Stormflow and Land Use Change:
Low Density Development in the
Ferson−Otter Creek Watershed, 1960−1996

by
Patrick A. Stewart, Michael T. Ritsche and Douglas Krieger
March 13, 1999

Abstract

Due to a combination of factors, including development of open space land, increasing precipitation trends in the United States and demands on Federal Emergency Management Agency funds, flooding is considered potentially to be the "dust bowl of the 21st century." Current and potential public and private financial burden suggests the need for government intervention to address the issue, most likely through land use planning. To explore the impact of development on flooding, this study focuses on the Ferson−Otter Creek watershed in Kane County, Illinois, a Chicago collar county. To do this, a variable measuring warm season (April−October) stormflow is created. This variable considers the change of stormflow over a 48−hour period before and after rainfall events equal to or greater than 1.5 inches. This variable is then plotted against a variable measuring low density subdivision development in the watershed from the years 1960 to 1996. Using locally weighted regression (lowess) we find that recent development has led to a substantial increase in stormflow. While the findings are preliminary and suggestive in nature, policy makers should consider the influence of land use decisions on the increased potential for flooding and the havoc and cost it brings.

Introduction

Flooding imposes substantial costs on individuals and society. Flooding is the single most expensive claim on Federal Emergency Management Agency funds. Continued development in floodplains and an aging flood protection infrastructure imply that the expense is not likely to decline (Floodplain Management, 1992:3−20). Some researchers predict that, in terms of property damage, flooding will be Athe dust bowl of the 21st century@ (Knudson and Vogel, 1997). Flooding is also responsible for a large number of injuries and deaths (Knudson and Vogel, 1997) and stress and suicide among flood survivors (Hannson et al., 1982; Krug et al., 1998).

It has been suggested that flooding is increasing due to poor land use decisions not taking into account the effect of development on a watershed. Particularly troubling is that this damage tends to be inequitable, affecting those who likely have no immediate control. Homeowners, farmers and communities downstream from new developments may face increased potential for flooding as well as sedimentation and reduced water quality through soil erosion and runoff of non−point fertilizer and pesticide pollution. Wildlife may face depleted or destroyed habitats through erosion and destruction of riparian areas. Finally, the general public is affected by the destruction of environmental amenities both psychologically and through a potential drop in water quality and quantity as aquifers near the surface may not be replenished due to high rates of runoff (EPA, 1997).

Recent studies demonstrate a significant relationship between urban development within watersheds and increased stream flows following storm events (D. Changnon et al., 1996; S. Changnon and Demissie, 1996). A particular challenge with these and other studies is finding an adequate measure of development. In the absence of a better measure, population is relied on as a proxy for development (Arnold et al., 1996; Stankowski, 1975). While population provides a means of measuring development, it lacks the accuracy required to understand the effects of specific land use changes on stormwater runoff. Specifically, impermeable area is likely the most significant determinant of runoff (Scheuler, 1994). The relationship between population and impermeable area likely changes over time with changes in preference for lot sizes, the ratio of residential to commercial development and transportation and drainage infrastructure.

This paper considers stormflow in the Ferson−Otter Creek watershed of Kane County, Illinois from 1960 to 1996. A variable is created considering the influence of major precipitation events on flooding potential in the watershed. Flooding potential is based on a streamflow measure in response to rainfall events of greater than 1.5 inches over 48 hours. Next, development in the watershed and its influence on stormflow rates is analyzed by considering the construction of low−density subdivisions over the 36−year time period under analysis. This study uses Geographic Information Systems data to establish a baseline of the percent of the watershed in developed uses while low−density subdivisions recording data from Kane County is used to gauge change over time. Finally, conclusions are drawn.

Study Site and Data

We chose the Ferson−Otter Creek watershed due mainly to its location in Kane County, a rapidly growing fringe county of the Chicago metropolitan area. This watershed, which is 34,481 acres in size, empties into the Fox River, in turn a tributary of the Illinois River and ultimately, the Mississippi River. Data on water flows and levels for Ferson−Otter Creek have been collected since 1960 by the U.S. Geological Survey, allowing for an analysis of the effect of land use changes over time on this environmental indicator.

Kane County, due to its location, is under high levels of development pressure as low−density subdivisions sprawl onto prime farmland. The watershed is almost entirely located in the county's Critical Growth Area, an area which "will be the county's litmus test − where the county and municipalities either surrender to conventional suburban sprawl or make a stand for managed growth and the preservation of countryside character and open space" (Kane County, 1996:79). This land use plan will soon be augmented by a county−wide stormwater plan initiated in response to extensive flooding in 1996.

Stormflow

An examination of the stormflow characteristics of the Ferson−Otter Creek drainage basin is carried out to determine if the flow characteristics associated with heavy rainfall events of the basin have changed over time from 1960 to 1996 and whether those changes have been due to land use changes through development. Daily mean net streamflow data are normalized for precipitation amount to minimize differences associated with varying rainfall amounts over time (peak average daily streamflow after rain event minus peak average daily streamflow prior to rain event divided by the 48−hour rainfall amount). The daily mean streamflow data was collected at a U.S. Geological Survey site, which is located in unincorporated St. Charles, north of Route 38 along Randall Road. The 24−hour precipitation amounts are obtained from a National Weather Service cooperative weather station located in Elgin, Illinois which is the closest recording site to the streamflow collection site. The daily mean streamflow and precipitation data have approximately 3 percent missing daily data, lending confidence to the use of these sites.

This study follows the methodology set forth by Changnon *et al.* (1996). The net stormflow (U_i) for rainstorms of 1.5 inches or greater (48−hour period) forms the basis for the analysis. This rainfall amount has been chosen for two reasons. First, this level of rainfall occurs relatively infrequently, approximately three times a year during the April−October period. Second, this threshold provides a large enough sample of events to allow useful statistical conclusions to be drawn.

The relationship among soil conditions, base flow and surface flow are considered to be complex and non−linear. Obtaining this data is difficult, as most sites do not record this data historically. Yet conditions prior to a rainstorm =s occurrence are an important consideration. Without taking antecedent conditions into account, stormflow values cannot be viewed objectively. The Changnon *et al*. (1996) study used the lowest mean stormflow (Q_{pre}) during the 48−hour period prior to a rainstorm as an estimate of the antecedent (wet or dry) surface conditions. Even though this value is basic in manner, it allows for a meaningful attempt at correcting for antecedent conditions.

Similar to the Changnon *et al*. (1996) study, subtracting the Q_{pre} from the Q_{post} to obtain the net mean stormflow (Q_{net}) allowed for a rudimentary normalization for antecedent conditions. Dividing the net mean stormflow (Q_{net}) by the amount of rainfall allowed for the creation of the net stormflow variable (U_i). Dividing by the rainfall amount attempts to normalize the net mean stormflow (Q_{net}) for differing amounts of rainfall. For example, a 48−hour rainfall event of 6.0 inches is expected to cause a greater stormflow than would a 1.5 inch event over the same period of time. Removing the effect of or normalizing for differing rainfall amounts allows for a more objective determination of trends over time. Otherwise, an increase or decrease in net stormflow (Q_{net}) over time may be obscured by "noise" generated by differing rainfall amounts.

Warm season (April B October) rainfall that fell over a 48−hour period and measured 1.5 inches or greater is used in this study. The Changnon *et al*. (1996) study finds most rainstorms occur for a period greater than 24−hours. In addition, 48−hour stormtotal precipitation (R_i) measuring greater than 1.5 inches is an infrequent event. A study by Keating *et al*. (1997) finds approximately 85 percent of all Northern Illinois warm season 24−hour rainfall amounts measure less than 0.26 in. As such, 48−hour stormtotal amounts of 1.5 inches or greater represent a useful value since these events are infrequent, yet there are sufficient numbers of these events (n = 122) during the 36 year period to still be meaningful.

Once the rainfall data are obtained, the warm season (April B October) 24−hour amounts are removed for examination and 48−hour storm total amounts are calculated. The 48−hour stormtotal amounts equaling or exceeding 1.5 inches, along with the date ending the 48−hour period, provide the basis for analysis. Once the ending date for each 48−hour stormtotal amount equaling or exceeding 1.5 inches is found, the mean daily Q_{pre} and Q_{post} may be determined (Table 1). The Q_{pre} is then subtracted from the Q_{post} to obtain Q_{net} and ultimately U_i (see Appendix 1 for a detailed listing).

A couple of points need to be addressed at this time. The 48−hour rainfall values that are used are determined from 24−hour rainfall amounts. The lack of information concerning intensity and duration of rainfall events may limit the scope of this study. Intensity and duration both impact runoff characteristics. A rainfall event measuring 3.0 inches that falls in three hours will have different runoff characteristics than a 3.0 inch event that falls in 48 hours. In addition, using a 48−hour time frame does not take into account the possibility of multiple events, each with different duration and intensity.

Table 1

Ferson−Otter Creek Land Use 1990:

Northeastern Illinois Planning Commission Regional GIS Database

Description	Area (acres)	Area (%)
Total Area	**34,481**	**100.%**
Developed Area	***8,929***	***25.90%***
Multi−family	*12*	*.04*
Single−Family	*7,855*	*22.78*
Commercial	*286*	*.83*
Industrial	*394*	*1.14*
Institutional	*251*	*.73*
Transportation/Utility	*131*	*.38*
Less/Undeveloped Area	***25,552***	***74.10%***
Agricultural	*19,049*	*55.24*
Forest, Grassland, Open Space	*3,463*	*10.04*
Vacant land	*1,029*	*2.98*
Wetland	*1,817*	*5.27*
Water	*194*	*.56*

Another weakness of the rainfall data used is that only one rainfall recording site is used. It is assumed that the amount measured fell over the entire Ferson−Otter Creek watershed. Therefore, the spatial extent of the storms is not taken into account. Since only one recording site is used the rainfall amounts measured may be over−under−estimating the actual amount falling over the entire area. This is problematic since convective storms are small in aerial extent and are found to occur predominantly in summer months in Northern Illinois (Huff, 1979). Additionally, convective rainfall dominates from mid−April to mid−October (Huff, 1979) and the highest relative variability has been found to occur with air mass storms (S. Changnon and Huff, 1980).

Development

While various studies have considered the impact of land use changes on runoff rates, there has been a tendency to rely on proxy information such as time or census data (Arnold et al, 1996; D. Changnon et al., 1996; S. Changnon and Demissie, 1996; Stankowski, 1975). While these measures provide an effective means of measuring change, they lack the desired accuracy to understand specific effects of different types of land use change on stormwater runoff. Specifically, the ability to analyze watersheds based upon total area covered by roofs and paved areas, such as roads, parking lots and driveways, would greatly enhance measurement of impermeable area and its effect on stormwater runoff. However, in the absence of extensive databases allowing for this, the use of proxy measures is still necessary.

In this study, an attempt is made to more accurately measure changes in runoff by considering the development of subdivisions within the Ferson−Otter Creek watershed over the period from 1960 to 1996. Information about subdivisions in the watershed was obtained from the Kane County Planning Office and provides information for location, total acreage developed, lots and the year the subdivision was recorded (Kane County, 1997). However, it must be noted that information is not provided for when each parcel within the subdivision was developed and how much impermeable area (in terms of driveway and rooftop footage) was created.

Because the data are based on recorded subdivisions outside of municipalities in Kane County and thus are incomplete because municipal development and single family homes apart from subdivisions are not taken into account, attempts to rectify this are carried out by setting a baseline from which comparisons over time may be established. Specifically, the 1990 Northeastern Illinois Planning Commission Geographic Information Systems database is used to establish a baseline acreage of developed, agricultural, open space and wetlands/water uses (Kane County, 1998:3−2). As can be seen in Table 1, nearly three−quarters (74.1 percent) of land in the Ferson−Otter Creek watershed in 1990 was in either agricultural (55 percent) or other open space uses (19 percent). A little over a quarter of the total land was in developed uses, with the great majority in single family homes. This type of home may predominantly be found in the subdivisions which form the basis of the measure of development in this study.

Percent developed land in the watershed is then computed by subtracting developed land use acreage (the years preceding the baseline) or adding acreage (the years after the baseline) and then calculating percent of land developed. Because subdivisions outside municipalities present the major form of growth in the Ferson−Otter Creek watershed, a finding supported in Figure 1, it is expected this data is an effective measure of growth in the watershed. While information about the year the subdivision was reported as commenced and when it was finished are both available, the starting date of the subdivision is chosen due to both a pattern of general high levels of immediate sales within the subdivision and, perhaps more important, the amount of permeable area created by the new streets and houses, as well as any structural changes to divert water away from the home sites and into the creek itself (Randrup, 1997).

Analysis shows a linear pattern of growth starting from 12 percent developed area in the Ferson−Otter Creek watershed in 1960 and progressing to 24 percent of the land being developed in 1979 (see Figure 1). At this point, development remained constant until 1985, whereupon growth resumed, albeit at a lesser rate. As of 1995 and 1996, growth remained at 28 percent of the land in developed uses.

Methods and Analysis

Due to the complex nature of watersheds and stormflow, a linear relationship between stormwater flow and development in the watershed is not expected. Therefore, the focus of this analysis is to model the type of relationship between percent of developed land in the Ferson−Otter Creek watershed and stormwater flow. As a result, we do not report coefficients and standard errors that are found when testing statistical relationships. To accomplish this and understand patterns in the data, bivariate analysis is carried out through lowess regression techniques.

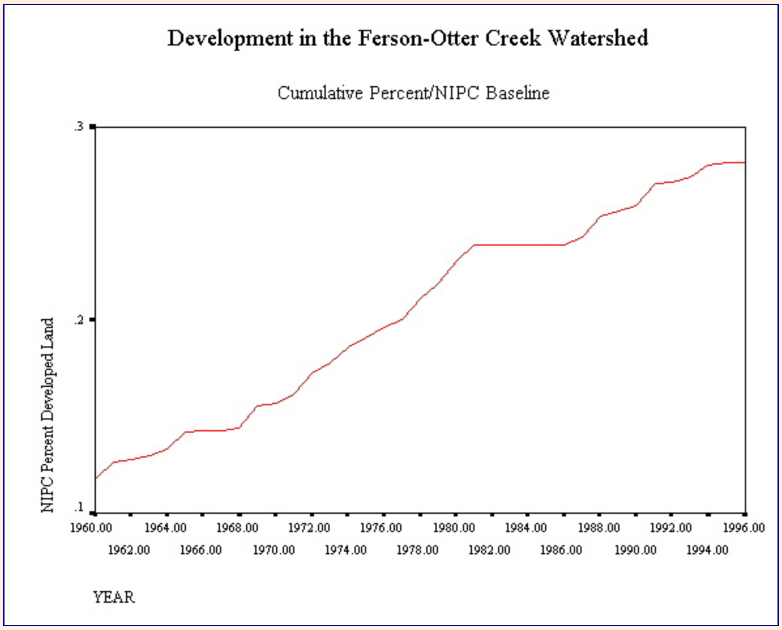

Figure 1

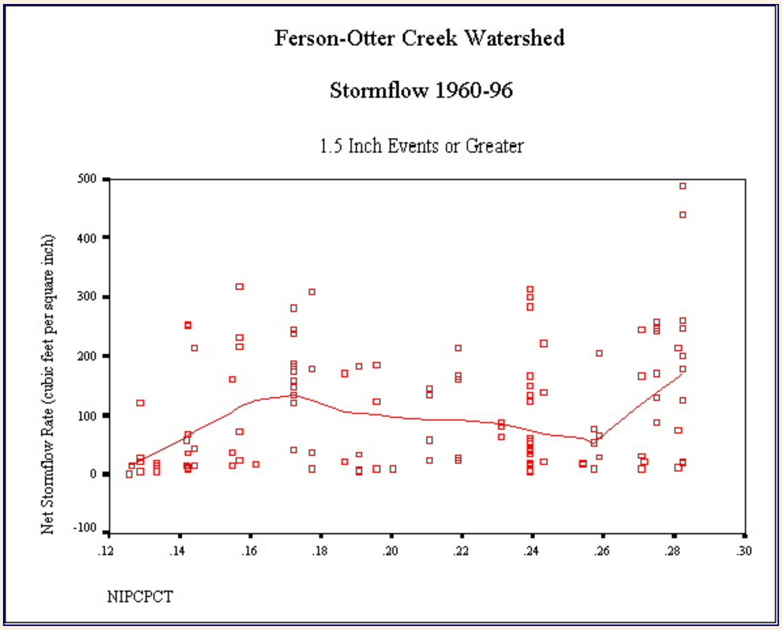

Figure 2

Lowess, which is an acronym for locally weigted regression, allows us to draw a regression line that better reflects the relationship of two variables than do straight lines of linear regression or curved lines produced through logarithmic or power transformations of variables. It does so by performing a series of regressions using a subset of observations to plot the line (Fox, 1997:417−424; Jacoby, 1997). In other words, instead of modeling the relationship between variables before determining the shape of the relationship, the data itself drives the analysis and presents the relationship. Specifically, lowess is an exploratory tool; while we expect increases in development leading to increases in stormflow, the form of the relationship is not known.

In this analysis we use a 35 percent span of data to analyze the relationship between stormflow (Ui on the Y axis) and development (the X axis). As seen in Figure 2, in which the stormflow events are identified on the scatterplot (see Appendix 1 for additional information), stormflow increased on a linear basis from an average of close to zero at 12 percent development to nearly 130 at 17 percent development. At this point, around event #41 at the beginning of the 1973 warm season there is a slight decrease in stormflow rates. This pattern holds until around event #94 (1989), at which time there is a sudden sharp increase at 26 percent of the Ferson−Otter Creek watershed in developed uses.

Discussion

As stated by Schueler (1994) of the two components of imperviousness (rooftops and the transport system) rooftops, especially in a low−density development area such as the Ferson−Otter Creek watershed, might not be as responsible for increased runoff as paved areas such as roads and parking lots This is due mainly to the permeable nature of lawns. On the other hand, a slight increase in impermeable area through any form of development might be enough to lead to change in the stream channel=s shape, its water=s quality and warmth, and the biodiversity in and around the stream. Additionally, increased impermeable area may be associated with reduced recharge of groundwater aquifers.

An important occurrence that bears mentioning is evident in Figure 2. Prior to 1996 net stormflow ratios above 350 ft^3/s/in were not observed. Yet, two net stormflow ratios exceeding 400 ft^3/s/in. occurred in 1996 (489.1 ft^3/s/in. May 28; 440.9 ft^3/s/in.July 18). While a possible explanation may be that since duration, intensity and aerial extent of storms are not considered, any one of these factors may contribute to the two high values of net stormflow rates. Yet, at no time prior to 1996 are the net stormflow rates greater than 350 ft^3/s/in. If duration, intensity and aerial extent are contributing factors, then values similar to events #118 and #120 are expected to occur at various times during the study period, and not just after 1990. This suggests that changes in the basin occur rapidly and in such a way to dramatically change the characteristics of the stormflow ratio compared to the previous 36 years. While critics may suggest these are random events, even when lowess is run with these events removed, the same pattern as seen in Figure 2 is observed. This suggests that recent, rapid land use change in the Ferson−Otter Creek watershed may be the reason that stormflow ratios greater than 400ft^3/s/in. have occurred recently, yet not in the previous 36 years.

Potential reasons for the relatively large increase in stormflow ratios may stem from land use changes in the watershed not captured by the data. In 1990 a shopping mall with a large amount of impermeable area was built in the headwaters of Otter Creek. Additionally, a good deal of farmland has been converted into golf courses, which due to saturation and compaction of the soil may have contributed to increased water runoff. Finally, due to the great majority of Kane County's soils being hydric and/or previously in wetland, the breakdown of the drainage tile system used by farmers over the past 60 to 70 years to keep farmland in production may lead to different patterns of stormwater drainage. However, it should be noted that inspection of aerial photographs of the watershed from 1961, 1967 and 1997 do not show any major changes in the shape of the river.

Conclusions and Future Research Suggestions

Ultimately, the lessons learned from this study are that more lessons need to be learned about the effect of different types of development on stormwater runoff. To our knowledge this is the first small scale study considering the effect of subdivision development on stormwater runoff over time. And because this type of development is most representative of suburban sprawl facing many American communities, it bears increased attention and future research.

An added incentive for research stems from a study by Karl et al. (1998) which finds that precipitation has increased across the United States over much of the twentieth century. Most noticeable are increases during spring and autumn months, although increases are seen across all four seasons. Most of the increases are contained in what the study defines as heavy and extreme events (2.0 inches). This is particularly troubling since many of the values of rainfall in this study are included in this range. If an increase in urbanization causes the greater net stormflow amounts seen after 1990, and the area is experiencing more heavy and extreme events, the possibility for increased flooding is a major concern.

Due to the limited nature of the study, a more in−depth investigation may be necessary. A second watershed experiencing limited growth, yet having a similar climate, topography and soil types, should be included for comparison. Determining if the net stormflow characteristics are different will help determine if climatic or other factors are driving the changes noticed in the Ferson−Otter Creek watershed. A better method for determining land use change also needs to be established. Collecting data by individual building permits and then entering this information into a GIS dataset, while labor and time intensive, may be the best method. Once this data is collected, actual impervious area based on roads and rooftops may be utilized. In addition, even seemingly small changes in land use, such as from farmland to golf course, may change infiltration rates of the soil, and ultimately runoff characteristics.

Impacts on water quality due to urbanization similar to that seen in Kane County certainly need to be studied. Flooding is not the only problem caused by increased urbanization, although it may be the most visible. Other issues such as biotic integrity, aquatic biodiversity, habitat degradation, stream warming, pollutant load increases, sediment loading and bank erosion need to be considered by policy makers. A geomorphological study being carried out by the St. Charles Park District on a two−mile stretch of Ferson Creek may add to policy makers knowledge base by incorporating more variables, as mentioned above. However, until more knowledge is gathered and then acted upon, policy makers can expect more flooding and associated costs.

References

Arnold, C.L. Jr. 1996. "Impervious Surface Coverage: The Emergence of a Key Environmental Indicator." **APA Journal**. Spring:244.

Changnon, David, Doug Fox, and Steve Bork. 1996. ADifferences in Warm Season, Rainstorm−Generated Stormflows for Northeastern Illinois Urbanized Basins.@**Water Resources Bulletin.** 32(6):1307−1317.

Changnon, Stanley A. and Misganaw Demissie. 1996. ADetection of Changes in Streamflow and Floods Resulting from Climate Fluctuations and Land Use−Drainage Changes.@**Climatic Change.** 32:411−421.

Changnon, Stanley A. and F.A. Huff. 1980. **Review of Illinois Summer Precipitation**. ISWS/Bul−64/80.

EPA (Environmental Protection Agency). 1997**. Urbanization and Streams: Studies of Hydrological Impacts.** Washington, DC: Office of Water 841−R−97−009.

Floodplain Management in the United States: An Assessment Report.

1992. Prepared for the Federal Interagency Floodplain Management Task Force. Boulder, CO: Natural Hazards Research and Applications Information Center.

Fox, John. 1997. **Applied Regression Analysis, Linear Models, and Related Methods**. Thousand Oaks, CA: Sage Publications.

Frech, H.E. III and Ronald N. Lafferty. 1984. AThe Effect of the California Coastal Commission on Housing Prices.@**Journal of Urban Economics**, 16:105−123.

Hansson, Robert O., Dianne Noulles, and Steven J. Bellovich. 1982. AKnowledge, Warning, and Stress: A Study of Comparative Roles in an Urban Floodplain.@**Environment and Behavior.** 14(2):171−185.

Huff, F.A., 1979. **Spatial and Temporal Correlation of Precipitation in Illinois**. ISWS/CIR−141/79.

Huff, F.A., 1979. **Hydrometeorological Characteristics of Severe Rainstorms in Illinois**. ISWS/Bul−64/80.

Jacoby, William G. 1997. **Statistical Graphics for Univariate and Bivariate Data**. Sage University Papers Series: Quantitative Applications in the Social Sciences; No. 117

Kane County. 1996. **2020 Land Resource Management Plan**. Kane County Development Department. Kane County, IL. June 11.

Kane County. 1998. **Comprehensive Stormwater Management Plan (Draft Report).** Geneva, IL: Kane County Stormwater Management Planning Committee.

Kane County Development Department. 1997. **Alphabetical Listing of Recorded Subdivisions Outside of All Municipalities: Kane County, Illinois.** Geneva, IL: The Kane County Development Department.

Kane County. 1996. **2020 Land Resource Management Plan**. Kane County Development Department. Kane County, IL. June 11.

Karl, T.R. and R.W. Knight. 1998. "Secular Trends of Precipitation Amount, Frequency, and Intensity in the United States." **Bulletin of the American Meteorlogical Society.** 79(2).

Keating, L. M. Ritsche and M. Stelford. 1997**. Spatial Variability of Temperature and Precipitation Across Northern Illinois.** A Report to Case Corporation.

Knudson, Tom, and Nancy Vogel. 1997. AThe Gathering Storm.@**Sacramento Bee.** http://www.sacbee.com/news/projects/gathering_storm/

Krug, Etienne G., Marcie−Jo Kresnow, John P. Peddicord, Linda L. Dahlberg, Kenneth E. Powell, Alex E. Crosby and Joseph L. Annest. 1998. ASuicide After Natural Disasters.@**The New England Journal of Medicine.** 338(6):373−378.

Randrup, Thomas B. 1997. ASoil Compaction on Construction Sites.@**Journal of Arboriculture.** 23(5): 207−210.

Schueler, Tom. 1994. AThe Importance of Imperviousness.@**Watershed Protection Techniques.** 1(3): http://www.pipeline.com/~mrrunoff/imperv.htm.

Stankowski, S.J. 1975. **Population Density as an Indicator of Urban and Suburban Land−Surface Modification**. USGS Professional Paper 800−b:B224.

Appendix 1

Listing of 1960 B 1996 Large Rainstorms for the Ferson−Otter Creek Basin.

Order of event, date of large rainstorm, R_i, Q_{pre}, Q_{post}, Q_{net}, and U_i are provided.

EVENT ORDER EVENT ORDER	DATE DATE	R_i (in.)	Q_{pre} (ft^3/s)	Q_{post} (ft^3/s)	Q_{net} (ft^3/s)	U_i (ft^3/s/in.)
1	9/1/1961	2.11	0.1	3.4	3.3	1.6
2	7/2/1962	1.9	8.2	33	24.8	13.1
3	4/28/1963	2.15	9.9	270	260.1	121.0
4	7/12/1963	1.58	0.5	5.3	4.8	3.0
5	7/18/1963	2.36	6.4	69	62.6	26.5
6	8/1/1963	1.53	2.2	33	30.8	20.1
7	6/15/1964	1.59	4.3	31	26.7	16.8
8	7/18/1964	3.52	1.7	43	41.3	11.7
9	9/21/1964	1.64	1.2	6.4	5.2	3.2
10	7/14/1965	2.35	1.5	139	137.5	58.5

11	8/9/1965	3.06	2.7	41	38.3	12.5
12	5/11/1966	2.88	31	765	734	254.9
13	7/27/1966	2.43	3.6	29	25.4	10.5
14	10/14/1966	2.12	1.7	17	15.3	7.2
15	4/1/1967	2.82	76	785	709	251.4
16	6/11/1967	3.96	19	283	264	66.7
17	8/18/1967	1.82	4.6	68	63.4	34.8
18	6/10/1968	2.01	6.6	31	24.4	12.1
19	6/24/1968	2.35	4.7	108	103.3	44.0
20	8/16/1968	4.37	3.2	943	939.8	215.1
21	6/7/1969	2.18	44	397	353	161.9
22	9/5/1969	2.6	5.2	37	31.8	12.2
23	10/10/1969	3.06	4.7	124	119.3	39.0
24	5/12/1970	1.53	33	367	334	218.3
25	6/1/1970	2.99	65	1020	955	319.4
26	7/19/1970	1.59	14	48	34	21.4
27	9/6/1970	2.28	11	174	163	71.5
28	9/23/1970	2.78	44	684	640	230.2
29	8/25/1971	1.77	0.41	26	25.59	14.5
30	4/15/1972	1.55	40	228	188	121.3
31	6/14/1972	3.13	13	760	747	238.7
32	6/20/1972	1.9	85	390	305	160.5
33	7/18/1972	2	93	362	269	134.5
34	8/2/1972	1.69	18	89	71	42.0
35	8/26/1972	1.63	87	330	243	149.1
36	9/12/1972	1.53	30	460	430	281.0
37	9/18/1972	2.39	115	699	584	244.4
38	9/21/1972	1.6	253	552	299	186.9
39	9/29/1972	1.5	93	368	275	183.3
40	10/22/1972	1.51	48	310	262	173.5
41	4/21/1973	3.38	83	1130	1047	309.8
42	6/16/1973	1.94	33	379	346	178.4
43	9/17/1973	1.58	4	17	13	8.2
44	9/29/1973	2.05	31	108	77	37.6
45	4/22/1974	2.1	157	516	359	171.0
46	10/14/1974	1.73	6.5	39	32.5	18.8
47	4/27/1975	1.93	49	400	351	181.9
48	5/24/1975	3.22	25	134	109	33.9
49	7/12/1975	1.7	23	33	10	5.9
50	8/21/1975	2.65	4.6	12	7.4	2.8
51	4/25/1976	1.68	30	236	206	122.6
52	5/6/1976	1.94	45	404	359	185.1
53	10/5/1976	1.88	1.8	19	17.2	9.1

54	6/30/1977	2.69	0.37	25	24.63	9.2
55	5/12/1978	1.8	30	274	244	135.6
56	6/16/1978	1.76	5.7	110	104.3	59.3
57	7/1/1978	4.86	20	725	705	145.1
58	9/13/1978	2.07	2.7	50	47.3	22.9
59	4/25/1979	2.12	68	526	458	216.0
60	6/8/1979	4.91	26	152	126	25.7
61	6/29/1979	1.62	19	54	35	21.6
62	8/9/1979	3.07	28	541	513	167.1
63	8/17/1979	1.85	42	343	301	162.7
64	8/31/1980	1.81	30	143	113	62.4
65	9/8/1980	4.66	38	450	412	88.4
66	10/16/1980	2.07	36	204	168	81.2
67	4/23/1981	1.63	23	243	220	135.0
68	6/13/1981	2.67	49	495	446	167.0
69	8/3/1981	2.72	12	179	167	61.4
70	10/18/1981	1.79	13	44	31	17.3
71	4/16/1982	1.69	58	314	256	151.5
72	7/7/1982	2.24	18	119	101	45.1
73	7/22/1982	3.39	15	190	175	51.6
74	8/7/1982	1.59	27	52	25	15.7
75	4/1/1983	1.83	88	637	549	300.0
76	4/9/1983	1.67	125	330	205	122.8
77	7/1/1983	2.86	34	934	900	314.7
78	8/17/1983	1.66	5.4	10	4.6	2.8
79	9/18/1983	2.73	12	25	13	4.8
80	10/21/1983	1.76	9.4	85	75.6	43.0
81	6/15/1985	1.6	9.8	38	28.2	17.6
82	7/14/1985	2.7	6.4	14	7.6	2.8
83	8/13/1985	2.17	6.4	79	72.6	33.5
84	5/17/1986	2.36	19	689	670	283.9
85	7/7/1986	1.62	15	81	66	40.7
86	9/22/1986	2.31	6.6	37	30.4	13.2
87	9/29/1986	2.26	17	146	129	57.1
88	5/18/1987	2.95	12	72	60	20.3
89	8/14/1987	4.51	4.1	635	630.9	139.9
90	8/26/1987	3.76	46	879	833	221.5
91	7/17/1988	1.67	2	28	26	15.6
92	10/18/1988	1.5	2.8	27	24.2	16.1
93	6/24/1989	1.65	6.9	19	12.1	7.3
94	7/19/1989	2.95	3.4	30	26.6	9.0
95	8/4/1989	3.89	9.4	305	295.6	76.0
96	9/1/1989	2.44	13	147	134	54.9

97	5/4/1990	1.66	26	135	109	65.7
98	5/9/1990	1.51	56	365	309	204.6
99	8/18/1990	3.81	7.5	120	112.5	29.5
100	4/14/1991	1.77	63	358	295	166.7
101	5/25/1991	2.4	36	624	588	245.0
102	8/8/1991	2.11	1.2	19	17.8	8.4
103	10/4/1991	2.76	1.2	84	82.8	30.0
104	7/13/1992	1.55	5.5	35	29.5	19.0
105	4/1/1993	1.62	86	505	419	258.6
106	4/15/1993	1.82	86	527	441	242.3
107	6/8/1993	2.11	45	320	275	130.3
108	6/18/1993	3.07	66	822	756	246.3
109	6/27/1993	1.55	55	320	265	171.0
110	7/18/1993	3.45	28	334	306	88.7
111	6/24/1994	2.83	14	624	610	215.5
112	7/21/1994	2.52	8.7	35	26.3	10.4
113	8/11/1994	1.65	2.6	126	123.4	74.8
114	4/26/1995	2.36	50	666	616	261.0
115	5/23/1995	2.02	43	450	407	201.5
116	10/20/1995	1.8	7	36	29	16.1
117	5/20/1996	2.52	63	377	314	124.6
118	5/28/1996	1.56	155	918	763	489.1
119	6/6/1996	1.61	115	512	397	246.6
120	7/18/1996	3.25	27	1460	1433	440.9
121	8/6/1996	3.69	24	680	656	177.8
122	9/26/1996	1.82	8.4	42	33.6	18.5

CAE/WP 99−3

You may purchase a print copy of this paper by contacting Teresa Bullock, Phone: (815) 753−9347, E−Mail: tbullock@niu.edu.

CONTACT INFORMATION:

American Farmland Trust
Center for Agriculture in the Environment
148 N. 3rd St.
P.O. Box 987
DeKalb, Ill. 60115
Phone: (815) 753−9347
Fax: (815) 753−9348
E−mail: Ann Sorensen (asorensen@niu.edu), Director.

Top of Document.

American Farmland Trust
Center for Agriculture in the Environment
http://www.aftresearch.org
URL=/current%20research/wp/wp99−3.html

2000 May 19