Hydraulics in the Time of Cholera: The Chicago River, Lake Michigan and Public Health

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Abstract. Situated at the southwest corner of Lake Michigan, in the United States of America, the Chicago metropolitan area straddles a low continental divide, which separates the upper Mississippi River system from the Great Lakes and the St. Lawrence River system. The first European explorers, Louis Joliet and Father Jacques Marquette arrived in 1673. They dragged their canoes though a marsh which connected the Des Plaines River, a remote tributary to the Mississippi River, and the Chicago River, which discharged directly into Lake Michigan. Marquette proposed that a canal be built to eliminate the portage and connect the Great Lakes to the Mississippi River. When the proposal was finally implemented, 150 years later, it had incalculable beneficial effects on the future of Chicago. In 1816, the first steps were taken to construct a canal between Lake Michigan and the Illinois River, to which the Des Plaines River is a tributary. In 1822 the United States government authorized the State of Illinois to construct the Illinois & Michigan Canal. But Illinois with a population of about 60,000 could not afford the construction costs. Thus in 1827 the United States Congress granted additional land near the canal right-of-way to Illinois so that the state could sell the land to speculators and raise the needed construction funds. Thus it was the sale of this land to finance the Illinois & Michigan Canal that promoted the beginnings of the actual town of Chicago, which was incorporated in 1833 with a population of 350. The canal was completed in 1848. By 1860, Chicago, with a population of about 110,000, was the trading center of the Midwestern United States.
From its outset, Chicago was plagued by sanitation problems. The original water sources were shallow wells, which soon became contaminated by wastes from outdoor privies. As early as 1836, water-borne diseases such as typhoid fever and amoebic dysentery became common. Drinking water was distributed from Lake Michigan, first by horse-drawn cart and later by pipeline. As sanitary waste systems were gradually connected to outfalls at the Chicago River, the increasing flow of sewage down the river contaminated the lake. The water intakes in the lake were successively moved farther away from shore, and connected to the city supply lines by tunnels under the lake. Storms continue to flush sewage into the lake and to carry pollution to the distant water intakes. Water-borne diseases raged, often killing as much as 5 % of the population of Chicago annually. In 1854, cholera alone killed 5.5 % of the population of Chicago.
In 1855, Chicago organized a Board of Sewerage to improve sewage disposal and appointed Ellis Chesbrough as the first City Engineer. To improve the drainage parts of the city were raised up to 5 m. Buildings were raised without disturbing the inhabitants. Most of the sewage was drained to the Chicago River. Chesbrough proposed a deep canal to reverse the flow of the Chicago River across the continental divide, in order to protect the Lake Michigan drinking water supply; but this was deemed too expensive. Instead, the Illinois & Michigan Canal was deepened in 1871 to carry wastes away from the lake. The enlarged canal did not perform well during storms. In 1884, pumps were installed in a vain attempt to pump flood flows from the Chicago River into the Illinois

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and Michigan Canal. This also proved unsatisfactory. By 1885 the population of Chicago had reached 750,000. In that year a large storm resulting in 15.7 cm of rainfall depth, again flushing overwhelming amounts of sewage pollution into the lake and the drinking water intakes. Finally engineering plans were drawn to construct the deep canal which Chesbrough envisioned, and permanently reversed the flow of the Chicago River away from the city's drinking water supply. In 1889, the Sanitary District of Chicago (SDC), which became the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) in 1989, was formed and work began in 1892 to construct the new canal. The population of Chicago had reached 1,000,000 by then. The main channel of the Chicago Sanitary and Ship Canal (CSSC), as originally constructed, was 45 km long, had a minimum cross-section 49 m wide and 7.2 m deep, and paralleled the old Illinois & Michigan Canal. New methods for handling of materials were developed, and the canal became known as the "Chicago School of Earth Moving." Several techniques were developed which later would facilitate the digging of the Panama Canal.

The new CSSC was designed to carry a nominal flow of 284 m^3/s and intended to treat the sewage entering by dilution and natural aeration for a population of 2.5 million. The canal was placed into operation in January 1900. Interceptor sewers were built along the lake front area to divert sewer outfalls to the canal. The desired effect was to convert the lake front area from sewage-covered shore to a fine swimming beach more than 30 km long. Eventually, law suits filed by the other Great Lakes States, resulted in a United States Supreme Court order which limits all diversions from the Lake Michigan into Illinois waterways to not exceed an average of 91 m^3/s. This diversion includes all uses-drinking water, leakages, navigation make-up, lock exchanges, and diversion for water quality.

In dealing with the challenges of urban growth in the early 1900s, the SDC decided that waste water would be delivered to centralized locations for treatment instead of being dumped into the river and diluted. The SDC built three wastewater treatment facilities. In cooperation with communities within its jurisdiction, the SDC also built a system of conduits and pumping stations to steer the storm-water runoff and sewage discharge from combined sewers away from the lake and the Chicago waterways and into the treatment plants. This system would begin to come on line in the late 1920s and would function effectively until the 1950s, when urban growth and development outstripped its capacity.

Today more than 5 million people live in the service area of the MWRDGC. Industrial and commercial wastewater adds the equivalent of another 5 million people. This amount of waste would have overwhelmed the Chicago River system if the MWRDGC had not experimented with and adopted sewage-disposal strategies other than dilution. The diversion of the river and dilution were never intended to handle the waste from a population of this size. In the 1890s when the canal system was designed it seemed inconceivable that Chicago would grow this large.

