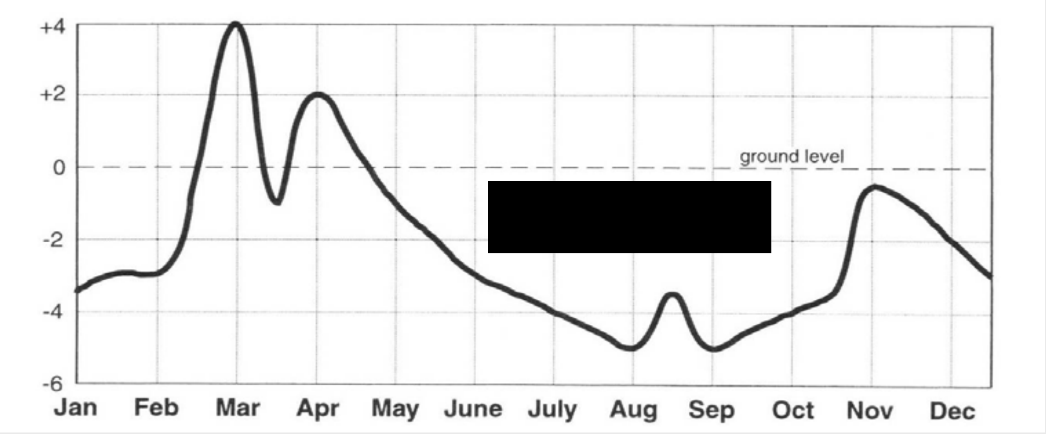
Water budget for wetlands

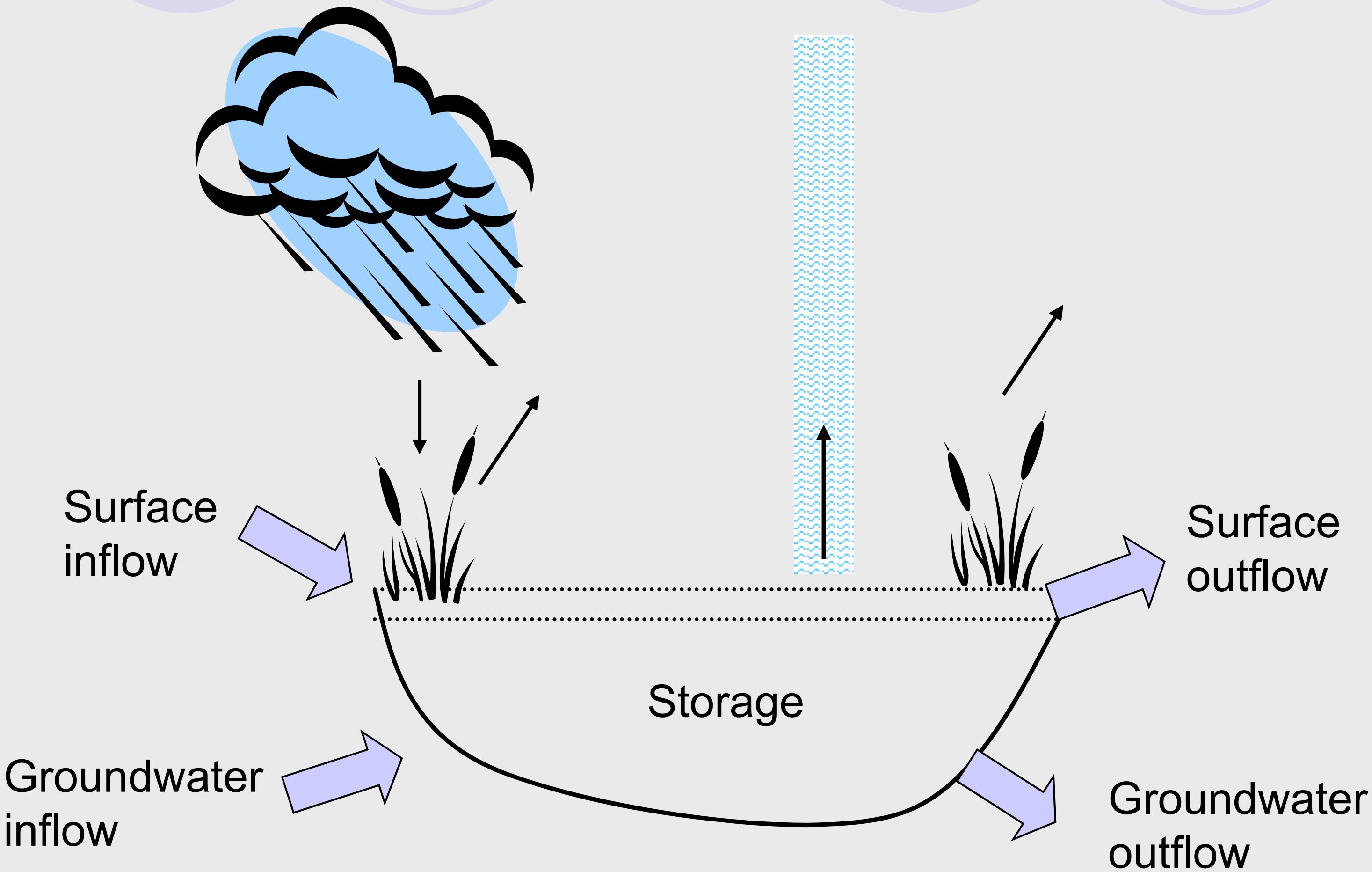
A wetland's hydroperiod is determined by:

