

**US Army Corps
of Engineers®**
Chicago District

**LAKE MICHIGAN
DIVERSION ACCOUNTING
WATER YEAR 2011
ANNUAL REPORT**

EXECUTIVE SUMMARY

This document is the Water Year (WY) 2011 Annual Report of the Chicago District, U. S. Army Corps of Engineers activities in the monitoring and review of the accounting of Lake Michigan diversion flows through Chicago, Illinois as directed by the 1980 amendment to the 1967 U. S. Supreme Court Decree. Additionally, this report serves to summarize the Corps' major accomplishments with respect to the mission as mandated by the Water Resources Development Act of 1986, PL99-662, Section 1142. This act gave the Corps complete responsibility for diversion accounting effective 1 October 1987. This report provides an overview and audit of flow measurements and accounting computed by the Corps of Engineers for WY 2011, 1 October 2010 through 30 September 2011.

The Lake Michigan Diversion Accounting Report for WY 2011 has been completed. The State of Illinois diverted 2,791 cfs during WY 2011. This diversion is 409 cfs less than the 3,200 cfs 40 year average diversion specified in the modified decree. The running average of the diversion for WY 1981 through WY 2011 is 3,143 cfs, or 57 cfs under the annual allocation. Also, the annual average diversion has exceeded the 3,680 cfs annual limit three times, once more than the maximum number of times allowed in the decree. Additionally, the absolute annual maximum of 3,840 cfs has been exceeded during the WY93 accounting period. The cumulative deviation is 1,772 cfs-years at the end of WY 2011. The positive sign indicates a cumulative flow surplus. The maximum allowable cumulative flow deficit specified in the decree is -2,000 cfs-years.

Table of Contents

EXECUTIVE SUMMARY	I
INTRODUCTION	1
AUTHORITY FOR REPORT	1
HISTORY OF THE DIVERSION	1
SIGNIFICANT HYDROLOGIC EVENTS	5
STATUS OF ACCOUNTING REPORTS.....	5
SOURCES OF DIVERSION	8
ACCOUNTING PROCEDURES.....	8
DIVERSION COMPUTATION.....	9
DIVERSION BUDGET CHECKS.....	9
ACTIVITIES FOR FY 2011.....	10
ACTIVITIES FOR FY 2012 – FY 2013.....	10
ACCOUNTING REPORTS.....	11
SUMMARY AND CONCLUSIONS.....	11
SUMMARY	11
CONCLUSIONS	11
REFERENCES	13

Table of Figures and Tables

FIGURE 1 DEVELOPMENT OF THE CHICAGO SANITARY AND SHIP CANAL SYSTEM	3
FIGURE 2 LOCATION PLAN - LAKE MICHIGAN DIVERSION AT CHICAGO	4
TABLE 1 WY 2011 MONTHLY AND ANNUAL PRECIPITATION (INCHES)	5
TABLE 2 STATUS OF THE STATE OF ILLINOIS DIVERSION	7

List of Appendices

APPENDIX A: WY 2011 LAKE MICHIGAN DIVERSION ACCOUNTING REPORT

APPENDIX B: CONTINUED OPERATION OF A 25-RAINGAGE NETWORK FOR COLLECTION, REDUCTION, AND ANALYSIS OF PRECIPITATION DATA FOR LAKE MICHIGAN DIVERSION ACCOUNTING: WATER YEAR 2011

APPENDIX C: EVALUATION OF THE POTENTIAL FOR HYSTERESIS IN INDEX-VELOCITY RATINGS FOR THE CHICAGO SANITARY AND SHIP CANAL NEAR LEMONT, ILLINOIS

INTRODUCTION

The diversion of water from the Lake Michigan watershed is important to the Great Lake states and to the Canadian province of Ontario. The states and province that border the Great Lakes have concerns with diversions during periods of low lake levels and the long-term effects of diversion. To insure these concerns are considered, the U.S. Army Corps of Engineers is responsible for the accounting of flow diverted from the Lake Michigan watershed.

The Water Year (WY) 2011 Annual Report on Lake Michigan Diversion Accounting presents activities by the Corps of Engineers in accounting for the diversion from Lake Michigan by the State of Illinois. The accounting of the diversion is performed according to the guidelines established in the 1980 modified U.S. Supreme Court Decree concerning the diversion.