In order to solve these problems, the MWRDGC now has seven sewage treatment plants and provides supplemental aeration of the waterways to meet water quality standards. To solve the combined sewer overflow problem, MWRDGC adopted the Tunnel and Reservoir Plan (TARP) in 1972. TARP is a second river system which was constructed by boring tunnels up to 11 m in diameter in rock as much as 100 m under the city. When the combined sewers' capacity is exceeded, the excess flow drops into TARP. Large reservoirs in existing limestone quarries totaling 150,000,000 m^3 capacity together with the tunnels will store the combined sewer overflows until they can be pumped back to the treatment plants once storm events subside. TARP has been divided into three service areas for economy of construction as shown in Figure 1. The three areas are the Upper Des Plaines System with O'Hare Reservoir, the Main Stream/ Des Plains System with McCook Reservoir, and the Calumet System with Thornton Reservoir. The construction costs of the TARP system exceed 3 Billion US dollars and construction is complete except for McCook Reservoir. The University of Illinois is currently developing a real-time hydrologic/hydraulic model for each one of the TARP subsystems with the goal of having a tool to

optimize the operation of the system of tunnels and reservoirs so that combined sewer overflows are virtually eliminated. A hydrodynamic and water quality model of Chicago's waterways is also being developed. In 1986, TARP was voted as the most outstanding project by the American Society of Civil Engineers (ASCE). The entire wastewater management system was designated as Project of the Millennium in 2000.

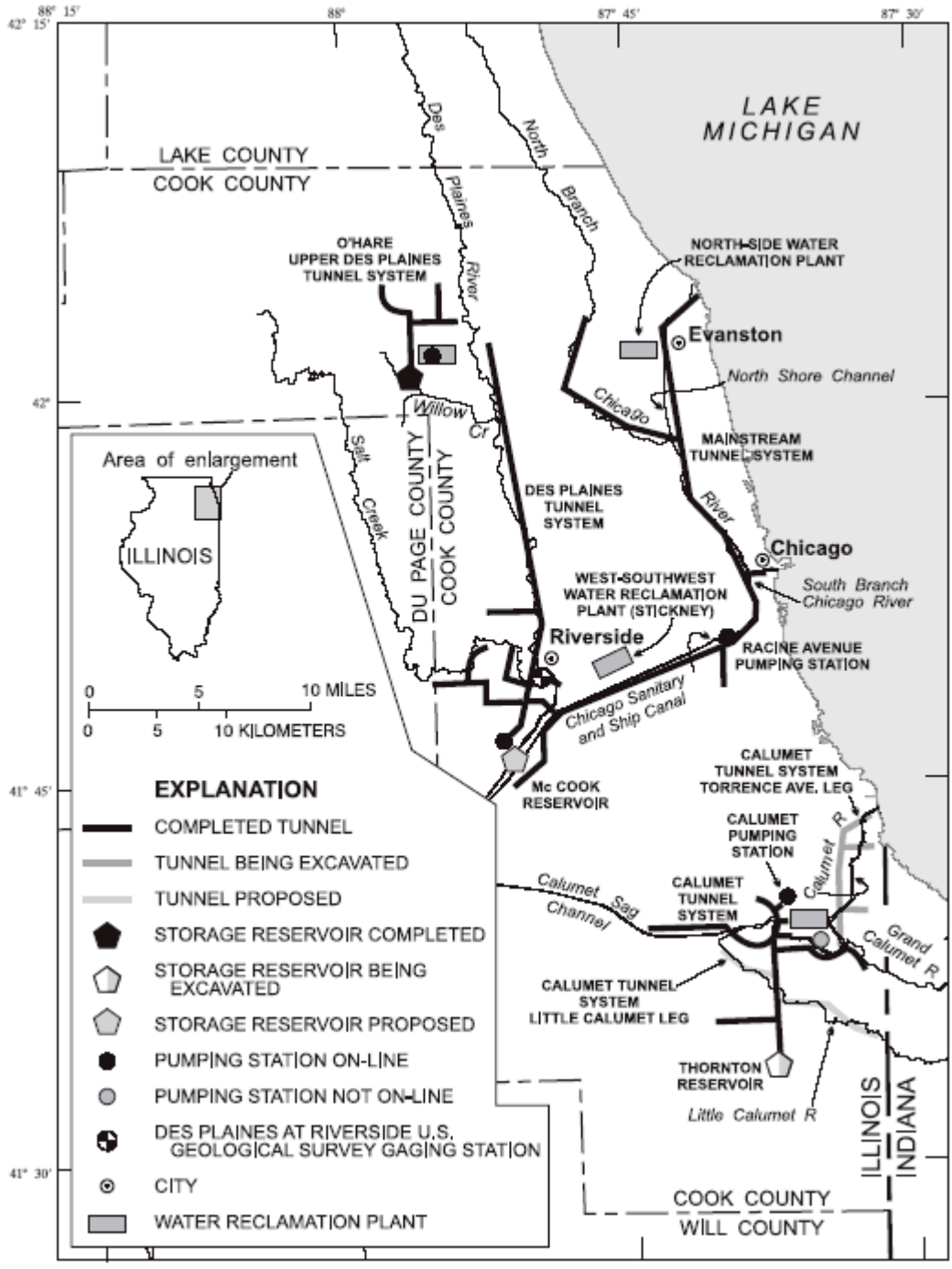

Figure 1 Location of Chicago's Tunnel and Reservoir Tunnel Plan (TARP)