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Modelling the Impact of Climate Change in Hydrology of Tamor River Basin

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Abstract

Climate change has emerged as a major challenge for water resources and hydropower generation in the Himalayan region, where rivers are highly sensitive to shifts in temperature and precipitation. This study investigates the potential impacts of climate change on the hydrology of the Tamor River Basin in Near Future (2026AD-2050AD), Mid Future (2051AD-2075AD) and Far Future (2076AD-2100AD). A combination of observed hydro meteorological data from the Department of Hydrology and Meteorology (DHM) and bias-corrected climate projections from CMIP6 under SSP245 and SSP585 scenarios were employed. The HEC-HMS model was calibrated and validated using discharge records from Majhitar(Q684) and Mulghat(Q690) stations, achieving strong statistical performance (NSE= 0.668, R^2= 0.7213, and PBIAS=+18.61%) during validation period(2020AD-2024AD) at Mulghat station(Q690), confirming its reliability for flow simulation in the basin. Monthly water flow variations in the SSP245 scenario could range from -27.28% in the dry season and -34.80% in the wet season in the near future(2026AD-2050AD),-27.30% to -34.60% in the mid future(2051AD-2075AD) and -29.64% to -34.80% in the far future(2076AD-2100AD).Under the SSP585 scenario, variations might range from -26.14% to -34.93% in the near future(2026AD-2050AD),-24.21% to -33.86% in the mid future(2051AD-2075AD) and -19.62% to -31.64% in the far future(2076AD-2100AD).

Keywords: Climate change, Hydrology, Tamor River Basin,CMIP6

1. Introduction

Climate change stands as one of the most pressing global challenges of the 21st century, threatening natural ecosystems, water resources, agriculture, and infrastructure (IPCC, 2021). Among the sectors most affected by shifting climatic conditions, water resource management and hydropower generation are especially at risk. Reports from the Intergovernmental Panel on Climate Change (IPCC) highlight that rising temperatures, shifting precipitation patterns, and the growing frequency of extreme weather events are already altering river flows and reducing the availability of water in many parts of the world (IPCC, 2022).

Hydrological modeling tools, such as the Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS), are widely employed to simulate watershed hydrology, analyze rainfall–runoff processes, and evaluate the impacts of climate change on river discharge (Feldman, 2000; Chu & Steinman, 2009).

When combined with climate projections from Global Climate Models (GCMs), these models offer critical insights into the potential future hydrological behavior of river basins (Mishra & Singh, 2010).
This study seeks to assess the impacts of climate change on the hydrology of the Tamor River Basin. Using the HEC-HMS model in combination with downscaled climate projections, the research aims to generate essential insights to support effective planning, management, and adaptation strategies under future climate uncertainties.

2. Study Area

Tamor river basin is an integral part of the Koshi River System and is situated in eastern part of Nepal, koshi province. The river originates from the Kanchenjunga and Makalu regions and flows south-west and ultimately confluences the Arun and Sunkoshi rivers to form the Sapta Koshi River. The basin is characterized by its rugged topography, high mountain peaks, and significant hydropower potential.

Table 1:- Geographic Extent of Tamor River Basin with Coordinates

S.N.	Boundary Direction	Latitude(ºN)	Longitude(ºE)
1	Northernmost Point	27.87° N	88.10° E
2	Southernmost Point	26.96° N	87.42° E
3	Easternmost Point	27.47° N	88.17° E
4	Westernmost Point	27.06° N	87.27° E

The Tamor River Basin encompasses a diverse physiographic setting, ranging from high Himalayan peaks exceeding 8,000 meters to mid-hill and low-lying valley regions. The topography significantly influences the basin's hydrology, with steep slopes contributing to high runoff potential during the monsoon season.

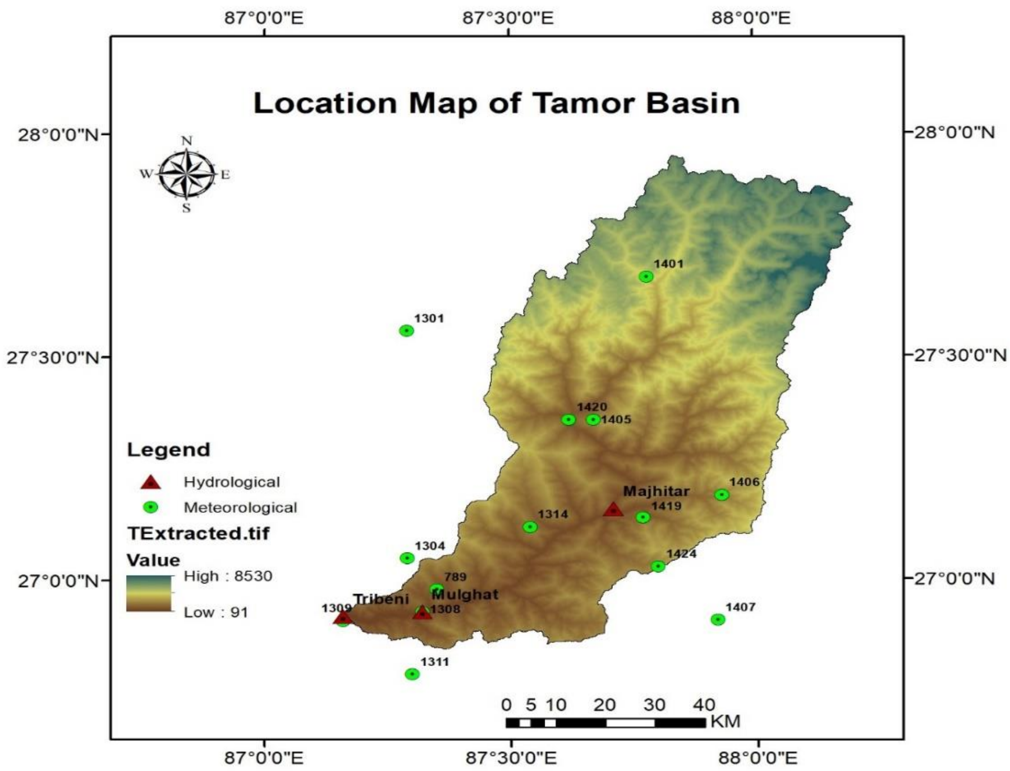

Figure 1:- Location, hydro-meteorological stations, and elevation details of Tamor River Basin

3. Methodology and data collection

A combination of data collection, model calibration, model validation, climate scenario integration, hydrological simulation, and analysis has been adopted. The methodology integrates both qualitative and quantitative approaches to ensure a comprehensive understanding of future hydrological changes in Near Future (2026AD-2050AD), Mid Future (2051AD-2075AD) and Far Future (2076AD-2100AD). This study adopts a quantitative, modelling-based approach to simulate the hydrological processes of the Tamor River Basin under both historical and future climate scenarios.

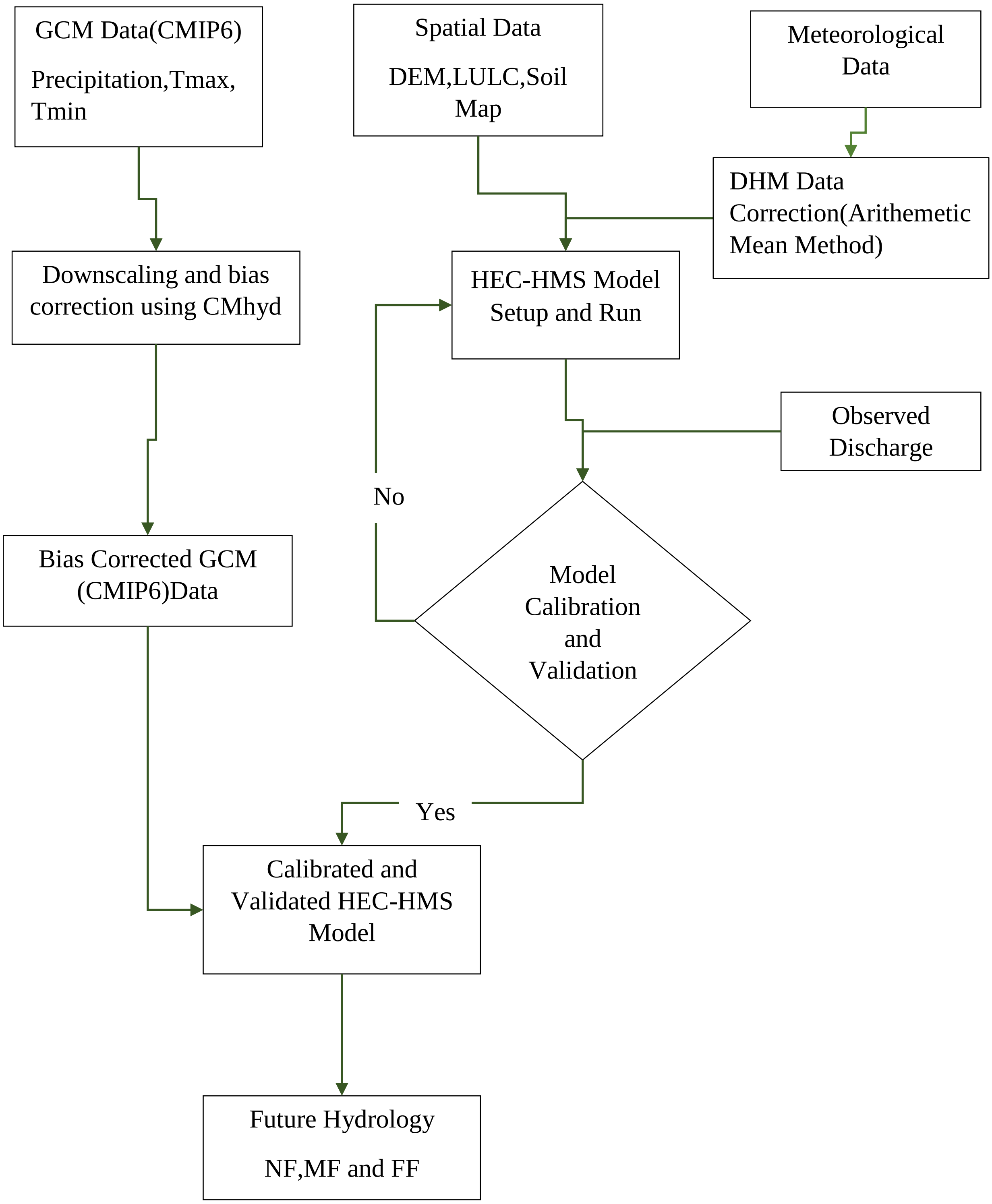

Figure 2:- Methodological framework for assessing climate change impacts on hydrological characteristics of Tamor River Basin

3.1 Data and Sources

To carry out the hydrological modelling and impact assessment, various datasets were collected from different national and international sources. The required data include hydro-meteorological, topographic, land use, soil, and climate projection datasets. Daily precipitation, temperature (maximum and minimum), and streamflow data were obtained from the Department of Hydrology and Meteorology (DHM), Government of Nepal. These data were essential for model calibration, validation, and baseline scenario simulations. Topographical data, including Digital Elevation Models (DEMs), were acquired from the Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER) [https://asterweb.jpl.nasa.gov/gdem.asp] with a resolution of 30 meters. Land use and land cover data were obtained from the International Centre for Integrated Mountain Development (ICIMOD) [https://rds.icimod.org]. Soil maps and relevant soil characteristics for the basin were acquired from the Food and Agriculture Organization of United States (FAO) [https://www.fao.org] and supplemented with national soil survey reports. Future climate projection data were obtained from the Coupled Model Intercomparison Project Phase 6 (CMIP6) under different Shared Socioeconomic Pathways (SSPs), namely SSP245 and SSP585 .These data were downscaled and bias-corrected to match the basin's scale.

