Fauntleroy Creek
Channel Conditions Report
2001

Prepared for

Seattle Public Utilities

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1. INTRODUCTION

Objectives

A channel inventory of Fauntleroy Creek was undertaken as one part of a comprehensive watershed investigation of the present basin and stream channel conditions. This report documents the inventory of the channel and stream bank materials, geometry, and processes that influence the channel and riparian conditions. To provide guidance for future stream and watershed management this channel inventory has been combined with inventories of the stream habitat conditions, investigations of the culverts and culvert passage, and basin hydrology

Location

Fauntleroy Creek is located in west Seattle, Washington and flows from east to west into Puget Sound under the Fauntleroy ferry dock.

2. METHODS

Field work for the 2001 Fauntleroy Creek channel inventory was done July 9, 2001. The field team included Bruce Stoker with Earth Systems. The channel survey was done between the river mouth and the culvert at California Ave SW. The upper watershed was inspected but channel measurements were not made.

Incremental distances along the channel were measured with laser range finders and heights with a 5 foot walking stick marked in tenths of a foot. Distances less than about 45 ft and when in thick brush were measured with a laser that measured in feet and longer distances were measured with a laser that measured in yards. Culvert lengths were generally not measured.

2.1 FEATURE

Each row of the field log is for a feature. The main features inventoried were the left (LB) or right (RB) banks. The channel bed (Ch) is noted if different than the previous segment. The bank or channel data was often the same for consecutive reaches so arrows or lines note that the parameter continues.

Additional features that were inventoried included;

- Culvert, U/S or D/S end that the creek goes through
- Out-falls, any kind of a pipe into the creek
- Tributary Creeks
- Weir, Concrete
- Weir, Log Built
- Weir, Log Natural
- Weir Rock (built)
- Scour Areas
- Bridges
- Rip Rap
- Concrete Bed
- Encroachments
- Knickpoints
- LWD
- LWD Jams

2.2 GEOLOGY

The geology column indicates the classification of the bank material. The bank materials that typical flows and small floods come in contact with were classified. Often this was a drape of alluvium deposited against older alluvium, valley bottom glacial deposits, valley wall glacial deposits, or bedrock. When glacial units are identified it is because the channel flows over or directly against it.

2.3 MATERIAL

Letter codes were used for the dominant and sub-dominant substrate material. The dominant material was listed followed by a slash, than the subdominant and density.

- B Boulder
- C Cobble
- G Gravel
- Sa Sand
- Si Silt
- Cl Clay
- Organic detritus

2.4 DENSITY

This is a general field test of the compactness of the material noted in the feature column.

- Loose (L) - easily disturbed by hand. Typical of alluvium, colluvium, recessional outwash, and fill

- Medium Dense (MD) - difficult to disturb by hand and can be easily disturbed by a pick or small shovel and mostly breaks into a loose mixture of material. Typical of older alluvium and compacted fill.

- Dense (D) - Difficult to excavate with a pick or shovel and tends to break into chunks not loose material. Typical of advance outwash, lake sediments, and till.

- Very Dense (VD) - A pick or small shovel has a very hard time excavating and mostly just dents or scraps the surface. Typical of over-consolidated deposits with higher clay content including lake sediments and till.

The density of bank materials relates to how fast they can erode. Very dense material is almost like concrete or rock and is difficult to excavate with a shovel, loose material is easily excavated.

Erosion rates of very dense bank material is limited whereas loose bank material can quickly erode. Along Fauntleroy Creek the Vashon tills and lake bottom sediments are typically dense to very dense, the older alluvium, advance outwash, and older fill deposits are typically medium dense, and the recessional outwash, recent alluvium, and most fills are loose.

2.5 GRADIENT

Gradient was not field measured on Fauntleroy Creek.

2.6 CHANNEL GEOMETRY DATA

The standard "Bankfull Depth" is not quite as well applied to highly disturbed urban streams. They often have been forced away from a natural alluvial self-forming condition and it is not clear what the banks really indicate. Therefore, the basic geometry of the channel was inventoried and when it was felt that the bank level indicated a bankfull depth or width for the non-constrained alluvial channel sections.

Active Cannel Width

The active width is usually apparent by the presence of unvegetated or sparsely vegetated bars and banks up to some level, sometimes it does include sparse annuals or berry bushes. The active channel width ends where trees start. Area within the active channel width would not have a soil zone and typically would have no more than 2 – 4 years of litter.

Full Width

The full width notes our best field estimate of how wide the flood zone is under current conditions. It was not always possible to estimate the full width because of rip rap, fills, and lawns along the channel. Encroachments into this zone were noted.

Bar Height

The maximum height of the main body of the channel bars were recorded.

Bank Height

This is the height above the typical channel bed level of the first step above the bar tops or channel substrate. Terrace levels record additional steps above this first one.

