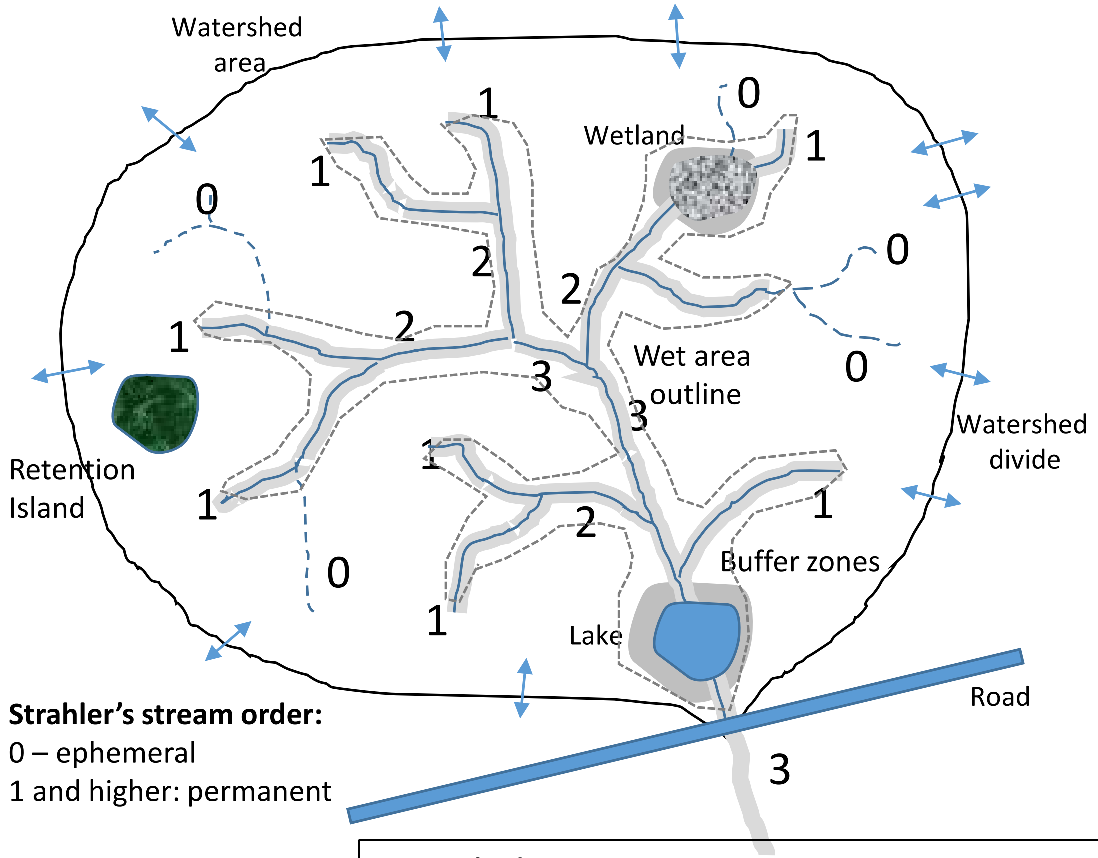
For 3456/3457 Lecture 1: The watershed concept