- Inflows – outflows
- Landscape pattern
- Subsurface geology



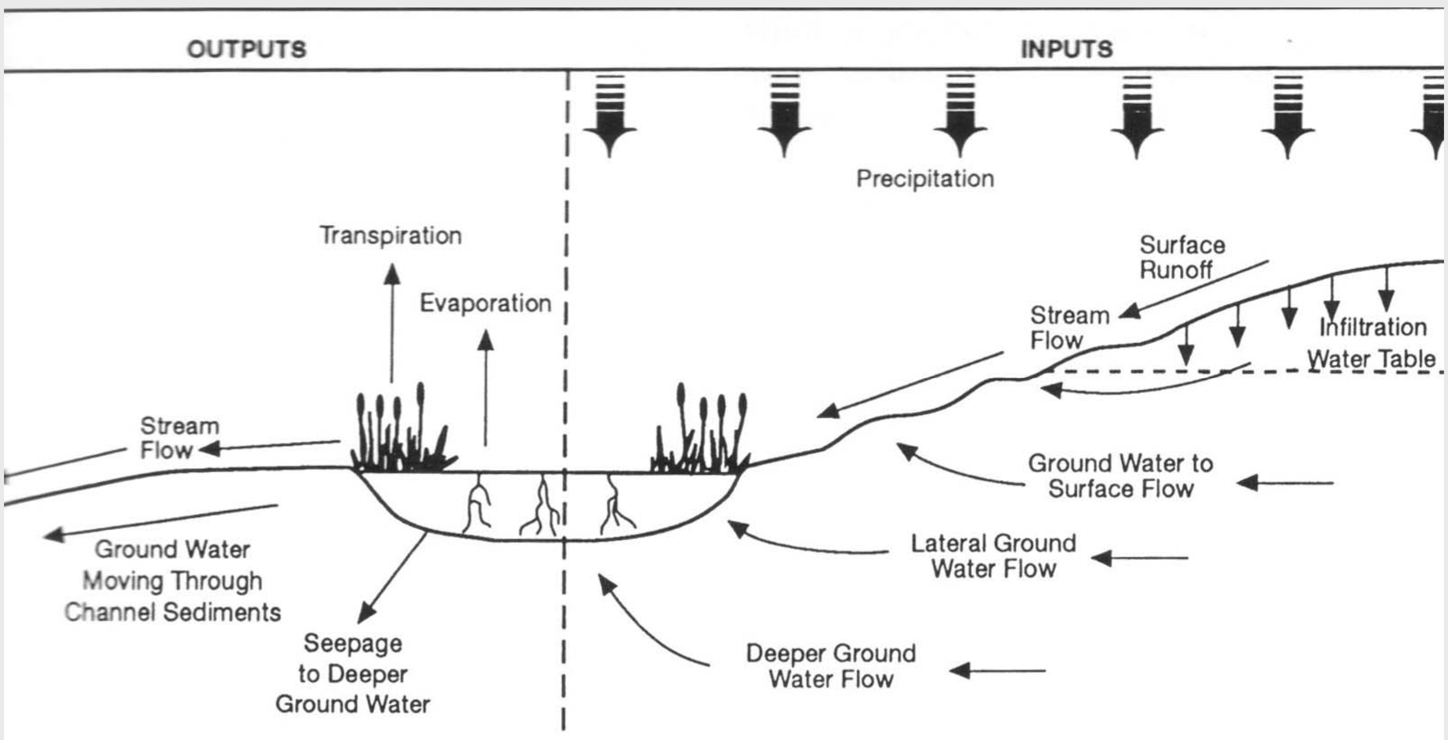
Water budget: inputs & outputs

Water budget



Generalized Wetland Water Budget

$$\Delta V/\Delta t = P_n + S_i + G_i - ET - S_o - G_o \pm T$$



Stone and Stone 1994

Water budget for wetlands

$$\Delta V/\Delta t = P_n + S_i + G_i - ET - S_o - G_o \pm T$$

V	**=**	**Water storage volume**
$\Delta V/\Delta t$	**=**	**Change in volume per unit time**
P_n	**=**	**Net precipitation**
S_i	**=**	**Surface & stream inflows**
G_i	**=**	**Groundwater inflows**
ET	**=**	**Evapotranspiration**
S_o	**=**	**Surface outflows**
G_o	**=**	**Groundwater outflows**
T	**=**	**Tidal inflow or outflow**

UNITS!

$$d = V/A$$

Renewal rate and residence time

$t^{-1} = Q_t/V$ V = volume; Q_t = inflow rate (vol/time)

Renewal rate = rate of water replacement

Residence time = avg time water remains in the basin

Lake	Residence time (t) (years)	Renewal rate (t^{-1}) (per year)
Superior	191	0.005
Michigan	99	
Huron	22	
Erie	2.6	
Ontario	6	

