09021

CRYSTAL CREEK FLOODING ANALYSIS

PREPARED FOR:

City of Crystal Lake
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Crystal Lake, Illinois 60014

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26575 W. COMMERCE DRIVE, SUITE 601, VOLO, ILLINOIS 60073
OFFICE (847) 740-0888 FAX (847) 740-2888

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INTRODUCTION

In August of 2007, the City of Crystal Lake received over 11 inches of rainfall. As a result of this rainfall, many residents around Crystal Lake in both the City of Crystal Lake and the Village of Lakewood had flooding problems. Both communities commissioned studies of the causes of flooding complaints.

The Crystal Lake report, named the "Crystal Lake Flooding Study" (the Study), concluded that the major causes of flooding around the Lake were high groundwater, excessive rainfall, and lack of adequate minor and major drainage pathways. The Crystal Lake Study reported the following specific problems for areas south of the Lake.

- About 250 properties are in the FEMA floodplain around Crystal Lake and another 70 properties are in the floodplain of Crystal Creek between Lake Avenue and St. Andrews Lane.
- 45 properties are in the floodway of Crystal Creek above St. Andrews Lane.
- High Lake levels contribute to flooding problems around Crystal Lake by restricting the rate that groundwater can drain to the Lake affecting over 400 properties.
- Areas south of the Lake in the City (termed "Area 4" in the report) between Broadway Avenue and Country Club Road have inadequate minor and major drainage systems affecting 85 properties and resulting in 10 flooding complaints.

The Crystal Lake Country Club also experiences frequent flooding of their property from Crystal Creek. South Elementary School and Lundahl Middle School also frequently experience flooding on their properties. Other properties along Crystal Creek also have filed flooding complaints with the City.

The 2009 Crystal Lake Flooding Study recommended analysis of the following alternatives to address flooding for Area 4 south of the Lake and also areas along Crystal Creek.

- Control leakage from the Lake into the 24-inch Lakewood storm sewer under Crystal Creek
- Improve the minor (10-year) drainage system for Area 4 with storage downstream to mitigate higher flows.
- Increase Lake outlet capacity to lower floodplain elevations and improve drainage around the Lake.
- Improve culvert capacity under Country Club Road to remove properties from the floodplain and the floodway.
- Analyze flooding along Crystal Creek above St. Andrews Lane to develop specific alternatives to reduce flooding by removing existing flow restrictions.

The Crystal Creek Flooding Analysis was commissioned by the City in March 2009 to analyze the feasibility and approximate cost to implement the above recommendations.

STUDY AREA

The study area for this project is shown on Exhibit 1. It is bounded by Crystal Lake on the north and St. Andrews Lane on the south. The hydraulic analyses of alternatives were carried to Rakow Road. The western boundary of the project was Huntley Road and the eastern boundary was near McHenry Avenue. The watershed that discharges to the Crystal Lake Park District (CLPD) detention facility and the Nash Road storm sewer was not explicitly studied (Exhibit 1). A 100-year discharge of 15 cfs was assumed for the

CLPD system. The Wedgewood subdivision also was not explicitly studied since its 100-year discharge was limited to only 1 cfs by detention. The impact of study area alternatives on the entire floodplain for the Lake also was considered.

BACKGROUND

Crystal Lake Flooding Study

The Crystal Lake Flooding Study was divided into four areas. All of the four areas are affected by high Lake levels and high groundwater. Area 4 south of the Lake is the only area influenced by Crystal Creek. Area 4 is bounded by Broadway Avenue on the north, Riverside Drive on the east, Country Club Road on the south and Meridian Lane on the west.

For Area 4, the Crystal Lake Flooding Study report noted that the minor drainage system was inadequate to convey routine runoff events. The northern portion of Area 4's minor drainage system relies on a tile which drains east under Broadway Avenue and then south to St. Andrews Lane. This 24-inch tile is very old and runs approximately 5 feet under the bed of Crystal Creek and never flows into the creek above St. Andrews Lane. The southern portion of Area 4's minor drainage system is a 21-inch storm sewer under Country Club Road that flows to Crystal Creek. This storm sewer is as much as 20 feet deep near Oxford Lane. This sewer is very flat and has insufficient capacity to drain Area 4 for routine rainfall events. The major drainage system for Area 4 is through the middle of the residential yards from west to east between Broadway Avenue and Country Club Road. Water ponds in depressions and seldom if ever actually reaches the Creek.

Lakewood Flooding Study

The Lakewood flooding study noted that the existing 24-inch tile has a maximum of about 10 cfs of capacity and is inadequate to convey routine runoff events. The Lakewood study also concluded that the existing Village minor and major drainage networks were inadequate. It noted that the existing 24-inch tile "…is not adequate to convey the surface drainage of the area." The fact that the tile did not have a free discharge until well below Lakewood at St. Andrews Lane and that it was old and had maintenance issues were also identified. The study expressed concern that even if a larger storm sewer system could be provided that it would increase discharges downstream leading to increased flooding. It recommended flood mitigation measures such as raingardens, infiltration and pumping when necessary.

