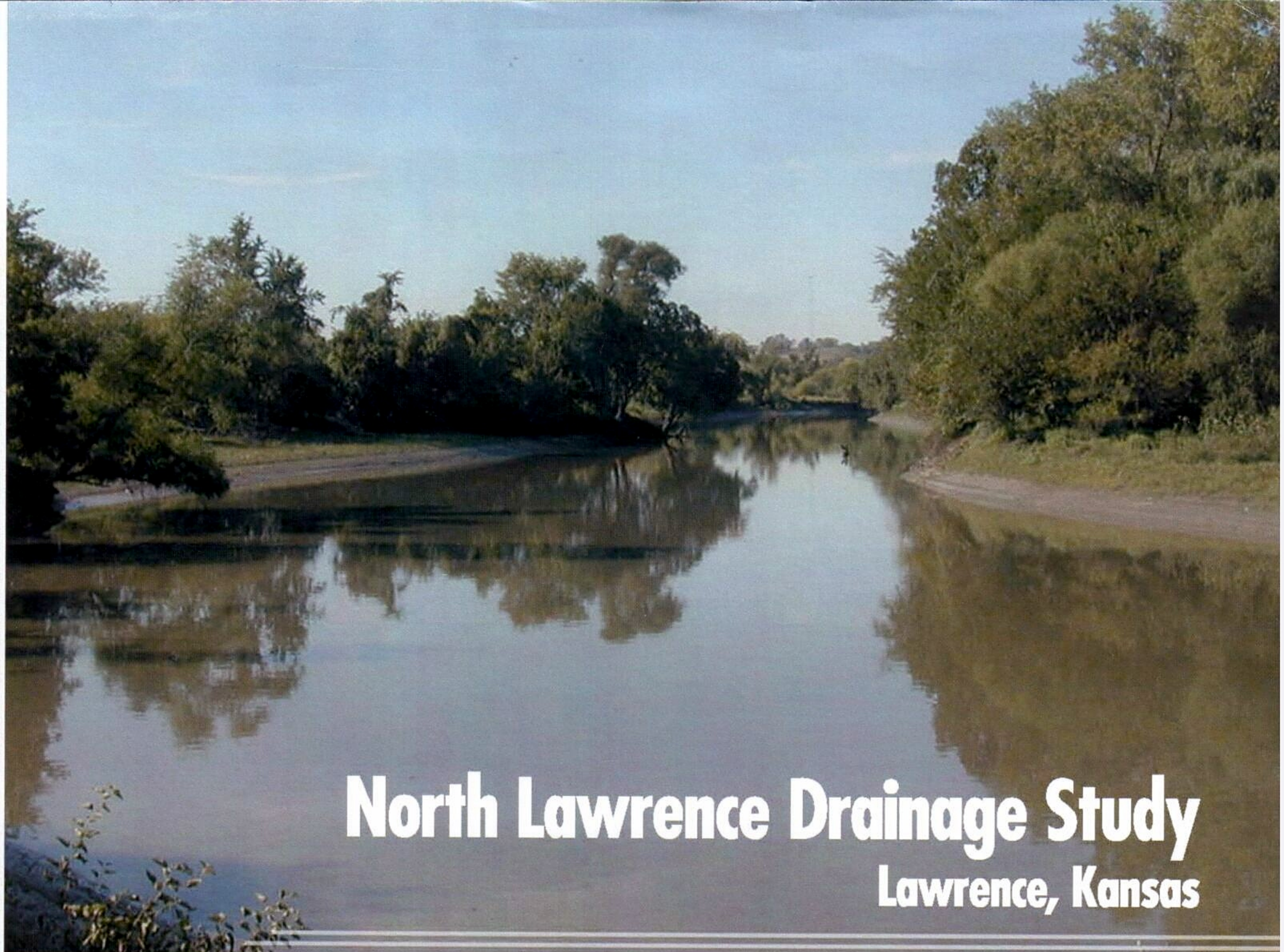

North Lawrence Drainage Study

Lawrence, Kansas

WATER RESOURCES

Submitted to

City of Lawrence

Submitted by

HNTB GBA

November 2005

NORTH LAWRENCE
DRAINAGE STUDY

Submitted to

City of Lawrence

HNTB / GBA

November 2005

NORTH LAWRENCE DRAINAGE STUDY
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EXECUTIVE SUMMARY

I. Introduction

The City of Lawrence has embarked on a program to develop a stormwater management plan for the North Lawrence watershed. This program is based on a recognized need to upgrade existing facilities to modern design standards and to provide coordinated facilities in developing areas. The economic well being of the City depends on its ability to attract and retain business and industry, as well as residents to live in the City. Part of the City's ability to attract businesses and residents depends on its ability to provide adequate services such as drinking water, sewers, transportation and stormwater management. With the ever expanding urban area and associated increases in impervious surfaces such as parking lots, the frequency with which drainage issues occur appears to be increasing. This has caused the City to focus its attention on the need to provide adequate stormwater management policies and infrastructure in all areas within the watershed. The North Lawrence Drainage Study is one important step in this process.

The North Lawrence Drainage Study was divided into two main focus areas. The Internal System consists of the City operated ditches, pipes, and pumps within the existing City boundaries. The overall watershed analysis modeled the less developed drainage aspects of the North Lawrence Drainage Area. More detailed descriptions of the two focus areas can be found later in the report.

II. Recommendations

A. Overall Watershed

Several alternatives were investigated in the overall North Lawrence Drainage Study watershed to reduce flood elevations, lessen impacts on the "Internal Drainage System" facilities, provide drainage in the event of high flows on the Kansas River, and assess the effects of development in the floodplain. The investigations led to the four major recommendations below. The first bullet item is the key to reducing the burden on the Internal System from areas beyond the existing city limits.

- Drainage from north of 24/40 Highway should be cutoff by the highway embankment and the water should be pumped over the levee at a point just east of the 24/40 intersection to reduce the burden on the 2nd Street Pump Station
- Future development in the watershed should maintain the current conveyance levels in the 100-year floodplain – development should not reduce the capacity for floodplain storage
- The City should purchase parcels of land as necessary for use as dedicated ponding areas
- Major roads and hydraulic structures should be improved to meet the current APWA criteria with regard to overtopping during the 100-year event, in order to provide adequate emergency services to the area

A cost summary with regard to these Watershed Analysis recommendations is shown in the table on the next page.

Watershed Recommendations Cost Summary

Description	Quantity	Unit Cost	Project Costs
Raise road west of 24/40 intersection	370 ft	$290/ft	$110,000
Remove 2 existing 24/40 culverts	Lump Sum		$75,000
Channel Excavation, MG0East to 24/40	3500 cu-yd	$4.31/cu-yd	$15,000
KDOT Entrance Culvert	30 ft	$8/ft/sq-ft	$27,000
New 24/40 Culvert	475 ft	$8/ft/sq-ft	$228,000
Remove Maple Grove East culvert	Lump Sum		$22,000
Property containing ponding easement	Full Parcels	Total Value	$942,000
Pump Station; west of airport, north of 24/40	361,000 gpm *	$30/gpm	$11,000,000
Main Channel, E. 1675 Rd., 155' Bridge	7750 sq-ft	$75/sq-ft	$1,364,000
Main Channel, E. 1675 Rd., Roadway	2700 ft	$290/ft	
Main Channel, E. 1600 Rd., 160' Bridge	8000 sq-ft	$75/sq-ft	$1,108,000
Main Channel, E. 1600 Rd., Roadway	1750 ft	$290/ft	
Main Channel, E. 1500 Rd., 155' Bridge	7750 sq-ft	$75/sq-ft	$929,000
Main Channel, E. 1500 Rd., Roadway	1200 ft	$290/ft	
Main Channel, E. 1400 Rd., 140' Bridge	7000 sq-ft	$75/sq-ft	$786,000
Main Channel, E. 1400 Rd., Roadway	900 ft	$290/ft	
Main Channel, E. 1900 Rd., 140' Bridge	7000 sq-ft	$75/sq-ft	$1,221,000
Main Channel, E. 1900 Rd., Roadway	2400 ft	$290/ft	
Maple Grove East, E. 1500 Rd., 100' Bridge	5000 sq-ft	$75/sq-ft	$1,419,000
Maple Grove East, E. 1500 Rd., Roadway	3600 ft	$290/ft	
Maple Grove East, E. 1900 Rd., 120' Bridge	6000 sq-ft	$75/sq-ft	$1,581,000
Maple Grove East, E. 1900 Rd., Roadway	3900 ft	$290/ft	
Maple Grove East, E. 1500 Rd., 120' Bridge	6000 sq-ft	$75/sq-ft	$711,000
Maple Grove East, E. 1500 Rd., Roadway	900 ft	$290/ft	
Trib. A, 24/40 Hwy., 2-11'x7' RCB	60 ft	$8/ft/sq-ft	$326,000
Trib. A, 24/40 Hwy., Roadway	870 ft	$290/ft	
Trib. A, E. 1600 Rd., 60' Bridge	3000 sq-ft	$75/sq-ft	$477,000
Trib. A, E. 1600 Rd., Roadway	870 ft	$290/ft	
Trib. B, E. 1700 Rd., 140' Bridge	7000 sq-ft	$75/sq-ft	$1,758,000
Trib. B, E. 1700 Rd., Roadway	4250 ft	$290/ft	
Trib. B, E. 1650 Rd., 100' Bridge	5000 sq-ft	$75/sq-ft	$703,000
Trib. B, E. 1650 Rd., Roadway	1130 ft	$290/ft	
Total			$24,802,000

Note: All costs are concept level estimates only. Actual costs may vary significantly.

* Required capacity at ultimate build-out

B. Internal System

Analyses for the Internal Drainage System provided areas of concern throughout the City operated drainage network. The excess peak flow was used to represent the degree to which a conduit is undersized for the ultimate build-out condition. Each investigated lateral flowing into the main stem of a system and each main stem conduit were ranked by excess peak flow. This led to the following priority listing of recommended improvements.

Prioritization of Internal Systems

Link Name	Excess Peak Flow (cfs)	Total Estimated Cost of Improvements (dollars)
S1-1	315	$9,163,000
S6-1	168	$3,994,000
S9-1	133	$1,132,000
S1L1-1	96	$333,000
S1L5-1	85	$235,000
S1L7-1	85	$59,000
S1L3-1	56	$187,000
S6L3-1	56	$195,000
S6L3-7D	New pipes	$181,000
S4-1	43	$60,000
S6L2-1	37	$5,000
S4L4-1	35	$53,000
S4L2-1	27	$36,000
S9L1-1	21	$7,000
S1L2-1	20	$240,000
S8-1	17	$115,000
S10L2-1	13	$4,000
S7-1	13	$38,000
S5-1	10	$56,000
S10-1	6	$106,000
S1L4-1	1	$7,000
S1L6-1	0	$0
S11-1	0	$0
S3-1	0	$0
S2-1	0	$0
S12-1	0	$0
Total		$16,206,000

The flows calculated in the analysis of the internal system assume that the cutoff north of 24/40 Highway, as recommended by the Watershed Analysis, is in place. However, the costs in the table for the Internal System Analysis are independent of the costs for the Watershed Analysis improvement recommendations. By adding the total costs from each of the two summary tables, the estimated cost of all recommendations is approximately $41 million.

As with the overall watershed, a viable option within the internal system is land purchase. In areas that naturally drain to a low point, it is often advantageous to preserve the ponding area by purchasing the parcel of land. Those costs are included in several of the system costs in the table.

III. Background

A. Watershed Description

The North Lawrence watershed is estimated to be 9,100 acres generally bordered by the Kansas River levee on the south and the Mud Creek levee on the east. Most of the drainage contributes to the Maple Grove system, which either conveys water south to the City or east eventually to Mud Creek. A few areas near the levee, to the northwest and southeast, drain directly to the Kansas River, while a thin strip of land along part of the northeastern portion of the watershed flows directly to Mud Creek. Refer to the North Lawrence Drainage Study map in Section I of the main report for an overview of the project area.

The Kansas River floodplain completely encompasses North Lawrence. The natural silt loam soils are highly permeable. However, increased development is replacing those soils with nearly impermeable clay material in certain areas. In addition, extremely mild slopes across the landform cause frequent ponding and roadway overtopping. Historically, North Lawrence has been an agricultural community with low density residential development. Pockets of commercial and industrial development now appear in areas of the watershed. While parts of North Lawrence will likely remain agricultural, the projected future land use in other areas will add more and more impervious surfaces.

B. Purpose

The Lawrence-Douglas County Planning Commission proposed this study to address repeated flooding concerns from residents of the North Lawrence area. Flooding problems occur in a number of areas within the North Lawrence watershed. The major causes are as follows:

- Development that has significantly increased runoff from design storm events
- Undersized drainage system components such as culverts, drainage channels, underground pipe systems and inlets
- Siltation within the storm drainage system
- Past development of flood-prone areas
- A shallow, flat and interrupted watershed drainage network

Public comments relating to current drainage issues, proposed developments, long-range plans, and floodplain regulations are at the root of this study. The purpose of this study is to identify areas with flooding problems, analyze the major elements of the storm drainage system with respect to long-term land use, and recommend needed improvements to correct or prevent systems from flooding. By doing this, proposed developments and long-range plans will be influenced. At the same time, regulations can be conceptualized to avoid potential pitfalls.

C. Scope of Project

The North Lawrence Drainage Study has several major components which work toward the generation of system requirements for stormwater conveyance and infrastructure in the ultimate buildout scenario. The following major tasks were included in the study:

- Integration of the public involvement program that gathered and used information from residents, business owners and property owners when considering alternatives or upgrades within the watershed
- Estimation of the ultimate land use for the watershed
- Survey and general inspection of the drainage system
- Development of a digital database that shows the existing components of the City’s drainage system
- Evaluation of the internal drainage system for the ultimate buildout scenario and recommendation of improvements
- Evaluation of the watershed drainage system for the ultimate buildout scenario and recommendation of improvements
- Completion of an analysis of Kansas River flooding resulting from levee overtopping

Along with the recommended improvements, the magnitude of the costs required to implement them were assessed. It should be noted though, that detailed design of the projects recommended in this report is required to produce proper construction documents and accurate cost estimates for system components.

The main body of the project report is divided up into seven sections. Summaries of the various sections are detailed below. For a detailed description of the methods or results of each section, refer to the main report.

IV. Public Involvement

The North Lawrence Drainage Study public involvement program was designed to establish meaningful and useful dialogue between stakeholders, businesses, residents in the area and the study team. A series of outreach efforts were conducted to catalogue and assess the public’s concerns. Members of the project team provided an overview of study activities and public input to the Lawrence Planning Commission.

V. Ultimate Land Use for Watershed

To accomplish the goals of the North Lawrence Drainage Study, the ultimate land use condition had to be determined for the study area. The future land uses within the watershed will help determine where to focus the stormwater system improvements and provide better insight into heading off potential development problems. The project team conferred with the Public Works Department, the Planning Office, and the Utilities Department of Lawrence. Information was gathered with regard to current zoning, potential developments and long-range plans and was used to produce an ultimate watershed land use guide.

While the information gathered was used to create the Ultimate Build-Out map, it was not intended to dictate specific policies with regard to land use in the North Lawrence Drainage Area. However, certain policies could be inferred from the findings of this study. For instance, lot splits currently require a hydraulic study to determine impacts. Due to the extensive hydraulic studies detailed in this report, it would not be necessary for developers to conduct individual studies, as long as the general recommendations of this study are followed (i.e. conveyance needs to be maintained within the floodplain).

VI. Data Collection

Several field visits were made to the study area to observe drainage patterns, take photographs and verify structure sizes and orientations. A significant portion of the North Lawrence watershed was surveyed for this project. This information was used in the development of computer models of the watershed. Information from the field survey forms was entered into GIS. The basis for the evaluation of the North Lawrence watershed is the digital base maps developed by the City. These maps also show land features with a 2-foot contour interval. The base maps include topographical drainage information such as open channels, bridges, culverts, manholes, inlets, and enclosed drainage systems. They also include houses, transportation and above ground utility locations. Field surveys were completed as part of this study to update and verify any existing information on size, location, and slope of the conveyance structures. Survey data on the conveyance system and watershed characteristics were combined with the City database to create a comprehensive database of the most up-to-date information.

VII. Internal Drainage System Analysis

The system of City operated ditches, pipes, and pumps throughout North Lawrence are collectively referred to as the “internal drainage system” in this report. This system collects the drainage from about 1.8 square miles and largely conveys it through gravity and pressure pipe to the Kansas River. The intent of the internal drainage system analysis portion of the North Lawrence Drainage Study was to investigate necessary improvements to the existing infrastructure system for a 10-year frequency event, assuming the land uses specified by the Buildout Scenario Map. The performance of the Maple Street Pump Station (529 Maple Street) and the 2nd Street Pump Station (732 N. 2nd Street) were closely considered in the overall evaluation.

Results of the hydrologic and hydraulic analyses for the set of 12 systems representing the existing stormwater infrastructure within North Lawrence identified many surcharge locations for the ultimate buildout condition.

Recommendations were determined for each conduit or channel in a system based on the analysis of the entire system. It should be noted that improvements are to generally be made in a downstream to upstream manner within the system, as there is no advantage trying to deliver more flow to a downstream component that cannot convey the existing flow. Overall costs for each system upgrade were estimated; however, for the purposes of prioritizing public improvements on a smaller scale, excess peak flow was determined for each main stem and each lateral draining to the main stem of the system.

VIII. Watershed Analysis

There were three main goals for this portion of the study: to reduce the demand on the 2nd Street Pump Station, to expel floodwater from the basin during times of high water on the Kansas River, and to investigate the effects of development in the floodplain. It is recommended that the drainage from the area north of 24/40 Highway be cut off and the water pumped over the levee. The recommendation for reducing the burden on the 2nd Street Pump Station appraises the 10-year event in conjunction with the design criteria of the internal drainage system, however the 100-year event is investigated as well.

The recommendation for future development in the watershed is to maintain the current conveyance levels in the 100-year floodplain. This will mean allowing no development in these areas that would reduce the capacity for floodplain storage, and may require the purchase of small parcels of land to set aside exclusively for ponding.

As the area develops, it will become necessary to provide emergency services to the homes and businesses that populate the area. This will require the improvement of the major roads in the area and significant improvement of the hydraulic structures which carry flow under the roads. With a more dense urban population, the roads should be raised to meet the current APWA criteria with regard to overtopping during the 100-year event. This will result in some significant increases in required flow capacity over the existing hydraulic structures.

IX. Kansas River Floodplain Analysis

The existing conditions FEMA hydraulic model was revised to assess the amount of flooding that would occur in the North Lawrence area in the event of a breach of the Kansas River levee system. A "most likely" breach location was determined for the purpose of this analysis. For the levee breech condition, a 100-year Kansas River event would result in flood levels 0 to 7 feet deep in the North Lawrence Watershed (refer to the exhibit titled Watershed Analysis – Kansas River Inundation in Section VII).

Section I

Introduction

I. Introduction

The City of Lawrence has embarked on a program to develop a stormwater management plan for the North Lawrence watershed. This program is based on a recognized need to upgrade existing facilities to modern design standards and to provide coordinated facilities in developing areas. The economic well being of the City depends on its ability to attract and retain business and industry, as well as residents to live in the City. Part of the City's ability to attract businesses and residents depends on its ability to provide adequate services such as drinking water, sewers, transportation and stormwater management. With the ever expanding urban area and associated increases in impervious surfaces such as parking lots, the frequency with which drainage issues occur appears to be increasing. This has caused the City to focus its attention on the need to provide adequate stormwater management policies and infrastructure in all areas within the watershed. The North Lawrence Drainage Study is one important step in this process.

A. Watershed Description

The North Lawrence watershed is estimated to be 9,100 acres generally bordered by the Kansas River levee on the west and south and the Mud Creek levee on the east. Most of the drainage contributes to the Maple Grove system, which either conveys water south to the City or east eventually to Mud Creek. A few areas near the levee, to the northwest and southeast, drain directly to the Kansas River, while a thin strip of land along part of the northeastern portion of the watershed flows directly to Mud Creek. Refer to the included North Lawrence Watershed map for an overview of the project area.

The Kansas River floodplain completely encompasses North Lawrence. The natural silt loam soils are highly permeable. However, increased development is replacing those soils with nearly impermeable clay material in certain areas. Extremely mild slopes across the landform cause frequent ponding and roadway overtopping. Historically, North Lawrence has been an agricultural community with low density residential development. Pockets of commercial and industrial development now appear in areas of the watershed. While parts of North Lawrence will likely remain agricultural, the projected future land use in other areas will add more and more impervious surfaces.

B. Purpose

The Lawrence-Douglas County Planning Commission proposed this study to address repeated concerns from residents of the North Lawrence area. Flooding problems occur in a number of areas within the North Lawrence watershed. The major causes are as follows:

- Development that has significantly increased runoff from design storm events
- Undersized drainage system components such as culverts, drainage channels, underground pipe systems and inlets
- Siltation within the storm drainage system
- Past development of flood-prone areas
- A shallow, flat and interrupted watershed drainage network

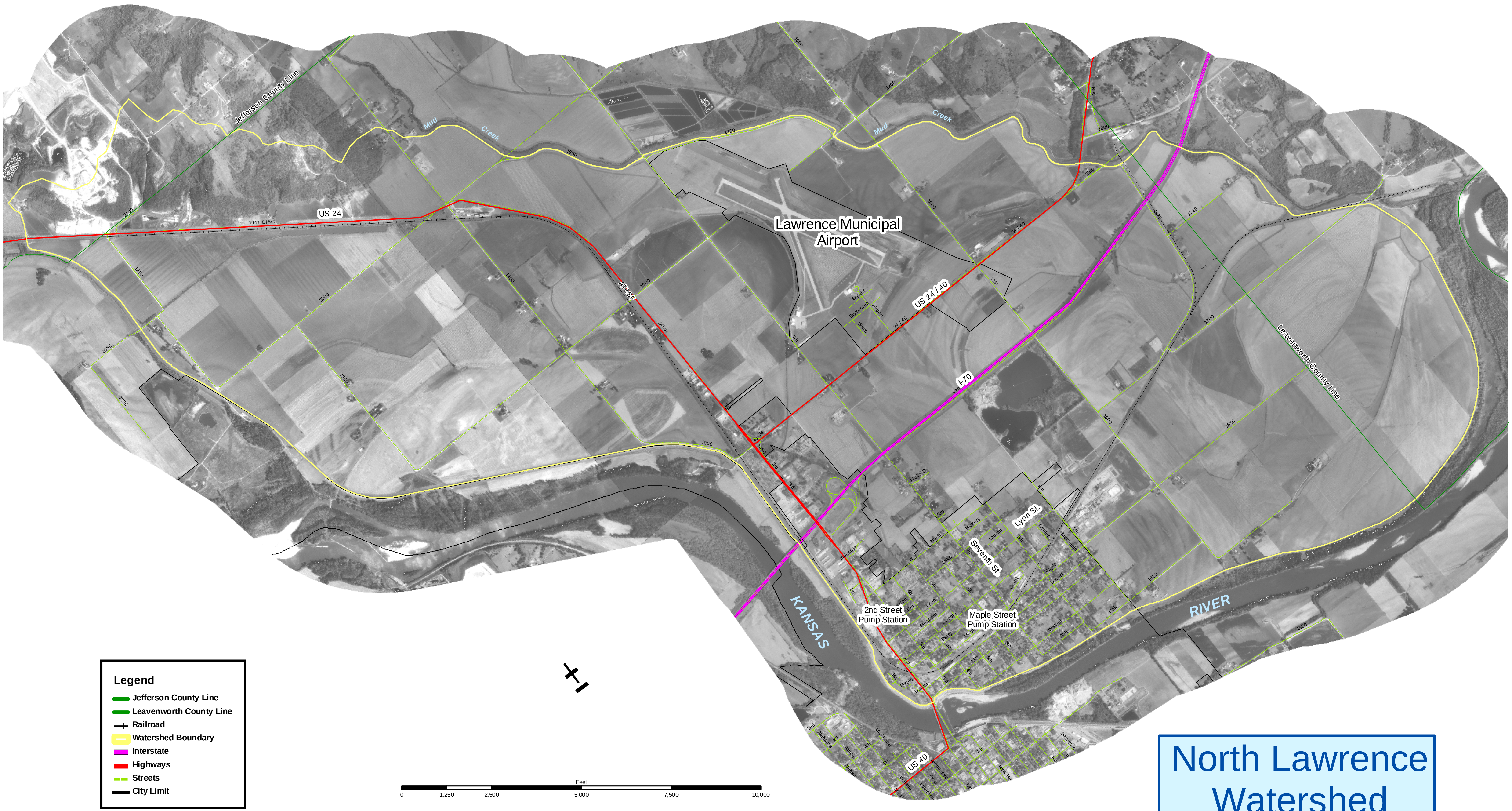
Public comments relating to current drainage issues, proposed developments, long-range plans, and floodplain regulations are at the root of this study. The purpose of this study is to identify areas with flooding problems, analyze the major elements of the storm drainage system with respect to long-term land use, and recommend needed improvements to correct or prevent systems from flooding. By doing this, proposed developments and long-range plans will be influenced. At the same time, regulations can be conceptualized to avoid potential pitfalls.

C. Scope of Project

The North Lawrence Drainage Study has several major components. They all worked toward producing requirements of the system of stormwater conveyance and infrastructure in an ultimate build-out scenario. The first step in doing this was obtaining accurate, reliable data about the watershed. This included past and current drainage issues and technical information on the conveyance systems themselves. Next, there had to be an understanding of what the build-out scenario will be and how to appropriately apply it to the analyses. Three distinct analyses were then performed to produce recommendations for alleviating potential problems within the watershed. The following major tasks were included in the study:

- Integration of a public involvement program that gathered and used information from residents, business owners, and property owners when considering alternatives or upgrades within the watershed
- Estimation of the ultimate land use for the watershed
- Surveying and general inspection of the drainage system
- Development of a digital database that shows the existing components of the City’s drainage system
- Evaluation of the internal drainage system for the ultimate build-out scenario and recommendation of improvements
- Evaluation of the watershed drainage system for the ultimate build-out scenario and recommendation of improvements
- Completion of an analysis of Kansas River flooding resulting from levee overtopping

Recommended improvements help to determine the magnitude of the costs required to implement the needed stormwater system upgrade. It should be noted, though, that detailed design beyond the master planning level is required to accurately produce cost estimates for system components.



North Lawrence Watershed
Lawrence Municipal Airport
Jefferson County Line
Leavenworth County Line
Mud Creek
US 24
US 24 / 40
US 40
I-70
AT&SF
KANSAS RIVER
Lyon St.
Seventh St.
2nd Street Pump Station
Maple Street Pump Station
Legend
Jefferson County Line
Leavenworth County Line
Railroad
Watershed Boundary
Interstate
Highways
Streets
City Limit
Feet
0
1,250
2,500
5,000
7,500
10,000

Section II

Public Involvement

II. Public Involvement

The North Lawrence Drainage Study public involvement program was designed to establish meaningful and useful dialogue between area stakeholders, businesses and residents in the area and the study team. A series of outreach efforts were conducted; summaries of those efforts follow.

A. Key Stakeholder Interviews:

During May and June, 2004, members of the team conducted stakeholder interviews to evaluate community leaders' perceptions and opinions about the area, drainage needs and stormwater management in North Lawrence. One-on-one interviews were conducted between consultant public involvement staff and Steve Glass of the Douglas County Kaw Drainage District, Keith Browning with Douglas County Public Works, and Ted Boyle of the North Lawrence Improvement Association.

The interview questions and responses are detailed below. Key themes included the need to efficiently address the problem in terms of infrastructure needs and costs, and to balance future development with current land use patterns.

What are your biggest concerns/problems related to stormwater management in North Lawrence?

- Area is notorious for flooding
- Better than it used to be; impression that work has already been done
- Pump station seems to help
- Disposal of stormwater – getting it to the river
- Dealing with areas not served by the pump station
- Getting the water into the river
- Several low-lying areas are frequently under water, including Lyons Park, 6th & Maple, and along Lyon

What do you see as the biggest challenge to improving stormwater management in North Lawrence?

- Topography
- Levee
- Money
- Area between river and tracks is higher than area north of tracks; difficult to move water from north of tracks to river

What types of stormwater management changes or improvements do you think would best serve the area?

- Stormwater removal is main concern
- Because of industry and planned development, stormwater treatment may be necessary
- Deal with future development – allows development, but does not make drainage worse
- Concerned about possible overly-strict land use regulations which would limit development

- Development requirements that allow percolation of water into the soil (ditches, retention basins, etc.)
- Suction pressure feed pumps to move water out of the retention ponds, regardless of river height
- Three or four locations (including areas where water already collects) for water retention systems, then grates and suction/pumps to move water from those places to the river

Some communities are now using “green” solutions such as wetlands and riparian setback buffers to reduce the rate of stormwater run off. Do you think a “green” solution is better for North Lawrence than “built” solutions?

- Problems with retention because of local concerns about mosquitoes, etc.
- Setbacks are a good idea
- Allowing water to re-infiltrate would be excellent
- Concerns if water stands for a significant amount of time
- Already required to some degree (setbacks)
- Probably ideal, given topography - question is to what degree
- Likes idea of combining retention areas with recreation facilities – perhaps creation of a permanent lake/pond in combination with water retention
- Lyon Park an ideal location for drainage/retention – water goes there anyway
- Do not want water to stand too long – mosquitoes, West Nile virus, etc.

Do you think North Lawrence should be more or less developed? What do you think it will look like in 20 years?

- Along highway – industrial/commercial development
- Residential – North Lawrence could help fix the lack of affordable housing
- Needs to be more development
- Development rules should be appropriate for area, especially related to affordable/low-income housing
- Lawrence should not be only for upper-class housing, etc. Must accommodate affordable housing
- More development to the north of town and turnpike; residential between river and turnpike
- Rezone for bigger lots (1/4 acre); make sure development patterns do not increase drainage problems or cause increased flooding/problems for neighbors
- Avoid use of clay soils, which do not allow infiltration, as fill
- Currently 78% owner-occupied; nice place to live and want to keep it that way

Should land use planning address management of stormwater runoff? If so, how?

