HEC HMS HYDROLOGICAL MODEL APPLICATION USING SCS CURVE NUMBER AND SOIL MOISTURE ACCOUNTING: CASE STUDY OF ALAŞEHİR BASIN

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ABSTRACT

HEC HMS HYDROLOGICAL MODEL APPLICATION USING SCS CURVE NUMBER AND SOIL MOISTURE ACCOUNTING: CASE STUDY OF ALAŞEHİR BASIN

Water is known as source of life throughout mankind's history. According to first records of written history; Sumerians and Akkadians used water for their inland transportation and irrigation systems. With first settlements, mankind's dependency to water has been increased and became one of the most substantial natural resource in our modern age. Importance of this resource even more solidifies when we consider its property of being limited. With realization of global climate change in early 19th century; treat to this limited resource has been revealed. Approximately 68% of the freshwater on earth reserved in glaciers and icecaps and 30% is reserved in groundwater systems according to United States Geological Survey's (USGS) studies. Owing to the quantity and less compromised to contaminants nature, majority of our freshwater needs met from groundwater. Although the importance of groundwater, its management have always been a challenge due to hard to quantify volumetric changings in aquifers. This study focused on creating a hydrological basin model to investigate volumetric recharge changings in groundwater system. Under scope of this study in an attempt to acquire groundwater recharge amounts; practicality of HEC-HMS hydrological modeling software has been investigated. A SCS Curve Number and Soil Moisture Accounting (SMA) loss methods has been chosen for HEC-HMS modeling application due to availability and accessibility of data that required for loss methods. After data collection from meteorological stations, core drill samples; both methods have been used in HEC-HMS simulation environment and their predictions have been compared. In the comparisons, it was determined that the SCS Curve Number method predicts higher flow potentials and groundwater infiltration amounts compared to the SMA method. Models foresee an average of 33.4 % of precipitation infiltrates into groundwater system.

ÖZET

SCS CURVE NUMBER VE SOIL MOISTURE ACCOUNTING YÖNTEMLERİYLE HEC-HMS HAVZA MODELLEMESİ: ALAŞEHİR HAVZASI ÖRNEĞİ

Su insanlık tarihi boyunca yaşamın kaynağı olarak bilinmiştir. Tarihin ilk yazılı kaynaklarına göre Sümerliler ve Akadlılar suyu ulaşım ve sulama amaçlı olarak kullanmışlardır. İlk yerleşim yerleriyle beraber insanoğlunun suya olan bağlılığı artıp modern çağın en önemli doğal kaynağı halini almıştır. Suyun sınırlı bir doğal kaynak olduğunu düşündüğümüzde bu önem dahada pekişmektedir. 19. yüzyılın başlarında küresel iklim değişikliğinin keşfi ile bu sınırlı doğal kayağa olan tehdit gözler önüne serilmiştir. Amerika Birleşik Devletleri Jeoloji Araştırmaları Kurumu'nun araştırmalarına göre dünya üzerindeki tatlı suyun yaklaşık %68'lik bir kısmı buzullarda ve buzul örtülerinde saklanmakta olup %30'luk bir kısmı yeraltı suyu sistemlerinde depolanmıştır. Miktarı ve dış kirleticilere daha az açık olması sebebiyle dünya tatlı su ihtiyacının büyük bölümünü yeraltı sularından karşılamaktadır. Yeraltı suyunun önemine karşın, yönetimi akifer içerisindeki hacimsel değişimlerin tespitindeki güçlükler sebebiyle oldukça zordur. Bu çalışma yeraltı suyuna olan girdisel değişikliklerin hidrolojik modelleme aracılığıyla tespitine odaklanmıştır. Çalışmada HEC-HMS hidrolojik modelleme yazılımının yeraltı suyu beslenim miktarlarının tespitinde uygulanabilirliği araştırılmıştır. Kayıp metotları için gerekli verilerin mevcudiyeti ve erişilebilirliği sebepleriyle SCS Eğri Numarası (Curve Number) ve Toprak Nem Hesabı (Soil Moisture Accounting, SMA) kayıp metotları HEC-HMS modelleme uygulaması için seçilmiştir. Meteoroloji istasyonlarından ve karot numenelerinden sağlanan verilerin yardımı ile HEC-HMS simülasyon ortamında modeler hazırlanmış ve tahminleri karşılaştırılmıştır. Yapılan karşılaştırmalarda SCS Eğri Numarası metodunun, SMA metoduna görece daha yüksek akış potansiyelleri ve yeraltı suyu beslenim miktarları öngördüğü tespit edilmiştir. Hazırlanan modeler senelik bazda ortalama % 33.4' lük bir yeraltı suyu beslenimi öngörmektedir.

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CHAPTER 1

INTRODUCTION

1.1. Groundwater Budget

In modern era managing natural resources in a way that ensures sustainability of that resources one of the most profound problem. Satisfying the demand without a sustainable plan can be volatile for natural resource in mostly high populated areas. This generalization is also valid for groundwater resources. According to the study of NASA in 2015, worldwide 21 aquifer out of 37 are under risk of depletion (Richey et al., 2015).

Beside risk of aquifers to be depleted pumping activities can be no longer viable due to high cost benefit ratio. Decline on water table, in time end up decreased water quality and unsustainable water circulation (Tsur & Zemel, 2004).

Another side of the problem is awareness of public. According to research 75% of European meets the drinking water needs from groundwater (European Commission, 2008). In USA it is estimated that 95% of the tap water need is met from groundwater in rural areas as well as half of the water used for livestock and irrigation (Todd, Tinlin, Schmidt, & Everett, 1976). However, the lack of public awareness on the subject is noteworthy compared to the surface waters. Source of the fact can be interpret as higher accessibility and visibility of surface waters, yields higher public awareness compare to groundwater (Boulton, 2005). Nevertheless, in recent years, studies on groundwater systems on the trend of increase and it is natural to expect that the awareness to the subject to be scale up.

Under these circumstances establishing an adequate groundwater management plan is vital for agricultural industry, human health care and urban society. On another hand management of total system requires constant monitoring and processing data which is appropriate task for computer aided models.

Groundwater monitoring activities around the world are generally carried out to monitor the quality or quantity of the resources. These activities require high amount of labor force, time and infrastructure. On another hand initial cost and constant maintenance requirement of monitoring devices comes with financial burden. These costs even expend with size of the designated area. Due to high scale of the problem modeling approach is sensible.

In most ideal condition total volume of the system should remain same through consecutive observation times. Volumetric changing in groundwater can be segregated two components as volumetric input and volumetric output.

- **Volumetric output**
  Amount of water withdrawn from aquifer and groundwater flow from aquifer to downstream as springs, artesian, or the water left aquifer volume. Outlet volume is dependent on aquifer properties like porosity and hydraulic conductivity of the vadose zone as well as withdrawn water for industrial and community use. Flow volume can be estimated by using aquifer parameters, but nonhomogeneous nature creates challenge. On the other hand, water withdrawal amounts dependent on accurate and consistent records which are hard to establish control over wells.

- **Volumetric input**
  Volumetric inputs consist of percolations from surface deposits like lakes and lagoons, streams and precipitation. Input estimations for lakes and lagoons can be done by investigating volume changings and for streams this calculation can be conducted over flow rate changings between upstream and downstream cross-sections. Input estimation from precipitation is highly dependent on soil types, urbanization and geo-morphology of the basin.

Due to high parameter dependency, obtaining volumetric input changings from precipitation is relatively difficult but for long term estimations and groundwater management this practice is significant. With using various of techniques groundwater recharge rates tried to be determined by researchers (Weight, 2011)(Scanlon & Cook, 2002)(Oteng Mensah, Alo, & Yidana, 2014). Creating a model that can investigate percolation to the groundwater system can access government organization and scientist to investigate and regulate withdrawal amounts from wells for granting sustainable groundwater aquifers.

1.2. Scope of Study

This study aimed to comprehend HEC-HMS can be a viable solution for determining groundwater volumetric inputs in Alaşehir Basin. Despite the groundwater monitoring systems, practicality of economically advantageous surface-based models have been investigated. SCS Curve Number and SMA methods are often used to produce flood hydrographs. Based upon determining groundwater recharge amounts, two distinct model with two different loss methods which is SCS Curve Number and SMA, has been created in HEC-HMS hydrological simulation program. Source data for models that presented in Chapter 3 has been obtained with support of TÜBİTAK.

1.3. Study Area

Alaşehir basin specifically selected for study due to involve high importance from aspect of agricultural product varieties (Karakuyu & Özçağlar, 2005). The study area Alaşehir sub-basin is a part of Gediz Basin which is one of the 25 basins in Turkey. Alaşehir sub-basin located in western part of Turkey and its area accounts for 15.8 % of the Gediz Basin (Figure 1.1.) Total area of Alaşehir sub-basin is 2710.5 km^2. There are 3 sub provinces (Salihli, Alaşehir and Sarıgöl) in the area with a total population of 297251. Majority of the irrigation tap water and industrial water consumption in this area supplied from groundwater system. Excessive water consumption in this area leads groundwater levels to be decreased and leaves residence of this area to be faced with water scarcity (Baba et al., 2011). Although the groundwater is a renewable water source excessive water withdrawal decreases the sustainability of the system. There are 3 cities located inside of the drainage area; Alaşehir, Salihli, Sarıgöl with population respectively 100254, 158568, 35966 according to census 2015. With including village populations total population of the study area is 320885. Economy of the area is highly dependent on agricultural and industrial activities.

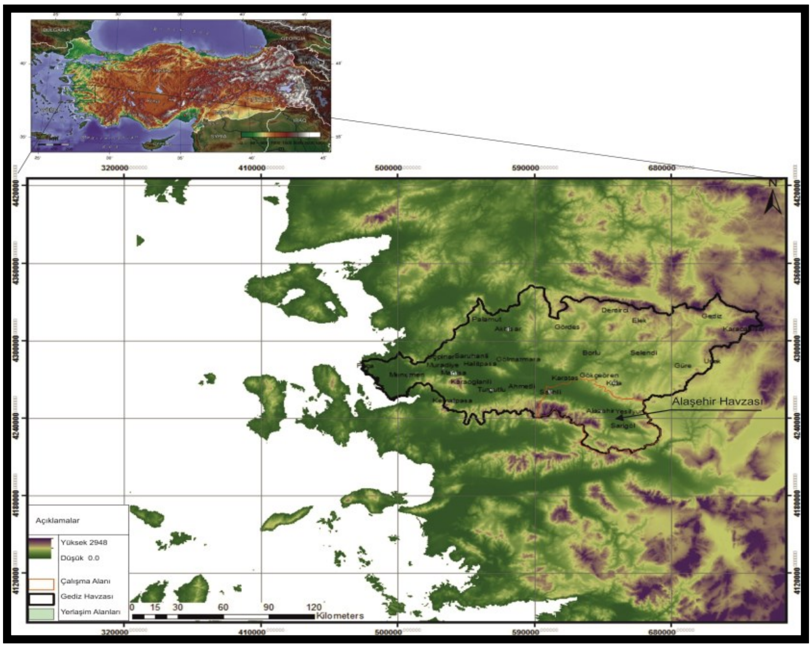


Figure 1.1 (Source: Şimşek et al., 2018)

Most important agricultural product that produced in the area is grape which is 60% of the raisin supply of the world met from Turkey and Aegean region is the prime area for this product. Alongside grape tobacco, cotton, corn, wheat and barley produces in the area. These products serve economical contribution to country through export and supports to stockbreeding sector. This economical and sectoral solidarity can only be achieved by sustainability of the water resources. Considering the share of groundwater used for drinking, irrigation, livestock and energy sector; sustainability of groundwater becomes more important. As well as groundwater potential of the area deep drilling reaches up to 3000 meters makes geothermal energy to available for the region (Tonkul, 2018). Consequently, Alaşehir Basin's contribution to multi sectorial development and economics of Turkey non-negligible.

1.4. Geological and Hydrological Properties of Study Area

Project site represents specification of graben structure, surrounded by mountains with elevations of up to 2155 m. Elevations in plain of the basin varies from 83 m to 90

m. Drainage of the basin can be observed in the southeast to northwest direction. The basement of the study area composed of gneiss, schist and marble of the Menderes metamorphic core complex. The hanging wall of the detachment fault comprises Miocene to Quaternary sedimentary units reaching up to 2500 m thickness (Baba & Sözbilir, 2012) (Şimşek et al., 2018). The Alasehir Plain is filled with Neogene sedimentary rocks that lie with unconformity over the Menderes metamorphic rocks. These series are composed of sandstone, conglomerate, claystone and limestone as well as volcanic layers (Seyitoğlu, Tekeli, Çemen, Şen, & Işık, 2002). Finally, the Quaternary-aged unconsolidated sediments cover these units with unconformity throughout the plain. This alluvial material mostly consists of clayey sands with gravel and thickness of these unconsolidated sediments reached up to 250 m. Karstic marbles of Menderes Massif is an aquifer of the geothermal systems in the study area. Impermeable Neogene terrestrial sediments, which are made up mainly of sandy and clayey conglomerates, are cap rocks of the geothermal systems in the region. An unconsolidated alluvial material is a good aquifer of the region.

1.5. Soil Profile

Vegetation and soil are the first layers where precipitation met with earth. Due to highly varying water retention and infiltration parameters among soil types; it is important to implement accurate soil information to model. For SCS Curve Number model instead of directly using soil information (maximum soil infiltration rate, soil storage); it uses curve number which contains topological and vegetative coverage information. Nevertheless, SMA model depended on soil storage and tension storage and maximum infiltration rates governed from soil types. According to generalized soil profile representation as it can be seen from Figure 3.6. soil layers consist of 4 main partition. Organic material content of the layers decreases from surface to deeper layers. Majority of the organic material are accumulated on “O”, “A”, “B” layers due to the being close to animal activity and plants root depth. Generally, when deeper layers investigated organic material content decreases drastically.

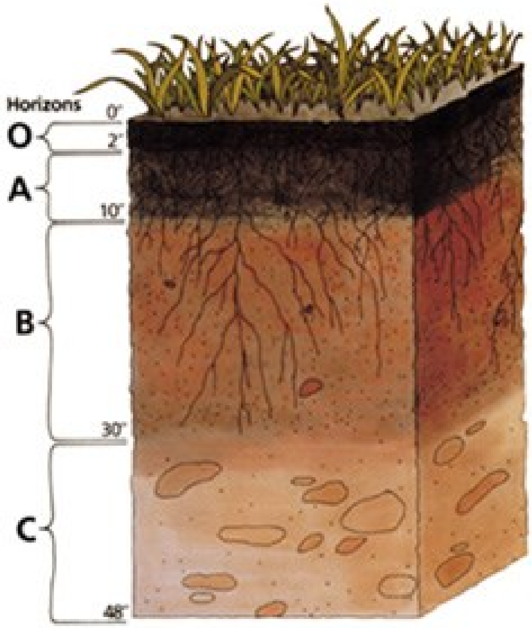


Figure 3.6 Generalized Soil Profile

(Source: Natural Resources Conservation Service, 2016)

According to research average tree root depths are not leading depth more than 2 m from soil surface (Dobson, 1995). But as a well-accepted by agricultural engineers, botanical activities commonly occur in 1.5 m depth from soil surface. As like as organic matter also soil grain sizes increases on the deeper level of soil profile. "C" commonly consists of degraded bedrock material, minerals and small amount of organic material.

Deeper layer than "C" loses specification of being soil and can be called as rocks and degraded versions of rocks. But this conception is not valid for alluvial zones. Thousands of years of accumulated alluvium can form dozens of layers of soil. Since alluvial layers are comprise of sedimentary particles; it's expected that grain sizes are small. On another hand, deep alluvial layers can also contain decent amount of carbon molecules due to being compromise to the atmosphere after being deposited. In other words, alluvial layers can hold specification of being soil even, tens of meters below soil surface.

Soil profiles are closely related with the soil water retention capabilities. Higher porosity with smaller particle size layer can retain significantly more water compare to coarse materials. More detailed information of alluvial zone on Alaşehir graben has been given in Chapter 3.

CHAPTER 2

METHODOLOGY

A surface hydrological model (Soil Moisture Accounting, SCS Curve Number, Green and Ampt) creates a relation between inputs (precipitation, source, etc.) and outputs (evapotranspiration, stream outlet, infiltration etc.). These relations usually require high number of parameters and at the same time accuracy of the models are dependent of these parameters. Decision of the suitable and applicable model for a certain area is dependent on number of data that available as well as time array of time variable data.

2.1. Loss Methods

Hec-HMS version 4.2. asks user to select one of 11 loss methods in total. Due to the accessibility and quality of data, SCS Curve Number and Soil Moisture Accounting loss methods have been selected for implementation.

2.1.1. SCS Curve Number Method

SCS Curve Number method is an event base method hence it largely used to generate flood hydrographs. SCS Curve Number method distinguishes with relatively less parameter requirement. Method developed by United States Department of Agriculture (USDA) under department of Soil Conservation Service (SCS) newly know as Natural Resource Conservation Service (NRCS). The aim of method is to achieve simple and accurate enough run-off rates corresponding to a given precipitation and soil data. Method has been established by USDA via thousands of infiltration test conducted in control basins (Woodward, 2002). As a result, an empirical relation between precipitation, soil storage, initial abstraction and run-off. Regardless of development purpose of the method; in this study soil infiltration rates have been observed for the use of interpret groundwater recharge. Soil storage and initial abstraction amounts as model parameters have been calculated as in Equation 2.1 and Equation 2.2.

$$S = \frac{1000}{CN} - 10 \quad (2.1)$$

$$I_a = 0.2S \quad (2.2)$$

S (Soil Storage): Total amount of water that can be stored in soil porous (in).
Ia (Initial Abstraction): Amount of abstracted water before runoff begins such as canopy interception and infiltration (in).

CN (Curve Number): Dimensionless parameter that originated from basin characteristics. Curve Numbers are determined by classifying the surface coverage, development condition and vegetation of the area as follows in Table A.1, Table A.2, Table A.3, Table A.4 and Table A.5 (USDA, 1986). As is understood from Equation 1 and Equation 2; increment on curve number results in decrement on soil storage and initial abstraction. Also this relation has been introducing by USDA in Figure 2.1. (USDA, 1986).

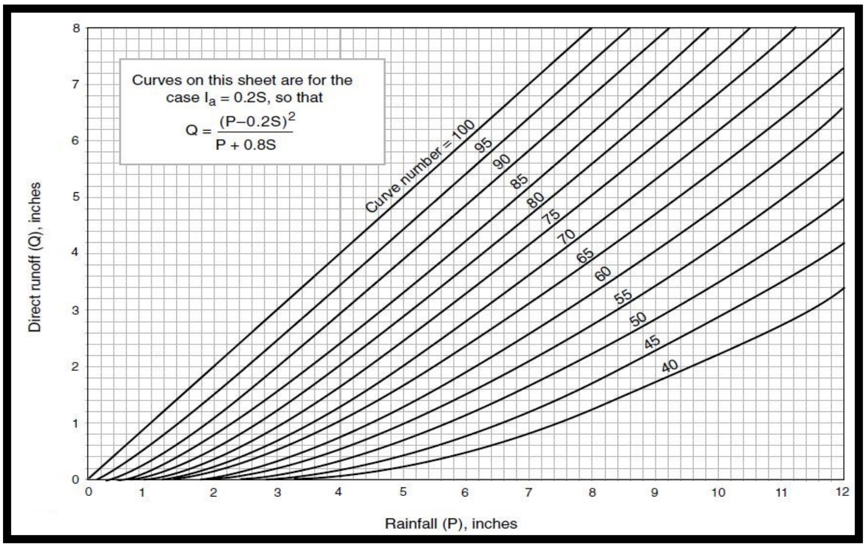


Figure 2.1. Rainfall run-off and curve number relation (Source: USDA, 1986)

Figure 2.1. represents the relation between P (Rainfall in inches) and Q (Runoff amount in inches) regarding to curve numbers from 40 to 100.

2.1.2. Soil Moisture Accounting (SMA)

Soil moisture is one of the most essential parts of hydrological cycle. It can affect total evapotranspiration rates over an area or directly can influence run-off process. Method in fundamental basis represents the basin budget balancing reduced to individual sub-basins. Compare to other methods canopy, surface, and soil designed as separated containers. This allows model to make their prediction more natural. Moisture levels calculated after every time step for each container allows model to create better prediction on successive rainfall events. Hence model is assumed to be more successful in continuous simulations. Despite increase in the use of the method in recent years, excess parameter requirement of the method can be interpreted as disadvantage. This method established by classifying soil groups in the area and applying SMA flow diagram to each sub-basin. Method uses hourly precipitation and potential evapotranspiration (PET) as input data. Method calculates amount of water retained in pores of soil layers for each time step. This characteristic allows model to determine retained water on succession of precipitation events thus SMA models are viable on continues hydrological models (USACE, 2000). SMA model fundamental execution principle can be seen on Figure 2.2. Model first calculates the amount of water accumulated on canopy coverage and decides that if the canopy storage is full filed or not. If the canopy storage full; precipitation starts to come in contact with soil surface. According to the soil types; each different type has specific soil infiltration rates determined as input data to the model. Model makes another decision on this point if precipitation rates are higher than maximum infiltration rate of the soil or lower. If precipitation rate is higher than soil maximum infiltration rate precipitation starts to fill surface storage (amount of the water required to accumulate over the surface before water starts to runoff.) of the land.

In the case of maximum infiltration rate of the soil higher than precipitation intensity, model controls the soil storage saturation. If soil upper layer (0.3 m depth form soil surface) is saturated excess water from precipitation contributes to fill surface storage (US Army Corps of Engineers, 2016). The amount of water that goes to percolation to groundwater is can be determined by calculating the difference between current soil storage and field capacity.

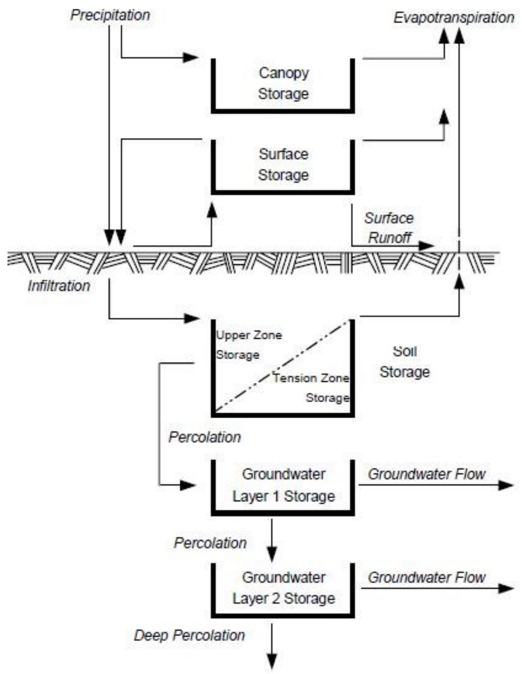


Figure 2.2. Conceptual Schematic of the Continues Soil Moisture Accounting Loss Method (Source: Bennett & Peters, 2000)

Maximum infiltration rates highly vary according to the soil texture as well as soil storage, tension storage and percolation rates. Gravels don't show soil characteristics; in many hydrological models, gravel fields are deem to be ignored.

CHAPTER 3

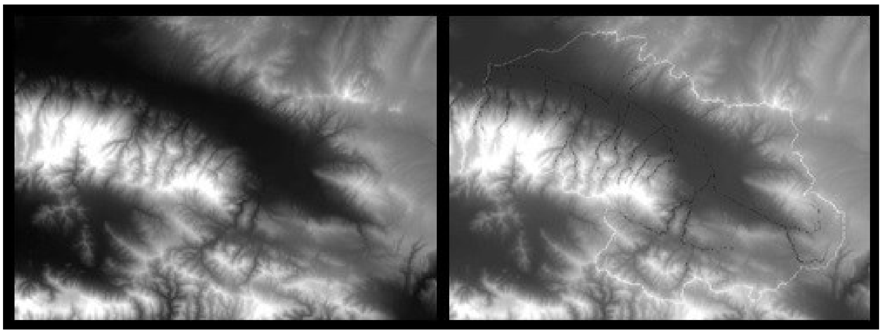
USED DATA

3.1. Geomorphologic Data

For this study geomorphologic variation of the field obtained from 30 m resolution digital elevation model (DEM) with geographic coordinate system (GIS) of ED_1950_UTM_Zone_35N. Geomorphologic data abstraction achieved by HEC-Geo HMS toolbar in ArcGIS mapping software. Some of important processes applied to DEM by HEC-Geo HMS toolbar as follows.

- Build Walls: Process physically manipulates DEM by increasing elevation of the basin boundaries. This process ensures that there is no precipitation participation to the basin from outside of the border. Reason of the applied process is uncertainty of elevation data in DEM. Issue widely discussed in literature regarding to vagueness of elevation information of DEM's (Wechsler, 2007).
- DEM Reconditioning: DEM manipulation techniques usually use bias-based interpolation. This cause lower elevation and small-scale morphologic variation to be hard to determent. Therefore, by this tool main drainage line polygon locations are deduced.
- Fill Sink: During creation of the map or during the mentioned operations up above there can be empty cells can occur. In order to fix the problem, Fill Sink operation uses interpolation techniques and creates smoother surface.
- Stream Definition: Stream definition is the process that represents the prediction that the amount of precipitation falling in an area will generate flow. Smaller predetermined areas generally results in more dendric drainage polygons.

Before and after using this two surface manipulation technique difference can be seen in Figure 3.1.a and Figure 3.1.b.



(a) (b)

Figure 3.1 (a) (Raw DEM), (b) (DEM after surface manipulations)

3.2. Precipitation and Temperature Data

Precipitation data has been gathered from 3 meteorology station placed in Alaşehir sub-basin and data distributed to nearby sub-basins (Figure 3.6). According to historical precipitation data collected from government organization meteorology stations; average precipitation of the area is 574.3 mm/year (Şimşek et al., 2018). Also, precipitation tends to decrease in recent years as it can be seen in Figure 3.2 Recordings of 3 precipitation gages that used as model input has been given in Figure 3.3 Figure 3.4 and Figure 3.5.

Averaged daily temperatures between 2014 and 2016 are given in Figure 3.2. According to historical data average temperature ranges from 13.5 C° to 17 C°. The highest temperature is recorded in July as 29 C° and the lowest temperature observed in January with 5.8 C°. Temperature data that has been used for Potential Evapotranspiration (PET) calculations collected from 3 meteorology stations (Figure 3.7, 3.8, 3.9).

