HYDROLOGY MANUAL



Los Angeles County Department of Public Works
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Los Angeles County Department of Public Works

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Water Resources Division
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HYDROLOGY MANUAL

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CHAPTER

1

Introduction

1.1 PURPOSE AND SCOPE

This manual establishes the Los Angeles County Department of Public Works' hydrologic design procedures and serves as a reference and training guide. This manual contains charts, graphs, and tables necessary to conduct a hydrologic study within the County of Los Angeles. Examples provide guidance on using the hydrologic methods.

The primary purpose of this manual is to explain the steps involved in converting rainfall to runoff flow rates and volumes using Public Works' standards. This manual contains procedures and standards developed and revised by the Water Resources Division based on historic rainfall and runoff data collected within the county. The hydrologic techniques in this manual apply to the design of local storm drains, retention and detention basins, pump stations, and major channel projects. The techniques also apply to storm drain deficiency and flood hazard evaluations. Low flow hydrology methods related to water quality standards are also discussed.

This manual compiles information from previous editions of the County of Los Angeles Hydrology Manual, the 2002 Hydrology Manual Addendum, and other reference materials. The standards set forth in this manual govern all hydrology calculations done under Public Works' jurisdiction. Hydrologic procedures in manuals prepared for use by other Divisions within Public Works must be compatible with this manual.

1.2 OVERVIEW OF HYDROLOGIC METHOD

The Los Angeles County Flood Control District initiated its Comprehensive Plan in 1931. Engineers determined that the runoff data within the District was insufficient to create empirical runoff calculations due to limited stream flow data. Lack of stream flow data made it difficult to establish standards

and a hydrologic method based on runoff observations. Therefore, the engineers decided that computing design flows based on rainfall was necessary. A rainfall based hydrologic method was deemed more acceptable due to the availability of rainfall data. Figure 1.2.1 shows a rain gage used to collect rainfall data for hydrologic analysis.



Figure 1.2.1
Rain Gage #47D Located at Clear Creek School

Using rainfall-runoff relationships, methods are developed to compute flow rates and define hydrographs based on a design storm event. The two rainfall-runoff methods that apply to hydrology studies within the County of Los Angeles are the Rational and Modified Rational Methods. The use of these rainfall-runoff methods depends on the study requirements.

The Rational Method, Q = CIA, is used for simple hydrology studies within the County of Los Angeles. This method produces a peak flow rate and is only applicable to small areas. The Rational Method applies to development

of small areas when no storage volume information is required and overland flow is the primary collection method.

The primary method, in use since the 1930's, is the Modified Rational Method (MODRAT). MODRAT is based on the Rational Method, but uses a time of concentration and a design storm to determine intensities throughout the storm period. The intensities are used to determine the soil runoff coefficient. The rational formula then provides a flow rate for a specific time. Plotting the time specific flow rate provides a hydrograph and an associated flow volume. MODRAT is the standard method for hydrologic studies within the county. Computer programs implement MODRAT to compute runoff data from input parameters.

MODRAT relies on a design storm defined by a time-intensity relationship and a spatial precipitation pattern. The temporal and spatial distributions of rainfall used with MODRAT have changed over the years based on analysis of historic rainfall records. A dimensionless design storm represents rainfall events commonly observed during major extratropical storms in the Los Angeles area. The storm duration is four days. The maximum rainfall quantity occurs on the fourth day.

Rainfall isohyets show the spatial distribution of rainfall over the county. The isohyets represent the depth of rainfall for a standard design frequency over a specified period of time. Multiplying the unit hyetograph by the rainfall isohyetal depth produces the design storm for a specific area. Figure 1.2.2 shows rainfall isohyets in the County of Los Angeles. This area-specific design storm and an area-specific time of concentration define the time-intensity relationship for a particular subarea. Each subarea requires an area specific time of concentration and design storm.

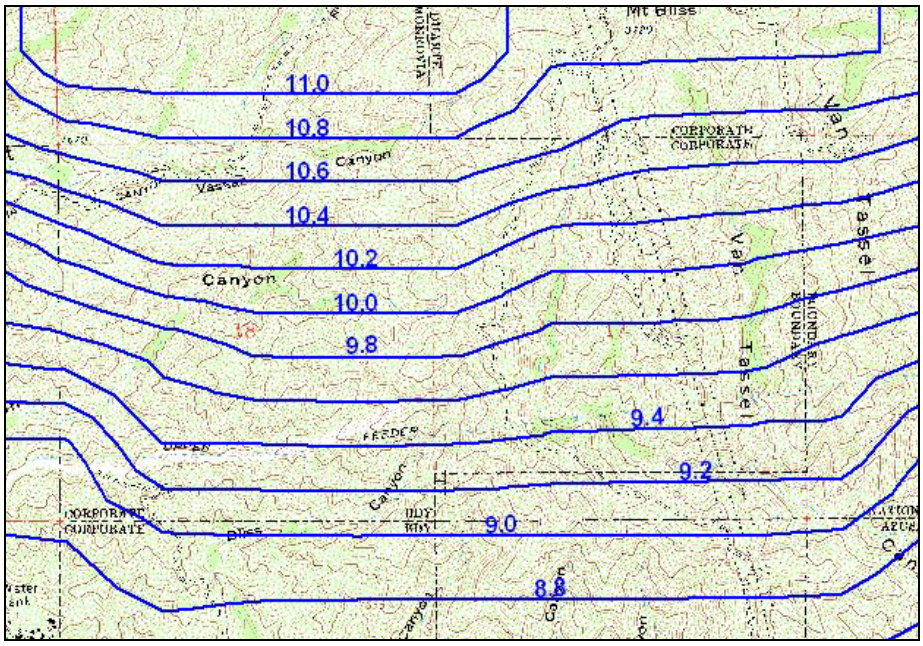


Figure 1.2.2
50-year, 24-hour Rainfall Isohyets in the County of Los Angeles

Calculation of the time of concentration has evolved over time. Currently, time of concentration calculations rely on a regression equation based on the kinematic wave theory.

Reservoir routing of hydrographs for storage uses the Modified Puls method. This method is based on a finite difference approximation of the continuity equation coupled with an empirical representation of the momentum equation.[1] This method is widely used for reservoir routing in hydrologic studies and is the approved method for use within the County of Los Angeles.

Figure 1.2.3 shows Morris Reservoir located in the San Gabriel Mountains.



Figure 1.2.3
Morris Reservoir

[1] US Army Corps of Engineers. Hydrologic Modeling System HEC-HMS Technical Reference Manual. Washington, D.C. 2002

CHAPTER

2

Physical Factors Affecting Hydrology

2.1 TOPOGRAPHY

The County of Los Angeles covers 4,083 square miles and measures approximately 66 miles from east to west and 73 miles from north to south. The topography within the county is 25 percent mountains, 10 percent coastal plain, and 65 percent foothills, valley, or desert. Elevations range from sea level to a maximum of 10,064 feet at the summit of Mount San Antonio. The county is divided into five principal drainage systems: Los Angeles River Basin, San Gabriel River Basin, Santa Clara River Basin, Coastal Basin, and Antelope Valley.

The coastal plain slopes mildly and contains relatively few depressions or natural ponding areas. The slopes of the main river systems crossing the coastal plain, such as San Gabriel River, Los Angeles River, and Ballona Creek, range from 4 to 14 feet per mile.

The mountain ranges within the County of Los Angeles are generally aligned in an east-west direction and are part of the Transverse Ranges. The major range in the county is the San Gabriel Mountains. Most of the mountainous areas lie below 5,000 feet with only 210 square miles above this elevation. The mountainous area is rugged. The deep “V”-shaped canyons with steep walls are separated by sharp dividing ridges. The average slope of the canyon floors ranges from 150 to 850 feet/mile in the San Gabriel Mountains.

2.2 GEOLOGY AND SOILS

The geologic setting of the County of Los Angeles is largely the result of the tectonic plate boundary between the North American and Pacific plates that runs along the northern edge of the county. The San Andreas Fault forms the boundary between these plates and bisects the state in a northwest to southeast direction. In the Los Angeles area, the fault bends to an east-west

orientation before returning to its former course. Crustal forces resulting from this change in geometry are uplifting the San Gabriel Mountains. The San Gabriel Mountains experience a high rate of uplift that is being counteracted by high erosion rates. As a result, the county's valleys contain deep deposits of alluvial sediments.[1]

Igneous, sedimentary, and metamorphic rock groups are present within the county. The San Gabriel Mountains and Verdugo Hills are composed primarily of highly fractured igneous rock, with large formations of granitic rock exposed above coarse and porous alluvial soils. Faulting and deep weathering have produced pervious zones in the rock formations. These rock masses have a comparatively shallow soil mantle caused by accelerated erosion on the steep slopes. Figure 2.2.1 illustrates a weathered igneous rock outcrop along Highway 39 in San Gabriel Canyon.



Figure 2.2.1
Weathered Igneous Rock Outcrop Along Highway 39 in San Gabriel Canyon

Other mountainous and hilly areas within the county are composed primarily of folded and faulted sedimentary rocks, including shale, sandstone, and

conglomerate. Residual soils in these areas are shallow and are generally less pervious than those of the San Gabriel Mountains.

Valley and desert surface soils are alluvial and grade from coarse sand and gravel near canyon mouths to silty clay and clay in the lower valleys and coastal plain. The alluvium builds up through repeated deposition of debris and reaches depths as great as 2,000 feet. Where there is little clay, this material is quite porous. Impervious lenses and irregularities divide the alluvium into several distinct groundwater basins. Valley soils are generally well drained with relatively few perched water or artesian areas.

2.3 VEGETATIVE COVER AND LAND USE

The principal vegetative cover of upper mountain areas consists of various species of brush and shrubs known as chaparral. Most trees found on mountain slopes are oak. Figure 2.3.1 shows oak trees along a stream in the San Gabriel Mountains. Pine, cedar, and juniper are found in ravines at higher elevations and along high mountain summits. Alder, willow, and sycamore are found along streambeds at lower elevations.



Figure 2.3.1
Oaks Trees Along a Stream in the San Gabriel Mountains

The chaparral is extremely flammable, and extensive burning of the mountain vegetation frequently occurs during dry, windy weather. Chaparral depends on fire to germinate and has the ability to sprout quickly after fire, reestablishing the watershed cover within a period of five to ten years. Figure 2.3.2 shows the revegetation of chaparral after a fire.



Figure 2.3.2
Revegetation of Chaparral After Fire

Grasses are the principal vegetation on the low elevation hills. Most of the hills and valleys have been converted to urban and suburban use in the portion of the county south of the San Gabriel Mountains. Development of the desert areas north of the San Gabriel Mountains and in the Santa Clarita Valley has increased in recent years and is proceeding at an accelerated rate.

2.4 CLIMATE

The climate within the county varies greatly. The windward side of the San Gabriel Mountain range is subtropical while the leeward side in the Mojave Desert is arid. Seasonal, normal precipitation totals for representative areas are shown in Table 2.4.1.

Location	Average Annual Precipitation (in)
Coastal Plain	15.5
San Gabriel Mountains	32.9
Desert – Antelope Valley	7.8

Table 2.4.1
Seasonal Normal Precipitation for Various Climate Zones

Most precipitation occurs between December and March. Precipitation during summer months is infrequent, and rainless periods of several months are common.

Snow rarely falls on the coastal plain. Snowfall at elevations above 5,000 feet frequently occurs during winter storms. This snow melts rapidly except on the higher peaks and north facing slopes.

January and July are the coldest and warmest months of the year, respectively. Table 2.4.2 illustrates the seasonal variation of temperature in the mountain and coastal plain areas.

	Los Angeles (Coastal Plain)	Mt Wilson (San Gabriel Mts)
Average January Minimum Temperature	48°	35°
Average July Maximum Temperature	84°	80°
Record High	112°	99°
Record Low	28°	9°

Table 2.4.2
Characteristic Temperatures of the Mountain and Coastal Plain Areas

2.5 HYDROMETEOROLOGIC CHARACTERISTICS

Hydrometeorological characteristics are greatly influenced by the mountains within the county. Winter storms affect the coastal areas while convective storms affect the desert areas.

Coastal and Mountain Areas

Most precipitation in the Los Angeles area occurs in the winter due to extratropical cyclones from the North Pacific. Major storms consist of one or more frontal systems, extending 500 to 1,000 miles in length. The frontal systems produce rainfall simultaneously throughout the county, occasionally lasting four days or longer.

These storms approach Southern California from the west or southwest with southerly winds that continue until the front passes. The mountain ranges lie directly across the path of the inflowing warm, moist air. The coastal and inland ranges cause the warm air to rise. As it rises, precipitation forms and falls. This orographic effect intensifies rainfall along the mountains and coastal areas. As a result, rainfall intensities and totals in these areas increase. The effect of snow melt on flood runoff is significant only in the few cases where warm spring rains from southerly storms fall on a snow pack. Temperatures throughout the county usually remain above freezing during major storms. Figure 2.5.1 is a view of the coastal area within the County of Los Angeles.



Figure 2.5.1
Coastal Area

Desert Areas

Orographic precipitation over the mountains produces a rain shadow on the leeward side of the mountains. As a result, the northern San Gabriel Mountains and the Mojave Desert regions experience primarily summer convective rainfall. The most serious floods in many desert areas may result from convective summer storms. Figure 2.5.2 shows a view of the desert area within the County of Los Angeles.



Figure 2.5.2
Desert Area Near Lancaster

2.6 RUNOFF CHARACTERISTICS

Runoff characteristics are influenced by soil type, slope, vegetation, and many other conditions. General regions behave differently based on these factors and runoff varies greatly between mountain and valley areas.

Mountain Areas

Steep canyon walls and channel slopes rapidly concentrate storm runoff in mountainous areas. Depression and detention storage effects are minor in this rugged terrain.

The moisture content of mountain soils has a pronounced effect on runoff during a storm. Precipitation during periods of low soil moisture is almost entirely absorbed by the porous soils. Soil moisture is lowest at the beginning of the rainy season due to evapotranspiration during the preceding summer months. Significant surface runoff does not occur until soil moisture is near field capacity, except during extremely intense rainfall. Consequently, in certain areas, significant runoff occurs as subsurface flow, or interflow, rather than direct runoff. Most streams in the county are intermittent. Natural year-round perennial discharge is mostly limited to springs in portions of the San Gabriel Mountains.

Hill and Valley Areas

Runoff concentrates rapidly below the generally steep slopes in hilly areas. Runoff rates from undeveloped hilly areas are normally smaller than those from mountain areas of the same size. Development in hilly areas decreases runoff concentration times considerably due to increased channelization. Runoff volumes and rates increase due to increased imperviousness.

Debris production from undeveloped hilly areas is normally less than debris production from mountainous areas of the same size. Increased development reduces erosion and limits debris in storm flow.

Figure 2.6.1 shows a hilly area located in the Santa Clara River Watershed.



Figure 2.6.1
Hills in Santa Clara River Watershed

Runoff in the valleys and coastal plain is affected by ponding and spreading of flows. Valley areas are affected by development. In highly developed valley areas, local runoff volumes increase as impervious materials replace the soil. Peak runoff rates for valley areas increase due to the elimination of natural ponding areas and improved hydraulic efficiency. Conveyances, such as streets and storm drain systems carry the water to the ocean more rapidly and do not allow infiltration. Figure 2.6.2 shows a view of the Los Angeles basin from the San Gabriel Mountains.



Figure 2.6.2
Los Angeles Basin from the San Gabriel Mountains

[1] *San Gabriel River Corridor Master Plan, March 2004.*

CHAPTER

3

Major Watersheds and Tributaries

There are five major watersheds within the County of Los Angeles. Four of these drain to the ocean and the fifth enters dry lakes in the desert. The watersheds are unique and are developed to different extents. Watershed descriptions and a location map shown in Figure 3.1 are provided to help understand the hydrologic conditions within each watershed.



Figure 3.1
Major Watersheds in the County of Los Angeles

3.1 LOS ANGELES RIVER[1]

The Los Angeles River Watershed covers over 830 square miles. The watershed includes the western portion of the San Gabriel Mountains, the Santa Susana Mountains, the Verdugo Hills, and the northern slope of the Santa Monica Mountains. The river flows from the headwaters in the western San Fernando Valley and outlets in San Pedro Bay near Long Beach. The river crosses the San Fernando Valley and the central portion of the Los Angeles Basin. The watershed terrain consists of mountains, foothills, valleys, and the coastal plain.

The Los Angeles River and many of its tributaries have been the subject of extensive engineering work to reduce the impacts of flood events. Prior to development, the Los Angeles River system was typical of other streams in the southwest. The river's channel was broad and often shifted location within the flood plain due to the high sediment loads. The stream location within the coastal plain has varied greatly over the years. Between 1815 and 1825, the river changed course completely. Breaking its banks in what is now Downtown Los Angeles, the river followed the course of Ballona Creek, reaching the ocean at a location 20 miles from its current outlet.

Numerous flood control facilities were constructed in the early 20th century, as development began to take place on this wide flood plain. The concrete sections of the Los Angeles River were constructed between the late 1930's and the 1950's. Channel improvements and extensive watershed development decrease times of concentration and increase runoff flow rates and volumes. The Los Angeles County Flood Control district constructed three major dams during this period: Pacoima, Big Tujunga and Devil's Gate. The dams were built to reduce downstream flow rates and conserve water for ground water recharge purposes. In the Rio Hondo drainage area, several dams were constructed including Eaton Wash, Sierra Madre, Santa Anita and Sawpit. Additionally, the U.S. Army Corps of Engineers operates four major dams in the watershed to assist in flood control. The four dams are Hansen, Lopez, Sepulveda and Whittier Narrows. Figure 3.1.1 is a view of Big Tujunga Dam after the January 2005 storms.



Figure 3.1.1
Big Tujunga Dam
January 11, 2005

The parts of the San Gabriel Mountains tributary to the Los Angeles River contain some of the most prolific sediment producing streams in the world. Intense rainfall, coupled with highly erodible sediment, produces damaging debris discharges. Numerous debris basins have been constructed along the foothills of the San Gabriel Mountains to remove sediment from the flow.

The Los Angeles River Watershed has a diverse land use pattern. The upper portions of the watershed are covered by Angeles National Forest and other rural areas. The remainder of the watershed is highly developed. The watershed has large areas of commercial, residential, and industrial development. Few parks or natural areas exist in the lower watershed.

The major tributaries of the Los Angeles River include Burbank Western Channel, Pacoima Wash, Tujunga Wash, and Verdugo Wash in the San Fernando Valley; and the Arroyo Seco, Compton Creek, and Rio Hondo in the Los Angeles Basin. Much of this tributary network has also been lined with concrete to meet flood control needs. Figure 3.1.2 shows a view of the Los Angeles River at Willow Street.



Figure 3.1.2
Los Angeles River
At Willow Street

3.2 SAN GABRIEL RIVER

The San Gabriel River Watershed is located in the eastern portion of the county. The river drains the San Gabriel Mountains to the north and is bounded by the Los Angeles River Watershed and Santa Ana River Watersheds. The watershed drains 640 square miles. The watershed outlets into the Pacific Ocean between Long Beach and Seal Beach after passing through the Alamitos Bay estuary. Tributaries to the San Gabriel River include: Walnut Creek, San Jose Creek, and Coyote Creek.

The upper portions of the watershed are contained almost entirely within the Angeles National Forest and are nearly untouched by development. The mountains in this area are extremely rugged with steep V-shaped canyons. The vegetation is dominated by chaparral and coastal sage scrub with patches of oak woodlands. Conifers are dominant at higher elevations. The streambeds in the area contain sycamore and alder woodlands.[2]

In contrast, the lower part of the watershed is mostly developed below the mouth of the San Gabriel Canyon. The developments include commercial, residential, and industrial use. The developed area in the San Gabriel Valley and Los Angeles Basin comprises 26% of the total watershed area. Figure 3.2.1 shows the upper natural portion of the San Gabriel River.

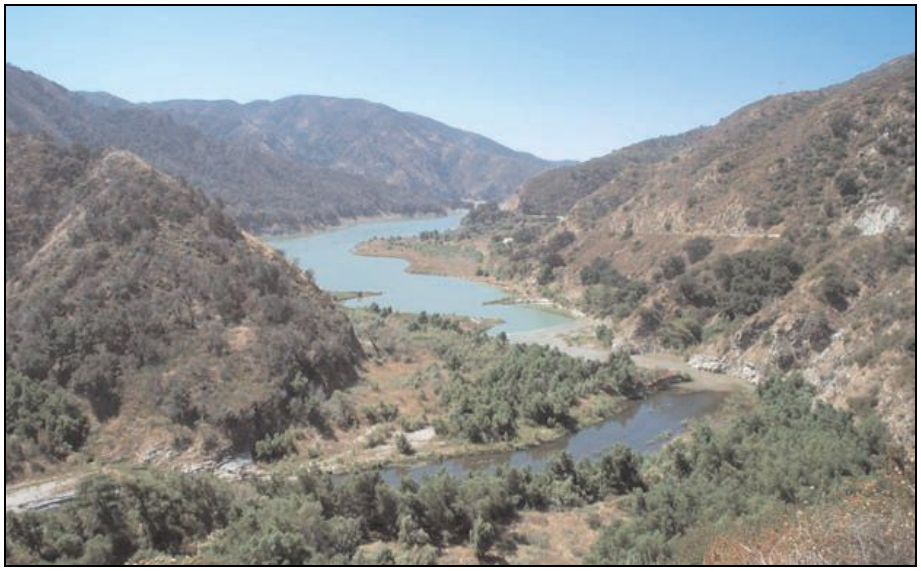


Figure 3.2.1
Upper Portion of the San Gabriel River

Similar to the Los Angeles River, the San Gabriel River once occupied a wide floodplain and shifted course to accommodate large flows and sediment loads. Development of the floodplain required changing the character of the river dramatically since periodic inundation of the floodplain was not compatible with the new land uses.

Several major dams and debris basins impound floodwaters and prevent debris flows originating in the San Gabriel Mountains. These include Cogswell Dam, San Gabriel Dam, Morris Dam, Big Dalton Dam, San Dimas Dam, Live Oak Dam, and Thompson Creek Dam. Many of these facilities were constructed in the 1930's and have proven their worth by preventing significant damage from large flood events. Major flood events occurred in 1938, 1969, 1978, 1983, 1998, and 2005. Additionally, the U.S. Army Corps of Engineers operates the Santa Fe Dam and Whittier Narrows Dam in the watershed to assist in flood control. Figure 3.2.2 shows the San Gabriel Dam at full capacity.



Figure 3.2.2
San Gabriel Dam at Full Capacity

The San Gabriel River has been channelized below Santa Fe Dam to aid in flood prevention. However, the channel invert was left unlined for much of its length between Santa Fe Dam and Florence Avenue in Downey. The unlined bottom promotes infiltration of flood waters released from upstream dams. Public Works installed rubber dams to further utilize the river bottom for ground water recharge. Figure 3.2.3 is a rubber dam located in the lower portion of the river.



Figure 3.2.3
Rubber Dam Located in the Lower Portion of the San Gabriel River

The most significant spreading ground facilities in the county are located in the San Gabriel River watershed. Runoff resulting from storm events is diverted into the spreading facilities and allowed to recharge groundwater. Major spreading grounds are located at the mouth of San Gabriel Canyon and in the Montebello area downstream of the Whittier Narrows Dam.

3.3 SANTA CLARA RIVER

The Santa Clara River originates in the northern slopes of the San Gabriel Mountains at Pacifico Mountain and travels west into Ventura County, discharging into the Pacific Ocean near the City of Ventura. The river runs approximately 100 miles from the headwaters near Acton, California, to the ocean. The river drains an area of approximately 1,600 square miles.

The upper portion of the river, within the County of Los Angeles, has a watershed area of approximately 644 square miles. Ninety percent of this area is mountainous with steep canyons; while the remaining ten percent is alluvial valleys.[3] The area is mostly undeveloped with a large portion in the Angeles National Forest. There are some mixed-use developed areas concentrated in or near the City of Santa Clarita. The watershed is currently experiencing an accelerated rate of development in areas adjacent to the river. Figure 3.3.1 shows the Santa Clara River after the 1978 storms.



Figure 3.3.1
Santa Clara River
Downstream of Magic
Mountain Parkway
March 4, 1978

The Santa Clara River and its tributaries are ephemeral streams characterized by alluvial soils. Discharge occurs quickly during rainfall events and diminishes quickly after rainfall has ceased. As in other county watersheds, the mountain and foothill areas are susceptible to debris-laden flows during intense rainfall, especially when a watershed is recovering from fire.[4]

The river remains in a generally natural state with some modifications related to the development of the floodplain. The expected population increase will continue to produce floodplain encroachment, requiring additional bank protection, channelization, and channel crossings. The expected population increase, as well as increased imperviousness, will impact the hydrologic characteristics of the river and the sediment balance.

Some of the major tributaries in the county's portion of the Santa Clara River watershed include: Castaic Creek, San Francisquito Canyon, Bouquet Canyon, Sand Canyon, Mint Canyon, and the South Fork of the Santa Clara River.

3.4 COASTAL[5]

The Coastal watershed is comprised of a number of individual watersheds that outlet into Santa Monica and San Pedro Bays. These include the major watersheds of Malibu Creek, Topanga Creek, Ballona Creek, and the Dominguez Channel. These watersheds have unique topographic and hydrologic characteristics ranging from undeveloped to highly urbanized. For simplicity, these coastal watersheds are grouped together due to their relatively small sizes.

The Malibu Creek Watershed is comprised of 109 square miles at the western end of the County of Los Angeles and extends into Ventura County. Most of the watershed is undeveloped public land. There is sporadic but increasing development throughout the area. The most extensive development is centered along US Highway 101. The northern portion is hilly while the southern portion, near the ocean, is rugged mountain terrain. Malibu Creek drains into the Pacific Ocean near the Malibu Civic Center. A portion of Malibu Creek is shown in Figure 3.4.1.



Figure 3.4.1
Malibu Creek

Topanga Creek drains 18 square miles in the central Santa Monica Mountains. The watershed is primarily rural with widely scattered residential and commercial development. The creek flows unobstructed along its course and empties into the Santa Monica Bay in an unincorporated portion of the county east of Malibu.

Ballona Creek is a flood control channel that drains the western Los Angeles basin. The watershed area is bounded by the Santa Monica Mountains on the north and the Baldwin Hills on the south. It extends east nearly to downtown Los Angeles. The total watershed area is roughly 130 square miles. The area is primarily developed but includes undeveloped areas on the south slope of the Santa Monica Mountains. The land use is 64%

residential, 8% commercial, 4% industrial, and 17% open space. The major tributaries to Ballona Creek include: Centinela Creek, Sepulveda Canyon Channel, Benedict Canyon Channel, and numerous storm drains. The watershed drains into Santa Monica Bay at Marina del Rey.

Figure 3.4.2 is a view of the concrete lined portion of Ballona Creek.



Figure 3.4.2
Ballona Creek

The Dominguez Watershed is comprised of approximately 133 square miles in the southern portion of the county. The watershed extends from near the Los Angeles International Airport to the Los Angeles Harbor. The area is almost completely developed with regions of residential, commercial, and industrial land use. The storm drains and flood control channel network, as opposed to natural drainage features, define the watershed.

There are many other smaller watersheds in the Coastal drainage area that drain developed and undeveloped areas directly to the Pacific Ocean.

3.5 ANTELOPE VALLEY

The Antelope Valley encompasses approximately 1,200 square miles in the northern portion of the County of Los Angeles. The valley is bounded on the north by the Tehachapi Mountains and on the south by the Sierra Pelona and the San Gabriel Mountains. Numerous streams from the mountains and foothills flow across the valley floor. The valley lacks defined drainage channels outside of the foothills and is subject to unpredictable drainage patterns.

Nearly all the surface water runoff from the Los Angeles portion of the Antelope Valley accumulates on Rosamond Dry Lake near the Kern County Line. A small portion is tributary to other dry lakes in the area. This 20 square mile playa is dry during most of the year, but is likely to be flooded during prolonged periods of winter precipitation. Surface runoff, as well as discharges from groundwater, remain on the dry lake until removed by infiltration and evaporation. Anecdotal evidence indicates that at times the playa may be underwater for up to five months at a time, as occurred during the winter of 1965-66.

The valley contains the developed areas of Lancaster and Palmdale. The remainder of the valley is sparsely developed. However, the valley is one of the most rapidly developing areas in the county. Rapid development is likely to continue for some time. This development will significantly alter the hydrologic characteristics of the basin.

A view of Antelope Valley is shown in Figure 3.5.1.



Figure 3.5.1
Antelope Valley

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1 *The Los Angeles River Master Plan.* "Flood Management and Water Conservation". Los Angeles County Department of Public Works. Approved June 13, 1996.

2 *San Gabriel River Corridor Master Plan,* March 2004, pages 2-4.

3 "Hydrologic Model of the Santa Clara River and its Tributaries". David Ford Consulting. December 1999.

4 "Hydrologic Model of the Santa Clara River and its Tributaries". David Ford Consulting. December 1999.

5 See North Santa Monica Bay Watersheds White Paper, November 6, 2003; Dominguez Watershed Management Master Plan, April 2004

6 Dettling, C., R.H. French, J.J. Miller, and J. Carr (2004). An Approach to Estimating the Frequency of Playa Lake Flooding.

CHAPTER

4

Policy on Levels of Protection

4.1 DEPARTMENT POLICY MEMORANDUM

A Department of Public Works memorandum dated March 31, 1986, General Files No. 2-15.321, established the policy on levels of flood protection. This policy describes degrees of flooding and which design storms should be used for certain conditions and structures. Chapter 5 defines the design storms for use in the County of Los Angeles.

4.2 CAPITAL FLOOD PROTECTION

The Capital Flood is the runoff produced by a 50-year frequency design storm falling on a saturated watershed (soil moisture at field capacity). A 50-year frequency design storm has a probability of 1/50 of being equaled or exceeded in any year. Capital Flood protection also requires adding the effects of fires and erosion under certain conditions. This section describes specific criteria for applying the burning and bulking requirements for Capital Flood protection.

The following sections describe facilities and structures required to meet the Capital Flood level of protection.

Natural Watercourses

The Capital Flood level of protection applies to all facilities, including open channels, closed conduits, bridges, dams, and debris basins not under State of California jurisdiction. These facilities must also be constructed in or intercept flood waters from natural watercourses. Facilities under the State of California jurisdiction must also meet the state's criteria, which may include the Probable Maximum Flood criteria described in Section 4.4.

A natural watercourse is a path along which water flows due to natural topographic features. For definition purposes, a natural watercourse drains a watershed greater than 100 acres. Natural watercourses have not been subject to major engineering works such as channel realignment or bank protection. The watercourse must also meet one or more of the following conditions during a Capital Flood:

1. Flow velocities greater than 5 ft/sec.

2. Flow depths greater than 1.5 feet.

Replacement of the natural watercourse with flood control facilities that do not provide the Capital Flood level of protection requires water surface elevation analysis. The water surface elevation must be at least one foot below the base of existing dwellings adjacent to the channel. The construction must also meet the requirement of the National Flood Insurance Program described in Section 4.6. An example of a natural watercourse in Bouquet Canyon is shown in Figure 4.2.1.



Figure 4.2.1
Bouquet Canyon
Natural Watercourse
in June 2005

Floodways

The Capital Flood applies to all areas mapped as floodways. See Section 4.6 for more information on floodways.

Natural Depressions or Sumps

The Capital Flood level of protection applies to all facilities constructed to drain natural depressions or sumps. These facilities include channels, closed conduits, retention basins, detention basins, pump stations, and highway underpasses. A depression or sump is an area from which there is no surface flow outlet and must meet one or more of the following conditions during a Capital Flood:

1. Ponded depth of 3 feet or greater.

2. Ponded water surface elevations within one foot below the base of adjacent dwellings resulting from construction of facilities with less than the Capital Flood capacity. This condition does not apply if ponded water can escape as surface flow before reaching the base of adjacent dwellings during the Capital Flood.

Figure 4.2.2 shows an example of a flooded sump at the intersection of San Fernando Road and Tuxford Street in Sun Valley.



Figure 4.2.2
Flooded Sump at Intersection of San Fernando Road and Tuxford Street
January 9, 2005

Sumps with drainage from roadways require special care. If flows reach the sump by following the roadway from upstream, use the Capital Flood on all areas upstream of the sump that drain to the roadway. The roadway must carry the Capital Flood capacity with a water surface elevation below the private property line. Otherwise, drainage facilities must be added beneath the roadway. See the Los Angeles County Highway Design Manual[1], and Chapter 44 of the Land Development Division Guidelines.

Culverts

The Capital Flood level of protection applies to all culverts under major and secondary highways.

Tributary Areas Subject to Burning

Canyons and mountainous areas within the County of Los Angeles are subject to burning. The Capital Flood applies to all areas likely to remain in a natural state, regardless of size. Burned canyons and mountainous areas also add debris to the runoff. Therefore, flow from "burned" areas must be "bulked." Bulking reflects increases in runoff volumes and peak flows related to inclusion and transport of sediment and debris.

Section 6.3 discusses the development of burned watershed hydrology. Section 3.3 of the Public Works' Sedimentation Manual contains information on bulking flows.

4.3 URBAN FLOOD PROTECTION

All drainage facilities in developed areas not covered under the Capital Flood protection conditions must meet the Urban Flood level of protection. The Urban Flood is runoff from a 25-year frequency design storm falling on a saturated watershed. A 25-year frequency design storm has a probability of 1/25 of being equaled or exceeded in any year.

Street flow due to the urban flood may not exceed the private property line elevation. However, runoff can be conveyed in drains under the street and on the street surface. Urban Flood runoff is allowed to flow in the street to the point where the flow reaches the street capacity at the property line. Depth analysis is to be started at the upstream end of the watershed. The flow should be split to allow conveyance in the street and in a drain below the street when flows exceed street capacity. Drains must at least carry flow

from the 10-year frequency design storm. See the Los Angeles County Highway Design Manual[1] and Chapter 44 of the Land Development Division Guidelines for road design requirements.

The street or highway must carry the balance of the 25-year frequency design storm below the property line. The drain may carry more flow to lower the water surface on the street to below the private property line or meet other requirements for vehicular or pedestrian traffic. See the Los Angeles County Highway Design Manual for the traffic requirements[1]. The maximum allowable pipe diameter for hydrology studies is 96 inches. Beyond this size, choose a rectangular channel conveyance. Figure 4.3.1 provides an example of street flow.



Figure 4.3.1
Street Flow After 1938 Storm

4.4 PROBABLE MAXIMUM FLOOD PROTECTION

The Probable Maximum Flood (PMF) results from the most severe combination of critical meteorological and hydrologic conditions that are reasonably possible in the region[2]. The Probable Maximum Precipitation[3] (PMP) represents the greatest depth of rainfall theoretically possible for a

given duration over a given drainage basin. The PMF occurs when the PMP falls over watersheds that have reached field capacity (saturated) conditions.

California's Division of Safety of Dams (DSOD) requires a PMF analysis for dams and debris basins that hold at least 1,000 acre-feet, are 50 feet or higher, would require at least 1,000 people to be evacuated, and have a damage potential of $25,000,000 or more. Most dams and debris basins (earth embankment, concrete, or other materials) in the County of Los Angeles must safely pass the PMF[4]. Figure 4.4.1 shows a chart of the State's height and storage parameters that define dam jurisdiction[5]:

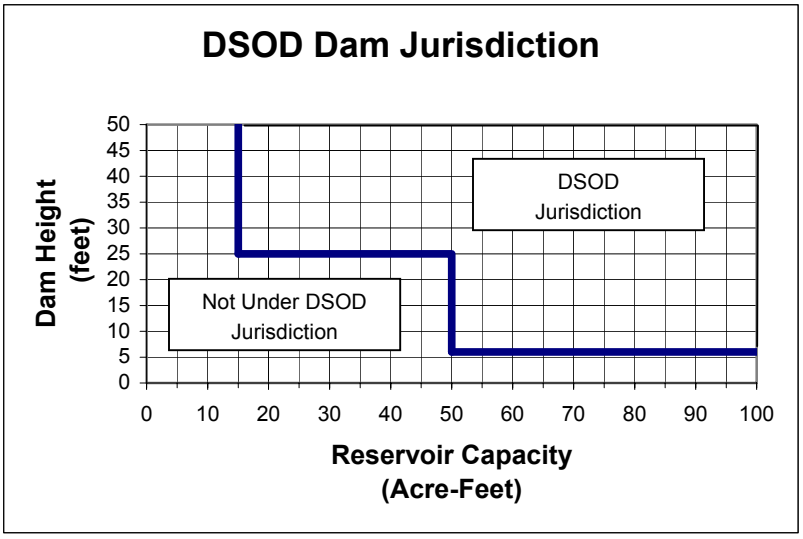


Figure 4.4.1
Dam Jurisdiction Chart

Spillway sizing requirements for dams and debris basins is available through the California Department of Water Resources, Division of Safety of Dams[4]. Figure 4.4.2 is a picture of Morris Dam, constructed in 1932, which falls under DSOD jurisdiction.

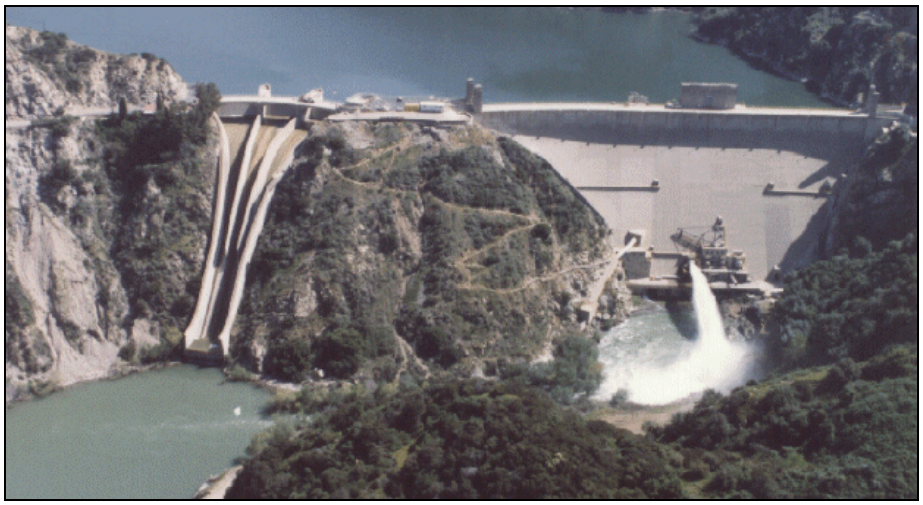


Figure 4.4.2
Morris Dam
1993

4.5 NATIONAL FLOOD INSURANCE PROGRAM

The National Flood Insurance Program (NFIP) set the 100-year flood as the standard for flood insurance protection. The 100-year flood relies on historic runoff records for definition. The standard makes no allowance for future urbanization or the possible inclusion of debris in the flow. In flood hazard areas, the federal standard requires the finished floor elevation of proposed dwellings to be at least 1 foot above the water surface elevation of the 100-year flood[5]. The Base Flood Elevation (BFE) refers to the water surface elevation of the 100-year flood on the pre-developed condition.

Public Works uses the Capital Flood peak flow rate for Los Angeles County floodway mapping standards. FEMA Flood Insurance Rate Maps (FIRM Maps) are available at: http://www.ladpw.org/apps/wmd/floodzone. More information about the NFIP level of protection requirements are available at the www.fema.gov/nfip/ website.

The floodway is determined using the 1-foot rise criterion. Some misinterpret this to mean that development in a floodway is permitted if it does not raise the BFE more than one foot. Floodplain management regulations dictate that any rise in the BFE, as a result of a floodway encroachment, is unacceptable without a Conditional Letter of Map Revision[6]. FEMA provides guidelines and standards for flood hazard mapping and requirements to meet the NFIP level of protection. More information on the FEMA requirements is found at http://www.fema.com/fhm/gs_main.shtm.

4.6 COMPATIBILITY WITH EXISTING SYSTEMS

The level of protection standards may require modification if the receiving system has limited capacity at the proposed drain's outlet. If the receiving drain will be replaced or relieved in the future, size the proposed drain for the appropriate level of protection. The proposed drain capacity is restricted to match the capacity available in the downstream drain when no future relief is planned.

Solutions to the situations with restricted capacities require project specific decisions. The Design Division of Public Works should review the proposed drainage system and the outlet conditions to determine the compatible level of protection.

4.7 EXISTING LEVEL OF FLOOD PROTECTION

Sub-surface drainage often replaces surface drainage when land is developed. Replacing or modifying surface drainage systems requires maintaining or increasing the original level of flood protection. The total capacity, sub-surface and surface, must equal or exceed the original surface capacity. Adequate surface drainage capacity must be retained if the proposed sub-surface drain provides a lower level of protection than the original surface drainage system.

4.8 MULTIPLE LEVELS OF FLOOD PROTECTION

There are numerous instances where a drainage system must provide more than a single level of flood protection. Drainage systems must meet the criteria described in this chapter of the Hydrology Manual.

For example, there may be a natural canyon area tributary to a proposed drainage system that drains an urban area containing a sump. The proposed drainage system must convey the burned and bulked Capital Flood flow from the canyon area, protect the sump from a Capital Flood, and protect the developed area from the Urban Flood. Refer to Table 4.1.1 of the Sedimentation Manual to determine if a structure, such as a debris basin, is needed for the natural canyon. If a structure is needed, then only the burned flow is carried through the drainage system.

Figure 4.8.1 is an example of a debris basin.



Figure 4.8.1
Sawpit Debris Basin
January 11, 2005
(Courtesy of Leopoldo A. Herrera)

1 Los Angeles County Highway Design Manual 5th edition. 2001.

2 US Army Corps of Engineers. Flood-Runoff Analysis (EM 1110-2-1417). page 13-7. Washington, D.C. 1994.

3 US Department of Commerce, National Oceanic and Atmospheric Administration, US Army Corps of Engineers. Hydrometeorological Report Number 59. Probable Maximum Precipitation for California. 1999.

4 Calzascia and Fitzpatric. Hydrologic Analysis Within California's Dam Safety Program. California Department of Water Resources, Division of Safety of Dams. http://wwwdsod.water.ca.gov/tech-ref/fitz-paper.pdf

5 National Flood Insurance Program Flood Insurance Manual. Federal Emergency Management Agency. October 2004.

6 Dyhouse, G., J. Hatchett, J. Benn. Floodplain Modeling Using HEC-RAS. Haestad Methods. Connecticut. 2003.

CHAPTER

5

Rainfall and Design Storm Characteristics

The Department of Public Works' hydrologic method uses a design storm derived from historic rainfall data. Observed major extratropical storms in the Los Angeles region provided a pattern for the design storm. The storm does not represent an actual event but is an idealized series of precipitation data that fits a specific design objective. The design storm is a composite determined by analysis of regional rainfall patterns. Three components define the design storm: an Intensity-Duration-Frequency (IDF) equation, a temporal distribution, and a spatial rainfall distribution.

Public Works developed the rainfall distribution and design storms in 2002. A network of approximately 250 rain gages allowed an accurate definition of the spatial and temporal variability of rainfall over the county. The average historic record length for these gages is 75 years.

Data analysis provided the three components needed for the design storm. Analysis of rainfall data within the county provided the IDF equation, which is a relationship between rainfall intensity, duration, and frequency. Then a 24-hour temporal distribution was established using the IDF relationship. The 24-hour temporal distribution is represented by the unit hyetograph, which plots rainfall intensity versus time. Finally, a set of isohyets was established for the county. The isohyets represent rainfall depths for a specific duration and frequency and are applied to the unit hyetograph. The result is a hyetograph for a given location and recurrence interval, which is the design storm for a specific subarea.

5.1 RAINFALL INTENSITY-DURATION-FREQUENCY

The fundamental unit of rainfall is depth. Rain gages directly measure depth. Measuring depth and time provides intensity. Intensity is the amount of rain that has fallen per unit of time. The average intensity is calculated by dividing a rainfall depth by the duration, the time over which the rainfall accumulated. The average intensity is:

Equation 5.1.1

$$\text{Intensity} = \frac{\text{Rain Depth}}{\text{Duration}}$$

The peak intensity produces the largest runoff rate. If rainfall were constant throughout a storm, any duration less than the storm duration would produce the same intensity. However, rainfall is rarely constant for the storm duration and intensity varies.

Table 5.1.1 shows the calculated intensity for various durations. Intensities are calculated using the rainfall depth and storm times in the first two rows. Each of the duration rows show intensities calculated based on different durations. For example, I_5 is the intensity calculated over a period of 5 minutes starting at t = 0 and ending at t = 5 minutes, or starting at t = 5 and ending at t = 10 minutes, etc. Bold text denotes the maximum intensity for each intensity duration. The table shows a decrease of maximum intensity as duration increases for a storm with non-uniform precipitation.

Table 5.1.1
Rainfall Intensity Calculations for Various Durations

	Storm Time (minutes)	0	5	10	15	20	25	30	35	40	45	50	55	60
	Cumulative Precipitation (in)	0	0.5	1.5	2.0	2.25	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
Durations	I_5 (in/hr)	-	6.0	12.0	6.0	3.0	3.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	I_{10} (in/hr)	-	-	9.0	9.0	4.5	3.0	1.5	0.0	0.0	0.0	0.0	0.0	0.0
	I_{30} (in/hr)	-	-	-	-	-	-	5.0	4.0	2.0	1.0	0.5	0.0	0.0
	I_{60} (in/hr)	-	-	-	-	-	-	-	-	-	-	-	-	2.5

Design decisions often require assigning a probability of occurrence to the rainfall event. Statistical analysis of rainfall intensity data yields a probability that such a rainfall will occur in a given year. The reciprocal of this probability is the frequency. The frequency represents the time between two occurrences of a specific rainfall event. The rainfall frequency is inversely proportional to the size of the event. Large rainfall events are much less common than small rainfall events.[1]

A study of rain gage data provided relationships between intensity, duration, and frequency within the County of Los Angeles. The study analyzed historic records for 107 rain gages and determined the maximum intensities for rainfall durations of 5, 10, 15, 30, 60, 120, 180, 240, 300, 720, and 1440 minutes. The analysis looked at the frequencies associated with the various intensities. Each intensity was assigned frequencies of 2-, 5-, 10-, 25-, 50-, 100-, and 500-years based on the Gumbel extreme value distribution of each gage.

The 1440 minute, or 24-hour duration, was a primary focus of this analysis. Sets of factors were developed to relate the rainfall depths of various frequencies to the 50-year rainfall frequency. Section 5.3 details the development of these factors.

The normalized intensity equation relates the intensity, duration, and frequency (IDF). The Hydrologic Method authorization memorandum outlines development of the equation.[2] Equation 5.1.2 provides the normalized IDF relationship:

$$\frac{I_t}{I_{1440}} = \left(\frac{1440}{t}\right)^{0.47} \qquad \textbf{Equation 5.1.2}$$

Where:
- t = Duration in minutes
- I_t = Rainfall intensity for the duration in in/hr
- I_{1440} = 24-hour rainfall intensity in in/hr
- $\frac{I_t}{I_{1440}}$ = Peak normalized intensity, dimensionless

Equation 5.1.2 allows calculation of the peak-normalized intensity for durations from 5 to 1440 minutes. For durations less than 5 minutes, $I_t / I_{1440} = 14.32$. Figure 5.1.1 graphically presents the peak-normalized intensity for durations of 5 minutes to 30 minutes.

In addition to its role in defining the design storm, Equation 5.1.2 is used to calculate the peak intensity for time of concentration calculations described in Section 7.3. The equation calculates the intensity for any duration when the 24-hour rainfall intensity is known. Section 5.4 contains an example that illustrates the use of Equation 5.1.2 and Table 5.1.1 to determine the 25-year, 10-minute intensity from the 50-year, 24-hour rainfall isohyetal data.

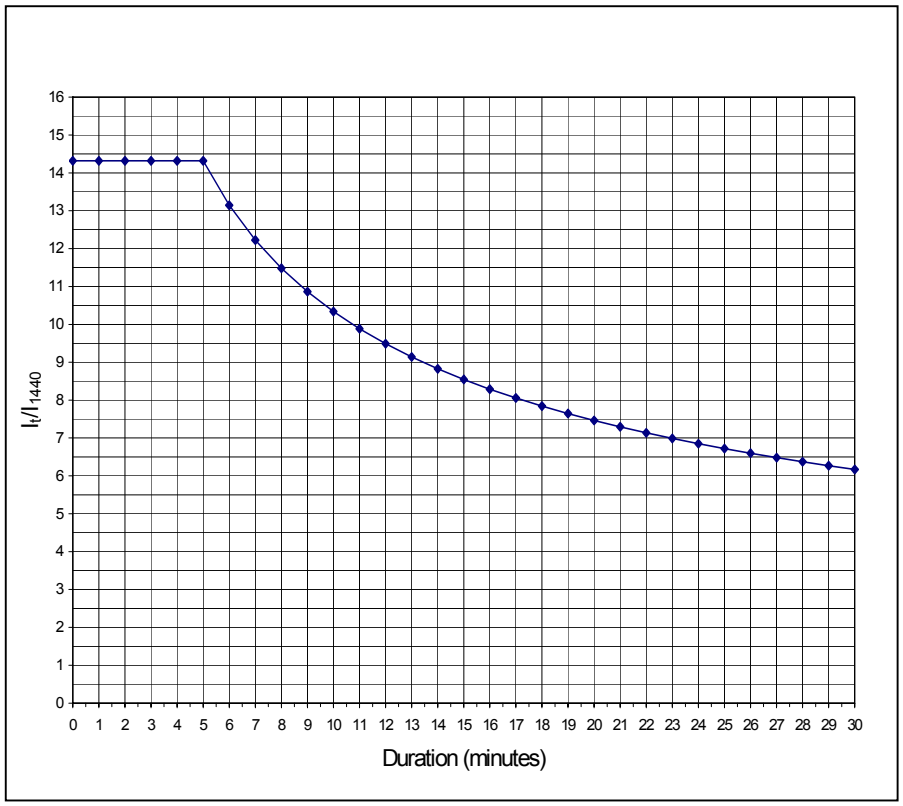


Figure 5.1.1
Normalized Intensity Curve

5.2 UNIT HYETOGRAPH

The definition of a design storm requires a description of how rainfall occurs over time. Public Works' design storm uses a 24-hour cumulative unit hyetograph to describe the temporal distribution of precipitation. The unit hyetograph provides the temporal distribution of one inch of rainfall occurring over a 24-hour period. Figure 5.2.1 shows an example of a cumulative hyetograph and its accompanying incremental hyetograph.

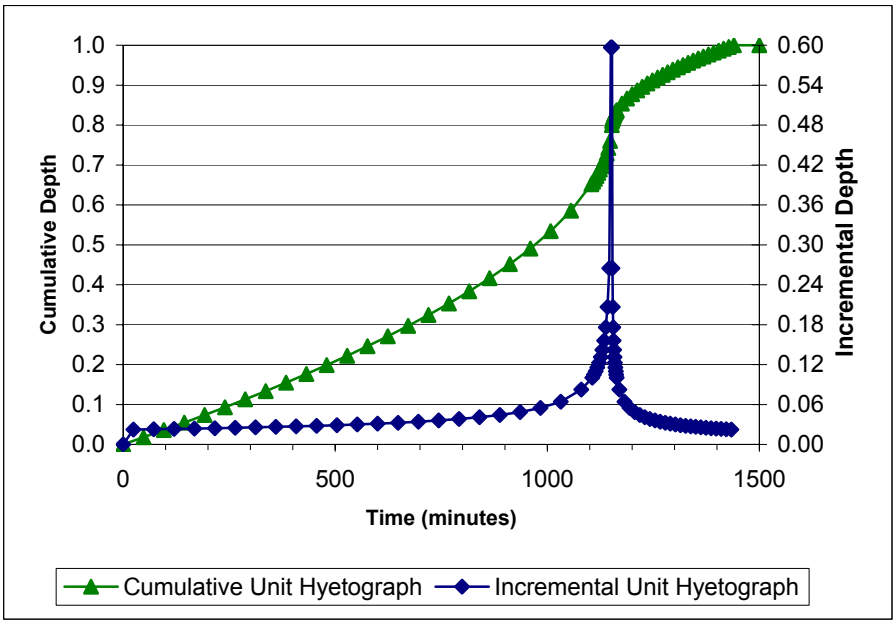


Figure 5.2.1
Relationship Between Cumulative and Incremental Unit Hyetographs

The unit hyetograph is scaled to match design rainfall depths. Design storm rainfall depths are determined from isohyets based on hydrologic design standards. Construction of the hyetograph used the normalized intensity equation solutions with an assumption about where the inflection point of the cumulative hyetograph occurs.

Development of the rainfall hyetograph used a modified alternating block method. See *Applied Hydrology* for a description and example of the alternating block method.[3] Modifications resulted from the use of the normalized intensity curve, instead of a traditional IDF curve, and the regionally specific location of the inflection point. This process produces an

incremental unit rainfall distribution for a 24-hour period. The cumulative distribution is developed by summing the incremental distribution at each time step.

Developing the unit hyetograph using the IDF equation required an assumption about the timing of the most intense rainfall. The inflection point of the cumulative unit hyetograph represents the highest intensity. An analysis of the hourly distribution of large historical 24-hour events showed rainfall intensities increasing during the first 70 to 90 percent of the period and decreasing for the remaining time. Approximately 80 percent of the total 24-hour rainfall occurs within the same 70 to 90 percent of the period.

The unit hyetograph assumes the rainfall inflection point occurs when 80 percent of the 24-hour rainfall total has fallen and 80 percent of the 24-hour period has elapsed. Ratios of the depth at a given time relative to the total 24-hour depth were derived from the intensity equation. These ratios were then used to define the unit hyetograph curve. The depth ratios shown in Figure 5.2.1 were calculated at 5-minute time steps from 5 to 60 minutes and 60-minute time steps between 60 and 1440 minutes.

The rainfall depth ratios for each intensity were placed on either side of the inflection point. The alternating blocks were placed around the inflection point. However, instead of alternating the blocks on either side with decreasing intensity, the depth ratios for each time step were split with 20 percent of depth for each time step after the inflection point and 80 percent before the inflection point. The distribution of the time steps was similarly divided using 80 percent before the time of inflection and 20 percent after. Table 5.2.1 illustrates the first few intervals in this process:

Table 5.2.1
Rainfall Distribution Around Hyetograph Inflection Point

t	(D_t/D_{1440})	t*20%	$0.8+(D_t/D_{1440})*20\%$	t*80%	$0.8-(D_t/D_{1440})*80\%$
5	0.0497	1	0.8099	4	0.7602
10	0.0717	2	0.8143	8	0.7425
15	0.0890	3	0.8178	12	0.7287

With the inflection point at 80 percent of the time (1152 minutes) and 80 percent of the rainfall depth (0.8), the t = 5 time step contributes a point above the inflection point at 1153 minutes, 0.8099 and below the inflection

point at 1148 minutes, 0.7602. Continuing this process provides the points that define the entire design unit hyetograph.

As described in Section 2.5.1, most major precipitation events in the county are the result of extratropical winter storms. Significant runoff tends to occur when these storms last several days and are comprised of several individual bands of intense precipitation. In the case of a multiple day storm, the most intense rainfall tends to occur on the last day. These observations form the basis for Public Works' 4-day design storm.

The unit hyetograph is multiplied by the 24-hour rainfall depth to produce a rainfall hyetograph for the fourth day. The first through third days have respectively 10, 40, and 35 percent of the fourth day's rainfall. Appendix A contains the unit hyetograph in tabular form. Multiplying the unit hyetograph by the depth for each day results in the daily hyetograph.

5.3 RAINFALL ISOHYETS

Historical data indicates that spatial distribution of precipitation across the county is not uniform during storm events. To account for this spatial variability of rainfall, Public Works developed rainfall isohyetal maps for the County of Los Angeles.

Isohyetal maps show the 24-hour rainfall depths expected for the 50-year storm frequency. The rainfall pattern depicted on these maps shows the influence of topography on rainfall.

The isohyetal maps incorporate information from Public Works' rain gages and the National Oceanic and Atmospheric Administration's (NOAA) gridded rainfall maps of the area. The process used NOAA's *Atlas 2,* 2-year, 24-hour isohyetal data to provide the spatial rainfall pattern. NOAA is a widely accepted source for meteorological data, and NOAA *Atlas 2* is a recognized standard for spatial rainfall distribution data.

Detailed rain gage analysis was performed to determine the various rainfall depth and frequency relationships. Table 5.3.1 summarizes the relationship between various frequencies as factors of the 50-year frequency depths. The factors are normalized to the 50-year event because this event is used for Capital Flood Hydrology.

Frequency	Multiplication Factor
2-yr	0.387
5-yr	0.584
10-yr	0.714
25-yr	0.878
50-yr	1.000
100-yr	1.122
500-yr	1.402

Table 5.3.1
Rainfall Frequency Multiplication Factors

Appendix B contains isohyetal maps for the 50-year, 24-hour rainfall depth. The isohyetal contour lines are spaced at intervals of two-tenths of an inch. The spatial rainfall distributions for the county design storms were converted to grid data for use with Geographic Information System (GIS) compatible hydrologic models.

5.4 DESIGN STORM

The three components of the design storm include the IDF equation, the unit hyetograph curve, and the isohyets. These components are used to define the design storm for a particular location and frequency. As an example, consider the 25-year design storm for the Palmer Canyon watershed in Figure 5.4.1. Subarea 1A of this watershed, shown in Figure 5.4.2, will be used for the sample calculations.

1. Compute the area between successive isohyetal lines and multiply by the average of the isohyet values. Table 5.4.1 shows the areas between isohyets for Subarea 1A.

2. The sum of these precipitation-area values divided by the total subarea area provides the area weighted average rainfall depth. The average rainfall should be calculated to the nearest two-tenths of an inch. Table 5.4.1 contains the calculations for the isohyetal values in this subarea.

It may be noted that for small subareas, the isohyet nearest the centroid of the subarea usually equals the design depth. Selecting the isohyets nearest the subarea centroid is an acceptable method for determining the design rainfall for subareas of approximately 40 acres.

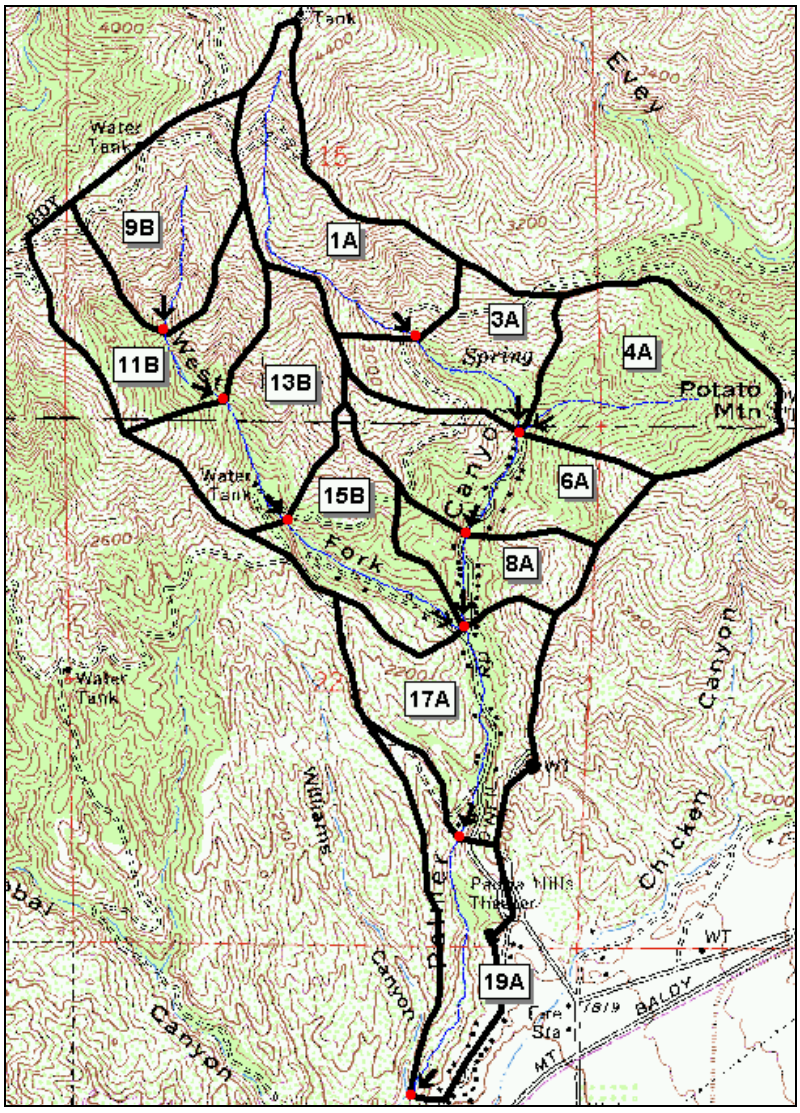


Figure 5.4.1
Palmer Canyon Watershed

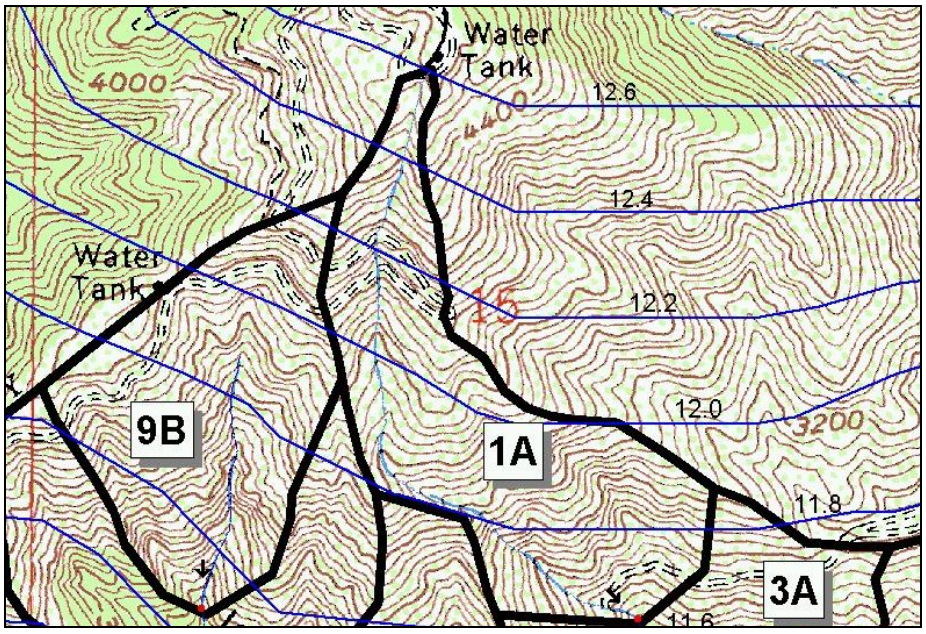


Figure 5.4.2
Subarea 1A with 50-Year, 24-Hour Rainfall Isohyets

Subarea 1A	Isohyet (in)	Area between Isohyets (acres)	Average Depth (in)	Precipitation * Area (in-acres)
	12.6			
	⟶	2.6 *	12.5 =	32.5
	12.4			
		6.9	12.3	84.9
	12.2			
		13.4	12.1	162.1
	12.0			
		29.7	11.9	353.4
	11.8			
		15.1	11.7	176.7
	11.6			
Total		67.7		809.6
809.6 in-acre / 67.7 acre = 11.96 in → 12.00 in				

Table 5.4.1
Subarea 1A Average Rainfall Depth Calculation

Table 5.4.2 shows average rainfall values calculated for the other subareas using the method from steps 1 and 2.

Table 5.4.2
Subarea Average Rainfall Depths

Subarea	Isohyetal Depth (in)
3A	11.4
4A	11.2
6A	11.0
8A	10.8
9B	11.4
11B	11.2
13B	11.0
15B	10.8
17A	10.2
19A	9.4

3. Using the rainfall frequency factor, the 50-year, 24-hour depths are scaled to match the required 25-year, 24-hour depths. The 25-year, 24-hour factor from Table 5.3.1 is 0.878.

Table 5.4.3
Scaling Rainfall Depths

Subarea	50-year depth (in)	50-year to 25-year factor	25-year depth (in)
1A	12.0	* 0.878 =	10.5
3A	11.4	* 0.878 =	10.0
4A	11.2	* 0.878 =	9.8
6A	11.0	* 0.878 =	9.7
8A	10.8	* 0.878 =	9.5
9B	11.4	* 0.878 =	10.0
11B	11.2	* 0.878 =	9.8
13B	11.0	* 0.878 =	9.7
15B	10.8	* 0.878 =	9.5
17A	10.2	* 0.878 =	9.0

4. Next, apply this 25-year, 24-hour depth to the unit hyetograph to produce the design storm hyetograph for the subarea. Multiply each depth on the

unit hyetograph by the 25-year, 24-hour rainfall depth. This produces a cumulative hyetograph for the fourth day. Calculate hyetographs for the first three days by multiplying the unit hyetograph by 10, 40, and 35 percent of the fourth day's rainfall depth. Figure 5.4.3 shows Subarea 1A's temporal rainfall distribution for each day of the design storm.

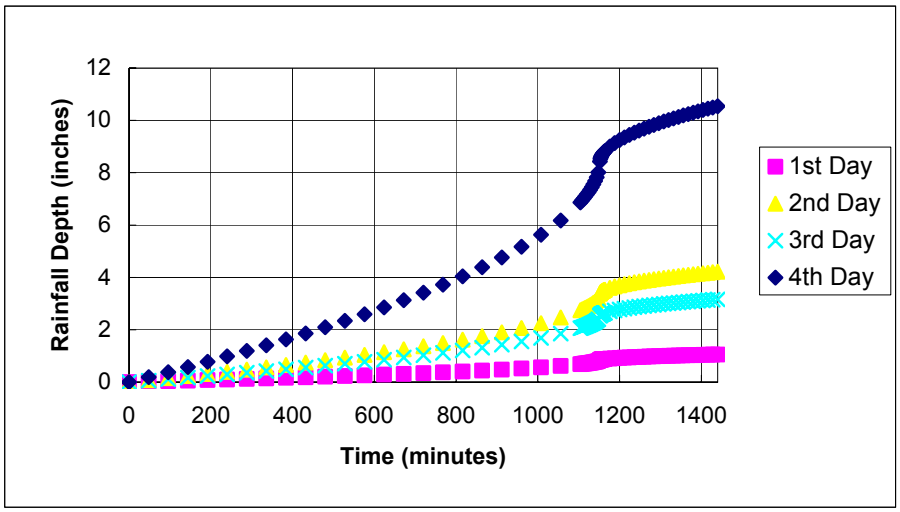


Figure 5.4.3
Hyetographs for Each Storm Day – Subarea 1A

Equation 5.1.2 determines the maximum intensity for the design storm assuming the time of concentration for Subarea 1A is 8 minutes.

$$\frac{I_t}{I_{1440}} = \left(\frac{1440}{t}\right)^{0.47}$$

(Equation 5.1.2)

Where: I_t = Rainfall intensity for the duration given in in/hr
t = 8 minutes
I_{1440} = 10.5 in / 24 hrs = 0.4375 in/hr

$$I_8 = \left(\frac{1440}{8\,\text{min}}\right)^{0.47} \times 0.4375 = 5.02 \ \text{in/hr}$$

The peak 8-minute intensity for the 25-year storm is 5.02 in/hr. If the time of concentration is 8 minutes, the peak flow will be Q = CIA, where I = 5.02 in/hr.

5.5 PROBABLE MAXIMUM PRECIPITATION (PMP)

As noted in Section 4.5, many dam spillways that fall under the State of California jurisdiction must safely pass runoff from the Probable Maximum Precipitation (PMP). The National Weather Service developed PMP design storms for use in the United States.

There are two types of PMP storms: the 3-day general-storm and the 6-hour local-storm. Facilities requiring protection from the Probable Maximum Flood must follow the PMP procedures to develop design storms. The National Weather Service's Hydrometeorological Reports No. 58 and 59 detail procedures for developing the design storm.[4,5] These reports are available at http://www.nws.noaa.gov/oh/hdsc/On-line_reports



Figure 5.5.1
Appian Way in Long Beach
January 21, 1969

[1] Applied Hydrology. Chow, Maidment, and Mays. page 466, McGraw-Hill, New York, 1988.
[2] Memorandum from Reza Izadi to Brian T. Sasaki, Re: Los Angeles County Hydrologic Method dated March 4, 2002.
[3] Applied Hydrology. Chow, Maidment, and Mays. page 466, McGraw-Hill, New York, 1988.
[4] Hydrometeorological Report No. 58, Probable Maximum Precipitation for California Calculation Procedures, National Weather Service. October 1998.
[5] Hydrometeorological Report No. 59, Probable Maximum Precipitation for California, National Weather Service. February 1999.

CHAPTER

6

Rainfall-Runoff Relationships

Only a portion of the rain that falls on a watershed appears as surface runoff in a stream. This section of the manual describes two methods for estimating the portion of rainfall that becomes runoff. This portion is called the rainfall excess or effective rainfall.

6.1 RAINFALL LOSSES AND RUNOFF PRODUCTION

Rainfall becomes runoff when all loss processes are satisfied. Runoff results from rainfall not lost to infiltration, interception, depression storage, and evaporation.

"Infiltration is the process of water penetrating the ground surface into the soil."[1] Interception loss occurs when water is retained on vegetation and other surfaces. Intercepted water may evaporate or infiltrate. Loss due to depression storage occurs when water accumulates in depressions of all sizes that are not connected to a flow path. Evapotranspiration, a dominant force in the hydrologic cycle, proceeds slowly during a storm.

Different methods have been developed to model rainfall losses. These include runoff coefficients, constant loss parameters, the Horton method, exponential loss calculations, and Green-Ampt losses. The Modified Rational Method uses runoff coefficients. The following sections discuss infiltration and loss methods used within the County of Los Angeles.

6.2 INFILTRATION

Infiltration losses have the greatest effect on surface runoff. The rate of infiltration is a function of the state of the soil and is highly heterogeneous over space and time. Hydraulic conductivity is a measure of the ease with which water can travel through the soil and is a measure of the infiltration

rate when the soil is saturated. Similar soils generally have similar hydraulic conductivities. However, the infiltration rate is also affected by the degree of soil saturation. Dry soil allows more infiltration than wet soil. Factors such as ground cover or recent fires within the watershed affect the soil surface and infiltration rates.

Public Works' hydrologic standards assume that watersheds subject to design rainfall are at a field capacity soil moisture condition. This condition is also referred to as a saturated condition. At field capacity, the forces due to gravity and the surface tension on a drop of water in the soil column are in balance. At this point, no water is draining from the soil. Adding water to the soil forces downward movement and allows infiltration to begin.

6.3 MODIFIED RATIONAL LOSS CALCULATIONS

The modified rational method (MODRAT) uses a runoff coefficient that is a function of the rainfall intensity. The runoff coefficient reflects the fraction of rainfall that does not infiltrate and is based on the rainfall intensity for a given time period.

The Modified Rational Method uses the following equation at each time step:

$$Q = C*I*A \qquad \textbf{Equation 6.3.1}$$

Where: Q = Volumetric flow rate in cfs
C = Runoff coefficient, dimensionless
I = Rainfall intensity at a given point in time in in/hr
A = Watershed area in acres

The following sections describe development of the unburned soil runoff coefficient, C_u, the developed soil runoff coefficient, C_D, and the burned soil runoff coefficient, C_{ba}. The appropriate coefficient represents runoff for different watershed conditions.

Undeveloped Runoff Coefficient (C_u)

MODRAT uses runoff coefficient curves to model the runoff response of the soil to changing intensity. The 179 undeveloped runoff coefficient curves, plotted in Appendix C, correspond to different soil types within the County of Los Angeles. Figure 6.3.1 shows the shape of a typical runoff coefficient curve.

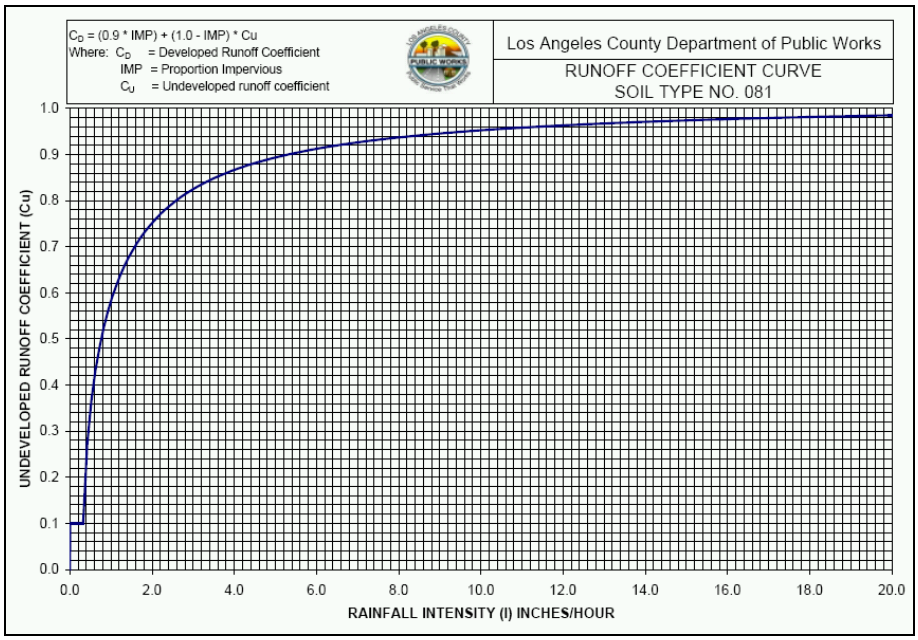


Figure 6.3.1
Runoff Coefficient Curve for Soil 081

Double ring infiltrometer tests provided data for the runoff coefficient curves. The infiltrometer tests used a department-designed, sprinkling–type infiltrometer. Before performing infiltrometer testing, the county was divided into regions of likely hydrologic homogeneity. Areas of homogenous runoff characteristics in the valley and desert areas were based on soil classifications published by the United States Department of Agriculture, Natural Resources Conservation Service. Criteria for homogeneity included topography, rock type, soil type, vegetative cover, and litter. Results from the infiltrometer tests within the homogenous areas determined the infiltration rate.

A series of runoff coefficient-intensity pairs compose each runoff coefficient curve. Each of the curves has a minimum coefficient (C_u) of 0.1 indicating that there is some runoff even at the smallest rainfall intensities. Appendix C contains the runoff coefficient curves for all the soils within the County of Los Angeles.

MODRAT requires assigning a single soil type for each subarea modeled. If a subarea contains more than one soil type, the predominant soil type in the subarea is used.

Developed Soil Runoff Coefficient Curves (C_D)

Each undeveloped runoff coefficient curve represents natural soil conditions. When precipitation occurs over a developed watershed, the rain falls on directly connected impervious areas and pervious areas. Runoff from pervious areas only occurs during heavy rainfall. Directly connected impervious area always produces direct runoff. As impervious area increases, the amount of direct runoff increases. The runoff coefficient curve must be modified to match the developed condition. Equation 6.3.2 accounts for the effects of development based on the undeveloped runoff coefficient and the amount of impervious area.

$$C_d = (0.9 * IMP) + (1 - IMP) * C_u$$ **Equation 6.3.2**

Where: C_d = Developed area runoff coefficient
IMP = Percent impervious
C_u = Undeveloped area runoff coefficient

The 0.9 in the equation represents the general assumption that no development is completely impervious. This assumption also accounts for initial abstraction losses in developed areas.

Imperviousness is assigned based on the land use types present in a subarea. Land use information requires existing and/or planned development patterns. If more than one type of development is present within a subarea, a composite impervious value must be determined using an area-weighted average. For example, consider a subarea with the characteristics in Table 6.3.1.

Table 6.3.1
Composite Impervious Values

	Percent Impervious	Area (acres)	Impervious*Area
	91%	20	1820
	42%	5	210
	21%	10	210
	1%	5	5
Total	-	40	2245

To determine the composite impervious value for this subarea, calculate the area weighted average of imperviousness. First, multiply each impervious

value by the area it represents. Then sum these products and divide by the total area. The composite area weighted imperviousness for the example subarea is:

$$\text{Composite imperviousness} = {}^{2245}\!/_{40} = 56\%$$

The Southern California Association of Governments (SCAG) land use studies establish the land use patterns within the county. SCAG creates land use maps based on development type. Public Works assigns imperviousness values to each development type and then verifies these values using previous studies and aerial photos. The current land use map is based on SCAG data from 2000.

Representative proportion impervious values have been developed by measuring sample areas for each land use type. Appendix D has a table of these values. For undeveloped rural areas, 1% of the area is assumed impervious. Table 6.3.2 shows the standard range of percent impervious values for different development types.

Table 6.3.2
Standard Range of Percent Impervious

Type of Development	Percent Impervious
Single-Family	21% to 45%
Multi-Family	40% to 80%
Commercial	48% to 92%
Industrial	60% to 92%
Institutional	70% to 90%

Burned Soil Runoff Coefficient Curves (C_{ba})

Wildfires frequently burn undeveloped watersheds within the County of Los Angeles. Infiltrometer tests conducted in burned chaparral-covered mountain watersheds indicate that these watersheds suffer from a decreased infiltration rate after a fire. The decrease results from calcification caused by intense heat, plugging of the soil pores by ash or other fines, and other chemical reactions that produce a hydrophobic condition. A lack of surface cover also promotes the formation of a crust of fine soil due to the impact of raindrops. This crust further impedes infiltration.[2]

Collection of field infiltrometer data in recently burned areas quantified the infiltration rate decrease for all soil types. Tests were done in burned and unburned portions of an area with previously homogenous infiltration.

Figure 6.3.2 is a picture of the 2002 Williams Fire in the San Gabriel Mountains viewed from Santa Fe Dam.



Figure 6.3.2
Williams Fire in the San Gabriel Mountains Viewed From Santa Fe Dam 2002

Burned area runoff calculations use a runoff coefficient curve adjusted for the burned watershed condition. For burned watersheds, the rational equation becomes $Q_{ba} = C_{ba}IA$, in which Q_{ba} and C_{ba} are respectively the peak runoff from a burned area and the statistically adjusted burned soil runoff coefficient. The burned runoff coefficient is adjusted using a fire factor. The fire factor is an index between the natural and completely burned watershed conditions, which ranges from 0 to 1 respectively. An analysis of historic fires in the major watersheds within the County of Los Angeles provided design fire factors for undeveloped watersheds.[3,4] Table 6.3.3 contains the design fire factors.

Watershed	Fire Factor
Santa Clara River Watershed & Antelope Valley	0.34
Los Angeles River Watershed	0.71
San Gabriel River Watershed	0.71
Coastal Watershed	0.83

Table 6.3.3
Design Fire Factors for Use with Burned Watershed Hydrology

Only undeveloped subareas with 15% or less imperviousness require burn calculations. Equation 6.3.3 calculates the burned runoff coefficient.

$$C_{ba} = FF \times [(1-K) \times (1-C_u)] + C_u$$ **Equation 6.3.3**

Where:
- C_{ba} = Adjusted burned soil runoff coefficient, dimensionless
- FF = Fire Factor, the effectively burned percentage of watershed area, dimensionless
- K = Ratio of burned to unburned infiltration rates for I, $0.677 \times I^{-0.102}$, dimensionless
- I = Rainfall intensity in in/hr
- C_u = Undeveloped runoff coefficient, dimensionless

The K factor represents the ratio of burned to unburned infiltration rates. The ratio varies with the rainfall intensity. Equation 6.3.4 is useful for determining the burned peak flow when an unburned flow and intensity are known.

$$Q_{ba} = FF \times [(0.677 \times I^{-0.102} - 1) \times (Q_u - A \times I)] + Q_u$$ **Equation 6.3.4**

Where:
- Q_{ba} = Peak runoff from a burned area in cfs
- FF = Fire Factor, the effectively burned percentage of watershed area
- I = Rainfall intensity in in/hr
- A = Watershed area in acres
- Q_u = Peak runoff from an unburned area in cfs

Fires increase runoff and debris production. Higher runoff rates entrain more debris and burned watersheds have more debris available for entrainment. Debris production yields as much as 120,000 cubic yards/square mile of watershed for major storms. Boulders up to eight feet in diameter have been deposited in valley areas at considerable distances from their source. Debris quantities equal in volume to the storm runoff (100 percent bulking) have been recorded in major storms. The Flood Control District and the

Department of Public Works have built many debris control and storage structures in the foothills to minimize the chance of channels clogging with debris.

Peak flows from burned watersheds are “bulked” to account for volume changes caused by debris entrainment. Debris basins remove the sediment so that downstream flows are equal to flows from burned watershed. For more information on debris production, bulking flows, sediment transport, and design of debris retaining structures and basins, see the Department of Public Works Sedimentation Manual.

6.4 CONSTANT LOSS METHOD

The constant loss method is a frequently used and generally accepted rainfall loss method for flood hydrology. The constant loss method models infiltration by allowing all rainfall to infiltrate when the rainfall intensity is below a certain rate. All rainfall exceeding this infiltration rate will run off. Table 6.4.1 contains example calculations of direct runoff using the constant loss method. A constant loss rate of 0.1 in/hr is applied to an incremental rainfall series. Rainfall exceeding the loss rate becomes runoff.

Table 6.4.1
Application of Constant Loss Method

Time (hours)	Incremental Rainfall (in)	Loss (CL=0.10 in/hr)	Runoff (in)
1	0.00	0.00	0.00
2	0.05	0.05	0.00
3	0.08	0.08	0.00
4	0.10	0.10	0.00
5	0.20	0.10	0.10
6	0.12	0.10	0.02
7	0.05	0.05	0.00

Figure 6.4.1 illustrates the relationship between the constant loss rate and the total rainfall. In this example, a total of 0.60 inches of rain fell in 7 hours. Of this rain, a total of 0.48 inches was lost to infiltration while 0.12 inches became runoff. The runoff coefficient for this entire period is 0.2, representing that 20 percent of rainfall becomes runoff.

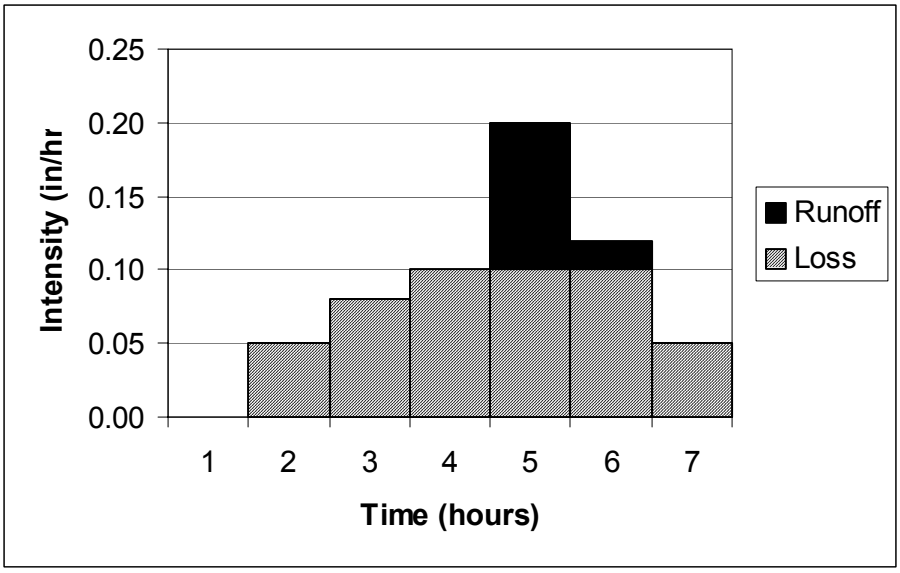


Figure 6.4.1
Rainfall Hyetograph and resulting Constant Loss Runoff

In general, application of a constant loss rate requires model calibration to estimate the loss rate parameters. Constant loss rates are highly variable and depend on the degree of saturation, soil type, storm duration, and rainfall intensity.

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1 *Applied Hydrology*. Chow, Ven Te; David R. Maidment; and Larry W. Mays. page 188. McGraw-Hill, Inc. New York, 1988.

2 *Handbook of Hydrology*. Ed. Maidment, David R. page 5.42. McGraw-Hill. New York, 1993.

3 "Development of Burn Policy Fire Factors." Los Angeles County Department of Public Works. August 5, 2004.

4 "Development of Burn Policy Methodology (Santa Clara River Pilot Project)." Los Angeles County Department of Public Works. June 2003.

CHAPTER

7

Runoff Calculation Methods

The design of drainage systems for stormwater conveyance within the County of Los Angeles requires converting rainfall into runoff volumes and flow rates. There are many methods available for converting the rainfall to runoff.

The Department of Public Works uses two basic methods for converting rainfall to runoff, depending on the conditions. The methods are facilitated by software for use on a personal computer. The sections in this chapter explain how to select the proper method for hydrologic studies and the theory and application of the two methods.

7.1 SELECTING THE PROPER METHOD

Table 7.1.1 provides a brief description of the uses and limitations of each method.

Table 7.1.1
County of Los Angeles
Hydrologic Methods

Method		Use / Limitations
Rational Method	Use:	For drainage areas 40 acres or less; finds the peak flow rate for any frequency design storm
	Limitations:	Does not create hydrographs or determine runoff volumes. Area limited to approximately 40 acres.
Modified Rational (MODRAT)	Use:	For any size watershed; for any combination of laterals; for any combination of developed and undeveloped drainage areas; to create hydrographs and runoff volumes at specified locations; to find peak subarea and mainline flow rates; recommended method for systems incorporating pumping or water impoundment.
	Limitations:	Underestimates volumes in rural areas when interflow and baseflow add to the runoff volume.

7.2 RATIONAL METHOD

Mulvaney first outlined the rational method[1], which assumes that a steady, uniform rainfall rate will produce maximum runoff when all parts of the watershed are contributing to outflow[2]. This occurs when the storm event lasts longer than the time of concentration. The time of concentration is the time it takes for rain in the most hydrologically remote part of the watershed to reach the outlet. The method assumes that the runoff coefficient remains constant during a storm. The rational method formula is Q = CIA, previously mentioned in Chapter 6 as Equation 6.3.1. The direct runoff volume is calculated using the following equation:

$$V = C * \left(\frac{P}{12} \right) * A$$ **Equation 7.2.1**

Where: V = Volume in ac-ft
C = Runoff coefficient, proportion of rainfall that runs off the surface
P = Rainfall depth in inches
A = Drainage area in acres

Use of the rational method for drainage system design in small urban areas is appropriate. Use within the County of Los Angeles requires subarea division when[3]:

- Subareas are larger than approximately 40 acres
- There is more than one drainage channel
- Hydrologic properties are different within the area
- The time of concentration is greater than 30 minutes

The following are disadvantages of the classic rational method:

- Does not produce a hydrograph
- Runoff coefficient, C, is usually the same regardless of rainfall intensity
- Results are unreliable for areas greater than 200 acres[8]

The rational method applies to small watersheds where storage routing is not necessary. The method is useful for determining peak flows from small subdivisions and development projects or to determine flows to catch basins.

Section 7.5 describes catch basin hydrology in detail. Section 12.2 contains an example using the rational method to compute runoff.

7.3 MODIFIED RATIONAL METHOD

The modified rational method (MODRAT) uses a design storm and a time of concentration to calculate runoff at different times throughout the storm. Section 5.2 describes the temporal distribution of the design storm. Section 5.3 describes the spatial distribution of design storm rainfall within the County of Los Angeles.

Calculating flows based on the rainfall distribution results in a runoff hydrograph. The volume of runoff equals the area under the hydrograph curve. MODRAT allows users to route hydrographs generated in each subarea through conveyances and combine hydrographs based on time. MODRAT produces peak flows equal to or lower than flows calculated using the rational method. The reduction in peak results from attenuation, channel storage, and combining flows that peak at different times. Figure 7.3.1 shows an example of channel flow and storage.



Figure 7.3.1
Water storage occurring in Bradbury Channel May 28, 1981

Time of Concentration

The time of concentration (T_C) is the time it takes for rain in the most hydrologically remote part of the watershed to reach the outlet. Using a rainfall duration equal to the T_C ensures that the runoff from the entire subarea is contributing flow at the outlet. MODRAT requires a time of concentration in order to calculate intensities for use with the rational equation.

There are several methods for calculating the T_C. Simple relationships use the length of flow multiplied by an assumed flow velocity based on the type of conveyance (overland flow, sheet flow, pipe flow, etc.) Other methods include empirical equations derived through research and the use of the kinematic wave theory. The T_C calculation method for hydrology studies within the County of Los Angeles relies on a regression equation derived from hundreds of studies using the kinematic wave theory.

Time of Concentration - Kinematic Wave Theory[4]

The kinematic wave theory is a method accepted by Public Works, to calculate the time of concentration, T_C. Use of the kinematic wave theory to calculate the T_C requires separating the longest flow path into two parts: overland flow and conveyance flow. Equation 7.3.1 demonstrates this:

$$T_C = t_o + t_c$$ **Equation 7.3.1**

Where: T_C = Time of concentration in minutes
t_o = Overland flow travel time in minutes
t_c = Sum of all conveyance travel times in minutes

Conservation of mass and the momentum equation are used to determine the time associated with overland flow. Equations 7.3.2 and 7.3.3 are used to calculate overland flow time, t_o:

$$t_o = \frac{0.94 * L_o^{0.6} * n_o^{0.6}}{I_x^{0.4} * S_o^{0.3}}$$ **Equation 7.3.2**

$$I_x = C * I$$ **Equation 7.3.3**

Where:
- t_o = Overland flow travel time in minutes
- L_o = Overland flow length in feet
- n_o = Roughness for overland flow surface, dimensionless
- I_x = Rainfall excess in in/hr
- S_o = Slope of overland flow in ft/ft
- C = Runoff coefficient, ratio of runoff rate to rainfall intensity in in/in
- I = Rainfall intensity in in/hr

Values for the roughness coefficient of overland flow surfaces are found in Table 7.3.1.

Table 7.3.1
Roughness Coefficients for Overland Flow Computation

Surface Cover[5]	n_o
Smooth Asphalt	0.012
Concrete Paving	0.014
Packed Clay	0.030
Light Turf	0.250
Dense Turf	0.350
Industrial/Commercial	0.014
Residential	0.040
Rural	0.060

Table 7.3.2 shows standard values for different types of lots. The kinematic wave method requires evaluation of each subarea to determine the overland flow length and slope.

Surface Cover[6]	Lot Length (ft)	Range of Lot Slope
Industrial/Commercial	200	0.005 - 0.020
Residential	100	0.010 - 0.050
Rural	200	0.050 - 1.000

Table 7.3.2
Standard Values for Overland Flow Computation

Figure 7.3.2 illustrates the different types of lots where overland flow occurs.

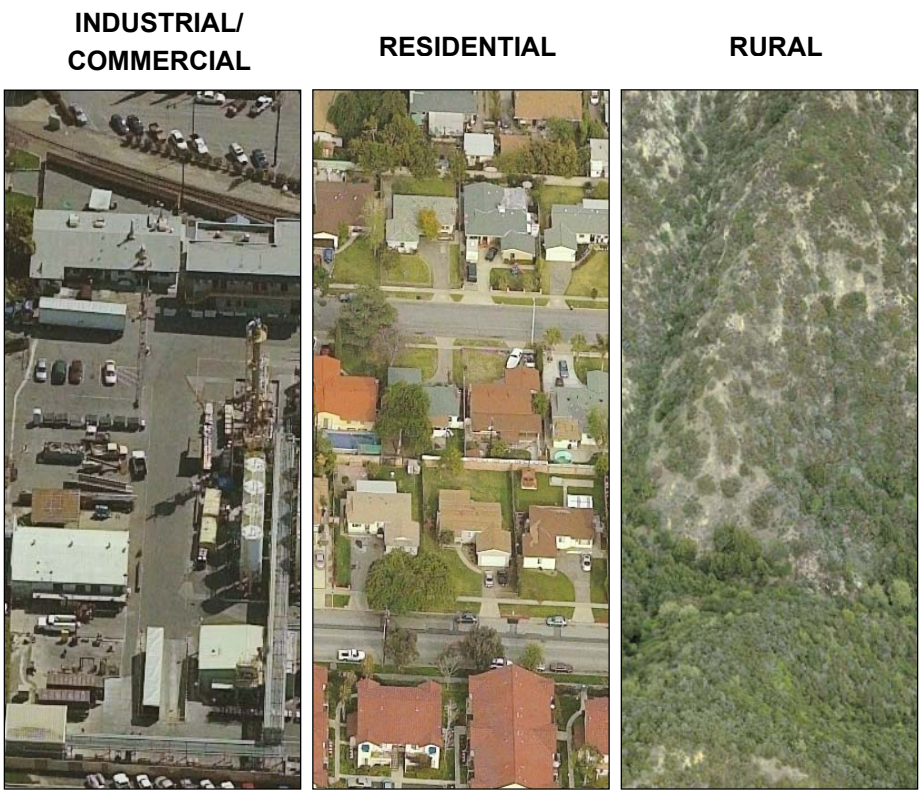


Figure 7.3.2
Different Types of Lots Where Overland Flow Occurs

The kinematic wave approach is applicable to channel flow as well as overland flow. The Manning equation is a form of kinematic wave theory for channels. The Manning equation is used to determine the average velocity in the channel. This velocity is used to determine travel times as shown in equation 7.3.4:

$$t_c = \left(\frac{1}{60}\right)\left(\frac{L_c}{V_{ave}}\right)$$

Equation 7.3.4

Where: t_c = Conveyance flow travel time in minutes
L_c = Conveyance flow length in feet
V_{ave} = Average conveyance velocity based on Manning equation in ft/sec

Comparison of results from Equation 7.3.1 with Izzard's overland flow experimental results and the results of Yu and McNown showed good correlation[6].

Use of the equations in this section requires an iterative approach since the rainfall excess and T_C are related to each other. An example problem illustrates application of the kinematic wave method for calculating T_C. Figure 7.3.3 shows the subarea that will be analyzed to determine the T_C using the kinematic wave method.

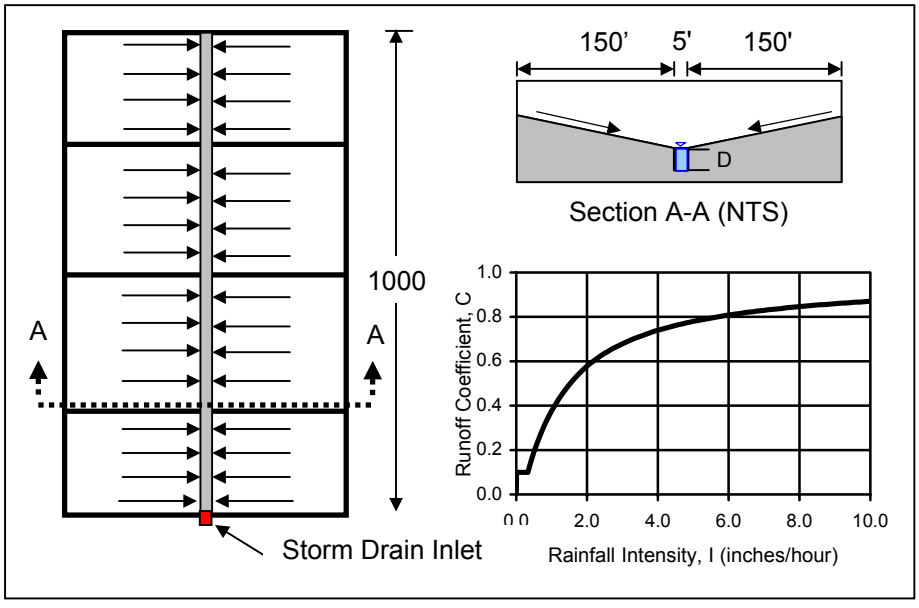


Figure 7.3.3
Example Subarea Demonstrating Kinematic Wave Method

This example shows eight residential lots that drain to a small grassy channel that eventually flows into a storm drain. Table 7.3.3 provides the lot and channel characteristics. The 50-year 24-hour rainfall for this area is 5 inches.

Table 7.3.3
Kinematic Wave Conveyance Data

Flow Path	Length (ft)	Slope (ft/ft)	Manning n	Width (ft)	Max. Depth (ft)
Overland Flow - Lot	150	0.020	0.040	-	-
Concrete Channel	1000	0.005	0.013	5	1

The steps involved in calculating a time of concentration using the kinematic wave method and example calculations are provided:

1. Assume an initial time of concentration

Assume a T_C of 12 minutes for the subarea in Figure 7.3.3

2. Calculate the intensity using Equation 5.1.2 and runoff coefficient using Equation 6.3.2 for overland flow using the time of concentration as the duration

$$I_t = I_{1440} * \left(\frac{1440}{t}\right)^{0.47} \Rightarrow I_{12} = \frac{5\,\text{in}}{24\,\text{hr}} * \left(\frac{1440}{12\,\text{min}}\right)^{0.47} = 1.98\ \text{in/hr}$$

With the 2.0 in/hr intensity, the runoff coefficient is determined from the runoff coefficient curve in Figure 7.3.3. The undeveloped runoff coefficient is 0.58. Assuming a percent impervious of 0.42 for residential land use, the developed runoff coefficient is:

$$C_d = (0.9 * IMP) + (1.0 - IMP) * C_u$$
$$= (0.9 * 0.42) + (1.0 - 0.42) * 0.58 = 0.71$$

3. Calculate the time required for overland flow to reach the channel using Equation 7.3.2

$$t_o = \frac{0.94 * L_o^{0.6} n_o^{0.6}}{i_x^{0.4} S_o^{0.3}} = \frac{0.94 * (150)^{0.6} (0.040)^{0.6}}{(1.98 * 0.71)^{0.4} (0.020)^{0.3}} = 7.78\ \text{minutes}$$

4. Calculate the average flow in the channel using the rational method

$$\frac{Q}{2} = \frac{C * I * A}{2} = \frac{0.71}{2} * 1.98 \frac{in}{hr} * (\frac{1000 \text{ ft} * 305 \text{ ft}}{43560 \text{ ft}^2/ac}) = 4.92 \text{ cfs}$$

5. Determine the velocity for the average channel flow

Solving Manning's Equation for V = 3.39 ft/s

6. Calculate the conveyance flow travel time using Equation 7.3.4

$$t_c = \left(\frac{1}{60}\right)\left(\frac{L_c}{V_{ave}}\right) = \left(\frac{1}{60}\right)\left(\frac{1000}{3.39}\right) = 4.92 \text{ minutes}$$

7. Add the overland flow time and the conveyance flow time to determine the time of concentration using Equation 7.3.1

$$T_C = t_o + t_c = 7.78 + 4.92 = 12.7 \text{ minutes}$$

8. If the value is within 0.5 minutes of the original estimate, use the estimate. If the value is not within 0.5 minutes, round the value from step 7 to the nearest minute and use the value as the new estimate to start the calculations again.

Round the value to 13 minutes and start at step 2. The second iteration provided the values used to find the final T_C:

I = 1.90 in/hr
t_o = 7.94 minutes
Q_{ave} = 4.66 cfs
V_{ave} = 3.33 ft/s
t_c = 5.00 minutes
T_C = 7.94 + 5.00 = 12.94 minutes

Public Works developed a computer program to calculate T_C for hydrologic study subareas. Public Works used the computer program from 1986 until 2001.

Time of Concentration - Regression Equation[7]

Determining the overland flow length and roughness was time consuming and determining the T_C for the conveyance often required solving the Manning equation many times. A 1999 study resulted in the creation of a regression equation for T_C calculations. The regression equation relied on T_C computations from a large number of subareas. The subareas were taken from diverse hydrology studies that used the kinematic wave theory equations to calculate T_C. This representative sample of subarea T_C's came from hydrologic studies performed between 1986 and 1999.

Equation 7.3.5 correlates the T_C to independent hydrologic parameters: flow path length and slope, land use, rainfall intensity, and the soil runoff coefficient. Equation 5.1.2 from Chapter 5 provides the relationship between the 24-hour intensity and the intensity related to the T_C. Equation 6.3.2 from Chapter 6 provides a relationship between the developed and undeveloped soil runoff coefficients.

$$T_C = \frac{0.31 * L^{0.483}}{(C_d * I_t)^{0.519} * S^{0.135}}$$ **Equation 7.3.5**

$$I_t = I_{1440} * \left(\frac{1440}{t}\right)^{0.47}$$ **(Equation 5.1.2)**

$$C_d = (0.9 * IMP) + (1.0 - IMP) * C_u$$ **(Equation 6.3.2)**

Where:
- T_C = Time of concentration in minutes
- L = Longest flow path length from watershed boundary to outlet in feet
- C_d = Developed runoff coefficient, ratio of runoff rate to rainfall intensity in in/in
- I_t = Intensity at time t in in/hr
- S = Slope of longest flow path in ft/ft
- IMP = Percent Impervious, percent expressed as 0.0 to 1.0
- C_u = Undeveloped runoff coefficient, ratio of runoff rate to rainfall intensity in in/in

The regression method still uses an iterative process to calculate the time of concentration. See Section 11.1 for sample time of concentration calculations using the regression equation.

Reviewing the example in Section 11.1 shows that the regression equation calculation is approximately one minute longer than the kinematic wave method calculation for the same example. This difference is explained by the fact that many studies and calculations were used to create the regression equation. The regression equation provides the best fit for all of the studies, but may not match kinematic wave calculations exactly.

Chapter 10 describes the data necessary for watershed modeling and calculation of the time of concentration. Spreadsheet applications and computer programs listed in Chapter 11 automate the iterative process.

Hydrograph Generation

MODRAT relies on the dimensionless temporal rainfall distribution, an isohyetal depth, and the T_C to generate hydrographs. The steps for calculating the runoff are:

1. Determine the rainfall intensity for a time period equal to the T_C
2. Determine the undeveloped soil runoff coefficient for the time period using the intensity
3. Adjust the soil runoff coefficient using Equation 6.3.2 or 6.3.3 to determine C_d or C_{ba}, depending on the subarea conditions
4. Use the rational equation, Equation 7.2.1, to determine the runoff for the time period
5. Repeat steps 1 through 4 for each time period

Figures 7.3.4, 7.3.5, and Table 7.3.4 illustrate how to determine three flow rates based on the design storm for a specific subarea. The following subarea information is needed:

Area: 40 acres
T_C: 30 minutes
Soil: 068
IMP: 20%
Rain: 10 inches

Figure 7.3.4 shows the steepest portion of the rainfall mass curve related to the 50-year 24-hour rainfall depth of 10 inches. The three time segments

represent the intensity at the end of each time period. Figure 7.3.5 shows the soil runoff coefficients for soil 068. Table 7.3.4 shows the intensity, undeveloped runoff coefficient, developed runoff coefficient, the area, and the runoff for each time period. Three time periods are shown to demonstrate the changes in intensity that occur around the inflection point on the mass curve.

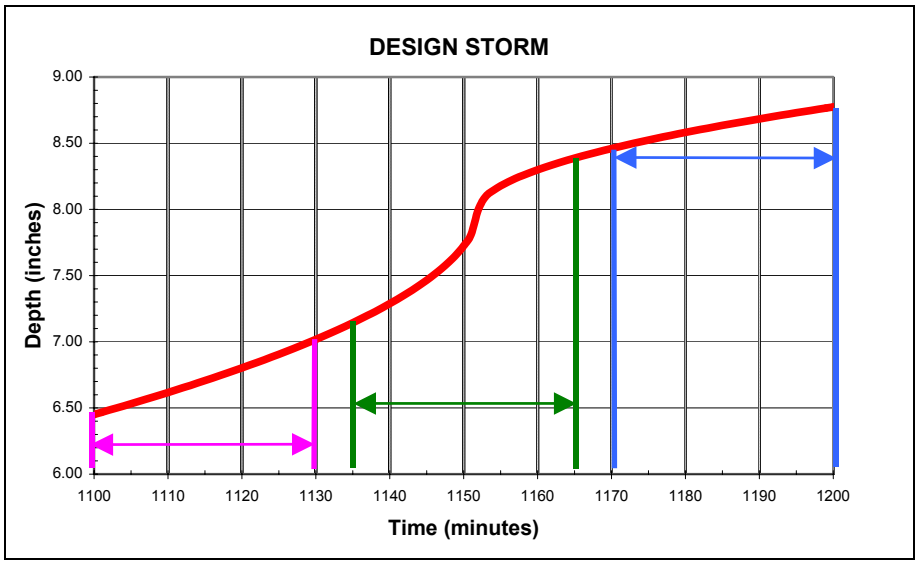


Figure 7.3.4
Three Time Steps for Modified Rational Runoff Calculations

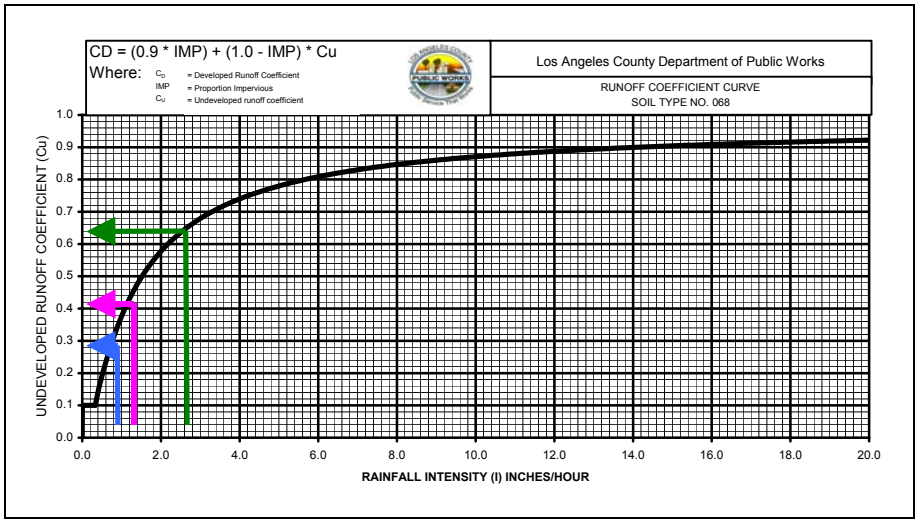


Figure 7.3.5
Undeveloped Runoff Coefficients for 3 Time Steps

Using Figures 7.3.4, 7.3.5 and Equation 6.3.2, Table 7.3.4 shows the runoff calculations for three time steps.

Table 7.3.4
Table of Runoff Calculations

Time (minutes) To	Time (minutes) From	Rainfall (in)	Intensity, I (in/hr)	Undeveloped Runoff Coefficient, C_u Fig. 7.3.3	Developed Runoff Coefficient, C_d Eq. 6.3.2	Area (acres)	Q = C_d*I*A (cfs)
1100	1130	0.567	1.134	0.39	0.492	40	22.3
1135	1165	1.243	2.487	0.62	0.676	40	69.6
1170	1200	0.314	0.627	0.26	0.388	40	9.7

Using the rainfall mass curve, the rainfall depth, and the time of concentration, the runoff value can be calculated for each one-minute increment. This is done by moving the time window forward one step and completing the process shown above. Computer programs or spreadsheets automate this time consuming process. Calculating the runoff at different time increments allows the user to create a hydrograph. Figure 7.3.6 shows the hydrograph for the three points calculated in Table 7.3.4. The figure assumes that at t = 0 and t = 1440 minutes, the flow rate is zero.

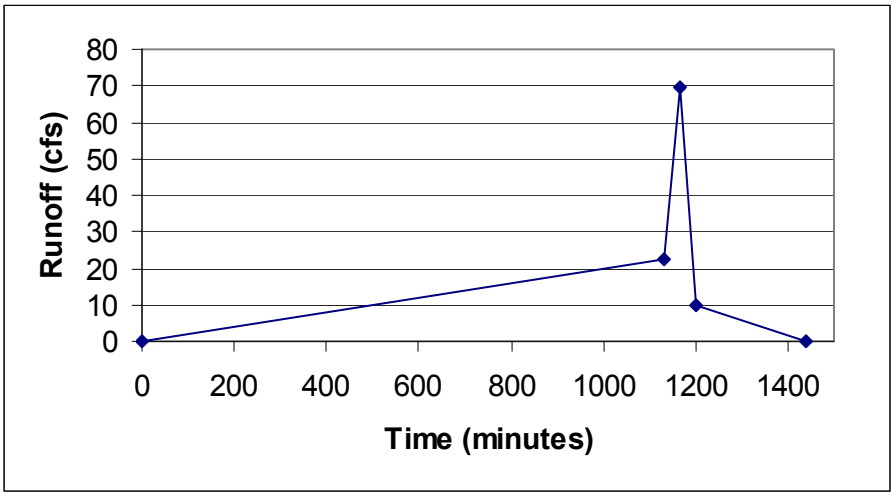


Figure 7.3.6
Hydrograph Generate Using MODRAT Method

The volume of runoff is calculated by summing up the area under the curve. For example, the volume for the first 1130 minutes is equal to the area under the curve. Finding the area of this triangle:

$$\text{Vol} = \frac{1}{2} * b * h = \frac{1}{2} * 1130 \text{ minutes} * 22.3 \frac{\text{ft}^3}{\text{sec}} * 60 \frac{\text{sec}}{\text{min}} = 755{,}970 \text{ ft}^3 = 17.35 \text{ ac - ft}$$

Defining the hydrograph with smaller time steps increases the accuracy of the flow rate and volume calculations. Hydrograph routing shows the affects of attenuation and allows superposition of hydrographs. This provides a more realistic evaluation of runoff than adding the peak flow rates calculated using the rational equation.

Channel Routing of Flows

Two types of channel routing exist: hydrologic and hydraulic. Hydrology studies within the County of Los Angeles use hydrologic routing to approximate unsteady flow through channels. Hydrologic routing balances inflow, outflow, and storage volume using the continuity equation. Routing the hydrographs results in outflow hydrographs that are smaller due to peak attenuation and occur later than the inflow due to flood wave translation.

Peak flow attenuation occurs when flows are stored in a channel reach. Figure 7.3.7 shows a graphical representation of peak attenuation. The volume of water stored increases as water fills the channel. Storage continues until the channel depth reaches the maximum water surface elevation. Storage then decreases as the peak flow passes and the water stored in the channel drains.

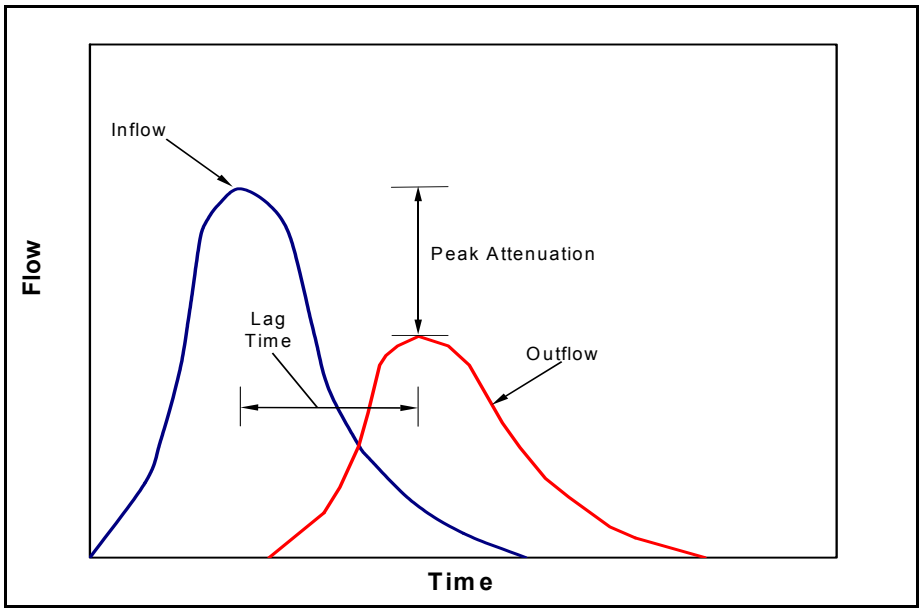


Figure 7.3.7
Peak Attenuation Related to Channel Storage

The water entering the channel must also travel from the upstream end of the section to the downstream end. Hydrologic routing considers this process by shifting the hydrograph in time. The shifting is related to the wave velocity for the specific channel.

There are many methods available for hydrologic routing[8]. The MODRAT method uses the Modified Puls, or level pool, routing method to determine channel storage effects. The method relies on a finite difference approximation of the continuity equation and an empirical representation of the momentum equation. Equation 7.3.8 is the basic equation for the Modified Puls method. The equation allows calculation of the outflow for each time step except the first. Chapter 8 shows another way to write the equation for the Modified Puls method that removes the need to calculate the storage for each time step.

$$\frac{1}{2}(I_i + I_{i-1}) - \frac{(S_i - S_{i-1})}{t_i - t_{i-1}} = \frac{1}{2}(O_{i-1} + O_i)$$

Equation 7.3.8

Where:
- I_{i-1} = Inflow at t_{i-1}
- I_i = Inflow at t_i
- t_i = Time at step i
- t_{i-1} = Time at step i-1
- S_{i-1} = Storage at t_{i-1}
- S_i = Storage at t_i
- O_{i-1} = Outflow at t_{i-1}
- O_i = Outflow at t_i

The method ignores wedge storage within the channel reach and assumes that lateral inflow effects are insignificant. A storage-discharge relationship is also required between the inflow rate and storage in the system[9]. The method requires a defined channel storage versus inflow relationship. The relationship is established using the Manning equation to determine depth of flow. Multiplying channel length, water depth, and cross sectional area provides the channel storage for a specific flow value. Using different flow values produces a storage curve. Figure 7.3.8 presents the channel storage relationship for a triangular channel with the following characteristics: slope = 0.001 ft/ft, length = 1000 ft, Manning n = 0.03, side slope = 1:1 ft:ft, and max depth = 6.8 ft.

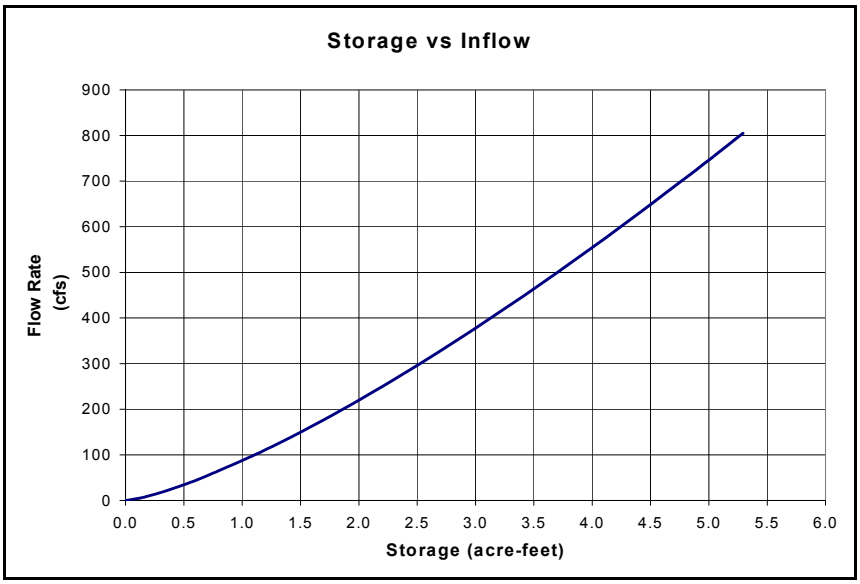


Figure 7.3.8
Storage-Inflow Relationship for a Triangular Channel

Calculation of translation time, the time it takes for the flood wave to travel from one end of the reach to another, requires using wave velocities. Table 7.3.5, Figure 7.3.9, and Figure 7.3.10 located at the end of the section provide more detail on velocity equations used for translation. Table 7.3.5 contains the equations used for translation time calculations. Figure 7.3.9 shows a typical street cross section. Figure 7.3.10 contains information for determining effective slopes of mountain and valley channels. The figure relates map slopes to slopes that match measured flow rates more accurately. The end of the section also contains a list of variables for the equations.

Correct hydrologic routing allows superposition of hydrographs at different locations within the study area. MODRAT starts at the upstream end of the watershed and calculates a runoff hydrograph. The hydrograph is then translated through the downstream channel. The Modified Puls routing then occurs to determine the effects of channel storage and the modified outflow hydrograph is computed. This hydrograph is then combined with the hydrographs from other subareas or is routed through another channel reach.

Computer programs implement this approach to reduce the amount of work required to define these relationships and route flows through the channels. Chapter 8 contains a detailed example of the Modified Puls routing method.

Table 7.3.5
Hydrograph Translation Equations

$T = \frac{L}{60 * V_W}$	Travel Time (minutes)
$V = \frac{Q}{A}$	Average Channel Velocity (ft/s)
$V = 5.6 * Q^{0.333} S_{eff}^{0.500}$	Velocity for Natural Mountain Channels (ft/s)
$V = (7.0 + 8.0 * Q^{0.352}) S_{eff}^{0.500}$	Velocity for Natural Valley Channels (ft/s)
$V_W = 1.5 * V$	Wave Velocity for Natural Mountain and Valley Channels (ft/s)
$D = \frac{B}{2 * \left(\left(Z^2 + 1 \right)^{0.500} - Z \right)}$	Most Efficient Rectangular or Trapezoidal Open Channel Section
$V = \frac{1.486}{n} * R^{0.667} S^{0.500}$	Pipe, Streets, Rectangular, or Trapezoidal Channels (ft/s)
$V_W = V * \left[\frac{\theta * (3 - 5\cos\theta) + \sin\theta}{3 * \theta(1 - \cos\theta)} \right]$	Wave Velocity for Partially Full Pipes (ft/s)
$V_W = V * \left[\frac{5}{3} - \frac{4 * (B + ZD)}{3 * (2 + B) * (B + 2ZD)} \right]$	Wave Velocity for Rectangular and Trapezoidal Channels (ft/s)
$\theta = 4 * \sin^{-1} \left(\frac{D}{d} \right)^{0.500}$	Angle Measurement to Determine Flow Depths in Pipes
$R = \frac{A}{P}$	Hydraulic Radius (ft)
$n = \frac{n_1 B + 2 * n_2 L_w}{B + 2 * L_w}$	Composite Manning's n for Trapezoidal Channels

Variables:

A	= Cross Sectional Area in ft^2
B	= Channel Bottom Width in feet
C	= Curb Height in feet
D	= Flow Depth in feet
d	= Pipe Diameter in feet
L	= Length of Channel Reach in feet
L_w	= Length of Wetted Channel Wall in feet
n	= Channel Roughness Coefficient
n_1	= Length of Wetted Channel Wall in feet
n_2	= Length of Wetted Channel Wall in feet
P	= Wetted Perimeter in feet
Q	= Flow Rate in cfs
R	= Hydraulic Radius in feet
S	= Slope of channel reach (ft/ft)
S_{eff}	= Effective channel slope, natural valley and mountain conveyances
T	= Travel Time in minutes
V	= Mean Velocity in ft/sec
V_w	= Wave Velocity in ft/sec
W_R	= Road Width From Curb to Curb in feet
Z	= Channel Side Slope Computed as Horizontal Projection of Wall Divided by Depth in ft/ft

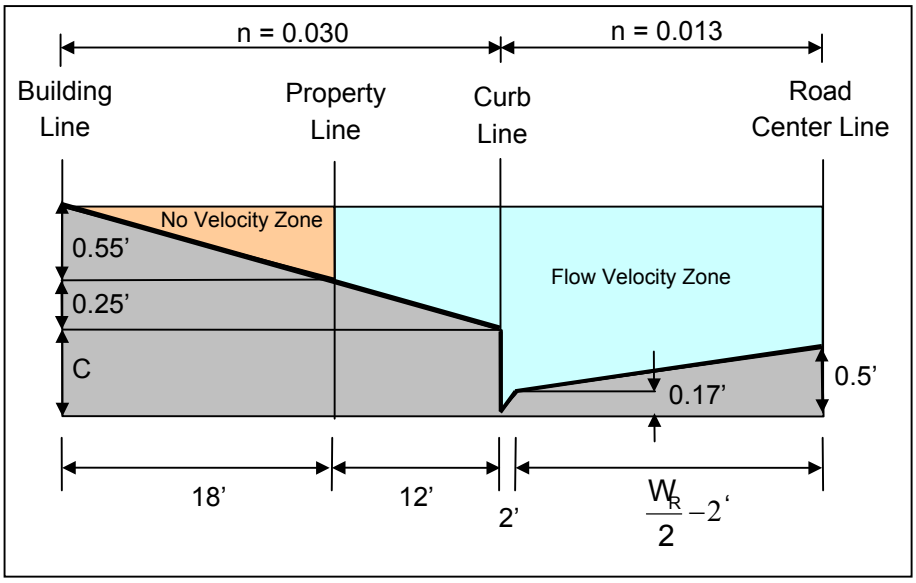
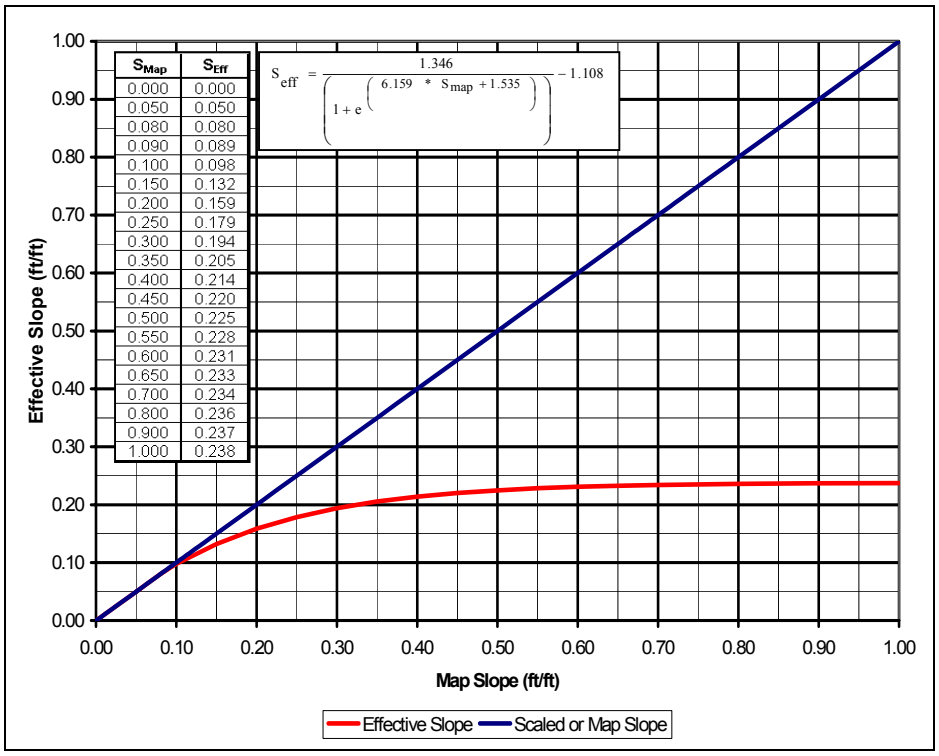


Figure 7.3.9
Typical Street Cross Section



S_{Map}	S_{Eff}
0.000	0.000
0.050	0.050
0.080	0.080
0.090	0.089
0.100	0.098
0.150	0.132
0.200	0.159
0.250	0.179
0.300	0.194
0.350	0.205
0.400	0.214
0.450	0.220
0.500	0.225
0.550	0.228
0.600	0.231
0.650	0.233
0.700	0.234
0.800	0.236
0.900	0.237
1.000	0.238

Figure 7.3.10
Effective Slope to Map Slope Relationship

7.4 CATCH BASIN FLOW CALCULATIONS

Flows that drain to catch basins usually come from areas smaller than the 40-acre subareas recommended in the hydrology manual. Determining flow to the catch basins is done by apportioning flow rates from the subarea based on the area draining to individual catch basins. Figure 7.4.1 shows a residential subarea of 35.5 acres that contains nine catch basins.

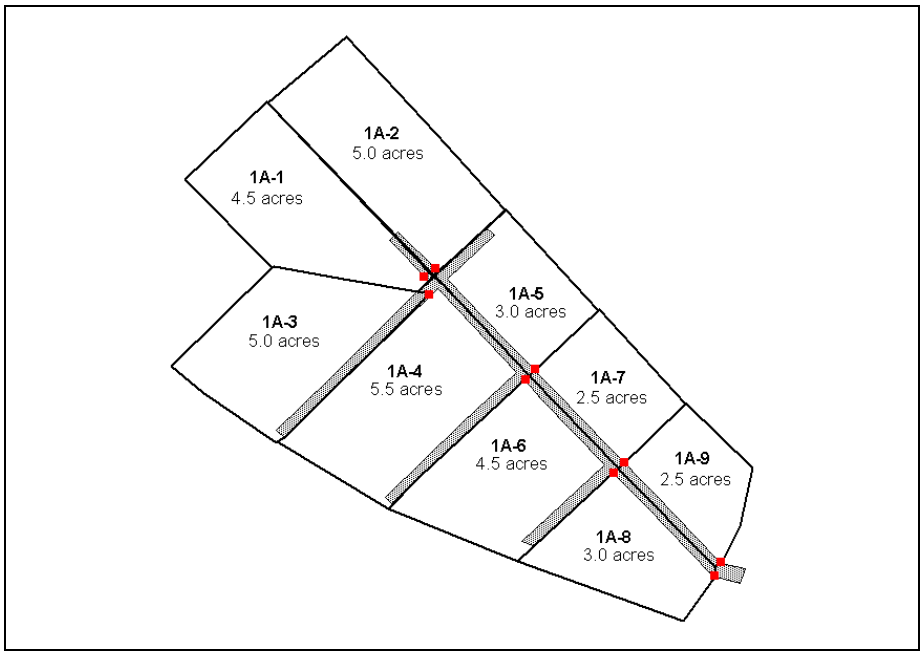


Figure 7.4.1
Catch Basin Flow Allotment

Catch basin allotment relates the peak subarea flow calculated using the MODRAT method to the subareas contributing flow. The steps for determining catch basin flow rates are:

1. Determine the area contributing flow to each proposed catch basin
2. Sum up the subarea areas to determine the total area
3. Divide each catch basin drainage area by the total area to get a weighting factor
4. Multiply the weighting factor by the MODRAT subarea watershed peak flow to get the catch basin peak flow rate for each basin

Table 7.4.1 contains the peak flow calculation for each catch basin in Figure 7.4.1. The total area for the MODRAT subarea 1A is 35.5 acres with a peak flow of 100 cfs.

Catch Basin Drainage Name	Area (A_i) (acres)	Weighting Factor (A_i/A_T)	Subarea Peak Flow (cfs)	Catch Basin Flows (cfs)
1A-1	4.5	0.13	100	13
1A-2	5.0	0.14	100	14
1A-3	5.0	0.14	100	14
1A-4	5.5	0.15	100	15
1A-5	3.0	0.08	100	8
1A-6	4.5	0.13	100	13
1A-7	2.5	0.07	100	7
1A-8	3.0	0.08	100	8
1A-9	2.5	0.07	100	7
Total Area (A_T)	35.5			

Table 7.4.1
Peak Flow Allotment for Catch Basins within Subarea 1A

7.5 REPORTING RUNOFF VALUES

Reporting official peak flow rates on maps and data sheets requires a standard method. This section describes two methods for flow reporting. The first method is used when reporting flow rates from each subarea and is consistent with the United States Geologic Survey (USGS) flow reporting procedures. The second method is for reporting burned and bulked flow rates using the reach grouping method.

Peak Flow Reporting - USGS Method

The USGS is recognized for expertise in flow measurement and reporting. Flow rates reported for subareas and reaches within The County of Los Angeles must use the USGS rounding rules. Table 7.5.1 shows the rules for reporting flow rates using the USGS standard.

Flow Rate (cfs)	Round Flow To Nearest
$0 \leq Q < 1$	0.01 cfs
$1 \leq Q < 10$	0.1 cfs
$10 \leq Q < 100$	1 cfs
$100 \leq Q < 10{,}000$	10 cfs
$10{,}000 \leq Q < 100{,}000$	100 cfs
$Q \geq 100{,}000$	1,000 cfs

Table 7.5.1
USGS Flow Reporting Rounding Rules

Peak Flow Reporting - Reach Grouping

Reporting flow rates for burned and bulked runoff requires grouping flow rates by reach. A reach is a segment of a watercourse between specified collection points. A grouped reach is a collection of reaches grouped together based on rounding rules listed below. Reach grouping reduces the number of calculations required when bulking flow rates.

Reach grouping involves dividing a watercourse into grouped reaches and then bulking each grouped reach individually. This eliminates the need to bulk flow rates at every collection point along a watercourse. Reach grouping must be used to report burned and bulked flow rates for debris-producing watersheds. The following is the procedure for determining grouped reaches used for bulking.

1. List the burned flow rates (Q_{burn}) for all collection points along the desired watercourse
2. Round the burned flow rates according to the rules in Table 7.5.2
3. Group reaches based on rounded burned flow rates of the same value
4. Determine the Debris Production Area (DPA) zone breakup using the most downstream collection point of the grouped reach to account for all DPA zone areas
5. Bulk the largest non-rounded burned flow rate value from the grouped reach
6. When reporting clear flow rates for the grouped reach, use the largest rounded clear flow rate value from the reaches within the grouped reach

When reporting final grouped reach flow rates, if the flow rate decreases downstream along a watercourse, use the flow rate from the immediate upstream grouped reach.

Table 7.5.2
Rounding Rules for Reach Grouping

Flow Rate (cfs)	Round Flow To Nearest
$0 \le Q_{burn} < 20$	0.1 cfs
$20 \le Q_{burn} < 100$	5 cfs
$100 \le Q_{burn} < 1{,}000$	10 cfs
$1{,}000 \le Q_{burn} < 100{,}000$	100 cfs
$Q_{burn} \ge 100{,}000$	1,000 cfs

EXAMPLE – Reach Grouping for Reporting Bulked Flow Rates

Figure 7.5.1 shows a portion of a watercourse that contains three reaches. Table 7.5.3 shows the burned flow rates for these reaches. Each of the burned flow rates is rounded using the rules in Table 7.5.2. Following the reach grouping steps, the burned flow rates for each collection point are listed and rounded. The flow rate at 6A is the largest unrounded burned flow rate and is used in the bulk flow calculations. The DPA zones are calculated from collection point 8A upstream to include the area tributary to the entire grouped reach and the bulked flow is calculated. The burned and bulked flow is then rounded for reporting based on Table 7.5.2. Chapter 3 of the Sedimentation Manual contains more information on bulking flows.

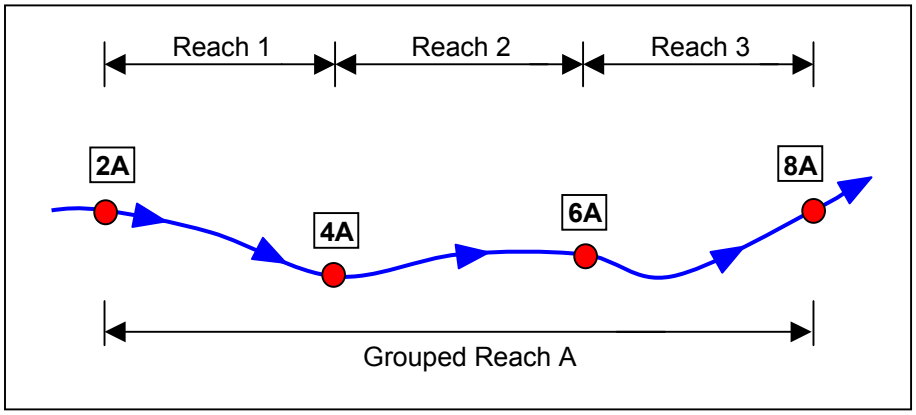


Figure 7.5.1
Grouped Channel Reach Based on Reach Flows

Reach	Grouped Reach	Collection Point	50-Year Q_{burn} (cfs)	50-Year Q_{burn} *Rounded* (cfs)	50-Year $Q_{burn\ \&\ bulk}$ (cfs)	50-Year $Q_{burn\ \&\ bulk}$ *Rounded* (cfs)
1	A	4A	6,714.7	6,700	8,939.4	8,900
2		6A	6,724.6	6,700		
3		8A	6,667.8	6,700		

Table 7.5.3
Grouped Reach Flow Rates

Figure 7.5.2 shows the aftermath of a bulked flow, downstream of Hook Canyon in Glendora after the January 1969 storm.

Figure 7.5.2
Downstream of Hook Canyon in Glendora
January 26, 1969



[1] Mulvaney, T.J. "On the Use of Self-Registering Rain and Flood Gauges. Inst. Civ. Eng. (Ireland) Trans. Vol. 4. pages 1-8. 1851.

[2] Bedient, P.B. and W.C. Huber. Hydrology and Floodplain Analysis, 3rd Ed. Prentice-Hall, Inc. NJ. page 84. 2002.

[3] US Army Corps of Engineers. Hydraulic Design of Stream Restoration (ERDC/CHL TR-01-28). page 24, Washington, D.C. 2001.

[4] Nasseri, I. Use of Kinematic Wave Theory With the Rational Method. ASCE Engineering Workshop on Peak Reduction for Drainage and Flood Control Projects. Proceedings May 9, 1987.

[5] Bedient, P.B. and W.C. Huber. Hydrology and Floodplain Analysis, 3rd Ed. Prentice-Hall, Inc. NJ. page 246. 2002.

[6] Nasseri, I. Use of Kinematic Wave Theory With the Rational Method. ASCE Engineering Workshop on Peak Reduction for Drainage and Flood Control Projects. Proceedings May 9, 1987. page 132.

[7] Los Angeles County Hydrologic Method Approval Memorandum. Los Angeles County Department of Public Works. March 4, 2002.

[8] US Army Corps of Engineers. Hydrologic Modeling System HEC-HMS Technical Reference Manual. CPD-74B. March 2000.

[9] Bedient, P.B. and W.C. Huber. Hydrology and Floodplain Analysis, 3rd Ed. Prentice-Hall, Inc. NJ. page 246. 2002.

CHAPTER

8

Reservoir and Basin Routing

Reservoirs and detention ponds are an important aspect of water resources management. Reservoirs and detention ponds change runoff timing and peak runoff rates while storing flows. Hydrologic studies must consider these effects when evaluating existing conditions or planning for future changes within the watershed. Figure 8.1 shows the San Gabriel Reservoir on April 28, 1975.



Figure 8.1
San Gabriel Reservoir
April 28, 1975

Reservoir routing for hydrologic studies within the County of Los Angeles uses the Modified Puls or Level Pool routing method. The method is similar to the method for channel routing, except that no translation is considered. Section 7.3, Channel Routing of Flows discusses the concepts of the

Modified Puls method in more detail. Equation 8.1 is the finite difference form of the continuity equation used for reservoir routing[1]. Equation 8.2 provides a relationship that is used to calculate outflow without actually calculating storage for a given time step. The example problem illustrates use of the equations.

$$(I_n + I_{n+1}) + \left(\frac{2S_n}{\Delta t} - O_n\right) = \left(\frac{2S_{n+1}}{\Delta t} + O_{n+1}\right)$$

Equation 8.1
Form of the Continuity Equation Used for Reservoir Routing

$$\left(\frac{2S_n}{\Delta t} - O_n\right) = \left(\frac{2S_n}{\Delta t} + O_n\right) - 2O_n$$

Equation 8.2
Relationship Used to Calculate Outflow Without Calculating Storage

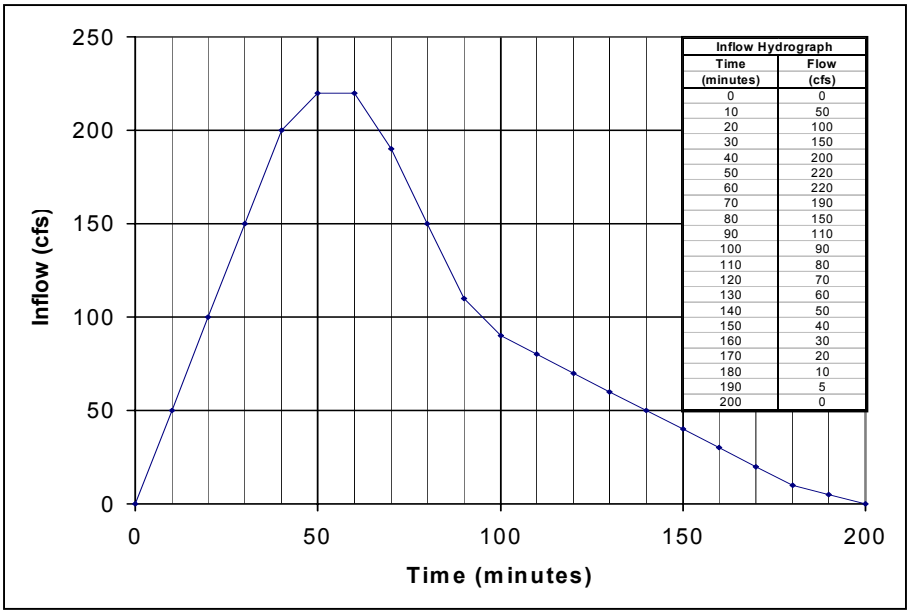
Where:
- I_n = Inflow at time$_n$
- I_{n+1} = Inflow at time$_{n+1}$
- Δt = Difference in time, time$_{n+1}$ - time$_n$
- S_n = Storage at time$_n$
- S_{n+1} = Storage at time$_{n+1}$
- O_n = Outflow at time$_n$
- O_{n+1} = Outflow at time$_{n+1}$

Reservoir routing using the Modified Puls method requires a storage-elevation relationship, an outflow-elevation relationship, and an inflow hydrograph. The relationships, the inflow hydrograph, and a known initial storage condition provide the information necessary to calculate outflow. The following example illustrates the use of the Modified Puls reservoir routing method.

EXAMPLE – Modified Puls Routing Through a Reservoir

This example routes an inflow hydrograph through a simple detention basin. Figure 8.2 defines the inflow hydrograph to be routed through the detention basin in this example.

The detention basin has the storage capacity shown in Table 8.1. Outflow from the basin occurs through an 24-inch drain when the water surface elevation is below 6 feet. When the water surface elevation is above 6 feet, outflow occurs through the drainpipe and over a weir. The weir is 20 feet long and has a weir coefficient of 3.5. Equations 8.3 and 8.4 provide the outflow relationships for the weir and drainpipe based on elevation as shown in Table 8.1.



Inflow Hydrograph	
Time (minutes)	Flow (cfs)
0	0
10	50
20	100
30	150
40	200
50	220
60	220
70	190
80	150
90	110
100	90
110	80
120	70
130	60
140	50
150	40
160	30
170	20
180	10
190	5
200	0

Figure 8.2
Inflow Hydrograph

Table 8.1 contains the storage-elevation and outflow-elevation relationships for this example. When outflow is based only on storage and no inflow is entering the reservoir, these relationships provide enough information to calculate outflow for a specified water surface. If there is inflow occurring at the same time as outflow, the Modified Puls method can be used to calculate outflow. The method requires building a storage indication curve using a specific time interval. The time interval must equal the time interval for the inflow hydrograph. This example uses a 10-minute time interval.

$$Q = CLH^{1.5}$$

Equation 8.3
Weir Flow Equation

$$Q = KA\sqrt{2gH}$$

Equation 8.4
Orifice Flow Equation

Where:
- Q = Outflow in cfs
- C = Weir Coefficient, 3.5
- L = Length of weir crest in feet
- H = Water surface elevation above weir in feet
- K = Orifice flow coefficient, 0.65
- A = Cross sectional area of orifice in ft^2
- g = Gravitational acceleration in ft/sec^2

Table 8.1
Storage-Elevation and Outflow-Elevation Relationships

Water Surface Elevation (ft)	Storage (ft^3)	Orifice Outflow (cfs)	Weir Outflow (cfs)	Total Outflow (cfs)	2S/Δt+O (cfs)	2S/Δt-O (cfs)
0.0	0	0.0	0.0	0.0	0.0	0.0
0.5	30,000	11.6	0.0	11.6	111.6	88.4
1.0	60,000	16.4	0.0	16.4	216.4	183.6
1.5	80,000	20.1	0.0	20.1	286.7	246.6
2.0	100,000	23.2	0.0	23.2	356.5	310.2
2.5	120,000	25.9	0.0	25.9	425.9	374.1
3.0	140,000	28.4	0.0	28.4	495.1	438.3
3.5	160,000	30.7	0.0	30.7	564.0	502.7
4.0	180,000	32.8	0.0	32.8	632.8	567.2
4.5	200,000	34.8	0.0	34.8	701.4	631.9
5.0	220,000	36.6	0.0	36.6	770.0	696.7
5.5	230,000	38.4	0.0	38.4	805.1	728.2
6.0	240,000	40.1	0.0	40.1	840.1	759.9
6.5	250,000	41.8	24.7	66.5	899.9	766.8
7.0	260,000	43.4	70.0	113.4	980.0	753.3
7.5	300,000	44.9	128.6	173.5	1173.5	826.5
8.0	340,000	46.4	198.0	244.3	1377.7	889.0

Figure 8.3 plots the storage indication curves for this detention pond using the 10-minute time increment. The storage indication curve relates storage to outflow and provides a graphical method for calculating outflow based on the Modified Puls Method. Without the graph, solving for outflow requires interpolation of Table 8.1.

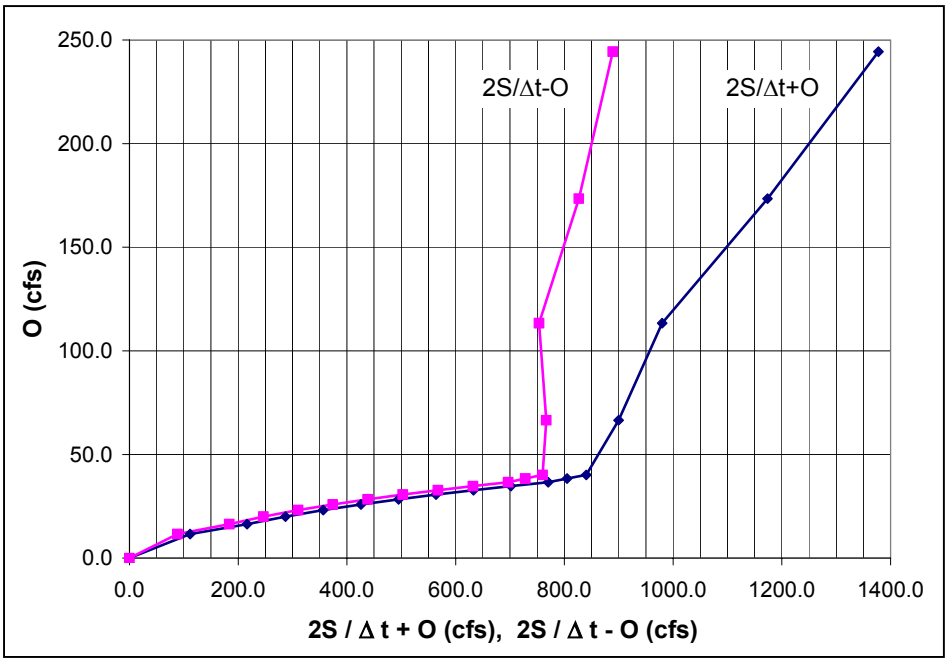


Figure 8.3
Storage-Indication Curve Based on 10-minute Time Interval

The storage-indication curve relates outflow to storage. Routing the flow through a reservoir requires solving graphically, or setting up a spreadsheet or computer program to perform the following steps:

1. Determine the initial storage, inflow, and outflow conditions and the inflow at the first time step (S_n, I_n, O_n, and I_{n+1}). The inflow cannot be greater than the outflow for the first time step.

2. Use the storage-indication curve to determine the storage and outflow for the second time step (S_{n+1} and O_{n+1}).

3. Repeat the steps 1 and 2 until the outflow hydrograph is completed.

The initial values for this example are:

S_1 = 0 ft^3
I_1 = 0 cfs
O_1 = 0 cfs
I_2 = 50 cfs
Δt = (10 minutes)*(60 sec/minute) = 600 sec

The initial values provide a solution to determine the first value on the storage indication curve. This value is calculated as follows:

$$(I_1 + I_2) + \left(\frac{2S_1}{\Delta t} - O_1\right) = \left(\frac{2S_2}{\Delta t} + O_2\right) \Rightarrow$$
$$(0 + 50) + (0) = \left(\frac{2S_2}{\Delta t} + O_2\right) = 50$$

The outflow value for the second time step is found by reading the storage indication curve for 50 cfs along the X-axis and finding the Y-axis value, or by interpolating between the values shown in the last two columns of Table 8.1.

O_2 = 5.2 cfs (from storage indication curve)

The outflow at 10 minutes is 5.2 cfs. This value then provides the information for the next time step.

Equation 8.2 provides the values for $2S_n/\Delta t - O_n$ at time steps after the initial time step:

$$\left(\frac{2S_2}{\Delta t} - O_2\right) = \left(\frac{2S_2}{\Delta t} + O_2\right) - 2O_2$$

The calculation for the second time step value of $2S_n/\Delta t - O_n$ is:

$$\left(\frac{2S_2}{\Delta t} - O_2\right) = (50) - 2(5.2) = 39.6 \text{ cfs}$$

The values for the second iteration are:

I_2 = 50 cfs
O_2 = 5.2 cfs
I_3 = 100 cfs
Δt = (10 minutes)*(60 sec/minute) = 600 sec

$$(I_2 + I_3) + \left(\frac{2S_2}{\Delta t} - O_2\right) = \left(\frac{2S_3}{\Delta t} + O_3\right) \Rightarrow$$
$$(50 + 100) + (39.6) = \left(\frac{2S_3}{\Delta t} + O_3\right) \Rightarrow 189.6$$

O_3 = 15.2 cfs (from storage indication curve)

Spreadsheets facilitate the Modified Puls calculations for reservoir routing. Table 8.2 provides the rest of the calculations for the detention basin routing problem. Many computer programs use this method to calculate outflow from reservoirs and detention basins.

Table 8.2
Outflow Hydrograph Calculation Using Modified Puls Method

Inflow Hydrograph			Outflow Hydrograph Calculations			
Time Index	Time (min)	Inflow (I_n) (cfs)	I_n+I_{n+1} (cfs)	$2S/\Delta t$-O (cfs)	$2S/\Delta t$+O (cfs)	Outflow O_{n+1} (cfs)
1	0	0.0	0.0	0.0	0.0	0.0
2	10	50.0	50.0	0.0	50.0	5.2
3	20	100.0	150.0	39.6	189.6	15.2
4	30	150.0	250.0	159.3	409.3	25.3
5	40	200.0	350.0	358.8	708.8	35.0
6	50	220.0	420.0	638.9	1058.9	137.9
7	60	220.0	440.0	783.1	1223.1	190.7
8	70	190.0	410.0	841.7	1251.7	200.6
9	80	150.0	340.0	850.5	1190.5	179.4
10	90	110.0	260.0	831.7	1091.7	148.1
11	100	90.0	200.0	795.6	995.6	118.2
12	110	80.0	170.0	759.2	929.2	83.7
13	120	70.0	150.0	761.9	911.9	73.5
14	130	60.0	130.0	764.8	894.8	64.3
15	140	50.0	110.0	766.2	876.2	56.1
16	150	40.0	90.0	764.1	854.1	46.3
17	160	30.0	70.0	761.5	831.5	39.7
18	170	20.0	50.0	752.0	802.0	38.3
19	180	10.0	30.0	725.5	755.5	36.2
20	190	5.0	15.0	683.0	698.0	34.7
21	200	0.0	5.0	628.7	633.7	32.8
22	210	0.0	0.0	568.1	568.1	30.8
23	220	0.0	0.0	506.5	506.5	28.8
24	230	0.0	0.0	449.0	449.0	26.7
25	240	0.0	0.0	395.5	395.5	24.7
26	250	0.0	0.0	346.1	346.1	22.7
27	260	0.0	0.0	300.7	300.7	20.7
28	270	0.0	0.0	259.3	259.3	18.6
29	280	0.0	0.0	222.0	222.0	16.7
30	290	0.0	0.0	188.7	188.7	15.1
31	300	0.0	0.0	158.4	158.4	13.7
32	310	0.0	0.0	131.0	131.0	12.5
33	320	0.0	0.0	106.0	106.0	11.0
34	330	0.0	0.0	84.0	84.0	8.7
35	340	0.0	0.0	66.5	66.5	6.9
36	350	0.0	0.0	52.7	52.7	5.5
37	360	0.0	0.0	41.8	41.8	4.3
38	370	0.0	0.0	33.1	33.1	3.4
39	380	0.0	0.0	26.2	26.2	2.7
40	390	0.0	0.0	20.8	20.8	2.2
41	400	0.0	0.0	16.5	16.5	1.7
42	410	0.0	0.0	13.0	13.0	1.4
43	420	0.0	0.0	10.3	10.3	1.1

[1] Bedient, P.B. and W.C. Huber. Hydrology and Floodplain Analysis, 3rd Ed. Prentice-Hall, Inc. NJ. page 256. 2002.

CHAPTER

9

Water Quality Hydrology

Water quality has been an important aspect of water resources planning and use for many years in Southern California[1]. Regulations protect water quality and seek to limit pollution in part by requiring that new developments meet certain criteria for pollution prevention. Other regulations sometimes result in the retrofitting of existing storm water conveyances to reduce pollution of impaired receiving water bodies. Since problems with the quality of runoff can be associated with common rainfall events, smaller, more frequent storms must be addressed. This section discusses several of the issues that relate hydrology to water quality issues.

9.1 STANDARD URBAN STORMWATER MITIGATION PLANS (SUSMP)[2]

The Standard Urban Stormwater Mitigation Plan (SUSMP) is part of the Development Planning Program of the National Pollution Discharge Elimination System, Phase I, Stormwater Permit for the County of Los Angeles. SUSMP applies to development and redevelopment projects within the County that fall within specific categories. The County of Los Angeles has developed a SUSMP manual that includes the permitting and inspection process for projects required to meet SUSMP regulations. Table 9.1.1 provides a summary of the types of development and activities that fall under SUSMP regulation. The SUSMP manual provides more specific information.

Table 9.1.1
Development or Redevelopment Activities Regulated by SUSMP

Development Type and Activities
• Single-family hillside homes
• Residential development of ten or more units
• Industrial/commercial developments with 1 acre or more of impervious surface area
• Automotive service facilities
• Retail gasoline outlets
• Restaurants
• Parking lots 5,000 ft^2 or more of surface area or with 25 or more parking spaces
• Redevelopment projects in these categories that meet redevelopment thresholds
• Locations within or directly adjacent to or discharging directly to an environmentally sensitive area
• Fueling Areas
• Equipment maintenance, washing and repair areas
• Commercial/Industrial waste handling or storage
• Outdoor hazardous material handling or storage
• Outdoor manufacturing areas
• Outdoor food handling or processing
• Outdoor animal care, confinement, or slaughter
• Outdoor horticultural activities

The objective of SUSMP is to effectively prohibit non-storm water discharges and reduce the discharge of pollutants from storm water conveyance systems to the Maximum Extent Practicable (MEP) statutory standard. SUSMP defines hydrology standards for designing volumetric and flow rate based Best Management Practices (BMPs).

Design of BMPs to meet hydrologic standards for SUSMP must follow the methods outlined in the SUSMP manual. The design must mitigate flows or volumes using one of the required runoff calculations.

SUSMP regulations allow four methods of runoff volume calculation for BMPs that treat stormwater on a volumetric basis. The four methods allowed to calculate flow volume are:

1. The 85th percentile 24-hour runoff event determined as the maximized capture storm water volume for the area, from the formula recommended in Urban Runoff Quality Management, WEF Manual of Practice No. 23/ ASCE Manual of Practice No. 87, (1998).

2. The volume of annual runoff based on unit basin storage water quality volume, to achieve 80 percent or more volume treatment by the method recommended in California Stormwater Best Management Practices Handbook – Industrial/Commercial, (1993).

3. The volume of runoff produced from a 0.75-inch storm event, prior to its discharge to a storm water conveyance system.

4. The volume of runoff produced from a historical-record based reference 24-hour rainfall criterion for “treatment” (0.75 inch average for the county area) that achieves approximately the same reduction in pollutant loads as the 85th percentile 24-hour runoff event.

SUSMP regulations also allow three methods to calculate flow rates for BMPs that treat stormwater on a flow through basis. The three methods allowed to calculate flow rates are:

1. The flow of runoff produced from a rain event equal to at least 0.2 in/hr intensity.

2. The flow of runoff produced from a rain event equal to at least two times the 85th percentile hourly rainfall intensity for the County of Los Angeles.

3. The flow of runoff produced from a rain event that will result in treatment of the same portion of runoff as treated using volumetric standards above.

SUSMP also requires controlling peak flow discharges to provide stream channel and overbank flood protection. This requirement relies on hydrology based on flow design criteria selected by the local regulatory agency. Chapter 4 specifies the peak flow discharge criteria.

Many of the references for the SUSMP manual are available online. The following web addresses are links to the SUSMP Manual and a few of the references.

SUSMP Manual:
http://ladpw.org/WMD/npdes/SUSMP_MANUAL.pdf

CalTrans Storm Water Quality Manual:
http://www.dot.ca.gov/hq/oppd/stormwtr/PPDG-stormwater-2002.pdf

California Storm Water Best Management Practices Handbooks (2003) for Construction Activity, Municipal, Industrial/Commercial, and new development:
http://www.cabmphandbooks.com/

Start at the Source (1999) by Bay Area Stormwater Management Agencies Association:
www.mcstoppp.org/acrobat/StartattheSourceManual.pdf

9.2 TOTAL MAXIMUM DAILY LOADS (TMDL)

Total Maximum Daily Loads fall under Section 303 of the Federal Clean Water Act, which is a different section than the NPDES permit section. Impaired water bodies require reducing the pollutant discharge to a level that the water body can assimilate. The reduction could decrease the pollutant discharges to levels lower than required by an NPDES permit in order to meet the TMDL. TMDLs apply to both wastewater and stormwater discharges. Control of stormwater pollutant concentrations and loads requires implementing Best Management Practices (BMPs). TMDL requirements can relate to storms greater than storms required by SUSMP[3].

Understanding and implementing the TMDL program mandated by the Clean Water Act (Section 303(d)) presents significant challenges for the responsible State Environmental Agencies. States develop TMDLs to determine how to reduce pollution from point sources and non-point sources so that the pollutant loads stay below the maximum specified in the TMDL. Point sources include industrial and municipal facilities that discharge to water bodies. Non-point sources of pollution include urban runoff, agriculture, forestry, septic systems, and air deposition[4].

States are required to prioritize waters/watersheds for TMDL development. States compile this information in a list and submit the list to the United States Environmental Protection Agency for review and approval. The list is known as the 303(d) list of impaired waters. TMDLs are documents that describe a specific water quality attainment strategy for a water body and the related impairment identified on the 303(d) list. TMDLs may include more than one water body and more than one pollutant.

The TMDL defines specific measurable features that describe attainment of the relevant water quality standards. TMDLs include a description of the total allowable level of the pollutant(s) in question and allocation of allowable loads to individual sources or groups of sources of the pollutant(s) of concern[5].

Each TMDL is for a specific water body and runoff mitigation can be represented by various hydrologic methods. For example, current trash TMDL regulations require that no man-made trash enter the water body at any time. However, hydrology studies for the trash TMDL use the 1-year, 1-hour storm to determine the flow rate that certain treatment systems must accommodate. The Santa Monica Bay Bacteria TMDL does not specify a design storm, but requires that bacteria levels remain below a certain concentration within the wave-wash of the bay. Figure 9.2.1 shows an example of low flow in a channel.



Figure 9.2.1
San Gabriel River
Low Flow Channel

Establishing TMDL hydrology requires data for rainfall, runoff, and water quality. Several agencies recognize the need to collect more water quality data, standardize collection methods, and create reporting methods that make this data more available[6,7]. Defining hydrology methods used to design systems to meet TMDL standards requires understanding of the TMDL and water quality issues. As more data is collected and more TMDLs are established, standard TMDL hydrology procedures must be established.

9.3 BEST MANAGEMENT PRACTICES (BMPS)

Best Management Practices (BMPs) are actions and devices that improve or prevent the pollution of urban runoff and stormwater. The 2001 Los Angeles Municipal Stormwater Permit defines BMPs as "…methods, or practices, designed and selected to reduce or eliminate the discharge of pollutants to surface waters from point and non-point source discharges including storm water. BMPs include, but are not limited to, structural and nonstructural controls, and operation and maintenance procedures. BMPs can be applied before, during, and after pollution-producing activities."

BMPs can be proprietary or nonproprietary. Proprietary BMPs include patented and/or manufactured devices. Nonproprietary BMP designs are public domain and include detention basins, grassy drainage swales, catch basin stenciling, and public education.

Under the stormwater requirements of the federal Clean Water Act, stormwater quality must be improved to the "Maximum Extent Practical." The installation of BMPs is considered to meet that requirement.

In Phase II of the Federal Stormwater Permit process, the EPA breaks BMPs into six categories that deal with prevention and treatment of stormwater. The list is:

1. Public education and outreach on stormwater impacts
2. Public involvement/participation
3. Illicit discharge detection and elimination
4. Construction site stormwater runoff control
5. Post-construction stormwater management in new development and redevelopment
6. Pollution prevention/good housekeeping for municipal operations

Each of the six categories contains specific BMPs targeted to improve water quality. More information on the categories and BMPs is available through the EPA[8]. Figure 9.3.1 shows an example of a coastal wetland.



Figure 9.3.1
Coastal Wetland

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1 California Environmental Protection Agency. State Water Resources Board History. www.calepa.ca.gov/About/History01/

2 Los Angeles County Department of Public Works. Development Planning for Stormwater Management:
A Manual for the Standard Urban Stormwater Mitigation Plan. September 2002.

3 Los Angeles County Department of Public Works. TMDL Information on Webpage. www.ladpw.org/general/faq/index.cfm?Action=searchResults

4 America's Clean Water Foundation and the Association of State and Interstate Water Pollution Control
Administrators. www.tmdls.net

5 California Environmental Protection Agency, State Water Resources Control Board. http://www.swrcb.ca.gov/tmdl/

6 Committee on Assessment of Water Resources Research, National Research Council. Confronting the
Nation's Water Problems: The Role of Research. The National Academies Press. Washington, D.C. 2001. http://books.nap.edu/catalog/11031.html

7 United States Government Accountability Office. Watershed Management: Better Coordination of Data

Collection Efforts Needed to Support Key Decisions. GAO-04-382. www.gao.gov/cgi-bin/getrpt?GAO-04-382

[8] National Menu of Best Management Practices for Stormwater Phase II. United States Environmental Protection Agency. http://cfpub.epa.gov/npdes/stormwater/menuofbmps/menu.cfm

CHAPTER

10

Hydrologic Data Requirements and Sources

Hydrologic studies require the use of mathematical models. A model is a representation of physical systems using equations. The parameters in these equations change to represent different hydrologic conditions. Hydrologic models have many forms and attempt to represent many different physical processes. The models used by the County of Los Angeles are lumped parameter models. This means that they consider the spatial variation of parameters only down to a certain level. Below this level, parameters are aggregated using an average.

Whether using hand or computer automated calculations, an important task of model preparation is gathering the input data. Section 10 provides information on obtaining various types of data required for hydrologic modeling.

10.1 REQUIRED DATA

Creating watershed models commonly requires the data types shown in Table 10.1.1. The following sections and chapters present the procedures for obtaining and using data for hydrologic modeling.

Table 10.1.1
Required Watershed Data

Required data	Description
Subarea Size	The surface area inside the subarea boundaries
Flow Path Length	Length of the conveyance between subarea collection points
Flow Path Slope	Slope of the flow path used for calculating the T_C
Conveyance Data	A description of the flow conveyance between subarea collection points (length, slope, width, roughness, etc.)
Soil Types	A soil classification identifying the hydrologic characteristics of the area's surface soils
Land Use / Imperviousness	A classification of impervious surface area based on development types within the subarea
Design Storm Definition	Each subarea has a unique design storm based on the location and the rainfall recurrence interval being modeled
Time of Concentration	The time required for runoff from the most hydrologically remote point in a subarea to reach the subarea collection point

10.2 DATA SOURCES

The Hydrology Manual is the official reference for developing design hydrology. There are several other resources available to provide data for hydrologic studies within the County of Los Angeles.

