### LIST OF NOTATIONS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ab</td>
<td>Number of selected best affinity antibodies</td>
</tr>
<tr>
<td>Ab&lt;sub&gt;in&lt;/sub&gt;</td>
<td>Initial antibody population</td>
</tr>
<tr>
<td>A&lt;sub&gt;c&lt;/sub&gt;</td>
<td>Area under crop c (ha)</td>
</tr>
<tr>
<td>AET</td>
<td>Actual evapotranspiration of crop</td>
</tr>
<tr>
<td>Aff&lt;sub&gt;1&lt;/sub&gt;</td>
<td>Affinity function for the monthly conjunctive use model</td>
</tr>
<tr>
<td>Aff&lt;sub&gt;2&lt;/sub&gt;</td>
<td>Affinity function for the intra-seasonal allocation model.</td>
</tr>
<tr>
<td>AIC</td>
<td>Akaike Information Criterion</td>
</tr>
<tr>
<td>AICSA</td>
<td>Adaptive Immune Clonal Strategy Algorithm</td>
</tr>
<tr>
<td>AINE</td>
<td>Artificial Immune Network</td>
</tr>
<tr>
<td>AIRS</td>
<td>Artificial Immune Recognition System</td>
</tr>
<tr>
<td>AIS</td>
<td>Artificial Immune System</td>
</tr>
<tr>
<td>ANN</td>
<td>Artificial Neural Network</td>
</tr>
<tr>
<td>ANSC</td>
<td>Artificial Negative Selection Classifier</td>
</tr>
<tr>
<td>AR</td>
<td>Autoregressive</td>
</tr>
<tr>
<td>ARB</td>
<td>Artificial Recognition Ball</td>
</tr>
<tr>
<td>ARIMA</td>
<td>Autoregressive Integrated Moving Average</td>
</tr>
<tr>
<td>ASM</td>
<td>Aquifer Simulation Model</td>
</tr>
<tr>
<td>ASMWIN</td>
<td>Aquifer Simulation Model for Windows</td>
</tr>
<tr>
<td>B</td>
<td>Backward shift operator</td>
</tr>
<tr>
<td>Bcem</td>
<td>Billion cubic metre</td>
</tr>
<tr>
<td>bgl</td>
<td>Below ground level</td>
</tr>
<tr>
<td>b&lt;sup&gt;-1&lt;/sup&gt;&lt;sub&gt;ij&lt;/sub&gt;</td>
<td>Saturated thickness of cell (i,j) at time t-1</td>
</tr>
<tr>
<td>C</td>
<td>Number of crops</td>
</tr>
</tbody>
</table>
CADA  Command Area Development Authority

CF1, CF2, CF3,…,CF7  Coefficients of the groundwater flow equation

CGWB  Central Ground Water Board

CH  Chromosome

CH1,CH2  Original chromosomes

CH1, CH2  Chromosomes after crossover

[COEF]  Square matrix of the coefficients of head

{CONS}  Vector of constants

Cn  Constant term in head dependent flow boundary

CSA  Clonal Selection Algorithm

CT  Constant term in ARIMA Model

Cumec  Cubic metre per second

CWR  Crop Water Requirement

d  Non seasonal differencing parameter

D  Seasonal differencing parameter

dmax  Maximum specified depth (m bgl)

dmin  Minimum specified depth (m bgl)

DP  Dynamic Programming

DPR  Dynamic Programming and Regression

ε  Exponent of penalty parameter

e_a  Actual vapour pressure (KPa)