Table 2:- Land use area percentage in Tamor river basin

S.N.	Landuse type	Percentage Area
1	Waterbody	0.29
2	Glacier	7.22
3	Snow	2.31
4	Forest	47.03
5	Riverbed	0.06
6	Built-Up Area	0.08
7	Cropland	14.04
8	Bare Soil	0.00
9	Bare Rock	17.65
10	Grassland	5.52
11	Other wooded land	5.79

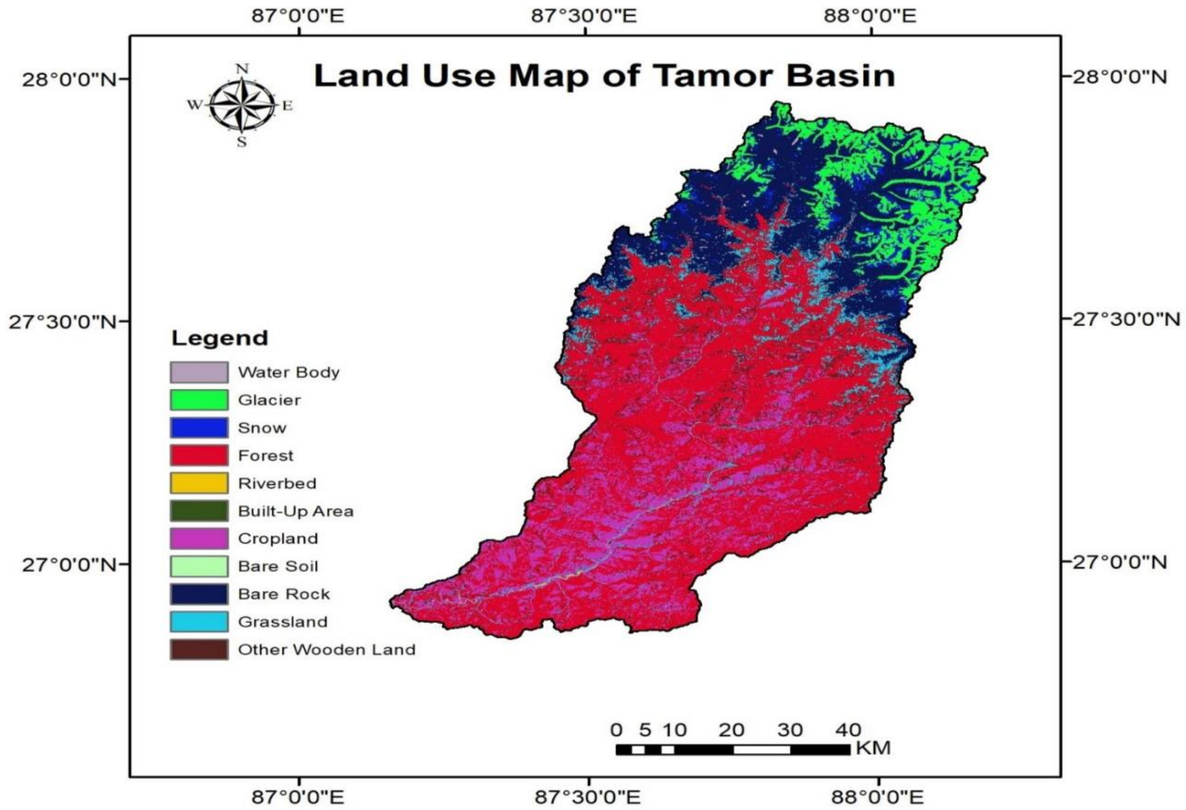

Figure 3:- Land use map of Tamor river basin

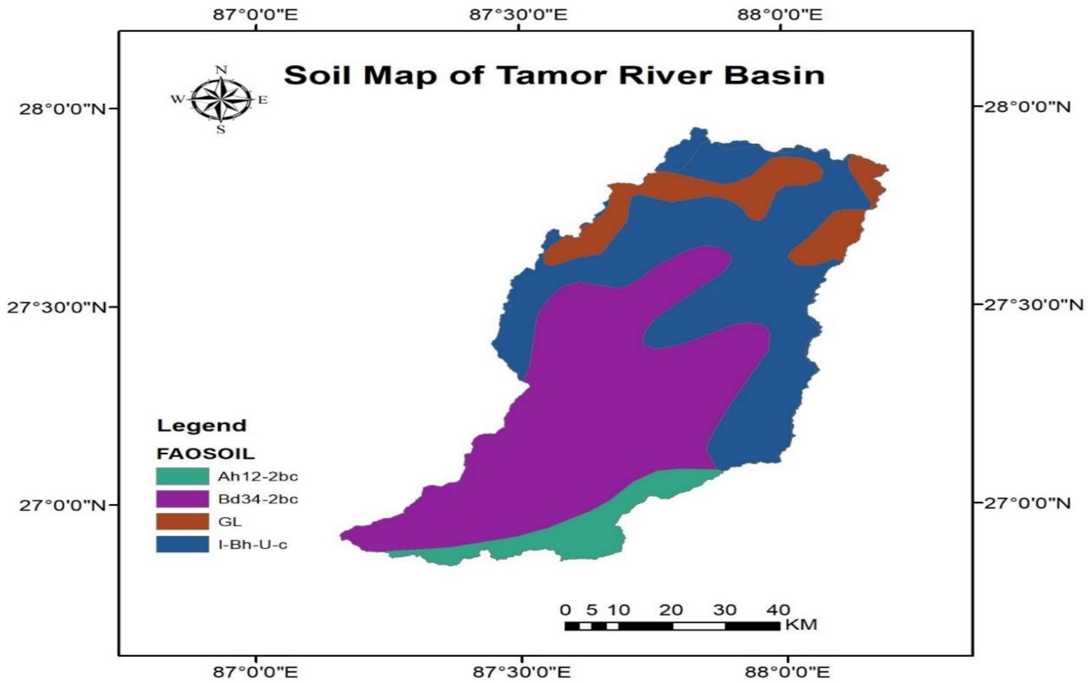

Figure 4:- Soil map of Tamor river basin

3.2 Hydrological Modelling

The U.S. Army Corps of Engineers developed the Hydrologic Modeling System (HEC-HMS), was chosen for this study owing to its effectiveness in simulating rainfall–runoff processes in complex mountainous basins. It is suitable for this research because of its flexibility, user-friendly interface, and ability to incorporate future climate scenarios. The model was calibrated using observed streamflow data for a selected period (2015AD-2019AD) at both Majhitar(Q684) and Mulghat(Q690) stations, ensuring that simulated flows matched observed data within acceptable error margins. Performance was evaluated using statistical indicators such as:Nash Sutcliffe efficiency(NSE),Coefficient of Determination(R^2) and Percent bias(PBIAS) The model was then validated using independent datasets for the validation period(2020AD-2024AD) to confirm its reliability for future scenario simulations.

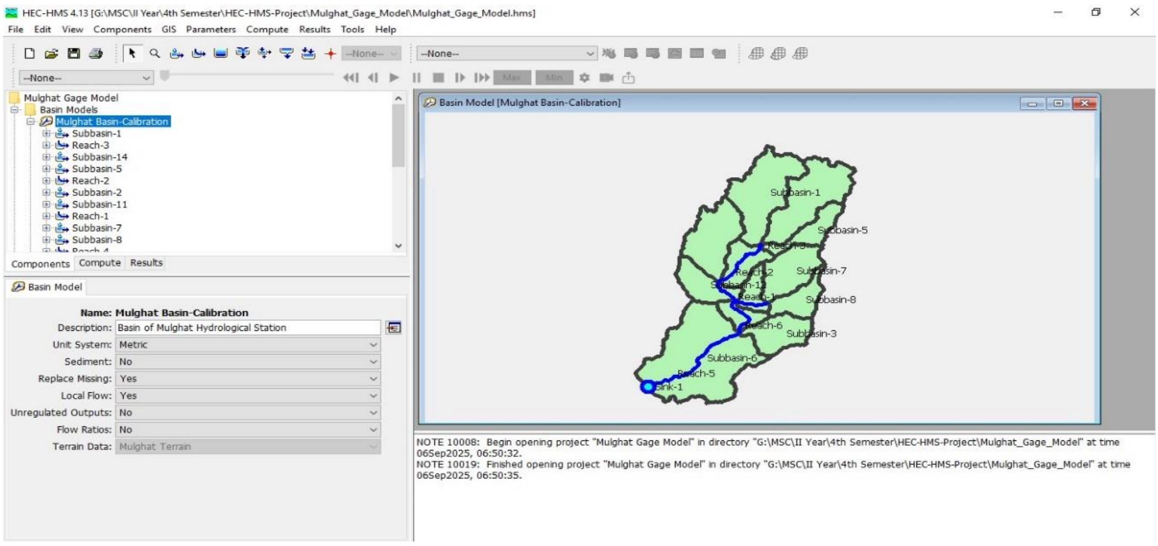

Figure 5:-Different sub basins in Tamor river basin

3.3 Climate change impact assessment

Downscaled and bias-corrected climate projections from selected GCMs under SSP245 (moderate emissions) and SSP585 (high emissions) were integrated into the HEC-HMS model to simulate the potential hydrological changes in the three future time frames i.e. Near future(2026AD-2050AD),Mid future(2051AD-2075AD) and Far future(2076AD-2100AD).

4. Results and Discussions

4.1 HEC-HMS model calibration and validation

The calibration and validation results for both Majhitar(Q684) and Mulghat(Q690) hydrological stations indicate that the HEC-HMS model performed consistently well across the basin. For Majhitar station (Q684), the calibration phase achieved an NSE of 0.778 and R^2 of 0.7898, with a slight underestimation of flows (PBIAS = –10.02%). Validation maintained high accuracy with an NSE of 0.691 and R^2 of 0.7106, though a minor underestimation was observed (PBIAS = -14.53%). This suggests the model is stable for both high- and low-flow conditions at this upstream location.

For Mulghat station (Q690), calibration results produced an NSE of 0.756 and R^2 of 0.7565, with a PBIAS of +1.82%, indicating a slight over prediction. Validation yielded an NSE of 0.668 and R^2 of 0.7213, with PBIAS = +18.61%, demonstrating similarly reliable performance. The close alignment of these results with those at Majhitar station(Q684) and Mulghat station(Q690) confirms that the model effectively captures hydrological responses throughout the Tamor River Basin, including both upstream and downstream locations.

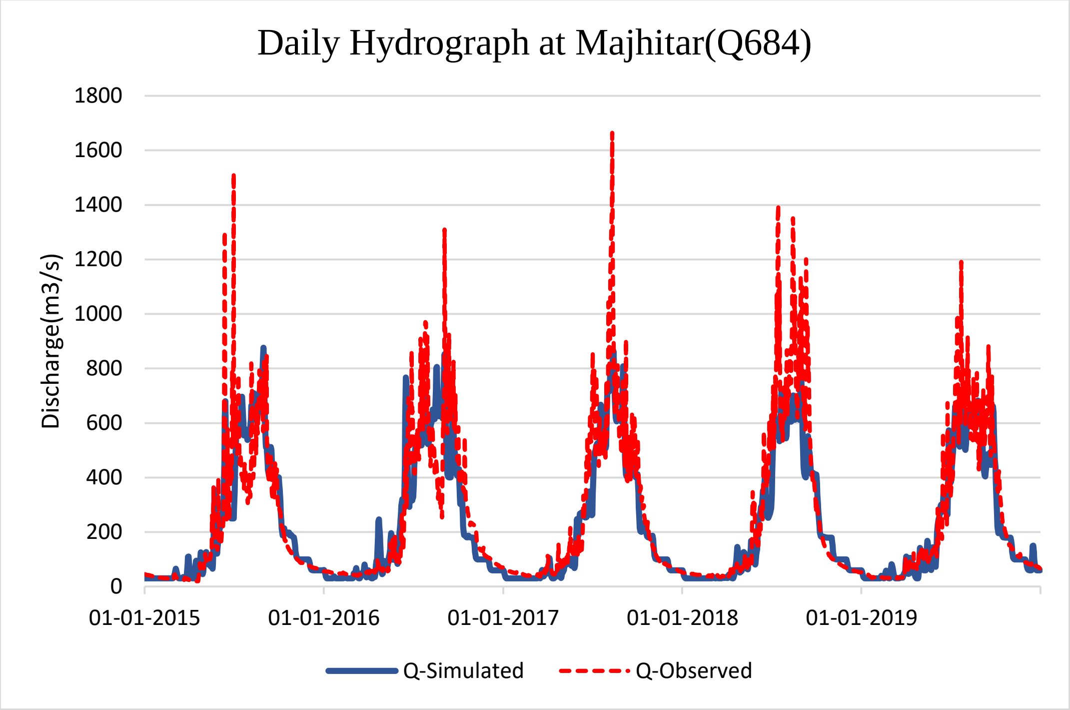

Figure 6:- Observed vs Simulated daily hydrograph at Majhitar(Q684) during Calibration

