ASSESSMENT OF WATER RESOURCE POTENTIAL AND ITS MANAGEMENT IN UPPER TUIRIAL WATERSHED, MIZORAM

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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Assessment of Water Resource Potential and its Management in Upper Tuirial Watershed, Mizoram

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CERTIFICATE

This is to certify that the thesis entitled “Assessment of Water Resources Potential and its Management in Upper Tuirial Watershed, Mizoram” submitted by VLK Dawngkima for the degree of Doctor of Philosophy in the Department of Geography and Resource Management, of Mizoram University, Aizawl, India, is a record of original investigations

carried out by him under my supervision. He has been duly registered and the thesis presented is worthy of consideration for the award of Ph.D. degree. The present thesis is submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy. As per the Ph.D. regulations o Mizoram University, he has fulfilled all the requirements. The

thesis is the result of his own research. This thesis has never been submitted to any other university for any research degree, either as a whole or as a part of it.

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CANDIDATE'S DECLARATION

I VLK Dawngkima, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to do the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/Institute.

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Abbreviations

ABY	Atal Bhujal Yojana
AMRUT	Atal Mission for Rejuvenation and Urban Transformation
ARWSP	Accelerated Rural Water Supply Program
BCM	Billion Cubic Meter
BIS	Bureau of Indian Standard
Cfs	cubic foot per second
CGWA	Central Ground Water Authority
CGWB	Central Ground Water Board
CSRIO	Commonwealth Scientific and Industrial Research Organisation
CWC	Central Water Commission
CWMI	Composite Water Management Index
DEM	Digital Elevation Model
EWS	Economically Weaker Sections of Society
GCM	General Circulation Model
GEC	Ground Water Estimation Committee
GIS	Geographical Information System
GPS	Global Positioning System
GWP	Global Water Partnership
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IPCC	International Panel on Climate Change
IRWR	Internal Renewable Water Resources

IS	Indian Standard
IWRM	Integrated Water Resources Management
JJM	Jal Jeevan Mission
LIG	Lower Income Groups
Lpcd	Liter per capita per day
LSM	Land Surface Model
MBBL	Model Building Bye Laws
MGNREGS	Mahatma Gandhi National Rural Employment Guarantee Scheme
MIRSAC	Mizoram Remote Sensing Application Centre
NGO	Non-Government Organisation
NRDWP	National Rural Drinking Water Programme
NTU	Nephelometric Turbidity Unit
PHED	Public Health Engineering Department
PMKSY	Pradhan Mantri Sinchayee Yojana
ppm	parts per million
SAPCC	State Action Plan on Climate Change
SCS-CN	Soil Conservation Service Curve Number
SPSS	Statistical Package for Social Science
SWAT	Soil and Water Assessment Tool
TRIP	Total Runoff Integrating Pathways
UBBL	Unified Building Bye Laws
UNESCO	United Nations Educational, Scientific and Cultural Organisation
UNICEF	United Nations International Children’s Emergency Fund

URDPFI	Urban and Regional Development Plan Formulation and Implementation
VSS	Village Spring Source
WASH	Water, Sanitation and Hygiene
WATSAN	Water and Sanitation
WRD	Water Resources Development
WRM	Water Resources Management
WRP	Water Resources Planning

Chapter - 1

Introduction

1.1. Introduction

A watershed is a ridge of land that separates rivers or a drainage divide that demarcates a specific river area. In geographical terms, a Watershed can also mean a ridge line with a definite boundary formed by a chain of mountains or hills, sending water to two different rivers on either side. The area may vary in size, even a specific watershed area may be divided into sub-watershed, mini-watershed, and micro-watershed areas. Watershed drains rainfall and snow melts into streams and rivers and confluence to basin rivers and into larger ones, including lakes, bays, and oceans. In simple terms, a watershed is a dividing ridge between drainage areas. Merriam-Webster Dictionary defines a Watershed as a region or area bounded peripherally by a divide and draining ultimately to a particular watercourse or body of water. Thus, watershed includes all the land and water areas in a given region which may be a few square miles or hundreds or thousands of square miles that drain into a stream from its mouth. According to ICRISAT Scientists (1984) Watershed is defined as the land area from which surface water drains into a single outlet.

The physical characteristics of the watershed determine the action of precipitation, some act as runoff that feeds directly to streams and rivers, while others seep into underground aquifers forming groundwater. Thus, the watershed becomes a system, a structured set of interactions that is defined for the purposes of understanding. That integrates the tightly coupled interactions among physical, ecological, and social processes. It is a functioning natural unit. The management of watershed areas requires the application of diverse disciplines of hydrology, climatology, biochemistry, forestry, soil, water, and the interaction of environmental management disciplines that too often operate in mutual isolation. The watershed concept encourages the interpretation of the unit of landscape as a dynamic series of mass balances and fluxes. Watershed management involves the planning, conservation, and sustainable use of land, forest, and water resources to protect the environment.

Management of water resources has been important for most cultures throughout history. The link between runoff in the lowlands and the conditions in the headwaters did not always have the necessary attention, whereby, the process of deforestation and the subsequent increase in bed load transport have created challenges in the management of downstream areas. Pollution of water sources, improper water resources management, shortcomings in the design and implementation of legislation and regulations, deforestation of catchment areas, and pressure of population on land have led to the fall in the quality and quantity of available water resources, and many of the mountain streams which are perennial till recent years have gone dry during winter. These further change the quantity and quality of water in ecosystems. The present study plan for the management of potential water resources by evaluating public participation at local council levels, and recognition of water as both an economic and social good within the Upper Tuirial Watershed area.

Water Resource Management has long been recognized as a desirable unit for planning and implementing developmental Programmes. It is an undertaking to maintain the equilibrium between elements of the natural ecosystem of vegetation, land, or water on the one hand and man's activities on the other hand. It refers to the conservation, development, and optimal utilization of land and water resources for the ultimate benefit of the people. Therefore, it is also important to note that no significant improvement can be expected without the people being brought to center stage (GWP, 2000). Water being a state subject, the projects on water conservation are planned, funded, executed, and maintained by the State Governments. The government of India supplements the efforts of the States through technical and financial assistance to them through various schemes and Programmes. Various schemes and Programmes such as Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), Atal Bhujal Yojana, Pradhan Mantri Sinchayee Yojana (PMKSY), Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Unified Building Bye Laws (UBBL) of Delhi, 2016, Model Building Bye Laws (MBBL), 2016, Urban and Regional Development Plan Formulation and Implementation (URDPFI) Guidelines, 2014 etc. are covered on continuous basis.

Traditional methods of water conservation and rainwater harvesting, depending upon the topography, climatic conditions, soil structure, etc. the state government encourages the best practices which vary from area to area with a view to bringing awareness and replication in other areas. The central government also advised enabling Rural Local Bodies or Panchayats to utilize 15th Finance Commission grants to take up rooftop rainwater harvesting in Government buildings like Panchayat, Bhawans, Anganwadis, Primary Health Centers, etc. and has prepared a Master Plan for Artificial Recharge to Groundwater- 2020 which envisages construction of rainwater harvesting and artificial recharge structures in the country. Different Projects under government schemes have been carried out in the Upper Tuirial Watershed covering farm ponds, fish ponds, water harvesting structures, stone embarkments, etc. It, therefore, becomes imperative that long-term measures be taken to retain the rainwater within the area and help the underground aquifers to maintain the potential of groundwater in particular and water resources as a whole. In order to boost water conservation and rainwater harvesting in the country, the Ministry of Jal Shakti has taken up a nationwide campaign "Jal Shakti Abhiyan - Catch the Rain" (JSA: CTR) with the theme **"**Catch the rain, where it falls, when it falls**"** for creating appropriate rainwater harvesting structures in urban and rural areas of all the districts in the country, with people's active participation, during the pre-monsoon and monsoon periods of 2021. The government organizes workshops, seminars/webinars, awards, etc., and encourages people to become active participants in water conservation and rainwater harvesting.

The main lifeline of the water supply of the study area is piped water supply by the government and Village Spring Source (VSS) or 'Tuikhur'. Other sources of water include rainwater and river water lifted using motors or vehicles as well as gravity-using pipes in the lowland and possible areas. Blessed with abundant rainfall with lush tropical vegetation, most of the rivers and streams are perennial yet fluctuation of river discharges is very high – peak discharge during the monsoon season is several times higher than that of the discharge during the lean season. The upper Tuirial Watershed area belongs to the 'tropical monsoon type' of climate indicating heavy rainfall during the summer season lasting for an average of eight months with only around four months of dry period with minimal rainfall. The physiographic characteristics and climatic factors of the upper Tuirial watershed reflect the possible development in water resources be it for power generation or for agricultural development, if utilized carefully and properly. The groundwater resources, which have accumulated over a span of many centuries, form the invisible, subsurface part of the natural hydrological cycle, in which evaporation, precipitation, seepage and discharge are the main components that emerged as the village springs. This groundwater resource is annually renewed through input of precipitation. It is a (hydrologic) process where the rainwater seeps downwards and gets collected in aquifers. The visible water sources especially local springs are strongly affected by weather and climate but generally, they recover at a quick rate. Groundwater is the largest regulator of freshwater resources and perhaps second to rivers as a distributor of fresh water in the study area. With careful, proper and channelized management, this freshwater resource can be used to create an integrated and continuous source of water supply. The total annual groundwater recharge of Mizoram is 0.22 BCM. After deducting the natural discharge, the Annual Extractable Ground Water Resources of the state is 1.19 BCM. Presently the annual domestic extraction is 0.007 BCM. Central Ground Water Authority (CGWA) has advised all States/UTs to take measures to promote/adopt artificial recharge to groundwater/rainwater harvesting. National Water Policy (2012) advocates water conservation and rainwater harvesting.

1.2. Statement of the Problems

The region as a whole receives around 2022.7 mm of rainfall annually, which is supposed to meet the demand of the area and be more than enough for domestic consumption for a lean period of not more than 4 months covering December to March. Maximum rainfall occurs during the monsoon period and minimum during the post-monsoon period. Some of the village spring water sources and wells dry up during the lean period (post-monsoon and pre-monsoon) of the year as the groundwater draft exceeds the recharge of the underground aquifers. This is mainly because there are no structures to intercept and retain the excess rainfall that occurs during the monsoon period and a huge amount of rainwater is lost as runoff. It, therefore, becomes imperative that effective measures be taken to entrap and retain rainwater during the monsoon period and utilize it in the lean period.

The average consumption of water in the study is supposed to be below the standard level of 55 lpcd given by the Ministry of Jal Shakti, 2019, which varies with seasonal change, indicating water shortage in water surplus areas of India. The field observation of the study area presumed that household consumption of water is about 30.11 lpcd during the dry season which increases during the rainy season.

There are insufficient structures to intercept and retain the rainfall that occurs during the monsoon period and a huge amount of rainwater is lost as runoff. The field survey opined from the household rooftop rainwater harvesting level, only 27.9% of rainwater is harvested, leading to a loss of more than 70% of available rooftop rainwater.

The population of the area largely depends on the piped supply of water by PHED, which is hauled from rivers using pipelines covering a long distance. Corroding pipes lose strength and are more vulnerable to leakage on a daily basis and damage in an earthquake or landslide. A deteriorated lengthy pipeline network will have an increased number of repairs, cause loss of water in the transaction, and exert high expenses on the construction of pipelines and tanks/reservoirs.

The river water potential resource available is also estimated from the average monthly discharge is as high as 1216.6 cfs which is left untapped. There is a deficit of agricultural water supply in the study area which is directly affecting the development of agriculture, the main occupation of the study area. The effective management of runoff with feasible methods and policies is supposed to boost the income of the people and replenish the ecosystem of the area.

1.3. Hypothesis

The present study hypothesis is that; The general analysis of regional rainfall intensity indicating 'water surplus area' does not mean sufficiency of water supply, it rather has the same possibility of deficiency and scarcity due to uneven rainfall from area to area with different intensity and frequency, if not maintained properly. For an area, particularly the study area, the scarcity of water during the dry season is only the result of negligence or ignorance about the potential of water resources and the importance of its management. Which may not be absolute in different localities.

Overdependence on the direct supply of domestic water from the government adversely affects the domestic water management of the area, creating more diverse problems during dry periods, and on the other hand, indirectly affects the rooftop rainwater harvesting development as well as the lack of domestic water storage systems.

Rainwater harvesting improves access to water and eases the burden on women and children who traditionally collect water.

1.4. Research Questions

The present study questions the water resource availability and their potential with the level of exploitation and possible measures to be taken for the same. In order to be self-sufficient in water resources in the long run, what methods are feasible and sustainable for the study area? What possible management and conservation measures are to be taken for the development of water resource potential? In addition to this, what possible traditional method can be adopted for the management of water resource potential in the upper Tuirial watershed is the main inquiry in this study.

1.5. Scope of the Study

General know-how of the water system and awareness is very important in order to one's participation in the project on water. Management and conservation of water resources within the catchment or basin area proved to be effective for the development of an area due to the reason that exploitation of water resources is limitless if judicious and proper implementation of technology is employed. Research into the patterns of runoff genesis in a watershed testify to a basin's sensitivity to future disturbance and can also contribute to the assessment of sustainable practices. In addition to this, the study of water resources potential gives a picture of the availability of water and highlights the necessary actions to be taken for the management and conservation in an area or regional basis for water deficit and water surplus areas. Judicious use and proper management of freshwater are crucial for even water-surplus areas. The sources of fresh water in the form of rainfall and groundwater in the forms of rivers and springs are needed to manage every area. Mismanagement and overexploitation of freshwater resources lead to scarcity and even crises in areas of surplus areas.

The scope of the study is to identify water resource availability and utilization that integrate water quality, watershed, and ecosystem restoration initiatives in order to create a water resources plan based on emerging technologies and models in the Upper Tuirial watershed area. The study would integrate physical systems such as watershed processes, water quality, and ecosystems at various spatial levels. To achieve this, it would include process-based simulation, geographic information systems (GIS), topographic data, agricultural and ecological valuation models, alternatives analysis, and evaluation. This research evaluation is limited only to the Upper Tuirial Watershed and may not be useful for other districts. The findings of this study will not only benefit the planners and decision-makers in formulating appropriate policies for sustainable utilization of the groundwater resource but will also open avenues for future researchers to carry out further studies in this aspect. Hence, this study has both academic significance as well as practical relevance.

1.6. Objectives

The objectives of the present study of "Assessment of Water Resource Potential and its Management in the Upper Tuirial Watershed" are:

1. To identify the major water sources in Upper Tuirial Watershed.
2. To asses water demand and supply in the study area.
3. To study the process of conservation and management of water resources.
4. To frame policies for management of potential water resources.

1.7. Study Area

The study area, the Upper Tuirial Watershed extends between 23^{o}51'12'' N to 23^{o}26'12''N latitude and 92^{o}41'51" E to 92^{o}51'46" E longitude. The Tropic of Cancer passes through it in the southern part near Maubuang in the western part and near Baktawng in the eastern catchment area. The Upper Tuirial Watershed covers approximately 535 square kilometers, out of which 88.7 percent falls under the Aizawl District and 11.3 percent falls under the Serchhip District. Aizawl, the state capital of Mizoram, is located in the northwestern part of the catchment boundary. From the administration of rural development, the area falls under three Rural Development Blocks viz. the Tlangnuam Rural Development Block and the Aibawk Rural Development Block at the northwest and the southwest watershed area respectively. The eastern part of the watershed area falls under the Thingsulthliah Rural Development Block. There are 29 villages within and on the catchment area with approximately 8561 households (Census of India, 2011). Settlements are usually linear patterns, arranged along the main road. The society is characterized by typical mizo culture with agrarian in nature.

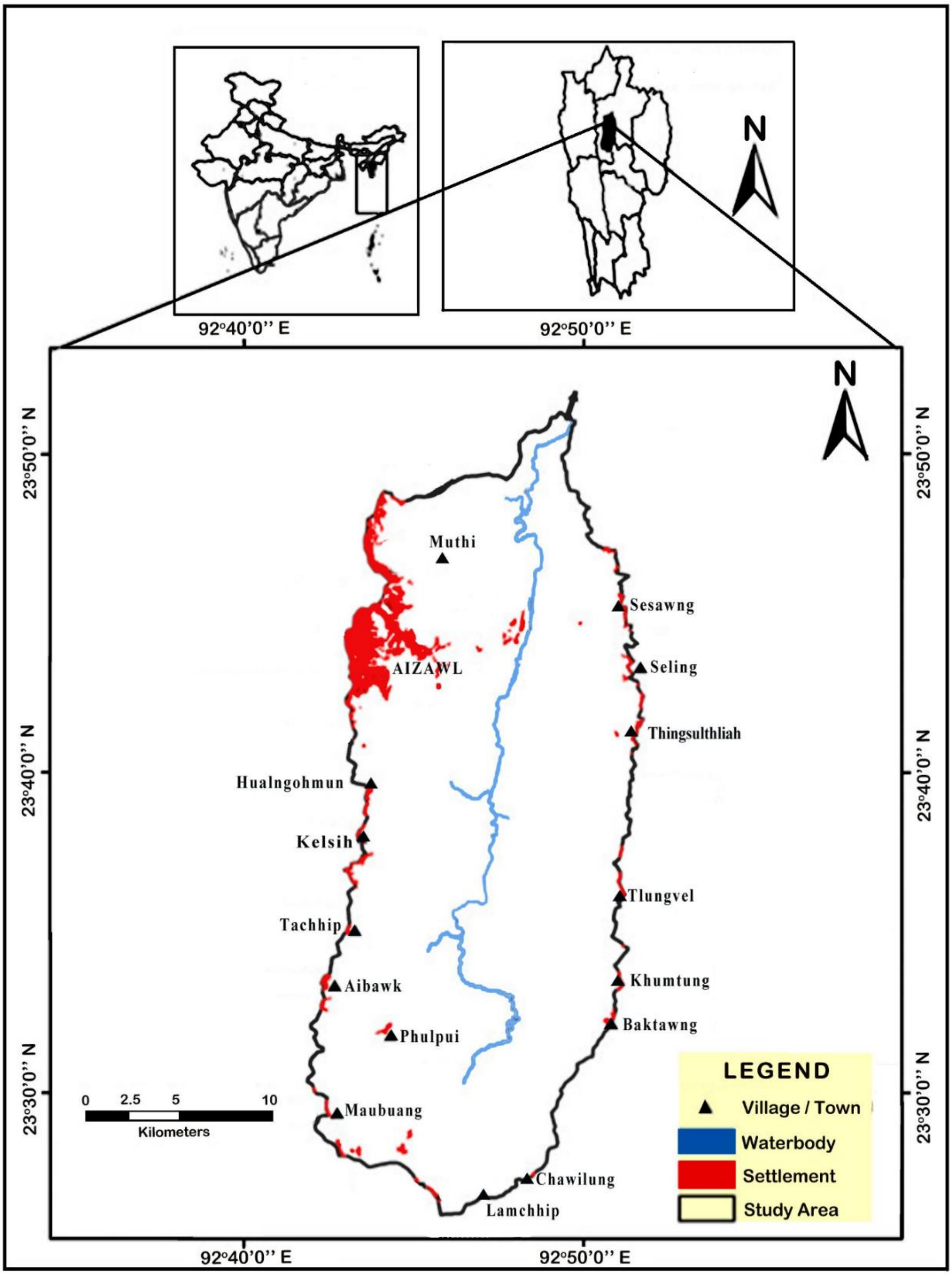

Figure 1.1: Study Area Map.

The Upper Tuirial Watershed area is a part of the Purvanchal Hills and is located in the central part of Mizoram. The physical characteristics show young folded landforms with sharp hills and V-shape valleys cut by rivers with deep gorges and rapids. Confirmed faults and lineament are present along the ridges. The structural hills range between 800m-1200m and run in a north-south direction at the eastern and western watershed boundary. The western boundary hills have fractured faults. The Hmuifang Tourist Resort, famous for its scenic location and landscapes, is also situated there. The geological structure represents a number of faults/fractures of varying magnitude which are mostly transverse in deposition, normally trending NNW-SSE and NNE-SSW direction (MIRSAC, 2009). The type of soil is ranging from inceptisols to ultisols. The natural vegetation belongs to sub-tropical wet evergreen forests mixed with semi-evergreen and tropical moist deciduous forests comprising mainly bamboo. The climate is humid tropical, characterized by short winters, and long summers with heavy rainfall.

Plate 1.1: Upper Tuirial River during monsoon. Source- Author.

The Tuirial River originates from North Chawilung hills, near Chawilung village of Aizawl District, located at 39 KMs south side of Aizawl City, and flows northward till its confluence with Barak River of Cachar District, Assam. The total length of the Tuirial River is approximately 117.53 km, of which 60.5 km falls under the upper Tuirial Watershed area. The upper Tuirial River is fed by many rivulets and streams. Due to heavy rainfall in addition to shallow water table, rivers are usually perennial, though the volume of water may be small. More than fifteen streams confluence to the main river. Among many small streams and rivulets, the important tributaries on the western side of the river are Tuirivang, Tuinghaleng, Suanghuan Lui, and Chite Lui. In the eastern catchment area rivers like Nghathup Lui, Saibual Lui, Ngharum Lui, Zilpui Lui and Belkhai Lui join the main river. Owing to steep topography, streams usually confluence with sharp right angles. Generally, streams and rivulets are perennial.

1.8. Methodologies

To bring out the result of the hypothesis, different methods relating to the research problems were selected and employed. Normally, simple and straightforward formulas and methods are used as far as possible to assist in finding answers. The complexities of data analysis often resulted in confusion of results in many areas of research. Clear-cut quantitative and qualitative analysis is still preferable to date. Methodologies applied are discussed based on the SPSS. The collected data were analyzed and represented in the form of maps, tables, charts, figures, etc.

1.8.1. Source of Data

The collection of primary data was taken out by using a structured questionnaire from randomly selected 13 villages (44.8 percent of the total villages). A household-level survey was carried out covering 26 % of the total households by using a purposive sampling method. In which water-related issues and problems are given stress in order to chalk out the desired outcome. Detailed uses of water and supply of water are collected at the household level. Primary data in relation to village profiles on demography, economic activities, and infrastructures were taken into consideration. The field investigation on domestic water demand and supply, river water discharge, water conservation, and management process were taken out from the study area. Interaction with Village Council/ Panchayat from respective villages enhances the reliability and accuracy of the data collected using a questionnaire.

An exhaustive personal field investigation related to the collection of soil samples from 42 selected coordinates and measuring river discharge from selected 9 rivers including the upper Tuirial River were also taken out. The water samples collected were tested and verified by PHED, Mizoram. Identification of village spring sources, their location, and usability to the local population gives the views on the groundwater potential of the area. Thus, the status of rainwater harvesting practices, water demand and supply of the community, process of water conservation, and management for the domestic, agricultural, institution, and industries are the main components of the questionnaire. Google Earth Pro and Global Positioning System (GPS) were also employed to collect geographical data.

Plate 1.2: Interaction with VCP, Sesawng-III. Source: Author.

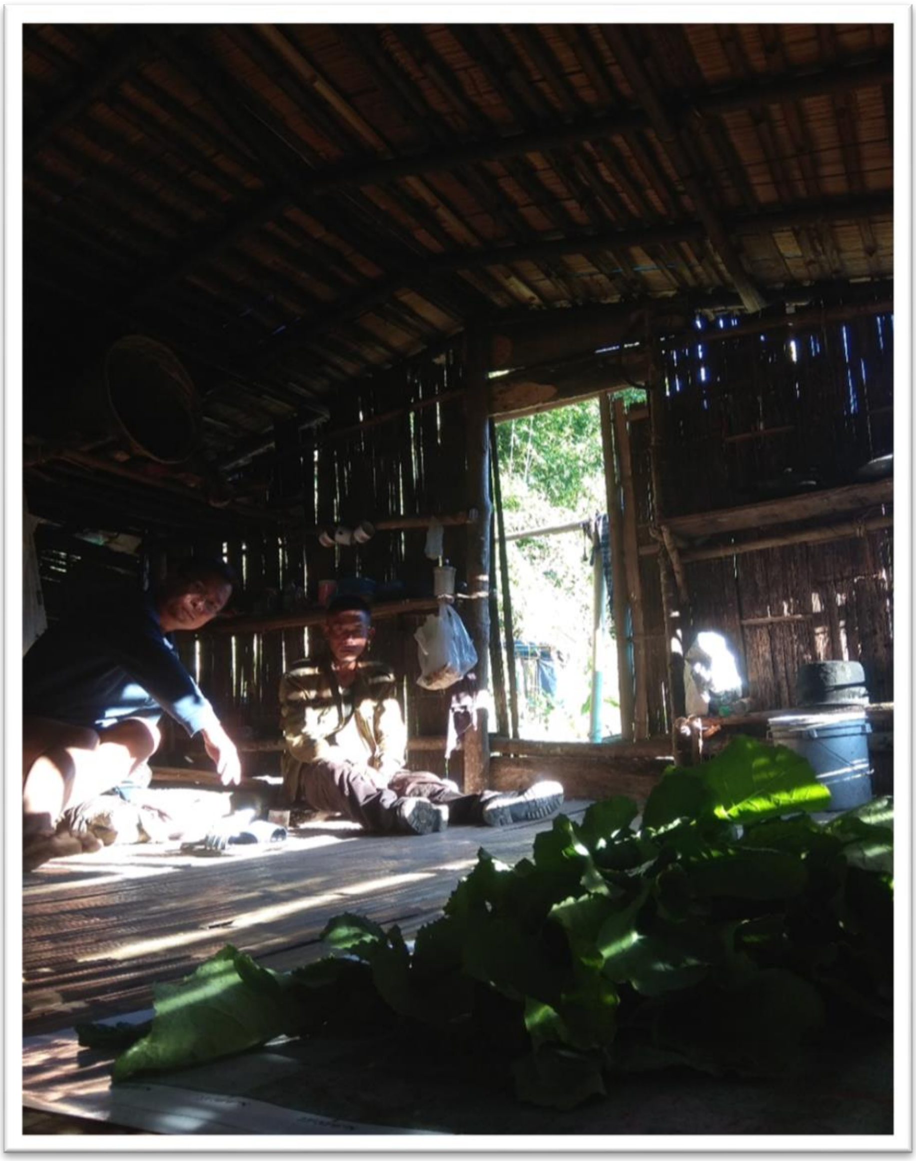

Plate 1.3: Camping for river water survey, upper Tuirial. Source: Author.

Secondary data are collected from the records of governmental and non-governmental agencies. Climatic data like rainfall, temperature, and humidity were collected from the State Meteorological Station for the period of 2000 – 2022. Underground water data was based on the Central Groundwater Board, Ministry of Water Resources. Project implementation and work done by different State Governments on water conservation, rainwater harvesting, soil statistics, etc. as well as private records were employed. Census of India, 2021 is consulted on the Socio-Economic status of the study area for comparison. Maps and satellite imagery were also taken from MIRSAC.

A B

Plate 1.4: A. Soil sample collection. B. Digital weight and soil temperature measurement. Source: Author.

1.8.2. Analysis of Data

The collected data were analyzed by using Microsoft Excel, Statistical Package for Social Science (SPSS), etc., and other appropriate statistical methods were used. Maps are constructed using the Geographical Information System (GIS). The level of soil moisture is measured by using the gravimetric method. GIS and remote sensing are adopted for the identification of groundwater potential zones, preparation of drainage density, and drainage patterns in the study area. River discharge is measured using a simple float/buoyancy method at the lower course of the river. Gravimetric water content (Standard Test Procedures, 2001) is expressed by mass (weight) as follows:

The moisture content of a soil sample is expressed as the mass of water in the sample expressed as a percentage of the dry mass, usually heating at 105^{0}C, i.e., thermostatically controlled drying oven capable of operating to 105 ± 5^{0}C.

moisture content, $\mathrm{w} = \frac{\mathrm{Mw}}{\mathrm{MD}} 100(\%)$

where, M_W = mass of water

M_D = dry mass of sample

Calculation and expression of results

Moisture content, $$w = \frac{\text{mass of moisture}}{\text{mass of dry soil}} x100(\%)$$

$$= \frac{(\text{mass of container+wet soil})-(\text{mass of container+dry soil})}{(\text{mass of container+dry soil})-(\text{ mass of container})} x100(\%)$$

A simple and inexpensive float method (Michaud et al. 2005) to measure the water discharge level of streams is common in remote areas. A buoyant object (yellow tennis ball weight 91.40 gram is used by the author) is time how long it takes to travel a specific distance. Stream flow is then calculated using the time, along with the estimated width and depth of the stream segment. Usually, a buoyant object is floated three times and takes the average time for final output.

Stream flow = Area x Velocity x Correction factor

Calculate area:

Multiply the width of the stream by the depth.

Calculate average float time:

Add up all the individual times and divide by the number of times the float was released (in seconds).

Calculate average velocity:

Divide the distance the item floated (i.e., the length of the segment measured in feet) by the average float time.

Calculate stream flow:

Multiply the average velocity by the area and by a correction factor (0.85). The correction factor takes into account the effects of friction from the stream bed. It is expressed in cubic feet per second (cfs)

Water in motion is measured in units of flow— units of volume for a convenient time unit. It is important that the difference between a unit of volume and a unit of flow must be kept in mind. The following equivalents are useful for converting from one unit to another and for calculating volumes from flow units. One of the most commonly used methods is Cubic foot per second(cfs)- The quantity of water equivalent to a stream one foot wide by one foot deep flowing with a velocity of one foot per second. A flow of one cfs is approximately equal to either 450 gpm, one acre-inch per hour, or two acre-feet per day (24 hours).

It is also converted into:

One cubic foot= 1,728 cubic inches

= 7.481 gallons (7.5 for ordinary calculations)

It is also converted into:

One cubic foot per second(cfs)

= 448.83 gallons per minute (450 for ordinary calculations)

= 1 acre-inch in 1 hour and 30 seconds (1 hour for ordinary calculations)

= 1 acre-foot in 12 hours and 6 minutes (12 hours for ordinary calculations)

= 1.984 acre-feet per (24 hours) day (2 acre-feet for ordinary calculations)

The above table can be also used to convert from a flow unit to a volume unit and vice-versa, or to estimate the operating hours required to deliver a desired volume of water. The following examples and graphs provide a better understanding of how such conversions can be carried out.

Table 1.1: Conversion of stream flow calculation (Taghvaeian S., 2006)

To convert from	To	Multiply by
Cubic-ft	Gallons	7.5
Acre-in	Cubic-ft	3,630
Acre-ft	Cubic-ft	43,560
Acre-ft	Acre-in	12
Cfs	gpm	450
Acre-in per hr	cfs	1
Acre-ft per hr	cfs	12

1.9. Organization of the Thesis

The present study on "Assessment of Water Resources Potential and its Management in Upper Tuirial Watershed, Mizoram" is analyzed, compiled and arranged in the following chapters:

Chapter 1: Introduction

The first chapter presents an introduction to the theme, a statement of the problem, the hypotheses of the work, the significance of the study, deals with the objectives identified for the study, and the methodology adopted for achieving the identified objectives. The data sources primary data and secondary are identified. Compilation of an elaborate household survey-based questionnaire, methods of calculating water discharge, and interpretation of satellite imageries are highlighted.

Chapter 2: Review of Literature

Reviews of literature relating to methods and systems for the calculation of water resources availability, their potential, and estimation methods for groundwater potentials are carried out at international, national, state, and local levels. It discusses various literature available for water resources management and conservation systems in this chapter.

Chapter 3: Geographical Background and Socio-economic Profile

The analysis of the study area's geographical features and elements like the physiography, geological features, major landforms, drainage system, climatic condition, demographic features, and economy are the main themes of this chapter. Interpretation of satellite imagery and the use of remote sensing data for deriving spatial information have also been discussed.

Chapter 4: Potential Water Resources

In this chapter, the demarcation of the watershed into eight (8) sub-watersheds for estimation of their water discharge level is followed by the discussion of annual rainfall, the revival of springs, river discharge, and groundwater potential analysis. The part played by private, government, and NGOs is highlighted. It traces available sources of water and their estimated potential.

Chapter 5: Water Demand and Supply

The various types of water demand for domestic, institutional, commercial, and agriculture are taken into consideration. Domestic demand is given priority. The pivotal role played by the government water distribution in addition to privately owned water truck distribution and for the community are taken into consideration in this chapter.

Chapter 6: Water Resource Management and Conservation

This chapter highlights the different water resource management and conservation methods implemented in the region and discusses the Programme and initiatives taken for the study area in particular.

Chapter 7: Conclusions

The last chapter concluded that the water resources of the area in terms of rainfall, river water, and groundwater have the utilization potential for the area. It is suggested that rainwater harvesting and spring shed development is the important key factor for the management and conservation. The additional activity will be grey water management and forest conservation for the development of water potential.

References

American Society of Civil Engineers (1998), Water Resource Planning and Management Division. Task Committee for Sustainability Criteria, ASCE and the working group of UNESCO/IHP IV Project M-4.3. *Sustainability criteria for water resource systems.*, ASCE, Reston Va. P. 253.

Bo Xiao, Qing-Hai Wang, Jun Fan, Feng-Peng Han and Quan-Hou Dai (2011). Application of the SCS-CN Model to Runoff Estimation in a Small Watershed with High Spatial Heterogeneity. *Pedosphere* vol.21 (6), December 2011, pp. 738-749.

Directorate of Census Operations, Mizoram (2011). District Census Handbook, Aizawl. Village and Town Directory. Series 16 Part-XII A.

Directorate of Census Operations: Census of India (2011): Provisional Population Totals, Directorate of Census Operations, Mizoram. Paper 2, Volume 1 of 2011.

Environmental Protection Agency, Ireland (2001). Parameters of Water Quality: Interpretation and Standards. ISBN 1-84096-015-3

Global Water Partnership (2005). Integrated water resources management plans: training manual and operational guide.

Global Water Partnership (2009) A handbook for integrated water resources management in basins.

Global Water Partnership, 2000. *Integrated water resources management.* TAC Background Paper No. 4. Global Water Partnership, Stockholm.

Government of Mizoram (2021). Directorate of Economics & Statistics, Mizoram Statistical Abstract 2021.

Greisinger (2006). Moisture Conversions electronic GmbH. http://www.greisinger.de 17.03.2006, BR

Kumaraswamy K., (2009): "Sustainable Development of Water Resources - A Case Study from Tamil Nadu", *Enrich Environment- Multidisciplinary International Research Journal*, Vol.2 (5), pp. 55- 61.

Lalmalsawmzauva K.C.(2016). Regional Disparities of Water Supply in Mizoram. National Seminar on "Regional Disparities and Its Consequences". September, 2016. https://www.researchgate.net/publication/327744339

Liu Xianzhao and Li Jiazhu (2008). Application of SCS Model in Estimation of Runoff from Small Watershed in Loess Plateau of China, 2008. *Chinese Geographical Science*. Volume-18(3), pp. 235-241.

Ministry of Water Resources; Government of India (2009): *"Ground Water Resource Estimation Methodology",* pp. 1-107.

Nilufer Arshad (2009): "*Environmental Management of Water Resources for Sustainable Development in Western Part of Hunsur, Karnataka, India Using Remote Sensing and GIS*", Published Ph. D. Thesis, Dept, of Geology, University of Mysore.

Patil J.P., Sarangi A., Singh A.K., Ahmad T., (2008). Evaluation of modified CN methods for watershed runoff estimation using a GIS-based interface. *Biosystems Engineering* Vol. 100 (1), May 2008, pp. 137-146.

Rekha V.B., George A.V. and Rita M., (2011). Morphometric Analysis and Micro-watershed Prioritization of Peruvanthanam Sub- watershed, the Manimala River Basin, Kerala, South India. *Environmental Research, Engineering and Management*. Volume-3(57), pp. 6-14.

Soulis K. X. and Valiantzas J.D., (2012). SCS-CN parameter determination using rainfall-runoff data in heterogeneous watersheds – the two-CN system approach. *Hydrology and Earth system Sciences,* Volume 16, pp. 1001-1015.

Sridhar. P, Chandra Bose. A.S, Giridhar. M.V.S.S and Viswanadh. G.K., (2012). Prioritization of mini-watersheds based on Morphometric analysis using GIS. *International Journal of Geomatics and Geosciences*.Volume- 3 (2), 2012. Pp. 314-338.

Srinivasa V. S., Govindaiah S. and Honne Gowda H., (2008). Prioritization of sub-watersheds for sustainable development and management of natural resources: An integrated approach using remote sensing, GIS and Socio-Economic data. *Current Science*, Volume 95(3), 10 August, 2008. pp. 345-354.

Tejram Nayak, Verma M.K and Hema Bindu.S., (2012). SCS curve number method in Narmada basin. *International Journal of Geomatics and Geosciences* Vol. 3 (1),2012. pp. 219-228.

Thakkar A.K. and Dhiman S.D., (2007). Morphometric analysis and prioritization of mini-watersheds in Mohr watershed, Gujarat using remote sensing and GIS techniques. *Journal of the Indian Society of Remote Sensing*, Vol. 35(4), 2007.

World Commission on Environment and Development (1987), *Our common future. Report of the Brundtland Commission*. Oxford University Press, Oxford.

Balasubramanian A. (2017). Surface Runoff. Technical Report https://www.researchgate.net/ publication/320331329

Francis S.W. (1861), Water; Its History, Characteristics, Hygienic and Therapeutic Uses.

Peña H. (2011). Social Equity and Integrated Water Resources Management by Global Water Partnership Technical Committee (TEC)

Chapter - 2

Review of Literature

2.1. Introduction

From nomads to city dwellers, water is indispensable for existence, the level of expression in terms of value and utility counted is different from region to region according to each convenience. Water has a mythological history and famous myths, roles, and uses from different cultures of the world. Historical writings and archaeological research have taught us that many old civilizations flourished with advanced methods of managing water resources. However, for thousands of years, water is primarily regarded as a natural resource to be exploited for the benefit of man. The disembodied modern conceptualization of water as a product, property, and commodity has to be complemented that connect water to the natural or cultural environment.

Water is a gift of nature. Villiers M.D.'s (1999) work, "Water: The Fate of Our Most Precious Resource" provides a historical account of how people are using, misusing, and abusing water resources. He studied diverse areas from Las Vegas, and the Middle East to China where the growth of population and development have stressed fresh water supplies nearly beyond remedy. It also demonstrates that pre-modern and modern meanings of water continue to be relevant in present times even as post-modern meanings- a perspective of water as a natural element beyond human control are becoming more significant (Villiers M.D.,1999). Human activities affect the water cycle in many ways, which need to be understood and quantified to manage water resources responsibly and sustainably. Relating to climatic changes and environmental degradation, the issue of water resource management becomes increasingly important. In order to hand out proper planning, reliable information on water sources, the quality and quantity of available water, its potential, availability as well as causes of scarcity, depletion, and level of exploitation is needed.