- Definitely
- Need new development, but must also deal with impervious areas
- Use modern stormwater management techniques, like infiltration
- This study should reduce need for individual water management studies, at least in a general sense
- New flood standards already impose some requirements throughout community

- Looking to this study for guidelines for development
- Absolutely
- Not against development, but it must be planned and cannot jeopardize existing homes and businesses
- Long-term solution has to manage water north of the turnpike
- Codes must address stormwater management, but not be so restrictive as to hurt future development

What should new streets in North Lawrence look like?

- Need curbs; hard to get ditches to work correctly because of flat topography
- Open ditch is at least part of the solution
- Sandy soil makes installation of curb and pipe more costly and difficult; flat topography – hard to get water to flow; even main drainage ditch is essentially flat
- Existing streets are too narrow for curb & gutters
- Ditches are good because they allow infiltration/percolation, but not large ditches like those that have been built in some areas because they hard to mow and maintain
- Curb and gutters create concrete rivers; there is no place for the water to go

Do you or your constituents have additional concerns that we should know about?

- Need to get the public involved; need to hear their concerns
- Do not be too restrictive on future development
- Do not harm value of land – older residents are counting on ability to sell land
- Some of the new developments/housing have created problems for long-term residents in terms of additional run-off – fallout is that there is contention between neighbors; developers need to be held accountable
- Study needs to present workable, realistic solutions to drainage problems

Who else do we need to make sure to include in the process?

- Douglas County Kaw Drainage District
- Elected officials
- Planning Commission
- Developers

How do most people in your community get their news/information?

- Lawrence Journal World
- TV 6
- Post notice at Depot; Johnny’s Bar

B. Area Business and Resident Survey

On June 15, 2004, 1,384 surveys were mailed to residences and businesses in the North Lawrence area. Ninety-eight surveys were returned either at the public drop-in center, held on June 30th, or by return mail by the deadline of July 8, 2004.
The majority of the responses reflected property-specific concerns and problems. Standing water in the area and associated concerns about mosquito control were among

the most common problems noted. Recurring concerns related specifically to development patterns, current stormwater management practices and future construction impacts, as well as a desire to limit new development. With those comments came concerns about enforcement of stormwater management controls with new development and construction. The concerns were both in terms of fears of too great of restrictions and desires for stringent development controls.

Survey questions and responses:

How often in the past 10 years have you had a problem with stormwater on your property?

[32] – 0 times

Address	Frequency
1567 Hwy 40	Yes
1728 E. 1500 Road	Twice really bad, but every time with a heavy rain
1804 E. 1600 Road	15
1480 N. 1700 Road	Too many to count
1662 N. 1700 Road	3 or 4
792 N. 2nd	Several
645 N. 3rd	Frequently
1001 N. 3rd	1993 & 1997
624 N. 5th	1
725 N. 5th	8
649 N. 6th	Every time it rains
625 N. 7th	Every time it rains
227 N. 8th	1
625 N. 8th	2-3 times over the last two years
769 Ash	5
600 Center	When it rains
310 Elm	20
411 Elm	Every time it rains
761 Grant	When it rains more than 1 day
711 Maple	2
819 Maple	Every time it rains
321 Maiden Lane	2
403 Lincoln	4
624 Lincoln	During heavy rains
641 Lincoln	Continual erosion; habitual standing water
628 Locust	Ongoing
788 Locust	Every time it rains
806 Locust	Continuous
818 Locust	Yearly
836 Locust	10
520 Lyon	2
835 Lyon	20
711 North Street	Often

Address	Frequency
732 North Street	Every time it rains
501 Perry	Every 1" or more
517 Perry	2
304 Pleasant	Too many to count
786 Walnut	Every time it rains

What types of problems have you had?	Never	Sometimes	Often
Erosion	[37]	[20]	[5]
Home or business flooded	[45]	[10]	[4]
Over flowing ditches/culverts	[22]	[23]	[26]
Standing water outside	[22]	[28]	[30]
Street or driveway access flooded	[32]	[24]	[21]

Other:

- 1480 N. 1700 Road – pasture flooded/electric fences out of service
- 1567 Hwy 40 – Farm fields due to inadequate landscaping and car accidents in Hwy 24/40 due to flooding
- 1662 N. 1700 Road – Water runs across road into our field
- 1735 E. 1500 Road – Front ditch plugged
- 411 Elm Street – Alley always floods
- 625 Lake Street – Up the street the water stands
- 628 Locust – Curb water does not flow off, drainage easement not graded properly
- 800 Walnut – Water does not pass through culvert under drive
- 818 Locust – Storm runoff from several nearby properties, mainly from the east of our property
- 827 Maple – some ditches do not drain
- Ditches and culvert need to be cleaned
- Fields with standing water
- I have noticed the (train) underpass flooded on 2nd Street
- Mainly standing water in culverts
- Mosquitoes
- Mosquitoes due to standing water (health hazard)
- Mosquitoes heavy/standing water
- No curbs on streets
- Problem corrected with cleaning ditches and culverts
- Water backing up in basement
- Water crosses road and erodes ditches that we mow; I’ve seen 6” – 8” of water pooled at Roanoke and 7th Street.

What do you see as major storm water problems in your area? (Check all that apply)

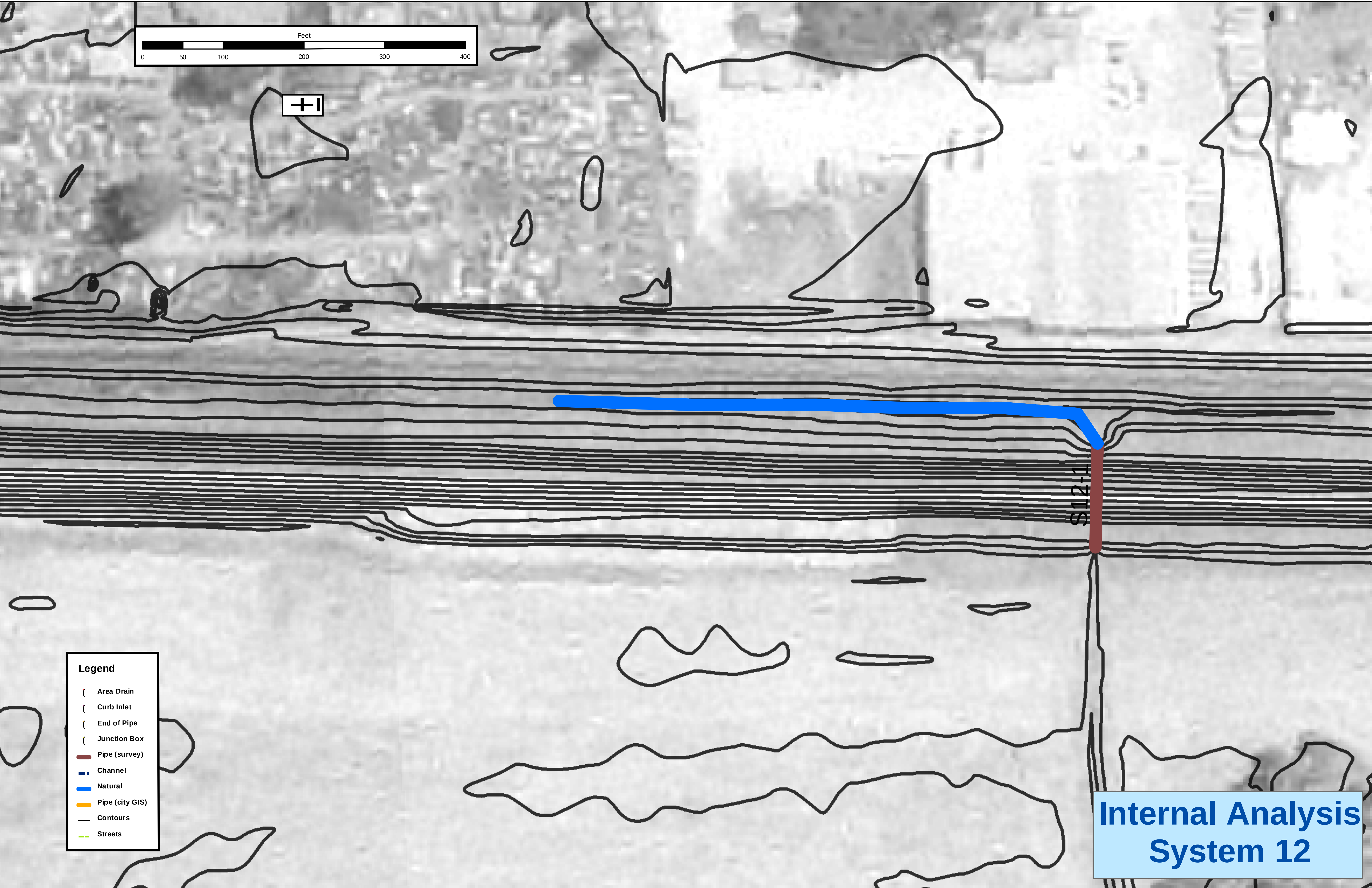
[61] Poor drainage
[37] Excessive run-off from streets
[35] Loss of property values

[31] Flooding
[13] Trash removal/odors
[12] Loss of property through erosion
[8] Poor water quality
[7] Loss of natural habitat
[4] Unsafe stream/stream bank conditions
Other:

- 1662 N. 1700 Road – Road contour to keep water from running into our field
- 1804 E. 1600 Road – Runoff from airport
- 800 Walnut – Redo the ditch created in my yard, which was not done properly anyway; also do something about the property across the street
- Drainage driveway tubes block or no tube at all
- Hazard of flooding at 1732 & 1500 E. Road
- Inadequate ditches along major highway 24-40
- Install curb and gutter on some streets
- Lack of curb and gutters
- Loss of use of pasture
- Main concern is river flooding and levy breaks
- Mosquitoes!
- Mosquitoes from improper drainage in easement
- Need storm drain
- No drainage
- No stormwater system
- No well planned stormwater control at all – we are fortunate at least to have sandy soil to absorb the water
- Poor alley upkeep holds water all the time when it rains
- Standing water
- Uncared for property

What types of stormwater management tools do you think would best correct the problem? (Check all that apply)
[48] Stormwater inlet and pipe systems
[45] Limit new construction that does not absorb stormwater (impervious surfaces)
[30] Enhanced natural waterways
[23] Pump stations
[18] Open channel drainage systems
[15] Stormwater retention lakes/lagoons
Other

- All runoff from impervious surfaces should be retained onsite
- Appropriate ditches along highway 24-40
- Better code enforcement by city, proper grading of drainage easement
- Cisterns to reuse roof run off for grey water – i.e., lawns & toilets. Water is too precious to waste!
- Curbs on streets
- Curbs, gutters, storm drains, wider streets


Feet
0
50
100
200
300
400
S12-1
Legend
Area Drain
Curb Inlet
End of Pipe
Junction Box
Pipe (survey)
Channel
Natural
Pipe (city GIS)
Contours
Streets
Internal Analysis
System 12

- Drop us from the floodplain
- Find out why ditch west of 1500 east will not carry water when we have heavy rains; east ditch is fine
- Keep equipment from collapsing storm ditches and culverts
- Keep things maintained on a regular basis
- Make sure drainage ditches are in the proper areas and maintained
- Maybe if the city took care of the ditches – cleaning/fixing/maintaining etc.; sometimes you clear your ditch but the neighbor does not and the water stays
- No stormwater retention lakes/lagoons – too many mosquitoes already
- Pump stations – expensive to maintain – tax increase
- Put in curbs and gutters
- Stormwater detention that is underground
- Study low points and promote natural drainage into storm drains

Development patterns can impact how stormwater is best managed. How do you think North Lawrence should develop? (Check all that apply)

- Cease development and new construction
- Limit on amount of impervious surfaces as percent of pervious; enforce pervious fill regulations – a 30 degree clay slope is not pervious in a practical sense; require use of permeable paving such as gravel and open pavers; offer rebates to homeowners installing such paving, whether new or replacement; also to install cistern systems
- North Lawrence has enough homes – they need to quit building, but I guess this will never happen

Homes

[51] Large (1/4-acre+) home lots
[37] Suburban-style single-family
[6] Apartments and/or town homes
Other:

- Large lots to keep areas for gardening - this is the best soil for raising food and flowers
- Limit development
- None
- None
- Residential single family homes
- Restrict residential development
- Very large ½ acre-plus home lots

Business

[35] Light industrial
[32] Office
[30] Agricultural
[6] Heavy industrial
Other

- Light industrial north of turnpike
- None

- None
- Small business

Retail/Restaurant

[47] Stand-alone storefronts
[18] Grocery Store
[12] Strip malls
[7] Enclosed malls

Other

- More grocery and variety stores
- No bars
- NO MORE – current impervious areas are WAY under-utilized.
- No retail
- None
- None of these; this mess that Clay Heine has is bound to effect stormwater drainage - I cannot imagine the county allowing this to be built when we already have drainage problems
- None or vertical – maintain footprint
- Pharmacy, hardware store, banking facility, laundry
- Sit-down family restaurant besides Chinese & Mexican – suggestion – buffet restaurant
- Strip malls – limit two
- Use Tanger Mall I-70 Business Center or tear it down!; put in a grocery store; we'll take a Wal-Mart Supercenter
- We have empty stores and malls - let's use them!

Additional comments or suggestions:

Site-Specific Concerns

- 1480 N. 1700 Road – My farm lies at the first low spot north of the pump station on Maple Grove Tributary, the confluence of the MGTJ with the ditch that drains Clark's pond. When pump malfunctions or is overwhelmed by runoff from up in the hills or airport area, my pasture ends up being used against my will as a detention pond for other people's stormwater. This is unacceptable. Make them detain their own storm water. Mandate 0% runoff from any new construction anywhere in the county!
- 1502 N. 1732 Rd. - Please come by and visit with me. We have been living here since 1958 (46 years). I've personally done a lot of work to improve drainage on my property … grading, fill dirt, waterways, etc. The biggest single problem is drainage on Roanoke (1732 Rd) and west ditch along 1500 East road. The east ditch will carry most every situation. The west one overflows over the road when we have a fast heavy rain. Something is wrong.
- 1728 E. 1500 Road - Dale Black had a pond of some type dug on his property for fill dirt to raise the height of a modular home installed across from my property. Since that time there has been a severe water problem coming across N. 7th (E 1500 Road) and into my front ditch from his property. This has caused erosion in my ditch and driveway. I also think their driveway culverts are too small to

handle the water flow. I do know I have lived at my property for 40 years and never had this problem until the modular home was installed. Twice water overflowed my front ditch and came halfway across my front yard – all from the excessive run-off from across the road at Black's property.

- 403 Lincoln - Storms and or minor rains sits in the ditch on two sides of my property. Terrible mosquito breeding area and dangerous when it runs across Lincoln repeatedly. Thanks for the questionnaire, I appreciate the concern.
- 440 Lyon - As we live on a corner lot, we get a lot of drainage from 2 street ways – in return, the city digs our drainage ditches deeper – thus eroding our lawn. We would like to see pipes and tubes along these streets to preserve our lawn and property values. As well as mosquitoes downsized due to standing water.
- 501 Perry - We have a ditch on 2 sides of our property and the neighbors to the east do not even have a drainage tube or ditch, so between runoff and that, we have quite a bit of water standing for a while after a rain.
- 520 Lyon - I built my home in 1995. Value would be far greater if I had storm water collection instead of ditch; water always standing in my driveway – so bad that I am having concrete replaced in 2 weeks. I'm paying the same taxes as anyone else in our city/community; why not give me the same service. When I built in 1995 my home was out of the floodplain – since November 2001, I now am paying flood insurance – fix the problem – stormwater runoff!
- 5th & Perry - The older houses in our area seem to suffer the worst – even moderate rains flood the yard at NW 5th and Perry. Heavy rains flood the intersection.
- 600-700 block Lincoln floods – always standing water
- 625 N 7th - Stormwater stands in ditch in front of my house because the tube under my driveway is higher than the bottom of my ditch. The sides of my ditch are too steep to mow. I wish there wasn't a ditch in front of my house. I would prefer to have storm sewers instead.
- 628 Locust – Neighbors and I have had problems with a drainage easement. It is not graded properly. City has been no help. Also, the curb at the end of my driveway is deeper than the adjoining ones causing improper drainage. Mosquitoes are a big problem. 6th & Lyons – stagnant water standing a lot of the time.
- 700 block of N. 7th does not drain.
- 760 N. 5th - David Krouse has been notified two times about our standing water problem.
- 761 Grant - The lot behind my property is owned by a church. They rarely mow it - hardly ever mow the ditches between property. Those weeds get to be 10 feet high. The east ditch does not drain. It holds a good amount of water (mosquito lagoon). This has been a concern for several years. All I can suggest is that the ditch be redone and filled with a drainable base so weeds won't grow so bad, and maybe some other things. Please look at it.
- 786 Walnut - When electricity is off, lift station shuts off and water backs up into our basement. Need alternative energy source to keep pump station working. Also persistent bad odor in outside air due to lift station. Need to burn off excessive sewer gases to prevent smell in area.

- 8th & Lyon – See attached picture. We have concerns about the properties on 8th & Lyon. We have problems with the ditch shown on the picture as well as with the lines and grades of an undeveloped lot on the other side of the street. I'm a Kansas licensed geotechnical engineer. You may contact me at (913) 458-3955 for additional questions or comments.
- 800 Walnut – Rainwater did not stand on my property prior to improvements made a few years ago. The culvert pipe under my driveway was dug up, then put back in place. Unfortunately, it was not done carefully and water doesn't flow through it well as it is too high now. Also the ditch created by the city has a depression right by the entry to the east of the pipe that allows water to pool. When they dug up my front yard to make the ditch (which really was not needed on my side of the street) it was done by eye. No on used any plum line or other visual aid to see if water would flow toward the inlet pipe; they just eyeballed it. The resulting ditch has walls that are uneven and very difficult to mow. They did not plant grass on my property, although they did re-seed and cover my neighbor's property to the north, across the street. Finally there was a second culvert/driveway to the east of my driveway. It belonged to my neighbor according to him, but technically about 1.5 feet of it was on my property. He talked the workers into moving it a few yards to the east. Water does not flow well between these two culverts now, and standing water develops during/after steady rain. There needs to be a better drainage system across the street. My yard needs to be either re-done so it is both mowable (easily) and drains well, or redone so that water flows toward the inlet better. The area east of my drive needs to be redone (with small depression filled) and perhaps the culvert pipe replaced or moved (although filling in the depression should do). Over the years, I have tried to dig here and there to promote flow. This is a small problem, but since I had no problem before it is important to me. Also I contacted the city about this years ago; to no avail.
- 9th and Locust; fix culverts and clean ditches; anything would help.

Capital Improvements/Maintenance

- First impressions for those traveling into Lawrence are not very good since they must drive on poor main roads in North Lawrence and poorly kept used car lots. It is a shame that the "squeaky wheel gets the grease" and a high percentage of the community money goes west of Iowa. I am pleased to see this survey and hope the study is not just a political ploy to calm emotions.
- I suggest paving the streets, eliminating the deep ditches, install storm sewers, clean frequently, Wow! North Lawrence!
- I would like to have ditches replaced with stormwater drain system so ditches would be gone and have ground level and put sidewalks along streets at least on 1 side. A lot of people like to walk dogs and exercise and street (7th) is very narrow and dangerous. Thanks for your help!
- I would love to see the ditches removed and replaced with drainage systems. Most ditches in North Lawrence retain water after it rains and do not drain properly if they drain at all. The ditches are very difficult to maintain and the new ditches at the new elevated properties seem to be impossible to mow.

- My property is elevated high enough that I don't have a problem with it. However, the property to the rear with a field floods more and more now that many inbound lots are built on. North Lawrence needs a storm drain system badly. Insects are very bad due to standing water. The wrecker businesses on Maple have made it worse yet due to dead cars and semi-paved areas.
- Need curbs
- North Lawrence has been neglected long enough. We need many improvements. Water drainage would be a good place to start, then street improvement. Next, property improvement and an invitation to businesses.
- North Lawrence maintenance seems to always lag behind compared to other parts of the city. The concern and dedication to keep up by those responsible just doesn't seem to be there (maintenance department, etc.) Perhaps consistent and regular attention and evaluation could help solve some of the problems.
- Stop bringing clay for fill. Our ditches don't need to be dug out any deeper. The ones that have been dug out deeper are not getting mowed.
- The alleys in North Lawrence are poorly maintained – when they finally do a storm will come and they are right back to the same condition as before – full of holes and full of water
- We would like to see more curb and gutters instead of ditches. The height requirements for new lots seem too high, especially when a new lot is built up next to an established residence. Great improvements have been made since 1993.
- Would like for sewer lines and stormwater lines to be separated.

Development & Planning

- City of Lawrence needs to address allowances for permeable paving in development guidelines. City should <u>not</u> ever allow new development that forces existing homes to buy flood insurance (i.e., development around 7th and Lake – they are <u>taking</u> property value from long time residents and it is criminal).
- City requires businesses to retain their runoff. I think the city should retain the runoff from the airport.
- Elevated buildings should be removed and returned to the condition they were in previously. Building those homes up like that was a slap in the face of North Lawrence residents. The water shed from those properties must be absorbed by the rest of us.
- Grade new construction so water does not pool on existing undeveloped property on floodplain. New pump station has improved water management. Cudos!
- I think all deep ditches where new homes are built should have enclosed drainage under driveways connecting – example 700 block of Lake Street, south side.
- Large lots for housing – to keep this excellent soil for gardens. Large developments need excellent engineering so large impermeable surfaces do not overwhelm storm drainage systems. Natural drainage areas – grassy – contoured for mowing work well most of the time because our soils allow water to move through them quickly.
- Let North Lawrence develop like we do other areas. Address the drainage issues and take into account the airport, I-70, 24 hwy, 59 Hwy – let's be smart, do things

in a way that showcase our city and make it stand out compared to other I-70 cities.

- Mr. Chaney is allowed to build shoddy houses on landfilled lots that erode into ditches and cause foundation and drainage problems, not to mention yards full of weeds because the ditches are so steep they cannot be tended. This type of careless building also leads to standing water and out of control problems associated with stagnant water.
- My property is located in the highest part of NL so I have had no water problems. Most of the problems are on the north side of the tracks (the lowest part in NL). New home development has really grown (especially in the lower part) on every vacant lot available – elevating these buildings has only increased the runoff on older existing homes.
- North Lawrence is in a floodplain. No amount of conferencing can change that. It is no exaggeration to say that it is also some of the richest land in the world. Common sense should dictate that it be dedicated to green space/farming. The latter should focus on appropriate tech/organics due to proximity of residential; a diversified product with eager local and regional markets.
- Our incredibly rich, well draining native soil is some of the best agricultural soil in the world. We should treasure it for its best use – food for people – and not pave or build on it.
- People like to live in North Lawrence because it is convenient to the downtown area for work or shopping.
- Preserve green space to allow absorption of runoff. Larger lots, less concrete (drives, patios, etc). Better management of ditches. Ours is so uneven in the bottom, water is always in it making it hard to keep weeds cut. When ditches are cleaned out, adjacent property owners should be allowed to have some of the soil back on their property.
- Storm water poses a major impediment to redevelopment of North Lawrence. Most North Lawrence sandrats want a grocery store in North Lawrence, yet grocery stores won’t consider North Lawrence because there aren’t enough roof tops to justify. Yet North Lawrence sandrats (many) want no more development. You can’t have it both ways.
- Take a drive around North Lawrence after a heavy rain and you’ll see the problems. Save money and get the job done. No more surveys.
- The mosquitoes are terrible due to the standing water in the ditches of the 700 block of Lake Street because of the new houses built. This is a health risk.
- The street side open ditch drainage system for the 700 block of Elm Street appears to work fine, so long as the ditches are kept clear of leaves, grass and other debris, except in times of exceptionally extensive rainfall. Some minor problems arise when some of those responsible for maintaining their portion of the ditch and driveway pipes fail to do so. The only potential for improvement would appear to be an underground storm sewer system with additional gradient, which is apparently not practical without an extensive and expensive pumping system to elevate the outflow above the applicable river level. A proposal for the funding for installation of such a system would very likely meet with strong opposition. I think that any kind of additional development which does not engender

- The town homes would be great for retired or single females, males who really can't tackle lawn work or repairs.

Miscellaneous

- I have not had any problems with stormwater so I would not like to see any policies or procedures that would cost me in either taxes or fees, or loss of property value through increased regulation.
- I would like my property at 2nd and Locust re-zoned so I can build a salon there.
- My home hasn't flooded since the 1951 flood.
- Present builders keep their property mowed and cleaned (example 4th & Lyons). Rental properties should be taken care of and alleys should be taken care of also.
- Smell from water treatment plant!
- When will I get rural water?

C. Public Drop-in Center:

On June 30, 2004, a public drop-in center was organized to collect completed questionnaires and discuss input/concerns directly with residents and businesses in the area. In addition to returning questionnaires, meeting participants provided the study team with additional information on specific concerns, including digital photography of problem areas. Thirty-three members of the public visited the drop-in center, which was open from 11 a.m. to 6 p.m. at the Union Pacific Depot at 2nd and Locust in Lawrence, Kansas.

The meeting was publicized through the mailed survey and through a press release to local media. There was also a notice on the North Lawrence Improvement Area Website.

Exhibits included information on various stormwater management tools, an overview of plans and development for North Lawrence, and a large aerial photograph of the area. Over the course of the afternoon, *in addition to the information provided in the surveys*, the public provided the following information, concerns and questions to the study team.

- 616 Locust – City check on weather shed is within utility easement.
- 628 Locust – Problem with water ponding on south road ditch (neighbor at 624 has had water problems). Development problem? City has assisted developer to fix ditch; stopped issuing permits, but no positive improvement has resulted. Concerned with mosquitoes and health. Also, water ponds along C & G where it has to evaporate. No water has impacted house.
- 904 N 7th – Standing water in backyard; also, poor drainage in front yard. Ditch is very shallow. Ends of pipe are crushed - would like it repaired. Sump in backyard does not drain; concerns with mosquitoes. Ponds a couple of days after

rains. Also concerned with house to the north, which is unoccupied and rarely maintained.

- 5th & Levee – Pipe drains under levee, but roadway ditch (with minimal area) is generally dry (not really a problem)
- Likes idea of ponds with pipes and pumps at central locations, such as adjacent to Lyons Park, Lincoln, Third, Pleasant from 5th to 7th. Developer filled property south of park with red clay but has not built on it - "solved" local ponding problem. Also concerned with very narrow width of Lake Street west of 8th Street.
- Oak between 8th & 9th: Drainage problem has been fixed with removal of old structure
- Planned clean-out of ditch and culverts on Walnut
- 300 block of Funston already cleaned – money acquired by NLIA; maintenance of culverts, ditches and pipes are an ongoing concern, including culverts at 2nd Street intersection, which are filled with sand and not maintained
- 701 Maple – City-built pipe under 7th & a driveway - water in warehouse twice recently
- 513 Lincoln – 8 year resident, no serious flooding issues. Noted that 2nd Street railroad underpass is vulnerable to clogging.
- 818 Locust – culverts along locust, ponds on property
- 308 N. 8th – 1993 sink hole at 2nd and Locust.
- 422 Locust, next to Tropicana. Locust floods; basement floods although not much in past couple of years since the Tropicana parking lot was built. Low place in yard collects Locust run-off after heavy rainfall and ponds – stays flooded for one day or so.
- 7th & Lyon is deepest street ponding problem area; ponding also at 6th & Lyon.
- 3rd & Perry – NW corner – water in basement through rock wall. Started after city sanitary sewer work that penetrated clay layers.
- 3rd & Lyon – sewage back-ups with heavy rains.
- 820 Oak – Recent Monday evening rain, standing water on most streets, including bridge.
- Did not like survey or meeting time; pit problems adds to street

D. Lawrence Planning Commission Update:

Members of the project team provided an overview of study activities and public input to the Lawrence Planning Commission on October 13, 2004. That overview included information about the study goals, process and timeline, as well as a review of survey results.

Section III

Ultimate Land Use for Watershed

III. Ultimate Land Use for Watershed

To accomplish the goals of the North Lawrence Drainage Study, the ultimate land use condition had to be determined for the study area. The future land uses within the watershed will help determine where to focus the stormwater system improvements and provide better insight into heading off potential problems with development. The project team conferred with the Public Works Department, the Planning Office, and the Utilities Department of Lawrence. Information was gathered with regard to current zoning, potential developments, and long-range plans.

A. Key Land Use Assumptions

The study team was tasked with developing possible future land uses for the North Lawrence study area at full build-out. There are numerous definitions for what true build-out of an area entails. For the purposes of this study, the definition of build-out was the probable, ultimate development within the study area that can be reasonably accommodated within existing environmental constraints and likely urban service area expansions, including roads, utilities (sewer and water) and City services. It is not assumed that the entire study area will ultimately urbanize. There are areas that are likely to remain "rural" or in agricultural use. These areas are noted as "Agricultural" on the Build-Out Scenario Map at the end of this section.

A second key assumption deals with the purpose of the ultimate future land use map. The study utilized Horizon 2020 as a resource for the creation of the Build-Out Scenario Map. However, it should be noted that Horizon 2020 is the guiding policy document which defines a land use vision for the next twenty years. This drainage study was tasked with developing a plan for ultimate build-out which will reflect possible land uses beyond a twenty year horizon. For this reason, possible future land uses were identified outside of the Horizon 2020 Plan area to reflect ultimate growth within the study area. As a rule, Horizon 2020 land use delineations and definitions were used in the final scenario map. The Build-Out Scenario Map was developed for the drainage study for the purpose of determining the impact of an ultimate development scenario. It is not a policy document and may not reflect best planning practices. The Lawrence City Commission and Planning Commissions may change priorities over time, impacting future land use. Therefore, delineations shown on the Build-Out Scenario Map were based on a combination of existing land use policies and recent development trends.