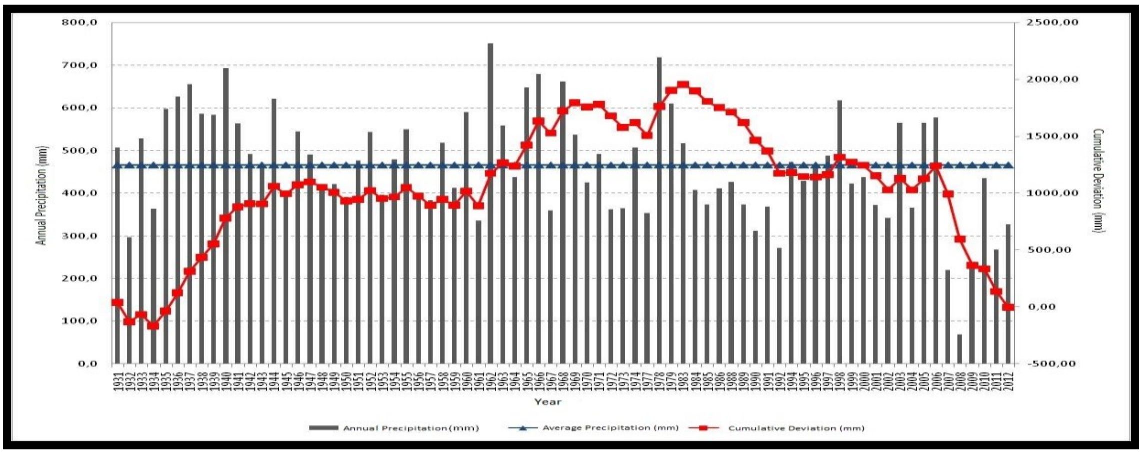


Figure 3.2 Long Term Precipitation Graphic

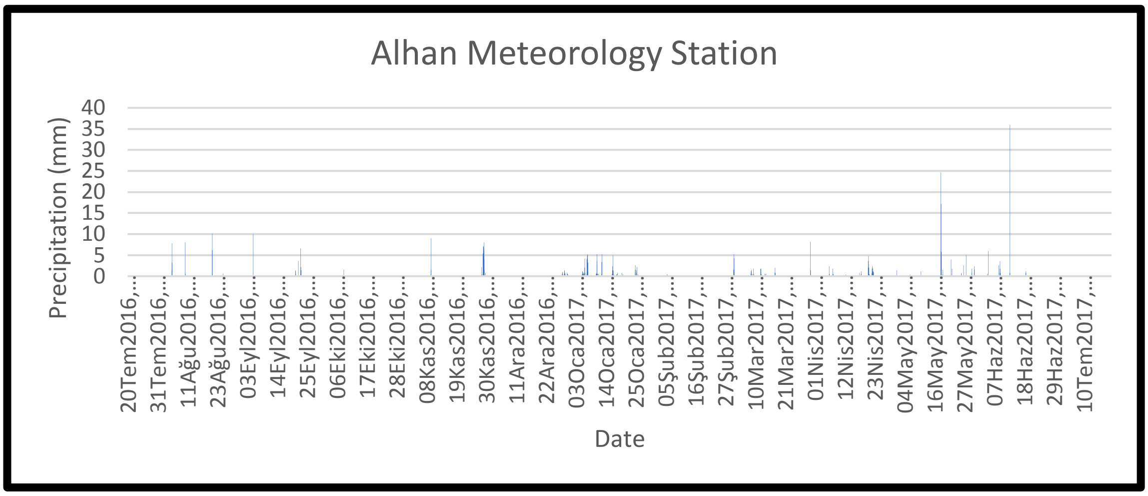


Figure 3.3 Precipitation data from Alhan Meteorology Station between July 2016 and July 2017

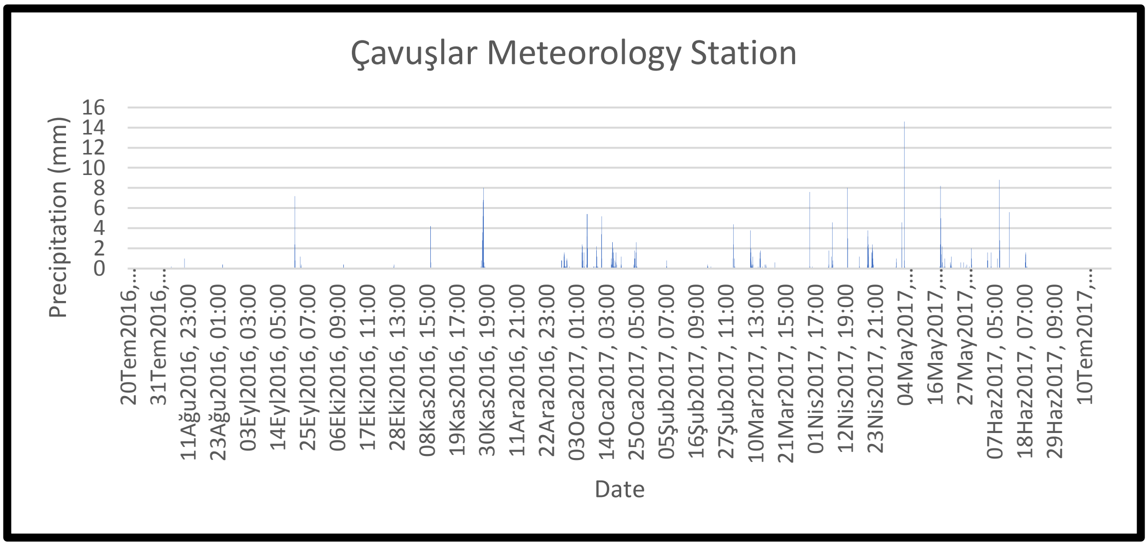


Figure 3.4 Precipitation data from Çavuşlar Meteorology Station between July 2016 and July 2017

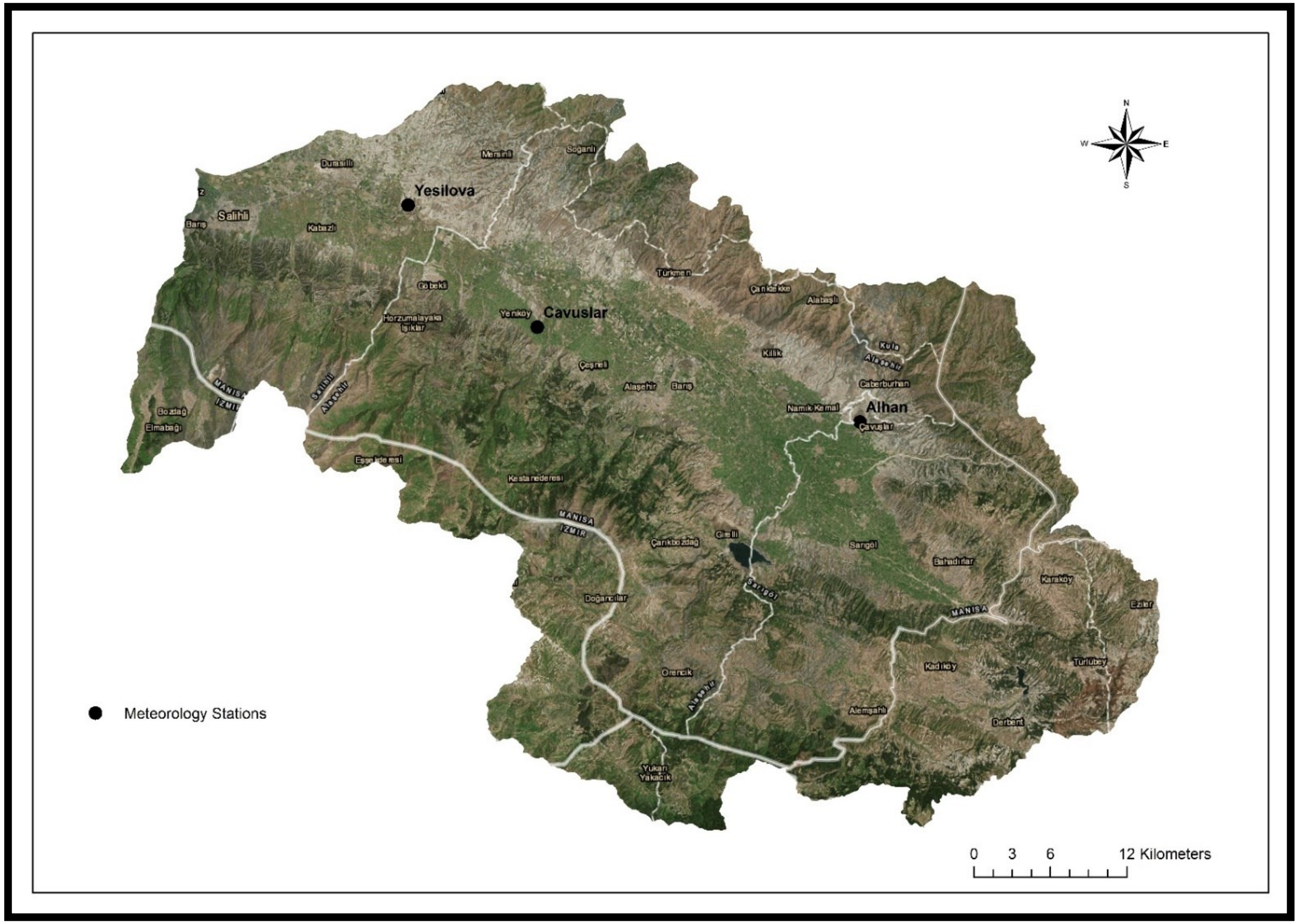


Figure 3.6 Meteorology stations and cities in Alaşehir Basin

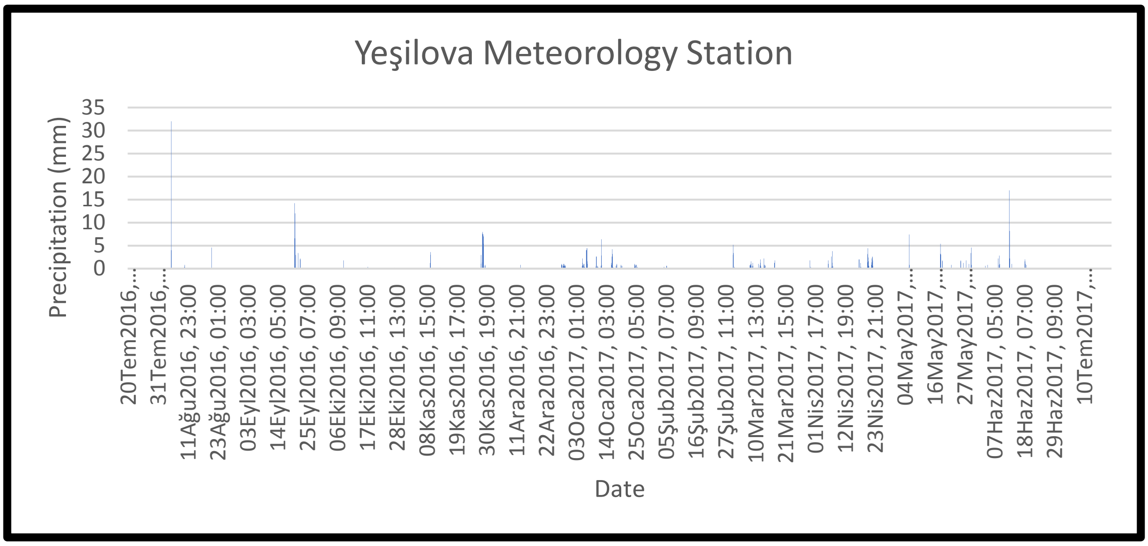


Figure 3.5 Precipitation data from Çavuşlar Meteorology Station between July 2016 and July 2017

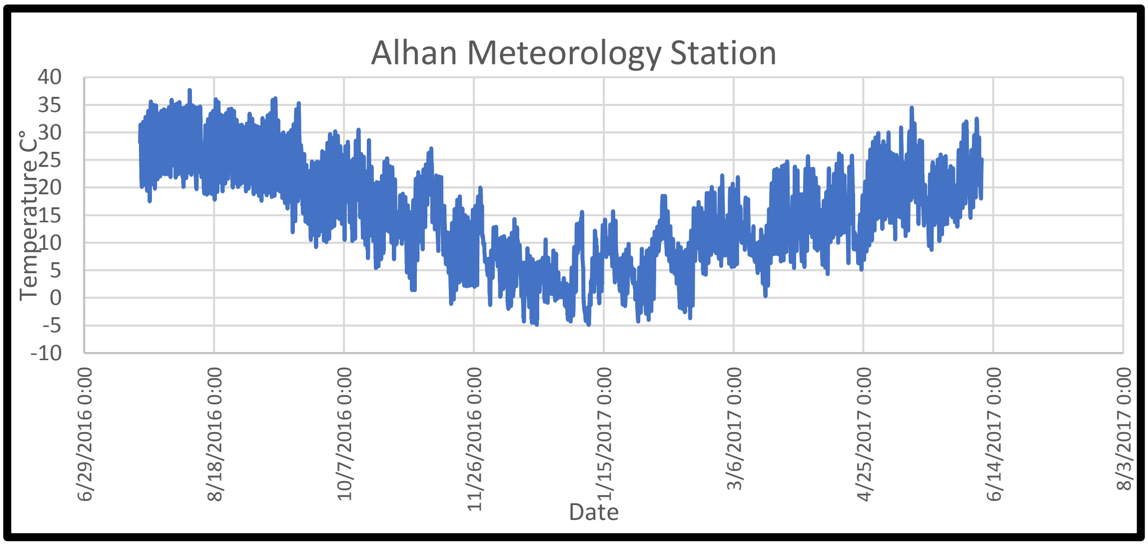


Figure 3.7 Alhan Meteorology Station, temperature recordings between July 2016 and July 2017

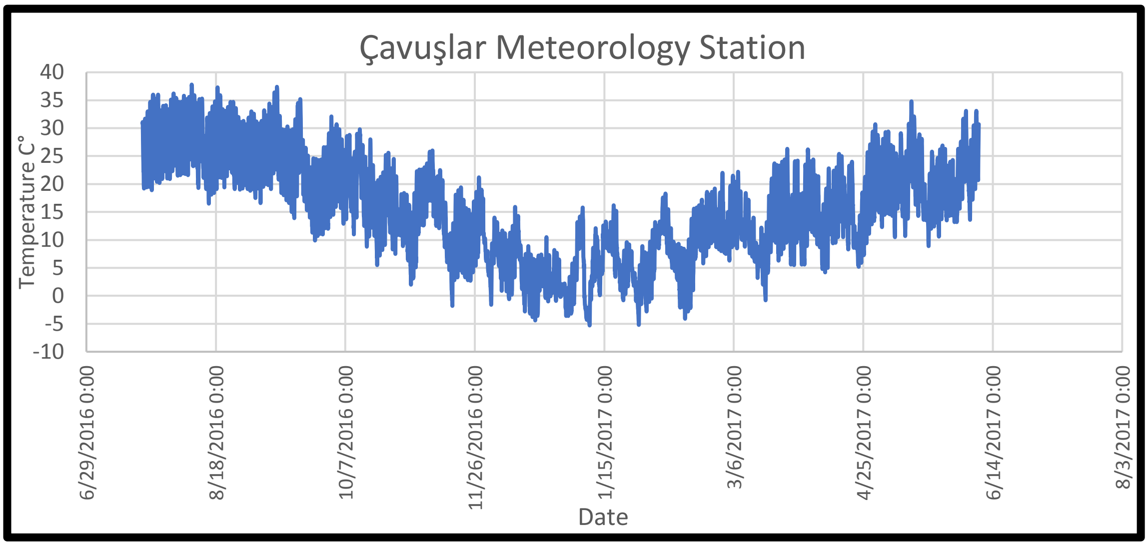


Figure 3.8 Çavuşlar Meteorology Station, temperature recordings between July 2016 and July 2017

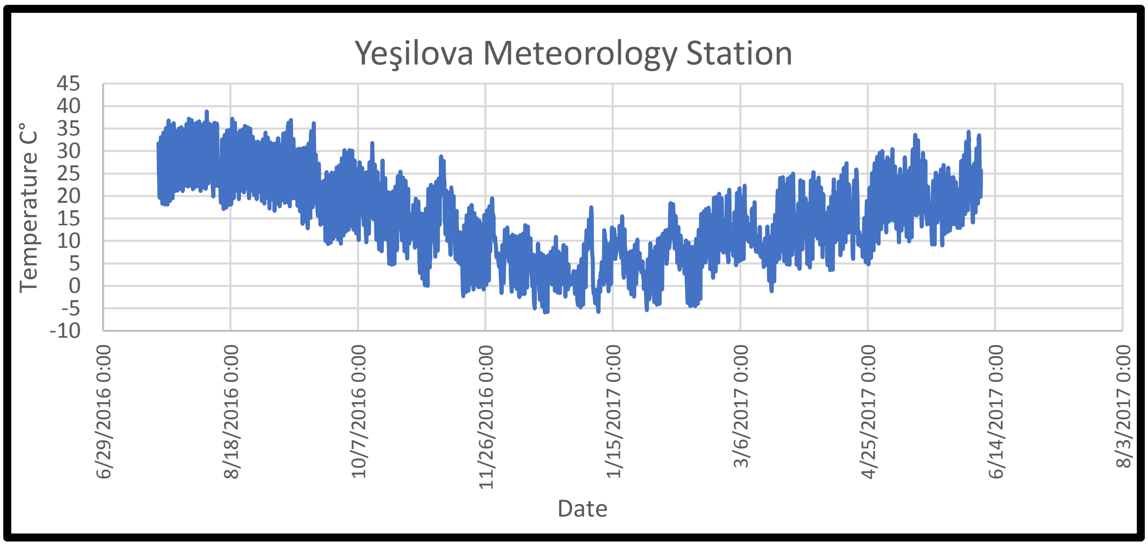


Figure 3.9 Çavuşlar Meteorology Station, temperature recordings between July 2016 and July 2017

3.3. Core Samples and Soil Information

In order to obtain more deeper knowledge about sub-agricultural soil layers and water retention capabilities; total 25 research well have been drilled in alluvial zone of the basin. Depth of the wells are ranges from 20 m to 50 m (Tonkul, 2018). Core samples gathered from drilling has been tested in the laboratory; porosity and soil classes according to unified soil classification determined. An example of laboratory result from research well no:14 has been given in Table 3.1 and Table 3.2.

Table 3.1 Laboratory results for Research Well No:14 for the range 1 m to 14 m

Research Well No 14. Laboratory Analysis Results (1m to 14m)						
Depth from (m)	Depth to (m)	Water Content (%)	Natural Density (g/cm3)	Specific Gravity	Porosity	Soil Class
1	1.5	31.23		2.65		CL
2	3	31.50		2.72		CL
4	4.5	33.21	1.84	2.73	0.49	CL
5.4	6	37.62	1.71	2.83	0.56	CL
7.1	7.5	37.55	1.81	2.71	0.51	CL
8.2	9	34.92	1.96			CL
10	10.5	39.60		2.90		CL
11	12	42.98	1.80			CL
14	15	33.07	1.74	2.67	0.51	SC

Table 3.2 Laboratory results for Research Well No:14 for the range 17 m to 50 m

Research Well No 14. Laboratory Analysis Results (17m to 50m)						
Depth from (m)	Depth to (m)	Water Content (%)	Natural Density (g/cm3)	Specific Gravity	Porosity	Soil Class
17	18	22.26		2.70		SC
20.1	21	41.17				SC
23	24	44.63				SC
26	27	28.94				CL
29.5	30	28.49	1.86	2.61	0.45	CL
32	33	22.10		2.89		GC
41	42	17.81				GC
42.5	43.5	35.27	1.91	2.72	0.48	CL
44	45	23.12	2.10	2.65	0.36	SC
45.5	46.5	20.23	2.05	2.67	0.36	SC
48.5	50	19.78	1.74	2.67	0.46	

As it can be seen from Table 3.1 and Table 3.2 porosity of layers ranges from 0.36 to 0.56 which indicates fine materials. Regardless from coarse material between 32 m and 42 m, majority of soil profile consist of clay and silty clay accumulated over top of each other, possibly for thousands of years. One can interpret saturated water content of each layer by using porosity in Equation 3.1.

$$n = \frac{V_v}{V_T} \tag{3.1}$$

n: Porosity

V_v(Volume of Void): Describes the total void volume between soil particles; including air and water volume.

V_T (Total Volume): Describes the total sample volume, including air, water and soil particles.

Saturated water content which equivalent of soil storage can be calculated by assuming all voids inside of soil sample full of water. By this means for 1 m of a layer with porosity of 0.36 should have soil storage of 0.36 m/m. In SMA model top identified soil layer storage for 0.3 m depth has been calculated in this manner. If the porosity of the first layer couldn't be determined average soil storage, field capacity, and infiltration rate for that specific soil class has been used.

CHAPTER 4

APPLICATIONS AND EVALUATIONS

4.1. Evapotranspiration

Evapotranspiration in general terms can be expressed as combination of evaporation (vapor removal from variety of surfaces and moisture from porous of soil) and transpiration (water removal from plants). Evapotranspiration highly dependent on air temperature and there is variety of different evapotranspiration measurement methods in literature (Rana & Katerji, 2000). In most cases due to lack of direct measured ET data, ET frequently obtained from potential evapotranspiration (PET) data. Evapotranspiration only occurs if there is water in environment. Hence hydrologic models compare the PET and available moisture to decide actual ET. In this study PET data calculated by using Thornthwaite Method that first introduced in 1984. Method requires relatively less parameters but as it shown in several studies it also creates spatially less accurate predictions. Thornthwaite Method requires average monthly temperatures and hours of sunshine in order to predict PET data. Average monthly temperature data collected from meteorology stations in basin (Figure 4.1).

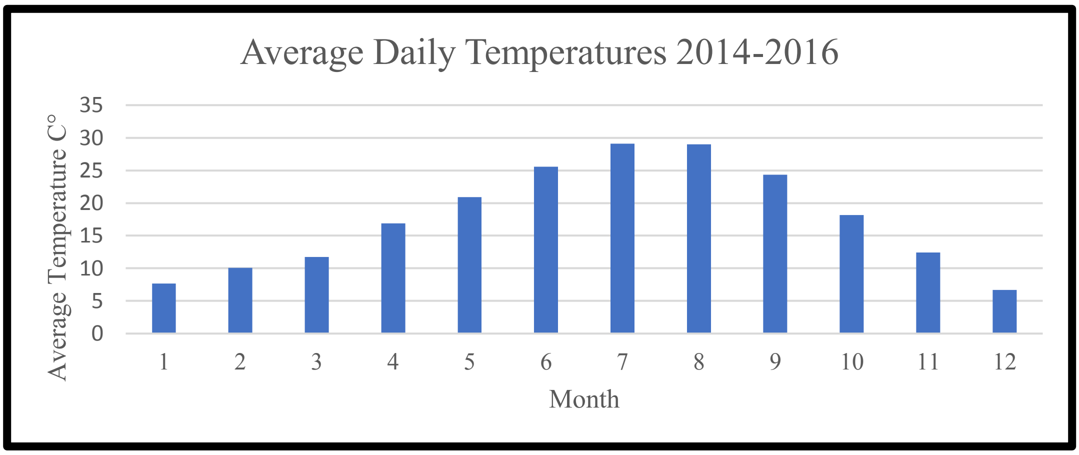


Figure 4.1. Average Monthly Temperatures

Table 4.1 Thornthwaite Method PET Prediction

Thornthwaite Method PET Prediction					
Month	Average Temperature C° (t)	Heat Index (i)	PET Raw (mm/month)	Hours of sunshine (hour)	PET (mm/month)
January	6.8	1.6	9.04	4.6	3.583
February	12.7	4.1	31.28	5.45	14.206
March	12.6	4.0	30.66	6.57	17.343
April	19.4	7.8	72.60	7.62	46.104
May	20.8	8.7	83.28	9.49	68.057
June	28.0	13.5	149.84	11.32	141.350
July	29.2	14.5	163.75	11.77	165.962
August	28.8	14.2	159.26	11.06	151.682
September	23.9	10.7	109.43	9.26	84.443
October	17.9	6.9	62.03	7.11	37.977
November	11.9	3.7	27.72	5.22	12.059
December	4.3	0.8	3.65	3.94	1.238
	Total Heat Index (I)	90.5			

$$i=\left(\frac{t}{5}\right)^{1.514} \qquad (4.1)$$

By using average monthly temperatures Heat Index per month has been calculated. This data has been used for determining annual heat index and PetRaw calculations.

$$a = 675 \times 10^{-9} \times I^3 - 771 \times 10^{-7} \times I^2 + 1792 \times 10^{-5} \times I + 0.49239 \qquad (4.2)$$

According to study of Thornthwaite there is no direct relation between average temperatures and potential evapotranspiration, especially in cold climates. In order to overcome this problem study presents “a coefficient” and “heat index”. Relation between alpha coefficient and heat index can be seen in Equation 4.2. By this empirical formula Thornthwaite achieved to converge PET for both cold and warm climates (Thornthwaite, 1948).

$$PETraw = 16 \times \left(\frac{10 \times t}{I}\right)^{a} \qquad (4.3)$$

PET raw data has been calculated by using annual heat index, alpha coefficient and mean monthly temperature for each month.

$$PET = PETraw \times \frac{N}{12} \times \frac{d}{30} \tag{4.4}$$

Pet raw data has been adjusted according to hours of sunshine which obtained from Government Meteorology Organization data for Manisa province and days of month.

t (C°): Average daily temperature parameter refers to average temperature that observed in a day for a specific month which calculated from Alaşehir meteorology station.

i: Heat index

I: Total heat index

a: Correction coefficient

N: hours of sunshine

d: days of month

Heat index and Raw PET data has been calculated by using monthly average temperature data with Equation 4.1. Raw PET data has been calculated by using Equation 4.3, average monthly temperatures and total heat index. Finally, PET data calculated with Equation 4.4 by using hours of sunshine and day amount in month. Monthly PET values can be seen in Figure 4.2. As pointed out in the work of Thornthwaite; pet data are arranged with hours of sunshine. It can be seen from Figure 4.2; adjusted PET data varies from 0 to just over 150 mm. Heat index values are represented in Figure 4.3.

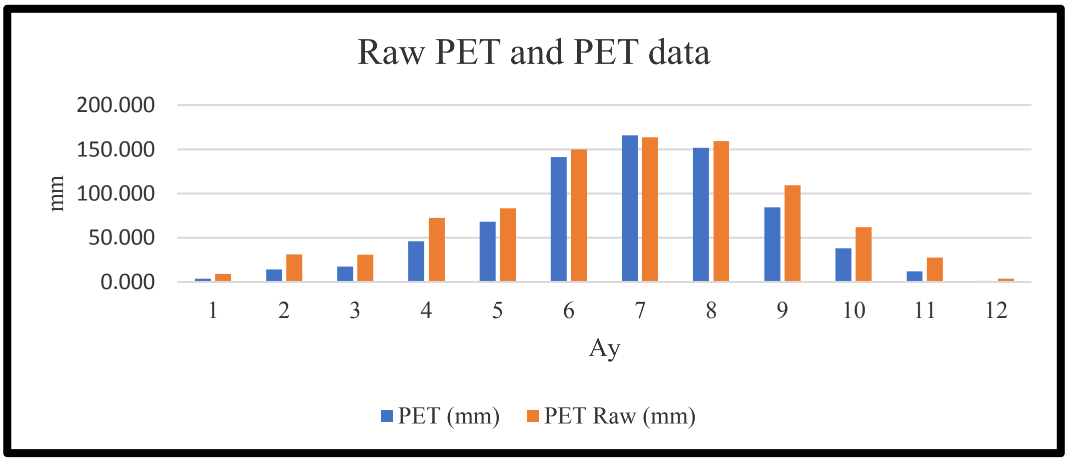


Figure 4.2. Raw PET and Pet data

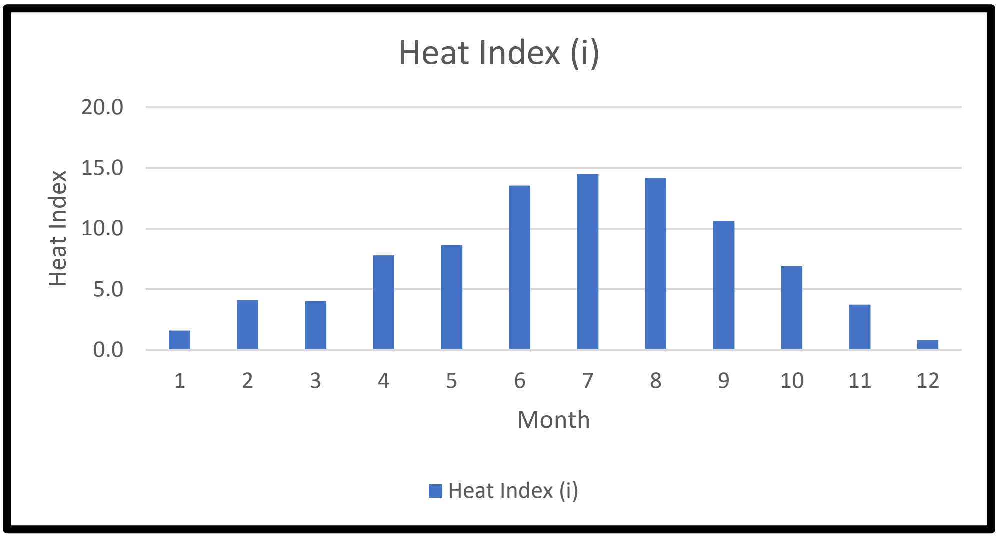


Figure 4.3 Heat Index data according to month of the year

4.2. Impervious Surface

Impervious surfaces one of the most influential parameter for urban area. As it stated on Chapter 1. there is 3 sub-province, industrial facilities and agricultural sites in the study area. For both SCS Curve Number and SMA models investigate the percentage of impervious surface ratio for each sub-basin before precipitation and soil or canopy interaction. Amount of precipitation regarding to the impervious surface percentage of the area, directly be calculated as run-off for both models. In an effort to identify impervious surfaces; Open Street Map (OSM) addon in ArcGIS program has been used. Data that gathered from OSM database distributed over study area and classified according to zoning types. Total land use data for both models are given in Table A.9 and Table A.10. Area coverage of industrial facilities, residential area, roads and concrete covered surfaces counted as impervious areas. By making an assumption of all road coverage extent as 10 m and calculated the surface areas respectively. All data congregate as in Table A.5, Table A.6, Table A.7 and Table A.8. Total impervious surface percentages achieved as it can be seen in Figure 4.4 and Figure 4.5. As it can be clearly seen from Figure 4.4 Figure 4.5 impervious surface percentages are relatively high on urban areas.

