Streamline
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Hydrology

Forest Hydrologic Cycle Basics

Robin Pike

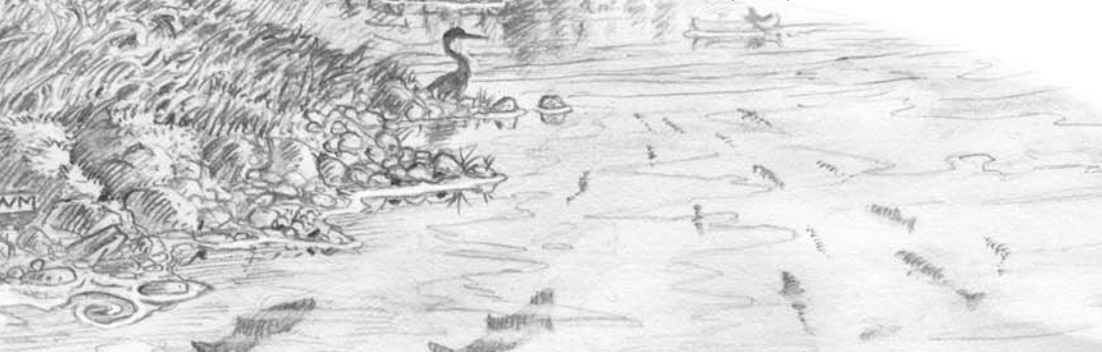
An understanding of the effects humans have on water quantity is an important precursor for making watershed management decisions in British Columbia. The amount of streamflow and the seasonal timing are important for many reasons. Water that is delivered too much, too little, or too soon can have major environmental and human implications. Watersheds and their regimes, however, can be notoriously complex to understand especially when management of multiple resources occurs simultaneously within a watershed.

The purpose of this article is to provide an overview of the hydrologic cycle using forest management as an example of one land practice that may affect these components. For the experienced, I hope you can use this article to introduce others to the concepts of forest hydrology.

Precipitation and Streamflow Background

Precipitation (rain and snow) supplies water that moves through the hydrologic cycle, eventually emerging at the outlet of the watershed (Figure 1, p.4). Precipitation is water from the atmosphere that is deposited in various forms (snow, hail, rain) depending on temperature. Precipitation is highly variable in space and time and, on an annual basis, varies more than evapotranspiration. The amount and type of precipitation that falls in an area ultimately affects the volume and timing of discharge from a watershed. The observable, surface discharge from a basin is generally termed runoff or streamflow. However, the total amount of water flowing from a watershed, through surface and subsurface flow, is properly known as water yield. Most discussions of water yield are analogous to observable streamflow and typically constitute the total area under a streamflow hydrograph (Figures 2 and 3, p.5). In areas where the majority of annual precipitation falls as snow to form a snowpack, watersheds are snowmelt-dominated. In coastal areas where rain predominates, watersheds are rain-dominated. Transitional or "transient" snow zones (rain on snow zones) describe the areas between the two types of regimes. Researchers Satterlund and Adams addressed the often debated question of whether forests cause precipitation or precipitation causes forests by concluding that: "On the whole, it seems that the idea that forests importantly affect precipitation is rejected by most meteorologists, except where fog drip and rime occur frequently." (1992: 85). Fog drip is water from the atmosphere (fog) that is collected/deposited on vegetation surfaces and subsequently falls to the ground once vegetation storage

Continued on page 2



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Information in this publication is presented to increase communication and understanding of innovative knowledge and current research results in watershed management. Articles on technical information, research results, perspectives, news releases, conference/workshop highlights, and other relevant submissions are welcomed. All material published reflects the opinions and conclusions of the contributing author(s), not necessarily those of FORREX–Forest Research Extension Partnership, our editorial staff, or our funding partners. We welcome your feedback on ideas or opinions that have appeared in past issues of Streamline. We reserve the right to edit all submissions for content, style, and relevance to Streamline.

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Continued from page 1

capacities are exceeded. Rime is the formation of ice on vegetation surfaces through the process of water droplets freezing onto cold surfaces.