Bank Angle

The angle of the bank was measured with an inclinometer or estimated based on nearby measurements. The angle measurement was for the typical bank angle for the channel segment. Angles over 90-degrees indicate an undercut bank. Undercut banks were also noted in the field logs.

Terrace Height

The heights above the channel bed of one or more terrace levels were measured when observed.

2.7 MONTGOMERY AND BUFFINGTON CLASS

Montgomery and Buffington (1993) developed a classification of channels based on process-based landscape and channel conditions. The six alluvial channel types were used to classify channel reaches;

- Cascade
- Step-Pool
- Plane-bed
- Pool-riffle
- Braided
- Regime

2.8 CHANNEL STABILITY CLASS

Channel stability class is a general index of the channel condition modified from Henshaw (1999). Because armored banks are so common armored is added as a separate class.

ARMORED
- Stream banks and/or stream bed have been armored with rip rap or other resistant material

4 STABLE
- perennial vegetation to waterline
- no raw or undercut banks (some erosion on outside of meander bends OK)
- no recently exposed roots
- no recent tree falls

3 SLIGHTLY UNSTABLE
- perennial vegetation to waterline in most places
- some scalloping of banks
- minor erosion and/or bank undercutting
- recently exposed tree roots rare but present

2 MODERATELY UNSTABLE
- perennial vegetation to waterline sparse (mainly scoured or stripped by lateral erosion)
- bank held by hard points (trees, boulders) and eroded back elsewhere
- extensive erosion and bank undercutting
- recently exposed tree roots and fine root hairs common

1 COMPLETELY UNSTABLE
- no perennial vegetation at waterline
- banks held only by hard points
- severe erosion of both banks
- recently exposed tree roots common
- tree falls and/or severely undercut trees common

2.9 CHANNEL EVOLUTION STAGE

Stages of channel evolution were modified from Henshaw (1999) (Table 2-1). Henshaw's approach was a modification of Simons (1995) (Appendix B).

Table 2-1. Stages of Channel Evolution. Modified from Henshaw's 1999 summary of Simons' stages. The letter "f" following the numeric stage (e.g., "4f") indicates that bank armoring has frozen the channel in place and halted further evolution.

Stage	**Characteristics**
1 Pre-modified	Natural channel, stable banks with minimal mass wasting, width/depth ratio 6-10, established woody vegetation.
2 Constructed	Dredging and/or straightening of channel
3 Degradation	Rapid bed erosion, bank heightening and steepening
4 Degradation & Widening	Active channel widening, bank scalloping, further heightening and steepening of banks; landsliding may occur
5 Aggradation & Widening	Onset of bed aggradation, creation of bars, low angle surfaces from upper bank, woody vegetation reestablishes on low angle area; active bank erosion; continuous alluvial bed
6 Restabilization	Reduction of bank heights by aggradation of bed and lower banks, woody vegetation extends upslope narrowing active channel width

2.10 EROSION

Erosion Type

Significant sources of sediment to the channel were noted. The material being delivered and density is listed back in the material type.

- Bank Erosion (Bk),

- Landslides (Ls)
- Ravines (RV)

Erosion Activity

The erosion activity level/age was used to give some since of the magnitude or age of erosion. If an age could be estimated based on vegetation or other indicators it was noted. Otherwise relative terms of slight, moderate, and active were used.

2.11 NOTES

Typical or site specific cross sections, samples, photographs, or notes are listed in the last column.

- Cross Section #
- Sample #
- Photograph #
- Note#

3. GEOLOGY

3.1 GEOLOGY

Fauntleroy Creek and its tributaries flow over glacial sediments deposited during the most recent glacial advance into this part of Puget Sound, the Vashon Stade of the Fraser Glaciation (Armstrong and others 1965; Booth 1987; Yount 1993). In general, the Vashon glacial sediments occur in a layer sequence common throughout the Puget Lowland.

Glacial lake clays and silt deposited in front of the advancing ice once the Strait of Juan De Fuca was blocked. As the ice advanced closer advance outwash, typically consisting of fine to medium sand at first, and often grading upward to coarser sand and gravely sand was deposited. Eventually the ice overran the Seattle area and deposited a dense poorly sorted lodgment till over the surface of the advance outwash. As the ice melted away recessional outwash, from rivers flowing off the receding glacier, eroded into the earlier deposits and deposited river sands and gravel.

The main geologic units in the Fauntleroy watershed are:

Modified Lands - Extensive filling and grading has occurred along lower and middle Fauntleroy Creek. The entire area from downstream of Fauntleroy Way SW to the upstream end of the culvert at California Ave SW has been modified by excavation, grading, and fill. Fill is generally loose to medium dense, poorly sorted, with a mix of local materials.

Historic Alluvium - recent, loose, poorly to well sorted, sand and gravely sand deposited by the present river channel. Deposits are generally only 0.5 ft to 3 ft thick in a narrow strip along the river channel. The alluvium is derived from upstream transport and bank erosion. The streambed is dominantly sand to gravely sand. The narrow Fauntleroy Creek floodplains are composed primarily of sand and silty sand. The current stream bed alluvium formed in the past few hundred years and is generally limited to the confined present-day migration zone. The young alluvium forms the present floodplain and the first terrace typically between 1 ft and 3 ft above the channel.

