US Army Corps
of Engineers ®
Rock Island District

Cedar Rapids, Linn County, Iowa
Cedar River, Indian Creek, and Dry Creek Watersheds and Time Check Levee
CWIS No. 181244

Section 205
Initial Assessment for Flood Damage Reduction

May 2004

CEDAR RAPIDS, LINN COUNTY, IOWA
CEDAR RIVER, INDIAN CREEK, AND DRY CREEK
CWIS No. 181244

SECTION 205
INITIAL ASSESSMENT FOR FLOOD DAMAGE REDUCTION

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Aerial photograph of Cedar Rapids, Iowa.
Time Check neighborhood is in the left of the photo.

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SECTION 205
INITIAL ASSESSMENT FOR FLOOD DAMAGE REDUCTION

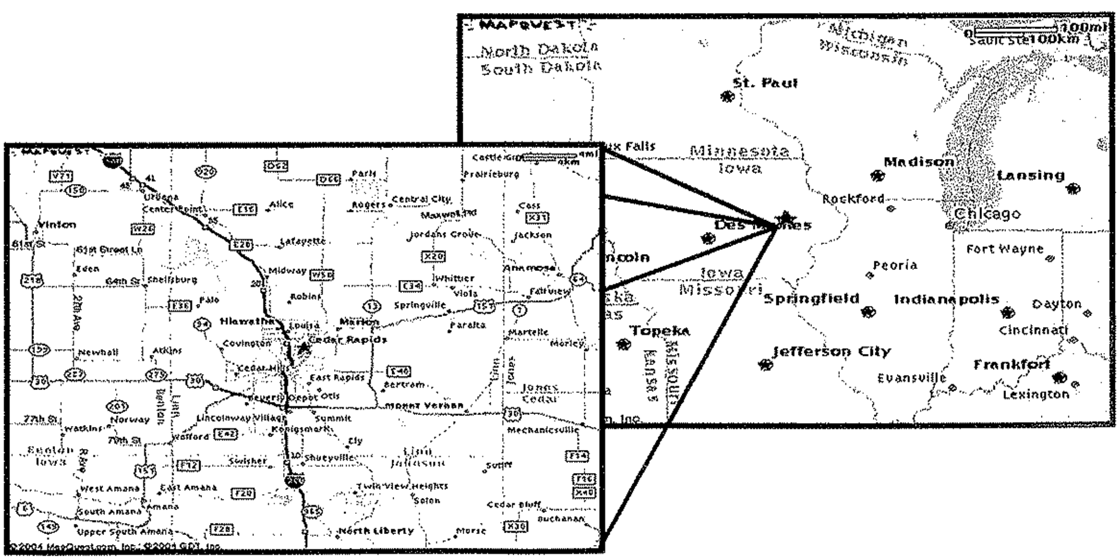
1. INTRODUCTION

The Rock Island District of the U.S. Army Corps of Engineers has prepared this Initial Assessment under the authority provided in Section 205 of the Flood Control Act of 1948, as amended. In a letter dated April 25, 2003, the City of Cedar Rapids, Iowa, acting on behalf of itself and other impacted communities in the Indian Creek and Dry Creek watersheds, requested the Rock Island District to undertake a study effort to identify economical flood damage reduction measures (Appendix A). This request was prompted by a flashflood, which occurred on June 4, 2002. The City's request was twofold: first, the City requested the Corps to evaluate flood reduction measures in the Indian Creek and Dry Creek watersheds; second, the City requested the Corps to review the adequacy of the level of protection provided by an existing levee along the Cedar River. This Initial Assessment constitutes the first step of the planning process in response to the City's request for assistance. This assessment will determine if there is a Federal interest to enter into a feasibility report called a Detailed Project Report (DPR).

2. STUDY AREA

The City of Cedar Rapids, Iowa, is the designated local sponsor for this Initial Assessment and is acting on behalf of Linn County and three other communities in the Indian Creek and Dry Creek watersheds. The communities include the cities of Marion, Hiawatha, and Robins. Figure 1 shows the location and general vicinity of these municipalities. Plate 1 is a comprehensive view of the study area.

Figure 1 – Location and Vicinity Maps



a. Indian Creek and Dry Creek Watersheds. The Indian Creek and Dry Creek watersheds are located in Linn County, Iowa, and have a combined drainage area of 77.6 square miles (sq. mi.) (See plate 1 for the boundary of these two watersheds). On June 4, 2002, these watersheds experienced a significant rainfall event. The 24-hour rainfall totals ranged from 4.5 inches to 6.5 inches. Antecedent rainfall had brought the creeks to near capacity and saturated the soils, thereby significantly magnifying the flashflood event. The June flood caused damage to both public and private property. Damages were widely disbursed throughout the various communities, affecting only a select number of properties along various reaches of Indian and Dry Creeks. The Sun Valley neighborhood, shown on Figure 2, had the most properties impacted. Because of the event's magnitude, the Linn County Regional Planning Commission established a Flood Study Technical Advisory Committee (TAC). The TAC's goal was to define structural and nonstructural flood reduction methods for both the watersheds' existing development patterns and a future scenario assuming full development.

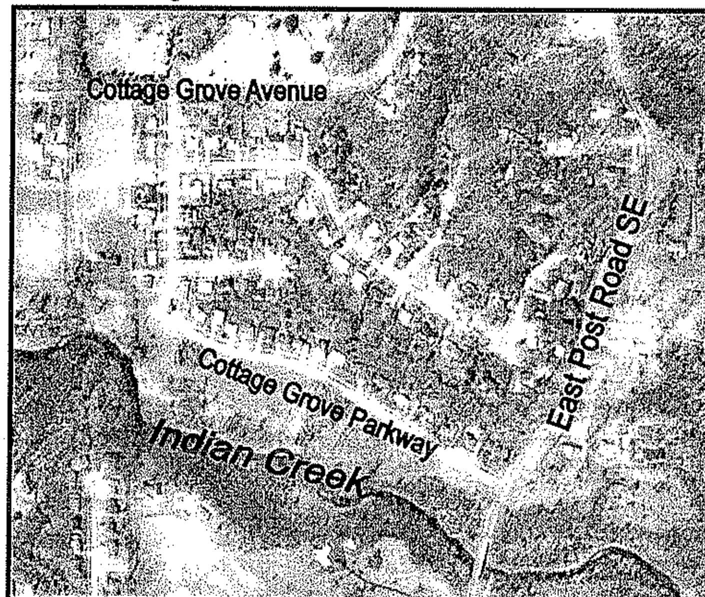


Figure 2 - Sun Valley Neighborhood

b. Cedar River Levee. An existing levee along the right descending bank of the Cedar River protects the Time Check neighborhood, a high-density residential and commercial area with approximately 1,800 structures within the 500-year floodplain. As shown on Plate 2, a significant number of structures are within the 100-year and 500-year floodplain of the Cedar River. These structures could be impacted by a failure of the levee. The area is estimated at approximately 200 acres. The existing levee is a non-Federal levee and is not participating in the Public Law 84-99 program. The location of this levee is shown in Figure 3,

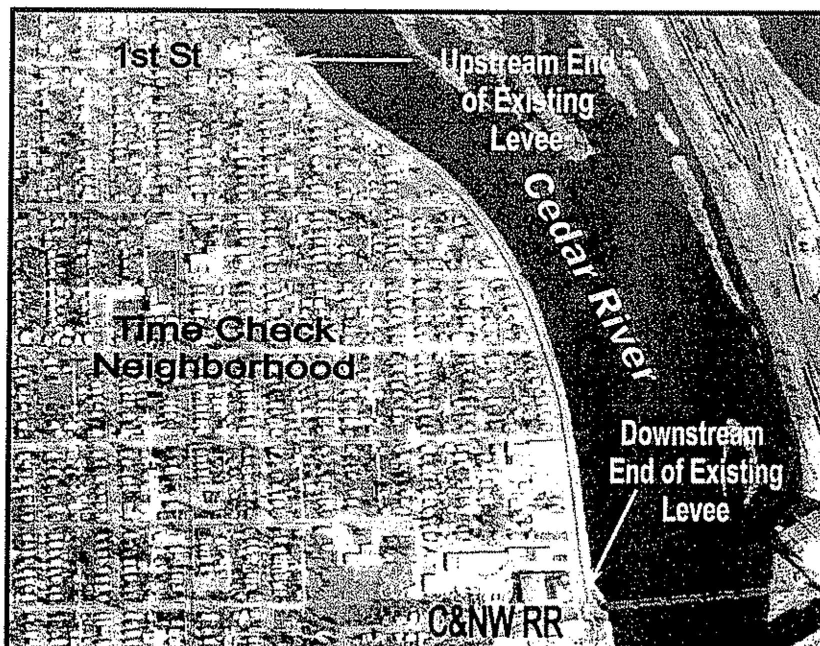


Figure 3 – Time Check Neighborhood

just upstream of the existing railroad bridge and downtown Cedar Rapids. The City is concerned about potential flanking of the levee system.

3. FLOOD HISTORY

a. Indian Creek and Dry Creek. The combined watershed area of these two Cedar River tributaries is 77.6 sq. mi. There are no stream gages on either Indian Creek or Dry Creek. Within the combined watershed, significant floods have occurred in 1929, 1937, 1945, 1946, 1947, 1959, 1960, 1961, 1969, 1977, and 2002. Previous studies have determined that the August 1969 flood had a recurrence interval of 20 years and a discharge of 6,700 cfs (cubic feet per second). The 1977 event was estimated to have a discharge of 7,900 cfs with a recurrence interval of 90 years.

The June 4, 2002, flood resulted from a rainfall event that produced 24-hour rainfall totals ranging from 4.5 to 6.5 inches. Precipitation occurred throughout the watersheds. Antecedent rainfall brought the streams to near capacity and saturated the soil matrix. This increased the amount of runoff and amplified the magnitude of the flashflood. No stream gages exist on Indian Creek or Dry Creek; however, stream discharges were estimated by the U.S. Geological Survey for the Flood of 2002. The peak discharge of Indian Creek was estimated to be 12,500 cfs at County Home Road and 24,300 cfs at East Post Road. These discharges are larger than the 0.2% chance event (500-year recurrence interval) at these locations. The Cedar River rose from a stage of 4.6 ft (feet) to a maximum of 6.7 ft due to this storm. The record high stage at the Cedar River gage in Cedar Rapids is 20.0 ft. These data indicate that flooding along the Cedar River is independent of events on the Indian Creek tributary due to the large difference in drainage areas, 6,997 sq. mi. versus 77.6 sq. mi., respectively. Conversely, the smaller tributaries will respond quickly to and potentially sustain damages from events equal to or smaller than that which occurred on June 4, 2002. Understanding this basic relationship will cause stormwater management planning in the Cedar Rapids metropolitan area/Indian Creek and Dry Creek watersheds to be focused on strategies that can be effectively implemented at the sub-basin level.

b. Cedar River. The drainage area of the Cedar River is 6,997 sq. mi. and much of downtown Cedar Rapids lies within its 100-year floodplain. Historically, major floods have been caused by a combination of rainfall and snowmelt or by heavy rainfall alone. On the Cedar River, the flood of record is the March 1961 event. This flood was the result of the rapid melting of a heavy snow pack and rainfall. In Cedar Rapids, the river crested on March 31st at an elevation of 720.13 ft NGVD, roughly 3 ft below the 100-year flood stage at the gage, and a discharge of 73,000 cfs. The recurrence interval for the 1961 flood has been estimated at 33 years.