$$\Delta V/\Delta t = P_n + S_i + G_i - ET - S_o - G_o \pm T$$

Precipitation

$P_g = I + TF + SF$

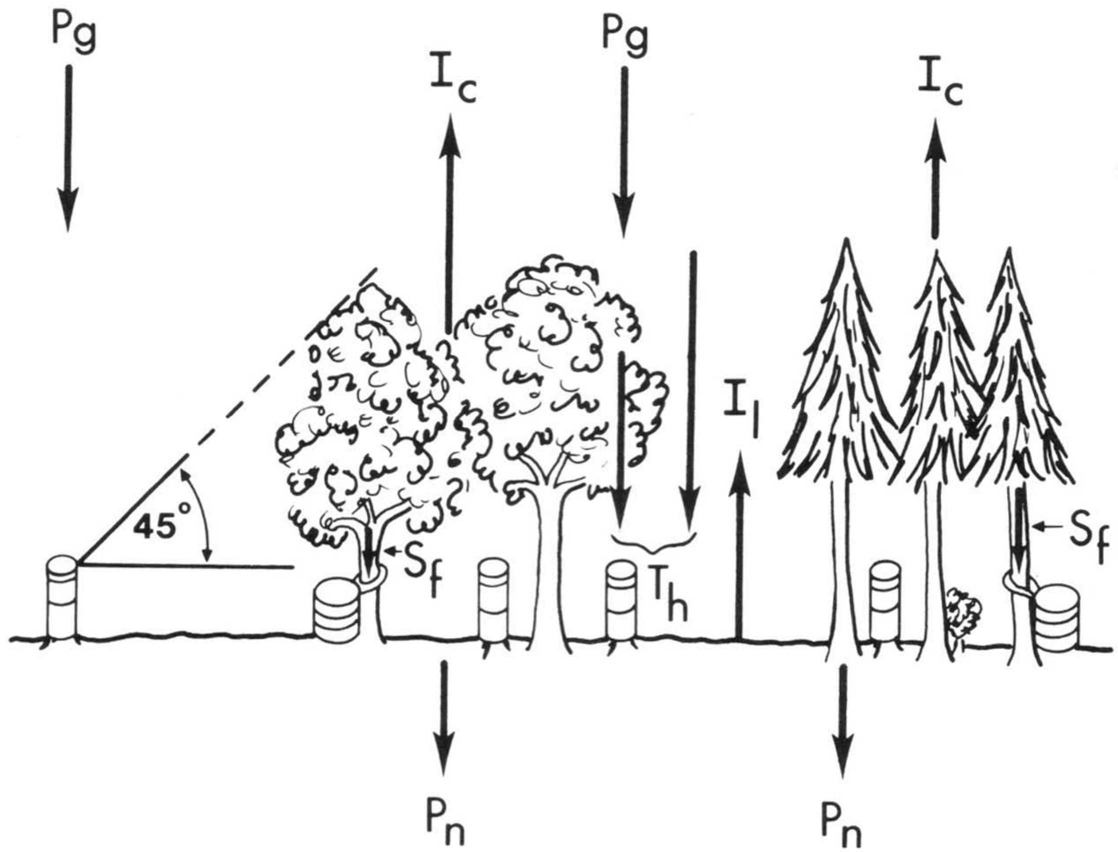
I = Interception
TF = Throughfall
SF = Stemflow

$P_n = TF + SF$

or

$P_n = P_g - I$

Precipitation



Interception total $= I = I_c + I_l$
The amount reaching the forest floor $= T_h + S_f$
Interception by canopy (overstory + understory) $I_c = P_g - T_h - S_f$
Net precipitation $P_n = T_h + S_f - I_l$

2.10. Components of interception (from Hewlett 1982, © Univ. Georgia Press, by permission). I_c = canopy interception; I_l = litter interception; P_g = gross percipitation; P_n = net precipitation; S_f = stemflow; T_h = throughfall.

Brooks et al. 1991

Does interception really matter?

Forest type	Precip (mm)	Interception (%)	Interception (mm)
Rainforest	281	9	25
Mature white pine	203	9	18
Sitka spruce	100	49	49
Hardwoods	130	13	17
Mixed pines	60	36	22

From Jackson 2006

$$\Delta V/\Delta t = P_n + S_i + G_i - ET - S_o - G_o \pm T$$

Surface flow

Overland flow

$$S_{i(ov)} = R_p P A_w$$

R_p = hydrologic response coefficient

(look up in table; typically < 20%)

P = mean precipitation (m)

A_w = watershed area (m^2)

$$S_{i(pk)} = 0.278 C I A_w$$

C = rational runoff coefficient

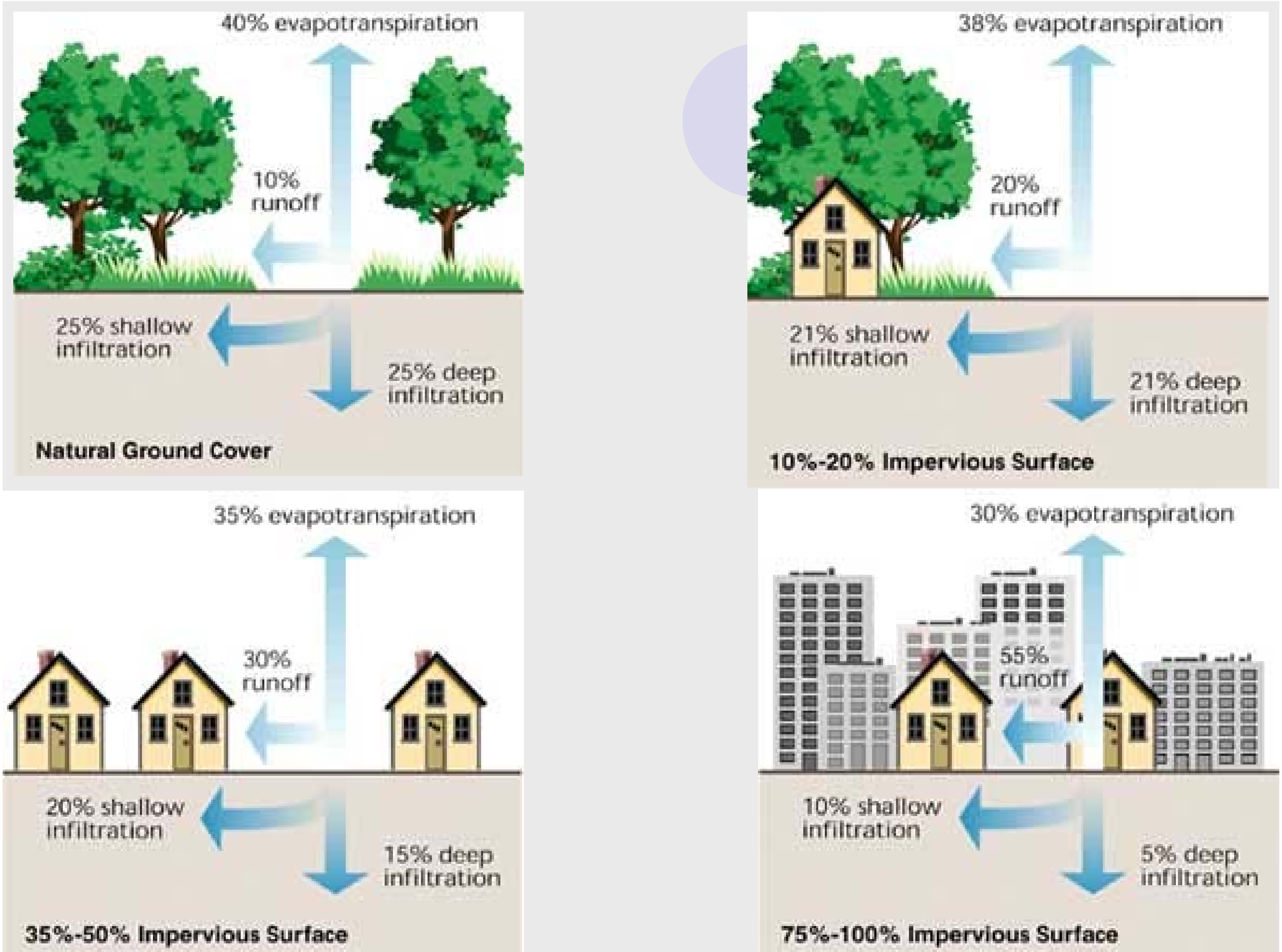
(look up in table)