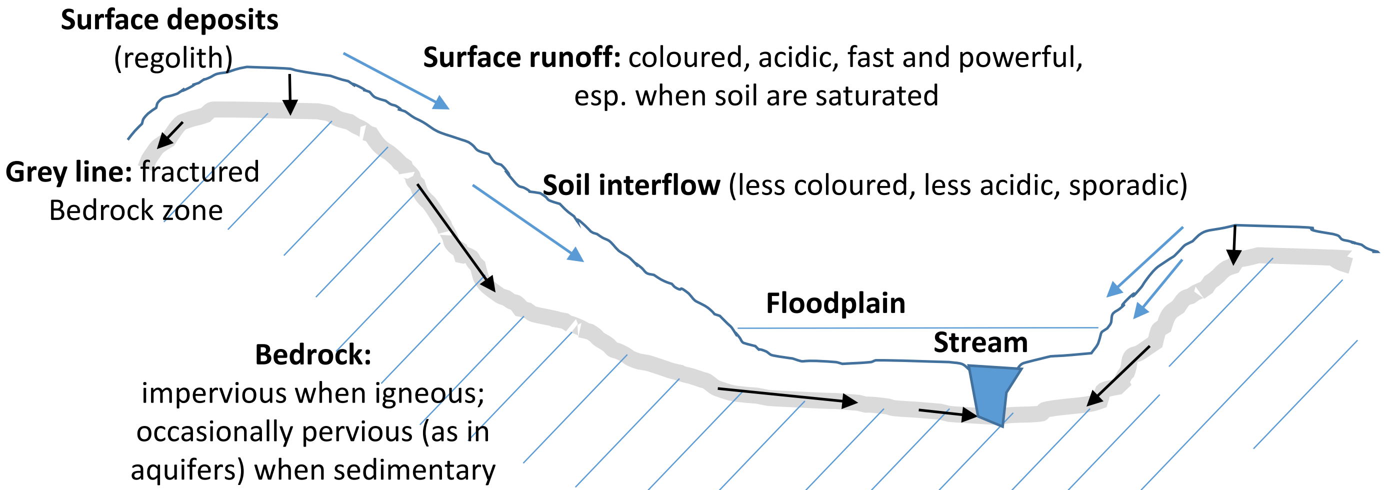


Strahler's stream order:
0 – ephemeral
1 and higher: permanent

Watershed area matters:
To estimate rate of water flow (discharge, worst case)
for proper culverts, bridges installations, including maintenance

Watershed and stream delineations now based on flow accumulation algorithms now based on digital elevation models (DEMs) generated through NASA SRTM ansd ASTER satellite survey at 90m, 30 m and 10 m resolution, globally, and generated through airborne laser scanning (ALS), or "Light Detection and Ranging" (LiDAR) locally/regionallyat 1 m resolution and better, using raster-based flow accumulation algorithms. LiDAR therefore leads to much improved watershed, stream wet soil and depression delineations, meter-by - meter. In addition, LiDAR revolutionizes forest inventory updating, with directly verifiable tree-by-tree results regarding standing wood volume, canopy structures, with research slowly moving towards automatic single-tree cognition.

Flow of water through watersheds towards streams



Base flow through fractured bedrock zone: clear, 6°C generally, acid neutral, steady, ideal for salmon and trout nesting habitats

Watershed management matters:

(i) to protect streams , wetlands and lakes (1st orders and above), through riparian, wetland and lake buffers, to avoid water quality and stream habitat degradation;
(ii) to protect soils through machine-free zones (MFZs) across wet areas, to avoid soil rutting, flow blockages, soil and streambank erosion (includes 0 stream-order protection);(iii) to protect dry- as well as wet-area biodiversities, through retention islands and buffers.

Distinguish between ephemeral and permanent streams: permanent streams generally require a minimum upstream watershed area of 4 ha.
Wet areas: change seasonally, by expanding along flow channels towards ridges along shallow slopes. Vary in soil permeability and drainage by soil type (e.g., sandy versus clayey).
End-of summer wet-areas are due to very poor to moderately well drainage. This includes wetlands. More areas remain wet for a while in depressions, such as vernal pools.

For 3456/3457 Forest Watershed Management Lab Exercises / Reporting (overview)

From sampling design through data management to statistical evaluations, modelling and mapping

Report 1: soil permeability, evaluating rate of flow in relation to soil properties (soil permeability, plastic and liquid limits) before and after compaction; production, organization and reporting of data and results
Report 2: Statistical evaluation of water retention and soil permeability of compacted and uncompacted soil: equations relating soil water rention and permeability to texture, density, organic matter content.
Report 3: Applying the results from Report # 2 (equations) to model the flow of water through watersheds, using a 4-year daily weather record for precipitation and air temperature (Fredericton), with emphasis on watershed variations in soils and forest cover (harvesting) on daily changes on snow accumulations, frost, soil moisture content, soil trafficability, and stream discharge.
Report 4, 5: Examining forest biomass and nutrient (N, S, Ca, Mg, K) sustainability of forest management within the context of atmospheric deposition and soil weathering, focussing on particular forest sites.
Report 6: Watershed mapping exercises: watershed and stream delineations, dealing with storm-expected run-off and erosion

