Impacts of Urbanization on Water Resources

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Registered Professional Hydrologist

Wastewater leak

Area inundated by 1981 flood in Austin

Austin, 1981, Shoal Creek near 12th Street

“The goal of life is living in agreement with nature.”

Zeno (335 BC - 264 BC)

Urbanization can impair the quantity and water quality of surface and groundwater

Major components of urbanization shown in blue below

Effects of the component shown in red

Impacts due to the effects shown in black

Urban Construction

Creation of construction sediment, exposure to construction materials and waste, loss of vegetation

Degradation of water quality and loss of biological life in streams, reservoirs, and aquifers due to sediment and runoff contaminated by construction materials and waste

Degradation of water quality due to loss of vegetation to attenuate contaminants in runoff

Impervious ground cover

Increased storm runoff and decreased infiltration

Increase in flooding damages and frequency

Erosion of channels and banks causing loss of property and additional stream sediment

Decrease in recharge volumes to aquifers

Urban land use

Industry, automobiles, lawn fertilizers and pesticides, pets, parking lot sealants

Degradation of water quality for receiving streams, reservoirs, and ground water

Dense population

Increased water use, sewage, and waste disposal

Decrease in surface water and groundwater availability due to increased water use

Degradation of water quality due to sewage leaks and waste-contaminated runoff

Organization of Presentation

Urban Hydrology 101

Impacts of: Urban Construction

Impervious ground cover

Urban land use

Increased water use

Managing development

Mitigation of urbanization impacts

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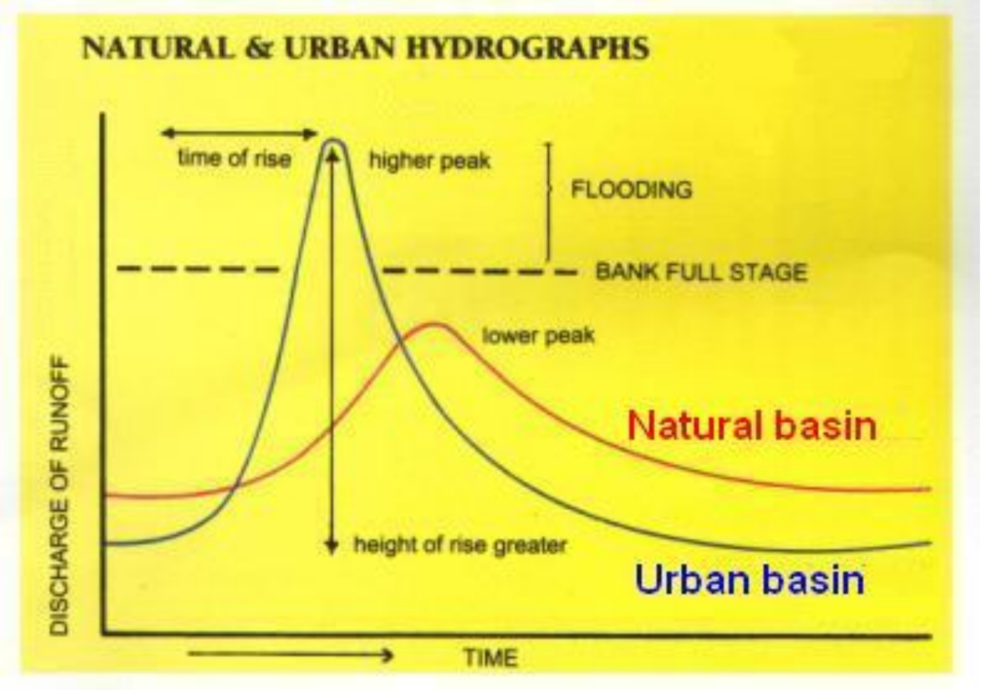
Runoff increased by impervious cover

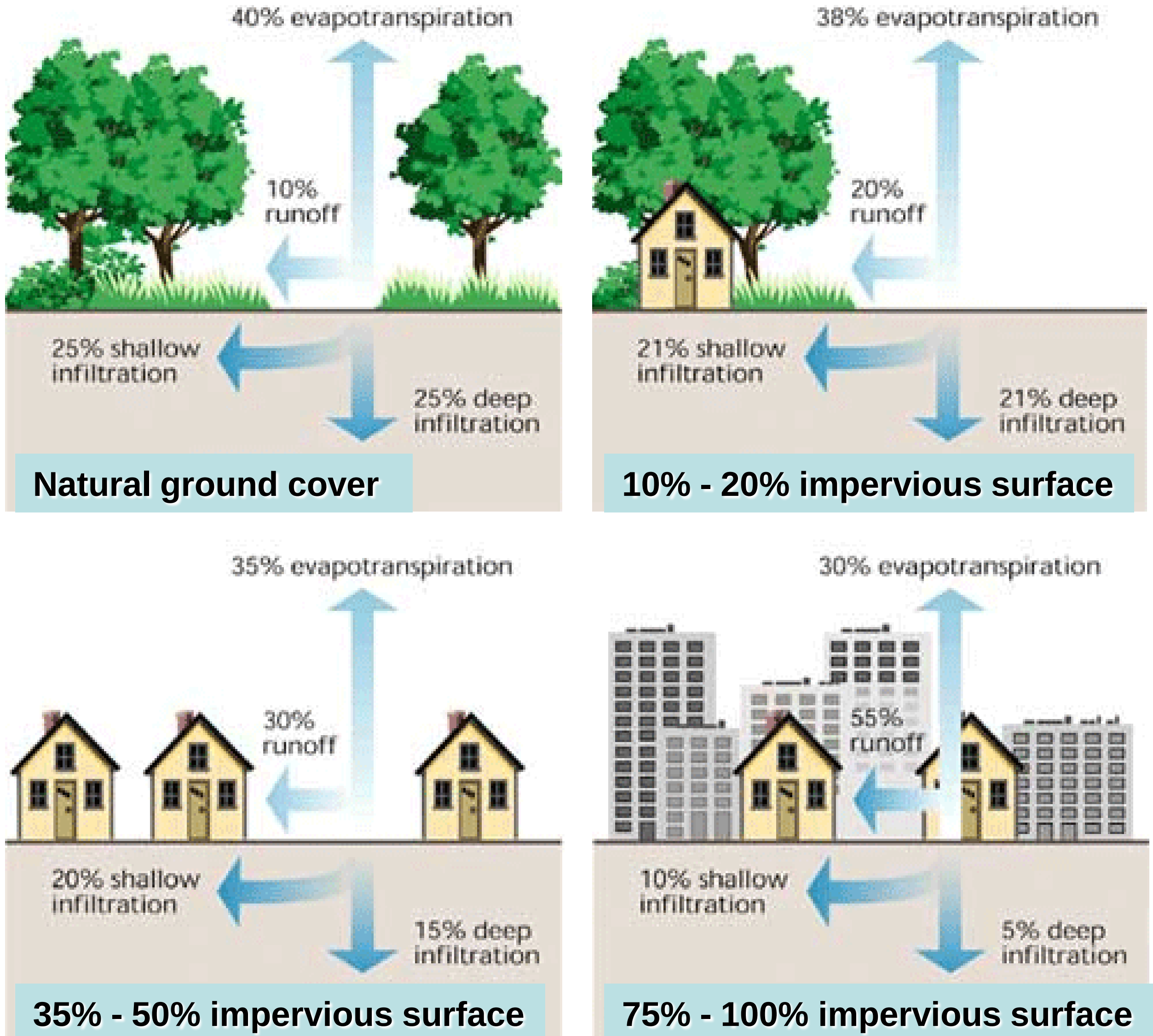
Urbanization increases flood peaks for all floods, causing greater losses of life and property. A US Geological Survey study in the Central Texas area documents that a 2-year flood peak (that with a 50% chance of occurring each year) increases by 99% when a rural basin is fully urbanized. Also, a 100-year flood peak increases by 73% when a basin is fully urbanized.



