CHAPTER 4
Hydrology: Tryon Creek Watershed

This chapter characterizes the hydrology of the Tryon Creek Watershed. It includes:

- Watershed Description
- Historic Conditions
- Landscape Factors
- Human Influences
- Gaged Stream Flows
- Current Hydrologic Assessment

WATERSHED DESCRIPTION *

The Tryon Creek Watershed in southwest Portland covers an area of approximately 4,142 acres, or 6.5 square miles. Approximately 3,058 acres (nearly 80 percent of the watershed) is within Portland's city limits. The remaining watershed area is within the jurisdictions of Multnomah County, Clackamas County, and the City of Lake Oswego.

The Tryon Creek Watershed is divided into three subwatersheds: Tryon Creek mainstem, Arnold Creek, and Falling Creek:

- The **Tryon Creek mainstem** is about seven miles long and flows southeast from its headwaters near Multnomah Village (just north of Interstate 5 and Highway 99) to its confluence with the Willamette River in Lake Oswego at the Highway 43 crossing. The Tryon Creek mainstem subwatershed comprises about 3,083 acres.

- Arnold Creek joins Tryon Creek at the SW Boones Ferry Road crossing. The Arnold Creek subwatershed comprises about 775 acres.

- Falling Creek joins Tryon Creek at SW 26th Avenue and Taylors Ferry Road. The Falling Creek subwatershed comprises about 283 acres.

Other smaller tributaries flow into Tryon Creek both within and outside Portland's city limits.

HISTORIC CONDITIONS

The historic hydrology of Tryon Creek and its tributaries was typical of low to moderate gradient Willamette Valley headwater streams with steep landscape slopes. The annual hydrograph reflected the climatic precipitation pattern, with an extended wet period exhibiting higher flows and frequent storm flow events from approximately October through May, followed by a dry summer season with low flows from June through September. Stream flows during the summer low-flow period were dominated by groundwater recharge to the streams. The topography,

* Refer to Chapter 2: Tryon Creek Watershed Overview, for additional description and maps.

including steep slopes, and the native soil characteristics, which limited infiltration, contributed to a rapid response of flows to storm events and moderate runoff volume. This response was moderated by the native vegetation, including a mature forest with a surficial forest duff layer, that provided precipitation storage (May et al. 1997). Topographic features confined many of the headwater tributary stream channels, with lower reaches of the streams exhibiting more meandering and interaction with the floodplain (e.g., lower Tryon Creek mainstem within Tryon Creek State Natural Area).

LANDSCAPE FACTORS

Landscape factors are broad-scale influences such as climate, rainfall/precipitation, topography, geology, and soils that play a major role in determining the structure, dynamics, and function of a watershed. Landscape factors set constraints on, and can be a determining factor in, the form and function of a watershed (City of Portland 2004).

Climate

The climate in the Tryon Creek Watershed is classified as Mediterranean, characterized by mild winters with prolonged winter rainfall and cool, dry summers. Temperatures range from 25 to 45 degrees Fahrenheit (^{o} F) in the winter and from 70 to 90 degrees Fahrenheit (^{o} F) in the summer (Johnson 1987).

Rainfall/Precipitation

Rainfall data are available from the Bureau of Environmental Services' (BES) Hydrologic Data and Acquisition (HYDRA) system, which collects five-minute rainfall data from rain gages located throughout the City of Portland, including the Tryon Creek Watershed. Table 4-1 summarizes the seasonal frequency of rainfall events. Table 4-2 shows the average seasonal and annual rainfall amounts for the three operational rainfall gages in or near the Tryon Creek Watershed. Figure 4-1 shows the average annual precipitation by month.

Table 4-1
Annual Average Rainfall at PCC Sylvania Campus (PCC)[1] and Portland International Airport (PDX)[2]

Characteristic	Winter (November through May)		Summer (June through October)		Annual	
Station	***PCC***	***PDX***	***PCC***	***PDX***	***PCC***	***PDX***
Rainfall, days per season or year	98	101	42	48	140	149
Rainfall depth, inches per season or year	**25.7**	**27.7**	**9.5**	**9.7**	**35.2**	**37.4**
Rain events per season or year	36	37	24	25	60	62
Volume per event, inches	0.74	0.75	0.38	0.39	0.59	0.61
Peak intensity, inches per hour	0.094	.095	0.091	0.092	0.093	0.094
Duration per event, hours	40	45	20	24	34	36
Dry time between storms, hours	75	74	155	154	107	106

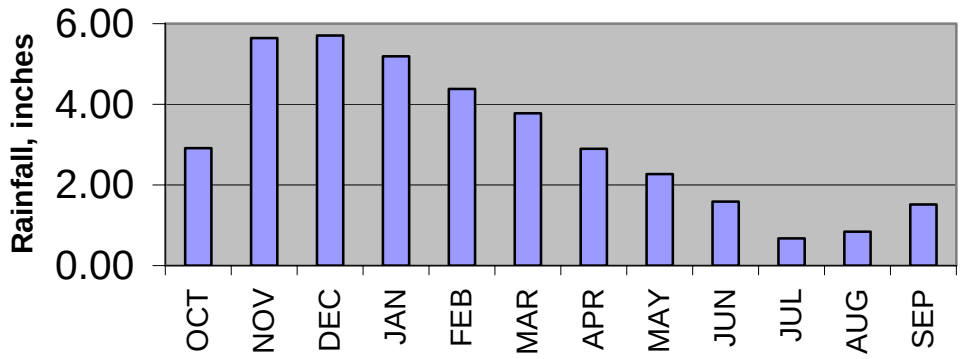
[1]PCC period of record, 1976-1998; Source: HYDRA system data compiled by the BES Modeling Group.
[2]PDX period of record, 1946-1991; Source: Combined Sewer Overflow Management Plan; Characterization Report; CH2M Hill, December 1992;

TABLE 4-2
Annual Average Rainfall
(Rainfall depth, inches per season or year)

Gage Station	Winter (November through May)	Summer (June through October)	Annual
Vermont Hills	32.46	9.81	42.26
Collins	31.63	10.47	42.11
Sylvania	31.47	9.77	42.13
AVERAGE	**31.85**	**10.02**	**42.17**

Note: Period of record, 1995-2002.

Figure 4-1
Average Monthly Rainfall



Source: BES Modeling Group

The rainfall monitoring results show the pattern typical of the Mediterranean-type climate. The average annual precipitation is 42.17 inches, with 76 percent (31.85 inches) of the precipitation occurring during the winter season and only 24 percent (10.02 inches) occurring during the summer season. The summer season typically has extended periods without any precipitation, with both July and August averaging less then one inch of rain.

The monitoring results also show fairly uniform rainfall amounts over the region. However, localized variability in precipitation patterns could be expected, based on orographic effects (i.e. increased precipitation at higher elevation in the watershed).

The annual rainfall pattern strongly influences stream flow regimes in the watershed, particularly the low flows that are characteristic during the late summer.

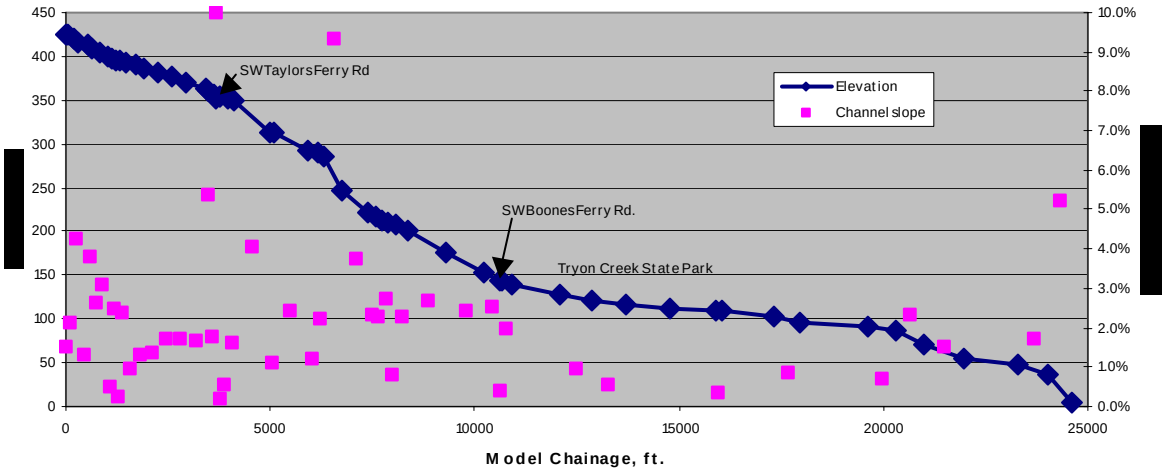
Topography

Topography (elevation) in the Tryon Creek Watershed varies from near mean sea level (msl) to 970 feet above msl. The lowest point in the watershed, about 10 feet above msl, is the confluence of Tryon Creek with the Willamette River; the highest point is at the top of Mt. Sylvania (BES 1997). Approximately 60 to 75 percent of the slopes within the watershed exceed a 30 percent grade (BES 1997). Some slopes exceed 50 percent grade, especially in the upper watershed (Map 9-Tryon Creek Contour Map, Map Atlas). The *Southwest Hills Resource Protection Plan* (Bureau of Planning 1992) classifies slopes in excess of 30 percent grade as generally having "severe landslide potential." Prominent topographic features in the Tryon Creek Watershed are the Palatine Hills, Portland's West Hills, and Mt. Sylvania.

Stream Profiles

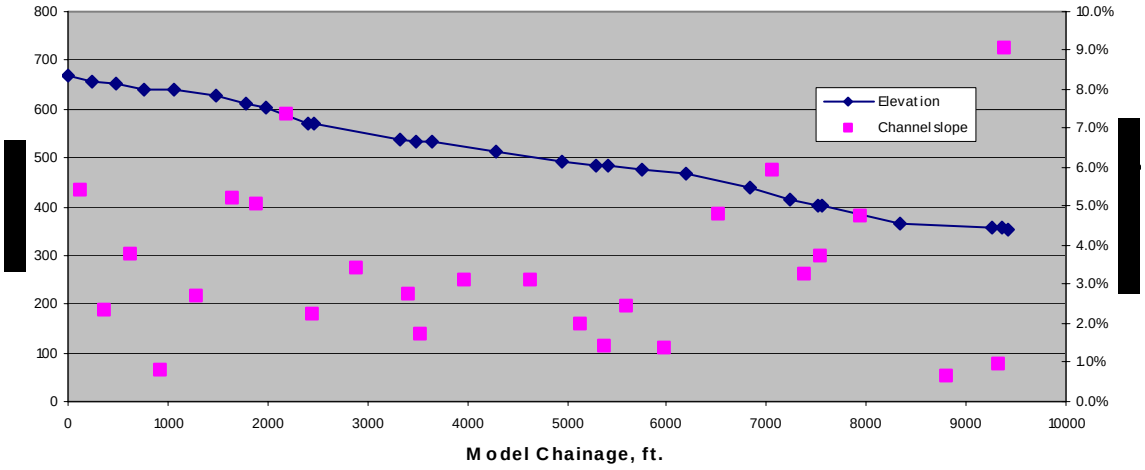
Figures 4-2, 4-3, and 4-4 show the modeled stream profile and channel slopes for Tryon, Falling, and Arnold Creeks, respectively.

