Investigation of Runoff and Flooding in Urban Areas based on Hydrological Models: A Literature Review

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Abstract
Hydrological models significantly estimate water movements and their distribution at local and catchment sizes. They have been used to simulate the relative between rainfall and runoff. They enhance city planners and hydrology communities to investigate the complex relationship between precipitation and runoff in catchment and city sizes. Water movement is a vital matter, especially on the ground. This study reviews several hydrological modeling studies in different environments, including spatial analysis in the Watershed Modelling System (WMS). It seeks to consider only the most critical Hydrology and Hydraulic Modelling to investigate water in a watershed. Furthermore, this review gives a fundamental understanding of the empirical hydrology methods used to calculate runoff and a brief for 2D denominational. This review found that Hydrology Modelling is based on a) Loss Methods, b) Direct Run-off, and c) 2 Dimensional. This review concluded that the popular hydrology models applied in different environments are the Hydrologic Engineering Center-Hedrologic Modeling System (HEC-HMS) and Soil Water Assessment Tool (SWAT). Also, Hydrologic Engineering Center-River Analysis System (HEC-RAS) sites are at the top of the hydraulic water depth (1D) and water Distributed (2D) models to assess flood plans. Hydrological models became a postnatal application to understand flood risk in both gauged and ungauged catchments.

Keywords: Hydrology Modelling, Hydraulic Modelling, Runoff Volume, Ungauged Catchment, Watershed Modelling Systems

1. Introduction

In recent years, researchers have shown an increased interest in hydrology because it's a critical subject for people and the environment [1]. Hydrology models are a branch of earth science [2]; they guide water resources planning and management [3]. Furthermore, these models are widely used to enhance the discussion of water control [4]. These models are widely used as accessible tools in the subjects of water resources, engineering, and management [5]. Furthermore, most of these models can also be used to forecast and flood perdition [6]. Hydrological models are developed to manage, predict, and understand catchment water rescues [7]. Hydrologic models are essential for estimating water resources, including environmental management [8]. The goal of a hydrologic model is to conduct an analysis of the nonlinear and intricate relationship that exists between rainfall and runoff using empirical equations and a variety of parameters [9]; also, understanding to improves our knowledge in decision-making in water resource planning, and water movements on the surface and into the ground [10].

Furthermore, there has been a dramatic increase in hydrology and hydraulic modeling in humid and arid zones, which have been used to understand the impacts of some factors to generate Run-off [11] and water distribution. The application of hydrology and hydraulic models in environmental studies has been increased. Hydrologic models have become a vital tool for analysis of the impact of modern anthropogenic factors on hydrologic regimes [12]. Also, they are essential to investigations and estimates of the effect of land use (LU) and land cover (LC) on runoff and flood inundation [13] and analysis of the impacts of their activities on runoff [14]. Hydrological watershed studies pay much attention to surface runoff in a watershed because most hydrological processes are directly or indirectly influenced by it [15].

The hydrologic model aims to predict stream features and peak discharge, and its application has improved since RS data was developed [16]. Calculating and estimating runoff is the primary task in hydrology studies [17]. The application of hydrology models has value in improving city and urbanization catchment to reduce flood risk. Data access makes these models available in most developed nations [18]. Most of the hydrology data is absent in developing countries, especially those related to observation [19].

Therefore, Remote Sensing (RS) data enhancement extraction of flood inundation areas can be used to simulate flooding through integration with hydrology models. According to Sayama et al [20] hydrology models can simulate flood characteristics based on RS data. Wilson, Mitasova, and Wright [21] stated that with the fast improvement of WMS, geographic data frameworks and RSs have assumed a central role in building up these hydrological models. RS domain has improved the accessibility of information, and Geographical Information System (GIS) is an integral asset that forms a few sorts of information. Besides, WMS and its integration with

GIS and RS can improve the more explicit estimation of water management at small and catchment sizes.

RS data enhancement estimates floods and inundation areas. These models also investigate the impacts of human activities on runoff [22]. Also, Hydrological models have been improved since RS and GIS logarithms were developed [23]. Thus, RS technique and computing improvements leave out vital information about hydrological processes that generate runoff and hydrology celebration [24]. This review gives a brief fundamental of theoretical hydrology modeling based on Geographical background. To be able approaches to the article's purpose is divided into four sections: General Hydrological classification, description of some of the majority models, Application of Hydrology and Hydraulic Models, and implication of these models in ungauged catchments.

2. Methodology

Hydrology and hydraulic models have been developed to assess and simulate water movement. These models have been established as engineering models to solve water movement from this time rainfall runs and are distributed on the surface, subsurface, and ground. The study aims to explore the application of hydrology models and their application. So, this paper reviews many published articles based on a) Google Scholar. B) SCOPUS. So, research focused on the terms "hydrology modeling," "runoff models," "hydrodynamic model," "ungauged-catchment," and "ungauged-Basin." So, this paper focused only on these terms. In addition, this paper extracted massive articles related to hydrology and hydraulic models to investigate their application in different environmental conditions. Also, snowball methods have been adapted to cite articles from others.

3. Classifications / Theoretical Hydrological Models

Hydrology models have been established for water source management, and their application started in the middle of the 19th century with rational methods to estimate the relationships between rainfall and runoff [1]. In the last few years, primarily in the water resources domain, there has been a dramatic increase in the number of populated urban areas globally. This increase led to more demand for water resources and urbanised lands. On the other hand, environmental modeling became necessary to understand this dynamic. Hydrological models give a disentangled numerical portrayal of the hydrology framework [25]. They are intended to show surface stream conveyed and sub-surface procedures and include primary devices for controlling and overseeing water assets.

Hydrological models are regularly utilised because of the impediments of hydrology estimation methods. Likewise, hydrology models may appropriately expand our comprehension of streamflow recurrence water. The movement of flood waters through the landscape can be approximated using many other methods and modeling. Hydrology is one of the most significant environmental models used to estimate a catchment's runoff volume and peak discharge. Thus, it is also used widely in different environmental conditions, such as humidity and drylands [26]. However, hydrology modeling has likely been applied for more than 165 years for various purposes. For example, in rural to urban areas, land change typically results in increased erosive processes, storm runoff quantity, and discharges in a catchment, and travel time is affected by surface soil [27].