Young Alluvium – Exposures of loose to medium dense, sand and gravely sand alluvium along the current channel are from the pre-development creek or formed in graded and filled creek side areas. They form terraces typically between 3 ft and 4 ft above the channel. Older alluvium likely exists along the channel but was not recognized because of extensive grading and filling that has occurred since about 1910.

Mass Wastage – recent to ancient loose to medium compact deposits from landslides and hillslope erosion off of scarps, cliffs, and steep hillslopes.

Beach Deposits – present day beach deposits of loose sand are found along the shoreline and worked by tidal and storm currents and waves.

Uplifted Beach Deposits – older sand and gravely sand deposits along the shoreline that have been raised above the present tidal zone by tectonic uplift and glacial rebound.

Colluvium – covers the valley walls in most locations. Colluvium is material derived from the hillslope and moved downhill by gravity. Colluvium is of a similar age to the historic to older alluvium and is often inter-mixed with layers deposited from landslides.

Recessional Outwash - Loose to medium compact, mostly stratified, moderately to well sorted sand and sandy gravel. Recessional outwash is found along the lower and middle reaches of Fauntleroy Creek.

Glacial Till (Vashon till): a poorly sorted mixture of sand, silt, clay and gravel deposited by the glacier. Till deposits were overridden by the ice, forming a dense to very dense consistency. It is compact to very compact due to the weight of the overriding ice, erosion resistant and nearly impermeable to water. Till is exposed on the tops of the valley walls around Fauntleroy Park and along the streambed in the lower channel where the creek has eroded through the recessional outwash.

Advance Outwash (Esperance sand): medium dense to dense, well to moderately well sorted mostly sands and some gravel deposited by rivers emanating from the advancing glacier, then overridden and compacted by the glacier. Although dense due to the glacial consolidation, it is generally permeable, non-cohesive and easily eroded by flowing water or once disturbed. The contact with the underlying lake sediments is typically transitional, with alternating beds of sand and silt.

Glacial Lake Sediment (Lawton Clay): laminated, dense to very dense, gray silts and clay deposited in a proglacial lake, then overridden and compacted by the glacier. Although compact and fairly resistant to erosion by flowing water, the clay and silt beds are prone to landsliding due to their high moisture content and plasticity. Landslides often occur at the contact between the advance outwash and lake clay deposits.

Pre-Fraser Deposits – the Pre-Fraser deposits from the Olympia nonglacial interval prior to the most recent glacial advances. Most of the valley floor of Fauntleroy Creek has not been eroded deep enough to expose these older deposits. They are likely found subsurface beneath the beach and outwash deposits at the creek mouth. They are typically very dense weathered red-brown cliff forming deposits located inland from the present and raised beach deposits.

Channel Sediment Supply

Most of the sediment supply to Fauntleroy Creek is from mass wasting of the steep valley walls of the upper basin. Surface erosion off landslide scars, valley walls, and trails is a secondary sediment supply source.

The hillslopes along Puget Sound are eroding away by mass wasting and surface erosion. The steep slopes have deep-seated and shallow landslides, both recent and ancient. The contact zone between the Esperance Sand and underlying relatively impermeable silt and clay of the lake sediments are typically saturated with groundwater. This contact is the location of frequent landslides (Wilson 1989, Tubbs 1974). In the Fauntleroy valley this contact marks the end of the main channel where the creek branches into 4 tributary ravines eroded into the glacial advance outwash and glacial till cap.

Erosion of the upper valley walls is controlled by the denser glacial till unit that is now also the main source of gravel to the creek. The contact between the advance outwash sands and glacial till is often expressed as scarps and steep slopes with down slope loose and shallow to relatively thick colluvium and mass wasting deposits. This contact is often a source of coarse sediment including sand, gravel, cobbles, and boulders.

Erosion off the upper valley walls by mass wasting, surface erosion, and soil creep moves debris eroded from the advance outwash and till contact down slope to the creek. It takes a larger flood to move the gravel patches compared to the abundant sand in the channel. There is a lot more sand in the lower creek channel because there is more erosion and delivery of sand from the advance outwash deposit that dominants the valley walls and this sand is more easily transported through the middle reaches to the lower valley bottom and coastal zone.

Below Fauntleroy Park the creek eroded through Vashon recessional outwash that formed the dominant valley wall material in the lower valley. Erosion of the original valley wall colluvium and outwash by the meandering creek was probably a source of gravel to the lower creek prior to restructuring the valley bottom and walls.

4. CHANNEL MORPHOLOGY

4.1 CHANNEL CONDITIONS

The primary changes to Fauntleroy Creek are the extensive valley filling in the middle and lower reaches. The Fauntleroy Park area leaves most of the steep tributary ravines fairly well forested with some LWD supply to provide channel structure and sediment storage.

