Impacts of Urbanization on Water Resources

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Area inundated by 1981 flood in Austin

Wastewater leak

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
Organization of Presentation

Urban Hydrology 101

Impacts of: Urban Construction
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Managing development

Mitigation of urbanization impacts
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
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
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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Urban Hydrology 101
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

Managing development
Mitigation of urbanization impacts
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%

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
in blue

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

Press release after flood

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.
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.
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Urban Hydrology 101

Impacts of: Urban Construction

- Impervious ground cover
- Urban land use creates degradation of runoff quality for receiving streams, reservoirs, and aquifers
- Increased water use

Managing development

Mitigation of urbanization impacts
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.
Another example of non-point source contamination:
Leaking sewer line in Tannehill Branch, Austin
Wastewater leak in Barton Creek

Algae blooms
March 2, 2002
Leaking sewer line in Barton Creek immediately upstream from Barton Springs, Austin

Algae blooms
May 14, 2004
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

<table>
<thead>
<tr>
<th>Water-quality constituent</th>
<th>Median value for rural basins</th>
<th>Median value for urban basins</th>
<th>Percent change in median concentration from rural to urban basin</th>
</tr>
</thead>
<tbody>
<tr>
<td>dissolved solids</td>
<td>245</td>
<td>130</td>
<td>47% decrease</td>
</tr>
<tr>
<td>suspended solids</td>
<td>6.0</td>
<td>410</td>
<td>6700% increase</td>
</tr>
<tr>
<td>biochemical oxygen demand</td>
<td>0.95</td>
<td>6.0</td>
<td>530% increase</td>
</tr>
<tr>
<td>total organic carbon</td>
<td>4.0</td>
<td>18</td>
<td>350% increase</td>
</tr>
<tr>
<td>total nitrogen</td>
<td>0.5</td>
<td>2.15</td>
<td>330% increase</td>
</tr>
<tr>
<td>total phosphorus</td>
<td>0.02</td>
<td>0.45</td>
<td>2150% increase</td>
</tr>
<tr>
<td>fecal coliform</td>
<td>1,000</td>
<td>42,000</td>
<td>4100% increase</td>
</tr>
<tr>
<td>fecal streptococci</td>
<td>1,200</td>
<td>75,000</td>
<td>6150% increase</td>
</tr>
</tbody>
</table>
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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Mitigation of urbanization impacts
Projected total unmet water needs by county, 2050

Data at http://wiid.twdb.state.tx.us/
Groundwater model recommends 28 acre grid well spacing (this size) to maintain water availability.

Note: Drought continued through end of 2006—additional wells dried up.

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](http://www.cwp.org)

- The Storm Water Center is a technical clearinghouse for stormwater practitioners and managers [http://www.stormwatercenter.net](http://www.stormwatercenter.net)


Click on hyperlinks to access sites
Tools to protect watersheds

- Vulnerability analyses
  [http://www.cwp.org/Vulnerability_Analysis.pdf](http://www.cwp.org/Vulnerability_Analysis.pdf)

- Watershed assessments
  [http://www.cwp.org/st_marys_assessment.htm](http://www.cwp.org/st_marys_assessment.htm)

- Retrofit assessment
  [http://www.cwp.org/retrofit_article.htm](http://www.cwp.org/retrofit_article.htm)

- Watershed restoration

- Rapid stream assessment technique

- Conservation assessment
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Managing development

Mitigation of urbanization impacts
  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

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

Note: Many of these practices are not used in Texas
Effect of erosion and sediment controls on suspended sediment concentrations

![Graph showing the effect of erosion and sediment controls on suspended sediment concentrations. The graph compares different construction site conditions: No BMPs, Erosion BMPs only, Erosion & Sediment BMPs, Post Construction, and Undeveloped. The data is from Piedmont, Ca. (Schueler and Lugbill, 1990).](image-url)
Construction controls most used in Texas

Silt fences which often fail during large storms
Additional sediment construction controls

- Swale to divert runoff around construction site in non-erosive manner
- Mulching with hay
- Hay mulching
- Hydroseeding operation
Additional sediment construction controls (cont.)

Sedimentation basin with standpipe

Checkdams

Berm dividing multi-cell sedimentation basin

Source: MDE, 2001
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

- Pervious parking lot
- Infiltration basin
- Sand filter – Barton Creek Mall
- Grass swell
- Flood peak attenuation
- Wet pond or wetland
Slideshows with additional information on stormwater management

- Why watersheds

- Impacts of urbanization
  [http://www.stormwatercenter.net/Slideshows/impacts%20for%20smrc/sld001.htm](http://www.stormwatercenter.net/Slideshows/impacts%20for%20smrc/sld001.htm)

- Better site design
  [http://www.stormwatercenter.net/Slideshows/bsd%20for%20smrc/sld001.htm](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](http://www.stormwatercenter.net/Slideshows/8tools%20for%20smrc/sld001.htm)

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