Section 4 Management of Freshwater Wetlands in the Central Puget Sound Basin

CHAPTER 13 MANAGING WETLAND HYDROPERIOD: ISSUES AND CONCERNS

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INTRODUCTION

Land use changes and stormwater management practices usually alter hydrology within a watershed. A major finding of our study was that hydrologic changes were having more immediate and greater effects on the composition of vegetation and amphibian communities than other environmental conditions we monitored. Early study results showed wetland hydroperiod, which refers to the depth, duration, frequency and pattern of wetland inundation to be a key factor in determining biological responses.

Continuous recording gages were unavailable for the study, but we were able to monitor hydroperiod in the wetlands with instantaneous staff and crest stage gages. From these measurements a metric was developed called water level fluctuation (WLF) which showed statistically significant relationships with several measures of biological health (Azous 1991a). WLF is measured as the average difference between the maximum depth and average instantaneous or base depth in a time period (Taylor 1993, Taylor, Ludwa and Horner 1995).

Consistently we observed reduced numbers of plant and amphibian species when WLF was high in wetland areas (Azous 1991b, Cooke and Azous 1993, Richter and Azous 1995). As a result, substantial attention was given to understanding WLF and developing management guidelines for protecting wetland plants and animals.

A local jurisdiction, King County Surface Water Management (KCSWM) expressed an interest in developing wetland management guidelines that could be used in continuous flow event simulation computer models. In addition, only a few of the wetlands in the original 19 study wetlands showed extreme water level changes and we wanted to measure more plant and amphibian communities with high WLF conditions. We undertook a cooperative study to monitor the hydroperiods of six wetlands with continuous recording gages, and measure the plant and amphibian communities, in order to better understand the relationship between biological diversity, WLF, and the pattern of water depth, duration and frequency of inundation in wetlands.

This paper will discuss the methods and results of this study. The information has significant implications for evaluating the level of protection afforded wetlands from changing hydroperiod.

METHODS

Continuous recording gages were installed in six wetlands in late 1994 and early 1995. The gages were programmed to record water surface elevations at 15-minute increments. Two of the wetlands we monitored were in relatively undisturbed watersheds and were already experimental controls in our ongoing study. The remaining four were recommended by KCSWM field staff as wetlands known to experience large changes in water depth throughout the year.

Water levels in all six wetlands were monitored over one year, however due to unexpected seasonable differences in rainfall and some losses of data due to malfunctioning equipment, there was only a partial water year for all the wetlands. The hydroperiod data was used to calculate WLF and to calibrate the computer model Hydrologic Simulation Program- FORTRAN (HSPF), a continuous event model with the ability to simulate hydrologic processes in a watershed. The model is used to predict rainfall runoff from different watershed conditions and is more accurate when field measurements are used to adjust runoff from simulated rainfall events with the outflows and stages resulting from actual events.

Of the six wetlands, two control wetlands were not calibrated nor modeled. The complexity of the wetlands' hydraulics were beyond the scope of this project. The remaining four wetlands all had well defined outlets, hydraulics and bethymetry which allowed reasonably accurate stage-storage-discharge relationships to be developed. Based on the margin of errors in the spatial distribution of precipitation represented by nearby gages and the length of the field record, the accuracy of the model's simulated wetland water levels to recorded water levels was limited to plus or minus 0.5 ft. (15 cm).

Emergent (PEM), scrub-shrub (PSS) and forested (PFO) wetland zones were surveyed and evaluated for plant species richness and the presence and dominance of exotic invasive species using the protocols for vegetation field work documented in Cooke et al. (Cooke et al. 1989). Disturbed commodities were those sample stations found to be dominated (>60%) by a weedy species. Amphibians were sampled during the fall and spring breeding seasons using methods described in Richter and Azous (1995).

The condition of plant and amphibian communities were compared with the observed and predicted water depths, the duration of storm events and the frequency of storm events for the whole season and the early growing season (March 1 through May 15). . We analyzed the emergent, scrub-shrub and forested zones to determine if there were significant differences in community composition related to hydroperiod regimes .