Figure 4-2
Modeled Stream Profile and Channel Slopes for Tryon Creek



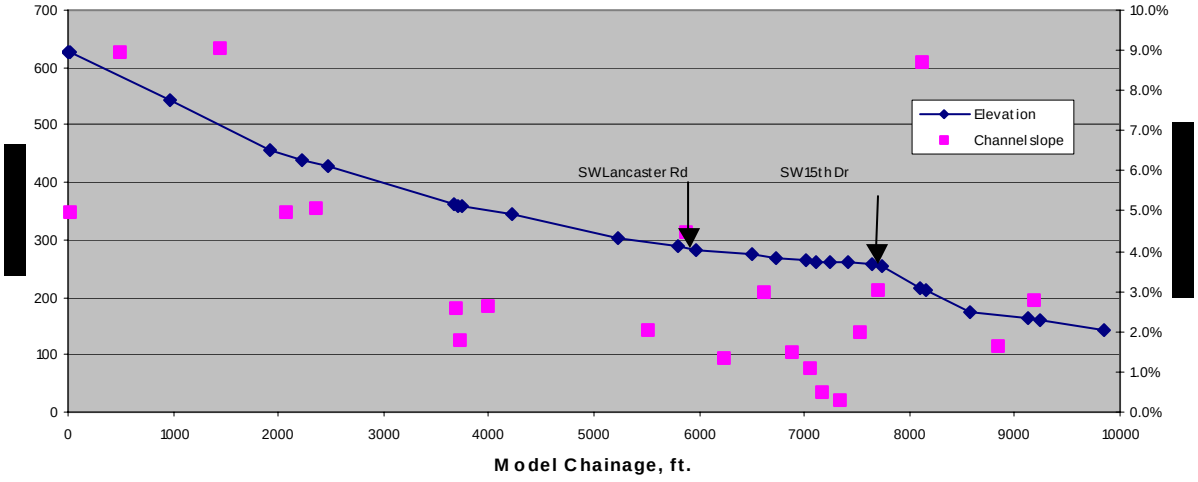
As shown in Figure 4-2, Tryon Creek upstream from SW Boones Ferry Road has a low to moderate gradient (average 2.3 percent slope). Downstream from SW Boones Ferry Road, within Tryon Creek State Natural Area, the stream slope flattens to a low gradient (average 0.7 percent slope); this approximately 1.8-mile reach of Tryon Creek is a potential depositional area for silt and sediments transported from the upper watershed. Downstream of the Tryon Creek State Natural Area, the stream slope increases back to a low to moderate gradient (average 2.3 percent slope). Further downstream, below State Street, there is another grade break, and Tryon Creek has moderate to steep gradients before it discharges into the Willamette River.

Figure 4-3
Modeled Stream Profile and Channel Slopes for Falling Creek



As shown in Figure 4-3, Falling Creek has a fairly uniform moderate gradient (average 3.4 percent slope).

Figure 4-4
Modeled Stream Profile and Channel Slopes for Arnold Creek



As shown in Figure 4-4, Arnold Creek has a moderate gradient stream (average 3.4 percent slope), with some moderate to steep reaches both in the upper headwaters and near the confluence with Tryon Creek.

Soils

The U.S. Geological Survey (USGS) Soil Survey Manual for Multnomah County shows the predominant soil classification in the Tryon Creek Watershed to be the Cascade series. The Cascade series is a moderately deep, poorly draining soil consisting primarily of dark brown silty loam. The percentage of Cascade soils in the three subwatersheds ranges from 80 to 96 percent. The remaining soils are made up of the Cornelius, Delena, Sifton, and Dabney series.
A fragipan layer exists throughout the Cascade series soils at a depth of 20 to 30 inches below the ground surface. This layer consists of a subsurface horizon of low porosity that is low in clays but high in silt or very fine sands, forming what appears to be a cemented layer that restricts root formation and infiltration. The fragipan layer ranges in thickness from two to four feet. When dry, the fragipan layer is very hard and dense. When wet, it tends to rupture suddenly under pressure. (U.S. Dept of Agriculture, 1983)

During the summer months, the Cascade soils can be dry to a depth of 4 to 12 inches, for up to 60 consecutive days. As a result of this dryness, the ground is hard and can act as an impervious surface, particularly for low-intensity, short-duration summer storms. In areas of relatively undisturbed soils, the permeability is slow, and available water capacity is between five and eight inches. In the months from December to April, the Cascade soils tend to have a water table at a depth of approximately 30 inches. The water table is typically perched on the fragipan layer. Depending on its location relative to the surface, the perched water table reduces the storage capacity of the soils, increasing the volume of runoff to the stormwater system during the winter season.

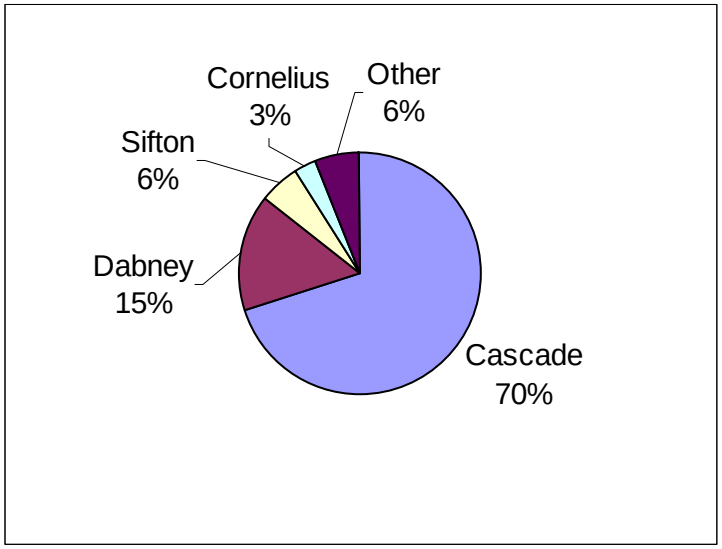
The Cascade series is further separated in two categories: Cascade silt loam and Cascade urban land complex . The Cascade soils in the developed portion of the upper watershed are classified primarily as the urban land complex. The Cascade silt loam is primarily native material, while the Cascade urban land complex consists of areas that are disrupted by urban development. These categories within the series are further subdivided based on land slope, with higher slopes having higher rates of runoff and erosion potential. The Cascade urban land complex is the predominant soil classification in the Tryon Creek Watershed.

The Delena soils are predominantly along the stream corridors and flat slope areas of the basin. These soils are also poorly drained and predominantly silty soils. The Delena soils make up the boundary surfaces of the streams and influence the streams' stability.

The remaining soils (Cornelius, Sifton, Dabney, and others) have minimal effect because of their limited distribution and area within the watershed.

Figures 4-5, 4-6, and 4-7 show the percentages of soil classifications in the Tryon Creek, Falling Creek, and Arnold Creek subwatersheds, respectively. (See Map 6-Tryon Creek Soil Maps by subwatershed, in the Map Atlas)

Figure 4-5
Tryon Creek Soils



igure 4-6
Falling Creek Soils

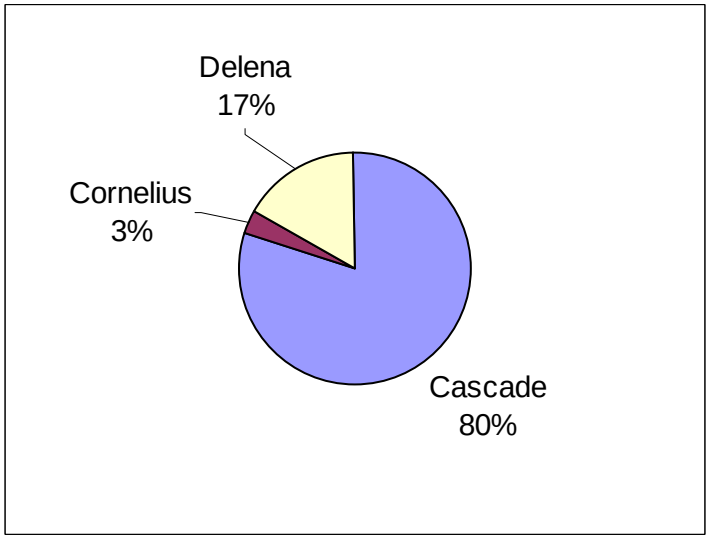
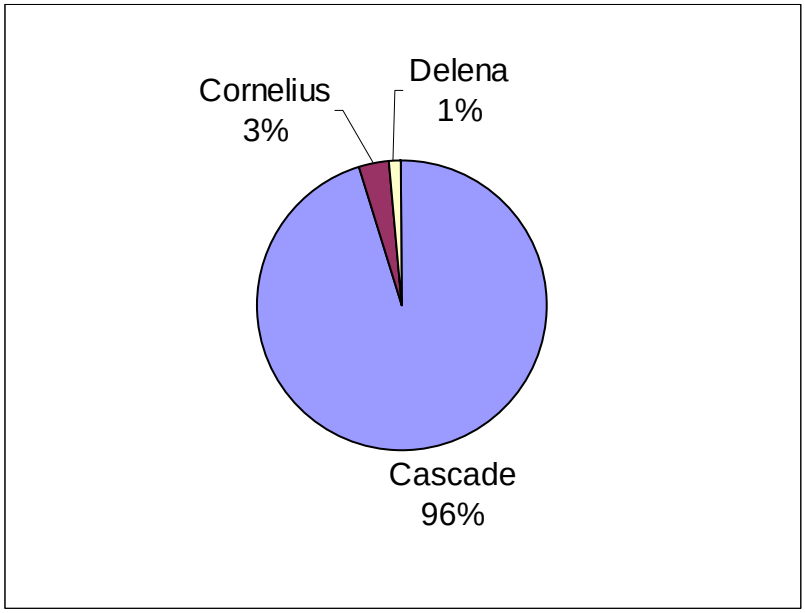


Figure 4-7
Arnold Creek Soils



HUMAN INFLUENCES

Land Use

Land use is a general indicator of the types of human and urban activities present in the watershed. Impacts from land use changes can include increased impervious area, alteration of natural flow patterns through development of urban infrastructure, and increased pollutant loads.

The predominant existing land use within the Tryon Creek watershed is single-family residential development (76 percent). Parks and open space are the second-largest land use, largely because of Tryon Creek State Natural Area (630 acres). The remaining commercial and multi-family residential land uses are concentrated along major transportation corridors, including Interstate 5 and SW Barbur Boulevard.

Figure 4-8 and Table 4-3 show land uses and associated coverage areas, based on current zoning adopted in the *Southwest Community Plan* (Bureau of Planning 2001).

