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Water and Land Planning: A Case for Better Coordination

By Vivek Shandas, PhD

Question: How much water does it take to quench the thirst of people living in the Portland metropolitan region for one day? Almost 408 Olympic size swimming pools. How much additional water will be needed to accommodate the population of 2030? Based on expected growth projections, an additional 90 pools. We will need to refill 500 Olympic size swimming pools each day to meet the water needs of one urban area in our State.

Over the next 30 years, the population of Oregon is expected to grow by 1.6 million residents, of which half is expected to locate in the three counties comprising the Portland metropolitan region[1] . At current rates of population growth and water use, by 2040 the region will consume the amount of water equivalent to Crater Lake[2]. Combine with this demand, climate projections which suggest a substantial decrease in available water during summer months when water use is highest[3]. Since Oregon's industries and households depend on the Cascade Mountains for water supply, these challenges pose serious threats to economic development plans and for sustaining current population growth trends. The convergence of higher demand and limited supply make for a perfect storm in water resource management, and we will need timely, effective, and coordinated actions for ensuring adequate water for all.

Despite these concerns, we currently have a limited understanding about the role of land use planning in water resource management. While readers of the Oregon Planners Journal are no strangers to the challenges of water planning, the role of land use planning decisions in water use remains unclear. Specifically, how can planning decisions affect the amount of water consumed in a region? What are the linkages between land use patterns and water consumption? Can land use policies play a part in shaping the water available for a growing state? At Portland State University (PSU), a group of researchers have been working in collaboration with the Portland Water Bureau to address these questions, revealing a complex interaction between land use patterns, temperature change, and water consumption. The results begin to describe mechanisms for improving water conservation through land use planning practices, and opportunities for increasing the coordination between land and water planning. This report summarizes the findings of recent research and aims to expand our understanding of planning as a tool for urban water conservation.

A Tenuous Relationship

One of the most common connections between water-resource management and urban planning occurs when municipalities require developers to provide evidence that adequate water exists when proposing a land use change. Notable examples of such restrictions include those in the cities of the Colorado front range, some of which aim to limit homeowner water use to specific times of the day. Based on an emerging concern, an explicit discussion about the connections between land use and water management took the form of a February 2003 conference entitled, *Wet Growth: Should Water Law Control Land Use?* Cosponsored by the Environmental Law Institute, the American Planning Association, and other organizations, the conference highlighted the immediate and serious threat of water scarcity in the western United States[4]. Despite the laudable aims of municipalities, conferences, and reports calling for identifying the explicit links between water-resource management and urban planning, few empirical studies describe opportunities for better coordination. The breadth of research on water pricing and conservation has largely excluded assessments of the impact of water demand as a function of land use patterns. Studies about water use generally provide accounts across different sectors, such as agriculture, energy, and urban development, and are helpful for assessing regional trends; however, the consideration of land-use planning as a tool for mediating water demand has received much less attention. As a result, water management agencies may not look to planning bureaus for improving conservation, while planners may be unfamiliar with water-efficient urban designs.

A Metropolitan 'Waterscape'

The Portland Metropolitan region (here forth called the Region), contains varied land use, growing populations, and dependence on the mountain snow pack, making it ideal for examining the opportunities for examining the role of land use patterns on water use. The Region's water supply comes from reservoirs in the Bull Run Watershed, which, east of downtown and covering 102 square miles, receives snowmelt from the Cascade mountain range. The water from the Bull Run watershed first flowed into Portland water taps on January 2, 1895, and consisted of water from Bull Run Lake and Bull Run River, with in-town storage reservoirs at Washington Park and Mt. Tabor Park. The Portland Water Bureau is responsible for the administrative and technical aspects of providing water resources to approximately 802,000 Oregonians, making it the largest provider in the state. In 2006-2007, the Bureau directly served over 146,000 residential households (both single and multi-family residences) and approximately 20,000 commercial and industrial customers. By many measures, the 'waterscape' of the region will likely look dramatically different in the coming decades.

