XII. Future Considerations

A. GIS Development/Mapping

Accurate and up-to-date mapping will be important to the overall success of the stormwater management program. The computer integration of the stormwater management program was started using M.J. Harden mapping; digital overlays to the basemap files from M.J. Harden were developed as part of this Stormwater Master Plan. The planning level information collected and refined as part of this project is now available of use on Microstation and/or AutoCad. It could be very beneficial to the City to include the design work in the digital mapping as it is completed. In this manner, the digital mapping will include the planned improvements as well as the completed projects. Using GIS, an inventory of manholes and junctions could be developed for the stormwater network, and used to coordinate the stormwater program with other utilities, to plan future design and construction schedules, and to develop a comprehensive maintenance program.

B. Management Plan Updates

This Stormwater Master Plan is not intended to be a static document. The City staff should periodically review the capital improvements program and present status reports and recommendations to the City Commission, and oversee updating of the Stormwater Master Plan every ten years. The periodic reviews and the ten-year updates will help assure that the plan meets the changing needs of the City, that it reflects the improvements made, and that it continues to address and prioritize both present and future flooding problems.

C. Maintenance

Maintenance is critical to proper operation of the stormwater conveyance system. Regular maintenance can extend the life of the system and reduce capital expenses. The capital improvements program will evolve with time; once improvements have been constructed, their maintenance will become important. Presently, the extent of maintenance of stormwater facilities varies throughout the City; in some areas, limited or no maintenance is performed by the City, whereas in areas adjacent to some creeks and tributaries the maintenance is done by the property owners. The City should work with the County to ensure that county jurisdiction properties are maintained appropriately and thus do not adversely affect the City's drainage system. To protect its investment in the capital improvements program, the City will find it prudent to keep the system in proper shape. The types of maintenance required for the stormwater system are discussed in Chapter VIII, Section D.

D. Regional Detention Facilities

Regional detention facilities are a new concept to Leavenworth. The facilities described in Chapter VIII, Section F, if constructed as planned, could eliminate some of the future flooding problems. There is also the potential for developing regional detention basins in some parts of the City. The undeveloped portions of the major watersheds, as well as those just beginning to develop, have locations suitable for regional detention basins. If detention basins are located in these watersheds before too much development occurs, Leavenworth could greatly reduce the potential for future flooding problems. Although the present push for the management program is to construct stormwater improvements to alleviate existing flooding problems, future plans should include regional detention basins where feasible. Regional basins will require large areas of land and can serve multiple purposes which include flood control for the downstream areas; limiting the expansion of downstream flood plains as development occurs; recreational opportunities in coordination with the Parks and Community Activities Department; and water quality enhancements. Regional detention can be a more appealing option than on-site detention basins, since one regional basin can perform the function of many on-site detention basins; simplify the operation of the conveyance system; reduce inspection and maintenance needs; and leave more land available for development.

The planning of detention basins could be done while capital improvements projects are being constructed to alleviate present flooding. In this manner, the design and construction of the regional detention basins could be integrated into the overall program as a truly regional approach.

E. Water Quality Issues

Best Management Practices (BMPs) are considered by many regulatory and area-wide planning agencies to be the most effective, practicable means of preventing or reducing the amount of non-point pollution to a level compatible with water quality goals. BMPs can be divided into two general categories: source controls, which improve the quality of stormwater runoff by reducing pollutant generation; and structural controls, which improve stormwater quality by reducing runoff rates and pollutant loads.

1. Source Controls

Source controls can usually be implemented on a city-wide basis because most do not require major investments in land or infrastructure. Source controls include erosion and sediment traps, street cleaning, lawn maintenance, litter removal, road salt application limits, ordinances to eliminate dumping of pollutants into storm sewers, and public education. These measures could be very effective in improving water quality and reducing maintenance needs if coordinated with the County.

a. Erosion and Sediment Traps. Soil erosion is accelerated when the soil is exposed to precipitation and surface runoff. Erosion and sediment can cause reservoir siltation, storm sewer clogging that increases maintenance costs and flooding frequency, and possible damage to the aquatic system of the receiving waters. Construction sites are the primary contributors of sediment in urban environments and agricultural fields are the main contributors in rural areas.

