Groundwater Flow Modelling Using Visual MODFLOW Flex- A Case Study of Thuthapuzha sub-basin, Kerala, India

Mamatha Prabhakar[1] and Sasikala D[1]

[1]Kerala Agricultural University

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Abstract

India is the largest user of groundwater in the world, accounting for a quarter of the world's annual groundwater extraction. In Kerala, a state in Southern India, groundwater is the drinking water source for 62% of the population. Groundwater management is vital to ensure the sustainable availability of water. However, it is complex due to uncertainties in subsurface parameters. Groundwater modeling can be used as an efficient tool to understand the regional flow as well as the hydrogeological condition of the groundwater system. The modular finite-difference groundwater flow model (MODFLOW) developed by the U.S. Geological Survey (USGS) is a widely used modular three-dimensional block-centered finite difference code used for simulating dynamic features and scenarios in groundwater systems. In this study, the Visual MODFLOW Flex 7.0 is used to simulate the flow of groundwater through aquifers in the Thuthapuzha sub-basin, a sixth-order sub-basin of the Bharathapuzha river basin Kerala's second-largest river basin. A four-layer model covering an area of 940 km^2 has been prepared using Visual MODFLOW Flex 7.0. Groundwater level data of 37 wells spread over the study area has been used for the model simulation. Model design, calibration, and validation have been carried out. Boundary conditions including recharge and evapotranspiration are derived from the Soil and Water Assessment Tool (SWAT) hydrologic model. The model calibration is performed in two stages, which include steady-state calibration and transient state calibration using observed groundwater levels from 2000 - 2016. The validation is done by using observed groundwater levels from 2017 - 2019. The spatial distribution of hydraulic conductivity and storage properties are optimized using a combination of the trial-and-error method. Model performance evaluation is done using Standard Error of the Estimate, Root Mean Squared and Normalized RMS, found to be in the optimum range. The results of the model are found in good agreement with the observed groundwater level data. Therefore, the model is suitable for studying the groundwater level changes in the study area. In addition, the model can be extended to study the groundwater flow dynamics of the whole Bharathapuzha river basin and similar subbasins for the sustainable planning and management of groundwater resources.

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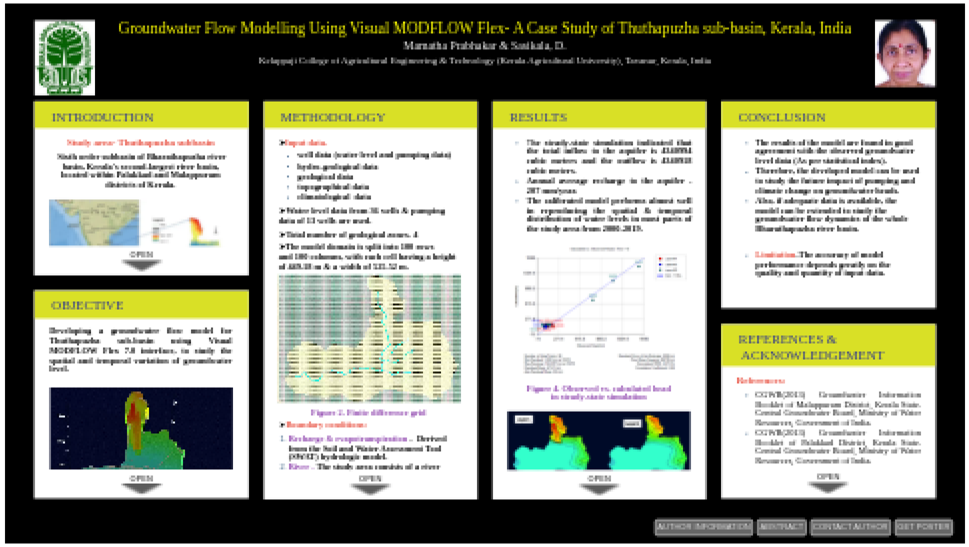

Mamatha Prabhakar & Sasikala, D.

