Estimating Impervious Surface in the Summer Chum ESU under Buildout Conditions

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EXECUTIVE SUMMARY

OBJECTIVE Estimate the increase in impervious surface (IP) expected if the study area were built out as allowed under current regulations.

STUDY AREA Hood Canal/Eastern Strait of Juan - de Fuca Summer Chum ESU

ANALYSES

1) Mason County – simplified population increase analysis
2) Clallam, Jefferson, and Kitsap Counties – detailed parcel analysis

METHODS

1) Used OFM (Office of Financial Management) population prediction to determine approximate increase in housing units expected; used average lot size and associated average IP for that lot size to determine corresponding increase in IP.

2) Separated parcels into groups; calculated average IP in each group; assigned those same groups to the parcels under a buildout scenario using zoning and other regulatory information; calculated the change in IP in each parcel from its current group designation to its buildout group designation; quantified this change as it occurred in different unit types applicable to summer chum: watersheds, riparian corridors, estuaries, and nearshore.

RESULTS

1) The estimated IP increase within the Mason County portion of the summer chum ESU is 17% between 2004 and 2025. This estimated IP increase accounts for residential changes only and does not include infrastructure, commercial, and industrial changes to the landscape that may occur.

2) For each unit type as a whole, the estimated IP increases are: watersheds (as measured by the total IP increase in all the parcels) – 29%, or an increase from 11,373 acres to 14,659 acres of IP; riparian corridors – 50% IP increase; estuaries – 50% IP increase; nearshore – 19% IP increase.
The average IP within each unit is:

Unit Area	Average Modeled Current IP	Average Buildout IP
Watershed*	5.20%	6.19%
Riparian Corridor	5.46%	7.79%
Estuary	4.10%	6.30%
Nearshore	10.90%	13.93%

* only includes watersheds with full parcel data

BACKGROUND

This buildout analysis was designed to gain an understanding of how existing zoning regulations could affect the amount of impervious surface (IP) in the watersheds, riparian corridors, estuaries, and nearshore of the Hood Canal summer chum salmon evolutionarily significant unit (ESU). The work was commissioned by the Hood Canal Coordinating Council (HCCC) for use in the development of the Hood Canal/Eastern Strait of Juan de Fuca Summer Chum Salmon Recovery Plan (The Plan).

Two methods of buildout analysis were employed: one in Mason County and the other in Jefferson, Kitsap, and Clallam Counties. In Mason County, a generalized population prediction was used to quantify additional housing units expected and the associated impervious surface increase. A parcel-based approach was used in Jefferson, Kitsap, and Clallam Counties. The parcel approach was a more detailed analysis of how each individual parcel can change under the current regulations.

MASON COUNTY

The current population of Mason County is 50,800 (OFM 2004) and the projected population for the year 2025 is 75,088 (Comp. Plan 2004). To determine the increase in IP expected from the projected addition of 24,288 people to Mason County by the year 2025, a simplified buildout analysis was completed. This approach differs from that in the other counties due to lack of comprehensive parcel and zone data for the county.

The average size of a platted lot in Mason County is 3/5 acre (Bob Fink, Planning Manager Mason County, personal communication, March 25, 2005), and this corresponds to the urban low landcode as defined in Table 2. The average impervious surface to land area ratio for parcels with urban low landcodes is 21.14% for parcels in Jefferson and Kitsap Counties as reported in Appendix A. This average was used as a proxy for Mason County, with the assumption that residential parcels in Mason County contain a similar amount of IP as those in neighboring Kitsap and Jefferson Counties.

Mason County's population projection for 2025 translates to an increase of 9,754 housing units for the entire county, given the average household size of 2.49 people per household (U.S. Census Bureau 2000). Using the average size of a platted lot (0.6 acres), this results in the addition of 5,852 parcel acres in the urban low category, for a total of 1,237 acres of additional IP.

If it is assumed that the number of new houses is distributed proportionately to the area within the ESU and outside of the ESU, the total IP increase inside the ESU is 606 acres. The present amount of IP within the Mason County portion of the ESU is 3,529 acres (see Figure 1). The estimated IP increase within the Mason County portion of the summer chum ESU, therefore, is 17% between 2004 and 2025 (606_{acres} / $3{,}529_{acres}$). This estimated IP increase accounts for residential changes only and does not include infrastructure, commercial, and industrial changes to the landscape that may occur.

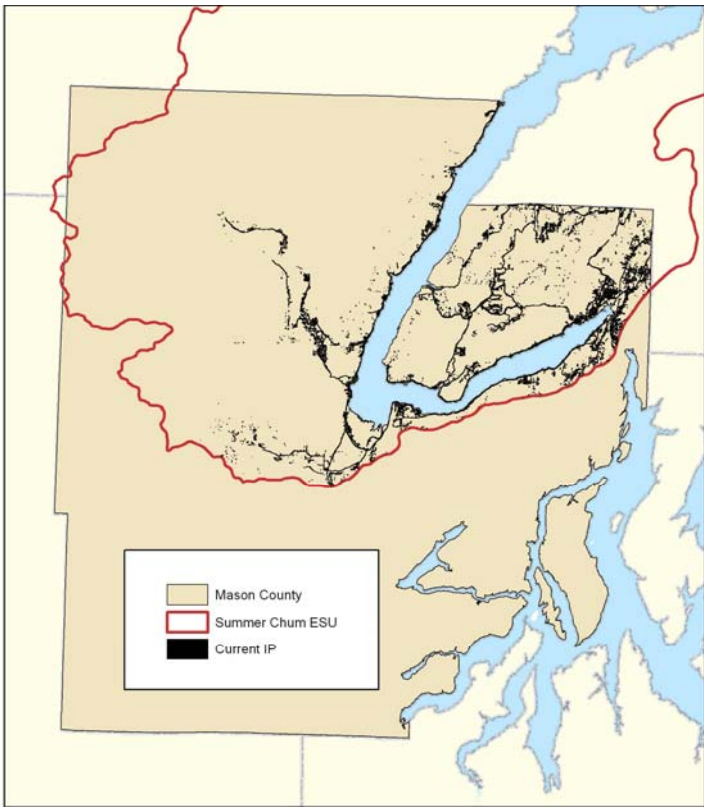

Figure 1 Current impervious surface in Mason County

JEFFERSON, KITSAP, AND CLALLAM COUNTIES

Methods

The parcel-based approach was developed in order to capture the effect of zoning regulations on each individual tax parcel within the study area. Every parcel's current landuse, housing density (if any), and zoning allowances and restrictions were considered in order to assign an appropriate buildout IP amount to that parcel. Residential, commercial, and industrial changes to the landscape were all quantified using this methodology.

The aggregate of all parcels within the four types of spatial organizing units: watersheds, riparian corridors, estuaries, and nearshore was calculated in order to estimate spatial buildout IP variations. Because the method of determining future buildout potential is derived directly from city and county zoning ordinances, the buildout time horizon is equal to those of the ordinances.

Products of this analysis include:

- Current parcel landcode
- Current parcel IP
- Current housing density in select landuses and zones
- Modeled buildout parcel landcode
- Buildout parcel IP based on estimates derived from current landuses
- Maximum buildout parcel IP based on maximum zoning allowances
- Summary of buildout estimates for summer chum in each of four unit types:
    - Hood Canal watersheds,
    - summer chum riparian corridors,
    - summer chum estuaries, and
    - Hood Canal nearshore

To begin the analysis, parcel layers were standardized and combined. Then, zones were overlayed onto the parcels and each parcel was assigned the appropriate zone code. After than, a system of grouping the parcel's landuses into appropriate IP categories was developed. The goal was to create groups of parcels that would be expected to contain similar amounts of IP. These groups were termed *landcodes* (not the same as the landuse codes). The landcodes were used in an overlay with 5-meter IP data to determine the average amount of IP within each landcode. A buildout landcode was assigned to each parcel based on its zone, housing density (if any), current landuse, and current landcode.

Using the IP percentages calculated with the current landcode data, the average IP of each landcode was assigned to parcels based on their buildout landcodes. Results were obtained by summing the current IP amount per parcel and summing the buildout IP amount per parcel within each of the four unit types. In addition to those two statistics, the maximum buildout IP amount was assigned to each parcel based on any IP maximums that were specified in the county and city zone codes. In summary, statistics for Hood Canal watersheds, riparian corridors, estuaries, and nearshore were calculated on current IP totals, buildout IP totals, and maximum buildout IP totals. A schematic of this analysis process is presented in Figure 2.

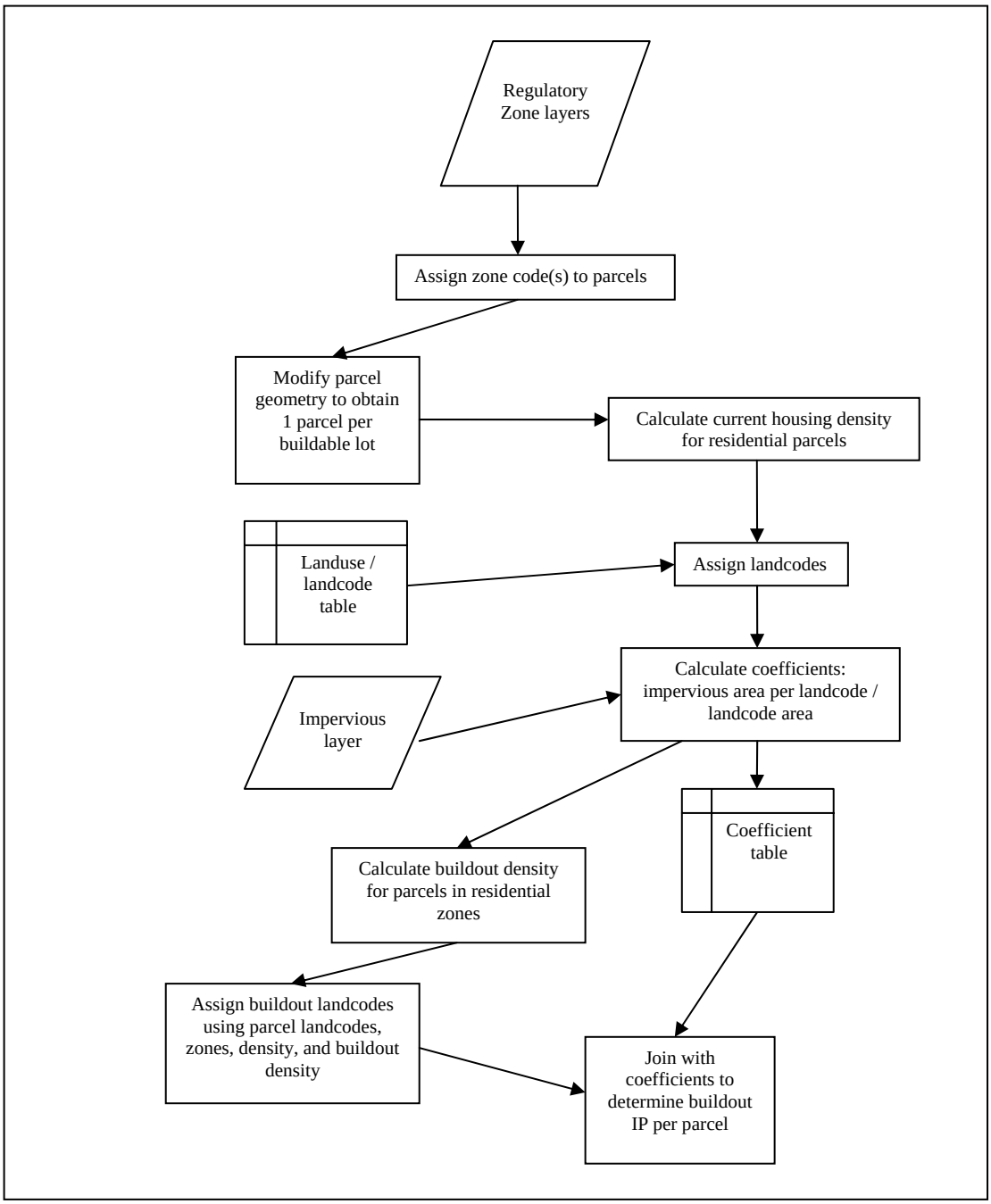

Figure 2 Buildout analysis process diagram

The analysis followed the assumption that many parcel-types have a potential for an increase in IP. Future changes considered were the further division of rural and open land areas into commercial, industrial, or higher-density residential landuses as well as changes in landuses such as residential to commercial or commercial forest to residential. These were considered likely if the zoning allowed such land division and other factors did not prohibit development (such as sewer requirements). Some landuses were assumed to have negligible future IP changes, such as parks, government facilities, utilities, and government-owned forest lands.

Input Data

Data relevant to impervious surfaces and zoning regulations within the Hood Canal summer chum ESU were gathered and assessed. Impervious surface (IP) data showing the location of IP versus non-IP lands at a 5-meter resolution were procured from Spatial Sciences and Imaging (see Figure 3). Parcel and zoning layers for Kitsap County, Jefferson County, and Clallam County were obtained. These included sub-areas of Jefferson County but did not include sub-areas of Kitsap County (City of Bremerton) zoning due to non-relevance to summer chum.

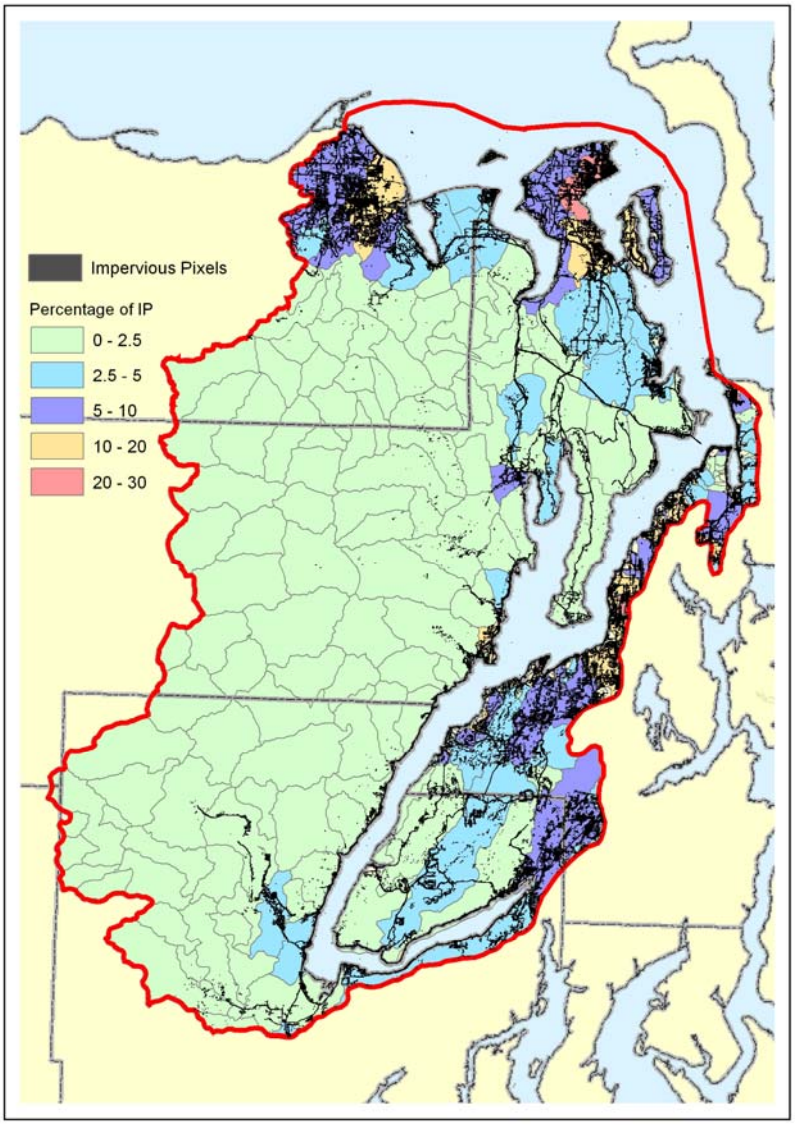

Figure 3 Impervious Surface Data

The IP data, parcels, and zones were the major layers used in the model. Other supporting data included digital orthophotos, streams, sewers, and aquifers. Summer chum distribution data from the Washington Department of Fish and Wildlife were used to determine upstream extents for the riparian corridor analysis. A few layers were created especially for the model

and represent composites of pre-existing data. These are the watershed, estuary, and nearshore layers. Table 1 shows the data used and their sources.

Table 1 Data Sources

Data	Source(s)
Aerial Imagery	Spatial Sciences and Imaging
Aquifers	Jefferson County
Bathymetry	Finlayson, University of Washington
Driftcells	WA Dept. of Ecology
Estuaries	UW, ESRI, WADNR, PetersonGIS
Hydrology	WA Dept. of Natural Resources
Impervious Surface	Spatial Sciences and Imaging
Nearshore zones	WA Dept. of Ecology, PetersonGIS
Parcels	Kitsap, Jefferson, and Clallam Counties
Sewers	Jefferson County
Summer chum distribution	WA Dept. of Fish and Wildlife
Watersheds	USGS, Kitsap County, PetersonGIS
Zoning	Kitsap, Jefferson, and Clallam Counties; City of Port Townsend

The zone assignments, housing densities, current landcode and buildout landcode assignments, and other calculations created during the course of the analysis were added to the existing parcel geometry and together make up the *buildout database* that is referred to in this document.

Parcel Data Standardization

Pre-processing of the parcel layers for all three counties was necessary in order to create uniform parcel layers with the desired characteristics. For example, the parcels needed to reflect individually held pieces of land with a single landuse designation (except in Clallam County where multiple landuse designations existed). In some cases parcels were coded with landuses that were not appropriate to this analysis (i.e., a null landuse or exempt code). It was also necessary that parcels not be grouped together, as this would create erroneous population density estimates and zone definitions. The GIS processing details for the Kitsap, Jefferson, and Clallam County parcel layers are expanded upon below.

Kitsap County's parcel layer contained individually held parcels and was mostly coded with landuses consistent with the needs of the analysis. However, there were some parcels that were assigned a landuse of vacant when there was a building on the property (D. Nash, GIS Analyst Kitsap County, personal communication, August 3, 2004). To identify these parcels, all polygons coded as vacant were selected. The applicant field showed 4 with utility applicants, one with a school applicant, and one with a gun club applicant. Because the purpose of identifying each parcel's landuse was to determine how much impervious surface is, on average, within certain groupings of landuses, it was essential to determine if any of these parcels had impervious surfaces on them so as to not skew the average impervious results for the vacant category. Digital orthophoto analysis determined that no significant imperviousness existed on the utility and school applicant parcels. The gun club parcel did have some existing IP so it was excluded from the vacant landuse IP quantification.

The Jefferson County parcel layer contained several parcels that were comprised of multiple polygons (J. Miller, personal communication, August 18, 2004). The lines that split these parcels were mostly section lines and are artifacts of the origination of the parcel layer. This situation would have caused the model to overestimate the IP in these parcels. For example, the model would have assigned one house for each polygon (for a total of two) when in fact only one house was allowed within the combined polygons. Another issue was that the parcel layer contained some parcels that were assigned the same parcel identification number (PIN), but were split into separate polygons. It was determined that these were, indeed, individual parcels despite their common PIN. Both issues were resolved within the GIS in order to achieve a one-to-one relationship between a parcel and its polygon.

Both the Kitsap and Jefferson County parcel layers were clipped to the summer chum ESU. Some parcel geometry was therefore cut off at the ESU boundary, resulting in a potential for error in that the IP included for those parcels may in fact have been on the non-ESU side of the parcels. However, due to the large number of parcels analyzed, the error involved in the relatively few split parcels is negligible. The modified Kitsap County and Jefferson County parcel layers contained 14,305 and 29,633 parcels, respectively.

A subset of the Clallam County parcel layer was used. The parcels lying within the Jimmycomelately watershed and estuary were analyzed for a total of 246 parcels. The Clallam County parcel layer was unique in that an individual parcel could contain one or more landuse codes. The area pertaining to each landuse code was included in the parcel layer. In the pre-processing stage, this was left as-is. A few parcels were originally split into two shapes (i.e., part a and part b) even though they were one parcel. These were combined. In total, 44,184 parcels were analyzed in the buildout analysis.

Zone-code Assignments

Once the parcel layers were pre-processed to resolve the coding and delineation anomalies discussed in the previous section, they were overlayed with the zoning layers in order to assign zone codes to each parcel. Most parcels in the study area overlapped with one or more of the zones. The Clallam County parcel layer already contained zone codes and was therefore not a part of this process. The zone-code assignment details for Kitsap and Jefferson Counties are expanded upon below.

The most recent zoning layers for Jefferson County, the Port Townsend UGA, the tri-area UGA, and Kitsap County were overlayed onto the parcel layers. A GIS selection process was then performed in order to assign the appropriate zone code to each parcel. In most cases parcels were located within a single zone designation. In cases where a parcel overlapped with multiple zones, the appropriate county or city zone code was consulted to determine how the parcel should be assigned (UDC 2000, PTMC 2003, KCZO 2004). For example, the City of Port Townsend municipal code, chapter 17.12.050, specifies that a parcel of less than one acre is assigned the zone that comprises the majority of the parcel. If a parcel is large enough, the codes may specify that it be split into two or more zones. To accommodate these aberrations, the buildout database was designed to allow up to three zone designations for a single parcel.

An exception to the overlay methodology was made for Kitsap County's right-of-way (ROW) parcels. Even though the ROW parcels overlapped with zone polygons, they were assigned a

null zone-code. These parcels will likely remain unchanged in buildout regardless of their zone. They were given the buildout landcode of *ROW*.

Some exceptions also occurred in the Jefferson County overlay. First, the rural residential (RR) zone was treated as three separate zones to reflect the three different population density allowances in this category. Second, some of the zone polygons did not have zone codes. These were Olympic National Forest, water, military, and other uncoded areas. These were not assigned zone codes in the buildout database but were assigned the appropriate landcode as described in the next section (e.g., military areas were assigned to the *facilities* landcode). Finally, four parcels in Jefferson County contained both a zone from the tri-area zoning layer and from the Jefferson County zoning layer. A reference to these parcels could not be located in the tri-area UGA literature. However, the Future Landuse Map splits these parcels where the zones change (FLM 2004). Therefore, for this analysis, the four parcels were split in the same manner.

Current Landcode Assignments

All the parcel layers contained landuse codes used by their respective tax assessment offices. The schema used for assigning codes is the same in the three counties. There are hundreds of landuse codes in this schema. For example, the Jefferson County portion of the study area contained 108 unique landuse codes. A smaller grouping of codes was developed for this project since many landuse codes have statistically similar impervious potential. The new grouping schema is referred to in the analysis as *landcodes*, representing both a grouping of the landuse codes as well as housing density in residential parcels.

The landcode grouping built upon similar work conducted by Dave Nash, Kitsap County GIS Analyst, in a previous buildout analysis. The process of assigning landcodes to the parcels involved creating a preliminary grouping schema and calculating housing density in residential parcels. The purpose of the landcode assignments was to create a code schema that could then be applied to the same parcels under buildout conditions and therefore enable a direct comparison between the current landcode and the buildout landcode.

The first step in the landcode assignment process was to determine which landuses could be grouped together. The goal was to group landuses with statistically similar IP densities together. Some of the landuses were assigned both current landcodes and buildout landcodes during this step if it was determined that they would remain the same regardless of zoning regulations. For example, in Kitsap County the landuse code 4600 represents parking. The current landcode group it was assigned to was *transportation*. The buildout landcode was also assigned to *transportation* since it was unlikely to show an increase in IP regardless of the zone. Other landcodes that remained the same in buildout were: schools, apartments, parks, institutional, utilities, transportation, mobile park, water, rail, streets/highways, church, and hotel/motel. Appendix C contains the landcode conversion tables.

The amount of IP in residential landuses can vary depending on the size of the parcels. For example, the Kitsap landuse code 1101 represents one mobile home per parcel. The percentage of IP in the parcel will be much greater for a 5,000 sq ft parcel than for a 5 acre parcel. Therefore, residential landuses were assigned landcodes based on housing density. Housing density was calculated using the number of homes per parcel as specified in the landuse code divided by the area of the parcel (see Table 2). For example, if a parcel

contains the landuse code for one mobile home and has a calculated housing density of 0.188 (or one housing unit on 5.3 acres), it was assigned a current landcode of rural.

Table 2 Residential Landcode Assignments

Landcode	Density
Open Land	<= 1 HU[1] per 10 acres
Rural	Between 1 HU per 10 acres and 1 HU per 5.2 acres
Estate	Between 1 HU per 5.2 acres and 1 HU per 2.6 acres
Suburban	Between 1 HU per 2.6 acres and 1 HU per 1 acre
Urban Low	Between 1 HU per 1 acre and 12,480 sq ft
Urban Standard	Between 1 HU per 12,480 sq ft and 6,150 sq ft
Urban Medium	Between 1 HU per 6,150 sq ft and 3,114 sq ft
Urban High	>= 1 HU per 3,114 sq ft

[1] Housing Unit

The following landuses presented special cases in Kitsap County: taxtitle, unknown, and null. Most of these were assigned the landcode *unbuildable* depending on their size. Parcels with these landuses that were less than one acre were given the *unbuildable* classification. Larger parcels were examined individually using aerial photography to determine their IP amounts, if any. If a parcel appeared to have a building or other source of IP, it was assigned a relevant landcode for the estimated amount of IP.

Some special cases existed in Jefferson County as well. One case involved parcels having a landuse of 0. The landcodes for these parcels were determined on an individual basis. For example, four of the parcels with landuse of 0 were on an island not relevant to the study so they were given a landcode of *OUT*. Another was the existence of two parcels with no landuse codes or descriptions. Digital orthophoto analysis did not reveal enough information. Ultimately, these parcels were assigned residential landcodes, assuming one home on each, due to their proximity to other residential areas. There were less than 50 of these special-case parcels out of 44,184 total parcels analyzed.

In Clallam County, many parcels contained multiple landuse codes. Rather than assign multiple landcodes to these parcels, these were consolidated into a single landcode. For example, several large parcels contained a one acre residential landuse such as single family residential while the rest of the parcel was assigned a wooded landuse. However, because zoning usually applied to the entire parcel with the dwelling unit included in zoning restrictions, these parcels were assigned residential landcodes: usually open land or rural depending on the total acreage. Additionally, parcels with landuse codes of 9750, or exempt, were assigned a landcode of vacant, except in one case where the landcode *facility* was assigned due to IP on that parcel. One parcel was assigned the landcode *unbuildable* due to not having any landuse codes associated with it.

Coefficient Calculations

Once the landcoding process was completed, the IP coefficients were calculated. This process included all the parcels from the Jefferson County and Kitsap County analysis, excluding those from the Clallam analysis, as it was completed at a later date. To determine

the average IP per landcode, the amount of IP in each landcode was calculated as well as the total area of parcels in each landcode. The total IP was then divided by the total land area for individual landcodes to arrive at average IP percentages per landcode. Results are presented in Appendix A.

In order to determine the difference between the estimated IP values calculated in the process described above and the actual IP values, the watershed polygons were used to tally, per watershed, the amount of IP according to the estimated values derived via the landcodes. These were compared to the actual IP in the watershed determined by summing the area of IP in the IP layer when clipped to each watershed. For example, in the Martha John watershed the amount of current IP as derived via the landcode method was 6.96% while the actual IP amount was 4.63%. A comparison of the two values is reported in Table 6 and a scatterplot is shown in Figure 38.

Buildout Landcode Assignments

Once the current landcodes were assigned and the coefficients calculated, buildout landcodes were assigned. Many of the parcels retained the same buildout landcode as their current landcode. These were: schools, apartments, parks, institutional, utilities, transportation, mobile park, water, rail, streets/highways, church, and hotel/motel. Additionally, most parcels with the current landcode of *wooded* were also assigned a buildout landcode of *wooded*. However, those with a landuse of 8300 – designated timberlands - were assigned residential buildout landcodes due to their location within rural residential zones and the potential for housing development if these lands were sold.

Assignment of buildout landcodes for residential zones was based on the current housing densities, potential buildout densities based on the zone regulations, and the current landcode for that parcel. For example, a one acre parcel in a rural residential zone (maximum of one house per 5 acres) that does not yet have a house on it has a current landcode of *open land*. Even though this parcel is smaller than the required 5 acres, a house can still be built on it since it is already delineated as a separate parcel. Therefore, this parcel would be assigned the buildout landcode *urban low* because it has the potential to contain a maximum of one house on one acre.

The process for assigning buildout landcodes was, for the example noted above:

- select all parcels with a current landcode of *open land*
- within that selection, select parcels in rural residential zones (one HU per 5 acres)
- for each selected parcel:
  - if the parcel area is less than 10 acres, the buildout landcode is assigned based on Table 2, with a buildout of one HU / parcel size
  - if the parcel area is greater than or equal to 10 acres, the buildout landcode is assigned based on Table 2 and the buildout of 2 HU / parcel size for parcels less than 15 acres, 3HU / parcel size for parcels less than 20 acres, etc.

