Water Management, Our Public Health Crisis for the 21st Century? ; Definitions, Scope, and a Causation Framework.

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- Assistant Professor, Environmental Law Clinic, University of Pittsburgh School of Law

Factors making water management the most important environmental public health dilemma of the 21st Century.

- Urbanization, population expansion, industrialization, source contamination, watershed and habitat destruction and agriculture have placed severe strains on both surface and groundwater sources.
- In arid and semi-arid areas of the developed and developing world, water is being removed from fossil aquifers at unsustainable rates.
- Overuse of impounded and diverted surface water for agriculture is responsible for soil salination and decreasing crop yields.
- Groundwater pumping is also responsible for loss of riparian and wetland habitats, intrusion of saltwater and the movement of toxic and carcinogenic substances from contaminated vadose zones into potable water supplies.
- Worldwide, pathogens in water remain a central public health issue they are widespread, endemic and epidemic.

Volz, C. D. (2007). A framework to understand the centrality of protection and restoration of ecosystem services to water management and preparedness: An all-hazards approach with implications for NATO plans and operations; Strengthening national public health preparedness and response for chemical, biological, and radiological agent threats: Springer-NATO Advanced Science Institute Series-Skopje, Macedonia, IOS Press – Nieuwe 6B, 1013 BG.

Factors making water management the most important environmental public health dilemma of the 21st Century.

- In the USA, waterborne pathogens have caused epidemics largely via wet weather events causing sewer overflows and runoff combined with municipal drinking water treatment failures.
- Evidence that the effects of global warming are being and will be experienced largely through water quantity and quality deficits.
- The USA is facing a national water crisis, which has been termed “the freshwater imperative”(Naiman et al., 1995); water quantity and quality issues are important internal as well as external national security threats.
- Water resources are the basis for many inter and intra-governmental armed conflicts and have been the focus of regional political problems within the USA.

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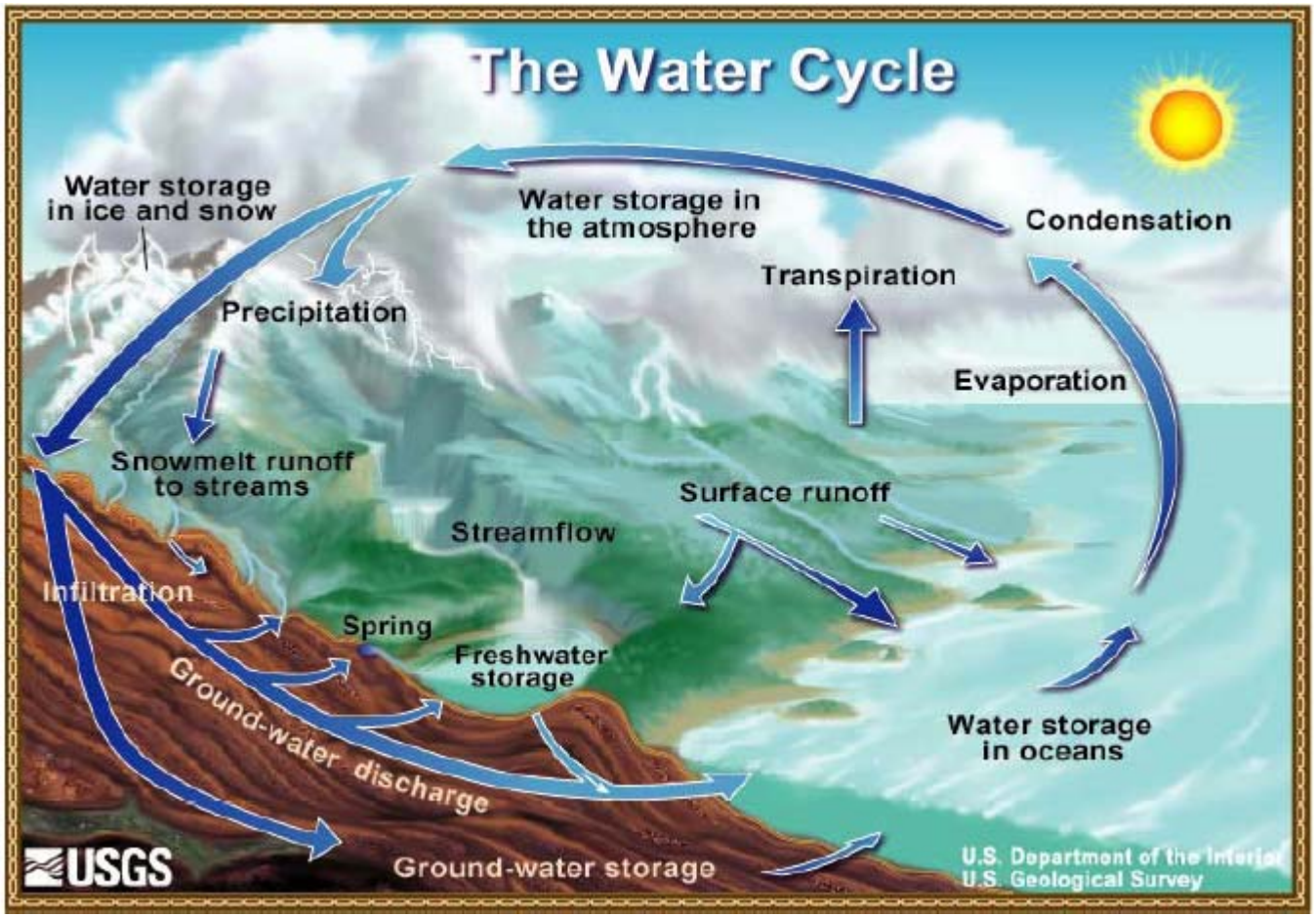
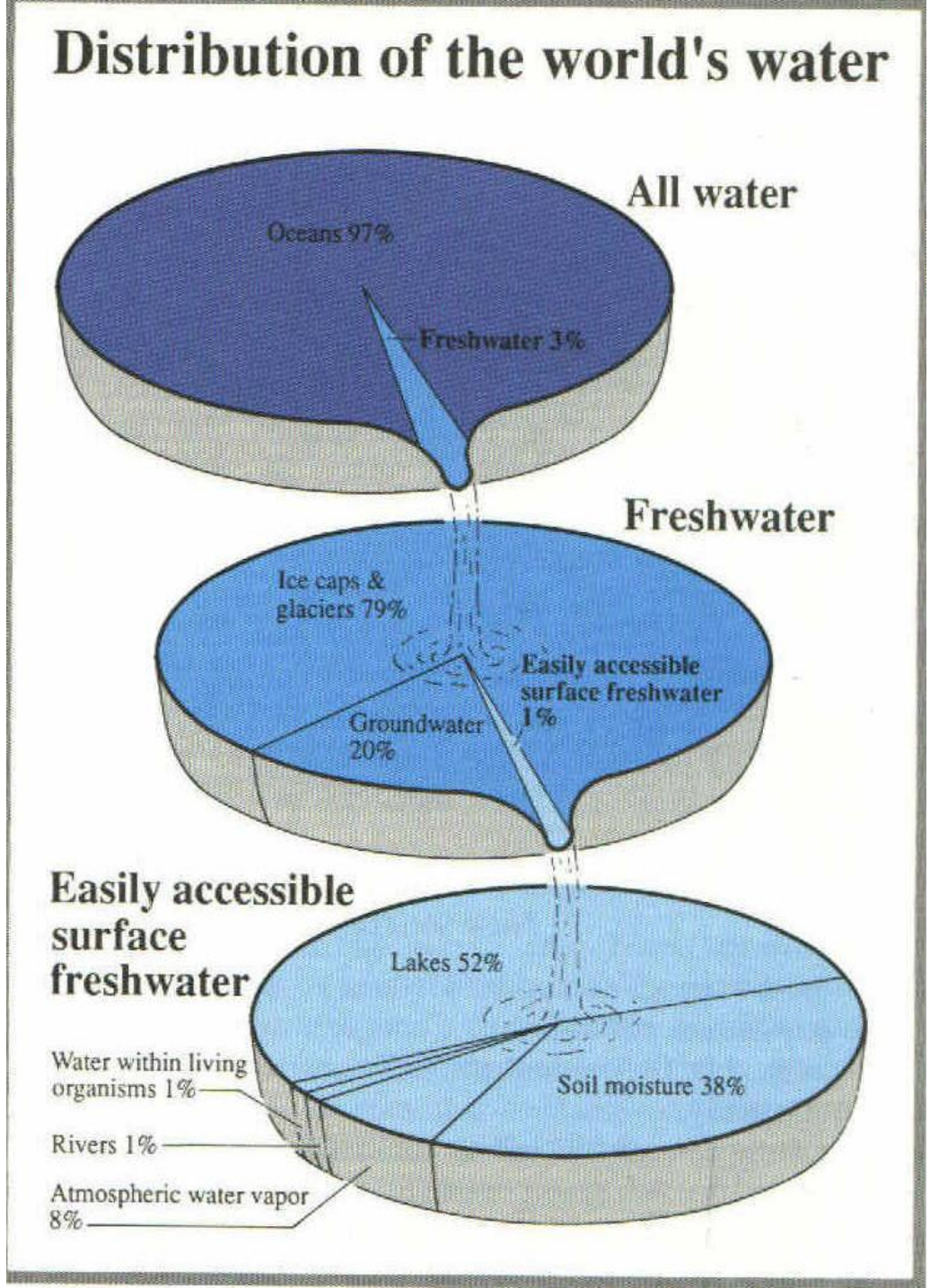
Definition-Water Management