The present study on "Assessment of water resources potential and its management in upper Tuirial watershed, Mizoram" stresses the status of available water sources and possible management for the study area. Discussing the issue, notable articles and methods are reviewed as under:

2.2. Water Supply and Demand Calculation

Understanding water availability and movements is crucial for rational water management. UNESCO (Miloradov M. et al. 1998) published “Guidelines for conducting water resources assessment”, as a contribution to the solution of world water problems. An assessment of present and future water demand for different purposes will help to control water scarcity in the future. Long-term data on the use of water is analyzed to forecast the trends of water consumption and demand in the future. The empirical relationship is mostly used to determine the water demand in settlements.

The specific water demand depends on the climatic condition, plant evapotranspiration, water reserve of the soil, groundwater level, and the empirical method used for computing reference evapotranspiration values. Water demand for livestock rearing and water demand for tourism is also given based on liter per capita per day (lpcd) consumption and facilities.

The Indian Standard 1172: 1993 indicates water supply for residences. The value of water supply to cities is 150 to 200 liters per head and 135 liters per head per day for houses for Lower Income Groups (LIG) and Economically Weaker Sections of Society (EWS), depending upon prevailing conditions.

National Jal Jeevan Mission (2019), resolved to ensure that all 18 crore households across all villages will have a potable water supply by 2024. As per the Ministry of Housing and Urban Affairs, 135 liter per capita per day (lpcd) has been suggested as the benchmark for urban water supply. In 2019, for rural areas, the minimum service delivery of 55 lpcd has been fixed under Jal Jeevan Mission, of prescribed quality (‘IS 10500:2012’ Indian Standard – Drinking Water Specification as amended from time to time)., i.e., BIS:10500 standard, on regular basis, i.e., continuous supply in long-term, which may be enhanced to a higher level by states.

Gibberd (2014), in his article, gives a brief outline of some calculations that can be used to design water systems in green buildings. Green buildings aim to develop systems of rainwater harvesting, plumbing, and ecological sanitation systems that enable buildings to be self-reliant for their water needs and avoid polluting water. This reduces the requirement for large-scale water consumption in the long run. Gibberd, further forwarded different aspects of the water conservation system which are simplified and easy to apply. He calculated potential rainwater harvesting capacity by multiplying the area of the roof by the annual rainfall. For example, a house with a $100m^2$ roof in an area with 500mm annual rainfall has an annual rainfall harvesting capacity of 50,000L. However, 10% losses may be deducted from the amount harvested. Due to the high variability of rainfall, contingency should always be allowed. Even fairly modestly sized rainwater tanks can make a significant contribution to reducing main potable water consumption.

Ren C. et al. (2019) Developed the model of water resources supply and demand. The main components of water supply are natural water resources and technical water resources. Natural water resources mainly consist of surface water x_1 (t) and groundwater x_2 (t). Technical water resources consist of seawater desalting recycling and purifying x_3 (t). Besides, environmental pollution will also decrease the water resources supply, marked as x_4 (t) Water resources demand mainly consist of industrial water y_1 (t), agricultural water y_2 (t), and domestic water y_3(t).

MPSC (2019) Environmental Engineering clearly highlights the Standard National Domestic Consumption (as per IS 1772:1993) as 135 lpcd for weaker economically section and low-income groups depending upon prevailing conditions. Calculate different amounts of water supply and demand for household, commercial and institution, agriculture, and industries. The total consumption of water for a water supply system in a year divided by the population and the number of days in the year is called per capita demand.

Apart from the Indian Standard, Water Demand Estimation (Winnipeg Water and Wastewater Department, **2020) of Manitoba, Canada** provides water demand calculation for the proposed development. Which lays down that all water demand calculations and assumptions must be stamped and signed by a Professional Engineer licensed to practice in the Province of Manitoba.

2.3. International

Assuming that there is no cheaper alternative to water, the monetary value of water in comparison to other commodities in the demand and supply system may result in negligence of management. Scarcity results in a rise in price, only then people are unable to buy a sufficient amount of water, so they will look for other options (Savenije H.H.G. 1996). Hence, it may be small or extensive, and the infrastructure or management and planning is used to match resources with demand. Three activities are distinguished: Water Resources Development (WRD), Water Resources Planning (WRP), and Water Resources Management (WRM). The planning of public water supply is governed by the Water Supply Act, which forms the legal basis for (e.g., drinking water standards, etc.) planning, and governmental and provincial supervision.

The water resources management system includes elements required to produce water and water-related goods and services. The totality of water, the physical, chemical and biological components (the natural elements) as well as man-made elements are taken into consideration. Management of this water resources system is essential in order to produce the required outputs in the most efficient way (Savenije H.H.G., 1996):

GWP (2000) initiated implementation strategies for comprehensive integrated water resources management (IWRM). Protection and restoration of water resources, and establishment of water policies are the major concerns. These strategies will enhance the demand and supply flow of water in different parts of the world. GWP was formulated to determine more accurately investment needs to achieve the Vision to ensure adequate resources for secure water in the future.

Karavitis C.A., et al. (2002) in their studies of the Aegean Archipelago, the fast and rapid runoff during winter causes a loss of water resources creating scarcity of water during summer when much of the activities are taking place. The estimated low level of surface water potential causes stress in future water demand. This raises the need for management of their available water resources. Therefore, suitable, reliable, and systematically collected data of discharge measurements, groundwater levels, soil moisture, etc. in addition to seawater treatment, will validate the model and estimation parameter values on future water security.

A key consideration for expanding water supply and sanitation services is selecting technologies and institutions that promote public health and the environment while also being financially viable. Brikké F. et al. (2003) focus on community water supply and sanitation in developing countries and provide essential information on the types of water supply and sanitation technologies that may be feasible, including descriptions of the operation and maintenance requirements of the technologies. It also highlights what is involved in choosing the water supply and sanitation technologies to be used in specific situations.

The JICA (2003) Studies on “Water Supply Systems in Mandalay City and in the Central Dry Zone” forwarded the need for the construction of rainwater storage dams in the Central Dry Zone to provide domestic water to villages, since surface water resources are scarce, utmost utilization of surface water is essential. These dams shall serve the people not only with good water but also with a very desirable natural and ecological environment. It further suggests the enactment of river laws and river development codes of practice for water resource development schemes as the legitimate right of the people living near the water resource and it shall be as much possible as “multi-purpose”. And propose a coordinating committee that will evaluate, examine, and monitors water resource development to ensure projects satisfy as many users as possible before implementation. Dam design criteria should incorporate guidelines for water quality, environmental factors, and indirect benefits gained from upgrading.

Oki T. et al. (2003) employ Total Runoff Integrating Pathways (TRIP) to derive Annual water availability from annual runoff land surface models. The Total Runoff Integrating Pathways (TRIP) was used for the river routing calculations to convert runoff from LSMs (Land Surface Model) into river discharge. Global distribution of water and withdrawal for each sector was estimated based on country-based statistics. Future projections of the global water resources considering population growth, climatic change, and the increase of water consumption per capita were carried out. The study concluded that the total withdrawal of water resources tends to increase in developing countries. Further, it projects that the increase in irrigation is proportional to population growth which highlights the stress on the virtual water trade focussing on the water resources saved by importing agricultural and cattle products.

The symposium on “water availability and global change” (Oki T. et al., 2003) projected that population growth alone will put 74% population of the world under strong water scarcity by 2050 according to the future projection used in this study. Two methods are applied here (UN et al. 1997), one method is to use the difference in General Circulation Model (GCM) simulation for current and future climatic conditions, and the other one is to use the ratio. Even though both methods may suffer technical problems when adjusting current river runoff to the future, but constant in the future. In this study, both are estimated and used for future water resources assessments.

Global Water Partnership (2005) published a Training Manual and Operational Guide based on the principles of Integrated Water Resources Management Plans, with the support of the Canadian International Development Agency, CIDA, in the framework of the PAWD program, Partnership for African Waters Development. This aims to provide an overview of the tools and techniques required for the development of such plans. The material identifies useful tools to support the planning process in each step and is designed for national IWRM plans, but can also be adapted for basin-level planning to suit local circumstances. It is essential to also consider social equity and economic efficiency to achieve sustainability. The standard approach to enhance water resources management involves engaging stakeholders in the planning and decision-making process. Therefore, preparing water resources management plans can be more involved than conventional government planning. Developing a water resources strategy is a crucial step toward creating a plan. The text strongly advocates the idea that planning is not a linear process but rather a cyclical one, which requires regular evaluation, assessment of progress, and re-planning. Although the material is aimed at national water resource management planning, it can be easily adapted for lower-level planning within a national IWRM policy and legal framework.

Ministry of Water and Irrigation, Kenya (2006) published that the management of water resources with issues relating to pollution control, water allocation mechanisms, and soil erosion in catchments, which have resulted in the deterioration of riparian lands, causing flash floods, turbidity, and siltation of water courses and storage facilities. Over-abstraction of surface water in some areas and inappropriate land use changes have also contributed to a serious decline in the quantity and quality of water resources. The quality of water has been negatively impacted by the poorly controlled discharge of effluent from industry and sewage outfalls, as well as excessive nutrient and agrochemical pollution from rural sources. In addition, there have been insufficient investments in hydraulic and storage structures for flood control, energy generation, irrigation development, and urban, industrial, rural, and livestock water supply. This National Water Resources Management Strategy (NWRMS) was prepared to outline the objectives and strategies that address the major issues and challenges that are currently faced by Kenya. The Strategy appreciates that integrated water resources management must be elevated and recognized as a national priority. The strategy is to develop a water resources assessment and monitoring system, based on a catchment approach that includes appropriate data and information dissemination systems. The publication of an annual water resources assessment report, institutional set-up and the strengthening of capacity (human resources and material), and the definition of roles and responsibilities are stages proposed to avoid duplication and to build lean, effective, and efficient water resources management institutions.

Monthly precipitation, temperature, and potential evaporation data analysis result in reliable projected future impact of climate on runoff, flows, water uses, and water availability (CSRIO 2008). The indicators may employ extensive time-bound indicators and mathematical calculation, yet result in reliable outcomes.

The implementation of the integrated water resources management (IWRM) approach in lake, river, and aquifer basins will retrain the level of water resources (GWP 2009). The water harvesting system and reclamation of the wetland is the most important aspect of the development of the water supply.

The ability to assess the availability of freshwater resources has been an issue of importance in most countries for many decades. A number of guidelines and manuals have been produced offering advice to staff of National Hydrological Services (NHSs) or water agencies on how to quantify their water resources (World Bank, 1994; WMO/UNESCO, 1991, 1997; UNESCO, 1998). Owing to advances in computerized geographical information systems (GIS), and with the increasing availability of high-resolution remotely sensed data, WMO (2012) provides technical material in a reasonably logical progression as required for carrying out a water resources assessment (WRA). Good quality, long-term records of climate (particularly precipitation), river flows, reservoir levels and groundwater levels are vital to ensure that current assessments of available freshwater resources are accurate. There is, therefore, a pressing need for new scenario-based approaches to future resource modelling and continuing, reliable long-term records to determine trends in water availability under a changing climate. Following the organization of workshops on the Water Resources – Handbook for Review of National Capabilities (WMO/UNESCO, 1997), it was realized that there was a need for further technical material to be provided for water resources assessment, focusing more on how such analyses should be carried out.

The studies of the American Water Resources Association (2012) in “Case Studies in Integrated Water Resources Management: From Local Stewardship to

National Vision" suggested that One of the most forward-thinking actions was to establish the Special Protection Waters Program that requires any new or expanding discharger to show no measurable change to the existing water quality. While Oregon's IWRS recommended policies to promote water reuse. California has invested heavily in water planning at the state level. The studies reveal that protection of the headwaters is important in order to maintain the high-water quality. The framework resulted in potential water resource management from the waterway corridor to education and involvement for stewardship.

ECLAC (2015) discusses water and its role in our future development, with a particular emphasis on water as a development issue in the Caribbean Small Island Developing States (SIDS). These include elements such as water resources, water governance, water-related diseases, wastewater pollution and water quality, drinking water, and sanitation and hygiene. According to the WHO and UNICEF (2014), 2.3 billion people have gained access to an improved drinking water source and 1.9 billion to an improved sanitation facility. Approximately 2.5 billion persons have access to improved drinking water under a specific target of the Millennium Development Goals (MDGs). Notwithstanding this significant milestone, global water demand is projected to increase by 55 % by 2050.

Krysanova et al. (2015) give appraisal applications of the Soil and Water Assessment Tool (SWAT) for water resources assessment. The review shows the availability of potential water resources is affected by the sloppiness of the land, soil erosion, and chemical uses in agriculture. The type of soil and its capacity to hold moisture affects agricultural production and their sustenance to their environment. The possibility of reproducing historical dynamics of nitrate concentrations in the aquifer is also highlighted.

Geo-Hazards International (2020), in their study on Water Supply Systems in Shimla, Aizawl, and Similar Hill Cities, the analysis cited local springs, wells, harvested rainwater, and a stream as a portion of the water used in Aizawl. They confirm that Aizawl city receives most of its water supply from the Public Health Engineering Department (PHED). However, due to a shortage of supply, municipal water is distributed on a rotating basis once a week to neighbourhood distribution points, homes, and businesses. To cope with this situation, homes and businesses have their own on-site tanks to store water from the periodic deliveries, as well as water collected from the rain and private lorry tanker deliveries. The Greater Aizawl

Water Supply Scheme (GAWSS) Phases I and II, transport water through separate pipelines to the Tlawng River at Reiek Kai. The treated water is pumped 1000 meters high to the main reservoir at Tuikhuahtlang, providing 24.8 MLD (million liters per day). An additional source of seasonal water from the Serlui River 30 MLD of raw water is fed by gravity to the treatment station. The treated water is also pumped to the Tuikhuahtlang main reservoir. From the main reservoir in Tuikhuahtlang, it is distributed to the Laipuitlang sub-reservoir via a booster station and to 41 zonal tanks around the city. The zonal tanks distribute water to households, businesses, facilities, and to distribution points.

According to Junati et al. (2021) the effectiveness of the rational method widely used in calculating water availability for spatial planning in Indonesia, suggests that SCS-CN performs better than the rational model in simulating the character of water catchment area and is suitable for the model of choice in water availability estimation.

Stringer L.C et al. (2021) observed and projected climate change impacts on water security across the world's drylands to the year 2100. We find that efficient water management, technology, and infrastructure, and better demand and supply management, can offer more equitable access to water resources. People are already adapting but need to be supported with coherent system-oriented policies and institutions that situate water security at their core, in line with the components of integrated water resources management. The study projected that water scarcity affects 1–2 billion people globally, most of whom live in drylands. More people will be subjected to severe water stress in the coming decades under the ongoing conditions of climate change and global warming.

The bottom-up recommendation by Barbara V.K. (2022) for the acceleration of water harvesting development by the WASH and irrigation sectors is to join forces and take customary water tenure at a community level as a starting point for support to self-supply and public systems in order to increase basic water supply to everyone's homestead, leaving no one behind. It is further recognized that people's priority use of 5 liters per capita per day, not necessarily more, should be safe for drinking, while enhancing the productivity of homestead irrigation and livestock to realize everyone's right to food. Inclusive community-driven resource mapping is key for participatory planning, design, and infrastructure construction. It leverages local capital in all three areas. While these findings identify how recognition of customary water tenure better enables the realization of the rights to water and food and the SDGs, more historical and interdisciplinary research is clearly needed and recommended.

Eid-Sabbagh, K. et al. (2022), in their study, contributed to knowledge on the expansion of water reuse in Lebanon. They assess the potential for water reuse at the national level, develop a technical assessment of the quantities of treated water available for safe reuse in irrigation, and identify the wastewater treatment plants (WWTPs) that have the highest potential for that purpose. It also examines the governance barriers hindering this potential from materializing in practice. The total volume of wastewater that is received and treated amounts to 81 Mm3 per year. Which is approximately 25-30% of the annually generated wastewater. The three largest wastewater treatment plants (WWTPs) in the country currently provide primary-level treatment to a total of 145,000 m^3/day, which adds up to 52.9 mm^3 per year. At the national scale, only 28 mm^3, or 34%, of the treated wastewater can be considered fit for reuse currently, which amounts to about 8-10% of the total municipal wastewater generated. It also found that in an actual potential scenario, 48 WWTPs would have a reasonably high reuse potential score, while in an ideal potential scenario, as many as 82 would be in the same bracket. The management is done by the segregation of wastewater which proves to be a worthwhile undertaking with regard to realizing wastewater treatment and reuse potential. However, the structural system does not lack shortcomings in the wastewater sector combined with challenges of governance and the lack of a regulatory framework for reuse management impede the materialization of this potential.

2.4. National

The National Water Policy of India (2002) recognizes that the development and management of water resources need to be governed by national perspectives in order to develop and conserve scarce water resources on an integrated and environmentally sound basis. The policy emphasizes the need for effective management of water resources by intensifying research efforts in the use of remote sensing technology and developing an information system. In this reference, a Memorandum of Understanding (MoU) was signed on December 3, 2008, between the Central Water Commission (CWC) and the National Remote Sensing Centre (NRSC), Indian Space Research Organisation (ISRO) to execute the project

“Generation of Database and Implementation of Web-enabled Water Resources Information System in the Country” short named as India-WRIS Web-GIS. It has been developed and is in the public domain and provides a ‘Single Window solution’ for all water resources data and information in a standardized national GIS framework and allows users to search, access, visualize, understand, and analyze comprehensive and contextual water resources data and information for planning, development and Integrated Water Resources Management (IWRM).

According to Shaban A. et al. (2007), the water consumption in Indian cities is far lower than the norms laid down by the Bureau of Indian Standards. The lower consumption is mainly because the water supply is not keeping pace with population growth and increasing users is the main reason for the insufficient supply of water. High water-consuming economic activities and population growth are responsible for declining per capita water availability. Increased consumption more so by the “privileged,” puts further pressure on this diminishing natural resource. Indian cities have been appropriating water resources traditionally meant for “subsistence” in rural areas.

The publication of the "Manual on Artificial Recharge of Ground Water" by the Central Ground Water Board (September 2007) provides information on various investigation techniques for selecting sites, planning and designing artificial recharge structures, evaluating their economics, monitoring and auditing schemes, and addressing issues related to the operation and maintenance of these structures. It also provides detailed information on rooftop rainwater harvesting. It also covers various aspects of groundwater augmentation schemes planning and implementation across the country. Groundwater development plays a crucial role in the Indian economy by stabilizing agriculture and managing drought. Over the years, there have been continuous efforts in India to develop groundwater resources to meet the growing demand for water supply in various sectors, particularly since the launch of Five-Year Plans. Over-exploitation of groundwater resources results in declining water levels, water shortages, intrusion of saline water in coastal areas, and deepening of groundwater abstraction structures. All of these factors have serious implications for the environment and the socio-economic conditions of the people.

According to Palanisami, K. (2009), the Indian experience with water markets has been positive, although markets have remained informal, localized and primitive. While these markets have improved efficiency and expanded access to irrigation for resource-poor farmers, inter-sectoral water transfers have not yet occurred. However, the water markets in water surplus regions are limited or rather water markets are not pervasive in these regions except in West Bengal, India. Hence, promoting water markets in water surplus regions can boost the agricultural economy by transforming it into a vibrant one with positive productivity and equity impacts.

Saleth R.M. (2011) summarizes six demand management options (water pricing, water markets, water rights, energy regulations, water-saving technologies, and user and community organizations) and one supply management option (the implementation of the National River Linking Project, NRLP). The overview covers their effectiveness and technical, institutional, and financial requirements. The paper then develops a framework that captures the analytics of water demand management in terms of both the impact pathways of and operational linkages among the options and their underlying institutions. Using this framework, the paper outlines a strategy for water demand management that can exploit the inherent synergies among the options and align them well with the underlying institutional structure and its environment. It proposed two approaches that require immediate policy attention. The first approach involves the revival and rehabilitation of the small and large tanks as storage mechanisms for capturing local water flows especially for the peninsular parts of India, where tank systems play a major role both in meeting irrigation and drinking water needs and in serving as groundwater recharge systems. The other approach involves the creation of a national water grid that can utilize fully the available water potential, minimize the impacts of the drought/flood syndrome, and create a balance in regional water supplies.

Verma R. (2012) asserts that for sustainable development of the watershed area, water resource development and proper rainwater harvesting system may be significant at large and further suggested stormwater management, rainwater treatment, and aquatic habitat restoration. A proper implementation of watershed development may increase in the productivity of agriculture and raise the level of groundwater

The "Empirical study on Impact of Integrated Watershed Development project in Mizoram state of North-East India" (Sundaram et al.2012) suggested further improvement in the sustainability of the implementation of the IWDP Scheme in Mizoram. The development of water harvesting activities especially rainwater harvesting is necessary for regional sufficiency of water supply in the area. Active participation of people/communities in watershed development programs will enhance water availability. Sundaram suggested that the development project be reoriented in favor of the people, animal husbandry, forest reclamation, community lands, wastelands, and fallow lands, etc. for their improved productivity. In each and every aspect of development in the hilly areas, proper supply and flow of water is one of the important aspects of the upliftment of regional activities.

Observations over the past decades and projections from climate change scenarios point towards an exacerbation of the spatial and temporal variations of water cycle dynamics (IPCC, 2013). As a result, discrepancies in water supply and demand are becoming increasingly aggravated. On the basis of the water balance approach, it is possible to make a quantitative evaluation of water resources in the basins and their change under the influence of people's activities.

Anandhi A. et al. (2014) demonstrate the use of GIS and digital elevation model (DEM) in the various stages of WRA through a case study of rainfall–runoff simulation. The Soil and Water Assessment Tool (SWAT) is selected for rainfall–runoff prediction, as this model has been widely used in hydrology and as the extensive data required for the model could be readily obtained for the study region from different sources. GIS and DEM were useful in providing necessary input to the AVSWAT (Arc View Soil and Water Assessment) model which performed fairly well in predicting runoff.

Sahora J. (2017) asserts that due to a high level of development of the groundwater potential, Punjab, Haryana, Rajasthan, and Delhi are experiencing a rapid fall in the water table and will face more severe shortages of groundwater in the future. He further argues that the most effective way to conserve water is to use it wisely. In India, the primary use of water is for irrigation. However, the traditional method of flood irrigation, where fields are flooded with water, is highly inefficient. A significant amount of water remains unutilized by plants and evaporates. Moreover, over-irrigation and seepage lead to waterlogging, which in turn results in the emergence of saline and alkaline wastelands. The overuse of tube wells leads to a decline in groundwater levels. To combat wasteful water usage and promote water reuse, drip irrigation, sprinkler irrigation, rainwater harvesting, and water pollution prevention and control are necessary. Drip irrigation is a form of irrigation that saves water and fertilizers. It allows water to drip slowly drop by drop to the roots of plants, either on the soil surface or directly on the root zone. Sahora further suggests rainwater harvesting as a highly effective method for the conservation and management of water. It refers to the process of collecting and storing rainwater for human, animal, and plant needs. This involves the collection and storage of rainwater on the surface or in underground aquifers, instead of letting it run off. Ministry of Jal Shakti (2019) defines 135 liters per capita per day (lpcd) has been suggested as the benchmark for urban water supply. For rural areas, minimum service delivery of 55 lpcd has been fixed under the Jal Jeevan Mission, which may be enhanced to a higher level by states. The functionality of a tap connection is defined as having infrastructure, i.e., household tap connection providing water in adequate quantity, i.e., at least 55 lpcd, of prescribed quality, i.e., BIS:10500 standard, on a regular basis, i.e., continuous supply in long-term. For better implementation and long-term Operation as well as maintenance of water supply systems, a 'sense of ownership' among the local community is essential. Decentralized, demand-driven, community-managed implementation of the program will also ensure equity in accessing supply for every household and regular supply, thus willingness to pay for services (operational guideline of JJM). The necessity for water resource planning is highlighted as the average annual per capita water availability assessed as 1816 cubic meters in the year 2001 was reduced to 1545 cubic meters in 2011 which may further reduce to 1367 cubic meters in the 2031 positively.

Aartsen M., et al. (2018) argue that water 'crises' are largely a result of mismanagement, with strong public governance implications. In opined that, connecting water science and policy is key in developing the necessary capacity to govern urban water challenges, cities first need to develop a common understanding of what their limiting and enabling conditions are before meaningful science policy in action can take shape. There is a need for feasible interactive approaches that may facilitate integration between science and policy. Developed in the context of Water share and the European Innovation Partnership on Water, this paper assesses to what extent the City Blueprint Approach may facilitate such meaningful science-policy interaction. It was found that the governance conditions regarding learning, stakeholder engagement, and implementing capacity are most in need of improvement. In addition, the method's standardized, integrated, and systematic assessments of water governance provide valuable insight into a city's strengths, weaknesses, and the potential impact of governance interventions.

Indian agriculture, hydropower generation, livestock production, industrial activities, forestry, fisheries, navigation, recreational activities, etc. depend on surface water and groundwater resources. Basin level assessment of water availability (Central Water Commission, 2019) resulted in the regeneration of water sources and greatly controlled the potential impact of global climate change on water resources including enhanced evaporation due to warming, geographical changes in precipitation intensity, duration and frequency, together affecting the hydrological parameters such as discharge, soil moisture, etc. Earlier, different commissions, agencies, and researchers have estimated the water resources of the country using different approaches. Reassessment of Average Annual Water Resources Potential (1993) is the last study done by CWC. The National Commission for Integrated Water Resources Development (NCIWRD) also presented the average annual water resources potential of the country in 1999.

Sharad K. Jain (2019) broadly categorized the challenges in water management in India into six categories ranging from (a) water availability, variability and increasing withdrawals of present water resources, (b) maintenance of water environment and quality, (c) project construction, (d) water sharing disputes between states, national, and region to region, (e) water governance and institutions, and (f) challenges induced due to climate and land-use cover changes. It further suggested that the conservation of water and management of variabilities should be a cornerstone of water resources management in India.

Kolhe V.M. et al. (2019) argues that scientific and technical structure design is needed for proper watershed development planning. Employs a simplified method for calculating water demand and supply ratio for a small area. Agricultural water demand is calculated based on crop pattern, which is calculated from the particular crop requirement estimated by the Agricultural Department of Maharashtra. He stated that the water demand is 10 times more than the available resources. The micro research work finds the need for precise field investigation and validation of data for population and livestock for on-site calculation. Indian standards for rural domestic water usage need to be improved as consumption in other modes is never considered during the calculation. He suggested having appropriate watershed management as well as conservation with the help of scientific and technical structure design.

Department of Water Resources (2022) divided India into safe, semi-critical, critical, and overexploited based on the availability of groundwater resources. The dynamic groundwater resources have been managed and regulated according to the categorization. The assessment of the groundwater resource for all states and union territories is being jointly conducted by the State/UT Ground Water Department and Central Ground using the INDIA-Ground Water Resource Estimation System (IN-GRES) software for the year 2022 (GWRA-2022). This methodology considers various factors that contribute to both the recharge and extraction of groundwater. The report titled 'National Compilation on Dynamic Ground Water Resources of India 2022' summarizes the results of the assessments, primarily in terms of resource availability, utilization, and categorization of assessment units. The level of groundwater potential of Mizoram is high and safe for extraction.

2.5. North-East

Goswami S. et al. (2011) argue the importance of management is particularly important in a state with relatively less developed natural resources. In a state like Mizoram, water management is sufficiently guided by water availability and demand. On the basis of the supply and demand of water, using available secondary data. The paper finds that Mizoram has a complex coexistence of government-led, individual family, and private vendor-supplied water management systems, unable to take care of proper water conservation. Institutional planning and monitoring, NGOs and community participation for the action of rainwater harvesting at the household level, and proper fund allocation is suggested. Demand management should also be focused on collective action at the community or village level.

The Ground Water Information Booklet of Aizawl District (2013), Ministry of Water Resources shows that geologically, Aizawl district is occupied by shale, siltstone, and sandstone of Surma Formation of Miocene age. Groundwater stored in the hill slopes emanates in the form of springs, which are being used as a source of water supply. From the quality point of view, most of the Chemical constituents are within the permissible limit. Groundwater is fresh and potable and is suitable for domestic purposes. The gross annual dynamic groundwater resource of Mizoram is estimated to be 3.86 mcm while net groundwater availability for future irrigation development is 3.21 mcm. The groundwater development stage is approximately 3.94 %. The actual occurrence of groundwater in tectonically young and immature terrain is mainly restricted to weak zones i.e., zones of fractures, lineaments, and weathered residuum. These weak zones create seepage conduits, which are sources of springs. In the major part of the district, tapping perennial springs and rainwater harvesting would remain the main source of water supply to the local populace. The existing water supply for drinking purposes is mainly from those springs tapped through gravity drainage.

All the springs are fractures and joints oriented. A large number of springs are perennial. In general, discharges of the springs are meager in high altitudes which progressively increase down the slope. The springs should be properly developed, conserved, and protected wherever they are used for domestic purposes. Some of the spring waters in lower altitudes may be impounded in some structures and pumped again for water supply. Discharges of the spring vary between 3,000 and 20,000 liters per day during the period from January to March, which is generally a dry period. Water level trend is also not available due to a lack of groundwater abstraction structures, hence the annual groundwater recharges of all the assessment units have been computed by the Rainfall Infiltration Factor Method.

Upadhyay A. et al. (2014) in their study "Status of Drinking Water under Government Schemes: A Case Study of Mizoram" based on secondary data sources and some field observations under the Project of Rajiv Gandhi National Water Mission, concluded that, the main source of water is the numerous perennial springs and the rivers, which flows variedly with seasonal change, leading to inconsistency in the supply. The majority of the piped water supply schemes are gravity-based. Most of the government supply of water through public stand posts are gravity-based which is the principal source of water to the community. Even though the water supply is sufficient, the high demand for community reservoirs and perennial sources of water supply for the dry season is highly proposed.

Report of Barak and Others Basin (2014) systematically describes the present status of water resources, including major projects, hydro-meteorological observations, surface and groundwater development scenarios, topographic characteristics, climatic variability, land use/land cover patterns, and the socio-economic profile of the basin as an outcome of the project "Generation of Database and Implementation of Web-enabled Water Resources Information System in the

Country" named India-WRIS Web-GIS. The basin is widely accepted as the most suitable and effective unit for managing water resources, as it provides a comprehensive understanding of the interactions between upstream and downstream hydrology. This assessment provides a comprehensive overview of the current status of water resources, topographic features, climatic variations, land use patterns, and other natural resources related to the "Barak and Others" basin. The information provided is valuable for understanding the topography, demography, climate, surface and groundwater resources, hydro-meteorological and water quality conditions of the basin. The basin spreads over the states of Meghalaya, Manipur, Mizoram, Assam, Tripura and Nagaland. It is bounded by the Barail range separating it from the Brahmaputra basin on the north, by the Naga and Lushai hills on the east and by Mizo hills and territory of Bangladesh on the south and west. Groundwater in the basin is of good quality, except for a few areas with high dissolved iron content and very few places affected by low saline water.

Sustainable water management must consider a state's developmental aspirations, geographical conditions, hydrological status, water allocation priorities, and specific needs. After the adoption of the revised National Water Policy in 2012, the Mizoram State Water Policy 2020 was proposed by the Irrigation and Water Resources Department to enunciate the guidance for developing a set of strategies for managing water resources. The State Water Policy for Mizoram was formulated by GIZ, a German Firm, under a bi-lateral cooperation program, with assistance from IORA Ecological Solutions Pvt. Ltd. and Mizoram State Water Policy-2019 was launched on 27th Feb, 2019. The objective of the State Water Policy is to take cognizance of the existing situation in Mizoram, to propose a framework for the creation of a system of laws and institutions, and for a plan of action with a unified perspective. The policy has been designed with the needs and aspirations of the people in mind, and the complexities involved in addressing water-related issues. The state recognizes that achieving the goals of this policy will require the participation of all concerned departments, as well as the support of all other stakeholders who must perform their respective roles and work together collaboratively to achieve the objectives of the policy.

Lalmalsawmzauva K.C. (2016) in his study on "Regional Disparities of Water Supply in Mizoram" gives the sufficient supply of clean water as important as achieving developmental goals. The unequal distribution of water resources is closely related to other development indicators. He argues that the level of access to tap water with treated sources is below the national average. There are significant disparities in water supply across the state leading to regional divides between districts. Northeastern districts have better access to water than their southwestern counterparts. He further suggested that the government should create a well-planned strategy to ensure that all citizens, regardless of their location, have access to essential goods and services. It is also evident that immediate action must be taken to improve water sources before the current poor condition worsens.

Laldintluanga H. et al. (2016) It was found that the pH value of rural spring water in Aizawl, Mamit, and Serchhip districts in Mizoram is within the normal range. However, the pH value of reservoir water is lower than the permissible limit. A study was conducted to investigate the physical parameters (such as pH and turbidity), inorganic or chemical properties (including hardness, calcium, and alkalinity), and toxic metals (like arsenic and iron) present in rural water sources.

According to Rattani et al. (2020), mismanagement of water resources and lack of regulatory framework are the reasons behind the acute shortage of water supply during the dry season especially from November to March. In this regard, the potential of spring water becomes the resort. Spring-shed management is hailed as one of the key objectives in the State Action Plan on Climate Change (SAPCC) and the State Water Policy of Mizoram (Rattani,2020). To implement recharging of aquifers a detailed hydro-geological mapping was conducted to identify specific recharge zones and interventions based on the properties of aquifers. For this, the program covers two aspects — one on recharging aquifers through soil and water conservation structures in targeted groundwater recharge zones identified through hydro-geological assessment, and the other on preparation of participatory village water security plans.

Barman B.K. et al. (2020) opine that regardless of the rugged mountainous terrain of the upper Tuirial River basin, the unscientific practice of shifting cultivation, associated with high intensity of rainfall is the principal cause of soil erosion. Improper planning and management of land use, seepage from unlined water courses, and non-conjunctive use of surface and groundwater are observed factors in the watershed. It is suggested that implementing certain mitigation techniques such as water harvesting, terracing, the use of natural geotextiles for vegetative barriers, mulching, conservation agriculture, reforestation, horticulture development, agroforestry, and integrated farming systems can help reduce soil erosion.

Biswas et al. (2021) in their study through the grassroots level of Phullen RD block of Aizawl District, Mizoram, the population depend on a three-tier system of water sources. Firstly, PHED, Government of Mizoram, Secondly, village spring known as ‘tuikhur’ and thirdly private household rainwater harvesting and buying from private vendors. The different water requirement, supply and management of the villages highlights socio–economic as well as ecological situation of the region. The abundance of rainfall during summer and the prevailing scarcity of water during winter reflect the necessity of water resource management in this region.

According to Kumar S. et al. (2021), in the surrounding areas of Aizawl City, the proper development of perennial springs would serve as the primary source of water for the local population. Some samples with high chloride levels may have been contaminated by sewage or wastewater. The water quality was deemed acceptable by WHO standards, with the exception of the issue previously mentioned.

References

Aartsen M., Koop S., Hegger D., Goswami B., Oost J, Leeuwen K.V. (2018). Connecting water science and policy in India: lessons from a systematic water governance assessment in the city of Ahmedabad. *Regional Environmental Change* (2018) Vol-18, pp2445–2457. https://doi.org/10.1007/s10113-018-1363-1

Ako A.A., Eneke G., Eyong T. and Nkeng G.E. (March, 2010). Water Resources Management and Integrated Water Resources Management (IWRM) in Cameroon. *Water Resources Management*. excerpts from https://www.researchgate.net /publication/257672926

American Water Resources Association (2012). Case Studies in Integrated Water Resources Management: From Local Stewardship to National Vision. http://www.awra.org

Anandhi A., Srinivas V.V., Kumar D.N. (2014). Water Resources Assessment in a River Basin Using AVSWAT Model. *Handbook of Engineering Hydrology: Environmental Hydrology and Water Management*. Pp 501-518 excerpts from https://www.researchgate.net/ publication/263619557

Barbara V.K. (2022). Living customary water tenure in rights-based water management in Sub-Saharan Africa. International Water Management Institute (IWMI), Colombo, Sri Lanka. 41p.[doi: https://doi.org/10.5337/2022.214]

Barman B.K., Rao K.S., Sonowal K., Zohmingliani,. Prasad N.S.R. and Sahoo U.K. (2020) Soil erosion assessment using revised universal soil loss equation model and geo-spatial technology: A case study of upper Tuirial river basin, Mizoram, India. *AIMS Geosciences*. Volume 6 (4), pp. 525–544.

Biswas B., Azyu A. (2021) Water Resources and Management System of the Himalayan Region: Case Study of Mizoram, India. *Nature Environment and Pollution Technology: An International Quarterly Scientific Journal*. Vol. 20. Pp. 193-201.

Borden C. and Roy D. (2015). International Institute for Sustainable Development, Water Quality Monitoring System Design

Brikké F. and Bredero M. (2003). Linking technology choice with operation and maintenance in the context of community water supply and sanitation. *A reference document for planners and project staff.* World Health Organization and IRC Water and Sanitation Centre Geneva, Switzerland.

Bureau of Indian Standard (2010).IS 1172: 1993: *Code of basic requirements for water supply, drainage and sanitation,1993*. Fourth Reprint DECEMBER 2010.

Bureau of Indian Standard (2012). *IS 10500 (2012): Drinking water. Indian Standard Drinking Water – Specification*. May 2012

Central Water Commission (2019), Reassessment of water availability in basins using space inputs. Basin Planning & Management Organisation.

Citizens' Charter for Public Health Engineering Department Aizawl (2018) excerpts from https://phed.mizoram.gov.in

Commonwealth Scientific and Industrial Research Organisation (2008) Mekong River Basin Water Resources Assessment: Impacts of Climate Change. Crissy & Markley, New York.

Directorate of Economics & Statistics, Government of Mizoram. (2021). Meteorological Data of Mizoram 2021.