Heavy rains were absorbed into a heavy snow cover and combined with high temperatures to cause a significant flooding event in April 1965. This flood had a discharge of 66,800 cfs and crested at 718.97 ft or approximately 4 ft below the 100-year flood stage at the gage.

Since 1903, the US Geological Survey (USGS) has maintained a stream gaging station on the Cedar River at Cedar Rapids. The gaging station is located roughly 400 ft upstream of the Eighth Avenue Bridge. The 10 major floods on the Cedar River are listed in Table 1 in decreasing order of the magnitude of their discharge.

Table 1 - Floods of Record
Cedar River, Cedar Rapids, IA

Year	Discharge (cfs)
1961	73,000
1993	71,000
1965	66,800
1851	65,000[1]
1929	64,000
1999	62,730
1933	58,400
1947	56,200
1906	55,700
1960	55,100

[1] Estimated from high water marks. U.S. Geological Survey, 2001, National Water Information System (NWISWeb) [http://waterdata.usgs.gov/nwisl]

4. RELEVANT STUDIES

a. **Review of Reports (Preliminary Examination) for Flood Control on the Iowa and Cedar Rivers, Iowa and Minnesota, War Department, Corps of Engineers, Rock Island District, 01 July 1946.** This is an inventory of flood control structures built along the Iowa and Cedar Rivers prior to 1946.

b. **House Document No 166, 89th Congress, 1st Session, Letter from the Secretary of the Army Transmitting a Letter from the Chief of Engineers, dated January 26, 1965; submitting a report, together with accompanying papers and illustrations on an Interim Report on the Iowa and Cedar Rivers, Iowa and Minnesota requested by Resolution of the Committee on Flood Control, House of Representatives, adopted July 16, 1945, the Committee on Commerce, United States Senate, adopted August 6, 1845 and the Committee on Public Works, House of Representatives, adopted July 29, 1955.** Damages resulting from the 1961 flood along the Cedar River in Cedar Rapids are discussed, along with the proposed flood damage reduction alternatives for the City. After a review of the options and their adverse impact on the scenic attraction of the river, the City decided not to participate in the implementation of the levee and floodwall system.

c. **Flood Plain Information on Indian and Dry Creeks, Linn County, Iowa, prepared for the Iowa Natural Resources Council by the U.S. Army Corps of Engineers, Rock Island, Illinois, December 1964.** It was the purpose of this study to ".... provide the state and local agencies with specific information on past and present flood hazards, as well as to provide a guide to the expected frequency of occurrence of future floods ..." The study area was limited to the lower reaches of Indian Creek and Dry Creek, incorporating the cities of Hiawatha and Marion as well as a portion of Cedar Rapids.

d. **Flood Plain Information, Cedar River, Linn County, Iowa, prepared for the State of Iowa, Iowa Natural Resources Council, by the U.S. Army Corps of Engineers, Rock Island District, October 1967.** This study provided additional river discharges and elevations and substantiated the Corps' conclusions that an out-of-bank event is a rare event in the Time Check area.

e. Iowa-Cedar River Basin, Stage 2 Document, U.S. Army Corps of Engineers, Rock Island District, March 1980. This is a collection of working papers that addresses problems and potential solutions under the "Iowa-Cedar Study Authorities." The document concludes that further study is warranted for reservoirs at Floyd and Finchford and that local flood protection work should be evaluated for the cities of La Porte City, Cedar Falls, and Waverly, Iowa. Regarding the Cedar Rapids area, the conclusion reached was that although there are flood protection options with benefit-cost ratios (BCRs) of between 0.9 and 1.1, the City was unwilling to implement them as they would detract from aesthetics of the riverfront. However, the City did support channel improvements, but there was no economic justification to support a Federal interest. Continuing the City's existing floodplain management program was the only remaining acceptable alternative.

f. Iowa-Cedar River Basin Feasibility Report, Main Report, June 1982, U.S. Army Corps of Engineers, Rock Island District. As it pertains to Cedar Rapids, this report again documents the City's reluctance to construct a levee and floodwall protection system.

g. Flood Insurance Study, County of Linn, Unincorporated Areas, June 15, 1982, Community No. 190829, Federal Emergency Management Agency. This study provides planners and decision makers with the basis to make knowledgeable decisions regarding land use and development in the floodplain. The hydraulic and hydrologic information contained in this report has been reviewed by Rock Island District staff and is considered suitable for use in this assessment.

h. Flood Insurance Study, City of Cedar Rapids, Iowa, Linn County, Revised March 18, 1991, Community No. 190187, Federal Emergency Management Agency. This study provides planners and decision makers with the basis to make knowledgeable decisions regarding land use and development in the floodplain. The hydraulic and hydrologic information contained in this report was reviewed by District staff and is considered to be suitable for use in this assessment.

i. Stormwater Master Plan, Cedar Rapids Metropolitan Area/Indian and Dry Run Watersheds Utility Study, Linn County Regional Planning Commission, Prepared by Camp Dresser & McKee (CDM) Inc., The Sears Tower, Suite 450, 233 South Wacker Drive, Chicago, Illinois, April 1998. This Stormwater Master Plan (SWMP) was prepared to provide the Cedar Rapids metropolitan area/Indian Creek and Dry Creek watersheds with guidance on how to accommodate future development and the resulting increase in stormwater runoff that would result without adversely impacting downstream areas. The SWMP's study area included Cedar Rapids, Hiawatha, Robins, Marion, and portions of unincorporated Linn County.

For the Time Check neighborhood, the SWMP recommends improvements to the storm sewer system including:

- Increased conveyance capacity
- Backflow prevention structures
- A stormwater pump station

CDM estimated the cost to construct these improvements at $1.25 million in 1998 dollars. Site-specific structural recommendations pertaining to other areas addressed in this assessment are not included in the SWMP.

j. Flood Management in Dry Creek and Indian Creek Watersheds – Issues and Concerns, Submitted to the Sun Valley Neighborhood Association and Residents along Indian Creek, Cedar Rapids, Iowa, A. Jacob Odgaard, IIHR Hydroscience and Engineering, University of Iowa, Iowa City, Iowa 52242, December 17, 2002. The purpose of this report is to address specific issues and concerns of the residents of the Sun Valley neighborhood of Cedar Rapids. This report was commissioned by the residents of the Sun Valley neighborhood to determine the causes of and potential remedies for the flood of 2002.

5. EXISTING STRUCTURAL CONTROLS

a. Indian Creek and Dry Creek. Throughout the Indian Creek and Dry Creek watersheds, there are a number of stormwater detention basins. The City of Marion, Iowa, is in the planning stages of building a 13-acre regional detention basin. The basin would be located in northwest Marion, west of Alburnett Road and north of East Robins Road, in Section 26, Township 84 North, and Range 7 West. It will provide additional detention capacity in the upper reaches of the basin during heavy runoff events and will serve as a park area when dry.

b. Cedar River. The existing levee adjacent to the Time Check neighborhood provides marginal protection for up to a 100-year flood event on the Cedar River. The existing levee has questionable dependability due to many substandard conditions when measured against Corps of Engineers standards. We were unable to obtain records of the fill materials used during the construction of the levee; although the City Engineer's Office reports that there was little seepage through the levee during the 1993, 1999, and 2004 high water events. No permanent pump station exists to pump interior ponding that occurs from interior runoff of a precipitation event during a high river stage event. Existing drainage outlets through the levee do not conform to Corps standards, but have performed satisfactory during high water events. The levee does not tie into high ground, is susceptible to be flanked at its upstream terminus, and ties into a railroad embankment at its downstream end that is likely constructed of pervious fill. There is no record of the levee being flanked, including during the 1993 flood when the Cedar River remained approximately 3 ft below the 100-year flood elevation. Previous studies have determined that the levee is not capable of protecting the area from a 100-year flood event. The City of Cedar Rapids currently has design standards to reduce the runoff impact from new developments, which requires detention basins for all new developments over one acre.

6. EXISTING NONSTRUCTURAL CONTROLS

Each of the communities in the study area enforces regulations for development in the floodplain. Additionally, the communities enforce stormwater detention requirements on all new land development activities. Specifically, new developments are required to restrict the amount of stormwater discharged from the developed site to the runoff that was generated from the site in its undeveloped condition because of a 5-year rainfall event and to accommodate the 100-year event.

7. PLAN FORMULATION

a. Process Description. A number of different factors could result in streams reaching flood stage and causing damage throughout the community. Since each flooding situation is different, it is necessary to evaluate the entire array of possible solutions prior to selecting the one that presents the best fit for a given community. Both structural and nonstructural measures are considered. Each measure is subjected to a two-tiered selection process. The initial step is designed to define those options that have a reasonable probability of achieving the desired flood reduction objectives. At this level, the measures are evaluated and compared in terms of:

- Effectiveness in reducing flood damage
- Environmental impacts
- Potential benefits
- Probable costs
- Public/community acceptance
- Technical feasibility

Those measures that appear to be the most feasible are carried forward for additional evaluation. In this final evaluation, the measures will be developed in sufficient detail to assess their flood reduction capabilities and estimate their approximate costs and benefits.

b. Alternative Screening and Evaluation. Applying this process to the Cedar Rapids metropolitan area/Indian Creek and Dry Creek watersheds resulted in identifying measures that should be considered further as indicated by an "**X**" in Table 2. These systems were also evaluated for their ability to address existing flood control concerns in developed areas and to provide a stratagem for stormwater management in urbanizing areas.

TABLE 2 - Flood Damage Reduction Measure Assessment Matrix [1]

	Screening and Evaluation Results	
Measure	**Indian Creek and Dry Creek**	**Time Check Neighborhood**
STRUCTURAL		
1. Bank Stabilization		X
2. Channel Modification		
3. Erosion Controls		
4. Levees and Floodwalls		X
5. Relocation of Structures	X	
6. Stream Channel Diversion		
7. Detention Systems	X	
8. Low Impact Development Conservation Systems	X	
NON-STRUCTURAL		
1. Floodproofing		
2. Flood-Warning Systems	X	
3. Land-Use Planning	X	
4. Stormwater Management	X	
5. Stormwater Utility District	X	

[1] If alternatives are determined likely to be economically justified (having a BCR greater than 1.0), environmentally acceptable, and if the local sponsor wishes to continue with the planning process, the alternatives will be studied in detail during the Feasibility Phase.

