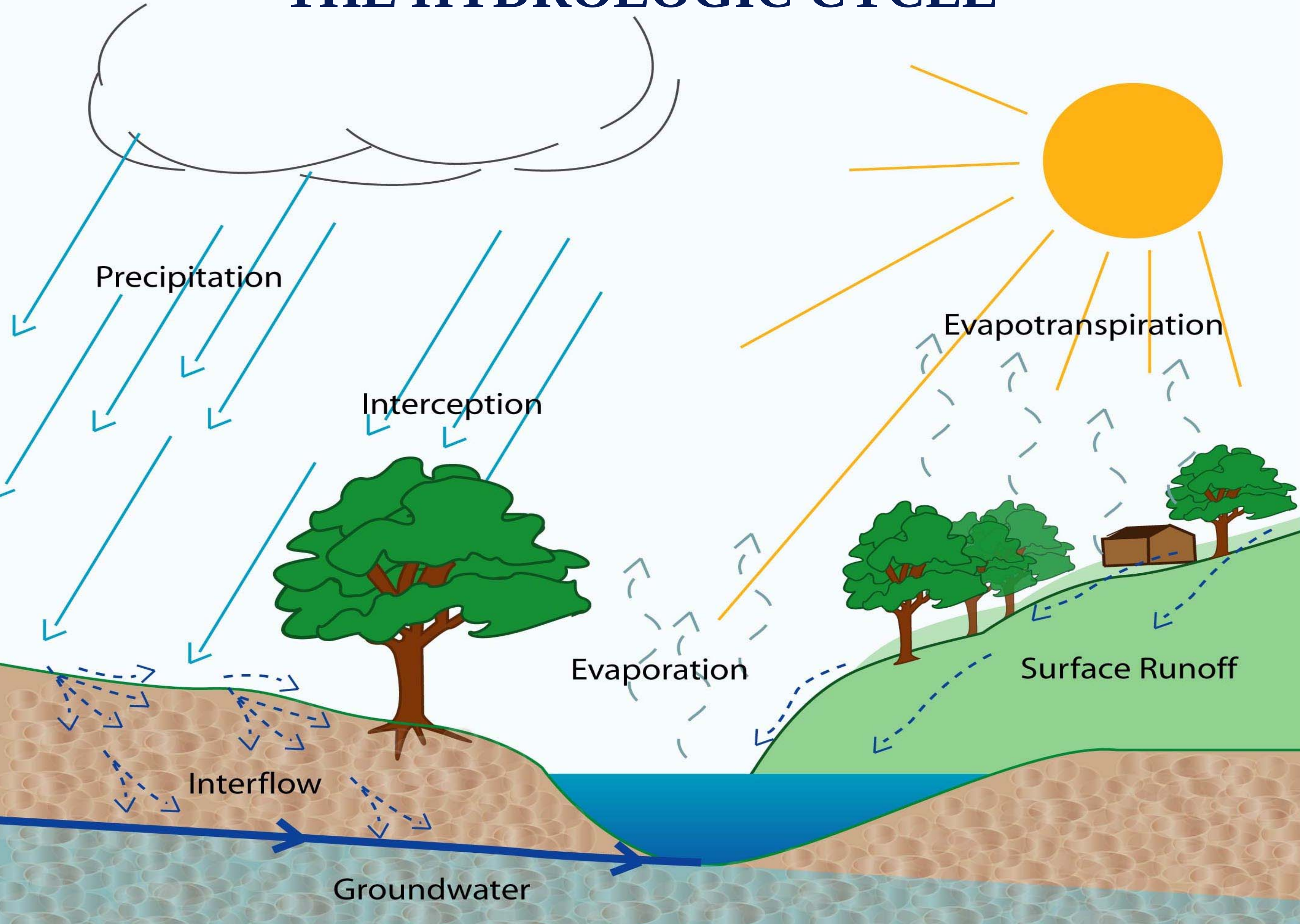
LECTURE #5

HYDROLOGIC PROCESSES, PARAMETERS, AND CALIBRATION

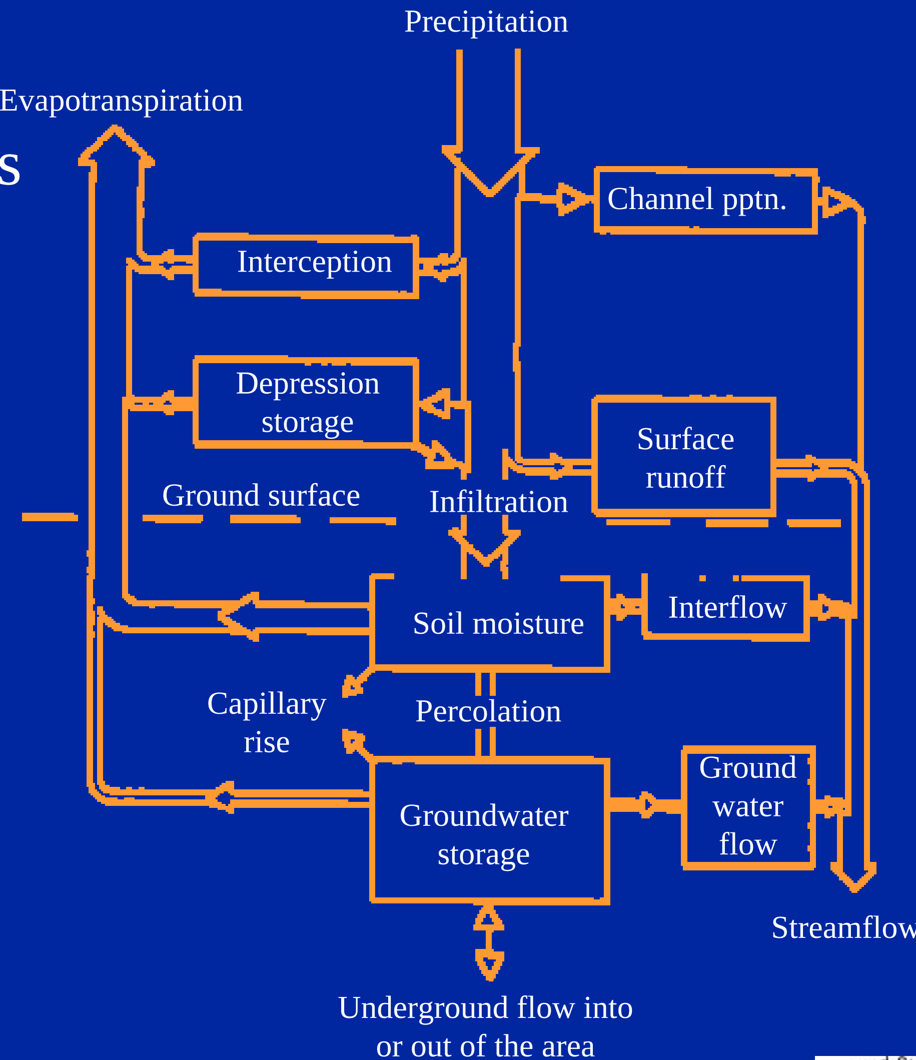
THE HYDROLOGIC CYCLE



HYDROLOGY - HYDROLOGIC COMPONENTS

Hydrologic Components

- Rainfall or Snow
- Interception
- Depression storage
- Evapotranspiration
- Infiltration
- Surface storage
- Runoff
- Interflow
- Groundwater flow



HYDROLOGY - WATER BALANCE

Water balance equation →

$$R = P - ET - IG - \Delta S$$

where:

