V.T. Chow Philosophy
Water balance: input = output ± storage
\[ p + w = Q_s + Q_B + \Delta D + \Delta S + E + A \] (1)

\( p \) = precipitation received on area A
\( w \) = water imported or exported by man
\( Q_s \) = net surface runoff
\( Q_B \) = net subsurface outflow as unsaturated or saturated porous media flow
\( \Delta D \) = change in surface storage (detention)
\( \Delta S \) = change in soil water storage
\( E \) = evaporation per unit area

Energy conservation equation:
\[ R_s (1 - \rho) = R_L + G + H + LE \] (2)

\( R_s \) = flux of total shortwave at surface
\( \rho \) = albedo reflected percentage of waves
\( R_L \) = flux of long wave
\( G \) = heat flux into ground
\( H \) = heat transfer into the atmosphere
\( L \) = latent heat of vaporization of water
\( E \) = evaporation rate

Equations (1) and (2) are coupled through “E”

Mass conservation is necessary, but not sufficient for short periods of time, to describe the dynamic phenomenon of watershed hydrology. A second equation based on the principles of conservation of energy or momentum is required. The two equations along with initial conditions (I.C.) in boundary conditions (B.C.) describe the dynamics of flow.

Model classifications:

We understand an event if we can give scientific explanation of it. So, in essence, formal models are the scientific explanation of the event/process (Hempel 1963).

Examples: Lysimeters are iconic representation model for water balance modeling.
An electric board representation of water system flow through electric current measurements
Empirical: data-based equation of crop growth.
(danger: some parameters may seem to be correlated while, in fact, they are not.) problems: omits laws, needs calibration, parameters do not mean a whole lot, valid only within data range.

Theoretical: usually simplifies reality ∴ are incorrect.
Example: kinematic wave simplification to overland flow problems.

Theory and empirism are so intermeshed so all models are somehow hybrids.

**Classification Criteria**

1. __ Model structure and modeling subject:
   “overheads”

2. ____ Rate of time
   static (time is not a factor) steady state (s.s.)
   dynamic time variant, transient

3. ____ Cognitive value of a model
   physically based: known equations
   conceptual model: unknown relations (ex. Linear or nonlinear, storage models)
   trend model

4. ____ Character of results obtained
   stochastic: output is a variable with probability
   distribution: variation is random
   deterministic = no random variation

5. ____ Approach or method of solution
   black box – system operator from input to output
   white box – physical laws are well understood and synthesized in a system operation

6. ____ Mathematical properties of operator function:
   Linear – nonlinear
   
   *i*  \[ x_1(t) + x_2(t) = y_1(t) + y_2(t) \]
   operator is additive (superposition)
   
   *ii*  statistical linearity
   \[ y = ax + b \]
   \[ y_1 + y_2 \neq a + b(x_1 + x_2) \]

Lumped (no spatial variability ODE (linked)) vs. distributed models (Pde)
Stochastic nature of hydrologic processes
1. Analytical models: mathematical relation very cumbersome so assumptions are made
2. Monte Carlo simulation – random sampling from input processes statistical analysis are tabulated later
3. Historical records: no predictions!!!

Sources of uncertainty:
1. Model uncertainty (approximation for real world) – related to Q
2. Sampling uncertainty (input data) – related to X
3. Simulation sampling – related to Y

\[ Y_t = Q(X_t, \theta) \quad t \in T, T = (0,1,2,...) \]
Q = math transformation
\( \theta \) = model parameters

Choice of models
Criteria:
- Accuracy of prediction
- Simplicity of the model
- Consistency of parameter estimates if parameters vary for similar watersheds – non-reliable
- Sensitivity of results to changes in parameter values. Models should not be too sensitive to parameters that are difficult to obtain.