While the Region's planning policies are unique in some respects (e.g. urban growth boundary, extensive 'green infrastructure', etc.), its planning policies are also similar to many other urban areas in that they do not require new developments to ensure an adequate water supply into the future nor are water efficient urban designs considered during the citing and development process. However, Goal 2, one of the 12 comprehensive goals in Portland's land-use plan (July 2006), which includes the Public Facilities Plan, identifies "water" as an infrastructure sub-system[5]. Although the plan identifies mechanisms for mitigating stormwater and watershed impacts, the current plan does not require developers of new structures or those making changes to existing structures to provide evidence of the long-term availability of water resources. To date, the primarily mechanism for coordinating water management efforts of the 22 water providers occurs through the Regional Water Providers Consortium, the organizing that implements and revises the Regional Water Supply Plan.

Assessing the Role of Land Use Patterns on Water Use

By combing information from tax assessor's files with water use billing records, we can begin to understanding the geography of water use within the Region (Figure 1). In addition, each tax lot can be separated according to different land uses, amount of built land, and structural attributes of the development. Using Geographic Information Systems (GIS) and statistical analysis, we can also assess how neighborhood conditions, such as age of development, income, and other demographic factors affect the spatial clustering of water use. For some households we also have daily water use, which when linked to regional temperatures, allow for an assessment of temperature-induced