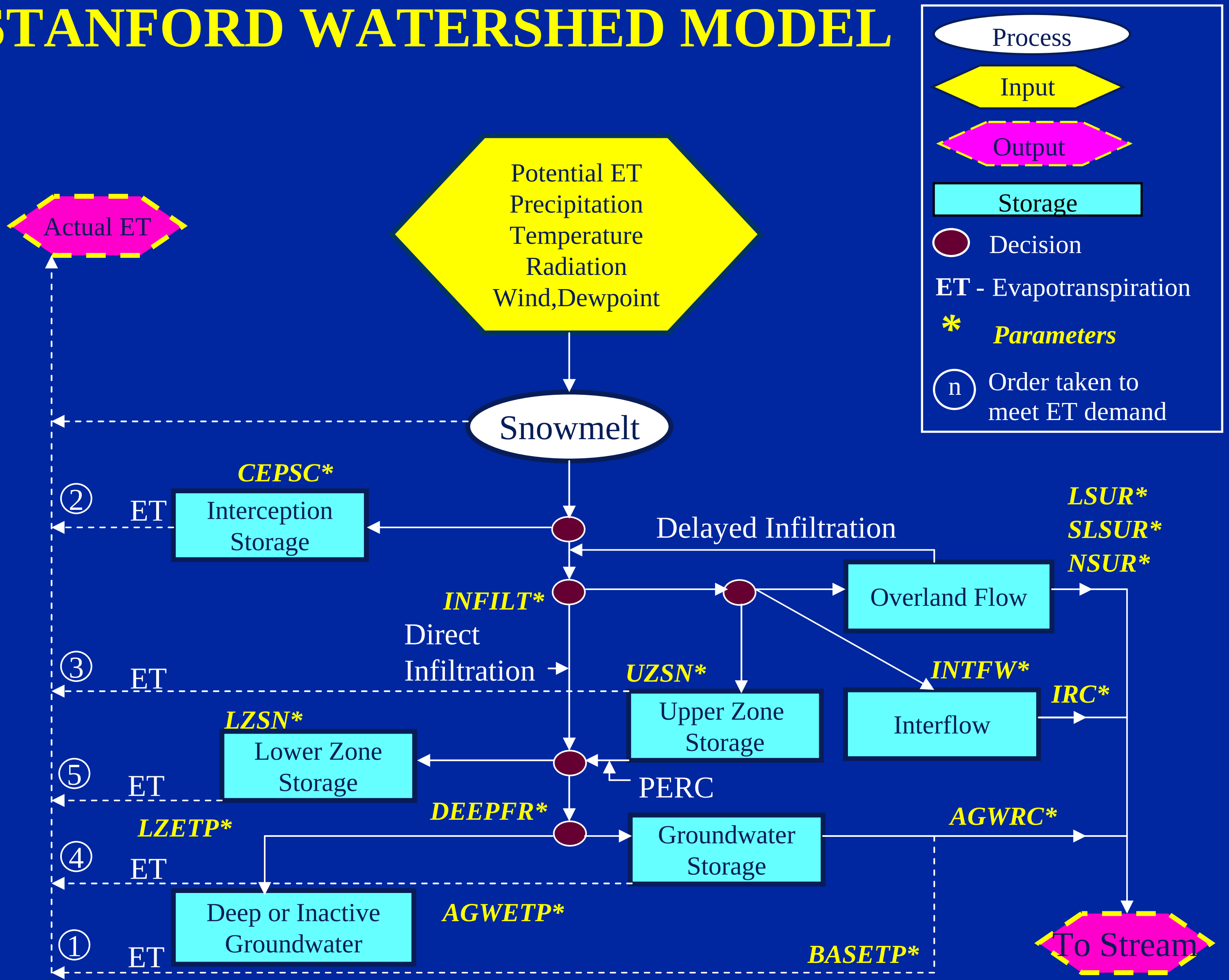
P	=	Precipitation
R	=	Runoff
ET	=	Evapotranspiration
IG	=	Deep/inactive groundwater
ΔS	=	Change in soil storage

Inter-relationships between components

Variation of components with time

- consideration of soil condition, cover, antecedent conditions, land practices

