

Surface Water Potential Assessment by Using HEC-HMS (Case Study Dabus Sub Basin, Abay/Nile Basin, Ethiopia)

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Abstract: The surface water resources potential assessment requires detailed insights into hydrological processes. This study mainly focused on the assessment of surface water resources potential in Dabus sub-basin of Ethiopia. HEC-HMS model was used to simulate the flow of the sub-basin through calibration and validation. The performance of the model was assessed via calibration at gauging station using Relative Volume Error (D), coefficient of determination (R^2) and Nash-Sutcliffe Efficiency (NSE) performance coefficients. Then the model was validated using the parameters optimized during model calibration. The potential of surface water resources assessed at different watershed created to see at local level and finally at outlet point to Main River for sub-basin. The HEC-HMS model calibrated and validated at three gauging station in the sub basin which shows a good performance at Dabus near Asosa which resulted $D=0.0066$, $R^2=0.91$ and $NSE=0.89$ during calibration and $D=4.9285$, $R^2=0.84$ and $NSE=0.82$ during validation. The parameters optimized at Dabus were used for flow simulation to assess surface water resources potential on monthly and annual basis. The flow components were also separated at small catchment considered for the sub-basin during catchment delineation. The result shows that high percentage of flow occupied by baseflow for the sub basin. So the sub basin has high surface water potential which should be allocated fairly and accurately for water resources projects for effective utilization of the country water resources.

Keywords: Dabus Sub-basin, HEC-HMS, Surface Water Resources Potential

1. Introduction

Sustainable Surface water resources management interventions are essential in Ethiopia to increase or sustain water resources, especially for the agriculture (Irrigation development), Power generation, Domestic water supply and livestock sectors. However, water resources assessment on the sub-basin scale is therefore one of the key activities to provide insight into water potential for the development of irrigation and also for different purposes.

The surface water resources potential assessment requires detailed insights into hydrological processes [9]. However, studying the complexity of hydrological processes, needed for sustainable sub-basin management, is basically based on understanding rainfall characteristics and Sub-basin properties, for which rainfall-runoff modeling studies are useful. Rainfall-runoff models have been widely used in hydrology over the last century for a number of applications and play an important role in in optimal planning and

management of water resources in basin [7].

The availability of adequate fresh water is a fundamental requirement for the sustainability of human and terrestrial landscapes [11-13]. Thus, the importance of understanding and improving predictive capacity regarding all aspects of the global and regional water cycle is certain to continue to increase. One fundamental component of the water cycle is streamflow. Thus forecasting stream flow under climate change is very indispensable.

Even though the decision maker and planner needs optimal potential, the optimal surface water resources potential of the sub-basin not known for optimal planning and management of the sub-basin water resources potentials. So the output of this research will help the planner to optimize and manage the Surface Water Resources of the sub-basin to utilize for small scale irrigation development, Small scale Hydropower plant, Domestic Water Supply for large community and livestock sectors [4].

The objectives of this study are: to analyze the spatial

variation of the runoff generation characteristics of Dabus sub-basins using a semi-distributed hydrological model and to Simulated water budget components (determination of surface water potential at local catchment level) depending on the importance of catchment area.

Generally, this research will provide the input for surface water allocation in sub-basin which will help policy/ decision maker in the sub-basin for future utilization of surface water resources.

2. Description of Study Area

2.1. General Features

Blue Nile (Abbay) basin is the most important river basin of Ethiopia. It accounts for almost 20 percent of Ethiopia's land area; 50percent of its total average rainfall; 25percent of its population; 39 percent of national cattle herd; and over 40 percent of cultivated land and crop production. The Abbay River itself has an average annual run off of about 56.7 BCM and it contributes about 62 percent of Nile total at Aswan [8].

The Blue Nile Basin (Abbay basin) is generally divided into 14 Sub-basins according to their configuration in topology. This Research highly emphasis on the assessment of surface water potential in Dabus Sub-basin which contribute relatively high percent of water to the Abbay basin next to Didessa sub-basin.

The Dabus River drains an area of approximately 21030 square kilometers. It originates in the high volcanic mountains

to the south and flows generally northwards into a large and flat basin known as the Dabus swamp then continuous northward to the Blue Nile River. The River course has a drop of 616 and 638m at upper and lower Dabus dam sites at elevations of 1384 and 1362 m.a.s.l. respectively. The river further drops into an extremely deep narrow canyon prior to leaving the area. The Dabus River has an average annual flow of about 6246Mm³ even though not yet exploited for hydropower and other Agricultural development.

The implementation of these hydropower projects will be expected to minimize the scarcity of the electric power in the country and will also create income at national level that might be used for different infrastructures.

2.2. Location

Blue Nile Basin which is found in the western part of Ethiopia, between 7°45' and 12°45'N and 34°05' and 39°45'E is one of the largest basins in the country with high population pressure, degradation of land and highly dependent on agricultural economy [3]. It covers an area of about 199812km² with total perimeter of 2440km.

Dabus river is fed by numerous tributaries that originate in the south-western and central parts of Wollega. Major tributaries are the Aleltu, Sechi, Hoha, Haffa, Dilla and the Keshmando. The river is known for its sustained flow even during the dry season, which is attributed to the presence of a swamp. The size of the swamp has been reported to be in the range of 600 to 900 km² [8].