- Water management refers to an integration of traditional and non-traditional public health issues that are very often treated separately like drinking water treatment, sewage, water contamination by toxic chemicals and metals, water quantity, stormwater and drainage, flooding, watershed protection and associated development and transportation project considerations.
- Each facet of water management goes together to form an interlocking whole, while single issues should be explored in depth in order to focus more attention on solutions – the effects of those solutions need to be incorporated in a holistic water management model.

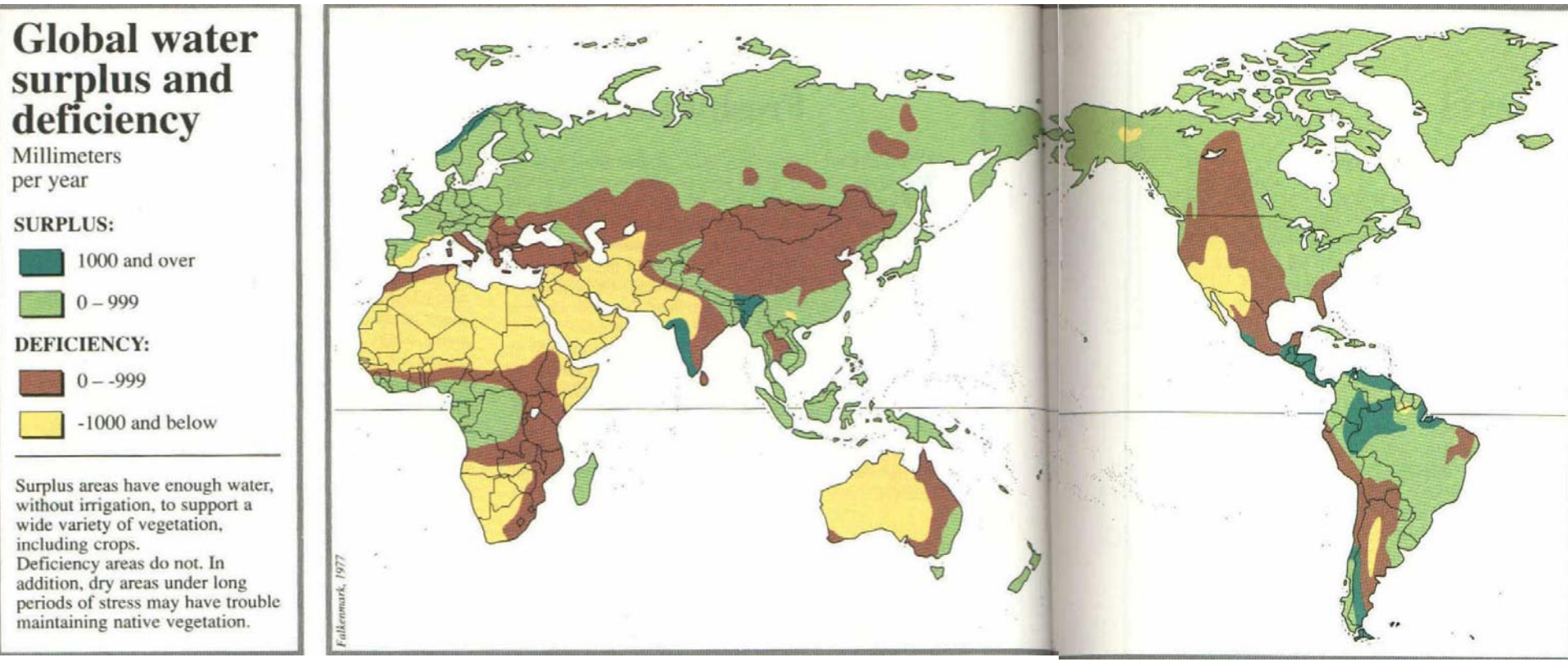
Volz, CD (2007), How do water, land management, ecological and contamination issues interact to produce tertiary public health, medical, social and economic problems? Journal of Occupational and Environmental Medicine. March 2007.


The Water Cycle
Water storage in ice and snow
Water storage in the atmosphere
Condensation
Transpiration
Precipitation
Evaporation
Snowmelt runoff to streams
Surface runoff
Streamflow
Infiltration
Spring
Freshwater storage
Ground-water discharge
Water storage in oceans
Ground-water storage
USGS
U.S. Department of the Interior
U.S. Geological Survey