STANFORD WATERSHED MODEL



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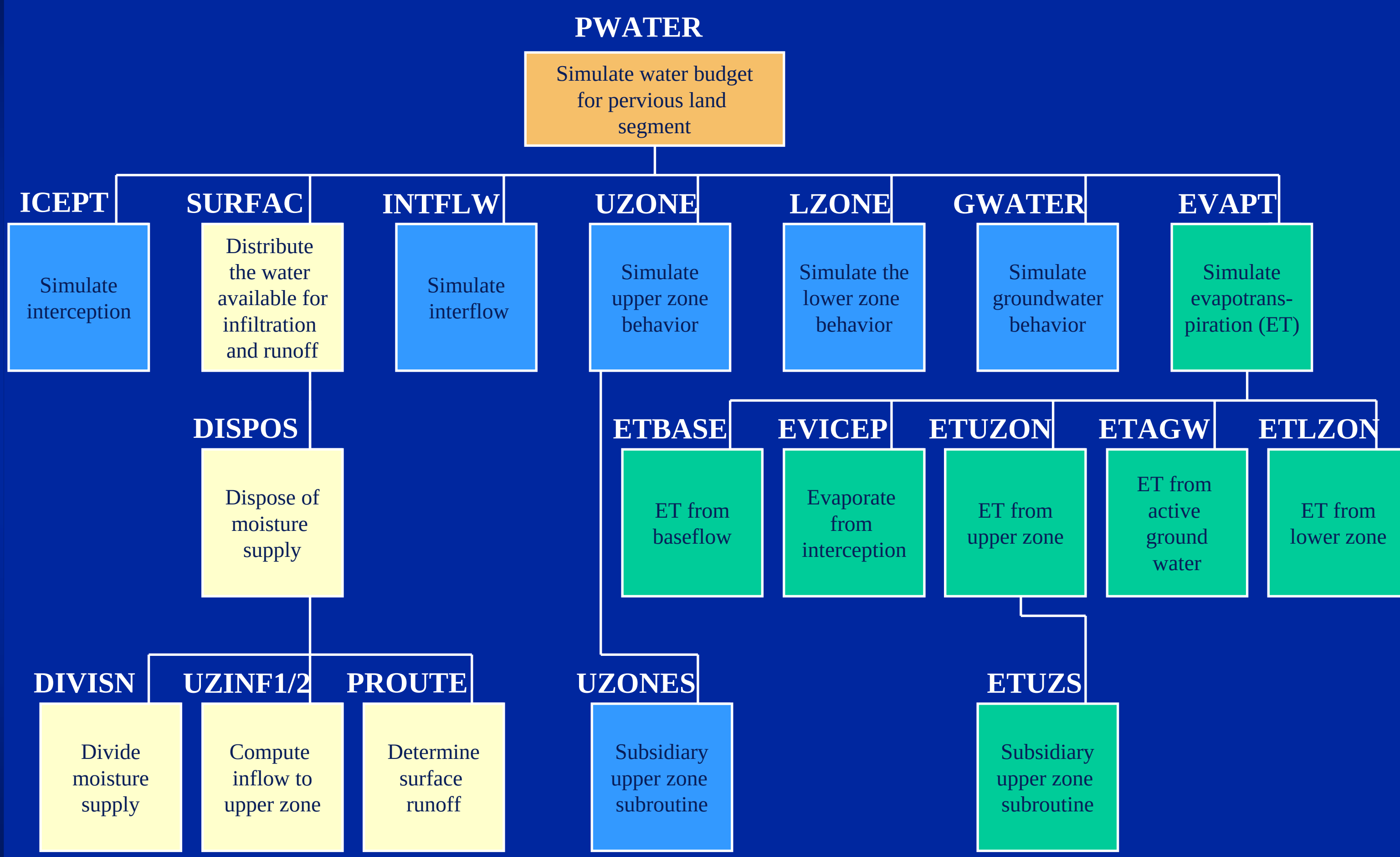
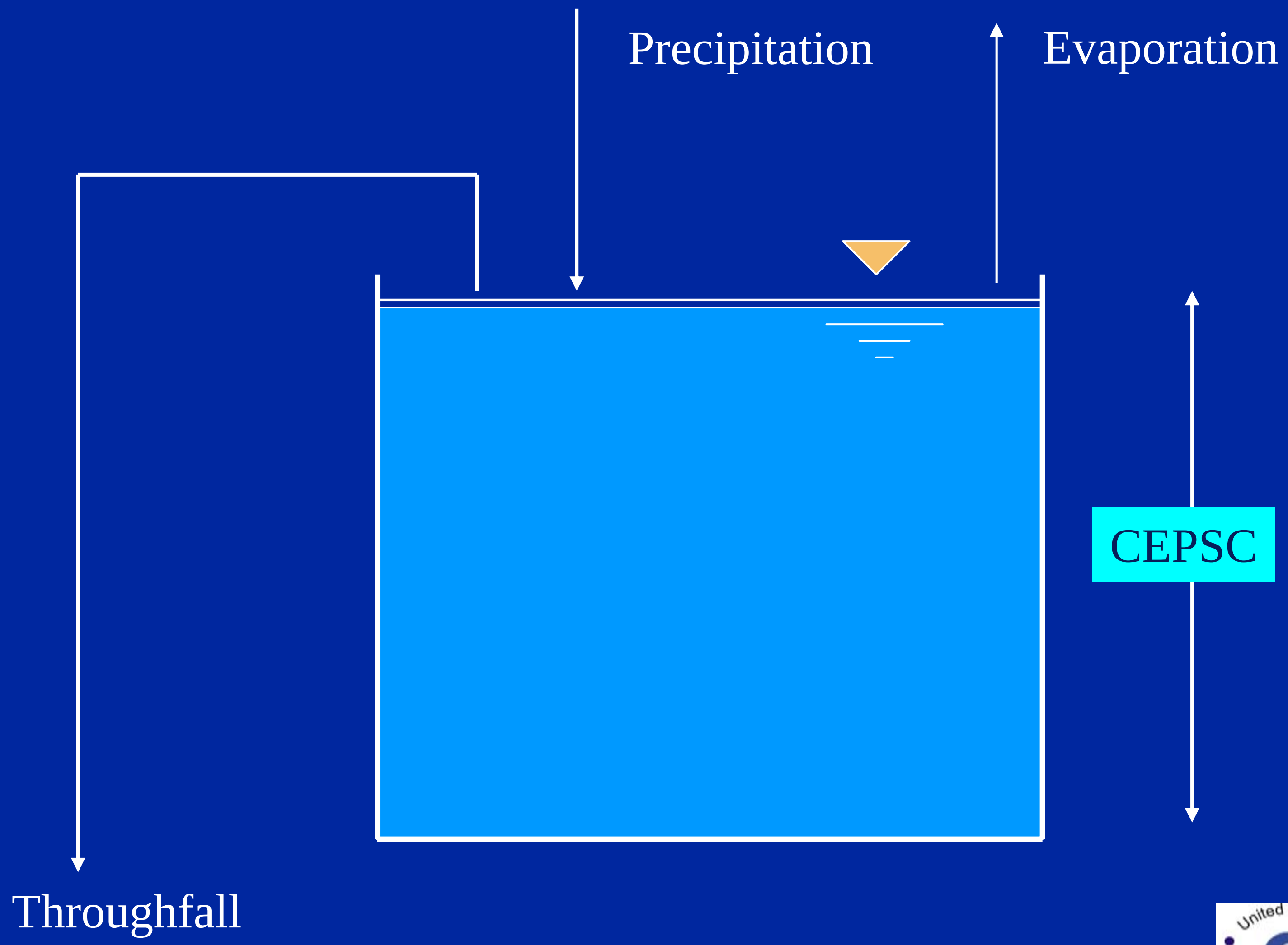
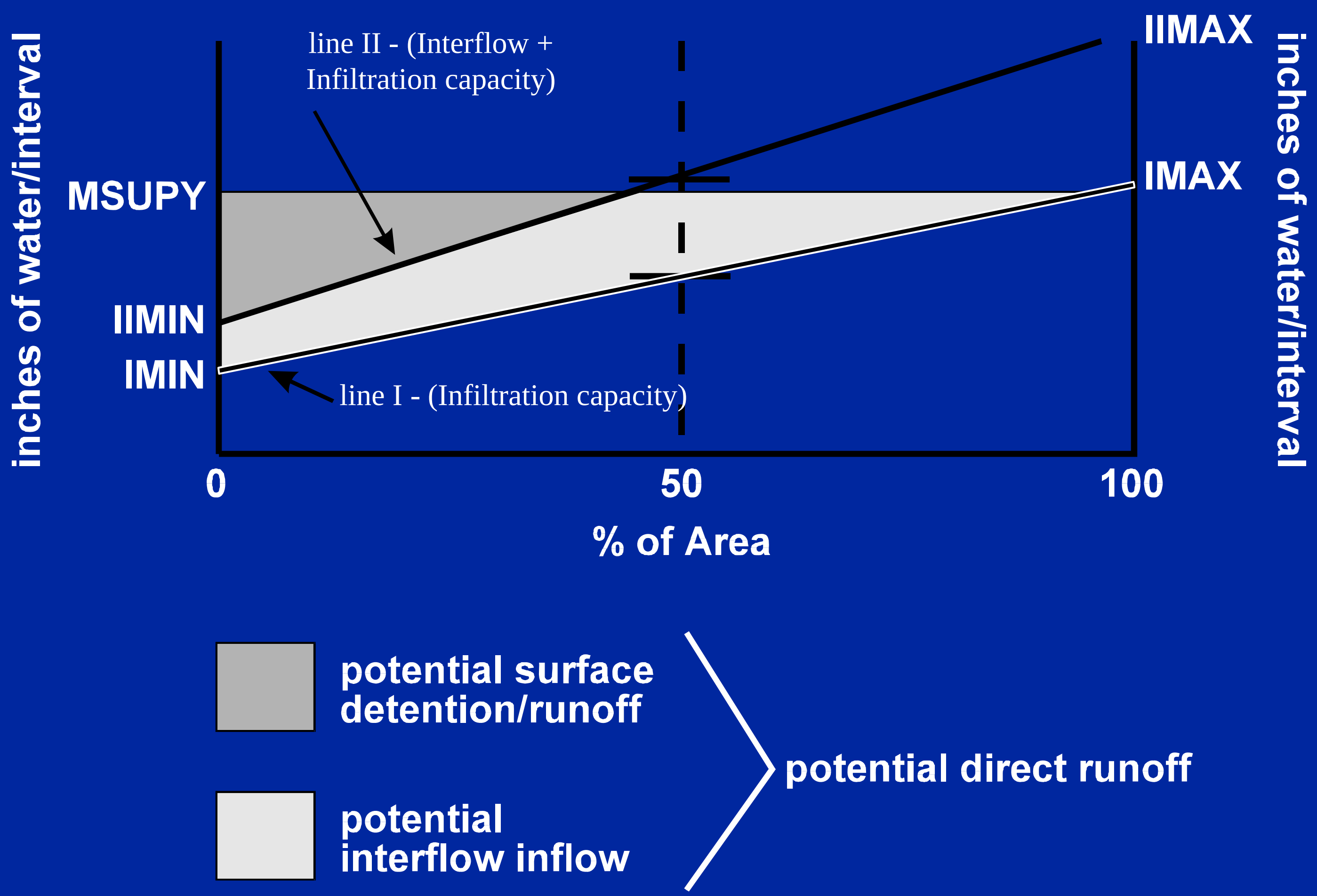
PWATER STRUCTURE CHART