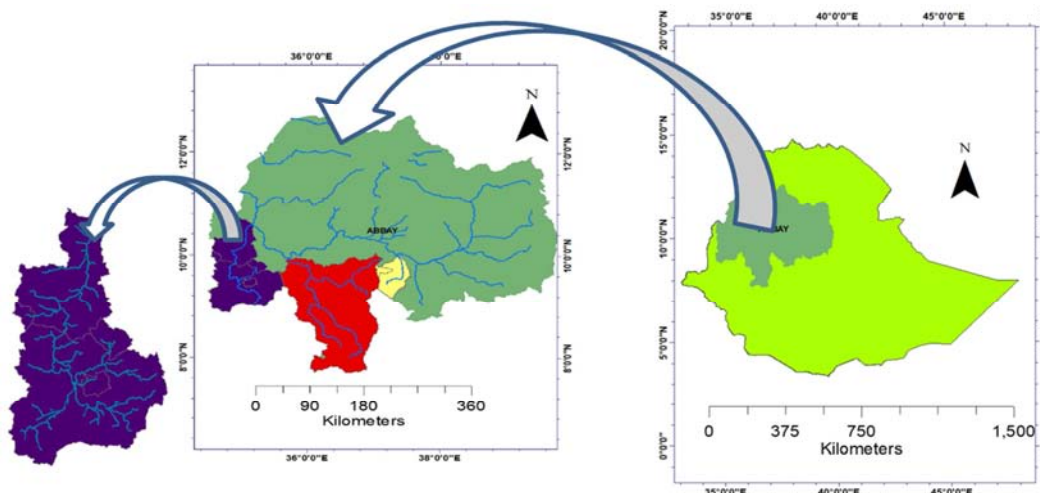


Figure 1. Location of Dabus Sub-basin.

2.3. Climate

The basin falls within the climatic classification of Tropical Climate II according to the modified Copen system. The climate is characterized by a mean annual rainfall between 680 to 1200 mm. The rainfall distribution in the Dabus sub-basin is monomial, with the length of the wet season decreasing as one goes to the north and north-west in the basin. The South-western part of the basin experiences longer rainy season extending from April/May to

October/November [3, 16].

3. Materials and Methods

3.1. Materials

The materials used in the research to achieve the objectives of the study were DEM, Arc GIS 10.5, HEC-GeoHMS, HEC-HMS, HEC-DSSve2.01, ETo Calculator and Spread Sheet/ Microsoft Excel.

3.2. Methodology

As any research requires clear methodology, the methodology used in this research work includes the following steps (1) Data collection; (2) Meteorological and Hydrological Data analysis (3) Watershed-based hydrological

modeling; (4) Surface Water potential assessment through model calibration and validation; (5) Flow component Separation

Generally the overall procedure that followed in the research work is as given in figure 2.

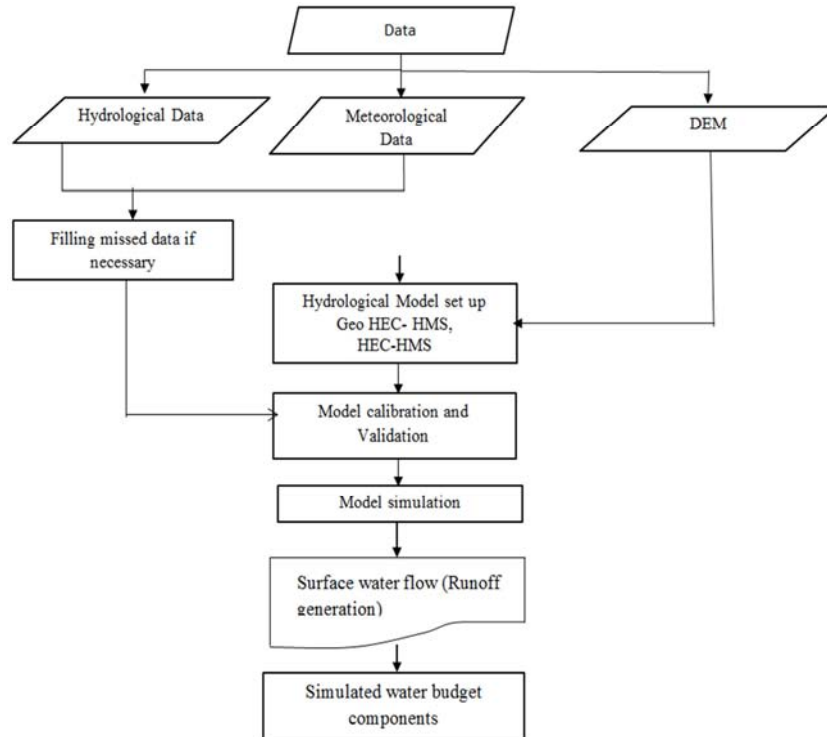


Figure 2. Methodology used for the research.

3.2.1. Watershed-based Hydrological Modeling

(i). HEC-GeoHMS Setup and Catchment Processing

HEC-GeoHMS operates on the DEM to derive sub-basin delineation and to prepare a number of hydrologic inputs. HEC-HMS accepts these hydrologic inputs as a starting point for hydrologic modeling (flow forecasting) in addition to precipitation time series data generally meteorological and hydrological data. The major steps in HEC-GeoHMS processes include: terrain preprocessing, hydrologic processing, basin processing, stream and watershed characteristics, and hydrologic parameters and HEC-HMS model files. The model also contains different utility Analysis that was mainly used to Assign HydroID and to create Gage Thiessen Polygon for areal data computation [15].

