

REBUILDING CHICAGO’S STORMWATER AND WASTEWATER SYSTEMS FOR THE 21ST CENTURY: UNDERSTANDING HYDROLOGIC CONDITIONS IN THE REGION TECHNICAL REPORT, OCTOBER, 2010

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INTRODUCTION

In response to a public health emergency more than 100 years ago, engineers reversed the Chicago River and built the Chicago Sanitary and Ship Canal to carry wastewater away from Lake Michigan, the city's source of drinking water. The canal also provides a shipping link between the Mississippi River and the Great Lakes, opening navigation not only to recreational boats and commercial barges, but also to invasive species, and it diverts massive amounts of water from Lake Michigan. The unfolding Asian carp crisis reveals more than just the challenges faced by local, state, and federal agencies in stopping invasive species from entering the Great lakes. It also exposes critical infrastructure deficiencies in the region's wastewater, stormwater, and transportation systems.

The Natural Resources Defense Council (NRDC) believes this crisis represents an unprecedented opportunity to rethink the way this infrastructure functions and develop comprehensive solutions to permanently stop invasive species traffic between the Great Lakes and the Mississippi River while protecting and enhancing the water resources that more than 40 million people throughout the Great Lakes region rely on for drinking water, fishing, recreation, and commerce.



**FIGURE 1
BIGHEAD CARP**

The Chicago Sanitary and Ship Canal is the only shipping link between the Great Lakes and the Mississippi River; it not only opens the door to boats and commercial barge traffic, but invasive species as well. While debate continues about how to best respond to the Asian carp threat, there is a growing consensus within the Great Lakes community, in both the United States and Canada, that the invasive species problem needs a permanent, long-term solution that separates the Lake Michigan from the Mississippi River Basins.¹

Hydrological or permanent separation does not mean arbitrarily closing the locks or the canal system. Under this alternative, barriers would be constructed strategically in the Chicago Area Waterway System, or CAWS, to minimize the disruption to existing navigation while eliminating any movement of water between the two ecosystems. Economic impacts on water-based commerce could even be turned into long-term benefits through the construction of new intermodal facilities and other support mechanisms.

Permanent separation could also enable the entire region to rethink its outdated systems for moving goods and managing wastewater and stormwater:

1. The region's transportation network is inadequate to meet current demand and will fail to capitalize on forecasted future demand without significant reinvestment.² Goods are forced to sit idle as they slowly work their way through an archaic network of holding facilities on their way to their final destination. Restoring the natural divide between the Great Lakes and the Mississippi River system could stimulate construction of new intermodal facilities that would reroute commercial traffic from the CAWS, resulting in economic gain and a more efficient and sustainable regional transportation system.
2. The Chicago area's basic means and theory of handling wastewater and stormwater have not evolved with the technological changes and improvements of the last decades, even as its traditional approach continues to escalate in cost. Canals and sewers are challenged by their inability to properly handle increasing runoff brought on by development and the predicted increased intensity of storm events due to climate change will further strain these systems. A comprehensive plan to permanently separate the watersheds would create an opportunity to incentivize investments to substantially reduce the risk of flooding and fix long-standing water quality problems through deployment of Green Infrastructure³ and long-overdue upgrades in sewer systems and wastewater treatment in the CAWS.

Permanent separation is complex and requires detailed analysis along a range of disciplines, including hydrology, commercial and recreational transportation, goods movement and logistics. This technical report describes the analysis done to date by Shaw Environmental, an international engineering firm working with NRDC, on the hydrologic impacts of permanent separation. It is the first step in gathering technical information regarding the existing performance and interaction of riverine and lake systems in the Chicago region over a range of hydrologic conditions. It identifies a range of engineering challenges that must be addressed and the stormwater or wastewater systems or infrastructure that could be impacted by the separation of the two watersheds.

Shaw studied how water currently flows through the region under normal and storm conditions, how the expected effects of climate change will impact wastewater and stormwater systems, and how permanent separation could affect the floodplain, stormwater management, combined sewer overflows, water quality, and basement flooding. Shaw also explored how Green Infrastructure, the use of natural systems, such as wetlands, street trees, and other types of vegetation to store and treat stormwater instead of the "hard infrastructure" that is traditionally used, including pipes, pumps, and storage tunnels, could mitigate some of those impacts.

DATA SOURCES AND ANALYSIS

Information utilized by this investigation was compiled from readily available sources from websites, agencies, and universities including: City of Chicago Department of Water Management,

Illinois Environmental Protection Agency (IEPA), Metropolitan Water Reclamation District of Greater Chicago (MWRD), United States Environmental Protection Agency (USEPA), United States Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), the Army Corps of Engineers (ACOE), and Marquette University. Descriptions of the facilities, systems, and operations were based on previously published information from these sources. No modeling of the waterways or sewer systems was included in this phase of study. Analyses completed as part of this investigation included a summary of rainfall frequencies, correlation of streamflow and water levels, and estimates of stormwater that could be retained by Green Infrastructure.

STAKEHOLDER INVOLVEMENT

As part of this analysis, NRDC and Shaw met individually with key stakeholders. NRDC also held two meetings with a range of government and nongovernment experts on hydrology, the CAWS and Green Infrastructure to review and critique findings and suggest additional areas of inquiry.

The first meeting, on May 20, 2010, focused on the water management issues surrounding the hydrologic separation of the Great Lakes and Mississippi River Watersheds and the hydraulics of the CAWS. In attendance were 27 individuals representing a range of federal, state, and local governments, as well as nonprofit and civic organizations (see the attached meeting notes and attendees list, “May 20, 2010”).

A number of issues raised were beyond the scope of this project or would have to be addressed later in the planning process. These topics were placed in what was termed a “parking lot” and would be recalled at the appropriate time in future discussions. Parking lot items included:

- Transportation (commerce & recreation) impacts need to be described, modeled, and understood.
 - Both should be improved by separation.
 - Should invite transportation interests into the planning process as soon as possible.
- A host of legal issues (permitting, National Environmental Policy Act review, etc.) will have to be considered.
- Construction specifications must be developed.
- All parking lot issues should be addressed in longer report.

The second presentation was attended by 35 individuals representing a similar mix of government and nongovernment participants (see the attached meeting notes and attendees list, “July 1, 2010”). Since a number of the participants had not attended the May 20, 2010 presentation, issues relating to the hydrologic operation of the CAWS were briefly reviewed. The emphasis of the presentation was the quantification of the reduction of CSOs and pollutant loads that could be realized with the implementation of Green Infrastructure.

DESCRIPTION OF THE CHICAGO AREA WATERWAYS SYSTEM (CAWS)⁴

The Chicago Area Waterways System (CAWS) owes its origins to the typhoid fever, cholera, and dysentery epidemics that frequented the City of Chicago from the mid 1850s to 1900. In order to

divert the disease-laden sewage away from its drinking water supply in Lake Michigan, the city in 1900 completed the construction of the Chicago Sanitary and Ship Canal that reversed the flow in the Chicago River away from Lake Michigan and toward the Illinois River.

Four major drainage systems make up the CAWS: the North Branch of the Chicago River, the South Branch of the Chicago River, the Calumet Sag Canal, and the Little Calumet River.

The drainage basin for the North Branch of the Chicago River is approximately 180 square miles, of which about 160 square miles rests in Cook County. The remaining 20 square miles is divided among the West Fork of the Chicago River, the Middle Fork of the Chicago River, and the Skokie River, all of which are in Lake County. In 1910, the city constructed the eight mile, 80 foot wide and 13 feet deep North Shore Channel to allow for the diversion of water from Lake Michigan to dilute pollution in the Chicago River (the diversion of Lake Michigan water is further discussed beginning on page 11). A control structure was built at the junction of the North Shore Channel and Lake Michigan at Wilmette to control the amount of water diverted from Lake Michigan. The Wilmette Control Works consists of a pump house and a large sluice gate measuring 32 foot by 16 foot. The four 250 cubic feet per second (cfs) pumps have not been used for diversion since the 1970s.

The Chicago River Control Works (CRCW) was built at the mouth of the Chicago River at Lake Michigan. It was constructed in 1938 to reduce lake diversion and provide better flood control to downtown Chicago. The CRCW consists of a low-lift lock and two sets of four 10 feet by 10 feet sluice gates. The CRCW is used for diverting lake water for maintaining mandated water elevation on the Chicago River and meeting the water quality standards in the CAWS.

The South Fork of the Chicago River begins at its confluence with the North Branch of the Chicago River and travels south for about four miles. The drainage basin covers almost 170 square miles, stretching from the main stem of the Chicago River in downtown Chicago on the north to almost 87th Street on the south.

The 1.25 mile long South Fork of the South Branch of the Chicago River is nicknamed Branch Bubbly Creek. It was brought to notoriety by Upton Sinclair in his 1906 book "The Jungle," an expose of the American meat packing industry at the turn of the 20th century. Bubbly Creek was converted, early in the history of the City of Chicago, from a creek draining a shallow wetland to a 20 foot deep channel that accumulated wastes from the meat processing plants and the sludge from metal plating industries. It got its name from the gases bubbling out of the riverbed from the decomposition of the accumulated wastes. Today, the Creek is largely stagnant except for the occasional storm discharge from the District's Racine Avenue Pump Station (Figure 2). The Racine Avenue Pump Station is capable of pumping millions of gallons a day of a mix of untreated sanitary and stormwater wastes from a roughly 26 square mile drainage basin into Bubbly Creek.

Construction of the Chicago Sanitary and Ship Canal was completed in January 1900. The canal is



FIGURE 2
RACINE AVENUE PUMP STATION
AT THE HEADWATERS OF
BUBBLY CREEK

currently 28 miles long, 202 feet wide and 24 feet deep. The canal links the South Branch of the Chicago River to the Des Plaines River at Lockport. Discharge from the canal is controlled by the lock and powerhouse at Lockport and by the Lockport Control Works, approximately two miles upstream of the lock and powerhouse. The Lockport Control Works has seven sluice gates with which to control water levels in the CAWS. The Lockport Lock and Powerhouse serves the multiple purposes of power generation, flood control, and navigation.

Though no longer operational, the Illinois and Michigan (I&M) Canal, constructed in 1848, was the first connection of the Great Lakes and Mississippi River watersheds. The I&M Canal gave way to the much larger Sanitary and Ship Canal.

In 1922, the Cal-Sag Channel was constructed between Blue Island and the Sag Bridge. The 16-mile channel linked the Little Calumet River to the Sanitary and Ship Canal. The Calumet-Sag Channel watershed area is approximately 126 square miles.

In 1961, the Calumet River was completely reversed by the construction of the Thomas J. O'Brien Lock and Dam. The O'Brien Lock and Dam is located seven miles southwest from the entrance to Lake Michigan along the Calumet River. The works control the movement of water between Lake Michigan and the Calumet River to maintain navigation, flood control, and water quality in the Cal-Sag Canal. The facility is composed of a low-lift sector gate navigational lock, fixed dam, and controlling works consisting of four large 10-feet by 10-feet vertical slide gates.

EXISTING FACILITIES IN THE CAWS

This section describes the major collection and treatment facilities of the wastewater operated by the City of Chicago and the MWRD and their influences on the water levels and water quality of the CAWS.

WATER RECLAMATION PLANTS

Four water reclamation plants would potentially be affected by a hydrologic separation of the two watersheds (Table 2). Stickney is the region's (and world's) largest wastewater treatment plant; the Calumet and North Side plants are similar in size; Lemont is the smallest. According to the MWRD, more than 70 percent of the annual flow in the CAWS is from the discharge of treated municipal wastewater effluent from these facilities. In the winter months, virtually 100 percent of the flow is from these facilities; in the summer, it is approximately 50 percent.⁵ Any hydrologic separation alternative would have to address the management of these discharges. Some hydrologic separation alternatives would redirect flows that are currently flowing south through the Chicago Sanitary and Ship Canal to Lake Michigan. The higher water quality standards of Lake Michigan could increase the priority of projects to reduce the frequency of combined sewer overflows (CSOs) and increase the level of treatment that is currently being provided by the water reclamation plants (CSOs are further described and discussed beginning on page 8).

TABLE 2⁶
CHARACTERISTICS OF MWRD'S WATER RECLAMATION PLANTS

Water Reclamation Plant	Receiving Waterbody	Mean Design Flow (ft³/s)	Maximum Design Flow (ft³/s)	2001 Average Annual Flow (ft³/s)
North Side	North Shore Channel	516	698	415
Calumet	Little Calumet River	549	667	398
Stickney	Chicago Sanitary & Ship Canal	1,860	2,232	1,159
Lemont	Chicago Sanitary & Ship Canal	5	6	3

PUMP STATIONS

The MWRD operates six pump stations; their main purpose is to move wastewater great distances to the water reclamation plants. The largest pumping capacity is at the Racine Avenue Pump Station (Racine), located at the headwaters of the South Fork of the South Branch of the Chicago River (Bubbly Creek). The Racine Pump Station transfers wastewater from the area just south of the Chicago River almost to 87th Street to the Stickney WRP, a distance of approximately 5.5 miles. Racine has greater capacity to pump water than the Stickney WRP, or the sewer connecting them, has to adequately deal with the water. During heavy rains, hydraulic calculations indicate that the discharge from the Racine Pump Station to Bubbly Creek can occur with such speed that water levels could rise by as much as 105 feet.