Presented in this report is the history of the diversion and its accounting, the certification of diversion flows for WY 2011, a description of the sources of the diversion, a description of the accounting procedures, and a summary of all significant activities that occurred during WY 2011 through to the present.

AUTHORITY FOR REPORT

Under the provisions of the U.S. Supreme Court Decree in the Wisconsin, et al v. Illinois et al, 388 U.S. 426, 87 S.Ct. 1774 (1967) as modified by 449 U.S. 48, 101 S. CT. 557 (1980), the Corps of Engineers monitors the measurement and computation of Lake Michigan diversion by the State of Illinois. The terms of the modified decree require the Corps of Engineers to prepare an annual report on the accounting of the Lake Michigan water diverted by the State of Illinois and actions taken by the involved agencies.

HISTORY OF THE DIVERSION

Water has been diverted from Lake Michigan at Chicago into the Mississippi River Watershed since the completion of the Illinois and Michigan (I & M) Canal in 1848. At that time, the diversion averaged about 500 cubic feet per second (cfs). The I & M Canal was built primarily to serve transportation needs by providing a connecting watercourse between the Great Lakes and the Mississippi River system.

With the development of the Chicago metropolitan area, sewer and drainage improvements led to severe sanitation problems in the mid to late 1800's. The newly constructed sewers moved water and wastes into the Chicago River, which until 1900 drained to Lake Michigan. The water quality of Lake Michigan deteriorated and contaminated the city's primary water supply.

A second problem that occurred during this time period was an increase in the overbank flooding within the city. As more roads were built and buildings constructed, the sewer system was correspondingly expanded. The increase in impervious area from the newly constructed roads and buildings increased the rate and volume of stormwater runoff and resulted in increased flooding.

As a solution to the sanitation and flooding problems, construction of the Chicago Sanitary and Ship Canal (CSSC) was undertaken. Construction of the CSSC allowed the flow direction of the Chicago River to be reversed (Figure 1). Construction of the Chicago Sanitary and Ship Canal was completed in 1900 by the MWRDGC. The CSSC followed the course of the older I & M Canal. The CSSC is much larger than the I & M canal and can handle the Chicago River flow, as well as increased shipping. In 1938, the Chicago River Controlling Works (CRCW) was constructed at the mouth of the Chicago River. The CRCW regulates the amount of Lake Michigan water allowed to pass into the river and restricts river flooding from entering Lake Michigan. The Lockport Lock and Dam controls the water level in the CSSC.

Between 1907 and 1910, the MWRDGC constructed a second canal called the North Shore Channel. It extended from Lake Michigan at Wilmette in a southerly direction 6.14 miles to the north branch of the Chicago River. The Wilmette Pumping Station, also known as the Wilmette Controlling Works, regulates the amount of Lake Michigan flow allowed down the channel through the use of one vertical lift gate, one 250 cfs pump (refurbished in 2002), and one 150 cfs pump (installed in 2010 during the rehabilitation of the structure). The MWRDGC uses the pumps to take discretionary flow from Lake Michigan due to the concern over Asian carp.

Construction of a third canal, the Calumet Sag Channel, was completed in 1922. The canal connects Lake Michigan through the Grand Calumet River, to the CSSC. The Calumet Sag Channel was constructed to carry sewage from South Chicago, Illinois and East Chicago, Indiana. The Blue Island Lock and Dam controlled flow through the canal. The O'Brien Lock and Dam, which replaced the Blue Island Lock and Dam, was completed in 1967 and is located on the Calumet River. The O'Brien Lock and Dam regulates the flow of Lake Michigan waters down the Calumet Sag Channel. Figure 2 shows the affected watershed.

