WATERSHED SIMULATION MODEL USING MATLAB

A DISSERTATION
SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT
FOR AWARD OF DEGREE

OF
MASTER OF TECHNOLOGY
IN
HYDRAULICS AND WATER RESOURCE ENGINEERING

Submitted by:
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CANDIDATE'S DECLARATION

I, Shubham Bansal (2K18/HFE/13) student of M.Tech (Hydraulics and Water Resource Engineering), hereby declare the project titled "WATERSHED SIMULATION MODEL USING MATLAB" which is submitted by me to the Department of civil Engineering, Delhi Technological University, Delhi in fulfilment of the requirement for the award of the degree of Master of Technology, is original and not copied from any source without proper citation. This work has not previously formed the basis for the award of any Degree, Diploma, Associate ship, Fellowship or other similar title of recognition.

Shubham.

Place : Delhi

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Date: 28 Aug 2020

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CERTIFICATE

I hereby certify that the project dissertation titled "**WATERSHED SIMULATION MODEL USING MATLAB**" which is submitted by Shubham Bansal (2K18/HFE/13), Department of Civil Engineering, Delhi Technological University, Delhi in fulfilment of the requirement for the award of the degree of Master of Technology, is a record of project work carried out by the student under my supervision. To the best of my knowledge this project work has not been submitted in part or full for any Degree or Diploma to this University or elsewhere.

Place : Delhi

Date: 02-09-2020

Dr. Rakesh Kumar

SUPERVISER

(Professor in Civil Department)

ABSTRACT

This paper aim to set-up a watershed simulation model to compute various hydrological variables on **MATLAB** platform. The paper aims to develop a simple model for hydrological processes. The simplicity of model allow to set it up on any watershed with relatively ease, it could be automatic calibrated using state of the art optimization algorithms.

This model is a **lumped**-conceptual hydrological model. To check validity of model, this paper also runs simulation of a hydrological model on MATLAB and compare the **simulated result** to **observed value** of stream flow.

KEYWORDS: watershed simulation model, Lumped model, scripted functions, MATLAB;

ACKNOWLEDGEMENT

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Finally, I want to thank my family for always believing in my abilities and for always showering their invaluable blessings, love and support.

This opportunity will be a significant stepping stone in my career development. I will try to use skills and knowledge gained here in best possible way, & continue working on their improvement.

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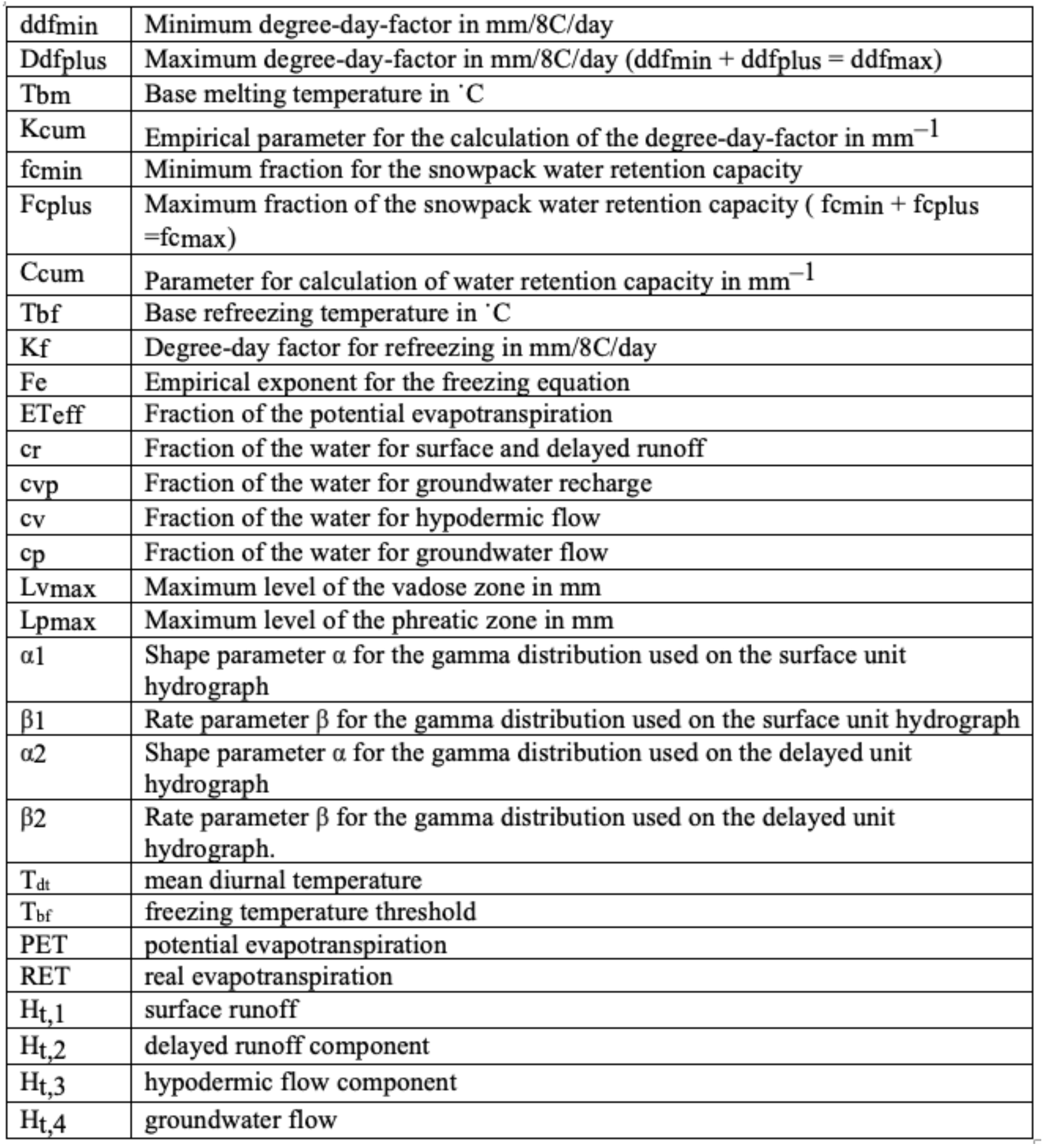


ddfmin	Minimum degree-day-factor in mm/8C/day
Ddfplus	Maximum degree-day-factor in mm/8C/day (ddfmin + ddfplus = ddfmax)
Tbm	Base melting temperature in ˙C
Kcum	Empirical parameter for the calculation of the degree-day-factor in mm^{-1}
fcmin	Minimum fraction for the snowpack water retention capacity
Fcplus	Maximum fraction of the snowpack water retention capacity (fcmin + fcplus =fcmax)
Ccum	Parameter for calculation of water retention capacity in mm^{-1}
Tbf	Base refreezing temperature in ˙C
Kf	Degree-day factor for refreezing in mm/8C/day
Fe	Empirical exponent for the freezing equation
ETeff	Fraction of the potential evapotranspiration
cr	Fraction of the water for surface and delayed runoff
cvp	Fraction of the water for groundwater recharge
cv	Fraction of the water for hypodermic flow
cp	Fraction of the water for groundwater flow
Lvmax	Maximum level of the vadose zone in mm
Lpmax	Maximum level of the phreatic zone in mm
$\alpha 1$	Shape parameter α for the gamma distribution used on the surface unit hydrograph
$\beta 1$	Rate parameter β for the gamma distribution used on the surface unit hydrograph
$\alpha 2$	Shape parameter α for the gamma distribution used on the delayed unit hydrograph
$\beta 2$	Rate parameter β for the gamma distribution used on the delayed unit hydrograph.
T_{dt}	mean diurnal temperature
T_{bf}	freezing temperature threshold
PET	potential evapotranspiration
RET	real evapotranspiration
$H_{t,1}$	surface runoff
$H_{t,2}$	delayed runoff component
$H_{t,3}$	hypodermic flow component
$H_{t,4}$	groundwater flow

CHAPTER-1

INTRODUCTION

1.1.1 Hydrology, a discipline of civil engineering used to study hydrological phenomena. Hydrological cycle, conceptualise dynamic & cyclical aspect of water in atmosphere. The component of hydrological cycle can be divided into two types i.e. transportation components (include precipitation, Evaporation, transpiration, Infiltration, Runoff) and Storage component (on land in form of lakes, in soil, as groundwater).

1.1.2 **Water budget equation** [1]: also known as hydrologic equation, it describe the interdependency of transport component due to principle of continuity.

mass inflow-mass outflow=change in storage

1.1.3 **Hydrologic model**: model essentially is explanation of natural phenomena in simple terms. Modelling is important for studying a phenomena scientifically. It usually is a simplification of real world systems. Hydrologic model are models dealing with hydrological phenomena, particularly hydrological cycle (Its component and/or its processes like surface water, soil water, wetland, groundwater, estuary) that aids in, predicting, controlling understanding & developing of discipline of water resources . Aim of such models is to widen the understanding of such natural phenomena and realize full potensial of resources.

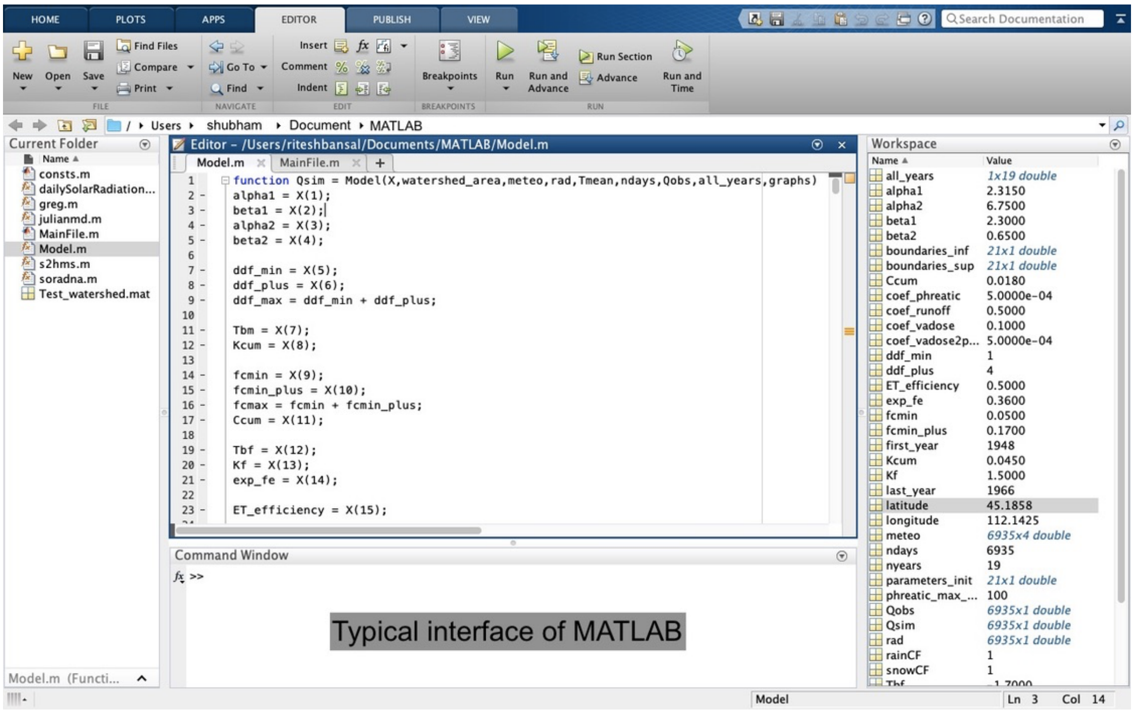
1.1.4 **Rainfall-runoff models** are one such tools used in discipline of hydrology. Rainfall-runoff models have been widely used to predict streamflow for a long time and are used in many applications like streamflow forecasting, agriculture, risk management, flood control and reservoir operations. With abundant access to computers, a large base of hydrological models with varying degrees of complexity are being developed since past 60 years (since 1960s) and used everywhere in world.

1.1.5 there are two type of Hydrological models [2], lumped and distributed. Lumped models assume catchment as an single entity and uses lumped/mean values of input variables and parameters. These have been developing since 1960s (like Stanford catchment model, Crawford & Lindsey). On other hand, distributed models takes into account spatial variability of processes within catchments, consequently predicting local hydrological responses for points within the catchment. In such models every spatial element & process has distinct variable.

Both of these model have their simultaneous boon & bane. This paper uses lumped model, as this model allows user to understand & simulate model with relative ease. simplicity is always preferred, but it is appropriate to state that this simplicity comes at cost of accuracy. But, that drawback can be overcome by proper calibration, which can be done by state of art calibration algorithm available.

The goal of this paper is to establish a lumped watershed simulation model. The said model is then introduced into MATLAB, and then running the simulation for a given dataset to compute appropriate variables (such as streamflow, meteorological data and internal variables like evapotranspiration and snow cover) and compare the simulated result to observed value of stream flow. Sensitivity analysis of model can be done by tweaking with parameter during calibration stage. This act as valuable tool when setting up model for a watershed with different properties, or analysis of field using different value of independent variable.