This conceptual hydrograph shows peaks in an urban basin to be higher than those in a natural basin

Also, urban peaks occur sooner after storms than rural peaks, thus less time is available for remedial actions or evacuation from severe floods.

Effects of urbanization on runoff and recharge



Values shown are for comparative purposes—actual values vary geographically

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Construction site runoff
Environmental Impacts

- Transports toxic pollutants and nutrients
- Turbidity limits sunlight penetration and photosynthesis
- Reduces oxygen availability
- Clogs fish gills
- Fills spawning and breeding grounds
- Smothers bottom Communities
- Reduces visibility for feeding and upsets food chain

Urban Construction

Construction typically involves removal of vegetation for work access roads and for building of structures, parking lots, and utility lines. Vegetation attenuates much of the contaminants in overland flow, thus its removal causes water-quality degradation of receiving streams. Also, many tons of loose sediment are created during this process—sediment which washes into receiving streams, reservoirs, and aquifers, often prohibiting the use of such water and causing loss of biological life.

Construction sediment can represent the greatest urban threat to aquatic resources.

Construction Sediment

Many studies Nationwide and in Texas document sediment loads in runoff to increase several orders of magnitude from construction areas that cover even much less than 1 percent of the drainage area for the basin. Degradation of water quality from construction sediment is often severe enough to limit or even prohibit water use and often requires expensive remedial action to correct.

Sediment in Barton Creek flood

Sediment in water sample from Barton Springs

Other Construction pollutants

Typical construction site pollutants include fluids from construction equipment, adhesives, paints, cleaners, masonry, cement, fertilizers, pesticides, and wastes from plumbing, heating, and air conditioning installations. Below is an example of pesticides in runoff from Bee Cave Galleria development in the Barton Creek basin.

Example of Construction Sediment

Hamilton Pool, West Travis County, prior to June 2007

Road cut for land development in Hamilton Creek basin began June, 2007

Example of Construction Sediment (cont.)

Road cut along Hamilton Creek after rainfall

Hamilton Pool--first rain after road cut construction began

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Impacts of: Urban Construction

- **Impervious ground cover**
  - **Increases in flooding damages and frequency**
  - **Erosion of channels and banks causing loss of property and additional stream sediment**
  - **Decreases in recharge volumes to aquifers**
- Urban land use
- Increased water use

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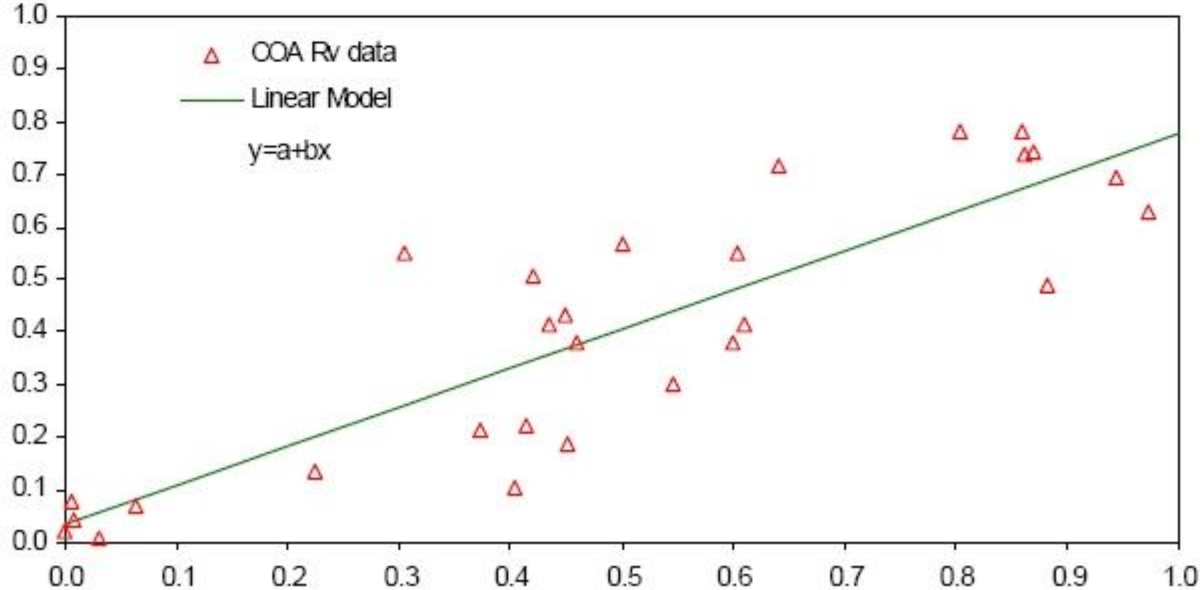
Relations between impervious cover and runoff

Runoff data from Austin streamflow gages shows runoff from rural areas to be about .05 or 5% of rainfall while runoff is about 40% or rainfall when impervious ground cover is 50%

Runoff as ratio of rainfall



Impervious cover as ratio of total area

Data from City of Austin

Austin, Texas, 1981 Memorial Day flood:
13 people drowned, $36 million damages

Urbanization increased this flood peak (deemed as a 100-year flood), but the inundated structures were located within the identified 100-year flood plain. At the time, at least 7,000 families were known to live within 100-year flood plains in Austin—most did not know.

Flooded area superimposed on aerial photo of part of Shoal Creek basin

Mayor wants city to tell residents about flood threat

By JANET WILSON
American-Statesman Staff

Mayor Carole McClellan wants more than 7,000 families notified that they live on the city's 100-year flood plain.

Bank Erosion

Urbanization causes increases in the number of bankfull flows. A watershed with 25% impervious surfaces is subjected about once every five years to a peak flow equivalent to the 100-year storm under undeveloped conditions. More frequent floods cause bank erosion as shown in photos of streams in developed basins in the Austin area.

Bank Erosion (cont.)

