Development of a surface runoff prediction model environmental sciences essay

The on-going enlargement of urbanised countries has placed increasing accent on related H2O direction jobs such as implosion therapy andpollutioncontrol. Urbanization increases the imperviable land country in a part, which in bend, decreases infiltration, increases overflow, and decreases the clip during which overflow occurs. Liu et al. , (2004) stated that as a watershed becomes more developed, it besides becomes more hydrologically active and in so making, changes the inundation volume, overflow constituents every bit good as the beginning of watercourse flow. The consequence is that inundations that one time occurred infrequently during the pre-development periods frequently become more frequent and more terrible due to the transmutation of the watershed from rural to urban land utilizations.

Previous research has besides shown that urbanisation and the addition in imperviable surfaces increases peak discharge (Ferguson and Suckling 1990 ; Booth and Jackson 1997) . Galster et al. , (2006) examined the effects of imperviable surfaces within urbanised landscapes on river discharge within drainage countries and found it to be nonlinear for extremum flows in little urbanised countries. The survey was conducted in two immediate and physically similar water partings in east-central Pennsylvania but which had different per centum urban land usage (20 % and 3 % severally) , and tested the premise that discharge exhibits a additive or close additive relationship with drainage country (hundred ~ 1) for an urbanised water parting. Linear grading of discharge with drainage country has the deduction that all parts of the drainage basin contribute about the same volume of H2O at about the same rate as either overflow or as recharge to the H2O tabular

array (Fleckenstein et al. 2004) . Galster et al. , (2006) argued that in the urban watershed they studied, they observed that the part of H2O from each unit of the drainage country was non equal with the downstream urbanised country lending a greater volume per unit country than the upstream forested or rural countries over the clip period represented by the extremum flows. The decision was hence that urbanisation reduces the infiltration capacity and increase overflow.

Runoff Determination

Runoff is generated by rainstorms and the happening and measure are dependent on the features of the peculiar rainfall event, i. e. strength, continuance and distribution. Water making the land surface infiltrates into the dirt until it reaches a phase where the rate of rainfall (strength) exceeds the infiltration capacity of the dirt. The infiltration capacity of the dirt depends on its texture and construction, every bit good as on the antecedent dirt wet status. The initial infiltration capacity of a dry dirt is high but, asthe stormcontinues, it decreases until it reaches a steady value termed as concluding infiltration rate.

[The procedure of overflow coevals continues every bit long as the rainfall strength exceeds the existent infiltration capacity of the dirt but will halt every bit shortly as the rate of rainfall beads below the existent rate of infiltration. The infiltration capacity of dirt will change depending on both the dirt texture and construction. Soil composed of a high per centum of sand consequences in rapid infiltration because these dirts have big, good connected pore infinites. Clay soils on the other manus have low infiltration

rates due to their smaller pore sized infinites. However, there is really less entire pore infinite in a unit volume of coarse, flaxen dirt than that of dirt composed largely of clay. As a consequence, sandy dirts fill quickly and normally bring forth overflow quicker than clay dirts (Ritter, 2006) Baharudin 2007. Ms. Thesis] Ritter 2006 - The PhysicalEnvironment]

Impact of Urbanization on Infiltration Capacity

Infiltration is the procedure by which precipitation percolates downward through the dirt and replenishes dirt wet, recharges the aquifers, and finally supports watercourse flows during dry periods. The rate of infiltration (degree Fahrenheit) is influenced by several factors which includes the type and extent of vegetive screen, the status of the surface crust, temperature, rainfall strength, physical belongingss of the dirt and H2O quality (Viessman Jr. and Lewis 2003 ; Liu et Al. 2004) .

Research has shown that one of the most outstanding land usage impacting hydrology is urban development (Finkenbine et al. , 2000 ; Lee and Bang, 2000 ; Bledsoe and Watson, 2001 ; Rose and Peters, 2001 ; Brezonik and Stadelmann, 2002) . Surveies have besides shown that additions in the proportion of imperviable surface (IS) of 10 % may significantly impact watercourse hydrology (Hammer, 1972 ; Hollis, 1975) . Hydrological effects of increased IS typically result in elevated quickflow coevals which produces both higher magnitudes and increase early extremums in storm hydrographs (Dunne and Leopold, 1978 ; Hirsch et al. , 1990) .

Goudie (1990) , describes urbanisation as the transition of other types of land utilizations associated with the growing of population and the economic system. This procedure has a considerable hydrological impact in footings of act uponing the nature of overflow and other hydrological features. Impact nevertheless varies harmonizing to the phase of development every bit good. In the early phases, the remotion of trees and flora may diminish the evapotranspiration and interception and may besides increase deposit in rivers. Subsequently in the development of these countries when building of houses, streets, and culverts Begins, the impacts may include reduced infiltration, lowered groundwater tabular array, increased storm H2O flows, and decreased base flows during dry periods. After the development of these residential and commercial edifices has been completed, increased impenetrability will finally cut down the clip of overflow and concentration so that extremum discharges are higher and occur Oklahoman after rainfall starts in basins. The volume of overflow and inundation harm potency is hence greatly increased. Furthermore, the installing of cloacas and storm drains accelerates overflow.

