2.6. CONCLUSION

The dense native vegetation originally present in the Lower Green River valley has been extensively modified over time, beginning with European settlement, and continuing with agriculture, industrialization, and construction of flood control facilities. Today, the river is characterized by some natural banks with a mix of native and invasive vegetation, rock-armored banks constructed mostly before 1990, and bioengineered repair sites that have vegetation incorporated as a bank stabilization design element.

Levee vegetation management practices along the Lower Green River have changed dramatically over time from mowing of primarily invasive vegetation on armored banks, to a more hands-off approach with incorporation of native vegetation into bank repairs, to selective tree cutting, willow thinning, and more extensive mowing in response to PL84-99 policy and maintenance requirements. King County declined to remove native trees and willows from the levees for several years, but since 2006, has removed several hundred trees and over 1,000 linear feet of willows. Regular mowing, in addition to rock armoring, has likely precluded establishment and growth of native vegetation on the sites that have not been repaired using bioengineering practices.

Approximately 20 levee projects were constructed and planted in the Lower Green River within the past seven years. Tree planting was included as a state permit requirement for most of these projects (some federal projects also required Endangered Species Act Section 7 consultation), and permits specify survival and percent cover performance standards. Though the majority of the vegetation planted more recently has not yet exceeded Corps standards, a key objective of the SWIF process will be guidance on how to manage vegetation while meeting permit requirements, protecting tribal treaty rights, protecting ESA-listed species, and achieving levee safety and reliability along with other multiple objectives for river management.
3. **Salmon Populations in the Green River Basin**

The many changes to the Green River basin from the multitude of human actions over time have affected salmon populations in the basin and contributed to the overall listings of Puget Sound populations of Chinook salmon and steelhead trout as threatened species under the ESA. It is important to understand the status of these species when considering an overall framework for future flood risk management and habitat improvements.

There is little reliable historical information on the abundance and distribution of anadromous and resident salmonid species in the Green River basin. Historically, spring-run and summer/fall-run Chinook, coho, pink, and chum salmon, winter and summer steelhead, bull trout and cutthroat trout have been reported in the Green River basin, and sockeye salmon were also likely present in low numbers. However, many of the fish entering the Duwamish River migrated into the Cedar or White Rivers, which are no longer connected to the Green River. Construction of the Tacoma Headworks Diversion Dam and Howard Hanson Dam effectively cut-off access to the upper Green River basin to all anadromous fish (Kerwin and Nelson 2000).

The following sections describe the historical and current populations of each major salmon species.

### 3.1. Chinook Salmon

Prior to development, both spring-run and summer/fall-run Chinook salmon spawned and reared in the Duwamish/Green River basin (King County and WRIA 9 2005). Spring Chinook (also referred to as stream-type) adults migrated to the upper Green River basin and parts of the White River, holding for several weeks or months prior to spawning (King County and WRIA 9 2005). However, re-routing of the White River away from the Duwamish Basin as well as the Tacoma Diversion eliminated access to much of the headwater habitat typically used by spring Chinook. In contrast to spring Chinook, spawning by summer/fall run Chinook was distributed throughout the watershed. While rerouting of the Cedar and White Rivers reduced the overall habitat accessible to fall Chinook, enough habitat remained in the Green River to maintain the population of fall Chinook.

Using Puget Sound commercial canning data from 1908 and making some assumptions on catch rates and basin sizes, a maximum historic annual run size of 37,700 Chinook is estimated for the Duwamish/Green watershed, with a minimum run size of 9,000-11,000 adults per year (King County and WRIA 9 2005). Kerwin and Nelson (2000) cited a variety of reports that listed a range of historic population estimates for Chinook salmon in the Green River basin. Historic annual spring Chinook run size estimates for the upper Green River basin (upstream of the Tacoma Diversion) ranged from 150-300 adults per year (cited as Riseling 1913 and Grette and Salo 1986) to as high as 1,286 adults per year (cited as Chapman 1981).

Historically, Chinook spawning occurred from approximately RM 24 to RM 91, as well as in larger tributaries such as Newaukum Creek and tributaries in the Upper Green River (King County and WRIA 9 2005).

Since dam construction, the majority of natural Chinook salmon production occurs in the Middle Green River below the Tacoma Diversion, and in Soos and Newaukum Creeks (Kerwin and Nelson 2000). Although spring Chinook salmon (stream-type) are occasionally found in the Green River, they are found...
in such low numbers that most biologists consider spring Chinook to be functionally extinct and they do not constitute a distinct stock in the Green River (Kerwin and Nelson 2000; Coffin et al. 2011). The recognized independent Chinook salmon population is the Green/Duwamish summer/fall Chinook stock (ocean-type), which now includes Newaukum Creek fish that were previously considered an independent stock (King County and WRIA 9 2005). Puget Sound Chinook salmon (including the Green River population) are listed as a threatened species under the federal ESA.

Table 2. Historic and current salmonid spawning in the Lower Green River.