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Urban land use creates degradation of runoff quality for receiving streams, reservoirs, and aquifers

Increased water use

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Point sources of urban runoff

Discharges from businesses, industry, mining

- Permitted – sewage & industry effluent discharges (liquid or solid)
- Non-permitted – leaking storage tanks, spills, dumps

Point Sources (cont)

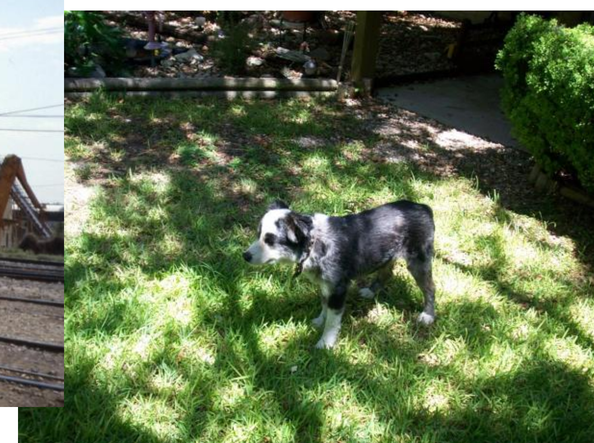
- **Other sources** – construction activities, waste dumps, cemeteries

Non-Point Sources of urban runoff

- **Urban development** – construction, sewage, autos, parking-lots, pesticides, fertilizers, industry, animals





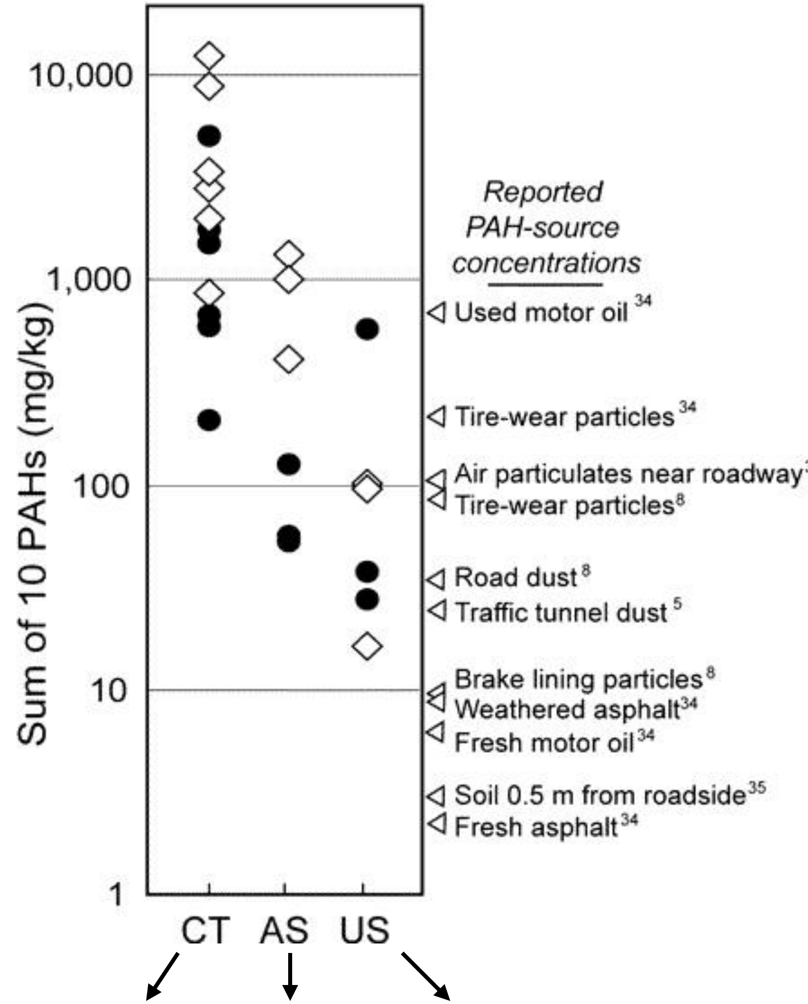



Examples of non-point source contamination

PAH from Parking lot sealants represent a newly discovered major source of urban contamination. PAH (polycyclic aromatic hydrocarbons), a group member of organic compounds formed during incomplete combustion of organic matter, are in fuels such as gasoline, coal, and fuel oil. As the graph shows, PAH levels in runoff from parking lots (including Austin) have been much greater than levels in used motor oil.

Sealants reapplied every few years. About 600,000 gallons of sealant are applied annually in Austin.

Levels of PAH sampled from parking lots



coal-tar-emulsion-sealed | **asphalt-emulsion-sealed** | **unsealed asphalt or concrete**

Another example of non-point source contamination: Leaking sewer line in Tannehill Branch, Austin

Wastewater leak in Barton Creek

Leaking sewer line in Barton Creek immediately upstream from Barton Springs, Austin

Urban Stormwater Hotspots

Definition: A land use or activity that produces higher concentrations of trace metals, hydrocarbons or priority pollutants than normally found in urban runoff.

- **Auto recycling**
- **Commercial parking lots**
- **Fleet storage areas**
- **Industrial rooftops**
- **Landscaping/nursery**
- **Industrial (outdoor storage or unloading)**
- **Public work areas**
- **Vehicle service & maintenance**
- **Vehicle washing/steam cleaning**

Urban and Industrial Stormwater: Typical Pollutants

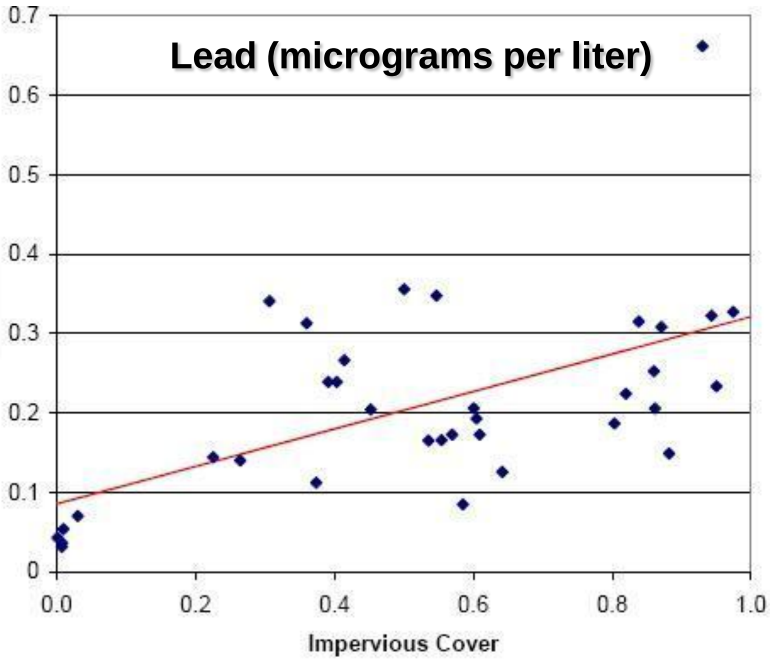
- Suspended solids/sediments
- Nutrients (nitrogen & phosphorus)
- Metals (copper, zinc, lead, and cadmium)
- Oil & greases (PAHs)
- Bacteria
- Pesticides & herbicides
- Temperature