Hydrology Manual Appendices

The Hydrology Manual and Appendices contain the maps and charts necessary to create the hydrologic models.

Appendix A includes a chart and a table representing the unit hyetograph used to develop design storms for the County of Los Angeles. Section 5.2 discusses the development and application of this temporal rainfall distribution.

Appendix B contains USGS Quadrangle maps overlaid with spatial data for the entire county. These include overlays of the 50-year, 24-hour rainfall isohyets, soil type, and debris production area (DPA) zones. Soil type boundaries assist in determining the predominate soil type within a subarea and the appropriate runoff coefficient curve. DPA zones are provided for use

in the bulking process and to determine sediment production rates (see the Sedimentation Manual).

Appendix C contains soil names and characteristic information for the 179 soils defined for use with the Modified Rational Method. A soil identification table relates the soil numbers used by Public Works to the Natural Resources Conservation Service (NRCS) or Public Works assigned soil names. Graphs of the soil runoff coefficient curves represent the relationship between undeveloped runoff coefficients and rainfall intensity.

Appendix D contains a table of proportion impervious values for each of the SCAG land use types. While not shown in Appendix B, the land use patterns for the entire county are available as Geographic Information System (GIS) shapefiles.

Geographic Information System (GIS) and Electronic Data

Geographic Information Systems have an important role in current Public Works hydrologic studies. Most watershed characteristics vary by location. These spatial distributions lend themselves to GIS uses. The use of GIS allows the modeler to collect data quickly and accurately. Some computer programs integrate GIS and hydrologic modeling. These programs import and extract GIS data and provide this data to the hydrologic model for use in calculations.

Table 10.2.1 contains information on the principle GIS data available for hydrologic studies within the County of Los Angeles.

Georeferenced USGS Quadrangle map images are used as topographic maps for developing county design hydrology. These images can be opened in the GIS. These maps serve as the basis for delineation of watershed subareas and flow paths. These maps also serve as the basis for delineating the location of hydrologically important structures. Since the image is georeferenced, the resulting lines and subarea polygons have an associated length and area.

Aerial photographs can serve a similar function to map images. Photographs are useful because they can be used to identify various features such as roads, structures, land use, vegetative cover, and bodies of water. Aerial photos are also georeferenced images.

Digital Elevation Models (DEMs) and Triangular Irregular Networks (TINs) are used to find slopes for each subarea. Some programs automatically delineate watershed boundaries and stream channels using these data sources. DEMs are grids with an elevation assigned to each grid block. USGS DEMs are available in 10 meter and 30 meter resolutions for most of the county. The resolution refers to the size of each block in the grid. TINs replicate the ground surface using triangles formed by irregularly spaced points with known X, Y, and Z coordinates. DEMs and TINs are created from topographic survey data.

Table 10.2.1
GIS Data Types

GIS Data Types	File Type
USGS Topographic “Quad” Maps	Image, typically “quad name”.tif
Aerial Photographs	Image, typically *.jpg, *.tif
Digital Elevation Models (DEMs)	*.asc,
Triangulated Irregular Networks (TINs)	*.tin
LA County soil shapefile	soils_2004.shp
LA County land use shapefile	ladpw_landuse_2005.shp
LA County rainfall grid	lac50year24hr.asc, for the 50-year frequency

The soil type is another attribute represented spatially as GIS data. A soil shapefile indicates the areas covered by each soil type. GIS models then assist in determining which soil type is predominate in a given subarea.

Land use data is available only as a GIS file. Each of the land use polygons represent a different development type and have an imperviousness value assigned. GIS based models can calculate and assign an area weighted composite imperviousness value to each subarea based on the land use data in the GIS files.

10.3 FIELD RECONNAISSANCE

A field investigation is necessary for all design hydrology projects. The purpose is to gather information that might not be apparent from the data sources discussed in Section 10.2, and to confirm that the data gathered is

correct. The field investigation is also an opportunity to resolve any discrepancies present in other data collected. Assumptions such as land use and roughness of conveyances should also be verified.

In urban areas, a field investigation is required. Watershed boundaries in these areas are influenced greatly by man-made drainage features. Many of these features are not significant enough to be represented in elevation data or topographic maps and are not visible on aerial photos. The only way to determine the flow pattern in these cases is by field investigation.

While no standard procedure suits all projects, listed below are some basic field check guidelines as a starting point for urban studies.

1. Take a base map overlaid with the existing and proposed flow paths and conveyances identified in the initial research. Take an enlarged street map to use as your field check map.

2. Start your field check at the outlet of the drainage area. Crisscross the watershed heading upstream while preparing the map.

3. Note the following on the field check map:

    - Surface flow directions at every street intersection for both sides of the street; note the flow direction with an arrow pointing downhill. Show gutters, cross gutters, catch basins, burpers, sumps and grade breaks. Also, note any streets without curbs. Use the field check symbols in Figure 10.3.1.

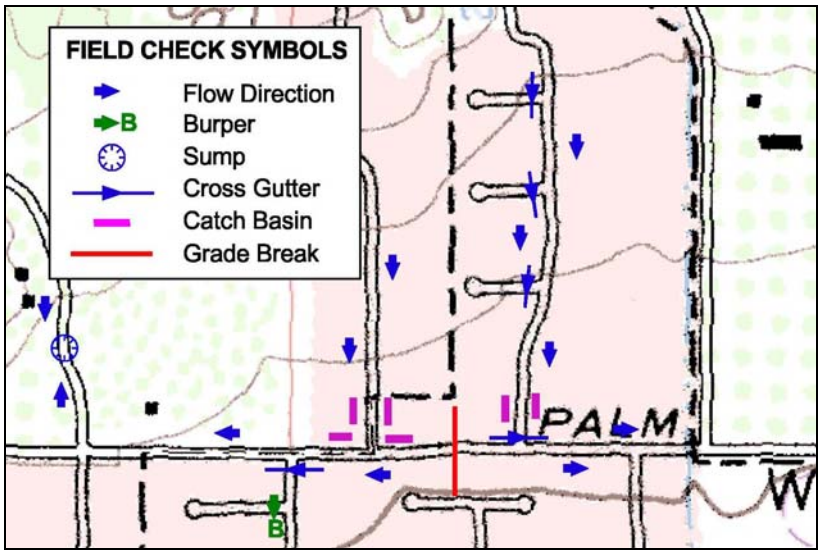


Figure 10.3.1
Field Check Symbols Map

- Check the types of development, such as single family or industrial, in order to verify the percent impervious.

- Check surface flow directions off property so that "frontage" along streets can be accounted for.

4. Get out of the car to investigate when there is uncertainty about flow directions.

5. Take a carpenter's level and place it in the gutter to determine the direction of flow on streets that are flat. Slopes are sometimes deceiving; use the level when in doubt.

6. Before leaving the area, check the map and note any flow contradictions. Now is the time to go back and resolve them. After the field check, research any new issues that may have come up such as unexpected drain locations or flow patterns.

10.4 WATERSHED DELINEATION

A watershed is an area of land that drains to a given location. The process of delineating the watershed for a given point is an important part of creating a hydrologic model.

Watershed delineation requires a source of elevation data such as a topographic map. For the purposes of delineation, there are several important things to remember about topographic maps.

The contour lines are of equal elevation.

Water will follow a path perpendicular to the contour lines. All streams are perpendicular to the contour lines. Contour lines will generally form a “V” or an arrow pointing upstream where they cross streams.

Ridgelines are lines of high ground separating one watershed from another. Ridges may also appear as “V”s or arrows pointing down hill. A watershed boundary follows ridgelines. A drainage boundary will not intersect a stream or flow path except at the drainage area outlet.

See Figure 10.4.1 for examples of typical topographic forms.

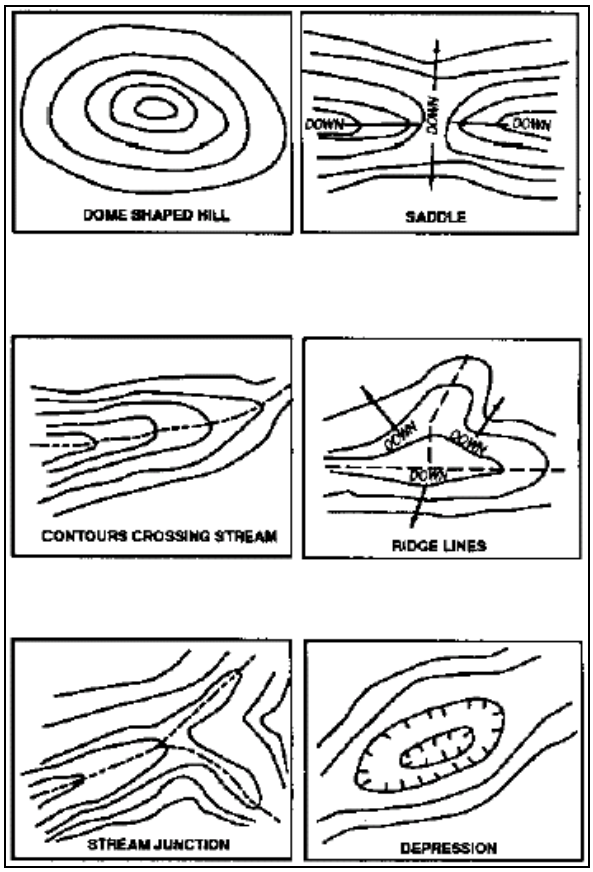


Figure 10.4.1
Typical Topographic Forms
Courtesy of Army Corps[1]

As an example, consider the watershed delineation of Webber Canyon. Figure 10.4.2 shows the topographic map in the area surrounding Webber Canyon.

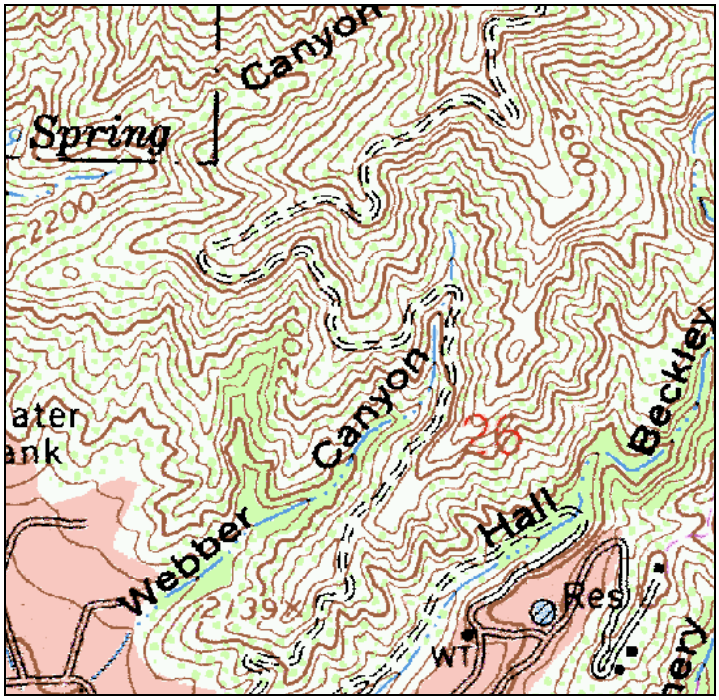


Figure 10.4.2
Topographic Map of Webber Canyon

Consider a point at the mouth of Webber Canyon, just below the "W" in the word "Webber". Webber Canyon and its tributaries upstream of this point comprise the watershed for the hydrology study.

Start by determining the outlet location where a flow rate value is needed, which for this example is location 1 in Figure 10.4.3. From this location, draw a line separating areas that contribute water to this location from areas that do not. Draw a line from the outlet point to the point on the adjacent contour. The line must be perpendicular to the contour line at the point where it crosses location 2.

Continue following and crossing the contours lines. Note that where the watershed boundary coincides with a sharp ridge, the line will be following

the “V”s. Where ridgelines meet, it is important to make sure that the areas enclosed within the boundary are part of the same stream network.

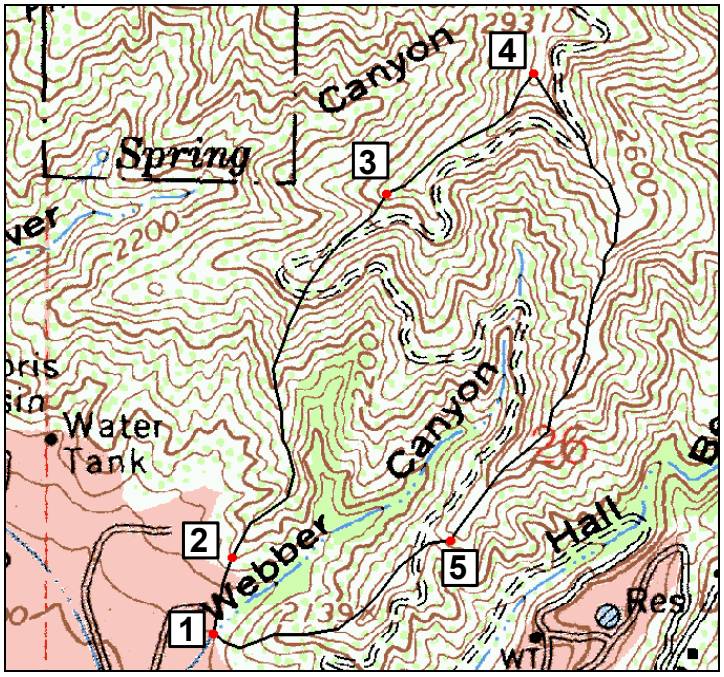


Figure 10.4.3
Webber Canyon Watershed Delineation

At location 3, continue connecting “V”s past the intersection of ridgelines because the intersecting ridge separates Webber Canyon from a tributary. However, location 4 shows the ridgeline intersection that separates Webber Canyon from other watersheds. Stop at a point on the nose of the ridge and then continue back downhill following the intersecting ridge along the arc between locations 4 and 5. Continue down this ridge until you reach the watershed outlet once again at location 1. The area inside the boundary you have drawn is the watershed tributary to the chosen outlet point.

For modeling purposes, it is sometimes necessary to break a watershed up into smaller pieces called subareas. This is done by adding additional outlets upstream of the final outlet and following the same procedure. Outlets should be added at break points on the flow path. These points might include changes in slope, changes in conveyance, entry of laterals or external flows, or points where catch basins are needed. Subarea definition often depends on the purpose of the hydrologic study.

This simple example shows watershed delineation using only a topographic map. As discussed in Section 10.2, topographic maps are insufficient to define the drainage pattern in flat areas and urban areas where man-made drainage features must be considered. In these cases, watershed delineation must account for the actual drainage patterns and collection systems.

Determine the drainage area boundaries for the entire project watershed first. Then draw in the flow paths. The flow paths should include existing and proposed drains. Divide the drainage area into subareas by locating significant collection points in the watershed and delineating the subareas. Subarea delineation follows the same steps as watershed delineation.

10.5 COLLECTING SUBAREA DATA

A primary task in any hydrology study is gathering site specific data that will dictate the way runoff is produced. After delineating the watershed and subareas as described in Section 10.4, it is now possible to collect subarea data. Studies commonly require the lengths and slopes of flow paths and time of concentration paths, characteristic soil types, and percent imperviousness. Data collection is described in the following list.

1. Determine the subarea size using a planimeter or GIS.

2. Determine the length and average slope of conveyances. Draw a path that follows the main watercourse between the outlet of the upstream subarea and the next downstream subarea outlet. Measure the conveyance length using a scale or GIS. Determine the top and bottom elevation and calculate the slope of each conveyance length.

3. Determine the length and average slope of time of concentration paths. The procedure for T_C paths is the same as for conveyances. However, T_C paths are drawn from the furthest or most hydrologically remote point in a watershed subarea to the outlet. This is not necessarily the longest path distance but the one that would take the longest time for water to travel to the outlet.

4. Locate the soil type boundaries on the maps in Appendix B or using GIS, and determine the predominate soil type in the subarea. For the Modified Rational Method, the selected soil's runoff coefficient curve will be used to carry out all the necessary runoff calculations in the subarea.

5. Determine the type and extent of development in each subarea. Land use helps determine the amount of directly connected impervious area and hence the amount of rain that will runoff directly. The land use types have been assigned a percent imperviousness as shown in Appendix D. Each subarea requires an area-weighted average of percent imperviousness.

10.6 COLLECTING RAINFALL DATA

For simulation of a single event, rather than using the rainfall data from a real storm, a design storm is used. The design storm is described in Chapter 5. In order to account for the spatial variability of rainfall, the design storm assumes different magnitudes based on its location. Each subarea has a distinct, 50-year, 24-hour rainfall depth based on its position within the rainfall grid. The procedure for determining the average design rainfall is called the Isohyetal Method.

1. Locate the isohyetal lines on the quad maps from Appendix B and use the methods from Section 5.4 to assign each subarea an isohyetal depth for the 50-year, 24-hour event.

2. If the modeled event will be other than the 50-year, use the Rainfall Frequency Factors in Table 5.3.1 to convert this isohyetal depth for the desired frequency.

3. Produce the design hyetograph by multiplying each point on the unit hyetograph by the isohyetal depth.

For some dams it is necessary to evaluate runoff from standard design storms and the Probable Maximum Flood (PMF). Development of the design storm for the PMF must follow the procedures of Hydrometerological Report (HMR) No. 59. In this case, other specific data about the watershed may need to be collected.

Chapter 5 describes the derivation of the design storm and the isohyetal maps from rain gage data collected in the county. Public Works' operates and maintains over 250 rain gages. These rain gages record rainfall amounts for durations from 5 minutes to 24 hours. Many of these rain gages have records that are greater than 50 years in length. Daily and annual rainfall amounts are available in the annual Public Works' Hydrologic Report

and at http://www.ladpw.org/wrd/report/. Intensities for other durations are available by contacting the Hydrologic Records Section.

Public Works collects rainfall data using non-recording and automatic recording rain gages. Non-recording gages collect rain and hold it in a container until it can be measured using a dipstick or graduated marking on the side of the collector. Volunteer observers typically read these gages daily at a specified time.

The automatic recording gages record the rainfall amounts for shorter time intervals. All of the Public Works' recording gages use tipping buckets to measure rainfall. The gages have a set of buckets that are alternately filled. When one of the buckets fills to a predefined amount, it tips. The other bucket then moves into the filling position. The frequency of the tipping allows the corresponding rainfall intensity to be calculated. This type of recording gage allows for very precise definition of a hyetograph. Most of the recording rain gages are connected to a central computer system using radio and satellite links so that rainfall amounts can be monitored in real-time. These gages are part of the Automatic Local Evaluation in Real-Time (ALERT) network. This network provides information for decision making during storm events.

10.7 CONVEYANCES

Conveyances are the links within a hydrologic model that simulate the flow of water through channel reaches. A hydrograph is specified at the top of a reach and a resulting outflow hydrograph is calculated at the bottom. Conveyance modeling is necessary due to the reduction of peak flow rates by attenuation and travel time. These processes affect the hydrograph at the downstream end of the conveyances.

The Modified Rational method uses six conveyance types: mountain, valley, street, circular pipe, rectangular channel, and trapezoidal channel. The types of conveyances between subarea collection points must be determined. The type of conveyance is important because water will flow much faster in a pipe than through a valley. Select the type that best characterizes the existing or planned conveyance. Several of the types require additional information about the dimensions and characteristics of the conveyance. The various conveyance types are described in detail in Section 7.3.

The length and slope of the conveyance between collection points are also important in determining the effects of hydrologic routing. The conveyance lengths are determined by measuring the flow path length using a scale or GIS. This length information is combined with the elevation data from a DEM or topographic map to determine the slope. For natural mountain and valley conveyances, the slope must be corrected using the slope correction curve, Figure 7.3.10.

Figure 10.7.1 shows water being conveyed on the streets of Lakewood after the 1950 storm season.



Figure 10.7.1
Streets of Lakewood Flooding After 1950 Storm

[1] US Army Corps of Engineers, "Topographic Surveying", Manual 1111-1-1005. Washington D.C. August 31, 1994.

CHAPTER

11

Time of Concentration Calculation

The time of concentration is the time required for runoff from the most hydrologically remote point in the subarea to reach the subarea outlet. The Modified Rational Method requires a time of concentration calculation for each subarea.

In the past, Public Works used kinematic wave theory to calculate the time of concentration (Section 7.3). To simplify these calculations, Public Works developed a regression equation based on hundreds of studies using kinematic wave theory. The regression equation replaces the original kinematic wave calculations.

Time of concentration calculations can either be done by hand (Section 11.1) or using the T_C calculator program (Section 11.2). Watershed Modeling System (WMS) and XP-SWMM software also incorporate these calculations.

11.1 TIME OF CONCENTRATION – HAND CALCULATIONS

The following provides a step-by-step approach for using the regression equation to calculate the time of concentration. The steps show the calculations for the example in Chapter 7 shown in Figure 7.3.3.

1. **Determine subarea boundaries and then calculate flow path length and flow path slope**

   L = 1,150 feet
   S = (150*0.02+1,000*0.005) / 1,150 = 0.007 ft/ft

2. **Assume an initial value for T_C**

   Assume T_C = 12 minutes

3. Use Equation 5.1.2 to calculate intensity at time t, I_t

$$I_t = I_{1440} * \left(\frac{1440}{t}\right)^{0.47} \Rightarrow I_{12} = \frac{5\,\text{in}}{24\,\text{hr}} * \left(\frac{1440}{12}\right)^{0.47}$$
$$= 1.98 \text{ in/hr}$$

4. Determine the developed soil runoff coefficient using the soil curve data and Equation 6.3.2.

$$C_d = (0.9 * IMP) + (1.0 - IMP) * C_u$$
$$= (0.9 * 0.42) + (1.0 - 0.42) * 0.58 = 0.71$$

5. Use Equation 7.3.5 to determine a new T_C value

$$T_C = \frac{0.31 * L^{0.483}}{(C_d * I_t)^{0.519} * S^{0.135}}$$

$$= \frac{0.31 * 1150^{0.483}}{(0.71 * 1.98)^{0.519} * 0.007^{0.135}} = 15.27 \text{ minutes}$$

6. Compare initial assumption with new T_C value

15.27 minutes > 12.0 minutes

7. If the value is not within 0.5 minutes of the assumed, use the new T_C value and begin at Step 3 to complete another iteration

Use T_C = 15 minutes for the next assumption

8. Iterate until initial and final T_C values are with 0.5 minutes

The new values using T_C = 15 minutes are:

I_t = 1.78 in/hr
C_u = 0.54
C_d = 0.69
T_C = 16.37 minutes

The difference between 15 and 16.37 is greater than 0.5 minutes
Use T_C = 17 minutes and recalculate

I_t = 1.68 in/hr
C_u = 0.53
C_d = 0.69
T_C = 16.87 minutes

The difference between 17 and 16.87 is less than 0.5 minutes, use T_C = 17 minutes for subarea.

The acceptable T_C range is from 5 to 30 minutes. If a T_C of less than 5 minutes is calculated, use 5 minutes. If a T_C greater than 30 minutes is calculated for the 50-year 24-hour design storm, the subarea must be divided into two subareas.

11.2 TIME OF CONCENTRATION - T_C CALCULATOR

Public Works developed a time of concentration calculator to automate time of concentration calculations. In addition to carrying out the T_C calculation process, the T_C Calculator completes the full modified rational runoff calculation process yielding peak runoff rates and volumes. Routing is not a feature in the calculator.

The T_C Calculator spreadsheet, “TC_calc_vol.xls”, has been included on the CD with the Hydrology Manual.

1. The inputs to the calculator are the same as for the hand calculation method and are summarized in Table 11.2.1:

Table 11.2.1
T_C Calculator Inputs

Subarea size	7 acres
Soil type	068
Land use	42% impervious
Flow path length	1150 feet
Flow path slope	0.007
Rainfall depth	5 inches

2. If burned flow rates are desired, the appropriate fire factor should be determined from Table 6.3.3. In this case, no burned flow rate was necessary. A fire factor of 0 was used.

3. Figure 11.2.1 shows the interface for the T_C calculator with the data for Subarea 1A entered. For calculating the runoff from a single subarea, fill out the boxes in the upper left hand corner of the calculator under "Subarea Parameters Manual Input." Depressing the "Calculate T_C" button in the lower right will display the results shown in the figure.

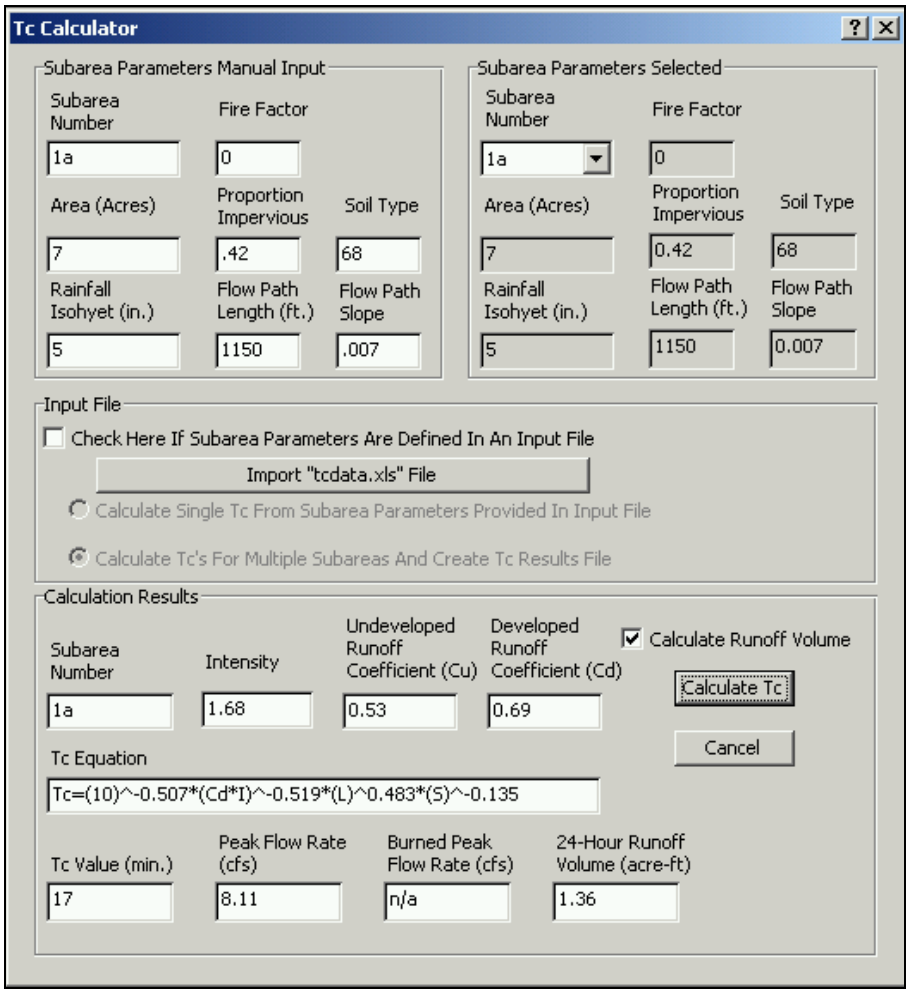


Figure 11.2.1
T_C Calculator Interface with Subarea 1A Results

The calculated T_C value, intensity, runoff coefficients, and peak flow rate are all the same as the values reached by hand calculation. Round off error and the uncertainties of reading table values cause the minor differences. The 24-hour runoff volume is also calculated if the "Calculate Runoff Volume" box is checked. By checking this box, the number of calculations increases and may take more time to display the results.

4. To calculate multiple subareas simultaneously, the T_C calculator can also accept Excel spreadsheets as input files containing a number of subareas. This file must be in the format specified in the “datasamp” sheet of the T_C calculator and in Figure 11.2.2

	A	B	C	D	E	F	G	H	I	J
1	Project	Subarea	Area	%imp	Frequency	Soil Type	Length	Slope	Isohyet	Fire Factor
2	Example	1a	7	0.42	standard	68	1150	0.007	5	0
3	Herondo Drainage	32j	30	0.92	standard	10	2525	0.008	4.52	0
4	Herondo Drainage	24g	19	0.92	standard	10	1950	0.006	4.38	0
5	Herondo Drainage	6a	11	0.92	standard	10	1600	0.017	4.24	0
6	Herondo Drainage	32j	30	0.92	standard	10	2525	0.008	4.1	0
7	Herondo Drainage	24g	19	0.92	standard	10	1950	0.006	3.96	0

Figure 11.2.2
T_C Calculator Input File Format

Name the Excel spreadsheet “tcdata.xls”. To use an input file with the program, first check the box on the input dialog that says, “Check Here If Subarea Parameters Are Defined In An Input File”. Then select the button labeled, “Calculate T_C’s for Multiple Subareas and Create a T_C Results File.”

Import the data by clicking “Import ‘tcdata.xls’ File” button. Once the data is imported, the box in the upper right corner of the calculator window displays data for individual subareas. You can select a subarea of interest by scrolling through the pull down box called “Subarea Number” at the right.

5. After pressing the “Calculate Tc” button, you will be prompted to name the results file. The results can then be viewed using Excel or individually using the pull down box. The results file shown in Figure 11.2.3 contains all the input and output information.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Project	Subarea	Area (acres)	%imp	Frequency	Soil Type	Length (ft)	Slope (ft/ft)	Isohyet (in.)	Tc-calculated (min.)	Intensity (in./hr)	Cu	Cd	Flow rate (cfs)
2	Example	1a	7	0.42	standard	68	1150	0.007	5	17	1.68	0.53	0.69	8.11
3	Herondo Drainage	32j	30	0.92	standard	10	2525	0.008	4.52	25	1.27	0.23	0.85	32.39
4	Herondo Drainage	24g	19	0.92	standard	10	1950	0.006	4.38	23	1.28	0.23	0.85	20.67
5	Herondo Drainage	6a	11	0.92	standard	10	1600	0.017	4.24	17	1.42	0.27	0.85	13.28
6	Herondo Drainage	32j	30	0.92	standard	10	2525	0.008	4.1	27	1.11	0.18	0.84	27.97
7	Herondo Drainage	24g	19	0.92	standard	10	1950	0.006	3.98	25	1.11	0.18	0.84	17.72

Figure 11.2.3
T_C Calculator Results File for Multiple Subareas

Peak Flow Rate and Volume Calculations

Runoff volumes are calculated by calculating runoff rates for multiple time steps. Section 7.3.2 explains the calculations needed to define a hydrograph. The volume of flow equals the total area under the hydrograph.

Calculating flow volume by hand is impractical for all but the simplest cases. The T_C Calculator program has an option that allows the user to calculate the total runoff volume. After indicating this intention by checking the box marked “Calculate Runoff Volume,” the user can produce the 4th day runoff volume by pressing the “Calculate Tc” button and naming the output file as before.

Substituting the rainfall depths for the first through third days into the calculator produces daily runoff volumes for the other days of the design storm. Rainfall depths for these days are a specified percentage of the fourth day as Table 11.2.2 indicates.

Day of Storm	Percentage
1st day	10%
2nd day	40%
3rd day	35%

Table 11.2.2
Percentage of Fourth Day Depth

The T_C calculator also produces a hydrograph plot when calculating runoff volumes. The hydrographs are accessed by pressing cancel in the calculator. This takes you to the workbook that contains the sheets that store the data behind the calculator interface. One of these sheets is labeled “hydrograph chart”. The hydrograph shown is from the last subarea selected for analysis. Figure 11.2.4 shows the runoff hydrograph for the previous example.

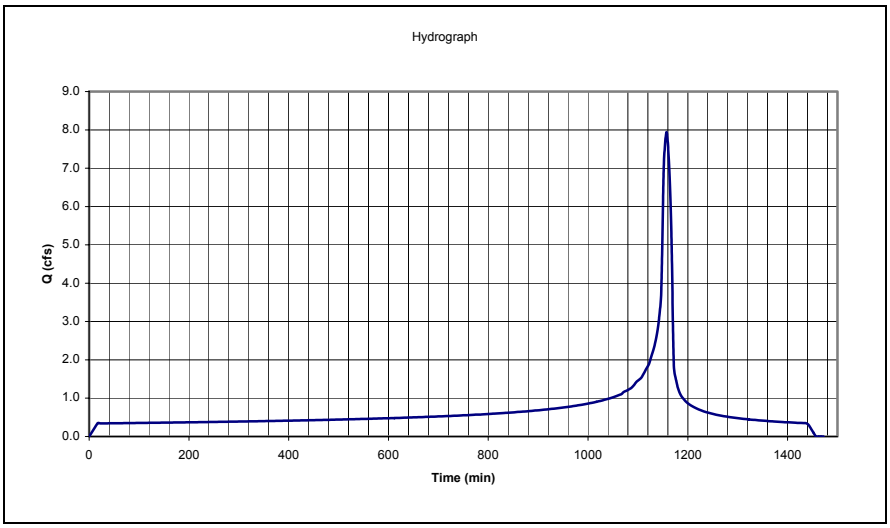


Figure 11.2.4
Runoff Hydrograph From the T_C Calculator

Storage Volume Requirements

Regional Basins

Regional Basins must be able to handle the 4-day design storm runoff volume. This may be accomplished by passing the first 3 days of storm flow through the basin, if the flow rate increase does not exceed pre-development flow rate levels. The regional basins must be able to store the post-development 4-day runoff volume, excluding the outflow during the storm. The basins must also meet other requirements determined by Land Development Division and Building and Safety Division.

∆Q Basins – Antelope Valley

∆Q Basins must store the change between pre- and post-development flow volumes, from all 4 days, for a 25-year event for percolation.

CHAPTER

12

Rational & Modified Rational Modeling

12.1 WATERSHED MODEL CREATION

The County of Los Angeles uses two related methods, the Rational and Modified Rational Method to calculate runoff rates. This section describes the necessary steps for creating a watershed model using both methods.

The first step in creating a model is to delineate the watershed using the methods described in Section 10.2. For countywide uniformity, subarea sizes should be approximately 40 acres. Smaller subarea sizes are acceptable.

Once the watershed and subareas are delineated, subareas and outlets must be numbered. The County of Los Angeles uses a subarea numbering system for hydrologic modeling that indicates the spatial relationships without the need for a diagram. A number and letter are assigned to each subarea and collection point.

Figure 12.1.1 shows an example of watershed numbering. Subarea IDs are indicated with a box and outlets are indicated with a leader. Numbers are assigned starting along the “mainline”. This is typically the longest stream channel in a watershed.

The upper most subarea on the mainline is assigned the label 1A. The watershed outlet of Subarea 1A is labeled 2A. The next watershed downstream from 1A is labeled 3A. In the example, Subarea 3A shares its outlet with another subarea, so instead of assigning the ID 4A to this outlet, 4A is assigned to the connecting subarea. The outlet downstream of 3A and 4A is labeled 5A. The numbering continues sequentially downstream.

When a confluence point with another stream or tributary is reached, numbering continues at the upstream end of the second stream or tributary. In the example, the A-line subarea upstream of the confluence is numbered

8A. The most upstream subarea in the confluencing stream is numbered 9B. The B-line is numbered the same way as the A-line. When the B-line reaches the confluence with the A-line, the confluence ID requires two suffix letters. One represents the mainline and the other represents the lateral. In this case, the confluence is labeled 16AB. This ends the B-line numbering. Continue the numbering in sequence using the suffix A. This numbering system can be extended to accommodate any number of confluencing laterals.

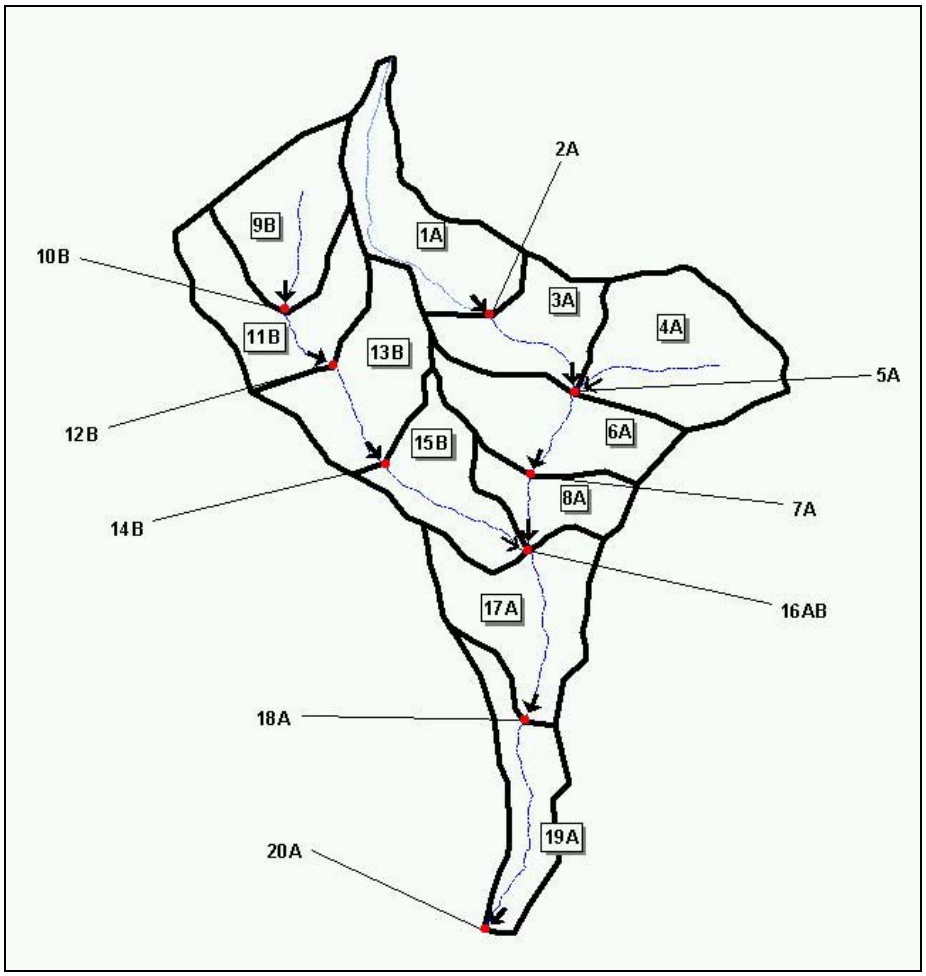


Figure 12.1.1
Watershed Numbering Example

Diversions are numbered as reverse confluences and begin at a collection point numbered with two suffix letters. The first letter represents the line where the diversion occurs. The second represents the letter for the diversion line. The diversion can be collected further downstream at a confluence or be allowed to divert water out of the watershed being studied. Figure 12.1.2 shows the same example of watershed numbering except with a diversion just upstream of the watershed outlet.

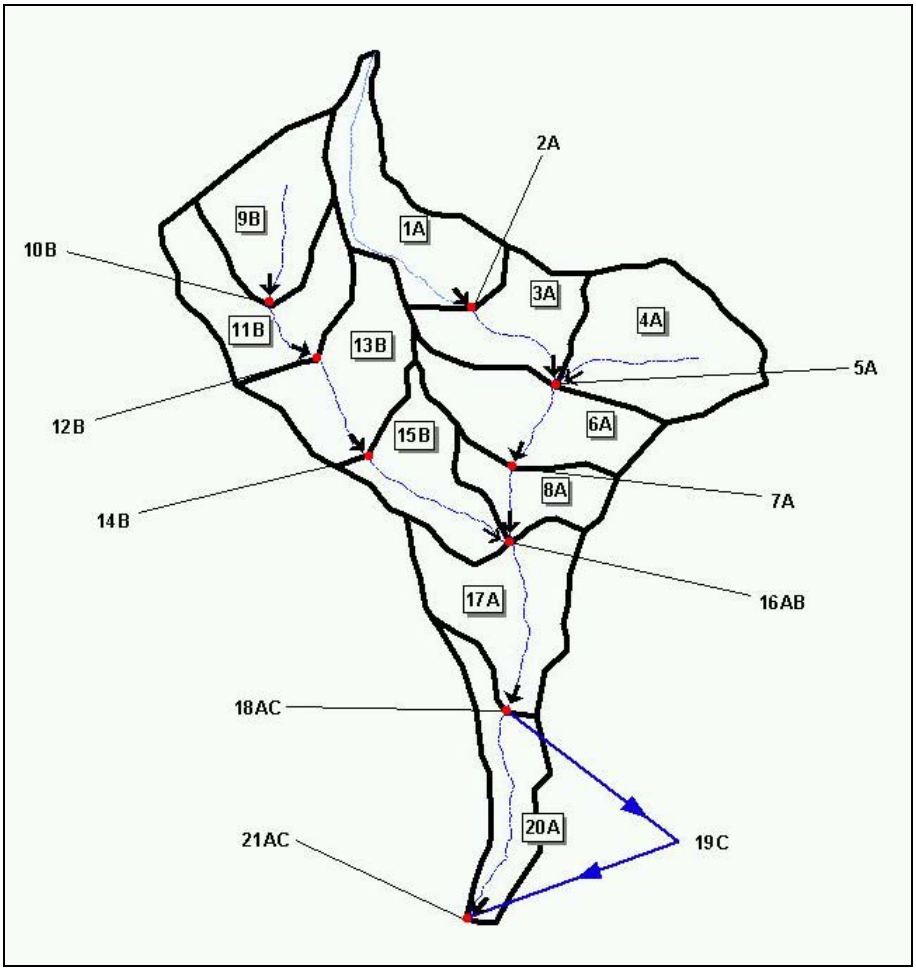


Figure 12.1.2
Watershed Numbering
Example With a Diversion

After labeling the subareas and collection points, subarea characteristics must be determined. Table 12.1.1 contains a description of each of these characteristics and the procedure for calculating them. These steps are illustrated in examples in the following two sections. Also, see Section 10.5.

Table 12.1.1
Required Parameters for Rational and Modified Rational Modeling

Parameter	Units	Symbol	Procedure	Related Section
Basin Area	Acres	A	Measure the drainage area from a scaled topographic map.	-
Conveyance Length	Feet	L	Measure the length of the conveyances between subarea collection points.	-
Conveyance Slope	Feet/Feet	S	Slope is the change in elevation between collection points divided by the conveyance length. If mountain or valley slopes exceed 0.1 see Figure 7.3.8.	-
Soil Type	-	-	Use the maps in Appendix B or the GIS shapefile to determine the predominate soil type.	Section 6.3
Percent Impervious	%	IMP	Assign each subarea a percent impervious based on land use. When more than one land use exists, assign an area-weighted imperviousness average.	Section 6.3
Rainfall Depth	Inches	-	Use the isohyetal method to determine the average rainfall depth for a subarea.	Section 5.4
Time of Concentration	Minutes	T_C	Use Regression Method Equation.	Sections 7.3, 11.1, 11.2

12.2 RATIONAL METHOD

The Los Angeles County Hydrology Method allows use of the rational method for runoff calculation in small watersheds. The Rational Method is the basis of the Modified Rational Method and allows calculation of the peak runoff rate for a single subarea.

Since the rational method generates only peak flow rates and not hydrographs, the only way to combine the flows from two subareas is to add the peak flow rates together. This method of combination neglects the effects of channel routing, peak flow attenuation, and variable times of concentration. These factors reduce the peak flow rate in larger watersheds.

The peak-to-peak method is overly conservative in watersheds larger than a few subareas.

Subarea 1A, a typical rural watershed from the example in Section 5.4, will be used to illustrate the rational method. Figure 12.1.1 shows the entire watershed. Figure 12.2.1 shows an enlarged view of Subarea 1A.

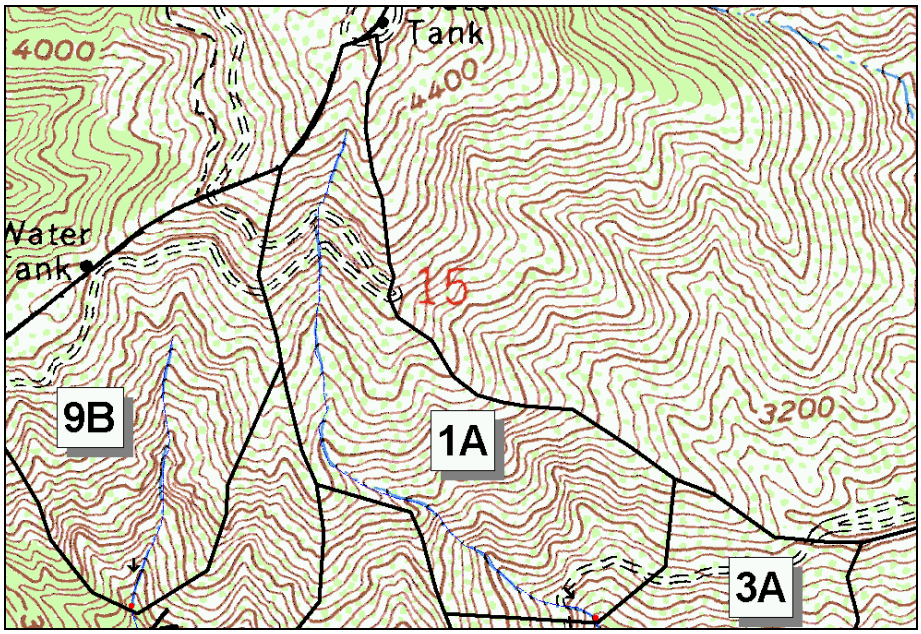


Figure 12.2.1
Subarea 1A

1. Section 5.4 contains the following data for Subarea 1A.

   Subarea size: 67.7 acres
   Rainfall Depth (50-year, 24-hour): 12.0 inches

2. Appendix B contains maps with hydrologic data. Figure 12.2.2 shows the Mount Baldy Quad, 1-H1-31, with soil types delineated. Subarea 1A contains soil types 081 and 088. However, the majority of the area is soil type 081. The characteristics of soil type 081 are used in the runoff calculation.

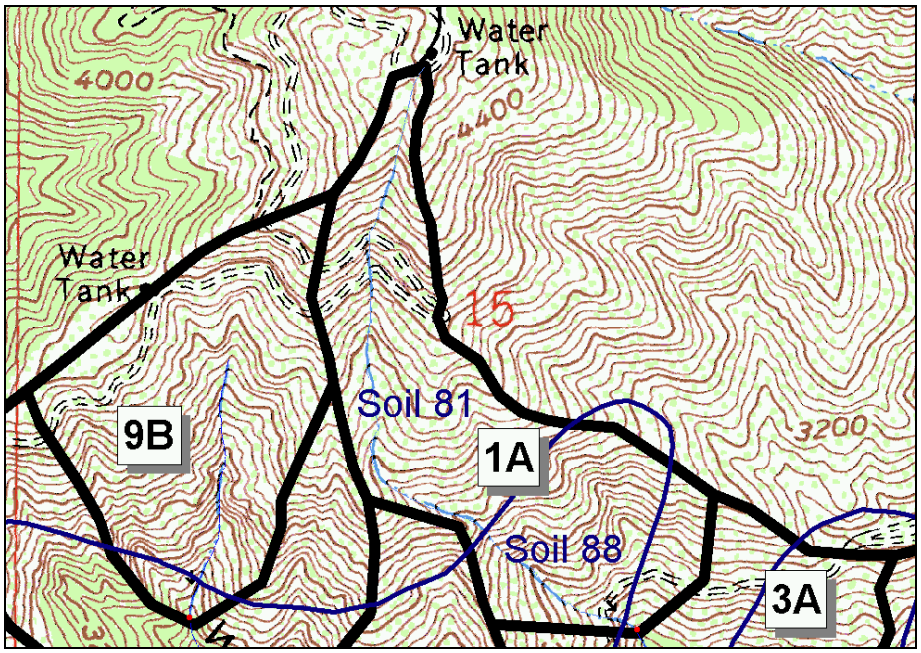


Figure 12.2.2
Appendix B Hydrologic Data Map – Mt. Baldy Quad with Subarea 1A and Soil Types Delineated

3. Appendix D contains information on imperviousness values based on land use. Subarea 1A is mountainous and undeveloped. Undeveloped rural areas are given an imperviousness of 1% in the Los Angeles County Method. For developed areas, the area-weighted imperviousness value is needed for each subarea. Section 6.3 illustrates area-weighted imperviousness calculations.

4. A time of concentration flow path is drawn from the most hydraulically remote location to the subarea outlet. The length and slope of this path needs to be determined. For Subarea 1A, the upper end of the T_C path is at an elevation of 4,612 feet and the collection point elevation is 2,739 feet. The flow path length measured using a planimeter is 4,109 feet.

   The slope is:

   Slope = (4,612 ft – 2,739 ft) / 4,109 ft = 0.456

5. Find the time of concentration by iteration:

   - Convert the 24-hour rainfall depth into intensity, I_{1440}.

     I_{1440} = 12.0 in / 24 hrs = 0.5 in/hr

   - Assume an initial T_C value of 12 minutes.

   - Use the rainfall intensity-duration-frequency relationship, Equation 5.1.2, to determine the ratio of the 12-minute intensity to the 24-hour intensity.

$$\left(\frac{I_{12}}{I_{1440}}\right) = \left(\frac{1440}{12}\right)^{0.47} = 9.49$$

   - Calculate the 12-minute intensity in in/hr;

$$I_{12\ min} = I_{1440} * \left(\frac{I_{12}}{I_{1440}}\right)$$

$$I_{12\,min} = 0.5 * 9.49 = 4.75 \text{ in/hr}$$

   - Figure 12.2.3 is the soil runoff coefficient curve for soil type 081 from Appendix C. Using the intensity, I_{12min}, determine the undeveloped runoff coefficient: C_u = 0.89.

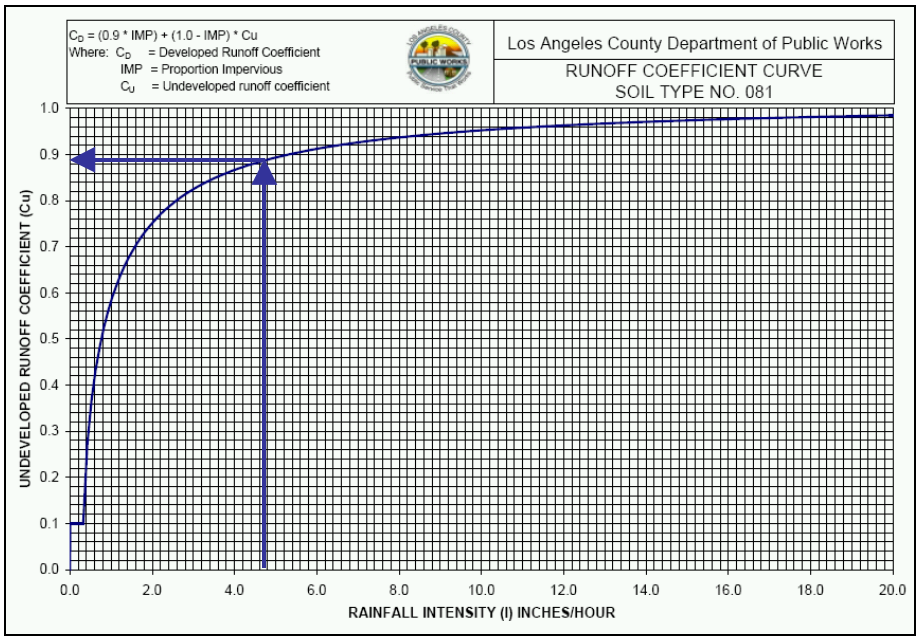


Figure 12.2.3
Soil Type No. 081, Runoff Coefficient Curve from Appendix C

- Calculate the developed runoff coefficient using Equation 6.3.2;

$$C_d = (0.9 * IMP) + (1.0 - IMP) * C_u$$

$$C_d = (0.9 * 0.01) + (1.0 - 0.01) * 0.89 = 0.89$$

- Calculate the value for rainfall excess;

Excess rainfall = C_d* I_{12min}
= 0.89 * 4.75 = 4.23 in/hr

- Calculate the time of concentration using Equation 7.3.5;

$$T_C = \frac{0.31 * L^{0.483}}{(C_d * I_t)^{0.519} * S^{0.135}}$$

$$= 0.31*4.23^{-0.519}*4{,}109^{0.483}*0.456^{-0.135} = 9.1 \text{ minutes}$$

- Since the resulting T_C, 9.1 minutes, is not within half a minute of the assumed T_C, 12.0 minutes, assume another T_C and repeat the calculations. Use the calculated T_C as the guess for the next iteration.

- Table 12.2.1 contains data for each iteration of the T_C calculations

Iteration Number	I_{1440} (in/hr)	Initial T_C (min)	$I_t/I1440$	I_t (in/hr)	C_u	C_d	C_d*I (in/hr)	Calculated T_C (min)	Difference (min)
1	0.5	12.00	9.49	4.75	0.89	0.89	4.23	9.1	2.9
2	0.5	9.1	10.8	5.4	0.90	0.90	4.86	8.4	.7
3	0.5	8.4	11.2	5.6	0.90	0.90	5.0	8.3	.1
Final	0.5	8.0	11.5	5.75	0.90	0.90	5.18		

Table 12.2.1
Iterative T_C Calculations for Subarea 1A

- When the T_C is within half a minute of the assumed T_C, round to the nearest minute to get the final T_C and calculate the I_t, C_u and C_d.

- The subarea peak flow rate in cfs is calculated using the rational method. Multiply the rainfall excess (in/hr) by the area of the catchment (acres) to get peak flow.

$$Q_{peak} = (C_d * I_t) * Area$$
$$= (0.90 * 5.75 \text{ in/hr}) * (67.7 \text{ ac}) = 350.3 \text{ cfs}$$

Using the rational method for multiple subareas requires adding peak flow rates. For example, Subarea 3A has a peak flow rate of 146.9 cfs. The total flow rate at outlet 4A is 497.2 cfs using the rational method.

12.3 MODIFIED RATIONAL METHOD

The Modified Rational Method is an extension of the rational method used to create runoff hydrographs from a watershed of any size over a specific time period. The Rational method is limited to considering storms with a duration equal to the time of concentration and provides only a peak flow. The Modified Rational Method can consider single event storms with changing intensities and longer durations. The Modified Rational Method was developed as a means to produce hydrographs for storage design based on the rational method.

In the Modified Rational Method, the rational method is applied to each subarea's hyetograph to produce a hydrograph for each subarea in the watershed. The hydrograph for Subarea 1A of the Palmer Canyon

watershed will be generated to show how calculations are performed. Computational implementations of the modified rational method use 1-minute timesteps to define the hyetograph. For illustration, only a few timesteps around the peak runoff at 1152 minutes will be used to define the hydrograph. The following information is needed:

Area:	67.7 acres
T_C:	8 minutes
Soil type:	088
Percent Impervious:	1%
4th day rainfall:	12.0 inches

The steps for hydrograph generation from Section 7.3 are as follows:

1. Determine the rainfall intensity for a time period equal to the T_C.
2. Determine the undeveloped soil runoff coefficient for the time period using the intensity.
3. Adjust the soil runoff coefficient using Equation 6.3.2 to determine C_d.
4. Use the rational equation, Equation 7.2.1, to determine the runoff for the time period.
5. Repeat steps 1 through 4 for each time period.

Illustration of hydrograph calculations will use time steps ending at 1128, 1153, and 1178 minutes. Figure 12.3.1 shows the three time periods used from the portion of the hyetograph near the peak rainfall intensity. Start with the time step ending at 1128. The 8 minute T_C calculated in Table 12.2.1 is used to define the time increment.

The first time interval of interest becomes minutes 1120 to 1128. The slope of the subarea hyetograph in Figure 12.3.1 changes during this period. The average intensity is used for the calculation. To calculate the average intensity, determine the total rainfall during this time and divide by the T_C in hours. The total rainfall from 1120 to 1128 is 0.203 inches in 8 minutes. This is equivalent to an intensity of 1.52 in/hr.

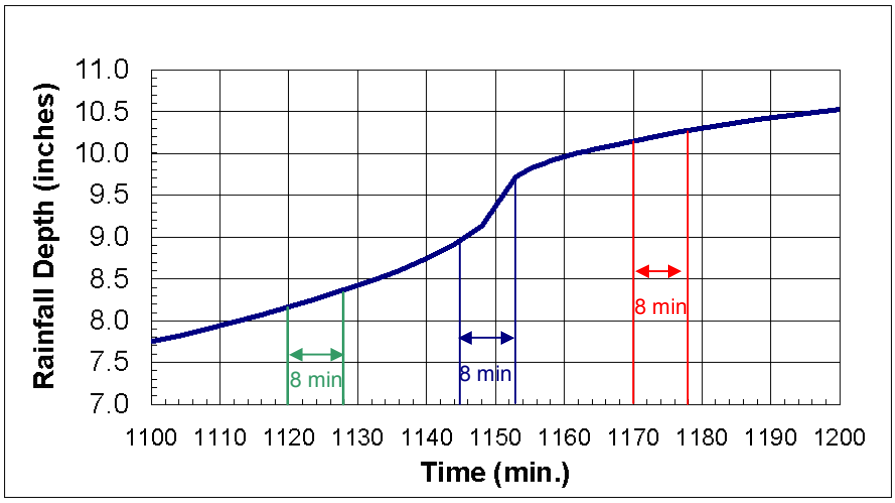


Figure 12.3.1
Subarea 1A Hyetograph With Calculation Points and T_C's Indicated

Figure 12.3.2 provides the C_u values for the three time steps of interest. From Figure 12.3.2, the undeveloped runoff coefficient for this intensity is 0.69.

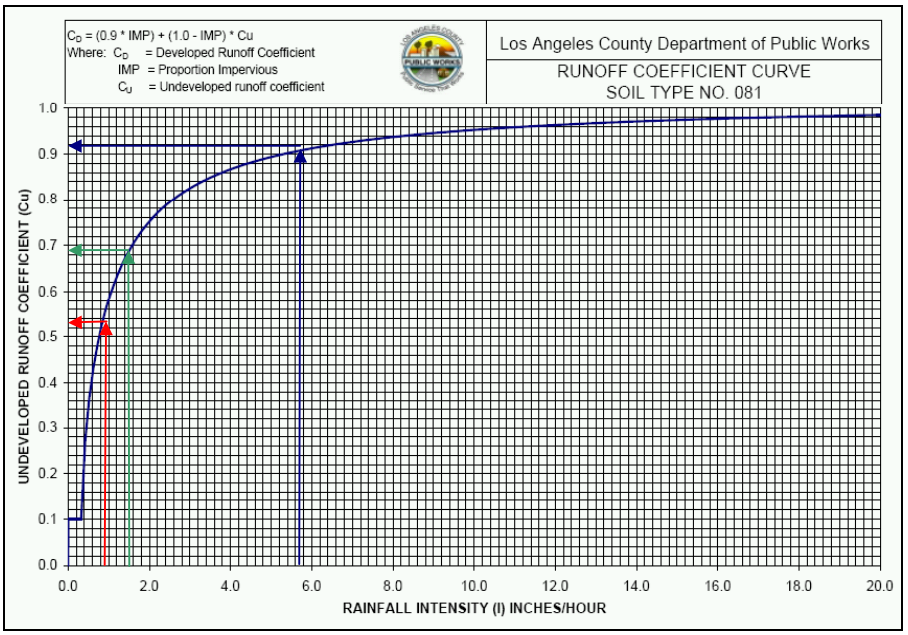


Figure 12.3.2
Soil Type 081 with Runoff Coefficients for 3 Time Steps Indicated.

Since this area has an imperviousness of 1%, the developed runoff coefficient as calculated using Equation 6.3.2 is also 0.69. The runoff for this time step is:

$$Q = C_d * I_t * A$$
$$= 0.69 * 1.52 * 67.7 = 71.0 \text{ cfs}$$

Table 12.3.1 shows the values used for the calculations at the end of each of the three time periods.

Table 12.3.1
Table of Runoff Calculations

Time (minutes) From	Time (minutes) To	Rainfall (in)	Intensity, I (in/hr)	Undeveloped Runoff Coefficient, C_u Fig. 7.3.3	Developed Runoff Coefficient, C_d Eq. 6.3.2	Area (acres)	Q = C_d *I*A (cfs)
1120	1128	0.20	1.52	0.69	0.69	67.7	71.0
1145	1153	0.76	5.71	0.90	0.90	67.7	348.0
1170	1178	0.12	0.89	0.53	0.53	67.7	23.52

Figure 12.3.3 shows the hydrograph made by connecting these points and assuming no flow at the start or end of the day. The shape would be further defined by calculating runoff at additional time increments.

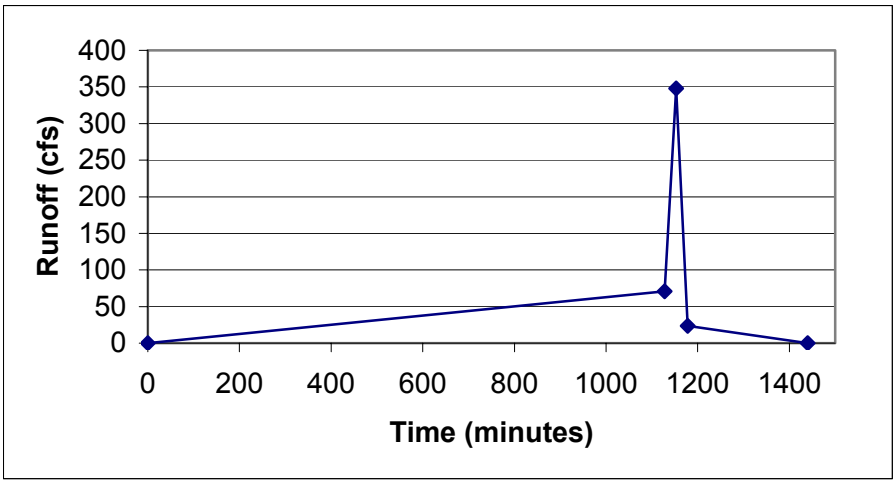


Figure 12.3.3
Hand Calculations Hydrograph for Subarea 1A

Figure 12.3.4 shows the hydrograph defined using 1-minute time shifts throughout the 24-hour time period.

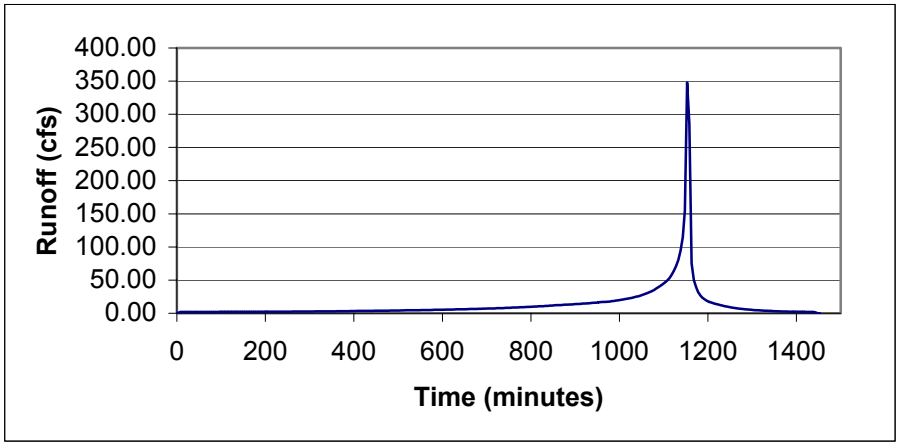


Figure 12.3.4
Subarea 1A Hydrograph,
Using 1-minute Time Shifts

The hydrographs produced from successive subareas or laterals are routed and combined to produce hydrographs for successively larger watersheds. Section 7.3 describes the hydrologic routing process. The hydrographs are subjected to routing time lags and attenuation. The flow values for each time increment from all the hydrographs are added together. This hydrograph superposition allows large watersheds to be modeled using the modified rational method.

Table 12.3.2 compares the peak outflow from the Palmer Canyon watershed created by combining hydrographs peak-to-peak and hydrograph superpositioning for each time period. As shown, combining peak-to-peak always results in higher peak flow rates than hydrograph superposition after routing and channel storage.

Method		Rational	Modified Rational
Flow Combination		Peak-to-Peak	Hydrograph Superposition
Subarea Id	Area (acres)	Total Q (cfs)	Total Q (cfs)
1A	67.7	350.3	350.3
3A	47.7	497.2	475.0
4A	82.9	821.6	799.4
6A	62.5	1,060.8	1,004.5
8A	31.5	1,177.7	1,092.3
9B	57.7	264.5	264.5
11B	60.8	498.2	490.0
13B	65.6	749.3	716.3
15B	48.9	924.0	836.6
16AB	233.0	2,101.7	1,928.4
17A	69.3	2,311.5	2,088.2
19A	46.0	2,448.4	2,173.2
Total	640.6	2,448.4	2,173.2

Table 12.3.2
Comparison of Peak Watershed Outflow using Peak-to-Peak Combination and Hydrograph Superposition

Figure 12.3.5 is the modified rational method hydrograph for the entire Palmer Canyon watershed.

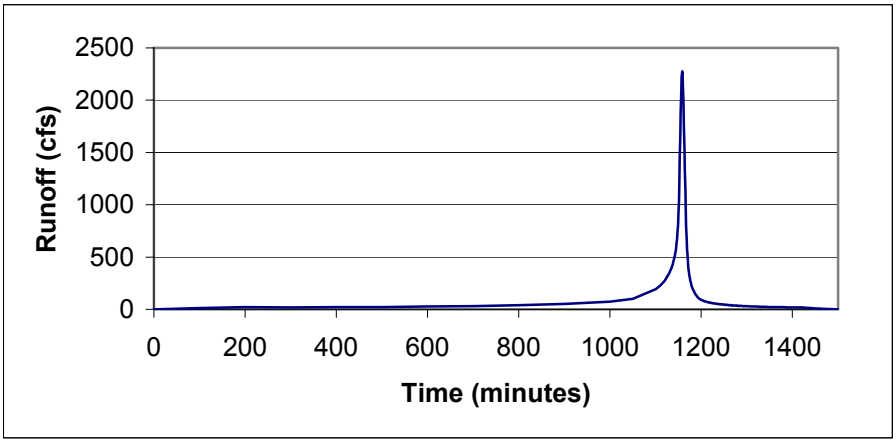


Figure 12.3.5
Modified Rational Method Hydrograph at Outlet of Palmer Canyon Watershed

Hand calculations for hydrographs, hydrograph routing, and superposition require a lot of time and careful organization. The calculations are ideally suited for computer programming and have been included in several software packages. Use of this software is encouraged to reduce the time required to reach a solution. Chapter 15 contains a list of software for Modified Rational Hydrology Studies within the County of Los Angeles.

Figure 12.3.6 is a view of the Palmer Canyon watershed used in the previous example.



Figure 12.3.6
Palmer Canyon Watershed
November 2003

CHAPTER

13

Classification of Hydrologic Models

13.1 EVENT VERSUS CONTINUOUS MODELS

Hydrologic models are divided into two categories: event or continuous models. Models that calculate runoff from a single storm lasting up to several days are called event models. The Los Angeles County Modified Rational Method model is an *event* model. Models that account for changes in the watershed over a long period of time and through several storm events are called *continuous* models. The Stanford Model and its descendant Hydrologic Simulation Program – Fortran (HSPF) are examples of continuous models. It is important to understand the differences between these types of models.

Hydrologists and engineers typically use event models to calculate runoff from a design storm event. This event may last from several hours to several days with nearly continuous rain. Event models lack mechanisms to account for changes over time in watershed conditions such as soil moisture. Event models must therefore use assumed watershed conditions. These assumptions work well for specific design criteria, but do not provide adequate results for longer periods. Watershed conditions may change between storms and through dry periods due to infiltration, evaporation, and transpiration. Watersheds also change over longer periods due to fire, construction, and changes in land uses. Event models have the advantage of being relatively simple to create and run.

Continuous models attempt to represent the effect of soil moisture and processes such as evaporation, transpiration, and flow through the subsurface on the runoff process. Continuous models account for changes in watershed characteristics at each time period and are suited to modeling runoff over long periods. Continuous model inputs require several months or years of historic data that contain most expected watershed conditions. The increased data requirements over event based models make the continuous models more complex to develop and calibrate. The spatial and temporal

variation of parameter values for soil infiltration rates, soil moisture capacity, evaporation rates, and rainfall are required. Table 13.1.1 contains examples of event and continuous models. The table also lists some of the parameters required by the models.

Table 13.1.1
Comparison of Event and Continuous Models

Model Type	Rainfall Input	Data Requirements	Examples
Event	Design Storm	Soil runoff characteristics, land use data, relevant rainfall duration.	HEC-HMS, SWMM, Modified Rational
Continuous	Historic Data or Design Storms	Land use, detailed soil and vegetation information, seasonal data, time series data including rainfall, runoff, evaporation, temperature, etc..	Stanford Model, HSPF, SWMM

13.2 LUMPED AND DISTRIBUTED PARAMETER MODELS

The Los Angeles County Modified Rational Method is classified as a lumped parameter model because parameters influencing runoff are lumped together and assumed uniform for each subarea. The model uses a combination of physical and analytical relationships to model runoff response to a rainfall design storm. Subareas are defined with reference to the drainage pattern of the watershed. Properties of a subarea such as rainfall, imperviousness, and soil properties are lumped for the entire subarea. Lumped parameter models usually require less data that is easier to obtain or estimate.

The alternative to a lumped parameter model is a distributed model. Instead of breaking up the watershed using drainage boundaries, a distributed model represents the properties of a watershed using small grid cells. These regularly spaced cells are assigned unique properties, reducing the simplification that occurs when parameters are lumped at the subarea level. Distributed modeling is compatible with watershed data inputs such as radar rainfall and soil moisture accounting. Distributed models generally require more data that may not be readily available.

CHAPTER

14

Divisions With Hydrologic and Hydraulic Responsibilities

In addition to the Water Resources Division, several divisions within the Los Angeles County Department of Public Works have responsibilities associated with hydrology and hydraulics. The divisions that provide these services are listed below along with key responsibilities that relate to hydrology and hydraulics.

14.1 BUILDING AND SAFETY DIVISION

The primary function of Building & Safety is the enforcement of Los Angeles County Building, Plumbing, Mechanical, and Electrical Codes, as well as other local and State requirements relevant to the construction and occupancy of public and private structures. The Division provides this enforcement through plan checking and inspection of new commercial and residential construction. The County's unincorporated area and 21 contracted cities are served by 25 branch or city inspection offices and a central administrative office. The Drainage and Grading Section provides the following services related to hydrology and hydraulics:

Hydrology Review Includes:

- Reviewing hydrologic studies for single lot residential and commercial projects based on Public Works' standards. The review identifies flood hazards due to inundation, overflow, or debris, and verifies that the appropriate levels of protection exist against these hazards.

- Verifying single lot residential and commercial project compliance with the Department's National Pollution Discharge Elimination System (NPDES) permit, including the enforcement of Standard Urban Stormwater Mitigation Plan (SUSMP) compliance.

- Verifying that post-development flow rates in watercourses adjacent to the development are no greater than pre-development flow rates.

Hydraulics Review Includes:

- Reviewing proposed drainage facilities and storm drains for capacity, appropriate levels of protection, and negative impacts on existing drainage systems.

- Checking pre- and post-development flows, velocities, and flow areas at the upstream and downstream of proposed single lot residential and commercial projects to verify that no negative impacts, including diversions, are created.

- Enforcing compliance with the National Flood Insurance Program (NFIP), including FEMA and County floodplain and floodway regulations.

- Reviewing hydraulic models of floodway and flood plain encroachments to determine development requirements and effects to upstream and downstream properties.

Grading Review Includes:

- Verifying that grading plans for single lot residential and commercial projects do not affect off-site areas negatively in terms of hydrology or debris production.

- Verifying compliance with the Department's NPDES permit by reviewing grading plans and inspecting the installation of required BMP's.

14.2 CONSTRUCTION DIVISION

The Construction Division is responsible for the administration and inspection of Public Works construction contracts; inspection of subdivision improvements; issuance and inspection of permits for road, drainage, and sewer projects; and utility coordination. In addition, the division awards and administers contracts to clean approximately 70,000 catch basins during the late summer months prior to each rainy season. Cleaning the basins improves storm water quality by minimizing the amount of debris that would otherwise flow through the storm drains and into the ocean. Construction Division's Permits and Subdivisions Section hydrology related responsibilities include:

- Confirming hydrology of tributary area and check the drainage area map of a proposed site with the existing sub-area map.

- Checking hydrology calculations using Public Works' standards. Check Design Hydrology peak flow rate and T_C calculations using the Public Works' T_C calculator.

- Submitting requests to Water Resources Division to perform hydrologic studies for the areas of interest, when no hydrologic study is available.

- Verifying that the allowable discharge flow rate, $Q_{Allowable}$ (cfs/acre), for the existing subarea has been obtained from Design Division.

- Comparing design hydrology with the system design hydraulics and requiring that any connections are designed based on the smaller value.

- Reviewing permit applications and construction projects for impacts of water releases into flood control facilities and coordinating with Water Resources Division on operational activities of Public Works' facilities.

14.3 DESIGN DIVISION

Design Division is responsible for preparing contract drawings, cost estimates, and specifications for Public Works' new construction, repair, retrofit, and rehabilitation projects. Projects include streets and highways, bridges, storm drains, water and sewer lines, debris control facilities, pumping plants, and facilities appurtenant to dams. The division also lends technical design support to other agencies and the public, and it publishes its *Standard Plan Manual* and *Standard Specifications Book* for construction contractors. The Design Division's Hydraulic Analysis Unit has the following duties:

- Providing the allowable discharge flow rate, $Q_{Allowable}$ (cfs/acre), which is the maximum discharge allowed for new connections to a drainage facility. The $Q_{Allowable}$ is based on the design hydrology study and any hydraulic capacity limitations of the subject drain or the downstream connecting system(s).

- Providing hydrologic data/information from facility design hydrologic studies including: the design storm frequency, scale-down factors, sub-area acreage, peak flow rates (including specific catch basin design subarea acreage and flow rates), and design reach peak flow rates throughout the system.

- Providing hydrology maps that graphically outline the limits of all subareas within the facility drainage area. Each subarea is individually identified with a corresponding number from the design hydrology study, as well as the acreage and peak flow rate.

- Providing hydraulic analysis calculations for drainage facilities. These include the hydraulic calculation sheets or Water Surface Pressure Gradient (WSPG) output data with the design flow rate, velocity, and hydraulic grade line (H.G.L.) or water surface elevation (W.S.E.) at various locations throughout the system. A WSPG hydraulic calculation for a proposed connection to a drainage facility must be based on the facility design H.G.L. or W.S. E. at the point of connection.

- Providing conceptual review on the preliminary hydraulic design of projects involving connections to, or modifications/realignment of, a drainage facility. The conceptual review determines the hydraulic,

hydrologic, and/or structural feasibility of the proposal prior to proceeding with the design.

14.4 ENVIRONMENTAL PROGRAMS DIVISION

The Environmental Programs Division is responsible for five major environmental programs within the County: Hazardous Material Underground Storage Tank (UST) Regulation; Solid and Hazardous Waste Management Planning and Implementation; Stormwater Discharge/Water Quality Monitoring and Control; Industrial Waste Control; and administration of the County's Garbage Disposal Districts. In addition, Environmental Programs provides technical support and advice for County recycling, composting, and hazardous waste programs, reviews road and utilities improvement plans relative to sanitary sewers, reviews building construction plans for the Methane Gas Intrusion Protection System, and provides waste management advice and coordination. Environmental Program's specific hydrologic duties include:

- Reviewing SUSMP plans for non-residential projects within the Industrial Waste Unit's areas of jurisdiction. After the commercial or industrial developer receives approval of the peak mitigated flow, "Q_{pm}", from the County Building and Safety, Land Development, or the local City Building & Safety office, the developer submits the approved "Q_{pm}" report and the required sets of plans to the Industrial Waste Unit. A permit application and fees for plan checking and permit processing are required. See the website http://www.ladpw.org/epd/industrial_waste/index.cfm for more information.

- Checking the storm water treatment devices and post-BMPs for suitability to the "Q_{pm}" and the site's storm water constituents. The approved storm water treatment devices are placed under a SUSMP permit.

- Inspecting storm water treatment devices to ensure that the devices are properly maintained.

14.5 LAND DEVELOPMENT DIVISION

Land Development Division is responsible for plan reviews and approval of all types of Public Works' infrastructure and final maps as part of the land development subdivision process. These subdivisions range in size from two lot parcel maps to 12,000-acre master plan communities including residential, commercial, and industrial development. In addition, this Division reviews and approves proposals to comply with storm water quality requirements of the Regional Water Quality Control Board. Land Development Division's responsibilities regarding hydrology are:

Hydrology Review Includes:

- Reviewing development plans to determine if on-site hydrology meets Public Works' standards.
- Checking SUSMP compliance and requiring use of BMPs during and after construction.
- Checking for required debris control structures for areas upstream of tracts and on-site locations.
- Checking post-development flow rates in adjacent watercourses to ensure that they do not exceed pre-development flow rates.

Hydraulics Review Includes:

- Reviewing proposed on-site drains for capacity, maintenance issues, and adequate downstream capacity. Ensuring that appropriate levels of protection exist.
- Checking pre- and post-development flows, velocities, and flow areas at the upstream and downstream tract boundaries to prevent negative off-site impacts.
- Enforcing floodplain and floodway regulations.
- Reviewing HEC-RAS models of floodway encroachments for compliance with regulations to prevent negative effects to the upstream and downstream areas.

Grading Review Includes:

- Reviewing grading plans to ensure that topographic changes do not affect off-site areas negatively in terms of hydrology or debris production.

14.6 WATERSHED MANAGEMENT DIVISION

Watershed Management Division is responsible for planning and implementing watershed management projects that protect the County's residents from flooding while integrating the elements of natural resources, groundwater, and stormwater conservation, improved stormwater runoff quality, and socio-economic, environmental, and recreational features. Watershed Management's hydrologic responsibilities include:

- Providing Flood Zone determinations for the public and lending institutions.

- Interpreting Flood Insurance Rate Maps (FIRMs) and identifying flood zone designations for properties and construction projects.

- Processing Letters of Map Revision (LOMR) and Conditional Letters of Map Revision (CLOMR).

CHAPTER

15

Computer Programs for Use in Los Angeles County Hydrologic Studies

Computer programs are powerful tools that simplify hydrologic computations. Several hydrologic software packages include the Los Angeles County Modified Rational Method. The software packages listed in Table 15.1 have been reviewed for use in hydrologic studies within the County of Los Angeles. The table provides contact information for purchasing the software and provides a brief description of approved uses for the software.

Table 15.1
Approved Computer Programs

Name	Version	Description	Publisher
Watershed Modeling System (WMS)	7.1 and later	Implements the Modified Rational Method with reservoir routing and optional GIS capability	Environmental Modeling Systems www.ems-i.com 1-801-302-1400
XP-SWMM	9.0 and later	Implements the Modified Rational Method with some enhancements and the ability to model hydraulics and water quality	XP Software www.xpsoftware.com 1-888-554-5022
HEC-HMS	2.2.2 and later	Physically based, single event model can be used for reservoir routing.	Corps of Engineers Hydrologic Engineering Center www.hec.usace.army.mil
LAR04		Implements the Modified Rational Method	Civildesign Corp www.civildesign.com 1-909-885-3806
RETARD		Performs reservoir routing using the Modified Puls method.	Civildesign Corp www.civildesign.com 1-909-885-3806
TC_calc_vol.xls TC_calc_depth.xls		Implements the Modified Rational Method into calculations for single subareas and small watersheds.	LA County Dept. of Public Works www.ladpw.org

15.1 WATERSHED MODELING SYSTEM (WMS)

Watershed Modeling System (WMS) is a hydrologic modeling software that incorporates many standard hydrologic models. A key capability of WMS is the extraction of model input parameters from GIS data such as DEMs, TINs, and shapefiles. The program also allows use of georeferenced images for

backgrounds. WMS is modular and pricing is based on the number of modules purchased.

The Los Angeles County Modified Rational Method has been fully implemented in WMS. This implementation maintains the functionality of the prior F0601 code with several useful additions. WMS includes a graphical user interface to the model which facilitates data input and model creation. Reservoir routing, automatic T_C calculation, and automatic burned watershed simulations are recently added features.

15.2 XP-SWMM

The Storm Water Management Model (SWMM) is widely used to model storm drain systems. The United States Environmental Protection Agency (EPA) maintains this model. XP-SWMM is a Windows based interface for the SWMM model developed by XP Software.

XP-SWMM version 9.0 allows for the simulation of runoff, water quality, and hydraulic routing using the Los Angeles County Modified Rational Method. The XP-SWMM software has a graphical interface with the Modified Rational Method. Reservoir routing, automatic T_C calculation, and automatic burned watershed simulations are included features. A scenario manager also allows simultaneous simulation of multiple design storms. Future upgrades of XP-SWMM plan to include GIS capabilities.

15.3 HEC-HMS

HEC-HMS was developed by Hydrologic Engineering Center (HEC), Corps of Engineers. HEC-HMS does not support the Modified Rational Method. However, HEC-HMS was adopted as a replacement for the Mountain Hydrology Method (Q-S Method)[1]. Currently, Public Works uses HEC-HMS to model debris basins and dams.

15.4 LAR04/RETARD

The LAR04 program is a modified version of Public Works' F0601 program. The modifications include changing the program to a Windows console program, adoption of the latest soil and rainfall data files distributed by Public

Works, and user options to select output data for design storms ranging from 2-year to 500-year events. There is also the option to output data in metric units, include volume calculations with hydrographs and, an input option for areas as small as 0.1 acres.

LAR04 is a text-based implementation of the Modified Rational Method similar to F0601. This program uses the Los Angeles County Flood Control District program source code for the F0601 series programs. It also includes an independent program module, which assists the user in preparing an input data file for use by the F0601 program.

The RETARD program reads F0601 hydrographs, up to a 4-day storm series, and performs detention basin calculations using the Modified Puls, or storage indication method. The resulting outflow hydrograph may be inputted into the LAR04/F0601 program.

15.5 T_C CALCULATOR

The T_C Calculator may be used to calculate runoff and runoff volumes for small subareas and for small watersheds. Since it has no routing capabilities, use for watersheds larger than 100 acres is discouraged because routing alters peak flows and changes timing. These changes normally reduce flow rates in a storm drain system.

[1] Los Angeles County Department of Public Works Hydrology Manual, 1982, page C-9

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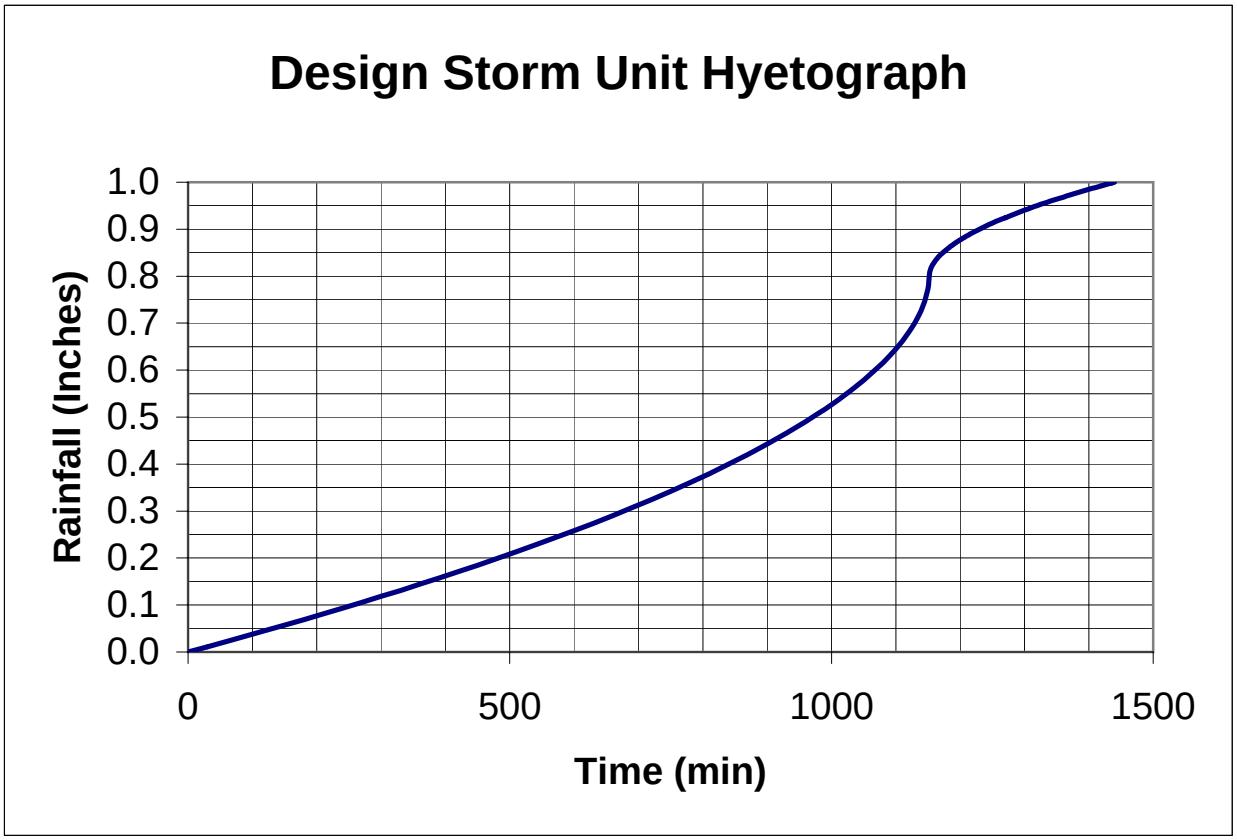
APPENDIX A

Design Storm Unit Hyetograph

Temporal Distribution of Unit Hyetograph

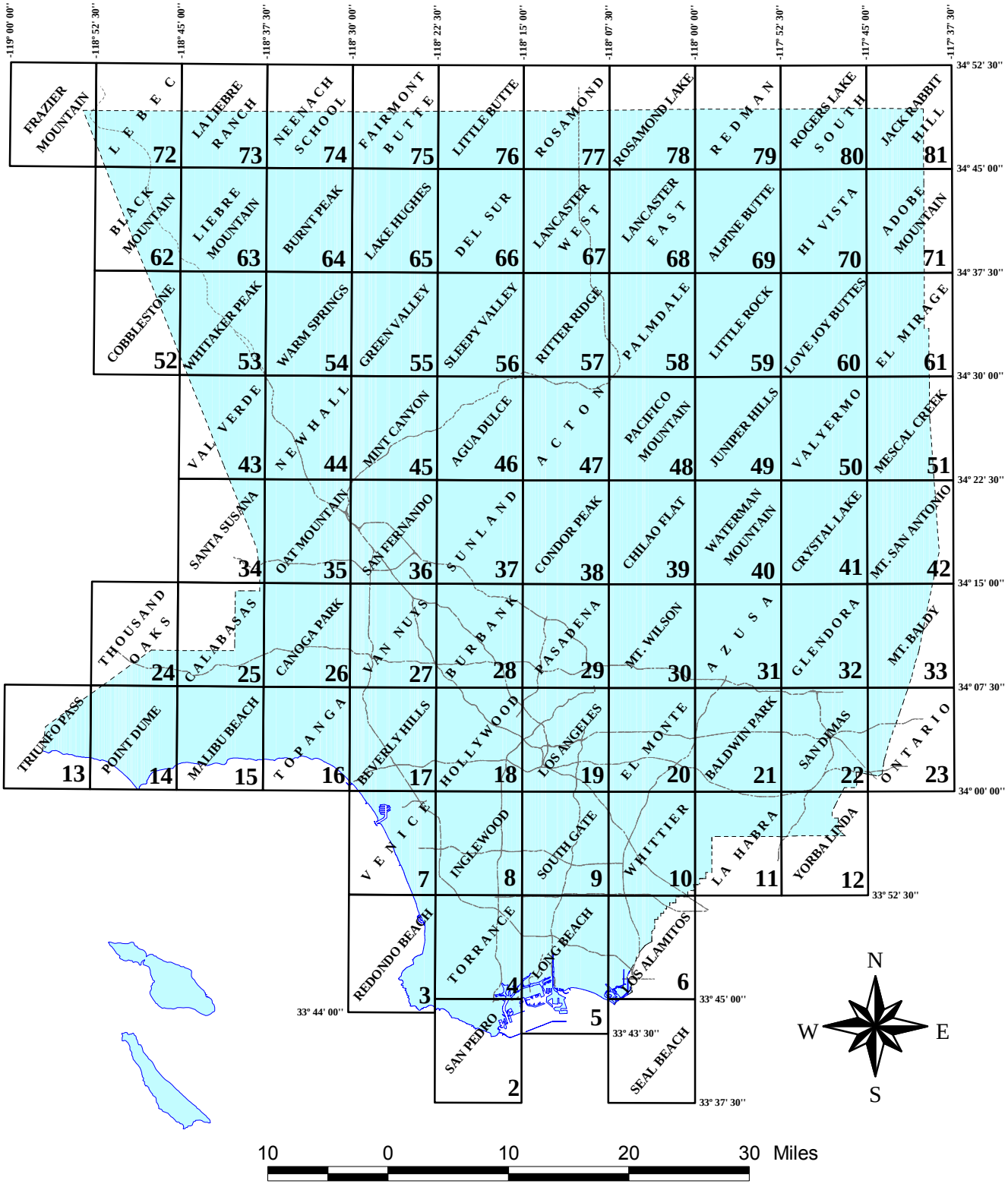
(Time in minutes, Depth in inches)

Time	Depth	Time	Depth	Time	Depth	Time	Depth
0	0.000000	1110	0.661694	1185	0.863440	1232	0.901435
30	0.011110	1115	0.670680	1186	0.864452	1233	0.902105
60	0.022361	1120	0.680257	1187	0.865450	1234	0.902772
90	0.033758	1125	0.690568	1188	0.866434	1235	0.903434
120	0.045307	1130	0.701824	1189	0.867406	1240	0.906691
150	0.057015	1135	0.714364	1190	0.868366	1245	0.909862
180	0.068889	1136	0.717072	1191	0.869313	1250	0.912954
210	0.080937	1137	0.719860	1192	0.870250	1255	0.915973
240	0.093166	1138	0.722738	1193	0.871175	1260	0.918923
270	0.105586	1139	0.725713	1194	0.872090	1265	0.921810
300	0.118206	1140	0.728799	1195	0.872995	1270	0.924638
330	0.131037	1145	0.746492	1196	0.873889	1275	0.927409
360	0.144090	1150	0.772454	1197	0.874775	1280	0.930129
390	0.157377	1151	0.780923	1198	0.875651	1285	0.932799
420	0.170913	1152	0.800000	1199	0.876518	1290	0.935422
450	0.184711	1153	0.809944	1200	0.877377	1295	0.938000
480	0.198790	1154	0.814358	1201	0.878227	1300	0.940537
510	0.213168	1155	0.817800	1202	0.879069	1305	0.943034
540	0.227865	1156	0.820732	1203	0.879903	1310	0.945492
570	0.242905	1157	0.823335	1204	0.880730	1315	0.947915
600	0.258314	1158	0.825702	1205	0.881549	1320	0.950302
630	0.274121	1159	0.827890	1206	0.882361	1325	0.952657
660	0.290362	1160	0.829936	1207	0.883166	1330	0.954980
690	0.307075	1161	0.831864	1208	0.883964	1335	0.957272
720	0.324307	1162	0.833694	1209	0.884755	1340	0.959535
750	0.342111	1163	0.835440	1210	0.885540	1345	0.961770
780	0.360552	1164	0.837112	1211	0.886318	1350	0.963978
810	0.379705	1165	0.838721	1212	0.887091	1355	0.966159
840	0.399666	1166	0.840272	1213	0.887857	1360	0.968316
870	0.420552	1167	0.841772	1214	0.888618	1365	0.970448
900	0.442511	1168	0.843225	1215	0.889372	1370	0.972558
930	0.465738	1169	0.844636	1216	0.890121	1375	0.974644
960	0.490493	1170	0.846009	1217	0.890865	1380	0.976709
970	0.499144	1171	0.847347	1218	0.891603	1385	0.978752
980	0.508022	1172	0.848652	1219	0.892336	1390	0.980775
990	0.517145	1173	0.849926	1220	0.893064	1395	0.982778
1000	0.526538	1174	0.851172	1221	0.893787	1400	0.984761
1010	0.536225	1175	0.852392	1222	0.894505	1405	0.986726
1020	0.546239	1176	0.853588	1223	0.895218	1410	0.988673
1030	0.556617	1177	0.854760	1224	0.895926	1415	0.990602
1040	0.567402	1178	0.855910	1225	0.896630	1420	0.992514
1050	0.578651	1179	0.857039	1226	0.897330	1425	0.994410
1060	0.590431	1180	0.858149	1227	0.898024	1430	0.996289
1070	0.602830	1181	0.859241	1228	0.898715	1435	0.998152
1080	0.615962	1182	0.860315	1229	0.899401	1440	1.000000
1090	0.629985	1183	0.861372	1230	0.900083		
1100	0.645118	1184	0.862414	1231	0.900761		


Design Storm Unit Hyetograph
Rainfall (Inches)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
500
1000
1500
Time (min)

APPENDIX B

Hydrologic Maps

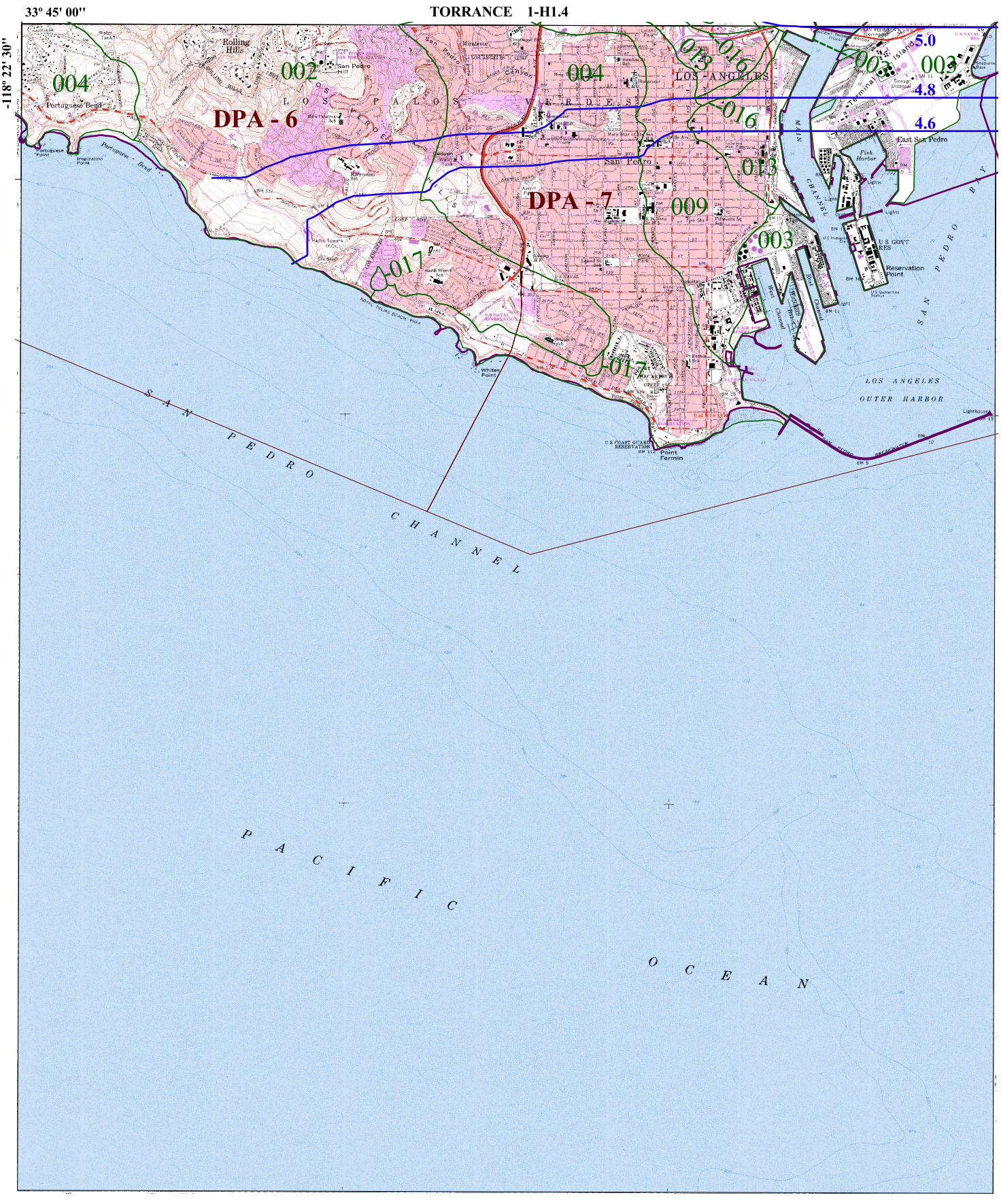


INDEX ISOHYETAL MAP

50-YEAR 24-HOUR ISOHYET

BASED ON USGS QUADRANGLE

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 — SOIL CLASSIFICATION AREA

7.2 — INCHES OF RAINFALL

DPA - 6 — DEBRIS POTENTIAL AREA

N W E S

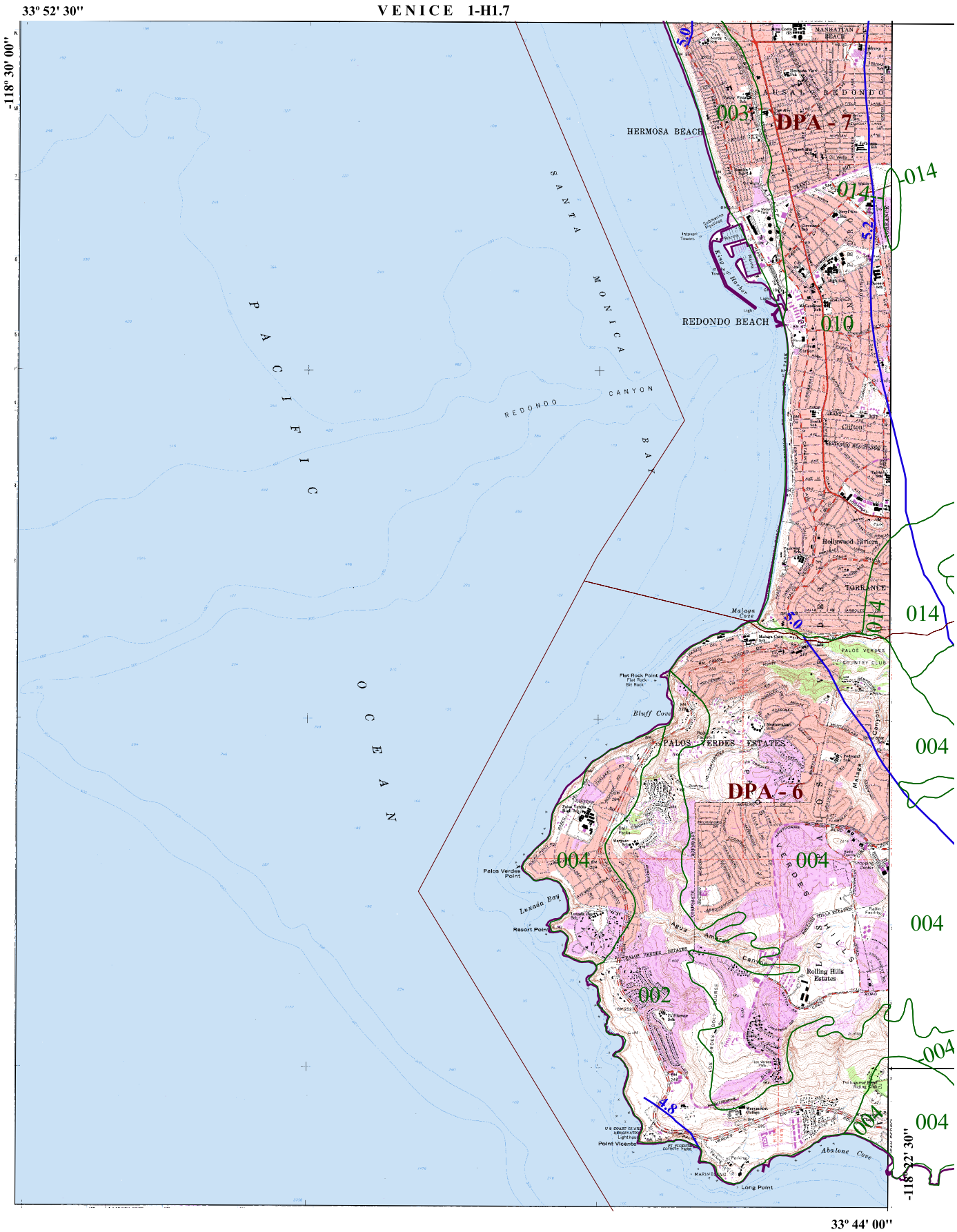
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

SAN PEDRO
50-YEAR 24-HOUR ISOHYET

1-H1.2

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



N
W E
S

016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

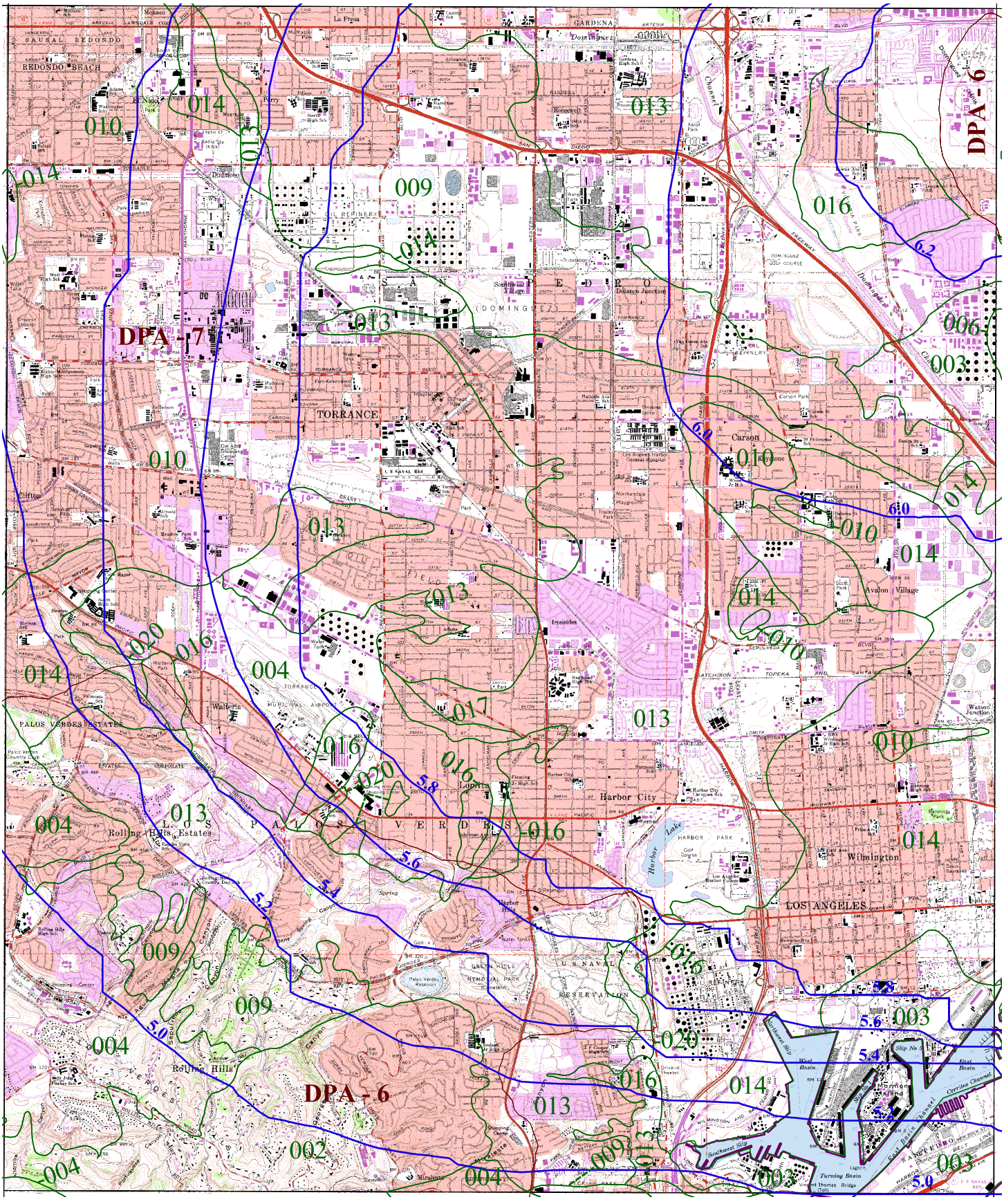
1 0 1 2 Miles

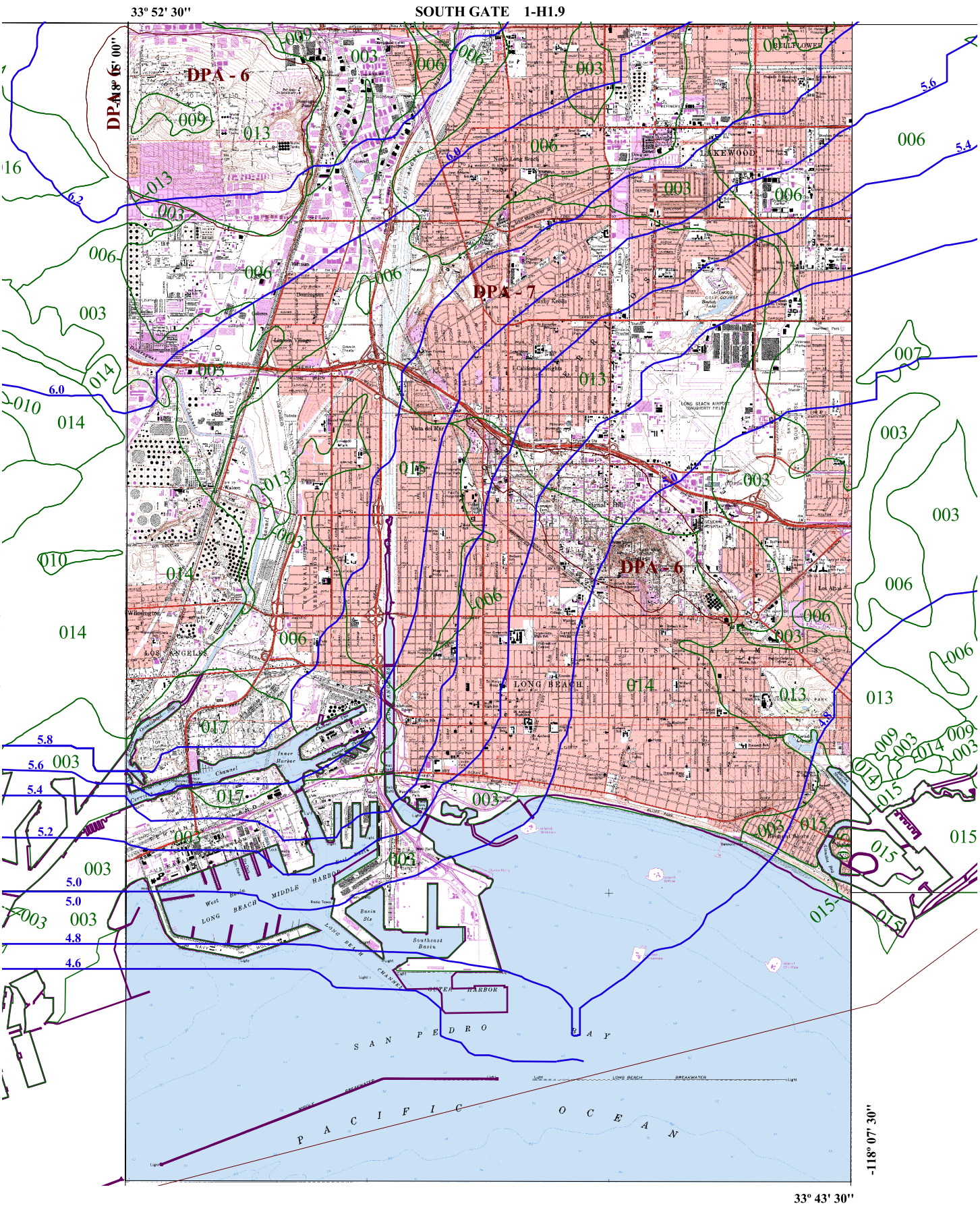
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

REDONDO BEACH
50-YEAR 24-HOUR ISOHYET

1-H1.3

LOS ANGELES COUNTY PUBLIC WORKS
Public Service That Works


33° 52' 30"
INGLEWOOD 1-H1.8
-118° 22' 30"
REDONDO BEACH 1-H1.3
LONG BEACH 1-H1.5
-118° 15' 00"
SAN PEDRO 1-H1.2
33° 45' 00"
DPA - 7
DPA - 6
DPA - 6
TORRANCE
REDONDO BEACH
GARDENA
Carson
Harbor City
Wilmington
LOS ANGELES
PALOS VERDES ESTATES
Rolling Hills Estates
Rolling Hills
Lomita
Ironsides
Avalon Village
Watson Junction
Waltersia
Southwest Village
Normandale Playgrounds
Los Angeles Harbor General Hospital
Dominguez Golf Course
Harbor Park Golf Course
Harbor Lake
Inner Harbor
Outer Harbor
Turning Basin
Vincent Thomas Bridge
Southwest Slip
Slip No 5
West Basin
East Basin
Cerritos Channel
Main Channel
Long Beach Harbor
Long Beach Channel
Pacific Coast Highway
Del Amo Shopping Center
Torrance Municipal Airport
Palos Verdes Reservoir
Palos Verdes Country Club
Harbor Regional Park
Dominguez Park
Carson Park
Ken Nicol Park
Walteria Park
Torrance Park
Wilmington Park
Scott Park
Fleming Jr High Sch
Harbor City Christian Sch
Rolling Hills High Sch
Walteria Sch
Watson Junction Sch
Wilmington Sch
Torrance Sch
Torrance Airport
Torrance Municipal Airport
Torrance Airport
Torrance Municipal Airport
Torrance Airport
Torrance Municipal Airport



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

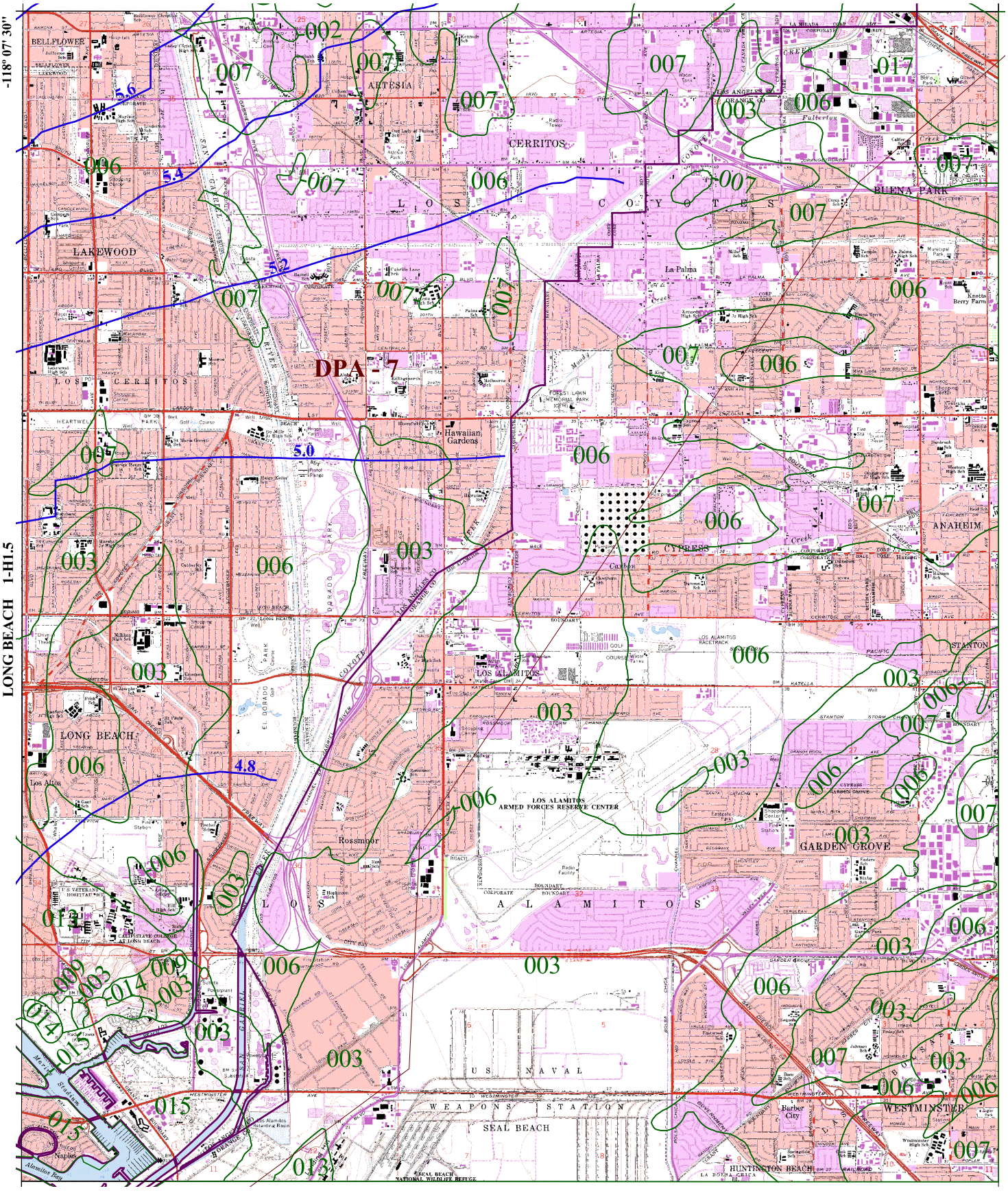
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

LONG BEACH
50-YEAR 24-HOUR ISOHYET

1-H1.5

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

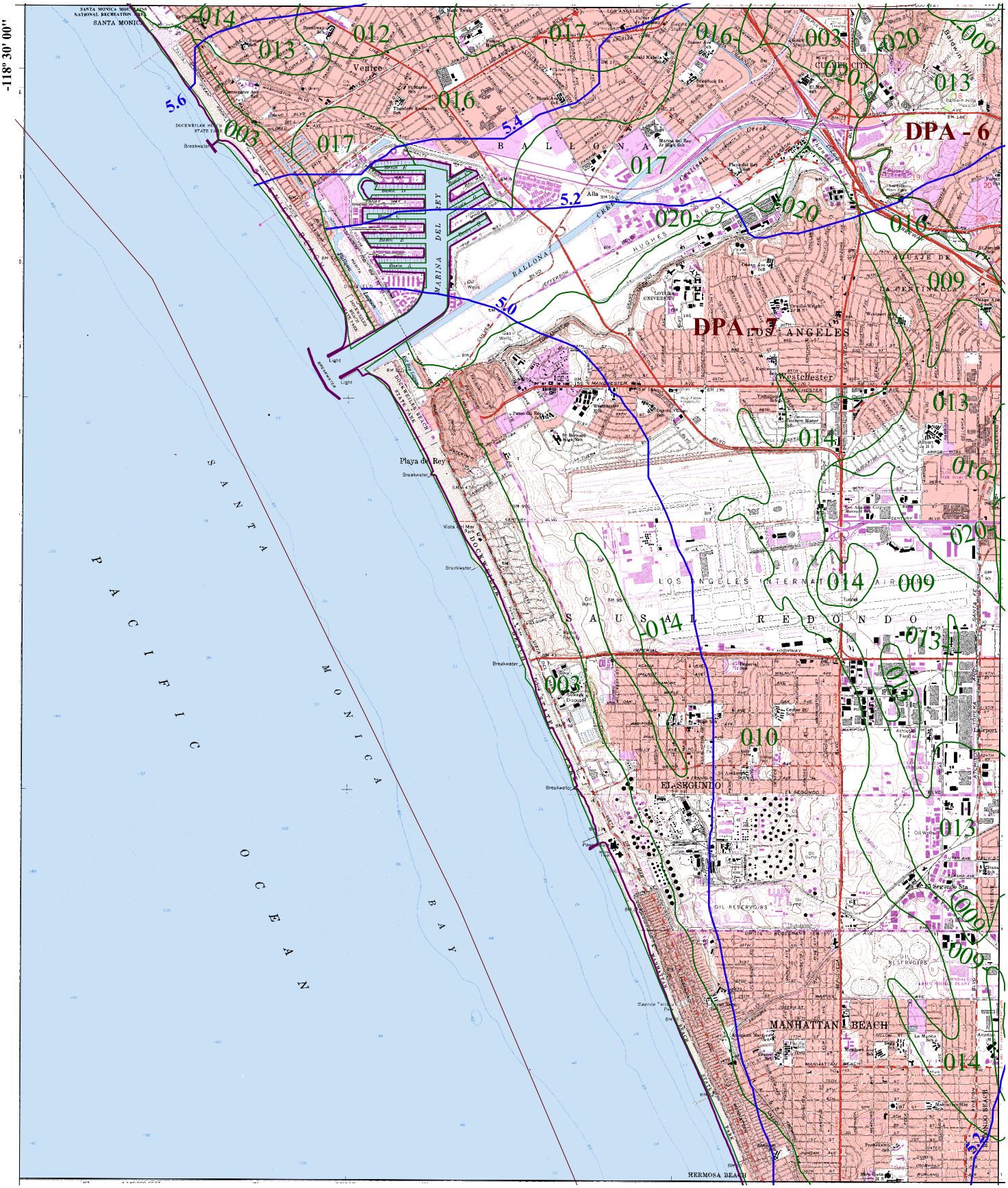
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

LOS ALAMITOS
50-YEAR 24-HOUR ISOHYET

1-H1.6

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



N
W E
S

016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

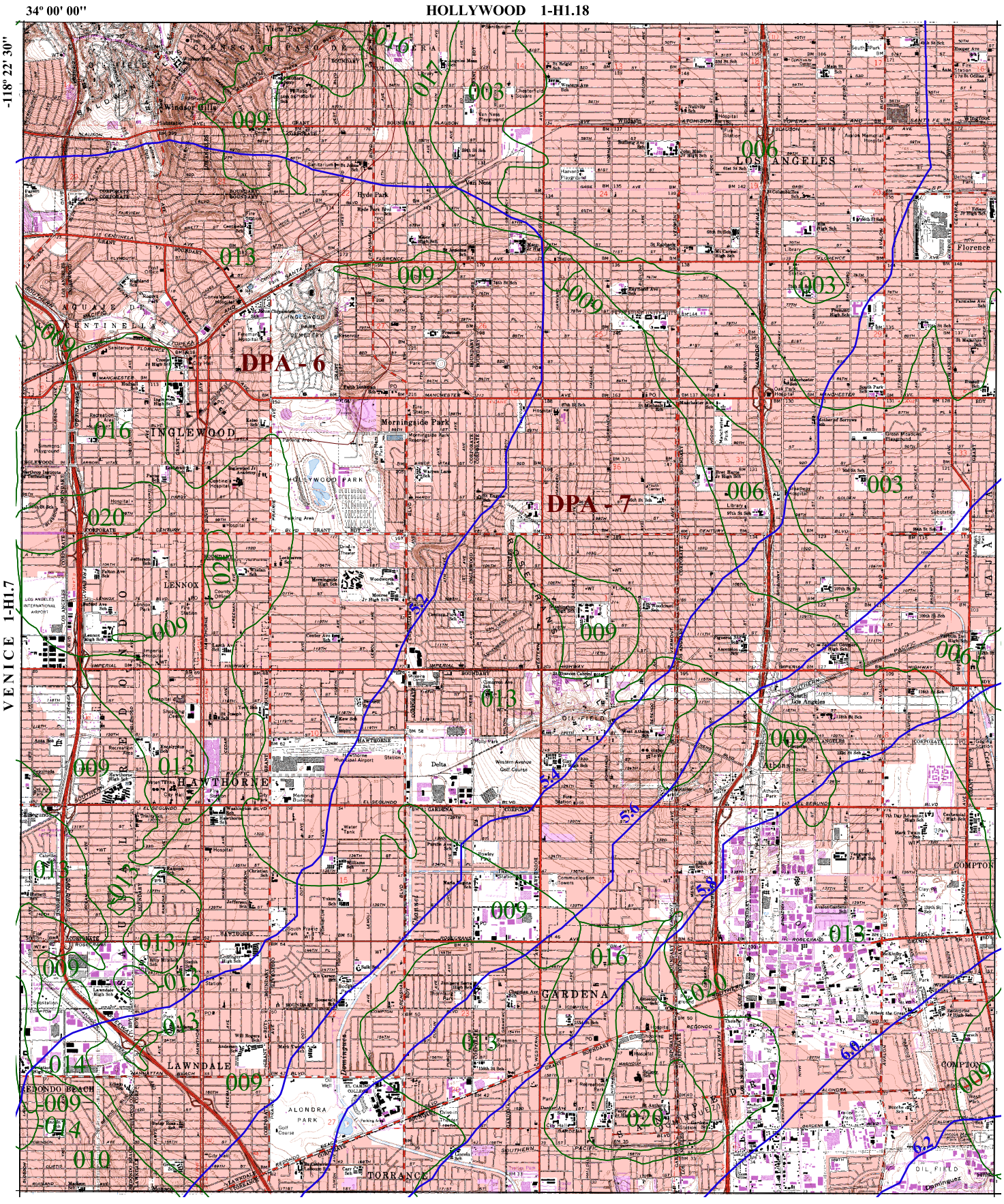
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

V E N I C E 1-H1.7

50-YEAR 24-HOUR ISOHYET

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

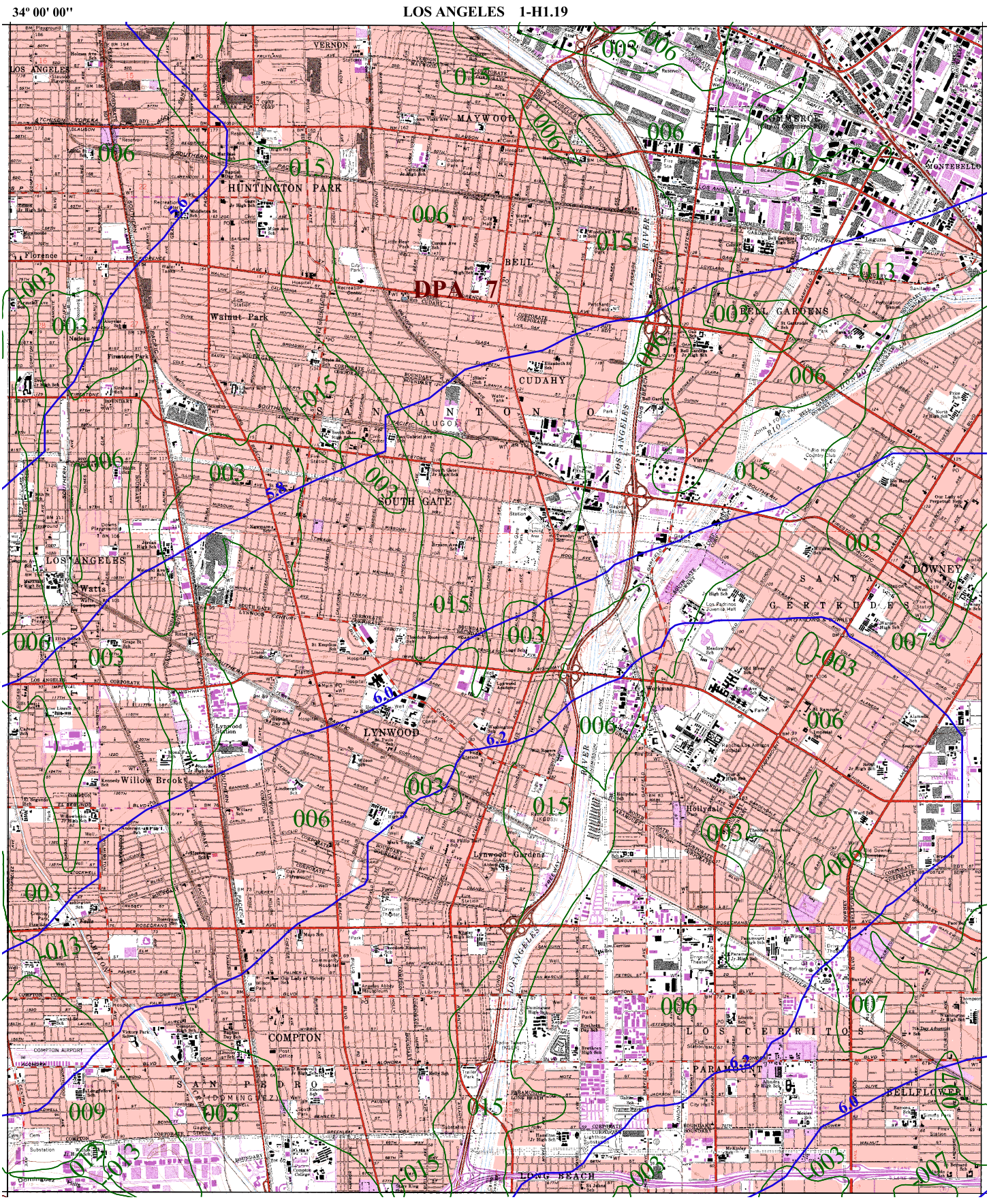
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

INGLEWOOD
50-YEAR 24-HOUR ISOHYET

1-H1.8

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

1 0 1 2 Miles

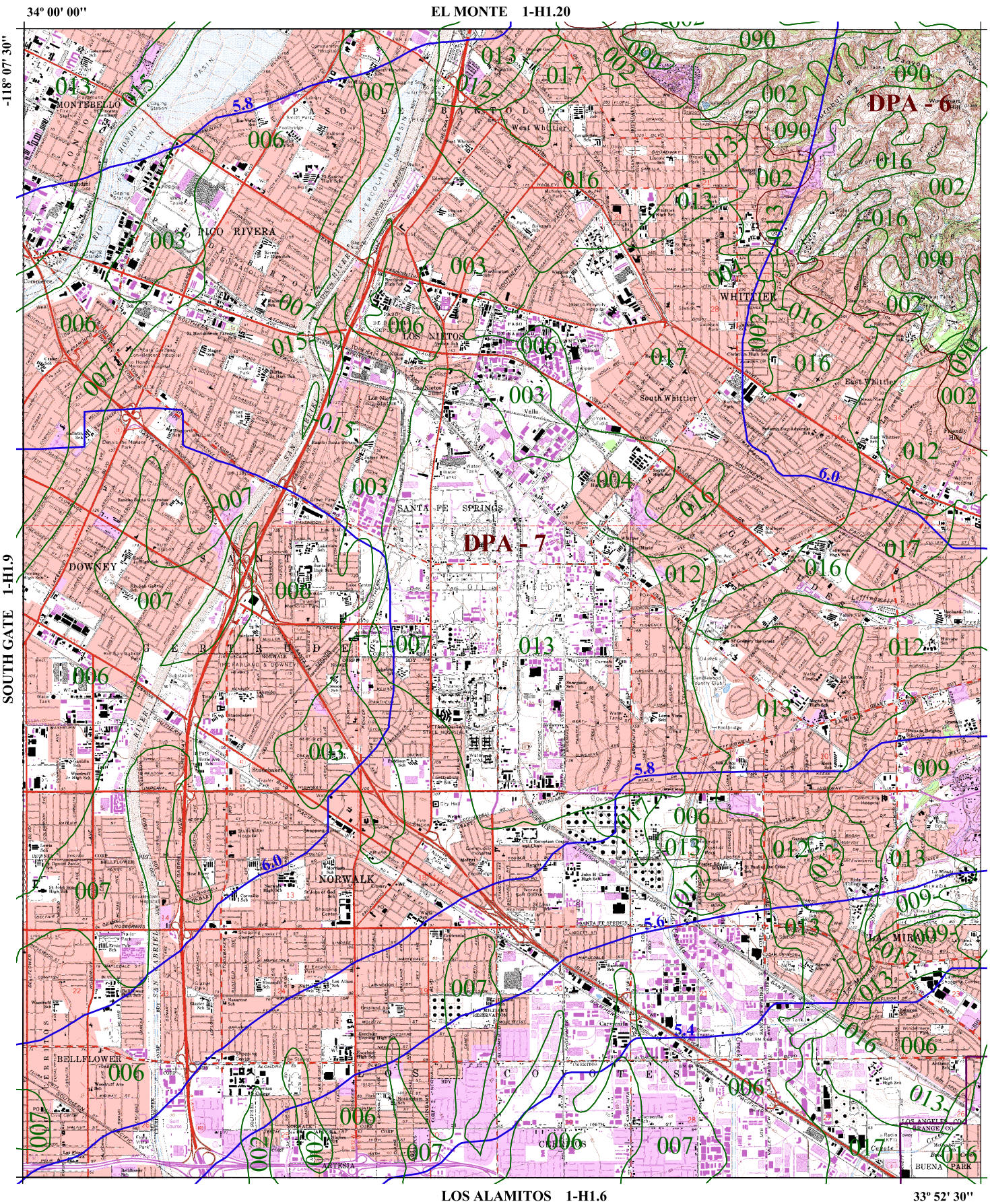
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878

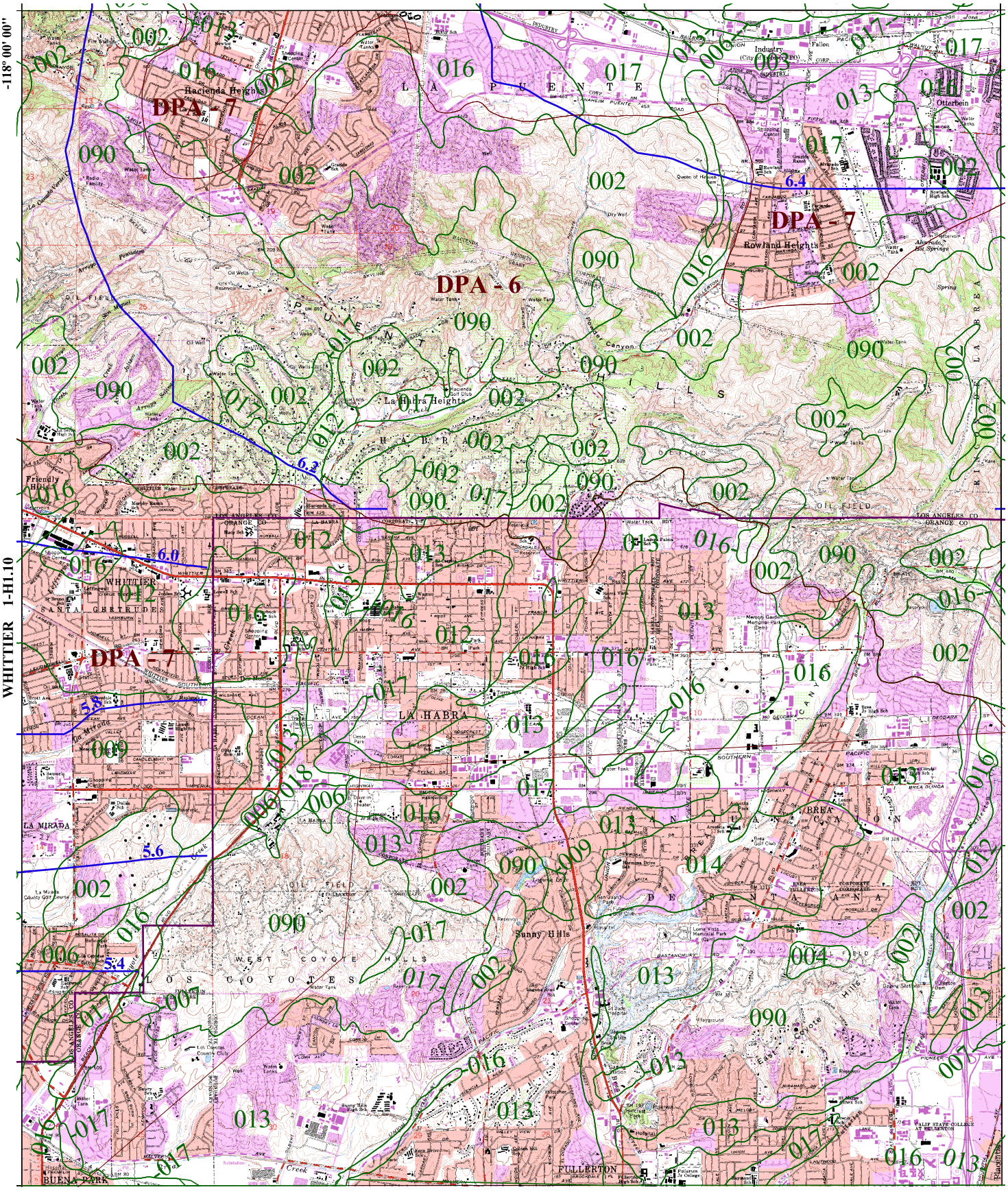
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

SOUTH GATE
50-YEAR 24-HOUR ISOHYET

1-H1.9

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works


34° 00' 00"
EL MONTE 1-H1.20
-118° 07' 30"
SOUTH GATE 1-H1.9
LA HABRA 1-H1.11
-118° 00' 00"
LOS ALAMITOS 1-H1.6
33° 52' 30"
DPA - 6
DPA - 7
MONTEBELLO
PICO RIVERA
WHITTIER
LOS NIETOS
SANTA FE SPRINGS
DOWNEY
NORWALK
BELLFLOWER
ARTESIA
West Whittier
East Whittier
South Whittier
016
7.2
DPA - 6
SOIL CLASSIFICATION AREA
INCHES OF RAINFALL
DEBRIS POTENTIAL AREA
N
W
E
S
1 0 1 2 Miles
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714
W H I T T I E R
50-YEAR 24-HOUR ISOHYET
1-H1.10
LOS ANGELES COUNTY
PUBLIC WORKS
Public Service That Works



N
W E
S

016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

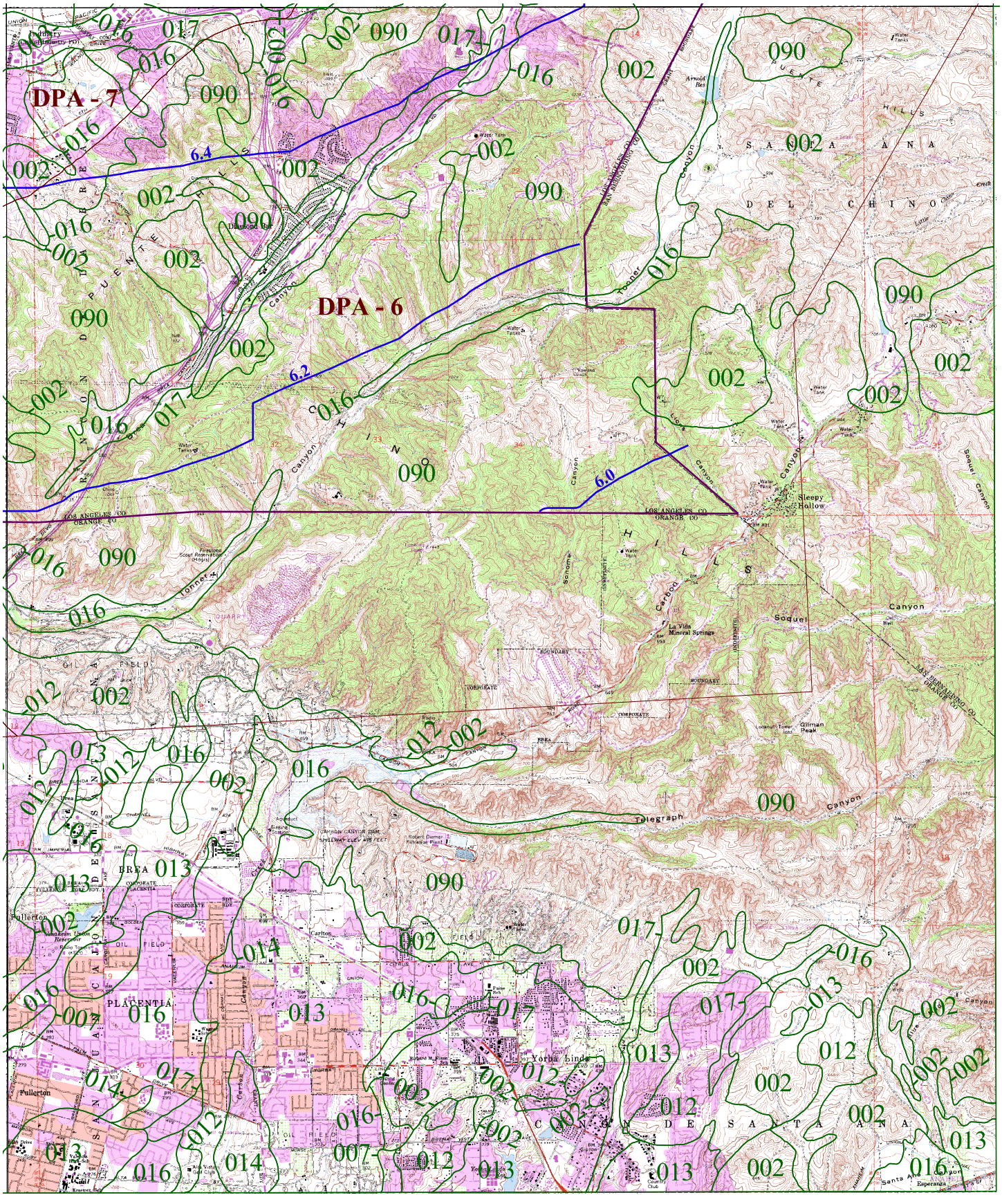
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

L A H A B R A
50-YEAR 24-HOUR ISOHYET

1-H1.11

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

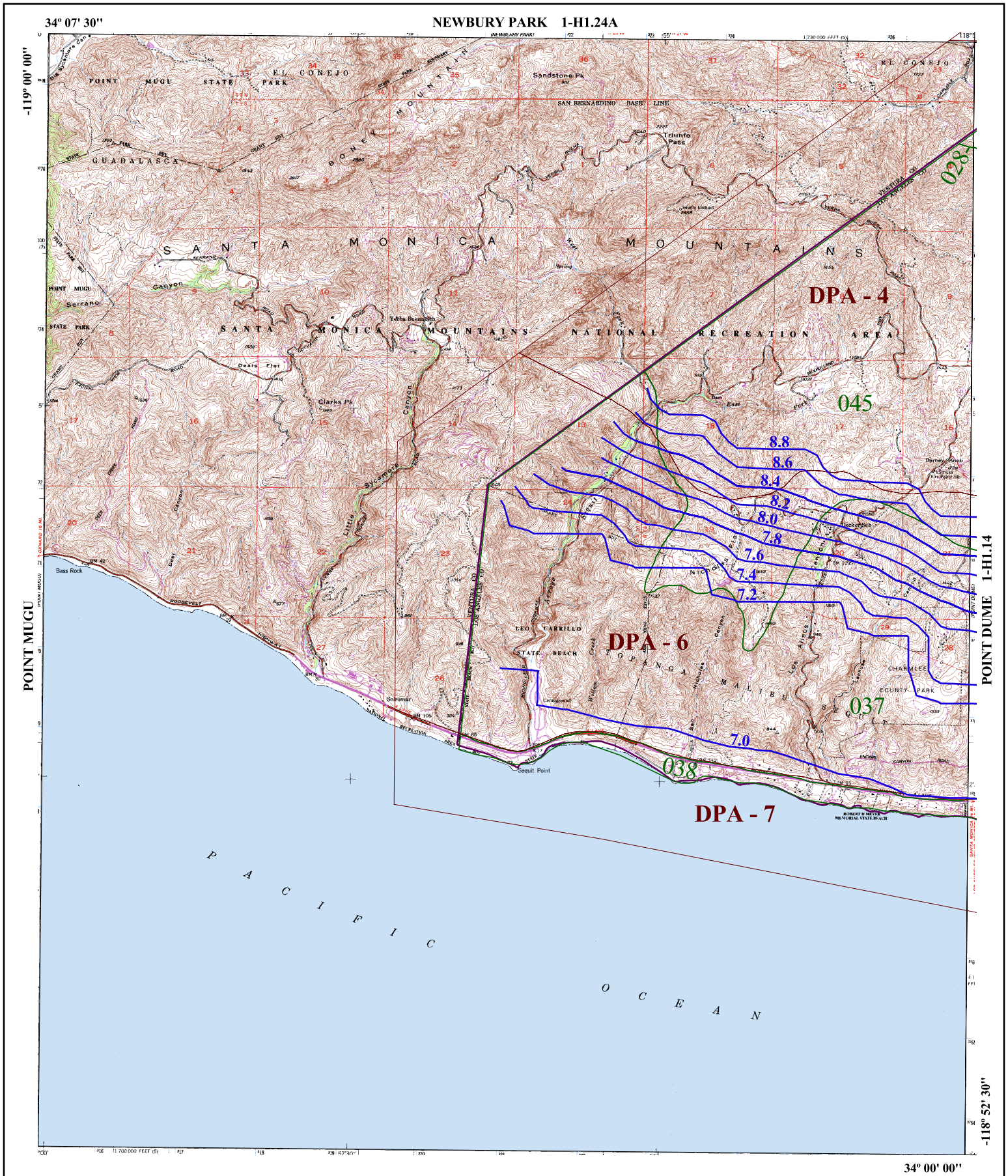
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

YORBA LINDA
50-YEAR 24-HOUR ISOHYET

1-H1.12

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



N
W E
S

016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

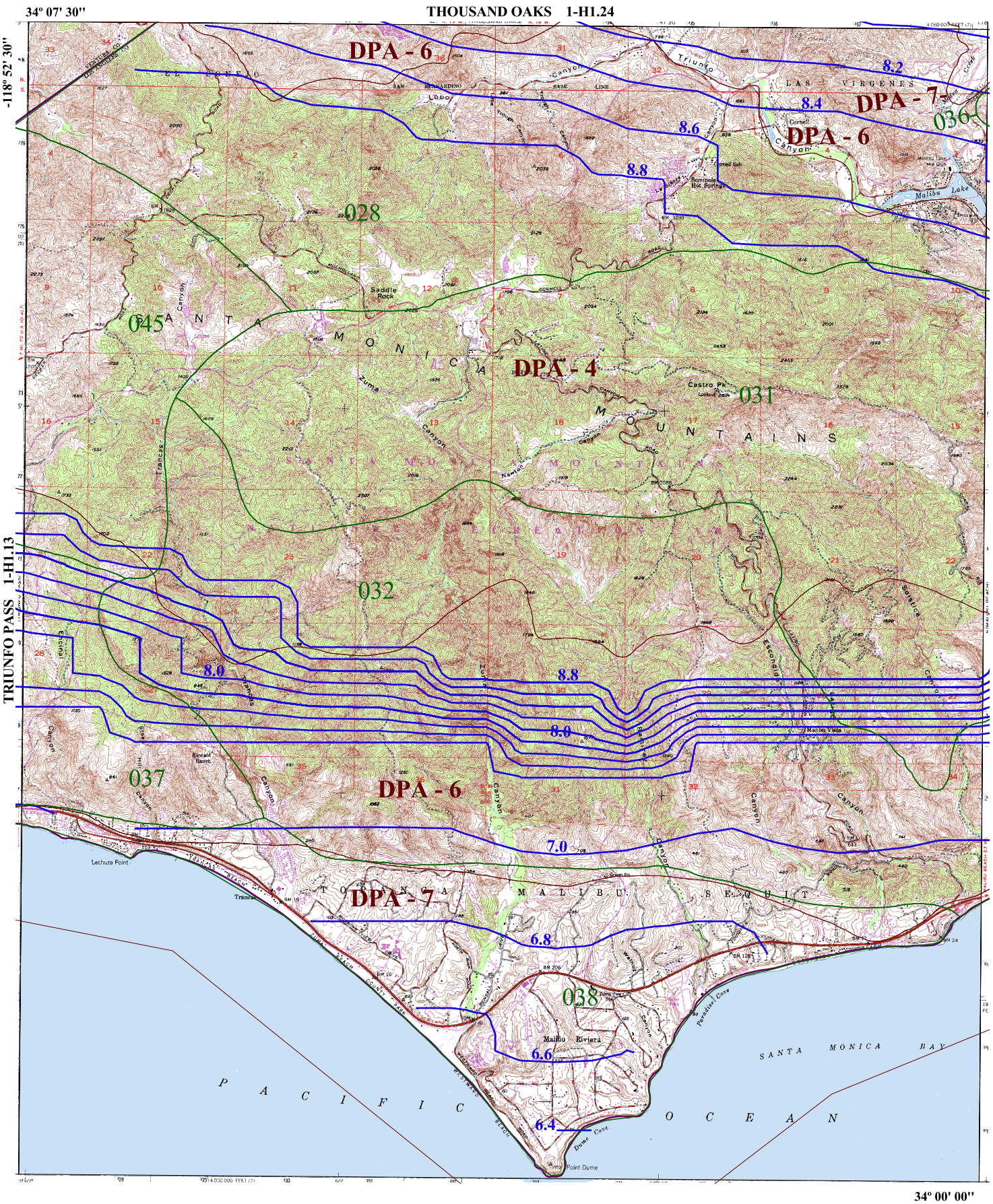
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

TRIUNFO PASS
50-YEAR 24-HOUR ISOHYET

1-H1.13

LOS ANGELES COUNTY PUBLIC WORKS
Public Service That Works



N
W E
S

016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

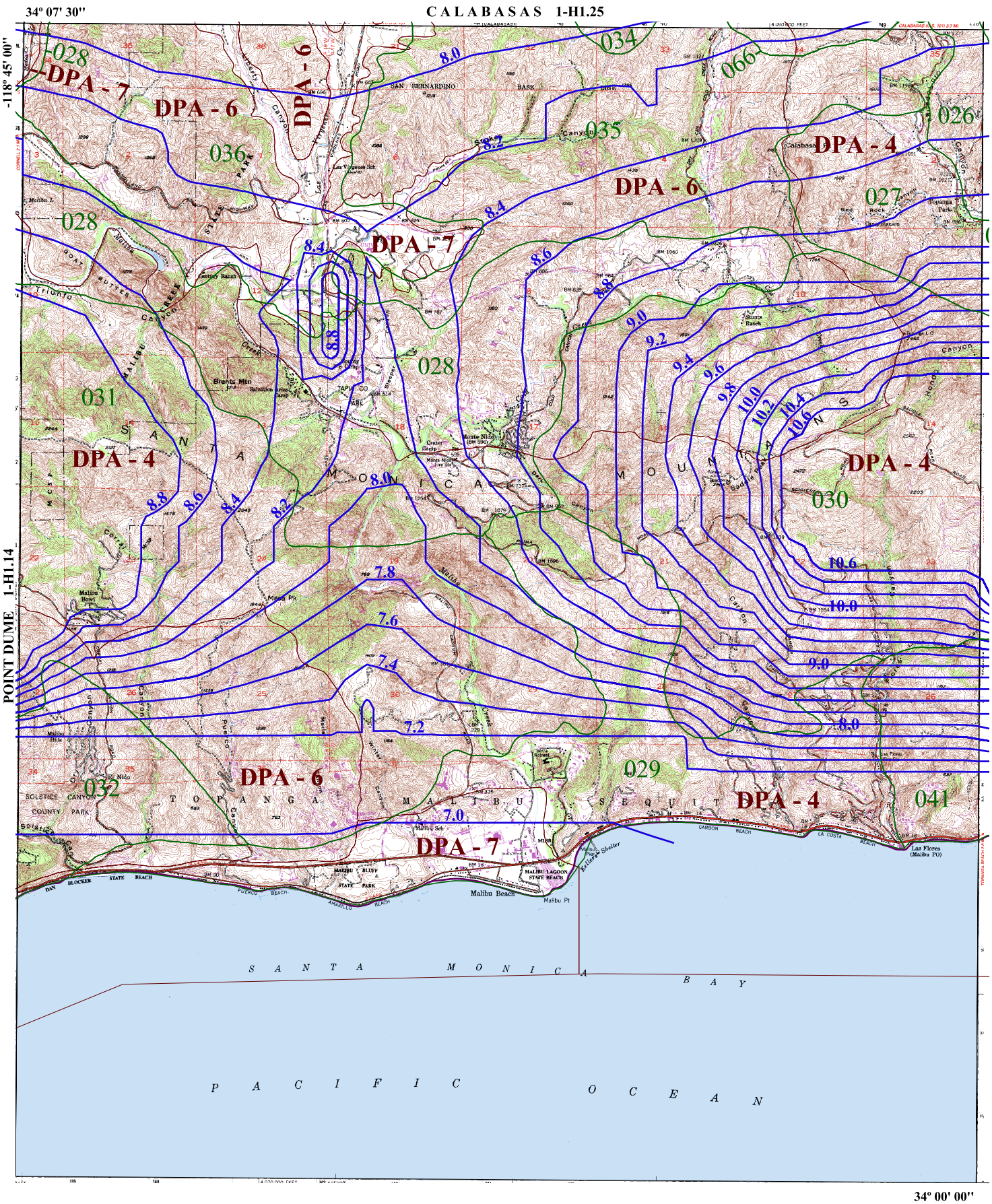
1 0 1 2 Miles

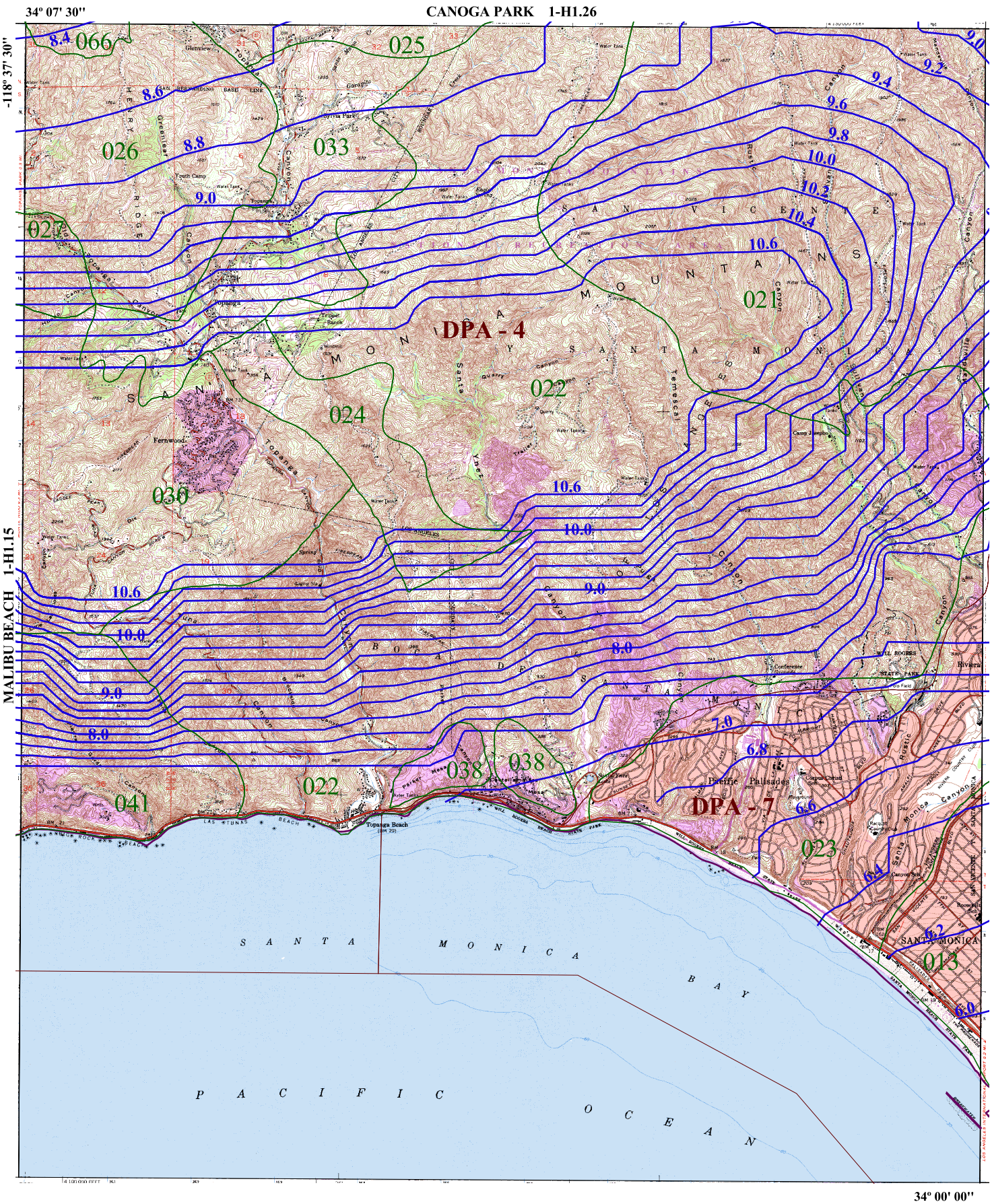
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

POINT DUME
50-YEAR 24-HOUR ISOHYET

1-H1.14

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works


34° 07' 30"
CALABASAS 1-H1.25
-118° 45' 00"
POINT DUME 1-H1.14
TOPANGA 1-H1.16
-118° 37' 30"
34° 00' 00"
DPA - 7
DPA - 6
DPA - 4
028
036
035
034
026
027
031
030
029
032
041
8.0
8.2
8.4
8.6
8.8
9.0
9.2
9.4
9.6
9.8
10.0
10.2
10.4
10.6
7.8
7.6
7.4
7.2
7.0
SANTA MONICA MOUNTAINS
SANTA MONICA BAY
PACIFIC OCEAN
Malibu Beach
Malibu Pt
Las Flores (Malibu PO)
Point Dume
Topanga
Malibu
Sequit
SOLSTICE CANYON COUNTY PARK
DAN BLOCKER STATE BEACH
MALIBU LAGOON STATE BEACH
CARBON BEACH
LA COSTA BEACH
PUERCO BEACH
AMARILLO BEACH
Zuma Ridge
Trancas Canyon
Zuma Canyon
Escondido Canyon
Latigo Canyon
Corral Canyon
Malibu Canyon
Solstice Canyon
Encinal Canyon
Trancas Ranch
Brents Mtn
Monte Nido
Malibu Hills
Mesa Pk
Malibu Bowl
Las Virgenes
Calabasas
Topanga Park
Red Rock
Saddle Rock
Stunt Ranch
Tapia Co
Center Camp
Malibu Seb
Malibu Lagoon
Killers Shelter
Malibu L
Triunfo
Goat Buttes
Stiles Reservoir
Las Virgenes Canyon
Las Virgenes Creek
Malibu Creek
Malibu Creek State Park
Las Virgenes Creek
Las Virgenes Canyon
Las Virgenes Creek
Las Virgenes Canyon
Las Virgenes Creek
Las Virgenes Canyon



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878

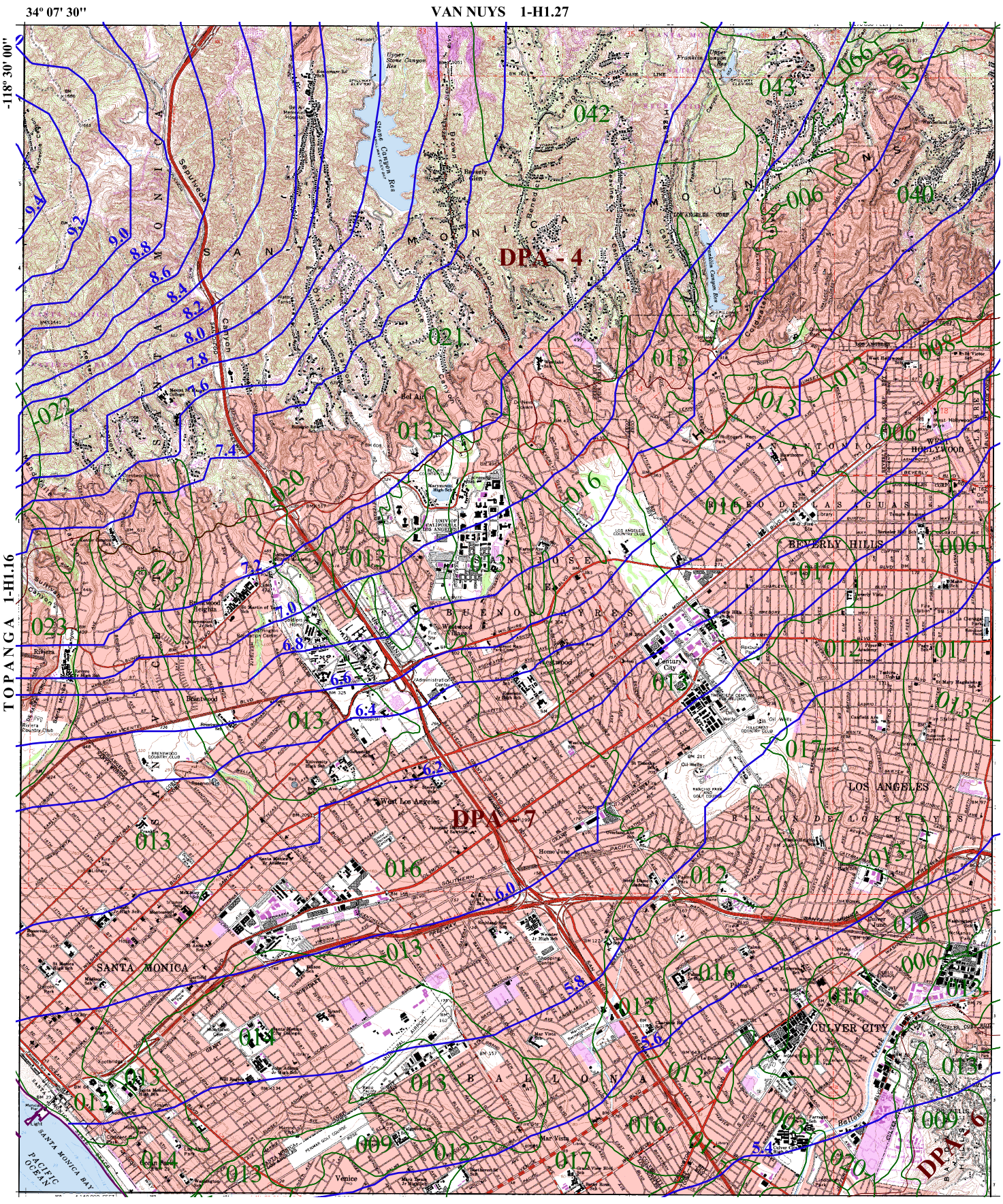
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