Terrain preprocessing is the first step in developing a HEC-GeoHMS project. In this step a terrain model was used to derive eight datasets that collectively describe the drainage pattern of the Dabus sub-basins delineation. Generally the results of terrain preprocessing were shown in Figure 3.

In hydrologic processing, HEC-HMS project setup menu has been used for extracting data that was used to develop the necessary information to create HEC-HMS project by specifying a control point at the downstream outlet. Then the HEC-GeoHMS was used to refine the sub-basin and stream delineations, extract physical characteristics of sub basins

and streams, estimate model parameters, and prepare input files for HEC-HMS [2].

Basin Processing. After the terrain preprocessing is completed and a new project is created, the basin processing menu in HEC-GeoHMS was used to revise the sub-basins delineation to create new watershed in the delineated sub-basin as Aleltu, Sechi and Lower dabus watershed since the data are available here for model calibration and validation as well as they are the points where flow forecasting is needed for surface water potential assessment.

Stream and Sub basin characteristics: was used for estimating hydrologic parameters of the delineated sub-basin such as river length, river slope, basin slope, longest flow path, basin centroid, centroid elevation, and centroidal flow.

Hydrologic Parameter Estimation: in this parameters such as initial, constant, and maximum soil loss rate, percent impervious, time of concentration, etc. based on the HMS process selected.

(ii). HEC-HMS Model Files

HEC-GeoHMS develops a number of hydrologic inputs for HEC-HMS: background-map files, basin model file, and meteorological model file. The background map layer captures the geographic information of the basin boundaries and stream reaches. The basin model captures the hydrologic elements, their connectivity, and related geographic information that were loaded in to HEC-HMS project. The

meteorological model file contains a list of precipitation gauges Mendi, Abadi, Shorekole and Gulliso used by the meteorological model for Dabus basins.

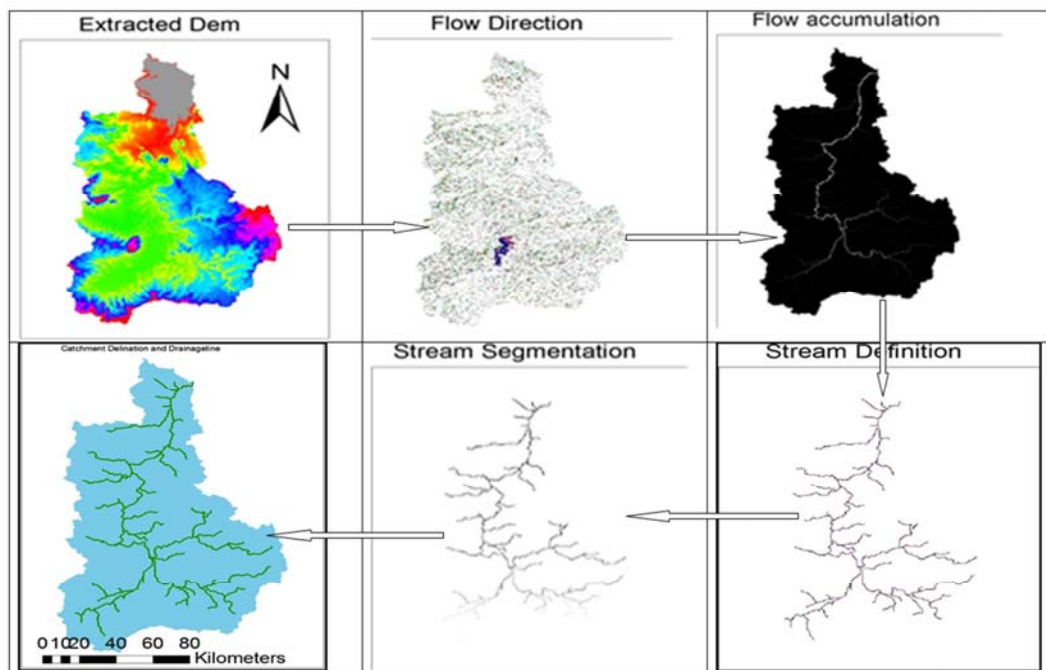


Figure 3. HEC-GeoHMS Terrain Processing of Dabus sub basin.

(iii). HEC-HMS Setup and Data Preparation

Basin Models

HEC-HMS has three major capabilities: watershed physical description through model components, simulations and parameter estimation to simulate the hydrologic response in a watershed. A simulation calculates the precipitation-runoff response in the basin model given input from the

meteorologic model. The control specification defines the time period and time step of the simulation run. Input data is required as parameter or boundary conditions in basin and meteorologic models. The physical properties of the watershed and the topology of the stream network of the sub-basin described here. (Figure 4)

