
Course Title: Floodplain Management

Module 2: Stream Systems on Dynamic Earth

Session 2: Geologic Framework – The Physical Processes That Produce Sediment

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Time 75 minutes

Objectives: (PP2.0-1)

2.1 Define a floodplain within a drainage (river) basin.
2.2 Identify the four fundamental functions of stream systems.
2.3 Explain how the size, shape, structure, and location of the major tectonic plates affect stream behavior.
2.4 Explain how vertical plate motion affects sediment production.
2.5 Identify the regional tectonic domains in the United States and their affect on floodplains.
2.6 Summarize how glacial conditions that have existed in North America for the last 100,000 years affect river basins.
2.7 Compare rates and processes of erosion, transport and deposition.

Scope:
Dynamic tectonic forces create a constantly changing surface environment on earth. The production and movement of sediment by the agents/processes of erosion —water, ice, gravity, and wind are key elements of that change.

The concept of a Drainage (River) Basin System is introduced and in the homework assignment, students prepare for a discussion of a floodplain within a river system and describe the geologic processes that produce sediment in that floodplain.

Readings:
Student and Instructor Reading:
<u>General Coverage:</u>
All current (1995 or later) introductory Geology textbooks cover the fundamentals of this Session. The instructor should choose the book(s) (or sections thereof) that are used locally.

Skinner, B.J. & Porter, S.C. 2000. *The Dynamic Earth*, 4th Edition, John Wiley & Sons, Inc.

<u>Tectonics:</u>
Kious, W.J. & Tilling, R.I. 1996. *The Dynamic Earth: The Story of Plate Tectonics*, USGS, 77pgs. (http://pubs.usgs.gov/publications/text/dynamic.html)

Other websites concerning tectonics;

(http://pubs.usgs.gov/publications/text/understanding.html) Explains the four plate types.
(http://pubs.usgs.gov/pdf/plantet.html) Map of Earth's physiographic features.
(http://www.ucmp.berkeley.edu.edu/geology/anim1.html) Animated images of plate motion.
(http://www.calstatela.edu/faculty/acolvil/plates.html) Introductory material on Tectonics.

Glaciation

The following web sites provide a wealth of information concerning recent glaciation:

(http://vulcan.wr.usgs.gov/Glossary/Glaciers/IceSheets/description_ice_sheets.html) Describes ice sheets and glaciations.

(http://www.homepage.montana.edu/~geol445/hyperglac/index.htm) Presents material prepared by senior level geology students.

(http://www.ux1.eiu.edu/~cfjps/1300/glaciers.html) Data sheet on glaciers.

(http://www.calstatela.edu/faculty/acolvil/glaciation.html) Good diagrams of glacial features.

(http://www.museum.state.il.us/exhibits/ice_ages/index.html) Data sheet on present glacial ice volumes and surface area.

(http://www.uoguelhp.ca/~pmartini/phbl.htm) Contains a more advanced publication list for topics concerning Hudson Bay and James Bay.

(http://www.geo.ucalgary.ca/~wu/Papers.html) Contains a more advanced publication list for topics concerning sea level, gravity, and earth's mantle.

Sea Level Change

Sea level is the ultimate gradient control for major river basins but it is not static. The following web sites provide a background for understanding past and future changes:

(http://www.salem.mass.edu/~lhanson/gls214/gls214_sealevel.html) Good starting introduction.

(Online search: tidesandcurrents.noaa.gov) Provides a complete database for recent measurements.

Student Homework References

Attachment 2 ---- Summary Spread Sheet
Attachment 3 ---- Columbia River
Attachment 4 ---- Mississippi River
Attachment 5 ---- Ohio River
Attachment 6 ---- Potomac River
Attachment 7 ---- Red River of the North
Attachment 8 ---- Rio Grande River
Attachment 9 ---- Santa Ana River

Additional Instructor Reading:

Cronin, T.M. 1999. *Principles of Paleoclimatology: Perspectives in Paleobiology and Earth History*, Columbia Univ. Press (Especially Ch. 4 - Orbital Climate Change, Ch. 6 – Holocene Centennial & Decadal Climate Variability, and Ch. 8 – Sea Level Change)

Farrand, W.R. 1998. *The Glacial Lakes Around Michigan*, Bulletin 4, Geological Survey Division, Michigan Dept. of Environmental Quality, 16 pgs.