T O P A N G A

50-YEAR 24-HOUR ISOHYET

1-H1.16

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

1 0 1 2 Miles

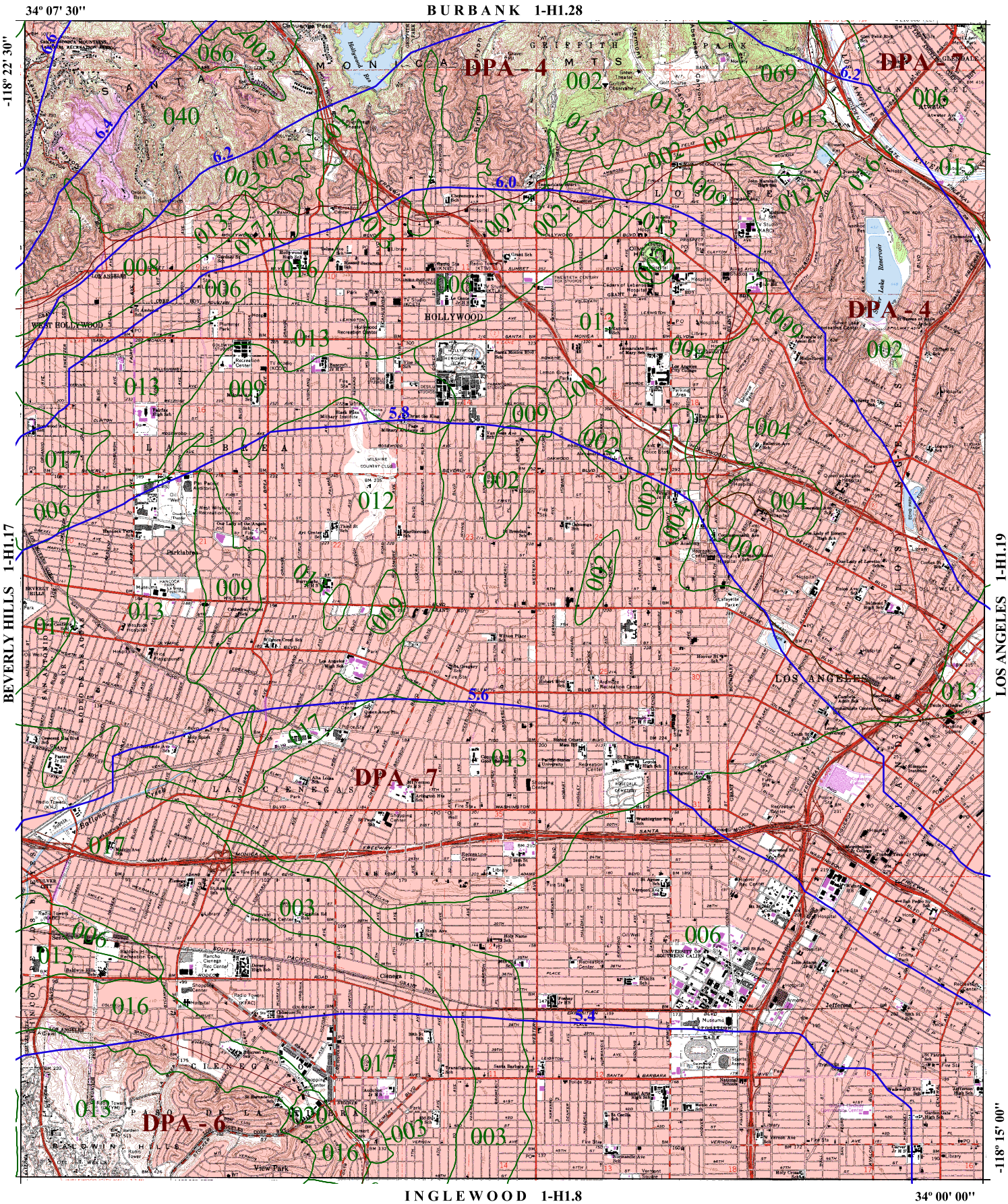
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878

10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

BEVERLY HILLS 1-H1.17

50-YEAR 24-HOUR ISOHYET

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

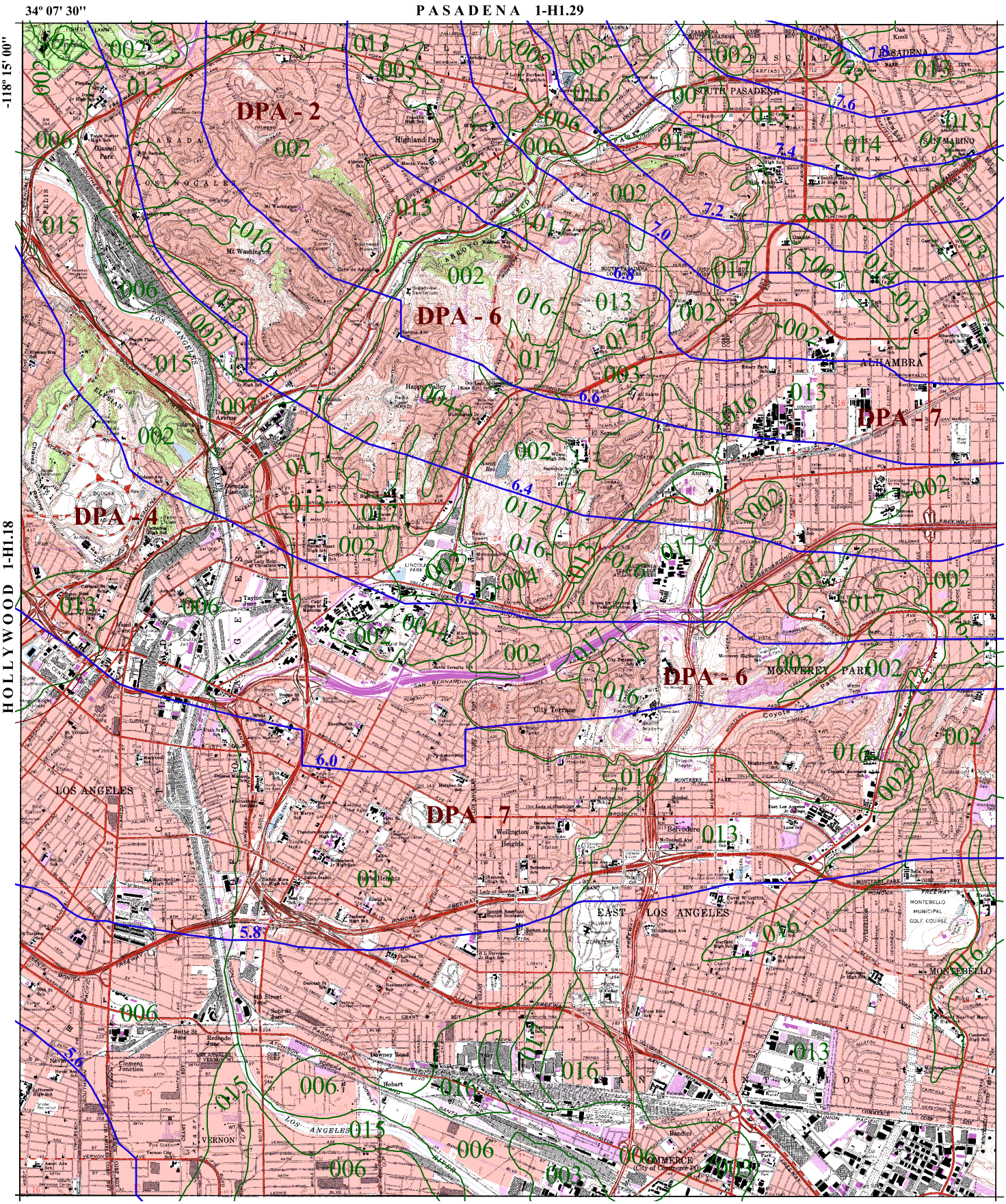
N W E S

1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

HOLLYWOOD 1-H1.18
50-YEAR 24-HOUR ISOHYET

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

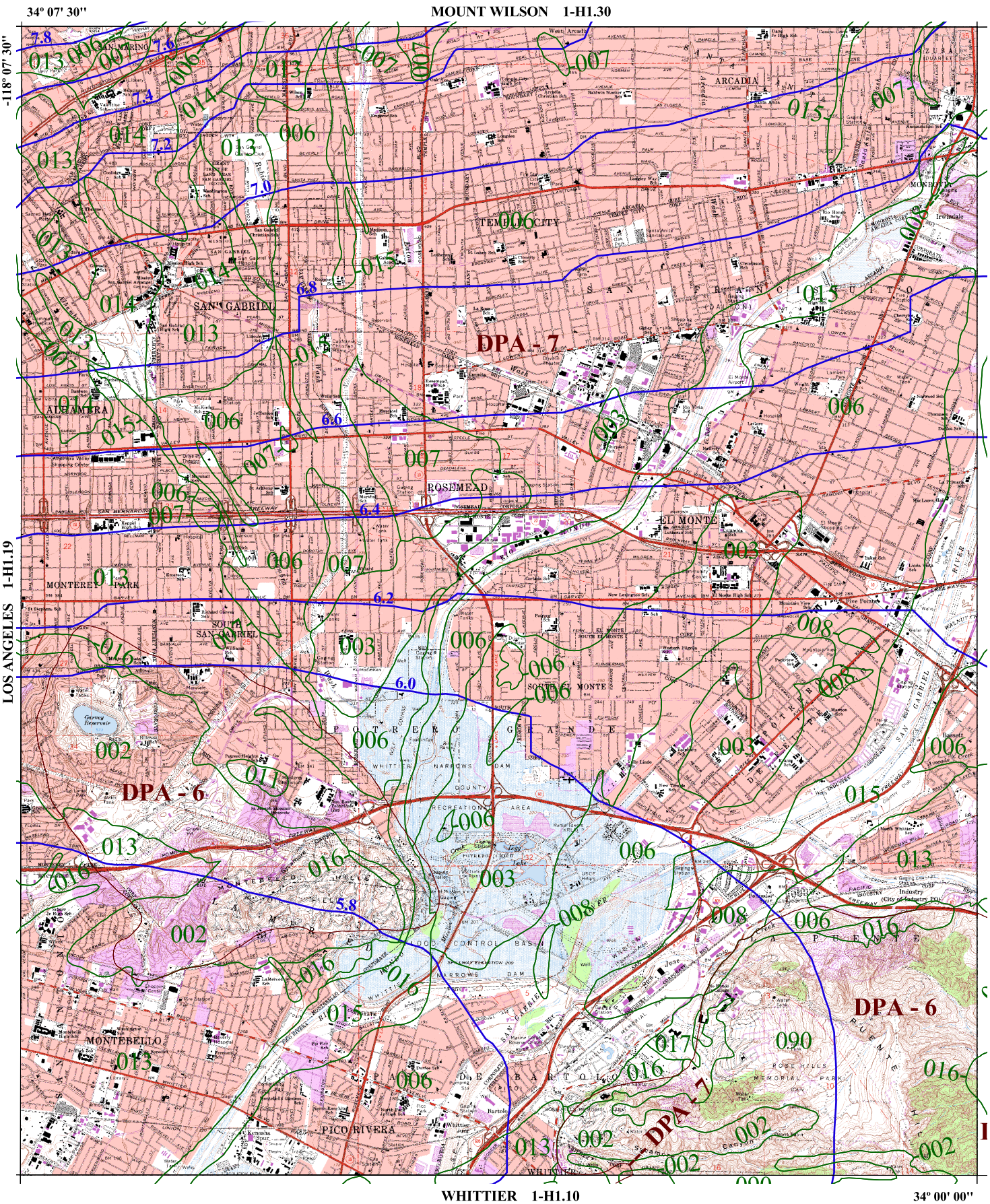
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

LOS ANGELES 50-YEAR 24-HOUR ISOHYET

1-H1.19

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



N
W E
S

016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

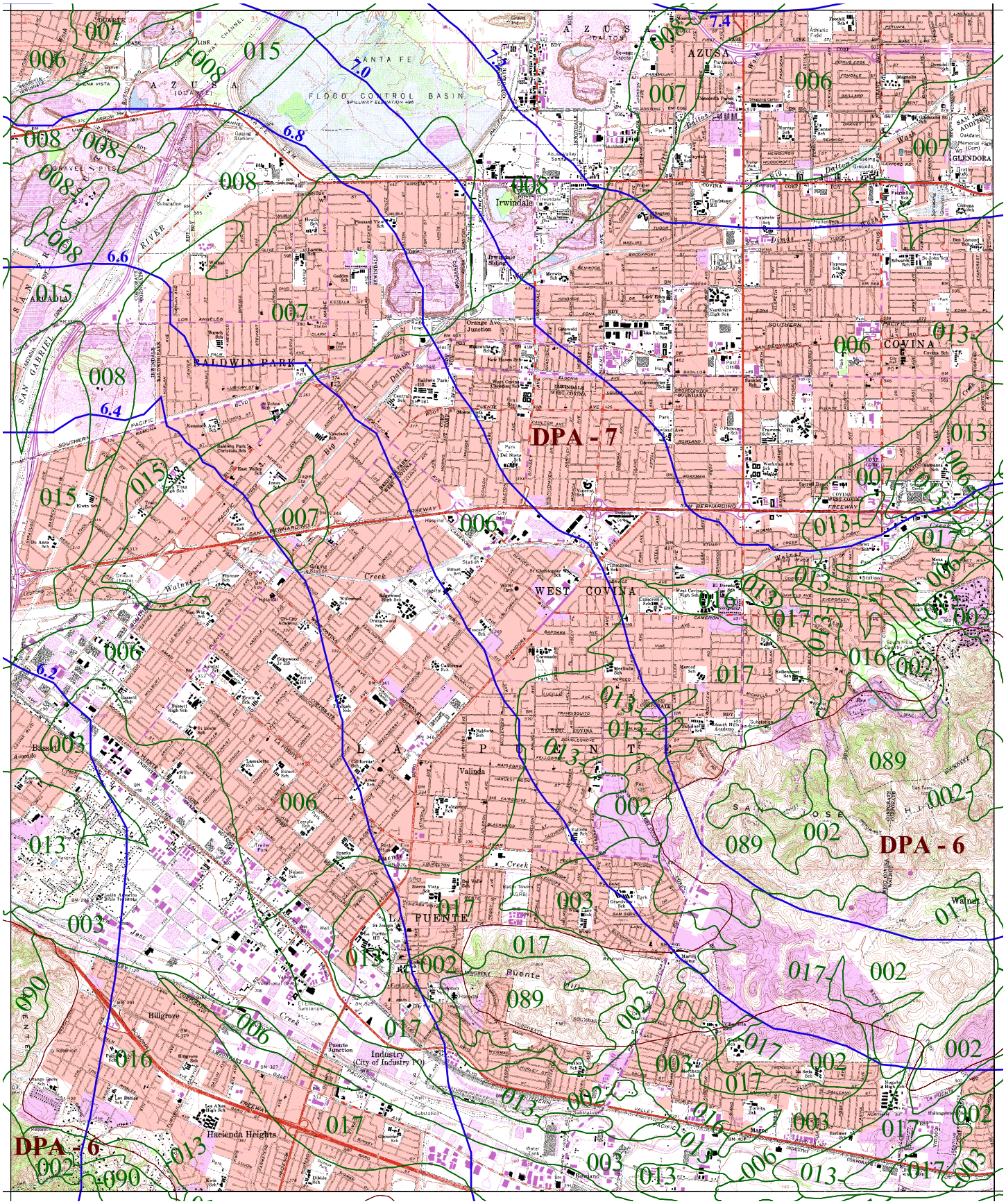
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

EL MONTE
50-YEAR 24-HOUR ISOHYET

1-H1.20

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

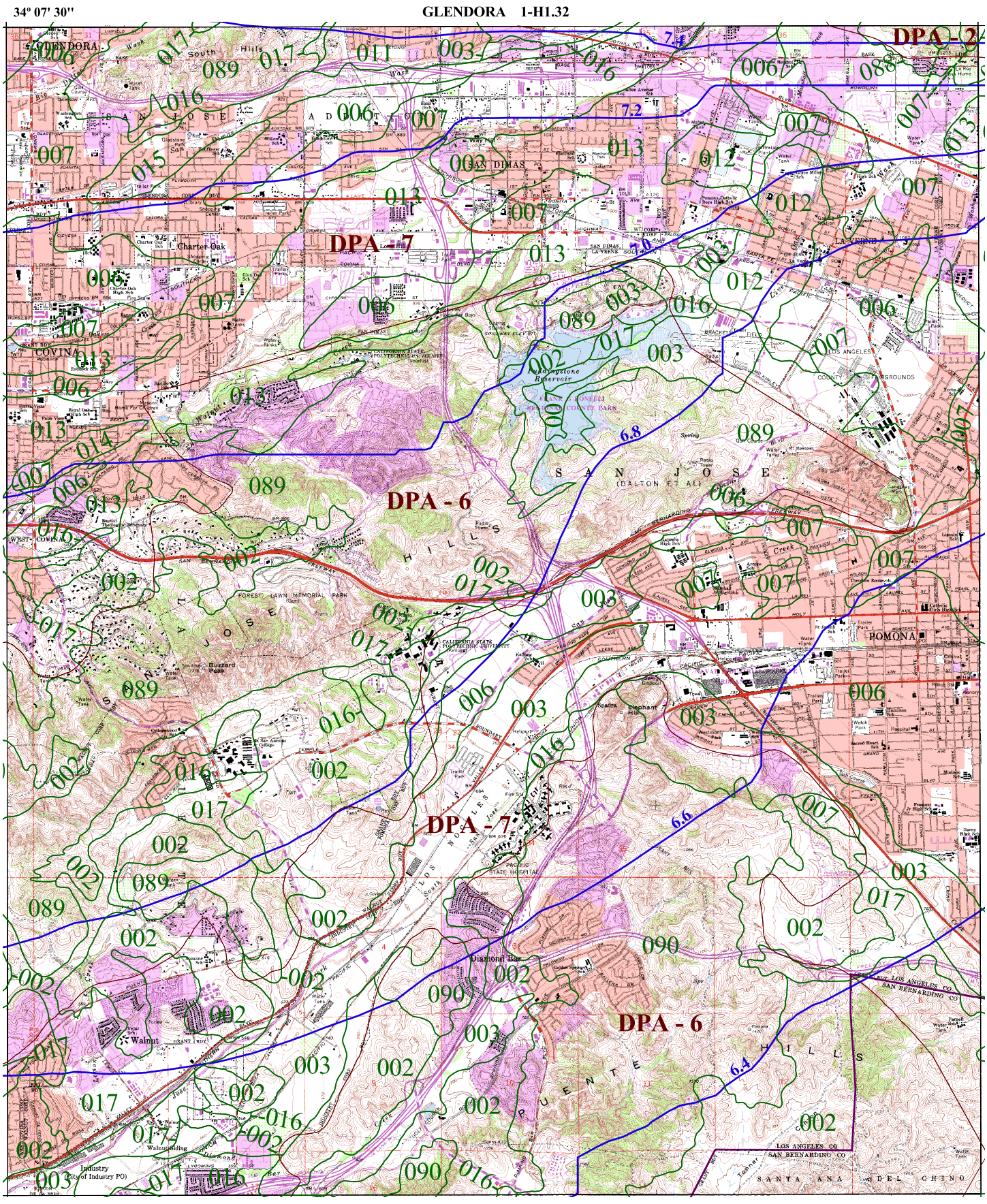
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

BALDWIN PARK
50-YEAR 24-HOUR ISOHYET

1-H1.21

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

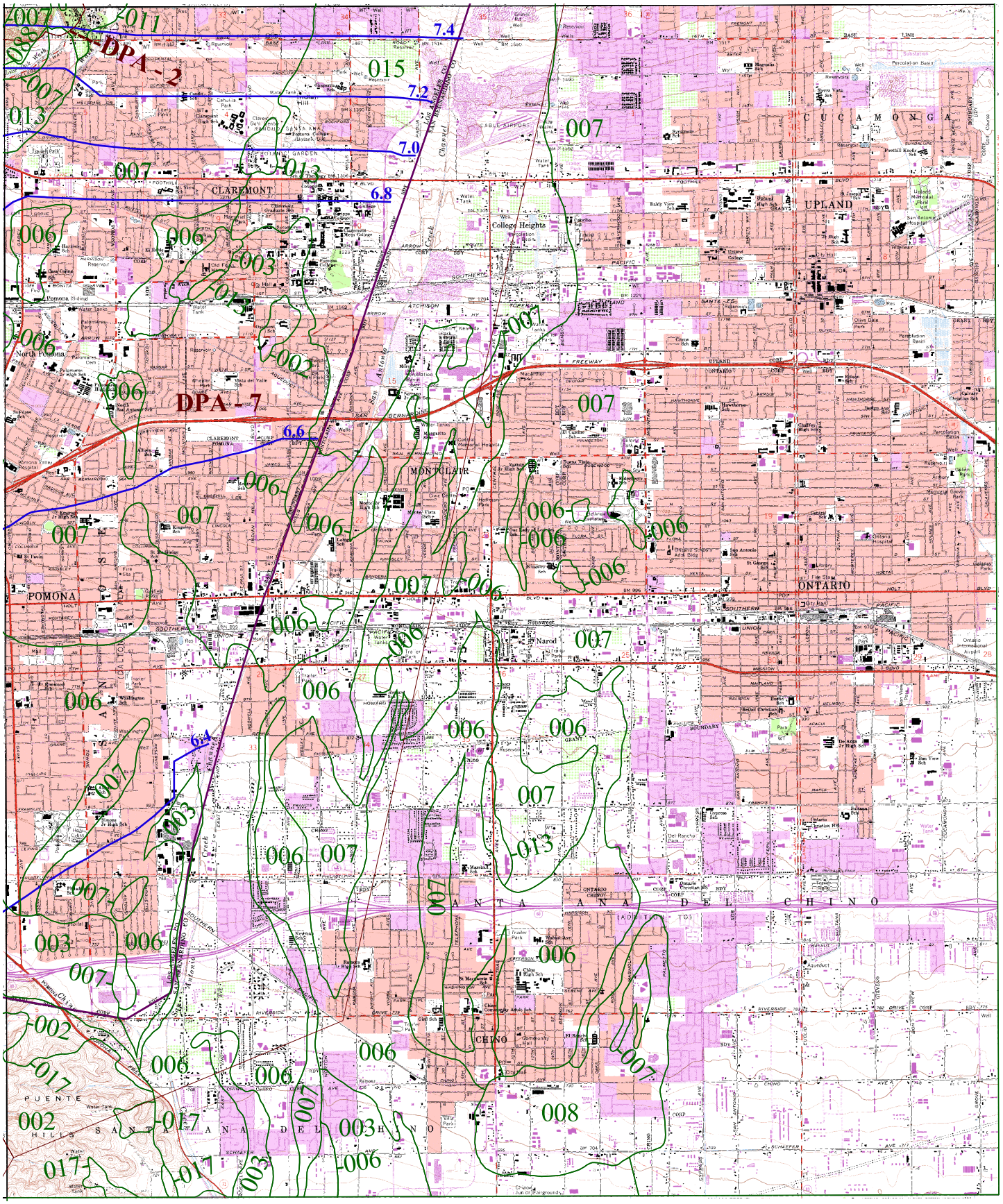
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

SAN DIMAS
50-YEAR 24-HOUR ISOHYET

1-H1.22

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

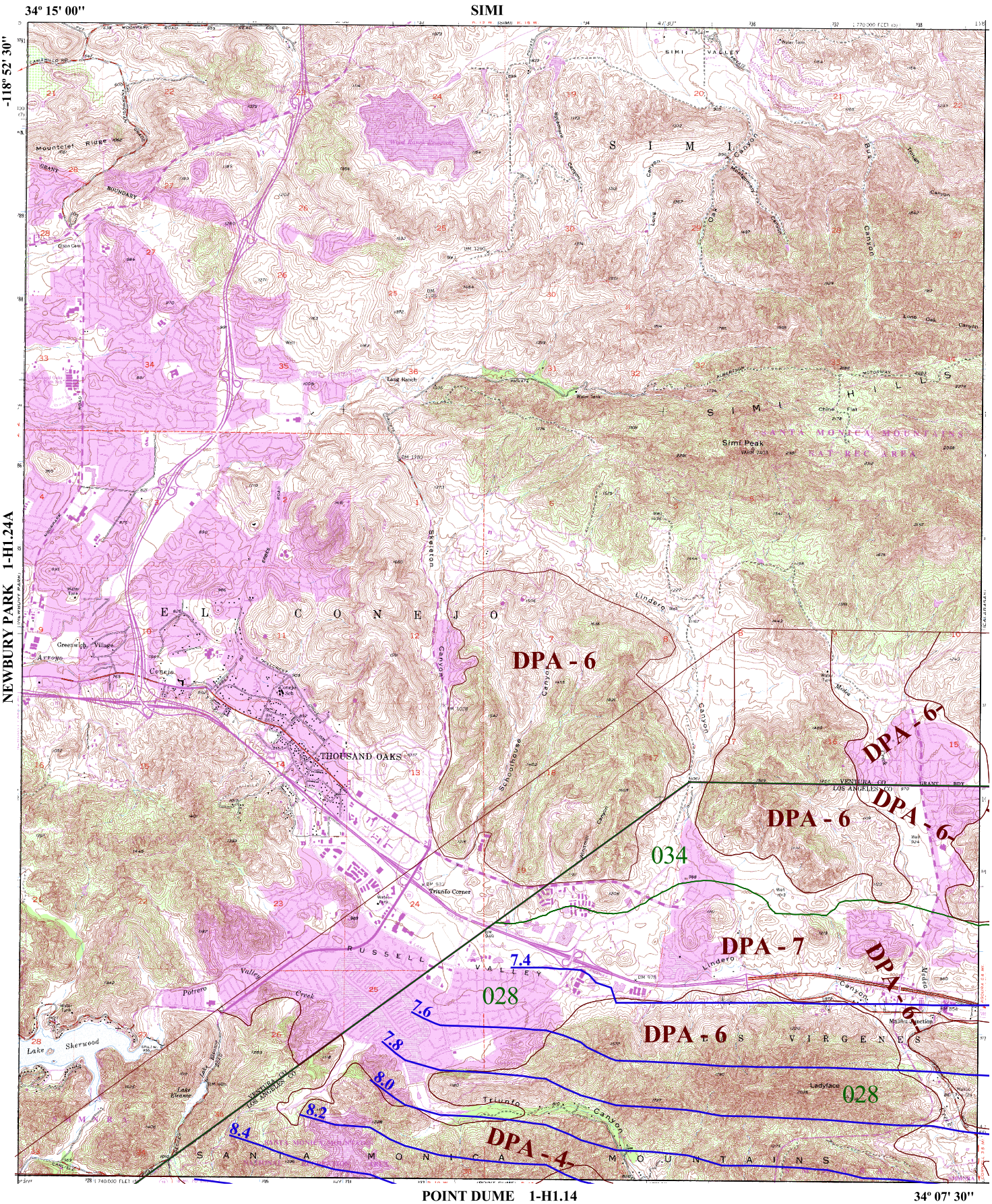
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

ONTARIO
50-YEAR 24-HOUR ISOHYET

1-H1.23

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



N
W E
S

016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

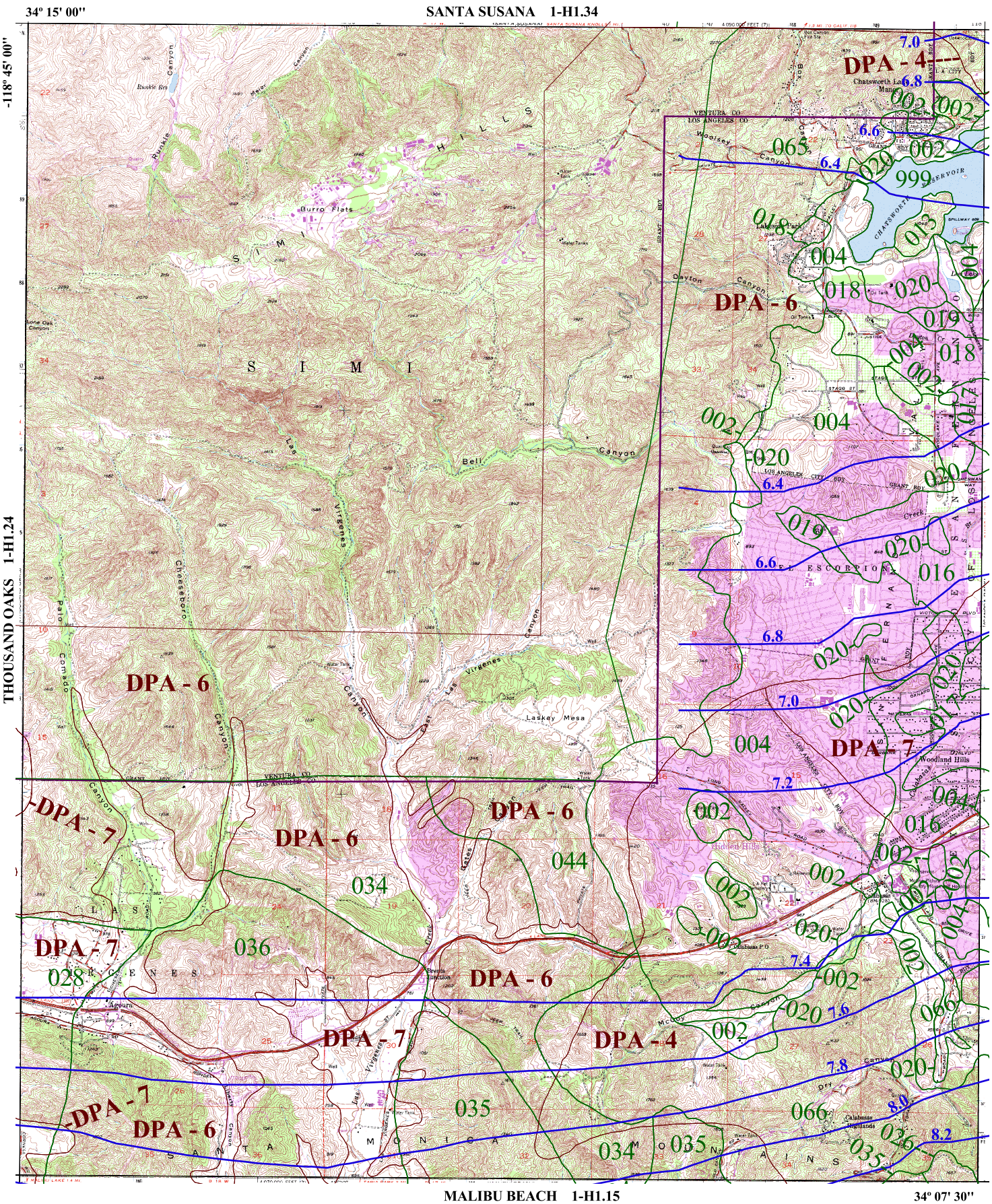
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

THOUSAND OAKS
50-YEAR 24-HOUR ISOHYET

1-H1.24

LOS ANGELES COUNTY PUBLIC WORKS
Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

1 0 1 2 Miles

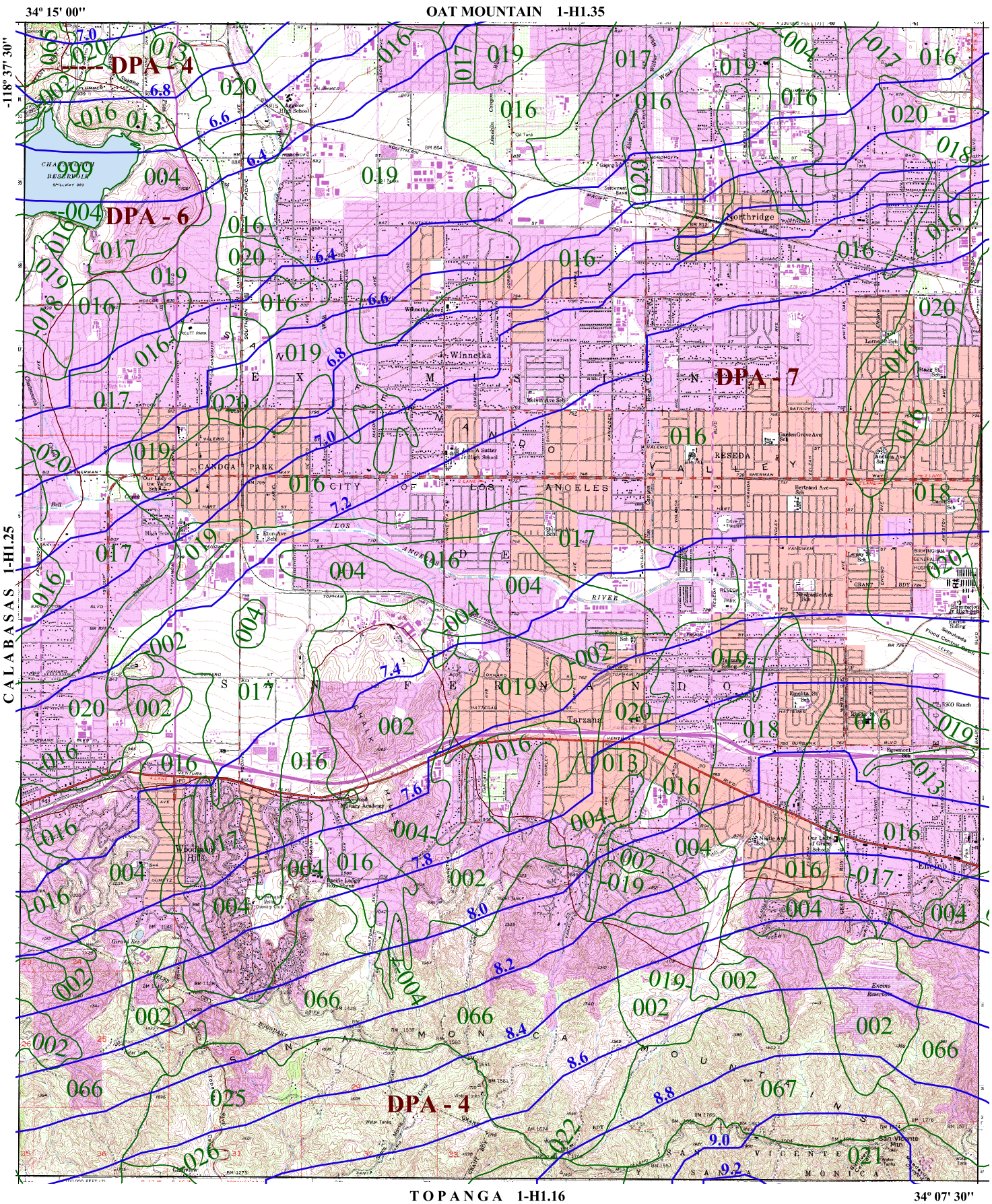
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878

10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

CALABASAS 1-H1.25

50-YEAR 24-HOUR ISOHYET

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

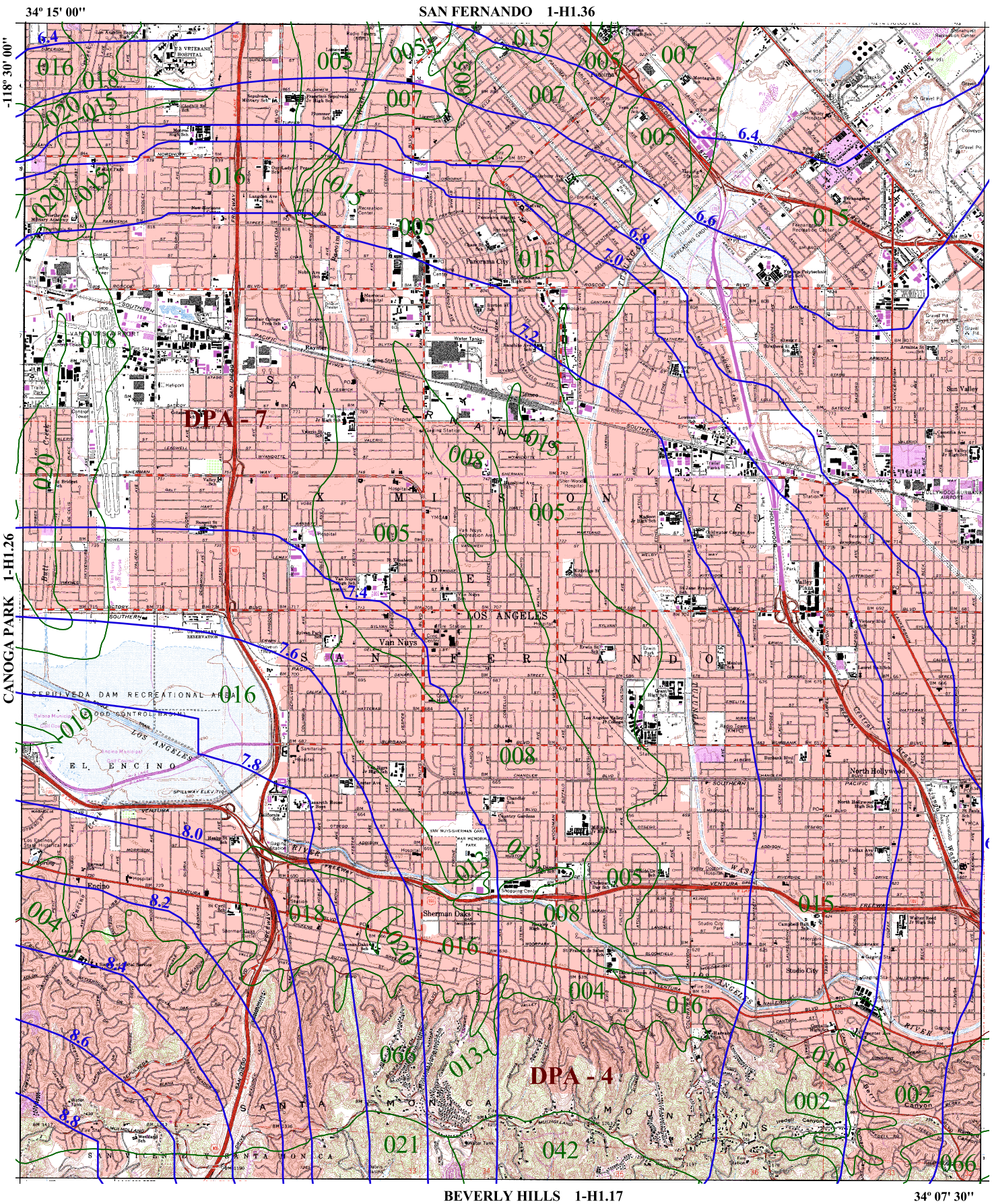
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

CANOGA PARK
50-YEAR 24-HOUR ISOHYET

1-H1.26

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

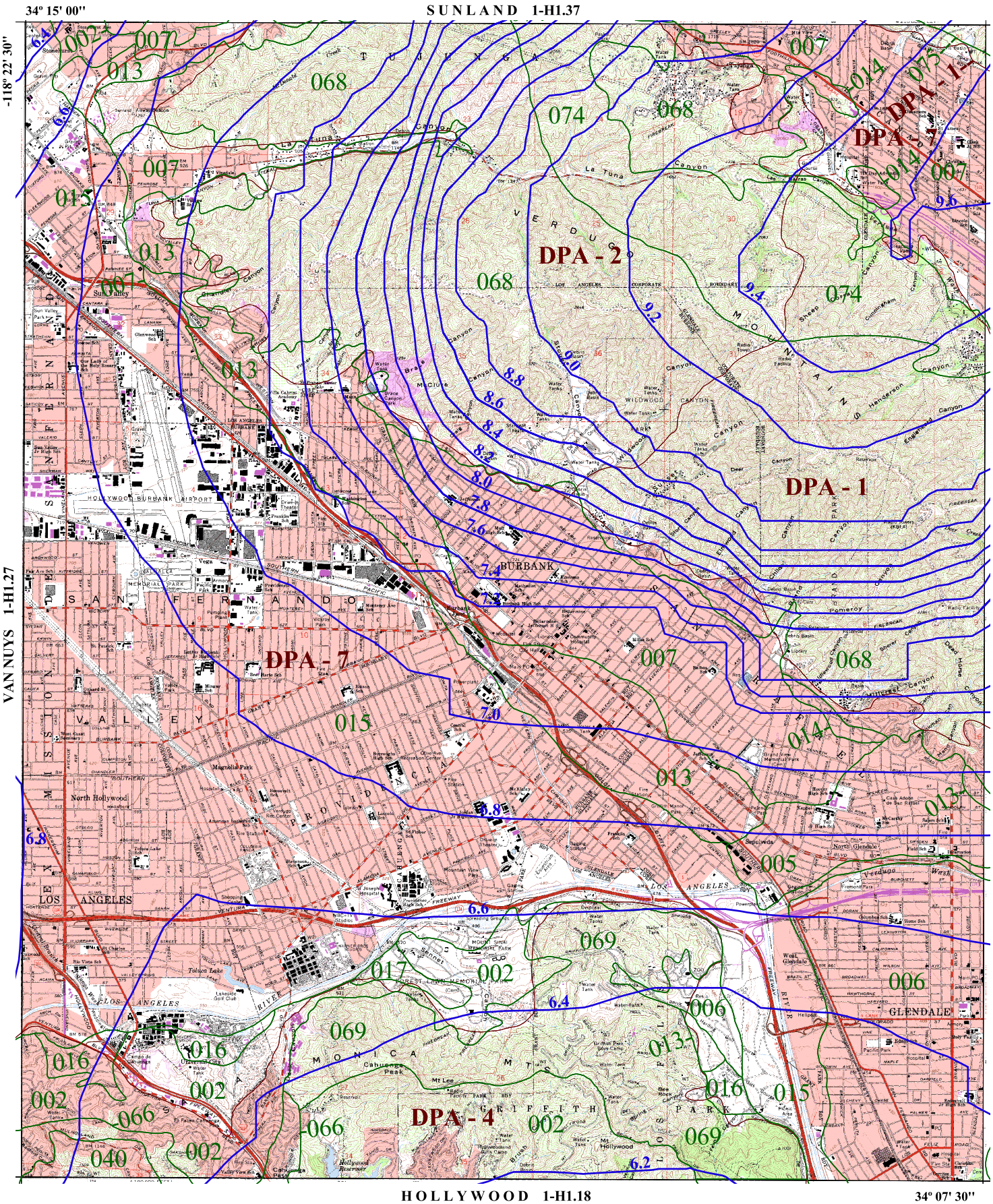
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

VAN NUYS
50-YEAR 24-HOUR ISOHYET

1-H1.27

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878

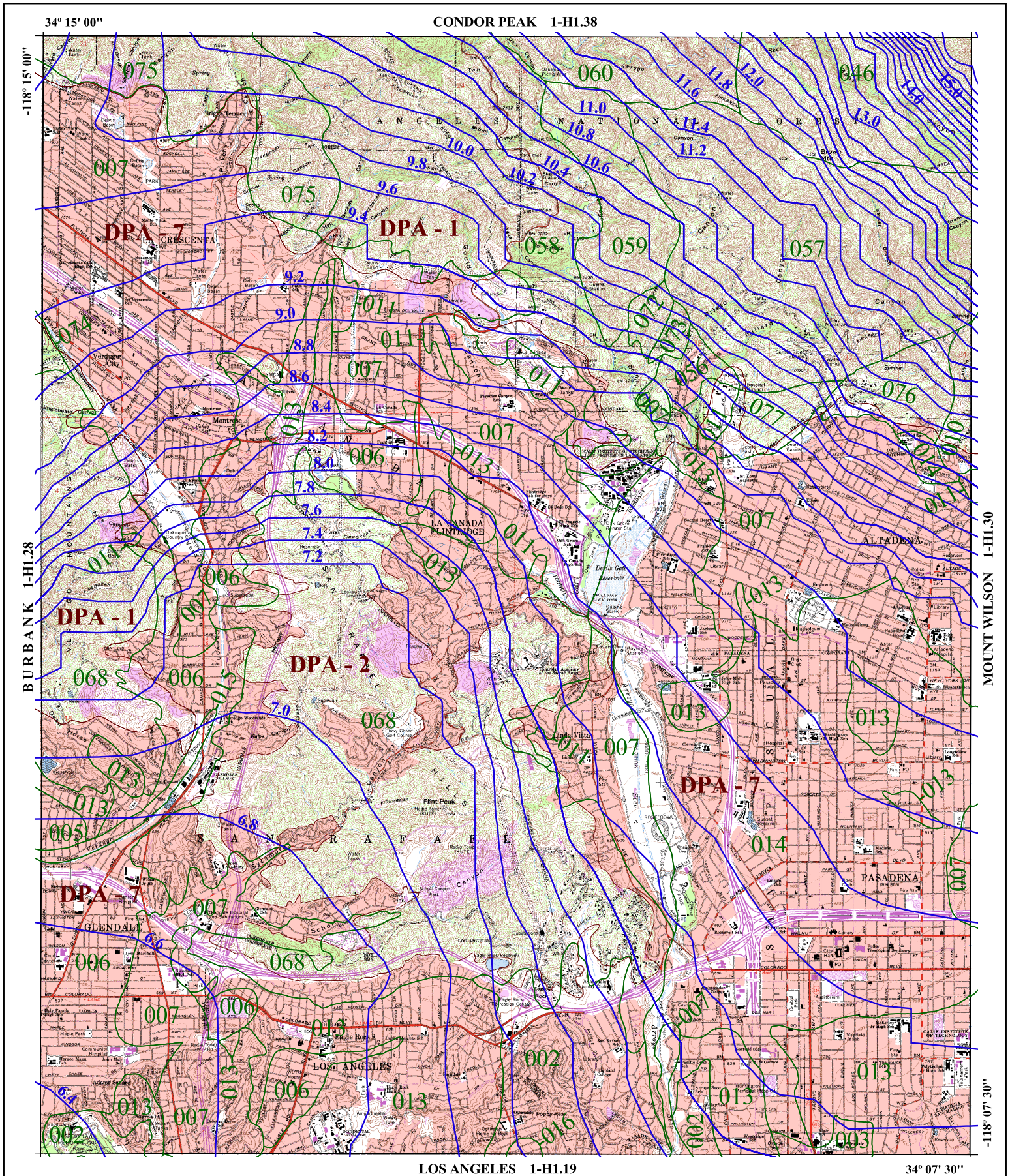
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

B U R B A N K

50-YEAR 24-HOUR ISOHYET

1-H1.28

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works

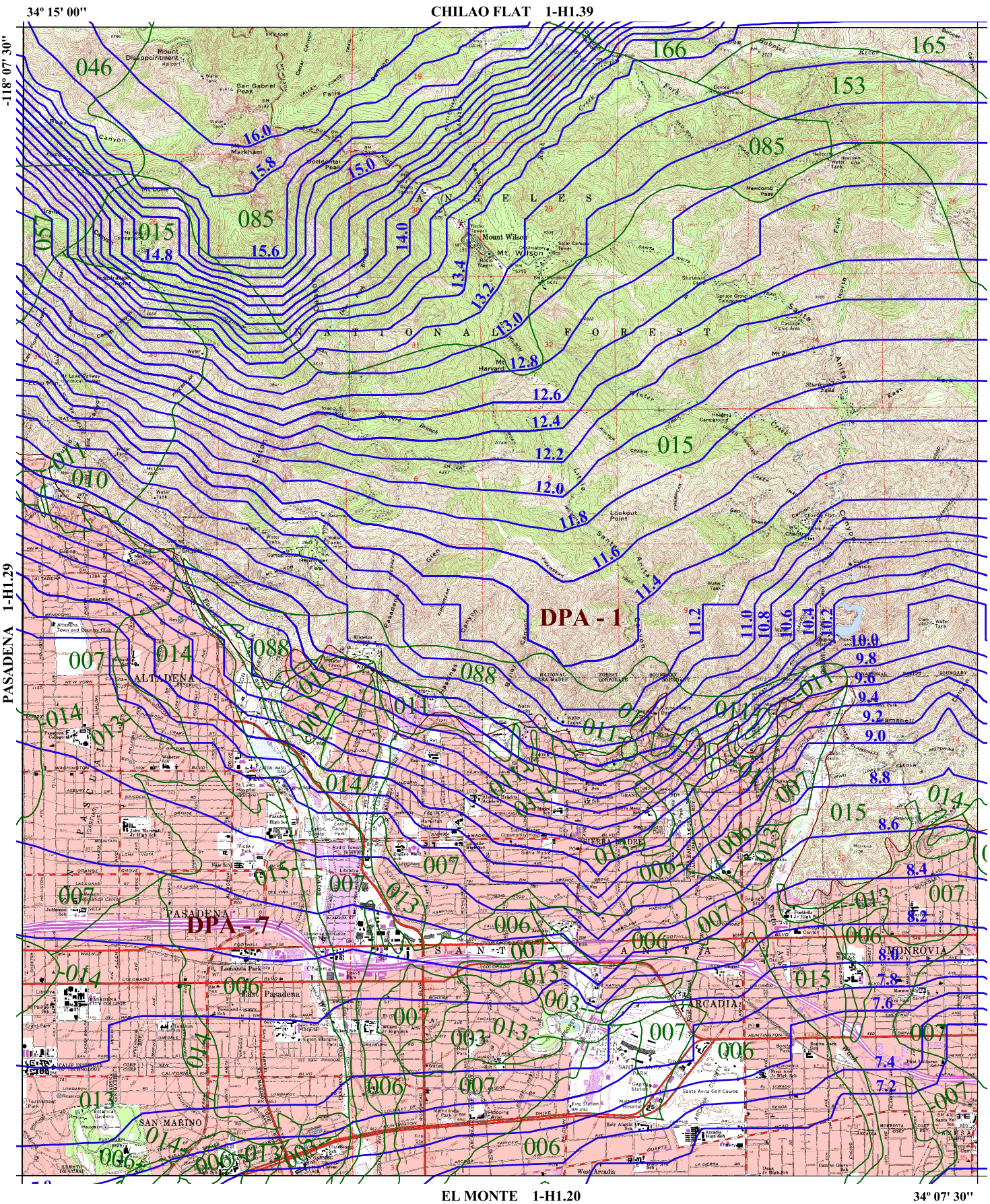


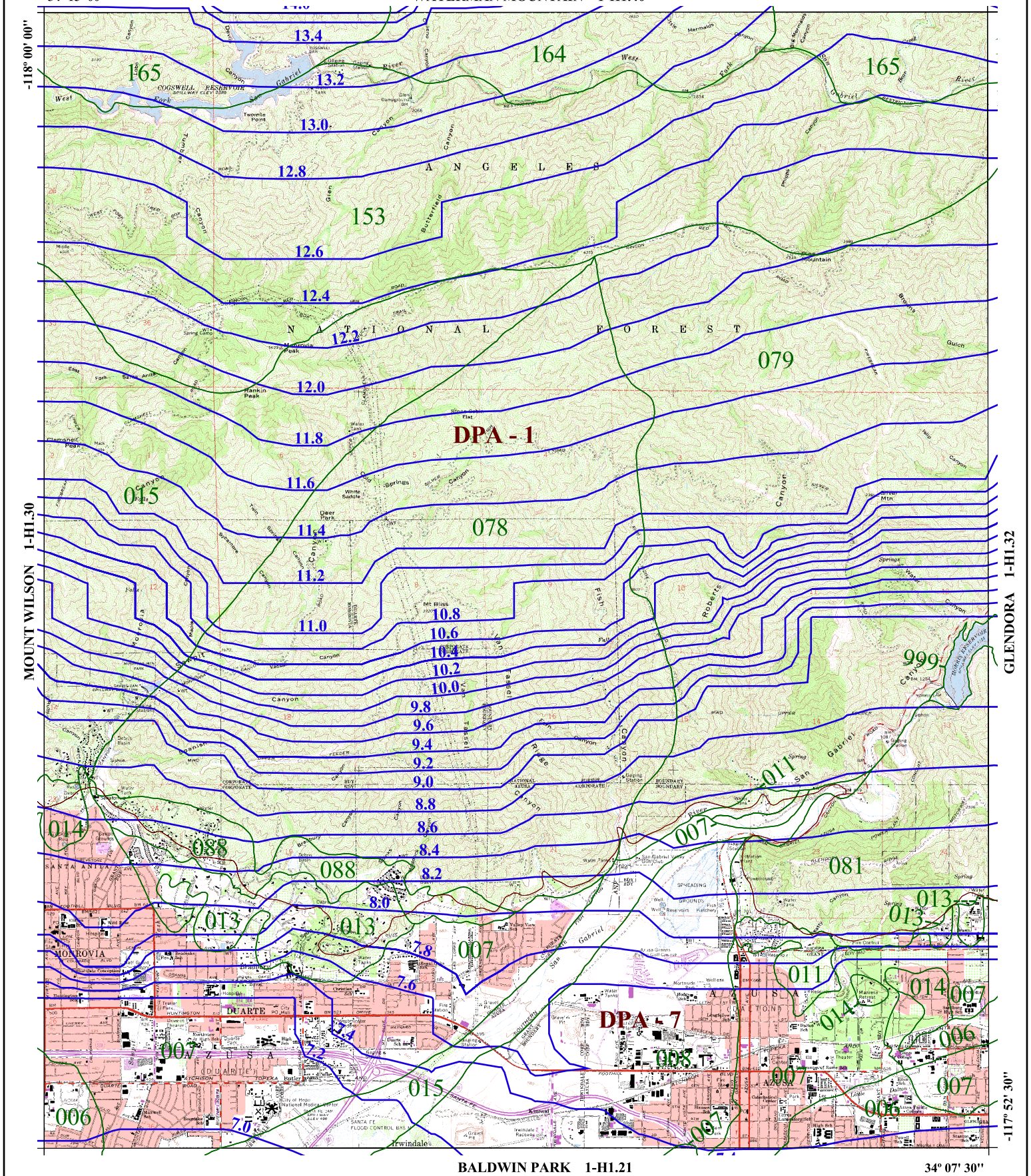
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

PASADENA
50-YEAR 24-HOUR ISOHYET

1-H1.29

LOS ANGELES COUNTY PUBLIC WORKS
Public Service That Works


34° 15' 00"
CHILAO FLAT 1-H1.39
-118° 07' 30"
PASADENA 1-H1.29
AZUSA 1-H1.31
-118° 00' 00"
EL MONTE 1-H1.20
34° 07' 30"
DPA - 1
DPA - 7
ALTADENA
PASADENA
SAN MARINO
ARCADIA
MONROVIA
SIERRA MADRE
Mount Wilson
Mt Wilson
Mount Disappointment
San Gabriel Peak
Mt Markham
Mt Harvard
Lookout Point
Newcomb Pass
Santa Anita Golf Course
West Arcadia
East Pasadena
Mt Lowe
Mt Zion
Sturtevant Falls
Eaton Canyon
Millard Canyon
Arroyo Seco
Santa Anita Canyon
Sawpit Canyon
Big Santa Anita Canyon
Winter Creek
Spruce Grove Campground
Chantry Flat
Idlehour Campground
Henninger Flats
Lookout Point
Sturtevant Camp
Mount Wilson Observatory
Radio Towers
Solar Canvas Tower
Mt Wilson Toll Road
Angeles Crest Highway
Rincon Trail
Gabrielino Trail
Sturtevant Trail
Sierra Madre Blvd
Foothill Blvd
Colorado Blvd
Huntington Dr
Santa Anita Ave
Rosemead Blvd
Baldwin Ave
Fair Oaks Ave
Lake Ave
Michillinda Ave
Sierra Madre Villa
Arcadia Park
Santa Anita Park
Pasadena Town and Country Club
Pasadena City College
Caltech
Huntington Hospital
Methodist Hospital
Arcadia High Sch
Monrovia High Sch
Pasadena High Sch
John Marshall Fundamental Sch
Eliot Arbuthnot Sch
Loma Alta Park
Victory Park
Lanterman Park
Library
Fire Station
Reservoir
Botanical Garden
Tournament Park
Arcadia Golf Course
Boys Republic
Boy Scouts Camp
Girl Scouts Camp
Camp Sierra Madre
Camp Trask
Camp Hi Hill
Camp Ben Hur
Camp Fremont
Camp Huntington
Camp Wilson
Camp Williams
Camp Rincon
Camp Sturtevant
Camp Eaton
Camp Newcomb
Camp Lowe
Camp Allen
Camp Ivy
Camp Lockett
Camp Lowell
Camp Lowe
Camp Lowell
Camp Lowe
Camp Lowell
Camp Lowe



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878

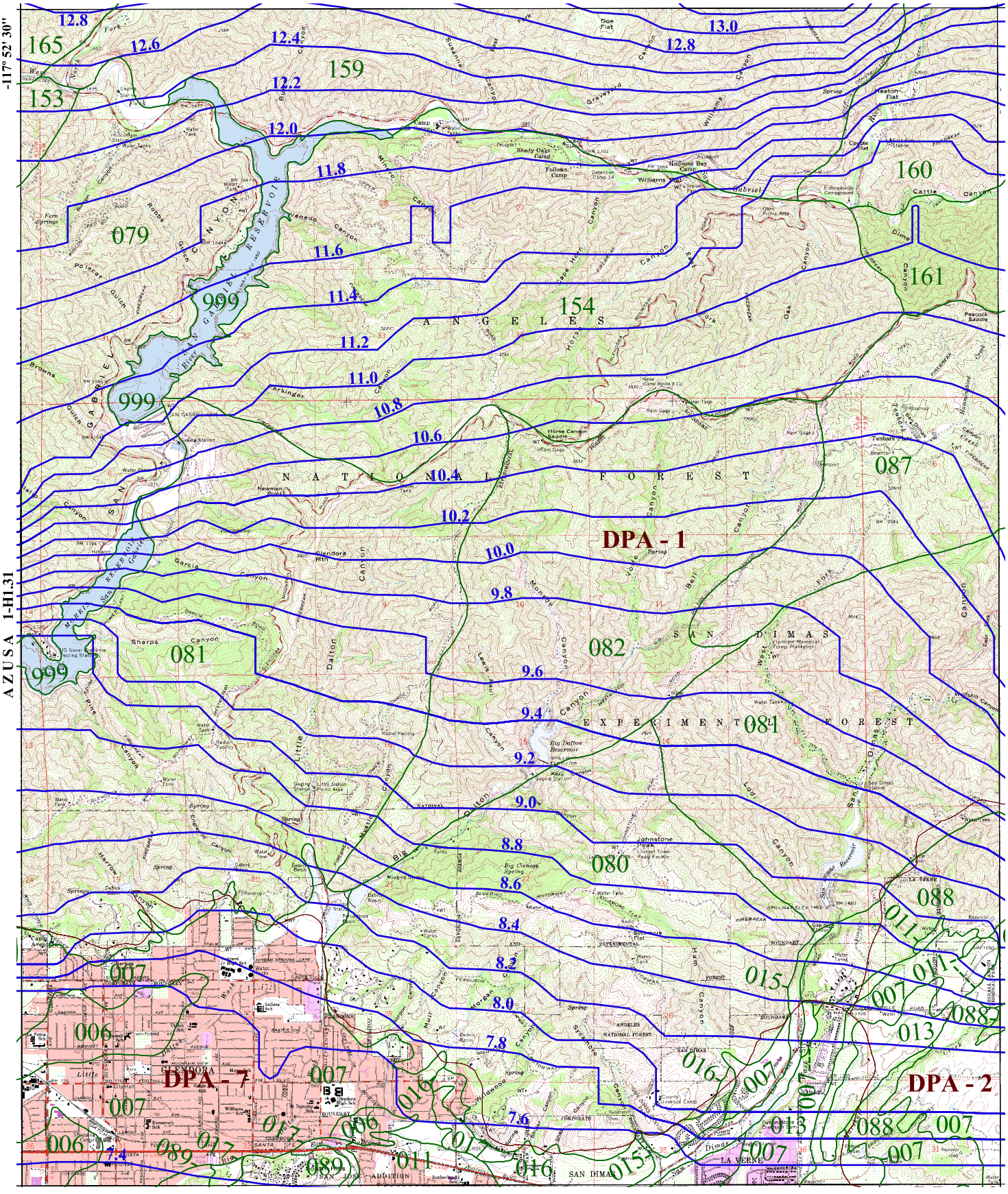
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

A Z U S A

50-YEAR 24-HOUR ISOHYET

1-H1.31

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

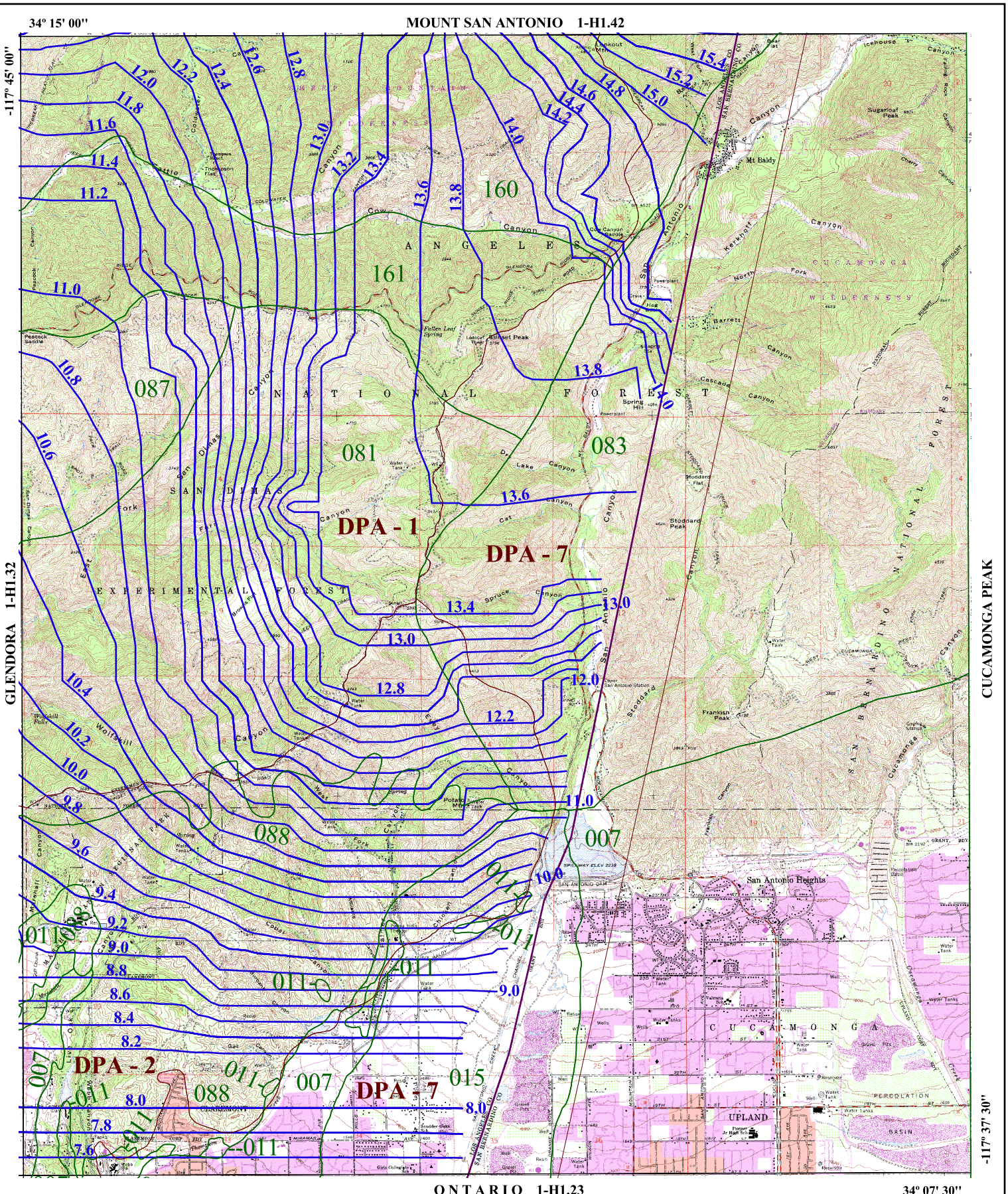
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878

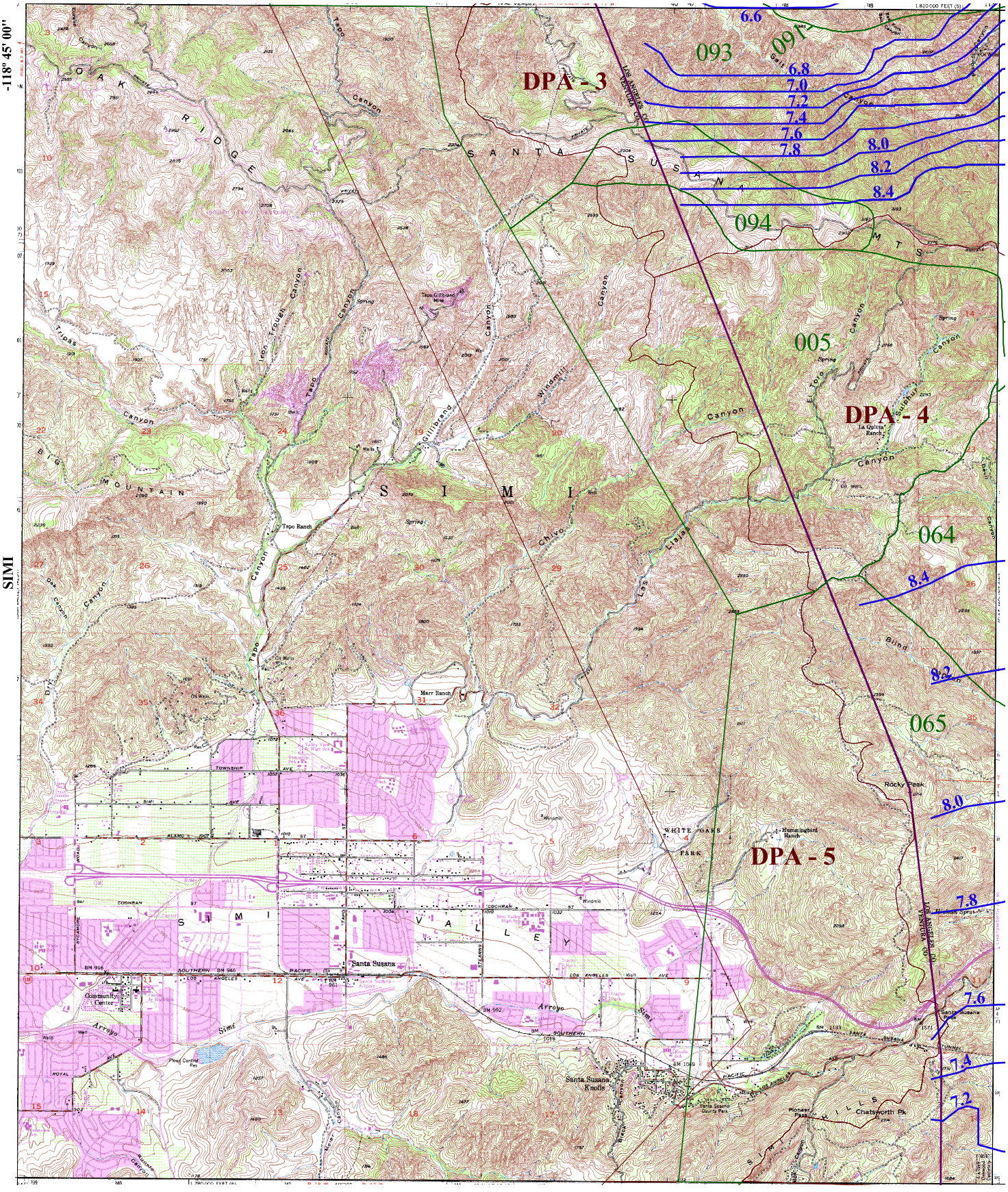
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

GLENDORA
50-YEAR 24-HOUR ISOHYET

1-H1.32

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works


34° 15' 00"
MOUNT SAN ANTONIO 1-H1.42
-117° 45' 00"
GLENDORA 1-H1.32
CUCAMONGA PEAK
-117° 37' 30"
ONTARIO 1-H1.23
34° 07' 30"
DPA - 1
DPA - 2
DPA - 6
DPA - 7
160
161
087
081
083
088
007
015
011
012
013
016
ANGELES
NATIONAL FOREST
SAN DIMAS EXPERIMENTAL FOREST
CUCAMONGA WILDERNESS
San Antonio Heights
CUCAMONGA
PERCOLATION
UPLAND
BASIN
Mt Baldy
Sugarloaf Peak
Stoddard Peak
Frankish Peak
Icehouse Canyon
Cow Canyon
Cascade Canyon
Lake Canyon
Spruce Canyon
Wolfskill Canyon
Day Canyon
Kerkhoff Canyon
Barrett Canyon
Fallen Leaf Spring
Spring Hill
Pescock Saddle
Cow Canyon Saddle
Stoddard Flat
Potato Canyon
San Antonio Dam
San Antonio Station
Powerplant
Water Tanks
Reservoir
Wells
Gravel Pits
Resn
Girls Collegiate
Thompson Peak
Telephone Peak
Lookout Mtn
Bluff Set Peak
Pumphill Peak
East San Dimas Canyon
West Fork San Dimas Canyon
North Fork San Dimas Canyon
Fork San Dimas Canyon
San Antonio Canyon
San Dimas Canyon
Day Creek
Cucamonga Creek
San Antonio Creek
San Antonio Dam
Spillway Elev 2238
Los Angeles Co
San Bernardino Co
10.0
10.4
10.6
10.8
11.0
11.2
11.4
11.6
11.8
12.0
12.2
12.4
12.6
12.8
13.0
13.2
13.4
13.6
13.8
14.0
14.2
14.4
14.6
14.8
15.0
15.2
15.4
9.0
9.2
9.4
9.6
9.8
8.0
8.2
8.4
8.6
8.8
7.6
7.8
N
S
E
W
1 0 1 2 Miles
016 SOIL CLASSIFICATION AREA
7.2 INCHES OF RAINFALL
DPA - 6 DEBRIS POTENTIAL AREA
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714
MOUNT BALDY
50-YEAR 24-HOUR ISOHYET
1-H1.33
LOS ANGELES COUNTY PUBLIC WORKS
Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

1 0 1 2 Miles

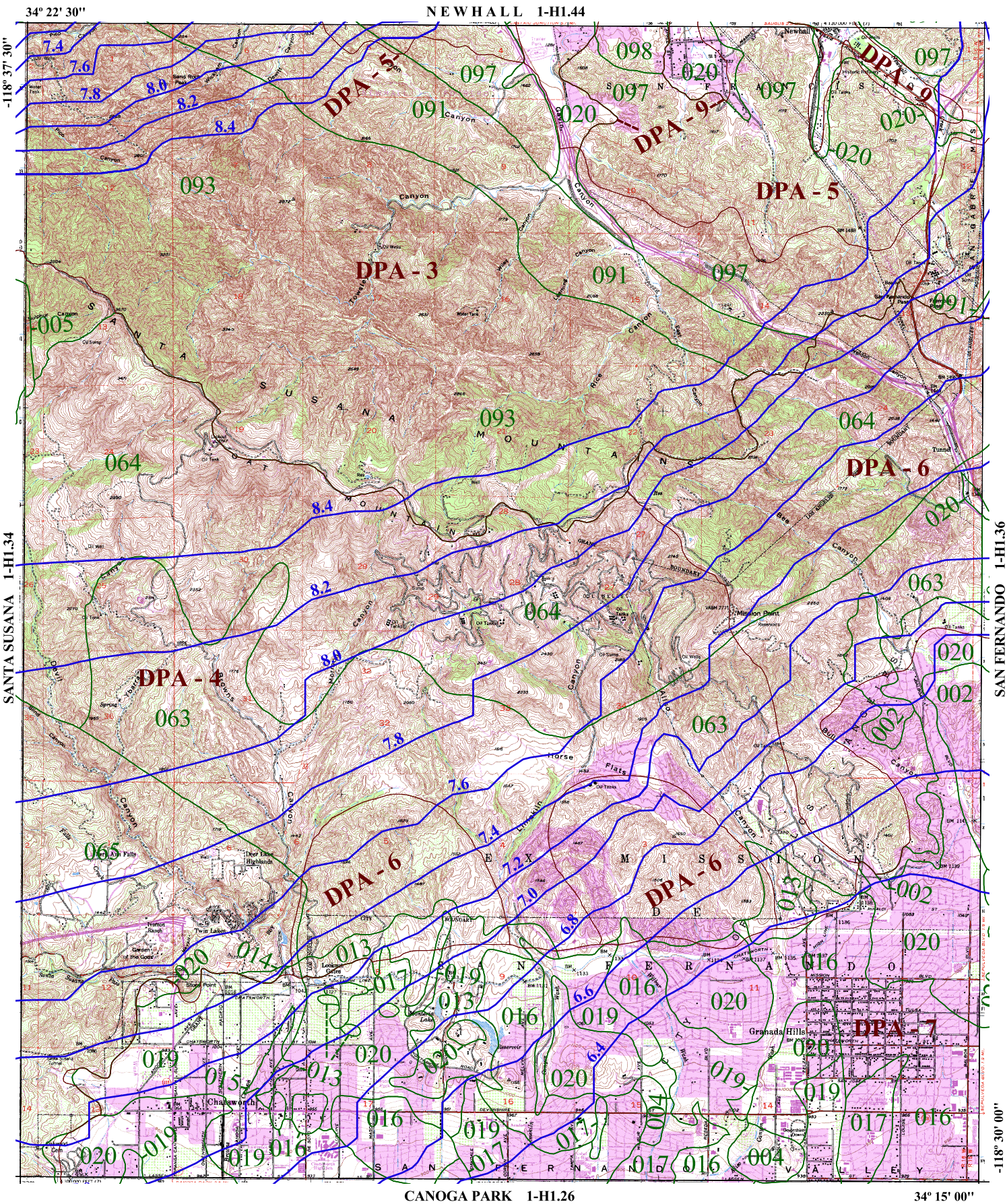
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878

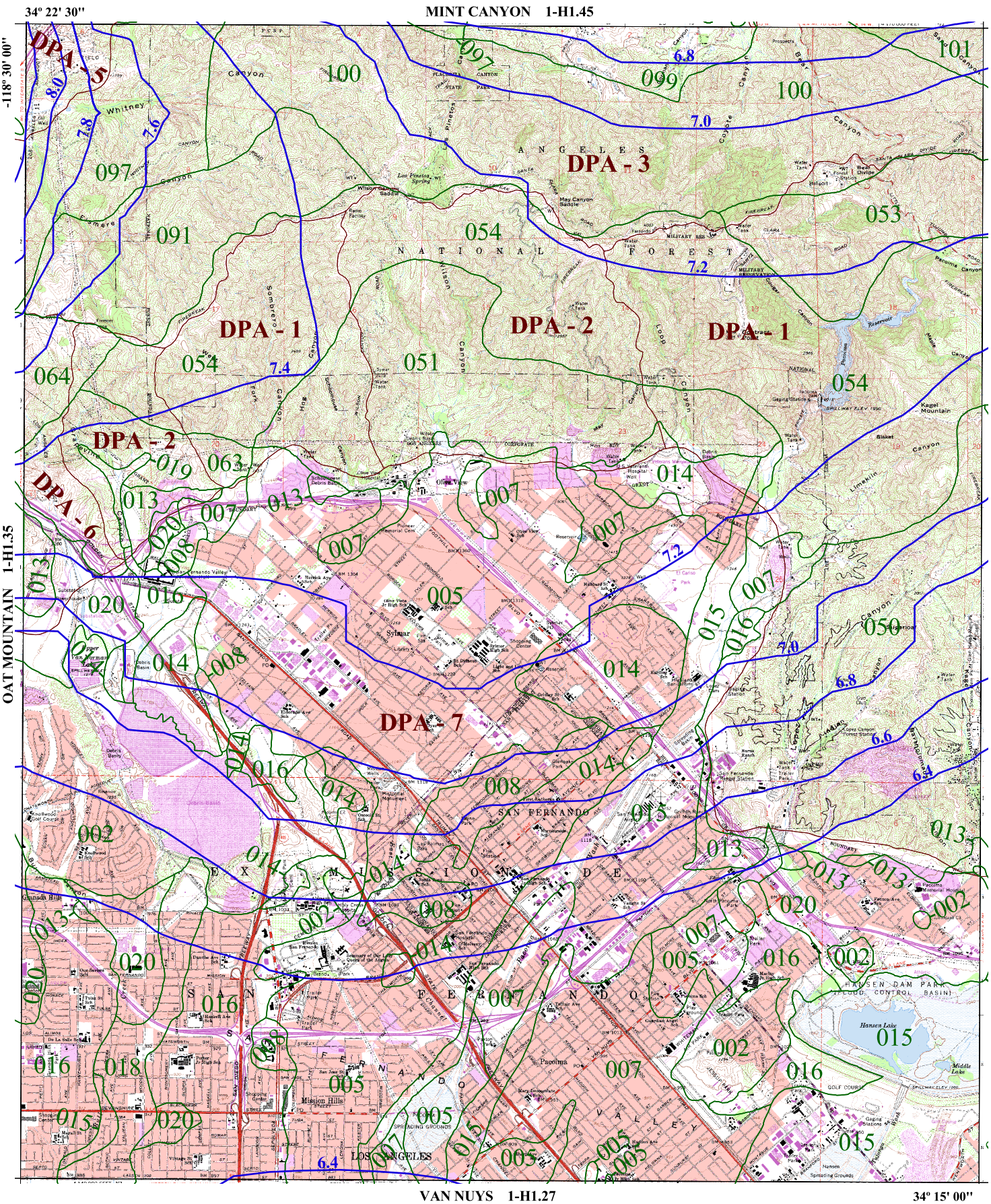
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

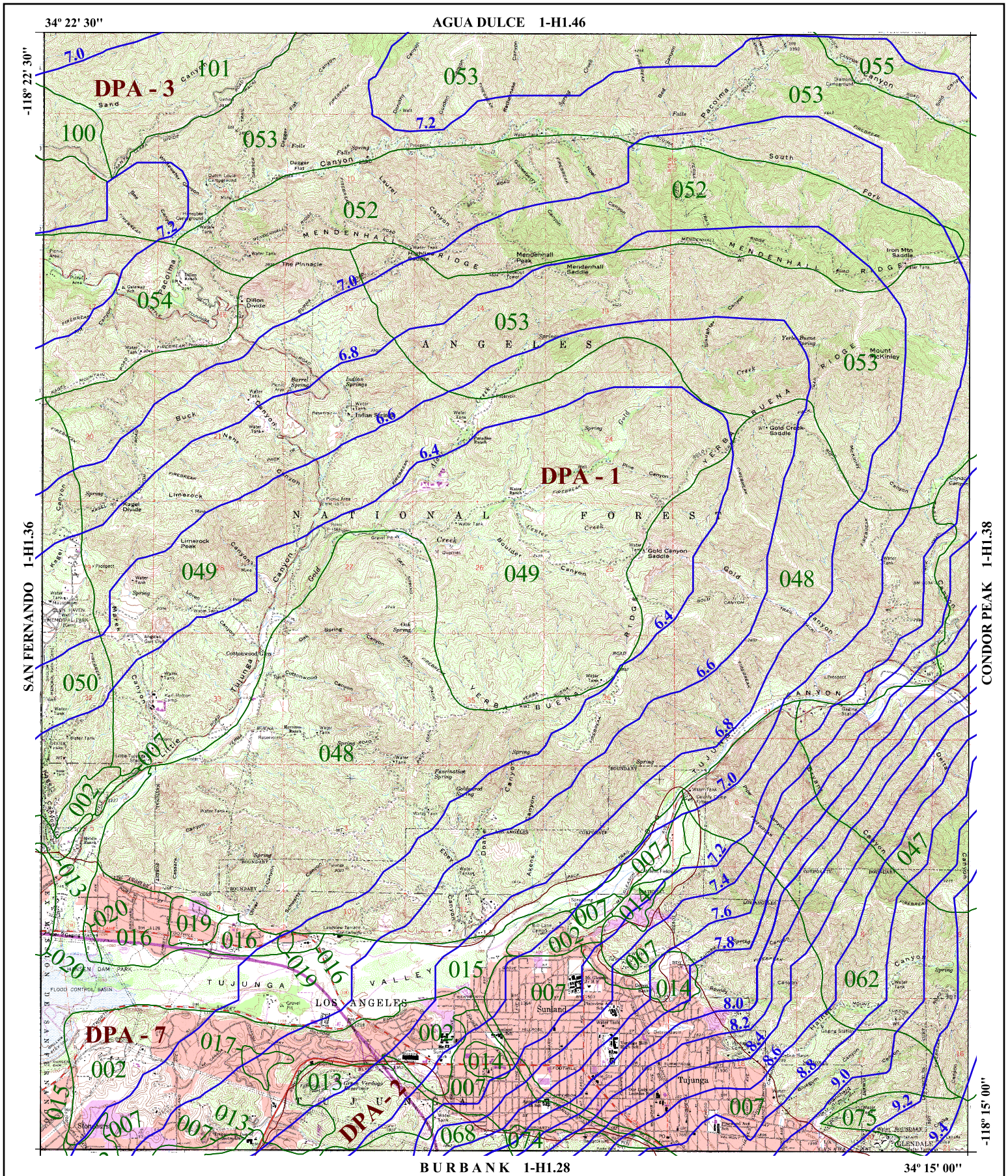
SANTA SUSANA
50-YEAR 24-HOUR ISOHYET

1-H1.34

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works


34° 22' 30"
NEWHALL 1-H1.44
-118° 37' 30"
SANTA SUSANA 1-H1.34
SAN FERNANDO 1-H1.36
-118° 30' 00"
CANOGA PARK 1-H1.26
34° 15' 00"
DPA - 3
DPA - 4
DPA - 5
DPA - 6
DPA - 7
DPA - 9
7.4
7.6
7.8
8.0
8.2
8.4
7.2
6.8
7.0
6.6
6.4
091
093
097
098
020
064
063
005
065
002
004
013
014
015
016
017
019
Newhall
Canyon
Mission Point
Horse Flats
Granada Hills
Chatsworth
Twin Lakes
Shoup Point
Lookout Gates
Oat Mountain
SANTA SUSANA MOUNTAINS
SAN FERNANDO VALLEY
MISSION HILLS
NORTH CHATSWORTH
DEVONSHIRE
1 0 1 2 Miles
N
S
E
W
016 SOIL CLASSIFICATION AREA
7.2 INCHES OF RAINFALL
DPA - 6 DEBRIS POTENTIAL AREA
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714
OAT MOUNTAIN
50-YEAR 24-HOUR ISOHYET
1-H1.35
LOS ANGELES COUNTY PUBLIC WORKS
Public Service That Works


34° 22' 30"
MINT CANYON 1-H1.45
-118° 30' 00"
OAT MOUNTAIN 1-H1.35
SUNLAND 1-H1.37
-118° 22' 30"
VAN NUYS 1-H1.27
34° 15' 00"
DPA - 1
DPA - 2
DPA - 3
DPA - 5
DPA - 6
DPA - 7
ANGELES NATIONAL FOREST
SAN FERNANDO
EXAMINER DIVISION
SAN FERNANDO VALLEY
Sylmar
Pacoima
Mission Hills
Granada Hills
Olive View
Hansen Lake
Middle Lake
HANSEN DAM PARK
Whitney Canyon
Sombrero Canyon
Wilson Canyon
Limekiln Canyon
Kagel Mountain
Lopez Canyon
Tujunga Canyon
Hansen Dam
Pacoima Canyon
Los Pinetos Canyon
Coyote Canyon
Bear Canyon
Bear Divide
May Canyon Saddle
Wilson Cabin Saddle
Lost Pinetos Spring
Pacoima Memorial Hospital
Olive View Medical Center
Veterans Hospital
Mission Wells
Pioneer Memorial Cem
Sylmar Park
Hansen Dam Golf Course
Hansen Spreading Grounds
Mary Immaculate Park
Lopez Canyon Forest Station
Bear Divide Forest Station
Tujunga Ranger Station
Mission San Fernando
Griffith Park Memorial Mausoleum
Sylmar Shopping Center
Mission Hills Shopping Center
Pacoima Shopping Center
Sylmar Water Tanks
Olive View Water Tanks
Pacoima Water Tanks
Bear Divide Water Tanks
Wilson Cabin Water Tanks
Tujunga Water Tanks
Hansen Dam Water Tanks
Sylmar Debris Basin
Olive View Debris Basin
Schoolhouse Debris Basin
Upper Wilson Debris Basin
Pacoima Debris Basin
Hansen Dam Debris Basin
Sylmar Park
Hansen Dam Park
Hansen Dam Golf Course
Hansen Dam Spillway Elev. 1950
Olive View Reservoir
Pacoima Reservoir
Tujunga Reservoir
Hansen Dam Flood Control Basin
Sylmar Water Tank
Olive View Water Tank
Pacoima Water Tank
Bear Divide Water Tank
Wilson Cabin Water Tank
Tujunga Water Tank
Hansen Dam Water Tank
Sylmar Trailer Park
Pacoima Trailer Park
Mission Wells Trailer Park
Tujunga Trailer Park
Hansen Dam Trailer Park
Sylmar Spreading Grounds
Hansen Dam Spreading Grounds
Pacoima Spreading Grounds
Mission Hills Spreading Grounds
Sylmar Substation
Pacoima Substation
Sylmar Fire Station
Pacoima Fire Station
Bear Divide Fire Station
Tujunga Fire Station
Hansen Dam Fire Station
Lopez Canyon Fire Station
Sylmar Elementary School
Pacoima Elementary School
Mission Hills Elementary School
Granada Hills Elementary School
San Fernando Elementary School
Sylmar Middle School
Pacoima Middle School
Mission Hills Middle School
Granada Hills Middle School
San Fernando Middle School
Sylmar High School
Pacoima High School
Mission Hills High School
Granada Hills High School
San Fernando High School
Sylmar Post Office
Pacoima Post Office
Mission Hills Post Office
Granada Hills Post Office
San Fernando Post Office
Sylmar Library
Pacoima Library
Mission Hills Library
Granada Hills Library
San Fernando Library
Sylmar Shopping Center
Pacoima Shopping Center
Mission Hills Shopping Center
Granada Hills Shopping Center
San Fernando Shopping Center
Sylmar Golf Course
Pacoima Golf Course
Mission Hills Golf Course
Granada Hills Golf Course
San Fernando Golf Course
Sylmar Cemetery
Pacoima Cemetery
Mission Hills Cemetery
Granada Hills Cemetery
San Fernando Cemetery
Sylmar Park
Pacoima Park
Mission Hills Park
Granada Hills Park
San Fernando Park
Sylmar Trailer Park
Pacoima Trailer Park
Mission Hills Trailer Park
Granada Hills Trailer Park
San Fernando Trailer Park
Sylmar Water Tank
Pacoima Water Tank
Mission Hills Water Tank
Granada Hills Water Tank
San Fernando Water Tank
Sylmar Debris Basin
Pacoima Debris Basin
Mission Hills Debris Basin
Granada Hills Debris Basin
San Fernando Debris Basin
Sylmar Reservoir
Pacoima Reservoir
Mission Hills Reservoir
Granada Hills Reservoir
San Fernando Reservoir
Sylmar Spillway Elev. 1950
Pacoima Spillway Elev. 1950
Mission Hills Spillway Elev. 1950
Granada Hills Spillway Elev. 1950
San Fernando Spillway Elev. 1950
Sylmar Flood Control Basin
Pacoima Flood Control Basin
Mission Hills Flood Control Basin
Granada Hills Flood Control Basin
San Fernando Flood Control Basin
Sylmar Spreading Grounds
Pacoima Spreading Grounds
Mission Hills Spreading Grounds
Granada Hills Spreading Grounds
San Fernando Spreading Grounds



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

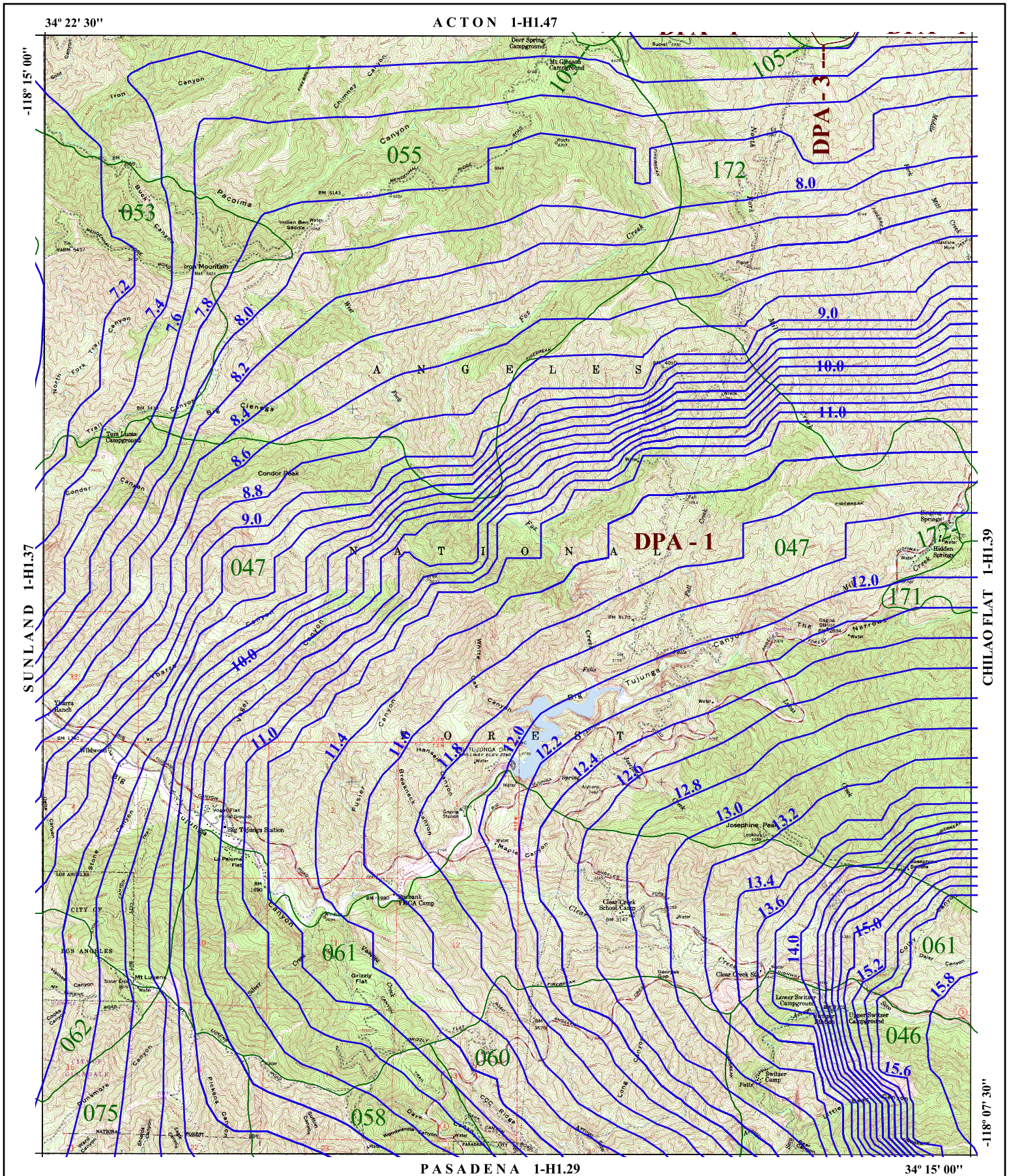
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

S U N L A N D
50-YEAR 24-HOUR ISOHYET

1-H1.37

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



N
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016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

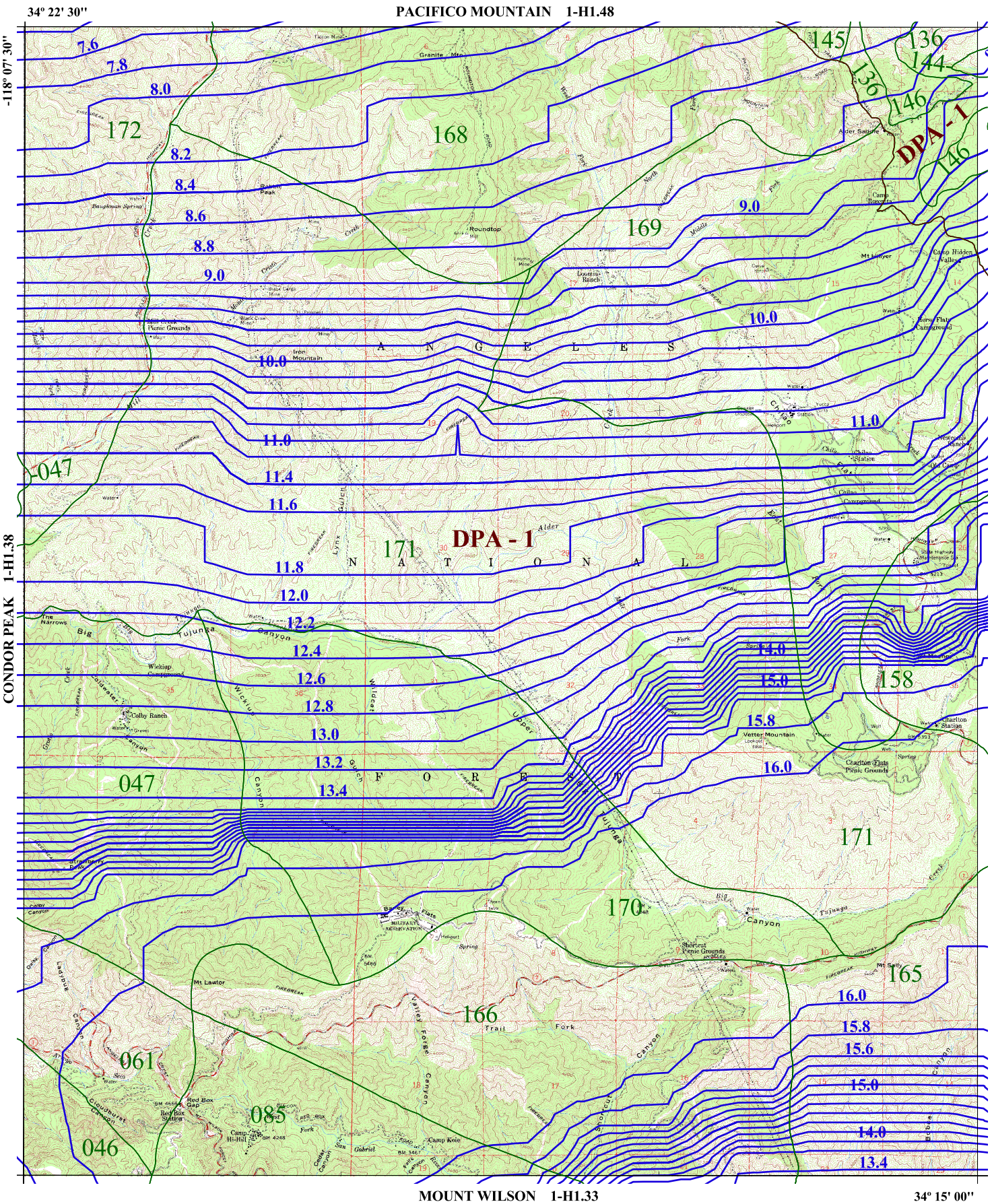
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

CONDOR PEAK
50-YEAR 24-HOUR ISOHYET

1-H1.38

LOS ANGELES COUNTY PUBLIC WORKS
Public Service That Works



N
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S

016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

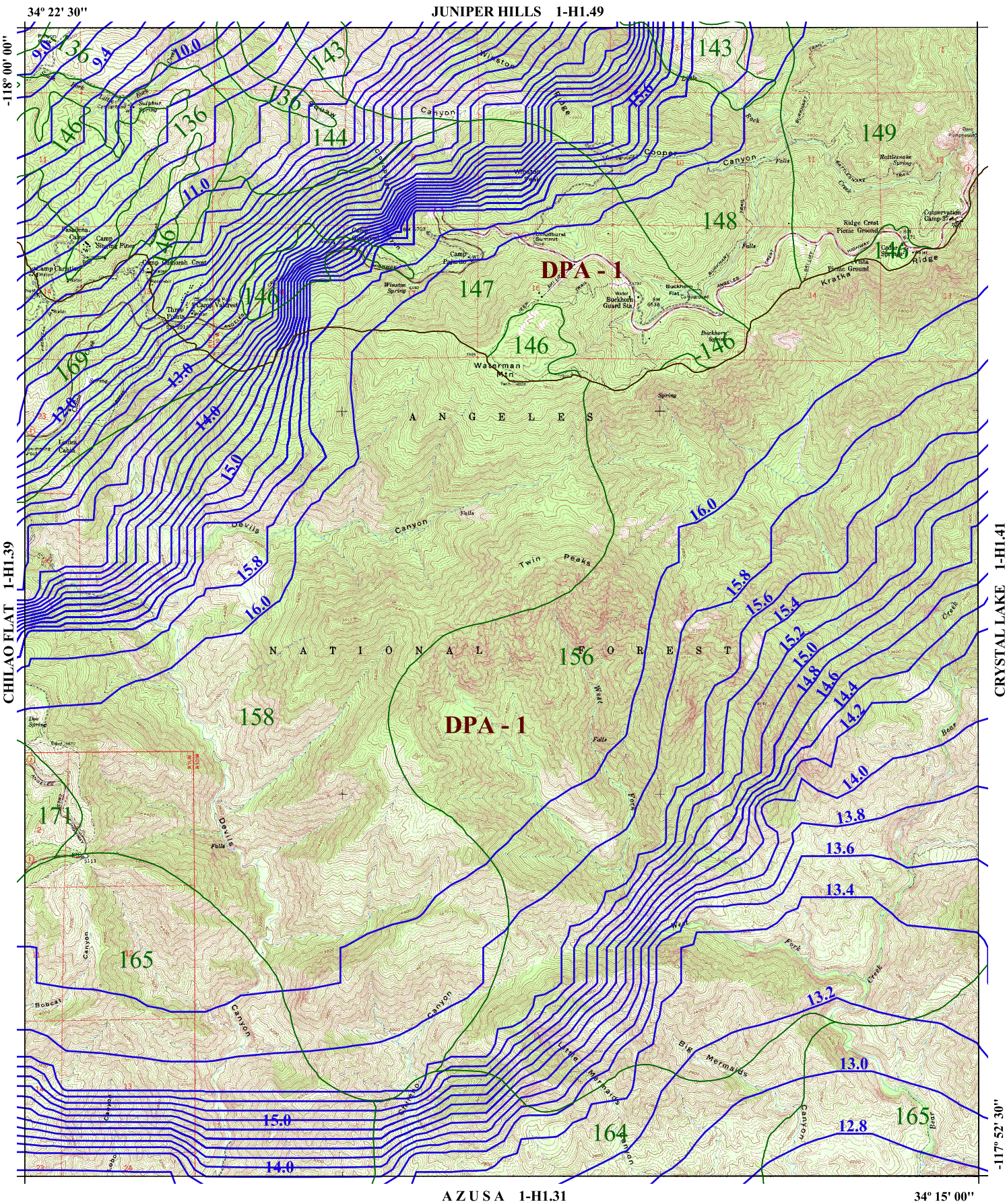
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

CHILAO FLAT
50-YEAR 24-HOUR ISOHYET

1-H1.39

LOS ANGELES COUNTY PUBLIC WORKS
Public Service That Works



N
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016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

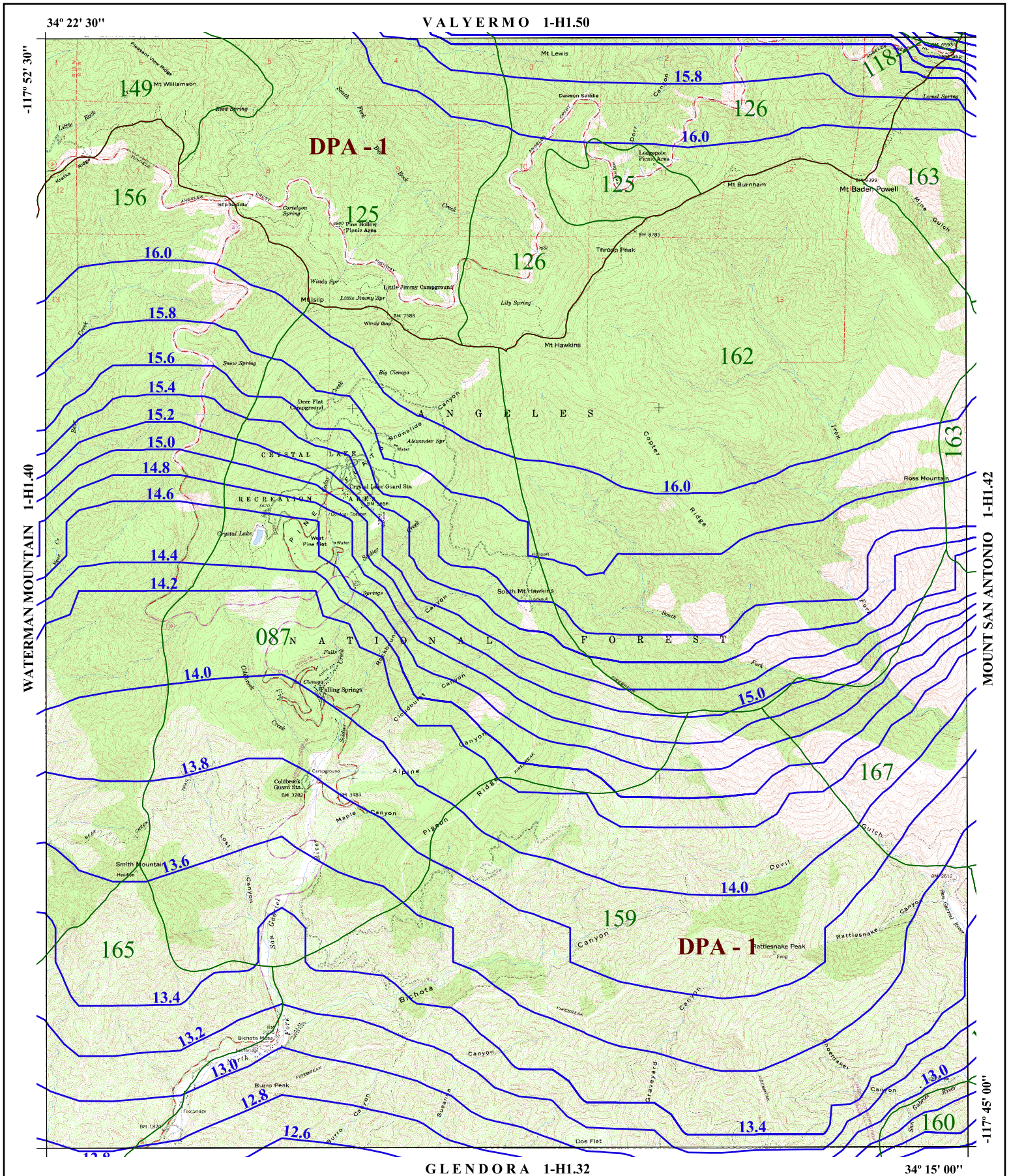
1 0 1 2 Miles

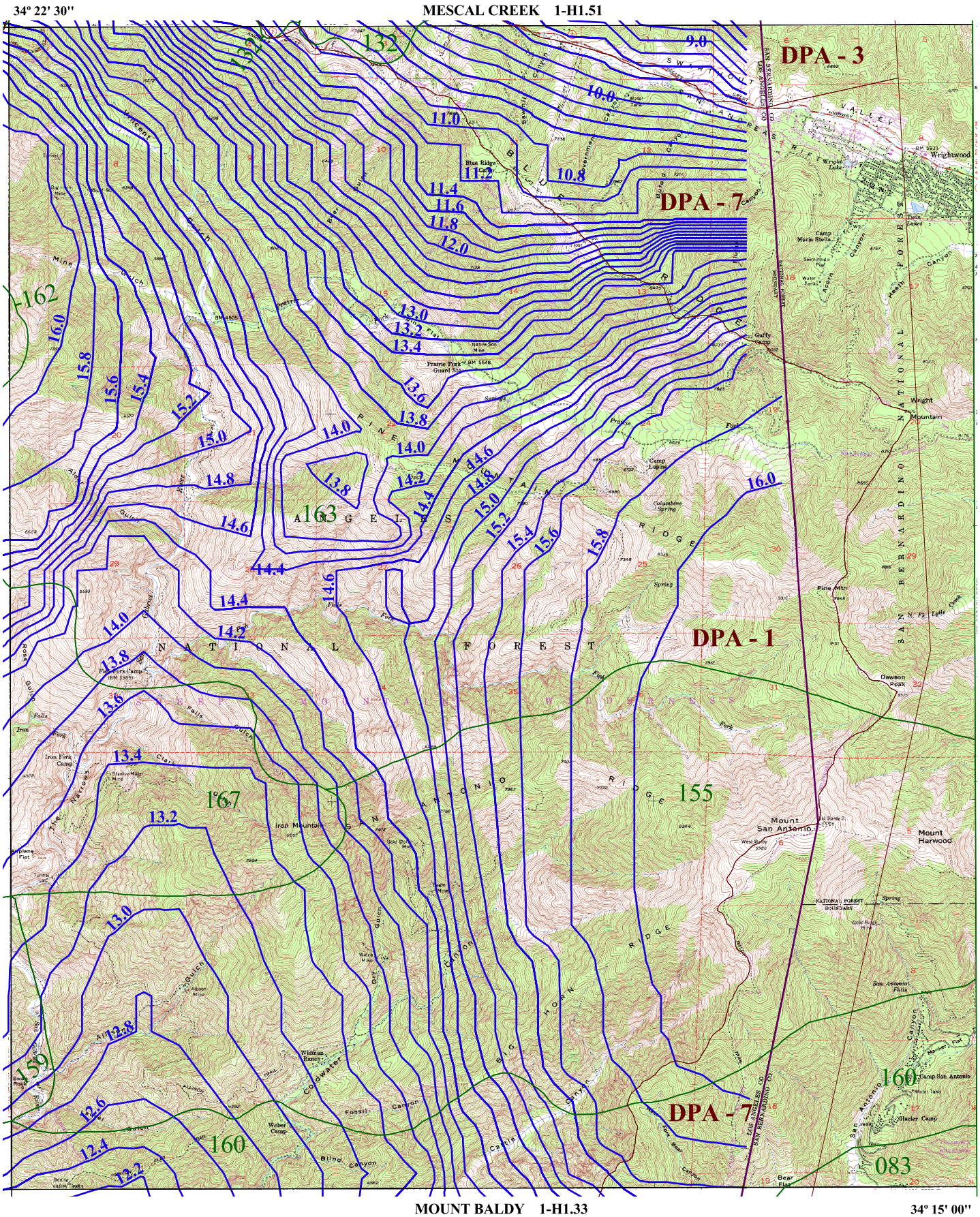
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

WATERMAN MOUNTAIN
50-YEAR 24-HOUR ISOHYET

1-H1.40

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works


34° 22' 30"
VALYERMO 1-H1.50
-117° 52' 30"
WATERMAN MOUNTAIN 1-H1.40
MOUNT SAN ANTONIO 1-H1.42
-117° 45' 00"
GLENDORA 1-H1.32
34° 15' 00"
DPA - 1
DPA - 1
15.8
16.0
15.8
15.6
15.4
15.2
15.0
14.8
14.6
14.4
14.2
14.0
13.8
13.6
13.4
13.2
13.0
12.8
12.6
16.0
15.0
14.0
13.4
13.0
149
156
125
126
125
126
118
163
162
163
167
159
165
160
087
Mt Lewis
Mt Williamson
Dawson Saddle
Lodgepole Picnic Area
Mt Burnham
Mt Baden Powell
Throop Peak
Pine Hollow Picnic Area
Little Jimmy Campground
Mt Islip
Windy Gap
Mt Hawkins
Deer Flat Campground
Crystal Lake Guard Sta
Crystal Lake
Recreation Area
Ross Mountain
South Mt Hawkins
Coldbrook Guard Sta
Smith Mountain
Rattlesnake Peak
Burro Peak
Doe Flat
ANGELES
NATIONAL FOREST
Big Cienega
Alpine
Maple Canyon
Pigeon Ridge
Bichota
Graveyard
Rattlesnake
Devil Gulch
Coldbrook
Cloudburst
Fullers
Falling Springs
Snowslide
Alexander Spr
Lily Spring
Little Jimmy Spr
Windy Spr
Snow Spring
Reed Spring
Cottonwood Spr
Lamel Spring
Dawson Saddle
Throop Peak
Ross Mountain
Mt Hawkins
Mt Islip
Mt Burnham
Mt Baden Powell
Rattlesnake Peak
Smith Mountain
Burro Peak
Doe Flat
Crystal Lake
Pine Flat
Coldbrook Guard Sta
Deer Flat Campground
Little Jimmy Campground
Lodgepole Picnic Area
Pine Hollow Picnic Area
Mt Williamson
Mt Lewis
Mt Islip
Mt Hawkins
Mt Burnham
Mt Baden Powell
Throop Peak
Ross Mountain
Smith Mountain
Rattlesnake Peak

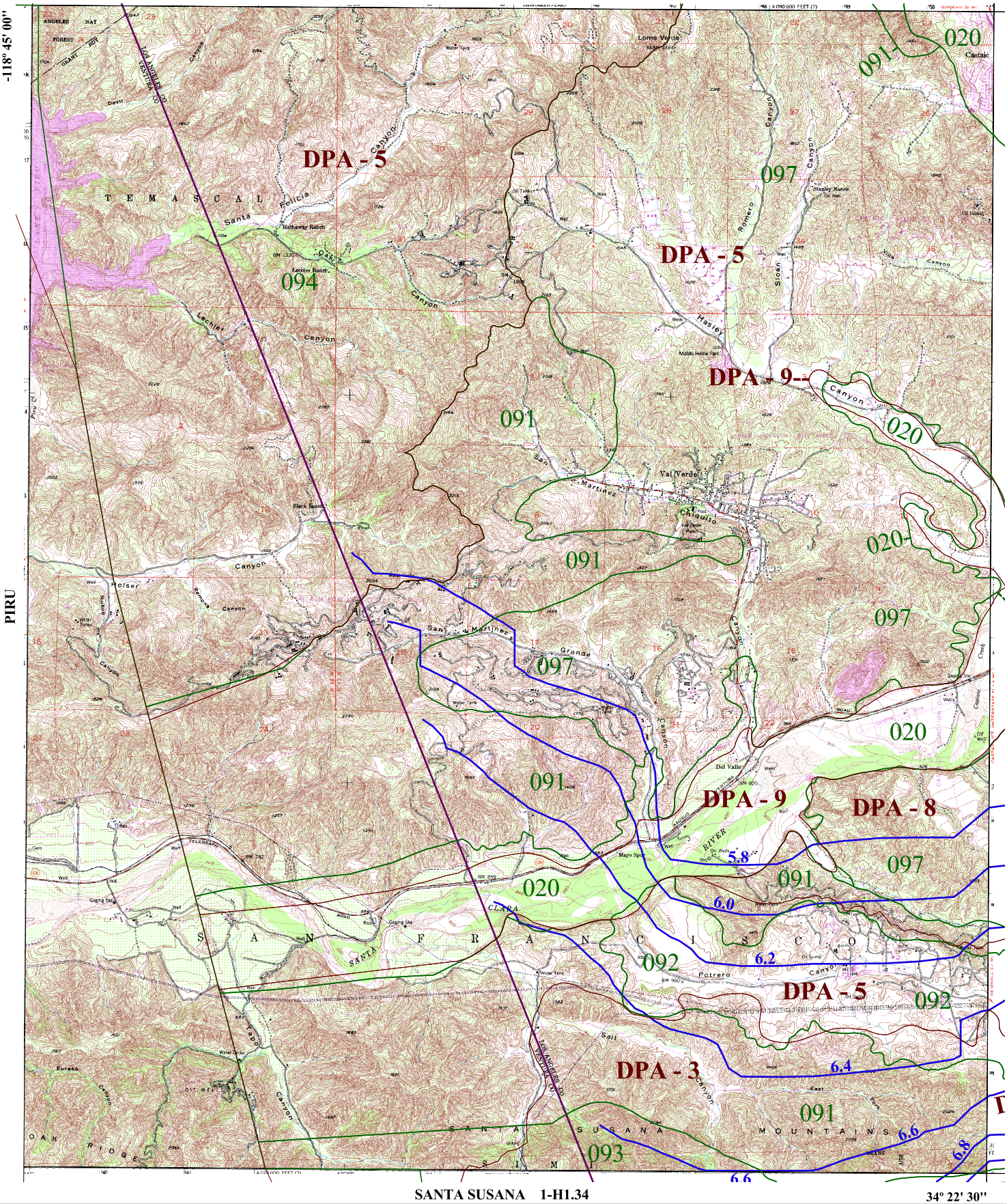


25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

MOUNT SAN ANTONIO
50-YEAR 24-HOUR ISOHYET

1-H1.42

LOS ANGELES COUNTY PUBLIC WORKS
Public Service That Works



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W E
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016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

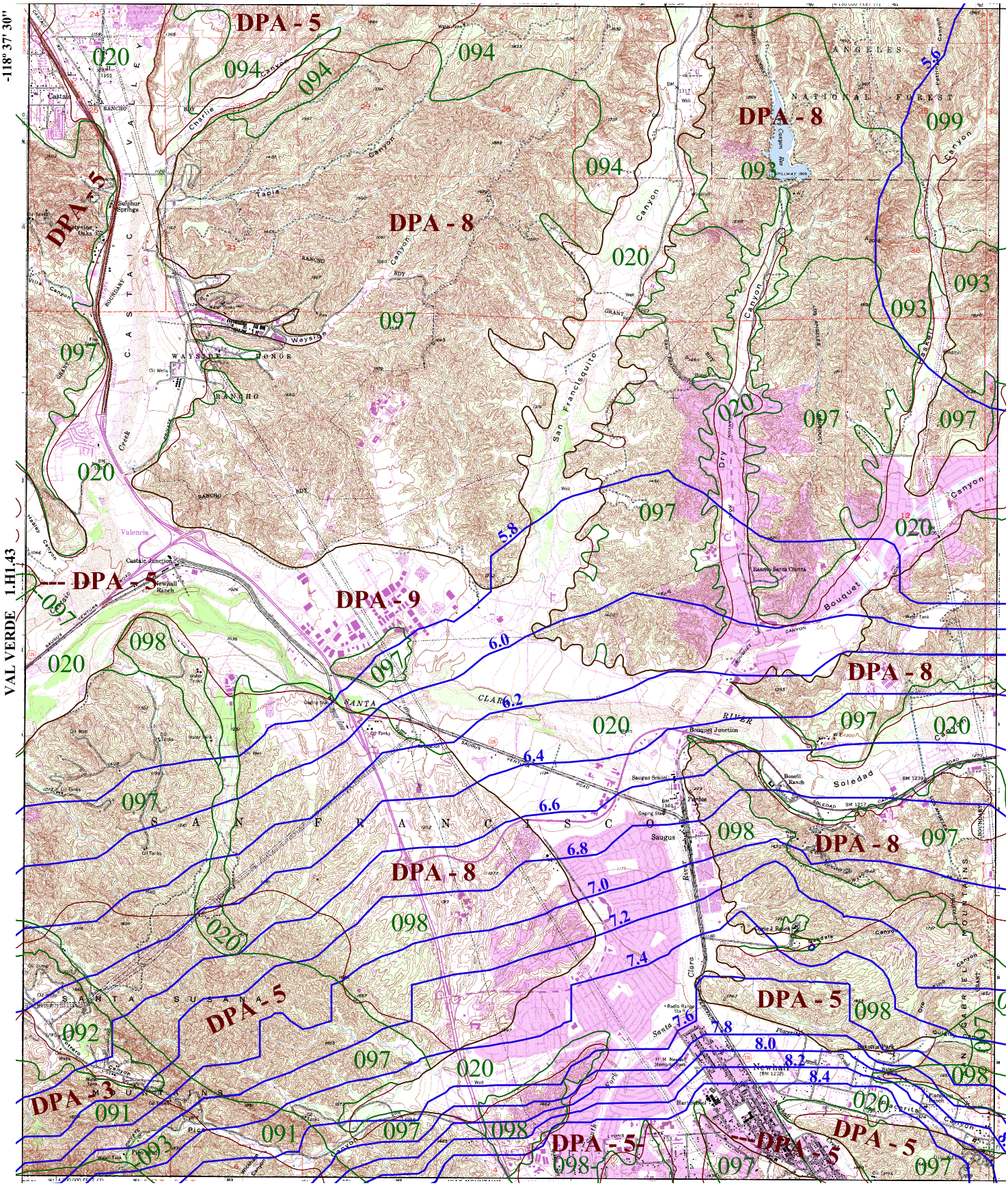
1 0 1 2 Miles

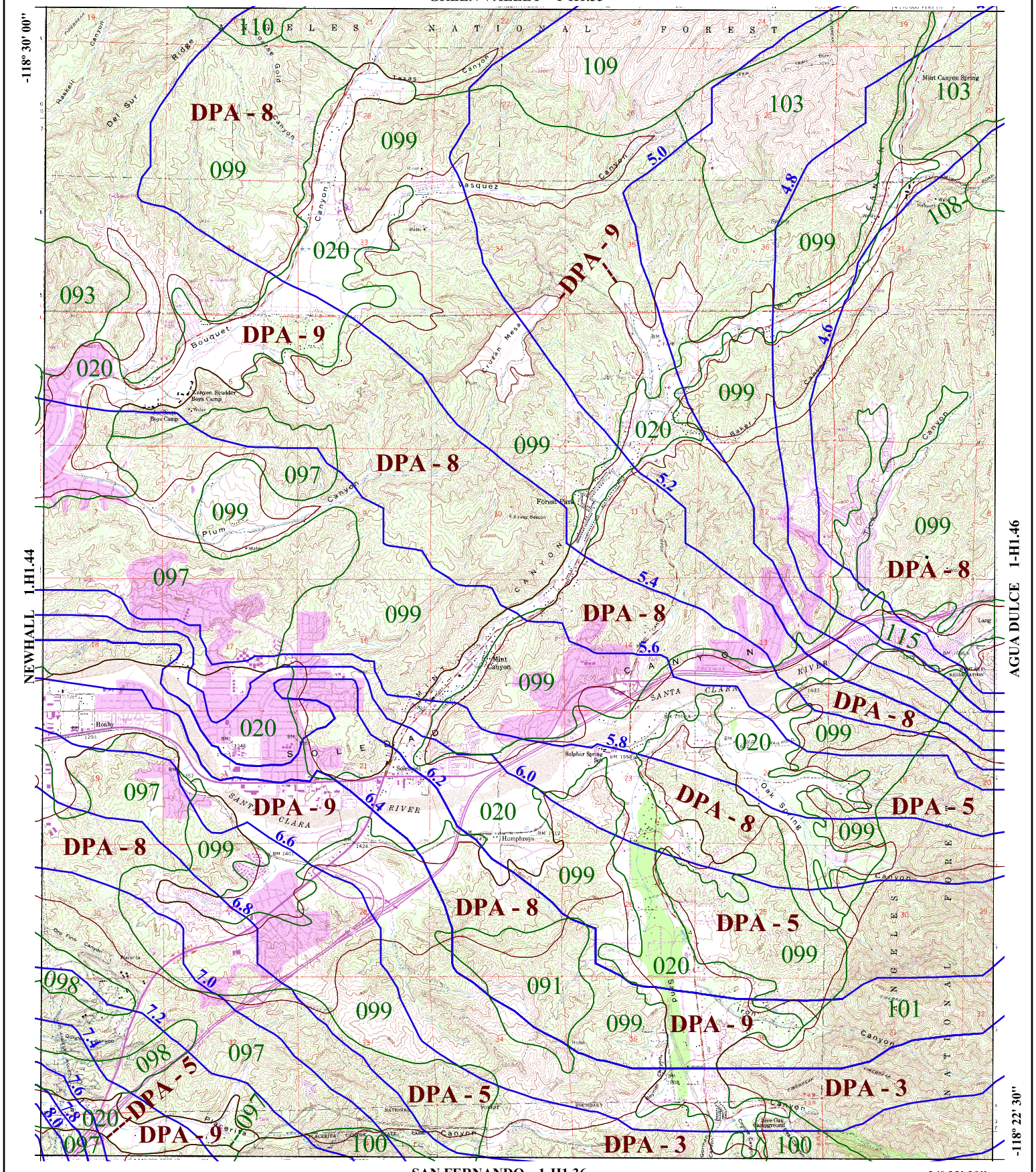
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

VAL VERDE
50-YEAR 24-HOUR ISOHYET

1-H1.43

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works


34° 30' 00"
WARM SPRINGS MOUNTAIN 1-H1.53
-118° 37' 30"
VAL VERDE 1.H1.43
MINT CANYON 1-H1.45
-118° 30' 00"
OAT MOUNTAIN 1-H1.35
34° 22' 30"
DPA - 5
DPA - 8
DPA - 9
DPA - 3
020
094
097
098
099
092
091
093
5.6
5.8
6.0
6.2
6.4
6.6
6.8
7.0
7.2
7.4
7.6
7.8
8.0
8.2
8.4
Castaic Junction
Valencia
Newhall Ranch
Bouquet Junction
Saugus
Soledad
Rancho Santa Clarita
Sulphur Springs
Waysde
Tapia
Charlie Canyon
Bouquet Canyon
San Francisquito Canyon
Dry Canyon
Santa Clara River
SANTA SUSANA MOUNTAINS
SAN FRANCISCO
CASTAIC VALLEY
ANGELES NATIONAL FOREST
016
SOIL CLASSIFICATION AREA
7.2
INCHES OF RAINFALL
DPA - 6
DEBRIS POTENTIAL AREA
N
W
E
S
1 0 1 2 Miles
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714
N E W H A L L
50-YEAR 24-HOUR ISOHYET
1-H1.44
LOS ANGELES COUNTY
PUBLIC WORKS
Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

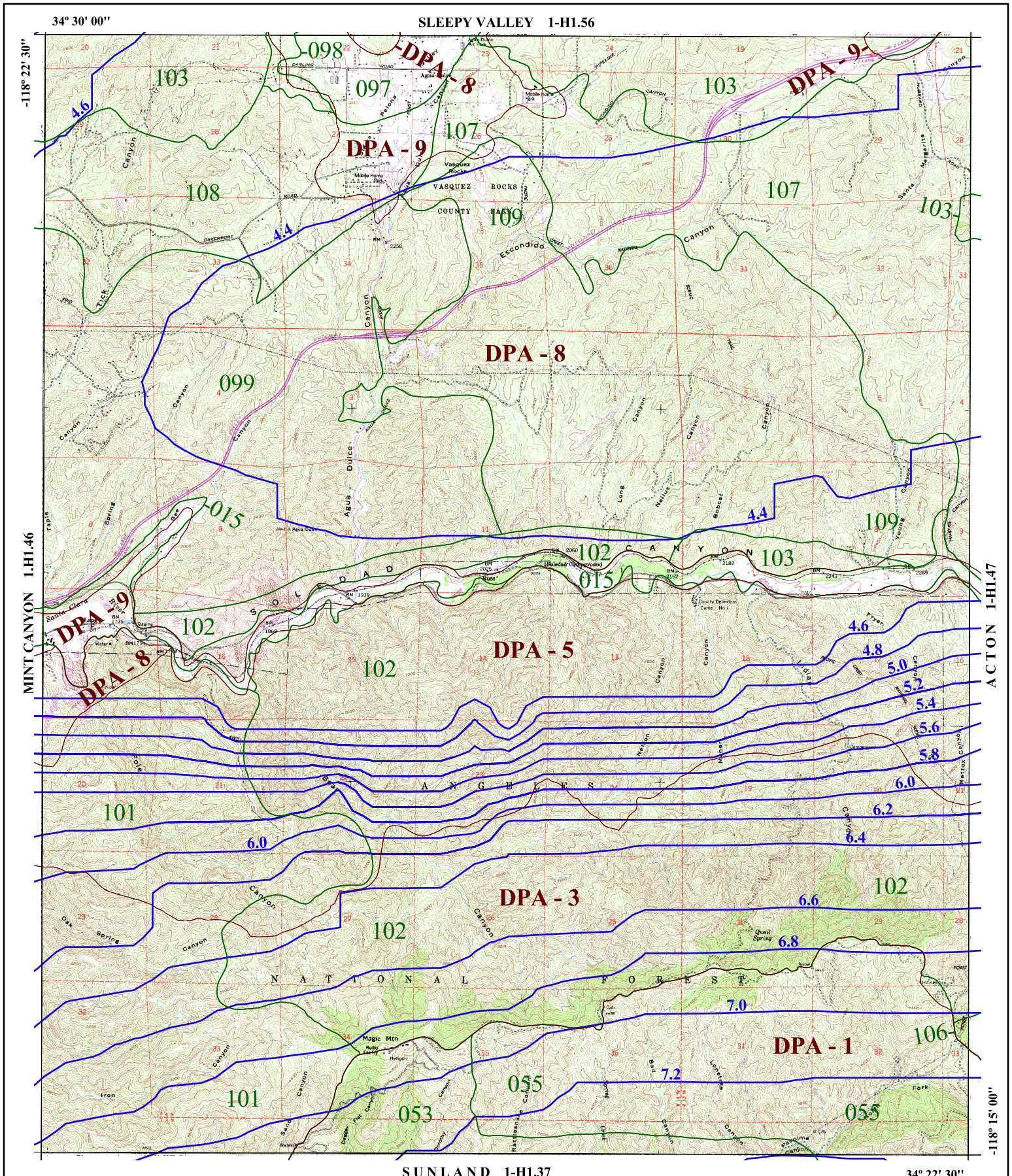
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

MINT CANYON
50-YEAR 24-HOUR ISOHYET

1-H1.45

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



1 0 1 2 Miles

N W E S

016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

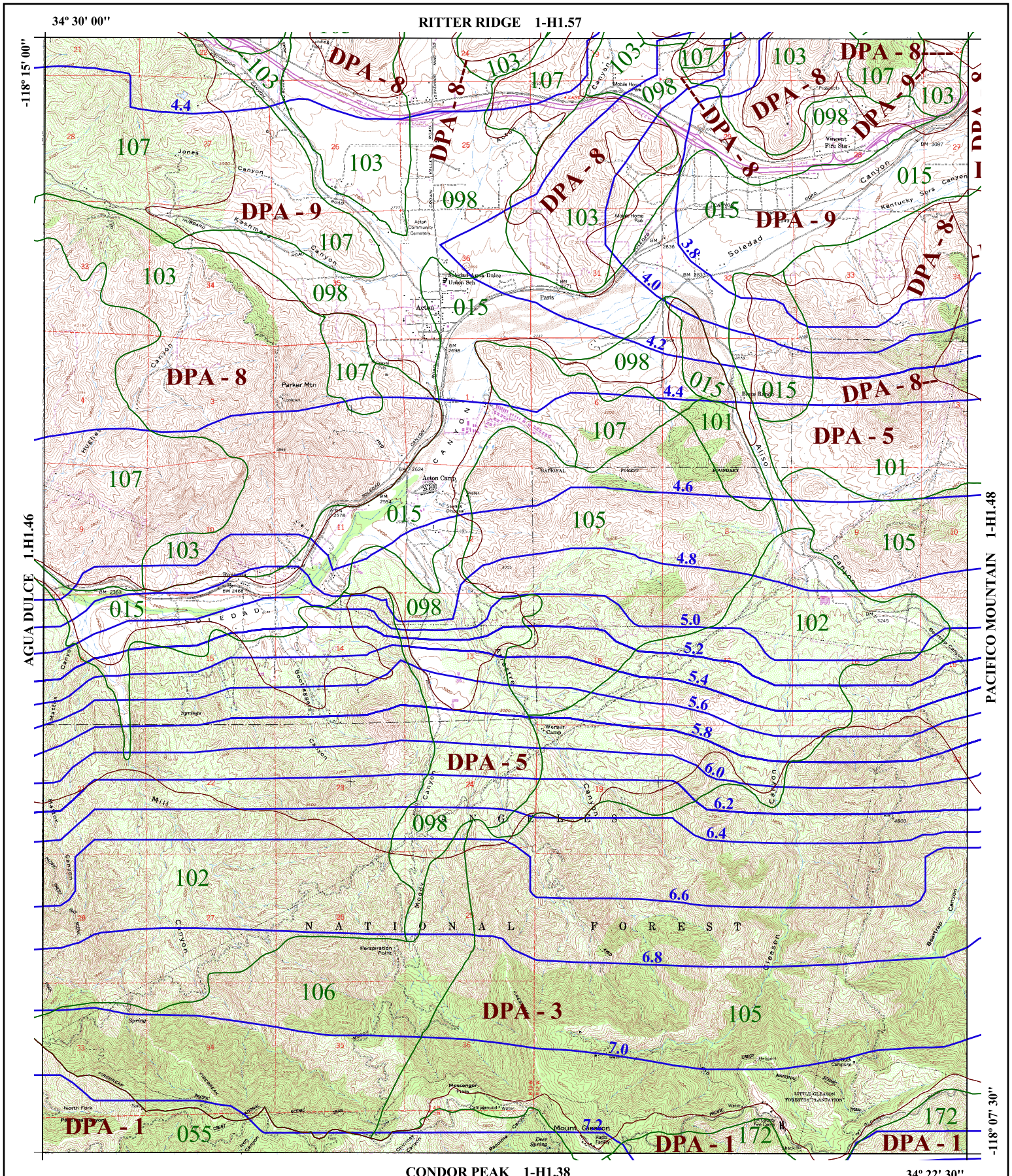
DPA - 6 DEBRIS POTENTIAL AREA

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

AGUA DULCE
50-YEAR 24-HOUR ISOHYET

1-H1.46

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



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016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

1 0 1 2 Miles

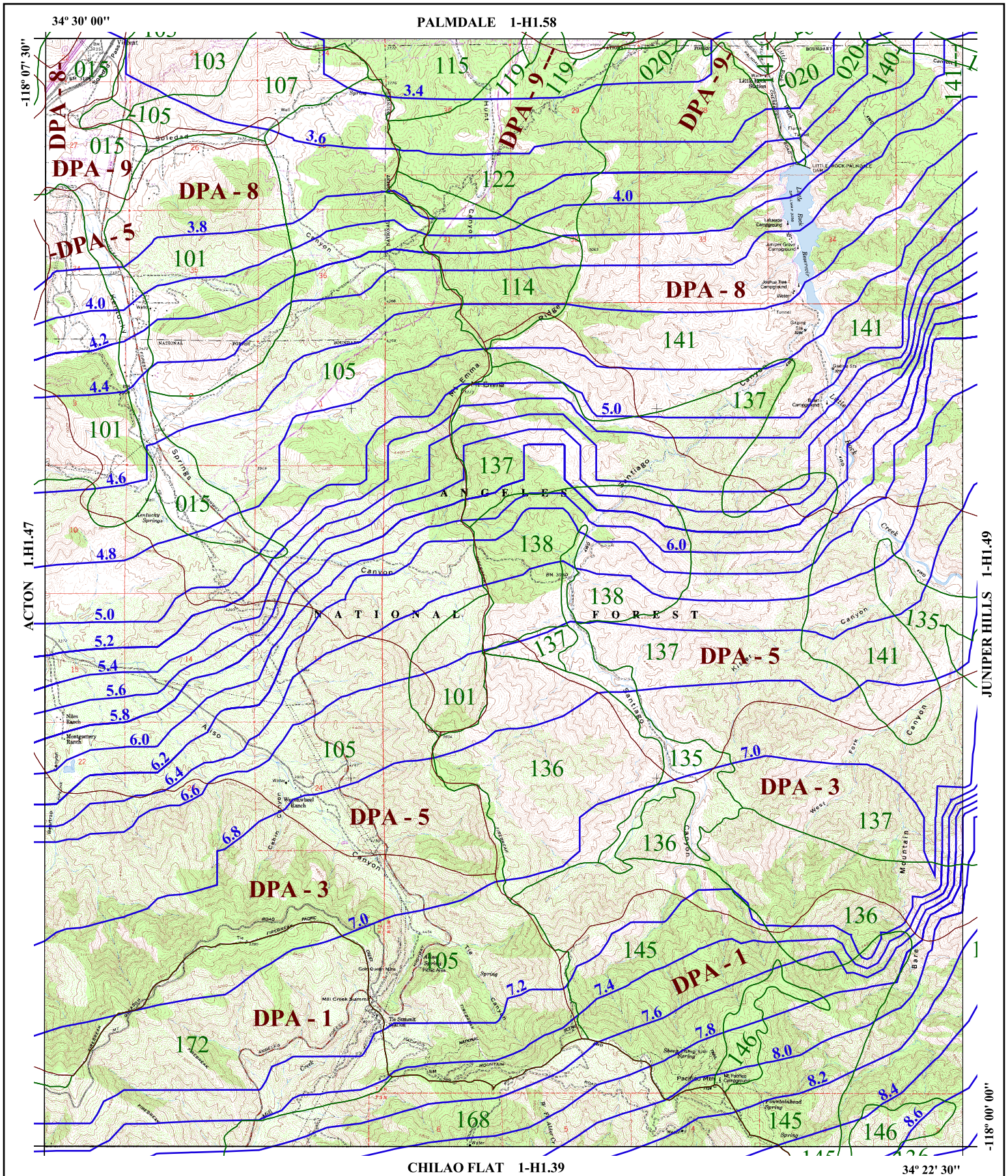
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

A C T O N

50-YEAR 24-HOUR ISOHYET

1-H1.47

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

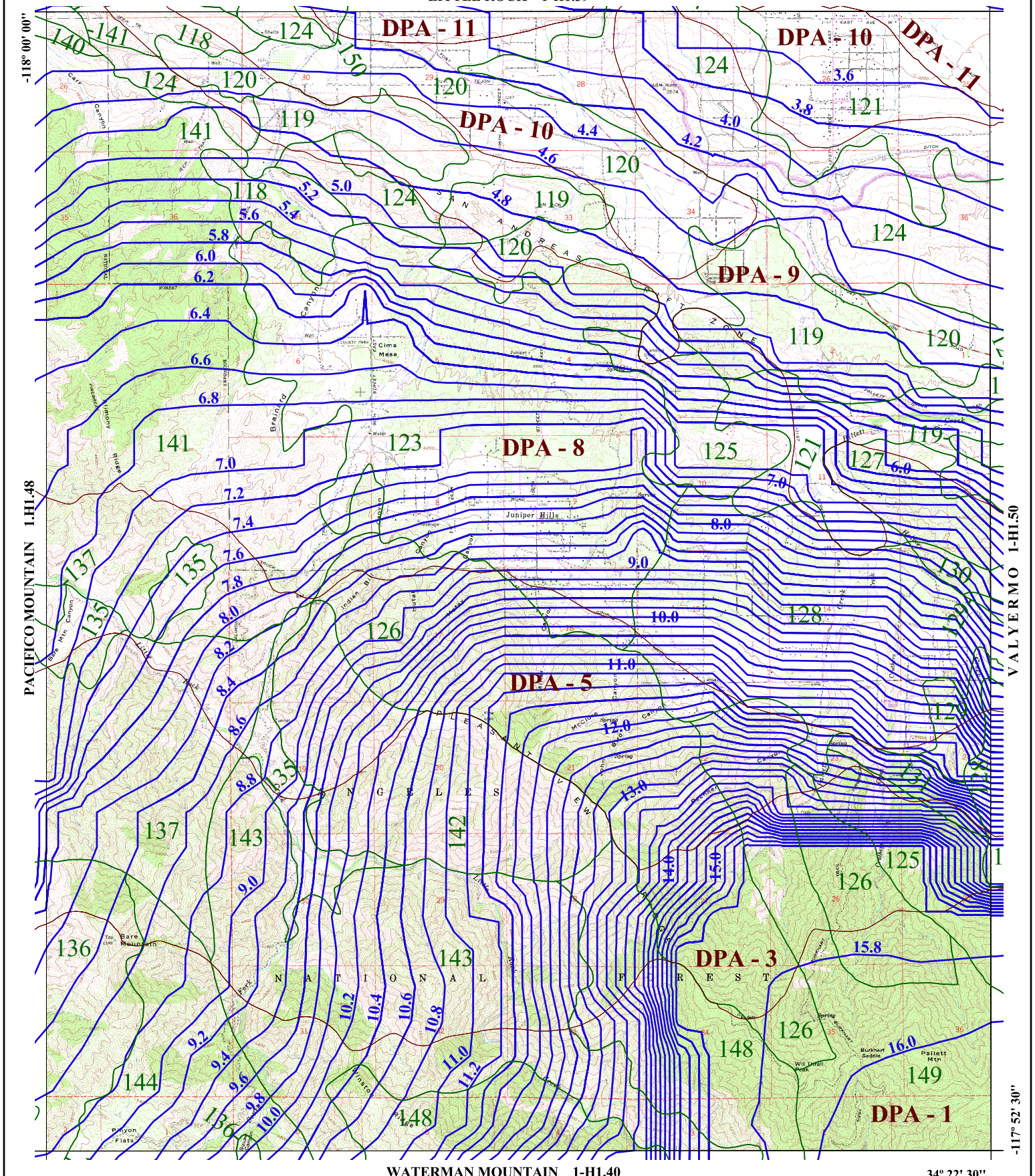
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

PACIFICO MOUNTAIN
50-YEAR 24-HOUR ISOHYET

1-H1.48

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

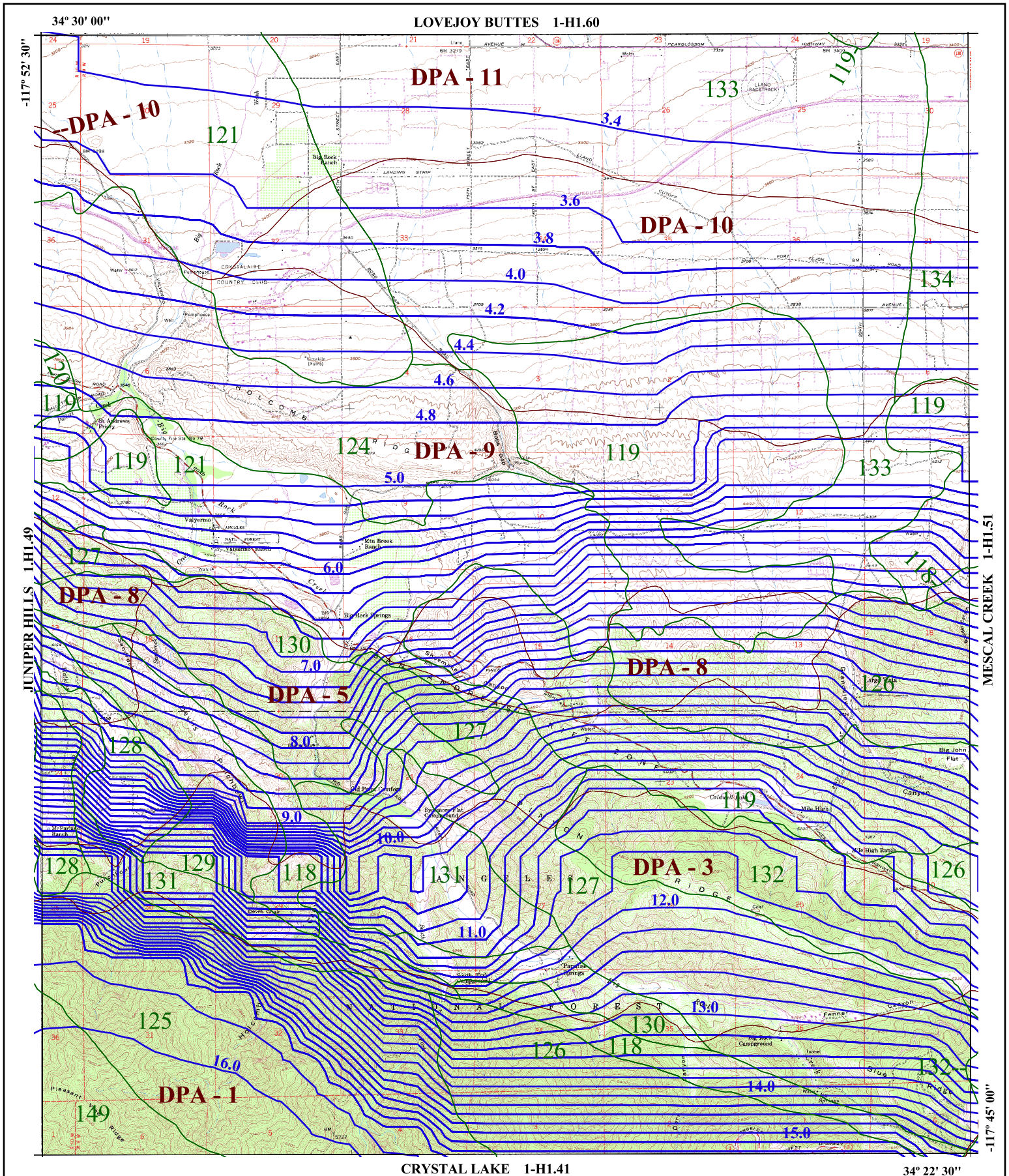
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

JUNIPER HILLS
50-YEAR 24-HOUR ISOHYET

1-H1.49

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

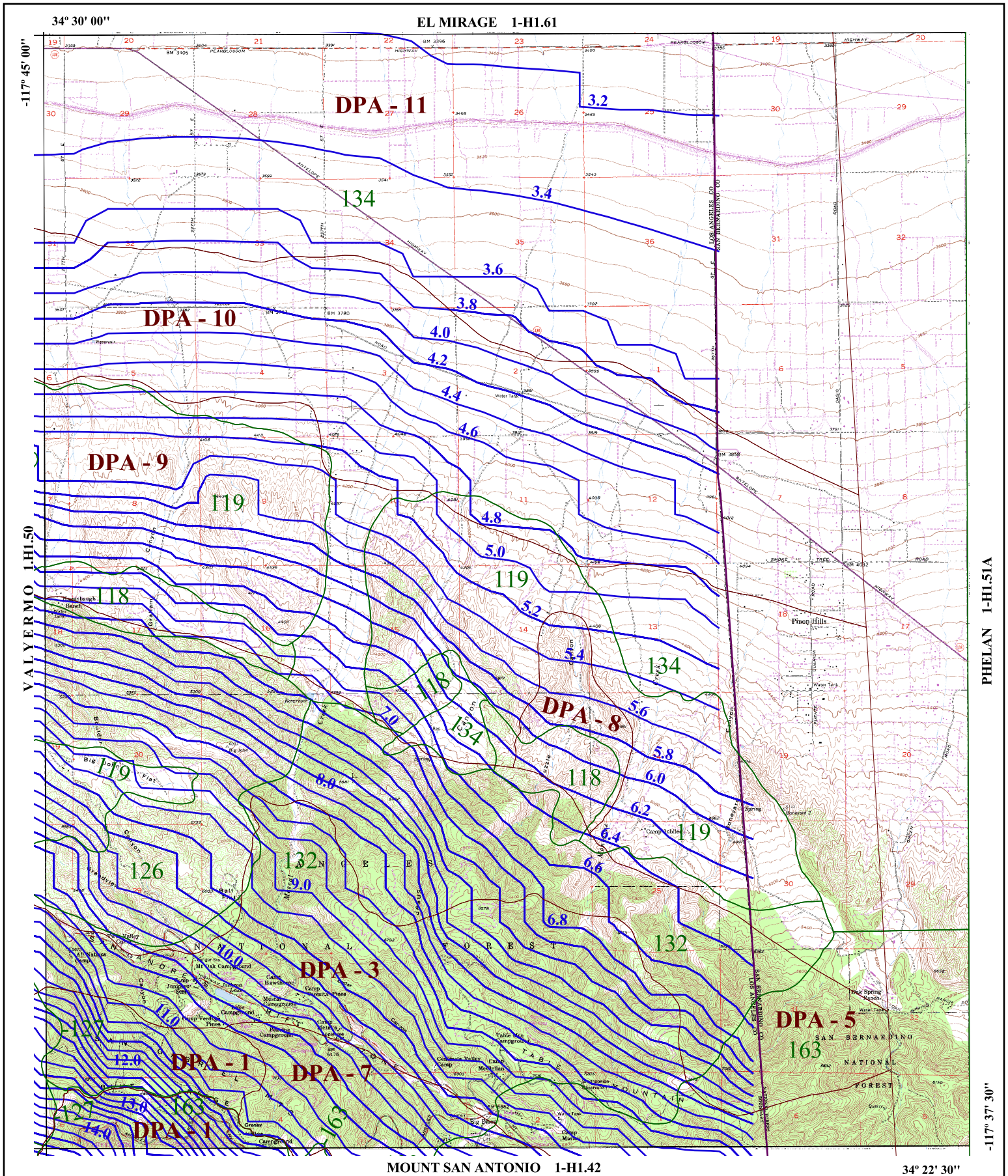
1 0 1 2 Miles

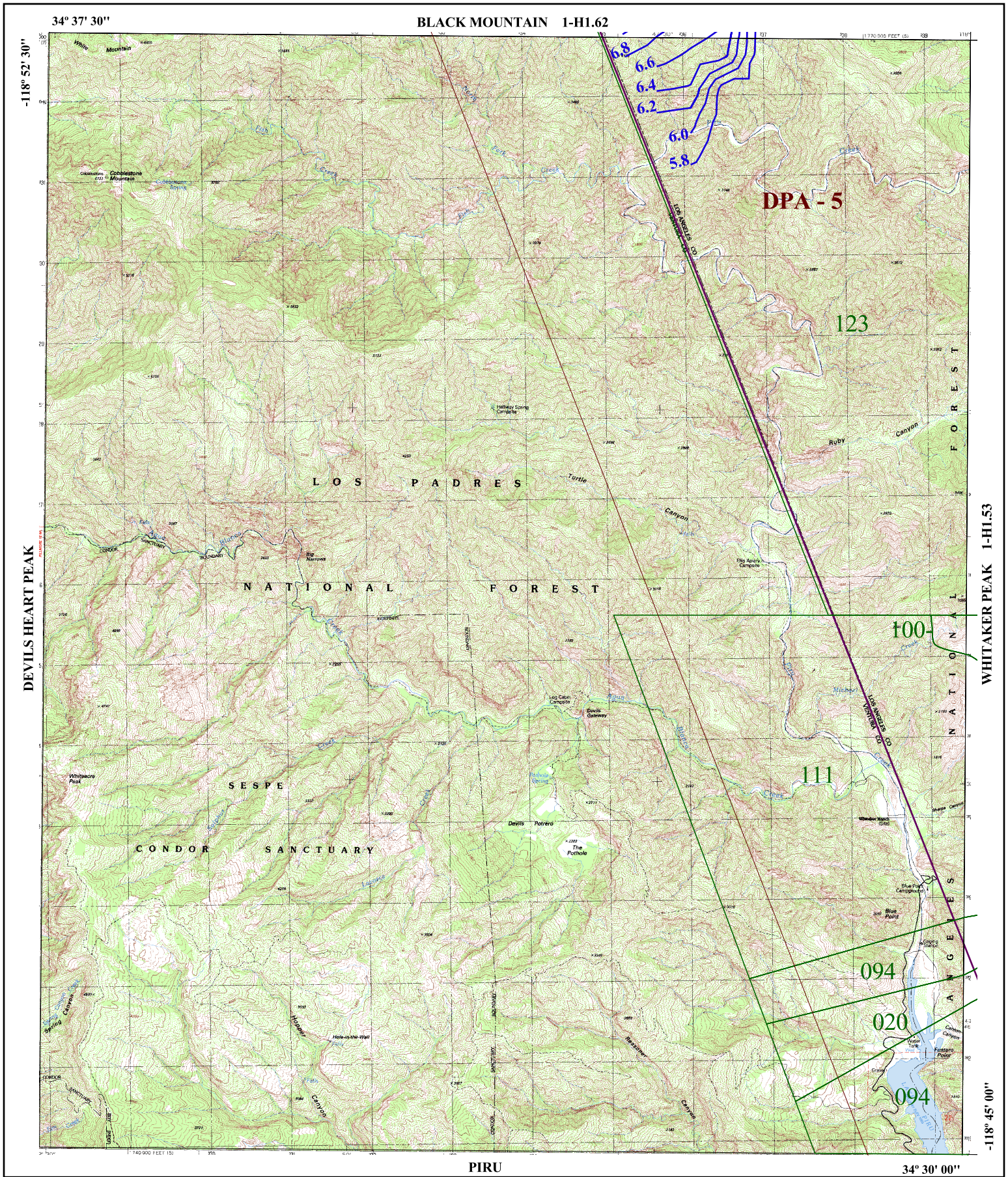
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

V A L Y E R M O
50-YEAR 24-HOUR ISOHYET

1-H1.50

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works


34° 30' 00"
EL MIRAGE 1-H1.61
-117° 45' 00"
DPA - 11
DPA - 10
DPA - 9
DPA - 8
DPA - 7
DPA - 6
DPA - 5
DPA - 4
DPA - 3
DPA - 2
DPA - 1
3.2
3.4
3.6
3.8
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0
6.2
6.4
6.6
6.8
7.0
8.0
9.0
10.0
11.0
12.0
13.0
14.0
134
119
118
132
126
122
127
163
VALYERMO 1-H1.50
PHELAN 1-H1.51A
MOUNT SAN ANTONIO 1-H1.42
34° 22' 30"
-117° 37' 30"
ANGELES NATIONAL FOREST
SAN BERNARDINO NATIONAL FOREST
Pinon Hills
Oak Spring Ranch
Camp Verdemont Pines
Table Mountain
Big Pines
Mescal Creek
Big John Flat
Grassy Hollow Campground
Table Mtn Campground
Camp Medellian
Camp Hawkins
Camp Juniper Springs
Mt Oak Campground
Camp Angeles
Camp Baldy Vista
Camp Marston
Camp Valley
Cedarpass Valley Camp
Camp Cajon
Camp Jameson
Camp Sierra Pines
Camp Verdemont Pines
Table Mtn Campground
Camp Medellian
Camp Marston
Big Pines
Camp Angeles
Camp Baldy Vista
Camp Valley
Camp Cajon
Camp Jameson
Camp Sierra Pines
Camp Hawkins
Mt Oak Campground
Camp Juniper Springs
Grassy Hollow Campground



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016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

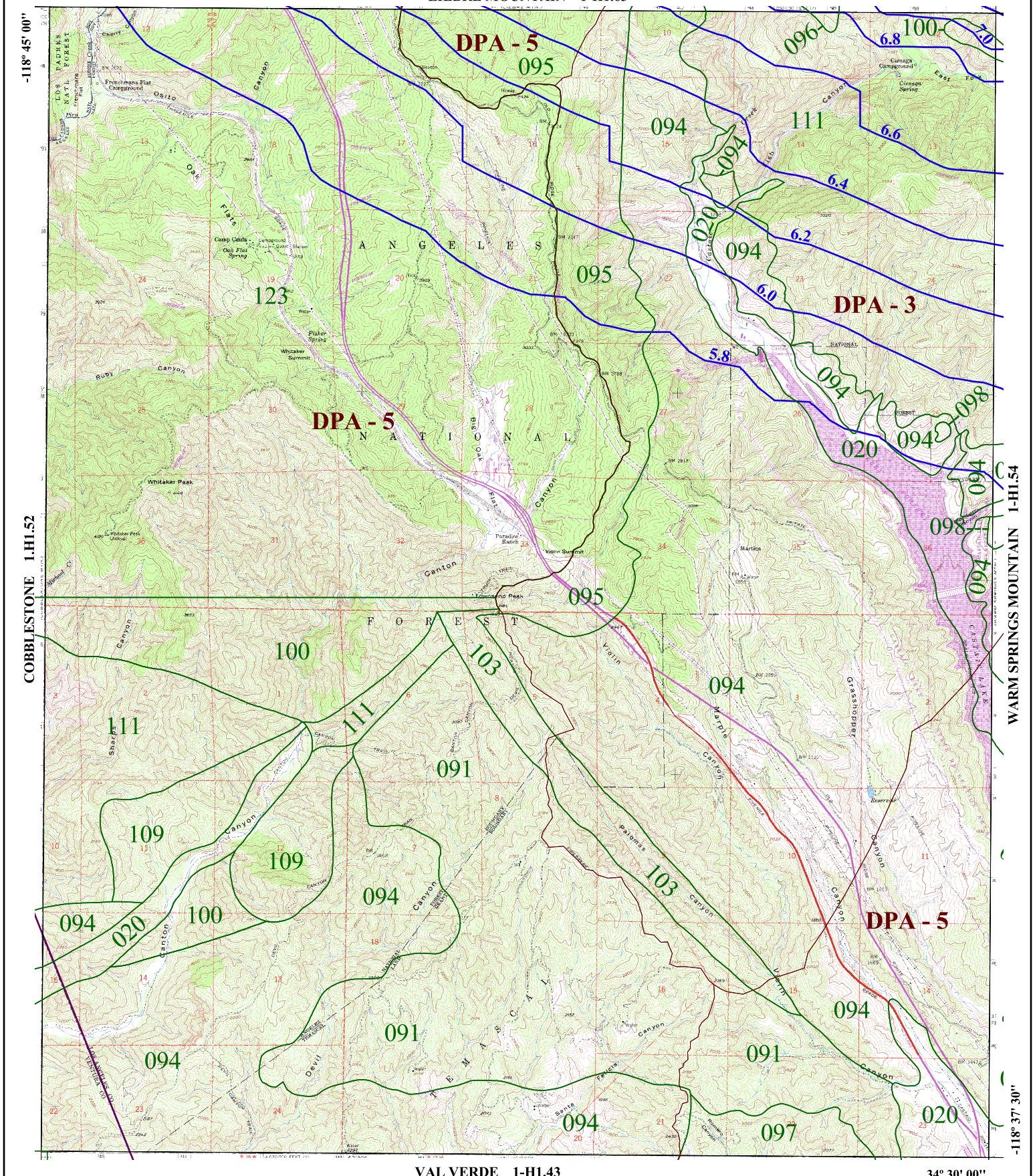
1 0 1 2 Miles

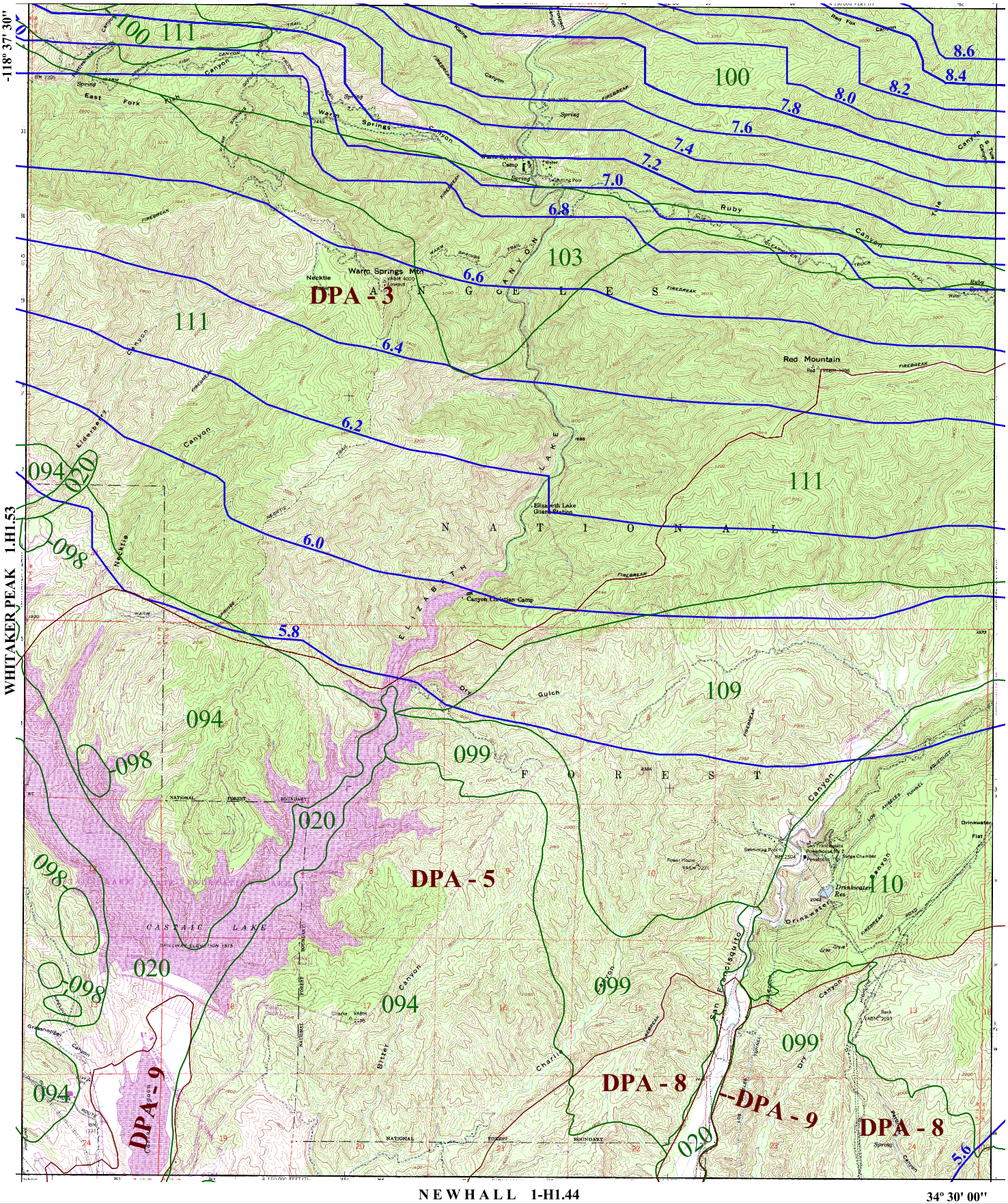
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

COBBLESTONE
50-YEAR 24-HOUR ISOHYET

1-H1.52

LOS ANGELES COUNTY PUBLIC WORKS
Public Service That Works


34° 37' 30"
LIEBRE MOUNTAIN 1-H1.63
-118° 45' 00"
DPA - 5
095
094
111
096
100
6.8
7.0
6.6
6.4
6.2
6.0
5.8
020
123
DPA - 3
DPA - 5
098
COBBLESTONE 1-H1.52
WARM SPRINGS MOUNTAIN 1-H1.54
100
103
091
109
DPA - 5
097
VAL VERDE 1-H1.43
34° 30' 00"
-118° 37' 30"
016
SOIL CLASSIFICATION AREA
7.2
INCHES OF RAINFALL
DPA - 6
DEBRIS POTENTIAL AREA
1 0 1 2 Miles
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714
WHITAKER PEAK
50-YEAR 24-HOUR ISOHYET
1-H1.53
LOS ANGELES COUNTY PUBLIC WORKS
Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

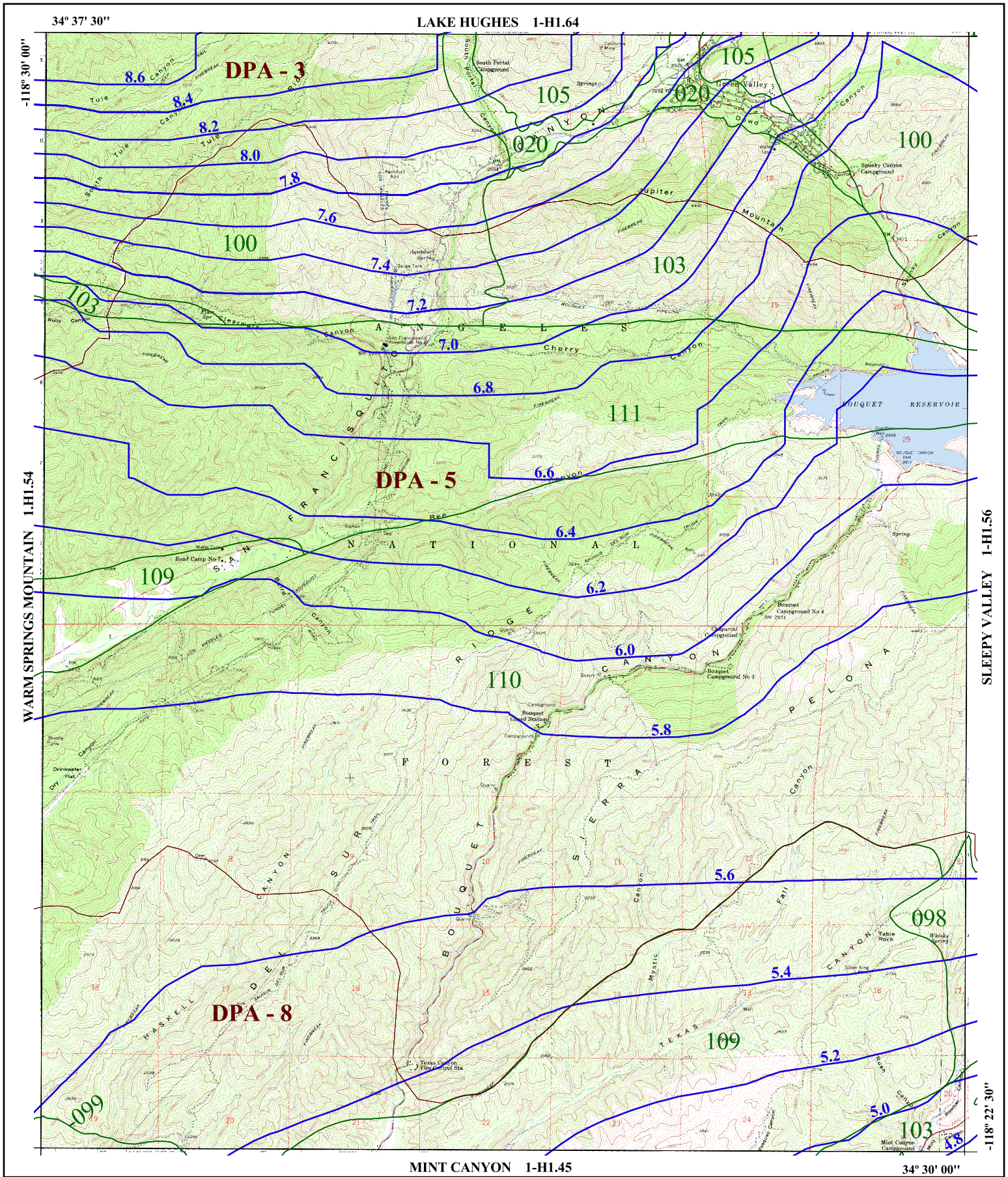
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