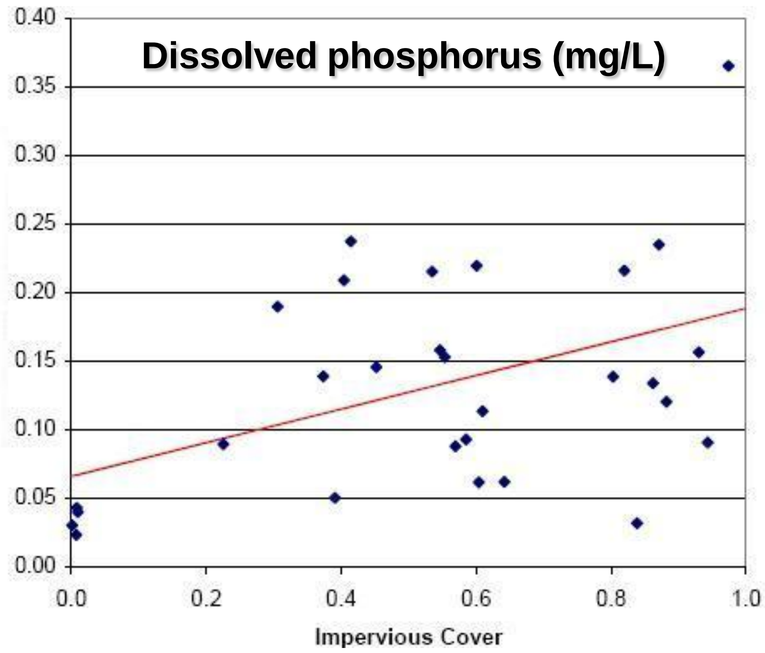
Urban Water Quality Degradation

Data from U.S. Geological Survey gages in Austin area

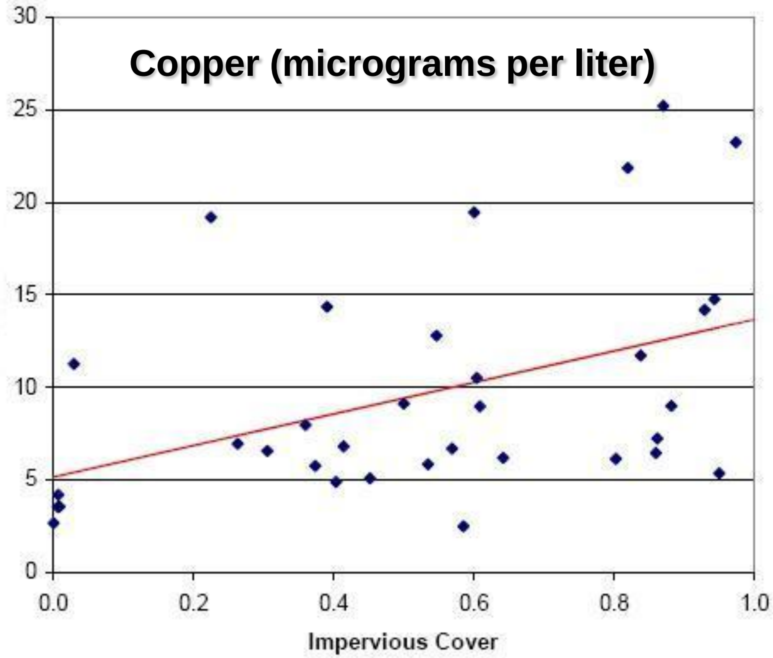
Median water-quality concentrations for rural and urban basins, for samples collected in Austin during rising stream stages

Water-quality constituent	Median value for rural basins	Median value for urban basins	Percent change in median concentration from rural to urban basin
dissolved solids	245	130	47 % decrease
suspended solids	6.0	410	6700 % increase
biochemical oxygen demand	0.95	6.0	530 % increase
total organic carbon	4.0	18	350 % increase
total nitrogen	0.5	2.15	330 % increase
total phosphorus	0.02	0.45	2150 % increase
fecal coliform	1,000	42,000	4100 % increase
fecal streptococci	1,200	75,000	6150 % increase

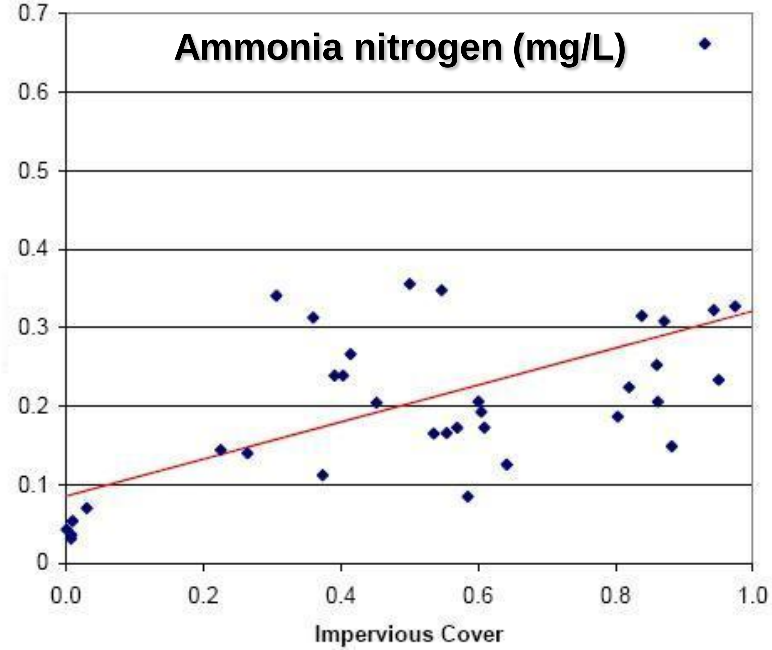




Relation of impervious cover (as ratio of total ground cover) to mean values of water quality constituents for gaged Austin streams



