CHAPTER 4

METHODOLOGY

4.1 GENERAL

The methodology focuses on developing a model driven by a policy requirement. This is to examine a plausible scenario of utilizing the flood flow in rivers to augment the groundwater resources in the river basin in response to human action and policy framework. The methodology comprises of analysing the river flows corresponding to extreme events of precipitation; detaining a percent of flood flow to be used for recharging the groundwater, and; evaluating the groundwater resources in the river basin due to natural and modified scenario. Ultimately, the aim is to introduce the concept of drainage basin to the study area to justify the dynamics of base flow and interflow as a conjunctive mechanism.

4.2 RIVER FLOODS

The interaction between the surface water (river flows) and the groundwater of the riverbed and basin is to be analysed for its exchange rate. The exchange rate of water is usually controlled by the difference in the hydraulic head (water level) between the river stage and piezometric or phreatic surface of groundwater and resistance, or permeability of the media between the groundwater and surface bodies. According to water levels of the river, the surface water bodies are classified as:
(i) **Influent:** The groundwater level is lower than the surface water level, and therefore surface water potentially recharges the groundwater.

(ii) **Effluent:** The groundwater level is higher than surface water level, and therefore groundwater is recharging the surface water.

(iii) **Intermittent:** The groundwater level is higher than the bed of the surface water bodies, but depending on the elevation of the water level, groundwater may recharge the surface water body, or the surface water body may recharge groundwater.

(iv) **No connection:** When the groundwater level is far below the surface water level, the two are not connected hydraulically.

(v) **Channel flow:** The channel flows in the rivers are classified into base flow, interflow and valley flow. They are generally termed as convergence flows of the river.

(vi) **Valley flow:** The valley slopes correspond to floodplain elevation drop over the valley lengths the channel slope corresponds to the water surface elevation drop over the channel length.

(vii) **Bank full flow:** The bank full flows in the river are classified as bank flows and floods flows. These are generally termed as flows along the storage flow section of the rivers.

(viii) **Flood plain management:** Floods are natural events that have always been an integral part of the geologic history of earth. Flooding occurs along rivers, streams, lakes and coastal areas. A flood plain provides both a conveyance
mechanism and a temporary storage area for excess water allowing obstructions to be placed in the flood plain, eliminates the temporary storage areas and in turn increases the hydraulic heads to increase flood levels both downstream and upstream of the flood plain development.

At engineering time scales it can be considered that the channel characteristics can change significantly during extreme flood events. Fig 4.1 depicts the definition of baseflow, interflow, valueflow, bankflow and flood flow that are adopted in this study (Julien, 2002).

![Diagram of Flow Geometry of River Floods](image)

**Figure 4.1 Flow geometry of river floods**

### 4.2.1 Overland Flow Hydrograph

Runoff refers to the surface flow occurring during and immediately after precipitation events. Base flow refers to seepage and groundwater flow between precipitation events. Surface runoff is added to the base flow to determine the total flow. The base flow from small watersheds can often be neglected in the computation of surface runoff from large rainstorms.
The basins for the rivers in the study area were delineated from SRTM DTM using HEC-GeoHMS (Geospatial Hydrologic Modelling Extension); it is a software package for use with Arc View and Spatial Analyst. This was prepared for providing the input data for estimation of flood hydrograph using the HEC-HMS software.

The flood flows at various nodes can be estimated for the river using the rainfall-runoff models. The Hydrologic Engineering Center’s Hydrologic Modelling System (HEC-HMS) is designed to simulate the precipitation-runoff processes of watersheds. The delineated watershed is used as the base for applying the wide array of capabilities of the software, such as watershed physical description, meteorology description, hydrologic simulation, and parameter estimation, and simulation analysis (HEC GeoHMS manual).

The principles of HEC-HMS are, it has three components as indicated below:

i. Basin characteristics describe the basin area, Sub-basin and their reach to water bodies, reservoir parameters, method of computation etc.

ii. Meteorological characteristics describe about the rain gauge stations and the quantity of precipitation etc.

iii. Control points describe about the model simulation duration.

There are number of methods of runoff computation such as Clark, Kinematic wave equation, SCS method etc. The method chosen for the study to develop a rainfall-runoff model is by using SCS-CN method as it considers land use for runoff estimation as given below.
### SCS METHOD

\[
Q = \frac{(P - I_a)^2}{(P - I_a) + S}
\]  \hspace{1cm} (4.1)

- \(Q\) = Runoff Depth (mm)
- \(P\) = Rainfall (mm)
- \(S\) = Potential maximum retention after runoff Begins (mm)
- \(I_a\) = Initial abstraction (mm) [all loses before runoff begins]

Also, \(I_a = (0.2S)\), empirical observation in small watersheds \hspace{1cm} (4.2)

\[
S = \frac{2540}{CN} - 254
\]  \hspace{1cm} (4.3)

\(CN\) = Curve number for land use pattern

The runoff between the nodes is routed by using Muskingum routing technique. The flood hydrograph are generated in HEC-HMS package using User Weighted hydrograph method for both natural and urbanized flow regimes respectively (Kafle et al, 2004).