Pitt et al. , (2002) reported that natural infiltration is significantly reduced in urban countries due to several factors: the reduced country of exposed dirts, remotion of surface dirts and exposing subsurface dirts, and besides the compression of dirts during Earth traveling and building operations. The reduced countries of dirts are typically associated with increased overflow volumes and peak flow rates.

Land usage and land screen alterations have both direct and indirect impacts on the hydrological rhythm, H2O quality, measure available to drinkable H2O, and clime. The four major impacts of land usage alteration includes: addition or reduced incidences of inundations and drouths, alterations in river and groundwater governments, and besides the negative or positive impact H2O quality (Roger 1994 ; Kim et Al. 2002) . In add-on there are besides indirect impacts on clime and later impact on H2O quality and measure. Kim et al. , (2002) in a survey of land-use alterations at both NASA 's John F. Kennedy Space Center (KSC) and the Indian River Lagoon (IRL) watershed, an addition in overflow of 49 % and 113 % severally from KSC and IRL over the period 1920-1990 was observed. Most of the addition in overflow came from urban landscape although increased agricultural land uses in the IRL besides contributed to increased overflow. Large differences in estimated overflow were due to differences in the sum of urban land usage within the several countries 35 % for the IRL versus 21 % for KSC. Harmonizing to Kim et al. , (2002) , land-use alteration can hold a dramatic impact on one-year overflow volume, therefore the effects of land-use alteration on one-year or long-run overflow should be considered in land-use planning.

SCS CN method

The sum of overflow produced by a watershed is chiefly controlled by both the ability of the dirt to `` soak up '' precipitation and the sum and type of vegetive screen found on the surface of the dirt. Acknowledging this, the United states Department of Agriculture (USDA) NRCS (antecedently called

the Soil Conservation Service, SCS) developed in the 1950 's a method for gauging the volume of direct overflow from rainfall. This figure varies from 0 (rainfall bring forthing no overflow) to 100 (all rainfall runs off) . The SCS curve figure is the most widely used method because of its comparative simpleness. Curve figure defines the watershed storage and is determined for a watershed or sub-watershed preponderantly from the types of dirts, vegetive screen, and land-use features. The CN method is an empirical attack to gauging direct overflow and was developed for little agricultural water partings.

During a rainfall event, there is a threshold which must be exceeded before overflow occurs and for this threshold to be exceeded, the storm must fulfill interception, depressionstorage, and infiltration volume. The rainfall required to fulfill the above status is termed initial abstraction (Ia) . It includes H_2O retained in surface depressions, H_2O intercepted by flora, and H_2O lost to vaporization and infiltration. Initial abstraction is nevertheless extremely variable but is by and large correlated with the type of dirt and cover stuff. After rainfall begins, accrued infiltration additions with increasing rainfall up to some maximal keeping point and as rainfall additions, overflow besides increases. The ratio of existent keeping to maximal keeping is assumed to be equal to the ratio of direct overflow to rainfall minus initial abstraction. Mathematically the H_2O balance of a storm event can be expressed as:

for P & gt ; Ia (Eq. 1)

Where:

F = existent keeping (millimeter)

S = possible upper limit keeping (millimeter)

Q = accumulated overflow deepness (millimeter)

P = possible upper limit overflow (millimeter)

I, = initial abstraction (millimeter)

After overflow has started, all extra rainfall becomes either overflow or existent keeping (i. e. the existent keeping is the difference between rainfall minus initial abstraction and overflow) .

F = (P- Ia) - Q (Eq. 2)

Uniting Equations 1 and 2 outputs

(Eq. 3)

Field informations indicated that initial abstraction was by and large in the part of 20 % of the maximal keeping for an single storm. The standard premise used therefore is that Ia = 0. 2S (SCS 1985) , where `` 0. 2 '' was based on watershed measurings with a big grade of variableness. Other research workers have reported utilizing values runing from 0. 0 to 0. 3 (SCS 1985 ; Ponce and Hawkins 1996) . The original estimations of Ia were determined by deducting rain that fell prior to the beginning of watershed response from the entire rainfall, measured at the mercantile establishment (SCS 1985) .

Ia = 0. 2S (Eq. 4)

This relation can be inserted into Equation 1 to give the followers:

(Eq. 5)

The possible maximal keeping can run from nothing on a smooth, imperviable surface to eternity in deep crushed rock countries. The `` S-values '' can be converted to runoff curve Numberss (CN 's) by the undermentioned transmutation:

(when H_2O deepnesss are expressed in inches) or

(Eq. 6)

(when H_2O deepnesss are expressed in millimeter)

Figure 1 shows the graphical solution of Equation 5, bespeaking values of overflow deepness Q as a map of rainfall deepness P for selected values of CN. For illustration, paved countries, S will be zero and CN will be 100 i. e. all rainfall will go overflow. For extremely permeable, flat-lying dirts, S will travel to eternity and CN will ' be zero i. e. all rainfall will infiltrate and there will be no overflow. Besides where entire effectual rainfall peers direct runoff the CN value will be 100.

Figure 1. Graphic solution of Equation 4. 5 demoing overflow deepness Q as a map of rainfall deepness P and swerve figure CN (after SCS 1972) .

Antecedent Moisture Condition, AMC) .