The fragility of freshwater supplies

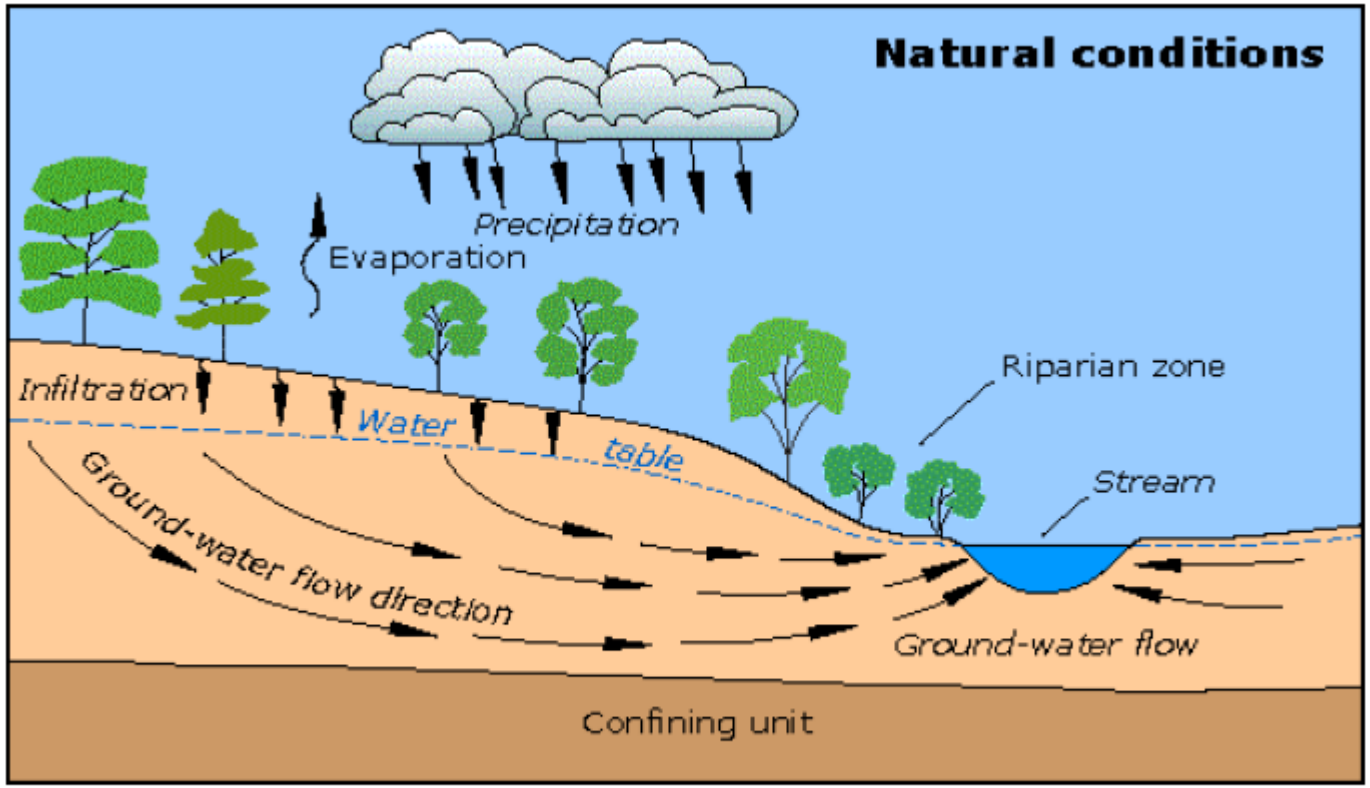


Global Water Surplus and Deficiency



Ali, 2006

Relationship Between Rainfall, Infiltration, Groundwater Flow and Stream-Lake Depth—Confirms the Intimate Relationship Between Surface Water and Groundwater



USGS NavGuide

USA Pathogens and Water Problems

- Many policymakers are under the impression that waterborne infectious diseases are now only of historical interest. These attitudes and perceptions need to be challenged because both endemic and epidemic waterborne disease occurs within the United States.
- Outbreaks of waterborne gastroenteritic disease are associated with ingestion of surface water contaminated with pathogenic bacteria, viruses and parasites. Ingestion of groundwater contaminated by failing on-lot septic systems, municipal sewage system failures and flooding have resulted in viral gastroenteritis (Hedberg and Osterholm, 1993).
- Although the burden of waterborne disease has decreased precipitously since the advent of modern filtration and purification, recreationalists (swimmers, boaters, and anglers) and home well water users remain at high risk for exposure to human pathogens.
- Municipal water systems sometimes fail to identify pathogens in water in real time and this has lead to a recent massive epidemic and numerous smaller outbreaks of gastrointestinal waterborne illness.

Volz, C. D. and Christen, C. 2006.Pathogen Contamination and Waterborne Disease as a Result of Wet Weather Releases from Combined and Sanitary Sewer Overflows and Stormwater Runoff: The Significance of Continued High Fecal Coliform Bacteria in Pittsburgh Main Stem Rivers and Tributaries as a Public Health Problem for Water Recreationalists and Municipal Treatment Facilities,University of Pittsburgh, Institute of Politics Regional Water Management Task Force Board

The Evidence

- There was a steady and significant increase in the number of **recreational water** gastroenteritis related disease outbreaks reported between 1989 and 2000 (Gerberding et al., 2002).
- The number of recreational outbreaks in 1998 was the highest seen since the inception of the CDC, EPA and Council of State and Territorial Epidemiologists (CSTE) waterborne disease tracking system in 1971.
- In the period between 1999 and 2000 Cryptosporidium parvum accounted for 44.4% of the outbreaks.
- Other outbreaks of known etiology were E. coli O157 (a bacteria that has caused deaths amongst children swimming in lakes), Norwalk-Like viruses and Shigella (4 species- bacteria).

Volz and Christen, 2006

Cryptosporidium parvum a human and animal intracellular parasite, has become the most important USA waterborne illness over the last 20 years.

- Its oocysts, shed by infected people into sewage systems and domestic and wild animal carriers into drainage basins and manure piles, are very resistant to environmental conditions, wastewater treatment and water purification (Robertson et al., 1992).
- Oocysts shed into the sewer system are released directly into our streams and rivers and groundwater during combined sewer overflows (CSO's), sanitary sewer overflows (SSO's), and wastewater treatment plant failures.
- A massive outbreak in Milwaukee of Cryptosporidium infection transmitted through the **public water supply** affected approximately 400,000 people with mild, moderate and severe watery diarrhea in 1993 (Mackenzie et al., 1994), deaths among the imunocompromised (the sub-population with HIV-AIDS, those receiving chemotherapy etc.) were reported (Hoxie, 1997) and the mortality rate among infected, imunocompromised individuals was estimated to be over 50% (Rose, 1997).
- The outbreak resulted in an estimated total cost of over US $93 million including direct medical costs and productivity losses (Corso, 2003). It is important to note that this outbreak was associated with **high water runoff from snowmelt and precipitation**, high water turbidity (cloudiness) at water intakes, and a failure of the water filtration system (this includes failure to recognize the increasing concentrations of the parasite in real time both in Lake Michigan and at the treatment plant).

Wet Weather Events and Pathogen Disease Outbreaks

- There is a strong correlation between the occurrence of both high monthly precipitation and wet weather events and disease outbreaks (Rose et al., 2000) (Curriero et al., 2001).
- Surface water outbreaks occurred most often in the month following the wet weather event and groundwater outbreaks were associated with a 2-month lag period between the precipitation event and waterborne disease outbreaks.

Ohio River Watershed (Allegheny and Monongahela Watershed and Ohio Headwaters Ares in Box)

Regional Cooperation for Water Quality Improvement in Southwestern Pennsylvania; 2005, National Academies of Science, http://www.nap.edu/catalog/11196.html

Southwestern Pennsylvania-CSO's, SSO's, and Runoff-Association with Increases in Fecal Coliform Bacteria, Cryptosporidium, and Giardia Parasites

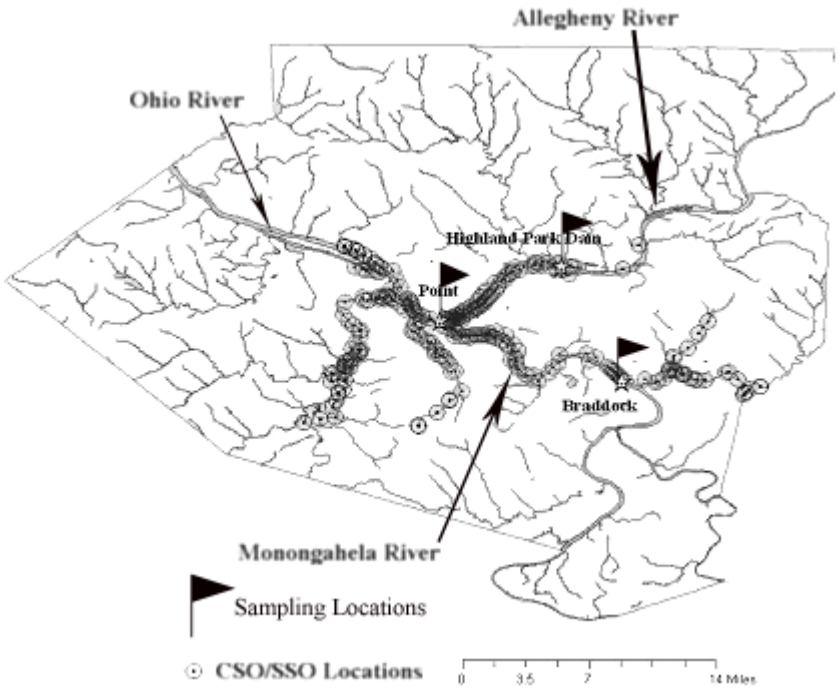
- Contamination of main stem rivers in Southwestern Pennsylvania by fecal coliform bacteria (FC) has greatly exceeded the national average **violation rate** for human contact from 1976-1995, sometimes by a factor of 2.
- Pittsburgh lead all other major cities in the Ohio River Basin in the percent of surface water samples violating the safe contact FC standard during the **2000-2001 recreational season, at 59%**. By contrast Cincinnati was in violation in 16% of water samples.
- Water sampling performed by the United States Geological Survey during the recreational boating seasons from 1980-1995 at **New, Kensington on the Allegheny River and at Braddock on the Monongahela River were in violation of FC standards in 72% and 97% of samples, respectively**.
- Eighteen (18) area streams have significant bacteriological contamination and extreme cases have exceeded standards by a factor of **200 and 1000**, respectively.