Data from City of Austin



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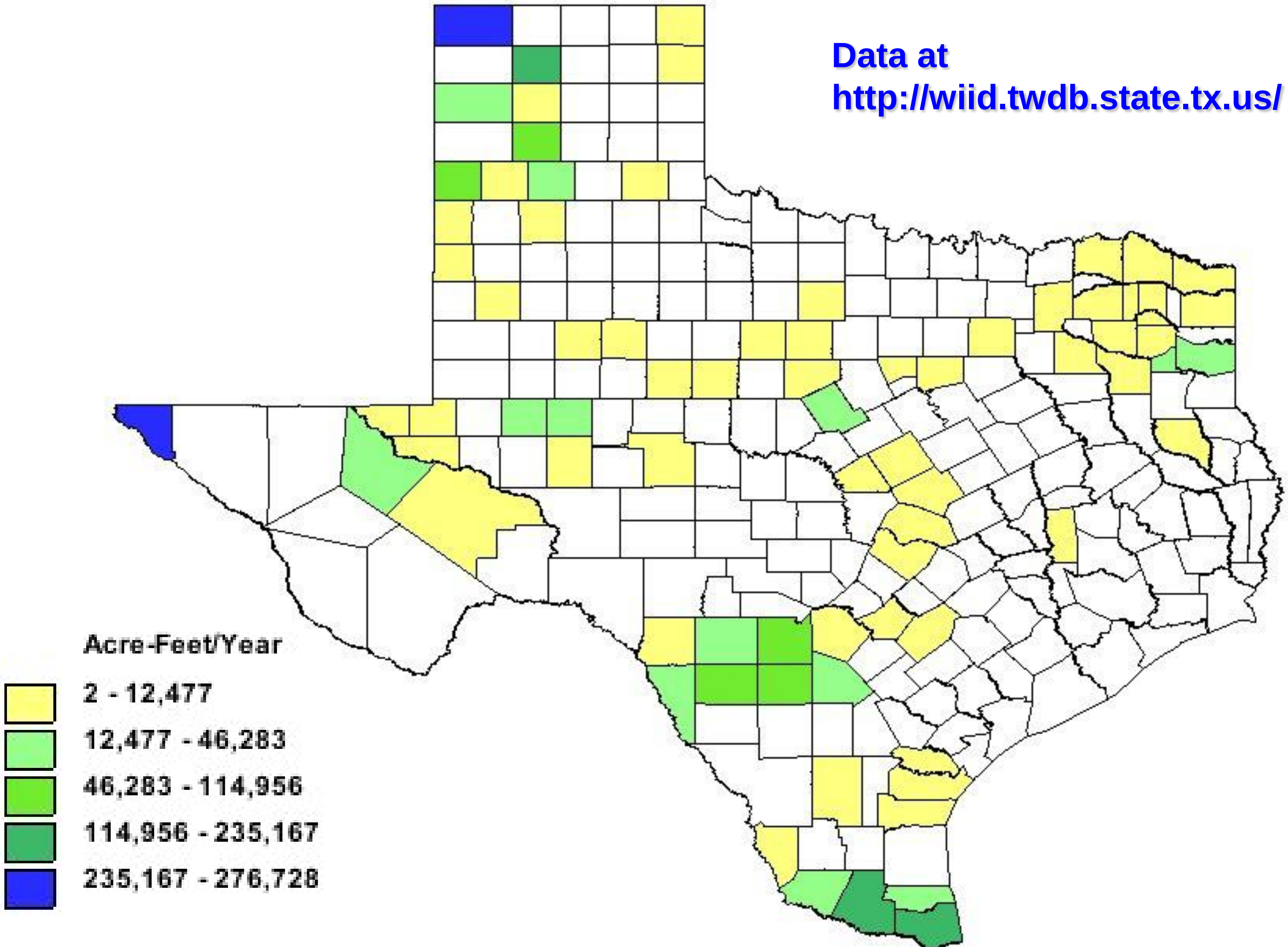
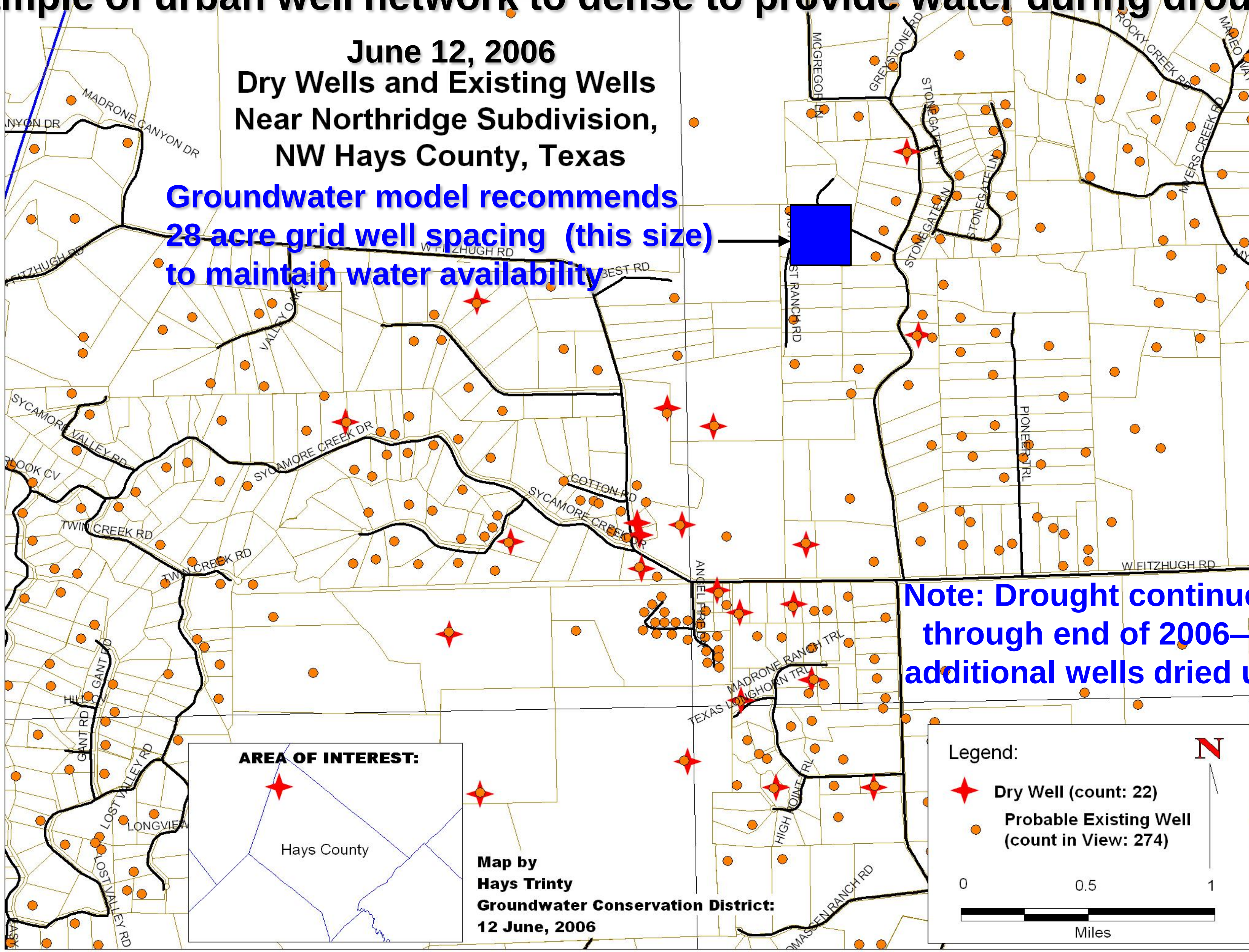
Projected total unmet water needs by county, 2050

Data at
http://wiid.twdb.state.tx.us/



Example of urban well network to dense to provide water during drought



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Urban Water Management Issues

- Stormwater Management
- Nonpoint Sources of Pollution
- Source Water Protection
- Water Conservation
- Wastewater Reuse
- Wastewater Infrastructure

Managing watershed development

Eight tools to protect or restore aquatic resources in a watershed

- Land Use Planning
  - Resource protection
  - Watershed based zoning
- Land Conservation
  - Conservation easements
  - Urban watershed forestation
- Aquatic Buffers
- Better Site Design
- Erosion and Sediment Control
- Stormwater Best Management Practices
- Non-Stormwater Discharges
- Watershed Stewardship Programs