Erosion and sediment control requires reducing the flow of, and the amount of solids in, the stormwater. Many of the structural BMPs described in the following section can be used during construction and can serve as permanent structures to control both the quantity and quality of runoff. Detention basins are the most obvious of such measures.

In controlling sedimentation caused by construction activities, the most important element is education of contractors, inspectors, and material suppliers. Ongoing inspection and enforcement are also key requirements of this program, and an informed public may be able to assist with enforcement by reporting violations to the authorities. By increasing these regulatory efforts, the City can reduce maintenance costs.

b. Street Cleaning. The make-up of street surface contaminants is site-specific and highly variable. Studies indicate that heavy metals are produced primarily by street activity, while organics and nutrients are carried in erosion from off-site areas. In general, most automotive fluids are high in volatile solids, and brake linings contribute high concentrations of lead, chromium, copper, and nickel. Other sources of heavy metals include rubber (lead and zinc), asphalt pavement (nickel), and cigarettes (lead, chromium, copper, nickel, and zinc).

The pollutant removal efficiency of a street cleaning program depends on the type of equipment, frequency of cleaning, concentrations and particle sizes of pollutants, street surface characteristics, particle accumulation rates, and parking restrictions. Studies indicate that removal efficiency is influenced more strongly by street surface characteristics than by the type of equipment. A rougher surface allows smaller particles, which generally contribute higher pollutant concentrations, to escape the brushes of street cleaners, regardless of the type of equipment.

Timing and frequency of cleaning can also have a major effect on the removal of pollutants. For example, studies have shown that street cleaning once or twice per day can remove up to 50 percent of the total solids and heavy metals and up to 10 percent of the organics and nutrients, while cleaning once or twice per month may remove only 5 percent of these pollutants. In Leavenworth, timing intensive street cleaning activities around the spring and summer storm seasons may significantly reduce pollutant loadings.

c. Lawn Maintenance. Lawn maintenance controls include restrictions on the application of nitrogen and phosphorus to green areas. Groundskeepers and gardeners of commercial and public facilities are generally more knowledgeable and more cost-conscious, and are therefore less likely to apply fertilizer at excessive rates and frequencies than individual homeowners.

Pollutant removal effectiveness involves informing users of fertilizers about the benefits of proper application rates, grass species, mowing heights, watering methods, and seasons of application. Encouraging landscapes that require minimal amounts of fertilizers can also increase the success of the program. However, the reduction in pollutants transported by stormwater will depend on the existing level of misuse and the extent to which the public is willing to participate in a voluntary pollution control program.

d. Litter Removal. Sources of litter include household wastes, commercial and industrial wastes, trash trucks, loading docks, construction sites, motorists, and pedestrians. Organic litter such as leaves and yard clippings can degrade water quality by consuming oxygen during decomposition. Litter also carries bacteria, pesticides, heavy metals, and other pollutants.

Litter can be controlled through periodic cleanup campaigns, public education, and law enforcement. It is difficult to quantify how much pollution can be eliminated through a litter collection program. However, the volume of litter collected can be measured and could be significant.

The benefits associated with such programs are visible and are easily understood by the public. Law enforcement agencies can assist with control of littering if they are made aware of illegal dumping and other sources of pollution. However, the success of a litter control program requires an active education campaign targeted at numerous audiences.

e. Road Salt Application Limits. Highway de-icing compounds include sodium chloride and calcium chloride, and are applied to prevent snow from sticking to the road surface. These chemicals are also applied by property owners to sidewalks, driveways, and parking areas. These chemicals are detrimental to roadside vegetation and can pollute groundwater and surface waters.