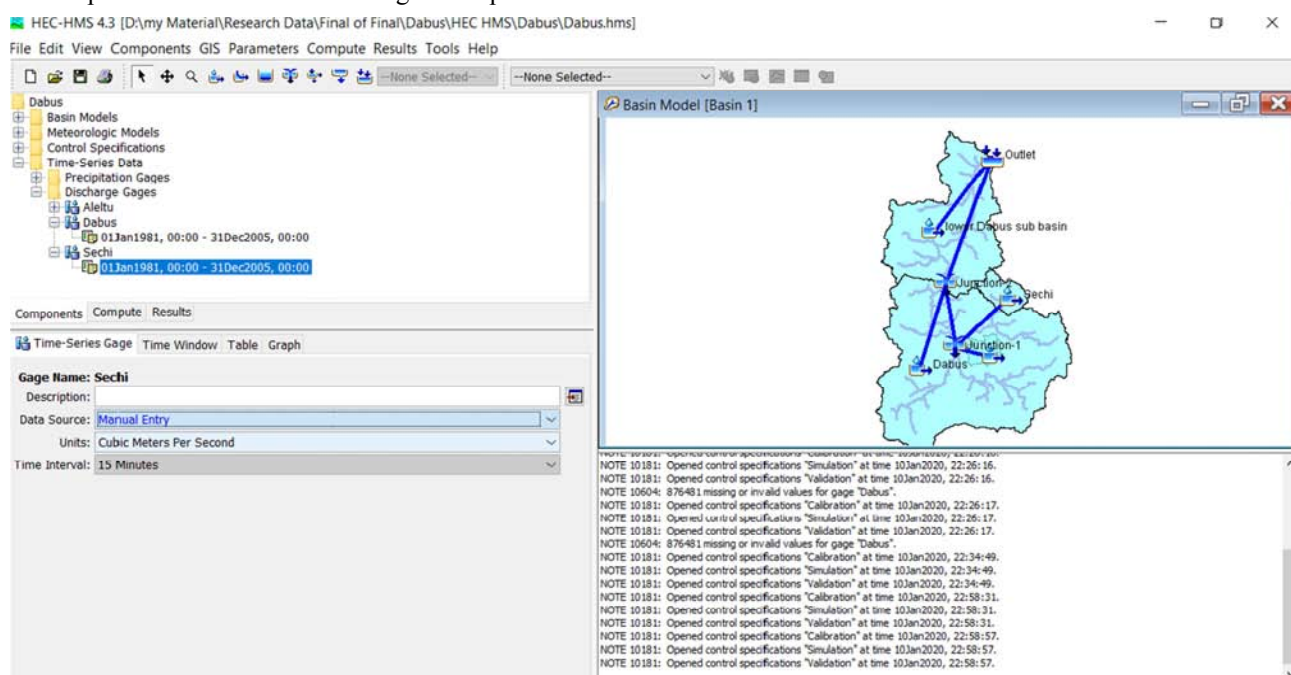


Figure 4. Dabus SubBasin model created by HEC-GeoHMS and imported to HEC-HMS model.

Meteorologic Models

It was used to create the sub-basin Meteorologic models components are one of the main components precipitation (where gauge type and weight can be specified), and evapotranspiration that allow entry of evapotranspiration loss.

Control Specifications

This was used to control when simulations start and stop, and what time interval is used in the simulation.

Input Data (Time series Data):

In this research measured precipitation data, Observed discharge from three gauging stations, Dabus Gauge near Asosa, Aleltu Gauge near Mendi and Sechi Gauge at Nedjo, in Dabus Sub basin were entered as time series data to the model. Time series data is stored in a gauge that is imported from HEC-GeoHMS as meteorologic model.

Hydrologic Simulations

Simulation run is the primary mode for performing simulations and forms the basis for additional analysis using optimization trials or analysis. Each run is composed of one basin model, one meteorologic model, and one control specification. Simulations runs have been created here using a wizard that can be accessed from “compute menu” or “run manager command” of the HEC-HMS model.

Parameter Estimation

In this particular study the Univariate-Gradient Algorithm search method and the sum of squared residuals measure for goodness of fit were applied. For the purpose of calibration of the model 10-years observed flow time-series data (1991 to 2000) of Dabus Gauge near Asosa, Aleltu Gauge near Mendi and Sechi Gauge at Nedjo were used. For validation purpose a 5 years' data was used. Since the other station shows poor performance, the parameter optimization with flow from Dabus Gauge near Asosa were used for flow simulation (surface water potential assessment).

Analytical Components of HEC-HMS

It consists of runoff volume models, models of direct runoff (overland flow and interflow), base flow models, channel flow models. HEC-HMS gives flexibility to the user by providing each component with suit of models. The researcher can choose a suitable combination of models depending on the availability of data, the purpose of modeling, their integrity and the required spatial and temporal scales.

Loss Models

Based on the general model selection criteria, the deficit and constant-rate loss model is selected in this particular research to compute the cumulative loss.

Transform Models

In this research Clark UH model was selected for modeling direct runoff inconsideration of availability of information for calibration and parameter estimation; appropriateness of the assumptions inherent in the model; and their previous application in the HEC-HMS model.

Clark Unit Hydrograph Transform

Time of concentration and storage coefficient are the two important parameters in Clark unit hydrograph transforming excess rainfall in to runoff. The time of concentration is used

in the development of the translation hydrograph whereas storage coefficient is used in the linear reservoir that accounts for storage change.

Application of the Clark model requires: properties of the time-area histogram and the storage coefficient, R . The linear routing model properties are defined implicitly by a time-area histogram. Studies at HEC- HMS have shown that, even though a watershed-specific relationship can be developed, a smooth function fitted to a typical time-area relationship represents the temporal distribution adequately for UH derivation for most watersheds.