Thus, practically all modeling has been created for applications in damp territories [28]. Precipitation Runoff Modelling covers a broad scope of uses and practices. This can be separated into two primary gatherings: I) flood examines (arranging and planning another pressure-driven structure, working and assessing existing water-driven structures, getting ready for and reacting to flood harm decrease, and controlling floodplain exercises), and II) stockpiling considers (catchment and store yield investigation, and water asset potential [29].

The hydrology model has been classified into three majority groups depending on special resolution: Lumped, Semi-Distributed, and Distributed, and they also can simulate any runoff in the catchment boundary Jajarmizadeh, Harun [30] and integrated with land use change models to simulate runoff [12]. Also, it is classified into two main categories: A) model structure, empirical Modell, Conceptual Modell, and Physical Modell. B) processing special resolution, for example, a) Lumped Model, b) Semi-Distributed Model, and c) Distributed Model [31

However, the application of hydrology and the domain of these models are surfaces, urbanization hydrology, and groundwater, and the quality of preference of any hydrology model consists of the availability of data and its accuracy [30]. The hydrology models are classified based on previous categories as shown in Figure 1. So, determining which model is used and applied undoubtedly involves studying the aim. Abdulkareem et al., [4] stated that the review paper investigated the application of hydrology modeling in Malaysia during 2007-20018. They found that 65% used the physical model, 37% applied the empirical model, and 6% used conceptual models. The above table illustrates hydrology model types based on both methods and resolution.

4. Brive and Descriptive of a Few Models

In recent years, there has been an increase in urbanization areas worldwide, both in developing nations and developed countries. The expansion has an advantage in human lives, such as modern housing life, but also a disadvantage in the environment and ecosystems, including air population and decreased natural ground cover and hydrology matters. This review investigates the application of hydrology models based on special resolution, which are lumped, seem distributed, and distributed models.

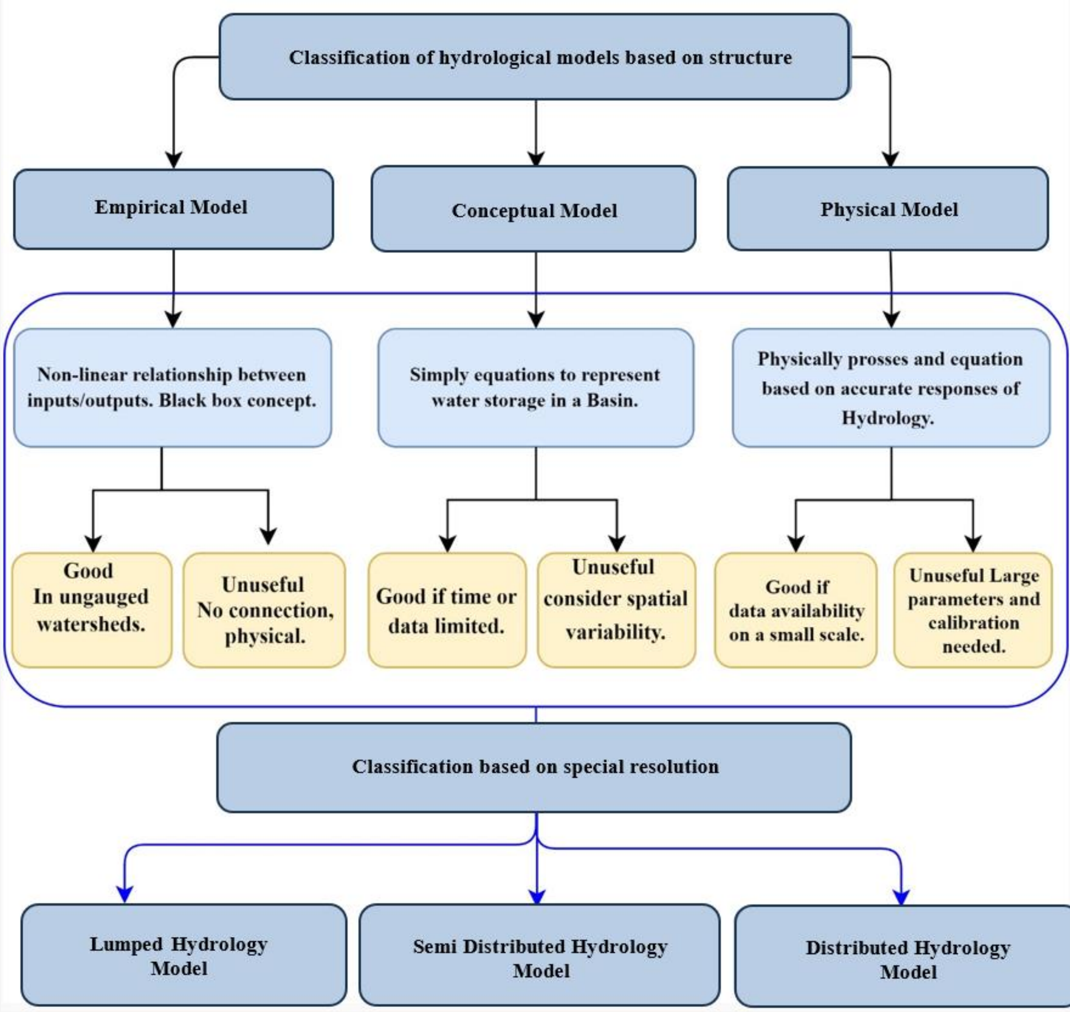

Figure 1: Application of Hydrology/Hydraulic Models Devia et al., [1] and Sitterson et al., [31]

4.1 Hydrological Engineering Centre-Hydrology Modelling System Model (HEC-HMS)

The US Army Corps of Engineers Hydrology developed the HEC-HMS. The model is intended to simulate precipitation runoff in watershed systems. The system can model various geographical areas, including large river catchments and small urban or natural watersheds [32]. Furthermore, the model has been widely applied to simulate and forecast stream flows for humid, topography, and arid watersheds [33]. Also, Gumindoga et al., [34] used HEC-HMS to simulate runoff at ten ungauged catchments in Zimbabwe. This study involved the transfer method from measured to ungauged catchments by Snyder methods. Furthermore, they concluded the suitability of applying HEC-HMS with micro sub-catchments to the runoff model. Yilma & Kebede [35] modeled runoff at the Dabus Subbasin, Blue Nile Basin, Ethiopia, based on HEC-HMS, and this study concluded that this model has value in simulating runoff in catchments facing a shortage in hydrology data. Ramli et al.,[36] have found that this model can be applied in both gauged and ungauged catchments.