The six special study wetlands were also added to the larger database of 19 wetlands and all the data analyzed for differences corresponding to WLF conditions. All sample stations that were inundated at least once during the year were included in the analysis of water level fluctuation. The data was analyzed using StatView (Abacus Concepts Inc. 1993) statistical applications program. The plant richness data were not normal; therefore the non-parametric Kruskal-Wallace (KW) and Mann-Whitney (MW) tests were used to compare the distributions among categories, depending on the number of variables in the category being compared. Both tests indicate whether the underlying distributions for different groups are the same. Both use ranked data and are resistant to outliers.

Much of the data was categorized to provide more statistical rigor given the small data set and the 0.5 ft. (15 cm.) margin of error. Categories were based on frequency distributions of the data and a very limited sensitivity analysis of statistically significant breaks in the data.

We measured frequency of storm events in a hydroperiod by defining an event as an excursion which we define as a water level increase above the monthly average depth of more than 0.5 ft. (15 cm.). Duration was defined as the time period of an excursion. In a stepwise regression, we looked at the statistical relationship between WLF, frequency and duration. Table 1 shows the categories used in the analysis.

Table 13-1. Category Definitions for Water Depth and Excursion Duration.

Frequency of Excursions	Water Depth*	Duration of Excursions
less than 6 per year	Greater than 2.0 ft. depth (>60 cm.)	less than 3 days
more than 6 per year	2 ft. to 0 ft. depth (-60 to 0 cm.)	3 to 6 days
	0 to 2.0 feet above water surface. (0 to +60 cm.)	more than 6 days

*Negative numbers are under water.

RESULTS

Plant richness in the sample stations ranged from three to 31 species in the POW zones, three to 22 in the PSS zones and 17 to 25 in the forested areas. Very few invasive weedy species were found and were dominant in only a few localized areas.

Frequency and Duration and Plant Richness

Plant richness was found to be significantly lower if water depths were usually deeper than 2 feet (60 cm.) (KW, $p < 0.0001$). To control for this, frequency and duration were evaluated separately for different water depths. The test for differences in duration and frequency showed that, in general, plant communities in areas subjected to more than six hydrologic excursions per year tended to have lower richness. In both the greater than 2.0 feet range and zero to 2.0 feet range the difference is statistically significant (MW, $p \le 0.004$). It was not significant for the -2.0 to zero range (Figure 13-1).