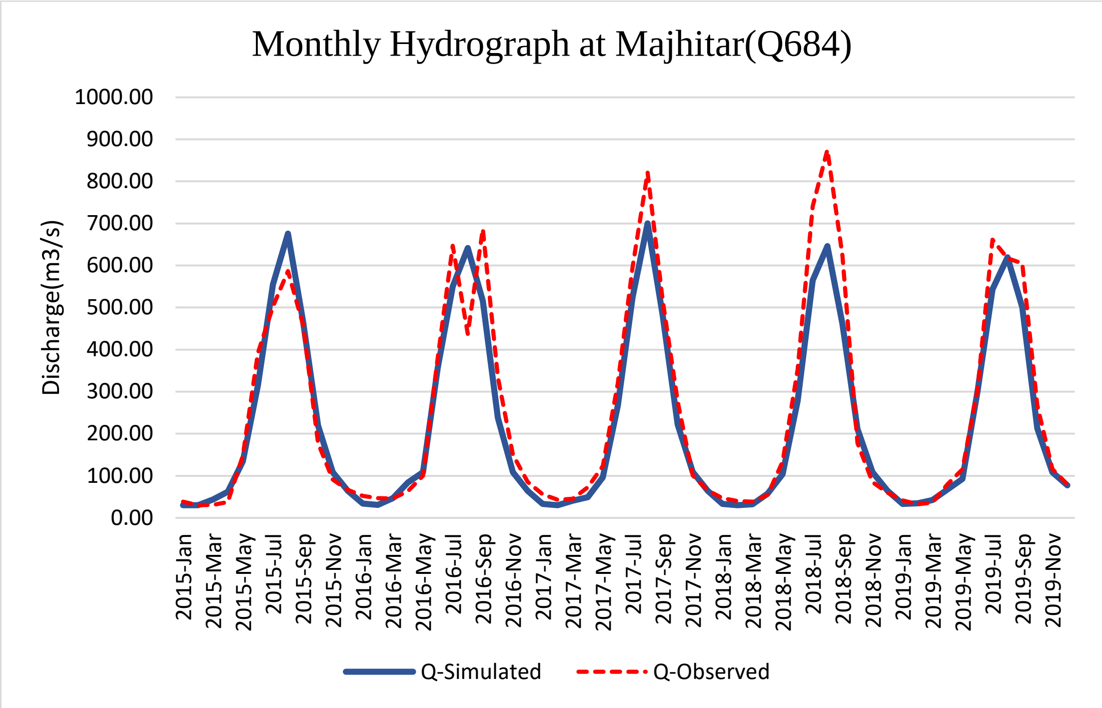

Figure 7:- Observed vs Simulated Monthly hydrograph at Majhitar(Q684) during calibration

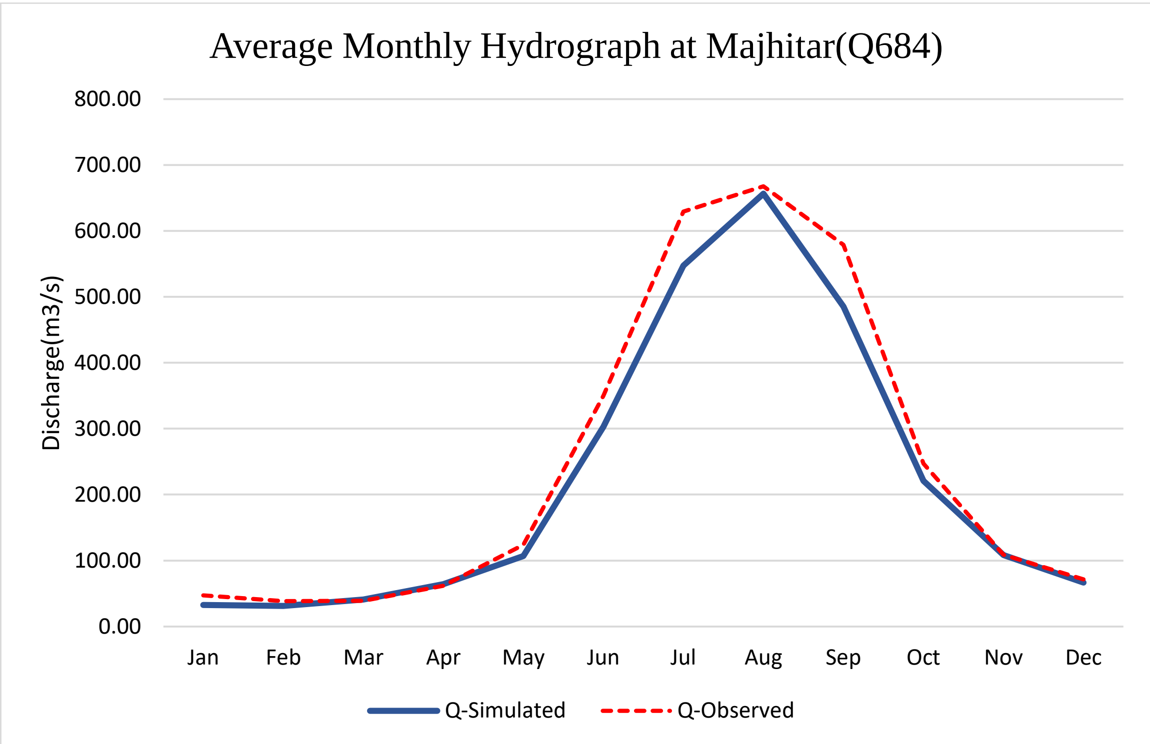

Figure 8:- Observed vs Simulated Average Monthly Hydrograph at Majhitar(Q684) during calibration

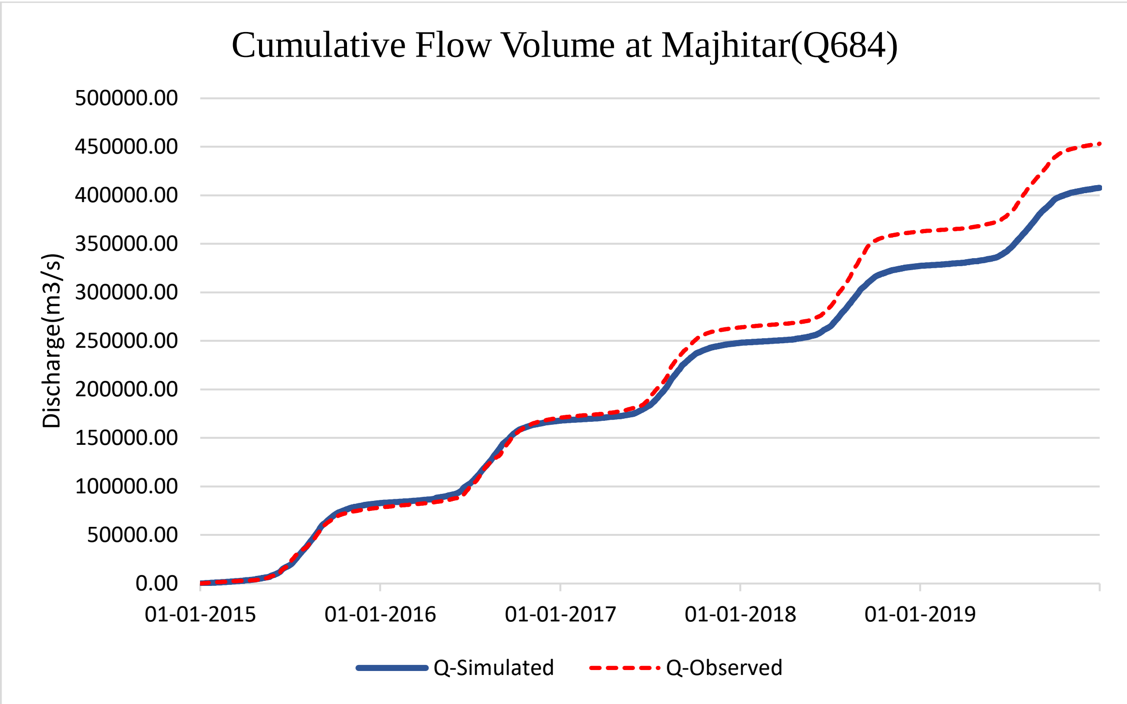

Figure 9:- Observed vs simulated cumulative flow volume at Majhitar(Q684) during calibration

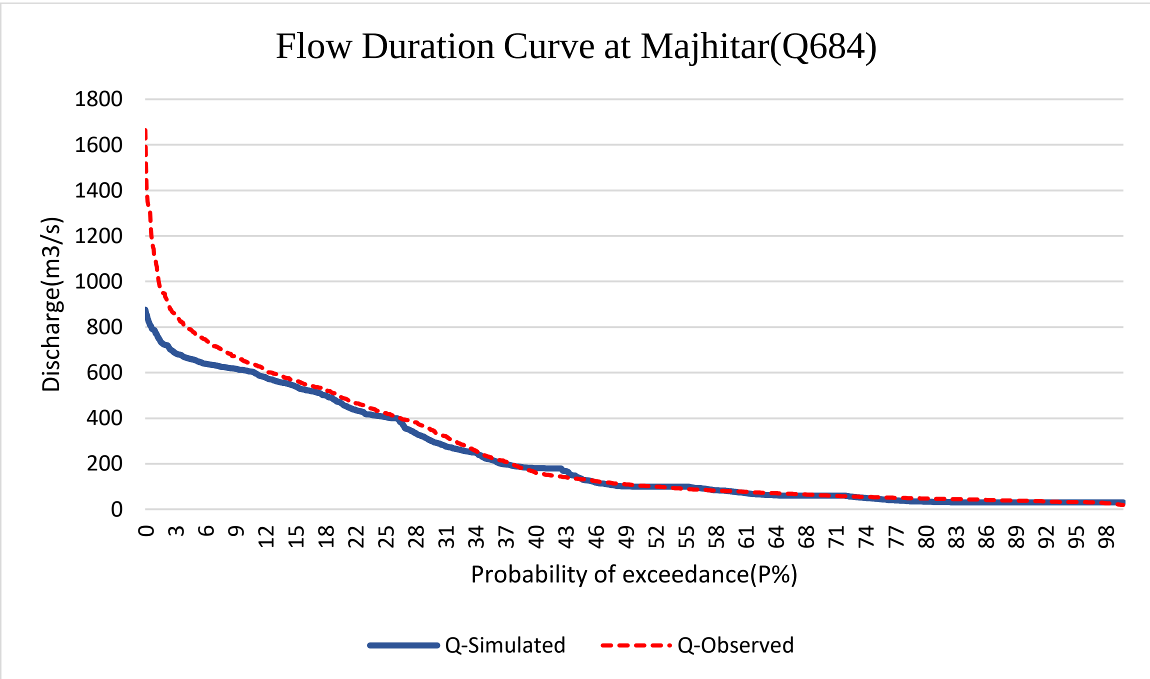

Figure 10:- Observed vs Simulated Flow Duration Curve at Majhitar(Q684) during calibration

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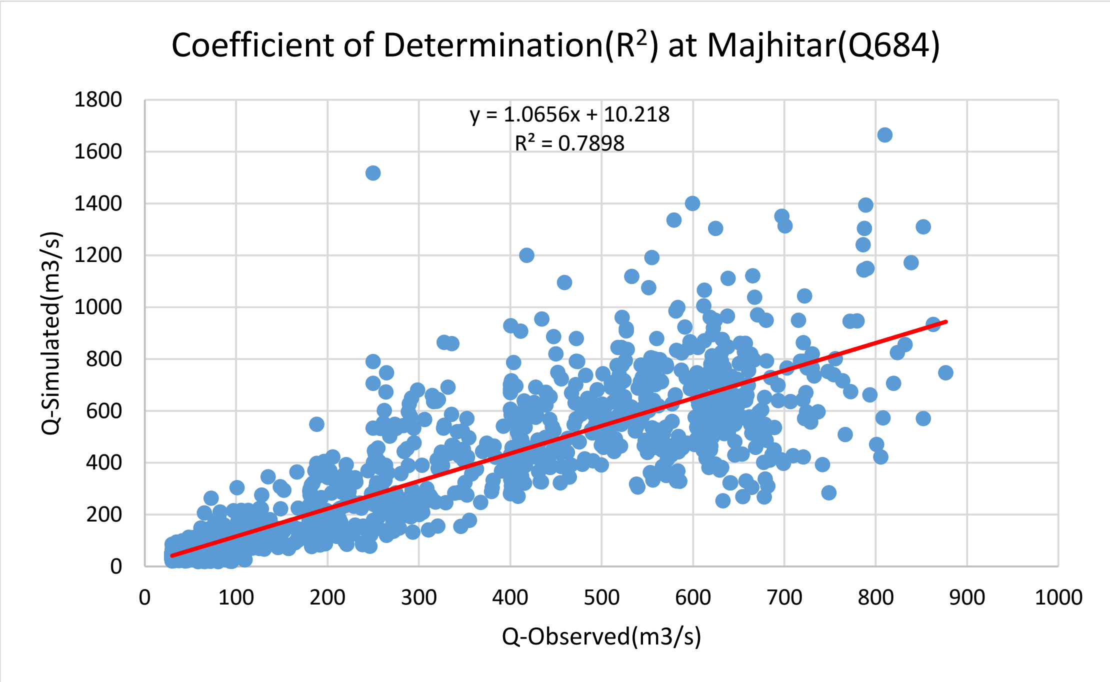