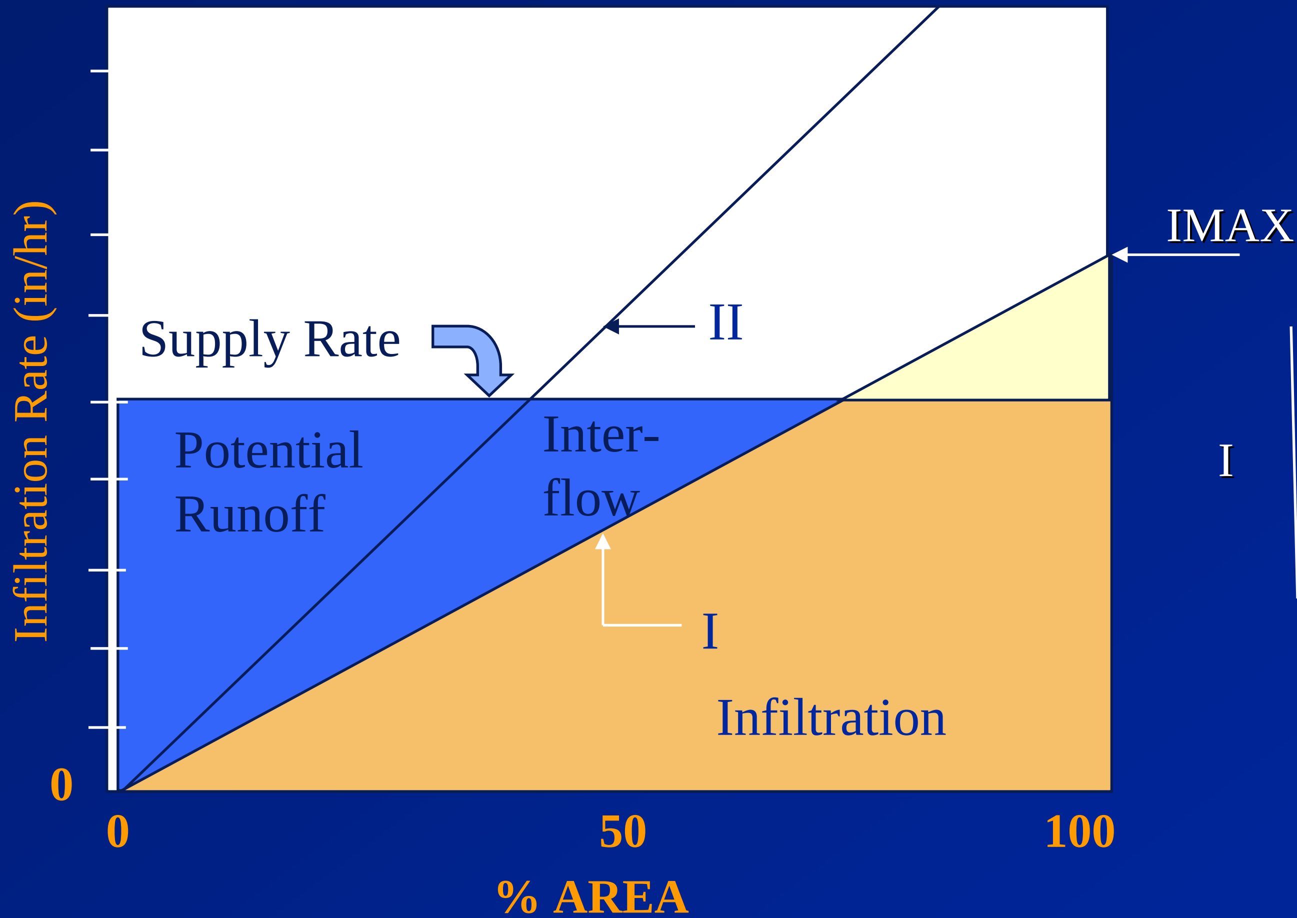
INTERCEPTION FUNCTION

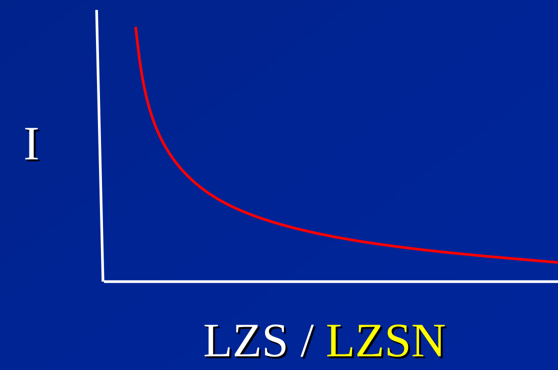


INFILTRATION DIAGRAM



INFILTRATION FUNCTION IN HSPF



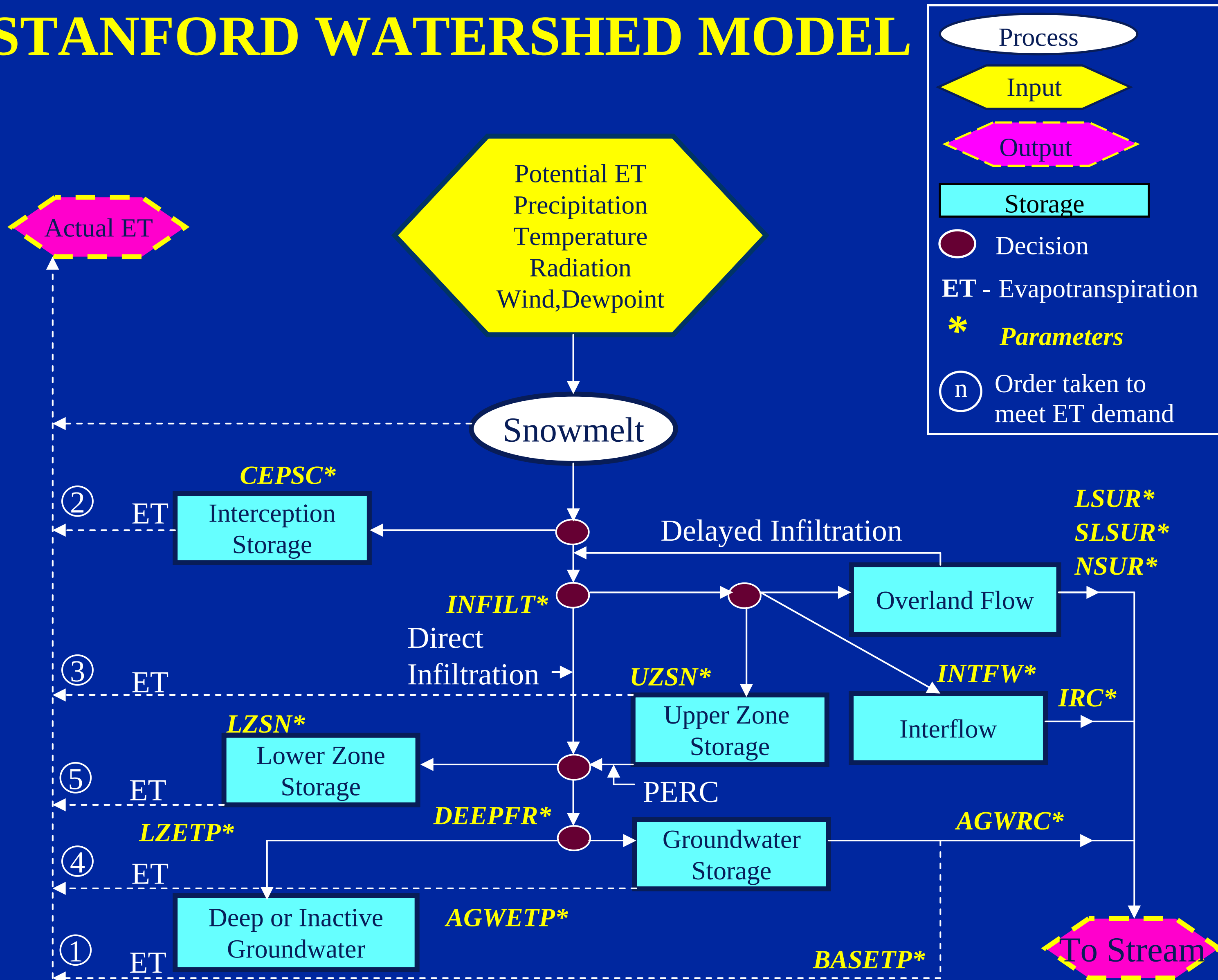


$$I = \frac{INFILT}{(LZS / LZSN)^{INFEXP}} * INFFAC$$

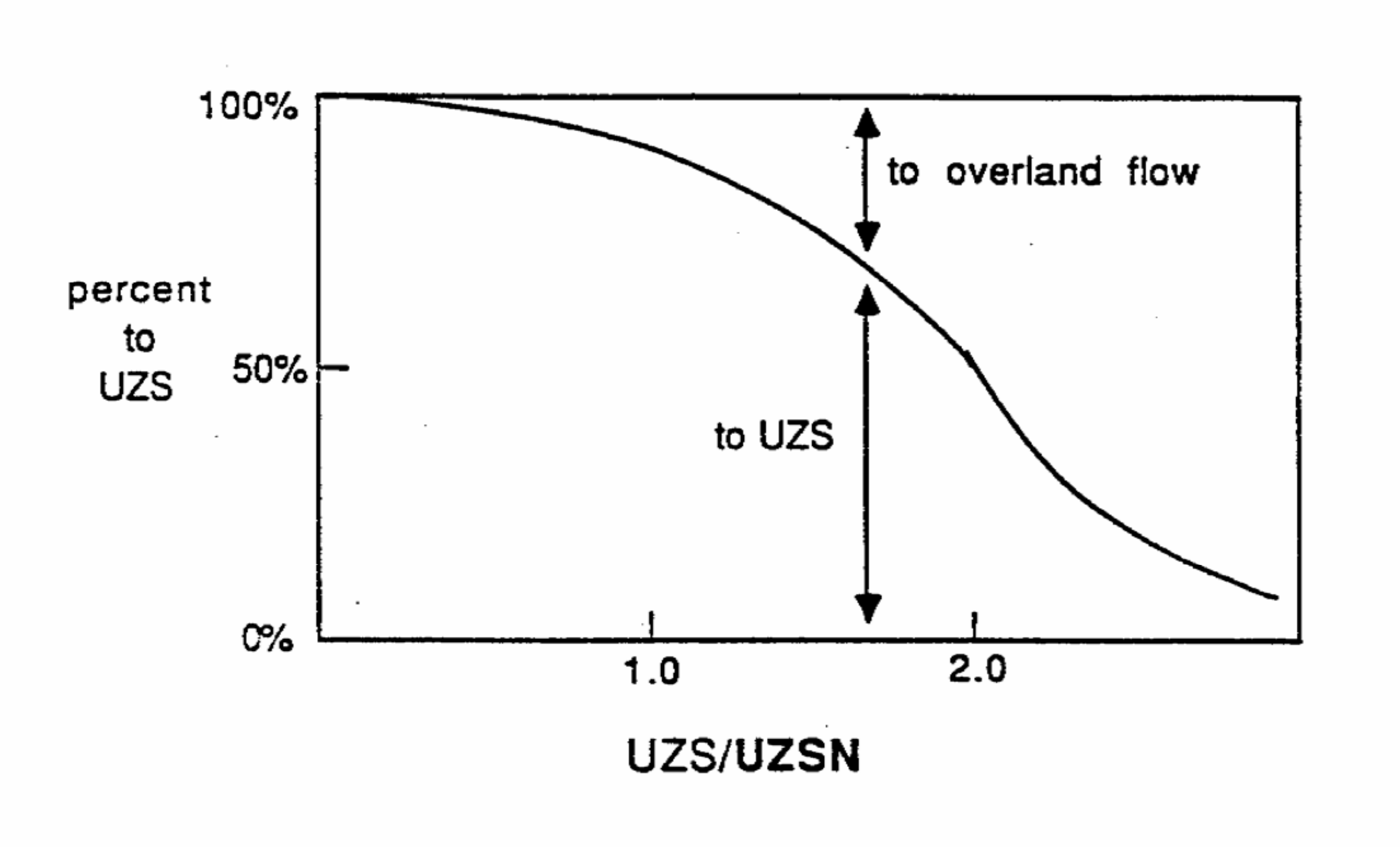
$$IMAX = I * INFILD$$

$$II = I * INTFW\ (2.0^{**}\ (LZS / LZSN))$$

STANFORD WATERSHED MODEL



UPPER ZONE STORAGE FUNCTION

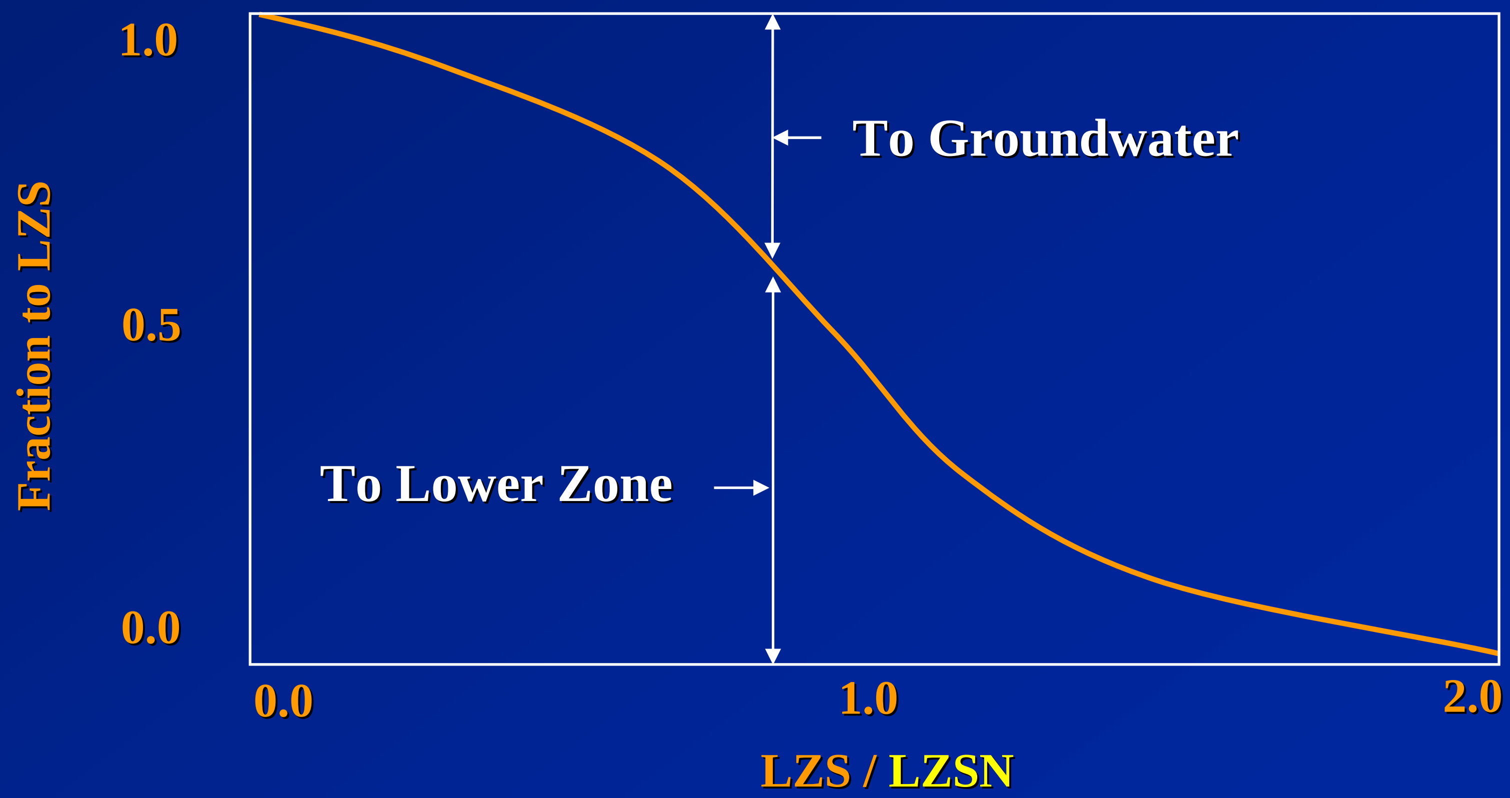


SOIL PROFILE DRAINAGE PROCESSES AND FUNCTIONS