Additionally, for all parcels with current landcodes of rural, estate, suburban, urban low, urban standard, urban medium, or urban high, in the rural residential zone (one HU per 5 acres), the parcel is already built-out to the maximum allowed. Therefore the buildout landcode would be equal to the current landcode. An example of the current landcode assignments as compared with buildout landcode assignments is shown in Figure 4. A large

number of unique combinations of densities and zones were present in the data. The combinations and their respective buildout landcodes are recorded in Appendix B.

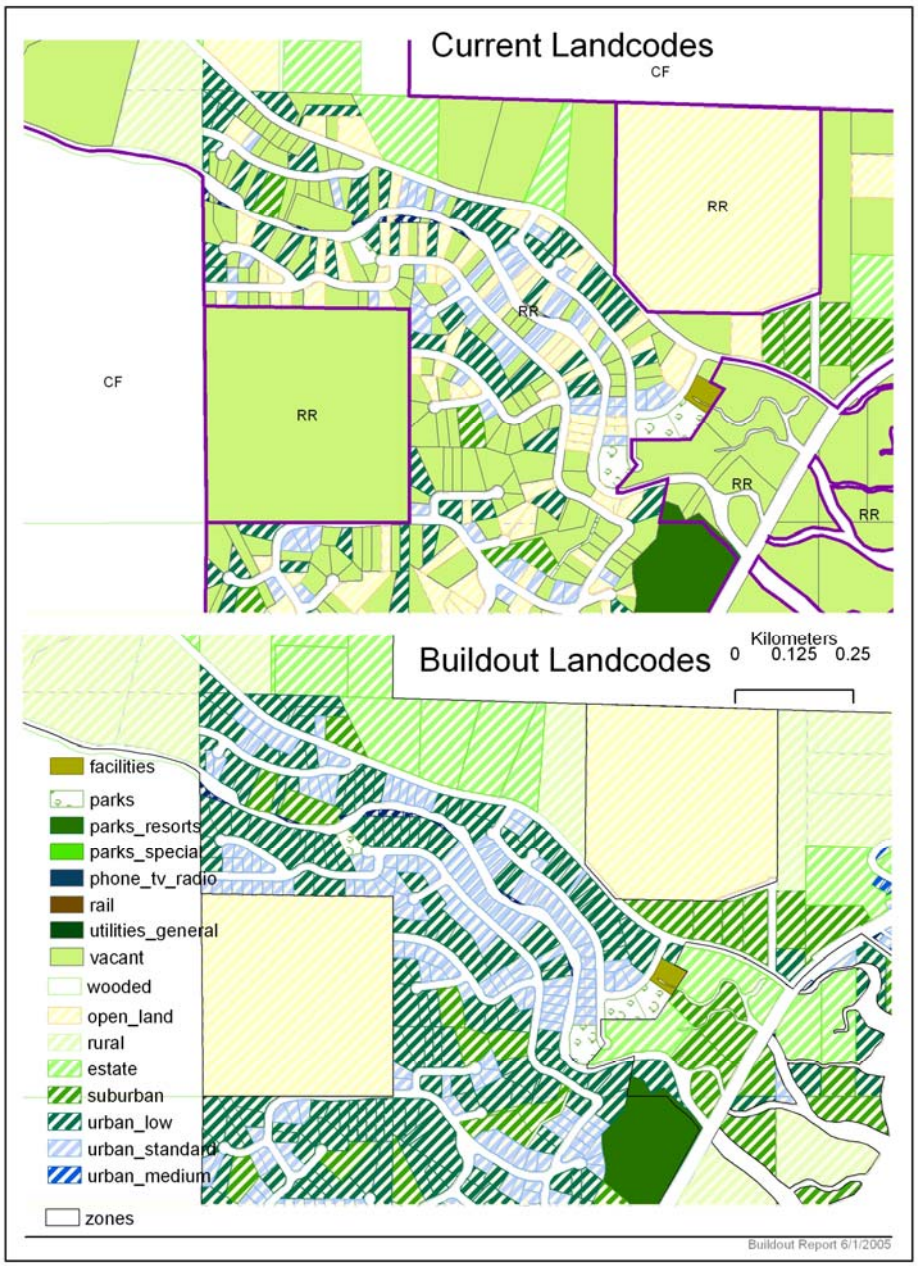

Figure 4 Buildout database illustration with RR zone code (one dwelling unit per 20 acres)

Buildout Analysis

Parcel buildout IP percentages were calculated using the buildout landcodes assigned in the previous step and the estimated IP percentages calculated from the current landcodes. A one-to-one relationship existed between the buildout landcode database and the current landcode estimated IP table. Current landcodes were also matched with the estimated landcode IP

table to arrive at an estimated current IP for that parcel. This estimated current IP figure is referred to as "modeled current IP" in the remainder of this report. It is distinct from "actual IP" which is not based on the coefficients, but rather via overlay of the IP layer with the unit being measured. For example, a one acre parcel with a current landcode of rural has a modeled current IP of 3,058 sq. ft. and an estimated buildout IP of 9,209 sq. ft. This is an increase of 6,151 sq. ft. of IP or 201%.

Maximum IP calculations were also figured. The zone codes for Jefferson and Kitsap counties contained information concerning the maximum allowable IP in select zones. These maximum IP percentages were assigned to the applicable parcels. The Clallam County zones in the study area did not have maximum IP percentages specified in the Clallam municipal code. Zones that didn't have specific maximum IP percentages stated in the city and county codes were assigned a maximum IP of 100%. Parcels that remained unchanged in buildout (i.e., current landcode = buildout landcode) were assigned the estimated IP for that landcode, not the maximum IP.

Once all of the IP estimates were calculated for both current and buildout landcodes, the parcels were grouped into four unit types: watersheds, riparian corridors, estuaries, and nearshore in order to report on the estimated change of IP within those units.

Watersheds

The difference between current IP and buildout IP in each watershed of the summer chum ESU (excluding Mason County) was calculated in order to illustrate where the zoning regulations and resulting development would have the greatest change if all parcels were built out. A watershed layer was built using existing watershed polygons from Kitsap County, USGS 7th field hydrologic unit codes (HUCs), and 30-meter digital elevation models. Totals for the current and buildout IP estimates were calculated on a per-watershed basis and are shown in Figure 8 and Figure 9. As mentioned earlier, the modeled current IP shown in the maps is calculated by using the coefficients for the current landcodes of each parcel. The actual IP, as determined via overlay of the parcels with the IP data, and the other watershed results are presented in Table 6.

Riparian Corridors

Natal watersheds of both the extant and extinct summer chum salmon populations were analyzed. Riparian corridors were delineated using a 200 foot buffer of the summer chum streams, from the mouth to the upward extent of chum distribution as identified by the Washington Department of Fish and Wildlife. The buildout database was clipped to the corridor polygons and totals for modeled current IP, buildout IP, and maximum buildout IP were calculated (see Table 8 for results and Figure 5 for an example).

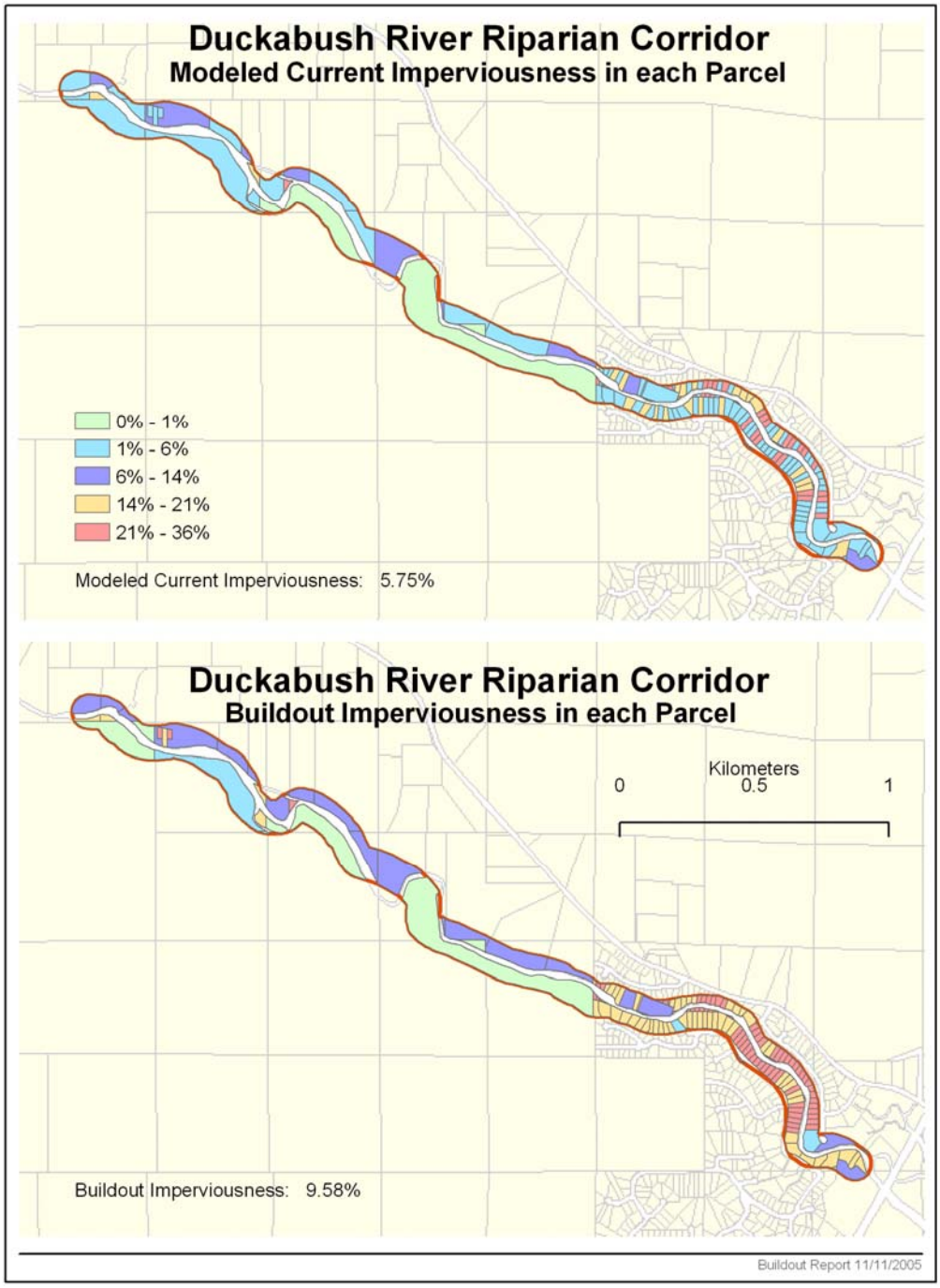

Figure 5 Example of riparian corridor delineation, parcel clipping, and IP statistics

Estuaries

In the estuarine analysis, the goal was to determine how the land directly contributing runoff to a major summer chum estuary would likely be changing over time with respect to impervious surfaces. Estuaries often have developments surrounding them and may even have impervious surfaces such as highways and docks over them. In order to capture the effect of the parcels surrounding the estuaries, it was necessary to delineate the estuarine boundaries augmented with parcels that touched those boundaries. Thus, the estuarine analysis began with the delineation of the impact areas (estuary plus surrounding parcels) and ended with the computation of both current and future imperviousness within those impact areas.

When this study began, no GIS coverage of estuaries in the study area existed so it was necessary to create them for the project. First, a one mile circular buffer polygon was drawn around the end points of each major summer chum stream. This determined the linear extent up the shoreline that the estuary polygon would encompass. The one exception is the Quilcene impact area, which is a combination of the Little Quilcene and the Big Quilcene linear extent. Next, a 200 foot inland buffer of the shoreline was used in order to capture the land immediately surrounding the estuary. Because there are several shoreline lines, none of which are perfect in all cases, the county boundary shoreline was used when it matched with underlying orthophotos and the inside DNR shoreline was used when it was a more appropriate match. The county shoreline represents the county boundary at a 1:24,000 scale as delineated by the U.S. Census Bureau. The DNR shoreline is close to ordinary high water, according to a note from Helen Berry of WA Department of Natural Resources in the hydrology metadata. Finally, the outer extents of the estuaries were determined using a -3.0 meter contour line from the Puget Sound digital elevation model developed by the University of Washington (Finlayson, 2000). The contour line is relative to the mean sea level datum used by older UGSS data (NGVD29).

The resultant estuary polygons (see Figure 6) were subsequently merged with the parcels that were wholly or partially contained within the estuary polygons. These merged polygons became the estuarine impact areas and formed the spatial boundaries for the estuarine results (see Figure 7).

Figure 6 Hama Hama estuary delineation using a one mile buffer of the stream endpoint, 200 foot inland buffer of the shoreline, and 3.0 meter bathymetric contour.

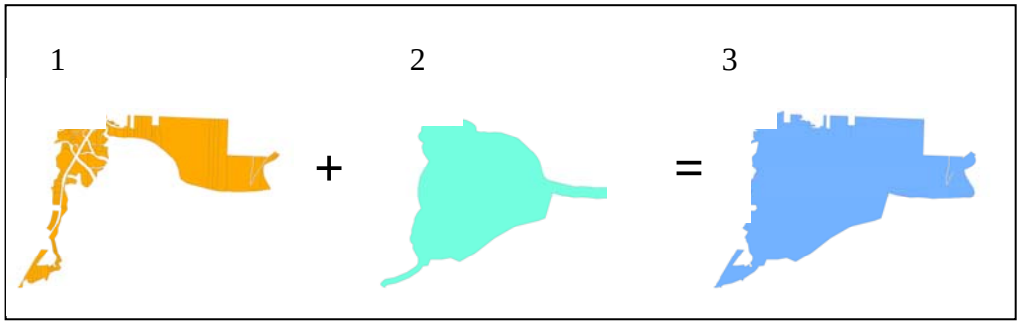

Figure 7 The Duckabush River impact area (3) is the result of overlaying parcels wholly or partially within the estuary (1) with the estuary itself (2).

Current impervious surface quantities were derived via two methods. The first was a simple quantification of the impervious surface area in each impact area by clipping the impervious surface data to each impact area and adding up the total pixel area within each. The shifted IP data was used for Jefferson County and Clallam County impact areas while the original IP data was used for the Mason County and Kitsap County impact areas (see shifted IP data discussion in the Accuracy/Error section). The second quantification method used the current landcode designations, their associated mean impervious percentages, combined with the parcel areas to determine the modeled current imperviousness.

Future impervious surface quantities under a buildout scenario were also derived via two methods. The first was an average buildout scenario using the mean impervious

percentages associated with each parcel's designated buildout landcode. A parcel's area, for example, was multiplied by its buildout landcode's mean imperviousness. A summation of all these calculations per each impact area divided by the total area of the impact area gave the expected future imperviousness per impact area. The second method was derived in order to determine the maximum buildout potential for the impact area using the zoning law's maximum IP allowable. In this case, the maximum IP percentages associated with each parcel's designated buildout landcode were multiplied by each parcel's area, summed, and then divided by the total area of the impact area. The results of that calculation illustrate the maximum allowable imperviousness per impact area. Results are reported in Table 7.

Nearshore

Nearshore polygons were created in order to analyze the localized buildout changes that could be expected in those parcels that follow the shoreline. To that end, the shoreline (as defined by the parcel layer) was buffered inland to 300 feet. The parcels were clipped to this 300 foot buffer area and assigned IDs according to which driftcell they were closest to. The total amount of impervious surface under current, buildout, and maximum buildout was summed for all the parcels that made up each driftcell ID. The total area within each driftcell ID was also computed. The percent of current, buildout, and maximum buildout IP was then calculated as a fraction of the total area, using the same process as described in the estuary section above. In order to visualize these results, the parcels were then dissolved by driftcell ID to create nearshore polygons showing the location of each nearshore unit. These nearshore units were subsequently joined to the statistics for visualization. The nearshore units and results are shown in Figure 36 and Figure 37.

Results

The amount of impervious surface was quantified within each of the four unit types (watersheds, riparian corridors, estuaries, and nearshore). A summary of the number of units within each 5% IP category for both modeled current and buildout scenarios are presented in Table 3 and Table 4. For example, there were 5 riparian corridors containing 0-5% IP and 7 riparian corridors containing 5-10% IP under the current modeled conditions. Under buildout conditions, there were 2 riparian corridors containing 0-5% IP, 7 riparian corridors containing 5-10% IP, and 3 riparian corridors containing 10-15% IP. Only those units with complete parcel information are included in these tables.

Table 3 Number of units within each IP category under modeled current conditions

	Riparian Corridors	Estuaries	Nearshore	Watersheds
< 5%	5	8	18	72
5-10%	7	2	46	30
10-15%	0	0	55	22
15-20%	0	0	16	3
20-25%	0	0	7	0
25-30%	0	0	3	0
30-35%	0	0	0	0
35-40%	0	0	0	0

Table 4 Number of units within each IP category under buildout conditions

	Riparian Corridors	Estuaries	Nearshore	Watersheds
< 5%	2	4	11	62
5-10%	7	6	34	31
10-15%	3	0	44	27
15-20%	0	0	34	4
20-25%	0	0	10	2
25-30%	0	0	6	1
30-35%	0	0	5	0
35-40%	0	0	1	0

The total IP increase in each of the unit types was calculated to give an overview of the amount of change predicted by the model. The following percentages are based on current IP versus buildout IP and are not normalized by total unit area. The percent IP increase, therefore, is simply:

$$(\text{buildout IP}_{acres} - \text{current modeled IP}_{acres}) / \text{current modeled IP}_{acres}$$

All the nearshore units together showed a 19% increase in IP. The riparian corridors showed an increase of 50% IP. Estuaries also showed an increase of 50% IP. The total increase in IP calculated for all the parcel data (i.e., not including the Mason County analysis) was 29% (11,372.28 acres to 14,658.95 acres).

The average IP within each unit type was calculated to determine how unit types compared with respect to the amount of IP within them (see Table 5). The following percentages are normalized by area because they are averages of all the entities within a given unit type. For example, for the watershed averages, the sum of the modeled current IP percentages for all the watersheds was calculated and then divided by the number of watersheds.

Table 5 Average IP for all entities within each unit type

Unit Area	Average Modeled Current IP	Average Buildout IP
Watershed*	5.20%	6.19%
Riparian Corridor	5.46%	7.79%
Estuary	4.10%	6.30%
Nearshore	10.90%	13.93%