The pump stations also play an integral role in dewatering the system during a rainfall event to avoid untreated sanitary and stormwater flows into the basements of residents and businesses. On occasion, greater amounts of water are pumped during the dewatering effort than can be handled by downstream pipes. In those cases, the excess water, consisting of untreated sanitary and stormwater, is discharged to the CAWS. Table 3 summarizes the number of times that these pump station discharge to the CAWS, as well as statistics that characterize the volume of water entering the CAWS. The large volume of untreated wastewater-stormwater is a concern for both potential flood and adverse water quality impacts.

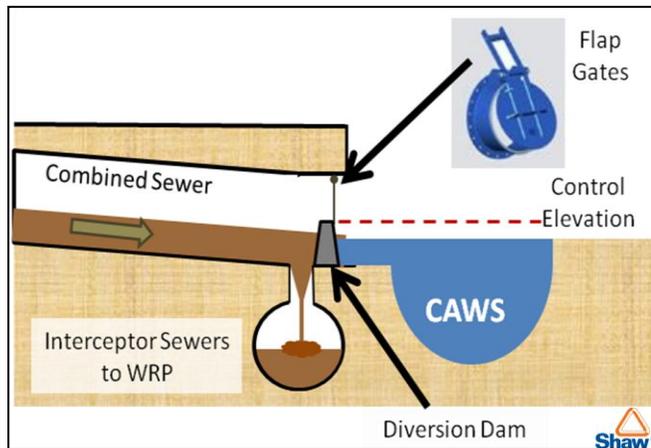
**TABLE 37
MWRD PUMP STATIONS**

	Pump Station	Reporting Period		Number of Discharge Events	Average Volume Discharged Per Event	Maximum Volume Discharged Per Event	Minimum Volume Discharged Per Event
		Starting Date	Final Date				
1	125th Street Pump Station	2000	2009	56	129	801	2
2	North Branch Pump Station	2000	2010	153	130	1,349	2
3	Racine Avenue Pump Station	2000	2010	150	396	4,018	4
4	Westchester Pump Station	2004	2010	65	499,324	5,412,034	24,000
5	95th Street Pump Station	2000	2009	14	56	137	0.6
6	122nd Street Pump Station	2000	2009	6	2	4	1

	Pump Station	Design Discharge Capacity (cfs)	Reporting Period		Number of Discharge Events	Average Volume Discharged Per Event	Maximum Volume Discharged Per Event	Minimum Volume Discharged Per Event
			Starting Date	Final Date				
1	125th Street Pump Station	1,140	2000	2009	56	129	801	2
2	North Branch Pump Station	1,500	2000	2010	153	130	1,349	2
3	Racine Avenue Pump Station	3,125	2000	2010	150	396	4,018	4
4	95th Street Pump Station	855	2000	2009	14	56	137	0.6
5	122nd Street Pump Station	375	2000	2009	6	2	4	1

COMBINED SEWER OUTFALLS

Chicago and many of its older suburbs are served by combined sewers. In a combined sewer system, both sanitary and storm flow are conveyed through the same pipes. Depending on flow conditions, these combined pipe systems have overflow structures which can discharge to either the CAWS or to the water reclamation plants (Figure 3). Diversion dams, often called weirs, direct flow to regional interceptor sewers that

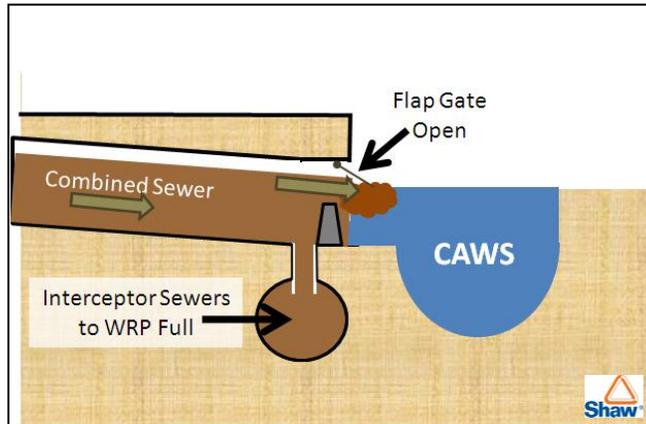


**FIGURE 3
PARTS OF A COMBINED SEWER OUTFALL**

Source: <http://www.fremontohio.org/rates/images/cso.jpg>

move the water to the water reclamation plants for treatment. The height at which the diversion dam is set prevents water levels in the pipes from reaching an elevation that might back sewage up into basements. Most combined sewer outfalls are equipped with flap gates which prevent water from entering the system.

When rain events exceed a certain size, the sewer system and water reclamation plants cannot accommodate the additional stormwater flow. Water levels in the pipe system exceed the height of the diversion dam and force open the flap gates, resulting in the discharge of untreated combined sewage-stormwater runoff into local waterways (Figure 4). This is called a CSO event. In 2009, there were 261 outfall locations in the CAWS; 2,036 discharge events occurred, resulting in flooded basements, closed beaches, and threats to drinking water quality.⁸



**FIGURE 4
COMBINED SEWER OVERFLOW (CSO)**

There are more than 200 combined sewer outfalls into the CAWS (Table 4). Ownership could not be determined for 82 of the CSOs from the source documentation. A number of suburbs north of Chicago, along the North Branch, also have combined sewer outfalls that are not accounted for in Table 4, which brings the total number of CSOs in the area served by combined sewers to more than 600.

**TABLE 4⁹
OWNERSHIP OF CSOs BY WATERWAY**

Owner	Totals by Jurisdiction	NUMBER OF CSOS BY WATERWAY								
		North Shore Channel	North Branch Chicago River	Chicago River	South Branch Chicago River	South Fork of the South Branch	Calumet River	Little Calumet River	Cal Sag Channel	Chicago Sanitary & Ship Canal
Unspecified	82	4	28	18		10	1	4	1	16
City of Chicago	128	18	48	1	48			11	2	
MWRD	16	6	1				2	2	5	
Wilmette	1	1								
Evanston	15	15								
Skokie	3	3								
Lincolnwood	3	3								
Calumet Park	2								2	
Blue Island	5								5	
Dolton	2							2		
Riverdale	3							3		
Summit	1									1
TOTALS	261	50	77	19	48	10	3	22	15	17

TUNNEL AND RESERVOIR PLAN (TARP)

In 1967, officials of the MWRD, the State of Illinois, Cook County, and the City of Chicago began a study of solutions to the area's massive flooding and water pollution problems caused by CSOs. Ultimately, a hybrid of the desirable features of several plans was chosen. The final plan, known as the Tunnel and Reservoir Plan (TARP), was adopted in 1972. TARP serves a 375 square mile combined sewer area composed of Chicago and 51 adjacent suburbs. When completed, the total cost will be more than \$4 billion.¹⁰

Phase I of TARP was primarily focused on the reduction of pollution caused by CSOs. Construction of the four distinct tunnel systems – Mainstream, Des Plaines, Calumet and Upper Des Plaines – began in 1975 and ended in 2006. Phase I consisted of 109 miles of deep tunnels,; over 250 drop shafts, three pump stations, and more than 600 surface connecting and flow control structures. The tunnels capture and store approximately 2.3 billion gallons of CSOs.

Phase II of TARP, recently renamed the Chicago Underflow Plan (CUP), is intended primarily for flood control. It consists of three large reservoirs:

- O'Hare CUP Reservoir serves the Upper Des Plaines system and went online in 1998. It has a storage capacity of approximately 340 million gallons. When and if deficiencies in the collection system are addressed, the O'Hare CUP Reservoir has sufficient volume to contain all of the CSOs from the service area. Until the system deficiencies of the collection system are corrected, however, some number of CSOs are expected to continue to occur.
- McCook Reservoir will serve the Mainstream and Des Plaines systems. When finished, it will have a total storage capacity of 10 billion gallons. The first stage (3.5 billion gallons of storage) is projected to be finished in 2015. The second stage will provide 6.5 billion gallons of storage and is slated for completion in 2029. While the McCook Reservoir is anticipated to reduce flooding for nearly 3,100,000 people and protect 1.2 million structures in 37 communities, it is important to note that the completion deadlines have repeatedly been pushed back.
- Thornton Composite Reservoir will serve the Calumet system. It will be constructed in two stages. The first stage (called the Thornton Transitional Reservoir) was completed in March 2003 by the USDA's Natural Resources Conservation Service. It provides overbank flood relief for nine communities by temporarily storing 3.1 billion gallons in the West Lobe of the Thornton Quarry. The second stage is a permanent 7.9 billion gallon combined NRCS/CUP reservoir, called the Thornton Composite Reservoir. It will be constructed in the North Lobe of the Thornton Quarry and is expected to be completed in 2014.

All captured combined sewer flow is pumped to one of the water reclamation plants where it receives secondary treatment prior to being discharged to the CAWS.

COMPONENTS OF LAKE MICHIGAN DIVERSION

As a result of the reversal of the Chicago River, Lake Michigan became tributary to the Chicago, Des Plaines, Illinois and Mississippi Rivers, as well as the Gulf of Mexico. The reversal also necessitated the diversion of water from Lake Michigan to support navigation and to help dilute treated sewage discharged to the CAWS.

The diversion spurred legal conflicts almost from the beginning. In 1967, the Supreme Court approved a new consent decree limiting the diversion to a five-year average of no more than 3,200 cubic feet per second (cfs) by Illinois and its municipalities for two primary uses: up to 35 cfs annually to support navigation (such as ensuring adequate water levels during drought); and up to 270 cfs annually to support discretionary diversion purposes, primarily to maintain water quality. The rest of the allocation is reserved for other water uses (such as drinking water).¹¹ A further amendment to the decree in 1980, as well as a 1996 Memorandum of Understanding among the parties, committed Illinois to more rigorous monitoring and accounting procedures.¹²

Today, the Chicago River Controlling Works (CRCW) controls the flow of water between Lake Michigan and the Chicago River. Now operated by the U.S. Army Corps of Engineers, "it consists of walls separating the river and the lake, a navigation lock, two sets of sluice gates, and a pumping station that is only capable of pumping from the river to the lake at a rate of about 90 cfs. [T]he sluice gates allow gravity flow from Lake Michigan to the Chicago River when the lake level is

higher than the Chicago River.”¹³ They also retain water in the Chicago River when lake levels are low.

Four other facilities allow the U.S. Army Corps of Engineers (ACOE) and MWRD to manage water moving through the CAWS:¹⁴

- *Lockport Controlling Works.* An auxiliary facility owned and operated by the MWRD, it is used during storm operations to discharge flood waters to the Des Plaines River. It is located two miles upstream of the Lockport Powerhouse and Lock and has seven sluice gates.
- *Lockport Powerhouse and Lock.* Also owned and operated by the MWRD, it has nine submerged sluice gates to discharge stormwater and one surface sluice gate for flushing debris. The lock is owned and operated by the U.S. Army Corps of Engineers.
- *O'Brien Lock and Dam.* Four submerged sluice gates regulate flow from the Lake. The gate opening for flow regulation is controlled by the MWRD, but ACOE performs the actual operation.
- *Wilmette Pumping Station.* Constructed by the MWRD between 1907 and 1910, and still operated by them, it regulates the flow of water from Lake Michigan to the North Shore Channel. Though it is referred to as a pumping station, the pumps have not been used for diversion since the 1970s.

The average annual value for each of the primary components of the Lake Michigan Diversion for accounting years 2004 and 2005 are compared to the authorized allocation for each of the component parts of the Lake Michigan diversion in Table 5. Allocation limits are averaged over a 40 year running average, making it permissible to exceed the numeric limit in a single year. The Corps of Engineers and MWRD track, estimate, and account for each component of the state's allocation on a yearly basis.