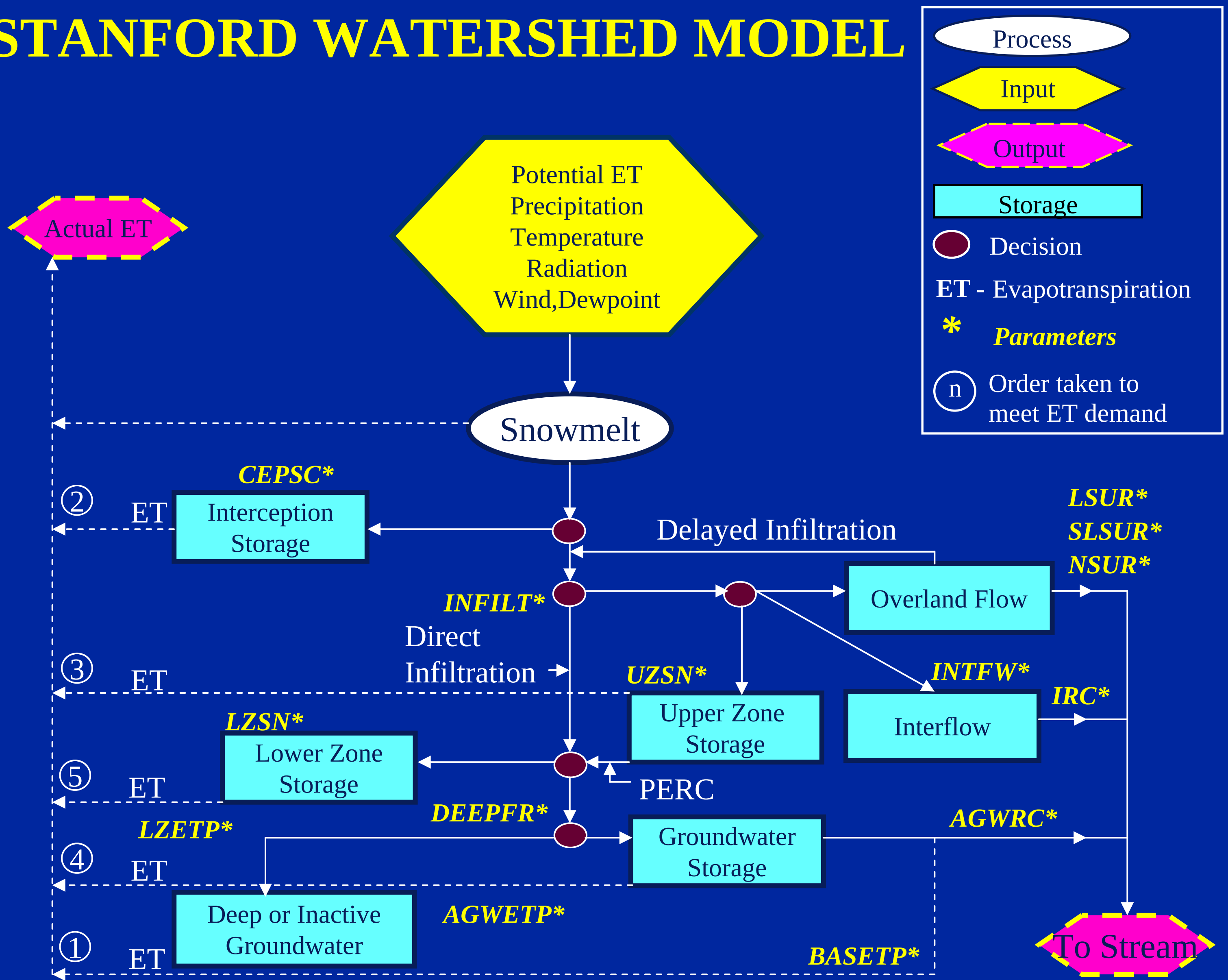
From UZS

$$PERC = 0.1 * INFILT * INFFAC * UZSN * \left(\frac{UZS}{UZSN} - \frac{LZS}{LZSN} \right)^3$$

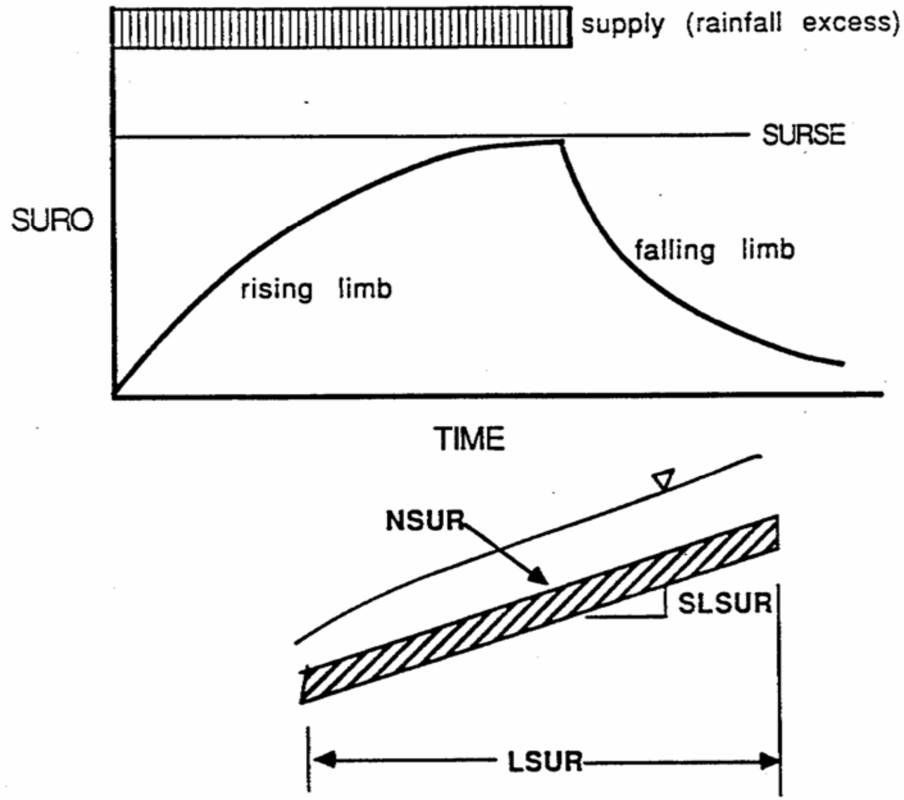
To lower zone or groundwater



STANFORD WATERSHED MODEL



OVERLAND FLOW FUNCTION



<u>rising limb</u>

$$SURO = SRC * (SURSM * (1.0 + 0.6 * (SURSM/SURSE)^{3})^{1.67}$$

$$SRC = 1020 * (SLSUR)^{0.5} / (NSUR / LSUR))$$

SURSM = mean depth (from water budget)

SURSE = equilibrium depth (from Manning's equation)