Sverdrup, K.A., Duxbury, A.C., & Duxbury, A.B. 2003. *An Introduction to the World's Oceans*, 7th Edition, McGraw-Hill.

General Requirements:

"... in speculating on catastrophes by water, we certainly anticipate great floods in the future, and we may, therefore presume that they have happened again and again in past times."

—Sir Charles Lyell, 1830

The instructor should encourage the students to develop a global understanding of the forces and interactions that operate in river basins. From the very beginning, the instructor should stress the concept of a river basin system. Students should be encouraged to use the Internet to find current information concerning the stream problems that they are trying to solve. To make this presentation more meaningful, the instructor should add locally significant examples and discuss with the students the local impact of these examples.

The instructor needs to assign the homework that will be due during Session 6.
Finally, the Instructor should validate the web sites listed under student readings.

Objective 2.1
Define a floodplain within a drainage (river) basin.

Requirements:
The information in this section is presented as a lecture using Power Point slides.

Remarks:
Drainage (River) Basins are built by competing geologic processes that cause the earth's surface to uplift and to be worn away. Stream corridors and their associated floodplains provide the primary paths by which debris created during erosion is transported from higher elevations to lower elevations through the basin.

I. A drainage (river) basin is defined as: (PP2.1-1)
"A region or area bounded by a topographic divide that contributes water to a particular stream channel (corridor) or other body of water."

- A. The term "watershed" will not be used in this presentation because it has two meanings.
  - 1. First, the same as drainage basin.
  - 2. Second, the same as topographic divide.

II. A floodplain is defined as: (PP2.1-2)
"That portion of a drainage basin that is covered by <u>Transported Sediment</u> that was deposited in or near a stream channel." This includes:

- A. Active Terraces – The area built by transported sediment deposited during the present regimen of the stream that is covered with water when the river overflows its banks during high flow conditions.
- B. Inactive Terraces – The area built by transported sediment deposited during a past stream regimen that is higher than present high flow.

C. Alluvial Fans – The area built by transported sediment often forming a triangular shaped deposit at the mouth of drainages that is presently capable of being randomly covered by water during significant meteorological events.

D. Bedrock Canyon Floors – The narrow area covered by a thin veneer of transported soils on the floor of bedrock-controlled canyons that is often covered by water during high flow conditions.

E. Buried Fill – Deposits of transported sediment on valley floors that occurred during earlier periods when sediment supplies exceeded the transport ability of the valleys' streams.

III. Each type of floodplain reflects different geologic processes and/or past environments.

A. There are different risks associated with each type.

1. Active terraces are subject to significant overland flow.
2. Inactive terrace can be destroyed by lateral stream shifting.
3. Channels on alluvial fans can abruptly change course.
4. Bedrock canyons can experience extreme but unpredictable flows. (i.e. Big Thompson Canyon in Colorado for example.)
5. Valley fill deposits can be generated over long time spans when different climate conditions occurred. This can cause different types of transported sediment having a range of mechanical properties to deposit.

B. Valley fill can serve many functions and have unique properties.

1. These fills are unconsolidated, easily eroded material.
2. The fills have high porosity (ranging up to 25%) and can store considerable amounts of water that can be easily withdrawn for various uses.
3. The fills have high permeability especially in horizontal directions that often allow water to reenter streams and increase base flow.
4. Exchange between surface and subsurface flow takes place in the fill. This action creates the hyporheic zone that is extremely important in the life cycles of stream insects. See (http://depts.washington.edu/cwws/Outreach/) for additional details or search Google using "hyporheic".
5. The deposits are often mined for construction of roads, concrete making and other uses.

IV. It is necessary to understand geologic processes that formed each type mentioned to effectively manage the floodplains.

A. The new concepts developed in the field of plate tectonics provide the starting point for understanding ongoing geologic processes.

B. The last major disruption of the earth's surface occurred during the last glaciation. Many areas still are recovering from this event, therefore it is important to fully understand what transpired during the last 20K (20,000) years.

Supplemental Considerations:

The instructor should make available topographic maps and photographs of nearby areas showing the different floodplain environments listed above.