Existing Federal Floodplain

Exhibit 2 shows the limits of the current Federal Emergency Management Agency Flood Insurance Study (FIS) floodplain limits. The current floodway limits for Crystal Creek also are shown. Exhibit 3 presents a profile view of the floodplain for Crystal Creek. The FIS model indicates that about 250 properties are in the floodplain around Crystal Lake. Another 70 properties are in the floodplain along Crystal Creek from Lake Avenue to St. Andrews Lane. Forty-five properties are in the floodway of Crystal Creek.

EXISTING CONDITIONS

Watersheds and Drainage

The subwatersheds flowing to Crystal Lake are shown on Exhibit 4. About 2305 acres flows to Crystal Lake through the Crystal Lake Drainage District field tile system and surface drainage. This flow reaches the Lake through a 30-inch storm sewer down Honeysuckle Lane. Another 640 acres flow to the Lake through Cove Pond and 55 acres flows to the Lake through the Woodland Channel. The Lake is about 234 acres in size at its normal elevation of 890.0.

Outflow from the Lake is the beginning of Crystal Creek. Surface discharge from the Lake is controlled by a 30-foot long weir that flows to a 2.5-foot by 3-foot box culvert under Lake Avenue (Exhibit 5). Specific drainage features for the watershed are shown on Exhibit 6. The Crystal Lake Clean Lakes Phase I Diagnostic Report (CLPD, 2008) has documented that water also appears to leave the Lake through undiscovered connections. This flow appears to reach the 24-inch tile that drains Area 4 and Lakewood. The constant flow from the Lake occupies pipe capacity that is needed for drainage from Area 4 and Lakewood.

Surface discharge leaving the Lake flows into Crystal Creek and then through culverts at Broadway Avenue and Country Club Road before entering a 30-inch culvert at Edgebrook Drive. This culvert continues underground past South Elementary School and Lundahl Middle School before entering Crystal Creek below St. Andrews Lane. The Creek continues under Barlina and McHenry Avenue to Rakow Road.

Stormwater runoff from the northern portion of Area 4 and Lakewood enters the 24-inch tile that flows about 5 feet below Crystal Creek. This is the only minor drainage system for the entire approximately 208 acre watershed and 300 properties around Broadway Avenue in both Crystal Lake and Lakewood. This tile discharges to the Creek below St. Andrews Lane.

Stormwater runoff from the southern portion of Area 4 flows into a 21-inch storm sewer down Country Club Road and enters the Creek. This sewer is very flat and has a very limited capacity of about 3 cfs, based upon City records, for the approximate 72 acres that drain to it. The 100-acre Wedgewood subdivision controls its discharge to this sewer discharge to about 1 cfs or 0.01 cfs per acre. This discharge was established under an agreement signed when the sewer was originally designed in the 1960s. This leaves about 72 acres that must drain through the 21-inch sewer.

The major drainage system for Area 4 and Lakewood is west to east through a series of depressions in the center of Area 4. These depressions receive flow from about 258 acres when minor drainage system capacity is filled with stormwater runoff.

Stormwater runoff from the southwestern portion of the Crystal Lake Country Club is trapped in a large depression. Overflows from this depression can enter culverts and flow into the Wedgewood development but this appears to be a rare occurrence. Runoff from the northwest portion of the Club is stored in depressions but if these overflow they will travel into Area 4 or the Country Club Road storm sewer.

The southeastern portion of the Club flows to a ditch that passes east of the clubhouse and enters Crystal Creek. The northeastern portion of the Club flows to either the Country Club Road storm sewer or to ponds near the clubhouse.

The Creek receives overland flow from about 440 acres between Country Club Road and Edgebrook Drive. At Edgebrook Drive smaller Creek flows enter a 30-inch culvert that continues past South school to the same structure as the 24-inch tile. It then flows south to St. Andrews Lane where it daylights to the open Creek below St. Andrews.

Flows from the CLPD detention basin/playing field near Main Beach join this sewer in a junction structure through the 27-inch Nash Road storm sewer. This sewer drains an area of about 300 acres north of Porter Avenue. This area does not flow overland to Crystal Creek. Its natural overland flow path is to Crystal Lake. However, infiltration to groundwater and storm sewers and tiles, surface drainage to the CLPD detention area and outflow to the Nash Road sewer drain this area away from the Lake to Crystal Creek.
The Nash Road storm sewer flows to the same structure as the 30-inch storm sewer that carries the Creek located in a small detention area southeast of Lundahl Middle School. These two pipes then flow to St. Andrews Lane. From there the Nash Road storm sewer, the Lakewood 24-inch tile and the 30-inch that carries Crystal Creek are joined by local storm sewers from St. Andrews Lane and McHenry Avenue. Discharge from these sewers is through three 33-inch to 36-inch sewers under St. Andrews to the Creek.