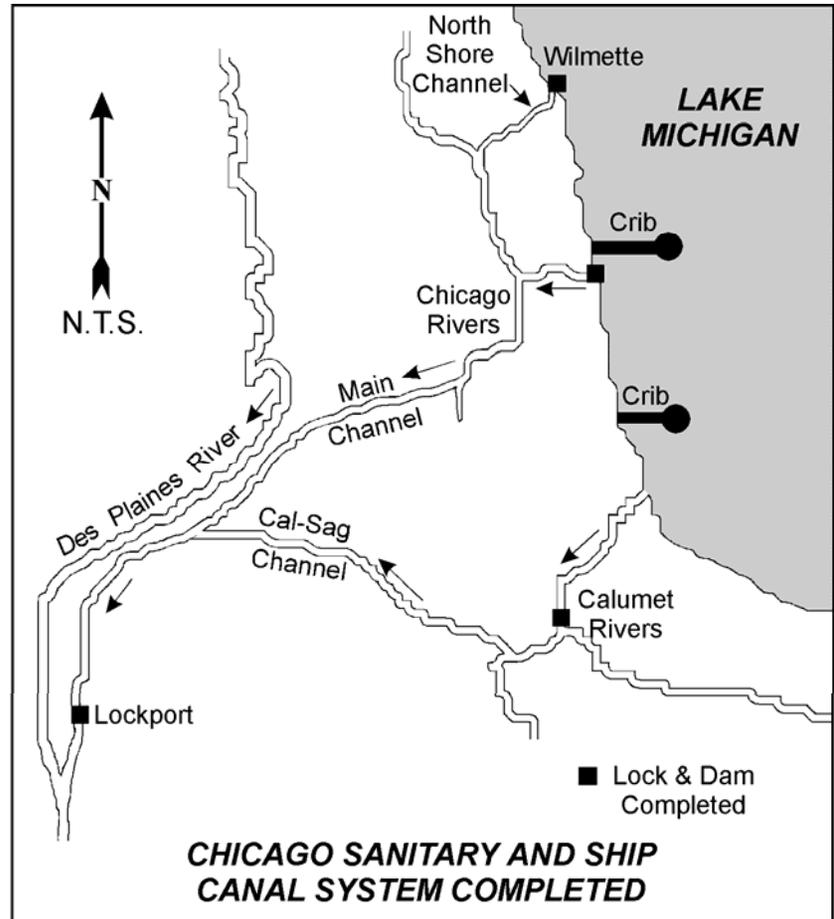
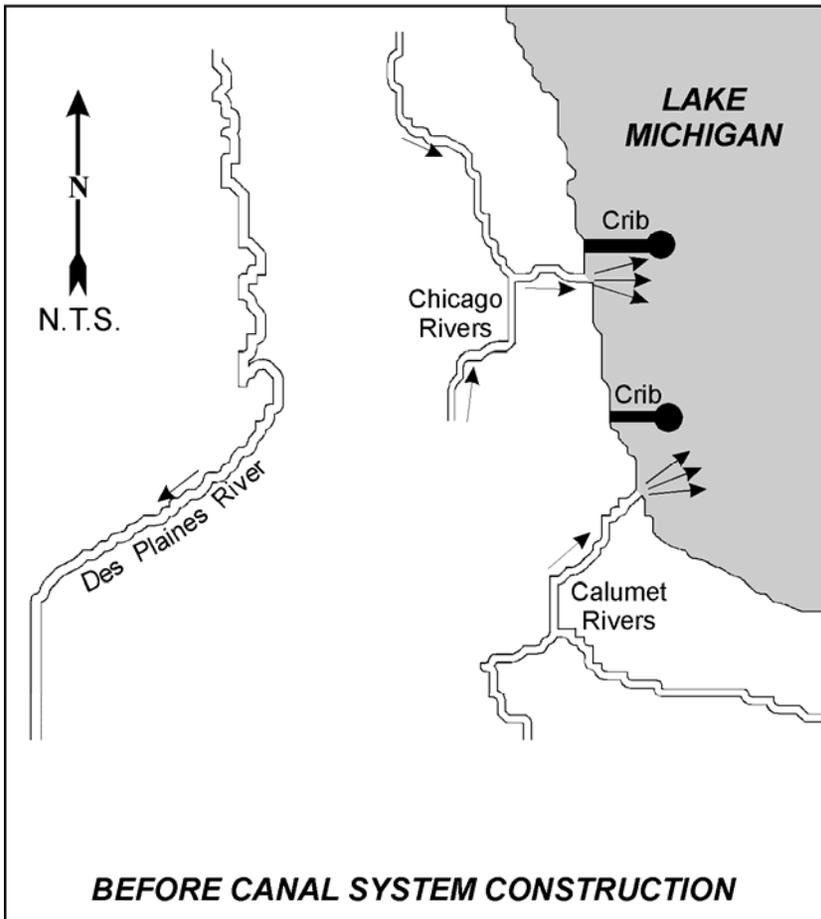


