Article 10

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Dry Weather Flow in Urban Streams

Not only does impervious cover lead to greater flooding during storms, but it is also believed to cause water levels in urban streams to decline during dry periods. An increase in impervious cover prevents rainwater from infiltrating into the soil. Consequently, the water table beneath is not resupplied, the water having been flushed away downstream rather than infiltrating through pervious surfaces to the water table.

If impervious cover significantly diminishes groundwater recharge, then not only do we have to deal with flooding and eroding of urban streams, but also the possibility that these same streams could experience severe decreases in water level in dry weather, with serious implications for habitat quality, especially for migrant species. Permanent streams may become intermittent and intermittent streams may disappear altogether.

While flood damage can be mitigated by stormwater detention practices, the problem of reduced dry-weather flows can only be approached from a whole-watershed perspective.

Imperviousness/Low-Flow Relationship: Difficult to Detect

The widely held belief that imperviousness decreases dry weather flows is based on principles of groundwater hydrology. However, a cause-and-effect relationship has yet to be directly observed. According to hydrological and geological principles, stream water levels depend on the level of the water table beneath the stream, and a rise or drop in the water table depends mainly on the amount of precipitation received from the surface. Therefore, groundwater recharge and stream water level are expected to decrease correspondingly with a reduction of pervious area above ground.

Attempts to detect the effect of imperviousness on low flow are constrained by the following:

1. The need for long-term, reliable hydrological records of an area that underwent steady development. USGS gauging stations are more apt to be found on large river systems where the effects of imperviousness on low flow is less obvious. Data for smaller streams are more recent and often collected less regularly.
2. The lack of a proven method for factoring out "scale effects" is needed in large, unevenly developed urban areas where many human and natural factors are at work.
3. The added confusion of storm drains and sanitary sewers, which intercept subsurface drainage and divert storm runoff that would otherwise infiltrate the soil.

This article describes two different studies that employed a similar approach of using historical data from gaging stations and comparing urbanized and rural streams.

Long Island: Urbanization Linked to Lowered Base Flows

The population of Nassau and Suffolk counties in Long Island has more than doubled since the 1940s Simmons and Reynolds, 1982). Development has occurred as an eastward wave across the island. The paving of land was accompanied by construction of recharge basins where possible; storm sewers were built in southern Nassau and Suffolk counties. Sanitary sewer lines were constructed over time as the population and housing density increased. Treated effluent is discharged into the ocean; therefore, there is a net loss of water from the system. In Long Island, the supply of water to streams is 95% from groundwater in rural areas, 84% from groundwater in semi-urban areas (impervious cover, no sewers), and only 20% from groundwater in urbanized areas (impervious cover plus stormwater and sanitary sewers).

If the remaining 80% of the water supply to an urbanized stream is from precipitation alone, then base flow would be severely decreased in dry periods. However, there is the possibility that some water is being returned to suburban streams from lawn watering.

Reduction of base flow in highly urbanized areas compared with less urban areas was clearly shown in Long Island (Figure 1). Though there were some years of drought, variation in rainfall could not account for the general downward trend in base flow. Urbanization clearly has an effect on lowered base flow. However, impervious cover is not the only component of urbanization. Residential wells are drawing a great deal of water that is not being returned to the system. This

would also be the case even in localities where effluent is not discharged into the sea. "Used" water is generally not returned to the same area where fresh water is drawn. Thus, a community may reduce the water supply that contributes to the supply (usable or not) of lower elevations in the watershed. Whether or not there is a net loss in a watershed depends on the scale.

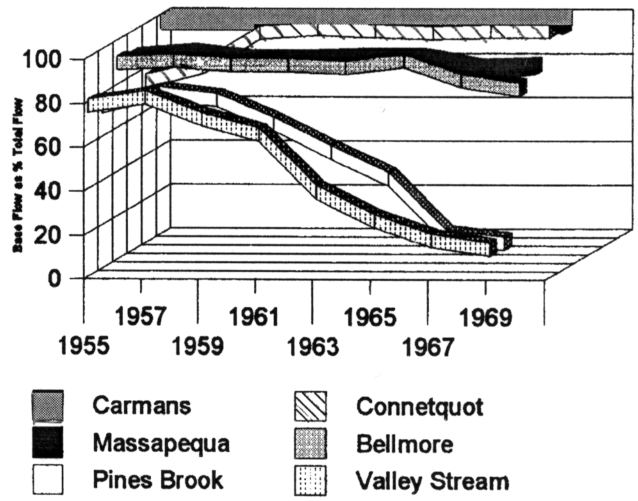
North Carolina: Mixed Results

Evett *et al.* (1994) analyzed base flow and precipitation trends at U.S. Geological Service stations in North Carolina. Stations were chosen to reflect typical urban settings without overly large water diversions (such as power dams). Stations were classified either as "urban" or "rural" on an individual and subjective basis, rather than using a rigid measure such as population.

In the case of four urban centers and surrounding "rural" areas, both urbanized and non-urbanized streams showed decreased base flows in recent years (Evett, 1994). While this would seem not to support the low flow/urbanization relation, the study also showed that trends in precipitation alone cannot account for the decreased flow in urban and rural streams. Regional land use effects could be exerting some negative effect on the "rural" streams as well.