<table>
<thead>
<tr>
<th>Species</th>
<th>Number of Spawners</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook salmon</td>
<td>900 to 37,700</td>
<td>King County &amp; WRIA 9, 2005</td>
</tr>
<tr>
<td>Summer/fall</td>
<td>NA</td>
<td>WDFW 2014</td>
</tr>
<tr>
<td>Naturally spawning summer/fall</td>
<td>NA</td>
<td>NOAA 2010</td>
</tr>
<tr>
<td>Coho salmon</td>
<td>5,400 to 6,200</td>
<td>Kerwin and Nelson, 2000</td>
</tr>
<tr>
<td>Newaukum Creek population</td>
<td>NA</td>
<td>Kerwin and Nelson, 2000</td>
</tr>
<tr>
<td>Chum salmon</td>
<td>11,300 (avg)</td>
<td>Kerwin and Nelson, 2000</td>
</tr>
<tr>
<td>Pink salmon</td>
<td>1,000</td>
<td>WDFW 2012</td>
</tr>
<tr>
<td>Sockeye salmon</td>
<td>1,000</td>
<td>Kerwin and Nelson, 2000</td>
</tr>
<tr>
<td>Winter Steelhead</td>
<td>500 to 2,500</td>
<td>Kerwin and Nelson, 2000</td>
</tr>
<tr>
<td>Native wild/hatchery supplement</td>
<td>950 to 2,750</td>
<td>Kerwin and Nelson, 2000</td>
</tr>
<tr>
<td>Early Winter hatchery</td>
<td>500</td>
<td>Kerwin and Nelson, 2000</td>
</tr>
<tr>
<td>Summer Steelhead</td>
<td>0 to 3,398</td>
<td>Kerwin and Nelson, 2000</td>
</tr>
<tr>
<td>Bull Trout</td>
<td>A few</td>
<td>Kerwin and Nelson, 2000</td>
</tr>
<tr>
<td>Cutthroat Trout</td>
<td>NA</td>
<td>King County &amp; WRIA 9, 2005</td>
</tr>
</tbody>
</table>

The Soos Creek Hatchery, operated by the Washington Department of Fish and Wildlife, raises and releases fall Chinook, coho, and summer and winter steelhead. The fall Chinook program goal is an integrated hatchery and natural population with hatchery fish primarily designated for harvest. Approximately 3,200,000 juvenile fall Chinook are produced annually leading to a return of over 18,000 adults (approximately 0.56% survival from smolt to adult). Approximately 1864 adults are required for brood stock and up to 16% of the brood stock are of natural origin. (All data from WDFW 2014b.)

Escapement for the natural spawning Green/Duwamish River summer/fall Chinook stock from 1986 to 1997 averaged 6,031 and ranged from 2,027 to 10,059 (Kerwin and Nelson 2000). Newaukum Creek summer/fall Chinook escapement from 1987 to 1997 averaged 1,135 adults, and ranged from 285 to 2,968 (Kerwin and Nelson 2000).

In 2004, three different Green River Basin natural Chinook salmon abundance estimates were summarized in King County and WRIA 9 (2005). These three basin-wide estimates of the existing adult natural Chinook salmon population levels vary by as much as 38 percent according to the methods and assumptions employed. Estimates vary depending on whether sport harvest and hatchery strays are included, with a range across estimates from 729 to 31,355 adult returns (generally from years 1968 to 2002). The mean return ranges from approximately 9,000 to over 14,000. The authors caution that none of these estimates incorporate WDFW spawning escapement analysis that suggests the traditional redd

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1 Puget Sound Chinook salmon were first listed as threatened on March 24, 1999 (64 FR 14308) and their threatened status was reaffirmed on June 28, 2005 (70 FR 37160).
count escapement estimates undercounted abundance by approximately 50 percent (King County and WRIA 9 2005). These estimates are higher than the earlier estimates from Kerwin and Nelson (2000).

The latest available spawner abundance estimates in the Green River for the run years 1968 through 2009 have ranged from a low of 796 (2009) to a high of 11,558 (1970) adults and averaged 5,924 adult spawners per year over this period (Figure 3-1; from NOAA 2014). The lowest return was in 2009, and the highest return between 2000 and 2009 was 8,321 adults in 2004. The estimated fraction of wild fish has ranged from 26 to 66% since 2003 (since mass marking of hatchery fish began). Recovery objectives are to increase natural origin salmon to between 1,000 to 4,200 adults annually in the short-term (10-15 years) and increase natural original salmon to 27,000 over the long-term (50-100 years; King County 2012). The component of hatchery stock in the natural spawning population is large. A viable salmon population should have sufficient productivity of naturally produced spawners (not hatchery derived) in order to maintain population abundance above viability thresholds in the absence of hatchery produced fish (McElhany et al. 2000).

![Figure 3-1. Green River Chinook Estimated Spawners and Recent Fraction of Wild Spawners (from NOAA 2010).](image)

Current fish distribution maps show that Chinook spawning occurs starting at RM 25, and in the mainstem up to the Tacoma Diversion, as well as tributaries such as Soos and Newaukum Creeks. Juvenile Chinook salmon have been observed in Mill Creek (confluence with Green River at RM 24) (King
County and WRIA 9 2005), Mullen Slough (confluence at RM 22) and Springbrook Creek above the Black River Pump Station (confluence at RM 11) (WDFW 2014; Kerwin and Nelson 2000).

Juvenile summer/fall Chinook salmon in the Green River exhibit a bi-modal migration timing, with early migrants moving downstream shortly after hatching as fry (peak timing at WDFW screw trap at RM 34.5 in March), and likely rearing along the mainstem shorelines and any side-channels available in the Lower Green River and Duwamish Estuary as they progress towards the sea. The later parr migrants (peak timing at WDFW screw trap at RM 34.5 in June) have reared in habitats upstream near spawning grounds and migrate more rapidly to the sea in late spring and summer (WDFW 2012). Juvenile salmon in larger mainstem rivers such as the Green River are frequently associated with lateral, or margin habitat, which provides riparian-related cover as protection from predation and also provides low velocity shallow water refuge from swift mid-channel flows (R2 2001). Juvenile Chinook are well known for using floodplain habitats for extended rearing during their downstream journey. Floodplain habitats, including wetlands and side channels, provide protection from predation and frequently result in enhanced growth over individuals rearing in mainstem habitats (Sommer et al. 2001, Jeffries et al. 2008).