FIGURE 1 DEVELOPMENT OF THE CHICAGO SANITARY AND SHIP CANAL SYSTEM

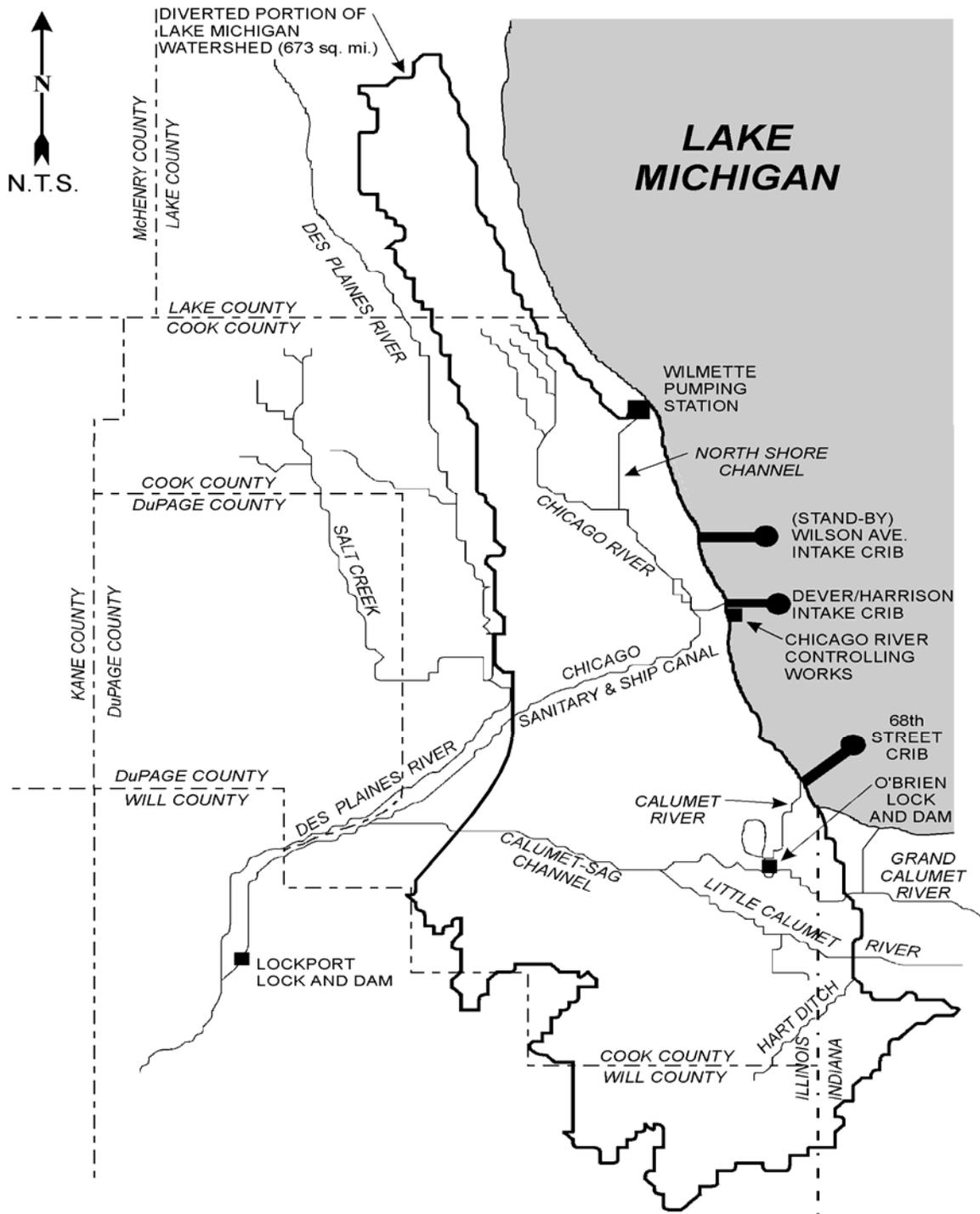


FIGURE 2 LOCATION PLAN - LAKE MICHIGAN DIVERSION AT CHICAGO

SIGNIFICANT HYDROLOGIC EVENTS

During WY 2011, an average total of 41.78 inches of precipitation fell at the 25 Illinois State Water Survey (ISWS) raingages that make up the Lake Michigan Diversion Accounting raingage network (Westcott, 2012). The WY 2011 average total precipitation of 41.78 inches was about 113 percent of the 21-year (1990-2010) average of 36.93 inches for the 25 raingage network and was about 113% of the 1981-2010 Chicago O’Hare Airport annual precipitation average of 36.89 inches. Table 1 tabulates the recorded monthly rainfall data during WY 2011, and the deviation from the ISWS 21-year annual and monthly average precipitation.