Objective 2.2
Identify the four fundamental functions of stream systems. (PP2.2-1)

Requirements:
This material can be significantly enhanced if the instructor will add material of local interest to the presentation.

Remarks:
Why is an understanding of tectonics a starting point to understanding floodplains? After all isn't this a floodplain course and not geological hazards course?

To understand floodplains our journey begins with what caused the mountains and hills that form our stream basins. Floodplains are parts of stream corridors that move sediment when energized by gravity. All rivers flow down hill and, to flow down hill, there must be an uphill. This high ground is almost always the result of tectonic processes with a little help from wind and glaciation. It is also important to understand that water, sediment, chemicals and in-stream creatures are inseparable partners on this journey down hill.

I. **Removing erosional debris from the landscape is most important and acts over long time spans**.
    A. This topic will be covered in detail, in this, the second lecture, The Geological Framework,
    B. Three fields of geology need to be studied to understand the production of sediment. **(PP2.2-2)**
        1. Tectonics, the study plate movements.
            a) Understanding active margins, passive margins, stable platforms and hot spots is critical.
            b) Earthquakes and volcanoes are associated with tectonics.
        2. Glaciation, the study of climate change and ice.
            a) Understanding continental and alpine glaciers in critical.
            b) Climate change causes cycles of glaciation.
        3. Geomorphology, the study of surface forming forces.
            a) Understanding how water, ice, gravity and wind produce and move sediments is important.
            b) Temperature and precipitation are key variables.

II. **Removing excess water from the drainage basin is of secondary importance and acts sporadically over short periods.**
    A. This topic will be covered in detail in the third lecture, The Meteorological Framework,

III. **Providing a stable fresh water supply to sustain life on land and in streams.**
    A. This topic will be covered in detail in the forth lecture, The Biologic Framework.

IV. **Transporting chemicals and nutrients to support life and remove toxins.**
    A. This topic will also be covered in the forth lecture.

Supplemental Considerations:
Presenting local examples of the interaction of these parameters should spark student interest.

Objective 2.3
Explain how the size, shape, structure, and location of the major tectonic plates affect stream behavior.

Remarks:

I. The earth's surface is covered by seven large (continental-sized) and eight smaller tectonic plates. (PP2.3-1)
   A. The six continents are each located on a separate large plate.
   B. Areas below sea level consist primarily of heavier basaltic type material.
   C. Presently, the continents are concentrated in the northern hemisphere.
   D. The northern land masses disrupt atmospheric airflow and ocean current flows that affect rainfall patterns.
   E. Unimpeded ocean currents and airflow tend to circle Antarctica.

II. The plates float on the denser Asthenosphere; shift position due to the earth's internal convection cells, and periodically run into each other ("play bumper cars").
   A. There are three fundamental modes of movement. **(PP2.3-2)**
      1. There are **divergent** boundaries where plates move away from each other. These boundaries are usually found in oceans.
      2. There are **convergent** boundaries where plates move toward each other forming ocean trenches and mountains.
      3. There are **transform** boundaries where plates slide past each other as is happening along the San Andreas Fault in California.

III. Each continent is made up of three principle age and behavior zones. (PP2.3-3)
   A. Shield area is the oldest zone.
      1. These areas are located in the central part of the continents and the bedrock in these areas is made up of mostly igneous and metamorphic rocks.
      2. The rocks have been eroded down to low elevation, relatively flat surfaces and drainage patterns are normally well established and stable.
      3. The North American Shield is located in Northern Canada and Greenland.
   B. Platform area is the next oldest zone.
      1. These areas normally surround the shield areas and bedrock in these areas is sedimentary and often consists of limestone deposited in shallow water
      2. The rocks show little deformation, the beds normally are flat lying, and streams usually have low gradients and can carry heavy sediment loads.
      3. The Great Plains and areas south of the Great Lakes are located on the Platform.
   C. Mobile Belt is the youngest zone.
      1. These areas normally surround the Platform areas and often are bounded by water.
      2. The rocks are usually highly deformed and can be any composition (igneous, metamorphic or sedimentary).
      3. The rocks often show signs of faulting and volcanic activity.
      4. Streams often show signs of channel change; usually have high gradients and carry large sediment loads.