Existing FIS Floodplain Calculations

FEMA published new floodplain studies for Crystal Lake and Crystal Creek on November 16, 2006. The FIS models for Crystal Lake and Crystal Creek consist of a HEC-1 hydrology model and a HEC-RAS hydraulic model. The actual recent HEC-1 model for Crystal Lake and Crystal Creek could not be recovered despite extensive efforts with the Illinois State Water Survey (ISWS), FEMA and FEMA's consultants. A HEC-1 model was recovered by FEMA's consultant but its output did not match the regulatory floodplain elevation or discharges out of Crystal Lake. This model is included in Appendix A.

The correct HEC-RAS hydraulic model was recovered from FEMA. It included the explicit representation of Broadway Avenue, Country Club Road, and the 30-inch storm sewer at Edgebrook Drive. The hydraulic model is also included in Appendix A. The model used the following discharges at the indicated locations. Regulatory floodplain elevations also are shown.

Station	Discharge (cfs)	Regulatory Floodplain
Lake Avenue	50	892.60
Broadway Avenue	175	891.80
Country Club Road	175	890.29
Edgebrook Drive	175	888.39
St. Andrews Lane	268	884.51
Barlina Avenue	954	883.78
McHenry Avenue	954	883.10
Rakow Road	954	877.73

The FIS model shows that the 100-year runoff event must pond 2 to 3 feet at Country Club Road because the culverts are too small to carry the flow. It also shows that the 10-year event exceeds the capacity of the 30-inch sewer intended to carry the Creek past South and Lundahl schools. This causes the Creek to flow overland across School District property.

Crystal Creek Aquatic Ecology

On April 23, 2009 instream habitat assessments and macroinvertebrate surveys were conducted on three 330-foot stream reaches on Crystal Creek. Site 1 is located just downstream from Lake Avenue. Site 2 is located just downstream from the Crystal Lake Country Club. Site 3 is located downstream from St. Andrews Lane. The habitat assessment method was the Qualitative Habitat Evaluation Index (QHEI; Rankin 1989 and Ohio Environmental Protection Agency 2006). The macroinvertebrate survey results were classified using the Qualitative Multi-Habitat (QMH) method for field collection (Illinois Environmental Protection Agency 2005) and the Illinois RiverWatch program's guidelines for laboratory identification of specimens (Illinois Department of Natural Resources 2000). Appendix B contains the full aquatic ecology assessment for the Creek

The water was very clear at all three sites and there was a mixture of gravel, sand, and silt substrates on the stream bottom. The only fish observed during the site investigation were a small number of large common carp.

The QHEI score of Site 1 was 40.5 resulting in classification as Modified Warmwater Habitat. Modified Warmwater Habitat applies to extensively modified habitats that are capable of supporting the semblance of a warmwater biological community, but fall short of attaining Warmwater Habitat because of functional and structural deficiencies due primarily to altered macrohabitat. Site 1 is lacking in suitable substrate (sand and silt dominated), contains sparse instream cover, displays poor channel morphology, contains a virtually nonexistent riparian zone, exhibits poor riffle-run and pool-glide quality, and supports generally shallow water levels. Additional issues at Site 1 include isolation from potential downstream fish communities due to the significant underground portion of the channel downstream from Site 2, culverts that may be impassable to smaller fish species, and intermittent flows. The macroinvertebrate community at Site 1 is classified as poor to very poor with a score of 6.05. The macroinvertebrate community was dominated by Back Fly and Midge larvae and included other pollution tolerant organisms.

The QHEI score of Site 2 was 50.5 and was classified as Modified Warmwater Habitat. Site 2 is dominated by silt and sand substrates although gravel, cobble, and boulders are present in small quantities. Instream cover is present in moderate amounts including shallows in slow water, rootwads, boulders, aquatic macrophytes, and woody debris. The overall channel morphology is poor with low sinuosity, poor development, and moderate channel stability. The riparian zone is narrow to moderate in width along the reach. The floodplain is a mixture of wooded areas and residential development. The banks exhibit a moderate amount of erosion. The pool-glide and riffle-run quality is fair with moderate depths, pool widths, and riffle-run stability. Because of its isolation from downstream reaches this section of stream will not likely support a high quality warmwater fish community. The macroinvertebrate community at Site 2 is classified as poor to very poor and an MBI score of 6.16. Species are similar to Site 1.

The QHEI score of 61 for Site 3 results in a classification of Warmwater Habitat. In terms of habitat, this section of stream is capable of supporting and maintaining a balanced, integrated, adaptive community of warmwater aquatic organisms having a species composition, diversity, and functional organization. The substrate at Site 3 is dominated by sand and gravel with small amounts of silt along the stream margin. The instream cover is moderate and includes shallows in slow moving waters, rootwads, and boulders. The channel morphology is poor characterized by low sinuosity, fair development, and moderate stability. The riparian zone is narrow to moderate with wider areas of woods on the left downstream bank. Bank is erosion is moderate along most portions of the reach. Pool-glide and riffle-run quality is fair with a diverse

current velocity regime. The macroinvertebrate community at Site 3 is classified as very poor with an MBI of 6.01. Midge and Black Fly larvae dominate the community.