* only includes watersheds with full parcel data

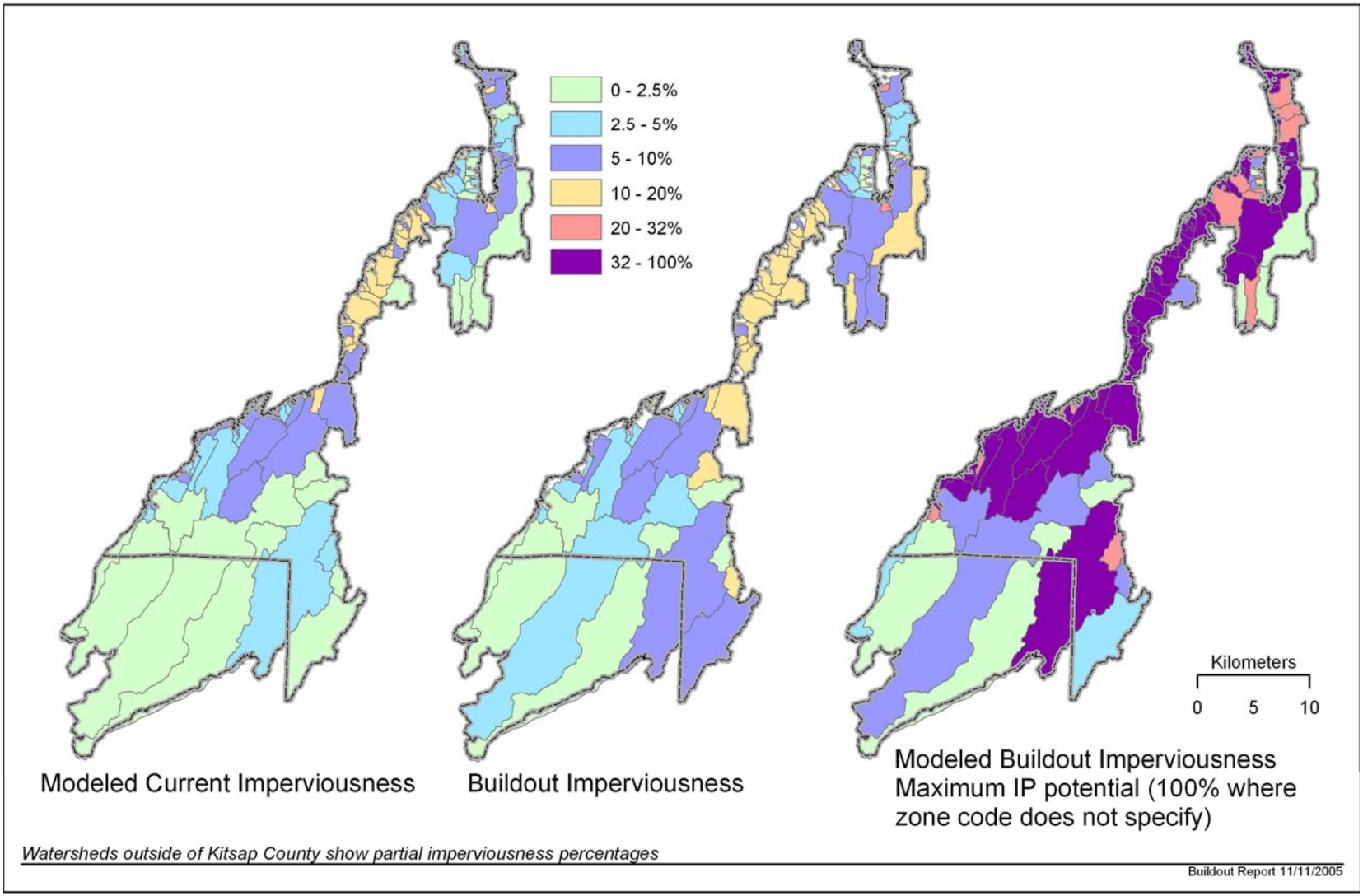

Figure 8 Kitsap County watershed results

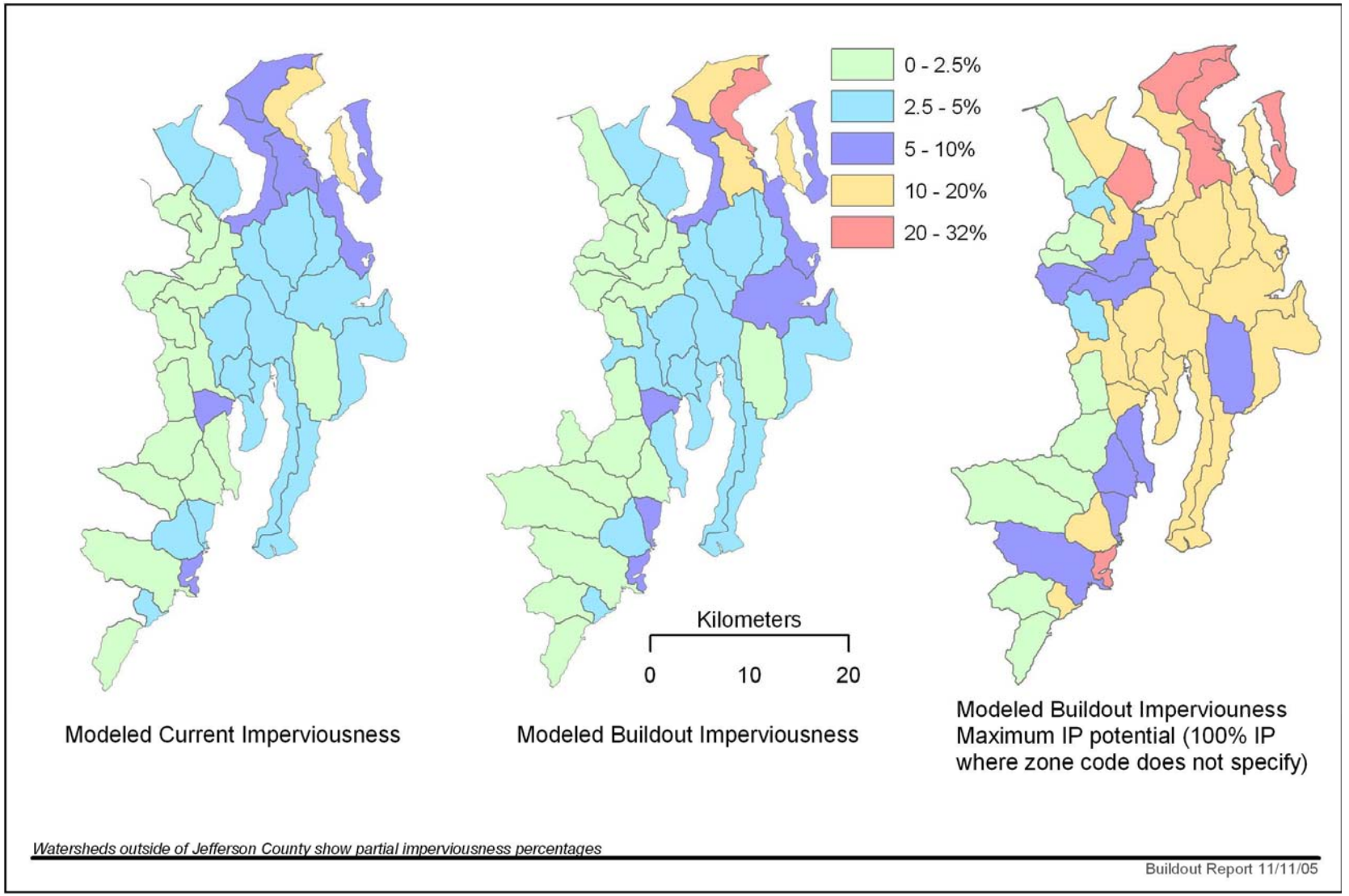

Figure 9 Jefferson County watershed results

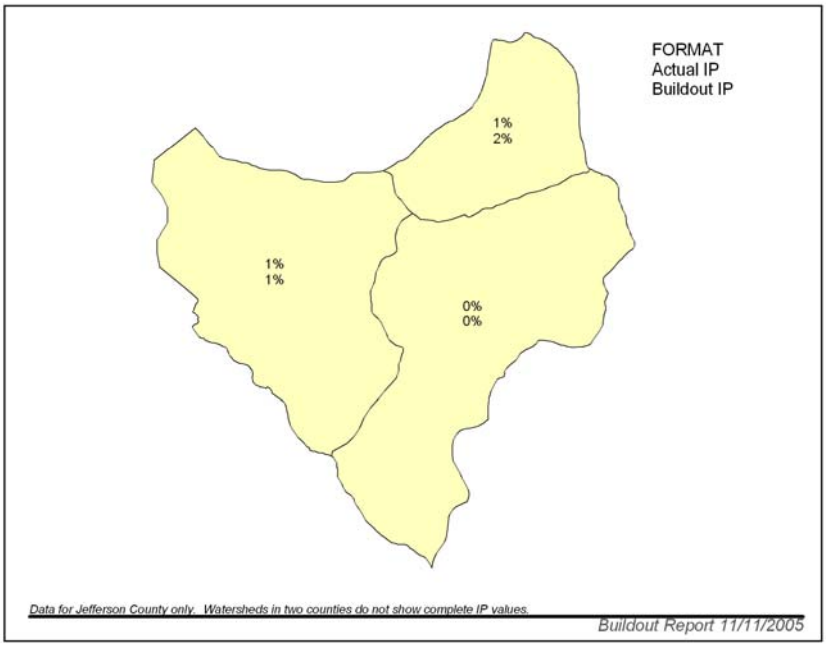

Figure 10 Jimmycomelately Creek buildout statistics

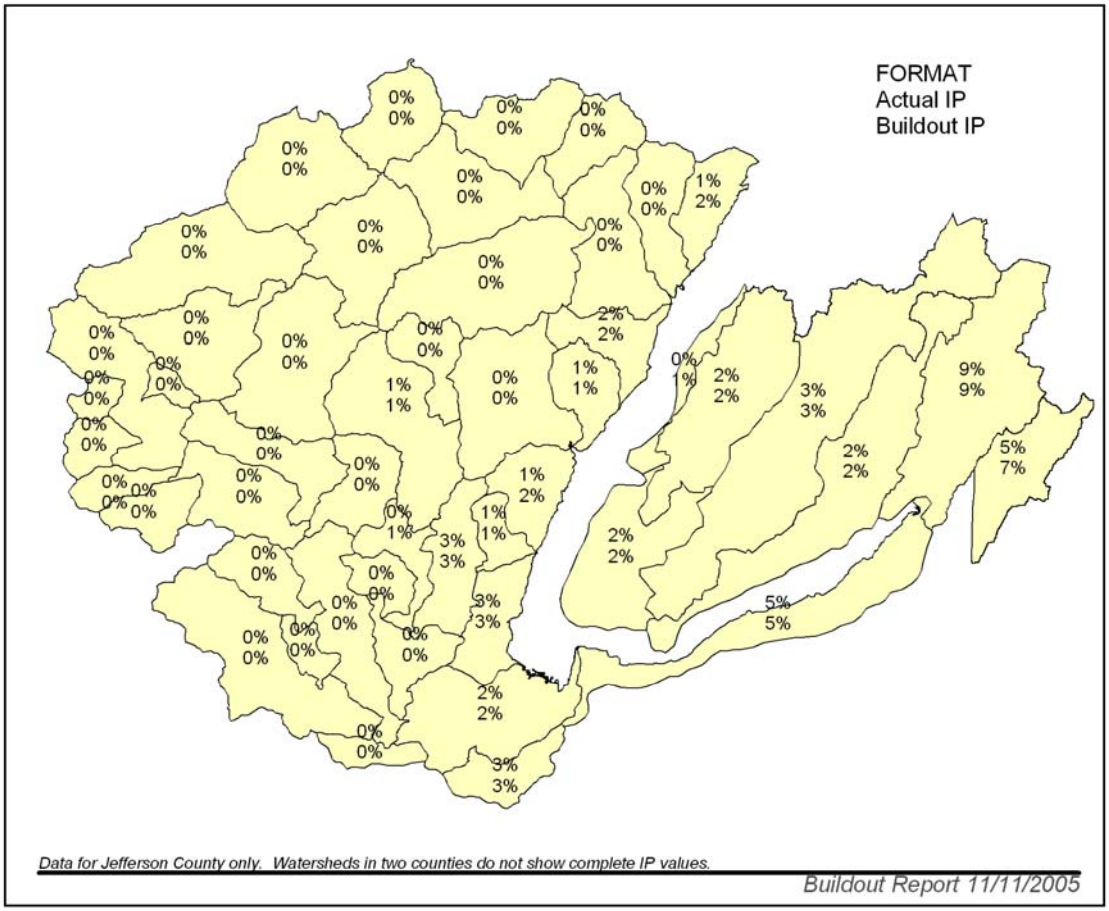

Figure 11 Mason County buildout statistics

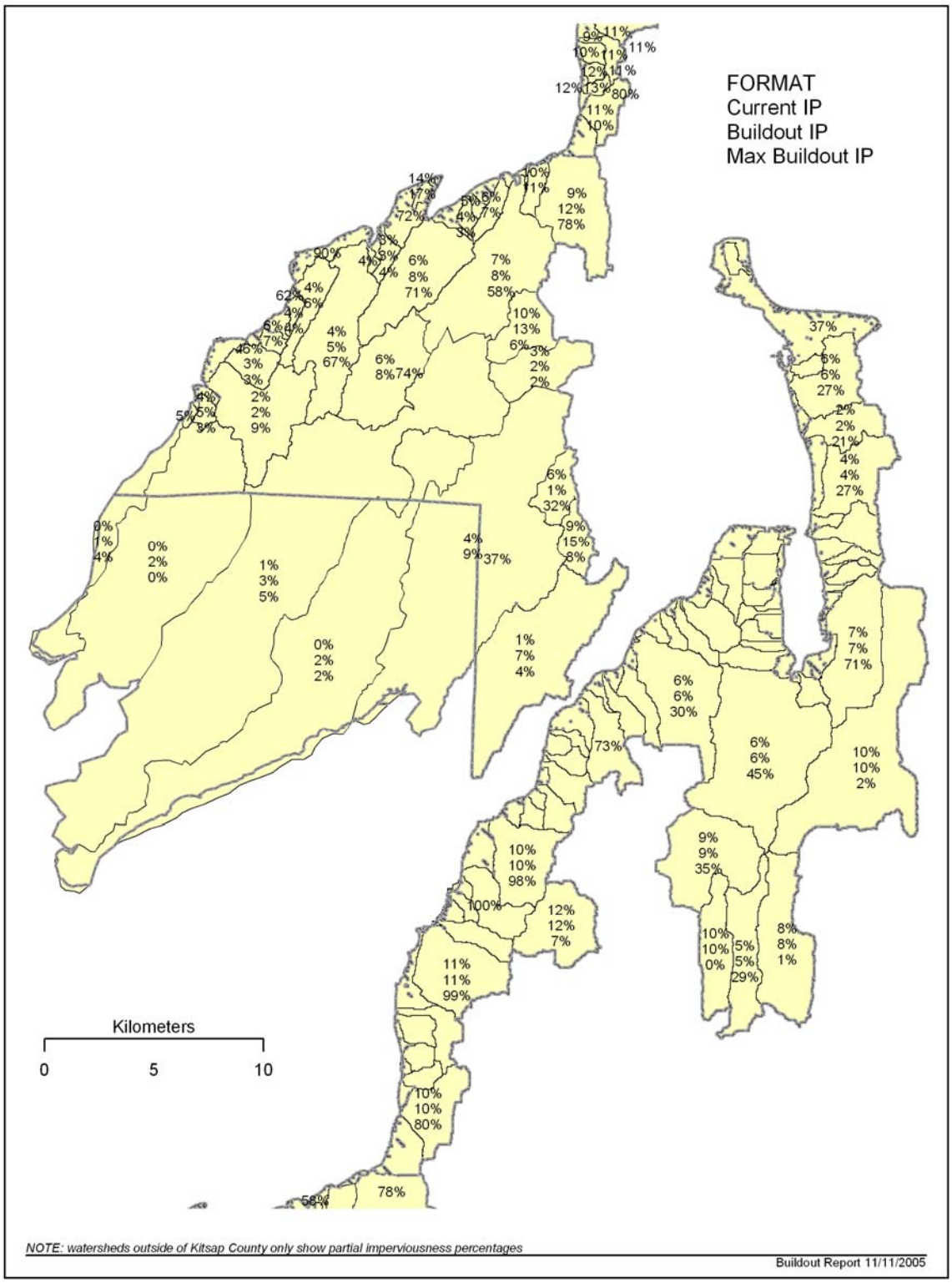

Figure 12 Kitsap County buildout statistics

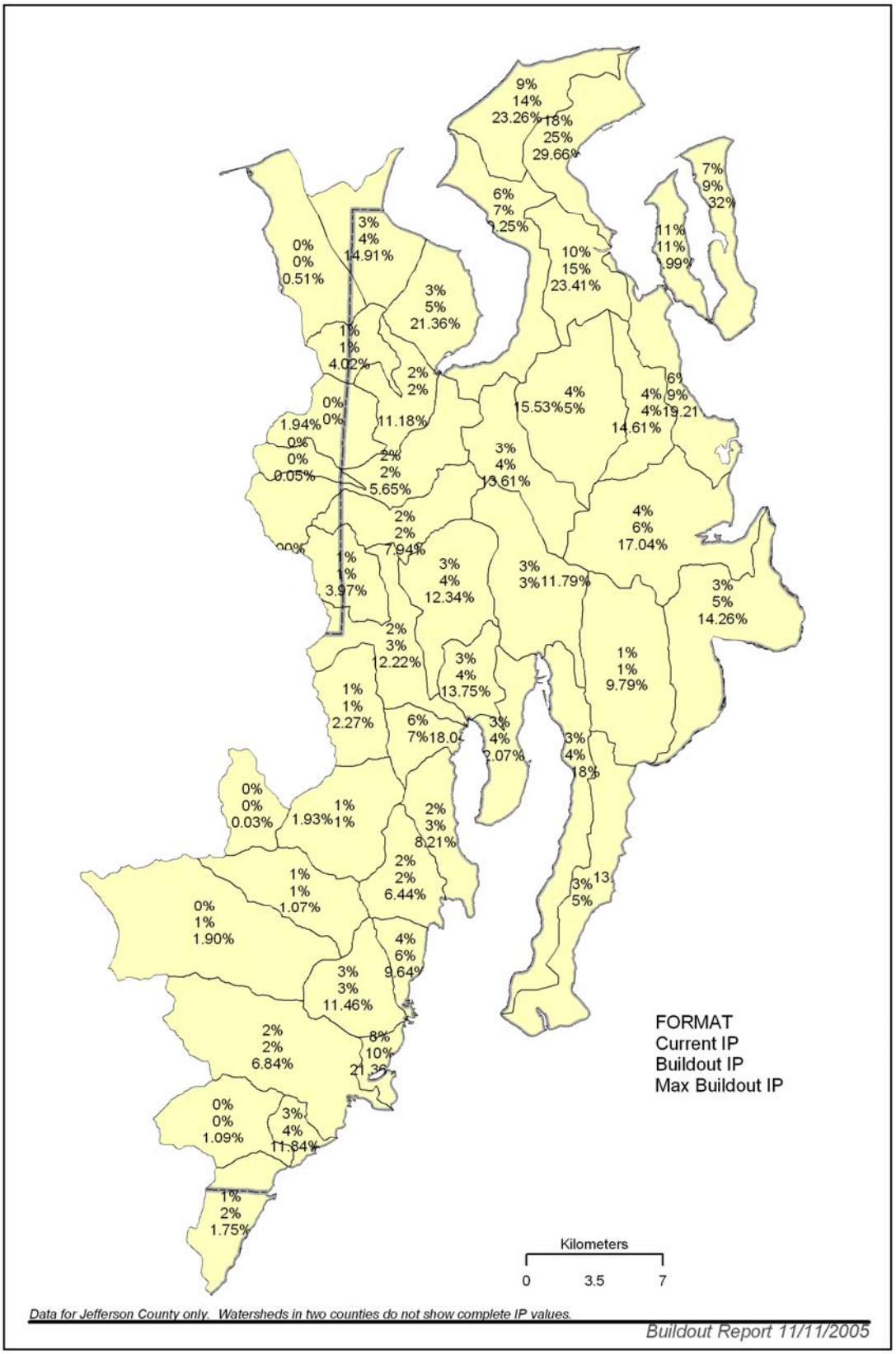

Figure 13 Jefferson County buildout statistics

Table 6 Watershed level buildout statistics

**Grayed results represent watersheds containing only partial parcel coverage: those that are partially within Mason County or in un-analyzed areas of Clallam County. The gray figures, therefore, under-represent the impervious surface.*
***NA signifies a complete lack of parcels and/or parcel analysis for the watershed; no modeled current IP was calculated.*
****Mason County buildout IP results are based on an increase of 0.2% over the actual IP (see the Mason County section of the report). Watersheds spanning both Mason County and another county contain results representing the total of 0.2% plus the buildout IP estimated for the non-Mason County portion of the watershed plus the actual IP in the Mason County portion of the watershed.*

No.	WATERSHED NAME	ACTUAL IP	MODELED CURRENT IP	MODELED BUILDOUT IP	MAXIMUM BUILDOUT IP
	Kitsap County				
1	150349	2.77%	3.53%	3.75%	26.86%
2	150362	2.32%	5.17%	6.17%	44.08%
3	150371	9.02%	11.00%	11.08%	99.81%
4	150372	16.00%	10.88%	10.87%	98.90%
5	150373	7.58%	10.99%	10.98%	99.95%
6	150374	11.83%	10.93%	10.92%	99.06%
7	150375	37.48%	12.33%	12.88%	98.11%
8	Bangor Creek	18.87%	10.16%	11.14%	80.34%
9	Big Anderson	3.03%	1.89%	1.97%	8.95%
10	Big Beef (Lower)	8.73%	6.64%	7.75%	58.31%
11	Big Beef (Upper)	8.74%	6.46%	7.66%	73.68%
12	Big Cedar Creek	2.51%	2.83%	3.28%	42.31%
13	Boyce	5.98%	4.36%	5.79%	61.92%
14	Cattail	5.06%	10.48%	11.08%	97.68%
15	Coulter	4.83%	0.64%	6.68%	4.17%
16	Dogfish (East)	14.50%	9.30%	10.39%	34.55%
17	Fern	2.86%	3.01%	3.35%	24.40%
18	Gamble	6.48%	5.64%	6.64%	45.02%
19	Gorst (South Headwaters)	23.32%	9.32%	14.73%	7.69%
20	Gorst (Upper)	3.44%	5.52%	0.56%	31.98%
21	Grovers	3.28%	9.51%	11.60%	1.79%
22	Harding	6.57%	3.18%	3.21%	45.92%
23	Hawks Hole	5.36%	5.99%	7.10%	26.89%
24	Hudson	1.17%	3.52%	4.15%	36.69%
25	Johnson (Lone Rock)	12.65%	10.02%	11.47%	93.67%
26	Johnson (Poulsbo)	2.84%	12.46%	13.17%	7.23%
27	Jump Off Joe	14.54%	14.69%	16.44%	73.06%
28	Kinman	4.59%	5.55%	6.09%	30.44%
29	Laudine Decouteau	0.37%	1.43%	1.63%	9.61%
30	Lemolo-Klaebel	7.60%	9.69%	10.87%	0.47%
31	Little Anderson	13.29%	9.36%	12.47%	77.73%
32	Little Beef	3.76%	5.95%	7.14%	64.88%
33	Little Boston	2.92%	3.92%	4.32%	55.26%
34	Lost	0.00%	3.10%	2.06%	1.88%
35	Martha John Creek	4.63%	6.96%	8.18%	71.33%
36	Middle	3.06%	8.15%	8.14%	81.46%
37	Nellita	10.88%	5.92%	7.38%	62.97%
38	Sam Snyder	4.67%	5.46%	6.23%	29.23%

No.	WATERSHED NAME	ACTUAL IP	MODELED CURRENT IP	MODELED BUILDOUT IP	MAXIMUM BUILDOUT IP
39	Seabeck	9.40%	6.09%	7.53%	71.34%
40	Springa	4.18%	5.00%	6.12%	33.62%
41	Stavis	4.95%	4.25%	5.07%	66.63%
42	Thomas	6.08%	4.11%	5.04%	28.51%
43	Thompson	0.00%	7.74%	8.16%	1.38%
44	Todhunter	1.09%	2.21%	2.65%	23.88%
45	Unnumbered10	23.16%	10.96%	10.97%	98.15%
46	Unnumbered11	12.81%	10.42%	13.09%	74.73%
47	Unnumbered12	15.80%	14.02%	15.91%	88.81%
48	Unnumbered16	13.29%	12.11%	14.93%	88.64%
49	Unnumbered17	0.35%	1.17%	1.17%	5.50%
50	Unnumbered19	10.68%	10.43%	11.91%	85.29%
51	Unnumbered20	13.96%	9.28%	9.86%	81.66%
52	Unnumbered23	5.20%	2.97%	3.92%	35.24%
53	Unnumbered30	10.02%	4.00%	4.16%	29.29%
54	Unnumbered34	33.39%	19.37%	23.89%	84.11%
55	Unnumbered35	7.07%	4.26%	5.97%	28.41%
56	Unnumbered36	10.72%	10.04%	11.50%	89.55%
57	Unnumbered38	24.81%	11.23%	12.34%	97.66%
58	Unnumbered43	1.66%	8.32%	11.80%	86.11%
59	Unnumbered49	0.36%	1.10%	1.10%	1.97%
60	Unnumbered51	11.54%	11.41%	12.93%	85.48%
61	Unnumbered52	19.42%	12.94%	14.44%	97.05%
62	Unnumbered53	24.53%	16.30%	22.91%	57.43%
63	Unnumbered55	21.61%	14.39%	17.23%	77.74%
64	Unnumbered6	0.76%	2.30%	2.67%	21.08%
65	Unnumbered64	6.48%	4.39%	5.18%	24.52%
66	Unnumbered68	1.78%	5.78%	10.48%	56.53%
67	Unnumbered71	6.77%	3.24%	4.96%	24.06%
68	Unnumbered75	5.49%	7.33%	8.99%	79.09%
69	Unnumbered76	1.94%	3.65%	3.82%	75.75%
70	Unnumbered78	0.74%	1.49%	1.49%	6.01%
71	Wildcat	17.04%	9.80%	12.66%	5.55%
	Jefferson County				
72	Andrews Creek	1.48%	2.18%	2.38%	7.94%
74	Big Quilcene River Lower	5.35%	5.53%	7.23%	18.05%
75	Big Quilcene River Middle	0.36%	1.28%	1.17%	1.93%
76	Big Quilcene River Upper	0.04%	0.00%	0.00%	0.00%
77	Bolton Peninsula	2.84%	3.06%	4.14%	12.07%
79	Cabin Creek	0.00%	0.00%	0.00%	0.00%
84	Chimacum Creek East Fork	2.65%	3.69%	4.16%	14.61%
85	Chimacum Creek Lower	11.35%	10.30%	15.06%	23.41%
86	Chimacum Creek Middle	2.82%	4.37%	4.87%	15.53%
87	Chimacum Creek Upper	2.12%	3.02%	3.52%	13.61%
88	Cliff/Murhut Creek	0.00%	0.00%	0.00%	0.00%
89	Copper Creek	0.00%	0.00%	0.00%	0.00%
90	Crazy Creek	0.00%	0.00%	0.00%	0.00%
92	Devils Lake	0.83%	2.16%	2.56%	8.21%
93	Discovery Bay East Shore Frontal	5.34%	5.82%	7.44%	19.25%
94	Discovery Bay West Shore Lower	2.09%	2.69%	5.13%	21.36%
95	Discovery Bay West Shore Upper	4.11%	2.64%	4.21%	14.91%

No.	WATERSHED NAME	ACTUAL IP	MODELED CURRENT IP	MODELED BUILDOUT IP	MAXIMUM BUILDOUT IP
97	Donovan Creek	1.90%	2.78%	3.57%	13.75%
98	Dosewallips River Headwaters	0.00%	0.00%	0.00%	0.00%
99	Dosewallips River Lower	1.34%	2.62%	3.22%	11.46%
100	Dosewallips River Middle	0.03%	0.39%	0.53%	1.90%
101	Dosewallips River Upper	0.00%	0.00%	0.00%	0.00%
102	Dosewallips River West Fork	0.00%	0.00%	0.00%	0.00%
103	Duckabush River Headwaters	0.00%	0.00%	0.00%	0.00%
104	Duckabush River Lower	1.09%	1.61%	2.14%	6.84%
105	Duckabush River Middle	0.00%	0.00%	0.00%	0.00%
106	Duckabush River Upper	0.00%	0.00%	0.00%	0.00%
112	Fulton Creek	0.08%	0.45%	0.32%	1.09%
118	Heather/Home Creek	0.00%	0.00%	0.00%	0.00%
119	Hidden/Twin Creek	0.00%	0.00%	0.00%	0.00%
121	Indian Island	11.00%	11.00%	10.99%	10.99%
127	Leland Creek	2.55%	2.83%	3.53%	12.34%
128	Lena Creek	0.00%	0.00%	0.00%	0.00%
129	Little Quilcene Lower	1.47%	1.80%	2.59%	12.22%
131	Marrowstone Island	6.82%	7.34%	9.31%	20.32%
133	Mcdonald Creek	1.29%	3.02%	3.86%	11.84%
134	Milk/Ghoul Creek	0.00%	0.00%	0.00%	0.00%
137	Oak/Mats Mats Bay	4.99%	6.38%	8.68%	19.21%
139	Penny Creek	0.01%	0.87%	0.92%	2.27%
140	Port Ludlow	4.41%	4.48%	6.05%	17.04%
141	Port Townsend Bay	22.59%	17.67%	25.22%	29.66%
142	Quimper Peninsula	7.66%	8.77%	13.65%	23.26%
143	Rocky Brook	0.61%	0.79%	0.82%	1.07%
145	Salmon Creek Lower	0.30%	1.64%	1.98%	11.18%
146	Salmon Creek North	0.11%	0.70%	0.78%	4.01%
150	Silt Creek	0.00%	0.00%	0.00%	0.00%
155	Snow Creek	1.11%	1.67%	1.96%	5.65%
156	Spencer/Marple Creek	1.11%	2.08%	2.39%	6.44%
157	Squamish Harbor	2.47%	3.47%	5.27%	14.26%
158	Still Creek	0.00%	0.00%	0.00%	0.00%
159	Tarboo Creek	2.18%	2.69%	3.01%	11.79%
160	Thorndyke Creek	0.81%	1.16%	1.22%	9.79%
161	Toandos Peninsula East Shore Frontal	1.40%	3.50%	5.17%	13.95%
162	Toandos Peninsula West Shore Frontal	1.75%	2.88%	3.68%	13.18%
163	Townsend Creek	0.17%	0.00%	0.00%	0.00%
165	Tunnel Creek	0.04%	0.03%	0.03%	0.03%
166	Tunnel Creek North Fork	0.00%	0.00%	0.00%	0.00%
167	Tunnel Creek South Fork	0.04%	0.00%	0.00%	0.00%
168	Turner Creek	4.04%	4.23%	5.93%	9.64%
169	Walkers Creek	11.04%	7.56%	9.86%	21.36%
	Mason County				
170	Big Creek	0.00%	NA	0.20%	NA
171	Brown Creek	0.00%	NA	0.20%	NA
172	Cedar Creek	0.00%	NA	0.20%	NA
173	Church Creek	0.00%	NA	0.20%	NA
174	Dow Creek	2.69%	NA	2.89%	NA
175	Dry Creek	0.06%	NA	0.26%	NA
176	Dewatto	1.99%	0.37%	2.24%	0.37%

No.	WATERSHED NAME	ACTUAL IP	MODELED CURRENT IP	MODELED BUILDOUT IP	MAXIMUM BUILDOUT IP
177	Eagle Creek	0.59%	NA	0.79%	NA
178	Finch Creek	1.17%	NA	1.37%	NA
179	Fir Creek	0.03%	NA	0.23%	NA
180	Flat Creek	0.00%	NA	0.20%	NA
181	Four Stream	0.00%	NA	0.20%	NA
182	Frigid Creek	0.00%	NA	0.20%	NA
183	Hama Hama River Lower	0.12%	NA	0.32%	NA
184	Hama Hama River Middle	0.00%	NA	0.20%	NA
185	Hama Hama River Upper	0.00%	NA	0.20%	NA
186	Jefferson Creek	0.00%	NA	0.20%	NA
187	Jorsted/Ayock Creek	2.12%	NA	2.32%	NA
188	Lake Cushman Frontal	1.19%	NA	1.39%	NA
189	Lebar Creek	0.00%	NA	0.20%	NA
190	Lilliwaup Creek	0.02%	NA	0.22%	NA
191	Mctaggert Creek	0.33%	NA	0.53%	NA
192	Mission	2.25%	0.40%	2.35%	2.43%
193	Pine Creek	0.00%	NA	0.20%	NA
194	Potlatch Creek	2.54%	NA	2.74%	NA
195	Purdy Creek	2.90%	NA	3.10%	NA
196	Rule Creek	0.00%	NA	0.20%	NA
197	Rendsland	1.57%	NA	1.77%	NA
198	Schaerer Creek	1.26%	0.71%	1.81%	1.75%
199	Skokomish River North Fork Headwaters	0.00%	NA	0.20%	NA
200	Skokomish River North Fork Lower	0.02%	NA	0.22%	NA
201	Skokomish River North Fork Upper	0.00%	NA	0.20%	NA
202	Skokomish River South Fork Lower	0.20%	NA	0.40%	NA
203	Skokomish River South Fork Middle	0.00%	NA	0.20%	NA
204	Skokomish River South Fork Upper	0.00%	NA	0.20%	NA
205	Skokomish River Valley	1.92%	NA	2.12%	NA
206	Steel Creek	0.00%	NA	0.20%	NA
207	Sund/Miller Creek	1.37%	NA	1.57%	NA
208	Shoreline	0.19%	0.40%	0.57%	3.52%
209	Tahuya	2.72%	0.94%	3.17%	5.22%
210	Union	8.72%	3.99%	8.80%	37.12%
211	Vance Creek	0.15%	NA	0.35%	NA
212	Waketickeh/Cummings Creek	0.20%	NA	0.40%	NA
213	Mc2	4.64%	NA	4.84%	NA
214	Mc1	0.05%	NA	0.25%	NA
	Clallam County				
73	Bear Creek	3.96%	NA	NA	NA
78	Bungalow/Skookum Creek	0.02%	NA	NA	NA
80	Cameron Creek	0.00%	NA	NA	NA
81	Canyon Creek	0.18%	NA	NA	NA
82	Caraco Creek	0.01%	NA	NA	NA
83	Cassalery Creek	9.51%	NA	NA	NA
91	Deadfall Creek	0.03%	NA	NA	NA
96	Divide Creek	0.00%	NA	NA	NA
107	Dungeness River Below Canyon Creek	5.78%	NA	NA	NA
108	Dungeness River Below Grey Wolf River	0.11%	NA	NA	NA
109	Dungeness River Lower	9.37%	NA	NA	NA
110	Dungeness River Mouth	8.41%	NA	NA	NA

No.	WATERSHED NAME	ACTUAL IP	MODELED CURRENT IP	MODELED BUILDOUT IP	MAXIMUM BUILDOUT IP
111	Eddy Creek	0.04%	NA	NA	NA
113	Gierin Creek	11.40%	NA	NA	NA
114	Gold Creek	0.00%	NA	NA	NA
115	Grand Creek	0.05%	NA	NA	NA
116	Grey Wolf River Lower	0.01%	NA	NA	NA
117	Grey Wolf River Upper	0.00%	NA	NA	NA
120	Howe Creek	0.00%	0.61%	0.93%	3.97%
122	Jimmy-Come-Lately Creek East Fork	0.00%	0.00%	0.00%	0%
123	Jimmy-Come-Lately Creek Lower	1.49%	0.83%	2.42%	6.44%
124	Jimmy-Come-Lately Creek West Fork	0.53%	0.51%	0.67%	3.73%
125	Johnson Creek	5.24%	NA	NA	NA
130	Little Quilcene Upper	0.05%	NA	NA	NA
132	Matriotti Creek	6.59%	NA	NA	NA
135	Miller Peninsula	4.23%	NA	NA	NA
136	Mueller Creek	0.00%	NA	NA	NA
138	Pats Creek	0.63%	NA	NA	NA
144	Royal Creek	0.00%	NA	NA	NA
147	Salmon Creek Upper	0.00%	0.39%	0.39%	1.94%
148	Sequim Bay East Shore	2.83%	0.03%	0.07%	0.51%
149	Sequim Bay West Shore	4.46%	NA	NA	NA
151	Silver Creek	0.01%	NA	NA	NA
152	Slab Camp Creek	0.01%	NA	NA	NA
153	Sleepy Hollow Creek	0.00%	NA	NA	NA
154	Slide Creek	0.00%	NA	NA	NA
164	Trapper Creek	0.00%	0.05%	0.05%	0.05%