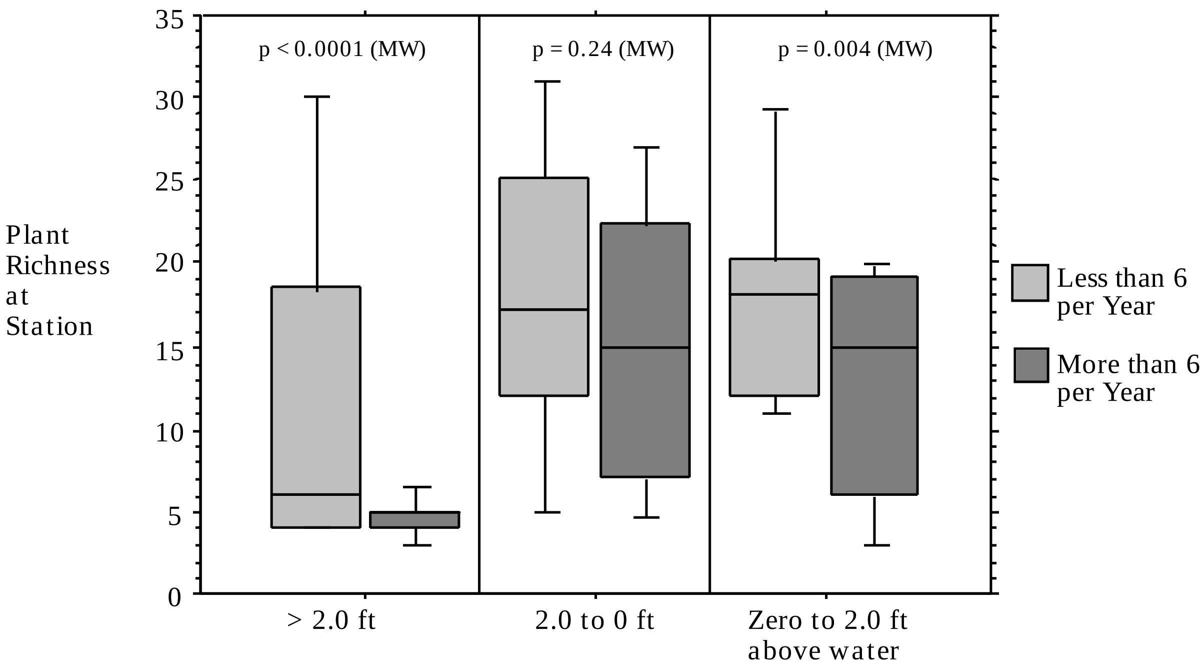

Figure 13-1. Plant richness, water depth and frequency of excursions.

The duration of excursions was compared to plant richness and water depth. Duration alone was a significant factor only in the deepest zones of -8.0 to -2.0 feet (KW, $p < 0.001$) (Figure 13-2). From -2.0 feet to 2.0 feet, increased duration did not significantly contribute to the variability of plant richness.

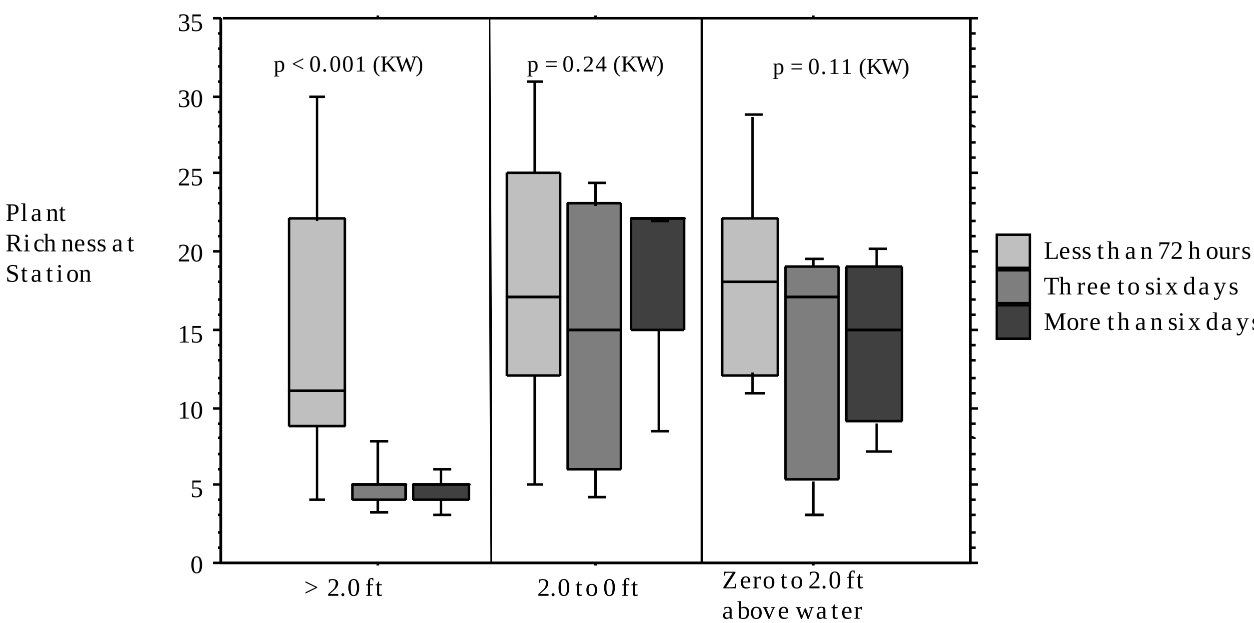

Figure 13-2. Plant richness, water depth and duration of excursions.