Although a fish survey was not conducted, none of the three sites would qualify for an Index of Biotic Integrity (IBI) rating of 35 or greater and therefore would not be classified as high quality habitat. The USFWS and the IDNR viewed the Creek on April 9, 2009 and agreed that it was not high quality habitat and that stream restoration may provide benefits.

Crystal Lake Water Levels Management Issues

Crystal Lake has long been known to have relatively large fluctuations in its water surface elevation. The CLPD Clean Lakes Report confirmed the 1957 ISWS conclusion that lake levels were directly related to precipitation surplus or deficit from normal conditions. Monitoring by the CLPD has shown that Lake levels have ranged from a low of 888.0 to a high of 892.5 over a period of just two years. The ISWS also concluded that the Lake level only reaches the elevation of its outlet weir (890.8) about one-third of the time. Water loss through apparent direct connection to sewers downstream of the Lake was established by a detailed daily water budget in the Clean Lakes Report although the precise location of these sewers remains unknown and unstudied.

The management of water levels for Crystal Lake is critical to its recreational usage. When the Lake falls below elevation 889 it loses about 30 acres of its surface area, especially on the north and west shorelines. This has been a relatively frequent occurrence and appears to occur once every 5 years on average.

Flooding around the Lake is directly related to high Lake levels as explained in the Crystal Lake Flooding Study. High Lake levels increase the groundwater levels above the Lake. High groundwater levels above the Lake reduce the ability of the soils to hold water. During periods of large rainfall flooding results because water cannot infiltrate due to high groundwater levels. The areas around the Lake have inadequate minor and major drainage systems to carry runoff safely to the Lake so flooding occurs.

High water levels on the Lake also reduce its flood storage capability. Exhibit 7 shows that as Lake levels rise, discharge from the Lake is controlled by the box culvert under Lake Avenue. This culvert has less capacity than the weir when Lake levels reach about 891.25. Lake levels begin to rise faster than if the weir capacity were fully available. This causes higher peak flood elevations on the Lake than if just the weir controlled Lake outflow.

Managing Lake levels for both recreation and flood storage could lead to more recreational usage, remove properties from the floodplain and improve drainage around the Lake.

METHODOLOGY

Existing Conditions Floodplain Model

To evaluate alternative improvements to drainage, a more detailed model of the existing drainage network was needed. The absence of the final FIS HEC-1 hydrology model prevented its use to accomplish this task. The FIS hydrology model below the Lake also was inaccurate. XP-SWMM was chosen to replace this model because of its ability to represent pressure storm sewer flow from Area 4 and Lakewood and its ability to simulate hydraulics directly with hydrology. The Existing Conditions XP-SWMM model that was

prepared for this study contains 20 watersheds and includes Crystal Creek from the Lake outlet to St. Andrews Lane. It incorporates the FIS hydraulics model. Below St. Andrews Lane the FIS hydraulics model was used to evaluate changes to floodplain elevations resulting from alternative drainage improvements.

Although it was beyond the scope of this project, a simple model for the watershed above the Crystal Lake outlet also was created because the FEMA model was missing. This model contained subwatersheds for the area directly tributary to the Lake and one for the Lake itself. It assumed a constant 15 cfs discharge from the 2305 acre watershed tributary to the Honeysuckle storm sewer. The rating of the weir and box culvert under Lake Avenue shown in Exhibit 7 was incorporated into this model.

Alternatives 1 through 6 were modeled first to see their impacts. Alternative 7 was then modeled with storage to mitigate impacts.

Appendix C contains the XP-SWMM and Lake hydrology model schematics and documentation for model parameter selection including additional field survey. Exhibit 8 shows watershed boundaries for the XP-SWMM model and Exhibit 4 shows the watershed for the Lake model.

Lake Level Model

An existing conditions water budget model was prepared to evaluate potential Lake level management alternatives. The model was based on the detailed daily water budget prepared for Crystal Lake during the CLPD Clean Lakes Report in 2006.

The model was calibrated against the following measured data from 1998 through 2008.

Groundwater level at Lippold Park	2005-2008
Lake levels	2005-2008
Cove Pond water levels	1998-2008

Annual yields to and from the Lake also were evaluated for reasonableness. The water budget model calibration is shown in Appendix D.

After model parameters were established using the calibration data, the model was verified against Lake levels for the period 1946 through 1957. The water budget model verification is shown in Appendix D.

POSSIBLE PROJECTS

Eleven possible projects (Exhibit 9) to improve flooding along Crystal Creek and around Crystal Lake were identified. Most of these projects were identified as possibilities in the Crystal Lake Flooding Study.

A. Submit a LOMR for Crystal Creek using the project model
B. Prepare a new hydrologic model for Crystal Lake watershed above Lake Avenue for a LOMR
C. Investigate leakage into the Lakewood storm sewer
D. Larger culvert under Lake Avenue
E. Notch Lake outlet weir to 890.0 from current 890.9
F. Larger culvert under Country Club Road

G. Lower Crystal Creek five feet from Broadway Avenue to Edgebrook Drive
H. Add 10-year storm sewer system to Area 4
I. Lower overland flow channel from Edgebrook Drive to St. Andrews Lane by 1.5 feet
J. Restore Crystal Creek to its original open channel from Edgebrook Drive to St. Andrews Lane
K. Storage on School District property to mitigate increased discharges from alternatives

ALTERNATIVES ANALYZED

Seven alternatives were developed from the eleven possible projects. These alternatives were based on input from the Flooding Study including the Open House, the Lakewood Flooding Study, discussion with Crystal Lake engineering staff, Lakewood engineering staff and meetings with the Crystal Lake Country Club and School District.