Kelappaji College of Agricultural Engineering & Technology (Kerala Agricultural University), Tavanur, Kerala, India

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INTRODUCTION

Study area- Thuthapuzha subbasin

Sixth order subbasin of Bharathapuzha river basin, Kerala's second-largest river basin, located within Palakkad and Malappuram districts of Kerala.

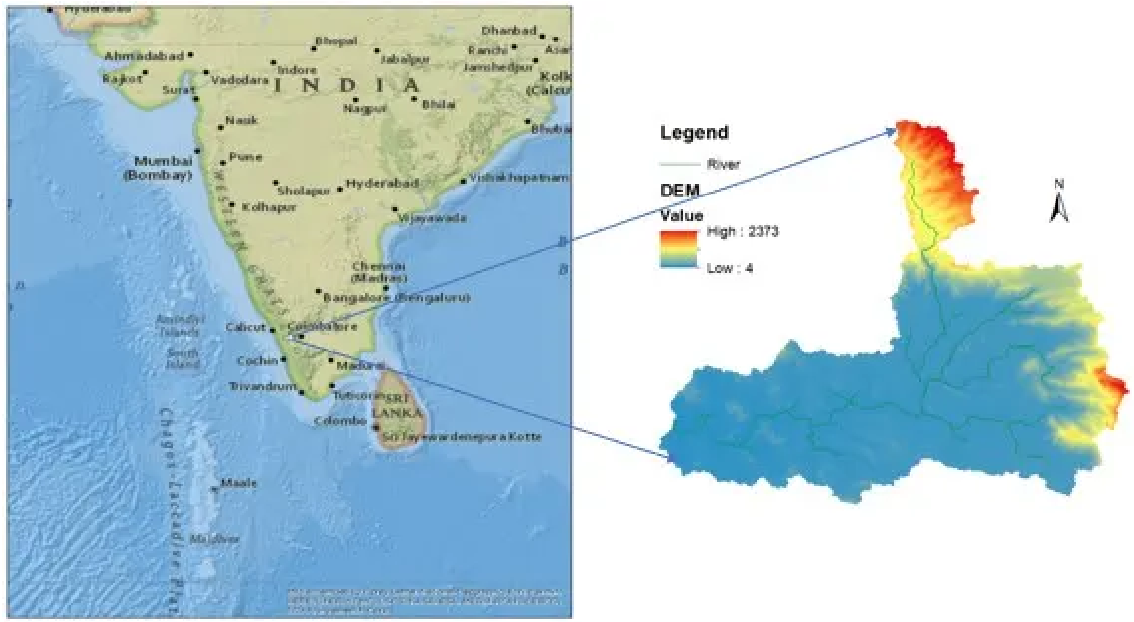

Figure 1. Location of the study area

Practical Utility:

- Lowering of water table & inadequate availability of groundwater during the peak requirement period (Dec-May) are major issues in Palakkad & Malappuram districts, as the rural areas depend heavily on groundwater resources for domestic, irrigation & industrial purposes **(CGWB, 2013).**
- Hence, groundwater management is vital to ensure sustainable availability of water in such areas.
- **Groundwater modeling** - Tool to understand the regional flow as well as the hydrogeological condition of the complex groundwater system.
- **MODFLOW**-Modular finite-difference groundwater flow model (MODFLOW) developed by the U.S. Geological Survey (USGS) → Simulate dynamic features and scenarios in groundwater systems.

OBJECTIVE

Developing a groundwater flow model for Thuthapuzha sub-basin using Visual MODFLOW Flex 7.0 interface, to study the spatial and temporal variation of groundwater level.