Trees growing out of the channel and channel banks and tree falls provide structure to the channel. The channel structure formed by trees and fallen logs stores sand and gravel along the channel and provides a stable profile during storm flows. The park area has moderate amounts of channel structure provided by trees and fallen logs, but could use more in local areas.

If the floodway is wide enough, sand and gravely sand transported down Fauntleroy Creek forms into bars with a low flow channel that meanders around them. The bars form the stream bottom shape that creates the riffles that form the classic riffle:run:pool pattern important to aquatic habitat. As the channel is confined to the point where flood flow conveyance is reduced, higher velocity and water depth washes out the bed into a smoother profile and cross section with more glide habitat. Most of the valley bottom in the upper basin is confined so adequate LWD and mature bank trees are very important in holding the channel together and preventing deep and often rapid channel incision and related bank slumps.

4.2 CHANNEL CONDITIONS BY REACH

F1 The Beach

Fauntleroy Creek flows across a raised relatively low gradient beach below the Fauntleroy Way SW culvert. The first 140 feet of the channel flows inside and parallel to the present beach deposit. The creek flows towards the low area under the ferry dock. The location that the creek breaks through the beach deposit changes from year to year as beach sands are altered with tides, waves, and floods. At low tides and during low flow periods portions of this reach could be very shallow or subsurface.

F2 Lower Fauntleroy Creek

The Pre-Fraser deposits form a scarp along much of the shoreline. Starting at the Fauntleroy Way SW culvert the creek formally traversed what was likely a higher gradient reach where it flows over the dense Pre-Fraser deposit before hitting the nearly level raised beach area. This reach is built fairly straight along most of it's length. Sand dominates the channel bed because it is the main upstream source. Rock weirs built in this reach provide good channel structure. A few more could be built along with a few bends in the channel.

F3 Fauntleroy Way SW Culvert

F4 Fish Ladder

F5 Middle Reach

Log weirs and bank vegetation added above the fish ladder are providing good channel and bank structure in the lower portion of this reach. Prior to clearing of the original forests small creeks like this had trees and tree roots on the floodplain and channel banks and right in the channel. Additional logs and stream bank vegetation could be added in the upper half of this reach with emphasis in adding trees to the stream banks.

F6 45th Ave SW Culvert

F7 Kilbourne Park

Additional logs and stream bank vegetation could be added in the upper half of this reach. The steep fill or excavated valley walls at the upper end of this reach were likely a sediment source from surface slides and are now covered in dense blackberries. Streambanks and valley walls could benefit from a revegetation plan to restore trees and native brush. Most of this reach was filled for roads and parking.

F8 California Ave SW Culvert

F9 Lower Fauntleroy Park

Above the valley bottom fill of Reach F4 the creek is in Fauntleroy Park and is in fairly good condition. There are a few areas with local incision that could use additional log weirs but some areas of erosion is needed to refresh the sediment supply downstream. Additional trees could be planted in and on the channel streambanks.

Reach F5 ends where the channel branches into 4 separate ravines. This is also the long-term knickpoint of channel erosion (Appendix B) that is controlled by the dense and cohesive glacial lake bottom sediments that form the valley bottom in the lower part of the park. Above this reach the flows are divided and much lower than downstream. A lower gradient portion of this reach is caused by deposition of sediment from the upstream source areas.

F10 Middle Fauntleroy Park

The main channel continues across a wet area created by the lake bed and advance outwash contact. Slope deposits fill the valley bottom and the presence of some LWD helps hold the sediment in place. This reach is in fairly good conditions but could use some additional bank trees and channel logs. Reach F6 ends where the channel gradient increases on the upper valley walls.

F11 Upper Fauntleroy Park Ravine

The upper valley walls are steeper because of the more resistant till that caps the erosive advance outwash unit. The mainstem and tributary channels were probably swales with limited surface flow prior to development. Landslides from this portion of the valley are common because of the steep slopes and concentrated storm runoff that makes its way over the side. Side casting of yard wastes, loss of valley edge vegetation, and discharge of flow over the valley walls should be avoided because it can lead to excessive landslides that are costly to repair. Runoff concentrated by trails can also lead to riling and surface slumps during storms.