5. In North America the Mobile Belt consists of the more mountainous regions including: Alaska, the Rocky Mtns. and areas to the west; most of Mexico and Central America; the Ouachita Mtns. centered in Oklahoma; the Appalachian Mtns. along the Eastern Seaboard; the East Greenland Mtn. Belt and finally the Franklin Mobile Belt along the Arctic Ocean.

IV. Over-time, the continental plates have drifted into different climatic and depositional zones.

A. Limestone can only form in tropical seas. **(PP2.3-4)**
   1. In humid environments, limestone on land is attacked by organic acids.
   2. Often solution caverns form in the rock mass (Karst).
   3. Stream flow is often diverted underground in these areas.
   4. In colder climates, limestone is one of the most durable rocks.
      a) Often large limestone cliffs form along drainages.
      b) Stream grade (Base Level) is often controlled at locations where streams pass over limestone bedrock.

B. Shale forms by compaction of mud that was deposited in quite water. **(PP2.3-5)**
   1. On land, shale is very erodible.
   2. Streams flowing over shale quickly shift laterally and vertically to establish equilibrium.
   3. Shale formations that originated in Cretaceous Time cover large areas in the Mississippi River Basin and produce large sediment loads in the area's streams.

Supplemental Considerations:

It is recommended that the instructor provide examples of tectonic plate influence on local streams.

Objective 2.4

Explain how vertical plate motion affects sediment production. (PP2.4-1)

Remarks:

I. Land changes elevation to reach Isostatic Equilibrium during tectonic/earthquake activity.

A. When two continental land masses collide, (Continental-Continental Convergence) the lithosphere is thickened because both are too light to subduct.
   1. During this process, lighter granitic material is pushed both higher into the air and downward into the Asthenosphere in order to maintain isostatic equilibrium.
   2. The higher the material raises above sea level the greater the erosion potential.
   3. The temperature is colder so freeze-thaw action increases.
   4. The gradients are steeper so there is more available energy to cause erosion.
   5. Precipitation normally is higher.

B. The Himalayan Mountains are a good example. **(PP2.4-2 & PP2.4-3)**

1. The maximum elevation is about 9 km (30,000 feet) and these mountains are now raising more than 1 cm per year. Uplift and erosion are now balanced so the mountains cannot become much higher.
2. Rivers (Ganges, etc.) flowing south off the mountains carry some of the highest sediment loads known**. (PP2.4-4)**

C. When oceanic and continental plates collide (Oceanic-Continental Convergence), the oceanic plate is subducted under the continental plate. **(PP2.4-5)**

1. Lighter material trapped on the subducting plate melts and rises to the surface forming volcanoes. Volcanoes form significant mountains with steep sides. The material is highly erodible and considerable sediment is produced.
2. The Continental Plate is deformed and thickened by the collision forces. The surface rises so that isostatic equilibrium is maintained. Mountain chains form paralleling the Subduction Zone. Steepened gradients and shattered rock significantly increase erosion rates.
3. The Mobile Zone along the Pacific Ocean is affected by this action. At present the Coast Ranges, the Cascades and the Sierra Nevada Mountains are all producing large quantities of sediment. Earlier, the Pacific Ocean was located just west of the Rocky Mountains and this action caused the Rockies to form and rapidly erode.
4. Often the plates temporarily lock. **(PP2.4-6)**
    a) Buckles then form causing areas on land to both rise and sink.
    b) When an earthquake unlocks the section, abrupt vertical motion occurs when the compression is released
    c) These motions change steam gradients causing both deposition and erosion to occur.

II. Erosion, sediment transport and deposition affect vertical stability. (PP2.4-7)

A. Mountains rise when erosion occurs because they become lighter.

B. When erosion in mountains removes weight, less root is necessary to maintain isostatic equilibrium.

C. Deposition of sediment adds weight to the basin receiving the material. This added weight causes the basin to sink to reestablish isostatic equilibrium.