TABLE 1 WY 2011 MONTHLY AND ANNUAL PRECIPITATION (INCHES)
Illinois State Water Survey Average Across the 25 Raingage Network

<u>Month</u>	<u>1990 - 2010</u>			
	<u>Precipitation</u>	<u>Precipitation</u>	<u>Deviation</u>	<u>Average</u>
Oct-10	1.68	3.21	-1.53	52%
Nov-10	2.25	2.78	-0.53	81%
Dec-10	2.66	2.08	0.58	128%
Jan-11	0.63	2.12	-1.49	30%
Feb-11	3.24	1.82	1.42	178%
Mar-11	2.24	2.46	-0.22	91%
Apr-11	5.10	3.51	1.59	145%
May-11	5.26	3.92	1.34	134%
Jun-11	5.41	3.90	1.51	139%
Jul-11	6.04	3.67	2.37	165%
Aug-11	3.53	4.33	-0.80	82%
Sep-11	3.74	3.12	0.62	120%
Annual	41.78	36.93	4.85	113%

There were 111 precipitation events in Water Year 2011. Nine of the 111 precipitation events included at least one site at which the storm total exceeded one-year recurrence interval. These precipitation events occurred from October 2010 through September 2011.

Two backflow events occurred during WY 2011. On May 29, 2011, 107.0 MG was discharged at the Wilmette Pumping Station. On July 23, 2011, 1,716.2 MG was discharged at the Chicago River Controlling Works and 504.3 MG was discharged at the Wilmette Pumping Station.

STATUS OF ACCOUNTING REPORTS

Lake Michigan diversion flow data is summarized in accounting reports prepared on an annual basis as flows are certified. Since implementation of the modified Supreme Court Decree of 1 December 1980 and before this report, the Corps of Engineers has certified diversion flows for WY 1981 through WY 2009. The WY 2011 Lake Michigan Diversion Accounting Report is certified and included as Appendix A of this Water Year 2011 Annual Report. The State of Illinois diverted 2,791 cfs during WY 2011. This diversion is 409 cfs less than the 3,200 cfs 40 year average diversion

specified in the 1980 modified decree. Table 2 shows the accounting year, the certified flows, the running average flows, and the cumulative deviation from the allowable diversion of 3,200 cfs.

The running average diversion for the period WY 1981 through WY 2011 is 3,143 cfs, 57 cfs less than the 3,200 cfs 40 year average diversion specified by the modified decree. Also, the annual average diversion has exceeded the 3,680 cfs annual limit three times, once more than the maximum number of times allowed in the decree. Additionally, the absolute annual maximum of 3,840 cfs has been exceeded during the WY93 accounting period. The cumulative deviation, the sum of the differences between the annual average flows and 3,200 cfs, is 1,772 cfs-years at the end of WY 2011. The positive cumulative deviation indicates a cumulative flow surplus. The decree specifies a maximum allowable deficit of -2,000 cfs-years over the first 39 years of the 40-year averaging period.

Data collection and compilation for the WY 2011 accounting report were done by the Corps. Hydrologic and hydraulic modeling and diversion accounting for Water Year 2011 were also performed by the Corps. Data collection and compilation for this report began in Fiscal Year (FY) 2011.

