

**ESTIMATING WATERSHED IMPERVIOUSNESS FOR CURRENT AND BUILD-OUT
CONDITIONS**
A CASE STUDY IN THE SACRAMENTO METROPOLITAN AREA
(A WORKING DRAFT)

Introduction

An impervious surface coefficient (ISC) is a value that reflects the average percent of hardscape in a single generalized land use category. By multiplying these coefficients by the area (acres) of the relevant land use type, one can estimate the amount of impervious cover for each land use category. The coefficients can be used to estimate impervious cover in any area of interest, such as a city or a watershed. The calculations can be made for both current and future or build out conditions. This fact sheet summarizes the methods used to develop the ISC.

Methods Used for Determining the Coefficients

Step 1: Assemble necessary GIS layers

The coefficients were calculated using **geographic information systems (GIS)**. The GIS layers used for the calculations were:

- Digital **orthophotograph** of the watershed with 2-foot resolution
- Layer of watershed boundaries
- Land use layer with area for each land use type calculated
- Layer of randomly selected sample sites with a unique identifier and an assigned land use type within the watershed.

The General Land Use Category (GLUC) GIS data layer used to calculate the coefficients for the Sacramento region was provided by the Sacramento Area Council of Governments, the regional planning organization. They were based on the current and planned uses of land and derived from existing **zoning, general and specific plans**. The majority of the sites used for these ISC calculations were located within the Dry Creek watershed in western Placer and northern Sacramento Counties.

Step 2: Select sample sites and digitizing methods

With assistance from the Dr. Tony Olsen, Western Ecology Division, Environmental Monitoring and Assessment Program, US EPA, we used a probabilistic sampling design to identify 1700 sample sites for digitizing on the land use map of the watershed. For each site used in this analysis, a 40,000 m² square was drawn around each sample point. Although multiple GLUCs were typically found within each square, only impervious cover (IC) within the GLUC in which the sample point was located, were digitized. For example, if the sample point was located in the low density residential GLUC, all the impervious areas within the square that were designated low density residential were digitized. By layering the land use categories over the aerial photo, the impervious surfaces were identified and outlined digitally. If the selected site fell on vacant or undeveloped land, data from the site was disregarded.

Step 3: Digitize all impervious areas for each land use category

Imperviousness within all 19 GLUC was identified in a pilot study of 15 to 30 sites per GLUC. Based on the variability of the initial coefficients for each GLUC, the total number of sample site required to achieve 90 percent confidence was calculated using standard statistical methods. Percent of IC for each sample site's GLUC was then calculated using the formula:

$$(IC \text{ Area} / \text{Total Area of GLUC within grid}) * 100 = ISC$$

The average of each GLUC's ISCs determined the GLUC's final coefficient.

Table 1. Final Impervious Surface Coefficients

LAND USE TYPE	Density	ISC (%)
Agriculture	N/A	4
Community/Neighborhood Commercial Office	N/A	71
Community /Neighborhood Retail	<.03	80
Forest	N/A	0
Heavy Industrial	N/A	91
High Intensity Office	1.1+	85
Low Density Residential	4.1-8.0	40
Light Industrial	N/A	84
Medium Density Residential	8.1-12.0	55
Medium-High/ High Density Residential	12.1+	60
Medium Intensity Office	.3-1.0	69
Mixed Use	N/A	82
Open Space	N/A	2
Public/Quasi- Public	N/A	26
Rural Residential	<=1.0	6
Roads	N/A	*
Very-Low Density Residential	1.1-4.0	26

* Note that currently the road coefficients are being analyzed. We will be determining one coefficient for existing development and a second for new development, both residential and commercial, that considers various types of roadways (highways, arterials, collectors, and locals).

USING THE ISC TO DETERMINE IMPERVIOUS AREA

1. Calculating Imperviousness

To determine impervious area within a watershed or within a city, the impervious areas for each land use type within the designated boundaries are calculated. This value is the product of the total area x ISC. For example:

Total low density residential (LDR) area within watershed = 1200 acres
ISC for LDR = 35
 $1200 \times .35 = 420$ acres are impervious

This process is repeated for all land use categories. The sum of these values will yield the total impervious area. The total percent imperviousness within the watershed can then be calculated by dividing the total impervious acres by the total acres.