Figure 11:-Coefficient of Determination (R^2) at Majhitar (Q684) during calibration

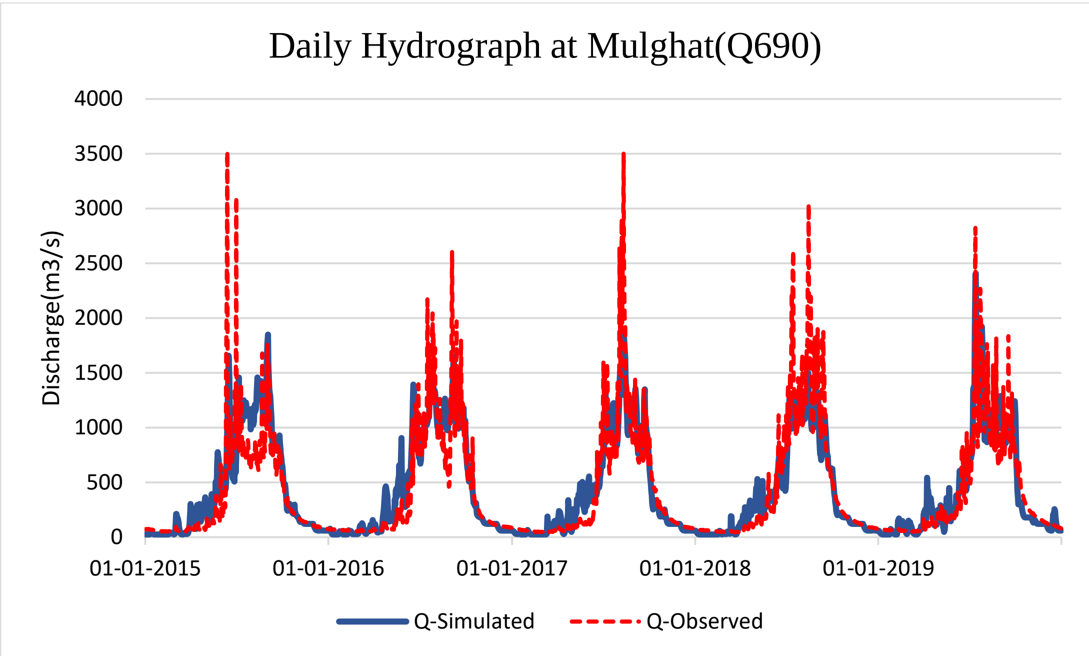

Figure 12:- Observed vs Simulated daily hydrograph at Mulghat(Q690) during calibration

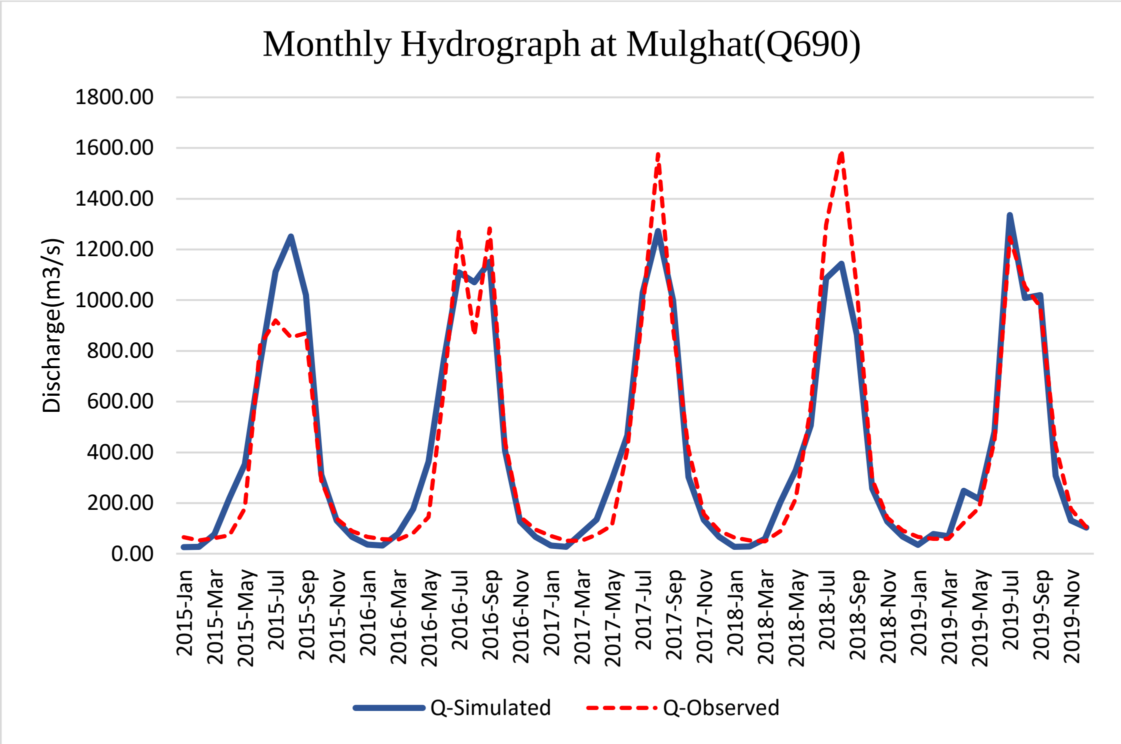

Figure 13:- Observed vs Simulated Monthly hydrograph at Mulghat(Q690) during calibration

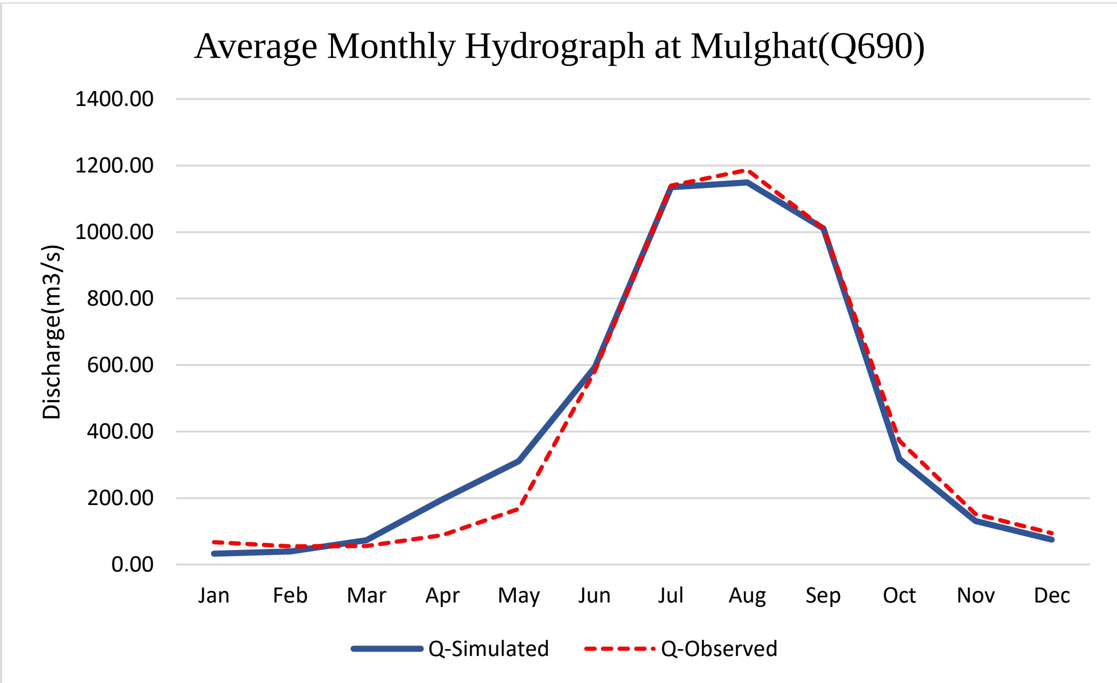

Figure 14:- Observed vs Simulated Average Monthly Hydrograph at Mulghat(Q690) during calibration

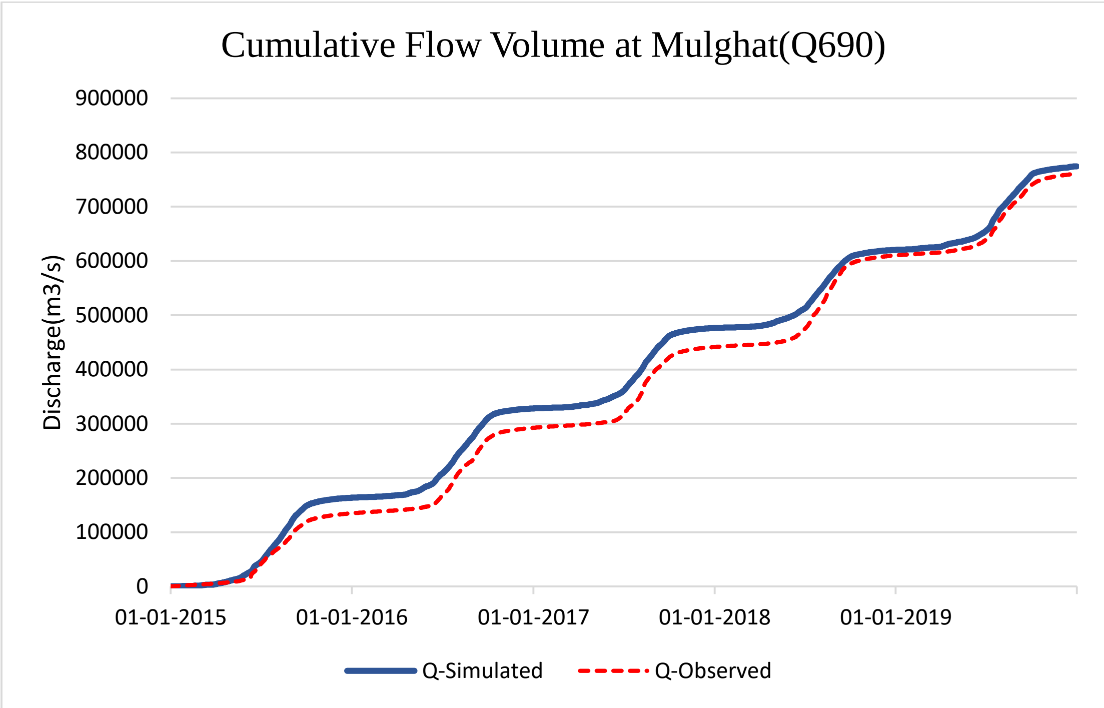

Figure 15:- Observed vs Simulated Cumulative Flow Volume at Mulghat(Q690) during calibration

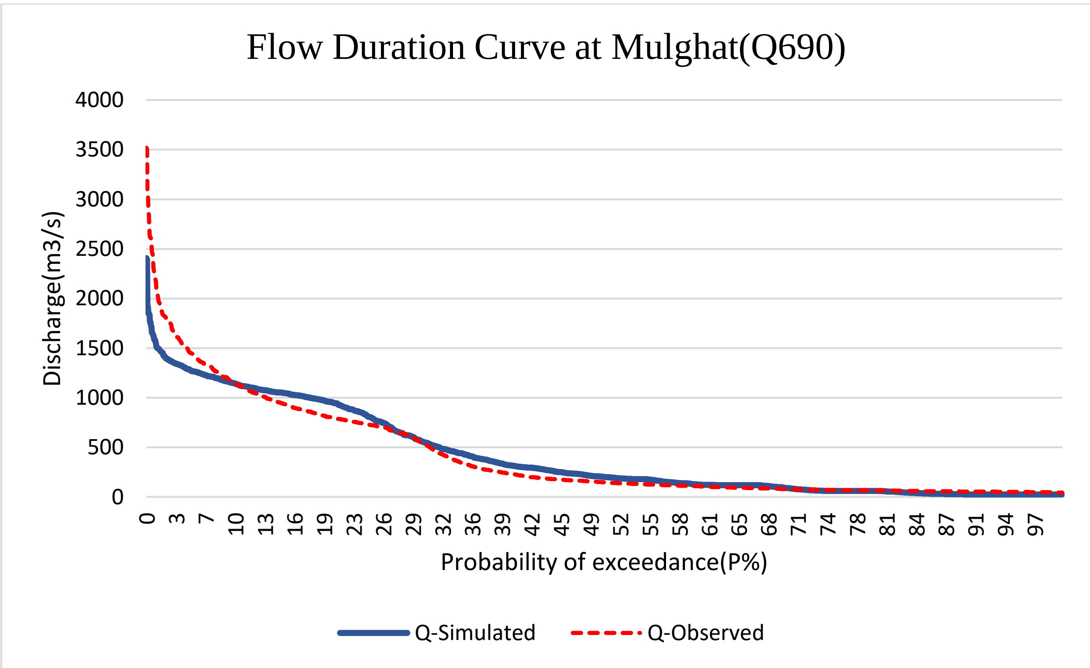

Figure 16:- Observed vs Simulated Flow Duration Curve at Mulghat(Q690) during calibration