The reduction in the pollutant loads associated with de-icing materials depends on the current level of use, the expected reduction in use, and current operating practices. Eliminating the use of de-icing compounds is not a practical alternative. However, pollution caused by de-icing materials can be reduced by establishing salt-tolerant roadside vegetation, and by maintaining clean loading areas. Application should be limited to the lowest practicable rates. Streets should be swept as soon as possible after snowstorms. Wash water from equipment cleaning should be collected in a holding tank.

f. Dumping Ordinances. EPA has identified pollution control ordinances as an important element in developing public participation in pollution control programs. These ordinances may include restrictions on dumping trash and other materials in open areas and in storm sewer inlets.

g. Public Education and Awareness. Public awareness is an integral component of the management program discussed above. The success of these programs will require a significant and ongoing effort to educate the public as well as the responsible officials and civic and business leaders about the importance of pollution control. Both print and electronic media should be used to deliver information on these programs to Leavenworth residents.

2. Structural Controls

Problems associated with implementing structural BMPs in urban areas include the high cost of control technology, the lack of available land area, and the unsuitable topography for control structures, particularly large structures such as detention basins. The most common structural BMPs are wet ponds, extended detention dry ponds, infiltration trenches, grit-oil separators, porous pavements, grassed swales, vegetative filter strips, and underground storage facilities.

a. Infiltration Trenches. Infiltration trenches are surface or underground trenches lined with a filter fabric and filled with coarse aggregate. Stormwater may flow into the infiltration trench from surface runoff, or through a pipe or other inlet structure. The collected stormwater is stored in the voids between the aggregate and gradually infiltrates into the soil. Infiltration trenches are not designed to remove coarse particles. A pretreatment device, such as a vegetative filter strip or a grit-oil separator, should be used to screen out coarse particles; and soluble pollutants are removed after they exfiltrate through the trench and into the soil. Maintenance of infiltration trenches consists of periodic inspection of the trench and grass filter strip during the first year and annual inspections thereafter, and mowing and sediment removal from inlet and outlet structures as required. Structural maintenance consists primarily of rehabilitating after the trenches become clogged with silt.

Infiltration trenches are typically used with drainage areas of 1 to 10 acres. The two most important site limitations for infiltration trenches are soil type and the depth of the water table. This eliminates some areas of primarily clayey soils that have low infiltration rates. Sandier soils with low groundwater levels are better suited for infiltration trenches.

The advantages of infiltration trenches include natural groundwater recharge, possible low flow augmentation, and control of streambank erosion. Infiltration trenches are the most economical BMP for small sites. Wet ponds are generally not recommended for small watersheds; and extended detention dry ponds are seldom economically competitive when compared to infiltration trenches. In addition, infiltration trenches typically require less area and can be easily incorporated into multi-use areas. The major disadvantage is the risk of groundwater contamination.

b. Grassed Swales. Grassed swales are designed to convey runoff or to allow it to infiltrate into the soil. Pollutants are removed by the filtering action of the grass, deposition in low velocity areas, or by infiltration into the subsoil.

Maintenance requirements include mowing and collection of loose debris and litter. For this BMP in particular, the individual landowners can be held responsible for these functions. Additional maintenance includes removal of accumulated sediment.

Grassed swales are best suited for single-family residential developments or institutional grounds. They should not be constructed where the groundwater table extends to within 2 feet of the bottom of the swale. As with infiltration trenches, the underlying soils must be reasonably permeable.

The primary benefit of grassed swales is that they are typically less expensive to construct than curbs and gutters. In addition, much of the maintenance can be performed by property owners, which reduces publicly-funded maintenance costs. However, grassed swales eliminate the opportunity for collection of pollutants by street sweepers, and they are not technically feasible in clayey soils.

c. Vegetative Filter Strips. Filter strips are areas of vegetative cover over which stormwater runoff is conveyed. They are typically used as a component of an integrated stormwater management system. Stormwater runoff must be evenly distributed across the vegetative filter strip, and flow velocity should be minimal. Pollutants are removed by the filtering action of the grass, deposition in low velocity areas, or by infiltration into the subsoil. Vegetative filter strips should be at least 20 feet wide. To prevent formation of concentrated flows and erosion, the tributary served by a vegetative filter strip should be no larger than 5 acres.