2. Future Imperviousness

This calculation reflects the impervious area at build out. Build out refers to the condition that will exist when all land is built according to the region's **general plan**. General plans have a long-range emphasis on how development and where development will occur in a region. Although they do not reflect any given date in the future, general plans typically reflect the community's next 10 to 20 years of development. Thus the land use outlined by the general plan is the independent variable in the equation. If the general plan outlines 1200 acres of low density residential within a watershed, then the percent of imperviousness is calculated as follows:

In a 1500-acre watershed:

Total low density residential (LDR) (planned and existing use) = 1200 acres
ISC for LDR = 35
 $1200 \times .35 = 420$ acres are impervious

Total Community/ Neighborhood Retail (CRET) (planned and existing use) = 300 acres
ISC for CRET = 71
 $300 \times .71 = 213$ acres are impervious

$(420 + 213) / (1200 + 300)$

OR

$(633 / 1500) = 42\%$ build out impervious cover in a watershed

3. Current Imperviousness

At any one time, a certain percentage of the land remains vacant or less developed. For example, many times agricultural land is **zoned** for residential development but will remain under cultivation for many years before houses are built. To determine the current amount of imperviousness, the area of undeveloped parcels needs to be subtracted from the total area for each zoned land use type. By subtracting the area of undeveloped parcels within any single GLUC from the total area of the GLUC, an estimate can be made of the current developed acreage. It is this area which is multiplied by the ISC to

determine current amount of impervious cover. This adjustment, termed the *undeveloped parcel correction factor (UPC)*, can be identified in a variety of ways.

Method 1: Visual Selection

The simplest method for identifying undeveloped parcels is a visual method. Beginning with an **orthophotograph**, overlay a land use layer. Developed parcels can be visually identified, the area of each calculated and subtracted from the total area for each land use type. Finally, the corrected area is then multiplied by the ISC to determine current IC.

Method 2: Database Selection

This approach relies on obtaining data, from the appropriate local government department, that identifies vacant parcels. This information may be found in one or more of the following locations:

- The housing element in a general plan or general plan update, which contains a vacant land inventory
- County assessor's office which maintains a list of parcels on the tax roll with an improvement value of < \$10,000.

This data will permit calculation of the total area of those parcels in each land use category that are unimproved or undeveloped. The UPC is subtracted from the total area of each GLUC prior to multiplying it by the ISC. The result is an estimate of current impervious cover.

In a 1500-acre watershed:

Total low density residential (LDR) (zoned use) = 1200 acres
1200 acres - 400 acres of vacant or undeveloped land (*UPC*) = 800 acres
ISC for LDR = 35
800 x .35 = 280 acres are impervious

Total Community/ Neighborhood Retail (CRET) (planned and existing use) = 300 acres
300 acres - 200 acres of vacant or undeveloped land (*UPC*) = 100 acres
ISC for CRET = 71
100 x .71 = 71 acres are impervious

$(280 + 71) / (1200 + 300)$
OR
 $(351 / 1500) = 23\%$ Current impervious cover in a watershed

In the analysis performed in the Sacramento area, the UPC was based on data from the county assessor's office. We found this data was 98 accurate in identifying vacant parcels, based on visual inspection of the identified parcels.

Caveats: Some underlying assumptions

The following assumptions were made about the growth and land use patterns in the watershed.

- Growth patterns of unoccupied land will be developed in manner consistent with existing trends; at build out under-utilized land will persist at existing rates.
- Undeveloped or vacant land is defined as lots without structures, or having structures with an accessed value of less than \$10,000.
- Development techniques to reduce impact through either choice or use of materials (low impact development) were not considered.
- Only paved surfaces were considered impervious, impermeability due to nature soil characteristics or anthropogenic compaction was not calculated.
- The roads GLUC contained only public and right-of-way roads. All other GLUCs absorbed private roads in the calculation of the ISCs (e.g., rural residential).