Southwestern Pennsylvania Pathogen Problems

- The human parasites-**giardia and cryptosporidium** are present at highly elevated levels at and downstream from CSO's both in Pittsburgh and in feeder streams.
- FC have been shown to be in excess of water quality standards over the past 25 years in both the Allegheny and Monongahela rivers (WSIP, 2002).
- From July to September of 2001 the United States Geological Survey in partnership with the Allegheny County Health department sampled water from the Allegheny, Monongahela and Ohio Rivers for fecal coliform, *E. coli* and *enterococci*. They found that wet weather samples exceeded standards in 56%, 71% and 81% of total samples for FC, *E. coli* and *enterococci*, respectively (Fulton and Buckwalter, 2001).
- **There have been reports from angling recreationalists in the Pittsburgh region of gastrointestinal problems associated with water contact following wet weather releases of sewage (Volz and Christen, 2007. Focus Group Results Indicate Recreationalists are at High Risk for Gastrointestinal Disease After Contact with River Water. Journal of Occupational Environmental Medicine, January 2007**.
- There is a direct correlation between wet weather and CSO, SSO and stormwater runoff and an increase in FC concentrations in the Three Rivers of Pittsburgh.
- The City of Pittsburgh and County of Allegheny have more CSO's and SSO's (over 300) than any city in the United States. These deposit over 16 billion gallons of raw sewage in the Three Rivers every year.

Volz, C. D. and Christen, C. 2006.Pathogen Contamination and Waterborne Disease as a Result of Wet Weather Releases from Combined and Sanitary Sewer Overflows and Stormwater Runoff: The Significance of Continued High Fecal Coliform Bacteria in Pittsburgh Main Stem Rivers and Tributaries as a Public Health Problem for Water Recreationalists and Municipal Treatment Facilities,University of Pittsburgh, Institute of Politics Regional Water Management Task Force Board

Combined and Sanitary Sewer Overflows in the ALCOSAN Sewershed, Allegheny County, PA.



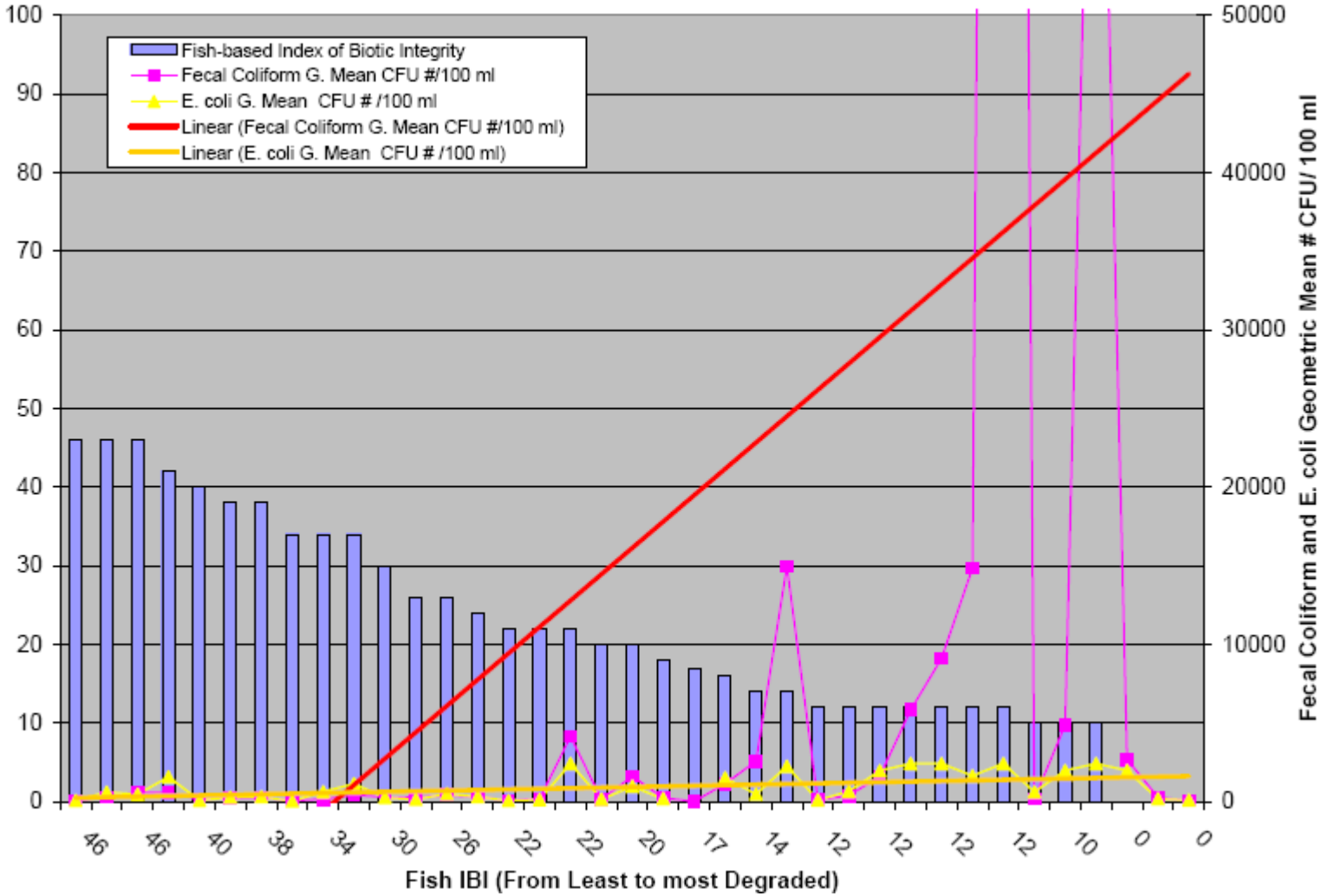
Volz, C.D., 2008. Estrogenicity of Channel Catfish Tissue is Related to the Density of Sewer Overflows, in Proceedings of the Third National Conference on Environmental Science and Technology, in press, Springer Publications. From data accessed from the EPA-ALCOSAN Consent Decree of 2007.

Concentrations of fecal-indicator bacteria in composite samples collected during wet-weather events, Allegheny, Monongahela, and Ohio Rivers near Pittsburgh, Pennsylvania, August-September 2001.