Antecedent wet status (AMC) is an indicant of the wetness of the watershed and the handiness of dirt wet storage prior to a storm. Ponce and Hawkins (1996) indicated that curve figure can be adjusted to gauge less overflow under dry conditions and more overflow under wet conditions. AMC hence, can hold a important consequence on overflow. Soil AMC is determined by the rainfall sum 5 yearss prior to the event of involvement. AMC 1 applies if the 5-day ancestor rainfall is less than 36 millimeter. AMC II and III refers to 5-day antecedent rainfall 36- 53 millimeter and greater than 53 millimeter severally.

Hydrologic dirt groups

The NRCS classified over 8, 500 dirt series into four hydrologic groups harmonizing to their infiltration features. The hydrologic groups have been designated as A, B, C, and D and description of each dirt group are provided in the Table 1 below ;

Table 1: Hydrological Soil Group and Infiltration Characteristics

- Soil Group

- Description

- Infiltration Rate

- (mm/h)

- Dirt

Lowest overflow potency. Includes deep littorals with really small silt and clay, besides deep, quickly permeable loess. These dirts considered to hold a

low overflow potency and a high infiltration rate even when exhaustively wetted, e. g. deep overly drained littorals and crushed rocks.

8-12

Sand, loamy sand, flaxen loam.

Bacillus

Reasonably low overflow potency. Mostly sandy dirts less deep than A, and loess less but the group as a whole has above-average infiltration after thorough wetting i. e. dirts have a moderate infiltration rate when exhaustively wetted e. g. shallow loess and flaxen loam.

4-8

Silt loam, loam.

Reasonably high overflow potency. Comprises shallow dirts and dirts incorporating considerable clay and colloids, though less than those of group D. The group has below-average infiltration after presaturation e. g. clay loams, shallow sandy loam and dirt with low organic content.

1-4

Sandy clay loam.

Calciferol

Highest overflow potency. Includes largely clays of high swelling possible, but the group besides includes some shoal dirts with about impermeable

some shallow dirts with about impermeable subhorizons near the surface. These dirts have a high potency for overflow, since they have really slow infiltration rates when exhaustively wetted

0-1

Clay loam, silty clay loam, clay, flaxen clay, silty clay.

Beginning: SCS, 1975 ; Schulze et al. , 1996

Cover type

Cover type affects overflow in several ways, the leaf and its litter maintains the dirt 's infiltration potency by forestalling the impact of the raindrops from sealing the dirt surface. Other factors, such as the per centum of imperviable country and the agencies of

conveying overflow from imperviable countries to the drainage system should be considered in calculating CN for urban countries. Table 2 describes the CN value for a combination of land usage description and hydrologic dirt group.

Table2. Land Use Description and Curve Numbers

- Description of Land Use

- Hydrologic Soil Group

- Bacillus

- Calciferol

Paved parking tonss, roofs, private roads

98

98

98

98

Streets and Roadss:

Paved with kerbs and storm cloacas

98

98

98

98

A A A A Gravel

76

85

89

91

A A A A Dirt

72

82

87

89

Cultivated (Agricultural Crop) Land* :

A A A A Without preservation intervention (no patios)

72

81

88

91

A A A A With preservation intervention (patios, contours)

62

71

78

81

Pasture or Range Land:

A A A A Poor (& lt ; 50 % land screen or to a great extent grazed)

68

79

86

89

A A A A Good (50-75 % land screen ; non to a great extent grazed)

39

61

74

80

Meadow (grass, no graze, mowed for hay)

30

58

71

78

Brush (good, & gt ; 75 % land screen)

30

48

65

73

Forests and Forests:

A A A A Poor (little trees/brush destroyed by over-grazing or combustion)

45

66

77

83

A A A A Fair (croping but non burned ; some coppice)

36

60

73

79

A A A A Good (no graze ; brush screens land)

30

55

70

77

Open Spaces (lawns, Parkss, golf classs, graveyards, etc.) :

A A A A Fair (grass covers 50-75 % of country)

49

69

79

84

A A A A Good (grass covers & gt ; 75 % of country)

39

61

74

80

Commercial and Business Districts (85 % imperviable)

89

92

94

95

Industrial Districts (72 % imperviable)

81

88

91

93

Residential Areas:

A A A A 1/8 Acre tonss, approximately 65 % imperviable

77

85

90

92

A A A A 1/4 Acre tonss, approximately 38 % imperviable

61

75

83

87

A A A A 1/2 Acre tonss, approximately 25 % imperviable

54

70

80

85

A A A A 1 Acre tonss, approximately 20 % imperviable

51

68

79

84

from Chow et Al. (1988)

Appraisal of CN values for Urban Land Uses

Urbanized water partings are those in which imperviable surfaces cover a considerable per centum of an country. These imperviable surfaces include roads, pavements, parking tonss, and edifices. In these countries, natural flow waies in the water parting may be replaced or supplemented by paved troughs, storm cloacas, or other elements of unreal drainage. Urbanization therefore alterations a water parting 's response to precipitation. The most common effects are reduced infiltration and decreased travel clip which significantly increase peak discharges and overflow (SCS 1986) .

Urban CN values (Table 3) were developed for typical land usage relationships based on specific assumed per centums of imperviable country. These CN valleies were developed based on the premises that (a) pervious urban countries are tantamount to crop in good hydrologic status and (B) imperviable countries have a CN of 98 and are straight connected to the drainage system. Some assumed per centums of imperviable country are shown in Table 3 (SCS 1986) .