I = rainfall intensity (mm/hr)

Rational runoff Coefficient

Description of Area	C
Business	
Downtown	0.70–0.95
Neighborhood	0.50–0.70
Residential	
Single-family	0.30–0.50
Multiunits, detached	0.40–0.60
Multiunits, attached	0.60–0.75
Residential suburban	0.25–0.40
Apartment	0.50–0.70
Industrial	
Light	0.50–0.80
Heavy	0.60–0.90
Parks, cemeteries	0.10–0.25
Playgrounds	0.20–0.35
Railroad yard	0.20–0.35
Unimproved	0.10–0.30
Character of surface	
Pavement	
Asphalt and concrete	0.70–0.95
Brick	0.70–0.85
Roofs	0.75–0.95
Lawns, sandy soil	
Flat, up to 2% grade	0.05–0.10
Average, 2%–7% grade	0.10–0.15
Steep, over 7%	0.15–0.20
Lawns, heavy soil	
Flat, up to 2% grade	0.13–0.17
Average, 2%–7% grade	0.18–0.22
Steep, over 7%	0.25–0.35

Source: American Society of Civil Engineers, "Design and Construction of Sanitary and Storm Sewers," *Manuals and Reports of Engineering Practice No. 37,* 1970.


40% evapotranspiration
10% runoff
25% shallow infiltration
25% deep infiltration
Natural Ground Cover
38% evapotranspiration
20% runoff
21% shallow infiltration
21% deep infiltration
10%-20% Impervious Surface
35% evapotranspiration
30% runoff
20% shallow infiltration
15% deep infiltration
35%-50% Impervious Surface
30% evapotranspiration
55% runoff
10% shallow infiltration
5% deep infiltration
75%-100% Impervious Surface

$$\Delta V/\Delta t = P_n + S_i + G_i - ET - S_o - G_o \pm T$$

Surface flow

Streamflow

$S_{(i\ or\ o)} = A_x v$

A_x = area (cross sect) (m^2)

v = mean velocity (m/s)

$v = (1/n)R^{2/3}S^{1/2}$

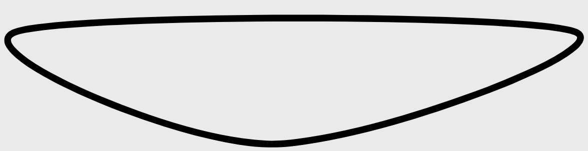
R = hydraulic radius

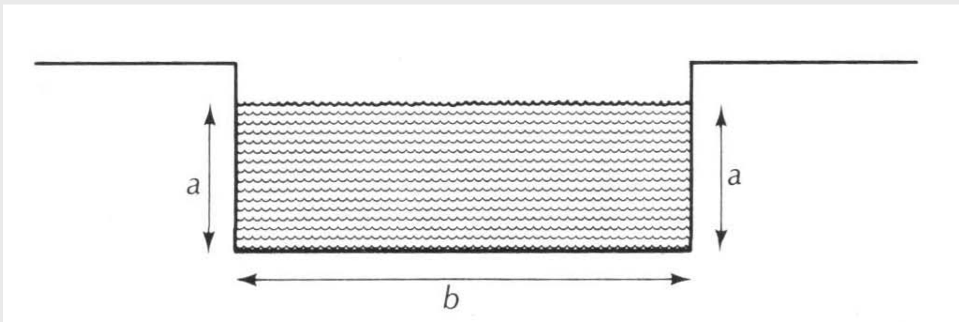
S = energy gradient (~ slope)

n = manning roughness coefficient

$R = A_x/wp$

wp = wetted perimeter (m) (don't include surface)





Manning's roughness coefficients

Stream Type	Manning's n
Canal or ditch	0.02
Winding natural stream , few plants	0.035
Rocky, mountain stream	0.04-0.05
Winding stream, lots of plants	0.042-0.052
Sluggish stream, lots of plants	0.065
Very sluggish stream, lots of plants	0.112

Back

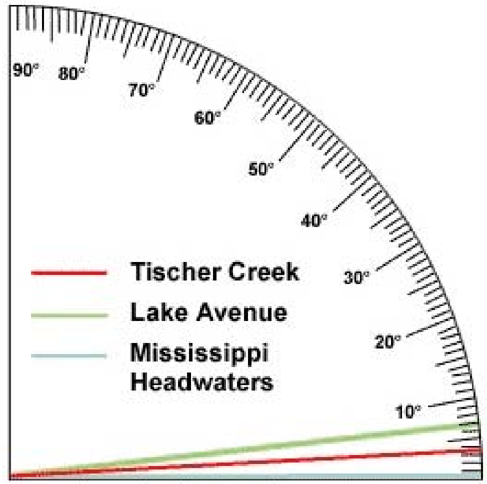
Slope

lake superior duluth streams.org

lake superior communities
understanding
citizens and schools
stormwater

the streams

Select a Stream | Trout Streams | About Data | Current Data | Reports | QA/QC | Weber Restoration