WARM SPRINGS MOUNTAIN 50-YEAR 24-HOUR ISOHYET

1-H1.54

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

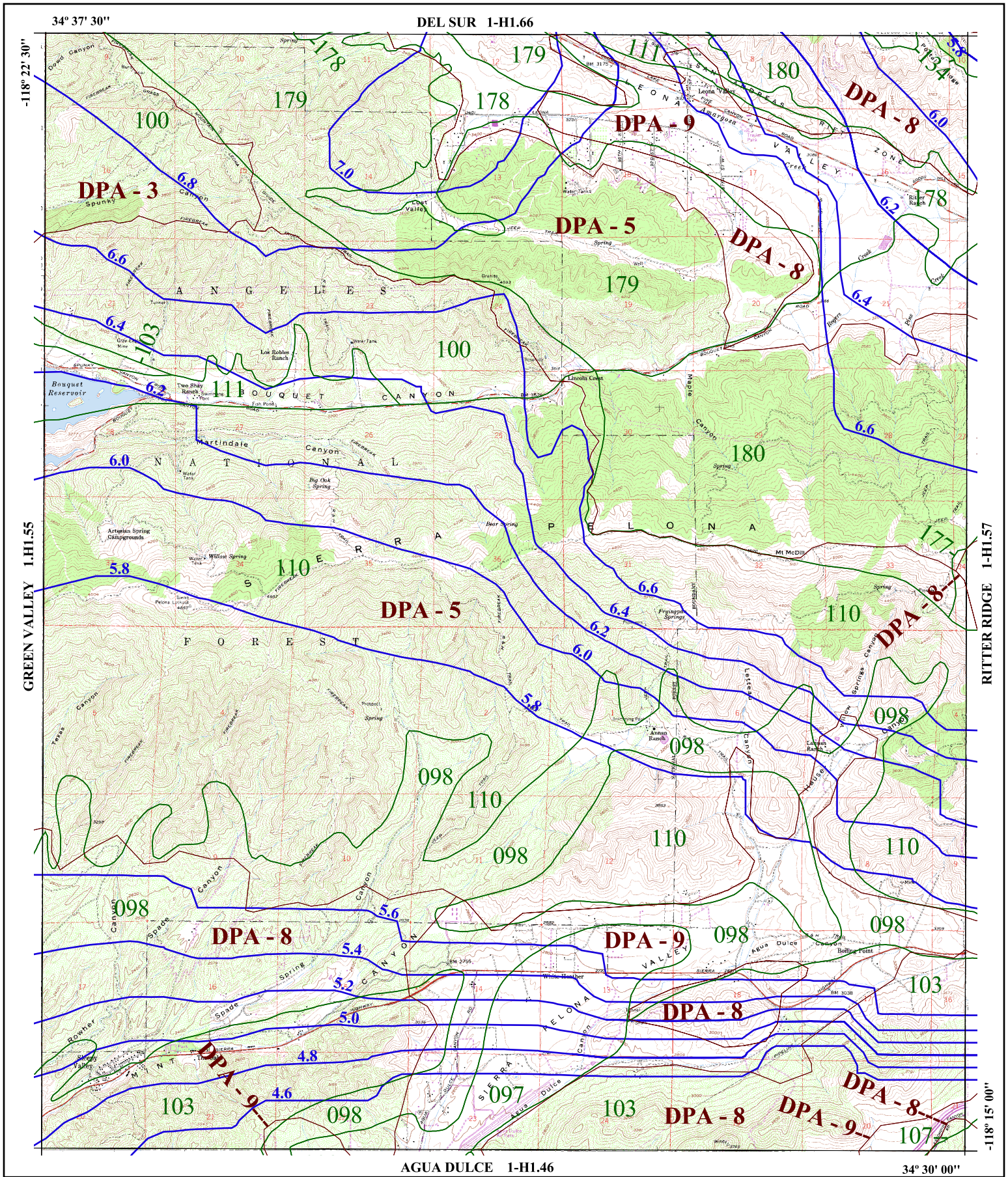
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

GREEN VALLEY 50-YEAR 24-HOUR ISOHYET

1-H1.55

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

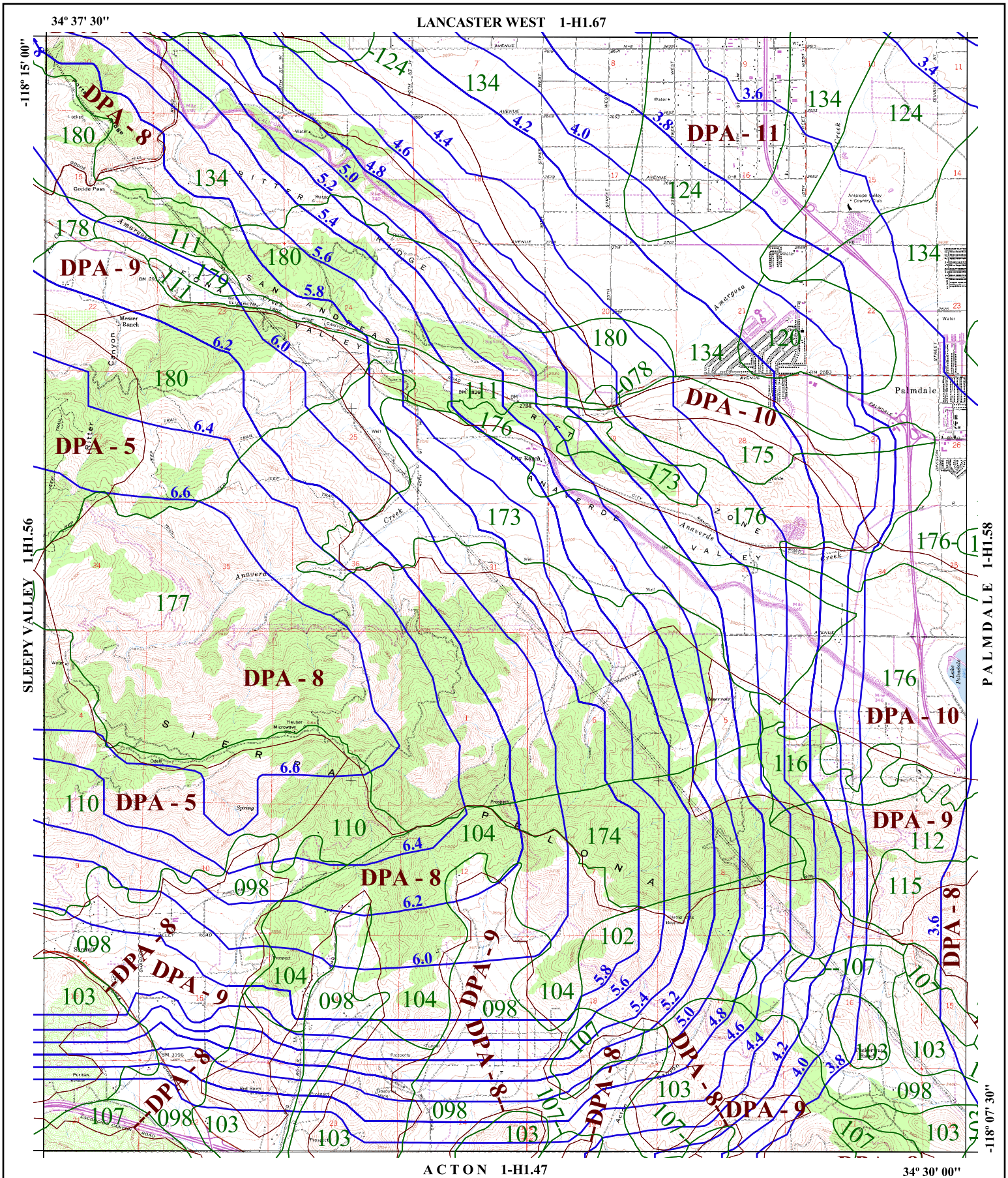
1 0 1 2 Miles

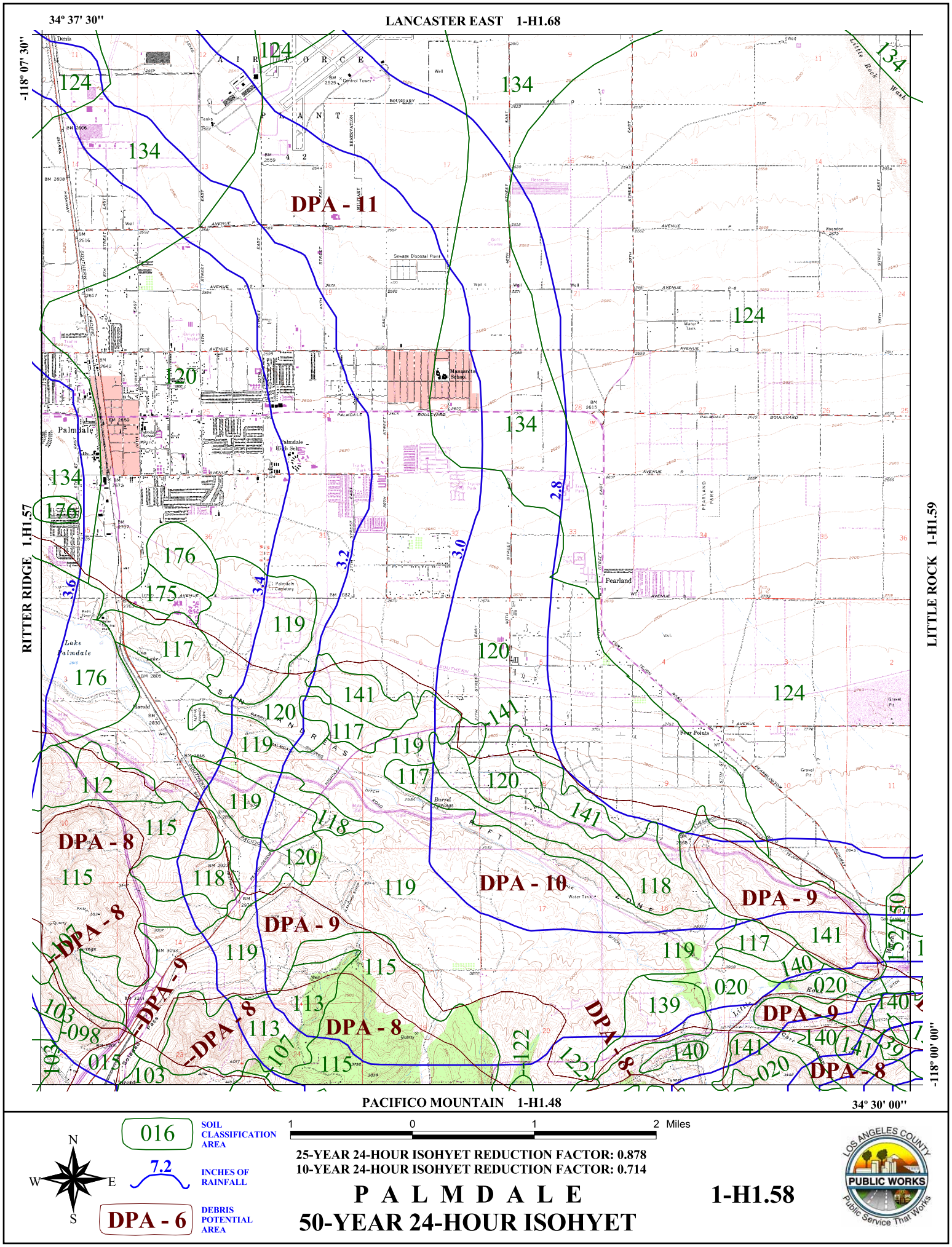
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

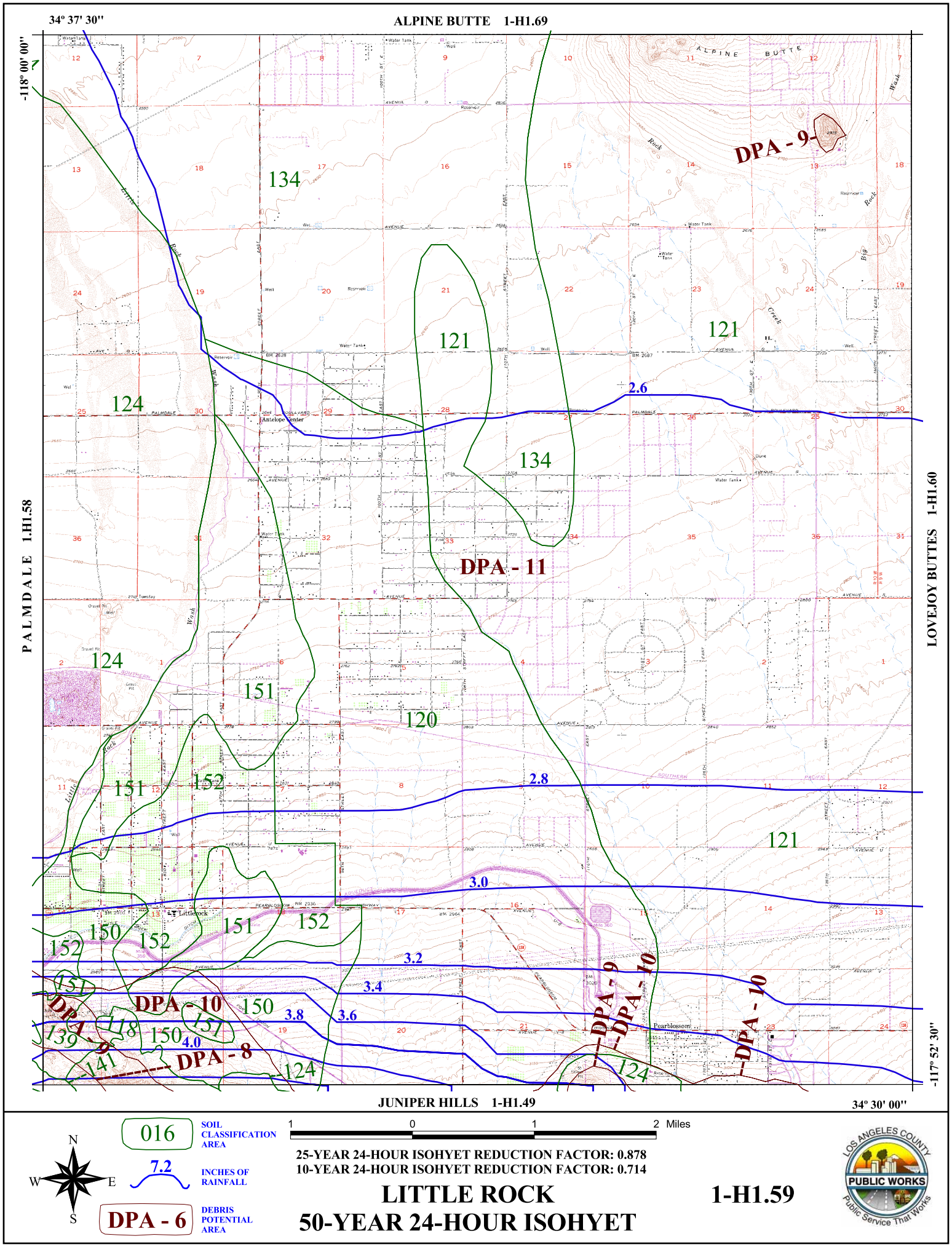
SLEEPY VALLEY
50-YEAR 24-HOUR ISOHYET

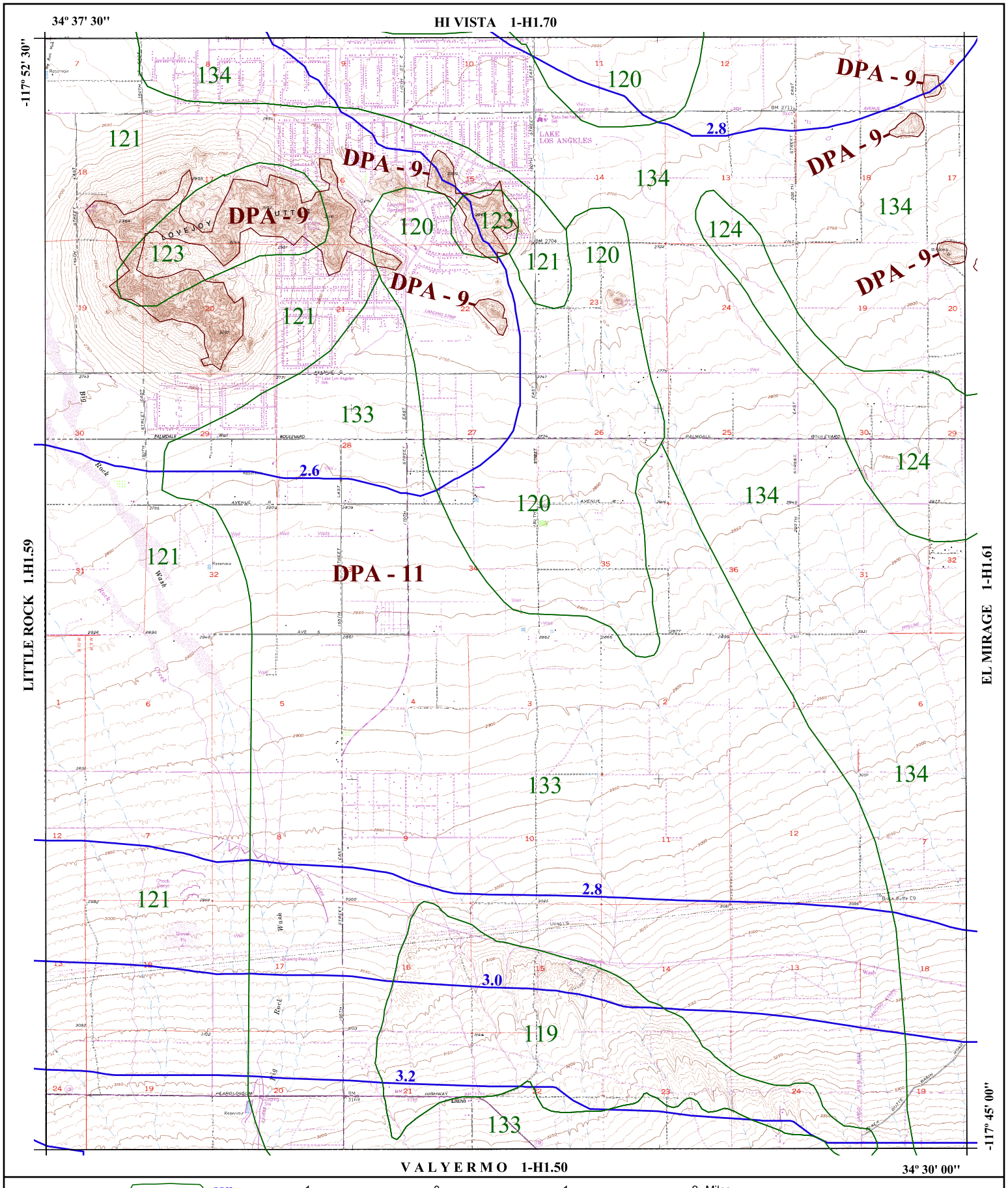
1-H1.56

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works


34° 37' 30"
LANCASTER WEST 1-H1.67
-118° 15' 00"
SLEEPY VALLEY 1-H1.56
PALMDALE 1-H1.58
-118° 07' 30"
ACTON 1-H1.47
34° 30' 00"
DPA - 8
DPA - 11
DPA - 9
DPA - 10
DPA - 5
DPA - 6
Palmdale
Lake Palmdale
RITTER RIDGE
SAN ANDREAS RIFT ZONE
ANTELOPE VALLEY
SIERRA PELONA
Goode Pass
Messer Ranch
Oak Ranch
Harold Arts Boulevard
Amargosa Creek
Anaverde Creek
Anaverde Valley
Prospect
Puritan
Red Rover
Mountain View
Antelope Valley Country Club
Hauser Microwave Station
Spring
Well
Water
Trail
Jeep Trail
Pipeline
Power Line
Aqueduct
Division St.
Sierra Hwy
Amargosa Rd.
Palmdale Blvd.
Avenue
Street
Road
Canyon
Creek
Ridge
Valley
Zone
Mine
Tank
Reservoir
Sump
Cemetery
Golf Course
Landfill
Substation
Microwave Station
Power Line
Aqueduct
Pipeline
Trail
Jeep Trail
Well
Water
Spring
Tank
Reservoir
Sump
Cemetery
Golf Course
Landfill
Substation
Microwave Station
Mine
Division St.
Sierra Hwy
Amargosa Rd.
Palmdale Blvd.
Avenue
Street
Road
Canyon
Creek
Ridge
Valley
Zone
Mountain View
Puritan
Red Rover
Prospect
Oak Ranch
Harold Arts Boulevard
Anaverde Creek
Anaverde Valley
Amargosa Creek
Antelope Valley Country Club
Hauser Microwave Station
Goode Pass
Messer Ranch
SAN ANDREAS RIFT ZONE
RITTER RIDGE
ANTELOPE VALLEY
SIERRA PELONA
Palmdale
Lake Palmdale
N
S
E
W
016
SOIL CLASSIFICATION AREA
7.2
INCHES OF RAINFALL
DPA - 6
DEBRIS POTENTIAL AREA
1 0 1 2 Miles
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714
RITTER RIDGE
50-YEAR 24-HOUR ISOHYET
1-H1.57
LOS ANGELES COUNTY
PUBLIC WORKS
Public Service That Works


34° 37' 30"
LANCASTER EAST 1-H1.68
-118° 07' 30"
RITTER RIDGE 1-H1.57
LITTLE ROCK 1-H1.59
-118° 00' 00"
PACIFICO MOUNTAIN 1-H1.48
34° 30' 00"
DPA - 11
DPA - 8
DPA - 9
DPA - 10
DPA - 6
Palmdale
Pearland
Lake Palmdale
Four Points
Sewage Disposal Plant
Palmdale High Sch
Palmdale Cemetery
Harold
Barrel Springs
Little Rock Wash
SAN ANDREAS FAULT ZONE
AIR FORCE PLANT 42
016 SOIL CLASSIFICATION AREA
7.2 INCHES OF RAINFALL
DPA - 6 DEBRIS POTENTIAL AREA
N
W
E
S
1 0 1 2 Miles
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714
P A L M D A L E
50-YEAR 24-HOUR ISOHYET
1-H1.58
LOS ANGELES COUNTY PUBLIC WORKS
Public Service That Works


34° 37' 30"
ALPINE BUTTE 1-H1.69
-118° 00' 00"
PALMDALE 1.H1.58
LOVEJOY BUTTES 1-H1.60
-117° 52' 30"
JUNIPER HILLS 1-H1.49
34° 30' 00"
DPA - 9
DPA - 11
DPA - 10
DPA - 8
DPA - 6
134
121
124
151
120
152
150
139
118
141
2.6
2.8
3.0
3.2
3.4
3.6
3.8
4.0
Antelope Center
Littlerock
Pearblossom
1 0 1 2 Miles
016 SOIL CLASSIFICATION AREA
7.2 INCHES OF RAINFALL
DPA - 6 DEBRIS POTENTIAL AREA
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714
LITTLE ROCK
50-YEAR 24-HOUR ISOHYET
1-H1.59
LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



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S

016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

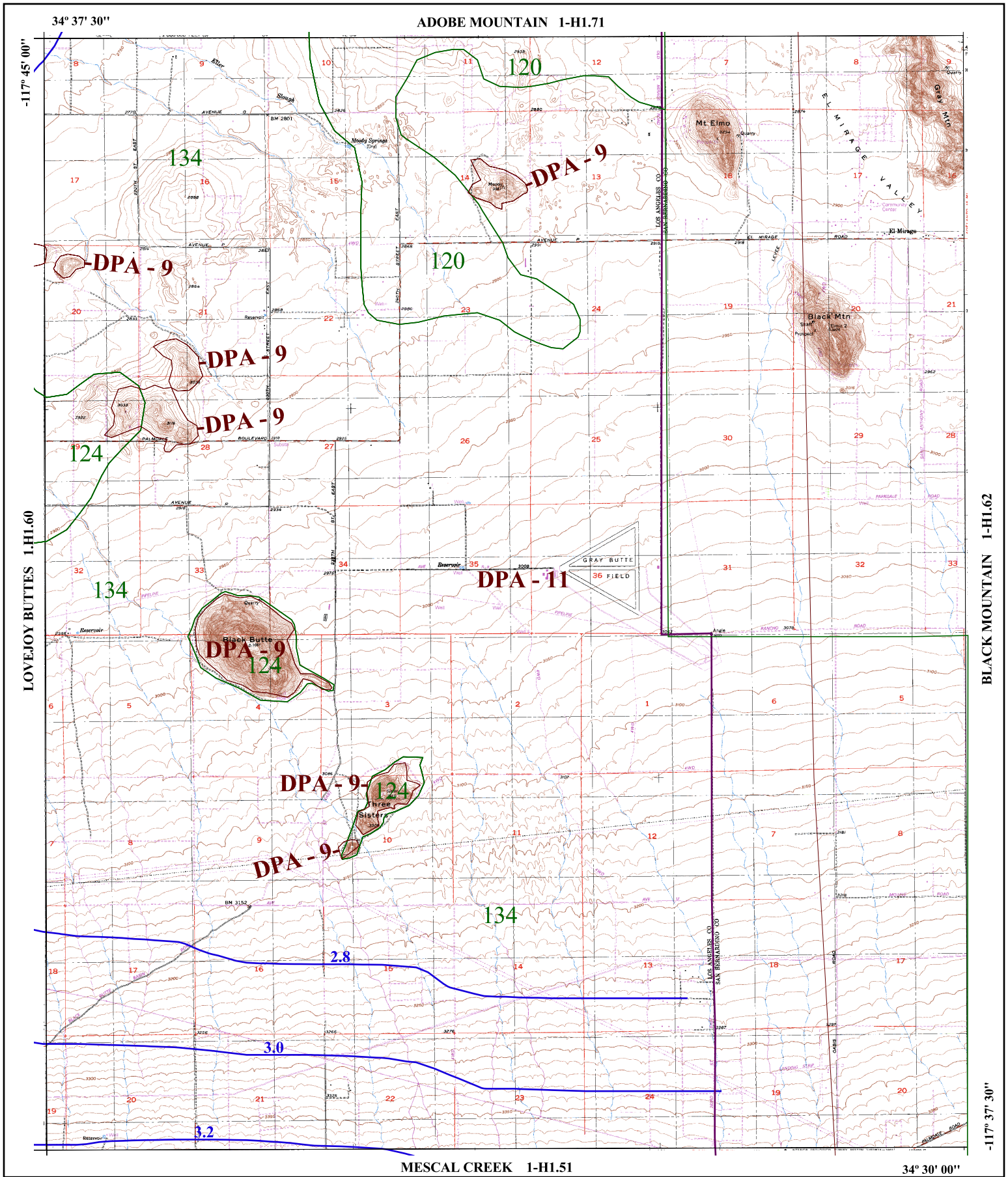
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

LOVEJOY BUTTES
50-YEAR 24-HOUR ISOHYET

1-H1.60

LOS ANGELES COUNTY PUBLIC WORKS
Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

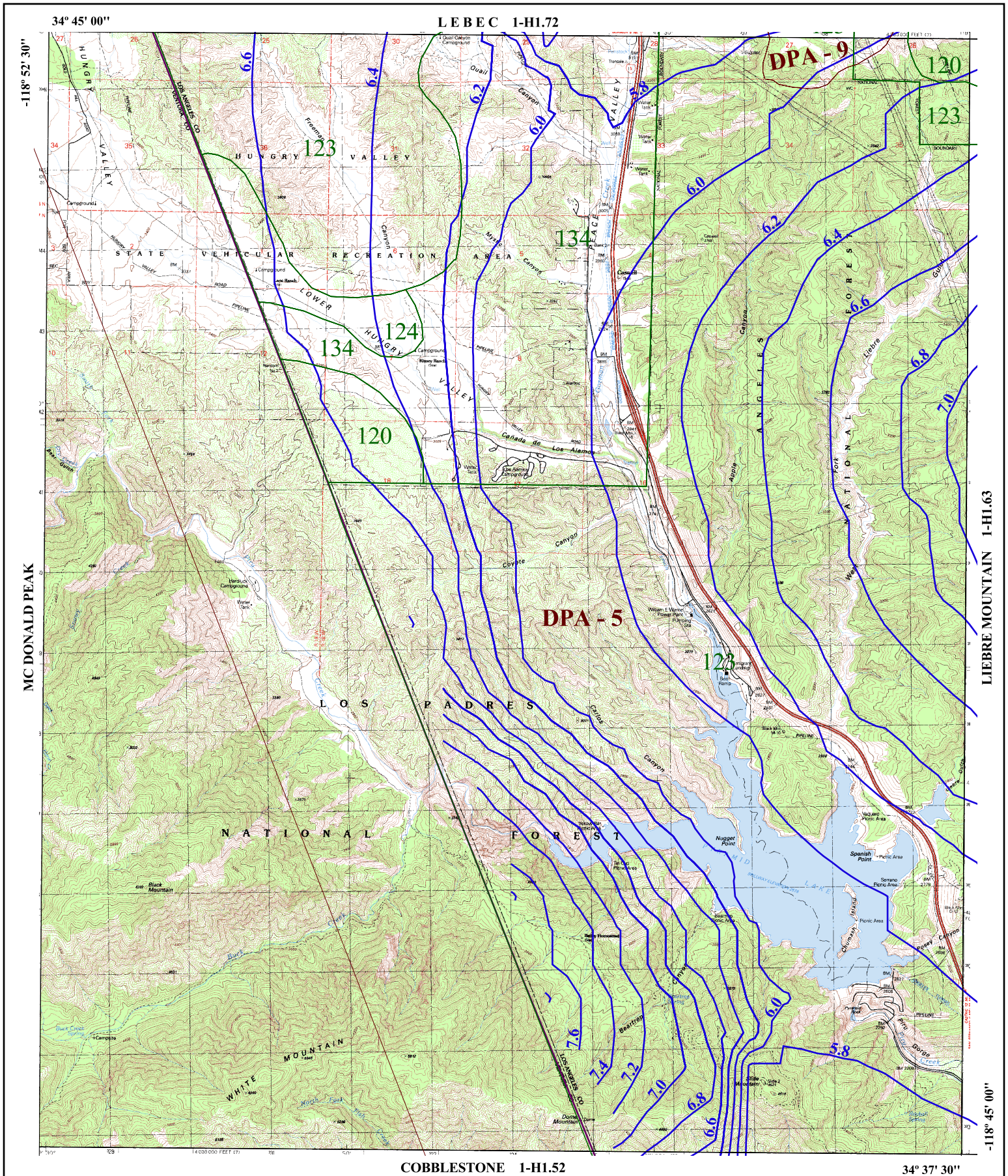
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

EL MIRAGE
50-YEAR 24-HOUR ISOHYET

1-H1.61

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 — SOIL CLASSIFICATION AREA

7.2 — INCHES OF RAINFALL

DPA - 6 — DEBRIS POTENTIAL AREA

N W E S

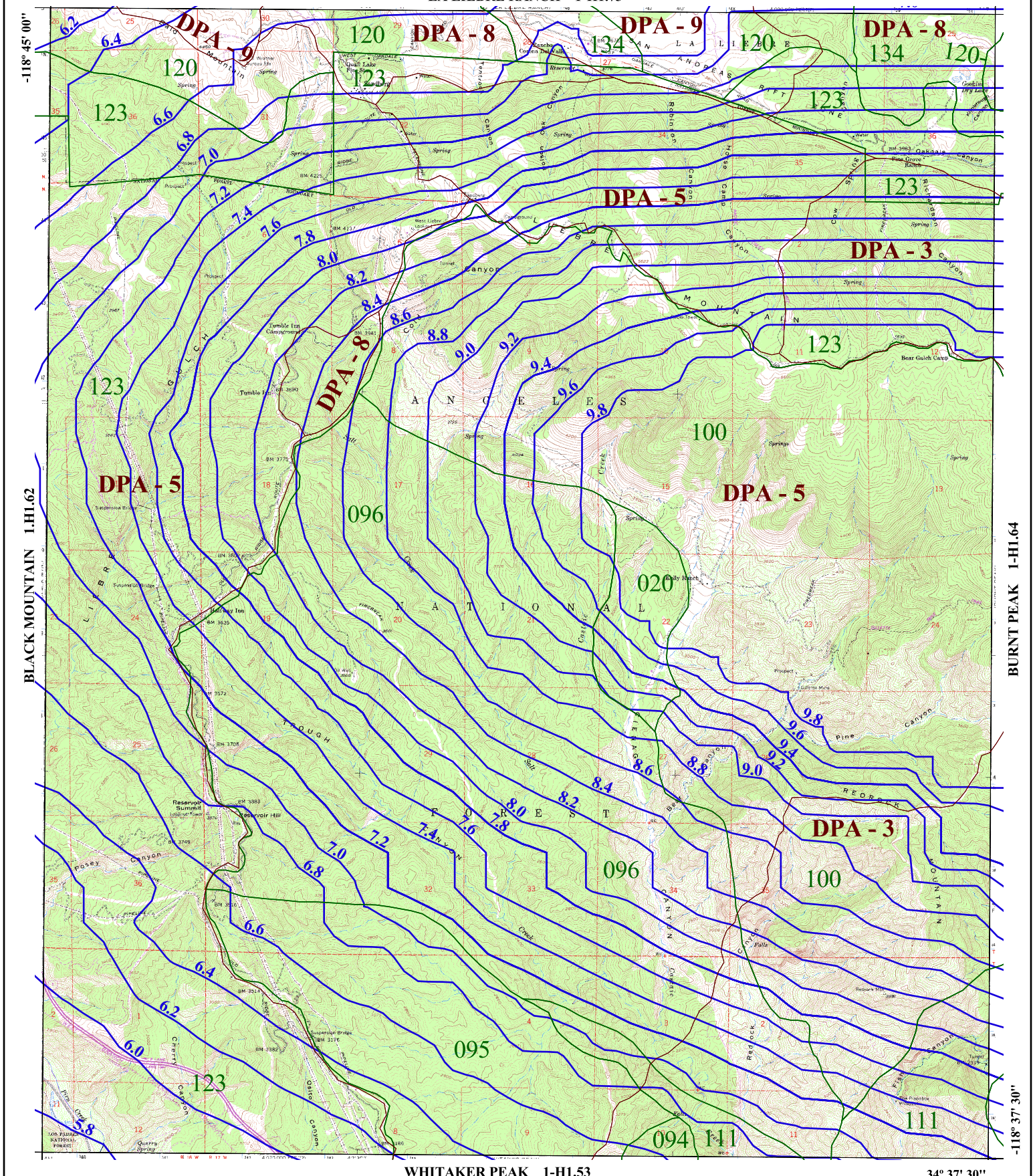
1 0 1 2 Miles

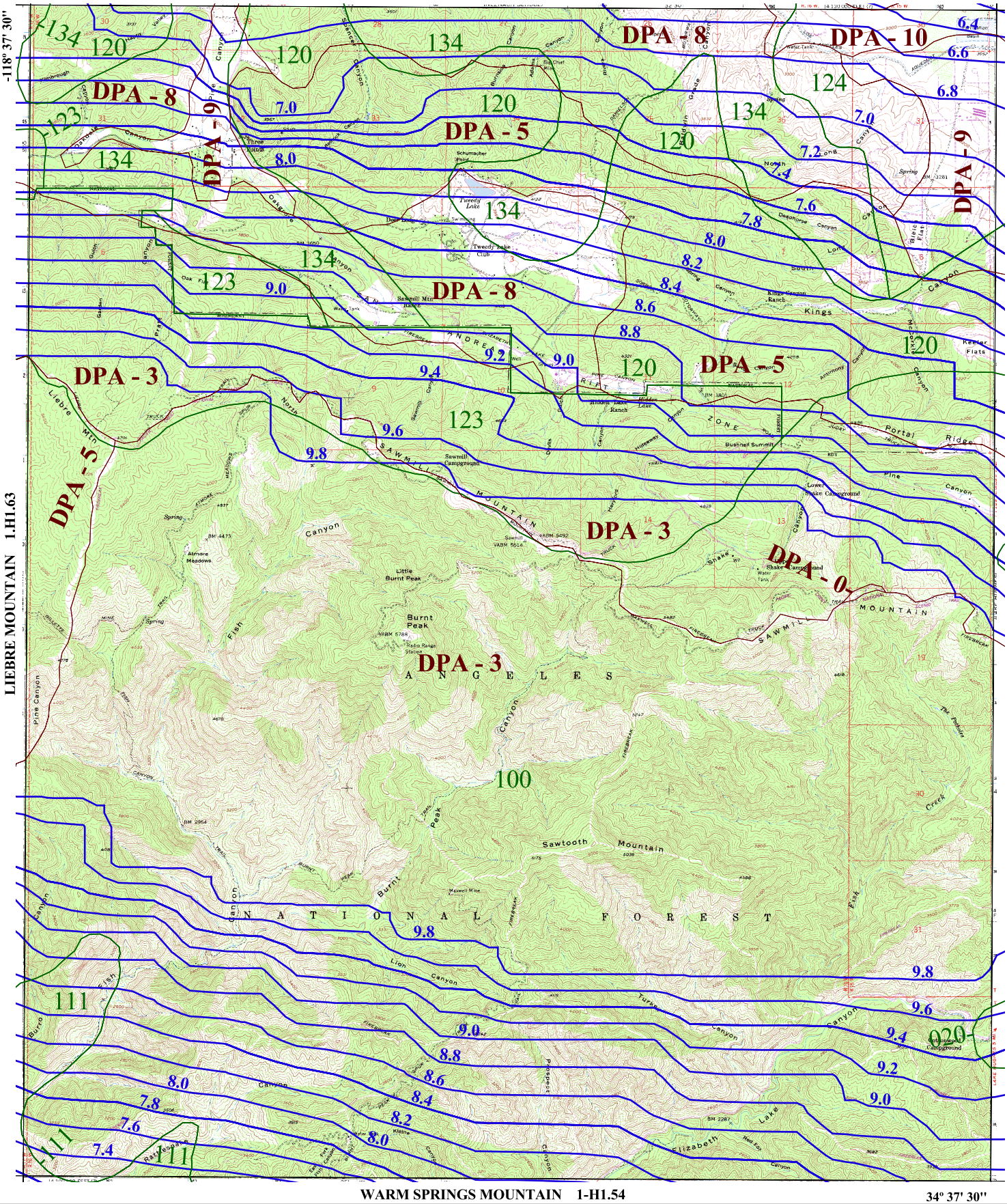
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

BLACK MOUNTAIN
50-YEAR 24-HOUR ISOHYET

1-H1.62

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works


34° 45' 00"
LA LIEBRE RANCH 1-H1.73
-118° 45' 00"
BLACK MOUNTAIN 1.H1.62
BURNT PEAK 1-H1.64
-118° 37' 30"
WHITAKER PEAK 1-H1.53
34° 37' 30"
DPA - 9
DPA - 8
DPA - 5
DPA - 3
DPA - 6
120
123
124
134
096
100
020
095
094
111
6.2
6.4
6.6
6.8
7.0
7.2
7.4
7.6
7.8
8.0
8.2
8.4
8.6
8.8
9.0
9.2
9.4
9.6
9.8
5.8
6.0
SAN ANDREAS RIFT ZONE
LA LIEBRE MOUNTAIN
ANGELES NATIONAL FOREST
TROUGH
016
SOIL CLASSIFICATION AREA
7.2
INCHES OF RAINFALL
DEBRIS POTENTIAL AREA
N
S
E
W
1 0 1 2 Miles
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714
LIEBRE MOUNTAIN
50-YEAR 24-HOUR ISOHYET
1-H1.63
LOS ANGELES COUNTY
PUBLIC WORKS
Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

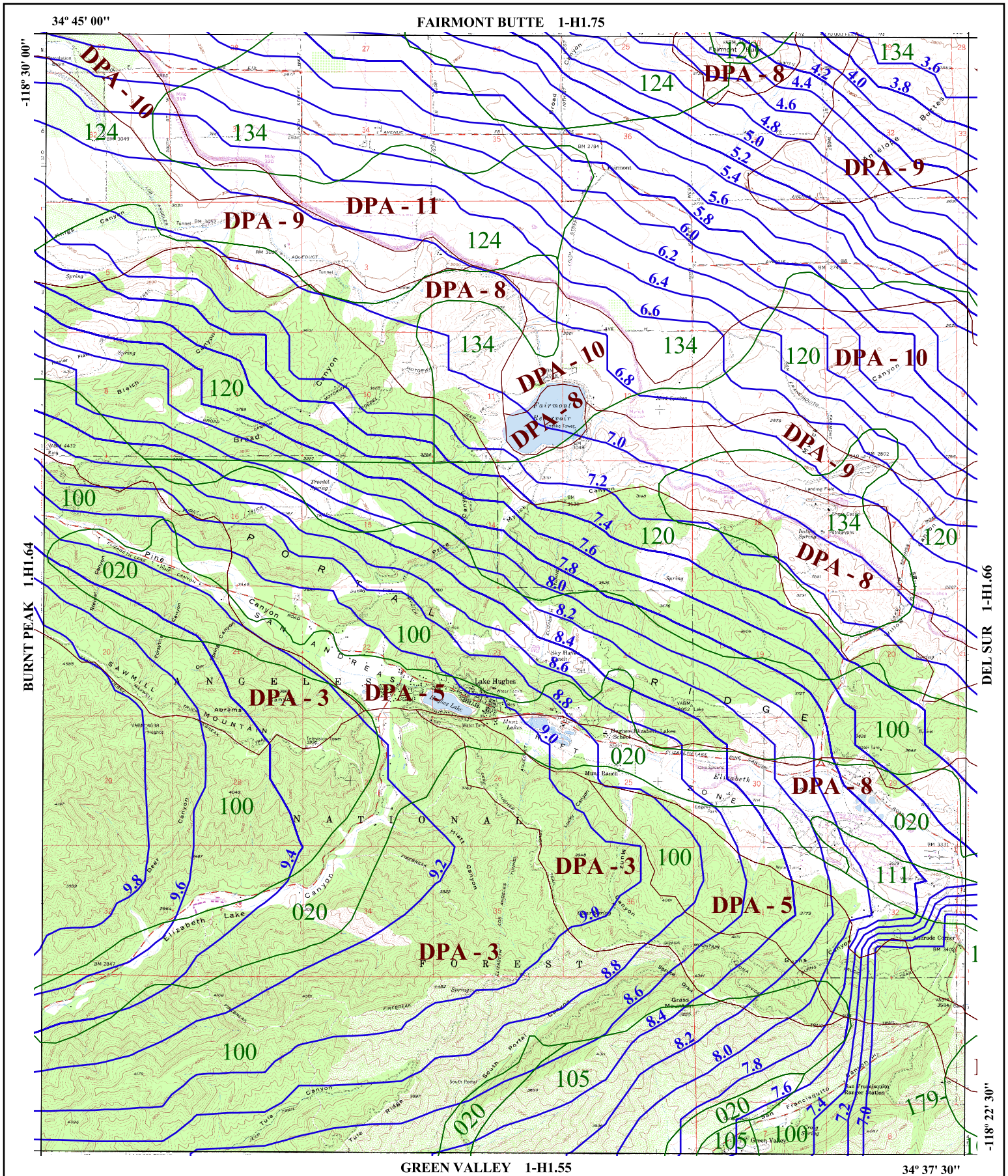
1 0 1 2 Miles

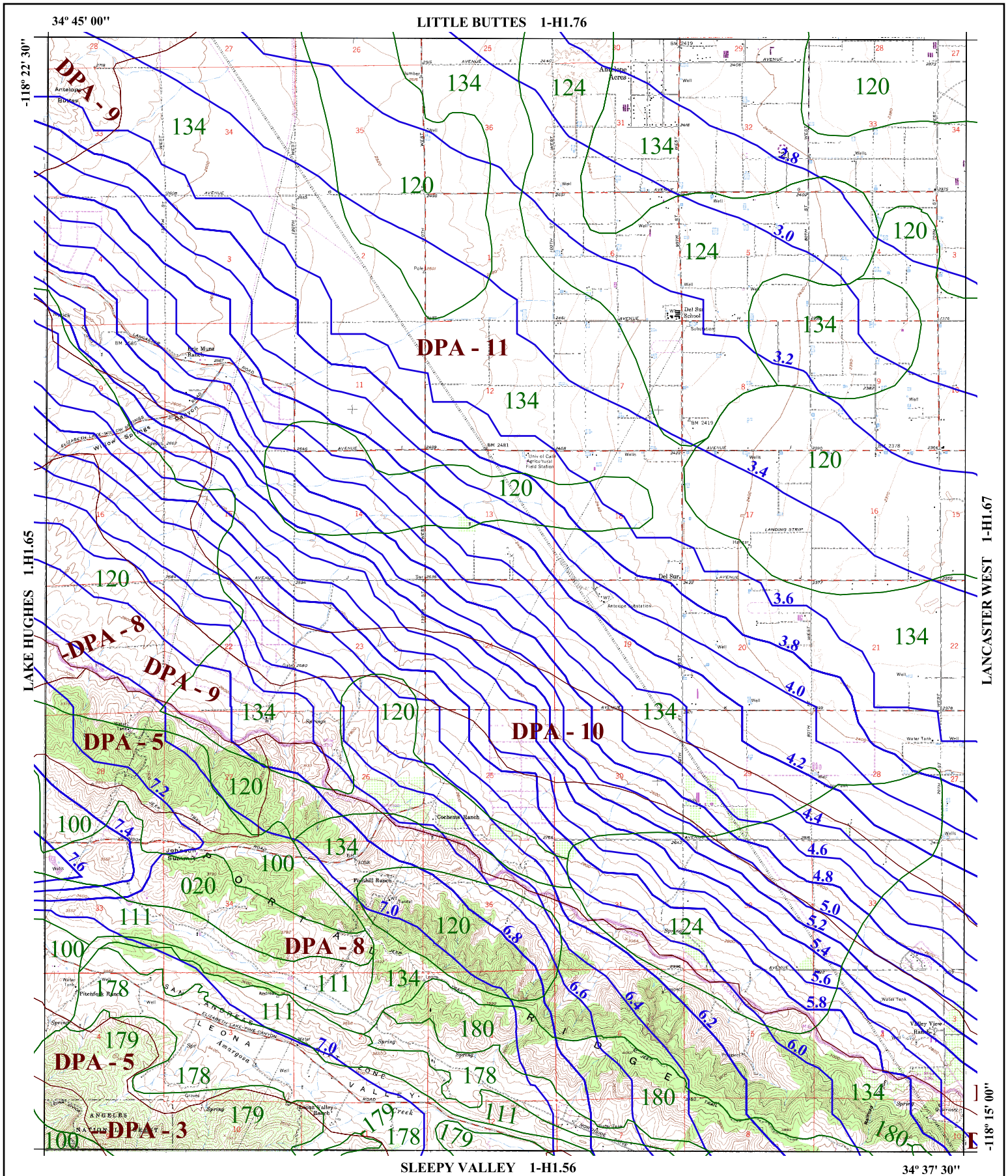
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

BURNT PEAK
50-YEAR 24-HOUR ISOHYET

1-H1.64

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works


34° 45' 00"
FAIRMONT BUTTE 1-H1.75
-118° 30' 00"
BURNT PEAK 1,H1.64
DEL SUR 1-H1.66
-118° 22' 30"
GREEN VALLEY 1-H1.55
34° 37' 30"
DPA - 10
DPA - 8
DPA - 9
DPA - 11
DPA - 3
DPA - 5
124
134
120
100
020
105
111
179
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0
6.2
6.4
6.6
6.8
7.0
7.2
7.4
7.6
7.8
8.0
8.2
8.4
8.6
8.8
9.0
9.2
9.4
9.6
9.8
Fairmont Reservoir
Lake Hughes
Elizabeth Lake
Bleich Canyon
Broad Canyon
Pine Canyon
Sawmill Canyon
Abrams Mountain
Grass Mountain
Bliss Canyon
Andrade Corner
San Francisquito Canyon
Ranger Station
POR SCAL
SAN ANDREAS
ANGELES
RIDGE
NATIONAL
FOREST
016
SOIL CLASSIFICATION AREA
7.2
INCHES OF RAINFALL
DPA - 6
DEBRIS POTENTIAL AREA
N
S
E
W
1 0 1 2 Miles
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714
LAKE HUGHES
50-YEAR 24-HOUR ISOHYET
1-H1.65
LOS ANGELES COUNTY
PUBLIC WORKS
Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

1 0 1 2 Miles

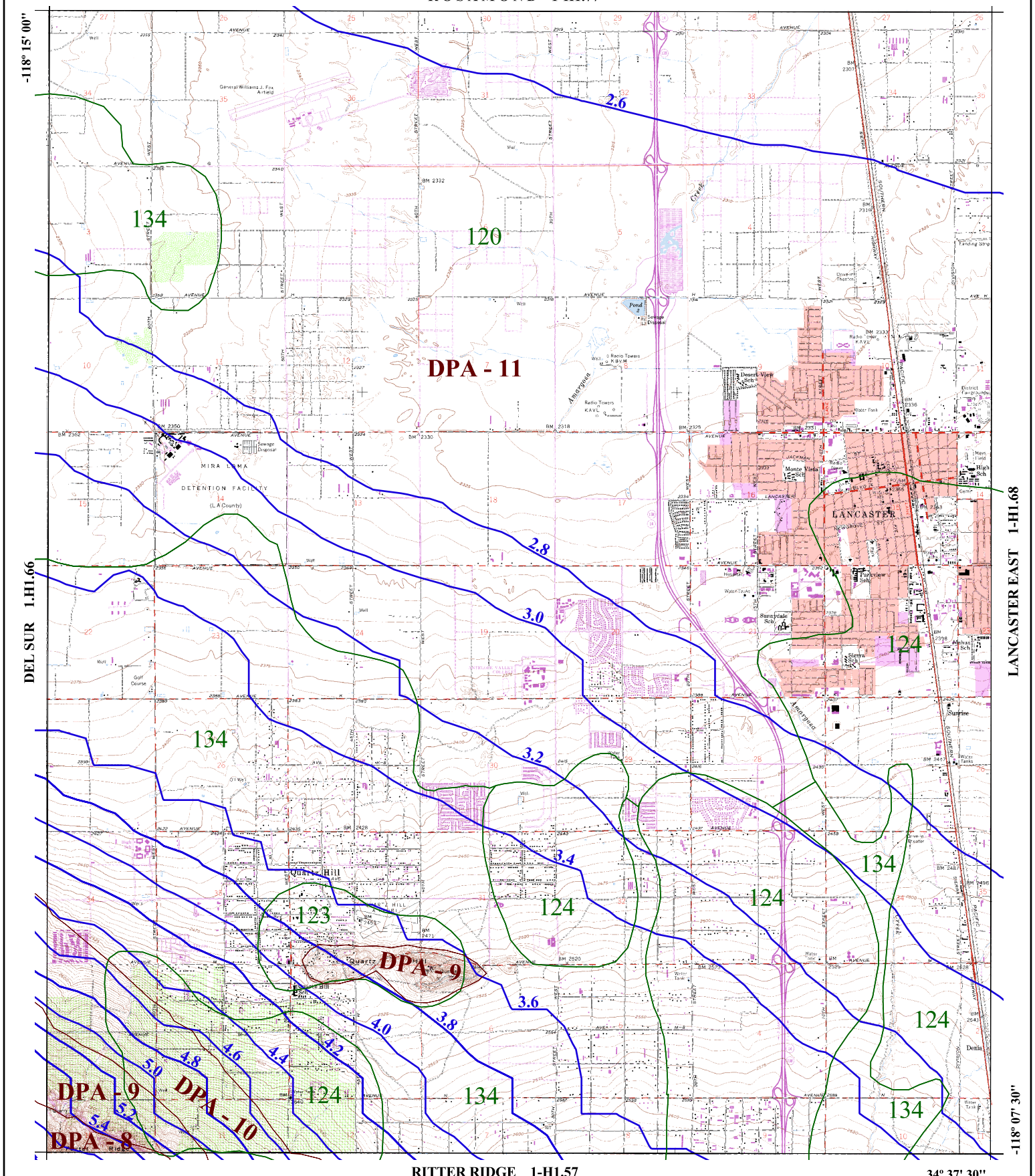
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

D E L S U R

50-YEAR 24-HOUR ISOHYET

1-H1.66

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

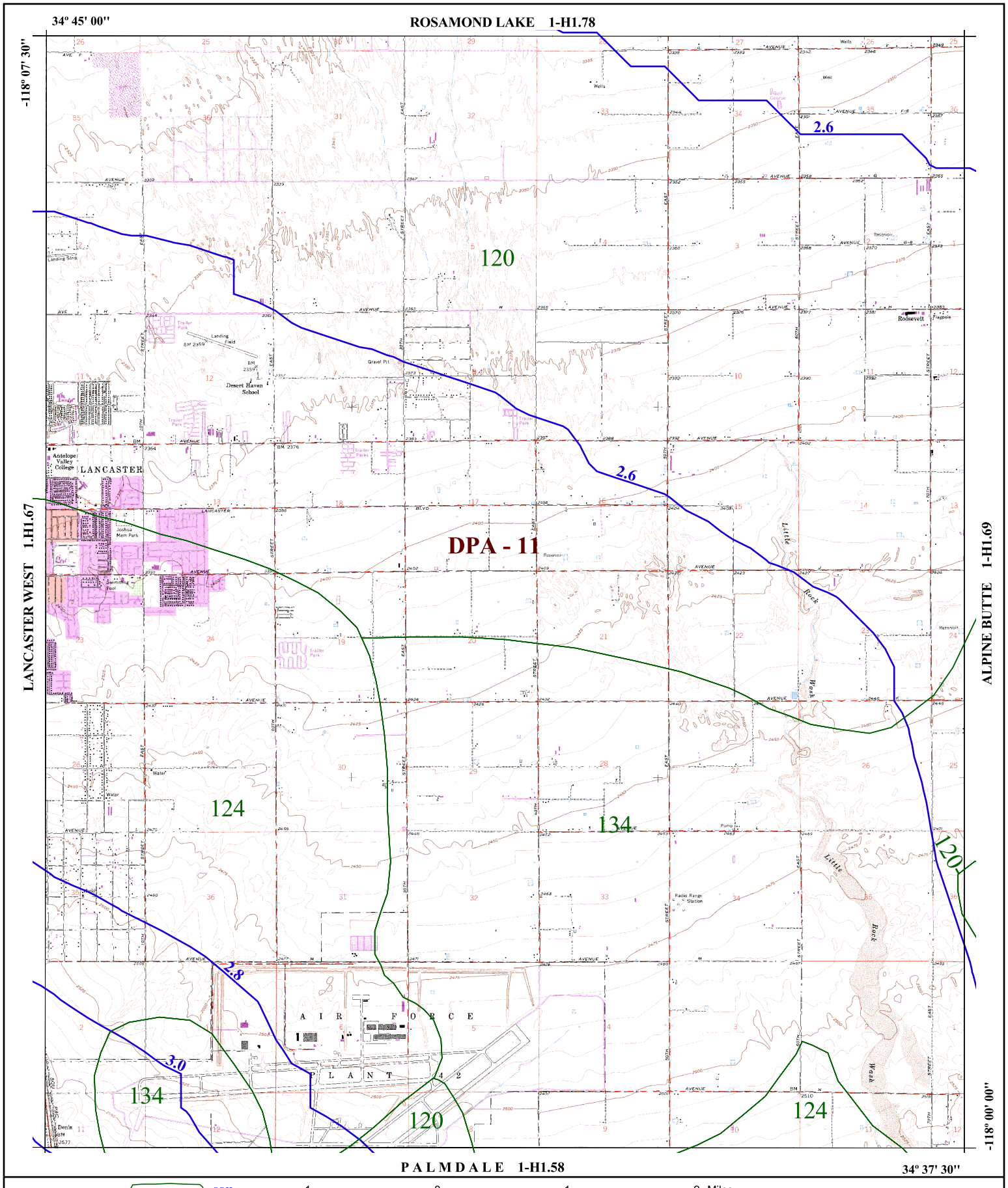
N W E S

1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

LANCASTER WEST 1-H1.67
50-YEAR 24-HOUR ISOHYET

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



N
W E
S

016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

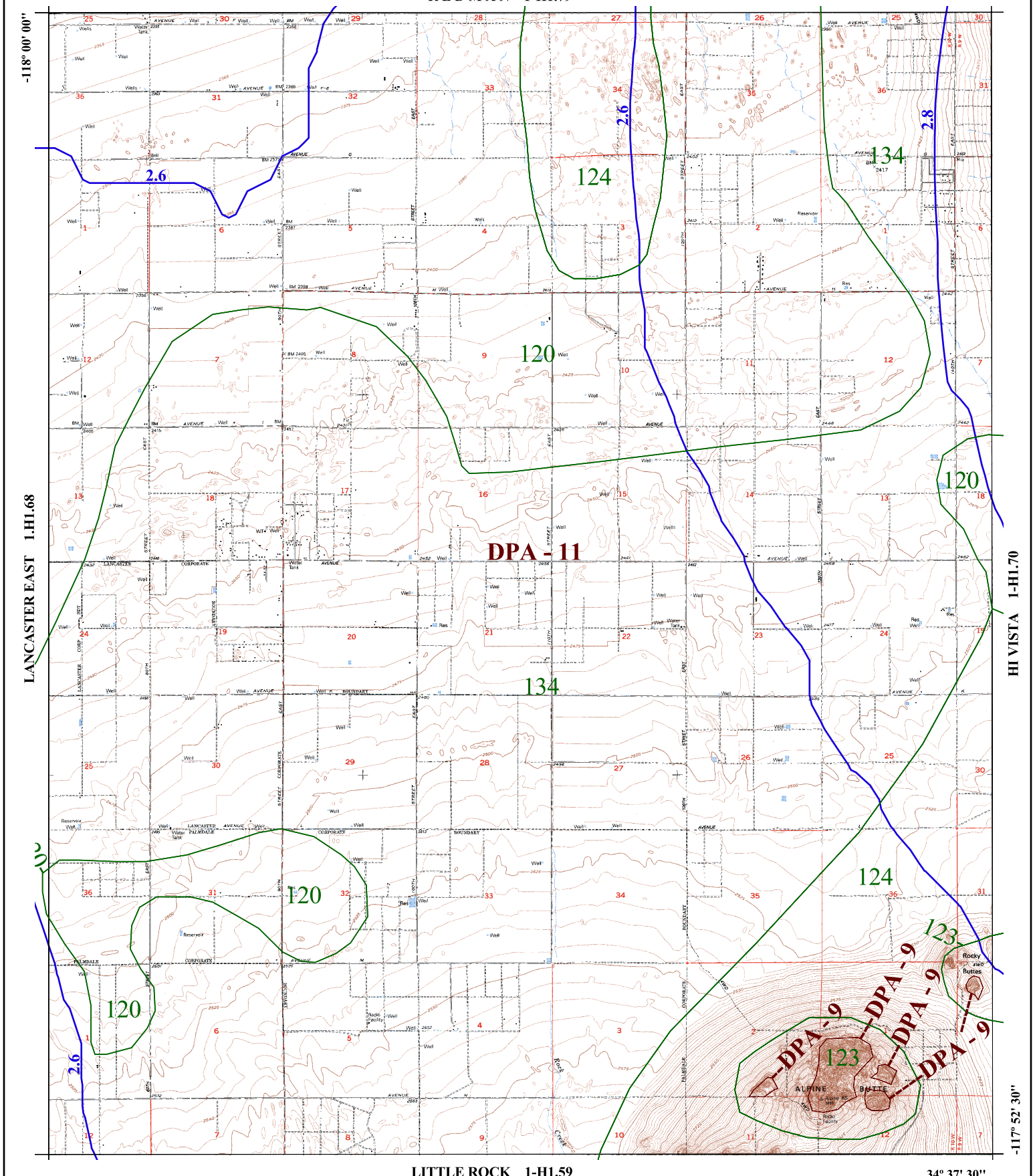
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

LANCASTER EAST
50-YEAR 24-HOUR ISOHYET

1-H1.68

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

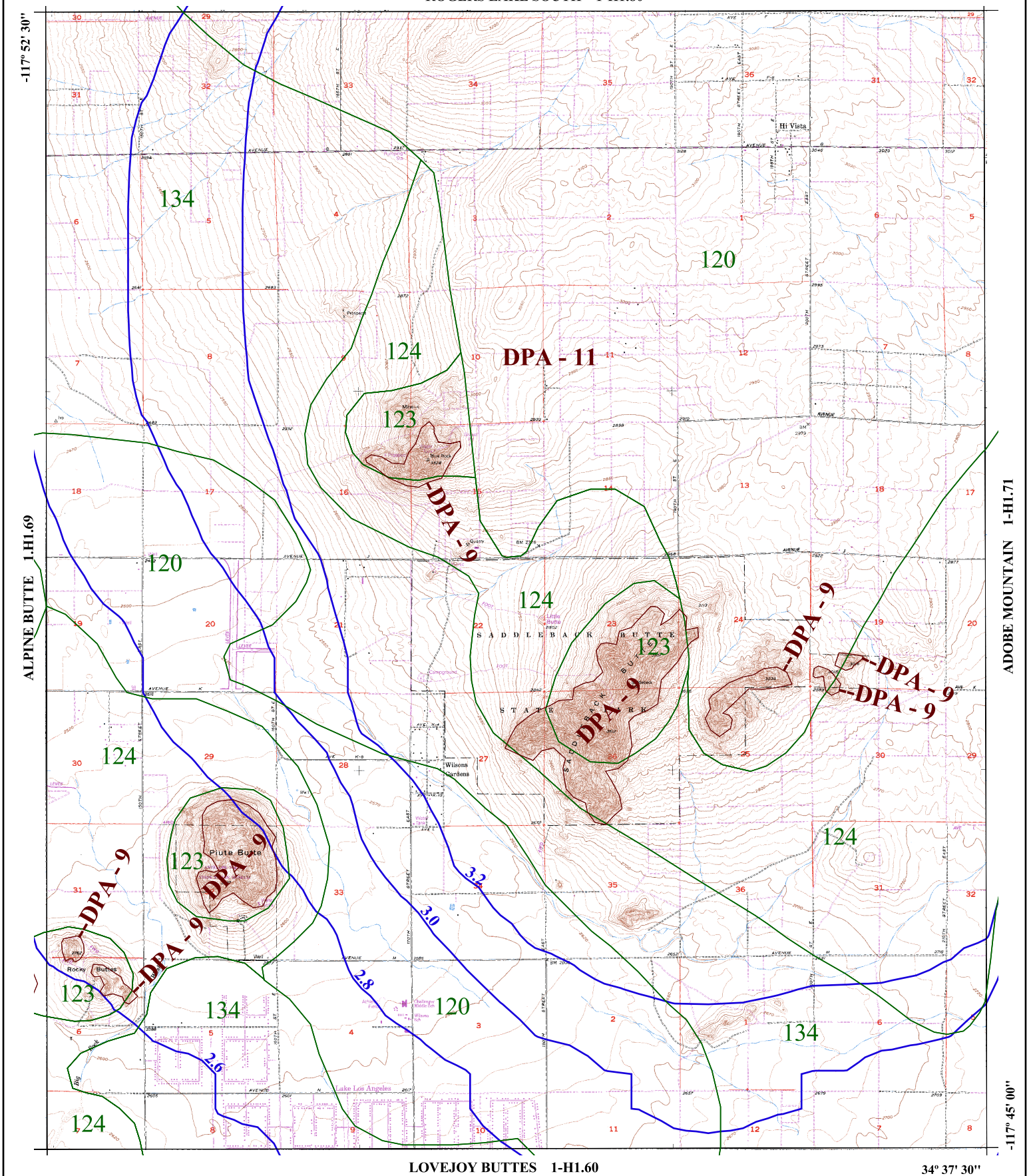
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

ALPINE BUTTE
50-YEAR 24-HOUR ISOHYET

1-H1.69

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

1 0 1 2 Miles

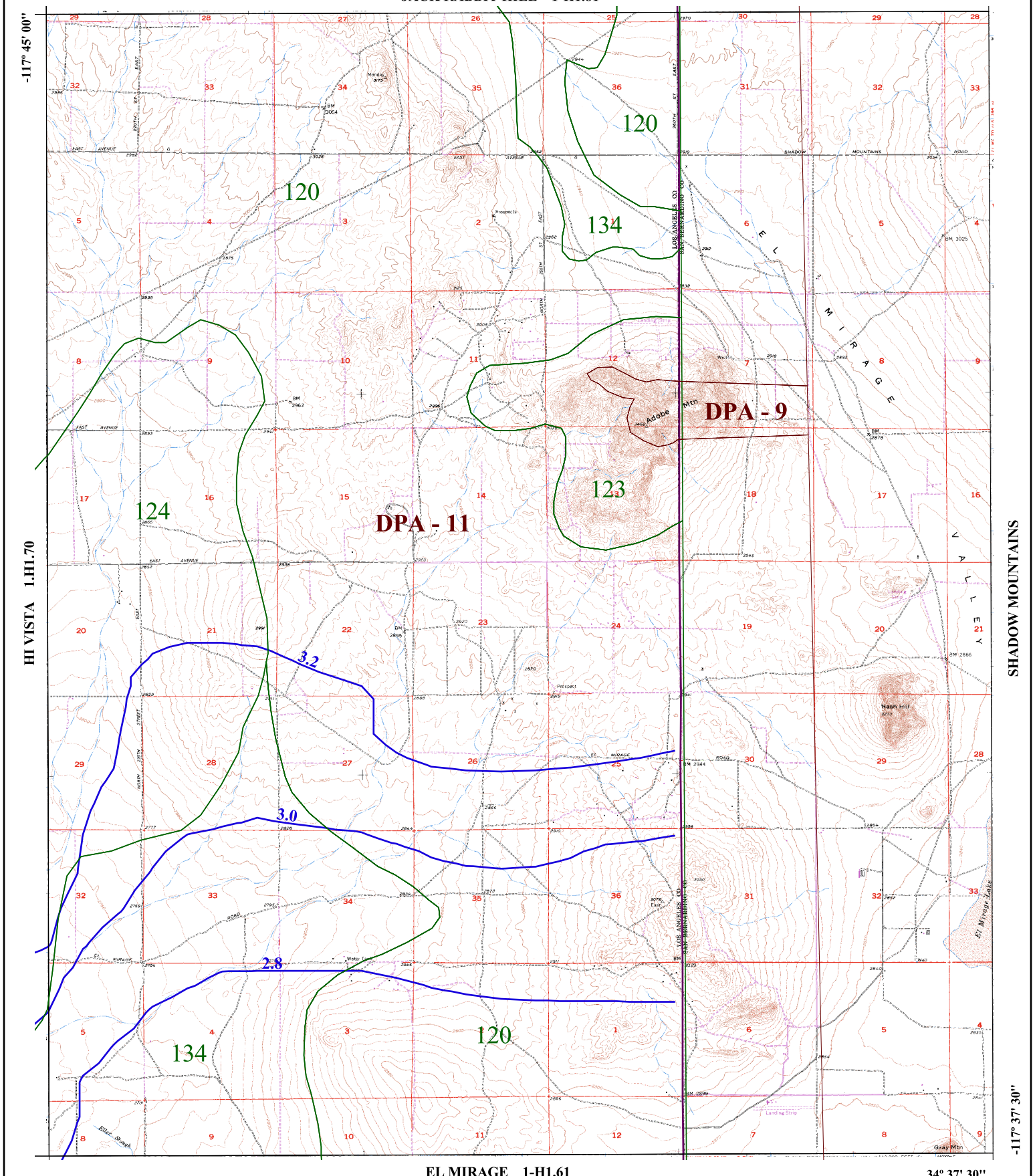
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878

10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

HI VISTA
50-YEAR 24-HOUR ISOHYET

1-H1.70

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

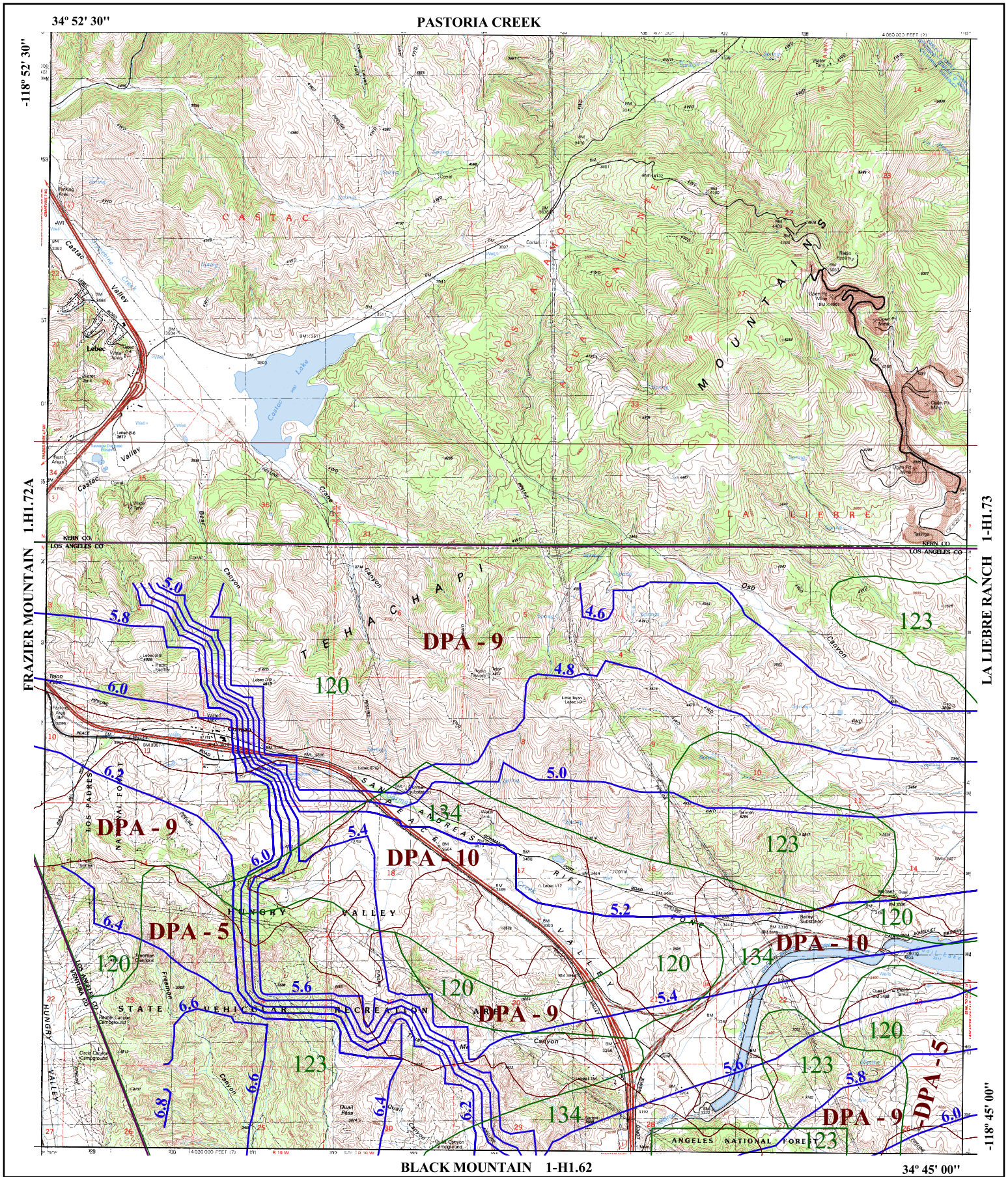
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

ADOBE MOUNTAIN
50-YEAR 24-HOUR ISOHYET

1-H1.71

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

1 0 1 2 Miles

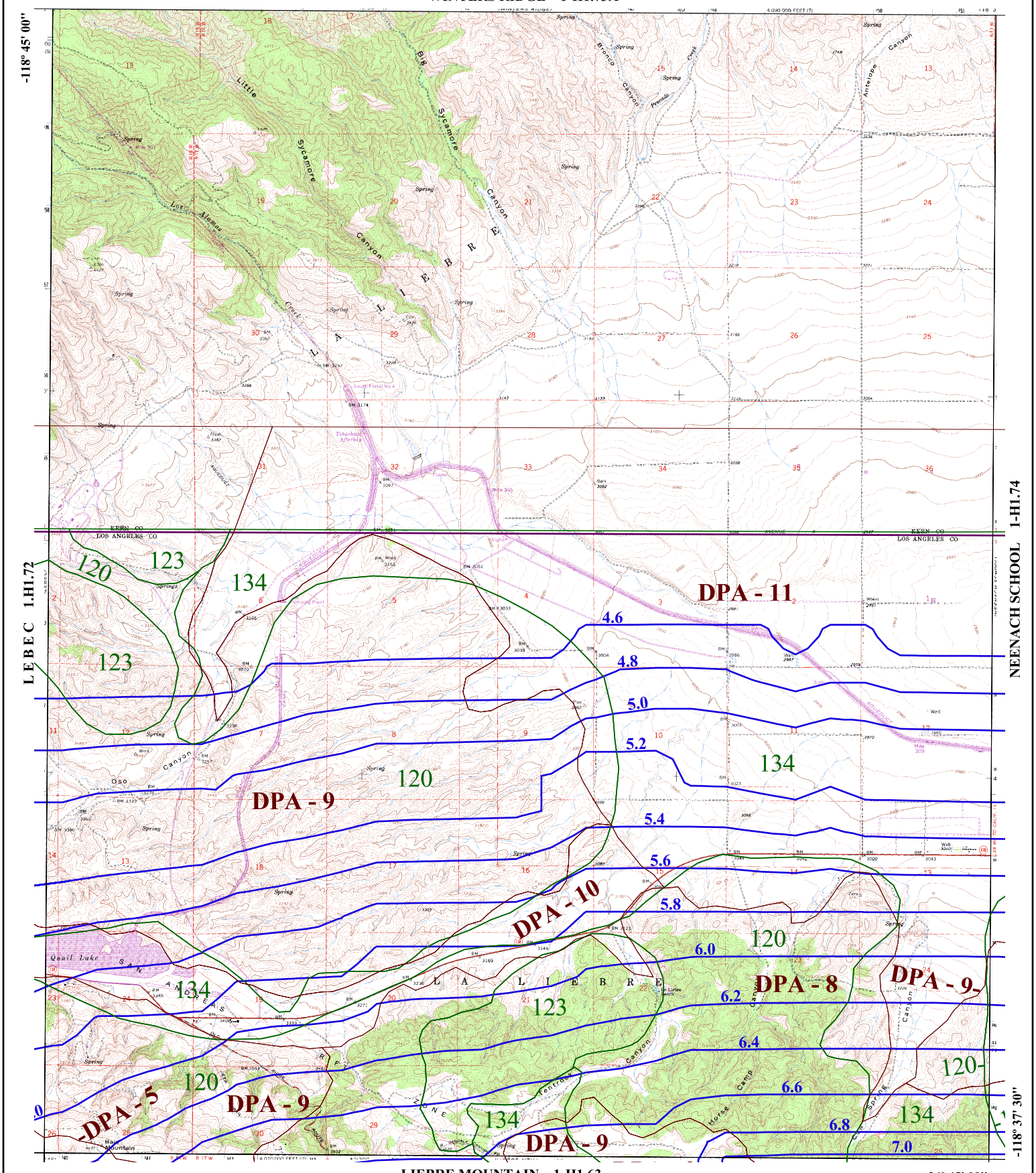
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

L E B E C

50-YEAR 24-HOUR ISOHYET

1-H1.72

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



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S

016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

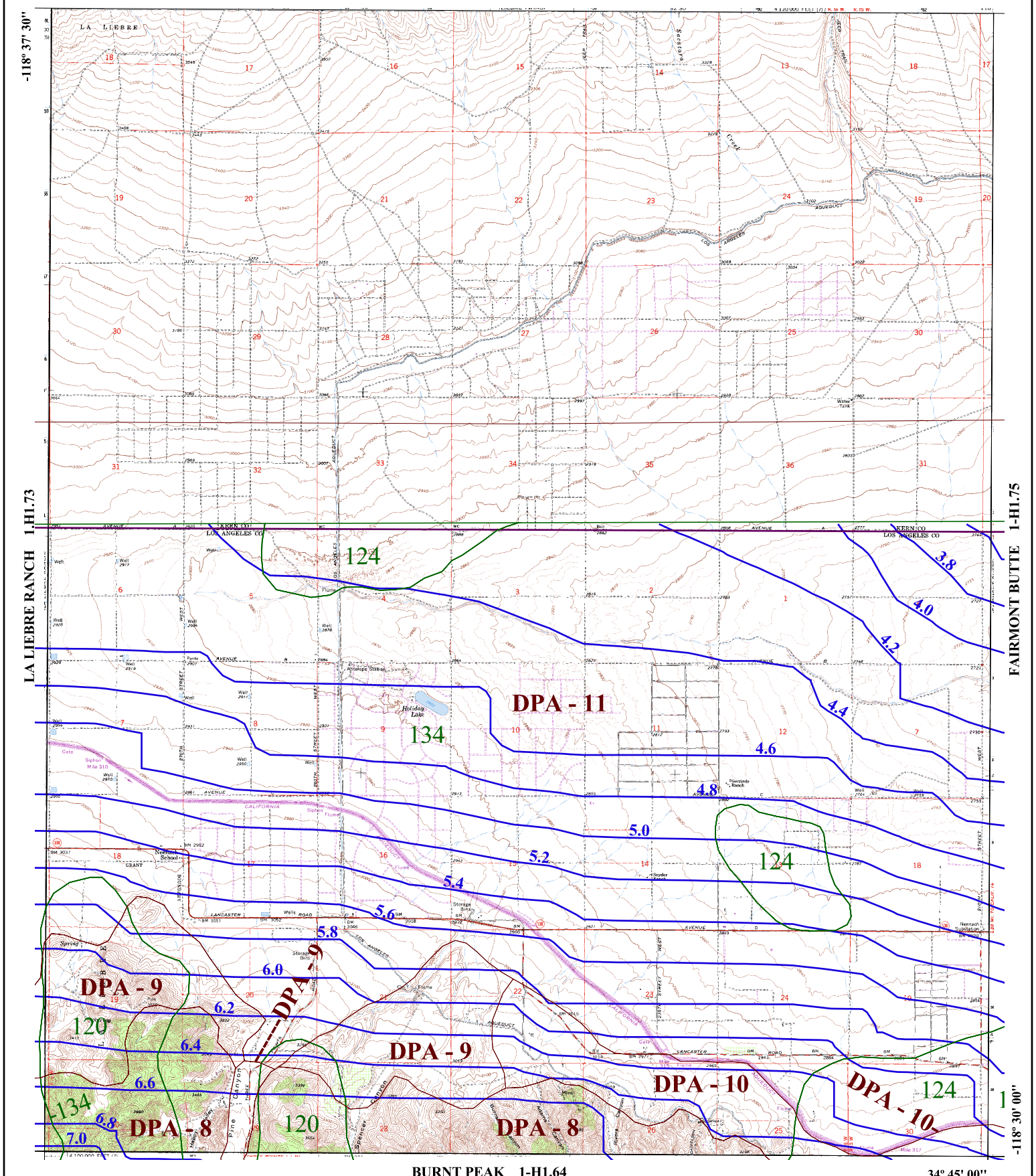
1 0 1 2 Miles

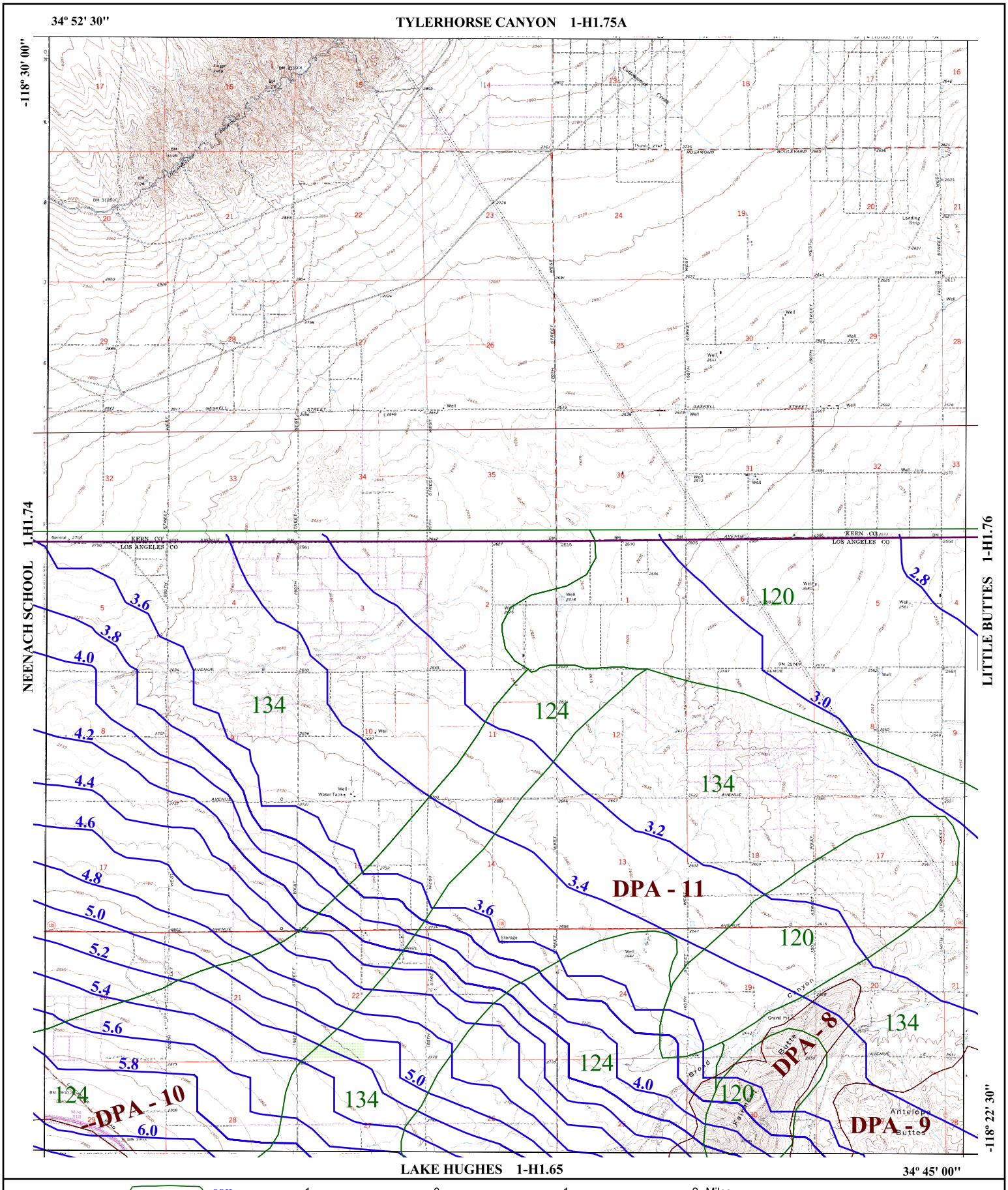
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

LA LIEBRE RANCH
50-YEAR 24-HOUR ISOHYET

1-H1.73

LOS ANGELES COUNTY PUBLIC WORKS
Public Service That Works


34° 52' 30"
LIEBRE TWINS 1-H1.74A
-118° 37' 30"
LA LIEBRE RANCH 1-H1.73
FAIRMONT BUTTE 1-H1.75
-118° 30' 00"
BURNT PEAK 1-H1.64
34° 45' 00"
DPA - 11
DPA - 9
DPA - 8
DPA - 10
124
134
120
3.8
4.0
4.2
4.4
4.6
4.8
5.0
5.2
5.4
5.6
5.8
6.0
6.2
6.4
6.6
6.8
7.0
LA LIEBRE
KERN CO
LOS ANGELES CO
AVENUE A
AVENUE B
AVENUE D
LANCASTER ROAD
Holiday Lake
Antelope Station
Neenach School
Neenach Substation
Spring
Pine Canyon
Spencer Canyon
Mine
Water Tank
Aqueduct
Flume
Siphon Mile 310
Gate
Storage Bins
Ranch
Well
Wells
Pass
Mine 317
BM 3037
BM 2962
BM 3051
BM 3054
BM 3346
BM 2018
BM 2970
BM 3022
BM 3055
BM 3065
BM 3066
BM 3067
BM 3068
BM 3069
BM 3070
BM 3071
BM 3072
BM 3073
BM 3074
BM 3075
BM 3076
BM 3077
BM 3078
BM 3079
BM 3080
BM 3081
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BM



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

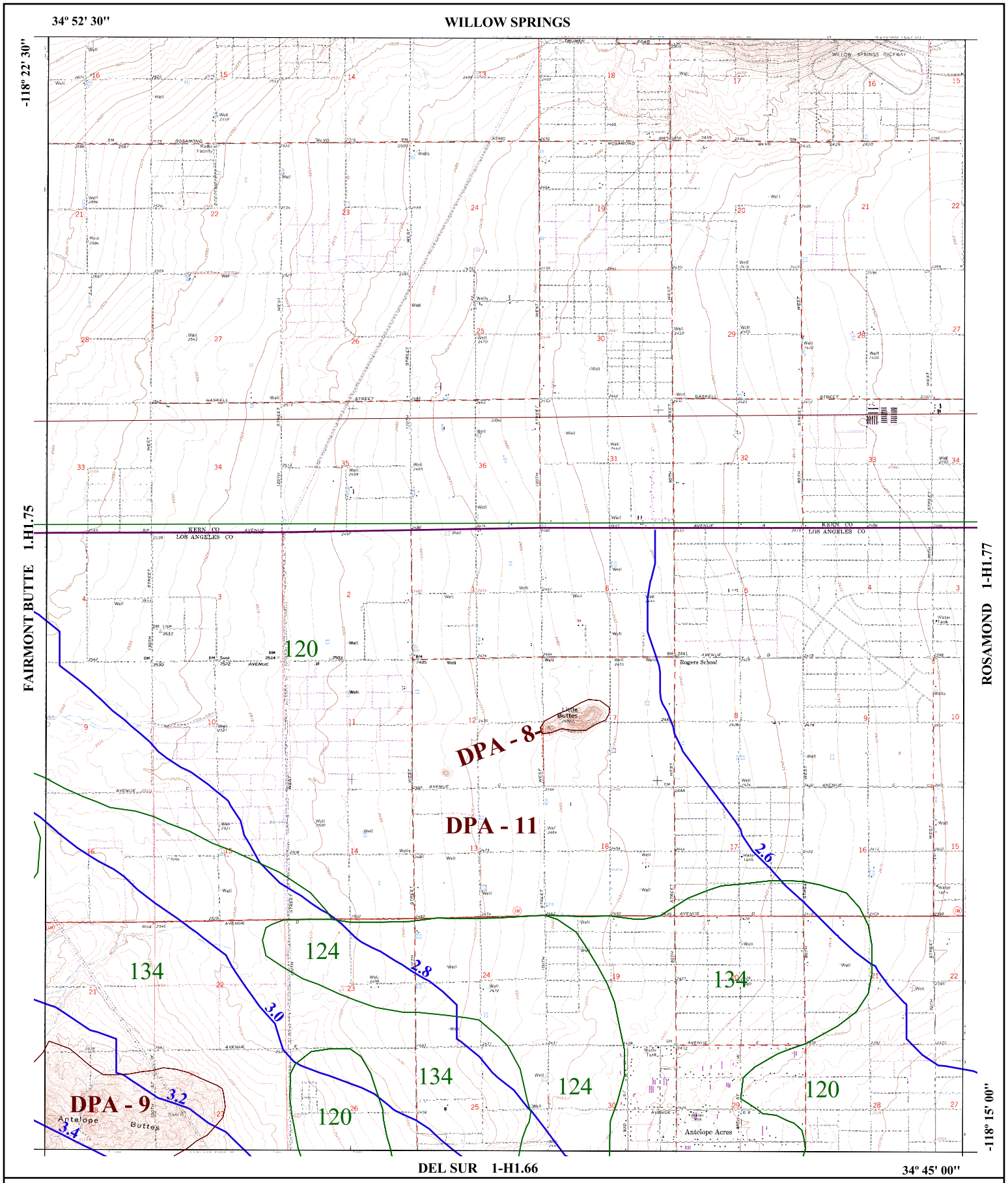
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

FAIRMONT BUTTE
50-YEAR 24-HOUR ISOHYET

1-H1.75

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



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S

016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

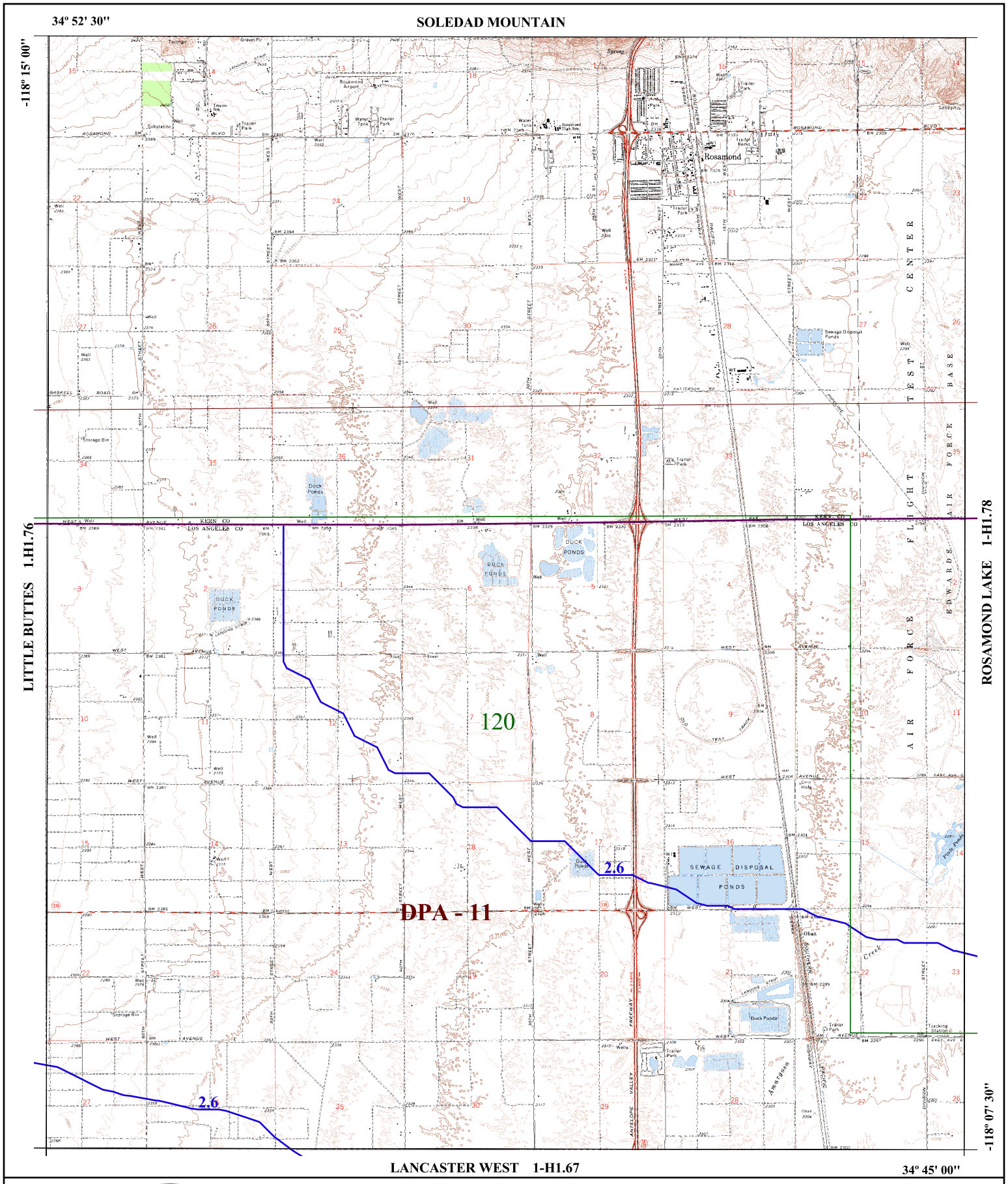
1 0 1 2 Miles

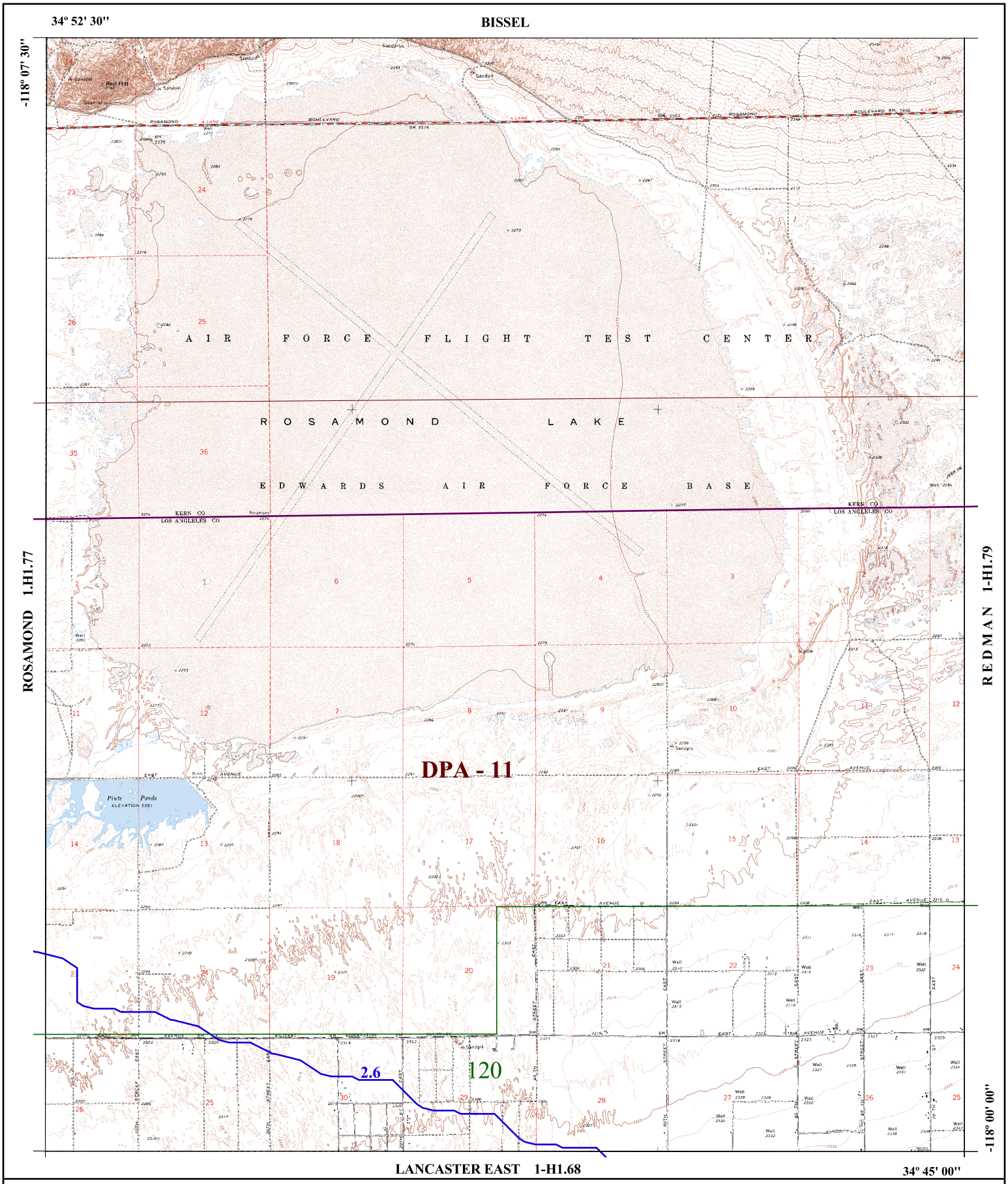
25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

LITTLE BUTTES
50-YEAR 24-HOUR ISOHYET

1-H1.76

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works


34° 52' 30"
SOLEDAD MOUNTAIN
-118° 15' 00"
LITTLE BUTTES 1.H1.76
ROSAMOND LAKE 1-H1.78
-118° 07' 30"
LANCASTER WEST 1-H1.67
34° 45' 00"
Rosamond
Rosamond Airport
Rosamond High Sch
Trailer Park
Sewage Disposal Ponds
Duck Ponds
DUCK PONDS
SEWAGE DISPOSAL PONDS
Oban
Tracking Station
Substation
Water Tanks
Gravel Pit
Tailings
Spring
Storage Bin
Trailer Parks
Sandpits
Creek
Hoss Ponds
Antelope Valley Freeway
Amargosa
GASKELL ROAD
PATTERSON RD
ROSAMOND BLVD
EAST AVE E
WEST AVENUE A
WEST AVENUE B
WEST AVENUE C
WEST AVENUE D
WEST AVENUE E
WEST AVENUE F
WEST AVENUE G
WEST AVENUE H
WEST AVENUE I
WEST AVENUE J
WEST AVENUE K
WEST AVENUE L
WEST 5TH STREET
WEST 10TH STREET
WEST 20TH STREET
WEST 30TH STREET
WEST 40TH STREET
WEST 50TH STREET
WEST 60TH STREET
WEST 70TH STREET
WEST 80TH STREET
WEST 90TH STREET
WEST 100TH STREET
WEST 110TH STREET
WEST 120TH STREET
WEST 130TH STREET
WEST



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

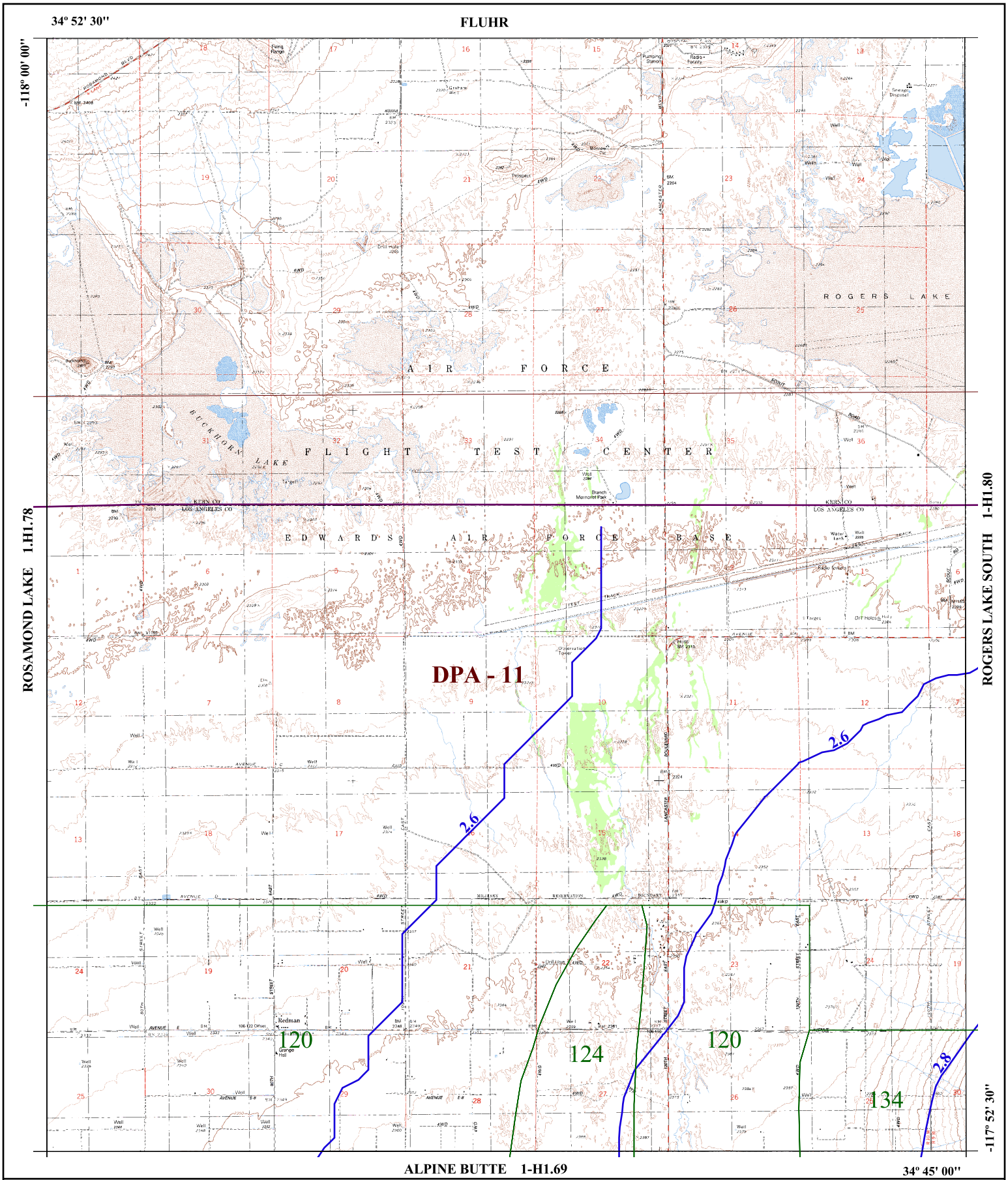
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

ROSAMOND LAKE
50-YEAR 24-HOUR ISOHYET

1-H1.78

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



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W E
S

016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

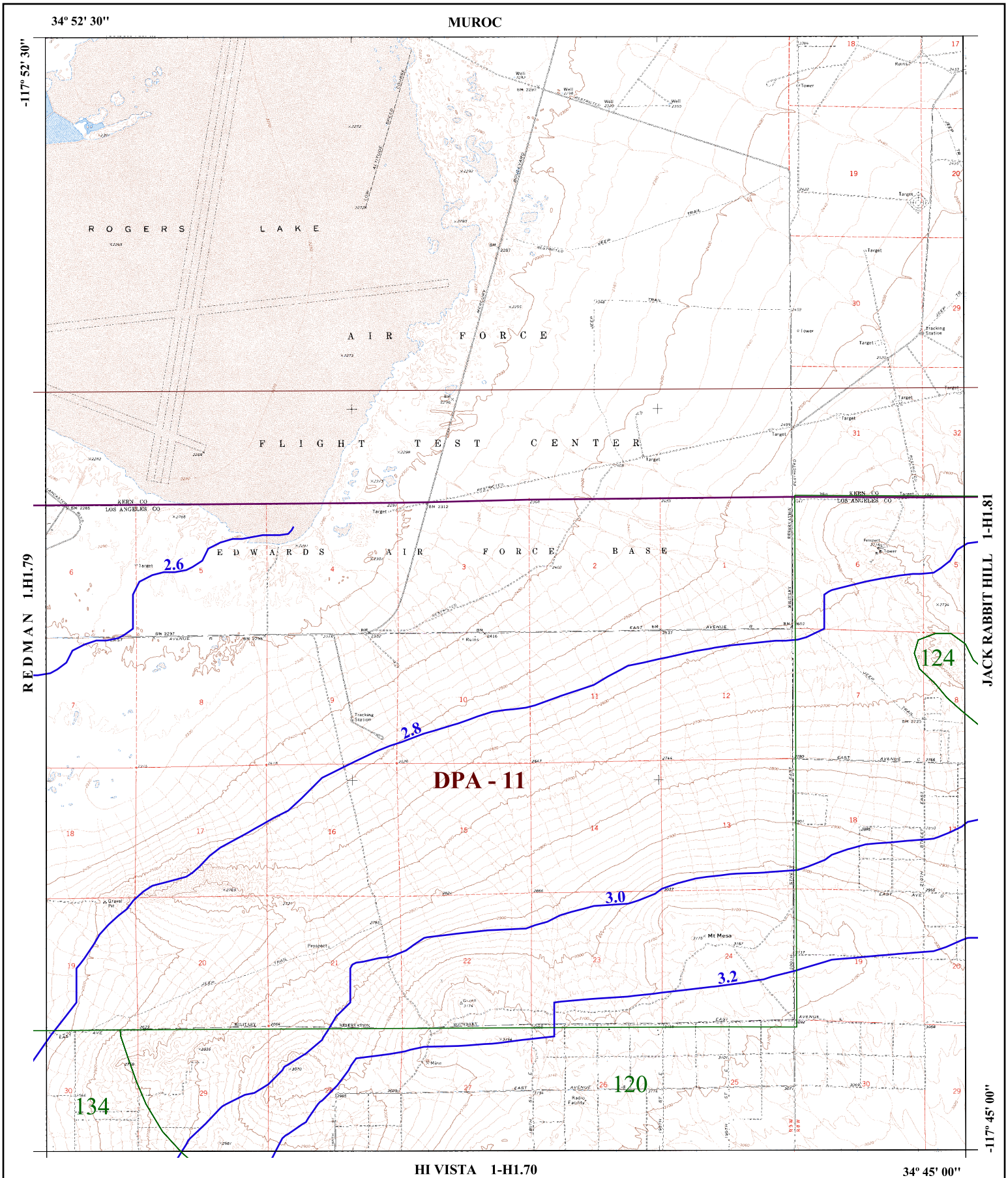
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

R E D M A N
50-YEAR 24-HOUR ISOHYET

1-H1.79

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

N W E S

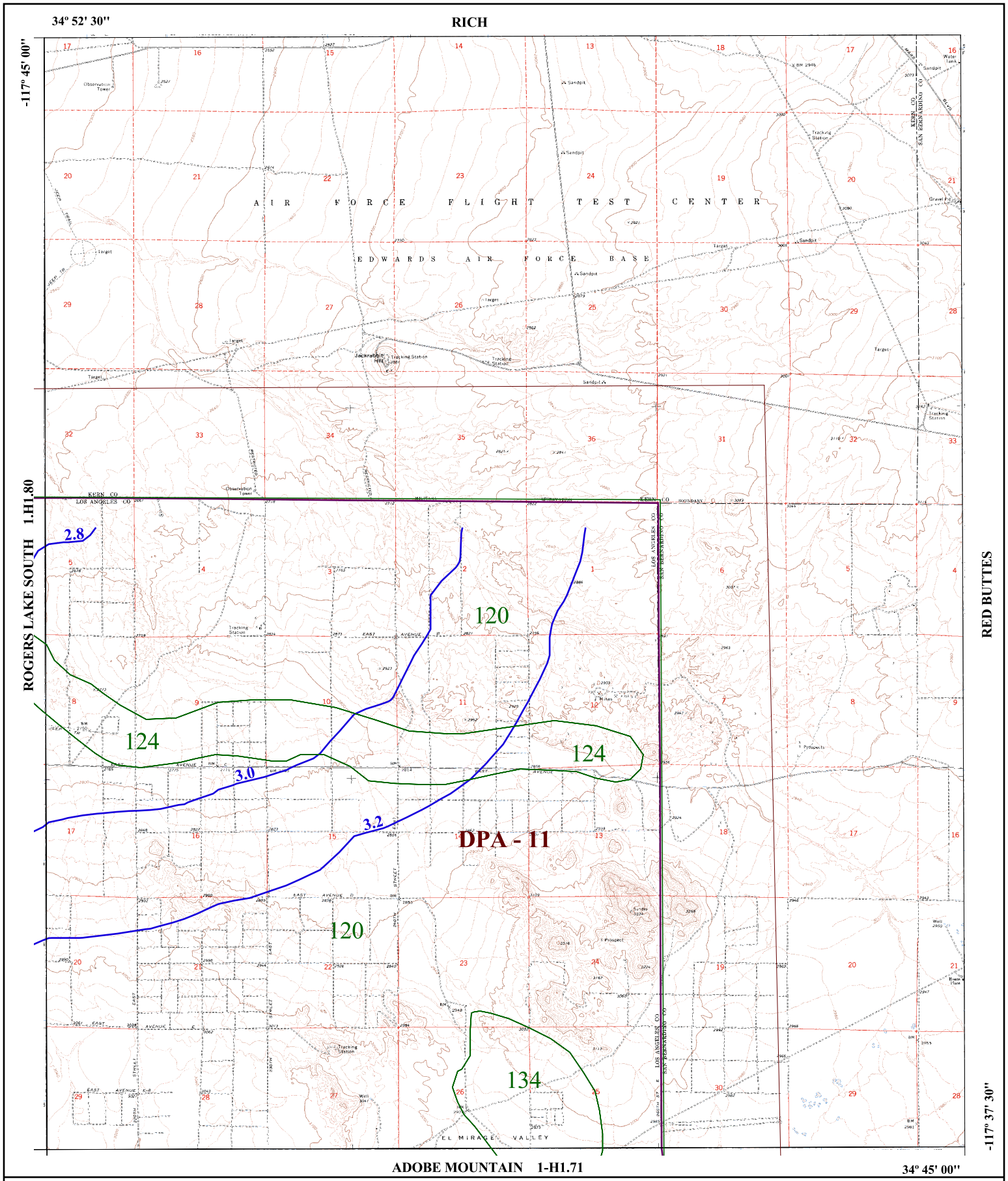
1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

ROGERS LAKE SOUTH
50-YEAR 24-HOUR ISOHYET

1-H1.80

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works



N
W E
S

016 SOIL CLASSIFICATION AREA

7.2 INCHES OF RAINFALL

DPA - 6 DEBRIS POTENTIAL AREA

1 0 1 2 Miles

25-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.878
10-YEAR 24-HOUR ISOHYET REDUCTION FACTOR: 0.714

JACK RABBIT HILL
50-YEAR 24-HOUR ISOHYET

1-H1.81

LOS ANGELES COUNTY PUBLIC WORKS Public Service That Works

APPENDIX C

Soil Type & Runoff Coefficient Data

Soil Identification Table

Number	Name	Original Name
2	ALTAMONT CLAY LOAM	A
3	CHINO SILT LOAM	CS-1
4	DIABLO CLAY LOAM	DY
5	HANFORD FINE SANDY LOAM	HF
6	HANFORD FINE SANDY LOAM	HF-1
7	HANFORD GRAVELLY SANDY LOAM	HG
8	HANFORD SILT LOAM	HN
9	MONTEZUMA CLAY ADOBE	M
10	OAKLEY FINE SAND	OS
11	PLACENTIA LOAM	PL
12	RAMONA CLAY LOAM	RC- 1
13	RAMONA LOAM	RO
14	RAMONA SANDY LOAM	RS
15	TUJUNGA FINE SANDY LOAM	TF
16	YOLO LOAM	Y
17	YOLO CLAY LOAM	YC
18	YOLO FINE SANDY LOAM	YF
19	YOLO GRAVELLY SANDY LOAM	YG
20	YOLO SANDY LOAM	YS
21	SANTA MONICA MOUNTAINS	SMM-1
22	SANTA MONICA MOUNTAINS	SMM-2
23	SANTA MONICA MOUNTAINS	SMM-3
24	SANTA MONICA MOUNTAINS	SMM-4
25	SANTA MONICA MOUNTAINS	SMM-5
26	SANTA MONICA MOUNTAINS	SMM-6
27	SANTA MONICA MOUNTAINS	SMM-7
28	SANTA MONICA MOUNTAINS	SMM-8
29	SANTA MONICA MOUNTAINS	SMM-9
30	SANTA MONICA MOUNTAINS	SMM-10
31	SANTA MONICA MOUNTAINS	SMM- 11
32	SANTA MONICA MOUNTAINS	SMM-12
33	SANTA MONICA MOUNTAINS	SMM-13
34	SANTA MONICA MOUNTAINS	SMM-14
35	SANTA MONICA MOUNTAINS	SMM-15
36	SANTA MONICA MOUNTAINS	SMM-16
37	SANTA MONICA MOUNTAINS	SMM- 17
38	SANTA MONICA MOUNTAINS	SMM- 18

Number	Name	Original Name
39	SANTA MONICA MOUNTAINS	SMM-19
40	SANTA MONICA MOUNTAINS	SMM-20
41	SANTA MONICA MOUNTAINS	SMM-21
42	SANTA MONICA MOUNTAINS	SMM-22
43	SANTA MONICA MOUNTAINS	SMM- 23
44	SANTA MONICA MOUNTAINS	SMM-24
45	SANTA MONICA MOUNTAINS	SMM-25
46	UPPER LOS ANGELES RIVER	ULAR-1
47	UPPER LOS ANGELES RIVER	ULAR-3
48	UPPER LOS ANGELES RIVER	ULAR-5
49	UPPER LOS ANGELES RIVER	ULAR-6AB
50	UPPER LOS ANGELES RIVER	ULAR-6 CD
51	UPPER LOS ANGELES RIVER	ULAR-6EF
52	UPPER LOS ANGELES RIVER	ULAR-7A
53	UPPER LOS ANGELES RIVER	ULAR-7B
54	UPPER LOS ANGELES RIVER	ULAR-7CD
55	UPPER LOS ANGELES RIVER	ULAR-8
56	UPPER LOS ANGELES RIVER	ULAR-9A
57	UPPER LOS ANGELES RIVER	ULAR-9B
58	UPPER LOS ANGELES RIVER	ULAR-9C
59	UPPER LOS ANGELES RIVER	ULAR-9D
60	UPPER LOS ANGELES RIVER	ULAR-9E
61	UPPER LOS ANGELES RIVER	ULAR-1OA
62	UPPER LOS ANGELES RIVER	ULAR-1OB
63	UPPER LOS ANGELES RIVER	ULAR-11
64	UPPER LOS ANGELES RIVER	ULAR-12
65	UPPER LOS ANGELES RIVER	ULAR-13
66	UPPER LOS ANGELES RIVER	ULAR-14
67	UPPER LOS ANGELES RIVER	ULAR-15
68	UPPER LOS ANGELES RIVER	ULAR-16
69	UPPER LOS ANGELES RIVER	ULAR-17
70	UPPER LOS ANGELES RIVER	ULAR-18
71	UPPER LOS ANGELES RIVER	ULAR-19
72	UPPER LOS ANGELES RIVER	ULAR-20A
73	UPPER LOS ANGELES RIVER	ULAR-20B
74	UPPER LOS ANGELES RIVER	ULAR-21
75	UPPER LOS ANGELES RIVER	ULAR-22
76	UPPER LOS ANGELES RIVER	ULAR-23A

Number	Name	Original Name
77	UPPER LOS ANGELES RIVER	ULAR-23B
78	UPPER SAN GABRIEL RIVER	USGR-B
79	UPPER SAN GABRIEL RIVER	USGR-D
80	UPPER SAN GABRIEL RIVER	USGR-F
81	UPPER SAN GABRIEL RIVER	USGR-G-1
82	UPPER SAN GABRIEL RIVER	USGR-G-2
83	UPPER SAN GABRIEL RIVER	USGR-H
84	UPPER SAN GABRIEL RIVER	USGR-0
85	UPPER SAN GABRIEL RIVER	USGR-S
86	UPPER SAN GABRIEL RIVER	USGR-T
87	UPPER SAN GABRIEL RIVER	USGR-U
88	UPPER SAN GABRIEL RIVER	USGR-V
89	UPPER SAN GABRIEL RIVER	USGR-X
90	UPPER SAN GABRIEL RIVER	USGR-Y
91	SANTA CLARA RIVER	SCR-1-1
92	SANTA CLARA RIVER	SCR-1-2
93	SANTA CLARA RIVER	SCR-2
94	SANTA CLARA RIVER	SCR-2-1
95	SANTA CLARA RIVER	SCR-4
96	SANTA CLARA RIVER	SCR-4-1
97	SANTA CLARA RIVER	SCR-5
98	SANTA CLARA RIVER	SCR-6
99	SANTA CLARA RIVER	SCR-7
100	SANTA CLARA RIVER	SCR-8-1
101	SANTA CLARA RIVER	SCR-8-2
102	SANTA CLARA RIVER	SCR-8-3
103	SANTA CLARA RIVER	SCR-8-4
104	SANTA CLARA RIVER	SCR-8-5
105	SANTA CLARA RIVER	SCR-8-6
106	SANTA CLARA RIVER	SCR-8-7
107	SANTA CLARA RIVER	SCR-9
108	SANTA CLARA RIVER	SCR-9-1
109	SANTA CLARA RIVER	SCR-10
110	SANTA CLARA RIVER	SCR-C3211
111	SANTA CLARA RIVER	SCR-12
112	ANTELOPE VALLEY	AV-1
113	ANTELOPE VALLEY	AV-2
114	ANTELOPE VALLEY	AV-3

Number	Name	Original Name
115	ANTELOPE VALLEY	AV-4
116	ANTELOPE VALLEY	AV-5
117	ANTELOPE VALLEY	AV-6
118	ANTELOPE VALLEY	AV-7
119	ANTELOPE VALLEY	AV-8
120	ANTELOPE VALLEY	AV-9
121	ANTELOPE VALLEY	AV-10
122	ANTELOPE VALLEY	AV-12
123	ANTELOPE VALLEY	AV-12
124	ANTELOPE VALLEY	AV-13
125	ANTELOPE VALLEY	AV-14
126	ANTELOPE VALLEY	AV-15
127	ANTELOPE VALLEY	AV-16
128	ANTELOPE VALLEY	AV-17
129	ANTELOPE VALLEY	AV-18
130	ANTELOPE VALLEY	AV-19
131	ANTELOPE VALLEY	AV-20
132	ANTELOPE VALLEY	AV-21
133	ANTELOPE VALLEY	AV-22
134	ANTELOPE VALLEY	AV-23
135	LITTLE ROCK CREEK	LR-1
136	LITTLE ROCK CREEK	LR-2
137	LITTLE ROCK CREEK	LR-3-7
138	LITTLE ROCK CREEK	LR-4
139	LITTLE ROCK CREEK	LR-5
140	LITTLE ROCK CREEK	LR-6
141	LITTLE ROCK CREEK	LR-8-9
142	LITTLE ROCK CREEK	LR-10
143	LITTLE ROCK CREEK	LR-11
144	LITTLE ROCK CREEK	LR-12
145	LITTLE ROCK CREEK	LR-13
146	LITTLE ROCK CREEK	LR-14
147	LITTLE ROCK CREEK	LR-15
148	LITTLE ROCK CREEK	LR-16
149	LITTLE ROCK CREEK	LR-17
150	LITTLE ROCK CREEK	LR-18
151	LITTLE ROCK CREEK	LR-19
152	LITTLE ROCK CREEK	LR-20

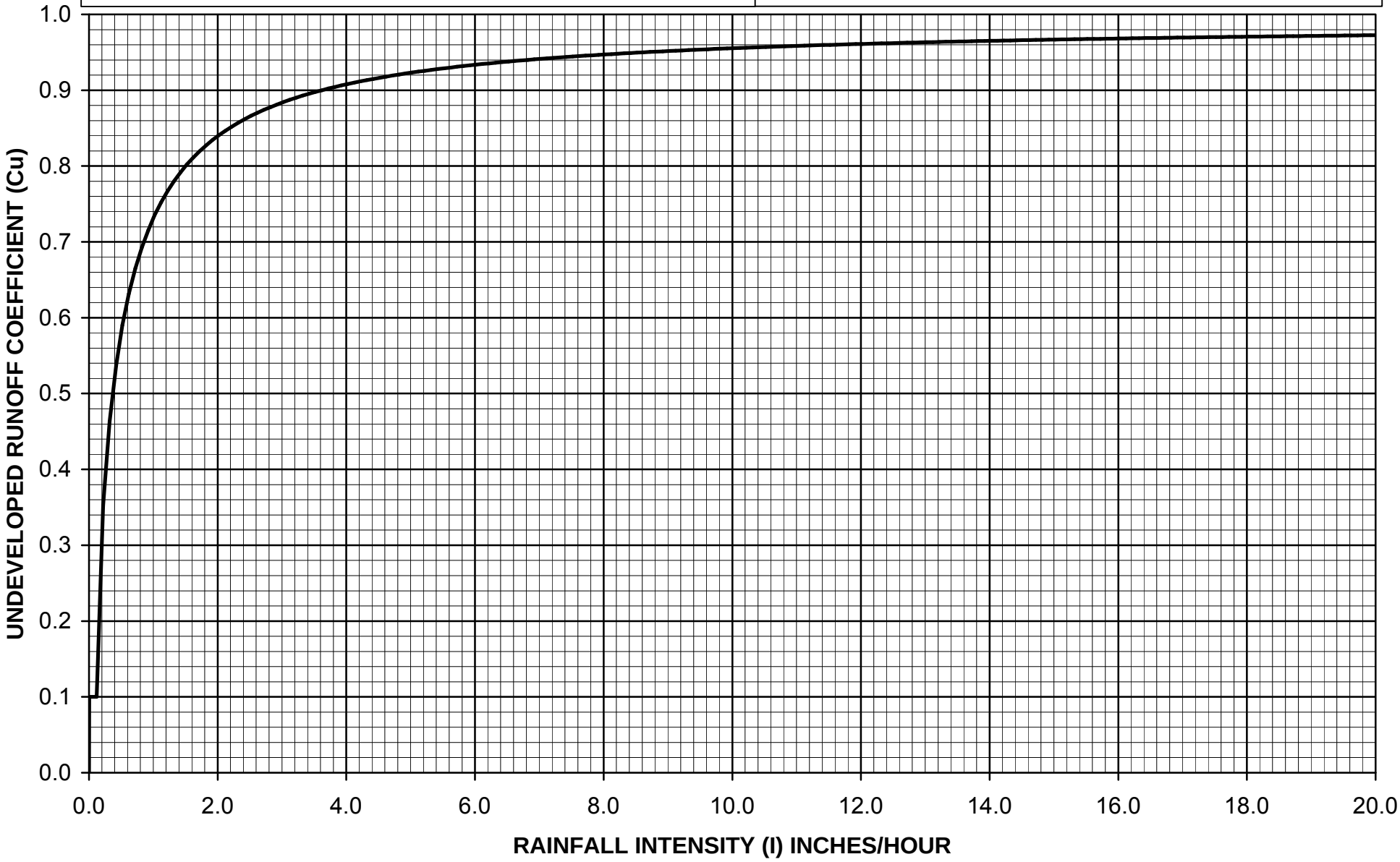
Number	Name	Original Name
153	UPPER SAN GABRIEL RIVER	USGR-A
154	UPPER SAN GABRIEL RIVER	USGR-C
155	UPPER SAN GABRIEL RIVER	USGR-E
156	UPPER SAN GABRIEL RIVER	USGR-I
157	UPPER SAN GABRIEL RIVER	USGR-J
158	UPPER SAN GABRIEL RIVER	USGR-K
159	UPPER SAN GABRIEL RIVER	USGR-L-1
160	UPPER SAN GABRIEL RIVER	USGR-L-2
161	UPPER SAN GABRIEL RIVER	USGR-M
162	UPPER SAN GABRIEL RIVER	USGR-N
163	UPPER SAN GABRIEL RIVER	USGR-P
164	UPPER SAN GABRIEL RIVER	USGR-Q-1
165	UPPER SAN GABRIEL RIVER	USGR-Q-2
166	UPPER SAN GABRIEL RIVER	USGR-R
167	UPPER SAN GABRIEL RIVER	USGR-W
168	UPPER LOS ANGELES RIVER	ULAR-2A
169	UPPER LOS ANGELES RIVER	ULAR-2B
170	UPPER LOS ANGELES RIVER	ULAR-2C
171	UPPER LOS ANGELES RIVER	ULAR-2D
172	UPPER LOS ANGELES RIVER	ULAR-4

$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 002

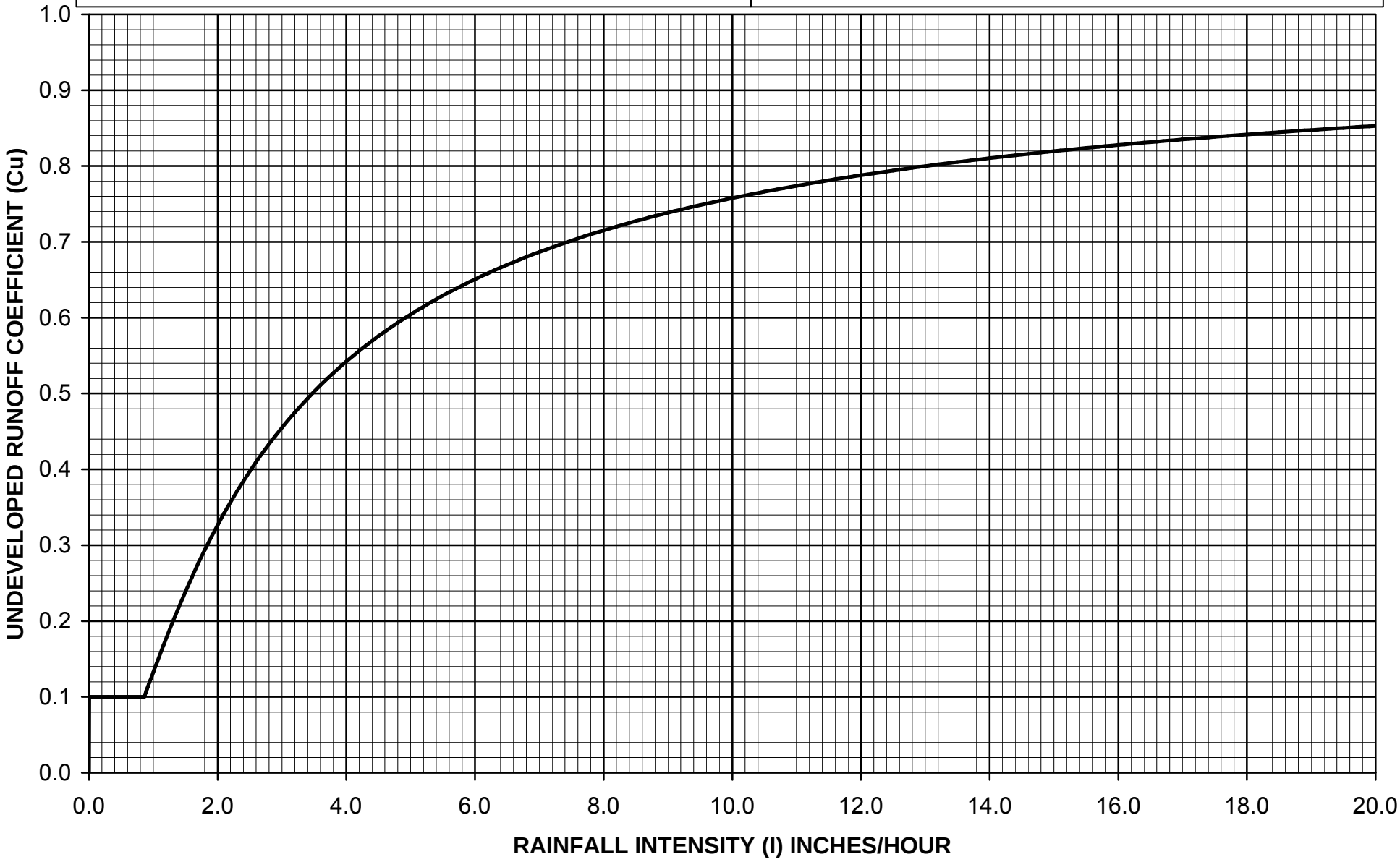


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 003

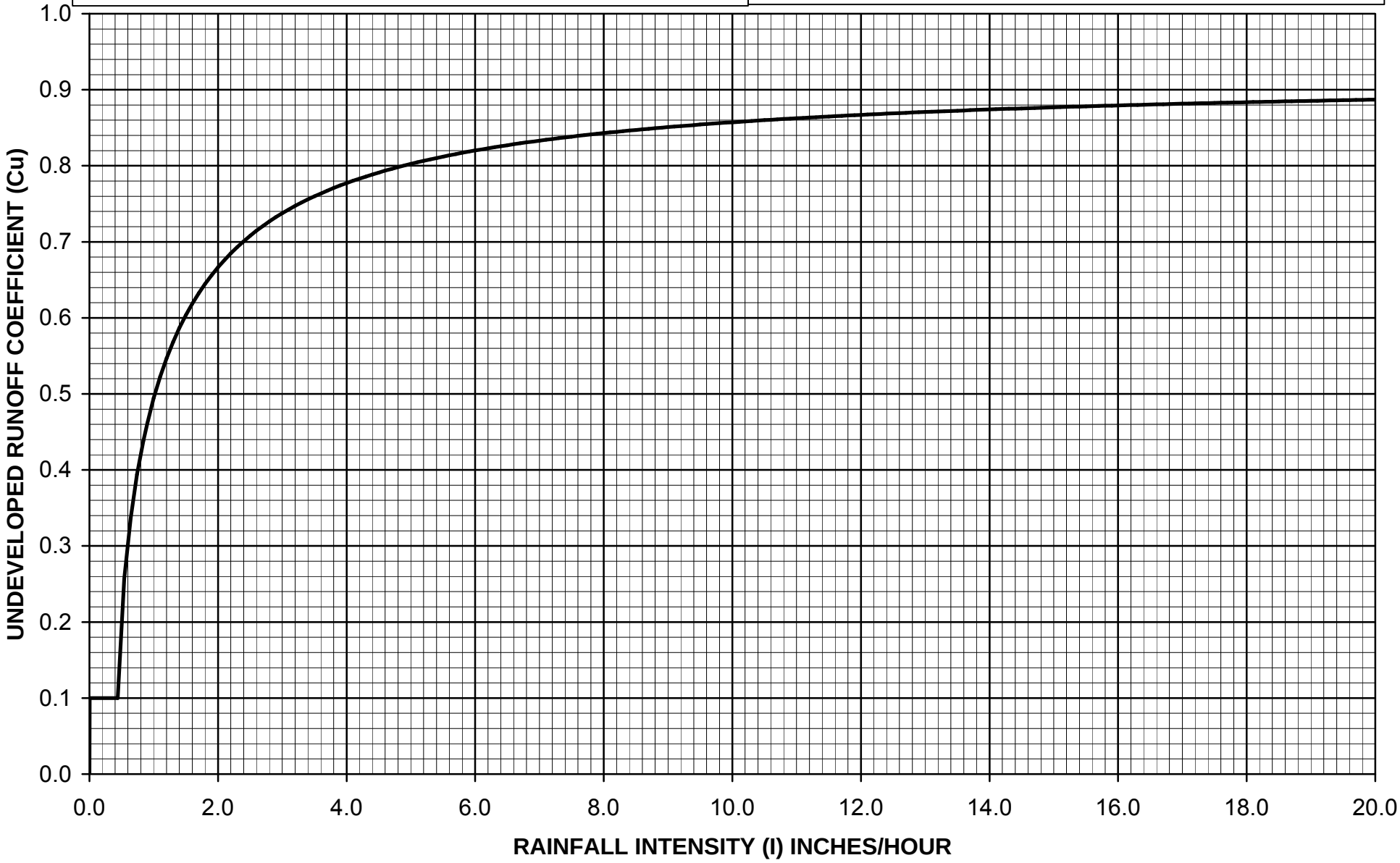


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 004

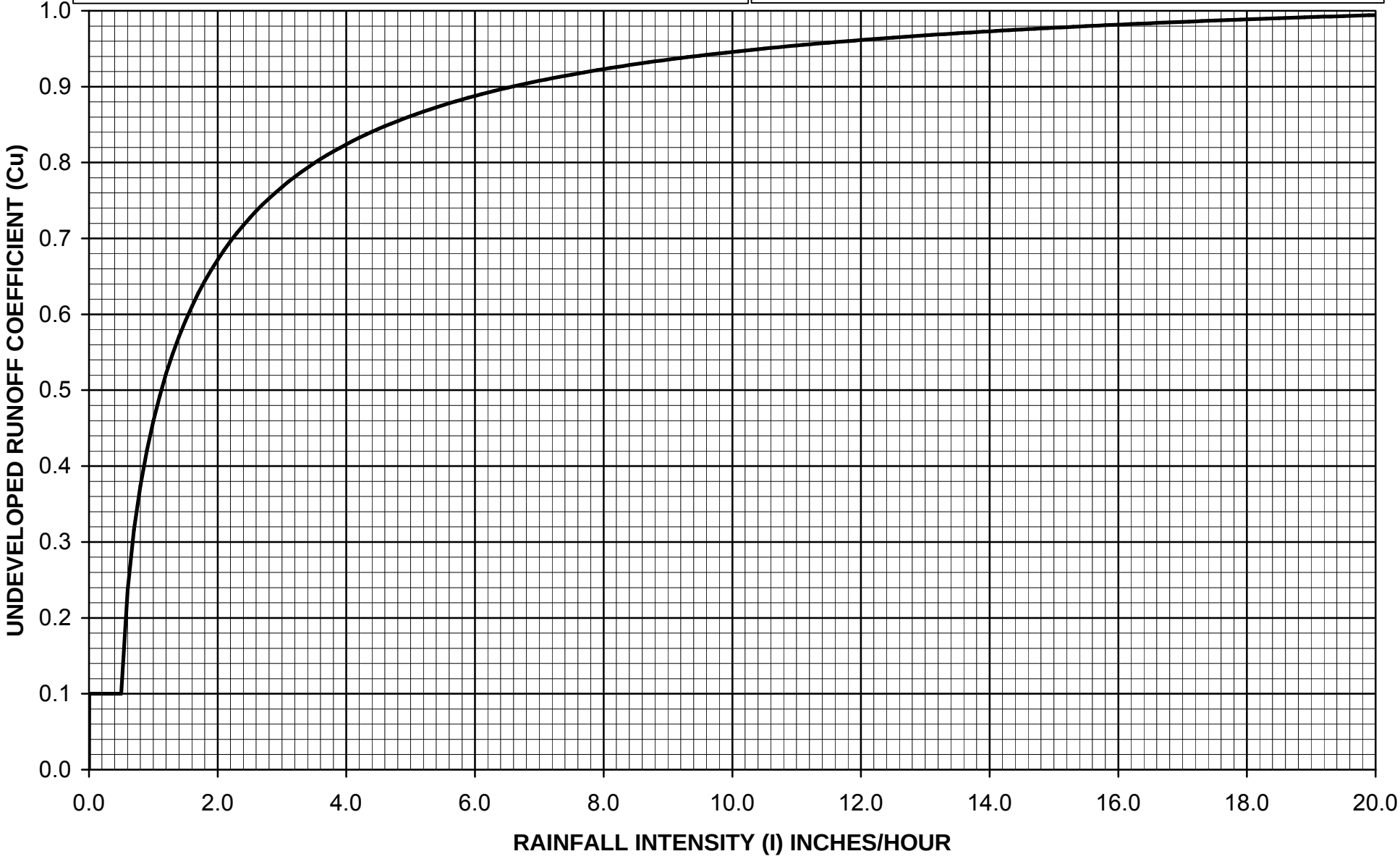


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 005

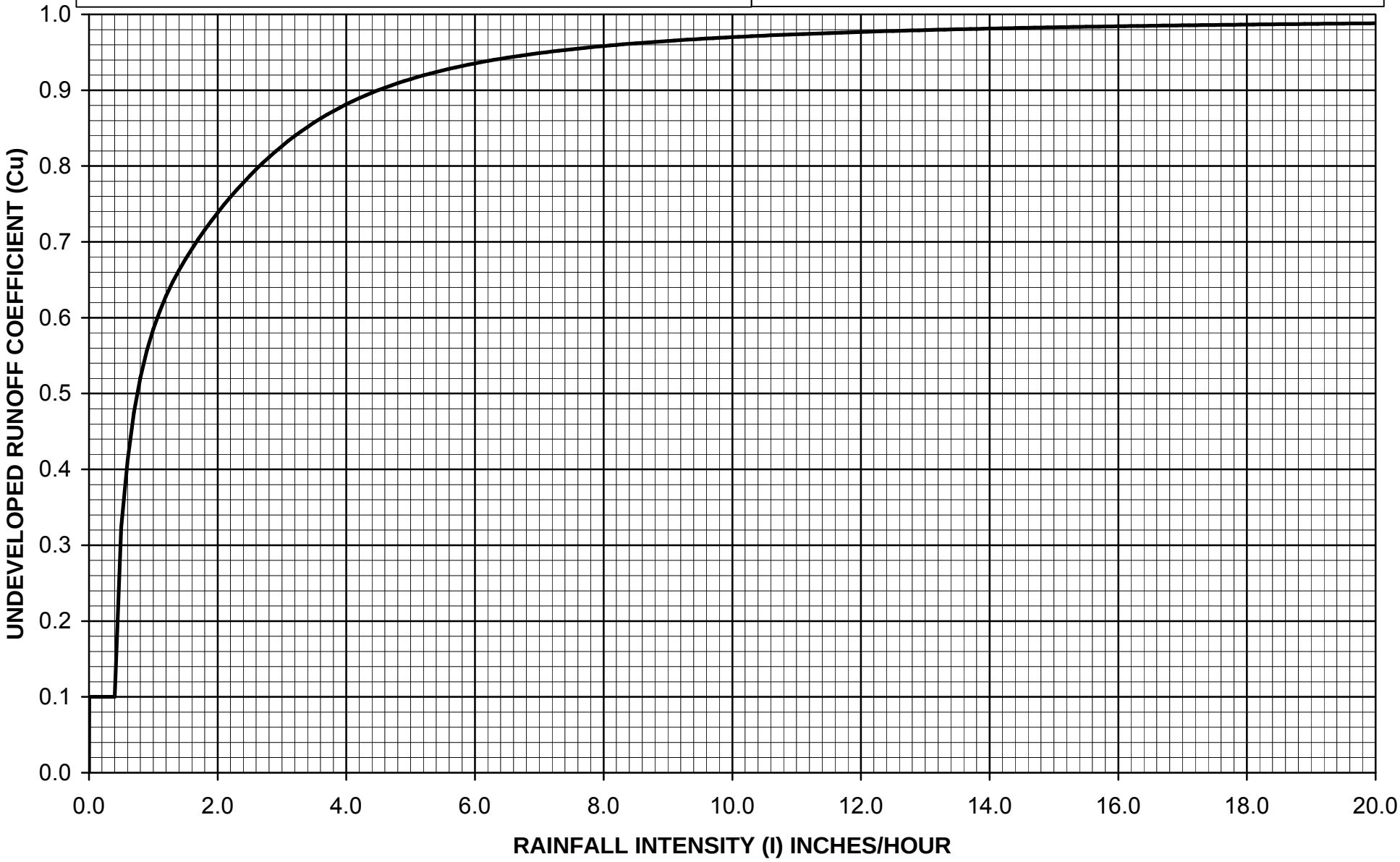


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 006

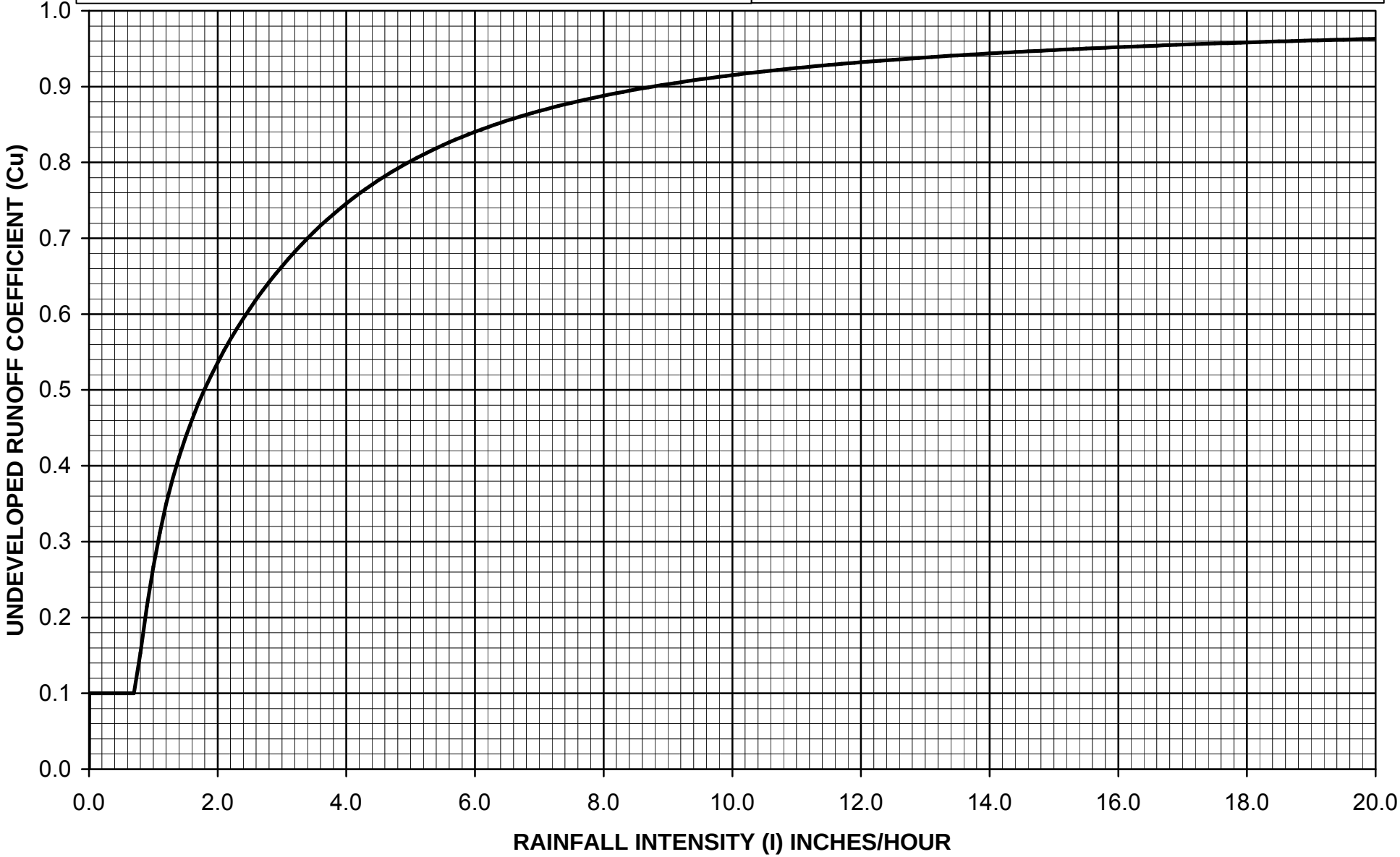


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 007

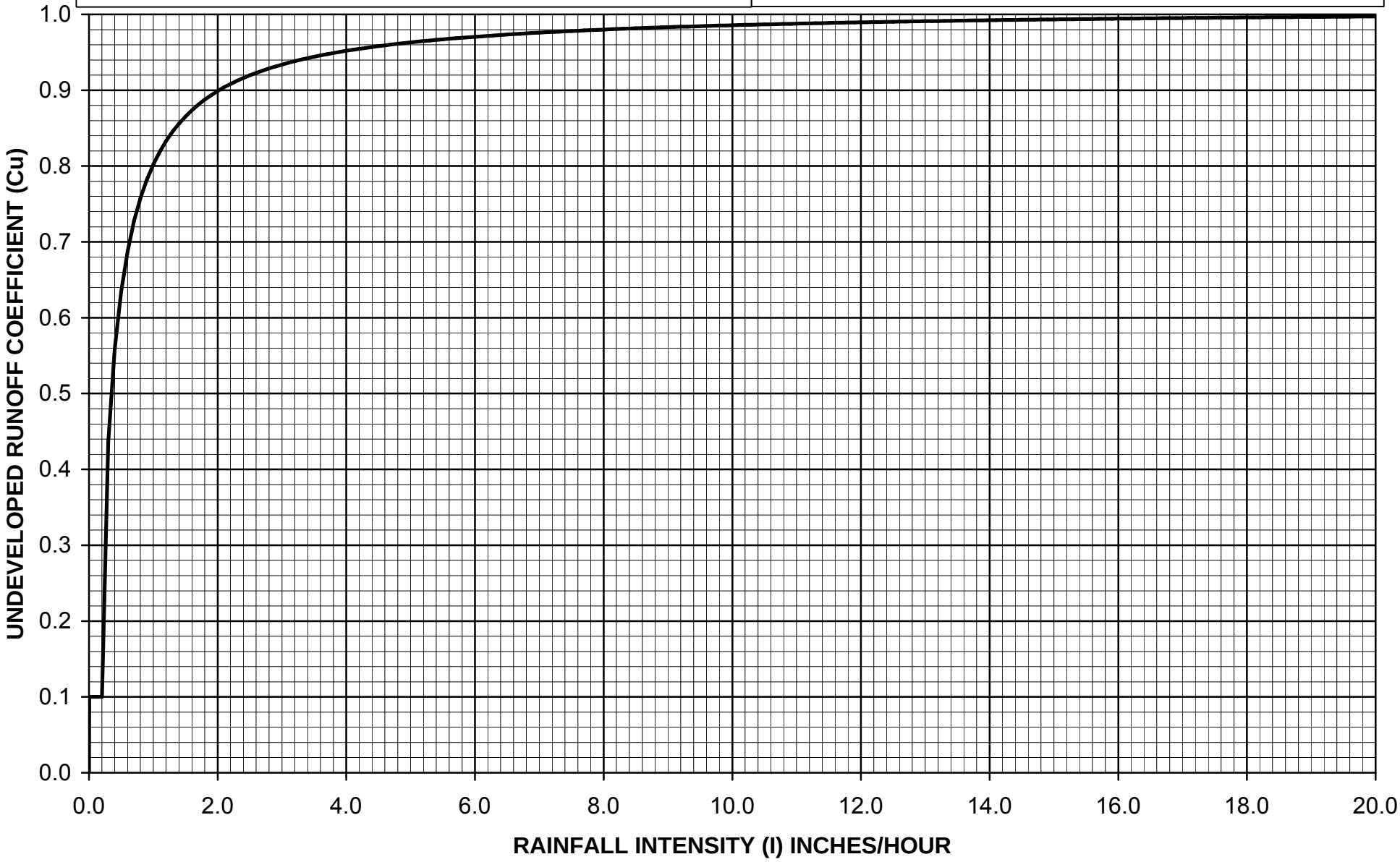


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 008

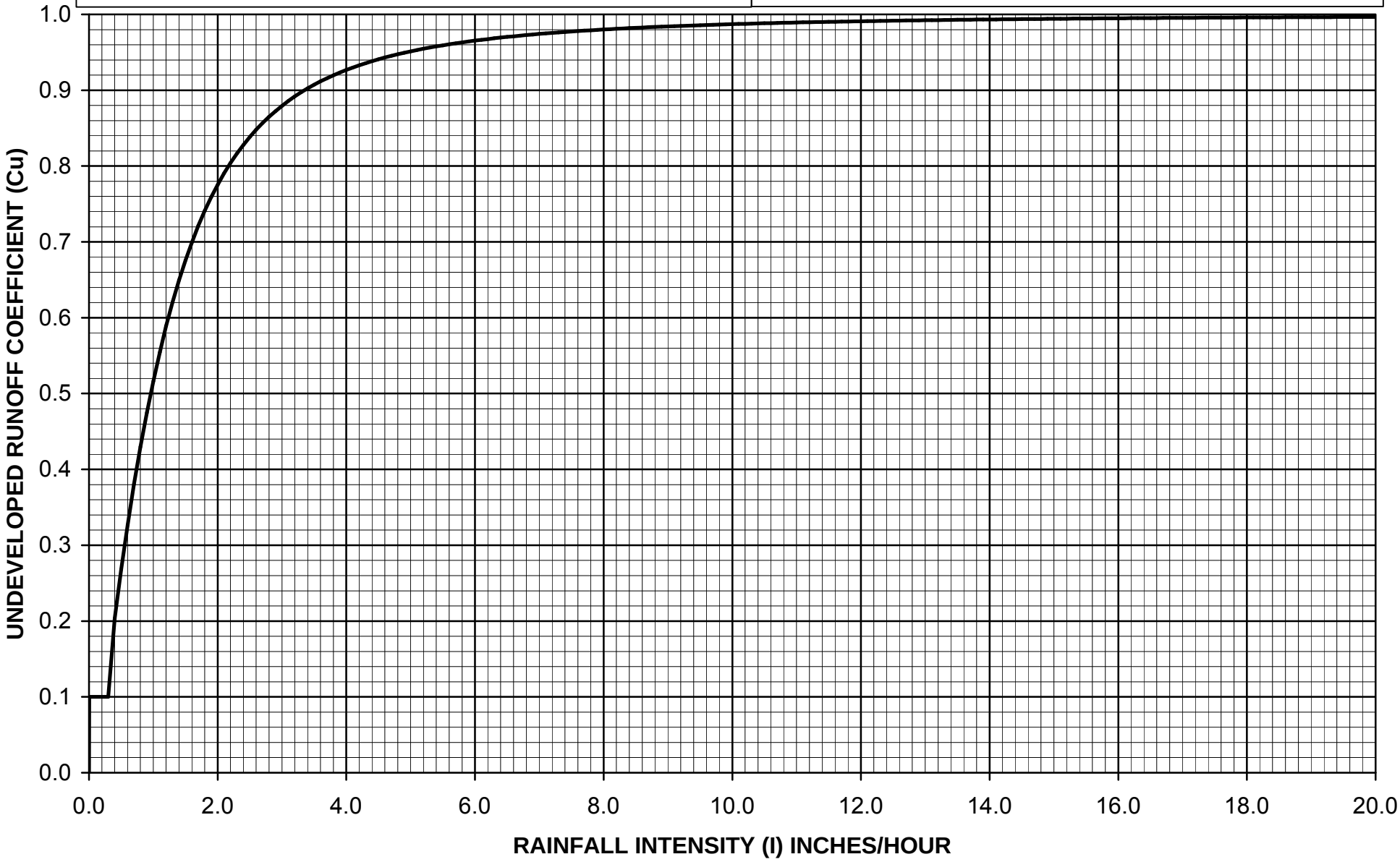


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 009

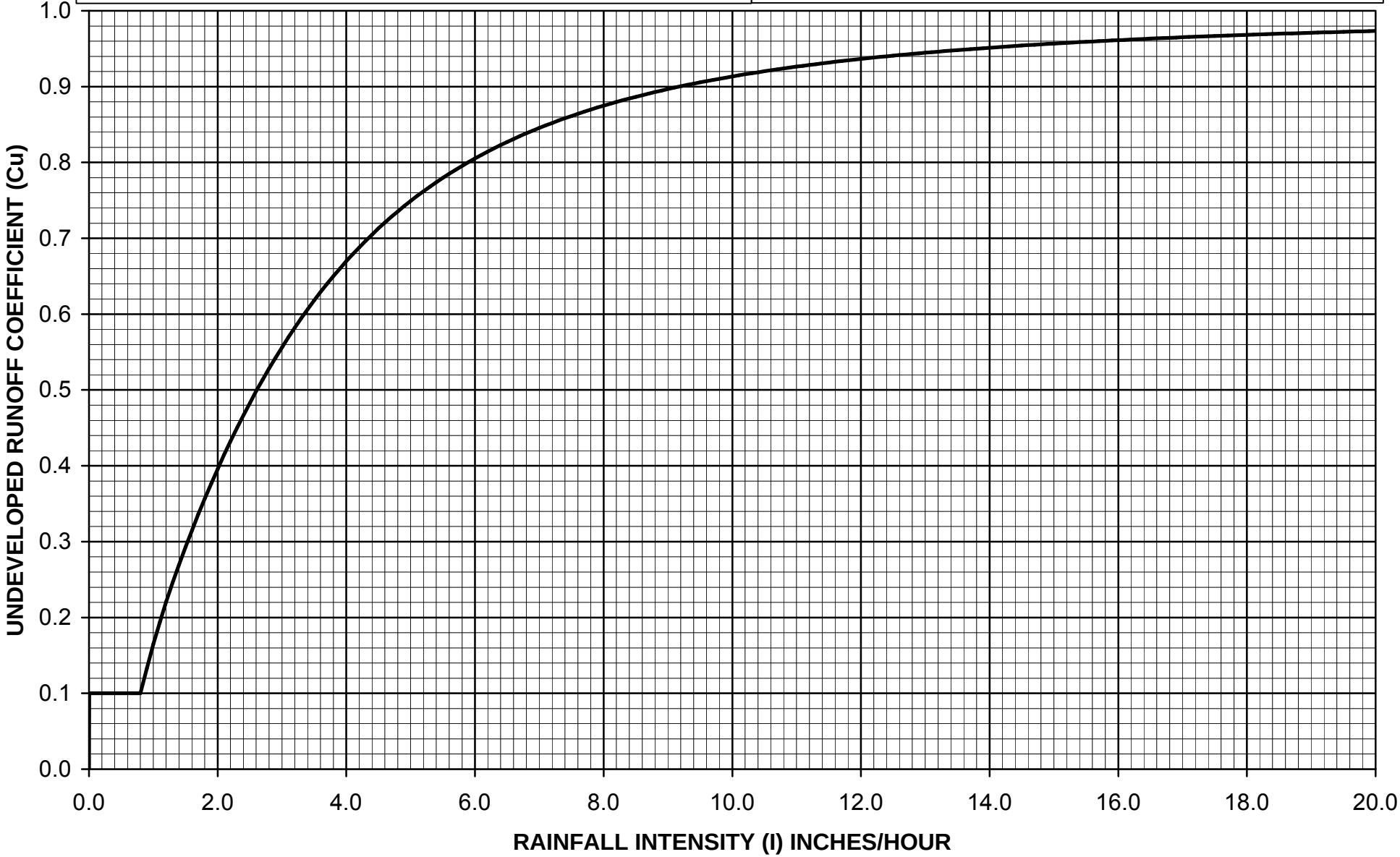


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 010

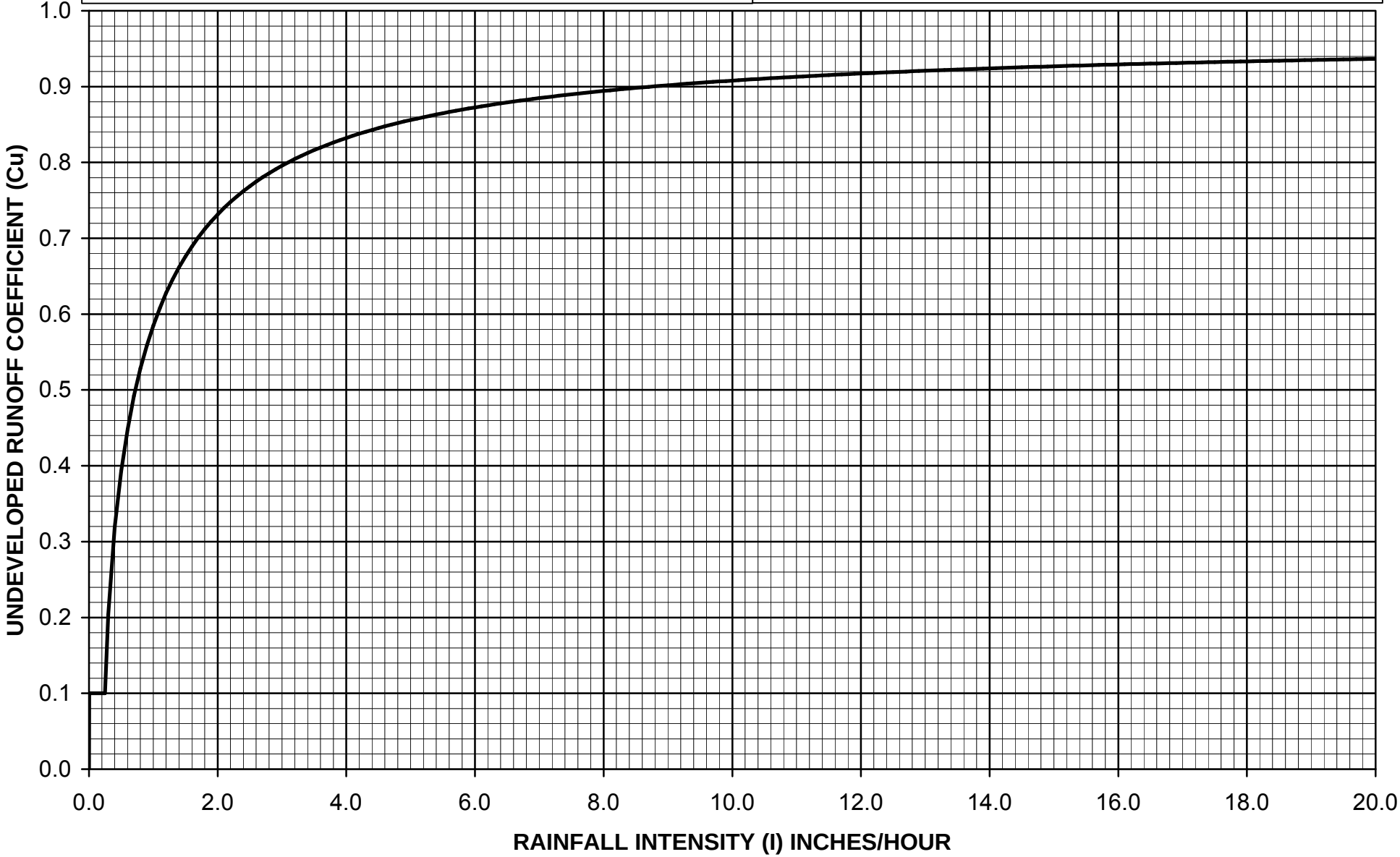


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 011



CD = (0.9 * IMP) + (1.0 - IMP) * Cu

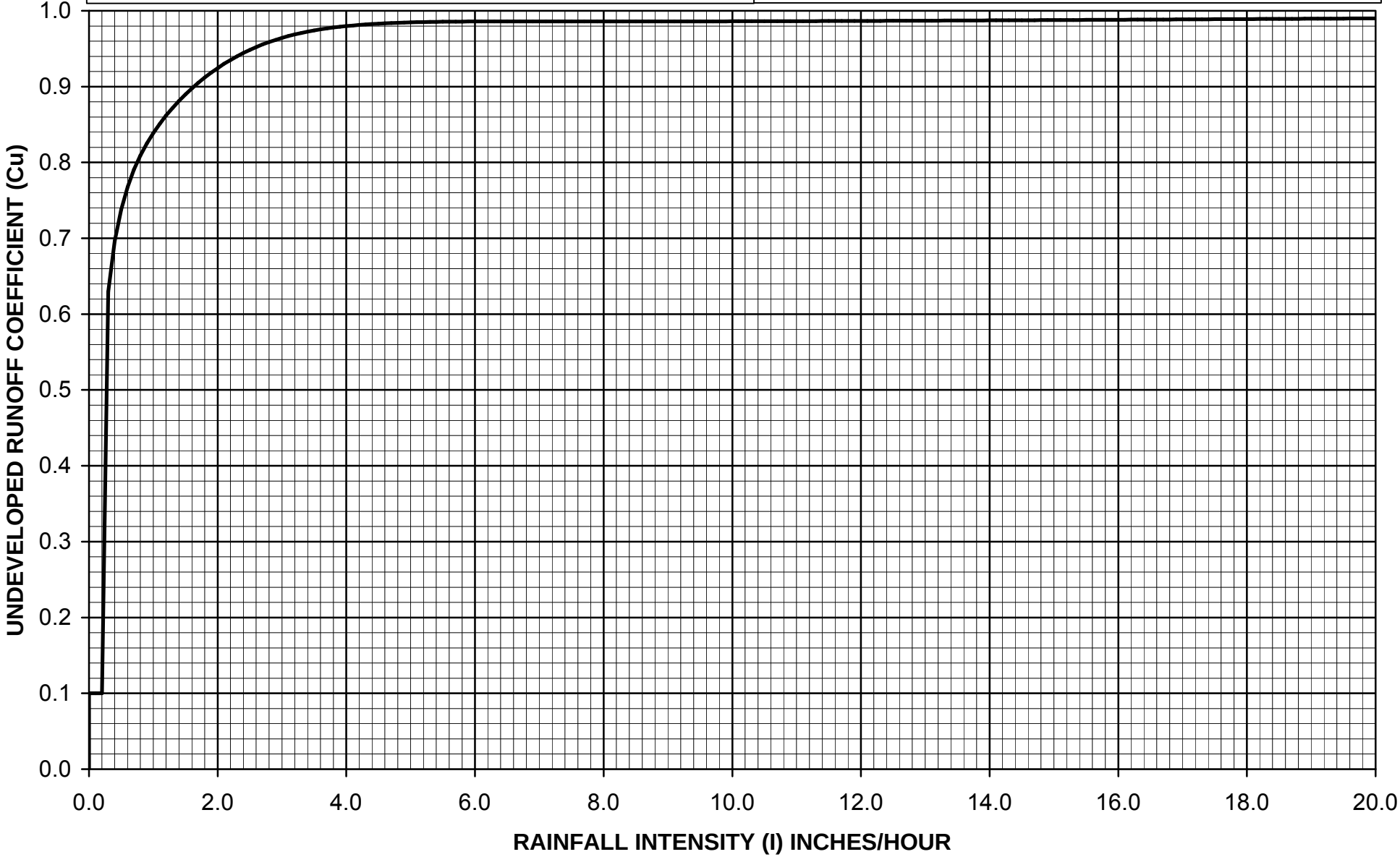
Where: C_D = Developed Runoff Coefficient