Of involvement from Table 3 is the description used to sort residential countries. A widely used method of sorting urban land usage is the Anderson Level III categorization (Anderson, et al. , 1976) , which makes the undermentioned differentiations: (1) low denseness residential land usage (0-5 brooding units per hectare) , (2) medium denseness residential land usage (5-20 brooding units per hectare) , and (3) townhouse-garden flat land usage (& gt ; 20 brooding units per hectare) .

The definition for urbanised water partings used by Cappiella et Al. (2005) was countries holding more than 10 % entire imperviable screen. Impervious screen includes any surface that does non let H2O to infiltrate, such as roads, edifices, parking tonss, and private roads. Crawford-Tilley, et Al. (1996) on the other manus, used a residential denseness of three houses per hectare as a threshold for urbanised land usage.

Many hydrologic theoretical accounts use the CN method to gauge direct overflow from Fieldss or water partings. However, change of the hydrologic dirt group due to the effects of urbanisation frequently consequences from

compression lending to structural debasement of the dirt. In urbanised water partings, land surfaces frequently become less pervious due to perturbation of the established dirt construction ensuing in increased overflow. Thus the usage of the original dirt study information for urbanised countries is frequently a hapless premise because important compression and perturbation of the dirt that has taken topographic point chiefly due to earthwork operations (Holman-Dodds et al. 2003, Gregory et Al. 1999) .

Table 3 Runoff Curve Numbers for Urban Areas

Beginning: Scandium 1986

Determination of overflow volume on inclining landscape

Watersheds in the Caribbean and in many parts of the universe are characterized by inclining landscape. Factors that control infiltration rate include dirt belongingss that are strongly affected by three forces. These forces are, hydraulic conduction, diffusivity and H2O keeping capacity. These dirt belongingss are related to the features of dirt texture, construction, composing, and grade of compression, which influence dirt matric forces and pore infinite. In add-on, antecedent wet status, type of vegetative or other land screen, incline, rainfall strength and motion every bit good as entrapment of dirt air are of import factors that besides affect infiltration rates.

Minidisk Infiltrometer

Accumulative infiltration, I, is described by the undermentioned map

(Eq. 7)

Where T is clip, C1 and C2 are parametric quantities specifying the sorptive and hydraulic conduction, severally (Phillips, 1969) .

Relationship between majority denseness and infiltration

The Ocean County Soil Conservation District (2001) , in New Jersey, conducted a survey on the effects of dirt alteration and compression on infiltration rates during building operations in urban countries. This survey was to find whether the effects of building activities were sufficient to change the hydrologic dirt group categorization. Measurements of majority denseness and infiltration rates were conducted both in situ to and demo that as dirt majority denseness increases to 1. 65 g/cm3, the infiltration rate lessenings quickly. The survey besides showed that with an addition in bulk denseness above 1. 65 g/cm3, infiltration rate diminutions easy, nearing zero therefore ensuing in permeableness going the confining factor for infiltration into the dirt profile. The permeableness measurings were so used to develop a technique to gauge infiltration rates of densenesss non specifically measured. The expression from the unmoved informations derived from plotting the graph of permeableness against bulk denseness (Figure 2) resulted in the undermentioned expression ; [Permeability = (42198) (Bulk Density) -21. 255] .

Figure 2. Graph demoing the relationship between majority denseness and permeableness

(Ocean County Soil Conservation District 2001)

The consequences indicated that the overflow from many late constructed lodging developments exceeds the simulated overflow based on the CN method utilizing undisturbed hydrologic dirt group values. The survey besides showed that the hydrologic dirt group at late urbanized sites that was recorded as dirt group A or B, based on dirt study informations and texture, recorded infiltration rates of less than 0. 38 cm/hr, proposing Hydrologic dirt group C or D. The Ocean County Soil Conservation District (2001) survey concluded that building operations significantly compact the dirt, ensuing in the change of the hydrologic dirt group categorization. The survey hence recommended that contrivers and interior decorators should account for the effects of dirt compression when gauging overflow.

Curse

Holman-Dobbs et Al. (2003) besides observed that land surfaces have become less pervious due to perturbation of set up dirt construction in urbanised water partings, which consequences in increased flow. Treading promotes surface dirt compression and waterproofing (Warren et al. , 1986) . The usage of the original hydrological dirt group value for urbanised countries is hence a hapless premise because earthwork operations frequently result in important compacted and disturbed dirt (Gregory et al. 1999) . Soil infiltration trials on loamy dirts to analyze the effects of age of urbanisation on dirt infiltration rates were conducted by the Wisconsin Deptartment of Natural Resources and the University of Wisconsin. The preliminary trials consequences indicated that every bit long as several decennaries could be necessary earlier compacted loam dirts recover to

conditions similar to pre-development conditions (Pitt, et Al. 2002) . Pitt, et Al. (2002) hence concluded that really big mistakes in dirt infiltration rates can easy be made with the usage of published dirt maps are used along with available theoretical account for typically disturbed urban dirts, as these tools ignore the effects of compression. The writer farther stated that cognition of compression can be used to more accurately predict stormwater overflow measure, and to better design bioretention stormwater control structures. Dirts that are left au naturel due to urbanisation and addition traffic by occupants frequently consequences in dirt crusting and decreased infiltration. This was reported by Blackburn (1989) , who observed that exposure of bare dirt to climate fluctuations enhances dirt crusting and slaking and as a consequence, infiltration of dirts was lower on bare dirt than beneath trees and bushs.