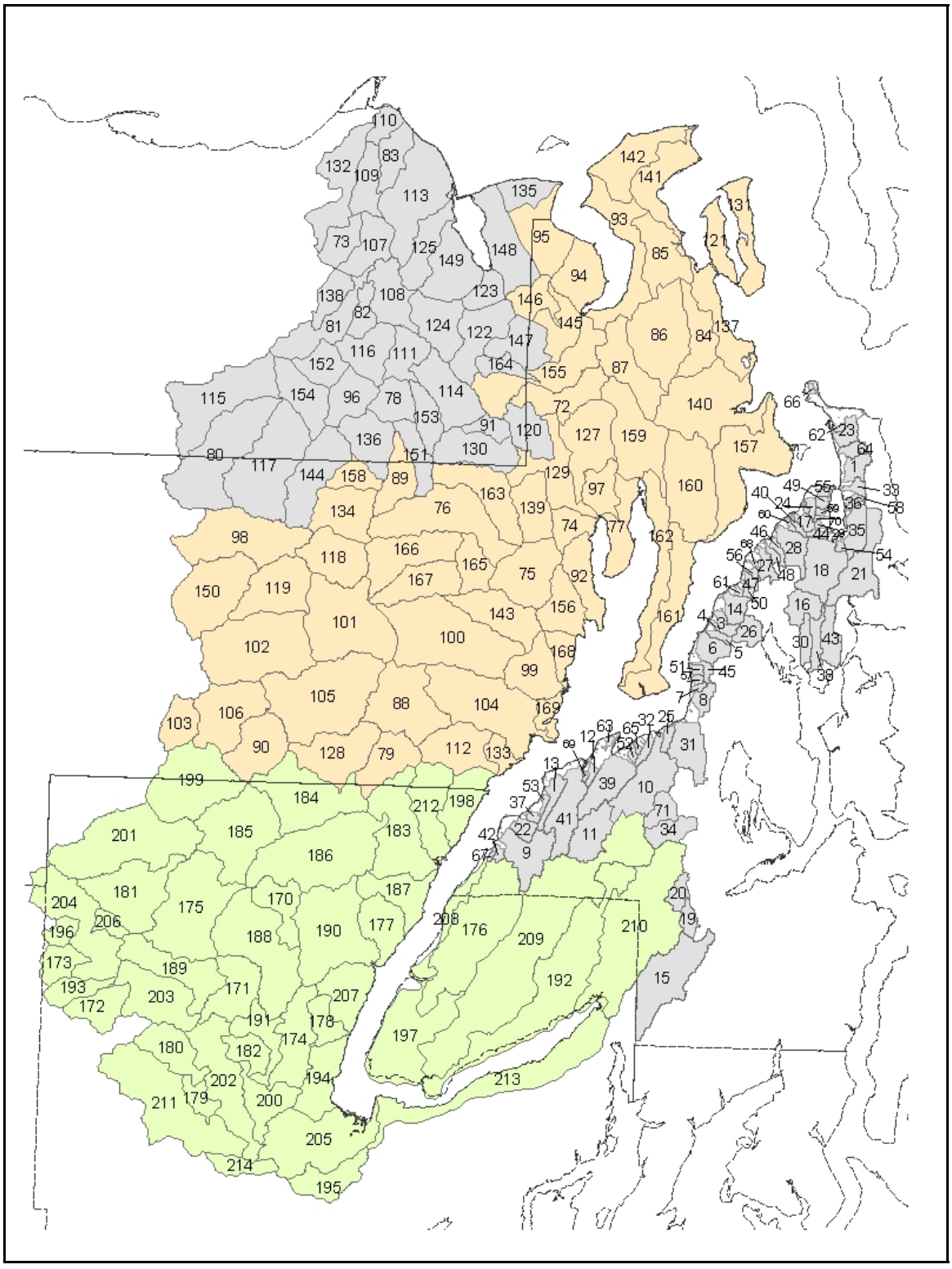

Figure 14 Watershed numbers referenced in Table 6

Table 7 Estuary results

Estuary	Modeled Current IP	Buildout IP	Maximum Buildout IP	Percent Increase from current to buildout
Big Anderson	7.01%	8.70%	45.80%	24.17%
Big Beef	3.74%	9.11%	54.85%	143.78%
Chimacum	3.04%	3.59%	5.65%	18.11%
Dosewallips	3.30%	4.11%	6.42%	24.56%
Duckabush	3.97%	5.27%	7.72%	32.74%
Fulton	7.26%	9.84%	12.25%	35.53%
Jimmycomelately	3.01%	8.61%	29.15%	186.05%
Little Anderson	4.49%	6.88%	82.98%	53.20%
Quilcene	2.20%	2.89%	7.76%	31.22%
Salmon/Snow	2.94%	4.02%	7.11%	36.63%

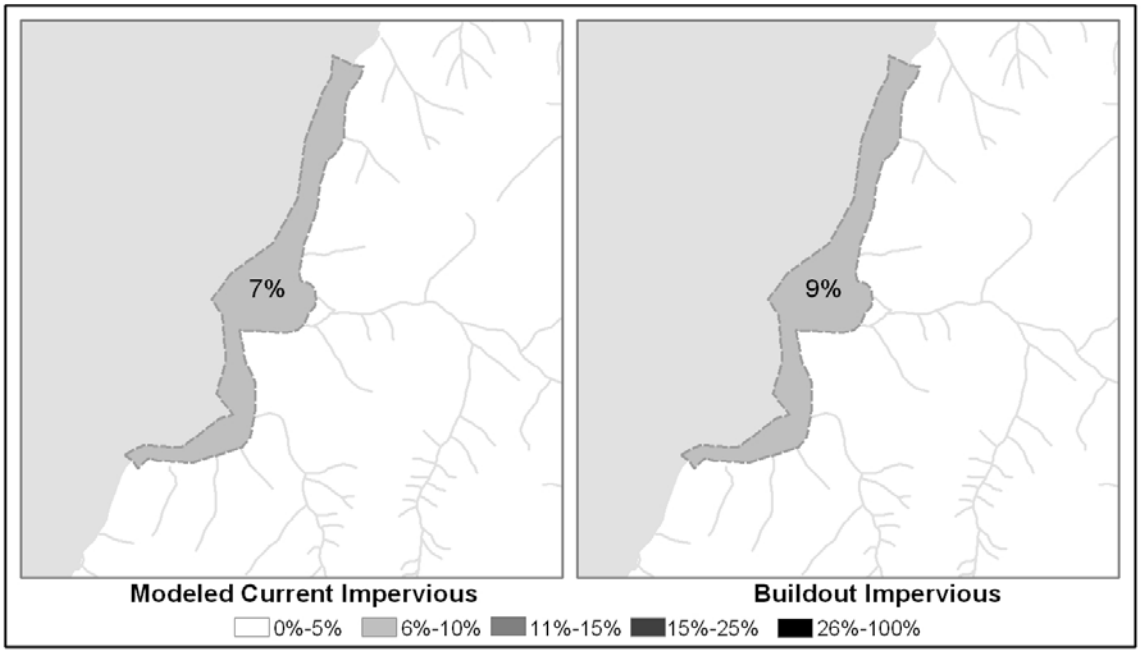

Figure 15 Big Anderson Creek estuary results

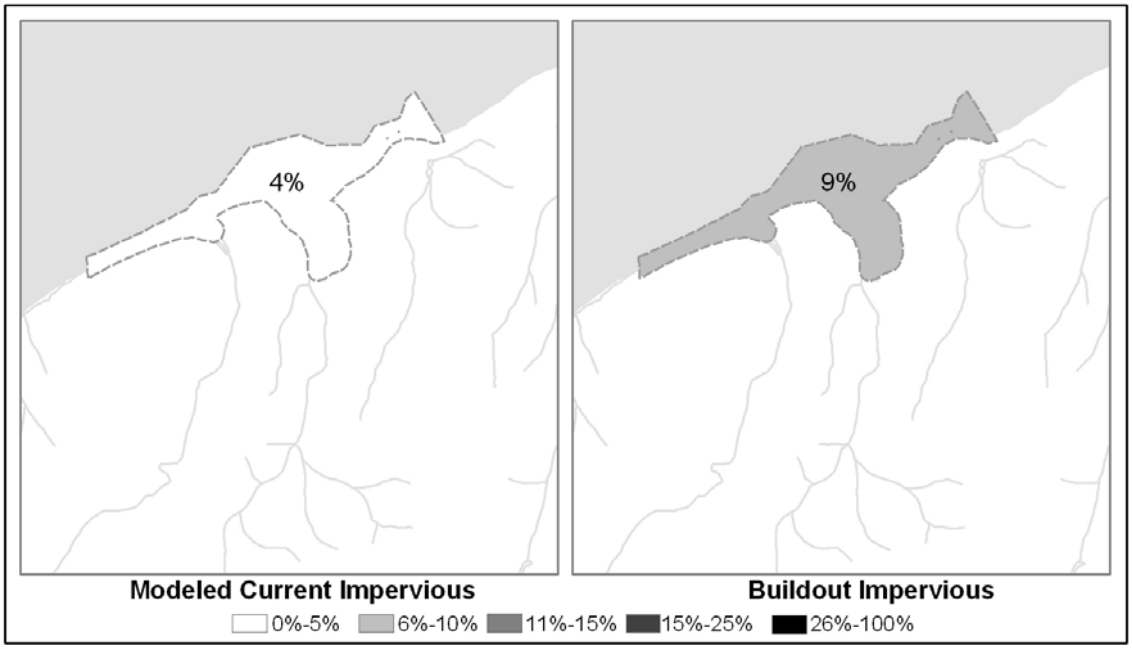

Figure 16 Big Beef Creek estuary results

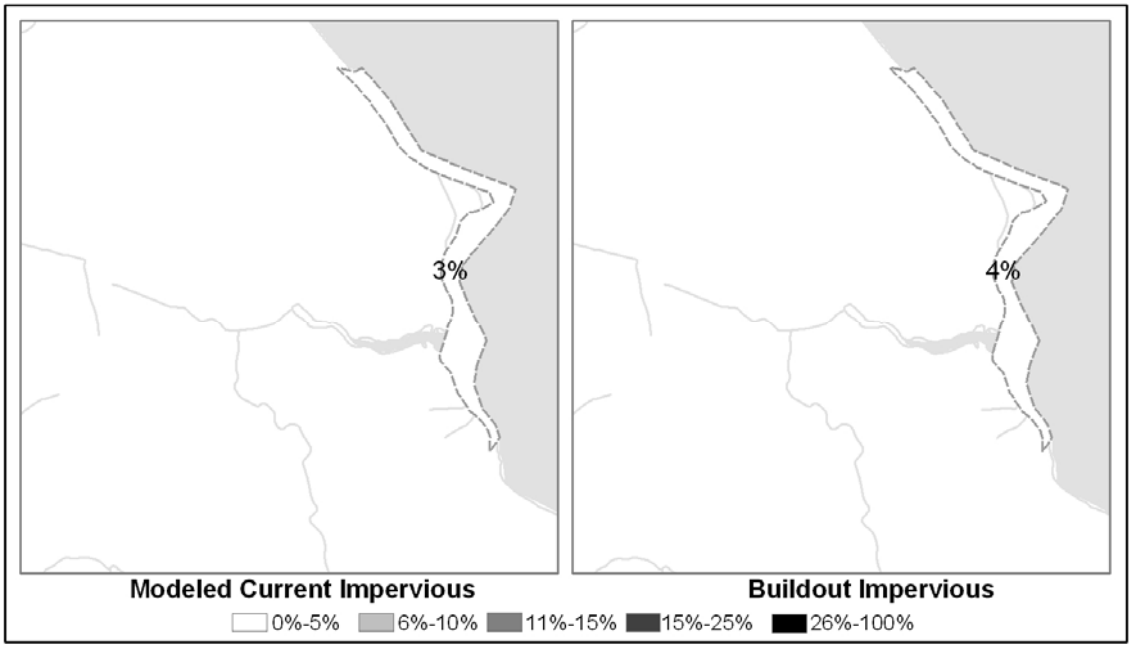

Figure 17 Chimacum Creek estuary results

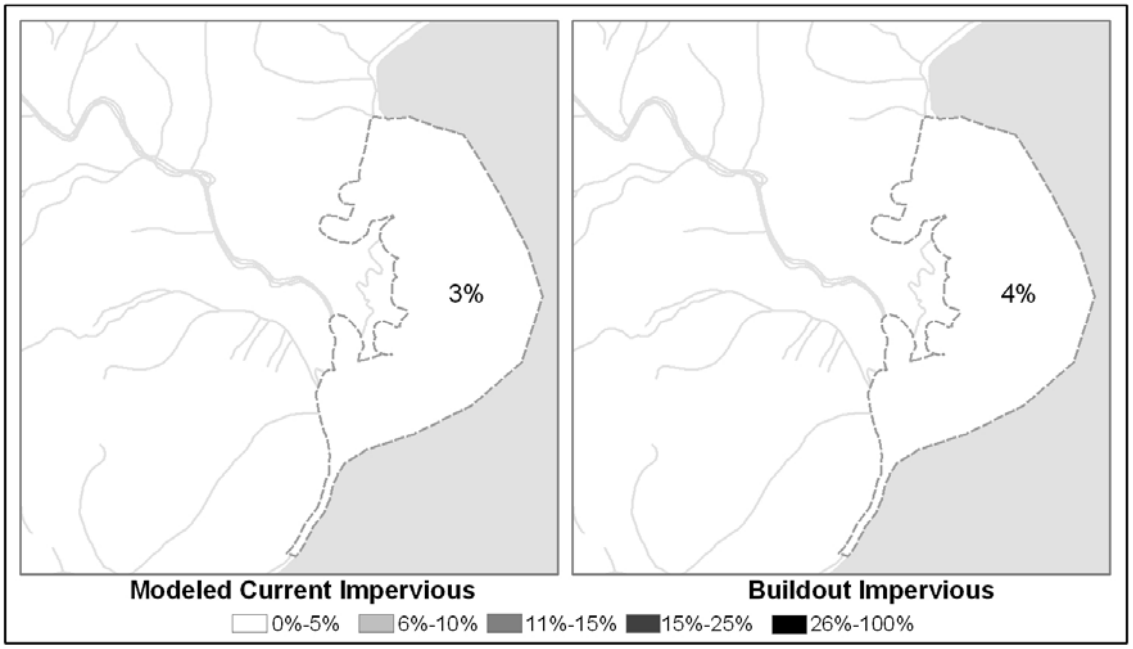

Figure 18 Dosewallips River estuary results

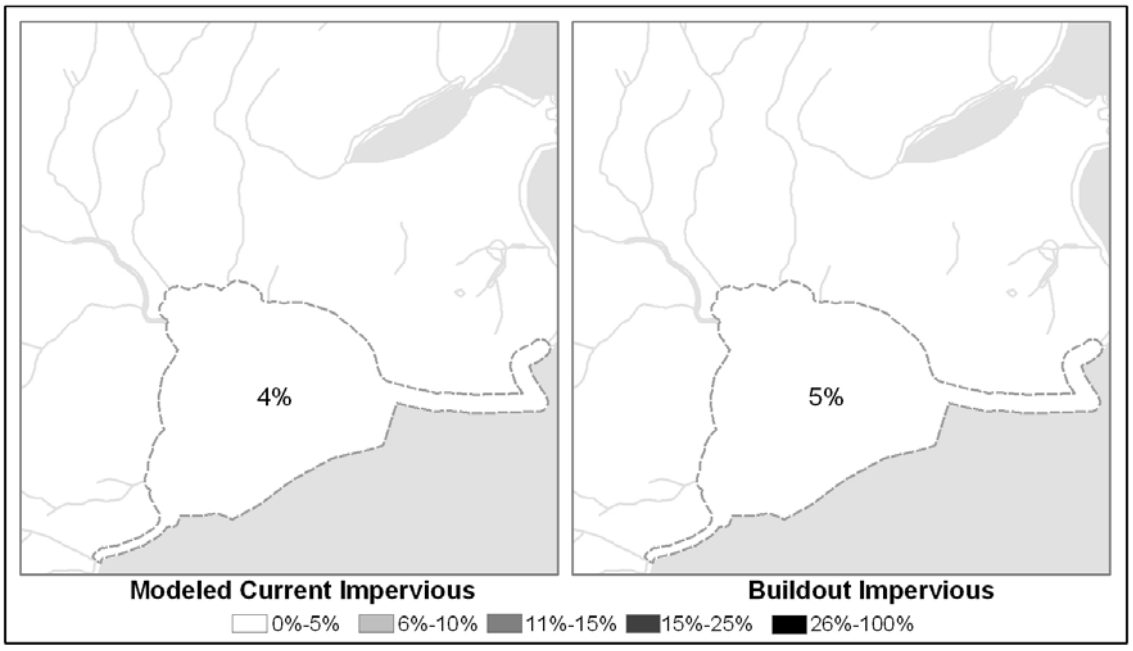

Figure 19 Duckabush River estuary results

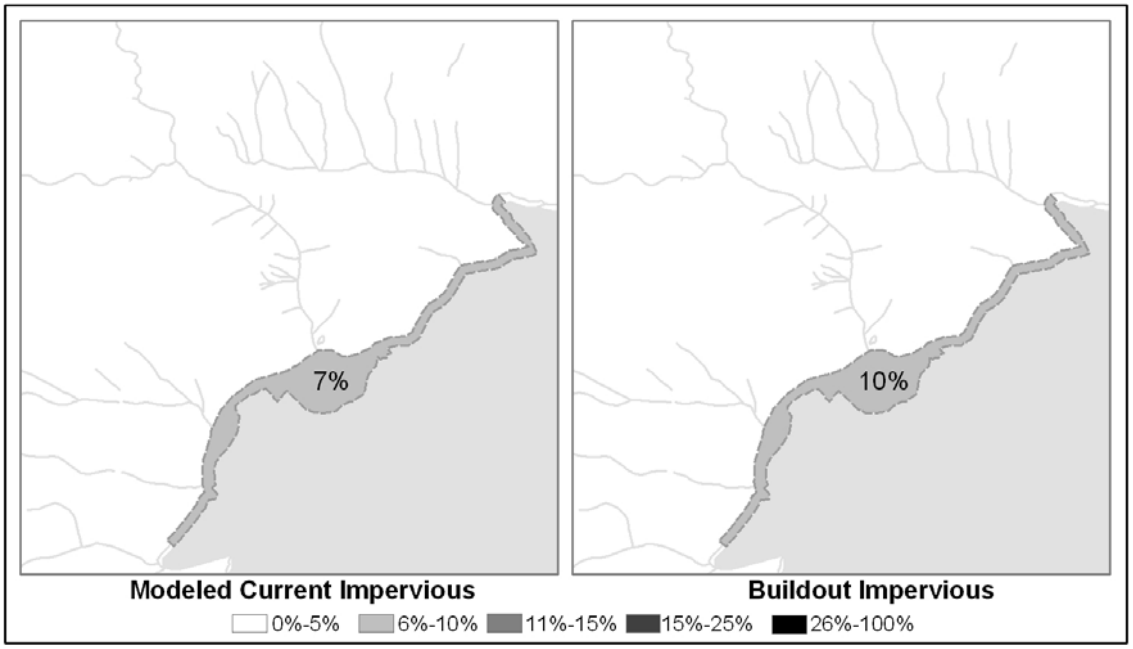

Figure 20 Fulton Creek estuary results

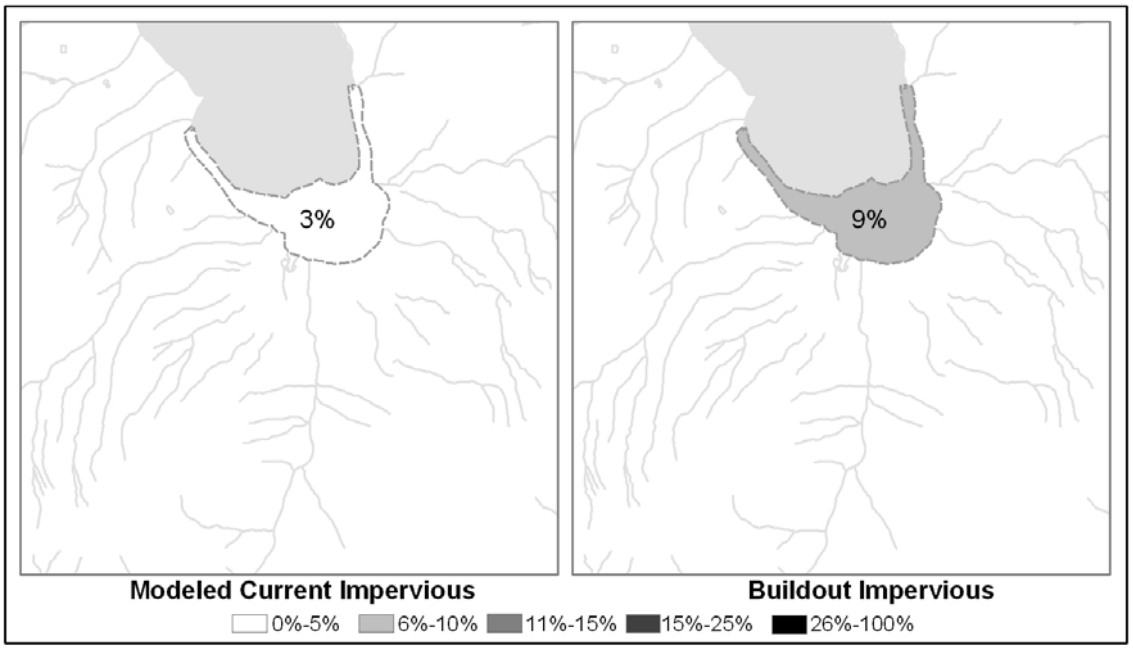

Figure 21 Jimmycomelately Creek estuary results

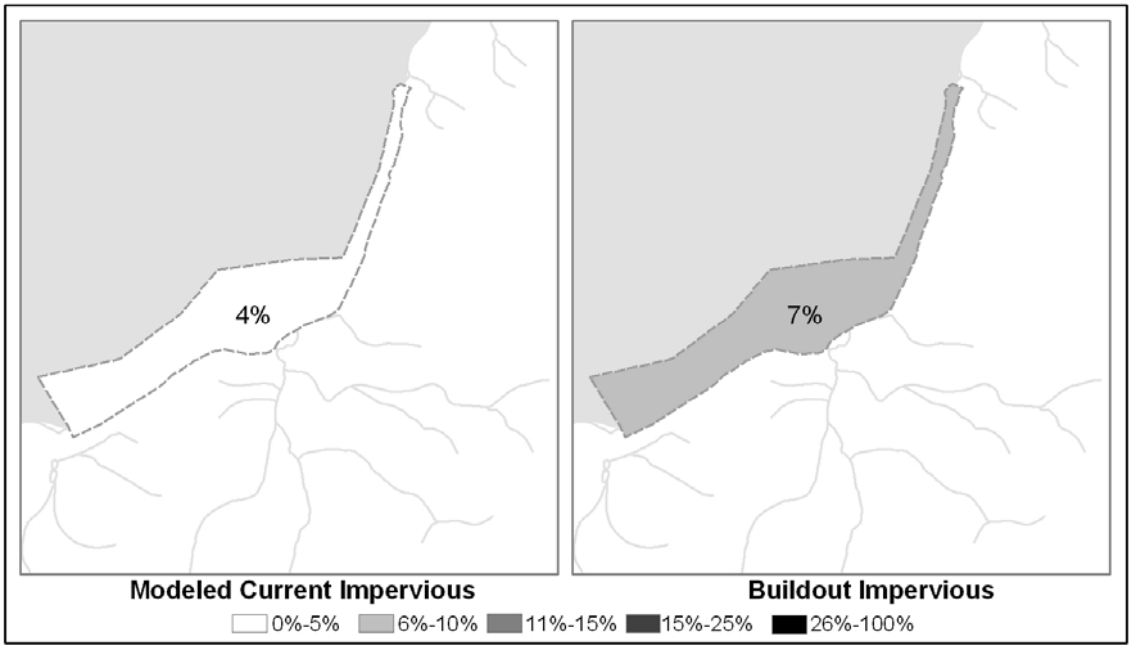

Figure 22 Little Anderson Creek estuary results

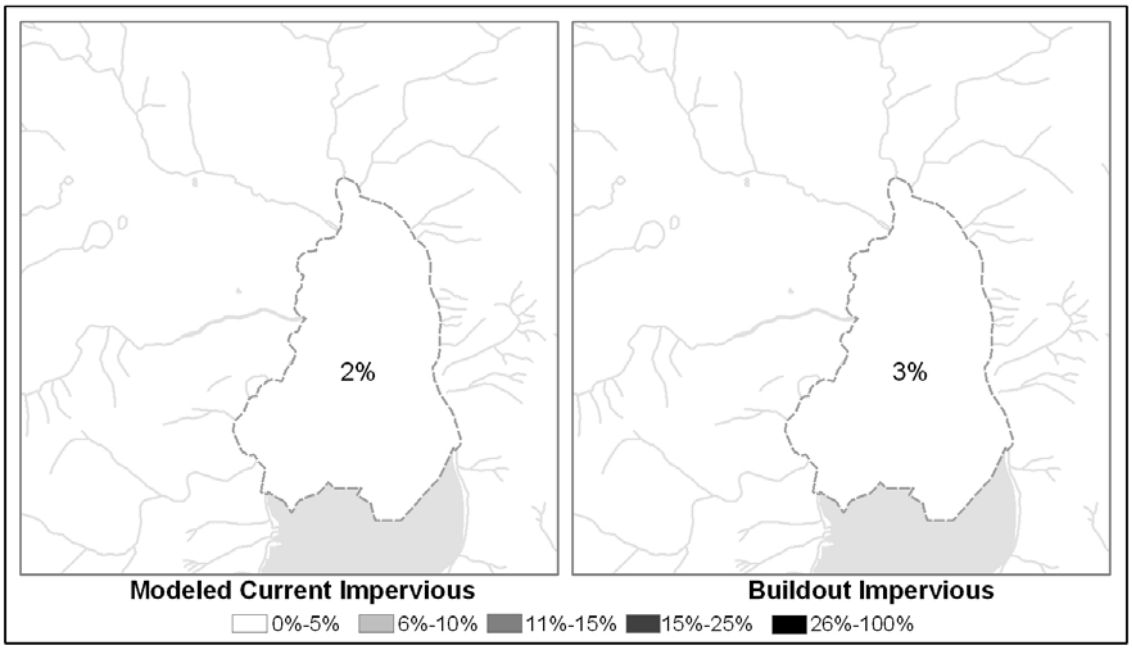

Figure 23 Quilcene estuary results

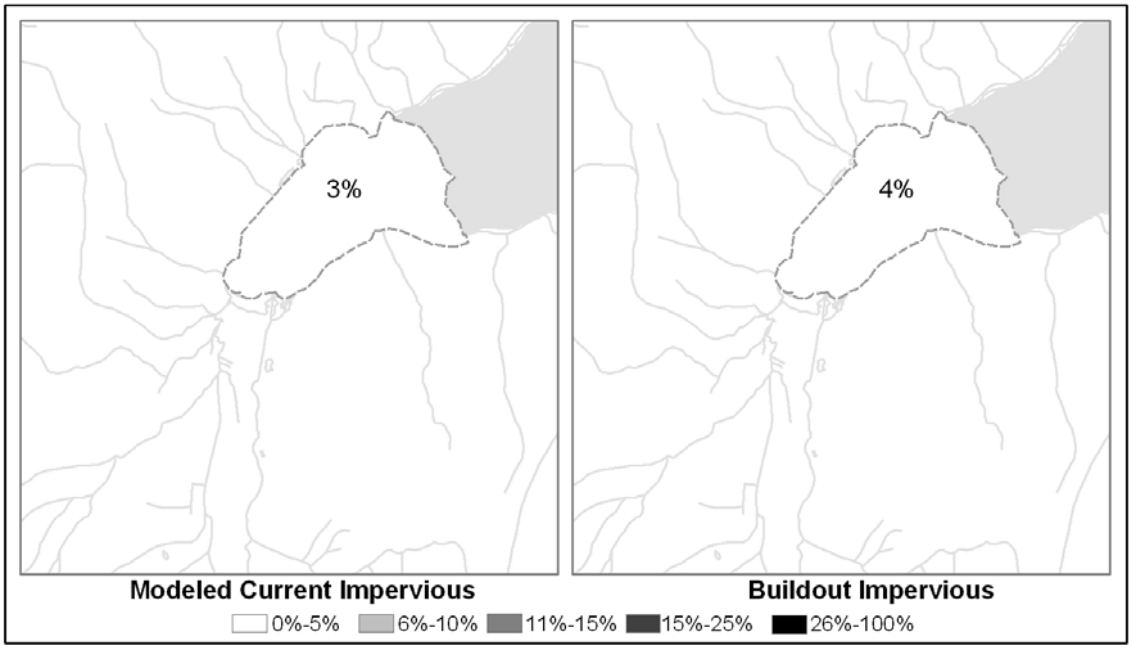

Figure 24 Salmon and Snow Creeks estuary results

Table 8 Riparian corridor results

Riparian Corridor	Corridor Area acres	Modeled Current IP acres	Modeled Current IP	Buildout IP acres	Buildout IP	Max Buildout IP acres	Max Buildout IP	Percent Increase From Current To Buildout
Big Anderson Creek	83.13	1.58	1.90%	1.79	2.16%	15.26	18.36%	13.47%
Big Beef Creek	308.07	19.51	6.33%	23.18	7.52%	235.70	76.51%	18.82%
Little Anderson Creek	28.02	2.18	7.77%	2.44	8.69%	27.11	96.74%	11.82%
Salmon Creek	100	3.48	3.49%	3.62	3.63%	11.63	11.65%	4.09%
Big Quilcene River	236	9.81	4.15%	16.42	6.95%	37.85	16.02%	67.37%
Little Quicene River	130	11.33	8.69%	15.13	11.62%	30.79	23.63%	33.57%
Chimacum Creek	299	19.70	6.59%	37.50	12.55%	56.88	19.03%	90.34%
Snow Creek	177	13.70	7.74%	18.08	10.21%	40.49	22.87%	31.94%
Fulton Creek	40	2.42	6.03%	2.01*	5.02%	6.61	16.45%	-16.74%
Duckabush River	114	6.54	5.75%	10.90	9.58%	17.91	15.75%	66.62%
Dosewallips River	166	8.11	4.89%	11.66	7.04%	26.44	15.96%	43.79%
Jimmycomelately Creek	96.59	2.07	2.14%	8.2	8.49%	50.47	52.25%	296.14%

*More than half of Fulton Creek's summer chum riparian corridor contains a *vacant* parcel that builds out to the *wooded* landcode. *Wooded* has a lower coefficient than *vacant*.