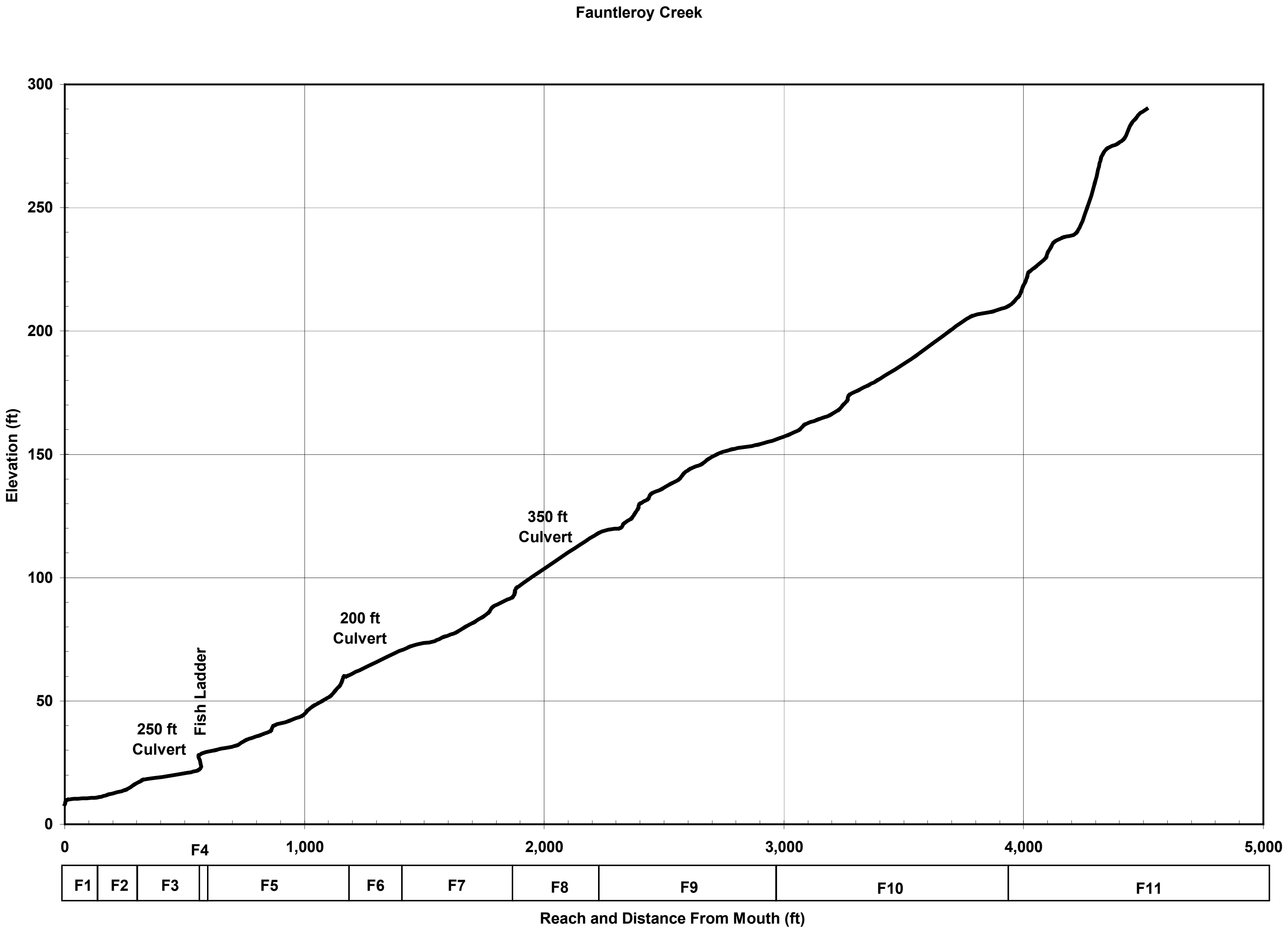

Figure 4-1. Fauntleroy Creek Channel Profile

Table 4-1. Fauntleroy Creek Channel Morphology By Reach

Reach	Reach Name	Geologic Unit	Length (ft)	Gradient %	Active Width (ft)	Entrenchment (Appendix B)	Confinement	Terrace Heights (ft)	Channel Types (1)
F1	Beach	Recent Beach and Tidal Zone	140	1 - 2	5	Not Entrenched	Partly Confined	N/A	Braided to Plane bed
F2	Lower Fauntleroy	Uplifted Beach and Fill	167	2 - 5	4 - 5	Not Entrenched	Unconfined	4	Plane bed
F3	Fauntleroy Way SW Culvert	Fill underlain by advance outwash or Pre-Olympia Glacial Deposits	250						
F4	Fish Ladder	Same as F3	93		5				
F5	Middle Reach	Modified Land and Recessional outwash	880	3 - 10	3 - 9	Not Entrenched	Confined	3, 4	Pool-riffle, Step-pool at ladder and weirs
F6	45th Ave SW Culvert	Modified Land and Recessional outwash							
F7	Kilbourne Park	Modified Land and Recessional outwash	438	4 - 7	4 - 7	Not Entrenched	Confined	3, 4	Pool-riffle
F8	California Ave SW Culvert	Modified Land and Recessional outwash	350						
F9	Lower Fauntleroy Park	Lawton Clay	795	5 - 10	4 - 7	Slight	Confined		Pool-riffle, Step-pool
F10	Middle Fauntleroy Park	Advance Outwash	969	3 - 7			Confined		Pool-riffle, Step-pool
F11	Upper Fauntleroy Park Ravine	Vashon till	532	10 - 30			Confined		Step-pool