TABLE 5¹⁵
TOTAL AVERAGE ANNUAL FLOW OF DIFFERENT COMPONENTS OF THE LAKE MICHIGAN
DIVERSION FOR 2004 AND 2005

Description	Authorized Allocation	2004		2005	
		Average Flow (cfs)	Percentage of Total Flow	Average Flow (cfs)	Percentage of Total Flow
Lake Michigan Pumpage by the State of Illinois	1,530	1,414.1	54.7	1,496.5	59.8
Runoff for Diverted Lake Michigan Watershed	800	832.6	32.2	693.2	27.7
Total Direct Diversions	435 cfs	338.2	13.1	311.6	12.5
Lockages	100 cfs	36.4	1.4	38.8	1.6
Leakages	50 cfs	21.4	0.8	23.6	0.9
Navigation Makeup Flow	35 cfs	27.6	1.1	19.7	0.8
Discretionary Flow	270 cfs	252.8	9.8	229.3	9.2
Total	3,200 cfs	2,584.9		2,501.3	

Water Supply

The water supply allocation is routed from Lake Michigan intake cribs and discharged into the CAWS or Des Plaines River. The Chicago Metropolitan Agency for Planning (CMAP) recently completed its Water 2050 Plan and estimates that the current allocations are adequate to meet the needs of all current water supply permittees until the year 2030.¹⁶

Stormwater Runoff

Stormwater runoff is the amount of water that would have flowed to Lake Michigan had the Chicago River not been redirected south by the Chicago Sanitary and Ship Canal. Over an 18 year period, the reported stormwater runoff from the 600 square mile Chicago River watershed averaged approximately 835 cfs. Planning for hydrologic separation alternatives must address whether the allocation for the diversion of flows of the Chicago River away from Lake Michigan should decrease the amount of water that Illinois is allowed to divert from the Lake.

Direct Diversions

Direct diversions are Lake Michigan water that enters the CAWS through one of three control works: the Chicago River Lock, the O'Brien Lock and Dam, or the Wilmette Pumping Station

Control Works (pumping station). Direct diversions are further broken down into allocations for lockage, navigation, leakage, and discretionary flow.

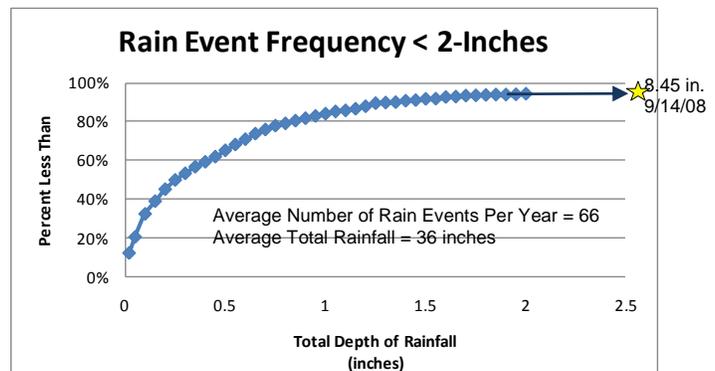
- **Lockage.** The volume of water needed for lockage depends on the number of boats that pass through the locks in a given year and on Lake Michigan water levels. In general, the greater the differential in water elevations, the more water is required to fill the locks. Federal navigation policy requires that locks are operated on demand, meaning that locks must be operated even if it is for one vessel.
- **Navigation.** Lake Michigan water is diverted into the CAWS to maintain adequate depths for safe navigation.
- **Leakage.** At one point, leakage of water through gates and structural walls represented a large volume of water. However, with the many improvements that have been made to the control works, the volume of water that enters the CAWS due to leakage is nearing zero.
- **Water Quality Discretionary Flow.** MWRD is permitted to divert Lake Michigan water into the CAWS to keep dissolved oxygen levels above the water quality standard for the CAWS of 3-4 milligrams per liter and to assist in moving water downstream to Lockport (water quality standards for water released in Lake Michigan differ from those of the CAWS and are discussed beginning on page 24).

DATA USED IN HYDROLOGIC ANALYSIS OF HYDROLOGIC SEPARATION SCENARIOS

CHICAGO RAINFALL

Using data from the National Oceanic Atmospheric Administration (NOAA), Shaw analyzed rainfall from the O'Hare Airport weather station from 1996 to 2010 to characterize rainfall that occurs annually throughout the region (Figure 7). During this 24-year period, there were more than 5,400 rain events separated by at least one day of no rain. The largest recorded rain event totaled 8.45 inches over the three-day period of September 12-14, 2008 (with most of the rain, 6.6 inches, falling on September 13, 2010). Figure 7 stops at a two inch rainfall to help the reader better see the part of the graph that contains data for most of the rain events. Half of all rain events in a year are typically less than 0.25 inches. About 60 percent of rain events are one half inch of rain or less and 90 percent of all rain events are less than 1.4 inches of rain. Just 10 percent, or 6-7 a year, of all rain events generate more than 1.4 inches of rain.

FIGURE 7
FREQUENCY OF DEPTH OF RAINFALL PER EVENT (0 TO 2 INCHES)



Source: NOAA Weather station @ O'Hare Airport 1996 - 2010

REGIONAL STREAM DATA

The purpose of this investigation was not to evaluate the operating rules, but rather examine how the CAWS has performed over time and identify how the performance could change by placing a hydrologic separation within the CAWS. This evaluation was based on discharge and stage information published online for 18 gauging stations operated by the US Geological Survey (USGS) and one gauging station operated by the Army Corps of Engineers (ACOE) in Lake Michigan. The period of record ranged from one year for the USGS Chicago Sanitary and Ship Canal gauge at Romeoville, Illinois to 107 years for the ACOE gauge at Calumet Harbor (Appendix, Table 6). Statistics for each gauge were used to help characterize flows throughout CAWS. Periods of overlapping records helped to describe how the system responds to individual rain events.

FLOW REVERSALS

Flows are generally from Lake Michigan to the CAWS. Therefore, discharges from the CAWS to Lake Michigan are considered flows going in the opposite direction of normal operation and are described as flow reversals. Flow reversals occur during periods of heavy rainfall when water levels in the CAWS exceed selected thresholds. Flow reversals relieve the flooding pressures on the City of Chicago.

The number of reversals from the CAWS to Lake Michigan have been reduced with the onset of TARP. There are two types of reversals: gate reversals and lock reversals. The more common is a gate reversal, which occurs when a smaller volume of water is released through gates adjacent to the Chicago and O'Brien Locks. During a lock flow reversal, the locks are opened to maximize flow, allowing a much greater volume of the floodwaters of the Chicago River water to return to the Lake Michigan. They are only necessary in cases of severe storms and have occurred three ten times between 2000 and 2009: September 13, 2008, August 22, 2002, and August 2, 2001. Both types of reversals are summarized in Table 7.

TABLE 7¹⁷
Reversals to Lake Michigan 1985 – 2009
(Million Gallons)

Source: “Combined Sewer Overflows,” Metropolitan Water Reclamation District of Chicago website, <http://www.mwrd.org/irj/portal/anonymous/overview>

Year	Total Volume of all Reversals (MG)	Number of Reversals	Average Volume per Reversal (MG)
2009	414	3	139
2008	11,530	2	5,765
2007	224	1	224
2006	0	0	-
2005	0	0	-
2004	0	0	-
2003	0	0	-
2002	1,752	1	1,752
2001	1,189	3	396
2000	0	0	-
1999	10	1	9
1998	0	0	-
1997	4,738	2	2,369
1996	1,551	1	1,551
1995	0	0	-
1994	0	0	-
1993	0	0	-
1992	0	0	-
1991	0	0	-
1990	9705	3	323
1989	52	1	52
1988	0	0	-
1987	1,975	2	987
1986	53	1	53
1985	211	2	106

GENERAL SYSTEM OPERATIONS

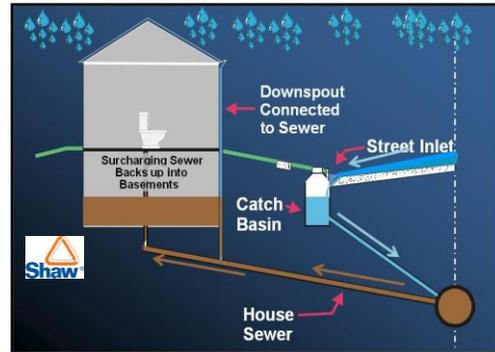
GUIDING OPERATION OBJECTIVE: PREVENT FLOODING

The operation of the controls works in the CAWS is closely linked to the operation of flows at the treatment plants and flows through the combined sewer system. Rules have been developed in close coordination between the ACOE and the MWRD. The water reclamation plants, sewers, pumps, tunnels and CAWS are operated to prevent “flooding”.¹⁸

Flooding takes a variety of forms, resulting in a complex set of operating rules. Flooding could be:

- Excess flow at the water reclamation plants that must bypass the plant and discharge into the CAWS;
- Stormwater that cannot be conveyed to the plants and tunnel system and must be discharged to the CAWS as a combined sewer overflow;
- The combined stormwater and sanitary sewage that backs up in the pipes and then into residential and business basements because of restrictions to flow in downstream pipes (Figure 5); or
- Street flooding (Figure 6) or the flooding of the CAWS.

**FIGURE 5
BASEMENT BACKUP IN A
COMBINED SEWER SYSTEM**



**FIGURE 6
CHICAGO STREET**

Source: weblogs.ctv.com/news/local/chicago/w



DESCRIPTION OF SYSTEM OPERATION

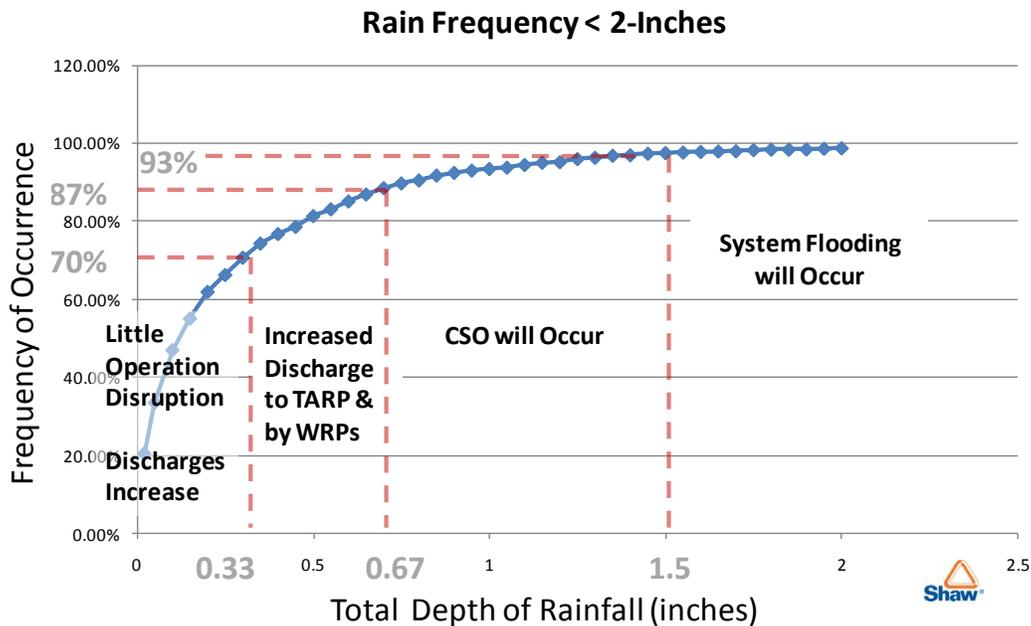
The three components of flow in the CAWS is natural watershed flow, treated effluent, and diversion of water from Lake Michigan.

Upstream of the CAWS, in Lake County, base flow for the North Branch of the Chicago River is on the order of magnitude of 27 to 70 cfs. The largest component of flow below the confluence of the North Branch of the Chicago River and the North Shore Channel is treated effluent, making up over 100 percent of the flow during wet weather. During normal dry weather flow treated effluent makes up more than 50 percent of the water discharged from the CAWS. During a rain event, untreated stormwater and wastewater from CSOs and pump stations can make up a larger percent of the

total streamflow. This increase can be in excess of 4,000 cfs more than the combination of natural flows and treated effluent.

Discharge from the treatment plants, runoff from the watershed, and the volume of CSOs discharged to the CAWS vary depending on the intensity and duration of the actual rain events. Short, intense, small rainfall could overwhelm the system resulting in CSOs. Likewise, a large amount of rain over a longer duration may result in no CSOs at all. The general performance of the MWRD's wastewater and stormwater systems can be summarized as follows. The overlapping

**FIGURE 7
GENERALIZED SYSTEM PERFORMANCE WITH INCREASING RAINFALL**



range of flows reported reflect the variability of actual rainfall and treatment plant discharges reported for those days:¹⁹

- Runoff from rains up to 0.33 inches can be conveyed -- for the most part -- to the water reclamation plants for treatment. This represents approximately 70 percent of all rain events seen in a given year (Figure 7). Discharge from the North Branch of the Chicago River will be on the order of 50 to 120 cfs; reclamation plants will discharge a little more than the average daily (2,600 to 2,800 cfs); the daily diversions from Lake Michigan average around 300 cfs; and the total discharge from the CAWS will be around 2,900 to 4,200 cfs. This leaves between 0 to 1,000 cfs of discharge from other sources such as direct runoff and CSOs.
- Runoff from rains between 0.33 and 0.67 inches require an increase in the volume of water treated by the reclamation plants but may require runoff to be shuffled to TARP for later treatment. Discharge from the North Branch of the Chicago River will be on the order of 50 to 450 cfs; reclamation plants will discharge a little more than the average daily (1,700 to 2,100 cfs); the daily diversions from Lake Michigan average around 300 cfs; and the total discharge

from the CAWS will be around 1,800 to 6,500 cfs. This leaves between 0 to 2,400 cfs of discharge from other sources such as direct runoff and CSOs.