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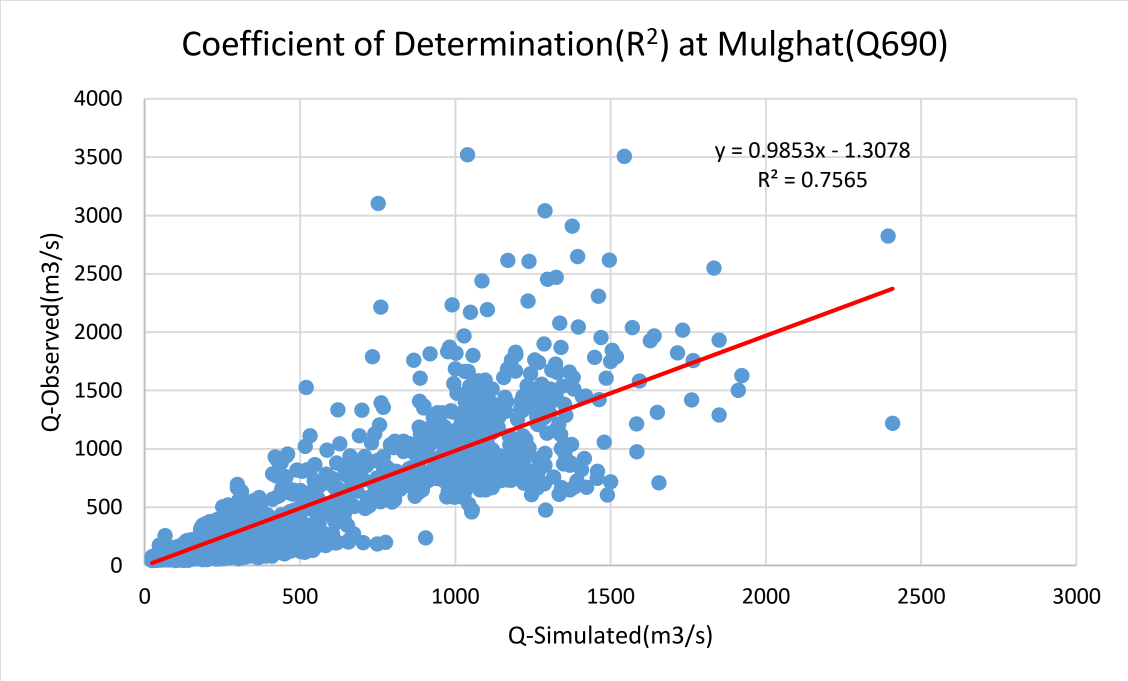

Figure 17:-Coefficient of Determination (R^2) at Mulghat(Q690) during calibration

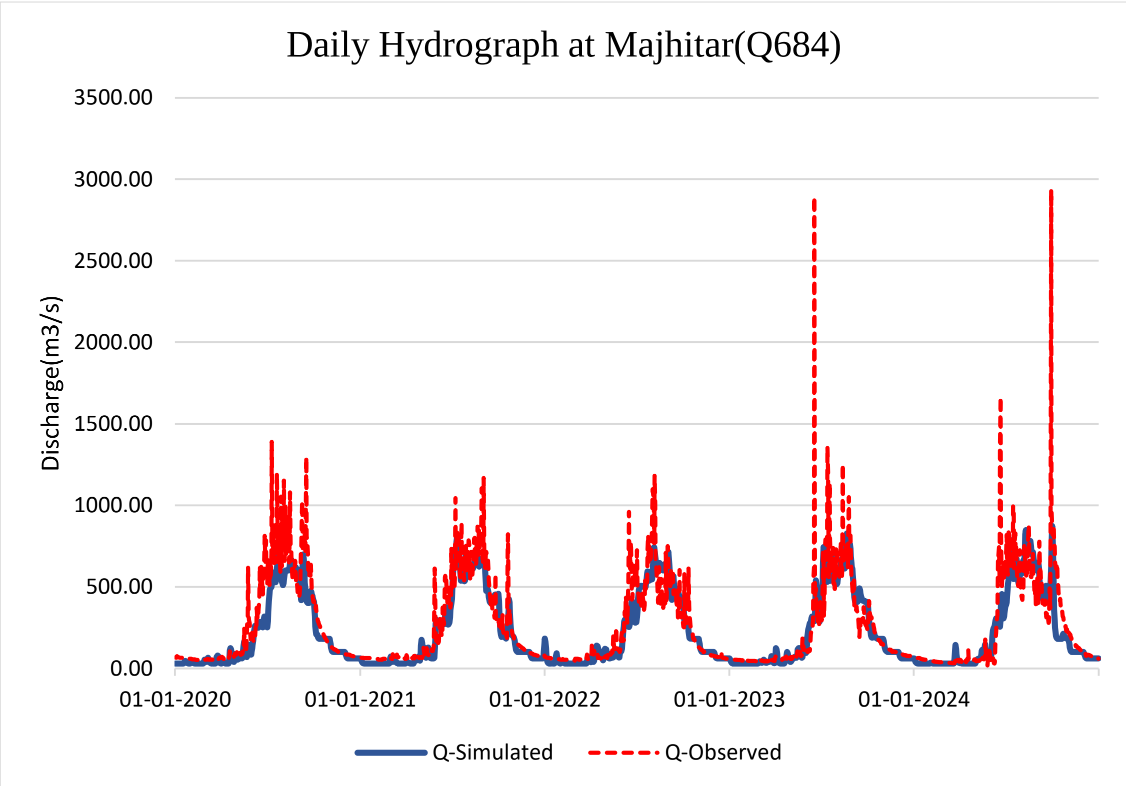

Figure 18:- Observed vs Simulated Daily Hydrograph at Majhitar(Q684) during validation

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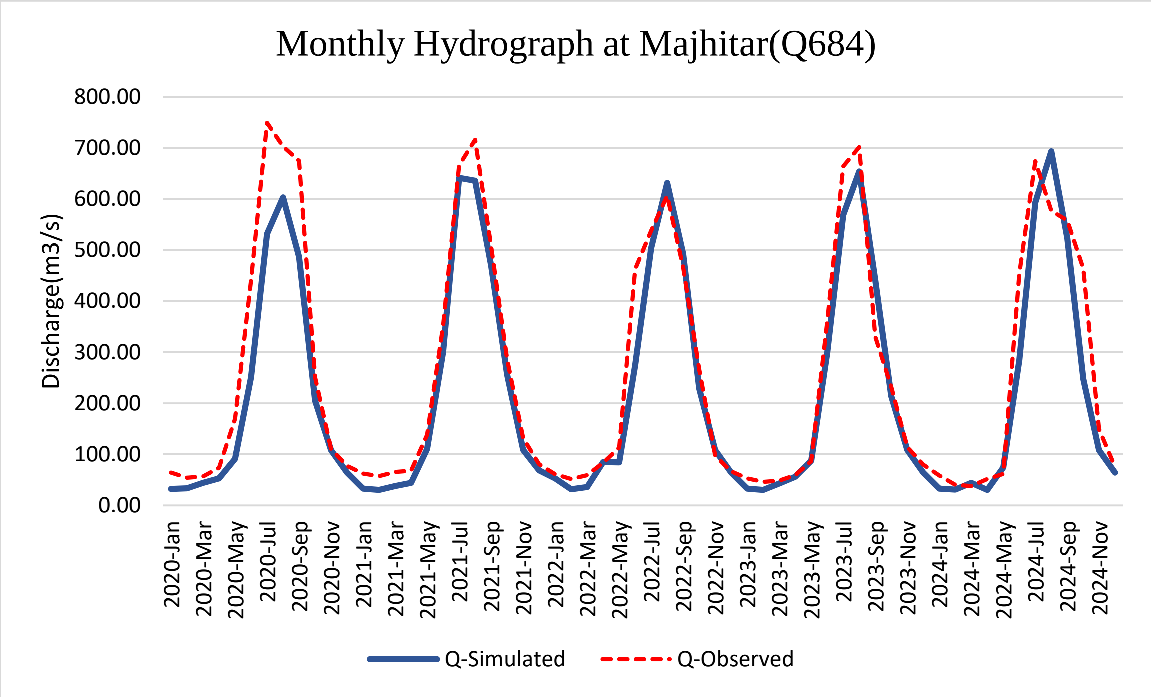

Figure 19:- Observed vs Simulated Monthly Hydrograph at Majhitar(Q684) during validation

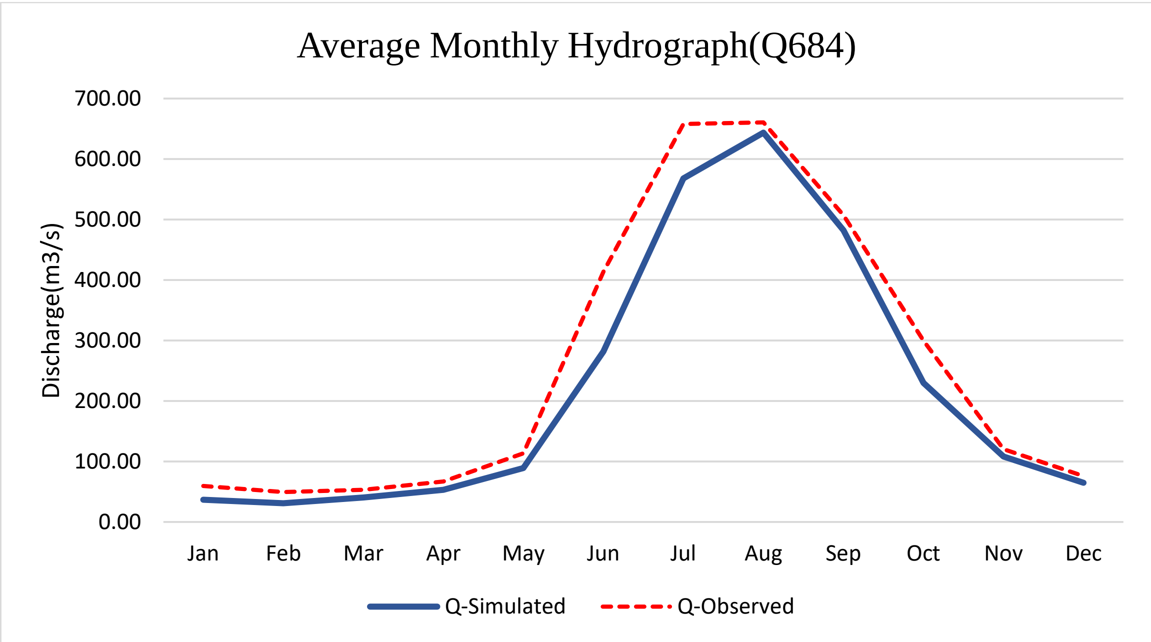

Figure 20:- Observed vs Simulated Average Monthly Hydrograph at Majhitar(Q684) during validation