Peak flows in snowmelt-dominated regimes generally occur in the spring (Figure 2) between April and mid-July when higher-elevation snowpacks melt. Peak flows are defined as the maximum instantaneous discharge (maximum stage) or maximum daily discharge. In coastal areas, maximum instantaneous discharge typically occurs in the winter from November to February when precipitation is moderate to high (Figure 3). Peak flows are important to consider as the larger the volume of water, the larger the potential erosive power and carrying capacity of a stream. This tenet has implications for everything from fish habitat to channel stability to water use.

Low flows are defined as minimum flow or absence of flow in a stream during the dry season (Figures 2 and 3). Unlike instantaneous peak flows, low flows are continuous and are often characterized by time period (e.g., lowest average flow in a 7-day period) although no standard definition appears to be adopted in the literature. Low flows are a normal part of the yearly water cycle. Low flows should not be confused with drought, as drought is a climatic trend resulting from abnormally low precipitation.

In snowmelt-dominated regimes, low flows typically occupy the portion of the annual streamflow hydrograph that occurs during late summer or early fall months and carries through the winter months until spring snowmelt (Figure 2). In coastal areas, low flows typically occur during the

Editor's Notes

Donna Underhill

Welcome to the new Streamline Watershed Management Bulletin.

It is hard to believe almost a year has passed since the Watershed Restoration Program last published Streamline. Behind the scenes, many of you wrote letters to support the continuance of Streamline. We are happy to say Streamline is back, with a new look, an expanded editorial team, and a new mandate. The goal of the new Streamline Watershed Management Bulletin is to increase the communication, understanding, and application of innovative knowledge and current research results in watershed management. The new focus will be on fisheries and forest management issues in the Pacific Northwest, though topics like urban stream issues may be included.

FORREX has taken the lead role in the management and design of Streamline and Robin Pike is our new project manager. Our new publication team includes myself as editor (Donna Underhill), Sue Thorne, and Julie Schooling. All technical articles are now passed through a review committee (Robin Pike, Rob Scherer, and Andrew Wilson) and I continue to act as the contact for mailing list inquiries. Financial partners include the BC Ministry of Water, Land and Air Protection–Living Rivers Strategy; FORREX–Forest Research Extension Partnership; Forestry Innovation Investment and the BC Ministry of Sustainable Resource Management. We are very happy to complement the FORREX suite of publications, which includes the BC Journal of Ecosystems and Management (JEM) and LINK newsletter. FORREX will also be the new repository for the electronic distribution of Streamline, as well as the existing archives. We are also proud to be able to continue to produce printed dry season of late July to early October. Low flows are maintained in the dry season through the release of water from groundwater storage and/or surface water discharge from melting glaciers, lakes, wetlands, and flow from channel banks (Smakhtin 2001). Low flow periods cease with the occurrence of spring freshet or sufficient rain.

Low flows are important for a variety of reasons. From a fisheries perspective, water levels can be critical to fish passage, can dictate the amount and quality of habitat available for fish, and can ultimately determine fish survival. Absence of water can be detrimental to aquatic habitat and can dramatically affect the distribution of organisms dependent upon it. Low water levels also place a limit on the amount of water that can be withdrawn for human and agricultural activities, which affects development and commercial activity.

Hydrologic Cycle

The hydrologic cycle (Figure 1) is a convenient model on which to further base this discussion. The reader can refer to Hetherington (1987), Brooks et al. (1997), and Satterlund and Adams (1992) for a more comprehensive discussion of the importance of forests and forestry in the hydrologic regime. Hydrologic processes that affect the amount of precipitation available for streamflow include interception, evaporation, transpiration, and changes in water storage.

Interception is the first hydrologic process that affects the amount of precipitation available for streamflow. Interception is both a process and an amount. As a process, it is the interruption of the downward movement of precipitation and its redistribution. As an amount, it is usually expressed in millimetres on an annual basis that are returned to the atmosphere. In most cases, interception denotes a "loss" of water, as temporarily stored rain or snow on vegetation surfaces evaporates. However, in coastal areas where there is a lot of fog (fog drip), interception can result in water gains.