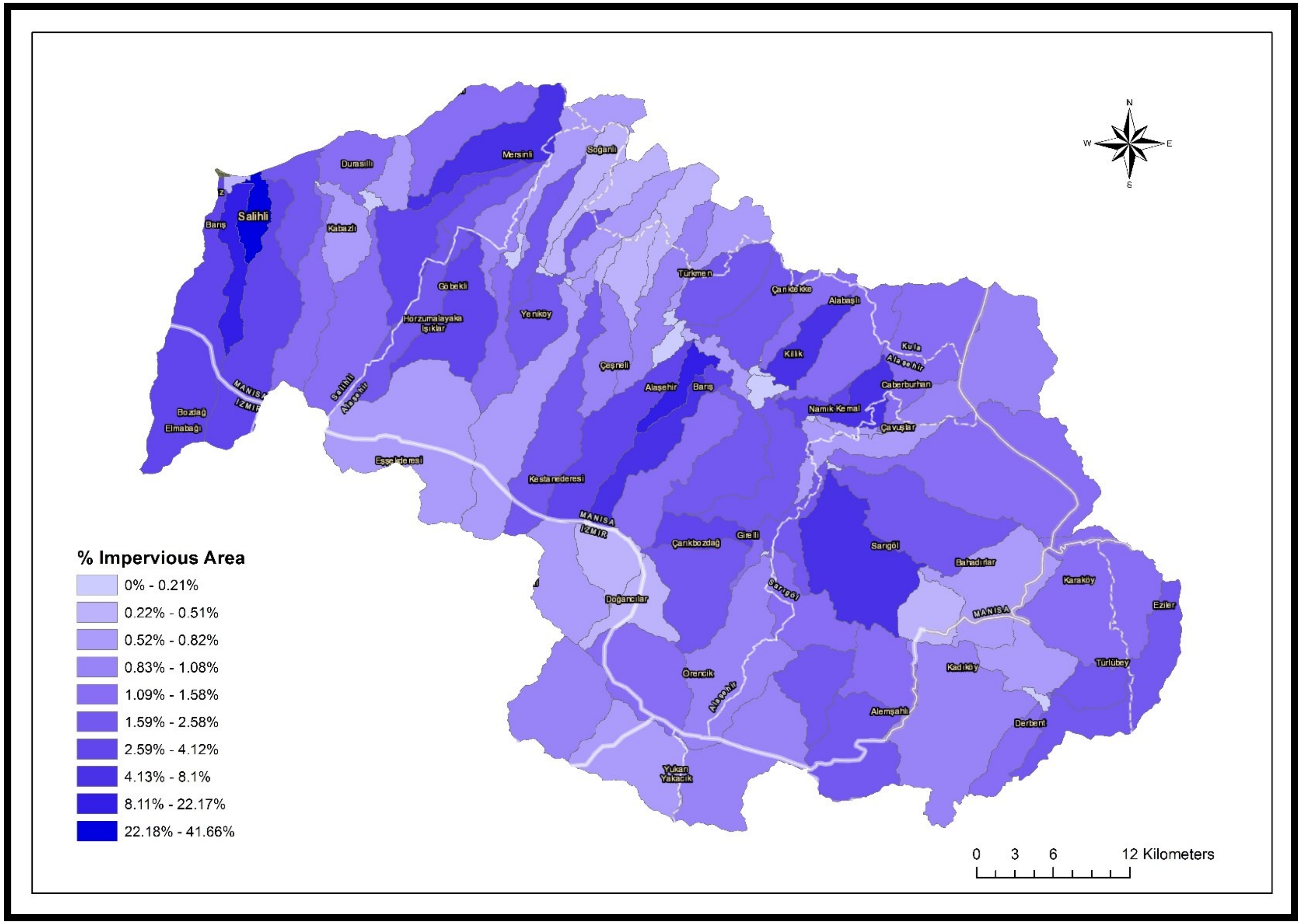


Figure 4.4 SCS Curve Number Model Impervious area percentages

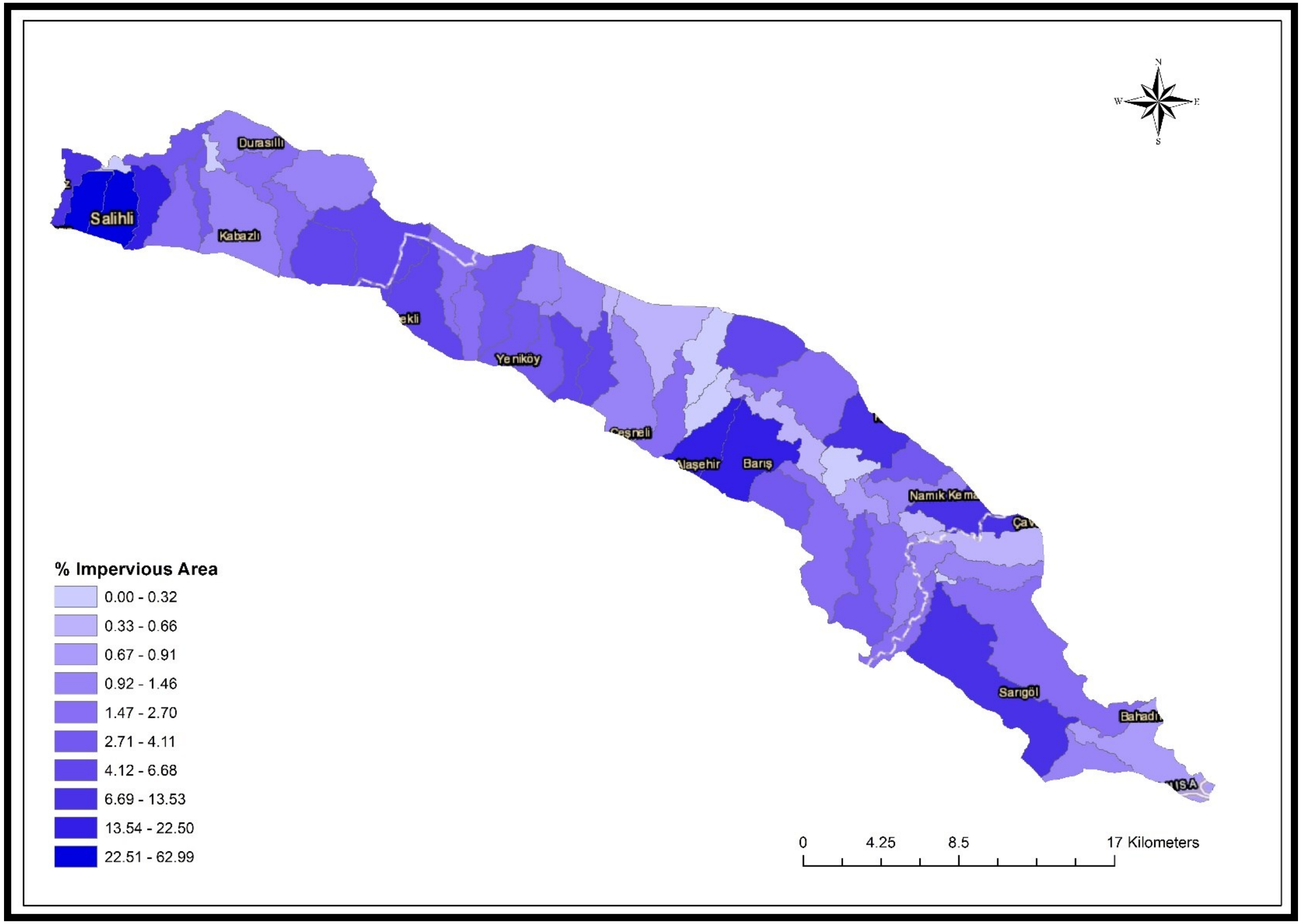


Figure 4.5 SCS Curve Number Model Impervious area percentage

4.3. Surface Storage

Surface deposition can be expressed as “amount of water that should be accumulate before runoff starts” (US Army Corps of Engineers, 2016). Field studies on the subject by Bennet on 1998 brought result of a relation between surface deposition amounts and surface slop as it can be seen in Table 4.2.

Table 4.2 Relation between surface slop and surface deposition (Source: Bennett, 1998)

Description	Slope %	Surface Storage (mm)		
		Min.	Ave.	Max.
Paved impervious	-	3.2	4.8	6.4
Steep	>30		1	
Moderate to gentle	5-30	6.4	9.55	12.7
Flat, furrow	0-5		50.8	

Average surface slopes have been calculated for each sub-basin from ArcGIS. By using relation from Table 4.2 and impervious surface percentages that calculated at sub-section 4.2 and average sub-basin slopes in Figure 4.6 and Figure 4.7 surface deposition amounts have been calculated. As it can be clearly seen from Figure 4.6, Figure 4.7, Figure 4.8 and Figure 4.9, milder slopes correspond to higher surface deposition amounts. From this perspective SMA model which is focused on alluvial zone located in the central of basin has higher surface storage amounts. From another perspective higher surface storage amounts corresponds to higher total infiltration outputs on models. The reason for this; precipitation that accumulate on the surface of the soil amount is high and this water will contribute to soil infiltration longer even after precipitation event ended. As it mentioned in the conclusion section, SMA model covering the alluvial zone; shows lower run-off potential than the SCS Curve Number model. This prediction is mostly resulting of marginal average slop differences between landscapes of two model and has been further discussed in conclusion section. Another component that drains surface deposition is evaporation from surface. Evapotranspiration from soil and evaporation from surface deposition combined corresponds to total evapotranspiration.

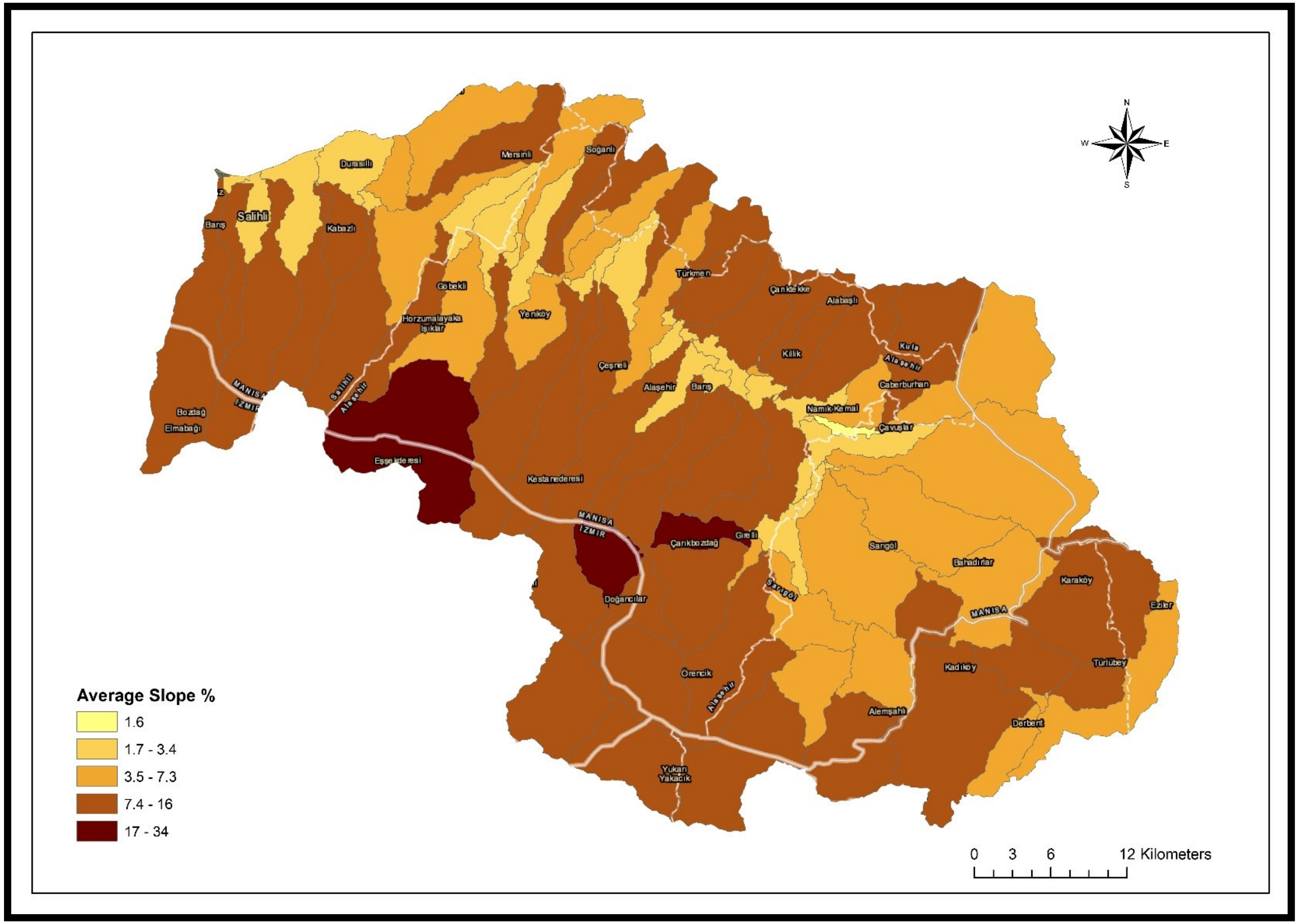


Figure 4.6 Average slopes of sub-basins SCS Curve Number model

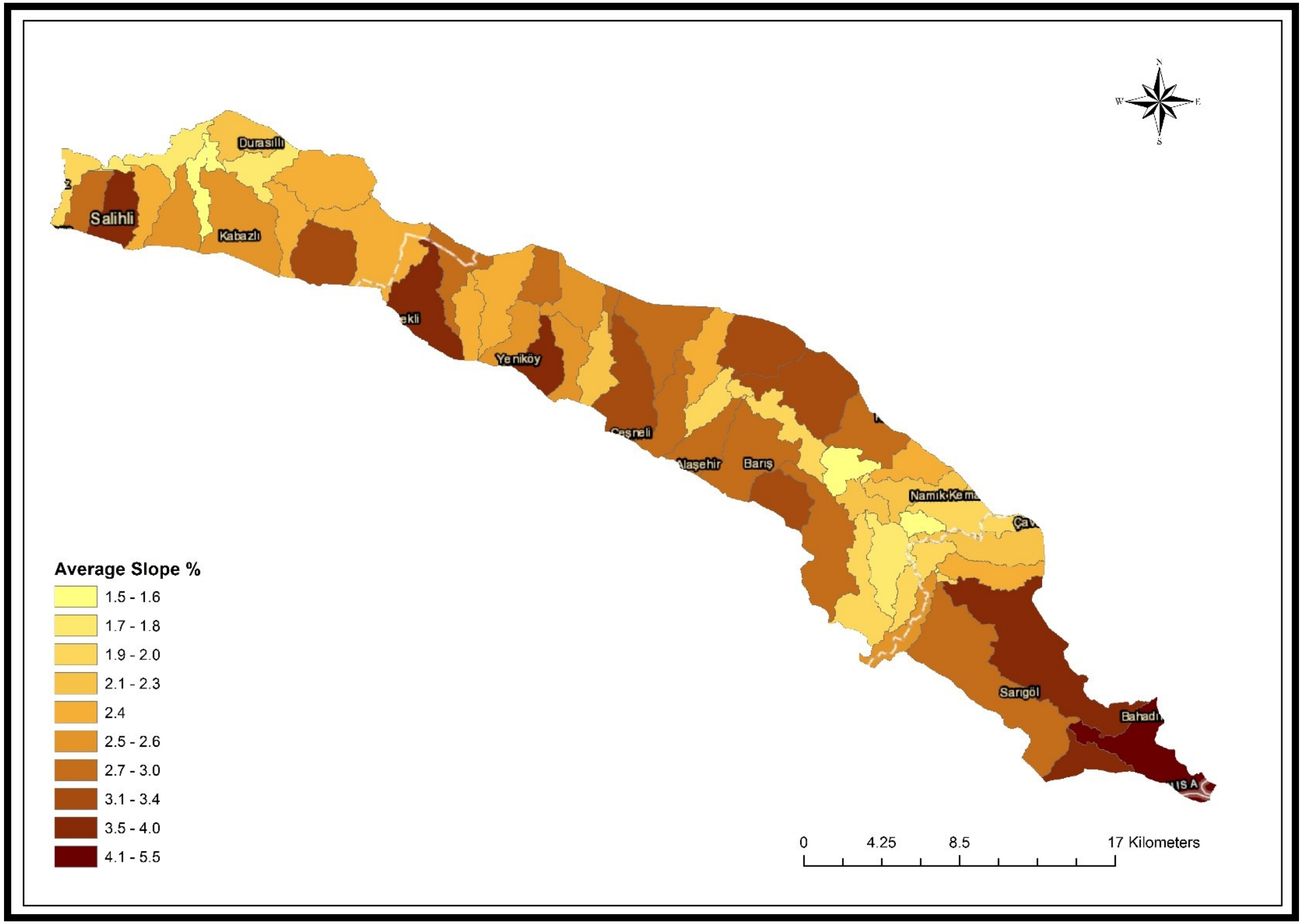


Figure 4.7 Average slopes of sub-basins SMA model

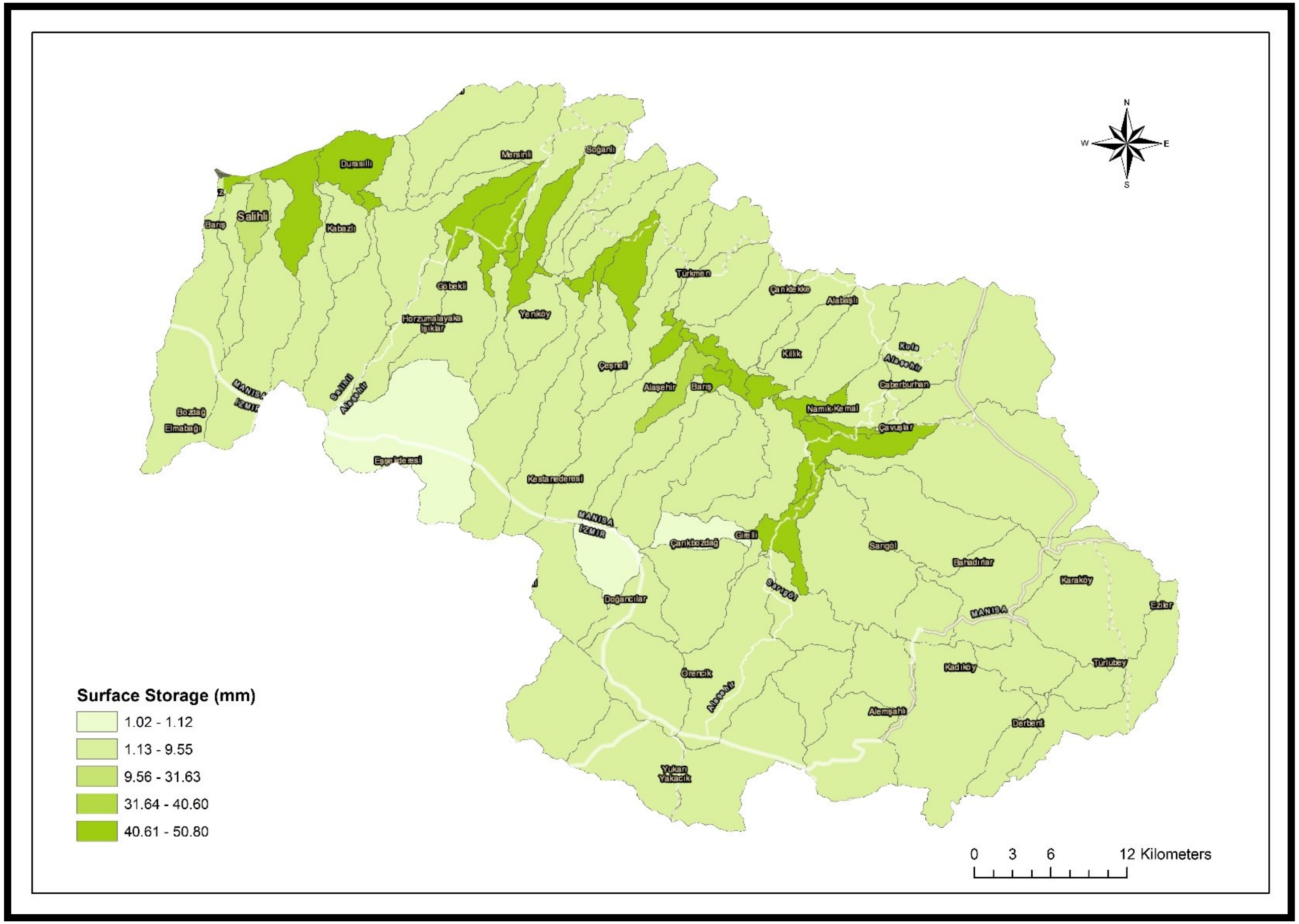


Figure 4.8 Surface storage of sub-basins SCS Curve Number model

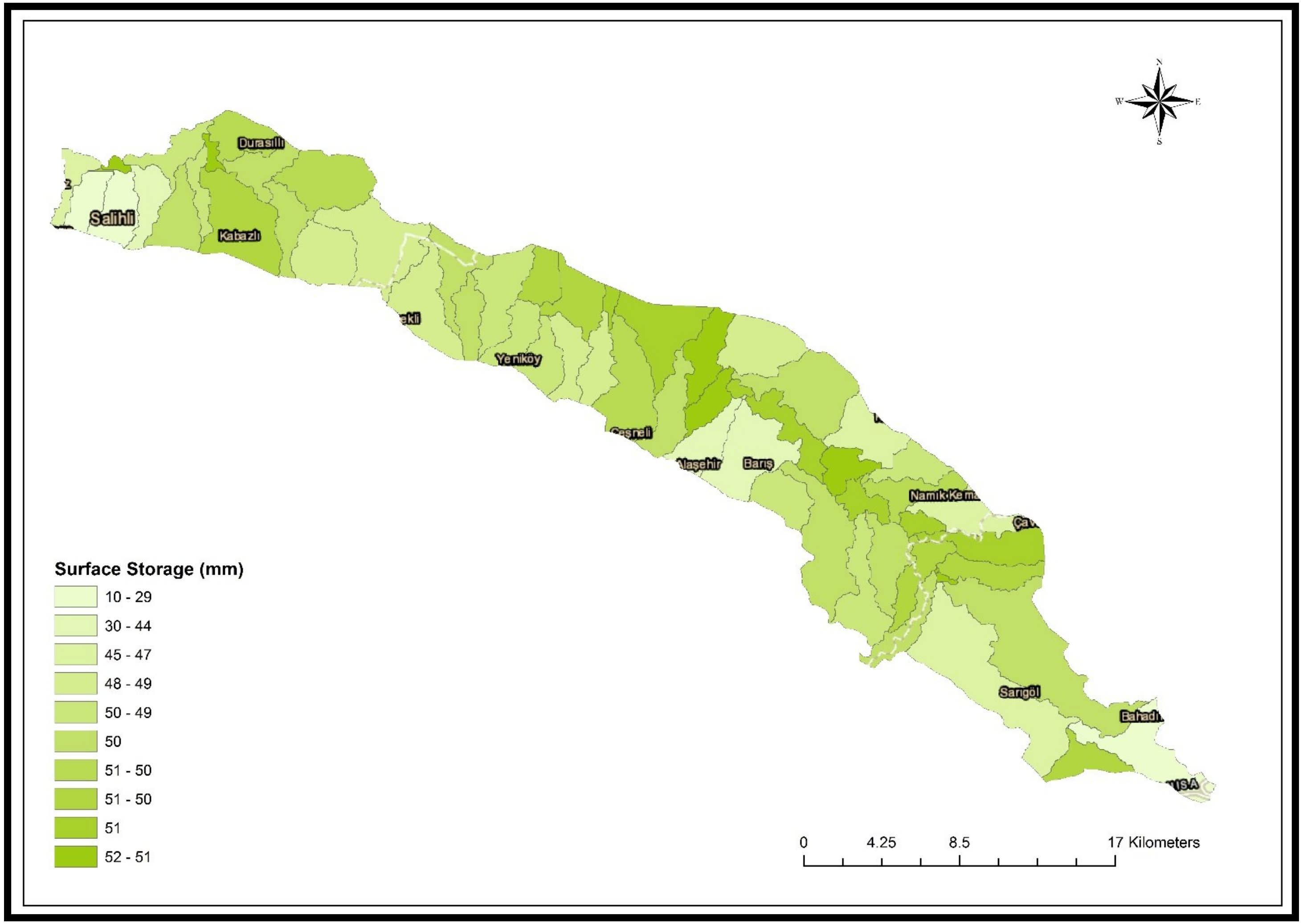


Figure 4.9 Surface storage for SMA model

4.4. Curve Number Distribution Soil Storage and Infiltration Rate

Water retention is a substantial parameter for both models. Amount of water that soil can capable to store in their pores determined by this parameter. SCS Curve number method calculates this information as mentioned in subsection 2.1.1. Towards establishing curve number distribution to the sub-basins, data that constituted from previous studies on the area has been used. Distribution has been done by weighting hydrological soil groups according to the portion of the area they covered for each sub-basin and this method also been mentioned in USDA SCS Curve Number manual (USDA, 1986). Example of curve number distribution has been given in Table 4.3. For all 100 sub-basins CN calculated in this manner and average CN value of sub-basins represented in Figure 4.10. Soil storage amounts for CN model has been calculated respect to weighted CN values and presented in Figure 4.11. Detailed calculation charts are given in Table A.11.

Table 4.3 Weighted curve number distribution (Source: USDA, 1986)

Project Heavenly Acres	By WJR	Date 10/1/85
Location Dyer County, Tennessee	Checked NM	Date 10/3/85

Check one: [X] Present [ ] Developed

1. Runoff curve number

Soil name and hydrologic group (appendix A)	Cover description (cover type, treatment, and hydrologic condition; percent impervious; unconnected/connected impervious area ratio)	CN 1/ Table 2-2	CN 1/ Figure 2-3	CN 1/ Figure 2-4	Area ☐acres ☐mi2 ☒%	Product of CN x area
Memphis, B	Pasture, good condition	61			30	1830
Loring, C	Pasture, good condition	74			70	5180
				Totals	100	7010

1/ Use only one CN source per line

CN (weighted) = $\frac{\text{total product}}{\text{total area}} = \frac{7010}{100} = 70.1$; Use CN 70

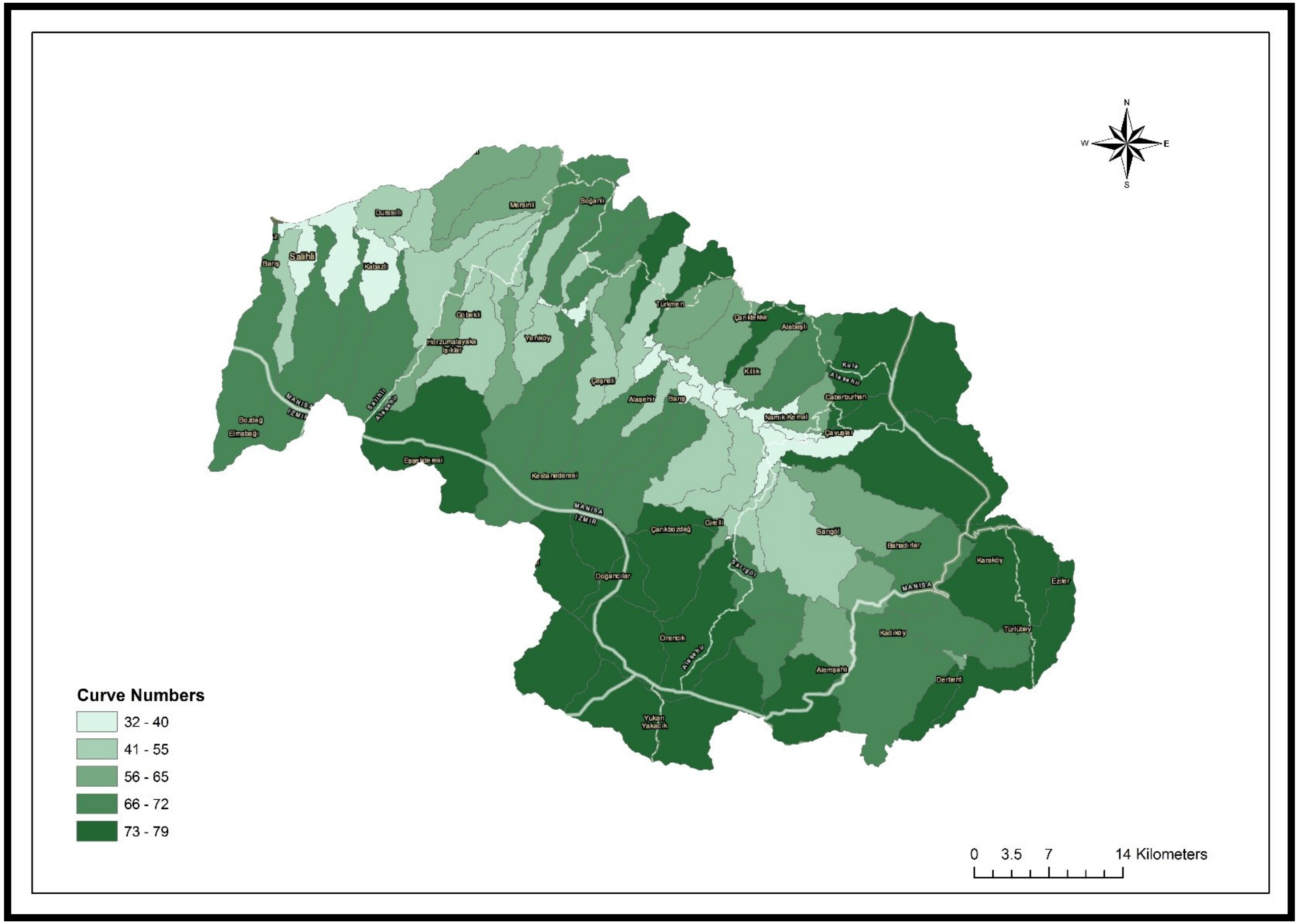


Figure 4.10 Weighted CN distribution over watershed

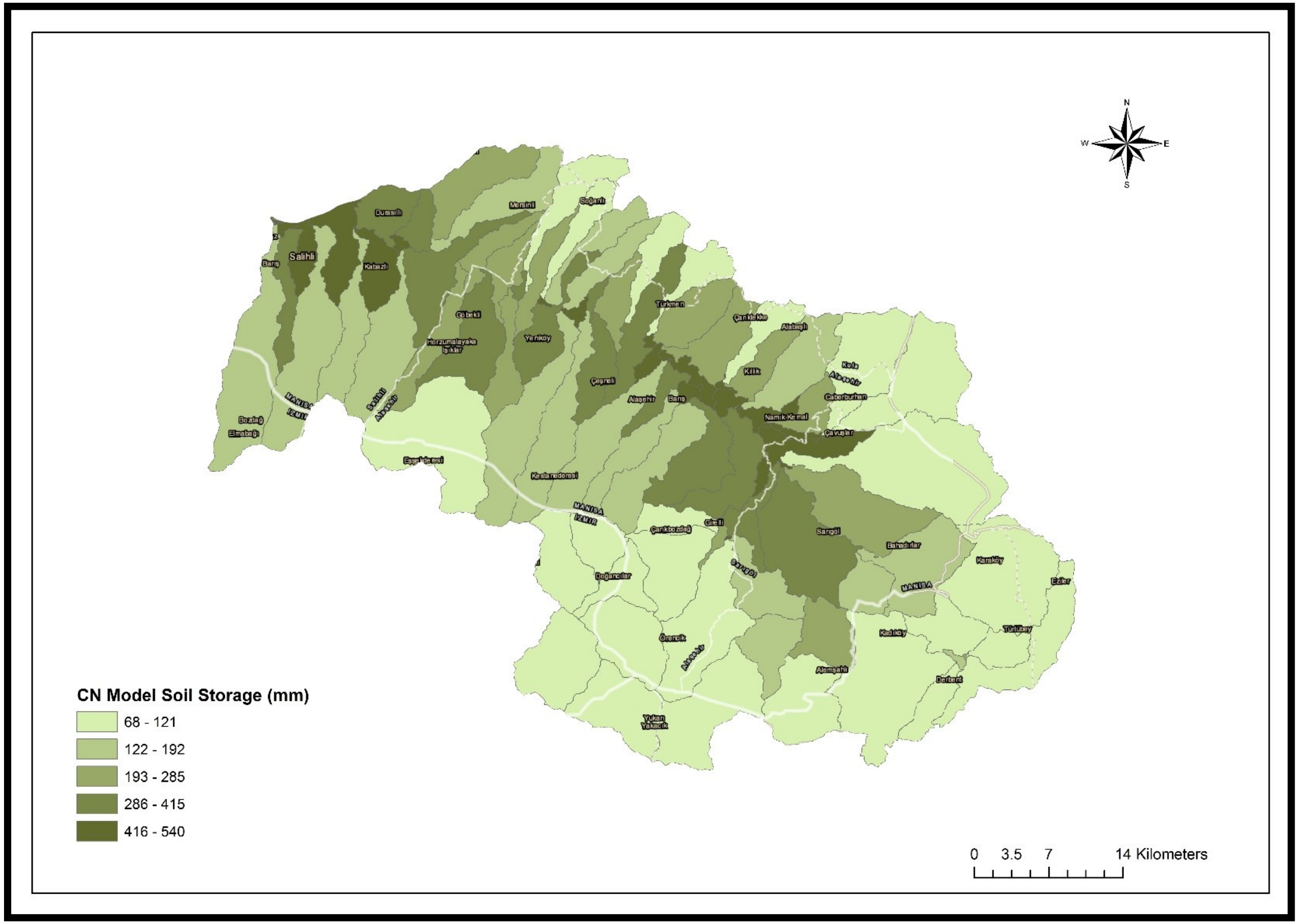
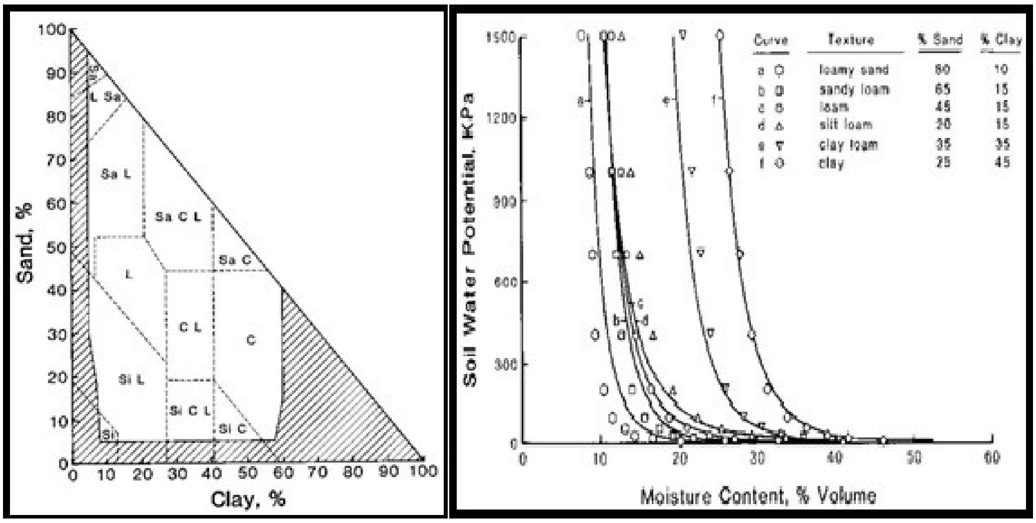


Figure 4.11 SCS Curve Number model weighted soil storage

Soil storage for SMA model directly obtained from laboratory studies conducted on core samples that gathered from 25 wells in the field. SMA algorithm requires soil top level storage parameter which is usually sampled as organic soil layer starting from 0.3 meters depth from soil surface (USACE, 2000). Core sampling usually starts from 0.5 meter from top surface level. However, due to the resemblance between organic soil layer and top identified core sample soil type; upper soil layer regarded as top identified core sample soil type. After identification of the samples, soil type distribution has been established with Thiessen Polygons by research team as it can be seen in Figure 4.12. Stage of soil storage determination Soil Water Characteristic (SWC) software developed by USDA has been used. Haan (1982) showed the correlation of sand, clay and organic matter content on the water retention of soils. According to study in 2006 soil storage amounts and field capacity amounts can be predicted with soil water potential and organic matter in soil (Saxton & Rawls, 2006). As it is shown in Figure 4.13 respect to different soil types moisture content has been calculated desired water potential (Saxton, Rawls, Romberger, Papendick, 1986). By using Soil Water Characteristic and Thiessen Polygons, soil water storage and tension storage capacities for each sub-basin calculated as it can be seen in Figure 4.14 and Figure 4.15.