Figure 4-8
Tryon Creek Watershed
Existing Zoning

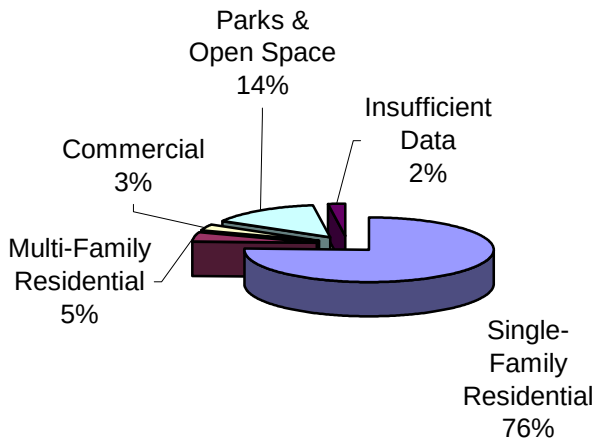


Table 4-3
Tryon Watershed Land Use Zoning

Land Use Category	Falling Creek Subwatershed		Arnold Creek Subwatershed		Tryon Creek Subwatershed		Outside City		Tryon Creek Watershed	
	Acres	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*	*Acres*	*Percent*
Commercial	7	2%	0	0%	120	5%	7	1%	134	3%
Multi-family Residential	43	15%	0	0%	142	6%	5	1%	191	5%
Parks/Open Space	37	13%	54	8%	502	23%	0	0%	593	14%
Single-family Residential	197	69%	629	92%	1,463	66%	845	89%	3,134	76%
Insufficient Data	0	0%	0	0%	0	0%	92	10%	92	2%
Totals	**284**		**683**		**2,227**		**949**		**4,142**	**100%**

Figures 4-9, 4-10, and 4-11 show the percentage of tax lots built on between 1910 and 2003 in the Falling Creek, Arnold Creek, and Tryon Creek subwatersheds, respectively. Development within the Tryon Creek subwatershed began in the early 1900s, with increased activity in the 1950s. Development in the Falling Creek and Arnold Creek subwatersheds is more recent, with most development occurring after 1970. This is reflected in the average age of development in

the three subwatersheds: Tryon Creek (43 years old), Falling Creek (34 years old), and Arnold Creek (26 years old).

It is estimated that the watershed is currently 80 percent "built out," based on tax lot data and the amount of vacant land in the watershed, as summarized in Table 4-4. Future growth will probably occur by in-filling of vacant land or minor parceling of large existing occupied lots, rather than by large land development projects. Based on the extent and age of development within the watershed, it would be expected that some impacts from construction and urbanization within the watershed have stabilized.

Figure 4-9
Tax Lots Built on in Falling Creek Subwatershed

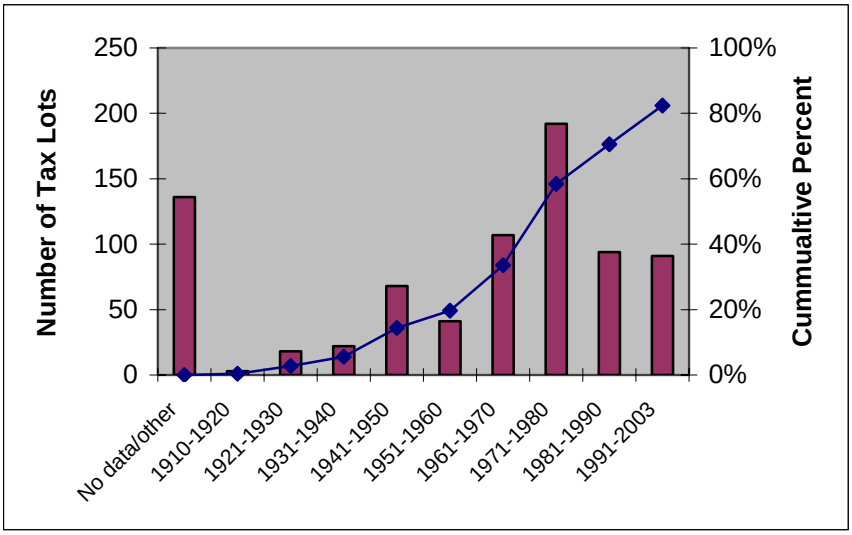


Figure 4-10
Tax Lots Built on in Arnold Creek Subwatershed

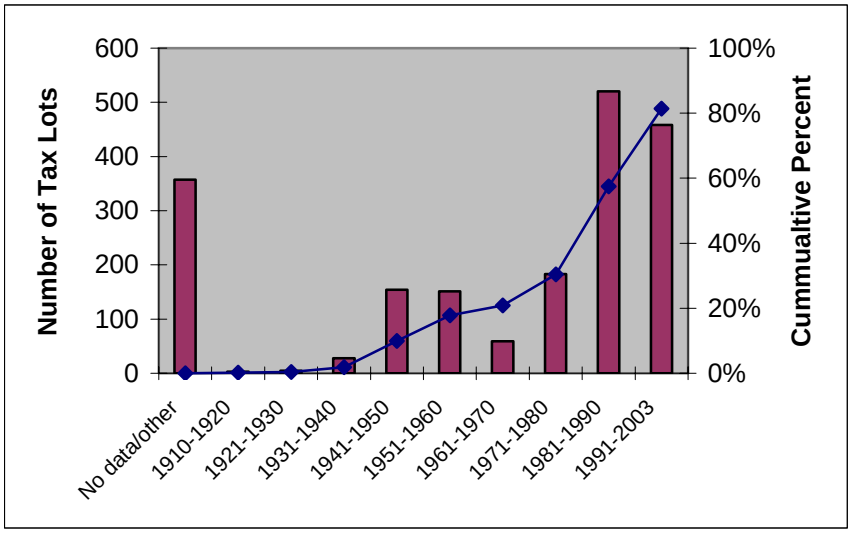


Figure 4-11
Tax Lots Built on in Tryon Creek Subwatershed

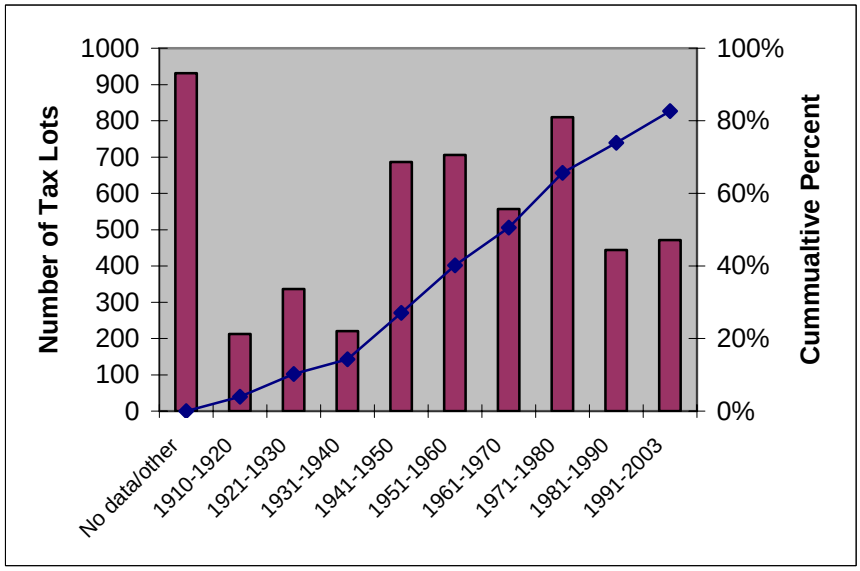


Table 4-4
Vacant Land in Tryon Creek Watershed

Subwatershed	Area, acres		Percent Vacant
	Vacant	*Total*	
Arnold Creek	152	775	19.6
Falling Creek	18	283	6.5
Tryon Creek	445	3,083	14.4
Total	**616**	**4,141**	**14.9**

In addition to land use designations, Portland has established environmental overlay zones to protect and conserve significant natural resources. The environmental overlay zones are based on extensive natural resource inventories that cover areas within the city. The environmental zoning program is also the City's primary tool for complying with State Land Use Planning Goal 5 to protect significant natural resources.

There are two types of environmental overlay zones, which currently affect approximately 1,017 acres in the Tryon Creek Watershed. **Protection (P) zones** have been established in areas that have very high-value resources and functional values. Development is approved in the protection zone only in very limited circumstances. Within **conservation (C) zones**, development is allowed if it meets certain standards and approval criteria to ensure that impacts on significant resources are avoided, limited, and mitigated.

Environmental overlay zones encompass many of the existing stream channels and riparian areas within the watershed and therefore serve to protect the natural hydrologic processes.
Table 4-5 summarizes environmental overlay zone coverage. (Also see Map 5-Tryon Creek Current Plan by subwatershed in the Map Atlas).

Table 4-5
Environmental Zone Coverage in Tryon Creek Watershed

Subwatershed	C zone (acres)	P zone (acres)	Total E zones (acres)	Subwatershed Area (acres)	Percentage of Subwatershed
Tryon Creek Mainstem	237.0	499.6	736.6	3,083.7	23.9
Arnold Creek	211.4	47.6	259.1	775.2	33.4
Falling Creek	17.6	4.2	21.7	283.6	7.7
Total (Watershed)	**466.0**	**551.4**	**1,017.4**	**4,142.3**	**24.6**

Impervious Area

One of the most pervasive and obvious changes to the natural system as the result of urbanization is an increase in impervious cover and a corresponding loss of natural vegetation (May et al. 1997). The increase of impervious area includes the construction of roads, parking lots,

driveways, sidewalks, and rooftops, along with compaction of native soils. The effect of this increased impervious area is to alter the natural hydrologic cycle by changing flow paths, increasing runoff, and decreasing infiltration. These changes subsequently drive many of the physical and biological responses that affect urban streams.

The total impervious area in a watershed is often used as a measure of urbanization and corresponding effects on watershed health (Schueler 1994; Arnold and Gibbons 1996). Research on urban streams has shown that significant impairment of stream ecosystems (including hydrologic factors) begins when total impervious area in a watershed reaches a threshold of approximately 10 percent. A second threshold appears at about 25-30 percent total impervious area, when most indicators of stream health shift to a poor condition (Schueler 1994; SMRC 2004).

The Center for Watershed Protection has developed the impervious cover model, which classifies urban stream ecological health based on total impervious area (SMRC 2004). Stream classifications, with key associated hydrologic factors, are summarized below:

- Sensitive Streams (0-10 percent total impervious area): These streams are generally characterized by stable channels and do not exhibit frequent flooding and other hydrological changes resulting from urbanization.

- Impacted Streams (11-25 percent total impervious area): These streams have elevated storm flows that begin to alter stream geometry. Erosion and channel widening are evident, and streambanks become unstable.

- Non-Supporting Streams (more than 25 percent total impervious area): These streams exhibit highly unstable stream channels, with many reaches with severe widening, downcutting, and streambank erosion.