<u>falling limb</u>

$$SURO = SRC * (1.6 * SURSM)^{1.67}$$

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SUB-SURFACE FLOW FUNCTIONS

Interflow

$$IFWO = K2 * IFWS + K1 * INFLO$$

IFWS = interflow storage at start of time step

INFLO = addition to interflow storage during time-step

$K2 = 1.0 - e^{-K}$

$K1 = 1.0 - K2/K$

$K = - \ln(IRC)^{dt/24}$

IRC = Interflow recession parameter

Baseflow

$$AGWO = KGW * AGWS * (1.0 + KVARY * GWVS)$$

AGWS = active groundwater storage

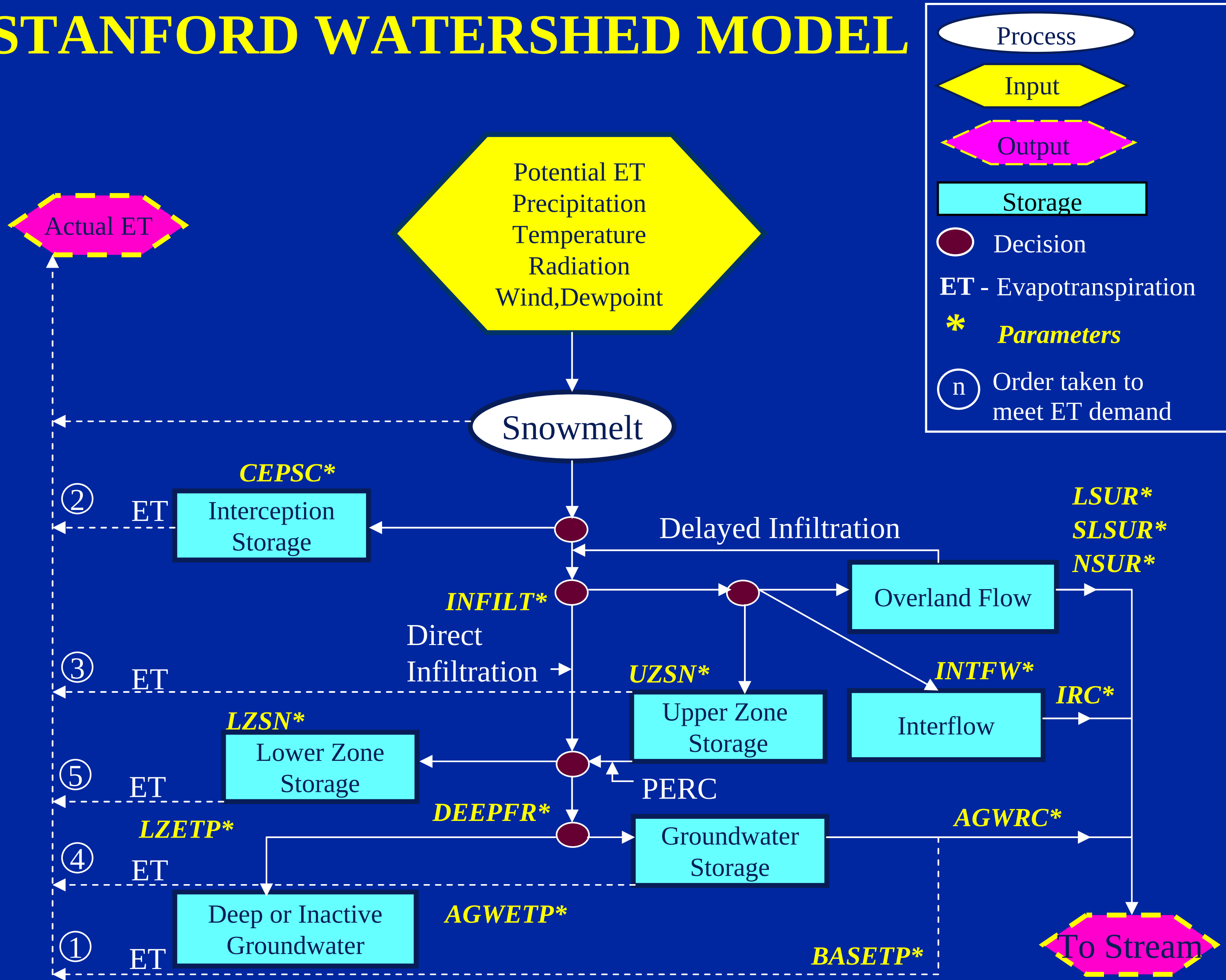
GWVS = antecedent index increased by drainage to AGWS, decreased 3% each day

KVARY = input parameter

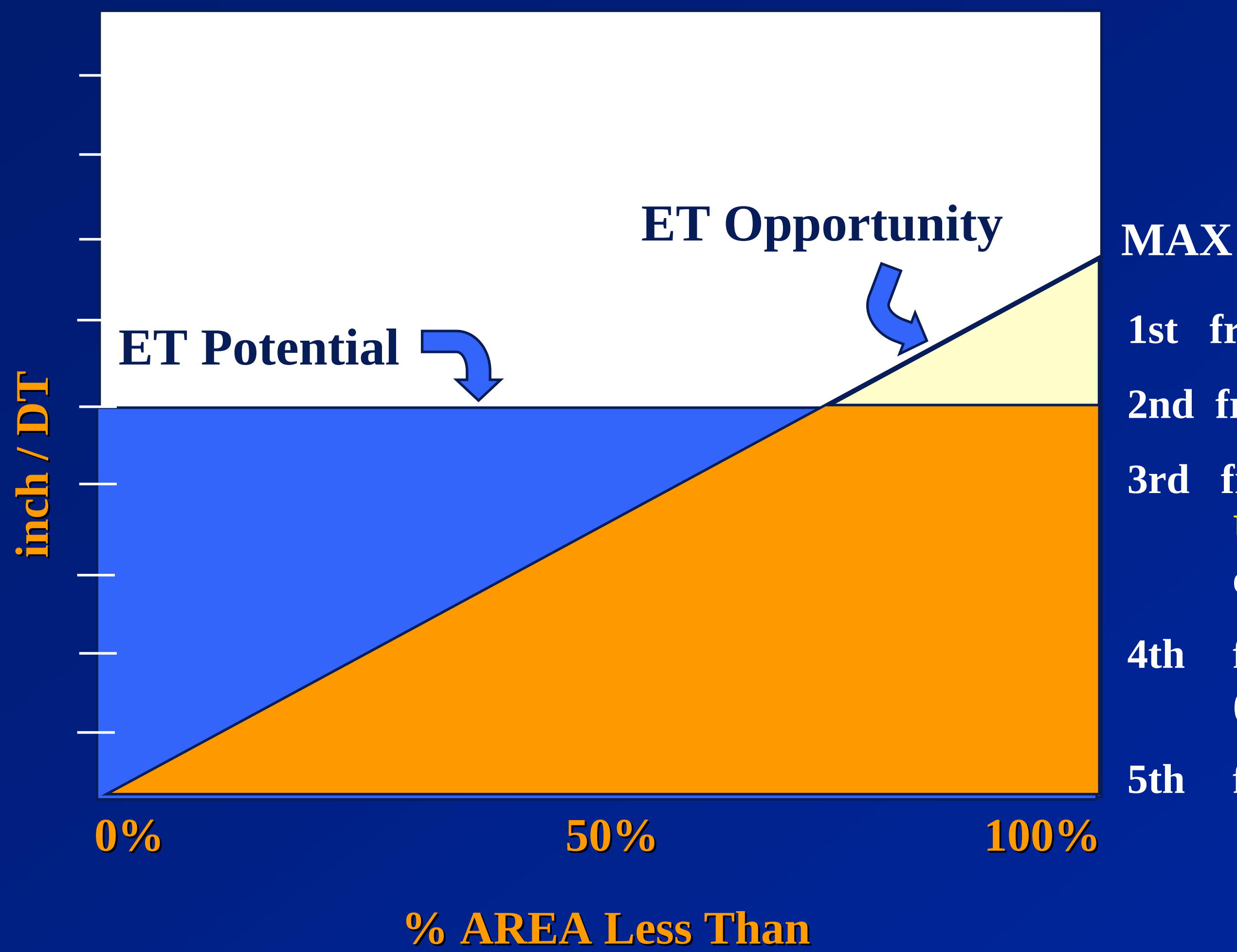
$KGW = 1.0 - (AGWRC)^{dt/24}$

AGWRC = Groundwater recession parameter

STANFORD WATERSHED MODEL



EVAPOTRANSPIRATION FUNCTIONS AND HIERARCHY



1st from baseflow (BASETP)

