



Table of Contents

1	Introduction to Hydrology	1
1.1	The Basics of Hydrology	1
1.2	Evolution of Hydrology	2
1.3	The classification of Hydrology	4
1.4	The Hydrological Cycle	6
1.5	Hydrological Variables	7
1.6	River Basin	8
1.7	Scale	9
1.7.1	Spatial Scale	9
1.7.2	Time Scale	10
1.8	Distribution of water worldwide	11
1.9	Hydrological Balance	12
1.10	Understanding Water Resource Development	14
1.11	References	14

2	Hydrologic Cycle and its Elements: Precipitation	15
2.1	Introduction	15
2.2	Available Water	16
2.2.1	Sources of Water	17
2.2.2	Types of Water available on Earth	19
2.3	Water Cycle	20
2.3.1	Importance of the Water Cycle	22
2.4	Water Balance Equation	24
2.5	Precipitation and its Forms	26
2.6	Analysing Point Precipitation	29
2.7	Converting Point Precipitation to Areal Precipitation	29
2.8	IDF Analysis and Precipitation	30
2.9	DAD Analysis and Storms	34
2.10	Conclusion	35
2.11	Reference	37
3	Hydrologic Cycle and its Elements: Evaporation and Transpiration	38
3.1	Introduction	38
3.2	Atmosphere and Water Loss	39
3.3	The Free – Water Bodies and Evaporation	40
3.4	Evaporation via Pans	41
3.4.1	Introduction	41
3.4.2	Mechanism	42
3.4.3	Reducing the Pan Evaporation trends	43
3.4.4	Evaporation from lakes vs. Evaporation from pans	44
3.4.5	Effects on the Hydrological Cycle	44
3.5	Aerodynamic Method of Evaporation	45
3.6	Energy Balance Method of Evaporation	46
3.7	Penman's Combination Method	47
3.8	Drainage Basins and Evapotranspiration	49
3.9	Measuring Evapotranspiration: Evapotranspirometers	50
3.10	The Penman-Monteith Method	51
3.11	The Blaney- Criddle Method	53
3.12	References	54

4	Hydrologic Cycle and its Element: Runoff	55
4.1	Introduction	55
4.1.1	Components of Hydrologic Cycle	57
4.2	Calculation of infiltration	58
4.2.1	General Budget of Hydrology	59
4.2.2	Horton's Equation	59
4.3	Direct runoff and NRCS Approach	60
4.3.1	Materials and Methods	62
4.3.2	Original NRCS-CN model	62
4.3.3	Mishra – Singh model (MS model)	64
4.3.4	Sahu-Misra-Eldho model	65
4.3.5	Sahu 1-p Model	66
4.3.6	Sahu 3-p model	67
4.3.7	Q-base Model	68
4.3.8	Direct Runoff from Snowmelt	69
4.4	References	70
5	Groundwater Flow Theory	71
5.1	Introduction	71
5.2	Groundwater	72
5.3	Classifying the Subsurface Water	75
5.4	Water-Bearing Formation	77
5.5	Fluid Potential and Hydraulic Heads	78
5.6	Darcy's Law	80
5.7	Factors Related to Groundwater Movement	81
5.8	Groundwater Storage and its Parameters	83
5.9	Generalizing Darcy's Law	85
5.10	Steady-State and Unsteady-State Flow	86
5.11	General Equation related to Groundwater Flow	87
5.12	Groundwater Flow Equation: Overview	87
5.13	Flow: Unsaturated and Two - phased	88
5.14	References	89
6	Groundwater Flow: Application and Flow	90
6.1	What is Groundwater?	90
6.2	Aquifers	93
6.2.1	Classification of Aquifers	94
6.2.2	Confined Aquifers	94

6.3	Wells near Boundaries and The Theory of Images	96
6.4	Design of a Well Field	96
6.5	References:	97
7	Conveyance System: Open Channel Flow	98
7.1	Introduction	98
7.2	Essentials of Channel Section	100
7.2.1	Velocity and Discharge of an Open Channel Flow	101
7.3	Variations of Fluid Flow	102
7.4	Flow States	103
7.5	Conditions of Critical Flow	104
7.6	Flow in a Uniform Channel	105
7.7	Transportation of Sediment Free Water (Rigid Channel)	106
7.8	Transportation of Sediment-Laden Water (Rigid Channel)	107
7.9	Transportation of Sediment Free Water (Loose – Boundary Channel)	108
7.10	Transportation of Sediment Laden Water (Loose Boundary Channel)	109
7.11	Gradually Varied Flow	111
7.12	Computing Flow Profile	111
7.13	Rapidly Varied Flow	112
7.14	Reference	112
8	Surface Water Flow and its Measurements	113
8.1	Introduction	113
8.2	Measuring Stream Stage	114
8.3	Measuring Discharge	115
8.3.1	Establishing the relation between stage and discharge	116
8.3.2	Distribution of velocity in a stream section	116
8.4	Velocity Measurement by Current Meter	117
8.4.1	Discharge computation for current meter method	124
8.5	The Simple Stage Discharge Curve	128
8.5.1	Fitting of the curve	129
8.5.2	The logarithmic method	130
8.6	Determination of stage of zero flow	130