Table 4-6 summarizes total impervious area for the Tryon Creek Watershed and tributary subwatersheds. The average total impervious area for the Tryon Creek Watershed is 24.0 percent. Subwatershed total impervious areas range from 22.6 to 37.3 percent. Based on the impervious cover model described above, these streams would be classified as either impacted or non-supporting streams.

The actual effects from impervious areas would be expected to vary within the watershed, based on a combination of other related factors, including localized impervious area percentages, land slope, location relative to the stream, the stormwater conveyance system, and any implementation of onsite stormwater control measures. In the Tryon Creek Watershed, several of these factors have a significant influence. The areas with the highest percentage of impervious area tend to be concentrated in the upper watershed, therefore, they effect hydrology throughout the mainstem of Tryon Creek. Also, the effects of impervious area may be moderated because the “effective impervious area” (i.e., the impervious area directly connected to the stream or storm conveyance system) is estimated to be lower than the total impervious area. (See GIS Analysis). Still, most streams within the watershed have reaches that exhibit

characteristics of impacted or non-supporting streams (increased storm flows, unstable streambanks, downcutting, and streambank erosion).

Table 4-6
Tryon Creek Watershed Impervious Area

Subwatershed	Impervious Area (Acres)	Subwatershed Area (Acres)	Percentage of Subwatershed
Tryon Creek Mainstem*	696.1	3,083.7	22.6
Arnold Creek	192.9	775.2	24.9
Falling Creek	105.9	283.6	37.3
Total (Watershed)	**994.9**	**4,142.3**	**24.0**

* If Tryon Creek State Natural Area (631 acres) is removed from the calculation, impervious area in Tryon Creek mainstem is 28.4 percent.

Infrastructure

Stormwater System

Along with the increase of impervious areas through urbanization, the construction of urban stormwater drainage systems is a major factor impacting the hydrology of urban streams. . These drainage systems invariably increase the drainage density of the subcatchment and reduce the time necessary for overland flow to reach the stream. This results in faster runoff and higher stream velocities, along with higher and “flashier” flood flows (Hollis 1975).

The construction of the urban stormwater system also typically results in the loss of small headwater streams that are critically important to watershed health. Small intact streams provide natural flood control, recharge groundwater, trap sediments and pollution from fertilizers, recycle nutrients, create and maintain biological diversity, and sustain the biological productivity of downstream rivers, lakes, and estuaries (Moyers et al. 2003).

The construction of the stormwater system in the Tryon Creek Watershed has followed the development pattern within the watershed. Stormwater systems have been constructed as required to convey stormwater from constructed impervious surfaces, redirect natural flow paths to allow for construction of structures, and convey stormwater for roads and streets. The highest density of stormwater infrastructure is typically located in the upper portions of the subwatersheds. The stormwater systems are typically small systems that provide for localized drainage, with discharge to the local stream systems for further conveyance.

Culverts are another major element of the stormwater conveyance system in the Tryon Creek Watershed. Culverts are typically located at all roadway stream crossings in the watershed. Also private culverts are a common element of the local stormwater systems. In addition to protecting public health and property by conveying flood flows, the culverts often act as hydraulic controls and modify the natural hydraulic response of the stream systems, especially during storm events.

A major infrastructure impact on the hydrology within the Tryon Creek Watershed occurred with the construction of both Barbur Boulevard and the I5 Freeway in the upper watershed. Both of these transportation corridors directly crossed Tryon Creek. During construction, portions of Tryon Creek were piped and rerouted with the natural creek channel eliminated. In addition, the natural drainage along the entire length of these transportation corridors was modified and replaced with a system of local culverts and storm drainage systems.

Sanitary Sewer System

The Tryon Creek sanitary sewer system conveys sewage from within the watershed to the Tryon Creek Wastewater Treatment Plant (TCWTP) located near the mouth of Tryon Creek for treatment and eventual discharge to the Willamette River. There are three primary sanitary sewer lines in the system: the Tryon Creek sanitary trunk, the Falling Creek collector, and the Arnold Creek collector.

The Tryon Creek sanitary trunk is the primary north-south conveyance line servicing the basin, ranging in size from 18-30 inches in diameter and also conveys some sanitary flows from the Fanno Creek watershed. The lower basin trunk, within the Tryon Creek Watershed begins at SW 31st Avenue and SW Multnomah and generally follows the natural drainage of Tryon Creek until it terminates at the TCWTP. The Tryon trunk collects flow from two major pipelines along its alignment: the Falling Creek and Arnold Creek collectors.

The Falling Creek collector ranges in size from 10 to 12 inches in diameter beginning south of I5 and following the alignment of Falling Creek until joining the main trunk line at SW Taylor Ferry Road and SW Spring Garden Road.

The Arnold Creek collector ranges in size from 10 to 15 inches in diameter and runs along SW Arnold Street until it joins the main trunk at SW Arnold Street and SW Boones Ferry Road.

The sewerage system throughout the watershed is a gravity system constructed of concrete pipe Because of the operating requirements of the gravity sewerage system and the watershed topography, the sanitary sewer pipes are often located within stream corridors, with numerous stream crossings. (See Map 10-Tryon Creek Existing Sanitary System Map in the Map Atlas)

The proximity of the sewers to the streams can also have impacts on the stream hydrology related to construction and maintenance. Studies have shown that installing sewers and other utilities in the riparian zone can alter groundwater flow patterns and the interaction of the stream with the saturated zone (ref ?). Required maintenance or reconstruction of these sewers can also impact hydrology without proper mitigation measures. This will be an increasingly important issue within the Tryon Creek Watershed, as the aging sewer infrastructure requires more frequent maintenance. Breaks or blockages of the existing sewer lines can cause sewage to discharge directly to the streams.

GAGED STREAM FLOWS

Continuous stream flow data for the Tryon Creek Watershed are limited. Through a cooperative agreement with BES, the USGS has maintained a stream flow monitoring station on Tryon Creek near Nettle Creek since August 2001.

Figures 4-12 and 4-13 show the annual hydrographs for Tryon Creek near Nettle Creek for the 2002 and 2003 water years. The hydrographs show the typical pattern for the streams in the Tryon Creek Watershed, with an extended wet period with frequent higher flows from October through the end of May, followed by a dry summer period of lower flows. Winter season base flow is approximately 10 cubic feet per second (cfs) with summer base flow declining to approximately 1 cfs

These figures also show the response of the watershed to rainfall events, with rapid changes in flows evident. Average daily flows during winter storm events ranged from 60 to 120 cfs with average daily flows during summer storm events generally less than 20 cfs. This "flashy" response to rainfall is even more evident when looking at recorded instantaneous peak flow rates which can be much higher than the daily average flow for the watershed. Peak instantaneous flows of 340 and 447 cfs were recorded for Water Years 2002 and 2003, respectively. These flows represent an increase in flow of 30 to 40 times of base flow.

Figure 4-12
Tryon Creek Water Year 2002
(near Nettle Creek)

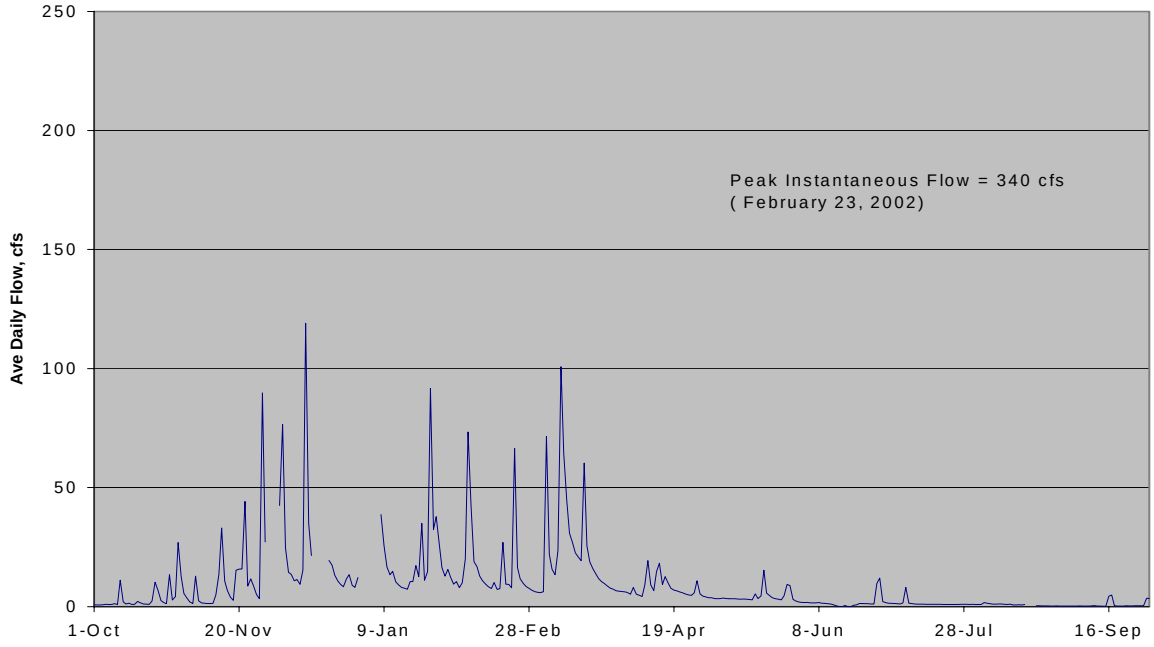


Figure 4-13
Tryon Creek Water Year 2003
(near Nettle Creek)

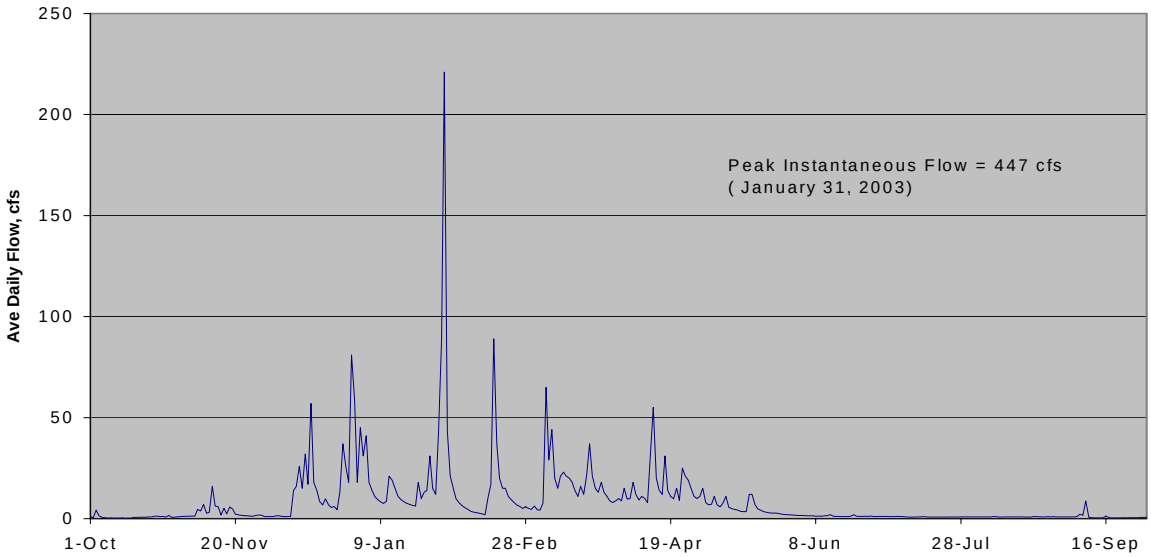


Figure 4-14 shows a flow duration curve for Tryon Creek (near Nettle Creek in the lower watershed) based on two years of flow gaging at this location. The flow duration curve shows the probability of exceeding any given flow. The curve is further divided into five flow regions: high flows, wet conditions, transition flows, dry conditions, and low flows. The curve indicates the two base flow conditions previously described of approximated 10 cfs (generally during the winter) and approximately 1 cfs (generally during the summer). It also shows the relatively infrequent but vary high flows resulting from rainfall storm events as well as infrequent low flows which have been measured as less than 1 cfs during summer dry periods.