The system data describes the watershed area in the basin model. Data for precipitation and evapotranspiration, which are required to simulate watershed processes, are stored in the meteorological model. In contrast, HEC-HMS can model infiltrations from the land's surface, but the system cannot model storage and water movements vertically within the soil layer. Instead, it combines the near-surface and overland flow and models it as a direct runoff [37]. As LU changed, Szwagrzyk et al., [38] analyzed that LU changes impact flood risk in the Ropa river basin, a 1000 km^2 area in Poland. Based on the SCS-CN method and application of the HEC-HMS model, they established different scenarios for future LU on flood risk and concluded that flood risk would increase. The HEC-HMS has been applied in different environmental locations to investigate the impacts of climate change and LU and LC in runoff and peak discharge. Therefore, the HEC-HMS model is classified as one of the vital hydrology models to estimate UH in the catchment. Abdulkareem et al., [4] argued that most Malaysian hydrology studies were published from 2007 to 2018. Model auto and manual calibration are better in HEC-HMS [39].

4.2 Soil and Water Assessment Tools SWAT

SWAT has been used widely in many environmental conditions. This model was initially developed to assist the United States Department of Agriculture (USDA) and the Agriculture Research Service (ARS) in their research [40]. The SWAT can estimate and compute runoff based on two essential methods: Soil Conversation Surface- Curve Number (SCS-CN) and Green Ampat (GA) [41]. Shafiei et al., [42] applied the SWAT model in Northwest Iran in the Maroon Basin (3801 km^2) to investigate LU development in the runoff. This study stated that runoff increased during the last forty years from 1970 to 2010 due to catchment changes and loss of vegetation. Also, the SWAT model analyzes the Impact of LU change in runoff at the Chennai Rahdar watershed, Southwest Iran [43]. Yamamoto et al., [44] investigated that runoff based on two hydrology methods based on SWAT models, such as SCS-CN and GA, were implemented at the Batanghari River basin in western Indonesia to evaluate the impacts of LU in hydrology. So, they found the difference in the runoff simulation under similar data.

This model has also been used to analyze the impacts of human activities such as LU on runoff. Tan et al., [45] Investigated LU change and Climate change for the hydrology regime at Johor River Basin (JRB), Malaysia; this study applied the SWAT model. Also, Aghakhani et al., [15] investigated the effect of LU in runoff at the Taloqan basin in Iran. This study suggested some scenarios to evaluate LU management in runoff based on the SWAT model. Therefore, this study focuses on applying the SWAT model to LU management. Tabassum [46] used the SWAT hydrology model to investigate how LU impacts the hydrology regime in Bloomington, Indiana. So, this study found that LU had a critical impact on runoff.

So, investigated LU impacts, especially in runoff and sub-surface water, can be simulated in SWAT. For example, Aga [47] examined anthropogenic effects in the basin of Gilgal Abay in Ethiopia, and this study found that climate change affects the amount of runoff. Kavian et al., [48] argued that LU development at Haraz River had increased runoff. This study was carried out in most Iranian basins. They suggested that, based on some scenarios, LU management should reduce runoff. Jodar et al., [49] evaluated the impacts of LU change in five Espin watersheds. They found that the increasing urban growth in this catchment affected soil quality and reduced its infiltration, and CN has increased from 85 to 90 due to the catchment urbanization, which covered 70% of these basins. Khadka et al., [50] have modeled the impacts of climate change and LU change in Mun River, Thailand, based on SWAT, and they found that runoff increases with development areas.

4.3 Hydraulic Model 1 D and 2D (HEC-RAS) Application

One-dimensional hydrodynamics are broadly applied for contemplating flood levels and releases in-stream frameworks. HEC-RAS is an essential hydraulic model used to understand depth and water distribution on the ground. As straightforward hydrological steering strategies, 1D and 2D hydrodynamic models consider rapidly assessing dispersed water levels and releases in dendritic and arranged stream frameworks, considering impacts, for example, backwater, a shift in weather conditions, and dissemination [51].

In water-distributed one- and two-dimensional models, hydrodynamics is regularly parameterized through a progression of cross-areas of the channel opposite to the stream course and floodplain geography, which can be obtained from a ground study at a sensible expense. Two-dimensional models consider stream bearings in both flatways, permitting estimation of progressively point-by-point water levels along the waterway [53]. This brings about better expectations of potential flooding and volumes of water leaving the virtual waterway channel. Furthermore, the water leaving the main track can be steered through the levees or overbank, dependent on the stream course, and alters to the stream course.

Since RS data enhancement, the HEC-RAS 2D has been applied to estimate the inundation area. The primary input data are the DEM, rainfall data, and boundary conditions [54]. Utilisations of such models to normal waterway floodplains have shifted in scale, both as far as the length of the stream arrived at the spatial goals of the model work or advanced rise model (DEM) used to speak to the channel and floodplain geology. Consequently, it has become mainstream in flood displaying, particularly in a perplexing geology floodplain region. An estimated water depth in an urban area should be done using a 1D / 2D model to get water depth and establish flood map risk.

Thus, Huţanu et al.,[55] found that integrating hydrology models, enhancement of RS data, and GIS increased the accuracy of the suitability of flood risk, so they applied the HEC-RAS model to stimulate urban flooding in Jijla, Romania. This study used DEM high resolution 0.5 M derived from LiDAR data. Mawasha and Britz [56] estimated that flood depth at the Alexandra Township, South Africa, based on the HEC-RAS model, and found that flood depth increased from 2.3m in 1987 to 3m in 2015 due to LU change along the Jukskei River. Muthusamy et al., [54] estimated urban flooding using HEC-RAS, and they compared the outcome of modeling with the extent of water depth, the effect of the fluvial flooding, and the combined effect of both fluvial and pluvial flooding. Gholami [57] investigated the flood in the Hyrcanian forests of northern Iran based on HEC-RAS, and he calibrated the hydraulic model based on making flood depth in the field.

5. Watershed Modelling System (WMS)

Hydrological models give a streamlined scientific portrayal of the hydrology framework, are intended to show surface stream and groundwater forms, and involve fundamental instruments for controlling and overseeing water assets [58]. WMS has been established based on two significant subjects: GIS and hydrology, recognizing watershed information and supporting hydrology processing [59]. With increasing computer technology, the performance of hydrology modeling is becoming more accurate and significant [21].