The 15-year trend in natural origin spawner abundance is less than 1.0, which means the population is continually declining (WRIA 9 2012), although it is difficult to predict exactly the status of the population. The mainstem habitat in the Lower Green River historically likely provided a substantially larger area of shallow shoreline and riparian fringe rearing habitat than currently exists; while the associated floodplain provided a vast area of high quality rearing habitat for out-migrant juveniles. The much reduced habitat available in the river is likely a factor of decline for the population.

### 3.1.1. Coho Salmon

Kerwin and Nelson (2000) cited a variety of reports that listed a range of historic population estimates for coho salmon in the Green River basin. Prior to the completion of the Tacoma Diversion, it was estimated that 9,000 to 25,000 coho salmon spawned in the upper Green River upstream of the Tacoma Diversion (Kerwin and Nelson 2000). Grette and Salo (1986, cited in Kerwin and Nelson 2000) estimated an annual coho escapement upstream of the Tacoma Headworks as 5,400 to 6,200 adults, while Chapman (1981, cited in Kerwin and Nelson 2000) provided a similar escapement estimate for upper Green River basin of 4,270 coho adults that produced an estimated 213,516 smolts annually.

Soos Creek Hatchery production of coho has a goal of an integrated hatchery and natural population with hatchery stock designated primarily for harvest. Approximately 555,000 juveniles are produced annually with approximately 45,000 adults returning (approximate 8.7% survival from smolt to adult). Approximately 1452 adults are required for brood stock and approximately 34% are of natural origin. (All data from WDFW 2014b.)

The coho salmon that enter the Green River Basin are composed of two stocks that have different spawning patterns (Kerwin and Nelson 2000). The Green/Duwamish stock returns to the Green River and Soos Creek in September and typically spawns to mid-November, while the Newaukum Creek stock spawns as late as mid-January. Escapement estimates for the Green/Duwamish River stock from 1967 to 1998 averaged 3,816 and ranged from 700 to 12,500. Spawning escapement estimates for the Newaukum coho stock for the years 1960 to 1996 averaged 5,029 adults per year, and ranged from 1,034 to 9,300 (Kerwin and Nelson 2000).

Juvenile coho salmon typically rear for one year prior to outmigrating as smolts. Coho juveniles are closely linked with woody debris cover in slow water habitats; off-channel habitats containing slow velocities and abundant instream cover are also important for juvenile survival over the winter months.
Such habitat was historically abundant in the Lower Green River floodplain prior to diversions, flow reductions, and levee construction (Collins & Sheikh 2005), and likely provided high growth rates and high overwinter survival for pre-smolt juveniles. Currently such habitat is largely lacking in the Lower Green River, although distribution maps show coho use of Mill Creek and possibly several smaller unnamed tributaries to the lower river (Kerwin and Nelson 2000, King County and WRIA 9 2005; WDFW 2014a). Overall, however, most rearing of juvenile coho is expected to occur in the Middle Green River and its principal tributaries due to high temperatures in the Lower Green River.

### 3.1.2. Chum Salmon

Historic run sizes and escapement estimates for chum salmon are more difficult to quantify. Williams (1975, cited in Kerwin and Nelson 2000 and King County and WRIA 9 2005) reported an average annual escapement for the Duwamish/Green River basin of 11,300 for the years 1966-71 inclusive.

The chum salmon that enter the Green River basin are separated into two stocks: Green River fall-run and Crisp Creek (also referred to as Keta Creek) fall-run chum salmon (Kerwin and Nelson 2000). Adults typically return to their natal rivers in the Puget Sound area in mid-September through mid-October (Kerwin and Nelson 2000). Unlike Chinook and coho salmon, chum salmon fry typically migrate downstream soon after emergence and rear in freshwater for a relatively short period. Despite this abbreviated rearing, habitat conditions encountered along the mainstem Green River during outmigration likely influence growth and survival of chum salmon smolts.

### 3.1.3. Pink Salmon

Pink salmon were historically reported in relatively small numbers in the lower and middle Green River basin. Fuerstenberg et al (Draft 1999, cited in Kerwin and Nelson 2000) estimated the historic pink salmon escapement as 1,000 adults in odd numbered years.

Williams et al. (1975) estimated that pink salmon were extinct from the basin. However, pink salmon runs on the Green River have increased dramatically in recent years. In 2001, an estimated 20,000 pink salmon entered the Green River, and in 2003, an estimated 300,000 pink salmon spawned. The 2013 preseason forecast was for the run of pink salmon in the Green River to be over 1.3 million fish (WDFW 2012). Juvenile pink salmon display similar life-history traits to chum salmon, with early emigration to the sea and abbreviated freshwater rearing.

### 3.1.4. Sockeye Salmon

Little historical information was obtained concerning early runs of sockeye salmon. Other than Lake Washington itself, Eagle Lake (sometimes referred to as Enapooh Lake), at 53.2 surface acres, is the only lake of sufficient size to have historically provided a rearing opportunity for lake rearing sockeye juveniles in this basin (Kerwin and Nelson 2000). Neither of the lakes is now accessible to anadromous fish via the Duwamish River.