III. Human activity can cause vertical (especially settlement) changes to occur. (PP2.4-8)

A. The weight from filling large lakes has caused significant settlements to occur.

B. Pumping fluids (water, oil and gas) out of the ground often causes settlement.

1. Weight loss which should cause uplift is insignificant.
2. Soil/geologic formation consolidation causes settlement.
    a) When fluid pressure is removed, soil particles must compress to support the vertical load.
    b) This normally is an irreversible process.
    c) For example, flooding problems due to settlement in Houston, Texas have been increased by oil field extractions.

IV. The U.S. has a complex pattern of ongoing uplift and sinking. (PP2.4-9)

A. The Rocky Mtn region is rising due to tectonic activity.

B. The Upper Mid-West is rising due to glacial rebound.

C. The Northeast is sinking due to lithospheric cooling along the Passive Plate Margin

D. The Gulf Coast is sinking due to the sediment load coming down the Mississippi River.
E. The Southeast is rising due primarily to buckling from the Gulf Coast settlement and weigh removal from erosion.

Objective 2.5
Identify the regional tectonic domains in the United States and their affect on floodplains.

Remarks:

I. The Western United States contains numerous regional tectonic domains that are highly active. (The following tectonic domains are listed in the order of activity) (PP2.5-1 & PP2.5-2)

- A. Alaska is in the tectonically active mobile belt (Active Margin)
  1. Southeast area has a Transform Boundary between the Pacific Plate and the North American Plate.
  2. Aleutian Chain has Oceanic-oceanic convergence between Pacific Plate and the North American Plate.
  3. Many areas have been over-steepened by active faulting causing sediment production to increase.
- B. Pacific Northwest is in the tectonically active mobile belt (Active Margin).
  1. Coast has Oceanic-continental convergence between the Juan de Fuca Plate and the North American Plate.
  2. Numerous active volcanoes cause considerable instability and produce large sediment loads.
  3. The coastline is now being uplifted and coastal cliffs are common.
     - a) The cliffs are often unstable and highly erosive.
     - b) Landslides are common and produce large sediment loads.
- C. California is in the tectonically active mobile belt (Active Margin).
  1. The San Andreas Fault is a Transform Boundary.
     - a) Numerous drainages have been offset and altered.
     - b) Sediment production is mostly controlled by precipitation patterns.
  2. The Central Valley and Death Valley areas are sinking at the rate of five to ten mm per year and are sediment sinks.
  3. The Sierra Nevada Mtns. are uplifted block mountains that produce considerable sediment especially at high elevations.
- D. Hawaiian Islands are in the middle of the Pacific Plate. **(PP2.5-3 & PP2.5-4)**
  1. The islands are/were formed by a Hot Spot.
  2. The islands get progressively older to the north and show decreases in erosive and sediment production activity.
- E. Basin & Range is presently contained within the North American Plate.
  1. The topography is controlled by east-west spreading that is forming Block Mtns. and Valleys.
  2. The area is currently quite arid and streams have only internal (nonintegrated) drainage.
- F. Rocky Mountain Region is presently within the North American Plate.

1. The mountains were formed by Oceanic-continental Convergence between the Farallon Plate (now consumed) and the North American Plate.
2. The vast area is currently rising at the rate of 1 to 5 mm per year but there are regions in northern Nevada; northern Utah and the Yellowstone Park area that are rising 5 to 10 mm per year.
3. High elevations combined with poor vegetation cover caused by spotty-precipitation cause erosion and sediment production to be high.

II. The Eastern United States and the Gulf Coast are located on the Eastern Passive Margin. (PP2.5-5)

A. The Northern Appalachian Mountains are old eroded mountains; are stable vertically and have low sediment production.

B. Florida forms the southern part of the Eastern Passive Margin.
1. Most of the state is a stable, limestone dominated platform (Karst).
2. The east-central coast is sinking at the rate of 5 to 10 mm per year.
3. Sediment production is quite low.

C. The Gulf Coast is part of the gently dipping, coastal plain.
1. The entire coast is sinking at 5 to 10 mm per year.
2. The sinking is caused primarily by sediment loading in the Gulf of Mexico by the Mississippi River.
3. Many of the formations are highly erodible and streams often down-cut.

D. The Eastern Seaboard is part of the Eastern Passive Margin.
1. The Virginia and North Carolina coast is sinking 1 to 5 mm per year.
2. The coast north of Chesapeake Bay is sinking 5 to 10 mm per year.
3. The river valleys are being submerged and estuaries are located at their mouths.