That typical time area relationship, which is built into the program, is:-

$$\frac{A_t}{A} = \begin{cases} 1.414 \left(\frac{t}{t_c}\right)^{1.5} & \text{for } t \leq \frac{t_c}{2} \\ 1 - 1.414 \left(1 - \frac{t}{t_c}\right)^{1.5} & \text{for } t \geq \frac{t_c}{2} \end{cases} \quad (1)$$

Where A_t =cumulative watershed area contributing at time t ; A =total watershed area; and t_c =time of concentration of watershed. Application of this implementation only requires the parameter t_c , the time of concentration. This can be estimated through model calibration. The basin storage coefficient, R , is an index of the temporary storage of precipitation excess in the watershed as it drains to the outlet point. It can also be optimized during model calibration.

Base Flow Models

The constant, monthly varying base flow method, selected for this research, allows the specification of a constant base flow for each month of the year. It is intended primarily for continuous simulation in sub-basins where the base flow is nicely approximated by a constant flow for each month [10].

Routing Models

In this thesis work Muskingum Routing Model is selected for flow routing in reach elements inconsideration of availability of information for calibration and parameter estimation.

Muskingum route

The Muskingum routing method uses simple conservation of mass approach to route flow through the stream reach. The Muskingum K is the travel time through the reach. The Muskingum X is the weighting between inflow and outflow influence; it ranges from 0 to 0.5. The travel time of a flood wave passing through the reach (k) and the measure of degree of storage (x) need to be determined through calibration. The Muskingum method is often used in channel routing. The method is dependent primarily upon the following factors: the number of integer steps for the routing, Muskingum K coefficient and Muskingum x coefficient. This model uses a simple finite difference approximation of the storage continuity equation. Storage is modeled as the sum of prism storage and wedge storage. According to Muskingum, storage is expressed as;

$$S_t = KO_t + kX(I_t - Q_t) = K[XI_t - (1 - X)Q_t] \quad (2)$$

Where K =travel time of the flood wave through routing reach; and X =dimensionless weight, X ranges 0 up to 0.5. The quantity on the right hand side is weighted discharge.

Generally the routed out flow of a given reach is estimated by the following equation,

$$O_t = \left\langle \frac{\Delta t - 2kx}{2k(1-k) + \Delta t} \right\rangle I_t + \left\langle \frac{\Delta t + 2kx}{2k(1-x) + \Delta t} \right\rangle I_{t-1} + \left\langle \frac{2k(1-x) - \Delta t}{2k(1-k) + \Delta t} \right\rangle O_{t-1} \quad (3)$$

Surface Water Potential Assessment

HEC-HMS Model Calibration and Validation

Model calibration is a systematic process of adjusting model parameter values until model results match acceptably the observed data. The objective function described by the quantitative measure of the match. In the precipitation-runoff models, this function measures the degree of variation between the observed and the computed hydrographs. The calibration process finds the optimal parameter values that minimize the objective function. Manual calibration relies on user's knowledge of basin physical properties and expertise in hydrologic modeling. In the automated calibration model parameters iteratively adjusted until the value of the selected objective function is minimize [5, 6, 14].

The latest version of HEC-HMS (4.3) model includes optimization manager that allows automated model calibration. The quantitative measure of the goodness-of-fit between the computed result from the model and the observed flow is called objective function. An objective function measures the degree of variation between computed and observed hydrographs. It is equal to zero if the hydrographs are exactly identical. The key to automated parameter estimation is a search method for adjusting parameters to minimize the objective function value and find optimal parameter values. There are six different functions are provided that measure the goodness-of-fit in different ways in the optimization manager these are: - Peak-weighted root mean square error function (PWRMSE), Sum of squared residuals function (SSR), Sum of absolute residuals function (SAR), Percent error in volume function (PEV) and The percent error in peak flow function (PEQ)

There are also two search methods (Univariate gradient method (UG) and Nelder and Mead method) are available in HEC-HMS model for minimizing the objective function and finding

In this research Sum of squared residuals function (SSR) with Nelder and Mead Method (NM) was used to search optimal parameter value since it can optimize several parameters simultaneously.

Model validation is the process of testing model ability to simulate observed data other than used for the calibration, with acceptable accuracy. During this process, calibrated model parameters are not subject to change, their values are kept constant. The quantitative measure of the match is again the degree of variation between computed and observed hydrographs. A total of 10 years historical data from 1991 to 2000 was used for calibration, 5years was used for validation (2001-2005).

HEC-HMS Model Performance

The model performance in simulating observed discharge was evaluated during calibration and validation by observing simulated and observed hydrograph visually and by calculating Nash and Sutcliffe efficiency criteria (NSE), coefficient of determination (R^2), and Percent

difference/Relative Volume Error (D) were used.

Nash-Sutcliffe Efficiency, NSE

The Nash and Sutcliffe coefficient (NSE) is a measure of efficiency that relates the goodness-of-fit of the model to the variance of measured data. NSE can range from $-\infty$ to 1 and an efficiency of 1 indicates a perfect match between observed and simulated discharges. NSE value between 0.9 and 1 indicate that the model performs very well while values between 0.6 and 0.8 indicate the model performs well [1].