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METHODOLOGY

➤**Input data-**

- **well data (water level and pumping data)**
- **hydro-geological data**
- **geological data**
- **topographical data**
- **climatological data**

➤**Water level data from 36 wells & pumping data of 13 wells are used.**

➤**Total number of geological zones- 4**

➤**The model domain is split into 100 rows and 100 columns, with each cell having a height of 449.18 m & a width of 525.52 m.**

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Figure 2. Finite difference grid

➤**Boundary conditions:**

1. **Recharge & evapotranspiration - Derived from the Soil and Water Assessment Tool (SWAT) hydrologic model.**
2. **River - The study area consists of a river boundary at the middle intersected by its tributaries, assigned based on the river stage and river bottom elevation.**

➤**Model calibration- Steady state & transient state calibration using observed groundwater levels from 2000 - 2016**.

➤**Model validation- Validated using observed groundwater levels from 2017 - 2019.**

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Figure 3. Geological zones

➤**Each geological layer is assigned by a uniform value of hydraulic conductivity & storage properties.**

➤**Initial conditions for the transient model were developed from the calibrated steady-state model.**

RESULTS

- The steady-state simulation indicated that the total inflow to the aquifer is 4340994 cubic meters and the outflow is 4340918 cubic meters.
- Annual average recharge to the aquifer - 207 mm/year.
- The calibrated model performs almost well in reproducing the spatial & temporal distribution of water levels in most parts of the study area from 2000-2019.

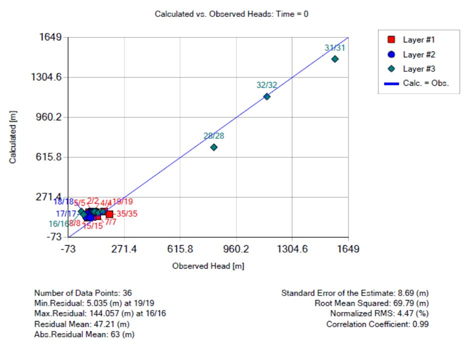

Figure 4. Observed vs. calculated head in steady-state simulation

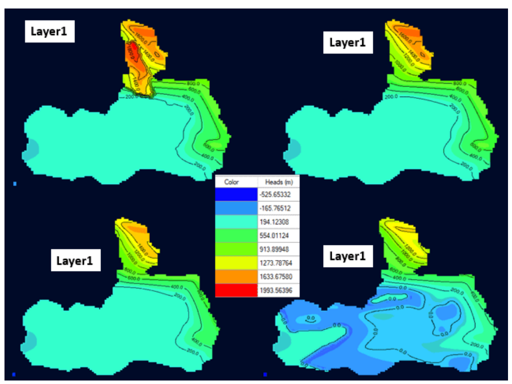

Figure 5. Groundwater head contour maps for each geological layer in steady-state simulation

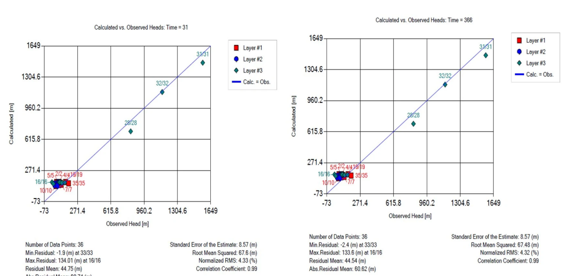

Figure 6. Observed vs. calculated head for 31 & 366 days of calibration in transient state simulation

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Figure 7. Groundwater head contour maps generated from the transient model for 2003, 2009, 2016 & 2019 years

- **Groundwater contour maps obtained after transient simulation almost match the observed water level fluctuations and follow the topography of the area.**
- **The observed and simulated groundwater heads are well fitted with Normalised RMS error <5%.**
- **By trial and error method hydraulic conductivity is found to be the most sensitive parameter in correlating observed and simulated results.**

Table 1. Hydraulic conductivity of each geological layer after calibration

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CONCLUSION

- **The results of the model are found in good agreement with the observed groundwater level data (As per statistical index).**
- **Therefore, the developed model can be used to study the future impact of pumping and climate change on groundwater heads.**
- **Also, if adequate data is available, the model can be extended to study the groundwater flow dynamics of the whole Bharathapuzha river basin.**

- **Limitation-The accuracy of model performance depends greatly on the quality and quantity of input data.**

REFERENCES & ACKNOWLEDGEMENT

References:

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- CGWB(2013) Groundwater Information Booklet of Palakkad District, Kerala State. Central Groundwater Board, Ministry of Water Resources, Government of India.