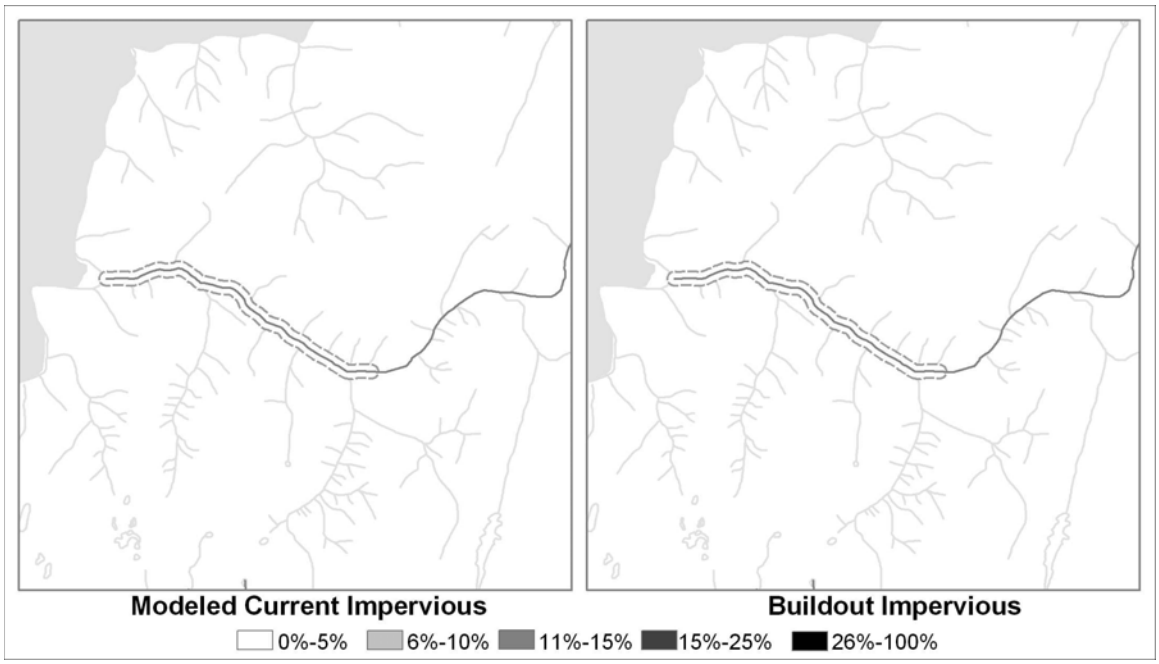

Figure 25 Big Anderson Creek riparian corridor results

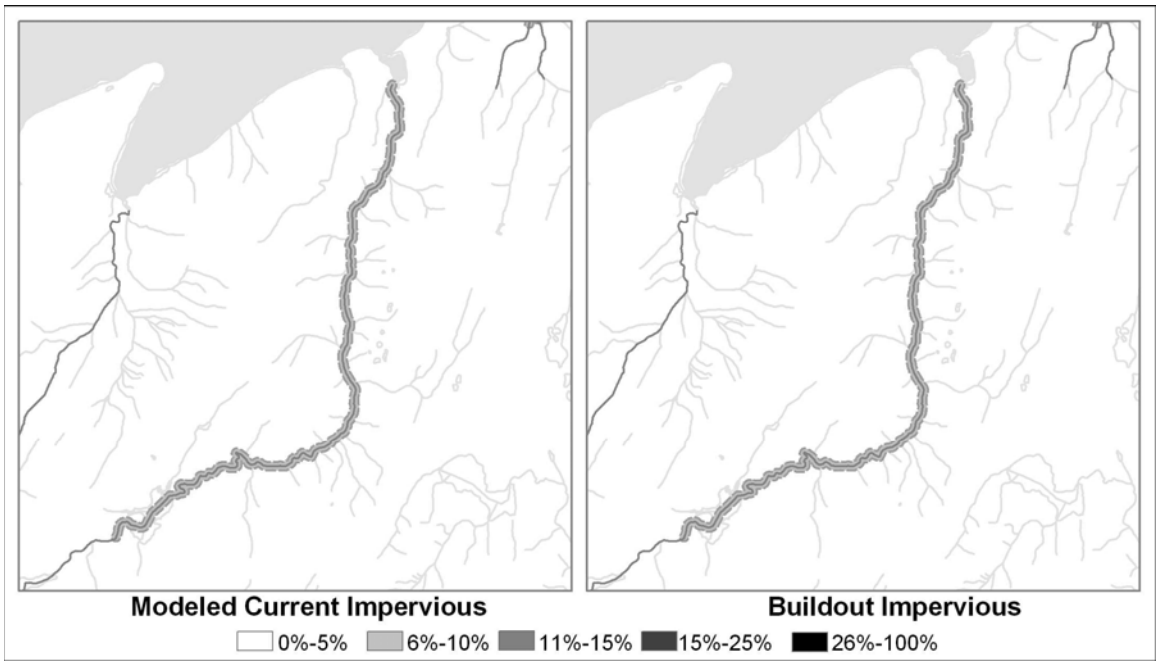

Figure 26 Big Beef Creek riparian corridor results

Figure 27 Little Anderson Creek riparian corridor results

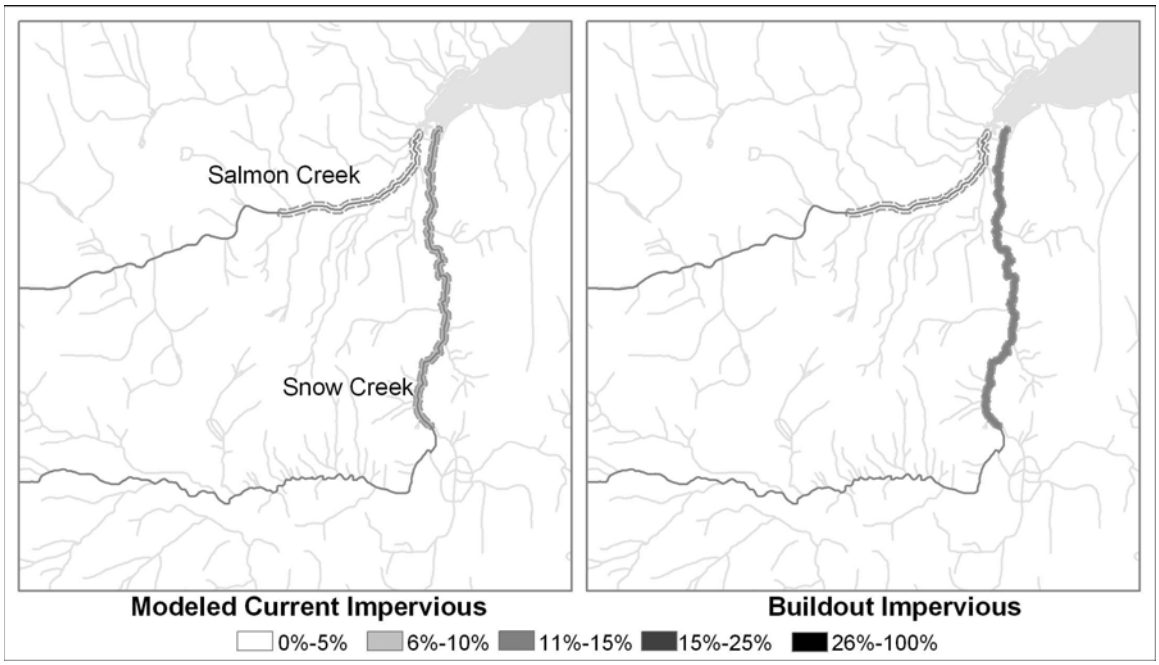

Figure 28 Salmon and Snow Creeks: riparian corridor results

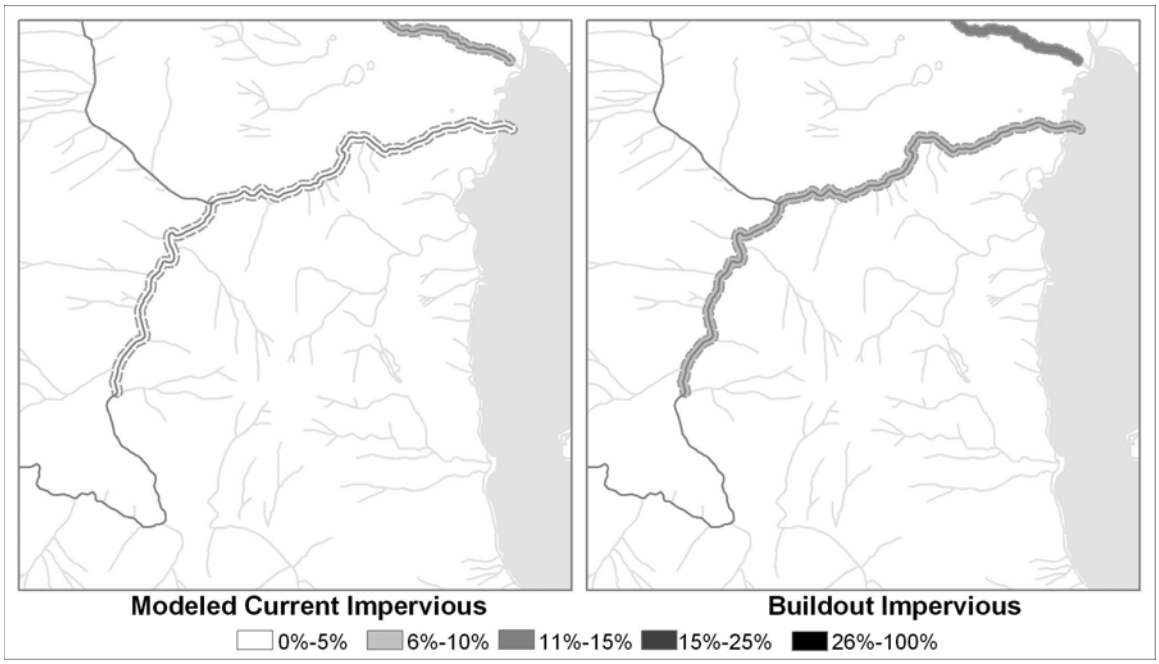

Figure 29 Big Quilcene River riparian corridor results

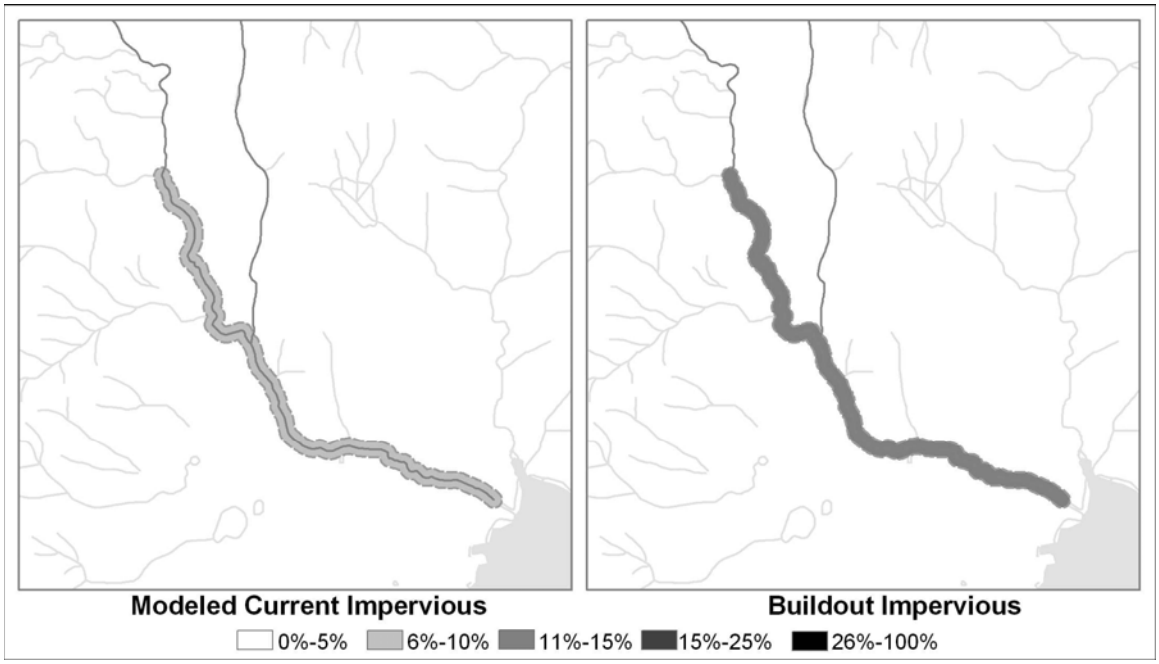

Figure 30 Little Quilcene River riparian corridor results

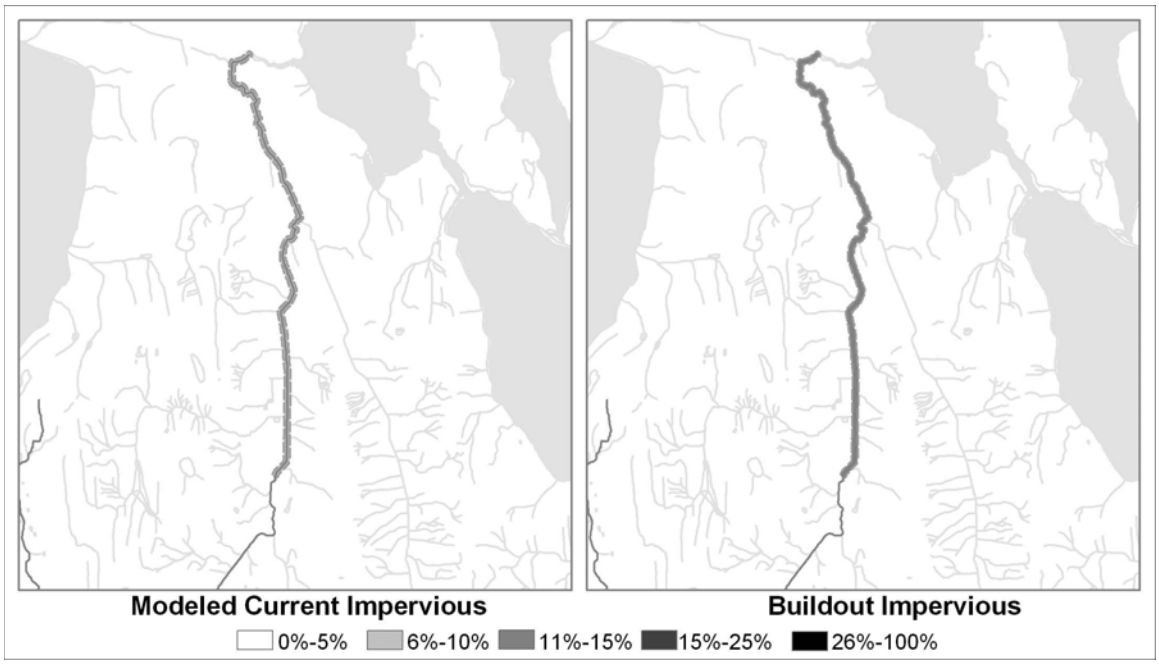

Figure 31 Chimacum Creek riparian corridor results

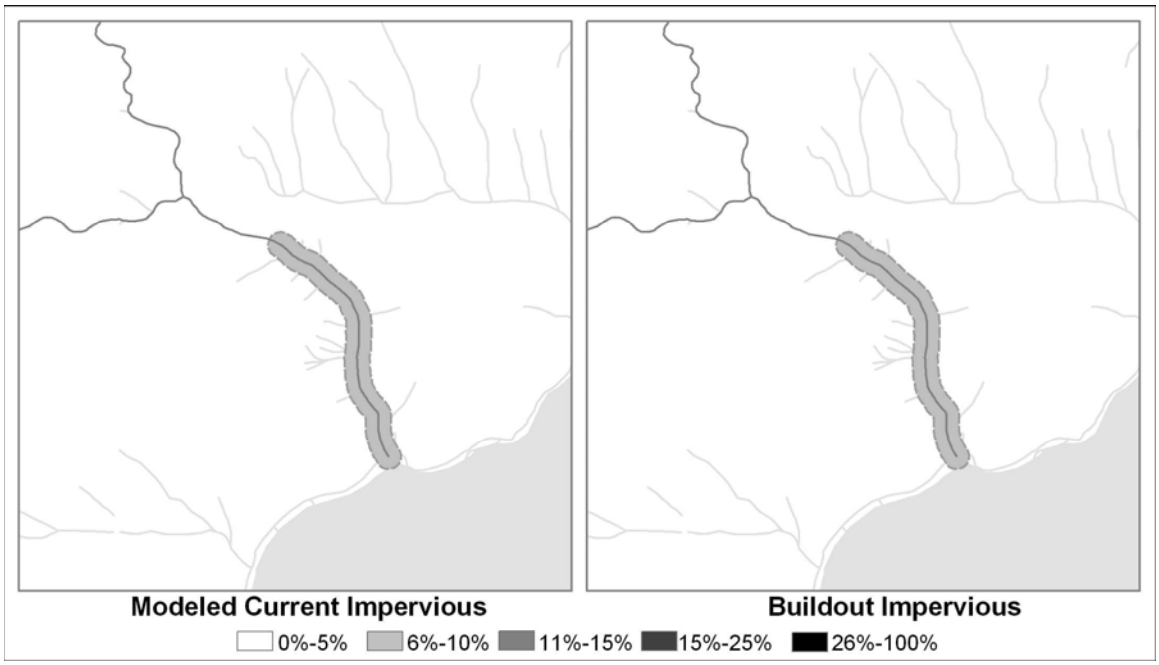

Figure 32 Fulton Creek riparian corridor results

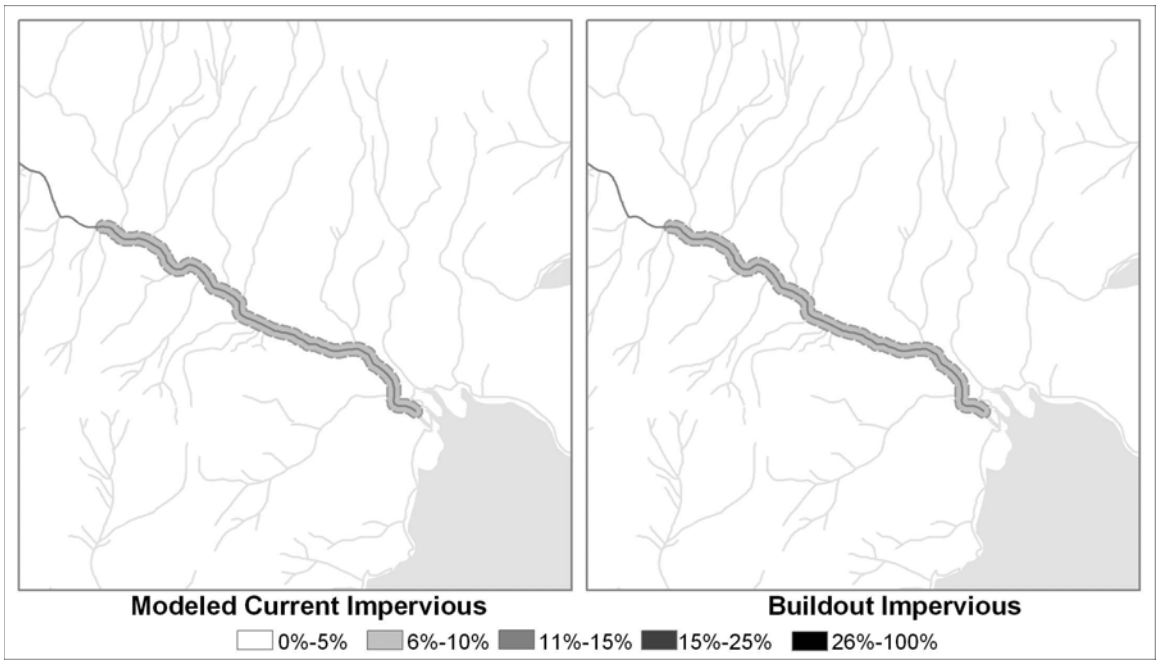

Figure 33 Duckabush River riparian corridor results

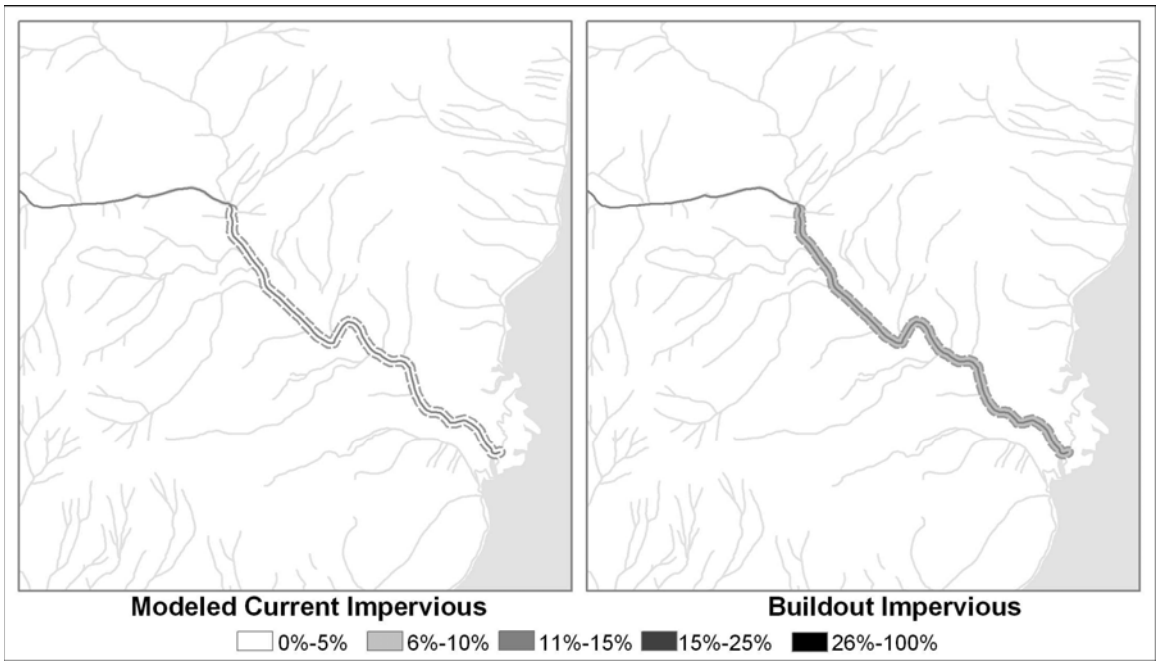

Figure 34 Dosewallips River riparian corridor results

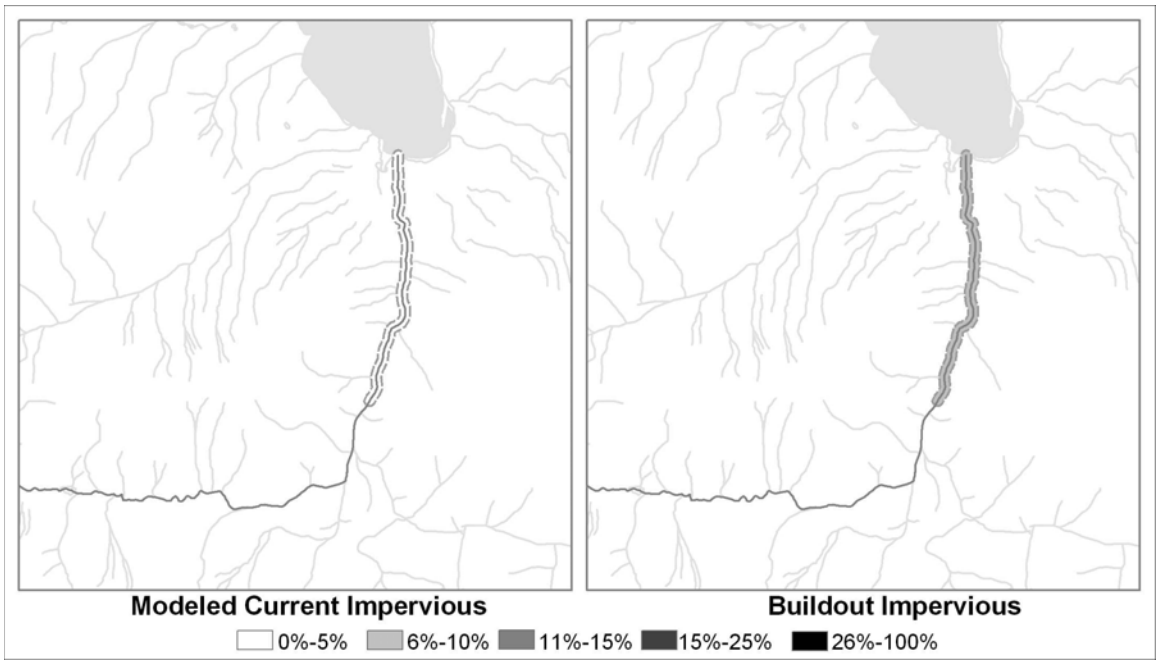

Figure 35 Jimmycomelately Creek riparian corridor results

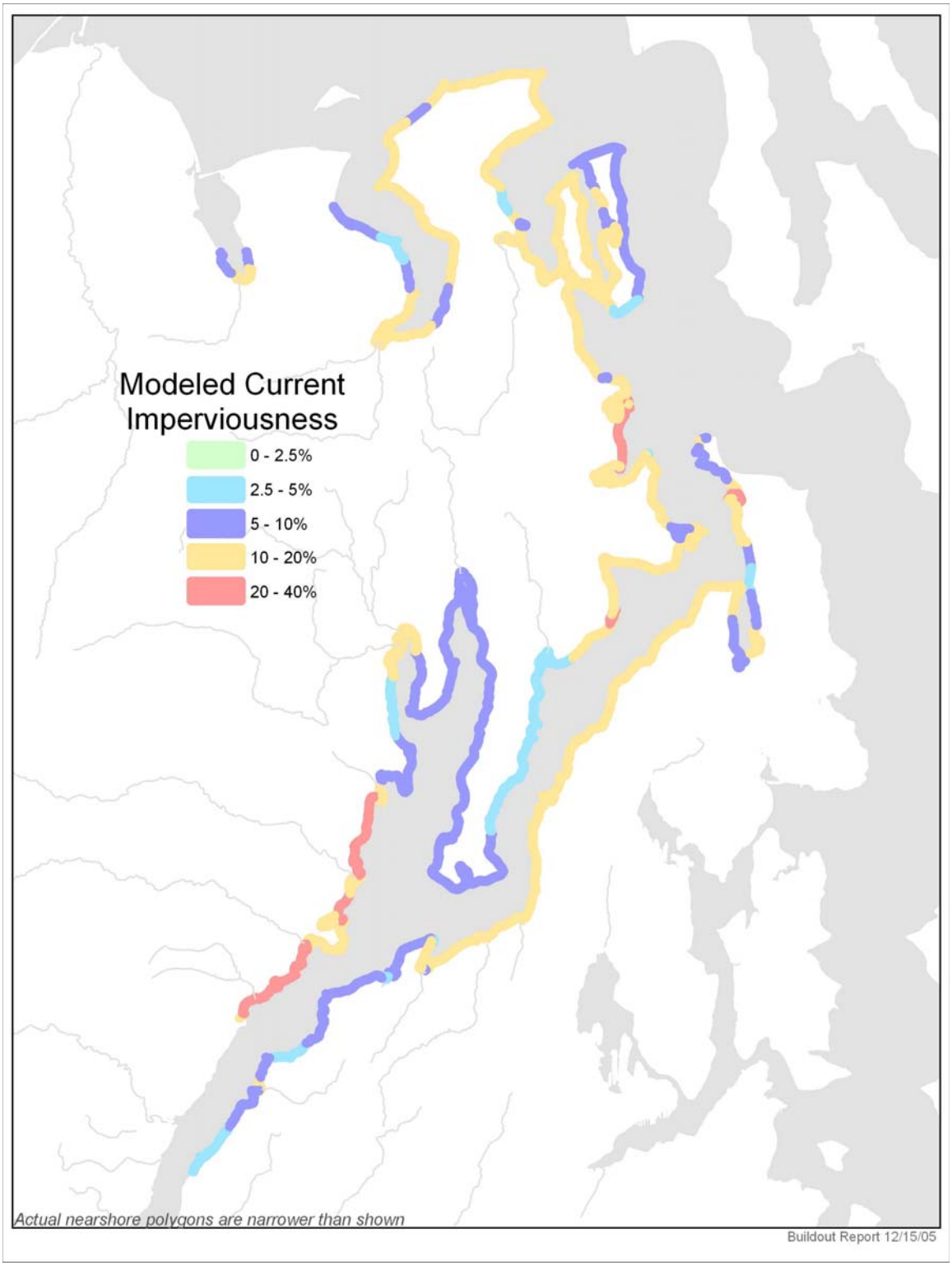

Figure 36 Nearshore results – modeled current statistics

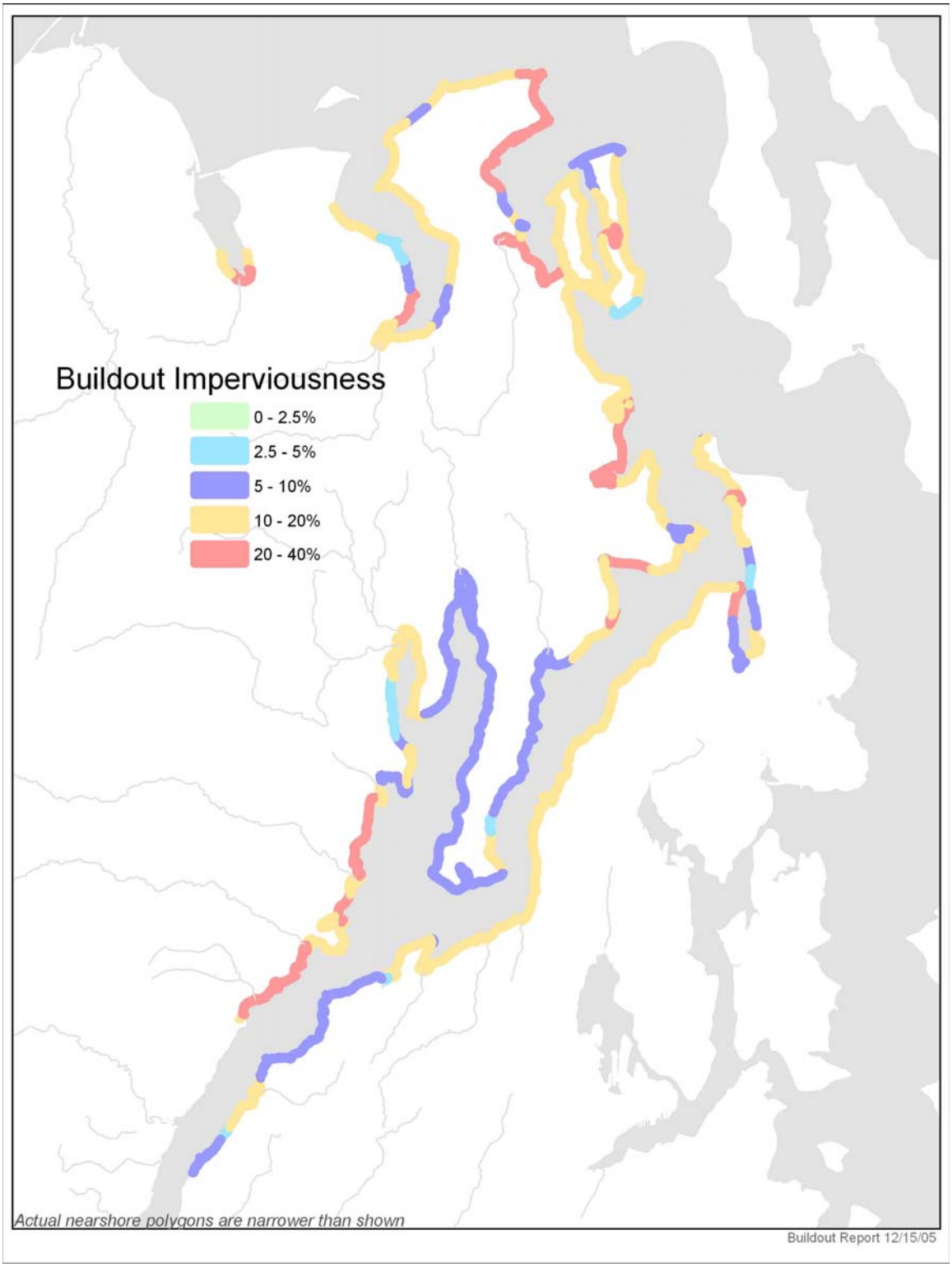

Figure 37 Nearshore results – buildout statistics

Accuracy/Error

Input Data

Details concerning the accuracy and precision of the input data are enumerated here. Both aerial imagery layers (LandSat and Indian Remote Sensing) were collected in August 2003. The publish date for the Kitsap parcel data was August 2003. Jefferson County parcel data did not have a specific publish date; it was received in August of 2004.