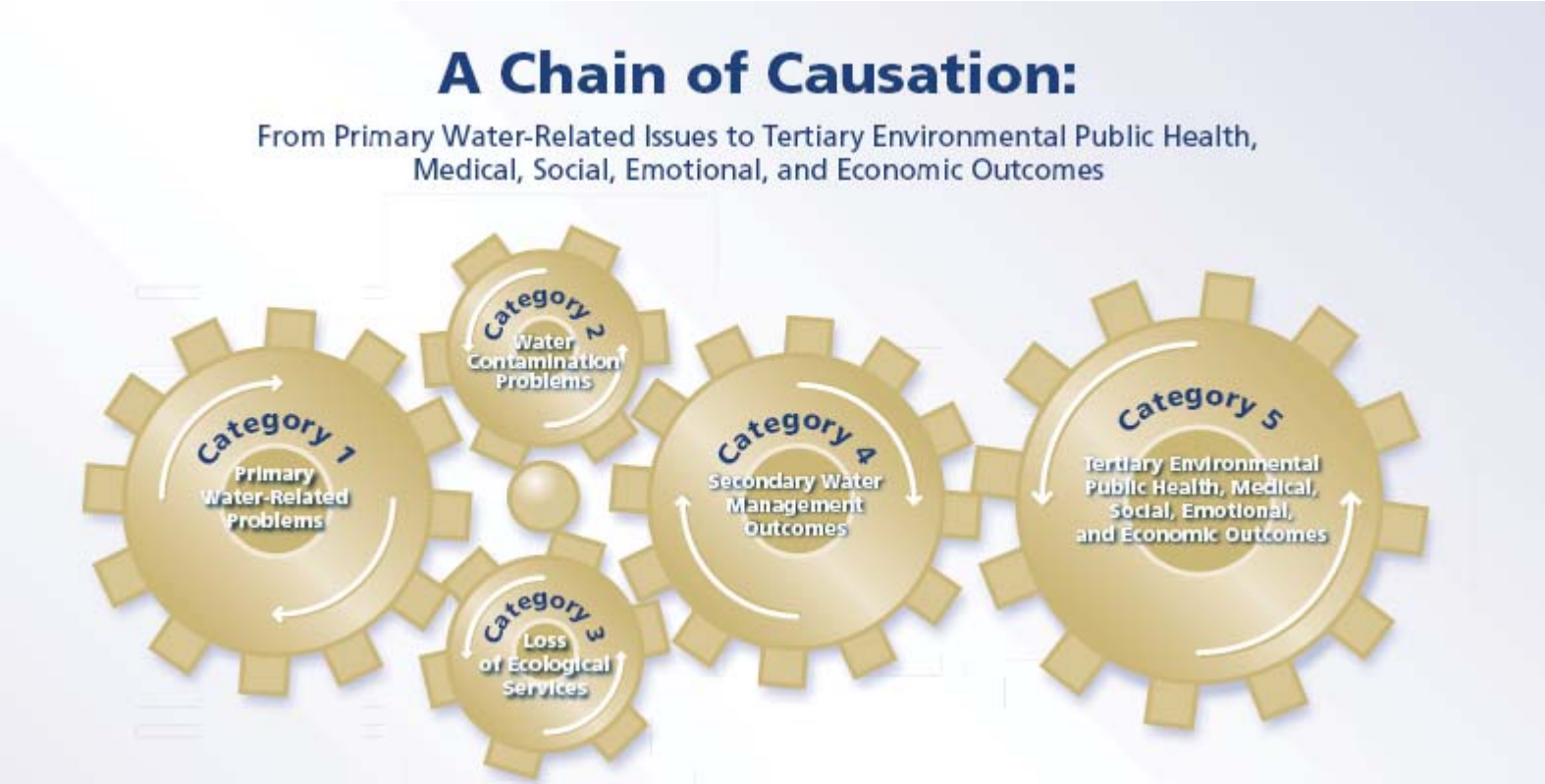
Site name	Sampling date					
	August			August		
	8	9	10	28	29	30
	Escherichia coli, in colonies per 100 milliliters					
Ohio River at Sewickley	1,300	400	420	240	2,300	2,300
Monongahela River at Braddock	6,000	35	510	520	2,000	50
Allegheny River at Oakmont	2.5	2.5	2.5	25	2.5	15
Allegheny River at 9th Street Bridge	2,700	440	6,400	420	2,200	35
Monongahela River at Pittsburgh	1,800	180	2,000	280	2,300	260
	Enterococci, in colonies per 100 milliliters					
Ohio River at Sewickley	350	115	70	10	310	180
Monongahela River at Braddock	125	20	15	130	250	150
Allegheny River at Oakmont	2.5	2.5	2.5	25	2.5	25
Allegheny River at 9th Street Bridge	230	20	225	20	265	100
Monongahela River at Pittsburgh	130	15	195	20	90	685
	Fecal coliform, in colonies per 100 milliliters					
Ohio River at Sewickley	650	580	250	760	2,200	770
Monongahela River at Braddock	8,000	90	840	1,500	1,700	740
Allegheny River at Oakmont	2.5	5.0	35	50	5	10
Allegheny River at 9th Street Bridge	4,400	560	14,000	750	3,300	540
Monongahela River at Pittsburgh	3,500	3,400	2,800	650	2,600	3,900

Fulton, J. W. and T. F. Buckwalter. 2004. *Fecal Indicator Bacteria in the Allegheny, Monongahela, and Ohio Rivers, Near Pittsburgh, Pennsylvania, July–September 2001*. United States Geological Survey Scientific Investigations Report 2004–5009. Reston, VA: USGS.

Relationships Between Fish Index of Biotic Integrity (IBI) and Pathogens in Mainstem Rivers and Tributaries of the Three Rivers



THREE RIVERS SECOND NATURE PHASE IV REPORT Integration and Review of Phases I, II, and III Chemical, Physical, and Biological Data, Collected from streams Tributary to the Allegheny, Monongahela, and Ohio Rivers in Allegheny County, Pennsylvania, and Characterization of Tributary Streams Based on Stream Water Quality and Ecosystem Health 2000-2003; Carnegie Mellon University.



Editors; Miller, T., Gorley, T., and Baron, B., Author; **Volz, C.D.,** 2007. **"Southwestern Pennsylvania's Water Quality Problems and How to Address Them Regionally",** Institute of Politics, University of Pittsburgh, 60 pages.

Volz, C. D. A framework to understand the centrality of protection and restoration of ecosystem services to water management and preparedness: An all-hazards approach with implications for NATO plans and operations . In Maria Calpinskiene, MD, PhD,Curtis Cummings, MD, MPH , Nataliya Gudzenko, MD, PhD, Elin Gursky, ScD, Faina Linkov, PhD, Alessandra Rossodivita, MD, Eugene Shubnikov, MD, Elisaveta Stikova, MD, PhD, Andrey Trufanov, PhD, **Conrad Volz, DrPH, MPH** Editors, Strengthening national public health preparedness and response for chemical, biological, and radiological agent threats: Springer-NATO Advanced Science Institute Series, IOS Press – Nieuwe 6B, 1013 BG

Volz, CD (2007), How do water, land management, ecological and contamination issues interact to produce tertiary public health, medical, social and economic problems? Journal of Occupational and Environmental Medicine. March 2007

Category 1: Primary Water-Related Problems

Release of municipal and household sanitary wastes directly into area water.

Aging/inadequate municipal sewer infrastructure.

Wildcat sewers and failing on-lot septic systems.

Fragmentation of water and sewer planning and management.

Abandoned and active mines.

Issues related to nonsustainable development.

Lack of coordinated water and land management plans.

Development in headwaters and critical watersheds.

Sprawl.

Past and ongoing industrial pollution.

Contamination from the iron and steel industry.

Superfund, waste dump, and brownfield sites.

Deposition of contaminants from power plants and other industrial sources.

Nonpoint-source pollution.

Household hazardous waste.

Application of lawn pesticides and nutrients.

Road topping compounds.

Vehicle exhaust.

Past and present agricultural chemical use.

Personal and societal attitudes toward water usage.

Fragmented local, state, and federal regulatory climate.

Spills or accidental releases of toxic and hazardous substances.

Gravel and sand mining in mainstem rivers.

Drought.

Global Warming.

Editors; Miller, T., Gorley, T., and Baron, B., Author; **Volz, C.D.,** 2007. **"Southwestern Pennsylvania's Water Quality Problems and How to Address Them Regionally",** Institute of Politics, University of Pittsburgh, 60 pages.

A Chain of Causation:

From Primary Water-Related Issues to Tertiary Environmental Public Health, Medical, Social, Emotional, and Economic Outcomes

Category 2: Water Contamination Problems

Pathogens.

Nitrates.

Heavy metals: mercury, lead, copper, chromium, and cadmium.

Arsenic: naturally occurring or from agricultural and/or industrial operations.

Volatile organic compounds (VOCs).

Contaminants associated with mine drainage.

Pesticides and herbicides.

Polychlorinated biphenyls (PCBs) and other organohalogen substances (OHSs).

Endocrine-disrupting compounds (EDCs).

Radon.

Highly acidic or alkaline water.

