Impervious Surface Coefficients

A tool for environmental analysis and management

WHY IMPERVIOUSNESS IS IMPORTANT

Impervious Cover (IC): All hard surfaces that permit little or no water to penetrate into the soil, such as rooftops, driveways, streets, swimming pools and patios.

When undeveloped land, such as farmland and forests, are converted into cities and suburbs, natural land cover is replaced by impervious cover (IC). Numerous studies have demonstrated that there is a negative correlation between the amount of IC and water quality within a watershed. Imperviousness decreases the ability of the ground to absorb water and recharge the aquifer. The increased volume and velocity of stormwater associated with IC erodes streambanks (see picture left), causing increased turbidity, degrading habitat, and filling the streambeds with sediment. Water flowing over concrete and lawns picks up contaminants such as nutrients from fertilizer, oil and grease from roads, pesticides, and other pollutants from residential and commercial areas. These contaminants can have a negative effect on the biotic communities living in the aquatic ecosystem as well as reducing the safety of water for drinking, swimming, and fishing. Numerous studies have shown that as impervious cover increases, stream quality decreases.

Typical incision in an urban creek caused by faster flows and greater volume of storm-water associated with impervious cover.

USING THE IMPERVIOUS SURFACE COEFFICIENTS (ISC) AS A TOOL

Estimates of existing and projected IC based on a community's general plan can be used to reduce total imperviousness and/or design appropriate stormwater management practices to reduce the negative effects caused by increased IC. In order to facilitate these analyses, a set of impervious surface coefficients, representing the average amount of IC in each of the major land use categories (LUC) in California, have been developed. The LUCs and their corresponding coefficients are provided for commercial and residential land uses as well as roads. These coefficients, based on data collected from Sacramento, Irvine, and Santa Cruz, reflect the average percent of IC for any single LUC. When combined with information on the total area of each LUC, the total amount of IC within any defined area can be estimated.

Commercial/ General Land Use Impervious Surface Coefficients

Using high-resolution aerial photographs and local land use GIS data layers, ground surfaces covered by IC were digitized at randomly selected sites. Aerial photo (right) of a sample site illustrates the white sample point, around which a 10 acre box (red) was constructed. All IC of the land use within the box in which the sample point was located was digitized (yellow). The impervious area for all the sample sites was calculated and the mean was determined for each LUC. Sufficient data was collected to provide 90% confidence in the mean impervious surface coeffecient (ISC) with a 10% level of precision. Because commercial LUCs are developed in a similar fashion throughout California, there were no statistically significant differences for any of the commercial land uses between the three cities from which data was collected. The exception was the Public/Quasi-Public category.

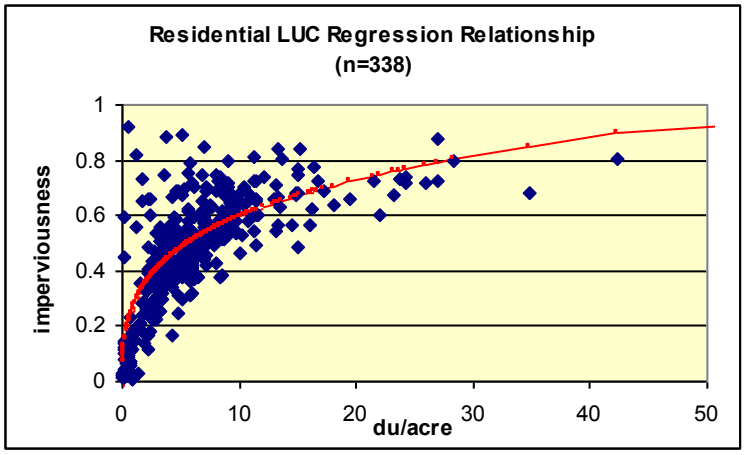
COMMERCIAL/ GENERAL LAND USE CATEGORIES, CONTINUED.