2nd from interception

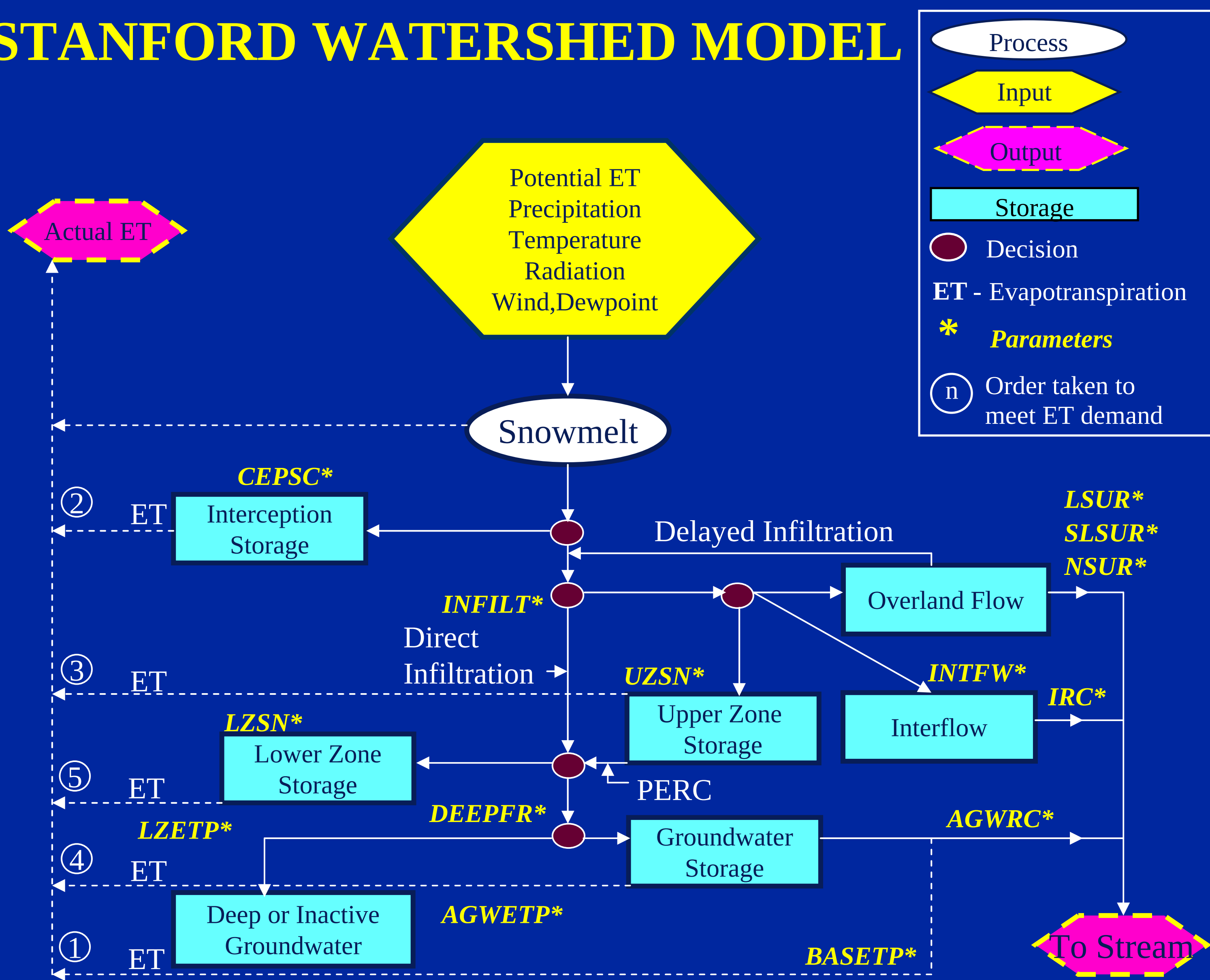
3rd from UZS @ potential if UZS / UZSN > 2.0; else prorated for effective area

4th from active groundwater (AGWETP)

5th from LZS

$$MAX = \left(\frac{0.25}{1 - LZETP} \right) * \left(\frac{LZS}{LZSN} \right) * \left(\frac{DT}{24} \right)$$

STANFORD WATERSHED MODEL



PWATER PARAMETERS: PWAT-PARM2

FOREST - Fraction of the PLS covered by forest

LZSN - Lower zone nominal soil moisture storage

INFILT - Index to the infiltration capacity of the soil

LSUR - Length of the assumed overland flow plane

SLSUR - Slope of the assumed overland flow plane

KVARY - Variable groundwater recession parameter

AGWRC - Basic groundwater recession rate (when KVARY is zero)

PWATER PARAMETERS: PWAT-PARM3

PETMAX - Air temperature below which ET will be reduced below the input value (used when CSNOFG = 1)

PETMIN - Air temperature below which ET will be zero regardless of the input value (used when CSNOFG = 1)

INFEXP - Exponent in the infiltration equation

INFILD - Ratio between the max and mean infiltration capacities over the PLS

DEEPFR - Fraction of groundwater inflow which will enter deep (inactive) groundwater

BASETP - Fraction of remaining potential ET which can be satisfied from baseflow

AGWETP - Fraction of remaining potential ET which can be satisfied from active groundwater storage

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PWATER PARAMETERS: PWAT-PARM4

CEPSC - Interception storage capacity

UZSN - Upper zone nominal soil moisture storage

NSUR - Manning's N for the assumed overland flow plane

INTFW - Interflow inflow parameter

IRC - Interflow recession parameter, i.e., the ratio of interflow outflow rate today / rate yesterday

LZETP - Lower zone ET parameter; an index to the density of deep-rooted vegetation

CALIBRATION ISSUES

‘Basic Truths’ in modeling natural systems

- Models are approximations of reality; they can not precisely represent natural systems
- There is no single, accepted statistic or test that determines whether or not a model is valid
- Both graphical comparisons and statistical tests are required in model calibration and validation
- Models cannot be expected to be more accurate than the errors (confidence intervals) in the input and observed data
- A ‘weight-of-evidence’ approach is becoming the preferred practice for model calibration and validation

CALIBRATION/VALIDATION COMPARISONS

"Weight-of-Evidence" Approach

- Mean runoff volume for simulation period (inches)
- Annual and monthly runoff volume (inches)
- Daily flow timeseries (cfs)
  - observed and simulated daily flow
  - scatter plots
- Flow frequency (flow duration) curves (cfs)
- Storm hydrographs, hourly or less, (cfs)

CALIBRATION/VALIDATION COMPARISONS

Water Balance Components

- Precipitation
- Total Runoff (sum of following components)
  - Overland flow
  - Interflow
  - Baseflow
- Total Actual Evapotranspiration (ET) (sum of following components)
  - Interception ET
  - Upper Zone ET
  - Lower Zone ET
  - Baseflow ET
  - Active Groundwater ET
- Deep Groundwater Recharge/Losses

CALIBRATION/VALIDATION COMPARISONS

Graphical/Statistical Procedures & Tests

Graphical Comparisons:

- Timeseries plots of observed and simulated values for fluxes (e.g., flow) or state variables (e.g., stage, sediment concentration, biomass concentration)
- Observed and simulated scatter plots, with 45^{o} linear regression line displayed, for fluxes or state variables
- Cumulative frequency distributions of observed and simulated fluxes or state variable (e.g., flow duration curves)

Statistical Tests:

- Error statistics, e.g., mean error, absolute mean error, relative error, relative bias, standard error of estimate, etc.
- Correlation tests, e.g., correlation coefficient, coefficient of model-fit efficiency, etc.
- Cumulative Distribution tests, e.g., Kolmogorov-Smirnov (KS) test

R & R^2 VALUE RANGES FOR MODEL PERFORMANCE

Criteria

R	← 0.75 —— 0.80 —— 0.85 —— 0.90 —— 0.95 →
R^2	← —— 0.6 —— 0.7 —— 0.8 —— 0.9 —— →
Daily Flows	Poor · Fair · Good · Very Good
Monthly Flows	Poor | Fair | Good | Very Good

HYDROLOGIC (PWATER) CALIBRATION

- **Annual Water Balance -**

  Runoff = Prec. - Actual ET - Deep Perc. - Δ Storage

  Key Parameters: Repre. Precipitation (MFACT)
  LZSN
  LZETP
  INFILT
  DEEPFR

- **Groundwater (Baseflow) Volume and Recession -**

  Runoff = Surface Runoff + Interflow + Baseflow

  Key Parameters: INFILT
  AGWRC/KVARY
  DEEPFR
  BASETP/AGWETP

- **Surface Runoff + Interflow (Hydrograph Shape) -**

  Key Parameters: UZSN
  INTFW
  IRC
  LSUR, NSUR, SLSUR

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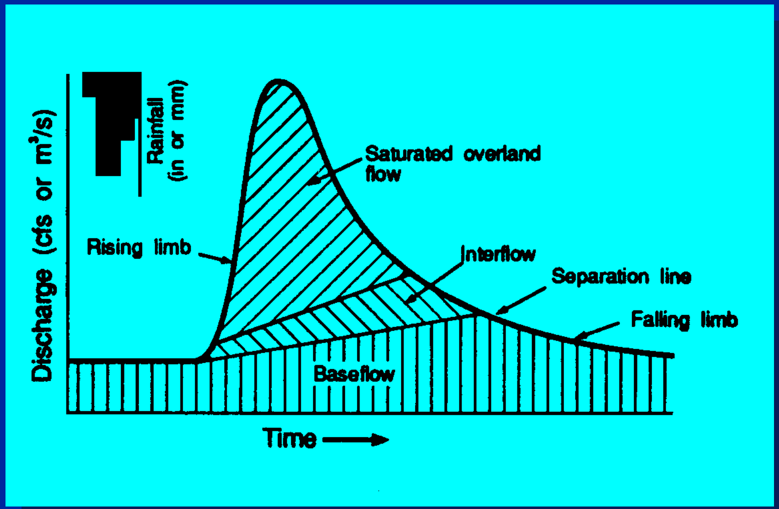
COMPONENTS OF HYDROGRAPH