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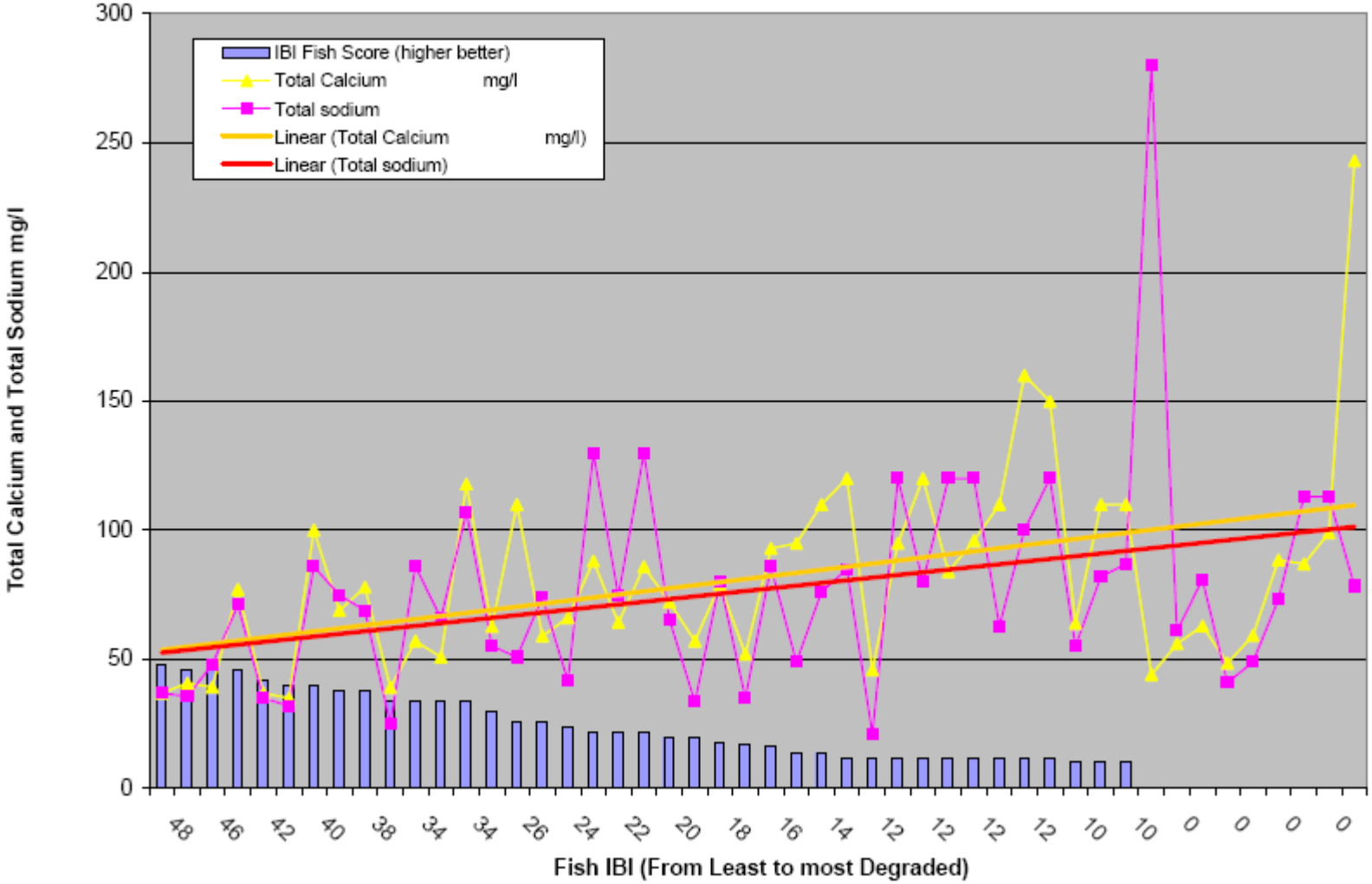
Relationships Between Fish Index of Biotic Integrity (IBI), Total Calcium, and Total Sodium (TDS-Conductivity) in the Three Rivers Watershed



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A Chain of Causation:

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Category 3: Loss of Ecological or Ecosystem Services

Wetland loss.

Deforestation.

Loss of topsoil and plant cover.

Loss of native plant species

Loss of subsoil integrity.

Loss of natural drainage patterns.

Uptake of contaminants in nature's food web.

Changes in stream and river flow characteristics.

Decrease in groundwater recharge.

Land and streambed erosion.

Endocrine disruption in aquatic species and feeders.

Riparian habitat loss.

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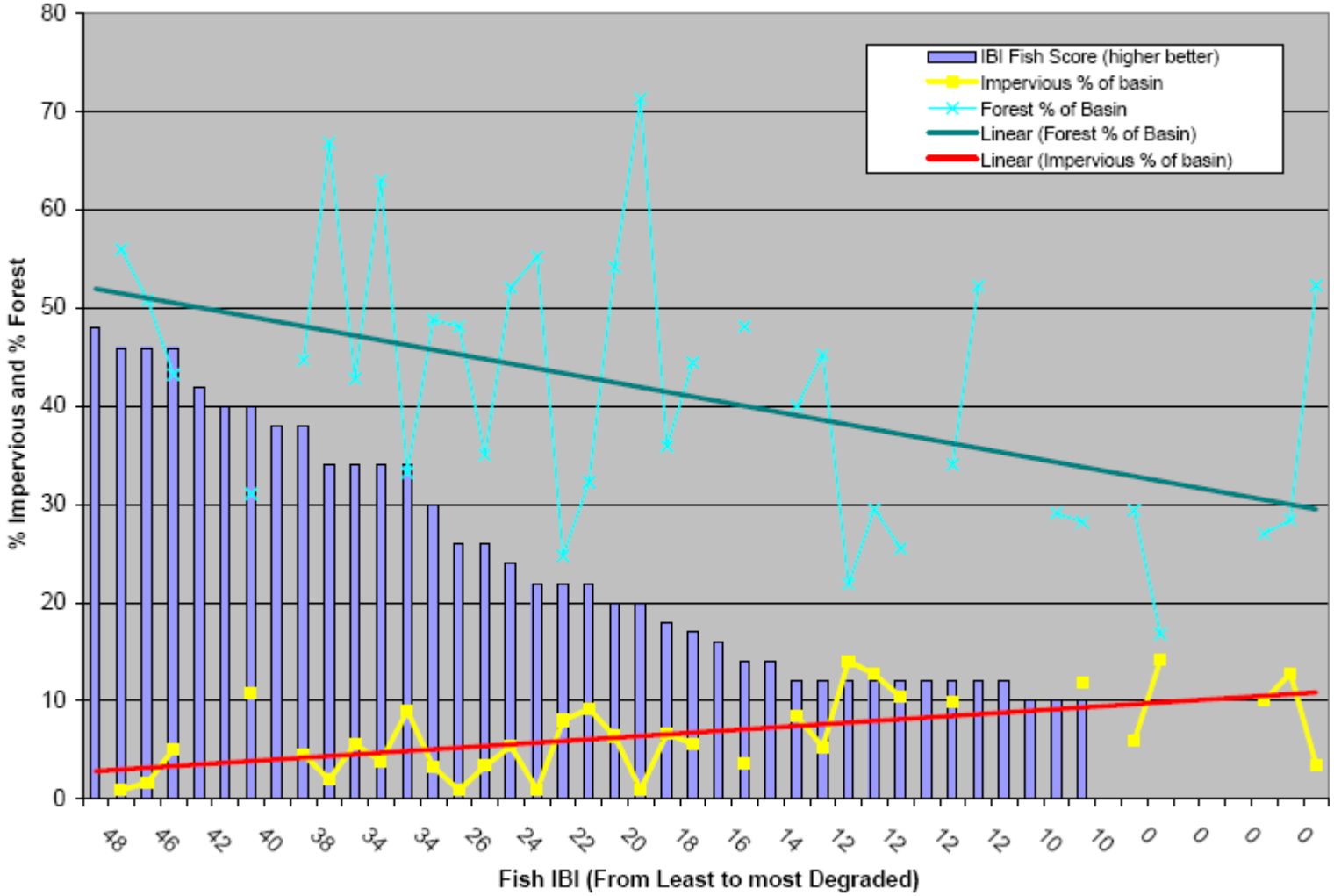
Relationships Between Fish Index of Biotic Integrity (IBI), % Impervious Surface, and % Forest in the Three Rivers Watershed



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% Removal of Contaminants Using Wetlands

Performance of Storm Water Wetlands[13]

Pollutant	Removal Rate
Total Suspended Solids	67%
Total Phosphorus	49%
Total Nitrogen	28%
Organic Carbon	34%
Petroleum Hydrocarbons	87%
Cadmium	36%
Copper	41%
Lead	62%
Zinc	45%
Bacteria	77%

Pine Creek Assessment, 2006

A Chain of Causation:

From Primary Water-Related Issues to Tertiary Environmental Public Health, Medical, Social, Emotional, and Economic Outcomes

Category 4: Secondary Water Management Outcomes

Human pathogens in surface water.