Average Slope	slope in degrees	slope in percent
Tischer Creek	3.4	5.9
Lake Avenue (Downtown Duluth, MN)	6.8	11.9
Mississippi River Headwaters	0.0	0.03

note: 45° slope = 100%

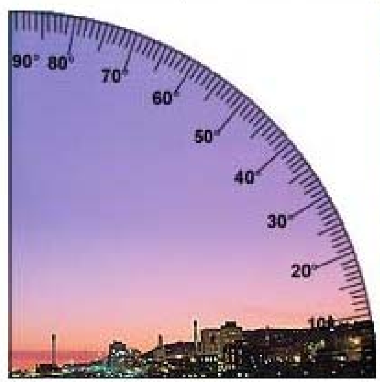
Click here to view this graph for another stream (opens a new window)

Remember that the graph represents AVERAGE slope. Some sections of the stream or road may be steeper, while other sections are less steep.

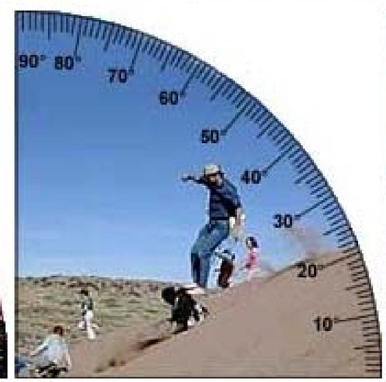
Flat as Farmland?
Lake Avenue in downtown Duluth, with a slope of 11.9% or 6.8°, is a pretty steep street - REALLY!

The lines on the graph above look pretty flat, but consider the following:

- The maximum street slope allowed by the MN Department of Transportation for new road construction is 12% or 6.8° (and only 3% or 1.7° on freeways)
- Sand dunes (that can be very difficult to climb!) have maximum slopes of 68% or 34°.