TABLE 2 STATUS OF THE STATE OF ILLINOIS DIVERSION
Under the 1980 Modified U.S. Supreme Court Decree

Accounting Year	Certified Flow (cfs)	Running Average (cfs)	Cumulative Deviation (cfs-yrs)
1981	3,106	3,106	94
1982	3,087	3,097	207
1983	3,613	3,269	-206
1984	3,432	3,310	-438
1985	3,472	3,342	-710
1986	3,751	3,410	-1,261
1987	3,774	3,462	-1,835
1988	3,376	3,451	-2,011
1989	3,378	3,443	-2,189
1990	3,531	3,452	-2,520
1991	3,555	3,461	-2,875
1992	3,409	3,457	-3,084
1993	3,841	3,487	-3,725
1994	3,064	3,456	-3,589
1995	3,197	3,439	-3,586
1996	3,108	3,418	-3,494
1997	3,114	3,400	-3,408
1998	3,060	3,382	-3,268
1999	2,909	3,357	-2,977
2000	2,584	3,318	-2,361
2001	2,698	3,289	-1,859
2002	2,919	3,272	-1,578
2003	2,398	3,234	-776
2004	2,757	3,214	-333
2005	2,771	3,196	96
2006	2,628	3,174	668
2007	3,094	3,171	774
2008	3,002	3,165	972
2009	3,135	3,164	1,037
2010	2,874	3,155	1,363
2011	2,791	3,143	1,772

SOURCES OF DIVERSION

The Lake Michigan diversion consists of three primary components. These components are domestic pumpage from Lake Michigan used for water supply and not returned to Lake Michigan, stormwater runoff from the diverted Lake Michigan watershed, and direct diversions through the three lakefront control structures.

Domestic pumpage from Lake Michigan is used for water supply and its effluent is discharged to the canals by various Water Reclamation Plants (WRP's). Currently, the WRP's that divert domestic pumpage from the lake either discharge to the canal system or to the Des Plaines River and its tributaries. In the future as more communities convert to Lake Michigan water supply, water supply effluent may also be discharged to the Fox River. The Fox River is approximately 35 miles west of downtown Chicago.

Stormwater runoff that previously drained to Lake Michigan through the Chicago River and the Calumet River now drains to the Chicago Sanitary and Ship Canal (CSSC) and the Calumet Sag Channel, respectively. The Calumet Sag Channel drains to the CSSC, and the CSSC ultimately drains into the Illinois River and the Mississippi River. The drainage area of the diverted Lake Michigan watershed is approximately 673 square miles.

Direct diversions occur at three lakefront locations — the CRCW, the O'Brien Lock and Dam, and the Wilmette Pumping Station. These controlling structures are located downtown, at the south end, and at the north end of the Chicago area, respectively. The direct diversion at CRCW and O'Brien Lock and Dam consists of four components: lockage, leakage, discretionary flow, and navigation makeup flow, whereas only leakage and discretionary flow occur at Wilmette. The lockage component is the flow used in locking vessels to and from the lake. The leakage component is water estimated to pass, in an uncontrolled way, through or around the three lakefront structures. The purpose of the discretionary diversion is to dilute effluent from sewage discharges and improve water quality in the canal system. Navigation makeup water is composed of two parts. When large storms are forecast, the canal is drawn down before the storm to prevent flooding, and navigation makeup water is used during this draw down period to maintain navigation depths. If the runoff is not enough to refill the canal, additional navigation makeup water is allowed to pass from Lake Michigan to return the canal system to its normal operating stages.

ACCOUNTING PROCEDURES

Diversion accounting uses both measured and estimated flows. A series of hydrologic and hydraulic computer models use various meteorological data to simulate flows not measured. These simulated flows as well as measured flows are used to compute the diversion. Along with the diversion calculation, a number of water budgets verify simulated flows and estimate the reliability of the computed diversion.

DIVERSION COMPUTATION

An acoustic velocity meter (AVM) was installed and has been operating at Romeoville (five miles upstream of the Lockport Powerhouse and three miles upstream of the Lockport Controlling Works) since June 12, 1984. Due to installation of the electrical dispersal barrier II on the CSSC at Romeoville the AVM was relocated to Lemont, about six miles upstream from the Romeoville site, in 2006. The AVM directly measures total flow through the canal above both the Powerhouse and the Controlling Works. The overwhelming majority of the Lake Michigan diversion and some non-Lake Michigan flows pass through the AVM. The diversion accounting procedure uses the flow measured at Lemont and deducts flows not accountable in the diversion. Diversion flows which bypass Lockport are added to yield the net computed diversion of water from Lake Michigan. This procedure represents the accounting technique as required by the modified Supreme Court Decree.

The flow measured at Lemont was approximately 103.5% of the annual diversion during WY 2011. Approximately 91.7% of the diverted water was measured by the AVM during WY 2011.

