G473 Environmental Geology
Gravel Aquifer - Fluvial System Notes

I. Overview
  A. Speaker: Jack Arendt, OR DEQ

  B. Study Areas
    1. Willamette River Basin
    2. Grand Ronde River Basin (E. OR)
    3. Flathead River (Montana)

  C. Objective of Presentation
    1. To discuss the significance of hydraulic communication between gravel aquifers and river discharge in a valley-fill setting.

II. Key Terms and Concepts with Respect to Fluvial Systems and Groundwater
  A. Valley-Fill Gravels (Alluvial Gravel Aquifers)
    1. Coarse bedload rivers are commonly associated with gravelly valley fill
    2. Gravel as Aquifer Material
      a. Very High Porosity
        (1) Range: 25-50% open void space between grains
      b. Very High Permeability
        (1) Range: 0.01 to 1 cm /sec = 8.64 - 864 m/day = 29 - 2900 ft/day
        (2) Think of permeability as the velocity of a water molecule traveling through an interconnected network of pore openings
          (a) NOTE: this is an incredibly high permeability range, it doesn't get any faster than this (see examples below)

Range of Hydraulic Conductivities for Unconsolidated Sediments
(Hydraulic Conductivity = "horizontal permeability" through and aquifer

Material	Hydraulic Conductivity (cm/sec)	
Clay	10^{-9} to 10^{-6}	(very slow)
Silty Sands / Clayey sands	10^{-6} to 10^{-4}	
Fine Sands	10^{-5} to 10^{-3}	
Well Sorted Sands	10^{-3} to 10^{-1}	
Well-Sorted Gravels	10^{-2} to 1.0	(screaming fast)

          (b) Moral of Storey: open framework gravel is an excellent aquifer material, both in terms of storage and flow of water

  B. Gaining Stream
    1. A river/stream which is actively receiving groundwater discharge
      a. groundwater pressure surface is at or above the channel bottom

C. Losing Stream
   1. A river/stream which is actively losing discharge by infiltration to the groundwater system
      a. groundwater pressure surface is below the channel bottom

D. Stream Channel Morphology
   1. Active Channel - conduit of flow
   2. Floodplain - low-lying area surrounding channel, inundated every 1-3 yrs
   3. Knickpoint - abrupt vertical drop in stream channel gradient
      a. e.g. a water fall is a good example of a knick point
   4. Riffles - shallow, rapid-flow reaches of the stream / river
   5. Pools - deep, more slowly-flowing reaches of the stream / river
   6. Pool-Riffle Sequence: alternating stretches of pools and riffles along a stream course

E. Fish / Salmonid Habitat
   1. Aquatic Conditions Conducive to Fish Habitat
      a. Water Temperature: fish are sensitive to water temperature
         (1) critical upper temperature for Salmon is 64 F (according to our speaker)
      b. pH / Salinity conditions: fish are sensitive to pH and salinity (amount of dissolved salts / ions) in a stream
      c. Food Supply
         (1) Fish eat bugs (water-loving bugs, e.g. stoneflies)
         (2) Bugs feed on aquatic plants / algae

F. Groundwater-Fluvial Interaction and Water Temperature
   1. In general:
      a. groundwater = cooler temperature (insolated from sun)
      b. surface water = warmer temperature (subject to evaporation and solar heating)
      c. Hot water cooks the fish... they don't like that
   2. Groundwater discharge to streams
      a. cool water source in the stream thermal regime
         (1) conducive to salmonid habitat
   3. River temp data collection
      a. Aerial infrared photography
         (1) i.d. of thermal regimes in river
         (2) Groundwater associated with cold water discharge to streams, is reflected in IR photography
         (3) Groundwater seeps / discharge in river i.d. by cooler surface water temperatures
         (4) river discharge into subsurface i.d. by warmer surface water temperatures