- Center of Watershed Protection

Managing development

Resources

- **The Center for Watershed Protection** presents many strategies for protecting, preserving and restoring watersheds http://www.cwp.org
- **The Storm Water Center** is a technical clearinghouse for stormwater practitioners and managers **http://www.stormwatercenter.net**
- **The EPA Stormwater Program** **http://cfpub.epa.gov/npdes/home.cfm?program_id=6**
- **The EPA National Menu of Stormwater Best Management Practices** **http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm**
- **The International BMP Stormwater Database** features a database of BMP studies, performance analysis results, tools for use in BMP performance studies, monitoring guidance and other study-related publications. **http://www.bmpdatabase.org/**

Click on hyperlinks to access sites

Tools to protect watersheds

- **Vulnerability analyses**
  http://www.cwp.org/Vulnerability_Analysis.pdf

- **Watershed assessments**
  http://www.cwp.org/st_marys_assessment.htm

- **Retrofit assessment**
  http://www.cwp.org/retrofit_article.htm

- **Watershed restoration**
  http://www.cwp.org/tools_restoration.htm

- **Rapid stream assessment technique**
  http://www.stormwatercenter.net/monitoring%20and%20assessment/rsat/smrc%20rsat.pdf

- **Conservation assessment**

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Location of development within watersheds

Best Management Practices

Mitigation of impacts of urbanization

The two major topics below involve several tools to protect aquatic resources

- **Location of development within watersheds**
  - **Land Use Planning**
  - **Land Conservation**
  - **Aquatic Buffers**
  - **Better Site Design**

- **Best Management Practices**
  - **Construction pollution prevention**
  - **Development pollution prevention**
  - **Stormwater treatment**

Location of development within watersheds

The location of development within a basin can be more important in mitigating flooding and water quality degradation than the amount of development.

•Only about 10% of rainfall from a natural basin becomes runoff

•The remaining 90% of rain is captured by the soil and vegetation in overland flow before entering streams.

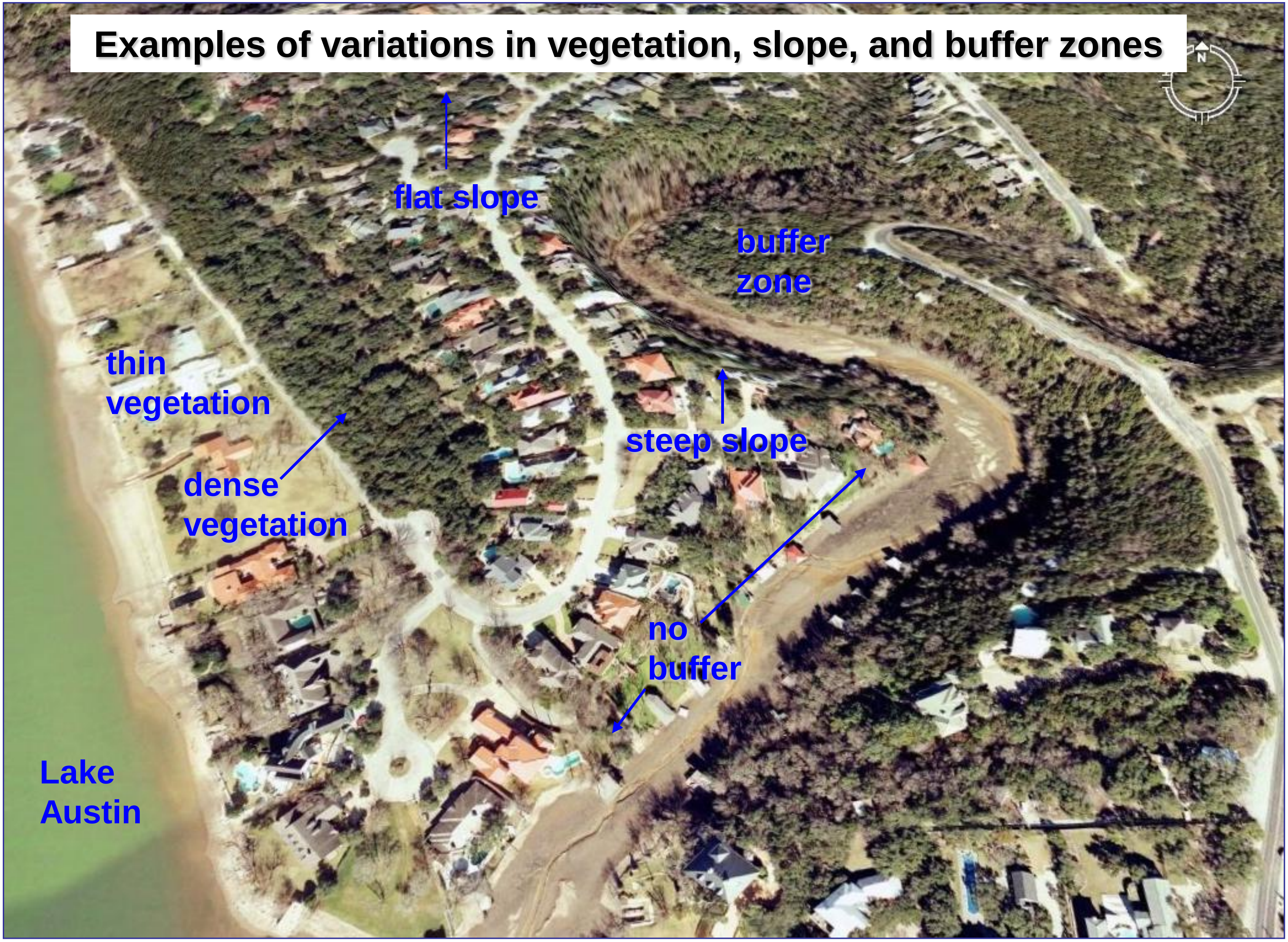
•Soils and vegetation also attenuate water-quality contaminants in overland flow.

•Development can increase runoff volume and degrade water quality by several hundred percent

•Contaminated runoff from developed areas adjacent to stream channels receives minimal attenuation by soils and vegetation before entering receiving streams.