Economic Commission for Latin America and the Caribbean (2015) Water Resource Management, Climate Change and Sustainable Development in the Caribbean. ISSUE 4 /ECLAC

Eid-Sabbagh, K., Roukoz, S., Marie-Helene N., Naga V., Javier M.S. (2022). Analysis of water reuse potential for irrigation in Lebanon. International Water Management Institute (IWMI). Colombo, Sri Lanka. 145p. [doi: https://doi.org/10.5337/2022.211]

Elhag M. and Bahrawi J.A. (2014)Potential Rainwater Harvesting Improvement Using Advanced Remote Sensing Applications. *The Scientific World Journal* Vol-20, pp 1-8. Article ID 806959, Hindawi Publishing Corporation. http://dx.doi.org/10.1155/2014/806959

Geo Hazards International. September 25, 2020. A Way Forward to Increase Earthquake and Landslide Resilience of Water Supply Systems in Shimla, Aizawl, and Similar Hill Cities

Gibberd J. (2014). Water Conservation. Green Building Handbook for South Africa. CSIR Built Environment. Link. https://www.researchgate.net/publication/30511177

Global Water Partnership (2005) Integrated Water Resources Management Plans. Training Manual and Operational Guide

Global Water Partnership (2009) A handbook for integrated water resources management in basins.

Global Water Partnership. (2000) Towards Water Security: A Framework for Action. Indicative Global Water Security Targets.

Goswami S. & Guha S. (November 2011). Status of Water Resources in Mizoram: Institutions and Management Practices. *The IUP Journal of Environmental Sciences*, Vol. V, No. 4, pp. 7-20.

Government of India, Department of Water Resources (2022). National Compilation on Dynamic Ground Water Resources of India, 2022.

Government of India. Central Ground Water Board (September 2007) Manual on Artificial Recharge of Ground Water.
Government of India. Ministry of Water Resources (March 2014) Barak and Others Basin.

Government of Kenya. Ministry of Water and Irrigation (2006). The National Water Resources Management Strategy (NWRMS)

Government of Mizoram. Irrigation and Water Resources Department (2020). Mizoram State Water Policy -2020:

IPCC, 2013: Climate Change (2013), The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, New York, USA. Excerpts from https://indiaclimatedialogue.net

Japan International Cooperation Agency (2003). The Study on Water Supply Systems in Mandalay City and in the Central Dry Zone. Kyowa Engineering Consultants Co., Ltd.

Juniati A.T., Kusratmoko E., Sutjiningsih D. (2021). Estimation of potential water availability and water resources carrying capacity for Bogor City spatial plan. *Journal of Geography of Tropical Environments.* Vol- 5 (1), pp. 23-39

Karavitis C.A., Kerkides P. (2002) Estimation of the Water Resources Potential in the Island System of the Aegean Archipelago, Greece. *Water International*, Vol. 27(2), Pp 1-12.

Kolhe V.M. & Sathe N.J. (June 2019,) Water balance study from Akkalkot area, Solapur District: A case study of Dahitane and Chapalgaon region. *Journal of Emerging Technologies and Innovative Research (JETIR).* Vol- 6 (6). Pp 342-348.

Krysanova V., & White M. (2015) Advances in water resources assessment with SWAT—an overview. *Hydrological Sciences Journal*. Vol- 60(5), pp. 771-783.

Kumar S., Singh K. B. (2021). Study of potable water quality in peripheral areas of Aizawl city in Mizoram. *Science Vision*. Volume 2021(3), pp. 76–80.

Laldintluanga H., Lalbiakmawia F., Lalbiaknungi R.(2016) Assessment of Rural Water Quality in Aizawl, Mamit and Serchhip District of Mizoram, India. *IJSTE - International Journal of Science Technology & Engineering*. Volume 3 (06),pp 111-118.

Maharashtra Public Service Commission (2019) Environmental Engineering. Made easy Publications.

Manning L.J., Hall J.W., Fowler H.J., Kilsby C.G. and Tebaldi C. (2001) Using probabilistic climate change information from a multi-model ensemble for water resources assessment. *Water resources research*. Vol. 45, pp. 14-29, doi:10.1029/2007WR006674,

McCabe G.J. and Markstrom S.L. (2007). A Monthly Water-Balance Model Driven by a Graphical User Interface. U.S. Geological Survey, Reston, Virginia.

Michaud J.P. and Wierenga M. (July 2005). Estimating Discharge and Stream Flows: A Guide for Sand and Gravel Operators. Ecology Publication, EnviroVision. Number 05-10-070

Miloradov M.& Marjanovic P. (1998) Guidelines for conducting water resources assessment. UNESCO Publication.

Ministry of Jal Shakti, Govt. of India (December, 2019). Department of Drinking Water and Sanitation

Ministry of Water and Irrigation, Kenya (2006) The National Water Resources Management Strategy (NWRMS)

Ministry of Water Resources, Guwahati, (2013) Ground Water Information Booklet Aizawl District, Mizoram. Published by Central Ground Water Board, North Eastern Region

Moriarty P.B., Batchelor C.H., Laban P. and Fahmy H. (2010). Developing a practical approach to 'light IWRM' in the Middle East. *Water Alternatives*. Vol. 3(1). pp 122-136

National Jal Jeevan Mission. Government of India.

NRSC, 2009, Water Resources Assessment the National Perspective- A Technical Guide for Research and Practice, NRSC--TR98.

Oki T., Agata Y., Kanae S., Saruhasti T. & Musiake K. (2003) Global water resources assessment under climatic change in 2050 using TRIP. *Water Resources Systems—Water availability and global change (Proceedings of symposium HS02a held during IUGG2003 at Sapporo).* pp 124-133. IÂHS Publ. no. 280.

Palanisami, K., 2009. Water markets as a demand management option: potentials, problems, and prospects. In: R.M. Saleth, ed. *Promoting irrigation demand management in India: Potentials, problems, and prospects*. Colombo: International Water Management Institute.

Parvathi C (2011) "Impact Assessment of Watershed Intervention Technology on Selected Farm Households in Coimbatore District", Department of Economics

Rainwater Harvesting in Yemen: A Durable Solution for Water Scarcity. (2022) excerpts from https://www.worldbank.org

Rattani V. & Phukan I. (Jan 24, 2020) Revive springs for water security in Mizoram. India Climate Dialogue.

Ren C., Dong Y., Xue P., Xu W. (2019). Analysis of Water Supply and Demand based on Logistic Model. Conf. Series: *Earth and Environmental Science*. doi:10.1088/1755-1315/300/2/022013

Saleth R.M. (2011). Water scarcity and climatic change in India: the need for water demand and supply management. *Hydrological Sciences Journal*. Vol-56(4), pp. 671-686, DOI: 10.1080/02626667.2011.572074

Saroha J. (2017). Water Resource Potential, Utilization and Conservation in India. *IJRAR- International Journal of Research and Analytical Reviews* Vol- 4 (3) pp 27-35. e ISSN 2348 –1269, Print ISSN 2349-5138

Savenije H.H.G. (1996). Water Resources Management, Concepts and tools. Delft publication

Shaban A. & Sharma R.N. (June 2007). Water Consumption Patterns in Domestic Households in Major Cities. *Economic and Political Weekly*. June 9, 2007. pp. 2190-2197

Sharad K. Jain (2019) Water resources management in India – challenges and the way forward. *Current Science*. Vol- 117 (4), pp. 569-576.

Standard Test Procedures (2001) Link https://www.rhd.gov.bd /Documents/Contract Documents / Standard Test Procedures/ Determination.

Stringer L.C., Mirzabaev A., Benjaminsen T.A., Harris R.B.M., Jafari M., Lissner T.K., Stevens N., and Pahlen C.T. (2021) Climate change impacts on water security in global drylands, Review. *One Earth*. Vol-4, June 18, 2021 Elsevier Inc. pp. 851-864

Sundaram A. (2012) Empirical Study on Impact of Integrated watershed Development

The Mizoram Gazette (2020), Mizoram State Water Policy 2020. Vol XLIX Issue. 637. Mizoram Government Press.

UN, UNDP, UNEP, FAO, UNESCO, WMO, World Bank, WHO, UNIDO & SEI (1997) Comprehensive Assessment of the Freshwater Resources of the World. World Meteorological Organization, Geneva, Switzerland.

UNESCO & WMO (1997). Water resources Assessment Handbook for review of National capabilities

United Nations Environment Programme (2012). Status Report on The Application of Integrated Approaches to Water Resources Management. ISBN: 978-92-807-3264-1

Upadhyay A. & Lalroneiha K.C.T (August 2014). Status of Drinking Water under Government Schemes: A Case Study of Mizoram. *Research Forum: International Journal of Social Sciences*. Vol-2 (4) pp. 26- 32 ISSN: 2348 4411

Verma R. (August 2012). Sustainable Growth through watershed development: A case Study of Mizoram. Excerpts from https://www.researchgate.net/publication/281851907.

Villiers M.D. (1999), Water: The Fate of Our Most Precious Resource, Jacobas Communication Corporation, Canada.

Water and waste water department, Winnipeg **(2020),** MB, Canada. Water Demand Estimation and Design Guidelines, extract from https://legacy.winnipeg.ca/waterandwaste/dept/ waterdemand.stm

World Meteorological Organization (2012). Technical Material for Water Resources Assessment. ISBN 978-92-63-11095-4

XU C.Y. and SINGH V.P. (2004) Review on Regional Water Resources Assessment Models under Stationary and Changing Climate. *Water Resources Management*. Vol. 18, pp. 591–612. Kluwer Academic Publishers.

Chapter - 3

Geographical Background and Socio-economic Profile

3.1 Introduction

The Upper Tuirial Watershed area, a central part of Mizoram, is geologically formed by a sedimentary rock during the late Jurassic and early tertiary periods (Khullar, 2018). The Physical feature shows structural hills running north-south direction encircling the watershed area. The rugged topography has steep slopes from towards the middle of the watershed area. The watershed's landform is like a leaf with the main Tuirial River flowing at the center. The length of main river Tuirial originates from North Chawilung Hills in the Aizawl District and it flows northward and merges with the Barak River in the Cachar District in Assam, the length of the river within Mizoram is about 117 km the length of the river within the study area is 60.5 Km. The Upper Tuirial Watershed area covers 534 Km^2. The Tuirial River Basin provides an important avenue for livelihood activities for the rural residents from natural forests and shifting cultivation lands.

3.2. Geographical Setting

The upper Tuirial River basin covers 534 Km^2 of land and lies between longitudes 92°42′E–92°52′E and latitudes 23°26′N–23°52′N at an elevation of about

1690 m above MSL at the highest point and about 76 m above MSL at the lowest, in the state of Mizoram, which is basically a rugged mountainous state in India. The state experiences the direct influence of southwest monsoon with an annual average precipitation of about 2500 mm. The onset of monsoon is usually encountered during the early month of May while the months of July-August sustain the wettest months and December-January the driest month of the year. Rainfall and temperature data collected for the period of 2007 to 2016 at the study area gives the average annual rainfall of 2732 mm and, average monthly temperature of 21.24 °C with maximum and minimum temperatures of 15.39 °C and 27.19 °C respectively.

3.3. Physiography and Major Landforms

The physiography of the upper Tuirial Watershed shows a parallel structural hill running north to south direction. The average altitude of the rugged terrain ranges from 1200m – 1400m. The highest point in the southwestern part is located at Hmuifang peak (1634 m) and the northern Durtlang is also located at a height of 1409m above mean sea level. The structural hills are descending towards the northern side of the watershed area as low as 139 meters above mean sea level at Tuirinikai, the northern tip of the catchment boundary. The watershed area is demarcated into the eastern part and western part more or less with equal area by the main Tuirial river. The young structural hills are cut by streams and rivulets that join the main river at right angles from the east and west boundary. Physiographic mapping of the upper Tuirial watershed was carried out by using remote sensing and GIS techniques.

The Physiography of the study area can be divided as under: -

High structural Hills: The high structural hills cover the western side of the watershed boundary expanding at the southern side and at the northwestern part of the watershed area. The highest point of Hmufang Peak in the southwestern part rise above 1600 meter above mean sea level. The ridge line elevations generally vary between 1000-1500m. It covers an area of 113 Km^2. The notable peaks are Hmuifang (1634m), Durtlang and Muthi peak.

Medium structural hills: Hill ranges ranging between 1199m-800m were categorized as Medium structural hills. They cover the eastern part along the watershed boundary and parts of the western side following the high structural hills.

Low Structural Hills: Low structural hills cover the majority area. Sharp rolling hills are Characterized by scarp and spurs. The V-shaped valleys have steep slopes with fast-flowing streams and rivers between them. It covers an area of 260 Km^2, which is 48.68 % of the upper Tuirial watershed area.

Valley Fill and Flood plain: Valley Fill is of fluvial origin. They are formed by erosional work of water characterized by the unconsolidated sediments deposited by river and streams. They are mainly found along the lower course of the river.

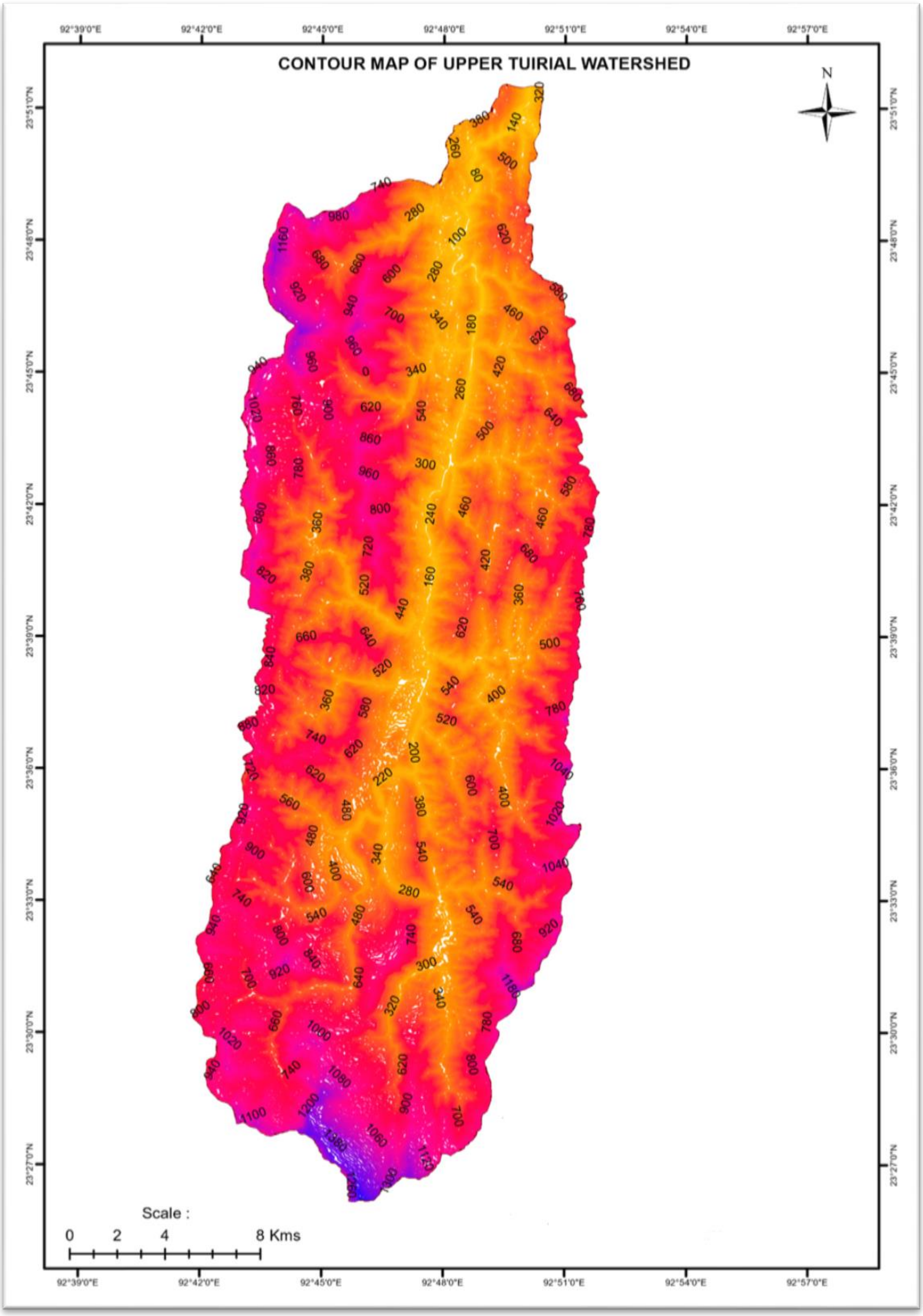

Figure 3.1: Contour map of Upper Tuirial Watershed.

3.4. Soil

Soils are formed by a complex and continuous process that takes place over a long period of time, influenced by different factors. Different regions can have unique soil properties based on variations in climate, parent material, vegetation, topography and time. The soils of the Upper Tuirial watershed are mainly dominated by mountain soil characterized by loamy to loamy skeletal in texture (Figure 3.3). Due to heavy rainfall and steep topography, the soils are leached resulting in high acidity of the soil. They are rich in organic carbon but deficient in potassium and phosphorus, nitrogen and humus content. From the genetic aspect of the soil formation, they are mainly derived from sandstones, shales and siltstone. Water retention of the soil is low.

Soils of the Upper Tuirial Watershed Area can be divided into three soil order viz. Entisols, Inceptisols and Ultisols. Inceptisols is the dominant order (Colney L et al,2013). The soils on the top of the ridge line are mostly shallow and have a thin layer of soil mostly underlain by weathered rock. The series of soil at the western part of the study area is characterized by loamy to fine loamy and belongs to the subgroup Typic owing to a decrease in organic carbon content with depth. Generally, the soils are deep, dark yellowish to dark brown, strongly acidic surfaces. The hillside slopes are well drained with moderate to severe erosion. The soils/pedons series have Cambic horizon and thus were categorized as Inceptisols and Ochrepts suborder. The eastern part of the upper Tuirial Watershed is characterized by loamy skeletal to fine loamy.

The soil series have clay-enriched subsurface horizons, so they are classified under the soil order Ultisols and Udults suborder owing to the udic soil moisture regime. These soils are freely drained soils and have an Ochric epipedon. The Soils are very deep, dark yellowish brown to brownish yellow, strongly acidic with sandy clay loam surface and clay loam to clay sub-surface, well-drained on hillside slopes and hill crest/top, and characterized by moderate to severe erosion along the hill slope.

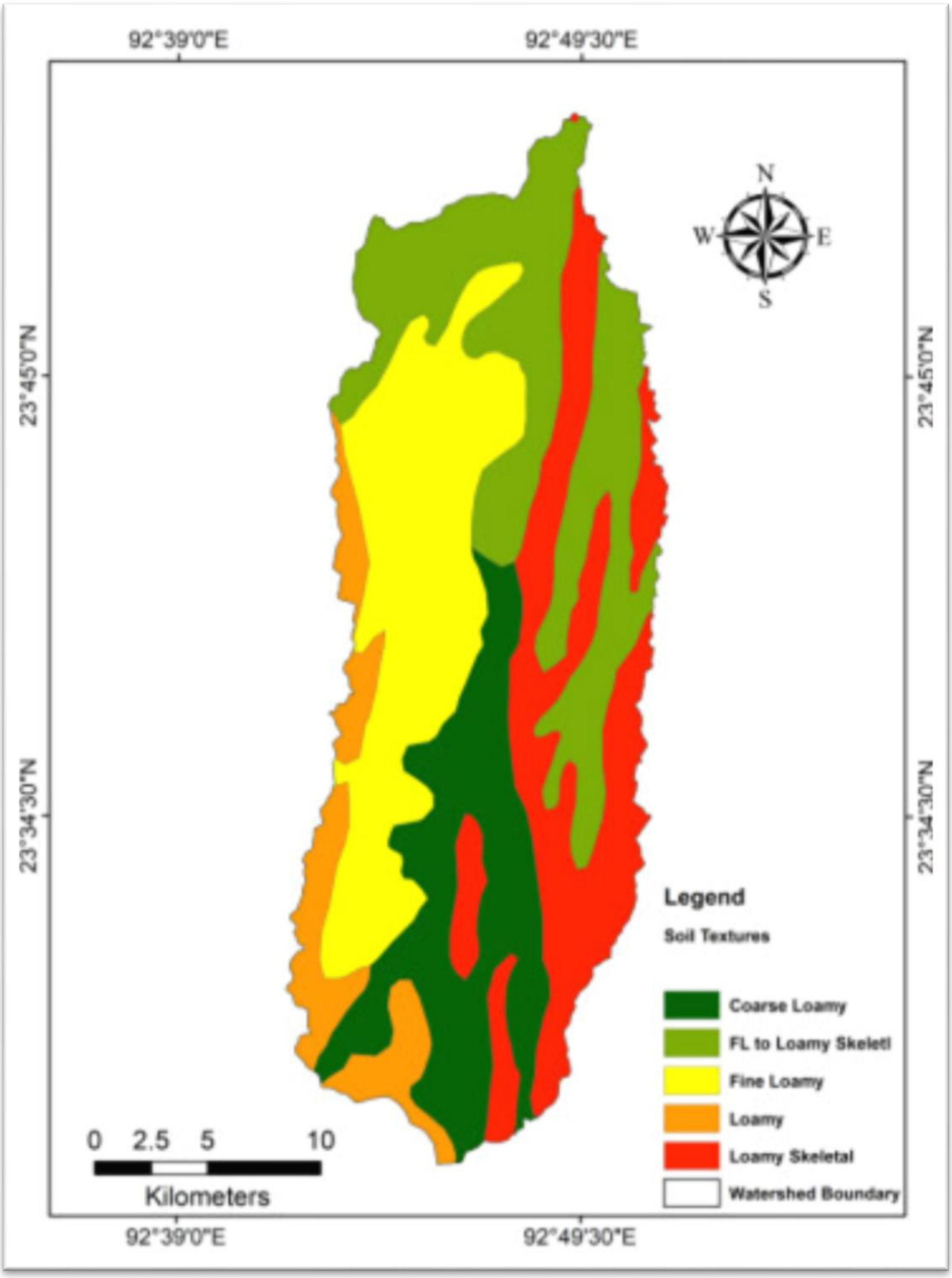

Figure 3.2: Soil texture of Upper Tuirial Watershed.

It can be concluded from the observations that the dominant soil order of the Upper Tuirial Watershed area is ‘Inceptisols’, indicating that the soil is young. Soils are moderately deep to very deep from steep to very steep slopes including hill ridges. However, the area is suitable for agricultural and horticultural cultivation and allied activities such as sericulture and forest plantation, etc. for sustainable management of land resources.

3.5. Vegetation

The location of the study area enjoys a tropical climate with heavy rainfall supported a lush natural vegetation. Tropical Vegetation covers the whole area, forest including open forest and bamboo forest covers more than 79.85% of the area, and scrubland and agricultural land cover 5.33 % and 10.22% respectively.

The natural vegetation of the upper Tuirial Watershed can be classified as under:

Tropical Wet Evergreen;
Semi-Evergreen Forest;
Bamboo Forest and
Scrubland.

3.5.1. Tropical Wet Evergreen Forest

The tropical climate with conducive climatic conditions such as adequate rainfall, moderate temperature, soil and topography favors the luxurious growth of vegetation. The different types of trees found in the area are Albizzia lebeck (Thingri), Artocarpus chama (Tatkawng), Artocarpus heterophyllus (Lamkhuang), Averrhoa carambola (Theiherawt), Bombax ceiba (Phunchawng), Calicarpa arborea (Hnahkiah), Debregeasia velutina(Lehngo), Emblica officinalis(Sunhlu), Gmelina arborea(Thlanvawng), Litsea monopetala(Nauthak), Rhus javanica(Khawmhma), Syzygium cumini(Lenhmui), Tamarindus indica(Tengtere), Tectona grandis(Teak/ Tlawr), Ficus religiosa(Hmawng). Herbs like Ageratum conyzoides(Vailenhlo), Blumea alata(Buar), Bidens Pilosa(Vawkpuithal), Chromolaena odorata(Tlangsam), Rubus birmanicus(Sialinuchhu), Amomum dealbata(Aidu), Chlerodendron colebrookianum(Phuihnam), Clereodendron infortunatum (Phuihnamchhia) are also thriving in the tropical forest areas.

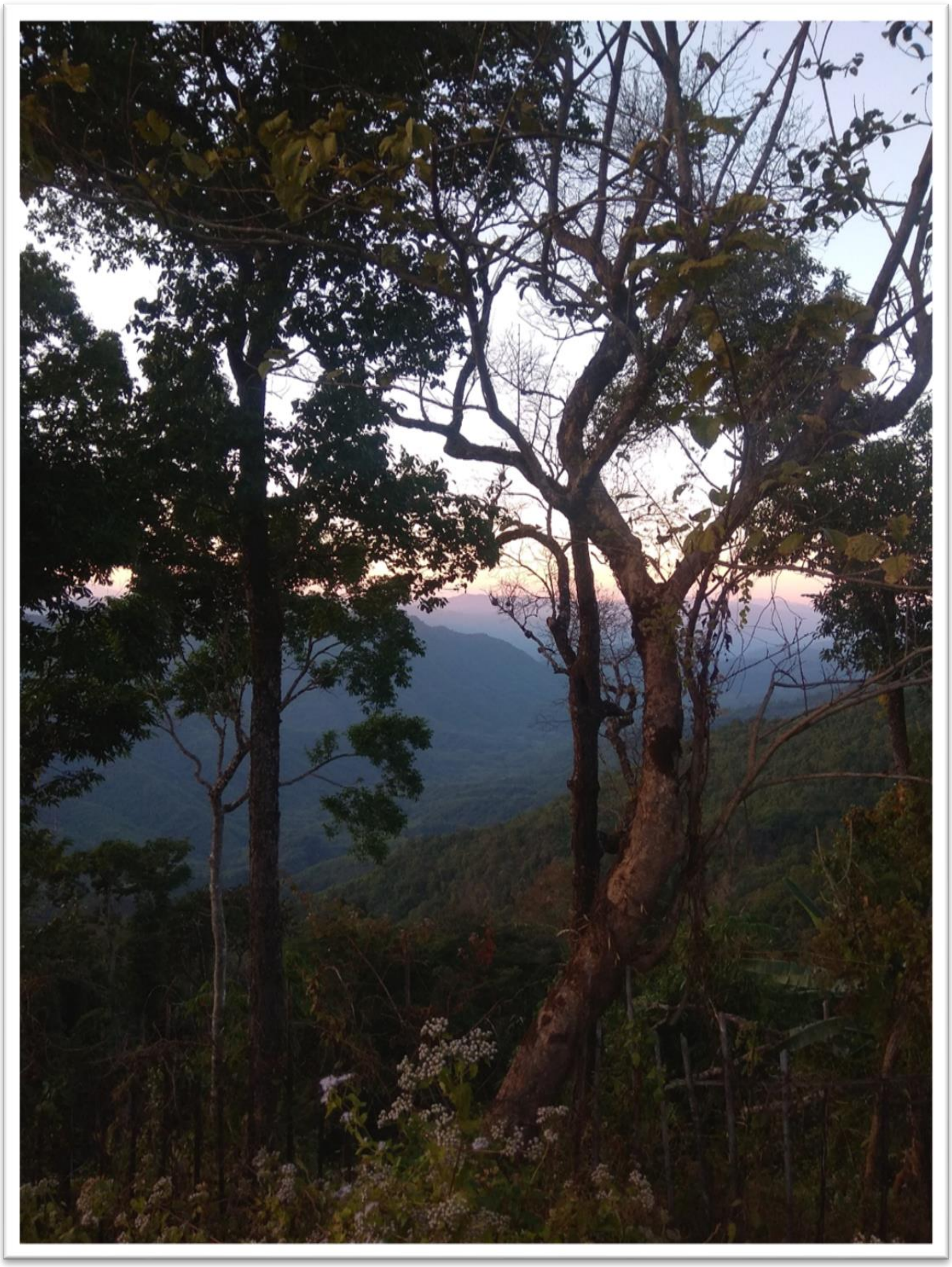

Plate 3.1: Vegetation of Upper Tuirial Watershed. Source: Author.

3.5.2. Semi-Evergreen Forest

The semi-evergreen forest is mixed with different types of vegetation. Plantation of trees like teak, and rubber is also practiced in the area. Climbers and epiphytes like Mikania micrantha (Japanhlo), Mucuna exserta (Hruiduk), Entada pursaetha(Kawihrui),

3.5.3. Bamboo Forest

The bamboo forest dominated the lowland areas, it covers 186.98 Km2 which is more than 40% of the forest area. Different types of bamboo are extensively thrive along the river banks and slope, Dendrocalamus longispathus(Rawnal), Melocana baccifera(Mautak), are commonly found. Along with bamboo, different types of trees and climbers are also growing in these areas.

3.5.4. Scrubland.

Scrublands cover the study area in patches here and there, it covers approximately 5.33% of the total area. Grasses like Saccharum longisetosum(Luang), Imperata cylindrica(Di) and Thysandaena maxima(Hmunphiah) with common grasses and climbers are commonly found.

Table 3.1: Land use/land cover of the study area. Source: MIRSAC.

Sl.No.	Class	Description	Area (Km^2)	% to the total area
1.	Forest	Forest-Evergreen/Semi Evergreen-Dense/Closed	147.08	27.49
2.	Open forest	Forest-Forest Plantation	93.23	17.42
3.	Agricultural Land	Agricultural Land-Kharif crop	54.70	10.22
4.	Bamboo	Forest-Tree Clad Area-Open	186.98	34.94
5.	Waterbody	Waterbodies-Reservoir/Tank-Permanent	1.43	0.26
6.	Scrubland	Wastelands-Scrubland-Dense/Closed	28.52	5.33
7.	Settlement	Built up-Compact	23.36	4.36

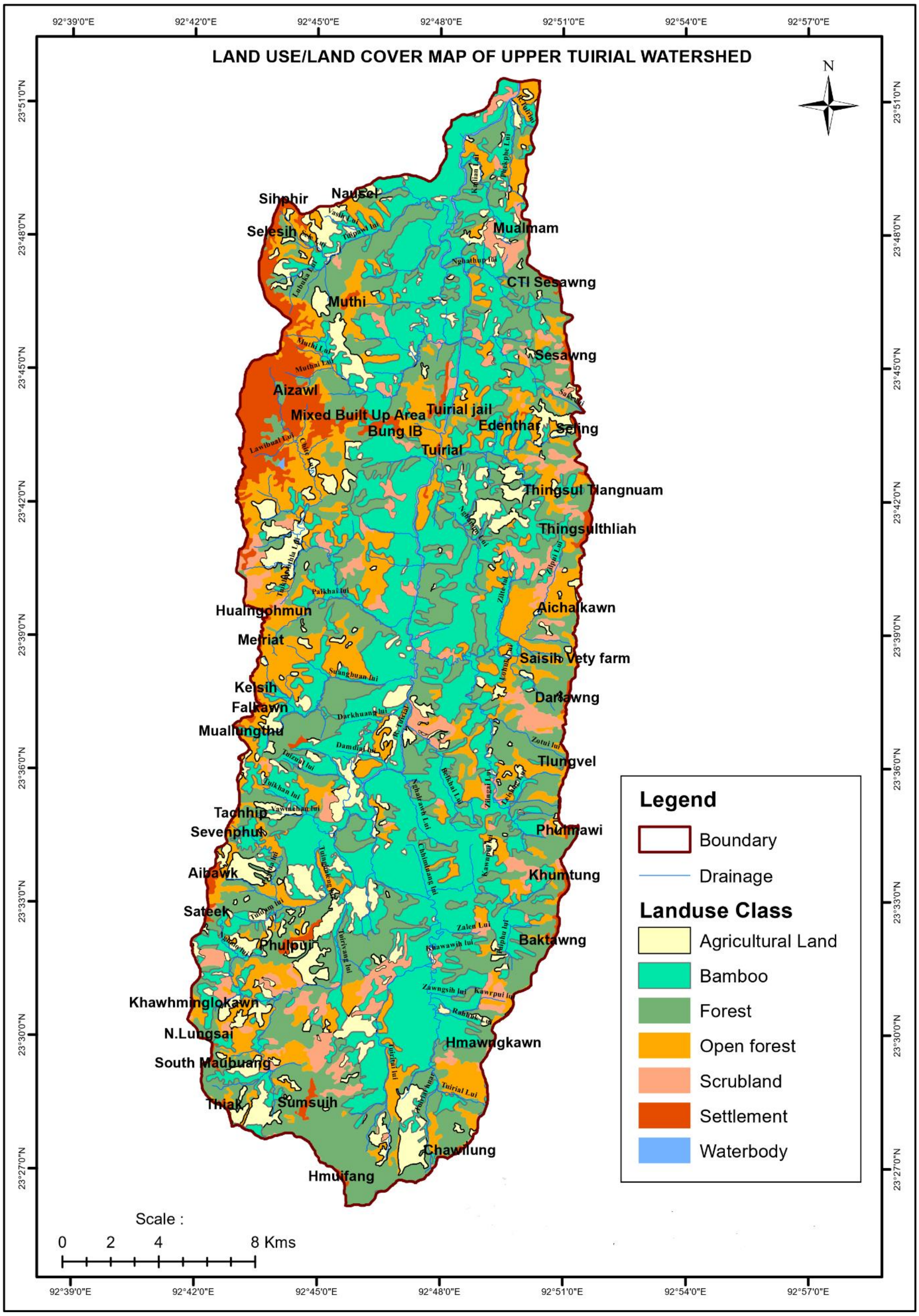

Figure 3.3: Land Use/ Land Cover Map of Upper Tuirial Watershed.

3.6. Geological Features

The geology of the Upper Tuirial Watershed area is primarily characterized by a majority of sedimentary rocks that were deposited during different geological periods. It is related to the tectonic activity of Indian and Burmese Plates which resulted in the folded structure of the Arakan Yoma and Tripura ranges, contributing to the upliftment and folding of rocks in the area forming ranges running north-south direction. It is generally referred to as the Indo-Burmese fold-thrust belt, the prominent feature is the northwest-southeast trending longitudinal plunging anticlines and synclines.

To the north, there are anticlines that were scored by exposure of the Middle Bhuban Formation and flanked by synclines underlain by either the Middle Bhuban Formation or the Upper Bhuban Formation. The major succession of the anticlines is also present at the side of Aibawk and Seling, it has a thickness of 1200m – 2400m of Bhuban Formation.

The major outcrop of stratigraphic succession comprises of repetitive succession of sedimentary rocks of the Bokabil formation of the Surma group (lower to middle Miocene) and Tipam formation (late Miocene to early Pliocene). The Bokabil Formation is dominantly argillaceous and arenaceous in nature and represented by the intraformational conglomerate, grey and brown colored shale, subordinate siltstone and calcareous sandstone. The Tipam group mostly comprises loose, friable, medium-grained sandstone. The region consists of shale and sandstone of Tertiary age, the major rocks comprise of sandstone, shale and limestone formations that were formed during the early Jurassic to early tertiary period.

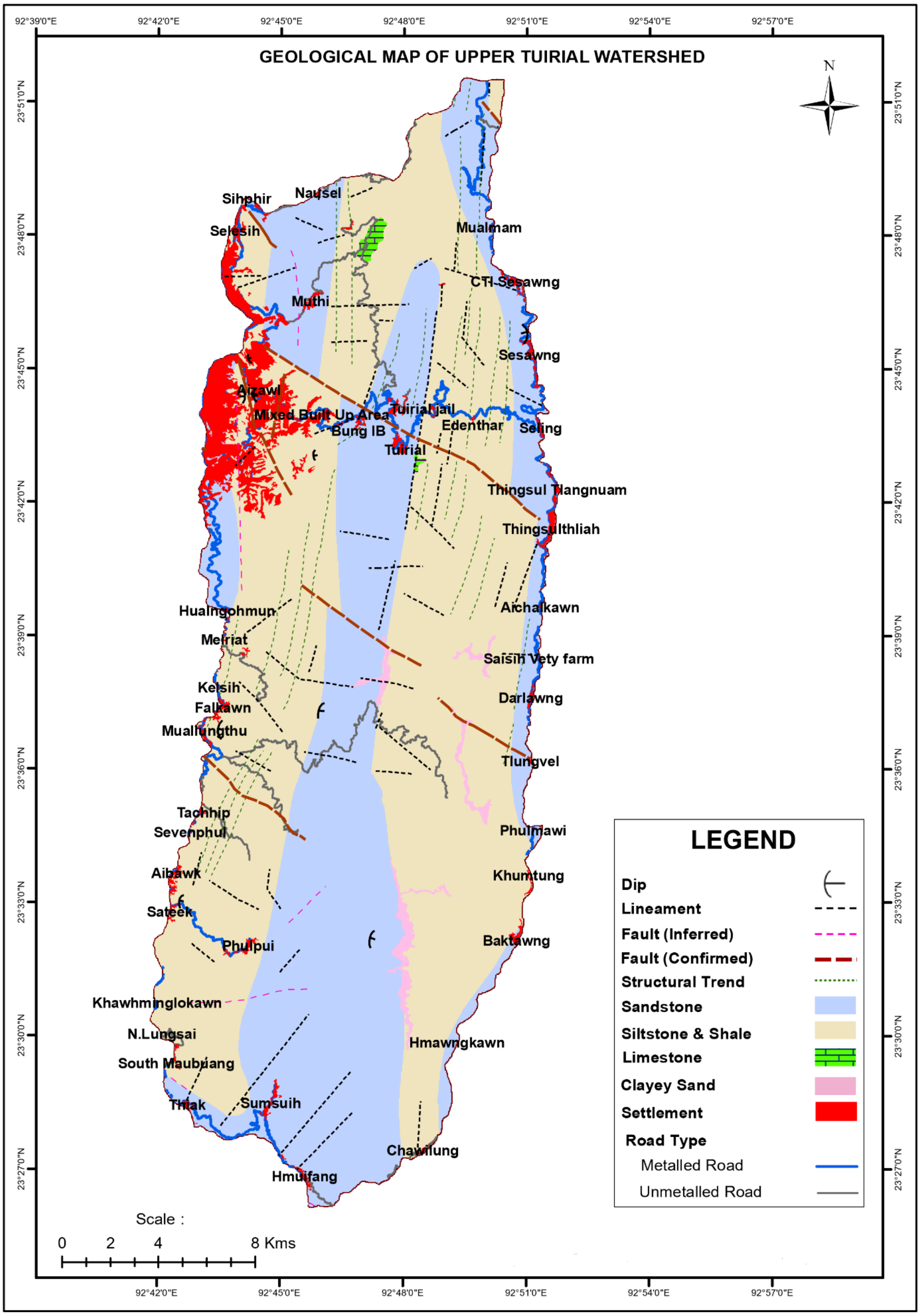

Figure 3.4: Geological Map of Upper Tuirial Watershed.