E. The Southern Appalachians including areas in Louisiana and Mississippi are rising at the rate of 1 to 10 mm per year causing erosion rates to increase.

III. The Central and Northern Plains including North Texas are on the stable Intra-plate Platform.

A. The northern region is affected by glacial rebound and is rising between 5 to 15 mm per year.
1. Stream gradients are changing.
2. Deposition is common in north flowing sections.

B. The southern region is stable vertically and sediment production is not significantly affected by tectonic changes.

Supplemental Considerations:

The instructor should identify the local tectonic domain and provide some examples of how tectonics affects nearby streams.

Objective 2.6
Summarize how glacial conditions that have existed in North America for the last 20,000 years affect river basins. (PP2.6-1)

Remarks:

I. Two types of glaciers have impacted North America in the last 20,000 years. (PP2.6-2)

- A. Continental Glaciers covered much of the Canadian Shield and North American Platform (including all of the Great Lakes Region). **(PP2.6-3)**
  1. The ice reached a thickness of about 3000 meters (9000 feet) in the Hudson Bay Region.
  2. Many large lakes formed along the southern ice margin. Considerable deposition of fine-grained material occurred in these lakes.
     - a) Streams easily erode these lakebed deposits because the material is unconsolidated.
     - b) Lake Agassiz is an example of an ice marginal lake that covered a large part of the Dakotas.
  3. Many streams were forced to flow in different directions because the preglacial drainages were blocked by ice.
     - a) The Upper Missouri River used to flow to Hudson Bay but was diverted into the Mississippi River System.
     - b) The preglacial Teays River located south of the Great Lakes was largely filled by glacial debris and the area is now drained by the Ohio River that was constructed from bits and pieces of other preglacial river systems. **(PP2.6-4)**
- B. Alpine Glaciers were found in many of the mountain drainages in western North America.
  1. The glacial valleys normally were heavily scoured into U-shaped valleys.
  2. The upper parts of the valleys were over-steepened causing considerable erosion to now take place.
  3. Terminal and lateral moraines formed at the sides and ends of the glaciers. Often lakes form above terminal moraines that provide more constant downstream flow. The material eroded by alpine glaciers often chokes streams with an excessive sediment load.
  4. The Rocky Mtn. region was considerably wetter during glaciation.
     - a) Many lakes formed in closed basins in Utah, Nevada and surrounding areas. **(PP2.6-5)**
     - b) The Great Salt Lake in Utah is the remnant Lake Bonneville, the largest, that at its peak drained into the Snake River in southeastern Idaho.

II. When the glaciers retreated, large areas of unvegetated terrain were exposed.

- A. Glacially derived features such as kettles, drumlins, and moraines were exposed that altered the preexisting drainage systems.
- B. Large amounts of wind blown silt (Loess) were blown off these areas.
  1. Areas previously covered by ice were a major source.
     - a) Nebraska contains deposits up to 200 feet thick derived from sediment produced along the Rocky Mtn. Front.

2. Glacially generated sediment deposited of floodplains was a source.
    a) The Columbia River Valley has significant deposits.
    b) Large deposits occur east of the Missouri and Mississippi Rivers. **(PP2.6-6)**
3. Silt derived from the Lake Missoula Floods has covered a large area called the Palouse in eastern Washington and the pan-handle of Idaho.
4. Loess is easily eroded by streams
    a) Stream banks are normally vertical.
    b) If vegetation is removed or the banks sloped, new erosion usually follows.

III. The weight of the ice mass caused the Lithosphere to be pushed downward into the Asthenosphere and later to rebound when the ice mass melted.