Table 4-2. Fauntleroy Creek Channel Stability, Geology, and Sediment Supply

Reach	Stability Class	Bank Condition	Substrate	Evolution Stage	Geology along Channel	Sediment Sources
F1	1	Beach Sand	Sand and Gravel	Natural	Beach	Upstream and Longshore
F2	4	Beach Sand and Alluvium	Sand and Gravel	3	Fill and Alluvium	Upstream and Banks
F3	3 - 4	Alluvium and Till	Sand and Gravel	1 lower part, 3 upper	River alluvium, Till, and fill	Upstream and Banks
F4	4	Alluvium and Fill	Sand and Gravel	5	River alluvium and Fill	Upstream and Banks
F5	4	Alluvium	Sand and Gravel	Natural	River alluvium, Slide debris, Colluvium	Upstream and Banks
F6	3	Alluvium	Sand and Gravel	Natural	River alluvium, Slide debris, Colluvium	Upstream and Banks
F7	2	Alluvium	Sand and Gravel	Natural	River alluvium, Slide debris, Colluvium	Banks

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APPENDIX A

Channel Entrenchment, Confinement, and Evolution Stage

Channel Entrenchment and Confinement

As channels cut down, they become separated from their floodplains. The channel becomes entrenched between the remnants of the former floodplain, forming terraces that are no longer flood prone. Terraces are common on many creeks but are limited in Fauntleroy Creek because of the confined valley bottom, active slope processes, and the dominance of groundwater runoff. The first set of terraces in Fauntleroy Creek are 3 to 4 ft high (Table 4-1). In contrast to the terraces, the floodplains are generally no more than 1 ft to 1.5 ft above the channel bed.

Once entrenchment occurs, flows can no longer spread out across the floodplain. This concentrates the stream energy in the main channel often leading to erosion the bed and banks. During the later stages of channel evolution, entrenchment lessens due to bank erosion of a wider floodway confined within the terraces. The entrenchment ratio method developed by Rosgen (1996) was modified for this analysis by using the ratio of the full width to the active width (Section 2). The full flood flow width was sometimes quite easy to estimate but often lawns and rip rap banks combined with the increased flood peaks make estimating a "bankfull" width impractical for highly modified urban creeks.

Knickpoints and Grade Controls

Knickpoints (also called headcuts) are an abrupt change in channel gradient within the channel profile (Figure 4-1). Knickpoints formed of erodible material migrate upstream, which causes the bed elevation to drop abruptly. Upstream passage of a knickpoint can transform the channel from a relatively wide, shallow shape to a narrow, deep shape with steep, eroding bank. The long-term (thousands of years) erosion into the glacial valley floor of Fauntleroy Creek, up to about SW Orchard St., is the only apparent knickpoint. Other knickpoints were not obvious in Fauntleroy Creek, probably because the lower channel is locked in between grade controling culverts and the upper basin has active valley wall slopes supplying sediment to the narrow valley bottom.

Grade controls are erosion-resistant features that prevent (or greatly slow) degradation of the stream bed. Several types of grade controls exist in the Fauntleroy Creek watershed:

- Culverts at road crossings are the most common and stable grade controls.
- Concrete lined portions of the channel form a grade control.
- Resistant glacial substrates like till and glacial lake clay beds form fairly effective grade controls, although slow channel incision and movement of knickpoints can occur. These materials occur in the bed in parts of Fauntleroy Creek.
- Boulders can form stable steps in steeper channels with step-pool and cascade morphology. Boulders and blocks are often used to construct rock weirs for effective grade control.

- Log jams and single spanning logs can provide grade control if enough large wood is present. LWD grade controls can sometimes be quite transitory, however, since they may fail due to floating, decay, or undermining from downstream erosion. When a LWD jam fails, it becomes an unstable knickpoint that can cause rapid degradation of the channel upstream. Natural streams with abundant rock or LWD steps can be quite stable. Steps in the channel profile dissipates the energy of falling water limiting erosion to the plunge pool between steps.