IMP = Proportion Impervious

C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 012

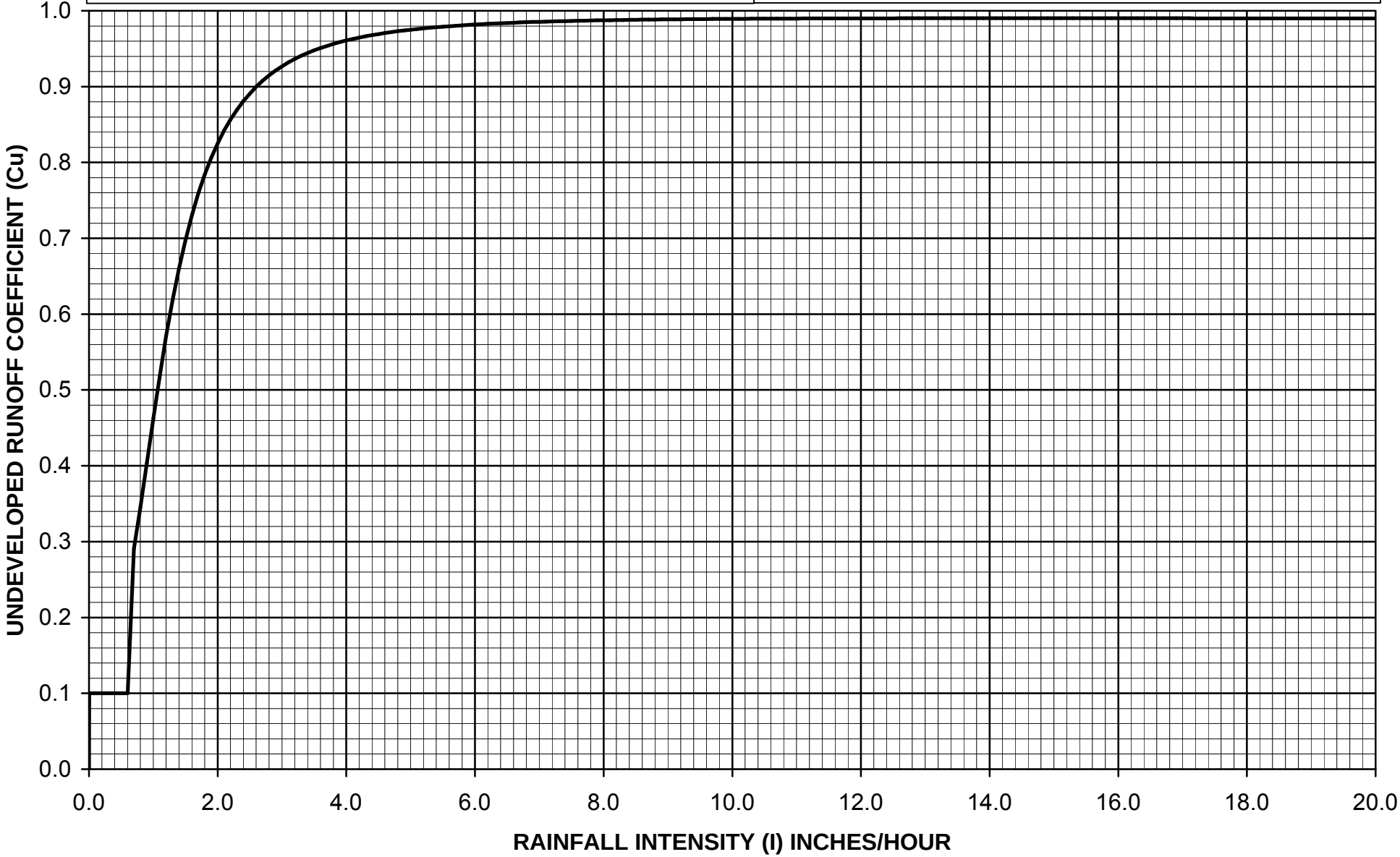


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 013

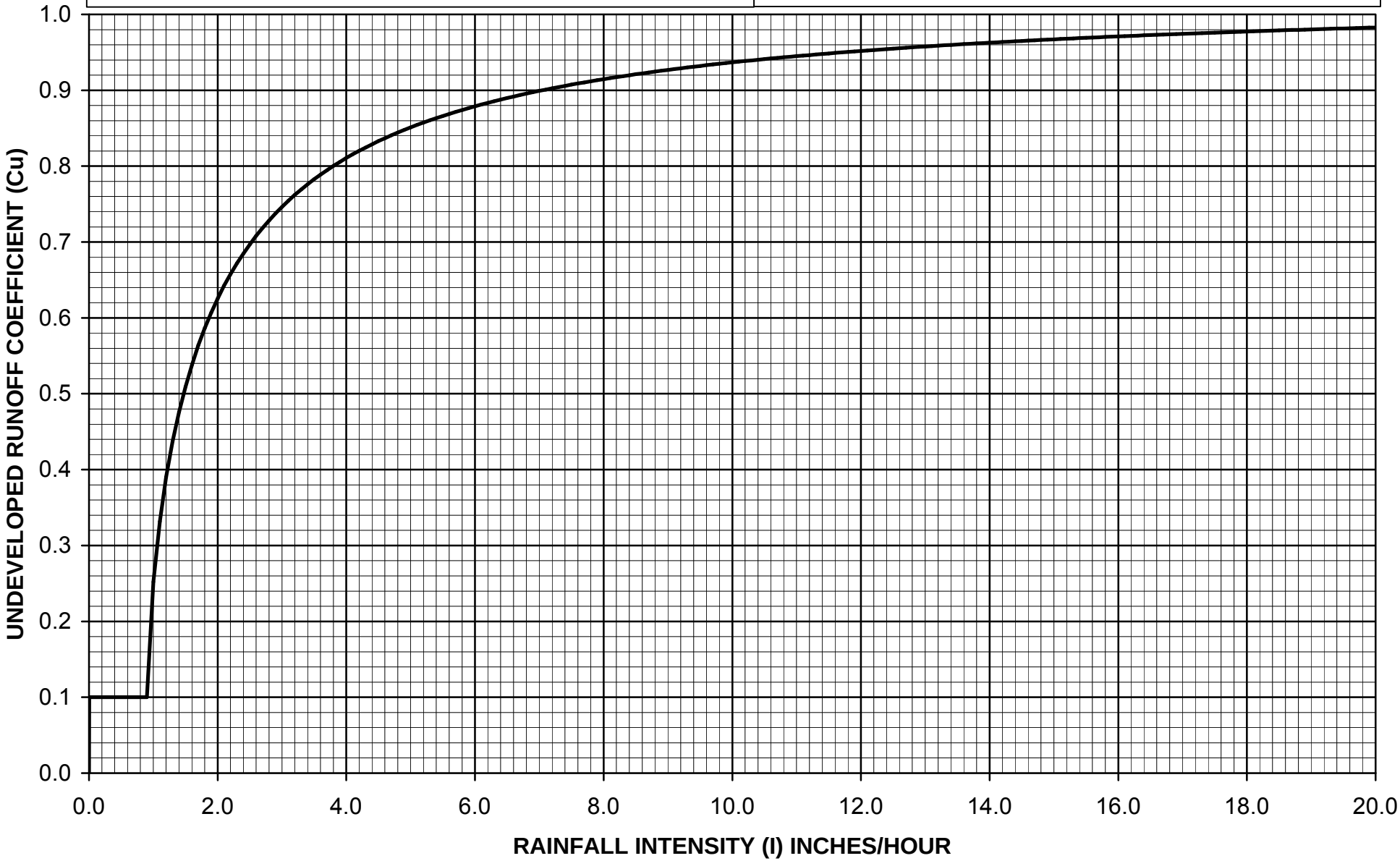


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 014

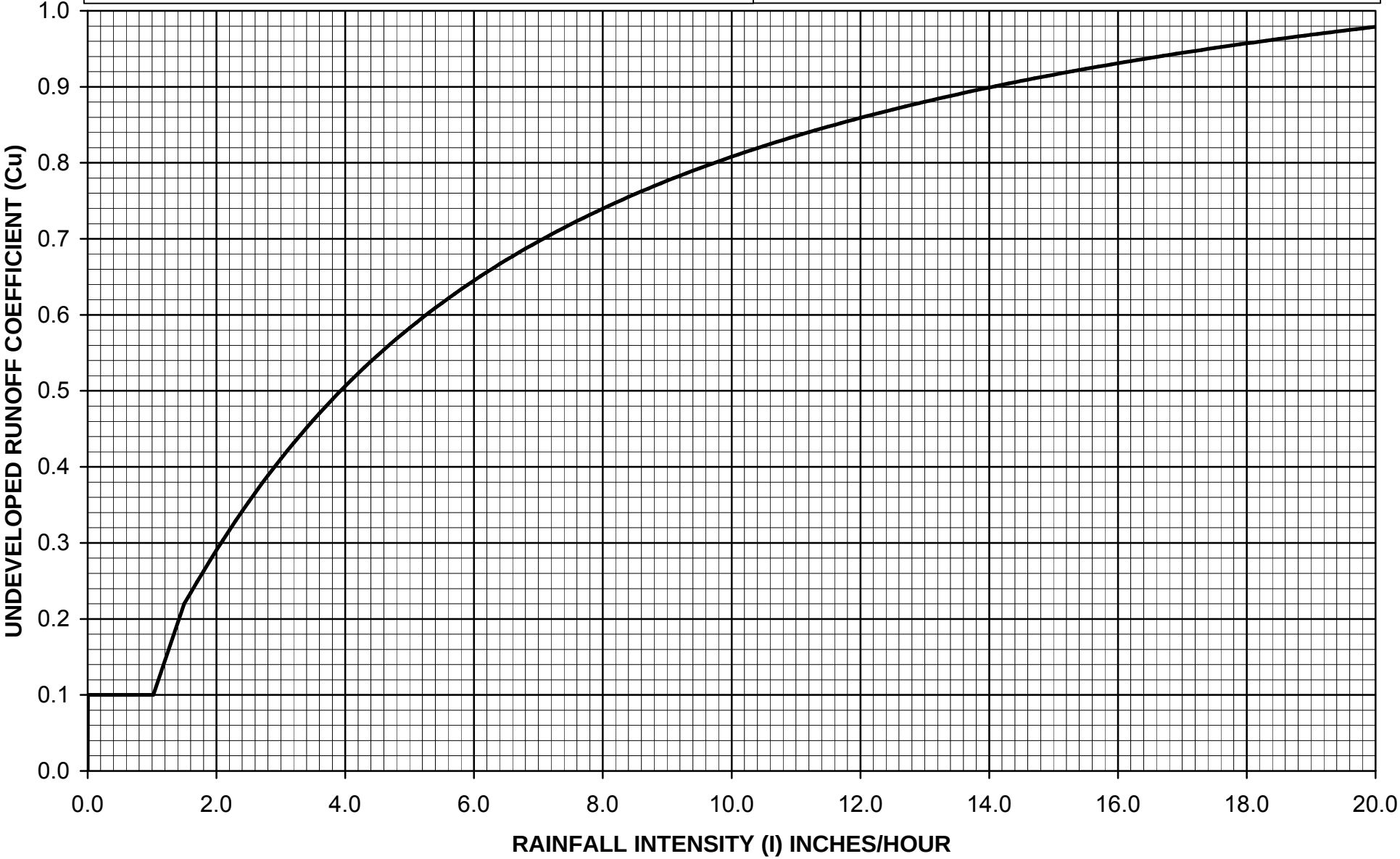


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 015

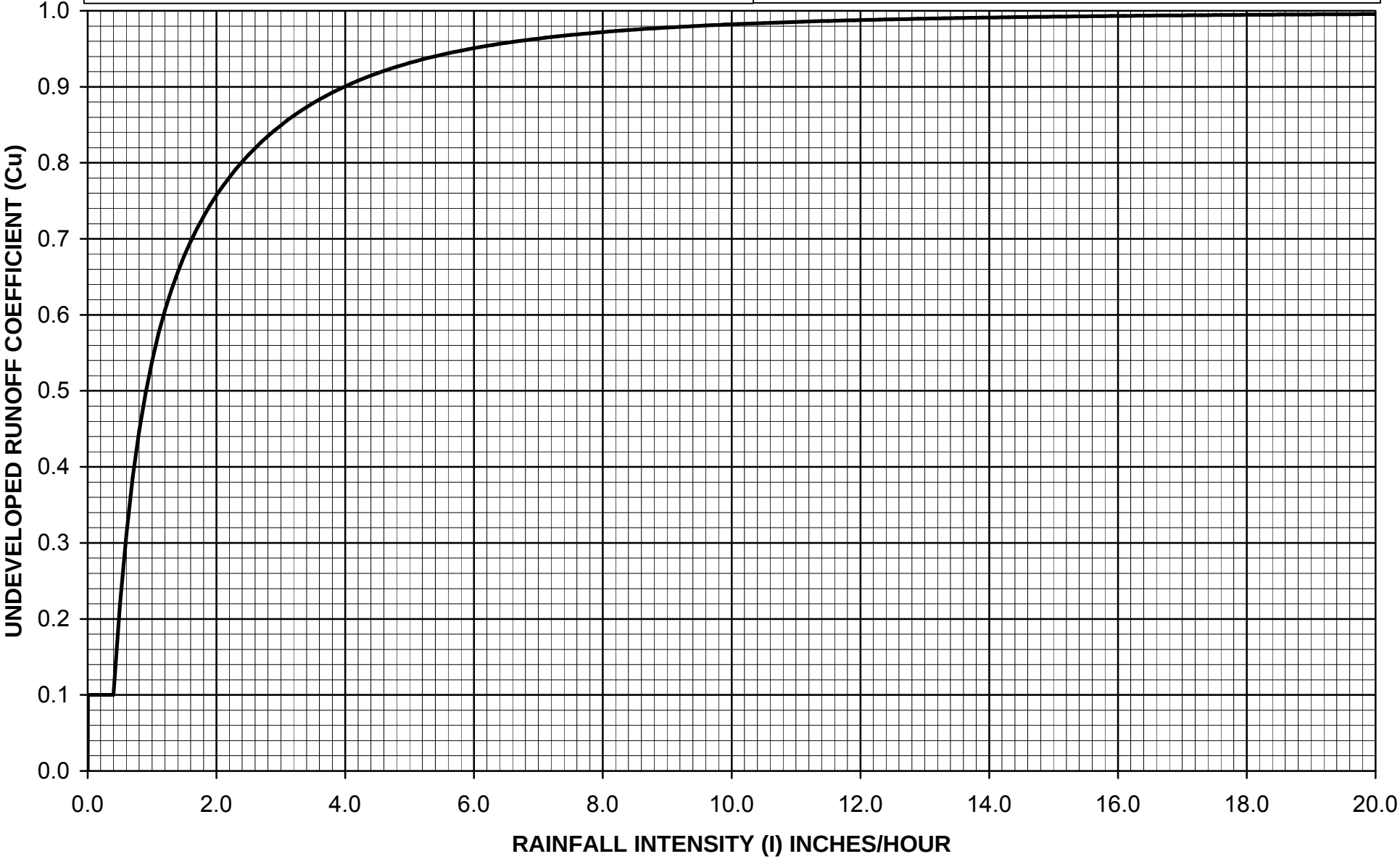


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 016

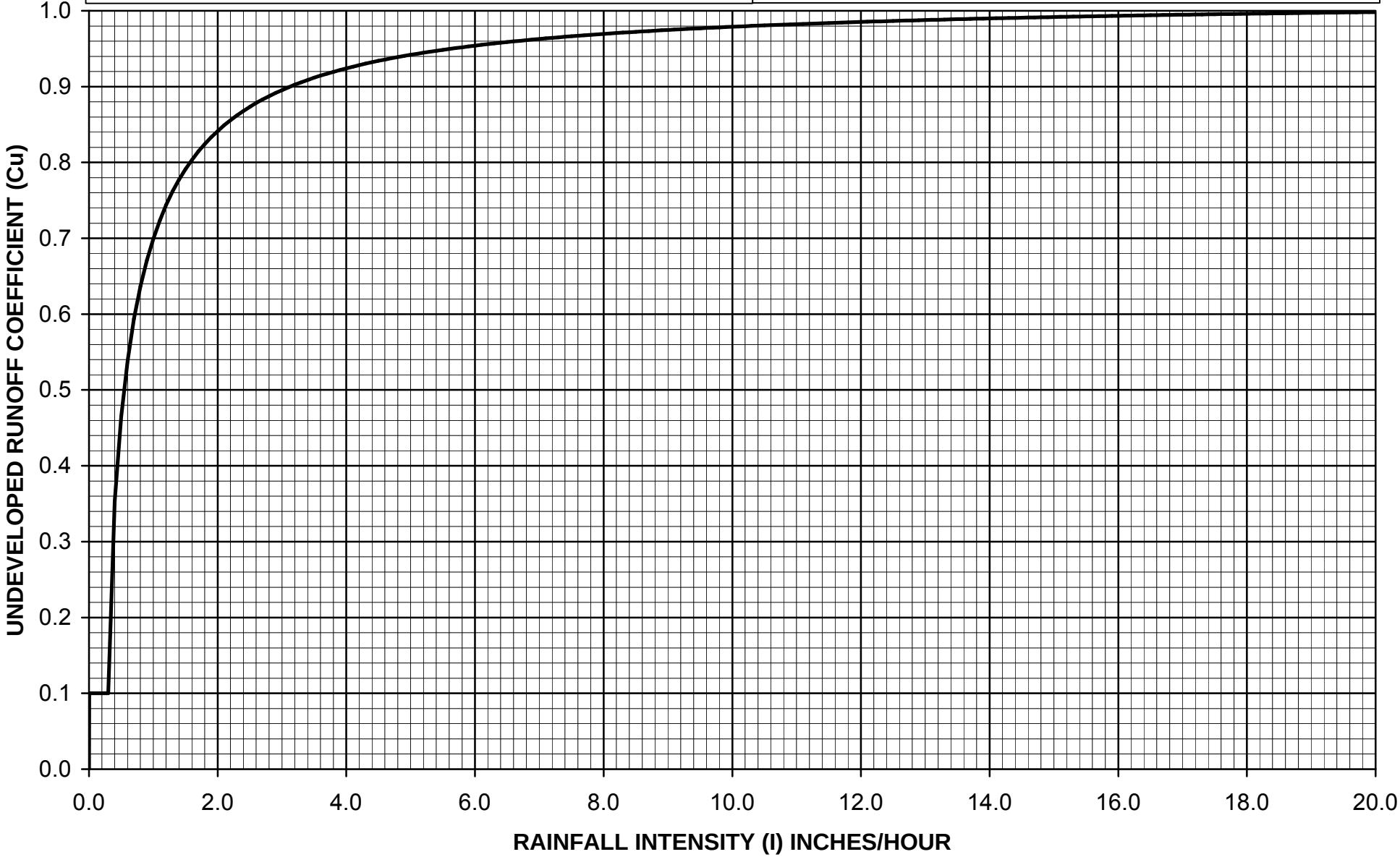


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 017

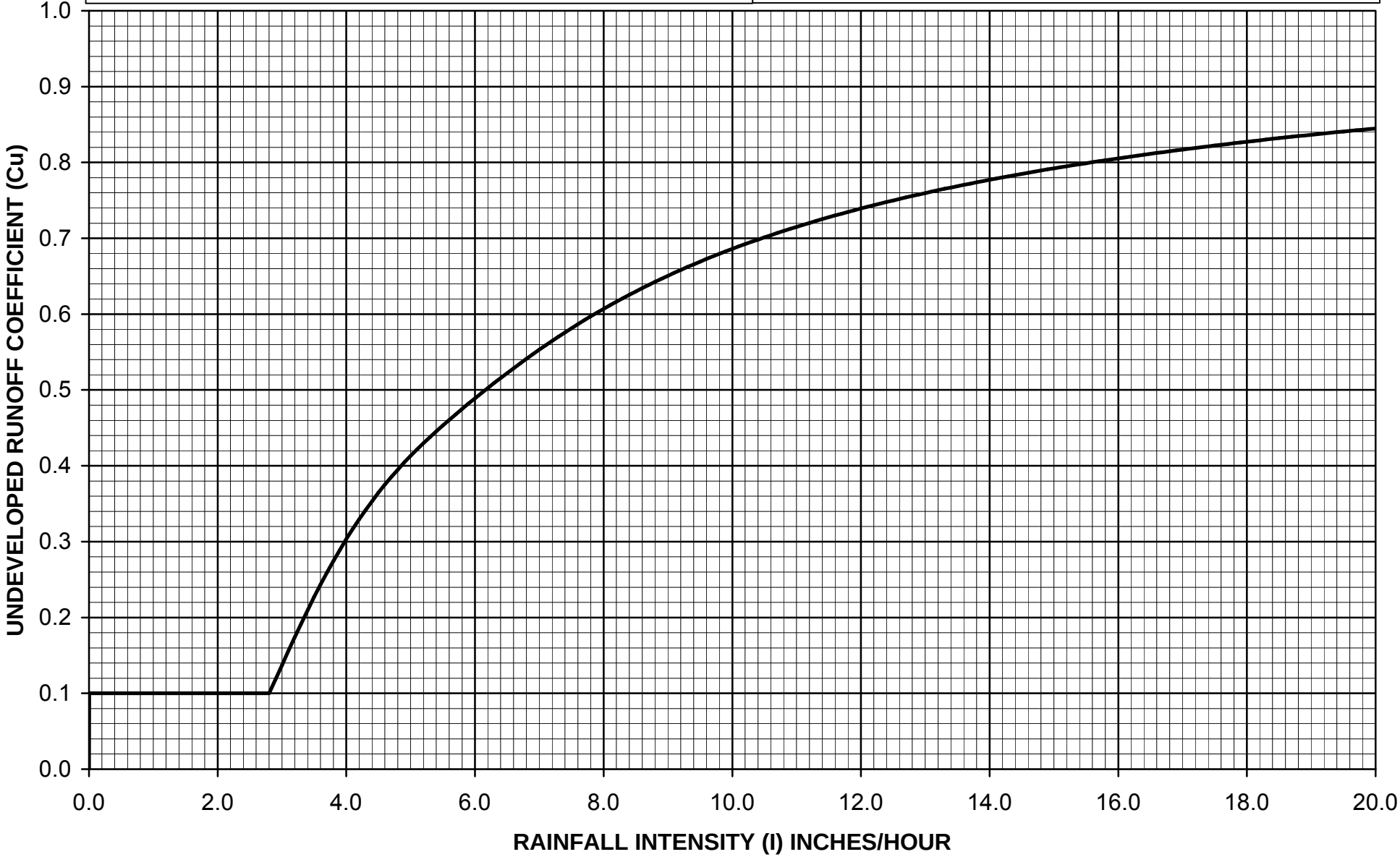


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 018

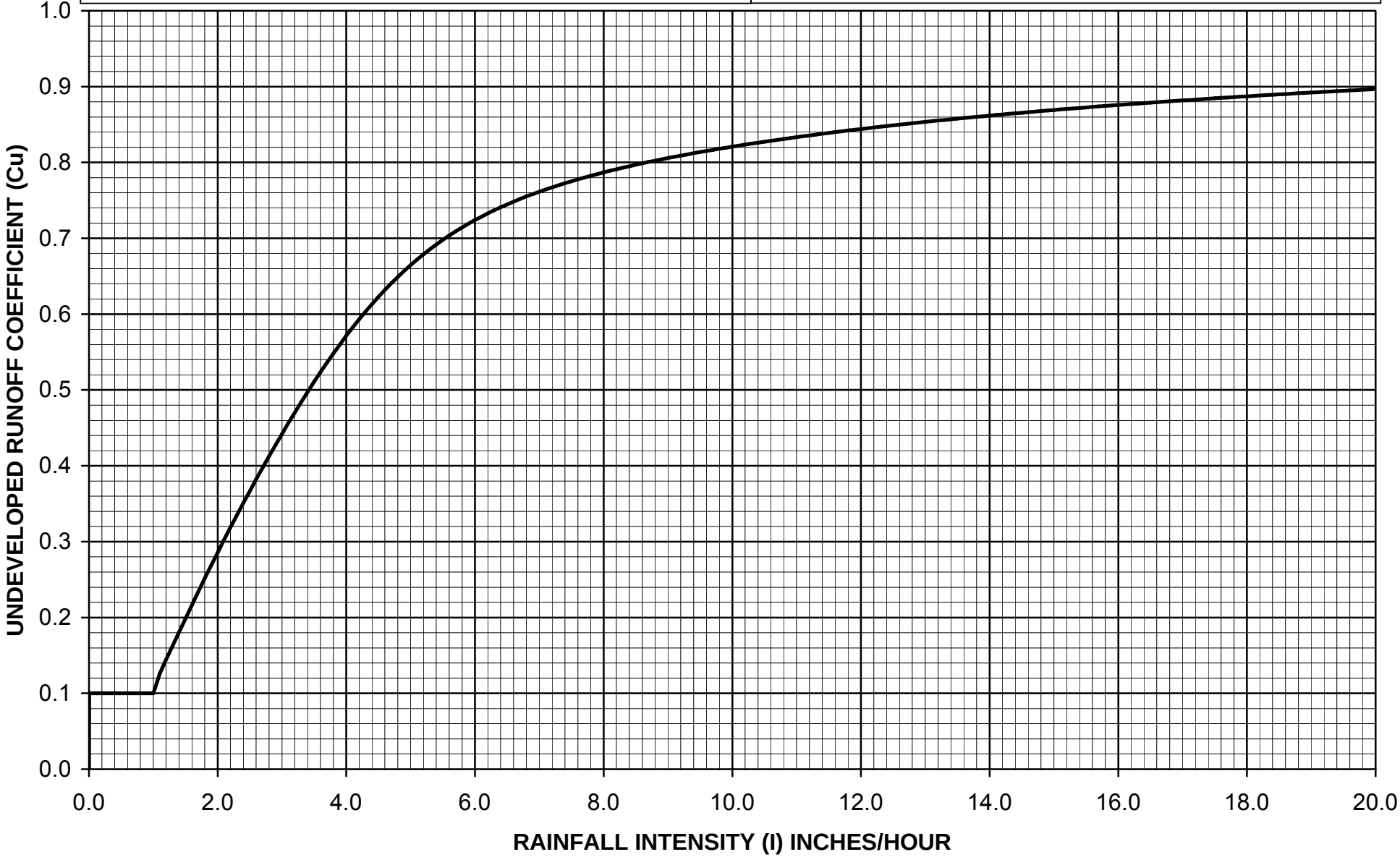


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 019

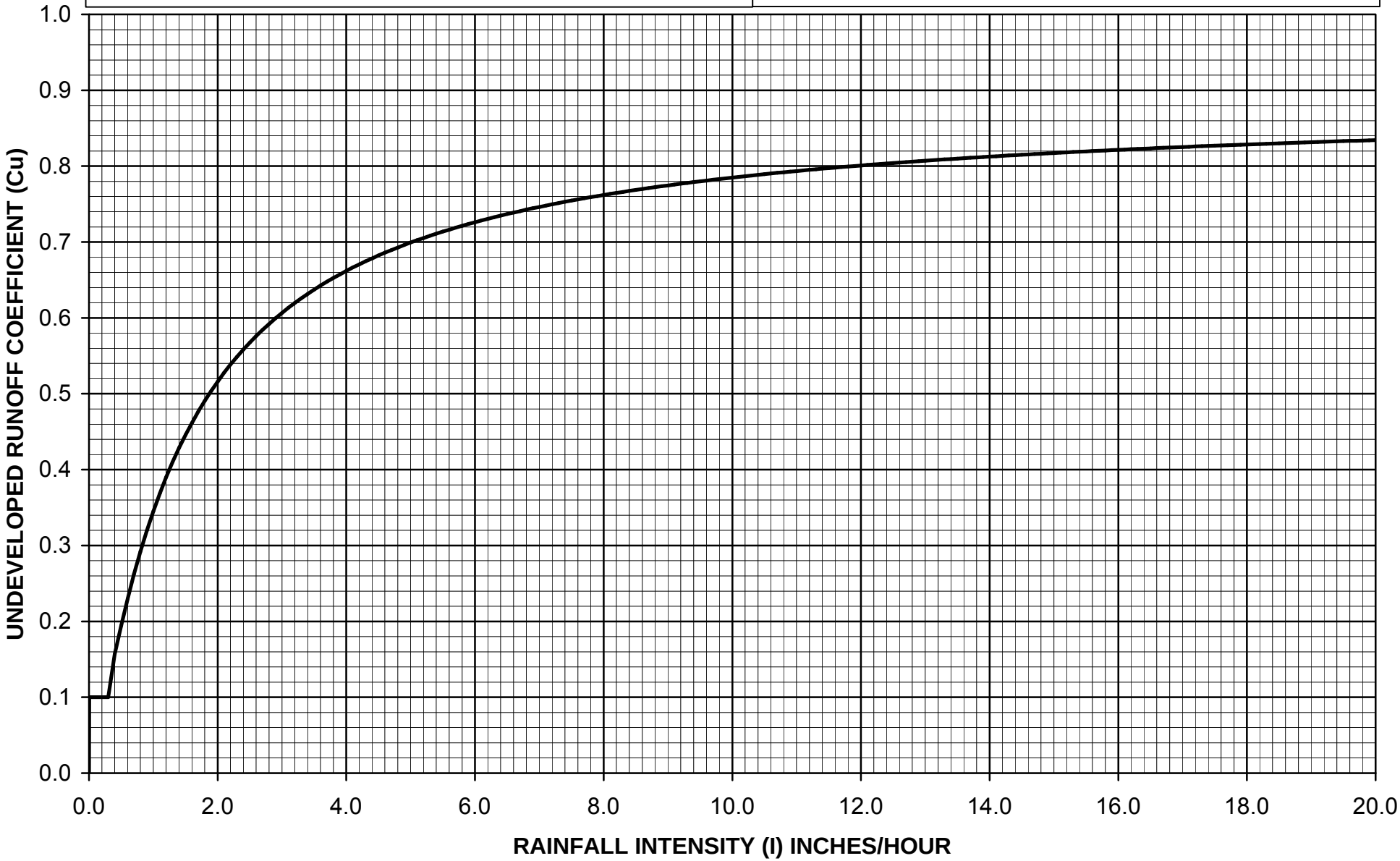


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 020

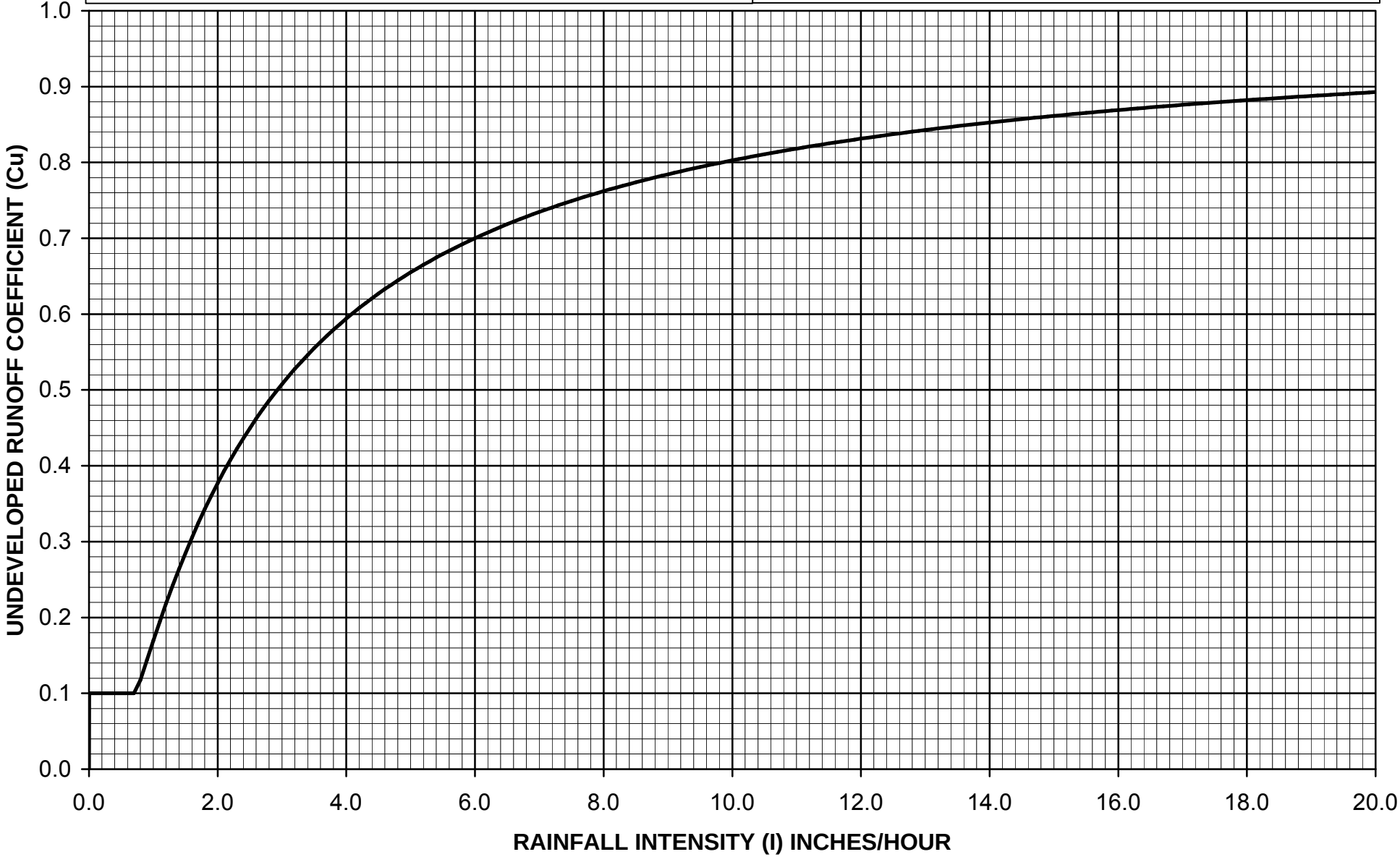


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 021

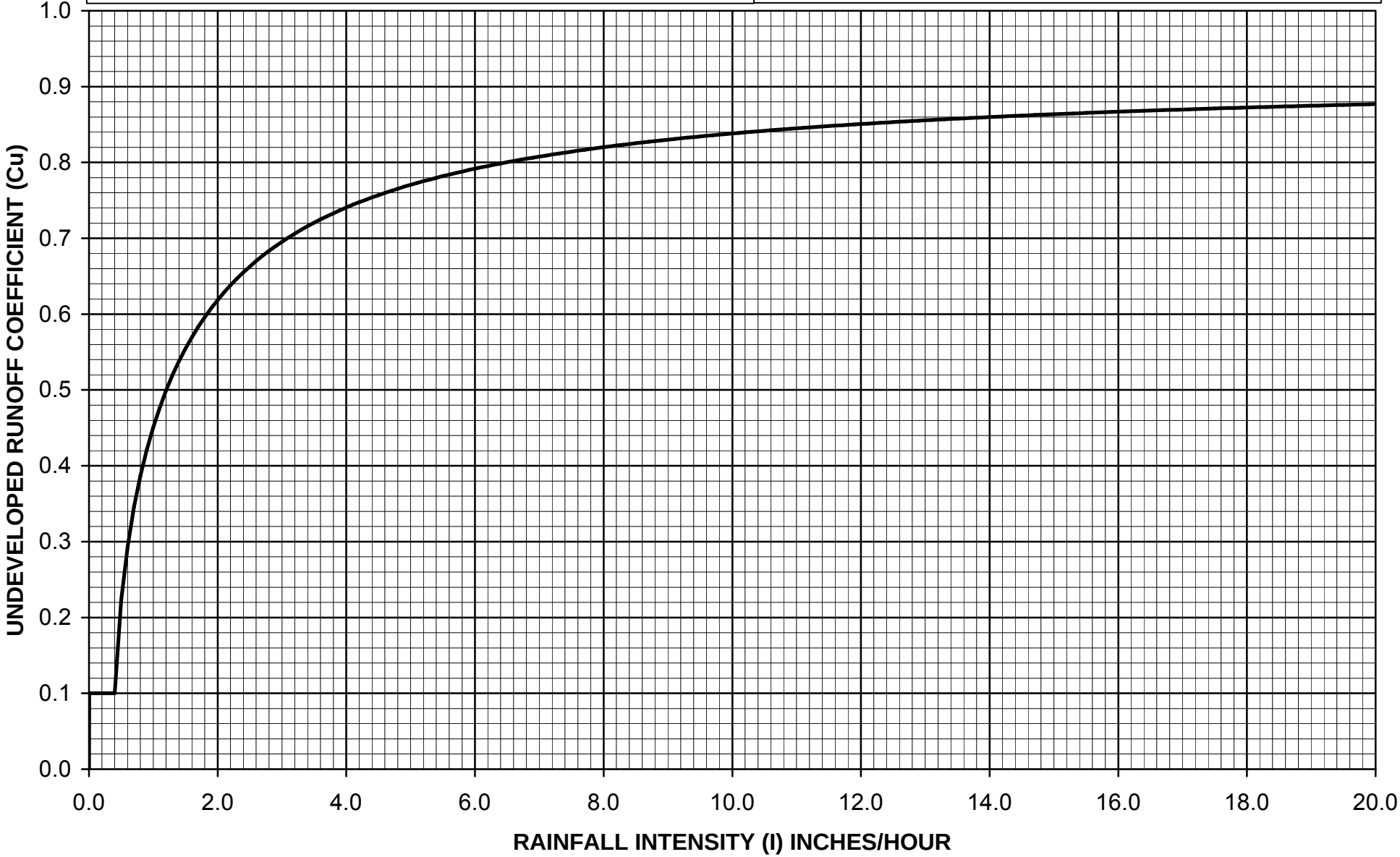


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 022

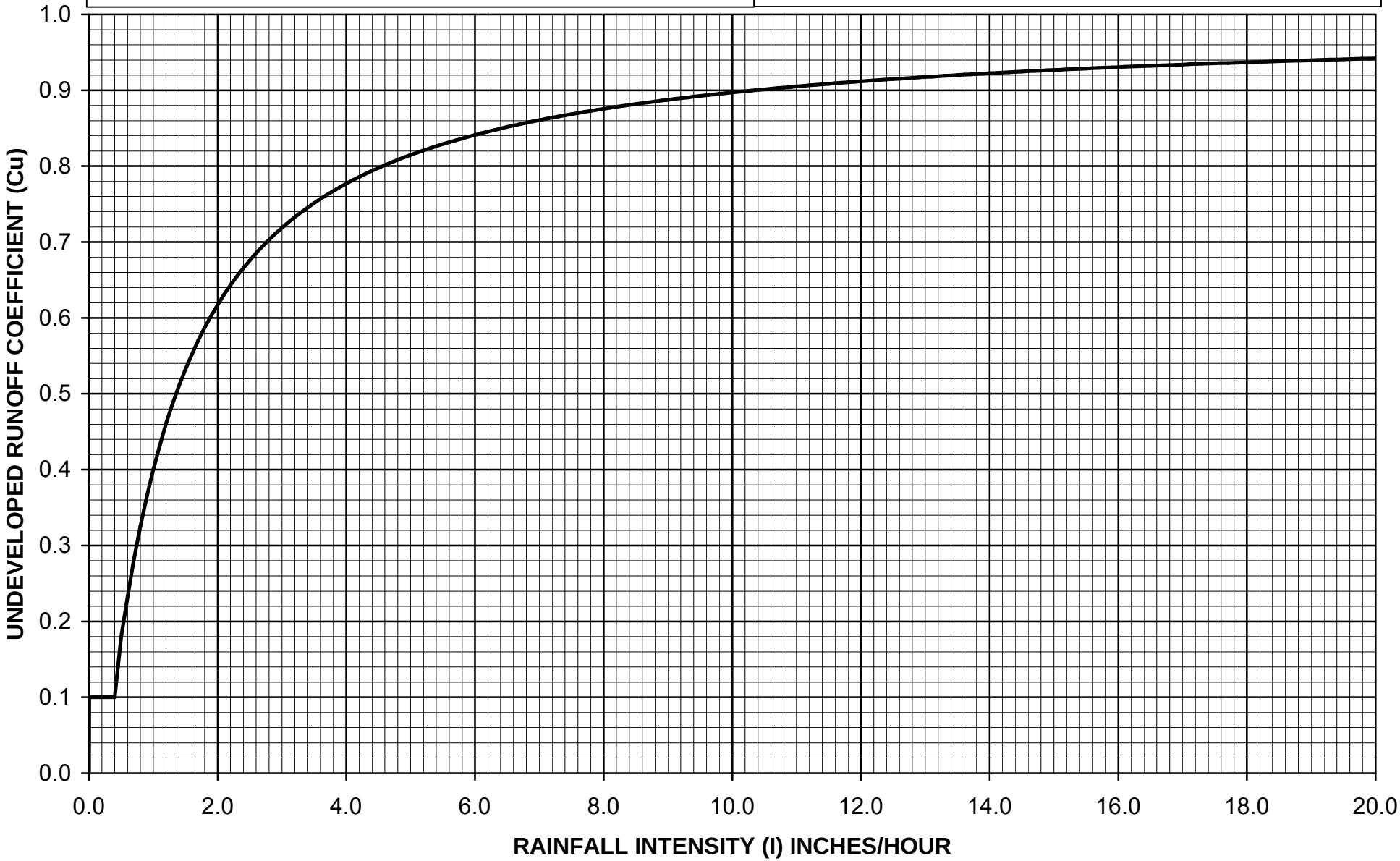


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 023

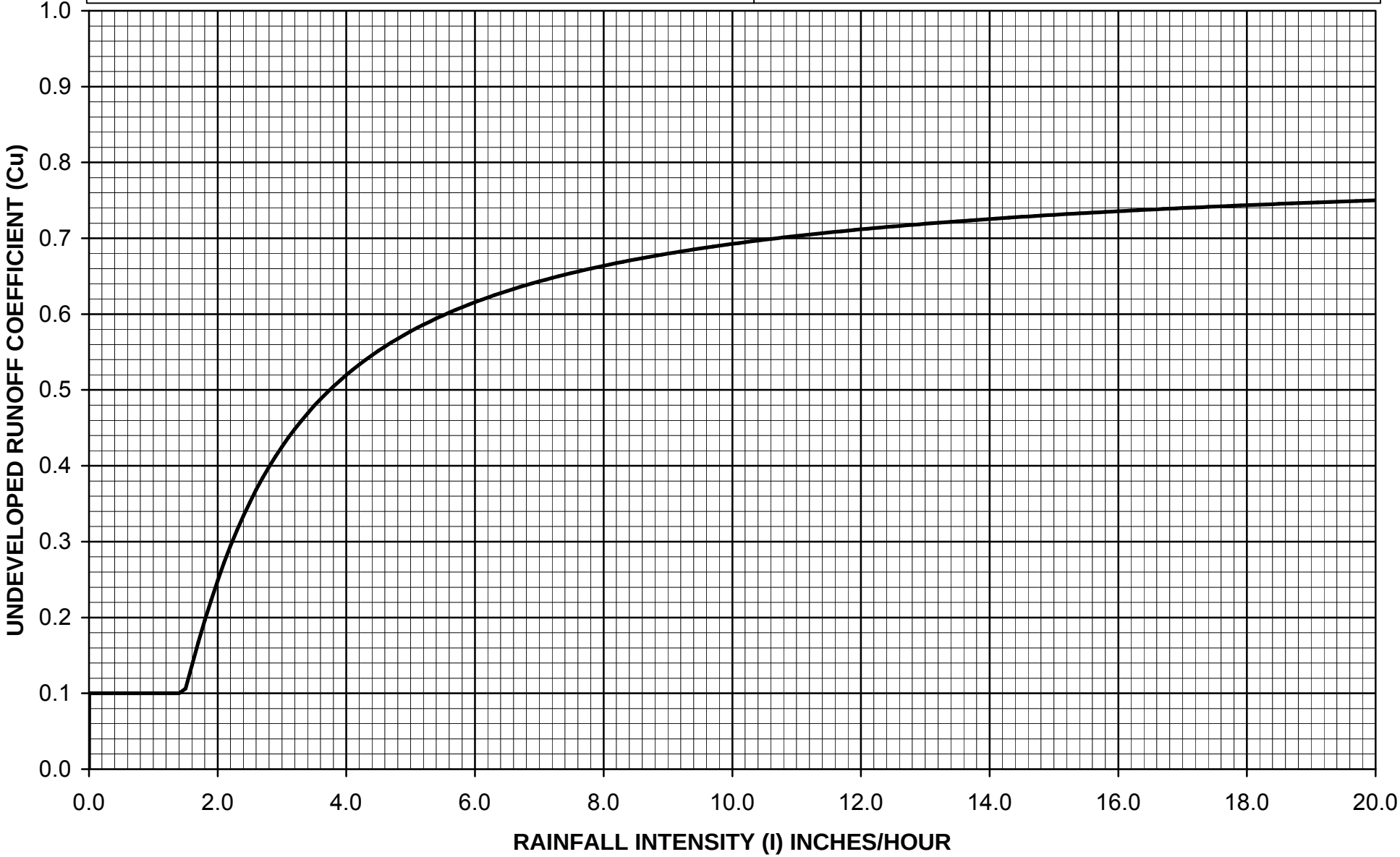


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 024

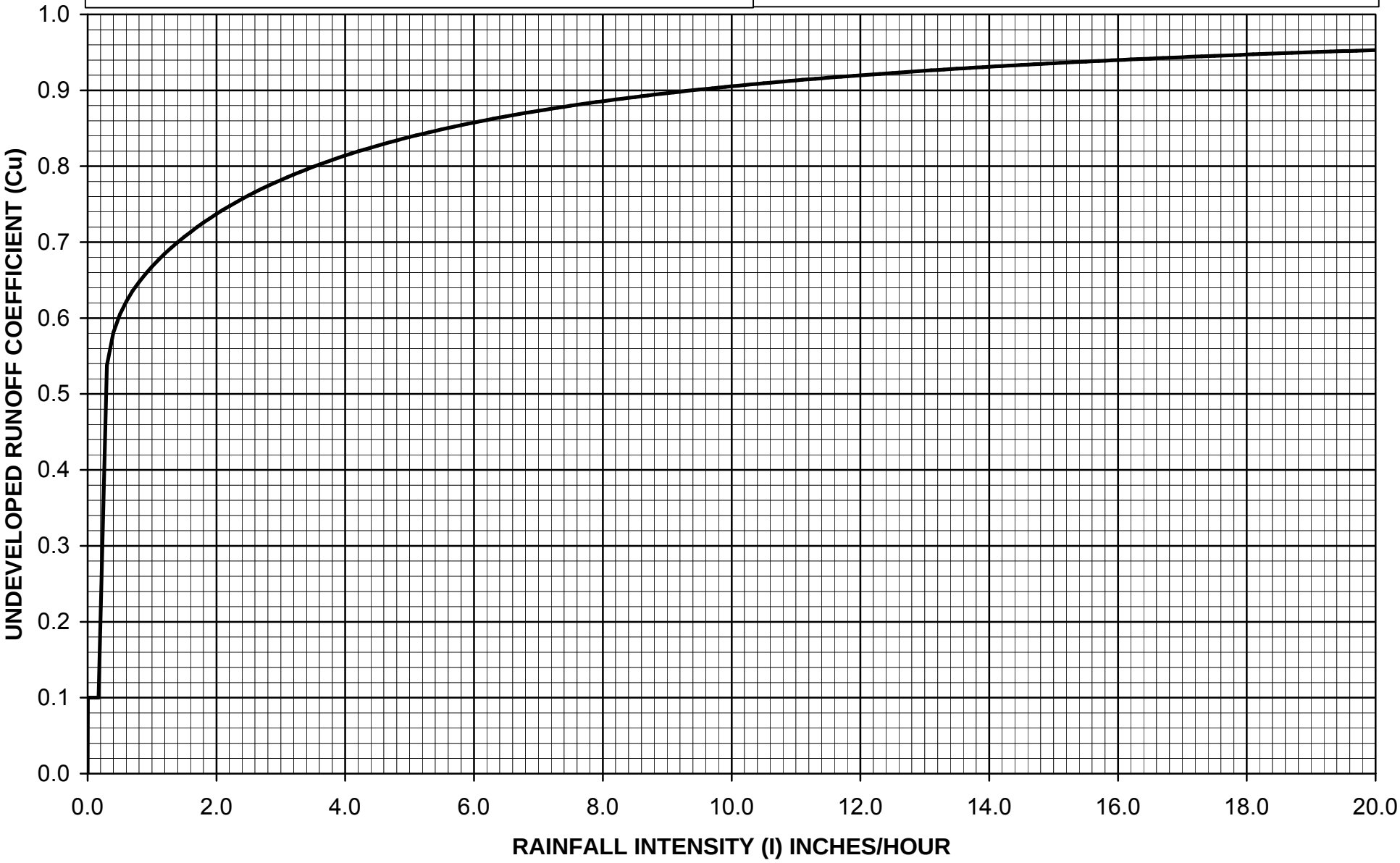


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 025

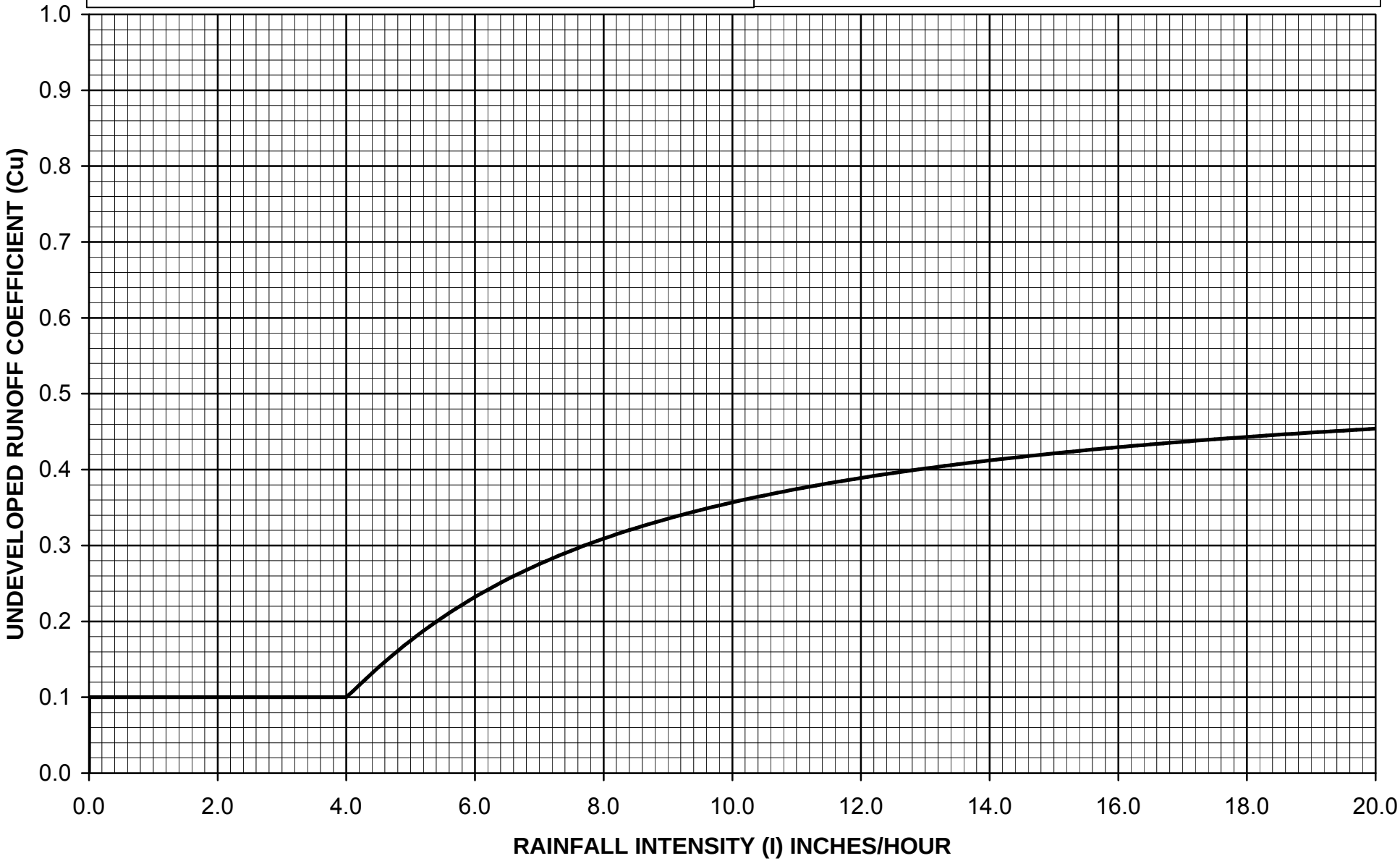


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 026

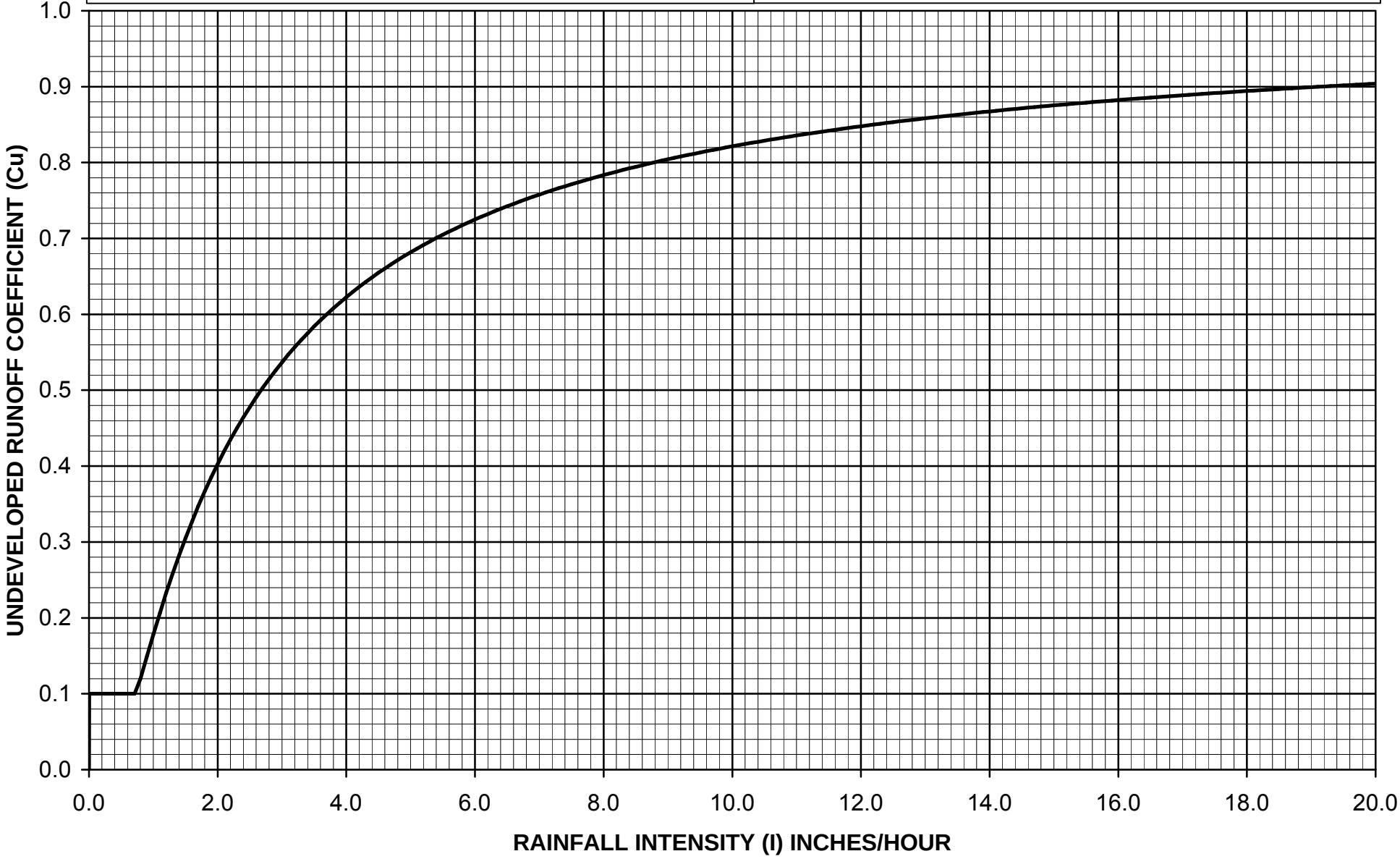


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 027

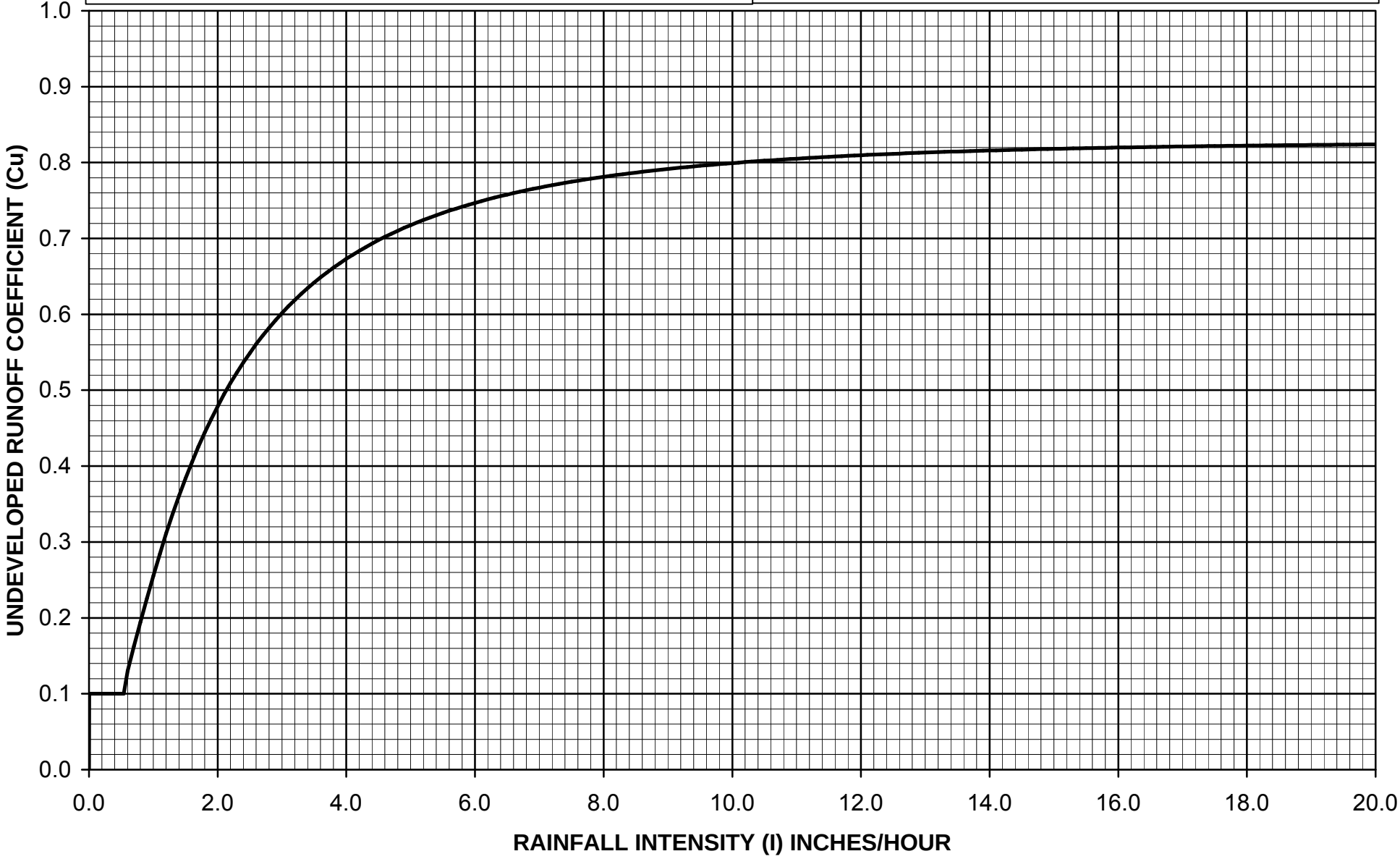


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 028

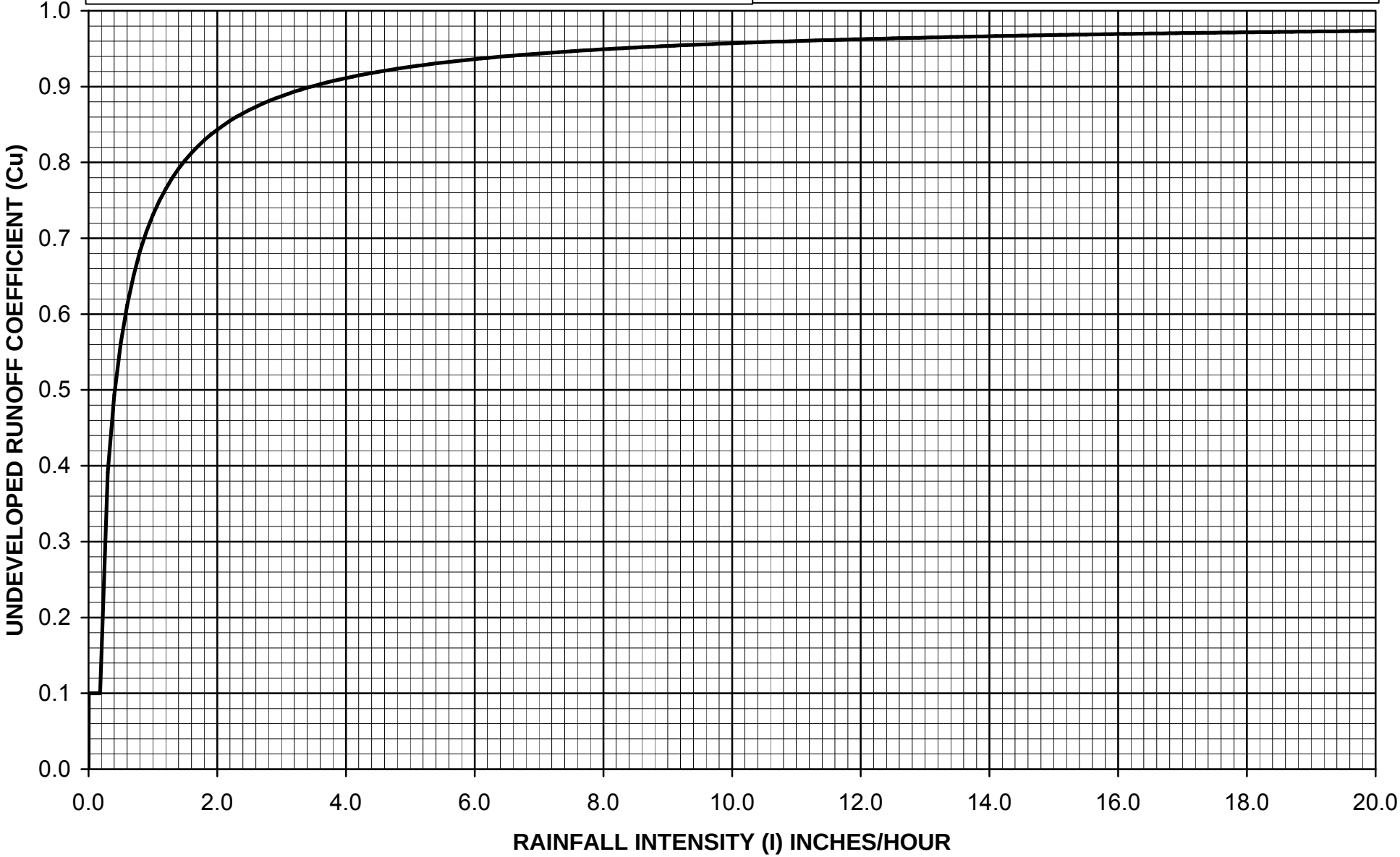


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 029

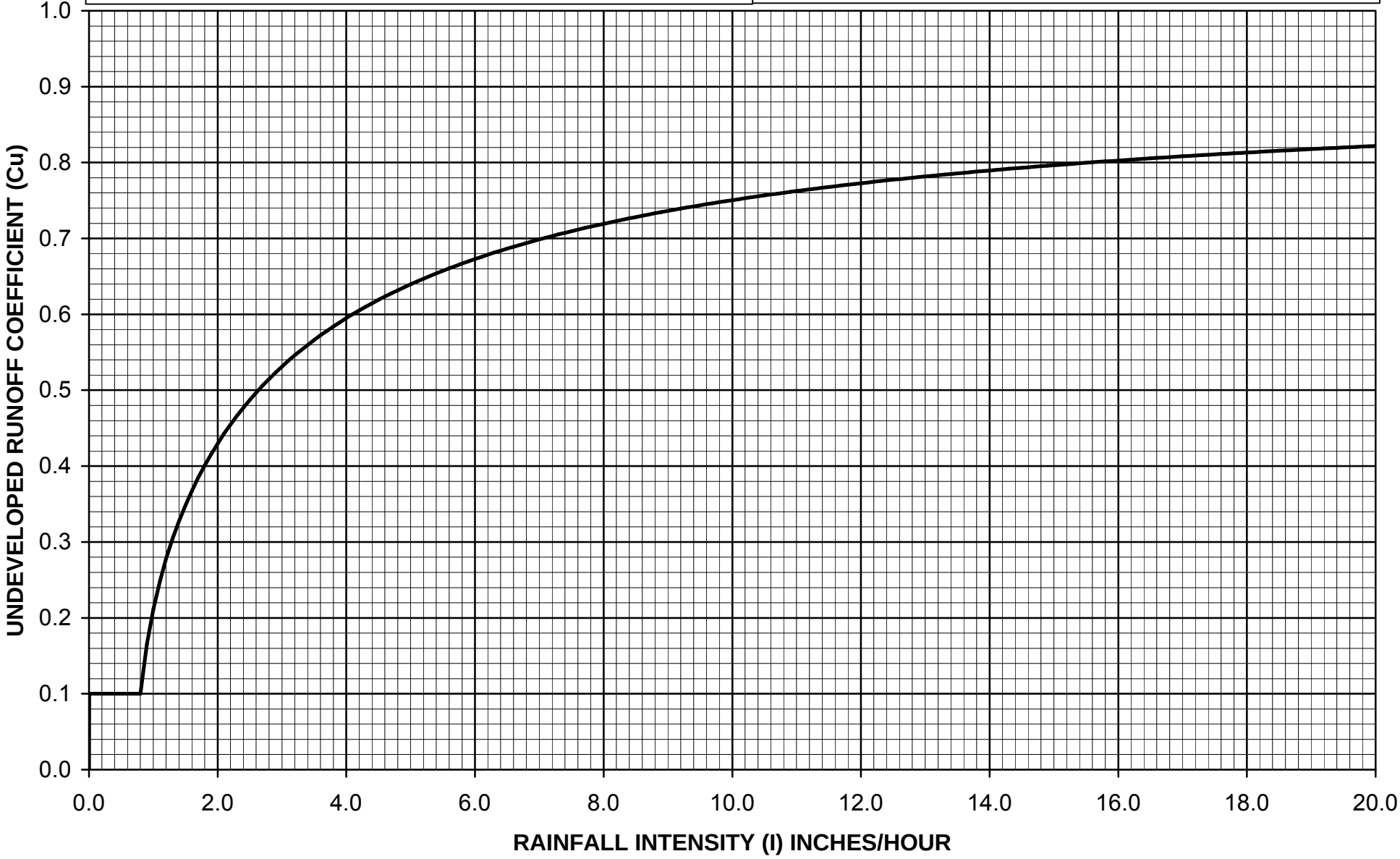


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 030

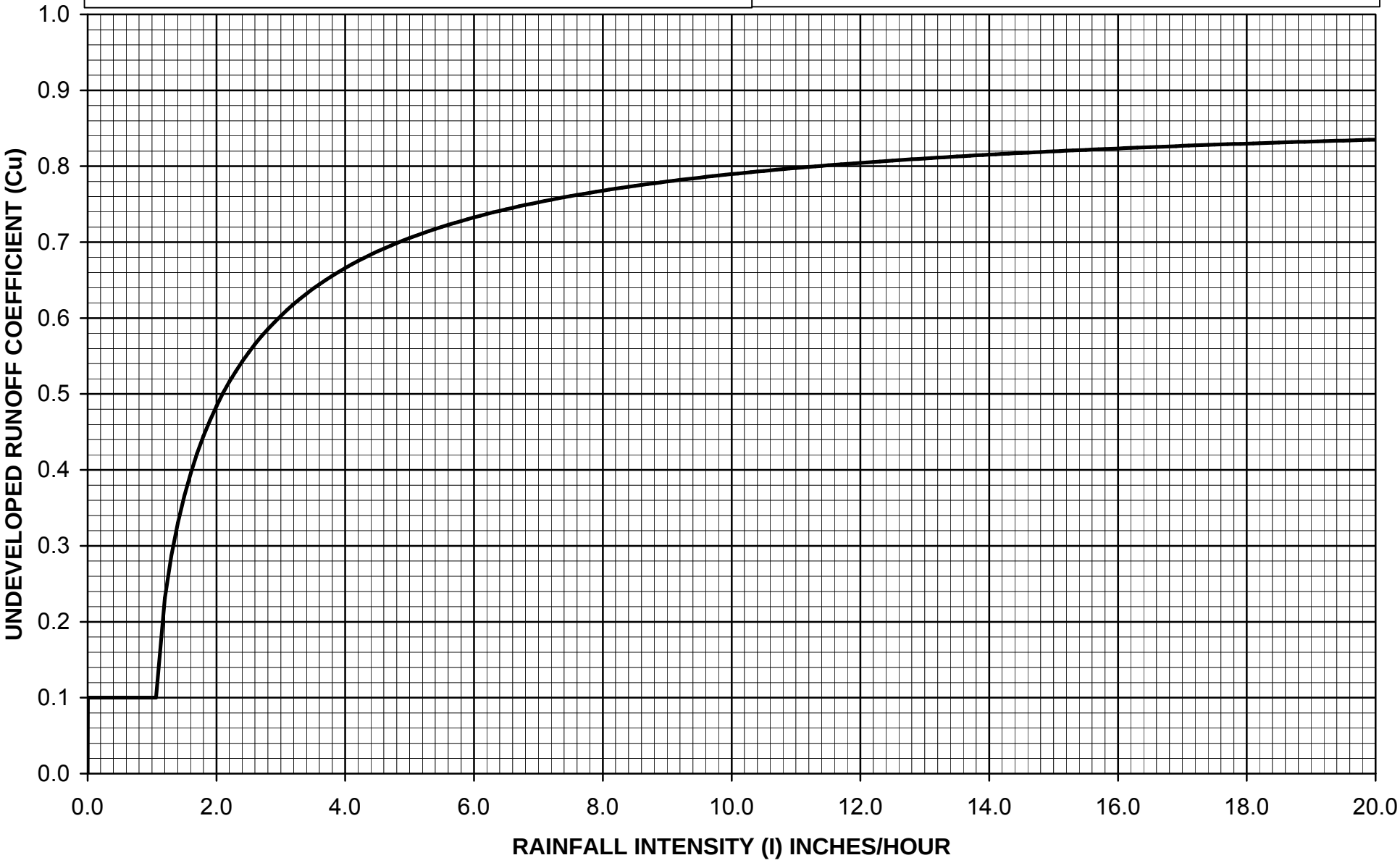


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 031

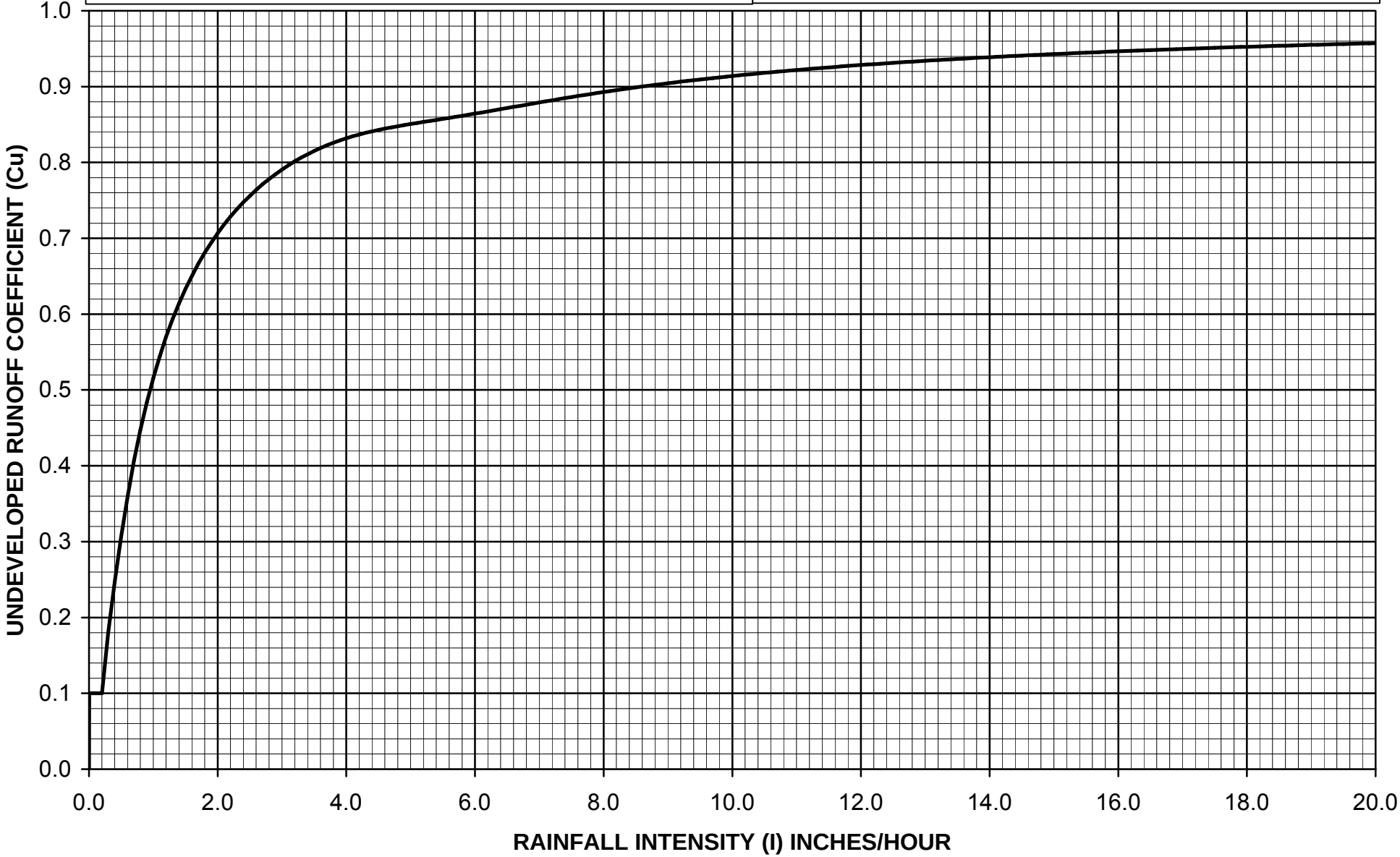


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 032

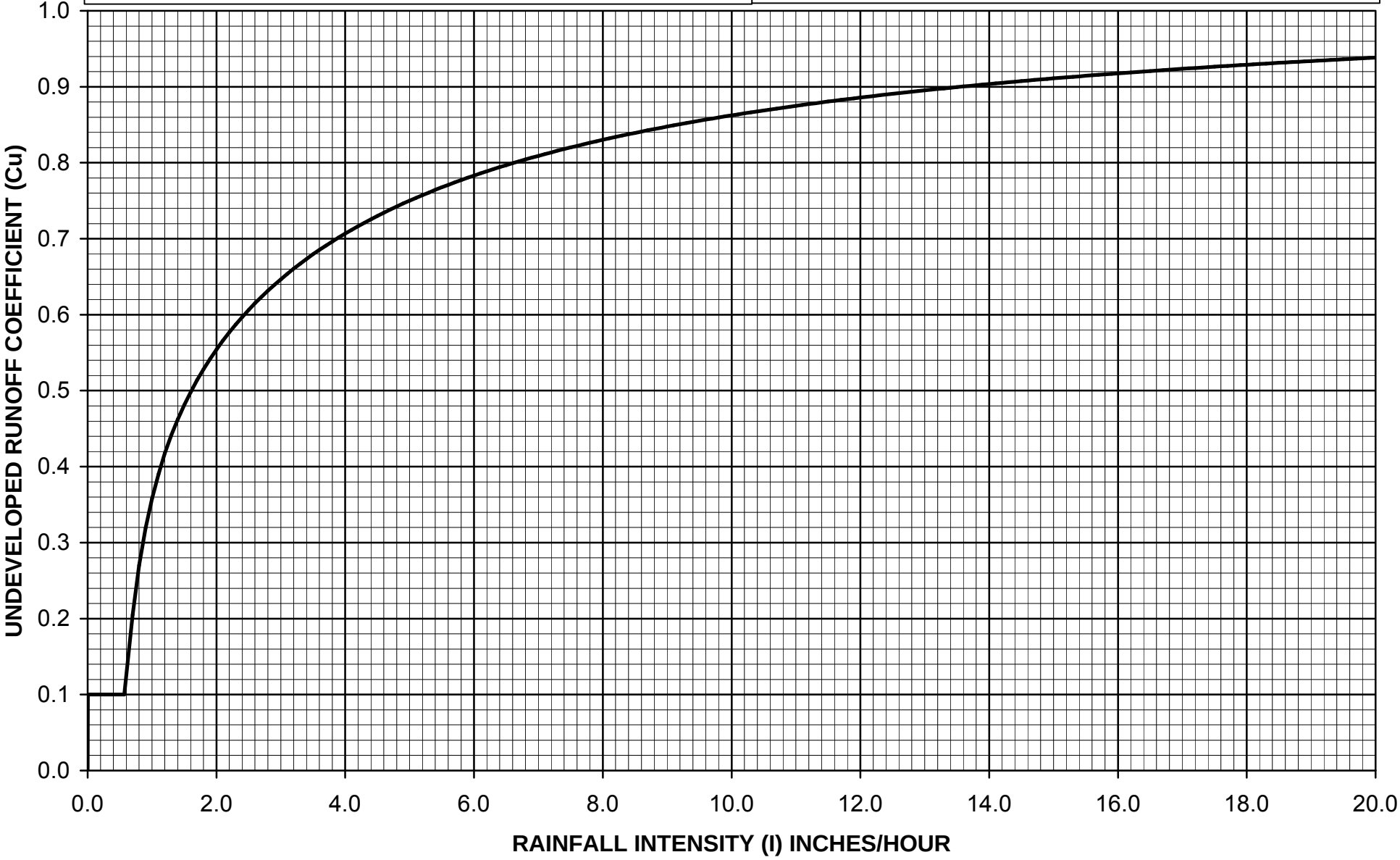


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 033

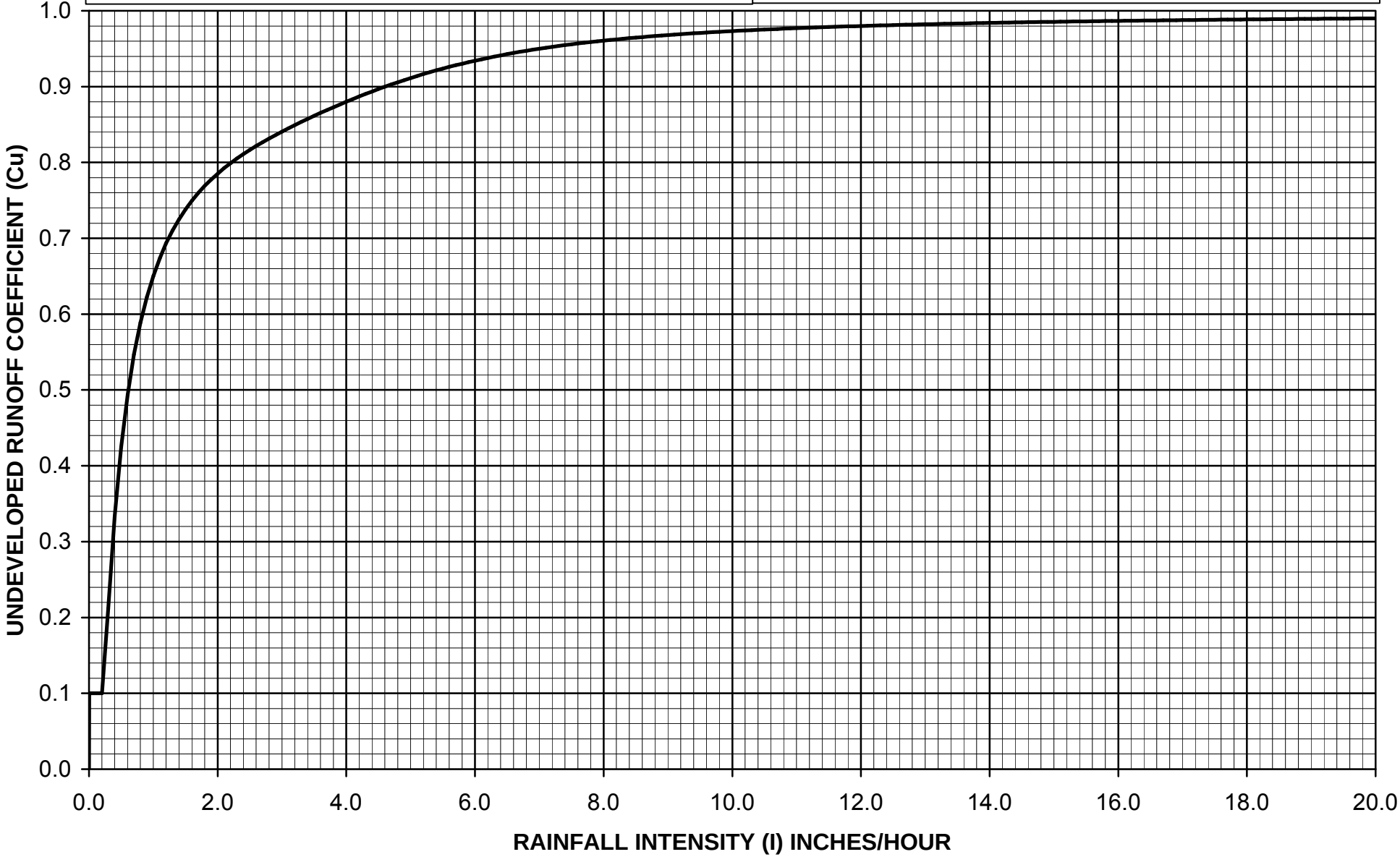


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 034

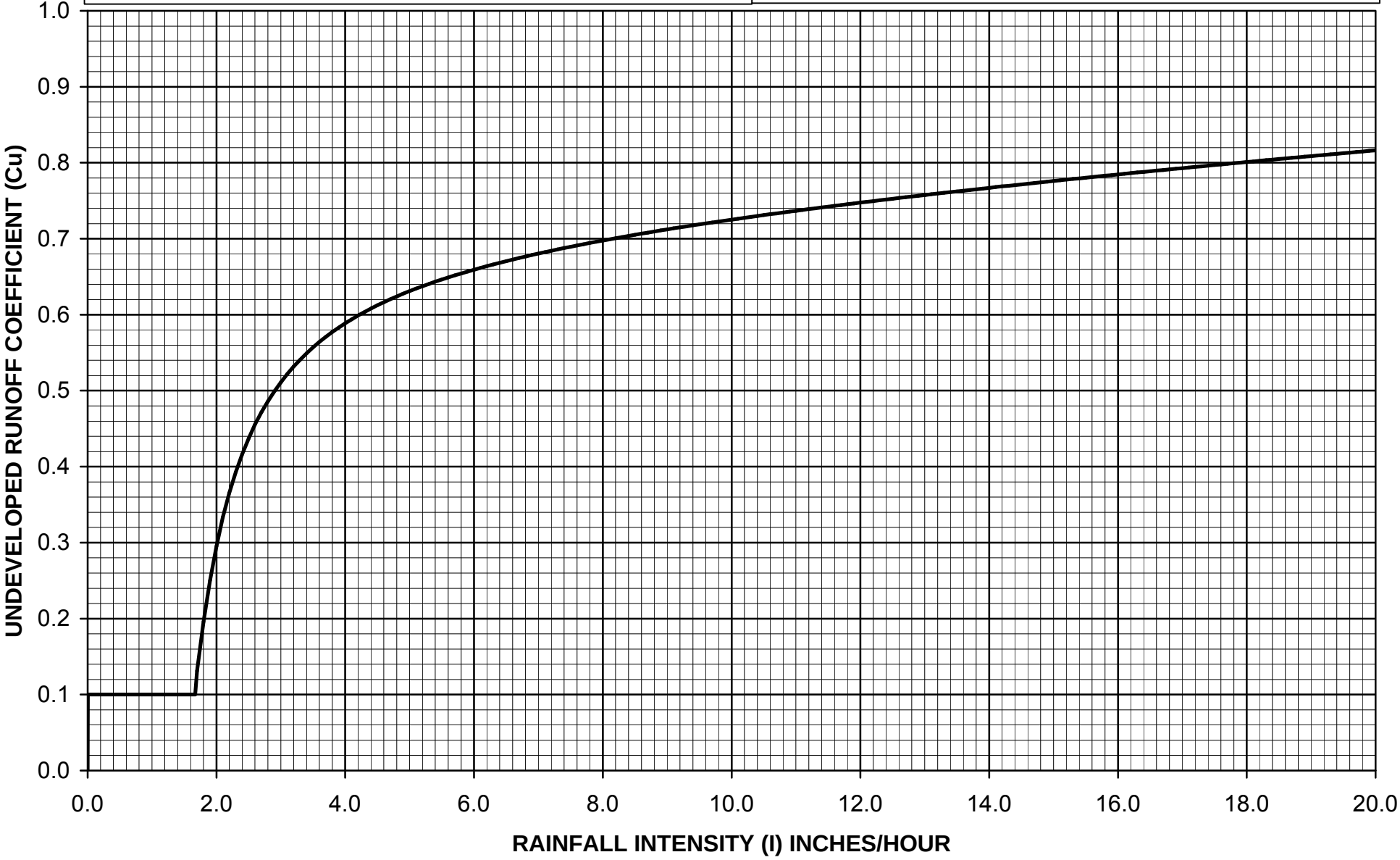


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 035

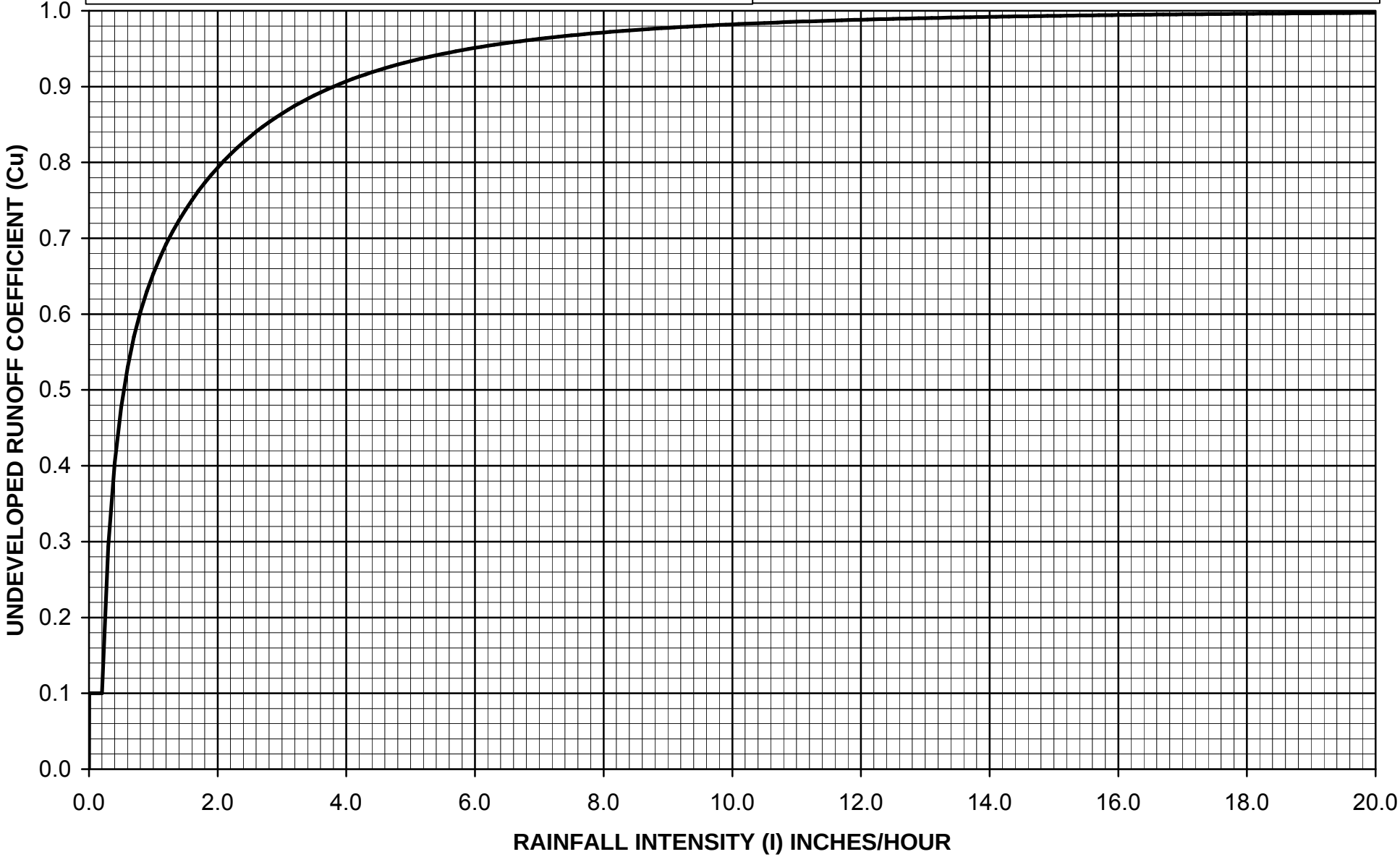


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 036

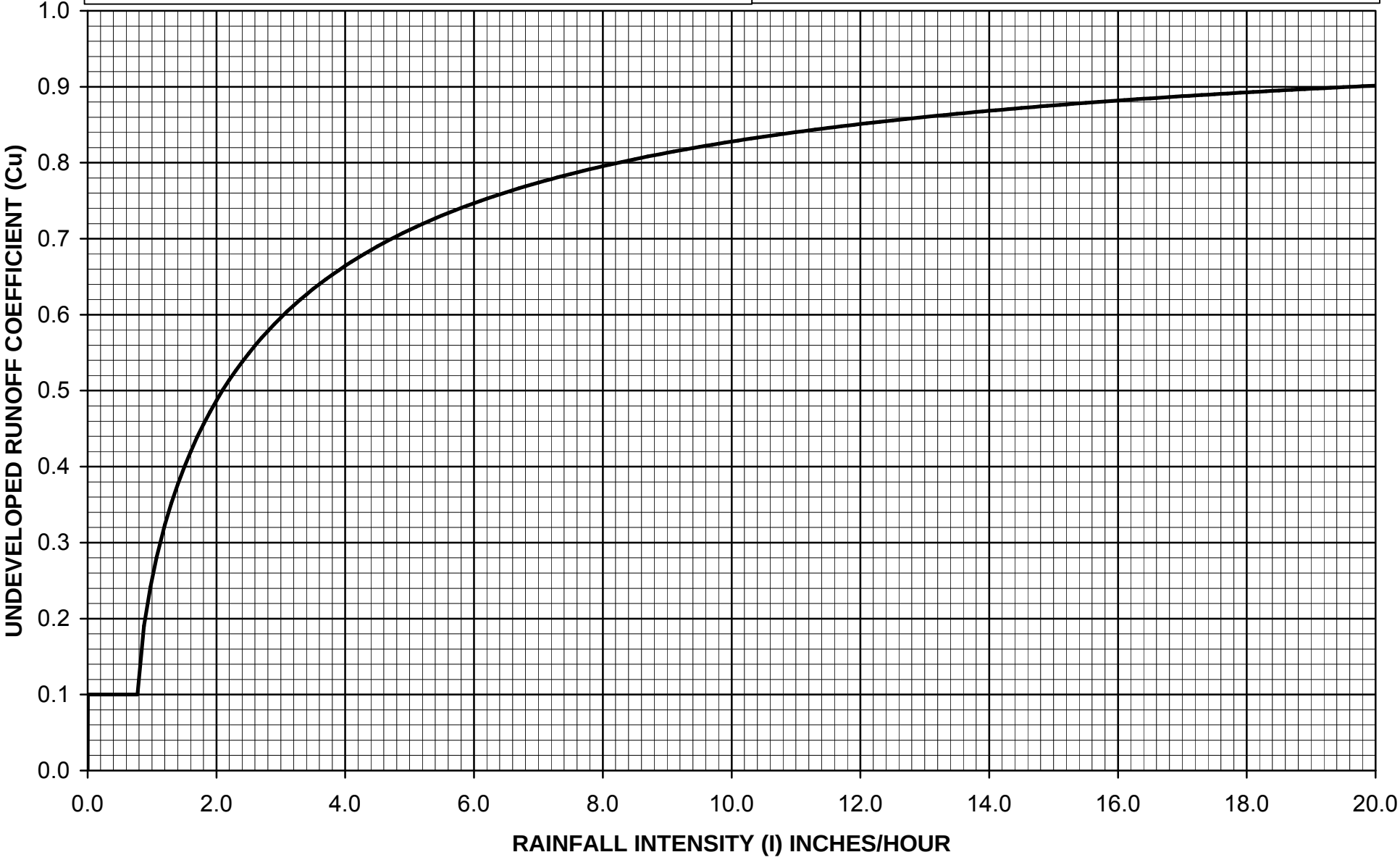


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 037

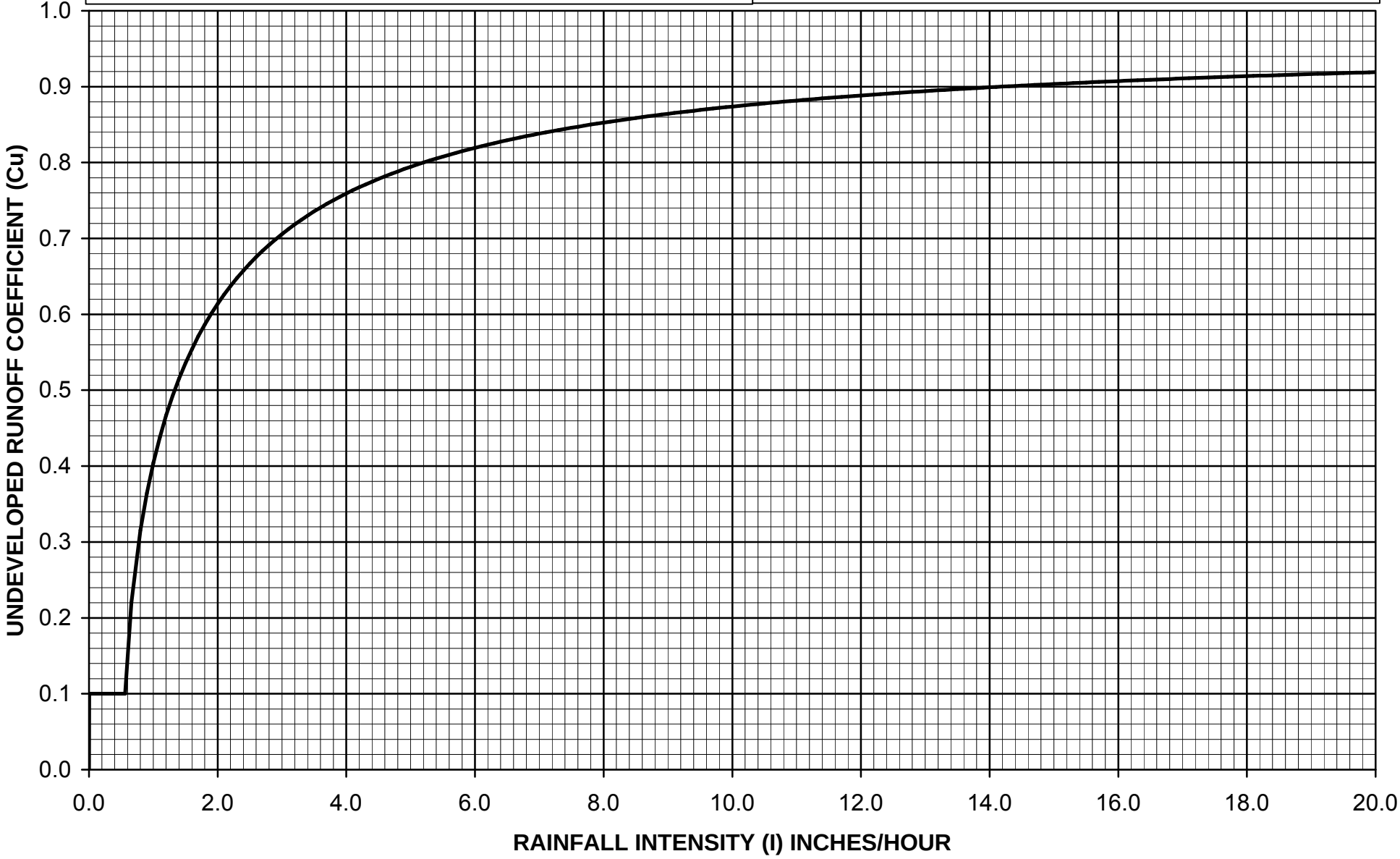


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 038

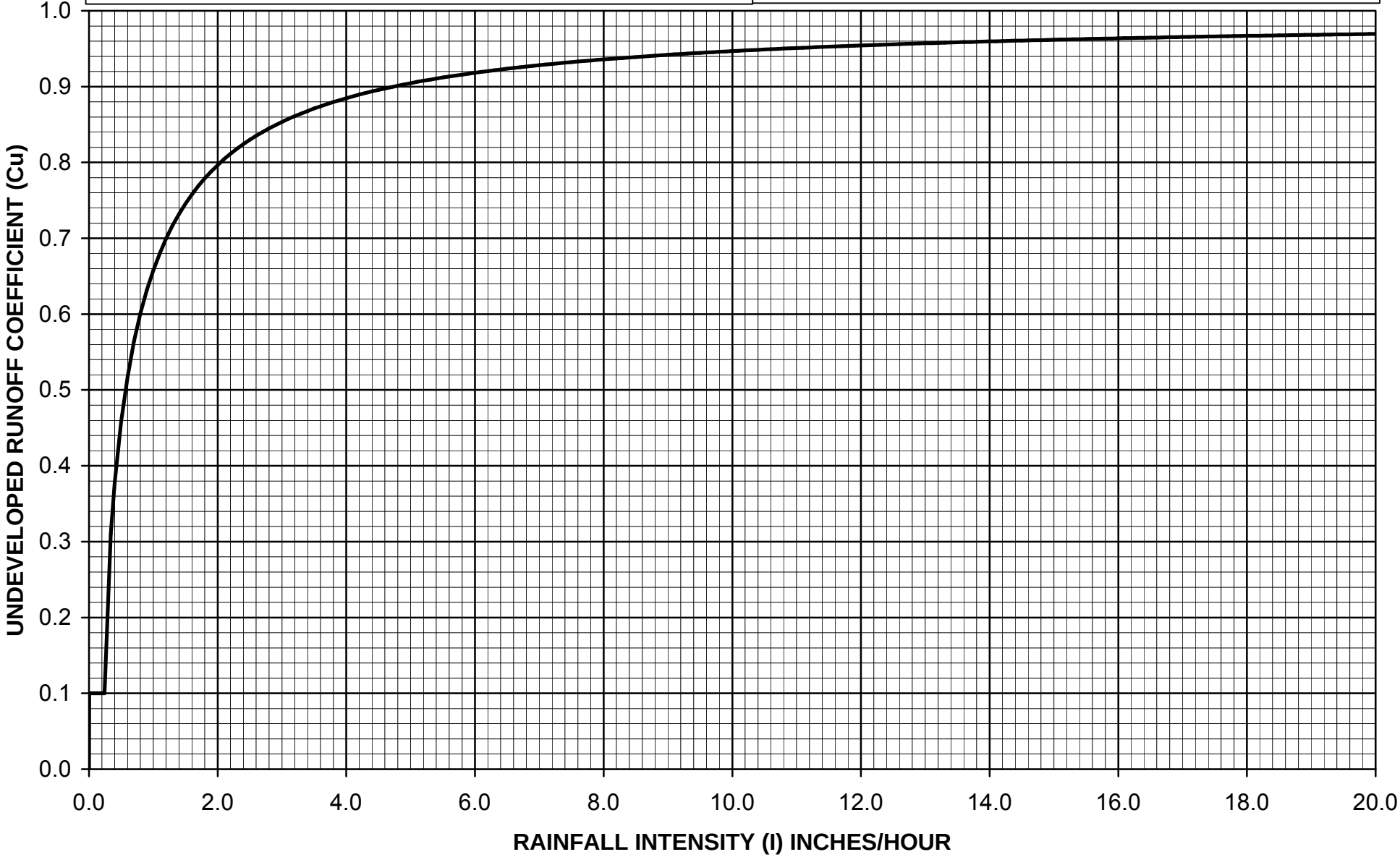


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 039

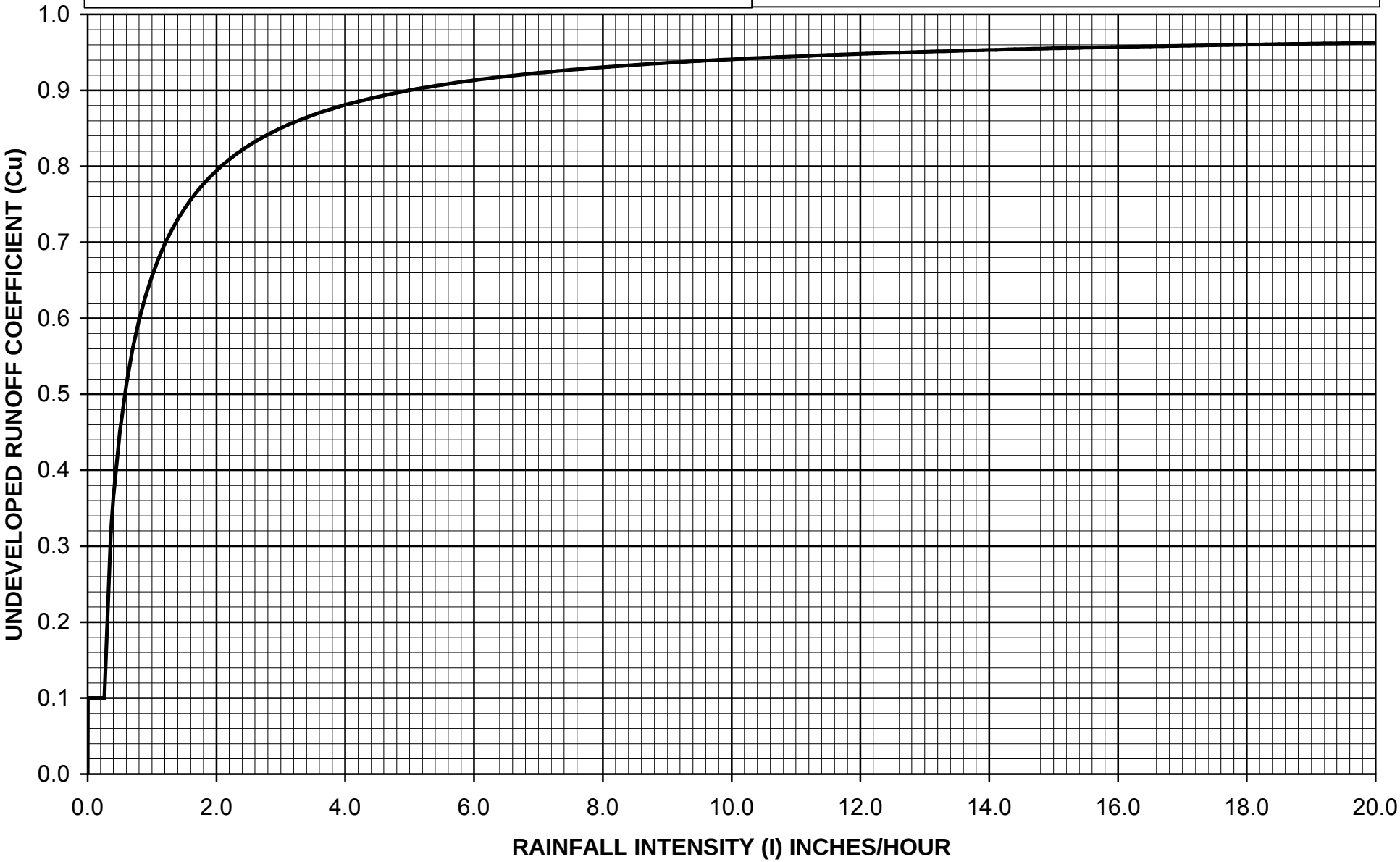


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 040

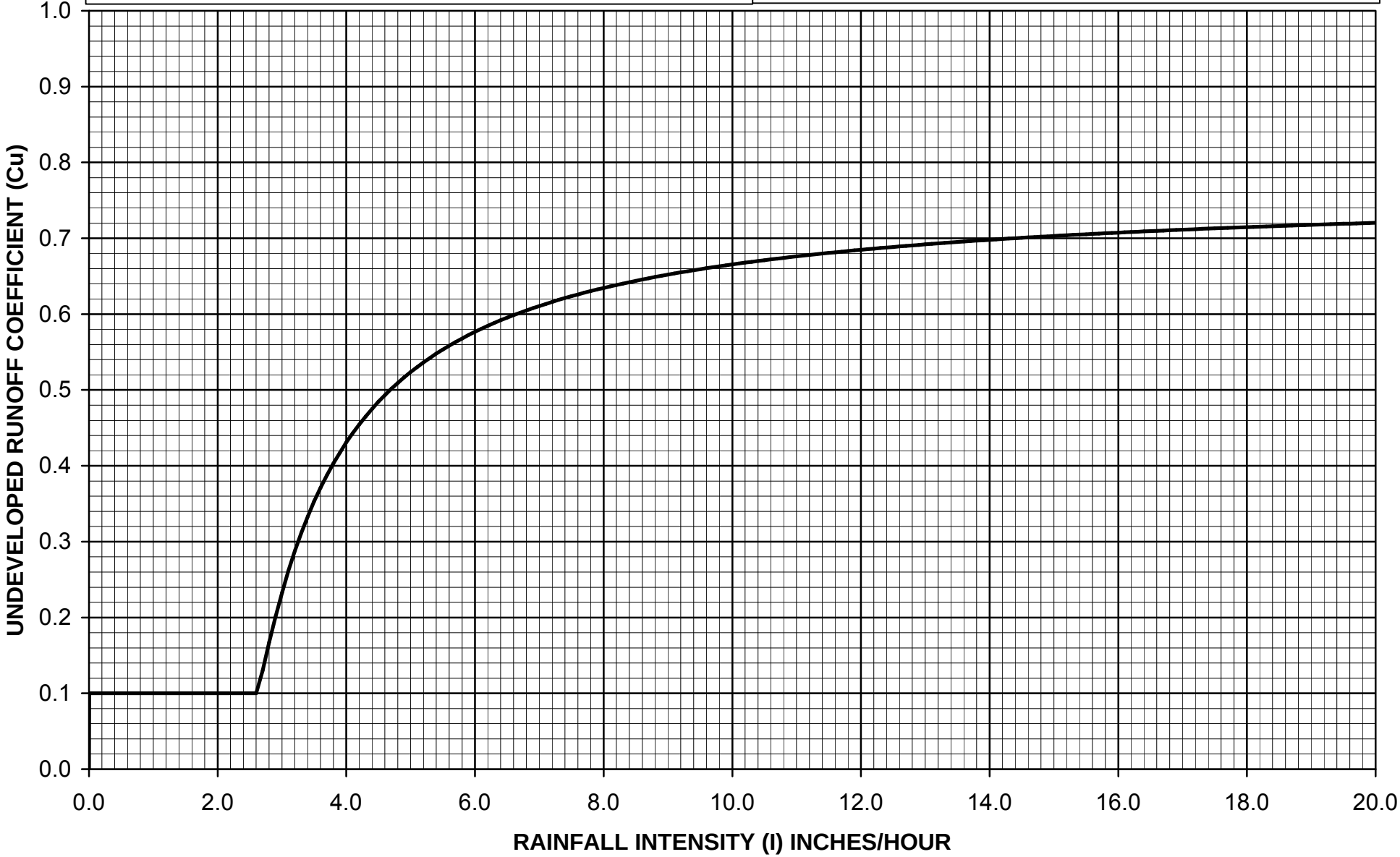


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 041

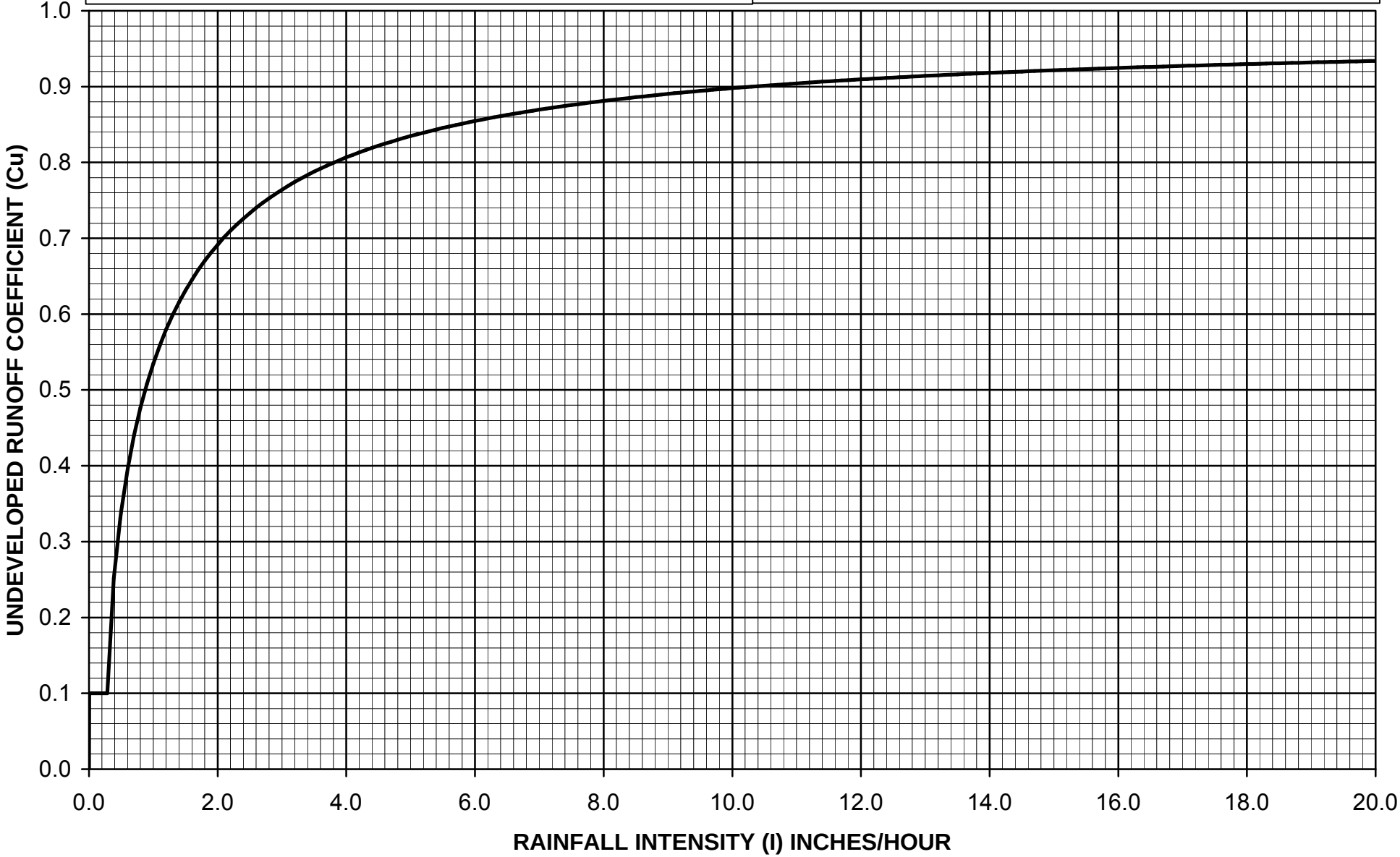


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 042

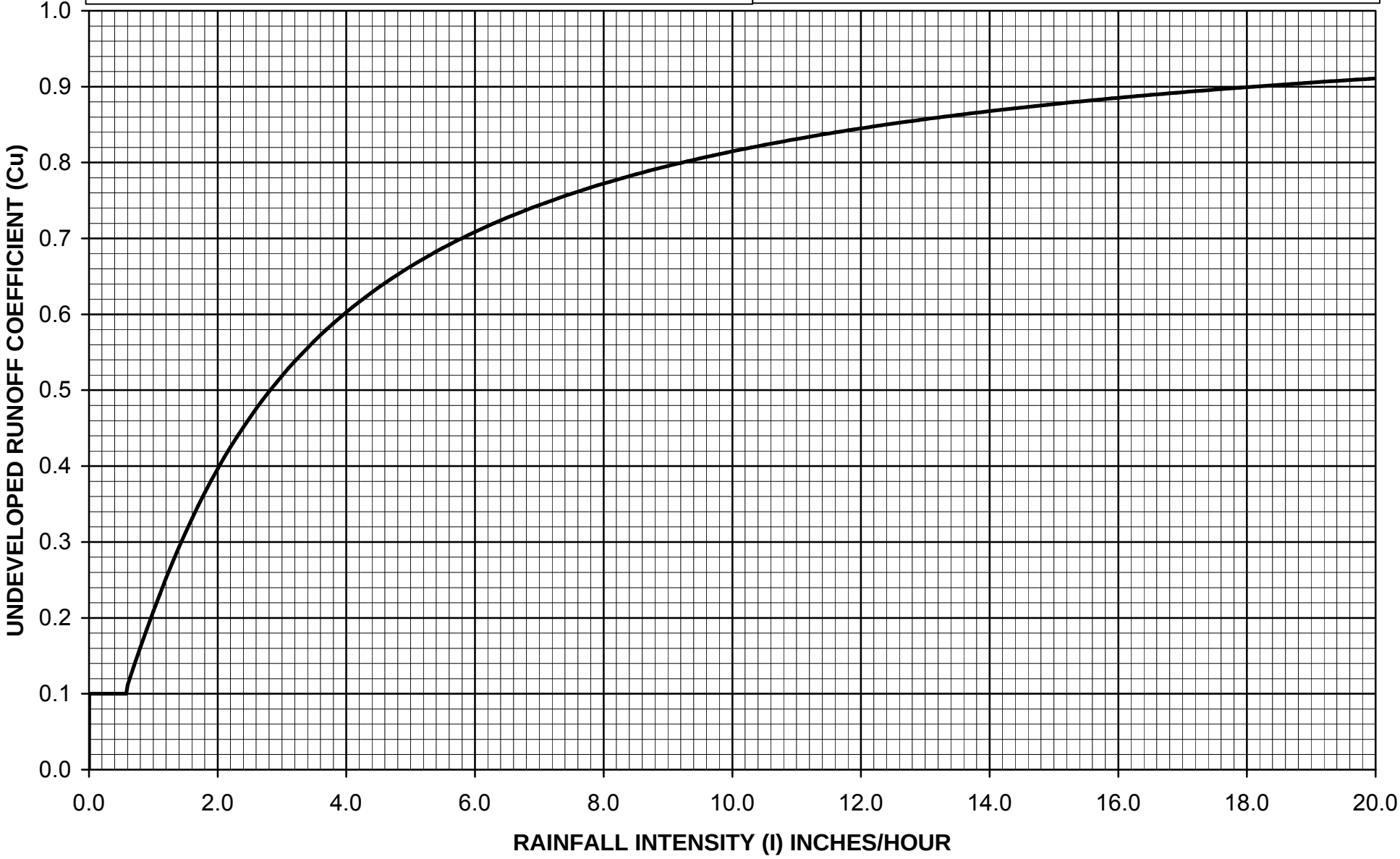


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 043

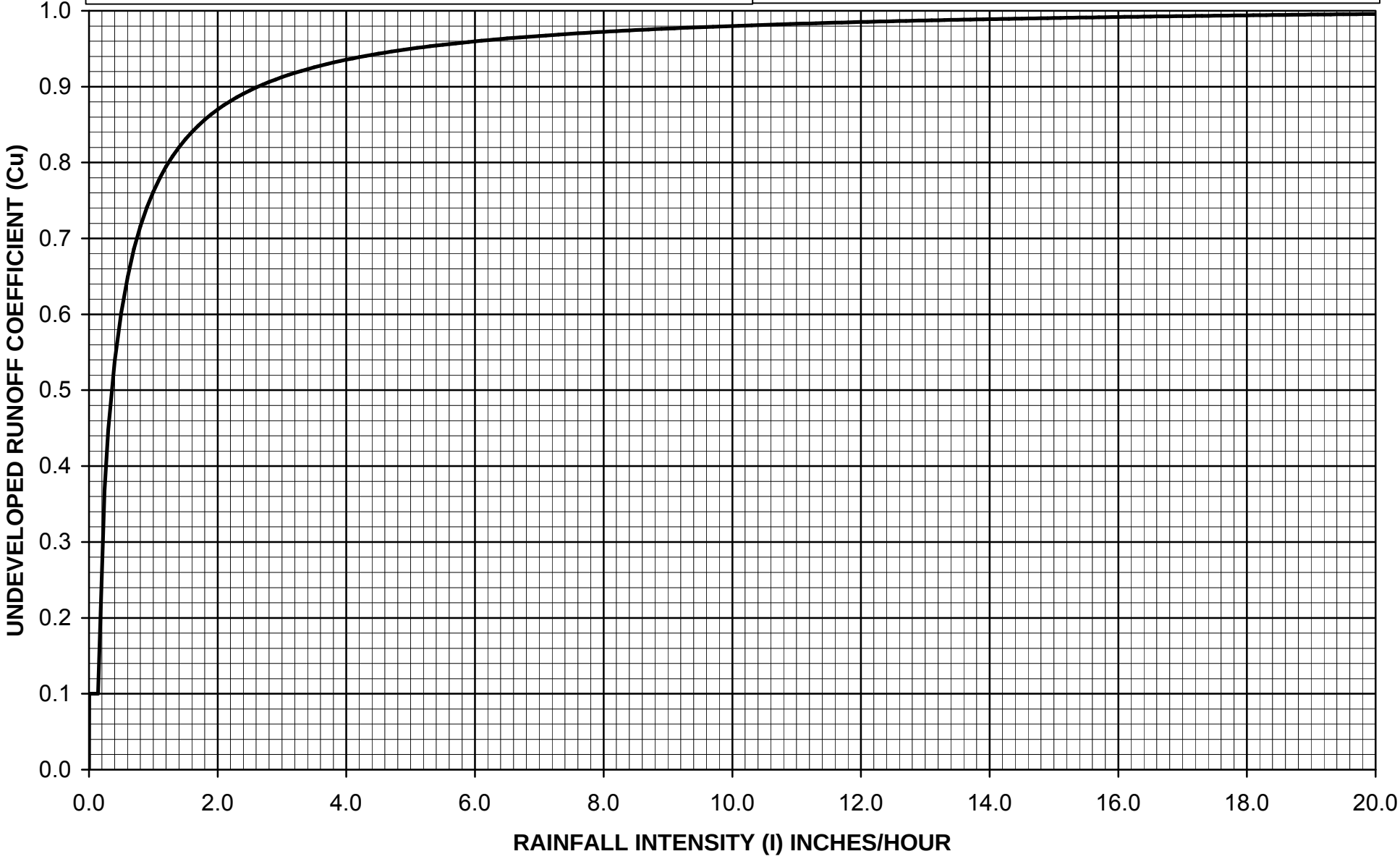


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 044

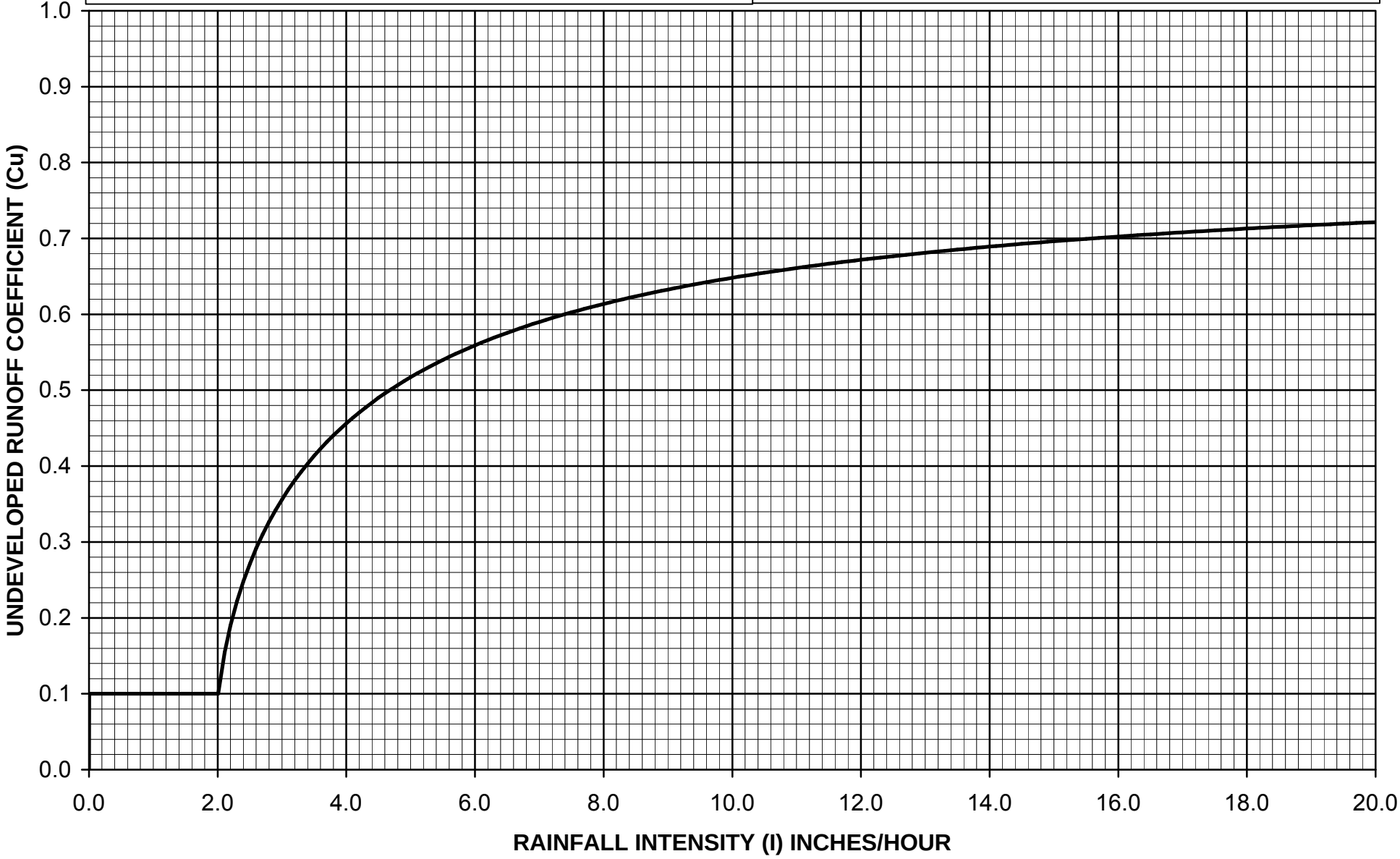


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 045

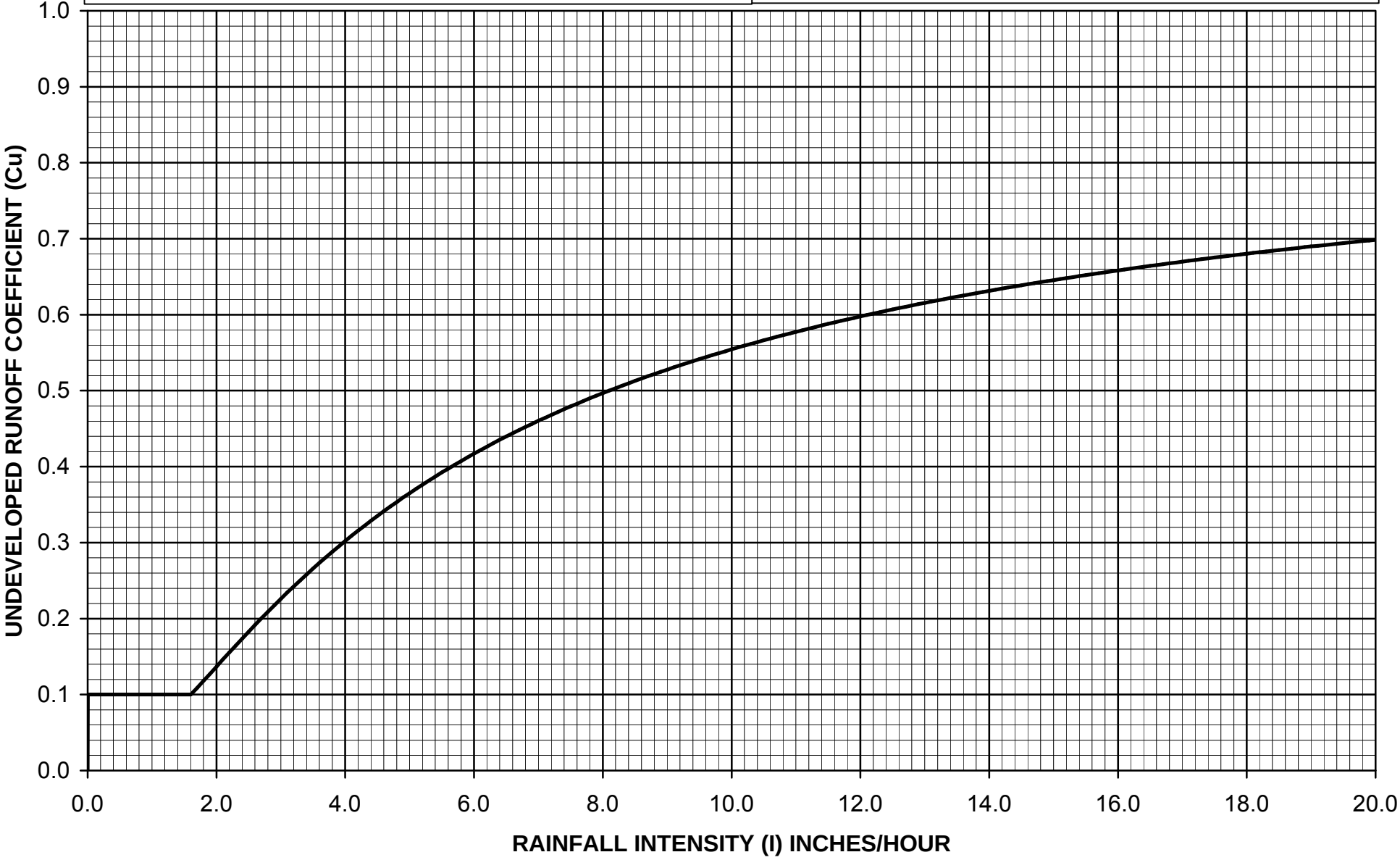


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 046

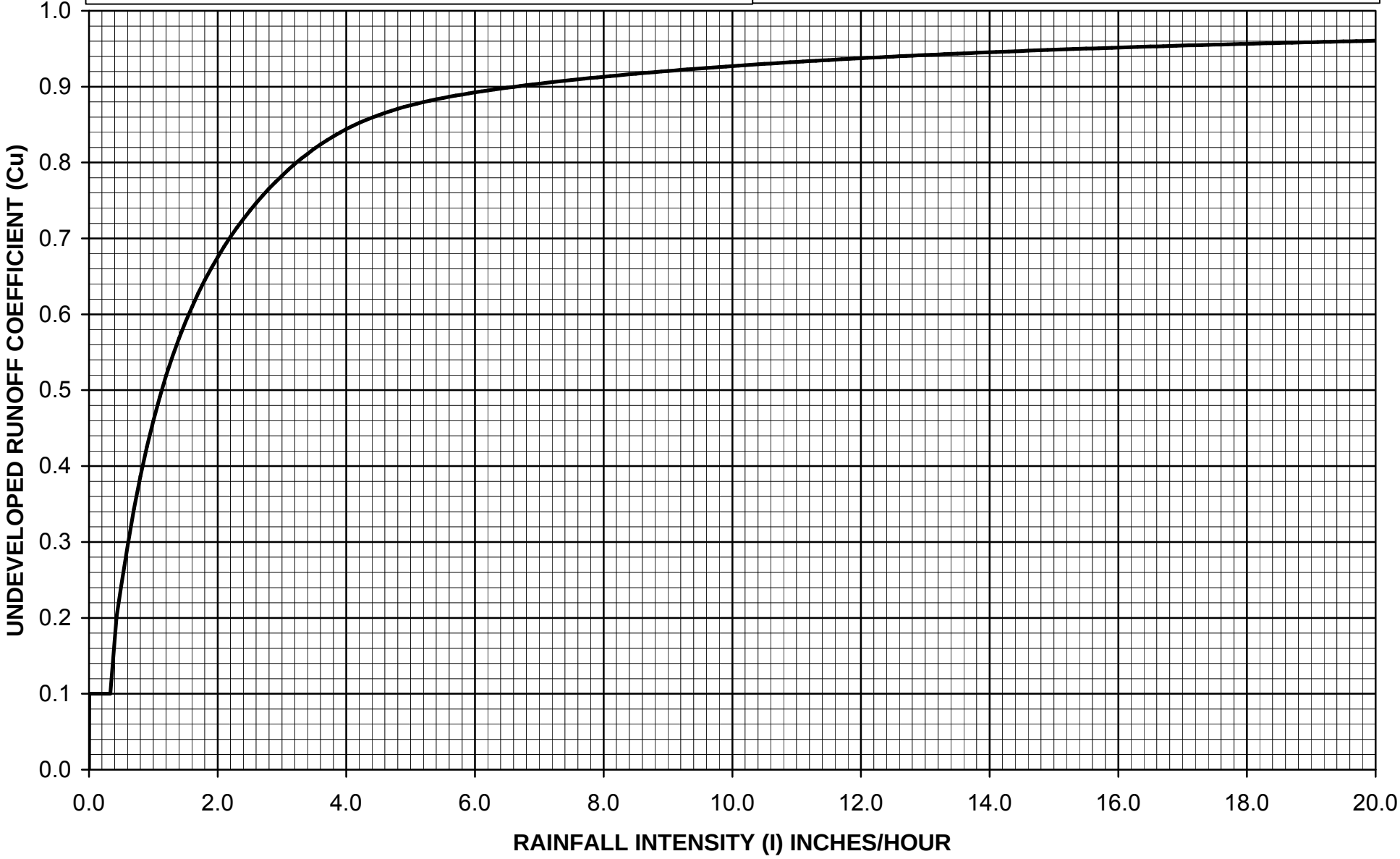


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 047

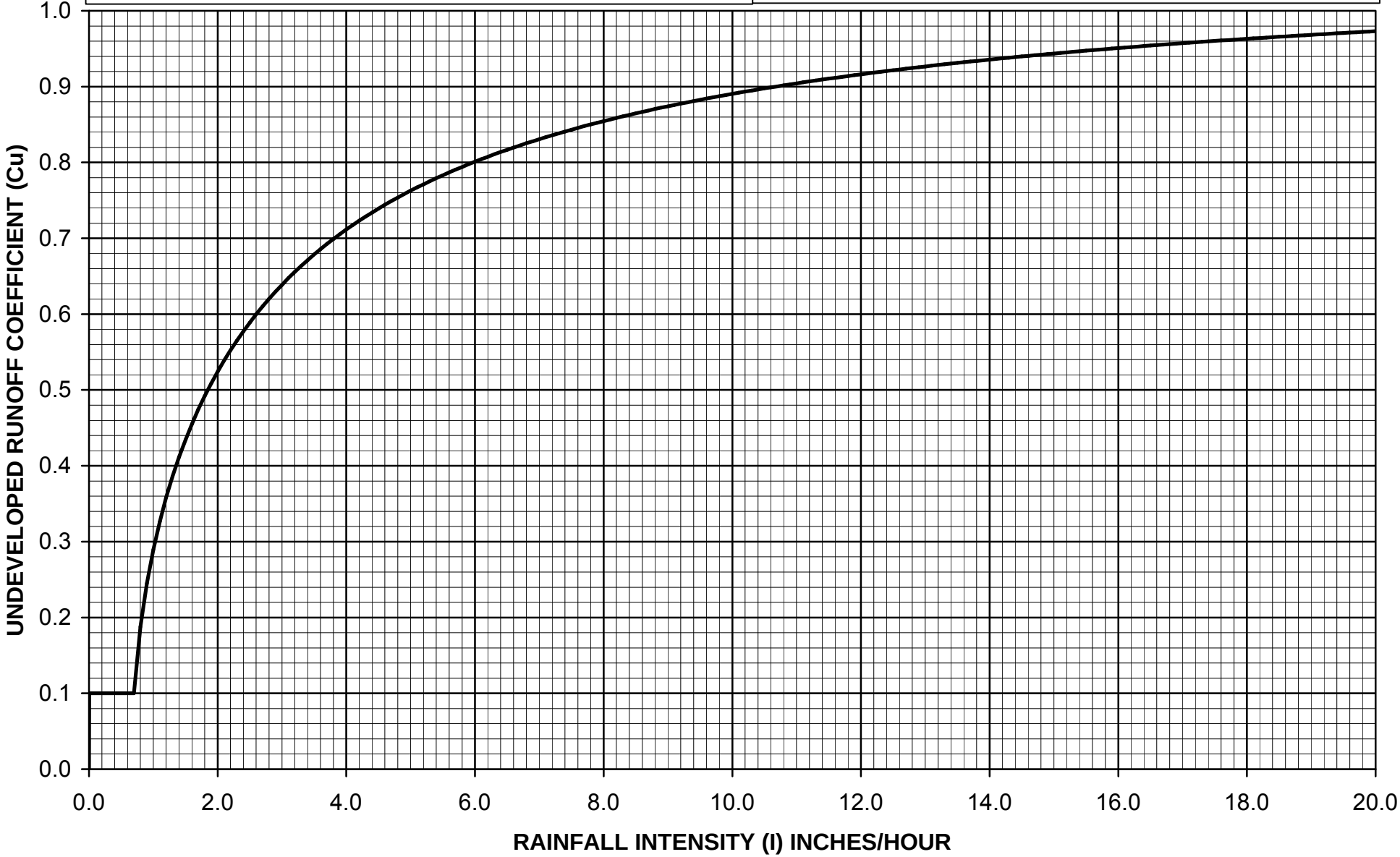


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 048

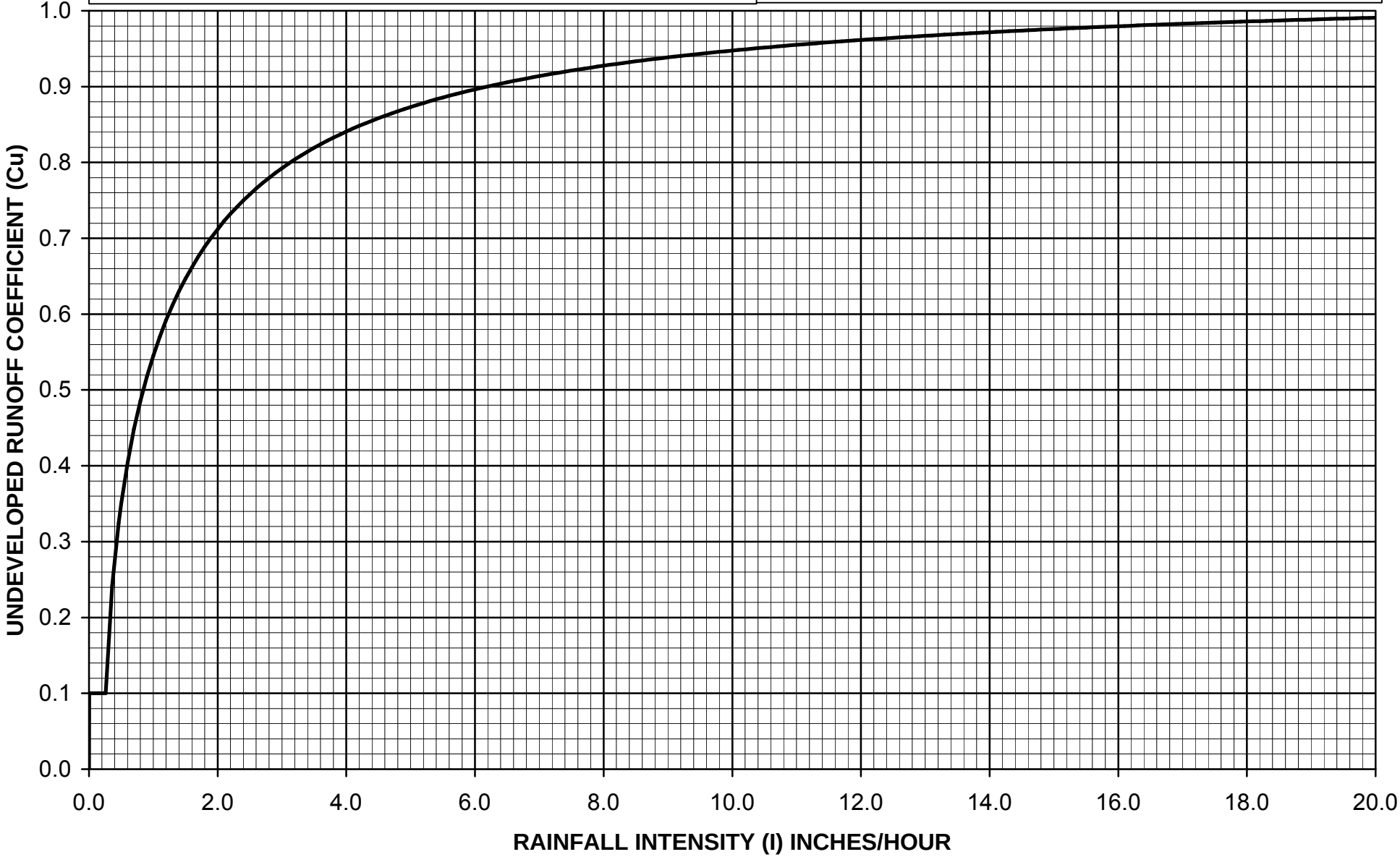


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 049

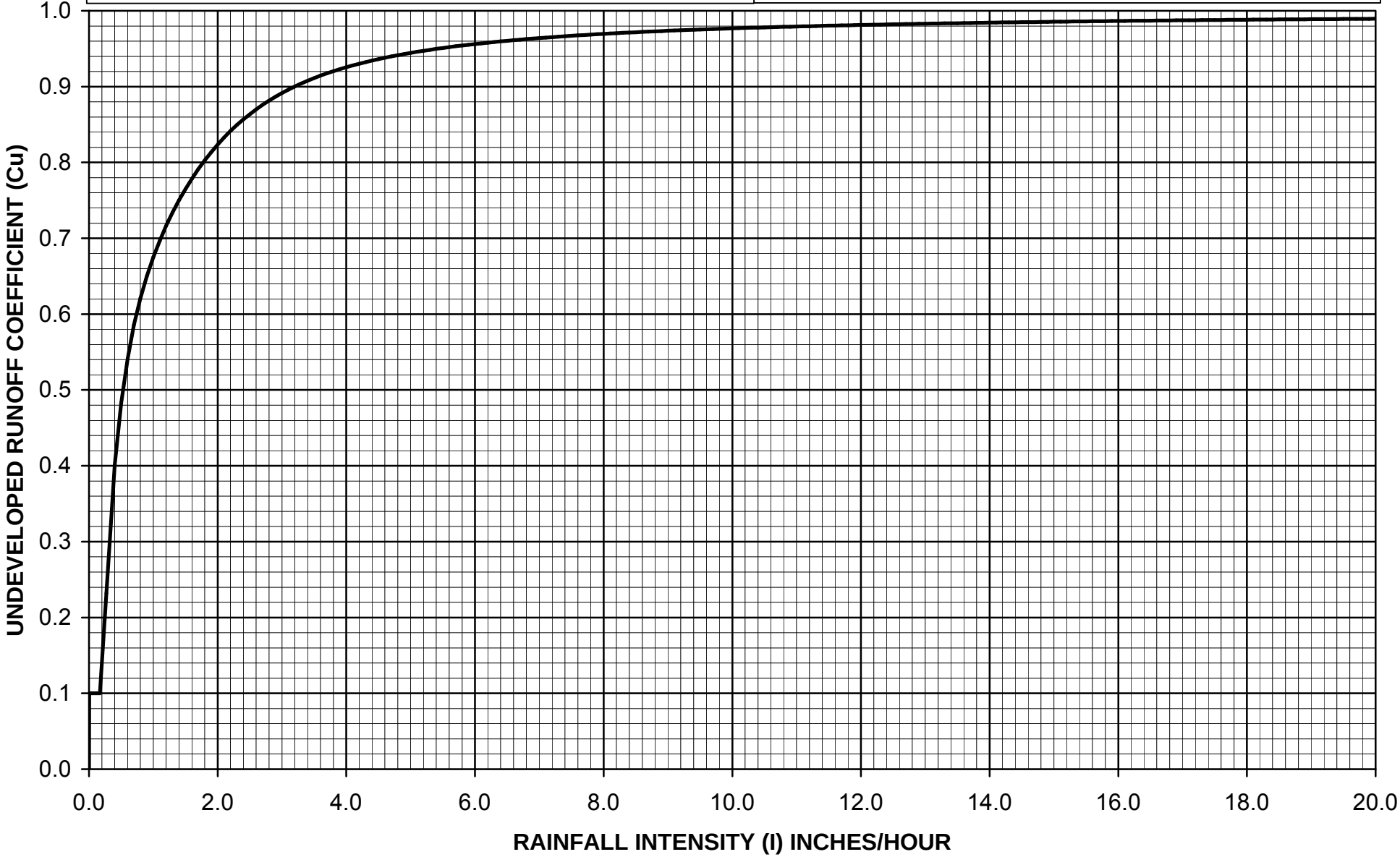


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 050

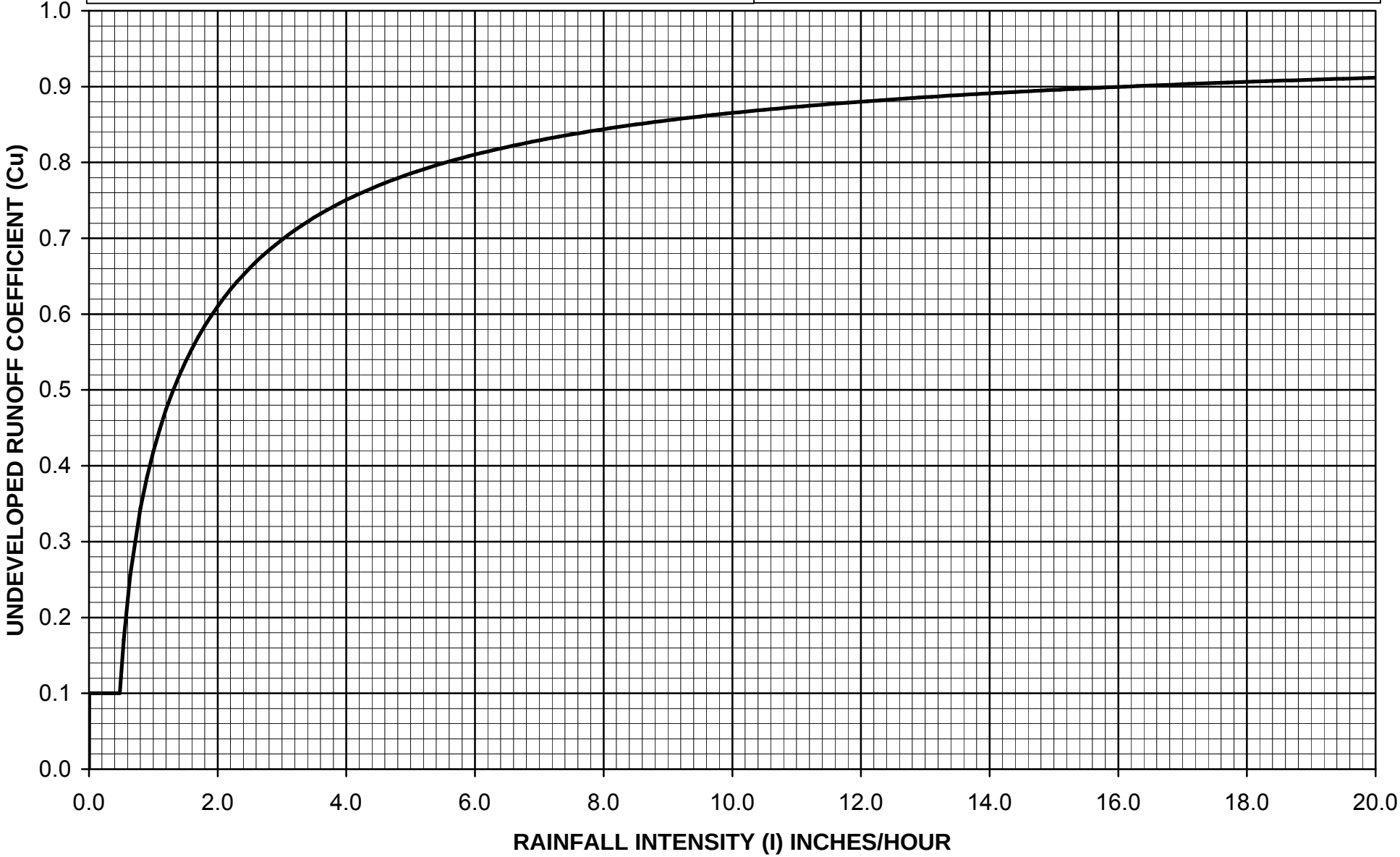


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 051

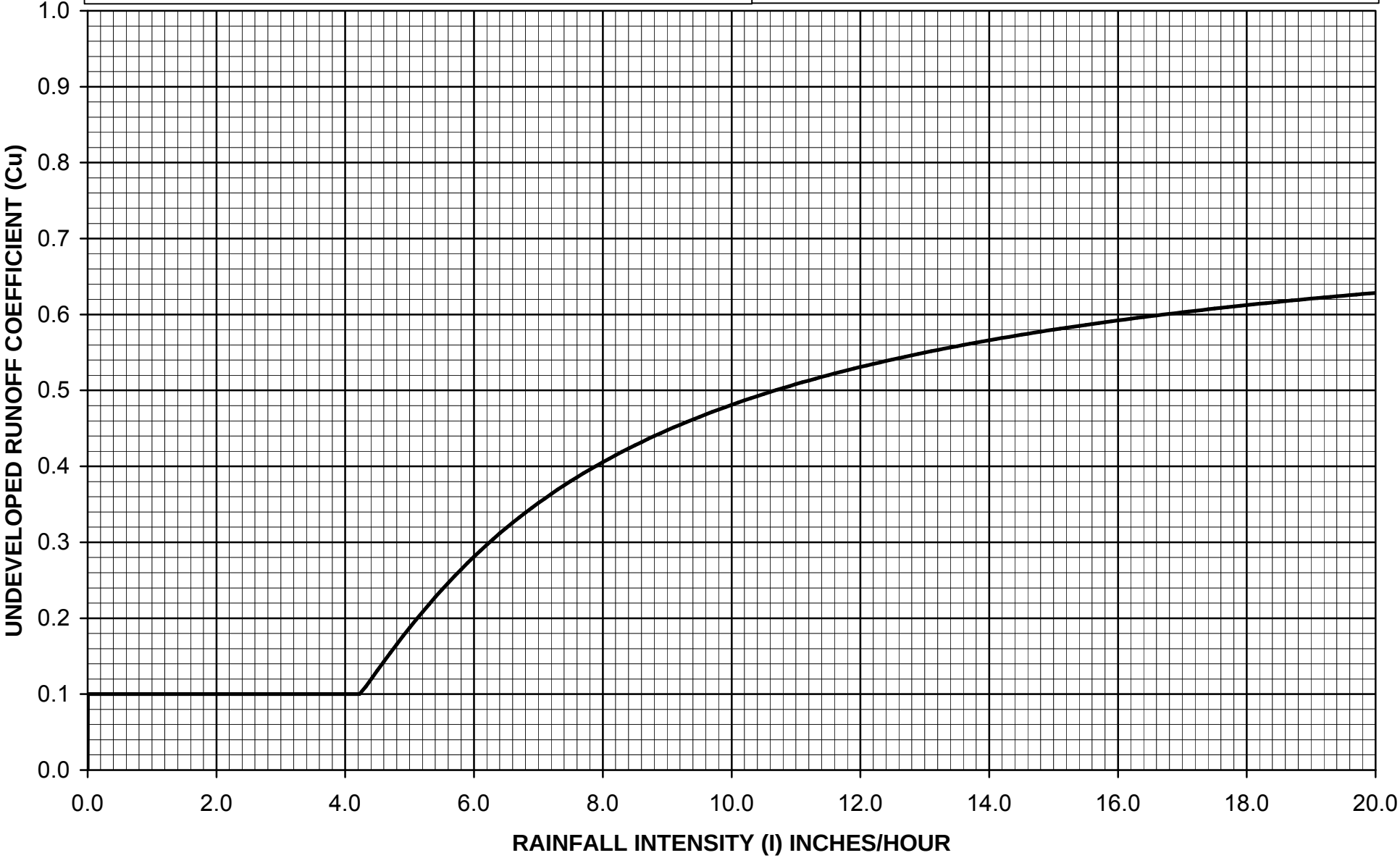


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 052

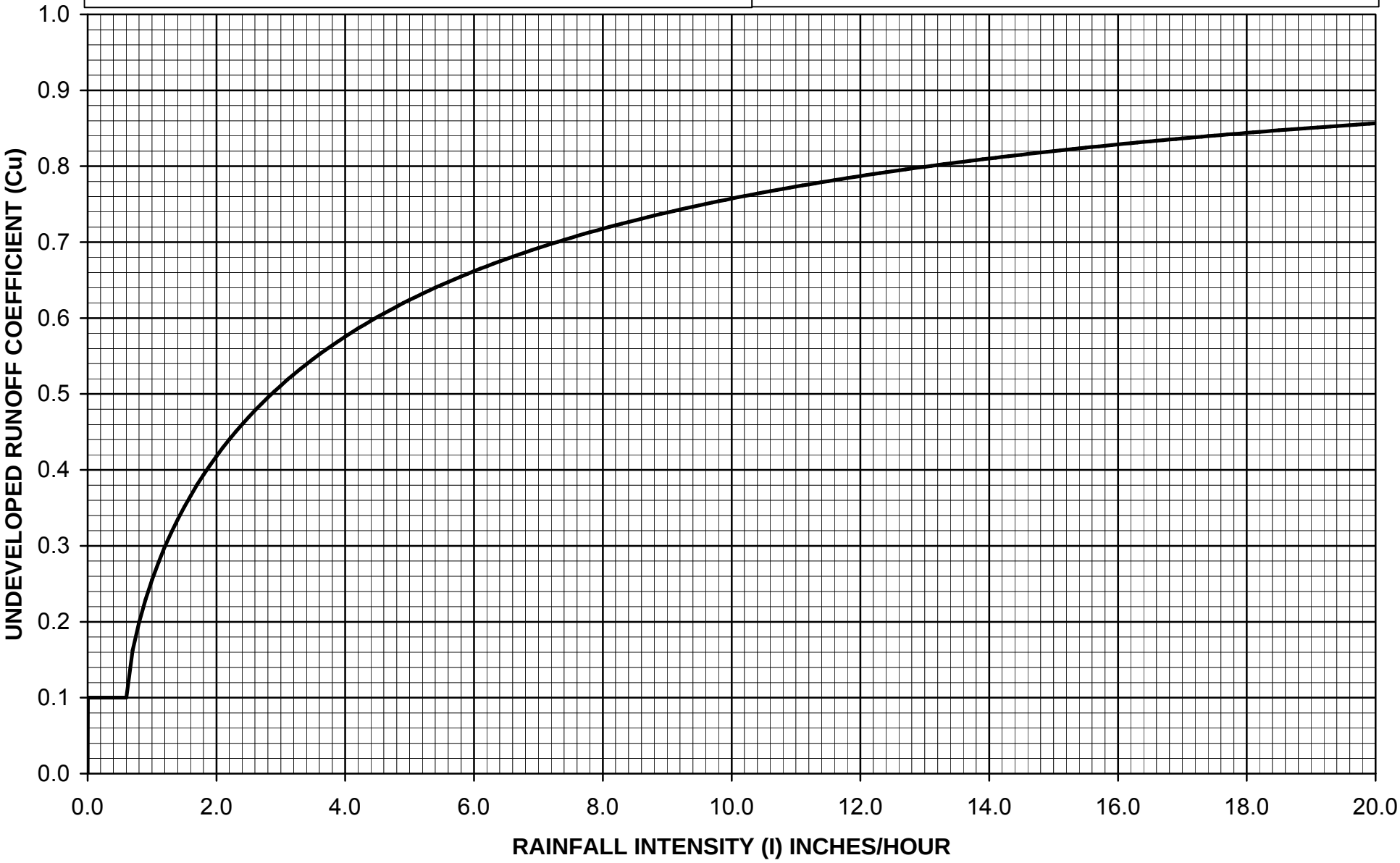


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 053

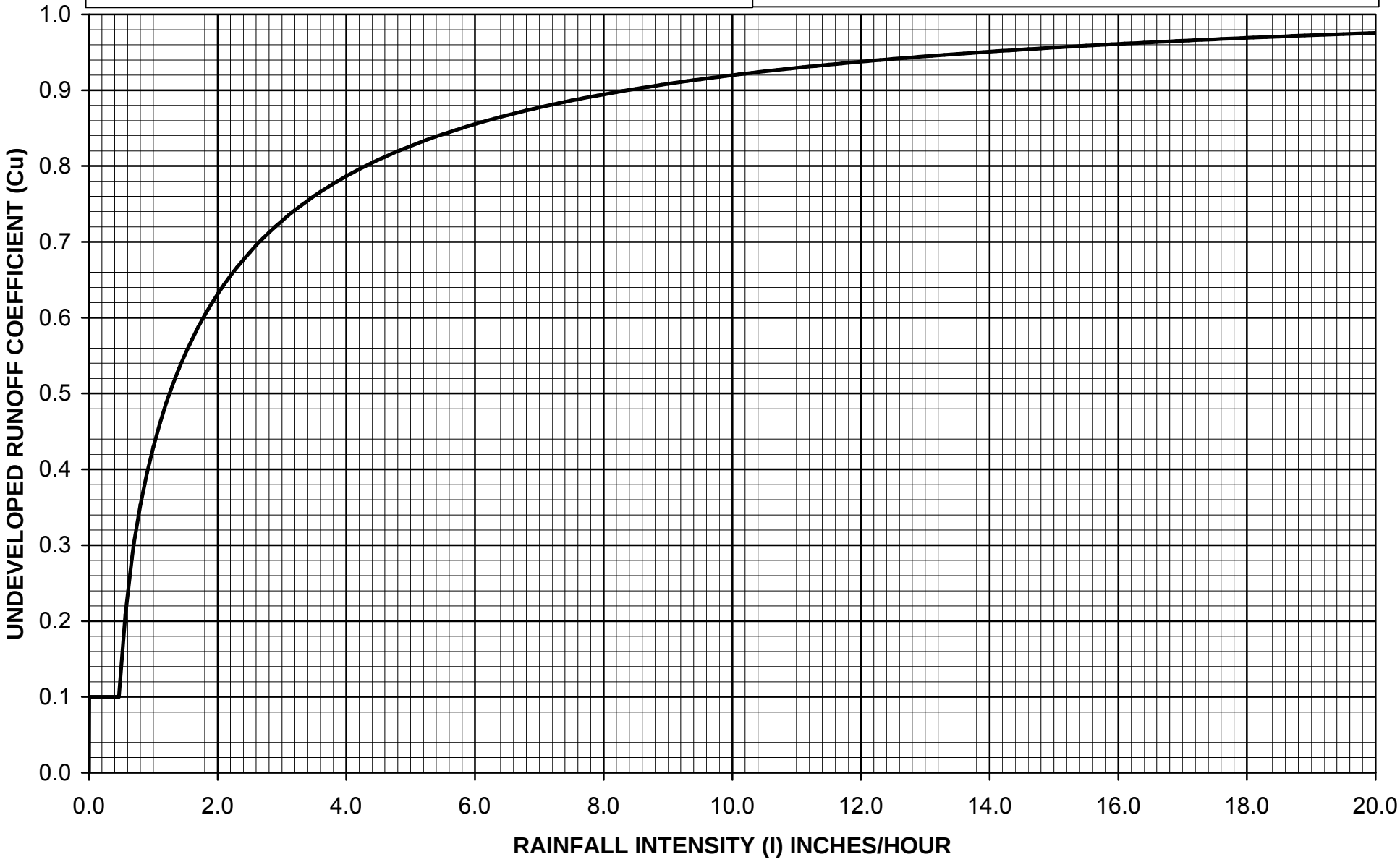


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 054

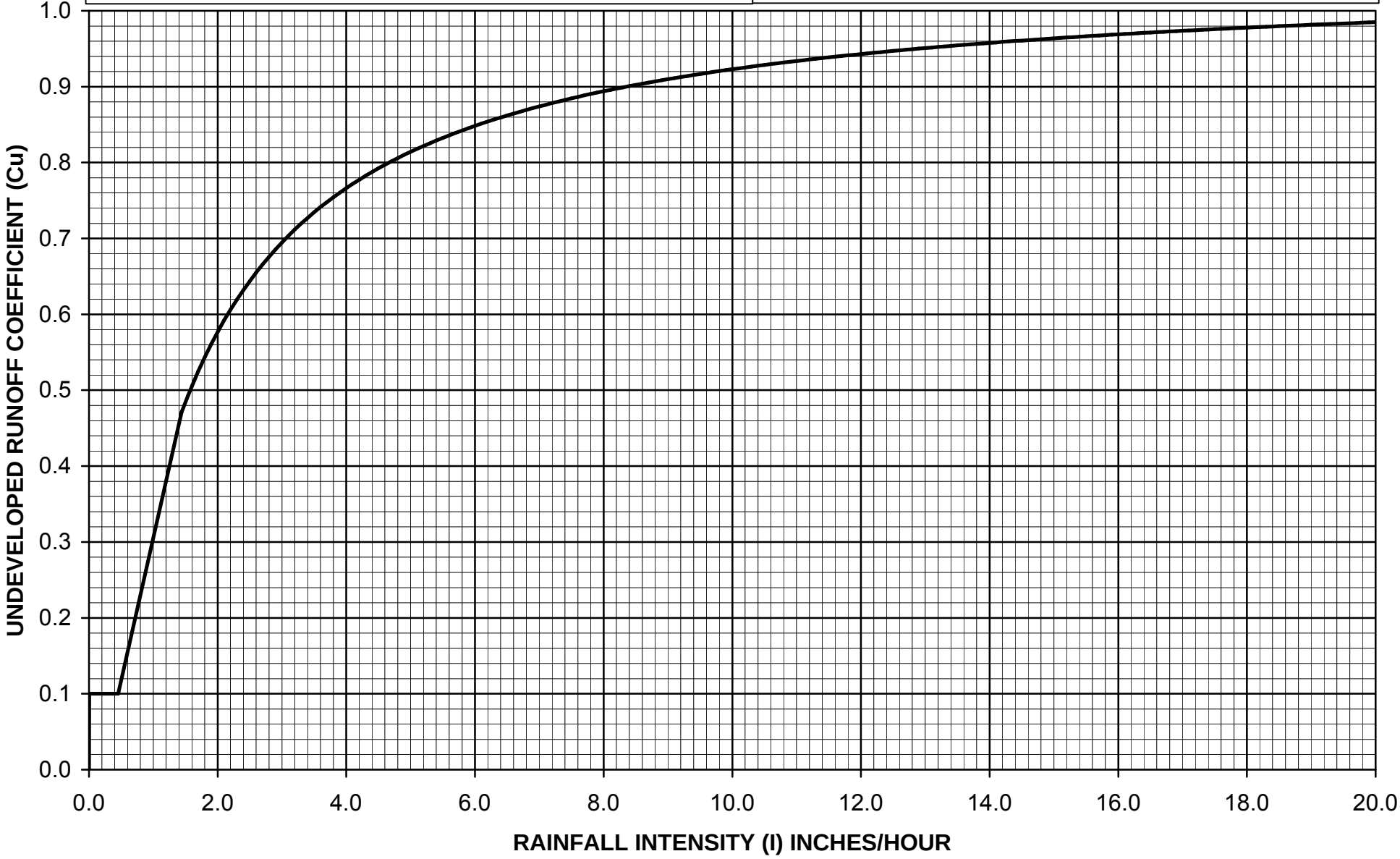


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 055

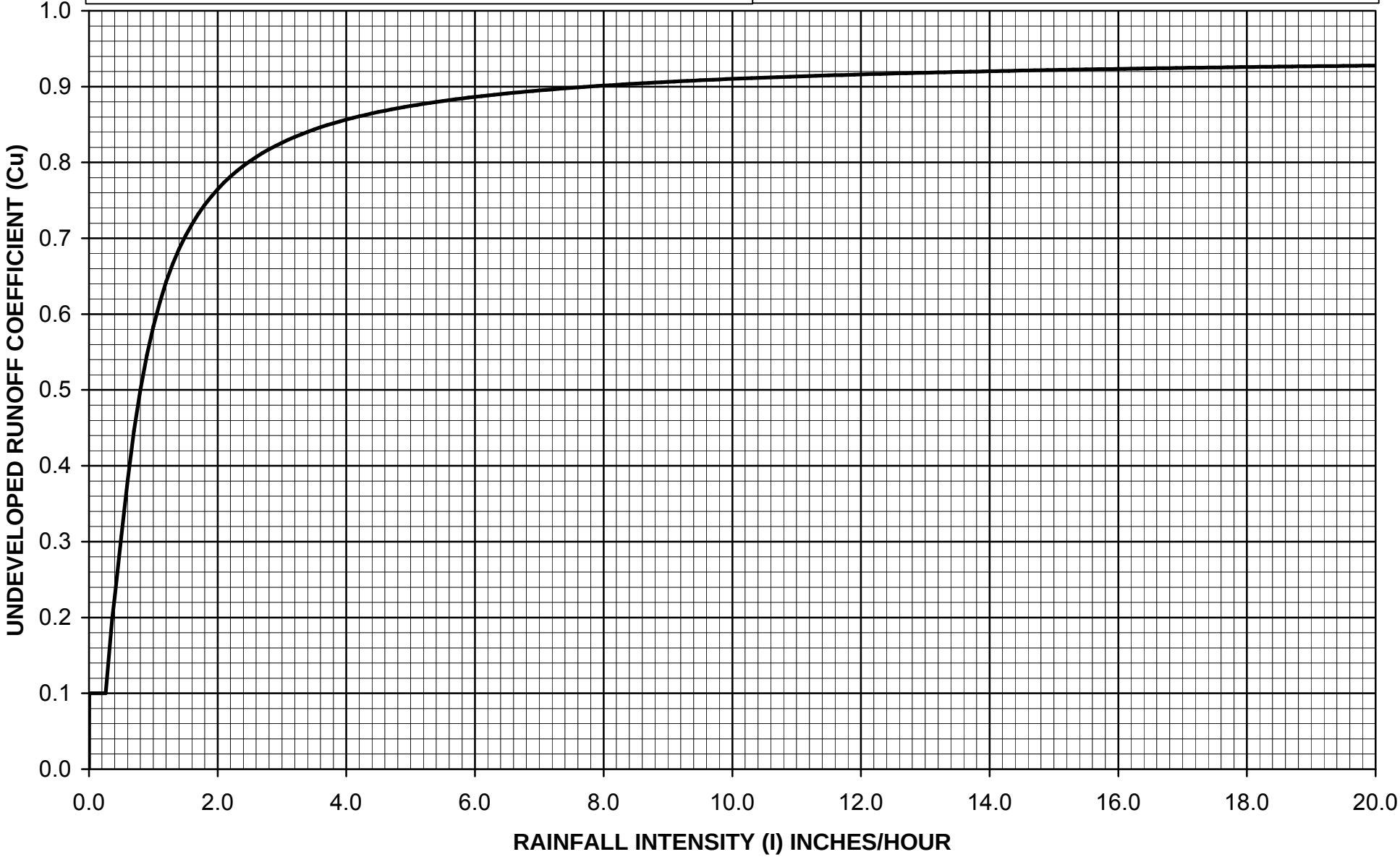


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 056

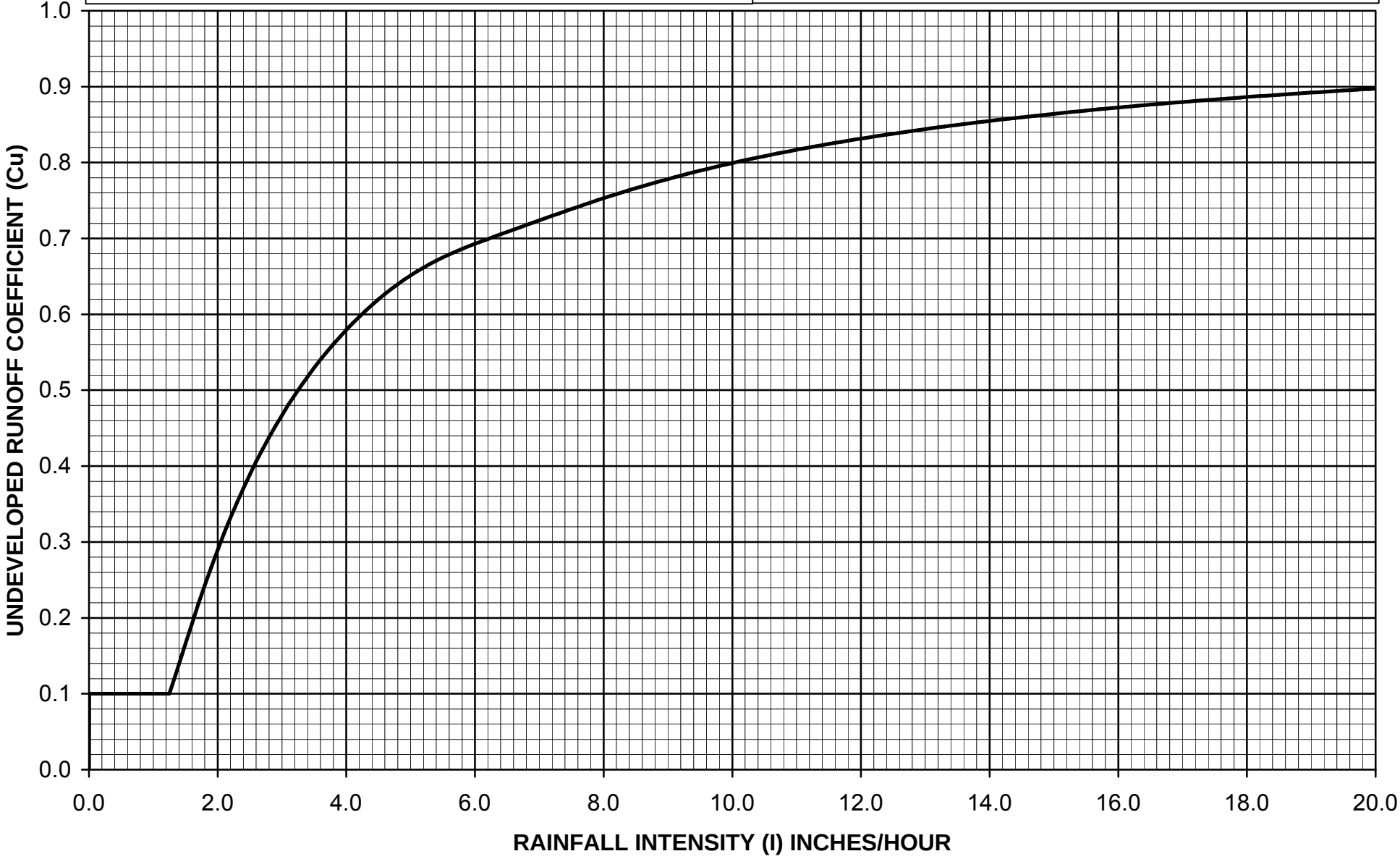


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 057

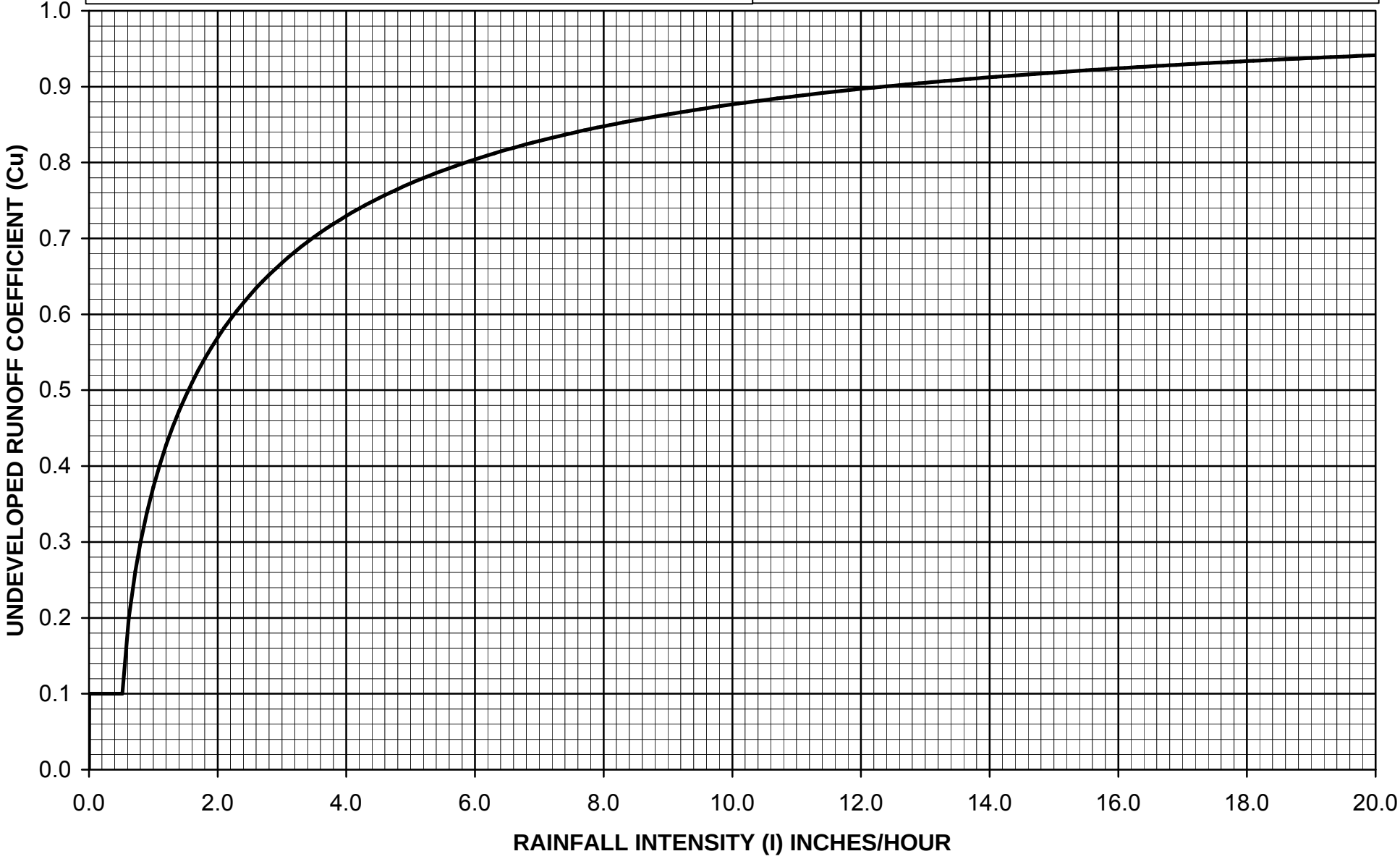


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 058

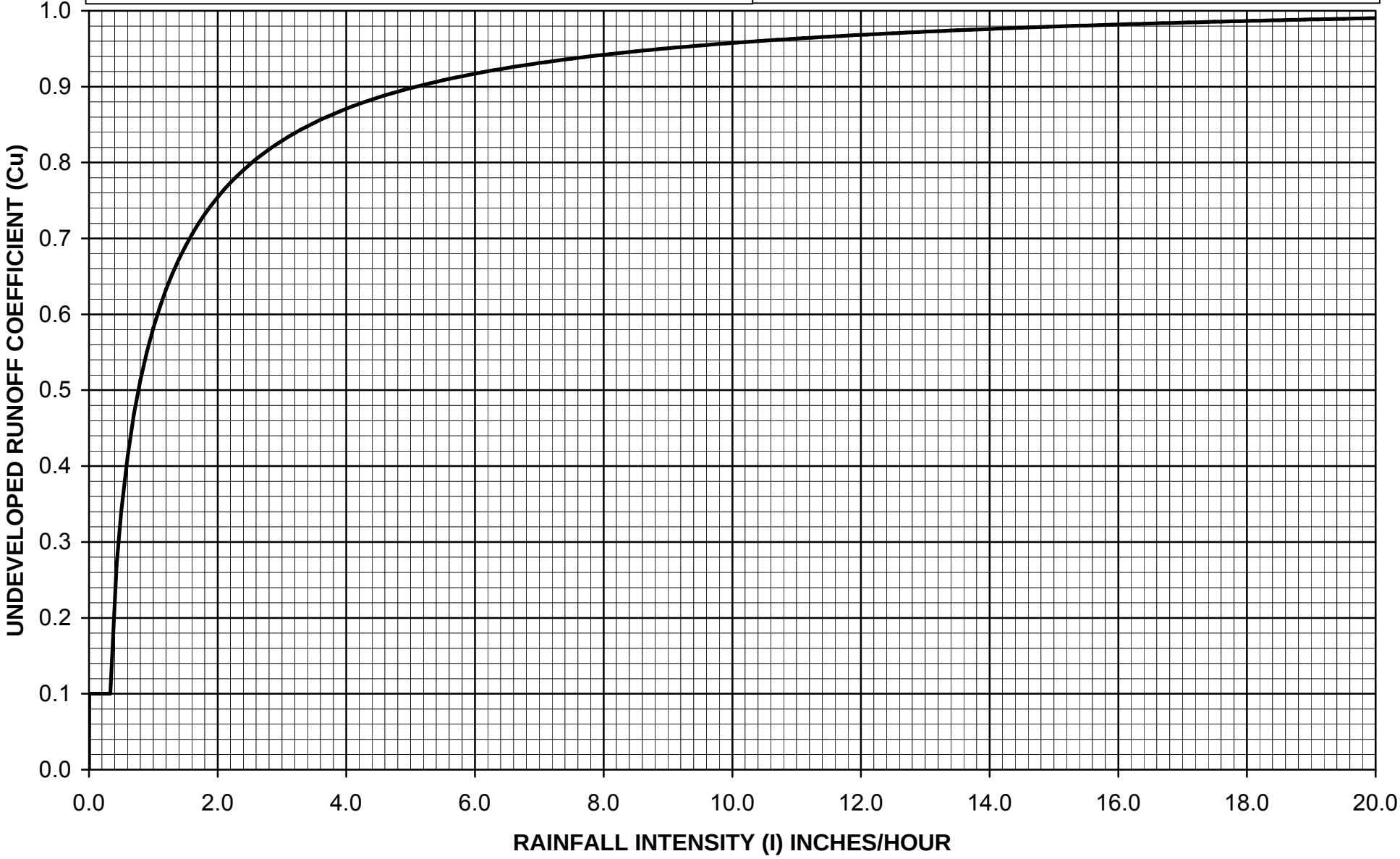


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 059

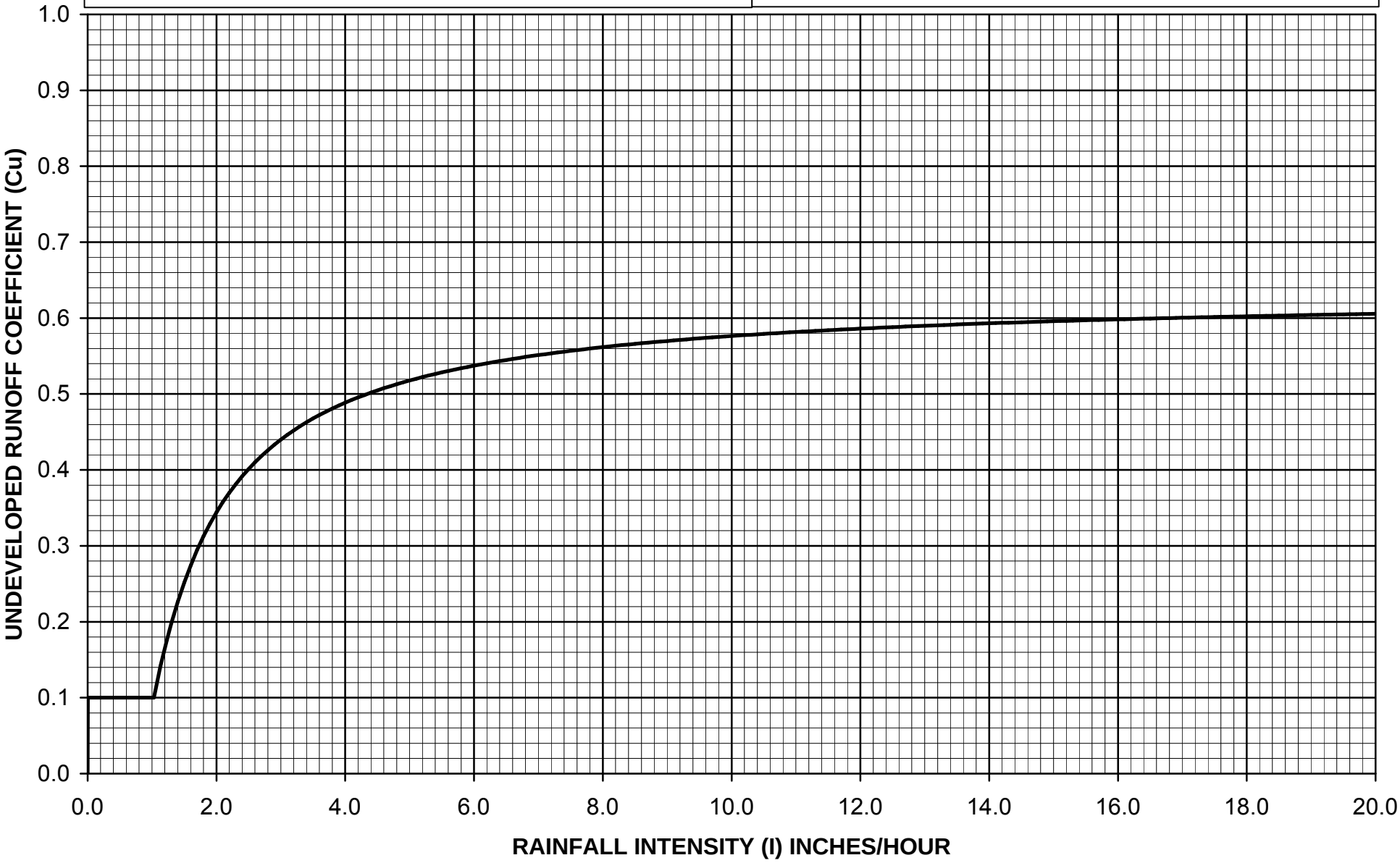


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 060

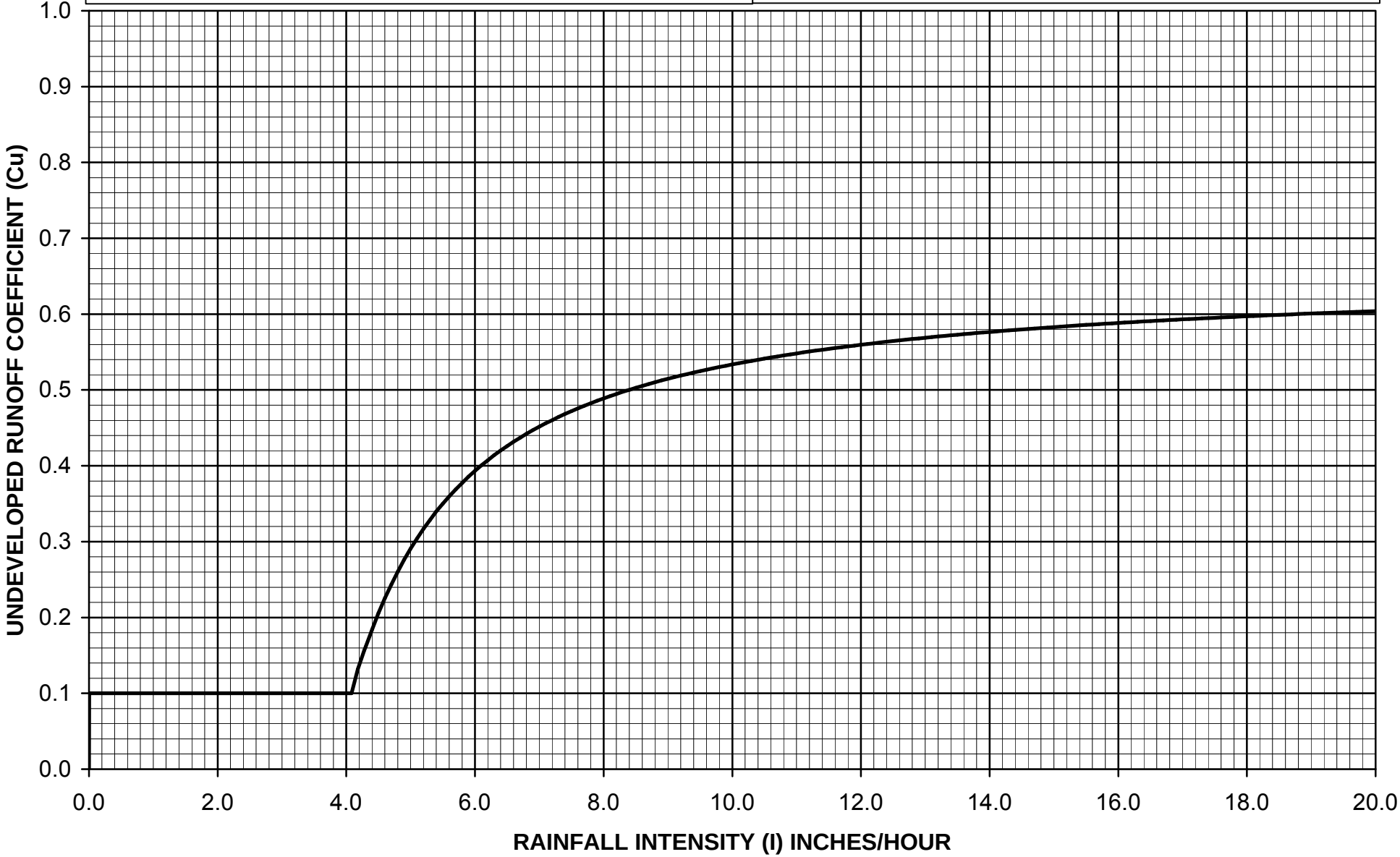


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 061

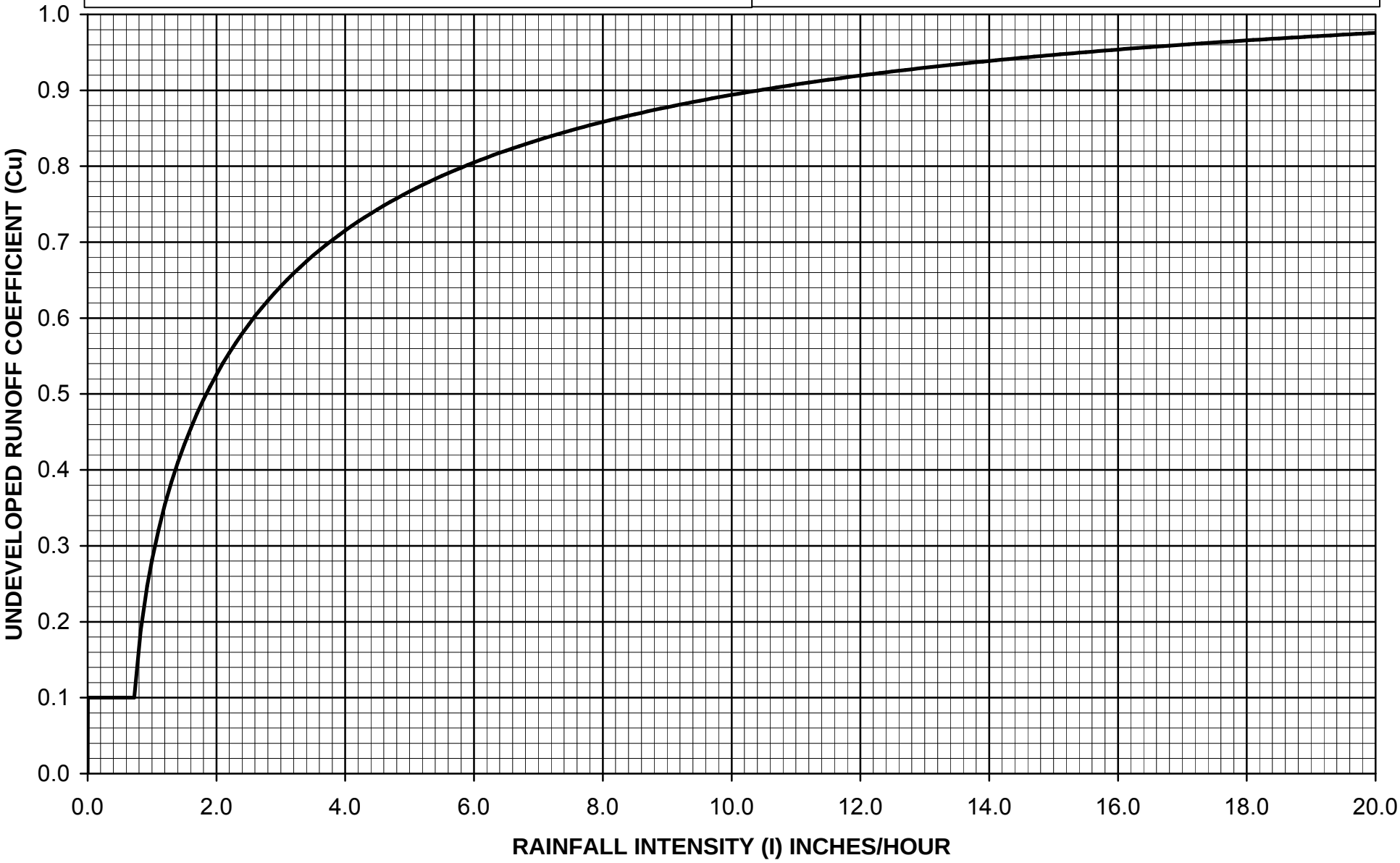


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 062

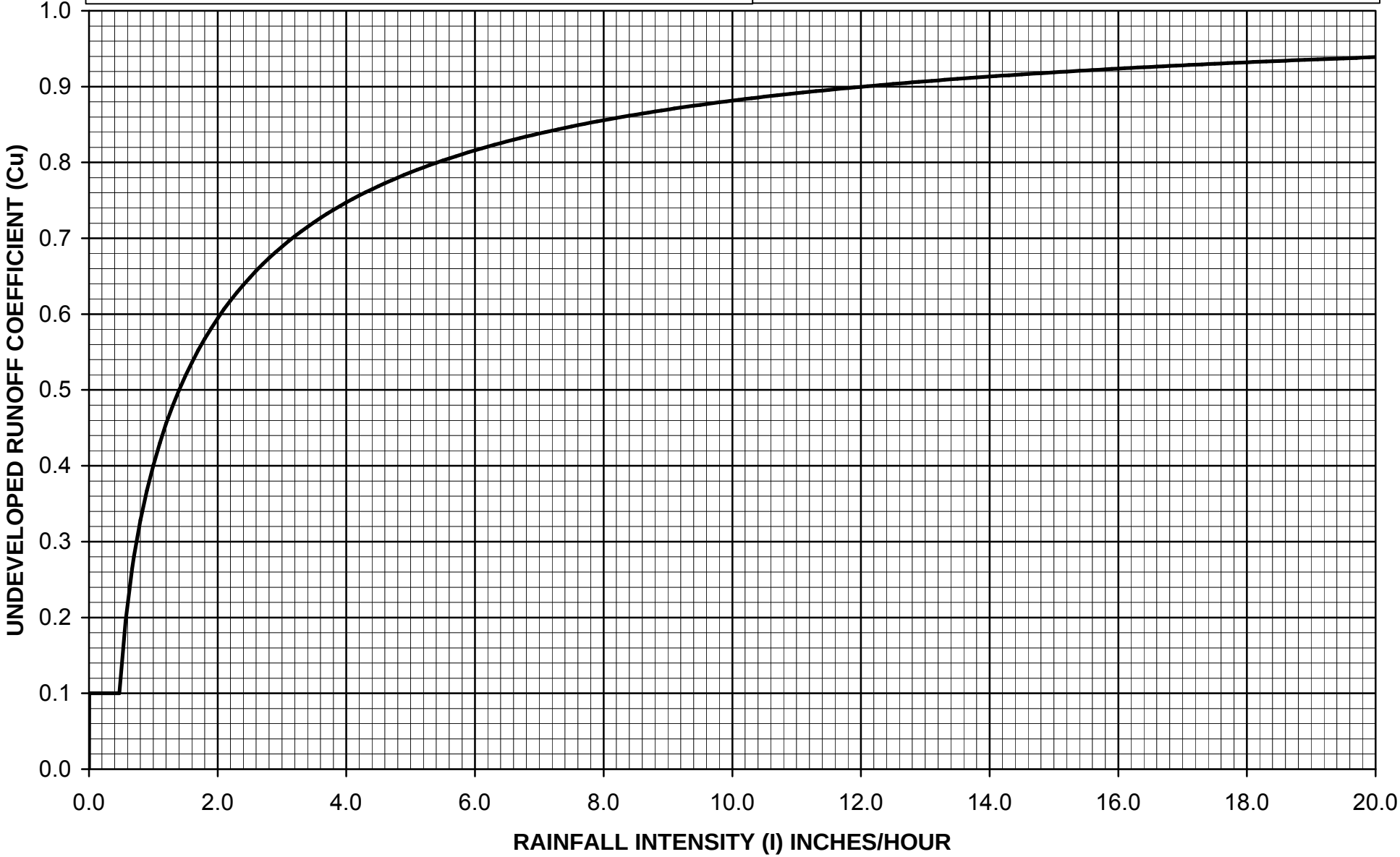


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 063

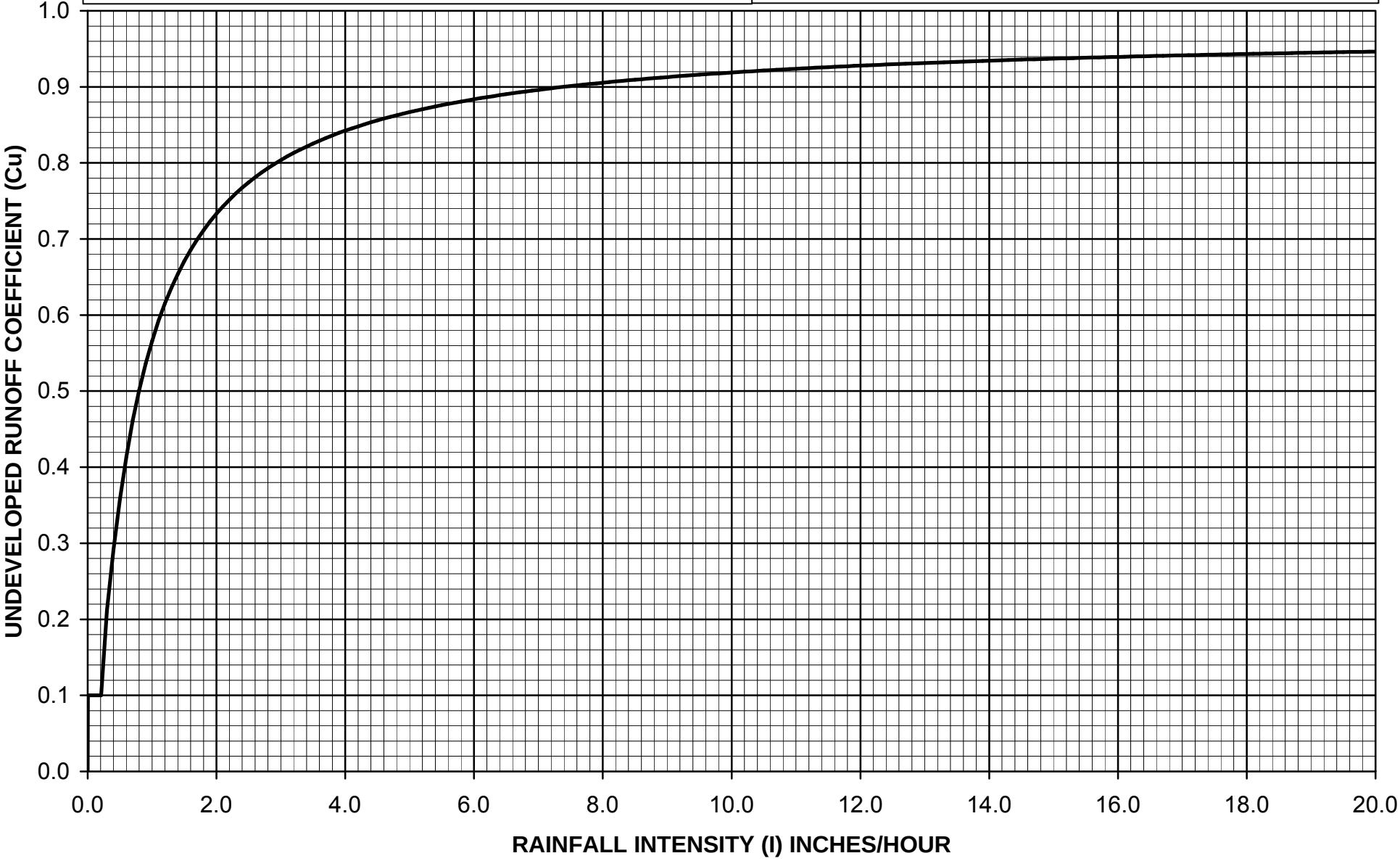


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 064

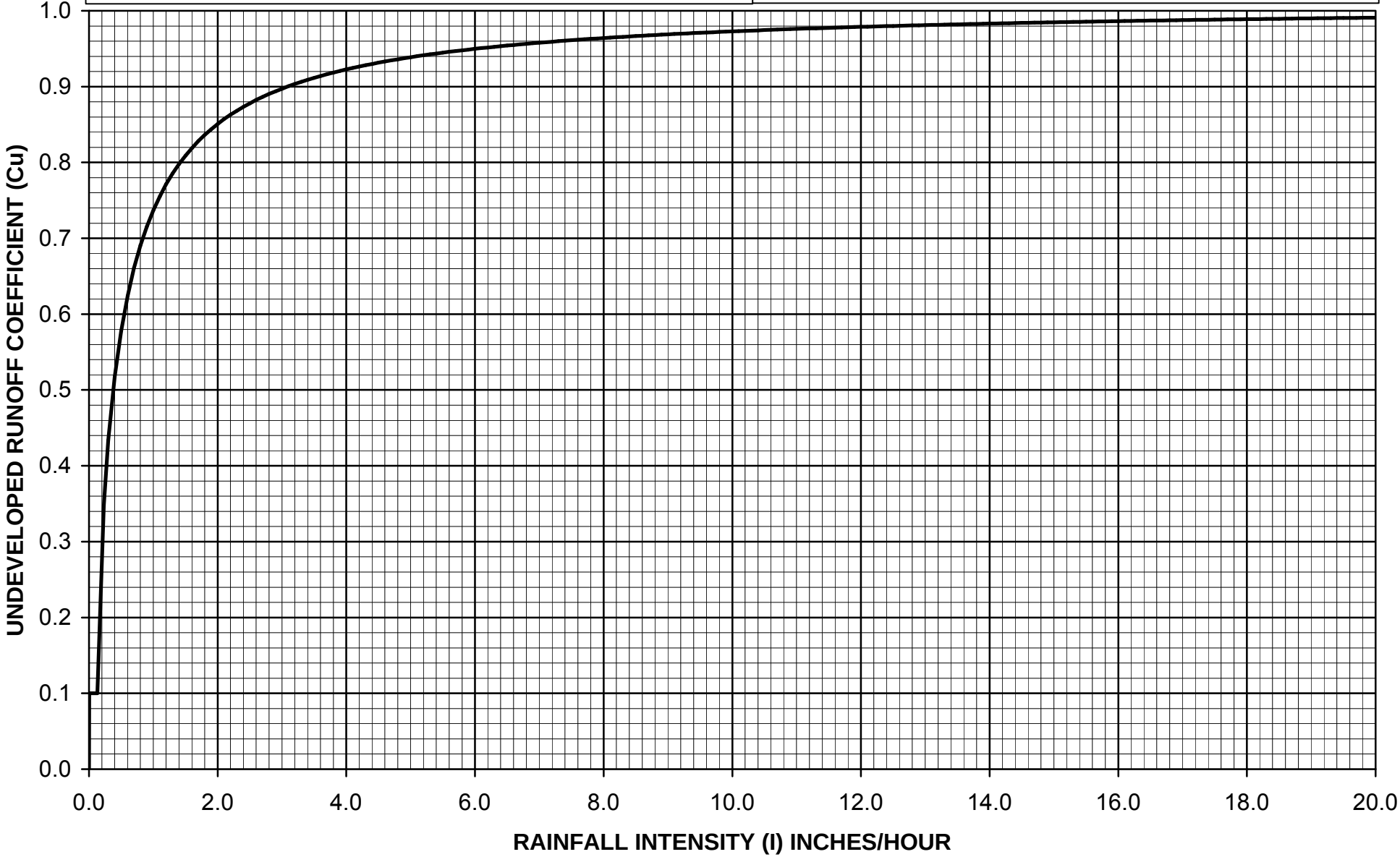


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 065

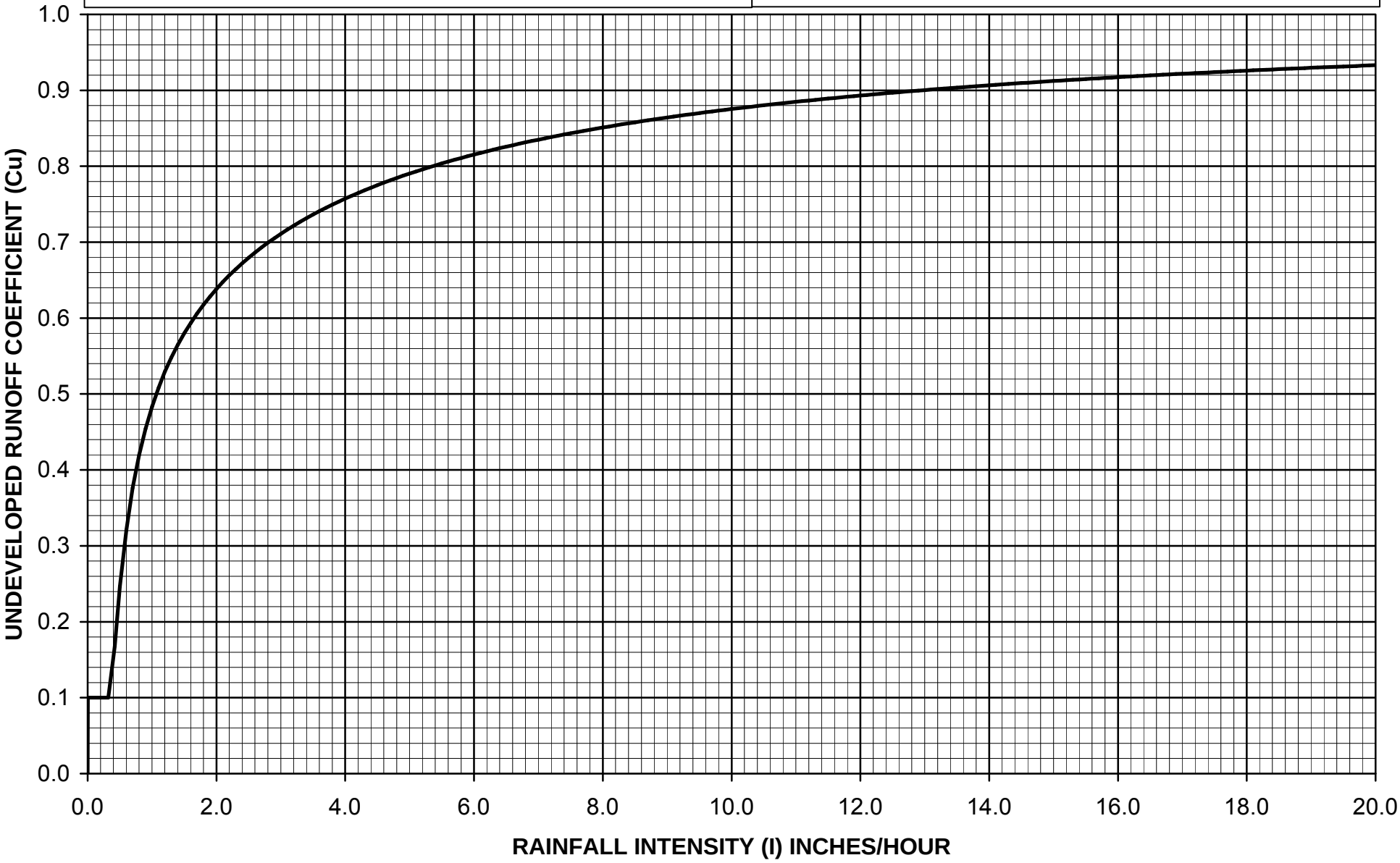


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 066

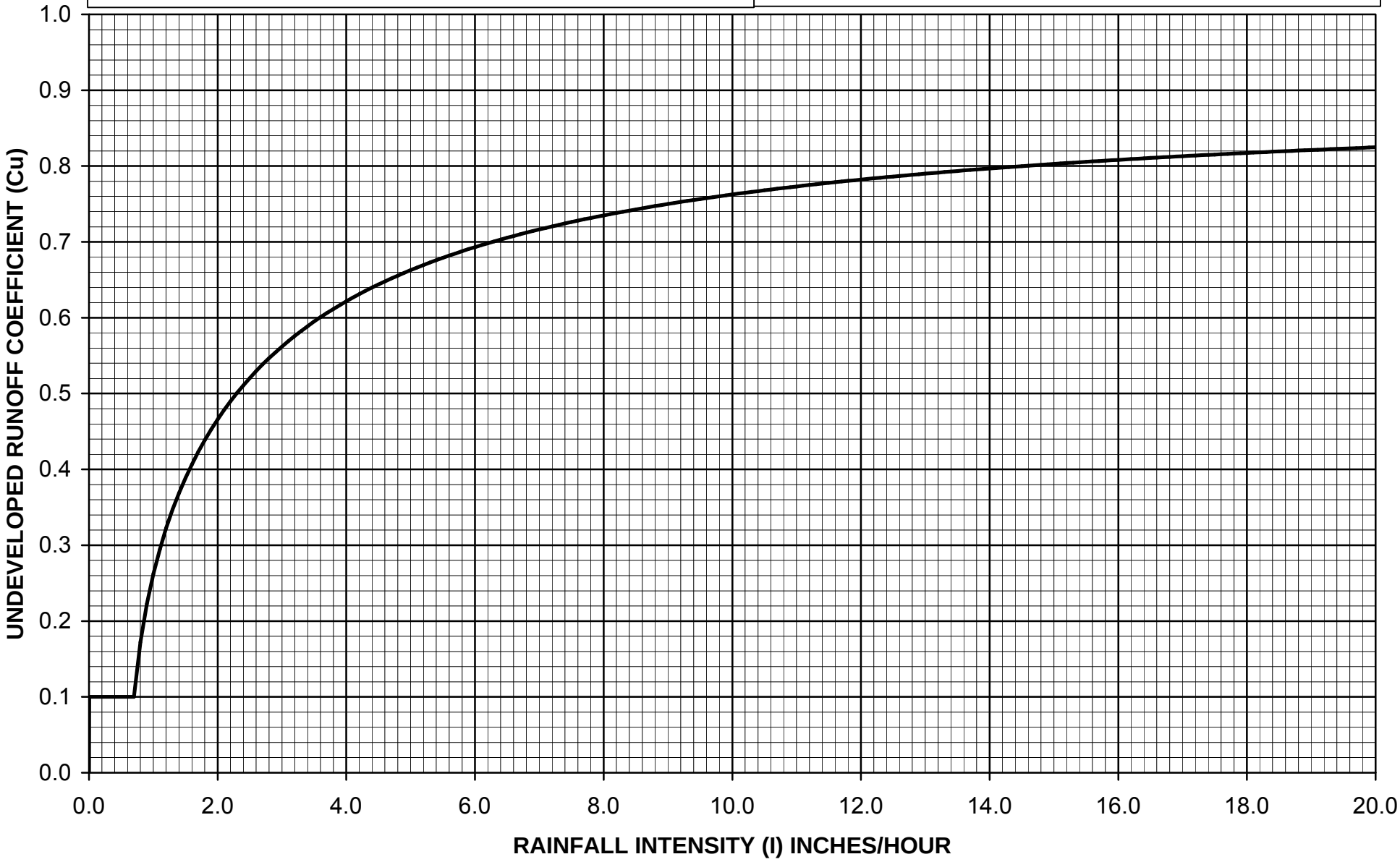


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 067

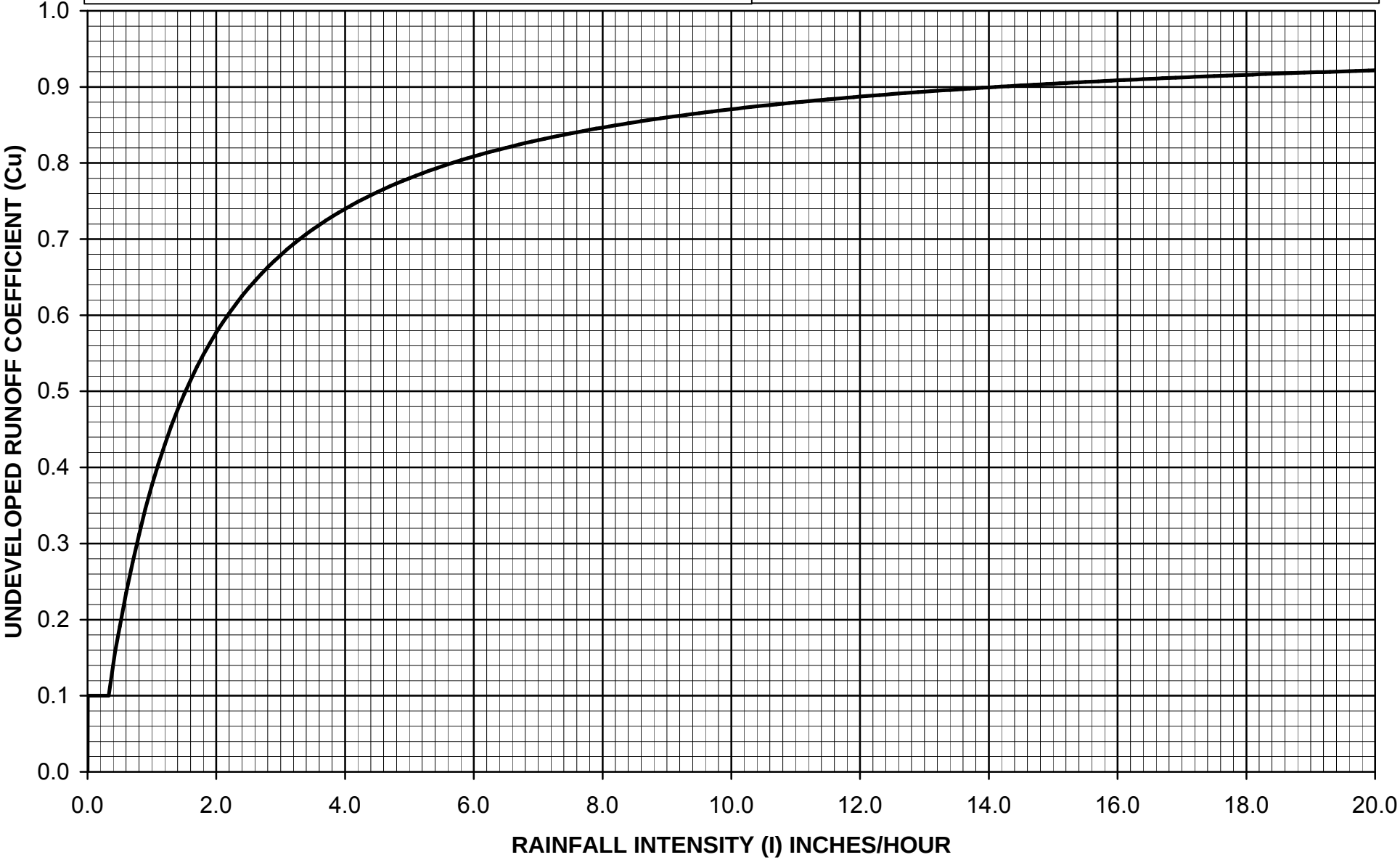


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 068