Alternative 1 - Increase Culvert Capacity Under Lake Avenue

This alternative is shown on Exhibit 10. Two approximately 6-foot by 3-foot box culverts would be added under Lake Avenue to replace the existing 3-foot by 2.5-foot box culvert. The expected benefit of this alternative is to lower the 100-year floodplain on Crystal Lake.

Alternative 2 - Notch Crystal Lake Weir and Increase Culvert Capacity Under Lake Avenue

This alternative is shown on Exhibit 11. In addition to adding another culvert under Lake Avenue (Alternative 1) the outlet weir from the Lake would be notched to elevation 890.0. The expected benefit of this alternative would be to further lower the 100-year floodplain elevation on Crystal Lake. It also may help to stabilize routine Lake elevations around the historic average of 890.0 allowing better routine drainage for properties around the Lake. It is critical that the leakage from the Lake be eliminated (Project C) for this alternative to be effective and not result in lower Lake levels.

Alternative 3A - Increase Culvert Capacity Under Country Club Road

The FIS study (Exhibit 3) shows a 2.5 foot head loss at Country Club Road. This head loss results in a higher floodplain between Country Club Road and the Lake that results in properties being located in the floodplain and the floodway of Crystal Creek. Alternative 3A is larger culverts under Country Club Road. Exhibit 12 shows Alternative 3A. The expected benefit of Alternative 3A is to eliminate the head loss and lower the floodplain to a level that would remove most if not all properties between Country Club Road and the Lake from the floodplain and floodway. This alternative was evaluated using the project XP-SWMM model.

Alternative 3B - LOMR Using Project Model

Alternative 3B is an improved mapping of the Crystal Creek floodplain based on the XP-SWMM results.

Alternative 4 - Add Overland Flow Conveyance Downstream of the 30-inch Culvert at Edgebrook Drive

The FIS study (Exhibit 3) shows that the 10-year flood event will not fit into the 30-inch Edgebrook Drive culvert causing Crystal Creek to pond back through the Country Club past Country Club Drive. This

alternative (Exhibit 13) would lower the overflow elevation near Edgebrook Drive from 887.7 to 886.0, which in turn should lower the floodplain elevation upstream. The expected benefit of this alternative is to lower the floodplain elevation in the reach from Edgebrook Drive to Country Club Road and minimize flooding of riparian properties including the Crystal Lake Country Club. This Alternative would also require lowering of overflows at two downstream access drives.

Alternative 5 - Provide 10-Year Storm Sewer Capacity for Area 4

This alternative would include the following components.

- A 10-year capacity storm sewer down Broadway Avenue discharging to a reconfigured Crystal Creek
- A 10-year capacity storm sewer down Country Club Road discharging to a reconfigured Crystal Creek
- Lowering the channel of Crystal Creek from Broadway to Edgebrook Drive to allow free discharge for storm sewers
- Increasing channel capacity at a lower elevation below Edgebrook Drive (Alternative 4)

Exhibit 14 shows that Crystal Creek would need to be lowered about four to five feet to allow free discharge for the new Broadway Avenue and Country Club Road storm sewers. Crystal Creek would then be graded at a new slope to Edgebrook Drive (Alternative 4). The storm sewer sizes were estimated so that Lakewood could tie into them to improve their drainage as well.

Although not explicitly evaluated, Alternative 5 could also be constructed without the proposed storm sewer, resulting in a lower groundwater table in Area 4 that should theoretically improve drainage in this area. This alternative would also lower floodplain elevations on Crystal Creek between the Lake and Edgebrook Drive and allow for the future installation of the storm sewer. Finally, it could serve as a partial alternative to storage on School District property.

Alternative 6 – Provide 10-year Storm Sewer Capacity for Area 4, Lower Creek and add Alternative 4 or Restore Crystal Creek to St. Andrews Lane

Crystal Creek was enclosed within a 30-inch culvert from Edgebrook Drive to St. Andrews Lane sometime in the 1960s. The effect of enclosing the Creek in a pipe has been described above and is shown on the current FIS profile and floodplain mapping. Alternative 6 is the same as Alternative 5 except that Crystal Creek is re-opened from Edgebrook Drive to St. Andrews Lane. Exhibit 15 shows the restored channel for Crystal Creek. The expected benefits of this alternative are to lower the existing floodplain elevation and storage and to restore the ecology of Crystal Creek.

Alternative 7 - Combined Alternatives 1, 2, 3 and 4

Alternative 7 (Exhibit 16) combines the following previous alternatives into a new alternative to provide as many benefits as possible without the expense of a new storm sewer system for Area 4 and Lakewood.