The flow duration curve and analysis when combined with associated water quality data can be very useful in understanding the relationship between stream flow and water quality and the development of management strategies.

Figure 4-14
Flow Duration Curve for Tryon Creek near Nettle Creek
USGS Gage 14211315 (10-01-01 to 9-30-03)

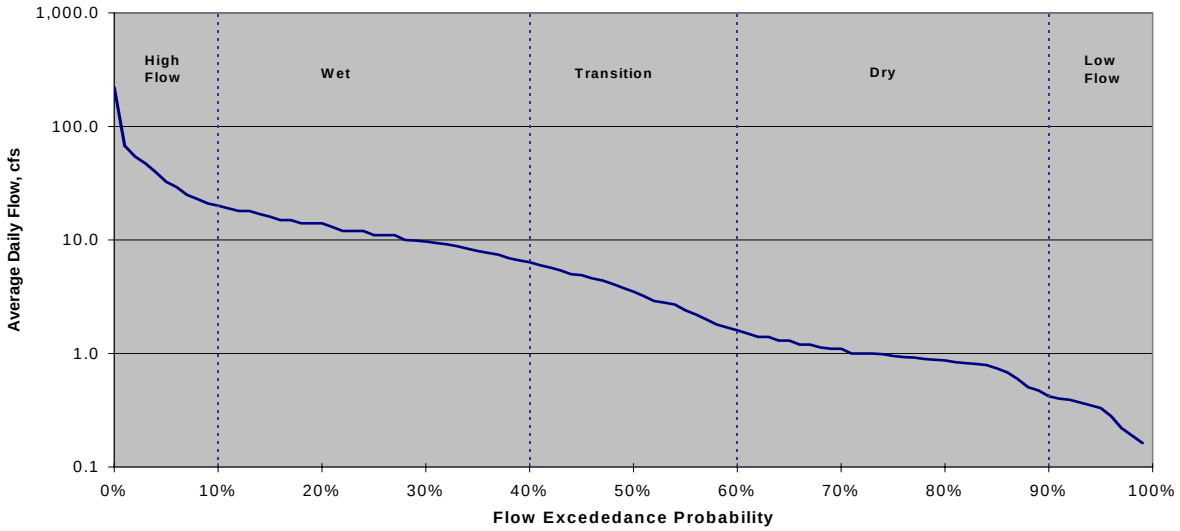
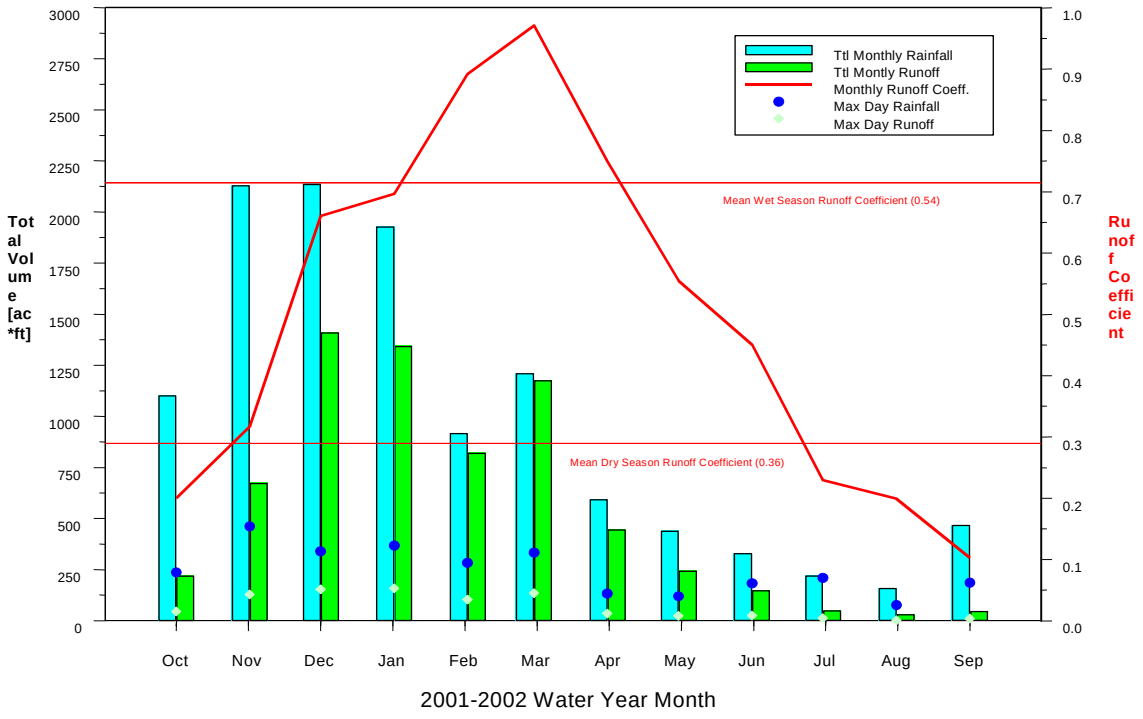


Figure 4-15 shows mean monthly rainfall and runoff volumes for the USGS Tryon Creek gage location. The figure also shows the monthly runoff coefficient (runoff volume/rainfall volume). The mean monthly volumes for both rainfall and runoff show the same general annual pattern as described above. Based on the monthly runoff coefficient, however, there appear to be significant differences in hydrologic response during different periods of the year. During the early part of the wet season, starting in September, the runoff coefficient is low, with only about 10-20 percent of the rainfall recorded as runoff. The percentage of runoff then steadily increases during the wet season until about March, when the runoff coefficient peaks at about 90 percent. This is followed by a decrease in the runoff coefficient throughout the summer dry season. It is hypothesized that this lag in system response at the beginning of the wet season is caused by a recharge of the shallow groundwater (soil profile) until it reaches saturation, along with possible higher rates of interception by deciduous vegetation and trees prior to leaf fall.

Figure 4-15
Tryon Creek Watershed Drainage for USGS Stream Gage below Nettle Creek
2001-2002 Water Year



Stream gaging data are not available for other subwatersheds within the Tryon Creek Watershed. Based on model results and observations, however, yearly stream hydrograph patterns and response to storm events would be expected to be similar. Flow magnitudes would be different, based on the drainage areas of the other subwatersheds.

CURRENT HYDROLOGIC ASSESSMENT

To support development of the Tryon Creek Watershed Plan, BES selected the Danish Hydraulics Institute's (DHI) MIKE SHE and MIKE 11 models to perform additional hydrologic modeling of the watershed. The MIKE SHE and MIKE 11 models are integrated surface and groundwater models that simulate hydrologic, hydraulic, upland pollutant loading, and instream processes within a watershed. The MIKE models can simulate continuous rainfall events to generate seasonal and annual flows

The MIKE SHE model is a physically based, dynamic, fully distributed hydrologic model that simulates all major hydrological processes occurring in the land phase of the hydrologic cycle.

Modeled hydrologic components include interception-evapotranspiration, infiltration, snow melt, overland flow, subsurface flow, groundwater flow, and stream-aquifer exchange.

Runoff flows generated by the MIKE SHE model are input into the MIKE 11model for routing through the modeled stormwater conveyance and stream system. The MIKE 11 model is a dynamic one-dimensional hydraulic model.

The MIKE SHE and MIKE 11 models are based on a grid system, where each model area is divided into a network of square grids. For the Tryon Creek Watershed, a constant 100-foot-square grid size was used, based on basin characteristics and computational constraints of the models.

Separate MIKE SHE and MIKE 11 models were developed for the major drainage subwatersheds in the Tryon Creek watershed: Tryon Creek mainstem, Falling Creek, and Arnold Creek. The models were calibrated and run for two basic model scenarios:

- An evaluation of subwatershed hydrology, using a continuous rainfall record developed for a "typical year," based on an analysis of actual rainfall recorded in the watershed.

- An evaluation of the capacity of the existing drainage system to convey stormwater, using design storms with recurrence intervals of 2, 10, 25, and 100 years.

The technical memoranda at the end of this report provide a detailed description of how the MIKE models were developed and used for this project.

Modeling Results

Table 4-7 shows design storm flows for Tryon Creek at Boones Ferry Road.

Table 4-7
Design Storm Flow Results for Tryon Creek Basin Model

			Tryon Creek Gage at Boones Ferry Road Basin Area = 4,290 acres				
Storm Event	**Date**	**Rainfall (in.)**	**Modeled Peak Flow (cfs)**	**Rainfall Volume (M gal.)**	**Total Model Flow Volume (M gal.)**	**Modeled Flow Vol. per Acre (M gal./ac.)**	**Runoff Coefficient**
2-yr	12/1- 12/2/96	2.53	290.5	294.7	160.9	0.038	0.54
10-yr	12/1- 12/2/96	3.36	465.1	391.4	219.4	0.051	0.56
25-yr	12/1- 12/2/96	3.84	587.0	447.3	305.0	0.071	0.68
100-yr	12/1- 12/2/96	4.49	762.1	523.1	362.5	0.084	0.69

The Mike SHE and MIKE 11 models were also used to evaluate the capacity of the drainage system to convey stormwater under existing land use conditions. The evaluation was based on criteria in the City of Portland's Sewer Design Manual (BES 1991). A brief synopsis from the manual follows:

> All storm drainage facilities shall be designed to pass a 10-year storm without surcharge. Surcharging during a 25-year storm is permitted with a "stormwater only" system. Surcharged pipes and bankfull channels are acceptable for conveyance of the 100-year design storm provided that several health and safety conditions are met. The allowable headwater depth for culverts should be as great as practical, as long as it does not compromise safety, flood plain regulations, environmental considerations or property rights.

In general, the City designs a culvert or storm drainpipe to convey the 25-year flow without surcharge.

Table 4-8 summarizes the capacity deficiencies identified by the modeling evaluation.