Hydrology models may expand our comprehension of streamflow recurrence. Also, most of the hydrology data is prepared using WMS, including a) catchment parameters and boundaries and b) running its data through an interface of this software. WMS was established to analyze watersheds and is the critical tool for running hydrology data and transferring massive amounts of information in GIS format [60]. Thus, many aspects should be considered before choosing any hydrological modeling. Therefore, there are various benefits to implementing WMS in hydrologic studies. According to Ritzema [58], WMS has been developed to enhance watershed and drainage analysis and hydrological management. So. The first step in each hydrology project is to determine the catchment boundary. This process usually consists of DEM quality, which can generally be extracted in WMS to identify catchment boundaries.

After extracting catchment boundaries, computing morphological and morphometrical catchment areas is significant information to analyze and evaluate area study, which became available and more accessible in the WMS model. Catchment characteristics are critical elements in hydrology studies for modeling runoff and inundation lands; these characteristics, such as geomorphological and morphometrical characteristics, are the backbone of hydrology and catchment management, and WMS has a powerful preference for analyzing catchment features. After extracting the basin boundary, this software has many verities, such as preparing data to run in many hydrological subjects. Figure 2 illustrates the application of WMS in many hydrology subjects. WMS is a critical model for analyzing watersheds and preparing data for the GIS program.

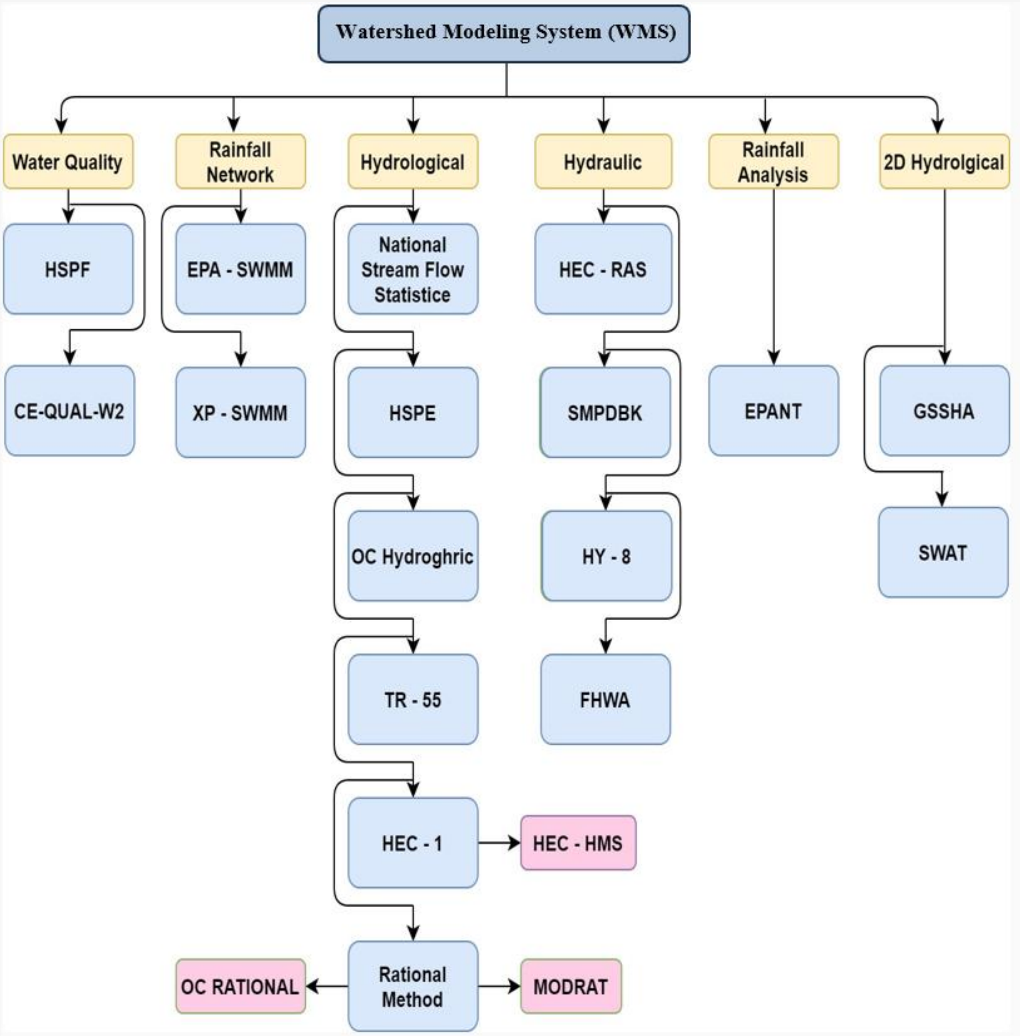

Figure 2: Hydrology classification in WMS Abdulkarim [61]

Hydrology and hydraulic models are established for water movement, runoff, and inundation [2]. Undoubtedly, many factors, including soil hydrology groups, LU, LC, elevation, geomorphology, and rainfall, are the most input data to evaluate these models. Hydrological parameters and catchment boundaries, including their morphometric and geometric dimensions, can be determined by applying WMS. This model has been used in many catchments, such as Khan et al., [62], which investigated catchment characters at Abha, Saudi Arabia. So, they applied WMS to estimate catchment parameters. Hosseini et al., [63] used WMS to simulate runoff in the Khuzestan Catchment, Iran. Also, Saudi Arabia modeled the Jeddah flooding in 2009 by applying WMS River tools to construct the HEC-RAS flow model.

6. Application of Hydrology and Hydraulic Models

Hydrology and hydraulic models have been incredibly applicable in many environmental studies. They are used widely in the water cycle and their movement on or in the ground. Hydrology models are critical for understanding water problems in surface and sub-surface domains [64]. Also, it estimates basin hydrology response to rainfall and LU impacts in hydrology regimes [4]. In addition, hydrology models are used to investigate the effects of climate change on runoff and peak discharge Yang et al., [65]; also established to estimate runoff: a) Runoff Volume, b) Direct Run-off, c) Base Flow, and d) Channel Flow [66]. Hydrology models use many approaches to simulate and extract unit hydrographs. Estimating runoff and flood at any catchment level and condition can be computed using various models depending on the study aim and quality data.