Human pathogens in groundwater.

Increased potential for mine blowouts.

Increased sediments in surface water.

Decreased production of clean surface water and groundwater.

Flooding.

Increased stormwater/snowmelt runoff.

Increased contaminant loads in surface water and groundwater.

Consumption of contaminated fish.

Human exposure to carcinogens, toxic substances, and endocrine active substances.

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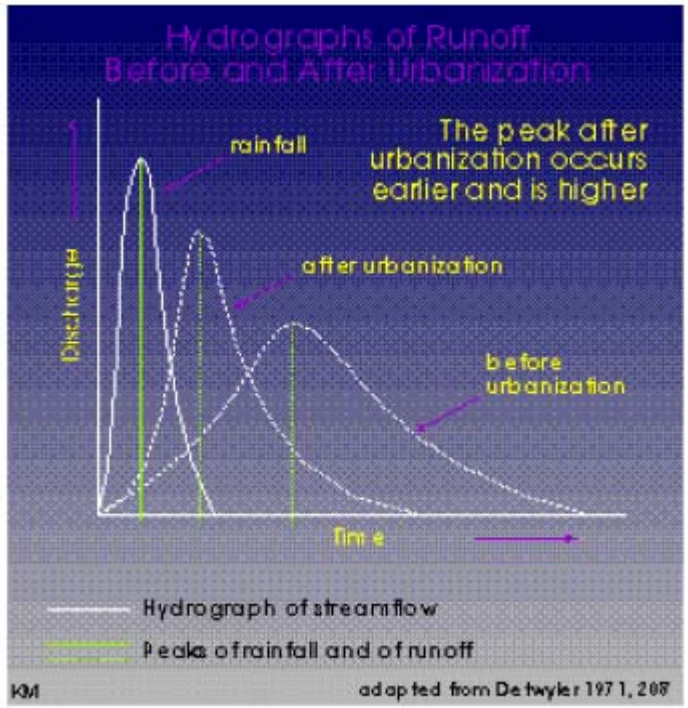
Figure showing the relationship between loss of ecosystem services and stormwater runoff.



A Chain of Causation:

From Primary Water-Related Issues to Tertiary Environmental Public Health, Medical, Social, Emotional, and Economic Outcomes

Category 5: Tertiary Environmental Public Health, Medical, Social, Emotional, and Economic Outcomes

Loss of life and property due to flood damage.

Increased environmental asthma.

Increased stormwater management costs.

Increased cost of water purification.

Decreased recreational and aesthetic value.

Decreased economic growth.

Loss of aquatic and terrestrial species.

Increased cost of flood insurance.

Increased risk of cancer, waterborne pathogen diseases, and other environmental diseases.

Unavailability of safe drinking water.

USA intrastate, regional and interstate political conflict over water.

Water scarcity driven insurrections and interstate war.

Volz, C. D. A framework to understand the centrality of protection and restoration of ecosystem services to water management and preparedness: An all-hazards approach with implications for NATO plans and operations ., Strengthening national public health preparedness and response for chemical, biological, and radiological agent threats: Springer-NATO Advanced Science Institute Series, IOS Press – Nieuwe 6B, 1013 BG

Focus Group Results – Semi-subsistence and Recreational Fishers; A Community-Participatory Based Approach to Rich Narrative on Pollution Sources in the Three Rivers Area

•These fishers reported having to remove toilet paper from their lines and rod eyes during these events and that there were some cases among them of **development of gastrointestinal diseases that they associate with contact with contaminated water**.

•**All 9 participants rated raw sewerage overflows in wet weather as the most important threat to water quality, fishing and to their health. All members said that these releases are not subtle, that as soon as it begins to rain even a small amount in some locations that the river conditions change very quickly, fish disappear, and large sewerage belches occur.**

•**Focus group members described in detail the contents of these overflows. During wet weather events the fishers stated that they saw large expulsions of raw sewage containing toilet paper, feminine hygiene products and condoms.**

•Almost half the group also reported frequently seeing **needles and syringes** coming from sewer overflows. Also half the group reported seeing medicine, household cleaner and other chemical bottles being released into the river.

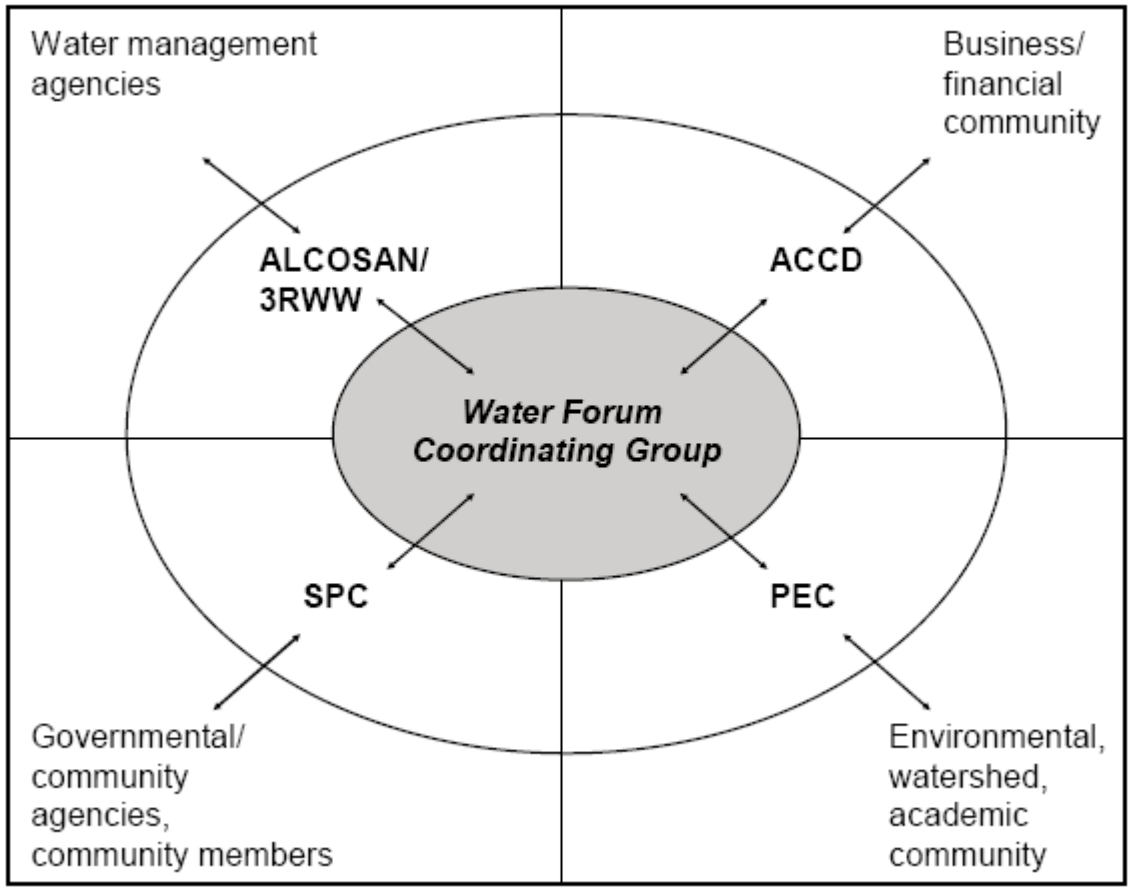
•These participants were outwardly disgusted as they detailed the contents of what they see going into the river during wet weather overflows. The group reported that these releases don't just occur in wet weather but also in **dry weather because the sewer gates get jammed open by debris**, which is often not cleaned out for extended periods of time.