Evapotranspiration is a term used to denote the combined "loss" (return) of water to the atmosphere through the processes of evaporation and transpiration. Evaporation can occur from the soil surface, from falling precipitation, from water bodies, and from vegetation surfaces (Figure 1). Transpiration is the movement of

Continued on page 4

versions of Streamline through the financial support of our partners. Our new look reflects our dedication to practising what Streamline promotes with new paper that is 100% recycled, containing 50% post-consumer waste.

The target audience for Streamline has always been diverse and made up of people involved in watershed management activities, hence the name change to “management” from “restoration.” Subscribers will continue to include operational personnel, policy- and decision-makers, researchers, students, associations, and stewardship groups. While our subscribers are generally from the Pacific Northwest, watershed management personnel in other parts of the world, including Malaysia, Australia, Norway, Sweden, Scotland, Switzerland, and Canada’s central and maritime provinces, also subscribe to Streamline.

In British Columbia, many of our watersheds are shared with our neighbours to the north and south. With this trans-boundary link comes recognition of the scientific solutions that have been successfully applied by the many US Department of Agriculture (USDA) Forest Service employees who subscribed to Streamline in the past. The USDA Forest Service has produced Aqua-Talk, a newsletter similar to Streamline that focused on their research and innovative techniques in fisheries and hydrology. We are currently in discussion with the Forest Service to include a regular section in Streamline to share the technical knowledge of our American colleagues.

Much work has been done on the new Streamline to date. We hope to publish four times in 2003. We plan to include a variety of technical tips, as well as some extension articles, such as the Hydrololgy Basics article featured in this issue. New to Streamline is a “Profile” section that will feature people doing interesting research and work in watershed management. The “Update” section will continue, and with input from the FORREX Watershed extension listserver, will be more extensive and complete. Please continue to send Streamline postings you would like to see in “Update.” In coming issues, we will continue to offer in-depth features, as well as a “Perspectives” section that will allow you to share a viewpoint. Please e-mail your article ideas to me at: ***streamline@axion.net.***

Future plans for Streamline include an evaluation strategy designed to make the publication more relevant to clients. We are also updating our mailing list, and many of you have asked to receive Streamline electronically instead of by mail. Please continue to advise me if that is the case, or if your address changes. More collaborative partnerships and monetary support will be sought in the future to further secure the bulletin’s presence. Thank you for reading Streamline!