Holman et Al (2003) observed that dirt construction debasement on farms in England and Wales during land direction operations, such as ploughing or harvest home led to compression and structural harm of the dirt i. e. the transition of wheels over the dirt surface lead to compression of the upper parts of the surface soil. This compression leads to decrease in dirt H2O storage and infiltration capacity therefore cut downing the ability of the dirt to absorb rain and cause addition implosion therapy. For this survey dirt construction conditions were linked via the hydrological dirt group, dirt conditions and antecedent rainfall conditions to SCS curve Numberss to measure the volume of enhanced overflow in each catchment. Land usage controls the infiltration of dirts. Other surveies have besides shown that

ploughing agricultural lands produces dirt compression (Voorhes and Lindstrom, 1984; Blackwell et al. , 1985 ; Allegre et al. , 1986 ; Hartge, 1988) . Because denseness of the largest dirt pores is reduced by the compression mechanism, the infiltration rate is besides diminished (Hartge, 1988) .

Van Der Plas and Bruijnzeel (1993) observed that the impact of selected logging of the rain forest in Malaysia resulted in soils compression by tractor path well increased the frequence and volume of over land flow. The survey was done on 10-35 % inclining land mensurating the surface soil (0-30cm) majority denseness and steady-state infiltration utilizing the dual ring method. Infiltration trial in the logged-over wood were made on former tractor paths and in the next retrieving forest. The consequences indicated that mean bulk densenesss increased with deepness in both woods (scope in undisturbed wood: 0. 98-1. 26 g cm-3 and logged-over wood outside tractor paths: 1. 11-1. 35 g cm-3) . For the sparsely vegetated tractor paths fluctuation was much less (scope: 1. 31-1. 37 g cm-3) . Topsoil majority denseness (0-18 centimeter) was extremely correlated with steady-state infiltration rates and the mean values were 88 (undisturbed wood) , 73 (retrieving forest) , and 15 millimeters h-1 (12-year-old tractor paths) .

Use of GIS in Watershed mold

Several surveies have been done to integrate GIS into watershed hydrologic patterning. These can be grouped into: I) calculation of input parametric quantities for bing hydrologic theoretical accounts ; two) function and show of hydrologic variables ; three) watershed surface representation ; and iv)

designation of hydrologic response units. Two of import countries where GIS has contributed to hydrological mold are that of hydrological stock list and appraisal and good as hydrological parametric quantity finding.

Hydrological Inventory and Appraisal

The usage of GIS for hydrological stock list and appraisal involves the usage of GIS for mapping hydrological factors that pertain to some state of affairs, normally as a agency of hazard appraisal (Maidment, 1993) . The developments in geographical information systems (GIS) engineering have coincided with moves within hydrology to supplying a more expressed accounting of infinite through distributed instead than lumped or topological representations. With GIS there is the ability to hive away, arrange, retrieve, classify, manipulate, analyze and present immense spatial informations and information in a simple mode. GIS supports spacial informations theoretical accounts and supply integration, mensurating and analytical capablenesss which are now been used in many hydrological applications runing from stock list and appraisal surveies to treat mold (McDonnel, 1996) .

Aspinall and Pearson (2000) used GIS to develop a series of indexs of H2O catchment wellness for the Yellowstone River in the Rocky Mountain USA, as portion of a geographic audit of environmental wellness and alteration at the regional graduated table. Sirnivasan et Al, (1998) identified GIS as one constituent to pull off spacial input and end product in the designing of a national river basin graduated table resource appraisal in developing the Hydrologic Unit Model for the United States (HUMUS) .

Hydrological Parameter Determination

The usage of GIS for theoretical account parametric quantity appraisal is a really active country of research (Maidment, 1993 ; McDonnell, 1996) . The aim is to find the parametric quantities that will be used as input into hydrological theoretical accounts by analysis of terrain and land screen characteristics such as incline, channel length, land usage and dirt features (Maidment, 1993) . Digital lift theoretical accounts (DEMs) have become utile tools for hydrological mold in ungauged water partings because topographic parametric quantities can now be rapidly and expeditiously derived utilizing GIS. These topographic parametric quantities help to specify the construction of water partings which give a specific hydrological signature and drainage form. It can be shown that landform form and features influence the flow of H2O, transit of deposits and pollutants. GIS provide an environment within which topographic parametric quantities can be rapidly and expeditiously extracted for hydrological application and as a consequence, DEMs are progressively being used (Armstrong and Martz, 2003 ; Martz and Garbrecht, 1998) .

DaRos and Borga, (1997) stated that the application of GIS provides an efficient and accurate agencies for the rating of watershed features and deducing structural instantaneous unit hydrographs (GIUH) . The survey showed that hydrologic response of a watershed is influenced by many factors some of which include dirt belongingss (e. g. , infiltration capacity, dirt deepness, and porousness) , morphological belongingss (e. g. , drainage country, incline, channel length, drainage denseness, and

alleviation ratio) , geologic belongingss (e. g. , lithologic and structural geologic belongingss) , and set down screen and land usage (e. g. , per centum forest, agricultural, and urban screen) . For ungauged catchments, structural instantaneous unit hydrographs have been proposed as a tool to imitate overflow hydrographs.