When the effects of excursion frequency and duration were combined, the relationship with plant richness was much stronger. Plant richness was found to decrease significantly with excursions longer than six days duration even with frequencies of less than six per year (KW, $p < 0.0001$). For excursion frequencies greater than six per year, richness dropped significantly when duration' exceeded three days per month (KW, $p < 0.0001$) (Figure 13-3)

These results were significant for both emergent and scrub-shrub zones and indicate that the average monthly duration of inundation can be significant to plant species richness, when the frequency of inundation is greater than six times per year on average or when the length of inundation exceeds three days per month. The frequency of excursions did not account for variability in species richness until excursion durations exceeded three days per month. There were an insufficient number of forested zones in the wetlands where frequency and duration were measured to adequately test for differences in the forested conditions and open water.

Water Level Fluctuation and Plant Richness

We looked at the relationship of water level fluctuation to plant richness in different zones of the wetlands. We examined all sample stations inundated at any time of the year and found richness was lower in wetlands with high WLF hydroperiods in the emergent and scrub-shrub zones but not the forested zones. There were not enough aquatic bed zones for adequate evaluation. Emergent zones subject to mean WLFs greater than 0.8 ft. (24 cm.) ranked significantly lower in the number of plant species present (MW, $U \geq 55$, $P \leq 0.003$) than emergent areas with mean WLF less than 0.8 ft. (24 cm.). This relationship was even more significant when richness was compared with water level fluctuation during the early growing season (Figure 13-4). Shrub-scrub zones also showed a significant difference in plant richness related to annual and early growing season water level fluctuation (MW, $U \geq 55$ $p < 0.0001$) (Figure 13-5). Forested zones showed no differences in richness accounted for by WLF.

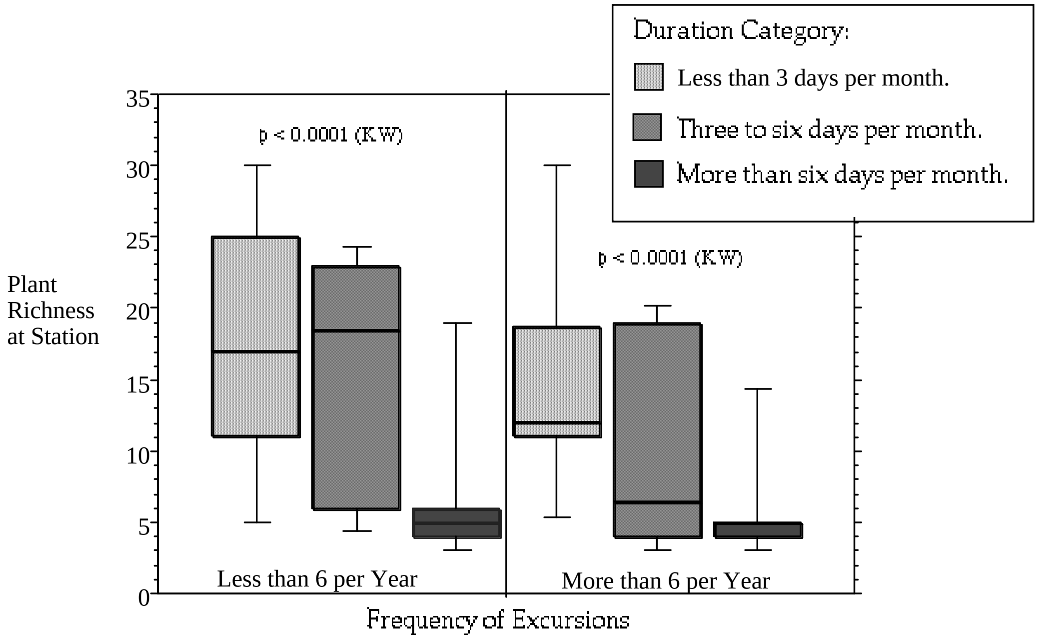

Figure 13-3. Plant richness, frequency and duration of excursions.