(a) (b)

Figure 4.13 (a) (soil types), (b) (SWP and moisture relation) (Source: Saxton et al., 1986)

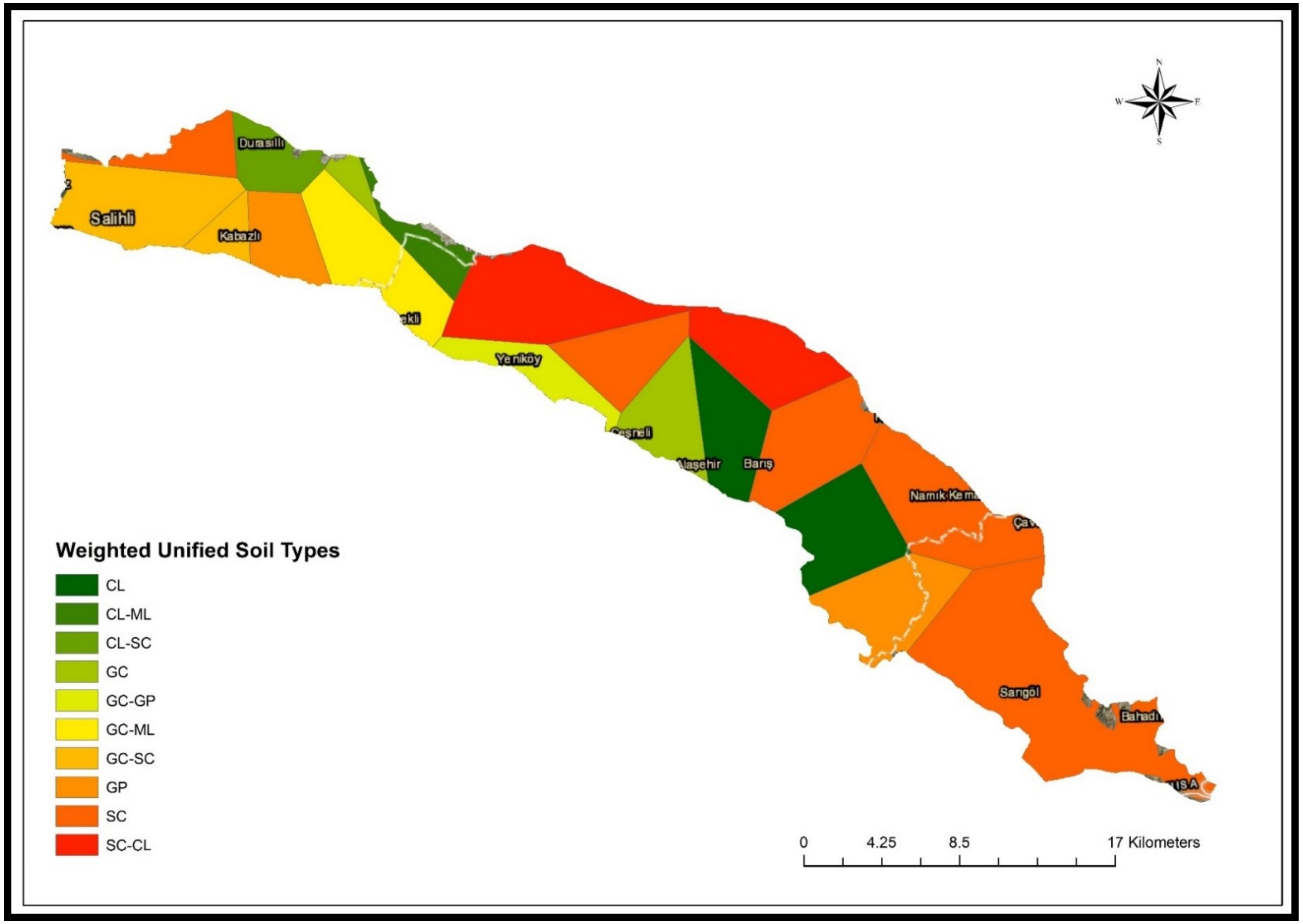


Figure 4.12 Weighted unified soil groups Thiessen Polygon Distribution

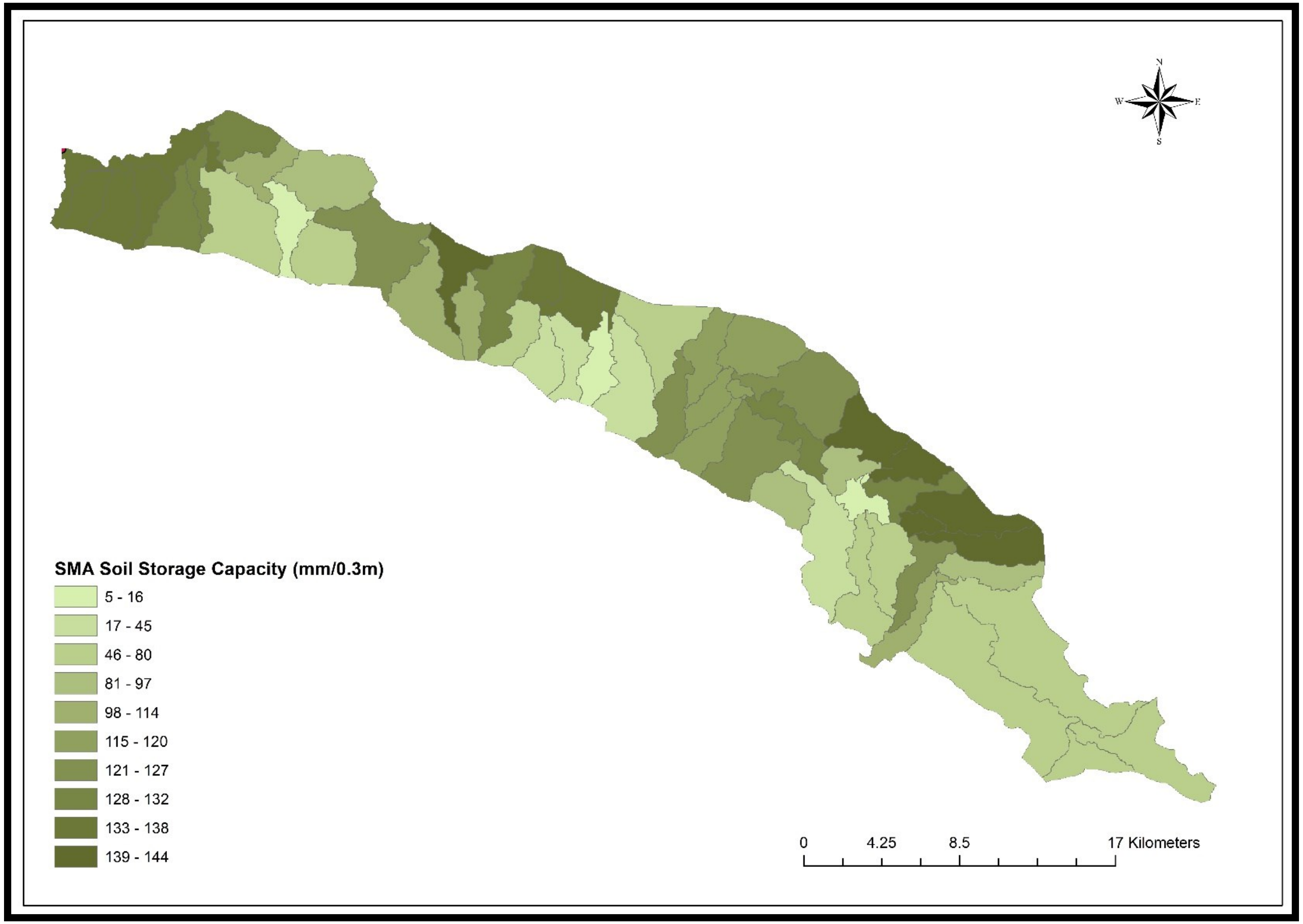


Figure 4.14. Weighted soil storage capacities distributed over sub-basins for 0.3 m upper soil layer in SMA model

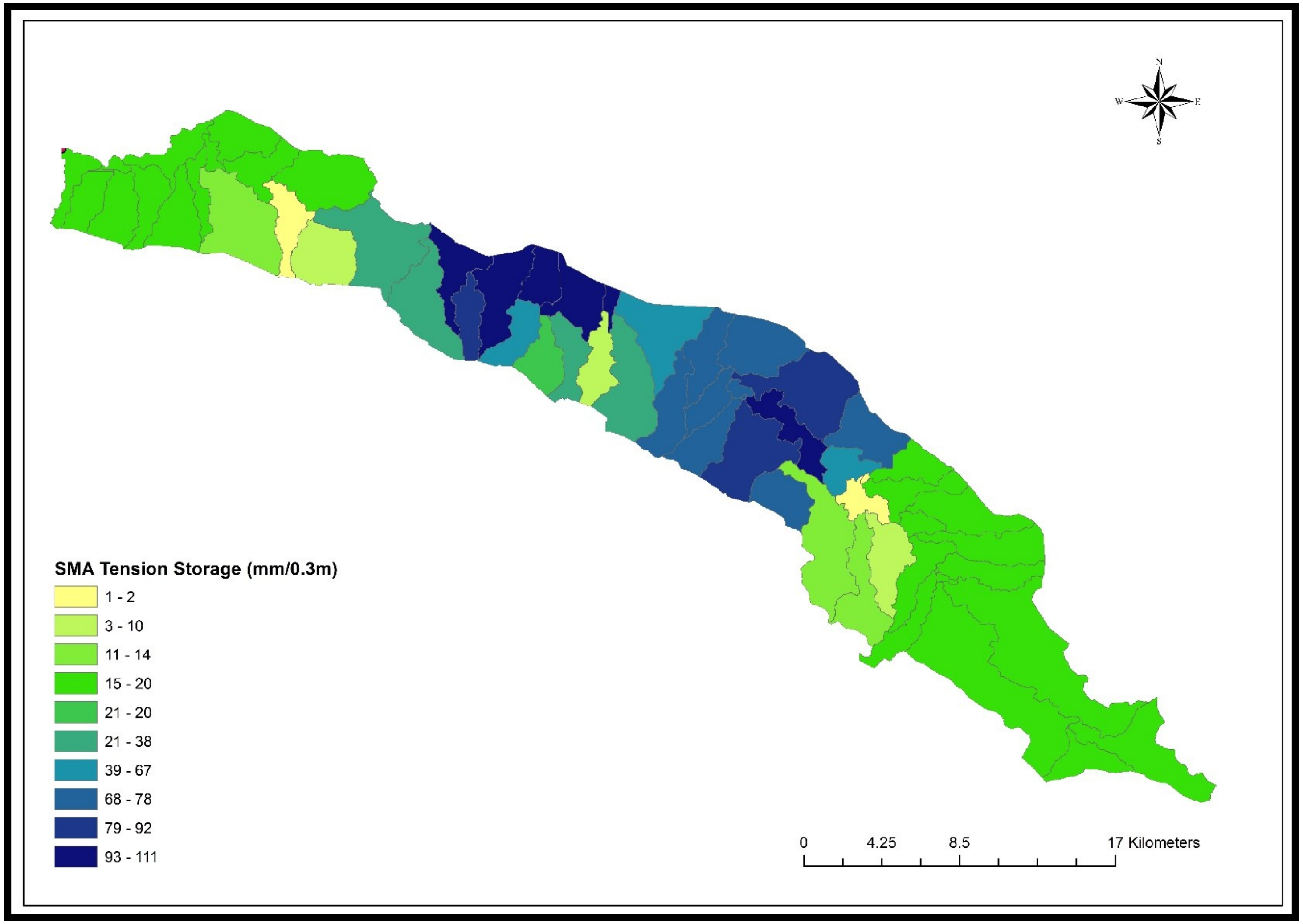
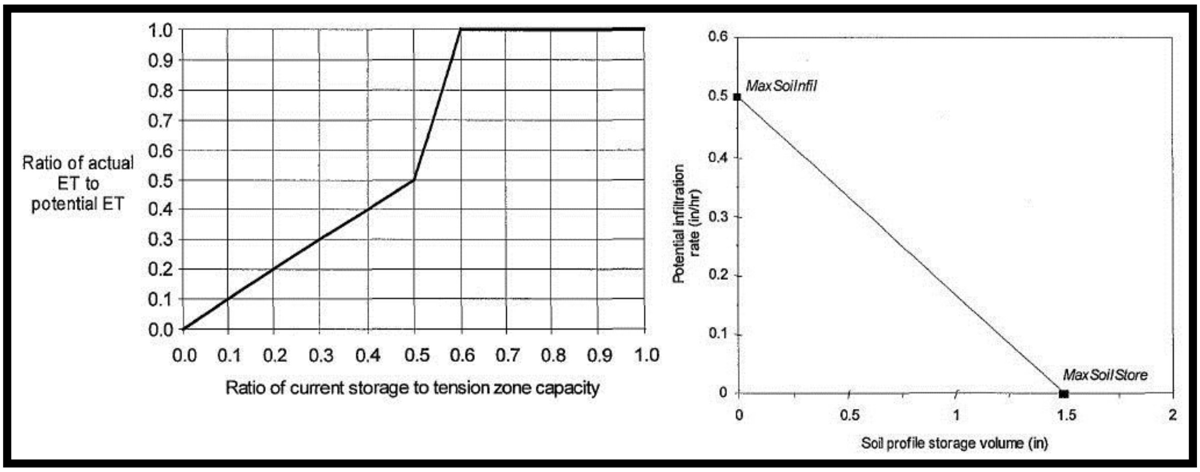


Figure 4.15. Tension storage distribution for SMA model

Tension storage as mentioned by US Army Corps of Engineers represents the layer that holds water in porous structures and doesn't allows to infiltrate to lower soil layers (USACE, 2000). This definition clearly refers to field capacity which is corresponds to -33 kPa or -0.33 bar suction pressure accepted by literature. Tension storage that illustrated in Figure 4.15 has been calculated by determining water content for weighted soil types of each sub-basin that corresponds -0.33 bar suction pressure. Detailed list of soil storage and tension storage data has been presented in Table A.12. Also Bennet (1998) published findings about evaporation and tension storage as it can be seen in Figure 4.16.



(a) (b)

Figure 4.16 (a) (Evapotranspiration and tension storage relation), (b) (Infiltration rate versus soil storage) (Source: Bennet, 1998)

As it can be understood from Figure 4.16,a with increment on soil water content also actual evapotranspiration increases with same ratio until half percent of the tension storage and after half percent actual evapotranspiration rate increases drastically. Also relation between infiltration rate and soil storage given through an example in Figure 4.16,b. As it can be understood from graph momentary soil infiltration rate is inversely proportional to momentary soil storage. When soil storage reaches the maximum soil storage which is saturated condition for the upper soil layer; momentary infiltration rate becomes zero. For both models maximum infiltration rates distributed over sub-basins in Figure 4.17 and Figure 4.18; detailed presentation is given in Table A.12 and Table A.13.

Potential infiltration and percolation rates for SMA model calculated by HEC-HMS in same manner as it shown in Equation 4.5 and Equation 4.6 (US Army Corps of Engineers, 2000).

$$PotentialSoilInf = MaxSoilInf - \left(\frac{CurSoilStor}{MaxSoilStor}\right) MaxSoilInf \qquad (4.5)$$

As it can be understood from Equation 4.5, relation between current soil storage and potential soil infiltration rate is linear. Maximum soil infiltration rate, can be observed during the soil storage is on empty state as well as minimum infiltration rates, should be observed in soil storage is near full.

$$PotSoilPerc = MaxSoilPerc \left(\frac{CurSoilStor}{MaxSoilStor}\right)\left(1 - \frac{CurGwStor}{MaxGwStor}\right) \qquad (4.6)$$

Equation 4.6 represents the relation between soil storage, groundwater storage, maximum soil percolation and potential soil percolation. Based on this, current soil percolation rates depend on repletion of groundwater storage and soil storage. Higher saturation levels on soil layer contributes to higher percolation rates yet, total opposite higher saturation levels on groundwater layer contributes to lower percolation rates.

As summery of Equation 4.5 and Equation 4.6 infiltration and percolation rates varies due to the momentary layer storage repletion, through the simulation duration of the models. This results in varying amounts of percolation and infiltration rates during the simulation period. The SMA model, especially organized in layer, make use of both equations at highest level. Storage information updated in each time step, enables simulation to make more realistic inferences in successive rainfall events. Although the model calculates the storage quantities during the simulation; as discussed in the conclusion section, the effects of storage changes resulting from movement of water in the opposite direction with the capillary effects are uncertain.

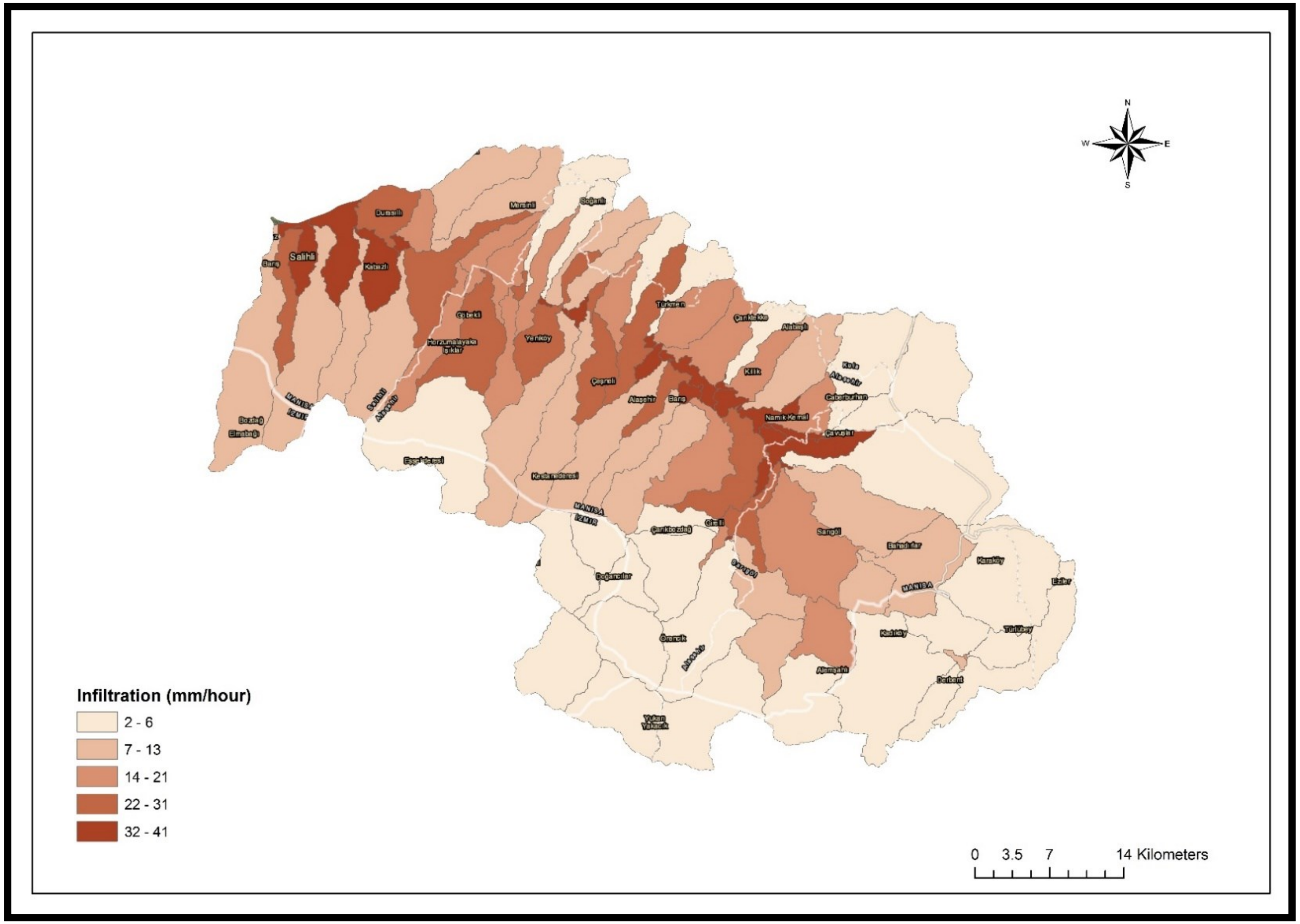


Figure 4.17 Maximum infiltration rates distributed over sub-basins for SCS Curve Number model

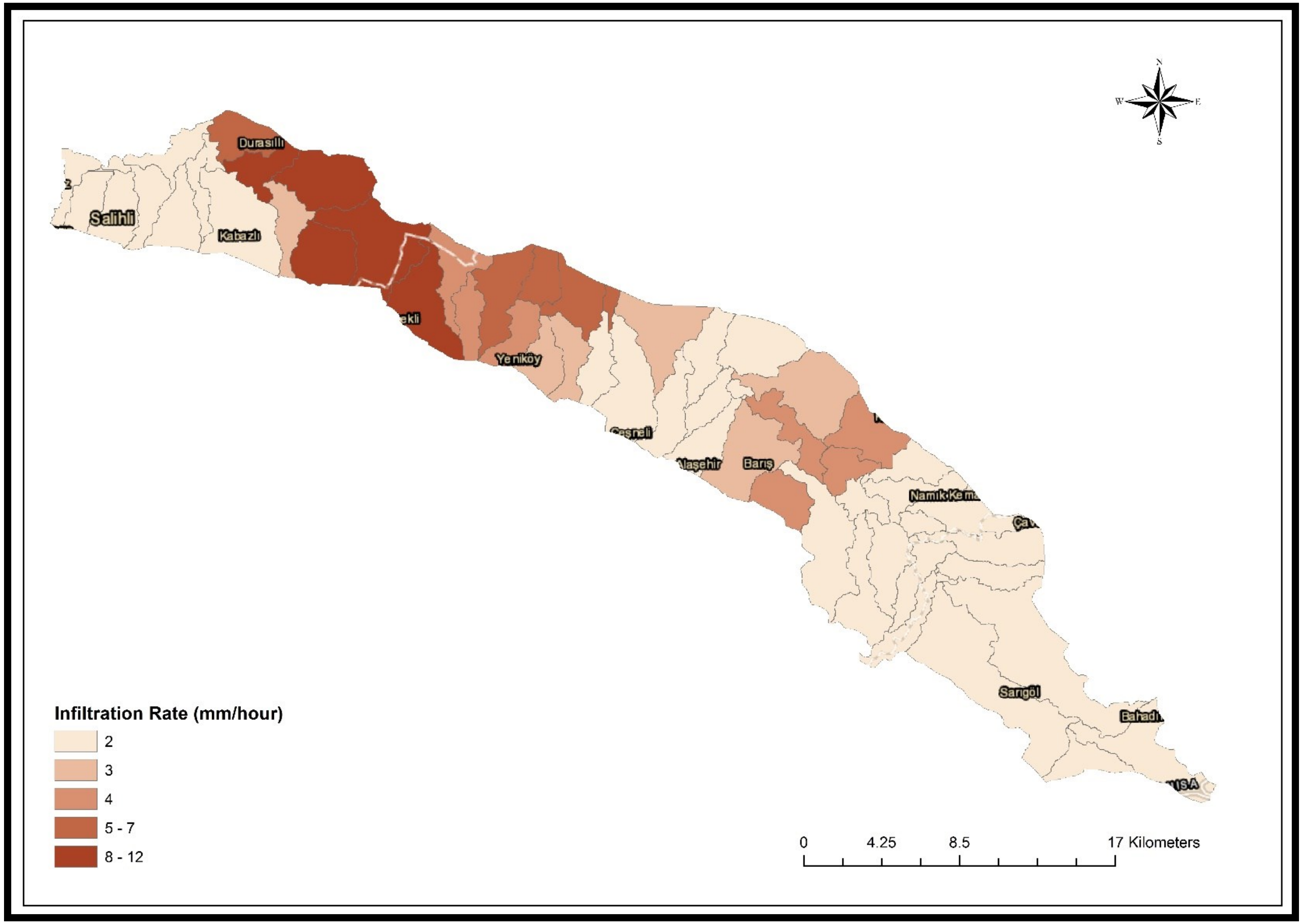


Figure 4.18 Maximum infiltration rates distributed over sub-basins for SMA model

4.5. HEC-HMS Basin Model Build

HEC-HMS is software that focused on simulating precipitation-runoff processes in dendritic watersheds. Program generally used for area of urban drainage, flow forecasting, future urbanization impact, reservoir spillway design, flood damage reduction, floodplain regulation and system operation (US Army Corps of Engineers, 2016). The process of creating a basin model in HEC-HMS can be summarized in 2 stages.

- Processing geomorphologic data: Geomorphology has a high impact on natural interaction between soil and precipitation. Surface depositions and total infiltrations are directly related to this regard. As it mentioned in subsection 3.1 geomorphologic data has been obtained from a DEM in ArcGIS program with help of HEC-GeoHMS toolbar. Processed surface data compiled and exported in to HEC-HMS with using HEC-GeoHMS toolbar. Geomorphologic variations and project area can be seen in Figure 4.19 and Figure 4.20.

- Setting up sub-basin parameters: HEC-HMS simulation environment requires homogeneous parameters for each sub-basin. Program offers user option of working on grid base or standard method. Grid based loss, surface and canopy methods stands on grid-based data (soil type grids, surface slope grids, etc.). However, such data are not available anywhere in the world as well as in our study area. Thus, in this study standard method has been chosen; all data processed such as surface deposition, impervious surface ratio, maximum soil infiltration, soil storage, tension storage, curve number, maximum percolation rates and have been weighted for each sub-basin as it shown in Chapter 4.