3.7. Drainage System

The systems and patterns generated by rivulets, streams, rivers, and lakes are referred to as drainage systems. It also refers to a region's river system. Under the influence of a land's topography and climate, drainage systems have different patterns and types. A drainage pattern is the appearance and shape of rivers developed over time, through erosion dominated by hard or soft rocks and the land's gradient. A single river system forms a river basin, which is the catchment of great rivers with a natural upland boundary dividing two drainage basins.

The drainage system of the upper Tuirial River exhibits a dendritic drainage pattern, a structure that has a shape similar to tree roots. The river channels follow the gradient slope of the topography and join bigger streams or river at sharp angles. The notable rivers on the eastern side of the catchment area are Nghathup Lui, Sakei Lui, Saibual Lui, Ngharum Lui, Zilpui Lui, Belkhai Lui, Nghalrawh Lui, Chhimluang Lui and khawawih Lui. Rivers at the western side are Tuipawl Lui, Muthi Lui, Chite Lui, Paikhai Lui, Suanghuan Lui, Damdiai Lui, Tuizual Lui, Tuirivang Lui and Tuiritai Lui are notable perennial rivers.

Table 3.2: Selected River Profile of Upper Tuirial Watershed. Source: Author.

Sl. No.	Name of River	Length (in KM.)	Direction of Flow	Location in Watershed	Water Quality	Annual Water Discharge (cfs)
1	Upper Tuirial	60.5	North	Center	potable	1216.6
2.	Saibual Lui	6.66	West	East	potable	63.2
3.	Ngharum Lui	6.98	West-North	East	potable	166.21
4.	Zilpui Lui	10	East	East	potable	69.8
5.	Tuiritai Lui	10.9	North	West	potable	143.5
6.	Tuirivang Lui	18.1	North	West	potable	195.7
7.	Suanghuan Lui	8.5	East	West	potable	55.45
8.	Chite Lui	18.2	South-East	West	moderate	251.7
9.	Muthi Lui	11.5	South-East	West	potable	149.7

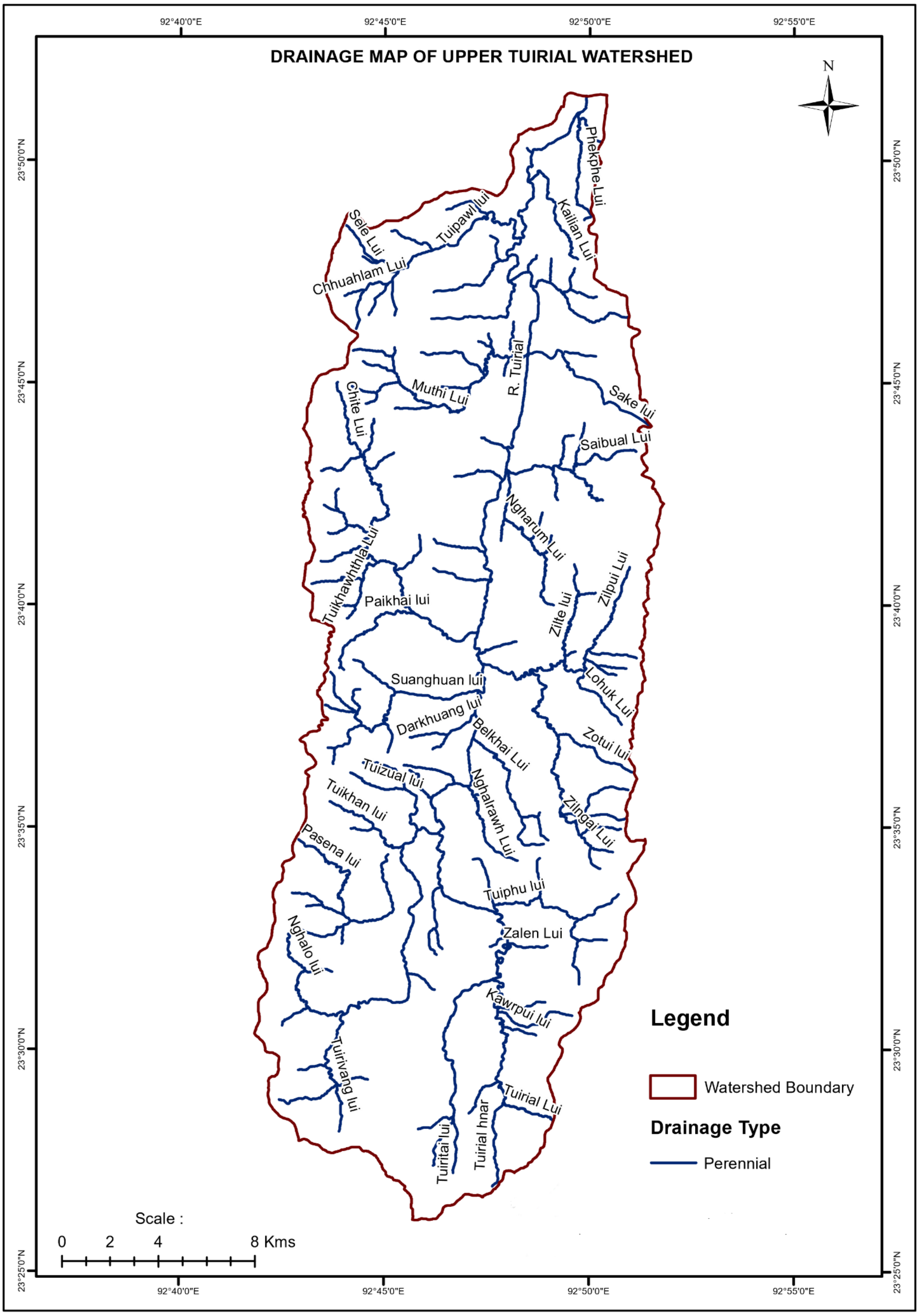

Figure 3.5: Drainage Map of Upper Tuirial Watershed.

Plate 3.2: Upper Tuirial River confluence with Belkhai Lui. Source: Author

3.8. Climatic Conditions

Tropic of Cancer passes through the study area on the southern side, indicating the tropical climatic type of the area. Indian Monsoon climate is also experienced with heavy rainfall during summer, covering more than 8 months of rainfall, and dry season during winter. The study area shows a pleasant and favorable climatic condition in terms of temperature and rainfall.

3.8.1. Temperature

The temperature in the region is quite moderate and does not experience any extreme variations both in summer as well as in winter. Winter sets in from around the end of October and lasts till the end of February. The minimum winter temperature varies between 8° C to 24° C. Summer arrives in the middle of May with the maximum summer temperature varying between 18° C to 32° C. The winter season is characterized by cold weather, occasional thunderstorms, and frequent fog in the morning. During the summer season, the temperature is high with occasional thunderstorms and a clear sky in the morning times. In the monsoon season, the weather is cloudy and humid with low-speed wind which blows from different directions.

Table 3.3: Monthly Average Temperature, Aizawl, 2022. Source: State Meteorological Station, Directorate of Science and Technology, Aizawl, Mizoram

Months	Average Minimum Temperature in ^{o}C	Average Maximum Temperature in ^{o}C	Months	Average Minimum Temperature in ^{o}C	Average Maximum Temperature in ^{o}C
January	13.1	19.2	July	21.3	27.2
February	13.2	20.1	August	21.2	27.1
March	19.3	26.8	September	21.4	26.7
April	20	27.9	October	20.4	25.9
May	20.3	26.8	November	18.5	24.4
June	20.3	26.6	December	15.3	21

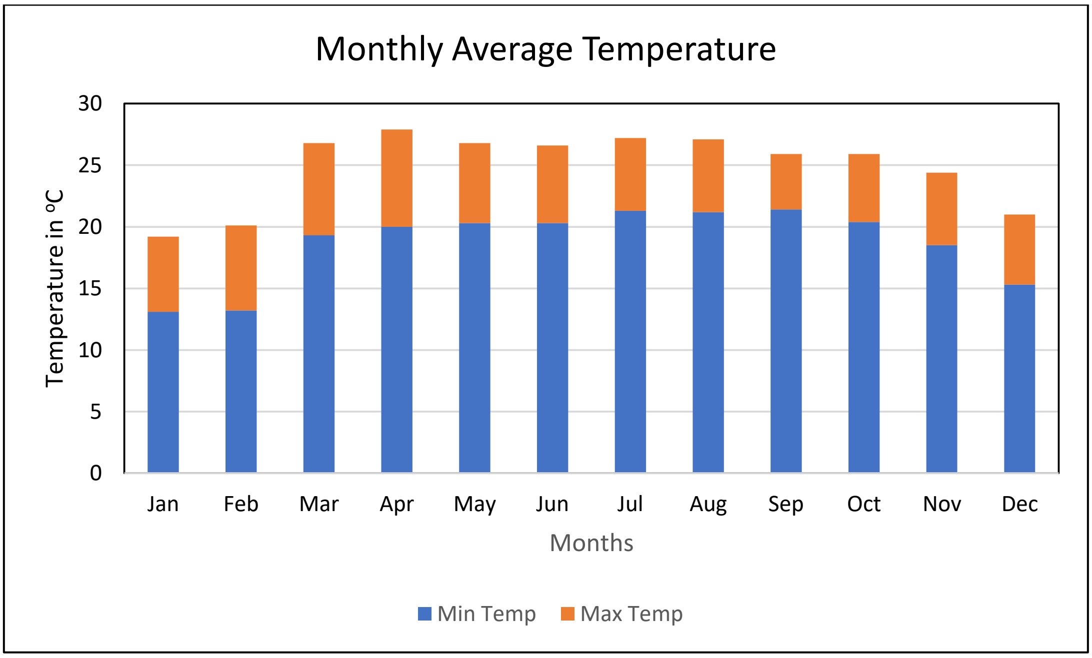

Figure 3.6: Monthly Average Temperature, Aizawl, 2022. Source: State Meteorological Station, Directorate of Science and Technology, Aizawl, Mizoram

3.8.2. Rainfall

The study area falls under the direct influence of the southwest monsoon and receives an adequate amount of rainfall. The frequent rains throughout the year however serve to moderate temperature. In the monsoon season, the weather is cloudy and humid with low-speed wind which blows from different directions. Rainfall is heavy in this season and the temperature starts falling with the onset of southwest monsoon during the beginning of June. In post-monsoon season, the rainfall gets reduced drastically followed by a clear sky and a decrease in temperature and morning fog. The average annual rainfall is 2246.3mm.

Table 3.4: Monthly Total Rainfall of Aizawl, 2022. Source: State Meteorological Station, Directorate of Science and Technology, Aizawl, Mizoram

Months	Total Rainfall in mm		Months	Total Rainfall in mm
January	23.9		July	460.2
February	17.2		August	277.8
March	53.3		September	195
April	73.2		October	211.1
May	327.8		November	2
June	355.3		December	18.3

The above Table 3.4 shows the monthly annual rainfall during 2022, which shows the rainfall pattern of the study area. Heavy rainfall is experienced during the monsoon season, usually covering the months of May to October. During these six months, the average monthly rainfall is calculated at 304.5 mm. The average monthly rainfall for the remaining months is estimated at 31.3mm. Practically there are no months without precipitation, but in reality, the uneven distribution of rainfall resulted in more than three months of significantly no rainfall in most parts of the area.

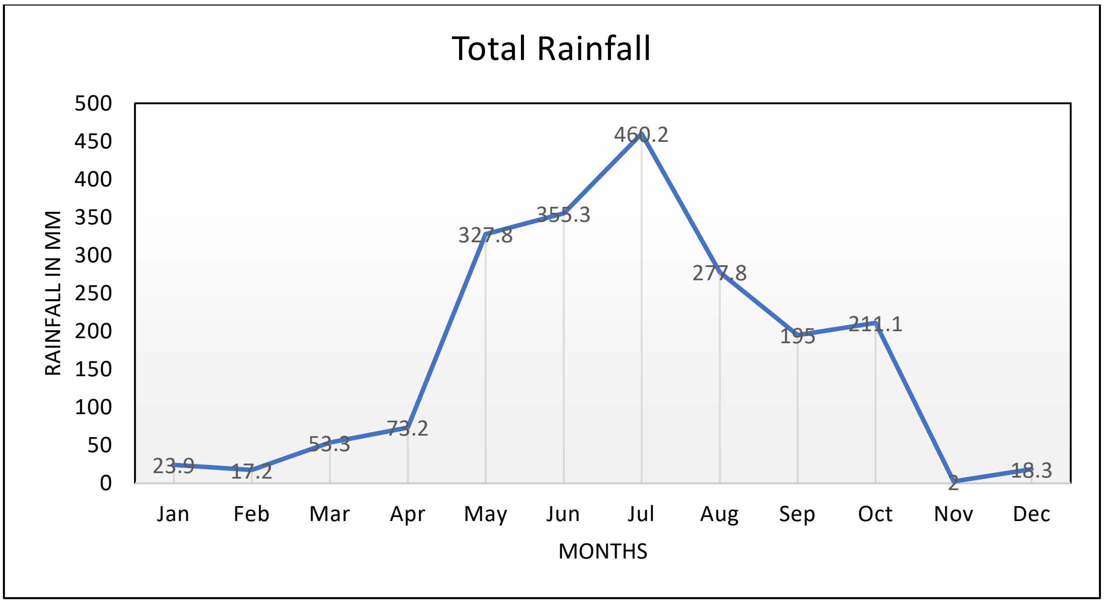

Figure 3.7: Monthly Total Rainfall of Aizawl, 2022. Source: State Meteorological Station, Directorate of Science and Technology, Aizawl, Mizoram

3.8.3 Relative Humidity

Humidity refers to the ratio of the amount of water vapor present in the air. It is also expressed in relative humidity and absolute humidity. The relative humidity is the amount of atmospheric moisture or water vapour present, which is relative to the amount of water that would be present if the air were saturated. It is expressed in percent. It is described as the difference between the maximum moisture content that the atmosphere can withstand at a given temperature and the quantity of moisture in the atmosphere at that temperature. The relative humidity is 100% while it is raining. On the other hand, relative humidity also affects atmospheric visibility and pressure, which may have adverse effects on living organisms. The relationship between temperature and humidity is inversely proportional. The air will become dryer as the temperature rises because the relative humidity will drop. Similarly, if the temperature drops, the air will become wet and the relative humidity will rise.

Absolute humidity in a particular volume of air is determined by the water vapour content. The moisture content in grams or kilograms per cubic meter of the provided air is used to express the absolute humidity.

The study area's relative humidity (Table 3.5) in the dry season is 60 –70 % and in the monsoon period is about 90%. During the southwest monsoon, February to April is comparatively dry when humidity is between 50 –70 %. The recommended relative humidity by The Health and Safety Executive (Britain's national regulator for workplace health and safety) is 40 to 70% for indoors. Absolute

Table 3.5: Monthly Average Humidity, Aizawl, 2022. Source: State Meteorological Station, Directorate of Science and Technology, Aizawl, Mizoram

Months	Average Minimum Humidity in %	Average Maximum Humidity in %		Months	Average Minimum Humidity in %	Average Maximum Humidity in %
January	57.6	71.8		July	68.1	85.3
February	46.3	61.7		August	63.2	83.9
March	45.9	58.5		September	64.9	87.1
April	51.2	65.6		October	62.2	82.4
May	67.4	82.9		November	58.8	73.2
June	70.5	87.1		December	55	68.6

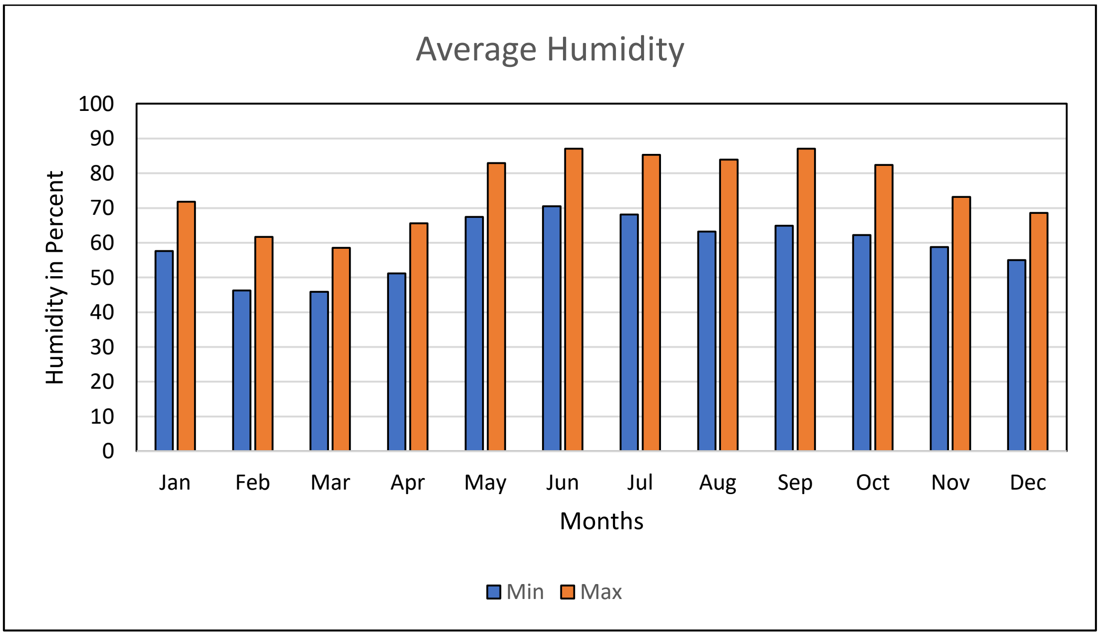

Figure 3.8: Monthly Average Humidity of Aizawl, 2022. Source: State Meteorological Station, Directorate of Science and Technology, Aizawl, Mizoram

3.9. Socio-economic Factors

The traditional Mizo society of the upper Tuirial Watershed is agrarian. The development initiatives within the society are a slow pace advancement. Assistance and development Programme from the government is expected to bring fruitful development in terms of occupation and living standard of the society. Socio-economic factors include occupation, education, income, wealth, and other indicators of living standard of the society. Socio-economics certainly exerts a profound impact on the lives of individuals, and their socio-economic status may strongly influence their future social development.

Table 3.6: Household Survey of the study area. Source: Author.

Sl.No	Village	Total Household	Surveyed Household	% of Surveyed Household	Sex ratio
1	Seling	547	140	25.5	1022.22
2.	Thingsulthliah	805	200	24.8	960.62
3.	Phulmawi	70	30	42.8	917.8
4.	Khumtung	263	80	30.4	1040
5.	Baktawng	686	170	24.7	992.18
6.	Chawilung	120	50	41.6	965.3
7.	Lamchhip	180	50	27.7	981.13
8.	Kelsih	220	60	27.2	970.87
9.	Aibawk	410	100	24.3	976.19
10.	Thiak	209	60	28.7	986.05
11.	Hualnghmun	206	60	29.1	977.71
12.	Muthi	224	60	26.7	980.48
13.	Sesawng	847	200	23.6	981.32
	TOTAL	**4787**	**1260**	**26.32**	

3.9.1. Sex Composition

Sex composition is a ratio between the observed average annual increment of an age group of the population during a certain period and the average population of that same age group in that period. Demographic analysis is crucial to analyze whole societies or just groups of people to hand out population projections of a society. Some examples of demographics are age, sex, education, nationality, ethnicity, or religion, to name a few. The sex ratio of Mizoram is 976 females for 1000 males, which is below the national average of 940 as latest census. The field observation shows that Seling and Khumtung have the highest sex ratio with 1022 and 1040 respectively. Phulmawi has the lowest sex ratio of 917 only. Other surveyed 10 villages range between 960 to 990. The average sex ratio within the study village is 980.

Table 3.7: Population of the selected village of the study area. Source: Author.

Sl.No	Village	Male	Female	Total	Sex ratio
1	Seling	1350	1380	2730	1022.22
2.	Thingsulthliah	2032	1952	3984	960.62
3.	Phulmawi	146	134	280	917.8
4.	Khumtung	850	884	1694	1040
5.	Baktawng	1792	1778	3570	992.18
6.	Chawilung	346	334	680	965.3
7.	Lamchhip	530	520	1050	981.13
8.	Kelsih	515	500	1015	970.87
9.	Aibawk	1050	1025	2075	976.19
10.	Thiak	502	495	997	986.05
11.	Hualnghmun	359	351	710	977.71
12.	Muthi	615	603	1218	980.48
13.	Sesawng	2035	1997	4032	981.32
	TOTAL	**12,122**	**11,953**	**24,035**	980

3.9.2. Culture and Religions

Villages located at the Upper Tuirial Watershed Area are inhabited by Mizo tribal communities that have inhabited the hilly terrains for several decades. The major tribes and sub-tribes that are found in the study area include Pachuau, Ralte, Jahau, Duhlian Pakhup, Paite, Thangur, Khuangli, Sukte, Fanai, Pawi, and other sub-tribes in small numbers. The Mizo tribal communities are of the Mongoloid racial stock, with saffron to yellow-brown skin, short flat nose, medium tall to medium short stature, well-built features, and eyes with common medial epicanthic fold (Hussain M. et al, 1994). The people of Mizoram are known to be skillful in various handicrafts. The inhabitants generally follow Christianity as a religion.

3.9.3. Economy

Agriculture, like many other regions of Mizoram, is the dominant occupation of the study area. According to the household survey taken from 13 (thirteen) selected villages of the study area, approximately 68 % of the population is engaged in agriculture and allied activities. Under agricultural practices shifting agriculture, horticulture, and terrace cultivation along the river whenever possible is common among the local population. Due to excessive stress on reserved forests, the jhum cycle usually reduces to 5 years following for regeneration of the soil. High soil erosion and the short cycle of jhum regeneration resulted in low productivity of farms. Rice, ginger, and vegetables are mainly grown crops.

The major crops cultivated were bananas, dragon fruits, rubber plantation, arecanut, papaya, and leafy vegetables. At the periphery of Aizawl, Hualngohmun, Melthum, Melriat, and adjacent villages practice the domestication of animals. Piggery and poultry farming are also practiced in areas of the western part of the watershed boundary. Plantation crops like banana, papaya, stink bean, sugarcane, arecanut, betel leaf, oil palm, and rubber are also grown. The agro-climatic conditions of the study area having semi-tropical climates are conducive to a wide variety of crops. It has well-distributed rainfall of 1900 mm to 3000 mm (75 to 118 inches) spread over eight to ten months in the year.

Hotels and Restaurants are common on the western side of the catchment area, hmuifang tourist resorts and muallungthu restaurants are very popular in the study area. Seling is also located in the highway junction many people engage in restaurants and grocery shops.

Table 3.8: Occupation of Population in the study area. Source: Author.

Sl.No	Village	Primary	Tertiary	Others	Literacy Rate
1	Seling	50	30	20	95.68
2.	Thingsulthliah	65	28	7	96.67
3.	Phulmawi	80	10	10	85.7
4.	Khumtung	70	20	10	98.7
5.	Baktawng	60	32	8	98.2
6.	Chawilung	75	10	15	98.1
7.	Lamchhip	75	15	10	87.89
8.	Kelsih	70	24	6	99.5
9.	Aibawk	46	48	6	98.1
10.	Thiak	75	18	7	98.4
11.	Hualngohmun	65	26	9	96.77
12.	Muthi	75	20	5	92.9
13.	Sesawng	60	40	10	94.8

The government of Mizoram has assisted and encouraged an array of small-scale industries at the village level. With financial assistance from different sources like PMKSY, KVI, Animal Husbandry, etc. people are starting businesses at different levels uplifting the living standard of the area, thereby reducing poverty in action. Such industries include sericulture (silk production), handloom and handicraft workshops, sawmills and furniture manufacturing, oil refining, and grain milling processing. Major manufacturing activities, however, have not been strongly established. The population of Baktawng is engaged in the furniture industry to a large extent.

The literacy rate in Mizoram is 91.33 %, out of that male literacy stands at 93.35% while female literacy is at 89.27%. The average literacy rate of study villages is 95.4 %, which is above average for the state except for Phulmawi (85.7 %) and Lamchhip (87.8%).

3.10. Specification of the Study Village

There are 29 villages in the study area, except Phulpui, villages are located on the watershed boundary ridge line. The villages at the western side of the catchment areas are Nausel, Durtlang, Muthi, Tuikhurhlu, Tuirial, Melthum, Hualngohmun, Melriat, Kelsih, Muallungthu, Tachhip, Aibawk, Sateek, Phulpui, Maubuang, Thiak, Sumsuih, Lamchhip and Chawilung. At the eastern side Mualmam, Sesawng, Seling, Tlangnuam, Thingsulthliah, Darlawng, Tlungvel, Phulmawi, Khumtung and Baktawng are located. Out of 29 villages,13 villages were selected for household survey. Randomly selecting seven villages from the western side and six villages from eastern catchment areas. Even though the capital city Aizawl is located in the northwestern catchment area, consideration is not given due to different technical problems and the feasibility of tackling the objective of the study. However, climatic data is based on the Meteorological Station of Aizawl.

Table 3.9: Geographical Coordinates of the selected village of the study area. Source: Author.

Sl.No	Village	Latitude	Longitude	Elevation
1	Seling	23^{o}42’56.93” N	92^{o}51’29.27” E	907 m
2.	Thingsul	23^{o}41’12.95” N	92^{o}51’34.22” E	949 m
3.	Phulmawi	23^{o}34’36.47” N	92^{o}51’08.98” E	1098 m
4.	Khumtung	23^{o}33’18.19” N	92^{o}51’05.89” E	1021 m
5.	Baktawng	23^{o}32’07.11” N	92^{o}50’46.66” E	1219 m
6.	Chawilung	23^{o}27’28.03” N	92^{o}48’31.72” E	1090 m
7.	Lamchhip	23^{o}26’11.12” N	92^{o}46’43.59” E	1389 m
8.	Kelsih	23^{o}38’02.25” N	92^{o}43’20.17” E	911 m
9.	Aibawk	23^{o}33’29.06” N	92^{o}42’19.14” E	839 m
10.	Thiak	23^{o}28’02.75” N	92^{o}42’51.50” E	1206 m
11.	Hualnghmun	23^{o}39’30.97” N	92^{o}43’38.90” E	904 m

12.	Muthi	23°46’31.03” N	92°45’42.30” E	1153 m
13.	Sesawng	23°45’14.64” N	92°51’07.43” E	840 m

3.11. Conclusion

The physical feature of the upper Tuirial watershed is sharply demarcated and encircled by young folded structural hills with an average elevation of 1200m. The aerial view of the study area looks like a leaf, with the bud at the northern tip of the watershed boundary. It is a part Purvanchal Hills formed from the compressing of sedimentary rock during the tertiary period. The geological formation shows the action of compression due to tectonic movements, with numerous subduction and ongoing continental collisions. The folded hilly or mountainous North South belts, with perpendicular faults, comprise sediments of the Surma (Middle Bhuban Formation), Barail and Tipam groups. A 560m thick rock succession of the Middle Bhuban type exposed between Bawngkawn and Durtlang shows 7 normal and 7 reverse magneto strata (North and South pole reversals) showing its age to be around 20 Million years old. Typical soils are sandy loam, and clay loam that have been heavily leached due to the high slopes leaving it porous and lacking in minerals or humus.

The study area enjoys a monsoon-type climate with heavy rainfall during summer and lesser rainfall or no rainfall during winter. The summer season starts in April when the area experiences a break in the monsoon and lasts till September. The majority of the population depends on agriculture. With the efforts of the government, many agricultural families changed their occupation to secondary or to subsistence farming and animal husbandry. The upper Tuirial Watershed shows the diverse resource potential of the area. the high annual rainfall encourages development in agriculture and supports to development of forest-based industries and other agriculturally based small-scale and medium-scale industries.

References

Directorate of Economics and Statistics Mizoram (2020). Statistical Handbook of Mizoram 2020.

Government of India, Ministry of MSME. (2014) Brief Industrial Profile of Aizawl District (Mizoram). Br.MSME- Development Institute (Ministry of MSME, Govt. of India), Aizawl.

Hauhnar M., Lalnunmawia J., Dawngliana O.MS., (2021). Geochemistry of Barail sandstone in Champhai, Mizoram: Implications on provenance and weathering history. *Journal of Earth System Science.* (2021) 130:27 pp. 1-19.

Hussain M. (1994). Human Geography, Rawat Publication. ISBN 81-7033-235-9.

Jha L.K.(1997). Natural Resource Management Volume-I, Mizoram. A.P.H. Publishing Corporation. ISBN81-7024-781-0

Khullar D.R. (2018). India- A comprehensive Geography. Kalyani Publication. ISBN 13-978-9327291483

Lokho K., Saxena R.K., Ruju D.S.N. and Kumar A. (2016). Middle Miocene calcareous nannofossils from the Upper Bhuban Formation of Mizoram, Indo-Burma Range. *Micropaleontology*. Vol. 62, (5) , pp. 341-352.

Singh O.P., S.K. De S.K. and Cajee L. (2016) State of Environment Report of Mizoram 2016. Department of Environment, Forests and Climate Change Government of Mizoram.

Soil & Water Conservation Department, Mizoram (2010). Detailed project report under IWDP Aizawl XI-XVI.

Tiwari P., Jauhri A.K., (February, 2014) Miocene Paleobiology of Mizoram: Present Status and Future Prospects. *Special Publication of the Paleontological Society of India*. No. 5; ISBN: 978-81-926033-2-2; pp. 189-204

Tiwari R.P., Rajkonwar C., Lalchawimawii, Lalnuntluanga P., Malsawma J., Ralte V.Z., Patel S.J. (2011). Trace fossils from Bhuban Formation, Surma Group (Lower to Middle Miocene) of Mizoram India and their palaeo-environmental significance. *Journal of Earth System Science.* (December, 2011) 120, No. 6, pp. 1127–1143.

Zoological Survey of India (2007). Fauna of Mizoram, *State Fauna Series - 14*: 1-691.

Chapter - 4

Potential of Water Resources

4.1. Introduction

Water is a potential source for many of the living beings who need water to live their life. Uses of water can be mentioned in many ways, which include agricultural, industrial, household, recreational, and environmental activities. From the perspective of the hydrological cycle, the availability of water can be calculated from the amount of water that can be utilized/stored after provisions have been made for evapotranspiration, infiltration, and overland flow (Dingman, 2015). The challenge of accurately estimating the amount of water that enters the catchment area, passes through and leaves the watershed area as well as the amount of water available for human use can be complicated. The management of water resources and calculation of water potential can be varied greatly since the individual components have complicated diverse magnitudes (Junati et al., 2021). Resources that are present in a particular region with uncountable quantity and quality to be utilized in the future are known as potential resources. The potential resources be utilized by creating awareness about the resources to the local people and innovating new skills and smart ideas. The concept of water availability is, apart from other indicators, distinguished between blue water reserves that are directly available and consumable by people, and green water reserves that are only available for plants and vegetation before getting into the air. (Falkenmark, 2006; Schuol et al., 2008; Menzel & Matovelle, 2010).

At the river basin level, the factors that are considered for the estimation of water availability include climate-related variables, soil topography, types of vegetation, and geological characteristics. The different methods of calculating water availability proposed by scholars range from the principle of hydrologic water balance (WB), Soil and Water Assessment Tool (SWAT), hydrological models such as Mock, Nreca, ad Rainrun, and long-term discharge data and runoff estimation using SCSCN method to estimate water availability. The utilizable surface water potential of India is estimated at 1869 cubic km. Out of this, the Central Water Commission estimates that only 690 cubic km, (which is about 36% of the total) is utilizable through the construction of structures. The reason for this wide difference is due to severe limitations posed by Physiography, topography, inter-state issues, and the present state of technology to harness water resources economically.

Potential of water availability estimation, from the upper Tuirial river basin area is needed to track river flow changes, as vital information in meeting the growing clean water needs of the settlements as well as regional spatial planning in general Tapping perennial springs and rainwater harvesting would remain the main source of domestic water supply in the major part of the upper Tuirial watershed area.

4.2 Potential Water Resources

A simulation model of rainfall data, discharge observation, spring source, water vendor, government supply as well as underground water reserves, is presented, which tries to estimate the potential surface runoff under physical, structural organizational, and institutional constraints (Junati et al,2021; Kavaritis C.A., 2002; K. Palanisami,2008).

4.2.1. Rainwater

Mizoram comes under the direct influence of the South-West Monsoon, as such it generally receives an adequate amount of rainfall. The rainy season (summer monsoon) generally starts from the month of April, it then rains heavily from May to September and lasts till late October. Heavy rainfall is experienced during summer and moderate rainfall is received more than half of the year. The Average Annual Rainfall for a period of 22 years i.e., from 2000 to 2022 is 2022.7 mm. While the annual rainfall in the year 2022 alone in the study region is recorded as 2015.1 mm. Which is more than two-fold of the globally average annual precipitation of 810mm. As a general rule in meteorology and weather forecasting, 1 mm (0.03 in) of precipitation equals one liter (0.21 gallons) of water per 1 square meter (10.7 foot^2) of area. The amount of precipitation is measured over a certain period of time, for example, per hour, day, a few days, a week, a month, or a year. The average rainfall in India is 118 cm / 1170 mm/ 46 inches according to annual data from the Meteorological Department. Thus, in the study area, every 1m2 catchment area receives as much as more than 2000 Liters of water annually. The record of the State Meteorological Station, Directorate of Science and Technology, Aizawl, Mizoram shows the fluctuation of annual rainfall as shown in Table 4.1.

Table 4.1: Annual Rainfall, Aizawl, 2000-2022. Source: State Meteorological Station, Directorate of Science and Technology, Aizawl, Mizoram

Year	**Annual Rainfall in mm**		**Year**	**Annual Rainfall in mm**
2000	1785.5		2012	2543.1
2001	2360.5		2013	1920.8
2002	1885.5		2014	1790.6
2003	2184.6		2015	2412.3
2004	1797.5		2016	2267.3
2005	1872.8		2017	2686.7
2006	1598.4		2018	1749
2007	2535.3		2019	1709.8
2008	1547.7		2020	1741.9
2009	1639.9		2021	1917.6
2010	2650.8		2022	2015.1
2011	1909.4		**Total Average**	**2022.7**

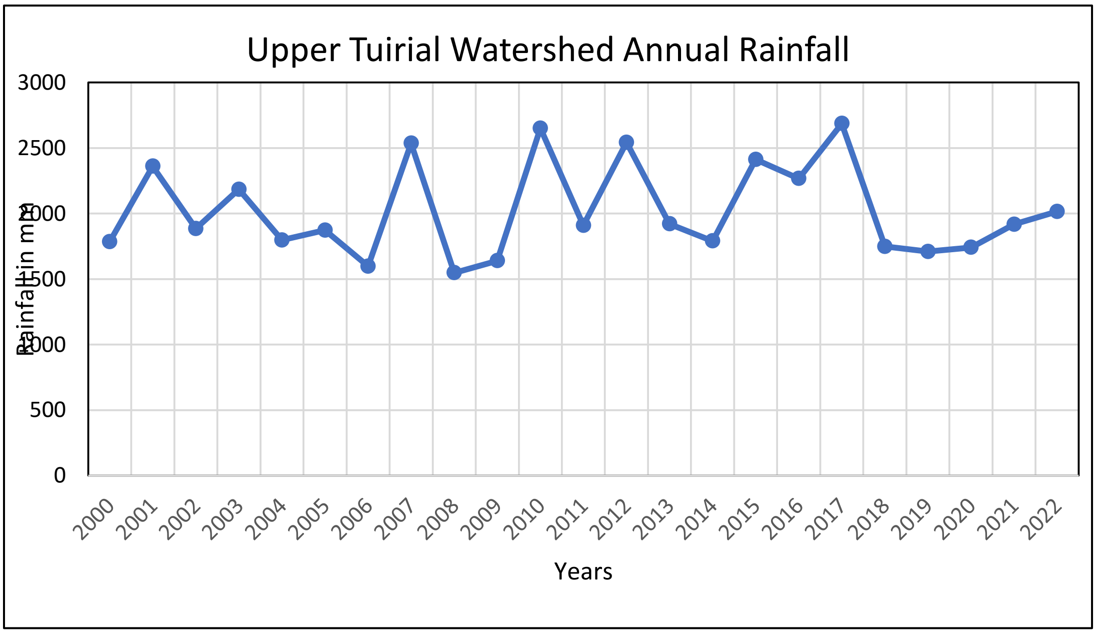

Figure 4.1: Average Annual Rainfall of Aizawl in mm. Source: State Meteorological Station, Directorate of Science and Technology, Aizawl, Mizoram

The line graph in Figure 4.1 shows the average annual rainfall of the study area with the highest annual rainfall of 2686.7mm in the year 2017 and the lowest in the year 2008 with an annual rainfall of 1547.7mm. The range of annual rainfall is 1139mm. Nevertheless, the lowest annual rainfall within the study period is almost double the annual average rainfall of the world.

The potential for rainfall can be projected from the utilization level in the study area. The annual rainfall reaching 2022.7 mm is sufficient to meet the water demand, be it actual or potential water resource. The consumption of water in domestic, agriculture, industry, and institutions comes from rainfall directly and indirectly. The recharge of river water and groundwater comes from rainfall only. The majority of households in the study area, usually have large barrels or containers capacity of 4000 liters for storing water.

In terms of the management of rainwater, the monthly variability of rainfall is also necessary to understand. The monthly rainfall variability is shown in Table 4.2., the lean period covers the months of November to February which may extend to the month of March, during these months there is usually no rainfall, and even if it rains the rapid downpours are usually dirty for domestic consumption.