Results

Table 2. BUILD OUT CONDITIONS

LAND USE TYPE	TOTAL AREA (Acres)	ISC	IMPERVIOUS SURFACE AREA
Agriculture	3.998	4	0.16
Community/Neighborhood Commercial Office	222.963	71	158.30
Community /Neighborhood Retail	643.543	80	514.83
Forest	1.276	-	0
Heavy Industrial	106.611	91	97.02
High Intensity Office	53.064	85	45.10
Low Density Residential	1,155.38	40	462.15
Light Industrial	249.585	84	209.65
Medium Density Residential	109.486	55	60.22
Medium-High Density Residential	18.59	60	11.15
Medium Intensity Office	55.035	69	37.97
Mixed Use	45.529	83	37.79
Open Space	911.989	2	18.24
Public/Quasi- Public	377.618	26	98.18
Rural Residential	8,894.29	6	533.66
Roads	1,025.31	58	594.68
Very-Low Density Residential	574.493	26	149.37
TOTALS	14,448.76		3028.47

3,028.47 / 14,448.76 = 15% Build out impervious cover in a watershed

Table 3. CURRENT CONDITIONS

LAND USE TYPE	TOTAL AREA (Acres)	UPC	ISC	IMPERVIOUS SURFACE AREA
Agriculture	3.998	0.52	4	0.139274051
Community/Neighborhood Commercial Office	222.963	79.14	71	102.1111503
Community /Neighborhood Retail	643.543	324.64	80	255.1190605
Forest	1.276	0.00	-	0
Heavy Industrial	106.611	13.25	91	84.96025863
High Intensity Office	53.064	3.44	85	42.17615762
Low Density Residential	1,155.38	279.41	40	350.3886723
Light Industrial	249.585	144.90	84	87.93448688
Medium Density Residential	109.486	16.47	55	51.15772983
Medium-High Density Residential	18.59	4.48	60	8.468196517
Medium Intensity Office	55.035	45.06	69	6.879841175
Mixed Use	45.529	4.68	83	33.905595
Open Space	911.989	339.34	2	11.45296895
Public/Quasi- Public	377.618	40.88	26	87.55243388
Rural Residential	8,894.29	1,872.02	6	421.3364299
Roads	1,025.31	43.73	58	569.3149342
Very-Low Density Residential	574.493	430.84	26	37.35100708
TOTALS	14,448.76			2150.248197

2150.248197 / 14,448.76 = 21% Current impervious cover in a watershed

Note: In the above analysis, we used a preliminary estimate of 58% imperviousness for roads. As noted above, a final set of ISC for roads are being developed.

References

- (1) Nissen, S. 2001. "A Citizen's Guide to Planning." Governor's Office of Planning and Research, Sacramento, CA.
- (2) Schuler, T. 1994. "The Importance of Imperviousness." *Watershed Protection Techniques* 1(3).
- (3) Environmental Systems Research Institute website: www.esri.com.

Glossary

General plan- A statement of policies, including text and diagrams setting forth objectives, principles, standards and plan proposals for the future physical development of the city or county. (Reference 1)

Geographic Information Systems-An integrated collection of computer software and data that people use to view and manage information about geographic places, analyze spatial relationships, and model spatial processes. A GIS provides a geographic framework for gathering and organizing spatial data and related information into layers of data that can be displayed and analyzed. (Reference 3)

Orthophotograph - A perspective aerial photograph from which distortions owing to camera tilt and ground relief have been removed. An orthophotograph has the same scale throughout and can be used as a map. (Reference 3)

Specific plan- A plan addressing land use distribution, open space availability, infrastructure, and infrastructure financing for a portion of the community. Specific plans put the provisions of the local general plan into action. (Reference 1)

Zoning- Local codes regulating the use and development of property. The zoning ordinance divides the city or county into land use districts or “zones”, represented on zoning maps, and specifies the allowable uses within each of those zones. (Reference 1)

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