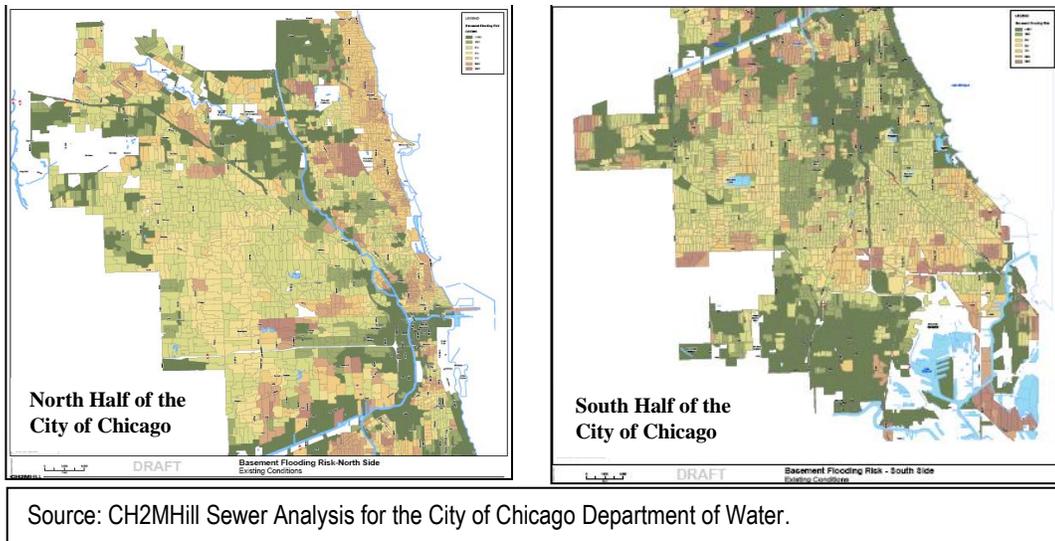
- As rainfall between 0.67 inches and 1.5 inches begins to exceed the capacity of MWRD's system, substantial CSOs occur. The number of CSOs depends on the amount of rainfall and how quickly it falls. Discharge from the North Branch of the Chicago River will be on the order of 100 to 800 cfs; reclamation plants will discharge a little more than the average daily (1,700 to 3,300 cfs); the daily diversions from Lake Michigan average around 300 cfs; and the total discharge from the CAWS will be around 2,200 to 6,600 cfs. This leaves between 100 to 2,200 cfs of discharge from other sources such as direct runoff and CSOs. The volume of CSOs is not that much greater than the previous scenario because of the system's ability to divert water to TARP.
- Rainfall that exceeds 1.5 inches requires water to be diverted to TARP and results in substantial CSO discharges. Storms of this magnitude could possibly require the reversal of flow to Lake Michigan. To give the reader a sense of the magnitude of this occurrence, 191 million gallons was released to Lake Michigan as a result of the June 19, 2009 storm; 11,000 million gallons was released for the September 12-14, 2008 storm. CSOs and flow reversal to Lake Michigan result in beach closures and flooded basements.

When and if the Thornton and McCook Reservoirs are completed, an additional 18 billion gallons of storage will become available. The added flood storage is expected to reduce the frequency of CSOs by 90 percent and increase flood protection to more than 1,400,000 homes in 52 communities. Discharge from the North Branch of the Chicago River would be on the order of 1,500 to 3,300 cfs; reclamation plants will discharge a little more than the average daily (3,400 to 3,600 cfs); and the total discharge from the CAWS will be around 8,400 to 9,100 cfs.²⁰

CURRENT EXTENT OF BASEMENT FLOODING

A detailed analysis completed by the City of Chicago Department of Water Management (DWM) of the City's combined sewers shows that basement flooding is a pervasive city-wide problem. The thematic maps in Figure 8 show the City's analysis. Sewers in the dark green areas provide flood protection greater than a 10-year design storm (about 2.1 inches of total rainfall). This is a common level of service provided by many communities. As the colors become lighter, the sewers are able to convey less and less rain without causing basements to flood. Finally, the areas shown with a reddish color offer the least level of flood protection, where residents and businesses could experience flooded basements with as little as 0.65 inches of rain, meaning 90 percent of the time.

**FIGURE 8
FREQUENCY OF BASEMENT FLOODING IN CHICAGO**



CSO THRESHOLDS OF CHICAGO'S COMBINED SEWERS

To obtain a better understanding of the frequency and volume of CSOs discharged to the CAWS, the City of Chicago performed a hydrologic-hydraulic analysis of its sewer system to determine at what point discharges to the CAWS become necessary to prevent basement flooding. Approximately 40 percent of the combined sewer systems could not even convey the 2-month, 1-hour storm of 0.65-inches of rainfall and more than 70 percent would be expected to have at least one CSO event a year with rains 1.18 inches or less (Table 8). Another way of looking at the data is that less than 10 percent of the system provides a level of service (conveyance of the runoff for the 5-year or 10-year design storm) that the City of Chicago has established for its sewer system and that is considered standard for many communities across the United States.

**TABLE 8²¹
SEWER SYSTEM THRESHOLDS FOR CSOs
LEVEL OF SERVICE PROVIDED**

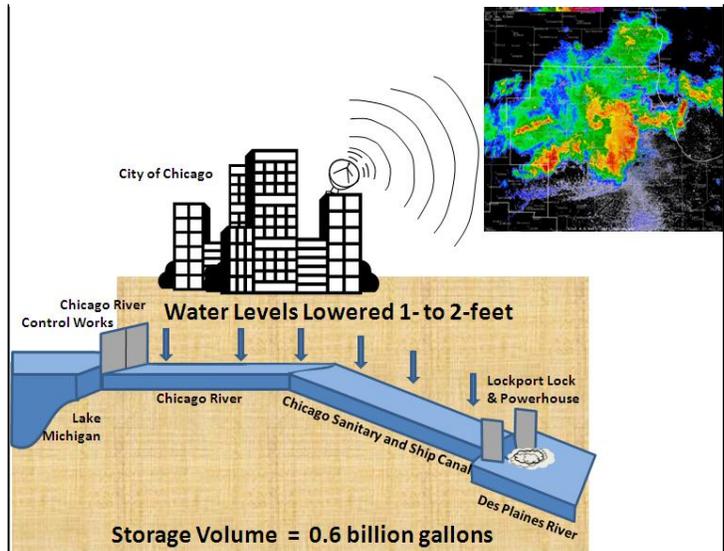
1-Hour Design Storm	Total Rainfall (inches)	Incremental Number of Systems with CSOs	Incremental Percent of Systems with CSOs	Cumulative Percent of Systems with CSOs
10-year	2.1	13	7.3%	100.0
5-year	1.79	22	12.2%	92.7
2-year	1.43	14	7.7%	80.5%
1-year	1.18	18	9.9%	72.8%
6-month	0.96	39	21.5%	62.9%
2-month	0.65	75	41.4%	41.4%
Total		181	100%	

RAINFALL FORECASTING TO PREVENT BASEMENT FLOODING AND CSOs

The MWRD contracts with a service provider to warn the District of potential large rain events. With enough warning, the MWRD can change operations to ensure there is adequate volume in the TARP system to hold excess flows and draw down water levels in the CAWS to provide approximately 600,000 gallons of flood storage (Figure 8).

This is also necessary because there can be as little as a couple of inches difference in water levels between downtown Chicago and the control structures at Lockport. Because of this, water levels in downtown Chicago must increase several feet to create sufficient drop in water levels to move the stormwater runoff to Lockport.

**FIGURE 8
ANTICIPATING OPERATION NEEDS USING RADAR TO FORECAST PRECIPITATION**



CHICAGO RIVER ELEVATION VERSUS LAKE MICHIGAN

Over the past 100 years, the elevation of Lake Michigan has gone up and down about seven times (Figure 9), with a swing between wet periods and dry periods of as much as six feet. The cycle between highs and lows appears to be 2 to 10 years. The average elevation for Lake Michigan is around 578.5 feet.

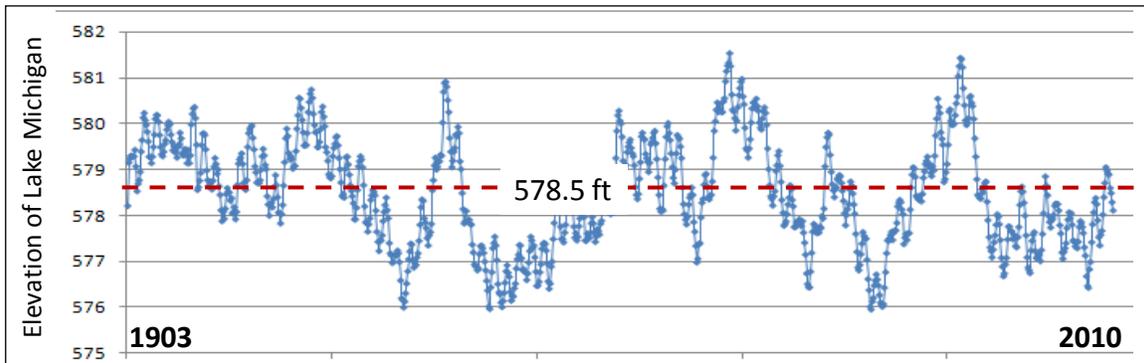


FIGURE 9

ELEVATION OF LAKE MICHIGAN 1903-2010

Source: Army Corps of Engineers, Calumet Harbor, IL Station No. 9087044.

The ACOE is required by the Supreme Court Decree of 1967 to maintain water elevations in the Chicago River between 578.98 and 577.48 to ensure adequate navigation levels and water flow to dilute sewage. Historical gauge information indicates that the average water elevation in the Chicago River is approximately 577.5 feet.²²

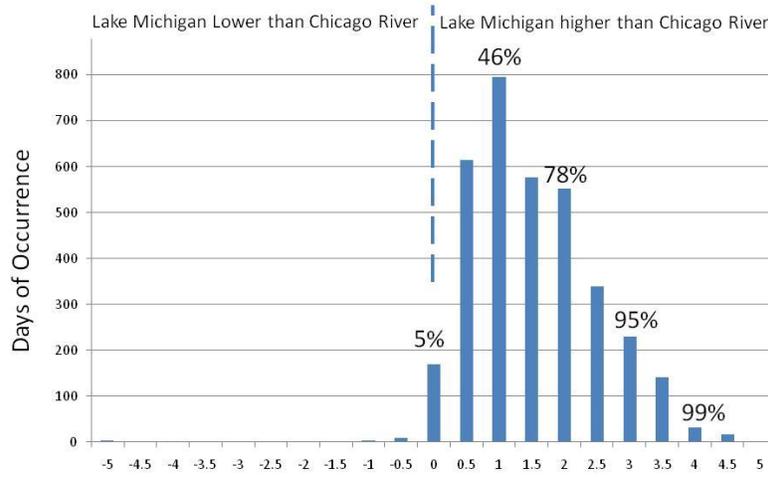
Figure 10 compares the natural fluctuation of Lake Michigan to the manipulated elevation of the Chicago River between August 15, 1997 and April 7, 2010. Key observations:

- The River and Lake were at the same elevation only five percent (170 days) of the time over the past 13 years.
- The Lake was a foot or less above the River more than 40 percent of the time;
- The Lake was two feet or less above the River 70 percent of the time; and
- The Lake level was three feet or less above the River 90 percent of the time.

The largest difference was 5.0 feet (August 25, 1997).

All of the sewers and sewer outfalls are designed assuming an average river level of approximately 577.5 feet. Any hydrologic separation alternative will likely have to maintain the artificially lower water levels in the river until CSOs are eliminated or reduced to a frequency that they are not adversely impacted by higher water levels.

FIGURE 10
HEIGHT THAT LAKE MICHIGAN EXCEEDS WATER LEVELS IN THE CHICAGO RIVER



Source: USGS Gaging Stations 05536121 Chicago River at Chicago lock and 04087440 Lake Michigan at Chicago Lock

POTENTIAL IMPACTS ON EXISTING FLOODPLAIN

Shaw identified a 1.5 mile stretch of the North Branch of the Chicago River (Figure 11) as the floodplain with the greatest potential for being impacted by hydrologic separation, regardless of the exact location of that separation. A detailed hydraulic analysis would be appropriate to determine if any impact to the regulated floodplain would result from a proposed hydrologic separation. Land use maps show that most of the stretch of the North Branch of the Chicago River that potentially might be affected is owned by the Cook County Forest Preserve District. This is important because it means the Forest Preserve holdings could help hold and retain stormwater (this concept, known as Green Infrastructure, is discussed beginning on page 30).

**FIGURE 11
POTENTIALLY IMPACTED FLOODPLAIN**



Source: Panel 401 map no. 17031C0401J, August 2008 and Panel 402 map no. 17031C0402J, August 2008.