1.1.4 **Watershed simulation**: simulation essentially mean a process which imitate a phenomena, used to represent the operations/processes involved as time passes. Watershed simulation are used in Hydrology to Predict, Control, Determine & Understand different dynamics of water cycle & help in development of civil engineering. Watershed simulation basically uses water budget equation for determining runoff for given period for a certain watershed. one aims here to develop a Deterministic watershed runoff (deterministic watershed runoff, is a technique when runoff is predicted due to given precipitation, seen in contrast to Stochastic runoff). In preparing such simulation, following processes are involved. First, theoretical model is prepared (include all Independent variables). Then this model is calibrated. Calibration means numerical values of various coefficient determined by simulating known rain-runoff record. calibration need at least 5 yr of data for sufficient validity. In procedure of calibration initial guess value adjusted on trial & error basis till simulated value match recorded values. Then comes validification/verification part of model. It has two component internal validity & external validity. Internal validity is realised in this paper, by comparing the simulated runoff to observed runoff to compare the effectiveness of model. The external validity compares the prepared model with other valid models to compare effectiveness, here statistic variables can be used to compare such models (like nash-Sutcliffe efficiency). The external validity is currently outside scope of this paper as of now.



```
function Qsim = Model(X,watershed_area,meteo,rad,Tmean,ndays,Qobs,all_years,graphs)
alpha1 = X(1);
beta1 = X(2);
alpha2 = X(3);
beta2 = X(4);

ddf_min = X(5);
ddf_plus = X(6);
ddf_max = ddf_min + ddf_plus;

Tbm = X(7);
Kcum = X(8);

fcmin = X(9);
fcmin_plus = X(10);
fcmax = fcmin + fcmin_plus;
Ccum = X(11);

Tbf = X(12);
Kf = X(13);
exp_fe = X(14);

ET_efficiency = X(15);
```

```
>>
```

Name ▲	Value
all_years	1x19 double
alpha1	2.3150
alpha2	6.7500
beta1	2.3000
beta2	0.6500
boundaries_inf	21x1 double
boundaries_sup	21x1 double
Ccum	0.0180
coef_phreatic	5.0000e-04
coef_runoff	0.5000
coef_vadose	0.1000
coef_vadose2p...	5.0000e-04
ddf_min	1
ddf_plus	4
ET_efficiency	0.5000
exp_fe	0.3600
fcmin	0.0500
fcmin_plus	0.1700
first_year	1948
Kcum	0.0450
Kf	1.5000
last_year	1966
latitude	45.1858
longitude	112.1425
meteo	6935x4 double
ndays	6935
nyears	19
parameters_init	21x1 double
phreatic_max_...	100
Qobs	6935x1 double
Qsim	6935x1 double
rad	6935x1 double
rainCF	1
snowCF	1

Figure-1.1, Typical interface in MATLAB

1.1.5 **MATLAB**: aka Matrix laboratory, is a programming language. It helps in matrix manipulation of data points, symbolic depiction, analysis of such data point. Further, it helps identifying for any possible trends present inside such data matrix. Use of MATLAB for making decisions regarding policy & regulation has become the new normal. Thus, this paper tries to use this language to allow discipline of hydrology take advantage of this tool. Pre requisite knowledge- To undertake use of this tool, one must be acquainted with basic program writing (B tech graduate usually take 1 semester course in this regard in 1st year of their graduation).

1.2 LITERATURE REVIEW

V. P. Singh and **D. K. Frevert** [2], Watershed models is used to address a large number of environmental and water resources problems. This book presents brief historical perspective, new developments and challenges in watershed models. This paper has helped in preparing context of model. Also contemporary model being used in field are objectively presented in this book. This source has been of immense importance while contemplating philosophy of this research work.

S. Araghinejad 'Data driven modelling' [3], guide that helps use of MATLAB in water resource and environmental engineering. Analysis of data is quintessential to find possible trends, take policy decisions, identify anomalies. This reference book helped in understanding peculiarities of MATLAB & its application in water resources. such analysis & manipulation of data points, are important for bird eye view of possible trends in data.

Oudin et al [4], aimed to find the most relevant way to calculate potential evapotranspiration (PET) for use in a daily rainfall–runoff model. formulae based on temperature and radiation tend to provide the best streamflow simulations. Surprisingly, PE approaches based on the Penman approach seem less advantageous to feed rainfall–runoff models. This PE model require only mean air temperature derived over long term average.

A**. Caron and R. Leconte**, "An Improved Stochastic Weather Generator for Hydrological Impact Studies, uses HSAMI model [5], a 23 parameter distribute rainfall runoff model. This Rainfall-runoff model is being used by many authorities. But due to its complexity, its limited to commercial use. The snowfall model used in this model is very compex, thus not essential in Indian scenario.

Ghorbani et al [6]**,** probability distribution functions for unit hydrographs with optimization using genetic algorithm. This paper has allowed me to look at various mathematical function that can be used for understanding the relation with respect to Unit Hydrograph. On base of this, the decision to use 2 parameter gamma distribution density function was taken.

Vincent fortin [7]**,** distributed hydrological modelling with lumped inputs: paper make use of Distributed models in real world application with appropriation of input data into lumped format. Author uses three models on 3 different watershed to simulate runoff. This research help in understanding various dimension of distributed modelling.

CHAPTER-2

2. THEORETICAL MODEL

The model is a lumped-conceptual model using two connected reservoirs for the vadose and saturated zones. The model simulates the basic hydrological processes of evapotranspiration, infiltration, snow accumulation, melting and refreezing processes as well as the flow routing to the watershed outlet as illustrated in Fig. 2

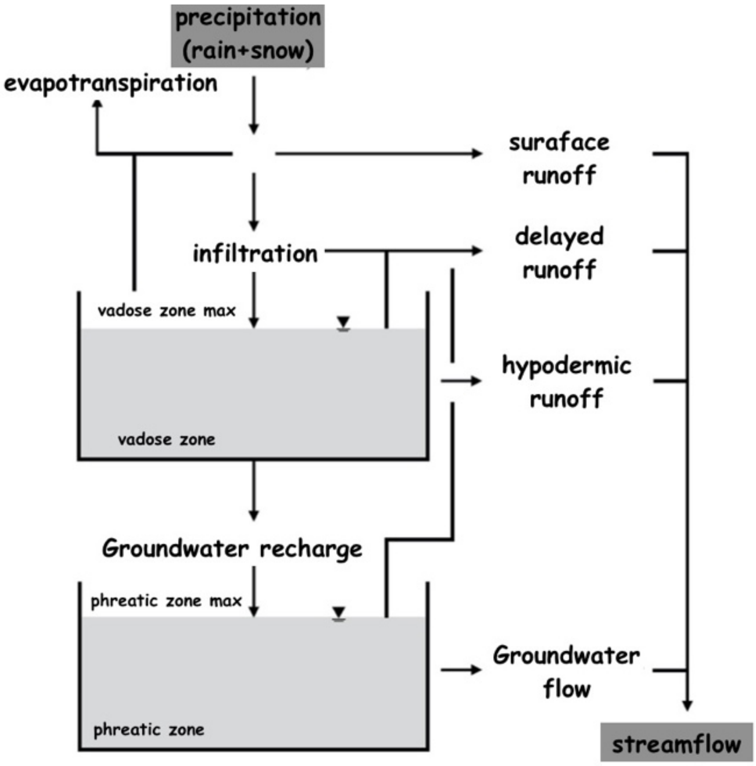
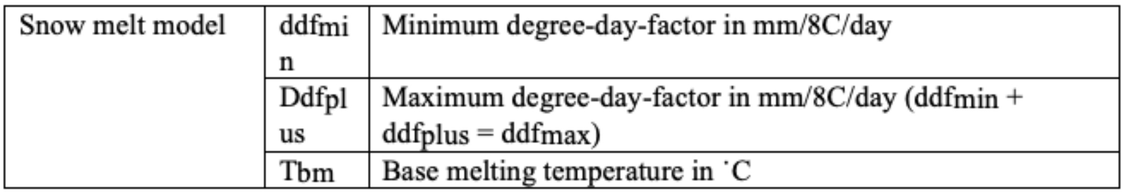


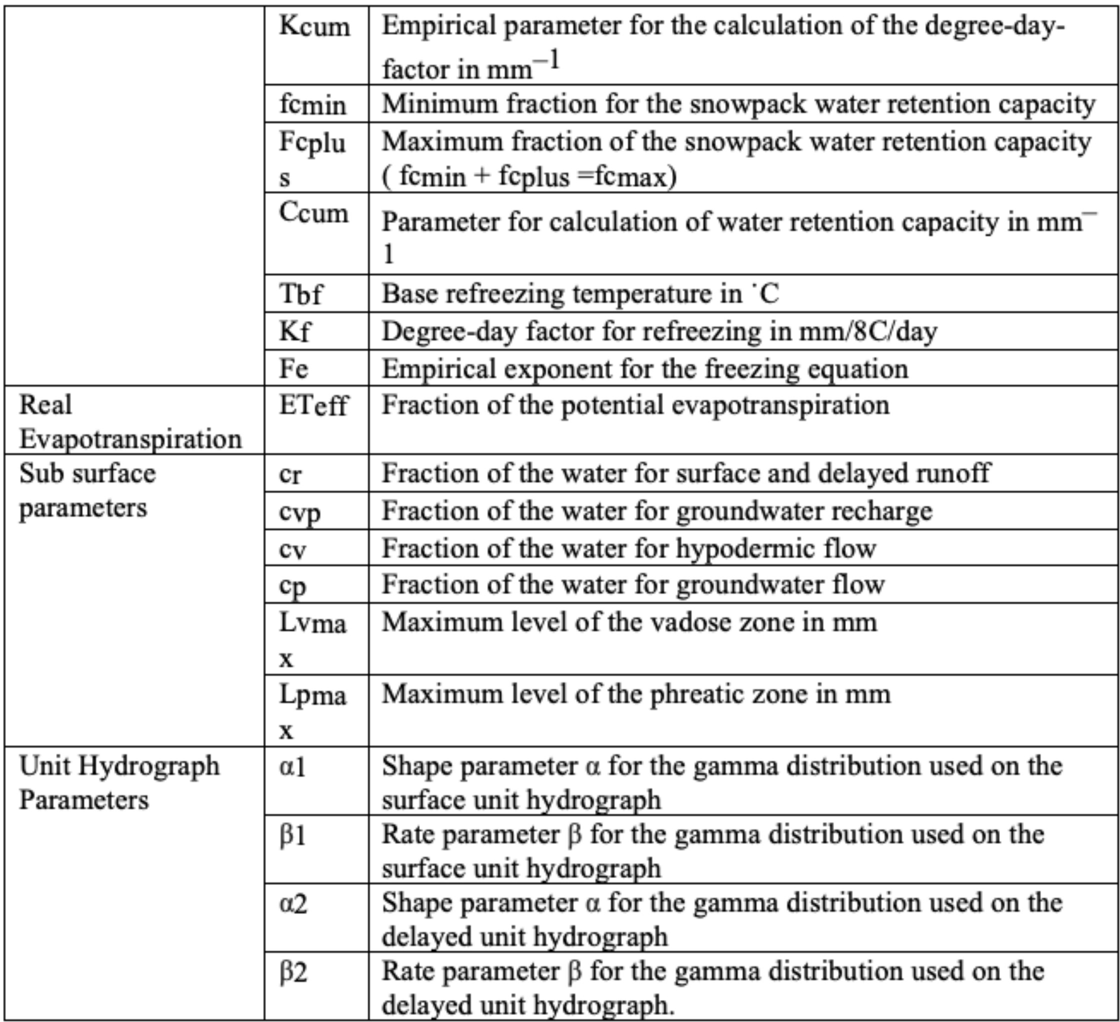
Figure-2.1, Model representation of hydrological processes.

2.1 Input data: model requires precipitation (liquid and solid), minimum and maximum temperatures only. However, Precipitation and temperature data must be averaged at the watershed scale (standard procedure in Lumped models). Daily observed streamflow must also be provided for model calibration.

2.2 Model parameter: the models has up to 21 parameters that can be optimized during calibration, which is detailed in Table 2.1.



Snow melt model	ddfmin	Minimum degree-day-factor in mm/8C/day
	Ddfplus	Maximum degree-day-factor in mm/8C/day (ddfmin + ddfplus = ddfmax)
	Tbm	Base melting temperature in ˚C



	Kcum	Empirical parameter for the calculation of the degree-day-factor in mm^{-1}
	fcmin	Minimum fraction for the snowpack water retention capacity
	Fcplus	Maximum fraction of the snowpack water retention capacity (fcmin + fcplus =fcmax)
	Ccum	Parameter for calculation of water retention capacity in mm^{-1}
	Tbf	Base refreezing temperature in ˙C
	Kf	Degree-day factor for refreezing in mm/8C/day
	Fe	Empirical exponent for the freezing equation
Real Evapotranspiration	ETeff	Fraction of the potential evapotranspiration
Sub surface parameters	cr	Fraction of the water for surface and delayed runoff
	cvp	Fraction of the water for groundwater recharge
	cv	Fraction of the water for hypodermic flow
	cp	Fraction of the water for groundwater flow
	Lvmax	Maximum level of the vadose zone in mm
	Lpmax	Maximum level of the phreatic zone in mm
Unit Hydrograph Parameters	α1	Shape parameter α for the gamma distribution used on the surface unit hydrograph
	β1	Rate parameter β for the gamma distribution used on the surface unit hydrograph
	α2	Shape parameter α for the gamma distribution used on the delayed unit hydrograph
	β2	Rate parameter β for the gamma distribution used on the delayed unit hydrograph.

Table 2.1, Parameter included in model

2.3 Snow Model [8]: a degree day model. It has 10 parameter there. there are 3 steps involved in it-

- Overnight refreezing process:

$$T_{dt} = (T_{mean\,t} + T_{min\,t})/2 \quad POR_t = K_f(T_{bf} - T_{dt})^{Fe} \tag{2.1}$$

Where, T_{dt} mean diurnal temperature T_{bf} freezing temperature threshold

- snowmelt: simulate the impact of the aging of the snowpack and its drop in surface albedo. model uses a variable degree day factor that depends on cumulative snowmelt (*CSM*). Snow melt occur only if mean temp. only occur if mean temp. above ddf.

$$Ddf_t = ddf_{min}(1 + K_{cum}.CSM_t) \quad PSM_t = \max(0, ddf_t(T_{mean\,t} - T_{bm})) \tag{2.2}$$

Where, ddf_{max} Degree day factor maximum; ddf_{min} Degree day factor minimum; PSM_t potential daily snowmelt; T_{bm} Base melting temperature in ˙C

- snowpack water retention capacity(WRF): function of snowpack ageing. C_{cum} Calculated as follow:

$$WRF_t = \max (fc_{min}, fc_{max}.(1 - C_{cum}.\ CSM_t)) \quad (2.3)$$

If the amount of water in the snowpack is higher than the water retention of the snowpack, the remaining is added to the water available for runoff (*WAR*).