Sockeye salmon adults are reported annually in the vicinity of the Tacoma Diversion, with estimates ranging from 100 to 400 adults (Kerwin and Nelson 2000). It is currently unknown if these fish are successfully reproducing since juveniles typically rear for extended periods in lakes prior to smolting and outmigration. However, the sockeye salmon seen each year on the spawning grounds could be river rearing sockeye, which we know very little about.
3.1.5. STEELHEAD


There are currently three Green River basin winter steelhead stocks: a native wild spawning population, a hatchery supplementation program of the native stock and an early winter hatchery stock (Kerwin and Nelson 2000). Both the native Green River stock and the winter steelhead hatchery supplementation program were listed under the ESA in 2007 (NOAA 2007). Soos Creek Hatchery production of steelhead includes an integrated hatchery and natural winter steelhead population and a segregated summer and winter steelhead hatchery population. Approximately 33,000 winter steelhead juveniles are produced for the integrated population with an unknown return of adults. The production goal for the segregated populations are 30,000 juvenile summer steelhead and 68,000 juvenile winter steelhead, but the hatchery has produced more juveniles than the goal in recent years: approximately 98,000 summer steelhead and nearly 150,000 winter steelhead. The adult returns are approximately 600 and 500, respectively, for summer and winter steelhead (survival of 0.6% and 0.3%, respectively, smolt to adult). For the integrated population, the vast majority of adults used for brood stock are of natural origin (approximately 87%), whereas no natural origin adults are used in the segregated brood stock.

Hatchery steelhead typically spawn between January and March while the native stock spawns primarily between March and May. Natural spawner escapement estimates from 1978 to 2012 show moderate annual variation and have ranged from a low of 304 to a high of 2,778 fish per year. The lowest returns have occurred in the last five years (WDFW 2014b).

Summer steelhead in the Green River basin are near the edge of the geographic range for this species. The run size and estimated escapement of this species is not available. The best indication of a historic run comes from Washington Department of Fish and Wildlife harvest records (1962-1982), which ranged from 0 to 3,398 fish per year, and averaged 1,269 fish annually after the hatchery program was started (Kerwin and Nelson 2000). Harvest prior to the hatchery program was minimal.

Juvenile steelhead display a longer period of freshwater rearing than most other species, with one to three years of freshwater residence (King County and WRIA 9 2005). Although juvenile steelhead are not as dependent on off-channel habitats as are juvenile Chinook and coho salmon (Hartman and Brown 1987, Swales and Levings 1989), high quality slow-water margin habitat is important to small juveniles, while larger juveniles are typically associated with fast-water riffle and run habitats. High quality margin habitats and fast-water habitats are very limited in the Lower Green River, and are found primarily present in the upper reaches. However, fish distribution maps indicate some steelhead use of tributaries to the Lower Green River, including Mill Creek and Springbrook Creek (Kerwin and Nelson 2000).

3.1.6. BULL TROUT

Historical information on the presence, abundance, distribution, use and life history of bull trout in the Green River basin is either unavailable or extremely limited (Kerwin and Nelson 2000). Pautzke and Megis (1940, cited in Kerwin and Nelson 2000) described the presence of a few Dolly Varden during the 1930’s in the Green River.

Bull trout have been occasionally reported in the lower Green/Duwamish River, but data are insufficient to assess the status of this species. Bull trout are particularly intolerant of warm water temperatures, which impose strict limitations in suitable spawning and rearing habitat (Fraley & Shepard 1989,
Dunham et al. 2003). Consequently, most self-sustaining populations of bull trout are those with access to high quality headwater streams with cool, year-round temperatures. In the 1990s, sampling was conducted by Plum Creek Timber biologists above Howard Hanson Dam to look for a disconnected population similar to the Cedar River population (Berge and Mavros 2001). While they were unable to find any native char, they were not able to rule out the possibility that there were bull trout above Howard Hanson Dam.

### 3.1.7. Cutthroat Trout

No information was found regarding the historical distribution or abundance of cutthroat trout in the Green River Basin, and Kerwin and Nelson (2000), note that data are scarce on this species. Coastal cutthroat trout can be anadromous or resident. Anadromous coastal cutthroat can be found year-round in shallow marine waters. Adults return to spawn in freshwater from December through spring (sometimes as late as June). Juveniles generally migrate from freshwater to marine waters at two or three years of age (Trotter 1989).

Coastal cutthroat trout have been reported throughout the Green River basin, but few data are available concerning present abundance or whether the fish are anadromous or resident (King County and WRIA 9 2005; Kerwin and Nelson 2000). They have been observed on the mainstem river up to the headwaters and all major tributaries (King County and WRIA 9 2005).

### 3.2. Conclusion

Fish populations have been substantially reduced from historic population sizes. Populations of Chinook and steelhead have continued declining, even with actions being taken to recover listed species. The primary species on an increasing trend is pink salmon, which spend very limited time in freshwater. Much more effort on addressing the limiting factors in the lower river is warranted. Actions to improve habitat and water quality in the Lower and Middle Green Rivers will be very important to the recovery of Chinook salmon that tend to spend all of their time in freshwater in the mainstem Green River.
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4. **CURRENT HABITAT CONDITIONS**

The habitat assessment study area has been delineated into three reaches that have differing aquatic and riparian habitat characteristics. Reach 1 extends from RM 5.5 to 11, Reach 2 extends from RM 11 to 26, and Reach 3 extends from RM 26 to 34 (Figure 4-1). These reaches were based on distinct habitat conditions and opportunities for habitat restoration. For example, Reach 1 is the upper portion of the Duwamish River and may provide opportunities for riparian enhancements and creation of shallow-water habitat; Reach 2 encompasses the bulk of the highly urbanized areas where there are many needs for riparian enhancements and several opportunities for floodplain and/or side-channel/tributary enhancement and Reach 3 includes both urbanized areas and agricultural lands and the zone where salmon spawning begins; there are opportunities for in-channel, riparian, and floodplain restoration.