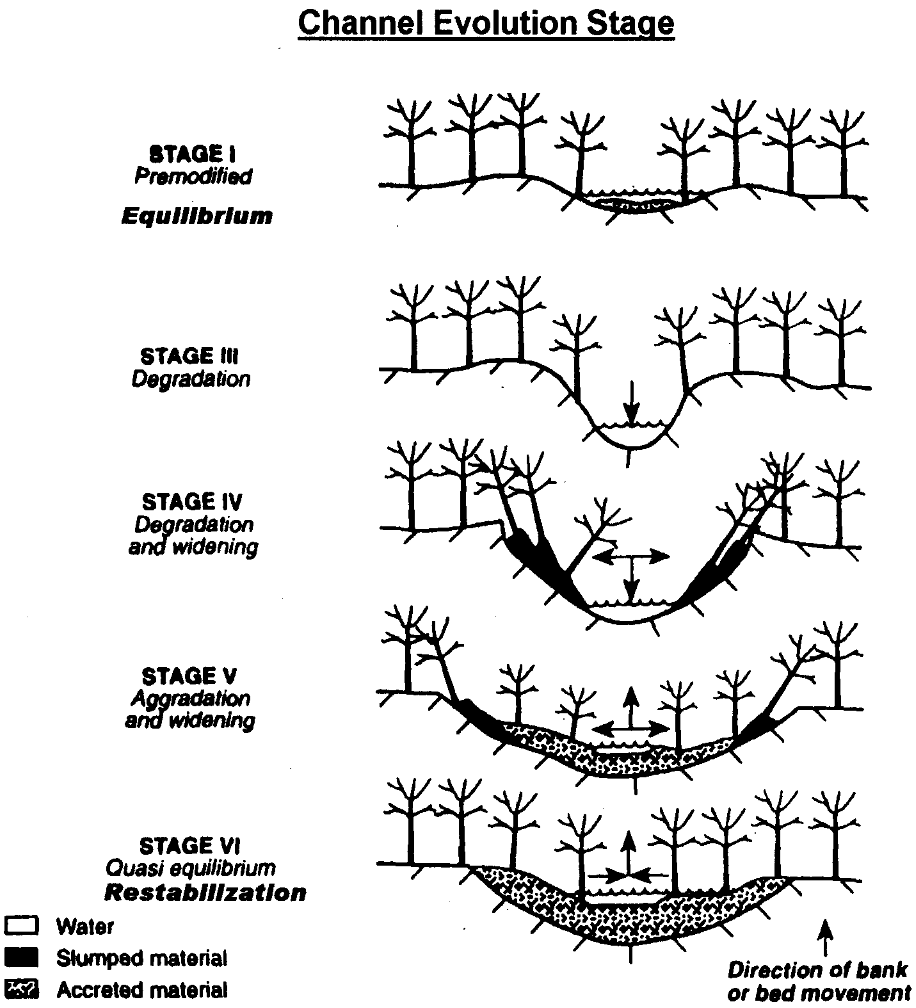
Channel Evolution Stage

Channels that experience downcutting (incision) go through a rather predictable evolution of forms until they restabilize. Conceptual models have been developed to explain a channel's response to downcutting by dredging (Simons, 1995) (Figure A-1) or to channel incision for a variety of reasons (Harvey and Watson, 1986) (Figure A-2).

In the case of response to a single disturbance (in this case incision due to flow increases), each point in the channel will tend to progress from stage 3 to stage 6 over time. Downcutting (stage 3) destabilizes the channel walls, which fail in a variety of possible ways depending on the geology. Bank failures widen the channel (stage 4) and produces sediment. Eventually the channel becomes wide enough that the stream can no longer transport all the eroded sediment while continuing to erode its bed downward. This tips the balance to aggradation (stage 5). Widening continues until the banks reach a stable angle. Sediment from upstream erosion is deposited in bars that protect the steep banks. Eventually vegetation grows on these bars, forming a new floodplain adjacent to the restabilized channel (stage 6).

If all other factors are equal, there should be a general progression from earlier to later stages as one moves down the channel network. This occurs because 1) upstream erosion generates sediment that deposits downstream, causing aggradation and 2) downcutting destabilizes the bed upstream, causing headward (upstream) erosion of knickpoints. This is illustrated in the channel evolution model by Harvey and Watson,1986 (Figure A-2).