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AUTHOR INFORMATION

1. Mamatha Prabhakar, PhD Scholar, Department of Irrigation & Drainage Engineering, Kelappaji College of Agricultural Engineering & Technology, Kerala Agricultural University, Kerala, India.
2. Sasikala, D, Professor & Head, Department of Irrigation and Drainage Engineeing, Kelappaji College of Agricultural Engineering & Technology, Kerala Agricultural University, Kerala, India.

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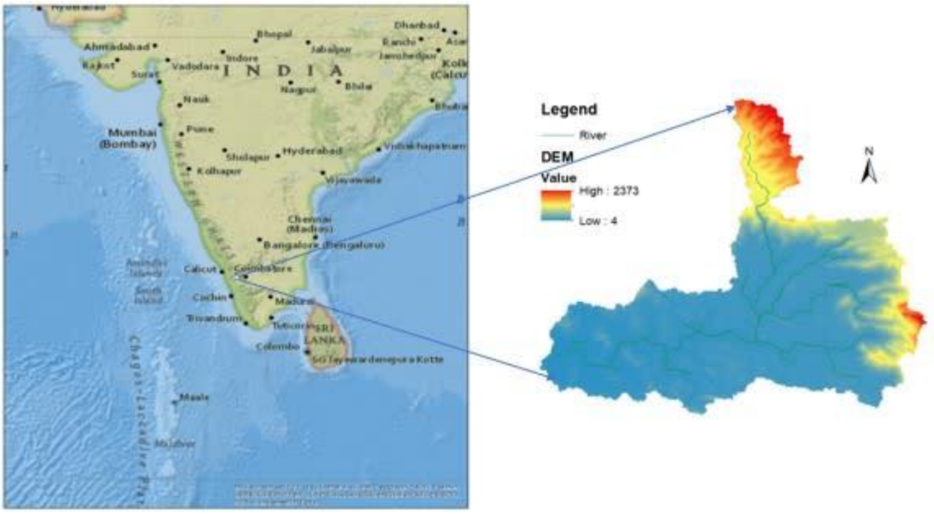

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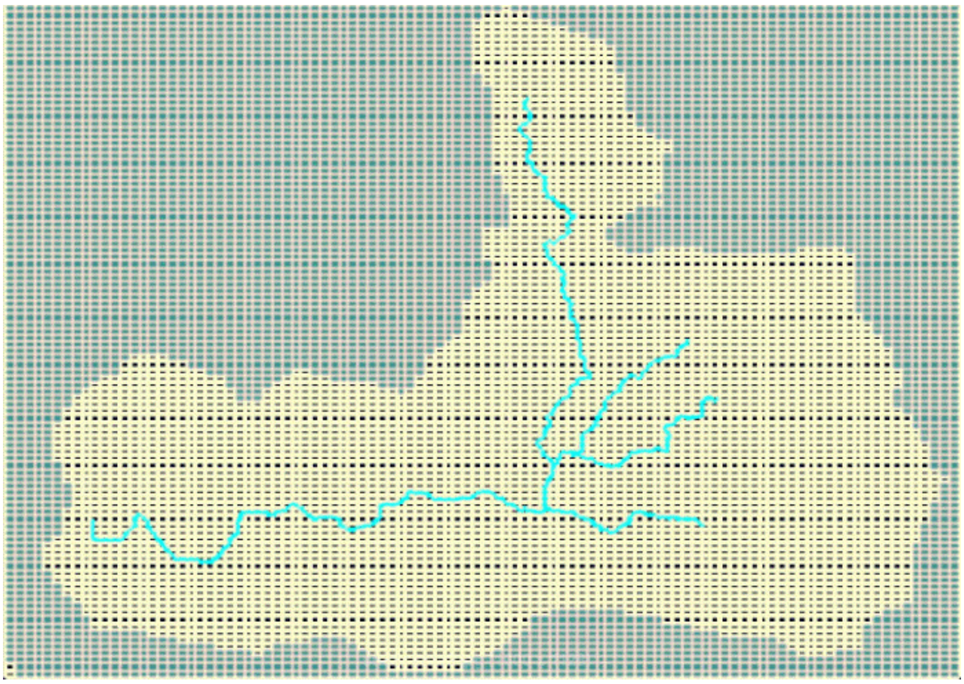