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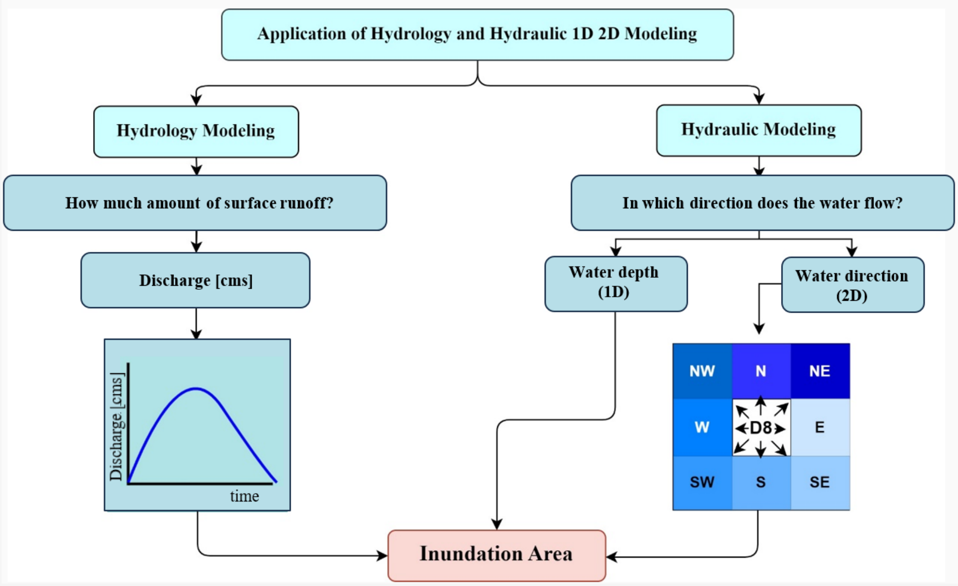

Figure 3: Application of Hydrology/Hydraulic Models Raghunath [2] Chow et al., [52]and Feldman [70]

So, the hydrology model can also be applicable in different environmental situations, such as arid, semi-arid, and humid zones [27]. Flooding and inundation can also be simulated using hydraulic models based on 1D water depth and 2D water distribution [53]. So, after a runoff, water can sometimes be flooded due to extreme weather, climate change, and the development of LULC changes [67]. Furthermore, these models increase hydrology and catchment planer to understand water management [68]. The hydrology model's essential domain is understanding and predicting water movements in catchment levels [69]. Figure 3 illustrates these applications for hydrology and hydraulic models, including peak dishrag and flow direction.

After perception runoff, water will move on a surface depending on the slope degree in each land part, gravity, water capacity, and morphology, and usually, the answer is, in which direction does the water flow and flow direction. Hydraulic modeling has become a utilised apparatus for concentrating on water-powered and ecological science and designing as often as possible. A broad scope of hydrodynamic displaying types is accessible today, and this ranges from sensibly basic pressure-driven (Water DI-D models to complex 2-D models, considering stream bearings. Water depth and velocity have become vital simulations of 2D [70], and inundation maps [71]. Most of the hydrodynamic flood models support 1D and 2D flood flow modeling.

The 1D model assumed that the flood flow is in the stream-wise direction (direction of the flow) of the channel, and the geometry is represented by cross-sections (lines) of the track, which can be automatically extracted from DTM. Each model type has different characteristics (assumptions, input parameters, and output). The roughness properties of the route can be described as points on the cross-section lines (one value per cross-section), and the computation process estimates the average velocity and floodwater depth at each cross-section. Finally, the surface water profile is compared with an elevation of channel banks (left and right). The 1D model is numerically stable and computationally efficient but cannot accurately model complex topography. Flood extent and depth, regardless of the source of the flooding, are almost always predicted from numerical modeling [54].

The application of hydrology models involves the relationship between water, soil, climate, and LU. Hydrology models can also be applied to investigate water movement in any catchment characters, including their geomorphology and morphometrics. The rational method is the most popular method used in hydrology due to its simplified runoff analysis, which was established to assess runoff in a small catchment [72]. Applying these models' enhancement understanding to answer most hydrological questions: how much water a runoff Discharge in m3/s will be, and in which direction does the water flow.

The first question, especially for hydrology modeling and the need to determine which strategies are helpful to apply from four main groups of computation processes, which are a) Excess rainfall (or runoff volume) computation, b) Direct runoff computation, c) Baseflow computation, and e) final one is channel flow routing computation. However, each computation process has several methods of calculation. The second question involves using 1D/2D and discussing water depth and distribution. Furthermore, information many guidebooks are published by [73].

Hydrology models estimate runoff from perception, which refers to channel water movements. Therefore, those models are essential to simulate the impacts of many factors, such as land use/cover in runoff and peak discharge. Furthermore, the application of the hydrology model still needs more improvement, especially in the arid zone, due to data limitations [74]. Unit Hydrograph as shown in Figure 4 (UH) is a substantial value in a catchment that shows a peak discharge using hydrology models [2]. So, peak discharge is vital in hydrology studies to determine and predict flood depth [63]. The UH is how peak discharge affects soil groups, LU, LC, rainfall, and geology [75]. Also, UH has many shapes and curves and differs from arid to humid zones. Hydrology models can be applied to simulate runoff, predict flood features based on UH, and investigate the impacts of LU and human activities to reduce the quality of the catchment area [13]. Also, they can be used to model runoff in many environment locations, including arid, same-arid, and humid zones. UH is also necessary for various hydrology studies, such as estimating flood and flood risk [76]. For example, Raghunath [2] observed that the peak curve of UH comes earlier in a dry zone, but in a humid location, it appears in the middle of the curve.

The above charts have been observed from massive review papers results. As we also see, in a short time of rainfall, the peak discharge occurs in a short time, such as flash flooding; on the other hand, in a humid zone, the peak discharge seems to be a standard curve. The difference between them may involve Soil condition and its physical. Chathuranika et al., [77] argued that observation data at the Mekong River watershed in northeastern Thailand differed between the wet and dry seasons. This study estimated runoff based on two hydrology models, SWAT and HEC-HMS.