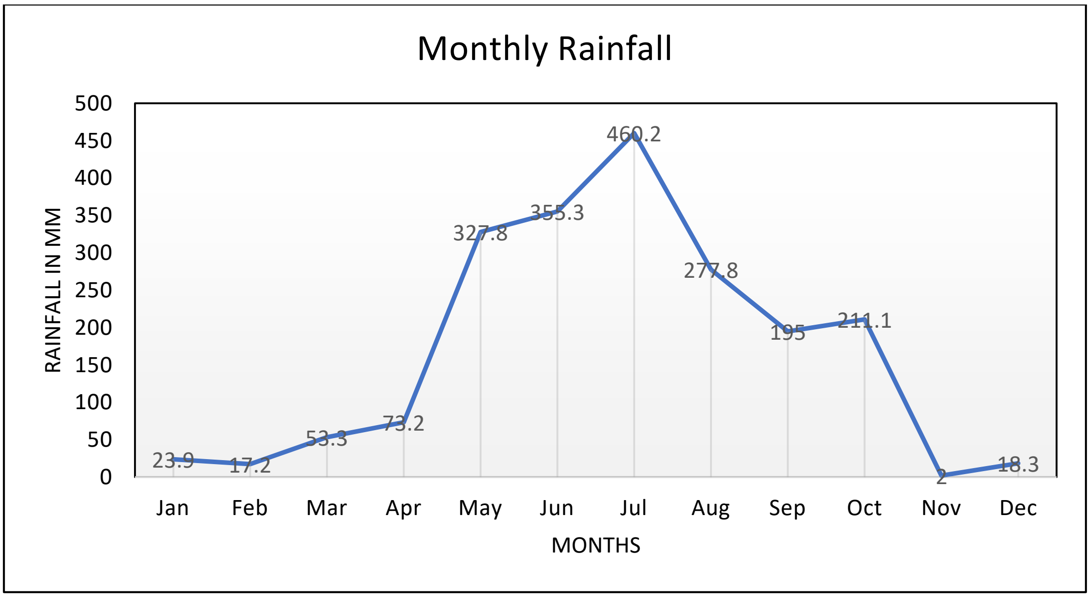

Figure 4.2: Monthly Rainfall of Aizawl, 2022. Source: State Meteorological Station, Directorate of Science and Technology, Aizawl, Mizoram.

Rainfall is usually collected during the monsoon period, it is to be noted that the first downpour in the break of the monsoon is left as runoff, they are dirty to be collected in a reservoir. A rough measurement of rainfall depth at home is estimated as follows:

Available annual rainfall = A x B x C.

A = Average annual rainfall of a region. B = Roof area of a building. C = Runoff coefficient (Runoff coefficient depends on roof surface material – generally taken as 0.8 to 0.9 for galvanized iron sheet and asbestos sheet).

For Example, the study area with an average monthly rainfall of 168mm, a catchment area of 81m^2 (30ft^2 approx.) will receive an average rainfall of 11566.8 liters per month (0.168x81x0.85 = 11566.8)

Rainwater is harvested during the rainy season. Owing to climatic conditions the houses have sloping roofs with corrugated sheets, aiding in the collection of rainwater. The same is stored in barrels or large plastic containers. During the monsoonal season, the water is used mainly for washing purposes and watering individual kitchen gardens. Sometimes it is even used for drinking after filtering it.

4.2.2. Rivers/ Streams

Surface water potential refers to the amount of water that is accessible on the surface of the Earth. It is a finite renewable resource, of which the quantity and quality are both space- and time-dependent. Careful estimation of the surface water potential of a river basin is essential for the future development of any kind of water-related project. The potential of a river may be assessed from different angles for development purposes. The potential level for the development of hydropower, industries, agriculture, human consumption, and even for environment itself. The present study stressed the potential level through the calculation of river discharge. Stream discharge (or flow) can be defined as the product of the velocity, width, and depth of the water flowing through the channel of a stream. It is directly related to the amount of water moving off the watershed into the channel of the stream. The volume of water flowing through a channel of the river (originating from the meeting of many streams) over a defined time is commonly termed river discharge. In other words, the discharge of a stream is a measure of the amount (or volume) of water that is carried by a stream past a point per second.

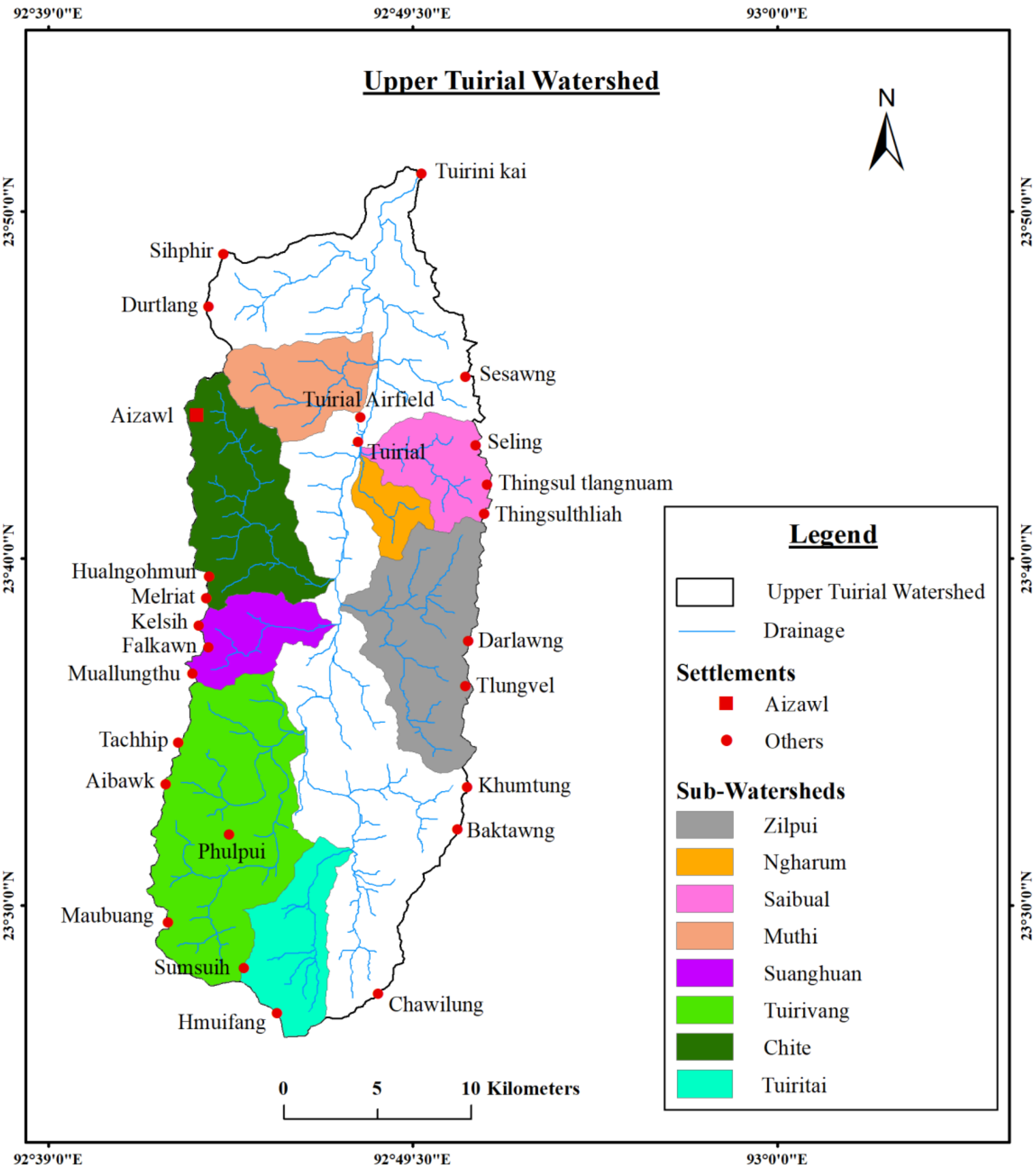

Figure 4.3: Sub-Watersheds of Upper Tuirial Watershed.

The Tuirial River originates from North Chawilung hills, near Chawilung village on the southern side of Aizawl District, and flows northward to enter the Cachar District of Assam. The river divided the watershed area into two more or less the same area. The dendritic river system of the watershed can be classified as the rivers of the eastern area and the rivers of the western area. Which supplies the water to the main river Tuirial. Among many small streams and rivulets, the important tributaries on the southern side of the river are Tuirivang, Tuinghaleng, Suanghuan lui, and Chite lui, they are perennial streams. According to the Natural Resources Atlas of Mizoram, MIRSAC 2009, the study area falls under Upper Tuirial Watershed Code No. 3C2B5a, 3C2B5b and 3C2B5c, which is within the area of North Flowing Upstream of Silchar Sonai Sub-Catchment Area. However, the present study demarcates the mini-watershed as feasible for the topic without giving less importance to the previous demarcation. The Upper Tuirial Watershed is demarcated into eight mini-watersheds for studying the availability of water in each small basin. The quality of water and the stream habitats is estimated from the addition of their performance. In addition, the discharge even indicates the condition of organisms underwater. The mini-watershed of the upper Tuirial Watershed is shown in Figure 4.3.

The distinct hydrologic area is covered by characterizing the surface water system through the study of discharge in tributary streams and rivers. It is not financially feasible or practical with the available resources to monitor all the tributaries, a subset of “representative” streams and rivers are selected to estimate discharge in similar ungauged smaller water bodies. These data allow us to estimate flows in non-monitored tributaries of similar physiographic, vegetative, and land-use character. The sub-watershed demarcation is purely done for the present study of river water potential in the upper Tuirial Watershed. They are:

1) Saibual Lui Mini-Watershed: Locating on the northeastern side of the watershed area, this watershed covers an area of 10.6 Km2. The length of the river is 6.66 Km approximately. The annual discharge of water is 63.2 cfs. The standard level of the water is potable in which the Turbidity (in NTU) is 1.71ppm, total dissolve solids is 78.4ppm and the total hardness is only 24ppm. The annual discharge of the river is 63.21 cfs. The villages like Seling, Thingsul tlangnuam and Thingsulthliah are located within the watershed area.

2) Ngharum Lui Mini-Watershed: Ngharum Lui is located at the southern boundary of Saibual Lui Mini-Watershed with a length of approximately 7 Km. The watershed covers an area of 10.6 Km2. The annual discharge of water is 166.21 cfs. The potential of the river is not harnessed.

3) Zilpui Lui Mini-Watershed: The southernmost mini-watershed located along the eastern part of the upper Tuirial Watershed covers an area of 54.4 Km2.

The total length of the river is 10 Km. The water is potable and the annual discharge is 69.8 cfs. the Turbidity (in NTU) level is 0.35ppm, total dissolve solids is 58.1 and the total hardness is only 22ppm and the ph level is 8.21. Darlawng village and Tlungvel village are located within the mini-watershed area.

4) Tuiritai Lui Mini-Watershed: The Tuiritai Lui Mini-Watershed is located at the southernmost part of the study area. It covers an area of 28.6 Km2 and the length of the main river is 10.9 Km. The annual discharge of water is 143.5 cfs.

5) Tuirivang Lui Mini-Watershed: The largest in area, Tuirivang Lui Mini-Watershed is located northern boundary of Tuiritai Lui Mini-watershed, which is south western part of the study area. It covers an area of 84.9 Km2. The length of the river is 18.1 Km. and the annual discharge of water is 195.7 cfs. The river water is potable in quality. The Turbidity (in NTU) level is 0.95ppm, the total dissolve solids are 48ppm and the total hardness is only 34ppm and the ph level is 8.1. Tachhip Village, Aibawk Village, Maubuang Village and Phulpui Village are located within the mini-watershed area.

6) Suanghuan Lui Mini-Watershed: The annual discharge of Suanghuan Lui is 55.45 cfs. The Mini-Watershed covers an area of 21.9 Km2 and the length of the river is approximately 8.5 Km. The quality of the water is normal.

7) Chite Lui Mini-Watershed: The watershed covers an area of 48.3 Km2 and the length of the river is 18.2 Km. Aizawl, Hualngohmun and melriat are located in the watershed area. The present dissolved solids in the water are as high as 206 ppm (parts per million). And is .6 above the norms for drinking water. The total hardness is 50ppm. The annual discharge of the river is 251.7 cubic foot per second.

8) Muthi Lui Mini-Watershed: Muthi Lui is located at the northwestern part of the study area. The mini-watershed covers an area of 28.4 km^2. The length of the river is 11.5 Km. and the annual discharge is 149.7 cfs. The river water quality is potable, the level of turbidity is 3.51 ppm, total dissolved solids present is 122 ppm.

From the international standard of calculating river discharge, one cubic foot per second = 448.83 gallons per minute (450 for ordinary calculations) = 1 acre-inch in 1 hour and 30 seconds (1 hour for ordinary calculations) = 1 acre-foot in 12 hours and 6 minutes (12 hours for ordinary calculations) = 1.984 acre-feet per (24 hours) day (2 acre-feet for ordinary calculations. The average monthly discharge of the upper Tuirial River is estimated to be 2,75,925 liters/hour. The annual discharge of rivers in the study is presented in Table 4.2.

Table 4.2: Annual water discharge of rivers. Source: Computed by author based on field survey.

Sl. No.	Name of River	Length (in Km.)	Catchment area (Km^2)	Water Quality	Annual Water Discharge (cfs)
1	Upper Tuirial	60.5	534	potable	1216.6
2.	Saibual Lui	6.66	24.4	potable	63.2
3.	Ngharum Lui	6.98	10.6	potable	166.21
4.	Zilpui Lui	10	54.4	potable	69.8
5.	Tuiritai Lui	10.9	28.6	potable	143.5
6.	Tuirivang Lui	18.1	84.9	potable	195.7
7.	Suanghuan Lui	8.5	21.9	potable	55.45
8.	Chite Lui	18.2	48.3	moderate	251.7
9.	Muthi Lui	11.5	28.4	potable	149.7

The rivers in the study are normally located in the valley while settlements are located along the ridgeline, which subsequently results draining human waste and pollutants towards the river valleys. The cultural as well as the physiographic nature of the study area largely influence the location of settlements which have a further impact on the quality and potential of the rivers. Water quality parameters that are typically determined through field-based monitoring include Turbidity, pH, dissolved solids, and turbidity. Samples are then transported and analyzed in a laboratory. Monitoring values are compared with standards set by regulatory agencies to determine if the water is suitable for a particular use. Different activities require different levels of water quality (e.g., water quality for drinking and irrigation have different standards). Mining and construction of roads are a particular form of development that has a unique set of impacts and implications for water quantity and quality. Pollution associated with these activities can affect both the long-term viability of the mine and the water and food sources of local communities. The stream discharge helps predict if streamflow is sufficient to provide people with enough drinking water, support agricultural irrigation, and meet industrial needs (Sreedevi et al. 2005). Understanding these impacts and managing them to the best possible extent is important to maintaining sustainability in mining systems. The water quality of the Upper Tuirial Watershed is given in Table 4.3.

Table 4.3: Water quality of upper Tuirial Watershed rivers. Source: Computed based on sample water collected during the field survey, tested at State Referral Institute PHED, Mizoram.

Sl.No.	River	Turbidity (in NTU)	solids (in mg/L)	Total hardness	PH	Remarks
1	Upper Tuirial	4.96	116	30	9.75	Higher turbidity is detected in most of the rivers. Chite Lui has the highest dissolved solids present in the water.
2	Saibual Lui	1.71	78.4	24	8.27	
3	Ngharum Lui	3.67	80.6	32	8.64	
4	Zilpui Lui	0.35	58.1	22	8.21	
5	Tuiritai Lui	0.74	42	25	8.1	
6	Tuirivang Lui	0.95	48	34	8.1	
7	Suanghuan Lui	1.63	74.9	28	8.4	
8.	Chite Lui	1.26	206	50	8.46	
9.	Muthi Lui	3.51	122	36	8.55	

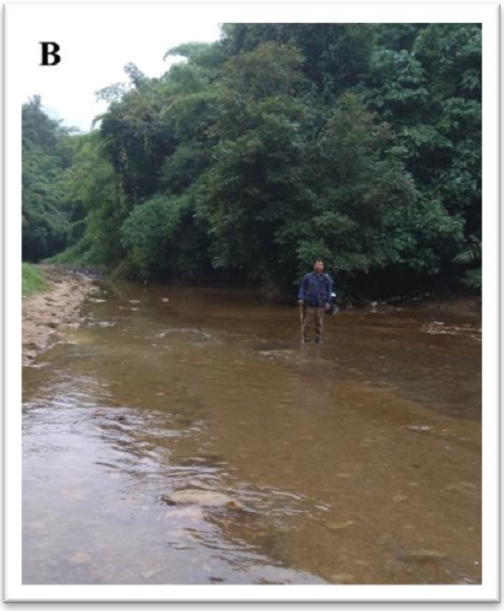

Plate 4.1: A) Zilpui Lui (dry season) B) Chite Lui (dry season)

4.2.3. Springs (Tuikhur)

Springs are discharge of groundwater where the levels of an aquifer are shallow and cut the surface topography. The spring discharge is equal to the groundwater recharge minus the outflow through evaporation and evapotranspiration and vertical and lateral sub-surface flow. Thus, Spring Discharge is a form of 'Annual Extractable Ground Water Recharge'. It is a renewable resource, though not to be used for Categorisation. The discharges of spring multiplied with time in days of each season will give the quantum of spring resources available during that season. Springs are the perennial source of water during the dry season in Mizoram village spring or tuikhur. The majority of the population in the village study area met their daily water requirement through this source. Springs (Tuikhur) play a vital role in the supply of water and have a higher potential for the supplement of water supply in the future, not only in the dry season but also during the monsoon season. They are one of the lifelines of water supply. Numerous spring sources are located in the study area, The number of springs identified during the field survey is shown in Table 4.4.

Table 4.4: Number of Springs in the selected village of the study area. Source: Computed by author based on field survey.

Sl.No	Village	Perennial Spring	Seasonal Spring	Total
1	Seling	7	5	12
2.	Thingsulthliah	8	6	14
3.	Phulmawi	4	4	8
4.	Khumtung	5	7	12
5.	Baktawng	4	7	11
6.	Chawilung	3	4	7
7.	Lamchhip	5	3	8
8.	Kelsih	5	4	9
9.	Aibawk	4	5	9
10.	Thiak	4	3	7
11.	Hualnghmun	4	6	11
12.	Muthi	5	7	11
13.	Sesawng	6	6	12
	TOTAL	64	67	131

Spring-shed management is hailed as one of the key objectives in the State Action Plan on Climate Change (SAPCC) and the State Water Policy of Mizoram. It aims at participatory spring-shed revival to promote sustainable and equitable management of groundwater resources with the overall goal of dealing with water scarcity. The program has worked with welfare schemes such as the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) and the National Rural Drinking Water Programme (NRDWP). Till today, one of the most important sources of water supply in rural areas can be considered as Tuikhur or village spring source (VSS). The average discharge of Tuikhur in the study area calculated from the field observation is 10 Liters/30 seconds. Thus, the average discharge of springs is estimated at 1200 liters/hour. In hilly areas with substantial potential for spring discharges, the recommended discharge measurement may be made at least 4 times a year in parity with the existing water level monitoring schedule.

Plate 4.2: (a)Spring shed with “tawlai”, Seling. (b) Spring, Phulmawi.

However, in recent years with rainfall variability and various anthropogenic reasons many of these sources either dried up or have reduced water quantity during the dry season or non-monsoonal season (Biswas et al., 2021). The reduction of water quantity of springs becomes a serious issue as the source of this water is related to the lithological structures below the surface and environmental degradation as well as waste pollution above the surface. The water resources from the springs are mainly used for drinking, cooking, cleaning, and washing purposes.

4.2.4. Private Vendor Water Supply

The importance of water carriage trucks was realized when the community people needed an extra supply of water. Even though it is naturally serviced on need basis only, approximately an average of 20000 Liters to 25000 Liters of water were supplied to the community daily during dry season. Water is pumped indiscriminately from streams or rivers, depending upon the source of water, the rate of water ranges from Rs. 500 to Rs.700 per 1000 Liters. The lifting of river or stream water from the local area provide best alternatives for supplementary water supply to the community without damaging the river ecology, and in addition it provides additional income to the local population. The discussion clearly defines that water carriage trucks are social duties in times of need and emergencies, on the other hand manifest the potential of water indirectly.

Plate 4.3: A) Truck collecting water (Maubuang). B) Truck water distribution (Tlangnuam).

4.2.5. Government Water Supply

PHED takes up Rural Water Supply Projects to provide drinking water supply facilities in Rural Areas of the state. The Rural Water Supply Programme is taken up under two programmes namely, the Central Sector National Rural Drinking Water Programme (NRDWP) earlier known as the Accelerated Rural Water Supply Program (ARWSP), State Sector Rural Water Supply Programme. Earlier it was named as Minimum Needs Programme (MNP). NRDWP (National Rural Drinking Water Programme) is a centrally sponsored scheme funded on a 90:10 basis by the Central and state Govt.

In most of the village, the State Government employs a piped water supply system is used where pump machines are used to draw water from rivers and lakes. In the study area, the majority of the villages hauled water from nearby hills namely

Chalfilh tlang and Tawi tlang. Water is transported and stored in a community reservoir which is usually constructed at a higher elevation to a nearby village for further distribution by gravity to household or community waterpoint. The public waterpoint distributes an average of 2000 liters per week to every household. The supply of water is very irregular during the dry season. With the introduction of the Jal Jeevan Mission in 2019, Village WATSAN takes responsibility with supervision under PHE to supply water for the community. During the survey period, WATSAN supplied 1500-2000 liters per household every week.

Plate 4.4: A) Public Water Point (Darlawng). B) Cluster of Public and Private water point (Lamchhip)

4.2.6. Ground Water Resources Potential

Groundwater resources have been estimated under the Central Ground Water Board Department of Water Resources, River Development & Ganga Rejuvenation Ministry of Jal Shakti Government of India in 2022, following the guidelines mentioned in the (Ground Water Estimation Committee) GEC 2015 methodology using appropriate assumptions depending on data availability. Aquifer-wise groundwater resource assessment of Replenishable or Dynamic Ground Water Resources and In-storage or Static Resources is recommended. In areas with a confirmed absence of groundwater extraction, the in-storage groundwater resources for the unconfined aquifer are to be assessed in the alluvial areas to the depth of 300m or bedrock. In the case of confined aquifers with ongoing groundwater extraction the dynamic as well as in-storage resources are to be estimated. Until aquifer geometry is established on an appropriate scale, the existing practice of using watersheds in hard rock areas and in soft rock areas may be continued.

Geologically, the upper Tuirial is characterized by semi-consolidated structural hills belonging to the Surma Formation of the Miocene Age. In general, the terrain is tectonically young and immature. The moderate linear ridges are underlain by shale, sandstone, and siltstone alternations and are characterized by low permeability and infiltration capacity. Thus, resulting in low groundwater potential. In addition to this, steep slopes of the hill ranges do not allow computation of groundwater recharge potential in this area. The rainfall infiltration method is usually used to assess the groundwater recharge due to the unavailability of groundwater abstraction structures. Groundwater is confined only to valley-filled areas and secondary porosities of semi-consolidated rocks. These aquifers are the main source of springs. Groundwater stored in the hill slopes emanates in the form of springs, which are being used as a source for water supply. The groundwater resources for the state have been assessed block-wise. The total Annual Ground Water Recharge has been assessed as 0.222 bcm and the Annual Extractable Ground Water Resource is 0.200 bcm. The Annual Ground Water Extraction is 0.008 bcm and the stage of Ground Water Extraction is 3.96 %. All 26 assessed blocks have been categorized as 'Safe'. There are no saline areas in the state. As compared to the 2020 assessment, there is an increase in annual extractable groundwater resources by 0.01 BCM in the 2022 estimate. The stage of GW Extraction has increased from 3.81 % in 2020 to 3.96 % in 2022. (Central Ground Water Board, 2022.) The groundwater development level is 3.94%. The natural discharge of water during the lean season is negligible. The available gross dynamic resources of groundwater are estimated to be 3.86 MCM, net annual draft is 0.14 MCM. The groundwater prospects of the Upper Tuirial Watershed are shown in Figure 4.2.

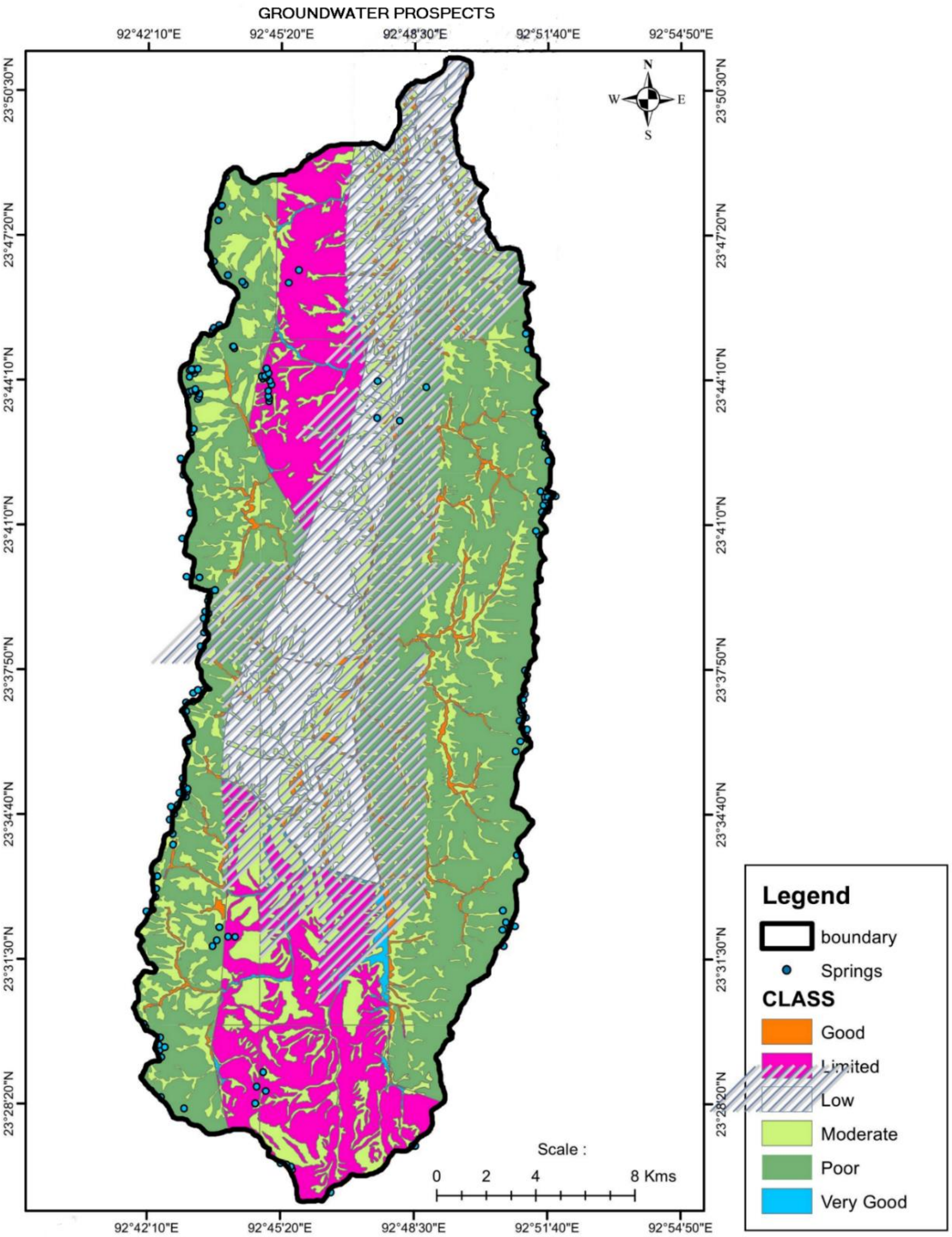

Figure 4.4: Ground Water Prospects of Upper Tuirial Watershed

The Assessment of Total Ground Water Availability of Confined unexploited Aquifer is taken out of only one component i.e., the In-storage Ground Water Resources of that confined aquifer. In semi-confined aquifers, the different aquifers are recommended to be assessed separately. In areas of confirmed unassessed aquifers, the resources are to be assessed following a methodology similar to that used in assessing the resources of Confined aquifers. The total groundwater availability in an area is the sum of dynamic and static/in-storage groundwater resources in the unconfined aquifer and the dynamic and In-storage groundwater resources of the Confined aquifers and semi-confined aquifers in the area. In areas with high humidity, rivers' base flow mainly comes from draining groundwater reservoirs. Thus, a significant part of the groundwater resources is included in the estimation of surface water resources. Therefore, the groundwater resources in humid areas have been assumed to be equal to the base flow of the rivers where data are available. All the assessed sites of groundwater in Mizoram, including the study area, by The Central Groundwater Board resulted in 100% saved storage site (Dynamic Ground Water Resources, Mizoram, 2022)

The potential resource of groundwater due to spring discharge is estimated from the volumetric discharge of the springs. Spring discharge occurs at the places where groundwater levels are shallow and cuts the surface topography. The spring discharge is equal to the groundwater recharge minus the outflow through evaporation and evapotranspiration and vertical and lateral sub-surface flow. Thus, Spring Discharge is a form of ‘Annual Extractable Ground Water Recharge’. It is a renewable resource, though not to be used for Categorisation. The discharges of spring multiplied with time in days of each season will give the quantum of spring resources available during that season. In hilly areas with substantial potential for spring discharges, the recommended discharge measurement may be made at least 4 times a year in parity with the existing water level monitoring schedule. The Net Annual Ground Water Availability for Future Use is obtained by deducting the allocation for domestic use and current extraction for Irrigation and Industrial uses from the Annual Extractable Ground Water Recharge. The resulting groundwater potential is termed as the net annual groundwater availability for future use. The average discharge of springs during dry season is calculated at 10 liters/30 seconds. Thus, the average discharge of springs is estimated at 28,800 liters/day during the dry season. The potential level of groundwater in the study area is also directly related to the annual discharge of springs even though Government-recorded data are not available, the assessment of the groundwater potential of the study area is relative with the spring discharge level.

4.3. Discussion and Conclusions

Discharge of streams and Rainfall Data is obtained from observation stations within the area of the Upper Tuirial River watershed area. It suggests that river flow is in good condition for utilization. The amount of utilizable surface water potential that can be actually put to beneficial use is much less due to severe limitations posed by Physiography, topography, transportation and storage issues and the present state of technology to harness water resources.

4.3.1 Rainwater Resource Potential

Rainwater harvesting has high potential in this area. A simple conclusion is that every roof of the household has the potential to feed the domestic needs of the household as per the norms laid down by per capita consumption if proper rainwater harvesting is done (IS 15797: 2008. Indian Standard Roof Top Rainwater Harvesting- Guidelines). The field observation shows that more than half of the settlements does not practice rainwater harvesting or does not have storage facilities in order to stock water for domestic need during the dry season. Economic backwardness in addition to over-dependence on government supply and reliance on climatic factors are the main reasons behind low practice or unawareness of rainwater harvesting in the study area. The introduction of well-known Rainwater harvesting to the people of the area can also be developed to solve the scarcity of potable water.

4.3.2 River/ Stream Potential

Internal Renewable Water Resources (IRWR) are usually defined as the potential water resource of the surface water produced within a country. It is that part of the water resources generated from endogenous precipitation. It is the sum of the surface runoff and groundwater recharge occurring inside the countries' borders. The IRWR figures are the only water resources figures that can be added up for regional assessment and they are being used for this purpose.

Heavy rainfall during monsoon period and quick and rapid runoff due to steep topography causes flooding of small river channel. Rivers in highlands usually carries high debris of sand and gravel due to rapid runoff in the slope topography with more than 20% and heavy outburst during monsoon period. The construction of barriers or Dams, built across a stream or river, usually fill with debris of sand and gravel transported by river which will not allow water to store with sufficient depth. The only river pond that are available are natural normally not suited for pumping site due to unfavourable location. However, the construction of a dam across a stream or river is proposed for pumping site. The recent introduction of solar pumping and reverse flow method is highly recommended for harnessing the potential of water in the study area.

The factors that affect the discharge of river/stream are weather, seasons of the year, water withdrawals, construction of dams, and others. These factors ultimately impact the velocity and the water depth and stream width parameters. The discharge of a stream or river happens to decrease during dry weather while increasing during rainstorms. High evaporation rates during the winter months and deforestation in terms of shifting cultivation and construction of road often result in a decreased stream discharge. The Upper Tuirial River with a length of approximately 60.5 KM with an area of 534 Km^2. Have annual discharge of 1216 cfs. The lowest during March at 121.3 cfs and highest during July reaching 2867.7 cfs. During rainy season, the river usually carries dissolved solids/sediments resulting high turbidity of more than 6 in total.

4.3.3 Springs Potential

Groundwater that flows naturally from the ground at the surface is called a spring; where the flow is diffused, it may be called a seep or seepage. Many rivers receive water from diffuse seepage. The occurrence of most springs is controlled by the structure of the rock formations. If the impermeable bedrock prevents the downward flow of water/rainfall, the thickness of the soil, the size of the upslope area and the amount and frequency of precipitation will affect the duration of spring flow. The tilted and eroded rock strata will possibly contribute to spring or seepage flow towards the direction of the tilt thus it is important to protect the source/origin site for adequate recharge of water. When water moves through weathered zones, joints and fractures an impermeable layer causes water to reach the surface as spring. In situations where rocks are fractured along the line of a geologic fault, it may result in a spring supplied from an aquifer in contact with the fault (Stone A. May 2001.). Springs have provided sources of drinking water for humans since time immemorial.

The Government of Mizoram has studied and provided with a block-wise number of springs all over the state and accordingly, annual potential recharge from those springs was estimated. The difference in spring water discharge fluctuates during the rainy season and in the dry season. It was considered that during monsoon season discharge of a spring ranges from 2.0 - 168.0 litre per second and during non-monsoon season the discharge ranges from 1.0 - 84.0 litre per second (CGWB,2021)

Springs in the upper Tuirial watershed are generally fractures and joints oriented (Central Ground Water Board, 2013). A large number of springs are perennial. In general, discharges of the springs are meager in high altitudes which progressively increase down slope. The average discharge of the perennial spring is estimated at 28800 litres per day during the period from January to March, which is generally dry period. These springs can be developed scientifically to provide safe drinking water to rural people. As per earlier field investigation reports, it is found that the water sample collected from springs indicates that pH values range between 6.5 and 8.5. In general, the chemical quality of groundwater in the study area is fresh and potable and is suitable for domestic and industrial purposes. Afforestation is a crucial need for controlling runoff and enhancing the infiltration of rainwater into the ground. Which will result in the maintenance of spring water and groundwater recharge.

4.3.4. Water Vendor Resource Potential

The potential level at which vending water relies on the distance of the water source, the amount of water in a liter, and the hire rate of the vehicle in the area. It may also suggest the source should be clean and potable. Due to the supply-in-need basis, it is difficult to give suggestions in terms of social development and the economy. In times of need and during emergencies like household and domestic water shortage, fire conflagration, and even during a natural disaster, the potential of motor water supply is realized.

4.3.5. Government Distribution Resource Potential

To provide adequate water supply to the community, the government initiated different schemes and programs. Prospects are recorded with ongoing population growth to feed. It should be remembered that the government also needed clean, perennial, and approachable water sources for distribution to the populace.

4.3.6 Groundwater Resource Potential

Groundwater potential is seen in terms of springs and seepage conduit, which is used mainly for drinking/domestic purposes. Groundwater utilization for irrigation may be considered negligible. The unavailability of tools to measure the actual availability is the constraint for estimating the groundwater in the study area. The recuperation of groundwater is called the groundwater recharge which is done to increase the groundwater table elevation. This can be done by many artificial techniques called a water-spreading dam or a dike, to store the flood waters and allow for subsequent seepage of water into the soil, so as to increase the groundwater table. It can also be done by the method of rainwater harvesting on a small scale, even at individual houses. Groundwater recharge is principally governed by the intensity of rainfall as well as the soil and aquifer conditions. This is a dynamic resource and is replenished every year from natural precipitation, seepage from surface water bodies conveyance systems return flow from irrigation water, etc.

The groundwater exploration done by the Central Ground Water Board (CGWB) indicates that there is considerable potential for exploration of groundwater within a depth range of 200 m with a potential yield ranging from 120 liters to 330 liters per minute for a drawdown of 13 m to 20 m (CGB, Guwahati, 2021). The quality of groundwater is found to be potable from the hydro-chemical point of view. To increase groundwater, the Reserve Forests are also being well maintained and protected. Water body revival like spring source renovation and water source points was taken up through the active participation of the community by contour trenching and plantation of trees and marking reserved forest areas. These forests are sources of groundwater recharge. Water from the springs in these forests is being supplied through gravity for consumption to the local communities. However, average consumption during the dry season is not more than 50 lpcd and it is much less than rainy season.

References

Ahmed, F., and Srinivasa, R.K. (2016) Morphotectonic studies of the Tuirini drainage basin: A remote sensing and geographic information system perspective. *International Journal of Geology, Earth Environment and Science*. Vol..6(1), pp.54–65.

Atkins, C.H. (1957). "Development of the National Water Supply and Sanitation. Program in India. *American journal of Public Health*, Vol 47(10), pp 1257-1264.

Ayers M. (2018), Hydrology and water resources Excerpts from climate change for the *hydrological* cycle, *water resources*, and their management. IPCC published

Barman B.K., Rao C.U.B., Rao K.S., Patel A., Kushwaha K. & Singh S.K.(2021). Geomorphic Analysis, Morphometric-based Prioritization and Tectonic Implications in Chite Lui River, *Northeast India* *Journal of the Geological Society of India*. volume 97, pp. 385–395.

Barman, B.K., Bawri, G.R., Rao, K.S., Singh, S.K. and Patel, D. (2021). Drainage network analysis to understand the morphotectonic significance in upper Tuirial watershed, Aizawl, Mizoram. *India: Agricultural Water Management*, Academic Press, pp.349–373.

Behailu, S., Melesse, A. M., Bhat, M. G., & McClaine, M. E. (2014). Catena Assessment of water resources availability and demand in the Mara River Basin. *Catena*, Vol-115, pp. 104–114. https://doi.org/10.1016/j.catena.2013.11.017

Biswas B., Azyu A. (2021) Water Resources and Management System of the Himalayan Region: Case Study of Mizoram, India. *Nature Environment and Pollution Technology: An International Quarterly Scientific Journal*. Vol. 20 pp. 193-201.

Bureau of Indian Standards (2008). IS 15797: 2008. Indian Standard, Roof top Rainwater Harvesting – Guidelines.

Central Groundwater Board, Guwahati (2013). Ground Water Information Booklet Aizawl District, Mizoram.

Central Groundwater Board, Guwahati (2021). Dynamic Groundwater Resources of Mizoram (As on March 2020).

CSRIO (Commonwealth Scientific and Industrial Research Organization) (2008) Mekong River Basin Water Resources Assessment: Impacts of Climate Change.

Dingman, S. L. (2015). Physical Hydrology (Third Edit). Waveland Press, Inc.

European Environment Agency (1997). Water resources problems in Southern Europe. ISBN: 92-9167-056-1

Falkenmark, M. (2006). The New Blue and Green Water Paradigm: Breaking New Ground for Water Resources Planning and Management. *Journal of Water Resources Planning and Management, ASCE,* June,2006. Pp. 129–132.