(1) Measures Not Considered Further. The following flood reduction measures were not considered further for the Cedar Rapids metropolitan area/Indian Creek and Dry Creek watersheds for the reasons stated:

- *Channel Modification or Diversion*: Changes to the channel's alignment or cross-sectional geometry typically have high initial costs that are not offset by their ability to reduce flood damage. Items that impact the cost of this strategy include land acquisition and modifying structures such as bridges and outfalls to accommodate the new stream channel configuration.
- *Erosion Control*: Sedimentation has not been identified as a concern in both the Indian Creek and Dry Creek watersheds or in the Time Check area; therefore, control of erosion from upstream construction, agricultural, or other disturbed land areas would not have a significant impact on flooding in the study area. However, an erosion and sedimentation control component in a Stormwater Master Plan (SWMP) will help improve water quality.
- *Floodproofing*: Floodproofing is an effective tool in reducing flood-related damages. In the Time Check neighborhood, floodproofing is both impractical and costly when considering the number of units that would be flooded by a failure or flanking of the existing levee. Damages have not been repetitive in the Sun Valley area, and the costs are thought to exceed the benefits. Other areas in the watersheds may be amenable to this approach; however, identifying potential candidates is beyond the scope of this Initial Assessment. Floodproofing should be evaluated as eligible properties are identified.

(2) Measures Considered Further for Indian Creek and Dry Creek. The following measures are potentially viable techniques to reduce flood damages:

- *Bank Stabilization*: In the event that it is not subjected to full-scale improvements, appropriate bank stabilization is recommended for the Time Check levee. Existing bankline slopes on the levee are steeper than 1H:1V so will require additional work beyond just revetment. This flood reduction measure was deemed inappropriate for the Indian and Dry Creek watersheds where flooding is caused by a combination of high in-stream flows and backwater conditions created by the Cedar River.
- *Levees and Floodwalls*: These structural controls can provide an increased level of protection and are considered viable flood reduction measures for the Time Check neighborhood of Cedar Rapids. Levees and floodwalls in other portions of the study area are not considered viable because of the lack of substantial economic benefits to justify the expense of their construction.
- *Relocation of Structures*: The buyout of flood-prone properties is a viable approach to reducing flood-related damages. Local governments should encourage and assist in the purchase of the property to the extent property owners are willing to participate in this program.
- *Detention Systems:* Stormwater detention systems are constructed to capture runoff from a specific developed area to control discharges within a

certain percentage of the pre-development runoff. Detention systems are a proven stormwater management strategy and are considered to have potential in the urbanizing areas of the Indian Creek and Dry Creek watersheds. Other non-typical systems are referred to as Low Impact Development/Conservation Systems. These stormwater management techniques can reduce the impact of stormwater runoff from existing urban areas and in developing suburban areas, including:

(a) Parking lot storage

(b) Underground detention systems

(c) Infiltration systems

(d) Porous pavement

- *Low Impact Development Conservation Systems:*

(a) Rain barrels

(b) Roof top gardens

(c) Rain garden

- *Flood-Warning System:* A flood-warning system could provide the municipalities with advanced warning of an impending flood. This will allow first responders additional time to implement response plans and to erect temporary levees, evacuate threatened areas, and otherwise alert the community. A flood-warning system can be either a stand-alone flood damage reduction measure or it can be integrated with other structural controls at the local level or as part of a basin-wide early warning system.

- *Land-Use Planning*: Land-use planning, along with an effective stormwater management program, is an effective way to prevent future flood damages. Land-use planning in the developing areas of the watershed should be used to aid in implementing an effective basin-wide stormwater management plan. Typical flood control elements of land-use planning are geared toward reducing or controlling runoff and may include:

(a) Reducing cul-de-sac radii

(b) Regulating the percent impervious cover in a development

(c) Designating open space requirements for developments

(d) Establishing minimal soil compaction standards for disturbed areas and erosion control during construction

(e) Preserving open space, including: stream corridor, wetland, aquifer recharge, and habitat area protection

(f) Directing growth

(g) Reducing impervious areas

- *Stormwater Management*: A region-wide stormwater management agency could oversee new development and improvements made within the system on a basin-wide level. This authority could enforce exiting regulations, determine the need for and locations of stormwater measures, and prioritize the expenditure of funds for stormwater improvements. It could also serve as a regional focal point for various stormwater and flood control initiatives in the watersheds.

Application of these alternatives within the Cedar Rapids metropolitan area and outlying areas within the Indian Creek and Dry Creek watersheds can be determined on a site-by-site basis since no single strategy will address all stormwater management issues. A combination of approaches, tailored to individual site conditions, may result in the best solution. By addressing stormwater runoff at its point of origin rather than as an "end of pipe" problem could reduce the need for regional systems to manage stormwater from developed and developing areas of the watersheds.[1]

c. Evaluation Strategies. There are recommended flood damage reduction strategies for both the Indian Creek and Dry Creek watersheds and the Time Check neighborhood along the Cedar River. These strategies are discussed in the following paragraphs.

(1) Indian Creek and Dry Creek Watersheds. The Indian Creek and Dry Creek watersheds are one of several developing areas in Linn County. If a comprehensive stormwater management program is not implemented, this development will cause an increase in the amount and rate of stormwater runoff and could cause increasingly more severe flooding events with a concurrent increase in property damage and threats to public health and welfare. To address this potential threat, a subsequent feasibility study would review various strategies to determine which would be the most beneficial, identify the institutional arrangements required for implementation, and review the various stormwater-modeling options. There are hydrologic and hydraulic models available to simulate the origin, movement, and flow of surface water in the environment. Hydrologic models simulate the quantity of water that will arrive at a location along a stream channel, while hydraulic models compute the elevation of the water surface at a location along the stream channel. Both types of models are commonly used in unison to complete flood insurance studies and to evaluate the effects on land-use change in planning and evaluating future community growth and development. To properly evaluate water surface elevations at locations along Indian Creek, both types of models should be developed and used together to evaluate land use changes that may be planned in the watershed. Appendix C contains a discussion of the available models.

Geographical Information Systems data, or GIS data, are available for use in hydrologic and hydraulic analyses of the Indian Creek Basin. DEMs (Digital Elevation Models) are available that can be used to determine watershed boundaries, slope, and other information pertinent to terrain analyses. Land-use/land cover, soils, urbanized areas, roads, and several other pertinent layers are also available to further define watershed characteristics. The GIS data layers can be used in a GIS-based model pre-processor that will extract information from the data layers to aid in deriving initial model parameters.

There are at least two functioning precipitation-measuring stations in close proximity to the Indian Creek watershed. The data observed at these stations could be used in hydrologic model development.

[1] USEPA, Preliminary Data Summary of Urban Stormwater Best Management Practices, EPA-821-R-99-012, August 1999.

There are no currently active streamflow measuring stations within the Indian Creek Basin. This makes it particularly difficult to calibrate any hydrologic or hydraulic models that are developed for the basin. The USGS, however, has documented peak flows and high-water marks that have been observed during previous large flood events. The June 4, 2002, flood event that occurred in the basin was thoroughly documented by the USGS (Eash 2004). The USGS measured peak discharges at two locations in the basin and used high-water marks to construct a flood profile. The observations recorded for this event could be used for both hydrologic and hydraulic model calibration.

The Federal Emergency Management Agency, FEMA, has completed Flood Insurance Studies in the basin in 1981, 1982, and 1991 (FEMA, 1981, 1982a, 1982b, 1982c, 1991). It is estimated that 15 river miles of Indian Creek and Dry Creek have been modeled. The existing river cross-section data used for the FEMA studies was gathered in the 1970's. These data can be easily incorporated into a new hydraulic model for a rudimentary analysis. However, to represent current conditions, new cross-section data should be gathered. The results of the FEMA studies also could be used to aid hydraulic model calibration.

However, to properly support a model of the Indian Creek and Dry Creek Watershed a network of gages through the watershed is appropriate. The gauging network could also serve as a flood warning system for the watershed.

(2) Cedar River Levee. A detailed feasibility report would consider options to remove and replace the existing levee system that is of questionable dependability and would look at the benefits of providing higher levels of protection from events in excess of the 100-year event. Alternatives would explore how to tie off proposed flood protection system alignments into high ground while being sensitive to the community's view and connection to the Cedar River. Options to handle internal runoff would be developed to include a stormwater pump station, gravity outlet closure gates, and reworking of internal stormwater drainage pipes.

A flood warning system is made up of a number of stream and rain gages strategically located throughout the watershed so that water surface elevations river main stem and its significant tributaries can be monitored and evaluated in real time. This gaging system for the Indian and Dry Creek watersheds would consist of both rain gages and stream gages. A minimum of three gages will be required.[2] The number of stream gages required is variable and cannot be determined or positioned without modeling.

8. REAL ESTATE ISSUES

In the event that this study goes into the feasibility phase, the Real Estate Division will evaluate all project areas to determine if additional real estate interests are required. A Real Estate Plan would be developed to detail any real estate requirements.

The City of Cedar Rapids, as the local sponsor, would enter into a Project Cooperation Agreement with the Government to cost share 35% of total project costs. The City would be afforded credit up to 30% of total project costs for existing project lands and any

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[2] U. S. Army Corps of Engineers, DOD, ETL 111-2-540, Hydrologic Aspects of Flood Warning – Preparedness Programs. Sep. 1996

additional lands, easements, relocations, rights-of-way, and disposal/borrow areas (LERRDs) required for the project as defined above.

9. ANNUALIZED DAMAGE EVALUATION

Federal interest for this potential Section 205 Flood Damage Reduction Project at the Time Check area of Cedar Rapids, Iowa, was evaluated based upon ER 1105-2-100. Annual damages under existing conditions were evaluated using study area property inventories and frequency-damage relationships estimated from information provided by the City. There are more than 1,500 residential structures, 150 commercial and industrial structures, and public property and infrastructure in this study area.

In addition to potential flood damage reduction benefits, reduction in Flood Insurance administrative costs may accrue to alternatives that remove properties from Flood Insurance requirements. Cedar Rapids floodplain occupants had 515 Flood Insurance policies in force as of December 31, 2003. If a DPR is pursued, information about numbers of insured properties within the specific study area will be acquired.

There is an existing berm along the Cedar River in the Time Check area. This berm varies widely in breadth and height, with unknown construction design and materials. The Rock Island District maintains the opinion that this berm does not meet minimum Federal standards and provides no long-term reliable flood protection.