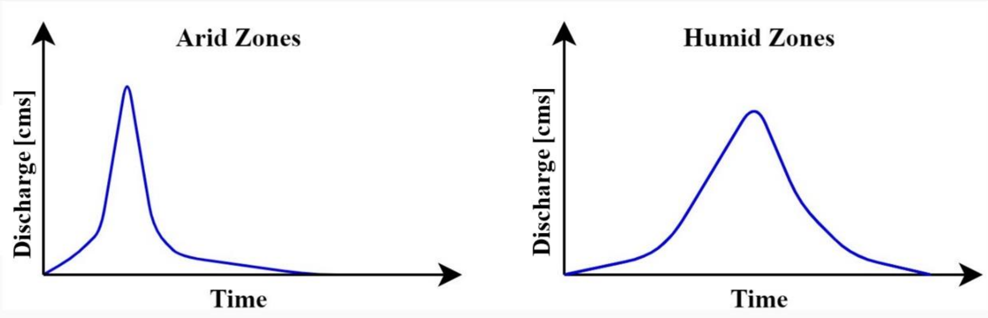

Figure 4: Unit Hydrograph in different environmental conditions Sen [78]

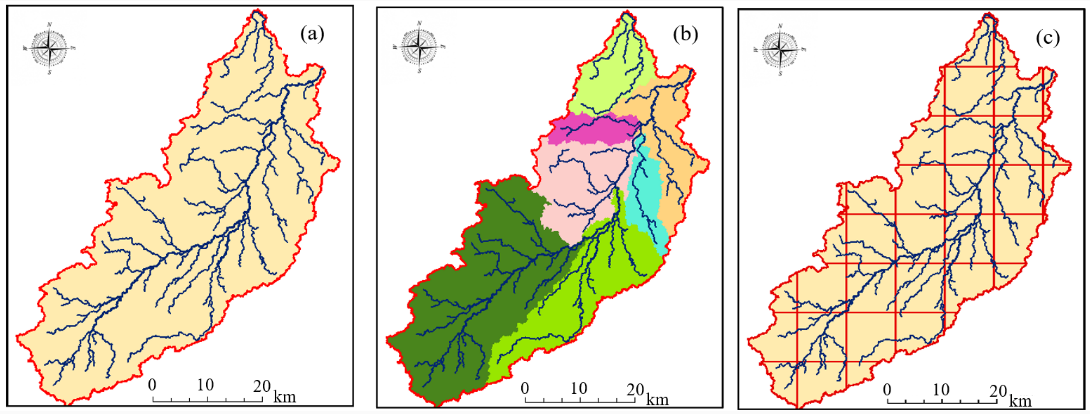

Figure 5: Hydrological Model-based Resolution. Ha'il City Catchment Saudi Arabia Alzamil (a) Lumped (b) Semi Distributed (c) Distributed model [79]

Hence, Figure 5 shows the primary Hydrology model based on data input (LU, Rainfall Record, Topography, Soil Types) into three Modell A- Lumped, B- Semi Distributed, and C-distributed models. In addition, these models can be applied based on three resolutions, including a) Lumped. b) Semi Distributed. c) Distributed model.

In addition, the hydrology model enhances knowledge about runoff, peak discharge, and flooding at any catchment characters. It would be great to run data in different hydrology models to increase hydrologists' determination using two or more models. For example, Aliye et al., [51] Also compared the preference of two hydrology models, SWAT and HEC-HMS, in the Katar Basin, Ethiopia, to simulate runoff. So, they concluded that HEC-HMS was more predictive in this area with the performance value. Sith and Nadaoka compared the performance of both GSSHA and SWAT to predict streamflow and suspended sedimented concentration. This study took place in a small agricultural watershed in Japan; it also found that both models have advantages in simulating that flood, but in considerable time, SWAT is better than GSSHA.

Therefore, on a large scale, such as a catchment, the Lumped model is a practical application of runoff; on the other hand, on a small scale, a city-size Distributed model gives a high result. Applying a hydrology model based on some methods is the best way to analyze LU and LC impacts on runoff and peak discharge [80]. They are a valuable model for investigating LU and LC and their runoff change. Hydrology models have been used to estimate and predict water movement on the surface and subsurface of the earth and its impacts on a) LU development on water resources [81], b) LU development on climate change [82], and c) LU on water distributed [83] estimating runoff at a catchment scale faces many challenges depending on factors such as the identity of LU, topography, and LC [84].

Hydrology studies on a large scale, such as catchment, become available to simulate runoff and flooding using integrated GIS and hydrology models such as HEC-HMS and HEC-RAS. Hydrology similitude to runoff at The San Antonio River Basin (about 4000 square miles, 10,000 km2) in Central Texas, USA [85]. Therefore, hydrology models can also be applied in gauged and ungauged catchments to simulate runoff and flood management [6]. Many methods and models can be used to study water movement at small and large catchment sizes determined by topography, geology, and vegetation cover [52].

7. Ungauged Catchments

Runoff prediction is a crucial yet challenging task in surface hydrology. This is especially important in headwater basins since these areas are typically the primary water supply for their respective regions. An accurate runoff prediction is essential for successful water management for human life, agriculture, industry, and the environment and for developing infrastructure [86]. Therefore, studying runoff at ungauged catchments increased dramatically a few years ago in different journals [87]. Throughout the world, unengaged catchments exist where direct stream flow data monitoring is unavailable.

Most catchments worldwide are ungauged, and observation hydrology data is missing [88]. Furthermore, estimation catchments, parameters, and evaluation are enhanced knowledge to understand a flow character in an ungauged basin [89]. Understanding catchment system characteristics, including hydrological processes, would be improved and increase our knowledge of the management of water resources, including (a) topographical conditions of the catchments, (b) degree of urbanization, (b) scales or shapes of basins, (c) total amounts of rainfall and rainfall duration in upstream and mountainous areas, (d) ranges of soil permeability on the river channels, (e) variation of runoff features in wadi basins, and (f) scarcity of data and limitation of methods for flash floods forecasting [90]. Thus, in gauged basins, the standard method of calibration, classical calibration, must rely on based on outdated or unreliable hydrological and precipitation records, separated geographically or temporally from one another. Celebrating a hydrological model at the ungauged watershed can be implemented with many data sources and methods [91]. Ungauged catchments are distributed worldwide in dry and humid environments [88]. For example, the catchment of the Imjin is extended between North and South Korea, classified as one the most critical basins in Korea, and management of flood there is hard to do due to the limitation and sharing of hydrology data between North and South Korea [92]. In Russia, a large country in Asia, nearly 2.6 million streams are still recorded as ungauged or poorly observed data [93], and they developed a hydrology model Multi-Layer Conceptual Model, 3rd generation) (MLCM3) by the Russian State Hydrometeorological University. This model devolved for ungauged Russian catchments. Zhang et al.,[86] simulated runoff at 222 ungauged catchments in different Australian regions based on two lumped models using the genetic algorithm global to optimize 14 parameters in the Xinjiang model and the nine parameters in the SIMHYD model.