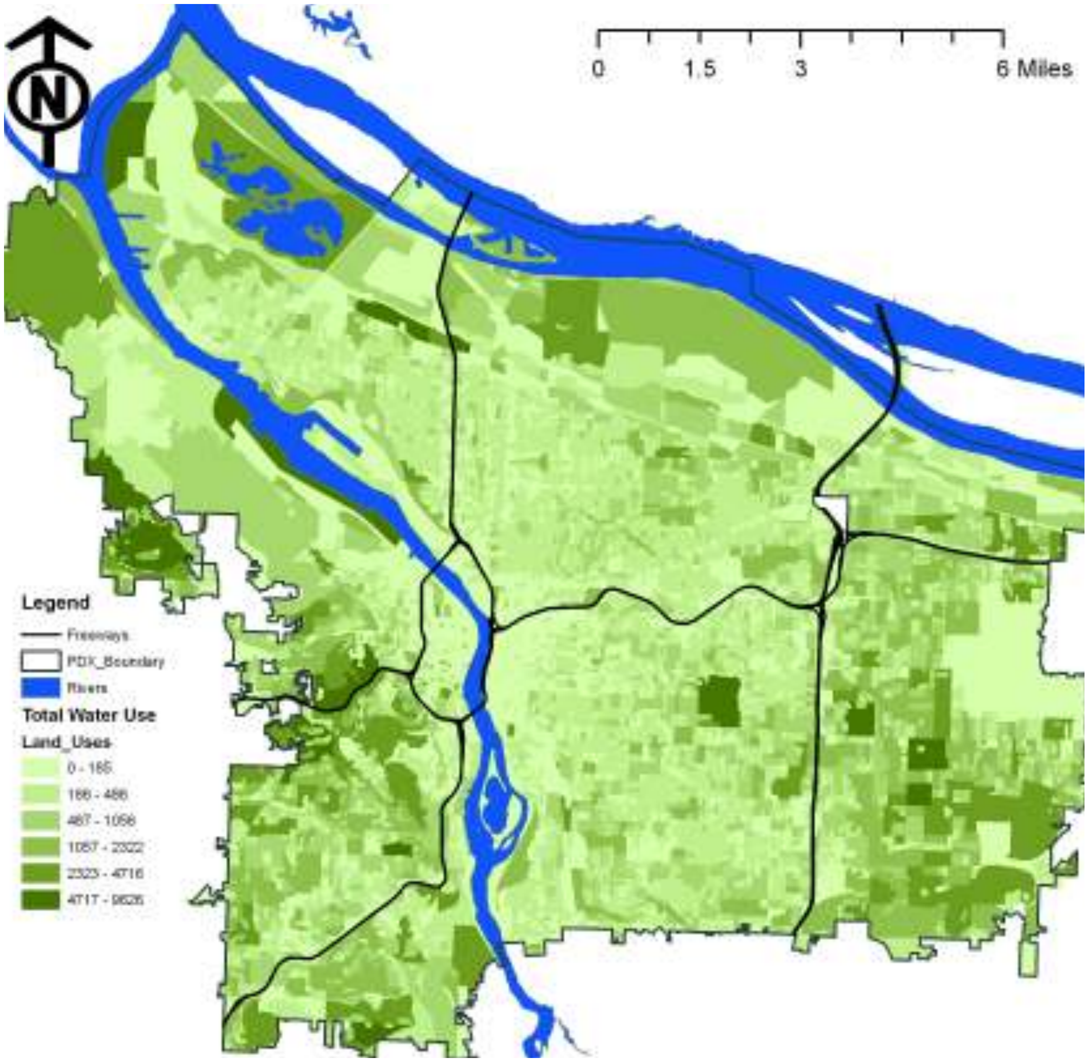

Figure 1: Total daily water use (gallons) among of all land uses in Portland Oregon (Census Block geography).

water consumption.

The total annual water consumption in the Region is approximately 6.4 billion gallons (25 billion liters), which reflects water use among four land uses -- Single Family Residential (SFR), Multi-Family Residential (MFR), Commercial, and Industrial. The amounts vary considerably across land uses. In 2005, the total consumption of SFR was 23 million gallons, MFR was 8 million gallons, and Commercial and Industrial was 22 million gallons. More specifically, by looking at the relationship between the developed area for each land use and the amount of water consumed per year, we can identify specific water demands for each land use[6]. In the case of MFR, one acre in the Region will require an additional 1.3 million gallons of water per year. SFR developments use similar amounts, with an annual water requirement of 1.24 million gallons for every acre. Since MFR developments includes more than one household, a per-unit analysis, identifies SFR developments as the largest water consumers in the Region. Commercial and industrial land use require about half the amount of water as MFR and SFR use per unit area, suggesting that every acre increase in commercial or industrial land results in an additional 528 thousand gallons of water per year.

Since SFR is the largest consumer of water in the Region, a closer examination of the household and neighborhood characteristics can improve our understanding of the impact SFR development patterns on water use (Figure 2). SFR development patterns in relation to water use can be assessed in two ways: (1) the total area of SFR, which consists of the square footage of each development; and (2) the density of SFR, which can be characterized by the number of developments per acre. In terms of total areas each 100 square feet (9.3 square meters) of SFR development, is associated with an annual increase of water consumption by 978 thousand gallons – approximately one and a half Olympic size swimming pools. An ongoing discussion in planning is whether higher densities of development affect conservation behavior. In terms of water use behavior, the answer is an unequivocal yes! Our analysis suggests that an increase in one household per acre is associated with an annual decrease of water use by 411 thousand gallons when controlling for demographic factors. We also observed that areas with more than 5 households per acre provided for highly predictable water use trends, while those with neighborhoods with lower densities had greater variability.

Water use is also affected by regional temperature, which couples with development patterns to have varying impacts on household water use. By looking at 500 representative households in the Region, each of which had a water meter for assessing daily water use, we could evaluate change in human behavior as a result of daily temperature variability. Our general findings suggest that water use during winter months varies only slightly, but when temperatures reach above 700F, we observed an increase of water use by 4.5 gallons per household per day. For a neighborhood with 100 houses, an 800 F day would result in an increase of 4,500 gallons of water per day. In addition, if that 800 F day occurred on a weekend, we observed an additional 28 gallons per household per day, creating a total increase in water use of 7,300 gallons per day. Conventional wisdom would suggest that warm weekends provide opportunities for households to recreate, and we are now conducting household surveys to gage what specific behaviors may be responsible for these increases in demand.