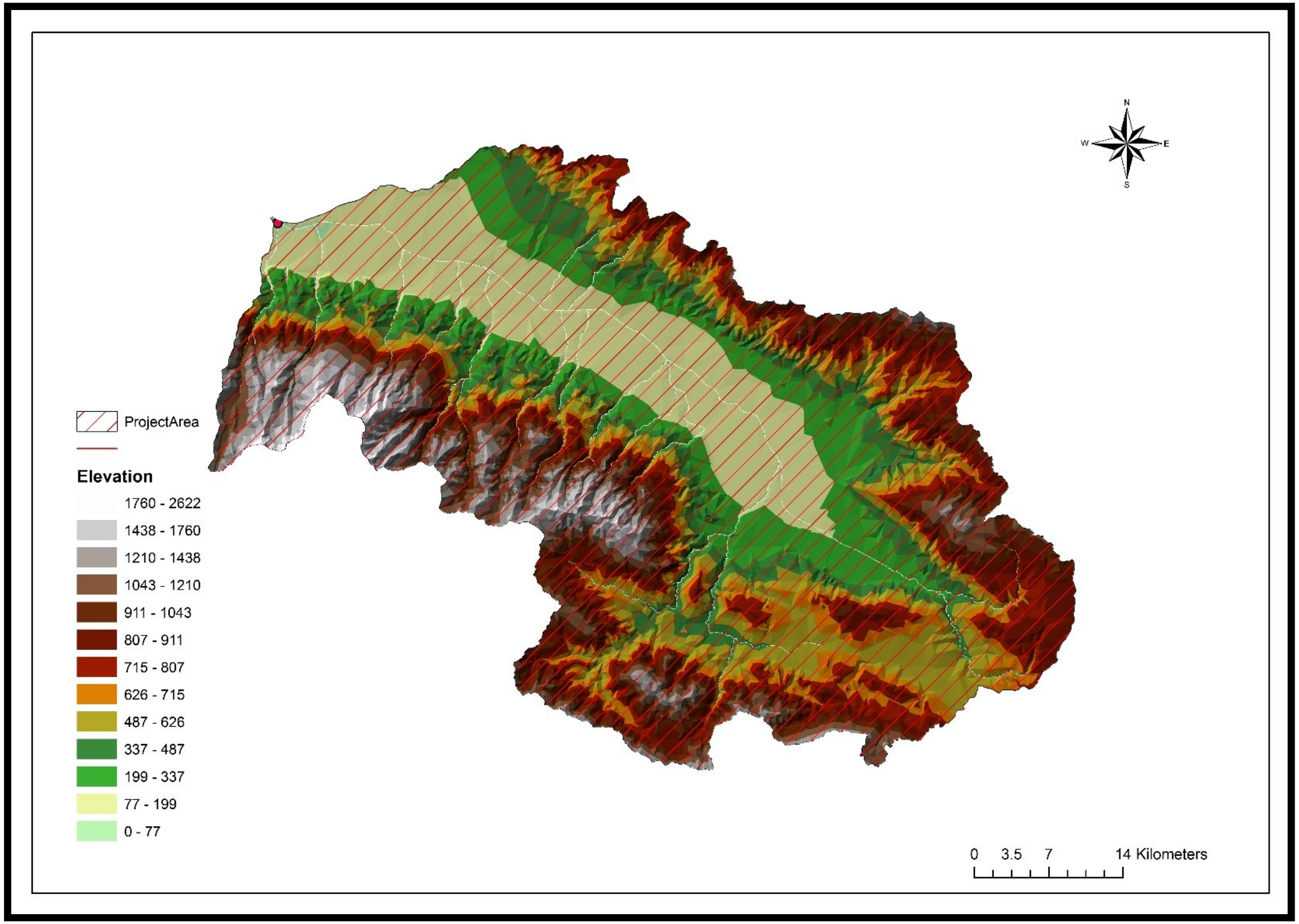


Figure 4.19 SCS Curve Number model topography and project area

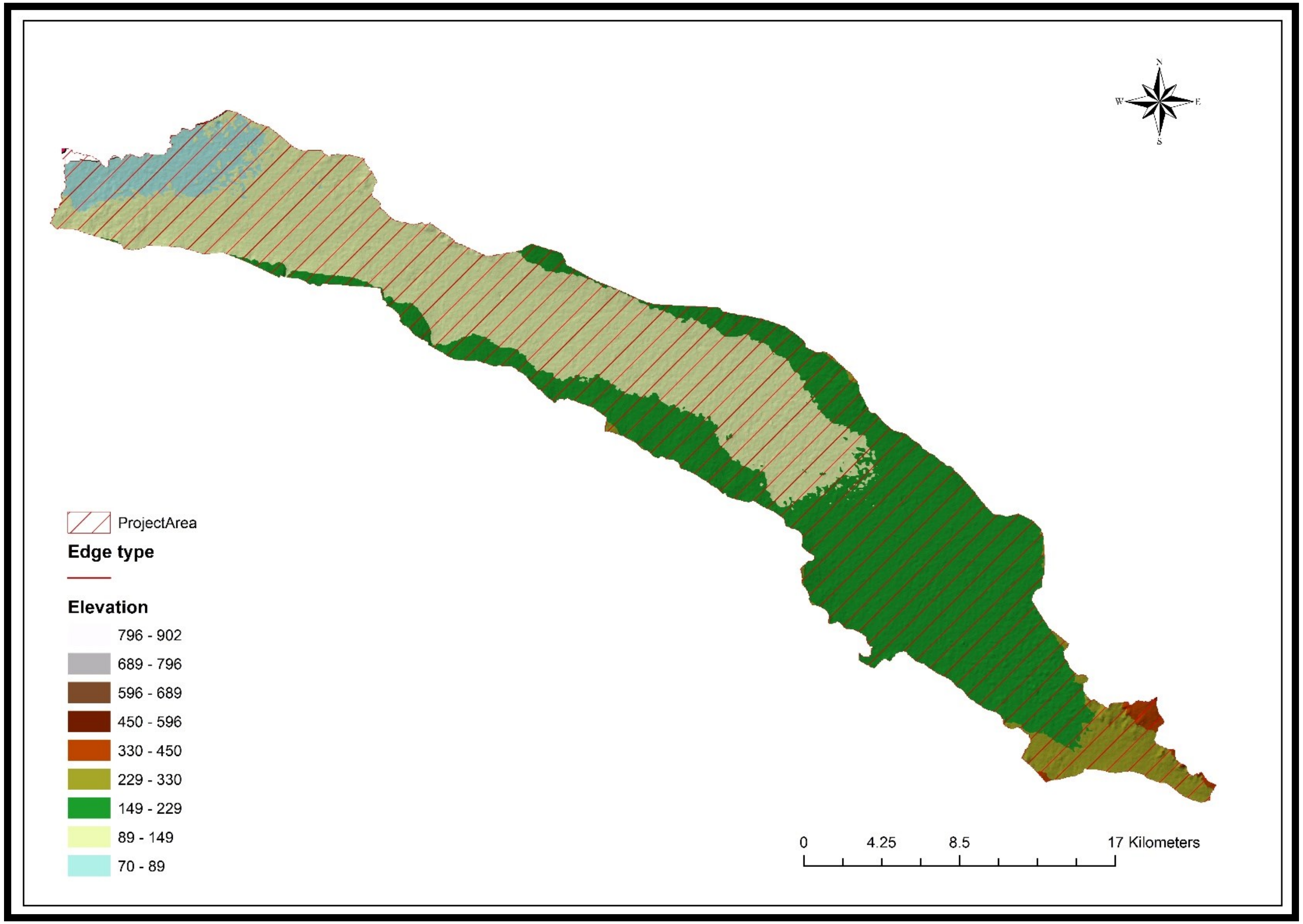


Figure 4.20 SMA model topography and project area

CHAPTER 5

CONCLUSION

Both models are objected to one year of precipitation input data with a time step of 1-hour density. Model time steps also have been chosen as 1 hour for compatibility reason with input data time steps. Due to lack of sufficient data canopy storage for SMA model assumed as 1 mm for all sub-basins. SMA algorithm capable of independently print groundwater volumetric input results which is percolation. None the less SCS Curve Number model does not capable of directly presenting groundwater input results. Therefor infiltration output of SCS Curve number model has been substituent as volumetric input to groundwater system. As simulation results for both models 1 years of groundwater recharge yield has been presented in Figure 5.1 and Figure 5.2. Simulation results have been aggregated for each sub-basin and weighted according to area of the sub-basin to project area. Weighted distribution of total hydrologic elements can be seen in Figure 5.3 and Figure 5.4.

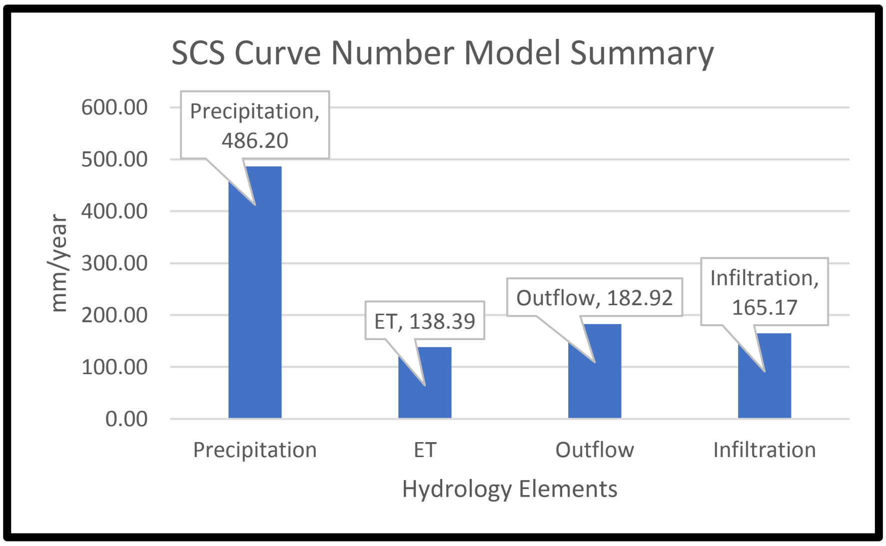


Figure 5.3 SCS Curve Number model element summary

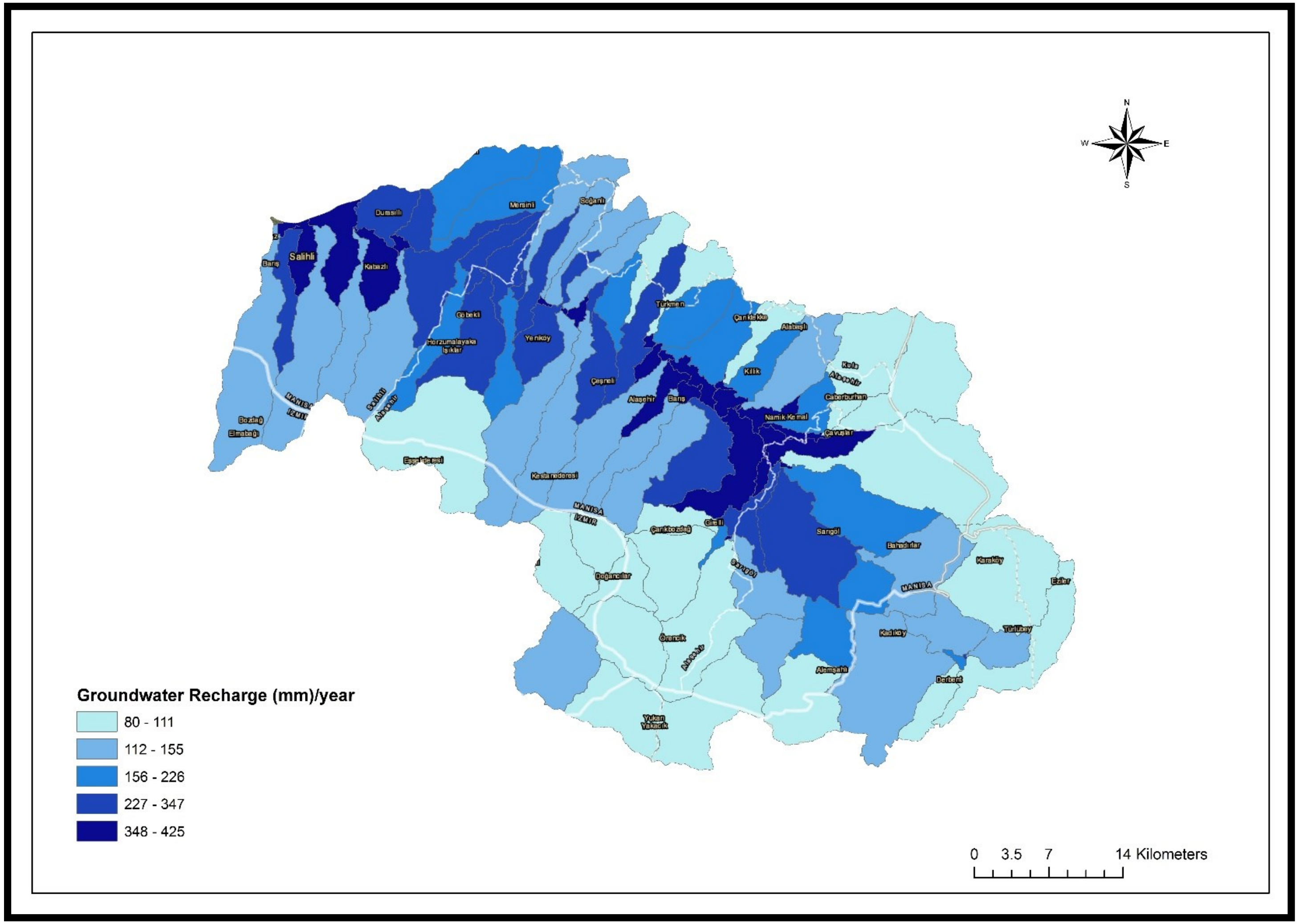


Figure 5.1 SCS Curve Number model groundwater recharge estimation per year

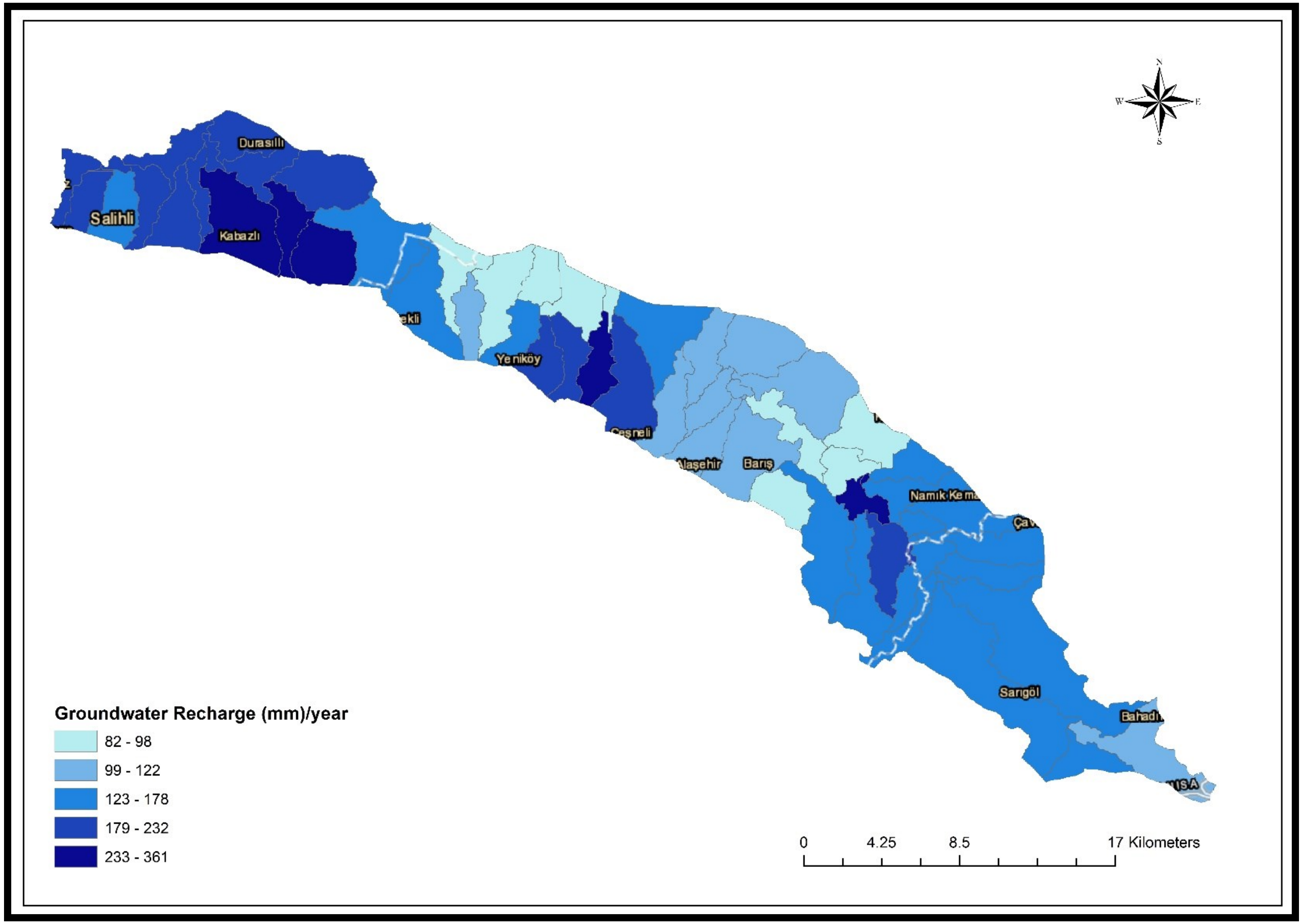


Figure 5.2 SMA model groundwater recharge estimation per year

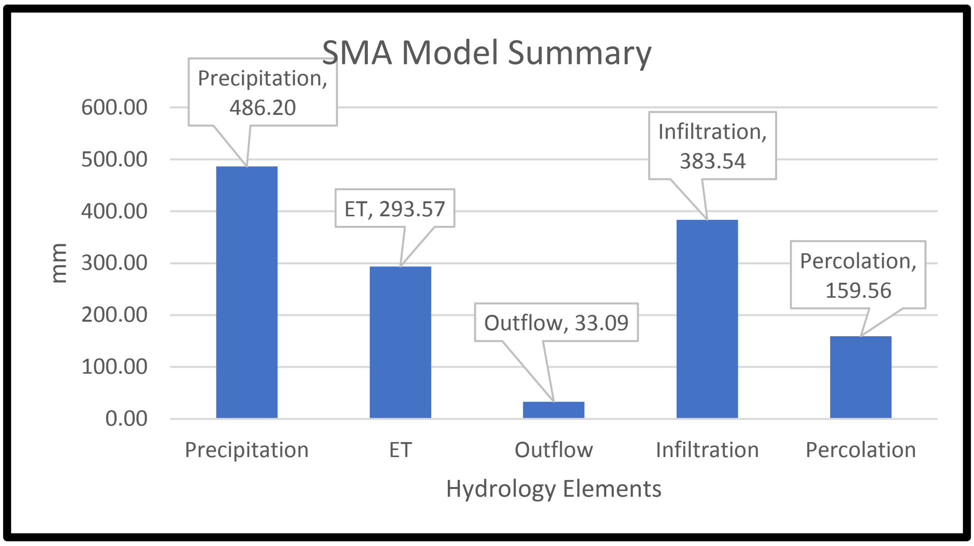


Figure 5.4 SMA model element summary

Regardless from spatial distributions; summary comparison of models shows that SCS Curve Number model has higher outflow capacity as well as higher infiltration rates. Substantial part of this estimation arises from geomorphological variation. SMA model built for alluvial zone located at the center of the basin. Therefore, land surface slopes are shallow, surface storage capacities are higher; consequently, it has less outflow capacity. On the other hand, SCS Curve Number model built for total basin and has a strongly variant land surface with slopes of 1.6% to 34%. This variety results in, higher outflow capacity and lower surface storage as it can be seen Figure 5.1 and Figure 5.3. Identical inference can be made for infiltration and evapotranspiration summaries.

Hydrological model predictions are as accurate as parameters used to build model. For SCS Curve Number model most significant parameter can be considered as Curve Number. Regardless of reliability of Curve Number data, due to subjective determination nature of curve numbers method can be questioned. Lack of soil moisture information in SCS Curve number method also decreases credibility on successive rain events and long-term modeling studies. Basin model component of both models have been build based on digital elevation model with a resolution of 30 m. With improvement on remote sensing technologies 30 m resolution models deemed to be outdated. From this point of view accuracy of land surface data can have high impact on accuracy of the models. In other respects, land use data is collected from OSM and its actuality and accuracy can be questioned.

Despite attempts to acquire calibration data from various organizations; attempts turn out negative due to hard to find calibration basin, lack of observation data or low resolution observed data.

On another hand during implementation of SMA method, physical limits of soil storage and tension storage parameters in HEC-HMS 4.2 determined as 1.5 m. From agricultural point of view this limit are sensible since all agricultural and botanical activity majorly continues in first 1.5 m from the soil surface. Correspondingly, soil storage and tension storage should be less than 1.5 m. Also according to research ET extinction level for variety of soil texture is not more than 3 m (Shah, Nachabe, & Ross, 2007). HEC-HMS user manual denotes that programs itself is not a vadose zone modeling program (US Army Corps of Engineers, 2016). Nevertheless, soil profile between botanical level and water table should be considered. Theoretically, maximum percolation rate is limited with the least permeable soil layer between soil top surface and water table. Relation between actual percolation rate and actual groundwater deposition can be interpreted from Equation 4.6. On another hand capillary rise levels can lead up to 1.5 m depending on the soil texture. Relation assumption in Equation 4.6 between percolation rate and receiving groundwater layer has potential to be change in capillary zone. Therefore, method should be applied with caution, especially on the areas which has low permeability layers in soil profile and groundwater table close to each other.

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APPENDIX A

SCS CURVE NUMBER TABLES AND MODEL PARAMETER CALCULATIONS

Table A.1 Curve Number for Urban Areas (Source: USDA, 1986)

	Cover description		Curve numbers for Hydrological Soil Groups			
	Cover type and hydrologic condition	Average percentage of Impervious Area	A	B	C	D
	Fully developed urban areas (vegetation established)					
	Open space (lawns, parks, golf courses, cemeteries, etc.) 3/:					
	Poor condition (grass cover < 50%)		68	79	86	89
	Fair condition (grass cover 50% to 75%)		49	69	79	84
	Good condition (grass cover > 75%)		39	61	74	80
Impervious areas:						
	Paved parking lots, roofs, driveways, etc.					
	(excluding right-of-way)		98	98	98	98
Streets and roads:						
	Paved; curbs and storm sewers (excluding					
right-of-way)			98	98	98	98
	Paved; open ditches (including right-of-way)		83	89	92	93
	Gravel (including right-of-way)		76	85	89	91
	Dirt (including right-of-way)		72	82	87	89
Western desert urban areas:						
	Natural desert landscaping (pervious areas only) 4/		63	77	85	88
	Artificial desert landscaping (impervious weed barrier,					
	desert shrub with 1- to 2-inch sand or gravel mulch					
	and basin borders)		96	96	96	96
Urban districts:						
	Commercial and business	85	89	92	94	95

(cont. on next page)

Table A.1 (cont.)

Industrial		72	81	88	91	93
	Residential districts by average lot size:					
	1/8 acre or less (town houses)	65	77	85	90	92
1/4 acre		38	61	75	83	87
1/3 acre		30	57	72	81	86
1/2 acre		25	54	70	80	85
1 acre		20	51	68	79	84
2 acres		12	46	65	77	82
Developing urban areas						
Newly graded areas						
	(pervious areas only, no vegetation) 5/		77	86	91	94

Idle lands (CN's are determined using cover types
similar to those in table 2-2c).

1. Average runoff condition, and Ia = 0.2S.
2. The average percent impervious area shown was used to develop the composite CN's. Other assumptions are as follows: impervious areas are directly connected to the drainage system, impervious areas have a CN of 98, and pervious areas are considered equivalent to open space in good hydrologic condition. CN's for other combinations of conditions may be computed using figure 2-3 or 2-4.
3. CN's shown are equivalent to those of pasture. Composite CN's may be computed for other combinations of open space cover type.
4. Composite CN's for natural desert landscaping should be computed using figures 2-3 or 2-4 based on the impervious area percentage (CN = 98) and the pervious area CN. The pervious area CN's are assumed equivalent to desert shrub in poor hydrologic condition.
5. Composite CN's to use for the design of temporary measures during grading and construction should be computed using figure 2-3 or 2-4 based on the degree of development (impervious area percentage) and the CN's for the newly graded pervious areas.

Table A.2 Urban Hydrology for Small Watersheds (USDA, 1986)

Cover type	Treatment	Hydrologic Condition	Hydrologic Soil Group			
			A	B	C	D
Fallow	Bare soil	—	77	86	91	94
	Crop residue cover (CR)	Poor	76	85	90	93
		Good	74	83	88	90
Row crops	Straight row (SR)	Poor	72	81	88	91
		Good	67	78	85	89
	SR + CR	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured (C)	Poor	70	79	84	88
		Good	65	75	82	86
	C + CR	Poor	69	78	83	87
		Good	64	74	81	85

(cont. on next page)

Table A.2 (cont.)

	Contoured & terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	C&T+ CR	Poor	65	73	79	81
		Good	61	70	77	80
Small grain	SR	Poor	65	76	84	88
		Good	63	75	83	87
	SR + CR	Poor	64	75	83	86
		Good	60	72	80	84
	C	Poor	63	74	82	85
		Good	61	73	81	84
	C + CR	Poor	62	73	81	84
		Good	60	72	80	83
	C&T	Poor	61	72	79	82
		Good	59	70	78	81
	C&T+ CR	Poor	60	71	78	81
		Good	58	69	77	80
Close-seeded or broadcast legumes or rotation meadow	SR	Poor	66	77	85	89
		Good	58	72	81	85
	C	Poor	64	75	83	85
		Good	55	69	78	83
	C&T	Poor	63	73	80	83
		Good	51	67	76	80

1 Average runoff condition, and Ia=0.2S

2 Crop residue cover applies only if residue is on at least 5% of the surface throughout the year.

3 Hydraulic condition is based on combination factors that affect infiltration and runoff, including
(a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes,
(d) percent of residue cover on the land surface (good ≥ 20%) and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.

Good: Factors encourage average and better than average infiltration and tend to decrease runoff.

Table A.3 Runoff curve numbers for other agricultural lands (USDA, 1986)

Cover type	Hydrologic condition	Curve numbers for hydrologic soil group			
		A	B	C	D
Pasture, grassland, or range—continuous forage for grazing. 2/	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow—continuous grass, protected from	—	30	58	71	78

(cont. on next page)

Table A.3 (cont.)

grazing and generally mowed for hay.					
Brush—brush-weed-grass mixture with brush the major element. 3/	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30 4/	48	65	73
Woods—grass combination (orchard or tree farm). 5/	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods. 6/	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30 4/	55	70	77
Farmsteads—buildings, lanes, driveways, and surrounding lots.	—	59	74	82	86

1 Average runoff condition, and Ia = 0.2S.

2 Poor: <50%) ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: > 75% ground cover and lightly or only occasionally grazed.

3 Poor: <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.

4 Actual curve number is less than 30; use CN = 30 for runoff computations.

5 CN's shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the CN's for woods and pasture.

6 Poor: Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

Table A.4 Urban Hydrology for Small Watersheds (Runoff curve numbers for arid and semiarid rangelands 1/) (USDA, 1986)

Cover description	Hydrologic condition 2/	Curve numbers for hydrologic soil group			
		A 3/	B	C	D
Herbaceous—mixture of grass, weeds, and	Poor		80	87	93
low-growing brush, with brush the	Fair		71	81	89

(cont. on next page)

Table A.4 (cont.)

minor element.	Good		62	74	85
Oak-aspen—mountain brush mixture of oak brush,	Poor		66	74	79
aspen, mountain mahogany, bitter brush, maple,	Fair		48	57	63
and other brush.	Good		30	41	48
Pinyon-juniper—pinyon, juniper, or both;	Poor		75	85	89
grass understory.	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory.	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub—major plants include saltbush,	Poor	63	77	85	88
greasewood, creosotebush, blackbrush, bursage,	Fair	55	72	81	86
palo verde, mesquite, and cactus.	Good	49	68	79	84

1 Average runoff condition, and Ia, = 0.2S. For range in humid regions, use table 2-2c.
2 Poor: <30% ground cover (litter, grass, and brush overstory).
Fair: 30 to 70% ground cover.
Good: > 70% ground cover.
3 Curve numbers for group A have been developed only for desert shrub.

Table A.5 Impervious Surface Calculation for SMA Model

	A	B	C	D
Sub-basin Name	Total Sub-basin Areas (m²)	Residential and Industrial Areas (m²)	Urban Roads (m)	Total Roads (m)
W640	7170257.8	0.0	0.0	9184.9
W650	4054007.2	545085.3	4363.5	4709.6
W660	5568911.9	0.0	0.0	16058.1
W670	6163522.9	0.0	0.0	16625.7
W680	3466381.3	57596.4	1029.1	7303.5
W690	7952594.9	50985.8	271.3	15145.1
W700	804165.5	0.0	0.0	155.5
W710	6080574.2	1285740.2	14902.5	23147.2
W720	1273917.0	0.0	0.0	260.6
W730	103031.0	0.0	0.0	61.3
W740	7481970.2	4711778.8	79897.5	80035.5
W750	5294744.6	2480675.7	46159.7	50136.4
W760	13098032.0	83236.7	402.3	11235.8
W770	16649981.3	0.0	0.0	18376.0
W780	6209799.6	86032.1	1082.1	5006.4
W790	10151171.2	261360.9	3977.1	23588.8

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Table A.5 (cont.)

W800	16836834.2	663606.1	13354.3	30979.9
W810	7192959.6	55264.4	1461.6	13375.8
W820	12464129.4	641498.2	14165.5	23234.4
W830	5301729.9	25593.6	176.1	8078.7
W840	10570280.3	231485.4	2166.7	12848.8
W850	5229258.9	0.0	0.0	5699.6
W860	6109388.1	131894.3	916.9	9495.0
W870	12783700.2	0.0	0.0	7361.4
W880	1241610.7	0.0	0.0	813.7
W900	13944981.5	31459.4	682.4	14729.5
W910	7896713.6	0.0	0.0	8452.4
W920	6285763.0	319317.8	6749.2	16833.9
W930	6460391.8	105873.6	1098.1	11010.5
W940	6056126.2	166076.6	2454.5	12570.3
W950	7536105.1	0.0	0.0	2430.5
W960	8245971.1	105601.5	2380.0	9773.8
W970	11441677.9	443250.6	8861.0	18295.2
W980	4631155.4	0.0	0.0	622.9
W990	15995123.4	251716.1	435.6	8700.4
W1000	970936.1	0.0	0.0	456.9
W1010	6976419.9	962848.1	25150.6	35723.3
W1020	55881.2	0.0	0.0	247.7
W1030	7100406.3	13217.5	601.9	3362.0
W1040	14500301.0	2377767.3	66961.9	86738.5
W1050	9022196.1	764181.7	2631.0	7120.3
W1060	7095167.4	173015.1	1374.7	13243.3
W1070	5073839.4	0.0	0.0	1003.7
W1080	5602091.3	164084.3	3028.9	5509.0
W1090	3833974.9	0.0	0.0	2903.4
W1100	178994.5	0.0	0.0	232.4
W1110	16353112.5	152539.4	2407.8	17612.2
W1120	6049141.1	34158.5	299.5	5296.0
W1130	9571403.6	1054140.3	18567.8	29338.7
W1140	9997497.8	202390.0	1089.8	16291.9
W1150	8713976.3	166662.8	1861.3	8379.4
W1160	2344391.4	0.0	0.0	1145.1
W1170	9140070.4	0.0	0.0	3709.4
W1180	6760753.4	61369.3	942.9	2586.8
W1190	6504049.0	0.0	0.0	6990.6
W1200	50642.3	0.0	0.0	0.0
W1210	6136455.4	97727.4	385.8	5265.5

(cont. on next page)

Table A.5 (cont.)