* The amount of urban contaminants entering streams and aquifers can be minimized by:
1. locating developed areas remote from receiving streams and/or the use of buffer zones,
2. increased vegetation to attenuate contaminants
3. flat slopes between development and stream--flat land create slower velocities of overland flow, thus providing great time for attenuation of contaminants

Examples of variations in vegetation, slope, and buffer zones



Erosion and Soil Control Practices

http://www.stormwatercenter.net/Slideshows/ESC.htm

Note: Many of these practices are not used in Texas

1. Minimize Clearing

2.a. Protect Waterways

   Buffers and special crossings for waterways

2.b. Stabilize Drainageways

   Checkdams, sod, erosion control blankets, rip rap

3. Phase Construction

4. Rapid Soil Stabilization

   hydroseed, mulch, erosion control blankets

5. Protect Steep Slopes

6. Perimeter Controls

   Earth dikes, diversions, silt fences, stabilize construction entrance

7. Employ Advance Settling Devices

   sediment traps & sediment basins

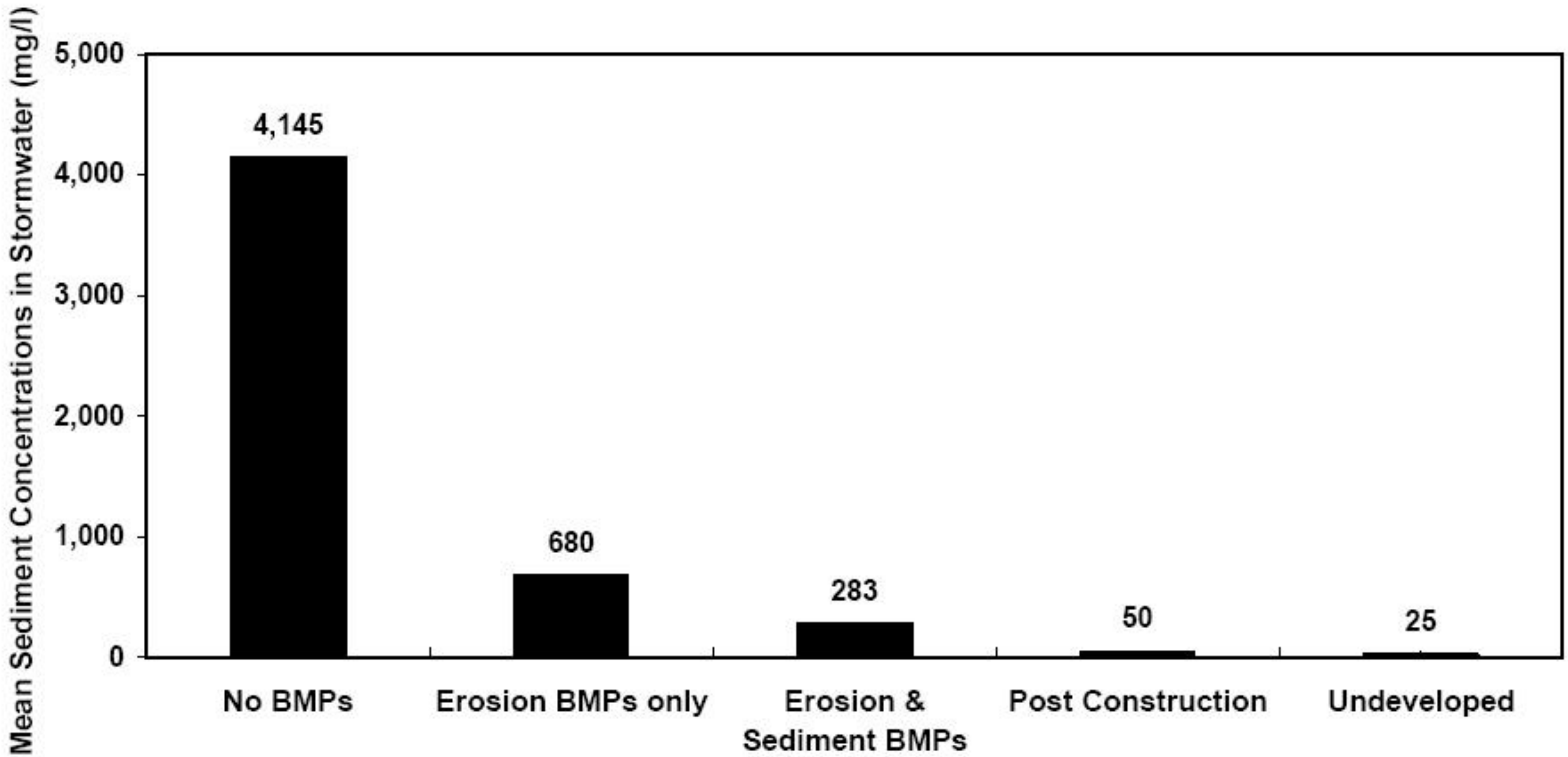
8. Certified Contractors Implement Plan

9. Adjust Plan as Field Conditions change

10. Assess and Revise Practices After Storms

   Repair damage, modify practices, reinforce, cleanout

Effect of erosion and sediment controls on suspended sediment concentrations



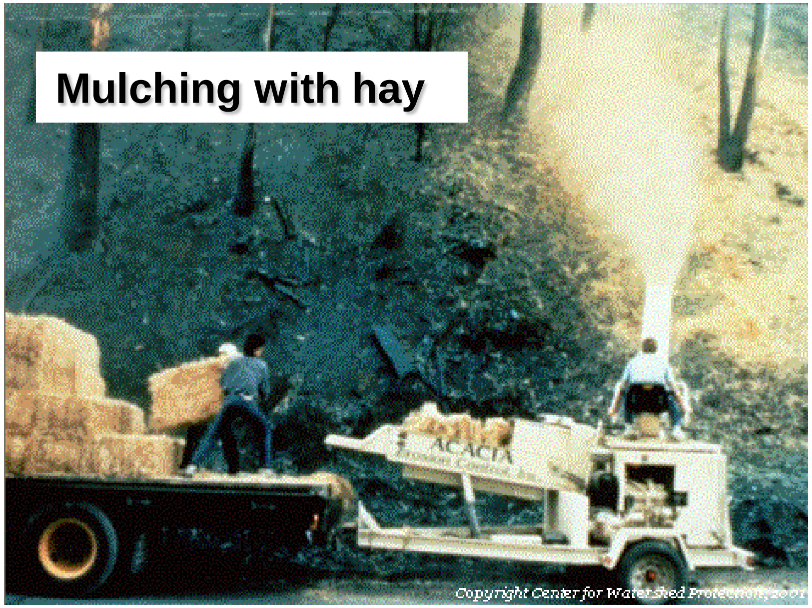
Construction site condition

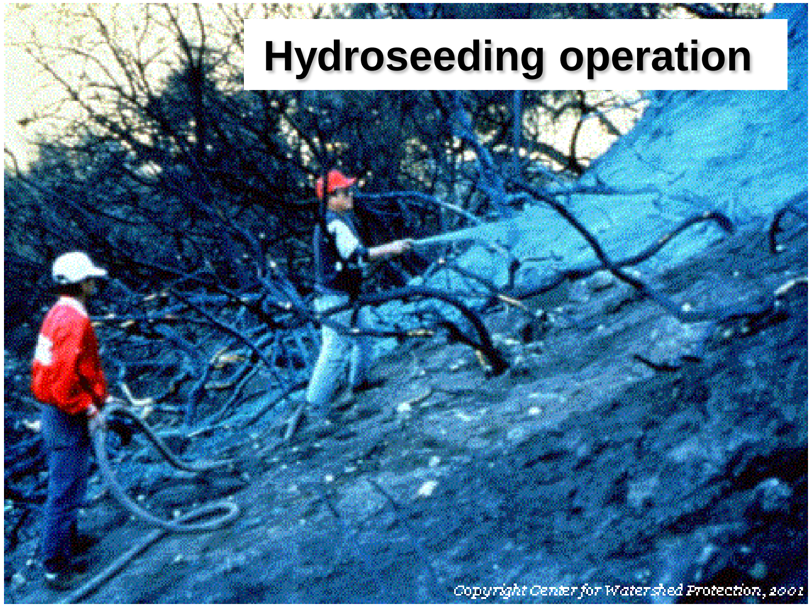
Data from Piedmont, Ca.
(Schueler and Lugbill, 1990)