Despite the shortage of observation data, many methods apply to model celebration, such as physical models and data-driven approaches. In the first method, water is simulated from rainfall to runoff, and the second method is used for statistical relationships between independent and dependent variables. Hydrology parameters can be done using many forms, such as transfer from gauged to ungauged data Bárdossy [6] and driving data, such as statistics in ungauged catchments [91]. In hydrology studies, transfer parameters to ungauged data can be accepted for similar catchment caricatures [94. Flood frequency can be helpful for flood modeling due to the lack of rainfall observation and water discharged at ungauged catchments [95]. So, Chiew et al., [96] investigated runoff modeling in 780 engaged Australian catchments. They found that flow medium and high flows have significant results in model celebration, but low flows have uncertain outcomes. In an ungauged catchment, many methods should be implemented to evaluate and celebrate the hydrology model, such as Mapping floods through RS-applicable data, which helps calibrate and validate hydrology models and improve understood management, especially in ungauged catchments [97]. Furthermore, RS images can be used to support model calibration in ungauged catchments using water boundaries. To improve the Hydrology model celebration [98] argued that serious Landsat images are alternative data to observe floods from space and enhance the hydrologist community for their model's celebration. The most common changes for modeling runoff in ungauged catchments are soil types and land management [99].

Modify and adjust observation data one of these solutions to celebrate the hydrology model. Zanial et al., [100] argued that due to the limitation of hydrology data, adjustment observation data is better to celebrate the hydrology model in the ungauged catchment. Kannan et al., [101] estimated that and modeled runoff in the large catchment in the USA, including the entire Mississippi and Atchafalaya River Basin. The most significant study challenge was the availability of data to calibrate and validate hydrology models and topography characters. Also, Demisse et al., [102] estimated runoff at Omo-Gibe, Ethiopia, based on HEC-HMS; this study used catchment information from the gauged and ungauged surface of the catchment. HEC-HMS can predict runoff at ungauged catchments [7].

On the other hand, Ungauged catchments are facing the absence of observation hydrology data distributed in both developed and developing nations worldwide. Observation data is used to determine accurate hydrology simulation. In an ungauged basin with a shortage of hydrology data, the best method to simulate runoff is using two or more hydrology models, especially in countries in arid and similar arid zones [103]. They implemented two approaches to simulate runoff: transfer information from the nearest catchment gauge and regional location. Hydrological models also became important methods to estimate and investigate water resources and their cycle in different environmental conditions in local and catchment sizes.

Hrachowitz et al., [91] argued that the lack of observation data at ungauged catchments sets out the critical subject in hydrology studies, making runoff modeling hard to expect. Thus, in some cases, driven data methods are another solution to a celebration of hydrology models. These methods would increase the prediction and celebration of hydrology models. Also, integrating GIS and RS has improved knowledge of simulation and extraction of hydrological parameters, and it became an alternative method and tool in hydrology studies due to missing observation data resulting from some significant factors such as optimizing of simulated output hydrology model with critical ground data, massive hydrology studies are carried out in different environmental conditions around the world. So, this review has extracted some of the thesis's studies listed in Table 1. Furthermore, most methods and techniques used in these studies are hydrological models, GIS, and RS, which would be great to flow up any methods, especially in ungauged catchments at different levels and conditions. As we have read in the previous section, hydrology studies aim to consider water movements on the ground based on gravity and infiltration of water. Observation data is to be attributed to significant field information calculated in m3s to understand the water capacity at the outlet point for the catchment level. The following table shows some studies carried out at ungauged catchments.

8. Conclusion

Summary This article investigates the application of hydrology modeling in both runoff and flooding. Hydrology models became the most significant for the analysis of runoff and flooding. Hydrology models are widely implemented in water sources, and their risks are investigated. Water source management, including urban area hydrology and human activities, is also applicable to the hydrology model. Implementing GIS and RS associated with the hydrology model has an advantage and critical simulation and prediction of runoff and flooding.

Table 1: Summarize some of the Hydrology studies carried out in ungauged and gauged catchments in different environmental conditions