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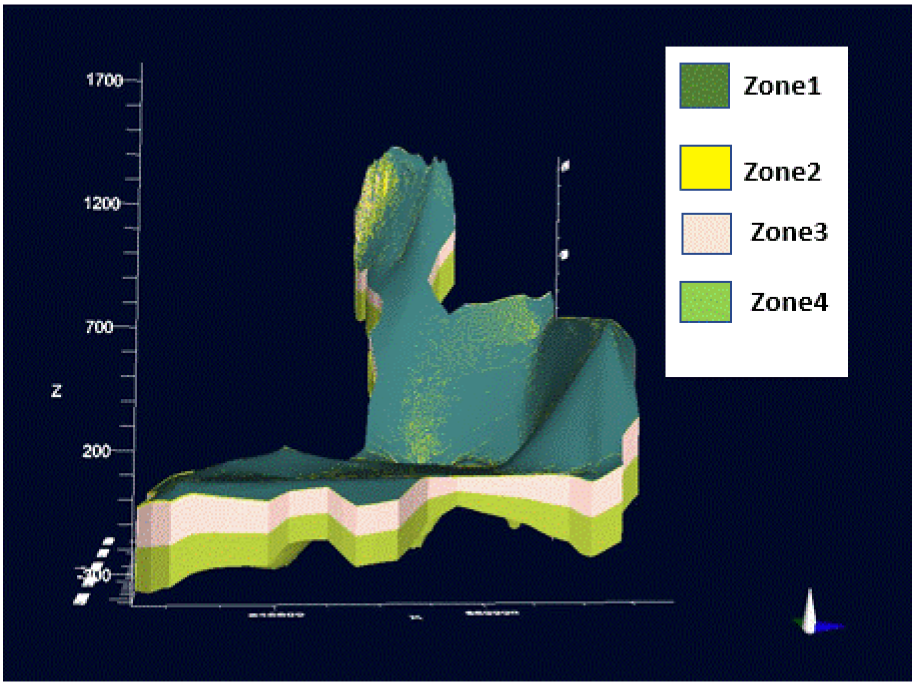

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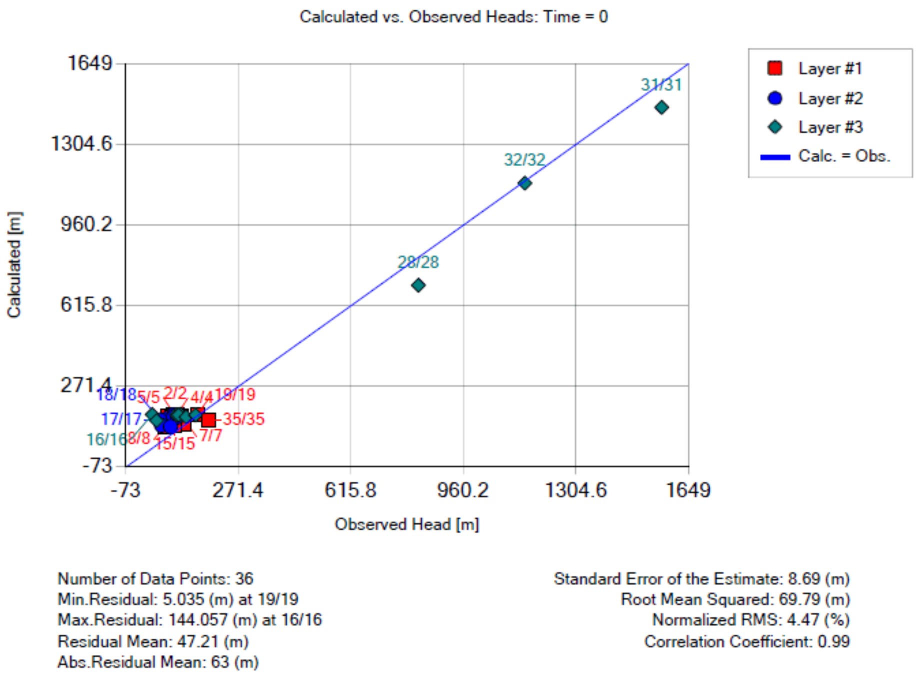