The efficiency, E proposed by Nash and Sutcliffe (Nash, 1970) is defined as one minus the sum of the absolute squared differences between the predicted and observed values normalized by the variance of the observed values during the period under investigation.

$$NSE = 1 - \frac{\sum_{i=1}^n [Q_o - Q_s]^2}{\sum_{i=1}^n [Q_o - \bar{Q}_o]^2} \quad (4)$$

Where, Q_o =observed flow, Q_s =Simulated flow and \bar{Q}_o =Average of observed flow

Moriasi et al (2007) recommended for monthly time steps that NSE values between 0.75 and 1 is very good and NSE-value between 0.65 and 0.75 is good.

According to (Motovilov Y. G., 1999), the NSE values can vary from 0 to 1, with 1 indicating a perfect fit of the data. According to common practice, simulation results are considered to be good for values of NSE greater than or equal to 0.75, while for values of NSE between 0.75 and 0.36 the simulation results are considered to be satisfactory.

Coefficient of Determination, R^2

The coefficient of determination R^2 is defined as the squared value of the coefficient of correlation. It is estimated as

$$R^2 = \frac{[\sum_{i=1}^n (Q_o - \bar{Q}_s)(Q_o - \bar{Q}_o)]^2}{[\sum_{i=1}^n (Q_s - \bar{Q}_s)]^2 [\sum_{i=1}^n (Q_o - \bar{Q}_o)]^2} \quad (5)$$

Where, Q_o =observed flow, Q_s =Simulated flow, \bar{Q}_o =Average of observed flow and \bar{Q}_s =Average of simulated flow.

Percent Difference, D

The percent difference for a quantity (D) over a specified period with total days calculated from measured and simulated values of the quantity in each model time step as:

$$D = 100\% * \left[\frac{\sum_{i=1}^n Q_o - \sum_{i=1}^n Q_s}{\sum_{i=1}^n Q_o} \right] \quad (6)$$

Where, Q_o =Observed flow, Q_s =Simulated flow

The percent difference (D) can vary between ∞ and $-\infty$ but it performs best when a value of 0 (zero) is generated. A percent difference between +5% or -5% indicates that a model performs well while percent difference between +5% and +10% and -5% and -10% indicates a model with reasonable performance [1].

4. Results and Discussion

4.1. Hydrologic Model (HEC-HMS) Results

In this research HEC-HMS Hydrologic Model was used for

Dabus sub basin surface water potential assessment. The basin model created by HEC-GeoHMS was imported to HEC-HMS and the parameter estimated in HEC-GeoHMS such as Clark time of Concentration, Clark storage coefficient, initial Deficit, Maximum deficit, Constant Rate and etc. were used as initial parameters for model simulation which later optimized based on the acceptable value of NSE and R^2 .

4.2. HEC-HMS Model Calibration and Validation Results

In this research, among the existing methods in the model, the Nelder and Mead Method (NM) and the sum of squared residuals measure for goodness of fit have been applied for

calibrating the model. Figure 5 shows Hydrograph of Model Calibration at Dabus Gauge near Asosa. The 10- years of observed flow time-series data (1991 - 2000) of Dabus Gauge near Asosa, Sechi Gauge near Mendi and Aleltu Gauge at Nedjo have been used for model calibration whereas 5- years of observed flow time-series data (2001 - 2005) of the same stations was used Model validation. During both calibration and validation the peak flow was not captured in all gauging stations, as a result of this precipitation loss become unrealistically large. Figure 6 shows

Hydrograph of Model Validation at Dabus Gauge near Asosa.

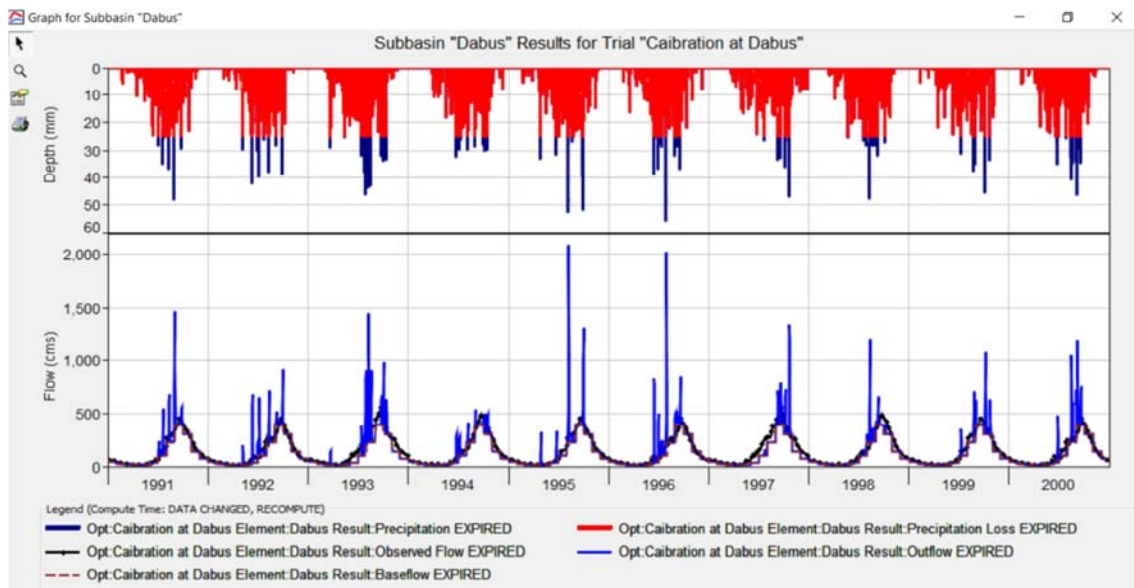


Figure 5. Daily Simulated flow Hydrograph calibrated and Observed flow at Dabus Gauge Nr Asosa Station Comparison (1991-2000).