B. City Input

Understanding the importance of input and concurrence from City staff and stakeholders, the Build-Out Scenario Map was reviewed by various City departments prior to using the information in watershed modeling. The following is a list of responses to comments received on January 31, 2005 concerning the drainage study's future land use map. The project team made appropriate modifications to the map based upon the review comments. The bulleted list provides the City's questions/comments (Q/C) followed by the drainage study team's answer/modifications and/or clarifications (A):

Q/C: *Have you asked Parks and Recreation for any long-term plans? The open space would need to reflect corridors, paths, etc. They will not want to inherit random tracts to maintain.*

A: The Parks and Recreation Department was contacted to inquire about a long-term plan for parks, open space, and trails. Parks and Recreation are currently in the process of developing a plan and standards for developing areas. However, to date, no plans have been delineated for the project study area beyond Horizon 2020. The Build-Out Scenario Map was amended to show floodplain and open space areas as well as riparian corridors for possible green space connections. As previously mentioned, the goal of this effort is not to develop a policy map. Rather, the intention is to delineate how the study area will likely develop at build-out.

Q/C: *A lot of the low density areas are very low-lying. Should we have another symbol for low density that would require several (6+) feet of fill relative to current FEMA? These could be argued as permanent agricultural.*

A: The Build-Out Scenario Map was changed to reflect the 100-year floodplain areas for the study area. Best practices advocate that these areas be delineated as permanent agricultural or at least Very Low Density Residential. However, there are few tools available to FEMA, the City and Counties to actively enforce such policies. Developers may fill floodplain areas or raise structures above base flood elevations per FEMA standards. The floodplain and low lying areas on the Build-Out Scenario Map were amended to either Parks & Open Space or Agricultural.

Q/C: *How closely was Horizon 2020 followed? It seems that prevailing development activity is moving to commercial/industrial along the highways.*

A: As mentioned previously, we amended the Build-Out Scenario Map to reflect the Horizon 2020 as closely as possible. For the purposes of this study, some land use delineations were combined (there are several categories of industrial and office) to simplify designations. Additionally, some of the low-lying areas were designated Agricultural. It is assumed that an average density within these areas is 1 Dwelling Unit per 5-Acres. The balance of the designations on the Build-Out Scenario Map is consistent with Horizon 2020.

The industrial and commercial trends are expanding along the highways. Best practices advocate a clustering of these uses at designated nodes with access to infrastructure and compatible uses. This policy is reflected in Horizon 2020. The study team amended the Build-Out Scenario Map to show commercial areas along the Highways and intersections of major roads. Industrial developments are shown near the Lawrence Municipal Airport.

Q/C: *The KU Endowment Association owns substantial parcels.*

A: The KU Endowment Association was contacted during the study. The Association does own a substantial amount of property around the airport (approximately 220-acres). Currently, much of this property is farmed.

However, the Association anticipates that the property will eventually develop. There have been discussions to develop the remaining property adjacent to the airport into commercial and/or industrial uses.

Q/C: *Contiguous green space would be desirable for linkages and connectivity*.

A: As mentioned previously, we amended the Build-Out Scenario Map to show riparian corridors. Parks and Recreation is in the process of developing a plan and standards for future development areas.

Q/C: *The Low Density assumption of 3 dwelling units per acre (du/acre) varies from Horizon 2020 which defines low density as 6 du/acre or less.*

A: Future suburban areas are unlikely to develop at the same density as areas within the established core. The task within this drainage study requires developing densities for areas outside of Horizon 2020. Prevailing trends show that a majority of development in suburban areas consist primarily of single-family detached homes with approximate densities of 3 units per acre. To reflect these trends, the designation "Suburban Residential" is provided on the Build-Out Scenario Map for areas outside of Horizon 2020.

Q/C: *Need to note that Very Low Density is defined in Horizon 2020 as 1 du/acre or less.*

A: This is reflected in the latest Build-Out Scenario Map.

Q/C: *Need to identify areas for continued Ag uses: either along Hwy 24/40; east of E1600 Rd; southeast part of study area. Ag uses could be combined with the Very Low Density residential uses.*

A: As mentioned previously, the Build-Out Scenario Map was updated to show the designation of Agricultural. The study team agrees that some areas are likely to remain in agricultural use while other areas may develop at very low densities. We assume that future development will follow Horizon 2020 policies that encourage residential clustering. A probable build-out assumption for these areas would be an average of 1 dwelling unit per 5-acres.

Q/C: *The Very Low Density residential land use at the east end of the railroad tracks seems odd. This area might work better as an active parks area. The area along E 1600 Rd south of Hwy 24 might also be good area for active parks use or Ag uses.*

A: The Build-Out Scenario Map was amended to show this area as Agricultural.

Q/C: *Might be helpful to show planned bike route (N 7th [E 1500 Rd north to County line] to N 2000 Rd to E 1600 Rd to N 1650 Rd).*

A: The intended purpose of the Build-Out Scenario Map is developing probable land uses at build-out for the drainage model. Bike routes and other information that is usually depicted on land use plans and development guides have not been included.

Q/C: *Horizon 2020 anticipates a new neighborhood commercial node at N 7th & Hwy 24/40. It looks really large on map (may be the scale issue).*

A: Part of this was a scale issue. However, the commercial node on the Build-Out Scenario Map was modified to show a modest expansion of this area reflecting growth beyond the time horizon depicted in Horizon 2020.

Q/C: *Horizon 2020 does not show any type of commercial node east of City at N 1600 Road.*

A: Again, the purpose of the Build-Out Scenario Map is to anticipate development beyond Horizon 2020. For the purposes of this exercise, it was prudent to show realistic expansions of commercial. However, further review led to the final version of the map showing this particular area as agricultural.

Q/C: *Map extends into Leavenworth County. Need to accurately show Douglas County line on east side.*

A: The County lines are depicted on the latest version of the Build-Out Scenario Map.

Q/C: *We would like to see less industrial uses along Locust Street from 2nd to 8th Streets, along Maple Street from 2nd to 8th Streets and along Grant Street from 7th to 9th Streets.*

A: The Build-Out Scenario Map is not a policy document; it is for study purposes only. The industrial land use designations pointed out in the comment from the North Lawrence Improvement Association are within the Lawrence City Limits and are shown as industrial in Horizon 2020. The requested changes should occur only through a plan amendment of Horizon 2020.

Q/C: *What is developable open space and how would it be used?*

A: Currently, the developable open space has been removed from the Build-Out Scenario Map. This is a topic that needs to be discussed with the City because, as stated earlier, HNTB amended the Build-Out Scenario Map to reflect the 100-year floodplain areas for the Study Area. Best practices advocate that these areas be delineated as permanent agricultural or at least Very Low Density Residential. However, there are few tools available to FEMA, the City and Counties to actively enforce such policies. Developers may fill floodplain areas or raise structures above base flood elevations per FEMA standards. HNTB amended the floodplain and low lying areas on the Build-Out Scenario Map as either open space or Agricultural.

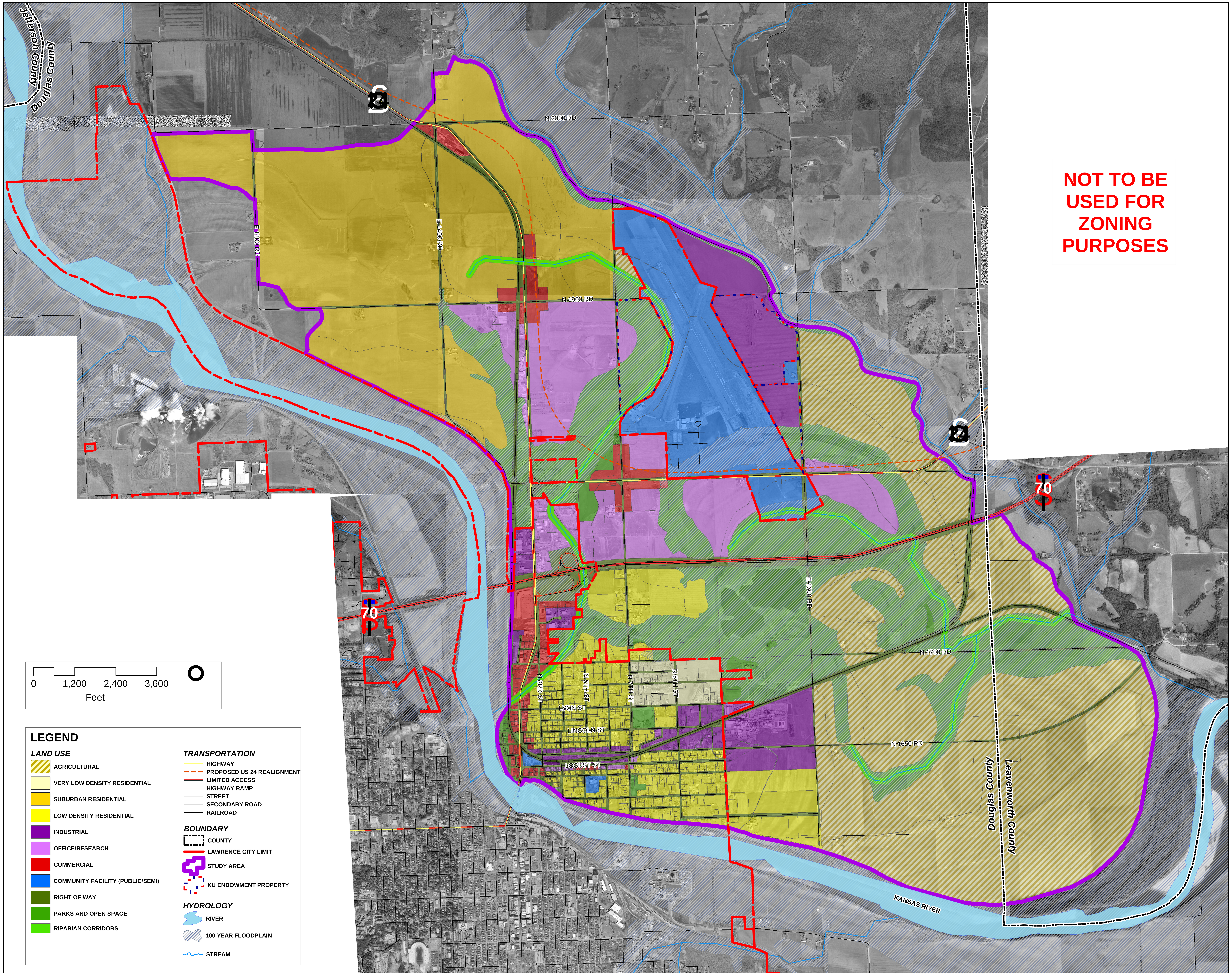
C. Mapping Results

The final scenario map used in the hydrologic analysis of the study contained the land use categories shown in the table. Several defined uses for residential were used to demonstrate the likely variance in potential development.

Land Use Categories

Land Use	Density
Agricultural	1 unit / 5 acres
Very Low Density Residential	1 unit /1 acre
Suburban Residential	3 units / 1 acre
Low Density Residential	6 units / 1 acre
Industrial	-
Office / Research	-
Commercial	-
Community Facility	-
Right-of-way	-
Parks and Open Space	-
Riparian Corridors	-

The next page is the final Build-Out Scenario Map produced for the North Lawrence Drainage Study.



North Lawrence Drainage Study
Build-Out Scenario Map

March, 2005

HNTB

Section IV

Data Collection

IV. Data Collection

A. Field Investigation

Several field visits were made to observe drainage patterns, take photographs, and verify structure sizes and orientations. A few photos of significant features are shown below.

Ponding downstream of 1400/1900 intersection, south of Midland

3-108” CMP under RR tracks, west of 24/40 intersection


Tributary B, near the mouth


Lake adjacent to RR and 24 Highway, NW of Midland

B. Surveys

The entire drainage system in the North Lawrence watershed study was surveyed by Landplan Engineering, P.A. System characteristics determined in the field included the following:

Culverts and Bridges

- Location
- Structure type
- Size
- General condition

- Flow line elevations
- Overtopping Elevations

Inlets
- Location
- Grate/curb dimensions
- Construction material
- General condition
- Invert information
- Flow direction
- Size of incoming and outgoing pipes
- Depth and elevation of incoming and outgoing pipes

Manholes
- Location
- Rim/cover/barrel elevation
- Wall material
- Invert type and condition
- Depth (rim to flow line) and pipe diameter

Open Channel Hydraulic Data
- Cross Sections

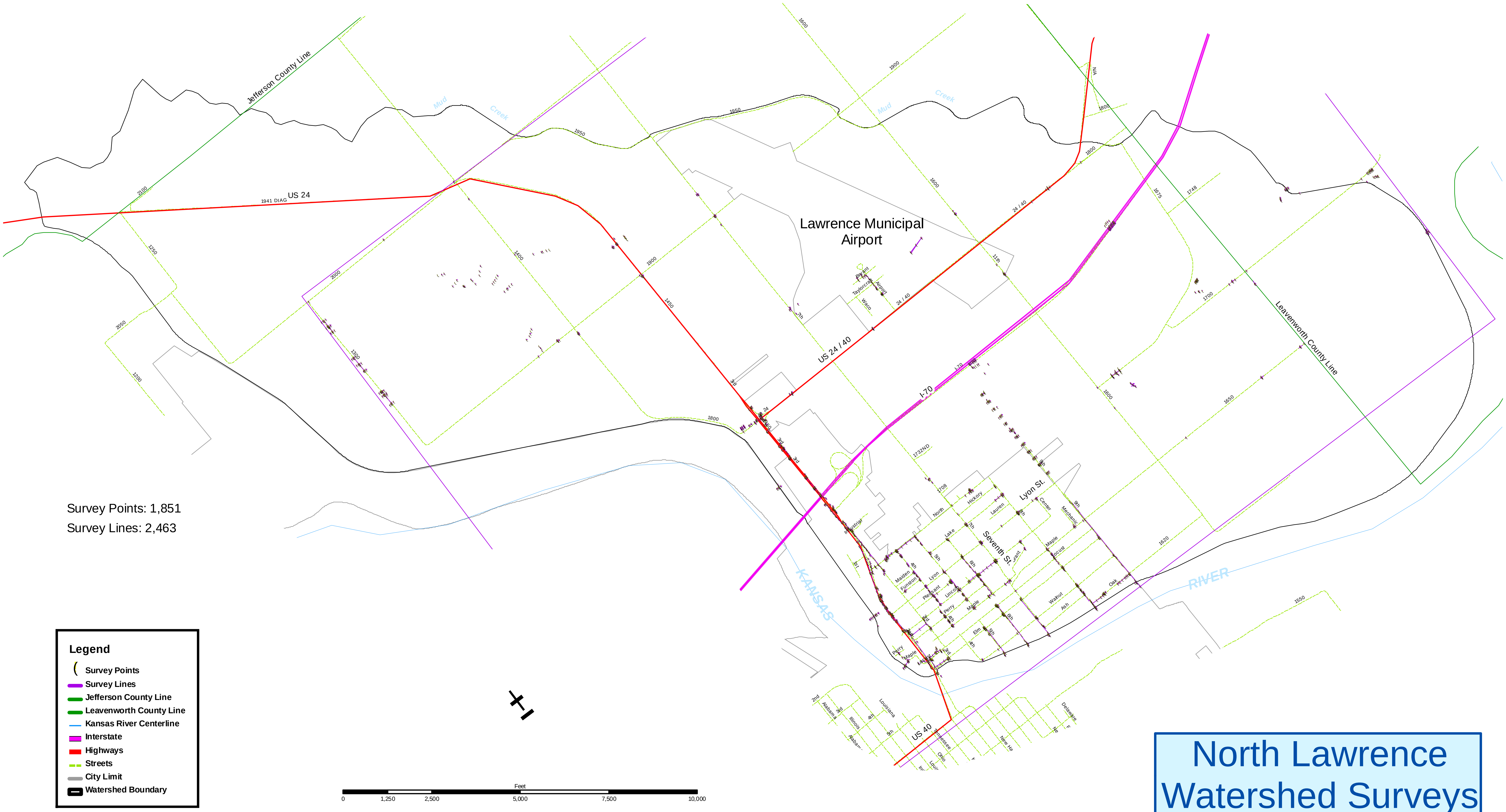
This information was used in the development of computer models. Information from the field survey forms was entered into the GIS database and mapping.

C. GIS Mapping

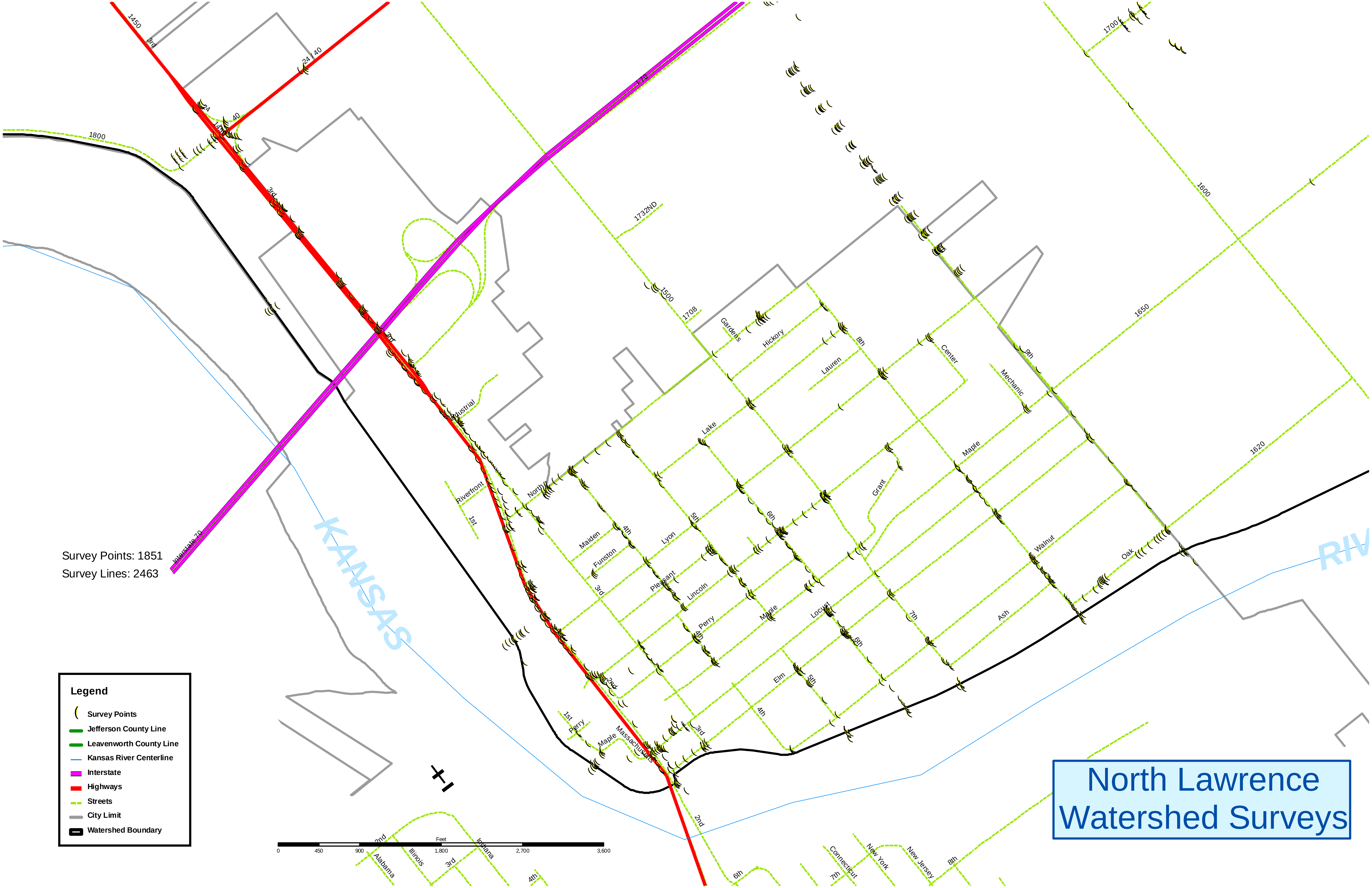
The basis for the evaluation of the North Lawrence watershed is the digital base maps developed by the City. These maps also show land features with a 2 foot contour interval. The base maps include topographical drainage information such as open channels, bridges, culverts, manholes, inlets and enclosed system drainage. They also include houses, transportation and above ground utility locations.

The City's surveyed as-builts were used to digitize the pipe location and an existing data base provided information on the pipe network. Field surveys were completed as part of this study to update and verify any existing information on size, location and slope of the conveyance structures. Survey data on the conveyance system and watershed characteristics were combined with the city database to create a comprehensive database with the most up-to-date information.

Two reports reviewed, "Internal Drainage Study, North Lawrence Flood Protection Unit" and "Lawrence, Kansas, Stormwater Management Master Plan," also provided insight into the drainage problems in the North Lawrence watershed.



Jefferson County Line
US 24
1941 DIAG
Mud
Creek
Lawrence Municipal
Airport
US 24 / 40
I-70
Leavenworth County Line
Lyon St.
Seventh St.
KANSAS
RIVER
US 40
Survey Points: 1,851
Survey Lines: 2,463
Legend
Survey Points
Survey Lines
Jefferson County Line
Leavenworth County Line
Kansas River Centerline
Interstate
Highways
Streets
City Limit
Watershed Boundary
Feet
0
1,250
2,500
5,000
7,500
10,000
North Lawrence
Watershed Surveys


North Lawrence
Watershed Surveys
Survey Points: 1851
Survey Lines: 2463
Legend
Survey Points
Jefferson County Line
Leavenworth County Line
Kansas River Centerline
Interstate
Highways
Streets
City Limit
Watershed Boundary
Feet
0
450
900
1,800
2,700
3,600
KANSAS
RIV
Interstate 70
1800
1450
3rd
24
40
1732ND
1500
1708
1700
1600
1650
1620
Gardens
Hickory
Lauren
8th
Center
Mechanic
9th
Industrial
Riverfront
1st
North
Maiden
Funston
4th
Lyon
Lake
5th
6th
Pleasant
Lincoln
Perry
Maple
Locust
Grant
Walnut
Oak
Ash
7th
Elm
2nd
Massachusetts
Alabama
Illinois
Indiana
Connecticut
New York
New Jersey

Section V

Internal Drainage System Analysis

Internal Analysis

V. Internal Drainage System Analysis

The system of City operated ditches, pipes, and pumps throughout North Lawrence are collectively referred to as the "internal drainage system". This system collects the drainage from about 1.8 square miles and largely conveys it through gravity and pressure pipe to the Kansas River (refer to the Internal Analysis map at the beginning of this section). The intent of the internal system analysis portion of the North Lawrence Drainage Study was to investigate necessary improvements to the existing infrastructure system for a 10-year frequency event assuming the land uses specified by the Build-Out Scenario Map. The performance of the Maple Street Pump Station (529 Maple Street) and the 2nd Street Pump Station (732 N. 2nd Street) were closely considered in the overall evaluation.

A. General Methodology

The drainage area contributing to stormwater system infrastructure within the City limits was divided into 64 sub-areas having an average size of about 17 acres. The smallest sub-area was about 0.5 acres, with the largest covering about 64 acres. The modeling of the internal drainage system was broken into 12 individual systems based upon natural topographic division and unique outlets. Seven systems currently drain through the levee by gravity means, two are pumped, and the remaining three drain to low-lying areas. A combination of survey data, City GIS data, and minimal interpolated data provided the database for the system of inlets, manholes, and pipes. Typical ditch sections were assumed from field investigation and survey notes.

The approach to determining appropriate improvements for the North Lawrence Drainage Study's internal drainage system began with several guiding principles:

- In areas not near a pump plant, increase pipe sizes and/or channel capacity
- At the Maple Street pump plant, investigate an increase in the plant capacity
- Investigate the adequacy of the 2nd Street pump plant, assuming no contributing flow from the watershed north of US 24
- Detention should be accomplished on existing topography – avoid excavation
- If ditch sizes are increased, avoid changing the slope
- Do not modify pipes extending through the levee

Taking these items into consideration, the 12 individual systems were analyzed. As each one was modeled, the determination was to be made if that system would remain separate or potentially contribute flow to another system. The 10-year event was run for each existing network of manholes, inlets, junction boxes, pipes, and channels to determine problem areas and provide recommendations for those areas.

B. Findings and Recommendations

Results of the hydrologic and hydraulic analyses for the set of 12 systems representing the existing stormwater infrastructure within North Lawrence identified many surcharge locations for the ultimate build-out condition. Recommendations for potential improvement followed the guiding principles outlined above as closely as possible.

For areas that drain by gravity flow to the river (no pump plant), various pipe and channel configuration upgrades were tested. The shallow cover on most of the pipes within the drainage network did not allow for keeping the same slope in the line.

Usually, to eliminate a ponding situation, most of the system had to be redesigned. In other words, increasing pipe and channel sizes in conjunction with changing grades was necessary. The structure draining through the levee, however, was able to remain in place with the recommended redesign of the upstream portion of the system in all of these situations.

The second case is where the system is essentially self-contained (flowing to a low-lying area) and the analysis shows that it has areas of surcharge or ponding. The total volume of ponding was compared to available ponding area at that location. If adequate volume was available, then no recommended changes were necessary. The recommendation only includes the cost of acquiring the parcel(s) of land that is used for ponding. If the volume available according to surveys and contour information was inadequate, then the flow might need to be re-routed at one or more locations. The three cases for North Lawrence had ample ponding area available to handle the volume of surcharge.

A final situation involves the systems which include the Maple Street pump station and 2nd Street pump station. Investigation of potential upgrades to the pump stations were included as part of the alternatives analysis process, along with alterations to conduits and channels. Significant upgrades to the pump stations in terms of pumping capacity were determined necessary for the ultimate build-out condition. While the original intent was to maintain the use of the existing discharge pipes from each pump plant, it turned out that those pipes were grossly inadequate and alternative recommendations had to be made.

Recommendations were determined for each conduit or channel in a system based on the analysis of the entire system. It should be noted that improvements are to generally be made in a downstream to upstream manner within the system, as there is no advantage trying to deliver more flow to a downstream component that cannot convey the existing flow. Overall costs for each system upgrade are summarized in the spreadsheets on the following pages. However, for the purposes of prioritizing public improvements on a smaller scale, excess peak flow was determined for each lateral draining to the main stem of the system. A comparison of the discharge through the existing lateral at the main stem location - that which does not surcharge and exit the lateral somewhere along its path - and the recommended configuration provided the excess flow values. The excess peak flows were also recorded for the most downstream pipe or channel on the main stem of each system. The most downstream conveyance link of a system is the only item included in prioritization for some systems because the drainage area of the entire system is relatively small (less than about 100 acres) and no laterals were modeled. A priority listing encompassing the 12 system study area is given in the table.

Prioritization of Systems

Link Name	Excess Peak Flow (cfs)	Total Estimated Cost of Improvements (dollars)
S1-1	315	$9,163,000
S6-1	168	$3,994,000
S9-1	133	$1,132,000
S1L1-1	96	$333,000
S1L5-1	85	$235,000
S1L7-1	85	$59,000
S1L3-1	56	$187,000
S6L3-1	56	$195,000
S6L3-7D	0	$181,000
S4-1	43	$60,000
S6L2-1	37	$5,000
S4L4-1	35	$53,000
S4L2-1	27	$36,000
S9L1-1	21	$7,000
S1L2-1	20	$240,000
S8-1	17	$115,000
S10L2-1	13	$4,000
S7-1	13	$38,000
S5-1	10	$56,000
S10-1	6	$106,000
S1L4-1	1	$7,000
S1L6-1	0	$0
S11-1	0	$0
S3-1	0	$0
S2-1	0	$0
S12-1	0	$0
Total	0	$16,206,000

The costs shown in the table provide a conceptual level estimate of capital costs to implement the recommendation for each lateral. Labor and construction costs are included, but items such as engineering design and maintenance of those structures are not. Unit prices for labor and construction were obtained from the 2005 RS Means Construction Cost Manual. Land/easement acquisition costs, obtained from the Douglas County online appraisal system (http://www.douglas-county.com/egovt/egovt.asp), were added to the appropriate systems as part of the total cost.

It is important to note that specific conditions of a site can significantly affect the cost to replace structures or implement other solutions. Extraordinary circumstances were not taken into account for the conceptual level costs determined by this study. Reasonable unit costs were determined and applied to recommended improvements across the entire study area. Also, the implementation costs for recommended improvements on the laterals do not reflect the main stem improvements that may be necessary in conjunction with the lateral improvements. In other words, whatever portion of the main stem is recommended for improvement downstream of the lateral should be implemented at the same time (or prior to) as the lateral improvements. The cost of the lateral improvement in the listing, however, is exclusive of that downstream cost.

The next several pages provide details of the recommendations for the individual systems included in the internal system analysis portion of the study. A description is followed by a map of the system identifying each conduit, channel, or pump plant that is recommended for improvement and its respective cost. The two numbers below the cost figure (shown as X/Y) represent a comparison between full-flow capacity of the existing conduit and the flow through the recommended conduit. Additional detail for pipe and grade changes, as well as pump plant upgrades, is shown on the spreadsheets for each system. Costs for each lateral are broken down as subtotals to the overall system cost.

1. System 1

System 1 has a pressure flow outlet pipe through the levee originating from the 2nd Street pump station. Each conduit and channel, as well as the pump plant, was analyzed with regard to capacity during a 10-year flow event. A method of upsizing pipe and changing grade from downstream to upstream was utilized to eliminate those that were over capacity. There are a total of 60 conduits in this system, of which 52 are exceeding capacity. Channels total 28, of which 26 are over capacity. The 2nd Street pump station receives 549 cfs in the ultimate build-out condition, assuming that the recommended flow cut-off at US-24 is in place. The Maple Grove cut-off is discussed in detail in Section VI of this report and should be considered with regard to the inundation area represented on the System 1 mapping. The current pumping capacity of the 2nd Street station is 107 cfs, which is 442 cfs deficient for the ultimate condition.