- Fixing the Lake "leak" and elimination of excess flow in the Lakewood storm sewer
- More Lake outlet capacity at a lower weir elevation (Alternatives 1 and 2)
- Larger culverts under Country Club Road (Alternative 3)

- A lower overflow channel below Edgebrook Drive (Alternative 4)
- Storage on School District property to mitigate increased discharges

Alternative 7 addresses the Flooding Study recommendations to remove properties from the floodplain and floodway, lower Lake levels to improve drainage in the Study area, fix the Lake "leak", and to generally decrease flooding along Crystal Creek above Edgebrook Drive by removing obstructions. Larger culverts under Country Club Road are needed in this alternative because increased flows from the Lake resulting from Alternatives 1 and 2 were anticipated.

To maintain flood discharges and elevations below St. Andrews Lane after the implementation of Alternative 7, storage on School District property (or possibly along Crystal Creek) also will be needed. Several possible locations are shown on Exhibit 17 that provide about 30 acre-feet of storage; however, additional analysis beyond this project may be needed to finalize mitigation.

RESULTS

The results of the existing conditions analyses with the Lake hydrology model and XP-SWMM versus the FIS discharges and HEC-RAS models are shown in Table 1.

The 100-year discharge out of the Lake drops from 50 cfs to 45 cfs in this study but the Lake floodplain elevation rises from 892.6 to 893.1. This change results from a better description of the actual weir-culvert outlet rating and a balancing of tailwater with Lake hydrology. This study calculated lower discharges at all cross sections and crossings below the Lake when compared to the FIS study as shown in Table 1.

A discussion of the analytical results for each alternative follows. It is important to note that each alternative was considered primarily on its own merits. This was done to highlight the impacts on downstream flooding of each alternative. Storage generally was not modeled except in Alternative 7. Table 2 provides detailed discharge and floodplain results for each alternative. Table 3 presents a summary of the benefits and costs associated with each alternative. Exhibit 18 is a mapping of the existing floodplain based on this project's XP-SWMM model.

1 - Increase Culvert Capacity Under Lake Avenue

Increasing culvert capacity under Lake Avenue will have the following effects.

1. The 100-year floodplain elevation on the Lake would be reduced to 892.18.
2. About 200 properties could be removed from the current FIS floodplain around the Lake.
3. Drainage would be improved for properties around the Lake because high water levels will be reduced.
4. Discharges will be increased immediately downstream of Lake Avenue from 45 cfs to 131 cfs for the 100-year event.
5. The floodplain downstream would be increased by 0.2 to 0.4 feet unless storage is added.

This alternative also was simulated using the Lake Water Budget Model (Table 4). It caused almost no impact on long term routine Lake levels. This was to be expected since the weir elevation was not changed. The following additional projects would also be needed to support Alternative 1 based on project analysis: A, B, F, I and K. Exhibit 19 shows the potential revised floodplain for Alternative 1. The cost of Alternative 1 was estimated at $1,387,000 including storage.

2 - Notch Weir and Increase Culvert Capacity Under Lake Avenue

Creating an 18-foot wide notch in the Crystal Lake outlet weir at elevation 890.0 with Alternative 1 would have the following effects.

1. The 100-year floodplain elevation on the Lake would be reduced to 891.55.
2. About 250 properties would be removed from the current FIS floodplain around the Lake.
3. Drainage would be improved for properties around the Lake because high water levels will be reduced.
4. Discharges will be increased immediately downstream of Lake Avenue from 45 cfs to 123 cfs for the 100-year event.
5. The floodplain downstream would be increased by 0.2 to 0.3 feet unless storage is added.

This alternative also was simulated using the Lake Water Budget Model (Table 3). It caused almost a one-foot drop in long term routine Lake levels. Average June through August water levels also dropped about a foot.

If the leakage from the Lake were to be reduced by 90 percent, Lake levels would average 890.12. This average elevation is 0.5 feet higher than the current simulated long-term Lake level average. The drops in water level below 889.0 also would be minimized according to the water budget model.

Model results indicated that Alternative 2 also would need Projects A, B, C, F, I and K. The revised floodplain for Alternative 2 is similar to Alternative 1. Notching the weir adds $76,000 to the Alternative 1 cost for a total cost of $1,463,000.

3A - Increase Culvert Capacity Under Country Club Road

Increasing culvert capacity under Country Club Road (3A) to prevent overtopping will reduce the floodplain elevation from the FIS level of 890.29 to 888.2. However, this improvement may not be necessary based on the existing conditions XP-SWMM model results (3B).

Alternative 3A slightly increases discharges at St. Andrews Lane from 162 cfs in this study's Existing Conditions model to 176 cfs. Additional storage likely would not be needed to offset this increased discharge after final design changes. Exhibit 20 shows the effect Alternative 3A or 3B has on the floodplain. The cost for larger culverts under Country Club Road would be $169,000.