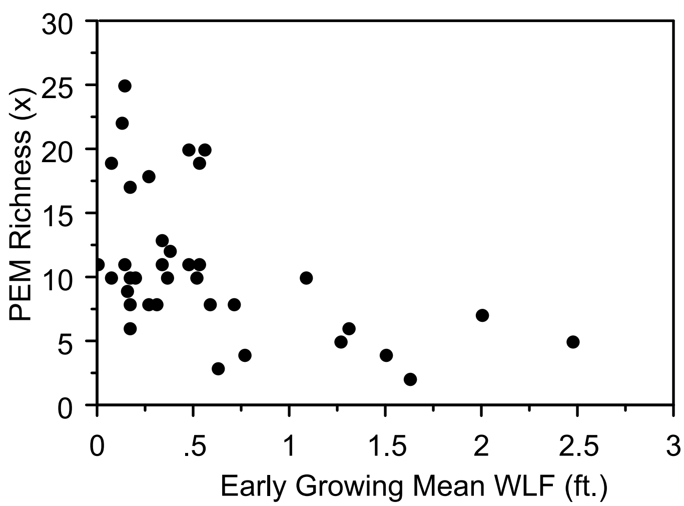

Figure 13-4. Plant rchness in the emergent zones in relation to mean WLF.

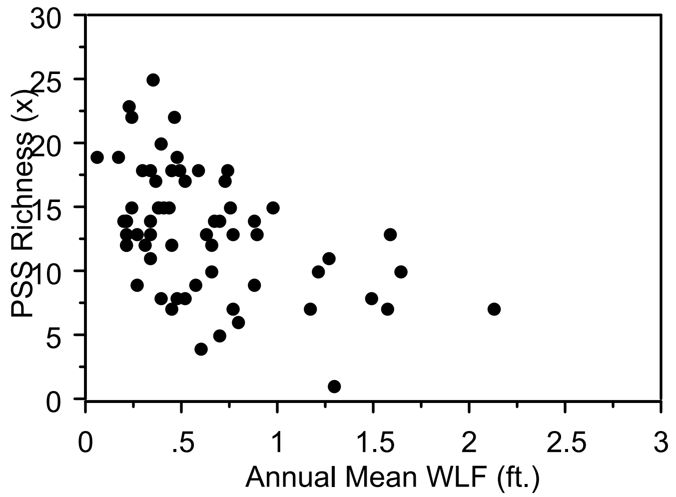

Figure 13-5. Plant richness in the scrub-shrub zones in relation to mean WLF.

Amphibian Results

Our study of amphibians left us with an incomplete picture. All of the wetlands in this study as well as the PSWSRP study had far fewer amphibian species in 1995 than collected in previously years. For example, seven species were collected in a rural wetland, BBC24, in 1989 and only three in 1995. Five species were collected in the urban surrounded wetland, LPS9, in 1989, compared with none in 1995. Eight were captured in SR24 in 1989 and again none were captured in 1995. Figure 13-6 shows amphibian richness for each wetland for both 1989 and 1995 trapping years. The lack of captures prevented analysis of frequency and duration effects for this study's wetlands.

Nevertheless, we were able to measure WLF relationships between amphibian communities over all years and all wetlands using the PSWSMRP wetlands database. The richness of amphibian communities was found to be lower in wetlands with WLF less than 0.8 ft. (24 cm). Wetlands with greater WLF were significantly more likely to have low amphibian richness with three or fewer different species present (*FE*, P = 0.046) as compared with four to eight.