Harmonizing to Olivera and Maidment (1998) , GIS provides tools that allow one to travel from lumped to spatially distributed hydrologic theoretical accounts. GIS provided an first-class environment for patterning spatially distributed hydrologic procedures. This is so because they have spacial maps in the vector and raster sphere (some of which are specifically developed for hydrologic intents) and a database direction system, which combined, let one to execute hydrologic mold and computations that are connected to geographic locations.

Weng (2001) on the other manus used the advantage of GIS engineering for incorporating GIS with distant feeling engineering and successfully applied these engineerings to come up overflow patterning. His survey uses GIS to deduce two cardinal parametric quantities: rainfall and hydrological dirt groups. Based on these informations and land screen digital informations, the surface overflow images could be obtained through the map algebra and overlay maps of GIS. Thus, the integrating has automated the SCS mold. Similarly other surveies have demonstrated the usage of GIS-based systems to develop parametric quantity estimations (Stuebe and Johnson, 1990 ; Green and Cruise, 1995 ; De Smedt et al. , 2000 ; Liu et Al,

2004 ; Olivera and Maidment, 1999) and for CN computation (Engel, 1997 ;

Xu, 2006 ; Gumbo et Al, 2001 ; Halley et al. , 2007) .

CN Determination utilizing GIS

Craciun et. al (2007) in his survey tested a theoretical account of hydric

overflow appraisal (SCS CN) , based on the calculus relation of hydric

balance, in which GIS was used in the analysis of parametric quantities that

compose the equation of the theoretical account. The parametric quantities

which are included in the concretion of the hydric volume entered in the

basin system can be customized and computed, successfully, by utilizing the

GIS. Craciun et. al (2007) concluded that uniting GIS maps with the SCS-CN

theoretical account, for analyzing the overflow on a watershed degree, can

be an efficient solution in the context of a uninterrupted addition in the

demand of calculating the hydric jeopardies.

M. MANCINI & A ; R. ROSSO (1989)

Calibration of Soil Conservation Service Curve Number (CN)

is performed within a distributed model. This is based on the

detailed information from the Geographic Information System (GIS)

Spatial variableness of Curve Number

has been investigated in order to analyze (I) the extension of local

countries which can be taken as homogenous, (two) the common

relationships

among different countries in the basin, and (three) the local variableness

of overflow estimations.

Runoff Hydrograph

Hydrologist and applied scientists depend on measured or computed

hydrographs to supply extremum flow rates that is so used to plan hydraulic

constructions to suit flows safely. Hydrographs besides allows for the

analysis of sizes of reservoirs, storage armored combat vehicles, detainment

pools, and other installations that accommodate volumes of overflow

(Viessman Jr. and Lewis 2003) . A hydrograph is basically a secret plan of

rate against clip with the country beneath the hydrograph between any two

points in clip giving the entire volume of H2O go throughing a peculiar point

of involvement during the clip interval.

Unit of measurement Hydrograph

The construct of unit hydrograph was foremost introduced by Sherman

(1932) and can be described as a hydrograph of stormflow from 1 unit of

effectual rainfall happening at a unvarying rate over a peculiar period and

some specific areal distribution over the watershed. The hydrograph

demoing the rates at which overflow occurred can be considered a unit

graph for a peculiar water parting (Viessman Jr. and Lewis 2003 ; Brooks et

Al. 1997) . As a watershed becomes more urbanised, the impact of

increasing imperviable country, decreased potency for infiltration into the

dirt, and loss of natural depression storage will alter the response to rainfall

and therefore the form (top out and clip base) of the ensuing overflow

hydrograph. Figure 3 shows the relationship between a storm or rainfall event the unit hydrograph developed and direct overflow. Runoff normally occurs after the initial abstraction or storage capacity of the dirt is satisfied.

Figure 3: Relationship between storm, unit hydrograph, and direct overflow hydrograph (McCuen 1989)

Rational Method

The most widely used method for planing drainage installations for little urban and rural water partings is the Rational Method. Mathematically, the rational method relates the peak discharge (Q) to the drainage country (A) , the rainfall strength (I) , and the overflow coefficient (C) . Using this method, extremum flow is expressed as

Qp = CIA (Eq. 13)

Where Qp = the peak overflow rate (m3/sec)

C = the overflow coefficient (dimensionless)

I = the mean rainfall strength (mm/hr) for a storm with continuance

equal a critical period of clip technetium

A = size of drainage country (Km2)

The value of C is dependent on the dirt, land usage screen status and rainfall features.

Time of concentration (tc) of the water parting is the clip that is required for H2O to go from the most distant subdivision of the watershed to the mercantile establishment point one time the status of dirt impregnation and minor depressions are filled. Time of concentration influences the form and extremum of the overflow hydrograph and is affected by surface raggedness, channel form, flow form and incline. Time of concentration can be calculated utilizing the Kirpich method (1940) which was developed from SCS informations for seven rural basins in Tennessee. The water partings used in developing this expression had good defined channels and steep inclines (3 % to 10 %) . The Kirpich expression is as follows:

(Eq. 14)

Where:

technetium = clip of concentration (min.)