Sampling question & design

Data
generating, organizing, spreadsheet reporting

Spreadsheets
Column headings: variable names, units
Column types: numerical, categorical
Codes for categorical columns/variables: text, binary (0, 1), linear classification (e.g., -1, 0, 1)
Binary example: compacted 1, uncompacted 0

Data analysis
to determine relationships among data varaibales

Multivariate regression analysis:
Predicting dependent variables from independent(predictor) variables, using best-fitted equations.
Best-fitted coefficients are deemed significant or insignificant, as discerned from their P values (different from 0?) and t-values (strong signal to noise ratio?).
Signal to noise: best-fitted coefficient estimate / error of best-fitted coefficient estimate

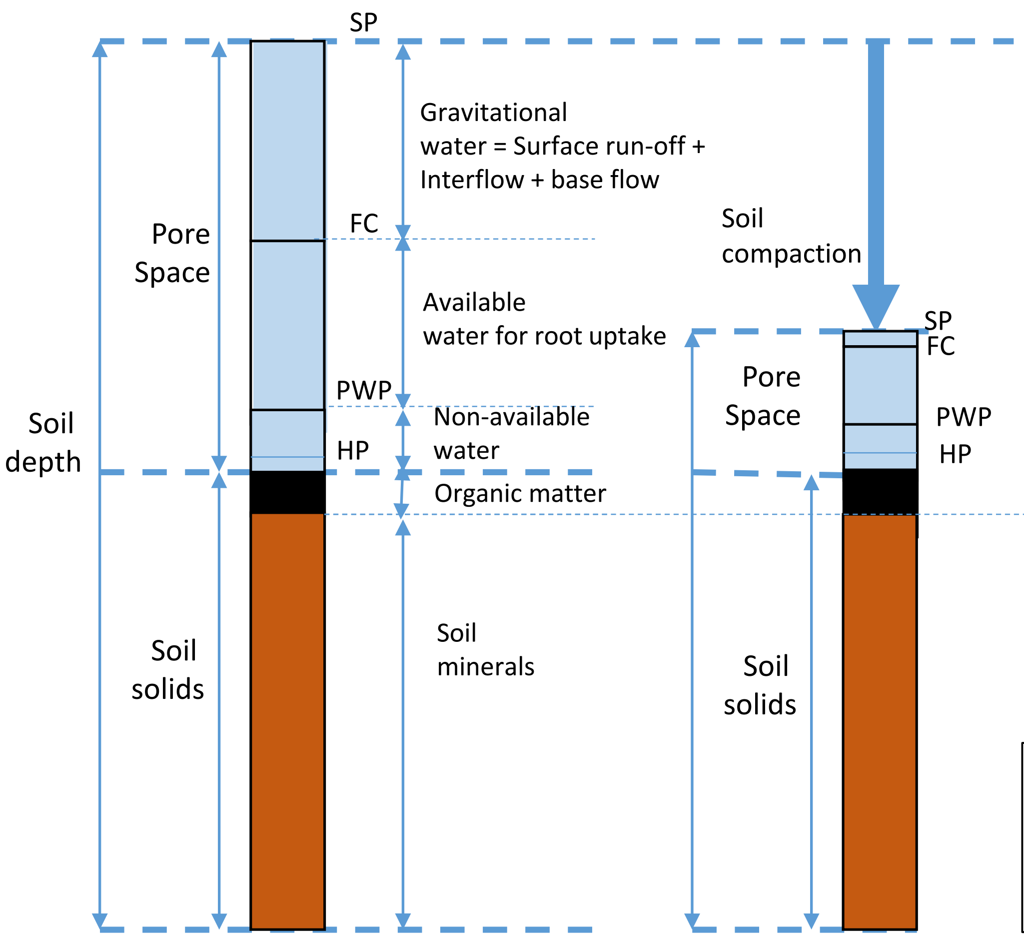
Models
based on data-generated relationships among variables

Model design: components and expected component interactions. Outcome evaluation of the functional relationships between model components.
Model components: emulating accumulations and/or drawdowns of stocks, as in inventories.
Functional relationships: derived from conceptual (theoretical) and statistical (empirical) considerations; generally referring to component to component transfers, one time or gradual.