Table 3 depicts flood-frequency/damage information and average annual damages. As quantified in these tables, there appears to be a significant risk of flooding (and risk of significant flood-related damages) in the Time Check study area. The cost of providing damage reduction measures and the benefits accruing to those measures will be analyzed in the Feasibility Study phase.

Table 3. Time Check study area stage/frequency/damage relationships

Stage	Return Frequency		$ Damage
	%	Year	
720	0.0750	13	0
722	0.0400	25	1,621,000
723	0.0300	33	2,566,600
724	0.0200	50	3,466,800
725	0.0140	71	16,504,600
726	0.0100	100	27,331,800
728	0.0050	200	71,155,100
731	0.0020	500	128,126,600
	Average Annual Damage		**800,600**

10. ENVIRONMENTAL AND CULTURAL ISSUES

The flood damage reduction alternatives for Cedar Rapids and the Indian and Dry Creek Watershed include activities that affect the waters of the United States. The National Environmental Policy Act (NEPA) and the Clean Water Act with Section 404(b)(1) regulatory permit requirements would address issues of concern for the environment and the waters of the United States during the feasibility study. Coordination with concerned agencies and processing Section 404(b)(1) applications would reveal the environmental concerns and issues that must be addressed to meet NEPA and the Clean Water Act requirements

No knowledge of historic properties eligible for the National Register of Historic Places is indicated within areas affected by the alternatives presented herein. It is possible, however, that undocumented historic properties exist within the study area. Any recommended alternative would require a determination of effect to documented and undocumented historic properties eligible for inclusion to the National Register of Historic Places pursuant to Section 106 of the National Historic Preservation Act of 1966, as amended, and its implementing regulations 36CFR Part 800.

11. CONCLUSIONS

This Initial Assessment indicates that a significant number of homes and businesses in the Time Check neighborhood are with in the 100-year floodplain of the Cedar River. The failure of the existing Time Check levee could result in these structures sustaining major damage. This Initial Assessment has determined that an improved or reconstructed levee system will reduce potential flood damage to the Time Check neighborhood of Cedar Rapids. It is therefore the conclusion of this Initial Assessment that an acceptable alternative could be developed in the DPR that will satisfy Federal interest criteria.

Along Indian and Dry Creeks, the communities have been repeatedly flooded, and the implementation of the flood damage reduction project presented in this Initial Assessment will reduce recurring flood damages. Further it has been determined that within the Indian Creek watershed there are numerous growth areas that provide opportunities for the development and implementation of a variety of structural and non-structural strategies to mitigate the impact of floods on Indian Creek. Preliminary findings indicate that non-structural solutions to reduce flood damage along Indian Creek are technically feasible, have the support of the Local Sponsor, may be economically justified and implemented with few if any environmental impacts. Alternatives considered are:

1. a flood warning system
2. relocating structures from the floodplain, and
3. improved floodplain management measures.

Local flood protection is necessary along the Cedar River in Cedar Rapids, IA and in the Indian and Dry Creek watersheds. Cedar Rapids, acting as the lead sponsor for the Local Sponsors of Linn County, Cedar Rapids, Marion, Hiawatha, and Robins, has expressed a desire to continue into the feasibility phase as indicated by the Letter of Assurance contained in Appendix A.

12. RECOMMENDATIONS AND IMPLEMENTATION

a. Recommendations. It is recommended that a DPR be conducted for the Time Check neighborhood and the Indian Creek and Dry Run Creek watersheds in order to evaluate potential alternatives along with their associated benefit-cost ratios. Because the Time Check and Indian Creek study areas are likely to be sponsored by different governmental entities and because flooding problems and potential solutions of each area are different, it is recommended that separate feasibility studies be conducted for each area. This will provide for efficient study management and will facilitate the completion technical study task. Depending on the local sponsors' concurrence, the next steps to implement an in-depth DPR are as follows:

(1) Furnish Final Draft of the Initial Assessment Report to the Mississippi Valley Division, U.S. Army Corps of Engineers, for review and approval.

(2) Negotiate and execute the Feasibility Cost Sharing Agreements (FSCA).

(3) Complete the DPR's with Environmental Assessment for the proposed levee flood-warning system and stormwater management/flood assessment plan. The feasibility studies would develop the proposed plans in detail; evaluate their potential impacts to the environmental, cultural, and historic resources of the project areas; delineate the projects' real estate requirements and costs; and develop an engineering estimate of the probable costs of implementation.

b. Implementation Costs and Schedule. The proposed feasibility study would be cost shared on a 50% Federal, 50% local basis. The first $100,000 of feasibility phase costs is fully paid by the Federal Government. It is estimated that the feasibility phase would cost between $800,000.00 and $1,200,000.00 to complete. This translates to a local share estimated at between $350,000.00 and $550,000.00.

The Feasibility Phase would be implemented in accordance with the following schedule:

1. Prepare Project Management Plan	01 August 2004
2. Negotiate and Execute FCSA	01 September 2004
3. Convene Feasibility Scoping Meeting	01 November 2004
4. Prepare Detailed Project Report	01 December 2004
a. Plan Formulation	
b. Selected Plan	
c. Economic Consideration	
d. Social Effects	
e. Environmental Impacts	
f. Historical and Archeological Concerns	
g. Real Estate Plan	
h. Cost Estimate	
i. Prepare Draft PCA	
5. Conduct Internal Technical Review	01 December 2005
6. Alternative Formulation Briefing	15 January 2006
7. Review DPR with the Local Sponsors	01 February 2006
8. Public Review	01 March 2006
9. Submit DPR and PCA to Mississippi Valley Division	01 April 2006

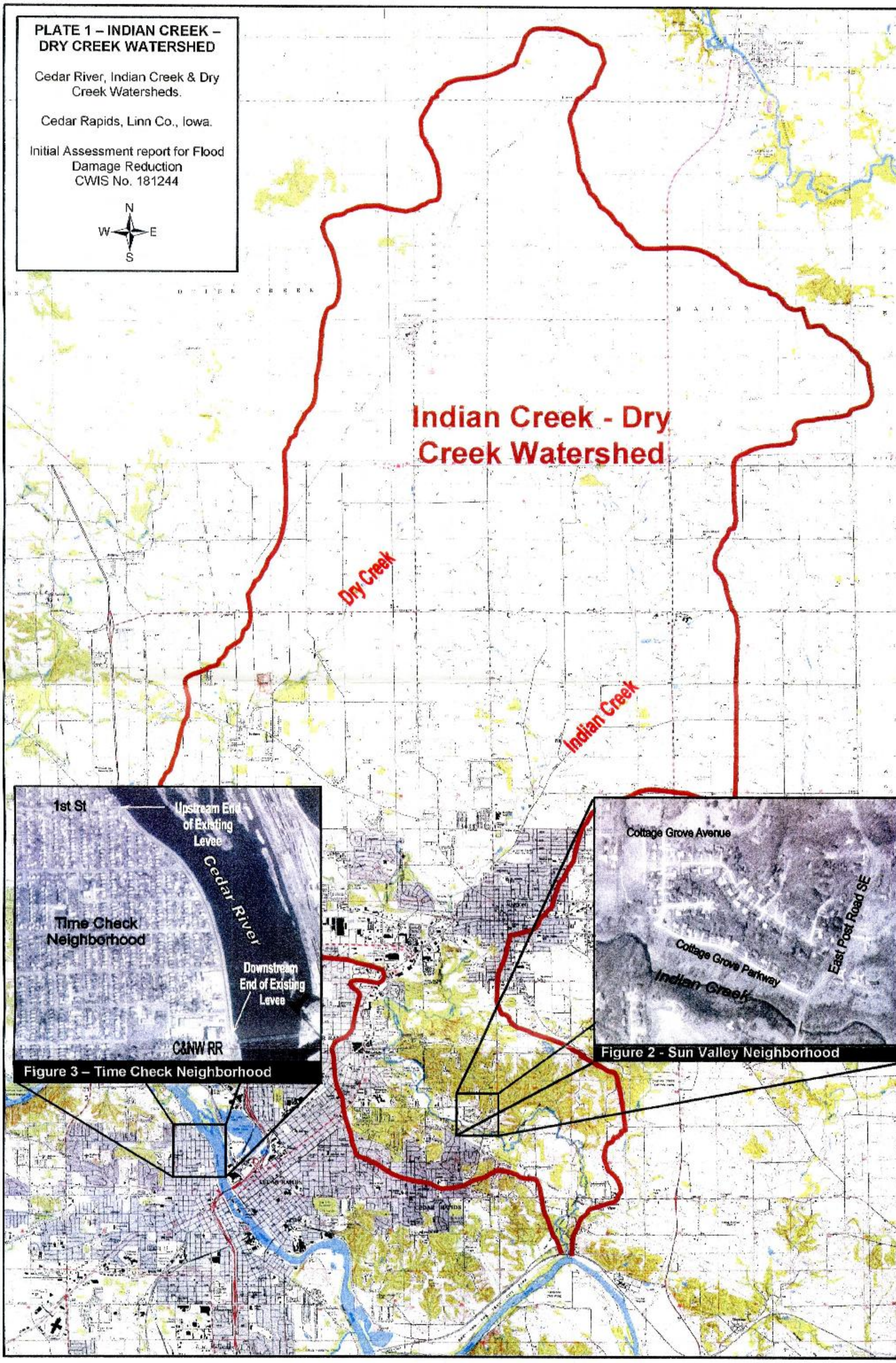
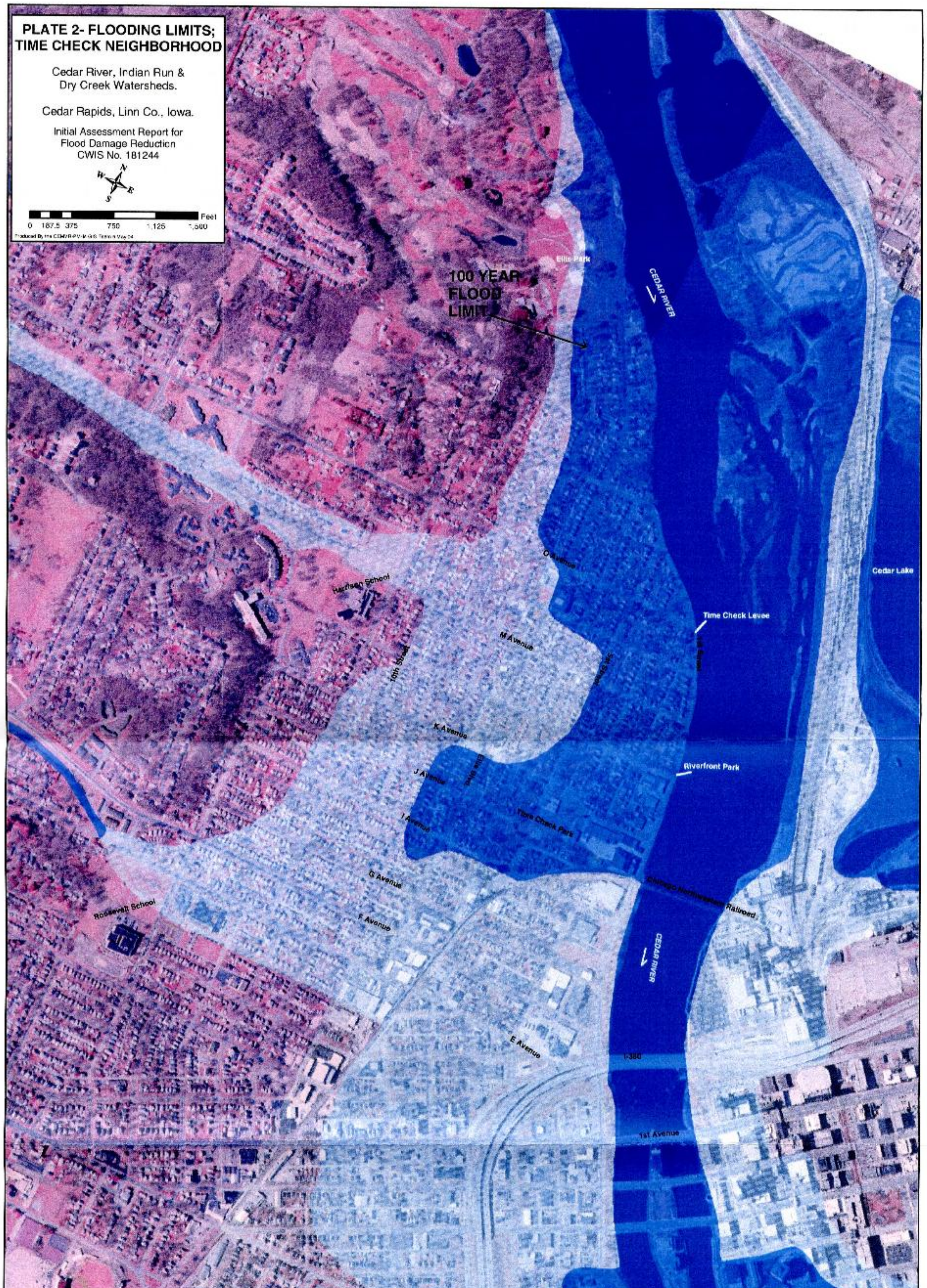