2.4 Evapo-transpiration model [4]**:**

$$\text{If } T+5 > 0,\ PET = \text{Rad}\ (T+5)/\ \lambda\ \rho \quad (2.4)$$

Otherwise, PET= 0

Where PET is potential evapotranspiration in mm/day, Rad is the extra-terrestrial radiation in $MJ/m^2/day$, λ is the latent heat flux (equal to 2.26 MJ/kg) and ρ is the average water density (1000 kg/m^3), T is daily mean temperature

The real evapotranspiration (RET) is then computed as a function of potential evapotranspiration (PET) using a single free parameter:

$$RET_t = ET_{eff}.\ PET_t \quad (2.5)$$

2.5 vertical water balance:

vertical water balance takes into consideration all the exchanges made between the surface, vadose and saturated zones.

$$H_{t,1} = c_r .(\ LV_{t-1} /\ LV_{max}).WAR_t \quad (2.6)$$

$$I_t = WAR_t - H_{t,1} - RET_t \quad (2.7)$$

surface runoff ($H_{t,1}$), fraction of water available for runoff (c_r), vadose zone reservoir water level (LV_t), (WAR) water available for runoff, (I_t) amount of water that will infiltrate the vadose zone reservoir, (RET) real evapotranspiration

$$H_{t,2} = c_r\ .\ I_t(LV_{t-1}\ /\ LV_{max})^2 \quad (2.8)$$

$$H_{t,3} = c_v\ .\ LV_{t-1} \quad (2.9)$$

$$GR_t = c_{vp}\ .\ LV_{t-1} \quad (2.10)$$

Where, **delayed runoff** component ($H_{t,2}$), hypodermic flow component ($H_{t,3}$) , (c_v) Fraction of the water for hypodermic flow, (GR_t) is exchange between Vadose & saturated zone.

After this, vadose reservoir water level is updated based on following equation.

$$LV_t = LV_{t-1} + I_t - RET_t - H_{t,2} - H_{t,3} - GR_t \quad (2.11)$$

If vadose level fills up, overflow is added to delayed runoff $H_{t,2}$ as shown below

$$Ht,2 = Ht,2 + LVt - LVmax \qquad (2.12)$$

saturated zone is represented by a linear reservoir releasing **groundwater flow** ($H_{t,4}$). Water balanced in this reservoir as below.

$$H_{t},4 = c_p \, . \, LP_{t-1} \qquad (2.13)$$
$$LP_t = LPt\text{-}1 + q_t - Ht,4 \qquad (2.14)$$

If ($H_{t,4}$) exceed its maximum value, excess is sent to ($H_{t,2}$) component .

$$Ht,2 = Ht,2 + LPt - Lpmax \qquad (2.15)$$

2.6 Horizontal transport

Streamflow is calculated based on four component of horizontal flow i.e. (Ht,1) (Ht,2 (Ht,3) (Ht,4).

To transfer water at the outlet, 2 unit hydrographs (for surface and delayed runoff) are used. The unit hydrograph shapes are based on a two parameter gamma distribution density function (*gampdf*) [6] with shape parameter α and rate parameter β with *x* in days.

$$gampdf = (\beta^{\alpha} / T(\alpha)\,)\, x^{\alpha-1} \, . \, \exp^{-\beta\alpha} \qquad (2.16)$$

where, *T(α) is gamma distribution of alpha.* Both unit hydrographs are then computed and converted to $m^3/s/mm$ as follows:

$$UH = gampdf * (0.001) * A * 100000/(3600.\ 24)\ 2$$

Where A is the watershed area in km .

The **streamflow** for the surface runoff ($H_{t,1}$) and the delayed runoff ($H_{t,2}$) are then computed using their respective unit hydrograph as shown below:

$$Q_t = \Sigma i(1,n)\ (UH_i \, . \, H_{t-i+1}) \qquad (2.17)$$

Where n is the length (in days) of the unit hydrograph.

The hypodermic flow ($H_{t,3}$) and the base flow ($H_{t,4}$), components are converted from mm to m^3/s:

$$Q_t = H_t \, . \, 0.001 \, . \, A \, . \, 100000/(3600.24) \qquad (2.18)$$

At last, the modelled streamflow in found when we add up all four horizontal component together.

2.7 Repatriation of simulated streamflow components

Finally, modelled streamflow is computed by summing up all four horizontal flow components together:

$$Qm,t = \Sigma_{i}(1,4)\ Q_{t,I} \tag{2.19}$$

Chapter-3

3.1 Source code [3]

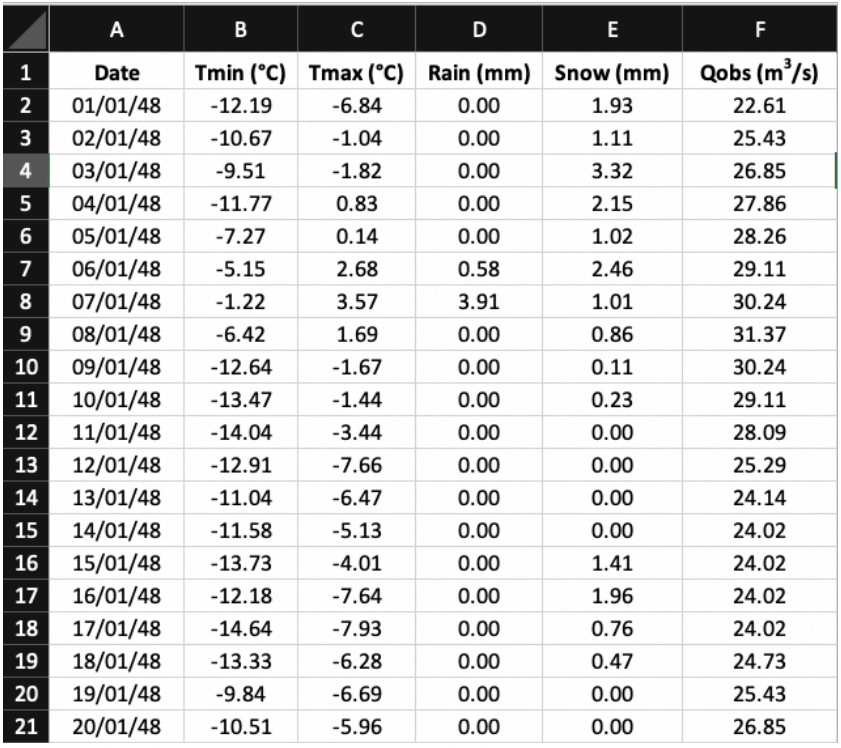
Name of the Scripted functions
Consts.m
dailySolarRadiation.m
Gerg.m
Julianmd.m
Model.m
s2hms.m
Soradna.m

Table 3.1, MATLAB scripted function (for complete function please refer to Apendix1)

The model requires precipitation (liquid and solid), minimum and maximum temperatures only. Precipitation and temperature data must be averaged at the watershed scale. Daily observed streamflow must also be provided for model calibration.

Inputs to the model are provided via a Microsoft Excel spreadsheet. Steps involved are: (1)import data set with respect to given watershed (2)source code representing the theoretical framework is written (3)the code is scripted and saved (4) computation are run & appropriate graphs are plotted representing various results

3.1.1 importing data from Microsoft excel



	A	B	C	D	E	F
1	Date	Tmin (°C)	Tmax (°C)	Rain (mm)	Snow (mm)	Qobs (m^3/s)
2	01/01/48	-12.19	-6.84	0.00	1.93	22.61
3	02/01/48	-10.67	-1.04	0.00	1.11	25.43
4	03/01/48	-9.51	-1.82	0.00	3.32	26.85
5	04/01/48	-11.77	0.83	0.00	2.15	27.86
6	05/01/48	-7.27	0.14	0.00	1.02	28.26
7	06/01/48	-5.15	2.68	0.58	2.46	29.11
8	07/01/48	-1.22	3.57	3.91	1.01	30.24
9	08/01/48	-6.42	1.69	0.00	0.86	31.37
10	09/01/48	-12.64	-1.67	0.00	0.11	30.24
11	10/01/48	-13.47	-1.44	0.00	0.23	29.11
12	11/01/48	-14.04	-3.44	0.00	0.00	28.09
13	12/01/48	-12.91	-7.66	0.00	0.00	25.29
14	13/01/48	-11.04	-6.47	0.00	0.00	24.14
15	14/01/48	-11.58	-5.13	0.00	0.00	24.02
16	15/01/48	-13.73	-4.01	0.00	1.41	24.02
17	16/01/48	-12.18	-7.64	0.00	1.96	24.02
18	17/01/48	-14.64	-7.93	0.00	0.76	24.02
19	18/01/48	-13.33	-6.28	0.00	0.47	24.73
20	19/01/48	-9.84	-6.69	0.00	0.00	25.43
21	20/01/48	-10.51	-5.96	0.00	0.00	26.85

Figure-3.1, Sample of imported data

3.1.2 writing the function (For complete source code please refer to annexure 1)

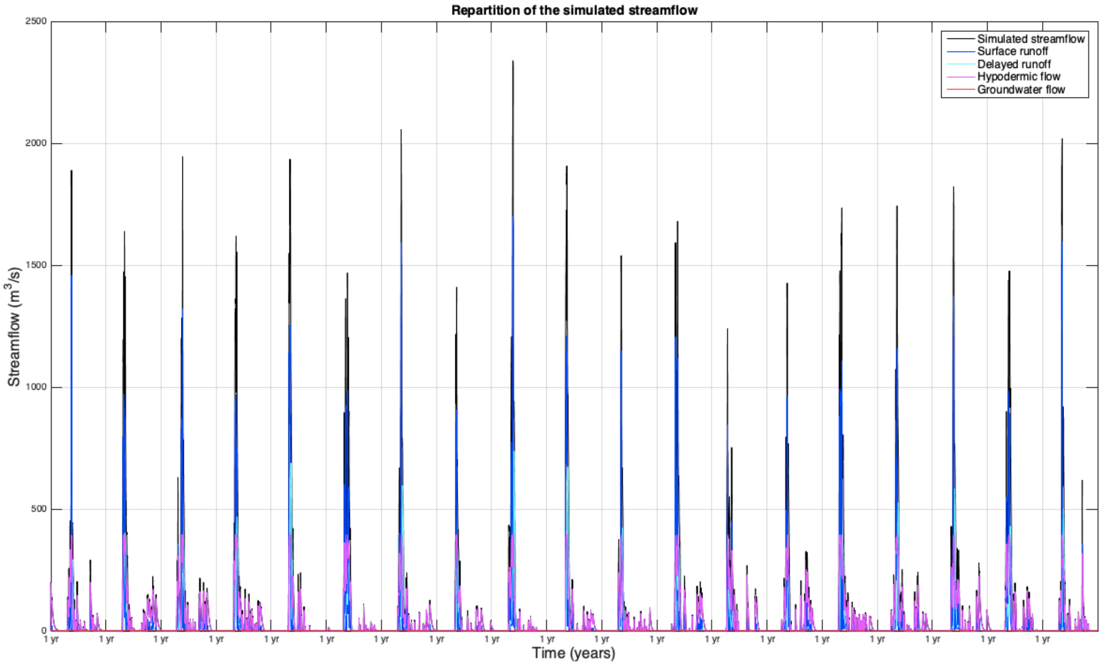
3.1.3 code is scripted and saved

3.1.4 computations are run. different variable are correlated to achieve graphs. Such graphs are scripted for future use.

Data set consist of 6900+ data points over 19 years, representing Precipitation (solid and liquid), Temperature (minimum & maximum). Script Test_watershed.m imports such mentioned data point into MATLAB. The functions greg.m, julianmd.m, s2hms.m, soradna.m and consts that are called with script mainfile.m come from the Air-Sea toolbox of the USGS Woods Hole Science Center [9]. The original files can be found at: woodshole.er.usgs.gov/operations/sea-mat/air_sea- html/index.html

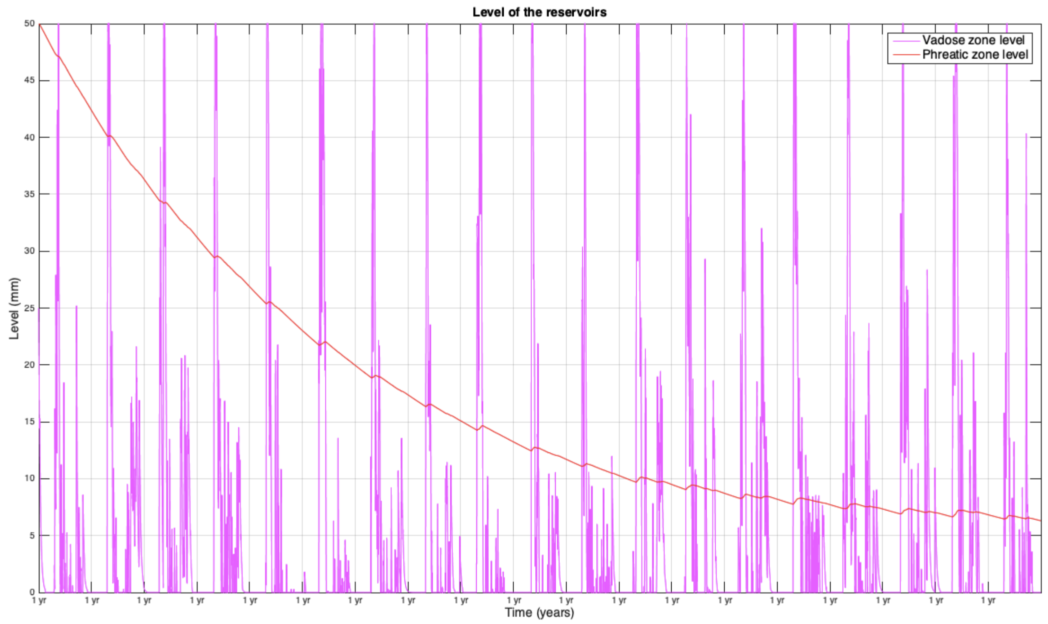
3.2 OBSERVATION

When the model is simulated in MATLAB software, following graphs are generated. These graphs represent the analysis done on base of theoretical model & Input Data. So this analysis is unique to chosen watershed. But, this model can be applied to any watershed with proper configuration & data input & graphs in reference to that particular watershed are generated. After running simulation for given data set following result can be seen:



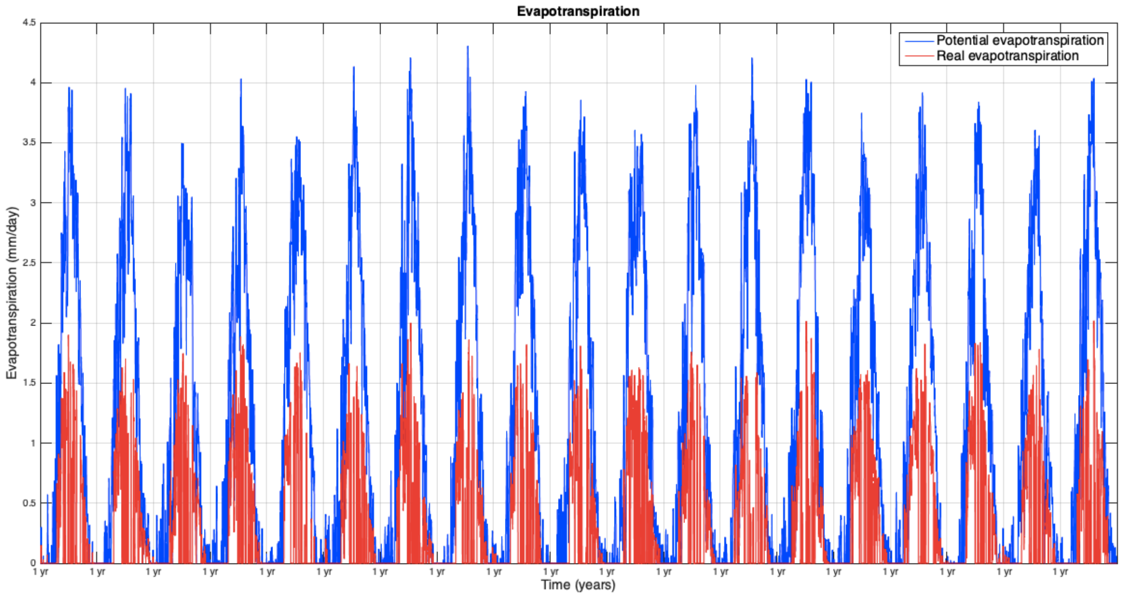
Graph 3.1, Repatriation of Simulated streamflow

Graph-3.1 represent the repartition of **simulated streamflow**. It includes stream runoff, delayed runoff, Hypodermic runoff and groundwater flow.