Deductions from the Lemont AVM flow include runoff from 217 square miles of the Des Plaines River watershed discharged to the canal, groundwater supply effluent and groundwater seepage into the Tunnel and Reservoir Plan (TARP) tunnels discharged to the canal, and Indiana water supply discharged to the canal through the Calumet River system and the Calumet Sag Channel (see figure 2 for locations). The computer models of the Des Plaines watershed area estimate the runoff deduction. The groundwater pumpage deductions are obtained directly from pumping records. The Indiana water supply is computed from pumping records and a calculation to determine the portion of the water supply draining west to the Calumet Sag Channel.

The additions for diversion flow that do not flow through Lemont are primarily Lake Michigan water supply pumpage effluent treated and released to the Des Plaines River or its tributaries. This flow is obtained directly through pumping records of the communities involved and accounts for approximately 8.3% of the diversion in WY 2011. If more communities convert to Lake Michigan water supply, the percentage will increase.

DIVERSION BUDGET CHECKS

Water budgets verify those flows that are not measured. Most of the budgets compare simulated flows to recorded flows and these comparisons indicate the accuracy of the diversion accounting. The four primary budgets are the budgets for the three major Water Reclamation Plants (WRP's) that serve the area involved in diversion accounting and the canal balance budget for the CSSC. The Upper Des Plaines pump station budget is also an important budget. The remaining budgets estimate runoff from stream gaged areas in the Lake Michigan watershed or are budgets of non-simulated flows such as water supply pumpage. The budgets are discussed in detail in the WY 2011 accounting report.

ACTIVITIES FOR FY 2011

The activities in FY 2011 included data collection for WY 2011, and completion of Lemont accounting computations for WY 2006 and WY 2007. The Lemont accounting computations for WY 2008 and WY 2009 were also begun at this time. The Corps installed new lock gates at Chicago Lock that would help reduce leakage. In August 2011 the Corps met with model developers from the University of Illinois to discuss the current progress made on several hydrologic and hydraulic models. It is being evaluated that several of these models – in particular the Illinois Transient Model (ITM) and Illinois Conveyance Analysis Program (ICAP) - may take the place of the current TNET models.

ACTIVITIES FOR FY 2012 – FY 2013

The activities in FY 2012 included data collection for WY 2012, and completion of Lemont accounting computations for WY 2008 and WY 2009. The Lemont accounting computations for WY 2010 and WY 2011 were also begun at this time. Revisions to the Diversion Accounting manual were incorporated into the electronic document as the document was brought up-to-date. The USGS published the report on "Comparison of Index Velocity Measurements Made with a Horizontal Acoustic Doppler Current Profiler and a Three-Path Acoustic Velocity Meter for Computation of Discharge in the Chicago Sanitary and Ship Canal near Lemont, Illinois." This report provides a detailed analysis of the flow structure and index velocity measurements in the CSSC near Lemont, Illinois, to ensure that decisions regarding the future of this streamgage will be made with the best possible understanding of the site and the characteristics of the flow. The USGS published the report on "Monitoring of Stage and Velocity, for Computation of Discharge in the Summit Conduit near Summit, Illinois, 2010-2012". This report provides a detailed analysis of the index-velocity method used to establish a rated discharge for the nonstandard site conditions present in the Summit Conduit. The USGS published a report on the "Role of the U.S. Geological Survey in Lake Michigan Diversion Accounting in Illinois, 1984-2010". This report provides a summary of the role the USGS has played in LMDA from 1984 to 2010 including the responses to the comments from the technical review committees. The USGS completed the discharge rating of the sluice gates at Lockport Controlling Works. This study was based on flow measurements in the CSSC and Des Plaines River, rather than physical model testing performed by the University of Illinois in 1960s or the Corps Waterway Experimental Station (WES) in 1980s. A pilot study on the consumptive use was initiated using water supply and sewer flow measurement data in the northwestern suburban of Chicago. Under a research grant the University of Illinois is modifying their TARP modeling software to include the data I/O interface with HEC-DSS and accept user-specified inflow hydrographs at the drop shaft locations. These modifications allow the Corps to evaluate the tunnel hydraulic computations using the runoff and sanitary inflows simulated by HSPF and SCALP.