PLATE 1 – INDIAN CREEK – DRY CREEK WATERSHED
Cedar River, Indian Creek & Dry Creek Watersheds.
Cedar Rapids, Linn Co., Iowa.
Initial Assessment report for Flood Damage Reduction CWIS No. 181244
N
W
E
S
Indian Creek - Dry Creek Watershed
Dry Creek
Indian Creek
1st St
Upstream End of Existing Levee
Cedar River
Time Check Neighborhood
Downstream End of Existing Levee
C&NW RR
Figure 3 – Time Check Neighborhood
Cottage Grove Avenue
East Post Road SE
Cottage Grove Parkway
Indian Creek
Figure 2 - Sun Valley Neighborhood



Flood Limits Taken From 3/18/91; Flood Insurance Study, City of Cedar Rapids Iowa; Linn County, FEMA, Community No. 190187

APPENDIX A

Letter of Intent

CEDAR RAPIDS
City of Five Seasons

April 28, 2003

District Engineer
U.S. Army Engineer District, Rock Island
ATTN: Planning, Programs and Project Management Division
Clock Tower Building, P.O. Box 2004
Rock Island, Illinois 61204-2004

Dear Sir:

In accordance with the provisions of Section 205 of the Flood Control Act of 1948, as amended, which authorizes the Federal government to initiate investigations and studies to be made in the interest of flood damage reduction, the City of Cedar Rapids, Iowa on behalf of the Linn County Regional Planning Commission (LCRPC) hereby makes formal application for a study of:

Indian and Dry Creek watershed, and

Cedar River levy erosion on the west bank of the river between Penn Avenue and the 5-in-1 dam in Cedar Rapids,

both located in Linn County, Iowa.

On June 4, 2001 the Indian Creek/Dry Creek watershed in Linn County was subjected to substantial amounts of rainfall while the ground was in a saturated state, leading to substantial runoff from both agricultural and nonagricultural lands and property damage from rapidly rising water with strong currents. Over $1,785,000 in estimated damage to public property resulted, and over 800 property owners registered locally for flood damage consideration. The FEMA Flood After-Action Report specifying private damage estimates and assistance is currently pending. Attachment A to this letter outlines local action taken to date regarding this situation.

The City and LCRPC can provide the following local cooperation and participation.

1. Provide without cost to the United States all necessary land, easements and rights-of-way, access routes and relocation of utilities necessary for project construction and subsequent operation and maintenance.

2. Hold and save the United States free from claims for damages which may result from construction and subsequent maintenance of the project, except damages due to the fault of negligence of the United States or its contractors.

3. Assume full responsibility for all project costs in excess of the Federal cost limitation of $7,000,000.

4. Assure maintenance and repair during the useful life of the works as required to serve the project's intended purpose.

DEPARTMENT OF DEVELOPMENT
50 Second Avenue Bridge • Sixth Floor, City Hall • Cedar Rapids, Iowa 52401-1256
Phone (319) 286-5041 • FAX (319) 286-5141 • Fax-on-Demand (319) 286-5146

5. Provide a minimum cash contribution of 5 percent of the project cost.

6. If the value of the sponsor's contributions above is less than 35 percent of the project cost, provide a cash contribution to make the sponsor's total contributions equal 35 percent.

We understand a cost-sharing agreement would be required to complete the feasibility study if the cost exceeds $100,000, and are willing to enter into appropriate negotiations following completion of the reconnaissance report. This letter constitutes only an expression of our intent and is not intended as a contractual obligation.

The point of contact for this action is A. Dean Wheatley, Long-Range Planning Manager, (319-286-5067).

Sincerely,

A. Dean Wheatley, Long-Range Planning Manager

Attachment A

The local Metropolitan Planning Organization, the LCRPC, appointed a special committee of local engineers and planners to assess the event and to recommend actions that might be taken to avoid future similar events. That committee has recommended the following project scope:

Task 1. Mapping and flood hazard/risk assessment based on the 2002 flood event.
Utilizing flood frequency discharge rates currently being calculated by the USGS, prepare maps of the Indian/Dry Creek drainage area illustrating floodway and floodplain elevations suitable for Flood Rate Insurance Map amendment submission(s).

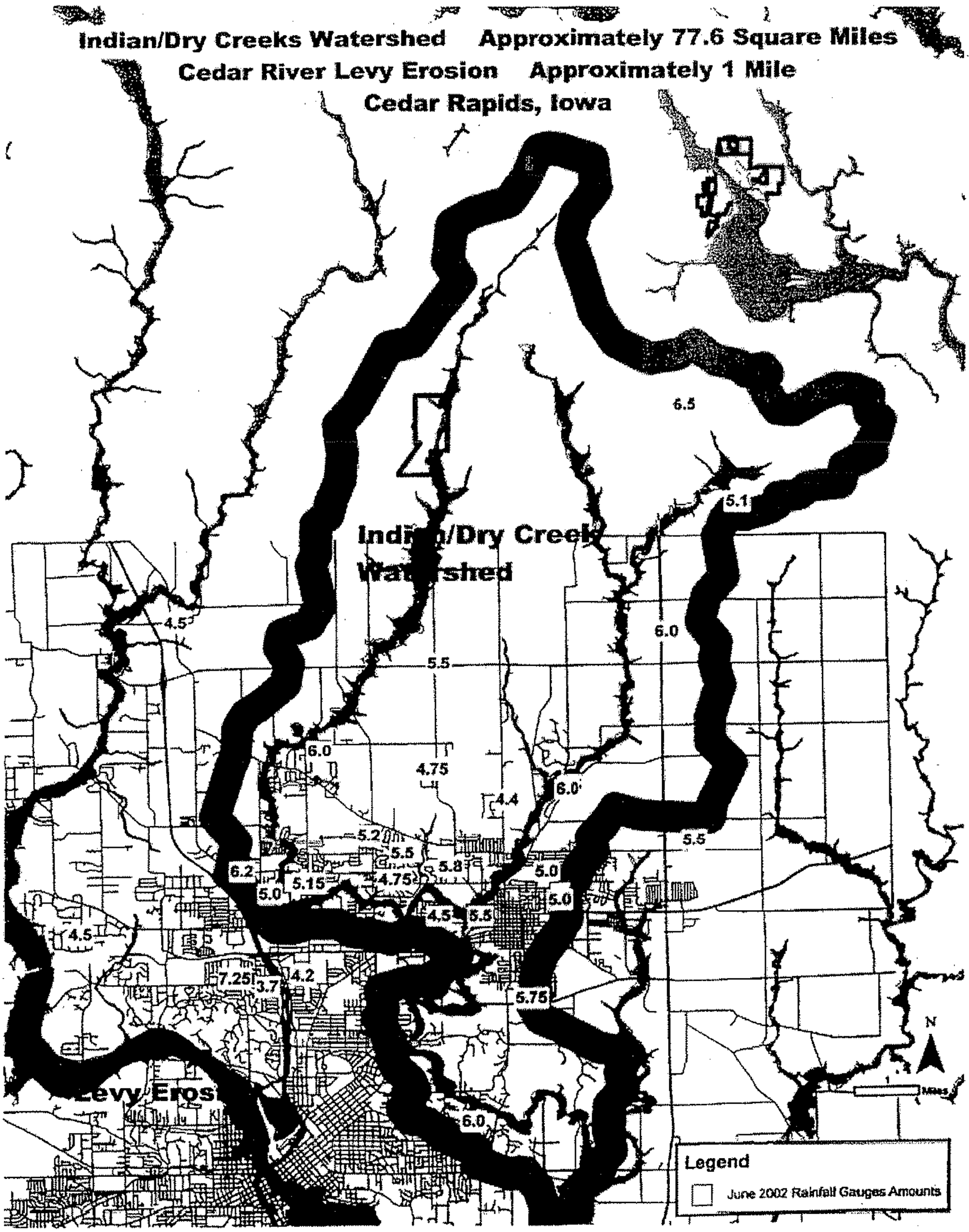
Task 2. Mapping and flood hazard/risk assessment based on future conditions.
Expanding on Task 1, model the Indian/Dry Creek floodway and floodplain elevations with 5 different regulatory scenarios:

- No change from present policies.
- Flood limits for the 100 year flood allowing a 1' rise in flood elevation for current development.
- Flood limits for the 100 year flood allowing a 1' rise in flood elevation for future development, according to local land use policy plans.
- Flood limits for the 100 year flood allowing a .1' rise in flood elevation for future development, according to local land use policy plans.
- Flood limits for the 100 year flood allowing a .5' rise in flood elevation for future development, according to local land use policy plans.