The Duluth, MN hillside at 9°

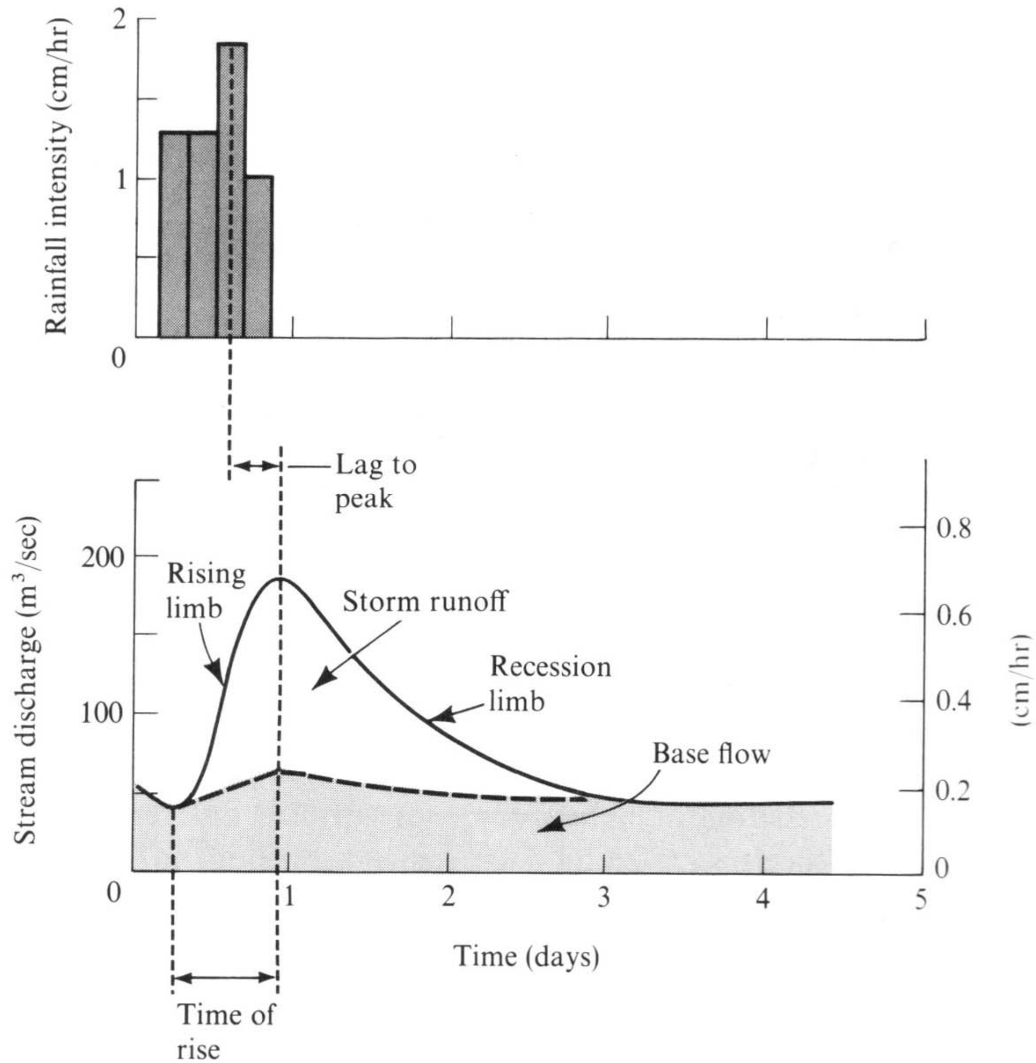


This steep sand dune is only 22°

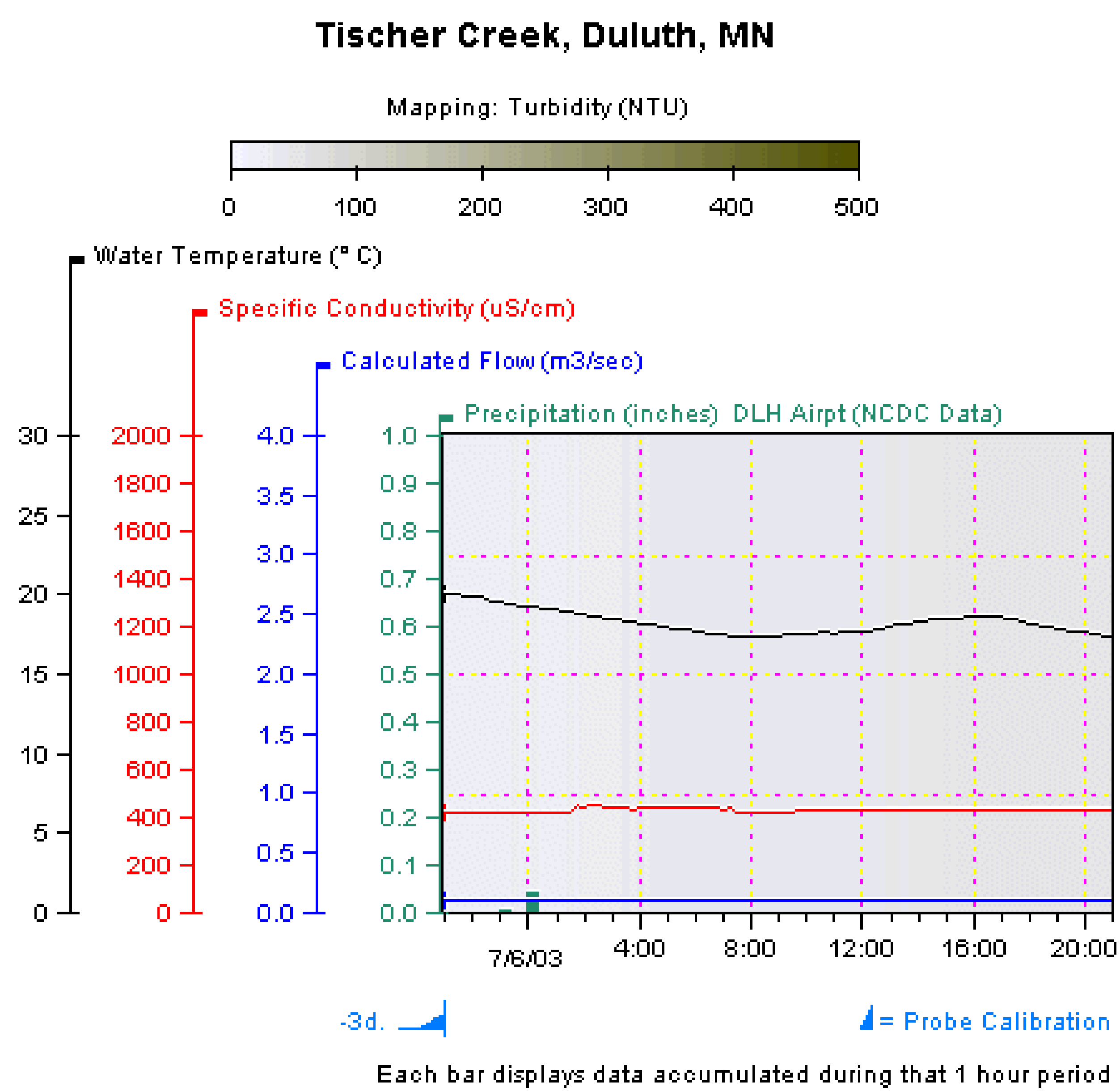
A challenging ski slope - only 40°!

[Back](#)