W1220	378944.5	0.0	0.0	0.0
W1230	30368818.5	2433355.2	18773.5	30663.1
W1240	30661322.0	539440.3	8614.0	33214.2
W1250	5722585.2	0.0	0.0	6537.7
W1260	14128341.7	27695.4	377.6	10497.1

Table A.6 Impervious Surface Calculation for SMA Model

D-E	(D-E)*10	B+((D-E)*10)	(B+((D-E)*10)/A)*100
Rural Roads (m)	Rural Road Areas (m²)	Total Impervious Areas (m²)	Impervious Area Percentage %
9184.9	91849.3	91849.3	1.3
346.1	3460.8	548546.0	13.5
16058.1	160581.3	160581.3	2.9
16625.7	166257.1	166257.1	2.7
6274.4	62744.1	120340.6	3.5
14873.9	148738.7	199724.4	2.5
155.5	1555.2	1555.2	0.2
8244.7	82446.9	1368187.1	22.5
260.6	2606.5	2606.5	0.2
61.3	613.4	613.4	0.6
138.0	1379.8	4713158.5	63.0
3976.7	39767.3	2520442.9	47.6
10833.5	108335.0	191571.6	1.5
18376.0	183760.1	183760.1	1.1
3924.3	39242.9	125275.0	2.0
19611.8	196117.8	457478.6	4.5
17625.6	176255.5	839861.7	5.0
11914.2	119142.1	174406.4	2.4
9068.9	90688.9	732187.1	5.9
7902.5	79025.5	104619.1	2.0
10682.1	106820.9	338306.3	3.2
5699.6	56996.0	56996.0	1.1
8578.1	85780.6	217674.9	3.6
7361.4	73614.3	73614.3	0.6
813.7	8136.5	8136.5	0.7
14047.1	140470.7	171930.1	1.2
8452.4	84523.7	84523.7	1.1

(cont. on next page)

Table A.6 (cont.)

3709.4	37094.3	37094.3	0.4
10084.7	100846.6	420164.3	6.7
9912.3	99123.5	204997.1	3.2
10115.9	101158.6	267235.2	4.4
2430.5	24304.7	24304.7	0.3
7393.8	73937.8	179539.3	2.2
9434.2	94341.8	537592.4	4.7
622.9	6229.3	6229.3	0.1
8264.8	82648.0	334364.1	2.1
456.9	4569.1	4569.1	0.5
10572.7	105727.2	1068575.3	15.3
247.7	2476.7	2476.7	4.4
2760.0	27600.3	40817.8	0.6
19776.6	197765.9	2575533.2	17.8
4489.4	44893.5	809075.2	9.0
11868.6	118686.4	291701.4	4.1
1003.7	10037.3	10037.3	0.2
2480.1	24800.8	188885.1	3.4
2903.4	29034.2	29034.2	0.8
232.4	2323.9	2323.9	1.3
15204.4	152044.4	304583.8	1.9
4996.6	49965.6	84124.1	1.4
10770.9	107708.7	1161849.0	12.1
15202.1	152021.4	354411.4	3.5
6518.1	65180.9	231843.6	2.7
1145.1	11451.2	11451.2	0.5
1643.9	16439.5	77808.8	1.2
6990.6	69906.4	69906.4	1.1
0.0	0.0	0.0	0.0
4879.7	48797.2	146524.6	2.4
0.0	0.0	0.0	0.0
11889.5	118895.4	2552250.6	8.4
24600.1	246001.4	785441.7	2.6
6537.7	65377.3	65377.3	1.1
10119.5	101195.0	128890.4	0.9

Table A.7 Impervious Surface Calculation for SCS Curve Number Model

	A	B	C	D
Sub-basin Name	Total Sub-basin Areas (m²)	Residential and Industrial Areas (m²)	Urban Roads (m)	Total Roads (m)
W1040	38.9	303245.5	2094.0	18194.0
W1050	29.3	0.0	0.0	23974.0
W1060	37.0	1424768.9	7838.0	32413.0
W1070	23.8	142364.2	1509.0	42497.0
W1080	0.0	0.0	0.0	0.0
W1090	73.8	1175439.1	11168.0	99466.0
W1100	1.5	0.0	0.0	434.0
W1110	21.7	0.0	0.0	26762.0
W1120	11.7	4837984.0	79889.0	83431.0
W1130	65.8	1625544.1	17797.0	47601.0
W1140	0.1	0.0	0.0	0.0
W1150	30.8	138052.5	808.0	35775.0
W1160	19.2	2856940.6	47868.0	59451.0
W1170	12.3	0.0	0.0	7427.0
W1180	20.7	0.0	0.0	12628.0
W1190	1.8	0.0	0.0	217.0
W1200	21.1	0.0	0.0	9228.0
W1210	19.5	0.0	0.0	6971.0
W1220	49.0	340716.6	3226.0	33315.0
W1230	40.2	757094.2	12313.0	50000.0
W1240	16.6	289697.7	5046.0	11440.0
W1250	27.4	176954.3	1048.0	31332.0
W1260	17.2	55264.4	1463.0	13381.0
W1270	41.4	886733.1	16907.0	47290.0
W1280	19.7	0.0	0.0	5524.0
W1290	19.9	48777.7	295.0	7421.0
W1300	20.6	105972.0	607.0	18481.0
W1310	2.0	0.0	0.0	417.0
W1320	21.5	0.0	0.0	16232.0
W1330	17.8	231485.4	2168.0	10868.0
W1340	0.6	0.0	0.0	0.0
W1350	29.3	406087.6	4489.0	30203.0
W1360	17.7	0.0	0.0	9108.0
W1370	3.1	0.0	0.0	1410.0
W1380	2.8	0.0	0.0	1839.0
W1390	23.5	62684.8	919.0	20168.0

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Table A.7 (cont.)

W1400	49.2	483020.9	7992.0	52527.0
W1410	0.3	0.0	0.0	0.0
W1420	60.7	166076.6	2454.0	33642.0
W1430	32.3	105601.5	2380.0	21456.0
W1440	1.1	0.0	0.0	0.0
W1450	29.5	443266.6	8861.0	23502.0
W1460	4.6	0.0	0.0	623.0
W1470	30.5	443994.8	972.0	22411.0
W1480	1.0	0.0	0.0	457.0
W1490	46.4	1327257.3	32102.0	64035.0
W1500	0.1	0.0	0.0	248.0
W1510	7.1	13217.5	602.0	3362.0
W1520	11.5	2468405.7	67550.0	75087.0
W1530	55.4	205326.6	1406.0	47430.0
W1540	38.6	422510.4	3640.0	19296.0
W1560	95.3	72194.8	145.0	47811.0
W1570	18.5	126023.8	156.0	8894.0
W1580	66.1	239069.4	1573.0	38365.0
W1590	0.8	0.0	0.0	0.0
W1600	18.8	1001378.8	3312.0	16226.0
W1610	3.3	110022.7	4564.0	7327.0
W1620	25.9	961281.4	27469.0	48455.0
W1630	40.0	265263.1	1830.0	30683.0
W1640	5.1	0.0	0.0	1003.0
W1650	33.1	476975.4	3725.0	35396.0
W1660	0.2	0.0	0.0	232.0
W1670	37.9	581248.9	7171.0	39598.0
W1680	6.5	166696.1	723.0	6562.0
W1710	17.1	1204998.5	18895.0	37034.0
W1720	0.3	0.0	0.0	0.0
W1730	22.6	97356.6	1686.0	8288.0
W1740	3.2	0.0	0.0	2625.0
W1750	111.7	826153.9	5730.0	80847.0
W1760	0.1	0.0	0.0	0.0
W1770	16.8	191349.4	844.0	10717.0
W1780	0.4	0.0	0.0	0.0
W1790	68.0	2785737.6	17083.0	60474.0
W1800	57.3	854417.5	14251.0	43262.0
W1810	15.7	233668.4	2052.0	26725.0
W1820	42.7	633842.8	5197.0	51777.0
W1830	3.1	241.4	0.0	3786.0

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Table A.7 (cont.)

W1840	0.2	0.0	0.0	0.0
W1850	65.9	189379.1	1074.0	38449.0
W1860	29.1	214688.0	817.0	13530.0
W1870	20.3	0.0	0.0	8803.0
W1880	22.5	27724.0	71.0	7127.0
W1890	50.6	186384.9	1445.0	22222.0
W1900	35.4	151263.9	583.0	13935.0
W1910	21.3	7421.7	78.0	7012.0
W1920	84.3	431343.1	8396.0	76461.0
W1930	25.1	11879.1	139.0	17622.0
W1940	44.1	159750.4	1143.0	36106.0
W1950	63.5	387506.4	3130.0	30151.0
W1960	27.7	221014.6	924.0	18937.0
W1970	26.3	413316.3	5624.0	17188.0
W1980	48.5	17764.5	19.0	44597.0
W1990	46.6	486327.4	2857.0	35337.0
W2000	15.3	229095.4	228.0	10036.0
W2010	0.2	1954.1	0.0	0.0
W2020	1.6	0.0	0.0	0.0
W2030	45.5	27454.9	365.0	28257.0
W2040	91.0	228015.1	2146.0	70317.0
W2050	16.4	112566.5	2316.0	12341.0
W2060	49.1	418771.5	1543.0	46855.0

Table A.8 Impervious Surface Calculation for scs Model

D-E	(D-E)*10	B+((D-E)*10)	((B+((D-E)*10)*0.000001)/A)*100
Rural Roads (m)	Rural Road Areas (m²)	Total Impervious Areas (m²)	Impervious Area Percentage %
16100.0	161000.0	464245.5	1.2
23974.0	239740.0	239740.0	0.8
24575.0	245750.0	1670518.9	4.5
40988.0	409880.0	552244.2	2.3
0.0	0.0	0.0	0.0
88298.0	882980.0	2058419.1	2.8
434.0	4340.0	4340.0	0.3
26762.0	267620.0	267620.0	1.2
3542.0	35420.0	4873404.0	41.7

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Table A.8 (cont.)

29804.0	298040.0	1923584.1	2.9
0.0	0.0	0.0	0.0
34967.0	349670.0	487722.5	1.6
11583.0	115830.0	2972770.6	15.5
7427.0	74270.0	74270.0	0.6
12628.0	126280.0	126280.0	0.6
217.0	2170.0	2170.0	0.1
9228.0	92280.0	92280.0	0.4
6971.0	69710.0	69710.0	0.4
30089.0	300890.0	641606.6	1.3
37687.0	376870.0	1133964.2	2.8
6394.0	63940.0	353637.7	2.1
30284.0	302840.0	479794.3	1.7
11918.0	119180.0	174444.4	1.0
30383.0	303830.0	1190563.1	2.9
5524.0	55240.0	55240.0	0.3
7126.0	71260.0	120037.7	0.6
17874.0	178740.0	284712.0	1.4
417.0	4170.0	4170.0	0.2
16232.0	162320.0	162320.0	0.8
8700.0	87000.0	318485.4	1.8
0.0	0.0	0.0	0.0
25714.0	257140.0	663227.6	2.3
9108.0	91080.0	91080.0	0.5
1410.0	14100.0	14100.0	0.5
1839.0	18390.0	18390.0	0.7
19249.0	192490.0	255174.8	1.1
44535.0	445350.0	928370.9	1.9
0.0	0.0	0.0	0.0
31188.0	311880.0	477956.6	0.8
19076.0	190760.0	296361.5	0.9
0.0	0.0	0.0	0.0
14641.0	146410.0	589676.6	2.0
623.0	6230.0	6230.0	0.1
21439.0	214390.0	658384.8	2.2
457.0	4570.0	4570.0	0.5
31933.0	319330.0	1646587.3	3.5
248.0	2480.0	2480.0	4.4
2760.0	27600.0	40817.5	0.6
7537.0	75370.0	2543775.7	22.2
46024.0	460240.0	665566.6	1.2

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Table A.8 (cont.)

15656.0	156560.0	579070.4	1.5
47666.0	476660.0	548854.8	0.6
8738.0	87380.0	213403.8	1.2
36792.0	367920.0	606989.4	0.9
0.0	0.0	0.0	0.0
12914.0	129140.0	1130518.8	6.0
2763.0	27630.0	137652.7	4.1
20986.0	209860.0	1171141.4	4.5
28853.0	288530.0	553793.1	1.4
1003.0	10030.0	10030.0	0.2
31671.0	316710.0	793685.4	2.4
232.0	2320.0	2320.0	1.3
32427.0	324270.0	905518.9	2.4
5839.0	58390.0	225086.1	3.4
18139.0	181390.0	1386388.5	8.1
0.0	0.0	0.0	0.0
6602.0	66020.0	163376.6	0.7
2625.0	26250.0	26250.0	0.8
75117.0	751170.0	1577323.9	1.4
0.0	0.0	0.0	0.0
9873.0	98730.0	290079.4	1.7
0.0	0.0	0.0	0.0
43391.0	433910.0	3219647.6	4.7
29011.0	290110.0	1144527.5	2.0
24673.0	246730.0	480398.4	3.1
46580.0	465800.0	1099642.8	2.6
3786.0	37860.0	38101.4	1.2
0.0	0.0	0.0	0.0
37375.0	373750.0	563129.1	0.9
12713.0	127130.0	341818.0	1.2
8803.0	88030.0	88030.0	0.4
7056.0	70560.0	98284.0	0.4
20777.0	207770.0	394154.9	0.8
13352.0	133520.0	284783.9	0.8
6934.0	69340.0	76761.7	0.4
68065.0	680650.0	1111993.1	1.3
17483.0	174830.0	186709.1	0.7
34963.0	349630.0	509380.4	1.2
27021.0	270210.0	657716.4	1.0
18013.0	180130.0	401144.6	1.4
11564.0	115640.0	528956.3	2.0
44578.0	445780.0	463544.5	1.0
32480.0	324800.0	811127.4	1.7

Table A.9. Total land use data for SCS Curve Number model

Perimeter (m)	Name of Sub-Basin	Area of Sub-Basin (km²)	Land Use Code	Land Use	Land Use Area (m²)
44678.1	W1040	38.92	7206	cemetery	20214.9
44678.1	W1040	38.92	7203	residential	155097.3
44678.1	W1040	38.92	7203	residential	77188.1
44678.1	W1040	38.92	7204	industrial	70960.1
44678.1	W1040	38.92	7206	cemetery	7233.7
50942.5	W1060	37.05	7203	residential	14200.9
50942.5	W1060	37.05	7203	residential	7018.1
50942.5	W1060	37.05	7203	residential	21794.9
50942.5	W1060	37.05	7203	residential	22715.3
50942.5	W1060	37.05	7204	industrial	647.6
50942.5	W1060	37.05	7204	industrial	1065165.2
50942.5	W1060	37.05	7203	residential	293227.0
39182.0	W1070	23.76	7203	residential	65207.1
39182.0	W1070	23.76	7203	residential	15277.0
39182.0	W1070	23.76	7203	residential	9711.7
39182.0	W1070	23.76	7203	residential	52168.3
39182.0	W1070	23.76	7206	cemetery	39319.5
70090.2	W1090	73.75	7203	residential	50249.6
70090.2	W1090	73.75	7203	residential	651694.8
70090.2	W1090	73.75	7203	residential	23537.3
70090.2	W1090	73.75	7203	residential	36568.1
70090.2	W1090	73.75	7203	residential	64675.1
70090.2	W1090	73.75	7203	residential	113190.3
70090.2	W1090	73.75	7203	residential	14498.0
70090.2	W1090	73.75	7202	park	31985.0
70090.2	W1090	73.75	7203	residential	34721.7
70090.2	W1090	73.75	7206	cemetery	3006.0
70090.2	W1090	73.75	7203	residential	132411.5
70090.2	W1090	73.75	7206	cemetery	2410.2
70090.2	W1090	73.75	7203	residential	1640.6
70090.2	W1090	73.75	7203	residential	1414.2
70090.2	W1090	73.75	7203	residential	4161.7
70090.2	W1090	73.75	7206	cemetery	7128.4
70090.2	W1090	73.75	7204	industrial	26773.2
70090.2	W1090	73.75	7203	residential	2242.5

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Table A.9 (cont.)

70090.2	W1090	73.75	7203	residential	13574.3
7741.8	W1100	1.50	7216	vineyard	85137.0
28780.7	W1110	21.69	7201	forest	12438.5
28780.7	W1110	21.69	7206	cemetery	37834.1
26416.8	W1120	11.70	7203	residential	4721034.8
26416.8	W1120	11.70	7216	vineyard	20974.1
69794.8	W1130	65.79	7203	residential	1220742.6
69794.8	W1130	65.79	7203	residential	10530.8
69794.8	W1130	65.79	7203	residential	81725.5
69794.8	W1130	65.79	7203	residential	60920.7
69794.8	W1130	65.79	7203	residential	29422.1
69794.8	W1130	65.79	7203	residential	1417.2
69794.8	W1130	65.79	7203	residential	6207.2
69794.8	W1130	65.79	7203	residential	8893.8
69794.8	W1130	65.79	7203	residential	3880.6
69794.8	W1130	65.79	7203	residential	56299.4
69794.8	W1130	65.79	7203	residential	14644.1
69794.8	W1130	65.79	7203	residential	33065.8
69794.8	W1130	65.79	7203	residential	28159.9
69794.8	W1130	65.79	7203	residential	3036.4
69794.8	W1130	65.79	7203	residential	6538.2
69794.8	W1130	65.79	7203	residential	5592.9
55374.8	W1150	30.83	7203	residential	22889.0
55374.8	W1150	30.83	7203	residential	32210.1
55374.8	W1150	30.83	7203	residential	5634.2
55374.8	W1150	30.83	7203	residential	2226.9
55374.8	W1150	30.83	7203	residential	12832.4
55374.8	W1150	30.83	7203	residential	17062.5
55374.8	W1150	30.83	7203	residential	37225.2
55374.8	W1150	30.83	7203	residential	7972.3
41959.6	W1160	19.24	7203	residential	2715785.4
41959.6	W1160	19.24	7203	residential	45789.5
41959.6	W1160	19.24	7203	residential	3299.4
41959.6	W1160	19.24	7201	forest	2545.8
52951.8	W1220	49.04	7203	residential	18359.0
52951.8	W1220	49.04	7203	residential	55457.2
52951.8	W1220	49.04	7203	residential	15239.5

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Table A.9 (cont.)

52951.8	W1220	49.04	7203	residential	67527.5
52951.8	W1220	49.04	7214	quarry	30880.5
52951.8	W1220	49.04	7203	residential	16.7
52951.8	W1220	49.04	7203	residential	16098.5
52951.8	W1220	49.04	7203	residential	53682.4
52951.8	W1220	49.04	7203	residential	2080.3
52951.8	W1220	49.04	7203	residential	1674.3
52951.8	W1220	49.04	7203	residential	1957.5
52951.8	W1220	49.04	7203	residential	1300.9
52951.8	W1220	49.04	7203	residential	2060.8
52951.8	W1220	49.04	7203	residential	1128.4
52951.8	W1220	49.04	7203	residential	1547.5
52951.8	W1220	49.04	7203	residential	3465.6
52951.8	W1220	49.04	7203	residential	3004.0
52951.8	W1220	49.04	7203	residential	14943.3
52951.8	W1220	49.04	7203	residential	4943.4
52951.8	W1220	49.04	7203	residential	8252.0
52951.8	W1220	49.04	7203	residential	8136.9
52951.8	W1220	49.04	7203	residential	29739.4
52951.8	W1220	49.04	7203	residential	13158.3
52951.8	W1220	49.04	7203	residential	11710.1
52951.8	W1220	49.04	7203	residential	5233.3
60220.9	W1230	40.22	7203	residential	120314.8
60220.9	W1230	40.22	7203	residential	245194.1
60220.9	W1230	40.22	7206	cemetery	17926.4
60220.9	W1230	40.22	7203	residential	39127.0
60220.9	W1230	40.22	7203	residential	136402.4
60220.9	W1230	40.22	7203	residential	215992.1
60220.9	W1230	40.22	7215	orchard	4614.9
60220.9	W1230	40.22	7203	residential	63.9
37290.8	W1240	16.58	7203	residential	147832.8
37290.8	W1240	16.58	7203	residential	674.6
37290.8	W1240	16.58	7203	residential	96123.7
37290.8	W1240	16.58	7203	residential	45066.6
48755.9	W1250	27.44	7203	residential	20764.8
48755.9	W1250	27.44	7203	residential	15452.0
48755.9	W1250	27.44	7203	residential	43818.2

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Table A.9 (cont.)

48755.9	W1250	27.44	7203	residential	31085.8
48755.9	W1250	27.44	7203	residential	42639.4
48755.9	W1250	27.44	7203	residential	4267.2
48755.9	W1250	27.44	7203	residential	18927.0
35517.9	W1260	17.18	7203	residential	55264.4
51415.3	W1270	41.45	7203	residential	34324.7
51415.3	W1270	41.45	7203	residential	79249.7
51415.3	W1270	41.45	7203	residential	1015.3
51415.3	W1270	41.45	7203	residential	991.8
51415.3	W1270	41.45	7203	residential	1174.9
51415.3	W1270	41.45	7203	residential	2649.7
51415.3	W1270	41.45	7203	residential	2163.4
51415.3	W1270	41.45	7203	residential	731872.3
51415.3	W1270	41.45	7203	residential	1803.9
51415.3	W1270	41.45	7203	residential	31315.2
39063.8	W1290	19.87	7203	residential	995.6
39063.8	W1290	19.87	7203	residential	2469.9
39063.8	W1290	19.87	7203	residential	5623.8
39063.8	W1290	19.87	7203	residential	20352.6
39063.8	W1290	19.87	7203	residential	3611.0
39063.8	W1290	19.87	7203	residential	15724.9
40009.4	W1300	20.56	7203	residential	80378.4
40009.4	W1300	20.56	7203	residential	25593.6
43377.9	W1330	17.82	7204	industrial	18954.8
43377.9	W1330	17.82	7204	industrial	6251.8
43377.9	W1330	17.82	7205	farm	24003.2
43377.9	W1330	17.82	7205	farm	25141.6
43377.9	W1330	17.82	7205	farm	62346.3
43377.9	W1330	17.82	7205	farm	35516.6
43377.9	W1330	17.82	7205	farm	10652.3
43377.9	W1330	17.82	7205	farm	11135.2
43377.9	W1330	17.82	7204	industrial	64131.6
43377.9	W1330	17.82	7204	industrial	5370.4
43377.9	W1330	17.82	7204	industrial	10379.5
43377.9	W1330	17.82	7203	residential	126397.3
50587.9	W1350	29.29	7203	residential	104244.4
50587.9	W1350	29.29	7203	residential	1629.2

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Table A.9 (cont.)

50587.9	W1350	29.29	7204	industrial	18355.0
50587.9	W1350	29.29	7205	farm	385.6
50587.9	W1350	29.29	7204	industrial	5664.1
50587.9	W1350	29.29	7204	industrial	16476.9
50587.9	W1350	29.29	7203	residential	259717.9
37409.0	W1390	23.54	7203	residential	29702.0
37409.0	W1390	23.54	7203	residential	14030.2
37409.0	W1390	23.54	7203	residential	18952.7
66839.9	W1400	49.20	7203	residential	172130.6
66839.9	W1400	49.20	7203	residential	147187.2
66839.9	W1400	49.20	7203	residential	76812.0
66839.9	W1400	49.20	7203	residential	86891.2
70503.9	W1420	60.68	7203	residential	44193.2
70503.9	W1420	60.68	7203	residential	69632.0
70503.9	W1420	60.68	7203	residential	52251.4
55374.8	W1430	32.34	7203	residential	105601.5
32326.6	W1450	29.52	7203	residential	443250.7
32326.6	W1450	29.52	7206	cemetery	4418.4
32326.6	W1450	29.52	7203	residential	15.9
45210.0	W1470	30.48	7203	residential	16925.7
45210.0	W1470	30.48	7203	residential	131704.5
45210.0	W1470	30.48	7206	cemetery	6492.9
45210.0	W1470	30.48	7206	cemetery	5698.6
45210.0	W1470	30.48	7203	residential	8761.0
45210.0	W1470	30.48	7203	residential	34887.5
45210.0	W1470	30.48	7203	residential	251716.1
54547.5	W1490	46.41	7203	residential	359411.0
54547.5	W1490	46.41	7203	residential	824670.2
54547.5	W1490	46.41	7203	residential	21022.5
54547.5	W1490	46.41	7206	cemetery	9869.8
54547.5	W1490	46.41	7203	residential	10227.6
54547.5	W1490	46.41	7203	residential	5589.0
54547.5	W1490	46.41	7206	cemetery	3287.0
54547.5	W1490	46.41	7203	residential	106336.9
26771.4	W1510	7.10	7213	military	240993.4
26771.4	W1510	7.10	7203	residential	13217.5
30731.0	W1520	11.47	7203	residential	244501.4

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Table A.9 (cont.)

30731.0	W1520	11.47	7203	residential	1937156.6
30731.0	W1520	11.47	7203	residential	3921.1
30731.0	W1520	11.47	7213	military	1273267.7
30731.0	W1520	11.47	7203	residential	242305.5
49583.2	W1530	55.37	7214	quarry	28391.9
49583.2	W1530	55.37	7203	residential	53344.4
49583.2	W1530	55.37	7203	residential	6675.8
49583.2	W1530	55.37	7203	residential	32483.1
49583.2	W1530	55.37	7203	residential	16901.4
49583.2	W1530	55.37	7203	residential	7515.8
49583.2	W1530	55.37	7203	residential	10043.9
49583.2	W1530	55.37	7203	residential	12610.2
49583.2	W1530	55.37	7203	residential	8710.0
49583.2	W1530	55.37	7203	residential	12131.1
49583.2	W1530	55.37	7203	residential	20376.4
49583.2	W1530	55.37	7203	residential	7486.9
49583.2	W1530	55.37	7203	residential	17047.5
43614.3	W1540	38.58	7203	residential	22688.5
43614.3	W1540	38.58	7203	residential	164084.3
43614.3	W1540	38.58	7203	residential	14289.2
43614.3	W1540	38.58	7203	residential	33542.9
43614.3	W1540	38.58	7203	residential	19800.6
43614.3	W1540	38.58	7203	residential	48767.3
43614.3	W1540	38.58	7203	residential	20198.0
43614.3	W1540	38.58	7203	residential	90700.0
43614.3	W1540	38.58	7203	residential	8439.6
60693.7	W1560	95.32	7203	residential	3206.6
60693.7	W1560	95.32	7203	residential	862.4
60693.7	W1560	95.32	7203	residential	1434.7
60693.7	W1560	95.32	7203	residential	1945.7
60693.7	W1560	95.32	7203	residential	955.4
60693.7	W1560	95.32	7203	residential	939.6
60693.7	W1560	95.32	7203	residential	1631.8
60693.7	W1560	95.32	7203	residential	1430.2
60693.7	W1560	95.32	7203	residential	981.3
60693.7	W1560	95.32	7203	residential	904.7
60693.7	W1560	95.32	7203	residential	841.1

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Table A.9 (cont.)

60693.7	W1560	95.32	7203	residential	2361.7
60693.7	W1560	95.32	7203	residential	2043.1
60693.7	W1560	95.32	7203	residential	1913.7
60693.7	W1560	95.32	7203	residential	2302.5
60693.7	W1560	95.32	7203	residential	3020.4
60693.7	W1560	95.32	7203	residential	3553.9
60693.7	W1560	95.32	7203	residential	1637.3
60693.7	W1560	95.32	7203	residential	908.2
60693.7	W1560	95.32	7203	residential	6484.1
60693.7	W1560	95.32	7203	residential	2235.3
60693.7	W1560	95.32	7203	residential	3109.6
60693.7	W1560	95.32	7203	residential	1062.2
60693.7	W1560	95.32	7203	residential	2395.9
60693.7	W1560	95.32	7203	residential	2065.2
60693.7	W1560	95.32	7203	residential	1383.1
60693.7	W1560	95.32	7203	residential	9759.9
60693.7	W1560	95.32	7203	residential	10825.1
34926.9	W1570	18.50	7203	residential	3441.6
34926.9	W1570	18.50	7203	residential	14392.8
34926.9	W1570	18.50	7203	residential	10336.2
34926.9	W1570	18.50	7203	residential	11037.9
34926.9	W1570	18.50	7203	residential	12301.8
34926.9	W1570	18.50	7203	residential	27343.2
34926.9	W1570	18.50	7203	residential	15965.0
34926.9	W1570	18.50	7203	residential	31205.4
60161.8	W1580	66.07	7203	residential	411.5
60161.8	W1580	66.07	7203	residential	1536.1
60161.8	W1580	66.07	7203	residential	3634.9
60161.8	W1580	66.07	7203	residential	2006.8
60161.8	W1580	66.07	7203	residential	14484.8
60161.8	W1580	66.07	7203	residential	20931.0
60161.8	W1580	66.07	7203	residential	95529.2
60161.8	W1580	66.07	7203	residential	13624.2
60161.8	W1580	66.07	7203	residential	9108.3
60161.8	W1580	66.07	7203	residential	14828.2
60161.8	W1580	66.07	7203	residential	6609.2
60161.8	W1580	66.07	7203	residential	23702.1

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Table A.9 (cont.)