3B - New Floodplain Mapping

The Existing Conditions model, built for this project, shows that with the existing Lake outlet the 100-year discharge fits through the existing Country Club Road culverts. This result highlights the need for an approved hydrology model to use for a Letter of Map Revision (LOMR) submittal to remap a lower floodplain. Finalizing the XP-SWMM modeling and submitting to FEMA for a LOMR would likely result in the removal of 40 properties from the floodplain and 25 from the floodway. The cost to prepare a Crystal Creek LOMR submittal to FEMA (Project A) would be $35,000.

4 - Add Overland Flow Conveyance at Edgebrook Drive and Downstream of the 30-inch Culvert at Edgebrook Drive

Lowering the overland flow route from Edgebrook Drive to St. Andrews Lane and keeping the existing 30-inch culvert without modification results in a floodplain elevation of 887.4 at Country Club Road and 886.5 at Edgebrook Drive. The FIS floodplain elevation at Edgebrook Drive is 888.39 and is 890.29 at Country Club Road as previously stated.

The effect of this alternative is to remove 40 properties from the regulatory floodplain and 25 properties from the regulatory floodway. It also will lower the floodplain elevation at the Crystal Lake Country Club parking lot to 887.3 from the current FIS level of 888.5. Storage lost between the existing 30-inch sewer and Country Club Road would increase discharges from 162 cfs to 211 cfs below St. Andrews Lane. While these discharges are below the FIS discharge of 268 cfs they still represent an increase over this study's Existing Conditions model. Storage as shown above (Project K) would need to be added to offset these increased discharges. A LOMR (Project A) also would be needed. Exhibit 21 shows the effect that Alternative 4 has on the floodplain. The estimated cost for Alternative 4 would be $1,089,000.

5 - Provide 10-Year Storm Sewer Capacity for Area 4 Lower Crystal Creek and Implement Alternative 4

To provide for increased capacity out of Area 4 for routine drainage up to the 10-year event, the invert of Crystal Creek must be lowered approximately four to five feet from Edgebrook Drive to Broadway Avenue. This would allow for installation of a 48-inch storm sewer down Broadway with a downstream invert of 883.0 and a 30-inch culvert to replace the 21-inch culvert down Country Club Road with a new outlet invert of 883.0. This alternative would also include the lowered overtop at Edgebrook Drive and the downstream access roads as detailed under Alternative 4. Significant channel storage would be added by lowering the Creek. Discharges at St. Andrews Lane would decrease from 162 cfs to 159 cfs. Exhibit 22 shows the effect on the floodplain of Alternative 5.

40 properties would be removed from the floodplain and 25 properties from the floodway above Country Club Road. This alternative would alleviate routine drainage complaints from Area 4. Areas in Lakewood tributary to the new storm sewers also could benefit if they were connected. It also will help to lower routine groundwater levels to provide more storage within watershed soils. It does not solve the major drainage system problems however. This would be an even more difficult project since the existing major drainage system routes would have to be re-created along Broadway Avenue and Country Club Road. Existing grades on these two routes are very unfavorable and significant property acquisition and excavation would be needed. Based on project analysis, Alternative 5 also would need Project A and K. The cost for this Alternative 5 with these additions is estimated at $4,702,000.

This alternative also could be implemented without the storm sewer with the resulting benefits being a lowered groundwater table in Area 4 and lower floodplain elevation along Crystal Creek upstream of Edgebrook Drive. Lowering the creek channel would also allow for installation of the storm sewers in the future. The estimated cost just to lower Crystal Creek would be $1,187,000.

6 - Provide 10-Year Storm Sewer Capacity for Area 4 and Lakewood, Lower Crystal Creek and Restore Crystal Creek from Edgebrook Drive to St. Andrews Lane

Alternative 6 involves the work described in Alternative 5 in addition to restoring Crystal Creek to a natural open channel from Edgebrook Drive to St. Andrews Lane. The estimated cost for this alternative is $5,002,000.

Crystal Creek must be lowered at least four to five feet to provide an outlet for a new minor drainage system from Area 4 in Crystal Lake and for Lakewood. Removing the restriction at Edgebrook Drive downstream and through School District property would increase discharges at St. Andrews Lane from 162 cfs to 362 cfs. This is because the channel storage created by lowering the Creek is not fully utilized particularly above Edgebrook Drive. With careful design, this impact might be eliminated.

This alternative would need to be designed to utilize the significant storage created by restoring Crystal Creek to mitigate the increased discharges. Additional storage also may be needed to control these increased discharges to existing conditions using the floodplain channel through School District property (Project K). Exhibit 23 shows the effect on the floodplain of Alternative 6. A LOMR (Project A) also would be needed.

This alternative will minimize routine drainage complaints from Area 4. If Lakewood connects it also will reduce their drainage complaints. It also will help to lower routine groundwater levels to provide more storage within watershed soils. It does not solve the Area 4 major drainage system problems however. This would be an even more difficult project since the existing major drainage system routes would have to be re-created along Broadway Avenue and Country Club Road. Existing grades on these two routes are unfavorable and significant property acquisition and excavation would be needed. About 40 properties would be removed from the floodplain and 25 from the floodway for Alternative 6.

7 - Combination of Alternatives 1, 2, 3 and 4

This alternative would provide the following benefits.