The activities for FY 2013 included data collection for WY2013, and completing the Lemont accounting computations for WY 2010 and WY 2011. Revisions to the Diversion Accounting manual included the introduction of a section describing the incorporation and execution of the Lower Des Plaines River Bypass models. Three service contracts for the 7th Technical Committee were established in May 2013. During this FY, Committee members attended workshops and meetings to listen to the briefings of various activities and technical procedures related to Lake Michigan Diversion

Accounting. The Corps invited the stakeholders from various Great Lake states and the Province of Ontario, and conducted the first workshop in July 2013. The USGS hosted the second workshop that included a two-day meeting at Urbana in September 2013. The USGS published the report "Evaluation of the Potential for Hysteresis in Index-Velocity Ratings for the Chicago Sanitary and Ship Canal near Lemont, Illinois". This report was generated in response to a concern expressed by the previous Technical Committee that the index-velocity rating of the Lemont gage may be subject to hysteresis because of the unique, unsteady hydraulics of the canal. Based on the study, the USGS concluded that there was no conclusive evidence for the existence of hysteresis in the index-velocity rating at the USGS streamgage on the CSSC near Lemont, Illinois. The USGS installed a vertical Acoustic Doppler Velocity Meter in the CSSC at Lemont in July 2013. This instrument will collect continuous velocity data in the water column and verify if the velocity distribution during the rising and falling phase of the discharge hydrograph will be different that may affect the index velocity rating. The University of Iowa is analyzing the flow measurement data for the Lemont gaging station for several rain events in 2010 and 2012 to evaluate the index velocity rating for different flow regimes in the CSSC.

ACCOUNTING REPORTS

The Lemont accounting report for WY 2006 (contained in the WY 2006 annual report) and WY 2007 (contained in the WY 2007 annual report) was completed and distributed in FY 2011 (USACE, 2011a). The Lemont accounting report for WY 2008 (contained in the WY 2008 annual report) and WY 2009 (contained in the WY 2009 annual report) was completed and distributed in FY 2012 (USACE, 2012). The Lemont accounting report for WY 2010 was included in the WY 2010 annual report. The Lemont accounting report for WY 2011 is included in this annual report.

SUMMARY AND CONCLUSIONS

SUMMARY

The Lake Michigan Diversion Accounting procedure continues to evolve and improve. Further improvements to the Lemont Accounting are being implemented.

CONCLUSIONS

The Lake Michigan Diversion Accounting Report for WY 2011 has been completed as required by the Supreme Court Decree. The State of Illinois diverted 2,791 cfs during WY 2011. This flow is 409 cfs less than the 3,200 cfs limit specified in the decree. The running average of the diversion for WY 1981 through WY 2011 is 3,143 cfs, or 57 cfs under the annual allocation. Also, the annual average diversion has exceeded the 3,680 cfs annual limit three times, once more than the maximum number of times allowed in the decree. Additionally, the absolute annual maximum of 3,840 cfs has been exceeded during the WY93 accounting period. The cumulative deviation is 1,772 cfs-years at the end of WY 2011. The positive number indicates a cumulative flow

surplus. The maximum allowable cumulative flow deficit specified in the decree is -2,000 cfs-years.

References

1. U.S. Army Corps of Engineers. (USACE) 2011a. Lake Michigan Diversion Accounting Water Year 2006 Annual Report. *Contains Lake Michigan Diversion Accounting Water Year 2006 Report.*
2. U.S. Army Corps of Engineers. (USACE) 2011b. Lake Michigan Diversion Accounting Water Year 2007 Annual Report. *Contains Lake Michigan Diversion Accounting Water Year 2007 Report.*
3. U.S. Army Corps of Engineers. (USACE) 2012a. Lake Michigan Diversion Accounting Water Year 2008 Annual Report. *Contains Lake Michigan Diversion Accounting Water Year 2008 Report.*
4. U.S. Army Corps of Engineers. (USACE) 2012b. Lake Michigan Diversion Accounting Water Year 2009 Annual Report. *Contains Lake Michigan Diversion Accounting Water Year 2009 Report.*
5. U.S. Army Corps of Engineers. (USACE) 2013. Lake Michigan Diversion Accounting Water Year 2010 Annual Report. *Contains Lake Michigan Diversion Accounting Water Year 2010 Report.*
6. Wisconsin et. al., v. Illinois et. al., Michigan v. Illinois et. al. New York v. Illinois et. al. U.S. 2, 3, and 4, Original 1 - 18, 1980.