Government of India, Central Ground Water Board Department of Water Resources, River Development & Ganga Rejuvenation Ministry of Jal Shakti. *National Compilation on Dynamic Ground Water Resources of India, 2022*

Government of India, Ministry of Drinking Water & Sanitation (2013). Guidelines, National Rural Drinking Water Programme, Movement towards *ensuring people's Drinking Water Security in Rural India.*

Government of India, Ministry of Water Resources, (2007) Manual on Artificial Recharge of Ground Water. Central Ground Water Board.

Government of India, Ministry of Water Resources, (2014). Barak and others Basin. www.india-wris.nrsc.gov.in

Government of India. Department of Drinking Water and Sanitation Ministry of Rural Development (2010). "Ensuring Drinking Water Security In Rural India. Strategic Plan – 2011- 2022.

Government of India. NITI Aayog (August 2019). Composite Water Management Index. Ministry of Jal Shakti and Ministry of Rural Development.

Indian National Committee on Irrigation and Drainage ((2011)) Surface & Ground Water Resources in River Basins. Central Water Commission, Ministry of Water Resources.

Indian Water Resources Society, 2023. https://iwrs.org. in

Japan International Cooperation Agency (2003). The study on water supply systems in Mandalay City and in the central dry zone in the Union of Myanmar: final report; Vol. 3. Supporting report.

Jha B.M. & Sinha S.K. (2009)Towards Better Management of Ground Water Resources in India. Pub. Central Ground Water Board

Juniati A.T., Kusratmoko E., Sutjiningsih D. (April, 2021), Estimation of potential water availability and water resources carrying capacity for Bogor City spatial plan. *Journal of Geography of Tropical Environments*, Vol. 5 (1), Pp. 23-39. www.jglitrop.ui .ac.id

K. Palanisami(2008) Water Markets as a Demand Management Option: Potentials, Problems and Prospects IWMI-TATA Water Policy Program, International Water Management Institute, Hyderabad, India. https://publications.iwmi.org/pdf/H042160.pdf

Karavitis C. A. and Kerkides P. (2002). Estimation of the Water Resources Potential in the Island System of the Aegean Archipelago, Greece. *International Water Resources Association Water International.* Volume 27(2), Pages 1-12.

Kusre B.C., Baruah D.C., Bordoloi P.K., PatraS.C. (2010). Assessment of hydropower potential using GIS and hydrological modelling technique in Kopili River basin in Assam (India). *Applied Energy*. Vol 87 (1), pp. 298-309. https://doi.org

Lalbiakmawia F. (2015) Application of Remote Sensing and GIS techniques for ground water potential zones mapping in Aizawl District, Mizoram. *International Journal of Engineering Sciences & Research Technology* vol4(1), pp 292-299. http://www.ijesrt.com

Laldintluanga H., Lalbiakmawia F. & Lalbiaknungi R. (December 2016)Assessment of Rural Water Quality in Aizawl, Mamit and Serchhip District of Mizoram, India. *IJSTE - International Journal of Science Technology & Engineering*. Vol 3 (06). Pp. 111-118. ISSN (online): 2349-784X

Mei H., & Duhuan, L. (2010). Advances in Study on Water Resources Carrying Capacity in China. *Procedia Environmental Sciences.* Volume 2(5). Pp- 1894-1903.

Menzel, L., & Matovelle, A. (2010). Current state and future development of blue water availability and blue water demand: A view at seven case studies. *Journal of Hydrology*, 384(3–4), 245–263. https://doi.org/10.1016/j.jhydrol.2010.02.018

Miloradov M.& Marjanovic P. (1998) Guidelines for conducting water resources assessment. UNESCO Publication.

MIRSAC (2009). Natural Resources Atlas of Mizoram. Science, Technology & Environment Wing. Planning Department. Mizoram.

PHE Department, Government of Mizoram (2020). Ground water depletion survey report (Abstract) Prepared by Ground Water Resources Assessment Cell project in Mizoram state of north east India. *IOSR Journal of Humanities and Social Science (JHSS)* Vol 5 (3). pp. 07-13. ISSN: 2279-0837, ISBN: 2279-0845.

Pune Municipal Corporation (2014). Water Supply System for Pune City. Detailed Project Report.

Ragendran V., Vijayakumar G. (2017). Water resources and irrigation engineering. Sri Krishna Hitech Publishing company Pvt. Ltd.

Rasul (2019), Runoff Calculation. Mustansiriyah University. https://uomustansiriyah.edu.iq/ media/lectures/5/5_2019

*Rattani V. and Phukan I. (*24.1.2020). India: Revive springs for water security in Mizoram Source(s). *India Climate Dialogue*.

Rousta, B. A. and Araghinejad, S. (2015) Development of a multi criteria decision making tool for a water resources decision support system. *Water Resource Management*. Vol.29(15), pp.5713–5727.

Roy R. (2019) An Introduction to Water Quality Analysis. *International Research Journal of Engineering and Technology*, 6(1), pp. 201-205 [Link: https://irjet.net/archives/V6/i1/IRJET-V6I134. pdf

Saroha J. (2017). Water Resource Potential, Utilization and Conservation in India. *IJRAR- International Journal of Research and Analytical Reviews.* Vol. 4 (3). Pp. 27-35.

Schuol, J., Abbaspour, K. C., Srinivasan, R., & Yang, H. (2008). Estimation of freshwater availability in the West African sub-continent using the SWAT hydrologic model. *Journal of Hydrology*, Vol. 352(1–2), Pp. 30–49. https://doi.org/10.1016/j.jhydrol.2007.12.025

Shikhar Kumar S., Singh K.B. (2021). Study of potable water quality in peripheral areas of Aizawl city in Mizoram. *Science Vision.* Vol 20 (3), Pp. 76–80 30.

Sreedevi, P. D., Subrahmanyam, K. and Ahmed, S. (2005) The significance of morphometric analysis for obtaining groundwater potential zones in a structurally controlled terrain. *Environmental Geology*. Vol.47(3), pp.412–420.

Standard Test Procedures (2001) Link https://www.rhd.gov.bd /Documents/Contract Documents / Standard Test Procedures/ Determination.
Stone A. (2001). Springs as Water Source. *The Driller* e news.

Taghvaeian S. (2006). Water Measurement Units and Conversion Factors. http://osufacts.okstate.

Valentina Krysanova & Mike White (2015) Advances in water resources assessment with SWAT—an overview, Hydrological Sciences Journal, 60:5, 771-783, DOI: 10.1080/02626667.2015.1029482

Verma R. (2011). River Systems of Mizoram: Potential Avenue in the multi modal transport system in the region. *Community Based Water Resource Management in North East India: Lessons from a Global Context*. Vol1(1). pp.27-35.

Wikipedia, the free encyclopaedia. Water resources

Chapter - 5

Water Demand and Supply

5.1 Introduction

Water Demand and supply systems with their complexity and relevance exhibit the potential of Water resources. The uniqueness of water made it difficult to express its character and utility. The water demand and supply changes with region, places, and even with time. The consumption or use of water affects the state of the water resource system, some activities require large amounts of water of moderate quality (e.g., for industry), while others may require a very high quality of small quantities (e.g., for household water supply), and for others it may just make use of it without really influencing the state of the resource (e.g., for water-based recreation). Further, uses of water can be distinguished between withdrawal use which includes consumptive and non-consumptive use of water resources from the source (groundwater or surface water), and non-withdrawal use, which are on-site uses like navigation, wildlife, etc. The terms “consumption” and “demand” may not be confused as only a portion of the water demand is actually consumed (Savenije.H.H.G., 1996).

The Demand of Water is growing fast due to rapid population growth and economic development, but water supply is not growing at the same rate because of serious financial and physical limits for supply augmentation. Water resources developed at present amount to about 680 km3, which constitutes 61% of the utilizable potential of 1122 km3. The present norms for the minimum amount of water supply to domestic is limited at 2500 liters/month/per household, it may diverse in different regions. However, it is negative to add supply beyond this level due to heavy costs, environmental concerns and inter-state water conflicts. In addition to this, the country has a replenishable groundwater potential amounting to 433 cubic km. If used judiciously, this resource can be used in a sustainable manner.

However, with the increasing population, the per capita availability of water has been continuously decreasing. It amounted to about 6008 cubic metres in 1947, 5177 cubic metres in 1951, 1820 cubic metres in 2001, and stands at about 1545 cubic metres according to the 2011 population of India. At the world level, less than 1700 cubic metres per capita represents the condition of water stress. According to an estimate in 2025 per capita water availability of water will be 1340 cubic metres and in 2050 only 1140 cubic metres. Estimates suggest that the water demand-supply gap in agriculture could be as high as 570 BCM by 2030 (CWMI, 2019).

'Abundance with scarcity' is common in terms of water resources in many places on the earth. The study area faces the same situation of scarcity in plenty. The economic scarcity of water resources is prevalent, especially in areas with poor surface water sources which resulted in ill management of water pipelines and a lack of infrastructure to set up additional pipelines in order to switch pipelines whenever necessary. Proper implementation of planning, awareness, and assistance is crucial to overcome the problems of dry season water scarcity in the study area. Even the small initiatives taken as well as the systematic research on how to solve water scarcity are of great value. The increasing population with living standards increases the demand for water, and the use of water has been growing at twice the rate of population over the last century. From the analysis of precipitation patterns from 1901 to 2015 shows annual declining trends of rainfall at a rate of 3.94 mm/year (Mizoram State Water Policy, 2020). The study of water resource demand and supply gives information on the capacity of the region or area to offer clean water.

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5.2. Demand of Water

Demand for Water is defined as the volume of water requested by users or consumers to satisfy their needs. The unit of liters per capita per day (lpcd) is usually used to determine the water demand of an area. The various types of water demands may be divided into (a) Domestic water demand includes water for residential uses like drinking, bathing, cooking, washing, etc., (b) Industrial and commercial water demand includes water needed by various industries, commercial institutions, and buildings, (c) Demand for public uses includes amount of water for public utility excluding domestic, (d) Fire demand and (e) Water required compensating losses in wastes and thefts. Generally, the availability of water of more than 1700 m3

/person/year is considered a normal acceptable rate. In areas with less than 1000 m^3 /person/year, the scarcity of water limits different types of human activities, while less than 500 m^3/person/year is viewed as a main constraint to human life (Mueller et al., 2015). The World Health Organization specifies 50 liters per person per day as the recommended 'intermediate' quantity needed to maintain health, hygiene and for all domestic uses (WHO, 2003). In India, the average annual per capita water availability in the years 2001 and 2011 was assessed as 1816 m^3 and 1545 m^3 respectively, which may further reduce to 1486 m^3 and 1367 m^3 in the years 2021 and 2031 respectively. The per capita water availability in the country is reducing due to an increase in population (Ministry of Jal Shakti 2020).

5.2.1. Household/ Domestic Water Demand

Generally, the household consumption of water depends on the personal habits of people, the social status of individuals, local climatic conditions, and customs of the local people. This made it difficult to calculate the exact amount of water demand as the indicators change from time to time. As per the Bureau of Indian Standards, IS:1172-1993, the minimum consumption rate per capita per day for villages and for communities with a population up to 20000 and without a flushing system, is calculated at 40 lpcd, as the villages within the surveyed fall under this category, this demand is taken into consideration. While, the Jal Jeevan Mission (2019) launched by Govt of India set a goal to provide adequate drinking water of prescribed quality, on a regular and long-term basis to every village household by 2024. The JJM then, upgrade the daily demand to 55 lpcd for every household. In continuation of this, The National Rural Drinking Water Programme (NRDWD) 2013 enhanced service level from 40 lpcd to 55 lpcd wherever possible (Ministry of Jal Shakti.2020). The water supply is enormous by natural springs in the study villages (Fig. 5.1)

The household survey and interviews with different persons reveal that the per capita per day demand ranges from 30 lpcd to 40 lpcd for a period of five days and an average of 50 lpcd – 60 lpcd for two days only. Thus, the average household consumption for one week is estimated to be 320 lpcd with an average of 45.7 lpcd without deduction in the transaction of water supply during the dry season (Table

5.1). The water demand of a household is met by government distribution, spring water, and from private vendors.

Table 5.1: Household Water Demand Calculation of selected villages in upper Tuirial watershed. Source: Computed by author based on field survey.

Sl. No.	Village	Population	No. of Household	Projected Demand (JJM guidelines of 55 lpcd)	Average daily water demand (45.7 lpcd X population X $0.001m^3$)
1.	Seling	2730	547	150150	124.761 m^3
2.	Thingsul	3984	805	219120	182.068 m^3
3.	Phulmawi	280	60	15400	12.796 m^3
4.	Khumtung	1694	263	93170	77.416 m^3
5.	Baktawng	3570	686	196350	163.149 m^3
6.	Chawilung	680	120	37400	31.076 m^3
7.	Lamchhip	1050	180	57750	47.985 m^3
8.	Kelsih	1015	220	55825	46.385 m^3
9.	Aibawk	2075	410	114125	94.827 m^3
10.	Thiak	997	209	54835	45.563 m^3
11.	Hualngohmun	710	206	39050	32.447 m^3
12.	Muthi	1218	224	66990	55.663 m^3
13.	Sesawng	4032	847	221760	184.263 m^3
	TOTAL	**24035**	**4777**	**1321925**	

5.2.2. Institutional Demand

The consumption of water in a building is usually estimated through a volume of water divided by the number of consumer agents, which is expressed as the Consumption Indicator (CI), the most representative variable of water consumption in the system. The values of CI can be used as references according to the typology of the building, such as liter/student/day at schools, liter/bed/day at hospitals, and liter/person/day in a residential building or an office building. With it, schools or other institutions with a limited supply of clean water or those that are above average, for example, are identified. Both cases require attention in the search for the sustainable use of water in the school environment.

UNICEF (2012), in its standards for school building projects in developing countries, considers 5 L/person/day for all school children and staff at day schools, and 15–20 L/person/day for boarding schools. In addition, water for flushing toilets must be considered separately. The Bureau of Indian Standards (2010) fixed 45 lpcd and 135 lpcd for daytime school and boarding school respectively. The actual water consumption of a school may be calculated by relating the volume of water consumed within a certain period of time reflecting its particular characteristics as well as the consumption patterns of its population. From the survey of 30 schools in the study area, the consumption of water in school ranges from 1 lpcd to 2 lpcd. Normally, student bring along their own water bottle for the day.

Table 5.2: School Water Demand of Selected Villages. Source: Computed by author based on field survey.

Sl. No.	Village	Total Number of Schools	Total Number of Students	Total water demand per day (45 lpcd)
1.	Seling	9	556	25020
2.	Thingsul	7	142	6390
3.	Phulmawi	2	43	1935
4.	Khumtung	3	106	4770
5.	Baktawng	9	456	20520
6.	Chawilung	2	42	1890
7.	Lamchhip	3	161	7245
8.	Kelsih	2	90	4050
9.	Aibawk	4	191	8595
10.	Thiak	3	167	7515
11.	Hualngohmun	2	49	2205
12.	Muthi	4	260	11700
13.	Sesawng	14	561	25245
	TOTAL	**64**	**2824**	**127080**

The introduction of mid-day meals increases the demand and consumption of water especially in primary schools. Even though some schools collect or raise funds to construct their water reservoir, many water tanks in schools are provided under government aid funds like IWDP, etc. Due to the unavailability of pipe connections, most of the educational institutions rely on rainwater only. The observation concluded that the majority of the schools give less priority to rainwater harvesting or collection of usable water. Poor management of gutter systems, leakage of tanks, etc. are common, water losses due to leaks were high and the schools did not use water-economizing equipment. However, Through the identification of the actual consumption indicator (CI), it is possible to create benchmarks that characterize an ideal consumption situation and use of water-conserving equipment and user consumption habits. School Water Demand is shown in Table 5.2.

5.2.3. Livestock Water Demand

A proper balance of water, carbohydrates, vitamins, protein, and minerals is required for the optimal performance of livestock. Out of these, the most critical is water, which also includes its quality. The important properties often considered in assessing the quality of water for livestock are physiochemical properties (pH, total dissolved solids, total dissolved oxygen, and hardness), presence of excess minerals or compounds (nitrates, sodium sulfates, and iron), organoleptic properties (Odor and taste), presence of toxic compounds (heavy metals, toxic minerals, organophosphates, and hydrocarbons), and presence of bacteria (Faries, et al., 2007).

Livestock rearing goes hand in hand with village life. Poultry farming is very common in the study area. Almost every household in the village will domesticate pigs or poultry or even cows usually in small numbers. Cattle rearing is practiced in Muthi Village, with more than 40 households engaged in these activities. More than 600 cattle were domesticated, which is more than 57% of the total cattle reared in the surveyed area. Hualngohmun, Melthum, Muallungthu, thiak and Aibawk villages are concentrated in piggery and poultry farming. The demand for water for livestock is difficult to calculate, due to the fact that different regions with different climatic conditions with different breeds usually consume different quantities. From the Field investigation by consulting different indices, it is concluded as the table provided below.

A separate water connection for farming or animal husbandry is not available, thus water supply for different livestock is dependent on rainwater. Normally, water demands for farms are managed by constructing a reservoir big enough to provide or store water for the livestock. The livestock population and water demand are shown in Table 5.3.

Table 5.3: Livestock population and water demand of selected villages (Winnipeg, **2020).** Source: Computed by author based on field survey.

Sl. No.	Village	Big animals (Cattle, buffaloes etc.)	Medium animals (pigs, dogs, goats, etc.)	Birds (Duck, hen, pigeon, etc.)	Total (lpcd)
	Per day/ per animal requirement in liters	40	8	.5	
1.	Seling	Nil	250	800	2400
2.	Thingsul	20	500	740	5157
3.	Phulmawi	12	50	400	1080
4.	Khumtung	30	200	1200	3400
5.	Baktawng	20	750	1400	7500
6.	Chawilung	30	45	700	1910
7.	Lamchhip	20	200	500	2650
8.	Kelsih	25	200	600	2900
9.	Aibawk	65	800	1600	9800
10.	Thiak	25	600	1000	6300
11.	Hualngohmun	Nil	800	2000	7400
12.	Muthi	400	200	800	18000
13.	Sesawng	50	450	1300	6250
	TOTAL	**697**	**5048**	**13040**	**74760**

5.2.4. Agricultural Water Demand

Irrigation is the major focus in agriculture water demand. The availability of sufficient potable water for irrigation affects the practice of agriculture as well as its production. Agricultural practices are generally based on monsoon rains; thus, summer crops and plantation crops are grown in the fields and there are negligible practices of agriculture during the winter season. Beans, mustard, tomatoes, and cabbage are generally grown in gardens for domestic consumption during the dry season. Thus, agricultural water demand is not possible to calculate for the study area.

The practice of irrigation in the upper Tuirial watershed is minimal. A handful of farmers practice irrigation in pockets near the banks of the Tuirial River on a Small scale and may extend to the Tuirini River from the household survey. But only a handful of families practically irrigate the crop. They usually depend on the soil moisture and river soil nutrients. Thus, out of 60% population engaged in agriculture, less than 5% practiced irrigation during the dry season.

5.3. Supply of Water

Water supply is the provision of water by public utilities, commercial organizations, community endeavors, or by individuals, usually via a system of pumps and pipes (*Wikipedia*). Regular, clean, and sufficient supply of water are crucial to properly functioning communities. The responsibility of institutions is assigned differently in different countries and regions or areas (urban and rural). The policy and regulations, service provisions, and standardization are related to the aspect of service quality such as water pressure, water quality, and continuity of supply.

PHE supplies water to the community through pipes, providing private tap water connections, supporting the community with public water points, and even further extending to commercial and institutional connections in the area. Development and rejuvenation of springs and their management were one of the priorities of IWDP, they constructed spring sheds and water canals in the potential zones. Apart from this, community water supply by Truck and private water vendors are supplying water on a need/order basis as and when needed. The cost of supplying water consists of fixed costs (capital costs and personnel costs) and variable costs that depend on the amount of water consumed (mainly energy and chemicals). Referring to the water supply of the study area, it usually focuses on the domestic water supply due to the absence of industry and minimal supply for agriculture and institutions.

5.3.1 Domestic Water Supply

The distribution of water is usually done per household level rather than lpcd. Availability of storage tank is as important as installing gutter. PHE Department of Mizoram has been mandated to manage the water supply and take sole responsibility for domestic water supply, the minimum norm for the distribution of water is taken as 2500 liters per month (The Mizoram Water Supplies (Control) Act, 2004). In addition to PHED The village level supply of water is added by WATSAN under Village Council. The WATSAN usually distributes 1000 – 2000 liters per household per month.

Table 5.4: Water supply of selected villages. Source: Computed by author based on field survey.

Sl. No.	Village	Population	No. of Household	Distribution per month/ household in liters (dry season)	Liter per capita per day (dry season)
1.	Seling	2730	547	6000	40.07
2.	Thingsul	3984	805	2600	17.4
3.	Phulmawi	280	60	4000	28.5
4.	Khumtung	1694	263	4000	26.6
5.	Baktawng	3570	686	6000	38.4
6.	Chawilung	680	120	1700	9.9
7.	Lamchhip	1050	180	3500	19.9
8.	Kelsih	1015	220	5000	36.1
9.	Aibawk	2075	410	8000	52.6
10.	Thiak	997	209	7000	48.9
11.	Hualngohmun	710	206	4000	20.6
12.	Muthi	1218	224	4000	24.5
13.	Sesawng	4032	847	4000	28
	TOTAL	**24035**	**4777**	**59800**	**391.47**

The Government of India provides assistance to the State under the program of Accelerated Rural Water Supply Programme (ARWSP) while insisting upon the State Government to provide an equally matching share under the Minimum Needs

Programme/Pradhan Mantra Gram Yojana (PMGY). Under this program, water supply to the rural habitation is provided based upon local resources available through piped water supply scheme, installation of hand pump tube wells, construction of rainwater harvesting tanks, improvement of village spring sources, and construction of impounding reservoirs. Besides, rural schools are also covered under the provision of drinking water.

The average distribution of water for 13 villages is 30.11 lpcd. This is taken for granted that the average for the whole area is also considered 30.11 lpcd as per distribution by the government for the dry season. The deficit level of water supply is met through Springwater and local water vendors. The distribution of water is normally fixed but only during the winter season, when there is less rainfall, the fixed amount is strictly undertaken while during summer the community will take as much as they can store.

5.3.2. Commercial and Institutional Water Supply

Schools mainly depend on rainwater. They may buy from vendors during winter. One of the most important in this area is that during the dry season winter vacation is for one and half months. Institutions are usually provided with water storage systems. So, the supply of water connection through a pipe is not provided to a majority of schools by the government

5.3.3. Agriculture and Livestock Water Supply

Generally, farmers manage the water supply, assistance was given from the Department of Irrigation, Soil Department, and Horticulture provided with a storage tank mainly a rainwater feeding system. Farm ponds and rainwater harvester tanks are also provided by the government to the farmers through IWDP, Fisheries Department, Agriculture Department, and Soil and Irrigation Department.

5.4. Actual Water Demand and Supply of Upper Tuirial Watershed

The actual Water Requirement of the study may be difficult to calculate, however, the estimation of water demand and supply can be calculated for further reference for planning and implementation of infrastructure and development of utilization of water resources for the whole area. Availability of storage tank is as important as installing gutter.

Table 5.5: Water Storage/ Reservoir availability in the selected villages and their capacity. Source: Computed by author based on field survey.

Sl. No.	Village	Number of Tanks	The gross capacity of tanks in ‘000 liters	Total water demand per day (taking 65 lpcd)	IS 1172:1963 normal water demand for rural area (135 lpcd)
1.	Seling	7	2850	177450	368550
2.	Thingsul	5	1300	256620	537840
3.	Phulmawi	3	620	18200	37800
4.	Khumtung	5	2400	110110	228690
5.	Baktawng	6	2820	232050	481950
6.	Chawilung	3	1200	44200	91800
7.	Lamchhip	4	2000	68250	141750
8.	Kelsih	5	2100	65975	137025
9.	Aibawk	5	4200	134875	280125
10.	Thiak	4	2100	64805	134595
11.	Hualngohmun	4	2400	46150	95850
12.	Muthi	4	1900	79170	164430
13.	Sesawng	7	2600	262080	544590

5.5. Discussion and Conclusions

In spite of changes in price, the demand for water is inelastic. However, the inelasticity of water demand may be affected by the amount of precipitation and temperature changes. The case study of Phoenix, Balling, and Gober determined that a 10% decrease in annual precipitation would result in a 3.9% increase in per capita annual water demand, while a 1°C increase in annual temperature would cause a 6.6% increase in per capita annual water demand. [Lily A. et al., 2011]. Overall, the average precipitation of the area for 23 years is 2022.5 mm (ref. Table No. 4.1), calculating from the annual rainfall which is reciprocal to the water discharge of the area, it is projected that the water demand of the study area can be managed by proper exploitation of water resources potential. The ethnic ideas over reverence of community efforts and government propaganda for the upliftment of society, if prevalent among the rural people in the study area may cause negligence or ignorance, towards the private efforts for funds saving to buy private storage tank, proper installation of gutter and judicious use of water. Which is the first and foremost duty of the household for water resource management. The simplest and easy-to-understand method for effective water resource preservation and management will reduce the exploitation of energy resources and river water; thus, it will automatically enhance the potential of rivers and the sustainability of the environment indirectly in the long run.

The agreeable response during field observation, towards rising demand for water was resorted to storage of surface water in reservoirs, never the less rainwater harvesting is the key factor for sustainable water supply in the hilly region with plenty of rainfall. Rainwater harvesting was supported but financial constraints usually put an end to the efforts. The field survey observation of the water reservoir (Table No.5.5) concluded that the infrastructure of storage devices is provided but there is not sufficient water to fill the storage tank. The use of solar water pumps for hauling water from rivers or sources is highly proposed, due to the inadequate source of water through gravity method due to the decline in river water volume every year. Notwithstanding the efforts made by the government and other agencies, the survey concludes there is a possibility that 80% of domestic demand can be met through rainwater harvesting.

Production of agriculture usually increased with sufficient water supply, availability of water supply automatically promoted the development of agriculture and allied activities. The available river water use and exploitation are negligible. Yet, the pollution of rivers in terms of abusing the species of living organisms and fish takes place at an exorbitant rate by the local population. The agricultural practices are mainly dependent on monsoon rains and private water supply lifting from the river on a small scale especially as mentioned earlier supply in need basis for livestock and human consumption only. The partial practice of irrigation is more or less practiced in small pockets for the subsistence of the farmers. Thus, there is a wider scope of development of agriculture with the help of water supply, but the bottleneck is the lack of capital assets and proper transportation. The initiatives taken by the government are mainly confined to providing farm ponds and water harvesting tanks.

Schools, government offices, and other institutions are the most important indicators of the level of water supply in the area. A sufficient household supply of water naturally steps up to a sufficient supply of water to different public institutions. Normally, schools are provided with storage tanks.

The observation concluded that the scarcity of water is mainly due to the low level of water harvesting practices. Due to high supply costs, the government is facing a problem of repairing infrastructure. Damage due to road construction has been very frequent recently. There is an important need to upgrade the present distribution system and rehabilitation of pumping types of machinery. Most of the distribution lines are metallic and have a design life of 30 years, they are rusted due to prolonged service, and most of them are more than 50 years in service. There are high leakage losses through these very service lines as well as supply tanks. As the system is getting older, the leakages and losses of hard-earned pumped water are increasing in the system and anticipated losses have been assessed to the tune of 50%. What is required is direct feeding of water to the zonal reservoirs and distribution lines need to be extended to cover all the households due to demand basis. It is necessary to develop accurate and reliable water demand forecast models, especially for assessing peak demand. There are two types of demand forecasting. The first are short-term forecasts, which are used for operation and management. The second is the long-term forecasts, which are required for planning and infrastructure design. Currently, water managers produce demand estimates using long-term climate trends and the principle of stationarity (the idea that natural systems fluctuate within an unchanging envelope of variability) [Lily A. et al., 2011].

References

Atkins C. H. (Oct,1957). Development of the National Water Supply and Sanitation Program in India. *Sanitation Program in India*. Vol. 47. Pp-1257-1264

Attanasi E.D., Close E. R., and Lopez M.A. (1975). Techniques for water demand analysis and forecasting: Puerto Rico, A case study. United States Department of the Interior Geological Survey.

Bachrach M. & Vaughan M.J. (March1994). Household Water Demand Estimation. Inter-American Development Bank Productive Sectors and Environment Sub-department Environment Protection Division. Inter-American Development Bank N.Y., N.W. Washington, D.C.

Balling, R. C. and Gober P. (2007). Climate variability and residential water use in the city of Phoenix, Arizona. *Journal of Applied Meteorology and Climatology*. Vol. 46, Pp. 1130–1137. doi:10.1175/JAM2518.1

BIS (2010).IS 1172: 1993: Code of basic requirements for water supply, drainage and sanitation,1993. Fourth Reprint, December, 2010.

BIS (2012). IS 10500 (2012): Drinking water. Indian Standard Drinking Water – Specification. May, 2012

Bureau of Indian Standards (2010). Indian Standard: Code of Basic Requirements for Water Supply, Drainage and Sanitation, 4th edition, New Delhi, India.

European Union (2015). Guidance document on the application of water balances for supporting the implementation of the WFD (Water Framework Directives), Technical Report. ISBN 978-92-79-52021-1

FAO (2004) Comprehensive Review of Water Resources, Malta. The Malta Resources Authority.

FAO (2019). Water use in livestock production systems and supply chains – Guidelines for assessment (Version 1). Livestock Environmental Assessment and Performance (LEAP) Partnership. Rome.

Faries F. C., Reagor J.C., Sweeten J. M. and Loneragan G. H. (2007). Livestock Water Quality Standards. *Encyclopaedia of Water Science.* Second Edition;172.

Florke M, Kynast E, Barlund I., Eisner S, Wimmer F, Alcamo J (2013). Domestic and industrial water uses over the past 60 years as a mirror of socio-economic development: a global simulation study. *Global Environmental Change*. Vol. 23, Pp. 144–156.

Hickey H.E. (2008). Water Supply Systems and Evaluation Methods Volume I: Water Supply System Concepts. U.S. Fire Administration.

Kumar A. (2011). Water Demand, Sources and Population Forecasting. IIT Delhi.

Lalroneiha K.C.T. (2014). Status of Drinking Water under Government Schemes: A Case Study of Mizoram Aakash Upadhyay. *International Journal of Social Sciences*. Vol. 2 (4), Pp. 26-32. ISSN: 2348 4411

Lily A., Peters H. and Chang H. (2011). Urban water demand modeling: Review of concepts, methods, and organizing principles. *Water resources research*. Vol. 47, Pp 1-15

McCabe G.J. and Markstrom S.L. (2007). A Monthly Water-Balance Model Driven by a Graphical User Interface. U.S. Geological Survey, Reston, Virginia.

Ministry of Jal Shakti (March 2020). Per Capita Availability of Water. Posted On: 02 MAR 2020. PIB Delhi

Ministry of Jal Shakti. (2020). Water Demand.

MJP (2012). Basics of water supply system, Module 1. Training Module for Local Water and Sanitation Management. CEPT University

Mueller S.A., Carlile A., Bras B., Niemann T.A., Rokosz S.M., McKenzie H.L., Kim H.C., Wallington T.J. (2015). Requirements for water assessment tools: An automotive industry perspective. *Water Resources and Industry*. Vol. 9, Pp. 30–44.

Nunes. L. G., Soares .A.E.P., Soares W.A., Silva S.R. (2019). Water consumption in public schools: a case study. *Journal of Water, Sanitation and Hygiene for Development*. Vol. 9 (1), Pp. 119–128. https://doi.org/10.2166/washdev.2019.074

P.H.E. (December, 2014) The Mizoram Water Supplies (Control) Act, 2004 (Act No. 11 of 2004)

Palanisami K. (2009). Water Markets as a Demand Management Option: Potentials, Problems and Prospects. Link - https://ageconsearch.umn.edu/ record/127980/files/26.pdf

Ren C., Dong Y., Xue P., Xu W. (2019). Analysis of Water Supply and Demand based on Logistic Model. Conf. Series: *Earth and Environmental Science*. doi:10.1088/1755-1315/300/2/022013

Roy B. Hunter Water Demand Calculator developed by in a 1923 National Bureau of Standards publication, Recommended Minimum Requirements for Plumbing in Dwellings and Similar Buildings (http://www.iapmo.org/ water-demand-calculator).

Shaban A. & Sharma R.N. (June 2007). Water Consumption Patterns in Domestic Households in Major Cities. *Economic and Political Weekly*. June 9, 2007. pp. 2190-2197

SIPMIU (March 2015) North-Eastern Region Capital Cities Development Investment Program (Tranche 2) – *Aizawl Water Supply and Sewerage Subproject*. Link; http://www.adb.org/ sites/default/files/ project-document/ 60163/35290-033-ind-iee-06.pdf

Taghvaeian S. (2006). Water Measurement Units and Conversion Factors.

The Mizoram Gazette (12.10.2020). The Mizoram State Water Policy 2020. Vol. XLIX (637).

UNICEF (2012). Water, Sanitation, and Hygiene (WASH) in Schools: A Companion to the Child-Friendly Schools Manual. Division of Communication, New York, USA.

Water and Wastewater Department, Winnipeg **(2020),** MB, Canada. Water Demand Estimation and Design Guidelines, extracted from https://legacy.winnipeg.ca/ water and waste/dept/ water demand. stim

World Health Organization (2003): www.who.int/water_sanitation_ health/ diseases /en / WSH03. 02. pdf.

Chapter - 6

Water Resource Management and Conservation

6.1. Introduction

The interplay of various factors that govern access and utilization of water resources and in view of the increasing demand for water, the planning and management of water resources has become a matter of the utmost urgency. It becomes important to look for holistic and people-centered approaches to water management. The Dublin principles on water management, established in the International Conference on Water and the Environment in the year 1992 focus on the finite and vulnerability of fresh water, highlighting the need for a holistic and people-centered approach for social and economic development with protection of natural ecosystem. The importance of implementing a community-based participatory approach, involving users, planners, and policymakers at all levels. The Participatory approach takes into account the different institutional levels involved in water resources management which broadens the context into socioeconomic development policy and environmental management. Effective management links land and water use across the whole of a catchment area or groundwater aquifer.

Analysis of water availability in India as a whole will picture North East India as a water surplus area on a regional basis, yet the scarcity and deficit of water for consumption is experienced by the majority of the region, this may be due to the poor management of water resources and negligence of its potential. As technology improves, what new resources could we exploit as water sources? Effective water resources management can promote development. Reliable irrigation, access to clean drinking water, and local water sources availability all are the cornerstones for area development. Flood and drought management mitigate the impact of water-related natural disasters. Hydroelectricity provides electricity in remote areas, enabling industry and development. In simple terms, effective management of water resources encompasses social, economic, and environmental development.

With an objective to plan, develop and manage water resources, the Mizoram State Water Policy 2020 is passed keeping in view the need to be governed by a common integrated perspective considering local, regional, state and national context. (The Mizoram Gazette,2020). The common basic units of planning for conservation and management of water are micro watersheds of the larger river basins in the State, ensuring a resource-based approach. However, the direct implementation of projects under water resource management and conservation is limited, departments like Land Resources, Soil and Water Conservation Department, MNREGA, Ministry of Drinking Water & Sanitation Department, Irrigation & Water Resources Department, Agriculture Department, and IWMP take initiatives of collecting rainwater and led rainwater harvesting structures under different heads. These are still working hand in hand with the objectives to manage water resources for agricultural development and control of soil erosion. In every action taken active participation of people, Community-based NGOs, and society-based organizations is important in the execution of plans and strategies.

6.2. Management of Water Resource

Water management is the process of planning, developing, and managing water resources. The study and evaluation of water resource management can be divided into two distinct levels. The first level known as external management refers to the central objectives of the water manager and actual tasks that are directly aimed at the sustainable use of water resources, the allocation of clean water to different sectors of society, flood management and protection, etc. Management at the second level focuses on management organization and the process itself. Management at the second level known as internal management questions the objectives, the institutional structure, the operational standard, and the systems. Institutional efficiency and effectiveness in water resource management are an important concern.

Consideration of the water resources in totality (i.e., surface water and groundwater) is important, rather than managing surface water and groundwater separately. Three distinct actions are required viz. water conservation and management of water across geographies, ecological consideration, and reduction of demands. The field observation reveals that water resource management within the study area is identified in rainwater management, which is directly linked with the collection, use, and management of rainwater in traditional systems, groundwater management through spring shed development, afforestation, and dug pits for groundwater recharge, control of flash flood and grey water management at the household level.

6.2.1. Rainwater Management

The Upper Tuirial Watershed area received 2022.5 mm annually for a period of 23 years i.e., from 2000-2022. While the annual rainfall in 2022 is 2015.1 mm. Even though the data shows declining trends, the amount of annual rainfall received in the study area is practically having a high potential for rainwater if managed properly. However, of the total rainfall received, a higher percentage is wasted due to surface run-off and leaching and a very small amount remains available for use. To utilize the abundant rainfall, the construction of farm ponds and water storage structures for both crop and household use was taken up. The work was taken out and monitored by the district administration through MNREGA, Dept. of Irrigation, IWDP, and Agriculture Dept. etc. in the whole region.

Rainwater harvesting is the most important method for the conservation and management of water resources. The State Government proposed different rainwater management techniques including traditional water harvesting methods, which are generally convenient for the population. The techniques that are feasible for the study area may cover domestic rooftop harvesting, the construction of a water harvesting tank, and the construction of a dam or pond to collect runoff at a convenient site or at a small river channel. Rain Water Harvesting scheme was implemented under the Water Policy of Mizoram 2020 and Jal Shakti Abhiyan: Catch the Rain, 2021 to retain a sufficient amount of rain water.

6.2.1.1. Rooftop Water Harvesting

Traditionally, rainwater is harvested from a rooftop using gutters, channelling into downspouts, and then into a storage vessel, most commonly known as a rain barrel. The rainwater collected is used as potable water for the household. After the breaking of the monsoon in late April, rainwater is the main source of water for domestic consumption. The locational factor plays an important role in the potable nature of rainwater in the study area. In areas with minimal industries and favorable environmental conditions enjoyed in the state as a whole, rainwater is potable in many areas including the Upper Tuirial Watershed Area.