Aquatic habitats in the Lower Green River were assessed in 2004 by Anchor QEA (2004) and in 2013 by R2 Resource Consultants (2014) for the WRIA 9 committee. Key aquatic habitat types that are being tracked over time for salmon recovery include large wood, pools, spawning gravel, and slow-water channel edge. Current conditions described herein are primarily based on 2013 data (R2 Resource Consultants 2014). Slow-water edge habitat was not quantified and is a key data gap for understanding the potential capacity of the river to provide juvenile rearing habitat.

Floodplain habitats that are being tracked over time include the riparian zone (defined as extending 200 feet from the ordinary high water mark on each bank), wetlands, ponds, forested floodplain (beyond the 200 foot riparian zone), and unvegetated land cover.

This section describes the existing conditions of the various habitats in separate subsections: first by aquatic habitat unit types, then spawning gravel, large wood, off-channel floodplain habitats, and finally riparian vegetation.
Figure 4-1. Aquatic Habitat Assessment Study Area Reaches.
4.1.1. IN-STREAM HABITAT UNITS

The Lower Green River is a low elevation, low gradient mainstem river segment. Major tributaries that enter the study area include the Black River/Springbrook Creek at RM 11, Mullen Slough at RM 21.7, and Mill Creek (Auburn) at RM 23.9. Several small unnamed tributaries also enter the Green River in the study area from both the west and east hill slopes. Conditions below RM 5.5 are not included in this memo.

The 2013 habitat assessment (R2 Resource Consultants 2014) evaluated glide, run, riffle, cascade, pool, and pocket estuary in-stream habitat units from RM 32.1 down to RM 0 at the mouth of the Duwamish River. The in-stream habitat in the study area is dominated by glides (88% of habitat area; Figure 4-2). Pools were infrequent (1% of habitat area). Riffles, runs, and backwaters comprised the remaining 11% of habitat area. Note that while the 2013 habitat assessment (R2 Resource Consultants 2014) defined pools the same as the 2003 assessment (Anchor QEA 2004), they found dramatically fewer pools in the lower Green River. The reason for this difference in the number of pools is not known, but two potential reasons are that they were collected at different flows and/or there were field interpretation differences between surveyors. Data from the 2012 bathymetry TIN provided by the Muckleshoot Indian Tribe (using a five foot residual pool depth), indicates that many of the pools mapped by Anchor QEA (2004) were still present and were missed in the recent surveys. To be inclusive, both data sets are described below.

In general, habitat is more complex at the upstream end of the study area, becoming increasingly uniform with distance downstream (Figure 4.2). For reference, the National Oceanic and Atmospheric Administration (NOAA) considers properly functioning stream habitat to have approximately 23 pools per mile for a channel width of 75 feet or more, and instream habitat types should be in fairly even proportions, not dominated by a single habitat type (NOAA 1996).

![Figure 4-2. Aquatic habitat distribution in the Lower Green River (data from R2 2014).](image)

Reach 1 (RM 5.5 to 11) is within the Duwamish River and is tidally influenced. Glides are the predominant habitat unit type (93%), with two backwaters (5%), two pools (2%), and a limited section of run (<1%) also present. Figure 4-3 shows the location of in-stream habitat units for Reach 1. The pools are located at RM 6.2 adjacent to the backwater described below (North Winds Weir) and at RM 10.3 on...
a meander bend confined by riprap adjacent to the railroad line and Foster Golf Links. The short section of run is located at RM 10.2 in a relatively straight section. The backwaters are both recent restoration sites located at RM 6.2 (North Winds Weir) and 8.5 (Codiga Park), both on the right bank side, and each slightly over one acre in size. Additional deeper areas identified as pools in the 2003 assessment (Anchor QEA 2004) that were not mapped as pools in 2013 were located at RM 9.6, 9.8, and 10.6; all three were identified as associated with riprap scour. Over 20,000 linear feet of this reach is armored; approximately 35% of both banks (Anchor QEA 2004).

The in-stream habitat in Reach 1 is of low diversity and low quality. Pool habitat is extremely rare and limited in size. The once vast, intermixed system of wetlands has been essentially eliminated. Shallow water habitats, wetlands, and cover are primary missing elements. Due to the tidal nature of the reach, water velocities are fairly low; however, there are limited mud flats or shallow shorelines, marsh, or tidal delta and slough habitats that are used by juvenile salmon during their outmigration, particularly Chinook salmon. Use of delta habitat prior to entering saltwater can increase smolt to adult survival by increasing growth rates after juvenile Chinook enter the marine nearshore (Beamer & Larson 2004).