- SlL1 – The excess peak flow in S1L1-1, the pipe discharging to the main stem of System 1, is 96 cfs. Almost all of the points along the lateral were shown to be surcharging. Minimal cover and slope issues forced the entire lateral to be redesigned. A more consistent grade was set and sizes were changed on a segment-by-segment basis in order to eliminate surcharge points. The process continued until each component of the lateral could handle the flow without surcharge. Eight out of nine pipes have recommendations for size change, while all have slope changes.
- S1L2 – The excess peak flow in S1L2-1, the channel discharging to the main stem of System 1, is 20 cfs. A majority of the points along the lateral were shown to be surcharging. Minimal cover and slope issues forced most of the lateral to be redesigned. A more consistent grade was set and sizes were changed on a segment-by-segment basis in order to eliminate surcharge points. By improving one situation, problems often progressed to (or added to flooding problems at) adjacent pipes. The process continued until each component of the lateral could handle the flow without surcharge. All 20 pipes/channels have recommendations for size change; while 17 have slope change recommendations.

- S1L3 – The excess peak flow in S1L3-1, the channel discharging to the main stem of System 1, is 56 cfs. All of the points along the lateral were shown to be surcharging. Minimal cover and slope issues forced the entire lateral to be redesigned. A more consistent grade was set and sizes were changed on a segment-by-segment basis in order to eliminate surcharge points. The process continued until each component of the lateral could handle the flow without surcharge. All 10 pipes/channels have recommendations for size and grade changes.
- S1L4 – The excess peak flow in S1L4-1, the channel discharging to the main stem of System 1, is 0 cfs. No changes in size or slope are necessary for these pipes.
- S1L5 – The excess peak flow in S1L5-1, the channel discharging to the main stem of System 1, is 85 cfs. A majority of the points along the lateral were shown to be surcharging. Minimal cover and slope issues forced most of the lateral to be redesigned. A more consistent grade was set and sizes were changed on a segment-by-segment basis in order to eliminate surcharge points. By improving one situation, problems often progressed to (or added to flooding problems at) adjacent pipes. The process continued until each component of the lateral could handle the flow without surcharge. All 11 pipes/channels have recommendations for size and slope change.
- S1L6 – The excess peak flow in S1L6-1, the pipe discharging to the main stem of System 1, is 1 cfs. This is the only pipe in the lateral, and a change in grade is recommended. The size of the pipe was determined to be adequate for the ultimate build-out condition.
- S1L7 – The excess peak flow in S1L7-1, the channel discharging to the main stem of System 1, is 84 cfs. All of the points along the lateral were shown to be surcharging. Minimal cover and slope issues forced the entire lateral to be redesigned. A more consistent grade was set and sizes were changed on a segment-by-segment basis in order to eliminate surcharge points. By improving one situation, problems often progressed to (or added to flooding problems at) adjacent pipes. The process continued until each component of the lateral could handle the flow without surcharge. Five out of six pipes/channels have recommendations for size change, while all have slope changes.

SYSTEM 1

Conduits and Channels							
ID	Existing			Recommendation			Total Cost
	Size	Grade (%)	Q_{cap} (cfs)	Size	Grade (%)	Q_{10yr} (cfs)	
S1-1	24"	-0.54	17	5 - 60"	-0.54	549	$376,000
S1-2	30"	-0.50	16	5 - 60"	-0.50	549	$954,000
S1-3	36"	-0.49	25	5 - 60"	-0.49	549	$43,000
S1-4	5' flat bottom	0.12	7	20' flat bottom	0.12	328	$21,000
S1-5	60"	0.03	26	2 - 9'x5'	0.03	323	$83,000
S1-6	5' flat bottom	0.28	11	20' flat bottom	0.28	323	$1,000
S1-7	5' flat bottom	0.10	25	22' flat bottom	0.17	319	$9,000
S1-8	5' flat bottom	0.09	6	22' flat bottom	0.09	315	$1,000
S1-9	60"	0.02	19	2 - 8'x5'	0.02	315	$74,000
S1-10	5' flat bottom	0.06	5	22' flat bottom	0.06	315	$1,000
S1-11	5' flat bottom	0.01	2	22' flat bottom	0.01	315	$35,000
S1-12	60"	0.93	136	2 - 6'x5'	0.93	317	$9,000
S1-13	5' flat bottom	0.04	4	22' flat bottom	0.04	267	$69,000
S1-14	5' flat bottom	0.04	4	20' flat bottom	0.04	233	$21,000
S1-15	5' flat bottom	0.04	4	15' flat bottom	0.04	89	$48,000
S1-16	5' flat bottom	0.04	4	10' flat bottom	0.04	43	$11,000
S1-17	5' flat bottom	0.04	4	10' flat bottom	0.04	30	$15,000
S1-18	5'x5'	0.49	232	5'x5'	0.49	1	$0
S1-19	6' flat bottom	0.37	14	The diversion at US-24 will eliminate these components from the internal drainage system			$0
S1-20	6' flat bottom	0.38	14				$0
S1-21	4'x6'	0.67	254				$0
						Subtotal Cost =	**$1,771,000**
S1L1-1	30"	0.80	37	60"	0.50	142	$13,000
S1L1-2	30"	0.07	6	60"	0.47	142	$6,000
S1L1-3	30"	0.06	6	60"	0.50	142	$12,000
S1L1-4	36"	0.73	57	60"	0.50	142	$51,000
S1L1-5	36"	0.70	30	60"	0.50	143	$87,000
S1L1-6	36"	0.47	60	60"	0.50	85	$55,000
S1L1-7	36"	0.31	37	60"	0.50	83	$36,000
S1L1-8	36"	0.73	223	60"	0.50	80	$22,000
S1L1-9	30"	0.31	23	60"	0.50	76	$51,000
						Subtotal Cost =	**$333,000**
S1L2-1	4' flat bottom	0.49	13	10' flat bottom	0.31	36	$1,000
S1L2-2	30"	0.08	6	36"	0.21	37	$4,000
S1L2-3	30"	0.20	18	36"	0.26	37	$16,000
S1L2-4	30"	0.30	22	36"	0.34	37	$42,000
S1L2-5	30"	0.19	18	36"	0.24	37	$11,000
S1L2-6	30"	0.32	23	36"	0.37	38	$10,000
S1L2-7	30"	0.22	19	36"	0.53	38	$13,000
S1L2-8	24"	0.43	15	36"	0.43	38	$6,000
S1L2-9	24"	0.35	13	36"	0.36	38	$18,000
S1L2-10	24"	0.37	14	36"	0.42	38	$11,000
S1L2-11	24"	0.65	18	36"	0.65	30	$7,000
S1L2-12	24"	0.32	13	36"	0.42	30	$9,000

SYSTEM 1

Conduits and Channels

ID	Existing			Recommendation			Total Cost
	Size	Grade (%)	Q_{cap} (cfs)	Size	Grade (%)	Q_{10yr} (cfs)	
S1L2-13	18"	0.53	8	36"	0.53	30	$20,000
S1L2-14	18"	0.14	4	36"	0.00	30	$6,000
S1L2-15	15"	0.46	4	36"	0.57	7	$24,000
S1L2-16	15"	0.52	5	36"	0.48	6	$20,000
S1L2-17	15"	0.47	2	36"	0.53	6	$21,000
S1L2-18	3' ellipse	0.25	8	3' ellipse	0.25	6	$0
S1L2T1-1	24"	1.87	31	36"	0.25	14	$1,000
S1L2T1-2	24"	0.28	12	24"	0.28	15	$0
S1L2T2-1	15"	3.28	12	15"	---	---	---
						Subtotal Cost =	**$240,000**
S1L3-1	4' flat bottom	8.41	52	6' flat bottom	0.55	59	$1,000
S1L3-2	15"	2.11	5	36"	1.00	60	$10,000
S1L3-3	15"	0.15	1	36"	1.00	60	$10,000
S1L3-4	4' flat bottom	1.33	21	6' flat bottom	0.55	58	$8,000
S1L3-5	15"	3.75	7	36"	1.01	58	$4,000
S1L3-6	2.5' ellipse	1.53	16	36"	1.00	33	$7,000
S1L3-7	15"	0.45	2	36"	1.00	32	$58,000
S1L3-8	15"	0.54	3	36"	1.00	32	$55,000
S1L3-9	15"	0.67	5	30"	1.00	14	$26,000
S1L3T1-1	15"	4.54	7	36"	0.98	26	$8,000
						Subtotal Cost =	**$187,000**
S1L4-1	4' flat bottom	13.71	66	4' flat bottom	0.39	7	$1,000
S1L4-2	15"	3.58	7	15"	0.99	7	$1,000
S1L4-3	15"	1.55	4	15"	1.00	8	$5,000
						Subtotal Cost =	**$7,000**
S1L5-1	4' flat bottom	6.29	45	15' flat bottom	0.25	118	$1,000
S1L5-2	36"	1.49	81	2 - 8'x4'	1.01	121	$69,000
S1L5-3	4' flat bottom	1.15	19	15' flat bottom	0.30	121	$2,000
S1L5-4	30"	1.25	46	2 - 8'x4'	1.00	124	$78,000
S1L5-5	4' flat bottom	0.09	5	15' flat bottom	0.30	90	$27,000
S1L5-6	4' flat bottom	0.09	5	6' flat bottom	0.29	5	$5,000
S1L5-7	18"	1.57	7	24"	0.99	3	$3,000
S1L5T1-1	4' flat bottom	0.23	9	15' flat bottom	0.30	88	$9,000
S1L5T1-2	24"	0.84	21	30"	0.50	89	$37,000
S1L5T2-1	15"	0.35	2	18"	1.00	3	$3,000
S1L5T2-2	15"	0.77	3	18"	0.95	3	$1,000
						Subtotal Cost =	**$235,000**
S1L6-1	30"	1.89	56	30"	1.89	12	$0
						Subtotal Cost =	**$0**
S1L7-1	4' flat bottom	0.82	16	4' flat bottom	0.46	101	$17,000
S1L7-2	18"	2.74	17	36"	0.49	101	$3,000
S1L7-3	15"	2.00	9	36"	0.50	61	$13,000
S1L7T1-1	15"	0.73	6	30"	0.50	40	$21,000
S1L7T1-2	15"	1.44	8	30"	0.51	40	$3,000

SYSTEM 1

Conduits and Channels

ID	Existing			Recommendation			Total Cost
	Size	Grade (%)	Q_{cap} (cfs)	Size	Grade (%)	Q_{10yr} (cfs)	
S1L7T1-3	15"	0.89	6	30"	0.52	40	$2,000
						Subtotal Cost =	**$59,000**
S1L8-1	4' flat bottom	0.19	8	---	---	---	---
S1L8-2	60"	0.32	237	---	---	---	---
						Subtotal Cost =	**$0**
S1L9-1	4' flat bottom	5.99	41	The diversion at US-24 will eliminate these components from the internal drainage system			$0
S1L9-2	36"	3.98	133				$0
S1L9-3	5' flat bottom	0.84	19				$0
S1L9-4	36"	0.61	52				$0
						Subtotal Cost =	**$0**

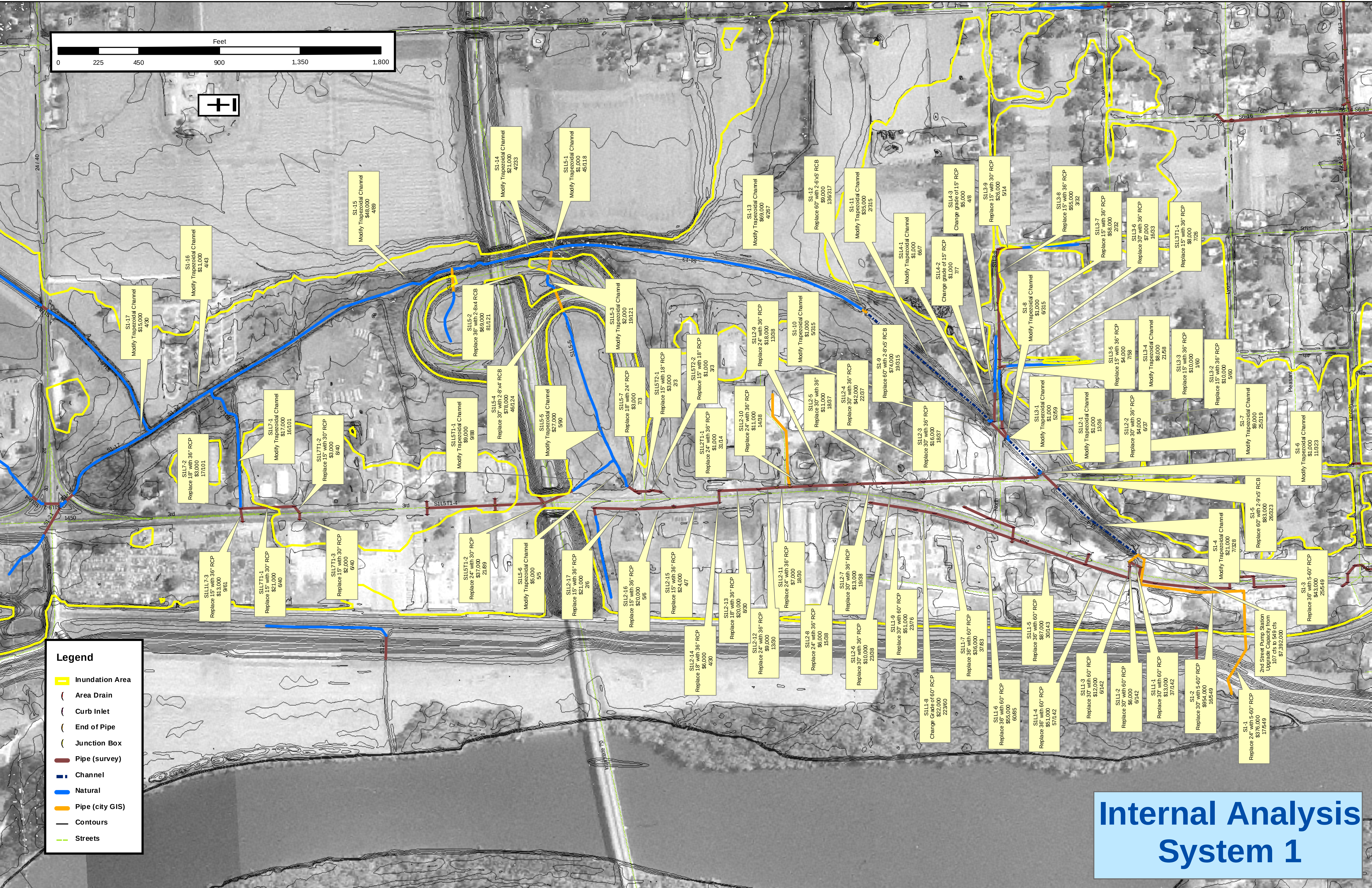
Pump Stations

ID	Existing		Recommendation		Total Estimated Cost
	Wet-well (ft^3)	Pump (gpm)	Wet-well (ft^3)	Pump (gpm)	
2nd Street	5,832	48,000	32,940	246,392	$7,392,000
				Subtotal Cost =	**$7,392,000**

Notes:

1. Dashed entries refer to pieces of the system that are included in GIS mapping, but did not meet the study criteria for having individual analysis in the hydrologic model. Therefore, no recommendation could be given.
2. All proposed pump station wet-wells are 20-ft deep
3. All pump station costs are highly variable and depend on the level of redundancy desired with regard to backup pumps, pump supplies, outlet works, etc.
4. Assume total cost of pump station to be $30/gpm

Total Cost of System = $10,224,000


Internal Analysis
System 1
Feet
0 225 450 900 1,350 1,800
Legend
Inundation Area
Area Drain
Curb Inlet
End of Pipe
Junction Box
Pipe (survey)
Channel
Natural
Pipe (city GIS)
Contours
Streets

2. System 2

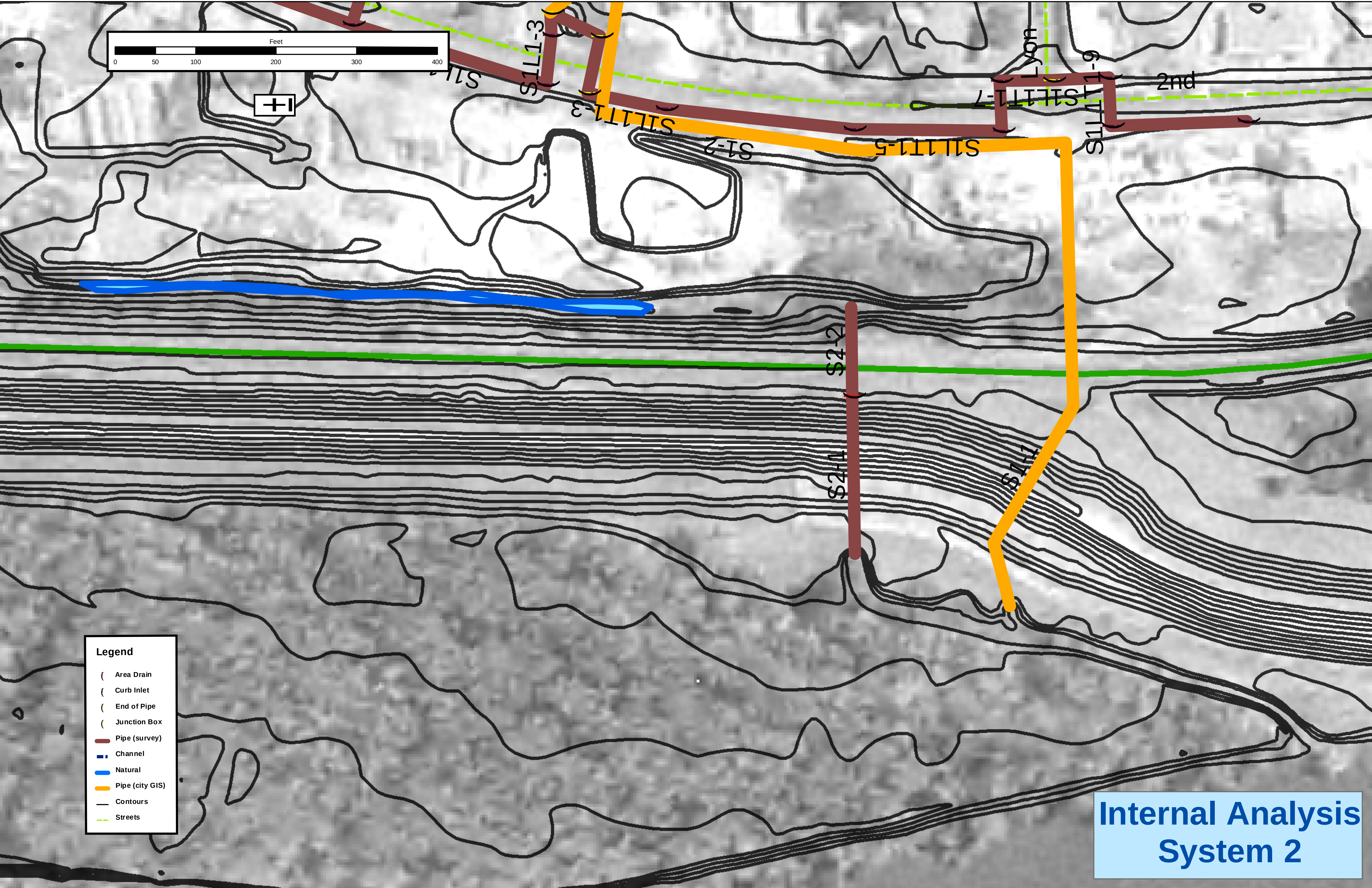
This system has a gravity flow outlet through the Kansas River levee for approximately a five acre area. Each pipe was analyzed with regard to capacity during a 10-year flow event. The two pipes in this system were determined to be adequate; however, it was discovered during the study that the gate on the outlet pipe is permanently closed. The analysis, therefore, turned to a determination of available storage area for ponding. The volume of flow is relatively minor and can remain on site beyond the base of the levee as shown on the System 2 map. As no changes are recommended, the map for System 2 does not have any callouts.

SYSTEM 2

Conduits

ID	Existing			Recommendation			Total Cost
	Size	Grade (%)	Q_{cap} (cfs)	Size	Grade (%)	Q_{10yr} (cfs)	
S2-1	60"	0.84	130	60"	0.84	10	$0
S2-2	60"	1.05	144	60"	1.05	10	$0
						Subtotal Cost =	**$0**

Total Cost of System =	**$0**


Feet
0 50 100 200 300 400
S1L1-3
S1L1T1-3
S1-2
S1L1T1-5
S1L1T1-7
S1L1T1-9
Lyon
2nd
S2-2
S2-1
S1-1
Legend
Area Drain
Curb Inlet
End of Pipe
Junction Box
Pipe (survey)
Channel
Natural
Pipe (city GIS)
Contours
Streets
Internal Analysis
System 2

3. System 3

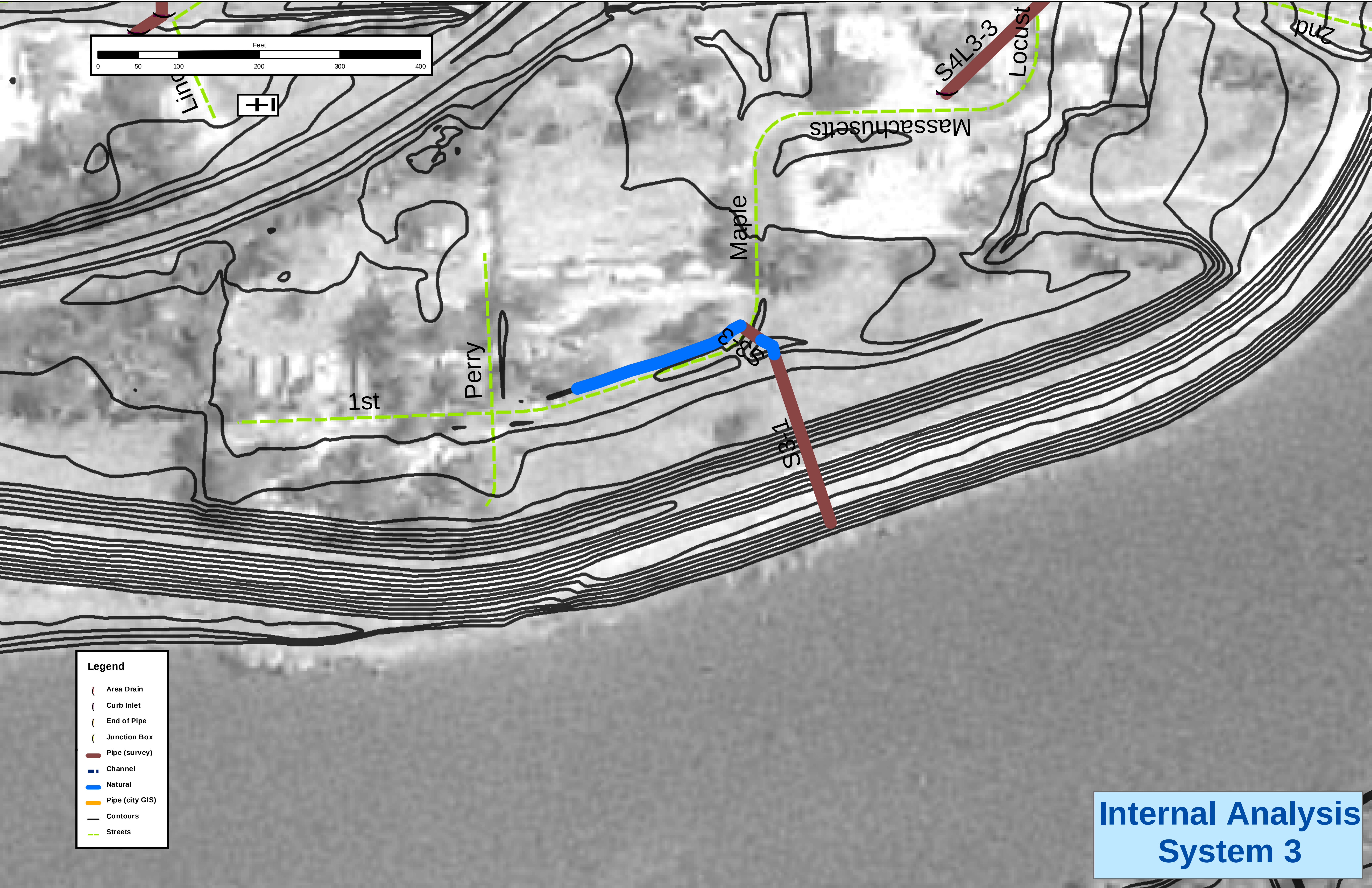
This system has a gravity flow outlet through the Kansas River levee for approximately a 23 acre area. Only the outlet pipe met the study criteria of having an individual drainage area in the hydrologic model, and therefore could be analyzed with regard to capacity during a 10-year flow event. However, an additional small pipe and natural channel are included in the GIS mapping for the system. The outlet pipe was determined to be adequate and the recommendation is to keep the existing infrastructure in place. As no changes are recommended, the map for System 3 does not have any callouts.

SYSTEM 3

Conduits							
ID	Existing			Recommendation			Total Cost
	Size	Grade (%)	Q_{cap} (cfs)	Size	Grade (%)	Q_{10yr} (cfs)	
S3-1	48"	1.00	143	48"	1.00	51	$0
S3-2	4' flat bottom	8.78	53	---	---	---	---
S3-3	12"	0.03	1	---	---	---	---
						Subtotal Cost =	$0

Note: Dashed entries refer to pieces of the system that are included in GIS mapping, but did not meet the study criteria for having individual analysis in the hydrologic model. Therefore, no recommendation could be given.

Total Cost of System =	**$0**



Internal Analysis System 3

4. System 4

This system has a gravity flow pipe outlet to the Kansas River. Each conduit was analyzed with regard to capacity during a 10-year flow event. A method of upsizing pipe and changing grade from downstream to upstream was utilized to eliminate those that were over capacity. A total of 13 pipes met criteria for analysis in System 4 (31 pipes are shown in GIS), of which 8 are exceeding capacity. On the main stem, two out of seven pipes are recommended for an upgrade in size and change in slope. The other five are determined to be adequate for the ultimate build-out condition. A breakdown of each lateral coming into the main system is given below. A map of this system identifies all recommended improvements along with an estimated total cost. Additional detail for improvements is shown on the System 4 spreadsheet.

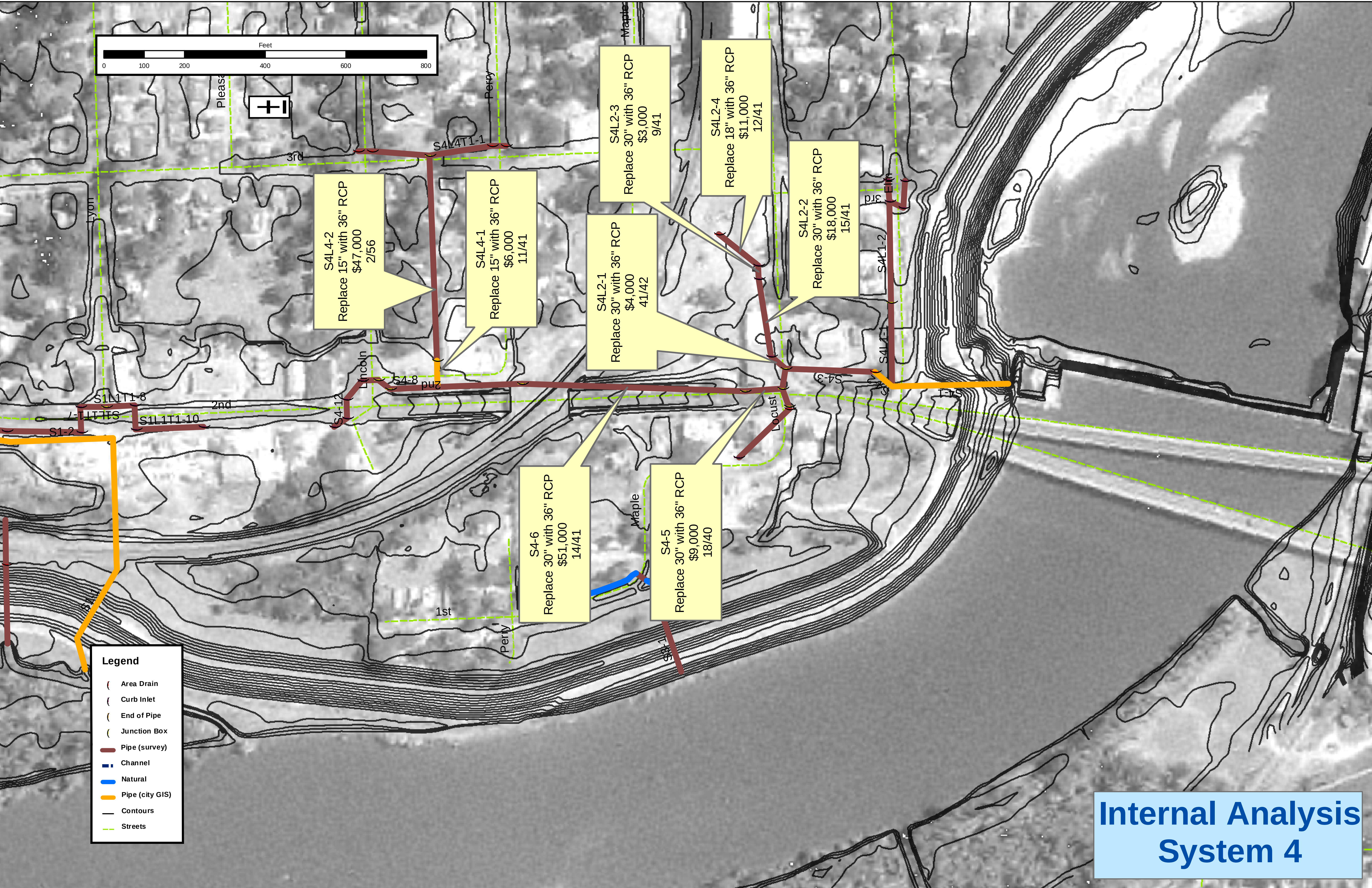
- S4L2 – The excess peak flow in S4L2-1, the pipe discharging to the main stem of System 4, is 27 cfs. One of the points along the lateral was shown to be surcharging. In order to provide an adequate conveyance system, all four of the pipes are recommended for size increases. However, the existing grades can accommodate the new sizes.
- S4L4 – The excess peak flow in S4L4-1, the pipe discharging to the main stem of System 4, is 35 cfs. Both the discharge pipe and the one other pipe along the lateral were shown to be surcharging. In order to eliminate the ponding, size increases are recommended. As with the other System 4 lateral, the existing grades can accommodate the new sizes.