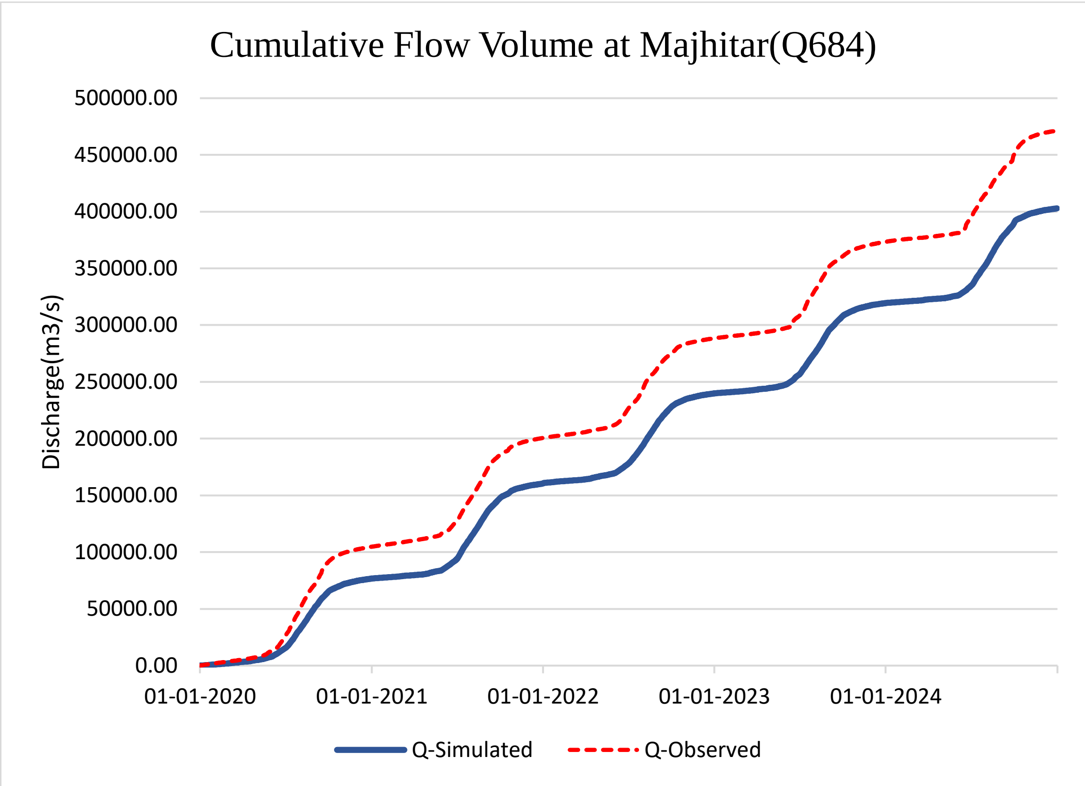

Figure 21:- Observed vs Simulated Cumulative Flow Volume at Majhitar(Q684) during validation

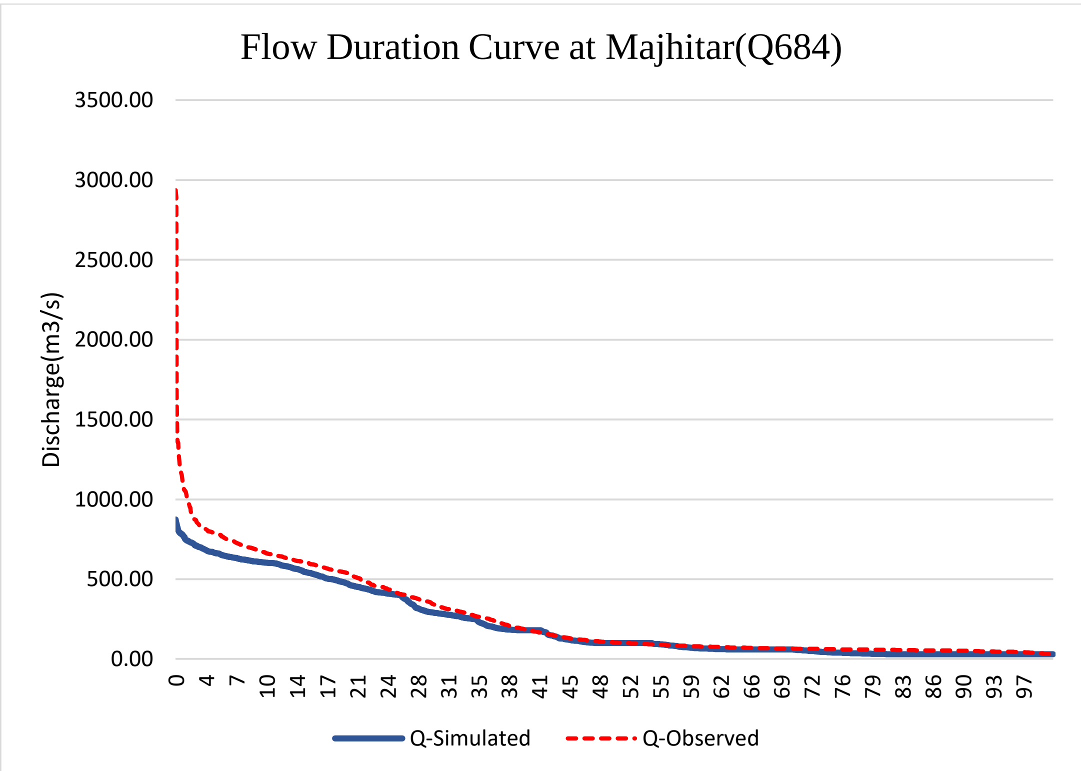

Figure 22:- Observed vs Simulated Flow Duration Curve at Majhitar(Q684) during validation

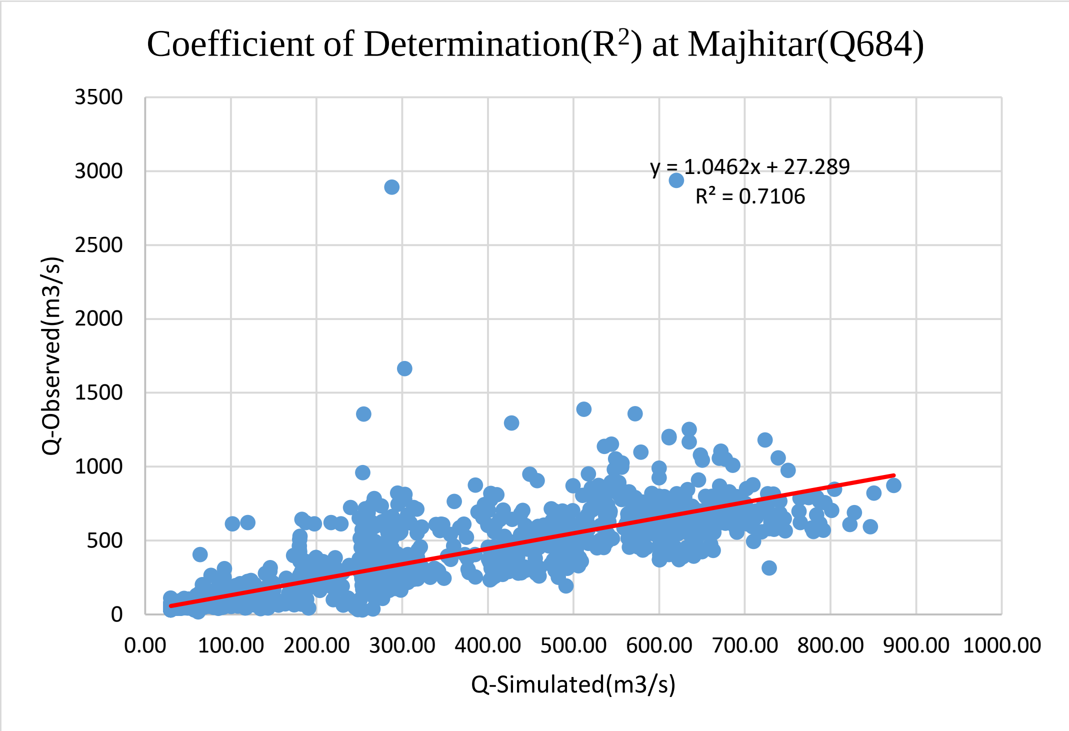

Figure 23:-Coefficient of Determination (R^2) at Majhitar(Q684) during validation

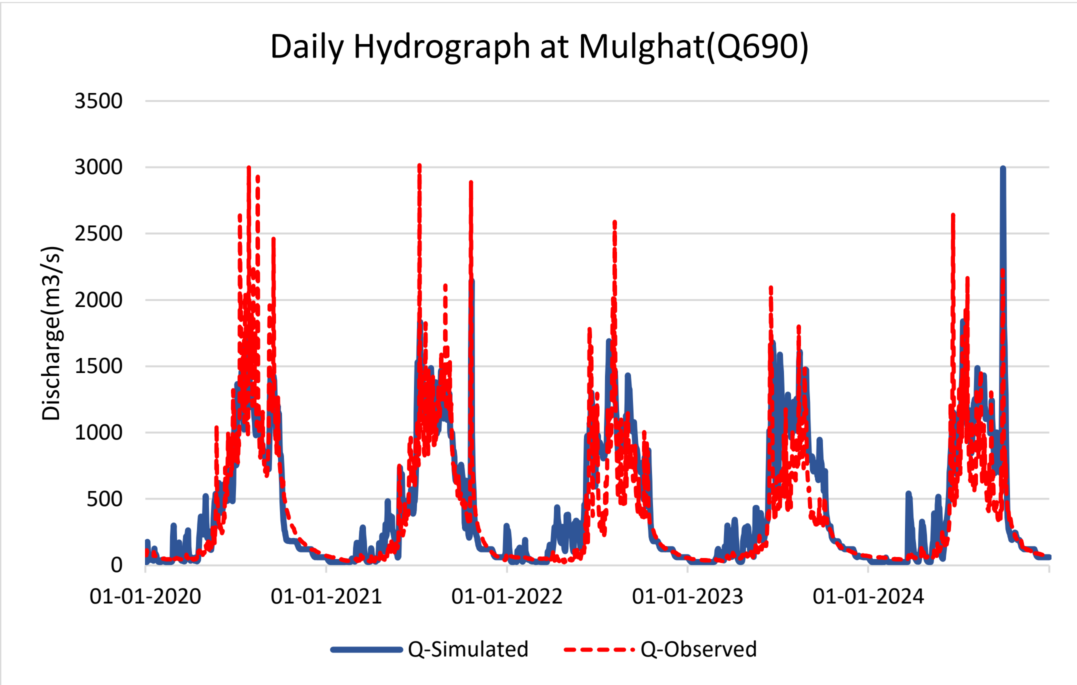

Figure 24:- Observed vs Simulated Daily Hydrograph at Mulghat (Q690) during validation

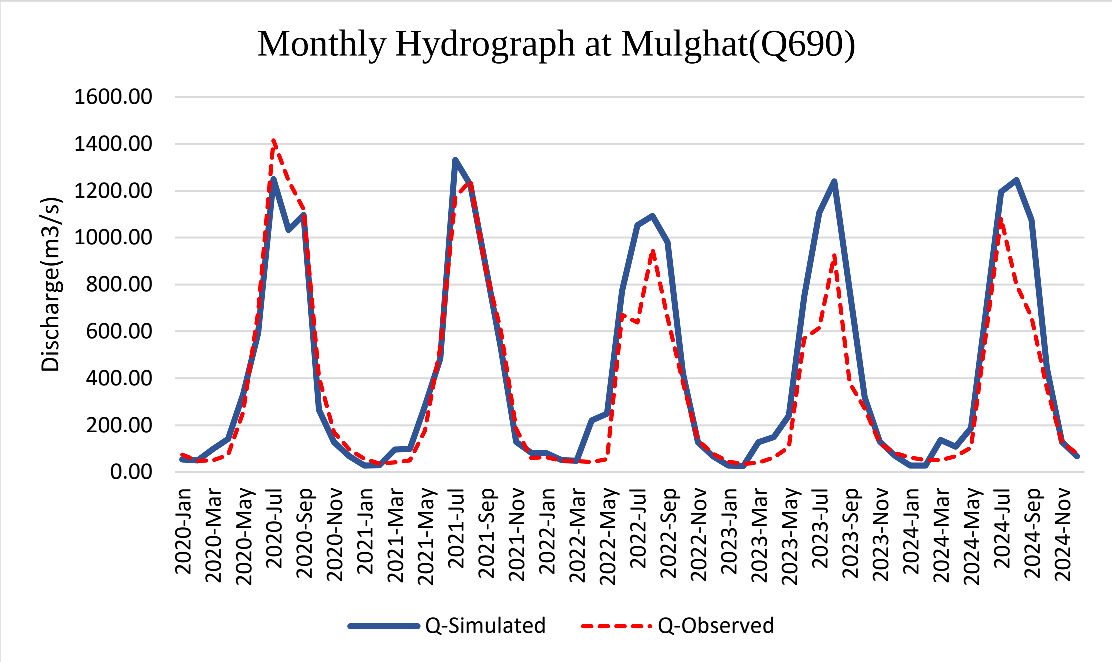

Figure 25:- Observed vs Simulated Monthly Hydrograph at Mulghat(Q690) during validation