Task 3. Evaluation of potentially feasible structural mitigation measures.
Utilizing the hydrological model developed for Tasks 1 and 2, identify developed areas subject to flooding both currently and in each of the 5 different scenarios developed in Task 2. For those areas, explore physical structural measures that may be used to effectively protect them from flooding, including berms, levies, detention basins, plantings, and others to be developed by the consultant.

Task 4. Evaluation of potentially feasible nonstructural mitigation measures.
Utilizing the hydrological model developed for Tasks 1 and 2, identify developed areas subject to flooding both currently and in each of the 5 different scenarios developed in Task 2. For those areas, explore nonstructural measures that may be used to effectively protect them from flooding, including floodplain restrictions, construction practices, public land acquisition, and others to be developed by the consultant.

Task 5. Summary and Report.
Prepare a report documenting all research, assumptions and conclusions. Report to include a matrix of measures and costs for each as determined in Tasks 3 and 4, so that local decision-makers can assemble a cost-effective program to address local existing and forecasted conditions identified in Tasks 1 and 2.


Indian/Dry Creeks Watershed Approximately 77.6 Square Miles
Cedar River Levy Erosion Approximately 1 Mile
Cedar Rapids, Iowa
Indian/Dry Creek Watershed
Levy Erosi
6.5
5.1
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June 2002 Rainfall Gauges Amounts

APPENDIX B

Cedar Rapids, Iowa, Indian Creek and Dry Creek Site Visit
15 October 2003

CEMVR-PM-F

15 October 2003
SUNDERMAN/ZUKOWSKI/5140/5890

MEMORANDUM FOR RECORD

SUBJECT: Cedar Rapids, Iowa, Indian Creek and Dry Run Site Visit

1. The subject meeting was held in the Department of Development Conference Room at Cedar Rapids City Hall on 22 September 2003, beginning at approximately 10 a.m. and adjourning about 4 p.m. after a tour of the areas impacted by the June 2002 flood and the "Time Check" levee. This memorandum documents the discussions that occurred during this meeting.

2. The following representatives from Cedar Rapids, Iowa, and surrounding communities and the Rock Island District of the U.S. Army Corps of Engineers (Corps) attended the meeting.

Dick Ransom	(Hall & Hall Engineers), Hiawatha City Engineer, and Technical Advisory Committee (TAC) Chair
A. Dean Wheatley	Cedar Rapids, Long Range Planning Manager
Dave Elgin	Cedar Rapids Engineer (PM session only)
Darin Ligtenberg	(Snyder & Associates), Robins City Engineer
Dan Whitlow	Marion City Engineer
Steve Gannon	Linn County Engineer
Ken Bickner	Cedar Rapids, Stormwater Management Project Engineer
Kirk Sunderman	Corps Project Engineer
Michael Zukowski	Corps Study Manager

3. Mr. Wheatley provided a Compact Disk (CD) of the Indian Creek watershed, which includes the watershed boundary, topography at 5-foot intervals, and proposed land use. He also furnished a copy of the 17 December 2002 study report entitled, Flood Management in Dry Run and Indian Creek Watersheds - Issues and Concerns, prepared by Professor A. Jacob Odgaard, University of Iowa, Iowa City, Iowa. Copies of the Camp Dresser and McKee Study and The Urban Design Standards will be provided separately.

4. Mr. Gannon provided a copy of the Flood Plain Information Report, Indian and Dry Creeks, Linn County, Iowa, dated 1964. The U.S. Army Corps of Engineers, Rock Island District, prepared this report for the State of Iowa, Iowa Department of Natural Resources.

5. The members of the Flood Study TAC provided the following historical perspective of the impact that the June 2002 storm had on their respective communities:

a. Marion: Marion sustained $3,100, 000.00 in damages as a result of the June 2002 flood. Approximately 135 homes were flooded due to either creek overflows or sanitary sewer backups. Two homes were bought out. The confluence of Dry Run and Indian Creek is in Marion.

b. Robins: Troy Road Bridge was overtopped and is closed and scheduled for reconstruction. Several homes were flooded.

c. Hiawatha: Three to four homes were flooded, some due to sanitary sewer backups.

d. Linn County: The County sustained $99,000.00 in infrastructure damages; there was roughly an additional 50 percent in damages that were note eligible for Federal Emergency Management Agency (FEMA) reimbursement. (***NOTE***: It was stressed that FEMA eligibility is not a consideration for consideration in the Corps economic analysis.)

6. Each of the communities allows filling of the 100-year floodplain. They also require detention basins/ponds for all developments; discharge is limited to the 5-year pre-development discharge, and the required storage is equal to the 100-year post development runoff. The TAC is interested in increasing the required building first floor heights in the floodplain from the current 1-foot elevation up to a 2- or 3-foot requirement.

7. The Cottage Grove Avenue Bridge and the East Post Road Bridge may cause a backwater conditions. A new bridge is proposed for East Post Road.

8. The U.S. Geological Survey has completed a study that proposes the construction of 30 detention basins throughout the watershed, as opposed to regional detention basins.

9. Marion is about to construct a 13-acre regional retention basin at a cost of $500,000.00.

10. Donnelly Park may present a potential for floodplain enhancement. The area has been filled to the current grade. The proposal is to excavate the area to return it to its previous grade and create additional volume for flood storage.

11. The TAC expressed an interest in the possible planting of prairie grass to enhance the infiltration of stormwater (Jim Patchet, Conservation Design Forum, Chicago, Illinois).

12. Public land acquisition may be required if ordinance changes result in a taking of development right.

13. Construction practices are not a consideration.

14. Mr. Wheatley and Mr. Bickner conducted a tour of the major damage areas.

MICHAEL P. ZUKOWSKI, P.E.
Study Manager
Project Management Branch

DISTRIBUTION:
All Attendees

CF:
Dist File (PM-M)
PM-F (Zukowski)
PM-F (Schroeder)
PM-M (Hamilton)
PM-A (Fetes)
PM-A (McGuire)
ED-DM (Sunderman)
ED-DM (Less)
ED-HH (Gambucci)
ED-G (Barnes)
RE-M (Riddell)

APPENDIX C

Discussion of Hydrologic and Hydraulic Models

CEDAR RAPIDS, LINN COUNTY, IOWA
CEDAR RIVER, INDIAN CREEK, AND DRY CREEK
CWIS No. 181244

SECTION 205
INITIAL ASSESSMENT FOR FLOOD DAMAGE REDUCTION

APPENDIX C
DISCUSSION OF HYDROLOGIC AND HYDRAULIC MODELS

Hydrologic & Hydraulic Model Overview

Several tools are available to simulate the origin, movement and flow of surface water in the environment. These tools, or models can be grouped into two categories: hydrologic models and hydraulic models. Hydrologic models simulate the quantity of water that will arrive at a location along a stream channel, while hydraulic models compute the elevation of the water surface at a location along the stream channel. Both types of models are commonly used in conjunction to complete flood insurance studies and to evaluate the effects of land-use change in planning and evaluating future community growth and development.

Hydrologic Models

For the purpose of this discussion, hydrologic models are grouped into the following categories: (1) simple, single-event rainfall-runoff models, and (2) continuous-streamflow simulation models. For the single-event rainfall runoff models, the goal is to develop the streamflow hydrograph for a particular precipitation event of interest. The calculations are conducted from upstream to downstream in the watershed. The basic data requirements for hydrograph simulation are basin precipitation, channel geometry for routing, soils information, and land-use/land cover data to estimate rainfall losses and rainfall-runoff response. The single-event rainfall-runoff models are useful for simulating a design storm (i.e., 24-hour, 100-year) or for evaluating hydrologic response where modeling long-term processes are not needed. HEC-HMS, TR-20, and TR-55 are examples of single-event rainfall-runoff models.

The continuous-streamflow simulation models are much more complex than the single-event rainfall-runoff models described above. They continuously account in time for all precipitation that falls on the watershed and the movement of water, both on and under the surface to the watershed outlet. The models analyze soil moisture, evapotranspiration, snowmelt, and subsurface flows in the unsaturated and saturated zones. The input data for these models is very extensive and is often unavailable. Continuous-streamflow models are particularly useful in water quality simulations where constituent concentrations over long periods are of interest. Ideally, these models should only be used in watersheds where extensive precipitation and streamflow records are available for use in calibrating the many parameters that are used in model development. HSPF and GSSHA are examples of continuous-streamflow simulation models.

The following discussion covers the most widely used single-event rainfall-runoff and continuous-streamflow hydrologic models.

Simple, Single-Event Hydrologic Models

- **TR-20**

The Natural Resources Conservation Service (NRCS) TR-20 (Technical Release No. 20) computer program is a single-event rainfall-runoff model that is normally used with a design storm as rainfall input. The program computes runoff hydrographs, routes flows through channel reaches and reservoirs, and combines hydrographs at confluences of the watershed stream system. Runoff hydrographs are computed by using the SCS runoff equation and the SCS dimensionless unit hydrograph. The software can also evaluate several watershed alternatives in a single computer run. These alternatives include different combinations of rainfall distribution, land use, hydraulic structures, and channel modifications.

TR-20 uses land-use information and soils maps to define the SCS curve number for specific land uses and soil types. The SCS dimensionless unit hydrograph is defined by the watershed lag and the sub-basin area. Standard procedures are available for computing the lag. The advantage of this method is that it is simple to apply, and because it is a standardized procedure, similar results can be obtained by different hydrologists applying the method to the same watershed.

Required input for the TR-20 model includes: land-use/land cover, soil types, hydrograph data, rainfall data, hydraulic structure data, and stream cross-section data (for flood routing). Each sub-watershed is assumed to be hydrologically homogeneous and generally should not have an area greater than 25 sq. mi. Model setup and execution are fairly quick and easy. TR-20 is well supported by the Watershed Modeling System (WMS) (discussed later in this appendix) with tools and an interface to generate model parameters from available Geographic Information Systems (GIS) data coverages. The software can operate on a modern desktop computer and is freely available for download from the NRCS website.

The TR-20 model had been widely used in the United States for urban and rural watershed planning, flood insurance studies, and design of reservoirs and channel projects. Table E-1 summarizes the model's capabilities and compares TR-20 to the other hydrologic models discussed in this document.

TR-55

The NRCS TR-55 (Technical Release No. 55) presents simplified procedures for calculating storm runoff volume, peak discharge, and hydrographs. The model is intended for small watersheds, especially urbanized watersheds in the United States. TR-55 is perhaps the most widely used approach to hydrology in the U.S. Originally released in 1975, TR-55 is a simplified version of TR-20 and provides a number of techniques that are useful for modeling small watersheds.