60161.8	W1580	66.07	7203	residential	10252.7
60161.8	W1580	66.07	7203	residential	8942.9
60161.8	W1580	66.07	7203	residential	1769.9
60161.8	W1580	66.07	7203	residential	11697.4
33035.8	W1600	18.77	7203	residential	885372.4
33035.8	W1600	18.77	7203	residential	11785.3
33035.8	W1600	18.77	7203	residential	9019.7
33035.8	W1600	18.77	7203	residential	10071.7
33035.8	W1600	18.77	7203	residential	7804.0
33035.8	W1600	18.77	7203	residential	17297.6
33035.8	W1600	18.77	7203	residential	22729.6
33035.8	W1600	18.77	7203	residential	11547.0
33035.8	W1600	18.77	7203	residential	7798.1
33035.8	W1600	18.77	7203	residential	12764.5
33035.8	W1600	18.77	7203	residential	4256.4
33035.8	W1600	18.77	7203	residential	932.6
11760.5	W1610	3.34	7213	military	719118.1
11760.5	W1610	3.34	7203	residential	110022.7
46214.6	W1620	25.85	7203	residential	735102.9
46214.6	W1620	25.85	7203	residential	1109.7
46214.6	W1620	25.85	7203	residential	292.9
46214.6	W1620	25.85	7203	residential	1701.7
46214.6	W1620	25.85	7203	residential	1149.9
46214.6	W1620	25.85	7203	residential	1684.4
46214.6	W1620	25.85	7203	residential	2560.1
46214.6	W1620	25.85	7203	residential	3738.8
46214.6	W1620	25.85	7203	residential	2907.1
46214.6	W1620	25.85	7203	residential	9607.2
46214.6	W1620	25.85	7203	residential	1883.4
46214.6	W1620	25.85	7203	residential	3913.9
46214.6	W1620	25.85	7203	residential	193798.3
50292.4	W1630	40.04	7203	residential	31370.8
50292.4	W1630	40.04	7214	quarry	29200.6
50292.4	W1630	40.04	7203	residential	57605.7
50292.4	W1630	40.04	7203	residential	7066.5
50292.4	W1630	40.04	7203	residential	758.1
50292.4	W1630	40.04	7203	residential	33425.9

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Table A.9 (cont.)

50292.4	W1630	40.04	7203	residential	1978.9
50292.4	W1630	40.04	7203	residential	63.7
50292.4	W1630	40.04	7203	residential	1157.7
50292.4	W1630	40.04	7203	residential	2168.3
50292.4	W1630	40.04	7203	residential	475.7
50292.4	W1630	40.04	7203	residential	1750.7
50292.4	W1630	40.04	7203	residential	1912.1
50292.4	W1630	40.04	7203	residential	1553.8
50292.4	W1630	40.04	7203	residential	1555.1
50292.4	W1630	40.04	7203	residential	1065.1
50292.4	W1630	40.04	7203	residential	645.0
50292.4	W1630	40.04	7203	residential	4944.8
50292.4	W1630	40.04	7203	residential	868.8
50292.4	W1630	40.04	7203	residential	3453.8
50292.4	W1630	40.04	7203	residential	3438.3
50292.4	W1630	40.04	7203	residential	2841.8
50292.4	W1630	40.04	7203	residential	1922.6
50292.4	W1630	40.04	7203	residential	1586.0
50292.4	W1630	40.04	7203	residential	1058.7
50292.4	W1630	40.04	7203	residential	9402.5
50292.4	W1630	40.04	7203	residential	7154.3
50292.4	W1630	40.04	7204	industrial	84038.5
54724.8	W1650	33.14	7203	residential	161648.4
54724.8	W1650	33.14	7203	residential	407.9
54724.8	W1650	33.14	7203	residential	2298.5
54724.8	W1650	33.14	7203	residential	5958.6
54724.8	W1650	33.14	7203	residential	8397.6
54724.8	W1650	33.14	7203	residential	2744.0
54724.8	W1650	33.14	7203	residential	31693.7
54724.8	W1650	33.14	7203	residential	17497.3
54724.8	W1650	33.14	7203	residential	28525.2
54724.8	W1650	33.14	7206	cemetery	28088.3
54724.8	W1650	33.14	7203	residential	75251.6
54724.8	W1650	33.14	7203	residential	1854.8
54724.8	W1650	33.14	7203	residential	5022.4
54724.8	W1650	33.14	7203	residential	86261.1
54724.8	W1650	33.14	7203	residential	3538.9

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Table A.9 (cont.)

54724.8	W1650	33.14	7203	residential	3318.9
54724.8	W1650	33.14	7203	residential	14627.4
54724.8	W1650	33.14	7203	residential	27929.1
49996.9	W1670	37.92	7206	cemetery	19403.4
49996.9	W1670	37.92	7203	residential	17719.7
49996.9	W1670	37.92	7203	residential	11973.3
49996.9	W1670	37.92	7203	residential	34963.4
49996.9	W1670	37.92	7203	residential	1609.8
49996.9	W1670	37.92	7203	residential	813.4
49996.9	W1670	37.92	7203	residential	1844.4
49996.9	W1670	37.92	7203	residential	5467.7
49996.9	W1670	37.92	7203	residential	4565.1
49996.9	W1670	37.92	7203	residential	4474.5
49996.9	W1670	37.92	7203	residential	9320.8
49996.9	W1670	37.92	7203	residential	8809.5
49996.9	W1670	37.92	7203	residential	7793.8
49996.9	W1670	37.92	7203	residential	31576.8
49996.9	W1670	37.92	7203	residential	33474.7
49996.9	W1670	37.92	7203	residential	35100.7
49996.9	W1670	37.92	7203	residential	111108.4
49996.9	W1670	37.92	7203	residential	122529.4
49996.9	W1670	37.92	7203	residential	4278.9
49996.9	W1670	37.92	7203	residential	3414.2
49996.9	W1670	37.92	7203	residential	3182.3
49996.9	W1670	37.92	7203	residential	4483.3
49996.9	W1670	37.92	7203	residential	6076.4
49996.9	W1670	37.92	7203	residential	3251.8
49996.9	W1670	37.92	7203	residential	113416.8
24703.0	W1680	6.55	7203	residential	21142.6
24703.0	W1680	6.55	7203	residential	145553.5
27657.9	W1710	17.12	7203	residential	1054140.3
27657.9	W1710	17.12	7214	quarry	311.5
27657.9	W1710	17.12	7215	orchard	6226.4
27657.9	W1710	17.12	7203	residential	150858.2
51474.4	W1730	22.63	7203	residential	35987.3
51474.4	W1730	22.63	7203	residential	57335.4
51474.4	W1730	22.63	7203	residential	4033.9

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Table A.9 (cont.)

78245.8	W1750	111.69	7203	residential	1373.7
78245.8	W1750	111.69	7203	residential	24700.6
78245.8	W1750	111.69	7203	residential	2898.6
78245.8	W1750	111.69	7203	residential	3443.4
78245.8	W1750	111.69	7203	residential	52305.4
78245.8	W1750	111.69	7203	residential	94300.6
78245.8	W1750	111.69	7203	residential	18093.0
78245.8	W1750	111.69	7203	residential	2242.6
78245.8	W1750	111.69	7203	residential	1585.5
78245.8	W1750	111.69	7203	residential	6580.5
78245.8	W1750	111.69	7203	residential	2417.5
78245.8	W1750	111.69	7203	residential	7457.7
78245.8	W1750	111.69	7203	residential	44011.8
78245.8	W1750	111.69	7203	residential	46725.4
78245.8	W1750	111.69	7203	residential	55825.3
78245.8	W1750	111.69	7203	residential	96085.8
78245.8	W1750	111.69	7203	residential	3244.0
78245.8	W1750	111.69	7203	residential	496.5
78245.8	W1750	111.69	7203	residential	1974.8
78245.8	W1750	111.69	7203	residential	2247.1
78245.8	W1750	111.69	7203	residential	1872.4
78245.8	W1750	111.69	7203	residential	2871.0
78245.8	W1750	111.69	7203	residential	3509.5
78245.8	W1750	111.69	7203	residential	36376.6
78245.8	W1750	111.69	7203	residential	30349.1
78245.8	W1750	111.69	7203	residential	15116.1
78245.8	W1750	111.69	7203	residential	10686.5
78245.8	W1750	111.69	7203	residential	103313.7
78245.8	W1750	111.69	7203	residential	12481.2
78245.8	W1750	111.69	7203	residential	18484.9
78245.8	W1750	111.69	7203	residential	17650.3
78245.8	W1750	111.69	7203	residential	34039.9
78245.8	W1750	111.69	7203	residential	10386.3
78245.8	W1750	111.69	7203	residential	61006.4
41605.0	W1770	16.76	7203	residential	25226.5
41605.0	W1770	16.76	7203	residential	49505.9
41605.0	W1770	16.76	7203	residential	51853.5

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Table A.9 (cont.)

41605.0	W1770	16.76	7203	residential	6600.3
41605.0	W1770	16.76	7203	residential	58163.3
57266.0	W1790	67.99	7203	residential	8948.0
57266.0	W1790	67.99	7203	residential	1145.8
57266.0	W1790	67.99	7204	industrial	23819.4
57266.0	W1790	67.99	7203	residential	2299805.4
57266.0	W1790	67.99	7203	residential	43824.7
57266.0	W1790	67.99	7203	residential	23208.3
57266.0	W1790	67.99	7206	cemetery	25794.0
57266.0	W1790	67.99	7203	residential	151726.2
57266.0	W1790	67.99	7203	residential	2921.4
57266.0	W1790	67.99	7203	residential	213407.5
57266.0	W1790	67.99	7203	residential	3980.4
57266.0	W1790	67.99	7206	cemetery	13283.7
57266.0	W1790	67.99	7203	residential	12950.4
57266.0	W1790	67.99	7206	cemetery	13717.9
57266.0	W1790	67.99	7206	cemetery	10685.8
57797.9	W1800	57.26	7203	residential	463697.8
57797.9	W1800	57.26	7203	residential	16503.1
57797.9	W1800	57.26	7203	residential	8291.3
57797.9	W1800	57.26	7203	residential	162.2
57797.9	W1800	57.26	7203	residential	347302.5
57797.9	W1800	57.26	7203	residential	6751.2
26653.2	W1810	15.71	7203	residential	8927.9
26653.2	W1810	15.71	7203	residential	28615.8
26653.2	W1810	15.71	7203	residential	20934.8
26653.2	W1810	15.71	7203	residential	48821.5
26653.2	W1810	15.71	7203	residential	650.9
26653.2	W1810	15.71	7203	residential	689.5
26653.2	W1810	15.71	7203	residential	2127.1
26653.2	W1810	15.71	7203	residential	3901.8
26653.2	W1810	15.71	7203	residential	1783.2
26653.2	W1810	15.71	7203	residential	595.5
26653.2	W1810	15.71	7203	residential	4051.2
26653.2	W1810	15.71	7203	residential	2223.0
26653.2	W1810	15.71	7203	residential	479.0
26653.2	W1810	15.71	7203	residential	1629.8

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Table A.9 (cont.)

26653.2	W1810	15.71	7203	residential	2401.9
26653.2	W1810	15.71	7203	residential	1865.3
26653.2	W1810	15.71	7203	residential	6211.1
26653.2	W1810	15.71	7203	residential	4862.4
26653.2	W1810	15.71	7203	residential	6864.1
26653.2	W1810	15.71	7203	residential	3492.7
26653.2	W1810	15.71	7203	residential	2103.6
26653.2	W1810	15.71	7203	residential	2434.3
26653.2	W1810	15.71	7203	residential	8342.9
26653.2	W1810	15.71	7203	residential	2871.4
26653.2	W1810	15.71	7203	residential	5675.3
26653.2	W1810	15.71	7203	residential	11340.6
26653.2	W1810	15.71	7203	residential	4288.3
26653.2	W1810	15.71	7203	residential	3020.0
26653.2	W1810	15.71	7203	residential	7782.8
26653.2	W1810	15.71	7203	residential	2625.1
26653.2	W1810	15.71	7203	residential	16800.6
26653.2	W1810	15.71	7203	residential	4842.7
26653.2	W1810	15.71	7203	residential	5283.6
26653.2	W1810	15.71	7203	residential	5128.5
26653.2	W1810	15.71	7201	forest	21368.6
26653.2	W1810	15.71	7201	forest	12088.1
26653.2	W1810	15.71	7201	forest	1677.0
40363.9	W1820	42.69	7203	residential	58244.6
40363.9	W1820	42.69	7203	residential	147277.0
40363.9	W1820	42.69	7203	residential	126503.6
40363.9	W1820	42.69	7203	residential	4748.2
40363.9	W1820	42.69	7203	residential	1950.7
40363.9	W1820	42.69	7203	residential	2263.7
40363.9	W1820	42.69	7203	residential	1980.1
40363.9	W1820	42.69	7203	residential	2329.0
40363.9	W1820	42.69	7203	residential	10880.8
40363.9	W1820	42.69	7203	residential	9853.4
40363.9	W1820	42.69	7203	residential	7989.9
40363.9	W1820	42.69	7203	residential	5231.0
40363.9	W1820	42.69	7203	residential	144417.4
40363.9	W1820	42.69	7203	residential	1712.7

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Table A.9 (cont.)

40363.9	W1820	42.69	7203	residential	1955.4
40363.9	W1820	42.69	7203	residential	1380.5
40363.9	W1820	42.69	7203	residential	1582.2
40363.9	W1820	42.69	7203	residential	3329.3
40363.9	W1820	42.69	7203	residential	740.1
40363.9	W1820	42.69	7203	residential	2945.1
40363.9	W1820	42.69	7203	residential	3774.0
40363.9	W1820	42.69	7203	residential	2585.5
40363.9	W1820	42.69	7203	residential	5660.9
40363.9	W1820	42.69	7203	residential	7831.1
40363.9	W1820	42.69	7203	residential	10597.8
40363.9	W1820	42.69	7203	residential	8973.1
40363.9	W1820	42.69	7203	residential	1691.8
40363.9	W1820	42.69	7203	residential	2865.9
40363.9	W1820	42.69	7203	residential	2811.7
40363.9	W1820	42.69	7203	residential	8542.9
40363.9	W1820	42.69	7203	residential	3264.4
40363.9	W1820	42.69	7203	residential	9450.4
40363.9	W1820	42.69	7203	residential	9934.2
40363.9	W1820	42.69	7203	residential	4052.1
40363.9	W1820	42.69	7203	residential	4633.2
40363.9	W1820	42.69	7203	residential	9859.5
15542.8	W1830	3.12	7203	residential	241.4
56852.3	W1850	65.91	7203	residential	12552.8
56852.3	W1850	65.91	7203	residential	55221.7
56852.3	W1850	65.91	7203	residential	1309.9
56852.3	W1850	65.91	7203	residential	1121.2
56852.3	W1850	65.91	7203	residential	241.3
56852.3	W1850	65.91	7203	residential	1832.5
56852.3	W1850	65.91	7203	residential	993.0
56852.3	W1850	65.91	7203	residential	2500.2
56852.3	W1850	65.91	7203	residential	2504.1
56852.3	W1850	65.91	7203	residential	6992.2
56852.3	W1850	65.91	7203	residential	3704.0
56852.3	W1850	65.91	7203	residential	5717.1
56852.3	W1850	65.91	7203	residential	4445.8
56852.3	W1850	65.91	7203	residential	4195.2

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Table A.9 (cont.)

56852.3	W1850	65.91	7203	residential	2664.8
56852.3	W1850	65.91	7203	residential	6668.6
56852.3	W1850	65.91	7203	residential	15699.7
56852.3	W1850	65.91	7203	residential	10791.0
56852.3	W1850	65.91	7203	residential	2547.3
56852.3	W1850	65.91	7203	residential	2804.9
56852.3	W1850	65.91	7203	residential	4668.5
56852.3	W1850	65.91	7203	residential	6472.6
56852.3	W1850	65.91	7203	residential	1135.1
56852.3	W1850	65.91	7203	residential	899.1
56852.3	W1850	65.91	7203	residential	1437.1
56852.3	W1850	65.91	7203	residential	560.0
56852.3	W1850	65.91	7203	residential	1374.8
56852.3	W1850	65.91	7203	residential	1988.5
56852.3	W1850	65.91	7203	residential	1849.4
56852.3	W1850	65.91	7203	residential	1432.7
56852.3	W1850	65.91	7203	residential	2465.7
56852.3	W1850	65.91	7203	residential	1707.3
56852.3	W1850	65.91	7203	residential	807.7
56852.3	W1850	65.91	7203	residential	1764.6
56852.3	W1850	65.91	7203	residential	1997.7
56852.3	W1850	65.91	7203	residential	6118.7
56852.3	W1850	65.91	7203	residential	8192.5
56852.3	W1850	65.91	7215	orchard	7822.4
41191.3	W1860	29.05	7203	residential	2260.7
41191.3	W1860	29.05	7203	residential	1405.5
41191.3	W1860	29.05	7203	residential	35.3
41191.3	W1860	29.05	7203	residential	16880.5
41191.3	W1860	29.05	7203	residential	5766.6
41191.3	W1860	29.05	7203	residential	188339.5
27126.0	W1880	22.52	7203	residential	2527.5
27126.0	W1880	22.52	7203	residential	3068.3
27126.0	W1880	22.52	7203	residential	4942.3
27126.0	W1880	22.52	7203	residential	7462.6
27126.0	W1880	22.52	7203	residential	9723.2
51533.5	W1890	50.61	7203	residential	29942.1
51533.5	W1890	50.61	7203	residential	71072.7

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Table A.9 (cont.)

51533.5	W1890	50.61	7203	residential	69128.5
51533.5	W1890	50.61	7203	residential	2675.1
51533.5	W1890	50.61	7203	residential	7586.7
51533.5	W1890	50.61	7203	residential	5979.8
36759.0	W1900	35.41	7203	residential	15169.8
36759.0	W1900	35.41	7203	residential	1656.9
36759.0	W1900	35.41	7203	residential	964.0
36759.0	W1900	35.41	7203	residential	3632.6
36759.0	W1900	35.41	7203	residential	18140.9
36759.0	W1900	35.41	7203	residential	7388.8
36759.0	W1900	35.41	7203	residential	8893.5
36759.0	W1900	35.41	7203	residential	95417.4
38827.4	W1910	21.28	7203	residential	0.8
38827.4	W1910	21.28	7203	residential	1385.4
38827.4	W1910	21.28	7203	residential	3195.4
38827.4	W1910	21.28	7203	residential	2840.1
55374.8	W1920	84.26	7203	residential	41.4
55374.8	W1920	84.26	7217	scrub	6765.7
55374.8	W1920	84.26	7217	scrub	6701.8
55374.8	W1920	84.26	7203	residential	12340.3
55374.8	W1920	84.26	7203	residential	87895.3
55374.8	W1920	84.26	7203	residential	68217.9
55374.8	W1920	84.26	7203	residential	1522.5
55374.8	W1920	84.26	7203	residential	1848.3
55374.8	W1920	84.26	7203	residential	119688.4
55374.8	W1920	84.26	7206	cemetery	1546.0
55374.8	W1920	84.26	7203	residential	6966.3
55374.8	W1920	84.26	7203	residential	2556.0
55374.8	W1920	84.26	7205	farm	7781.6
55374.8	W1920	84.26	7206	cemetery	8192.0
55374.8	W1920	84.26	7203	residential	14745.0
55374.8	W1920	84.26	7203	residential	47999.8
55374.8	W1920	84.26	7203	residential	45848.8
55374.8	W1920	84.26	7206	cemetery	9364.5
55374.8	W1920	84.26	7203	residential	1489.5
55374.8	W1920	84.26	7203	residential	967.4
55374.8	W1920	84.26	7203	residential	1739.1

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Table A.9 (cont.)

55374.8	W1920	84.26	7203	residential	4346.6
55374.8	W1920	84.26	7203	residential	2193.4
55374.8	W1920	84.26	7203	residential	4664.9
55374.8	W1920	84.26	7203	residential	1917.1
55374.8	W1920	84.26	7206	cemetery	3077.3
34217.8	W1930	25.15	7203	residential	764.2
34217.8	W1930	25.15	7203	residential	6147.5
34217.8	W1930	25.15	7203	residential	4967.3
37527.2	W1940	44.14	7203	residential	2868.6
37527.2	W1940	44.14	7203	residential	3117.4
37527.2	W1940	44.14	7203	residential	11176.7
37527.2	W1940	44.14	7203	residential	936.7
37527.2	W1940	44.14	7203	residential	341.4
37527.2	W1940	44.14	7203	residential	1614.0
37527.2	W1940	44.14	7203	residential	630.3
37527.2	W1940	44.14	7203	residential	942.0
37527.2	W1940	44.14	7203	residential	2197.6
37527.2	W1940	44.14	7203	residential	2222.2
37527.2	W1940	44.14	7203	residential	853.7
37527.2	W1940	44.14	7203	residential	682.1
37527.2	W1940	44.14	7203	residential	2710.1
37527.2	W1940	44.14	7203	residential	1705.4
37527.2	W1940	44.14	7203	residential	1374.7
37527.2	W1940	44.14	7203	residential	1086.8
37527.2	W1940	44.14	7203	residential	1651.3
37527.2	W1940	44.14	7203	residential	1893.0
37527.2	W1940	44.14	7203	residential	3240.9
37527.2	W1940	44.14	7203	residential	4069.2
37527.2	W1940	44.14	7203	residential	2885.0
37527.2	W1940	44.14	7203	residential	10571.6
37527.2	W1940	44.14	7203	residential	1865.9
37527.2	W1940	44.14	7203	residential	7376.4
37527.2	W1940	44.14	7203	residential	4741.7
37527.2	W1940	44.14	7203	residential	3814.9
37527.2	W1940	44.14	7203	residential	3990.4
37527.2	W1940	44.14	7203	residential	3111.5
37527.2	W1940	44.14	7203	residential	9834.1

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Table A.9 (cont.)

37527.2	W1940	44.14	7203	residential	3930.6
37527.2	W1940	44.14	7203	residential	2842.3
37527.2	W1940	44.14	7203	residential	14698.4
37527.2	W1940	44.14	7203	residential	4749.6
37527.2	W1940	44.14	7203	residential	7564.9
37527.2	W1940	44.14	7203	residential	4681.6
37527.2	W1940	44.14	7203	residential	7053.3
37527.2	W1940	44.14	7203	residential	4836.7
37527.2	W1940	44.14	7203	residential	15887.3
54133.8	W1950	63.46	7203	residential	25446.6
54133.8	W1950	63.46	7203	residential	51152.1
54133.8	W1950	63.46	7203	residential	20171.9
54133.8	W1950	63.46	7203	residential	2071.7
54133.8	W1950	63.46	7203	residential	48152.6
54133.8	W1950	63.46	7203	residential	2155.8
54133.8	W1950	63.46	7203	residential	1753.8
54133.8	W1950	63.46	7203	residential	208147.7
54133.8	W1950	63.46	7203	residential	4140.3
54133.8	W1950	63.46	7203	residential	6546.8
54133.8	W1950	63.46	7203	residential	6625.8
54133.8	W1950	63.46	7203	residential	5748.9
54133.8	W1950	63.46	7203	residential	5392.5
32858.5	W1960	27.67	7203	residential	213169.6
32858.5	W1960	27.67	7206	cemetery	6676.6
32858.5	W1960	27.67	7203	residential	7845.0
33035.8	W1970	26.29	7206	cemetery	14434.4
33035.8	W1970	26.29	7203	residential	13456.3
33035.8	W1970	26.29	7203	residential	237094.6
33035.8	W1970	26.29	7203	residential	119088.5
33035.8	W1970	26.29	7203	residential	3331.4
33035.8	W1970	26.29	7203	residential	1594.2
33035.8	W1970	26.29	7203	residential	9230.7
33035.8	W1970	26.29	7203	residential	2651.1
33035.8	W1970	26.29	7203	residential	6125.5
33035.8	W1970	26.29	7203	residential	3533.1
33035.8	W1970	26.29	7203	residential	17210.8
39122.9	W1980	48.52	7203	residential	15249.4

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Table A.9 (cont.)

39122.9	W1980	48.52	7203	residential	2515.1
40718.5	W1990	46.55	7203	residential	11140.4
40718.5	W1990	46.55	7203	residential	15038.9
40718.5	W1990	46.55	7203	residential	4014.6
40718.5	W1990	46.55	7203	residential	10556.5
40718.5	W1990	46.55	7203	residential	325322.5
40718.5	W1990	46.55	7203	residential	8865.1
40718.5	W1990	46.55	7203	residential	5381.5
40718.5	W1990	46.55	7203	residential	5022.5
40718.5	W1990	46.55	7203	residential	8882.4
40718.5	W1990	46.55	7203	residential	1831.1
40718.5	W1990	46.55	7203	residential	1358.3
40718.5	W1990	46.55	7203	residential	63135.8
40718.5	W1990	46.55	7201	forest	63177.3
40718.5	W1990	46.55	7203	residential	1539.9
40718.5	W1990	46.55	7203	residential	1604.8
40718.5	W1990	46.55	7203	residential	3883.2
40718.5	W1990	46.55	7203	residential	3789.9
40718.5	W1990	46.55	7203	residential	2383.7
40718.5	W1990	46.55	7203	residential	6987.0
40718.5	W1990	46.55	7203	residential	3401.4
40718.5	W1990	46.55	7203	residential	2187.9
24171.1	W2000	15.26	7203	residential	14603.4
24171.1	W2000	15.26	7203	residential	132.4
24171.1	W2000	15.26	7203	residential	193148.6
24171.1	W2000	15.26	7203	residential	21211.0
2836.7	W2010	0.17	7203	residential	1954.1
40068.5	W2030	45.45	7203	residential	3104.3
40068.5	W2030	45.45	7203	residential	3352.4
40068.5	W2030	45.45	7203	residential	910.4
40068.5	W2030	45.45	7203	residential	1511.9
40068.5	W2030	45.45	7203	residential	1389.6
40068.5	W2030	45.45	7203	residential	3810.9
40068.5	W2030	45.45	7203	residential	2597.8
40068.5	W2030	45.45	7203	residential	1234.1
40068.5	W2030	45.45	7203	residential	2073.4
40068.5	W2030	45.45	7203	residential	1175.0

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Table A.9 (cont.)

40068.5	W2030	45.45	7203	residential	6295.3
66839.9	W2040	91.04	7203	residential	7404.9
66839.9	W2040	91.04	7203	residential	7873.0
66839.9	W2040	91.04	7203	residential	4049.6
66839.9	W2040	91.04	7203	residential	12689.1
66839.9	W2040	91.04	7203	residential	38406.1
66839.9	W2040	91.04	7203	residential	18985.3
66839.9	W2040	91.04	7203	residential	34852.3
66839.9	W2040	91.04	7203	residential	1979.0
66839.9	W2040	91.04	7203	residential	2612.0
66839.9	W2040	91.04	7203	residential	872.1
66839.9	W2040	91.04	7203	residential	1806.1
66839.9	W2040	91.04	7203	residential	2670.5
66839.9	W2040	91.04	7203	residential	3729.1
66839.9	W2040	91.04	7203	residential	791.1
66839.9	W2040	91.04	7203	residential	1758.2
66839.9	W2040	91.04	7203	residential	2686.6
66839.9	W2040	91.04	7203	residential	3050.2
66839.9	W2040	91.04	7203	residential	5117.9
66839.9	W2040	91.04	7203	residential	3047.1
66839.9	W2040	91.04	7203	residential	2778.1
66839.9	W2040	91.04	7203	residential	1391.8
66839.9	W2040	91.04	7203	residential	5981.0
66839.9	W2040	91.04	7203	residential	1560.4
66839.9	W2040	91.04	7203	residential	4919.2
66839.9	W2040	91.04	7203	residential	4155.2
66839.9	W2040	91.04	7203	residential	8799.6
66839.9	W2040	91.04	7203	residential	5072.5
66839.9	W2040	91.04	7203	residential	2514.0
66839.9	W2040	91.04	7203	residential	3782.1
66839.9	W2040	91.04	7203	residential	2067.8
66839.9	W2040	91.04	7203	residential	5229.3
66839.9	W2040	91.04	7203	residential	10607.3
66839.9	W2040	91.04	7203	residential	5874.9
66839.9	W2040	91.04	7203	residential	8901.9
29726.3	W2050	16.43	7203	residential	112566.5
29726.3	W2050	16.43	7201	forest	6421.2

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Table A.9 (cont.)

71390.4	W2060	49.11	7203	residential	27879.4
71390.4	W2060	49.11	7203	residential	3939.5
71390.4	W2060	49.11	7203	residential	180317.2
71390.4	W2060	49.11	7203	residential	51563.0
71390.4	W2060	49.11	7203	residential	15768.4
71390.4	W2060	49.11	7203	residential	21078.6
71390.4	W2060	49.11	7217	scrub	15.2
71390.4	W2060	49.11	7217	scrub	2415.3
71390.4	W2060	49.11	7217	scrub	751.8
71390.4	W2060	49.11	7203	residential	2421.2
71390.4	W2060	49.11	7203	residential	1298.8
71390.4	W2060	49.11	7203	residential	111598.3
71390.4	W2060	49.11	7203	residential	2907.0
70090.2	W1090	73.75	7203	residential	285.8
70090.2	W1090	73.75	7202	park	285.8
70090.2	W1090	73.75	7203	residential	2199.6
70090.2	W1090	73.75	7202	park	2199.6
70090.2	W1090	73.75	7203	residential	1495.9
70090.2	W1090	73.75	7202	park	1495.9
70090.2	W1090	73.75	7203	residential	104.9
70090.2	W1090	73.75	7202	park	104.9
26416.8	W1120	11.70	7203	residential	13328.9
26416.8	W1120	11.70	7202	park	13328.9
26416.8	W1120	11.70	7203	residential	4691.2
26416.8	W1120	11.70	7202	park	4691.2
26416.8	W1120	11.70	7203	residential	3959.9
26416.8	W1120	11.70	7202	park	3959.9
26416.8	W1120	11.70	7203	residential	1604.2
26416.8	W1120	11.70	7202	park	1604.2
26416.8	W1120	11.70	7203	residential	4524.7
26416.8	W1120	11.70	7202	park	4524.7
26416.8	W1120	11.70	7203	residential	2380.1
26416.8	W1120	11.70	7202	park	2380.1
26416.8	W1120	11.70	7203	residential	2871.8
26416.8	W1120	11.70	7202	park	2871.8
26416.8	W1120	11.70	7203	residential	5113.1
26416.8	W1120	11.70	7202	park	5113.1

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Table A.9 (cont.)