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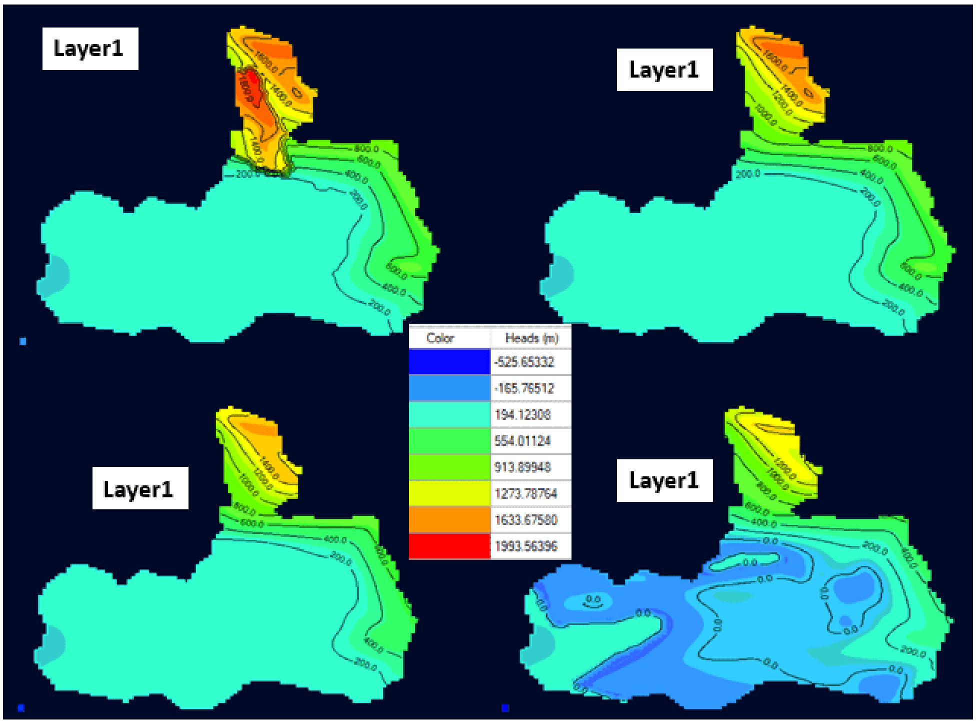