G. Groundwater Supply to River Discharge
   1. Groundwater important source of water supply to streams
      a. delayed storage and discharge via springs and direct seepage
   2. Examples in OR
      a. Willamette River - fed by 40% groundwater recharge
      b. Deschutes River - fed by 75% groundwater recharge
         (1) remainder from direct surface runoff, snowmelt, rainfall

H. Pool-Riffle-Knickpoint Configuration
   1. Pools, Riffles and Knickpoints set up localized areas of groundwater discharge, and stream infiltration within the river basin

I. Groundwater Flow in Alluvial Valley Aquifers of Oregon
   1. Based on the groundwater data from wells...
      a. groundwater flow is parallel to the main valley gradient
      b. flow is not necessarily perpendicular to the channel
      c. flow is controlled by, and parallels, the overall river gradient
         (1) result: in most cases, groundwater flow is parallel to river flow

III. Other Related Ideas / Terminology
A. Surface / Subsurface Water Zones
   1. Free surface water zone (flowing water in channel)
   2. Hyporheic Zone
      a. Zone of active mixing between groundwater below channel and surface water in channel
      b. Upwelling of groundwater into surface water environment
      c. Downwelling of surface water into groundwater environment
   3. Phreatic Zone
      a. Groundwater that is not actively mixing with surface water
      b. Generally below the Hyporheic Zone
      c. This is essentially the area below the "water table", where there is 100% saturation of the pore space

B. Bugs as a food source for fish
   1. Types of Fauna (bugs)
      a. Stygoxen
         (1) bugs that spend their entire life cycle in the surface water environment
      b. Stygophile
         (1) bugs that spend their larvae stage in interstitial pore spaces between sediment grains ("mud bugs")
            (a) occupying saturated sediment environments
         (2) spend their adult life in the surface water environment
      c. Stygobite
         (1) bugs that spend their entire life cycle in the pores spaces between sediment grains
            (a) occupying saturated sediment environments
   2. Benthic Organisms
      a. Bottom dwellers that live in the channel
   3. Riparian Biota
      a. Plants and animals that live in the floodplain environment, outside, but near the channel

C. Analytical Techniques Used in Study
    1. Gravel Piezometers
        a. A piezometer is essentially a mini-well that allows monitoring of water levels (the potentiometric surface) in an aquifer
        b. The author installed temporary piezometers into the gravel aquifers by driving plastic pipe into the ground
        c. Water levels relative to the surface could then be measured
    2. Piezometer Results
        a. Groundwater levels below the base of the channel
            (1) documents losing stream conditions
            (2) "downwelling" of river water into the aquifer
        b. Groundwater levels above the base of the channel, or above the surface of the stream
            (1) documents gaining stream conditions
            (2) "upwelling" of groundwater into the river
    3. Infiltration Tanks / Pits
        a. Installation of an open tank into the river gravel
        b. Fill tank with water, or observe tank water leves
            (1) infiltration from tank into gravel suggests losing conditions
            (2) rising water level in tank suggests gaining conditions
    4. Interstitial (between gravel grains) Bug Collection System
        a. A wide-slotted pipe is installed into the gravel
            (1) wides slots allow bugs and water to flow into the "monitoring well"
        b. Water is pumped and filtered from the collection well
            (1) bugs are separated for identification / analysis
            (2) water is collected for chemical analysis

IV. The significance of gravel aquifers to the fluvial ecosystem
A. Gravel aquifers provide a ready and abundant supply of fresh, cool water to the stream
    1. rapid through-flow / discharge of groundwater
B. Gravel aquifers can also serve as a hydraulic sink in cases of losing streams
C. The high porosity and permeability of gravel aquifers provide a critical environment for the Stygophile / stygobite bugs.
    1. Groundwater discharge from gravel aquifers to the river provides a pathway for stygophiles to enter the food chain in the river system
        a. good deal for hungry fish
D. The stygophile bugs were found up to several km from the active channel, suggesting the entire valley-bottom gravel aquifer is a very important habitat for fish-related food.
E. Moral of the story: Save the Gravel Aquifers!!!!