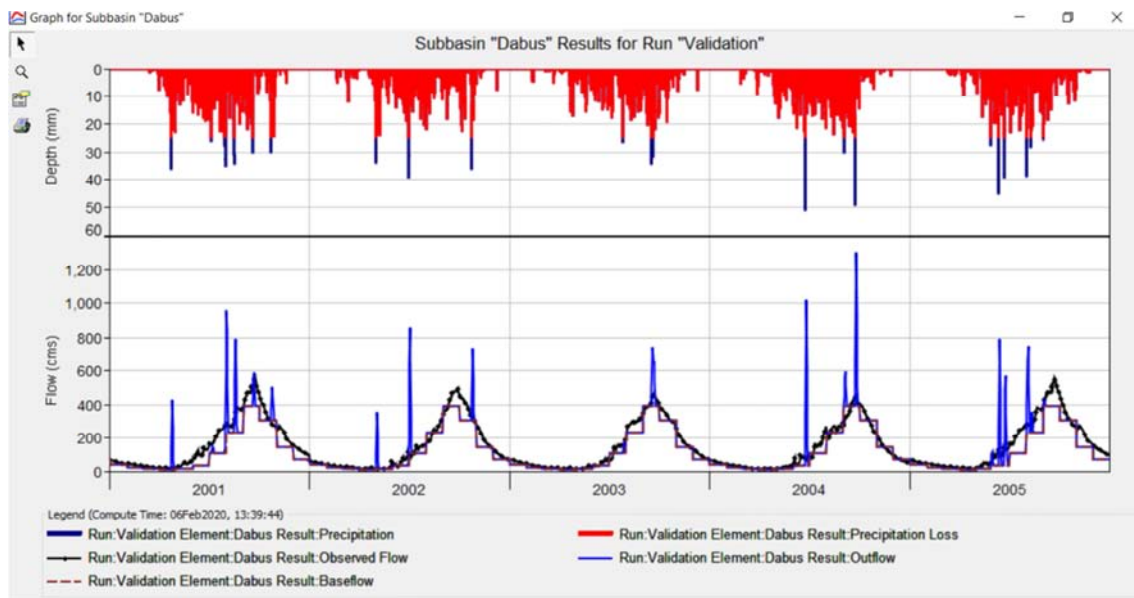


Figure 6. Daily Simulated flow Hydrograph Validated and Observed flow at Dabus Gauge near Asosa Station Comparison (2001-2005).

Both Calibration and validation have shown a very good counterpart with the corresponding observed hydrographs of equivalent time of consideration in volume but little bit it

shows less performance in peak flow.

In this research, the model performance in simulating observed discharge has been evaluated using Nash and

Sutcliffe efficiency criteria (NSE), coefficient of determination (R^2), Percent difference /Relative Volume Error (D) in both calibration and Validation for the sub-

basins selected stations. The results of the performance evaluation criteria of the HEC-HMS model are summarized in tabular form as shown in Table 1.

Table 1. Performance indices of model during Calibration and Validation of Dabus sub basin.

| Indices | Gauging Stations | | | | | |
|---------|---------------------|------------|---------------------|------------|-------------------|------------|
| | DabusGauge Nr Asosa | | SechiGauge Nr Mendi | | AleltuGauge@Nedjo | |
| | Calibration | Validation | Calibration | Validation | Calibration | Validation |
| NSE | 0.89 | 0.82 | 0.52 | 0.59 | 0.32 | 0.44 |
| R^2 | 0.91 | 0.84 | 0.52 | 0.59 | 0.34 | 0.44 |
| D | 0.0066 | 4.9285 | -0.1047 | -2.0995 | -0.0096 | -1.5131 |

The result of Calibration and Validation has revealed a very good simulation performance, satisfactory performance and less performance for all sub basins considered in the this research work. Since all stations shows a very good performance indices in Percent difference /Relative Volume Error (D) due to the great difference in other two performance indices only the parameters optimized at the Dabus gauge were used for flow simulation (surface water potential assessment) in the sub basin.

4.3. Surface Water Potential

The water availability was assessed as sub-basin level and small watershed depending on the importance of the watershed

and availability gauging stations that were used for model calibration and validation. So the availability of water in Dabus Sub basin was assessed for the whole sub-basin at outlet and small catchment like Aleltu, Sechi and upper Dabus watershed. The result of Water availability shown by Figure 7 and 8 as follow on average monthly basis and annual basis.

The flow components of the sub-basin were also separated at considered watershed in the sub-basin. The result mostly shows that the high percentage of flow the existing baseflow of the river in the considered watershed. So this is indication excess water availability in the sub-basin which was not yet effectively utilized. Table 2 shows the annual flow components and its percentage.