Public/Quasi-Public is based on ownership, not actual land use, so there was significantly more variability in the amount of IC on these parcels. Finally, the general plans of Irvine, Sacramento, and Santa Cruz were reviewed to ensure that , regardless of name, the actual land uses for each category were comparable. The 10 LUCs, their descriptions, and the ISC are listed in the table below:

LUC	DESCRIPTION	ISC %
Agriculture	Commercial nurseries, grazing, farming	4
Retail	Community, neighborhood, or regional retail; office up to 5%	86
Retail/ Office	Community, neighborhood, or regional retail; office up to 25%	80
Office Parks	Office complexes, commonly found in suburban areas	69
Urban Office	Urban office buildings	85
Heavy Industrial	100% industrial	91
Light Industrial	Industrial and/or warehouse with some offices	81
Mixed Use	Retail, office, residential mix	80
Open Space	Natural areas	2
Public/Quasi—Public	Publicly owned & used land including churches, schools, cemeteries, military bases, railroads, airports, and hospitals	50*

*** provisional ISC**

Residential Land Use Impervious Surface Coefficients



Because each community's general plan designates a different set of criteria for defining residential categories, an alternative approach was used for the determination of the ISCs for residential LUCs. Density, the number of dwelling units per acre (du/acre), was treated as a continuous variable and a regression equation was calculated. As density increases up to about 10 du/acre, IC also increases. Above 10 du/ acre, the amount of buildable land becomes limiting, and additional units are obtained by building up rather then out. This is the reason that the regression relationship begins to plateau at higher density levels. The regression relationship spans a range of imperviousness and is applicable to any community in the state. The equation used to calculate the ISC for each residential land use type is: $\mathbf{y = -.02304 + .04961\ x^{0.2196}}$. To determine the ISC for any category, substitute the typical densities for each residential LUC for x and calculate y, the impervious surface coefficient.

USING THE REGRESSION EQUATION TO FIND RESIDENTIAL ISC

Calculate the ISC for any residential area using equation for ISC = -.02304 + .04961 $\mathbf{x}^{0.2196}$

Where **x** = density [dwelling unit / acre]

Example :

- For low density residential (LDR) with 6 du/acre, ISC = -.2304 + 0.4961 (**6**) $^{.2196}$= .51 or 51 %
- For medium density residential (MDR) with 12 du/acre, ISC= -.2304 + 0.4961 (**12**) $^{.2196}$= .63 or 63 %

Road Impervious Surface Coefficients

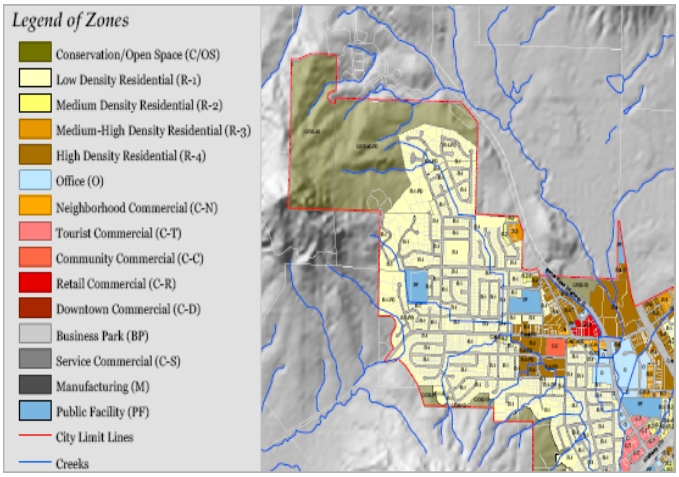
Name	Description	ISC %
Urban	Typical grid pattern of roads found in older urban areas, streets tend to be narrower with more green space than newer suburban roads.	92
Suburban	Typical suburban cul-de-sac road pattern, wider lanes, less green space.	96
Rural	Country roads.	47
Highways	Major freeways.	50

To determine road ISCs, the imperviousness of the three key non-highway road types: locals, collectors, and arterials, and their frequency in the 3 major development environments: urban, suburban, and rural areas, was determined. Using this information, ISCs for rural, suburban, and urban roads were calculated by weighting the ISC for each environment by the frequency of occurrence of each road type in each development environment. For example: urban ISC = [(ISC for local roads * frequency of local roads in urban areas) + (ISC collectors * frequency of collectors) + (ISC for arterials * their frequency)] / 3. The data from each community were averaged to arrive at a final ISC associated with the typical amount of imperviousness associated with road and streets in each setting. Imperviousness associated with highways was analyzed independently. The highway ISC is surprisingly low due to larger landscaped areas such as on/off ramps.