Figure A-1. Channel Evolution Stages, Simons Model

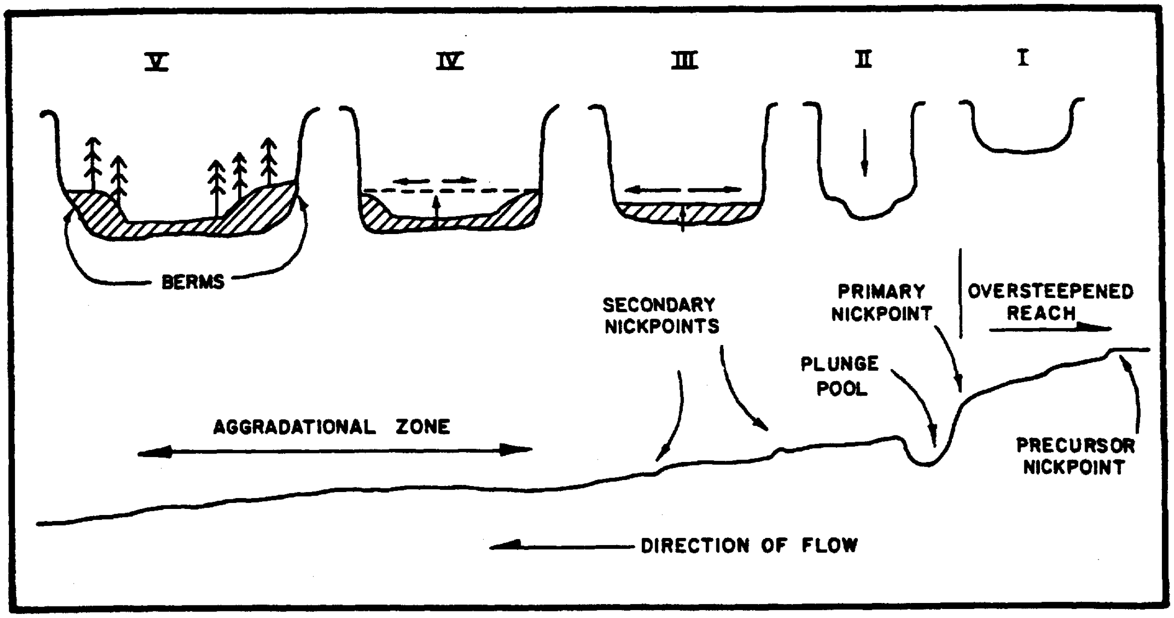


Channel Evolution Stage

From Simons, 1995

Figure A-2. Channel Evolution Associated with Upstream Migration of Knickpoints, Harvey and Watson Model

Modified from Harvey and Watson (1986). Schematic diagram of the channel evolution model developed for Oaklimiter Creek, Mississippi. Changing cross-section morphologies along the longitudinal profile represent the five reach types (I to V) in the model. The arrows show the direction of the dominant change in each of the cross sections.



Channel Adjustment Time

In the Fauntleroy Creek watershed the creek have had over 100 years in which to adjust to the probable flow increases from logging, grading, and urban development. Channels adjust to increased flows in several ways: downcutting, armoring of the bed (if coarse material is available), bank erosion, and formation of a new floodplain in locations where the valley is wide enough (Figure B-1). Eventually, these adjustments lead to a coarser bed with a flatter gradient and wider channel, in equilibrium with the increased flows. The stream has then obtained a stable shape that is capable of transporting more water and sediment than the original channel. Several studies have investigated the time needed for channel adjustment to occur.

Henshaw (1999) investigated the long-term response of channels to urbanization in seven small watersheds in the Puget Sound Lowlands. She found that:

In general, Puget Sound lowland streams are likely to restabilize within one or two decades of constant land use in the watershed, and possibly even more rapidly. However, when (and if) an *individual channel will restabilize depends on hydrologic and geomorphic characteristics of the channel and watershed. The extent of hydrologic change and the responsiveness of the channel and watershed, as characterized by geology, local grade control, and riparian corridor conditions, appear to be the important controlling factors.*

Henshaw's stability evaluations were based on surveyed cross-sections in low-gradient channels (0.1% to 1%) near the downstream end of each watershed. This would be equivalent to evaluating the stability of the lower end of Fauntleroy Creek. She did not investigate channel stability in ravine sections farther upstream, where adjustment can take longer.

Booth (1989) indicated that channels in ravines may take much longer to recover:

Stream channels respond rapidly to basin urbanization…the channel itself may re-equilibrate with the increased flows within a few years. Yet the hillslope failures resulting from increased bank undercutting may not achieve an equivalent, pre-development rate for decades or perhaps centuries following even a single episode of channel enlargement.

Booth and Henshaw (2001) tracked rates of channel cross-section change for up to 11 years in Puget Sound Lowland channels in steeper channels (1.3 % to 52 %). They found that the average rate of channel change typically varied about 5-fold between years, depending upon how dry or wet the winter was. This inter-year variation was so large that no stabilization trend would have been noticeable within the 2- to 11-year monitoring periods. The authors noted that headward migration of a knickpoint can destabilize a particular site again after a long period of apparent channel stability.

Booth and Henshaw found that virtually all cases of extreme incision occurred in channels flowing over outwash sand that is non-cohesive and easily eroded. Incision is particularly severe in sandy outwash that lacks gravel and cobbles to armor the bed (Booth, 1989).

Studies from elsewhere in the US have documented the time needed for channels to restabilize after initial incision. In Mississippi, where incision was caused by channelization in downstream reaches, it was found that a given stream reach would progress from initial incision to a state of quasi-equilibrium in a 9 to 15 year period (Schumm et al., 1984). If repeated events leading to incision occurred, this progression could be interrupted by the upstream progression of new headcuts (Figure B-2). Since incision proceeds upstream, an entire watershed takes much longer than 15 years to adjust to initial channel incision low in the watershed. For instance, studies in the Chaco Canyon area of New Mexico suggest an adjustment time of 50 to 100 years, following initial incision caused by grazing and drought (Schumm et al., 1984).

The findings of this study, together with the studies cited above, suggest Fauntleroy Creek channel is moderatly stable with the main destabilizing factor being response to occasional landslides from the steep valley walls into the confined valley bottom.