Maintenance costs for filter strips are quite low when compared to other BMPs. The strips should be inspected annually for damage by traffic, gully erosion, density of vegetation, and evidence of concentrated flows through or around the strip. Studies indicate that filter strips effectively remove sediment, organic material, and many trace metals. The removal efficiency is a function of the length, slope, and soil permeability of the strip; size of the tributary area; and runoff velocity.

d. Porous Pavements. Porous pavement is an asphaltic concrete product with a high void content, generally consisting of a porous asphaltic concrete layer that covers alternating courses of gravel and sand on top of solid subbase. Stormwater that seeps through the porous asphalt is filtered through the underlying layers into the underlying soil. If infiltration into the soil is not practical, the filtered runoff can be discharged through a buried drainage system into a storm sewer system, to another BMP, or to a natural watercourse. Porous pavements are not recommended for slopes steeper than 5 percent.

Because pollutant removal in a porous pavement system occurs primarily through infiltration, it is important to keep the voids in the pavement free of coarse-grained particles. Maintenance consists of vacuum sweeping followed by high-pressure hosing at least four times per year, several inspections during construction and annual inspections thereafter, patching of cracks and potholes, and spot cleaning. Sand or ashes should never be applied for snow removal, since they clog the pores in the asphalt.

Porous pavements have lower tensile strength than conventional pavements, and are best-suited for parking areas and roads of low traffic volume. Porous pavements should be restricted to drainage areas of 1/4 to 10 acres.

Benefits of porous pavements include elimination of the need for curbs and gutters and downstream conveyance systems, control of streambank erosion, and better skid resistance. The major drawback is vulnerability to clogging, possible groundwater contamination, and limited applicability.

e. Underground Storage. Underground storage usually consists of a buried chamber, such as a long pipe or large tank, where first-flush runoff can be collected and stored for later reuse or release to a receiving stream or treatment facility. Underground storage tanks can be used practically anywhere. They are not dependent upon physiographic conditions, and their sizes may vary considerably. Maintenance of underground storage chambers includes annual inspections and periodic removal of sediment and debris.

Advantages of underground storage chambers include capture of the first-flush runoff, which usually contains large amounts of pollutants and reduction of downstream erosion. Disadvantages include the possibility of disrupting the natural water balance and the generally higher cost compared with other structural BMPs. Underground storage should be considered only in places where lack of space or impermeable soils make other BMPs impracticable.

f. Grit-oil Separators. A typical grit-oil separator consists of three concrete chambers. The first chamber receives the storm runoff through a drain or curb inlet. Grit and sediment are trapped in the first chamber along with floating material such as leaves and litter. From the second chamber the flow passes through an inverted pipe elbow into the third chamber, where floating oil and gas films are captured on the surface of the permanent pool. The third chamber connects to the storm drain system or to another BMP. The storage provided by a grit-oil separator is limited and the detention time provided is relatively short.

Grit-oil separators are typically installed in parking lots or commercial sites no larger than 1 acre. They are best suited for areas of considerable automobile traffic, convenience stores, and gasoline stations. Routine maintenance includes semi-annual inspections and cleaning. The usual method of cleaning grit-oil separators is by pumping out the contents, which are then hauled to a landfill.