POTENTIAL IMPACT OF CLIMATE CHANGE

Research conducted by the University of Illinois and Texas Tech University for the Chicago Climate Plan suggests that precipitation could increase by as much as 20 percent by the end of the century.²³ However, the frequency of extreme storm events, when more than 2.5 inches of rain fall within a 24-hour period of time, could increase 50 percent by 2039 and 80-160 percent by the end of the century.²⁴ These events would be seen mostly in the spring and winter. If this were to happen, there would be fewer storm events that the system is capable of handling (up 0.67 inches of rain) and more storm events of a greater magnitude that result in CSOs and the bypassing of treatment at the water reclamation plants.

WATER QUALITY CONSTRAINTS

WATER QUALITY STANDARDS

The Illinois Pollution Control Board (IPCB) has established narrative and numeric Water Quality Standards (WQS) for four primary designated uses (or categories) for surface waters: General Use; Public and Food Processing; Secondary Contact and Indigenous Aquatic Life; and Lake Michigan Basin Standards. The Illinois WQS are established in the Illinois Administrative Rules

Title 35, Environmental Protection; Subtitle C, Water Pollution; Chapter I, Pollution Control Board; Part 302, Water Quality Standards. Waterbodies that compose the Upper North Branch of the Chicago River Watershed are classified as General Use Waters (Table 7). Waterbodies in the CAWS (North Shore Channel, lower portion of the North Branch of the Chicago River, South Branch of the Chicago River, South Fork of the South Branch of the Chicago River, Calumet Sag Canal, and the Sanitary and Ship Canal are classified as Secondary Contact (Table 8) and Lake Michigan has its own WQS (Table 9).

Currently, the MWRD does not have to meet much stricter Lake Michigan Water Quality Standards for the water it treats and pumps into the Chicago Sanitary and Ship Canal. Of particular concern would be potential levels of bacteria, phosphorous, and possibly ammonia and mercury.

GENERAL USE

The *General Use Standards* protect the health of individuals who participate in recreation activities that involve full-body contact (e.g., swimming, water skiing) where water ingestion or submergence is likely to occur. This is also referred to as primary contact. General Use Standards also allow aquatic life wildlife, agricultural use, secondary contact use and most industrial uses and ensure the aesthetic quality of the State's aquatic environment (Appendix, Table 9).

Secondary Contact and Indigenous Aquatic Life Standards

Secondary Contact and Indigenous Aquatic Life Standards (also called partial-body or incidental contact) apply where the water quality may pose a health hazard if ingested. Therefore, use of the waterbody is limited to activities where the possibility of immersion and, hence, ingestion is very low, i.e. boating, fishing. New aquatic life use standards are currently under review, which will, in all likelihood, make the existing "secondary contact" designation obsolete (Appendix, Table 10).

Lake Michigan Basin Water Quality Standards

The waters of the Lake Michigan Basin must meet the *Lake Michigan Basin Water Quality Standards* of 35 Ill. Adm. Code 302 Subpart E. Lake Michigan WQS are the most restrictive and support both primary contact activities and use as a potable water supply (Appendix, Table 11).

IMPAIRED WATERS IN THE CAWS

The National Pollution Discharge Elimination System (NPDES) is a federal (USEPA) program administered by the IEPA that regulates the amount of point source pollution discharged to waterways. It was developed to reduce pollutants in industrial and municipal wastewater and stormwater discharges into the nation's waterways. Discharge limits for point sources are required to be established at to a level that, among other things, allows water bodies to meet designated uses (such as to support recreation or fish consumption).. If WQS are not met, the water bodies are placed on the State's 303(d) list of impaired waters and greater restrictions are placed on the sanitary and stormwater permits that are issued by the State affecting those waterbodies.. Each of the waterbodies that makes up the CAWS is considered an impaired water for certain uses, as illustrated by Appendix, Table 12.

Water quality in the CAWS has actually improved in the last 25 years. In fact, the Illinois Pollution Control Board is currently reviewing improved water quality standards for the Chicago and Calumet

River systems. A five-year study conducted by the IEPA examined the rivers' current and potential uses and found that the water systems had improved substantially enough to warrant higher water quality standards that would better serve current and future use by people and aquatic life. If approved, the standards will result in the most significant water quality improvements in more than 20 years.

NPDES Permits

Under the NPDES program, there are a total of 12 additional permitted point source discharges in the CAWS and the North Branch of the Chicago River, in addition to the four water reclamation plants operated by the MWRD (Appendix, Table 13). Addressing the water quality of the Chicago River so that it may someday be discharged to Lake Michigan will have to include a management plan to mitigate the pollutant impacts covered by these permits.

The two wastewater treatment plants upstream of Chicago are the North Shore Sanitary District Clavey Road plant and the Deerfield Wastewater treatment plant.

North Shore Sanitary District - Clavey Road WWTP

The NSSD Clavey Road WWTP discharges to the Skokie River and has an average daily flow (ADF) of 21 million gallons per day (MGD), a design average flow (DAF) of 17.8 MGD, and a design maximum flow (DMF) of 28 MGD. The plant has a series of backup retention basins that will store an additional 20.5 million gallons during wet weather flows.

Deerfield WWTP

The main treatment facility is located on Hackberry Road in Deerfield. The Deerfield wastewater plant discharges to the West Fork of the North Branch Chicago River. The main plant has an average flow of 3.4 MGD, a DAF of 3.5 MGD, and a DMF of 8.0 MGD. Excess flows are diverted to either the Deerfield Road lift station that discharges to the West Fork or the Warwick Road lift station that discharges to the Middle Fork. Excess flows receive primary treatment and chlorination prior to discharge to the West Fork and Middle Fork.

DISINFECTION

While MWRD treats its sewage, it does not disinfect it to eliminate all of the harmful viruses and bacteria associated with human waste before discharging the wastewater into the CAWS. Disinfection is common practice almost everywhere else in the country.

The Illinois Environmental Protection Agency (IEPA) recommended disinfection after conducting a five-year study to review existing and potential uses of the river. In 2005, the City of Chicago also endorsed disinfection. A study commissioned by the U.S. Environmental Protection Agency (USEPA) concluded that using ultraviolet light, a widespread disinfection technology, would cost each household in the region \$1.94 per month.²⁵ Disinfection could have broader benefits, including new homes and businesses along the River and increased property values.

Disinfection continues to be debated between regulators and the MWRD, as have performance goals for phosphorus and mercury. Currently, the water quality standards for the CAWS (of

Secondary Contact and Aquatic Life) hold the MWRD to a lower standard than other treatment plants on the North Branch of the Chicago River and others throughout the state of Illinois. Most all waters in Illinois are classified as General Use. Therefore, most wastewater treatment plants in the state already provide treatment for these pollutants that the MWRD does not.

It is likely that hydrologic separation would result in more water ultimately being discharged to Lake Michigan. Therefore, hydrologic separation would possibly change the water quality designation to General Use and possibly to Lake Michigan Standards. Compliance with the new water quality standards would be incorporated into the District's NPDES permits at the time of renewal (every five years). However, increasing the level of treatment that is provided by the MWRD to the level that is provided by most all other treatment plants in the state is an issue that should stand on its own merits. Hydrologic separation is only a catalyst for moving these discussions forward.

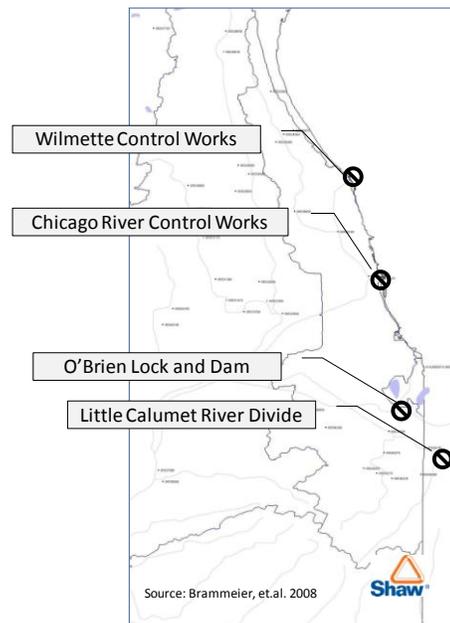
POSSIBLE HYDROLOGIC SEPARATION LOCATIONS

The Great Lakes Fishery Commission report, *“Preliminary Feasibility of Ecological Separation of the Mississippi River and the Great Lakes to Prevent the Transfer of Aquatic Invasive Species”* (Brammeier, 2008) recommended ecological separation of the Great Lakes and Mississippi River Watersheds. Ecological separation was defined as “no inter-basin transfer of aquatic organisms via the Chicago waterway system [CAWS] at any time.”²⁶

Under this alternative – a.k.a. “hydrological, or permanent, separation” – barriers would be strategically constructed in the CAWS to completely eliminate any movement of water between the two ecosystems that might allow organisms to move with it.²⁷ The Brammeier report stated that hydrological separation was assumed to be “the only way to guarantee 100 percent elimination of movement of all life stages of organisms via waterway routes.”²⁸

The Brammeier report identifies and prioritizes, multiple points within the system where permanent physical barriers could be placed to deal effectively with invasive species.²⁹ It found that direct diversions of Lake Michigan water into the CAWS were diminishing and navigation largely confined to specific portions of the system.³⁰ Further, the majority of the commodity traffic moving through the CAWS does not go all the way to Lake Michigan.³¹ The report recommended reviewing separation strategies at six locations: Lockport/Romeoville, the south branch of the Chicago River, the Chicago Lock to Lake Michigan, and the Calumet, Grand Calumet, and Little Calumet Rivers.³² For discussion here, these recommendations are grouped into three separation strategies.

FIGURE 12
POTENTIAL POINTS OF HYDROLOGIC SEPARATION
STRATEGY 1: CLOSURE AT LAKE MICHIGAN



Strategy 1: Closure at Lake Michigan

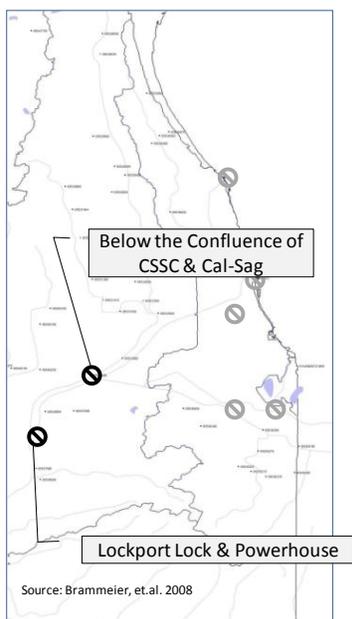
Legal challenges have petitioned that the water control structures along Lake Michigan be closed to prevent the migration of Asian carp into the Great Lakes (Figure 12).³³ This would involve the closing of the water control structures at:

1. Wilmette Water Control Works;
2. Chicago Water Locks and Water Control Works;
3. O'Brien Lock and Dam; and
4. Establishment of a hydrologic divide on the Little Calumet River around its natural divide near Hammond, Indiana.

It would also require the construction of a separation structure at the hydrologic divide on the Little Calumet River near Hammond, Indiana. These closures could be achieved almost immediately. These closures would eliminate the direct diversion of approximately 435 cfs of water from Lake

Michigan to maintain water quality, navigation, or lockage in the CAWS. The most serious negative of this strategy would be the loss of the ability to reverse flow into Lake Michigan to relieve flooding in the City of Chicago. This was a point successfully argued in the most recent litigation that ruled the locks should remain open. The disruption of the high traffic volume between the Chicago River and Lake Michigan further solidified this alternative as an undesirable strategy.

**FIGURE 13
POTENTIAL POINTS OF HYDROLOGIC
SEPARATION
STRATEGY 2: SINGLE CLOSURE
STRUCTURE**



hydrologic separation structure from the CAWS downstream to the Des Plaines River. However, separation at this location was not considered because it could result in the greatest disruption to barge traffic.

Strategy 2: Single Closure Structure

Closing the facilities at Lockport or constructing a hydrologic separation structure at a location downstream of the confluence of the Calumet Sag Canal and the Sanitary and Ship Canal would require the construction and operation of only one structure to prevent the Asian carp from reaching Lake Michigan (Figure 13). This would disrupt the high volume of barge traffic that traverses the lower reaches of the CAWS while the operation of the water works throughout the CAWS would remain unchanged. The challenge would be the development of the means to move water across the

Strategy 3: Mid-Point Separation

The third group of separation strategies described in the Brammeier report were locations around the South Fork of the South Branch of the Chicago River and the Calumet Water Reclamation Plant (Figure 14). Two specific locations were presented as part of this evaluation. Neither is proposed as the only possible location, but rather are used to identify issues related to the strategy of a mid-point separation. This strategy would also require the construction of a hydrologic divide on the Little Calumet River at the hydrologic divide near Hammond, Indiana.