Table 4-8
Summary of Capacity Deficiencies

Subwatershed	Number of Culverts Modeled	Number and Percentage of Culverts Surcharged under 2-yr & 10-yr Storm	Number and Percentage of Culverts Expected To Have Roadway Flooding Problems	Number of Storm Pipes Modeled	Number and Percentage of Storm Pipes Surcharged under 2-yr & 10-yr Storm
Arnold Creek	12	12 (100%)	4 (33%)	6	5 (83%)
Falling Creek	16	14 (88%)	10 (62%)	2	2(100%)
Nettle Creek	5	9 (1%)	0 (0%)	0	0 (0%)
Tryon Mainstem	31	21 (68%)	6 (19%)	13	12(92%)

The capacity analysis indicates that most of the modeled culverts in the watershed have some surcharging for storms with a 10-year or less return frequency. A much smaller percentage of the modeled culverts were expected to have roadway flooding problems (defined as water depth exceeding the roadway elevation for a 10-yr return frequency storm. Most of the modeled pipes in the watershed were surcharged for storms with a 10-year or less return frequency.

GIS Analysis

A GIS analysis, using the 100-foot by 100-foot grid system established for the MIKE SHE/MIKE 11 modeling, was performed to evaluate three indicators of human influence on hydrology: impervious area, zoning, and the stormwater system (ratio of piped storm infrastructure to open channels). To perform the analysis, the Tryon Creek watershed was first divided into 18 major drainage subcatchments based on topography and modeled stream segments (e.g. TRY329, TRY258, etc.), as shown in Figure 4-14. After an initial review of the

GIS analysis results, these subcatchments were recombined into three major drainage areas within the watershed, which exhibited significant differences as follows:

- Drainage Area 1 – This area includes the upper two subcatchments,TRY329 (Falling Creek) and TRY258, which drain the areas upstream from SW Taylors Ferry Road.

- Drainage Area 2 – This area includes all the subcatchments between SW Taylors Ferry Road and SW Boones Ferry Road. This drainage area includes the Arnold Creek tributary.

- Drainage Area 3 – This area includes all the subcatchments downstream of SW Boones Ferry Road and includes the area within Tryon Creek State Natural Area as well as significant area outside the City of Portland.

The results of the GIS analysis for each subcatchment and the three major drainage areas described above are summarized in Table 4-9.

Figure 4-14

Tryon Creek Watershed Modeled Subcatchments

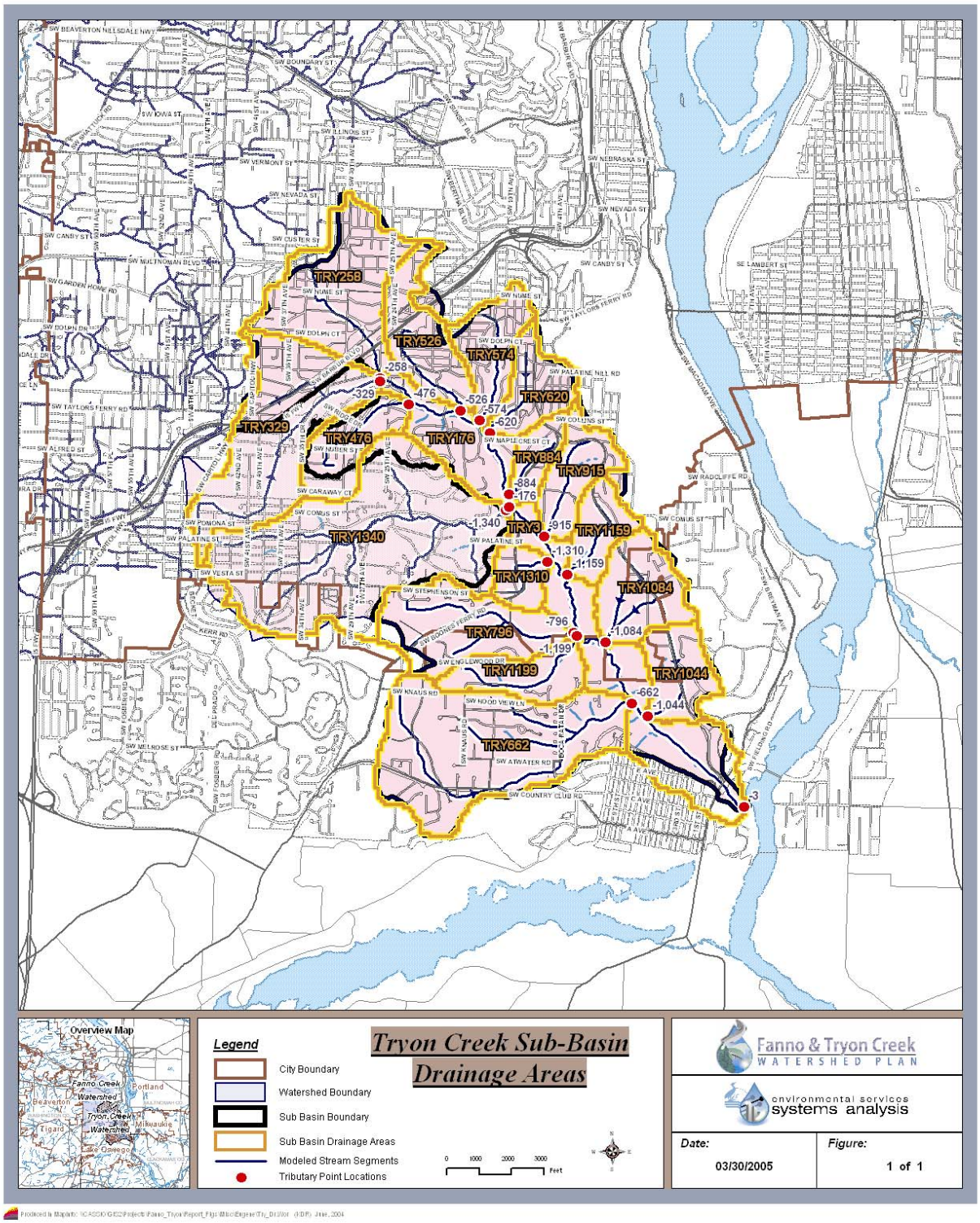


Table 4-9 GIS Anaylysis Results

Drainage Units	AREA				ZONING					DRAINAGE SYSTEM			COMMENTS
	Total	Non-City	IMPERVIOUS		COM	IND	SFR	MFR	POS	CHNL_FT	PIP_FT	Ratio	
	Acres	Acres	Acres	%	%	%	%	%	%	FT	FT		
(Upstream from SW Taylors Ferry Rd.)													
TRY329	412		180	44	12	0	67	11	10	16,500.03	44,876.17	2.7	Falling Cr
TRY258	330		138	42	16	0	65	17	2	13,435.86	35,323.72	2.6	Tryon Cr
Subtotal	742	0	318	43	14	0	66	14	6	29,935.89	80,199.89	2.7	
(SW Taylors Ferry Rd to SW Boones Ferry Rd.)													
TRY1340	780	75	167	24	0	0	92	2	6	61,123.74	49,705.77	0.8	Arnold Cr
TRY526	170		65	38	12	0	74	11	4	7,321.29	11,661.68	1.6	
TRY574	135		50	37	1	0	98	1	0	9,294.30	8,686.44	0.9	
TRY620	120		45	38	2	0	88	2	8	9,038.21	9,299.73	1.0	
TRY476	141		40	28	0	0	95	0	5	7,260.16	8,784.89	1.2	
TRY884	67		15	23	0	0	68	18	14	8,263.97	4,303.02	0.5	
TRY176	170		30	17	0	0	73	0	27	24,881.78	6,868.78	0.3	Direct Drainage
Subtotal	1,583	75	412	27	2	0	87	3	8	127,183.45	99,310.31	0.8	
(Downstream of SW Boones Ferry Rd.)													
TRY915	126		16	13	0	0	41	24	36	11,665.81	2,704.34	0.2	
TRY1310	68		8	12	0	0	65	0	35	5,164.07	1,418.45	0.3	
TRY1159	99		10	10	0	0	30	3	67	9,531.65	2,479.04	0.3	
TRY796	260	76	20	11	0	0	77	0	23	15,736.51	8,493.07	0.5	
TRY1199	128	126	0	0	0	0	99	0	1	2,965.59	69.99	0.0	
TRY1084	169	61	8	7	0	0	38	6	56	10,854.37	1,729.30	0.2	
TRY662	544	544	0	0	0	0	100	0	0				Nettle Creek
TRY1044	127	111	1	6	0	0	89	0	11	5,023.19	829.09	0.2	
TRY3	369	232	4	3	2	4	59	3	32	21,472.70	1,103.07	0.1	Direct Drainage
Subtotal	1,890	1,150	67	9	0	1	74	3	22	82,413.89	18,826.34	0.2	
Totals	4,216	1,225	797	27	3	<1	78	5	14	239,533	198,337	0.8	Watershed Totals

As shown in Table 4-9, the three major drainage areas exhibit different characteristics for the three indicators analyzed as follows:

- Drainage Area 1 - The land use within these subcatchments includes significant areas of commercial and multi-family zoning, in addition to the transportation system facilities. This includes both the I5 and Barbour Boulevard transportation corridors and adjacent developments. This drainage area has the highest impervious area percentage (43% average) within the watershed. The high degree of development is also indicated by the degree of piped stormwater systems in these subcatchments (ratio of piped to open channel systems = 2.7). All these measures indicate that development has highly impacted the hydrology in the upper watershed. This impact on hydrologic response will be further discussed later in this chapter, based on modeled flow results.

- Drainage Area 2 – The land use within this area is predominately single family residential (87%). The percent impervious area is much lower (27% average) compared to Drainage Area 1 upstream in the watershed. The lower degree of development is also reflected in the degree of piped stormwater systems in these subcatchments (ratio of piped to open channel systems = 0.8) which is over three times lower than Drainage Area 1.

- Drainage Area 3 – Sixty percent of this drainage area is outside the City of Portland. Land use within the area is dominated by parks and open space (Tryon Creek State Natural Area) and single-family residential development outside the City of Portland. Areas within the City have a very low percentage of impervious area (9% average) and few piped stormwater systems (ratio of piped to open channel systems = 0.2)

Overall the results of the GIS analysis show that major human influences on hydrology in the Tryon Creek Watershed are concentrated in the upper watershed. Because of this fact, analysis of hydrologic conditions and any desired modification to hydrologic conditions throughout the watershed will have to consider and address hydrologic conditions in the upper watershed.