SYSTEM 4

Conduits							
ID	Existing			Recommendation			Total Cost
	Size	Grade (%)	Q_{cap} (cfs)	Size	Grade (%)	Q_{10yr} (cfs)	
S4-1	36"	0.10	12	36"	0.10	62	$0
S4-2	36"	0.51	26	36"	0.51	62	$0
S4-3	36"	0.05	4	36"	0.05	62	$0
S4-4	36"	0.59	25	36"	0.59	40	$0
S4-5	30"	0.42	18	36"	0.42	40	$9,000
S4-6	30"	0.11	14	36"	0.11	41	$51,000
S4-7	36"	0.14	25	36"	0.14	41	$0
S4-8	36"	0.09	11	---	---	---	---
S4-9	18"	2.68	17	---	---	---	---
S4-10	21"	1.29	18	---	---	---	---
S4-11	15"	1.64	8	---	---	---	---
S4-12	15"	1.10	7	---	---	---	---
S4-13	12"	1.89	3	---	---	---	---
						Subtotal Cost =	**$60,000**
S4L1-1	15"	2.10	5	---	---	---	---
S4L1-2	15"	0.79	6	---	---	---	---
S4L1-3	15"	2.86	11	---	---	---	---
S4L1T1-1	15"	0.29	4	---	---	---	---
S4L1T1-2	15"	1.06	7	---	---	---	---
						Subtotal Cost =	**---**
S4L2-1	30"	3.39	41	36"	3.39	42	$4,000
S4L2-2	30"	0.48	15	36"	0.48	41	$18,000
S4L2-3	30"	0.15	9	36"	0.15	41	$3,000
S4L2-4	18"	4.75	12	36"	4.75	41	$11,000
						Subtotal Cost =	**$36,000**
S4L3-1	18"	3.97	11	---	---	---	---
S4L3-2	18"	3.18	19	---	---	---	---
S4L3-3	15"	0.71	3	---	---	---	---
						Subtotal Cost =	**---**
S4L4-1	15"	9.08	11	36"	9.08	41	$6,000
S4L4-2	15"	0.49	2	36"	0.49	56	$47,000
S4L4T1-1	12"	1.76	3	---	---	---	---
S4L4T1-2	12"	3.35	4	---	---	---	---
S4L4T2-1	12"	1.08	2	---	---	---	---
S4L4T2-2	12"	0.87	2	---	---	---	---
						Subtotal Cost =	**$53,000**

Note: Dashed entries refer to pieces of the system that are included in GIS mapping, but did not meet the study criteria for having individual analysis in the hydrologic model. Therefore, no recommendation could be given.

Total Cost of System = $149,000



Internal Analysis System 4
Feet
0 100 200 400 600 800
Legend
Area Drain
Curb Inlet
End of Pipe
Junction Box
Pipe (survey)
Channel
Natural
Pipe (city GIS)
Contours
Streets
S4L4-2 Replace 15" with 36" RCP $47,000 2/56
S4L4-1 Replace 15" with 36" RCP $6,000 11/41
S4L2-3 Replace 30" with 36" RCP $3,000 9/41
S4L2-4 Replace 18" with 36" RCP $11,000 12/41
S4L2-2 Replace 30" with 36" RCP $18,000 15/41
S4L2-1 Replace 30" with 36" RCP $4,000 41/42
S4-6 Replace 30" with 36" RCP $51,000 14/41
S4-5 Replace 30" with 36" RCP $9,000 18/40
S4L4T1-1
S4-8
S4-3
S4L1-2
S4L1-1
S1L1T1-8
S1L1T1-10
S1-2
3rd
2nd
1st
Lyon
Pleasa
Perry
Maple
Lincoln
Locust
Elm

5. System 5

This system has a gravity flow outlet through the Kansas River levee. Each of the two pipes in this system was analyzed with regard to capacity during a 10-year flow event. One of the pipes, the upstream conduit, was determined to be exceeding its capacity. An upgrade to the size of that pipe, while keeping the slope constant, provides adequate drainage for the system. The levee pipe can handle the additional flow delivered by the upsized pipe upstream. So, it is recommended to keep the existing infrastructure in place at that location. A map of this system identifies the recommended improvement along with an estimated total cost. Additional detail is provided on the System 5 spreadsheet.

SYSTEM 5

Conduits

ID	Existing			Recommendation			Total Cost
	Size	Grade (%)	Q_{cap} (cfs)	Size	Grade (%)	Q_{10yr} (cfs)	
S5-1	30"	1.81	30	30"	1.81	49	$0
S5-2	18"	1.23	6	30"	1.23	27	$56,000
						Subtotal Cost =	**$56,000**

Total Cost of System = $56,000


Feet
0 50 100 200 300 400
Elm
5th
S5-2
S5-1
Walnut
4th
S5-2
Replace 18" with 30" RCP
$56,000
6/27
Legend
Area Drain
Curb Inlet
End of Pipe
Junction Box
Pipe (survey)
Channel
Natural
Pipe (city GIS)
Contours
Streets
Internal Analysis
System 5

6. System 6

This system contains the Maple Street pump station, which discharges stormwater to the south side of the railroad tracks running south of Maple Street. It then flows by gravity down 6th Street through the levee to the Kansas River. Each conduit and channel, as well as the pump plant, was analyzed with regard to capacity during a 10-year flow event. It was quickly recognized that the existing pump station force main is extremely inadequate. The station was converted from a sanitary lift station and the discharge is only a 9” conduit. In order to pump significant stormwater flows, the velocity through the outlet pipe would be very high. A consistent approach of increasing pipe sizes and changing grades from downstream to upstream was utilized to eliminate all pipes in the system that were over capacity. It was found that 21 out of 33 pipes are over capacity within the system, along with the one natural channel. Following upgrades to the piping system, the Maple Street pump station would need to pump a peak of 302 cfs from its wet well.

Based upon a specific standing water concern in the block between 7th, 8th, Lincoln, and Lyon Streets, an alternative for Section 6 looked at re-routing some discharge to System 10. It turned out that diversion of a portion of flow to System 10 provided an overall cost savings. While there was additional cost for placing a new pipe along Lyon Street from 7th to 8th Streets and land acquisition cost to provide a drainage path to the System 10 ponding area, there was a significant reduction in the cost of upgrading the Maple Street pump station. Following upgrades to the piping system, the Maple Street pump station would need to pump a peak of 238 cfs from its wet well. It was assumed that the new diversion pipe would be placed within City right-of-way so that no additional land acquisition would be necessary. Also, a cost for purchasing land at the ponding area is included in System 10 already. The contribution from System 6 does not change the number of parcels slated for acquisition. The recommendation for System 6, therefore, is to implement the flow diversion alternative.

Even with the flow diversion, though, local drainage would continue to cause some standing water due to the fill currently being placed on the east side of the lot. The City was unable to determine the ultimate location and elevation of fill at the time of this report, but a natural drainage path to the northeast is already being cut off. Therefore, part of the recommendation for System 6 is to grade the local area of concern to drain to a new 30” RCP lateral which would be connected to the new pipe along Lyon Street.

On the main stem of System 6, 7 out of 16 pipes are recommended for a change in slope, while all are recommended for an upgrade in size. A breakdown of each lateral coming into the main system is given below. A map of this system identifies all recommended improvements along with an estimated total cost. Additional detail for improvements is shown on the System 6 spreadsheet.

- S6L2 – The excess peak flow in S6L2-1, the pipe discharging to the main stem of System 6, is 37 cfs. This is the only pipe meeting study criteria for hydrologic analysis on that branch of the system. In order to provide an adequate conveyance system, the pipe is recommended for a size increase and a grade change.
- S6L3 – The excess peak flow in S6L3-1, the pipe discharging to the main stem of System 6, is 56 cfs. All of the points along the lateral were shown to be surcharging. Minimal cover and slope issues forced the entire lateral to be

redesigned. A more consistent grade was set and sizes were changed on a segment-by-segment basis in order to eliminate surcharge points. The process continued until each component of the lateral could handle the flow without surcharge. All 10 pipes/channels have recommendations for size and grade changes.

SYSTEM 6

Conduits and Channels							
ID	Existing			Recommendation			Total Cost
	Size	Grade (%)	Q_{cap} (cfs)	Size	Grade (%)	Q_{10yr} (cfs)	
S6-1	30"	1.96	31	2-42"	1.96	238	$18,000
S6-2	18"	0.01	1	2-42"	0.01	238	$24,000
S6-3	24"	0.34	7	2-42"	0.34	238	$69,000
S6-4	24"	0.16	5	2-42"	0.16	238	$113,000
S6-5	24"	0.23	6	2-42"	0.23	238	$25,000
S6-6	24"	0.17	5	2-42"	0.17	238	$71,000
S6-7	24"	0.58	9	2-42"	0.58	238	$10,000
S6-8	24"	2.66	20	2-42"	2.66	238	$2,000
S6-9	9"	-5.08	28	2-42"	-5.08	238	$77,000
S6-10	15"	5.33	8	60"	0.50	173	$27,000
S6-11	15"	0.21	2	60"	0.50	173	$59,000
S6-12	15"	0.43	2	60"	0.49	143	$10,000
S6-13	15"	0.34	2	60"	0.50	143	$54,000
S6-14	15"	0.48	2	60"	0.50	87	$13,000
S6-15	15"	0.72	3	60"	0.50	87	$60,000
S6-16	15"	0.64	3	60"	0.50	54	$62,000
S6-17	15"	0.42	2	15"	---	---	---
S6-18	15"	0.67	3	15"	---	---	---
						Subtotal Cost =	**$694,000**
S6L1-1	15"	27.69	18	15"	---	---	$0
						Subtotal Cost =	**$0**
S6L2-1	15"	46.16	24	60"	0.98	65	$5,000
						Subtotal Cost =	**$5,000**
S6L3-1	15"	0.05	1	60"	0.30	61	$17,000
S6L3-2	18"	0.55	4	60"	0.27	64	$7,000
S6L3-3	18"	0.44	4	60"	0.30	65	$73,000
S6L3-4	18"	0.42	4	60"	0.30	66	$74,000
S6L3-5	18"	0.91	2	60"	0.25	67	$3,000
S6L3-6	18"	0.16	1	60"	0.29	68	$15,000
S6L3-7B	18"	0.57	4	60"	0.28	44	$6,000
S6L3-8B	4' flat bottom	0.31	21	4' flat bottom	---	---	---
S6L3-10	12"	0.35	1	12"	---	---	---
S6L3T1-1	15"	8.47	10	15"	---	---	---
						Subtotal Cost =	**$195,000**
S6L3-7A	---	---	---	42"	0.10	41	$114,000
S6L3-7C	---	---	---	30"	2.18	23	$4,000
S6L3-7D	---	---	---	2-30"	0.10	29	$54,000
S6L3-8A	4' flat bottom	0.31	316	6' flat bottom	0.42	46	$6,000
S6L3-9A	12"	1.43	2	30"	0.02	40	$3,000
						Subtotal Cost =	**$181,000**
S6L4-1	15"	0.59	3	15"	---	---	---
S6L4-2	15"	0.80	3	15"	---	---	---
						Subtotal Cost =	**$0**
S6L5-1	8"	3.24	3	8"	---	---	---
						Subtotal Cost =	**$0**

SYSTEM 6

Pump Stations

ID	Existing		Recommendation		Total Cost
	Wet-well (ft^3)	Pump (gpm)	Wet-well (ft^3)	Pump (gpm)	
Maple Street	Not Available	Not Available	14,280	106,814	$3,204,000
				Subtotal Cost =	**$3,204,000**

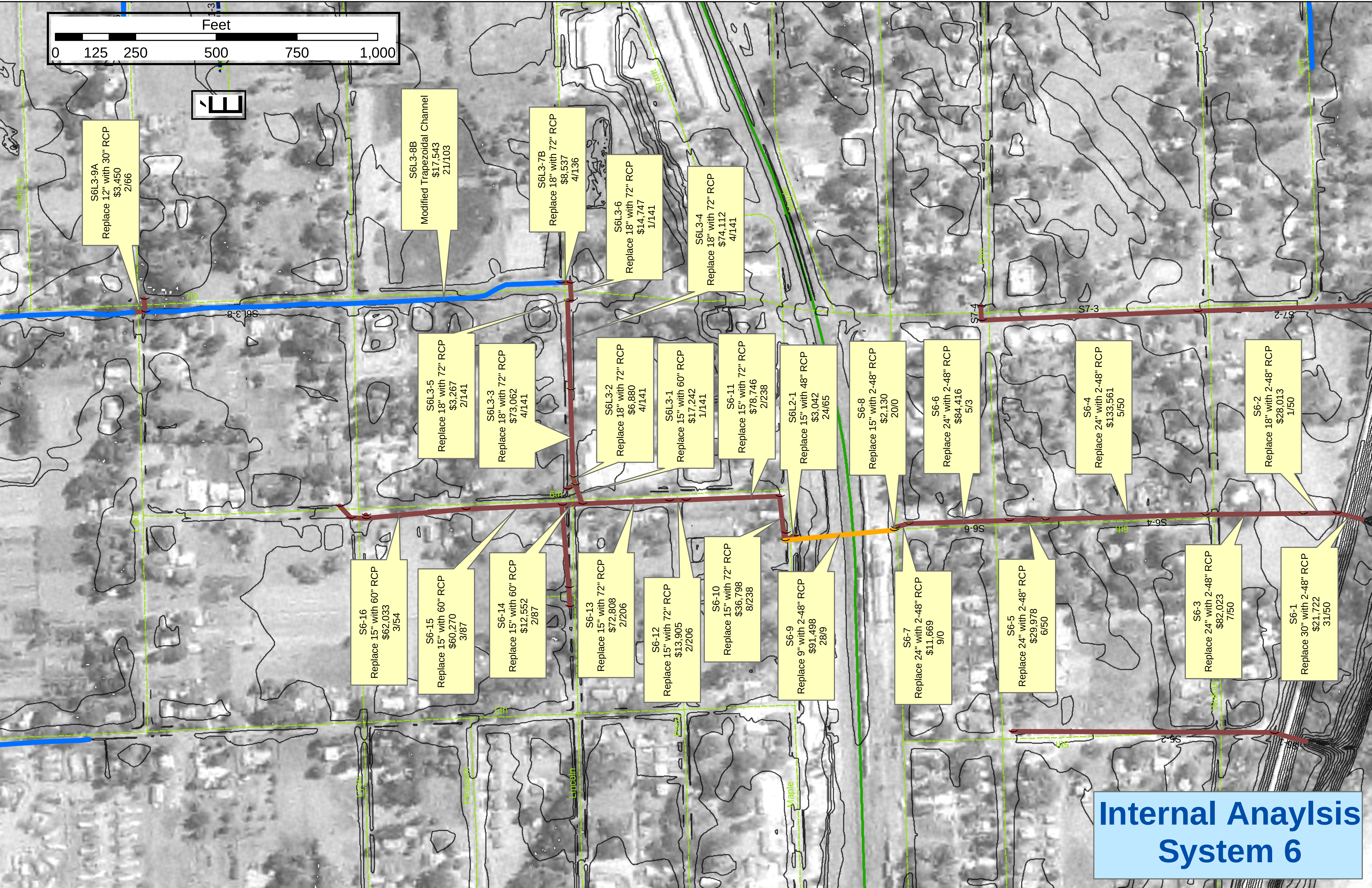
Land Acquisitions

Plate #	Appraised		Total Cost
	Land	Improvements	
N07659A	$36,680	$56,820	$94,000
N07660A	$1,900	$0	$2,000
		Subtotal Cost =	**$96,000**

Notes:

1. Dashed entries refer to pieces of the system that are included in GIS mapping, but did not meet the study criteria for having individual analysis in the hydrologic model. Therefore, no recommendation could be given.
2. All proposed pump station wet-wells are 20-ft deep
3. All pump station costs are highly variable and depend on the level of redundancy desired with regard to backup pumps, pump supplies, outlet works, etc.
4. Assume total cost of pump station to be $30/gpm

Total Cost of System =	**$4,375,000**



Feet
0 125 250 500 750 1,000
S6L3-9A Replace 12" with 30" RCP $3,450 2/66
S6L3-8B Modified Trapezoidal Channel $17,543 21/103
S6L3-7B Replace 18" with 72" RCP $8,537 4/136
S6L3-6 Replace 18" with 72" RCP $14,747 1/141
S6L3-4 Replace 18" with 72" RCP $74,112 4/141
S6L3-5 Replace 18" with 72" RCP $3,267 2/141
S6L3-3 Replace 18" with 72" RCP $73,062 4/141
S6L3-2 Replace 18" with 72" RCP $6,880 4/141
S6L3-1 Replace 15" with 60" RCP $17,242 1/141
S6-11 Replace 15" with 72" RCP $78,746 2/238
S6L2-1 Replace 15" with 48" RCP $3,042 24/65
S6-8 Replace 15" with 2-48" RCP $2,130 20/0
S6-6 Replace 24" with 2-48" RCP $84,416 5/3
S6-4 Replace 24" with 2-48" RCP $133,561 5/50
S6-2 Replace 18" with 2-48" RCP $28,013 1/50
S6-16 Replace 15" with 60" RCP $62,033 3/54
S6-15 Replace 15" with 60" RCP $60,270 3/87
S6-14 Replace 15" with 60" RCP $12,552 2/87
S6-13 Replace 15" with 72" RCP $72,808 2/206
S6-12 Replace 15" with 72" RCP $13,905 2/206
S6-10 Replace 15" with 72" RCP $36,798 8/238
S6-9 Replace 9" with 2-48" RCP $91,498 28/9
S6-7 Replace 24" with 2-48" RCP $11,669 9/0
S6-5 Replace 24" with 2-48" RCP $29,978 6/50
S6-3 Replace 24" with 2-48" RCP $82,023 7/50
S6-1 Replace 30" with 2-48" RCP $21,722 31/50
S6L3-8
S7-4
S7-3
S7-2
7th
6th
5th
Lincoln
Maple
Internal Anaylsis System 6

7. System 7

This system has a gravity flow outlet through the Kansas River levee. Each of the two modeled pipes in this system was analyzed with regard to capacity during a 10-year flow event. One of the pipes, the upstream conduit, was determined to be exceeding its capacity. An upgrade to the size of that pipe, while keeping the slope constant, provides adequate drainage for the system. The levee pipe can handle the additional flow delivered by the upsized pipe upstream. So, it is recommended to keep the existing infrastructure in place at that location. A map of this system identifies the recommended improvement along with an estimated total cost. Additional detail is provided on the System 7 spreadsheet.

SYSTEM 7

Conduits

ID	Existing			Recommendation			Total Cost
	Size	Grade (%)	Q_{cap} (cfs)	Size	Grade (%)	Q_{10yr} (cfs)	
S7-1	30"	2.14	33	30"	2.14	53	$0
S7-2	18"	0.89	5	30"	0.89	26	$38,000
S7-3	15"	0.51	3	15"	---	---	---
S7-4	15"	0.86	5	15"	---	---	---
					Subtotal Cost =		**$38,000**

Note: Dashed entries refer to pieces of the system that are included in GIS mapping, but did not meet the study criteria for having individual analysis in the hydrologic model. Therefore, no recommendation could be given.

Total Cost of System =	**$38,000**

Feet
0 50 100 200 300 400
S7-2
Replace 18" with 30" RCP
$38,000
5/26
Ash
Walnut
7th
S7-1
S7-2
S7-3
S7-4
Legend
Area Drain
Curb Inlet
End of Pipe
Junction Box
Pipe (survey)
Channel
Natural
Pipe (city GIS)
Contours
Streets
Internal Analysis
System 7

8. System 8

This system has a gravity flow outlet through the Kansas River levee. Only the main stem components of the system met the study criteria of having an individual analysis in the hydrologic model, and therefore could be analyzed with regard to capacity during a 10-year flow event. However, six additional small laterals are included in the GIS mapping for the system. Almost all of the points along the main line of the system were shown to be surcharging. Minimal cover and slope issues forced the entire line to be redesigned. A more consistent grade was set and sizes were changed on a segment-by-segment basis in order to eliminate surcharge points. The process continued until each component of the system could handle the flow without surcharge. Fourteen out of 15 pipes have recommendations for size and slope changes. The outlet pipe was determined to be adequate and the recommendation is to keep the existing infrastructure in place. A map of this system identifies all recommended improvements along with an estimated total cost. Additional detail for improvements is shown on the individual system spreadsheet.

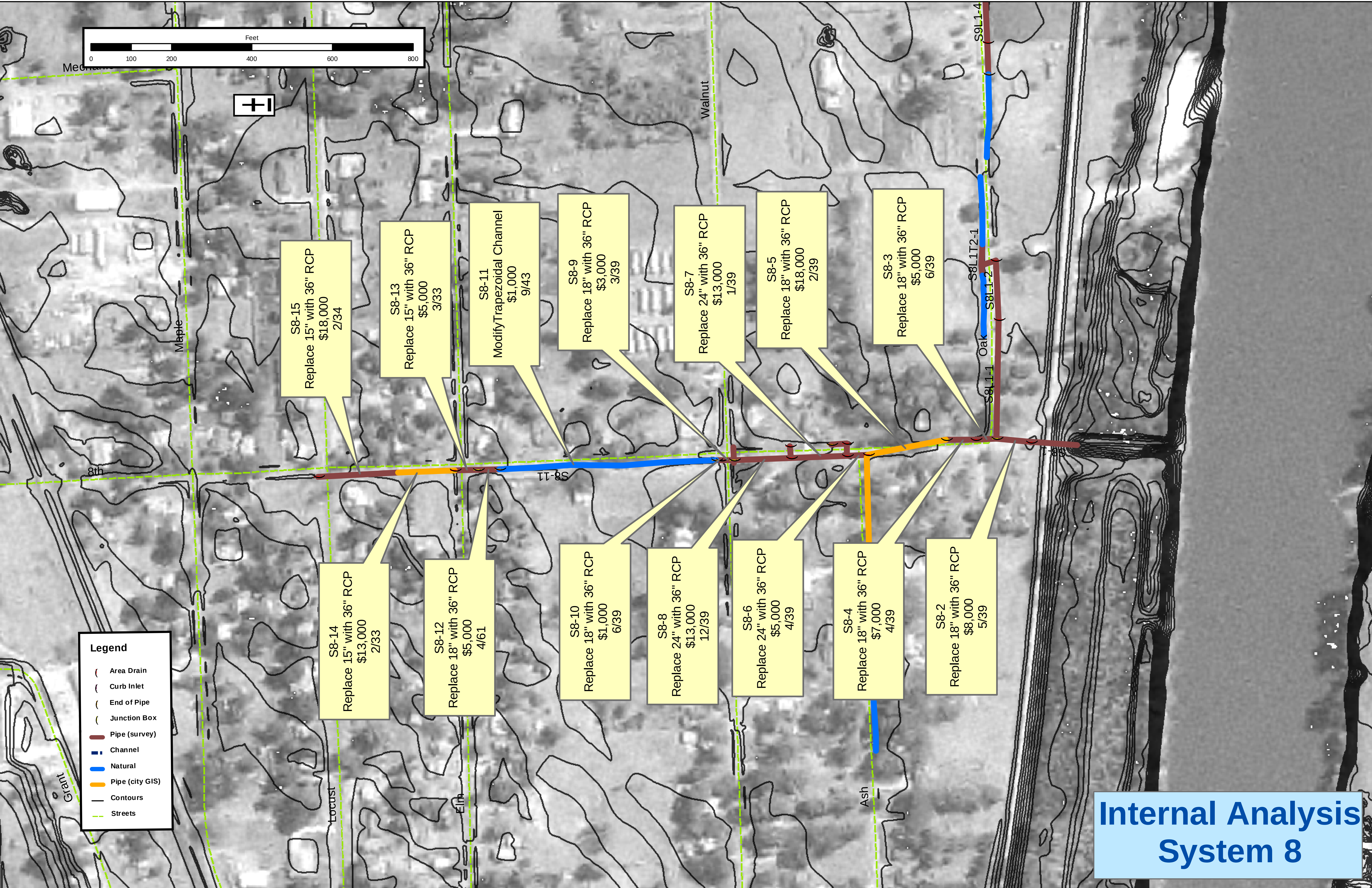
SYSTEM 8

Conduits and Channels

ID	Existing			Recommendation			Total Cost
	Size	Grade (%)	Q_{cap} (cfs)	Size	Grade (%)	Q_{10yr} (cfs)	
S8-1	30"	1.87	30	30"	1.87	50	$0
S8-2	18"	0.87	5	36"	0.50	39	$8,000
S8-3	18"	1.14	6	36"	0.49	39	$5,000
S8-4	18"	0.58	4	36"	0.50	39	$7,000
S8-5	18"	0.16	2	36"	0.50	39	$18,000
S8-6	24"	0.12	4	36"	0.50	39	$5,000
S8-7	24"	0.00	0	36"	0.50	39	$13,000
S8-8	24"	0.93	12	36"	0.50	39	$13,000
S8-9	18"	0.22	3	36"	0.50	39	$3,000
S8-10	18"	1.25	6	36"	0.47	39	$1,000
S8-11	4' flat bottom	0.06	9	4' flat bottom	0.50	43	$1,000
S8-12	18"	0.38	4	36"	0.50	61	$5,000
S8-13	15"	0.92	3	36"	0.50	33	$5,000
S8-14	15"	0.36	2	36"	0.50	33	$13,000
S8-15	15"	0.50	2	36"	0.50	34	$18,000
						Subtotal Cost =	**$115,000**
S8L1-1	24"	0.65	10	24"	---	---	---
S8L1-2	24"	0.21	6	24"	---	---	---
S8L1-3	18"	1.23	6	18"	---	---	---
S8L1T1-1	18"	4.86	13	18"	---	---	---
S8L1T2-1	15"	1.36	4	15"	---	---	---
						Subtotal Cost =	**$0**
S8L2-1	15"	0.02	0	15"	---	---	---
						Subtotal Cost =	**$0**
S8L3-1	12"	3.73	4	12"	---	---	---
S8L3-2	12"	4.12	4	12"	---	---	---
						Subtotal Cost =	**$0**
S8L4-1	12"	3.19	3	12"	---	---	---
						Subtotal Cost =	**$0**
S8L5-1	12"	3.72	4	12"	---	---	---
						Subtotal Cost =	**$0**
S8L6-1	12"	3.36	4	12"	---	---	---
						Subtotal Cost =	**$0**

Note: Dashed entries refer to pieces of the system that are included in GIS mapping, but did not meet the study criteria for having individual analysis in the hydrologic model. Therefore, no recommendation could be given.

Total Cost of System =	**$115,000**


Internal Analysis
System 8
Feet
0 100 200 400 600 800
Legend
Area Drain
Curb Inlet
End of Pipe
Junction Box
Pipe (survey)
Channel
Natural
Pipe (city GIS)
Contours
Streets
S8-15
Replace 15" with 36" RCP
$18,000
2/34
S8-13
Replace 15" with 36" RCP
$5,000
3/33
S8-11
Modify Trapezoidal Channel
$1,000
9/43
S8-9
Replace 18" with 36" RCP
$3,000
3/39
S8-7
Replace 24" with 36" RCP
$13,000
1/39
S8-5
Replace 18" with 36" RCP
$18,000
2/39
S8-3
Replace 18" with 36" RCP
$5,000
6/39
S8-14
Replace 15" with 36" RCP
$13,000
2/33
S8-12
Replace 18" with 36" RCP
$5,000
4/61
S8-10
Replace 18" with 36" RCP
$1,000
6/39
S8-8
Replace 24" with 36" RCP
$13,000
12/39
S8-6
Replace 24" with 36" RCP
$5,000
4/39
S8-4
Replace 18" with 36" RCP
$7,000
4/39
S8-2
Replace 18" with 36" RCP
$8,000
5/39
S8-11
S9L1-4
S8L1T2-1
S8L1-2
S8L1-1
Mechanic
Maple
8th
Walnut
Oak
Grant
Locust
Elm
Ash

9. System 9

This system has a gravity flow outlet through the Kansas River levee. Each of the five modeled pipes in this system was analyzed with regard to capacity during a 10-year flow event and was found to be exceeding their capacity. An upgrade to the size of the pipes, and a change in the slope, provides adequate drainage for the system.

The levee pipe cannot handle the additional flow delivered by the upsized pipe network upstream. Water will surcharge from the end of pipe S9-2 and overland flow into the ponding area denoted in the map. In a more populated area this would require construction of a pump plant to take the water to the river, but at this point it runs to an uninhabited area. Further investigation and land acquisition purchases may be necessary prior to future development in the area. For the current situation, though, it is recommended to keep the existing infrastructure in place at the levee location.

A breakdown of each lateral coming into the main system is given below. A map of this system identifies the recommended improvements along with an estimated total cost. Additional detail is provided on the System 9 spreadsheet.

- S9L1 – The excess peak flow in S9L1-1, the pipe discharging to the main stem of System 9, is 21 cfs. This is the only pipe meeting study criteria for hydrologic analysis on that branch of the system. In order to provide an adequate conveyance system, the pipe is recommended for a size increase and a grade change.