The first separation point, on the Chicago River System, would be located between the South Fork of the South Branch (Bubbly Creek) at the confluence of the North and South Forks of the Chicago River. North of the divide, the North Branch of the Chicago River would continue to flow south to the Chicago Water Works. South of the divide, discharge from the Racine Pumping Station would flow north to the South Branch of the Chicago River and then south through the Chicago Sanitary and Ship Canal. Water levels in the Chicago River would be maintained by pumping the water from the Chicago River over the hydrologic separation structure to the South Branch of the Chicago River. This would allow the north half of the system to continue to operate as it currently does until such time as water quality control facilities could be constructed that would sufficiently improve the water quality where it could be discharged to Lake Michigan. Those improvements would include, but would not be limited to, a higher level of treatment by the North Side WRP and the reduction (if not the elimination) of CSOs. South of the divide, this strategy would not be dependent on the upgrade or modification of the existing facilities. This is particularly true for the Racine Pump Station, which discharges a tremendous volume of water of very poor water quality.

The separation point in the Calumet system would be between the Calumet Water Reclamation Plant and Lake Michigan. This strategy would not be dependent on the upgrade or modification of the Calumet Water Reclamation Plan since it would not discharge to Lake Michigan. However, there are CSOs between the divide and Lake Michigan that would need to be reduced or eliminated.

**FIGURE 14
POTENTIAL LOCATIONS FOR HYDROLOGIC SEPARATION IN THE CHICAGO RIVER AND
CALUMET RIVER SYSTEMS**



ROLE OF GREEN INFRASTRUCTURE

Magnitude of the Stormwater Problem

In Cook County, every drop of rain must be collected by the combined sewer system and conveyed to and treated by one of MWRD's water reclamation plants. As previously mentioned, more than 70 percent of the water in the CAWS is effluent from MWRD's wastewater treatment plants. During larger rain events, flow in the CAWS is comprised of increasing amounts of effluent discharges, combined untreated sanitary-storm by-pass of treatment at the plants, combined sewer discharges, and untreated stormwater runoff.

In Lake County, most communities have separated storm and sanitary sewers. The impervious surfaces of homes, businesses, industries, and roads prevent rainfall from soaking into the ground. This results in lower baseflows in the West Fork or Middle Fork of the Chicago Rivers or the Skokie River and greater peak storm flows that often overwhelm natural channels. Flooding of the river system backs up water in the collection systems, contributing to basement backups of the storm and sanitary systems.

Need Equal Investment in Local Infrastructure Improvements

While MWRD continues to undertake major capital projects to correct some of the system flooding problems and reduce the number of CSOs in the region, investments are needed to improve the performance of the local collection systems. Replacing all of the undersized pipes in the local collection system is an undertaking that is very costly, complex, and long-term.

Investments of the regional (MWRD) facilities will not eliminate basement flooding or CSOs. Both basement flooding and CSOs will continue to occur until deficiencies are corrected in the combined sewers and separate storm and sanitary sewer systems that are owned and operated by the City of Chicago and other communities. CSOs and stormwater nonpoint pollution will continue to cause flooding and water quality problems throughout the CAWS and the North Branch of the Chicago River that extends into Lake County.

An alternative to replacing pipes (conventional grey infrastructure) is the use of Green Infrastructure. Green Infrastructure is the use of natural systems, such as wetlands, street trees, and other types of vegetation to store and treat stormwater instead of the "hard infrastructure" that is traditionally used, including pipes, pumps, and storage tunnels.

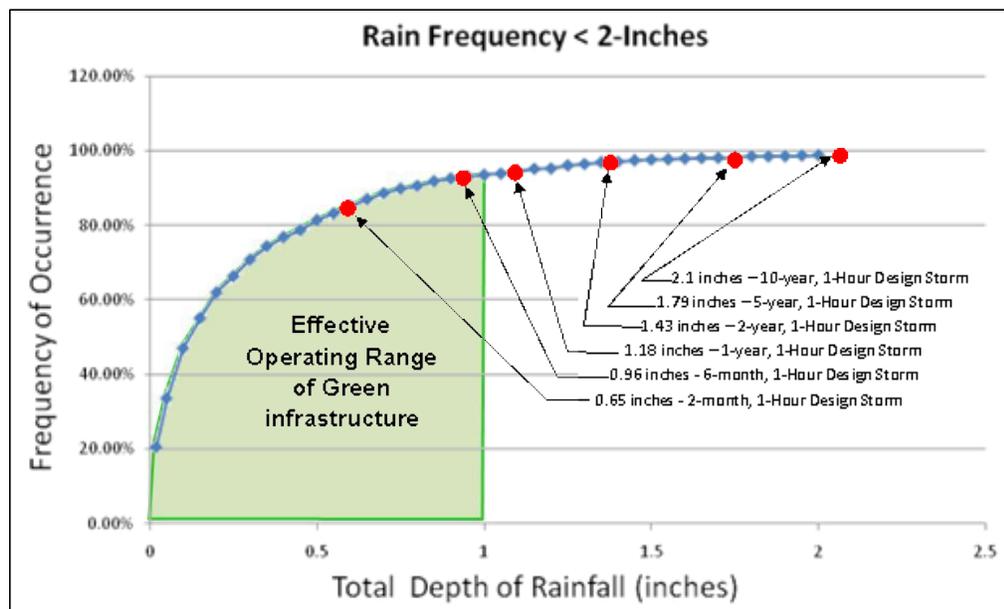
The strategic use of Green Infrastructure has a number of benefits – it can keep rainwater out of the sewer system, reducing the frequency of basement backups and sewer overflows that impair surface waters. Green Infrastructure absorbs runoff that is then infiltrated into the soil or slowly released at a rate that can be handled by the sewer system. Green Infrastructure can also remove pollutants and debris carried by stormwater into the sewer, reducing the frequency that maintenance must be performed on hard (grey) infrastructure and prolonging its useful life.

Green Infrastructure also makes sense economically because it decreases the costs of building expensive hard infrastructure and increases property values. Studies show that Green Infrastructure also improves people's health and safety, creates green jobs³⁴, helps facilitate urban farming, and saves energy used to heat and cool buildings.³⁵

Scores of municipalities apply Green Infrastructure to solve specific problems. These communities include the City of Chicago, Milwaukee Metropolitan Sewerage District, Pittsburgh, Pennsylvania, Seattle, Washington and Portland, Oregon. In 2006, NRDC produced the *Rooftops to Rivers-Green Strategies for Controlling Stormwater and Combined Sewer Overflows* report documenting applications of Green Infrastructure in 17 cities to address the root cause of a critical problem: stormwater and combined sewer overflow pollution.³⁶

In 2009, NRDC and Shaw Environmental released "*Rooftops to Rivers: Aurora – A Case Study in the Power of Green Infrastructure*"³⁷ that analyzes Aurora's approach. The City of Aurora, situated along the Fox River in northern Illinois, has an aging gray infrastructure system nearing capacity to support the city's rapid growing population and planned revitalization projects. Aurora's leaders recognized that their redevelopment projects would be enhanced through the integration of Green Infrastructure. With the help of NRDC and Shaw Environmental, Aurora's Mayor Tom Weisner adapted the "Rooftops to Rivers" approach and developed a comprehensive strategy to use Green Infrastructure to reduce stormwater volume and remove pollutants, offer decentralized, flexible and site-specific solutions, adjust to development patterns, and provide ancillary benefits, such as

**FIGURE 15
COMPARISON OF EFFECTIVE RANGE OF GREEN INFRASTRUCTURE AND CITY OF CHICAGO'S DESIGN RAINFALLS**



mitigation of the urban heat island effect, improved property values, and increased recreational space.

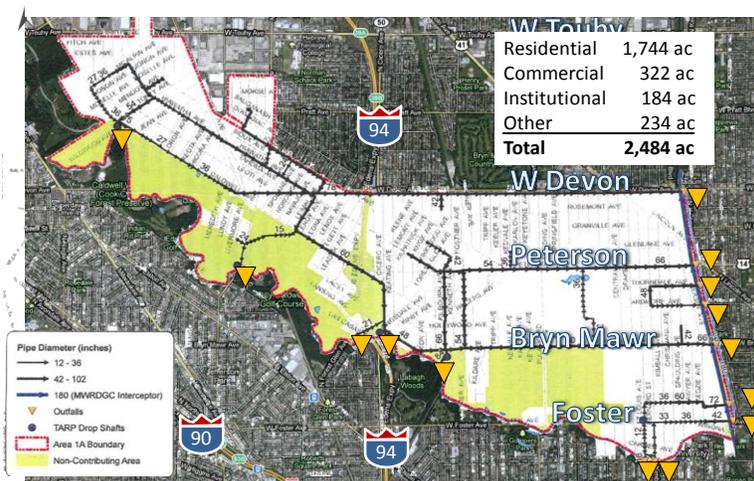
Green Infrastructure Role in Solving Chicago's Stormwater Management Problems

Green Infrastructure works very well in managing stormwater runoff from rainfalls of less than one inch (Figure 15). Depending on site conditions in Chicago, Green Infrastructure could contain all of the rainfall for the 1-month and 2-month design storms and could potentially capture almost half of the runoff from the 10-year, 1-hour design storm.

Green Infrastructure could potentially be used in areas where it would be costly to construct a relief sewer to serve the improvements in an area or where the marginal improvement in stormwater would result in an increase in level of protection (level of service) that could be provided by the municipality.

DEMONSTRATING THE BENEFIT OF GREEN INFRASTRUCTURE

FIGURE 16
Drainage Area for Trunk Sewer A1



Long term success of hydrologic separation depends on the successful reduction in basement flooding and improvement in water quality of the CAWS. To demonstrate and quantify how Green Infrastructure is part of the solution for stormwater management problems, a 60-acre area was selected on the north side of Chicago.

PILOT AREA LOCATION

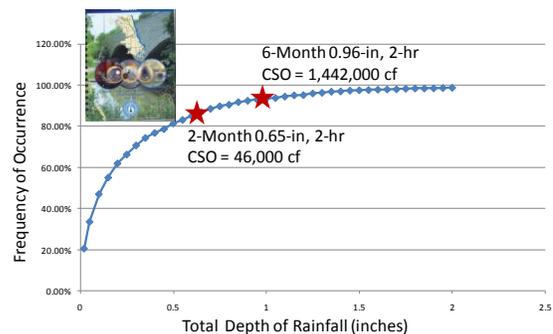
The 60-acre pilot area is in the southeast corner of 2,484 acres of the drainage area of Trunk

Sewer A1 (Figure 16) -- MWRD defines trunk sewers as pipes that are 42-inches in diameter or larger. The pilot area is at the confluence of the North Side Channel and the North Branch of the Chicago River; it is bounded by West Foster Avenue on the north, North Kimball Avenue on the east, the North Branch of the Chicago River on the south, and North Monticello Avenue on the west.

CAPACITY ANALYSIS OF TRUNK SEWER A1

The 2008 modeling report for Trunk Sewer A1 reported that it has 14 combined sewer overflows that ranged in size from 15 inches to 7.5 feet in diameter. Modeling of the capacity of approximately 79 miles of sewers 12-inch or larger estimated that during a 2-month design storm (0.65 inches), approximately 46,000 cubic feet of water would be released to either the

FIGURE 17
SIMULATED CSO EVENTS FOR TRUNK SEWER A1



North Branch of the Chicago River or the North Side Channel and roughly 1,442,000 cubic feet of water would be released during a 6-month design storm (0.96 inches) (Figure 17).

These two points were used in the analysis of Green Infrastructure to approximate the volume of each storm event that would be collected and properly managed by the existing sewer system.

Land Use of the Pilot Area

The breakdown of the land use in the selected pilot area is summarized in Table 14. The roughly 60-acre pilot area is comprised mainly of typical dense urban single family homes (approximately 28 acres). Commercial development was dominant along Kimball Avenue and Foster Avenue. The campuses of Von Steuben High School and North Park University were classified as institutional.

**TABLE 14
LAND USE
BREAKDOWN
FOR PILOT AREA**

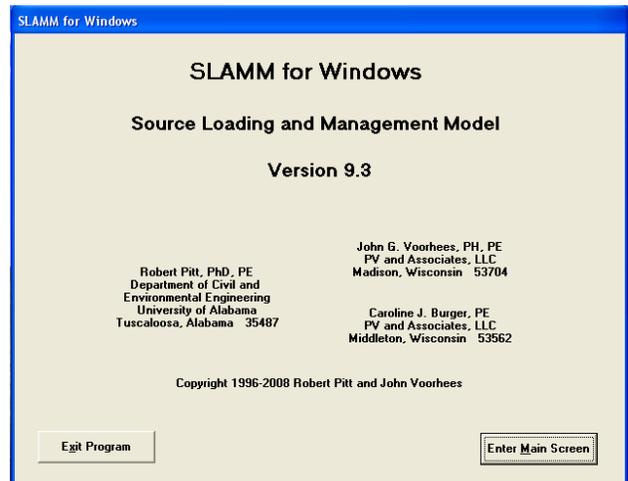
Land Use	Acres
Residential	28
Commercial	20
Institutional	12
Total	60

Analytical Tool

The computer model Source Loading and Management Model (SLAMM) was selected to estimate the volume of water and the nonpoint source pollution removed from the stormwater runoff (Figure 18). The strength of SLAMM is its ability to compute detention, retention, filtration, and removal of water and pollutants for a specific Green Infrastructure strategy given the design characteristics assigned to a Best Management Practice (BMP), rather than relying on a default value for removal.