The watershed unit boundaries were derived from a variety of sources with corresponding variations in accuracy. Some of the watersheds were delineated from a 30 meter DEM in-house, some were from a similar Kitsap County data layer, and others were 7th field USGS hydrologic unit code boundaries.

The Kitsap County Code specifies some accuracy details concerning the Kitsap zoning in chapter 17.200.040. The IP data, which were derived from the Landsat TM (30.0 meter color, bands 1-6) and Indian Remote Sensing (5.8 meter black and white with 6-bit radiometric resolution) imagery, have a 94% accuracy when compared to DOQQs. The positional accuracy for the IP data is +/- 40 feet due to the LandSat image and +/- 5 feet due to pixel location.

IP data for the Jefferson County portion of the study area were shifted using a rubber-sheeting technique to better match the IP data to the parcel data (projection differences between the layers account for the original shift). IP data for Kitsap County were in spatial conjunction with the Kitsap parcel layer and therefore were not shifted in that portion of the study area.

Model Implementation

Some over or under representation of IP in the Kitsap County portion of the study area may have occurred. Parcels were clipped to the ESU boundary during the modeling process (while the underlying attributes concerning amount of IP within the parcels were not changed) so some of the estimated IP may have actually occurred outside the ESU boundary. This error may not be significant due to the medium spatial scale of the ESU boundary when compared to the large spatial scale of the parcels.

Residential buildout for Port Hadlock in Jefferson County may be underestimated in the analysis. In this area there are parcels that, although they contain the same identification number, may have been platted into multiple lots. Those lots could potentially become separate parcels if the required infrastructure exists (e.g., public water and sewer) or if the County changed current policies to relax minimum land area requirements as specified in the County code (D. Christensen, former Manager Jefferson County Natural Resources Division, personal communication, December 28, 2004).

Measurements of Model Performance

In order to determine the performance of the model, a comparison was made between the watershed results for actual imperviousness versus modeled current imperviousness. If the model were to reflect ground-conditions perfectly, the actual and modeled current results would be equal (actual IP = modeled IP). To measure how closely they came to being equal, the results were plotted on a scatterplot (Figure 38) and the area-weighted root mean square (RMS) was calculated to be 1.97%. Note that the scatterplot includes only those watersheds that contained complete parcel information and that each circle represents an individual watershed. As expected, the larger watersheds (shown with proportionally larger circles) show less error than the smaller watersheds.

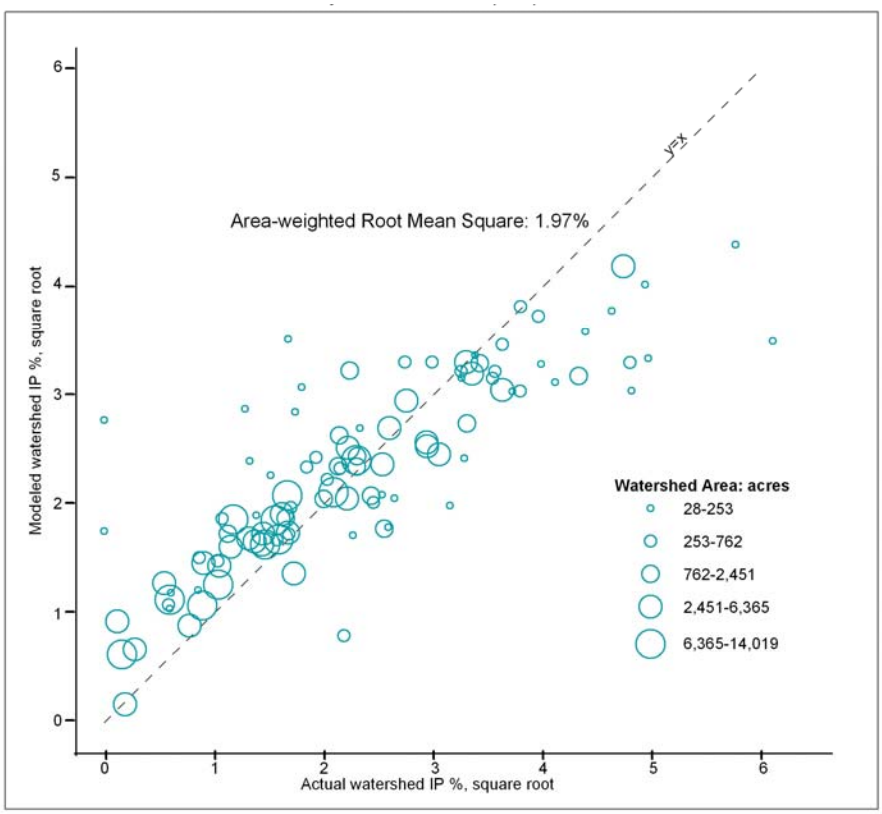

Figure 38 Scatterplot of actual impervious values versus modeled current impervious values

In order to investigate the results further, and perhaps pinpoint ways in which to improve the study in the future (i.e., lower the RMS value), an analysis of each landcode's contribution to the model was undertaken. To that end, two series of histograms were created. One series plotted the percentage of IP, for each landcode, against number of parcels. The other series plotted the percentage of IP, for each landcode, against total area. These histograms are presented in Appendix D. The area series, referred to as "area histograms," was helpful in determining which coefficients (described in the section titled Coefficient Calculations and reported in Appendix A) were a reasonable measurement of the average imperviousness.

Visual inspection of the area histograms yielded the following: 22 of the landcodes exhibit sharp peaks, 14 contain a large spread, and 4 are bimodal. These categorizations were further verified by calculating the means (equation 1) and standard deviations (equation 2) of the data once they had been split into 5% intervals, or bins.

$$\mu = \frac{\sum_{i=1}^{20} x_i \cdot b_i}{\sum_{i=1}^{20} x_i} \qquad \text{(Equation 1)}$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{20} x_i \cdot (b_i - \mu)^2}{\sum_{i=1}^{20} x_i}} \qquad \text{(Equation 2)}$$

Where:

μ is the weighted mean (in bin units),

x_i is the number of acres in a particular bin,

b is the bin number, and

20 is the number of bins.

The standard deviations were plotted graphically (Figure 39). The standard deviation graph shows, for example, that the *vacant* landcode's area histogram has a small spread (i.e., shows a distinctive peak) due to its relatively low standard deviation of 2 bins. That is, 68.26% of the acres designated as *vacant* contain within plus or minus 10% IP of the mean IP for the *vacant* landcode (in this case the mean bin was computed as 0.56, which is 2.8% IP). The mean bin value is not to be confused with the coefficient calculated for the landcode, as the coefficients were calculated on the entire layer while the histogram data were grouped into bins, a process by which some precision was lost. However, the relative spread, or confidence, of the coefficients can be approximated in this way.

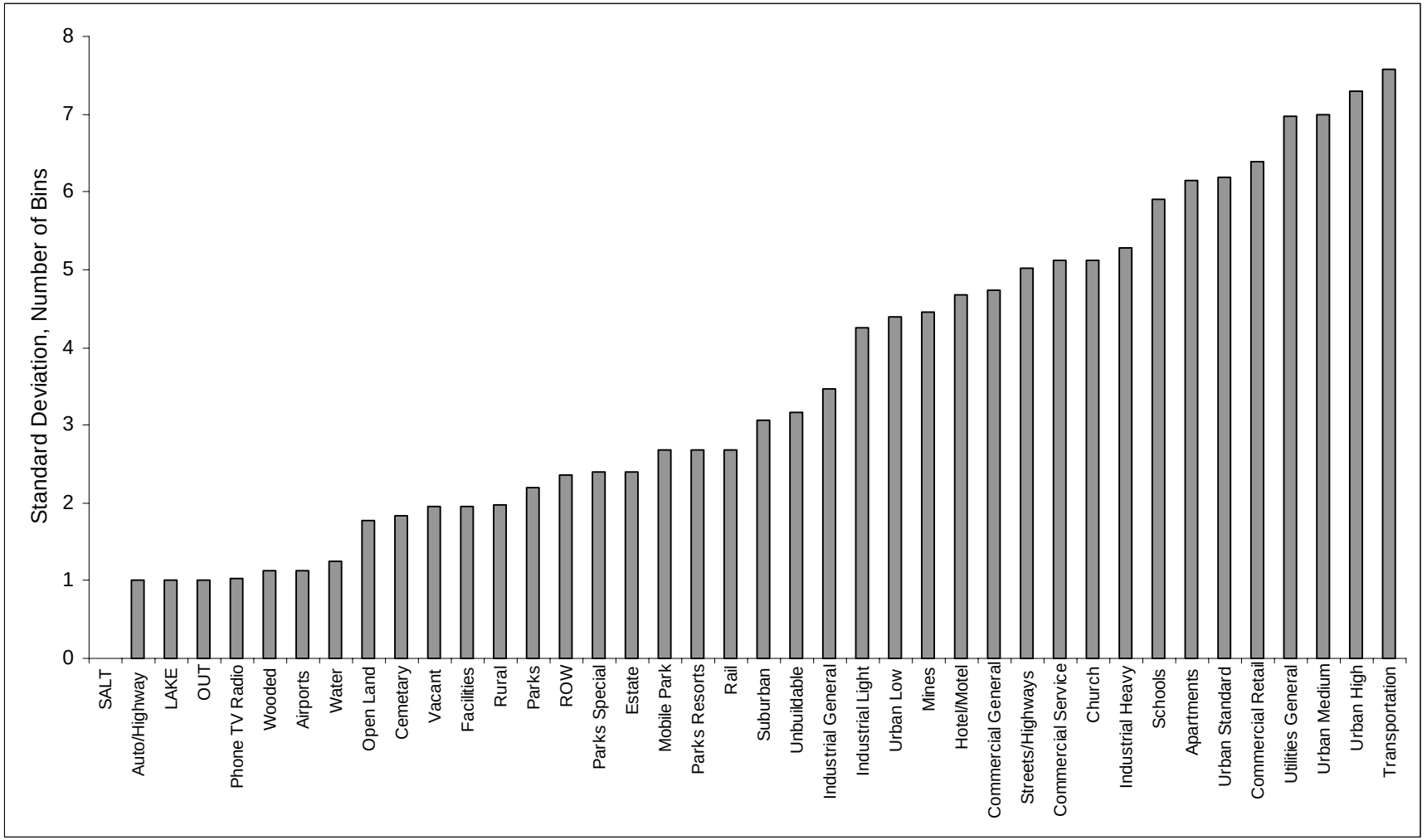

Figure 39 Standard deviations for landcode IP areas

The landcodes categorized as sharp-peaked from the area histograms had standard deviations of less than 3.17 bins. They are: airports, auto/highway, cemetery, estate, facilities, mobile park, open land, parks, parks resorts, parks special, phone TV radio, rail, rural, suburban, unbuildable, vacant, water, wooded, lake, out, ROW, salt. The landcodes categorized as having large-spreads in the area histograms had standard deviations of greater than 3.17 bins. They are: apartments, church, commercial general, commercial retail, commercial service, industrial heavy, industrial light, mines, schools, streets/highways, urban high, urban low, urban medium, urban standard. The remaining landcodes were categorized as bimodal in the area histograms due to the existence of two clear peaks and had standard deviations of greater than 3.7 bins. They are: hotel/motel, industrial general, transportation, utilities general.

Ideally, all of the landcodes would exhibit sharp peaks in the area histograms, revealing a high correlation between the landcode's average IP and the frequency that that IP occurs within those parcels. The large-spread histograms could indicate an improper landuse grouping and possibly result in a higher RMS for the model than could be obtained if these spreads were attempted to be remedied. The bimodal histograms show clearly that the parcels within those 4 landcodes could have been more adequately grouped into 8 landcodes. However, because the bimodal landcodes accounted for no more than 1% of the total land area and 2% of the total current IP, the effort to further refine these landcodes was not seen as worth the small difference in RMS they would likely yield.

Table 9 Histogram analysis

Description	Number of Landcodes	Total Area (acres)	Area as Percent of Total	Total IP (acres)	Percent IP
Sharp Peak	22	267,158	97%	9,060	81%
Large Spread	14	7,225	3%	1,876	17%
Bimodal	4	831	0%	239	2%

An investigation into the 14 landcodes that show a large-spread type histogram offered the following results. Table 9 shows that these landcodes do not account for much of the overall model (3% of the total land area). However, if the percent IP that these landcodes are responsible for is examined, the influence on the model is more prevalent (17% of the total IP). When the parcels containing landcodes corresponding to the 14 large-spread histograms are plotted, it appears that these parcels may be concentrated in certain watersheds (Figure 40). These are the watersheds for which the circles in Figure 38 are further from the y = x line. The corresponding error may be reduced by investigating the causes for the large-spreads in these histograms and then attempting to improve the landcode grouping. The amount of improvement would depend on the overlap between causes and available data.

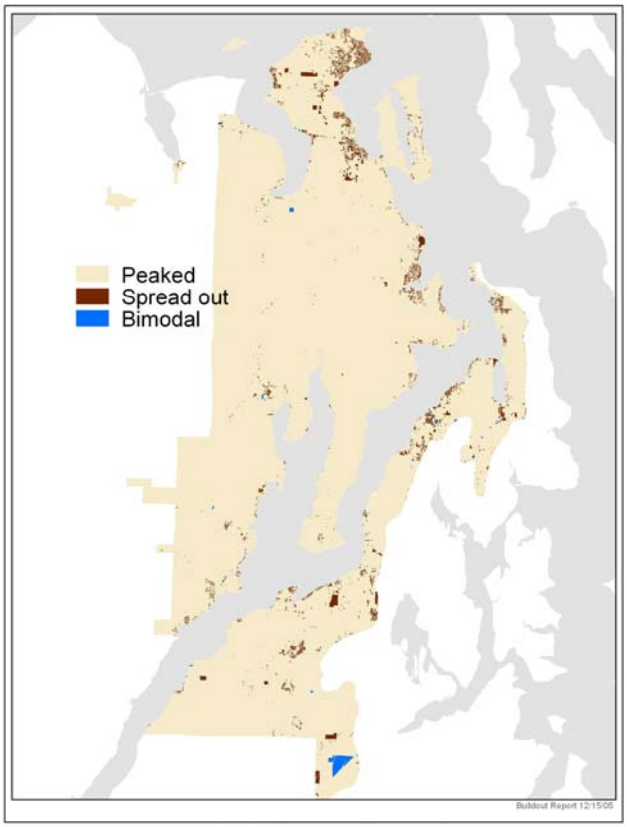

Figure 40 Distribution of parcels according to histogram interpretation

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APPENDIX A – Landcode Coefficients

Current Landcode	Number of Parcels	Impervious Acreage	Parcel Acreage	Coefficient[1]
LAKE	3	1	169	0.72%
ROW	67	924	1785	51.79%
SALT	1	1	26	4.52%
OUT	1	44	300	14.56%
Airports	68	212	1372	15.43%
Apartments	181	24	60	39.57%
Auto highway	1	1	3	24.74%
Cemetery	30	4	82	5.50%
Church	45	30	97	31.37%
Commercial general	14	3	9	30.40%
Commercial retail	217	77	215	36.05%
Commercial service	235	144	446	32.41%
Estate	2813	1067	11444	9.32%
Facilities	100	1009	8911	11.33%
Hotel motel	27	13	62	21.63%
Industrial general	46	171	564	30.40%
Industrial heavy	69	124	323	38.42%
Industrial light	63	42	356	11.88%
Mines	30	99	484	20.42%
Mobile park	18	53	552	9.68%
Open land	2895	874	20503	4.26%
Parks	616	273	4954	5.51%
Parks resorts	44	95	974	9.78%
Parks special	3	11	35	31.29%
Phone TV radio	6	0	647	0.04%
Rail	16	11	68	15.77%
Rural	981	482	6868	7.02%
Schools	49	67	179	37.53%
Streets highways	72	22	58	38.73%
Suburban	3917	1023	7120	14.36%
Transportation	18	7	18	37.47%
Unbuildable	57	4	61	7.30%
Urban high	229	3	8	31.70%
Urban low	7044	792	3747	21.14%
Urban medium	438	18	45	39.25%
Urban standard	5751	432	1207	35.81%
Utilities general	92	50	196	25.75%
Vacant	14838	1625	41256	3.94%
Water	57	9	721	1.25%
Wooded	2800	1338	159309	0.84%

[1]The coefficients are based on a larger number of significant digits than shown

APPENDIX B – Buildout Landcode Rules

Kitsap County

Notes: these are all for cases when the buildout landcode hadn't already been assigned during the original landcoding process.

Maximum buildouts for Kitsap were: 100% in all zones except IND and BP. IND max buildout was 60% and BP was 50%.

Not all possible combinations/permutations are presented here because not all possible combinations existed in the study area

If zone = RR AND current landcode = mines, unbuildable, industrial_light, commercial_service, industrial_general, OR industrial_heavy THEN buildout landcode = current landcode.

If zone = RP (1 HU per 10 acres) AND

- current landcode = mines, rail, commercial_retail, commercial_service, rural, estate, suburban, urban_low, urban_standard, urban_medium, urban_high, industrial_light, OR unbuildable THEN buildout landcode = current landcode.
- current landcode = open land AND
    - landuse NOT 91100, 91101, OR 91102 THEN buildout landcode = see Table 2
    - Landuse = 91100, 91101, OR 91102 THEN buildout landcode = open land

If zone = IND AND

- current landcode = [residential landcode] THEN buildout landcode = industrial heavy
- current landcode NOT [residential landcode] THEN buildout landcode = current landcode

If zone = BP (1 instance in study area) AND current landcode = Vacant AND buildout landcode = industrial general

If current landcode = ROW (zone = 0) THEN buildout landcode = ROW

If zone = LAKE THEN buildout landcode = LAKE

If zone = SALT THEN buildout landcode = water

If zone = RW (1 HU per 20 acres) AND

- current landcode = mines, rail, commercial_retail, commercial_service, rural, estate, suburban, urban_low, urban_standard, urban_medium, urban_high, industrial_light, OR unbuildable THEN buildout landcode = current landcode.
- current landcode = open_land THEN buildout landcode = see Table 2

If zone = NC AND

- current landcode = commercial_service THEN buildout landcode = commercial_service
- current landcode = open_land THEN buildout landcode = commercial_retail
- current landcode = urban_low THEN buildout landcode = commercial_retail

If zone = BC AND current landcode = open_land OR estate THEN buildout landcode = industrial general

If zone = CITY THEN buildout landcode = CITY (*note: City of Bremerton parcels not analyzed for buildout in this phase*)

If zone = T THEN buildout landcode = current landcode

If zone = A THEN buildout landcode = airports

If zone = FRL (1 HU per 40 acres) THEN buildout landcode = wooded

If zone = HTC AND
- IP coefficient for current landcode less than IP coefficient for industrial heavy THEN buildout landcode = industrial_heavy
- IP coefficient for current landcode greater than IP coefficient for industrial heavy THEN buildout landcode = current landcode

If zone = RHTW OR RHTR (2.5 HU per acre) AND
- Current landcode = industrial light, commercial service, OR commercial heavy THEN buildout landcode = current landcode
- Current landcode = [residential landcode] THEN buildout landcode = see Table 2 (all parcel densities were in the urban low buildout category)

If Zone = RL THEN buildout landcode = rural (*note only 2 parcels within this zone. Could not find information on this zone so this is a best-guess)*

If more than 1 zone existed then separate buildout landcodes for each portion of the parcel were assigned as per the above rules and the resultant coefficients multiplied only by the portion of the parcel that contained that zone

Jefferson County

Note maximum buildout landcodes and coefficients were assigned based on the rules found in the UGA and zoning documentation and are not enumerated here

If zone = EPF AND current landcode = airport THEN buildoutlandcode = airport

If zone = AL (1 HU per 20 acres) AND current landcode = open land THEN buildout = open_land

If zone = RR (1 HU per 5 acres) AND
- Current landcode = estate, suburban, urban_low, urban_standard, urban_medium, urban_high, OR rural THEN buildout landcode = current landcode.
- Current landcode NOT [residential landcode] THEN buildout landcode = current landcode
- Current landcode = open land THEN buildout landcode = see Table 2

Note similar process for all other RR zone densities

If zone = LI AND
- current landcode = open land THEN buildout landcode = industrial light
- current landcode = industrial heavy, industrial_general, or commercial_service THEN buildout landcode = current landcode

If zone = LI/C AND current landcode = open_land, commercial retail, commercial service, industrial heavy, industrial light, urban low, OR urban standard THEN buildout landcode = commercial service

If zone = LI/M AND
- current landcode = open land, industrial heavy, OR rural THEN buildout landcode = industrial heavy
- current landcode = commercial service THEN buildout = commercial service

If zone = HI THEN buildout landcode = industrial heavy

If zone = CF or RF or IF AND
- current landcode = vacant THEN buildout landcode = wooded
- current landcode NOT vacant THEN buildout landcode = current landcode

If zone = MPR-SF (4 HU per acre) AND
- current landcode = vacant AND
  - area < 3500 sq ft THEN buildout landcode = current landcode
  - area > 5000 sq ft THEN buildout landcode = see Table 2
- current landcode NOT vacant THEN buildout landcode = current landcode
- landuse = 8300 THEN buildout landcode = see Table 2

If zone = MPR-SFT (1 HU per 2.5 acres) AND
- current landcode = church THEN buildout landcode = church
- current landcode NOT church THEN buildout landcode = see Table 2

If zone = MPR-MF AND
- current landcode = parks OR apartments THEN buildout landcode = current landcode
- current landcode NOT parks OR apartments THEN buildout landcode = apartments

If zone = MPR-RC/CF
- current landcode = vacant THEN buildout landcode = urban high
- current landcode NOT vacant THEN buildout landcode = current landcode

If zone = MPR-VC AND current landcode = commercial retail, commercial service, OR parks resorts THEN buildout landcode = current landcode

If zone = MPR-RA AND current landcode = open land THEN buildout landcode = open land (note: open land buildout assignment due to existing golf courses assumed to remain golf courses in buildout)

If zone = MPR-OSR THEN buildout landcode = current landcode

If zone = AP AND
- current landcode = vacant THEN buildout landcode = open land
- current landcode NOT vacant THEN buildout landcode = current landcode

If zone = CC THEN buildout landcode = commercial retail

If zone = EPF THEN buildout landcode =current landcode

If zone = GC AND
- current landcode = commercial retail, commercial service, industrial general, OR industrial light THEN buildout landcode = current landcode
- current landcode = vacant OR [residential landcode] THEN buildout landcode = commercial service

If zone = NC AND
- current landcode = [residential landcode] OR vacant THEN buildout landcode = commercial service
- current landcode NOT [residential landcode] OR vacant THEN buildout landcode = current landcode

If zone = PPR AND
- current landcode = vacant THEN buildout landcode = parks
- current landcode NOT vacant THEN buildout landcode = current landcode

If zone = RI AND
- current landcode = industrial heavy THEN buildout landcode = current landcode
- current landcode = vacant THEN buildout landcode = open land (note the Jefferson County Code states that this zone is to allow for the continuation of existing saw-mills and related activities so it is assumed vacant land may be built out somewhat but not to the extent of an industrial heavy landcode. Only one parcel is in RI with current landcode = vacant.)