SYSTEM 9

Conduits

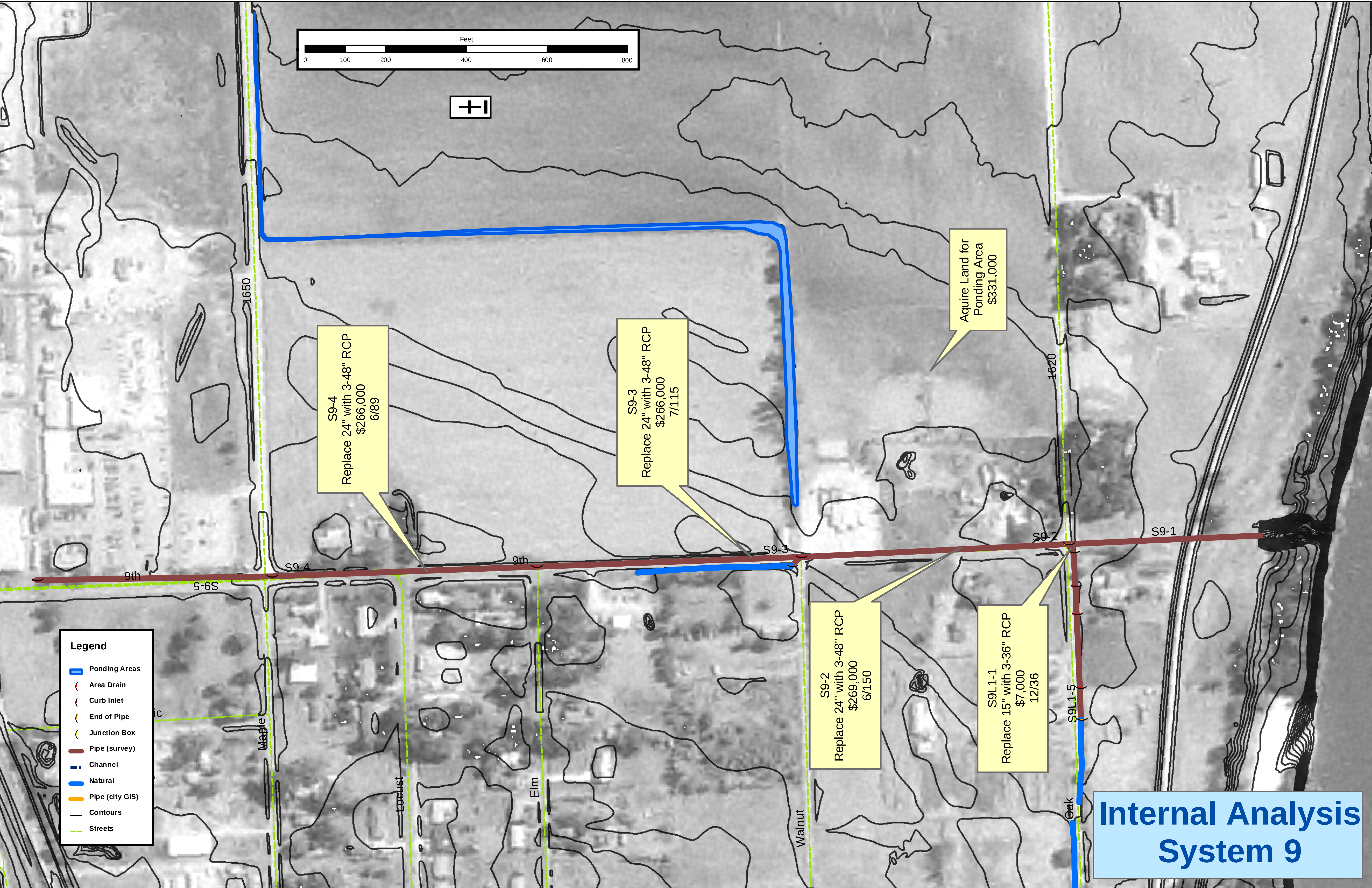
ID	Existing			Recommendation			Total Cost
	Size	Grade (%)	Q_{cap} (cfs)	Size	Grade (%)	Q_{10yr} (cfs)	
S9-1	30"	0.23	11	30"	0.23	160	$0
S9-2	24"	0.28	6	3 - 48"	0.50	150	$269,000
S9-3	24"	0.30	7	3 - 48"	0.50	115	$266,000
S9-4	24"	0.27	6	3 - 48"	0.50	89	$266,000
S9-5	24"	0.14	5	24"	---	---	---
						Subtotal Cost =	**$801,000**
S9L1-1	15"	11.67	12	3 - 36"	0.50	36	$7,000
S9L1-2	15"	0.37	2	15"	---	---	---
S9L1-3	15"	0.26	2	15"	---	---	---
S9L1-4	15"	0.67	3	15"	---	---	---
S9L1-5	15"	0.32	2	15"	---	---	---
						Subtotal Cost =	**$7,000**
S9L2-1	15"	10.50	11	15"	---	---	---
						Subtotal Cost =	**$0**

Land Acquisitions

Plate #	Appraised		Total Cost
	Land	Improvements	
300260	$101,790	$0	$102,000
300260-02	$1,800	$0	$2,000
300260A01	$59,150	$167,450	$227,000
		Subtotal Cost =	**$331,000**

Note: Dashed entries refer to pieces of the system that are included in GIS mapping, but did not meet the study criteria for having individual analysis in the hydrologic model. Therefore, no recommendation could be given.

Total Cost of System =	**$1,139,000**



Feet
0 100 200 400 600 800
Aquire Land for Ponding Area $331,000
S9-4 Replace 24" with 3-48" RCP $266,000 6/89
S9-3 Replace 24" with 3-48" RCP $266,000 7/115
S9-2 Replace 24" with 3-48" RCP $269,000 6/150
S9L1-1 Replace 15" with 3-36" RCP $7,000 12/36
S9-1
S9-2
S9-3
S9-4
S9-5
S9L1-5
9th
1650
1620
Maple
Locust
Elm
Walnut
Oak
Legend
Ponding Areas
Area Drain
Curb Inlet
End of Pipe
Junction Box
Pipe (survey)
Channel
Natural
Pipe (city GIS)
Contours
Streets
Internal Analysis
System 9

10. System 10

This system drains to a low-lying area on the east side of its drainage area. Each conduit was analyzed with regard to capacity during a 10-year flow event. A method of upsizing pipe and changing grade from downstream to upstream was utilized to eliminate those that were over capacity. A total of seven pipes/channels met criteria for analysis in System 10 (11 pipes are shown in GIS), of which 5 are exceeding capacity. On the main stem, the solitary pipe is recommended for an upgrade in size only. Of the three channels, none are recommended for an upgrade in size, but all four have recommended changes in slope. The ponding area spreads across parts of three properties. It is recommended to purchase these properties rather than convey the stormwater elsewhere.

A breakdown of each lateral coming into the main system is given below. A map of this system identifies all recommended improvements along with an estimated total cost. Additional detail for improvements is shown on the System 10 spreadsheet.

- S10L2 – The excess peak flow in S10L2-1, the pipe discharging to the main stem of System 10, is 13 cfs. Both the discharge pipe and the one other pipe along the lateral were shown to be surcharging. In order to eliminate the ponding, size increases and grade changes are recommended. The channel in between the two pipes adequately conveys flow through the system, so it is recommended to leave that existing infrastructure in place.

SYSTEM 10

Conduits and Channels

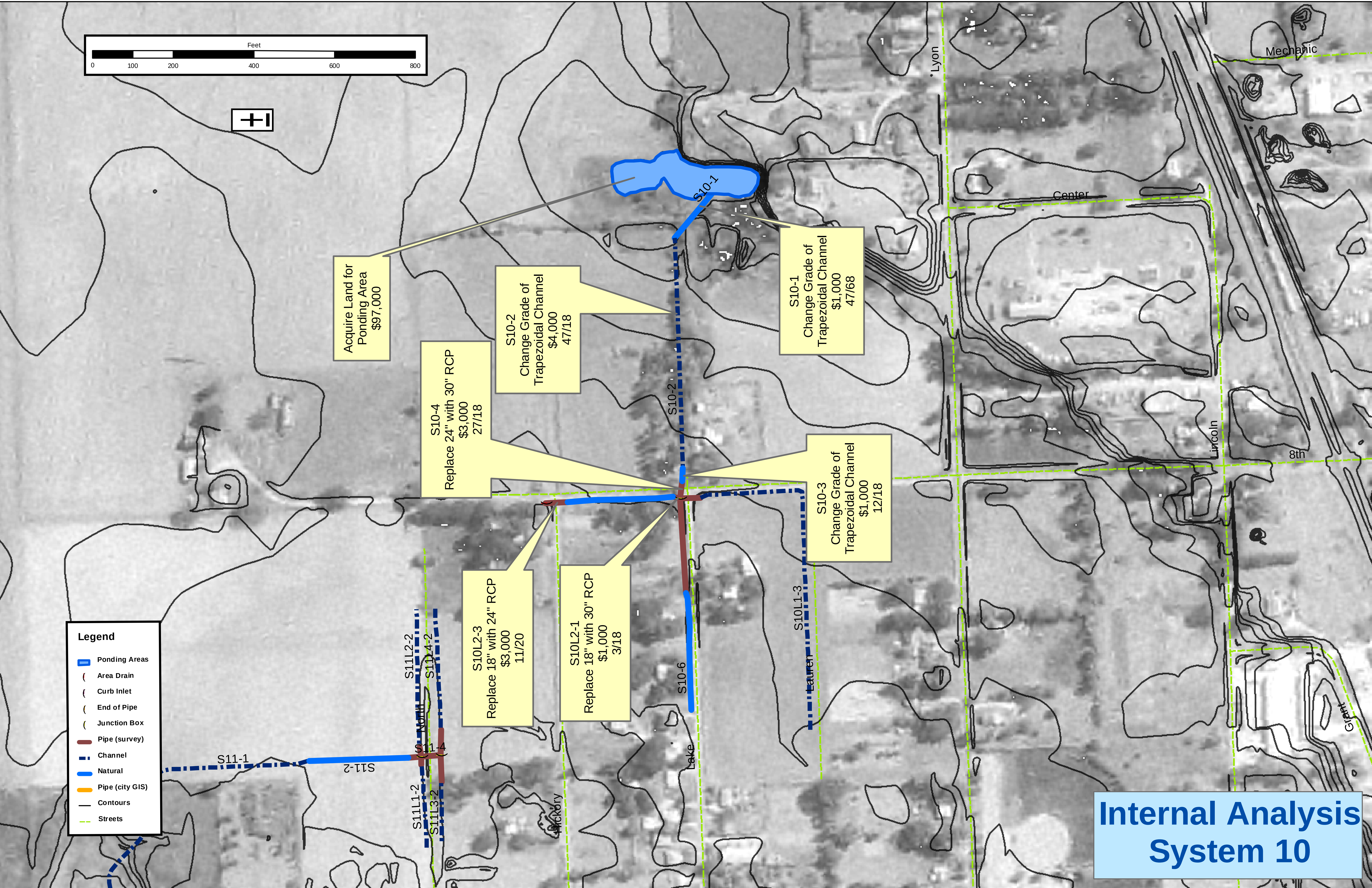
ID	Existing			Recommendation			Total Cost
	Size	Grade (%)	Q_{cap} (cfs)	Size	Grade (%)	Q_{10yr} (cfs)	
S10-1	5' flat bottom	1.08	47	5' flat bottom	0.50	68	$1,000
S10-2	5' flat bottom	0.42	47	5' flat bottom	0.50	18	$4,000
S10-3	4' flat bottom	0.41	12	4' flat bottom	0.48	18	$1,000
S10-4	24"	1.47	27	30"	1.47	18	$3,000
S10-5	24"	0.87	5	24"	---	---	---
						Subtotal Cost =	**$9,000**
S10L1-1	24"	0.85	21	24"	---	---	---
S10L1-2	5' flat bottom	0.49	13	5' flat bottom	---	---	---
S10L1-3	5' flat bottom	0.52	14	5' flat bottom	---	---	---
						Subtotal Cost =	**$0**
S10L2-1	18"	1.39	3	30"	0.46	18	$1,000
S10L2-2	4' flat bottom	0.50	49	4' flat bottom	0.50	19	$0
S10L2-3	18"	1.08	11	24"	0.49	20	$3,000
						Subtotal Cost =	**$4,000**

Land Acquisitions

Plate #	Appraised		Total Cost
	Land	Improvements	
N07659A	$36,680	$56,820	$94,000
N07660A	$3,110	$0	$3,000
		Subtotal Cost =	**$97,000**

Note: Dashed entries refer to pieces of the system that are included in GIS mapping, but did not meet the study criteria for having individual analysis in the hydrologic model. Therefore, no recommendation could be given.

Total Cost of System = $110,000



Feet
0
100
200
400
600
800
Acquire Land for Ponding Area $97,000
S10-2 Change Grade of Trapezoidal Channel $4,000 47/18
S10-1 Change Grade of Trapezoidal Channel $1,000 47/68
S10-4 Replace 24" with 30" RCP $3,000 27/18
S10-3 Change Grade of Trapezoidal Channel $1,000 12/18
S10L2-3 Replace 18" with 24" RCP $3,000 11/20
S10L2-1 Replace 18" with 30" RCP $1,000 3/18
S10-1
S10-2
S10-6
S10L1-3
S11-1
S11-2
S11-4
S11L2-2
S11L4-2
S11L1-2
S11L3-2
Lyon
Mechanic
Center
Lincoln
8th
Lauren
Lake
Hickory
Grant
Legend
Ponding Areas
Area Drain
Curb Inlet
End of Pipe
Junction Box
Pipe (survey)
Channel
Natural
Pipe (city GIS)
Contours
Streets
Internal Analysis
System 10

11. System 11

This system flows by gravity to a low-lying area on the north end of its drainage area. Only the outlet channel met the study criteria of having an individual drainage area in the hydrologic model, and therefore could be analyzed with regard to capacity during a 10-year flow event. However, an additional six pipes and five natural channels are included in the GIS mapping for the system. The outlet pipe was determined to be adequate and the recommendation is to keep the existing infrastructure in place. The ponding area sits on a single parcel of land which the City of Lawrence currently owns for use as a flooding easement.

SYSTEM 11

Conduits and Channels

ID	Existing			Recommendation			Total Cost
	Size	Grade (%)	Q_{cap} (cfs)	Size	Grade (%)	Q_{10yr} (cfs)	
S11-1	5' flat bottom	0.80	17	5' flat bottom	0.80	12	$0
S11-2	4' flat bottom	0.84	16	4' flat bottom	---	---	---
S11-3	30"	1.21	59	30"	---	---	---
S11-4	30"	1.12	43	30"	---	---	---
						Subtotal Cost =	**$0**
S11L1-1	24"	3.10	33	24"	---	---	---
S11L1-2	4' flat bottom	0.44	12	4' flat bottom	---	---	---
						Subtotal Cost =	**$0**
S11L2-1	24"	3.26	37	24"	---	---	---
S11L2-2	4' flat bottom	0.18	8	4' flat bottom	---	---	---
						Subtotal Cost =	**$0**
S11L3-1	24"	0.55	17	24"	---	---	---
S11L3-2	4' flat bottom	0.44	12	4' flat bottom	---	---	---
						Subtotal Cost =	**$0**
S11L4-1	24"	0.65	14	24"	---	---	---
S11L4-2	4' flat bottom	0.25	8	4' flat bottom	---	---	---
						Subtotal Cost =	**$0**

Note: Dashed entries refer to pieces of the system that are included in GIS mapping, but did not meet the study criteria for having individual analysis in the hydrologic model. Therefore, no recommendation could be given.

Total Cost of System = $0

Feet
0
50
100
200
300
400
S11-1
S11-2
S11L2-2
S11L4-2
North
S11L1-2
S11L3-2
Gardens
1708
1500
Legend
Ponding Areas
Area Drain
Curb Inlet
End of Pipe
Junction Box
Pipe (survey)
Channel
Natural
Pipe (city GIS)
Contours
Streets
Internal Analysis
System 11

12. System 12

This system has a gravity flow outlet through the Kansas River levee for approximately a 7 acre area. The pipe was analyzed with regard to capacity during a 10-year flow event. It was determined to be adequate and the recommendation is to keep the existing infrastructure in place. As no changes are recommended, the map for System 12 does not have any callouts.

SYSTEM 12

Conduits

ID	Existing			Recommendation			Total Cost
	Size	Grade (%)	Q_{cap} (cfs)	Size	Grade (%)	Q_{10yr} (cfs)	
S12-1	24"	1.72	9	24"	1.72	8	$0
						Subtotal Cost =	$0

Total Cost of System =	$0

C. System Naming Convention

To represent the location of each component within its respective piping network or system, a unique identification was provided. These designations are utilized within the GIS database and the XP-SWMM models. An "S" designation followed by a number is representative of the "System" that the component is within. An "L" refers to the "Lateral" within the specific system that is branching off of the main stem. A "T" refers to "Tributary" and represents the branch coming off of the lateral within the system. All numbers are consecutive and were labeled from downstream to upstream. A final number after a dash is simply the pipe or channel number. Two examples of the naming convention are provided below:

S1L2T1-2 identifies a component that is in **S**ystem **1**, **L**ateral **2**, **T**ributary **1**, and Pipe/Channel number **2**

S6L6-10 identifies a component that is in **S**ystem **6**, **L**ateral **6**, and Pipe/Channel number **10**

D. Hydrologic and Hydraulic Analyses

The hydrology of the watershed is defined by the rainfall-runoff process. APWA Section 5600 requires that the Rational Method be used to calculate peak rates of runoff to elements of enclosed and open channel systems, including inlets, when the total upstream area tributary to the point of consideration is less than 200 acres. The internal system analysis utilized the Rational Method to produce the 10-year frequency peak flow rates throughout the watershed. Rainfall was determined from an existing intensity-duration-frequency table. The runoff process is defined by the rainfall rate and a number of other factors including infiltration rate, percent impervious and slope of the land. All of these factors are site specific and can vary from sub-area to sub-area.

The XP-SWMM (StormWater Management Model) software (Version 9.5) was chosen as the primary tool for evaluation of the drainage system internal to North Lawrence. This program provides the necessary flexibility, ease of use, technical support of the company that developed the software, and the ability to integrate the GIS data.

The modeling software is modular which allows the user to choose the packages to be used for a particular model that has been created. For the watershed event simulation, the Runoff Block and Transport Block are used. The intensity-duration-frequency table, along with the characteristics of each sub-area, is used to calculate the individual runoff quantities. In the routing method of the Runoff Block, the Rational Formula applies a simplified timing technique based on the time of concentration for each sub-watershed to produce the complete hydrograph.

The Transport Block uses the results of the Runoff Block to route the hydrographs through the drainage system. The system hydraulics is defined within this module, which is used to identify system deficiencies. The hydraulic layer uses a dynamic wave routing system with a variable time step for the system.

1. Hydrologic Parameters

A rainfall intensity table for Douglas County, Kansas is provided as part of the Stormwater Management Design Criteria for the City of Lawrence. This table is included at the end of this section and was used to determine intensities for the design storm event in each of the various sub-watersheds. The total rainfall for a 10-minute duration is about 1 inch, whereas the total rainfall for a one-hour storm is about 2.5 inches for the 10 year chance of exceedence event.

The infiltration rate is a function of the moisture contained in the soil and the soil type. If a soil is saturated from recent rains, the amount of infiltration will be low as compared to a dry soil. The soil type also affects infiltration rates because certain soils will pass water more readily than others. In the North Lawrence watershed, the Wabash, Kennebec, Reading, Eudora and Kimo series are the primary soil types. The Wabash-Kennebec-Reading soils are classified as types B, C and D, which is a silt loam with a minimum infiltration rate of 0.06 to 2.0 inches per hour. The Eudora-Kimo soils are classified as types B and C, which is a sandy loam with a minimum infiltration rate of 0.6 to 2.0 inches per hour.

The type of land use is one of the most important factors controlling the amount of runoff from a watershed. The internal drainage analysis concentrated on the ultimate build-out condition in order to assess adequacy of infrastructure components. Refer to Section III of this report for details on the development of the Build-Out Scenario Map. The map provides land use categories which were related to Rational Method runoff coefficients through the use of various sources. The sources include:

- Land use assumptions in this report
- Horizon 2020
- TR-55 (Urban Hydrology for Small Watersheds from the Natural Resources Conservation Service)
- Lawrence Drainage Criteria
- APWA 5602.2

The runoff coefficient, “C”, considers the percent impervious and infiltration aspects of the watershed in a single value. The following table relates the percent impervious and corresponding Rational Method “C” value to the various land uses specified.

Land Use Hydrologic Parameters

Land Use	% Imp.	‘C’
Low Density Residential / Agricultural	10%	0.36
Very Low Density Residential	20%	0.42
Low Density Residential	50%	0.6
Suburban Residential	30%	0.48
Industrial	70%	0.72
Office / Research	60%	0.66
Commercial	90%	0.84
Community Facility	50%	0.6
Right-of-way	100%	0.9
Parks and Open Space	10%	0.36
Riparian Corridors	0%	0.3

The link between GIS and the XP-SWMM model made it possible to enter many of the parameters into the model directly from the database and mapping. After a significant effort to compile a complete, consistent map and database for the internal system, the GIS environment was used to delineate the sub-areas and develop time of concentrations. The downstream boundary of each sub-area was either at an inlet (or a manhole receiving flow from inlets) for the enclosed system, or a structure or confluence with a tributary for the open channel system. The delineated size of each area could be calculated from the polygons created during delineation. The length and slope parameters of overland flow and concentrated flow were determined in ArcView for use in a spreadsheet application.

The calculated time of concentration, T_C, is equal to the overland flow time to the most upstream inlet or other point of entry to the system, Inlet Time, T_I, plus the time for the flow in the system to travel to the point under consideration, Travel Time, T_T. $T_C = T_I + T_T$. The inlet time was calculated per the equation in section 5602.7, ensuring the inlet time was not less 5.0 minutes and not greater than 15.0 minutes. Travel Time, T_T, was calculated as the length of travel in the channelized system divided by the velocity of flow. The velocity of flow was calculated by Manning's equation assuming all system elements are flowing full without surcharge. Manual Rational Method calculations were performed for each sub-area within the watershed to verify accuracy.

A composite "C" value for each sub-area delineated during the internal analysis was created by utilizing the intersect function in ArcView. The future land use types were essentially placed on top of the drainage areas and dispersed. A breakdown of the percentage of each land use within a respective area could be obtained. Those percentages were then applied to the "C" values shown above for a weighted value.

The following hydrologic parameters were ultimately imported to the XP-SWMM modeling software:

- Drainage Area
- Runoff coefficient
- Time of concentration

2. Hydraulic Parameters

The existing drainage system components required physical characteristics such as conduit or channel size, conduit or channel length, and roughness. In addition, flowlines were needed for channels, pipes, manholes, and junction boxes. Most of this data was acquired from survey or existing City GIS. A relatively small number of values were interpolated or assumed – those interpolations and assumptions are noted in the final database.

Before transferring the database information to the hydrologic model, it was necessary to create the system in a spatially correct manner. Connectivity of the system was determined by combining the sources of data and creating the single, integrated GIS map. With that in place, coordinates of the manholes, inlets, and junction boxes were used to create the XP-SWMM model "nodes". The reliable connectivity allowed the direct transfer of pipe locations as "links" into the model.

Pipe and channel roughness values (Manning's "n") were determined using APWA 5600 and the Lawrence Stormwater Management Design Criteria. They were verified with field observations, aerial photographs, and engineering judgment. The following table shows the roughness values used to represent the piping and channels within the model.

Conduit Type	**Manning's "n"**
Concrete Pipe	0.013
Reinforced Concrete Box	0.013
Corrugated Metal Pipe	0.024
Concrete Channel	0.013
Grass Channel	0.05

The following hydraulic parameters were ultimately imported to the XP-SWMM modeling software:

- Conduit or channel dimensions
- Conduit or channel length
- Conduit or channel flowlines
- Manhole, inlet, and junction box flowlines
- Conduit roughness

THIS TABLE CONTAINS AVERAGE RAINFALL INTENSITIES
IN INCHES PER HOUR

DURATION, HR:MIN	1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
0:05	4.63	5.40	6.48	7.26	8.41	9.31	10.20
0:06	4.40	5.15	6.20	6.97	8.08	8.96	9.82
0:07	4.22	4.94	5.97	6.71	7.80	8.65	9.49
0:08	4.05	4.76	5.76	6.48	7.54	8.36	9.18
0:09	3.91	4.59	5.56	6.26	7.28	8.08	8.88
0:10	3.78	4.44	5.38	6.05	7.04	7.81	8.58
0:11	3.66	4.30	5.20	5.85	6.81	7.55	8.29
0:12	3.55	4.16	5.03	5.66	6.58	7.30	8.02
0:13	3.44	4.03	4.88	5.49	6.37	7.07	7.76
0:14	3.34	3.91	4.73	5.32	6.18	6.86	7.53
0:15	3.24	3.80	4.60	5.17	6.01	6.67	7.32
0:16	3.14	3.69	4.47	5.03	5.85	6.49	7.13
0:17	3.05	3.59	4.35	4.90	5.71	6.[illegible]4	6.96
0:18	2.96	3.49	4.24	4.79	5.57	6.19	6.80
0:19	2.88	3.40	4.14	4.67	5.45	6.06	6.66
0:20	2.80	3.31	4.04	4.57	5.33	5.93	6.52
0:21	2.72	3.23	3.95	4.47	5.22	5.81	5.40
0:22	2.65	3.15	3.87	4.38	5.12	5.70	6.27
0:23	2.58	3.07	3.78	4.29	5.02	5.59	6.16
0:24	2.51	3.00	3.71	4.21	4.93	5.49	6.05
0:25	2.45	2.93	3.63	4.13	4.84	5.39	5.95
0:26	2.39	2.87	3.56	4.05	4.75	5.30	5.85
0:27	2.34	2.81	3.49	3.97	4.67	5.21	5.75
0:28	2.28	2.75	3.43	3.90	4.59	5.13	5.66
0:29	2.23	2.69	3.36	3.84	4.51	5.04	5.57
0:30	2.19	2.64	3.30	3.77	4.44	4.96	5.48
0:31	2.14	2.59	3.24	3.71	4.37	4.88	5.40
0:32	2.10	2.54	3.19	3.65	4.30	4.81	5.31
0:33	2.06	2.49	3.14	3.59	4.23	4.73	5.23
0:34	2.02	2.45	3.08	3.53	4.17	4.66	5.16
0:35	1.98	2.41	3.03	3.47	4.10	4.59	5.08
0:36	1.94	2.36	2.99	3.42	4.04	4.53	5.01
0.37	1.91	2.33	2.94	3.37	3.98	4.46	4.93
0:38	1.87	2.29	2.89	3.32	3.92	4.40	4.86
0:39	1.84	2.25	2.85	3.27	3.87	4.33	4.80
0:40	1.81	2.21	2.81	3.22	3.81	4.27	4.73
0:41	1.78	2.18	2.77	3.18	3.76	4.21	4.67
0:42	1.75	2.15	2.73	3.13	3.71	4.16	4.60
0:43	1.73	2.12	2.69	3.09	3.66	4.10	4.54
0:44	1.70	2.08	2.65	3.05	3.61	4.05	4.48

**CITY OF LAWRENCE, KANSAS
STORMWATER MANAGEMENT
DESIGN CRITERIA**

**RAINFALL INTENSITY TABLE
DOUGLAS COUNTY, KANSAS**

TABLE A-1

THIS TABLE CONTAINS AVERAGE RAINFALL INTENSITIES
IN INCHES PER HOUR

DURATION, HR:MIN	1 YR	2 YR	5 YR	10 YR	25 YR	50 YR	100 YR
0:45	1.68	2.06	2.61	3.01	3.56	3.99	4.42
0:46	1.65	2.03	2.58	3.97	3.51	3.94	4.37
0:47	1.63	2.00	2.55	2.93	3.47	3.89	4.31
0:48	1.61	1.97	2.51	2.89	3.43	3.84	4.26
0:49	1.58	1.94	2.48	2.85	3.38	3.79	4.20
0:50	1.56	1.92	2.45	2.82	3.34	3.75	4.15
0:51	1.54	1.89	2.42	2.78	3.30	3.70	4.10
0:52	1.52	1.87	2.39	2.75	3.26	3.66	4.05
0:53	1.50	1.85	2.36	2.71	3.22	3.61	4.00
0:54	1.48	1.82	2.33	2.68	3.18	3.57	3.95
0:55	1.47	1.80	2.30	2.65	3.14	3.53	3.91
0:56	1.45	1.78	2.27	2.62	3.11	3.49	3.86
0:57	1.43	1.76	2.25	2.59	3.07	3.45	3.82
0:58	1.41	1.74	2.22	2.56	3.03	3.41	3.77
0:59	1.40	1.72	2.20	2.53	3.00	3.37	3.73
1:00	1.38	1.70	2.17	2.50	2.97	3.33	3.69
1:05	1.31	1.61	2.06	2.37	2.81	3.15	3.49
1:10	1.24	1.53	1.95	2.25	2.67	2.99	3.31
1:15	1.19	1.46	1.86	2.14	2.54	2.85	3.15
1:20	1.14	1.39	1.78	2.04	2.42	2.71	3.01
1:25	1.09	1.33	1.70	1.95	2.31	2.59	2.87
1:30	1.05	1.28	1.63	1.87	2.22	2.49	2.75
1:35	1.01	1.23	1.56	1.80	2.13	2.39	2.64
1:40	0.97	1.19	1.51	1.73	2.05	2.29	2.54
1:45	0.94	1.14	1.45	1.67	1.97	2.21	2.45
1:50	0.90	1.11	1.40	1.61	1.90	2.13	2.36
1:55	0.87	1.07	1.36	1.56	1.84	2.06	2.28
2:00	0.85	1.04	1.31	1.51	1.78	2.00	2.21
2:05	0.82	1.00	1.27	1.46	1.73	1.94	2.14
2:10	0.80	0.97	1.23	1.42	1.68	1.88	2.08
2:15	0.77	0.95	1.20	1.38	1.63	1.83	2.02
2:20	0.75	0.92	1.17	1.34	1.58	1.78	1.97
2:25	0.73	0.89	1.14	1.30	1.54	1.73	1.91
2:30	0.71	0.87	1.11	1.27	1.50	1.69	1.87
2:35	0.69	0.85	1.08	1.24	1.47	1.64	1.82
2:40	0.68	0.83	1.05	1.21	1.43	1.60	1.78
2:45	0.66	0.81	1.03	1.18	1.40	1.57	1.74
2:50	0.64	0.79	1.00	1.15	1.37	1.53	1.70
2:55	0.63	0.77	0.98	1.13	1.34	1.50	1.66
3:00	0.61	0.75	0.96	1.10	1.31	1.47	1.63

CITY OF LAWRENCE, KANSAS
STORMWATER MANAGEMENT
DESIGN CRITERIA

RAINFALL INTENSITY TABLE
DOUGLAS COUNTY, KANSAS

TABLE A-2

Section VI

Watershed Analysis

VI. Watershed Analysis

A. Overview

The North Lawrence Drainage Area is comprised of approximately 9100 acres (14 square miles), 7.9 square miles of which drain into the Kansas River through a structure in the levee along Mud Creek. This is located on the eastern edge of the drainage basin, just north of E. 1700 Road, in Leavenworth County. The North Lawrence Drainage Area is bounded by high ground on the north and a federal levee system providing protection from the Kansas River on the other three sides. There are also approximately 1.8 square miles of area, in the southwest portion of the basin, that are drained through other levee openings in that area. Those systems are addressed in the Internal Drainage System Analysis section of this report. There is approximately 0.6 square miles of overlap between the two systems along the western edge of the basin. North of 24/40 Highway and west of the airport, 3.1 square miles currently drains to the 2nd Street Pump Station in the Internal Drainage System, but the capacity of this station is quickly exceeded during significant storm events. A main focus of this section of the report addresses that issue. The purpose of this section is to explore methods of flood reduction, the consequences of development in the area and to provide recommendations for future development. Maps detailing the hydrologic and hydraulic configuration of the watershed and the recommended alternatives can be found throughout this section.