Table 6.1 shows the average 27.9 % harvest of rainwater from rooftops, resulting in more than 70% of rooftops wasted as runoff every year. This is due to the fact that storage facilities are deficient in the household. The backward economy cannot afford to buy rainwater storage structures and storage facilities. On the other side, the insignificant collection of rainwater is due to ignorance and negligence of the importance of rainwater harvesting. From the projected norms of 55lpcd under Jal Jeevan Mission, a person's consumption within a month will become 1650 liters/month (taking 30 days a month). Then, in order to cope with the consumption at least a reservoir of at least 2000 liters capacity is necessary.

Table 6.1: Rooftop Rainwater Harvesting Practice. Source-Author.

Sl. No	Village	Total Household	Surveyed Household	% of Surveyed Household	%of Household RWH practice
1	Seling	547	140	25.5	20
2.	Thingsulthliah	805	200	24.8	30
3.	Phulmawi	70	30	42.8	5
4.	Khumtung	263	80	30.4	30
5.	Baktawng	686	170	24.7	27
6.	Chawilung	120	50	41.6	15
7.	Lamchhip	180	50	27.7	17
8.	Kelsih	220	60	27.2	35

9.	Aibawk	410	100	24.3	37
10.	Thiak	209	60	28.7	10
11.	Hualnghmun	206	60	29.1	42
12.	Muthi	224	60	26.7	50
13.	Sesawng	847	200	23.6	45
	TOTAL	**4787**	**1260**	**26.32**	**27.9%**

Further, in every village, a Village Forest Conservation Committee and Water and Sanitation Committee (WATSAN) were set up in coordination with Public Health Engineering Department (PHED) staff to look after the village-level domestic water demand, consumption, and management. The villagers now preserve and conserve water even at their household level by not wasting any water. In some villages, all households have a proper roof-top rainwater harvesting system and at least 2000 liters capacity reservoir.

A B

Plate 6.1: A) Traditional Rooftop rainwater harvesting, Baktawng. B) Farm Pond under MGNREGS, Aibawk. Source: Author

6.2.1.2. Rainfall Runoff Management

The study area is characterized by hilly terrain and steep slopes, when the rain falls on the surface, it quickly drains along the slopes towards the lower level into the rivers as a rapid runoff. These fast movements of rainwater cause soil erosion, gully erosion, and debris transportation in many places of the area. The control and retention of rainwater runoff are crucial in heavy rainfall areas, especially in the study areas. The different methods and systems like contour bunding, planting of trees, and dug pits along the contour lines are proposed through the Department of Forest, Minor Irrigation Department, PMKSY and MNREGA which are in progress. Pit-dug systems are also practiced in Aibawk and adjacent villages. Retention of runoff has two effects; in one way it recharges groundwater enhancing spring water sources in many areas with favourable landforms. The adverse effect of high moisture content in the hilly topography with loose soil sometimes triggered landslides in the study area. Thus, rainfall-runoff management methods and systems should be carried out in accordance with the physio-hydrological, soil characteristics, and geological formation of the area.

Table 6.2: Construction of Farm Pond and Fish Ponds in the Selected Villages. Source: Computed by author based on field survey.

Sl. No.	Village	Total number of farm ponds constructed	Total No. of Fish Pond constructed
1.	Seling	26	7
2.	Thingsul	39	12
3.	Phulmawi	18	4
4.	Khumtung	34	13
5.	Baktawng	42	15

6.	Chawilung	16	8
7.	Lamchhip	35	14
8.	Kelsih	40	10
9.	Aibawk	32	11
10.	Thiak	27	9
11.	Hualngohmun	24	8
12.	Muthi	36	11
13.	Sesawng	42	14

6.2.2. River Water Management

The hard work and sacrifices of different local NGOs for protecting the riverine ecosystem, especially fish, is revered, yet managing the river as a whole is minimal. Upper Tuirial Watershed is drained by many perennial rivers of potable quality, which are needed to conserve their potential. The community's active participation in terms of the level of extracting resources and exploitation of its potential is needed in order to manage and it is high time to take action regarding source region pollution control, afforestation, and conservation and protection of its ecosystem from human encroachment. From the field survey, the management and conservation of rivers in the study are taken at the local level only.

6.2.3. Spring Water Management

Springwater is the most important potential water resource during the dry season, of which more than 40% of the village's domestic water consumption, directly and indirectly, depends on winter when there is no or less rainfall. The young folded physiographic structure with numerous structural trends, lineaments and faults encourages the formation of aquifers in shallow areas, which supported numerous spring sources in the study area. Normally, each village usually has more than 10 perennial springs with many seasonal springs. Spring-shed management is hailed as one of the key objectives in the State Action Plan on Climate Change (SAPCC) and the State Water Policy of Mizoram. Started in 2018, the initiative was undertaken under the auspices of Indo-German bilateral cooperation. The German development co-operation agency GIZ is supporting spring-shed development and management as a climate adaptation measure in Mizoram. For this, the program covers two aspects — one on recharging aquifers through soil and water conservation structures in targeted groundwater recharge zones identified through hydro-geological assessment, and the other on preparation of participatory village water security plans. The work is being done in partnership with various state departments and a consortium of NGOs.

Plate 6.2: A) Spring shed under PMKSY, Hmuifang. B) Spring shed under LAD, Thingsulthliah. Source: Author

The program has worked to align the construction of conservation structures with welfare schemes such as the Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) and the National Rural Drinking Water Programme (NRDWP). GIZ has supported the building of trenches, recharge ponds, percolation pits and water storage structures, Gabien rocks and check dams to prevent runoff and increase groundwater recharge in the hilly areas like Upper Tuirial Watershed Region. Such initiative covers Sumsuih, Sihphir, Lamchhip, Hmuifang, and Chamring villages, demonstrating that community-led conservation efforts could ensure water security around the year. Encouraged by the results of spring-shed development, Mizoram is aiming at upscaling the work to larger areas, with support from the centrally sponsored National Adaptation Fund for Climate Change (NAFCC).

6.2.4. Groundwater Management

Groundwater is mainly recharged through rainfall infiltration, the type of vegetation cover, the type of soil, and physiography influence the level of natural input to the aquifer. The flow of water vertically across the aquifer system, lateral flow of water along the aquifer system, transpiration, evaporation, and base flow are other important components. The study of specific groundwater recharge through groundwater fluctuation level and specific yield approach provides the desirable result for the groundwater status, however, it is a time-consuming and expensive method. During non-monsoon season, groundwater recharge may be estimated using the rainfall infiltration factor method. Such studies would help bring out the efficacy of various management interventions on the groundwater regime.

Due to the unavailability of data, groundwater management within the study area is impossible to access. Traditionally, planting trees and wild bananas are common method usually suggested for the management of groundwater recharge. By keeping the recharge areas covered with vegetation, villagers usually manage the level of ground aquifers. The construction of permanent water retention structures dug pits, and canal seepage methods for the recharge of groundwater is also introduced recently. However, better management of groundwater requires a scientific understanding of hydrogeology. Such an approach determines the type, structure, and properties of rock, their faults, fractures, and folds, which helps in determining the storage and transmission capacity of water-bearing rocks, or aquifers. It is also pertinent to add that as it is advisable to restrict groundwater development as far as possible to annual replenishable resources, the categorization also takes into account the relation between annual replenishment and groundwater development. An area devoid of groundwater potential may not be considered for development and may remain safe whereas an area with good groundwater potential may be developed and may become over-exploited over a period of time. Thus, water augmentation efforts can be successful in such areas, where the groundwater potential is high and there is scope for augmentation.

6.2.5. Flash Flood Management

Rapid downpours during monsoon cause rapid runoff in the hilly region like the study area. Which flooded the hilly riverine system. Contour bunding, Check dams and Terraces (Bench, Logwood bunding, Half-moon, etc.), are proposed by the state government to control rapid runoff during heavy rainfall season.

A B

Plate 6.3: A. Diverting spring with pipe for use in agriculture, Lamchhip. B.Contour Bunding for control of rapid runoff & soil erosion, Khumtung. Source: Author

6.2.6. Grey Water Management

Greywater refers to domestic wastewater without fecal contamination. Sources for greywater include tanks, baths, showers, washing machines, dishwashers – basically, any household water except the toilet. Greywater passes through a coarse filter to remove large dirt particles. Then, it is aerated in a treatment buffer tank. Finally, the water passes through a BMT (Berghof Membrane Technology) filter into a storage tank, where it can be used again in the home. Lack of technology and infrastructure, grey-water management is practiced at the household level in small numbers by directly used in household gardens, without chemically treating the wastewater.

6.2.7. Water Demand Management

Demand for water can be managed in many ways, which may range from proper scientific and social rationale to scope and focus for the present study area, we can consider five options; water rights, water market, water pricing, water saving technologies, and community-based user organization. The right to access water and its management is the responsibility of a citizen, recognizing the rights directly implies the duty for and against pollution and over-utilization of regional water resources. Due to ongoing demand, water is exploited in many ways, the supply of water and rates of charges are different in many areas, which may be affected by the source region, the discharge level and development, the water market, and water pricing systems should be regularised. Water-saving technologies and practices are the most effective method for controlling demand, for example, a surplus supply of water does not increase crop production as well as does not necessarily lead to the efficiency of water in domestic consumption. For the awareness of water resource potential and its implementation community-based organizations are efficient in many levels of operation. From the field observation, demand-side management can be effectively controlled through rainwater management and greywater management at the household level.

To ensure all rural and urban households' access to and use safe drinking water and sanitation facilities on a sustainable basis, the domestic demand for water is managed by the Department of Public Health Engineering, Government of Mizoram by Pumping or lifting water from rivers. Construction of reservoirs and channeling of water pipes from sources to public water points and private connections are also managed by the department. Water meters and feasible time fixing as well as liter per household distribution are applied for even distribution to the consumers. They keep track of water usage, fix leaks, and even give additional connections as per consumption of the area. Keeping track of water usage allows households to cut down on unnecessary use, thus saving water and money!

Apart from PHED, Water Users Associations (WUAs)/ Village WATSAN Committees are setting up to assist statutory powers to collect and retain a portion of water charges for managing the volumetric quantum of water allotted to the village and maintaining the distribution system in their jurisdiction. The water demand of the study area is also assisted by private water carriage trucks, on a call basis in times of need and emergencies

6.2.8. Water Supply and Sanitation Management

The PHED takes initiatives in water supply and sanitation management. Village in the study area is located in the ridgeline of the catchment area, thus, water supply is needed to lift water employing more than two reservoirs in order to distribute the water by gravity. This includes exhaustive management of multiple reservoirs and pipelines of more than three kilometers long in landslide-prone areas of steep slopes and thick vegetation. The average distribution of water to households meets 30.11lpcd (Table 5.4) during the dry season with more than 60lpcd during the rainy season. It is opined that the ability of the ability of water pricing to influence water use is severely limited, both by the supportive and technical systems applied by the users and enforcement systems. The most critical situation is that, despite the cost recovery focus by the government pricing, the water rates were able to cover no more than 40% of the cost in the current situation. Although water rates are relatively higher, they are also related more to average pumping costs than to water productivity. Although pricing policy is ineffective, supply regulations are effective in raising water-use efficiency.

Human wastes easily pollute the rivers at lower altitudes. Solid waste and debris are generally brought down to the river by runoff. The management of waste disposal, especially at the water source region in particular and for the river ecosystem in general, is important for clean water resource availability in the long run. The present scenario during the field survey confirms minimal management of waste disposal in the study area. Chite Lui becomes the most polluted with as high as 206 mg/L dissolved solids. Construction of river socks and embarkment will be necessary in the suitable location of the river.

Privately owned water trucks also help in the management of water distribution during emergencies and on-call basis. The Mizoram Water Supplies (Control) (Amendment) Rules 2011, sub-rule 30 of rule 7 states that all drinking water supplies through private truck carriage operated must be disinfected by adding requisite quantity of disinfectant like Bleaching Powder solution, Sodium Hydrochloride solution or any other convenient disinfectant at the level of 0.2 PPM (0.2 mg/litre0 after contact period of 30 minutes or as per IS 10500 or and as per World Health Organization's norms.

6.3. Conservation of Water Resources

The preservation, judicious use, and development of water resources, both surface water and groundwater as well as preventing water pollution is referred to as water resource conservation. Water conservation activities and actions understand the importance of water thereby using water efficiently to reduce unnecessary water usage and avoid its wastage, this will refer to control over exploitation of water resources. It encloses the various policies, strategies, and activities to use water as a sustainable resource and to safeguard the depletion of the water environment. The main objectives of water resource conservation include sustainable use of water resources and reduction of energy consumption.

Due to the increase in build-up area, rivers in the study area suffer from pollution of human waste and sediments from road construction. This affects the riverine ecosystem and drastically decreases the population of riverine animal species and the volume of water. The Mizoram Water Supplies (Control) (Amendment) Rules 2011, of rule 6 empowered the Department of Public Health Engineering (PHED) the right to preserve, protect, and reserve any water sources including groundwater within the catchment areas that prohibit any activities which can cause depletion, contamination and pollution of water in the catchment areas of the reserved sources or even utilization of water from the reserved sources without prior permission of the Department. Offending may be punishable under Rule 17 (5) of the Mizoram Water Supplies (Control) Act, 2004.

The conservation of water resources in the Upper Tuirial Watershed is observed as below.

6.3.1. Conservation of Chite Lui/River: The Chite Lui Act, 2018

Chite Lui/River originates at Bawngkawn, Aizawl and flows towards southeast till its confluence with the Tuirial River thereby covering the entire length estimated to be around 18 km. The location of the capital city, Aizawl at the source region is the main region of Chite Lui pollution in many cases. The plight of Chite Lui was first taken up in 2007 by Zoram Research Foundation (ZRF), a grassroots organization working with local communities on livelihood and traditional water management in Mizoram. On June 2, 2017, the Save Chite Lui Coordination Committee (SCLCC) was constituted by the state government with the state governor as its patron member. Subsequently, the Save Chite Lui Action Plan (SCALP) came into force whose main objective was to create awareness among the people regarding the river by undertaking various awareness campaigns and also to build check dams and other techniques to prevent the waste from flowing into the river.

In October 2017, scientists and scholars from the University of Minnesota and the Mississippi Watershed Management Organization (MWMO) conducted a survey of Chite Lui. They did a comprehensive study of the river and provided suggestions and guidance for the conservation and restoration of the river. Subsequently, A study done by the Mizoram Pollution Control Board (MPCB) found the oxygen level in the river to be 3.1 mg per liter against the desired level of 6 mg per liter (October 2018). The state government, fully aware of the sentiments attached to the river passed the Chite Lui (Prevention and Control of Water Pollution) Act, 2018 in this year, for the prevention and control of water pollution in Chite Lui including the river bank on both sides (50 meters from the boundary of the river) and the maintaining or restoring of wholesomeness of the entire river course, that prohibited the dumping of animal carcasses, bio-medical waste or any garbage and made the violation of offense as cognizable and non-bailable offence.

6.3.2. Ground Water Conservation

Planting trees and fault line protection where rainwater may percolate and recharge groundwater is the traditional method for the conservation of groundwater. Apart from this afforestation and control of human encroachment on land are also important methods for conservation practice in the study area. With the advancement in technology, private extraction of groundwater for commercial and private consumption has been introduced recently. This haphazard drilling of sub-surface formation of groundwater can have a negative effect like land subsidence, and reduction of water in the other sources like springs, streams, lakes, etc. Excessive pumping can lower the groundwater table and cause wells to no longer be able to reach groundwater. Therefore, the use or utilization of water from the reserve source region within the jurisdiction of the PHE Department is punishable under The Mizoram Water Supplies (Control) Rules, 2006.

6.3.3. Forest Conservation:

Forest Conservation is the most important and effective strategy to conserve potential water resources. Soil moisture retention, groundwater recharge, rainfall regularity and control of runoff and stormwater are all related to forest management. It is estimated that Mizoram loses approximately 50,000 ha of forest area every year due to shifting cultivation practices and other activities. The ever-deteriorating forests and vegetative covers in the headwater catchment areas greatly encourage higher runoff rates and soil erosion that negate recharge to the groundwater system resulting in less availability of water in the downstream areas. Under a CAMPA, MGNREGA, and PMKSY funding scheme, village forest conservation activities like planting and maintenance of trees and protection of water sources were undertaken and each village was given check dams.

6.4. Policies for Water Resource Management and Conservation

Water Conservation policies and Campaigns are important initiatives of the government to promote water conservation practices throughout the country, some of the related programs are highlighted as under;

1 The Mizoram State Water Policy 2020:

The basic principles for the Mizoram State Water Policy, 2020 is to plan, develop, and manage water resources keeping in view the need to be governed by a common integrated perspective considering local, regional, State, and national context.

2. The State-Specific Action Plans (SSAPs):

It was thought of as a comprehensive policy for integrated water resource management to be developed in each state/UT to promote a sustainable outlook on water governance aligned with the State Action Plan on Climate Change (SAPCCs) formulated by the States under the National Action Plan for Climate Change (NAPCC). The 'Framework for SSAP for the Water Sector' was developed in 2015 and consequently, SSAPs were taken up as a strategy in 2016 under the 5th Goal which aims to promote basin-level integrated water resource management. Under this strategy, Mizoram State falls under the North-Eastern Regional Institute of Water and Land Management (NERIWALM)

3. Jal Jeevan Mission (JJM) 2019:

The government of India, in partnership with the State Government, is implementing the Jal Jeevan Mission (JJM) to make provision for clean tap water supply to every rural household in the country by 2024.

4. Jal Shakti Abhiyan 2022:

For preparing the District Level Scientific Water Conservation Plans under the 'Jal Shakti Abhiyan: Catch the Rain', the two main tasks as mentioned below are carried out by the districts using geospatial tools like Q-GIS/Arc GIS/ERDAS tools and satellite data; First, to identify and prepare an inventory of existing water bodies/WHS and Second, identify locations for new water bodies/WHS locations. The third in the series of JSAs, campaign was launched on 29.3.2022 to cover rural and urban blocks and districts across the country. The focused interventions of the campaign include water conservation and rainwater harvesting, enumerating, geo-tagging, and making an inventory of all water bodies; preparation of scientific plans for water conservation based on it, Setting up of Jal Shakti Kendra's in all districts, intensive afforestation and awareness generation.

5. Pradhan Mantri Krishi Sinchayee Yojana (PMKSY):

Launched on 1st July 2015 with the motto of "Har Khet Ko Paani", the Pradhan Mantri Krishi Sinchayee Yojana (PMKSY) is being implemented to expand cultivated areas with assured irrigation, reduce wastage of water and improve water use efficiency. PMKSY not only focuses on creating sources for assured irrigation but also creates protective irrigation by harnessing rainwater at the micro level through "Jal Sanchay" and "Jal Sinchan". Micro irrigation is also incentivized through subsidy to ensure "Per drop-More crop". Under the PMKSY Water Harvesting System like Construction of Community tanks, on-farm ponds, check dams, and reservoirs as well as the construction of Tube Wells / Bore Wells (Shallow/Medium) Restoration and Renovation of spring-shed were taken out with different levels in the study area.

6. Command Area Development and Water Management (CADWM) Programme:

it has been brought under PMKSY – 'Har Khet Ko Pani' from 2015-16 onwards. The main objective of taking up CAD works is to enhance the utilization of irrigation potential created and improve agriculture production on a sustainable basis through Participatory Irrigation Management (PIM).

7. Mission Amrit Sarovar:

The Mission Amrit Sarovar was launched on National Panchayati Raj Day on 24 April 2022 as a part of the celebration of Azadi ka Amrit Mahotsav with an objective to conserve water for the future. The Mission is aimed at developing and rejuvenating 75 water bodies in each district of the country.

8. Bureau of Water Use Efficiency (BWUE)

The Bureau of Water Use Efficiency (BWUE) has been set up for the promotion, regulation, and control of efficient use of water in irrigation, industrial and domestic sectors. The Bureau will be a facilitator for the promotion of improving water use efficiency across various sectors namely irrigation, drinking water supply, power generation, industries, etc., in the country.

9. Awareness Generation Campaign:

An awareness generation campaign in collaboration with Nehru Yuva Kendra Sanghathan (NYKS) was launched on 21st December 2020 jointly by the Minister of Jal Shakti and the Minister of Youth Affairs & Sports. NYKS has been implementing the awareness generation campaign in the country since then. NYKS has engaged over 3.82 crore people in 36.60 lakh activities in the campaign through their many activities like rallies, Jal Choupals, quizzes, debates, slogan writing competitions, wall writings, etc.

10. Public Interaction Programs (PIP)

Public Interaction Programs (PIP) are being organized at the grassroots level to disseminate the outputs of National Aquifer Mapping and Management (NAQUIM) Studies for the benefit of the stakeholders. So far, 1300 such programs have been conducted in different parts of the country in which nearly one lakh people have participated.

11. National Water Awards and Water Heroes

Department of Water Resources, RD& GR has instituted National Water Awards and Water Heroes – "Share your Stories contest" to incentivize good practices in water conservation and groundwater recharge.

12. Information, Education & Communication (IEC) scheme of DoWR, RD & GR

Mass awareness programs (Training, Seminars, Workshops, Exhibitions, Trade Fares, Painting Competitions, etc.) are conducted from time to time each year under the Information, Education & Communication (IEC) scheme of DoWR, RD & GR in various parts of the country to promote rainwater harvesting and artificial recharge to groundwater.

6.5. Discussions and Conclusion

Recognizing that water resources management provides concepts and principles for the sustainable management of water resources the question arises of how to decide what measures and methods to put in place. What should be changed in the way we manage water resources available and what are the implications of the proposed changes? The planning and management of the resource is to be done on a holistic approach whereby the human, social, and economic needs are to be met giving priority to an environmentally sound basis. The desirable strategy should go beyond solving the current problems or achieve short-term objectives and formulate a clear long-term framework to achieve sustainable management and development of water resources. A policy (or a vision) is often the starting point for a statement of intent that seeks to meet certain goals through specific investments. In practice, starting with concrete issues can yield better results. Being too ambitious at the outset can result in a strategy that looks great on paper but doesn't translate into doable actions. It is noted that major initial reforms are not essential to catalyzing change, first steps that can easily be implemented are often enough to begin the process of moving towards more sustainable water development and management.

It is imperative that communities and watersheds take on the challenge of managing land and water systems in a way that maximizes their benefits and enhances human security. By doing so, we can ensure the preservation of these critical components of our ecosystem and secure a sustainable future for ourselves and future generations. In the present study, different approaches have been adopted to assess the potential status of water resources in the study area. The conclusions and suggestions will be based on the focus area only and may not be applied to other areas.

6.5.1. Policies Suggested for Management of Potential Water Resources

This module will address the potential water resources decisions, the water supply and demand decisions, and the implementation decisions of the Upper Tuirial Watershed Study Area.

6.5.1.1. Relating to the Management Principles

The principles include management within hydrological units (catchments), decentralization of responsibilities to the lowest appropriate level, participatory management and decision-making including gender mainstreaming, cooperative governance, and stakeholder consultations on strategies for policies and legislation. The development of an effective monitoring network is also crucial.

6.5.1.2. Relating to the Management of Rainwater Potential

It is opined that the amount of rainfall is sufficient to meet the domestic demand for water, including four months of lean period in a year. The following are suggested:

i) Provisions for compulsory rainwater harvesting to private and government buildings.

ii) Practice of runoff retention for groundwater recharge, vegetation, and ecological balance.

iii) Sub-surface reservoir located in a suitable hydrogeological situation for storing surplus monsoon runoff.

iv) Construction of rainfall-runoff retention structures like terraces, contour bunds, pits, etc. in a suitable place.

v) Maintenance of catchment areas, gutter and downspouts, storage tanks, water treatment, and the delivery systems of treated rainwater.

vi) Designing of settlement tank for optimum capacity should consider the catchment area, intensity of rainfall, the base structure, and the number of persons to support.

6.5.1.3. Relating to the Management of River Water Potential

The potential of a river may be diverse according to locational, climatic, and institutional control the river regime. In some cases, the possibility of hydro-power potential, industrial development potential, etc. may be highlighted, apart from that the study area may not be feasible for setting up large hydropower dam or forest-based industries, but the potential for human and environmental aspects is greater, some of the suggested policy is as under;

i) Diversion of river water through channels for agriculture.

ii) Development of Fisheries and Animal Husbandry along and within the river.

iii) Control of over-exploitation and other activities relating to the collection of river sand and activities deteriorating river ecology.

iv) Community participation relating to checking or control of hostile activities for river ecology like poisoning, bombing, etc. by creating Protected Areas and planning for Fishing Season.

v) Installation of river water monitoring instruments. Selection of the appropriate instrument will depend on the station purpose, presence of existing infrastructure (e.g., stilling well, bridge), distance to the water, desired accuracy, sedimentation rate, access, and cost.

6.5.1.4. Relating to the Management of Groundwater Potential

i) Installation of a groundwater monitoring well in a geo-hydrological unit to measure groundwater levels and water quality. Monitoring groundwater is performed to characterize groundwater quantity and quality in order to address issues regarding the proper assessment and protection of groundwater resources.

ii) Conservation of forests in any form including afforestation also helps in groundwater recharge and conservation.

iii) Spring source development is one of the most important factors for the management of groundwater.

iv) Contour Bunding, Dug Pit, etc. should be constructed to retain runoff for recharge of groundwater.

v) Control of drilling and excessive exploitation of groundwater.

vi) Encouragement of bore well and natural tank in any suitable location.

6.5.1.5. Relating to the Management of Greywater Potential

i) Wastewater from households (Greywater) should be filtered for use in the garden.

ii) Wastewater should be stored and used as groundwater recharge or be used in any other possible ways.

6.5.1.6. Relating to the Management of Water Supply and Water Demand

The main focus will be on the government supply of water and Domestic water demand within the study area.

i) Maintenance of pipelines and repairing system should be monitored, timely replacement of old pipelines is necessary to maintain water quality, reduction of water loss during transactions, and timely supply of water to consumers.

ii) Proper Monitoring of water source area in order to detect siltation, debris accumulation, and other factors that may be harmful to the operation of machines.

iii) Pricing of water relies upon the value of water to the consumer, but a proper meter should be installed to avoid false readings leading to overpricing.

iv) Domestic consumption patterns should be aware for utilizing clean water, the Indian system of flushing (bucket flushing) should be encouraged.

v) Leakage of domestic pipelines, and improper installation of taps should be monitored with the more efficient ways of using water as far as possible.

6.5.1.7. Relating to the Management of Pollution and Sanitation

Water is polluted in many ways, source pollution, storage pollution, and transaction pollution are the major factors in the study area. Rainfall pollution is recorded during the first flush of monsoon rain only, the majority of water pollution is related to river pollution and storage pollution.

i) Setting up of monitoring network and DMS (Data management System) construction, data collection ensues geographical and space-oriented data, time-oriented data (e.g., time series of meteorological, climatic, water quantity, water quality, and sediment data), and relation-oriented data (e.g., processed data and analysis). The process should be repeated after periodic reviews of requirements.

ii) Control and regulation of waste disposal especially in the study are necessary. Any form of waste and debris are transported towards the river contaminating and lowering the quality of the river water.

iii) Financial sustainability for water resources management is necessary, the full cost recovery within the management system, and users and polluters pay for the services. Charges and tariffs, subsidies, incentives, and disincentives are possible keys.

6.5.1.8. Relating to the Management of Minimum Environmental and Ecological Needs

i) Control Shifting cultivation as far as possible, if practiced, the ecologically friendly method of contour bunding, laying fell trees along contour lines, etc. should be applied or followed.

ii) Monitoring Temporal and spatial variability of the river flow, determined by climatic features like precipitation pattern in the catchment, evapotranspiration, and physiographic features of the river basin, like size, slope, shape, soils, land use, and drainage characteristics for planning the watershed ecological needs.

6.5.1.9. Relating to Awareness and Campaign

Due to ignorance and unawareness of the water resource potential, management and conservation of water is very limited. As discussed earlier, over-dependence on the government water supply adversely affects the level of rainwater harvesting. Keeping aside the financial deficiencies, setting up a proportional storage tank for family members is necessary at the first level which will be followed by the installation of a reliable gutter system.

i) Integrated campaign and interaction regarding problem or problem-solving interaction is necessary

ii) An integrated study of water resources at the village level is needed.

iii) Training to the community regarding principles, mechanization, and utilization of water resources, especially rainwater harvesting systems should be implemented at least two (2) times in a year.

The present study assumed that Rooftop Rainwater harvesting is an alternative water supply source and is recommended, while the financial constraints to install large-sized storage tanks are considered as a possible challenge. Thus, future research is needed to investigate the cost-benefit balance along with the invention of a cheap storage tank as they may affect the potential contribution of Rain Water Harvesting from rooftops. The variability in the availability of water because of climate change should be dealt with by incorporating appropriate water storage in various forms, namely, soil moisture, ponds, groundwater, small and large reservoirs, and their combination. The state should be incentivized to increase water storage capacity, which inter-alia should include the revival of traditional water harvesting structures and water bodies.

6.6. Conclusions

Water is a fundamental building block of life and an essential resource for healthy, stable, and sustainable societies. Scarcity can disrupt social stability, hamper economic prosperity, and damage ecosystems. The data from this year's Composite Water Management Index indicates that Indian states have made progress in water management. However, there is still a long way to go in order to improve the quality of life for citizens, support economic growth, and sustain ecosystems on a long-term basis. A focus on developing new systems or sources rather than managing existing ones, and top-down sector approaches to water management result in uncoordinated development and management of the resource. Numerous implementations of development projects mean greater impacts on the environment. The different Management and Conservation policies, projects, schemes, and programs described above are just a few of the different systems developed in accordance with the varied climatic, topographic, and geological conditions. By understanding that precipitation is asymmetric and available only for a few months of the year only a small portion is stored naturally, and the functions of the watershed that rainwater is distributed, such as surface runoff, soil moisture, and groundwater reserves. Analyzing these core structure enables us to understand the limitations of the area-specific water cycle and its components and help us identify sustainable ways to manage water.

The option in functional linkages and the institutional character of the demand management underline the need for the strategy to treat these strategies as an interrelated configuration functioning within an institutional structure, characterized by the overall legal, policy, and organizational factors. The current concerns demand improved management of water resources to cope with the more intense scarcity of water during the dry season, that only a combination of disciplines including culture, tradition, climate, and forest, land, and water engineering can help manage water sustainably; and that surface water (blue water) sources cannot be sustained if 'green water' i.e., water held in the soil available for plants and vegetation, is degraded. The sustainability of blue water sources depends on what fraction of rainwater has gone into the groundwater. This is where managing rainwater in upland areas becomes important for maintaining both green and blue water sources. Meaningful intensive participation, transparency and accountability should guide decision-making and regulation of water resources. Without forgetting that the traditional water harvesting systems carry a wealth of wisdom. In view of the present study watershed area, the participatory approach of the water resource management scheme is suggested.

References

Asian Development Research Institute (ADRI) (2017). Water Resources Management.

Central Groundwater Board, Guwahati (2021). Dynamic Groundwater Resources of Mizoram (As of March 2020).

Goswami, S. and Guha, S. (July 23, 2012). Status of Water Resources in Mizoram: Institutions and Management Practices. *The IUP Journal of Environmental Sciences*, Vol. V, No. 4, pp. 7-20, SSRN: https://ssrn.com/abstract=2115352

Government of India (2008). Common Guidelines for Watershed Development.

Government of India (2009). Ministry of Water Resources. Guidelines for Repair, Renovation and Restoration of Water Bodies with Domestic Support.

Government of India (2013). Ministry of Drinking Water & Sanitation. National Rural Drinking Water Programme Guidelines – 2013

Government of Mizoram (2018). Citizens' Charter for Public Health Engineering Department.

Government of Mizoram, Irrigation & Water Resources Department (May, 2020). E-book on Achievements of Irrigation & Water Resources Department, 2019-2020.

Government of Mizoram, Land Resources & Soil and Water Conservation Department (2020). Achievement Report 2019-2020.

Healy R.W., Winter T.C., Baugh J.W.L. and Franke O.L. (2007). Water Budgets: Foundations for Effective Water-Resources and Environmental Management. U.S. Geological Survey, Reston, Virginia. http://osufacts.okstate**.**

Hofer T. (2006). The new generation of watershed management programmes and projects.

Jain S.K. (Aug, 2019). Water resources management in India – challenges and the way forward. *Current Science*. Vol. 117 (4). Pp. 569-576.

Khadse G.K., Labhasetwar P.K., Wate S.R. (Oct, 2012). Water resource management: an Indian perspective. Journal Of Environmental Science Engineering. Vol-54(4): pp. 577-591.

Lily A., Peters H. and Chang H (2011). Urban water demand modelling: Review of concepts, methods, and organizing principles. *Water resources research*. Vol. 47, Pp 1-15

Loucks D.P. & Beek E.V. (2017). Water Resource Systems, Planning and Management, An overview. pp 1-48. Link (http://creativecommons.org /licenses/by-nc/4.0/)

Ministry of Jal Shakti (21 March, 2022). Initiatives taken for Water Conservation. PIB New Delhi.

Ministry of Jal Shakti, National Water Mission (2021). Guidelines for Preparation of GIS-Based Water Conservation Plans and Inventory of Water Bodies for Districts Under "*Jal Shakti Abhiyan: Catch the Rain*" Campaign.

P. C. Swain (2016) Water Resources Systems Planning & Management. Department Of Civil Engineering. VSSUT, Burla.

Ragunath H.M. (2006). Hydrology, Principles. Analysis. Design. New Age International(P) Limited, Publishers.

Rakhecha P.R. (2019). Management of Water Resources in India. International Journal of Hydrology. Vol3(5). Pp. 354-360. DOI: 10.15406/ijh.2019.03.00200

SIPMIU (2015) North-Eastern Region Capital Cities Development Investment Program (Tranche 2) – *Aizawl Water Supply and Sewerage Subproject*. Link; http://www.adb.org / sites/default/files/ project-document/ 60163/35290-033-ind-see-06.pdf

The Mizoram Gazette (2020), Mizoram State Water Policy 2020. Vol XLIX Issue. 637. Mizoram Government Press.

The World Bank (2019). Helping India Manage Its Complex Water Resources

Verma R. (2019). Role of Watershed Development in the Sustainable Growth: A Case Study of Mizoram. https://www.researchgate.net/ publication /281851907

Chapter – 7

Conclusion

7.1. Introduction

Rational water management should be founded upon a thorough understanding of water availability and its potential. Thus, as a contribution to the practical solution of water problems, the present research is directed towards the assessment of water resource potential and its management in the Upper Tuirial Watershed, Mizoram. The assessment perspective of socioeconomic as well as ecological conditions of the upper Tuirial Watershed highlights the positive aspects of water resources available in the area. It concluded that there is a potentiality of water available for human use and the region is blessed with water resources but a long way to reach the development stage to generate water potential. The potential water resources refer to the amount of water available in a given area, while taking into account existing limitations beyond the area. These restrictions, which are usually expressed are ensuring to maintenance of minimum quality standards in river reaches and aquifers, keeping minimum surface or groundwater flows to the sea, in order to maintain the rich and diverse biological habitats, preventing marine intrusion, ensuring that aquifers do not fall below a minimum level, etc. and the need to make sure that the flow does not fall below a minimum and has an acceptable quality when the water crosses a frontier. The exploitable water resource is the portion of the potential water resource that can be utilized under specific technical and economic conditions. These conditions are established by the characteristics of the demand that needs to be fulfilled. The definition's relative nature is evident since the technical and/or economic validity of certain systems determines their level of use which varies as a function of several factors like the technical and economic potential of the country, the economic importance of the demand, etc.

The availability of clean water is essential for human development and life. The water reserves are the natural volumes of water that exist in a specific area on a particular date. These include surface volumes, such as rivers, lakes, and snow, as well as groundwater stored in aquifers. The reserves fluctuate over time based on the differences between inflows and outflows. The reserves that exist in a system throughout a period that is sufficiently long to be considered representative, are taken to be the average reserves. It is important for a period to have roughly equal inflows and outflows to maintain balance. The renewable water resources in a territory are equivalent to the total yield. In physical terms, non-renewable water resources refer to the amount of water obtained by depleting the reserves in surface or groundwater systems. Non-renewable resources are characterized by the fact that they can only be used once during the period considered.

The basic objectives of water resource management are to make available, on a reliable basis, water of sufficient quantity and quality to meet abstractive needs of human habitats, and to preserve requirements for water in rivers, lakes, aquifers, and ecological needs. It further extended to develop and manage effluents arising from human use of water. Because of limited potential and unlimited demands, the balance between demand and supply interests is bound to arise. Under these circumstances, proper management of water resources becomes imperative. There is a problem of uncoordinated development of this precious resource and the need of the region for different uses has not been seen in a holistic perspective. In the present work, different approaches have been adopted to assess and manage water availability, the following conclusions and suggestions are drawn in the followings:

7.2. Results of the Hypothesis Tested

It is concluded from the findings that rainfall in any volume needs to be managed by understanding that precipitation is asymmetric and available only for a few months of the year and that only a small portion is stored naturally. It is imperative to adopt sustainable methods of harvesting water resources, with an emphasis on traditional techniques. Thus, the study area receiving more than 2000mm of rainfall annually, faces a problem of scarcity during the dry season proving the hypothesis tested is positive.

The second hypothesis is that the problem of over-dependence on the direct government supply of domestic water is proven on the ground that more than 60% of household consumption comes from government supply. This adversely affects the domestic water management of the area, that there happens to be a skinder and dish the dirt during the times when the water supply is delayed or hindered due to flooding, low volume of water, pipeline damages, etc. in society creating more diverse problems, especially during dry periods, which may not happen if every household is aware their water consumption pattern and the level of their conservation in proportion to the storage guideline. In addition to this, the problems of financial deficit can be solved indirectly. The underutilization of rooftop rainwater as well as the lack of domestic water storage systems is also found to be positive, that surface water harvesting is minimal and the annual household rooftop rainwater harvesting happens to be 27.9% only.

The third hypothesis is also proved to be positive as rainwater harvesting, especially rooftop harvesting, improves access to water and eases the burden on women and children who traditionally collect water.

7.3. Major Findings of the Research

The Major findings of the Assessment of Water Resources Potential and its Management in Upper Tuirial Watershed, Mizoram are as under;

7.3.1. The Profile of the Study Area

- The Upper Tuirial River Watershed covers an area of 534 Km^2 of land and lies between 92°42′E to 92°52′E longitudes and 23°26′N to 23°52′N latitudes at an elevation of about 1690 m above MSL at the highest point and about 76 m MSL at the lowest point.