Construction controls most used in Texas

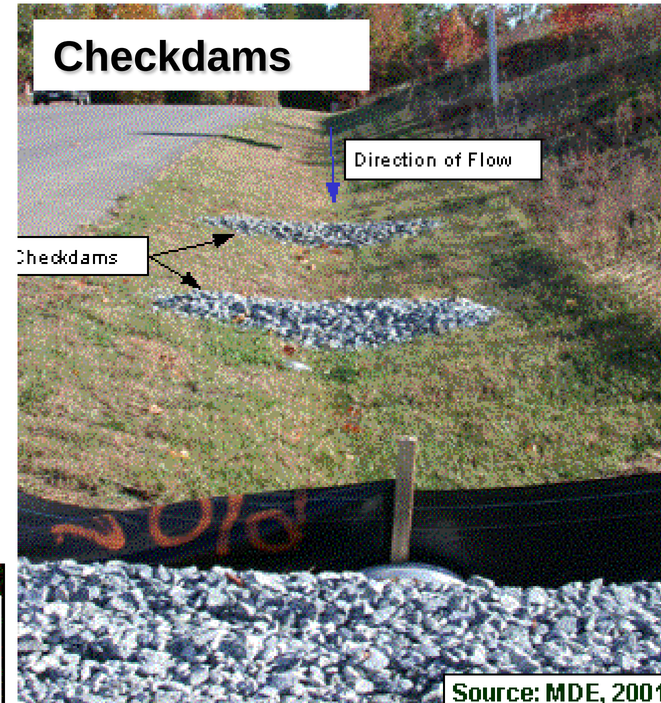
Silt fences which often fail during large storms

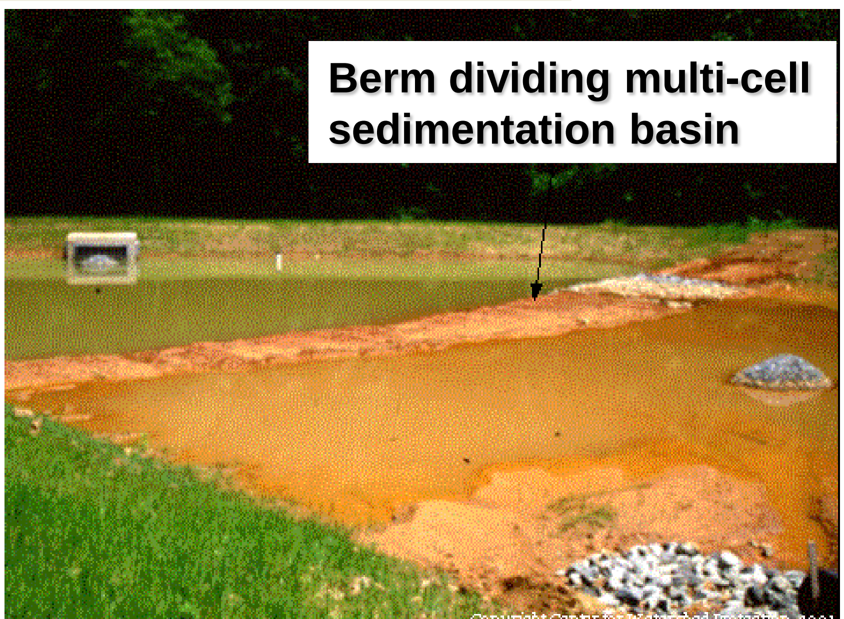
Additional sediment construction controls





Additional sediment construction controls (cont.)





Best Management Practices

Can attenuate flood peaks and/or reduce water quality degradation

Pollution prevention

Municipal - pest control, road and bridge maintenance, illegal dumping controls, parking lot and street cleaning, wastewater system controls

Residential - animal waste collection, landscaping and lawn care, car washing, pest control, automobile maintenance, rain barrels, septic system controls, green rooftops

Stormwater treatment

Ponds - wet, dry extended detention, multiple ponds

Wetlands - shallow marsh, submerged gravel, pond/wetland system

Filtering - grass filter strip, sand or organic filter, on-lot treatment, bio-retention

Infiltration - porous pavement, infiltration trench, infiltration basin,

Open channels - dry swell, wet swell, grass channels

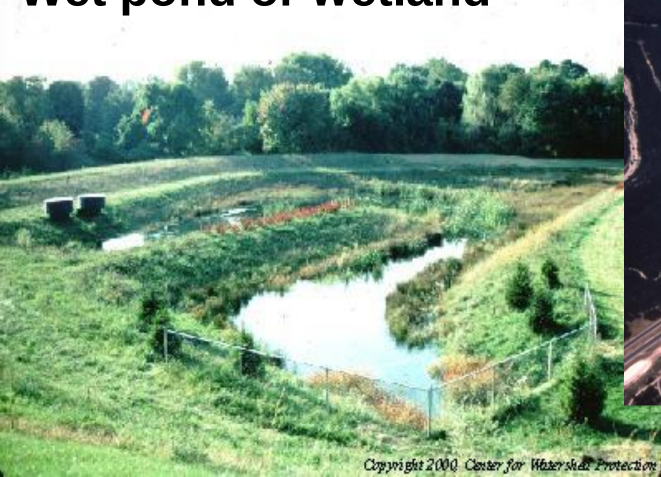
Examples of Stormwater Best Management Practices

Flood peak attenuation

Pervious parking lot

Infiltration basin

Wet pond or wetland



Sand filter – Barton Creek Mall

Grass swell

Slideshows with additional information on stormwater management

- **Why watersheds**
  http://www.cwp.org/whywatersheds_files/frame.htm

- **Impacts of urbanization**
  http://www.stormwatercenter.net/Slideshows/impacts%20for%20smrc/sld001.htm

- **Better site design**
  http://www.stormwatercenter.net/Slideshows/bsd%20for%20smrc/sld001.htm

- **Eight tools for watershed protection**
  http://www.stormwatercenter.net/Slideshows/8tools%20for%20smrc/sld001.htm

- **Stormwater Best Management Practices**
  http://www.stormwatercenter.net/Slideshows/smps%20for%20smrc/sld001.htm

In closing…

- I would feel more optimistic about a bright future for man if he spent less time proving that he can outwit Nature and more time tasting her sweetness and respecting her seniority.

-- E. B. White
US author & humorist (1899 - 1985)

Adapt or perish, now as ever, is nature's inexorable imperative.

-- H. G. Wells
English author, historian, & utopian (1866 - 1946)