B. Recommendations

There were three main goals of the improvement alternatives: To reduce the demand on the 2nd Street Pump Station, to expel floodwater from the basin during times of high water on the Kansas River and to investigate the effects of development in the floodplain. With regard to reducing demand on the 2nd Street Pump Station, it was decided in preliminary meetings with the City that building additional gravity flow structures through the levee was not a feasible option. This left pumping and diversion as usable methods for this problem. Due to the topography of the basin, the area north of 24/40 Highway was deemed as the most suitable for both. This is a large and currently undeveloped area that drains to the 2nd Street Pump Station. It is recommended that the drainage from this area be cut off by the highway embankment and the water pumped over the levee. The existing 24/40 Highway profile is not high enough to contain the 100-year flood elevation for either the existing conditions or the improved scenarios, so if this level of containment is desired, that roadway profile would also need to be raised. The recommendation for reducing the burden on the 2nd Street Pump Station appraises the 10-year event in conjunction with the design criteria of the Internal System, however the 100-year event is investigated as well. Detailed descriptions of the different scenarios and a summary of the potential costs of each scenario can be seen in the Section E.

The recommended alternative is to block the flow from north of 24/40 Highway and pump it over the levee at a point just east of the 24/40 intersection. This will accomplish two things. It will reduce the demand on the 2nd Street Pump Station, which will lessen the flooding in the currently populated area of North Lawrence, and it will reduce the overall volume of flood water that flows east towards the Mud Creek Levee during large events. This is not the natural path for this water, so cutting off the flow from north of 24/40 Highway should reduce the burden on this system. The pumping option is recommended over other alternatives because volume reduction is one of the most viable ways to address flooding in North Lawrence and the solution can be phased in as development occurs. The pump station will consist of multiple pumps and can be built in stages. Even cutting off the flow from north of the highway could be done a piece at a time. The most likely sequence would be raising the road west of the 24/40 intersection to create the ponding reservoir and build a few pumps, then reconfigure the culverts at the 24/40 intersection, then remove the culvert that carries Maple Grove East under 24/40 Highway, etc., all the while increasing the capacity of the pump station as more water is diverted to the ponding area. This will ease the burden on the City budget and could even be financed with some type of fee on developers, matching expenditures to the need for improvements at that time. It should also be noted that the ponding area will not flood any land that is not already flooded during high flow events. It should also be noted that the diversion option that was investigated would have had a lower over-all construction cost, but would have had to be constructed all at once and would have required cutting through some highly developable properties along 24/40 Highway, east of the intersection.

The recommendation for future development in the watershed is to maintain the current conveyance levels in the 100-year floodplain. This will mean allowing no development in these areas that would reduce the capacity for floodplain storage, and may require the purchase of small parcels of land to set aside exclusively for ponding. Methods of mitigation for blockage of or fill in the floodplain are impractical or of questionable value. Due to the flat topography and the lack of a proper conveyance path that extends all the way to the outlet at Mud Creek, locally increased channel areas would be of limited effectiveness, require regular maintenance and would require large scale cooperation and long term planning with the various property owners, developers and the City. Even if those things could be accomplished, hydraulic controls near the lower end of the watershed are owned by railroads or are in Leavenworth County, which places them beyond the ability of the City to control. In general, the nature of this drainage area dictates that the current floodplain storage be maintained.

As the area develops, it will become necessary to provide emergency services to the homes and businesses that populate the area. This will require the improvement of the major roads in the area and significant improvement of the hydraulic structures which carry flow under the roads. Currently, the roads are not raised far above the floodplain and the hydraulic structures are relatively small. The result of this is that there is significant overtopping of the road during times of high flow. During such times, it is very dangerous, if not impossible, for emergency vehicles to traverse these roads. With a dense urban population, this will become unacceptable. Therefore, the roads will not only have to be improved to increase traffic capacity, but will have to be raised to meet the current APWA criteria with regard to overtopping during the 100-year event. By raising the road, it cuts off the large amount of water that used to flow across the lower roads. It is therefore necessary to provide hydraulic structures capable of passing that large amount of additional flow, while not increasing water surface elevations upstream. This results in some significant increases in required flow capacity over the existing hydraulic structures.

In an effort to quantify the various issues confronting North Lawrence, several hydraulic and hydrologic models were created. The sections below detail those modeling efforts and a detailed examination of the alternatives follows.

C. HEC-1 Model Development

1. General Project Information

Rainfall runoff, overland flow, and channel flow processes for the North Lawrence Drainage Study were simulated using the HEC-1 program developed by the Army Corps of Engineers. The model provides an estimation of the timing and volume of flows as well as the peak discharge at selected locations within the watershed. The HEC-1 program also allows for modeling of storage or backwater to assist in the calibration of the peak flows to field conditions. The peak flow is used in the hydraulic modeling to produce the water surface elevations of the floodplains. This chapter describes the methods and development of the HEC-1 models for the North Lawrence Drainage Study.

2. Data and Model Development

Data and model development includes the process to determine the shape, size, sub-area break down, and hydraulic conveyance of the entire watershed. The data sources used were:

- 2-foot contour map provided by the City
- USGS contour map of the area
- Field surveys

Best professional engineering judgment in conjunction with industry-accepted practices was used in interpreting the data sources. From the above sources, data was collected and the input information for the hydrologic model was created. The watershed characteristics found using the maps are bulleted below

- Sub-area boundaries
- Sub-area flow paths and slopes
- Channel flow lengths and slopes

3. Input Parameter Development

Input Parameter development includes the collection and subsequent input of watershed characteristics into the HEC-1 modeling program. These input parameters are:

- Sub-area size (square miles)
- Curve number (CN) as it relates to future land use
- Lag time (Tlag) – is a characteristic of the watershed, which is defined as equal to the time from the center of mass of the excess rainfall to the time of the peak. The HEC-1 program assumes this relationship to be: Tlag = 0.6*Tc, where Tc is the time of concentration.
- 8 point representative channel cross section for the computation of Muskingum-Cunge channel routing.

Sub-area Size

Sub-area boundaries were determined using contour maps, but sub-area size was measured with ArcView GIS software. The average sub-area size was approximately 150 acres. The acreage of each sub-area was dependent upon its proximity to the location of confluences and structures.

Curve Number

The Build-Out Scenario Map was assigned Curve Numbers for each land use. ArcView used the land use and sub-areas coverages to determine which future land use polygons were contained in each sub-area. The future land use polygons contained within a sub-area boundary were labeled with the sub-area name and the area of each land use was calculated. A curve number was associated with each of these land uses and a weighted curve number was computed in a spreadsheet. Curve numbers are shown below**.**

Curve Numbers

Land Use	**Density**	**CN**
Agricultural	I unit/ 5 acres	75
Very Low Density Residential	1 unit/ 1 acre	78
Suburban Residential	3 units/ 1 acre	81
Low Density Residential	6 units/ 1 acre	86
Industrial	-	91
Office Research	-	88
Commercial	-	96
Community Facility	-	86
Right-of-Way	-	98
Parks and Open Space	-	75
Riparian Corridors	-	73

Lag Time

Lag times for the watersheds were found using the relationship $T_{lag} = 0.6*T_c$, where T_c is the time of concentration. The time of concentration was found using the Stormwater Management Criteria Manual of the city of Lawrence. The City defines time of concentration as the sum of the overland flow time, the shallow concentrated flow time and the channel flow time. Table D and Figures 1 and 2 from the Stormwater Management Criteria Manual were used to find these times respectively. Some sub-areas were extremely flat and a value could not be read off of Figure 2 to determine the channel flow time. In these instances, a minimum velocity of 1.5 feet per second was assumed to estimate the channel flow time.

8-point Representative Channel Cross Section

The Muskingum-Cunge reach routing methodology was used for this study. The physical channel properties used for Muskingum-Cunge routing methodology are an 8-point representative channel cross section, reach length, Manning's "n", and channel bed slope. The engineers selected the best representative 8-point cross section for each channel routing reach from contour mapping. The X and Y coordinates of the cross section, the Manning's "n", and the channel bed slope were then entered into HEC-1.

4. Naming Conventions

First order tributaries are streams that flow directly into the Kansas River, second order tributaries flow into first order tributaries, third order tributaries flow into second order tributaries and so on. One first order tributary and two second order tributaries were named on the current FEMA FIRM maps. These names were retained in the naming scheme for the hydrology and hydraulic models.

The HEC-1 program is a DOS program based on 8 character sets. The first two characters "KK" indicate a HEC-1 hydrograph calculating routine in which the last six characters are a unique identifier for that routine. A five-character name identifier followed by a one-letter modeling descriptor was used in the HEC-1 model for the North Lawrence Drainage Study.

Name Identifier

In order to represent the location of each sub-area relative to its location on the stream network, one character was used for each tributary (first through fourth) downstream of the sub-area being named. Along each stream, the sub-areas were then numbered (1, 2, 3, etc.) starting from the upstream end and proceeding downstream. Specific details about the HEC-1 naming at each tributary level are given in the following sections.

First Order Tributary

There is one first order tributary located in the study area. The tributary name is listed below with the single character identifier used in the HEC-1 naming convention.

M	Maple Grove Drainage

Second Order Tributaries

The four second order tributaries were named in one of two ways. Two of the second order tributaries have names on the current FEMA FIRM maps, Maple Grove East Fork and Maple Grove West Fork. In these instances either "E" or "W" was used as a second order identifier. The remaining tributaries were then named alphabetically (a, b) starting from the downstream end of the first order tributary they flow into. In the HEC-1 naming convention, the sub-areas going to a second order tributary use two characters to identify them. The first character is the first order tributary name and the second is the second order tributary name. Each second order tributary name is listed below with the two-character identifier used in the HEC-1 naming convention.

ME	Maple Grove Drainage East Fork
MW	Maple Grove Drainage West Fork
Ma, Mb	Tributaries Maple Grove Drainage

Modeling Descriptor

The last digit in the HEC-1 naming convention describes the hydrograph calculation process that the HEC-1 program is doing during each hydrograph calculation routine. The hydrographs are either (1) being created from the drainage basin, (2) being routed through a channel to a downstream location, or (3) being combined with other drainage basin hydrographs. The key for the single digit modeling descriptor is shown in the table.

Modeling Descriptor Key

Descriptor	Hydrograph Calculation Routine	Remarks
A	Drainage Area	Hydrograph calculated from sub-area characteristics and precipitation inputs.
R	Routing	Hydrograph routing through channels.
L	Local Combine	Points where hydrographs along a single stream are combined.
T	Tributary Combine	Points where tributary hydrographs are combined together to get total flow at a junction.

In the HEC-1 model, the modeling descriptor is attached to the name identifier. Some examples of a complete unique identifier used in the Maple Grove Drainage watershed are as follows:

MW_1A Drainage area routine for Basin "1" of Maple Grove West Fork to Maple Grove Drainage

ME_7L Combine multiple hydrographs at the downstream point of Basin "7" of Maple Grove East Fork

M_7T Combine tributary hydrograph with Maple Grove Drainage hydrograph at the downstream point of Basin "7" of Maple Grove Drainage.

Mb_3R Channel routing routine for Basin "3" on Trib "B" to downstream point of Basin "4" on Trib "B".

5. **Hydrologic Methodology**

For the North Lawrence Drainage Study, a 24-hour Type II design storm was utilized. The rainfall depths for the storm event were obtained from the Rainfall Frequency Atlas of the United States.

Rainfall Depths (inches) For a Type II 24-hour Duration Storm

Duration	Return Period					
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
24 hr	3.49	4.59	5.31	6.15	6.88	7.7

The North Lawrence Drainage study required storage routing behind Highway 24 at the East and West Fork confluence and at the downstream end of Maple Grove drainage at the Union Pacific Railroad. The dam routine in HEC-1 was utilized. Elevation-area and elevation-discharge data was developed. The rating curve (elevation-discharge data) was developed from the HEC-RAS model. A range of flows was entered into HEC-RAS for the tributary with the structure requiring storage calculations. The resulting water surface elevations versus the discharges were then recorded and entered into a spreadsheet to create the rating curve. Values from this curve were then entered into HEC-1. The peak elevations from the HEC-1 model output were then compared to the HEC-RAS developed curve again to make sure that the modeled structure and the hydrologic model were producing similar water surface elevations for a particular peak flow.

2nd Street Pump Station

The 2nd Street pump station consists of two pumps each with a capacity of 45 cfs. The pumps are located on 2nd Street in the south western part of the study area. The HEC1 flows were reduced by 90 cfs where appropriate before entering them into the HEC-RAS model to account for the pump station.

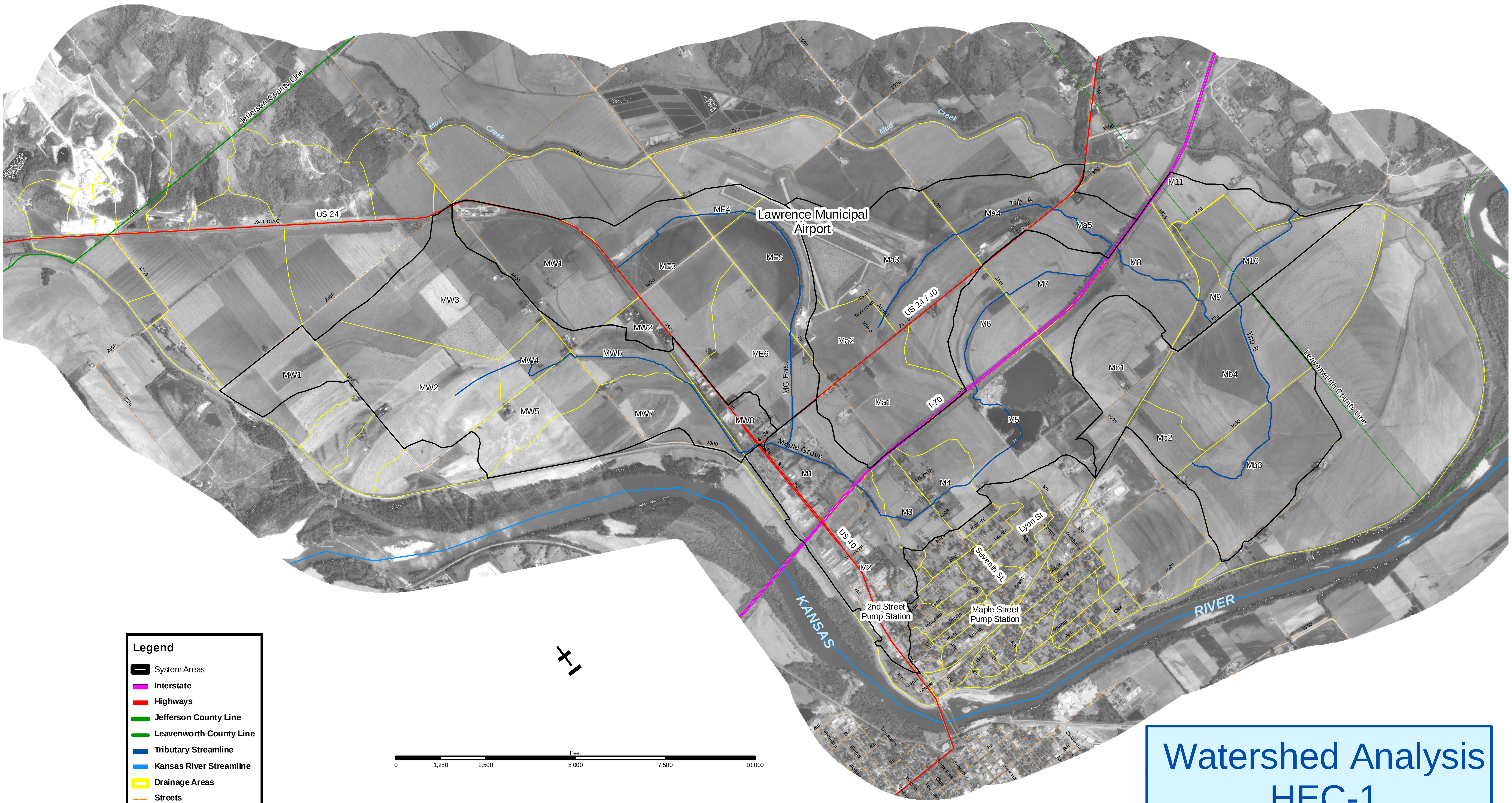
6. Model Comparison

The new HEC-1 model results were compared to the flows that are published in the FEMA study. This data is only available for Maple Grove drainage and East and West Forks. The comparison is shown in the table.

Previous Flows versus Restudy Flows (cfs)

	FEMA Study/**North Lawrence Drainage Study**					
	2 yr	5 yr	10 yr	25 yr	50 yr	100 yr
Maple Grove Drainage						
At Douglas-Leavenworth County line	**450**	**774**	2190/**1160**	**1548**	3730/**1893**	4490/**2348**
1,400 feet upstream of Interstate 70	**344**	**526**	1450/**741**	**947**	2470/**1126**	2960/**1337**
At Ninth Street	**428**	**630**	1280/**849**	**1068**	2180/**1265**	2610/**1510**
Upstream of confluence with Maple Grove Trib.	**323**	**498**	1030/**723**	**935**	1750/**1118**	2100/**1315**
Maple Grove Drainage East Fork						
Below U.S. Highway 40	**256**	**362**	559/**496**	**633**	952/**745**	1140/**879**
Downstream of County Road 173/1900	**201**	**294**	292/**406**	**515**	497/**602**	592/**707**
Maple Grove Drainage West Fork						
Below U.S. Highway 40	**406**	**632**	559/**894**	**1154**	952/**1365**	1140/**1631**

The difference between the flows from the two sources is the methodology used to calculate them. This study calculates flows based on the unusual characteristics specific to the North Lawrence Drainage Area. The FEMA Study uses equations developed by regression analysis using general characteristics common to streams of all sizes from across the entire region.



Watershed Analysis HEC-1

D. HEC-RAS Model Development

1. General Project Information

The HEC-RAS, version 3.1.1 hydraulic model was used to produce water surface elevations along each stream. The information required to build a hydraulic model is as follows: hydraulic characteristics of culverts, bridges, dams, low water crossings, and open channels, in conjunction with the peak flows determined in the HEC-1 model. This model was developed for the Maple Grove Drainage system, ignoring influence of the Kansas River.

2. Data Sources

Data and model development includes the process to determine the primary stream network, cross section geometry, flow lengths, bank stations, and Manning's "n" values for the entire watershed. The data sources used were:

- Planimetric information in GIS format provided by the City
- Topographic information provided by the City
- Digital elevation data in the form of a triangular irregular network (TIN) generated using GIS and topographic information
- Aerial photographs provided by the City
- Field surveys of stormwater drainage structures and roadways provided by Landplan Engineering of Lawrence
- Current FEMA HEC-2 model prepared by GBA

Best professional engineering judgment in conjunction with industry-accepted practices was used in interpreting the data sources.

3. Input Parameter Development

From the above sources, data was collected and the input information for the hydraulic models was created using GeoRAS, an ArcView extension that compiles GIS data into an input file for the HEC-RAS model. The development of these input parameters is described individually in the following sections.

Primary Stream Network

The primary stream network was developed using ArcView. The network includes channels that are fed by a drainage area of 240 acres or more. Small "stubs" or tributaries that are not long enough to place three or more cross sections along the stream were removed from the HEC-RAS model because the short distance is usually controlled by the receiving stream and mapped at that water surface elevation.

Naming Convention

Four separate streams were modeled in HEC-RAS. The first order tributary and two of the second order tributaries were named on the current FEMA FIRM maps. These names were retained in the hydraulic model. Maple Grove West Fork was combined with Maple Grove Drainage to model a continuous main stream. The remaining two second order tributaries were named alphabetically.

First Order Tributary
There is one first order tributary located in the study area. The tributary name is listed below with the identifier used in the hydraulic model

Maple Grove Fork   Maple Grove Drainage combined with Maple Grove West

Second Order Tributaries
There are four second order tributaries in the study area. Maple Grove West Fork was combined with Maple Grove Drainage and the remaining three tributary names are listed below along with the identifier used in the hydraulic Model

MG East   Maple Grove East Fork
Trib A   Tributary A to Maple Grove Drainage
Trib B   Tributary B to Maple Grove Drainage

Cross-Section Development

A cross section shape-file was created using ArcView. Cross sections were generally placed 200 to 500 feet apart along each stream centerline. Near structures, the cross sections were placed as recommended in the HEC-RAS modeling manual. A section was placed off of the embankment at the upstream and downstream face of each structure. Two more sections were then placed a distance upstream and downstream of the structure where the flow is fully expanded. Cross sections were drawn to best represent the channel and floodplains in the area. GeoRAS used this coverage to intersect the stream centerlines, flowpaths, and locate the TIN elevation that represents the ground surface in the HEC-RAS model.

Flowpath Lengths

A flowpath lengths shape-file was created for use in the GeoRAS export. The flowpaths follow the stream centerline at a distance to the right or left where approximately two-thirds of the water in the floodplain is contained. GeoRAS used this coverage to create left and right overbank reach lengths. GeoRAS used this file to create the geometry export file for HEC-RAS.

Manning's "n" Values

Manning's "n" values were determined using field observations, aerial photographs, and engineering judgment. The values were entered directly into the HEC-RAS model. The following table shows the Manning's "n" values used to represent the common groundcover or land use conditions.

Overbank Manning's "n" Values

Groundcover condition	**Manning's "n"**
Trees	0.10
Moderately treed	0.08
Crops or grassland	0.04
Natural Channel	0.045

The Manning’s “n” values for the channels in the North Lawrence Drainage study follow the trends shown. Some values may be slightly different in the HEC-RAS models due to engineering judgment of a specific location.

Structure Manning’s “n” Values

Structure Material	**Manning’s “n”**
Concrete	0.013
Corrugated Metal	0.021
Steel	0.013

Manning’s “n” values of structures were mainly determined by field observations. The guideline tables in the HEC-RAS manual were generally followed. Specific material type and Manning’s “n” values are shown in the table above.

Roadway Crossings

Structures at roadway crossings were entered directly into the HEC-RAS model. The cross sections upstream and downstream provided by GeoRAS were supplemented with survey information. This allowed for a more accurate representation of the channel and structure opening at roads and railroads. Road and railroad structures were mostly created by using field observations, photographs, and survey data. If the survey information along the roadway surface (deck) did not extend the length of the upstream and downstream cross sections, the elevation along the remaining length was determined using the contours provided by the City.

Modeling methods and parameters for each structure (such as Chart and Scale # for culverts or energy, momentum, Yarnell’s equation for bridges) were determined using field observations, photos, and engineering judgment. Coefficients used for each modeling method were chosen from the tables provided in the HEC-RAS manual.

Expansion/Contraction Coefficients

Expansion and contraction coefficients were left at the default 0.1 and 0.3, respectively, for all sections not near structures. As the HEC-RAS manual recommends, 0.3 and 0.5 were used as the coefficients on two cross sections upstream and one cross section downstream of any bridge or culvert.

Boundary Conditions

Normal depth was used to calculate the downstream boundary condition on all streams. The slope was calculated by reading elevations from the contours near the downstream end of each stream and dividing by the channel length between elevations.

Ineffective Flow Areas

Ineffective flow areas were placed near structures according to the HEC-RAS manual. The width of the ineffective flow stations was determined from a 1:1 ratio from the face of the structure on the upstream cross section and a 2:1 ratio from the face of the structure on the downstream cross section. The elevations were generally set at the low point in the embankment on the upstream side and between the embankment and the low chord on the downstream side.

Ineffective flow options were also used to limit flow in the floodplain on cross sections where engineering judgment deemed the flow could not extend across the entire area shown in the cross section. The locations were generally determined by contours and aerial photos as well as evaluating the model results. Obstructed areas were also used to prevent flow to specific areas. Most commonly obstructed areas are isolated low areas such as ponds.

Channel Bank Stations

Channel bank stations were placed at the point in which the ground broke its vertical climb out of the channel and changed to a gentler slope. The bank stations were set using the graphical cross section editor in HEC-RAS.

4. Results

The water surface elevations were very similar to the published FEMA values, despite the significantly lower discharges. This can be explained by the extremely wide flat floodplain with very little to no slope. Also, the significantly undersized culverts remain unchanged and are a controlling factor in the water surface elevation. Differences of one foot or more are listed below.

Maple Grove Drainage: The water surface elevation for the area between North 9th Street and North 7th Street decreased from approximately 821.5 ft to 820.0 ft.

Maple Grove East Fork: The water surface elevation at the mouth decreased from approximately 823.75 ft to 822.65 ft.

Maple Grove West Fork: The water surface elevation for the downstream portion increased from approximately 823.0 ft to 824.2 ft.

E. Alternatives for Future Development

Several alternatives were investigated to alleviate flooding problems in the North Lawrence watershed. Some had greater or lesser merits and some proved impractical altogether. Detailed below are some of the alternatives considered. Not all are included in the recommendations.

The External System was modeled as one main reach, extending from the Mud Creek Levee up through the northwest-most contributing area, and three tributary streams: Tributary A, just south of the airport; Tributary B, in the southeast portion of the basin; and Maple Grove East, just west of the airport. It should be noted that this is not a well defined stream throughout its entire length. During low flow events, water may pond and infiltrate or flow back towards the Internal Drainage System. During high flow this represents the flow path, with the lower five miles of the main reach coinciding with the FEMA floodway. It should be noted however, that this is not the natural flow path for the waters west of the airport. Refer to the accompanying maps for further clarification of the hydraulic and hydrologic configuration of the basin.

While the details of the modeling are discussed in previous sections of this report, there are a few key features pertinent to the alternatives discussed here that should be reiterated. This entire area is very flat, which results in significant ponding until enough hydraulic head can develop to push the water downstream. When the water does begin to flow, it has relatively low velocities. There are major hydraulic constrictions near the Mud Creek levee. Two of them are undersized structures through railroad embankments, which place them beyond the scope of this study to remediate. There is also the roadway embankment along 7th Street (1500 Road) and the high ground between there and 9th Street that has a significant effect on the hydraulic profile upstream. Several scenarios were investigated for alleviating the potential flooding in this area, but the topography of the basin prevents significant improvements in flood elevations on a large scale.

1. Flood Reduction Alternatives

As stated earlier, the cornerstone to the recommendations in this report is greatly reducing the burden on the 2nd Street Pump Station. This is to be accomplished by cutting off the flow from north of 24/40 Highway. This is a relatively large and currently undeveloped area that has the potential to add a great deal of volume to the existing flooding problem when developed.

A diversion channel was modeled along 24/40 Highway, from near the 24/40 intersection, east to connect with Tributary A near Airport Road. This would require the existing 6'x4' culvert that runs diagonally under the 24/40 intersection and the 36" culvert that drains the area to the northeast into the intersection be removed or greatly reduced in capacity to remove the flow from the 2nd Street Pump Station or allow only low flows to travel that path, as they do now. A new east-west 2-6'x5' culvert would be built under 24 Highway, north of the intersection to connect the northwest area to the diversion channel. Another 2-12'x10' culvert would be built to carry the diversion channel under 1500 Road. The diversion channel would be a trapezoidal channel with 3:1 side slopes and a five foot bottom width. The channel would have to flair out to match up with the 1500 Road culvert, and includes a high flow bench on the north side near the eastern end to allow a smoother transition to the Tributary A channel. This scenario would also require the elimination of the 6’x5’ RCB that currently carries Maple Grove East Tributary under 24/40 Highway. Unfortunately, this channel would have to be aligned through some of the highest ground in the entire basin, resulting in a deep and wide channel with approximately 90,000 cubic yards of excavation, which would result in construction costs on the order of $2.5 million.

Another method of dealing with the excess water from the northwest areas is to pump it over the levee. The culverts at the 24/40 intersection and the Maple Grove East culvert would be removed and the new east-west culvert under 24 Highway would still be required, as in the diversion option described above. A large area north of 1800 Road and east of 24 Highway would become a pumping reservoir, ponding to an elevation of approximately 822 feet for the 10-year and approximately 825 feet for the 100-year. It should be noted that the elevation at the intersection of 24 and 40 Highways is approximately 822 feet. To contain the 100-year event, would require raising 24/40 for approximately 2000 feet east of the railroad and 24 highway for approximately 1000 feet north of the intersection, at a cost of approximately $800,000. This ponding area could be reduced by building berms to protect certain areas and/or increasing pumping capacity to compensate for the loss of storage. Another alternative would be to build two pump stations. One at the current site would function in a reduced capacity, while another east of 24/40 Highway would pump the water from Maple Grove East directly over the levee. This would require a berm to capture the water and would probably be more expensive overall, but could be justified if property costs and location dictate the design. The cost for the pumps and controls to handle the 10-year flow, approximately 800 cfs, would be approximately $1.7 million. To pump the 100-year discharge, the cost would increase to approximately $3.0 million. Total costs for pumping stations are highly variable, and depend on the level of redundancy desired with regard to backup pumps, power supplies, outlet works, etc. and ancillary components such as pump houses and inlet and outlet works. Depending on the desired capacity and configuration, the total cost for the station could exceed $10 million. Pump costs for this scenario are independent of the Kansas River elevation. Because the system would route the water over the top of the levee, the total system head would be controlled by the top-of-levee elevation.