Eap  Application efficiency for both surface and groundwater

Ecs  Conveyance efficiency of surface water

EL  Elevation

[xxi]
EMPSO  Elitist-Mutated Particle Swarm Optimization
ER  Effective Rainfall
\(e_s\)  Saturation vapour pressure (K Pa)
\(E'\)  Evaporation from the reservoir
ET0  Reference evapotranspiration
F  Fitness function
f  Objective function
Ff1  Fitness function for the monthly conjunctive use model
f1  Objective function for the monthly conjunctive use model
f2  Objective function for the intra-seasonal allocation model
FAO  Food and Agriculture Organization
FIS  Fuzzy Interface System
FLA  Frog Leaping Algorithm
FLP  Fuzzy Linear programming
FNN  Fuzzy Neural Network
FRL  Full Reservoir Level
\(\hat{g}\)  New gene produced after mutation
G  Soil heat flux density (MJ/m\(^2\)/day)
g\(_1\), g\(_2\)…g\(_n\)  Genes of chromosome
GA  Genetic Algorithm
GCA  Gross Command Area
gen  Generation
gen\(_{max}\)  Maximum number of generations
GIR  Gross Irrigation Requirement
GL  Elevation of the ground (m above msl)
gs  Growth stage index
GS  Number of growth stages
GUI  Graphical User Interface
GWFM  Ground Water Flow Model
Gwh  Giga watt hour
GW^t  Groundwater withdrawal for irrigation during month t (m³)
h  Hydraulic head
h^i_cal  Calculated head at location i
h^i_obs  Observed head at location i
\bar{h}^i_cal  Mean of the calculated heads
\bar{h}^i_obs  Mean of the observed heads
(h_{GWFM})_{max}  Maximum value of hydraulic head from the developed model
(h_{GWFM})_{min}  Minimum value of hydraulic head from the developed model
(h_{PM})_{max}  Maximum value of hydraulic head obtained from PMWIN
(h_{PM})_{min}  Minimum value of hydraulic head obtained from PMWIN
H^t  Average head of the reservoir during month t (m)
HYV  High Yielding Varieties
I  Number of constraints handled in GA
IMD  India Meteorological Department
IP  Depth of irrigation actually provided (mm)
Kc  Crop coefficient
Kwh  Kilo watt hour
KWH^t  Energy generated during month t (Kwh)
(K_{xx})_{i,j}  Hydraulic conductivity of cell (i,j) along the x direction
ky  Yield response factor
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
</tr>
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<tbody>
<tr>
<td>lb&lt;sub&gt;i&lt;/sub&gt;</td>
<td>Lower bound on g&lt;sub&gt;i&lt;/sub&gt;</td>
</tr>
<tr>
<td>LP</td>
<td>Linear Programming</td>
</tr>
<tr>
<td>LSO</td>
<td>Linked Simulation Optimization</td>
</tr>
<tr>
<td>M</td>
<td>Number of target locations for groundwater model calibration</td>
</tr>
<tr>
<td>MA</td>
<td>Moving Average</td>
</tr>
<tr>
<td>MCDM</td>
<td>Multi Criteria Decision Making</td>
</tr>
<tr>
<td>Mcm</td>
<td>Million cubic metre</td>
</tr>
<tr>
<td>MDDL</td>
<td>Minimum Draw Down Level</td>
</tr>
<tr>
<td>Mha</td>
<td>Million hectare</td>
</tr>
<tr>
<td>MILA</td>
<td>Multilevel Immune Learning Algorithm</td>
</tr>
<tr>
<td>msl</td>
<td>mean sea level</td>
</tr>
<tr>
<td>Mw</td>
<td>Mega watt</td>
</tr>
<tr>
<td>MWL</td>
<td>Maximum Water Level</td>
</tr>
<tr>
<td>N</td>
<td>Number of wells</td>
</tr>
<tr>
<td>NC</td>
<td>Total number of clones produced</td>
</tr>
<tr>
<td>NIA</td>
<td>Net Irrigable Area</td>
</tr>
<tr>
<td>NIR</td>
<td>Net Irrigation Requirement</td>
</tr>
<tr>
<td>NIR&lt;sub&gt;c&lt;/sub&gt;&lt;sup&gt;t&lt;/sup&gt;</td>
<td>Net irrigation requirement of crop c during month t (mm)</td>
</tr>
<tr>
<td>NLP</td>
<td>Non Linear Programming</td>
</tr>
<tr>
<td>NR</td>
<td>Number of records</td>
</tr>
<tr>
<td>NRMSE</td>
<td>Normalized Root Mean Squared Error</td>
</tr>
<tr>
<td>Ø</td>
<td>Non-seasonal AR operator of order p</td>
</tr>
<tr>
<td>p</td>
<td>Non seasonal auto regressive parameter</td>
</tr>
<tr>
<td>P</td>
<td>Seasonal auto regressive parameter</td>
</tr>
<tr>
<td>PCM</td>
<td>Point Collocation Method</td>
</tr>
</tbody>
</table>
\( P_{cs} \)  
Crossover probability