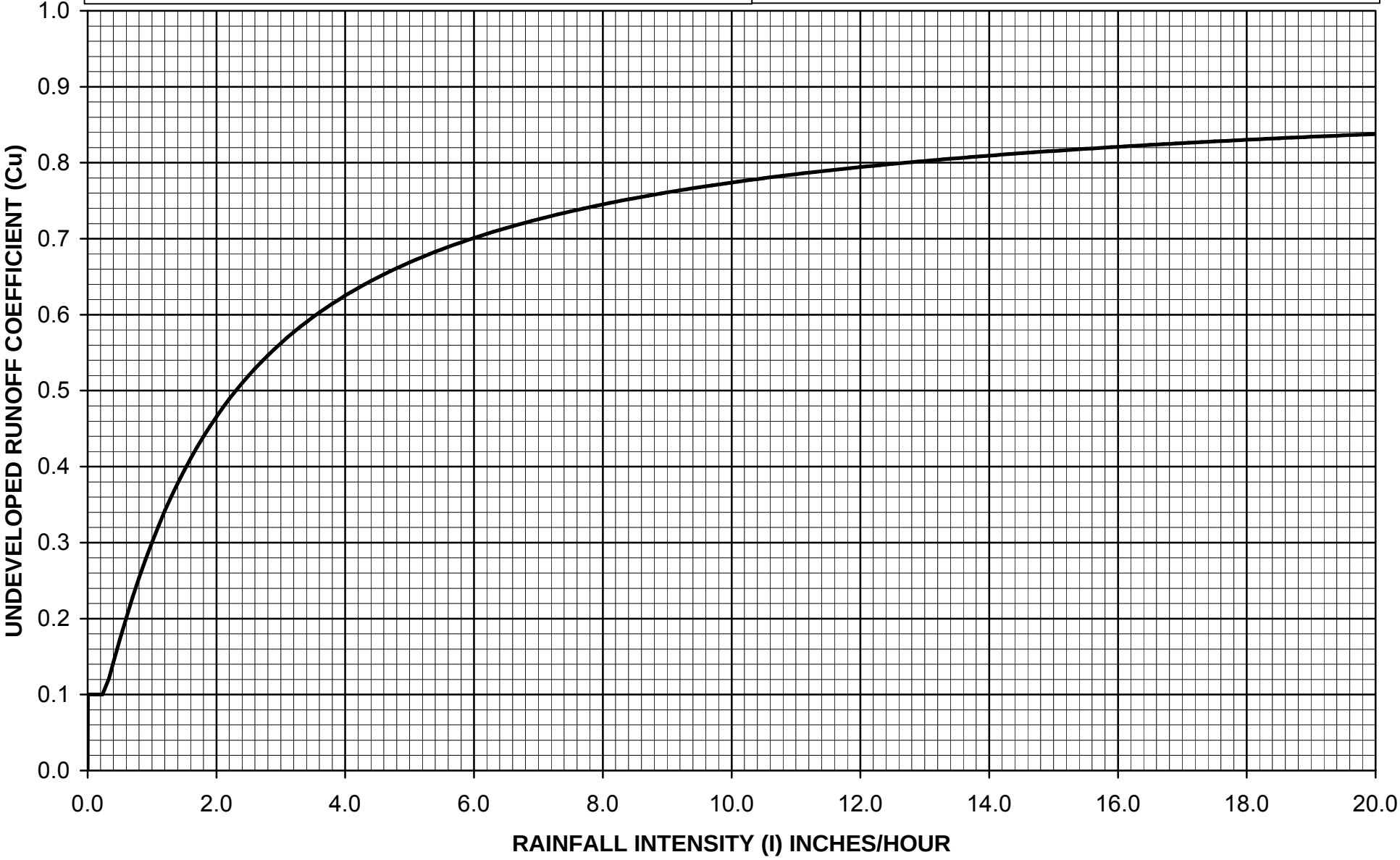


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 069

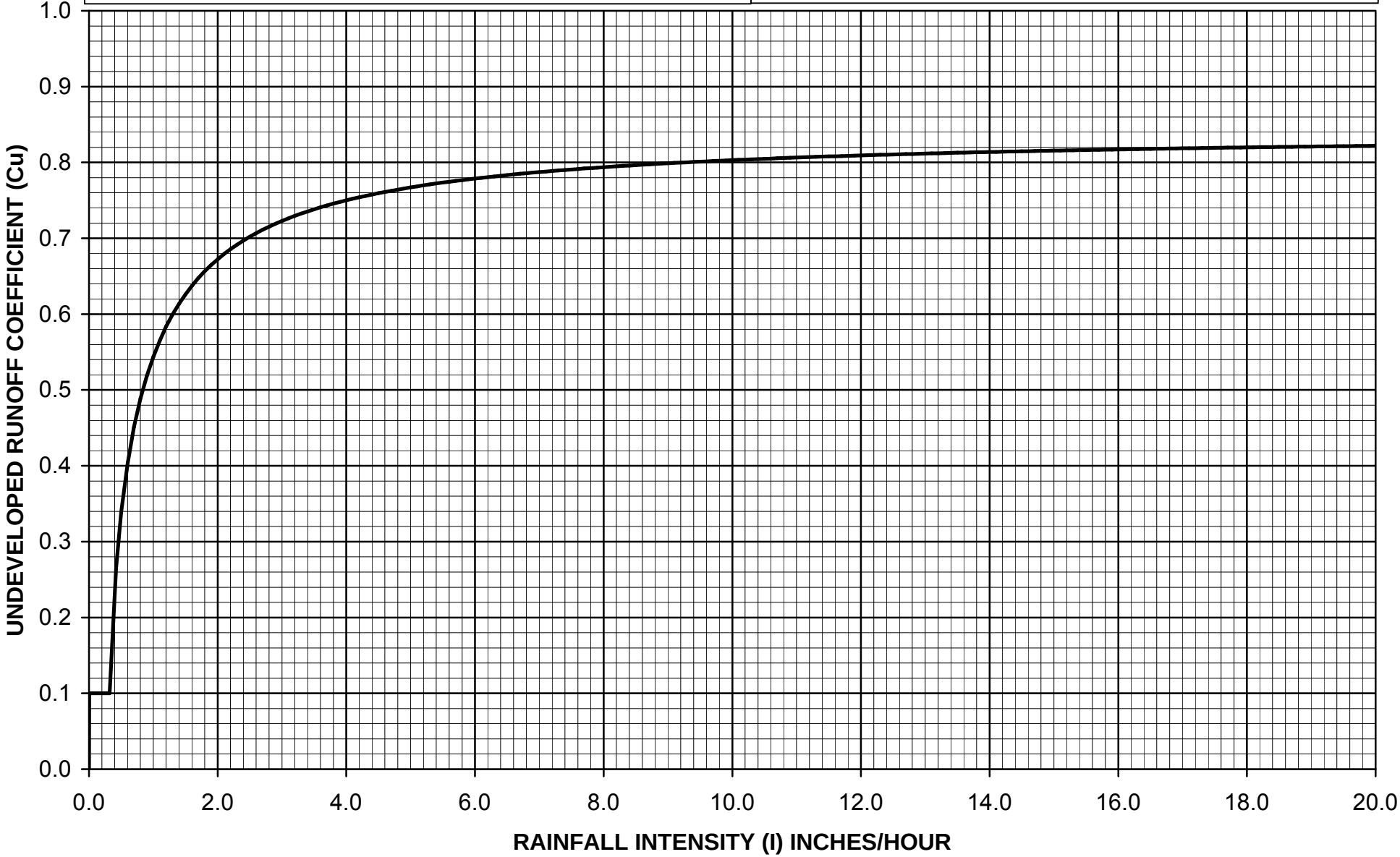


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 070

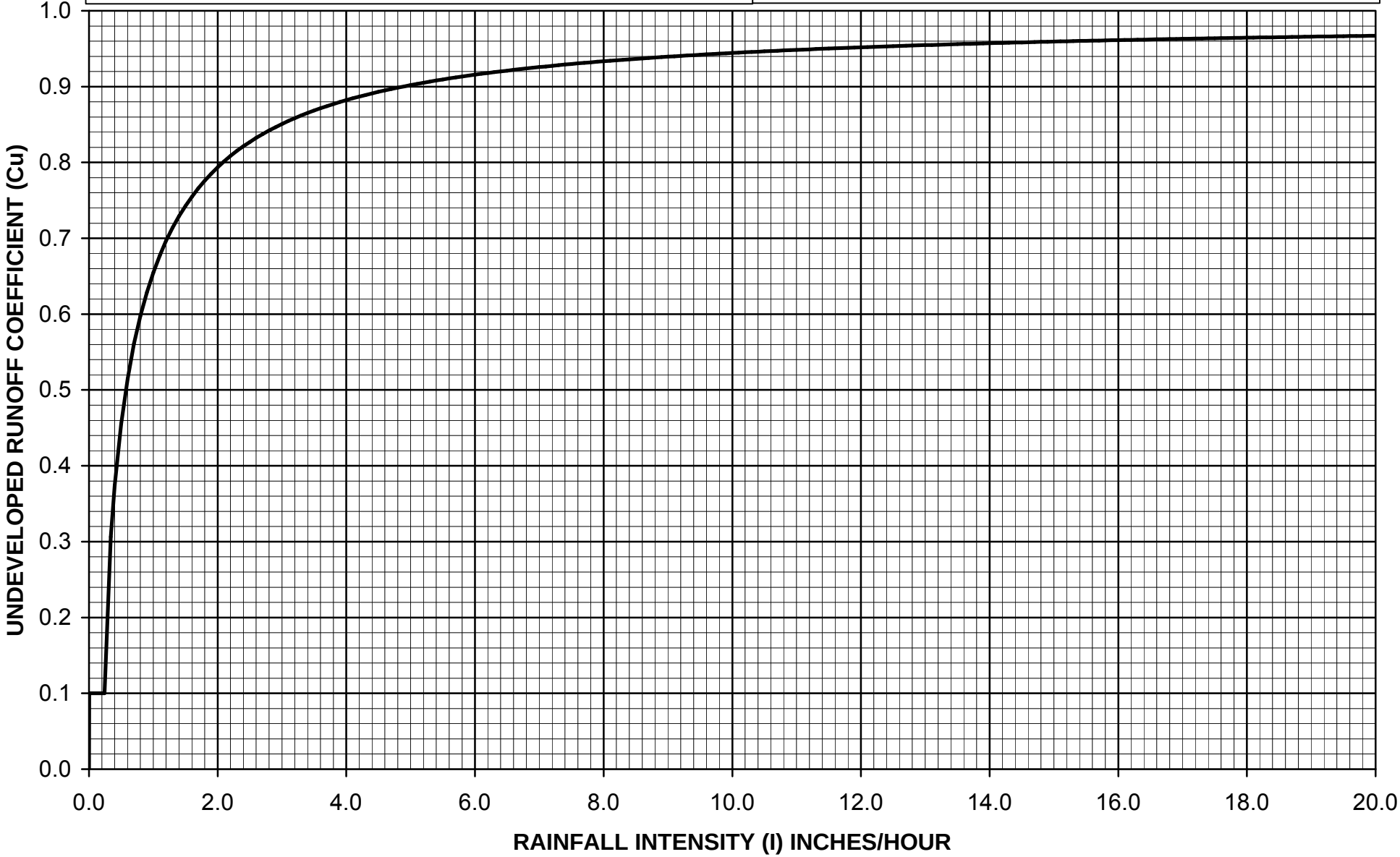


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 071

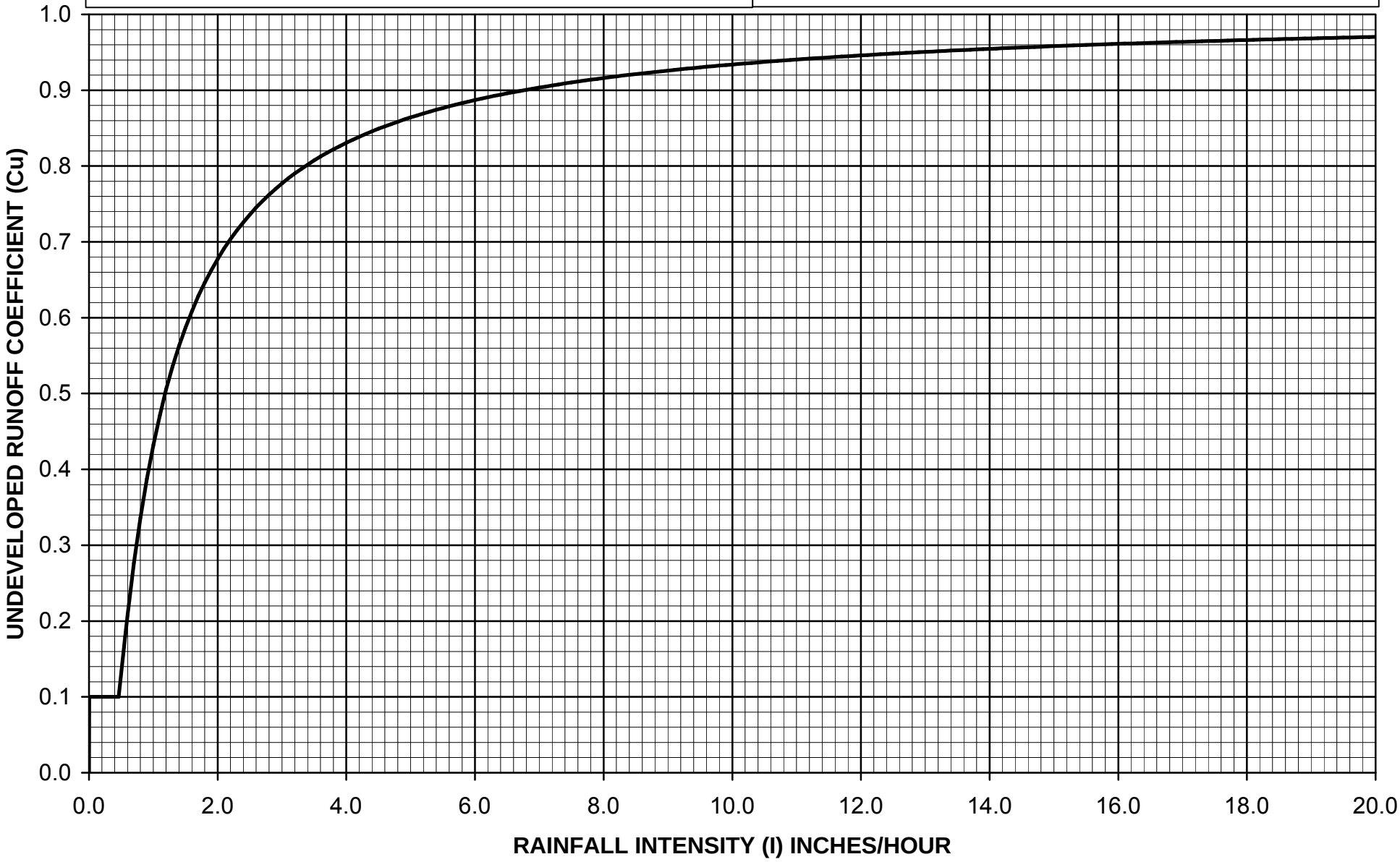


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 072

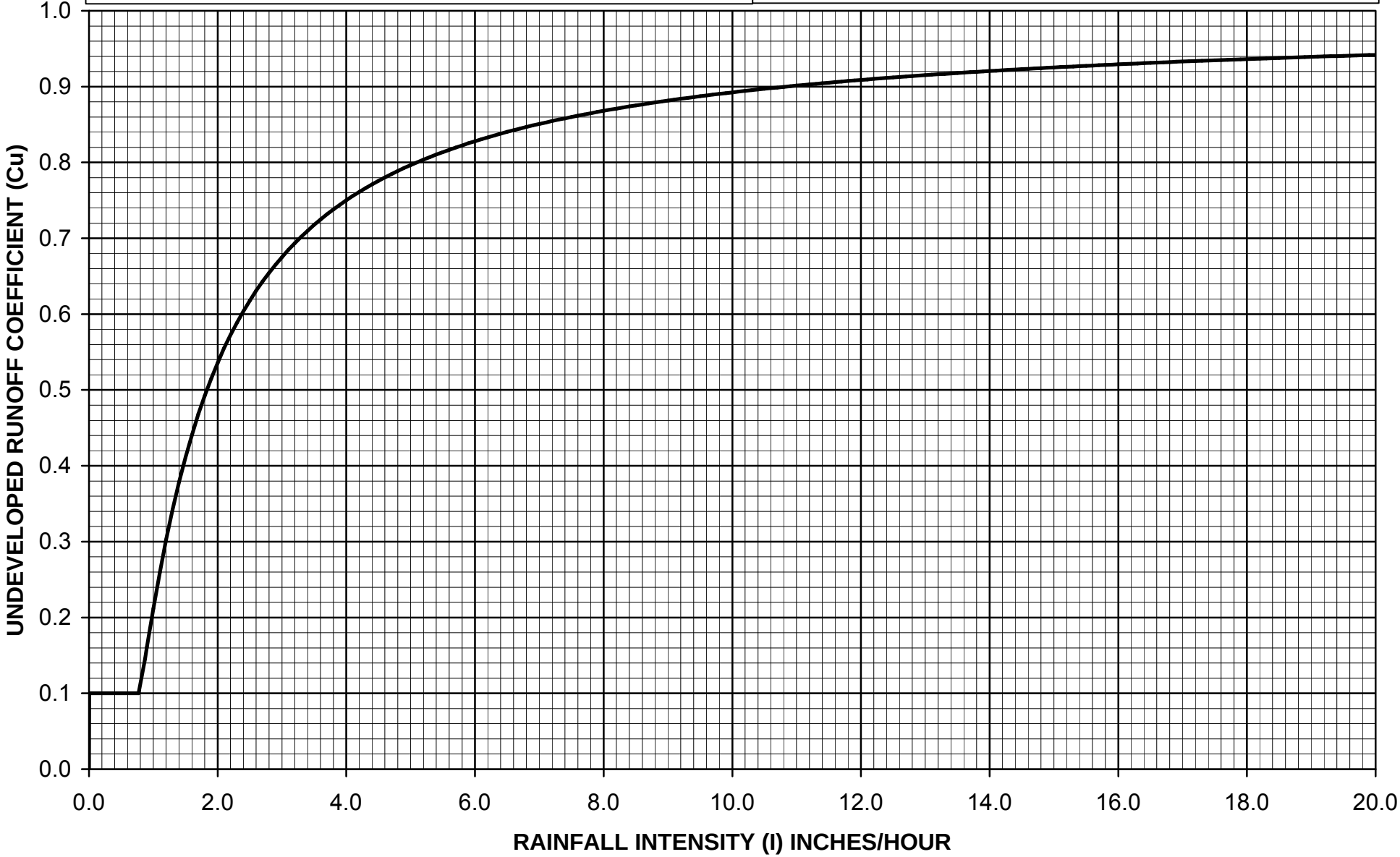


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 073

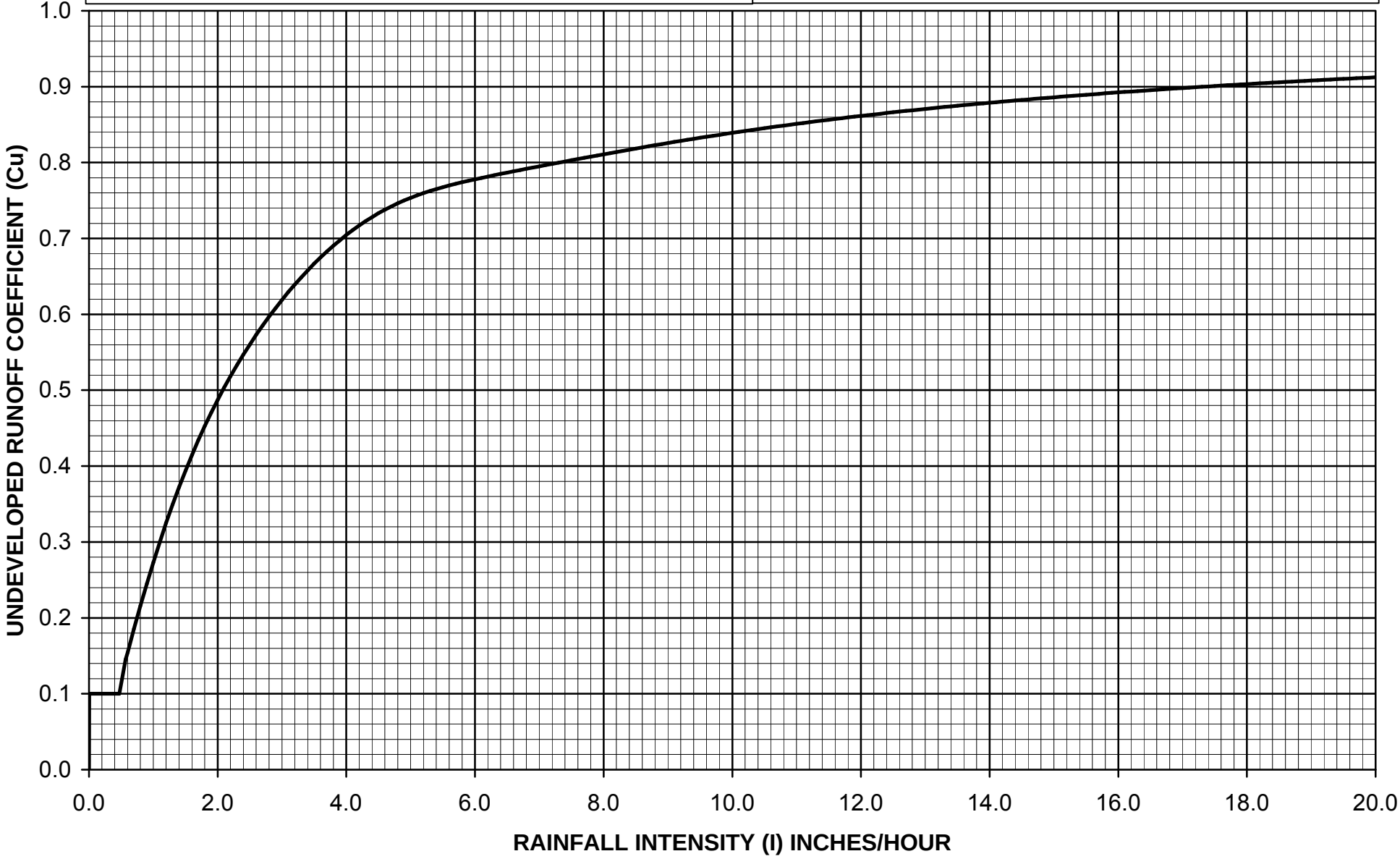


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 074

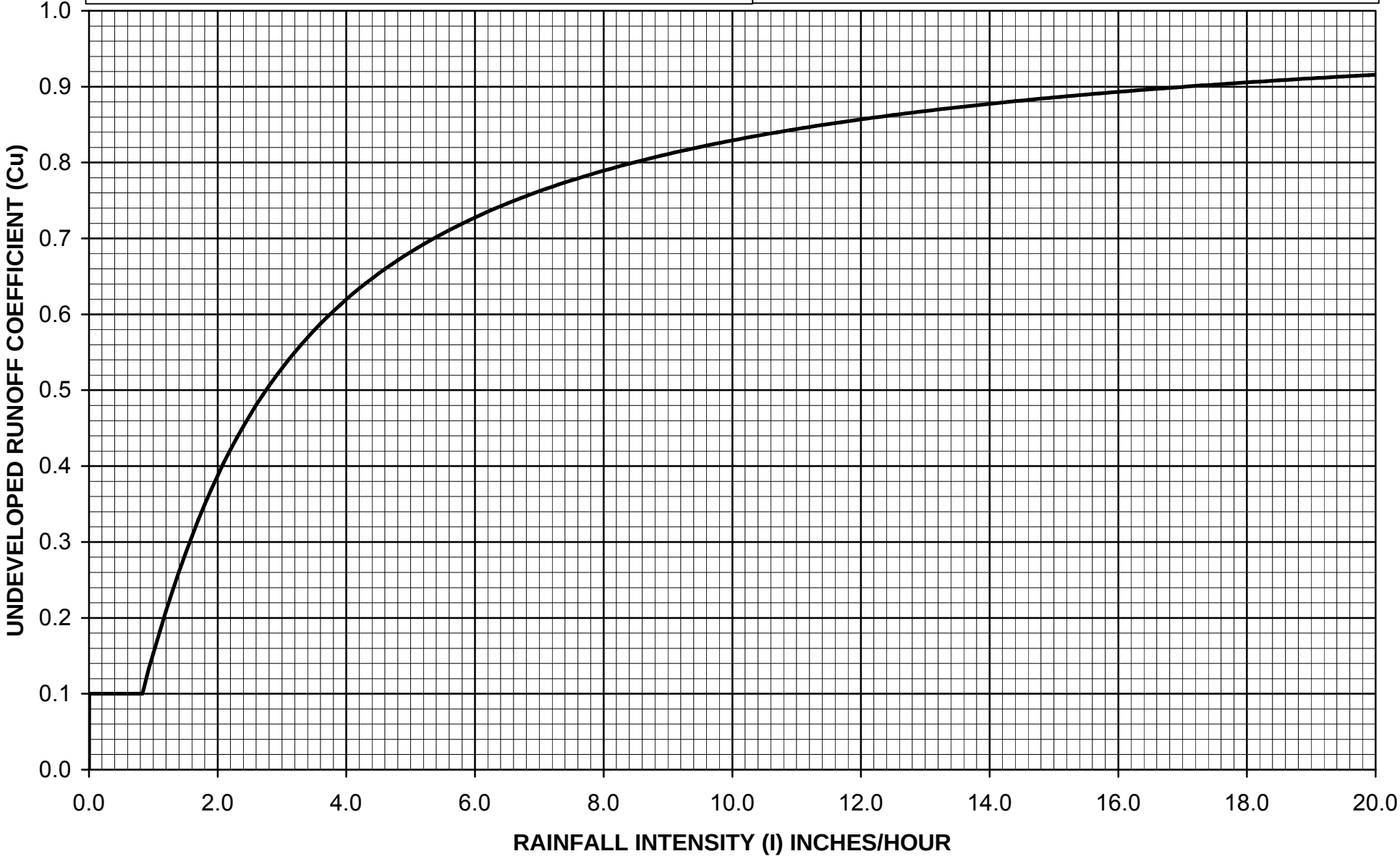


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 075

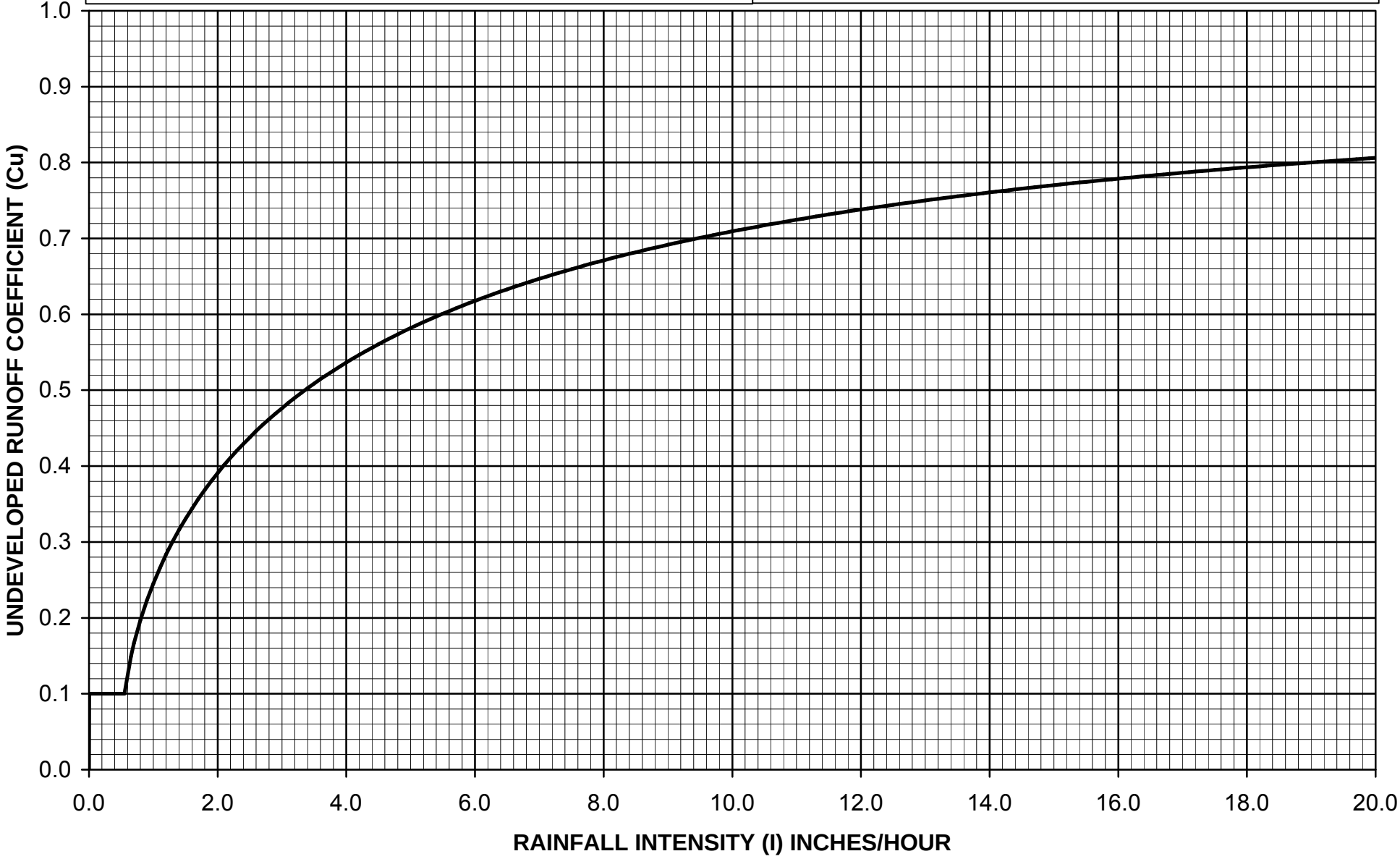


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 076

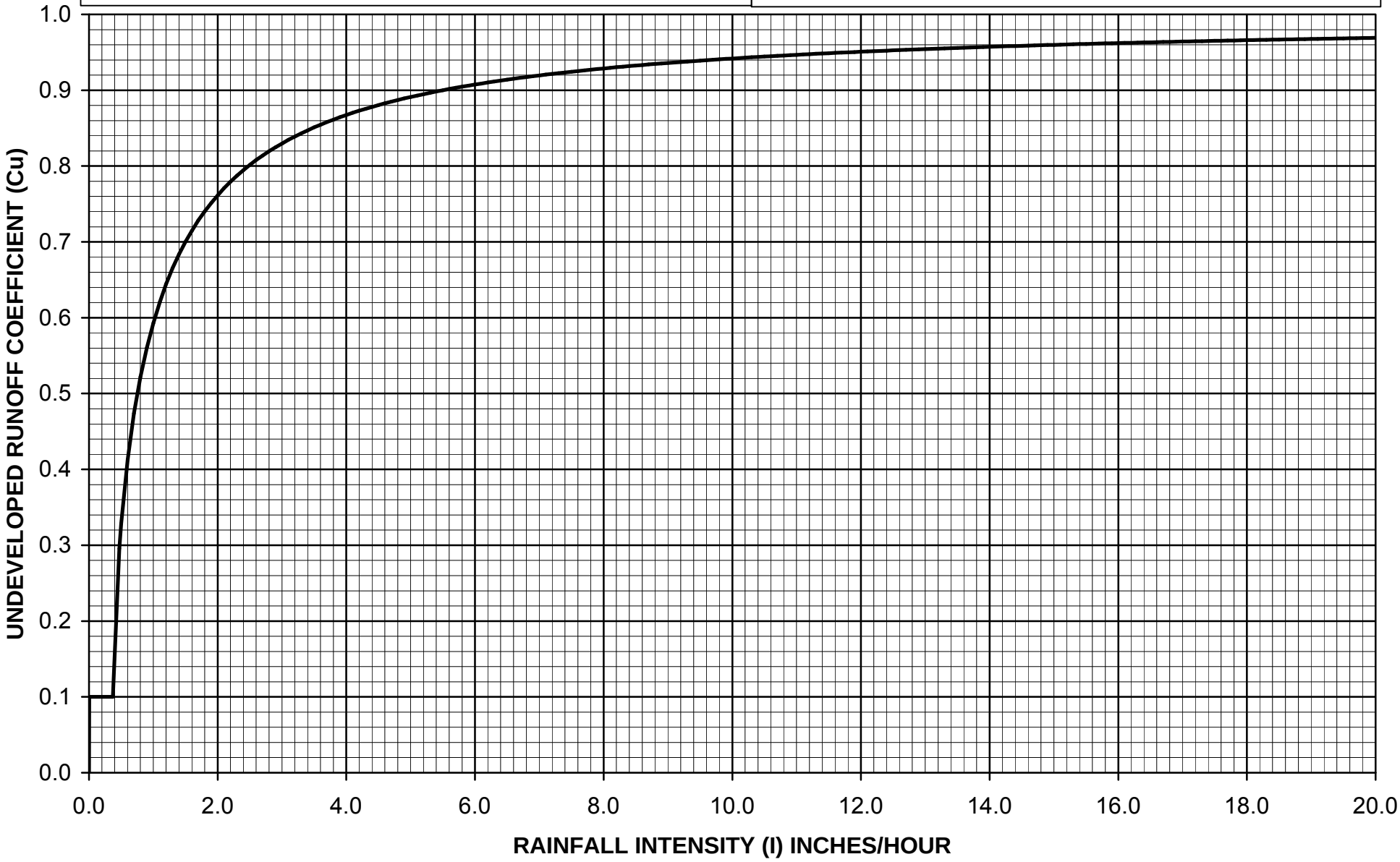


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 077

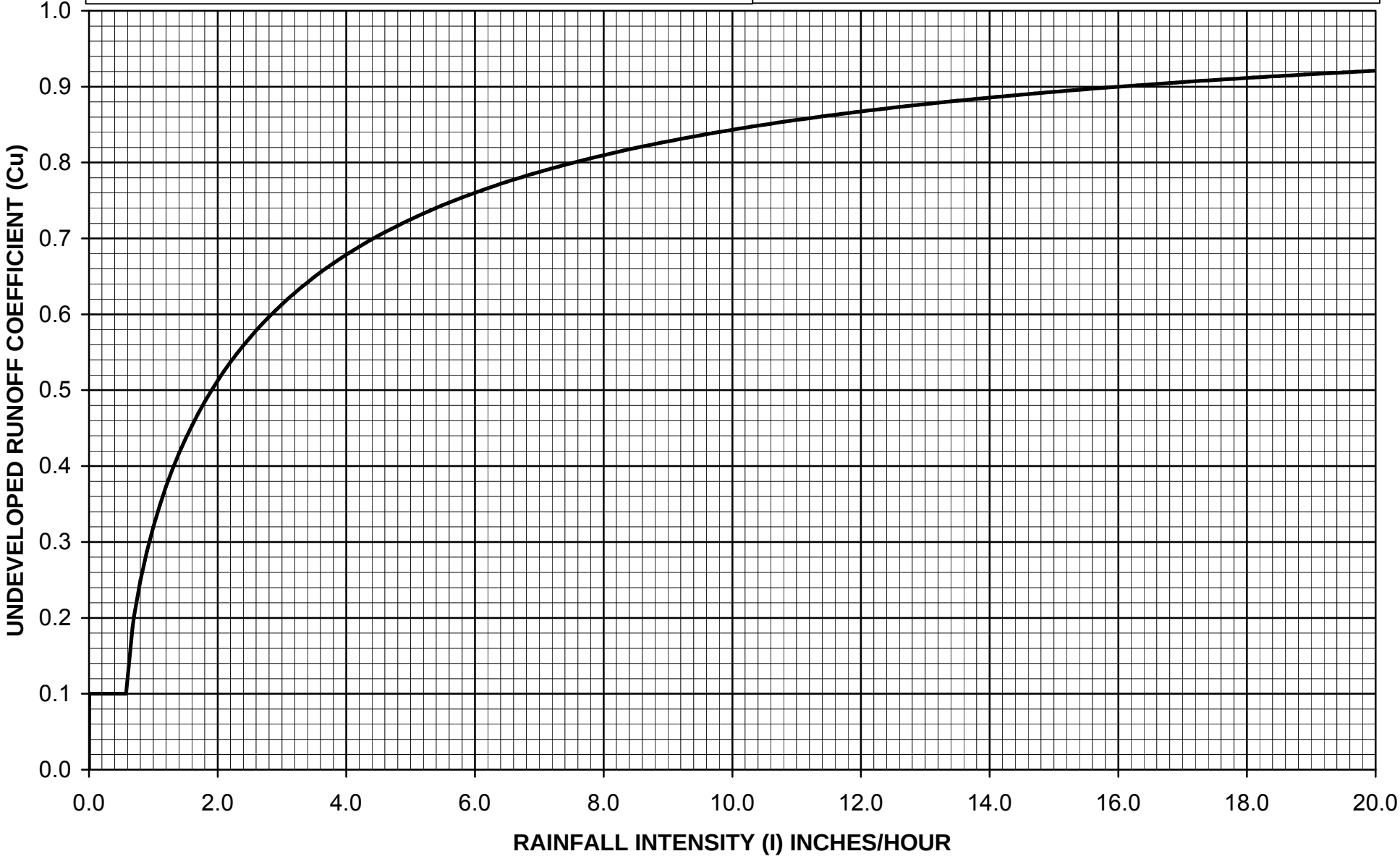


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 078

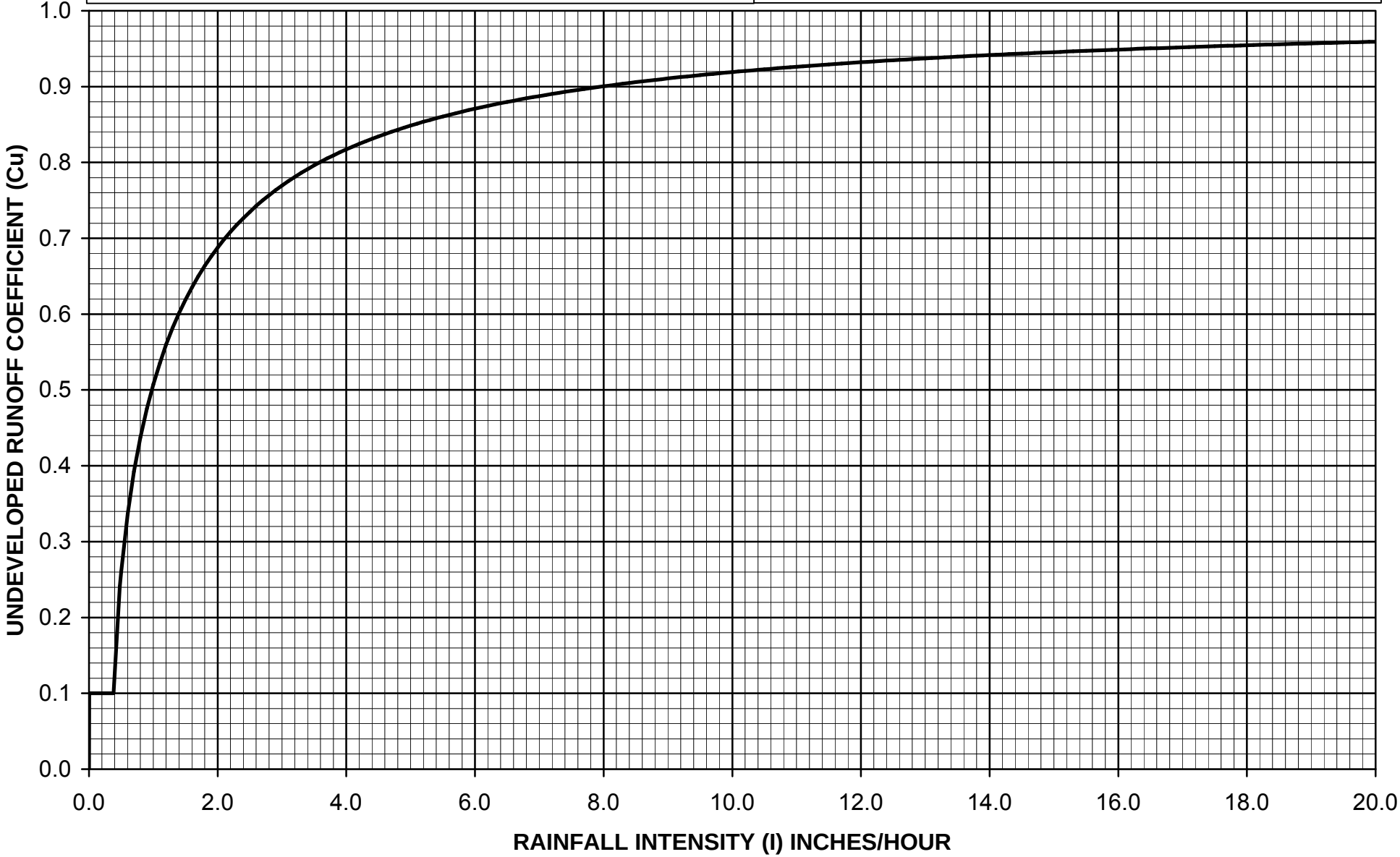


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 079

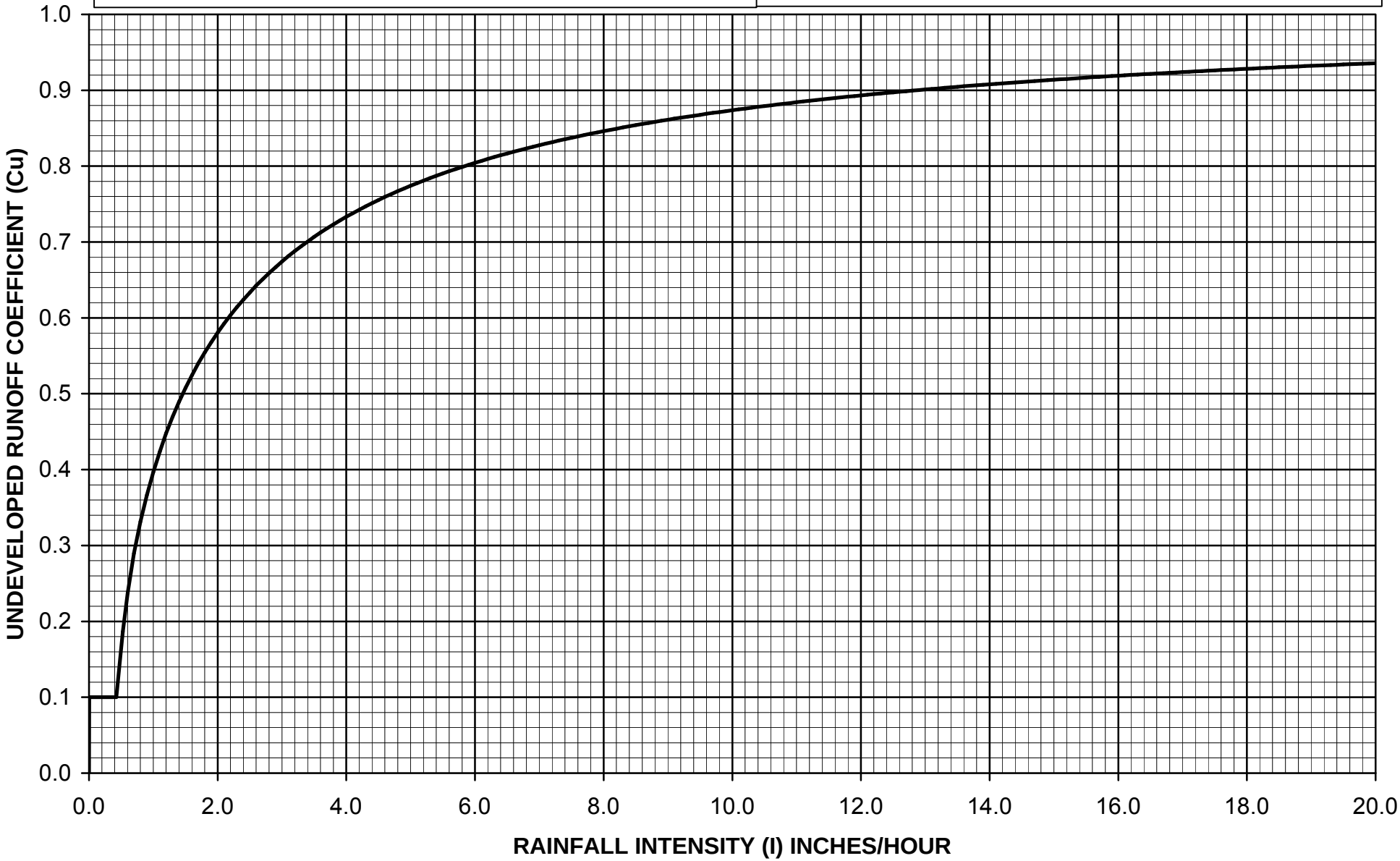


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 080

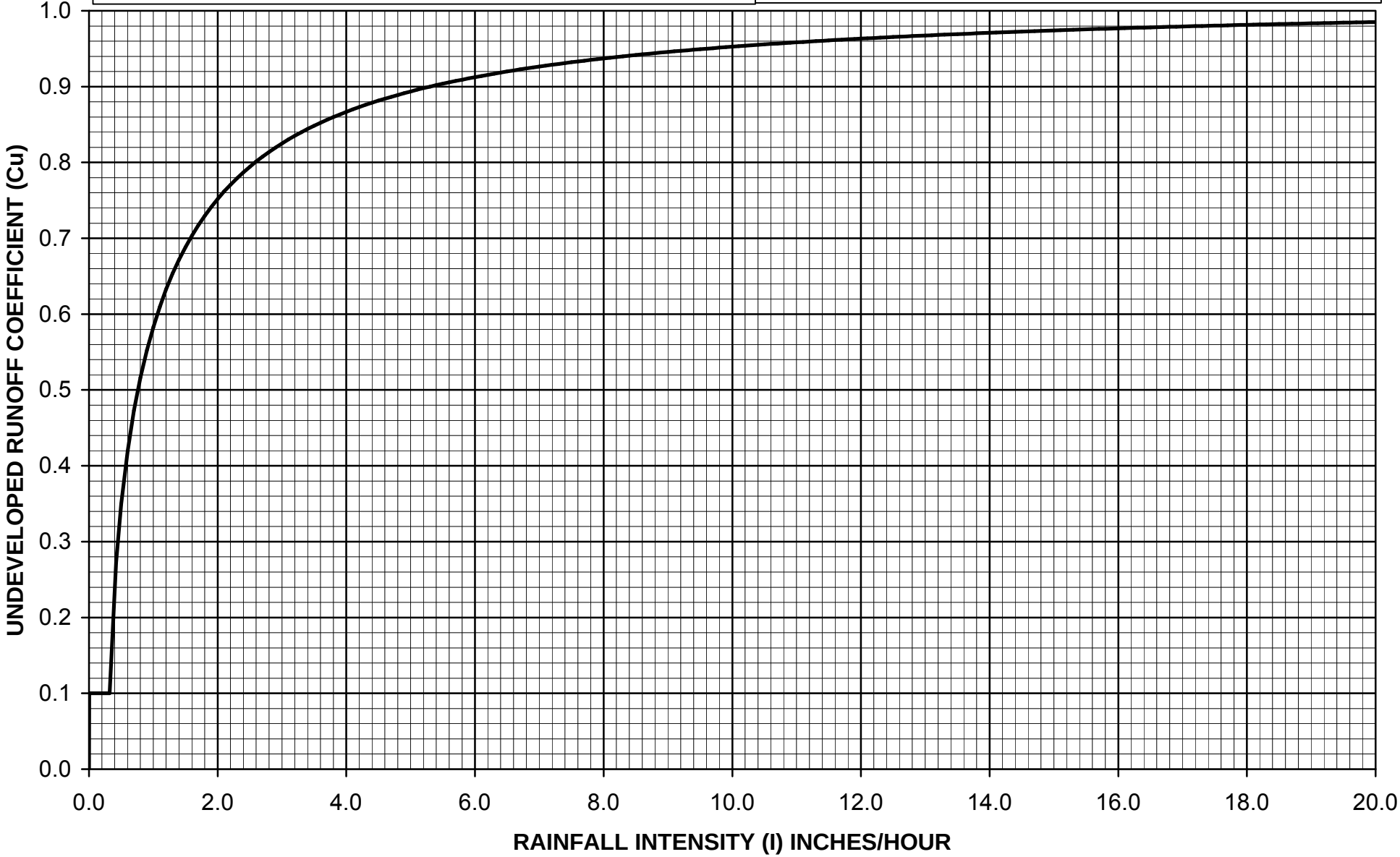


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 081

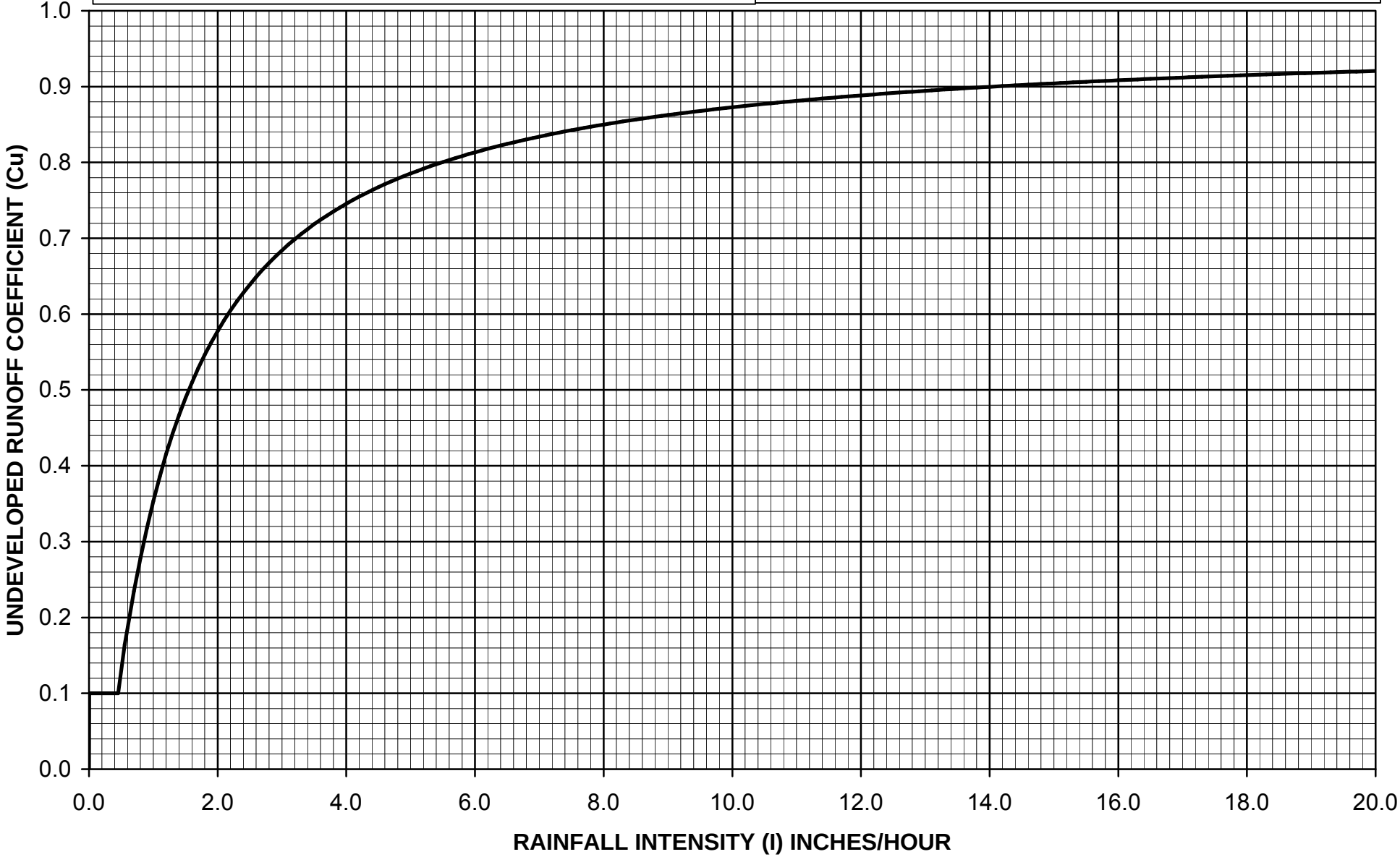


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 082

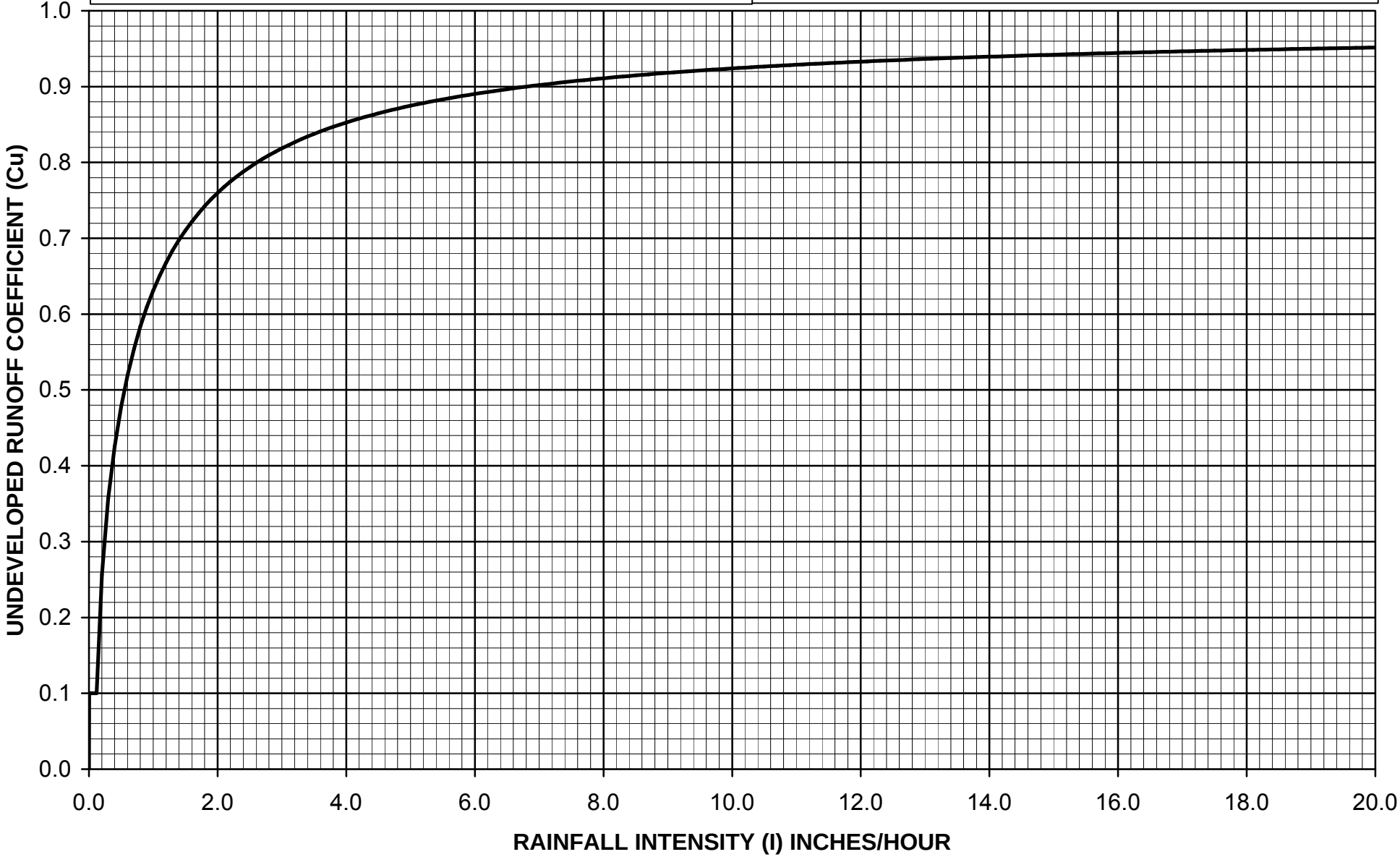


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 083

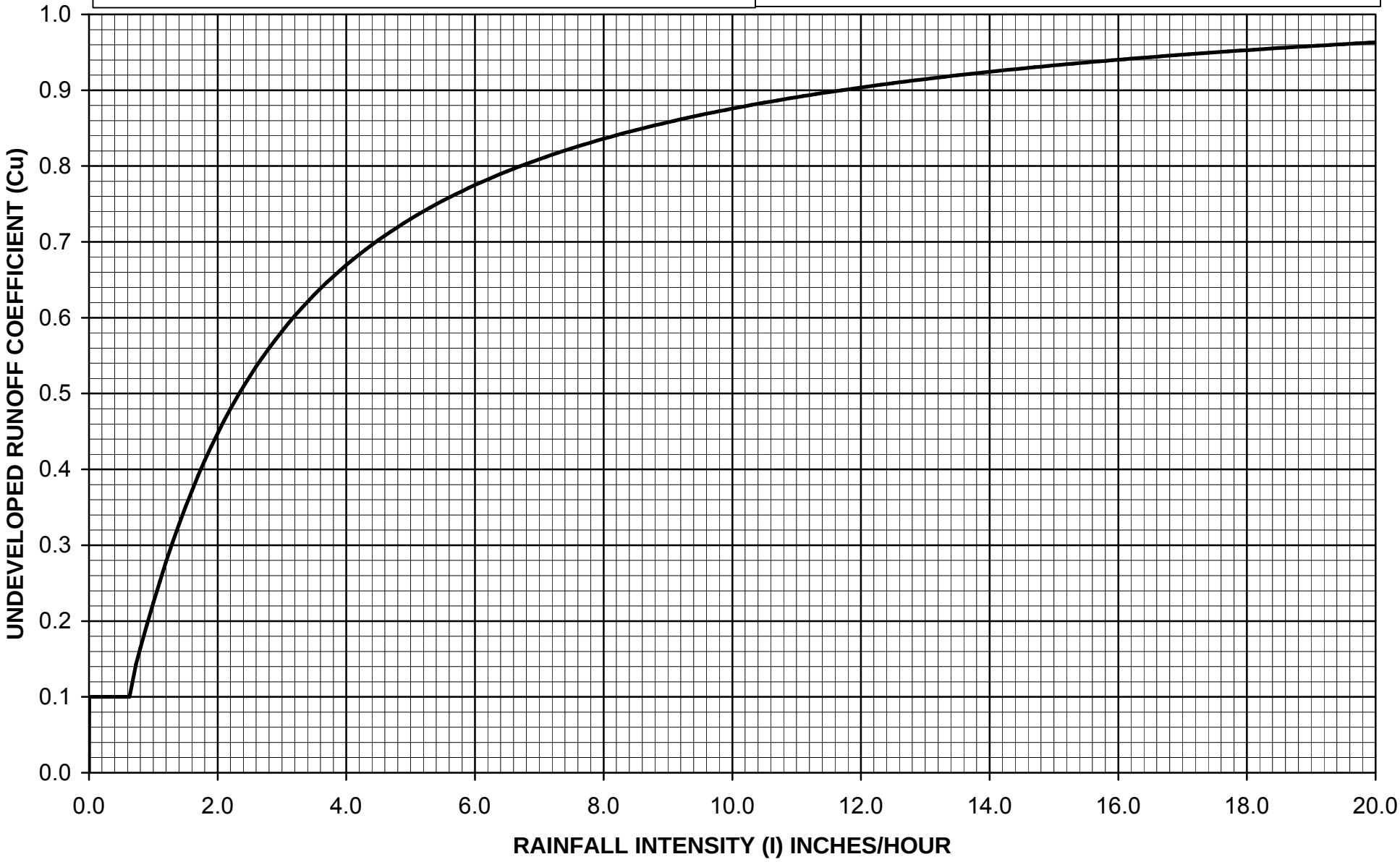


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 084

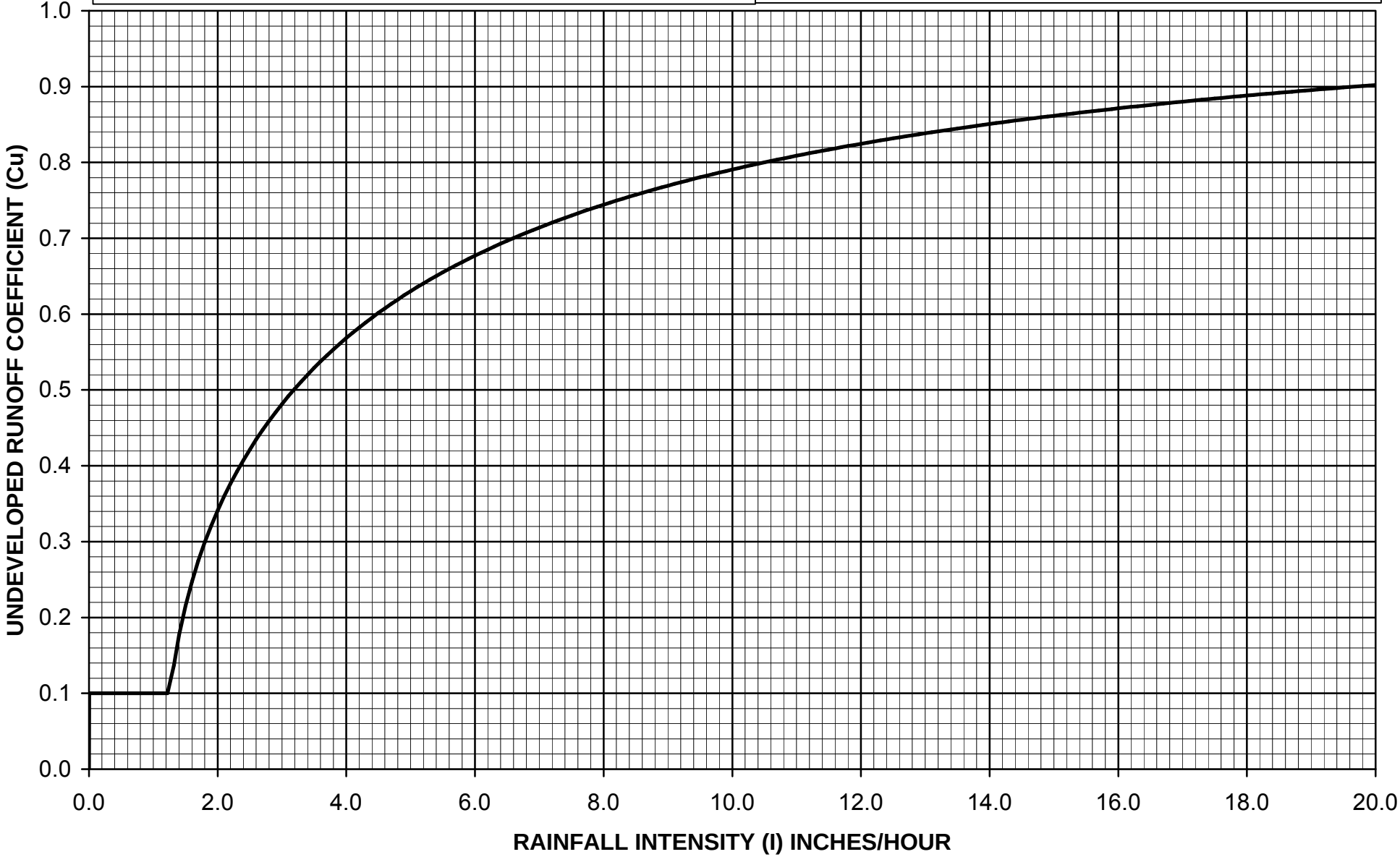


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 085

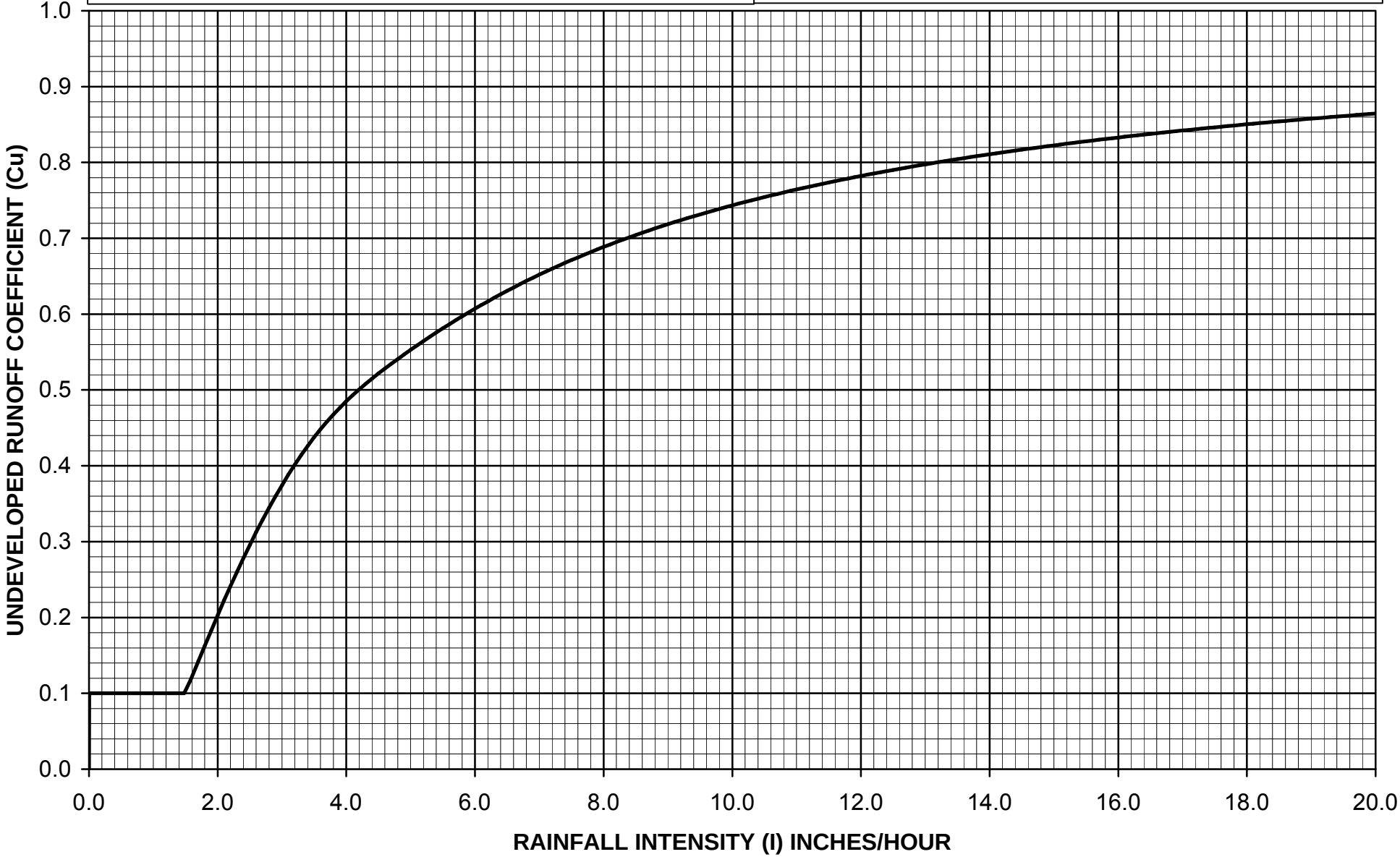


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 086

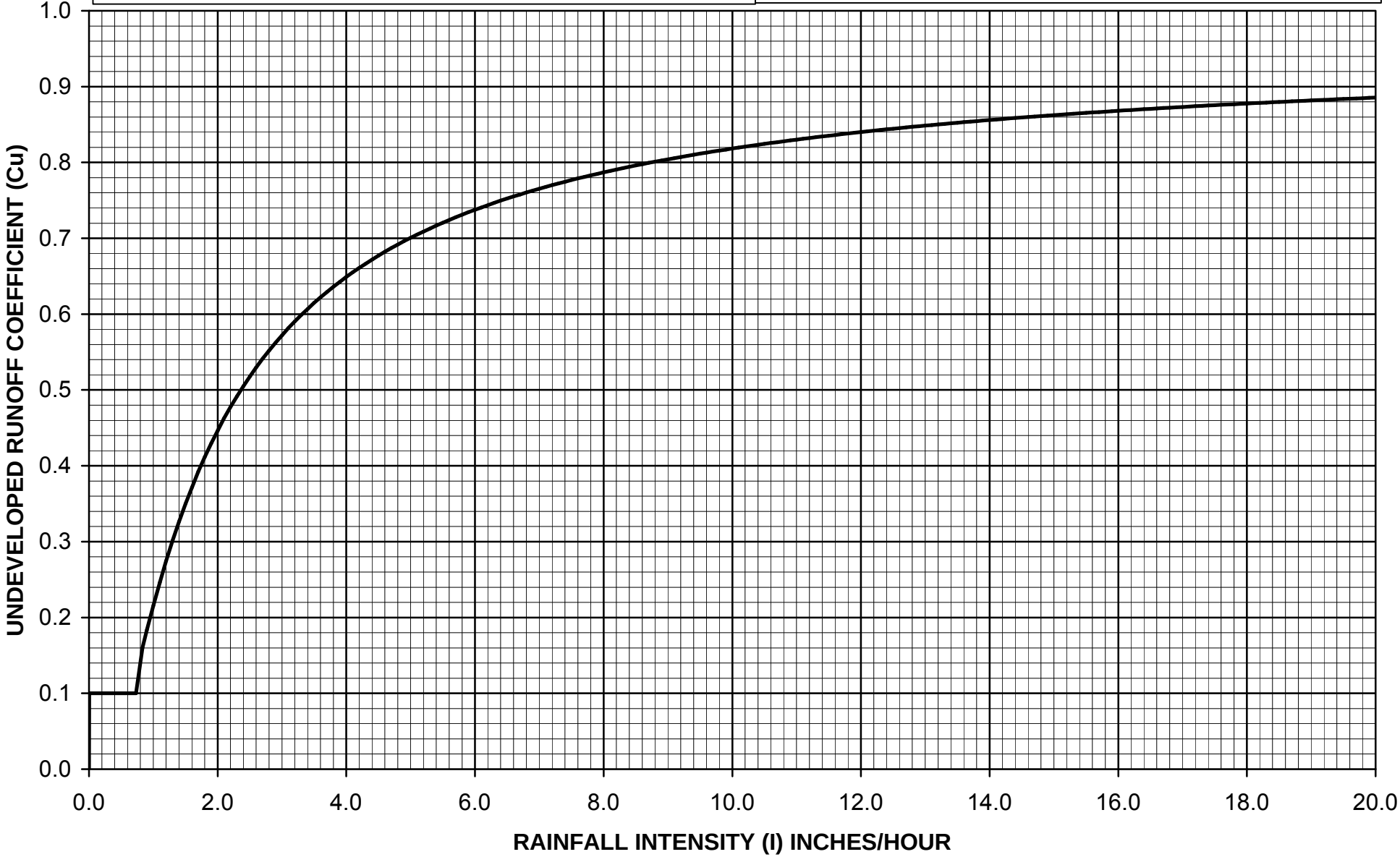


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 087

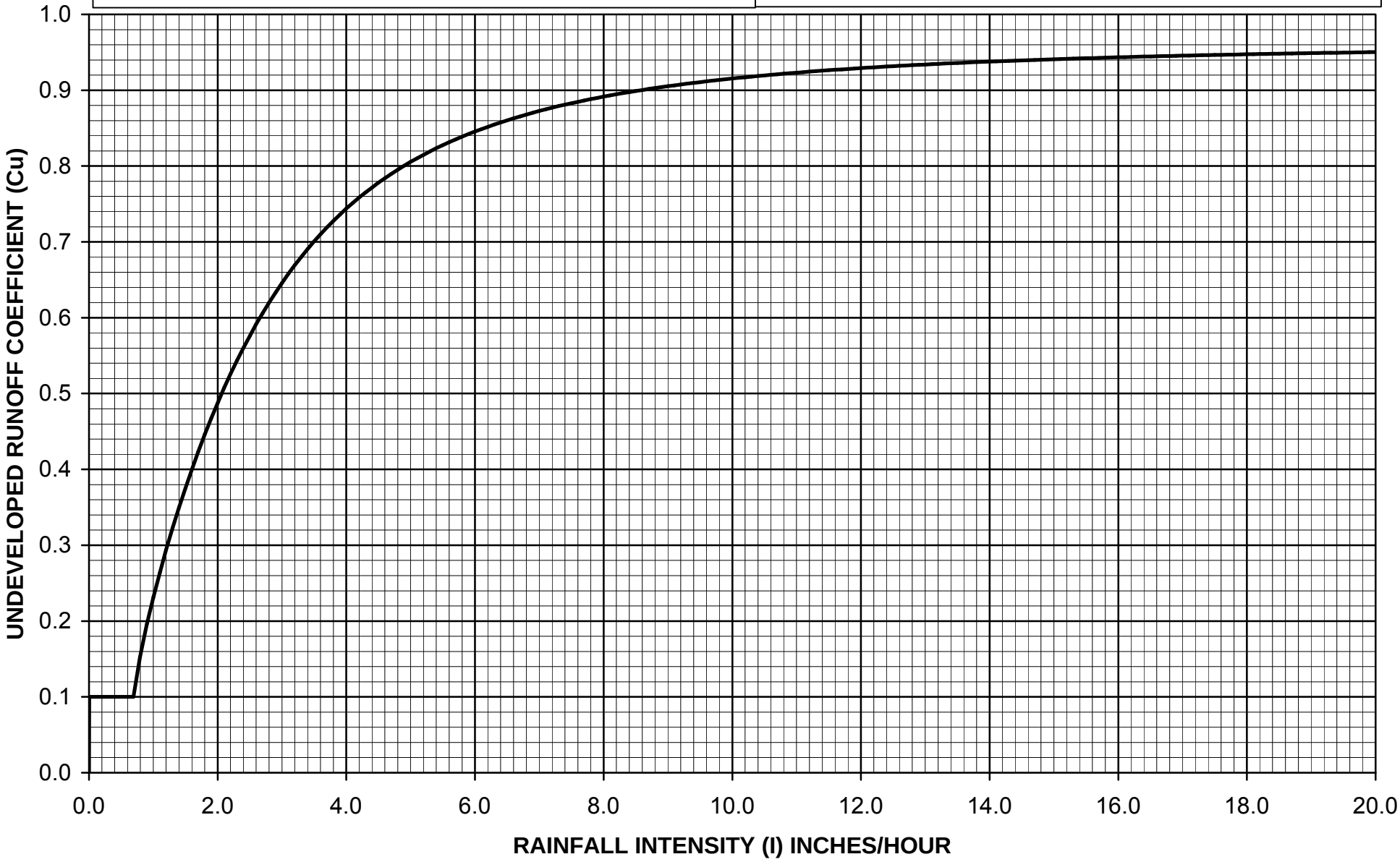


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 088

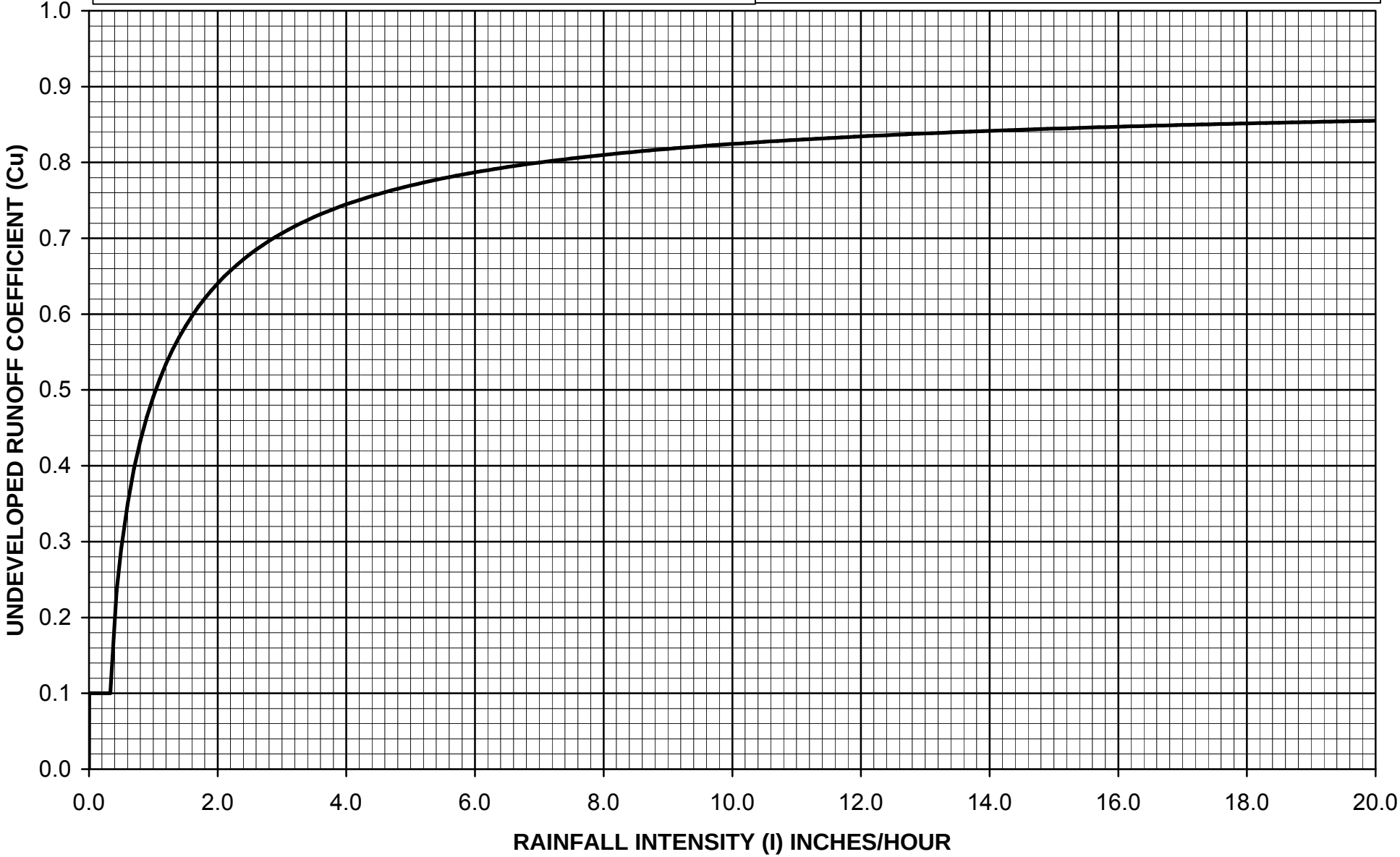


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 089

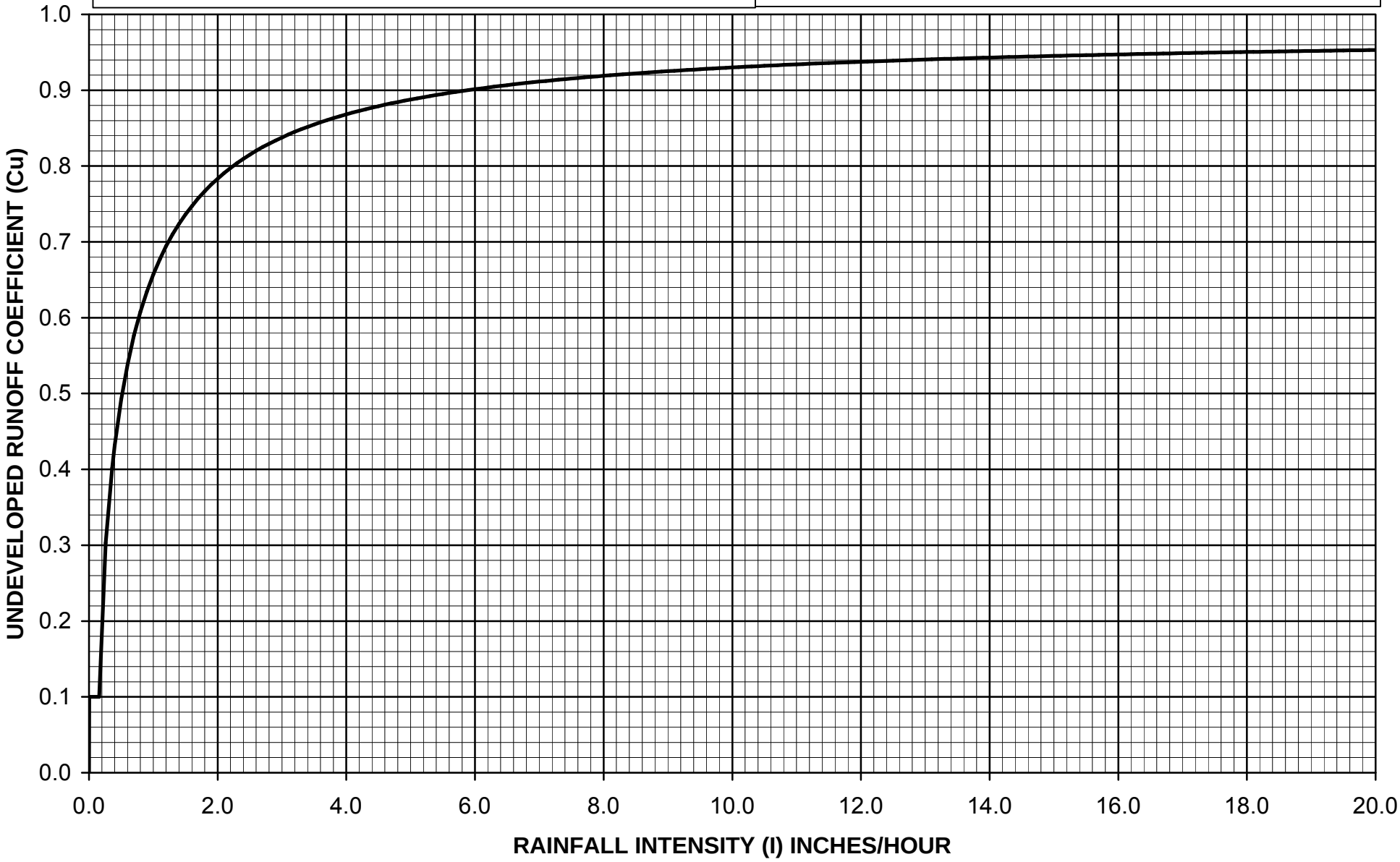


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 090

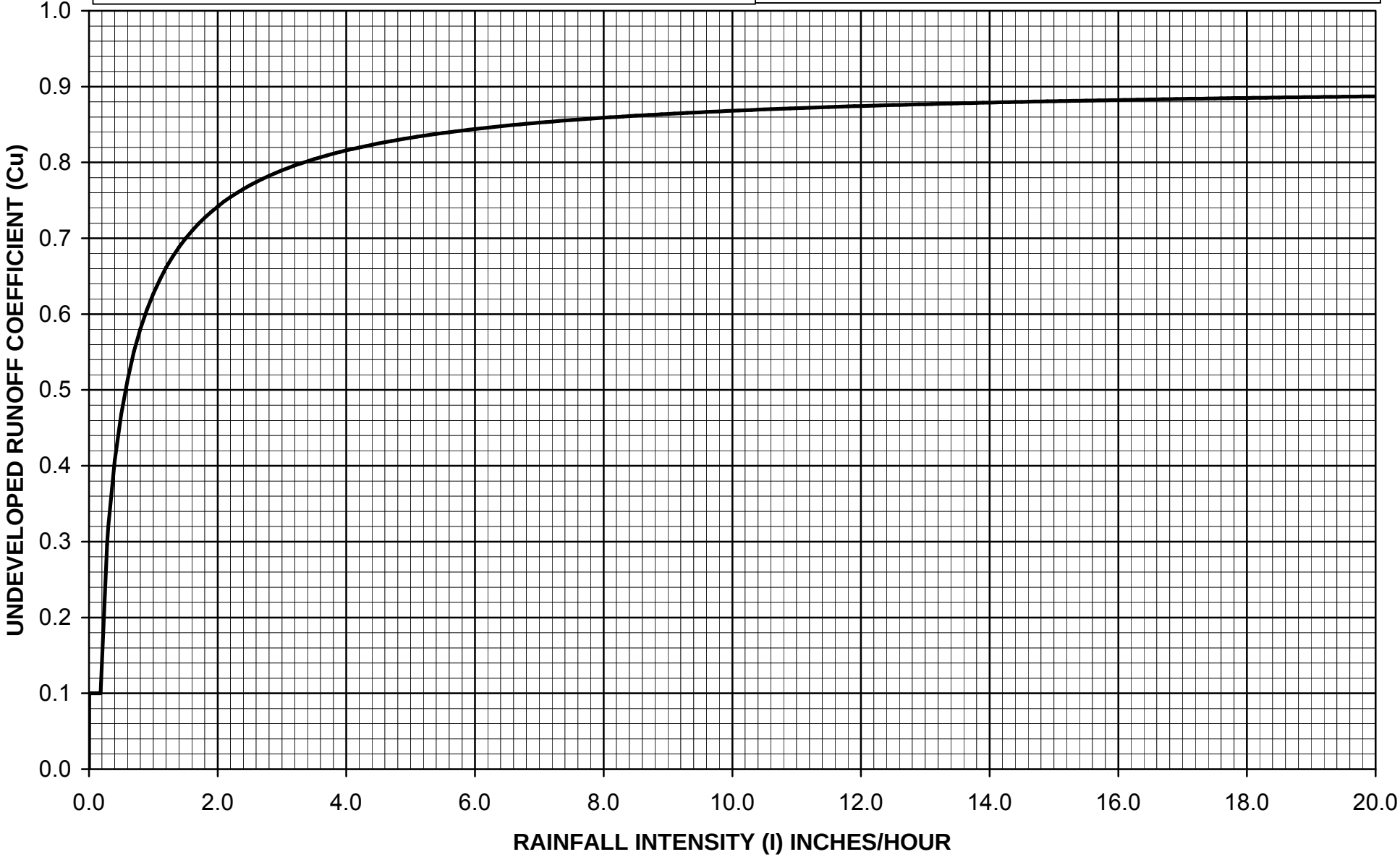


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 091

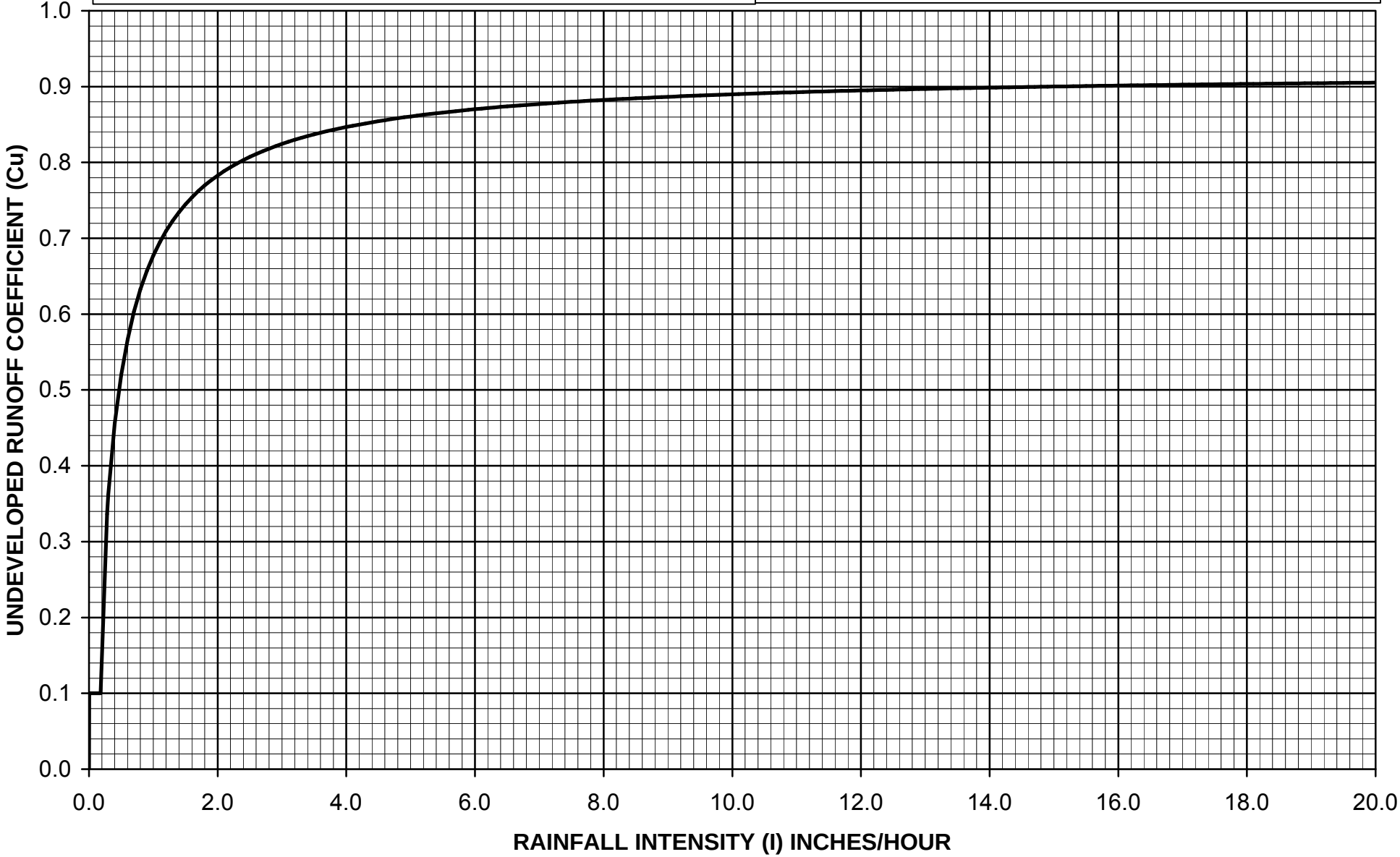


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 092

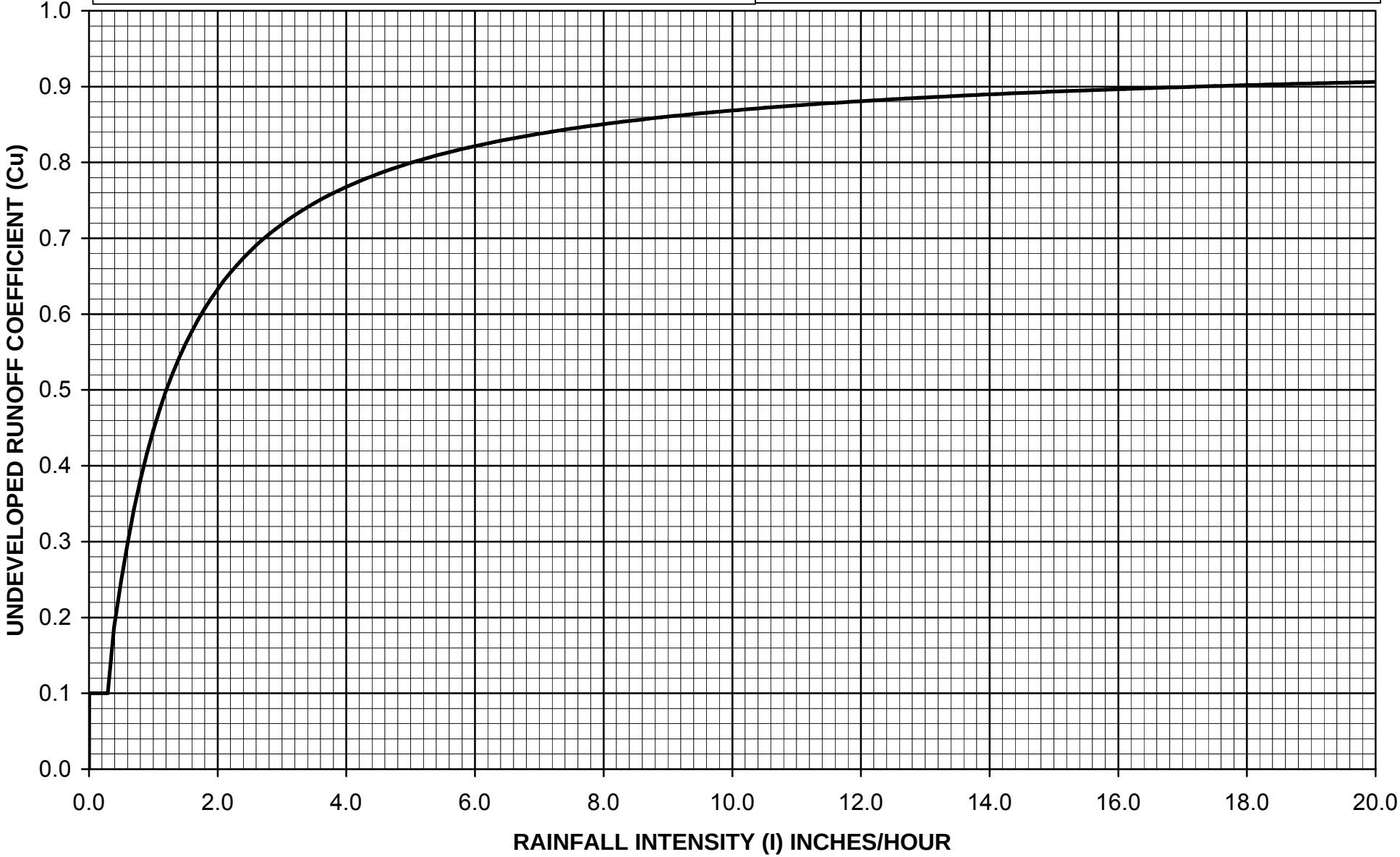


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 093

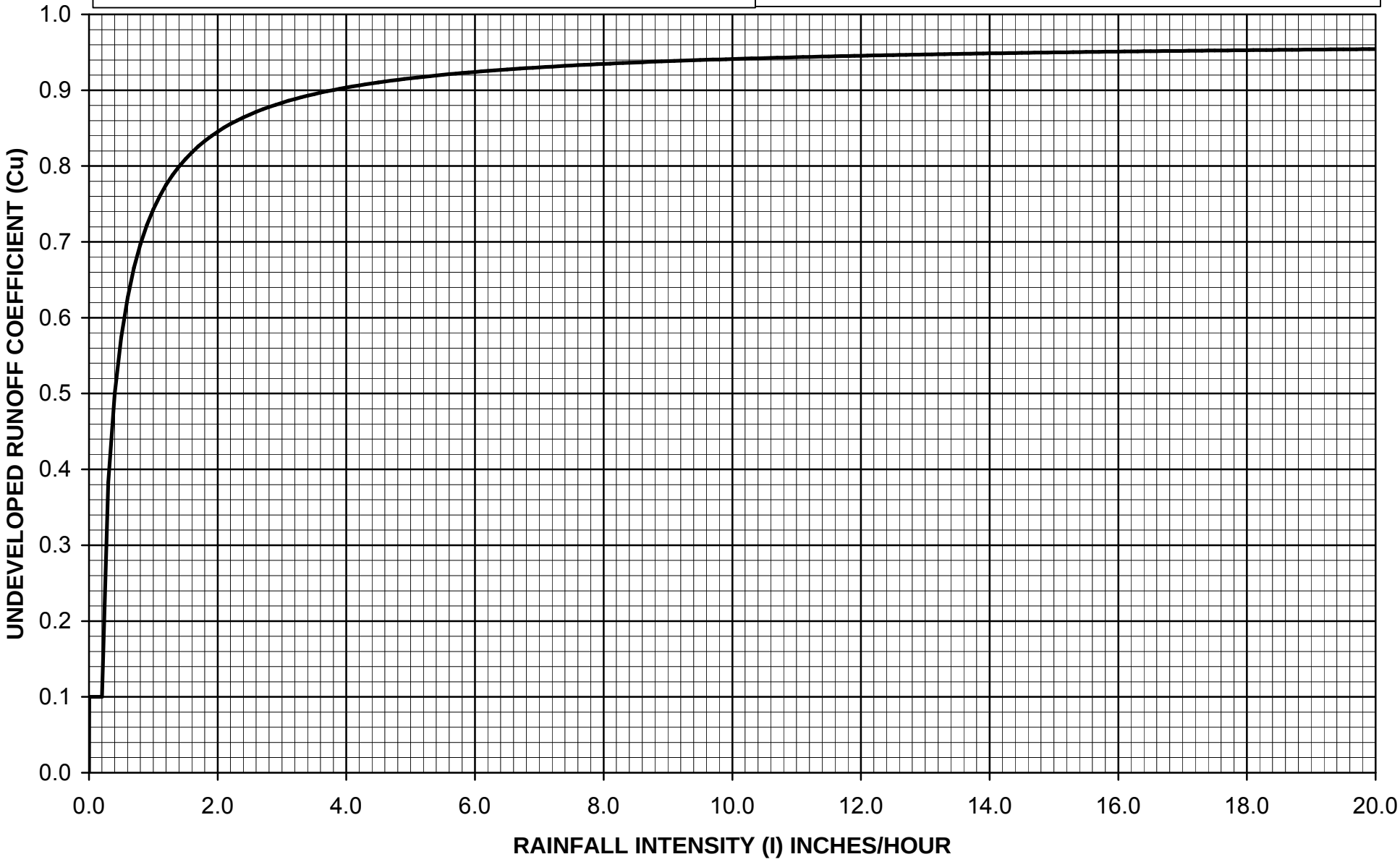


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 094

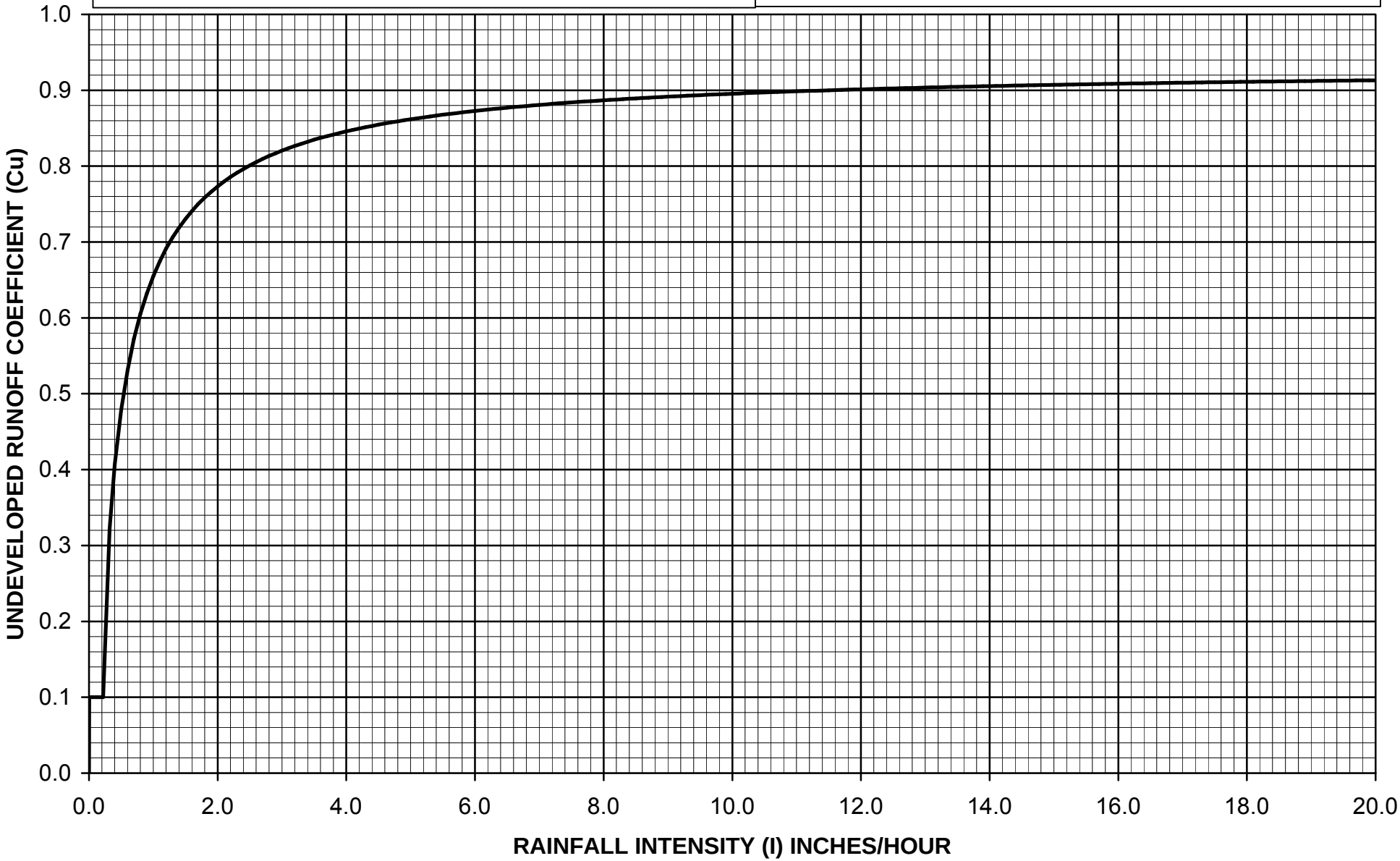


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 095

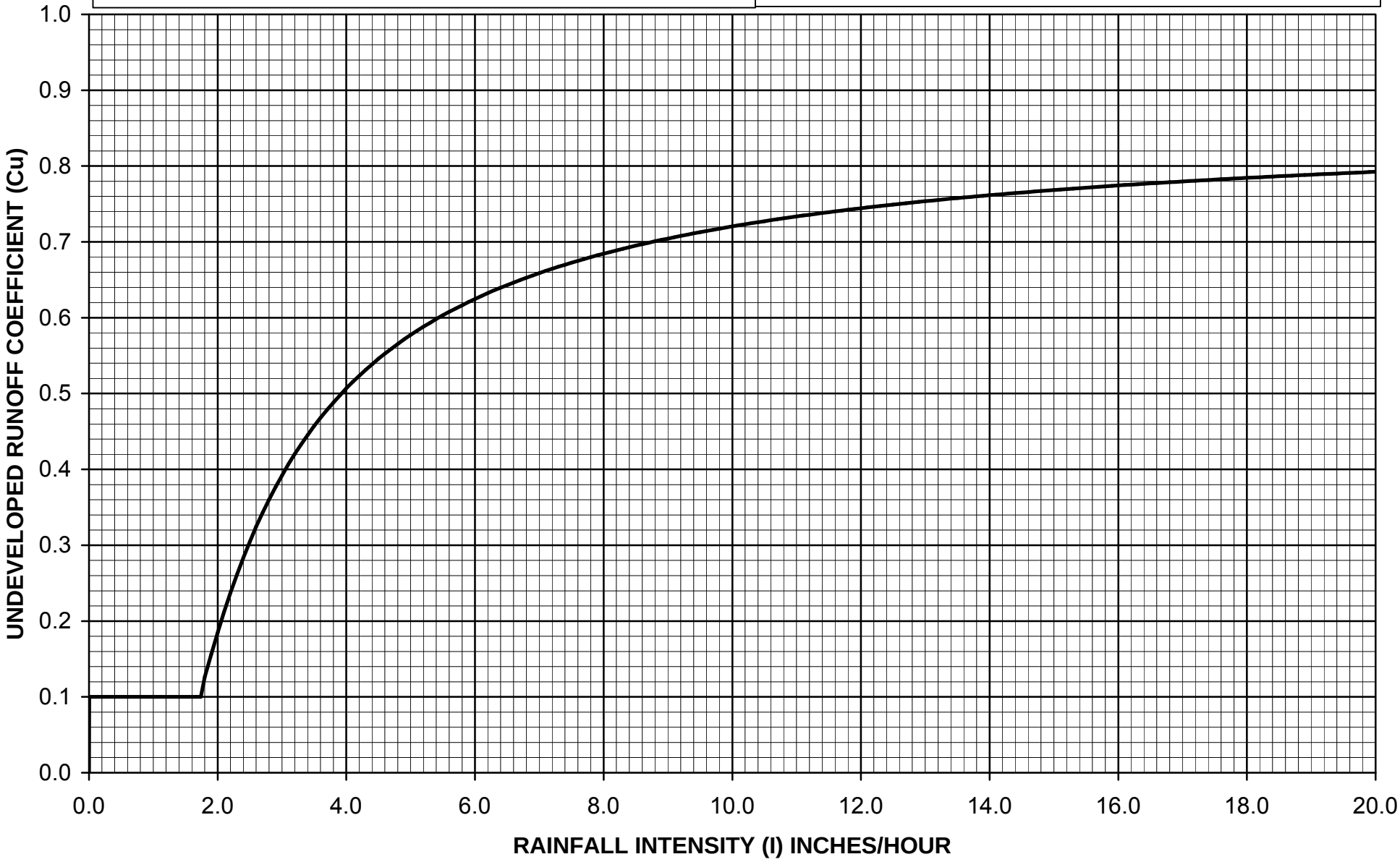


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 096

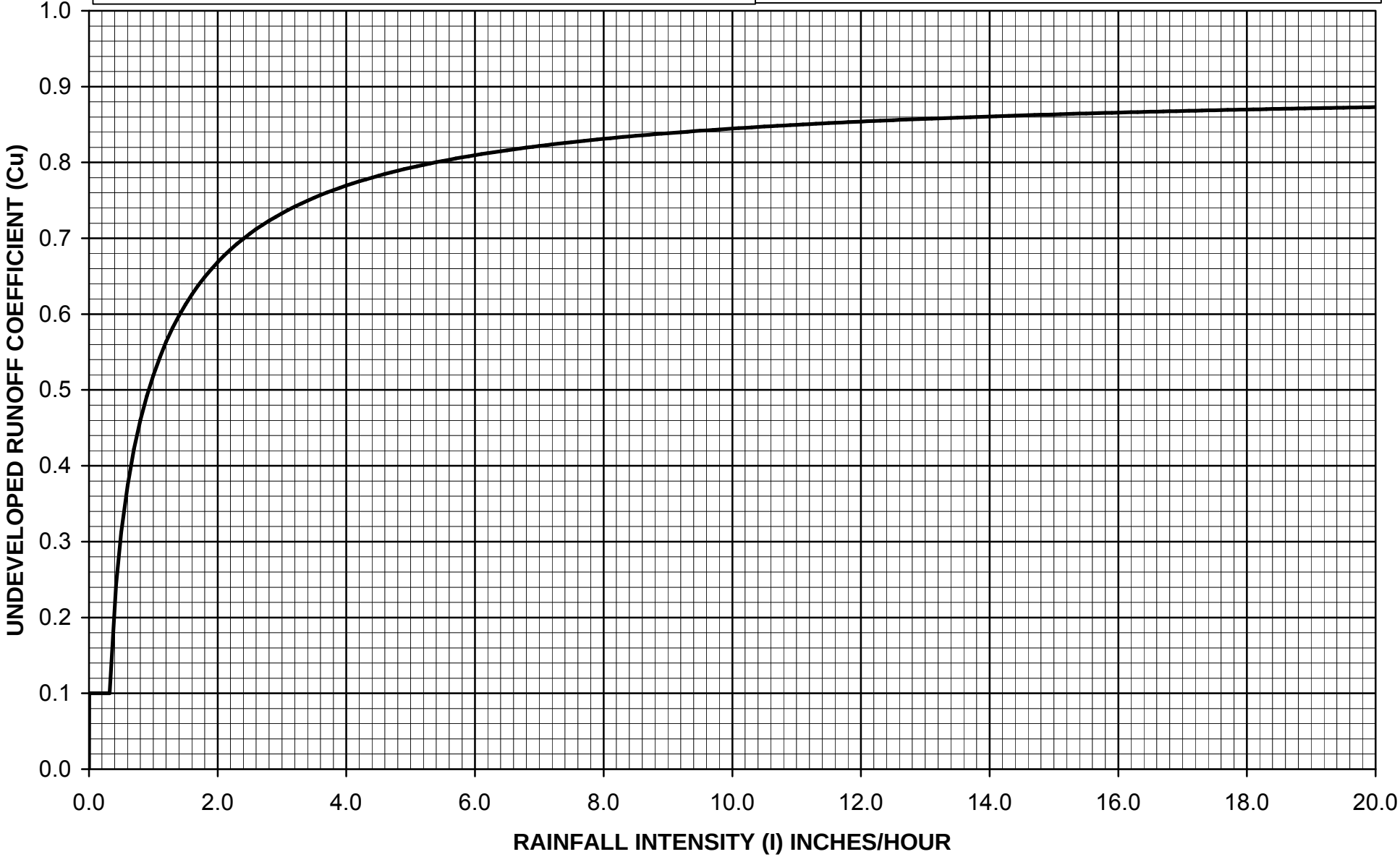


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 097

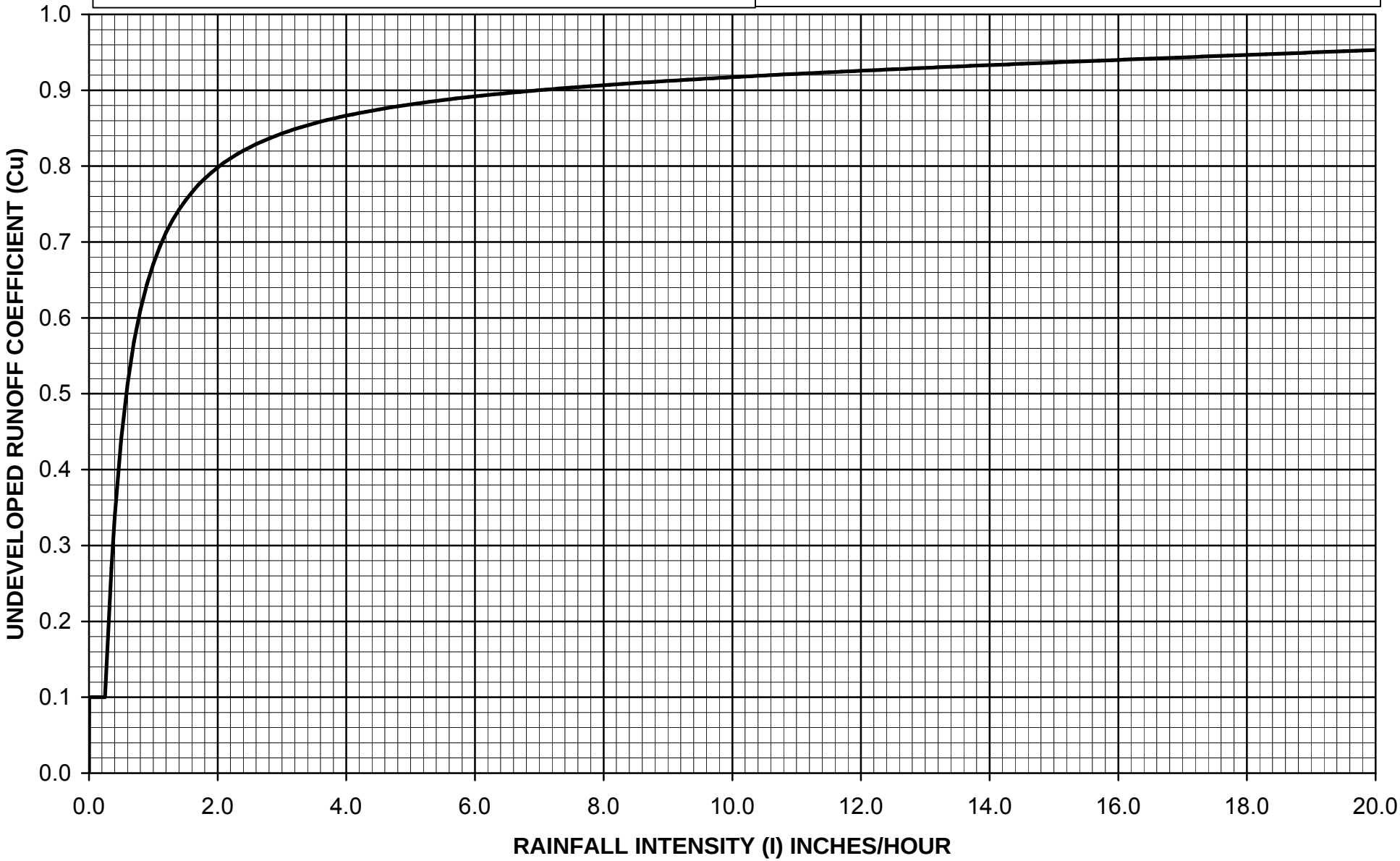


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 098

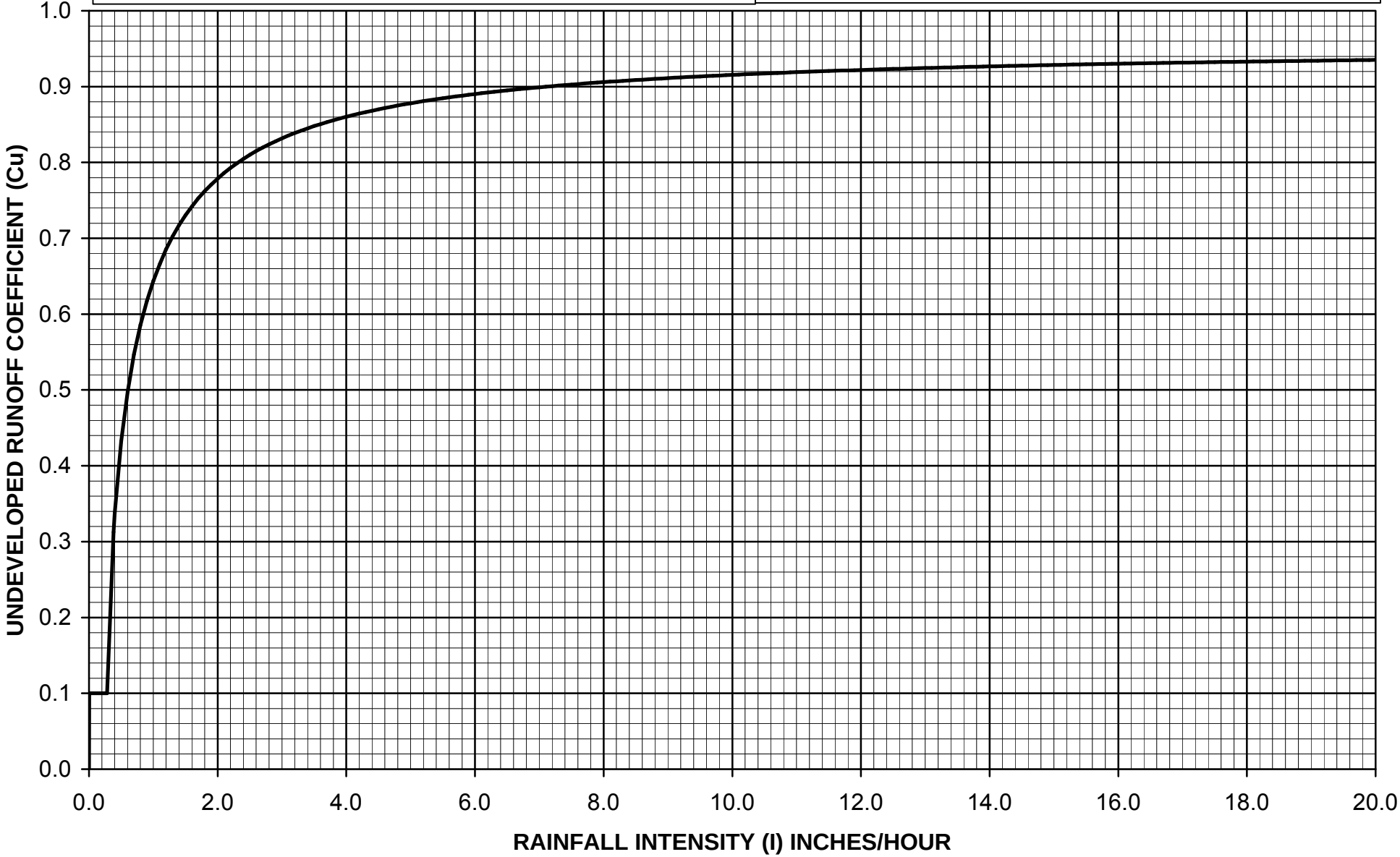


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 099

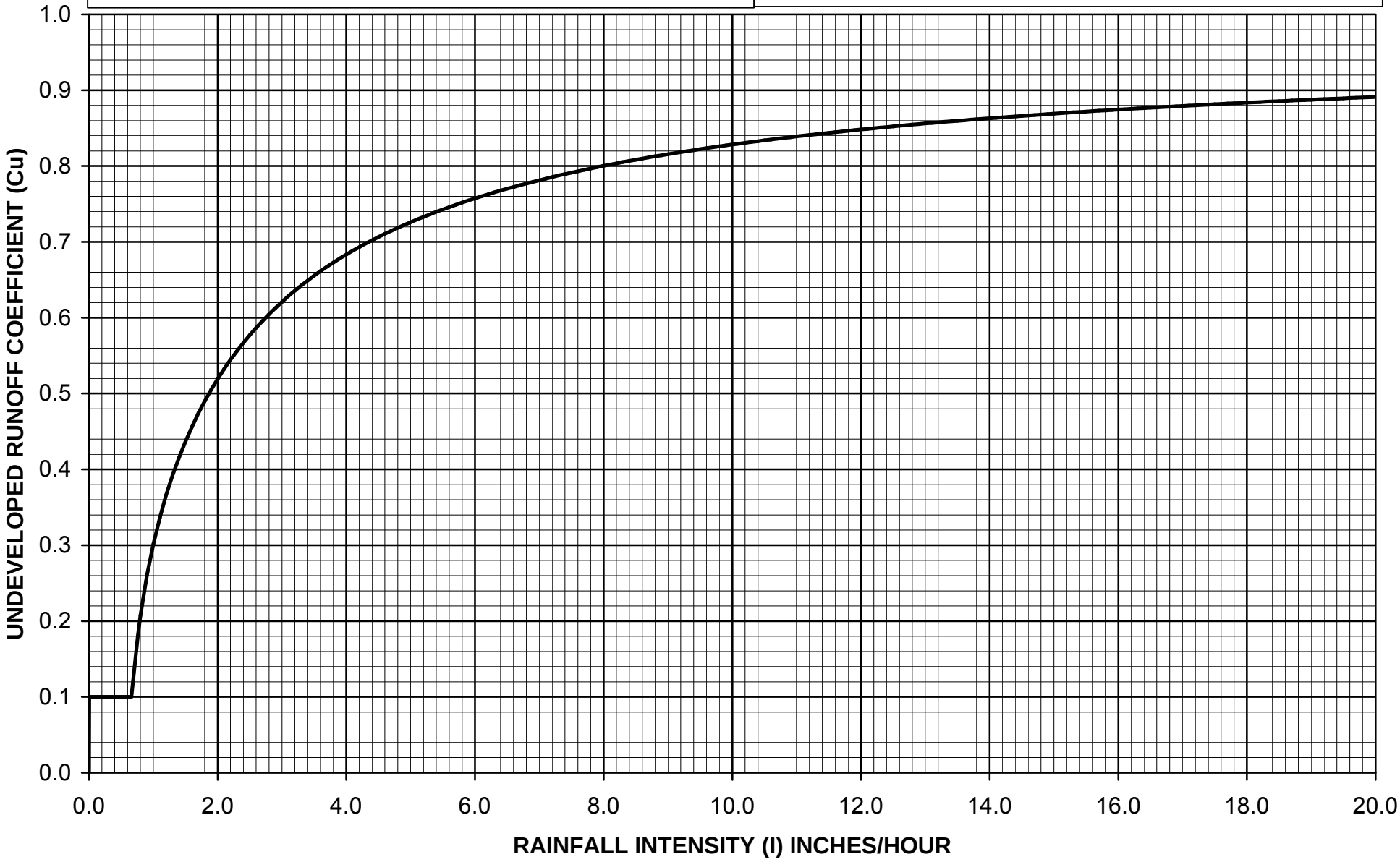


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 100

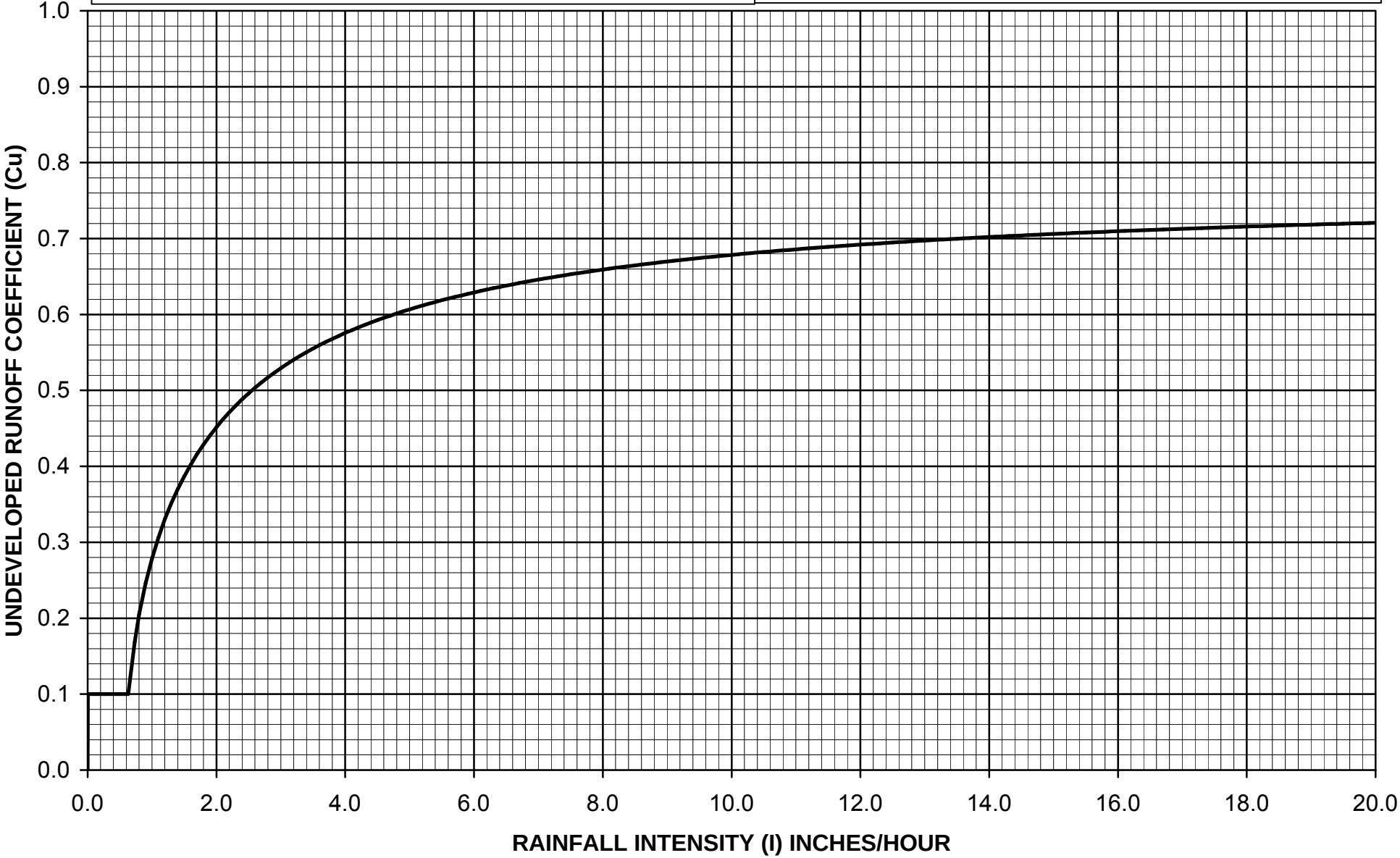


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 101

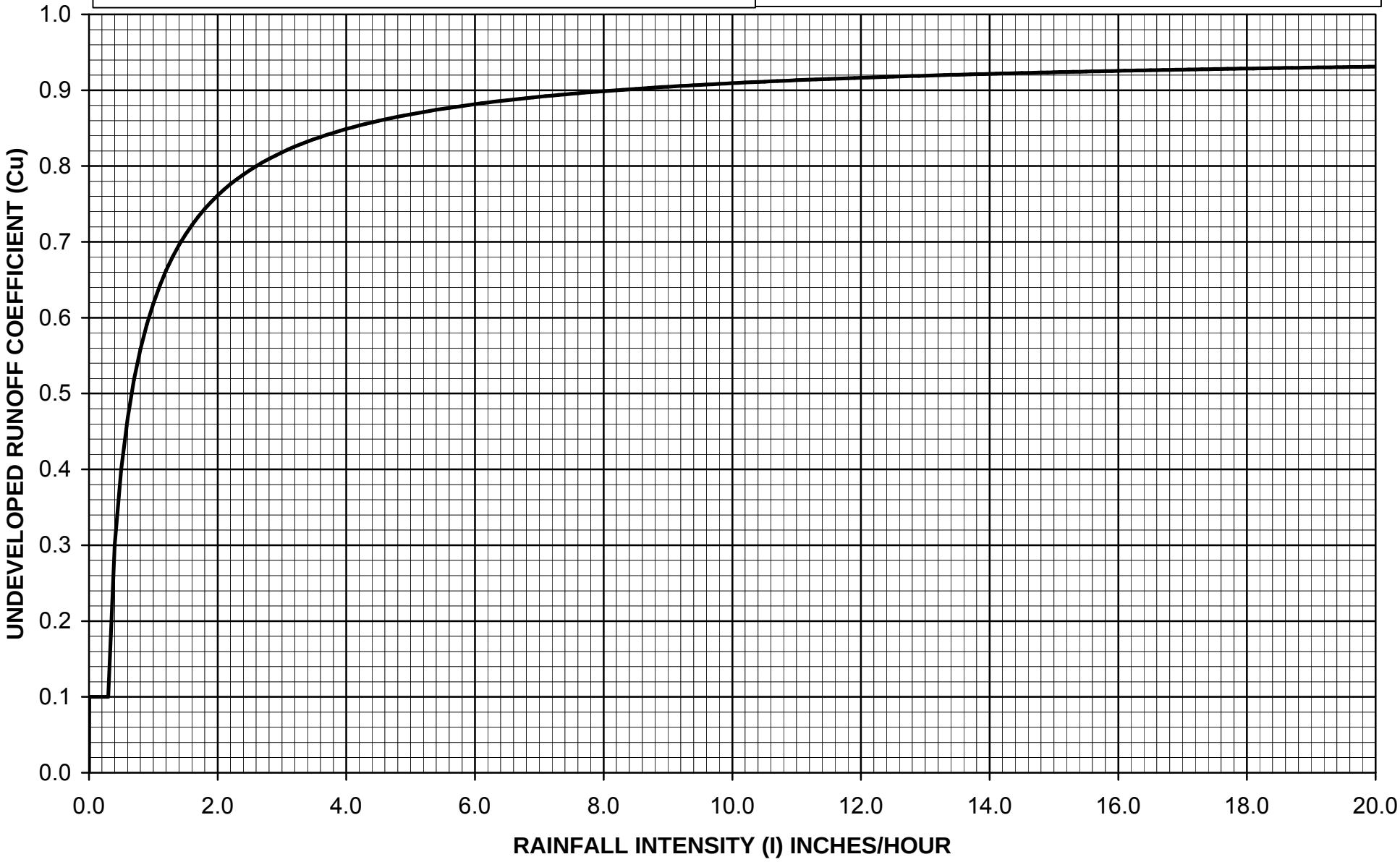


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 102

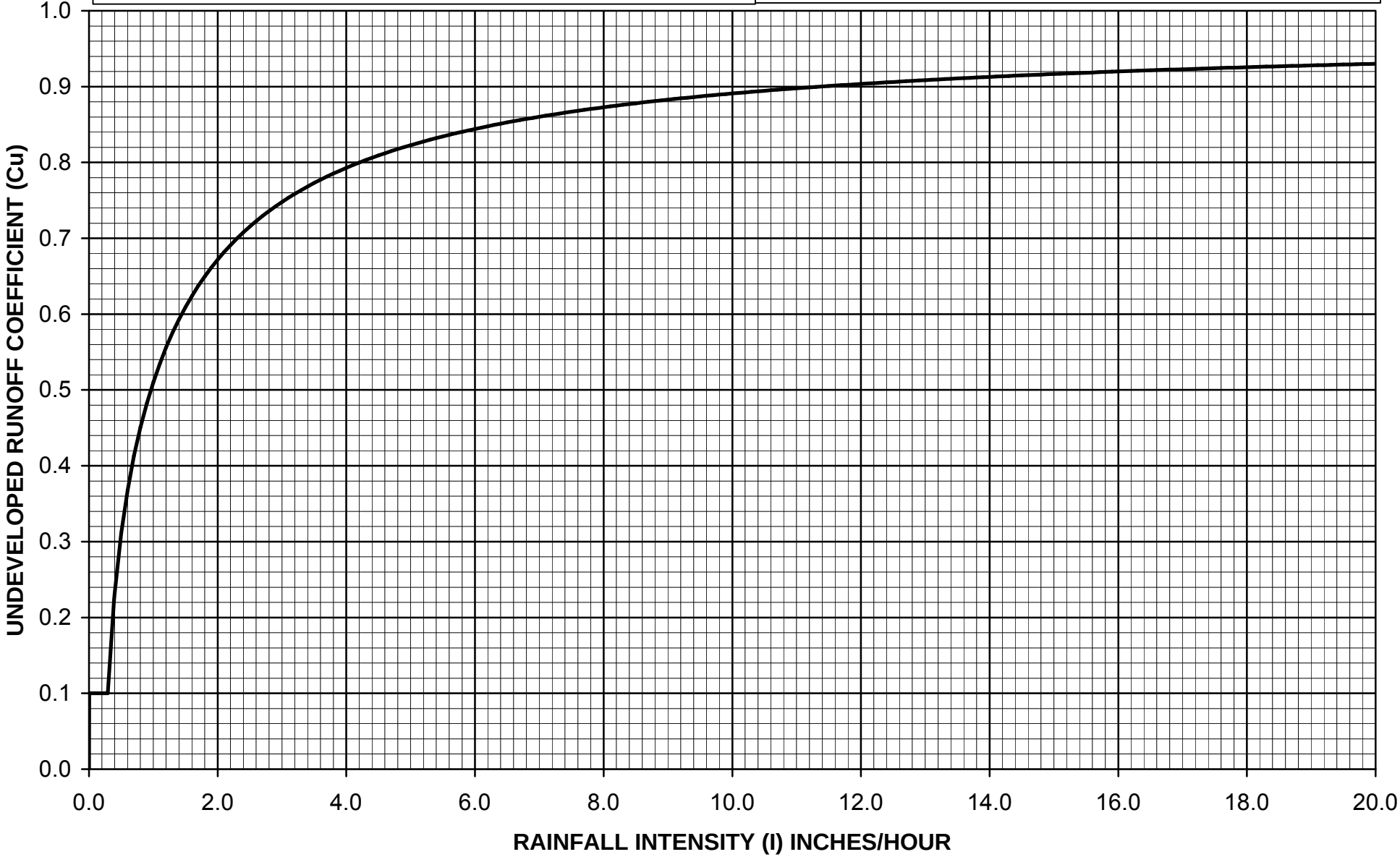


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 103

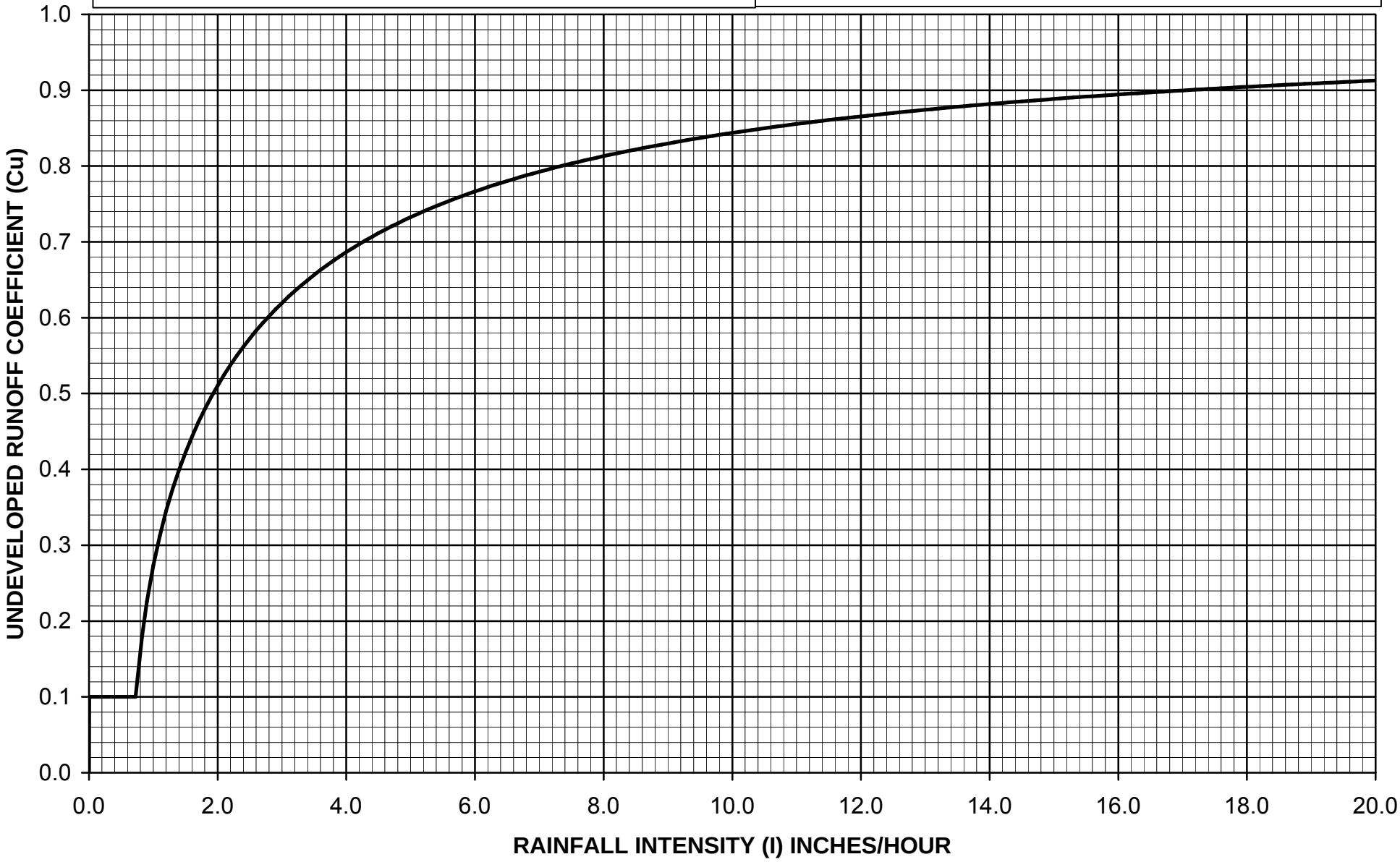


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 104

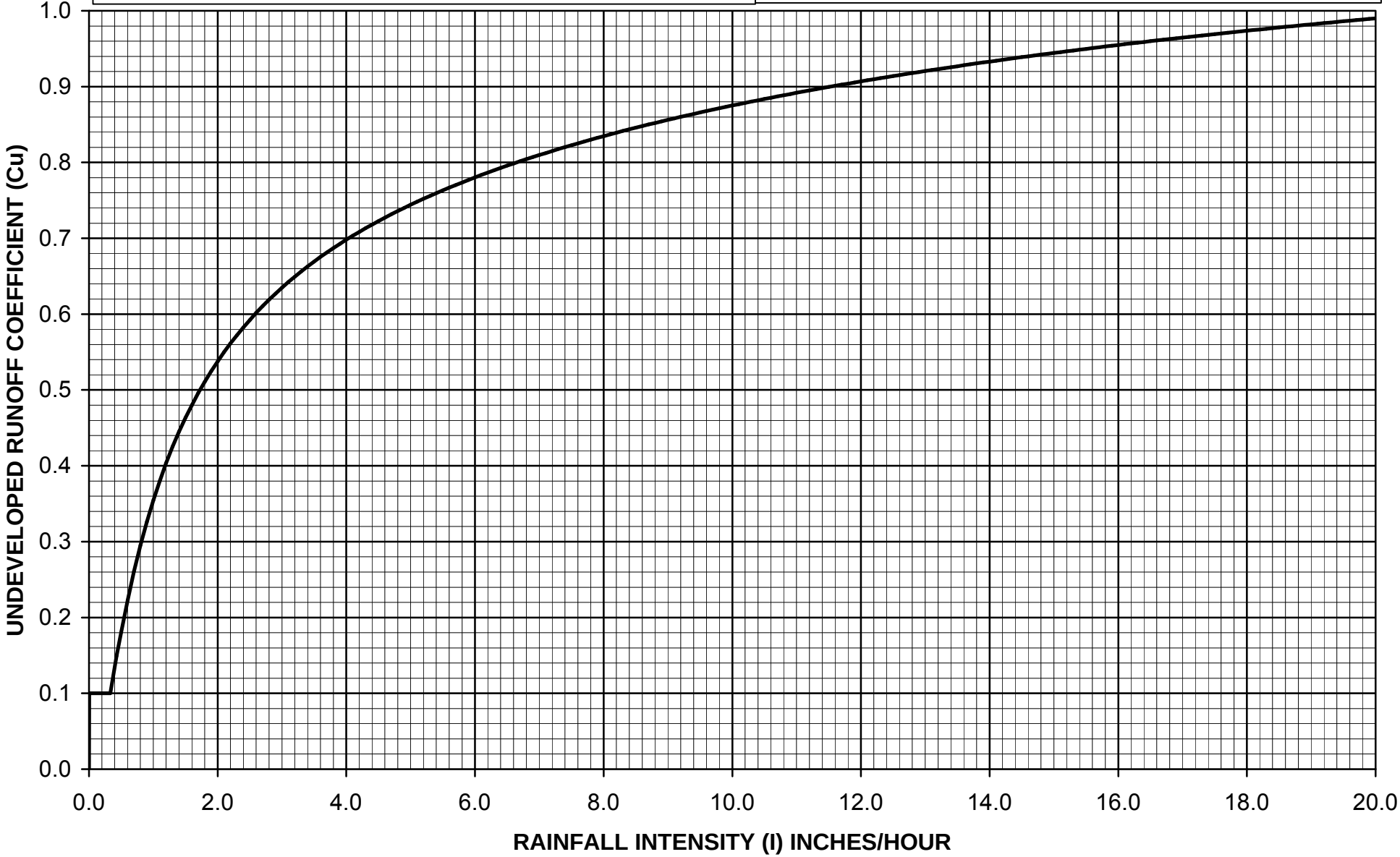


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 105

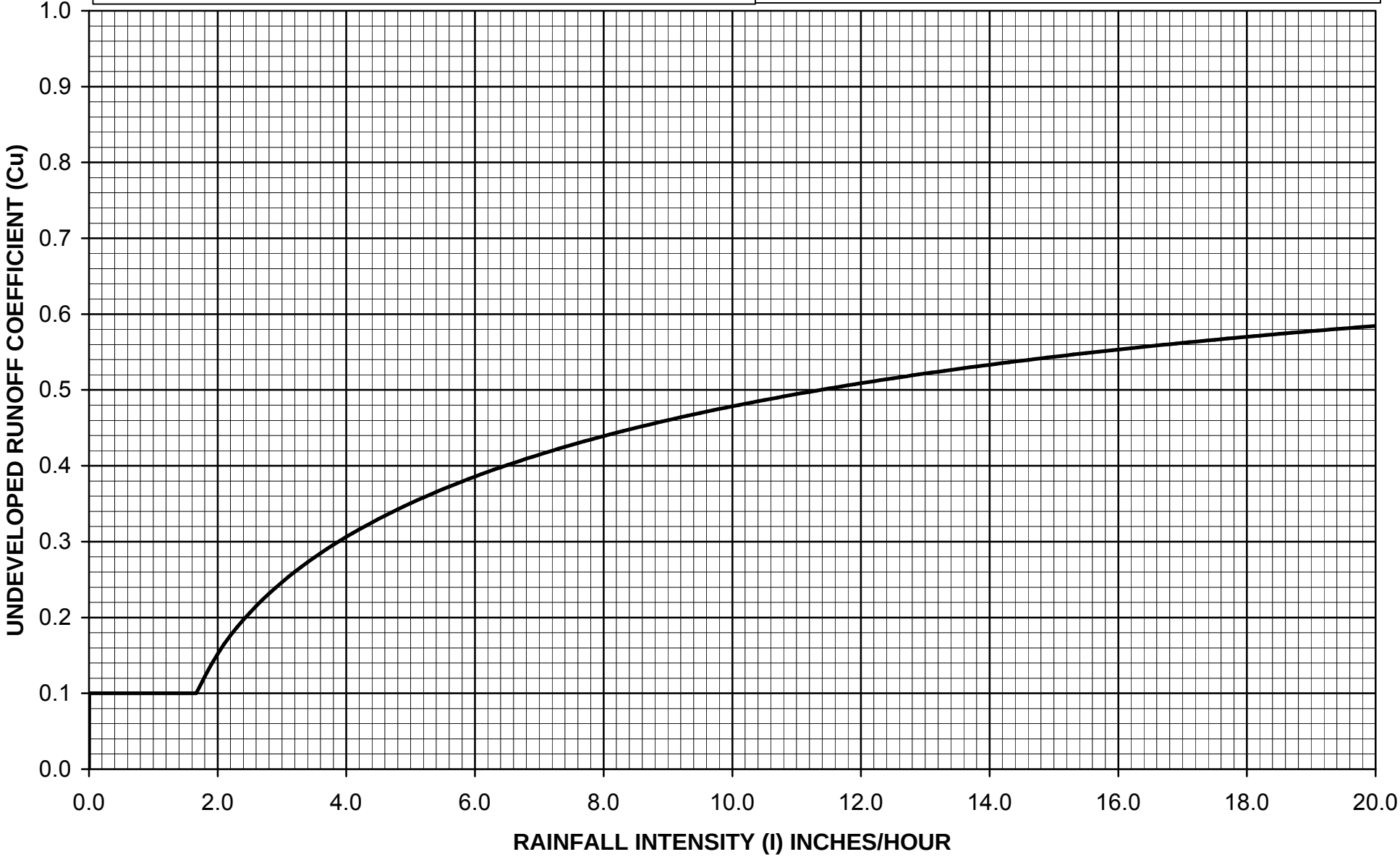


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 106

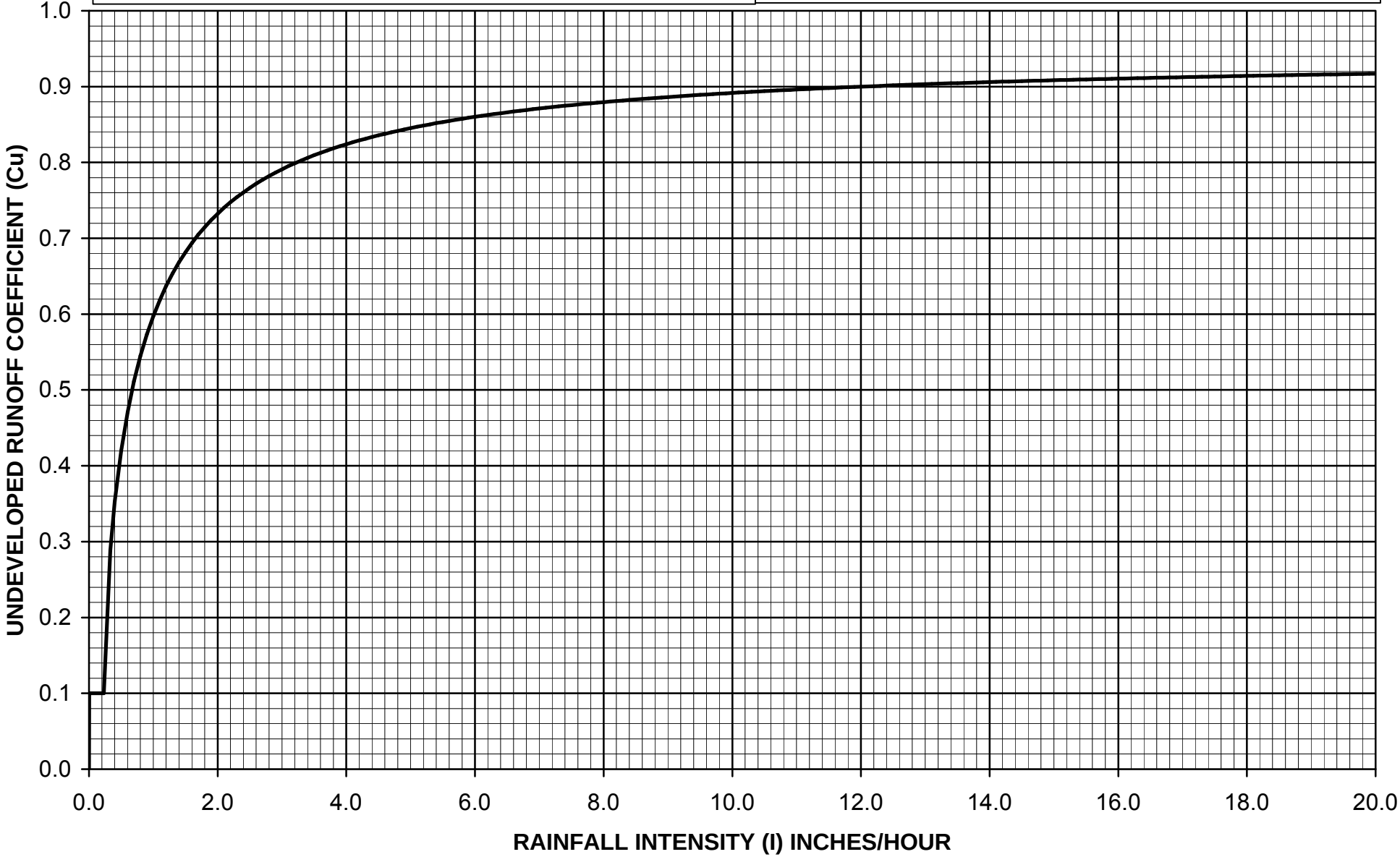


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 107

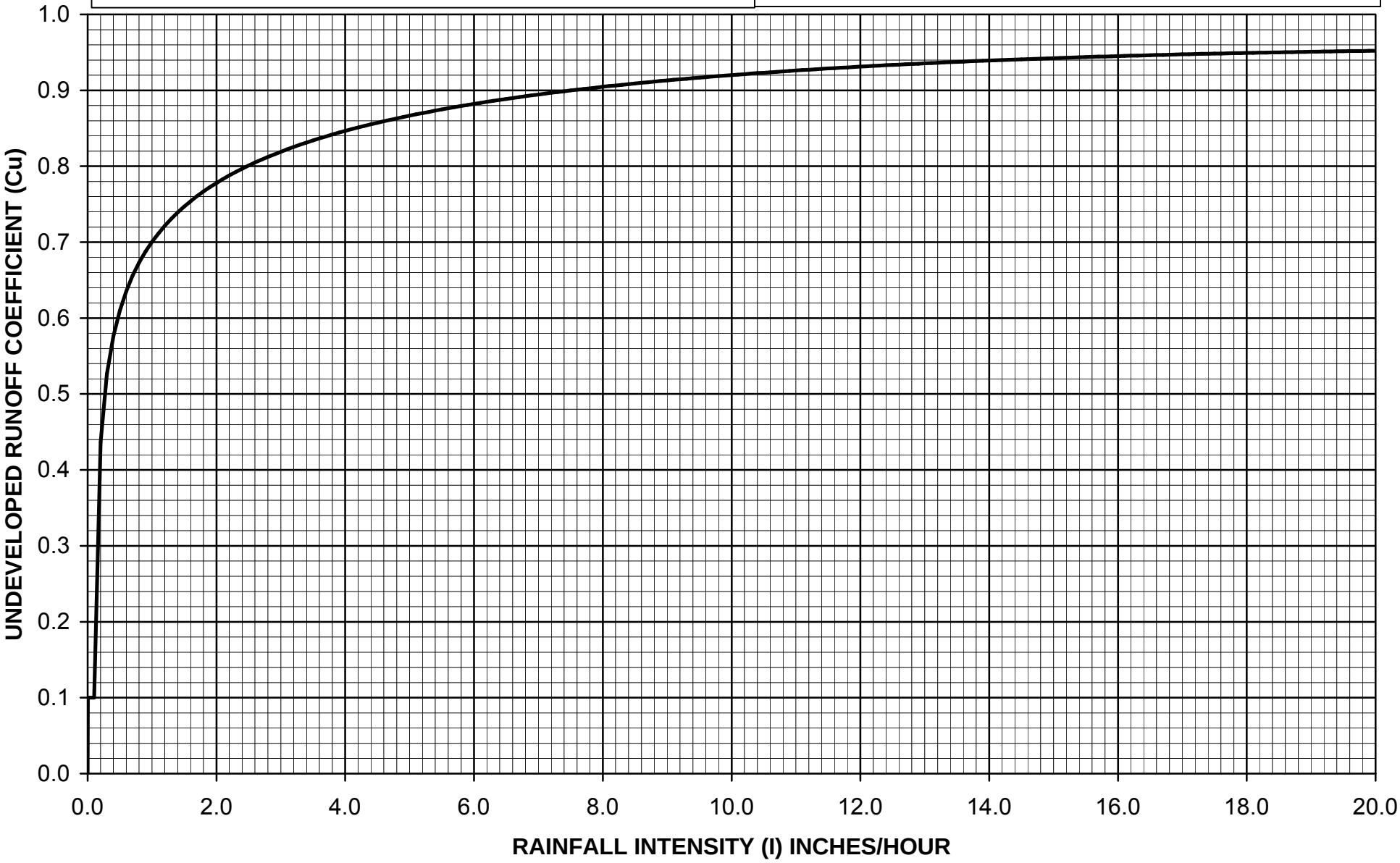


CD = (0.9 * IMP) + (1.0 - IMP) * Cu

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 108

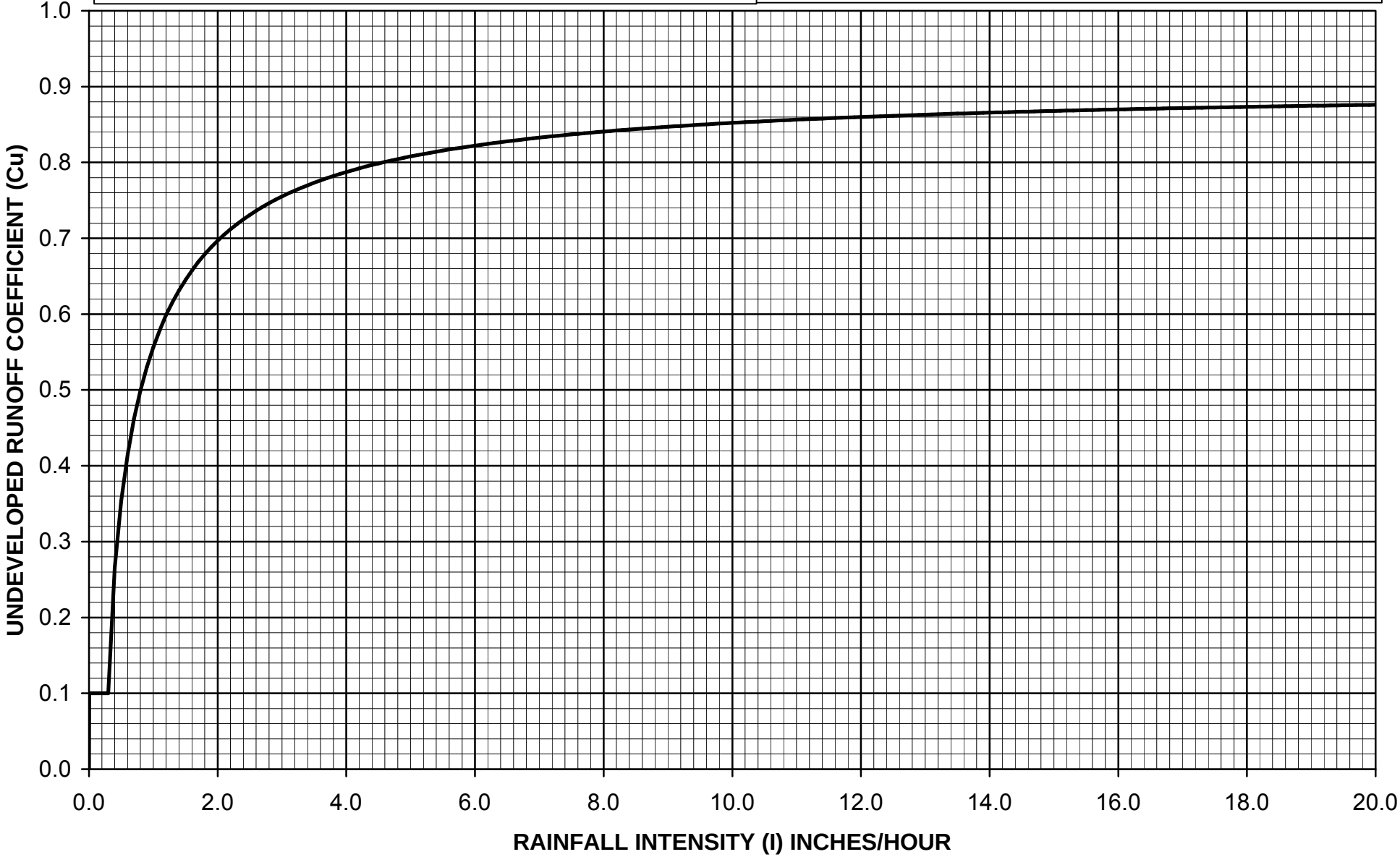


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 109

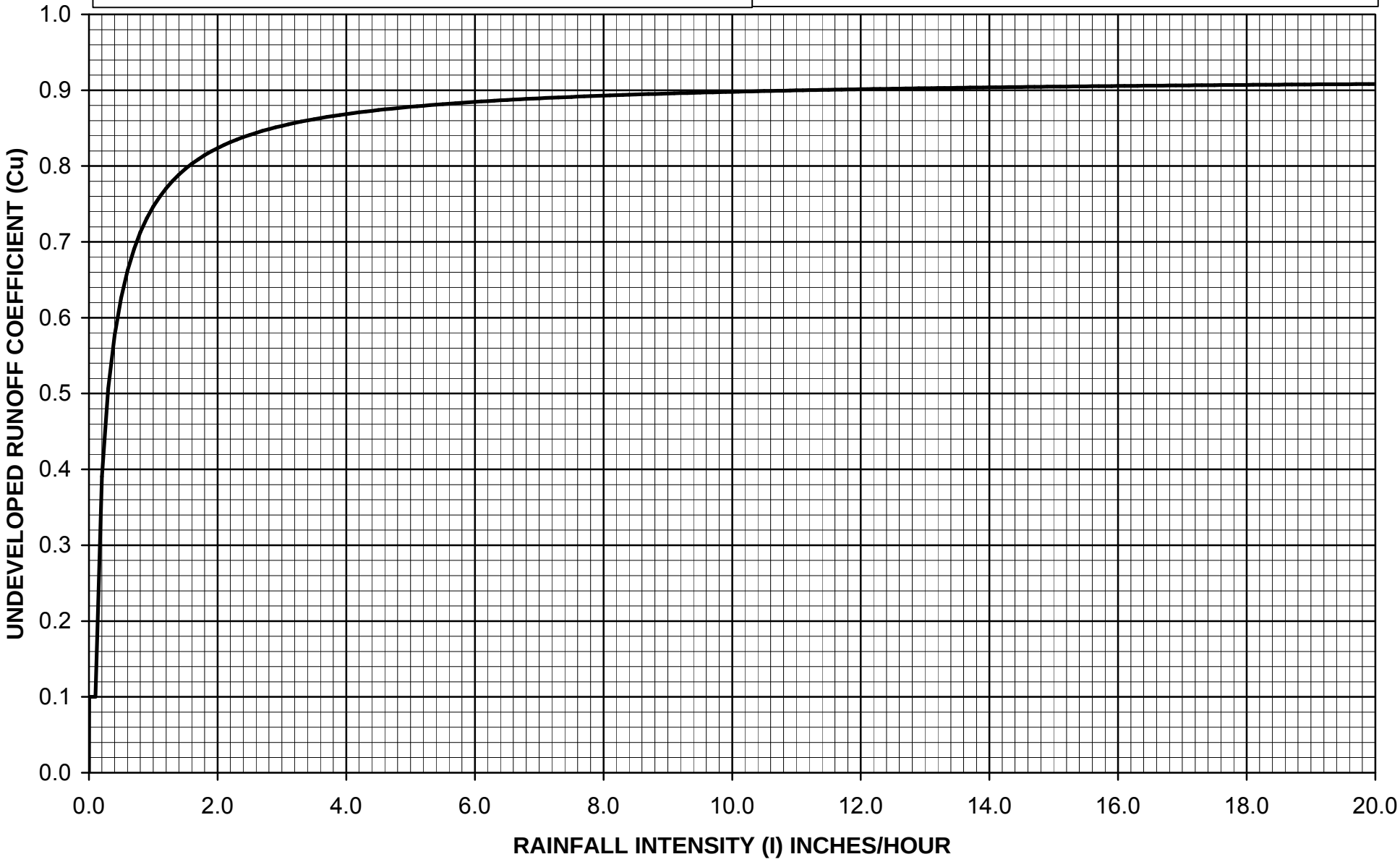


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 110

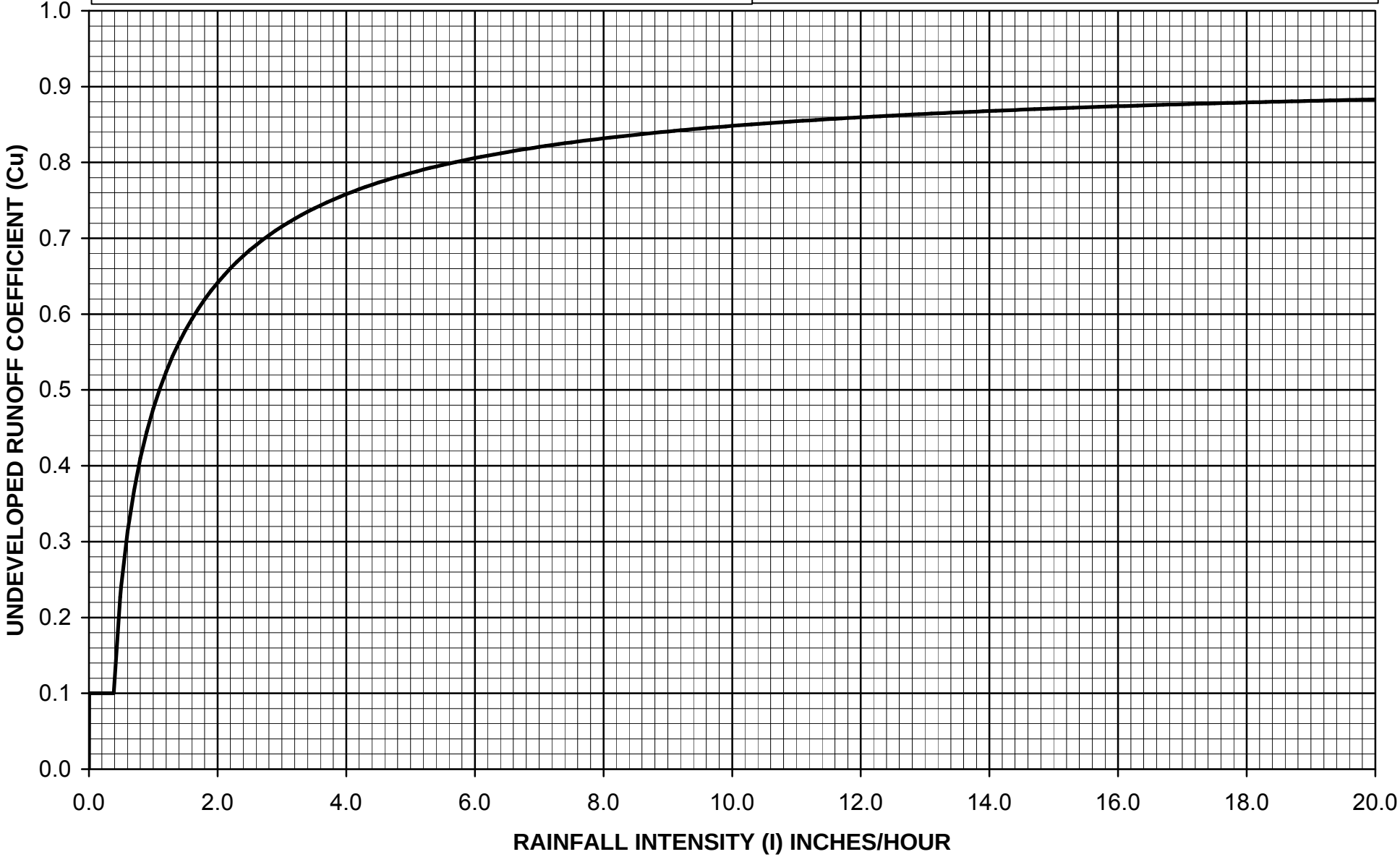


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 111

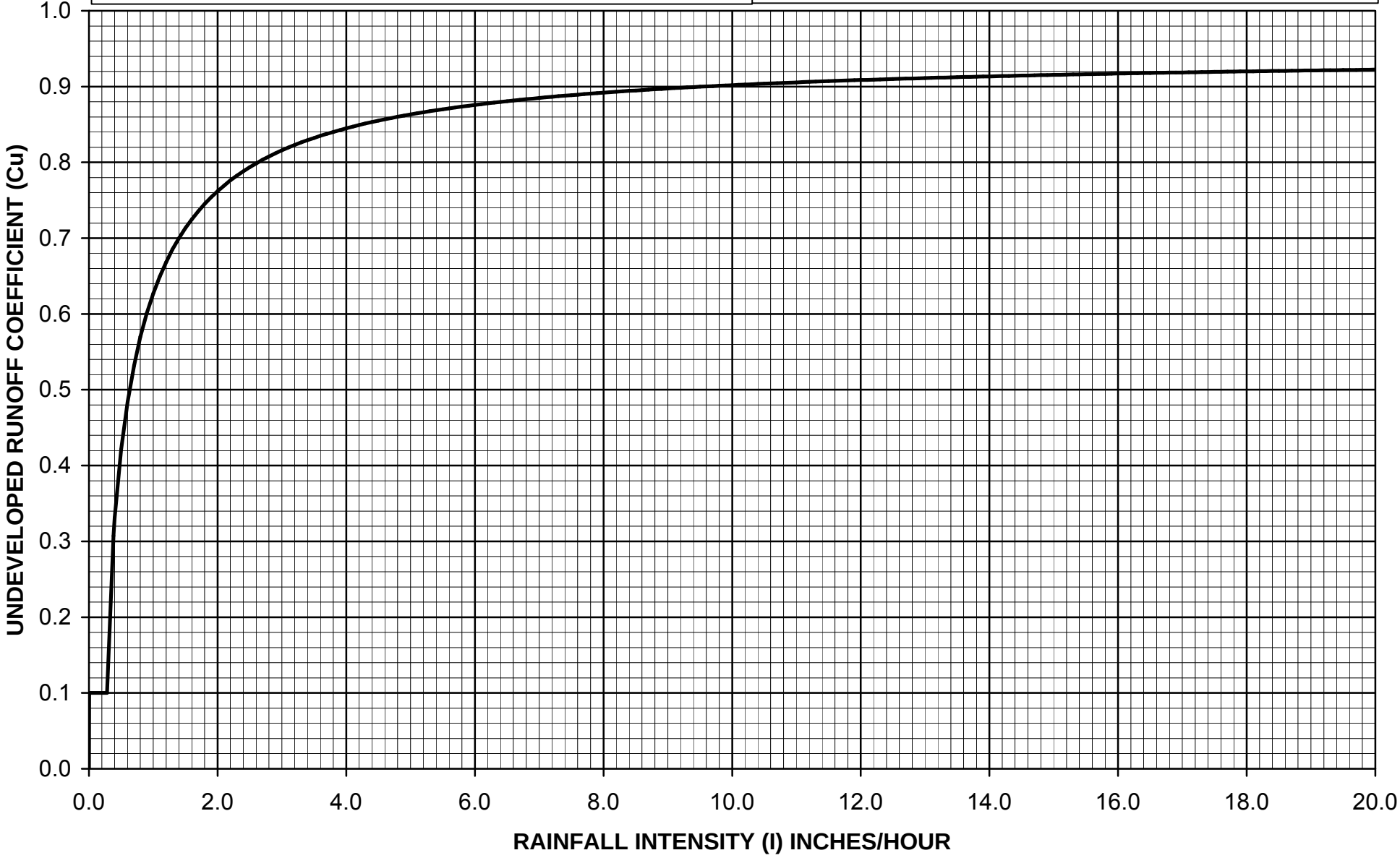


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 112

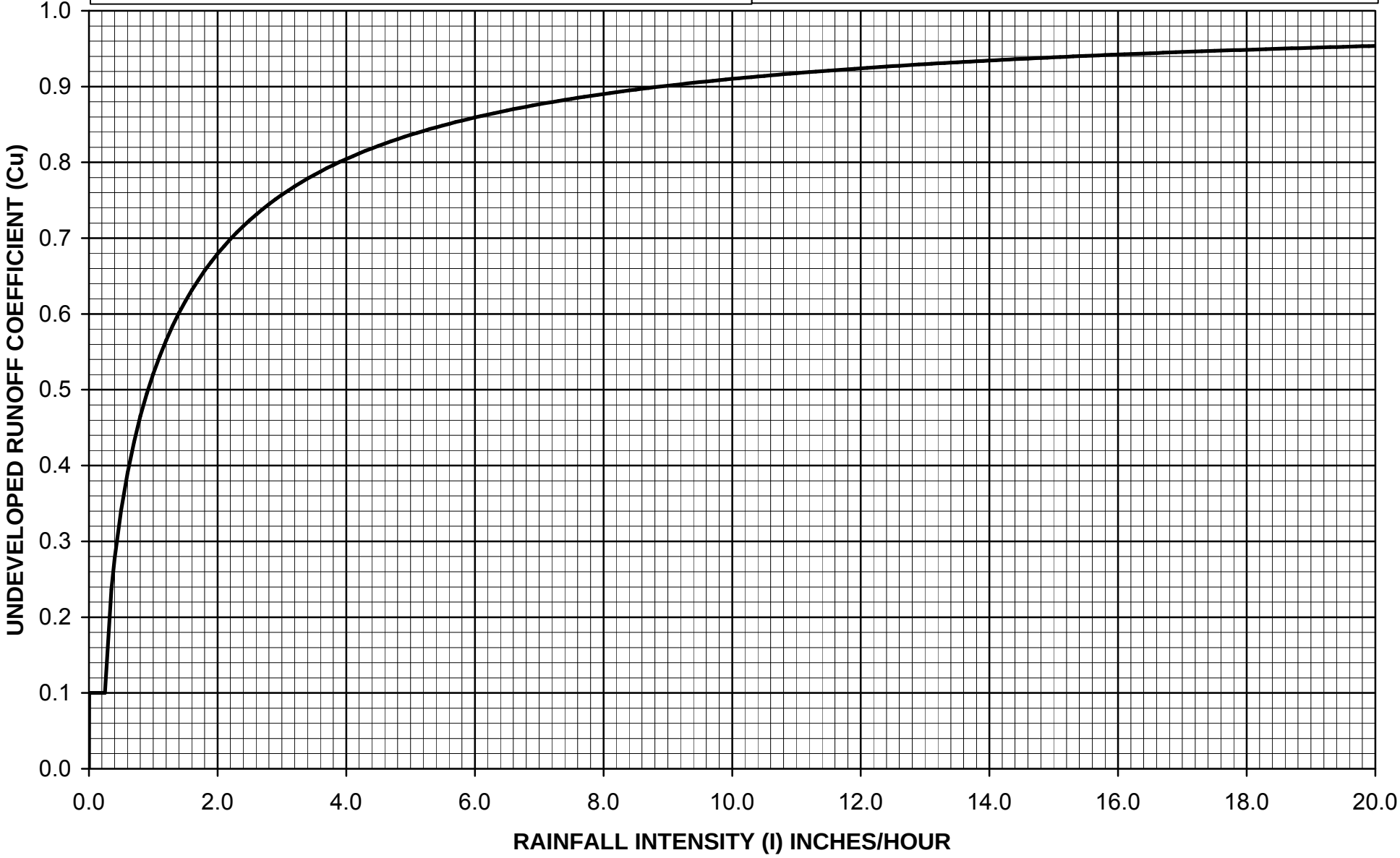


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 113

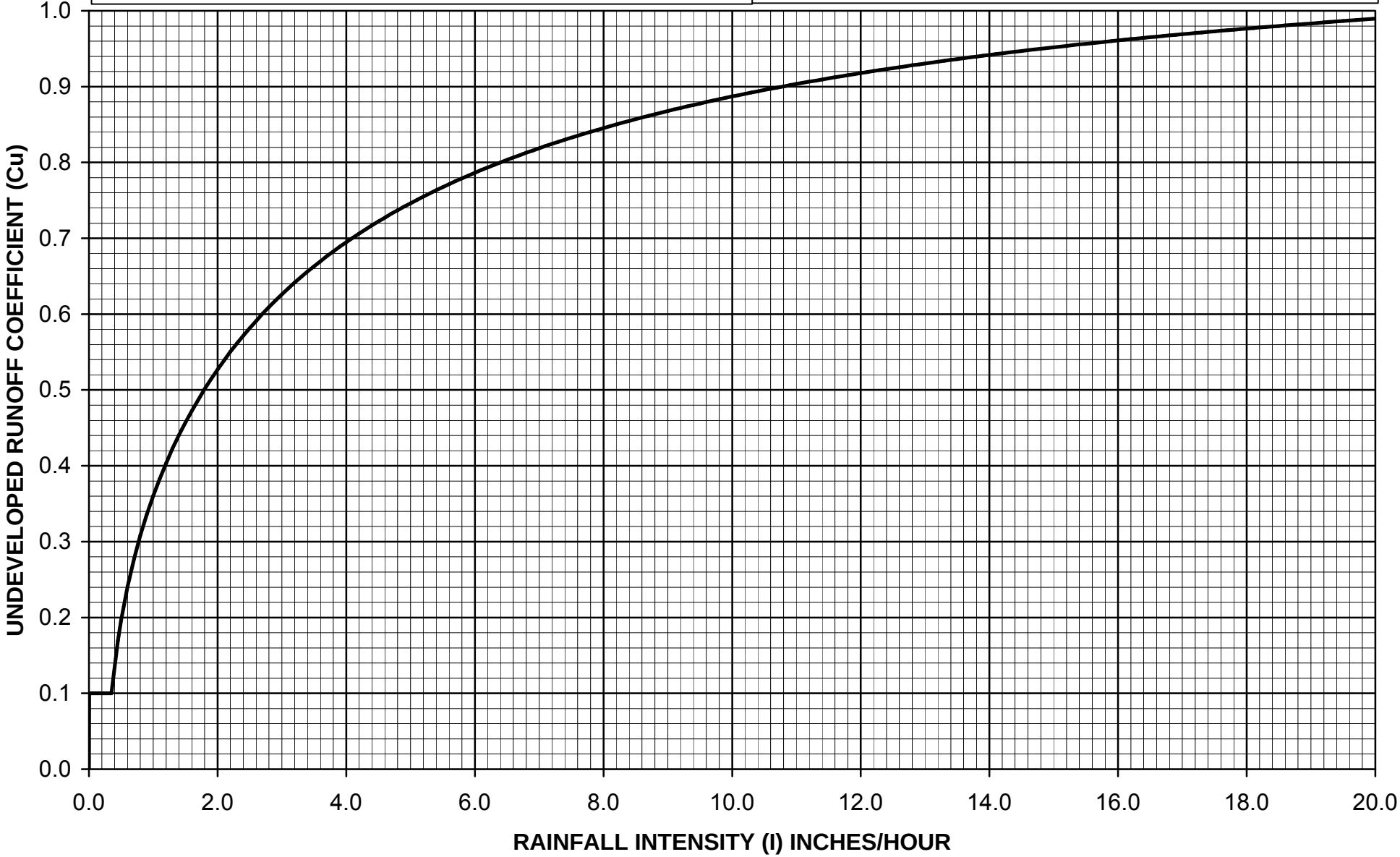


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 114

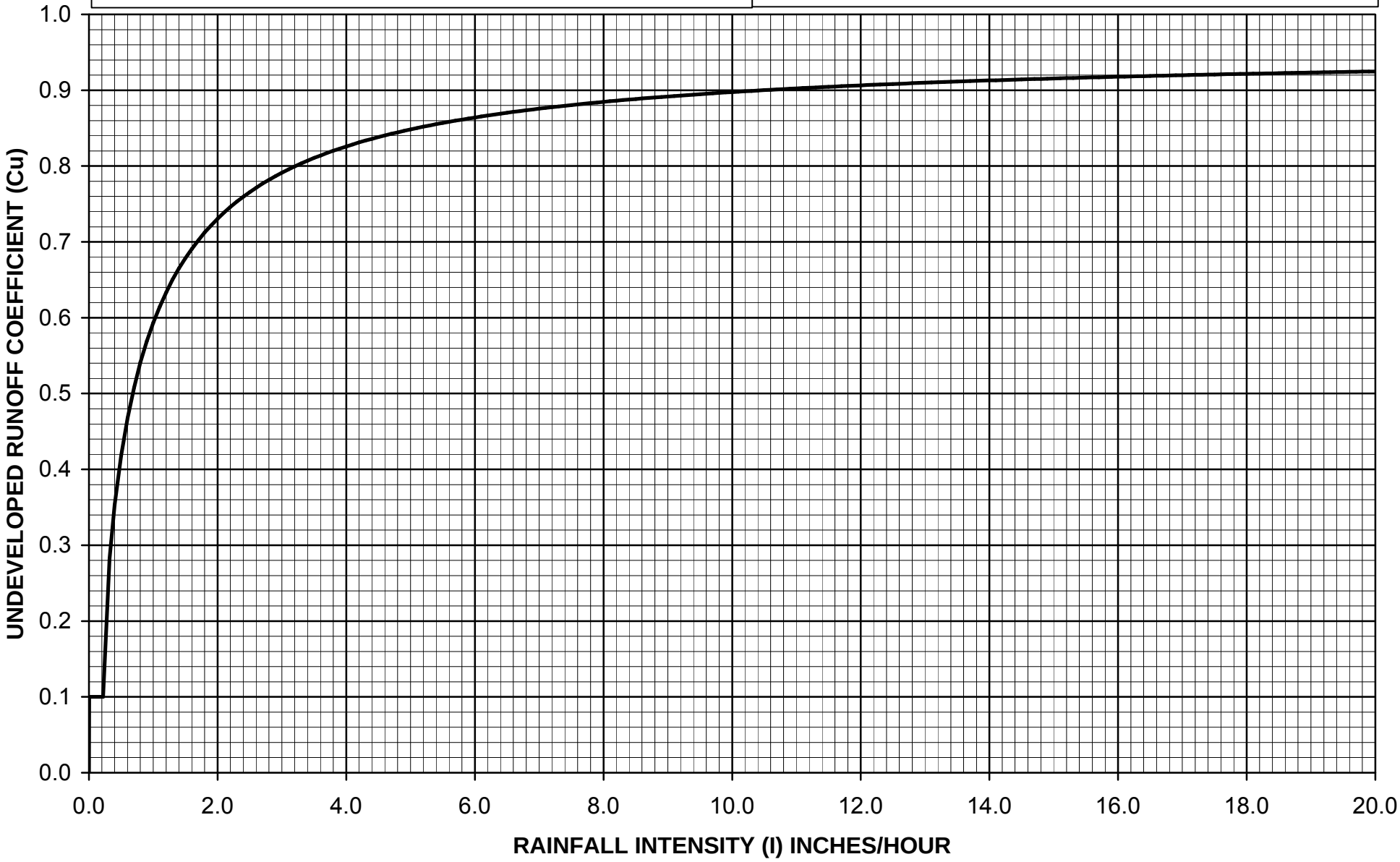


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 115

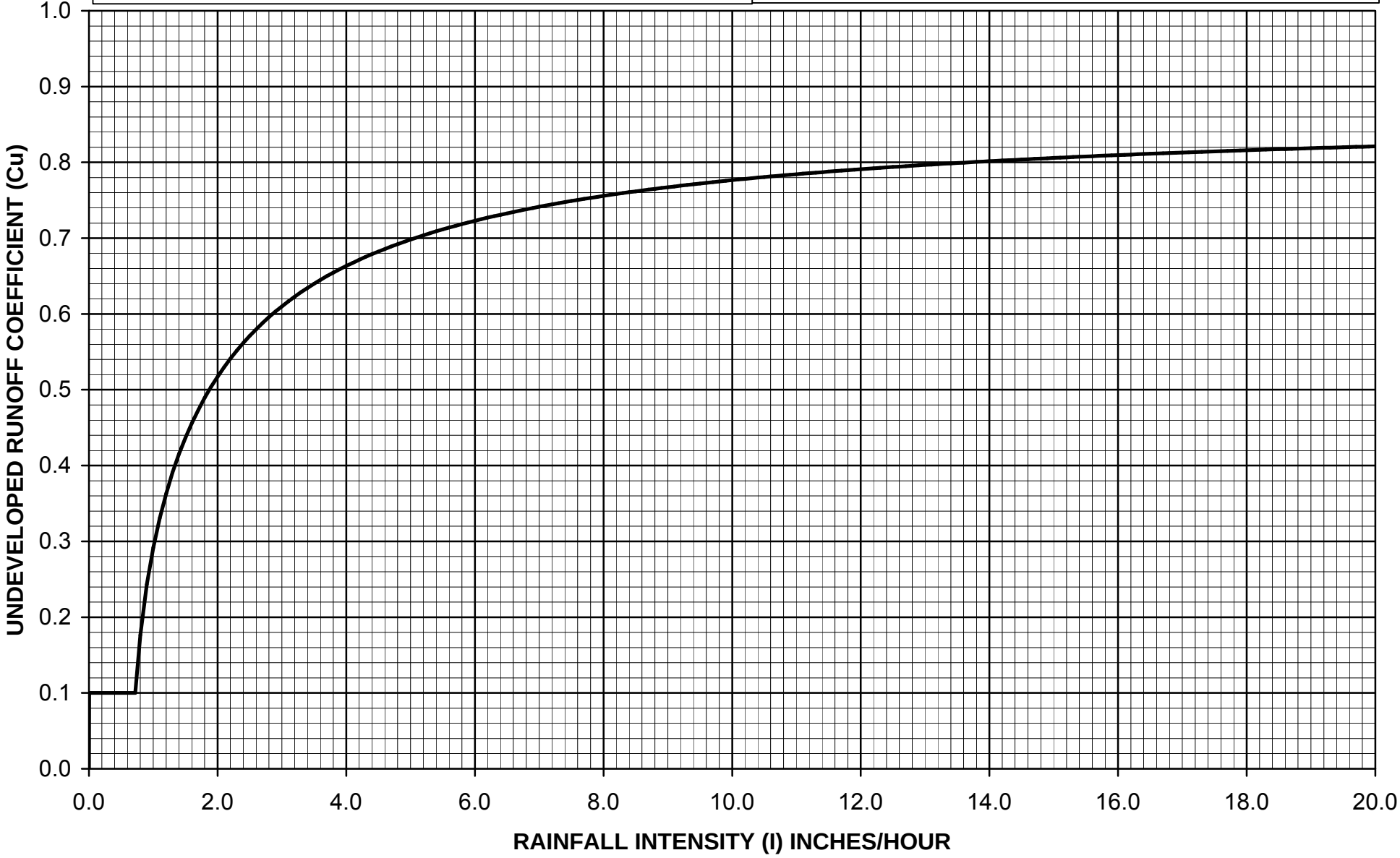


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 116

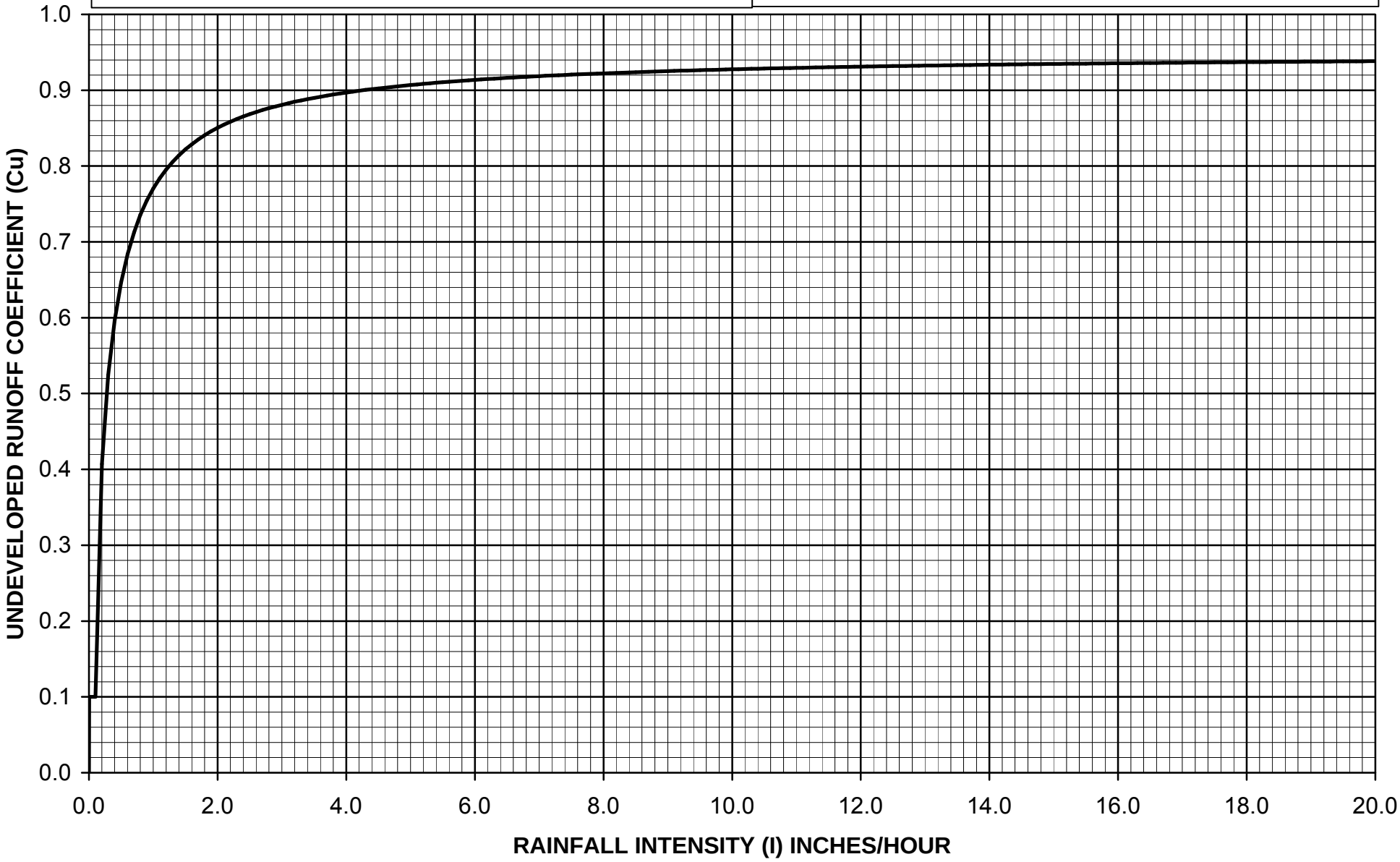


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 117

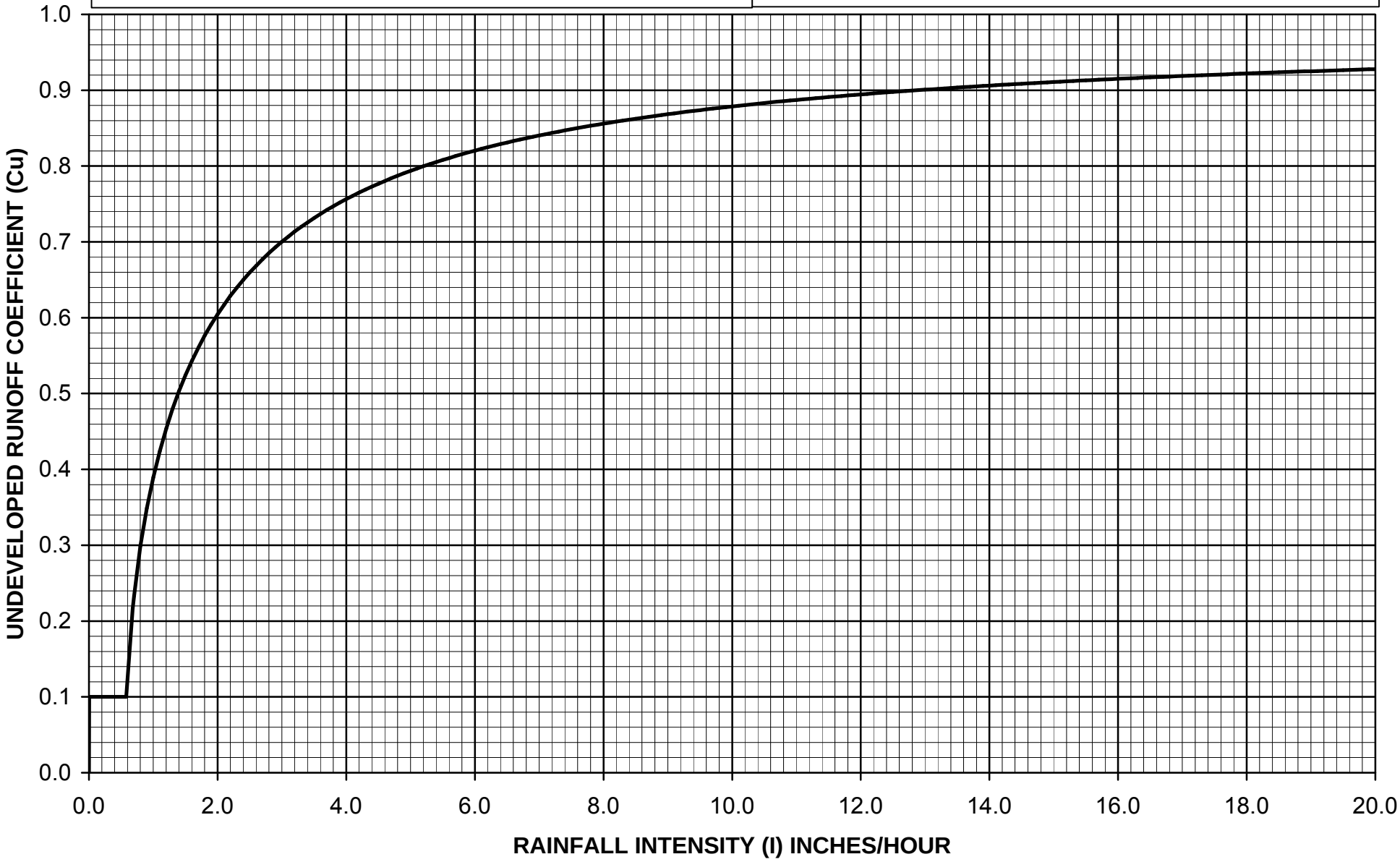


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 118

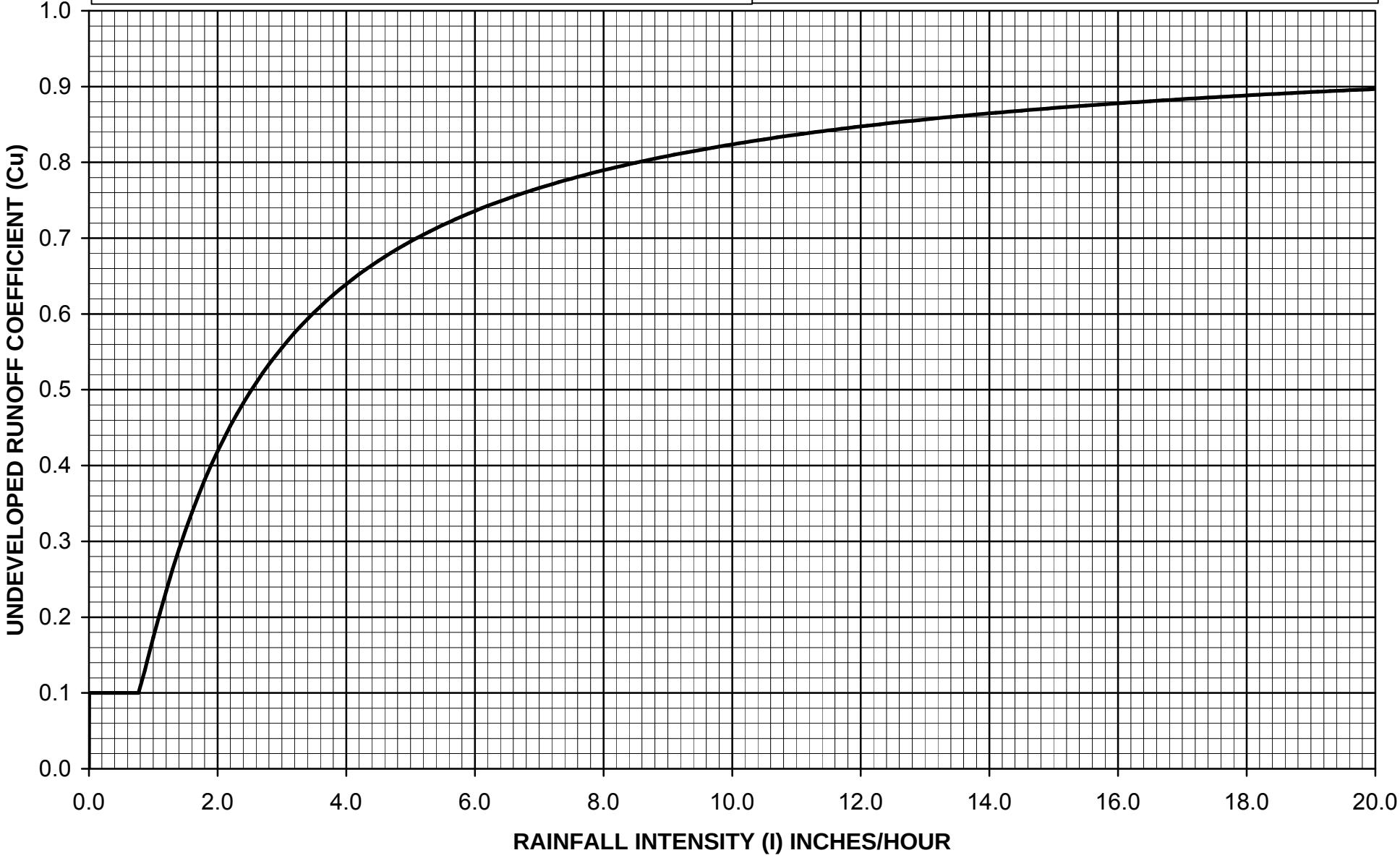


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 119

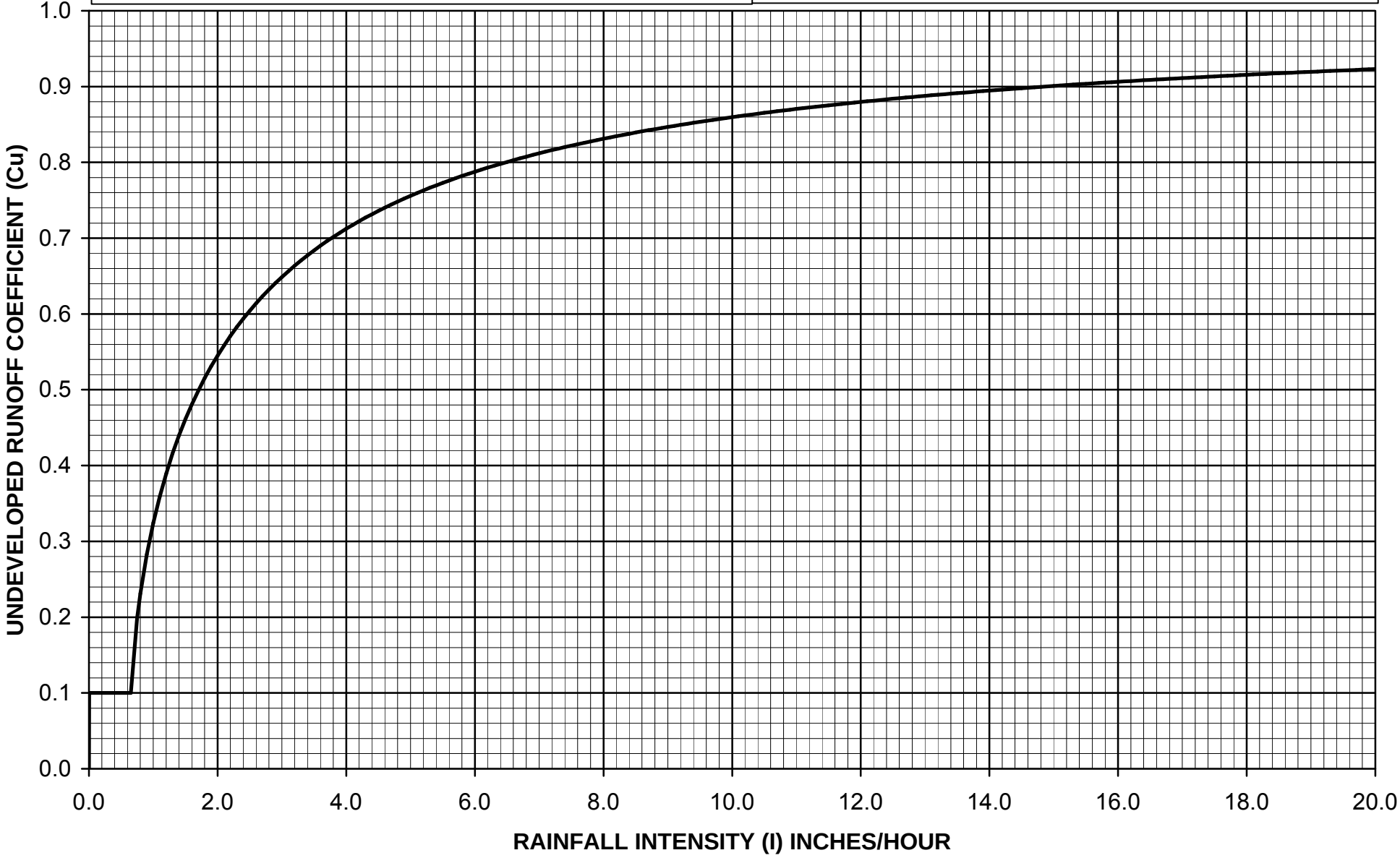


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 120

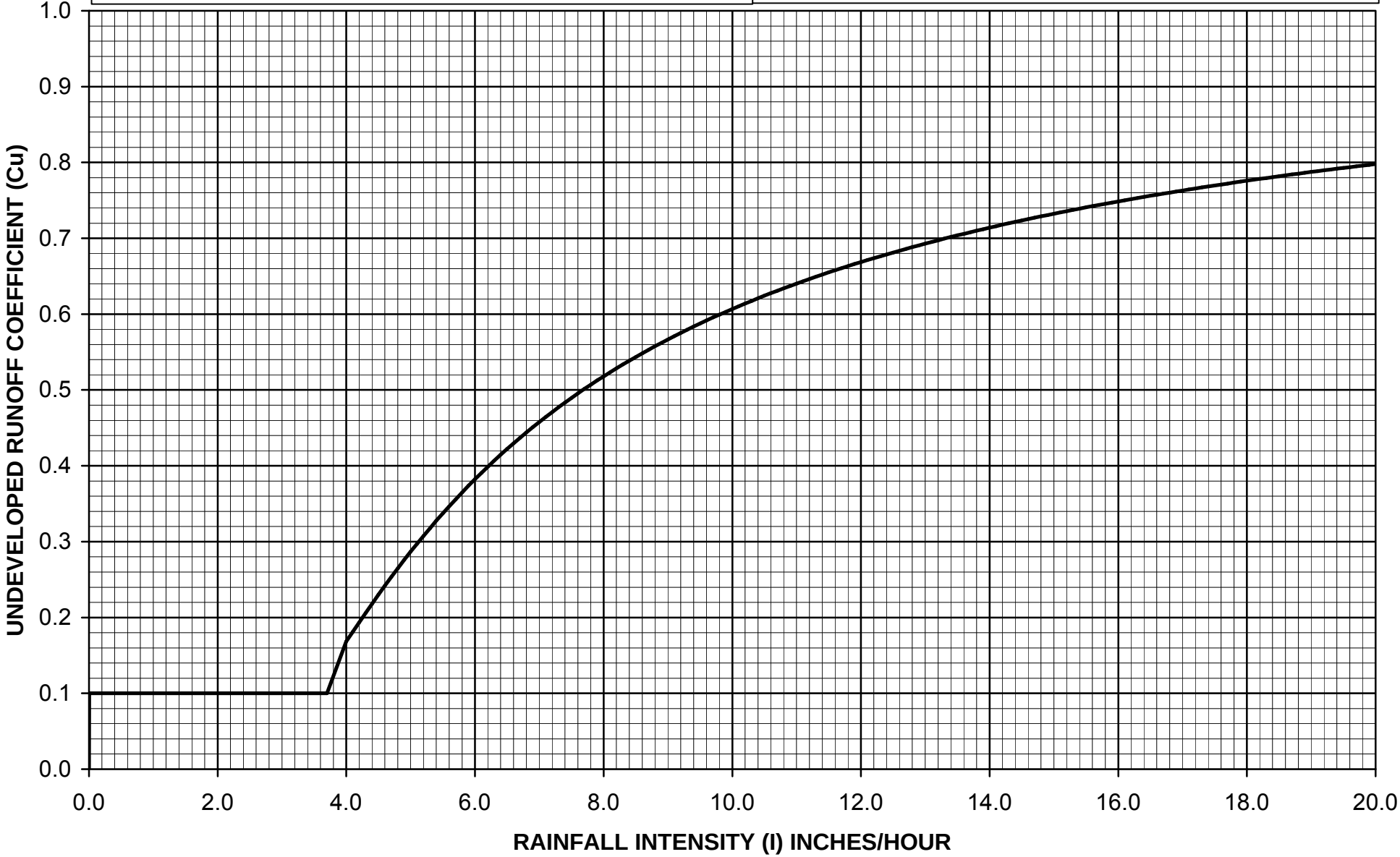


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 121

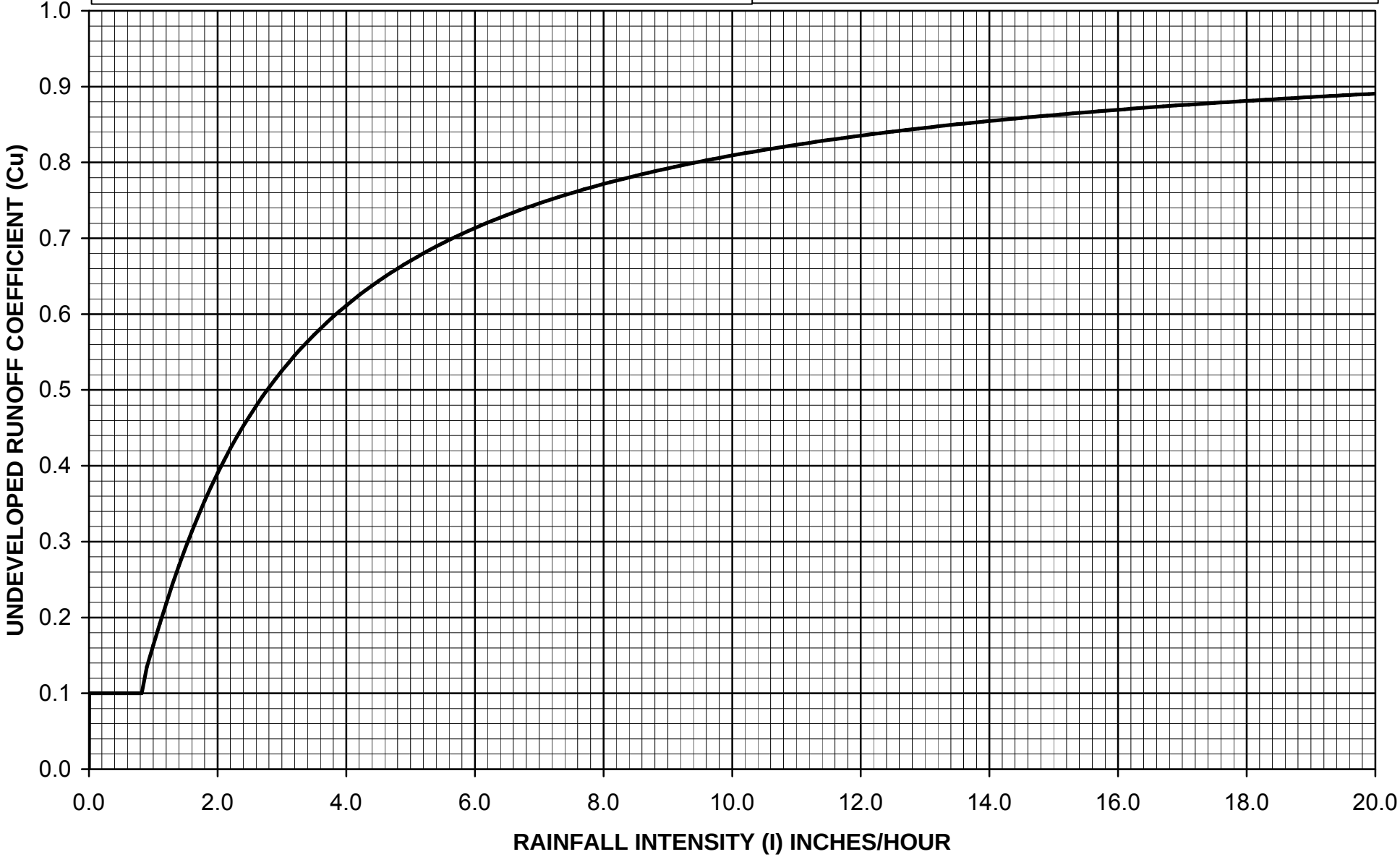


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 122

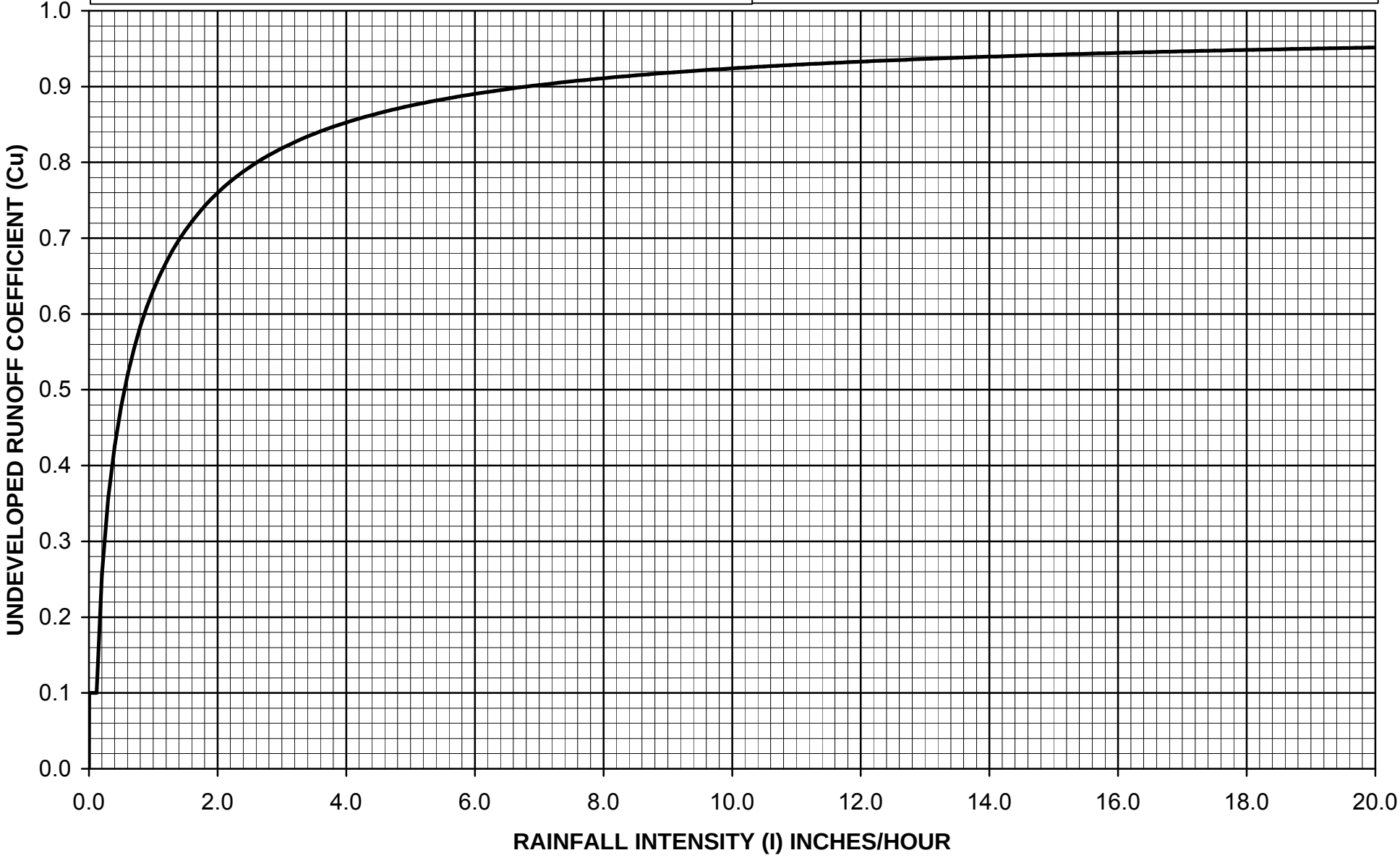


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 123

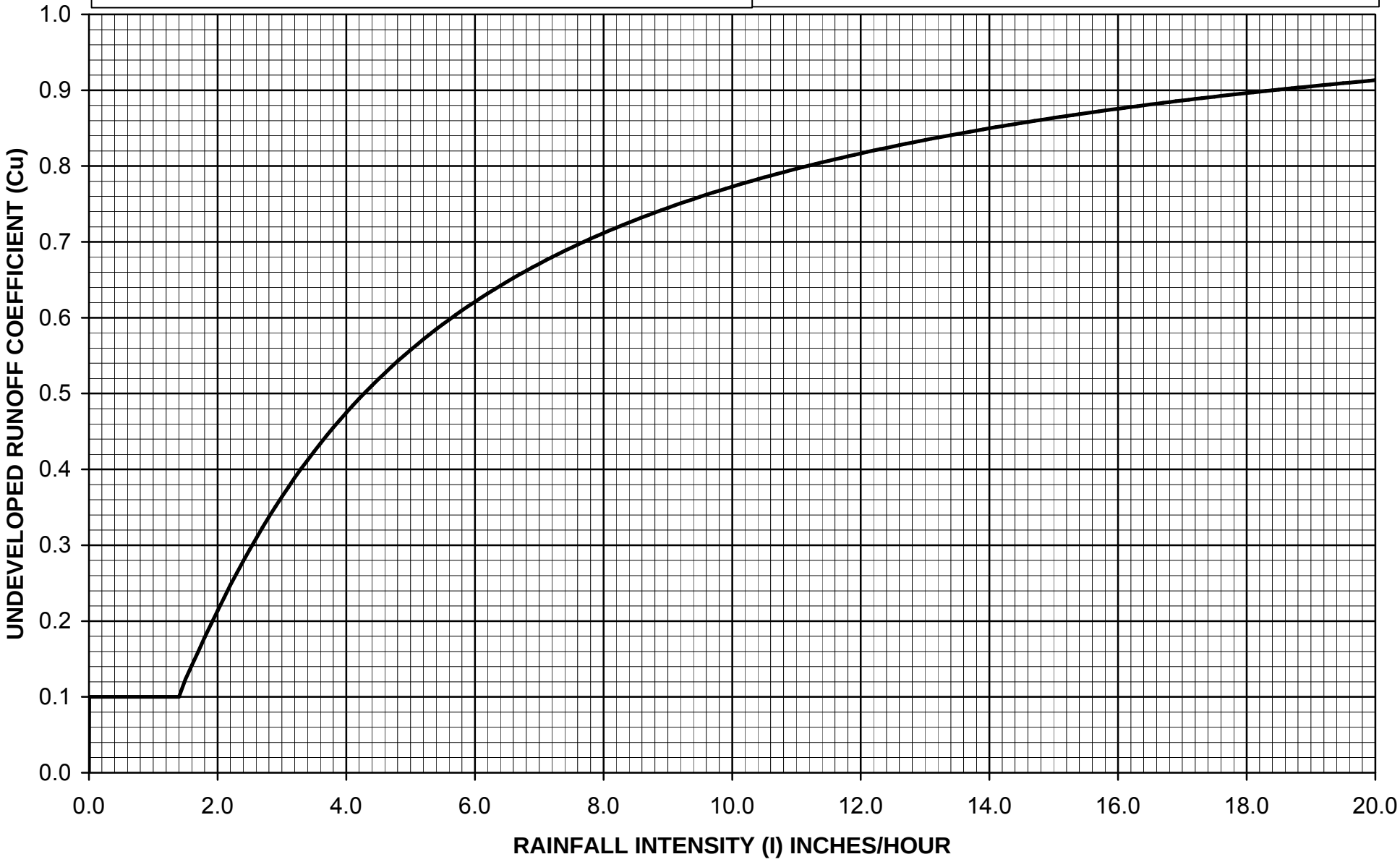


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 124

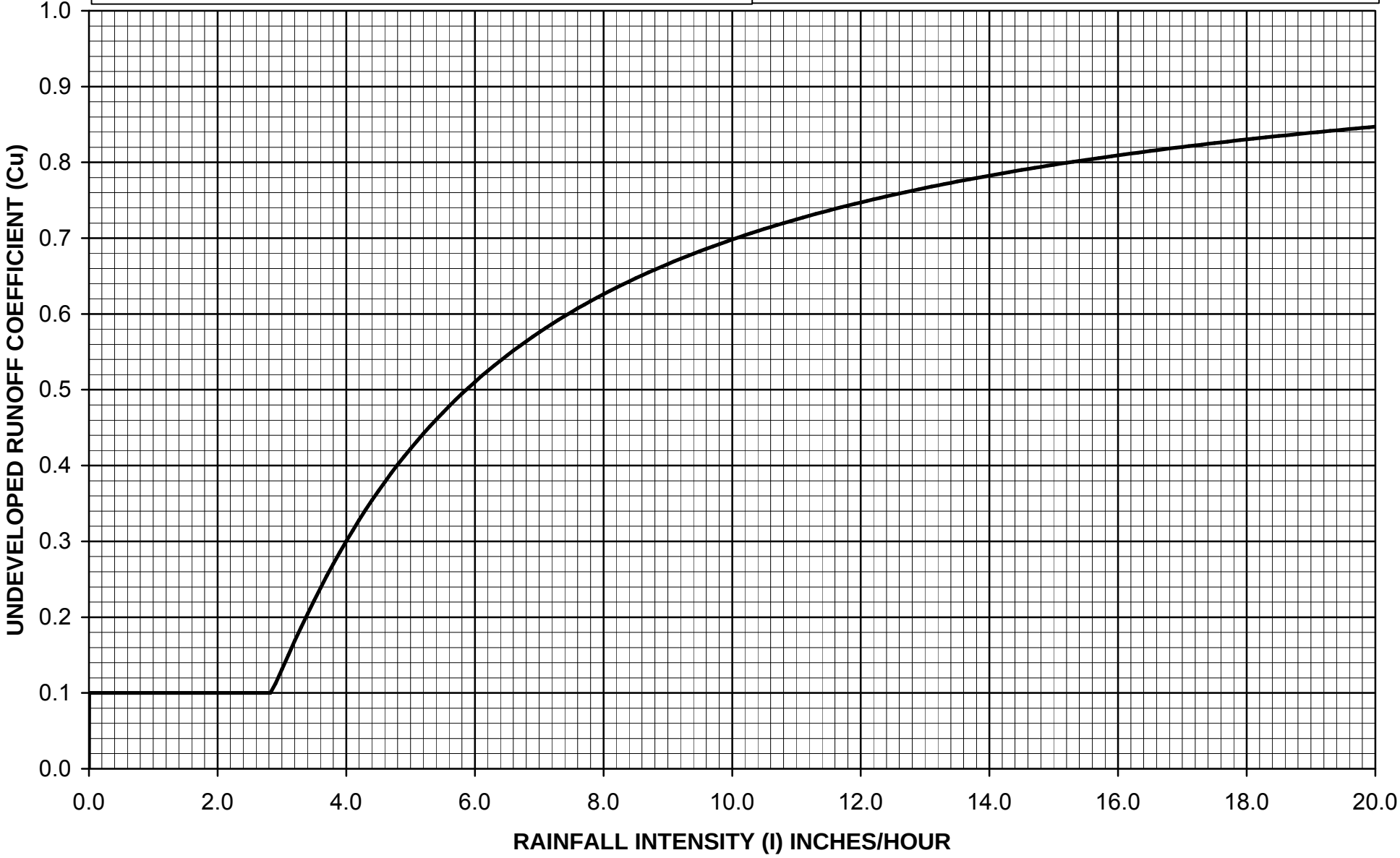


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 125