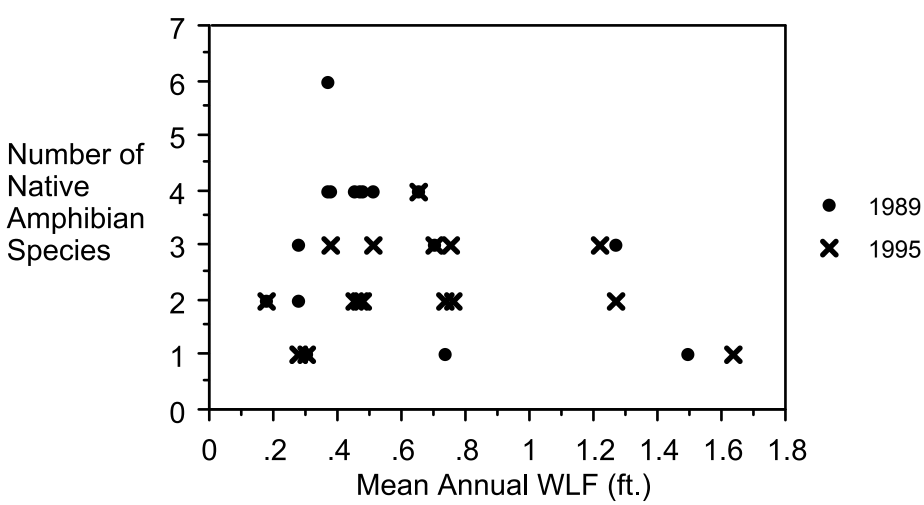

Figure 13-6. Amphibian richness as a function of mean WLF.

The reasons for the amphibian decline in 1995 are not understood. Amphibians sometimes breed in alternate years, hence in one year, populations could be much lower than the next. But we don't know if that phenomenon occurs across a population or just to particular individuals. The fact that low numbers were found in all wetlands suggests that it may be rainfall or climate related and 1995 was a drier spring than usual, but we are speculating.

WLF was found to be statistically related to excursion duration and frequency. Forty-one percent of the variation in WLF can be explained by the duration of events. Adding the effect of excursion frequency can explain as much as 53% of the variability in WLF ($p<0.0001$).

APPLICATION OF RESEARCH RESULTS

These results show that increasing the duration of storm events can be a significant factor in reducing wetland plant diversity. The frequency of storm peaks is also a factor and compounds the duration impact. Decreasing richness in the emergent and scrub-shrub zones and increasing frequency and duration are also associated with high mean water level fluctuation, annually, but particularly during the early spring growing season and amphibian breeding seasons.

Current stormwater protection measures primarily rely on stormwater detention for protecting wetlands. Detention acts to increase the duration of a storm event in order to reduce the peak depth. Water is captured, stored and released after the storm over a longer period of time. It was a management tool designed primarily for controlling floods and erosion in streams, however, it may operate counter to management goals as a tool for wetland protection.

The result of these findings has been to recommend for there to be limits on the durations of storm events as well as the frequency of excursions, when wetlands will be affected by changes in hydroperiod. The recommendations are that the frequency of water levels greater than 15 cm. (.5 ft.) above pre-development levels be limited to an annual average of six or less per year and that the durations of water levels greater than 15 cm. (.5 ft.) above or below pre-development levels be limited to less than three days per excursion.

The data set we analyzed was limited, as were time and funding and some questions remain about the potential for trading flood frequency and flood duration. For example, it might be possible to extend the durations of storm flows in wetlands if the frequency of those events is reduced. Similarly, it may also be possible to reduce durations in trade for allowing greater frequency. These areas of refinement remain largely unexplored.

Irrespective of any further results, it will be difficult for urbanizing jurisdictions to meet such standards in all areas. It is also not likely to happen if detention is the primary management tool. Achieving real resource protection of high value wetlands will require a more comprehensive approach.