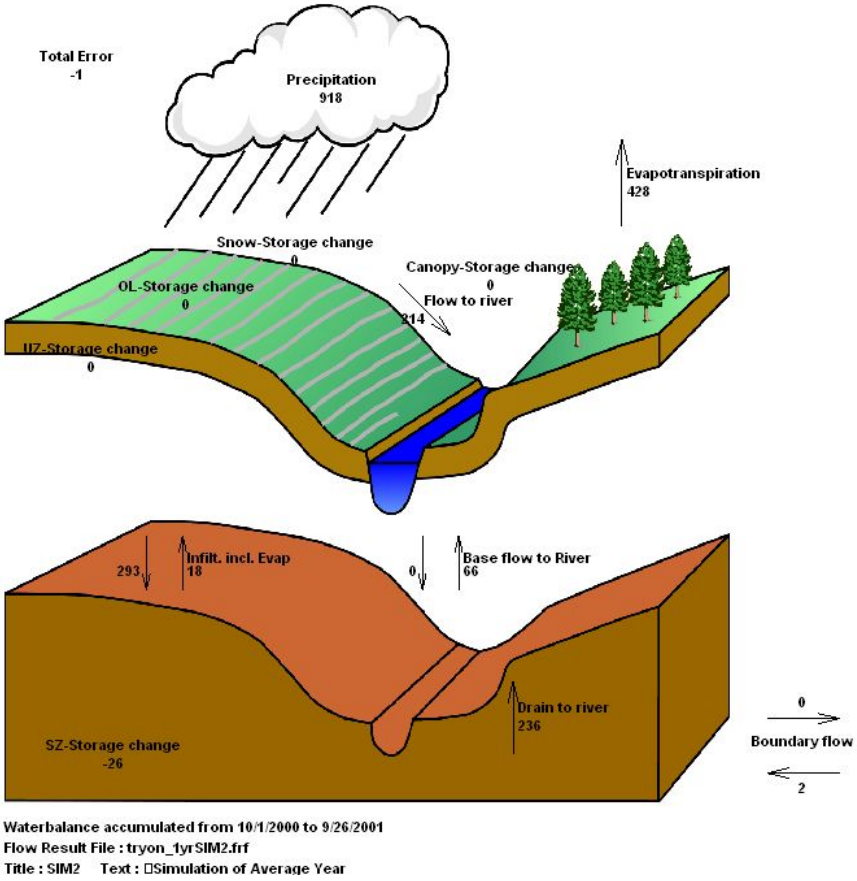
Typical Year Results

The Mike SHE/MIKE 11 model was run for the "typical year" rainfall record to evaluate hydrologic response in the watershed. Results of the modeling are discussed below.

Annual Water Balance

Figure 4-15 shows the annual water balance for the typical year rainfall. The results show that of the total annual precipitation, 23 percent is direct runoff to the stream, 26 percent drains to the stream as subsurface runoff, 47 percent is lost to evapotranspiration, and 7 percent drains to the stream as base flow during the year.

Figure 4-15
Annual Water Balance



Definition of the Terms in Water Balance Figure

Precipitation: Total precipitation falling in the watershed.
Canopy-storage change: Change in canopy interception storage, positive when increasing.
Evapotranspiration: Evaporation from canopy intercepted water (positive out) + evaporation from ponded water on ground + evaporation from oil (in unsaturated zone) + transpiration from root zone (in unsaturated zone) + evapotranspiration in saturated zone.
Snow-storage change: Not used in this study.
OL-storage change: Change in overland storage.
Overland boundary inflow: Potential flow into subcatchment or watershed.
Overland boundary outflow: Potential flow out of subcatchment + exchange from overland flooded areas to river outside the subcatchment.
Overland flow to river: Overland flow to river + overland flow directly to river (from paved areas) + exchange from overland flooded areas to river inside the subcatchment.
UZ-storage change: Unsaturated zone (UZ) and saturated zone (SZ) storage adjustment term (difference in unconfined storage capacity for UZ and SZ) + change in UZ deficit.
Infil. incl. Evap: Infiltration to SZ + UZ-SZ recharge – evapotranspiration from SZ (downwards arrow represents infiltration and other gains to SZ; upwards arrow represents loss from SZ).
Base flow to river: SZ aquifer inflow to river (upwards arrow) and river flow to SZ aquifer (downwards arrow).
Drain to river: SZ drainage flow (i.e., interflow) to river.
SZ-storage change: Change in SZ.

Annual Hydrographs

The annual hydrographs for the subwatersheds (Figures 4-16, 4-17, and 4-18) all show the same typical yearly runoff pattern, with frequent higher flows during the winter period and low summer flows. The hydrographs also show the fast system response to rainfall events.

Figure 4-16

Falling Creek Average Daily Flows

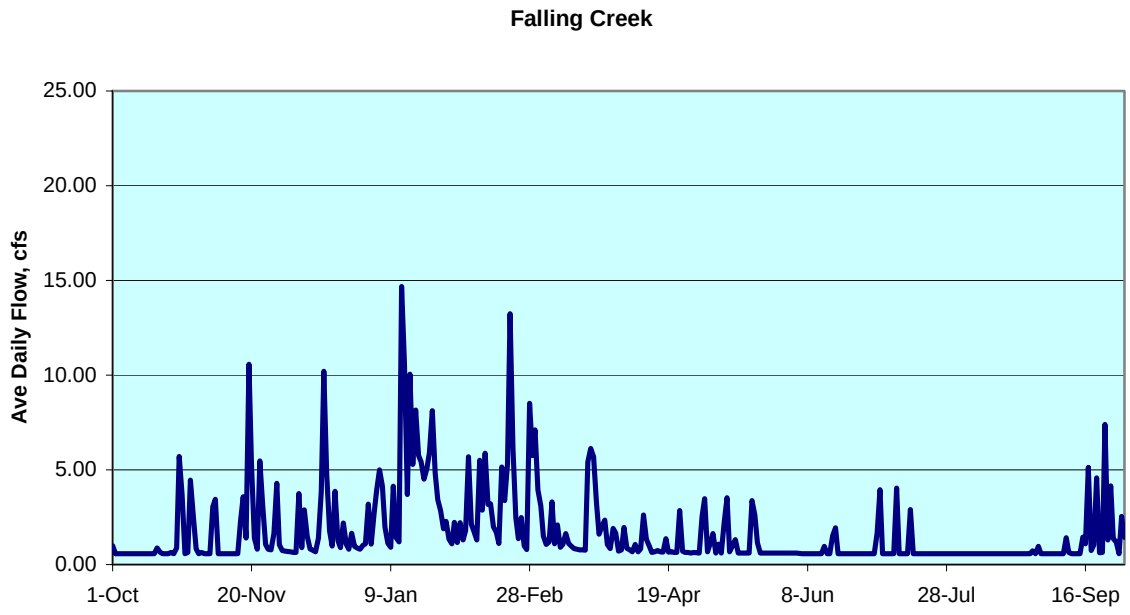


Figure 4-17 Arnold Creek Average Daily Flows

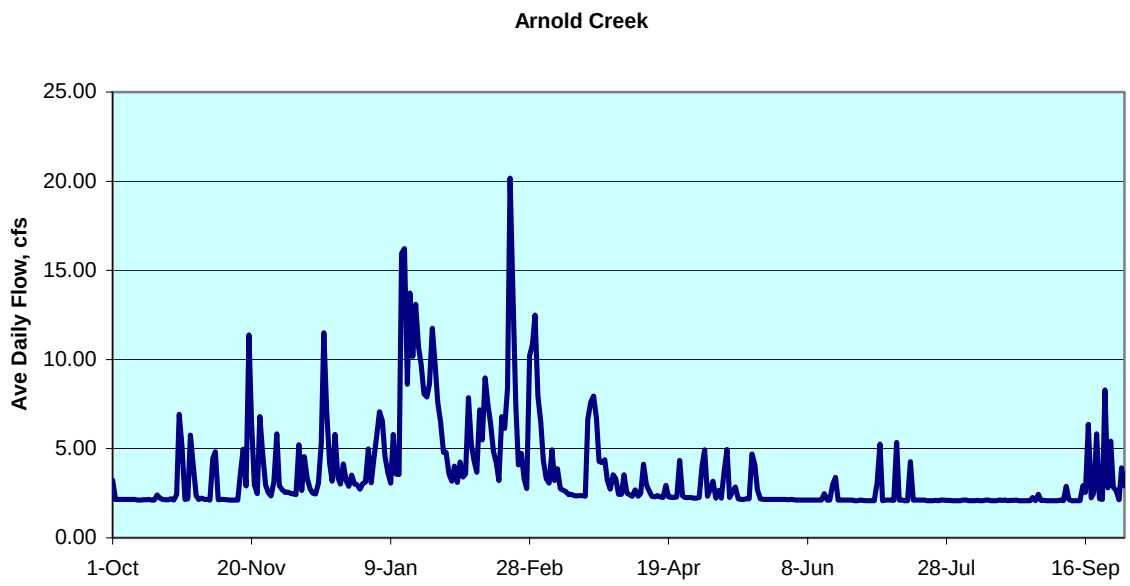
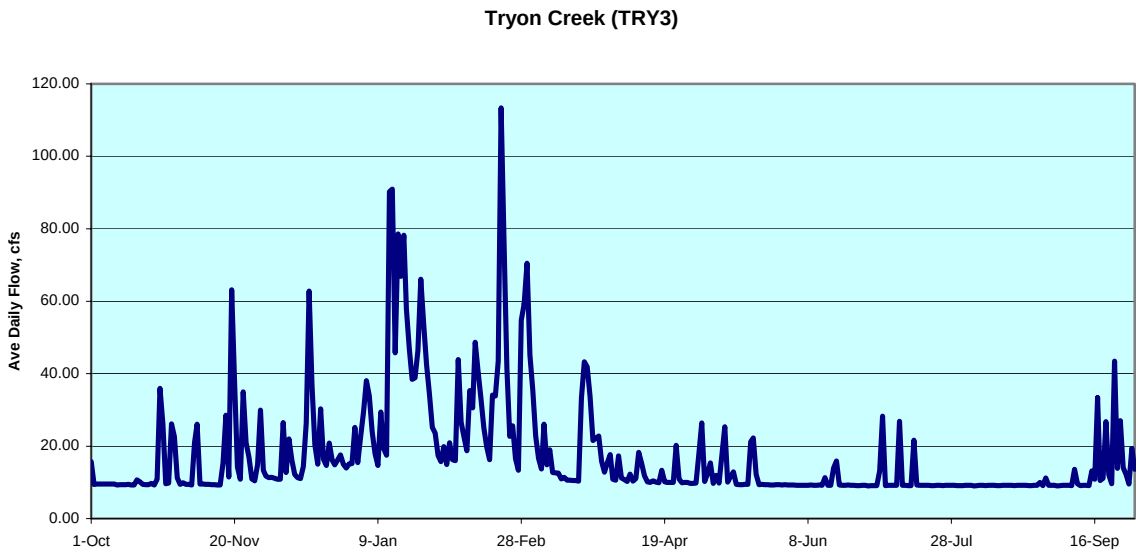


Figure 4-18
Tryon Creek Average Daily Flows



Average Monthly Flow

The average monthly flow charts (Figures 4-19, 4-20, and 4-21) also all show the same typical annual flow pattern. They also show the increased runoff rates during the later part of the wet season (December-February), as discussed previously under "Gaged Stream Flows."