Floods and Wetlands

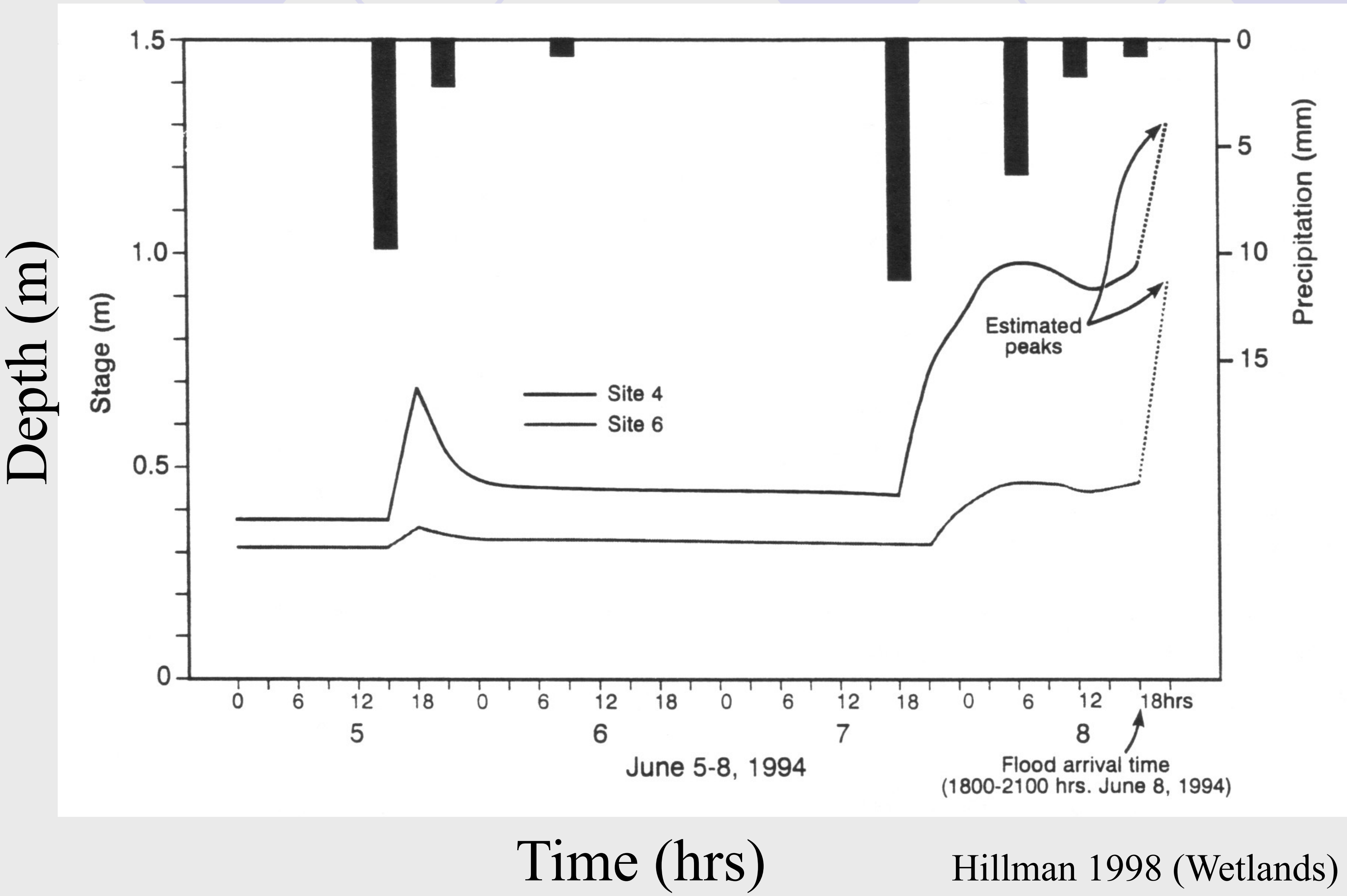


Dunne and Leopold 1978



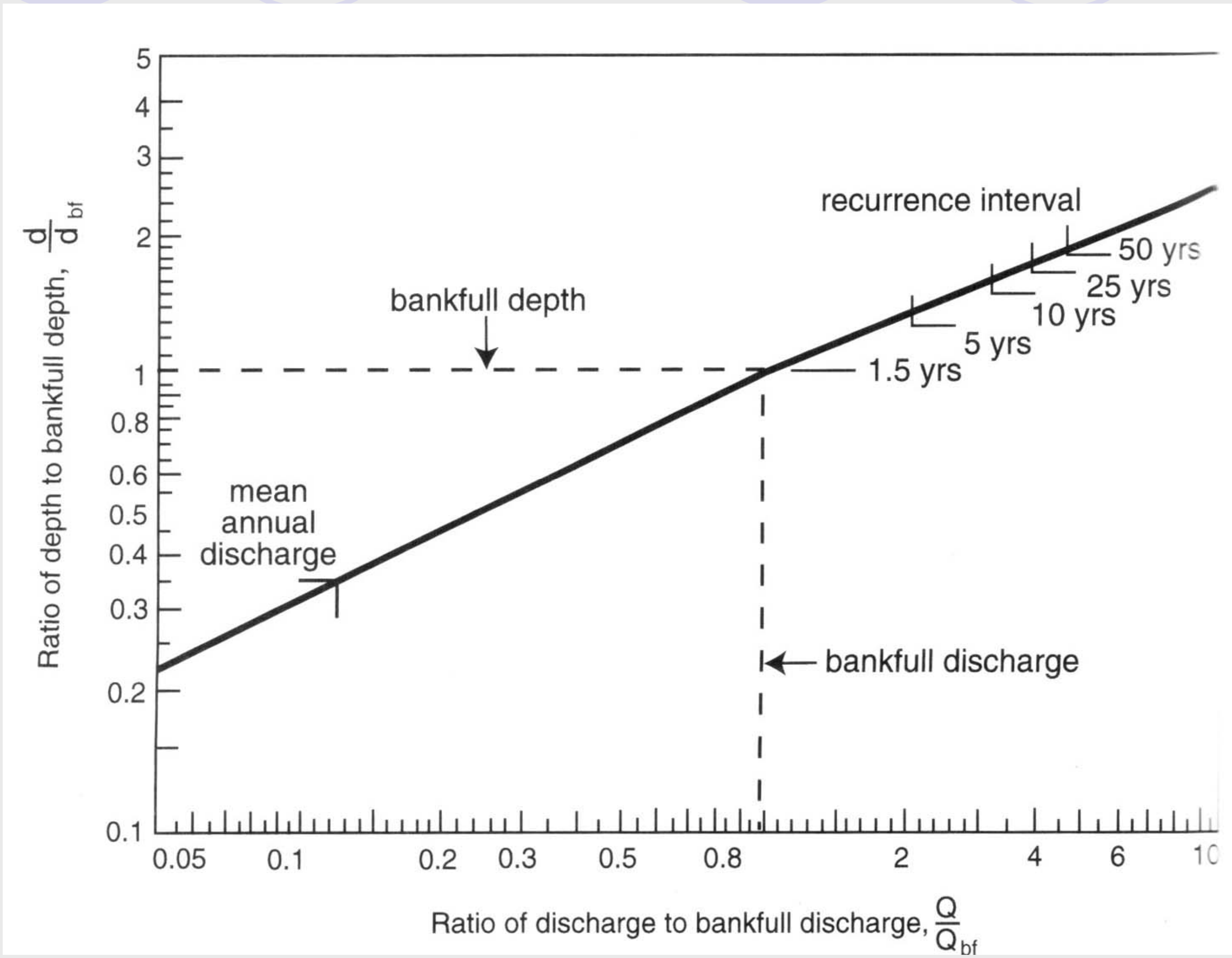
Tischer Creek, Duluth, MN
Mapping: Turbidity (NTU)
0 100 200 300 400 500
Water Temperature (° C)
Specific Conductivity (uS/cm)
Calculated Flow (m3/sec)
Precipitation (inches) DLH Airpt (NCDC Data)
30 25 20 15 10 5 0
2000 1800 1600 1400 1200 1000 800 600 400 200 0
4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0
1.0 0.9 0.8 0.7 0.6 0.5 0.4 0.3 0.2 0.1 0.0
7/6/03 4:00 8:00 12:00 16:00 20:00
-3d.
= Probe Calibration
Each bar displays data accumulated during that 1 hour period