An investigation was performed to evacuate flood water from the basin during times of high flow on the Kansas River. Using methodology developed by the Corps of Engineers, for determining coincident flows based on the ratio of drainage areas, it was determined that the coincident events for the North Lawrence Drainage Basin and the Kansas River were the 100-year and the 4-year events. This means that for a 100-year event on the Kansas River, you could expect a peak event equivalent to the 4-year event in the North Lawrence basin, and vise versa. The 10-year design for the northwest area described above would have the capacity for that coincident event and, as noted previously, that system is independent of the Kansas River elevation in any case. At the east end of the basin, where the discharge is by gravity flow through the levee, a 100-year Kansas River event would require the closing of the Mud Creek structure to prevent back flow from the Kansas River. A pump station at that location to handle the 4-year event would require approximately a 300 cfs capacity. The pumps and controls for that facility would cost approximately $0.8 million. Once again costs for the associated facilities are highly variable, but could cost approximately $4 million.

Of these alternatives, cutting off the flow from the 2nd Street Pump Station and pumping it over the levee is deemed the most feasible and as having the greatest benefit to the North Lawrence Drainage Area. The diversion channel, while less expensive to construct, would require a large section of developable property along more than half a mile of 24/40 Highway. Additionally, it would result in only localized improvements in flood elevations and would significantly increase flood elevations in the lower portions of Tributary A, due to the hydraulic restrictions discussed earlier. The pump station at the east end of the basin is not recommended due to its cost and the statistical improbability of the design event.

2. Future Hydraulic Drainage Improvements

As the area develops, the need for uninterrupted transportation and emergency services will increase. An investigation was undertaken to assess the requirements for raising the major roads above the 100-year elevation and building hydraulic structures that would pass the 100-year with out increasing the backwater. A summary of the improvements and associated costs can be found in the tables at the end of this section. In the North Lawrence basin there are approximately 5 miles of roads that would fall under these criteria. To construct major arterial streets on mostly borrowed fill and only across the 100-year floodplain and upgrade the associated hydraulic structures to pass the flows without causing increased flooding upstream would cost approximately $14.3 million. This does not include ancillary items such as interface with other roadways, bridges, traffic control devices, right-of-way acquisition, etc. There are fourteen hydraulic structures on these roads in the current model. The cost of each project is shown in the table at the end of this section.

There has been some development in this area already and questions have arisen regarding the effects of fill placed in the floodplain. A study was conducted to assess the effects and determine a general mitigation strategy for future development. In a test reach, a large area was blocked off in the 100-year floodplain to simulate development that might place fill in the area to elevate the property above the 100-year flood elevation. While this does not have a large effect on the flood profiles, due to the basin factors already discussed, the cumulative effect of large scale development will have a detrimental affect on the flood elevations upstream. Also a concern is the reduction in routing storage. One advantage to the low hydraulic gradient and low velocities in this system is a significant attenuation of flood peaks as they move through the basin. If the flow is constricted, it will reduce this phenomenon, resulting in increased peak flows. The investigation revealed that restoration of at least 70% of the flow area lost to fill, through overbank benching, would be required to mitigate the increase in flood elevations. However, this would reduce the routing storage and would require regular maintenance and large scale planning and coordination to achieve the desired affect. While these measures could theoretically maintain the 100-year flood elevations in the basin, this methodology is not deemed practical as a watershed planning program.

Watershed Recommendations Cost Summary

Description	Quantity	Unit Cost	Project Costs
Raise road west of 24/40 intersection	370 ft	$290/ft	$110,000
Remove 2 existing 24/40 culverts	Lump Sum		$75,000
Channel Excavation, MG0East to 24/40	3500 cu-yd	$4.31/cu-yd	$15,000
KDOT Entrance Culvert	30 ft	$8/ft/sq-ft	$27,000
New 24/40 Culvert	475 ft	$8/ft/sq-ft	$228,000
Remove Maple Grove East culvert	Lump Sum		$22,000
Property containing ponding easement	Full Parcels	Total Value	$942,000
Pump Station; west of airport, north of 24/40	361,000 gpm *	$30/gpm	$11,000,000
Main Channel, E. 1675 Rd., 155' Bridge	7750 sq-ft	$75/sq-ft	$1,364,000
Main Channel, E. 1675 Rd., Roadway	2700 ft	$290/ft	
Main Channel, E. 1600 Rd., 160' Bridge	8000 sq-ft	$75/sq-ft	$1,108,000
Main Channel, E. 1600 Rd., Roadway	1750 ft	$290/ft	
Main Channel, E. 1500 Rd., 155' Bridge	7750 sq-ft	$75/sq-ft	$929,000
Main Channel, E. 1500 Rd., Roadway	1200 ft	$290/ft	
Main Channel, E. 1400 Rd., 140' Bridge	7000 sq-ft	$75/sq-ft	$786,000
Main Channel, E. 1400 Rd., Roadway	900 ft	$290/ft	
Main Channel, E. 1900 Rd., 140' Bridge	7000 sq-ft	$75/sq-ft	$1,221,000
Main Channel, E. 1900 Rd., Roadway	2400 ft	$290/ft	
Maple Grove East, E. 1500 Rd., 100' Bridge	5000 sq-ft	$75/sq-ft	$1,419,000
Maple Grove East, E. 1500 Rd., Roadway	3600 ft	$290/ft	
Maple Grove East, E. 1900 Rd., 120' Bridge	6000 sq-ft	$75/sq-ft	$1,581,000
Maple Grove East, E. 1900 Rd., Roadway	3900 ft	$290/ft	
Maple Grove East, E. 1500 Rd., 120' Bridge	6000 sq-ft	$75/sq-ft	$711,000
Maple Grove East, E. 1500 Rd., Roadway	900 ft	$290/ft	
Trib. A, 24/40 Hwy., 2-11'x7' RCB	60 ft	$8/ft/sq-ft	$326,000
Trib. A, 24/40 Hwy., Roadway	870 ft	$290/ft	
Trib. A, E. 1600 Rd., 60' Bridge	3000 sq-ft	$75/sq-ft	$477,000
Trib. A, E. 1600 Rd., Roadway	870 ft	$290/ft	
Trib. B, E. 1700 Rd., 140' Bridge	7000 sq-ft	$75/sq-ft	$1,758,000
Trib. B, E. 1700 Rd., Roadway	4250 ft	$290/ft	
Trib. B, E. 1650 Rd., 100' Bridge	5000 sq-ft	$75/sq-ft	$703,000
Trib. B, E. 1650 Rd., Roadway	1130 ft	$290/ft	
Total			$24,802,000

Note: All costs are concept level estimates only. Actual costs may vary significantly.

* Required capacity at ultimate build-out

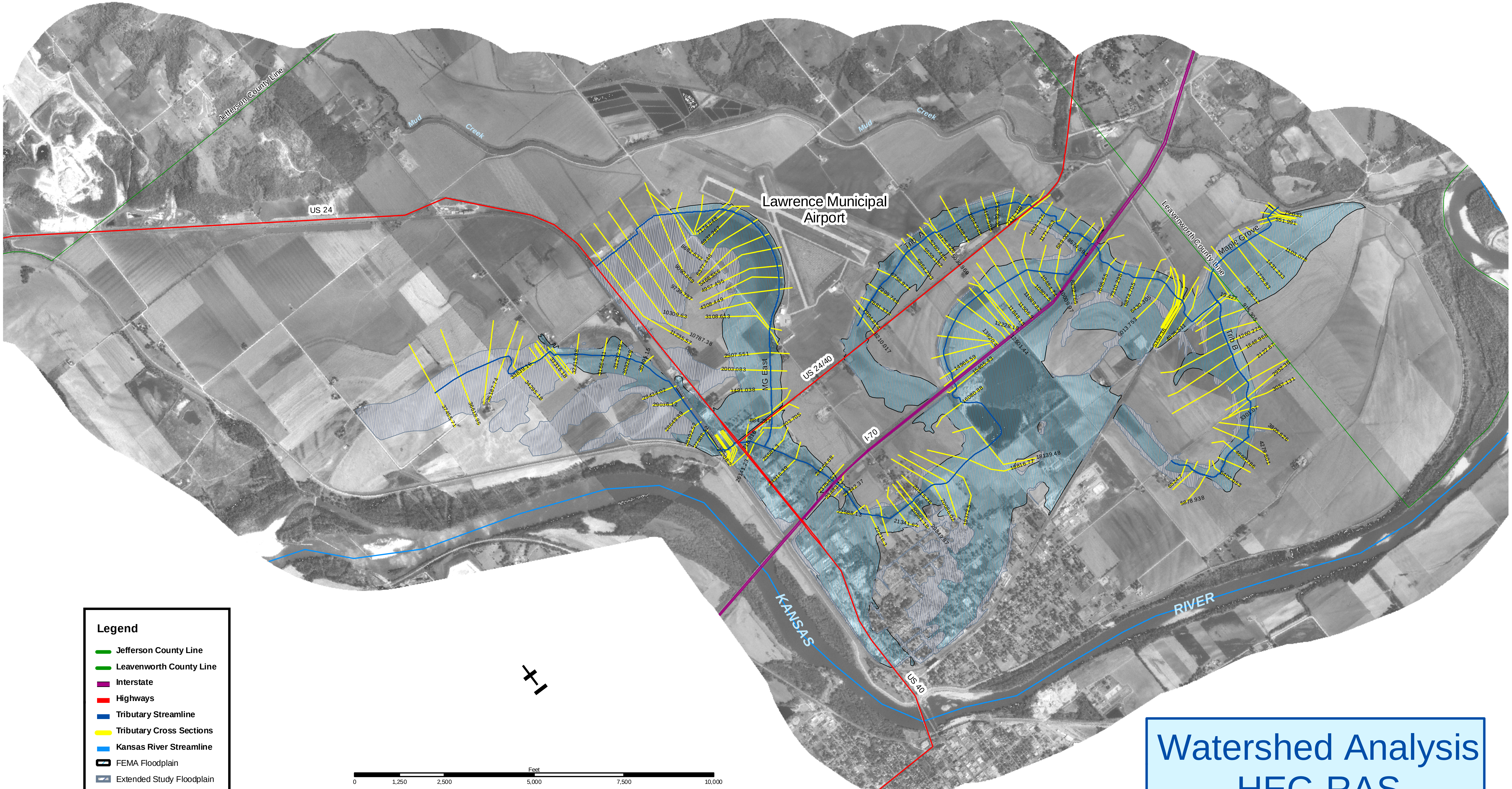
3. Summary

Several alternatives were investigated in the North Lawrence Drainage Basin to reduce flood elevations, lessen impacts on "Internal" facilities, provide drainage in the event of high flows on the Kansas River and assess the effects of development in the floodplain.

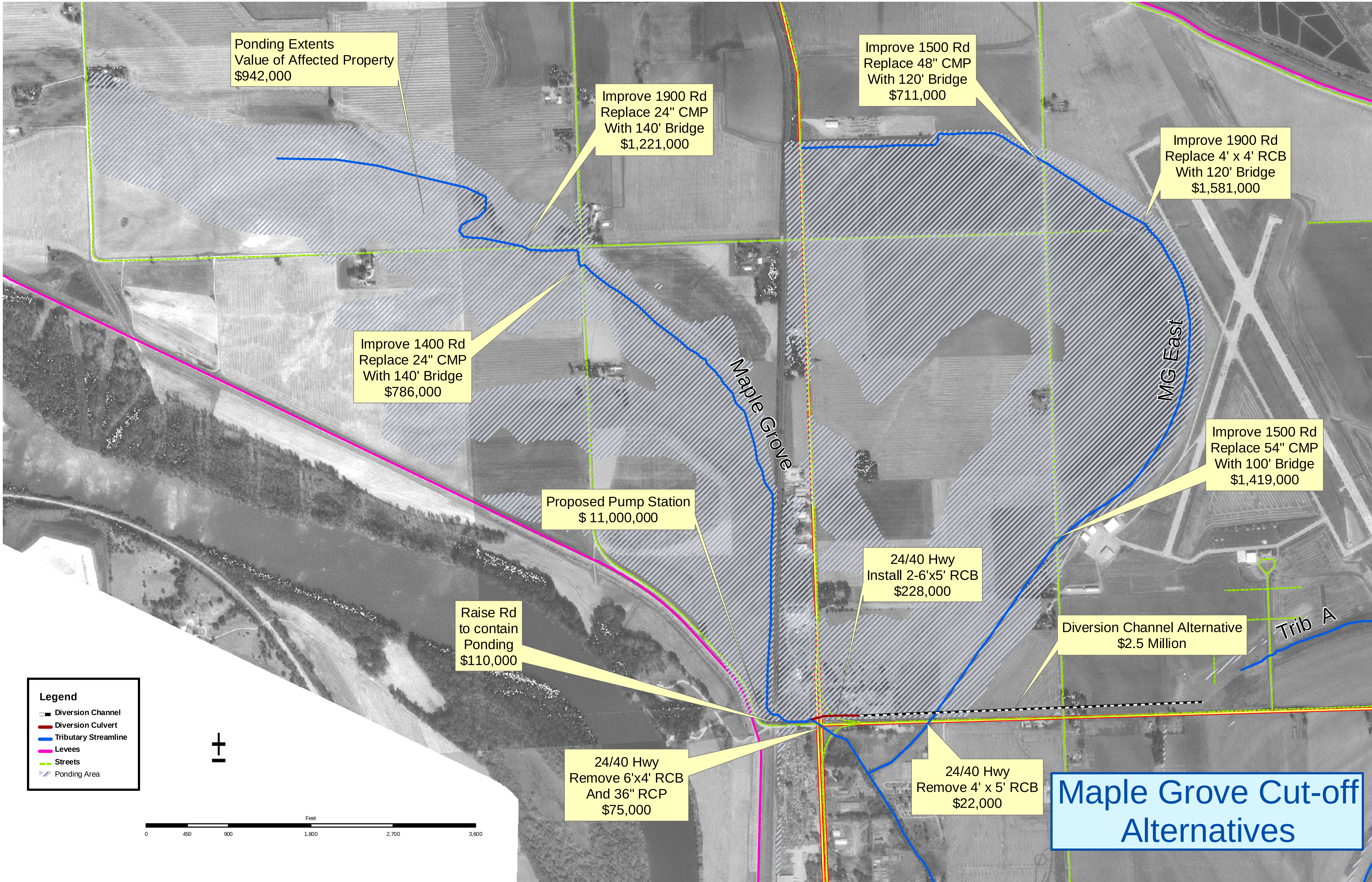
The recommended improvements begin with cutting off the flow from north of 24/40 Highway. This is necessary to reduce the burden on the 2nd Street Pump Station and the total volume of runoff flowing into the Maple Grove system. While other options were investigated, the recommended alternative is to cutoff the areas northwest of 24/40 Highway and then pump the water over the levee. This option is desirable due not only to its effectiveness, but also due to the fact that the solution can be constructed in phases. A staged solution lends itself to fiscal flexibility for the City and the possibility of financing the project(s), or a specific phase of the projects, with fees from developers as the area expands. For instance, the City could pay to raise the roads and alleviate the flooding in the airport area first, then development could help to fund the increase in capacity necessary to account for the increase in runoff caused by future development. Variations on the basic configuration are possible in this area, including allowing low flows to maintain their current path towards the 2nd Street Pump Station and increasing the pump station capacity to handle the 100-year discharge.

Future development in the project area will result in a need for improved roadways. The mile-section roads were modeled as being raised up out of the floodplain and fitted with hydraulic structures that resulted in no backwater. As the area develops, it will be necessary to keep the floodplain available for storage. Therefore no development should be allowed that reduces the capacity of the floodplain to attenuate the flood peaks.

While there are many options for improving the flooding issues in the North Lawrence Drainage Basin, the nature of the drainage area make some solutions more practical than others. This area lacks a well defined channel, at a consistent gradient for a significant portion of its length. Additionally, there are some significant impediments to conveyance throughout the reach, especially in the lower portion near Mud Creek. While construction of countermeasures may be effective in solving some of the problems, maintaining the existing storage volume will play a large part in the future flooding patterns. The portion of the drainage area in Leavenworth County faces the same kind of issues as described in this report and future development will likely increase flow in that area as well.



Watershed Analysis HEC-RAS


Ponding Extents
Value of Affected Property
$942,000
Improve 1900 Rd
Replace 24" CMP
With 140' Bridge
$1,221,000
Improve 1500 Rd
Replace 48" CMP
With 120' Bridge
$711,000
Improve 1900 Rd
Replace 4' x 4' RCB
With 120' Bridge
$1,581,000
Improve 1400 Rd
Replace 24" CMP
With 140' Bridge
$786,000
Maple Grove
MG East
Improve 1500 Rd
Replace 54" CMP
With 100' Bridge
$1,419,000
Proposed Pump Station
$ 11,000,000
24/40 Hwy
Install 2-6'x5' RCB
$228,000
Raise Rd
to contain
Ponding
$110,000
Diversion Channel Alternative
$2.5 Million
Trib A
24/40 Hwy
Remove 6'x4' RCB
And 36" RCP
$75,000
24/40 Hwy
Remove 4' x 5' RCB
$22,000
Legend
Diversion Channel
Diversion Culvert
Tributary Streamline
Levees
Streets
Ponding Area
Feet
0
450
900
1,800
2,700
3,600
Maple Grove Cut-off
Alternatives

Section VII

Kansas River Floodplain Analysis

VII. Kansas River Floodplain Analysis

A. Purpose

The effective FEMA hydraulic model was revised to approximate the amount of flooding that would occur in the North Lawrence area in the event of a breach of the Kansas River levee system. A "most likely" breach location was determined for the purpose of this analysis.

B. Results

To determine the "most likely" breach location the model was run with peak flows in excess of the 100-year storm to determine the first place of overtopping. This was located in the northwest portion of the study area, with a flow of approximately 375,000 cfs. By comparison, the 100-year and 500-year flows are 240,000 cfs and 347,000 cfs, respectively. A breach location was also assumed downstream of the City of Lawrence, where the levee system would again be overtopped by flood waters behind the levee.

The Kansas River water surface elevations with a levee breach condition were compared to the FEMA elevations with no levee breach. At the upstream and downstream ends of our study area the elevations were similar; however, up to 5' decrease was observed just upstream of I-70. As illustrated on the attached floodplain maps, this still results in significant flooding in this area. On average, the 100-year Kansas River flood levels during a levee breach condition were 0 to 7 feet higher than the Maple Grove Watershed flood levels. Again, these flood level were determined from a "most likely" scenario, but there are numerous other breach scenarios that could exist.

C. HEC-RAS Model Development

1. General Project Information

The HEC-RAS, version 3.1.1 hydraulic model produces water surface elevations along each stream. The information required to build a hydraulic model includes hydraulic characteristics of culverts, bridges, dams, low water crossings, and open channels. This model was based on the original HEC-2 hydraulic model.

2. Data Sources

Data and model development includes the process to determine the primary stream network, cross section geometry, flow lengths, bank stations, and Manning's "n" values for the entire watershed. The data sources used were:

- Planimetric information in GIS format provided by the City
- Topographic information provided by the City
- Digital elevation data in the form of a triangular irregular format (TIN) generated using GIS and topographic information
- Aerial photographs provided by the City
- Current FEMA HEC-2 model prepared by GBA

Best professional engineering judgment in conjunction with industry-accepted practices was used in interpreting the data sources.

3. Input Parameter Development

From the above sources, data was collected and the input information for the hydraulic models was created using GeoRAS, an ArcView extension that compiles GIS data into an input file for the HEC-RAS model. The development of these input parameters is described individually in the following sections.

Naming Convention

Only one reach was modeled. The Kansas River is named in the FEMA FIRM map, and that name was retained in the HEC-RAS model.

Cross-Section Development

The existing HEC-2 model was imported into HEC-RAS. The imported cross sections remained unchanged within the levee. No significant discrepancies were found between the FEMA modeled cross sections and the current mapping. By leaving the cross sectional information unchanged, we were also able to make a true comparison of the FEMA floodplain levels to that of the levee breach condition.

To model the breach failure condition the cross sections were extended to the northeast to the Mud Creek portion of the levee. The cross section extensions were created using GeoRAS. These new combined sections were used in the HEC-RAS model.

Flowpath Lengths

A flowpath lengths shape-file was created for use in the GeoRAS export. The flowpaths follow the stream centerline at a distance to the right or left where approximately two-thirds of the water in the floodplain is contained. GeoRAS used this coverage to create left and right overbank reach lengths. GeoRAS used this file to create the geometry export file for HEC-RAS.

Manning's "n" values

Manning's n values for the Kansas River model were imported from the HEC-2 model for the channel portion. For the extensions, a value of .04 was used to model the area behind the levee (North Lawrence).

Roadway Crossings

Structures at roadway crossing were imported from the HEC-2 model, including the bridge opening, roadway deck and position of the bridge in the channel. Some minor modifications were made so the model could be run in HEC-RAS.

Expansion/Contraction Coefficients

Expansion and contraction coefficients were left at the default 0.1 and 0.3, respectively, for all sections not near structures. As the HEC-RAS manual recommends, 0.3 and 0.5 were used as the coefficients on two cross sections upstream and one cross section downstream of any bridge or culvert.

Boundary Conditions

Known water surface elevations from the original HEC-2 model were used for the downstream boundary condition.

Ineffective Flow Areas

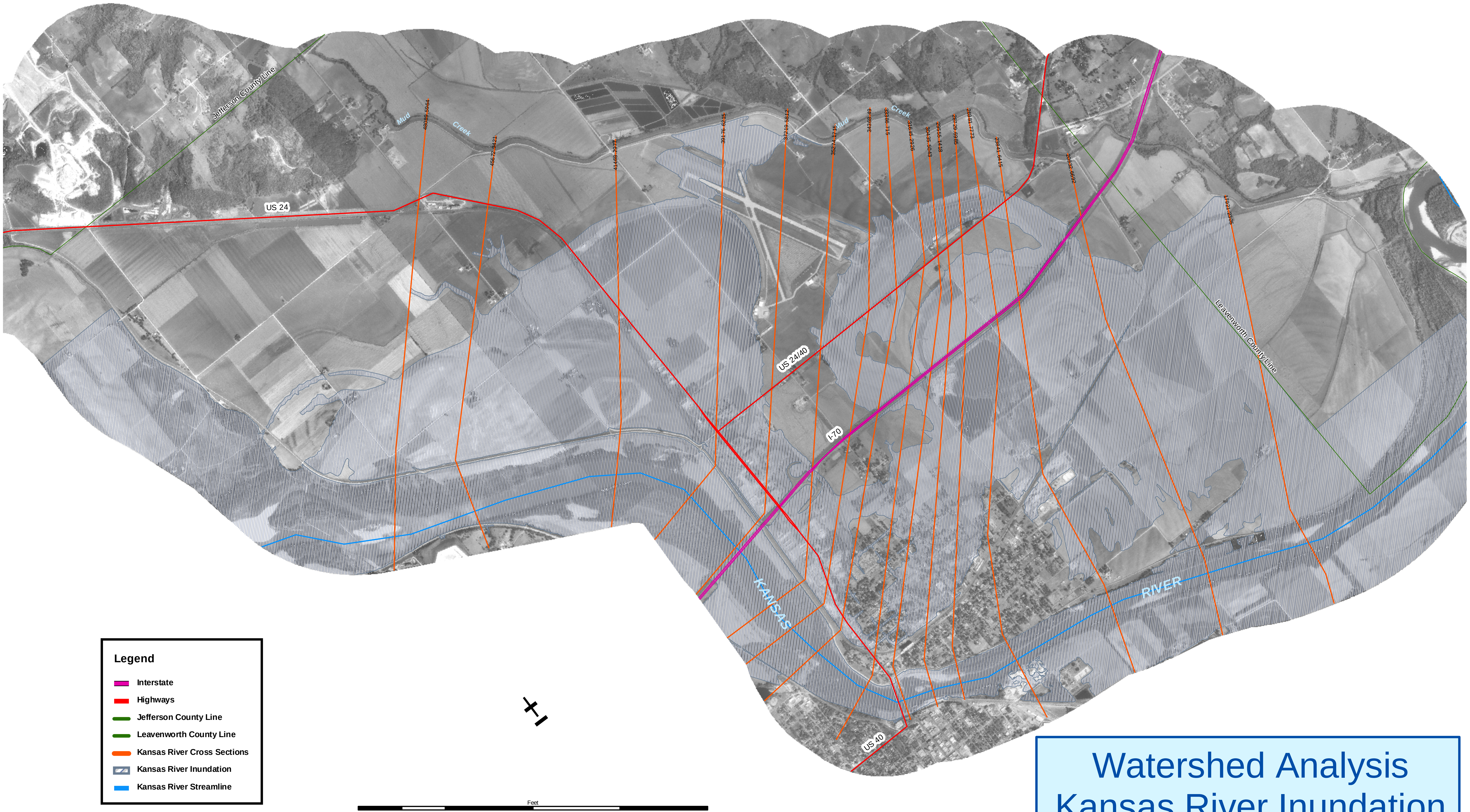
Ineffective flow areas were placed near structures according to the HEC-RAS manual. The width of the ineffective flow stations was determined from a 1:1 ratio from the face of the structure on the upstream cross section and a 2:1 ratio from the face of the structure on the downstream cross section. The elevations were generally set at the low point in the embankment on the upstream side and between the embankment and the low chord on the downstream side.

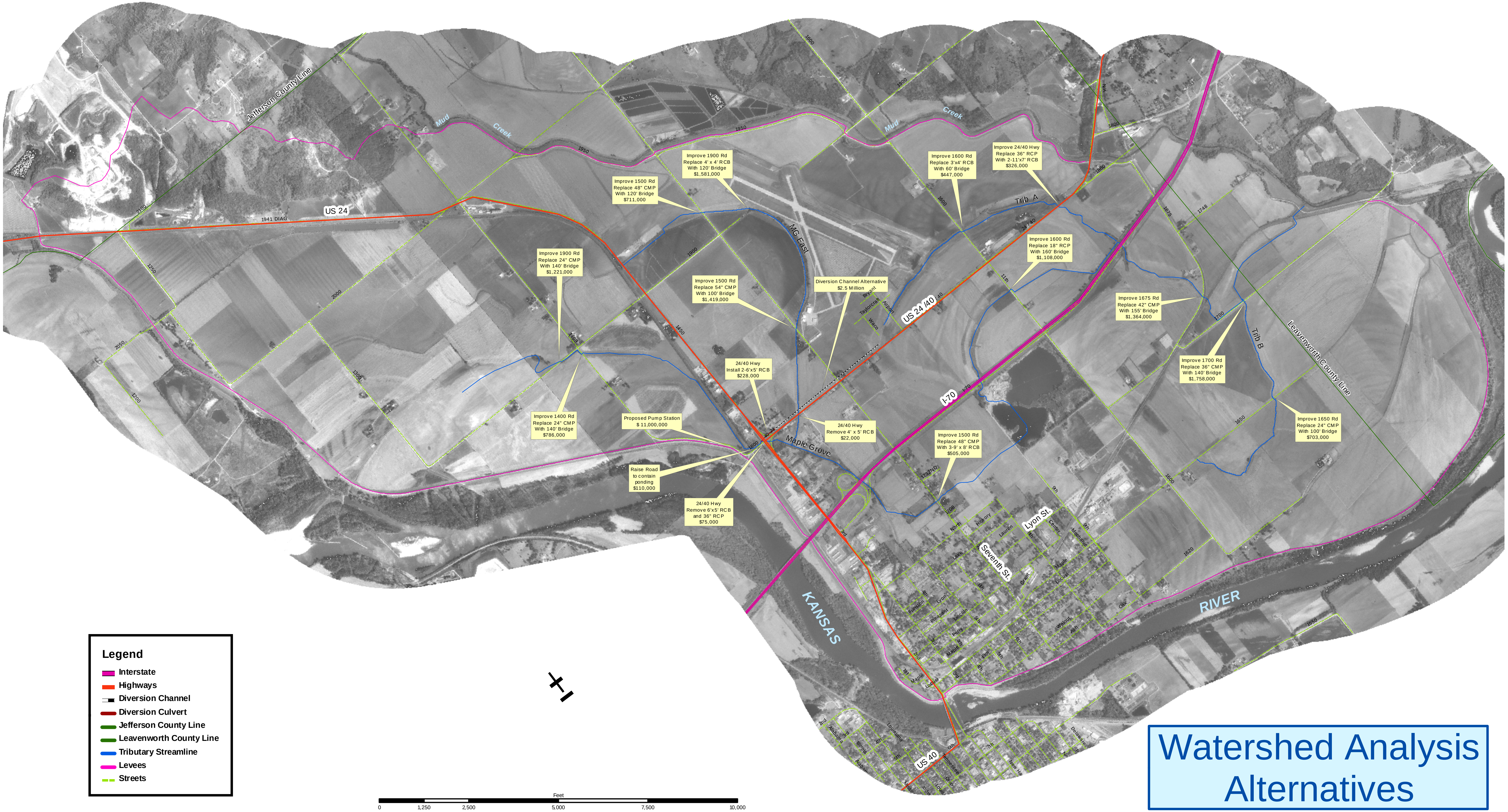
Ineffective flow options were also used to limit flow in the floodplain on cross sections where engineering judgment deemed the flow could not extend across the entire area shown in the cross section. The locations were generally determined by contours and aerial photos as well as evaluating the model results. Obstructed areas were also used to prevent flow to specific areas. Most commonly obstructed areas are isolated low areas such as ponds.

Channel Bank Stations

Channel bank stations were placed at the point in which the ground broke its vertical climb out of the channel and changed to a gentler slope. The bank stations were set using the graphical cross section editor in HEC-RAS.

Watershed Analysis
Kansas River Inundation





Watershed Analysis Alternatives