Early in the research the PSWSRP learned that wetland management must be holistic, that wetlands are part of a system in a larger landscape and should be managed accordingly. This view has a number of implications for management:

- It is necessary to consider incidental effects on wetlands of activities in their watersheds, along with any engineering performed on the wetland itself for stormwater management purposes;
- Wetland response and management depend on a host of landscape factors, including retention of forest and other natural cover, maintenance of natural storage reservoirs and drainage corridors; the separation of human activities from wetlands; and public awareness.
- Wetland protection means finding root cause solutions e.g. source control practices that prevent or minimize quantities of runoff and release of pollutants, with downstream retention/detention for quantity control and treatment for pollutant capture regarded as secondary back-up measures where source controls alone can not ensure resource protection.
- Potential runoff infiltration opportunities should be explored and those that are found to be workable hydrogeologically and not threaten groundwater quality should be explored.

The experience of King County in its attempts to meet the PSWSRP recom-mendations is noteworthy and affords a view of some alternative approaches to detention.

The PSWSRP guidelines have been used in King County in both the basin and master drainage planning processes. Most of the applications have focused on minimizing water level fluctuation, as it was identified as the most direct effect on wetland functioning, vegetation communities, and habitat for breeding amphibians. Regulations governing factors that affect WLF have been targeted at new development on the urban side of the Urban Growth Boundary (UGB), where the most significant impacts are likely to occur. The general information on construction impacts generated by the Wetlands Research Program has also led to the application of seasonal clearing limits in the drainage areas of Class 1 wetlands.

Basin Planning

The basin planning process was developed by King County to address the significant and rapid land use changes occurring in the county that have an impact on water resources, including flooding, habitat, and water quality. The outcome of the basin planning process is a way of developing a comprehensive set of management recommendations that involve development regulations, capital improvement projects, education programs, improved maintenance practices, and monitoring.

The East Lake Sammamish Basin Plan (King County Surface Water Management Division (KCSWM) 1992) is an example where the results of the Wetlands Research Program were directly applied to management solutions. The East Lake Sammamish basin encompasses about 16 square miles east of Lake Sammamish. Since 1980, the basin has experienced rapid development, converting from low-density residential and forested land uses to higher density residential and some commercial uses. The diversity of the basin's more than 40 inventoried wetlands is as great as anywhere in King County, with nine wetlands ranked as unique and outstanding (Class 1 rating). As one of the prime resources in the basin, wetlands received significant attention for protection from the County and the citizenry.

Wetland Management Areas

Prior to adoption of the basin plan, wetland protection in King County was achieved primarily through the Sensitive Areas Ordinance (SAO). The wetland protection in the SAO provides for discrete buffer widths as a function of assigned rating (e. g., 100 feet for Class 1 wetlands). Although these buffers confer some protection to wetlands, they are inadequate to protect other functions influenced by the broader watershed and surrounding landscape. To address these issues, King County developed wetland management areas (WMA) focused on watershed-based controls to protect the nine Class 1 wetlands. The intent of these controls was to minimize the stormwater-related impacts on wetlands by minimizing impervious surfaces, retaining forests, clustering, and providing constructed infiltration systems, where feasible.

A major component of the wetland management strategy was the limitation of total impervious area in the catchment to eight percent, where allowed by zoning. From the Wetlands Research Program data, it was clear that there were significant increases in WLF between wetlands with watersheds less than 4 percent and those with watersheds greater than 12 percent impervious surface (Taylor 1993; Taylor, Ludwa, and Horner 1995). It was difficult to define this more precisely, because of the absence of impervious surfaces between 4 and 12 percent. Booth and Reinelt (1994) summarized several data sets showing loss of aquatic system function with impervious surface areas above about 10 percent, as measured by changes in channel morphology, fish and amphibian populations, habitat, and water chemistry. While the precise threshold will vary by watershed and the effectiveness of mitigation strategies, 8-10 percent impervious surface appears to be an appropriate threshold.