Beaver pond and wetland effects



Hillman 1998 (Wetlands)

Floods and Wetlands



Rating curves

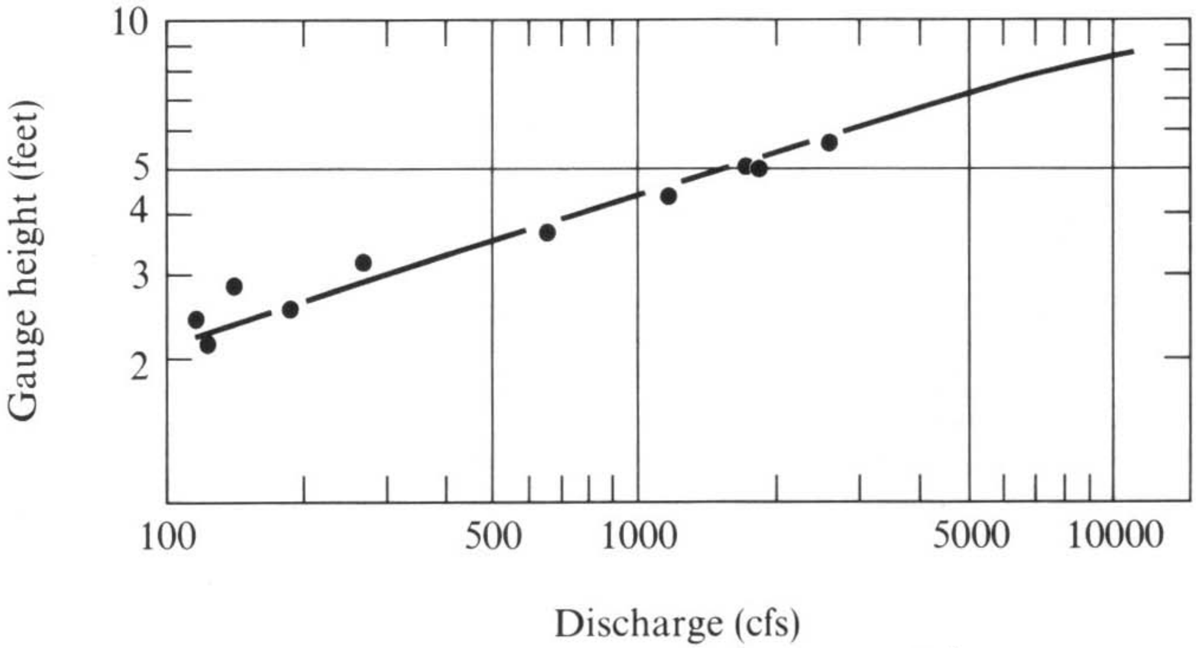
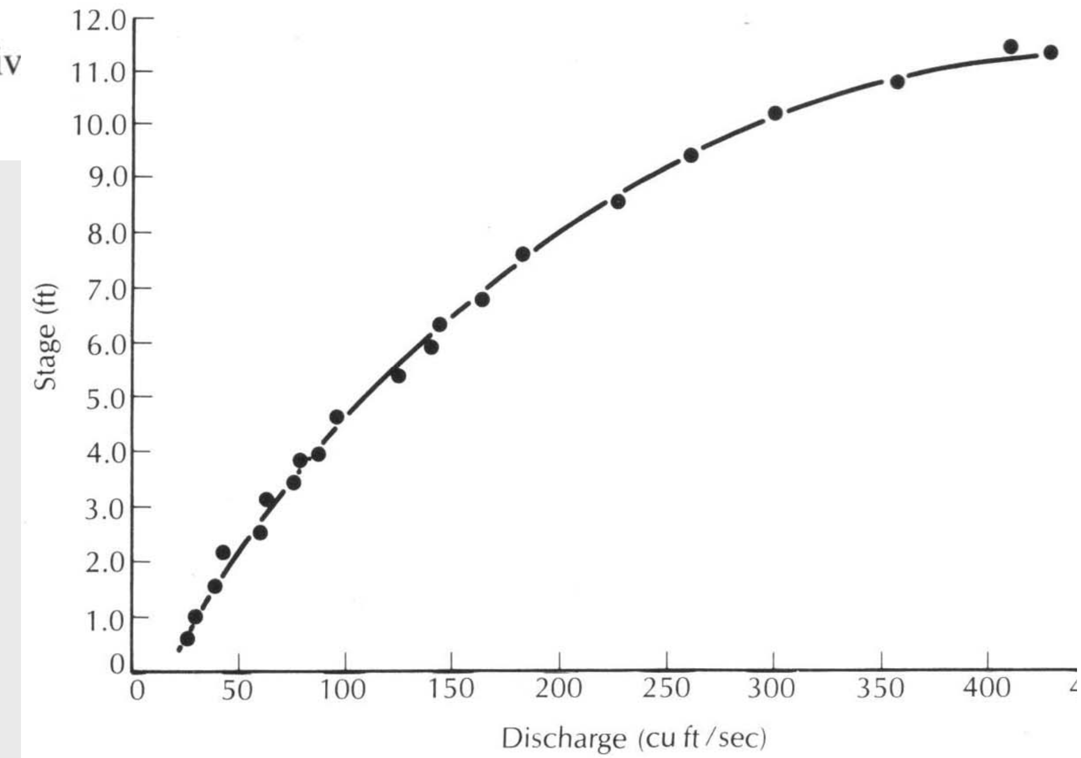


Figure 16-4 Rating curve for the New Fork Riv
Wyoming.



Strahler stream order