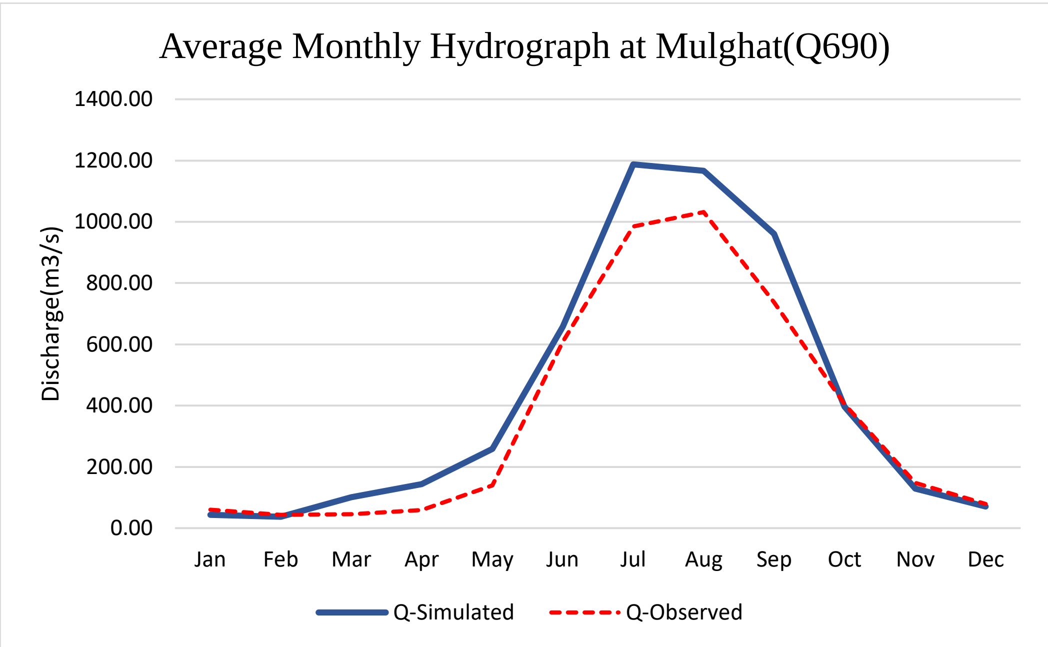

Figure 26:- Observed vs Simulated Average Monthly Hydrograph at Mulghat(Q690) during validation

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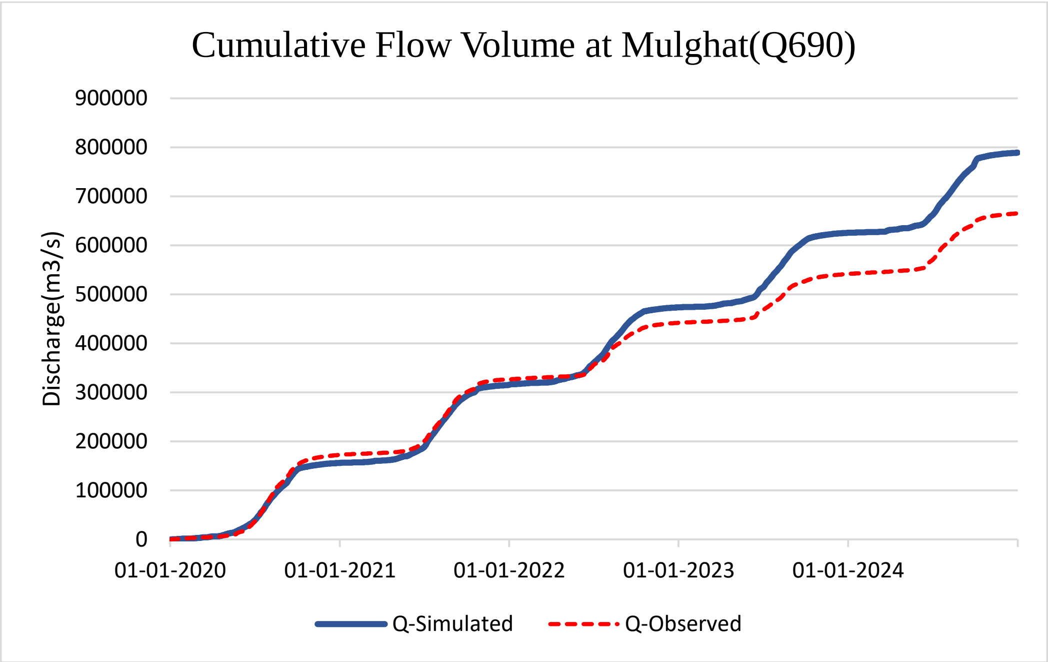

Figure 27:- Observed vs Simulated Cumulative Flow Volume at Mulghat(Q690) during validation

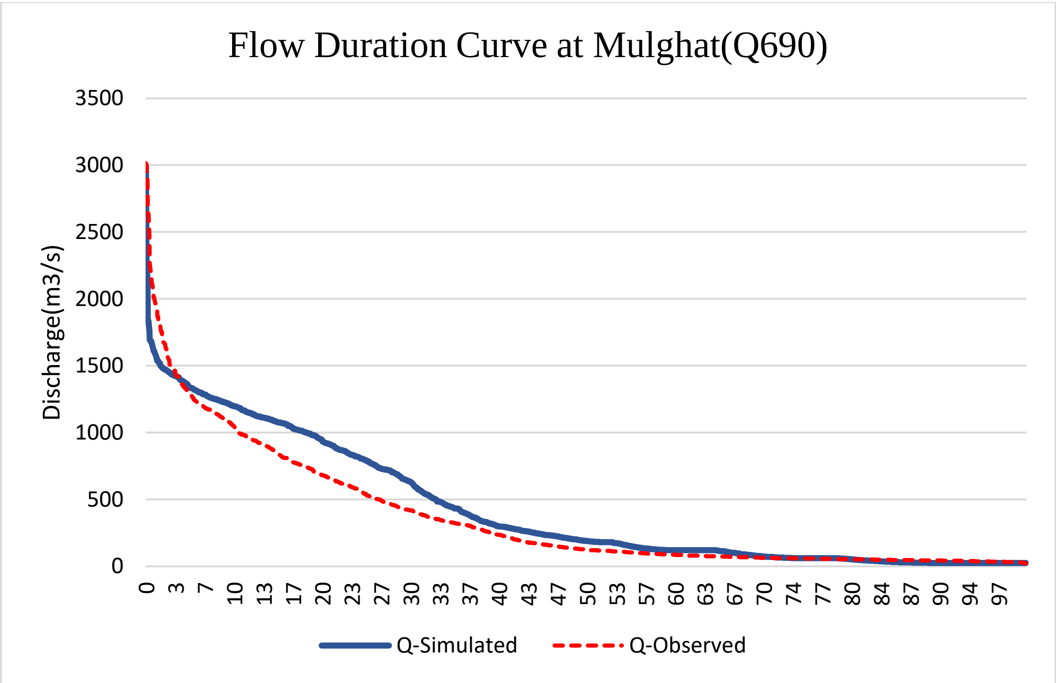

Figure 28:- Observed vs Simulated Flow Duration Curve at Mulghat(Q690) during validation

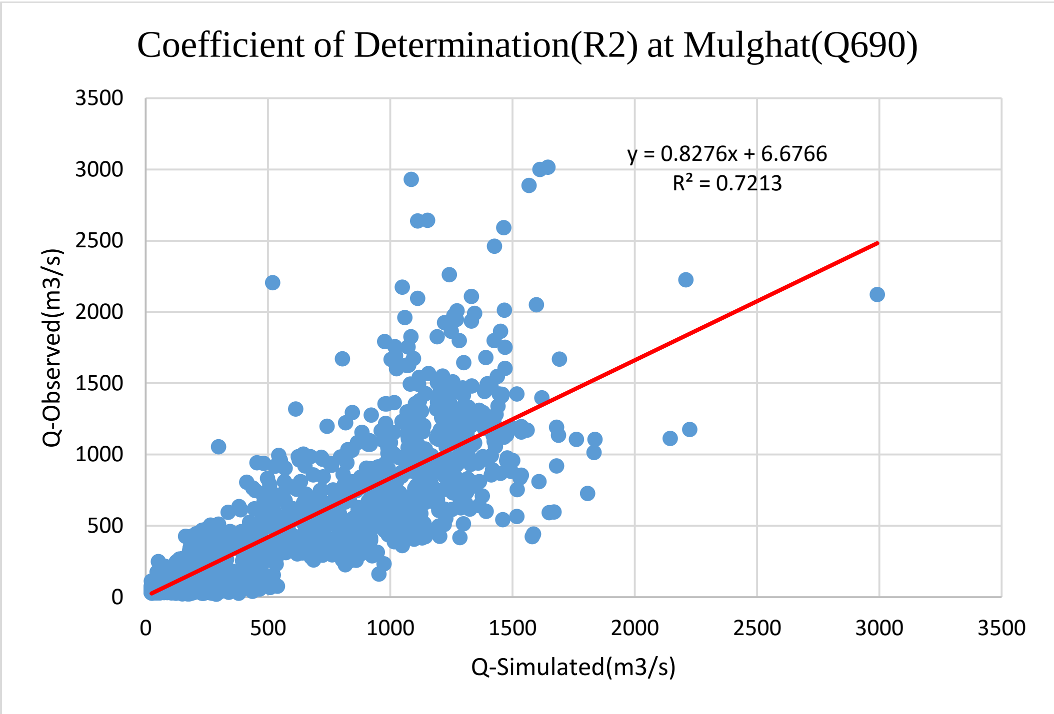

Figure 29:-Coefficient of Determination (R^2) at Mulghat(Q690) during validation

4.2 Historical hydrological characteristics of Tamor river basin

Long term average annual (2015AD-2024AD) discharge at the outlet of basin is 390.32 m^3/s and average annual volume in the river is 12309.13 MCM/year. The average monthly discharge at the basin outlet is estimated to vary from 49.42 m^3/s (in February) to 1109.57 m^3/s(in August).The average seasonal discharge in winter(December,January,February) season is 66.63 m^3/s, on pre-monsoon(March,April,May) season is 92.70 m^3/s, on monsoon(June,July,August,September) season is 910.37 m^3/s, on post monsoon(October, November) season is 269.49 m^3/s.

4.3 Projected climate change impact on hydrology

Monthly water flow variations in the SSP245 scenario could range from -27.28% in the dry season and -34.80% in the wet season in the near future(2026AD-2050AD),-27.30% to -34.60% in the mid future(2051AD-2075AD) and -29.64% to -34.48% in the far future(2076AD-2100AD).Under the SSP585 scenario, variations might range from -26.14% to -34.93% in the near future(2026AD-2050AD),-24.21% to -33.86% in the mid future(2051AD-2075AD) and -19.62% to -31.64% in the far future(2076AD-2100AD).

