance. This thesis work, in our opinion, has reached the standard, fulfilling the requirement of DOCTOR OF PHILOSOPHY degree. The research report and the result 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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ABSTRACT

As Rivers flow into reservoirs, part of the transported sediment gets deposited. Sedimentation in the reservoir may significantly reduce reservoir gross capacity as well as live capacity. Reservoir capacity can be recovered by removing deposited sediment by dredging or flushing. An accurate estimation of sedimentation volume and its removal are required for the development of a long-term operation plan in the design stage. If it is not maintained, sediments can reach the water outlets and thus, cause severe wear damage to the turbines.

The two case studies have been taken of RoR hydroelectric projects, first is of River Satluj (Kol Dam HEP) for first two objectives of research and second is of River Mandakini (Singoli Bhatwari HEP) for all present research's objectives.

The Sedimentation and Reservoir desiltation by numerical modeling have been proposed in this research. Sediment transport and reservoir desiltation or flushing have been studied by using three complementary procedures: one-dimensional simulations for time required for sediment level reaches up to invert level of bottom outlets of dam, two-dimensional simulations for reservoir desiltation or flushing and lateral movement of sediments, and three-dimensional simulations for vertical distribution of sediment near dam or barrage and detail of the sediment transport through bottom outlets.

Further, to keep the power intakes free of sediment and to ascertain the suitability of the hydraulic desiltation provision for improvement in reservoir performance using numerical modeling.

The focus of the present research is to minimise sediment deposition and increase the recover volume in the reservoir. The sediment inflow from watershed area has been considered based

on sediment rating curve generated from available inputs of sediment concentration and River discharge at gauge and discharge sites.

To perform the numerical modeling, HEC RAS 1-Dimensional, HEC RAS 2- Dimensional and FLOW 3-Dimensional HYDRO softwares are used. 1-Dimensional and 2- Dimensional HEC RAS models have been prepared for reservoir sedimentation and flushing simulations. It has the capabilities of simulating unsteady flow and coexistence of River and Reservoir regimes in the study area.

Flow 3-Dimensional Hydro is a powerful computational fluid dynamics tool that provide a detailed and high-resolution analysis of fluid flow characteristics, velocity distribution, pressure variations, turbulence patterns and sediment transport.

1-Dimensional, 2-Dimensional and 3-Dimensional numerical models have been prepared, calibrated and validated with the respective data received from project authorities and central water commission (Government agency). The reservoir operation plans have been formulated based on results of numerical models.

The live capacity of the RoR Hydroelectric project on River Mandakini (Singoli Bhatwari HEP) is very less (0.433 MCM) so it is great challenge to keep intake flow free from sediment which is further harmful for turbine underwater parts. The present research shows that reservoir itself with intermittent hydraulic desiltation techniques is efficient for sediment management. The reservoir operation plans as prepared in this research, will be quite beneficial for project authority to reduce cost of protective coating of turbine underwater parts and enhance power generation.

Keywords: Reservoir Sedimentation, Numerical Models, Sediment Rating Curve, Desiltation, Flushing

सारांश

जब नदियाँ जलाशयों में बहती हैं, तो परिवहित अवसाद का एक हिस्सा जमा हो जाता है। जलाशय में अवसादन जलाशय की कुल क्षमता और उपयोगी क्षमता को महत्वपूर्ण रूप से कम कर सकता है। जलाशय की क्षमता को जमा हुए अवसाद को खोदने या धुलाई के द्वारा बहाल किया जा सकता है। डिज़ाइन चरण में दीर्घकालिक संचालन योजना के विकास के लिए अवसादन मात्रा का सटीक अनुमान और उसके निष्कासन की आवश्यकता होती है। यदि इसका रखरखाव नहीं किया गया, तो अवसाद जल आउटलेट तक पहुँच सकते हैं और इस प्रकार, टरबाइनों को गंभीर घिसाव क्षति का कारण बन सकते हैं। वर्तमान अनुसंधान के लिए दो मामले अध्ययन रोआर जलविद्युत परियोजनाओं के लिए लिए गए हैं, पहली सतलुज नदी (कोल डैम एचईपी) की है जो शोध के पहले दो उद्देश्यों के लिए है और दूसरी मंदाकिनी नदी (सिंगोली भटवारी एचईपी) की है जो सभी वर्तमान शोध के उद्देश्यों के लिए है।