If zone = RVC AND
- current landcode = [residential landcode] THEN buildout landcode = commercial service
- current landcode NOT [residential landcode] THEN buildout landcode = current landcode

Port Townsend Urban Growth Area

If zone = c-1 THEN buildout landcode = commercial retail

If zone = c-I/MU (16 HU per 40,000 sq ft) THEN buildout landcode = commercial retail (note: buildout not assigned to urban high due to commercial retail having more realistic coefficient for this zone than urban high)

If zone = C-II AND
- current landcode = [residential landcode] THEN buildout landcode = commercial service
- current landcode NOT [residential landcode] THEN buildout landcode = current landcode

If zone = C-II(H) AND
- current landcode = [residential landcode] THEN buildout landcode = commercial service
- current landcode NOT [residential landcode] THEN buildout landcode = current landcode

If zone = C-II/MU AND
- current landcode = commercial retail THEN buildout landcode = commercial retail
- current landcode NOT commercial retail THEN buildout landcode = commercial service

If zone = CIII AND
- current landcode = urban standard, urban medium, vacant, OR open land THEN buildout landcode = commercial service
- current landcode NOT urban standard, urban medium, vacant, OR open land THEN buildout landcode = current landcode

If zone = M-C AND current landcode = [residential landcode] OR vacant THEN buildout landcode = industrial general

If zone = MII(A) OR MII(B) AND
- current landcode = vacant THEN buildout landcode = parks
- current landcode NOT vacant THEN buildout landcode = current landcode

If zone = PI AND current landcode = [residential parcels] THEN buildout landcode = utilities (note: could also be assigned buildout of schools or facilities, but erring on the upward end of the IP coefficients meant assigning these to utilities as it had a higher coefficient than the others)

If zone = P/OS AND
- current landcode = vacant THEN buildout landcode = parks
- current landcode NOT vacant THEN buildout landcode = current landcode

If zone = P/OS(B) AND
- current landcode = vacant THEN buildout landcode = facilities

- current landcode NOT vacant THEN buildout landcode = current landcode

If zone = RI(SF) 4 HU per 40,000 sq ft) AND current landcode = [residential landcode] THEN buildout landcode = see Table 2

If zone = RII(SF) AND current landcode = [residential landcode] THEN buildout landcode = see Table 2

If zone = RIII(MF) or RIV(MF) THEN buildout landcode = apartments

Port Hadlock/Irondale Urban Growth Area

If zone = commercial THEN buildout landcode = commercial service

If zone = visitor oriented commercial THEN buildout landcode = commercial retail

If zone = light industrial THEN buildout landcode = industrial light

If zone = public AND
- current landcode = vacant THEN buildout landcode = facilities
- current landcode NOT vacant THEN buildout landcode = current landcode

If zone = single family AND current landcode = vacant OR [residential landcode] AND
- parcel within a Critical Aquifer Recharge Area AND NOT within a sewer service area THEN 3.5 HU per acre, see Table 2 for buildout landcode
- parcel not within a Critical Aquifer Recharge Area OR is within a sewer service area THEN 6 HU per acre, see Table 2 for buildout landcode

If zone = multi-family (7-14 HU per acre) AND current landcode = vacant OR [residential landcode] THEN buildout landcode = see Table 2 (note density was calculating using 14 HU per acre)

If zone = mf15-24 THEN buildout landcode = apartments

If zone = null AND current landcode = wooded THEN buildout landcode = wooded

Clallam County

Zones in the study area: R2, R5, R20, CEN, CF

If zone1 = R20 (5.863 acres) and zone2 = CF (0.244 acres) and current landcode = vacant THEN assume one house added for a density of 1 / 6.24 and buildout = rural (even if density were 1 / 5.9 buildout would still = rural)

If zone = CEN THEN buildout = commercial retail (many landuses possible under CEN zone code but commercial retail is a conservative assumption)

4 parcels contained more than one zone where the second zone was less than or equal to 0.244 acres while the overall parcel size was greater than 6 acres. The amount of parcel area in the second zone was negligible for the purposes of this analysis and the buildout landcode was therefore based on the zone1 assignment.

1 parcel totaled 35 acres in landuse = 8800, landcode = wooded and buildout = wooded while 3.75 acres was assigned landcode = vacant and zone = CEN. For the 3.75 acres, the assumption was that buildout = commercial retail while the remaining acreage buildout = wooded. Because only one buildout landcode was assigned per parcel, the buildout landcode was assigned to wooded but the overall IP statistics for both buildout and max buildout were computed manually using the mix of commercial retail and wooded acres.

If landcode = vacant THEN buildout = residential landcode depending on allowable density

If landcode = vacant and zone = 20 and acres < 5 THEN buildout = vacant (minimum lot size is 5 acres for this zone)

If landcode = vacant and acres < 1 THEN buildout = vacant

APPENDIX C – Landcode Conversion Tables

Jefferson County:

Landuse Codes	Landcode	Buildout Landcode
RESIDENTIAL		
1100	depends on density	
1101	depends on density	
1102	depends on density	
1104	depends on density	
1200	depends on density	
1300	apartments	apartments
1400	apartments	apartments
1500	mobile_park	mobile_park
1600	hotel_motel	hotel_motel
1700	apartments	apartments
1900	depends on density	
MANUFACTURING		
2000	industrial_general	
2400	industrial_heavy	
2450	industrial_heavy	
2600	industrial_heavy	
3200	industrial_light	
3262	industrial_light	industrial_light
3270	industrial_heavy	industrial_heavy
3300	industrial_light	industrial_light
3432	industrial_light	industrial_light
3443	industrial_heavy	
TRANSPORTATION AND UTILITIES		
4111	rail	rail
4212	transportation	transportation
4300	airports	
4315	airports	
4411	facilities	facilities
4590	streets_highways	streets_highways
4600	transportation	transportation
4711	phone_tv_radio	phone_tv_radio
4800	utilities_general	utilities_general
4805	utilities_general	utilities_general
4833	utilities_general	utilities_general
4841	facilities	facilities
4854	facilities	facilities
TRADE		
5000	commercial_retail	
5100	commercial_retail	
5192	commercial_retail	
5200	commercial_retail	

Landuse Codes	Landcode	Buildout Landcode
5300	commercial_retail	
5360	commercial_retail	
5370	commercial_retail	
5400	commercial_retail	
5410	commercial_retail	
5500	industrial_heavy	
5530	industrial_heavy	
5600	commercial_retail	
5700	commercial_retail	
5800	commercial_retail	
5820	commercial_retail	
5830	commercial_retail	
5900	commercial_retail	
5920	commercial_retail	
5932	commercial_retail	
5969	commercial_retail	
SERVICES		
6000	commercial_service	
6100	commercial_service	
6154	commercial_service	
6200	commercial_service	
6242	cemetary	
6300	commercial_service	
6375	industrial_light	
6400	commercial_service	
6500	commercial_service	
6513	commercial_service	
6600	commercial_service	
6700	facilities	facilities
6721	facilities	facilities
6722	facilities	facilities
6730	facilities	facilities
6800	schools	schools
6813	schools	schools
6900	commercial_service	
6911	church	church
CULTURAL, ENTERTAINMENT, AND RECREATION		
7111	facilities	facilities
7112	facilities	facilities
7119	facilities	facilities
7200	commercial_service	commercial_service
7221	commercial_service	commercial_service
7311	parks_special	parks_special
7400	parks	parks
7442	parks	parks
7500	parks_resorts	parks_resorts
7600	parks	parks

Landuse Codes	Landcode	Buildout Landcode
7610	parks	parks
7620	parks	parks
7650	parks	parks
7670	parks	parks
7690	parks	parks
7700	parks	parks
7900	parks	parks
RESOURCE PRODUCTION AND EXTRACTION		
8000	open_land	
8100	open_land	
8110	open_land	
8120	open_land	
8300	wooded	
8400	industrial_light	
8543	mines	
UNDEVELOPED LAND AND WATER AREAS		
8900	wooded	
9100	vacant	
9300	water	water
9600	open_land	
9700	wooded	wooded
9720	wooded	wooded
9725	wooded	wooded
9730	wooded	wooded
9800	open_land	
9903	industrial_heavy	industrial_heavy

Kitsap County:

Landuse Codes	Landcode	Buildout Landcode
RESIDENTIAL		
11100	open_land	
11101	depends on density	
11102	depends on density	
11103	depends on density	
11104	depends on density	
11105	depends on density	
11900	open_land	
11901	depends on density	
11902	depends on density	
12101	depends on density	
15000	mobile_park	mobile_park
15001	mobile_park	mobile_park
16001	hotel_motel	hotel_motel
16101	hotel_motel	hotel_motel
18300	open_land	

	Landcode	Buildout Landcode
18301	open_land	
19800	open_land	
19801	depends on density	
19802	depends on density	
MANUFACTURING		
24000	industrial_heavy	
24001	industrial_heavy	industrial_heavy
39000	industrial_general	
39001	industrial_general	
39002	industrial_general	
39003	industrial_general	
TRANSPORTATION AND UTILITIES		
41000	rail	rail
43015	airports	
45000	streets_highways	streets_highways
45900	streets_highways	streets_highways
47000	phone_tv_radio	phone_tv_radio
47001	phone_tv_radio	phone_tv_radio
47005	phone_tv_radio	phone_tv_radio
48000	utilities_general	utilities_general
48300	utilities_general	utilities_general
48301	utilities_general	utilities_general
48500	facilities	facilities
48504	facilities	facilities
48900	utilities_general	utilities_general
49000	transportation	transportation
TRADE		
54101	commercial_retail	commercial_retail
54103	commercial_retail	commercial_retail
54301	commercial_retail	commercial_retail
54501	commercial_retail	commercial_retail
55902	industrial_heavy	industrial_heavy
58201	industrial_heavy	industrial_heavy
59001	industrial_heavy	
59002	commercial_retail	commercial_retail
59004	commercial_retail	commercial_retail
SERVICES		
61101	commercial_service	commercial_service
62400	cemetary	cemetary
63001	commercial_service	commercial_service
63700	industrial_heavy	
63701	industrial_heavy	
63703	industrial_heavy	industrial_heavy
63704	industrial_heavy	
63707	industrial_heavy	
63802	industrial_light	

	Landcode	Buildout Landcode
63804	industrial_light	
63806	industrial_light	
63809	industrial_light	
64101	auto_highway	
67000	facilities	facilities
67001	facilities	facilities
67002	facilities	facilities
67003	facilities	facilities
68000	schools	schools
68001	schools	schools
68003	schools	schools
69000	commercial_service	
69001	commercial_service	
69004	commercial_service	
69005	commercial_service	
69006	commercial_service	
69100	church	church
69101	church	church
CULTURAL, ENTERTAINMENT, AND RECREATION		
72001	facilities	facilities
74000	parks	parks
74001	parks	parks
74002	parks	parks
74004	parks	parks
74400	parks_special	parks_special
74403	parks_special	parks_special
75013	parks_resort	parks_resort
76000	parks	parks
76003	parks	parks
79000	parks	parks
79001	parks	parks
RESOURCE PRODUCTION AND EXTRACTION		
81002	open_land	
82002	industrial_light	
83000	open_land	
83001	open_land	
83002	open_land	
83003	open_land	
84000	industrial_light	
85000	mines	
85001	mines	
85003	mines	
88000	wooded	wooded
88001	wooded	wooded
88002	wooded	wooded
UNDEVELOPED LAND AND WATER AREAS		

	Landcode	Buildout Landcode
91000	vacant	
91001	vacant	
91100	open_land	open_land
91101	open_land	open_land
91102	open_land	open_land
92000	wooded	wooded
93000	water	water
93900	water	water
94000	open_land	
94001	open_land	
94002	open_land	
94003	open_land	
95000	wooded	wooded
95001	wooded	wooded
95002	wooded	wooded

Clallam County:

Landuse Codes	Landcode	Buildout Landcode
RESIDENTIAL		
1100	depends on density (1 house)	
1110	depends on density (1 house)	
1111	depends on density (1 house)	
1112	depends on density (1 house)	
1113	depends on density (1 house)	
1114	depends on density (1 house)	
1115	depends on density (1 house)	
1116	depends on density (1 house)	
1130	depends on density (1 house)	
1135	depends on density (1 house)	
1150	depends on density (1 house)	
1200	depends on density (1 house)	
1220	depends on density (1 house)	
1230	depends on density (1 house)	
1240	depends on density (1 house)	
1300	apartments	apartments
1400	apartments	apartments
1410	apartments	apartments
1500	mobile_park	mobile_park
1600	hotel_motel	hotel_motel
1731	apartments	apartments
1734	apartments	apartments
1800	apartments	apartments
1810	apartments	apartments
1900	depends on density	
1910	depends on density	
1920	depends on density	
MANUFACTURING		

Landuse Codes	Landcode	Buildout Landcode
2293	industrial_heavy	
3400	industrial_heavy	
3443	industrial_heavy	
3449	industrial_heavy	
3510	industrial_heavy	
TRANSPORTATION AND UTILITIES		
4111	rail	rail
4500	streets_highways	streets_highways
4580	streets_highways	streets_highways
4590	streets_highways	streets_highways
4600	transportation	transportation
4710	utilities_general	utilities_general
4749	utilities_general	utilities_general
4800	utilities_general	utilities_general
4830	utilities_general	utilities_general
4833	utilities_general	utilities_general
4834	utilities_general	utilities_general
4839	utilities_general	utilities_general
4843	utilities_general	utilities_general
TRADE		
5200	commercial_retail	
5211	industrial_general	
5212	industrial_general	
5220	industrial_general	
5300	commercial_retail	
5360	commercial_retail	
5370	commercial_retail	
5392	commercial_retail	
5400	commercial_retail	
5410	commercial_retail	
5462	commercial_retail	
5499	commercial_retail	
5500	industrial_heavy	
5511	industrial_heavy	
5520	industrial_heavy	
5530	industrial_heavy	
5535	industrial_heavy	
5600	commercial_retail	
5690	commercial_retail	
5720	commercial_retail	
5800	commercial_retail	
5805	commercial_retail	
5810	commercial_retail	
5820	commercial_retail	
5900	commercial_retail	
5931	commercial_retail	
5932	commercial_retail	
5941	commercial_retail	

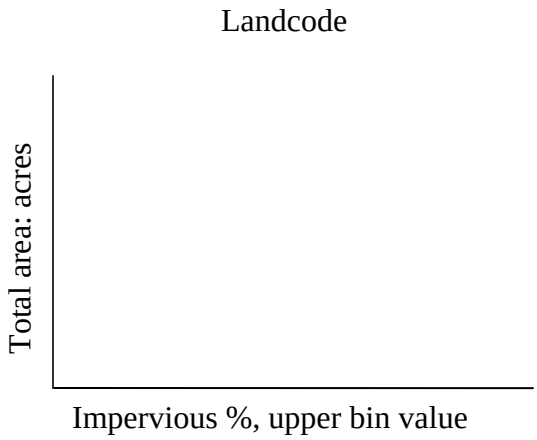
Landuse Codes	Landcode	Buildout Landcode
5991	commercial_retail	
5999	commercial_retail	
SERVICES		
6100	commercial_service	
6111	commercial_service	
6152	commercial_service	
6153	commercial_service	
6200	commercial_service	
6214	commercial_service	
6220	commercial_service	
6231	commercial_service	
6241	commercial_service	
6242	cemetary	
6290	commercial_service	
6300	commercial_service	
6319	commercial_service	
6370	commercial_service	
6375	industrial_light	
6379	industrial_light	
6391	commercial_service	
6400	commercial_service	
6411	industrial_heavy	
6419	industrial_heavy	
6500	commercial_service	
6510	commercial_service	
6511	commercial_service	
6512	commercial_service	
6513	commercial_service	
6517	commercial_service	
6519	commercial_service	
6520	commercial_service	
6593	commercial_service	
6599	commercial_service	
6611	industrial_light	
6621	commercial_service	
6623	commercial_service	
6629	industrial_light	
6722	facilities	facilities
6811	commercial_service	
6911	church	church
6919	commercial_service	
6994	commercial_service	
6999	commercial_service	
CULTURAL, ENTERTAINMENT, AND RECREATION		
7112	facilities	facilities
7200	commercial_service	commercial_service
7219	commercial_service	
7417	commercial_service	

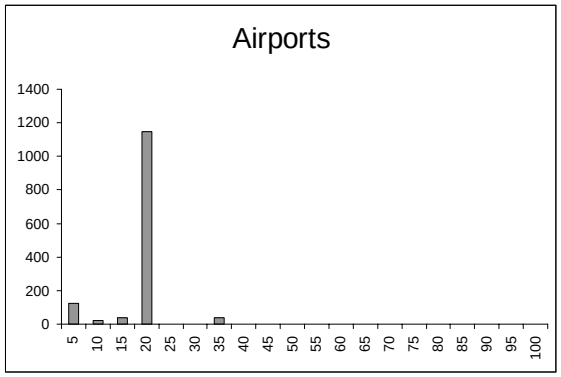
Landuse Codes	Landcode	Buildout Landcode
7422	parks	parks
7499	parks	parks
7500	parks_resorts	parks_resorts
7511	parks_resorts	
7516	parks_resorts	
7600	parks	parks
7650	parks	parks
7700	parks	parks
7800	open_land	open_land
RESOURCE PRODUCTION AND EXTRACTION		
8200	commercial_service	
8222	commercial_service	
8300	wooded	
8500	mines	
8543	mines	
8800	wooded	wooded
UNDEVELOPED LAND AND WATER AREAS		
8900	wooded	
9100	vacant	
9120	commercial_retail (for those parcels with a lot of IP), vacant for those with no IP	
9130	industrial_light	
9350	open_land	open_land
9400	open_land	
9500	wooded	
9600	open_land	
9700	wooded	wooded
9730	wooded	wooded
9750	vacant	

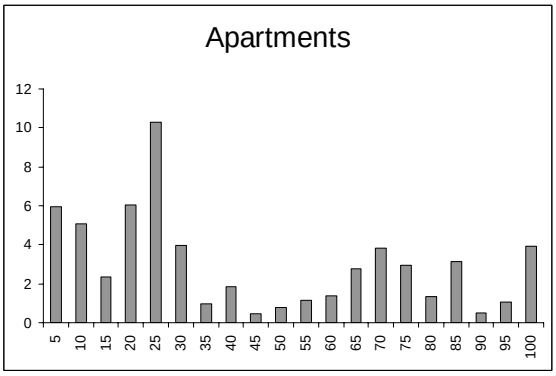
APPENDIX D – Landcode Coefficient Histograms

The following histograms plot the percentage of IP, for each landcode, against total area.

Format:




Airports
1400
1200
1000
800
600
400
200
0
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100


Apartments
12
10
8
6
4
2
0
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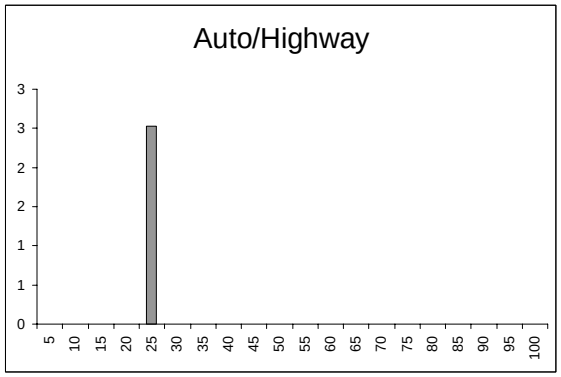
Auto/Highway
3
3
2
2
1
1
0
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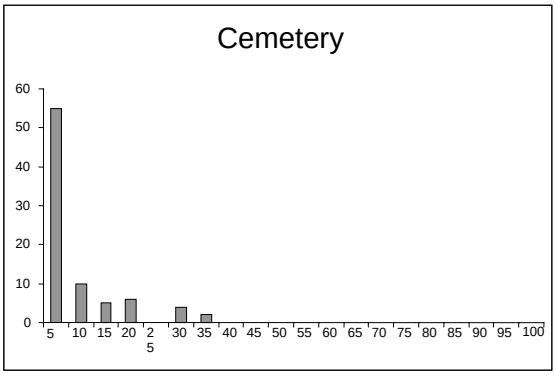
Cemetery
60
50
40
30
20
10
0
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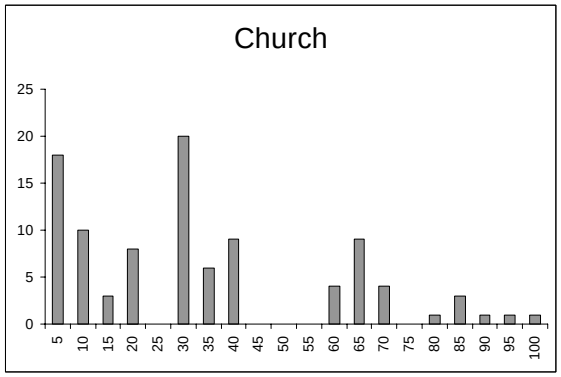
Church
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15
10
5
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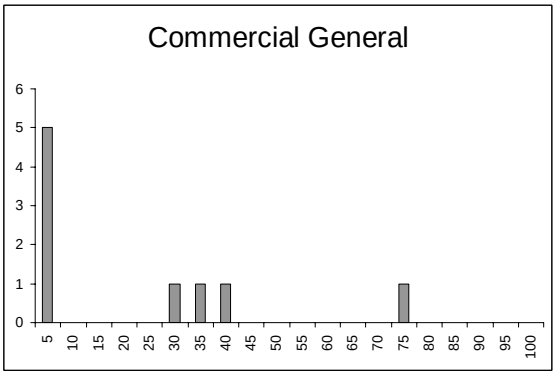
Commercial General
6
5
4
3
2
1
0
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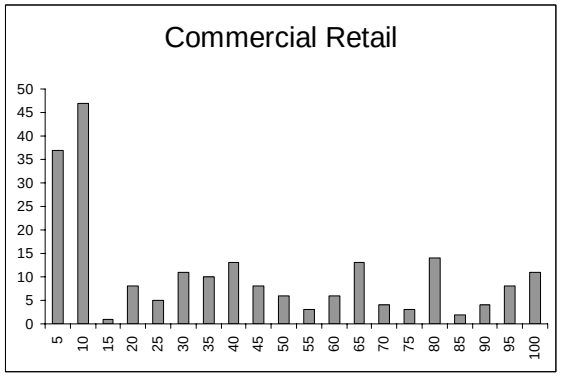
Commercial Retail
50
45
40
35
30
25
20
15
10
5
0
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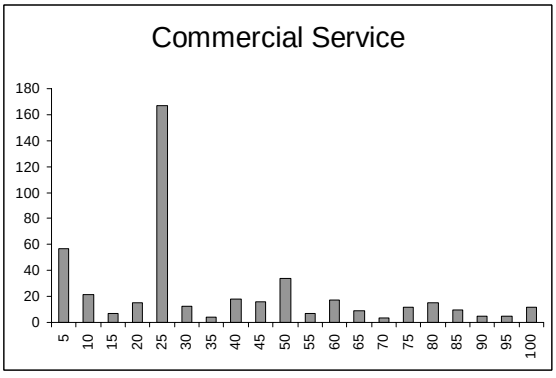
Commercial Service
180
160
140
120
100
80
60
40
20
0
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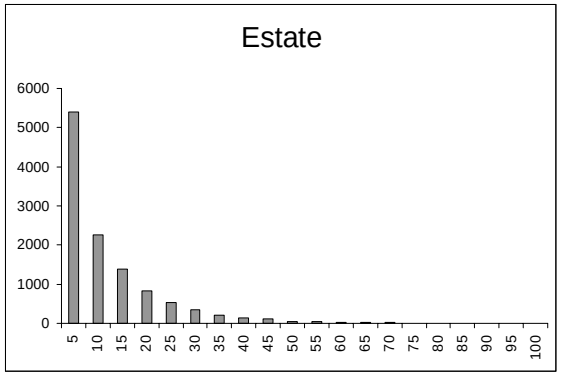
Estate
6000
5000
4000
3000
2000
1000
0
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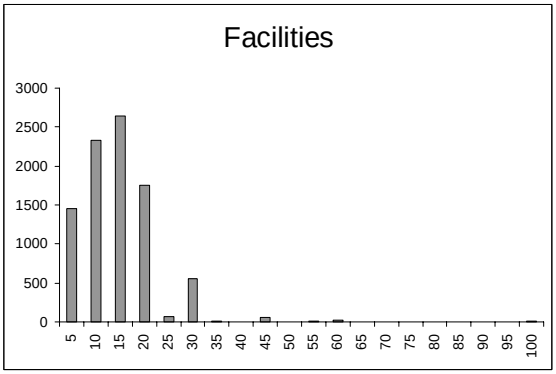
Facilities
3000
2500
2000
1500
1000
500
0
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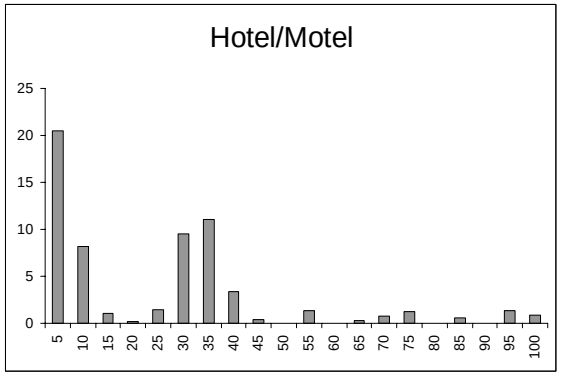
Hotel/Motel
25
20
15
10
5
0
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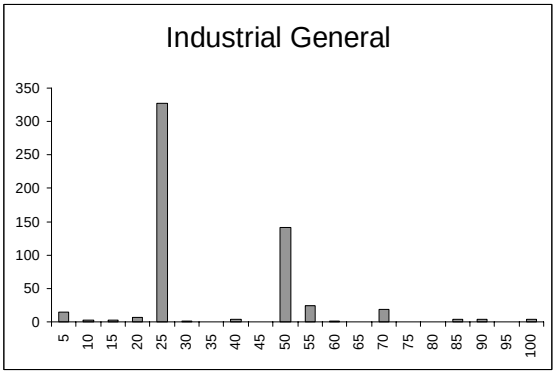
Industrial General
350
300
250
200
150
100
50
0
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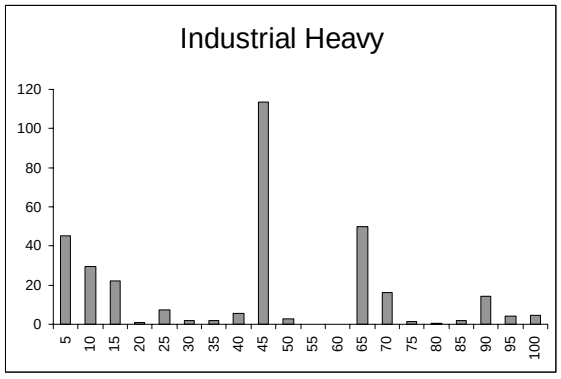
Industrial Heavy
120
100
80
60
40
20
0
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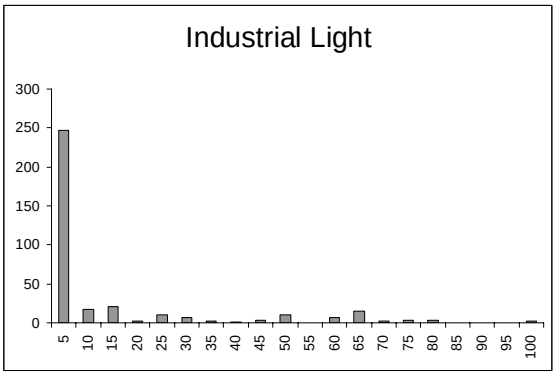
Industrial Light
300
250
200
150
100
50
0
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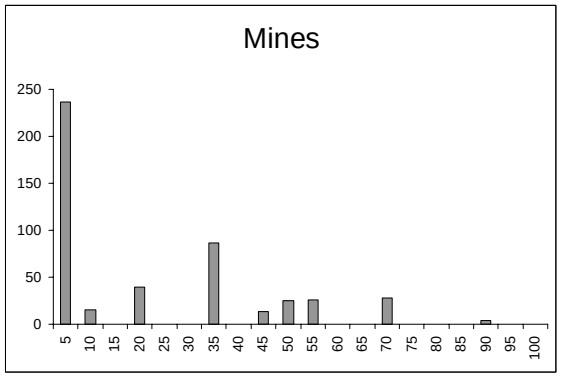
Mines
250
200
150
100
50
0
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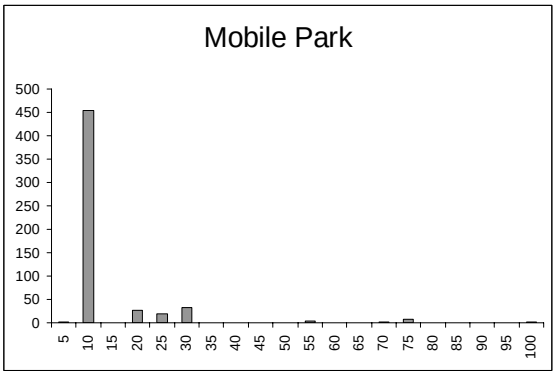
Mobile Park
500
450
400
350
300
250
200
150
100
50
0
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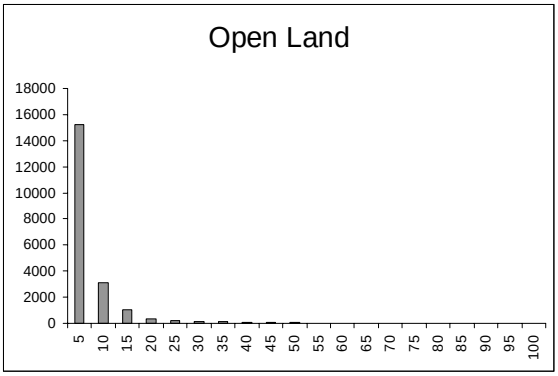
Open Land
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
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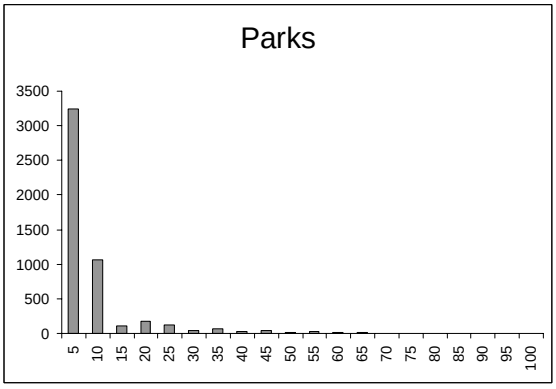
Parks
3500
3000
2500
2000
1500
1000
500
0
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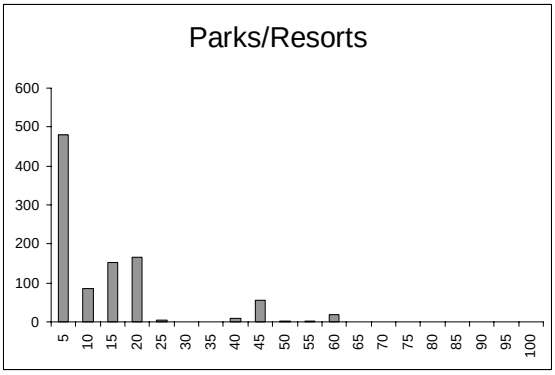
Parks/Resorts
600
500
400
300
200
100
0
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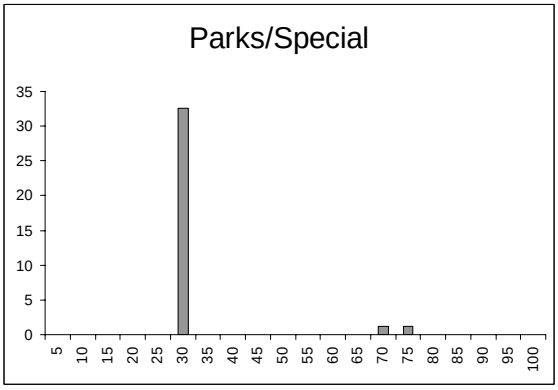
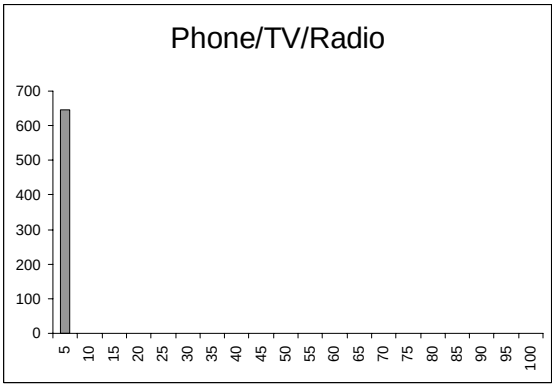