The advantages of grit-oil separators include unobtrusiveness, compatibility with the storm drainage network, easy access, and ability to pretreat the runoff before it enters the soil. Disadvantages include limited pollutant removal capabilities, frequent maintenance, and the need to dispose of sediments. Because of short detention times, only moderate removal can be expected. Even more limited removal is likely for fine-grained particulate pollutants, and soluble pollutants probably pass through the chambers without modification. Compared with other BMPs, the maintenance requirements for grit-oil separators are high.

g. Wet Ponds. Wet ponds are permanent pools of water surrounded by established aquatic vegetation. The basic pollutant removal mechanisms are gravity settling, biological uptake of nutrients, and to a lesser degree, infiltration of soluble nutrients through the soil profile. The long retention times provided by wet ponds make them very effective for improving stormwater quality. A properly designed wet pond can achieve a high removal rate for sediment, biochemical oxygen demand (BOD), trace metals, and soluble nutrients.

Wet ponds are most cost-effective in larger, intensely developed sites. A watershed of at least 10 acres is usually needed to maintain a permanent pool of water. Soil type at the site is also important; permeable soils could cause severe fluctuations in pond water level. Wet ponds are not a feasible BMP option in watersheds where land costs are high or space is limited. Maintenance of wet ponds includes regular mowing during the growing season; annual inspections; debris and litter removal; erosion control; and control of insects, weeds, burrowing rodents, odors, and algae. Additional maintenance includes structural repairs as needed, and sediment removal typically once every 10 to 20 years. The cost associated with sediment removal can be quite high; and the solids must be properly disposed of to prevent surface and groundwater pollution.

The benefits associated with wet ponds include creation of wildlife habitat, higher property values, and recreation and landscape amenities. Negative impacts include possible habitat degradation upstream and downstream; the potential for creation of safety hazards; occasional nuisance problems caused by odor, algae, and debris; and the need for periodic sediment removal. Compared with other BMPs, wet ponds have proven the most effective in terms of water quality protection. Compared with extended detention dry ponds, wet ponds are usually more readily accepted by local residents because of their pleasing appearance. Wet ponds are good candidates for regional stormwater management facilities, since they are most cost-effective on large, densely developed sites. A wet pond is not a cost-effective BMP option for smaller sites in residential areas. Usually, such locations can be more economically served by extended detention dry ponds or infiltration trenches.

h. Extended Detention Dry Ponds. Extended detention dry ponds are used to capture standing water for brief periods after a runoff event. Release of impounded water is controlled by an outlet device which can be designed to prolong the period of release. The basic pollutant removal mechanism in extended detention dry ponds is gravity settling of pollutants. Thus, such ponds are effective in removing particulates, but not the soluble forms of pollutants. In addition, they are more prone to turbulent flow than wet ponds, which is conducive to poor settling and resuspension of previously settled pollutants.

Because extended detention dry ponds detain water only for short periods, the site soil characteristics are not as important as for wet ponds. However, if the soils are impermeable, problems with standing water may develop. As with wet detention basins, extended detention dry ponds are not always feasible at sites where land costs are high or space is limited. Maintenance of extended detention dry ponds includes mowing; annual inspections; removal of litter and debris; sediment removal every 5 to 10 years; erosion control; and control of insects, odors, weeds, and burrowing rodents.

Benefits associated with extended detention dry ponds include reasonably good pollutant removal rates, the ability to reduce both runoff rates and pollutant loadings, and availability for use as a recreational area when not used for stormwater storage. In addition, extended detention dry ponds are less costly than wet ponds because of their smaller storage volume. Negative aspects include visual impacts; occasional problems with odors, debris, and weeds in the inundated portions; and the need for sediment removal.

F. Federal Programs

1. Evaluation of Future NPDES Requirements

On November 16, 1990, the US EPA issued a regulation requiring National Pollutant Discharge Elimination System (NPDES) permits for discharges of stormwater from certain point sources. This regulation, known as the "stormwater application rule," triggered a flurry of permitting activity nearly as extensive as that which followed the creation of the NPDES program in 1972. The "stormwater application rule" describes the types of facilities subject to the permitting program and the procedure they must follow to obtain stormwater permits. A second major rule, called the "stormwater implementation rule," was enacted in April 1992, and discusses the NPDES stormwater permit terms and conditions.