Key opportunities for restoration and enhancement in Reach 1 include riparian vegetation improvements (removing invasives and planting native trees and shrubs) where sufficient bank is available, sloping banks back to create shallow water habitat, placing additional wood or log jams specifically to form habitats (as opposed to bank protection), and creating alcoves and marshes. Locations could include RM 6-7 left bank (across from North Winds Weir site), RM 7-8 left bank along Green River Trail, RM 8 right and left banks in park areas, RM 8-9 left bank along Green River Trail, RM 9-11 near the golf course, and at the Black River confluence.

Reach 2 (RM 11 to 26) is a highly constrained and urbanized reach. Glides are again the predominant habitat unit type (80%), with several segments of run habitat (11%), a few very short riffles (5%), and eight pools (3%) also present. Figures 4-4 and 4-5 show the location of in-stream habitat units for Reach 2. The pools are located at RM 11.5, 12, 18.6, 21.3, 23.5, 24.2, and 24.8 (outside corner of Horseshoe Bend). The Riverview Park side-channel project at RM 23.5 has provided the only side-channel habitat available in the reach.

Additional deeper areas identified as pools in the 2003 assessment (Anchor QEA 2004), but not in 2013, were located at RM 11 (Black River confluence), 12.1, 13.2, 14.5, 16.2, 17.5, 18, 18.9, multiple small pools RM 19-20, multiple from RM 20-22 on bends, RM 22, 22.4, 22.5, 23, 23.8, and multiple locations from RM 24-26 on outside of Horseshoe Bend.

The instream habitat of Reach 2 is of slightly greater diversity than in Reach 1, but still of low diversity and quality. Deep pools are extremely rare and those pools that are present are limited in size. There are virtually no off-channel or floodplain areas that can be accessed and limited shallow water edge habitat. This reach has very poor shading conditions along the majority of its length. Armoring is present on over 72,000 linear feet of this reach (approximately 46% of the reach on both banks; Anchor QEA 2004).

Key opportunities for restoration and enhancement include riparian vegetation improvements (removing invasives and planting native trees and shrubs), sloping banks back to create more riparian area and shallow water habitat, placing additional wood or log jams for cover and pool formation, and floodplain and side-channel restoration, including creating off-channel or backwater habitats.

Reach 3 (RM 26 to 34) has more diversity of in-stream habitat types than the other two study reaches, with approximately 20% riffle, 58% glide, 17% run, and nearly 5% pool (by length). Figures 4-6 and 4-7 show the location of in-stream habitat units for Reach 3. The pools are located at RM 26.5, 27.5, 27.7, and 29. A recent levee setback project is present at RM 28.5 to 29 (Reddington).
Additional deeper areas identified as pools in the 2003 assessment (Anchor QEA 2004), but not in 2013, were located at RM 27.2, 27.9, 28.3, 28.4, 29.1, 29.4, 29.8, 30, 30.4, 30.5, 30.6, 31,9, and 32.

The instream habitat of Reach 3 is of moderate diversity, although of low quality in many areas. Deep pool habitat is extremely rare and limited in size. There are virtually no off-channel or floodplain areas that can be accessed and limited shallow water edge habitat. This reach has primarily fair shading conditions along the majority of its length. Armoring is present on over 24,000 linear feet (approximately 37% of the reach on both banks; Anchor QEA 2004).

Key opportunities for restoration and enhancement include riparian vegetation improvements (removing invasives and planting native trees and shrubs), sloping banks back to create more riparian area and shallow water habitat, placing additional wood or log jams for cover and pool formation, and floodplain and side-channel restoration, including off-channel or backwater habitats.

Although the focus is the Lower Green River, descriptions of the upper portion of reach 3 illustrates moderate quality habitat conditions for anadromous fish. Consequently, a brief description of the lower portion of the Middle Green River, which has been described as having the “best” habitat for anadromous fish in the Green River Basin (King County and WRIA 9 2005) and successfully rears significant numbers of juvenile salmonids (R2 2001), is included here for comparison with the Lower Green River.

Habitat surveys conducted in 2001 (King County and WRIA 9 2005) indicated that pools comprised about 27% of the habitat area of the Middle Green River, versus only 5% in Reach 3 of the Lower Green River. More recent comparisons of pools and large wood (TPU 2011) indicates that while the Middle Green River had widely spaced pools, the pools that do occur are deep (> 8 feet) and frequently formed by wood. There are approximately 45 pieces of large wood per mile in the Middle Green and approximately 2.5 jams per mile (TPU 2011). The placement of wood by the Corps since 2004 is substantially increasing large wood and log jams between RM 57 and 61 and individual pieces have moved as far downstream as RM 39.5. Natural recruitment is also increasing (TPU 2011).

The increased gradient present in the Middle Green River also results in a higher frequency of riffle and run habitats and increased habitat complexity than in downstream reaches. Spawning gravel is significantly more abundant in the Middle Green River than in downstream reaches, as evidenced by the abundant open bars visible in aerial imagery. Gravel availability decreases again as one progresses upstream towards the dams, which interrupt sediment transport, but the USACE has been placing gravel downstream of the dams in recent years to supplement the supply.

The Middle Green River has less development than the Lower Green River, and more agricultural land with less impact on riparian vegetation. The riparian zone is much more continuous than in the Lower Green River, with more extensive forested floodplain. Side channels are also more abundant in the lower portion of the Middle Green River; at least 17 side channels are visible in aerial imagery, including one channel over 2,000 feet in length. Overall, the Middle Green River possesses much greater complexity of aquatic and riparian habitat, with far less human influence than the Lower Green River.