इस शोध में संख्यात्मक मॉडलिंग द्वारा खाद्यान्न और जलाशय की सिल्ट हटाने का प्रस्ताव किया गया है। खाद्यान्न परिवहन और जलाशय की सिल्ट हटाने या फ्लशिंग का अध्ययन तीन पूरक प्रक्रियाओं का उपयोग करके किया गया है: एक-आयामी सिमुलेशन जो खाद्यान्न स्तर के डैम के निचले आउटलेट के उलट स्तर तक पहुंचने में समय आवश्यक है, जलाशय की सिल्ट हटाने या फ्लशिंग और खाद्यान्नों की पार्श्व गति के लिए दो-आयामी सिमुलेशन, और डैम या बैराज के निकट खाद्यान्न के ऊर्ध्वाधर वितरण और निचले आउटलेट के माध्यम से खाद्यान्न परिवहन का विवरण देने के लिए तीन-आयामी सिमुलेशन।

इसके अलावा, पावर इंटेक को अवशेषों से मुक्त रखने के लिए और जलाशय के प्रदर्शन में सुधार के लिए हाइड्रोलिक डीसिल्टेशन प्रावधान की उपयुक्तता की पुष्टि करने के लिए संख्यात्मक मॉडलिंग का उपयोग किया जाएगा।

वर्तमान अनुसंधान का ध्यान तलछट जमाव को कम करने और रिजर्वॉयर में पुनर्प्राप्ति मात्रा बढ़ाने पर है। जल निकासी क्षेत्र से आने वाली तलछट को उपलब्ध तलछट सांद्रता और गेज और जल निकासी स्थलों पर नदी के प्रवाह के इनपुट से उत्पन्न तलछट रेटिंग वक्र के आधार पर माना गया है।

संख्यात्मक मॉडलिंग करने के लिए, HEC RAS 1-आयामी, HEC RAS 2-आयामी और FLOW 3-आयामी हाइड्रो सॉफ्टवेयर का उपयोग किया जाता है। जलाशय अवसादन और फ्लशिंग सिमुलेशन के लिए 1-आयामी और 2-आयामी HEC RAS मॉडल तैयार किए गए हैं। इसमें अस्थिर प्रवाह और अध्ययन क्षेत्र में नदी और जलाशय के शासन की सह-अस्तित्व का सिमुलेशन करने की क्षमता है।

फ्लो 3-डायमेंशनल हाइड्रो एक शक्तिशाली संगणकीय तरल गतिकी उपकरण है जो तरल प्रवाह के गुणों, वेग वितरण, दबाव परिवर्तन, तूफान पैटर्न और तलछट परिवहन का विस्तृत और उच्च-रिज़ॉल्यूशन विश्लेषण प्रदान करता है।

1-आयामी, 2-आयामी और 3-आयामी संख्यात्मक मॉडल तैयार किए गए हैं, उन्हें परियोजना अधिकारियों और केंद्रीय जल आयोग (सरकारी एजेंसी) से प्राप्त डेटा के साथ कैलिब्रेट और मान्यता प्राप्त की गई है। जलाशय संचालन योजनाएँ संख्यात्मक मॉडलों के परिणामों के आधार पर तैयार की गई हैं।

मंदाकिनी नदी पर स्थित RoR जलविद्युत परियोजना (सिंगोली भटवारी HEP) की जीवित क्षमता बहुत कम है (0.433 MCM) इसलिए प्रवाह को अवशिष्ट मुक्त रखना एक बड़ी चुनौती है जो कि टरबाइन के पानी के नीचे के भागों के लिए हानिकारक है। वर्तमान शोध से पता चलता है कि अंतर्विभाज्य हाइड्रोलिक डीसिल्टेशन तकनीकों के साथ जलाशय स्वयं अवशिष्ट प्रबंधन के लिए प्रभावी है। इस शोध में तैयार की गई जलाशय संचालन योजनाएँ परियोजना प्राधिकरण के लिए टरबाइन के पानी के नीचे के भागों के सुरक्षात्मक कोटिंग की लागत को कम करने और विद्युत उत्पादन बढ़ाने के लिए लाभदायक होंगी।

महत्वपूर्ण शब्द - जलाशय का अवसादन, संख्यात्मक मॉडल, अवशेष रेटिंग वक्र, जलाशय की सिल्ट हटाने, फ्लशिंग

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List of Abbreviations

RoR	Run-of-the-River
DPR	Detailed Project Report
MW	Megawatt
EWS	Early Warning System
G&D	Gauge and Discharge
HEP	Hydroelectric Project
MCM	Million cubic meters
CFD	Computational Fluid Dynamics
Cumec	Cubic meter per second