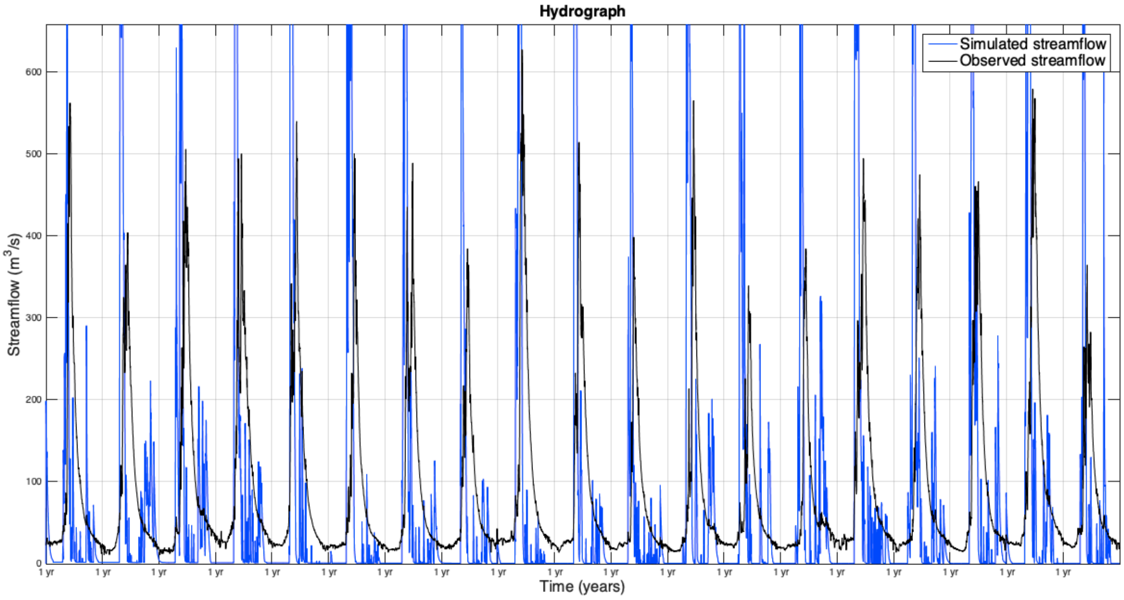
Graph 3.2, Level of Reservoirs

Graph 3.2 represents level of water in **Vadose and phreatic reservoir**. Although there data relating to vadose reservoir is largely stochastic, but a general trend in revealed in the phreatic zone. The gradual decline in the level of this reservoir depicts retreating Ground water level. This might be due to overexploitation of ground water resources.



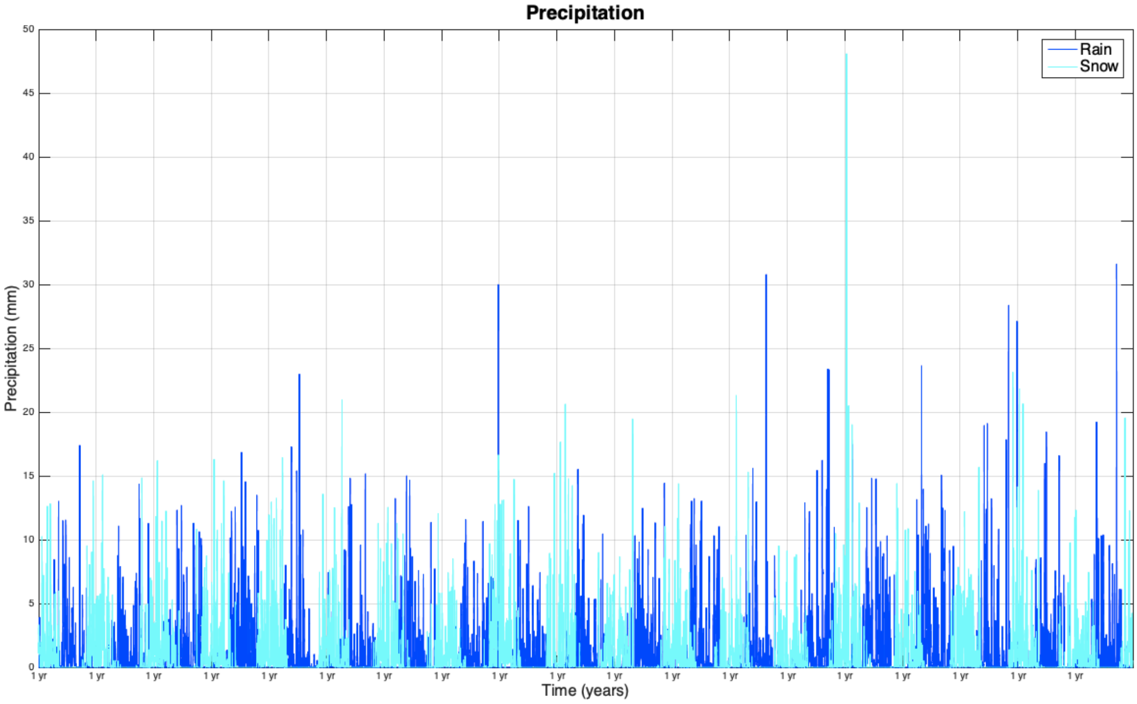
Graph 3.3, Evapotranspiration

Graph 3.3 capture the **evapotranspiration parameter** of the model. It depicts the potential evapotranspiration(PET) & real evapotranspiration (RET) against time. Here also one can observe the periodicity of data



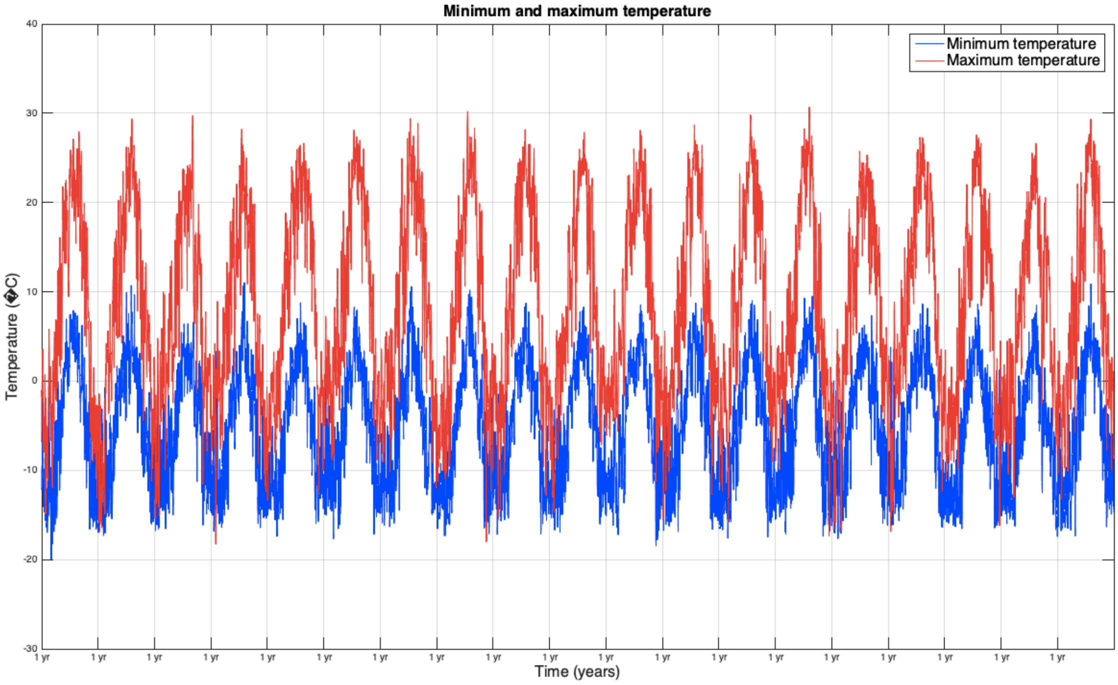
Graph 3.4, Hydrograph

Graph 3.4 depicts **hydrograph** for 19 years of data. The periodicity shown by simulated model is in closed convergence with observed data of stream flow. However, there are many points where there is drastic difference between observed and simulated discharge. But considering simplicity of the model, this trade-off is acceptable upto a certain extend (limit set by Statistical tools like NS efficiency). However, the data still show stochastic behaviour signifying room for further improvement.



Graph 3.5, Precipitation

Graph 3.5 depicts the **precipitation** state and range over the computed time. A trend in the liquid and solid can be seen in the graph computed.



Graph 3.6, Minimum and Maximum Temperature

Graph 3.6 captures **the minimum and maximum temperature range** of daily temperature over the watershed. Periodicity of temperature is captured and shown by this component of model.

Name	topic	remarks
Graph 3.1	Repatriation of Simulated streamflow	Represent simulated streamflow as summation of stream runoff, delayed runoff, Hypodermic runoff and groundwater flow.
Graph 3.2	Level of reservoir	Represent water stored in two conceived reservoir i.e. Phreatic reservoir & Vadose reservoir. Water level in Vadose reservoir is largely stochastic. Whereas, water level in phreatic zone shows consistent declining trend. This declining trend draws attention toward improper management of underground water resources.
Graph 3.3	Evapotranspiration	Measures Potensial Evapo-transpiration and Real Evapo-transpiration
Graph 3.4	Hydrograph	Compare the simulated streamflow with Observed streamflow. The simultaneous depiction of both (i.e. Qobs & Qsim) represent the culmination of relative importance of model. Its help in establish internal validity of model.
Graph 3.5	Precipitation	Depicts 2 major form of precipitation ie Snow & water. It depicts the months in which such data is received, representing season change.
Graph 3.6	Minimum and Maximum Temperature	Depicts periodicity shown by maximum & minimum temperature. it shows a small slope representing increasing values of temperature, correlated with Global warming.

Table 3.2 Summary of results

evaluation of model [10]: the evaluation is done using NSE nash-Sutcliffe efficiency. Q_o is observed streamflow and Q_m is modelled streamflow.

NSE= 1 – ∑(from t=1 to T) $(Q_o - Q_m)^2$/ ∑(from t=1 to T) $(Q_o - Q_{o(mean)})^2$

Range of NSE from $-\infty$ to 1. range from $-\infty$ to 1.

- NSE = 1, means perfect match between modeled & observed discharge.

- NSE = 0 means model predictions are as good as mean of observed discharge,

- NSE < 0 means observed mean is better predictor than model. In other words, the **residual variance** (numerator in expression above) > **data variance** (denominator).

- Threshold of sufficient quality model between 0.5 & 0.65

The NSE comes around approximately 0.60, means mode is sufficiently good. However the validity of model relative to models being used in field is still subject to future research.

3.3 CONCLUSION:

After running model for given data, one can easily see that model has been able to capture periodicity of variables, evident from NSE value. But, as the model has been simplified, the field validity as compared to other models like GSSHA is still in question. But, one thing is clear, relative to this level of simplicity & versatility, the performance of model is quite good. One of graphs depict how water in phreatic zone in watershed has been declining, signifying the probable overexploitation of groundwater resources. Thus objectively showing the declining trend in groundwater stating the practical use of the model.