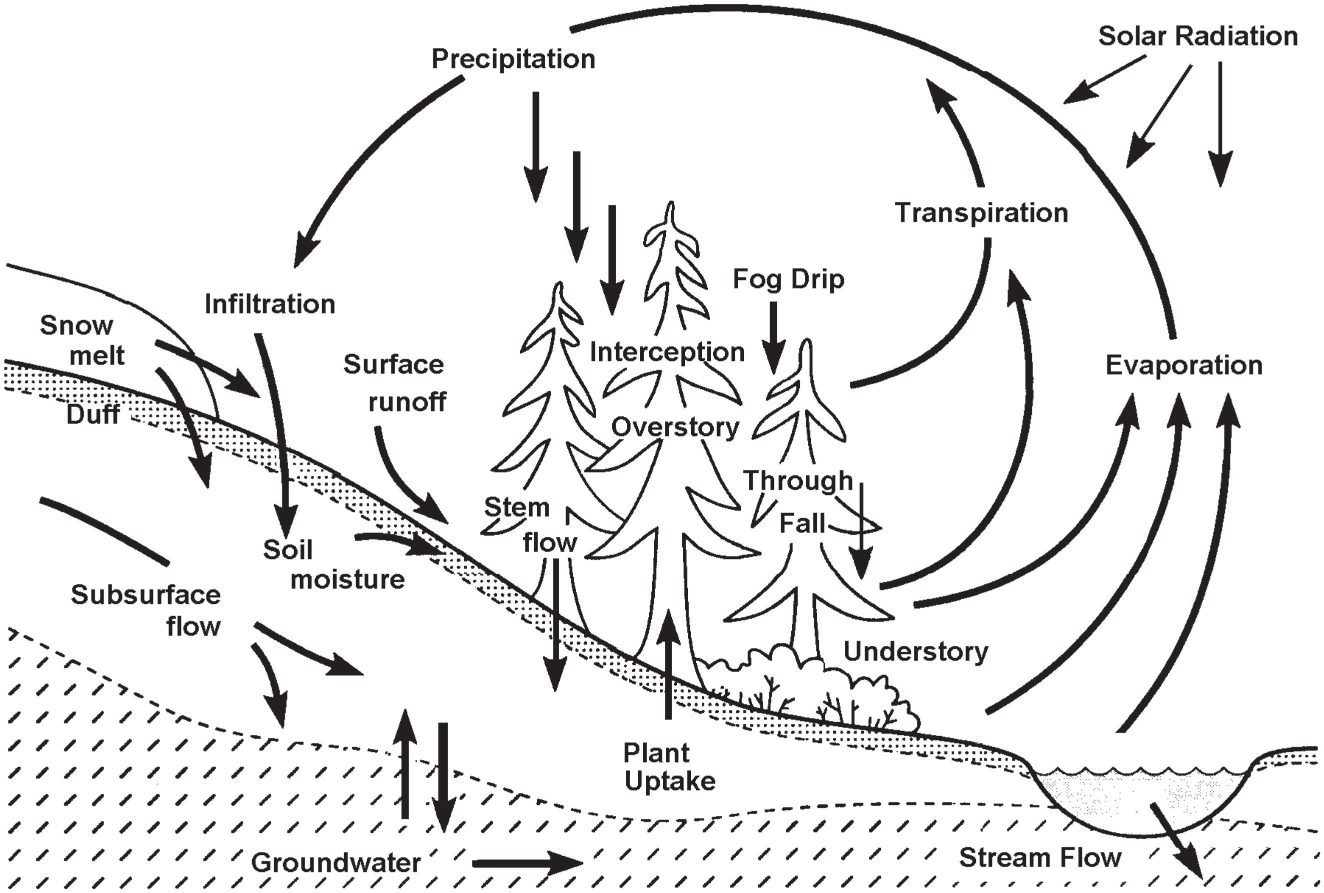

Figure 1. Forest Hydrologic Cycle. Used with permission from Pike (1998:98).

Continued from page 3

water from the ground through plant leaves into the atmosphere. Transpiration rates vary according to levels of radiant energy, soil moisture, humidity, wind, and stomata resistance imposed by vegetation.

Forest cover directly affects "rates of transpiration, evaporation, soil freezing and patterns of snow accumulation and melt" (Hetherington 1987: 183). Thus, changes in forest structure can modify processes that control water balance in space and time. Forest harvesting (including road construction) can increase the amount of solar radiation reaching the ground. Increased solar energy affects other hydrologic processes such as snowmelt, evapotranspiration, soil freezing, etc. Forest harvesting also reduces evapotranspiration/interception losses through "eliminating transpiration and evaporation from the elevated canopy" (Hetherington 1987: 186). This generally leads to increased soil moisture conditions and less storage capacity resulting in more water available for streamflow. Alteration of canopy properties also influences the accumulation and redistribution of snow and, the characteristics of snowmelt. (Winkler 1999).

Forests also influence how water is routed and stored in a watershed. Water that reaches the ground's surface will either infiltrate the soil or move over its surface. Infiltration is the rate at which water enters the soil matrix. Most forest soils readily absorb water and as a result, surface runoff (overland flow) rarely occurs outside of stream channels in forested areas (Hetherington 1987). Reduced water storage potentials in the soil matrix also leads to higher amounts of precipitation available for runoff. The result is typically higher water tables in cleared areas, although the upper layers of the soil may appear drier due to increased evaporation at the soil surface. Road building and other activities that cause soil disturbance can locally reduce infiltration and increase interception of surface and subsurface flow. If "hydrologically" connected, roads may lead to quicker delivery of runoff to stream networks in certain hydrologic regimes.

Overall, because forests are "consumers" of water, forest harvesting generally increases the amount of water available for streamflow. From the literature, the effect of forest management activities on water quantity, however, appears to be highly variable in magnitude, time, and space (Scherer and Pike 2003: in press). While annual water yield, low flows, and peak flows may increase in volume or magnitude because of forest management, it is difficult to predict actual response. As such, it is possible that similar forest management treatments occurring in different watersheds can result in different magnitudes of streamflow response. The longevity of response observed varies within the literature on snowmelt-dominated regimes. Returns to pre-treatment levels with the re-establishment of vegetation appear to vary between 10-30 years for annual water yield and peak flow, and between 3-6 years for low flows (Scherer and Pike 2003: in press).