A. Hudson Bay has rebounded about 100 meters (300 feet) since the last glacier in the region started to melt around 16,000 years ago. **(PP2.6-7)**
1. The rebound has created a vast complex of abandoned shorelines surrounding the bay.
2. Numerous rivers in Central Canada have been blocked and dammed by the uplift.
3. The land surrounding the Great Lakes is now tilting. . **(PP2.6-8)**
    a) The North Shore of Lake Superior rising at a rate of 0.5 meters (1.75 feet) per 100 years.
    b) Southern Lake Michigan is static

IV. Melting glaciers and warming the oceans causes sea level to rise. (PP2.6-9)

A. At the last glacial maximum 16K years ago, ocean levels were about 120 meters lower than present.
B. Most Northern Hemisphere glaciers, except Greenland, had melted by about 6K years ago and the oceans reached their present level. **(PP2.6-10)**
C. Global warming and complete melting ice in Greenland and Antarctica would cause sea level to rise about 70 meters above current level.
1. Large human populations presently live within 10 meters of the oceans.
2. Even moderate global warming and ice melt would cause massive human dislocations and huge economic cost.

Objective 2.7
Compare rates and processes of erosion, transport and deposition.

Remarks:

I. Erosion and deposition involve multiple steps.

A. First, tectonic action triggers erosion by rising rock (consolidated material) above sea level.
B. The second step in erosion is breaking the rock (consolidated material) into smaller pieces.
C. Then the liberated material is transported to different locations.
D. Finally, the transported material is deposited either on the earth’s surface or under water.

E. Often Steps “C” and “D” above are repeated multiple times.
   1. Each new movement requires new energy or a changed environment.
   2. Steps can occur at various time intervals from a few years to thousands of years.
   3. Ultimately, the transported material reaches a stable site (an ocean basin for example).

II. The resulting erosion rates are influenced by many factors. (PP2.7-1)

A. Ongoing tectonic activity can increase erosion rates.
B. The original strength and chemical stability of the uplifted material influences the rate of breakdown.
C. The River Basin Gradient determines the energy available to move material.
D. Erosion is strongly influenced by climate.

III. Once exposed, the surface is subjected to attack by other forces. (PP2.7-2)

A. This process is called weathering and includes both mechanical and chemical processes.
B. Freeze-thaw cycles (mechanical) tend to break the uplifted material into pieces that can be more readily moved.
   1. This mechanical action is most common in colder or higher elevation environments.
   2. Individual, separated pieces maintain most of their original strength.
C. Water and acids (chemical) attack minerals within the material.
   1. Some grains are dissolved.
   2. Some grains expand when water is absorbed. This action tends to weaken the material.
   3. Chemical attack predominates in hotter, moist areas.

IV. There are four agents/processes that create and transport sediment from bedrock. (PP2.7-3 & PP2.7-4)

A. Rates vary depending on the temperature and precipitation that occurs.
B. Water is the most common agent of erosion and transport.
   1. Water enters the molecular structure (hydration) of certain rock minerals on exposed surfaces. Upon hydrating, the rock minerals expand causing the exposed surface to be torn away from the intact rock (exfoliation) leaving an “onion skin” appearance. This chemical action greatly weakens the rock mass and particles can then be swept away.
   2. Certain rock minerals can be dissolved by the water entering the molecular structure. The dissolved rock can then be carried in solution in the flowing water.
   3. Dissolving minerals containing Calcium (Ca) and Magnesium (Mg) often lead to the “hard water” that leaves whitish deposits on sinks and faucets. Chemical weathering occurs most commonly in moist and humid climates.
C. Ice is the most powerful agent of erosion in colder climates.
   1. Rock can be broken apart by the freeze-thaw action that occurs when ice forms in small fractures and joints. This mechanical action causes the bedrock to break apart in pieces ranging in size from sand to large boulders.
   2. When stream velocity is sufficiently high, these pieces can be mobilized and move downstream.

3. Mechanical weathering normally occurs at higher elevations and in more northerly areas where cyclic freezing and thawing occur.
4. In areas where the average temperature is below freezing, glaciers tend to form. Moving ice is an extremely powerful force. Large pieces of rock can be broken away from bedrock outcrops and transported great distances, where later, they can be mobilized by flowing water.
5. Large quantities of rock are often ground into very fine, silt sized particles called rock flour that can be easily moved by wind or flowing water.
6. Large quantities of debris carried away from a glacier's terminal moraine by flowing water often form outwash plains or valley fills.
7. Sediment supply associated with glaciation is huge.
   a) Often river valleys below glaciers become filled with sediment.
   b) After glaciation, these filled valleys are often exhumed by the streams and only remnant terraces are left along the valley sides.