Applications of Impervious Surface Coefficients

Calculating Future or Build Out Imperviousness

The simplest use of the ISCs is for a build out calculation, an analysis of IC that will exist when the community and its general plan are fully implemented. The calculation is straightforward: multiply the total number of acres for each LUC by the appropriate ISC, then sum the values. At the scale of a development or specific plan, this data can be used by **stormwater managers** to size stormwater facilities such as swales, infiltration areas, and ponds. Because the ISCs are California-specific, they provide an excellent estimate of imperviousness, including 95% confidence intervals, and when combined with run-off coefficients, support an analysis of the total volume run-off from a site. **Planners** can use ISCs for determining the potential environmental impacts of new developments. With knowledge of the level of IC, alternative designs that reduce the impervious area and/or protect sensitive environmental areas can be considered. ISCs can also be used as part of a system of credits aimed at reducing the amount of imperviousness for various LUCs, as currently done in many other states.



Calculating Future or Build Out Impervious Cover

A development of 25 acres consists of:

- 10 acres mixed use
- 12 acres Medium Density Residential (MDR)
- 3 acres suburban road

IC can be calculated using : IC = [area of LUC] x ISC

- 10 acres x .81 (ISC mixed use) = 8 acres
- 12 acres x .6258 (ISC MDR) = 7.5acres
- 3 acres x .96 (ISC suburban road) = 2.9 acres

Total acres of IC future area = 18.4 acres of IC

A partial land use map identifies the zones in the city of San Luis Obispo, California (above left). Total imperviousness can be calculated by multiplying the acres of a designated LUC by the ISC. A simplified example demonstrates this calculation (above right).

Calculating Current Imperviousness

The calculation of current IC is more involved than analysis of build-out because in most cases, not all land zoned for a particular land has been developed. An *undeveloped parcel correction factor (UPCF)* can be used to account for the discrepancy between current and build-out conditions. The UPCF is subtracted from the build-out impervious area to account for acres not yet fully-developed, such as a rural residential area zoned for medium density residential. One source of data for the UPCF is the tax assessor's office, which retains information on the assessed values of parcels. Those parcels with very low assessed values (e.g. < $10,000) are likely under-developed. This information is free and available to the public. Refuse records can also be used to differentiate between vacant land and non-taxed parcels on the assessor's list, such as schools, churches, and county offices. This information is especially valuable to **watershed scientists** and **natural resource managers** who are interested in using imperviousness as an indicator of watershed health. Knowledge of the potential risks of current development plans might be helpful in calling this issue to the attention of local decision makers, who have the ability to identify alternative types of development or stormwater management practices, including the use of low Impact development (LID) techniques, to lessen the adverse impacts of increased run-off and associated pollutants.

Calculating Current Impervious Cover

Use the UPC to evaluate current impervious conditions of a 25 acre development:

- 10 acres mixed use - 3 acres undeveloped= 7 acres
- 12 acres MDR - 7 acres vacant = 5 acres
- Suburban road already completed (no UPCF) = 3 acres

Complete calculation as with build-out analysis:

- 7 acres x .81 (ISC Mixed Use) = 5.7 acres
- 5 acres x .63 (ISC MDR) = 3.1 acres
- 3 acres x .96 (suburban road ISC) = 2.9 acres

Total IC in development = 11.7 acres

Undeveloped land that is zoned for a particular LUC, such as this empty plot (above) zoned as neighboring retail, needs to be included when calculating the current level of imperviousness.

Conclusion

This set of impervious surface coefficients will facilitate the calculation of IC in any developed area within California. The coefficients were developed using high resolution aerial photography and analyzed using robust statistical methods. To facilitate their use, a User's Guide and accompanying spreadsheet with embedded formulas will be available in the fall 2008. Technical support will also be available for assistance with the applications of the coefficients (contact information below).

More Information

Office of Environmental Health Hazard Assessment	www.oehha.ca.gov/ecotoxicology
Center for Water & Land Use, UC Davis	https://extension.ucdavis.edu/areas-study/land-use-and-natural-resources
California Stormwater Quality Association	www.casqa.org
National NEMO Network	www.nemonet.uconn.edu

Literature:

Development of a Population Density and Land Use Based Regression Model to Calculate the Amount of Imperviousness. Posted at: http://clear.uconn.edu/publications/research/tech_papers/Chabaeva_et_al_ASPRS2004.pdf

Impervious Surfaces and Water Quality: A Review of Current Literature. Posted at: http://jpl.sagepub.com/cgi/content/abstract/16/4/499

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