A requirement for 50 percent forest retention was also imposed in the catchments of some wetlands. This limitation is consistent with King County's reserve tract requirements associated with clustering and growth-reserve zoning. Taylor (1993) found a correlation between forest retention and reduced WLF, but no specific threshold was identified in this work. Clustering of development away from hydrologic source areas (landscape features transmitting water to wetlands during the wet season) was also recommended. An additional requirement in one wetland watershed was the use of constructed infiltration systems to reduce increases in stormwater volumes. This was feasible given the extensive glacial outwash soils in this watershed that were amenable to substantial infiltration. Finally, seasonal clearing limits for construction activities were imposed in eight of the nine watersheds. This limitation prevents clearing and grading during the wet season (October-April) when up to 88 percent of erosion occurs (KCSWM 1992).

King County has continued this approach of wetland management areas for protection of Class 1 wetlands in the Cedar River Basin Plan currently under development. Four Class 1 wetlands in the Cedar basin that are on the urban side of the UGB or that receive runoff from urban areas have been targeted.

Master Drainage Planning and Guidelines

King County uses the Master Drainage Planning (MDP) process for large or complex development sites to assess the potential impacts of development on aquatic resources (KCSWM 1993). The MDP process is required for Urban Plan Developments (UPD), for subdivisions with more than 100 single-family residences, and for projects which clear 500 acres or more within a subbasin. In addition, there are lower thresholds for development in the drainage areas of Class 1 wetlands, regionally significant resource streams, or over sole source aquifers. For Class 1 wetlands, an MDP is required if a project seeks to convert more than 10 percent of the wetland's total watershed area to impervious surface.

The updated guidelines for MDP monitoring and studies (KCSWM 1993), supported in part by results of the Wetlands Research Program, require monitoring for purposes of: (1) assessing wetland functions in storing and releasing stormwater, (2) determining baseline WLF in relation to vegetation and amphibian communities, and (3) establishing baseline conditions from which to measure potential post-development changes. Specific concerns potentially resulting from development are: (1) loss of live storage and infiltration functions of wetlands, (2) stability of outlet control conditions, (3) the effects of increases in flow rates and volumes, (4) changes in spring WLF and resultant habitat changes, and (5) changes in groundwater and interflow.

For purposes of assessing wetland impacts, the MDP guidelines require determination of the following: bathymetry (morphometry) of the wetland; outlet control description and measurement; stage-discharge volume relationships; surface area of open water, including ordinary high water levels; and the dead and live storage maximum elevation and volume. Specific monitoring requirements are: (1) monthly instantaneous and crest water levels to determine WLF in the permanent pool area of the wetland; (2) inflow and outflow rates of the wetland; and (3) the duration of summer drying, if applicable.

For the North Fork Issaquah Creek Wetland 7 Management Area and Grand Ridge MDP, the East Sammamish Community Plan limited development in the drainage area tributary to North Fork Issaquah Creek Wetland 7 (NFIC-7), a Class 1 wetland, to no more than eight percent impervious surfaces and 65 percent forest retention. This condition applies to all development proposals submitted prior to adoption of the Issaquah Basin Plan (KCSWM 1994) and for all developments not going through the MDP process. In the basin plan, impervious surfaces are limited to a maximum of eight percent for all new subdivisions, short subdivision, and UPDs.

The proposed Grand Ridge development in the North and East Fork Issaquah Creek basins involved two development options: rural estates at a density of one unit per 5 acres and an urban proposal consisting of 580 acres of urban development and 1400 acres of permanent open space. In a study of potential development scenarios carried out using the Wetlands Research Program guidelines and a model developed by Taylor (1993), it was possible to examine the development impacts on the water level fluctuation of wetland NFIC-7. Based on the results of that analysis, mitigations were proposed that focused on maintaining greater forested area and utilizing infiltration to reduce stormwater volumes.

CONCLUSION

Fundamentally managing stormwater to protect wetland ecosystems must operate holistically within context of the hydrologic cycle. That requires that we consider infiltration and evapotranspiration in addition to storage, when we think about strategies. Controls focused on minimizing impervious surfaces and maximizing forest retention are likely to be the most widely usable effective strategies; however, additional mitigations that reduce stormwater volumes through infiltration are highly recommended when hydrogeological conditions permit.

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