Evett offers some explanations for the mixed results from this study:

- The urbanization effect on base flow exists but may be too small for the statistics to detect.
- Some substrate types are less vulnerable to reduced groundwater recharge than others (Table 1). Raleigh and Charlotte hydrological regions are rated as intermediate in ability to sustain low flow, whereas Greensboro is low in ability to sustain low flow. (However, the Asheville region would not be rated as particularly sensitive to a reduction in recharge and yet both urban and rural stations there showed decreased base flows.)



Notes:

Carmans and Connetquot: Rural/suburban, watersheds are unsewered

Bellmore and Massapequa: Moderately urbanized, not sewered until 1989

Valley Stream and Pine Brook: Urbanized and densely populated watersheds, sewer systems completed in 1960s

1953-1964: Period of sanitary sewer construction in eastern Nassau County

1962-1966: Drought years

Figure 1: Base Flow Trends in Long Island (Spinello and Simmons, 1992)

- The streams studied were large and of mixed land use; factors outside the station area may exert an effect at the measuring point.

What Do the Two Studies Contribute to Further Understanding of Urban Base Flows?

Many Elements of Urbanization

There is another possible explanation for the mixed results from the North Carolina study. The ambiguous results may have arisen from the uncertain character of the sampling sites. The sorting of stations into two

Table 1: Analysis of Base Flow Trend in North Carolina USGS Stations

Region	No. streams analyzed (urban, rural)	Urban streams with decreased base flow	Rural streams with decreased base flow	Urban-low flow relation shown?	Rainfall effect?	Regional substrate infiltration
Asheville	1, 1	1	1	No	No	High
Greensboro	3, 3	2 of 3	1 of 3	Yes	No	Low
Raleigh	1, 4	0	2 of 4	?	No	Moderate
Charlotte	5, 3	1 of 5	1 of 3	?	No	Moderate

categories, either “urban” or “rural,” is a somewhat limited and subjective classification of watersheds. The researchers were more or less forced to use this coarse distinction without going into an exhaustive land use analysis for each watershed. Urban and rural are not absolutes in the North American landscape; there are many gradations between city and country and some rural environments contain highly urban elements and vice versa. If a more *continuous* and *quantifiable* measure of urbanization—such as percent impervious cover—could be used, then we would be more certain that the success or failure of detecting a trend reflects the real physical processes taking place and not the ambiguity of the study sites.

With the help of the powerful new methods being developed in multivariate statistics and GIS, researchers may be able to organize the mass of available data in order to classify small watersheds more precisely. Some of the variables involved include the following:

- Substrate type of the locality and surrounding area, infiltration rates
- Percent impervious cover
- Number of wells and drainfields
- Linear footage of storm and sanitary sewers
- Household water usage
- Recharge from lawn and crop field irrigation
- Water movement beneath the surface

GIS can organize huge amounts of available data from diverse fields of research. Multivariate statistics are capable of teasing out the significant relationships from a tangle of interacting variables. Future research in this direction will hopefully discover which are the elements of urbanization that have a significant effect on groundwater recharge and base flows in small streams.

An alternative to massive data crunching is to turn down the scale and focus on very small watersheds, such that the degree of urbanization is obvious and describable. As Evett notes, reliable long-term records will be hard to find. New sampling stations can be set up but it will take some years before enough data is generated to give reliable results.

What Do We Do in the Meantime?

Theory tells us that increased impervious cover will result in reduced base flows in streams. Direct evidence of this has been difficult to obtain. What can we assume while we wait for sophisticated statistics to tackle the large watersheds or new data to be collected from smaller watersheds? Looking at the present research, one can either assume that urbanization is not the cause of lowered base flows or one can assume - more conservatively- that until any studies report otherwise, urbanization is lowering base flows in our streams.

Where the effect was clearly shown it was also found to manifest itself rather late in the urbanization process (Spinello and Simmons, 1992). Streams will experience the more immediate effects of urbanization, such as higher flood peaks, before dry-weather flows will be reduced, simply because it takes some time for the water table to be lowered. Far from being encouraging, this tells us that by the time we notice lowered base flow it is already too late to do anything about it - the water table in that locality has been diminished. On the bright side, increased storm flows in developing areas can be a good early warning that reductions in dry-weather flow will follow. Urban planners who observe this warning have time to put a plan into action to keep streams ecologically functional year-round.

—JMC

References

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Research: Ways to Improve Detection of Imperviousness Effect on Base Flow

- Better characterization of sampling sites: use impervious cover as a measure of urbanization. Percent impervious cover for an area is mapped from aerial photos or existing GIS data, effective impervious cover can then be derived using appropriate equations.
- Handling scale effects: apply more sensitive statistics to large watersheds or else collect data from smaller, more easily characterized sites.

Management: Ways to Preserve Base Flow in Developing Areas

- Reduce excessive parking and road surface; consider alternative designs.
- Build stormwater infiltration basins where possible.
- Given the choice of which sites will remain vegetated and which will be paved, choose the areas of highest infiltration to remain vegetated. This involves a geologist’s survey.
- Road culverts and in-stream habitat structures should be carefully placed below base flow level to prevent flow interruptions in dry weather.