### 4.3 GROUNDWATER MANAGEMENT

Groundwater management is broadly concerned with the evaluation of the environmental, hydrologic and economic impacts and trade-offs associated with the development and allocation of groundwater supply and quality to competing water uses or demands. The analysis of these management and planning problems is predicted on a system’s representation of the underlying physical, chemical and hydraulic transport process occurring within the groundwater basin.
The groundwater system is defined as shown in Fig.4.2 by

1. The set of controlled and partially controlled inputs to the system. For example, subsurface inflows, natural recharge, precipitation and replenishment from irrigation return flows, streams and artificial recharge practices are major inputs to the aquifer system.

2. The system outputs, which include subsurface outflows, discharges to surface waters, naturally occurring springs and evapotranspiration losses.

3. The parameters of the groundwater system: the parameters define the flow e.g., the storativity, transmissivities and dispersion parameters, quality and thermal properties of the aquifer system.

4. The control or decision variables: These decisions detail the pumping, injection and artificial recharge schedules of the ground and surface water system.

5. The state variables that characterize the condition of the system, e.g., the hydraulic head, pressure or temperature distribution or the concentrations of all constituents in the groundwater system.
4.4 GROUNDWATER MODEL

The different task required to construct a groundwater model is shown in figure 4.37. The main steps include layers;

(i) Evaluation of the available data/information: The data should be sufficient to provide the correct determination of hydraulic conductivity, storativity and thickness for each hydro-geologic unit; a relatively uniform distribution of hydraulic head measurements in the simulation domain; and, correct specification of initial and boundary conditions.

(ii) Conceptualization of this hydro-geological settings in a model frame work: this involves defining a simulation domain and the hydro-geological layers; dividing this domain into zones, each of which possess a unique set of hydraulic properties (hydraulic conductivity and storativity) for each zone; determining the outside boundary conditions.
along six sides of the model domain, determining the internal boundary conditions, such as rivers, wells, recharge, evapotranspiration, drain and head dependent fluxes also called stresses; collecting values of measured hydraulic head and determining cells that are inactive or a constant head.

(iii) Setup and running of the model, model setup is a process of translating the model conceptualization into the computer input files required by a groundwater model.

Groundwater modelling begins with a conceptual understanding of the physical problem. The next step modelling is translating the physical system into mathematical terms. In general, the results are the familiar groundwater flow equation and transport equations. The governing flow equation for three dimensional saturated flows in saturated porous media is:

\[
\frac{\partial}{\partial x}(K_{xx} \frac{\partial h}{\partial x}) + \frac{\partial}{\partial y}(K_{yy} \frac{\partial h}{\partial y}) + \frac{\partial}{\partial z}(K_{zz} \frac{\partial h}{\partial z}) - Q = S_s \frac{\partial h}{\partial t}. \tag{4.4}
\]

\(K_{xx}\) = hydraulic conductivity along the x-axis which is assumed to be parallel to the major axes of hydraulic conductivity

\(K_{yy}\) = hydraulic conductivity along the y-axis which is assumed to be parallel to the major axes of hydraulic conductivity

\(K_{zz}\) = hydraulic conductivity along the z-axis which is assumed to be parallel to the major axes of hydraulic conductivity

h= Piezometric head.

Q= volume flux per unit volume representing sources /sink terms

\(S_s\)=Specific storage coefficient defined as the volume of the water released from storage per unit change in head per unit volume of
porous material.

(iv) Model calibration is the hydraulic head prediction that comes from a flow model is commonly used as the basis for model calibration. Calibration is the process of selecting model parameters to achieve a good match between predicted and observed head, or other relevant parameters like hydrologic data like stream flow changes.

(v) Verification: Once calibration is complete a verification test is commonly added to check that the model is a valid representation of the hydro-geologic system.

Figure 4.3. Modflow
4.5 METHODOLOGY

The methodology adopted for research comprises of the principles of drainage basin, river floods and ground-water basin. The focus of this research will be to identify the study area as a drainage basin. This is to justify that one river receives baseflow and interflow from the other rivers to sustain its groundwater resources.

The flow chart for the three components of the research is shown in Figure 4.4 to achieve the stated objective. The first objective of flood estimation is obtained by delineating the basin, preparing the data base for application of HEC-HMS, applying the channel geometry to determine the components of flow geometry and finally evaluating the flood wave characteristics.

The second objective is shown in the middle column which characterizes the study area as a single groundwater basin for application of MODFLOW to determine the mass balance and time series.

The third objective is concerned with the conceptualisation of the study area as a drainage basin. The results of the flood are determined and its attenuation on the flood plains is treated as flood plain. The subsurface flow is classified as recharge (source) and discharge areas as sink to determine the capacity of the aquifer to absorb the attenuated flood as recharge.
Figure 4.4 Flow chart for methodology
4.6 ASSUMPTIONS AND LIMITATIONS

1. The extreme precipitation events are taken for the study. The peak rainfall was assumed to occur between 18.00 Hours of previous day to 06.00 Hours of next day.

2. The peak precipitation occurring for duration of 48 Hours within the monthly rainfall period was applied in this study.

3. The sub-basins of the Thiruvallur district were considered for the conjunctive management of fluvial groundwater.

4. The top unconfined aquifer of 30-meter thickness was considered for the simulation.

5. The porosity, specific yield and hydraulic conductivity applicable to sedimentary and alluvial formations were applied.

6. The river recharge head was proportioned according to the seasonal flows in the river.

The estimation of surface floods of the rivers and its characterisation as a flood attenuation is the first step of the research. The estimation of the recharge component of the groundwater flow forms the second step. The combination of surface flow and groundwater flow adopted as a drainage basin modelling in the third step of research methodology.