### 4.1.1.1. Implications and Priorities

In-stream habitat diversity is low due to the confinement of the Lower Green River between levees and revetments, channel incision that has occurred over time due to sustained moderate-high flows from Howard Hanson Dam, and the lack of sediment and wood inputs. There is limited space to provide instream habitat features, but installing large wood that will promote additional pool formation as well as providing cover for existing pools is a critical high priority in the study area. Pools are important features for adult salmon for holding during their upstream migration; pools could also be constructed...
to intercept groundwater or at tributary confluences to create localized slightly cooler areas for holding (R2 Resource Consultants 2010).

Shallow-water edge habitat is also a critical priority for the study area because it provides important rearing and refuge habitat for juvenile salmonids, particularly Chinook, as they migrate downstream. Shallow water provides habitat that larger predatory fish cannot access and provides rearing habitat for juvenile fish to grow to larger sizes before entering the Duwamish estuary. Vegetation overhanging the channel edge protects fish from birds and other predators from above, provides shade from solar radiation, and prey in the form of terrestrial insects to promote growth.
There is 1 log jam present in Reach 1

<table>
<thead>
<tr>
<th>Habitat Unit (Reach 1)</th>
<th>Acres</th>
<th>Percent of Total Area in Reach 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pool</td>
<td>3.7</td>
<td>3.1%</td>
</tr>
</tbody>
</table>

Green River SWIF
In Stream Salmon Habitat Description: Reach One

Figure 4-3. In-stream habitats present in Reach 1.
There are 17 log jams present in Reach 2

<table>
<thead>
<tr>
<th>Habitat Unit</th>
<th>Acres</th>
<th>Percent of Total Area in Reach 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spawning Gravel</td>
<td>3.78</td>
<td>2.0%</td>
</tr>
<tr>
<td>Pool</td>
<td>5.28</td>
<td>2.80%</td>
</tr>
<tr>
<td>Total Area</td>
<td>9.06</td>
<td>4.79%</td>
</tr>
</tbody>
</table>

Green River SWIF
In Stream Salmon Habitat Description: Reach Two-A

Figure 4-4. In-stream habitats present in the downstream half of Reach 2 (2A).
There are 17 log jams present in Reach 2

<table>
<thead>
<tr>
<th>Habitat Unit (Reach 2)</th>
<th>Acres</th>
<th>Percent of Total Area in Reach 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spawning Gravel</td>
<td>3.78</td>
<td>2.0%</td>
</tr>
<tr>
<td>Pool</td>
<td>5.28</td>
<td>2.80%</td>
</tr>
<tr>
<td>Total Area</td>
<td>9.06</td>
<td>4.74%</td>
</tr>
</tbody>
</table>

Green River SWIF
In Stream Salmon Habitat Description: Reach Two-B

Figure 4-5. In-stream habitats present in the upstream half of Reach 2 (2B).
There are 5 log jams present in Reach 3

<table>
<thead>
<tr>
<th>Habitat Unit</th>
<th>Acres</th>
<th>Percent of Total Area in Reach 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pools</td>
<td>4.13</td>
<td>2.0%</td>
</tr>
<tr>
<td>Spawning Gravel</td>
<td>18.51</td>
<td>2.80%</td>
</tr>
<tr>
<td><strong>Total Area</strong></td>
<td>22.64</td>
<td>4.79%</td>
</tr>
</tbody>
</table>

**Green River SWIF**

**In Stream Salmon Habitat Description: Reach Three-A**

Figure 4-6. Instream habitat in the downstream half of Reach 3 (3A).
There are 5 log jams present in Reach 3

<table>
<thead>
<tr>
<th>Habitat Unit (Reach 3)</th>
<th>Acres</th>
<th>Percent of Total Area in Reach 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pools</td>
<td>4.13</td>
<td>2.0%</td>
</tr>
<tr>
<td>Spawning Gravel</td>
<td>18.51</td>
<td>2.80%</td>
</tr>
<tr>
<td>Total Area</td>
<td>22.64</td>
<td>4.79%</td>
</tr>
</tbody>
</table>

Green River SWIF
In Stream Salmon Habitat Description: Reach Three-B

Figure 4-7. Instream habitat in the upstream half of Reach 3 (3B).
4.1.2. Spawning and Incubation Habitats

Gravels suitable for salmon spawning are typically found in riffles, runs, and pool tailouts. Using this simplistic definition, about 18.5 acres of suitable spawning gravel is present in Reach 3, and about 3.7 acres of suitable spawning gravel is present in the upstream-most portion of Reach 2. Pebble counts conducted in 2003 riffle habitats in Reaches 3 and 2 produced D50\(^2\) values of 5 cm and 2 cm, respectively (Anchor Environmental 2004). Subsequent pebble counts conducted in 2013 produced D50 values of 2.9 cm and 2.2 cm, respectively (R2 Resource Consultants 2014), see Figure 4-8. Pebble counts could not be conducted below RM 23 due to the lack of riffle habitat and dominance of sand and silt substrates. Suitable substrate size for Chinook spawning ranges from 1.3 to 10.2 cm (Bell 1986).