- Removal of nearly 300 properties from the floodplain
- Removal of 25 properties from the floodway
- Stabilization of Lake levels
- Restoration of existing Lakewood storm sewer capacity
- Improved routine drainage around the Lake and along Crystal Creek
- Less frequent flooding of Country Club property

Alternative 7 also would require Projects A, B and C. Exhibit 24 presents the effect on the floodplain of Alternative 7. The estimated cost for Alternative 7 is $1,463,000. The combination of more outlet capacity at a lower elevation from the Lake, eliminating excess flow from the Lakewood storm sewer, providing more culvert capacity under Country Club Road and providing a lower overflow channel below Edgebrook Drive can address most of the recommendations of the Crystal Lake Flooding Study. However, downstream impacts are not fully mitigated and additional storage and conveyance may need to be added during design.

COST ESTIMATES

Table 5 presents cost estimates for the projects.

PERMIT ASSESSMENT

Table 6 presents an assessment of permitting issues for each alternative.

CONCLUSIONS

1. Nearly all of the properties in the floodplain and floodway of Crystal Creek above St. Andrews Lane could be removed through a Letter of Map Revision (LOMR) for about $35,000. A new model for the Crystal Lake floodplain would add $25,000. Although the FEMA regulatory hydrology model for Crystal Lake and Crystal Creek is not available, the model developed for this project could be enhanced and used for the LOMR because it results in a lower floodplain on Crystal Creek (Alternative 3B). Alternative 3A larger culverts under Country Club Road is not necessary unless Alternatives 1 or 2 are selected.

2. The CLPD Clean Lakes Report determined that there appears to be a considerable amount of leakage from the Lake that causes relatively rapid downward fluctuations in water levels. The Crystal Creek Flooding Analysis found that if this leakage from the Lake were controlled, water levels would stabilize at the elevation of the outlet weir. Controlling leakage also could prevent Lake levels below 889.0.

3. Alternative 1, adding culvert capacity under Lake Avenue, would reduce the Crystal Lake floodplain elevation by about one foot to 892.2. This would remove about 200 properties from the FIS floodplain around the Lake (Exhibit 17 v. Exhibit 19). Discharges downstream to Crystal Creek would be increased from 45 cfs to 131 cfs and the floodplain elevation above Edgebrook Drive would be increased by 0.3 feet and above Broadway by 0.7 feet. Larger culverts at Country Club Road and storage downstream would be needed to implement this alternative.

4. Lowering the weir elevation from Crystal Lake to 890.0 (Alternative 2) combined with Alternative 1 would lower the Crystal Lake floodplain to 891.55. A total of 250 properties would be removed from the floodplain around the Lake. According to the Lake Level Model, water surface elevations would not be adversely affected if the "leak" was fixed. Larger culverts at Country Club Road and storage downstream would be needed.

5. Alternative 4 would lower the regulatory floodplain from Edgebrook Drive to Country Club Road by about one foot. This alternative would remove about 45 properties from the regulatory floodplain along Crystal Creek and 25 properties from the regulatory floodway. Alternative 4 also reduces flooding on the Crystal Lake Country Club. This alternative would slightly increase discharges downstream of St. Andrews Road, so storage would be needed to reduce discharges.

6. Crystal Creek would need to be lowered 4 to 5 feet to construct a new storm sewer system in Area 4 to improve routine drainage. If this alternative were implemented, it requires new storm sewers in Area 4 (and presumably Lakewood). It also may require additional storage downstream on Country Club and/or School District property to mitigate increased discharges to prevent higher regulatory floodplain elevations downstream of Country Club Road.

7. Alternative 7 appears to effectively address all of the following Crystal Lake Flooding Study objectives.

    - Lower Lake floodplain
    - Improved drainage for properties around the Lake
    - Lower Crystal Creek floodplain and removal of properties from the floodway
    - Improved drainage from Country Club Road to St. Andrews Lane

RECOMMENDATIONS

1. The City should consider applying for a LOMR for Crystal Creek to remove properties from the floodplain and floodway.
2. The City should consider implementing Alternative 7. The steps to implement Alternative 7 would be as follows.
    a. Complete a hydrology model for Crystal Lake and additional documentation for the model prepared in this project and submit to FEMA for a LOMR.
    b. Meet again with the School District, the CLPD, residents and the Country Club to obtain input and support for the components of Alternative 7.
    c. Form a cooperative effort among the CLPD, Lakewood and the City to investigate the "leak" from Crystal Lake and fix it.
    d. Complete preliminary engineering and submit a CLOMR for construction of a lower overflow channel through School District property from Country Club Road to St. Andrews Lane along with the storage needed for future alternatives.
    e. Complete final engineering, bid and construct the lower overflow channel and storage.
    f. Complete preliminary engineering and submit a CLOMR for larger culverts under Lake Avenue and Country Club Road and a lower weir elevation at the Lake outlet.
    g. Complete final engineering, bid and construction for the larger culverts and the lower weir.

    Steps d through g could be combined into a single project if affordable and desired by the City.