The procedure described in TR-55 begins with a rainfall amount uniformly imposed on the watershed over a specified time distribution. Like the TR-20 model, rainfall is converted to runoff through a runoff curve number (CN). The CN is based on soil type, plant cover, interception, surface storage, and amount of impervious area. Runoff is then transformed into a hydrograph by using unit hydrograph theory and routing procedures that depend on runoff travel time through segments of the watershed.

A very critical parameter in the model is the time of concentration (Tc). Tc is the time it takes for runoff to travel from the hydraulically most remote point in the watershed to the outlet (or other point of interest). Normally a rainfall duration equal to or greater than Tc is used in the model. The rainfall distributions used by the model are designed to contain the intensity of any duration of rainfall for the frequency of the event chosen. That is, if the 10-year frequency, 24-hour rainfall is used, the most intense hour will approximate the 10-year, 1-hour rainfall volume.

TR-55 includes four regional rainfall time distributions. All four distributions are for a 24-hour period. This period is used because of the general availability of daily rainfall data that were used to estimate 24-hour rainfall amounts. The 24-hour duration spans most of the typical applications of TR-55 and can be broken down into smaller segments.

TR-55 is a simple, easy to apply method of estimating peak discharge from a storm event. As noted above, TR-55 is one of the most widely used tools in the United States. TR-55 is well supported by WMS (discussed later in this document) with tools and an interface to generate model parameters from available GIS data coverages. The TR-55 procedures and program are available for download from the NRCS website. Table E-1 contains a comparison of TR-20, TR-55, and the other hydrologic models discussed below.

HEC-HMS

The Hydrologic Modeling System (HEC-HMS, current version 2.2.2) is designed to simulate the rainfall-runoff processes that occur in watersheds. HEC-HMS was developed by the Hydrologic Engineering Center (HEC) of the U.S. Army Corps of Engineers, and is the successor to HEC-1. Within HEC-HMS, hydrologic elements are divided into sub-basins, reaches, junctions, reservoirs, diversions, sources, and sinks. A wide range of loss rate, transformation, baseflow, and routing options is supported. Precipitation/Runoff can be entered as a defined rainfall distribution, weighted point (gage) rainfall, gridded precipitation, a (design) frequency storm, a Standard Project Storm, or as a SCS Hypothetical Storm.

HEC-HMS contains a parameter optimization routine that can be used to estimate optimal model parameters. The parameter optimization routine "searches" for the optimal model parameters by adjusting the model parameters to minimize the difference (called an objective function) between the computed hydrograph and a known, observed hydrograph. Four different objective functions are available in HEC-HMS, ranging from those designed to optimize fit to the peak discharge, to those designed to optimize fit to the hydrograph volume.

Future versions of the model will include capabilities for snow accumulation and melt, flow-frequency curve analysis, reservoir outlet structures, and dam break analysis. Because HEC-HMS supports a wide range of loss rate, runoff transformation, and routing options, it allows the user to select the most appropriate method for their application and/or the methods with which they are most familiar. HEC-HMS, and its predecessor HEC-1, have been widely used for engineering design and analysis. Setting up a basic hydrologic model within HEC-HMS can be accomplished very quickly. Data requirements are similar to those of TR-20, and HEC-HMS can be easily operated on a modern desktop computer. The software is freely available for download from the HEC website. See Table E-1 for a comparison of HEC-HMS, TR-20, TR-55, and the other models discussed below.

Continuous-Streamflow Simulation Hydrologic Models

- **HSPF**

HSPF (Hydrologic Simulation Program – Fortran; current version 12) is a continuous watershed simulation model designed to simulate the water quantity and water quality processes that occur in a watershed, including sediment transport and the movement of contaminants. Developed by the USGS (United States Geological Survey) and EPA (Environmental Protection Agency), HSPF simulates hydrologic and water quality processes on land surfaces, streams, and in impoundments. HSPF has typically been used to perform watershed-based analysis on the effects of land use, reservoir operations, point and non-point source treatment alternatives, and flow diversions. HSPF is accepted by the EPA as a tool for the development of TMDLs (Total Maximum Daily Loads).

HSPF can simulate processes in a single watershed or a system of sub-basins. The model requires land-use/land cover data, stream channel, or reach data, meteorological data (temperature, rainfall, cloud cover, dew point etc.), and information on the pollutants of interest in the watershed and the reaches. HPSF is designed to interact with the BASINS (described below) utilities and data sets to facilitate the extraction of appropriate information and the preparation of model input files. HSPF works with BASINS' post processing tools to facilitate display and interpretation of output data.

HSPF is a lumped parameter model. In order to represent spatial variability in model parameters, the basin must be divided into sub-basins. In HSPF, the various hydrologic processes are represented mathematically as flows and storages. Each flow is an outflow from a storage unit, and is expressed as a function of the current storage amount and the physical characteristics of the subsystem.

In HSPF, the basin is represented in terms of land segments and reaches/reservoirs. A land segment is a portion of the simulated watershed. The boundaries are established according to the user's needs, but generally, a segment is defined as an area with similar hydrologic characteristics. For modeling purposes, water, sediment, and water quality constituents leaving the watershed move laterally to a downslope segment or to a reach/reservoir.

Pervious and impervious land segments are considered separately (a segment of land that has the capacity to allow enough infiltration to influence the water budget is considered pervious). In pervious land segments, HSPF models the movement of water along three paths: overland flow, interflow, and groundwater flow. Each of these three paths experiences differences in time delay and differences in interaction between water and its various dissolved constituents. A variety of storage zones are used to represent the storage processes that occur on the land surface and in the soil horizons. Snow accumulation and melt are also included. In impervious land segments, precipitation, overland flow, and evaporation are computed and water quality constituents accumulate and are removed. The hydraulic and water quality processes that occur in the river channel network are simulated by reaches. Channel routing is done using a modified version of the kinematic wave equation.

The input time series data are more complex than the previously described models. HSPF requires not only precipitation data, but also temperature data, potential evaporation data, and other meteorological data. Input time series used by HSPF are organized in a separate software utility, WDMUtil. Output from HSPF must be viewed and analyzed in a separate software utility called GENSCN. The HSPF and associated utilities can be operated on a modern desktop computer, and are available free from the EPA website. It can be used as a stand-alone product, or can be initially parameterized using the BASINS software as described below.

HSPF, coupled with BASINS, provides a wide range of tools and simulation options. HSPF and BASINS are designed for long-term simulations where water quality, sediment transport, and contaminant transport are a major concern. For an ungaged and previously unmodeled basin, very little information would be available with which to fully utilize the model's capabilities. Table E-1 compares the modeling capabilities of HEC-HMS, TR-20, TR-55, HSPF and GSSHA, which is discussed below.

- **GSSHA**

The Gridded Surface Subsurface Hydrologic Analysis model, GSSHA, was developed by the Coastal and Hydraulics Laboratory of the U.S. Army Corps of Engineers' Waterways Experiment Station (now part of the Engineering Research and Development Center – ERDC). GSSHA is a physically based, distributed-parameter, structured grid, process-based hydrologic model that simulates the hydrologic response of a watershed subject to given hydrometeorological inputs. The watershed is divided into cells that make up a uniform finite difference grid. Processes that occur before, during, and after a rainfall event are calculated for each grid cell and then the responses from individual grid cells are integrated to produce the watershed response. Major components of the model include rainfall distribution, snowfall accumulation and melting, precipitation interception, infiltration, evapo-transpiration, surface water retention, surface runoff routing, channel flow routing, unsaturated zone modeling, saturated groundwater flow, overland sediment erosion, transport and deposition, and channel routing of sediments.

A GSSHA model can be initially constructed and parameterized using the WMS interface (described below). The problem with GSSHA and other physically based distributed models is that the parameters developed to drive the model computations are based on properties that vary from basin to basin and are not easily calibrated. They require intense, well-developed meteorological data that are not readily available in most watersheds. This makes it particularly difficult to apply this type of model to a basin without a continuous streamflow record. Without continuous observed flow measurements, it is impossible to calibrate a model of this type for any kind of practical application.

GSSHA is also computationally expensive. Depending on the size of the watershed, the number of designated grid cells that represent the watershed, and how many processes are being simulated, it could take hours to complete a simulation on a conventional desktop computer. For large applications, the GSSHA model requires a supercomputer to complete simulations. GSSHA is freely available to agencies within the Department of Defense. For the private sector, the model can be purchased with the WMS package.

Table E-1. Comparison of modeling capabilities of selected hydrologic models.

	TR-20	TR-55	HEC-HMS	HSPF	GSSHA
Types of Models Supported					
Empirical Method					
Unit-Hydrograph Method	✓	✓	✓		
Distributed Overland Flow Model			✓	✓	✓
Channel Routing	✓		✓	✓	✓
Other Model Capabilities					
Automated Parameter Estimation[1]	✓	✓	✓	✓	✓
Basin Delineation[1]	✓	✓	✓	✓	✓
Continuous Simulation			✓	✓	✓
Distributed Rainfall Module[1]			✓	✓	✓
Foodplain Innundation Mapping[1]	✓	✓		✓	
GIS Import/Export Capability[1]	✓	✓	✓	✓	✓
Incorporation of Uncertainty					
Parameter Optimization			✓		
Snowmelt Module				✓	✓
Water Quality Module				✓	
Hydrologic Model Pre- and Post-Processor Support					
BASINS				✓	
HEC-GeoHMS			✓		
WMS	✓	✓		✓	✓
Complexity of Model Use	Moderate	Low	Moderate-High	Moderate-High	High

[1] In combination with Pre- and Post-Processor

Hydrologic Model Pre- and Post-Data Processors

These software tools greatly facilitate the construction and initial parameterization of hydrologic models. They extract and analyze information from existing GIS (Geographical Information Systems) data layers and provide an easy interface to the hydrologic models described above. Once the initial model construction has been completed, these GIS utilities are no longer needed to complete a hydrologic analysis. However, some of the pre- and post-processors described below can also be used to display modeling results obtained from hydrologic analyses.

BASINS

Better Assessment Science Integrating point and Non-point Sources (BASINS, current version 3.0) was developed by the U.S. Environmental Protection Agency, Office of Water, to provide a modeling framework for watershed-scale analysis that incorporates simulation models to assess the movement of water, sediment, and point and nonpoint sources of pollutants. BASINS was written, using the Avenue programming language, for the proprietary ESRI ArcView GIS (version 3.1 - 3.3) environment, and requires the Spatial Analyst (version 1.1) extension for automatic watershed delineation.

BASINS integrates ArcView GIS, national watershed and meteorologic data, and environmental assessment and modeling tools (HSPF, QUAL2E, SWAT and TOXIROUTE) into one package designed to support the development of total maximum daily loads (TMDLs). BASINS supports the analysis of a variety of pollutants at multiple scales, using tools that range from simple to sophisticated.