SLAMM is a continuous simulation model. The daily rainfall runoff process for each of the given land uses and Green Infrastructure BMPs was estimated over 47 years of historic rainfall patterns (1953 through 1999) from Midway Airport.

**FIGURE 18
SOURCE LOADING AND MANAGEMENT
MODEL USED TO ANALYZE GREEN
INFRASTRUCTURE FOR PILOT AREA**



Finding Locations for Green Infrastructure

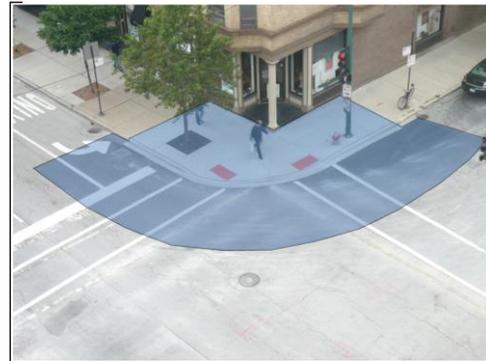
Two approaches can be used to select a location for Green Infrastructure. The first would be to select the location and type of practice, prepare plans and specifications and construct the project. Under this approach, the BMP carries the entire cost of the project, independent of other infrastructure improvements.

The second approach is to be opportunistic, incorporating Green Infrastructure in every construction project. Figure 19 and Figure 20 illustrate the point. Retrofit projects can often be opportunistic, incorporating Green Infrastructure into other capital improvements, such as road reconstruction, utility excavation, and sidewalk repaving. Figure 19 is a street planter constructed in an area of Chicago with a history of basement backups. The planter could have been constructed to collect stormwater runoff from the street and would have added very little to the overall cost of the project. In the second example (Figure 20) the street and sidewalk were dug up and replaced with new handicapped ramps. The City could have excavated a little more to install porous pavement that would increase the time it takes runoff to reach the sewer system. In the urban environment there is not enough room to come up with large fixes, such as digging up sewer pipes and increasing their size. To properly manage stormwater in an urban setting requires many small dispersed solutions.

**FIGURE 19
LOST OPPORTUNITY SIDEWALK
PLANTER STORMWATER**



**FIGURE 20
LOST OPPORTUNITY SIDEWALK
AND PAVING POROUS PAVING**



Retrofitting an urban area with Green Infrastructure is dependent on local conditions such as soil permeability, utility conflicts, land cover, and available land and tree canopy. The addition of Green Infrastructure could be incorporated into street beautification and other revitalization projects. Green Infrastructure generally improves the aesthetics of a street and neighborhood. Consider the pictures in Figure 21 below. The commercial strip on the left is devoid of vegetation and its appearance is unappealing. The same commercial strip is then shown with first a single Green Infrastructure practice and then a combination of practices. The views of the same street with rain (street) trees and bioswales are much more inviting. Shade from the rain trees provide protection from the heat of the sun. The addition of street trees, bioswales and a strip of permeable paving not only augment existing stormwater infrastructure by cleaning and slowing water's entry into a sewer system, but also provide a more aesthetically pleasing, functional environment.

**FIGURE 21
RENDERING OF COMMERCIAL AREA WITH GREEN
INFRASTRUCTURE ALTERNATIVES**



Existing View of Foster Avenue



With Urban Bioswale



With Porous Parking Lane



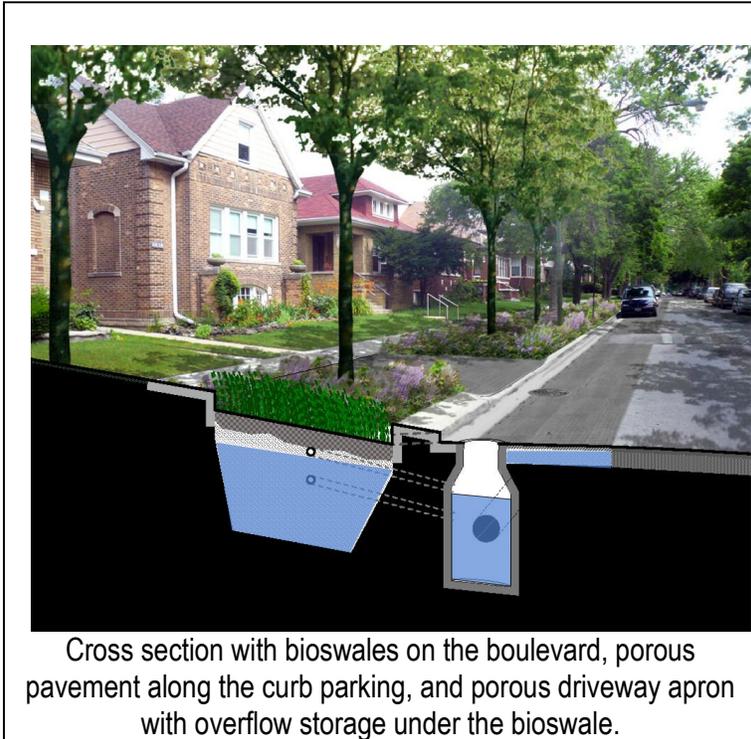
With Bioswale and Parking Lane



With Bioswale, Porous Parking,
and Rain Trees

Figure 22 is a scene from the pilot area of a residential neighborhood with a very intense level of Green Infrastructure. This example is presented to demonstrate that Green Infrastructure can be sizable to manage larger design storms. In this example, porous pavement is installed along the curb, while the center traveling lanes remain as traditional pavement. An additional storage layer that extends under the driveway aprons, which are shown here to also be porous, further enhances the bioswales and rain trees. Cross connections between this additional storage layer and sewer allow water that has already reached the sewer to overflow into the storage layer, thus reducing the potential of water trying to backflow into basements.

FIGURE 22
CONCEPTUAL RESIDENTIAL STREET CROSS-SECTION

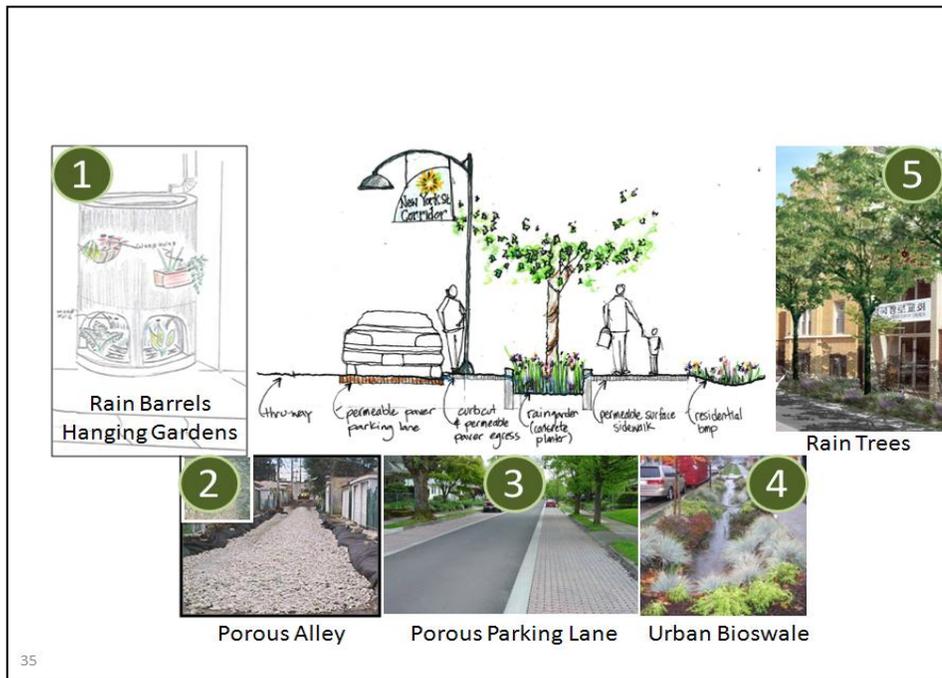


that extends under the driveway aprons, which are shown here to also be porous, further enhances the bioswales and rain trees. Cross connections between this additional storage layer and sewer allow water that has already reached the sewer to overflow into the storage layer, thus reducing the potential of water trying to backflow into basements.

Green Infrastructure Evaluated

The analysis focused on the application of five types of Green Infrastructure: rain barrels, porous alleys, porous parking lanes, urban bioswales and rain trees (Figure 23). Figure 24 shows the potential location for each of these BMPs.

**FIGURE 23
GREEN INFRASTRUCTURE SIMULATED IN PILOT AREA**



**FIGURE 24
POSSIBLE LOCATION FOR GREEN
INFRASTRUCTURE IN PILOT AREA**



Porous alleys and porous parking lanes were treated nearly identically by the analysis, differing only in the width of porous pavement. For this stage of planning, rain trees and urban bioswales

were assigned identical characteristics of permeability of engineered soils.

It was felt that it would be unlikely that all of the Green Infrastructure would be allowed to be built. Easements, cooperating partners, land acquisition, soil conditions, and utility conflicts are all possible reasons that the proposed Green Infrastructure would not be constructed. The analysis considered a best case scenario where up to half of all of all proposed Green Infrastructure was constructed (Table 15). Half is still very optimistic, but establishes the upper limit of what could be realized.

**TABLE 15
GREEN INFRASTRUCTURE
SIMULATED ASSUMING HALF OF
TOTAL POSSIBLE AREA
CONSTRUCTED IN PILOT AREA**

Green Infrastructure	Number or Area of BMP	Units
Trees	106	qyt
Bioswale	54,300	sf
Parking strips	54,700	sf
Perm alleys	58,300	sf
Rain barrels*	5,200	qyt

Reduction in Volume of CSOs Estimated for Green Infrastructure

The quantity of the reduction in the volume of stormwater runoff (and its corresponding pollutant reduction in CSOs) that could be taken up by specific Green Infrastructure practices, assuming that half of the total possible BMPs were constructed, is summarized in Table 14. Runoff from commercial areas is of greater volume than other land use types. Green Infrastructure practices are quickly filled and bypassed. Thus only a 14 percent reduction was achieved. If Green Infrastructure was selected as the approach to manage stormwater in commercial areas, a greater density of practices would need to be deployed as compared to areas with less intense land uses. The results further suggest that:

- The volume of stormwater entering the combined sewer system would be reduced by at least 25 percent;
- The volume of CSOs from the pilot area that would be discharged to the North Branch of the Chicago River would be reduced by a corresponding 25 percent; and
- A 25 percent reduction in pollutants entering the sewer system would be achieved, potentially reducing treatment needs further in the system. This would be a significant reduction in pollutant loads in communities with separated storm and sanitary sewers that are trying to meet pollutant reduction goals for their NPDES MS4 permit or local TMDL.

Table 16
ESTIMATED REDUCTION IN RUNOFF ASSUMING CONSTRUCTION OF HALF
OF THE POSSIBLE GREEN INFRASTRUCTURE

Land Use	Acres (ac)	Average Annual Runoff No BMPs (sq ft)	Average Annual Runoff With BMPs (sq ft)	Percent Reduction in Runoff Volume
Residential	28	212,000	160,000	25%
Commercial	20	263,000	226,000	14%
Institutional	12	128,000	68,000	47%
Total	60	603,000	454,000	25%

Cost of Green Infrastructure

Shaw worked with NRDC to develop a Green Infrastructure Calculator for the Milwaukee Metropolitan Sewerage District. A feature of that calculator is a cost estimator. The cost estimator uses average costs for each practice based on cumulated bid tabs and literature reviews. Using the Calculator, the estimated cost for the Green Infrastructure listed in Table 17 was approximately \$3,200,000.

TABLE 17 ESTIMATED IMPLEMENTATION COSTS OF GREEN INFRASTRUCTURE BMPs IN PILOT AREA	
Green Infrastructure BMP	Estimated Implementation Costs
Rain Trees	\$42,000
Bioswales	\$1,360,000
Parking Strips	\$520,000
Permeable Alleys	\$550,000
Rain Barrels	\$728,000
Total	\$3,200,000

CONCLUSION

NRDC has just begun its investigation into the feasibility of permanently separating the Great Lakes from the Mississippi River. We suggest solutions to the invasive species issue that could create neighborhood benefit, improve water quality, and bring key parts of Chicago's infrastructure into the 21st century. These issues must be addressed if the region is to grow and prosper. If we take advantage of the opportunities, the benefits will range far beyond northeastern Illinois. The Great Lakes provide drinking water to more than 40 million people. Tens of thousands of people depend on the Great Lakes multibillion dollar fishing and tourism industries. More than

a third of all the freight in this country moves through Chicago, and if Chicago's ports and railways can be modernized to move more goods, the economic benefit would be multiplied across the country. Many cities in this country face the same challenges of updating centuries-old wastewater and stormwater systems. Chicago can lead the way in determining how to maximize the use of new technology, such as Green Infrastructure, to make its infrastructure more resilient and extend its useful life. There is much more work to do. While the analysis is far from complete, it does suggest that a different future could await the region. NRDC will continue to refine this analysis to better understand how additional neighborhoods and treatment systems could be affected and improved by permanent separation; how the region can rethink goods movement to increase economic activity; and how to engage affected stakeholders in this process.