Parks/Special
35
30
25
20
15
10
5
0
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100


Phone/TV/Radio
700
600
500
400
300
200
100
0
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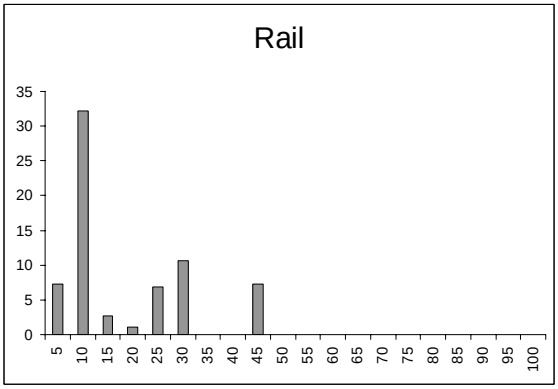
Rail
35
30
25
20
15
10
5
0
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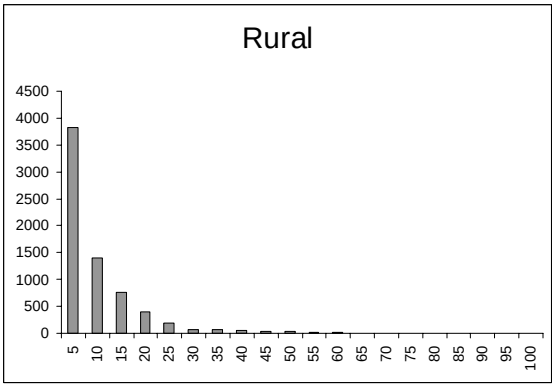
Rural
4500
4000
3500
3000
2500
2000
1500
1000
500
0
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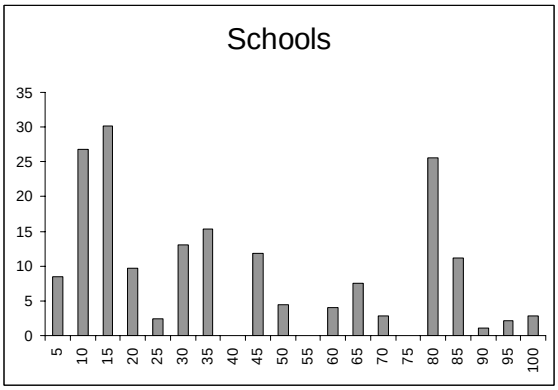
Schools
35
30
25
20
15
10
5
0
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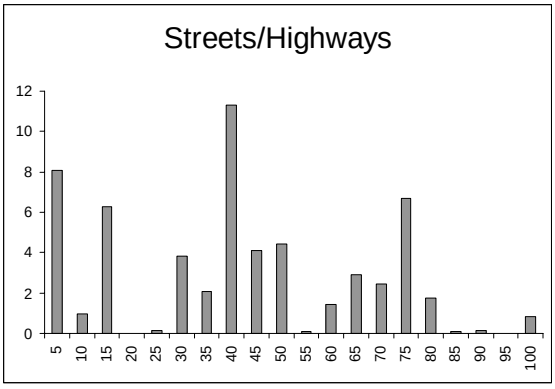
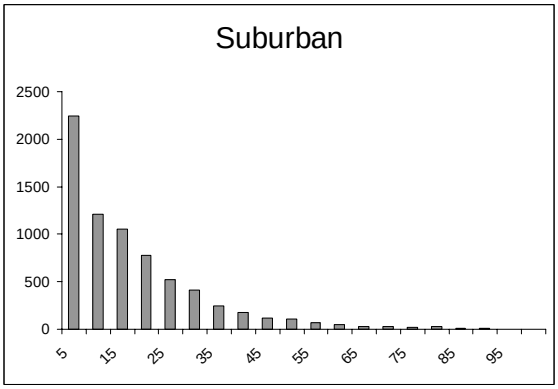
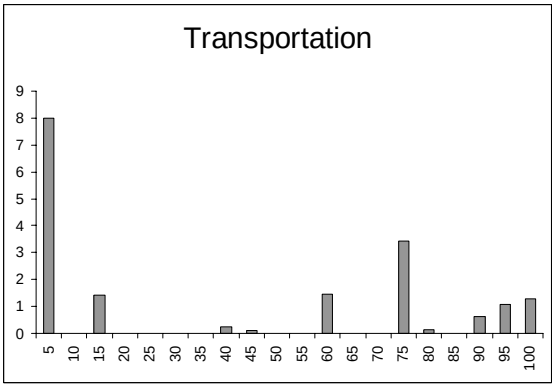

Streets/Highways
0 2 4 6 8 10 12
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100


Suburban
0 500 1000 1500 2000 2500
5 15 25 35 45 55 65 75 85 95


Transportation
0 1 2 3 4 5 6 7 8 9
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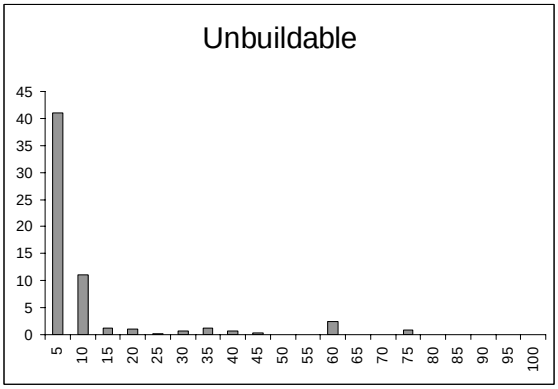
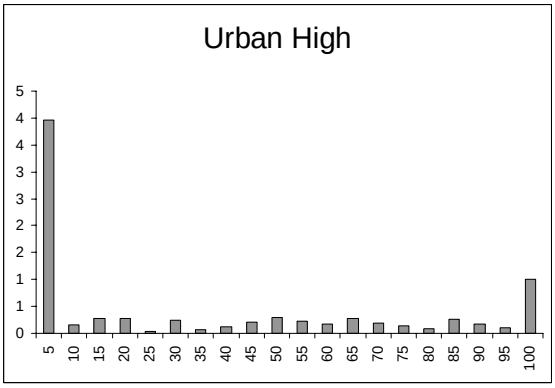
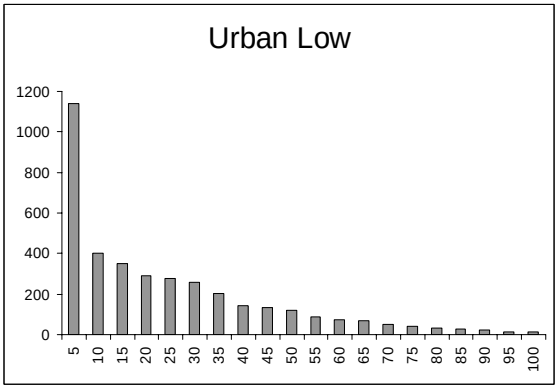

Unbuildable
0 5 10 15 20 25 30 35 40 45
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100


Urban High
0 1 1 2 2 3 3 4 4 5
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100


Urban Low
0 200 400 600 800 1000 1200
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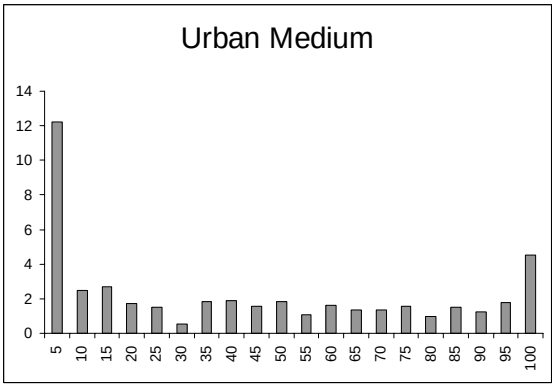
Urban Medium
0 2 4 6 8 10 12 14
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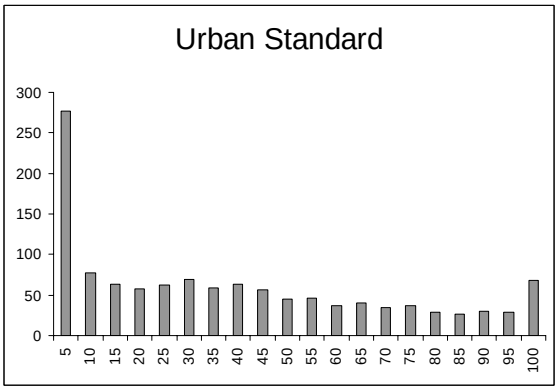
Urban Standard
0 50 100 150 200 250 300
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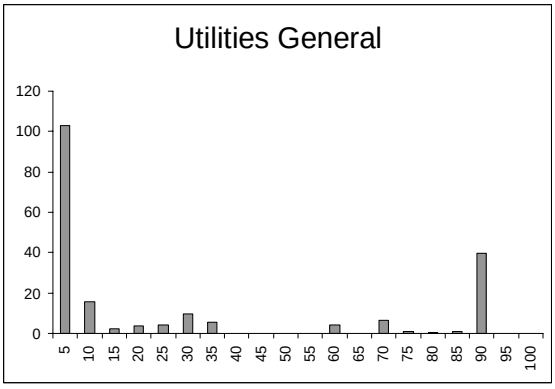
Utilities General
120
100
80
60
40
20
0
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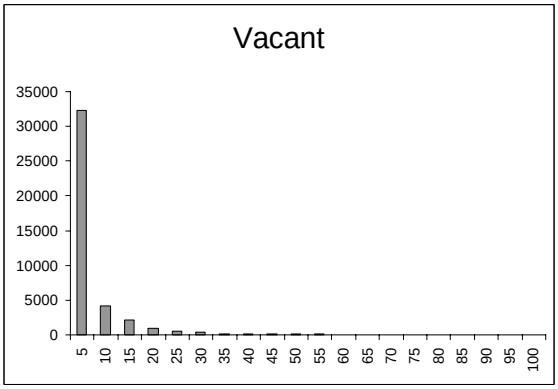
Vacant
35000
30000
25000
20000
15000
10000
5000
0
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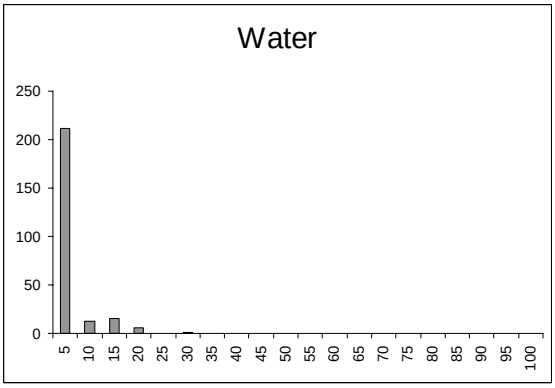
Water
250
200
150
100
50
0
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100


Wooded
180000
160000
140000
120000
100000
80000
60000
40000
20000
0
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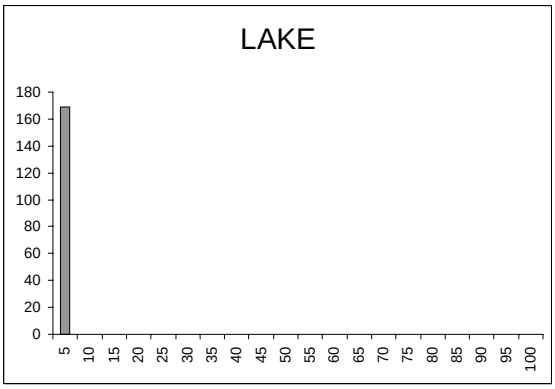
LAKE
180
160
140
120
100
80
60
40
20
0
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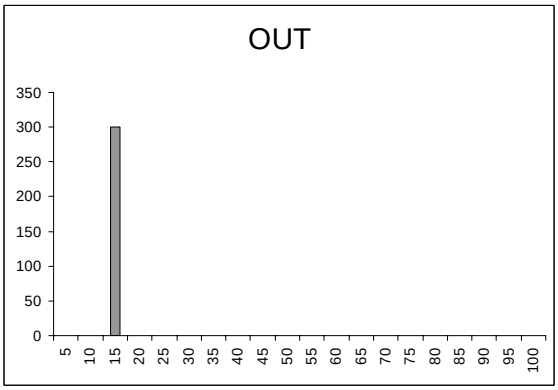
OUT
350
300
250
200
150
100
50
0
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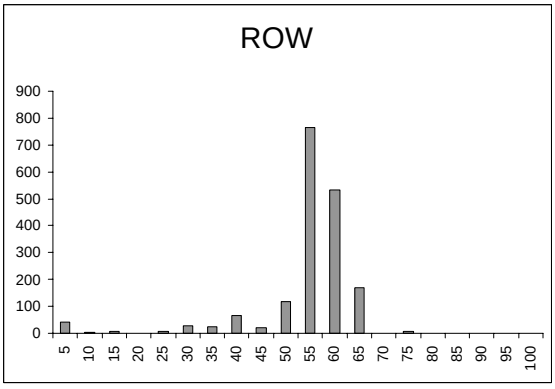
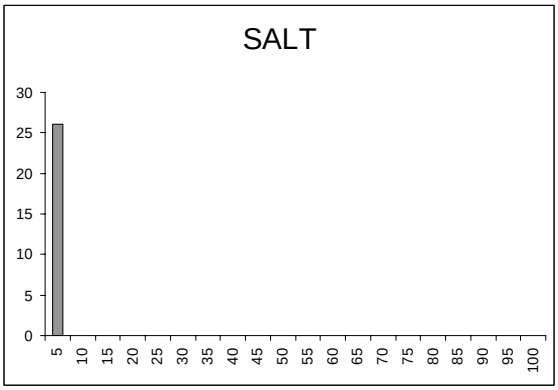
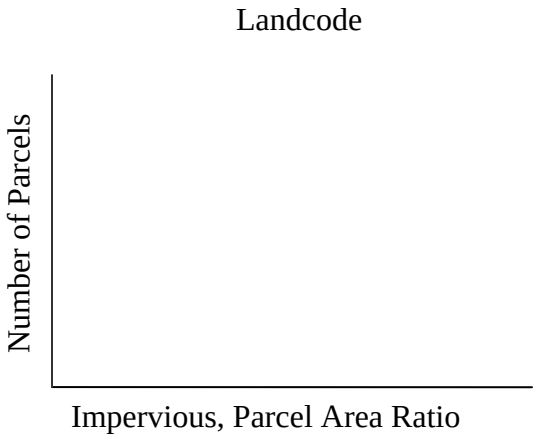

ROW
900
800
700
600
500
400
300
200
100
0
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100

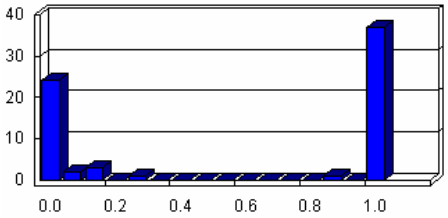

SALT
30
25
20
15
10
5
0
5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100

The next set of histograms plot the percentage of IP, for each landcode, against number of parcels.

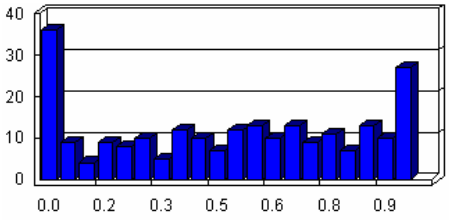
Format:



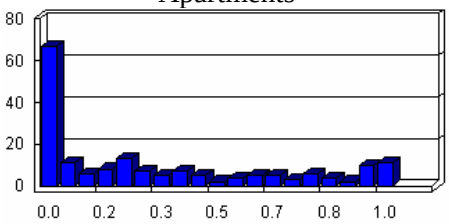
Airports



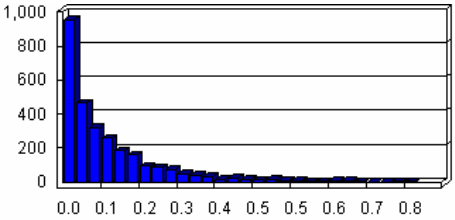
Commercial Service



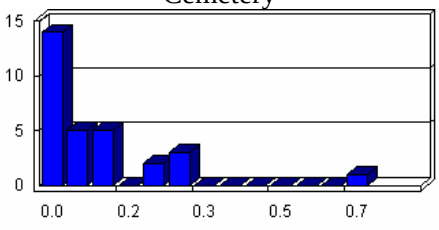
Apartments



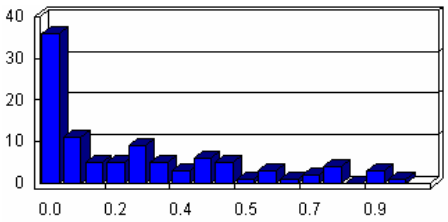
Estate



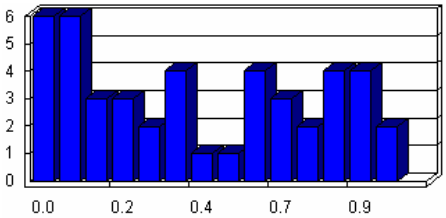
Cemetery



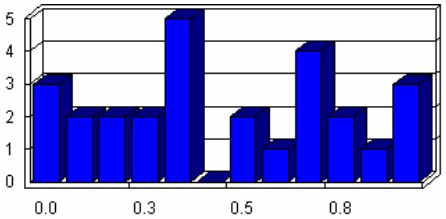
Facilities



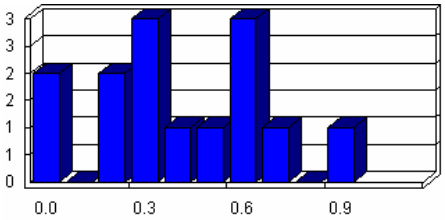
Church



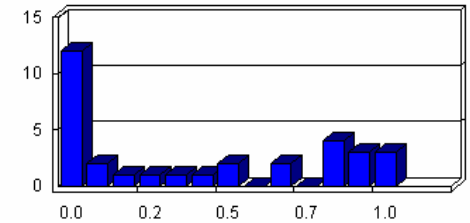
Hotel / Motel



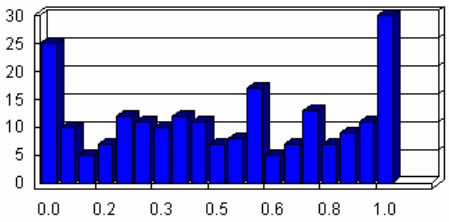
Commercial General



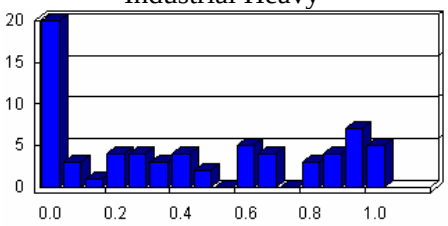
Industrial General



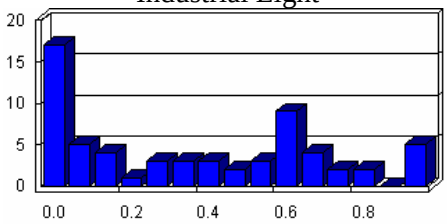
Commercial Retail



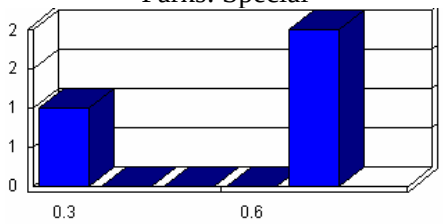
Industrial Heavy



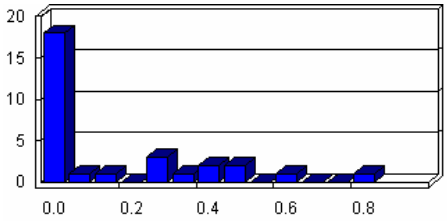
Industrial Light



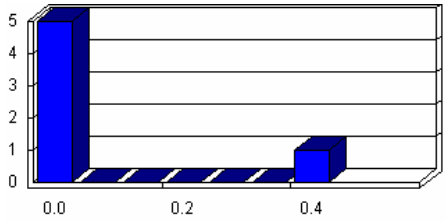
Parks: Special



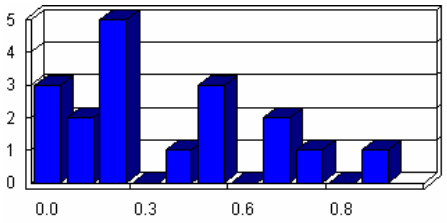
Mines



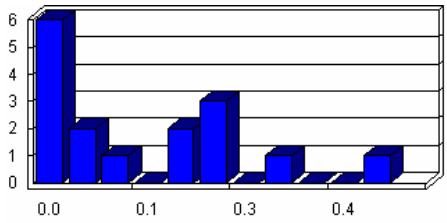
Phone TV Radio



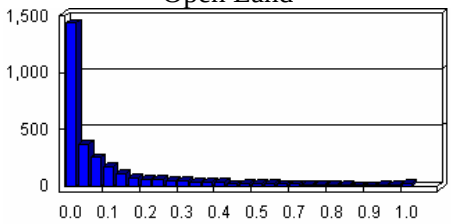
Mobile Park



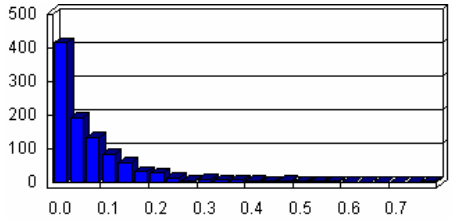
Rail



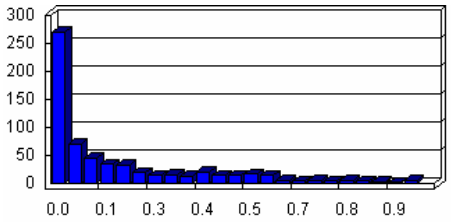
Open Land



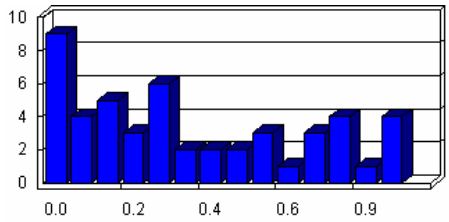
Rural



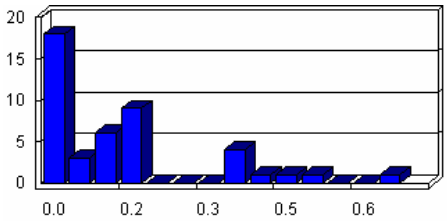
Parks



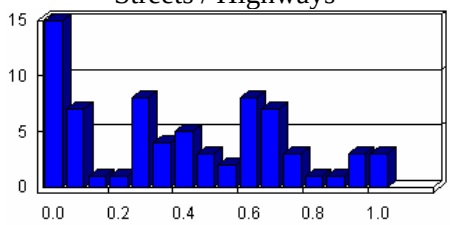
Schools



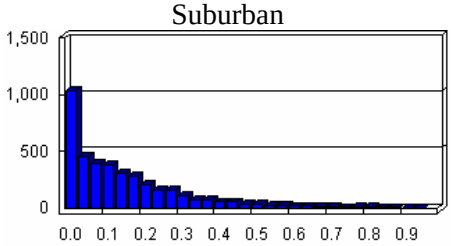
Parks: Resorts



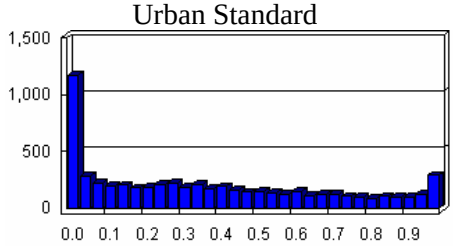
Streets / Highways



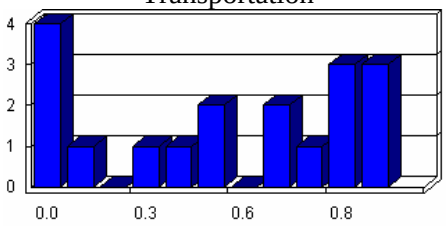
Suburban



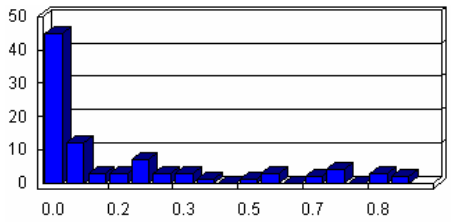
Urban Standard



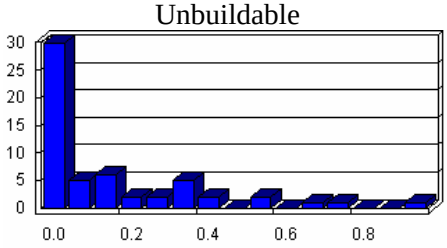
Transportation



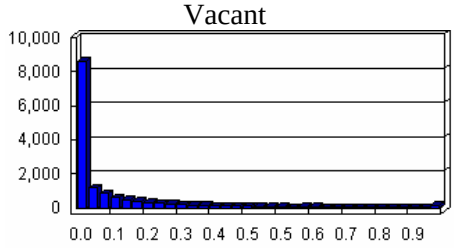
Utilities General



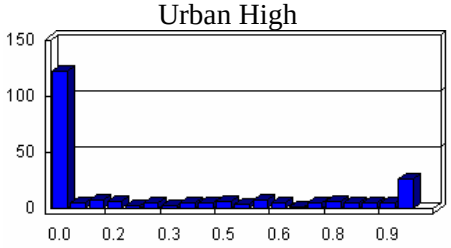
Unbuildable



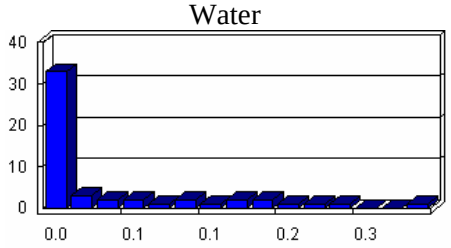
Vacant



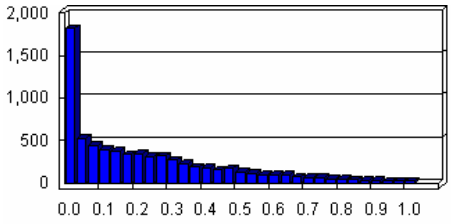
Urban High



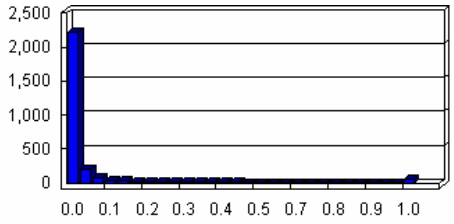
Water



Urban Low



Wooded



Urban Medium