BASINS provides support for the HSPF model. It can perform automatic watershed delineation on a DEM (Digital Elevation Model) to define the watershed boundaries (including sub-watersheds) and stream network for use by HSPF. BASINS' Avenue scripts are designed to automatically provide the computed model parameters to the simulation models and to provide visualization tools for viewing model results.

Using geospatial information, BASINS facilitates the construction of HSPF hydrologic models by performing analysis that used to be performed manually (delineation of drainage basins, stream lengths and slopes, etc.), and through routines designed to estimate hydrologic parameters. The BASINS package is freely available for download from the EPA website, but requires the proprietary ArcView GIS software to operate. It can be installed and operated on a modern desktop computer.

HEC-GeoHMS

HEC-GeoHMS (current version 1.0) was developed by the Hydrologic Engineering Center (HEC) and Environmental Systems Research Institute (ESRI). HEC-GeoHMS is an extension to the ArcView GIS software and its Spatial Analyst extension. HEC-GeoHMS consists of a series of ArcView scripts developed using the Avenue programming language and Spatial Analyst. It is designed to be a pre-processor for use with HEC-HMS, allowing for visualization of spatial data, documentation of watershed characteristics, performance of spatial analysis, delineation of sub-watersheds and stream networks, and generation of input parameters to HEC's Hydrologic Modeling System (HEC-HMS). Additional interactive capabilities allow users to construct a hydrologic schematic of the watershed at stream gages, hydraulic structures, and other control points. The hydrologic results from HEC-GeoHMS are then imported by HEC-HMS, where simulation is performed.

Through the use of geospatial information, GeoHMS has the potential to help construct HEC-HMS hydrologic models more efficiently by performing analysis that used to be performed manually (delineation of drainage basins, stream lengths and slopes, etc.), and through routines designed to estimate hydrologic parameters. Additionally, distributed hydrologic modeling using radar rainfall data and surface models can be performed. Specifically, the ModClark modeling approach contained in HEC-HMS is designed to make use of these capabilities.

HEC-GeoHMS requires the use of two proprietary ESRI products: ArcView 3.x, and the Spatial Analyst extension. HEC-GeoHMS, along with ArcView and its extensions can be used on a modern desktop computer. The HEC-GeoHMS package is freely available for download on the HEC website.

WMS

The Watershed Modeling System (WMS, current version 7.0) was developed by Brigham Young University in cooperation with the Coastal and Hydraulics Laboratory of the U.S. Army Corps of Engineers' Waterways Experiment Station (now part of the Engineering Research and Development Center – ERDC). WMS serves as a pre- and post-processor for developing inputs to, and displaying results from, hydrologic models. The current version of WMS supports a wide range of hydrologic models ranging from the Rational Method to the physically based, spatially distributed model GSSHA. The majority of the hydrologic models supported are simple lumped parameter, single-event models, including HEC-1, TR-20, TR-55, and F0601 (a modified Rational Method program). It also includes the continuous-streamflow simulation model HSPF. Individual model parameters can be defined in a series of menus within WMS.

WMS allows for the use of spatial GIS data in the form of TINs (triangulated irregular networks) and DEMs. Using this information, WMS can delineate watershed boundaries and stream networks, develop basin statistics (sub-basin areas, stream lengths, slopes, etc.), compute time of concentration and travel times for the sub-basins, and characterize the land-use and soil types present in each basin (used in the computation of a composite curve number). In addition, WMS allows the import of geo-referenced images (e.g., USGS Quadrangle Maps) upon which on-screen (or "heads-up") digitizing can be performed. Additionally, WMS can directly import and export AutoCAD and MicroStation DXF files. Land-use, soil type, and other data coverage types can be directly imported from an ESRI Arc/Info or ArcView GIS database. From land-use and soil type coverage data, the software will automatically compute a composite curve number for each sub-basin and the corresponding time of concentration.

In addition to developing inputs for hydrologic models, WMS can also be used to perform floodplain delineation and mapping. WMS does this by using stage values at selected locations within the floodplain, and then interpolating a smooth water surface based on the stage values at these locations and intersecting it with the land surface defined by the TIN.

WMS includes an interface to the TR-20 hydrologic program. The interface has been created in such a way that models can be built from TINs used to delineate basin boundaries and compute geometric data or by manually constructing a series of outlets and basins to form a topologic representation of the watershed. When a TIN is used, the topologic model is automatically constructed as outlets, and basins are defined. In addition, geometric parameters, computed by WMS, are automatically supplied to the corresponding TR-20 input fields. TR-20 can be launched directly from within WMS, and WMS can be used to display the computed hydrographs.

Unlike HEC-GeoHMS and BASINS (which are extensions of ArcView 3.x), WMS is a self-contained program for developing and executing hydrologic models using spatial GIS data. There are benefits in providing an "all in one" package, such as WMS, that is not dependent on third party software. However, a stand-alone program, such as WMS, constantly has to adjust its input/output routines as spatial data standards and formats continue to evolve.

WMS supports a wide variety of hydrologic models ranging from empirical (the Rational Method) to the complex spatially distributed model GSSHA. This allows modelers to utilize a common set of tools to extract data for the model that best suits their purposes, as well as to select the model that they feel the most comfortable. WMS is freely distributed to the U.S. Army Corps of Engineers offices, but is considered a proprietary product for the private sector. It can be deployed from a modern desktop computer.

Hydraulic Models

Hydraulic models compute water surface elevation profiles in open channels, and can represent flows in either manmade or natural systems. Cross-section data are necessary with the spacing being determined where significant changes in cross-section geometry occur. Hydraulic models can analyze streamflow through bridges and culverts, as well as on floodplains adjacent to the main river system. In addition to the cross-section data requirement, the streamflow data for a frequency of interest (i.e., the 100-year flow frequency) or for a selected streamflow must be supplied. These models are often used in conjunction with hydrologic modeling results to evaluate how significant changes in a watershed (i.e., land-use changes) impact water surface elevations at several locations along a stream. Calibration and verification of these models are often critical and typically rely on known discharge elevation relationships for points along the study reach. High-water marks at bridges and other landmarks, along with a continuous record of river stage (water elevation) are also useful in calibrating hydraulic models.

Hydraulic models can be categorized as steady flow or unsteady flow models. Steady flow models evaluate a single flow value that does not change with time. Steady flow models are the most common type used in practice to calculate water surface elevations for most applications. Unsteady flow models can evaluate a range of flows that change with time. Unlike a steady flow model that requires a single flow value for input, an entire streamflow hydrograph can be entered in an unsteady flow model. These models are typically used for complex applications, where a steady flow model will not adequately represent the system. Often these conditions result from impacts due to storage.

The following is a brief overview of the hydraulic model HEC-RAS. It is both a steady and an unsteady flow model that has been widely utilized in the United States.

HEC-RAS

HEC-RAS (River Analysis System, current version 3.1.1) was developed by the Hydrologic Engineering Center (HEC). HEC-RAS is capable of performing steady and unsteady, one-dimensional, hydraulic calculations for a full network of channels. The model can simulate subcritical, supercritical, and mixed flow regimes (the unsteady component was developed primarily for subcritical flow regimes). HEC-RAS is the successor of the steady-flow model HEC-2. The current model is capable of modeling the effects of various obstructions such as bridges, culverts, weirs, spillways, levees and other structures in the floodplain.

The basic computational procedure within HEC-RAS is based on the solution of the one-dimensional energy equation. Energy losses are evaluated by friction (Manning's equation) and contraction/expansion (coefficient multiplied by the change in velocity head). The momentum equation is utilized in situations where the water surface profile is rapidly varied. These situations include mixed flow regime calculations (i.e., hydraulic jumps), hydraulics of bridges, and evaluating profiles at river confluences (stream junctions). The HEC-RAS unsteady flow equation solver was adapted from Dr. Robert L. Barkau's UNET model.

HEC-RAS, and its predecessor HEC-2, are perhaps the most widely used tools for hydraulic engineering design and analysis in the United States. With adequate channel geometry data, and an acceptable level of model calibration, several different discharges can be simulated in one run of the model. After the initial model setup and calibration, evaluating water level elevations for different flow regimes can be done very quickly. The software is freely available for download from the HEC website and can be easily operated on a modern desktop computer. Table E-2 summarizes the main capabilities of the HEC-RAS software.

Table E-2. Summary of HEC-RAS modeling capabilities.

		HEC-RAS
Model Simulation Capabilities		
	Steady, Uniform Flow	✓
	Steady, Varied Flow	✓
	Unsteady Flow	✓
Other Model Capabilities		
	Direct Support for Floodplain Inundation Mapping[1]	✓
	Use of DEM/DTM to Create Cross-Sections[1]	✓
Hydraulic Model Pre- and Post-Processor Support[2]		
	HEC-GeoRAS	✓
Complexity of Model Use		Moderate

[1] In combination with Pre- and Post-Processor

Hydraulic Model Pre- and Post-Data Processors

Similar to the pre- and post-processors described for hydrologic models, these tools greatly facilitate the construction and initial parameterization of hydraulic models. These programs extract and analyze information from existing GIS data layers and provide an easy interface to hydraulic models. Once the initial model construction has been completed, these GIS utilities are no longer needed to complete a hydraulic analysis. However, the HEC-GeoRAS utility described below can be used to display results obtained from a HEC-RAS analyses.

HEC-GeoRAS

HEC-GeoRAS (current version 3.1.1) is an ArcView GIS extension (written in the Avenue programming language) specifically designed to process geospatial data for use with the

Hydrologic Engineering Center's River Analysis System (HEC-RAS). HEC-GeoRAS is designed to allow users, with limited GIS experience, to create an HEC-RAS import file containing geometric attribute data from an existing digital terrain model (DTM) and shapefiles that define the stream network, cross-section locations, and other hydraulic characteristics of the river system. HEC-GeoRAS requires a DTM represented by a triangulated irregular network (TIN). The DTM must be a continuous surface that includes the bottom of the river channel and floodplain to be modeled.

HEC-GeoRAS creates an import file to HEC-RAS containing river, reach and station identifiers; cross-sectional cut lines; cross-sectional surface lines; cross-sectional bank stations; downstream reach lengths for the left overbank, main channel, and right overbank; and cross-sectional roughness coefficients. After the hydraulic analysis is completed in HEC-RAS, HEC-GeoRAS can develop and display themes of inundated area, water depth, and water velocities from the results of that analysis. However, after the initial model setup has been completed, HEC-GeoRAS is no longer required to conduct analyses in HEC-RAS.

The proprietary ArcView GIS 3.x software and the 3-D Analyst extension are required to use HEC-GeoRAS. The Spatial Analyst extension is recommended to speed up post-processing. HEC-GeoRAS is freely available for download from the HEC website, and can be used on a modern desktop computer.