By the fall of 1994, EPA and the states had begun to issue individual permits to large and medium municipal separate storm sewer systems that are subject to the stormwater application rule.

In August 1995, EPA issued a final rule affecting Phase II dischargers--that is, those not originally required to obtain permits. Phase II facilities will be required to obtain permits by September 1, 2001, or to comply with other requirements developed by EPA before that time. Phase II permittees include:

- Commercial retail, light industrial and institutional facilities.
- Construction activities under 5 acres.
- Small municipal separate storm sewer systems (<100,000 population).

The City of Leavenworth is in the Phase II group.

In its August 7, 1995, Phase II stormwater rule, EPA stated that it will develop a supplemental Phase II rule by 1999 that will set forth specific requirements for Phase II dischargers. The supplemental rule is expected to answer the following questions:

- What types of facilities will be covered under Phase II of the stormwater program?
- Which of the identified Phase II sources will be required to obtain permits?
- Will BMPs or other stormwater controls replace permits in the Phase II program?
- Will state control of the stormwater program be broadened under Phase II?

EPA is required by a court order to propose the supplemental rule for Phase II sources by September 1, 1997, and to finalize the rule by March 1, 1999. However, the agency has said if the Clean Water Act is amended prior to these deadlines to address stormwater issues relative to Phase II dischargers, it will move more swiftly to implement the statutory changes.

EPA has established a committee of Phase II stakeholders to aid in development of the supplemental Phase II rule. The stormwater subcommittee is part of the Urban Wet Weather Flows Advisory Committee convened in 1995 to study a variety of watershed-related issues.

The Phase II group is composed of 33 members representing state, local, tribal, and federal governments; environmentalists; and industry. The purpose of assembling a variety of stakeholders--many of whom have differing agendas--is to develop a consensus. EPA has stated the agency is open and committed to exploring a number of non-permit control strategies for the Phase II program that will allow efficient and effective targeting of real environmental problems.

As reported in the "Stormwater Permit Manual Bulletin," of July 1996, members of the Phase II subcommittee at their May 29-30 meeting agreed to several general concepts affecting smaller stormwater dischargers, but have yet to reach consensus on how the program should be administered.

To date, very little information and no specific guidelines have been provided to help the City of Leavenworth anticipate permitting needs and take steps to achieve compliance with EPA regulations by the year 2001. However, each issue of the "Stormwater Permit Manual Bulletin" includes updates on the latest developments of the NPDES program. In a recent issue, for example, the EPA's permits improvement team proposed a new approach, called public performance-based permitting, or P3, for permits issued under the NPDES and other environmental programs. The concept paper, submitted to EPA Administrator Carol Browner on May 10, 1996, included specific recommendations for improving the NPDES stormwater permits program. The team approved of the ongoing reform efforts for both Phase I and Phase II, and endorsed the use and future development of general permits. Specifically, the team favors:

- General permits that emphasize pollution prevention and best management practices (BMPs).
- The establishment of appropriate monitoring requirements based on industry type, water quality, or capability to implement BMPs.

It appears that stormwater quality issues--including monitoring, treatment, and prevention--will be the primary focus for Phase II dischargers, including Leavenworth. The City can begin to evaluate the types and concentrations within the stormwater system by implementing a long-term monitoring program at any time.

A field monitoring program should be established to measure and record rainfall and stormwater quality and conveyance system data. The decision to proceed with the program should be based on stormwater NPDES permit requirements. At this time, it appears that Leavenworth will not be affected in the near future.