PDP  
Pagadia Dam Project

PE  
Probability of Exceedance

PET  
Potential Evapotranspiration

Pf  
Penalty function

Pf1  
Penalty function for the conjunctive use model, used with GA

Pf_{AIS1}  
Penalty function for the conjunctive use model, used with AIS

Pf_{AIS2}  
Penalty function for the intra-seasonal model, used with AIS

PM  
Processing MODFLOW

PMWIN  
Processing MODFLOW for Windows

PP  
Plotting position

Pr  
Total precipitation (mm)

R^t  
Rainfall into the reservoir during time period \( t \) (Mcm)

PSO  
Particle Swarm Organization

Q  
Seasonal moving average parameter

q  
Non seasonal moving average parameter

q_p  
Rate of pumping \((m^3/day)\)

Q_{PE}  
Yearly inflow at probability of exceedance \( PE \)% \((Mcm)\)

q_r  
Rate of recharge \((m^3/day)\)

Q^t  
Inflow into the reservoir during time period \( t \) (Mcm)

Q_{Av}^t  
Average inflow during month \( t \) (Mcm)

Q_{PE}^t  
Inflow at the probability of exceedance \( PE \)% during month \( t \)

r  
Random number in the interval \([0,1]\)

RC  
Rate at which cloning occurs

RCGA  
Real Coded Genetic Algorithm
RH   Relative Humidity
RMC   Regional Meteorological Centre
RMSE  Root Mean Squared Error
R_n   Net radiation (MJ/m²/day)
RN    Rank number
RRHp_\text{t}  Reservoir release for power generation during period t (m³)
RRIrr_\text{t}  Reservoir release for irrigation during month t (m³)
s    Seasonal length of ARIMA Model
SA    Simulated Annealing
S_{Av}  Average storage (m³)
SBC   Schwarz Bayesian Criterion
SDP   Stochastic Dynamic Programming
S_{\text{max}}  Maximum storage (m³)
S_{\text{min}}  Dead storage of the reservoir (m³)
SPC   Soil Profile Contribution
SRSP  Sri Ram Sagar Project
S_\text{t}  Reservoir storage at the beginning of month t (m³)
S_{\text{t+1}}  Reservoir storage at the end of month t (m³)
SWAT  Soil and Water Assessment Tool
S_y   Specific yield of the porous medium (dimensionless)
T     Mean daily air temperature at 2 m height (°C)
t    Time index
T_{xx}  Transmissivity along the x co-ordinate axis (m²/day)
T_{yy}  Transmissivity along the y co-ordinate axis (m²/day)
u_2   Wind speed at 2 m height (m/s)
ub_i \quad \text{Upper bound on } g_i

UN \quad \text{United Nations}

USA \quad \text{United States of America}

USDA-SCS \quad \text{US Department of Agriculture - Soil Conservation Service}

W \quad \text{Volumetric flow rate (m}^3/\text{day)}

WR \quad \text{Crop water requirement (m}^3\text{)}

WR^t \quad \text{Irrigation demand during month } t \text{ (m}^3\text{)}

x, y and z \quad \text{Groundwater flow directions}

x_i \quad \text{Discrete time series value at time } i

y_{act} \quad \text{Actual crop yield}

y_{max} \quad \text{Potential yield of crop}

\alpha_t \quad \text{White noise time series value at time } t

\beta \quad \text{Multiplier of penalty parameter}

\gamma \quad \text{Psychometric constant}

\Delta \quad \text{Slope of vapour pressure (K Pa/ } ^\circ \text{C)}

\delta_n \quad \text{Discharge rate of well } n \text{ (m}^3/\text{day)}

\Delta t \quad \text{Length of time step}

\Delta X \quad \text{Grid size in } x \text{ direction}

\Delta Y \quad \text{Grid size in } y \text{ direction}

\eta \quad \text{Efficiency of power plant}

\Theta \quad \text{Seasonal MA operator of order } Q

\theta \quad \text{Non-seasonal MA operator of order } q

\lambda_i \quad \text{Penalty for violation of constraint } i

\mu \quad \text{Mean level of the } \omega_t \text{ series}

\rho \quad \text{User defined parameter of non-uniform mutation}
\( \tau \)  
A random number

\( \chi \)  
Amount of change in parameter value in mutation

\( \psi \)  
Mutation function

\( \Omega \)  
A known function

\( \omega_t \)  
Seasonal ARIMA series at time \( t \)

\( \Phi \)  
Seasonal AR operator of order \( P \)

\( \perp \)  
Direction normal to flow boundary