Figure 4-19
Falling Creek Average Monthly Flow

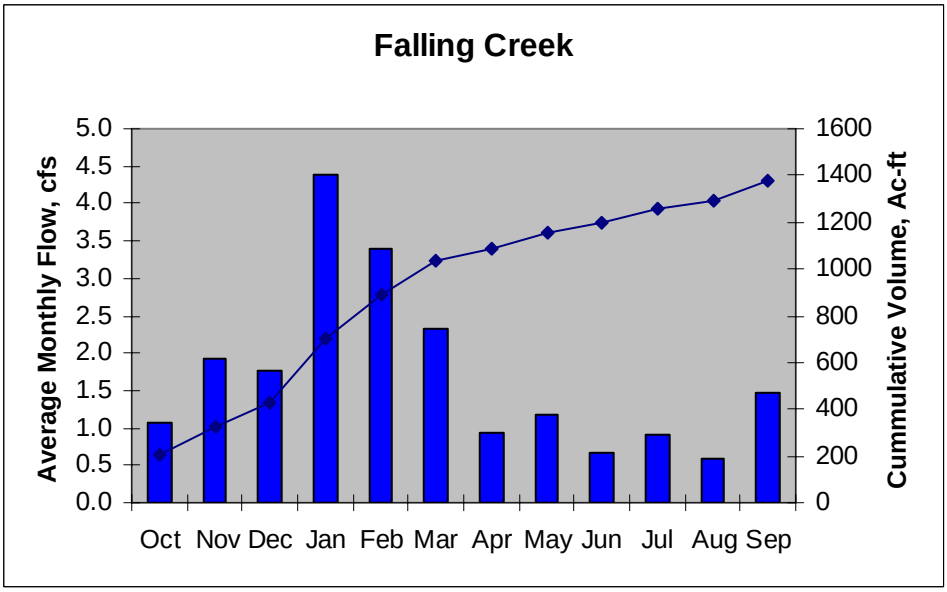


Figure 4-20

Arnold Creek Average Monthly Flow

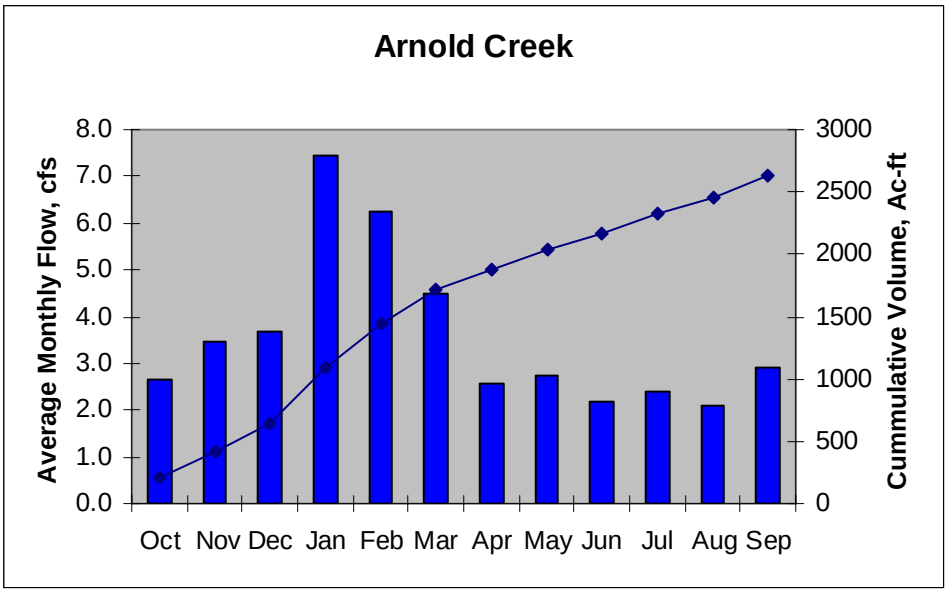
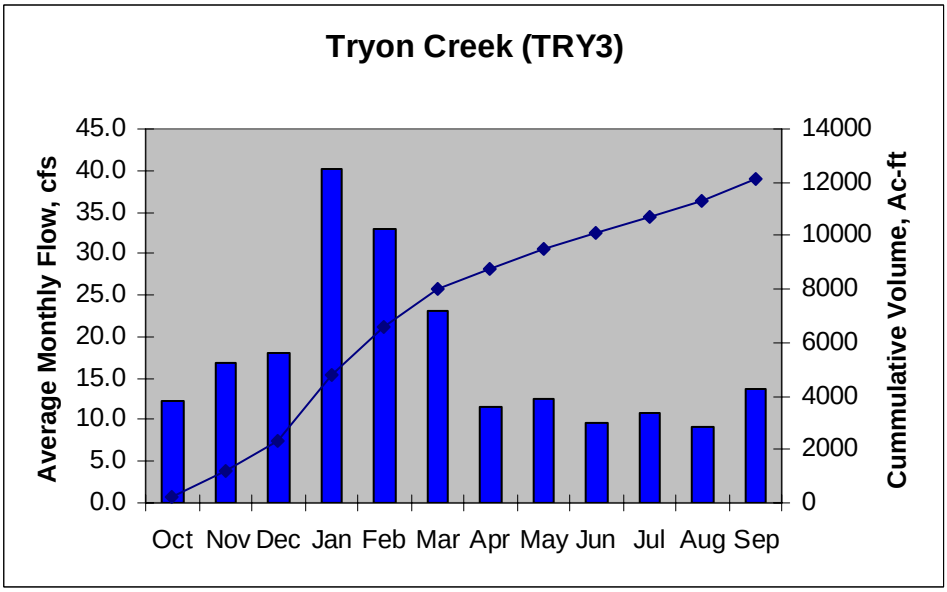


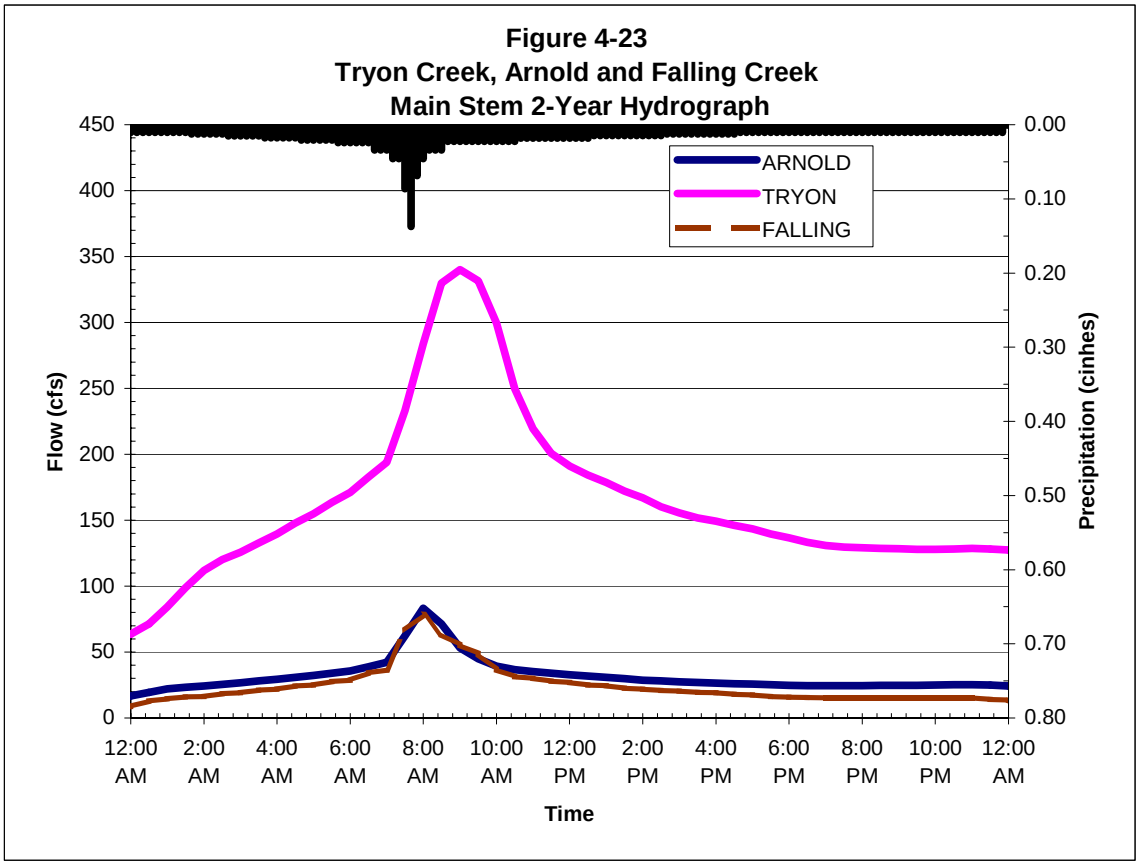
Figure 4-21
Tryon Creek Average Monthly Flow



Design Storm Results

The MIKE model was run for design storms with return frequencies of 2, 10, 25, and 100 years. Model results for key locations in the subwatershed were previously summarized in Table 4-10. Figure 4-23 shows the hydrograph for the 2-year storm.

As shown in Table 4-11, the volume of runoff (as measured by the runoff coefficient) and peak flows for the Falling Creek (TRY329) subbasin are approximately double those of the other locations in the watershed. This is consistent with the GIS analysis, which showed this subbasin to be the most highly impacted by development. The effects of the higher flows from the upper watershed are somewhat attenuated going downstream; however, they still clearly impact the hydrologic response in the lower watershed.



The hydrograph for the 2-year design storm shows the rapid response of the system to rainfall events and the high peak flows relative to base flow. Also, the peak flows for Falling Creek are approximately the same as those for Arnold Creek, even though the drainage area for Arnold Creek is twice as large.

SUMMARY OF FINDINGS

The hydrology of Tryon Creek and its tributaries is typical of low to moderate gradient Willamette Valley headwater streams with steep landscape slopes. The hydrologic response of the watershed has modified by the effects of development and urbanization with major factors including the following:

- Loss of native vegetation including mature forest cover.
- Increase of impervious surfaces.
- Construction of roads and streets including the I5 and Barbur Boulevard corridors.
- Construction of stormwater conveyance systems including storm sewer systems and culverts.

The development in the Tryon Creek Watershed is concentrated in the upper watershed and therefore affects the hydrology of the entire mainstem of Tryon Creek.

The annual hydrograph for Tryon Creek reflects the climatic precipitation pattern, with higher flows and frequent storm flow events during the wet period from approximately October through May, followed by lower flows during the summer dry period from June through September. Winter base flows average approximately 10 cfs with summer base flows of 1 cfs or less. The watershed also shows very quick, "flashy" response to storm events with instantaneous peak stream flows in the lower watershed as high as 30 to 40 times base flow. This flashy response is partially the result of the altered hydrology resulting from development in the watershed. The high storm even flows also contribute to streambank erosion, sedimentation and downcutting of stream beds in the watershed. Although not quantified, the summer base flows are probably lower then historic flows due to a decrease in groundwater imputs as the result of decreased infiltration of rainfall due to construction of impervious surfaces and stormwater conveyance systems.