Chinook salmon typically spawn in areas with water depths greater than 10 inches and water velocities of 1-3 feet/second (Bjorn and Reiser 1991). Coho, chum, and pink salmon and steelhead trout spawn in areas with similar depths and velocities, although coho and steelhead spawn more commonly in tributaries. Suitable temperatures for spawning typically range from 40 to 57° F (5 to 14° C; Bell 1986). The Washington Department of Ecology water quality standard (maximum) for salmon spawning is 63.5 F (17.5 C; Ecology 2011). Chinook have been documented spawning from RM 24.5 and on upstream through the Middle Green River (WDFW 2014a). Steelhead and pink salmon spawning is mapped as beginning at RM 27 and chum spawning begins at RM 29 (WDFW 2014a), although these species may spawn down to RM 24.5 similar to Chinook. The density of Chinook spawning is very low, only about 0.02 Standard Redd Density (SRD) in Reach 3 (King County and WRIA 9 2005).

Diversion of the White River, levee construction, and capture of upstream sediment at Howard Hanson Dam are primary factors associated with the loss of gravel habitat in the Lower Green River. The Corps has been adding spawning gravel to the river downstream of the Tacoma Diversion for the past several years. This material is slowly moving downstream and supplementing gravel supplies in the Middle Green River.

Figure 4-8. Substrate size in riffles in the Lower Green River (from Anchor QEA 2004 and R2 2014).

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\(^2\) D50 represents the median grain size of a sample; 50 percent is smaller and 50 percent is larger.
4.1.2.1. IMPLICATIONS AND PRIORITIES

Spawning habitat is not a major component of the larger study area. Reach 3 of the Lower Green represents an area of historic spawning habitat that has been heavily degraded through many different historic actions. If fish population sizes increase due to recovery actions and the highest priority actions in the Middle Green are completed, improving the spawning habitat in the Lower Green will become important for reaching the longer term population recovery goals. The placement of large wood could provide sorting of coarser gravels in Reach 3 and enhance the small area of spawning habitat that occurs currently. Over the long-term, recruitment of suitable spawning gravels into the river is required to maintain spawning habitat. It is not clear whether gravel augmentation downstream of the Tacoma Diversion Dam will yield sufficient gravel to maintain spawning habitat in the Lower Green River. Allowing channel migration and sediment transport in the Middle Green River will be most conducive to providing a long-term source of gravel to the Lower Green River.

4.1.3. LARGE WOOD

Large wood is present in all reaches, but at low numbers (R2 Resource Consultants 2014). In Reach 1, 234 pieces of wood and 2 log jams were counted, with approximately 50% of the individual wood and both log jams placed in revetments or other projects. In Reach 2, a total of 411 pieces of wood and 17 log jams were counted, with approximately 27% of the individual pieces and 100% of the jams placed as part of revetments or other projects. Thirty-five of the individual logs were placed in the recently constructed Riverview Park side channel. In Reach 3, a total of 120 pieces of wood and 5 log jams were counted; with approximately 40% of the individual pieces and jams placed as part of revetments or other projects. The three naturally formed log jams were located near RM 30.1 and are associated with a natural island complex, which is considered one of the most diverse and complex areas of habitat in the Lower Green River (R2 Resource Consultants 2014). However, on a per-mile basis, the large number of pieces of wood placed in Reach 1 now results in the highest number of pieces of wood per mile (Figure 4-9). For reference, NOAA defines properly functioning conditions for large wood as approximately 80 pieces/mile greater than 24 inches in diameter and greater than 50 feet in length (NOAA 1996).

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3 Large wood was defined in R2 (2002) using a modified protocol from the TFW Method Manual for LWD Surveys (Schuett-Hames et al. 1999). Debris jams must contain at least 10 pieces of wood that are in contact with each other.
4.1.3.1. IMPLICATIONS AND PRIORITIES

There is limited large wood in the study area, with the majority having been placed recently in Reach 1 in restored backwater habitats, or the placement of wood into bank protection sites. Naturally occurring large wood provides cover, food web support, and helps form in-stream habitats such as pools and bars. The current configuration of much of the placed wood (linear configurations mostly providing only cover) in the Lower Green are not as effective as natural wood at improving habitat conditions. It is important to both place additional wood in Reaches 2 and 3 in more natural configurations to promote pool formation, and to restore forested riparian vegetation to contribute natural wood over the long-term to the system. Part of restoring the riparian area to be a source of LWD to the river also requires allowing some future channel migration or bank erosion to occur.

4.1.4. OFF-CHANNEL FLOODPLAIN HABITAT

The combination of levee development, flow modifications, and reduced sediment and wood inputs following dam construction and diversion of the White River has led to almost complete elimination of the shallow slow-water edge, side channel, and wetland habitat that originally existed along the Lower Green River, as described in Section 2, previously (see Figure 3-1 and Table 2).

Only two side channels are currently evident based on aerial photos and habitat mapping: a 630 foot natural side channel with woody debris jams at RM 30 in Reach 3, and a constructed side channel 700 feet long at RM 23.5 in Reach 2. Combined, these side channels represent only about 1% of the length of the Lower Green River. Wetlands have been reduced by over 1,200 acres and are now highly fragmented into small parcels of low-lying woodlands, pastures, and farmed wetlands representing about 13% of the floodplain. Floodplain forest has been reduced by over 12,000 acres to about 8% of the floodplain, while ponds currently represent less than 1% of the floodplain. Developed lands now represent 74% of the floodplain (as compared to historic conditions when forested floodplain represented 75% of the floodplain), vastly reducing the potential habitat available for fish and wildlife (Figure 4-10). While these comparisons have been made with the historic floodplain that comprised 19,409 acres, the current mapped 100-year floodplain is now only about 1/3 of the size of the historic floodplain due to the diversion of the White River and the presence of Howard Hanson Dam.
Figure 4-10. Floodplain habitat types in study area.