Study and References	Modeling Aims			Model	Environment			Basin		Catchment location Country
	R	L	E		A	S	H	U	G	
Koneti et al., [8]	•	√	•	HEC-HMS	•	•	√	•	√	Godavari. India
Aghakhani et al.,[15]	•	√	•	SWAT	•	√	•	•	√	Taleqan, Iran
Gumindoga et al.,[34]	√	•	•	HEC-HMS	•	•	√	√	√	Zimbabwe
Jodar et al., [49	•	√	•	SWAT	•	√	•	√	•	SE.Spain.
Gholami [57]	√	•	•	HEC-RAS	•	√	•	√	•	Hyrcanian, North Iran
Zhang et al.,[86]	√	•	•	Xinanjiang.SIMHYD	•	√	√	√	•	Australia
Msilini et al [92]	√	•	•	RFA*1	•	•	√	√	•	11 Catchments. Canda
Sokolova et al.,[93]	√	•	•	MLCM3	•	•	√	√	•	50 Basins. Russa
Sisay et al., [94]	√	•	•	SWAT	•	•	√	√	•	Thien Hue. Vietnam
Pool et al., [104]	√	•	•	HBV	•	√	•	√	•	East. The USA
Nepal et al., [105]	√	•	•	J2000	•	√	•	√	•	Nepal
Kim et al., [106]	√	•	•	GR4J	•	√	•	√	•	S. Korea.
Zhang et al.,[107]	√	•	•	Disturbed	•	•	√	√	√	The. The UK
Derdour et al.,[108]	√	•	•	HEC-HMS	√	•	•	√	•	SW. Algeria
Bisri et al., [109]	•	√	•	Kineros	•	•	√	√	•	E.Java Indonesia
Al-Salamah et al., [110]	√	•	•	GIUH.DEM	•	√	•	√	•	Kala.Chitta. Pakistan
Papaioannou et al.,[111]	√	•	•	HEC-RAS	•	√	•	√	•	Xerias Basin, Greece.
Rabba et al., [112]	√	•	•	Disturbed	•	•	√	√		S.Africa&Ethopia.
Yang et al.,[113]	√	•	•	WASMOD	•	•	√	√	•	Norway
Lee et al., [114]*2	√	•	•	PDM	•	•	√	•	√	Geum River. Korea.
Mustafa et al., [115]	•	√	•	2D WOLF	•	•	√	•	√	Wallonia, Belgium.
Shakti et al., [116]	√	•	•	GSSHA	•	•	√	√	•	Norther Kyushu,Japan
Papaioannou et al., [117]	√	•	•	SCS/HE-RAS	•	√	•	√	•	Mangesia. Greece
Radwan et al., [118]	√	•	•	SCS/GIS.RS.	√	•	•	√	•	Riyadh. Saudi Arabia
Nigussie et al., [119]	•	√	•	SWAT	•	•	√	√	•	Ethiopia
Meresa [120]	√	•	•	HEC-HMS	•	•	√	√	•	Ethiopia
Boulomytis et al., [121]	√	•	•	GIS.AHP	•	•	√	√	•	Juqueriquere.Brazil.
Durocher et al.,[122]	√	•	•	N.Parmatic*3	•	•	√	√	•	Different lands.Canda
Kim et al., [123]	√	•	•	FRA	•	•	√	√	•	South. Korea
Kong et al., [124]	√	•	•	TOPKAPI	•	√	•	√	√	Xixian,.China.
Zahang et al., [125]	√	•	•	Early Wrong*4	•	√	•	√	•	Loses Plateau.China
Masoud et al., [126]	√	•	•	WMS.HMS	√	•	•	√	•	W.Dwaser. Saudi.
Papaioannou et al.,[127]	√	•	•	WRF. ARW. H-RAS*5	•	√	•	√	•	Volos City, Greece
Petroselli et al., [128]	√	•	•	EBA4SUB.H-RAS.FLO	•	•	√	√	•	Two Basins. Slovakia
Vojtek et al., [129]	√	•	•	EBA4SUB.HEC-RAS	•	•	√	√	•	Korytárka, Slovakia
Abdrabo et al., [130]	√	•	•	AHP. RRI	√	•	•	√	•	Hurghada, Egypt
Apollonio et al., [131]	•	√	•	SCS-CN. FLO2D	•	√	√	√	•	Apulia Region, S Italy
Natarajan & Radhakrishnan [132]	√	•	•	HEC-HMS	•	•	√	√	•	Canada
Dehghanian et al., [133]	√	•	•	Fuzzy.ANN.GA*6	•	√	•	√	•	Tangrah NE, Iran
Lee et al., [134]	√	•	•	FFA.DFFA*7	•	•	√	√	•	South Korea
Boota et al., [135]	√	•	•	HEC-HMS	•	√	•	√	•	Pakistan
Chakraborty & Biswas [136]	√	•	•	HEC-HMS	•	√	•	√	•	Teesta basin. India
Natarajan & Radhakrishnan [137]	√	•	•	HEC-HMS	•	√	•	√	•	Koraiyar basin. India
Khélifa & Mosbahi [138]	√	•	•	HEC-HMS	√	•	•	√	•	North-East of Tunisia
Mukolwe et al., [139]	√	•	•	ANN	•	•	√	√	•	Baringo basin, Kenya
Filipova et al., [140]	√	•	•	ANN	√	√	√	√	•	25 Regions. The USA
Houessou et al., [141	√	•	•	EBA4SUB	•	√	•	√	•	Narok town, Kenya.
Kim et al., [142]	√	•	•	CUH*8	•	•	√	√	•	Imjin.basin.N/S.Korea
Rasheed et al., [143]	√	•	•	Machine Learning	√	√	√	√	•	670 basins. The USA
Saha et al., [144]	√	•	•	Machine Deep Learning	•	•	√	√	•	Kunur basins. India
Zhang et al., [145]	√	•	•	Machine D Learning	•	√	√	√	•	35 mountio. China
Hegazy et al., [146]	•	√	•	WMS.HEC-HMS	√	•	•	√	•	West Cairo, Egypt
Imran et al., [147]	√	•	•	HEC-HMS	•	√	•	√	•	Manshar, Pakistan
Prasad & Bhardwaj [148]	√	•	•	SWAT	•	•	√	√	•	Salearn, North-w India
Prakasam et al., [149]	√	•	•	HEC-HMS	•	√	•	√	•	Himalayan basin, Indi
Alsaleh [150]	√	√	•	SWAT	√	•	•	√	•	Riyadh, Saudi Arabia
Siriwardana & Wijesekera [151]	√	•	•	HEC-HMS	•	•	√	√	•	Attanagalu, Sri Lanka
Sahraei et al., [152]	•	•	√	GIS.MCDM	•	√	•	√	•	Southwest, Iran

(R) Modeling Runoff. (L) Land Use impact on runoff. (E) Land Use impacts on Environmental issues. (A) Arid zone). (S)Same Arid. (H) Humid Zone. (U) Ungauged Catchment. (G) Gauged Catchment. (RFA*1) Regional Flood Analysis and Some Statical. *2 Typhoons Storms. *3 Nonparametric Models include local regression and generalized additive models. (Early Wrong*4) established based on rainfall and water stage. (*5) Combined Weather. Hydrology and Hydraulic models. (GA*6) The genetic algorithm can calibrate the rainfall-runoff. (FFA. DRRA*7) Flood Frequency Analysis and Design Rainfall–Runoff Analysis based on Machine Learning. (CUH*8) Clark unit hydrograph, Lumped model.

Specifically, the review concentrated on a few central parts of hydrological showing: hydrology and watershed models, computerized height model information, land-use/spread information, soil information, precipitation information, HEC-HMS, SWAT, and HEC-RAS model.

Conclusion Hydrological models can analyze most hydrology matters, such as runoff volume, direct runoff, and base and channel flow for gauged and ungauged catchments in different environmental climates. Dry regions require more specialists to beat the deterrents in hydrological demonstrating. For instance, specialists should consider new strategies for deciding spatial precipitation and penetration from ephemeral streams originating from streak floods. RS information can reproduce occasions in parched zones instead of checking the details. So, observation data can be collected from the field and compared to hydrology model results. This review found that massive application hydrology carried out in arid, semi-arid, and humid zones can predict runoff, flood peaks, and inundation areas based on a lumped, semi-distributed, and distributed model, which means all input data for catchment is a single factor. So, making a prediction and estimating runoff is safer to clarify. Recommendation This review concluded that applying hydrology models enhances the water resource community, city planners, and civil engineering to understand surface water and subsurface water management for sustainability. Also, flood risk and its mitigation are domain applications of these models. This study recommended that with increasingly populated cities in different environments, its ability to be more responsive to flood mitigation should be investigated, and this process must be done using a hydrology model. Hydrology models are significant methods for water management and prediction of the catchment's future. Two hydrology models should be employed in ungauged catchments for more accurate results. So, this review strongly suggests using high-resolution RS DEM to simulate runoff, especially in flat-plane lands.

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