8.7	Measurement by Electromagnetic Method	131
8.8	Measurement by the Ultrasonic Method	132
8.9	Basic Concepts of the Acoustic Doppler Current Profiler or the ADCP	132
8.9.1	Working Principle	132
8.9.2	Processing Method	133
8.9.3	Applications, Advantages and Disadvantages of ADCPs	134
8.10	References	135
9	Hydrograph Analysis	136
9.1	Introduction	136
9.2	Flow of Water: Runoff and Streamflow	136
9.3	Runoff- precipitation Mechanism	138
9.4	Methods of Estimating Streamflow	141
9.5	Measurement of Site discharge methods:	144
9.6	Hydrograph Separation Analysis	148
9.7	Deriving Unit Hydrograph	149
9.8	Estimation of instantaneous unit Hydrograph	152
9.9	Reference:	158
10	Streamflow Relationships	159
10.1	Introduction	159
10.2	Hydrological Cycles and Correlation Techniques	160
10.3	Stationary and Homogeneous Data	160
10.4	Precipitation Runoff Correlation for Estimating Streamflow	161
10.4.1	Rank analysis for Antecedent Precipitation Index (API)	165
10.5	Correlation of Gaging-Station Records	166
10.6	Correlation of Duration Curves for Estimation of Streamflow	167
10.7	Synthetic Methods related to Hydrology	168
10.8	Stochastic Time Series Analysis	169
10.9	AR Model or Markov Process	170
10.10	ARMA Model	170
10.11	Disaggregation Model in Hydrology	172
10.12	Auto-run Model	172

10.13 Stream flow in Un-gauged Sites	173
10.14 Estimation derived from Drainage area ratio	173
10.15 Calculations based on Regression equation	174
10.16 Inconsistency of Stream-flow	174
10.17 References	175

11 Calculating Extreme Flows 176

11.1 Introduction	176
11.2 Computation and Probability	178
11.3 Probability in Hydrology	178
11.4 Design flood and Hydraulic Structures	181
11.5 Statistical Techniques	182
11.6 Variety and Quality of the Data	183
11.7 Flood Frequency analysis and its Techniques	184
11.8 Generalised Skew co - efficient	187
11.9 Probability Adjustments and Confidence Limits	188
11.10 Flood Frequency Analysis	188
11.11 Computation of peak flow from Precipitation and Estimation of PMP	189
11.12 PMS and its Development	190
11.13 Peak Snowmelt Discharge	192
11.14 Regionalized Flood Relations for Ungauged Sites	192
11.15 Flood Flow Computation: Genetic and Empirical_ Equations	193
11.16 Measuring Peak Discharge by Indirect Techniques	194
11.17 Computing Low Flow	194
11.18 Low-flow Frequency analysis by the Empirical_Method	195
11.19 Low-flow Frequency analysis by the Empirical Method	196
11.20 References	196

12 Remote Sensing and Computer Modeling 197

12.1 Introduction	197
12.2 Principles of Remote sensing	198
12.3 Types of Remote Sensing	199
12.4 Integrating Remote Sensing and GIS	200
12.5 Remote Sensing of Hydrologic elements	200
12.6 Remote Sensing Applications	201
12.7 Models for Hydrology	202

12.8	Hydrological Modelling Software	206
12.9	Hydrologic and Hydraulic Modelling	207
12.10	References	210
13	Hydraulic Structure	211
13.1	Introduction	211
13.2	Flow Measuring Hydraulic Structures	212
13.2.1	Function of the Flow measuring Structures.	213
13.3	Orifice	215
13.3.1	Flow of liquid through orifice	216
13.3.2	Hydraulic co-efficient.	218
13.4	Mouthpieces	219
13.5	Notches and Wseirs	220
13.6	Broad-crested Weir	222
13.6.1	Head Discharge Relationship	223
13.7	Dams	226
13.7.1	Types of Dams	227
13.8	Flumes	233
13.9	Spillways	234
13.9.1	Types of spillways	234
13.10	References	235
14	Distribution Systems	236
14.1	Introduction	236
14.1.1	Segments of the Distribution System	239
14.2	Piping System	242
14.2.1	Types of pipes	243
14.2.2	Cost considerations	244
14.2.3	Health aspects	245
14.3	Pipes Network	245
14.4	Water Storage Tanks	246
14.4.1	Types of water tanks	247
14.5	Reference	248
15	Urban Drainage System	249
15.1	Introduction	249
15.2	Sustainable Drainage	251
15.3	Types of Drainage Pattern and Drainage Systems	251

15.4	Urban Drainage System – layout and Operation	254
15.4.1	Combined System	254
15.4.2	Separate System	256
15.4.3	Hybrid System	256
15.5	Design of Sanitary Sewer System	257
15.5.1	Design of Sanitary Sewers	257
15.6	Magnitude of Wastewater	258
15.7	Friction coefficient of sanitary sewers	259
15.8	Storm Sewer Project	261
15.8.1	Methods of determining run-off	261
15.8.2	Return periods	261
15.8.3	Designing of storm sewers	262
15.9	Quantity of a Storm Water	263
15.10	Rational Methods	264
15.11	Application of rational method	266
15.12	The NRCS (SCS) TR-55 method	267
15.12.1	Selection of curve number	267
15.12.2	Calculation of time of concentration	268
15.12.3	Tabular hydrograph method	269
15.13	Detention Basin Storage	269
15.14	References:	271
16	Other Types of Drainage Systems	272
16.1	Introduction	272
16.2	Agricultural Drainage	273
16.3	Agricultural Lands and Surface Drainage	278
16.4	Agricultural Land and Subsurface Drainage	280
16.5	Drains: Depth and Spacing	281
16.6	Roadway Drainage	284
16.7	Longitudinal Drainage	285
16.8	Cross Drainage System	286
16.9	Airport Drainage	290
16.10	References	291
	Index	292