**Resources and Reserves**

- **Total of a non-renewable resource**
  - Initial amts.
  - Sub-economic Reserves
  - Hypothetical + Speculative
  - After use
  - Increase in "reserves"

**World Petroleum Reserves**

- **World Petroleum Reserves**
  - Crude Oil (Billions of Barrels)
  - 600, 700, 800, 900, 1,000, 1,100, 1,200, 1,300

**US Petroleum Reserves**

  - 20, 22, 24, 26, 28, 30, 32

**How big is your ecological footprint?**

- A) Less than 10 acres
- B) 10-20 acres
- C) 20-30 acres
- D) 30-40 acres
- E) More than 40 acres
- F) Oops, I forgot to calculate mine

**Water Supply and Use**

- **Reading**
  - Chapter 10

**Water Quality: Constraints on Use**

- **TDS** – measure of "salinity" (but not only sodium and chloride)
  - < 10 ppm: "fresh"
  - 10-200 ppm: "brackish"
  - 200-20,000 ppm: "hypersaline brine"

- **pH**
  - pH = -log$_{10}$[H$^+$]

- **Hardness**
  - Hardness = 2.5°Ca + 4.1*Mg

- **Water Quality**
  - Colorful bar charts and maps showing TDS and pH ranges.
Water Quality Standards and Recommendations

Human Drinking Water
- TDS < 500 ppm
- pH 6.5-8.5
- Chloride < 250 ppm
- Sulfate < 250 ppm
- Iron < 0.3 ppm
- Hardness (for washing) < 80

Dairy Cows
- TDS < 4000 ppm
- pH 6.5-8.5
- Chloride < 1600 ppm

Trout
- TDS – wide range
- pH 6.5-8.0
- Hardness 10-400
- Oxygen > 5 ppm
- Temp. optimum 50-60°F

Consumptive Use:
water that is not returned to streams, lakes or aquifers

Rates of “offstream” use by class

Thermoelectric Power
Irrigation

Industrial

Public Supply

“In-stream” use:
Hydroelectric power
Excessive Consumptive Use of Surface Water – The Colorado River

- Diversions for public water supply and irrigation
- Evaporation losses from reservoirs
- Increased salinity of agricultural “return flow”
- Future needs for energy development and growing population

The Ogallala Aquifer (continued)

Average decline 1980-1997: 2.7 ft
Rate of decline: 0.16 ft/year

Factors contributing to reduced rates of decline
1) Decrease in ground water pumping
2) Higher than average rainfall

Decreases in pumping due to
a) Decreases in irrigated acres
b) More efficient irrigation technology
c) Return water re-use
d) Alternative crops
e) Regulation of ground water withdrawals
f) Increase production costs (energy, fertilizer)
g) Declining or stable crop prices

Excessive Consumptive Use of Ground Water – The Ogallala Aquifer

Average decline 1949-1980: 9.9 ft
Rate of decline: 0.33 ft/year

Ground Water and Surface Water as a Single Resource

Importance of “Conjunctive” Management and Use

Legislature Sends Pile Of Bills To Doyle
The Dozens Of Bills Sent To The Governor Include One On Rules For Wells And One On Job Training.
Wisconsin State Journal
Friday, March 12, 2004
Scott Milfred Wisconsin State Journal
Impacts of Urbanization

- Reduced Recharge
- Increased Consumptive Use

Strategies to Extend Water Supplies - Conservation

- Changing from spray or flood irrigation to drip irrigation
- Urban conservation, landscaping, and water recycling

Strategies to Extend Water Supplies - Interbasin Transfer

Strategies to Extend Water Supplies - Enhanced and Artificial Recharge

- Recharge basins and water importation to halt land subsidence near San Jose CA
- Reservoir Releases
- Recharge of Imported Water
Enhanced and Artificial Recharge - continued

Rain gardens
Injection wells and Aquifer Storage Recovery

Strategies to Extend Water Supplies - Desalination

Distillation

Disadvantages: Energy and Capital

<table>
<thead>
<tr>
<th>Method</th>
<th>Energy (GJ/ton)</th>
<th>Capital (mM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multi-stage Distillation (MSD)</td>
<td>3,000</td>
<td>4,000</td>
</tr>
<tr>
<td>Thermal Distillation (TD)</td>
<td>1,000</td>
<td>1,500</td>
</tr>
<tr>
<td>Microwave Distillation (MD)</td>
<td>500</td>
<td>750</td>
</tr>
<tr>
<td>Reverse Osmosis (RO)</td>
<td>250</td>
<td>250</td>
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</tbody>
</table>

Possible solutions: Renewable Energy, Desalination of brackish ground water

Membrane filtration