Future scope: the model has possibility:
(1) optimization of result
(2) comparison with other model like HSAMI models to check validity of model;
(3) development of graphic user interface to make model user friendly.
(4) Climate Change Impact studies;

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APPENDIX I

Scripted function used in MATLAB code:

Name of the Scripted functions
Consts.m
dailySolarRadiation.m
Gerg.m
Julianmd.m
Model.m
s2hms.m
Soradna.m

‘Model.m’

```
function Qsim = Model(X,watershed_area,meteo,rad,Tmean,ndays,Qobs,all_years,graphs)
alpha1 = X(1);
beta1 = X(2);
alpha2 = X(3);
beta2 = X(4);
ddf_min = X(5);
ddf_plus = X(6);
ddf_max = ddf_min + ddf_plus;

    Tbm = X(7);
    Kcum = X(8);

    fcmin = X(9);
    fcmin_plus = X(10);
    fcmax = fcmin + fcmin_plus;
    Ccum = X(11);

    Tbf = X(12);
    Kf = X(13);
    exp_fe = X(14);

    ET_efficiency = X(15);

    coef_runoff = X(16);
    coef_vadose2phreatic = X(17);
    coef_vadose = X(18);
    coef_phreatic = X(19);
    vadose_max_level = X(20);
    phreatic_max_level = X(21);

    UH_bt = 50;
    x = (1:UH_bt)';

```

```
gamma_pdf1 = beta1^alpha1/(gamma(alpha1)) * x.^(alpha1-1).* exp(-beta1 .* x);
gamma_pdf2 = beta2^alpha2/(gamma(alpha2)) * x.^(alpha2-1).* exp(-beta2 .* x);

UH1 = gamma_pdf1*0.001*watershed_area*1000000/(3600*24);
UH2 = gamma_pdf2*0.001*watershed_area*1000000/(3600*24);

snow_on_ground=zeros(ndays,1);
snowmelt=zeros(ndays,1);
cumsnowmelt=zeros(ndays,1);
water_in_snowpack=zeros(ndays,1);
water_available_for_runoff=zeros(ndays,1);
potential_overnight_freezing=zeros(ndays,1);
overnight_freezing=zeros(ndays,1);

RET=zeros(ndays,1);

vadose_level=ones(ndays,1)*0.5*vadose_max_level;
phreatic_level=ones(ndays,1)*0.5*phreatic_max_level;
infiltration=zeros(ndays,1);
vadose2phreatic=zeros(ndays,1);
horizontal_transfert=zeros(ndays,4);
streamflow_repartition=zeros(ndays,4);
latent_heat_flux = 2.26;
rho = 1000;

PET = rad/latent_heat_flux/rho.*((Tmean+5)./100);
i = Tmean<-5;
PET(i) = 0;
PET=PET*1000;


% Start of the model:
for i = 2:ndays

    % Beginning of the snowmelt model in three steps:
    % Step 1: calculation of the potential overnight refreezing process:
    Tdiurnal = 0.5*(Tmean(i)+meteo(i,1));
    if Tdiurnal < Tbf
       potential_overnight_freezing(i) = Kf*(Tbf-Tdiurnal)^exp_fe;
    end
    overnight_freezing(i) = min(potential_overnight_freezing(i),water_in_snowpack(i-1));
    water_in_snowpack(i-1) = water_in_snowpack(i-1)-overnight_freezing(i);
    snow_on_ground(i-1) = snow_on_ground(i-1)+overnight_freezing(i);

    % Step 2: Calculation of the degree-day factor as a function of cumulative snowmelt and computation of the potential snowmelt:
    ddf = ddf_min*(1+Kcum*cumsnowmelt(i-1));
```

```
        if ddf > ddf_max
            ddf = ddf_max;
        end
        snowmelt_potential = max(0,ddf*(Tmean(i)-Tbm));

        % Step 3: calculation of the snowpack water retention capacity:
        snow_on_ground_temp = snow_on_ground(i-1)+meteo(i,4);
        snowmelt(i) = min(snowmelt_potential,snow_on_ground_temp);
        cumsnowmelt(i) = cumsnowmelt(i-1)+snowmelt(i);
        snow_on_ground(i) = snow_on_ground_temp-snowmelt(i);

        if snow_on_ground(i) == 0
            cumsnowmelt(i) = 0;
        end

        water_retention_fraction = max(fcmin,fcmax*(1-Ccum*cumsnowmelt(i)));                    % Calculation of the water retention capacity of the snowpack.
        water_retention_mm = water_retention_fraction*snow_on_ground(i);                        % Calculation of the quantity of liquid water in mm that can be contained in the snowpack.
        water_in_snowpack_temp = water_in_snowpack(i-1)+snowmelt(i)+meteo(i,3);                 % Total potential water in snowpack.
        water_available_for_runoff(i) = max(0,water_in_snowpack_temp-water_retention_mm);      % For runoff, the water in the snowpack in mm must
                                                                                                % exceed the water retention capacity (mm)
        if water_available_for_runoff(i) > 0
            water_in_snowpack(i) = water_retention_mm;
        else
            water_in_snowpack(i) = water_in_snowpack_temp;
        end

        % End of the snowmelt model; there is water available at the surface or not

        RET(i) = ET_efficiency*PET(i);

        horizontal_transfert(i,1) = coef_runoff*(vadose_level(i-1)/vadose_max_level)*water_available_for_runoff(i);
        infiltration(i) = water_available_for_runoff(i)-horizontal_transfert(i,1)-RET(i);

        if infiltration(i) <= 0
            horizontal_transfert(i,2) = 0;  % If there is no infiltration, there is no delayed runoff
        else
            horizontal_transfert(i,2) = coef_runoff*infiltration(i)*(vadose_level(i-1)/vadose_max_level)^2; % Delayed runoff (mm)
        end
```

```

        horizontal_transfert(i,3) = coef_vadose*vadose_level(i-1);      % Hypodermic flow (mm)
        vadose2phreatic(i) = coef_vadose2phreatic*vadose_level(i-1);    % Groundwater recharge: flux going to the phreatic zone (mm)

        % Calculation of the new water level in the vadose zone
        vadose_level(i) = vadose_level(i-1)+infiltration(i)-RET(i)-horizontal_transfert(i,2)-horizontal_transfert(i,3)-vadose2phreatic(i);
        if vadose_level(i) < 0
            RET(i) = RET(i)+vadose_level(i);
            if RET(i) < 0
                RET(i) = 0;
            end
            vadose_level(i) = 0;
        elseif vadose_level(i) > vadose_max_level
            vadose_excess = vadose_level(i)-vadose_max_level; % If the vadose zone is empty: the real evapotranspiration is limited
            horizontal_transfert(i,2) = horizontal_transfert(i,2)+vadose_excess;
            vadose_level(i) = vadose_max_level;
        end

        % Calculation of the new water level in the vadose zone
        horizontal_transfert(i,4) = coef_phreatic*phreatic_level(i-1);
        % Calculation of the new water level in the phreatic zone
        phreatic_level(i) = phreatic_level(i-1)+vadose2phreatic(i)-horizontal_transfert(i,4);

        if phreatic_level(i) > phreatic_max_level
           horizontal_transfert(i,2) = horizontal_transfert(i,2)+(phreatic_level(i)-phreatic_max_level);
           phreatic_level(i) = phreatic_max_level;
        end

        % At this point we have the depth of runoff from surface, vadose zone and phreatic zone
        % Calculation of the streamflow repartition (m^3/s)

        k = 0;
        for j=i:i+UH_bt-1
            if j <= ndays
                k = k+1;
                streamflow_repartition(j,1) = streamflow_repartition(j,1)+ UH1(k)*horizontal_transfert(i,1);
                streamflow_repartition(j,2) = streamflow_repartition(j,2)+UH2(k)*horizontal_transfert(i,2);
            end
```

```
        end

        streamflow_repartition(i,3) = horizontal_transfert(i,3)*0.001*watershed_area*1000000/(3600*24);
        streamflow_repartition(i,4) = horizontal_transfert(i,4)*0.001*watershed_area*1000000/(3600*24);

    end

    % The simulated streamflow is the sum of the contribution form surface runoff, intermediate runoff and the baseflows.
    Qsim = sum(streamflow_repartition(:,1:4),2);


    if graphs == 1
        initial_date = datenum([all_years(1),01,01]);
        final_date = datenum([all_years(length(all_years)),12,31]);
        all_dates = datevec(initial_date:final_date);
        remove_29_february = find(all_dates(:,2) == 2 & all_dates(:,3) == 29);

        if isempty(Qobs) == 0
            mean_Qobs = Qobs;
            mean_Qobs(remove_29_february) = [];
            mean_Qobs = mean(reshape(mean_Qobs,365,[]),2);
        end

        mean_Qsim = Qsim;
        mean_Qsim(remove_29_february) = [];
        mean_Qsim = mean(reshape(mean_Qsim,365,[]),2);

        mean_Tmin = meteo(:,1);
        mean_Tmin(remove_29_february) = [];
        mean_Tmin = mean(reshape(mean_Tmin,365,[]),2);

        mean_Tmax = meteo(:,2);
        mean_Tmax(remove_29_february) = [];
        mean_Tmax = mean(reshape(mean_Tmax,365,[]),2);

        mean_rain = meteo(:,3);
        mean_rain(remove_29_february) = [];
        mean_rain = mean(reshape(mean_rain,365,[]),2);

        mean_snow = meteo(:,4);
        mean_snow(remove_29_february) = [];
        mean_snow = mean(reshape(mean_snow,365,[]),2);

        mean_PET = PET;
        mean_PET(remove_29_february) = [];
        mean_PET = mean(reshape(mean_PET,365,[]),2);

        mean_RET = RET;
```

```
        mean_RET(remove_29_february) = [];
        mean_RET = mean(reshape(mean_RET,365,[]),2);

        mean_snow_on_ground = snow_on_ground;
        mean_snow_on_ground(remove_29_february) = [];
        mean_snow_on_ground = mean(reshape(mean_snow_on_ground,365,[]),2);

        mean_cumsnowmelt = cumsnowmelt;
        mean_cumsnowmelt(remove_29_february) = [];
        mean_cumsnowmelt = mean(reshape(mean_cumsnowmelt,365,[]),2);

        mean_water_in_snowpack = water_in_snowpack;
        mean_water_in_snowpack(remove_29_february) = [];
        mean_water_in_snowpack = mean(reshape(mean_water_in_snowpack,365,[]),2);

        mean_vadose_level = vadose_level;
        mean_vadose_level(remove_29_february) = [];
        mean_vadose_level = mean(reshape(mean_vadose_level,365,[]),2);

        mean_phreatic_level = phreatic_level;
        mean_phreatic_level(remove_29_february) = [];
        mean_phreatic_level = mean(reshape(mean_phreatic_level,365,[]),2);

        mean_surface_runoff = streamflow_repartition(:,1);
        mean_surface_runoff(remove_29_february) = [];
        mean_surface_runoff = mean(reshape(mean_surface_runoff,365,[]),2);

        mean_delayed_runoff = streamflow_repartition(:,2);
        mean_delayed_runoff(remove_29_february) = [];
        mean_delayed_runoff = mean(reshape(mean_delayed_runoff,365,[]),2);

        mean_hypodermic_flow = streamflow_repartition(:,3);
        mean_hypodermic_flow(remove_29_february) = [];
        mean_hypodermic_flow = mean(reshape(mean_hypodermic_flow,365,[]),2);

        mean_groundwater_flow = streamflow_repartition(:,4);
        mean_groundwater_flow(remove_29_february) = [];
        mean_groundwater_flow = mean(reshape(mean_groundwater_flow,365,[]),2);

        h = get(0,'ScreenSize');
set(figure,'Color','w','Position',[h(1),h(2),h(3),h(4)],'Renderer','painters')

        subplot(321)
        hold on
```

```
        plot(1:365,mean_Qsim,'-b');
        if isempty(Qobs) == 0
            plot(1:365,mean_Qobs,'-k');
            legend('Simulated streamflow','Observed streamflow');
            ylim([0 max(mean_Qobs)*1.05])
        else
            legend('Simulated streamflow');
            ylim([0 max(mean_Qsim)*1.05])
        end
        title('Hydrograph')
        xlabel('Months')
        xlim([1 365])
        set(gca,'xtick',[1 31 59 90 120 151 181 212 243 273 304 334])
        set(gca,'xticklabel',{'Jan','Feb','Mar','Apr','May','Jun','Jul','Aug','Sep','Oct','Nov','Dec'})
        ylabel('Streamflow (m^3/s)')

        subplot(322)
        hold on
        plot(1:365,mean_Tmin,'-b')
        plot(1:365,mean_Tmax,'-r')
        title('Temperature')
        xlabel('Months')
        xlim([1 365])
        set(gca,'xtick',[1 31 59 90 120 151 181 212 243 273 304 334])
        set(gca,'xticklabel',{'Jan','Feb','Mar','Apr','May','Jun','Jul','Aug','Sep','Oct','Nov','Dec'})
        ylabel('Temperature (ÔøΩC)')
        legend('Minimum temperature','Maximum temperature')

        subplot(323)
        hold on
        plot(1:365,mean_rain,'-b')
        plot(1:365,mean_snow,'-c')
        plot(1:365,mean_PET,'-m')
        plot(1:365,mean_RET,'-r')
        title('Precipitation and evapotranspiration')
        xlabel('Months')
        xlim([1 365])
        set(gca,'xtick',[1 31 59 90 120 151 181 212 243 273 304 334])
        set(gca,'xticklabel',{'Jan','Feb','Mar','Apr','May','Jun','Jul','Aug','Sep','Oct','Nov','Dec'})
        ylabel('(mm)')
        legend('Rain','Snow','Potential evapotranspiration','Real evapotranspiration')

    %     subplot(324)
    %     hold on
    %     plot(1:365,mean_snow_on_ground,'-c')
```

```
%     plot(1:365,mean_cumsnowmelt,'-r')
%     plot(1:365,mean_water_in_snowpack,'-b')
%     title('Snowpack evolution')
%     xlabel('Months')
%     xlim([1 365])
%     set(gca,'xtick',[1 31 59 90 120 151 181 212 243 273 304 334])
%     set(gca,'xticklabel',{'Jan','Feb','Mar','Apr','May','Jun','Jul','Aug','Sep','Oct','Nov','Dec'})
%     ylabel('Streamflow (m^3/s)')
%     ylabel('Snow (mm)')
%     legend('Snow water equivalent','Cumulative snowmelt','Water in snowpack')

    subplot(325)
    hold on
    plot(1:365,mean_vadose_level,'-m')
    plot(1:365,mean_phreatic_level,'-r')
    title('Level of the reservoirs')
    xlabel('Months')
    xlim([1 365])
    set(gca,'xtick',[1 31 59 90 120 151 181 212 243 273 304 334])
    set(gca,'xticklabel',{'Jan','Feb','Mar','Apr','May','Jun','Jul','Aug','Sep','Oct','Nov','Dec'})
    ylabel('Streamflow (m^3/s)')
    ylabel('Level (mm)')
    legend('Vadose zone','Phreatic zone')

    subplot(326)
    hold on
    plot(1:365,mean_Qsim,'-k')
    legend('Simulated streamflow')
    plot(1:365,mean_surface_runoff,'-b')
    legend('Surface runoff')
    plot(1:365,mean_delayed_runoff,'-c')
    legend('Delayed runoff')
    plot(1:365,mean_hypodermic_flow,'-m')
    legend('Hypodermic flow')
    plot(1:365,mean_groundwater_flow,'-r')
    legend('Groundwater flow')
    title('Repartition of the simulated streamflow')
    xlabel('Months')
    xlim([1 365])
    set(gca,'xtick',[1 31 59 90 120 151 181 212 243 273 304 334])
    set(gca,'xticklabel',{'Jan','Feb','Mar','Apr','May','Jun','Jul','Aug','Sep','Oct','Nov','Dec'})
    ylabel('Streamflow (m^3/s)')
    legend('Simulated streamflow',...
        'Surface runoff',...
        'Delayed runoff',...
```

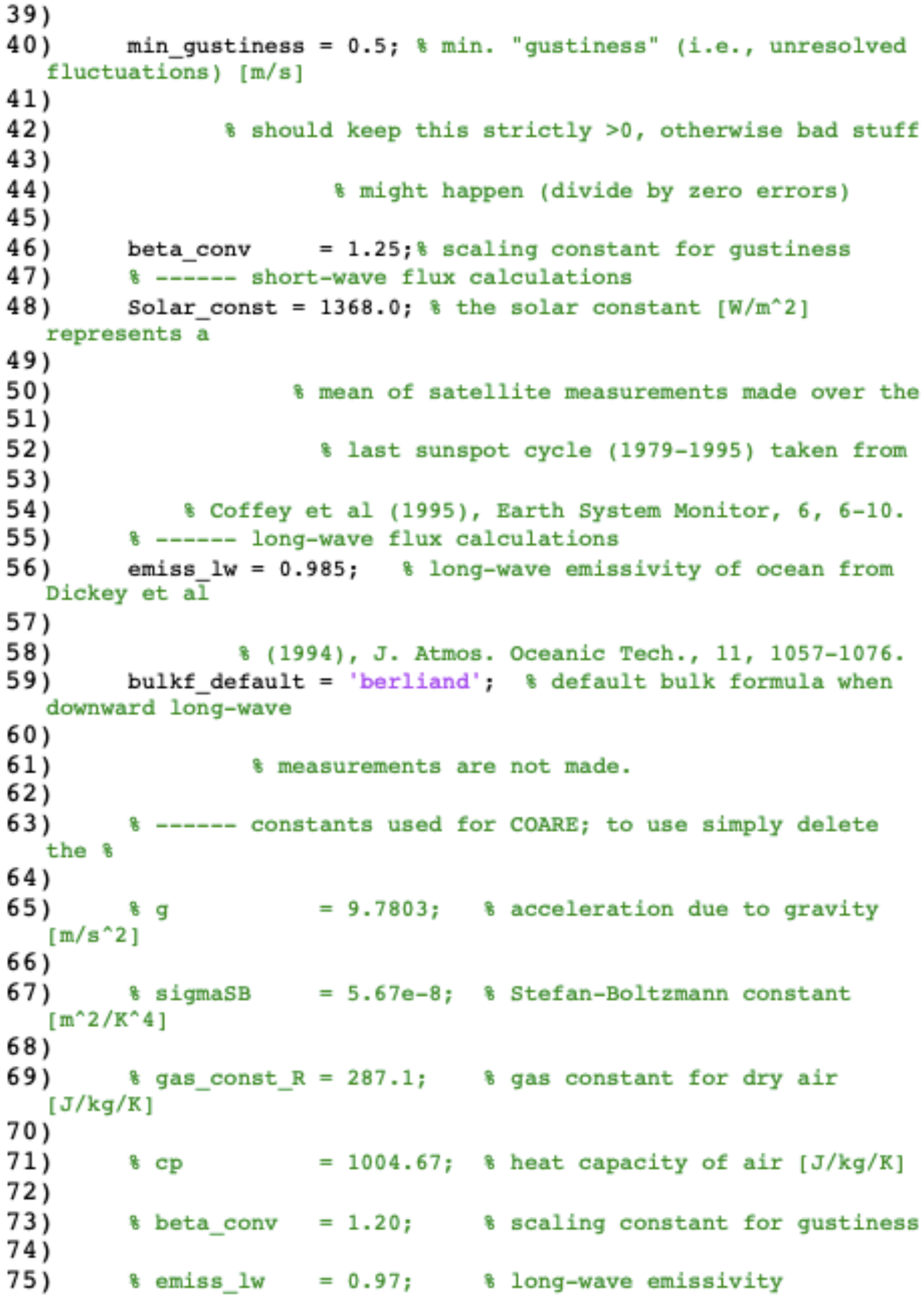
```
            'Hypodermic flow',...
            'Groundwater flow')

        % Hydrograph
        set(figure,'Color','w','Renderer','painters')
        hold on
        axis auto
        plot(Qsim,'-b');
        if isempty(Qobs) == 0
            plot(Qobs,'-k');
            legend('Simulated streamflow','Observed streamflow');
            ylim([0 max(Qobs)*1.05])
        else
            legend('Simulated streamflow');
            ylim([0 max(Qsim)*1.05])
        end
        title('Hydrograph')
        xlabel('Time (years)')
        xlim([1 numel(Qsim)])
        set(gca,'xtick',1:365:numel(Qsim))
        set(gca,'xticklabel','1 yr')
        ylabel('Streamflow (m^3/s)')
        grid on
        box on

        % Temperature
        set(figure,'Color','w','Renderer','painters')
        hold on
        plot(meteo(:,1),'-b')
        plot(meteo(:,2),'-r')
        title('Minimum and maximum temperature')
        xlabel('Time (years)')
        xlim([1 numel(Qsim)])
        set(gca,'xtick',1:365:numel(Qsim))
        set(gca,'xticklabel','1 yr')
        ylabel('Temperature (ÔøΩC)')
        legend('Minimum temperature','Maximum temperature')
        grid on
        box on

        % Precipitation
        set(figure,'Color','w','Renderer','painters')
        hold on
        plot(meteo(:,3),'-b')
        plot(meteo(:,4),'-c')
        title('Precipitation')
        xlabel('Time (years)')
        xlim([1 numel(Qsim)])
        set(gca,'xtick',1:365:numel(Qsim))
        set(gca,'xticklabel','1 yr')
        ylabel('Precipitation (mm)')
        legend('Rain','Snow')
        grid on
```

```
    box on

    % Evapotranspiration
    set(figure,'Color','w','Renderer','painters')
    hold on
    plot(PET,'-b')
    plot(RET,'-r')
    title('Evapotranspiration')
    xlabel('Time (years)')
    xlim([1 numel(Qsim)])
    set(gca,'xtick',1:365:numel(Qsim))
    set(gca,'xticklabel','1 yr')
    ylabel('Evapotranspiration (mm/day)')
    legend('Potential evapotranspiration','Real evapotranspiration')
    grid on
    box on

    % Level of the reservoirs
    set(figure,'Color','w','Renderer','painters')
    hold on
    plot(vadose_level,'-m')
    plot(phreatic_level,'-r')
    title('Level of the reservoirs')
    xlabel('Time (years)')
    xlim([1 numel(Qsim)])
    set(gca,'xtick',1:365:numel(Qsim))
    set(gca,'xticklabel','1 yr')
    ylabel('Level (mm)')
    legend('Vadose zone level','Phreatic zone level')
    grid on
    box on

    % Streamflow repartition
    set(figure,'Color','w','Renderer','painters')
    hold on
    plot(Qsim,'-k')
    legend('Simulated streamflow')
    plot(streamflow_repartition(:,1),'-b')
    legend('Surface runoff')
    plot(streamflow_repartition(:,2),'-c')
    legend('Delayed runoff')
    plot(streamflow_repartition(:,3),'-m')
    legend('Hypodermic flow')
    plot(streamflow_repartition(:,4),'-r')
    legend('Groundwater flow')
    title('Repartition of the simulated streamflow')
    xlabel('Time (years)')
    xlim([1 numel(Qsim)])
    set(gca,'xtick',1:365:numel(Qsim))
    set(gca,'xticklabel','1 yr')
    ylabel('Streamflow (m^3/s)')
    legend('Simulated streamflow',...
        'Surface runoff',...
```

```
            'Delayed runoff',...
            'Hypodermic flow',...
            'Groundwater flow')
        grid on
        box on

    end
```

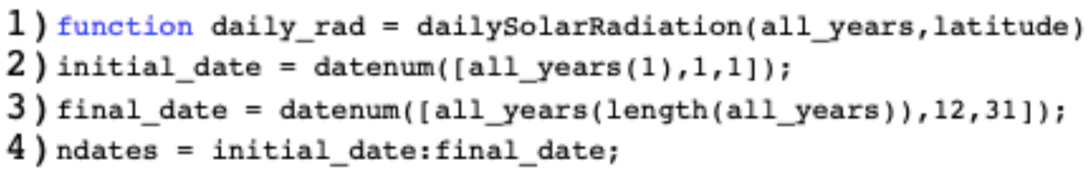
Constants used ‘**consts.m**

```
G            = 9.8;        % acceleration due to gravity
sigmaSB      = 5.6697e-8;  % Stefan-Boltzmann constant [W/m^2/K^4]
eps_air      = 0.62197;    % molecular weight ratio (water/air)
gas_const_R  = 287.04;     % gas constant for dry air [J/kg/K]
CtoK         = 273.16;     % conversion factor for [C] to [K]


% ------- meteorological constants
kappa           = 0.4;     % von Karman's constant
      Charnock_alpha = 0.011;  % Charnock constant (for
determining roughness length
               % at sea given friction velocity), used in Smith
                     % formulas for drag coefficient and also in
                               % Fairall
                % and Edson.  use alpha=0.011 for open-ocean and
              % alpha=0.018 for fetch-limited (coastal) regions.
                               %
      R_roughness   = 0.11; % limiting roughness Reynolds # for
aerodynamically
                               % smooth flow

      % ------ defaults suitable for boundary-layer studies
      cp            = 1004.7;   % heat capacity of air [J/kg/K]

      rho_air       = 1.22; % air density (when required as
constant) [kg/m^2]

      Ta_default    = 10;       % default air temperature [C]

      P_default     = 1020;      % default air pressure for
Kinneret [mbars]

      psych_default = 'screen'; % default psychmometer type (see
relhumid.m)

      Qsat_coeff    = 0.98;      % satur. specific humidity
coefficient reduced

                                % by 2% over salt water

      % the following are useful in hfbulktc.m

      % (and are the default values used in Fairall et al, 1996)
      CVB_depth     = 600; % depth of convective boundary layer
in atmosphere [m]
```



```

      min_gustiness = 0.5; % min. "gustiness" (i.e., unresolved fluctuations) [m/s]

             % should keep this strictly >0, otherwise bad stuff

                     % might happen (divide by zero errors)

      beta_conv     = 1.25;% scaling constant for gustiness
      % ------ short-wave flux calculations
      Solar_const = 1368.0; % the solar constant [W/m^2] represents a

                  % mean of satellite measurements made over the

                    % last sunspot cycle (1979-1995) taken from

          % Coffey et al (1995), Earth System Monitor, 6, 6-10.
      % ------ long-wave flux calculations
      emiss_lw = 0.985;   % long-wave emissivity of ocean from Dickey et al

              % (1994), J. Atmos. Oceanic Tech., 11, 1057-1076.
      bulkf_default = 'berliand';  % default bulk formula when downward long-wave

               % measurements are not made.

      % ------ constants used for COARE; to use simply delete the %

      % g            = 9.7803;    % acceleration due to gravity [m/s^2]

      % sigmaSB      = 5.67e-8;   % Stefan-Boltzmann constant [m^2/K^4]

      % gas_const_R = 287.1;      % gas constant for dry air [J/kg/K]

      % cp           = 1004.67;   % heat capacity of air [J/kg/K]

      % beta_conv    = 1.20;      % scaling constant for gustiness

      % emiss_lw     = 0.97;      % long-wave emissivity
```

transpiration function ‘**dailySolarRadiation.m**’



```
function daily_rad = dailySolarRadiation(all_years,latitude)
initial_date = datenum([all_years(1),1,1]);
final_date = datenum([all_years(length(all_years)),12,31]);
ndates = initial_date:final_date;
```

```
daily_rad = zeros(length(ndates),1);
ndates = datevec(ndates);
% Compute using a 10 min interval (centered from 5 to 1435)
% There are 144*10 minutes in one day

      int= 5:10:1435;
      int=int/1440;    % in decimal form


      for i=1:length(daily_rad)
       time = int+(i-1);       % This is the year date
                             % January 1st at 5 minutes is: 0.0035
                             % January 5th at 5 minutes is: 4.0035
        [~,sorad]=soradna(time,ndates(i,1),0,latitude);
        daily_rad(i)=mean(sorad);
      End
```

‘Gerg.m’

```
function gtime = greg(yd,yr)
js = julianmd(yr,01,01,00);
julian = js + yd;
julian=julian+5.e-9;  % kludge to prevent roundoff error on seconds

%       if you want Julian Days to start at noon...
%       h=rem(julian,1)*24+12;
%       i=(h >= 24);
%       julian(i)=julian(i)+1;
      %      h(i)=h(i)-24;  Otherwise,....

      secs=rem(julian,1)*24*3600;

      j = floor(julian) - 1721119;
      in = 4*j -1;
      y = floor(in/146097);
      j = in - 146097*y;
      in = floor(j/4);
      in = 4*in +3;
      j = floor(in/1461);
      d = floor(((in - 1461*j) +4)/4);
      in = 5*d -3;
      m = floor(in/153);
      d = floor(((in - 153*m) +5)/5);
      y = y*100 +j;
      mo=m-9;
      yr=y+1;
      i=(m<10);
      mo(i)=m(i)+3;
      yr(i)=y(i);
      [hour,min,sec]=s2hms(secs);
      gtime=[yr(:) mo(:) d(:) hour(:) min(:) sec(:)];
```

‘Julianmd.m’

```
function j = julianmd(y,m,d,h)

if nargin==3,
        h=0.;
elseif nargin==1,
        h=hms2h(y(:,4),y(:,5),y(:,6));
        d=y(:,3);
        m=y(:,2);
        y=y(:,1);
        end
        mo=m+9;
        yr=y-1;
        i=(m>2);
        mo(i)=m(i)-3;
        yr(i)=y(i);
        c = floor(yr/100);
        yr = yr - c*100;
        j = floor((146097*c)/4) + floor((1461*yr)/4) + floor((153*mo +2)/5) +d +1721119;

        %     if you want Julian days to start and end at noon,
        %     replace the following line with:
        %     j=j+(h-12)/24;


        j=j+h/24;
```

‘s2hms.m’

```
function [hr,min,sec] = s2hms(secs)
sec=round(secs);
hr=floor(sec./3600);
min=floor(rem(sec,3600)./60);
sec=round(rem(sec,60));
```

‘Soradna.m’

```
function [z,sorad] = soradna(yd,yr,long,lat)

consts;

% convert yd to column vector if necessary

[n,m]=size(yd);

```

```
if m > n
        yd=yd';
      end

      % convert yearday to calender time

      gtime=greg(yd,yr);

      SC=gtime(:,6);
      MN=fix(gtime(:,5));
      HR=fix(gtime(:,4));
      D=fix(gtime(:,3));
      M=fix(gtime(:,2));
      Y=fix(gtime(:,1));



      % convert to new variables

      LONG=long;
      LAT=lat;



      % two options - either long/lat are vectors, time is a scalar



      if length(LONG)==1 & length(LAT)>1,
         LONG=LONG(ones(size(LAT)));
      elseif length(LONG)>1 & length(LAT)==1,
        LAT=LAT(ones(size(LAT)));
      end;



      if length(SC)==1,
        osiz=ones(size(LONG));
        SC=SC(osiz);
        MN=MN(osiz);
        HR=HR(osiz);
        D=D(osiz);
        M=M(osiz);
        Y=Y(osiz);
      elseif length(LONG)==1,

       LONG=LONG(ones(size(SC)));
       LAT=LAT(ones(size(SC)));

      end;



```

```
    % constants

       DTR=3.14159265/180;
       RTD=1./DTR;



    % compute Universal Time in hours

       UT = HR+(MN+SC./60.)./60;



    % compute Julian ephemeris date in days (Day 1 is 1 Jan 4713 B.C.=-4712 Jan 1)

       JED=367.*Y-fix(7.*(Y+fix((M+9)./12))./4)+fix(275.*M./9)+D+1721013 + UT./24;



    % compute interval in Julian centuries since 1900

        T=(JED-2415020.0)./36525;



    % compute mean anomaly of the sun

        G=358.475833+35999.049750.*T-.000150.*T.^2;
        NG=fix(G./360);
        G=(G-NG.*360).*DTR;



    % compute mean longitude of sun

        L=279.696678+36000.768920.*T+.000303.*T.^2;
        NL=fix(L./360);
        L=(L-NL.*360).*DTR;



    % compute mean anomaly of Jupiter

      JUP=225.444651+2880.0.*T+154.906654.*T;
      NJUP=fix(JUP/360);
      JUP=(JUP-NJUP.*360).*DTR;



    % compute longitude of the ascending node of the moon's orbit

```

```
        NM=259.183275-1800.*T-134.142008.*T+.002078.*T.^2;
        NNM=fix(NM./360);
        NM=(NM-NNM.*360+360).*DTR;



     % compute mean anomaly of Venus

         V=212.603219+58320.*T+197.803875.*T+.001286.*T.^2;
         NV=fix(V/360);
         V=(V-NV.*360.).*DTR;



     % compute sun theta

      THETA=.397930.*sin(L)+.009999.*sin(G-L)+.003334.*sin(G+L)...
           -.000208.*T.*sin(L)+.000042.*sin(2.*G+L)-.000040.*cos(L)...
           -.000039.*sin(NM-L)-.000030.*T.*sin(G-L)-.000014.*sin(2.*G-L)...
           -.000010.*cos(G-L-JUP)-.000010.*T.*sin(G+L);

     % compute sun rho

       RHO=1.000421-.033503.*cos(G)-.000140.*cos(2*G)...
           +.000084.*T.*cos(G)-.000033.*sin(G-JUP)+.000027.*sin(2.*G-2.*V);



     % compute declination

        DECL=asin(THETA./sqrt(RHO));



     % compute equation of time (in seconds of time) (L in degrees)

         L = 276.697+0.98564734.*(JED-2415020.0);
         L = (L - 360.*fix(L./360.)).*DTR;
         EQT = -97.8.*sin(L)-431.3.*cos(L)+596.6.*sin(2.*L)-1.9.*cos(2.*L)...
              +4.0.*sin(3.*L)+19.3.*cos(3.*L)-12.7.*sin(4.*L);
         EQT = EQT./60;
         L = L.*RTD;



     % compute local hour angle

       GHA = 15.*(UT-12.) + 15.*EQT./60;
```

```
      LHA = GHA - LONG;



    % compute radius vector

       RV=sqrt(RHO);



    % compute solar altitude

    SZ=sin(DTR.*LAT).*sin(DECL)+cos(DTR.*LAT).*cos(DECL).*cos(DTR.*LHA);
        z=RTD.*asin(SZ);



    % compute solar radiation outside atmosphere

        [n,m]=size(z);
        sorad=zeros(n,m);
        ii=z>0;
        sorad(ii)=(Solar_const./RV(ii).^2).*sin(DTR.*z(ii));
```

APPENDIX II

The data has been procured from https://data.world/datasets/hydrology [11]

Reference year- 1948-1966 (19years)

Latitude 45.18W

Longitude 112.1425N

Area of watershed 6791km^2

Some of sample input data (two year) used in model: for complete data, can refer to above source

Date	Tmin (°C)	Tmax (°C)	Rain (mm)	Snow (mm)	Qobs (m^3/s)
01/01/48	-12.19	-6.84	0.00	1.93	22.61
02/01/48	-10.67	-1.04	0.00	1.11	25.43
03/01/48	-9.51	-1.82	0.00	3.32	26.85
04/01/48	-11.77	0.83	0.00	2.15	27.86
05/01/48	-7.27	0.14	0.00	1.02	28.26
06/01/48	-5.15	2.68	0.58	2.46	29.11
07/01/48	-1.22	3.57	3.91	1.01	30.24
08/01/48	-6.42	1.69	0.00	0.86	31.37
09/01/48	-12.64	-1.67	0.00	0.11	30.24
10/01/48	-13.47	-1.44	0.00	0.23	29.11
11/01/48	-14.04	-3.44	0.00	0.00	28.09
12/01/48	-12.91	-7.66	0.00	0.00	25.29
13/01/48	-11.04	-6.47	0.00	0.00	24.14
14/01/48	-11.58	-5.13	0.00	0.00	24.02
15/01/48	-13.73	-4.01	0.00	1.41	24.02
16/01/48	-12.18	-7.64	0.00	1.96	24.02
17/01/48	-14.64	-7.93	0.00	0.76	24.02
18/01/48	-13.33	-6.28	0.00	0.47	24.73
19/01/48	-9.84	-6.69	0.00	0.00	25.43
20/01/48	-10.51	-5.96	0.00	0.00	26.85
21/01/48	-13.86	-1.77	0.00	0.71	27.19
22/01/48	-8.62	0.70	0.00	10.23	27.41
23/01/48	-9.87	-0.78	0.00	8.68	27.41

24/01/48	-13.45	-2.53	0.00	6.92	27.41
25/01/48	-15.59	-9.38	0.00	1.10	26.96
26/01/48	-5.97	-14.92	0.00	0.00	23.57
27/01/48	-2.02	-13.34	0.00	0.00	21.20
28/01/48	-7.37	-7.57	0.00	0.00	21.20
29/01/48	-11.88	-1.99	0.00	0.00	22.61
30/01/48	-10.83	-4.57	0.00	0.00	24.02
31/01/48	-12.10	-5.28	0.00	0.00	26.73
01/02/48	-16.37	-5.08	0.00	7.18	26.51
02/02/48	-15.97	-7.08	0.00	0.54	26.28
03/02/48	-16.29	-8.48	0.00	0.91	25.29
04/02/48	-16.27	-7.42	0.00	0.62	24.73
05/02/48	-12.05	-10.83	0.00	2.81	24.02
06/02/48	-16.94	-8.12	0.00	0.72	24.02
07/02/48	-14.86	-8.08	0.00	0.49	24.02
08/02/48	-14.20	-6.02	0.00	2.61	24.02
09/02/48	-15.57	-5.36	0.00	0.66	23.31
10/02/48	-13.45	-11.18	0.00	0.37	22.61
11/02/48	-7.38	-9.30	0.00	0.00	22.61
12/02/48	-5.98	-6.92	0.00	0.00	23.74
13/02/48	-15.06	-4.82	0.00	1.02	25.29
14/02/48	-10.83	-1.81	0.00	0.14	25.89
15/02/48	-8.57	-0.09	0.00	0.49	25.49
16/02/48	-6.86	1.91	0.00	0.00	24.70
17/02/48	-1.42	5.79	0.23	0.00	25.68
18/02/48	-3.47	3.76	0.32	0.27	26.28
19/02/48	-11.27	-0.84	0.00	0.72	25.89
20/02/48	-13.13	-1.79	0.00	1.88	26.09
21/02/48	-10.54	-0.82	0.00	8.14	26.28
22/02/48	-6.93	0.61	0.00	0.60	26.96
23/02/48	-13.52	-2.45	0.00	0.00	27.19
24/02/48	-10.69	-2.51	0.00	0.00	25.89
25/02/48	-12.51	1.47	0.00	8.61	25.89
26/02/48	-9.66	1.63	0.00	12.61	27.19
27/02/48	-13.39	-3.01	0.00	1.32	27.64
28/02/48	-15.18	-3.92	0.00	0.36	26.96
29/02/48	-10.18	-4.32	0.00	0.00	26.51
01/03/48	-11.74	-2.86	0.00	1.90	25.68

02/03/48	-15.61	-4.52	0.00	3.56	26.73
03/03/48	-20.02	-6.67	0.00	0.85	27.19
04/03/48	-11.93	-5.83	0.00	0.00	25.68
05/03/48	-12.29	-4.95	0.00	0.00	25.29
06/03/48	-15.61	-3.07	0.00	1.01	25.89
07/03/48	-14.84	-2.56	0.00	2.42	26.51
08/03/48	-13.74	-3.74	0.00	2.18	26.73
09/03/48	-18.23	-10.69	0.00	0.34	26.73
10/03/48	-9.87	-12.00	0.00	0.00	24.70
11/03/48	-9.32	-3.98	0.00	0.00	23.40
12/03/48	-10.09	0.14	0.00	0.00	25.49
13/03/48	-11.80	2.24	0.00	3.95	25.68
14/03/48	-8.68	1.36	0.00	7.41	26.28
15/03/48	-11.08	-2.23	0.00	12.80	26.96
16/03/48	-14.78	-1.87	0.00	0.93	26.28
17/03/48	-13.72	0.90	0.00	1.52	26.28
18/03/48	-9.28	-1.27	0.00	5.51	26.51
19/03/48	-8.28	-1.80	0.00	7.42	26.73
20/03/48	-16.84	-4.63	0.00	2.22	26.96
21/03/48	-14.34	-2.85	0.00	0.25	25.89
22/03/48	-8.27	2.10	0.00	3.29	25.68
23/03/48	-4.62	4.42	0.20	0.22	27.86
24/03/48	-7.42	5.51	0.24	0.69	28.09
25/03/48	-8.24	0.67	0.00	1.48	27.86
26/03/48	-10.31	-0.58	0.00	0.19	26.96
27/03/48	-16.03	2.69	0.00	0.00	26.51
28/03/48	-12.46	4.76	0.00	0.00	26.96
29/03/48	-10.35	3.51	0.00	0.48	27.64
30/03/48	-9.62	0.76	0.00	1.05	28.09
31/03/48	-14.88	-2.06	0.00	0.00	26.09
01/04/48	-8.54	3.13	0.00	0.50	26.28
02/04/48	-7.09	6.86	1.80	2.02	28.83
03/04/48	-4.46	4.69	2.22	1.97	29.39
04/04/48	-9.49	0.36	0.00	1.96	28.26
05/04/48	-7.31	-0.14	0.00	1.69	28.09
06/04/48	-8.41	-0.67	0.00	0.85	28.09
07/04/48	-15.34	-2.23	0.00	0.43	26.73
08/04/48	-14.51	2.43	0.00	0.24	26.09

09/04/48	-4.38	6.73	8.43	2.19	28.09
10/04/48	-6.65	1.59	0.00	5.74	29.11
11/04/48	-11.03	-0.83	0.00	0.04	27.19
12/04/48	-12.75	1.13	0.00	0.04	28.26
13/04/48	-7.18	4.16	0.03	0.25	28.26
14/04/48	-4.81	4.89	0.29	0.27	28.55
15/04/48	-0.11	9.28	0.11	0.00	29.39
16/04/48	-1.33	12.38	1.29	0.00	32.22
17/04/48	-1.76	9.49	5.28	0.00	36.17
18/04/48	-3.43	2.85	4.39	5.88	39.56
19/04/48	-5.49	6.26	0.68	0.46	35.89
20/04/48	-8.91	10.53	0.13	0.05	36.17
21/04/48	-6.69	12.63	0.64	0.00	38.43
22/04/48	-2.61	8.35	1.60	0.00	42.11
23/04/48	-5.44	4.32	0.15	0.27	46.63
24/04/48	-5.32	4.76	0.60	0.79	44.65
25/04/48	-6.29	1.75	0.00	1.08	44.37
26/04/48	-12.23	1.73	0.00	0.25	41.55
27/04/48	-8.12	8.57	0.00	0.00	39.56
28/04/48	-5.11	16.08	0.11	0.00	40.70
29/04/48	-2.14	14.72	1.42	0.00	53.13
30/04/48	-9.02	4.13	0.00	0.00	61.89
01/05/48	-7.51	0.84	0.00	3.30	58.22
02/05/48	-8.00	1.83	0.00	2.61	52.56
03/05/48	-10.37	6.92	0.19	2.57	48.05
04/05/48	-4.92	4.06	0.75	1.15	50.87
05/05/48	-8.60	7.52	0.04	0.07	48.33
06/05/48	-6.30	13.16	4.99	0.00	50.30
07/05/48	0.24	10.52	13.00	0.00	59.91
08/05/48	-4.06	2.40	2.47	5.97	86.20
09/05/48	-5.31	2.45	0.84	5.04	75.45
10/05/48	-6.35	3.68	0.02	0.12	66.70
11/05/48	-5.01	4.93	0.00	0.00	61.89
12/05/48	-4.12	9.32	0.00	0.00	60.20
13/05/48	-1.52	9.54	1.29	0.00	61.04
14/05/48	-2.37	9.73	0.00	0.00	63.87
15/05/48	-6.23	13.46	0.00	0.00	66.98
16/05/48	-3.39	19.47	0.00	0.00	83.08