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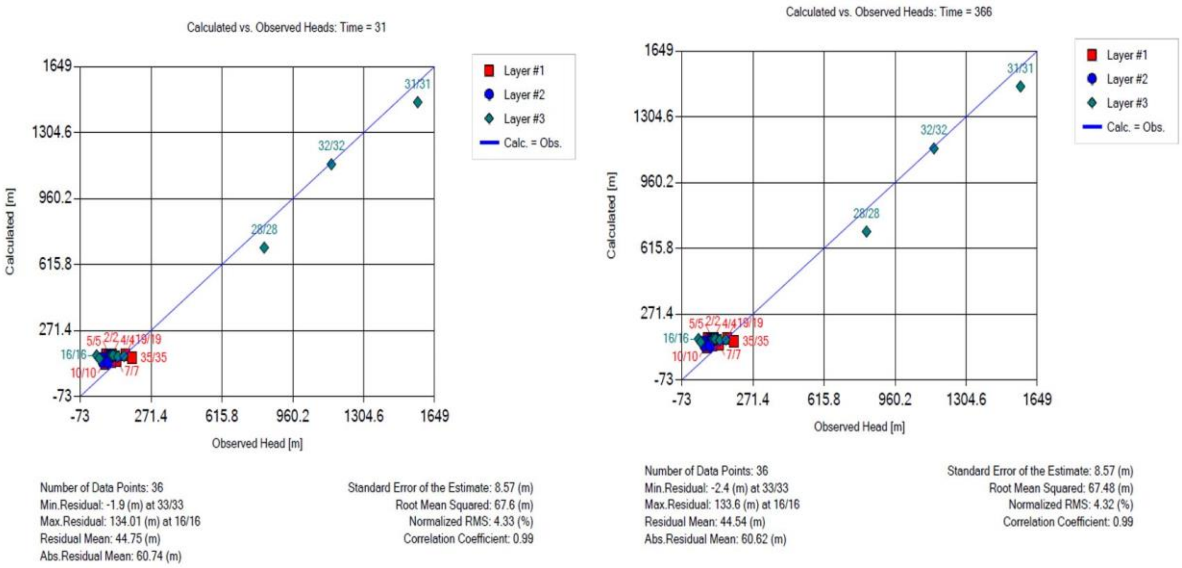

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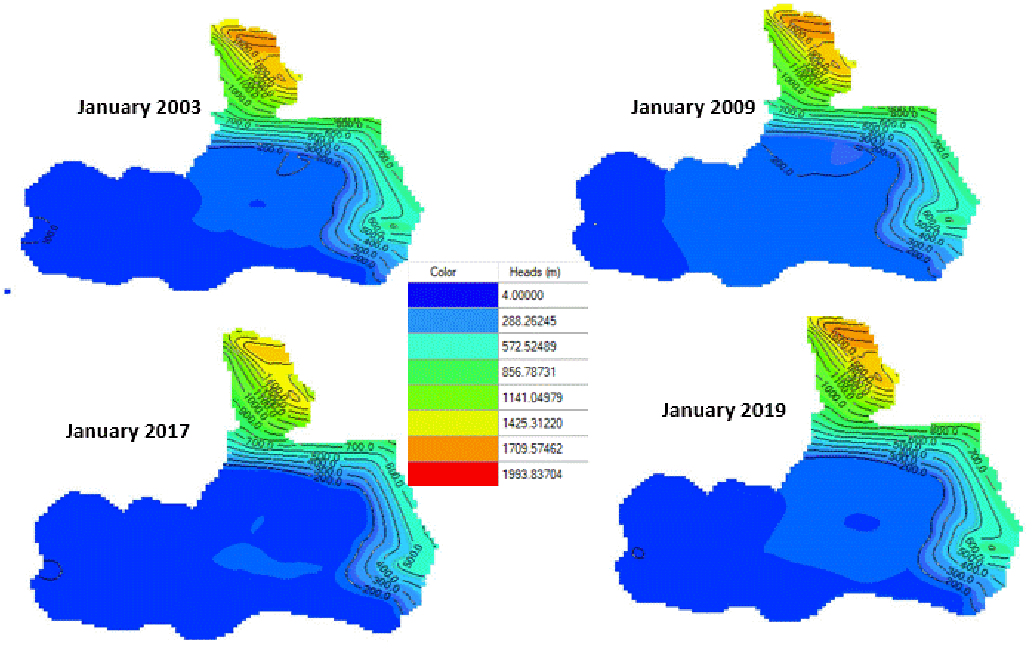

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