The relationship between forest management and hydrology is only one example of how human activities may alter streamflow in a watershed. It is crucial that we understand (or at least plan for) the effects that all human activities have in a watershed in order to truly practice integrated watershed management.

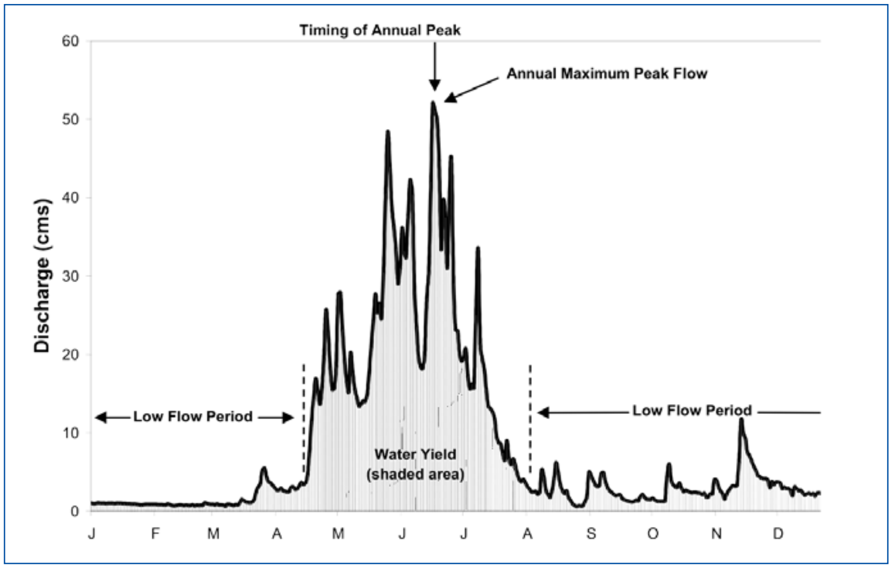

Figure 2. Example of an Interior Streamflow Hydrograph (Data Source Water Survey Canada, Mission Creek 1999).

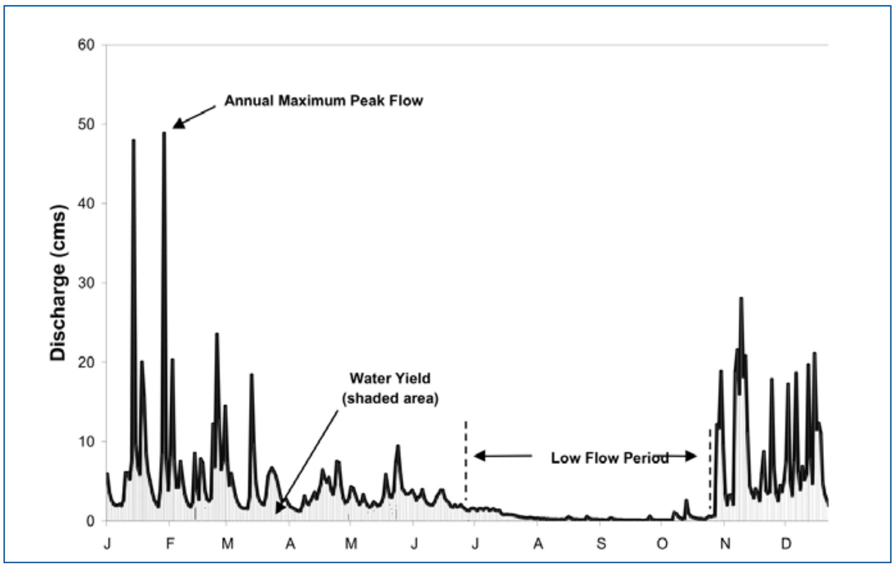

Figure 3. Example of a Coastal Streamflow Hydrograph (Data Source Water Survey Canada, Harris Creek 1999).

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