While an understanding that higher temperature on weekends creates increases in water use may not be surprising, we've also found that the development pattern of households couple with temperatures to affect a household's water use behavior[7]. By combining the building area of a household with daily water use and temperature profiles, we found that larger houses use more water on warmer days than smaller houses. Specifically, based on the average house size (~ 2000 square feet), each additional 1000 square feet of SFR house creates an additional water demand of 82 gallons, which is compounded when combined with temperature. Consider, for example, an 800F day in a development containing 100 new houses each of which are 4000 square feet. These houses are about 2000 square feet larger than the average house in the Region, and 10 degrees

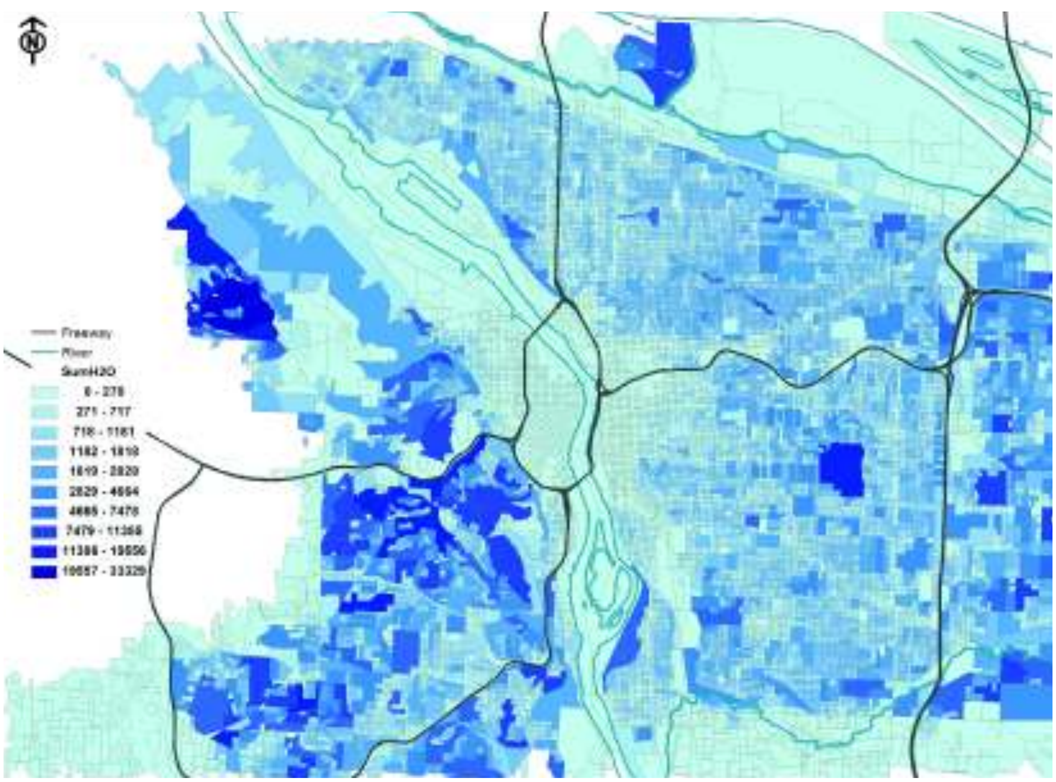

Figure 2: Total daily water use (gallons) among SFR households in Portland Oregon (Census Block geography).

above the 700F degree threshold. The combined impact of this new development is approximately 20,900 gallons per day, which is approximately the amount of water stored in a typical household swimming pool. If this development had contained smaller homes, and higher densities, the total water use will likely be lower. Although these relationships may not necessarily be linear (as portrayed here), we are continuing to examine these relationships across multiple temperature and development scenarios.