Two rain gauges and four water quality samplers can be utilized for the field monitoring. The water quality samplers will measure flow quantity and collect water samples for laboratory analysis. The four water quality samplers would be cycled between eight locations, while the two rainfall gauges would remain at the same locations for the duration of the monitoring program. Because storms typically track from the southwest to the northeast of a region, the rain gauges should be located near the northwest and southeast ends of an imaginary line through the City that is perpendicular to the direction of the storm track. By spacing them far enough apart, the gauges may be able to pick up rainfall variation across a storm front. The gauges should be installed on the roof of a public building that has a power source. Good locations appear to be the Brewer School near 17th and Osage and the fire station near 2nd Avenue and Limit Street. If these particular buildings are not available, alternatives should be located at easily accessible and "secure" sites.

The sites for the stormwater samplers should be finalized through field visits by project and City staff. The purpose of these visits will be to determine that each location is easily accessible, is not under a street, is in a storm sewer structure that has a 24 inch diameter minimum manhole lid for installation and maintenance of the equipment; includes a sufficient length of straight pipe on each side of the manhole and downstream of a junction to minimize flow turbulence; and that the diameter of the pipe is smaller than the maximum measurable level of the gauge's depth sensor. For compliance with NPDES guidelines, each sampler should monitor primarily one land use type, and there should be a sufficient number of samplers to represent the range of different land uses in the City. These samplers measure the change in flow and pollutant concentrations in a pipe or culvert due to a storm event. Each one should be placed in a storm sewer line downstream from a drainage area that is small and topographically homogeneous, but large enough to contribute adequate rainfall runoff to the sewer. The four recommended locations and corresponding land use types for monitoring gauges in the Three Mile Creek watershed are as follows: 21st Court south of Randolph Street, undeveloped open land; between Franklin and Newman and Quincy and Kansas Streets, low-density residential; between Columbia Avenue and Broadway and Frank and Spruce Streets, medium-density residential; between Broadway and 7th and Shawnee and Delaware Streets, downtown commercial. In the Five Mile Creek watershed, the recommendations include: 13th Street north of Eisenhower Road, undeveloped open land; downstream from the Revolutionary Court cul-de-sac, low-density residential; southwest of Limit Street and Hughes Road, suburban commercial; M.L. King Drive and south of Limit Street, high-density residential.

The monitoring should be conducted over a full year or for a specific number of storm events, whichever occurs later, to ensure that data on the events collected will identify the intensity and volume of the majority of storms.

2. Evaluation of Existing Flood Plain Delineations and Natural Drainageways

The adequacy of the Flood Insurance Study for the City of Leavenworth, Kansas, by the U.S. Department of Housing and Urban Development, Federal Insurance Administration (now FEMA), July 1977, was evaluated. A comparison was made between the water elevations used for the FEMA flood profiles and those from the XP-SWMM models developed for this Stormwater Master Plan. To complete this comparison, the models were rerun for the 100-year storm event. Since the 500-year flood is not used for zoning purposes, it was decided to analyze only the 100-year event. No additional field surveying (detailed cross-sections) was done, and all cross-section data for this study were taken from the digital mapping.

The water surface elevations at bridges and culverts on Three Mile and Five Mile Creeks computed by XP-SWMM were compared with the FEMA results, as indicated in Table XII-1. In general, the FEMA flood profile is higher than the XP-SWMM results. The City of Leavenworth has made several improvements to its bridges since the 1977 FEMA study, which has eliminated some of the constrictions and flooding. In the Five Mile Creek watershed, the Union Pacific Railroad and Shrine Park pedestrian bridges no longer exist; and the 2nd Avenue and Limit Street bridges have been replaced by a single bridge at the Limit Street and 2nd Avenue curve. In the Three Mile Creek watershed, two railroad bridges between 7th Street and Broadway and a railroad spur between Cherokee and Shawnee have been abandoned since the 1977 study. It is recommended that the City update the FEMA study based upon the modeling information from this study. This update is underway. Discrepancies between maps and model techniques between those used in 1977 and those used currently have been identified and are being resolved.

One of the limitations of XP-SWMM is that it cannot model flood depths greater than the top of bridges, and therefore predicts lower flood profiles than HEC-RAS--the model used for FEMA work.