- The physiography of the Upper Tuirial Watershed shows a parallel structural hill running north to south direction. The average altitude of the rugged terrain ranges from 1200m – 1400m. The highest point in the southwestern part is located at Hmuifang Peak (1634 m).
- The annual rainfall of the study area is 2022.5 mm approximately which is more than threefold of world annual rainfall of 810mm. The average monthly temperature is 21.24 ℃.
- Soils of the Upper Tuirial Watershed Area can be divided into three soil orders viz. Entisols, Inceptisols, and Ultisols. Inceptisols are the dominant order.
- Tropical Vegetation covers the whole area, forest including open forest and bamboo forest covers more than 79.85% of the area, scrubland, and agricultural land covers 5.33 % and 10.22% respectively
- The drainage system of the upper Tuirial River exhibits a dendritic drainage pattern, a structure that has a shape similar to tree roots. The river channels follow the gradient slope of the topography and join bigger streams or rivers at sharp angles.
- The notable rivers on the eastern side of the catchment area are Nghathup Lui, Sakei Lui, Saibual Lui, Ngharum Lui, Zilpui Lui, Belkhai Lui, Nghalrawh Lui, Chhimluang Lui and khawawih Lui. Rivers on the western side are Tuipawl Lui, Muthi Lui, Chite Lui, Paikhai Lui, Suanghuan Lui, Damdiai Lui, Tuizual Lui, Tuirivang Lui, and Tuiritai Lui are notable perennial rivers. Most of the rivers are perennial and potable.
- The traditional economy of Mizo society of the upper Tuirial Watershed is agrarian in nature.
- Approximately 68 % of the population is engaged in agriculture and allied activities. The major crops cultivated were bananas, dragon fruits, rubber plantation, arecanut, papaya, and leafy vegetables.
- Hotels and Restaurants are common on the western side of the catchment area, hmuifang tourist resorts and muallungthu restaurants are very popular in the study area. Seling is also located in the highway junction many people engage in restaurants and grocery shops.
- The average sex ratio within the study village is 980.

- The field observation shows that Seling and Khumtung have the highest sex ratio with 1022 and 1040 respectively. Phulmawi has the lowest sex ratio of 917 only. Other surveyed 10 villages range between 960 to 990.
- The reduction of water quantity of springs becomes a serious issue as the source of this water is related to the lithological structures below the surface and environmental degradation as well as waste pollution above the surface.
- Water Carriage Trucks are social duties in times of need and emergencies, on the other hand, manifest the potential of water indirectly.
- The PHED supply of water is very irregular during the dry season, due to an insufficient supply of water, most of the water storage tanks are emptied during the dry season
- The groundwater development level is 3.94%. The natural discharge of water during the dry season is negligible as they are mainly recharged through rainwater only. The available gross dynamic resources of groundwater are estimated to be 3.86 MCM, net annual draft is 0.14 MCM (Central Ground Water Board, 2013).
- The household survey and interviews with different persons reveal that the per capita per day demand ranges from 30 lpcd to 40 lpcd.
- The institutional demand is approximately 2 lpcd. The water demand of commercial and agriculture data is not possible to calculate.
- PHE Department of Mizoram has been mandated to manage the water supply and take sole responsibility for the domestic water supply, the minimum norm for the distribution of water is taken as 2500 liters per month.
- The average distribution of water during the dry season is calculated at 30.11 lpcd.
- The level of exploitation is minimal due to several factors including lack of infrastructure, unchecked allocation of funds, and unawareness of the local population. The high intensity of rainfall above 2000mm annually will normally support the initiatives for development projects
- The possible management and conservation measures suggested are improvement in rainwater harvesting structure and rejuvenation of groundwater.
- The majority of the stakeholders suggested the setting up of a solar water pump to supplement the fuel pump in order to reduce expenses on oil.

7.3.2. The Major Water Sources

The major water sources in the Upper Tuirial Watershed are rainwater, river water, underground water, spring water, water-carrying vehicles, and government water supply.

a) Rainwater- The study area received as high as 2022.7mm of rainfall annually. The majority of it is received within the monsoon period covering the months of April to October. For Example, the study area with an average monthly rainfall of 168mm, a catchment area of $81m^2$ ($30ft^2$ approx.) will receive an average rainfall of 11566.8 liters per month (0.168x81x0.85 = 11566.8)

b) River water- The Average Upper Tuirial Water Discharge is 1216 cubic feet per second; thus, the discharge of water is estimated to be 2025639 liters per minute (1 cubic foot per second = 1665 liters per minute). Which is projected to be regarded as a surplus water resource area in terms of rainfall and river discharge. It is interesting to note that the quality of river water is potable except Chite Lui.

c) Underground water- The potential resource of underground water is not feasible to calculate due to the unavailability of data and the absence of devices. The projected availability of groundwater may be a picture of the annual discharge calculated from the rivers and springs.

d) Spring water – Due to shallow aquifers in structured hills, many springs are located in the study area. But, more than half of the spring water sources are perennial. The field survey area's annual discharge of water during the dry season is estimated at 10 Liters/30 seconds. Thus, the average discharge of springs is 1200 liters/hour. Springs (Tuikhur) play a vital role in the supply of water and have a higher potential for the supplement of water supply in the future, not only in the dry season but also during the rainy season.

e) Water-carrying vehicles- They are the supplementary sources of domestic water demand in times of need. During the dry season, they supply water to domestic and commercial needs.

f) Government water supply- PHE Department of Mizoram has been mandated to manage the water supply and take sole responsibility for domestic water supply, the minimum norm for the distribution of water is taken as 2500 liters per month. The domestic water demand depends mainly on the government supply through household connections and public water points. Through JJM, many households are connected to water supply pipes.

7.3.3. The Status of Water Demand and Supply

Water is demanded for multiple uses and purposes. The uses that make most demand upon water supply and water-related services vary with the degree of development. However, certain needs are universal, such as for drinking purposes for man and animals and other domestic purposes. Meeting a continuous and ever-increasing demand for water requires efforts to compensate for natural variability, and to improve the quality and quantity available. Further, believing as a gift of nature and an inexhaustible resource, no account or data is available on the traditional remunerative uses of water. It is to be estimated. On the experience gained during fieldwork, it is presumed that, on average, per capita consumption of water is 40 – 45 liters per day for drinking, domestic, and animal purposes. During the dry season, the average direct distribution from the government is only 30.11 lpcd. Thus, the deficit amount is usually met from different sources like spring sources, private water-carriage trucks, and also from household storage.

Requirement for drinking and domestic purposes depends on physical as well as socioeconomic level of development. However, as per the Ministry of Water Resources, it is estimated that 55 liters would be sufficient for one person per day living in villages not using flash latrines. Taking these averages, requirements for drinking and domestic purposes have been estimated at 13,21,925 liters on the basis of thirteen selected villages. From the discharge of river water, the total discharge of the Upper Tuirial River is estimated at 1216.6 cfs, and the discharge of surveyed streams and rivers ranges from 63 to 251 cfs. Thus, sufficient to support the existing agricultural and industrial demand of the study area.

Water used for irrigation is minimal due to the fact that irrigation is practiced only during the rainy season for the sake of farm consumption and it is not possible to calculate due to the unavailability of data from the farmers. However, there is still vast potential for increasing the use of water for agricultural purposes. Domestication of animals is an integral part of farming in the western catchment area. From the field investigation, the total livestock population was projected at 8785 in numbers, with an average water demand of 74760 liters per capita per day. It is presumed that, the average daily requirement of big animals at 40lpcd, medium and birds at 8 lpcd and .5 lpcd respectively. The real problem is how best to reconcile the increasing use of a fixed supply with the needs and constraints of society in a way that will maintain a stable environment. Industries are negligible in the study area, the presence lo small-scale industries ore locally based and does not require much water supply to run the industries. Like water potential, the pattern of utilization also varies spatially.

The use of water resources as well as demand is recorded presumably by PHED only, people are not aware of recording and managing the system of water consumption pattern. Reliable data and proper records of such consumption, deficit, and surplus will help the study area plan for water resource potential and its utilization. Similar is the case with the other uses. Domestic, municipal, and livestock water losses can also be checked by the creation of general awareness.

7.3.4. The Process of Conservation and Management of Water Resources

The State and Central Government as well as NGOs have many plans and projects that are supposed to be prerequisites for the development of water resources. Construction of farm ponds, rainwater harvester ponds, and check dams are common methods for the management of water resources, while spring water rejuvenation and spring-shed construction are important initiatives taken. The other methods that will enhance or recharge groundwater like the construction of dam catching runoff, pit digging, and plantation of trees in many areas are in operation. A multifaceted approach would be necessary to ensure stability in water resources. Such as technical means can be applied to increase resources, purification of discharges, and reduction of water damage. Water resources can be increased by regularization over a period of time, intra-basin and inter-basin transfer of resources, judicious use of surface and groundwater, recycling of water after first use, and reducing demand for water.

Traditionally, water is regarded as a good gift and people hardly give any thought either to the quantity used or to the quality of their discharge but by now it has been proved that water is the most potent element of the environment and changes in its quantity and quality severely affects the conditions of other elements.

Experience has long shown that needs always exceeded available resources. Therefore, collective actions are essential to ensure a balance in the water system. The uses of surface and groundwater resources involve their development in such a manner that a shortage of one could be supplemented by the excess of the other. For instance, groundwater resources could be utilized during the dry season which would be recharged during the subsequent wet season. The combined yield of water from these two sources would thus be larger and more economical than the yield obtained from either source separately. This approach also helps in solving problems arising from the use of water and land such as water logging, and salinity.

Afforestation and planting of trees is the program taken out in the study area. Apart from roadside plantations, the plantation of different species of trees enhances the ecological system. Conservation of forests in relation to the control of felling trees are important factor for the conservation of the water source region. The Department of Forest and Environment takes initiatives in the study region.

It is evident from the preceding analysis that the central issue in water resource management is to match the supply and demand imbalance through structural facilities of storage, conveyance, processing, and operations. Groundwater and surface water are in hydraulic continuity and hence are components of the same system. Development and conservation should therefore involve the conjective uses of surface and ground water resources. Further, their allocation for different uses should be based on the principles of ecology and should aim at the optimization of social benefits rather than individual gains. It is particularly significant because water is a 'common property resource' and its benefits should reach all members of society. In fact, the objectives of development planning are economic progress, social development, and interregional balance with the least deterioration in the environmental conditions. These objectives are achieved by varied means such as intensification of agriculture, establishment of industries promotion of tourism, modernization of rural areas, and so on. These economic activities use water and then, after use, discharge it as waste.

7.4. Suggestions for Management of Water Resources

Water policies may be based on a sectoral integrated system linked to the different activities with respect to the use, conservation, and development of water resources preferably with a long-term policy. Its main objectives should include optimum utilization, conservation, and management of available water resources in light of water availability, population increase, and advances in technology. Water is not less valuable than land itself. With regard to content, an overall water policy might include the integrated management of land and water, the establishment and fulfilment of priorities in different fields of utilization, the adoption of measures to counteract the harmful effects of water and to control the quality of water so as to protect the environment and public health and adoption of guidelines concerning the economic and financial implications and participation of the people. This module will address the suggestions for the management of water resources in the upper Tuirial Watershed Area. The suggestions for the management of water resources were discussed in Chapter 6 (6.5).

The prevailing scarcity of water in the study area is seasonal in character. It is opined that management of rainfall will solve the problems. Collection of rainfall in a reliable and sophisticated manner is the first and foremost solution. This may need to be provisioned through compulsory rainwater harvesting to private and government buildings. The construction of the storage tank is in proportion to the number of persons residing in the building. Maintenance of flash floods and runoff in the catchment areas for different purposes like construction of contour bunding and pit dug for recharge of groundwater, depression pond for further use as well for agricultural purposes.

The potential of a river may be diverse according to locational, climatic, and institutional control of the river regime. River water is the lifeline of different living organisms and species; thus, the maintenance of its quality is very important. Installation of river water monitoring instruments is very important for recording up-to-date data on river regimes. The analysis of data will help timely monitoring of changing character that will be necessary for planning and management systems to control the quality and quantity of water that flows in a river. Initiatives regarding quality, reduced flow volume, and soil erosion constantly need to be monitored. Human activities that may hamper the river environment may be checked and controlled.

Monitoring groundwater is performed to characterize groundwater quantity and quality in order to address issues regarding the proper assessment and protection of groundwater resources. Installation of a groundwater monitoring well in a geo-hydrological unit in a suitable location will help in the conservation and development of water resources. Groundwater is one of the several components of the Hydrologic Cycle, the other important components being rainfall, surface water, soil moisture, and evapotranspiration. Holistic water resources management interventions require a proper understanding of the interactions between the different components of the hydrosphere. Studies for determining the Base flow and lateral flow components in the Water Balance equation need to be taken up to bring more accuracy to the Groundwater Resources Assessment.

The management of water demand and water supply system in the study area is deeply related to the Government distribution system. The provision for providing functional water connection to every household under JJM is in action. The laying of pipelines covered the whole area, which will be followed by private connection of tap water. But there is a long way to go for the provision of supply of sufficient water for every household. On the other hand, minimal rainwater harvesting in the study area (without reliable alternatives) reflects the community's high dependency on government water distribution. Apart from judicious and efficient use of water, the attitude towards the naturally available water resources should be revived. The duty of the household towards integrated management of water is the key to the community's sufficiency in water resources.

Water is polluted in many ways, source pollution, storage pollution, and transaction pollution are the major factors in the study area. Rainfall pollution is recorded during the first flush of monsoon rain only, the majority of water pollution is related to river pollution and storage pollution. Setting up of monitoring network and DMS (Data management System) construction, data collection ensues geographical and space-oriented data, time-oriented data (e.g., time series of meteorological, climatic, water quantity, water quality, and sediment data), and relation-oriented data (e.g., processed data and analysis). The process should be repeated after periodic reviews of requirements. Control and regulation of waste disposal especially in the study are necessary. Any form of waste and debris are transported towards the river contaminating and lowering the quality of the river water. Monitoring Temporal and spatial variability of the river flow, determined by climatic features like precipitation pattern in the catchment, evapotranspiration, and physiographic features of the river basin, like size, slope, shape, soils, land use, and drainage characteristics for planning the watershed ecological needs.

Raising awareness and launching campaigns on water resources has yielded positive results in many areas. Interaction regarding the problem on the water followed by problem-solving interaction is necessary. Training to the community regarding principles, mechanization, and utilization of water resources, especially rainwater harvesting systems is suggested for water resource development in the study area.

7.5. Scope for Further Research

In light of the study of water resources as a whole, there is a scope for integrated study or research in the field of runoff management, installation of rainwater harvesting structures, potential areas for the development of agriculture, groundwater potential, and even for hydro-power for further development of the planning system and implementation.

7.6. Conclusion

Potential Water resources that are utilized in the study are rainfall, river water, and groundwater through springs. The estimation of rainfall and river discharge of the area reveals the high tappable potential in terms of quality and quantity. While there is an elaborate system of institutions, ranging from the village level to the highest administrative level, there is not adequate provision of institutions engaged in the management of water resources. Specific attention to the study of river regimes in relation to rainfall discharge and seepage, an area-wise study of the hydrological cycle such as effective rainfall, evapotranspiration, soil moisture, run-off, and groundwater, in relation to the agricultural and water needs of specific crops, preparation of hydrological and geomorphologic maps and appraisal of water supply for different purposes should be the main aspects for coordinated management strategy.

For the given area, the regulation of water demand and supply approaches, involving water development based on the creation of additional water storages and water allocation based on sectoral and regional demand, cannot be an exclusive basis for managing water scarcity and deficiency. A rational strategy and systems are necessary for the development of both water demand and supply management options. The most important water resource allocation and management tools, such as water harvesting, water pricing systems, water market systems, water rights systems, water saving technologies, and community-based NGOs should be implemented. Similarly, the construction of new dams, the expansion of in situ water use and water recycling are the other options suggested for the area. Although water demand management has been very much in the policy discourse for a long time in India, a clearly articulated demand management strategy is conspicuous by its absence both at the national and state levels. The feasibility of water resource management may be different from region to region, however, the logical implications of water scarcity and their related problems, the employability of water use efficiency, and the prospect of judicious use, and as a part of food supply directly and indirectly is inevitable.

The importance of the water resource assessment lies in the fact that it establishes a wide and exhaustive framework for the sustainable management of water resources and the protection of water quality in all different types of water bodies (inland surface waters, transitional waters, and groundwater), having the ambitious objective of achieving a good water status. And for the development of water resource potential, relevant and reliable data is first needed. Therefore, an inventory of information on water and the collection of basic data are prerequisites of water resource management.

References

BIS (2010).IS 1172: 1993: *Code of basic requirements for water supply, drainage and sanitation,1993*. Fourth Reprint DECEMBER 2010.

BIS (2012). *IS 10500 (2012): Drinking water. Indian Standard Drinking water – Specification*. May 2012

Directorate of Economics & Statistics, Government of Mizoram. (2021). Meteorological Data of Mizoram 2021.

Government of India (2008). Common Guidelines for Watershed Development.

Government of Mizoram. Directorate of Economics & Statistics, Mizoram Statistical Abstract 2021.

Lily A., Peters H. and Chang H. (2011). Urban water demand modeling: Review of concepts, methods, and organizing principles. *Water resources research*. Vol. 47, Pp 1-15

Loucks D.P. & Beek E.V. (2017). Water Resource Systems, Planning and Management, An overview. pp 1-48. Link (http://creativecommons.org /licenses/by-nc/4.0/)

Maharashtra Public Service Commission (2019) Environmental Engineering. Made easy Publications.

Savenije H.G. & Hoekstra A.Y. (1992) Water Resources Management Vol. I. http://www.eolss.net/Eolss -sampleAllChapter.aspx Sample paper Encyclopaedia of Life Support Systems (EOLSS)

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ABSTRACT

ASSESSMENT OF WATER RESOURCE POTENTIAL AND ITS MANAGEMENT IN UPPER TUIRIAL WATERSHED, MIZORAM

AN ABSTRACT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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Assessment of Water Resource Potential and its Management in Upper Tuirial Watershed, Mizoram

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Abstract

The watershed is an area delineated to study a specific control point of a river, creating a boundary that represents the contributing area with the intent of characterization and analysis ofa portion of the study.In geographical terms, a Watershed can also mean a ridge line with a definite boundary formed by a chain of mountains or hills, sending water to two different rivers on either side. The area may vary in size, even a specific watershed area may be divided into sub-watershed, mini-watershed, and micro-watershed areas. The management of watershed areas requires the application of diverse disciplines of hydrology, climatology, biochemistry, forestry, soil, water, and the interaction of environmental management disciplines that too often operate in mutual isolation. The watershed concept encourages the interpretation of the unit of landscape as a dynamic series of mass balances and fluxes. The interplay of various factors that govern access and utilization of water resources and in view of the increasing demand for water, the planning and management of water resources has become a matter of the utmost urgency. It becomes important to look for holistic and people-centered approaches to water management. Thus, the present research selects the water resource potential of the upper Tuirial watershed area.

The Upper Tuirial Watershed covers approximately 535 square kilometers, of which 88.7 percent falls under the Aizawl District and 11.3 percent under the Serchhip District. It extends between 23^{o}51’12’’ N to 23^{o}26’12’’N latitude and 92^{o}41’51” E to 92^{o}51’46” E longitude. The study area is a part of the Purvanchal Hills and is located in the central part of Mizoram. The physical characteristics show young folded landforms with sharp hills and V-shape valleys cut by rivers with deep gorges and rapids. Confirmed faults and lineament are present along the ridges. The

structural hills range between 800m-1200m and run in a north-south direction at the eastern and western watershed boundary. The geological structure represents a number of faults/fractures of varying magnitude, mostly transverse in deposition, normally trending NNW-SSE and NNE-SSW direction (MIRSAC, 2009). The natural vegetation belongs to sub-tropical wet evergreen forests mixed with semi-evergreen and tropical moist deciduous forests comprising mainly bamboo.

The present paper tries to estimate the surface water resource potential in the upper Tuirial watershed with an effort to provide a means for the continuous development of the region, and, by extension, for similar possible applicable areas.

The objectives of the present study on "Assessment of Water Resources Potential and its Management in the Upper Tuirial Watershed, Mizoram" are;

1. To identify the major water sources in Upper Tuirial Watershed.
2. To asses water demand and supply in the study area.
3. To study the process of conservation and management of water resources.
4. To frame policies for management of potential water resources.

Simple and straightforward formulas and methods are used as far as possible to assist in finding answers. The collected data were analyzed and represented in the form of maps, tables, charts, figures, etc.The collection of primary data was taken out by using a structured questionnaire from randomly selected 13 villages (44.8 percent of the total villages). A household-level survey was carried out covering 26 % of the total households by using a purposive sampling method. Primary data in relation to village profiles on demography, economic activities, and infrastructures were taken into consideration. The field investigation on domestic water demand and supply, river water discharge, water conservation, and management process were taken out from the study area. Interaction with Village Council/ Panchayat from respective villages enhances the reliability and accuracy of the data collected using a questionnaire.

An exhaustive personal field investigation related to the collection of soil samples from 42 selected coordinates and measuring river discharge from selected 9 rivers including the upper Tuirial River were also taken out. The water samples collected were tested and verified by PHED, Mizoram. Identification of village spring sources, their location, and usability to the local population gives the views on the groundwater potential of the area. Thus, the status of rainwater harvesting practices, water demand and supply of the community, process of water conservation, and management for the domestic, agricultural, institution, and industries are the main components of the questionnaire. Google Earth Pro and Global Positioning System (GPS) were also employed to collect geographical data.

Secondary data are collected from the records of governmental and non-governmental agencies. Climatic data like rainfall, temperature, and humidity were collected from the State Meteorological Station for the period of 2000 – 2022. Underground water data was based on the Central Groundwater Board, Ministry of Water Resources. Project implementation and work done by different State Governments on water conservation, rainwater harvesting, soil statistics, etc. as well as private records were employed. Census of India, 2021 is consulted on the Socio-Economic status of the study area for comparison. Maps and satellite imagery were also taken from MIRSAC.

The collected data will be analyzed by using Microsoft Excel, Statistical Package for Social Science (SPSS), etc., and other appropriate statistical methods were used. Maps are constructed using the Geographical Information System (GIS). The level of soil moisture is measured by using the gravimetric method. GIS and remote sensing are adopted for the identification of groundwater potential zones, preparation of drainage density, and drainage patterns in the study area. River discharge is measured using a simple float/buoyancy method at the river's lower course. Gravimetric water content (Standard Test Procedures, 2001) is expressed by mass (weight) as follows:

The moisture content of a soil sample is expressed as the mass of water in the sample expressed as a percentage of the dry mass, usually heating at 105^0C, i.e., thermostatically controlled drying oven capable of operating to 105 ± 5^0C.

moisture content, $w = \frac{Mw}{MD} 100(\%)$

where, M_W = mass of water

M_D = dry mass of sample

Calculation and expression of results

Moisture content, $w = \frac{\text{mass of moisture}}{\text{mass of dry soil}} x100(\%)$

$$= \frac{(\text{mass of container+wet soil}) - (\text{mass of container+dry soil})}{(\text{mass of container+dry soil}) - (\text{ mass of container})} \text{x}100(\%)$$

A simple and inexpensive float method (Michaud et al. 2005) to measure the water discharge level of streams is common in remote areas. A buoyant object (yellow tennis ball weight 91.40 gram is used by the author) is time how long it takes to travel a specific distance. Stream flow is then calculated using the time, along with the estimated width and depth of the stream segment. Usually, a buoyant object is floated three times and takes the average time for final output.

Stream flow = Area x Velocity x Correction factor

Calculate area:

Multiply the width of the stream by the depth.

Calculate average float time:

Add up all the individual times and divide by the number of times the float was released (in seconds).

Calculate average velocity:

Divide the distance the item floated (i.e., the length of the segment measured in feet) by the average float time.

Calculate stream flow:

Multiply the average velocity by the area and by a correction factor (0.85). The correction factor takes into account the effects of friction from the stream bed. It is expressed in cubic feet per second (cfs)

Water in motion is measured in units of flow— units of volume for a convenient time unit. It is important that the difference between a unit of volume and a unit of flow be kept in mind. The following equivalents are useful for converting from one unit to another and for calculating volumes from flow units. One of the most commonly used methods is Cubic foot per second(cfs)- The quantity of water equivalent to a stream one foot wide by one foot deep flowing with a velocity of one foot per second. A flow of one cfs is approximately equal to either 450 gpm, one acre-inch per hour, or two acre-feet per day (24 hours). It is also converted into:

One cubic foot per second(cfs)

= 448.83 gallons per minute (450 for ordinary calculations)

= 1 acre-inch in 1 hour and 30 seconds (1 hour for ordinary calculations)

= 1 acre-foot in 12 hours and 6 minutes (12 hours for ordinary calculations)

= 1.984 acre-feet per (24 hours) day (2 acre-feet for ordinary calculations)

The above table can be also used to convert from a flow unit to a volume unit and vice-versa, or to estimate the operating hours required to deliver a desired volume of water.

The hypothesis tested is positive, in that, it concluded rainfall in any volume needs to be managed by understanding that precipitation is asymmetric and available only for a few months of the year and that only a small portion is stored naturally, stating the need to adopt any possible system and method to harvest water resources sustainable, especially encouraging the traditional method.

The second hypothesis of overdependence on the direct supply of domestic water from the government adversely affects the domestic water management of the area, creating more diverse problems during dry periods, and on the other hand, indirectly affects the rooftop rainwater harvesting development as well as the lack of domestic water storage systems is also found to be positive, that surface water harvesting is minimal and the annual household rooftop rainwater harvesting happens to be 27.9% only.

The third hypothesis is also proved to be positive as rainwater harvesting, especially rooftop harvesting, improves access to water and eases the burden on women and children who traditionally collect water.

The Major findings of the Assessment of Water Resources Potential and its Management in Upper Tuirial Watershed, Mizoram are as under;

- The Upper Tuirial River Watershed covers an area of 534 Km^2 of land and lies between 92°42′E to 92°52′E longitudes and 23°26′N to 23°52′N latitudes at an elevation of about 1690 m above MSL at the highest point and about 76 m MSL at the lowest point.
- The physiography of the Upper Tuirial Watershed shows a parallel structural hill running north to south direction. The average altitude of the rugged terrain ranges from 1200m – 1400m. The highest point in the southwestern part is located at Hmuifang Peak (1634 m).

- The annual rainfall of the study area is 2022.5 mm approximately which is more than threefold of world annual rainfall of 810mm. The average monthly temperature is 21.24 °C.
- Soils of the Upper Tuirial Watershed Area can be divided into three soil orders viz. Entisols, Inceptisols, and Ultisols. Inceptisols are the dominant order.
- Tropical Vegetation covers the whole area, forest including open forest and bamboo forest covers more than 79.85% of the area, scrubland, and agricultural land covers 5.33 % and 10.22% respectively
- The drainage system of the upper Tuirial River exhibits a dendritic drainage pattern, a structure that has a shape similar to tree roots. The river channels follow the gradient slope of the topography and join bigger streams or rivers at sharp angles.
- The notable rivers on the eastern side of the catchment area are Nghathup Lui, Sakei Lui, Saibual Lui, Ngharum Lui, Zilpui Lui, Belkhai Lui, Nghalrawh Lui, Chhimluang Lui and khawawih Lui. Rivers on the western side are Tuipawl Lui, Muthi Lui, Chite Lui, Paikhai Lui, Suanghuan Lui, Damdiai Lui, Tuizual Lui, Tuirivang Lui, and Tuiritai Lui are notable perennial rivers. Most of the rivers are perennial and potable.
- The traditional economy of Mizo society of the upper Tuirial Watershed is agrarian in nature.
- Approximately 68 % of the population is engaged in agriculture and allied activities. The major crops cultivated were bananas, dragon fruits, rubber plantation, arecanut, papaya, and leafy vegetables.
- Hotels and Restaurants are common on the western side of the catchment area, Hmuifang tourist resorts and Muallungthu restaurants are very popular in the study area. Seling is also located in the highway junction many people engage in restaurants and grocery shops.
- The average sex ratio within the study village is 980.
- The field observation shows that Seling and Khumtung have the highest sex ratio with 1022 and 1040 respectively. Phulmawi has the lowest sex ratio of 917 only. Other surveyed 10 villages range between 960 to 990.

- The reduction of water quantity of springs becomes a serious issue as the source of this water is related to the lithological structures below the surface and environmental degradation as well as waste pollution above the surface.
- Water Carriage Trucks are social duties in times of need and emergencies, on the other hand, manifest the potential of water indirectly.
- The PHED supply of water is very irregular during the dry season, due to an insufficient supply of water, most of the water storage tanks are emptied during the dry season
- The groundwater development level is 3.94%. The natural discharge of water during the dry season is negligible as they are mainly recharged through rainwater only. The available gross dynamic resources of groundwater are estimated to be 3.86 MCM, net annual draft is 0.14 MCM (Central Ground Water Board, 2013).
- The household survey and interviews with different persons reveal that the per capita per day demand ranges from 30 lpcd to 40 lpcd.
- The institutional demand is approximately 2 lpcd. The water demand of commercial and agriculture data are not available thus, it is not possible to calculate.
- PHE Department of Mizoram has been mandated to manage the water supply and take sole responsibility for the domestic water supply, the minimum norm for the distribution of water is taken as 2500 liters per month.
- The average distribution of water during the dry season is calculated at 30.11 lpcd.
- The level of exploitation is minimal due to several factors including lack of infrastructure, unchecked allocation of funds, and unawareness of the local population. The high intensity of rainfall above 2000mm annually will normally support the initiatives for development projects
- The possible management and conservation measures suggested are improvement in rainwater harvesting structure and rejuvenation of groundwater.
- The majority of the stakeholders suggested the setting up of a solar water pump to supplement the fuel pump in order to reduce expenses on oil.

The major water sources in the Upper Tuirial Watershed are rainwater, river water, underground water, spring water, water-carrying vehicles, and government water supply.

a) Rainwater- The study area received as high as 2022.7mm of rainfall annually. The majority of it is received within the monsoon period covering the months of April to October. Rainwater is the major source of potential water for the study area. Management of rainwater in the study area is minimal, from the field investigation only 27.9 % of household collect rooftop rainwater, that is loss of more than 70 % of rooftop water in the form rainfall runoff. For Example, the study area with an average monthly rainfall of 168mm, a catchment area of $81m^2$ ($30ft^2$ approx.) will receive an average rainfall of 11566.8 liters per month (0.168x81x0.85 = 11566.8)

b) River water- The Average Upper Tuirial Water Discharge is 1216 cubic feet per second; thus, the discharge of water is estimated to be 2025639 liters per minute (1 cubic foot per second = 1665 liters per minute). Which is projected to be regarded as a surplus water resource area in terms of rainfall and river discharge. It is interesting to note that the quality of river water is potable except Chite Lui.

c) Underground water- The potential resource of underground water is not feasible to calculate due to the unavailability of data and the absence of devices. The projected availability of groundwater may be a picture of the annual discharge calculated from the rivers and springs.

d) Spring water – Due to shallow aquifers in structured hills, many springs are located in the study area. But, more than half of the spring water sources are perennial. The field survey area’s annual discharge of water during the dry season is estimated at 10 Liters/30 seconds. Thus, the average discharge of springs is 1200 liters/hour. Springs (Tuikhur) play a vital role in the supply of water and have a higher potential for the supplement of water supply in the future, not only in the dry season but also during the rainy season.

e) Water-carrying vehicles- They are the supplementary sources of domestic water demand in times of need. During the dry season, they supply water to domestic and commercial needs.

f) Government water supply- PHE Department of Mizoram has been mandated to manage the water supply and take sole responsibility for domestic water supply, the minimum norm for the distribution of water is taken as 2500 liters per month. The domestic water demand depends mainly on the government supply through household connections and public water points. Through JJM, many households are connected to water supply pipes.

Water is demanded for multiple uses and purposes. The uses that make most demand upon water supply and water-related services vary with the degree of development. However, certain needs are universal, such as for drinking purposes for man and animals and other domestic purposes. Meeting a continuous and ever-increasing demand for water requires efforts to compensate for natural variability, and to improve the quality and quantity available. Further, believing as a gift of nature and an inexhaustible resource, no account or data is available on the traditional remunerative uses of water. It is to be estimated. On the experience gained during fieldwork, it is presumed that, on average, per capita consumption of water is 40 – 45 liters per day for drinking, domestic, and animal purposes. During the dry season, the average direct distribution from the government is only 30.11 lpcd. Thus, the deficit amount is usually met from different sources like spring sources, private water-carriage trucks, and also from household storage.

Requirement for drinking and domestic purposes depends on physical as well as socioeconomic level of development. However, as per the Ministry of Water Resources, it is estimated that 55 liters would be sufficient for one person per day living in villages not using flush latrines. Taking these averages, requirements for drinking and domestic purposes have been estimated at 13,21,925 liters on the basis of thirteen selected villages. From the discharge of river water, the total discharge of the Upper Tuirial River is estimated at 1216.6 cfs, and the discharge of surveyed streams and rivers ranges from 63 to 251 cfs. Thus, sufficient to support the existing agricultural and industrial demand of the study area.

Water used for irrigation is minimal due to the fact that irrigation is practiced only during the rainy season for the sake of farm consumption and it is not possible to calculate due to the unavailability of data from the farmers. However, there is still vast potential for increasing the use of water for agricultural purposes. Domestication of animals is an integral part of farming in the western catchment area. From the field investigation, the total livestock population was projected at 8785 in numbers, with an average water demand of 74760 liters per capita per day. It is presumed that, the average daily requirement of big animals at 40lpcd, medium and birds at 8 lpcd and .5 lpcd respectively.The real problem is how best to reconcile the increasing use of a fixed supply with the needs and constraints of society in a way that will maintain a stable environment. Industries are negligible in the study area, the presence lo small-scale industries ore locally based and does not require much water supply to run the industries. Like water potential, the pattern of utilization also varies spatially.

The use of water resources as well as demand is recorded presumably by PHED only, people are not aware of recording and managing the system of water consumption pattern. Reliable data and proper records of such consumption, deficit, and surplus will help the study area plan for water resource potential and its utilization. Similar is the case with the other uses. Domestic, municipal, and livestock water losses can also be checked by the creation of general awareness.

The State and Central Government as well as NGOs have many plans and projects that are supposed to be prerequisites for the development of water resources. Construction of farm ponds, rainwater harvester ponds, and check dams are common methods for the management of water resources, while spring water rejuvenation and spring-shed construction are important initiatives taken. The other methods that will enhance or recharge groundwater like the construction of dam catching runoff, pit digging, and plantation of trees in many areas are in operation. A multifaceted approach would be necessary to ensure stability in water resources. Such as technical means can be applied to increase resources, purification of discharges, and reduction of water damage. Water resources can be increased by regularization over a period of time, intra-basin and inter-basin transfer of resources, judicious use of surface and groundwater, recycling of water after first use, and reducing demand for water.

Traditionally, water is regarded as a good gift and people hardly give any thought either to the quantity used or to the quality of their discharge but by now it has been proved that water is the most potent element of the environment and changes in its quantity and quality severely affects the conditions of other elements.

Experience has long shown that needs always exceeded available resources. Therefore, collective actions are essential to ensure a balance in the water system. The uses of surface and groundwater resources involve their development in such a manner that a shortage of one could be supplemented by the excess of the other. For instance, groundwater resources could be utilized during the dry season which would be recharged during the subsequent wet season. The combined yield of water from these two sources would thus be larger and more economical than the yield obtained from either source separately. This approach also helps in solving problems arising from the use of water and land such as water logging, and salinity.

Afforestation and planting of trees is the program taken out in the study area. Apart from roadside plantations, the plantation of different species of trees enhances the ecological system. Conservation of forests in relation to the control of felling trees are important factor for the conservation of the water source region. The Department of Forest and Environment takes initiatives in the study region.It is evident from the preceding analysis that the central issue in water resource management is to match the supply and demand imbalance through structural facilities of storage, conveyance, processing, and operations. Groundwater and surface water are in hydraulic continuity and hence are components of the same system. Development and conservation should therefore involve the conjective uses of surface and ground water resources. Further, their allocation for different uses should be based on the principles of ecology and should aim at the optimization of social benefits rather than individual gains. It is particularly significant because water is a 'common property resource' and its benefits should reach all members of society.

In order to achieve adequate water management, it is also necessary to address key issues such as sectoral governance, access to financial resources, coherent regulatory and monitoring frameworks, and improvement of data quality. Data and innovative monitoring techniques are crucial to understanding the state of water resources and designing cohesive policies. Equitable, participatory, and accountable approaches should be accompanied by appropriate policy and legal frameworks, and institutional and human capacities and structures. Strengthening of water resource management through assessments of water resources, economic assessments of the sector, water forecasting and industrial reform, capacity building, and establishment of water monitoring networks.

The physical characteristics of the watershed determine the action of precipitation, some act as runoff that feeds directly to streams and rivers, while others seep into underground aquifers forming groundwater. Thus, the watershed becomes a system, a structured set of interactions that is defined for the purposes of understanding. That integrates the tightly coupled interactions among physical, ecological, and social processes. It is a functioning natural unit.Water Resource Management has long been recognized as a desirable unit for planning and implementing developmental Programmes. It is an undertaking to maintain the equilibrium between elements of the natural ecosystem of vegetation, land, or water on the one hand and man's activities on the other hand. It refers to the conservation, development, and optimal utilization of land and water resources for the ultimate benefit of the people. Therefore, it is also important to note that no significant improvement can be expected without the people being brought to center stage (GWP, 2000). The present study highly suggested the participatory approach for the development of the area

Water being a state subject, the projects on water conservation are planned, funded, executed, and maintained by the State Governments. The government of India supplements the efforts of the States through technical and financial assistance to them through various schemes and Programmes. Various schemes and Programmes such as Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), Atal Bhujal Yojana, Pradhan Mantri Sinchayee Yojana (PMKSY), Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Unified Building Bye Laws (UBBL) of Delhi, 2016, Model Building Bye Laws (MBBL), 2016, Urban and Regional Development Plan Formulation and Implementation (URDPFI) Guidelines, 2014 etc. are covered on continuous basis.

Lastly, in light of the study of water resources as a whole, there is a scope for integrated study or research in the field of runoff management, installation of rainwater harvesting structures, potential areas for the development of agriculture, groundwater potential, and even for hydro-power for further development of the planning system and implementation.