26416.8	W1120	11.70	7203	residential	2748.5
26416.8	W1120	11.70	7202	park	2748.5
26416.8	W1120	11.70	7203	residential	2609.1
26416.8	W1120	11.70	7202	park	2609.1
26416.8	W1120	11.70	7203	residential	2315.9
26416.8	W1120	11.70	7202	park	2315.9
26416.8	W1120	11.70	7203	residential	1247.7
26416.8	W1120	11.70	7202	park	1247.7
26416.8	W1120	11.70	7203	residential	55550.6
26416.8	W1120	11.70	7206	cemetery	55550.6
26416.8	W1120	11.70	7203	residential	4083.2
26416.8	W1120	11.70	7202	park	4083.2
26416.8	W1120	11.70	7203	residential	2094.7
26416.8	W1120	11.70	7202	park	2094.7
26416.8	W1120	11.70	7203	residential	3075.7
26416.8	W1120	11.70	7218	grass	3075.7
26416.8	W1120	11.70	7203	residential	1179.9
26416.8	W1120	11.70	7202	park	1179.9
26416.8	W1120	11.70	7203	residential	432.9
26416.8	W1120	11.70	7218	grass	432.9
26416.8	W1120	11.70	7203	residential	1018.8
26416.8	W1120	11.70	7202	park	1018.8
26416.8	W1120	11.70	7203	residential	201.6
26416.8	W1120	11.70	7218	grass	201.6
26416.8	W1120	11.70	7203	residential	1193.7
26416.8	W1120	11.70	7202	park	1193.7
26416.8	W1120	11.70	7203	residential	723.0
26416.8	W1120	11.70	7202	park	723.0
69794.8	W1130	65.79	7203	residential	2059.0
69794.8	W1130	65.79	7202	park	2059.0
69794.8	W1130	65.79	7203	residential	6865.3
69794.8	W1130	65.79	7202	park	6865.3
69794.8	W1130	65.79	7203	residential	1784.9
69794.8	W1130	65.79	7202	park	1784.9
69794.8	W1130	65.79	7203	residential	3185.8
69794.8	W1130	65.79	7202	park	3185.8
69794.8	W1130	65.79	7203	residential	1190.9

(cont. on next page)

Table A.9 (cont.)

69794.8	W1130	65.79	7202	park	1190.9
69794.8	W1130	65.79	7203	residential	36288.1
69794.8	W1130	65.79	7218	grass	36288.1
69794.8	W1130	65.79	7203	residential	3092.7
69794.8	W1130	65.79	7218	grass	3092.7
41959.6	W1160	19.24	7203	residential	144.9
41959.6	W1160	19.24	7202	park	144.9
41959.6	W1160	19.24	7203	residential	4957.3
41959.6	W1160	19.24	7202	park	4957.3
41959.6	W1160	19.24	7203	residential	7604.8
41959.6	W1160	19.24	7202	park	7604.8
41959.6	W1160	19.24	7203	residential	688.3
41959.6	W1160	19.24	7202	park	688.3
41959.6	W1160	19.24	7203	residential	1387.3
41959.6	W1160	19.24	7202	park	1387.3
41959.6	W1160	19.24	7203	residential	8693.5
41959.6	W1160	19.24	7218	grass	8693.5
41959.6	W1160	19.24	7203	residential	2586.6
41959.6	W1160	19.24	7202	park	2586.6
41959.6	W1160	19.24	7203	residential	1634.5
41959.6	W1160	19.24	7218	grass	1634.5
41959.6	W1160	19.24	7203	residential	4457.5
41959.6	W1160	19.24	7202	park	4457.5
41959.6	W1160	19.24	7203	residential	2471.4
41959.6	W1160	19.24	7202	park	2471.4
41959.6	W1160	19.24	7203	residential	34942.4
41959.6	W1160	19.24	7202	park	34942.4
41959.6	W1160	19.24	7203	residential	2580.6
41959.6	W1160	19.24	7218	grass	2580.6
41959.6	W1160	19.24	7203	residential	3889.8
41959.6	W1160	19.24	7202	park	3889.8
41959.6	W1160	19.24	7203	residential	198.7
41959.6	W1160	19.24	7218	grass	198.7
41959.6	W1160	19.24	7203	residential	1898.6
41959.6	W1160	19.24	7218	grass	1898.6
41959.6	W1160	19.24	7203	residential	3085.2
41959.6	W1160	19.24	7201	forest	3085.2

(cont. on next page)

Table A.9 (cont.)

41959.6	W1160	19.24	7203	residential	1641.6
41959.6	W1160	19.24	7202	park	1641.6
41959.6	W1160	19.24	7203	residential	1257.1
41959.6	W1160	19.24	7202	park	1257.1
41959.6	W1160	19.24	7203	residential	1093.2
41959.6	W1160	19.24	7202	park	1093.2
41959.6	W1160	19.24	7203	residential	1166.5
41959.6	W1160	19.24	7202	park	1166.5
41959.6	W1160	19.24	7203	residential	3140.2
41959.6	W1160	19.24	7202	park	3140.2
41959.6	W1160	19.24	7203	residential	1722.9
41959.6	W1160	19.24	7202	park	1722.9
41959.6	W1160	19.24	7203	residential	823.6
41959.6	W1160	19.24	7202	park	823.6
51415.3	W1270	41.45	7203	residential	172.4
51415.3	W1270	41.45	7218	grass	172.4
30731.0	W1520	11.47	7203	residential	1323.6
30731.0	W1520	11.47	7202	park	1323.6
30731.0	W1520	11.47	7203	residential	39197.4
30731.0	W1520	11.47	7206	cemetery	39197.4
46214.6	W1620	25.85	7203	residential	1830.8
46214.6	W1620	25.85	7206	cemetery	1830.8
57797.9	W1800	57.26	7203	residential	5210.7
57797.9	W1800	57.26	7206	cemetery	5210.7
57797.9	W1800	57.26	7203	residential	6498.7
57797.9	W1800	57.26	7202	park	6498.7
55374.8	W1920	84.26	7217	scrub	2084.8
55374.8	W1920	84.26	7203	residential	2084.8
55374.8	W1920	84.26	7203	residential	2270.6
55374.8	W1920	84.26	7205	farm	2270.6

Table A.10. Alluvial zone land use data for SMA model

Name of Sub-Basin	Area of Sub-Basin (km^2)	Land Use Code	Land Use	Perimeter (m)	Land Use Area (m^2)
W640	7.17	7201	forest	142.8	630.2

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Table A.10 (cont.)

W650	4.05	7203	residential	855.3	12138.4
W650	4.05	7203	residential	5660.9	528860.6
W650	4.05	7216	vineyard	1167.8	43226.7
W670	6.16	7201	forest	494.2	11808.3
W670	6.16	7206	cemetery	822.4	37834.1
W680	3.47	7203	residential	1179.0	57596.4
W690	7.95	7203	residential	428.5	7610.6
W690	7.95	7203	residential	522.5	15277.0
W690	7.95	7203	residential	466.8	9711.7
W690	7.95	7203	residential	617.9	18386.4
W690	7.95	7206	cemetery	853.4	39319.5
W700	0.80	7216	vineyard	723.6	19921.9
W710	6.08	7203	residential	13372.6	1220742.8
W710	6.08	7203	residential	632.7	10530.8
W730	0.10	7216	vineyard	72.3	179.1
W740	7.48	7203	residential	18906.9	4594829.6
W750	5.29	7203	residential	16288.1	2391080.8
W750	5.29	7201	forest	256.8	2545.8
W760	13.10	7203	residential	592.3	14200.9
W760	13.10	7204	industrial	1156.1	69035.8
W780	6.21	7203	residential	1153.0	56292.7
W780	6.21	7203	residential	709.7	29739.4
W790	10.15	7203	residential	987.1	38291.5
W790	10.15	7203	residential	1929.9	136402.4
W790	10.15	7203	residential	1881.8	86603.0
W790	10.15	7203	residential	38.6	63.9
W800	16.84	7203	residential	1643.2	147832.8
W800	16.84	7203	residential	2313.9	245194.0
W800	16.84	7206	cemetery	523.2	17926.4
W800	16.84	7203	residential	1310.6	96123.7
W800	16.84	7203	residential	1199.9	45066.6
W800	16.84	7203	residential	2346.8	129389.0
W800	16.84	7215	orchard	314.5	4614.9
W810	7.19	7203	residential	1513.2	55264.4
W820	12.46	7203	residential	6942.7	641325.8
W830	5.30	7203	residential	823.2	25593.6
W840	10.57	7204	industrial	758.7	18954.8

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Table A.10 (cont.)

W840	10.57	7204	industrial	319.5	6251.8
W840	10.57	7205	farm	671.4	24003.2
W840	10.57	7205	farm	637.1	25141.6
W840	10.57	7205	farm	1023.7	62346.3
W840	10.57	7205	farm	789.6	35516.6
W840	10.57	7205	farm	426.3	10652.3
W840	10.57	7205	farm	437.3	11135.1
W840	10.57	7204	industrial	1092.8	64131.6
W840	10.57	7204	industrial	321.4	5370.4
W840	10.57	7204	industrial	410.8	10379.5
W840	10.57	7203	residential	1531.4	126397.3
W860	6.11	7204	industrial	817.9	18355.0
W860	6.11	7205	farm	93.9	385.6
W860	6.11	7204	industrial	388.8	5664.1
W860	6.11	7204	industrial	565.5	16476.9
W860	6.11	7203	residential	2282.6	91398.2
W900	13.94	7203	residential	1344.6	29701.9
W900	13.94	7203	residential	191.3	1757.5
W920	6.29	7203	residential	2181.8	172130.6
W920	6.29	7203	residential	1668.7	147187.2
W930	6.46	7203	residential	1862.3	104244.4
W930	6.46	7203	residential	301.0	1629.2
W940	6.06	7203	residential	1204.5	44193.2
W940	6.06	7203	residential	1889.7	69632.0
W940	6.06	7203	residential	1159.2	52251.4
W960	8.25	7203	residential	1558.3	105601.5
W970	11.44	7203	residential	4395.9	443250.6
W990	16.00	7203	residential	2190.1	251716.1
W1010	6.98	7203	residential	4301.9	359411.0
W1010	6.98	7203	residential	4148.6	603437.1
W1030	7.10	7213	military	3635.9	240993.5
W1030	7.10	7203	residential	593.5	13217.5
W1040	14.50	7203	residential	2121.2	244501.4
W1040	14.50	7203	residential	9001.9	1539793.9
W1040	14.50	7203	residential	289.4	5030.9
W1040	14.50	7213	military	6251.8	1992385.8
W1040	14.50	7203	residential	1972.3	193798.3

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Table A.10 (cont.)

W1040	14.50	7203	residential	1591.5	110022.7
W1040	14.50	7203	residential	2632.8	242305.5
W1050	9.02	7203	residential	4413.0	764181.7
W1060	7.10	7203	residential	789.7	31370.8
W1060	7.10	7214	quarry	127.8	1012.7
W1060	7.10	7203	residential	936.8	57605.7
W1060	7.10	7204	industrial	1237.7	84038.5
W1080	5.60	7203	residential	1574.9	164084.3
W1110	16.35	7206	cemetery	634.4	19403.4
W1110	16.35	7203	residential	881.2	31576.8
W1110	16.35	7203	residential	31.0	15.0
W1110	16.35	7203	residential	262.8	4278.9
W1110	16.35	7203	residential	349.4	3251.8
W1110	16.35	7203	residential	1925.3	113416.8
W1120	6.05	7203	residential	1447.1	21142.6
W1120	6.05	7203	residential	903.1	13015.9
W1130	9.57	7203	residential	5205.8	1054140.3
W1130	9.57	7215	orchard	352.6	6226.4
W1140	10.00	7203	residential	1093.8	31693.7
W1140	10.00	7203	residential	733.9	17497.3
W1140	10.00	7203	residential	890.7	28525.2
W1140	10.00	7203	residential	1406.7	75251.6
W1140	10.00	7203	residential	495.2	5022.3
W1140	10.00	7203	residential	243.5	1843.4
W1140	10.00	7203	residential	526.4	14627.4
W1140	10.00	7203	residential	646.0	27929.1
W1150	8.71	7203	residential	4235.9	161648.3
W1150	8.71	7206	cemetery	837.2	28088.3
W1150	8.71	7203	residential	247.5	3538.9
W1150	8.71	7203	residential	154.2	1475.5
W1180	6.76	7203	residential	1406.4	57335.4
W1180	6.76	7203	residential	283.0	4033.9
W1210	6.14	7203	residential	1159.2	39273.6
W1210	6.14	7203	residential	1464.6	51853.5
W1210	6.14	7203	residential	402.3	6600.3
W1230	30.37	7203	residential	8783.5	2164826.9
W1230	30.37	7206	cemetery	260.1	3428.6

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Table A.10 (cont.)

W1230	30.37	7203	residential	2672.8	151726.2
W1230	30.37	7203	residential	2652.2	116802.0
W1230	30.37	7206	cemetery	476.5	13283.7
W1240	30.66	7203	residential	3379.8	463697.8
W1240	30.66	7203	residential	2316.9	69243.8
W1260	14.13	7203	residential	1031.1	27695.4
W1260	14.13	7206	cemetery	364.4	7710.7
W650	4.05	7203	residential	106.6	285.8
W650	4.05	7202	park	106.6	285.8
W650	4.05	7203	residential	248.9	2199.6
W650	4.05	7202	park	248.9	2199.6
W650	4.05	7203	residential	167.1	1495.9
W650	4.05	7202	park	167.1	1495.9
W650	4.05	7203	residential	156.5	104.9
W650	4.05	7202	park	156.5	104.9
W710	6.08	7203	residential	220.0	2059.0
W710	6.08	7202	park	220.0	2059.0
W710	6.08	7203	residential	357.6	6865.3
W710	6.08	7202	park	357.6	6865.3
W710	6.08	7203	residential	188.9	1784.9
W710	6.08	7202	park	188.9	1784.9
W710	6.08	7203	residential	243.4	3185.8
W710	6.08	7202	park	243.4	3185.8
W710	6.08	7203	residential	148.6	1191.0
W710	6.08	7202	park	148.6	1191.0
W710	6.08	7203	residential	1517.2	36288.1
W710	6.08	7218	grass	1517.2	36288.1
W710	6.08	7203	residential	306.5	3092.7
W710	6.08	7218	grass	306.5	3092.7
W740	7.48	7203	residential	511.8	13328.9
W740	7.48	7202	park	511.8	13328.9
W740	7.48	7203	residential	281.5	4691.2
W740	7.48	7202	park	281.5	4691.2
W740	7.48	7203	residential	265.2	3959.9
W740	7.48	7202	park	265.2	3959.9
W740	7.48	7203	residential	177.6	1604.2
W740	7.48	7202	park	177.6	1604.2

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Table A.10 (cont.)

W740	7.48	7203	residential	267.7	4524.7
W740	7.48	7202	park	267.7	4524.7
W740	7.48	7203	residential	229.9	2380.1
W740	7.48	7202	park	229.9	2380.1
W740	7.48	7203	residential	223.6	2871.8
W740	7.48	7202	park	223.6	2871.8
W740	7.48	7203	residential	279.8	5113.1
W740	7.48	7202	park	279.8	5113.1
W740	7.48	7203	residential	208.6	2748.5
W740	7.48	7202	park	208.6	2748.5
W740	7.48	7203	residential	234.0	2609.1
W740	7.48	7202	park	234.0	2609.1
W740	7.48	7203	residential	192.7	2315.9
W740	7.48	7202	park	192.7	2315.9
W740	7.48	7203	residential	156.9	1247.7
W740	7.48	7202	park	156.9	1247.7
W740	7.48	7203	residential	1030.8	55550.6
W740	7.48	7206	cemetery	1030.8	55550.6
W740	7.48	7203	residential	256.5	4083.2
W740	7.48	7202	park	256.5	4083.2
W740	7.48	7203	residential	193.2	2094.7
W740	7.48	7202	park	193.2	2094.7
W740	7.48	7203	residential	229.8	3075.7
W740	7.48	7218	grass	229.8	3075.7
W740	7.48	7203	residential	136.3	1179.9
W740	7.48	7202	park	136.3	1179.9
W740	7.48	7203	residential	170.5	432.9
W740	7.48	7218	grass	170.5	432.9
W740	7.48	7203	residential	130.7	1018.8
W740	7.48	7202	park	130.7	1018.8
W740	7.48	7203	residential	50.6	201.6
W740	7.48	7218	grass	50.6	201.6
W740	7.48	7203	residential	151.5	1193.7
W740	7.48	7202	park	151.5	1193.7
W740	7.48	7203	residential	129.9	723.0
W740	7.48	7202	park	129.9	723.0
W750	5.29	7203	residential	72.8	144.9

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Table A.10 (cont.)

W750	5.29	7202	park	72.8	144.9
W750	5.29	7203	residential	293.2	4957.3
W750	5.29	7202	park	293.2	4957.3
W750	5.29	7203	residential	335.7	7604.8
W750	5.29	7202	park	335.7	7604.8
W750	5.29	7203	residential	104.3	688.3
W750	5.29	7202	park	104.3	688.3
W750	5.29	7203	residential	162.8	1387.3
W750	5.29	7202	park	162.8	1387.3
W750	5.29	7203	residential	456.6	8693.5
W750	5.29	7218	grass	456.6	8693.5
W750	5.29	7203	residential	244.2	2586.6
W750	5.29	7202	park	244.2	2586.6
W750	5.29	7203	residential	156.1	1634.5
W750	5.29	7218	grass	156.1	1634.5
W750	5.29	7203	residential	358.9	4457.5
W750	5.29	7202	park	358.9	4457.5
W750	5.29	7203	residential	918.2	34942.4
W750	5.29	7202	park	918.2	34942.4
W750	5.29	7203	residential	247.4	2580.6
W750	5.29	7218	grass	247.4	2580.6
W750	5.29	7203	residential	351.7	3889.8
W750	5.29	7202	park	351.7	3889.8
W750	5.29	7203	residential	91.4	198.7
W750	5.29	7218	grass	91.4	198.7
W750	5.29	7203	residential	249.8	1898.6
W750	5.29	7218	grass	249.8	1898.6
W750	5.29	7203	residential	240.3	3085.2
W750	5.29	7201	forest	240.3	3085.2
W750	5.29	7203	residential	192.7	1641.6
W750	5.29	7202	park	192.7	1641.6
W750	5.29	7203	residential	142.7	1257.1
W750	5.29	7202	park	142.7	1257.1
W750	5.29	7203	residential	132.6	1093.2
W750	5.29	7202	park	132.6	1093.2
W750	5.29	7203	residential	150.2	1166.5
W750	5.29	7202	park	150.2	1166.5

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Table A.10 (cont.)

W750	5.29	7203	residential	360.7	3140.2
W750	5.29	7202	park	360.7	3140.2
W750	5.29	7203	residential	173.9	1722.9
W750	5.29	7202	park	173.9	1722.9
W750	5.29	7203	residential	146.4	823.6
W750	5.29	7202	park	146.4	823.6
W820	12.46	7203	residential	46.8	172.4
W820	12.46	7218	grass	46.8	172.4
W1040	14.50	7203	residential	143.6	1323.6
W1040	14.50	7202	park	143.6	1323.6
W1040	14.50	7203	residential	835.7	40990.9
W1040	14.50	7206	cemetery	835.7	40990.9
W1240	30.66	7203	residential	334.7	6498.7
W1240	30.66	7202	park	334.7	6498.7

Table A.11. Weighted soil storage and initial abstraction for SCS CN Model

	Area of Soil Types (m²)				Average Curve Numbers (CN)				Weighted Soil Storage (mm)	Initial Abstraction (mm)
Sub-basin	A	B	C	D	A	B	C	D		
W1040	4499465	27928309	0	6288315	32	58	72	79	206	41
W1050	27732	9506953	2671565	17059067	Soil Storage (S=(1000/CN)-10)				109	22
W1060	2055761	21503967	4777858	8490502	21	7	4	3	166	33
W1070	21618501	655842	780655	22388					514	103
W1080	15717	0	0	0					540	108
W1090	11985836	2165597	5347378	48487198					157	31
W1100	1450060	0	0	0					540	108
W1110	9084364	7102834	0	5002284					309	62
W1120	9901442	0	0	0					540	108
W1130	13431070	1787258	4610155	38803638					182	36
W1140	95246	0	0	0					540	108
W1150	7492182	430813	3772321	18175319					192	38
W1160	9820550	0	512269	8162869					319	64
W1170	4652170	5191195	0	2322325					298	60

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Table A.11 (cont.)

W1180	19057983	1032845	0	0					521	104
W1190	1633687	0	0	69472					520	104
W1200	3311990	545897	1925913	14597240					150	30
W1210	1136732	840137	8577227	8811578					114	23
W1220	8566246	3515992	3478448	29701518					168	34
W1230	19105472	11514669	2265896	6283342					334	67
W1240	3924228	11144853	1189145	0					264	53
W1250	8713385	995825	1657172	15652188					226	45
W1260	5013771	11101984	853855	0					285	57
W1270	22661248	4401843	2669331	10998532					345	69
W1280	891439	0	2227728	16477153					93	19
W1290	1215521	0	223352	18367313					97	19
W1300	6655479	2368950	1385324	9734785					239	48
W1310	987106	378701	599394	0					337	67
W1320	2449885	0	1811367	13138614					137	27
W1330	6640630	1458173	8972091	0					278	56
W1340	444636	0	0	0					540	108
W1350	13952975	8135089	47949	1980172					380	76
W1360	5548442	0	4878938	4638791					252	50
W1370	1084381	0	984758	3086					329	66
W1380	2383321	0	0	0					540	108
W1390	14118013	213133	4577737	4626624					358	72
W1400	7170479	171619	3104183	38374849					139	28
W1410	77951	0	0	0					540	108
W1420	7278428	2003879	3805339	43338679					135	27
W1430	17005363	492956	1069757	12923667					325	65
W1440	1063489	0	0	0					540	108
W1450	9864504	735634	0	18492841					231	46
W1460	4631155	0	0	0					540	108
W1470	11981581	3897585	0	14255497					270	54
W1480	970936	0	0	0					540	108
W1490	7215955	69491	9939920	28778602					149	30
W1500	55881	0	0	0					540	108
W1510	7002087	0	0	98320					533	107
W1520	6908369	0	2719963	18187					415	83
W1530	235267	0	12102847	42212101					76	15
W1540	5906455	0	9878266	22451851					149	30

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Table A.11 (cont.)

W1560	1587772	257149	26914643	63232404					85	17
W1570	703161	1433503	146891	16208259					95	19
W1580	531485	0	10499306	54858802					76	15
W1590	842584	0	0	0					540	108
W1600	5350128	126113	3446321	9119864					214	43
W1610	3341522	0	0	0					540	108
W1620	3730534	0	7942268	14131967					145	29
W1630	7176630	367690	7506768	24986052					159	32
W1640	5073839	0	0	0					540	108
W1650	23087636	1735274	4368888	3780786					408	82
W1660	178994	0	0	0					540	108
W1670	17216255	3850772	5955552	10896314					299	60
W1680	5239581	0	280286	0					517	103
W1710	5825124	0	8687085	2115022					249	50
W1720	281152	0	0	0					540	108
W1730	17216361	0	3495115	861806					449	90
W1740	3214976	0	0	0					540	108
W1750	6694483	0	32166534	70369788					106	21
W1760	33436	0	0	0					540	108
W1770	6568992	4995688	1029619	2186812					319	64
W1780	348900	0	0	0					540	108
W1790	27006311	14149948	2460438	19371401					297	59
W1800	15037095	1645142	14618708	24611921					206	41
W1810	479411	1070290	1639664	12519367					93	19
W1820	904006	500895	1555744	38168365					80	16
W1830	1369147	14046	0	1604914					284	57
W1840	141021	0	0	0					540	108
W1850	2242514	7185911	6436499	49595277					100	20
W1860	5268710	1403151	5025372	17159155					165	33
W1870	4563634	2548103	759776	12250889					191	38
W1880	0	33456	3292911	10534123					75	15
W1890	7319967	5442675	12732422	23552894					159	32
W1900	241507	509348	11772314	7743300					94	19
W1910	2038812	170201	3147092	14757085					121	24
W1920	2150	1298709	50085582	32480533					88	18
W1930	812001	16022	18674208	4835460					107	21
W1940	2881009	1583309	5690867	32886715					108	22

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Table A.11 (cont.)

W1950	737444	0	12559509	33201541					83	17
W1960	8812797	3659497	6527247	8541702					242	48
W1970	3221279	1080655	7664090	13799331					141	28
W1980	0	660103	14899459	25515107					81	16
W1990	4372964	578072	1763314	39006771					115	23
W2000	0	0	14960554	49819					99	20
W2010	33190	0	46617	0					282	56
W2020	372271	0	598194	616038					190	38
W2030	0	166318	0	39629199					68	14
W2040	6424186	2811761	38351409	42810493					118	24
W2050	13634	0	10512109	5893075					88	18
W2060	0	250524	39407712	9043764					93	19

Table A.12 SMA Model Parameters

Sub-basin	Σ Field Capacity (mm)	Σ Soil Storage (mm)	Perkolation (mm/hour)	Infiltration (mm/hour)
W1260	19.5	78.0	1.5	1.5
W1250	19.5	78.0	1.5	1.5
W1240	19.5	78.7	1.5	1.5
W1230	19.5	79.8	1.5	1.5
W1220	19.5	113.6	1.5	1.5
W1210	19.5	113.6	1.5	1.5
W1200	19.5	113.6	1.5	1.5
W1190	19.5	96.7	1.5	1.5
W1180	19.5	123.0	1.5	1.5
W1170	19.5	140.2	1.5	1.5
W1160	19.5	144.0	1.5	1.5
W1150	9.7	57.8	1.5	1.5
W1140	13.2	76.9	1.5	1.5
W1130	19.5	144.0	1.5	1.5
W1120	17.6	129.7	1.5	1.5
W1110	14.0	62.9	1.5	1.9
W1100	1.3	9.5	1.5	1.5
W1090	0.7	5.2	1.5	1.5
W1080	19.5	143.8	1.5	1.5
W1070	66.7	280.8	1.5	3.6
W1060	74.8	306.5	1.5	3.9
W1050	75.8	336.0	1.5	3.7
W1040	86.9	211.9	1.5	2.5

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Table A.12 (cont.)

W1030	101.8	363.1	1.5	4.1
W1020	77.7	118.8	1.5	1.5
W1010	77.7	120.4	1.5	1.5
W1000	77.7	118.8	1.5	1.5
W990	92.2	265.6	1.5	3.1
W980	77.7	119.7	1.5	1.5
W970	77.7	118.8	1.5	1.5
W960	77.7	122.2	1.5	1.5
W950	77.7	119.4	1.5	1.5
W940	32.3	40.0	1.5	2.5
W930	20.0	24.7	1.5	2.1
W920	9.7	12.0	1.5	1.8
W910	109.5	135.5	1.5	5.1
W900	29.7	45.5	1.5	1.6
W880	109.8	135.8	1.5	5.1
W870	49.6	67.0	1.5	2.5
W860	64.5	79.8	1.5	3.6
W850	111.0	137.3	1.5	5.1
W840	105.4	130.3	1.5	4.9
W830	87.9	108.9	1.5	4.3
W820	31.3	113.5	1.5	11.8
W810	111.0	140.1	1.5	3.9
W800	37.9	124.8	1.5	12.2
W790	7.6	69.5	1.5	9.4
W780	2.3	15.6	1.5	2.9
W770	12.3	63.4	1.5	1.6
W760	17.0	87.1	1.5	9.4
W750	19.5	135.2	1.5	1.5
W740	19.5	135.2	1.5	1.5
W730	19.5	135.2	1.5	1.5
W720	19.5	138.1	1.5	1.5
W710	19.5	135.3	1.5	1.5
W700	19.5	136.7	1.5	1.5
W690	19.5	131.0	1.5	1.5
W680	19.5	129.9	1.5	1.5
W670	18.0	114.1	1.5	9.9
W660	19.5	137.9	1.5	1.5
W650	19.5	135.7	1.5	1.5
W640	19.5	128.8	1.5	7.4

Table A.13. Infiltration rates for SCS Curve Number model

Sub-basin	Weighted Infiltration (mm/hour)	Sub-basin	Weighted Infiltration (mm/hour)
W1040	13.3	W1540	8.6
W1050	5.1	W1560	3.3
W1060	10.0	W1570	3.8
W1070	39.3	W1580	2.4
W1080	41.4	W1590	41.4
W1090	9.1	W1600	14.1
W1100	41.4	W1610	41.4
W1110	21.9	W1620	8.4
W1120	41.4	W1630	9.4
W1130	11.2	W1640	41.4
W1140	41.4	W1650	30.4
W1150	12.1	W1660	41.4
W1160	22.8	W1670	21.2
W1170	21.0	W1680	39.6
W1180	39.9	W1710	17.4
W1190	39.8	W1720	41.4
W1200	8.6	W1730	33.9
W1210	5.9	W1740	41.4
W1220	10.1	W1750	5.0
W1230	24.1	W1760	41.4
W1240	18.2	W1770	22.8
W1250	15.0	W1780	41.4
W1260	19.9	W1790	21.0
W1270	25.0	W1800	13.5
W1280	3.7	W1810	3.8
W1290	4.0	W1820	2.6
W1300	16.1	W1830	19.8
W1310	24.5	W1840	41.4
W1320	7.5	W1850	4.3
W1330	19.8	W1860	9.9
W1340	41.4	W1870	11.9
W1350	27.9	W1880	2.4
W1360	17.4	W1890	9.5
W1370	24.1	W1900	4.3
W1380	41.4	W1910	6.2

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Table A.13 (cont.)

W1390	26.2	W1920	3.8
W1400	7.6	W1930	5.6
W1410	41.4	W1940	5.0
W1420	7.2	W1950	3.1
W1430	23.3	W1960	16.4
W1440	41.4	W1970	8.0
W1450	15.3	W1980	3.0
W1460	41.4	W1990	5.6
W1470	18.6	W2000	5.1
W1480	41.4	W2010	20.2
W1490	8.6	W2020	12.2
W1500	41.4	W2030	1.5
W1510	40.8	W2040	6.2
W1520	31.1	W2050	3.8
W1530	2.5	W2060	4.5