Volz, CD and Christen, C., (2007), Why are river Recreationalists most at risk for development of waterborne infectious diseases; how can clinicians improve surveillance? Journal of Occupational and Environmental Medicine. 49(1):104-105, January 2007.

Regional Policy Perspectives on "How to Break the Chain of Causation of Water Related Problems?"

- **Treat Water as a Regional Asset with a Regional Approach.**
- **Holistic Watershed Social-Ecological-Economic Systems Thinking: Protecting and Rehabilitating Ecosystem Resources and Planning for Sustainable Development.**
- **Grow and Coordinate Our Social Capital—Nongovernmental Organizations, Watershed Groups.**
- **Use Integrated Water/Wastewater Planning.**
- **Educate Public Officials and Citizens on the Direct Relationship between Water Management and Public Health Issues**
- **Use Local University and Professional Strengths**
- **Encourage Stewardship of Both Public and Private Property**
- **Educational Programs Aimed at Lowest Possible Grade Levels Through Continuing Adult Education**
- **Enlist Anglers and Other Recreational Groups**

Concept diagram for a Three Rivers Regional Water Forum. Coordination of the forum would be provided by a group that represents major nongovernmental organizations, local, state, and federal government stakeholders; and regional academic experts, among others.



NOTE: 3RWW is the 3 Rivers Wet Weather Demonstration Program; PEC is the Pennsylvania Environmental Council

Regional Cooperation for Water Quality Improvement in Southwestern Pennsylvania; National Academies of Science, http://www.nap.edu/catalog/11196.html

Sewage Treatment Plant Processing

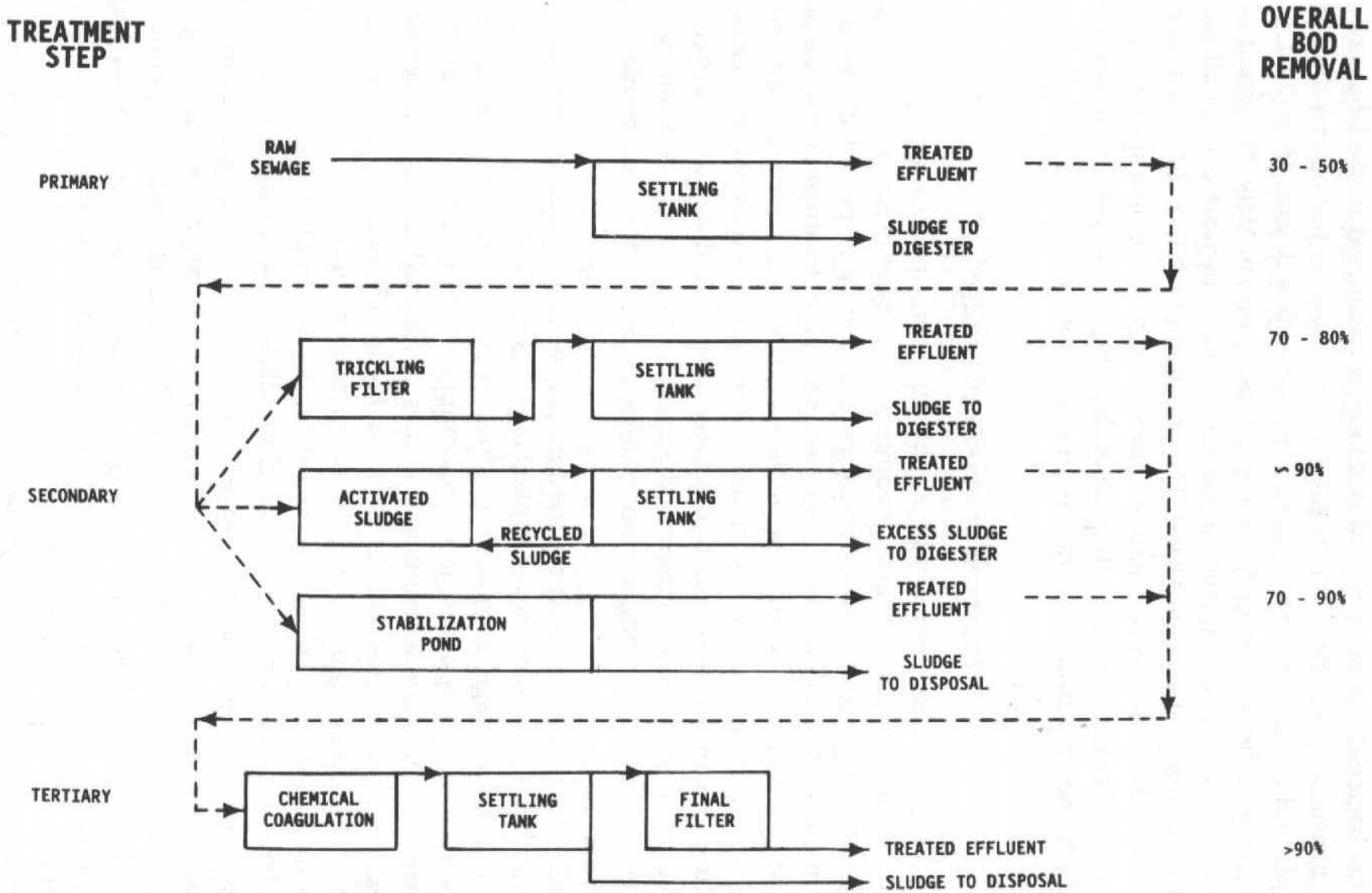


Figure 8.5 Primary, secondary, and tertiary stages in treatment of municipal sewage

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Release of municipal and household sanitary wastes directly into area water

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- Wildcat sewers and failing on-lot septic systems
- Fragmentation of water and sewer planning and management

Abandoned and active mines

Issues related to nonsustainable development

- Lack of coordinated water and land management plans
- Development in headwaters and critical watersheds
- Sprawl

Past and ongoing industrial pollution

- Contamination from the iron and steel industry
- Superfund, waste dump, and brownfield sites
- Deposition of contaminants from power plants and other industrial sources

Nonpoint-source pollution

- Household hazardous waste
- Application of lawn pesticides and nutrients
- Road topping compounds
- Vehicle exhaust

Past and present agricultural chemical use

Personal and societal attitudes toward water usage

Fragmented local, state, and federal regulatory climate

Spills or accidental releases of toxic and hazardous substances

Gravel and sand mining in main stem rivers

Category 2: Water Contamination Problems

Pathogens

Nitrates

Heavy metals: mercury, lead, copper, chromium, and cadmium

Arsenic: naturally occurring or from poultry or industrial operations

Volatile organic compounds (VOCs)

Contaminants associated with mine drainage

Pesticides and herbicides

Polychlorinated biphenyls (PCBs) and other organohalogen substances (OHSs)

Endocrine-disrupting compounds (EDCs)

Radon

Highly acidic or alkaline water

Category 3: Loss of Ecological Services

Wetland loss

Deforestation

Loss of topsoil and plant cover

Loss of native plant species

Loss of subsoil integrity

Loss of natural drainage patterns

Changes in stream and river flow characteristics

Decrease in groundwater recharge

Land and streambed erosion

Endocrine disruption in aquatic species and feeders

Uptake of contaminants in nature's food web

Riparian habitat loss

Category 4: Secondary Water Management Outcomes

Human pathogens in surface water

Human pathogens in groundwater

Increased potential for mine blowouts

Increased sediments in surface water

Decreased production of clean surface water and groundwater

Increased stormwater/snowmelt runoff

Increased contaminant loads in surface water and groundwater

Consumption of contaminated fish

Flooding

Human exposure to carcinogens, toxic substances, and endocrine-active substances

Category 5: Tertiary Environmental Public Health, Medical, Social, Emotional, and Economic Outcomes

Loss of life and property due to flood damage

Increased environmental asthma

Increased stormwater management costs

Increased cost of water purification

Decreased recreational and aesthetic value

Decreased economic growth

Loss of aquatic and terrestrial species

Increased cost of flood insurance

Increased risk of cancer, waterborne pathogen diseases, and other environmental diseases

Unavailability of safe drinking water

Further Readings and Lecture References;

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