Table XII-1
Evaluation of FEMA Floodplain Mapping
Comparison of FEMA and Stormwater Master Plan Results
at Bridges and Culverts on Three Mile Creek and Five Mile Creek

Basin ID	FEMA Study Station	Bridge/Culvert Location	xp-swmm Conduit	xp-swmm Up Node	FEMA 100-Year Flood Profile W.S. Elev, ft	SWMP xp-swmm 100 Year Flood W.S. Elev, ft
5mc	0.148 mi	Union Pacific/MO Pac RR	2617	92320	772.0	772.0
5mc	0.195	2nd Street	2615	92318	772.0	772.0
5mc	0.690	Marion Street	911	92250	773.5	776.0
5mc	0.790	Union Pacific RR	(aband)		777.0	Not in SWMP
5mc	0.900	4th Street	2555	92293	778.5	777.6
5mc	*	Limit Street/2nd Avenue	2626	92326	Not in FEMA	> 782.2
5mc	1.370	2nd Avenue	(aband)		785.0	Not in SWMP
5mc	1.410	AT&SF RR	850	92219	785.6	784.0
5mc	1.425	Limit Street	(aband)		786.0	Not in SWMP
5mc	1.950	Shrine Park Road	2846	92504	791.0	788.2
5mc	2.110	Shrine Park Footbridge	(aband)		798.5	Not in SWMP
5mc	2.650	10th Avenue	203	92136	815.7	> 815.7
5mc	3.270	N. Lawrence Rd	245	92061	836.0	> 835.2
5mc	**	County Hwy 5	454	92020	Not in FEMA	851.5
3mc	200 ft	Missouri Pacific Railroad	3228	92762	772.0	772.0
3mc	425	Union Pacific Railroad	3226	92760	772.0	772.0
3mc	775	2nd Street	3224	92758	772.0	772.0
3mc	1260	3rd Street	3222	92757	775.0	772.0
3mc	1725	4th Street	3220	92755	779.0	774.4
3mc	2210	5th Street	3218	92752	781.0	776.7
3mc	2760	6th Street	3215	86197	785.0	> 782.8
3mc	3270	7th Street	3166	92712	786.0	> 782.1
3mc	3575	Railroad	(aband)		786.5	Not in SWMP
3mc	3770	Railroad	(aband)		786.6	Not in SWMP
3mc	4205	Broadway	3160	92704	787.0	782.6
3mc	4470	Cherokee Street	3158	92703	787.5	783.0
3mc	4900	Railroad Spur	(aband)		789.0	Not in SWMP
3mc	5600	Shawnee	3016	92617	790.3	788.7
3mc	7245	10th Street	2994	92607	792.2	790.9
3mc	9240	Osage Street	2999	92612	799.8	800.9
3mc	9900	13th Street	3003	92614	803.4	> 804.0
3mc	10810	Ottawa Street	2578	92301	808.2	> 807.2
3mc	14000	18th Street	1418	92018	828.5	824
3mc	15805	20th Street	2595	86831	836.5	837.9
3mc sb	8166 ft	Shawnee Street	1368	92095	796.0	796.3
3mc sb	9141	11th Street	3140	92692	800.0	800.3
3mc sb	9351	Cherokee Street	1248	92083	804.0	> 808.0
3mc sb	11911	14th Street	3092	92650	813.4	812.5
3mc sb	18071	18th Street	940	92023	852.1	> 848.72
3mc sb	18731	19th Street	942	92646	861.0	> 861.4
3mc sb	18831	parking lot?	2300	86524	864.3	> 858.73
3mc sb	19391	parking lot?	1289	92643	869.0	> 865.9
3mc sb	20175	20th Street	1288	92642	869.8	858.8

* FEMA Report incl. 2nd Ave & Limit St (Sta 1.37 & 1.425) bridges, which have been replaced by a single Limit St/2nd Ave bridge.
** FEMA Report does not include this bridge because study limits end downstream of County Hwy 5.