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.

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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	\$1 264 000	
Main Channel, E. 1675 Rd., Roadway	2700 ft	\$290/ft	\$1,304,000	
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Main Channel, E. 1600 Rd., Roadway	1750 ft	\$290/ft	\$1,108,000	
Main Channel, E. 1500 Rd., 155' Bridge	7750 sq-ft	\$75/sq-ft	\$020.000	
Main Channel, E. 1500 Rd., Roadway	1200 ft	\$290/ft	\$929,000	
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	
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Maple Grove East, E. 1500 Rd., 100' Bridge	5000 sq-ft	\$75/sq-ft	\$1.419.000	
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Total			\$24,802,000	

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<u>S9-1</u>	133	\$1.132.000
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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
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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

Prioritization of Internal Systems

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

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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.

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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.

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There were three main goals for this portion of the study: to reduce the demand on the 2^{nd} 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 2^{nd} 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).

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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).

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.

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- 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

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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
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Prioritization of Internal Systems

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

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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
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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.

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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.

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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

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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 2^{nd} 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 2^{nd} 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).

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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.

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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.

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- 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

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S6L3-1	56	\$195,000
S6L3-7D	New pipes	\$181,000
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S6L2-1	37	\$5,000
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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.

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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
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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
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- 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.

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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 2^{nd} 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 2^{nd} 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.

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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).

EXECUTIVE SUMMARY

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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.

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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.

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

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S6L3-1	56	\$195,000
S6L3-7D	New pipes	\$181,000
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S6L2-1	37	\$5,000
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Prioritization of Internal Systems

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.

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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.

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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:

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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.

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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 2^{nd} 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 2^{nd} 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).