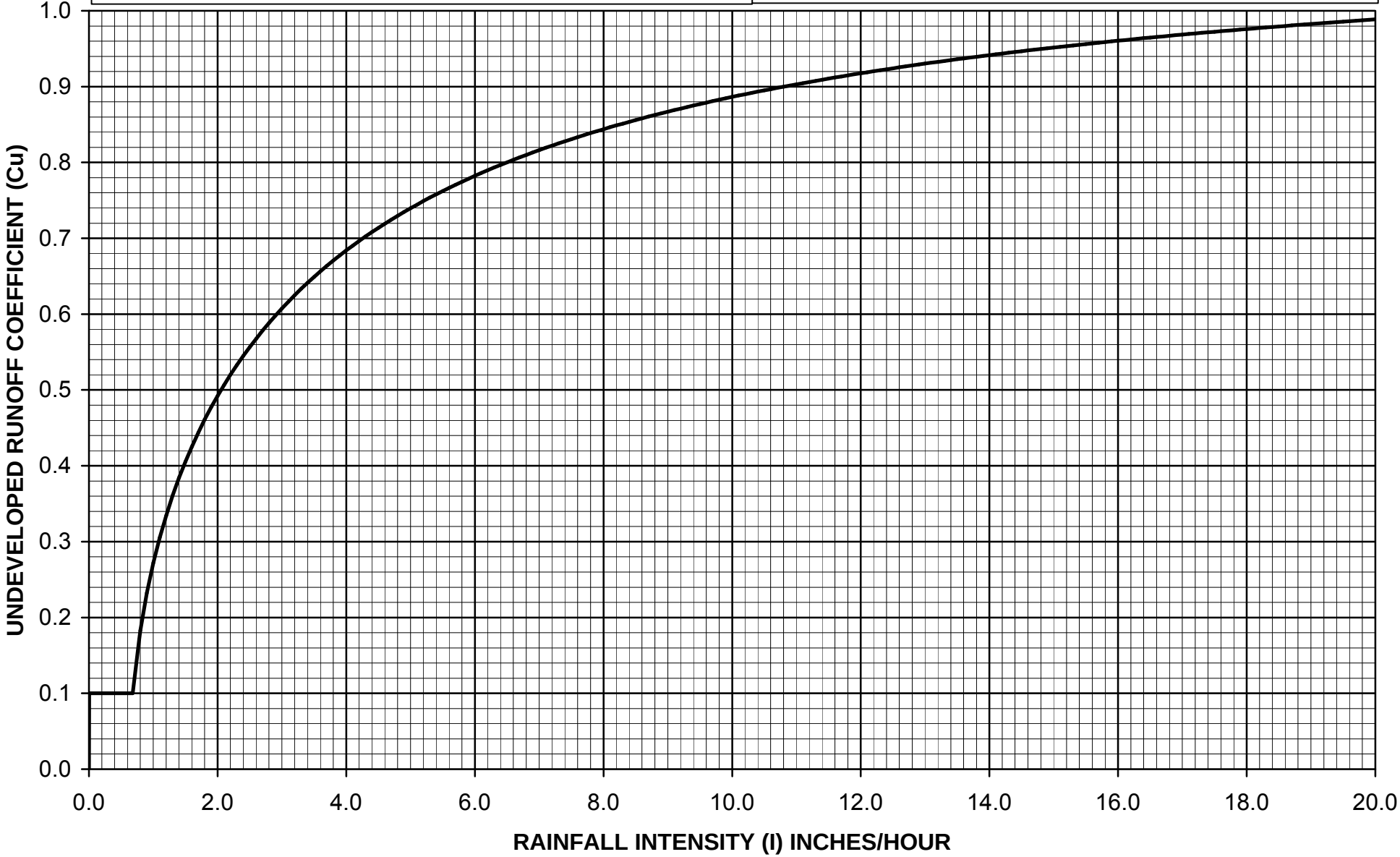


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 126

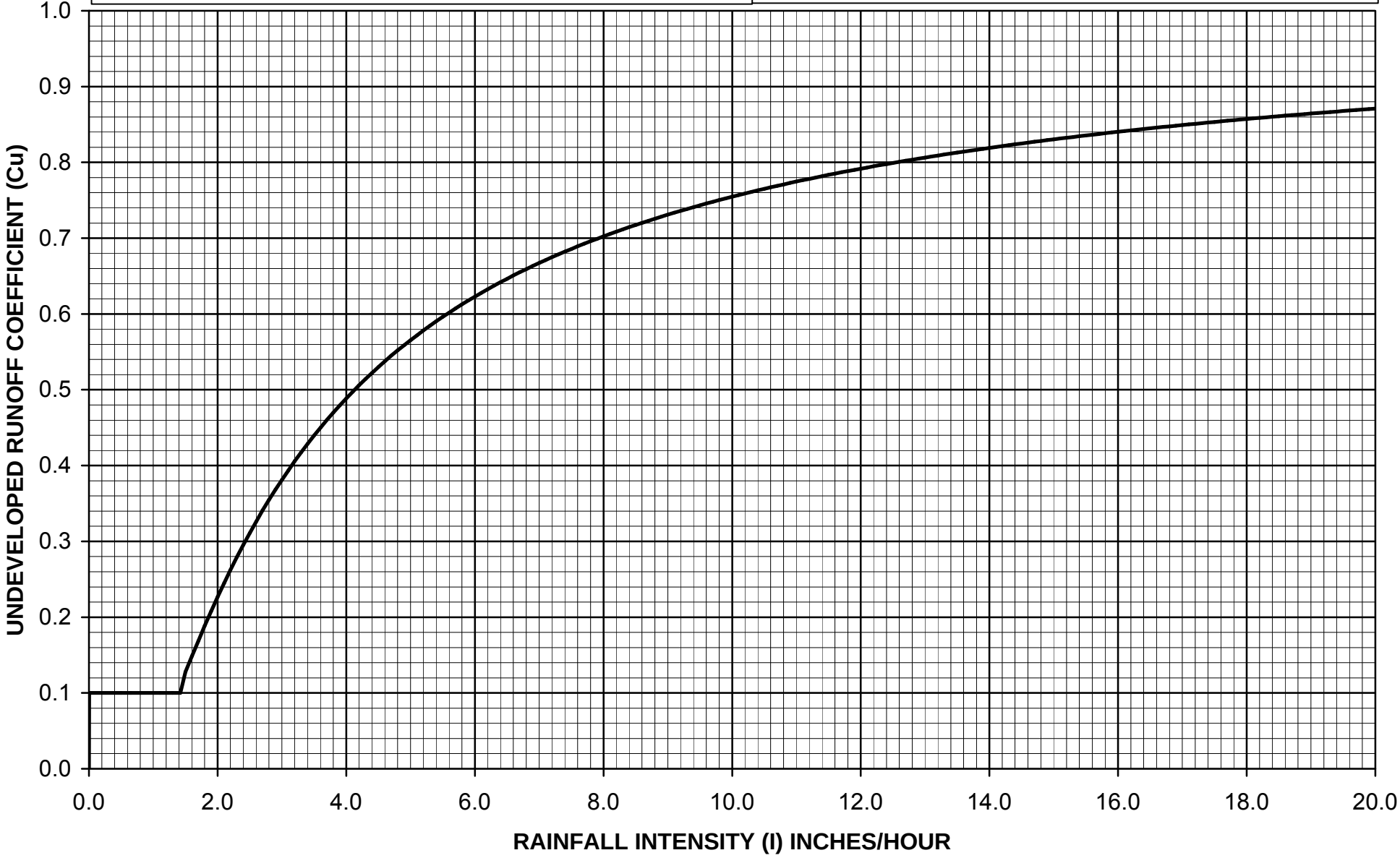


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 127

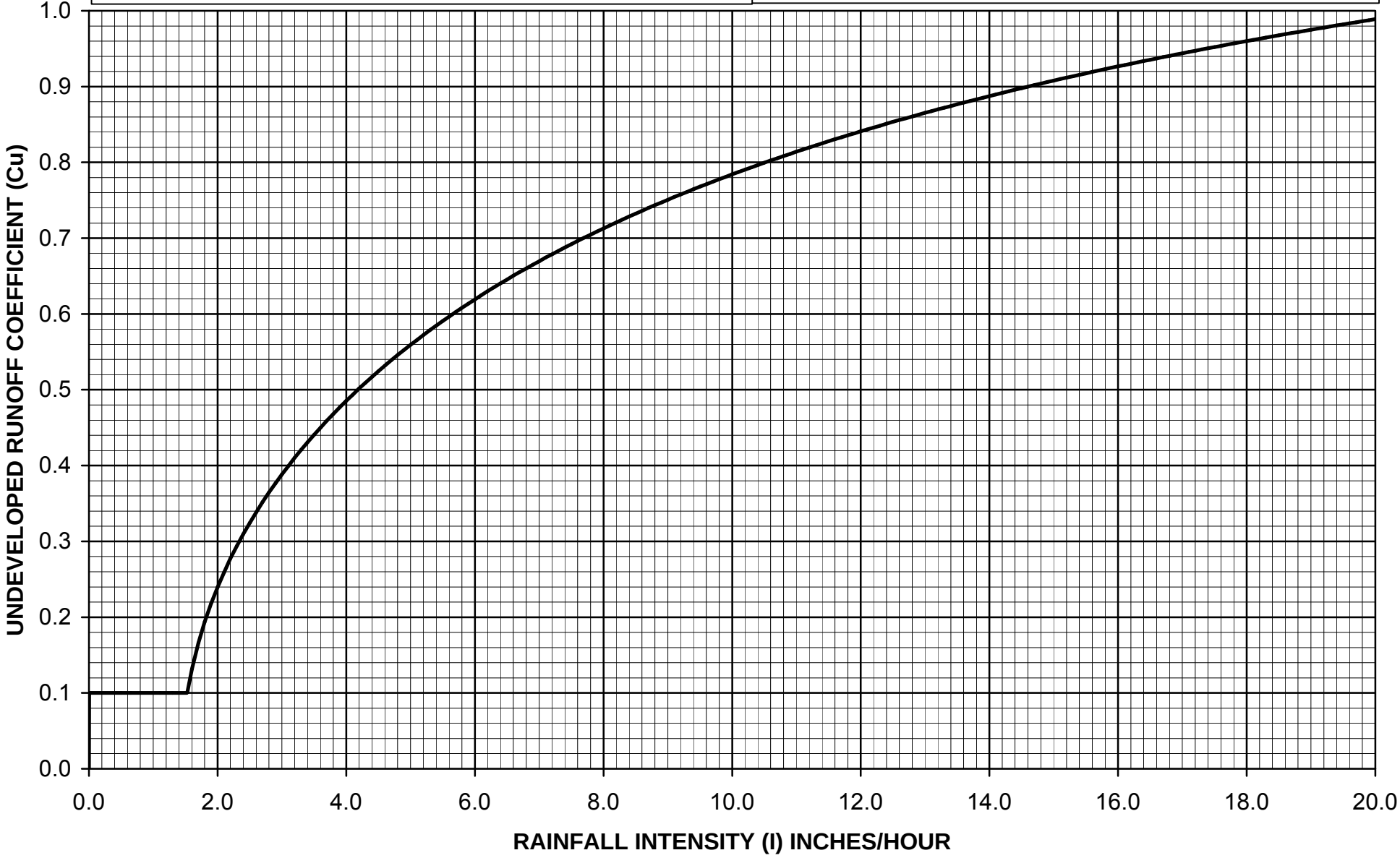


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 128

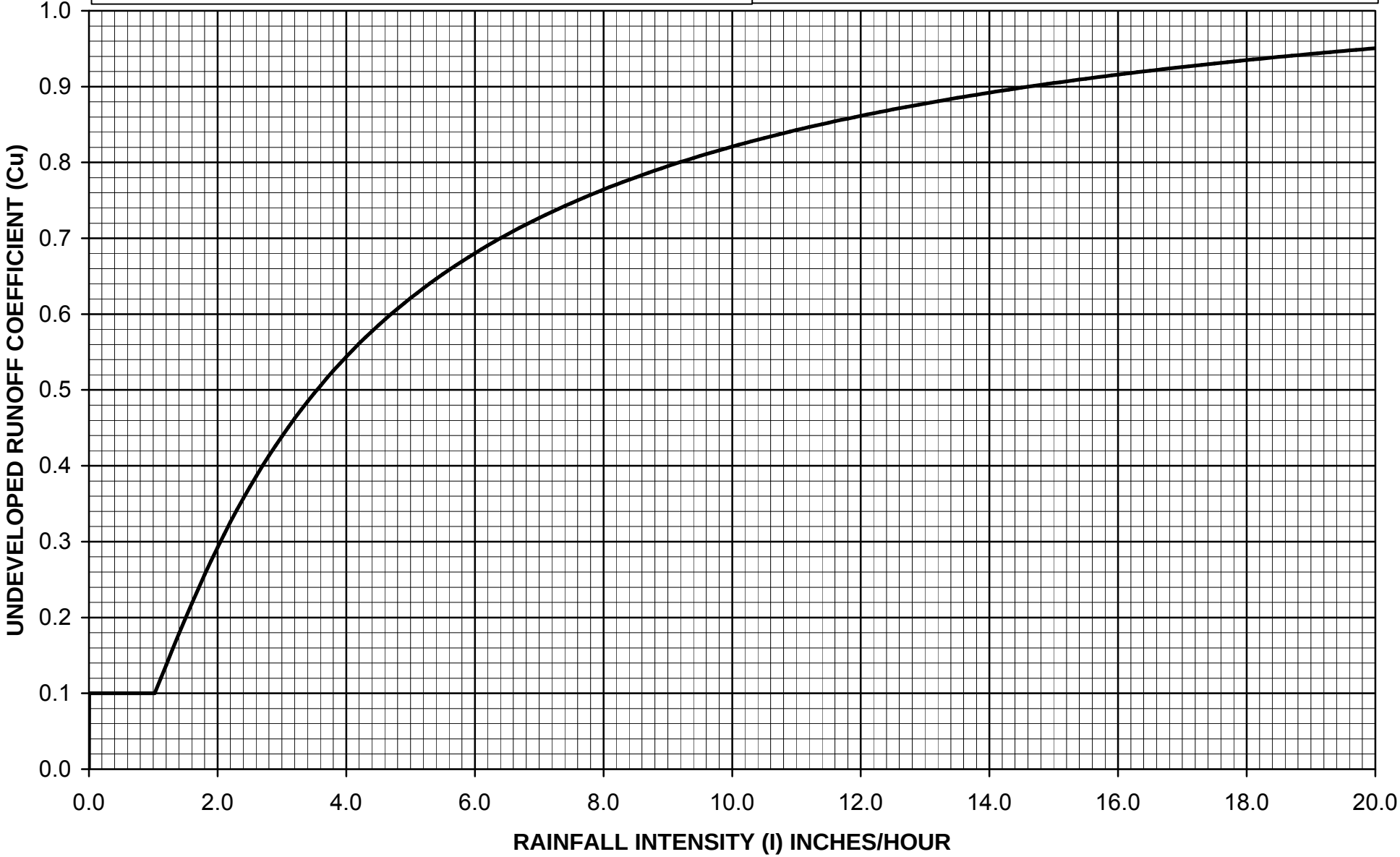


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 129

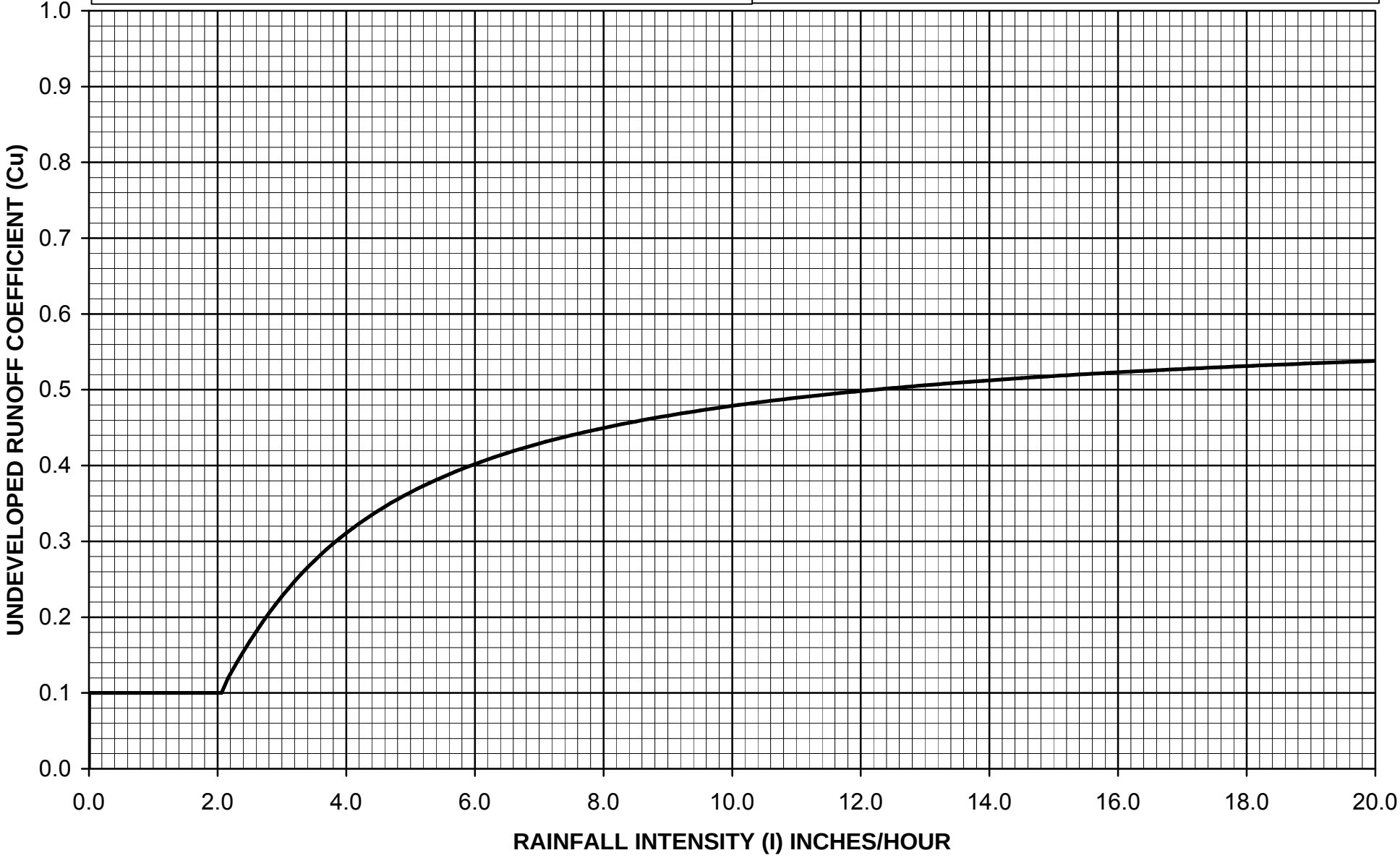


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 130

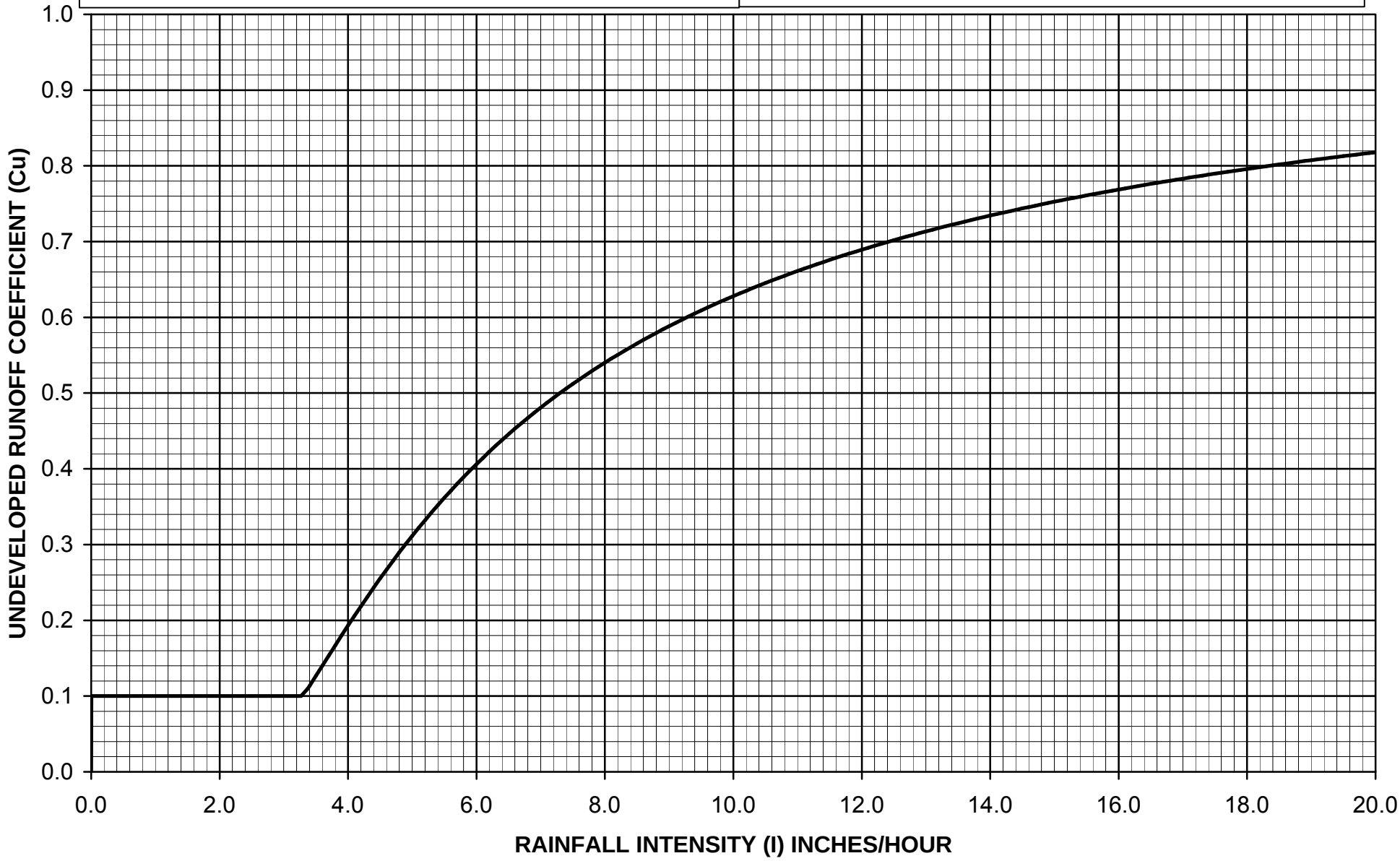


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 131

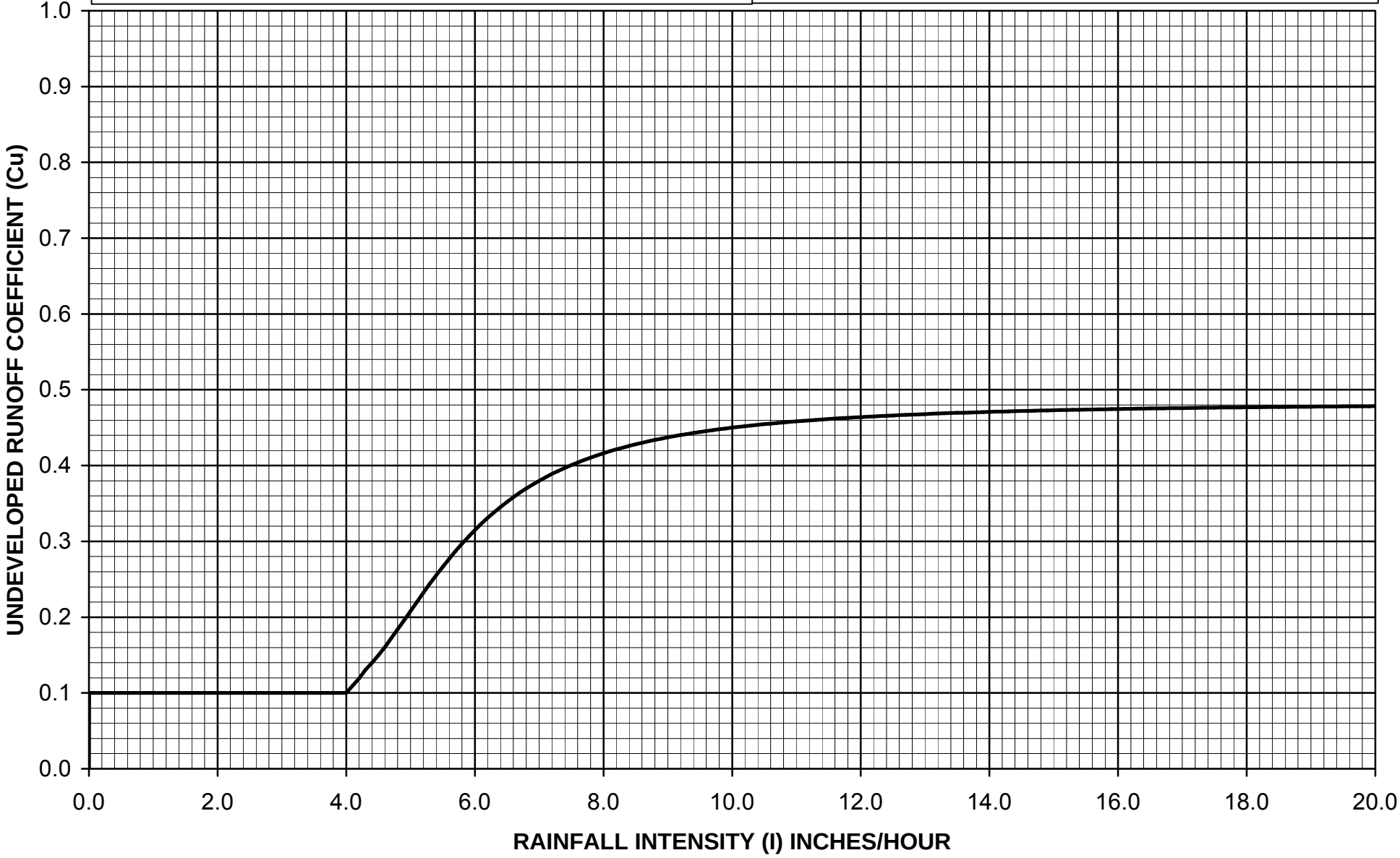


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 132

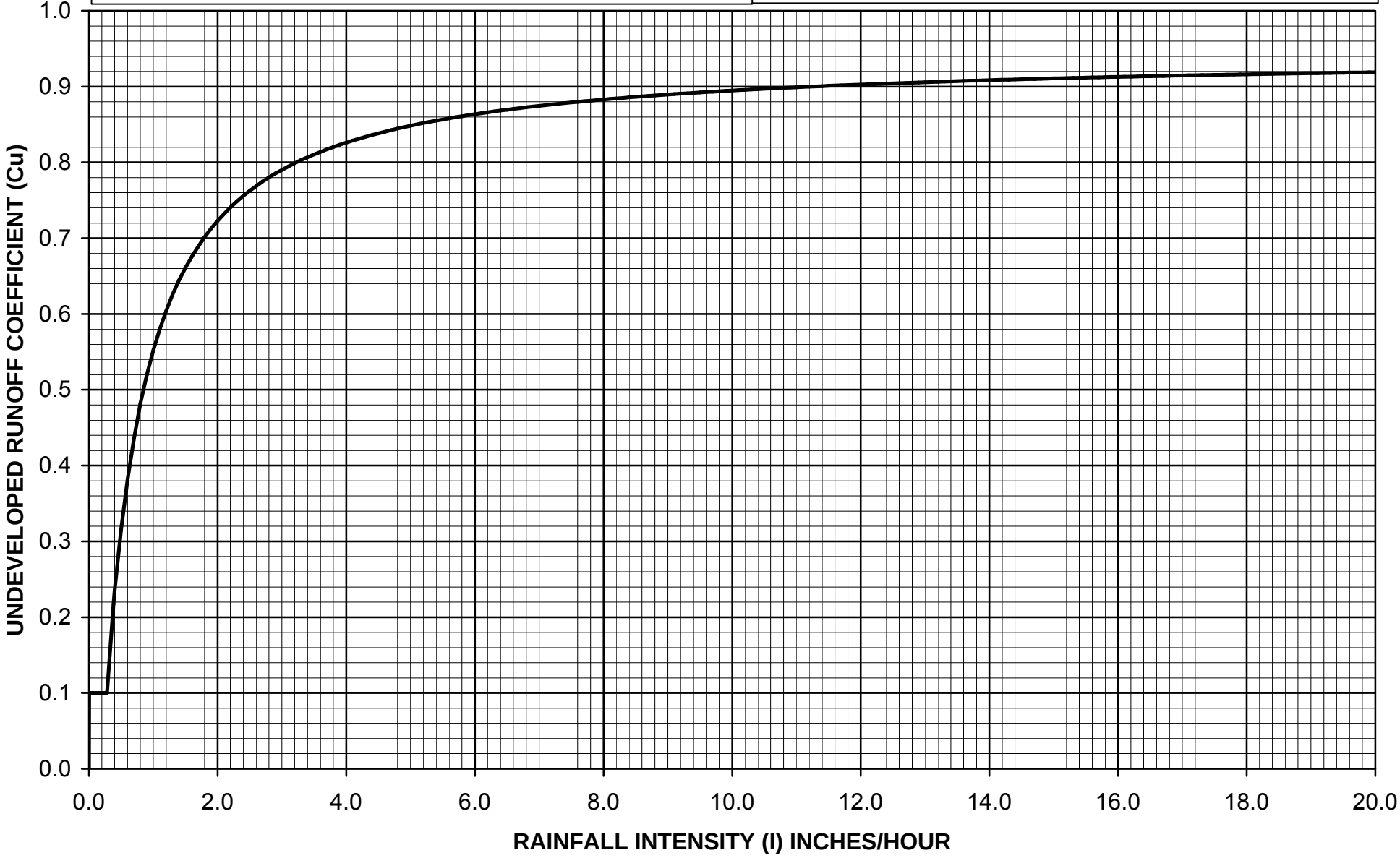


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 133

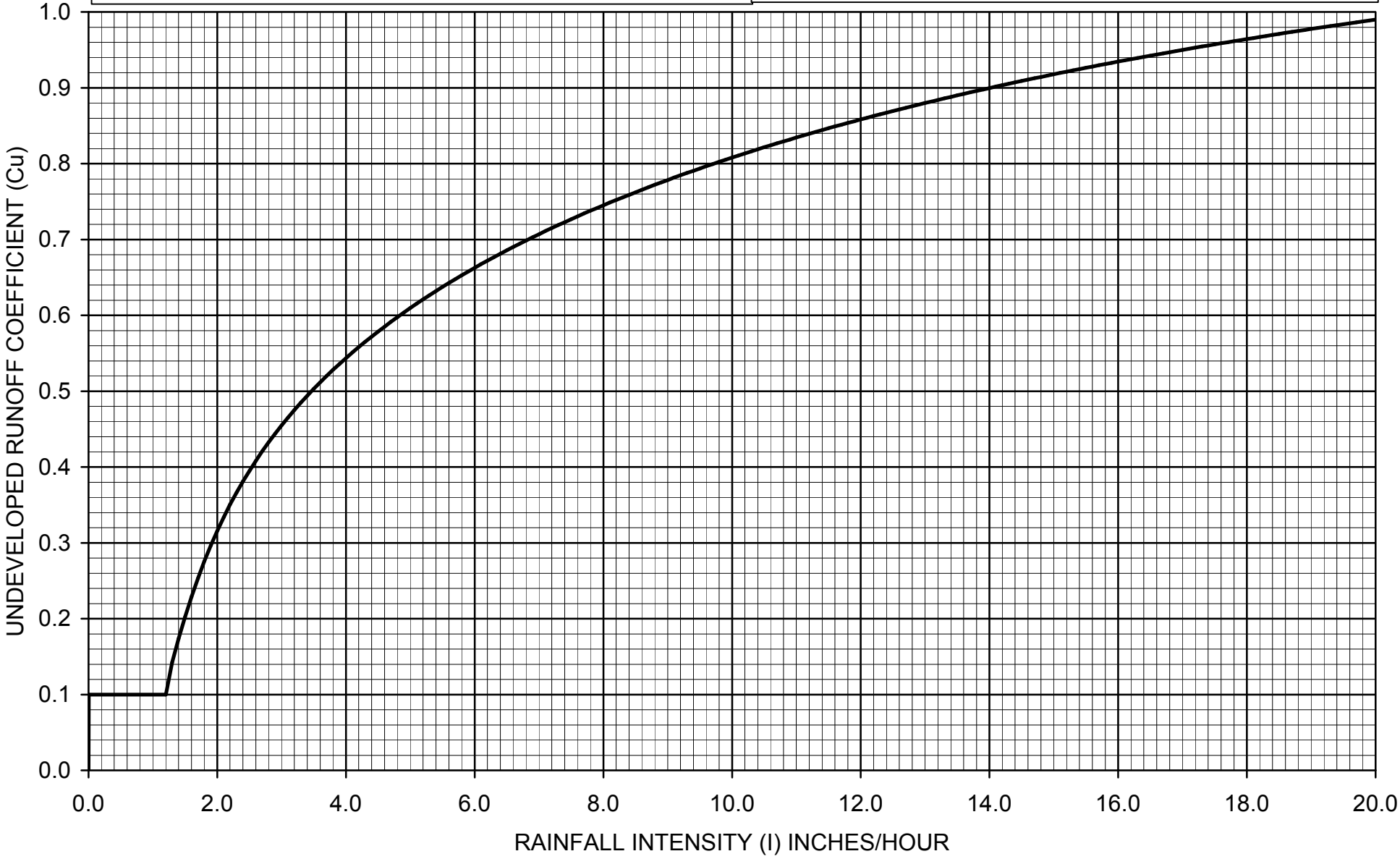


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 134

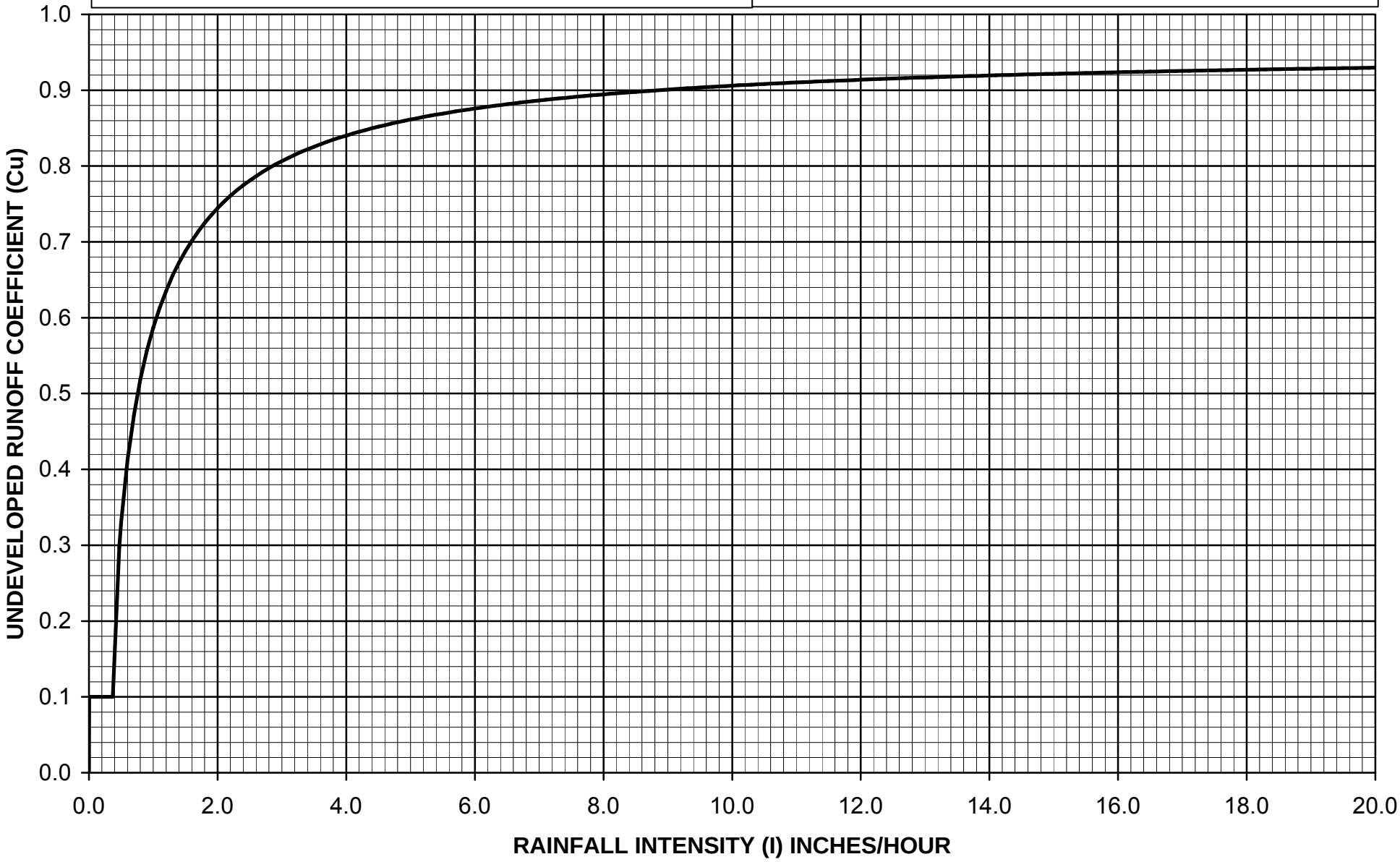


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 135

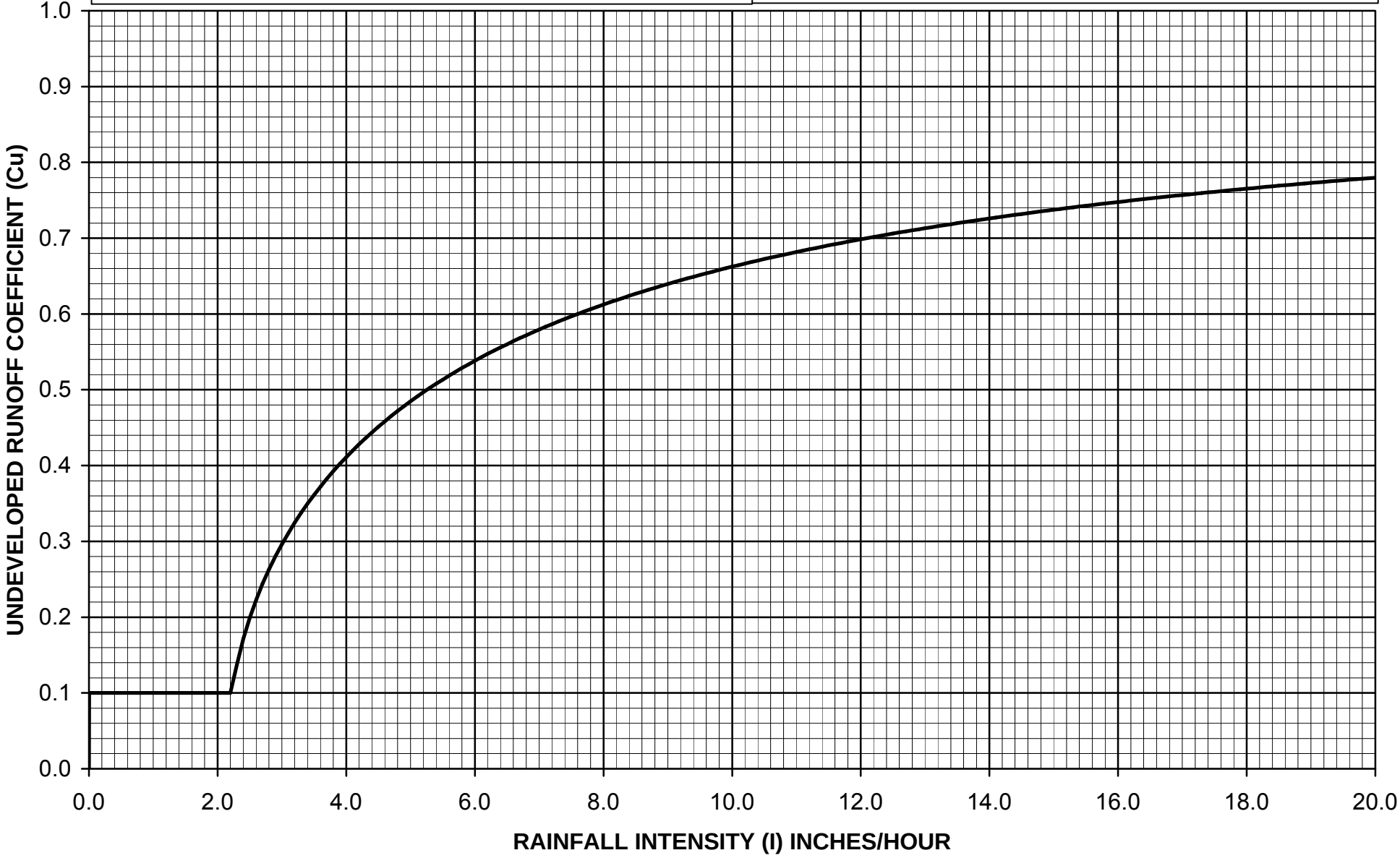


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 136

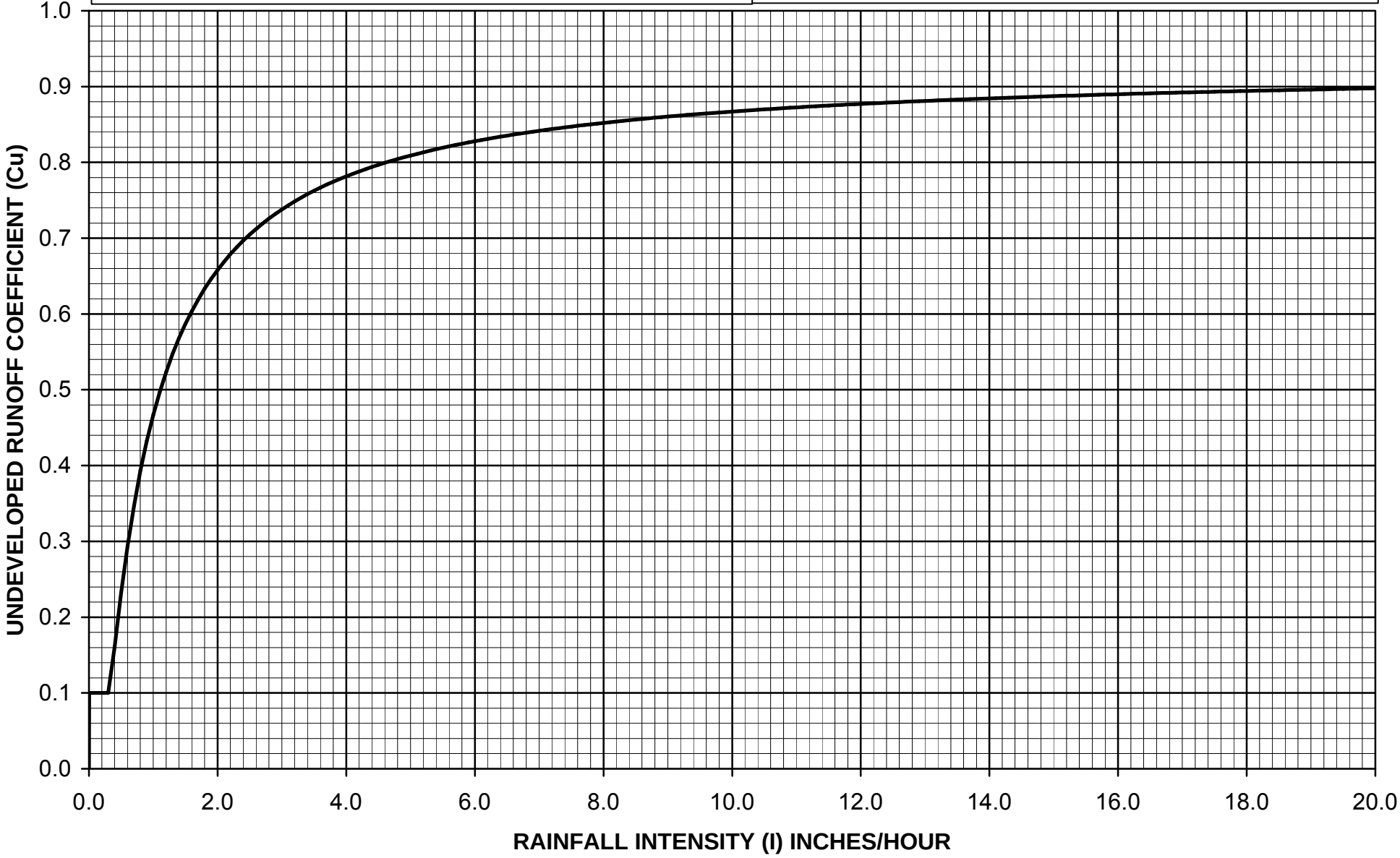


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 137

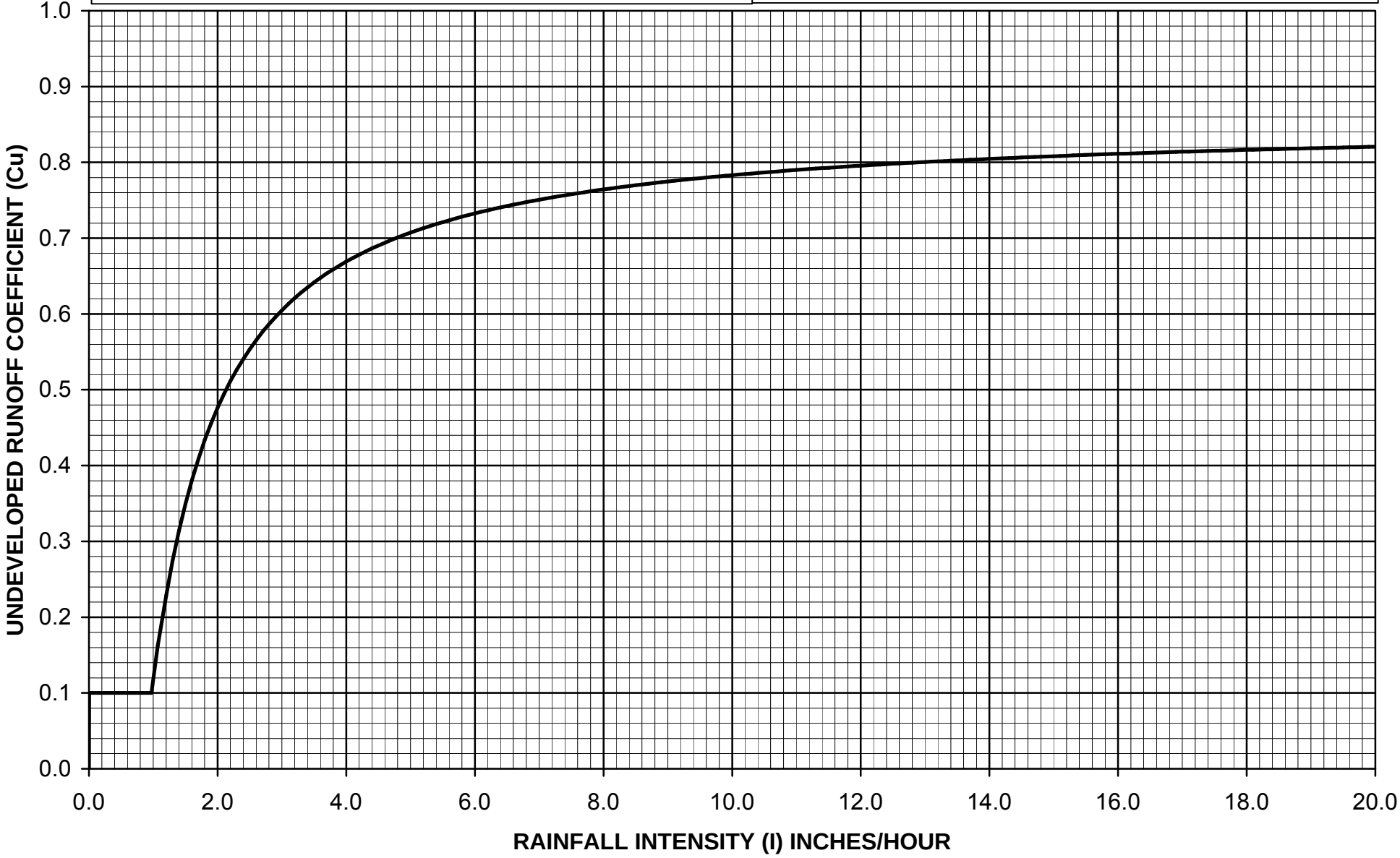


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 138

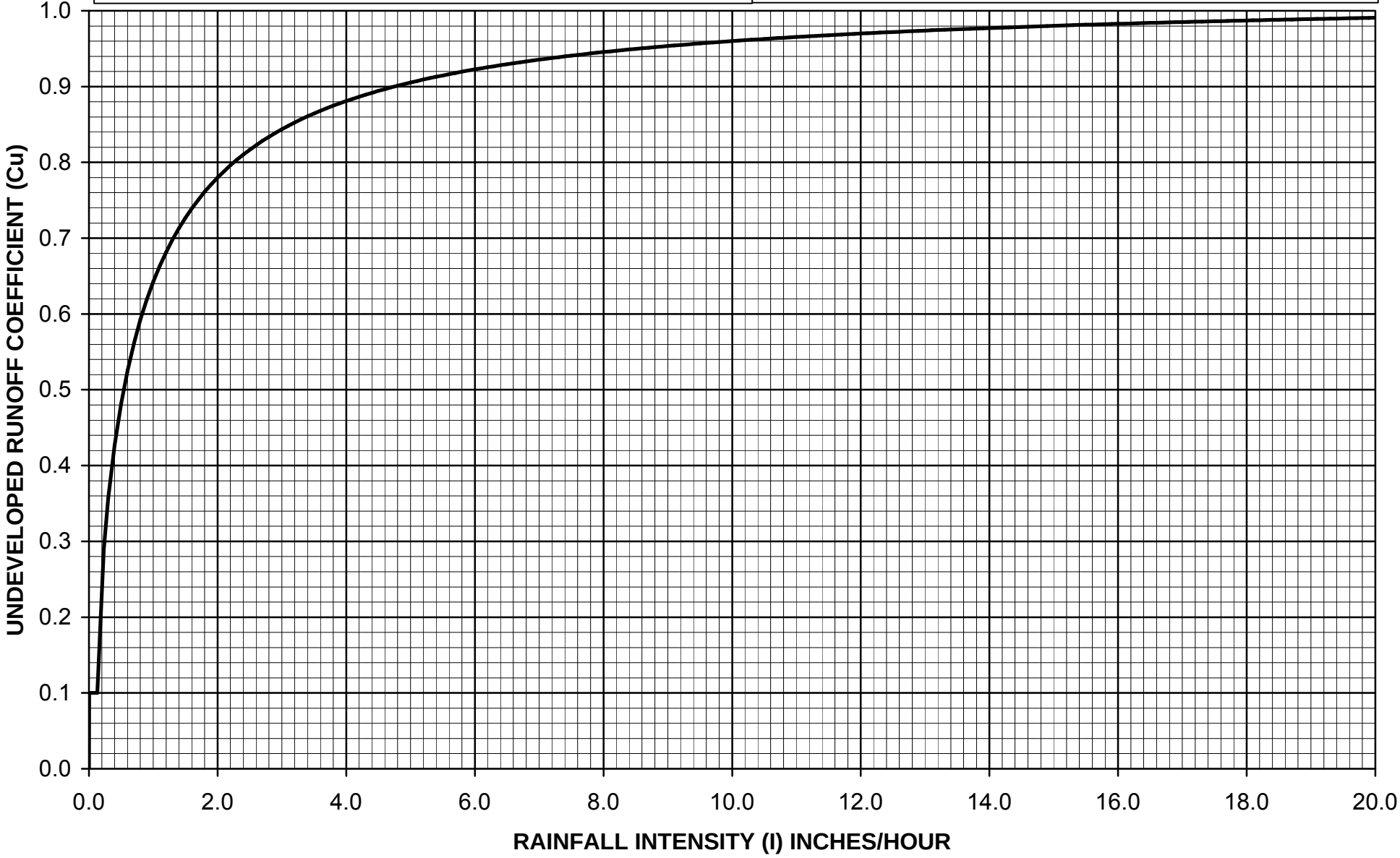


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 139

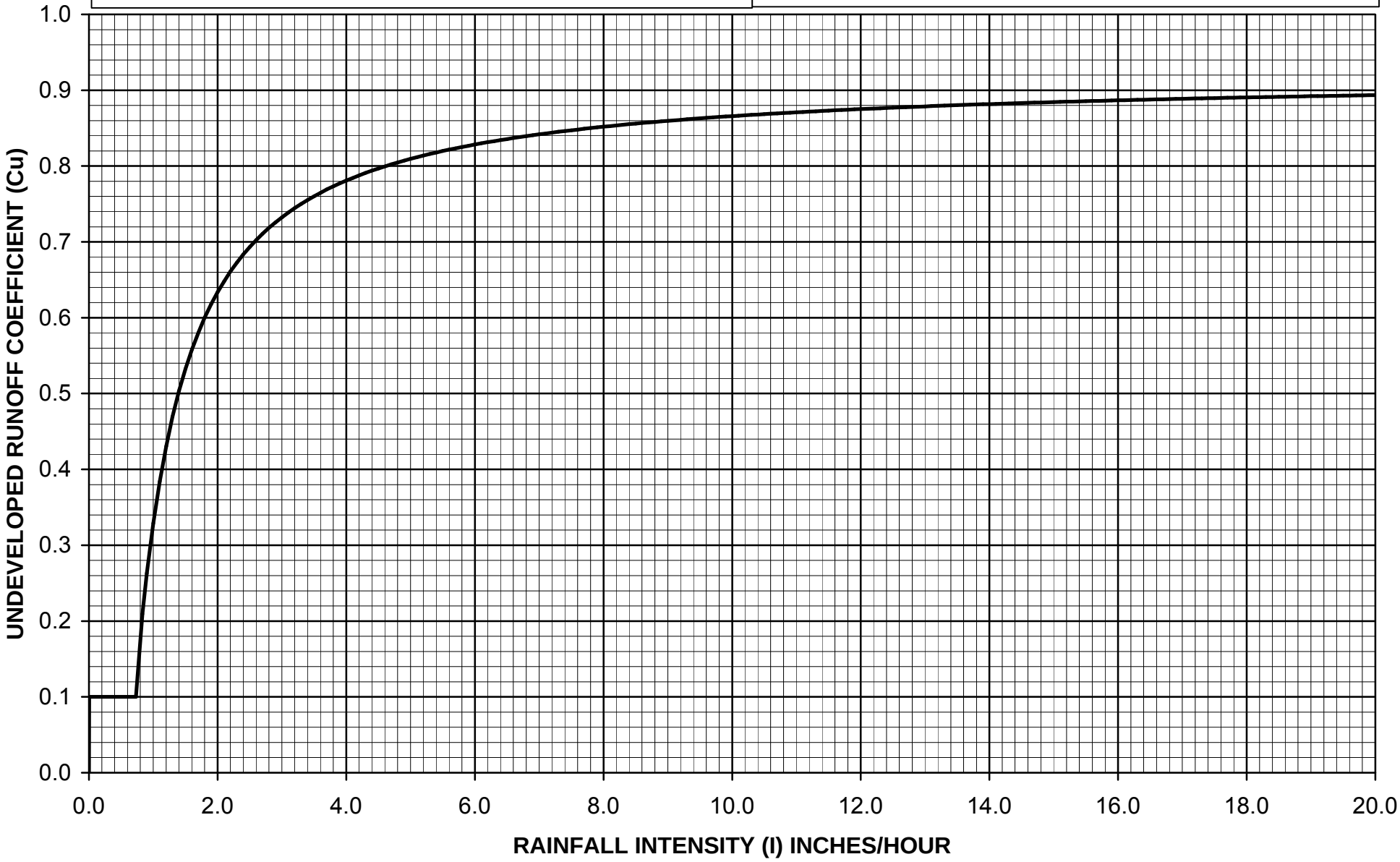


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 140

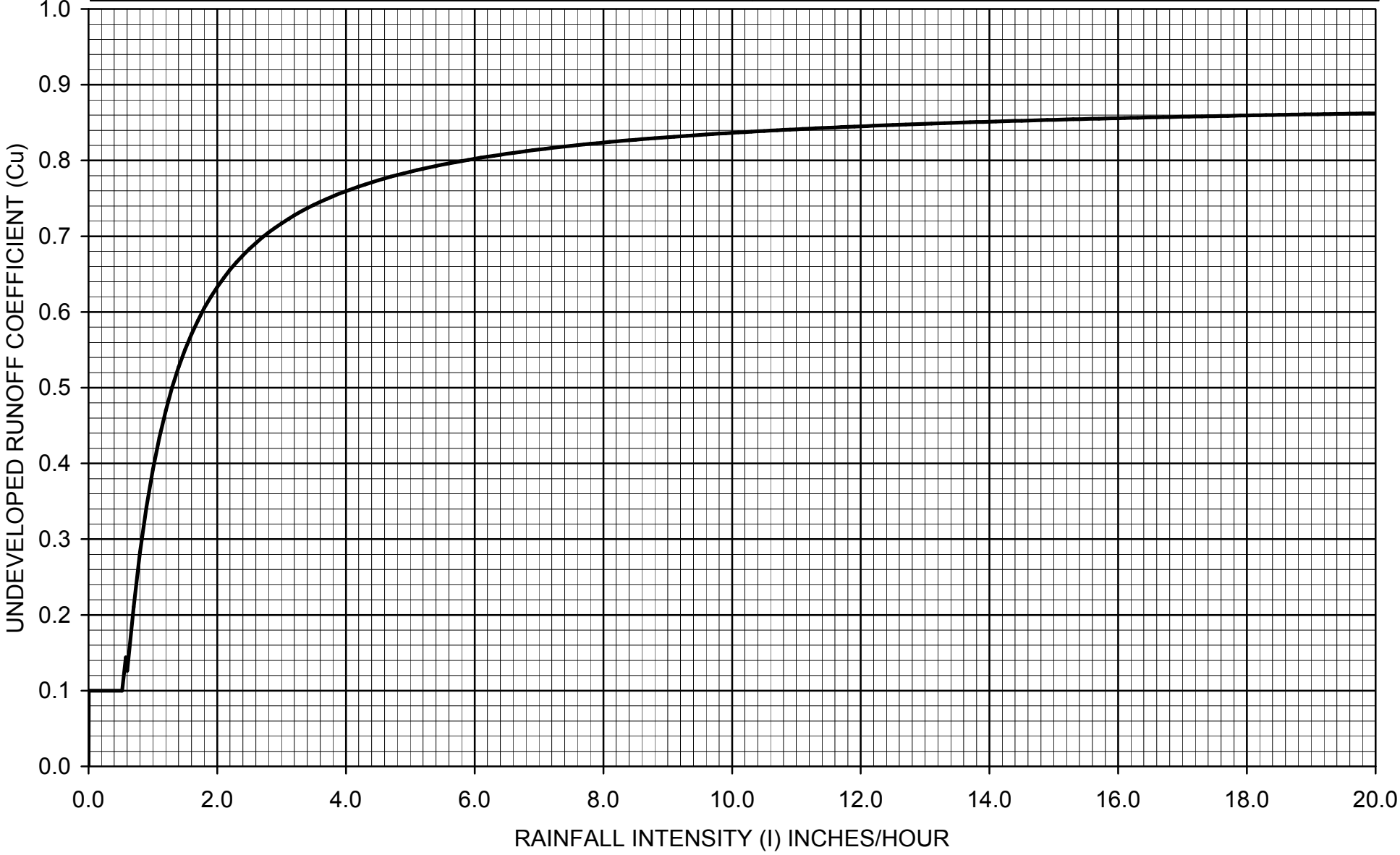


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 141

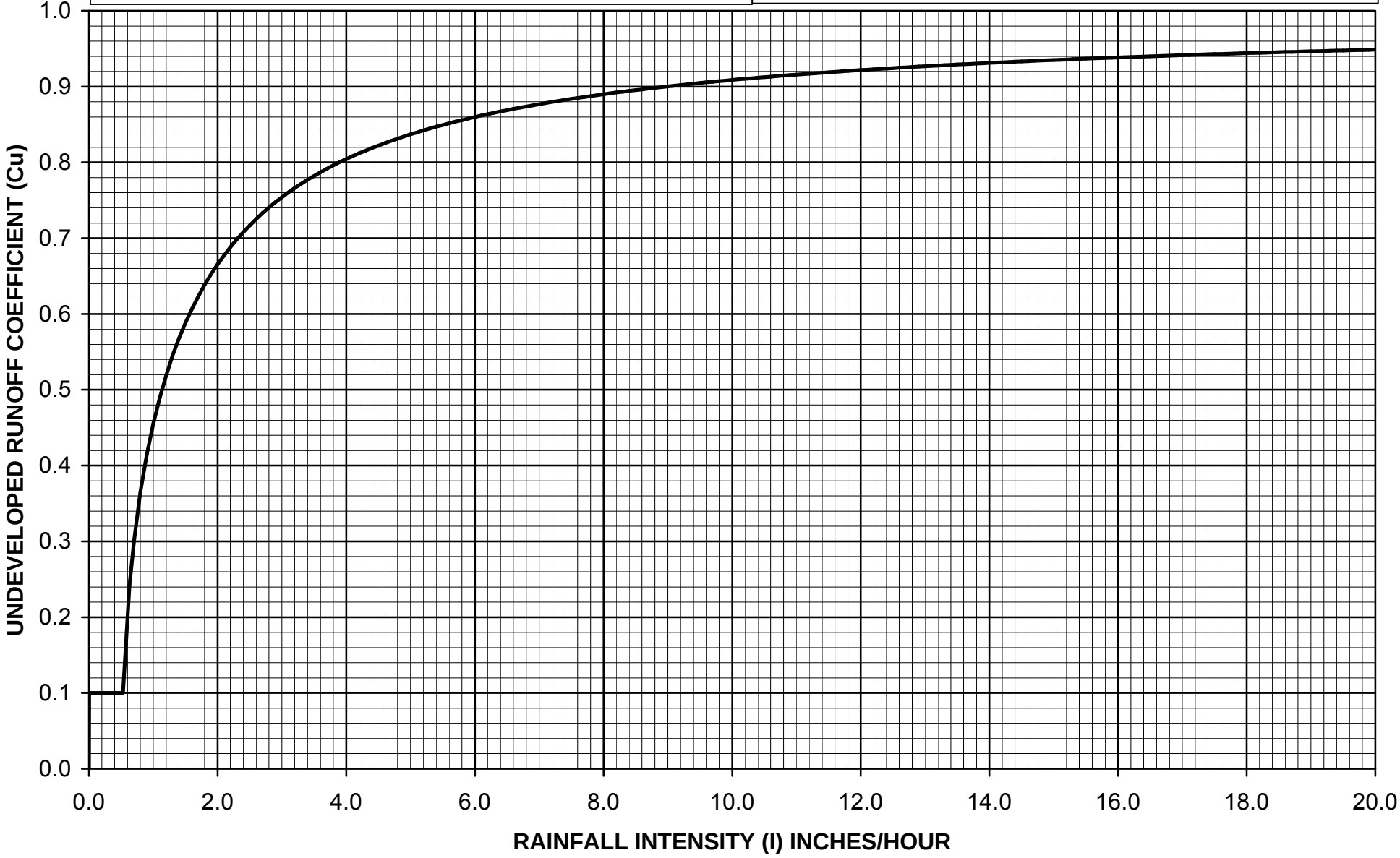


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 142

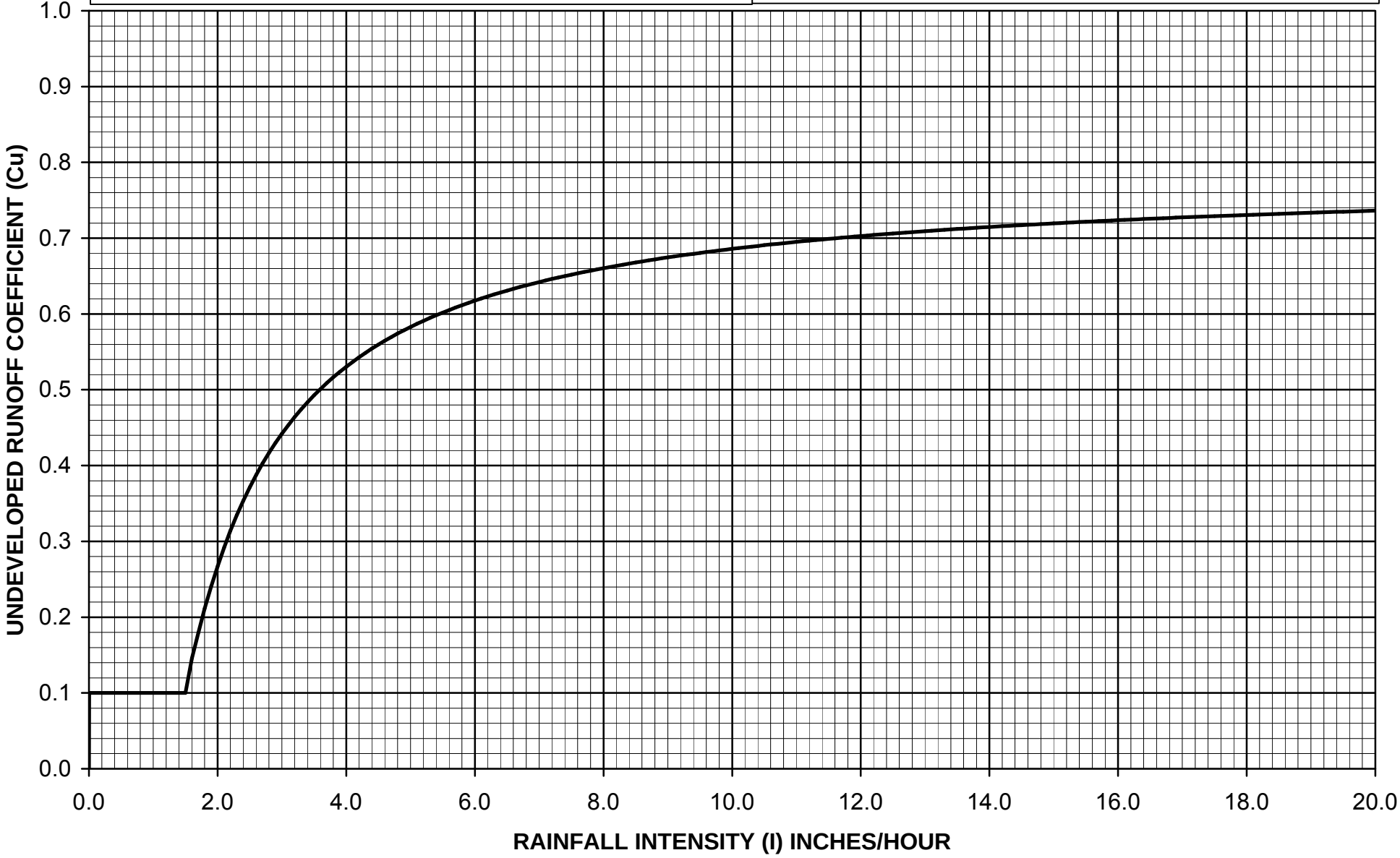


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 143

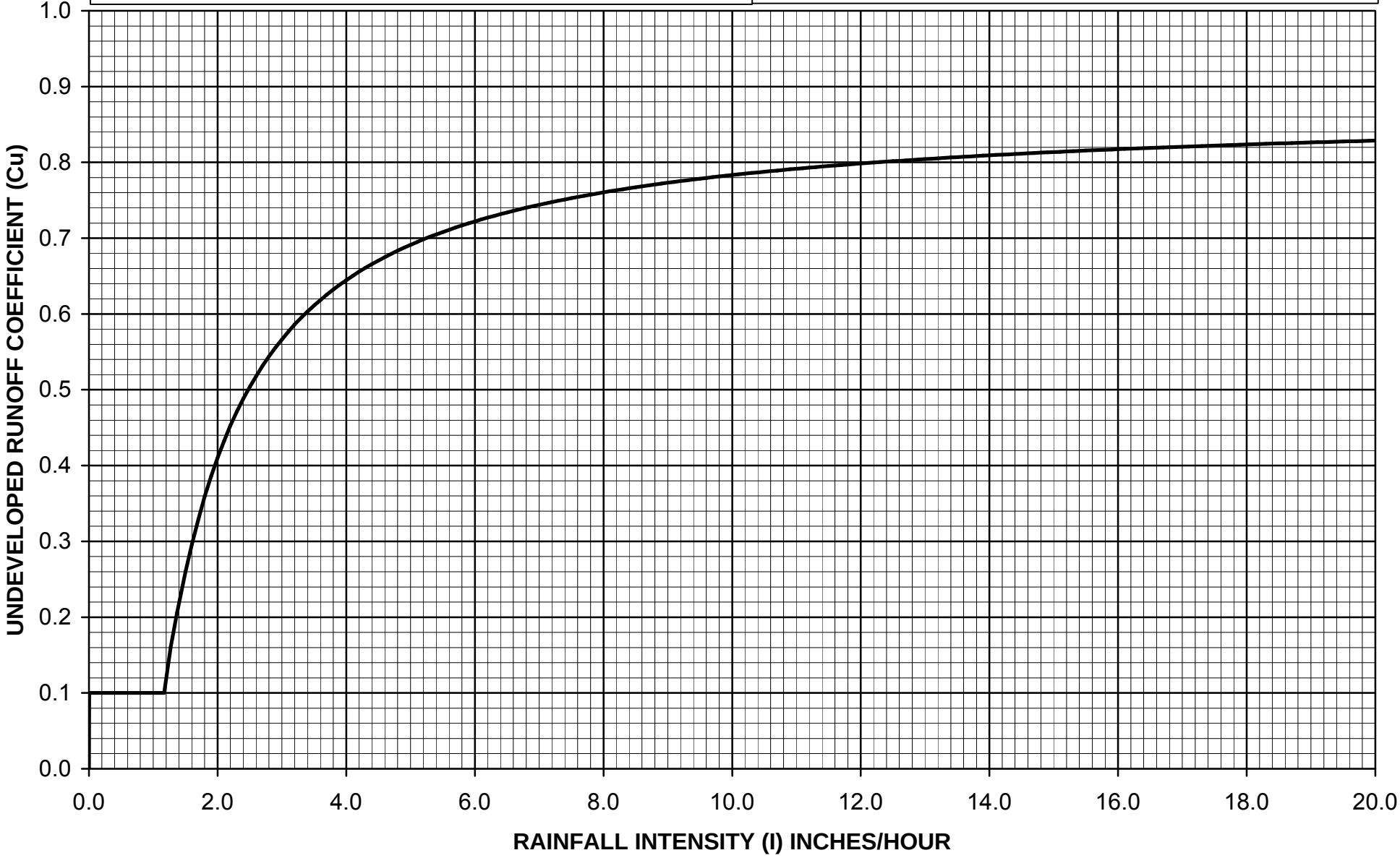


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 144

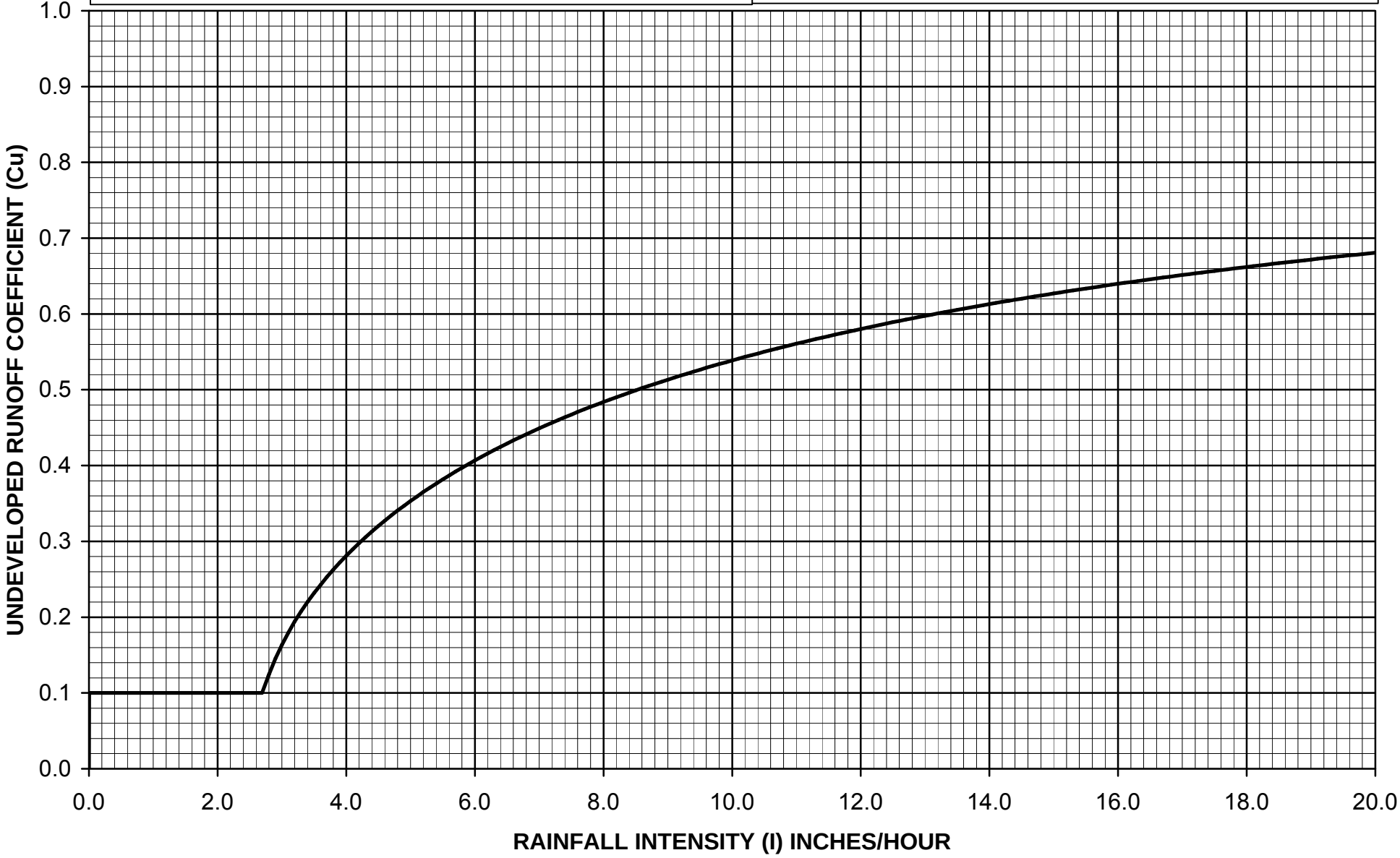


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 145

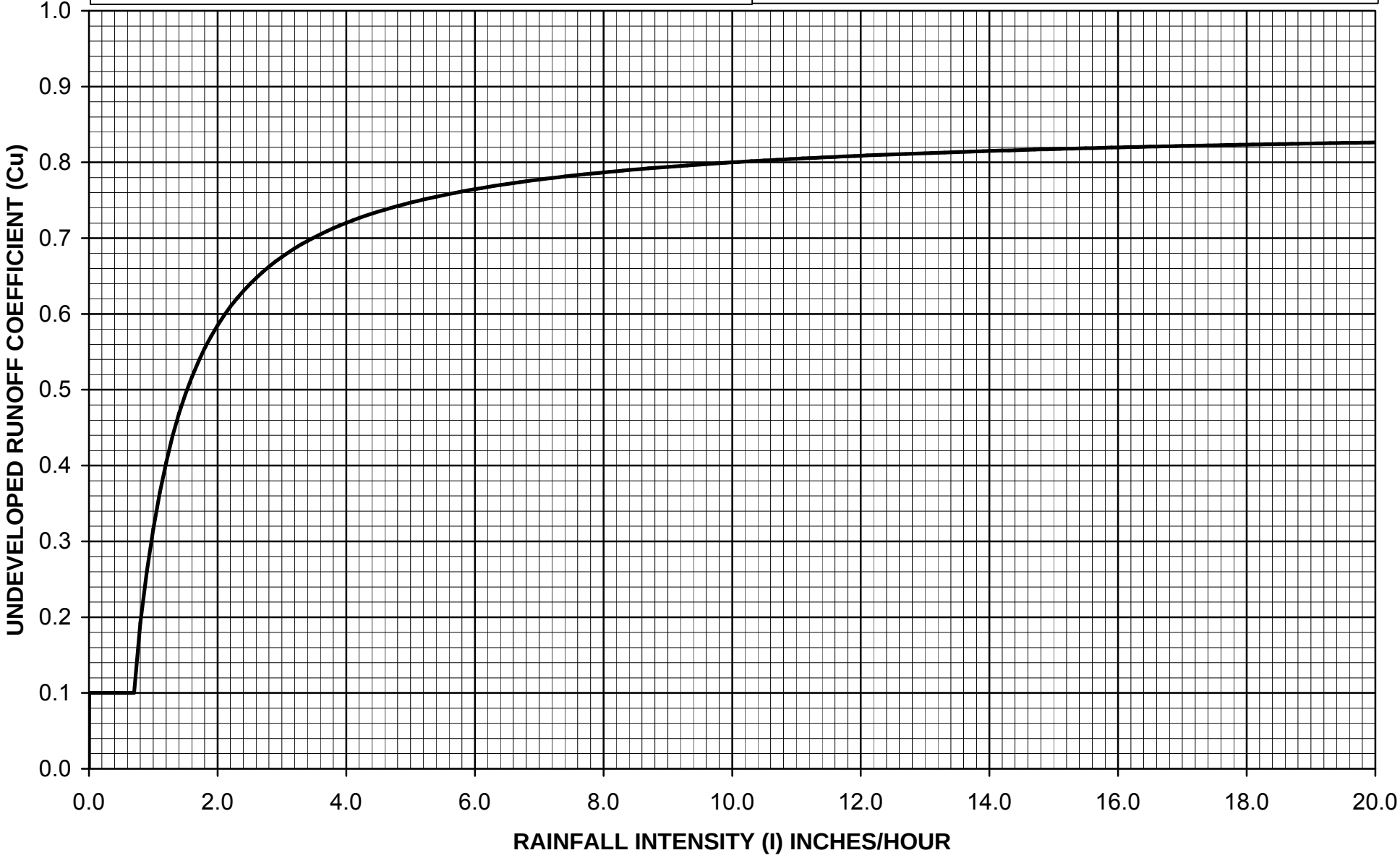


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 146

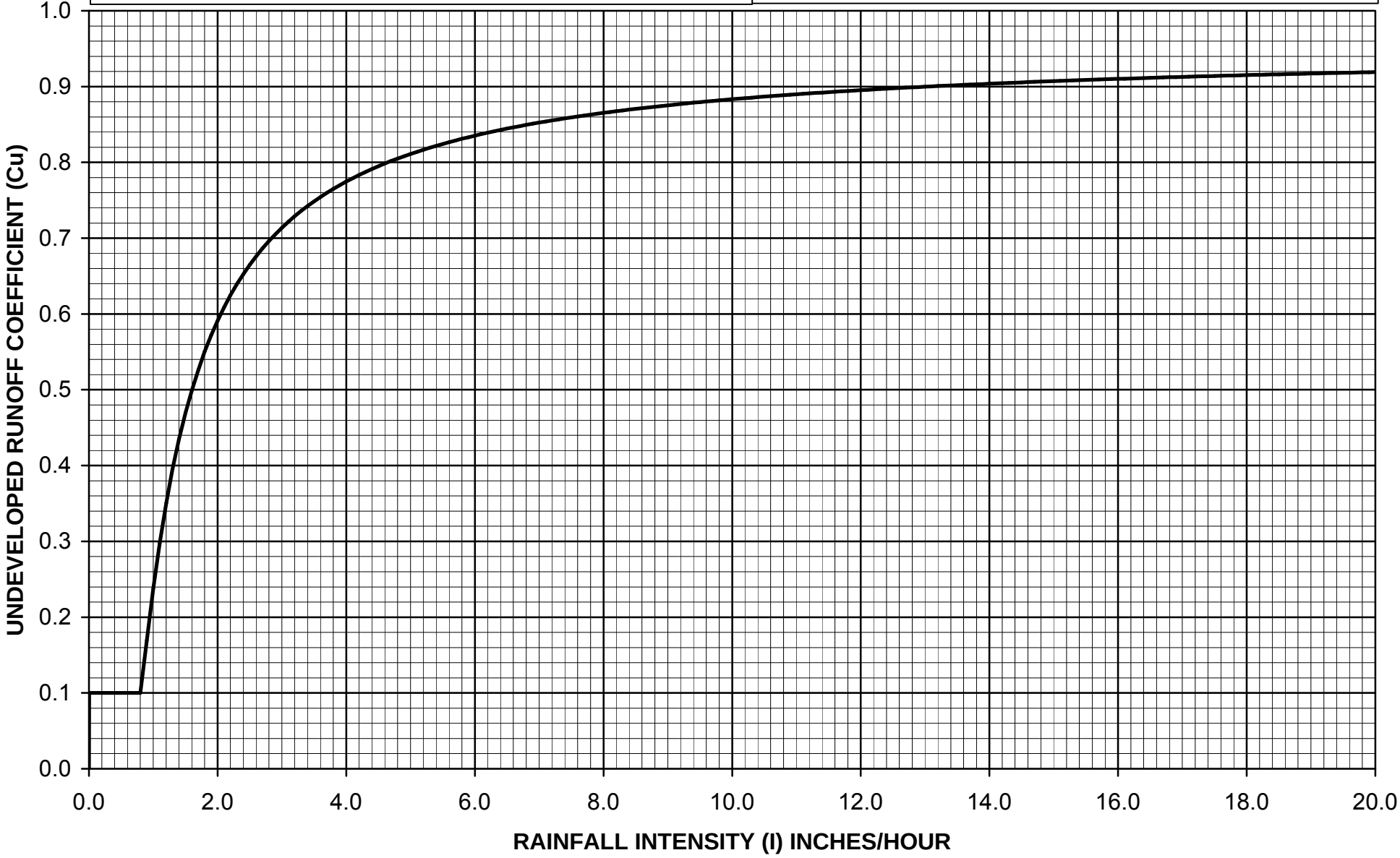


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 147

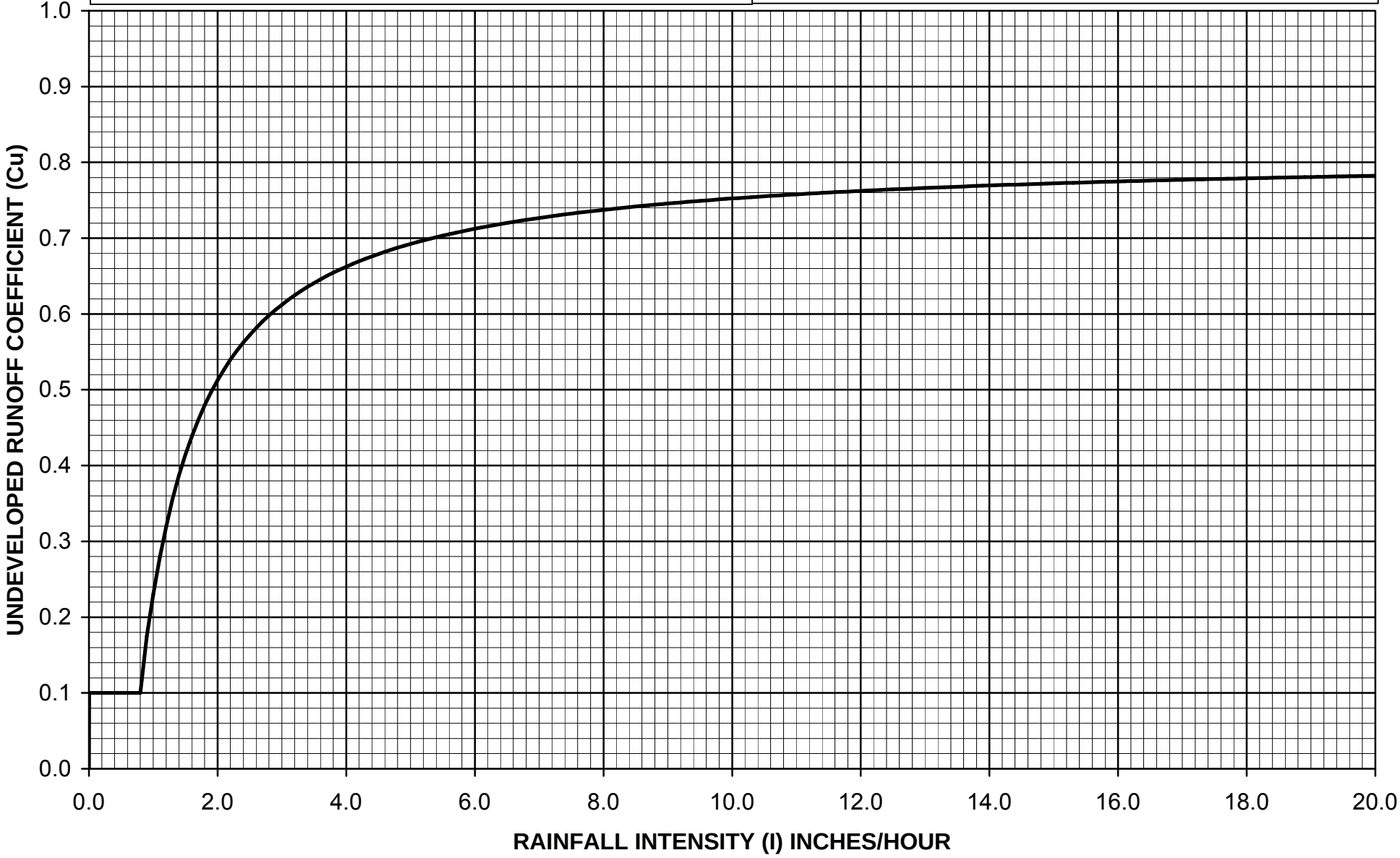


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 148

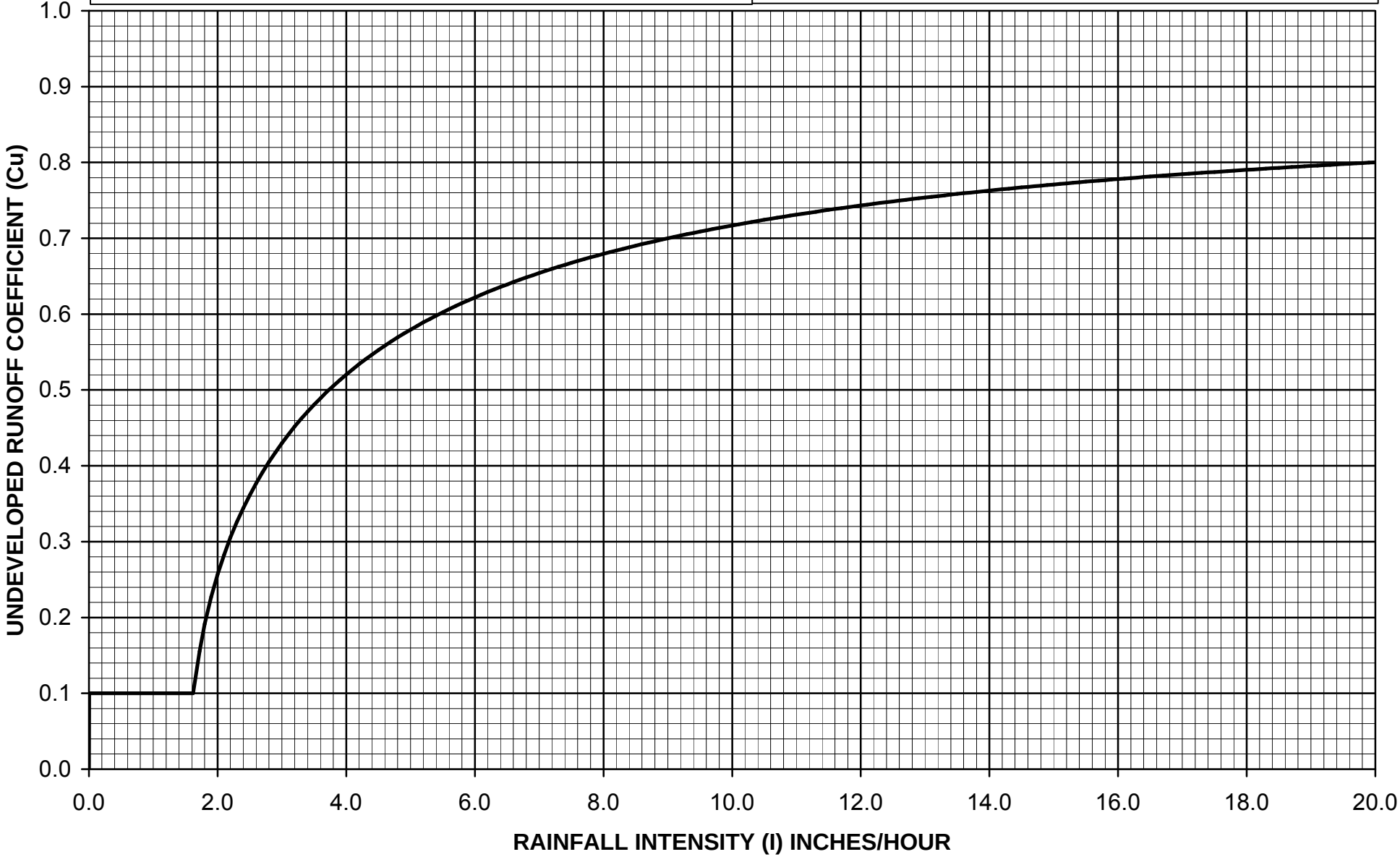


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 149

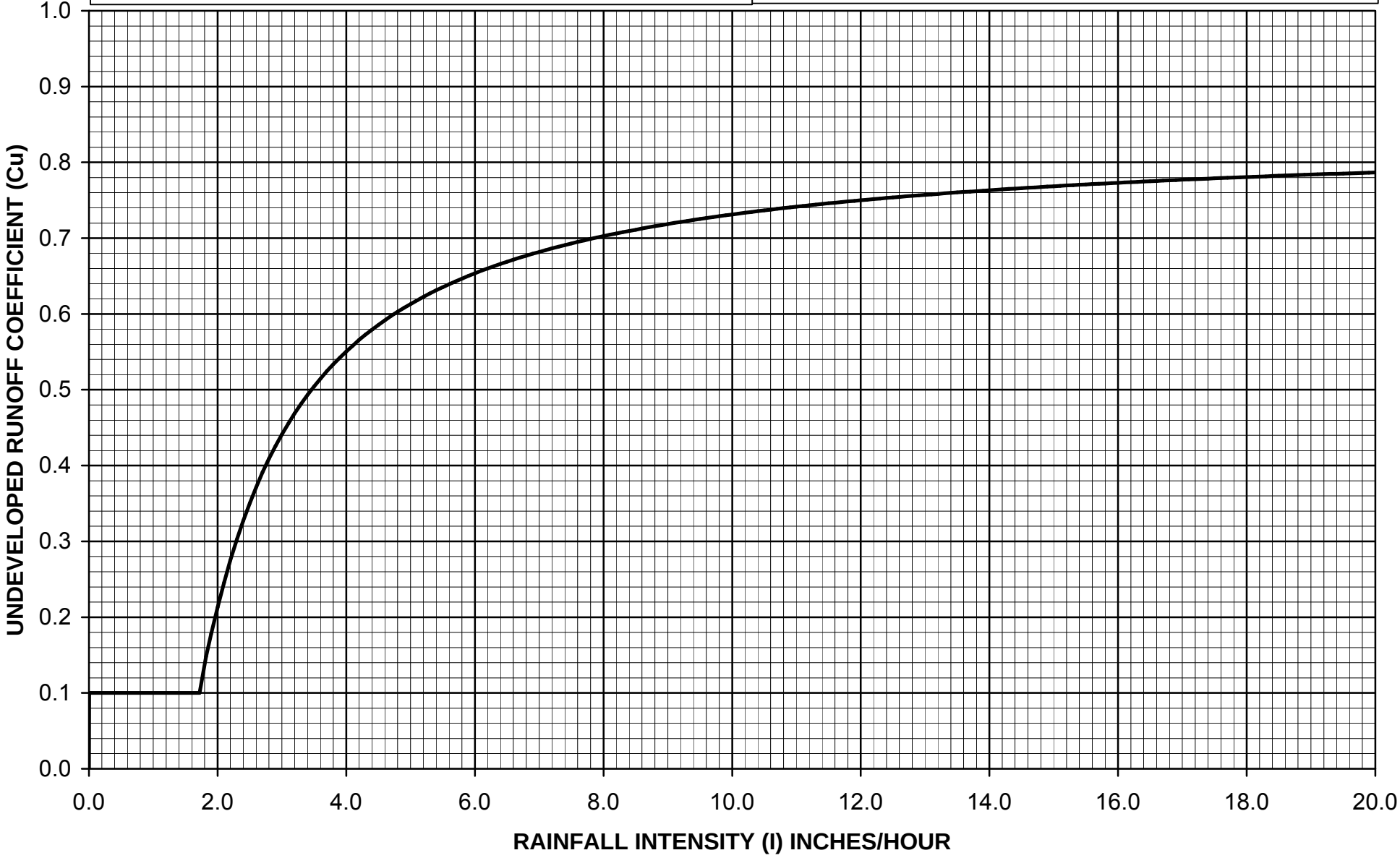


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 150

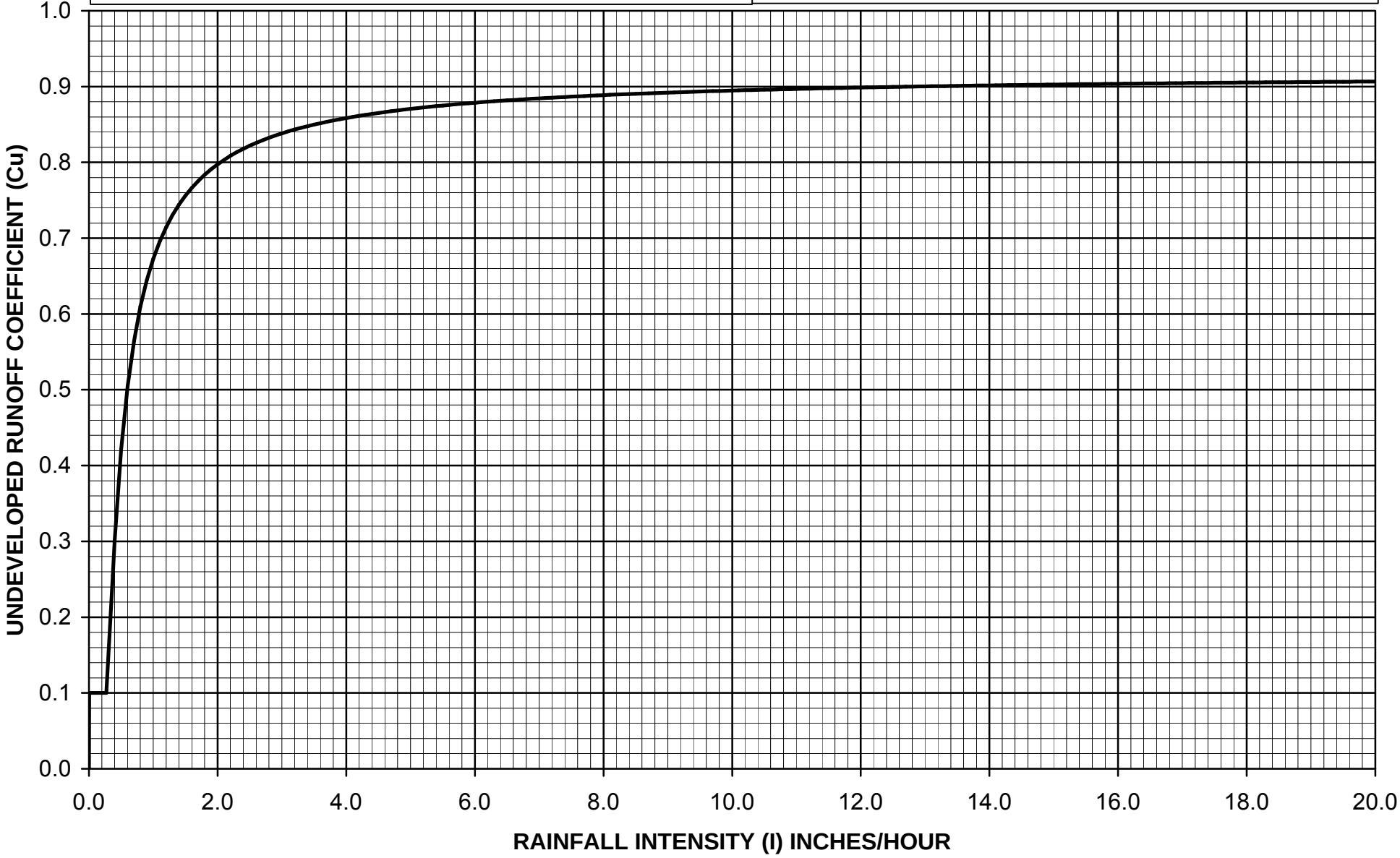


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 151

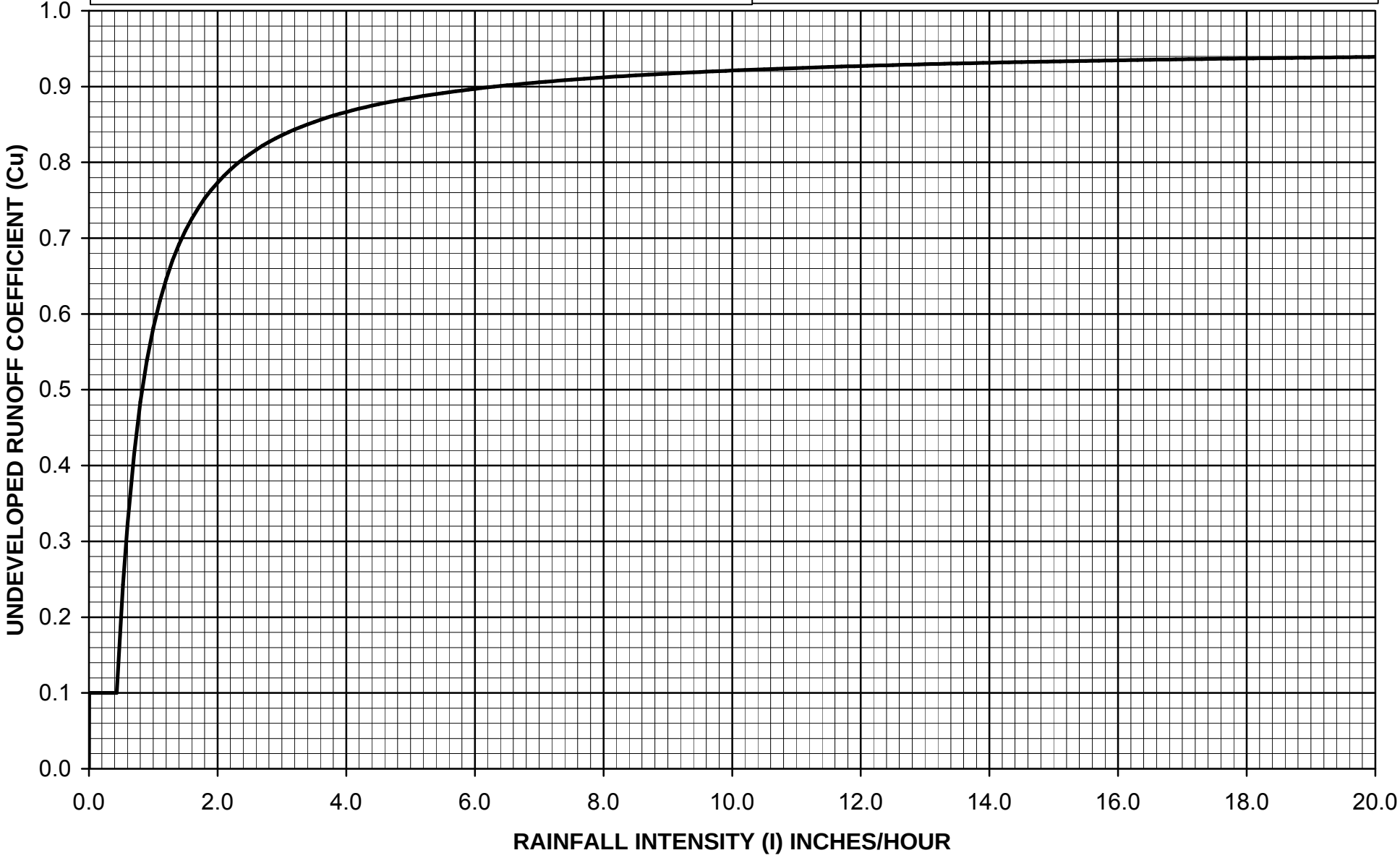


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 152

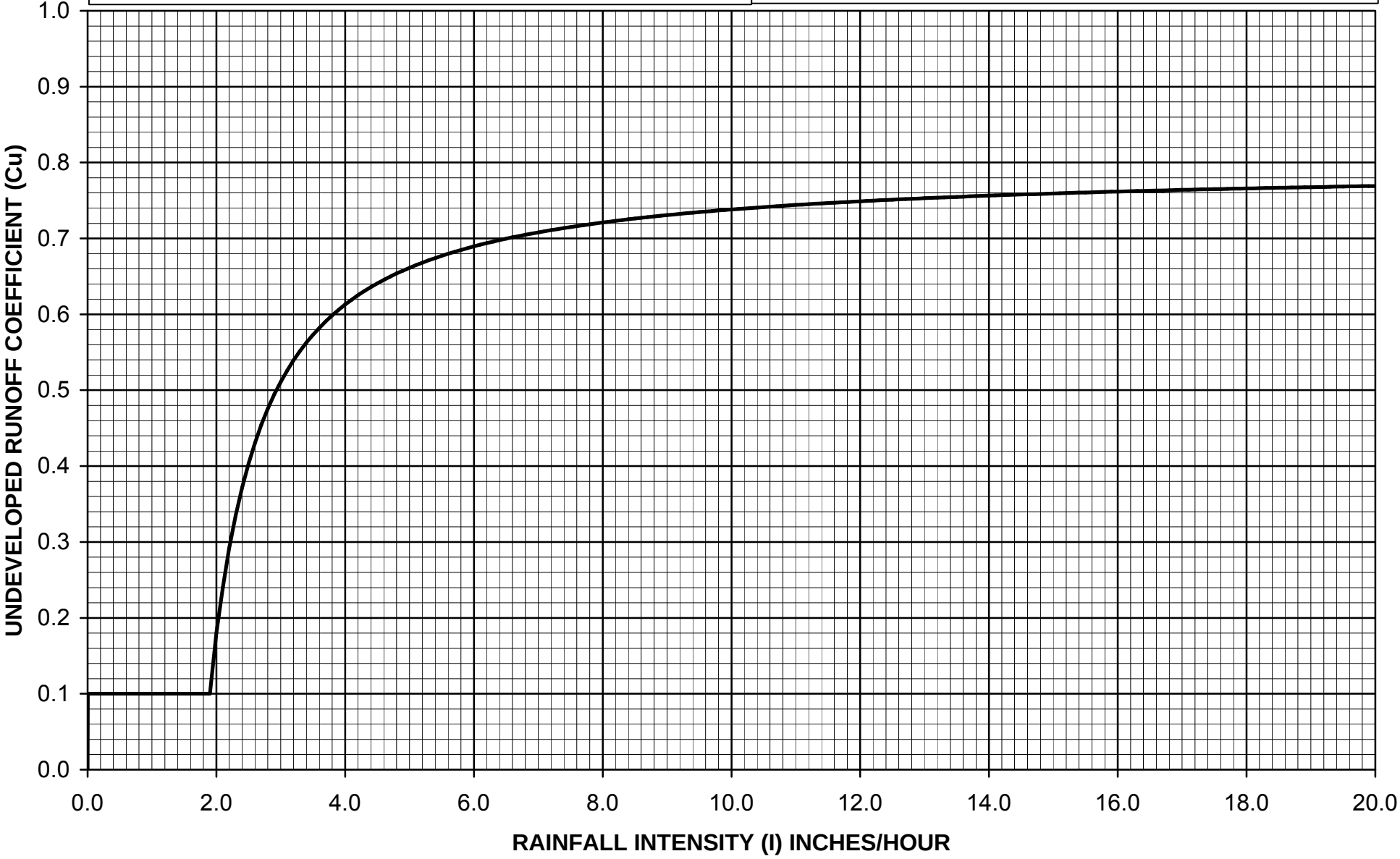


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 153

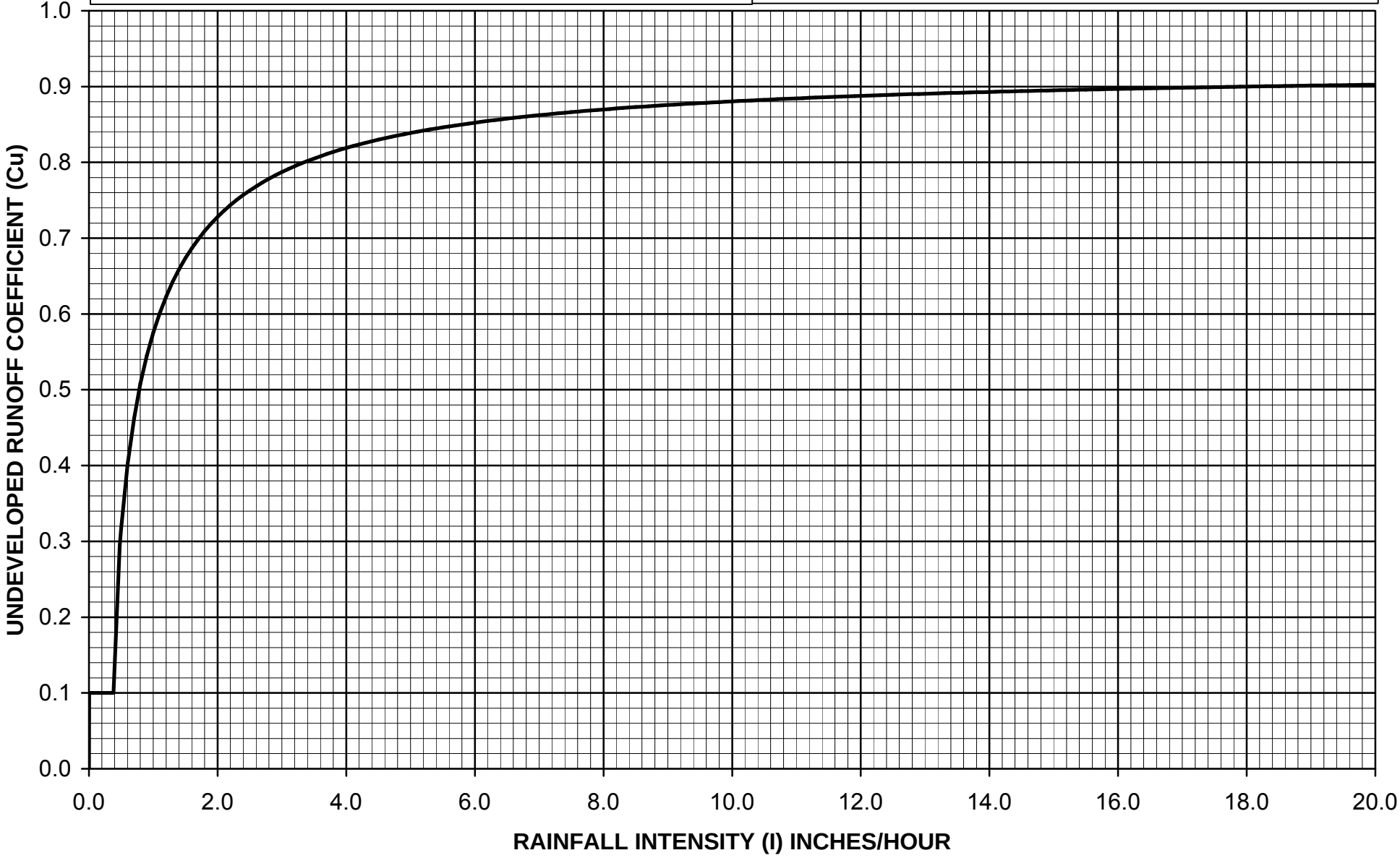


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 154

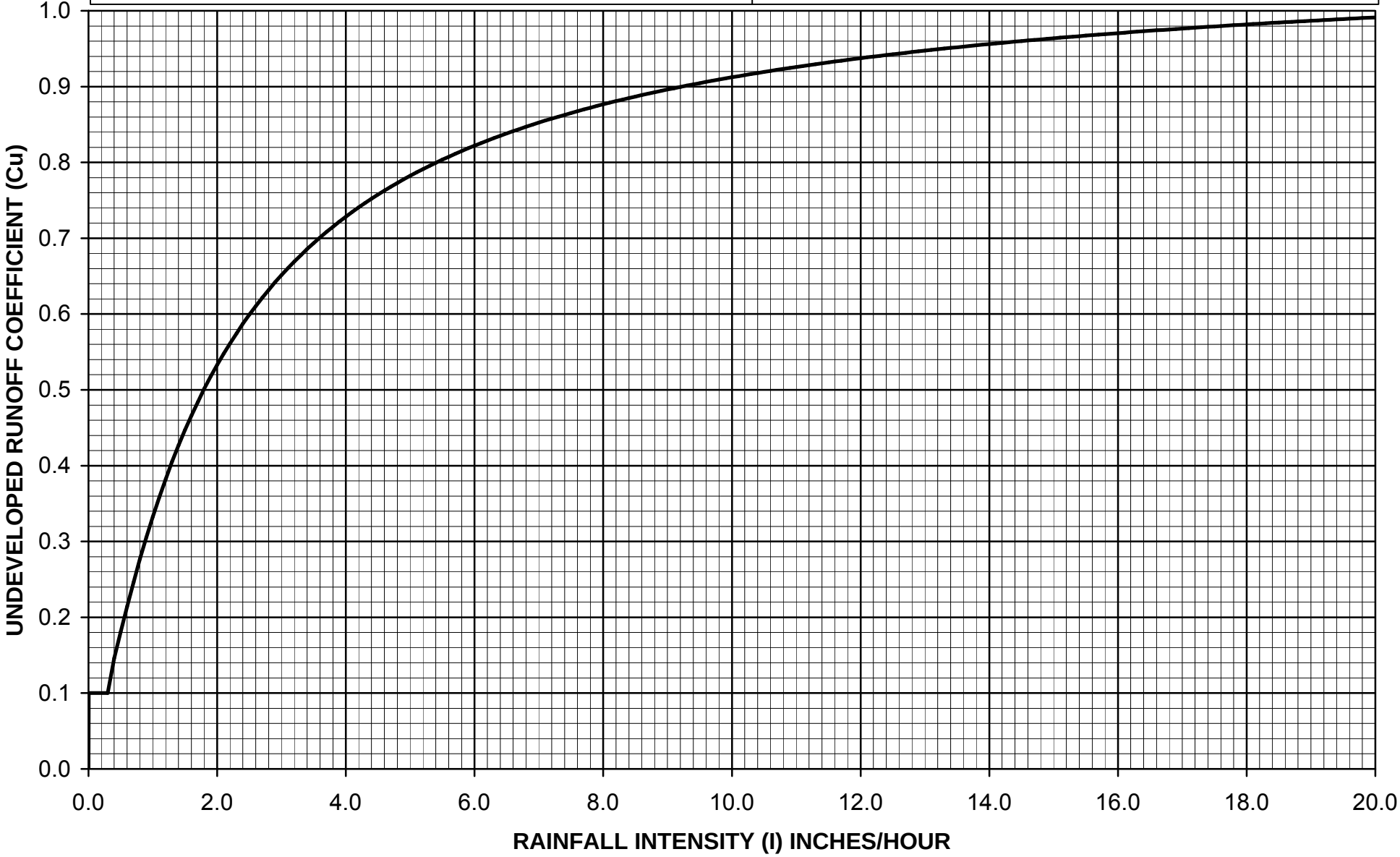


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 155

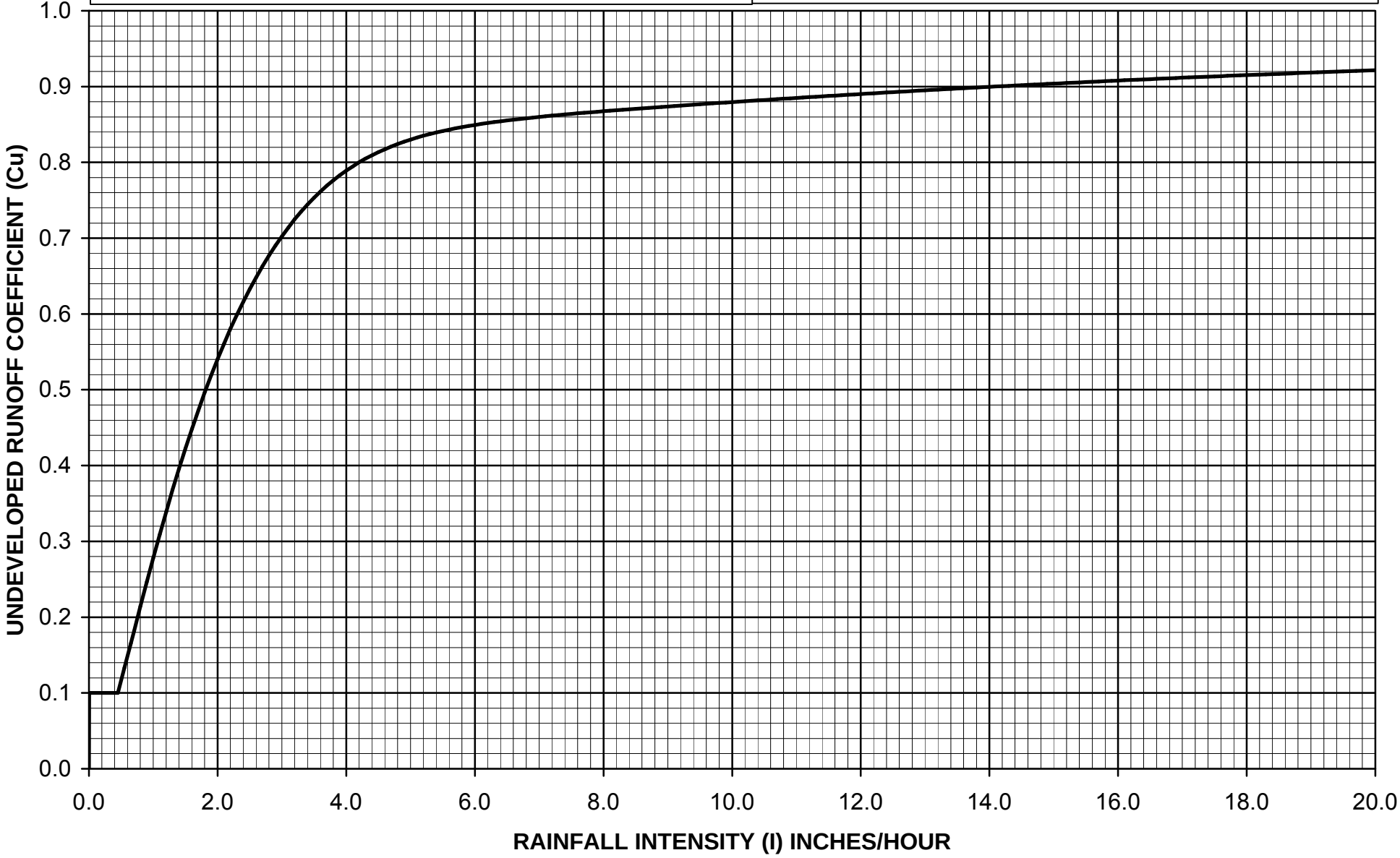


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 156

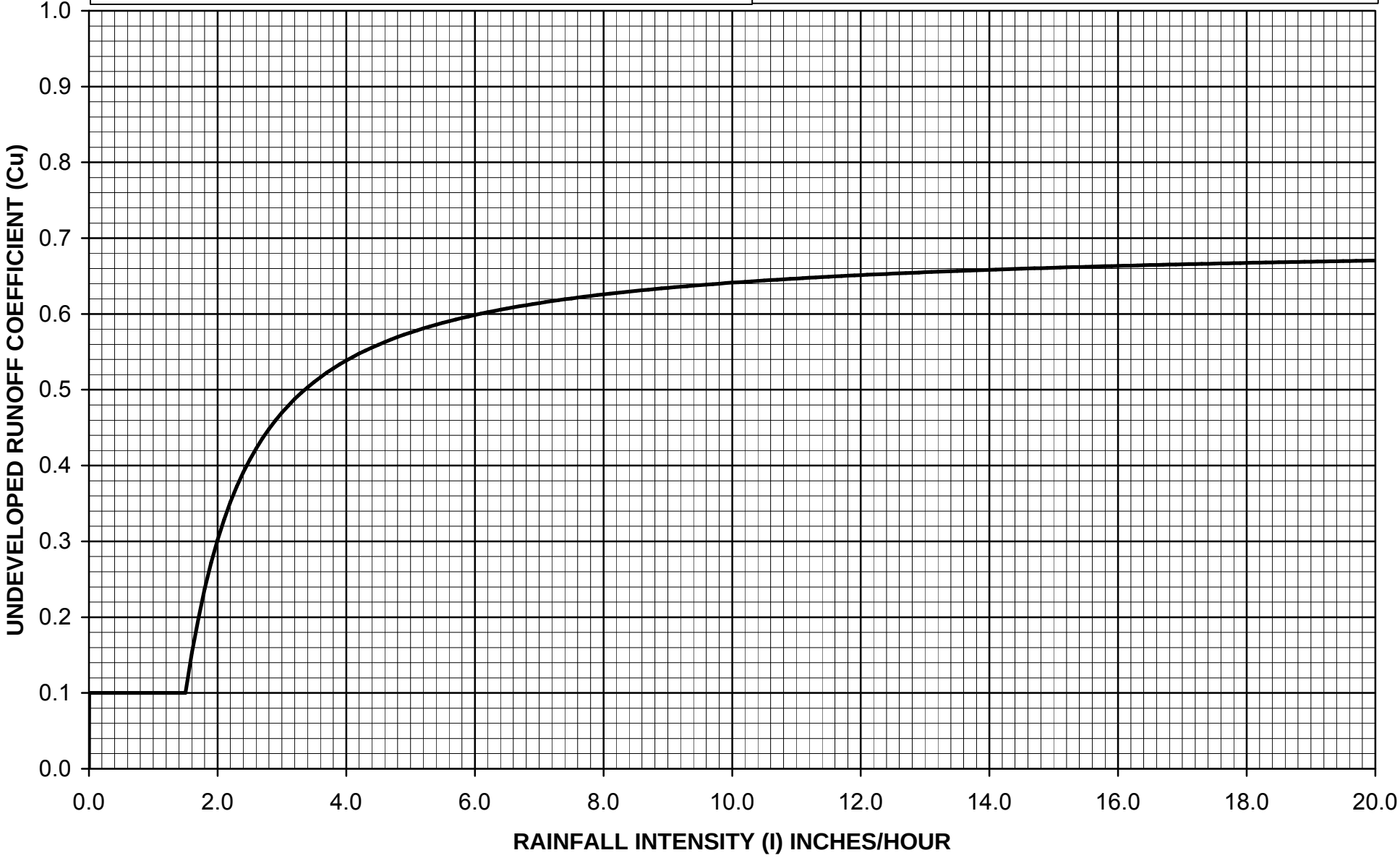


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 157

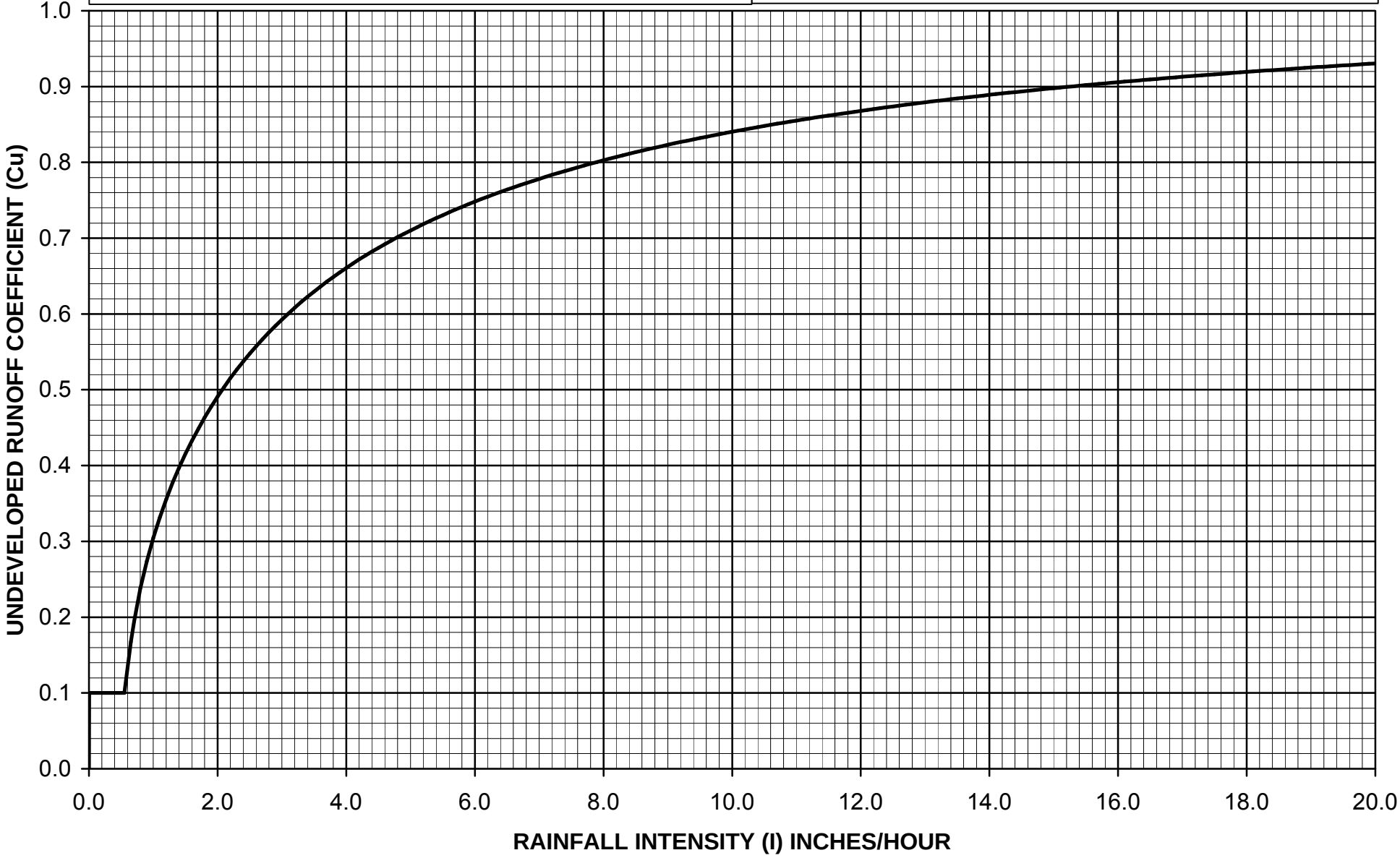


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 158

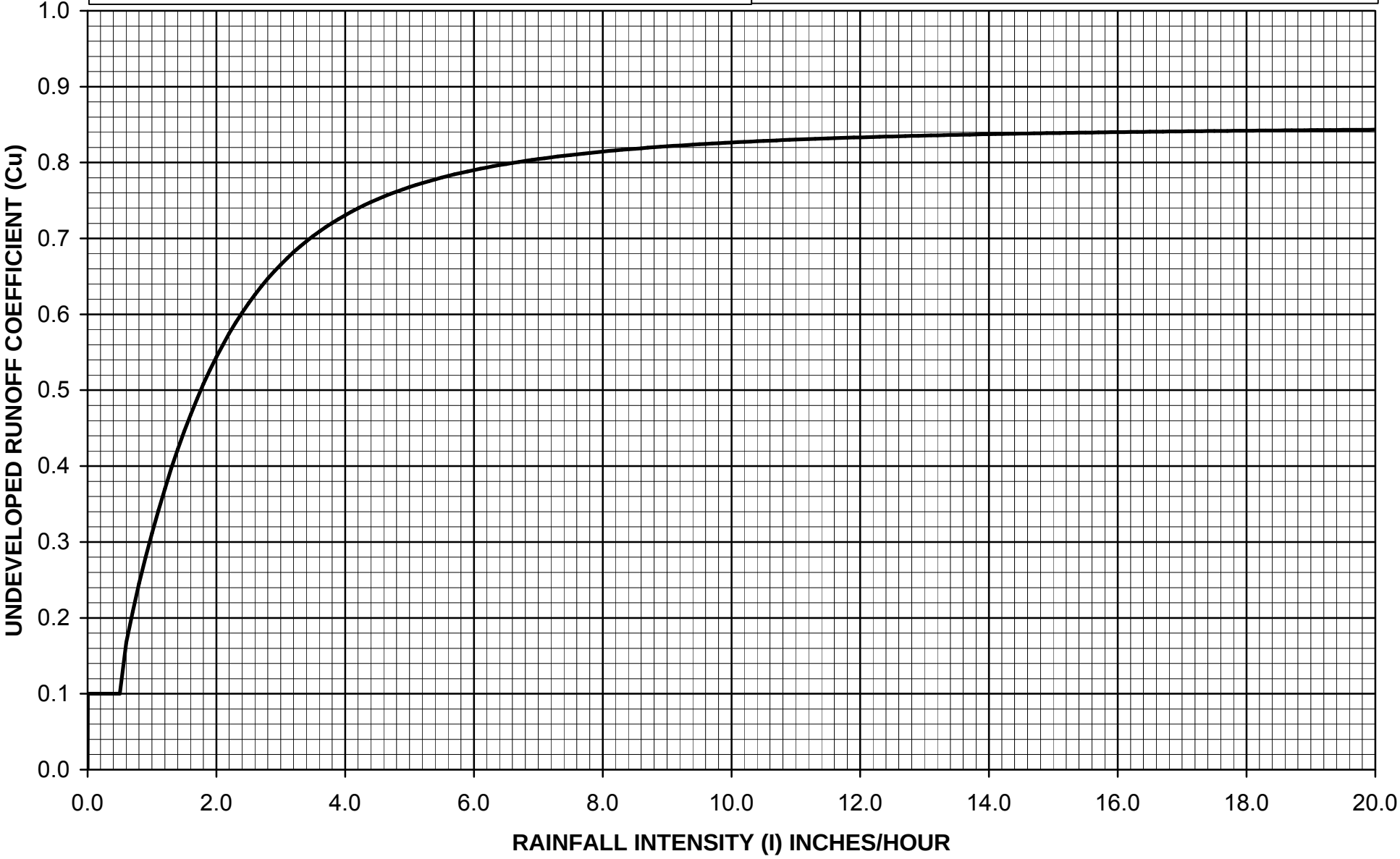


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 159

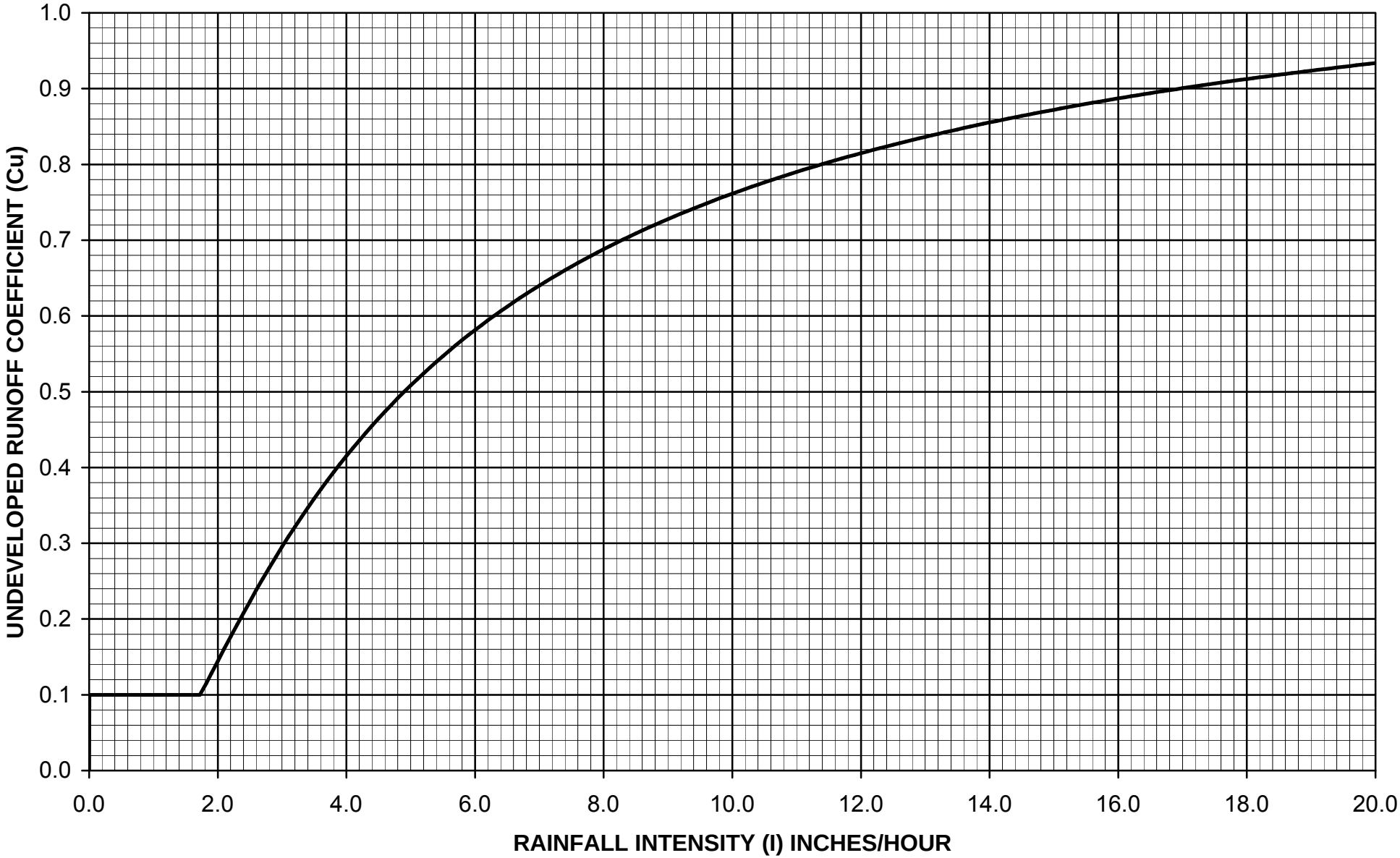


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 160

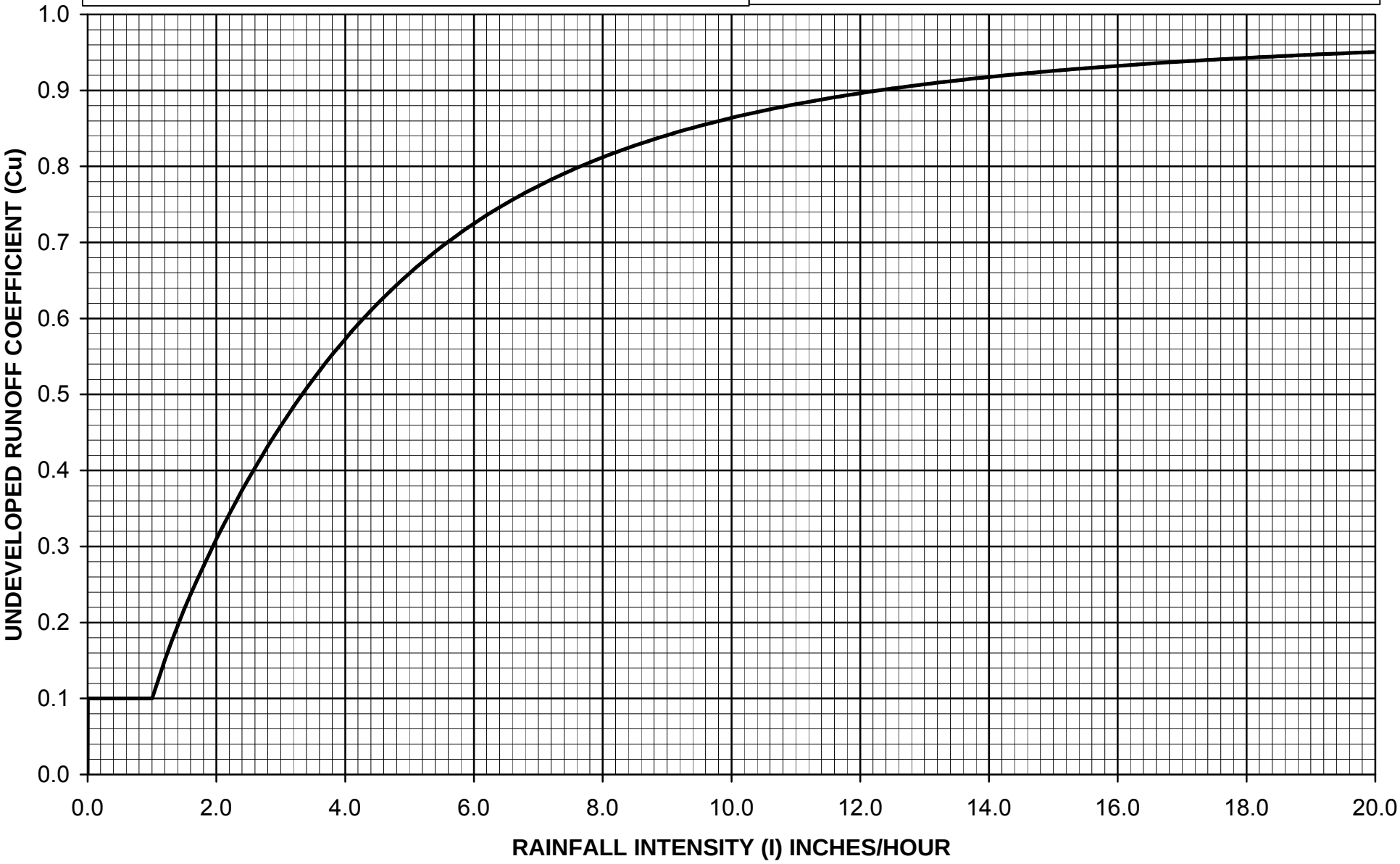


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 161

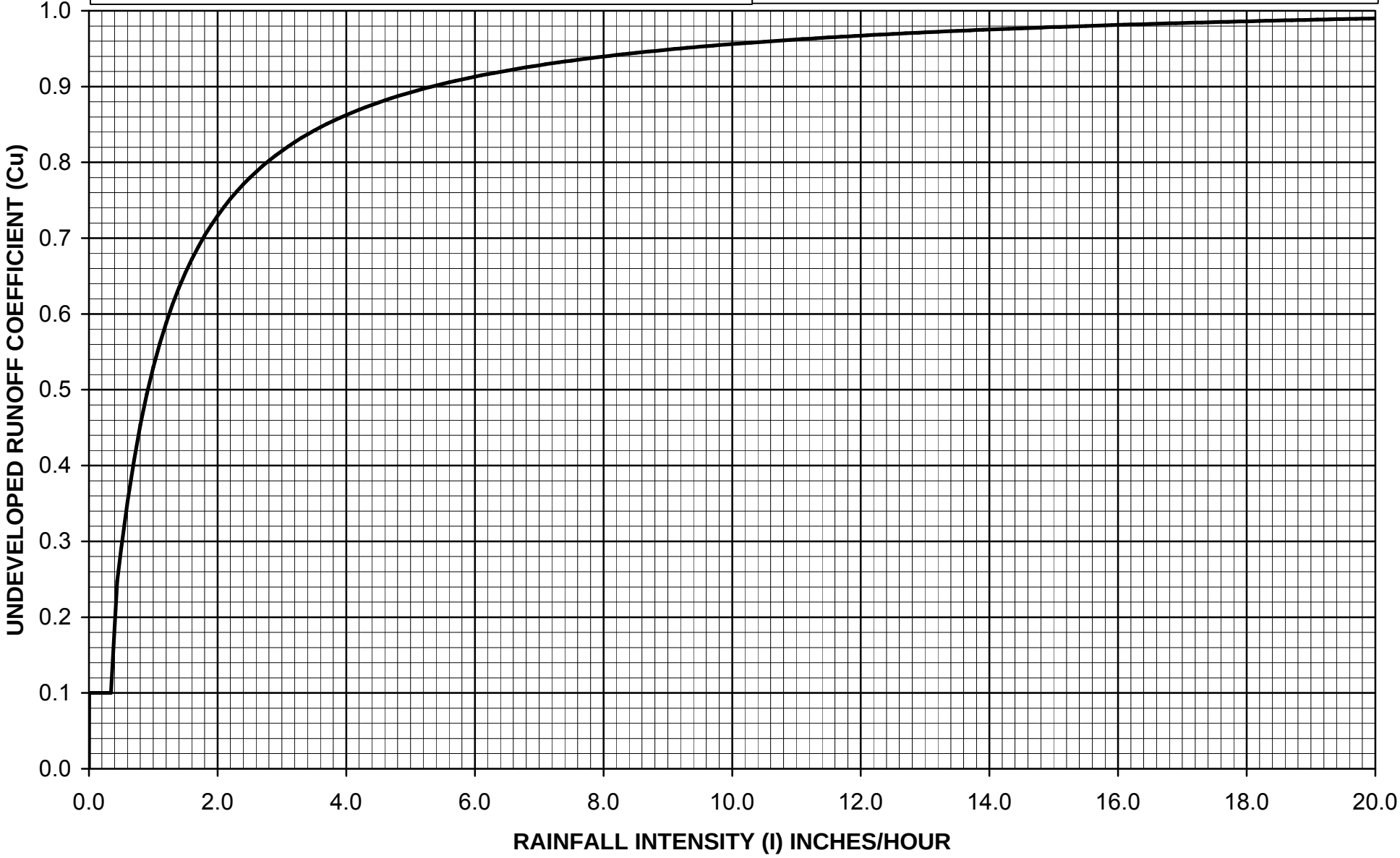


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 162

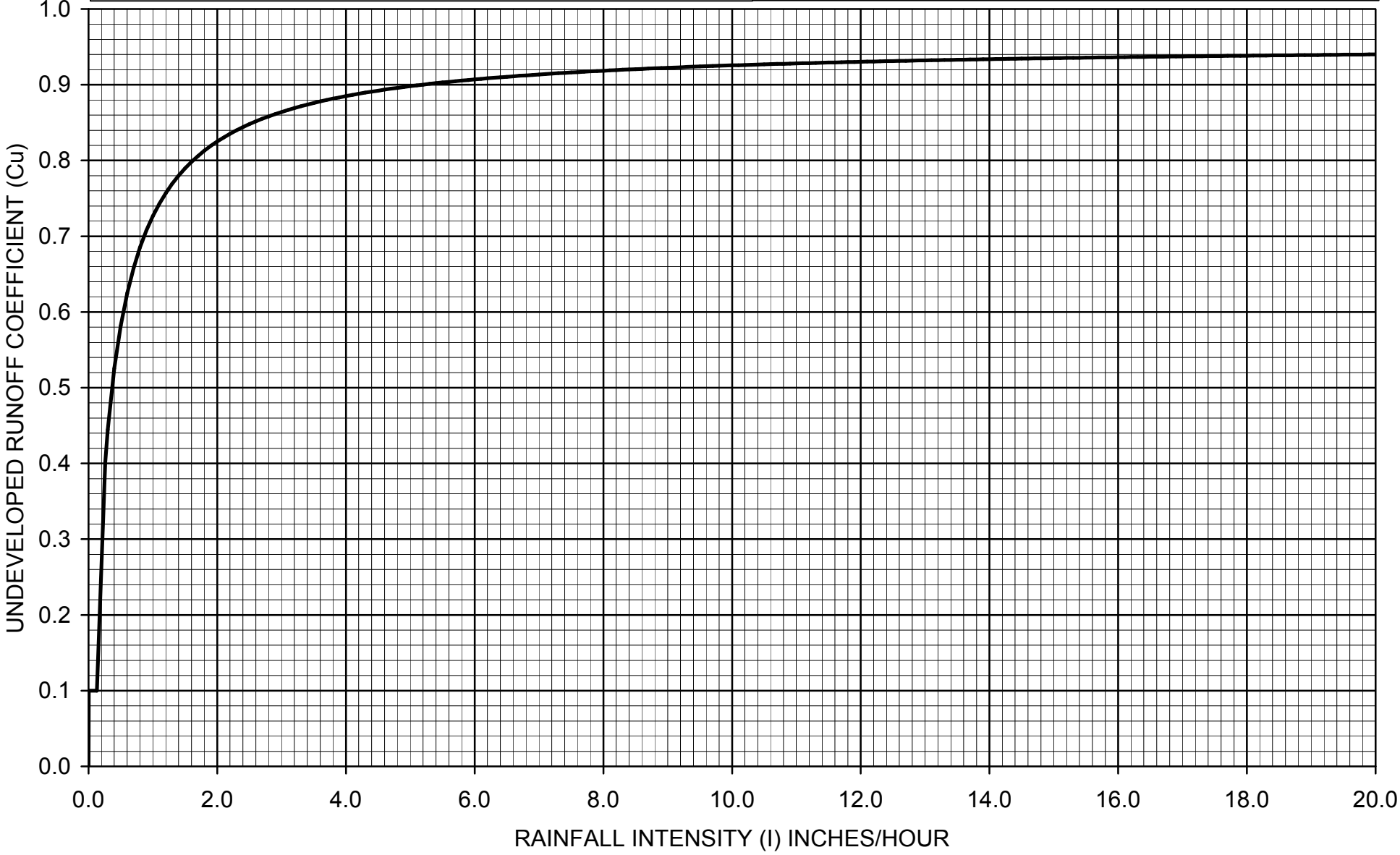


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 163

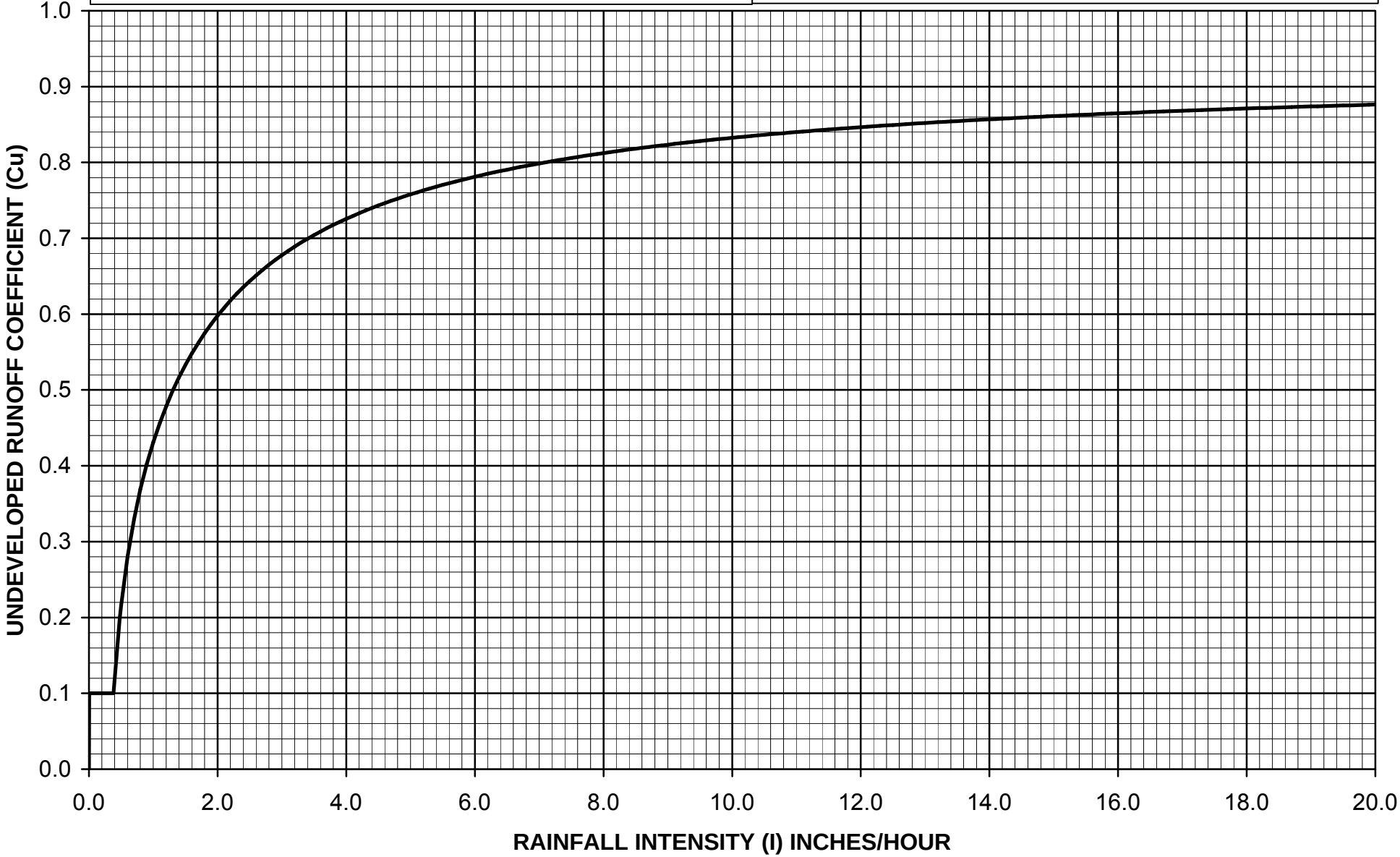


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 164

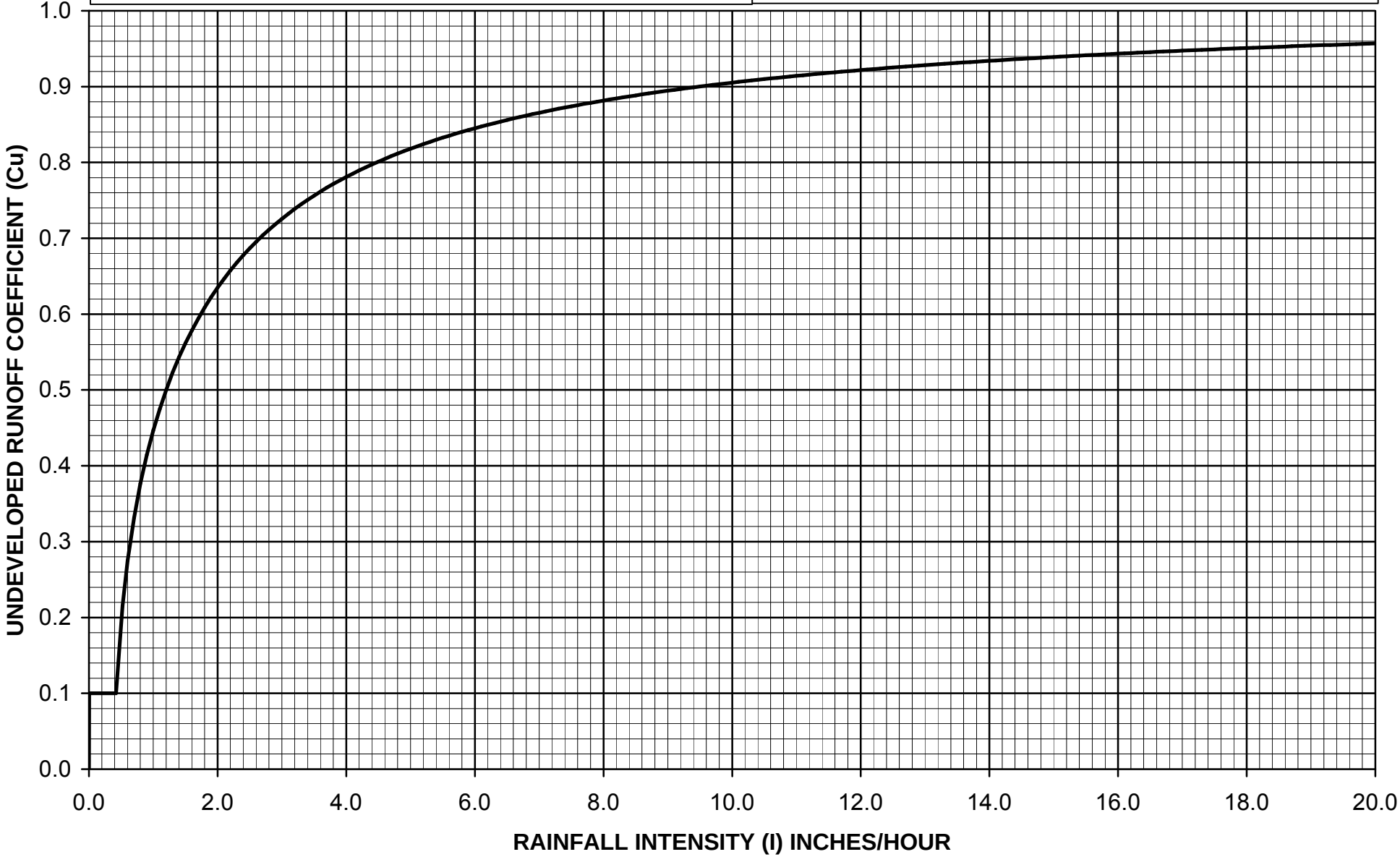


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 165

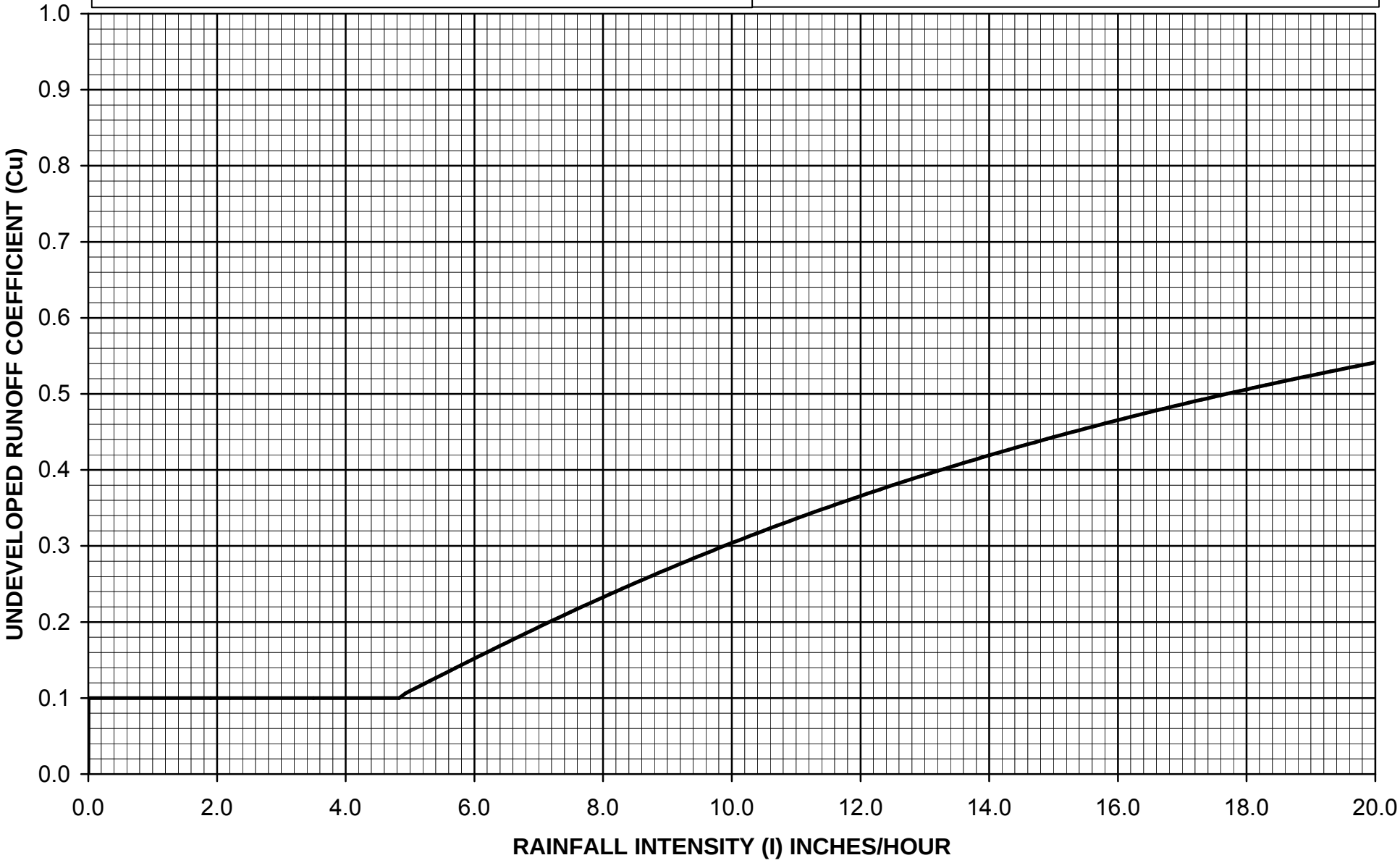


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 166

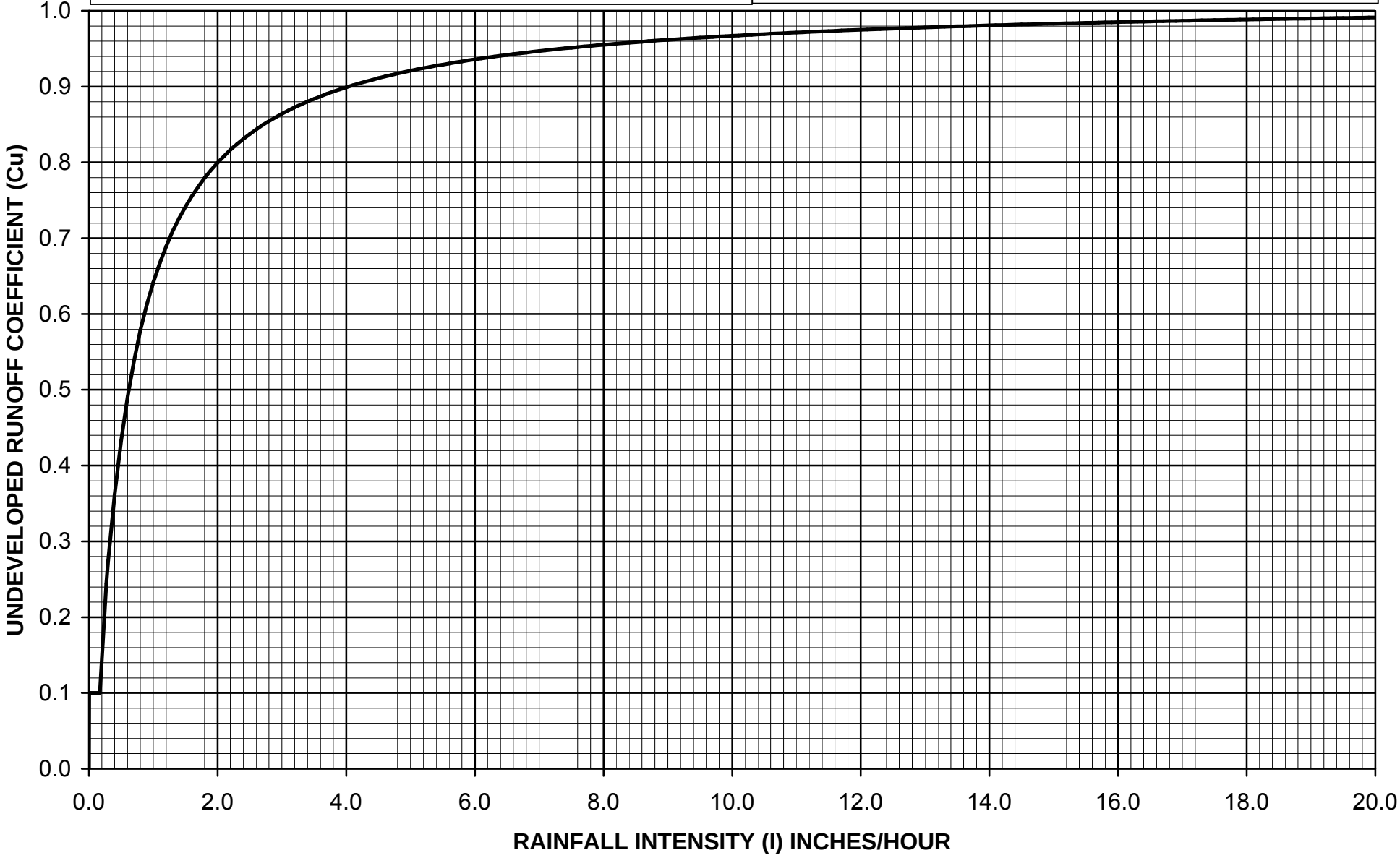


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 167

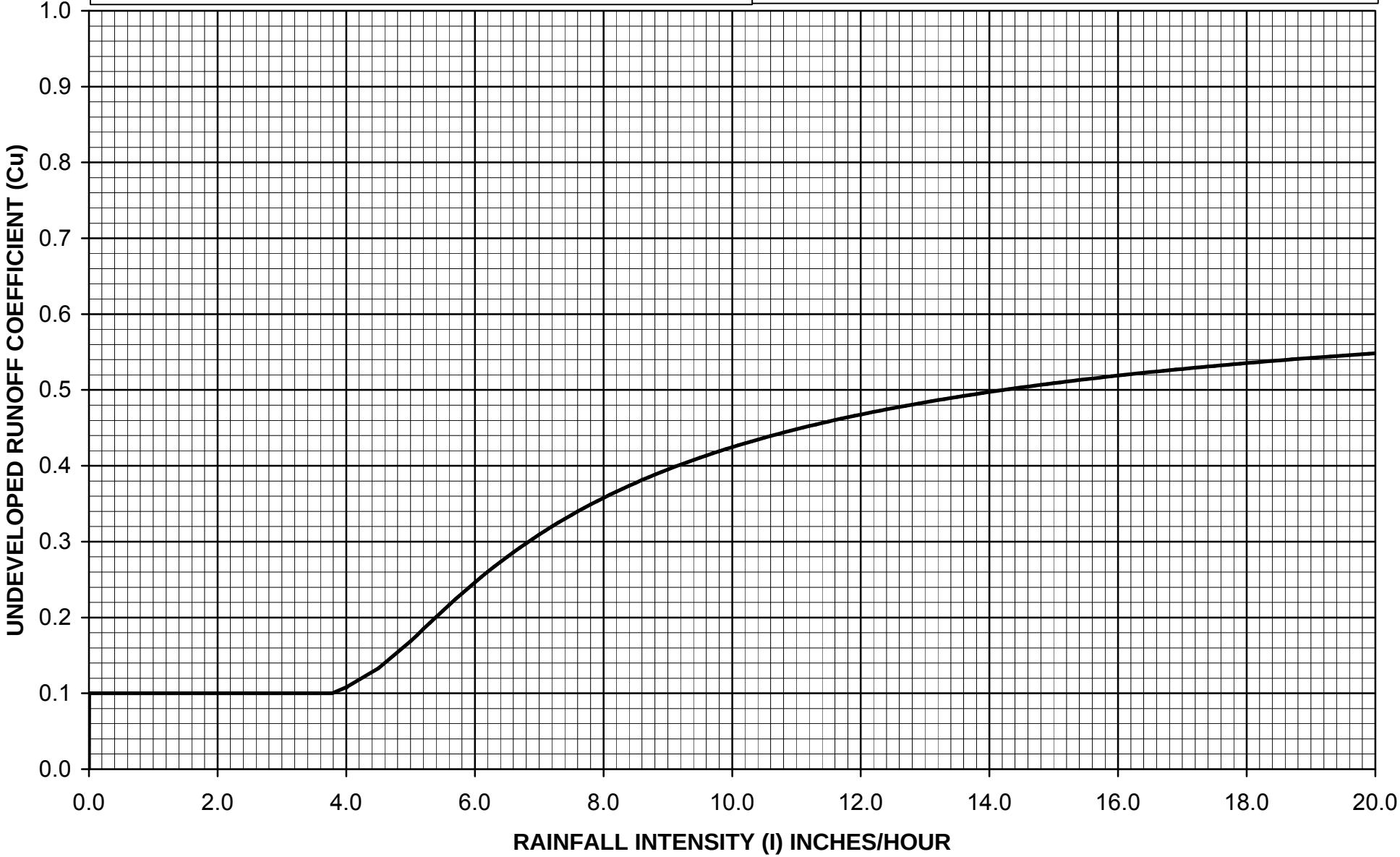


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 168

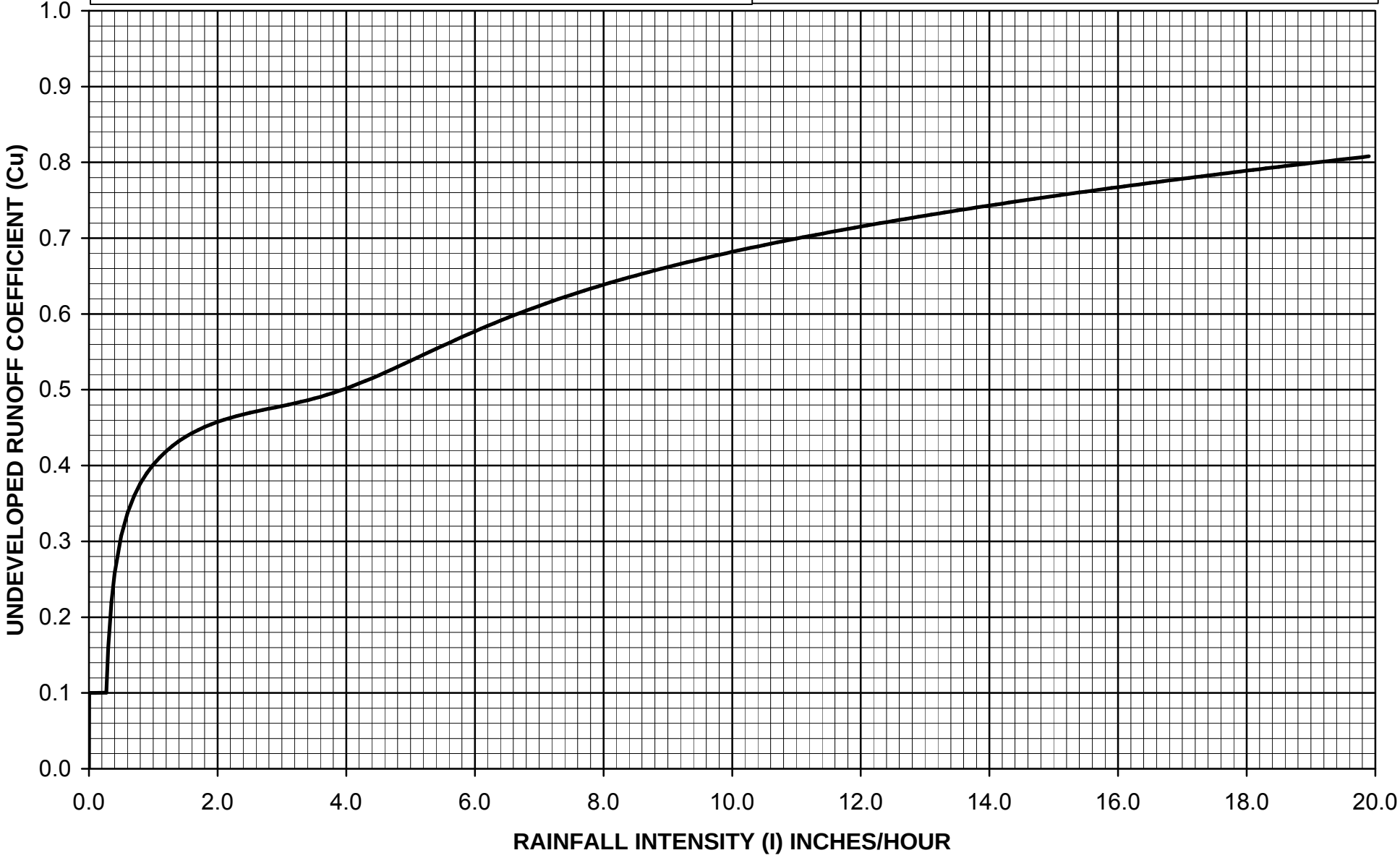


CD = (0.9 * IMP) + (1.0 - IMP) * Cu

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 169

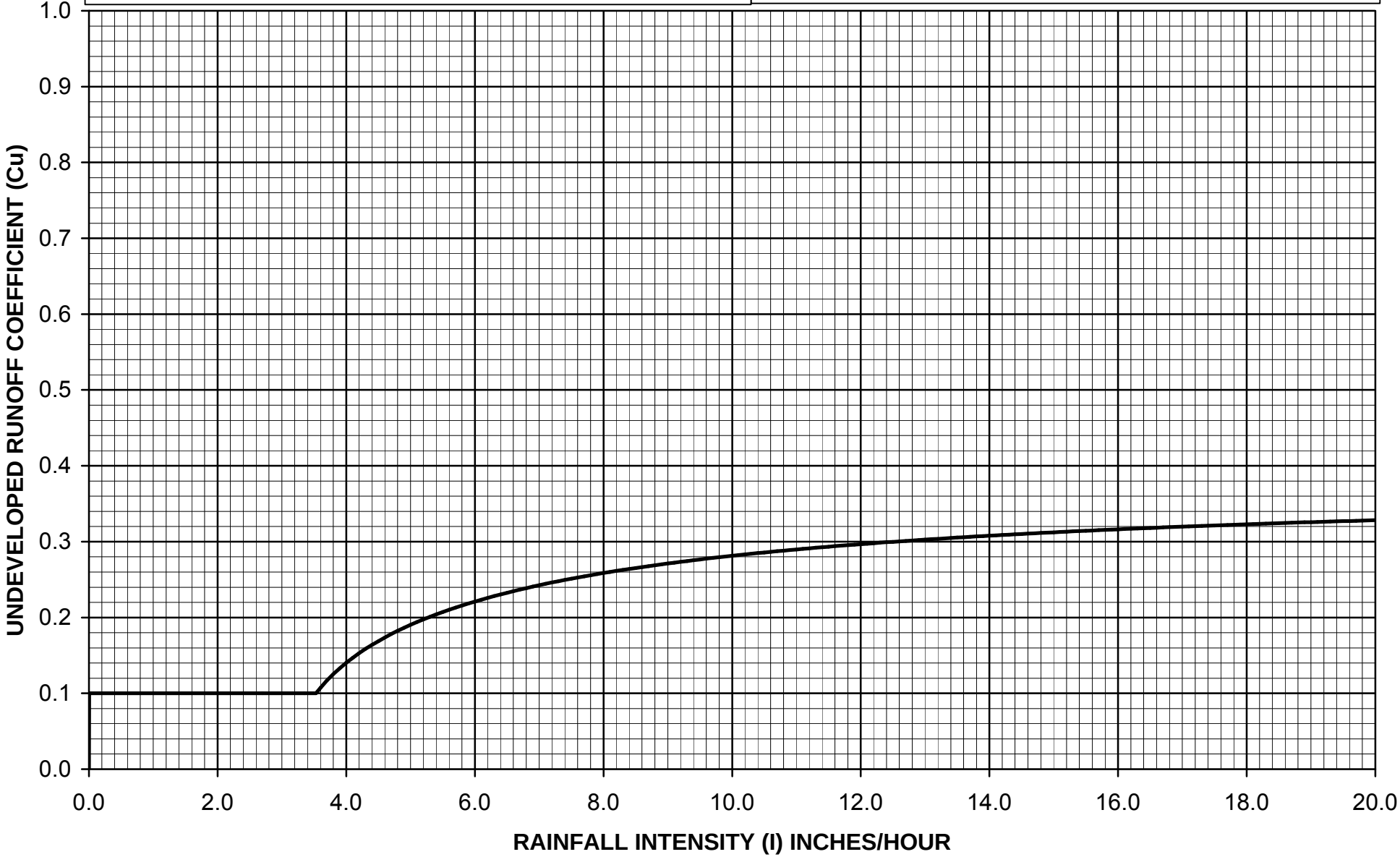


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 170

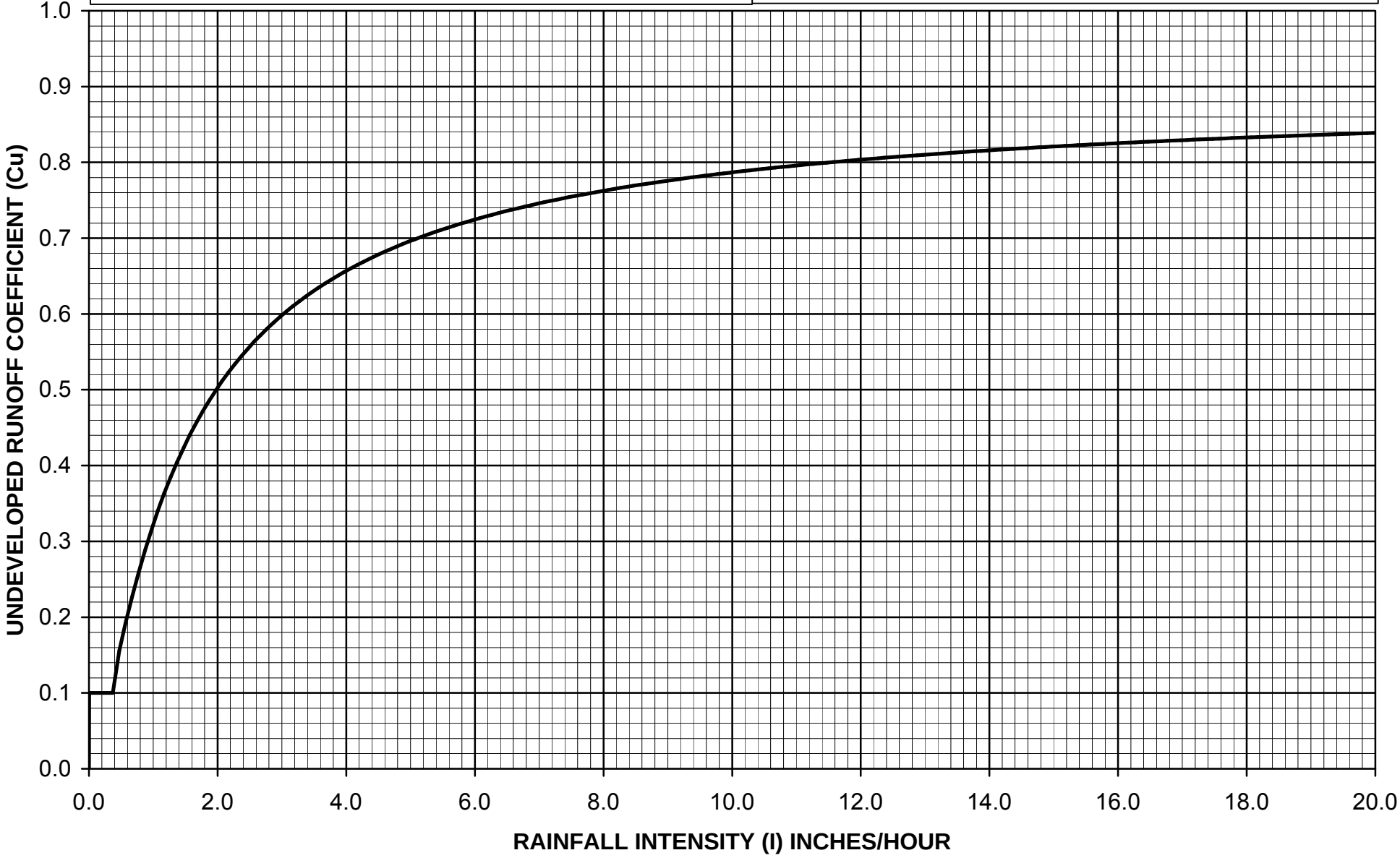


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 171

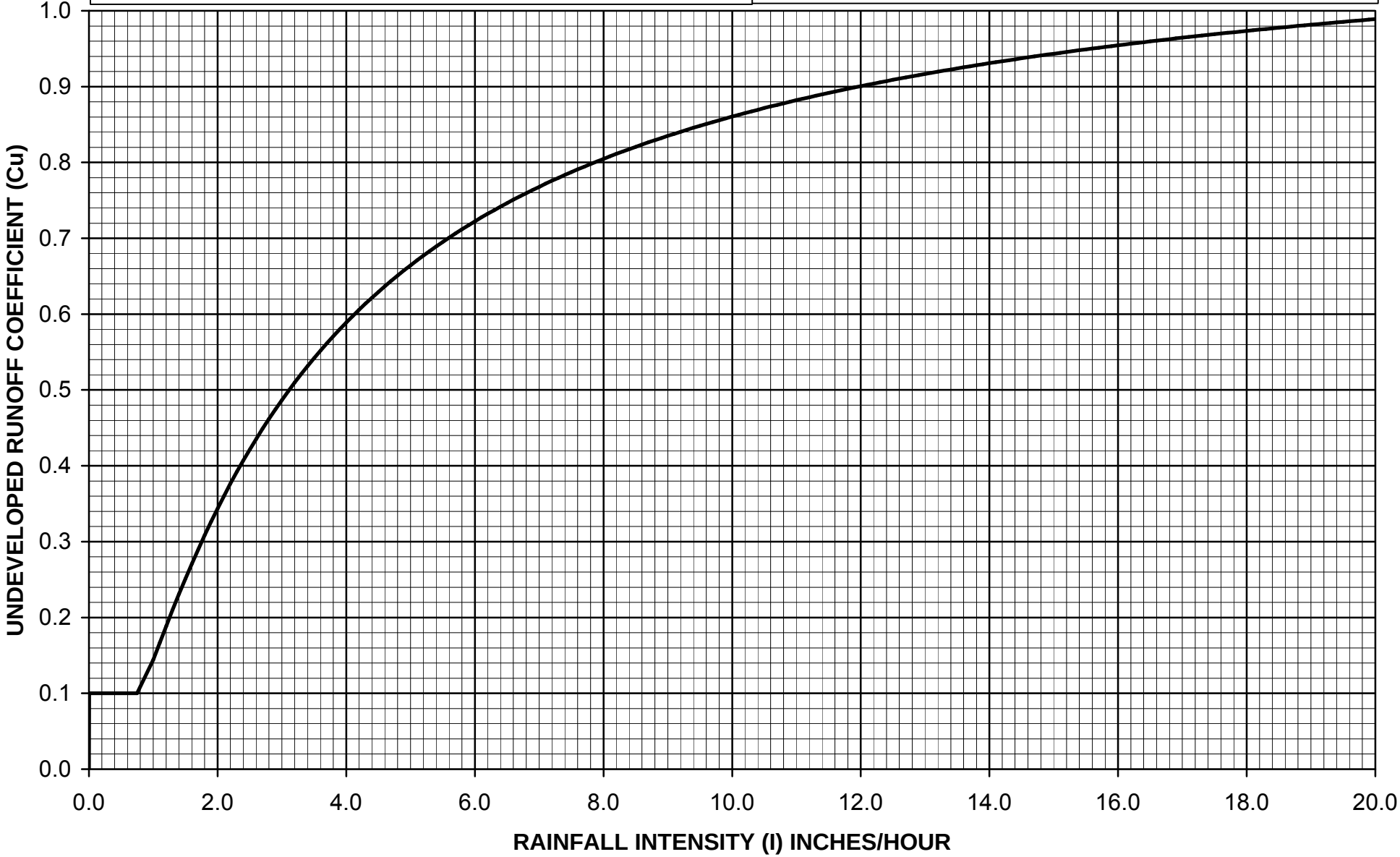


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 172

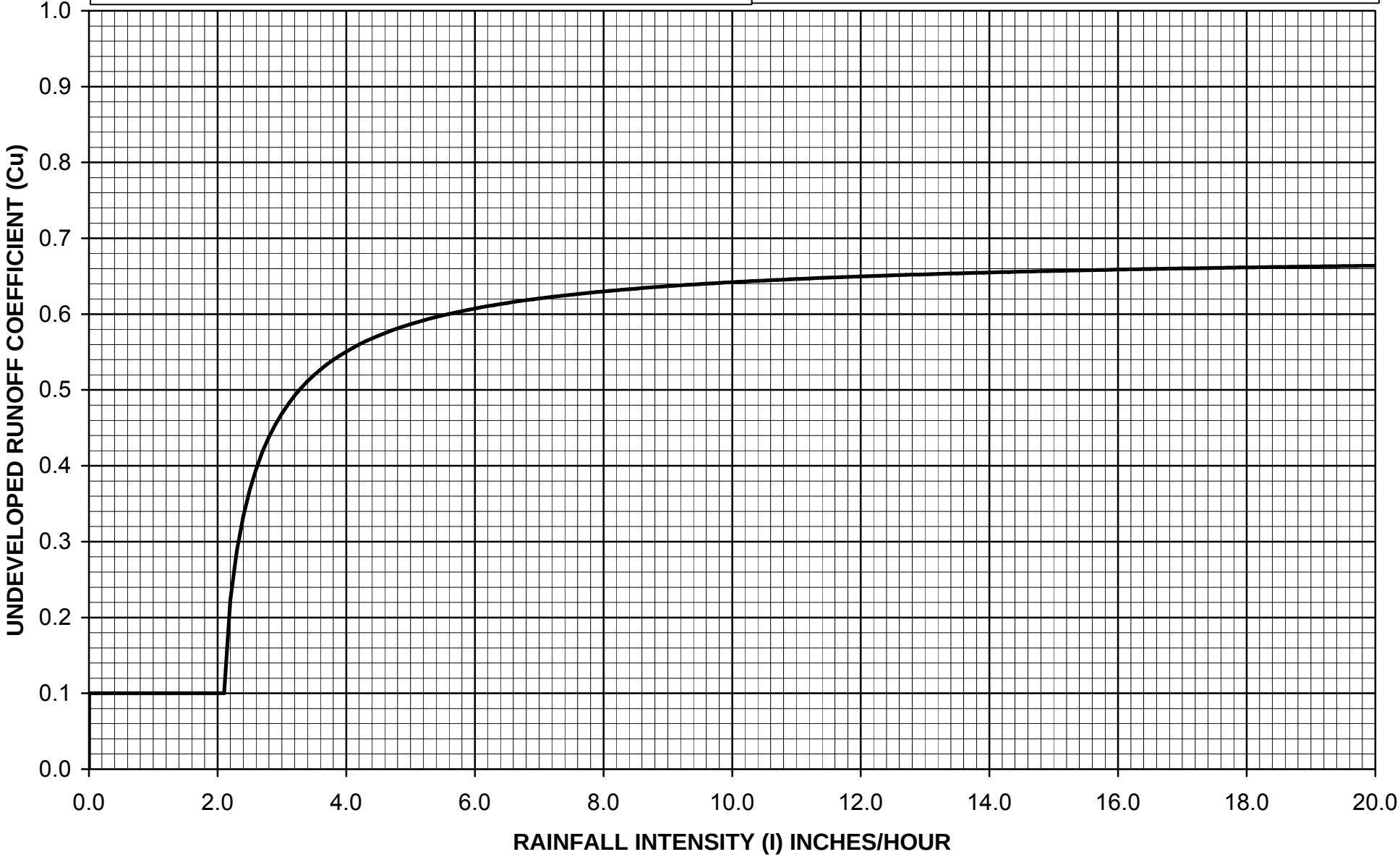


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 173

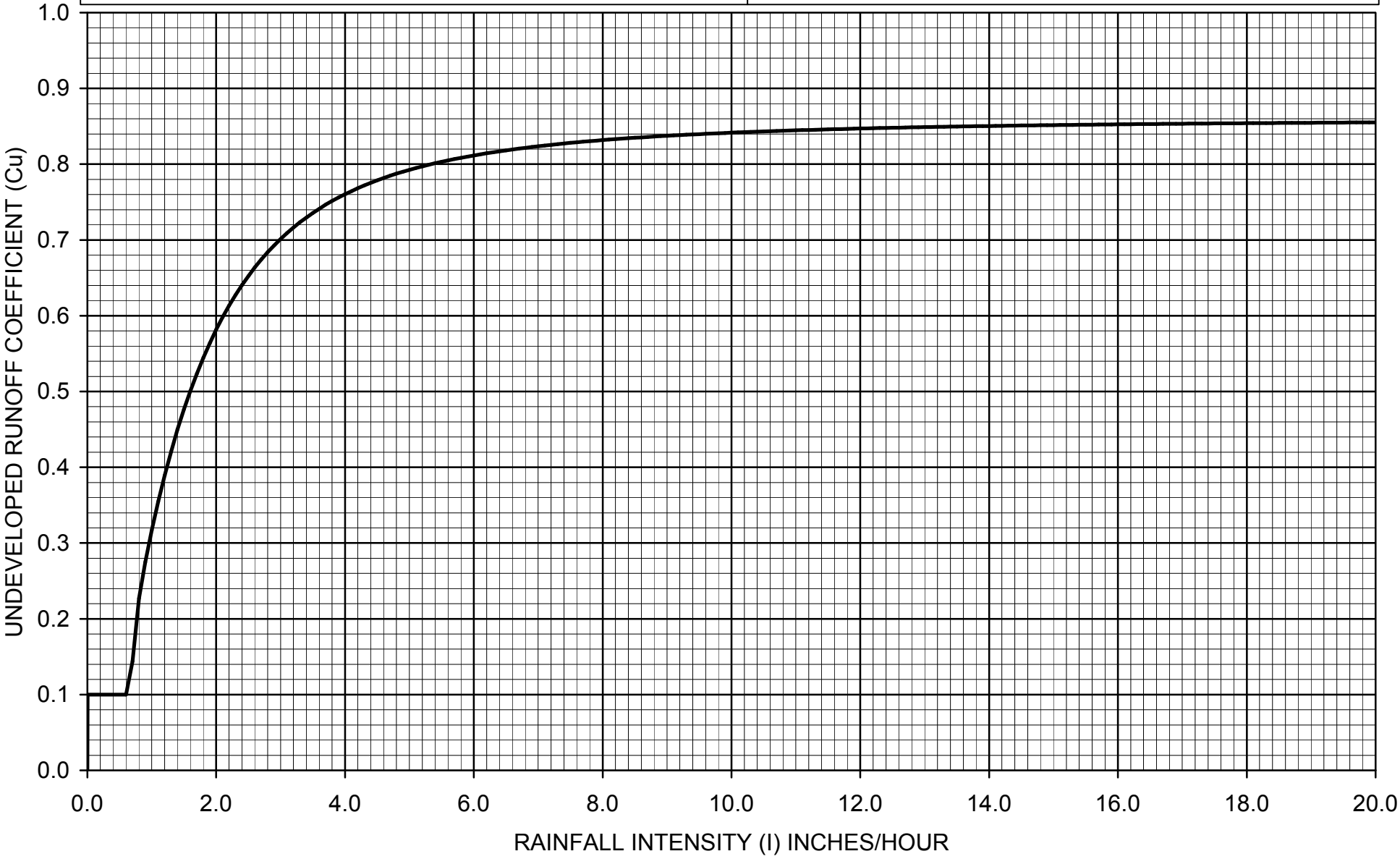


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 174

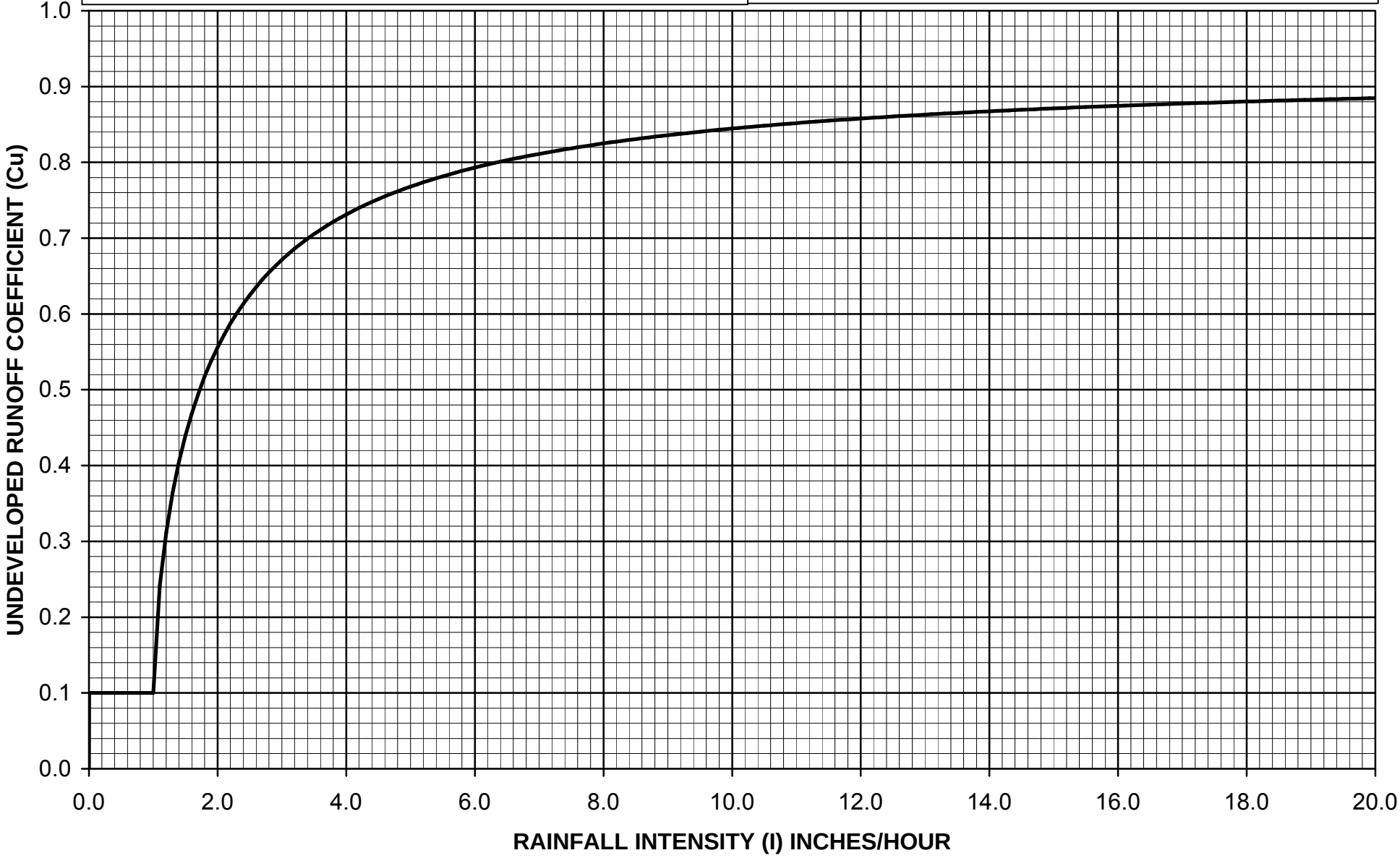


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 175

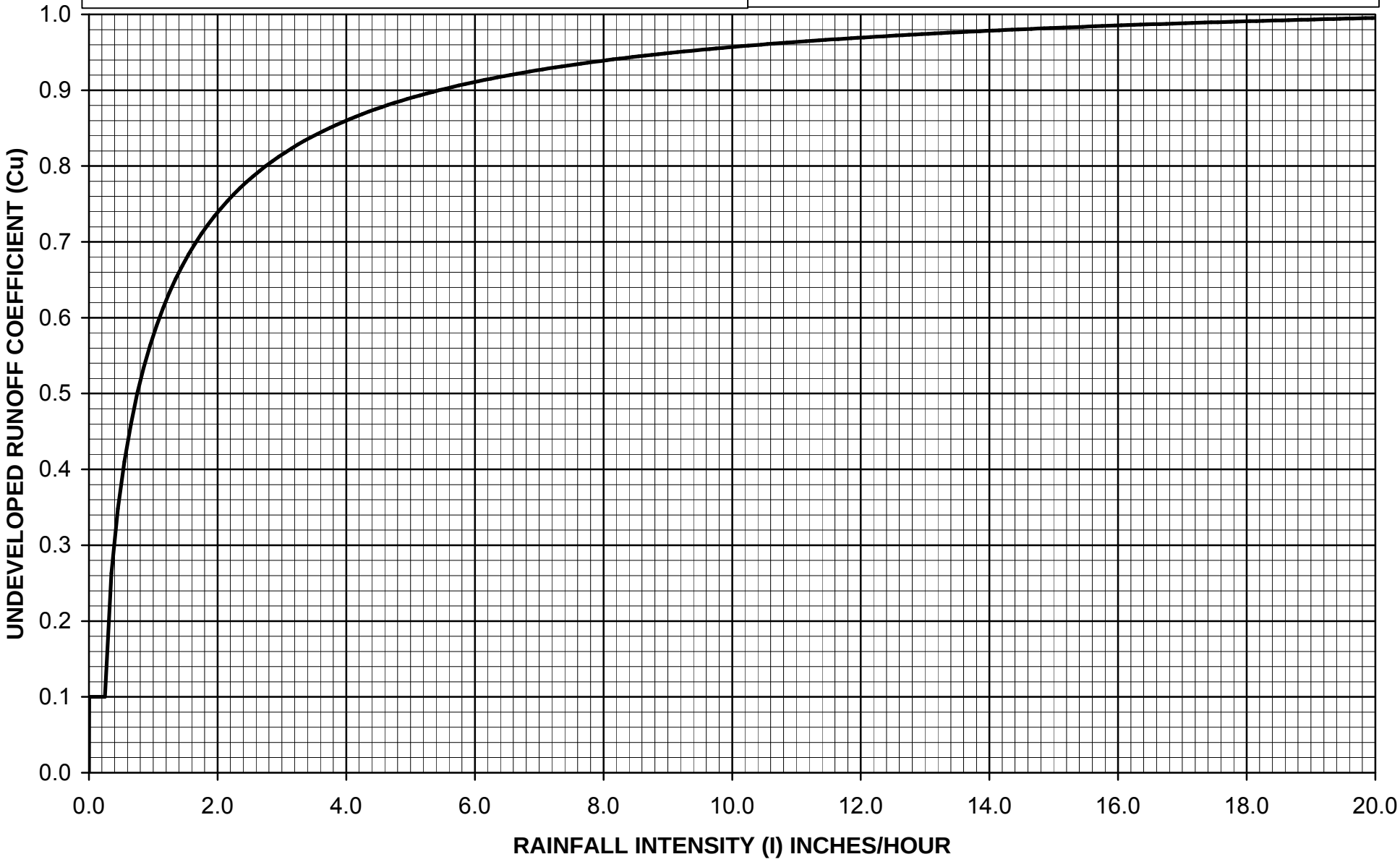


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 176

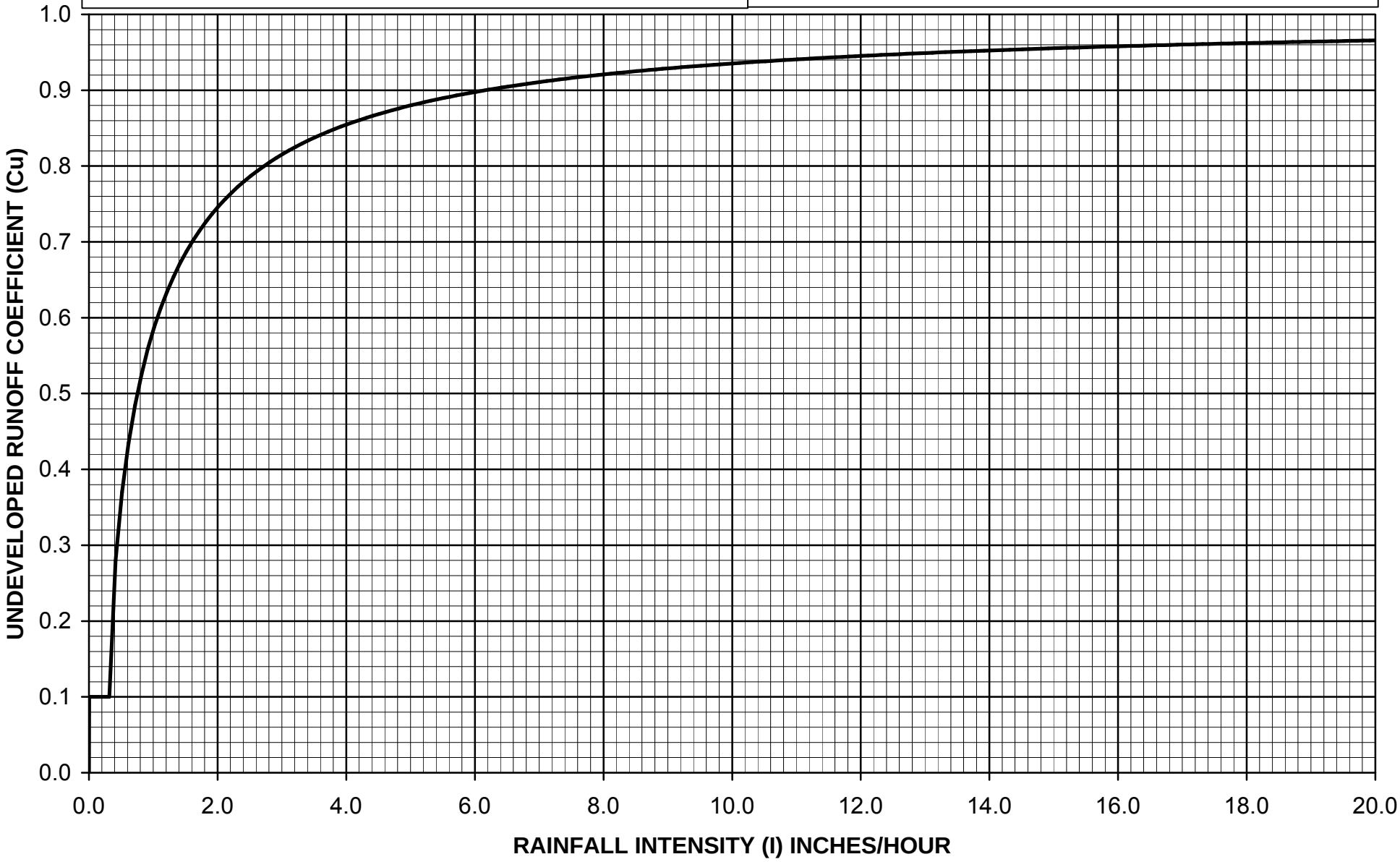


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 177

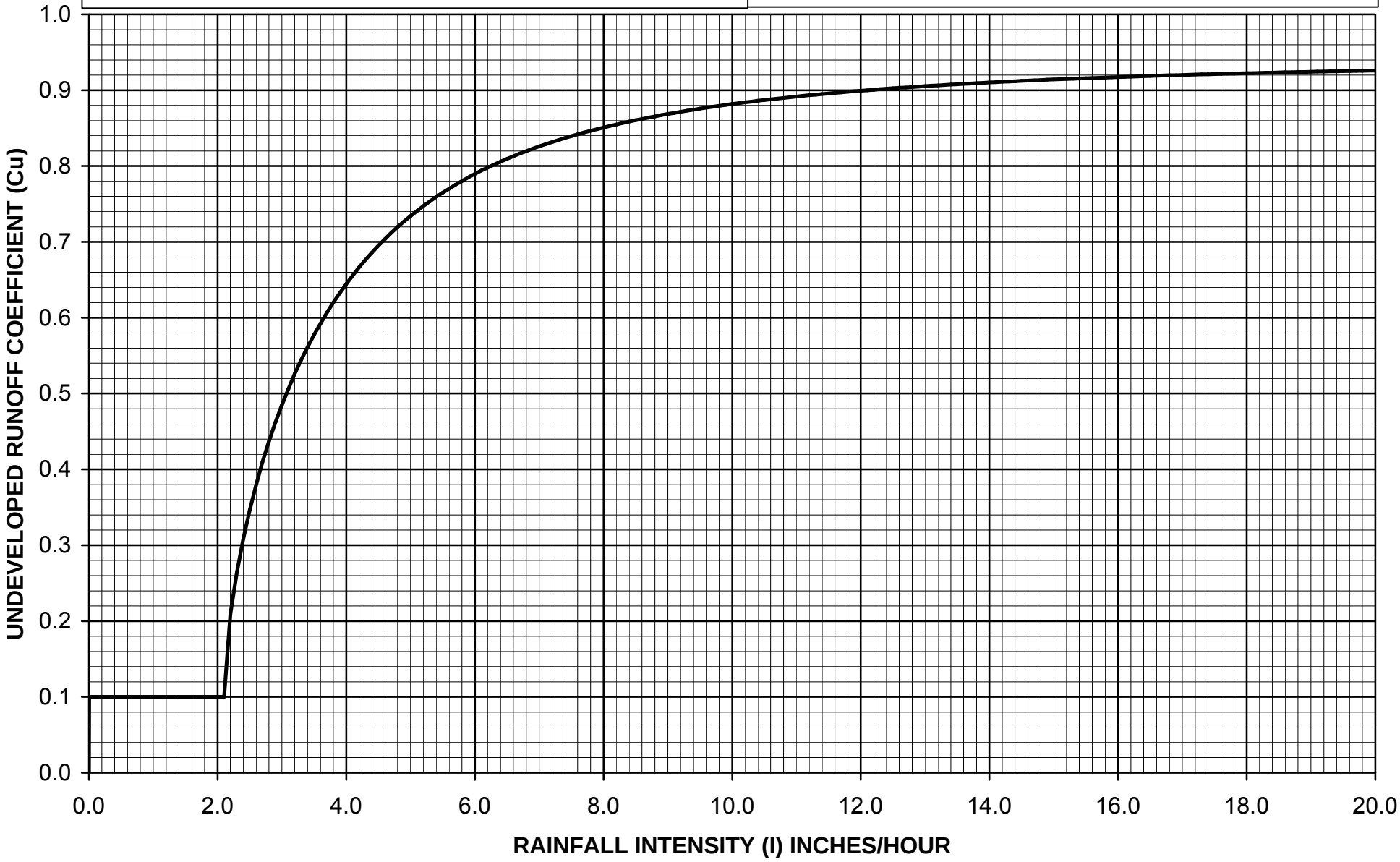


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 178

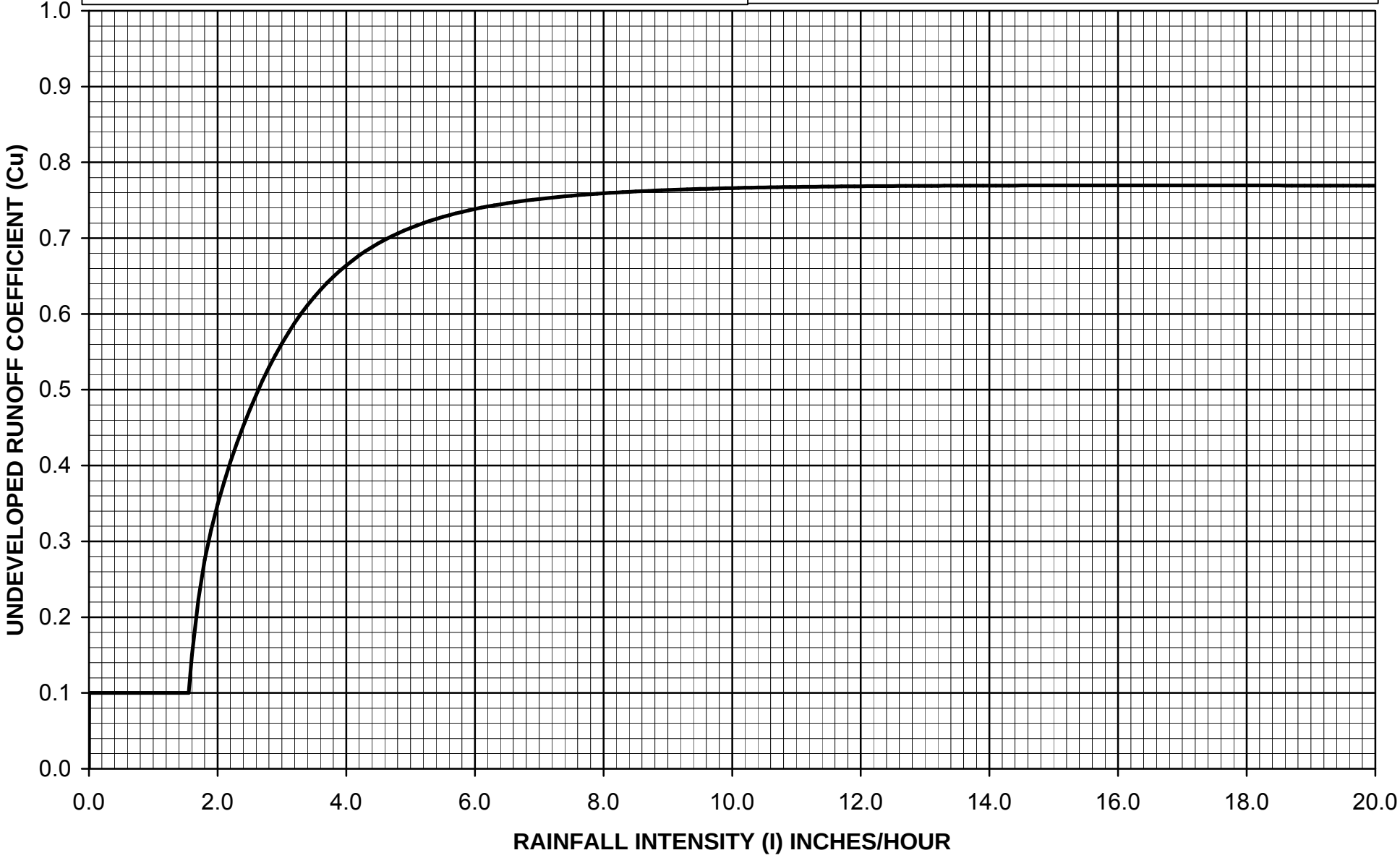


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 179

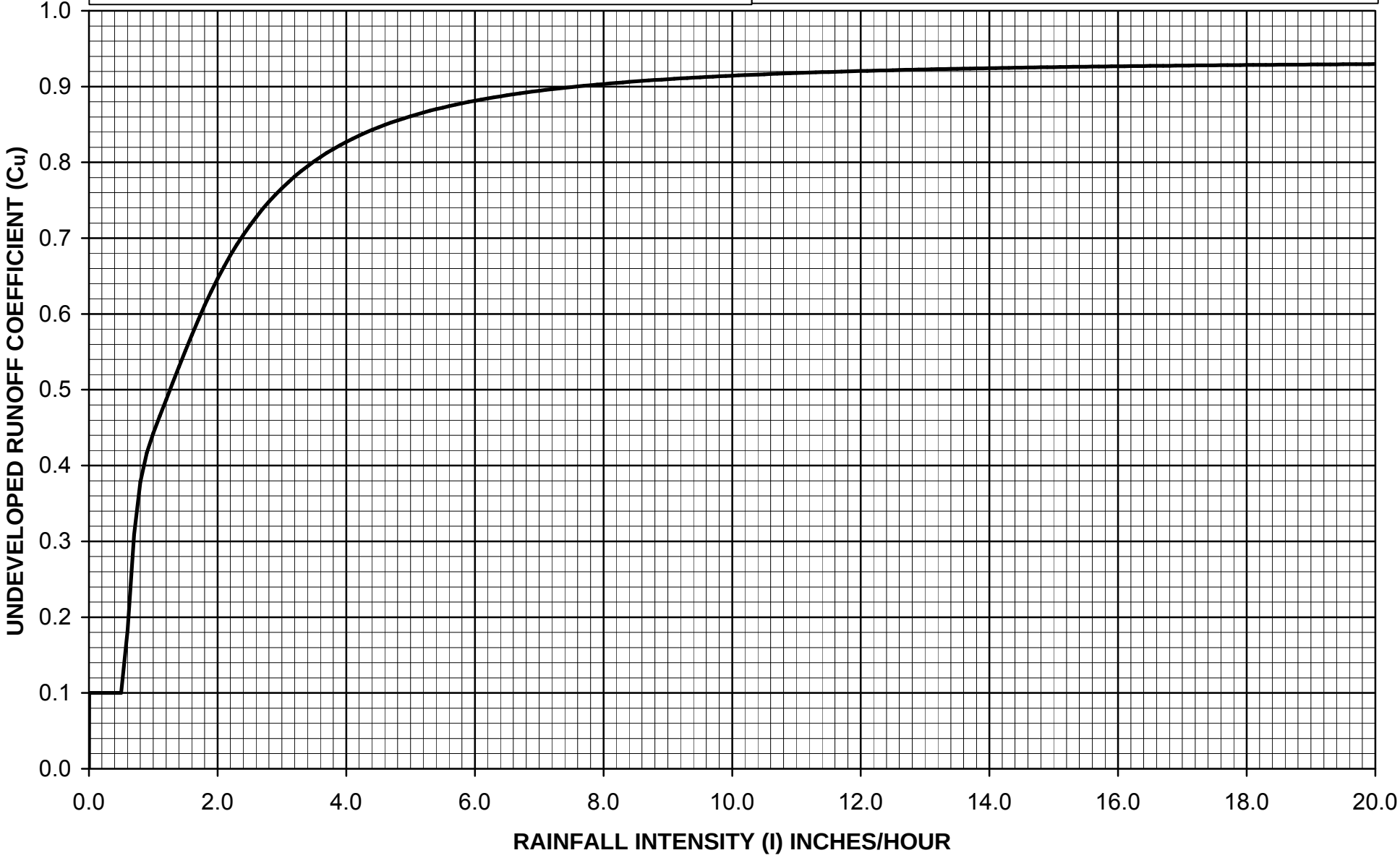


$C_D = (0.9 * IMP) + (1.0 - IMP) * C_U$

Where: C_D = Developed Runoff Coefficient
IMP = Proportion Impervious
C_U = Undeveloped runoff coefficient

Los Angeles County Department of Public Works