17/05/48	-0.32	21.77	0.00	0.00	124.35
18/05/48	0.09	21.03	0.10	0.00	197.26
19/05/48	1.44	18.67	0.07	0.00	233.43
20/05/48	-0.61	17.64	0.07	0.00	313.69
21/05/48	0.19	20.14	0.00	0.00	398.47
22/05/48	-0.46	14.72	0.00	0.00	415.42
23/05/48	-3.04	14.60	0.00	0.00	324.99
24/05/48	-2.53	19.22	0.00	0.00	319.34
25/05/48	-0.47	19.57	0.00	0.00	370.21
26/05/48	0.27	20.18	0.00	0.00	418.25
27/05/48	2.06	18.27	1.58	0.00	443.69
28/05/48	1.37	15.78	1.96	0.00	432.38
29/05/48	1.74	13.21	0.92	0.00	534.12
30/05/48	1.44	14.20	0.18	0.00	483.25
31/05/48	0.49	19.82	1.09	0.00	423.90
01/06/48	2.67	22.14	3.79	0.00	488.90
02/06/48	3.24	19.97	3.18	0.00	514.34
03/06/48	4.27	14.35	11.48	0.00	548.25
04/06/48	3.17	13.20	5.81	0.00	562.38
05/06/48	1.43	19.19	0.00	0.00	548.25
06/06/48	2.58	21.91	0.00	0.00	542.60
07/06/48	2.71	22.48	0.00	0.00	536.94
08/06/48	6.94	20.25	0.90	0.00	545.42
09/06/48	3.71	21.41	0.25	0.00	536.94
10/06/48	3.26	19.83	0.00	0.00	503.03
11/06/48	3.96	17.43	0.00	0.00	474.77
12/06/48	1.02	18.90	0.00	0.00	443.69
13/06/48	4.38	16.88	8.08	0.00	412.60
14/06/48	-0.37	17.56	0.38	0.00	381.51
15/06/48	1.99	19.13	0.97	0.00	361.73
16/06/48	2.25	18.14	5.70	0.00	358.91
17/06/48	2.73	14.38	4.07	0.00	339.12
18/06/48	-1.20	13.27	2.57	0.00	313.69
19/06/48	0.83	12.75	1.43	0.00	310.86
20/06/48	1.65	12.64	2.93	0.00	299.56
21/06/48	3.73	9.56	11.53	0.00	299.56
22/06/48	2.84	11.18	9.98	0.00	299.56
23/06/48	3.71	9.50	6.65	0.00	288.26

24/06/48	1.55	11.54	2.09	0.00	296.73
25/06/48	0.06	13.39	0.66	0.00	302.39
26/06/48	-0.52	14.08	0.08	0.00	273.28
27/06/48	-0.42	15.99	0.00	0.00	266.49
28/06/48	1.77	19.04	0.00	0.00	256.32
29/06/48	1.65	23.04	0.13	0.00	253.21
30/06/48	2.94	22.66	1.02	0.00	245.86
01/07/48	7.35	23.76	3.95	0.00	245.01
02/07/48	6.98	21.47	5.37	0.00	245.01
03/07/48	4.61	20.74	4.15	0.00	243.61
04/07/48	4.36	23.03	0.39	0.00	239.64
05/07/48	7.47	25.64	0.05	0.00	224.95
06/07/48	5.28	25.88	0.00	0.00	215.91
07/07/48	5.59	25.14	0.00	0.00	206.86
08/07/48	4.46	22.99	0.00	0.00	198.67
09/07/48	5.09	24.66	0.15	0.00	192.17
10/07/48	6.31	25.33	0.93	0.00	186.51
11/07/48	6.26	24.29	0.54	0.00	181.15
12/07/48	4.88	23.06	0.32	0.00	176.34
13/07/48	6.87	22.70	0.64	0.00	170.98
14/07/48	6.59	20.51	8.60	0.00	169.56
15/07/48	4.94	19.42	0.36	0.00	164.48
16/07/48	4.63	19.46	0.41	0.00	158.54
17/07/48	3.54	20.80	1.30	0.00	156.00
18/07/48	3.60	22.83	1.19	0.00	152.88
19/07/48	6.58	22.02	1.90	0.00	149.21
20/07/48	4.97	20.19	0.56	0.00	146.67
21/07/48	4.26	22.40	0.00	0.00	143.28
22/07/48	4.33	26.20	0.90	0.00	137.35
23/07/48	7.66	27.09	2.38	0.00	132.83
24/07/48	7.89	23.03	2.67	0.00	130.00
25/07/48	3.11	22.64	0.71	0.00	128.86
26/07/48	3.41	24.37	1.06	0.00	124.06
27/07/48	5.37	26.18	0.00	0.00	120.11
28/07/48	3.66	21.82	0.69	0.00	116.43
29/07/48	3.43	17.92	2.36	0.00	115.87
30/07/48	4.31	22.94	0.06	0.00	117.00
31/07/48	5.11	23.64	4.64	0.00	112.76

01/08/48	5.54	19.67	3.26	0.00	109.37
02/08/48	3.43	18.55	2.78	0.00	108.80
03/08/48	2.18	21.47	3.22	0.00	109.37
04/08/48	6.26	22.23	3.00	0.00	106.83
05/08/48	7.62	21.18	1.97	0.00	107.67
06/08/48	3.03	21.77	2.03	0.00	106.83
07/08/48	2.24	22.50	3.61	0.00	101.45
08/08/48	3.59	18.71	6.25	0.00	98.06
09/08/48	3.57	15.44	1.87	0.00	102.02
10/08/48	2.54	18.81	0.79	0.00	102.02
11/08/48	2.46	19.98	1.14	0.00	97.50
12/08/48	3.04	21.68	0.46	0.00	93.83
13/08/48	4.71	22.14	0.24	0.00	91.28
14/08/48	2.63	24.54	0.21	0.00	89.02
15/08/48	3.73	25.99	0.11	0.00	86.76
16/08/48	4.13	25.73	0.21	0.00	84.50
17/08/48	3.82	23.26	0.20	0.00	82.52
18/08/48	4.87	26.01	1.74	0.00	80.54
19/08/48	7.31	22.77	1.27	0.00	78.85
20/08/48	-0.16	19.52	0.14	0.00	78.56
21/08/48	0.23	23.46	0.96	0.00	76.30
22/08/48	4.40	23.34	3.47	0.00	74.33
23/08/48	5.32	20.91	0.50	0.00	73.48
24/08/48	3.29	18.39	0.12	0.00	73.48
25/08/48	2.69	19.97	0.10	0.00	71.78
26/08/48	2.06	22.33	0.25	0.00	69.80
27/08/48	4.49	23.94	0.04	0.00	68.39
28/08/48	3.10	25.82	0.00	0.00	67.54
29/08/48	4.57	27.93	0.00	0.00	66.41
30/08/48	5.38	27.03	0.00	0.00	64.72
31/08/48	1.37	24.09	0.00	0.00	62.45
01/09/48	1.78	25.63	0.00	0.00	61.33
02/09/48	0.96	26.06	0.00	0.00	60.20
03/09/48	0.62	25.12	0.00	0.00	59.06
04/09/48	0.73	21.62	0.00	0.00	57.65
05/09/48	-1.67	17.48	0.00	0.00	56.80
06/09/48	-1.92	14.56	0.01	0.00	55.67
07/09/48	-2.99	15.03	0.02	0.00	54.83

08/09/48	-4.59	18.19	0.00	0.00	53.70
09/09/48	-2.51	21.17	0.00	0.00	53.41
10/09/48	-1.68	23.64	0.00	0.00	52.28
11/09/48	-0.62	24.15	0.00	0.00	51.72
12/09/48	-0.82	23.47	0.00	0.00	50.58
13/09/48	-1.31	24.93	0.00	0.00	49.74
14/09/48	1.20	25.74	0.00	0.00	48.61
15/09/48	2.54	23.74	0.02	0.00	48.05
16/09/48	2.23	21.78	5.64	0.00	47.20
17/09/48	4.99	18.22	8.03	0.00	47.20
18/09/48	6.24	12.03	17.38	0.00	50.87
19/09/48	4.29	10.12	9.84	0.00	58.22
20/09/48	1.84	13.69	0.00	0.00	59.06
21/09/48	-0.10	18.55	0.03	0.00	55.67
22/09/48	0.43	18.64	0.08	0.00	52.28
23/09/48	2.95	15.22	0.08	0.00	50.58
24/09/48	-1.02	11.46	0.85	0.00	49.74
25/09/48	-0.57	12.39	0.63	0.00	48.33
26/09/48	-0.27	13.36	0.75	0.00	47.20
27/09/48	-3.04	12.14	0.00	0.00	47.20
28/09/48	-4.92	17.83	0.00	0.00	46.91
29/09/48	-3.19	17.30	0.00	0.00	45.50
30/09/48	-4.02	16.27	0.00	0.00	44.65
01/10/48	-3.60	15.77	0.00	0.00	44.37
02/10/48	-3.68	18.55	0.41	0.00	43.52
03/10/48	0.29	19.89	0.52	0.00	42.39
04/10/48	2.62	14.98	5.64	0.00	42.11
05/10/48	-4.23	7.16	3.95	0.61	42.95
06/10/48	-8.81	5.06	0.01	0.15	44.37
07/10/48	-4.62	11.58	0.00	0.00	43.52
08/10/48	-2.11	13.08	0.00	0.00	42.95
09/10/48	-5.11	16.21	0.00	0.00	42.95
10/10/48	-4.96	16.75	0.00	0.00	42.11
11/10/48	-4.95	17.03	0.00	0.00	41.55
12/10/48	-4.44	17.25	0.01	0.00	40.70
13/10/48	-3.19	17.81	0.22	0.00	39.56
14/10/48	-2.79	16.73	2.38	0.00	39.28
15/10/48	-0.39	10.28	2.87	0.00	39.00

16/10/48	-9.03	3.88	0.00	1.09	39.00
17/10/48	-11.99	10.11	0.00	0.00	37.58
18/10/48	-8.43	15.00	0.00	0.00	36.74
19/10/48	-7.46	15.47	0.00	0.00	36.74
20/10/48	-7.38	14.43	0.00	0.00	36.74
21/10/48	-7.46	15.52	0.00	0.00	36.45
22/10/48	-6.34	16.57	0.00	0.00	36.17
23/10/48	-5.61	17.17	0.00	0.00	35.89
24/10/48	-3.51	15.52	0.00	0.00	35.33
25/10/48	-4.34	10.61	0.34	0.00	35.33
26/10/48	-8.97	9.09	0.01	0.01	35.05
27/10/48	-5.72	5.86	0.15	0.13	34.48
28/10/48	-7.64	8.13	0.00	0.00	34.20
29/10/48	-7.30	6.71	0.06	0.09	33.63
30/10/48	-7.10	7.77	0.62	0.45	33.63
31/10/48	-6.60	5.98	0.69	0.95	33.07
01/11/48	-2.98	4.20	4.07	2.16	32.78
02/11/48	-2.36	3.81	6.22	2.92	33.63
03/11/48	-4.40	2.55	3.49	9.51	34.76
04/11/48	-9.77	-1.66	0.00	0.51	35.33
05/11/48	-14.49	-2.64	0.00	1.17	33.63
06/11/48	-9.97	-2.90	0.00	3.23	31.65
07/11/48	-16.57	-4.13	0.00	0.54	31.65
08/11/48	-15.77	-5.80	0.00	0.13	29.67
09/11/48	-13.08	-4.47	0.00	2.82	29.11
10/11/48	-10.71	-3.43	0.00	1.82	30.52
11/11/48	-14.43	-3.27	0.00	1.49	30.80
12/11/48	-8.56	-0.64	0.00	1.47	30.52
13/11/48	-3.94	2.31	0.24	0.58	30.80
14/11/48	-6.31	6.64	1.09	0.93	31.08
15/11/48	-5.14	3.66	2.53	5.52	30.80
16/11/48	-11.58	-2.13	0.00	2.92	30.80
17/11/48	-10.82	-2.46	0.00	1.21	30.24
18/11/48	-15.07	-3.64	0.00	0.12	29.39
19/11/48	-15.29	-6.69	0.00	8.04	26.28
20/11/48	-11.93	-3.78	0.00	3.36	26.51
21/11/48	-13.84	-2.51	0.00	1.63	30.52
22/11/48	-15.44	-4.63	0.00	3.41	30.80

23/11/48	-11.89	-2.97	0.00	3.16	30.24
24/11/48	-8.91	-1.88	0.00	4.16	29.67
25/11/48	-12.47	-5.07	0.00	1.60	29.11
26/11/48	-12.57	-6.84	0.00	1.64	28.55
27/11/48	-13.39	-9.09	0.00	0.00	26.96
28/11/48	-16.30	-4.83	0.00	0.95	25.10
29/11/48	-13.31	-4.58	0.00	0.52	27.41
30/11/48	-15.37	-6.19	0.00	1.64	26.51
01/12/48	-14.81	-5.13	0.00	2.14	28.09
02/12/48	-10.06	-0.98	0.00	2.93	28.09
03/12/48	-4.30	1.51	1.61	9.02	28.26
04/12/48	-12.34	-2.97	0.00	5.61	25.89
05/12/48	-15.78	-8.15	0.00	3.35	24.90
06/12/48	-14.88	-7.59	0.00	0.91	26.73
07/12/48	-14.82	-8.01	0.00	6.86	24.90
08/12/48	-13.97	-6.27	0.00	1.37	25.49
09/12/48	-14.58	-5.02	0.00	6.50	24.90
10/12/48	-8.71	-3.36	0.00	7.55	25.49
11/12/48	-10.17	-3.03	0.00	4.98	23.80
12/12/48	-8.10	-1.63	0.00	14.60	24.50
13/12/48	-10.18	-3.31	0.00	8.25	24.90
14/12/48	-13.63	-6.61	0.00	4.25	25.49
15/12/48	-15.66	-8.82	0.00	0.48	25.49
16/12/48	-15.67	-9.25	0.00	0.06	25.29
17/12/48	-13.16	-10.05	0.00	0.68	22.78
18/12/48	-16.57	-9.54	0.00	1.03	21.20
19/12/48	-15.12	-7.48	0.00	4.96	19.78
20/12/48	-11.10	-2.68	0.00	2.63	21.20
21/12/48	-12.93	-8.17	0.00	0.00	22.61
22/12/48	-7.44	-12.47	0.00	0.11	18.37
23/12/48	-5.54	-13.17	0.00	2.05	14.13
24/12/48	-15.34	-11.94	0.00	1.14	12.72
25/12/48	-8.01	-11.51	0.00	0.09	14.13
26/12/48	-7.79	-9.48	0.00	0.00	18.37
27/12/48	-11.92	-5.79	0.00	0.02	21.20
28/12/48	-16.42	-6.02	0.00	0.33	24.02
29/12/48	-14.79	-5.31	0.00	1.96	24.02
30/12/48	-15.91	-5.52	0.00	1.80	22.61

31/12/48	-11.57	-5.13	0.00	0.68	21.20
01/01/49	-11.56	-2.80	0.00	5.31	22.61
02/01/49	-16.97	-6.43	0.00	0.39	22.61
03/01/49	-9.04	-15.56	0.00	0.08	21.20