L = the maximal hydraulic flow length (foot)

H = the difference in lift between the watershed mercantile establishment and hydraulicly most

distant point in the water parting (ft/ft)

The cogency of the rational method is based on the set of premises some of which are listed below along with identified failings (Thompson et al. 2003 ; Viessman Jr. and Lewis 2003)

Premises in the Rational Method:

Rainfall occurs at a unvarying strength over the full country of the watershed for a specific continuance that is at least equal to the clip of concentration of the water parting.

Peak rate of overflow can be reflected by the rainfall averaged over a clip period equal to the clip of concentration of the drainage country.

The return period of the overflow event is the same as the return period of the precipitation event.

Failings of the Rational Method:

Appraisal of technetium. Particularly critical for little watershed where technetium is short and alterations in design strengths can happen rapidly.

Reflects merely the extremum and gives no indicant of the volume or the clip distribution of the overflow.

Lumps many watershed variables into one overflow coefficient.

Provides small penetration into our apprehension of overflow processes - particularly in instances where watershed conditions vary greatly across the water parting.

This method is a great simplism of a complicated procedure ; nevertheless, the method is considered sufficiently accurate for overflow appraisal in the design of comparatively cheap constructions where the effects offailureare limited.

Application of rational method is usually limited to water partings of less than 800 hour angle.

SCS Triangular Unit Hydrograph

The SCS triangular unit hydrograph was developed by Victor Mockus in the 1950s and is used to build a man-made unit hydrographs. This hydrograph is based on a dimensionless hydrograph derived from analysis of a big figure of unit hydrographs which varied in size and geographic locations (SCS 1972 ; Viessman Jr and Lewis 2003) . The hydrograph ordinate values are expressed as a dimensionless ratio of discharge to top out discharge (q/qp) and abscissa values are ratios of clip to clip to top out (t/Tp) (Figure 4) . The SCS triangular unit hydrograph is frequently used in concurrence with CN overflow equation to transform overflow volume into matching discharge hydrograph (Stone, 1995) .

scs_uhg

Figure 4: SCS Dimensionless unit hydrograph and mass curve (SCS 1972)

The dimensionless unit hydrograph can be represented by a triangular form. The relationships between major hydrograph constituents, presented in Figure 5, were derived for the geometric characteristics of a trigon. By utilizing the geometry of the trigons (country = 1/2 base times height) , the triangular unit hydrograph has 37. 5 % (or 3/8) of its volume on the lifting side and the staying 62. 5 % (or 5/8) of the volume on the recession side.

scs_uhg_triangle

Figure 5: Illustration of dimensionless curvilineal unit hydrograph and the tantamount triangular hydrograph (SCS 1972) .

The SCS CN method is based on constituents and their dealingss. The method requires the finding of the clip to top out and the peak discharge expressed as follows:

(Eq. 15)

Where: thallium = lag clip in hours

cubic decimeter = length of the longest drainage way in pess

S = (25400/CN) - 254 (CN = curve figure)

Y = norm watershed incline in %

(Eq. 16)

Where tp = clip from get downing of rainfall to top out discharge (H)

D = continuance of rainfall (H)

thallium = slowdown clip from the centroid of rainfall to top out discharge (H)

The continuance of rainfall (D) can be expressed utilizing the undermentioned expression:

(Eq. 17)

SCS (1972) relates clip of concentration (technetium) , to dawdle clip (thallium) , by:

(Eq. 18)

The recession clip (tr) , and clip of extremum (tp) is related as follows:

(Eq. 19)

H is a changeless and can be obtained from Table 5.

Table 5: Hydrograph top outing factors and recession limb ratio

- General Description

- Top outing Factor

- (H)

- Limb Ratio

- (Recession to raising)

Urban countries ; steep inclines

575

1. 25

Typical SCS

484

1. 67

Assorted urban/rural

400

2. 25

Rural, turn overing hills

300

3. 33

Rural, little inclines

200

5. 50

Rural, really level

100

12. 0

Beginning: Wanielista et Al. 1997

The base of the unit hydrograph can hence be calculated utilizing the undermentioned expression:

(Eq. 20)

The extremum flow (Qp) is developed by come closing the unit hydrograph as a triangular form with basal clip of tp and unit country. Peak discharge can be written as:

(Eq. 21)

Where Qp = extremum discharge (m3/s)

A = drainage country (mi2)

tp = clip from get downing of rainfall to top out discharge (H)

Steep terrain and urban countries tend to bring forth higher extremums that occur earlier ensuing in a peak factor be givening towards 600. Similarly, level swampy parts which tend to retain and hive away H2O, therefore doing a delayed and lower extremum may ensue in values be givening towards 300 or lower (SCS 1972 ; Wanielista, et Al. 1997) . Table 5 illustrates the possible values for a hydrograph top outing factor and the associate ratio of the recession limb length to raising limb.

CN values relate the sum of overflow produced by a watershed and is used to build man-made unit hydrographs. This hydrograph can so be used to steer the design standard fortechnologyconstructions. Figure 6 demonstrate that for different CN values the form of the hydrograph varies. At higher CN values there is a shorter clip to top out, a higher extremum value and a shorter recession clip. Design standards hence have to take into consideration these factors and therefore the demand for this methodological analysis to be calibrated to local conditions.