D. Gravity can cause large masses of material to move downslope if there is sufficient gradient.
1. Landslides commonly occur on steep saturated hillsides that have been either oversteepened and/or contain weak bedrock or unconsolidated deposits.
2. Debris flows can occur whenever unconsolidated deposits become saturated and unstable.
   a) Earthquakes and volcanic eruptions can trigger debris flows.
   b) Material can move great distances down stream channels and cause total destruction.
      (1) For example, the **Osceola Mudflow** carried more than one half cubic mile of material and traveled from the upper flanks of Mt. Rainier all the way to Puget Sound.
   c) Once these deposits are on the **valley floor**, it is easy for streams to entrain the material and carry it further downstream.

E. Wind is the primary erosion and transport in certain environments.
1. Wind borne silt (loess) can be carried great distances and be deposited in areas having wetter conditions.
2. In dry, hot climates (deserts for example) wind is the most important erosion agent.
3. After glaciation, bare sediment covered surfaces can be attacked by wind.
   a) Soon after the last glacial period, large quantities of silt (rock flour) were blown off barren outwash plains and deposited downwind.
   b) The Sand Hills of Nebraska, derived from wind borne glacial silt from the Rocky Mountain Region, cover more than 35,000 km^2 and averages 8 meters deep.
   c) The hills east of the Mississippi River contain large deposits of glacially derived silt coming off the post-glacial river floodplain. Silt deposits form vertical banks along streams because slopes are easily attacked by rain falling on the fine-grained soils.

V. The rates of geologic processes vary considerably.
(PP2.7-5 & Handout 1, Attachment 1)

A. Deposition in oceans is the slowest (average -- 0.003 meters per 1000 years).
B. Surface erosion from entire river basins is intermediate (average -- 0.09 meters per 1000 years).
C. Vertical tectonic movements are high (typical -- 1 meter per 1000 years).
D. Horizontal tectonic movements are higher (typical -- 10 meters per 1000 years).
E. Initial glacial rebound is the highest (typical -- 80 meters per 1000 years).

Supplemental Considerations:
The instructor should consider presenting local examples of sediment production and entrainment into the nearby streams.

Homework Assignment

Requirements:
The students must be **computer literate** and have access to the **Internet**. The instructor may have to provide out-of–class assistance to any student who is deficient in computer research methods.

Remarks:
The class should be divided into teams of 2 to 4 students. Each team will then be assigned one of the River Basins and associated areas shown on the **Handouts 2 & 3 (Spread Sheets in Attachment 2)** that have been provided**.** The instructor should use the **Spread Sheet** summaries to introduce the students to the seven (7) river basins that will be used for their case studies. Diagrams and photos related to each of these Drainage Basins have been included in the following attachments:
(Under Development 8/2/04)

Attachment 3 ---- Columbia River Basin
Attachment 4 ---- Mississippi River Basin
Attachment 5 ---- Ohio River Basin
Attachment 6 ---- Potomac River Basin
Attachment 7 ---- Red River of the North Basin
Attachment 8 ---- Rio Grande River Basin
Attachment 9 ---- Santa Ana River Basin

The students may choose to use or modify some of this material and incorporate it into their **Power Point** presentations. Of course, the students should be encouraged to do their own research and add additional and/or other material into their work. The final product must emphasize a **System Wide Analysis of the Entire Integrated River Basin**. Each student group will have approximately 15 minutes to present their material during Session 6.

Supplemental Considerations:
If additional out-of-class work is desired, the instructor should consider assigning one or more local drainage basins (ones not included above) for analysis. These drainage basins should be smaller and have local interest. Individually written papers presenting their Integrated System Drainage Basin Analysis for one local basin would be appropriate.

List of Attachments:

Attachment 1 ---- Rates of Geologic Processes Handout
Attachment 2 ---- Summary Spread Sheet Handouts (Geologic Setting & Recent Concerns)
Attachment 3 ---- Columbia River Basin
Attachment 4 ---- Mississippi River Basin
Attachment 5 ---- Ohio River Basin
Attachment 6 ---- Potomac River Basin
Attachment 7 ---- Red River of the North Basin
Attachment 8 ---- Rio Grande River Basin
Attachment 9 ---- Santa Ana River Basin

List of Power Point Slides: