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THE FLOODPLAIN FIASCO

By Andrew J. Kubiak†

I. Introduction

Flooding has long been a source of hardship for the people who work and live near bodies of water such as rivers, lakes, and streams. The United States has not been an exception. Only in recent decades has the United States taken proactive steps in an effort to mitigate the damage associated with flooding. These proactive measures predict the areas of the United States that flood, and require that people who live within those areas to purchase flood insurance. These predictions are in the form of a nationwide system of maps. Until recently, flood insurance was offered to affected property owners at a reduced rate.[1] The nationwide system of maps indicate the potential limits of flooding however these maps are plagued by systematic errors, which re-

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1. *See generally A Chronology of Major Events Affecting the National Flood Insurance Program*, The American Institutes for Research (Oct. 2002), http://www.dhs.gov/xlibrary/assets/privacy/privacy_pia_mip_apnd_h.pdf.

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duce their accuracy to the point where the flooding limits indicated on the maps are almost, if not completely, meaningless. These errors are caused by the use of stormwater runoff rates that are based on existing conditions,[2] the use of computer technology that cannot accurately model the effects of structures impeding the flow of stormwater,[3] and the use of survey equipment that does not accurately model the terrain that forms the basis of these limits of inundation.[4] For these reasons, the proposition of this Article is that the way flood insurance is managed should be changed. This Article also proposes several possible solutions to the problem of flood inundation mapping.

II. History, Purpose, and recent developments of the National Flood Insurance Program

Flooding control and mitigating the damage that flooding causes has long been an issue in the United States. Ostensibly beginning in 1824, there have been many laws and court cases associated with the management of the nation's waterways.[5] These first laws were primarily concerned with constructing levee systems near major waterways. These first laws only focused on preventing damage from occurring rather than proactively determining likely places where damage will occur and mitigating that damage after it occurrs.[6] According to the "Report on Floods and Flood Damage" produced by the American Insurance Association, "specific flood insurance covering fixed location properties cannot feasibly be written because of the virtual certainty of loss, its catastrophic nature and the reluctance or inability of the public to pay the premium charge."[7] Insurance companies could never offer flood insurance at a rate that would be accepted by the purchasing market.[8] Therefore, flood insurance was never a meaningful option for people to purchase.

2. Changes to General Provisions and Communities Eligible for the Sale of Insurance Required to Include Future-Conditions Flood Hazard Information on Flood Maps, 66 Fed. Reg. 59,166–67 (Nov. 27, 2001) (to be codified at 44 C.F.R. pts. 59 and 64).

3. *Compare* U.S. Army Corps of Eng'rs, The Hydraulic Engineering Center, HEC-2 Water Surface Profiles User's Manual (Sept. 1982), *with* CEIWR-HEC, U.S. Army Corps of Eng'rs, The Hydraulic Engineering Center, HEC-2 Water Surface Profiles Users Manual (Sept. 1990).

4. *See generally* K.W. Holmes et al., *Error in United States Geological Survey 30-meter digital elevation model and its impact on terrain modeling*, 233 Journal of Hydrology 154-73 (2000).

5. The America Institutes for Research, *supra* note 1, at 1.

6. *Id.*

7. *Report on Floods and Flood Damage*, American Insurance Association (Jan. 10, 1956), http://tera-3.ul.cs.cmu.edu/NASD/4dcb85c3-9fee-4c83-9e6d-fe6ce5522b59/China/disk4/77/77-3/31008019/PDF/00000013.pdf.

8. *Id.*

The first major law to change the way in which flood insurance was addressed was Title XIII of the Housing and Urban Development Act of 1968, also known as the National Flood Insurance Act of 1968.[9] The National Flood Insurance Act did many things, but the most relevant was that it mandated that the Department of Housing and Urban Development create an inventory of the areas in the United States subject to flooding[10] within fifteen years of the date of the enactment of the National Flood Insurance Act.[11] The National Flood Insurance Act also required that the flood insurance policies be offered at a subsidized rate.[12] The National Flood Insurance Act also required the Secretary of Housing and Urban Development to coordinate with other member agencies of the federal government to achieve these directives.[13]

This mapping effort led to the creation of the Flood Insurance Rate Maps.[14] These maps show the limits of the 100-year floodplain, that is the "area which is subject to inundation from a flood having a 1-percent chance of being equaled or exceeded in any given year."[15] The limits of these floodplains were established as a result of engineering, that is hydrologic and hydraulic, studies on these waterways.[16] Subsequent regulations passed by the Department of the Treasury then required that any structure whose purchase was secured by a loan and was within one of these established floodplain boundaries would be required to purchase flood insurance from an insurance provider.[17] The result of these two legislative efforts is that there are approximately 5.5 million flood insurance policies currently in place[18] insuring almost $1.3 billion in assets.[19] As a result, until recently, Americans have had access to flood insurance at a commercially viable cost to insure properties that are shown to be at risk of flooding during a 100-year storm.

The latest major development in the regulatory environment related to flood insurance is the passage of the Biggert-Waters Flood Insurance Reform Act of 2012.[20] This law passed because of recent

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9. Housing and Urban Development Act of 1968, Pub. L. No. 90-448, § 1301, 82 Stat. 572 (1968).

10. *Id.* § 1360.

11. *Id.* § 1360(2).

12. *Id.* § 1308 (b)(2).

13. *Id.* § 1360.

14. THE AMERICA INSTITUTES FOR RESEARCH, *supra* note 1, at 13.

15. 42 U.S.C.A. § 4004(a)(1) (West 2012).

16. THE AMERICA INSTITUTES FOR RESEARCH, *supra* note 1, at 17.

17. 12 C.F.R. § 22.3 (2014).

18. *Policies in Force by Month*, FEMA, http://www.fema.gov/flood-insurance-statistics-current-month/policies-force-month (last visited Dec. 21, 2013).

19. *Total Coverage by Calendar Year*, FEMA, http://www.fema.gov/policy-claim-statistics-flood-insurance/policy-claim-statistics-flood-insurance/policy-claim-13-12 (last visited Dec. 21, 2013).

20. Jay Landers, *Congress Delays Certain Changes to National Flood Insurance Program*, CIVIL ENGINEERING, February 2014, at 16.

major storms the United States has seen over the last decade. Major storms, such as Hurricane Katrina and Superstorm Sandy, have caused large-scale damage to urban areas of the country.[21] These storms, as well as many more less-notable storms have caused billions of dollars worth of damage to the United States, and the National Flood Insurance Porgram paid for this damage by borrowing money.[22] The National Flood Insurance Act also authorized a National Flood Insurance Fund,[23] whose purpose was to subsidize the flood insurance policies that would be required under this program.[24] This fund began with a pre-authorized borrowing limit of $250 million set by Congress in 1968.[25] Over the history of the National Flood Insurance Program, that limit has been raised many times, and the National Flood Insurance Program now has a pre-authorized borrowing limit of $500 million with over $30 billion allowed with presidential approval.[26] Presidential authorization was given, and currently the National Flood Insurance Program is $24 billion in debt.[27] The premiums levied as a result of the Department of the Treasury regulations noted above, that is those regulations requiring the purchase of flood insurance, have not been able to recoup the losses experienced by the Flood Insurance Program since 2004.[28]

In order to alleviate this issue, the Biggert-Waters Flood Insurance Reform Act of 2012 withdrew the subsidy for new flood insurance policies and those policies that have lapsed.[29] The subsidy withdrawal will have a phased implementation[30] that limits the amount of premium increase to only 20% per year until the premium that the insured paid reflects the actual risk based on recognized actuarial principles.[31] While there are no definitive amounts regarding what those premiums will be, preliminary estimates indicate that hundreds of thousands of properties will experience increased rates as a result of this new legislation.[32] Property owners that are compelled to buy flood insurance will be required to pay annual premiums of thousands

21. *Id.*

22. 158 Cong. Rec. H4616-01 (daily ed. June 29, 2012) (statement of Rep. Bachus), 2012 WL 2491406.

23. Housing and Urban Development Act of 1968, Pub. L. No. 90-448, § 1310(a), 82 Stat. 577 (1968).

24. *Id.* § 1334(a).

25. *Id.* § 1309(a).

26. 42 U.S.C.A § 4016(a) (West 2012).

27. Landers, *supra* note 20, at 16.

28. Rawle O. King, Cong. Research Serv., *R42850, The National Flood Insurance Program: Status and Remaining Issues for Congress* 18 (2013), *available at* https://www.fas.org/sgp/crs/misc/R42850.pdf.

29. Landers, *supra* note 20, at 16.

30. Moving Ahead for Progress in the 21st Century Act, Pub. L. No. 112-141, § 100205, 126 Stat. 918 (2012) (codified in 42 U.S.C. § 4015).

31. *Id.*

32. *Flood Insurance May End Up Being No Fix At All*, CNBC, http://www.cnbc.com/id/101539750#. (last visited Oct 7, 2014).

of dollars for the unsubsidized flood insurance policies as opposed to hundreds of dollars under the pre-Biggert-Waters subsidized insurance regime.[33]

Lawmakers have received negative feedback, especially from coastal states such as Louisiana and Florida, because of the increase in flood insurance premiums caused by the withdrawal of the flood insurance subsidy required by the Biggert-Waters Flood Insurance Reform Act.[34] This legislation had far-reaching consequences that were not considered by authors of Biggert-Waters. Congresswoman Maxine Waters, one of the legislators after whom the bill was named, stated that "neither the Republicans nor the Democrats envisioned that [Biggert-Waters] would inflict the pain and concern that many Americans are experiencing."[35] There were attempts to delay the implementation of the premium increases stated in Biggert-Waters.[36] However, given the financial situation that the National Flood Insurance Program is currently in, there must be some fundamental change to the way flood insurance is handled in this country. Otherwise, the National Flood Insurance Program will continue to be insolvent.

III. Basics of Floodplain Analysis

A. *Generally*

Generally, the establishment of a floodplain consists of two studies, a hydrologic study and a hydraulic study. Hydrology is specifically defined as "the study of the occurrence, circulation and distribution [of water] over the world's surface.[37]" The use of hydrology, as it relates to floodplains, is concerned with the estimation of a design event, that is the peak flow rate that the reach of a creek will experience within a probability.[38] Federally regulated floodplains shown on the Flood Insurance Rate Map, are based on the 100-year design event.[39] That is the peak flow rate of stormwater that will occur with a statistical probability of once every 100 years.[40] Put another way, a 100-year storm has a 1% chance of occurring in any given year. For a typical 30-year mortgage, this correlates to a 26% chance that a 100-year storm will happen during the life of the mortgage.[41]

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33. *Id.*
34. Landers, *supra* note 20, at 16.
35. *Id.* at 17.
36. *Id.*
37. Andrew Chadwick et al., Hydraulics in Civil and Environmental Engineering 308 (4th ed. 2004).
38. *Id.* at 313.
39. Managing Floodplain Development Through The National Flood Insurance Program, 3–37 *available at* www.fema.gov/pdf/floodplain/is_9_complete.pdf [hereinafter Managing Floodplain Development].
40. 42 U.S.C.A § 4004(a)(1).
41. Managing Floodplain Development, *supra* note 39, at 3-6.

Once that peak flow rate is established, the elevation or depth of the stormwater during that peak rate needs to be established. This is accomplished by way of the hydraulic study. The hydraulic study starts with the creation of a computer model of the subject creek that is being studied and applies the peak flow rate determined by the hydrologic analysis to that hydraulic model. The hydraulic model then determines the peak water surface elevation along the subject creek.[42] By comparing the peak water surface elevations with the terrain of the creek, the limits of inundation can be determined.

B. *Hydrology Basics*

The peak flow rate of stormwater that enters a reach of a creek at a given point is dependent on several factors that have to be determined as part of the engineering study. There are many methods that can be used to determine the peak 100-year flow rate used in the floodplain analysis[43]; however, the variables used in those methods are largely the same.[44] The primary elements that affect the peak flow rate during a 100-year storm are: watershed size, rainfall intensity in the area, average slope of channels in the watershed, amount of water stored in the basin, level of basin development, and impervious cover in the watershed.[45] While most of these variables are largely unchangeable in any meaningful way, human activities can change some of the variables in a watershed such as basin development and impervious cover.[46] By changing any of these variables in a watershed, the peak 100-year flow rate determined for a watershed can also change.

C. *Hydraulic Basics*

The hydraulic analysis of a creek establishes how high the water will get during the peak flow rate established during the hydrologic analysis. These peak elevations are usually determined through a computer program called "HEC-RAS," or its predecessor "HEC-2."[47] In order to determine the peak water surface elevations of a subject creek, the engineer has to develop a computer model of the creek. These programs determine the peak elevation based on a number of parameters the engineer performing the analysis inputs. These parameters include: the length of the creek; the hydraulic roughness of the creek; the shapes of the cross sections of the creek; backwater effects from

42. U.S. Army Corps of Eng'rs (Sept. 1990), *supra* note 3, at 3.
43. RICHARD MCCUEN, HYDROLOGIC ANALYSIS AND DESIGN 367–68 (Prentice Hall 2d ed. 1998).
44. *Id*.
45. *Id.*at 368.
46. *See id.*
47. GARY W. BRUNNER, HEC-RAS RIVER ANALYSIS SYSTEM USER'S MANUAL x (2010).

obstructions such as culverts, bridges, and other structures.[48] The final product of the hydraulic analysis is a series of water surface elevations, which, when compared with the existing terrain can be used to generate the limits of inundation.

IV. Sources of Systemic Errors in the Flood Insurance Rate Maps

The Flood Insurance Rate Maps noted above in Section II of this Article were created in conformance with the procedures noted in Section III of this Article. However, the methodologies used introduce several systemic errors into the mapping process, and these errors have created inaccurate maps. This Section will discuss some of those systemic errors and the result of those individual errors on the effectiveness of the maps.

A. *Existing Conditions Hydrology*

When the initial inventory was performed and the flood hazard boundaries established, the engineers performed the studies using existing conditions hydrology, that is the peak flow rate that would have occurred when the engineers performed the study in the 1970s.[49] As a result of the urbanization of many watersheds during the last forty years, the characteristics of many watersheds (that is size, slope, ground cover, etc.) are radically different. Therefore the peak 100-year stormwater runoff flow rate will be different as well. As noted above, the peak 100-year flow rate for a watershed partly depends on the ground cover and the level of development of the watershed.

1. Changes in Ground Cover

The United States has seen a massive boom in development during the last several decades.[50] The net result of this development is buildings, streets, and parking lots now replace areas of vegetated terrain. According to the 2010 National Resources Inventory, produced by the Natural Resources Conservation Service, between 1982 and 2010, the amount of 'developed land' has increased from almost 72 million acres to over 113 million acres.[51] This is a 58% increase in the amount of land dedicated to development in some form or fashion.[52] Put an-

48. *See* U.S. Army Corps of Eng'rs (Sept. 1990), *supra* note 3, at 1.
49. Changes to General Provisions and Communities Eligible for the Sale of Insurance Required to Include Future-Conditions Flood Hazard Information on Flood Maps, 66 Fed. Reg. 59,166–67 (Nov. 27, 2001) (to be codified at 44 C.F.R. pts. 59 and 64).
50. Natural Res. Conservation Serv. & Iowa State Univ. Ctr. for Survey Statistics & Methodology, U.S. Dep't of Agric., Summary Report: 2010 National Resources Inventory 8 (2013).
51. *Id.* at 56, 62.
52. *Id.* at 8.

other way, 37% of the currently developed land in the United States has been developed in the last twenty-eight years.[53] Development of previously undeveloped areas generally increases the peak stormwater runoff from those areas in two ways: the first is the increase of impervious area in a watershed, and the second is the reduction in a watershed's time to peak because of the channelization and concentration of stormwater runoff from the watershed.

Clearing a previously undeveloped watershed and replacing that area with impervious cover, such as rooftops and concrete, functions to increase the stormwater runoff in a watershed by eliminating the ability of stormwater to infiltrate into the ground.[54] During a rain event, stormwater will primarily go in only two directions. The majority of the stormwater that accumulates during a rain event will either infiltrate into the ground or it will runoff or enter a storm drainage system and eventually a larger natural body of water such as a river, creek, or lake.

Permeability is the typical measure of water's ability to pass through soil.[55] The more permeable a soil type is, the more water that will pass through the soil and enter the groundwater supply, therefore, a soil type that is more permeable will allow less stormwater to enter a surface drainage system, e.g. creeks and storm drain systems. Permeability is generally a function of the grain size, grain size distribution of the soil, and the latent water content of a soil profile.[56] For example, a soil that has much larger grains, such as sand, will be much more permeable because there is a larger amount of void space between the individual grains. Clayey soils have a much smaller grain diameter and can actually retain water in the void spaces between the soil particles.[57] This combination of small grain diameter and ability to retain water make clayey soils much less likely to absorb stormwater and make the amount of stormwater that will runoff higher than a similarly situated sandy soil. Additionally, grain size distribution is critical to determining the permeability of a soil profile. A "well graded" soil, that is a soil with a large number of diameters in the particle distribution will be less permeable than a soil with fewer diameters.[58] This is due to the simple fact that in a soil profile with a large number of diameters, the void spaces in between the larger particles can be occupied by smaller particles, thus creating a more densely packed soil

53. *Id.*

54. *Integrated Stormwater Management Technical Manual*, NORTH CENTRAL TEXAS COUNCIL OF GOVERNMENTS HO-35, http://iswm.nctcog.org/Documents/technical_manual/Hydrology_4-2010b.pdf.

55. MCCUEN, *supra* note 43, at 117.

56. *See* V. N. S. MURTHY, GEOTECHNICAL ENGINEERING PRINCIPLES AND PRACTICES OF SOIL MECHANICS AND FOUNDATION ENGINEERING 104-05 (Michael D. Meyer ed., 2003).

57. *Id.* at 107.

58. *Id.* at 44.

profile that is less likely to allow water to pass through it to lower soil strata.[59]

Additionally, the location and makeup of underlying rock strata, or generally impervious strata, can channel recently infiltrated stormwater through subterranean paths.[60] Generally, this phenomenon is known as ground water recharge, and while it is a significant legal issue, its scope, effects, and consequences are beyond the purview of this Article. Simply because stormwater has entered the ground does not necessarily mean that it will never enter any surface drainage systems. Groundwater can exfiltrate and enter surface drainage systems depending on the relative elevations of the rock layer, water table, and other percolation factors associated with the soil strata.[61] The primary effect that losing ground water recharge has on surface floodplains is that by covering watersheds with impermeable areas, ground water storage cannot be recharged because the stormwater is simply passing into nearby creeks and streams. This has the effect of increasing the flow in those creeks (and subsequent inundated areas) and reducing the stormwater that can infiltrate into the ground.

Replacing permeable ground cover, that is soil, grass, and other vegetative covers, with impermeable ground cover, e.g. concrete surfaces, roofs, etc., provides stormwater with less of an opportunity to infiltrate into groundwater sources and necessarily dictates that almost all of that stormwater enters some form of surface drainage system, either a storm drainage system, creek, river, and usually all three. Forcing more water into the natural drainage systems causes an increase in the peak 100-year runoff flow rate. Because creeks, streams, and rivers now have to carry more stormwater in an urbanized condition, the limits of inundation during this design event will be larger and therefore subject properties to flooding that may not have been during these undeveloped conditions.

2. Reductions in the Time to Peak

The reduction of time needed for a watershed to peak creates higher peak flow rates in a more indirect manner. When a 100-year design storm, that is a storm that will produce a 100-year peak flow rate, occurs, the stormwater requires a finite and measurable amount of time, minutes, hours, or even days, to progress through the watershed.[62] A watershed's time to peak (also known in some methodologies as the time of concentration) reflects the amount of time that it

59. *Id.*

60. *See* NEVEN KRESIC, GROUNDWATER RESOURCES SUSTAINABILITY, MANAGEMENT, AND RESTORATION 110 (Larry S. Hager ed., 2009).

61. *See id.* at 278–79.

62. *See* NORTH CENTRAL TEXAS COUNCIL OF GOVERNMENTS, *supra* note 54, at HO-19.

takes for a watershed to reach its maximum rate of discharge during a storm event.[63] For example, consider two watersheds that are identical with the only difference between the two being the time to peak, one having a time to peak of ten minutes and the other having a time to peak of twenty minutes. Then consider identical storms striking two watersheds and generating ten thousand cubic feet of stormwater runoff. In the first watershed, that is with a time to peak of ten minutes, the average rate of runoff will be one thousand cubic feet of runoff per minute. In contrast, the second watershed would have a time to peak of twenty minutes and the average rate of runoff would be five hundred cubic feet per minute. While this example oversimplifies the effects of reducing the time to peak on a watershed, the overall rule still holds that shorter times to peak necessarily mean higher stormwater runoff rates, and higher stormwater runoff rates correlate to larger limits of inundation during floods.

Time to peak in undeveloped watersheds are naturally longer than their developed counterparts because of increased channelization and the reduction of permeable ground cover.[64] Reduction of pervious and vegetated ground cover decreases the time to peak for a watershed by making it hydraulically smoother for stormwater passing over it.[65] For example, an unpaved surface, such as grass, will retard the flow of water over its surface more than a similar section of smooth concrete at the same slope.[66] Increased channelization of stormwater manifests in terms of concrete lined channels and other storm drainage structures. The usage of these types of structures allows municipalities and real estate developers to reduce the impact of drainage structures on real estate by concentrating stormwater and quickly moving it off their property and downstream, thus maximizing developable land. Therefore, reducing the time to peak also has the net result of increasing the stormwater burden on downstream property owners by increasing the peak flow rate.

There are many methods recognized by the engineering community for determining the peak stormwater discharge of a watershed, e.g. the SCS Method, the Green-Ampt Method, or the Initial and Constant Loss Method, just to name a few.[67] The SCS Method is one of the more popular methods due to its versatility and simplicity.[68] According to the SCS Method, which is a method for determining the stormwater runoff from a watershed of virtually any size, the unit

63. *Id.*
64. *Id.* at HO-24.
65. *Id.*
66. *Id.*
67. *See* William A. Scharffenberg & Matthew J. Fleming, *Hydrologic Modeling System HEC-HMS Users Manual*, U.S. ARMY CORPS OF ENG'RS 130-39 (Aug. 2009), http://www.hec.usace.army.mil/software/hec-hms/documentation/HEC-HMS_Users_Manual_3.4.pdf.
68. Urban Hydrology for Small Watersheds 2-1 (U.S.D.A. 1986).

peak discharge is inversely related to the time of concentration and time to peak of a watershed. Put another way, as the time to peak decreases, the unit peak discharge increases.[69] The unit peak discharge is defined as the peak rate of runoff that will be generated by a watershed per square mile per inch of excess precipitation, that is cfs/sq. mi.-in.[70] The peak rate of stormwater discharge from a watershed is determined in part by the peak unit discharge equation.[71] The peak unit discharge equation is a function of the watershed peaking factor, the watershed area, and the time to peak of the watershed.[72] Of these three parameters, the only parameter that urbanization of a watershed can affect is the time to peak; the remaining factors are related to the geometry of the watershed. The area of a watershed typically remains the same while the peaking factor is a function of the average slope of a watershed.[73] Therefore, absent any large-scale earthmoving projects or diversion streams that convey stormwater from one watershed into another, the area of a watershed and the average slope will remain the same.

Most areas of the United States have observed this phenomenon of increased peak stormwater runoff rates resulting from development. William B. Reed specifically studied this phenomenon in his essay entitled "An Evaluation of the Effects of Changing Land Use on the Urban Flood Frequency and Hydrograph Characteristics of Valley Creek."[74] His analysis discusses the changes in peak flow rates that occurred between the arrival of the European settlers in 1685 and 1995.[75] The results show that, because of development, that is reduction in the time to peak and increasing impervious ground cover in a watershed,[76] the peak 100-year stormwater flow rate has almost doubled between 1685 conditions and 1995 conditions.[77] Also, the results show a 14% increase between 1977 conditions and 1995 conditions.[78]

The use of existing conditions hydrology in the current hydrologic models that form the basis for the Flood Insurance Rate Maps underestimate the peak flow rate that will be experienced in a stream or

69. *Integrated Stormwater Management Manual* HO-28, North Central Texas Council of Governments, http://iswm.nctcog.org/Documents/technical_manual/Hydrology_4-2010b.pdf.

70. *Id.* at Fig. 1.10.

71. *Id.* at Eq. 1.15.

72. *Id.*

73. North Central Texas Council of Governments, *supra* note 54, at HO-28.

74. William B. Reed, *An Evaluation of the Effects of Changing Land Use on the Urban Flood Frequency and Hydrograph Characteristics of Valley Creek*, Symposium Proceedings on Urban Hydrology 23 (1990).

75. *Id.* at 24–25.

76. *Id.* at 28.

77. *Id.* at 29.

78. *Id.*

river. The use of existing conditions hydrology results in an actual peak 100-year flow rate that is greater than the peak flow rate used to generate the Flood Insurance Rate Maps, therefore the actual 100-year floodplain elevation should be higher and the limits of inundation should be wider than the floodplain limits indicated on the Flood Insurance Rate Maps. This is a systemic error that effects all Flood Insurance Rate Maps by underestimating the risk associated with properties that are near, but not technically inside the federally-regulated floodplain.

B. *Failures in the Software Analysis*

An essential part in any floodplain analysis is the evaluation of structures that will impede the flow of stormwater in a creek or stream; these structures include bridges, levees, and culverts. Due to their small size and low cost, culverts make up a significant percentage of structures crossing regulated floodplain hazard areas.[79] During the initial modeling of the creeks studied for the Flood Insurance Rate Maps, the primary program used was HEC-2.[80] HEC-2 was first developed in 1964 as a means of determining flood profiles in "irregularly shaped cross sections."[81] The major limitation of this software package was the fact that it could not model culverts until the 1991 version.[82] This means that any culvert's effects on surrounding properties would be an approximation at best because there was no way to accurately model them. Culvert and bridge hydraulics are governed by similar sets of equations.[83] Those equations are Manning's equation, the weir flow equation, and the pressure flow equation.[84] All three of these equations rely on the use of empirically-determined constants.[85] The Federal Highway Administration (along with other parties) performed an empirical analysis on culverts to determine the effects that its shapes have on the upstream and downstream hydraulics.[86] These coefficients accommodated the different types of culvert

79. Kornel Kerenyi, et al., U.S. Dep't of Transp., *FHWA-HRT-05-007, A Better Design of Box Culverts* (2005), *available at* http://www.fhwa.dot.gov/publications/publicroads/05sep/07.cfm.

80. MANAGING FLOODPLAIN DEVELOPMENT, 3-14.

81. *Id.* at 1.

82. *Compare* U.S. Army Corps of Eng'rs, The Hydraulic Engineering Center, HEC-2 WATER SURFACE PROFILES USER'S MANUAL, VII-2 (Sept. 1982), *with* CEIWR-HEC, U.S. Army Corps of Eng'rs, The Hydraulic Engineering Center, HEC-2 WATER SURFACE PROFILES USERS MANUAL, Appendix II-ii (Sept. 1990) [The pages cited indicate the available options for users to consider when creating models. The only structure referenced on the cited pages of the 1982 Manual are bridges. The 1990 Manual references both bridges and culverts.].

83. *Compare* GARY BRUNNER, HEC-RAS RIVER ANALYSIS SYSTEM HYDRAULIC REFERENCE MANUAL 5-18 & 5-19 (2010), *with* GARY BRUNNER, HEC-RAS RIVER ANALYSIS SYSTEM HYDRAULIC REFERENCE MANUAL 6-35 (2010).

84. *Id.*

85. *Id.* at 3-14, 5-19, and 5-23.

86. *Id.* at Table A-1.

(circular, square, elliptical, etc.), differing material types (concrete, corrugated metal, etc.), and differing headwall types (parallel, perpendicular, etc.).[87] The 1991 release of HEC-2 incorporated these Federal Highway Administration equations and coefficients into the HEC-2 program.[88] This incorporation allowed designers to accurately model the effects of culvert crossings on floodplains adjacent to those crossings.

The problem with the incorporation of this routine into the HEC software package is that it occurred in 1991, six years after the creation of the Flood Insurance Rate Maps. Therefore, none of the original models could have provided an accurate modeling of any culvert crossing a floodplain. Considering that the majority of structures that cross floodplains are in fact culverts, this is a massive potential source of error in floodplain mapping.

C. *Limitations in the Methods of Survey*

The hydraulic models that were created as the basis for the floodplain limits shown on the Flood Insurance Rate Maps were based on surveys that were performed contemporaneously with the hydraulic model development. In order to perform the floodplain determinations necessary for the Flood Insurance Rate Maps, a massive survey of the creeks and streams had to be completed in order to generate the computer models that would eventually become the basis of the Flood Insurance Rate Maps.[89] These surveys were performed using survey equipment that would have been typically available in the 1970s. During this same period, and possibly as a result of the floodplain mapping effort, the United States Geological Survey produced a nationwide survey. The fundamental problem with the survey methods and its use in the floodplain mapping effort was that the equipment was wrought with errors due to the fact that these areas were primarily mapped using aerial and photogrammetric technology, which had not yet achieved the level of accuracy necessary for engineering level studies.[90]

In 1999, a group from the University of California-Santa Barbara and Stanford selected an approximately 6,500 acre area of California, which represented a variation of terrain types, to determine the average error found between the maps produced by United States Geological Survey and maps produced as a result of modern survey methods using Global Positioning System equipment.[91] They tested the area by comparing the data shown on the United States Geological Survey map for the area with data acquired using a Global Positioning Sys-

87. *Id.*
88. *Id.* at 21.
89. MANAGING FLOODPLAIN DEVELOPMENT, supra note 39, at 3–7.
90. *See* K.W. Holmes et al., *supra* note 4, at 155.
91. *Id.* at 156–57.

tem.[92] The potential error reported on this particular United States Geological Survey map implied that the measurements shown on the map could be off by as much as 9 meters in the horizontal and vertical directions and 5 meters in the vertical direction.[93] The results of the study indicated that, on the average, the United States Geological Survey map, in this case, was much more accurate than the potential error reported, the average error being only about 10 centimeters[94], however, the error range discovered was found to be between +18 meters and -13 meters.[95] So while the average error for this area was low, the potential margin of error was much larger than that indicated on the published United States Geological Survey map. This indicates a large source of seemingly random errors that cannot be predicted or accommodated for in the mapping process that render the maps produced in this time period dubious at best. Consequentially, anything that is produced because of those maps, specifically drainage area determinations and hydraulic models, must be considered equally dubious.

Errors in the underlying survey data used to produce the hydraulic models can affect the delineated 100-year floodplain in two ways. First, the water surface elevations calculated during the hydraulic analysis are based on cross sections that are reflective of the survey data collected in the field. Second, the limits of inundation shown on the Flood Insurance Rate Maps are reflective of the correlation between the calculated water surface elevations of the floodplain and how it relates to the elevations of the cross sections taken from the survey data.

1. Effect of Survey Errors on the Models

The water surface elevations that represent the peak water surface elevations during the 100-year design storm shown on the Flood Insurance Rate Map are determined by using a computer analysis software package initially called HEC-2, and then later replaced by HEC-RAS.[96] This software package uses two equations to iterate to a solution, specifically the Energy Equation and Manning's Equation, in order to determine the water surface elevation that will appear at a cross section when a specified flow rate is applied to it.[97] The energy balancing equation uses several variables in order to determine the calculated water surface elevation at a given section, specifically, the water surface elevation and energy gradient elevation at the adjoining

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92. *Id.* at 157.
93. *Id.*
94. *Id.* at 172.
95. *See* K.W. Holmes et al., *supra* note 4, at 162.
96. Gary Brunner, HEC-RAS River Analysis System User Manual xi (Jan. 2010).
97. Gary Brunner, HEC-RAS River Analysis System Hydraulic Reference Manual 2-2 through 2-4 (2010).

cross section, the cross sectional area of the section, the wetted perimeter of the cross section, the hydraulic roughness of the cross section, the distance between the cross sections, and the slope of the stream being studied.[98] A change to any one of these variables will result in a change in the calculated water surface elevation at that section. Changes to any individual section will cause changes that can propagate through the entire stream being studied.[99] Therefore, the accuracy of the survey data used in a stream analysis is critical to the accuracy of the end product. Although the effects and extents of those errors cannot be determined, the effects of those errors are necessarily reflected in the water surface elevation determinations of the models in some manner.

2. Errors in the Limits of Inundation and Efforts to Reestablish Those Limits

The models noted above established the 100-year water surface elevations for the creeks and streams that were studied during the development of the Flood Insurance Rate Maps. Those models were based on survey data that was prone to errors, so the floodplain limits established by those models will have errors of a magnitude similar to those of the underlying survey data. This is one area of floodplain management where the federal government has tried to make some improvements.

The Biggert-Waters Flood Insurance Reform Act has authorized $2 billion for remapping the nation's floodplains.[100] This remapping effort consists of using new and more accurate aerial survey techniques to create new topographic surveys of the nation's waterways in order to establish new limits of inundation based on the new topography. This effort has one critical flaw. Regardless of how accurate the new survey data that forms the basis of the floodplain limits is, the water surface elevations that are used are based on the old erroneous survey data. Any changes to the cross sectional area or wetted perimeter of a stream will necessarily change the peak water surface elevation of the stream at that point.[101] Any changes to the water surface elevation at any point in a stream will cause changes that will propagate to upstream or downstream sections of the stream as well.[102] So the situation exists wherein old water surface elevations are being used to establish the floodplain limits with topographic data which has a high level of accuracy. The fact that the peak water surface elevations are

98. *Id.*

99. *Id.* at 2-2.

100. Moving Ahead for Progress in the 21st Century Act, Pub. L. No. 112-141, § 100216, 126 Stat. 927-8 (2012) (codified in 42 U.S.C.A. § 4101b).

101. Brunner, *supra* note 97, at 2-4.

102. *Id.*

not actually indicative of any real-world conditions is not an aspect being addressed in the Flood Insurance Reform Act.

V. Concerns and Analysis

The overall concern here is that federal law requires any person who owns property in a regulatory floodplain and wants to get a loan secured by that property, i.e. a mortgage, will be required to purchase flood insurance if they are shown within the limits of a floodplain.[103] The location of the property relative to flood hazard boundaries shown on the Flood Insurance Rate Map determines whether or not a structure is in a floodplain. Based on Section IV above, we can see that the maps are fundamentally flawed and the boundaries indicated on the maps do not relate to the actual limits of the 100-year floodplain. Therefore, a situation exists wherein property owners may be shown within the limits of the regulatory floodplain when in fact they may not actually be at risk for flooding, in this case, these homeowners would be wasting money on flood insurance that they do not actually need. The converse may also be true, where a property is not shown within the limits of the regulatory floodplain when in fact they are at risk, but not required to purchase the statutorily required flood insurance; this situation puts those homeowners at unnecessary risk of flood damage. Recent studies indicate that only about 18% of homeowners who actually are within floodplain areas actually have flood insurance.[104]

In the past, this would have represented a relatively harmless error. The federal government has subsidized flood insurance policies such that the average cost has been about $500 per year for properties within a recognized flood hazard zone.[105] With the passage of the Biggert-Waters Flood Insurance Reform Act of 2012, property owners with structures in floodplains will be required to pay the "real" cost of flood insurance on their properties. While the final cost of this unsubsidized insurance policy is unknown, preliminary estimates indicate that this can be several times the cost of the previously subsidized premium for flood insurance.[106]

Considering the level of error associated with the Flood Insurance Rate Maps, some change to the existing statutory scheme is necessary. I propose three potential solutions to the existing scheme, each of which individually would be able to mitigate the problems associated with errors in the floodplain maps. Either reevaluate the existing wa-

103. 12 C.F.R. § 22.3 (2014).

104. King, *supra* note 28, at 3.

105. *What Flood Zone Am I In?*, FloodFacts (Sept. 15, 2014, 10:12 AM), http://www.floodfacts.com/facts_flood_zone.html.

106. *Flood Insurance Costs Soaring for Thousands of Homeowners*, CNN Money, http://money.cnn.com/2013/10/21/real_estate/flood-insurance/(last visited Oct. 7, 2014).

terways of the United States and reestablish the base flood elevations and limits of flooding by using modern technology and practices; change the statutes such that a property within a flood hazard area is not required to purchase flood insurance; or make a new requirement for closing a home loan that a floodplain determination is performed by a professional engineer prior to closing on the home. As will be discussed below, only one of the potential solutions put forth will be ultimately amenable to all parties involved.

A. *Restudy the Streams*

A re-study of the nation's waterways would be an enormous undertaking in terms of both time and in terms of cost. According to the United States Environmental Protection Agency, the United States has approximately 3.5 million miles of streams and rivers.[107] Furthermore, average costs for performing detailed studies of streams and rivers are approximately $10,000 per linear mile of stream.[108] This leads to a cost of $35 billion to restudy all of the nation's creeks and streams. That cost does not even include the cost to restudy any coastal floodplains that are the result of storm surge events. This course of action is more appropriate for a long term solution that would definitively solve the problem of floodplain mapping and determination of the relative risks of structures in and near floodplains, however, the cost of restudying all of the creeks makes this solution infeasible in the current regulatory and fiscal climate.

B. *Make Insurance Optional*

The second proposed way of mitigating the errors associated with Flood Insurance Rate Maps would be to make flood insurance optional for home owners, contingent upon the disclosure of the existence of any floodplains regardless of whether or not the home is actually in the floodplain or just nearby. Making flood insurance optional for homeowners shifts the burden back onto the individual homeowner to make decisions regarding the purchase of insurance. The mandatory disclosure of the location of any nearby floodplains would ensure that homeowners are making intelligent decisions regarding the relative risk of flooding versus the cost of insurance over the life of their loan. Homeowners would be on notice of the possible presence of a floodplain near their property, and therefore any decision not to purchase flood insurance would constitute constructive assumption of risk of flooding. The elimination of premium discounts that are coming with the phased implementation of the Biggert-Waters Flood Insurance Reform Act mean that homeowners will now be

107. *Water: Rivers and Streams*, EPA http://water.epa.gov/type/rsl (last updated Mar. 13, 2013).

108. MANAGING FLOODPLAIN DEVELOPMENT, *supra* note 39, at 3–28.

paying the real cost of flood insurance, as opposed to the subsidized cost.[109] In this case, we have a truly free market scenario in which people are free to purchase insurance, or opt to not do so, at their own discretion.

This solution puts the final decision to purchase flood insurance back in the hands of the individual homeowner, however, it puts substantial risk on the banks holding the loans for those properties. In the event that a 100-year (or possibly even less) storm occurs and a home without flood insurance is damaged by flood waters, the cost to repair that home can be tens of thousands of dollars depending on the depth of the water and duration of inundation.[110] In this case, there is a substantial probability that the homeowner will declare bankruptcy or abandon the home in lieu of repairing it. This likelihood of abandonment in turn creates an unnecessary risk for the lending institutions, and makes this a possible but ultimately unreasonable solution.

C. *Independent Determinations*

A third solution is to make floodplain determinations performed by a professional engineer mandatory for all homes near a creek as part of the process of securing a loan. Flood insurance required for that property could be based on the relative risk assessment of that structure. Flood insurance can still be mandatory but it would be based on an actual determination by a professional engineer based on the conditions as they exist at the time of the purchase and those conditions which are predicted to exist in the future as opposed to using the Flood Insurance Rate Maps which are based on the conditions as they existed in the 1970s. By having professional engineers perform individualized floodplain limit determinations, they can pinpoint the exact probability of a structure being inundated, to what depth, and for what duration. With these parameters determined, each property can have a more precise determination of the appropriate risk and the insurance premium can take that risk level into account. Contrast this with the current Flood Insurance Rate Maps, which merely indicate the existence or absence of a 100-year floodplain with no regard to depth or duration of inundation.

While there is an appreciable cost associated with retaining a professional each time a home loan is processed, this cost can be borne by the individual homeowners themselves. The cost of retaining a professional engineer to perform a floodplain determination cost can be incorporated into the amount of money borrowed from the bank in

109. Carolyn Kousky & Howard Kunreuther, *Addressing Affordability in the National Flood Insurance Program*, RESOURCES OF THE FUTURE 8 (Aug. 2013), http://www.rff.org/RFF/Documents/RFF-IB-13-02.pdf.

110. *Cost of Flooding*, NATIONAL FLOOD INSURANCE PROGRAM (Sept. 11, 2012, 9:13 AM), http://www.floodsmart.gov/floodsmart/pages/flooding_flood_risks/the_cost_of_flooding.jsp.

addition to escrow and closing costs. A change to this setup makes sound fiscal sense as well. The cost of an independent floodplain determination can be thousands of dollars. Spending this money on an independent determination makes sense when compared to the tens of thousands of dollars that will be spent on unnecessary flood insurance over the life of a mortgage.

VI. Conclusion

Flooding is, and will continue to be, a problem for both the United States and the world. The National Flood Insurance Act of 1968 started a program to alleviate those problems by taking a proactive approach to the risk of flooding. It was the first time that the United States had ever tried to minimize the effects of flooding because of predictions related to flooding. To that end, it has been effective. However, due to the changes in technology and paradigms of development, the tools that the federal government developed to predict the effects of flooding are no longer appropriate. Because of that, this Article advocates for some change in the way flood insurance is administered by the federal government. Either through the elimination of the use of the Flood Insurance Rate Maps in the determination of the requirements of flood insurance, the restudying of all of the nation's creeks and streams, or through a fundamental change in the way that floodplain determinations are made for properties that may be at risk. One thing is certain though, regardless of the solution that is put into place, the current system cannot be allowed to continue due to its arbitrary and capricious nature of enforcement using maps that bear only a tenuous relationship to the risks that they purport to predict. Furthermore, considering that the subsidy, which so many people have relied on, is ending, it is more crucial now than it has ever been that reforms occur in the administration of flood insurance.