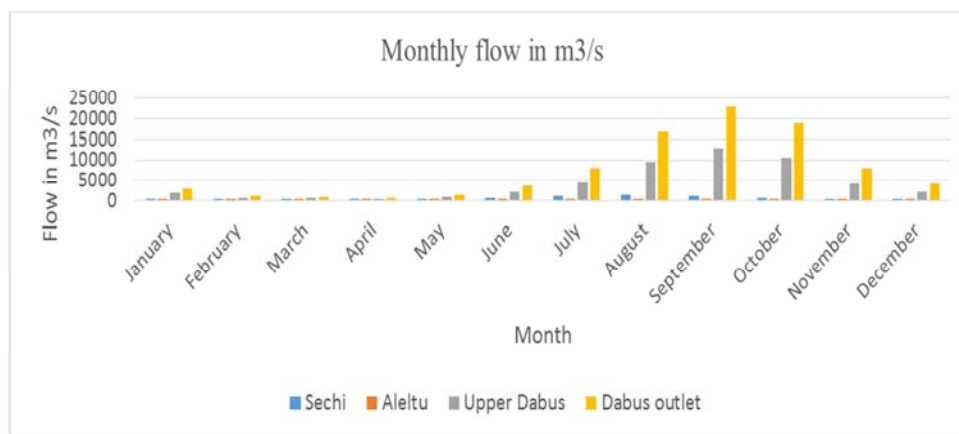


Figure 7. Average Monthly water availability of Dabus sub basin.

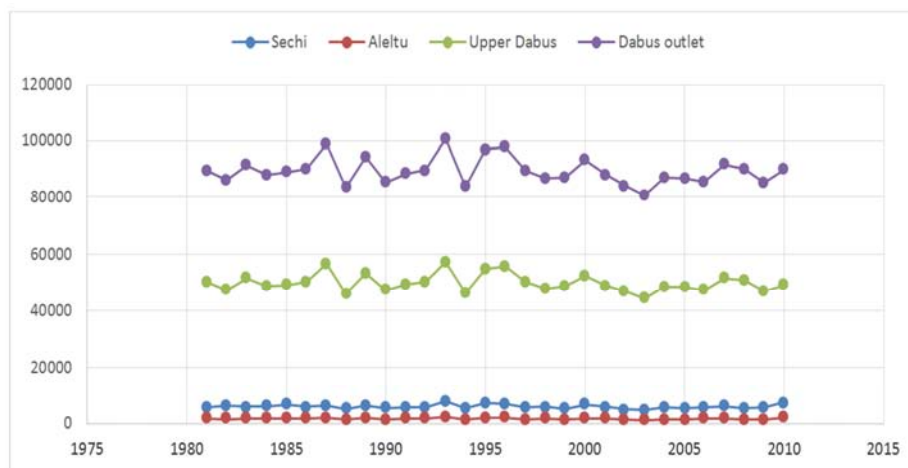


Figure 8. Annual water availability of Dabus sub basin.

Table 2. Budget component quantities for all Watershed in the sub-basin of 30 years.

| Sub Watershed | Total Rainfall (mm/year) | Evaporation (mm/year) | Deep percolation (mm/year) | Direct Runoff (mm/year) | Baseflow (mm/year) | Total flow (mm/year) | Percentage of base flow (%) | Percentage of Direct flow (%) |
|---------------|--------------------------|-----------------------|----------------------------|-------------------------|--------------------|----------------------|-----------------------------|-------------------------------|
| Upper Dabus | 1656.65 | 41.63 | 1559.65 | 7437.41 | 42492.84 | 49930.25 | 85.10 | 14.90 |
| Aleltu | 1656.65 | 41.63 | 1356.70 | 944.35 | 748.71 | 1693.06 | 44.22 | 55.78 |
| Sechi | 1656.65 | 41.63 | 1033.13 | 3671.96 | 2321.69 | 5993.66 | 38.74 | 61.26 |

interests/conflict of interest.

5. Conclusions and Recommendations

5.1. Conclusions

Surface Water Resources potential assessment is very crucial for water resources allocation of the given basin for better management of the basin. Extreme events of floods and droughts keep on claiming many lives all over the world and brought unlimited effects on Water Resources Developments so that the planner/decision maker adapt appropriate remedies for better management of water resources. As a result of these, the study of surface water resources potential of Dabus is highly requires emphases. In the research HEC-HMS model was used for surface water resource potential assessment. Based on the research result my conclusions summarized as follows:

The HEC-HMS model calibrated and validated on daily bases at Dabus near Asosa, Sechi near Mendi and Aleltu at nedjo for Dabus sub basin. The model shows good and satisfactory performance on different gauging station considered in all sub-basin considered in this research work. So the gauging at which model shows good performance selected for parameters optimization. Having the optimized parameters at Dabus near Asosa the model was simulate the observed discharge in reasonably good manner particularly in simulating runoff volume on the daily basis. Generally the model has revealed a good performance at Dabus near Asosa with performance indices of Nash and Sutcliffe Efficiency value=0.90, Coefficient of Determination R^2 value=0.89, and relative Volume, Error, D=0.0066. Hence, HEC-HMS model was used flow simulation for the assessment of Water Resources availability. The result of Water resources availability assessment shows that high percentage of flow occupied by baseflow. So the available water in the sub-basins should be allocated fairly and accurately for water resources projects for effective utilization of the country water resources.

5.2. Recommendations

From the result of the research, the following are highly recommended for further studies of the sub-basins water resources allocation.

Water Resources allocation studies should be conducted by considering the swamp, existing project and planned project for different purposes.

Conflict of Interest

The authors declare that they have no competing

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