Figure 6: Comparative hydrographs for different CN values (Woodward et Al.

2003)

Model Evaluation

Model rating involves standardization and proof and is frequently done

through quantitative and qualitative steps that involve both graphical

comparing and statistical trials. This is hence a procedure for consistently

analysing the mistakes or differences between theoretical account

anticipations and field observations. Tools are hence needed to do optimum

usage of the information available in the information to place theoretical

account construction and parametric quantities, and that allow elaborate

analysis of theoretical account behaviour (Wagner et al. 2001 ; Krause et Al.

2005) . These tools are frequently termed the efficiency standards for

theoretical account appraisal

Donigian and Rao (1990) describe patterning as comprising of three stages

(Figure 6) . The first stage (stage I) includes all the stairss needed to setup

a theoretical account, qualify the water parting, and fix for theoretical

account executings i. e. informations aggregation, theoretical account input

readying, and parameter rating. Phase II is the theoretical account proving

stage which involves standardization, proof, and, when possible, post-audit.

Phase II is where the theoretical account is evaluated to measure whether it

can reasonably stand for the watershed behaviour, for the intents of the

survey. The last stage (phase III) includes the ultimate usage of the

theoretical account, where it can be used as a determination support tool for direction and regulative intents.

Figure 6: Mold Procedure

Calibration and proof is of import because the result establishes how good the theoretical account represents the water partings, for the intent of the survey. Krause et Al. (2005) gave three grounds why hydrologists need to measure theoretical account public presentation: 1) to supply a quantitative estimation of the theoretical account 's ability to reproduce historic and future watershed behavior ; 2) to supply a agency for measuring betterments to the mold attack through accommodation of theoretical account parametric quantity values, model structural alterations, the inclusion of extra experimental information, and representation of of import spacial and temporal features of the watershed ; and 3) to compare current patterning attempts with old survey consequences.

Efficiency Criteria

Beven (2001) define efficiency standards as mathematical steps of how good exemplary simulations fit the available observations. Efficiency standards in general, incorporate a summing up of the error term (i. e. difference between the fake and the ascertained variable) normalized by a step of the variableness in the observations. To forestall the canceling of mistakes with opposite mark, the summing up of the absolute or squared mistakes is frequently use. The consequence is an accent is on larger mistakes while smaller mistakes tend to be neglected. Examples of two

efficiency standards frequently used are: 1) coefficient of finding (r2) and 2) Nash-Sutcliffe efficiency (E) .

Coefficient of finding r2

This can be defined as the squared value of the coefficient of correlativity and can be calculated as follows:

(Eq. 22)

Where O = observed, P = Predicted

The scope of r2 prevarications between 0 and 1 which depict how much of the observed is explained by the predicted. A value of zero means no correlativity, where as a value of one shows that there is perfect correlativity between the predicted and the observed.

In utilizing r2 information is provided by the gradient B and the intercept a of the arrested development on which r2 is based. For a good understanding the intercept a should be near to zero which means that an ascertained overflow of nothing would besides ensue in a anticipation near nothing and the gradient B should be near to one.

For a proper theoretical account assessment the gradient B should ever be discussed together with r2. To make this in a more operational manner the two parametric quantities can be combined to supply a leaden version (w R2) of R2. Such a weighting can be performed by:

tungsten r2 = | b| A· r2 for B a‰¤ 1

| b|-1 A· r2 for B & gt ; 1 (Eq. 23)

By burdening r2 under- or over anticipations are quantified together with the kineticss which consequences in a more comprehensive contemplation of theoretical account consequences.

Nash-Sutcliffe efficiency (E)

Developed in 1970, the Nash- Sutcliffe efficiency coefficient is defined as one minus the amount of the absolute squared difference between the predicted and observed values normalized by the discrepancy of the ascertained values during the period under which probes were undertaken. This coefficient can be calculated as:

(Eq. 24)

A disadvantage with the standardization of the discrepancy of theobservationseries is that is consequences in comparatively higher values of E in catchments with higher variableness and lower values of E in catchments with lower variableness. The scope of E lies between 1. 0 (perfect tantrum) and a?'a? z . An E value of lower than zero indicates that the average value of the ascertained clip series would hold been a better forecaster than the theoretical account.

Legates and McCabe (1999) stated that the largest disadvantage of the Nash-Sutcliffe efficiency is the fact that the differences between the ascertained and predicted values are calculated as squared values. As a consequence larger values are strongly overestimated whereas lower values

are neglected in a clip series. For the quantification of overflow anticipations this leads to an overestimate of the theoretical account public presentation during extremum flows and an underestimate during low flow conditions.

To cut down the job of the squared differences and the ensuing sensitiveness to extreme values the Nash-Sutcliffe efficiency E is frequently calculated utilizing logarithmic values of O and P. With the logarithmic transmutation of the overflow values the extremums are flattened and the low flows are kept more or less at the same degree. As a consequence the influence of the

low flow values is increased in comparing to the inundation extremums ensuing in an addition in sensitiveness of lnE to systematic theoretical account over- or underprediction.