Runoff → Surface runoff - overland flow

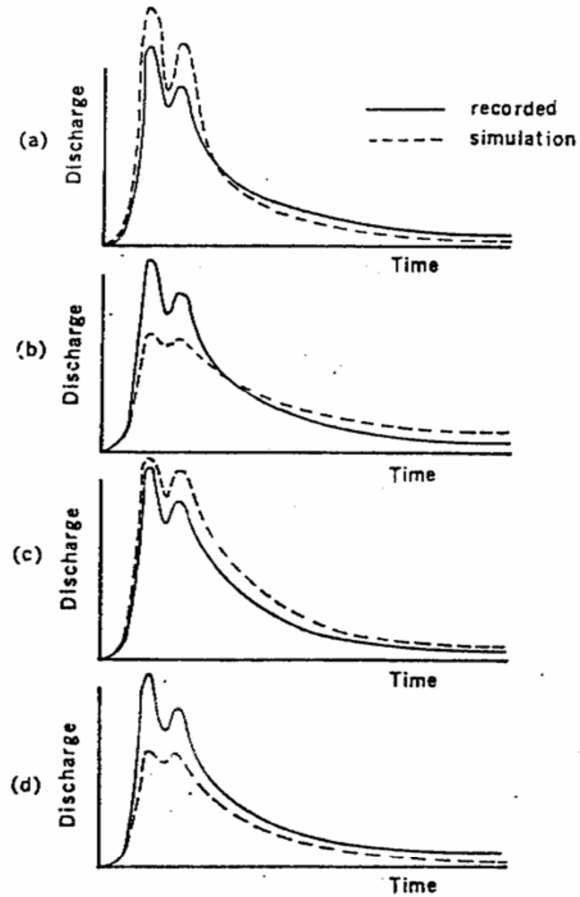
Interflow → Interflow - flow through surficial layers of soil

Baseflow → Baseflow - groundwater seepage from springs and aquifers directly to the stream channel



adapted from EPA BASINS workshop

HYDROGRAPH SENSITIVITY TO INFILT



Indicated change in INFILT	(a)	(b)	(c)	(d)
from surface runoff volume	increase	decrease	increase	decrease
from groundwater flow	increase	decrease	decrease	increase
Remarks on results	consistent		conflicting	

HYDROGRAPH SENSITIVITY TO INTFW

HSPF PWATER PARAMETERS AND TYPICAL/POSSIBLE VALUE RANGES (#1)

			RANGE OF VALUES					
NAME	DEFINITION	UNITS	TYPICAL		POSSIBLE		FUNCTION OF ...	COMMENT
			MIN	MAX	MIN	MAX		
PWAT - PARM2								
FOREST	Fraction forest cover	none	0.0	0.50	0.0	0.95	Forest cover	Only impact when Snow is active
LZSN	Lower Zone Nominal Soil Moisture Storage	inches	3.0	8.0	2.0	15.0	Soils, climate	**Calibration**
INFILT	Index to Infiltration Capacity	in/hr	0.01	0.25	0.001	0.50	Soils, land use	**Calibration**, divides surface and subsurface flow
LSUR	Length of overland flow	feet	200	500	100	700	Topography	Estimate from maps or GIS
SLSUR	Slope of overland flow plane	none	0.01	0.15	0.001	0.30	Topography	Estimate from maps or GIS
KVARY	Variable groundwater recession	none	1.0	3.0	1.0	5.0	Baseflow recession variation	Used when recession rate varies with GW levels
AGWRC	Base groundwater recession	none	0.92	0.99	0.85	0.999	Baseflow recession	**Calibration**

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HSPF PWATER PARAMETERS AND TYPICAL/POSSIBLE VALUE RANGES (#2)

			RANGE OF VALUES					
NAME	DEFINITION	UNITS	TYPICAL		POSSIBLE		FUNCTION OF ...	COMMENT
			MIN	MAX	MIN	MAX		
PWAT - PARM3								
PETMAX	Temp below which ET is reduced	deg. F	35.0	45.0	32.0	48.0	Climate	Reduces ET near freezing
PETMIN	Temp below which ET is set to zero	deg. F	30.0	35.0	30.0	40.0	Climate	Reduces ET near freezing
INFEXP	Exponent in infiltration equation	none	2.0	2.0	1.0	3.0	Soils variability	Usually default to 2.0
INFILD	Ratio of max/mean infiltration capacities	none	2.0	2.0	1.0	3.0	Soils variability	Usually default to 2.0
DEEPFR	Fraction of GW inflow to deep recharge	none	0.0	0.20	0.0	0.50	Geology, GW recharge	Accounts for subsurface losses
BASETP	Fraction of remaining ET from baseflow	none	0.0	0.05	0.0	0.20	Riparian vegetation	Direct ET from riparian vegetation
AGWETP	Fraction of remaining ET from active GW	none	0.0	0.05	0.0	0.20	Marsh/wetlands extent	Direct ET from shallow GW

HSPF PWATER PARAMETERS AND TYPICAL/POSSIBLE VALUE RANGES (#3)

NAME	DEFINITION	UNITS	RANGE OF VALUES: TYPICAL MIN	TYPICAL MAX	POSSIBLE MIN	POSSIBLE MAX	FUNCTION OF ...	COMMENT
PWAT - PARM4								
CEPSC	Interception storage capacity	inches	0.03	0.20	0.01	0.40	Vegetation type/density, land use	Monthly values usually used
NSUR	Mannings' n (roughness) for overland flow	none	0.15	0.35	0.10	0.50	Surface conditions, residue, etc.	Monthly values often used for croplands
UZSN	Upper zone nominal soil moisture storage	inches	0.10	1.0	0.05	2.0	Surface soil conditions, land use	Accounts for near surface retention
INTFW	Interflow inflow parameter	none	1.0	3.0	1.0	10.0	Soils, topography, land use	**Calibration,** based on hydrograph separation
IRC	Interflow recession parameter	none	0.5	0.7	0.3	0.85	Soils, topography, land use	Often start with a value of 0.7, and then adjust
LZETP	Lower zone ET parameter	none	0.2	0.7	0.1	0.9	Vegetation type/density, root depth	**Calibration**

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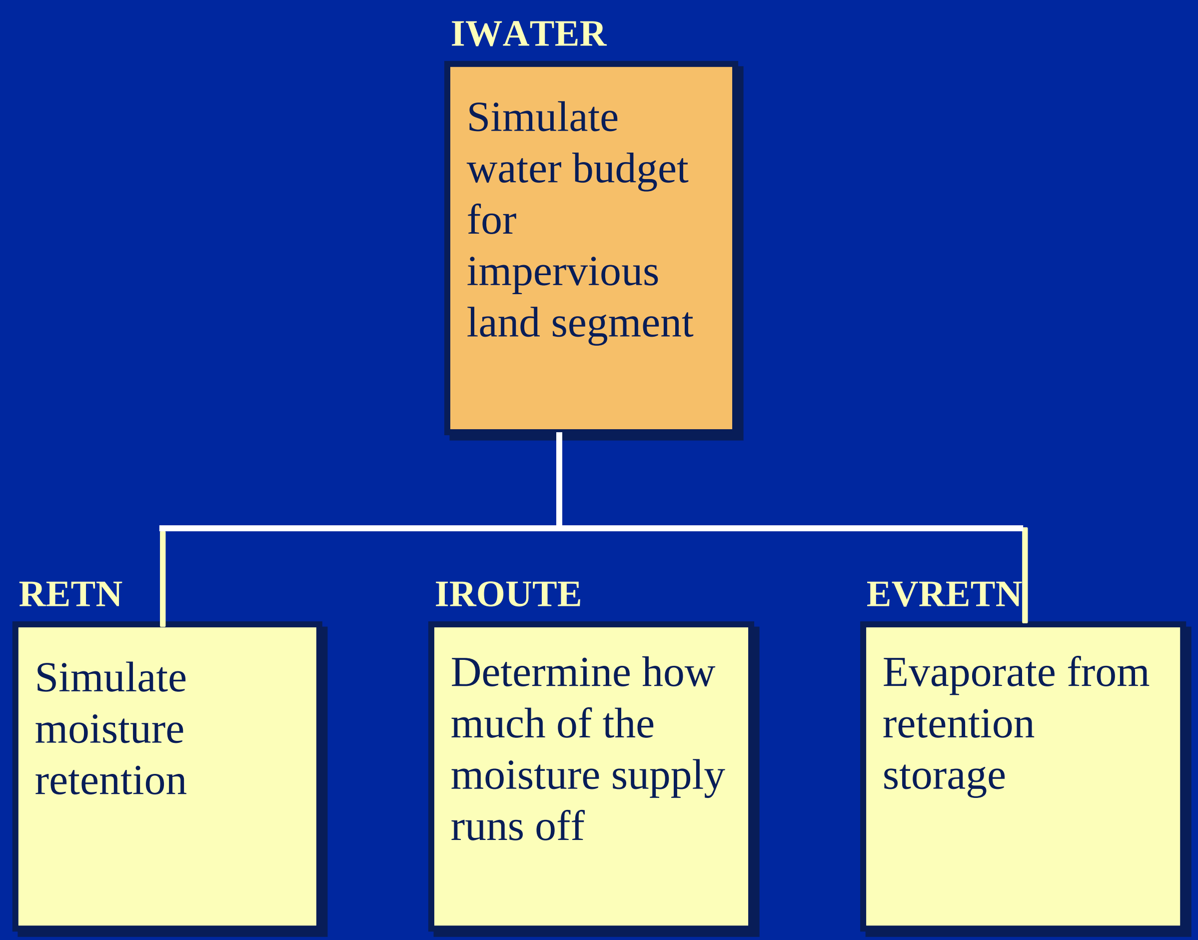
IWATER STRUCTURE CHART



IWATER CALIBRATION

Impervious area process	**IWATER parameter**
Interception	RETSC
Overland flow	LSUR, NSUR, SLSUR
Evaporation	(no parameter, occurs at PET)