Maps
based on data-generated models

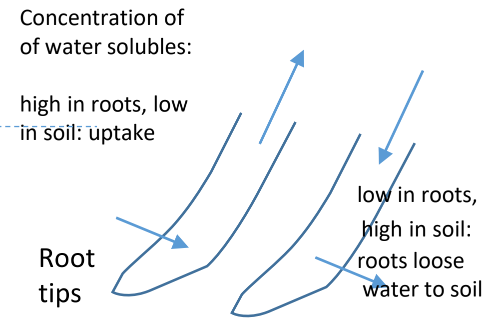
Using the model experience to generate watershed maps **through GIS(ArcMap) procedures** and using geographic data layers, with emphasis on geospatial and topo-hydrological correctness

For 3456/3457 Lecture 2: Soil Water - Volume Relationships



Soil Moisture points
SP: saturation point
FC: field capacity
PWP: permanent wilting point
HP: hygroscopic point
PL: plastic limt; LL: liquid limit

Soil water uptake from FC to PWP: follows osmotic gradient



Soil particle density (**Dp**):
for minerals, rocks = 2.7 g / cm^3
for organic matter = 1.35 g / cm^3
for soil with organic matter (OM, in %):
1/Dp = (OM/100)/1.35 + (1-OM/100)/Dp

Soil bulk density (**Db**) = Soil mass (**Ms**) / Soil bulk volume (**Vb**); hence **Db = Ms / Vb**

Soil moisture content by weight (**MCw**) = Water volume(**Vw**) / Soil mass (Ms); hence **MCw = Vw /Ms**

Soil moisture content by volume (**MCv**) = Water volume(**Vw**) / Soil bulk volume (Vb); hence **MCv = Vw / Vb**

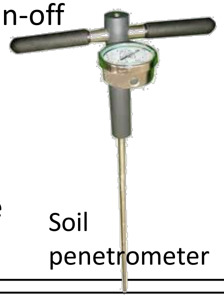
Pore-space filled soil moisture content (**MCps**) = Water volume(**Vw**) / Pore space volume(Vps); hence **MCps= Vw / Vps**

Soil particle density (Dp) = Soil (**Ms**)/ Soil solids volume (**Vs**); hence Dp = **Ms/Vs; also note: MCv = Db MCw.**

Pore space % = (Vb – Vs) / Vb = (Ms/Db – MS/Dp) / (Ms / Db) = (1/Db - 1/Dp) /(1/Db) **= (1 – Db/Dp) 100**

Soil compaction consequences

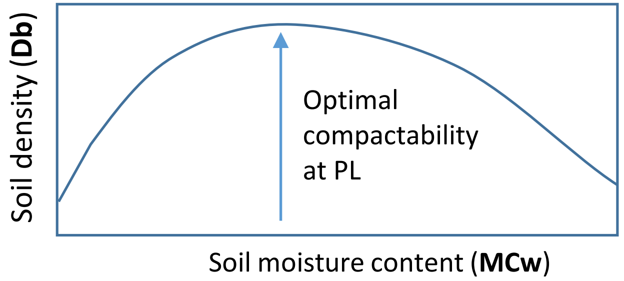
- Increases soil bulk density (Db): kills, restricts root development at ≈ Db > 1.5 g cm^3
- Decreases soil permeability: restricts flow into (**infiltration**) and through (**percolation**, **seep**) soil restricts soil aeration (low O_2 content for root respiration)
- Decreases soil water retention and soil available water
- Increases soil erosion through increased surface run-off
- Restricts soil rooting space
- Decreases soil friability; increases soil strength which increases soil clodding and crusting
- Depending on degree of compaction, soil may take 10 to 20 years to regain original state (e.g., abandoned logging roads)



Soil penetrometer

Soil physical properties

Soil resistance to compaction, penetration, shearing (ploughing).
Soil thermal properties (heat capacity and conductivity).
Soil permeability.
Soil moldability.
All these properties are affected by variations and changes in soil density, texture, moisture, organic matter and coarse fragment content



Soil is most compactable at the plastic limit. (PL). Soil is most easily penetrated at the liquid limt (LL).

Very useful things to know!