Towards a Water-Sensitive Physical Form

These studies suggest that an effective design-based strategy for reducing development-induced water consumption among SFR developments entails decreasing the size of residential developments and increasing residential density. The benefits of smaller development size and greater lot density are twofold[8]. First, a decrease in building size reduces the amount of area that directly contributes to water consumption. While we are unable to describe the role of other household structures on water use (e.g., bathroom, kitchen, or laundry room), we were able to identify the extent to which changes in the size of an SFR development contributes to water demand. For example, a 25% reduction in the average building size – a reduction from 2,800 ft2 to 2,100 ft2 in the study region – is associated with an annual saving of 6.6 million gallons of water. For a new residential development of 100 SFR units, such a reduction would reduce annual water consumption by almost 651 million gallons per year (or the volume to file almost 1000 Olympic size swimming pools).

Second, higher density neighborhoods result in decreased water consumption[9]. Without any change in the size of buildings, an increase in the residential density by one household per acre would reduce the amount of water consumed by 410 thousand per year. Therefore, for a new subdivision of 100 homes, a 25% increase in the number of households per acre – a reduction from 4 to 5 households per acre – would reduce cumulative water consumption by almost 41 million gallons. In addition, this modest increase in density would increase the land available for other uses. In addition, the uncertainties associated to climate change and variability can have profound and far-reaching impacts on social, economic, and ecological conditions of the Region. As a result, strategies that focus on smaller housing sizes, and increased density will also improve the Region's capacity for adapting to climate change and variability. These opportunities for water conservation in urban parts of the State are significant given the fact that water conservation measures in rapidly growing areas are inextricably linked to concern of reduced stream flows and other ecosystem impacts.

While these suggestions focus on urban designs as a tool for water conservation, the discussions of consumer preference for higher density and smaller homes will be an ongoing. In fact, we know that water conservation strategies such as pricing and technological improvements can reduce water consumption per capita, but less clear is the interaction between land use patterns and behavioral response to water use. With population growth and climate change affecting urban development patterns in profound and uncertain ways, approaching water use through the lens of urban planning can improve the effectiveness of water-conservation activities in a metropolitan region. Because the physical attributes of development can be readily manipulated through urban planning policies during the development or redevelopment process, land use planning can play a direct role in water-resource management. In addition, because planning agencies have discretionary authority on the types, location, and intensity of land use, they are positioned to have considerable impact on water consumption by varying land use patterns. Our research attempts to offers specific mechanisms through which planning and water-resource managers can work together to improve conservation efforts. In the coming years, we anticipate to have further evidence about the interaction of urban form, climate variability, and human behavior.

Notes

1. Oregon Office of Economic Analysis, http://www.oregon.gov/DAS/OEA/demographic.

shtml.

2. Assumes water consumption of 117 gallons per capita per day, and an increase of 800 thousand residents by 2040.

3. Palmer, R.N., and M.A. Hahn (2002). The Impacts of Climate Change on Portland's Water Supply: An Investigation of Potential Hydrologic and Management Impacts on the Bull Run System. Report prepared for the Portland Water Bureau, University of Washington, Seattle.

4. McKinny, M (2003). Linking Growth and Land Use to Water Supply. Land Lines, 15(2). Accessed at http://www.lincolninst.edu/pubs/PubDetail.aspx?pubid=794

5. City of Portland (2004), Comprehensive Plan Goals and Policies: http://www.portlandonline.com/shared/cfm/image.cfm?id=58799.

6. Shandas, V, and G.H. Parandvash (2010). Integrating Urban Form and Demographics in Water Demand Management: An Empirical Case Study of Portland Oregon (US). Environment and Planning B: Planning and Design

7. Shandas, V, M Rao, and MM McGrath (forthcoming). The implications of climate change on residential water use: A micro-scale analysis of Portland (OR). Journal of Climate and Water.

8. Chang, H, GH Parandvash, and V Shandas (2010). Spatial Variations of Single Family Residential Water Use in Portland, Oregon. Urban Geography.