¹. Numerous state and local governments, nonprofit organizations and editorial boards have called for permanent, i.e. ecological or hydrological, separation. See: The Great Lakes Commission, chaired by Illinois Governor Pat Quinn ("Actions to Address the Threat to the Great Lakes from Asian Carp," *Great Lakes Commission | Commission Des Grands Lacs*, <http://www.glc.org/about/resolutions/10/asiancarp.html>); Great Lakes United ("Battling Back the Asian Carp | Great Lakes United / Union Saint-Laurent Grands Lacs," <http://www.glu.org/asiancarp>), National Wildlife Federation; the governors of Ohio ("Governor, Lt. Governor Call for Vigilance, Collaborative Action to Protect Lake Erie from Invasive Species Asian Carp," Ohio.gov., State of Ohio, 8 Feb. 2010, <http://www.governor.ohio.gov/Default.aspx?tabid=1511>); Wisconsin ("Testimony by Matt Frank, Secretary of the Wisconsin Department of Natural Resources Before the U.S. House Transportation and Infrastructure Subcommittee on Water Resources and Environment," 2010); and Michigan ("Granholm, Cherry Urge Attorney General Cox to Pursue Every Legal Means to Keep Asian Carp Out of Great Lakes," *SOM - State of Michigan*, 2 December 2009, <http://michigan.gov/gov/0,1607,7-168-23442-227176--,00.html>); the Metropolitan Milwaukee Sewerage District ("Supporting Measures for Protecting Lake Michigan from Asian carp," Milwaukee Metropolitan Sewerage District, Certified Resolution No. 10-057-4. 26 April 2010, http://v3.mmsd.com/proceedings_resolutions.aspx). *The Cleveland Plain-Dealer* ("Shelve the Politicking and Do What's Necessary to Preserve the Great Lakes from a Devastating Asian Carp Infestation: Editorial," *Cleveland Plain-Dealer* 22 February 2010), the *Milwaukee Journal-Sentinel* ("A Futile Search," *Milwaukee Journal-Sentinel* 19 Mar. 2010, <http://www.jsonline.com/news/opinion/88691417.html>) and the *Kalamazoo Gazette* ("Time for Action to Halt Spread of Asian Carp," Editorial, *Kalamazoo Gazette* 6 December 2009, Mlive.com, 6 December 2009, http://www.mlive.com/opinion/kalamazoo/index.ssf/2009/12/editorial_time_for_action_to_h.html) have all editorialized on the need for a permanent separation. In 2003, a local, state, and federal interagency group hosted the Chicago Aquatic Invasive Species Summit, where more than 70 experts agreed that stopping water movement between the Great Lakes and Mississippi River was the only way to eliminate the movement of invasive species ("Proceedings of Closing the Revolving Door: Summary of the Aquatic Invasive Summit Proceedings," Chicago, 2003, <http://www.cityofchicago.org/.../InvasiveSpecies/AquaticInvasiveSpeciesSummitSummary2003.pdf>). A 2008 report released by the Great Lakes Fishery Commission and authored by the Alliance for the Great Lakes also recommended separation (Joel Brammeier, Irwin Polls, Scudder Mackey, "Preliminary Feasibility of Ecological Separation of the Mississippi River and the Great Lakes to Prevent the Transfer of Aquatic Invasive Species," Great Lakes Fishery Commission, 2008).

² Chicago Metropolitan 2020, "The Metropolis Freight Plan: Delivering the Goods," December, 2004, 3.

³Green Infrastructure is the use of natural systems, such as wetlands, street trees and other types of vegetation to store and treat stormwater instead of the "hard infrastructure" that is traditionally used, such as pipes, pumps and storage tunnels. Increased use of Green Infrastructure could provide additional storage capacity to wastewater and stormwater treatment facilities, potentially forestalling additional hard infrastructure investment.

⁴ See, generally, "Description of the Chicago Waterway System, Use Attainability Analysis Study," IL-EPA Bureau of Water; "Metropolitan Water Reclamation District of Greater Chicago's Response to Motion for Preliminary Injunction," Metropolitan Water Reclamation District of Greater Chicago, January 5, 2010.

⁵Affidavit of Richard Lanyon, dated Aug. 4, 2010. Filed in *State of Michigan, et al. v. U.S. Army Corps of Engineers, et al.*, Case No. 1:10-cv-04457 (N.D. Ill.), 6.

⁶ Joel Brammeier, Irwin Polls, Scudder Mackey, "Preliminary Feasibility Of Ecological Separation Of The Mississippi River And The Great Lakes To Prevent The Transfer Of Aquatic Invasive Species," Great Lakes Fishery Commission, 2008.

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- ⁷ “Description of the Chicago Waterway System for the Use Attainability Analysis,” May 2002; and “Combined Sewer Overflows,” Metropolitan Water Reclamation District, April 13, 2010. <http://www.mwrd.org/irj/portal/anonymous/overview>
- ⁸ Metropolitan Water Reclamation District, “CSO Event Synopsis Report.” <http://www.mwrd.org/irj/portal/anonymous?NavigationTarget=navurl://a5611bcef89c3cc2abca008c0ea969df>.
- ⁹ Citywide CSOs CH2M Hill and Letter from MWRD to US EPA January 4, 2006 re: NPDES Permit CSO Monitoring and Reporting Supplemental Information (CSO Outfall Elevations) and Model Integration and Identification of Priority Improvement Areas, City of Chicago Dept of Water, MWH, 2009.
- ¹⁰ See, generally, Marcelo H. Garcia and Arthur R. Schmidt, “Applied Research: Tunnel And Reservoir Plan,” <http://vtchl.uiuc.edu/applied-research/environmental-hydraulics/tarp> (last visited April 18, 2010); Marcella V. Landis, “One Deep Tunnel, Three Reservoirs...Cleaner Water,” March/April 2008, 15-17.
- ¹¹ *Wisconsin v. Illinois*, 388 U.S. 426 (1967); and Affidavit of Richard Lanyon, 10.
- ¹² See, generally, *Wisconsin v. Illinois*, 449 U.S. 48 (1980); Peter Annin, *The Great Lakes Water Wars* (Washington, D.C.: Island Press, 2006), 97-106.
- ¹³ Metropolitan Water Reclamation District of Greater Chicago, “Description of the Chicago Waterway System for the Use Attainability Analysis,” Research and Development Department, Report No. 08-15R, March 2008, 16.
- ¹⁴ *Ibid.*, 16-17.
- ¹⁵ Lake Michigan Diversion Committee Findings Of The Sixth Technical Committee For Review Of Diversion Flow Measurements and Accounting Procedures, United States Army Corps of Engineers Chicago District 2009.
- ¹⁶ Chicago Metropolitan Agency for Planning, “Water 2050.”
- ¹⁷ “Combined Sewer Overflows,” Metropolitan Water Reclamation District of Greater Chicago, <http://www.mwrd.org/irj/portal/anonymous/overview>.
- ¹⁸ “Description of the Chicago Waterway System, Use Attainability Analysis Study,” May 2002.
- ¹⁹ NOAA Weather station @ O’Hare Airport 1996 – 2010; and “Description of the Chicago Waterway System for the Use Attainability Analysis,” May 2002.
- ²⁰ Description Of The Chicago Waterway System, Use Attainability Analysis Study, Illinois Environmental Protection Agency Bureau Of Water, 2002.
- ²¹ Citywide CSO TARP 50% Full, CH2M Hill
- ²² “Chicago River at Chicago Lock at Chicago,” USGS Water Data for the Nation, USGS daily gage record 1997 – 2010 5536121; <http://waterdata.usgs.gov/nwis>.
- ²³ Katharine Hayhoe and Donald Wuebbles, “Climate Change and Chicago: Projections and Potential Impacts,” Chapter Three: Water, November 11, 2007, 3, 8.
- ²⁴ Hayhoe and Wuebbles, 8.
- ²⁵ Science International Applications Corporation, “Review of Technical Memorandum 1WQ - Disinfection Evaluation Prepared on Behalf of the Metropolitan Water Reclamation District of Greater Chicago,” Final Report, October 26, 2006, 15.
- ²⁶ Brammeier et al, ii.
- ²⁷ *Ibid.*, 83-92.
- ²⁸ *Ibid.*, 83.
- ²⁹ *Ibid.*, 83-92.
- ³⁰ *Ibid.*, 51-52.
- ³¹ *Ibid.*, 56.
- ³² *Ibid.*, 83-92
- ³² According to the Illinois Environmental Protection Agency, “the Chicago Area Waterways System, or CAWS, consists of 78 miles of canals and modified streams located within Cook and surrounding counties. The CAWS consists of the Chicago River, its two main branches (North Branch and South Branch), as well as the Cal-Sag Channel, the Chicago Sanitary and Ship Canal, and the tributaries in an area extending from the metropolitan Chicago area to the Lockport vicinity. It also includes Lake Calumet.” <http://www.epa.state.il.us/mailman/listinfo/chicago-area-waterways>.
- ³² “Carp creeps into Lake Calumet,” Joel Hood, Chicago Tribune, June 23, 2010, <http://www.chicagotribune.com/news/local/ct-met-0624-asian-carp-found-20100623,0,3511274.story>.
- ³² David Pimentel, Rodolfo Zuniga and Doug Morrison, “Update on the Environmental and Economic Costs Associated with Alien-Invasive Species in the United States,” *Ecological Economics* 52 (2005): 273.
- ³² Katharine Hayhoe and Donald Wuebbles, “Climate Change and Chicago: Projections and Potential Impacts,” Chapter Three: Water, November 11, 2007, 3, 8.

³² Hayhoe and Wuebbles, 8.

³² Green Infrastructure is the use of natural systems, such as wetlands, street trees and other types of vegetation to store and treat stormwater instead of the “hard infrastructure” that is traditionally used, such as pipes, pumps and storage tunnels. Increased use of Green Infrastructure could provide additional storage capacity to wastewater and stormwater treatment facilities, potentially forestalling additional hard infrastructure investment.

³²Katharine Hayhoe and Donald Wuebbles, “Climate Change and Chicago: Projections and Potential Impacts,” Chapter Three: Water, November 11, 2007, 3, 8.

³² Brammeier et al, ii.

³² Ibid., 83-92.

³² Ibid., 83.

³² Ibid., 89.

³² Ibid., 83-92.

³² Ibid., 51-52.

³² Ibid., 56.

³² Ibid., 83-92

³³ Wisconsin v. Illinois, Nos. 1, 2 & 3, Orig. (U.S.); citation *State of Michigan, et al. v. U.S. Army Corps of Engineers, et al.*, Case No. 1:10-cv-04457 (N.D. Ill.).

³⁴ According to the United Nations Environment Program, a green or “green-collar” job is “work in agricultural, manufacturing, research and development (R&D), administrative, and service activities that contribute(s) substantially to preserving or restoring environmental quality. Specifically, but not exclusively, this includes jobs that help to protect ecosystems and biodiversity; reduce energy, materials, and water consumption through high efficiency strategies; de-carbonize the economy; and minimize or altogether avoid generation of all forms of waste and pollution.” United Nations Environment Program, “Green Jobs: Towards Decent Work in a Sustainable, Low-Carbon Economy,” September, 2008, 3.

³⁵ See, generally, Christopher Kloss and Crystal Calarusse, “Rooftops to Rivers: Green Strategies for Controlling Stormwater and Combined Sewer Overflows,” Natural Resources Defense Council (2006); “How Does Green Infrastructure Benefit the Environment,” Alexandra Dapolito Dunn, *Siting Green Infrastructure: Legal & Policy Solutions to Alleviate Urban Poverty and Promote Healthy Communities*, 37 *ENVIRONMENTAL AFFAIRS* 41 (2010); USEPA, http://cfpub.epa.gov/npdes/home.cfm?program_id=298#benefit; Mark Benedict and Ed McMahon, “Green Infrastructure: Linking Landscapes and Communities,” (Washington, DC: Island Press, 2006).

³⁶ Christopher Kloss and Crystal Calarusse, “Rooftops to Rivers: Green Strategies for Controlling Stormwater and Combined Sewer Overflows,” Natural Resources Defense Council (2006).

³⁷ Natural Resources Defense Council and Shaw Environmental, “Rooftops to Rivers: Aurora – A Case Study in the Power of Green Infrastructure,” 2009.