RUNOFF COEFFICIENT CURVE
SOIL TYPE NO. 180



APPENDIX D

Proportion Impervious Data

Proportion Impervious Data

Code	Land Use Description	% Impervious
1111	High-Density Single Family Residential	42
1112	Low-Density Single Family Residential	21
1121	Mixed Multi-Family Residential	74
1122	Duplexes, Triplexes and 2-or 3-Unit Condominiums and Townhouses	55
1123	Low-Rise Apartments, Condominiums, and Townhouses	86
1124	Medium-Rise Apartments and Condominiums	86
1125	High-Rise Apartments and Condominiums	90
1131	Trailer Parks and Mobile Home Courts, High-Density	91
1132	Mobile Home Courts and Subdivisions, Low-Density	42
1140	Mixed Residential	59
1151	Rural Residential, High-Density	15
1152	Rural Residential, Low-Density	10
1211	Low- and Medium-Rise Major Office Use	91
1212	High-Rise Major Office Use	91
1213	Skyscrapers	91
1221	Regional Shopping Center	95
1222	Retail Centers (Non-Strip With Contiguous Interconnected Off-Street	96
1223	Modern Strip Development	96
1224	Older Strip Development	97
1231	Commercial Storage	90
1232	Commercial Recreation	90
1233	Hotels and Motels	96
1234	Attended Pay Public Parking Facilities	91
1241	Government Offices	91
1242	Police and Sheriff Stations	91
1243	Fire Stations	91
1244	Major Medical Health Care Facilities	74
1245	Religious Facilities	82
1246	Other Public Facilities	91
1247	Non-Attended Public Parking Facilities	91
1251	Correctional Facilities	91
1252	Special Care Facilities	74
1253	Other Special Use Facilities	86
1261	Pre-Schools/Day Care Centers	68
1262	Elementary Schools	82
1263	Junior or Intermediate High Schools	82
1264	Senior High Schools	82
1265	Colleges and Universities	47
1266	Trade Schools and Professional Training Facilities	91
1271	Base (Built-up Area)	65
1271.01	Base High-Density Single Family Residential	42
1271.02	Base Duplexes, Triplexes and 2-or 3-Unit Condominiums and T	55

Code	Land Use Description	% Impervious
1271.03	Base Government Offices	91
1271.04	Base Fire Stations	91
1271.05	Base Non-Attended Public Parking Facilities	91
1271.06	Base Air Field	45
1271.07	Base Petroleum Refining and Processing	91
1271.08	Base Mineral Extraction - Oil and Gas	10
1271.09	Base Harbor Facilities	91
1271.10	Base Navigation Aids	47
1271.11	Base Developed Local Parks and Recreation	10
1271.12	Base Vacant Undifferentiated	1
1272	Vacant Area	2
1273	Air Field	45
1274	Former Base (Built-up Area)	65
1275	Former Base Vacant Area	2
1276	Former Base Air Field	91
1311	Manufacturing, Assembly, and Industrial Services	91
1312	Motion Picture and Television Studio Lots	82
1313	Packing Houses and Grain Elevators	96
1314	Research and Development	91
1321	Manufacturing	91
1322	Petroleum Refining and Processing	91
1323	Open Storage	66
1324	Major Metal Processing	91
1325	Chemical Processing	91
1331	Mineral Extraction - Other Than Oil and Gas	10
1332	Mineral Extraction - Oil and Gas	10
1340	Wholesaling and Warehousing	91
1411	Airports	91
1411.01	Airstrip	10
1412	Railroads	15
1412.01	Railroads-Attended Pay Public Parking Facilities	91
1412.02	Railroads-Non-Attended Public Parking Facilities	91
1412.03	Railroads-Manufacturing, Assembly, and Industrial Services	91
1412.04	Railroads-Petroleum Refining and Processing	91
1412.05	Railroads-Open Storage	66
1412.06	Railroads-Truck Terminals	91
1413	Freeways and Major Roads	91
1414	Park-and-Ride Lots	91
1415	Bus Terminals and Yards	91
1416	Truck Terminals	91
1417	Harbor Facilities	91
1418	Navigation Aids	47
1420	Communication Facilities	82
1420.01	Communication Facilities-Antenna	2

Code	Land Use Description	% Impervious
1431	Electrical Power Facilities	47
1431.01	Electrical Power Facilities-Powerlines (Urban)	2
1431.02	Electrical Power Facilities-Powerlines (Rural)	1
1432	Solid Waste Disposal Facilities	15
1433	Liquid Waste Disposal Facilities	96
1434	Water Storage Facilities	91
1435	Natural Gas and Petroleum Facilities	91
1435.01	Natural Gas and Petroleum Facilities-Manufacturing, Assembly, and In	91
1435.02	Natural Gas and Petroleum Facilities-Petroleum Refining and Processing	91
1435.03	Natural Gas and Petroleum Facilities-Mineral Extraction – Oil and Gas	10
1435.04	Natural Gas and Petroleum Facilities-Vacant Undifferentiated	1
1436	Water Transfer Facilities	96
1437	Improved Flood Waterways and Structures	100
1440	Maintenance Yards	91
1450	Mixed Transportation	90
1460	Mixed Transportation and Utility	91
1460.01	Mixed Utility and Transportation-Improved Flood Waterways and Structures	100
1460.02	Mixed Utility and Transportation-Railroads	15
1460.03	Mixed Utility and Transportation-Freeways and Major Roads	91
1500	Mixed Commercial and Industrial	91
1600	Mixed Urban	89
1700	Under Construction (Use appropriate value)	91
1810	Golf Courses	3
1821	Developed Local Parks and Recreation	10
1822	Undeveloped Local Parks and Recreation	2
1831	Developed Regional Parks and Recreation	2
1832	Undeveloped Regional Parks and Recreation	1
1840	Cemeteries	10
1850	Wildlife Preserves and Sanctuaries	2
1850.01	Wildlife-Commercial Recreation	90
1850.02	Wildlife-Other Special Use Facilities	86
1850.03	Wildlife-Developed Local Parks and Recreation	10
1860	Specimen Gardens and Arboreta	15
1870	Beach Parks	10
1880	Other Open Space and Recreation	10
2110	Irrigated Cropland and Improved Pasture Land	2
2120	Non-Irrigated Cropland and Improved Pasture Land	2
2200	Orchards and Vineyards	2
2300	Nurseries	15
2400	Dairy, Intensive Livestock, and Associated Facilities	42
2500	Poultry Operations	62
2600	Other Agriculture	42
2700	Horse Ranches	42

Code	Land Use Description	% Impervious
3100	Vacant Undifferentiated	1
3200	Abandoned Orchards and Vineyards	2
3300	Vacant With Limited Improvements (Use appropriate value)	42
3400	Beaches (Vacant)	1
4100	Water, Undifferentiated	100
4200	Harbor Water Facilities	100
4300	Marina Water Facilities	100
4400	Water Within a Military Installation	100