Table 3:- Flow variation in percentage during dry season and wet season

% Change	**SSP245**			**SSP585**		
	Near	Mid	Far	Near	Mid	Far
Dry Season (%)	-27.28	-27.30	-29.64	-26.14	-24.21	-19.62

Wet Season (%)	-34.80	-34.60	-34.48	-34.93	-33.86	-31.64

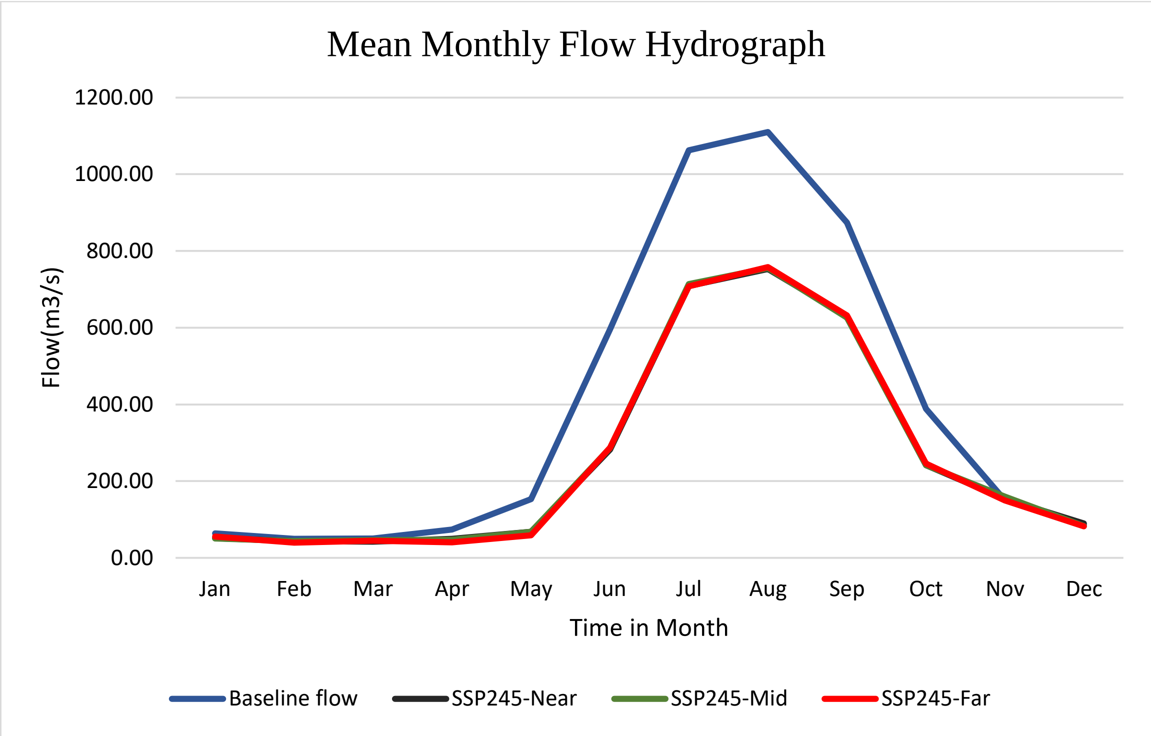

Figure 30:- Mean monthly flow hydrograph under SSP245

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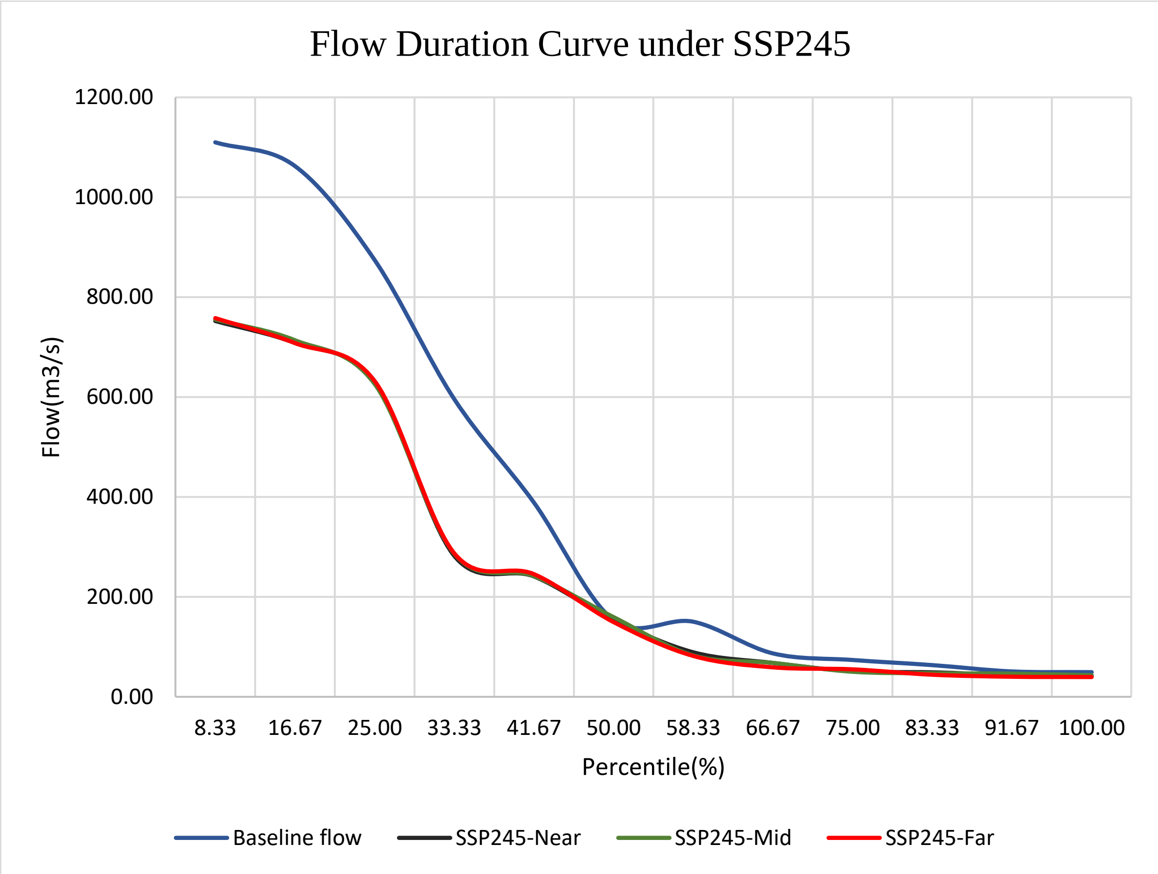

Figure 31:- Flow duration curve under SSP245

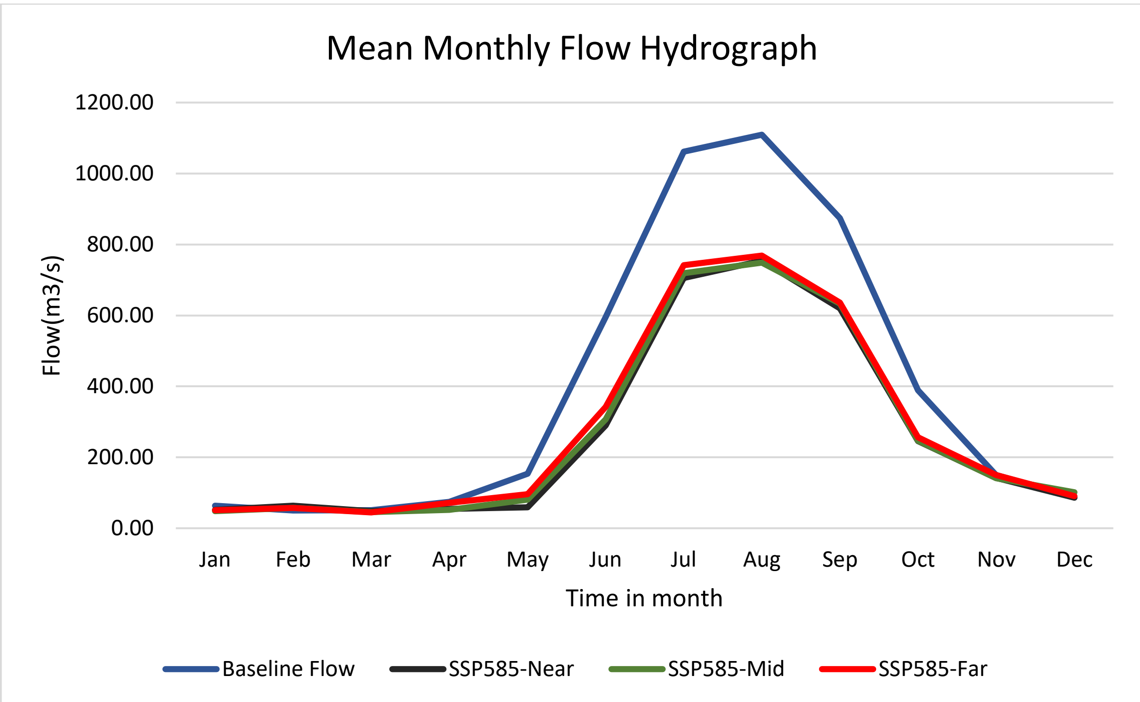

Figure 32:- Mean monthly flow hydrograph under SSP585

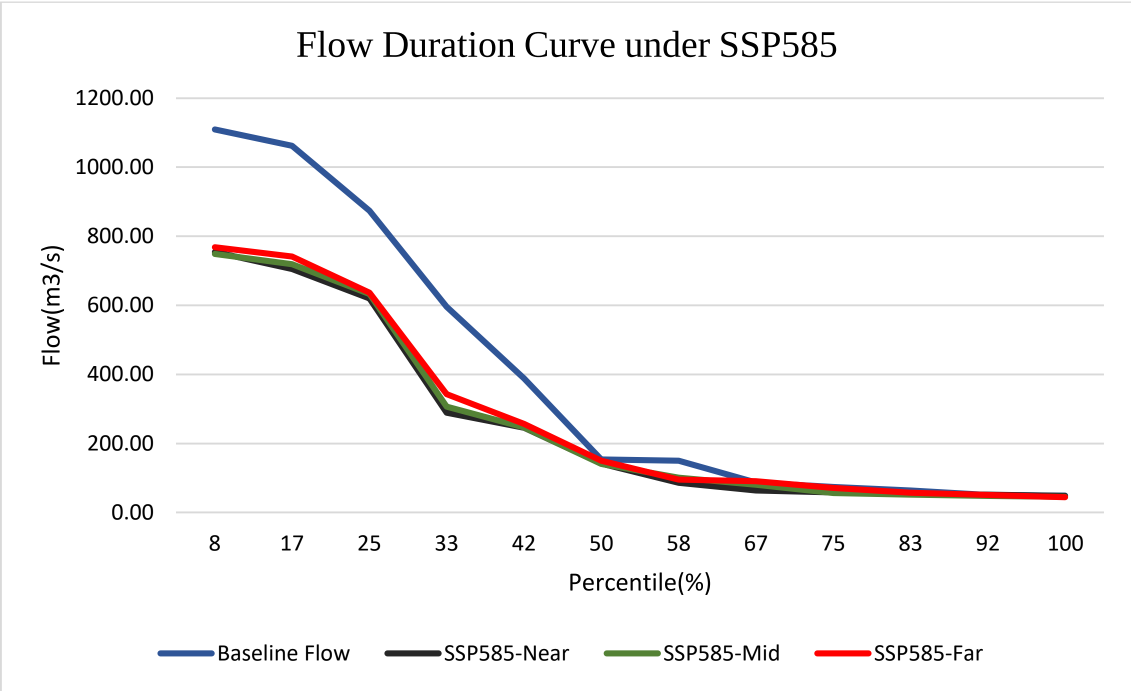

Figure 33:- Flow duration curve under SSP585

5. Conclusions

The analysis of historical hydrology revealed that the Tamor river basin is characterized by strong monsoon-driven flow regimes, with nearly 70%-80% of annual discharge occurring between June and September. During the calibration period (2015AD-2019AD), NSE is 0.778, R^2 is 0.7898 and PBIAS is -10.02% at Majhitar Station (Q684) and NSE, R^2 and PBIAS are 0.691, 0.7106 and -14.53% during validation period (2020AD-2024AD).Similarly, NSE, R2 and PBIAS are 0.756, 0.7565 and +1.82% during calibration period(2015AD-2019AD) at mulghat station(Q690)and 0.668,0.7213 and +18.61% during validation period(2020AD-2024AD). Calibration and validation of the HEC-HMS model showed satisfactory performance, confirming the model's reliability and strong capability in simulating runoff processes for the Tamor river basin.

References

1. Aryal, S., & Shrestha, A. B. (2019). Impacts of climate change on water resources in Nepal: A review. *Journal of Hydrology: Regional Studies, 23*, 100598. https://doi.org/10.1016/j.ejrh.2019.100598
2. Department of Hydrology and Meteorology (DHM). (2021). *Hydrological and meteorological data records of Nepal*. Government of Nepal, Ministry of Energy, Water Resources and Irrigation. Kathmandu, Nepal.
3. Devkota, L. P., & Gyawali, D. R. (2015). Impacts of climate change on hydrological regime and water resources management in Nepal. *Hydrology and Earth System Sciences, 19*(2), 641–654.
4. Ghimire, Y. N., & Shrestha, B. (2020). Climate change impact on hydropower generation in Nepal: A case study of Tamakoshi basin. *Hydro Nepal: Journal of Water, Energy and Environment, 27*, 15–23.
5. Gurung, D. R., & Koirala, H. L. (2018). Hydrological modeling of Himalayan catchments using HEC-HMS. *Nepal Journal of Hydrology and Meteorology, 14*(1), 1–12.

6. Hussain, A., Rasul, G., & Sabir, M. (2019). Climate change and hydropower in South Asia: Risks and opportunities. *Renewable and Sustainable Energy Reviews*, *98*, 123–135.
7. IPCC. (2021). *Climate Change 2021: The Physical Science Basis*. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press.
8. Jain, S. K., Goswami, A., & Saraf, A. K. (2017). Hydrological impacts of climate change: A review of case studies from India. *Current Science*, *113*(6), 1081–1091.
9. Kattel, D. B., & Yao, T. (2018). Recent temperature trends at high-altitude sites in the eastern Himalaya. *International Journal of Climatology*, *38*(3), 1254–1266.