APPENDIX B

LAKE MICHIGAN DIVERSION ACCOUNTING

WATER YEAR 1990 REPORT

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EXECUTIVE SUMMARY

In compliance with the modified 1980 U.S. Supreme Court decree (hereinafter the Decree), the WY90 diversion was computed using the best engineering technology available to date.

Given the complexity of the hydrologic cycle in the heavily urbanized Chicago metropolitan area, and given the number of human and other factors that cannot be adequately represented in numerical modeling procedures, the results of the simulations which compute diversion flows worked exceptionally well.

The WY90 diversion accountable to the State of Illinois is 3,531.2 cfs. This is 331.2 cfs greater than the 3,200 cfs average specified by the Decree. The 40 year running average, rounded to the nearest cfs, beginning with WY81 is 3,452 cfs and the cumulative deviation from the 3,200 cfs average is -2,520 cfs-years. The negative cumulative deviation indicates a water allocation deficit and the maximum allowable debt is 2,000 cfs-years.

INTRODUCTION

The diversion of water from the Lake Michigan watershed is of major importance to the Great Lake states and to the Canadian province of Ontario. The states and province that border the Great Lakes have concerns with both diversions during periods of low lake levels as well as the long term effects of diversion. To insure that the concerns of these interested parties are considered, the U. S. Army Corps of Engineers has been given the responsibility for the accounting of flow that is diverted from the Lake Michigan watershed.

The Corps of Engineers, Chicago District, is responsible for monitoring the measurements and the computation of the diversion of Lake Michigan water by the State of Illinois. The computations for Water Year 1983 (WY83), WY84 and WY85 (1 October 1984 through 30 September 1985) were completed by the Northeastern Illinois Planning Commission (NIPC) for the Illinois Department of Transportation (IDOT). Prior to the WY83 report, the calculations were made by the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) for IDOT. The Corps reviewed, modified, and updated the WY84 and WY85 diversion accounting completed by NIPC. The computations for WY86 were performed jointly by NIPC (under contract to the Corps of Engineers) and the Corps of Engineers. Beginning in WY87 the computations were performed solely by the Corps of Engineers. This report represents the final Lake Michigan diversion accounting for WY90.

AUTHORITY FOR REPORT

Under the provisions of the U.S. Supreme Court Decree in the Wisconsin, et al v. Illinois et al, 388 U.S. 426,87 S.Ct. 1774 (1967) as modified 449 U.S. 48, 101 S.Ct. 557 (1980), the Corps of Engineers is responsible for monitoring the measurement and computation of diversion of Lake Michigan water by the State of Illinois. The Water Resources Development Act of 1986 (Section 1142 of PL 99-662) gave the Corps total responsibility for the computation of diversion flows as formerly done by the State of Illinois. The Corps' new mission became effective 1 October 1987.

HISTORY OF THE DIVERSION

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

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

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

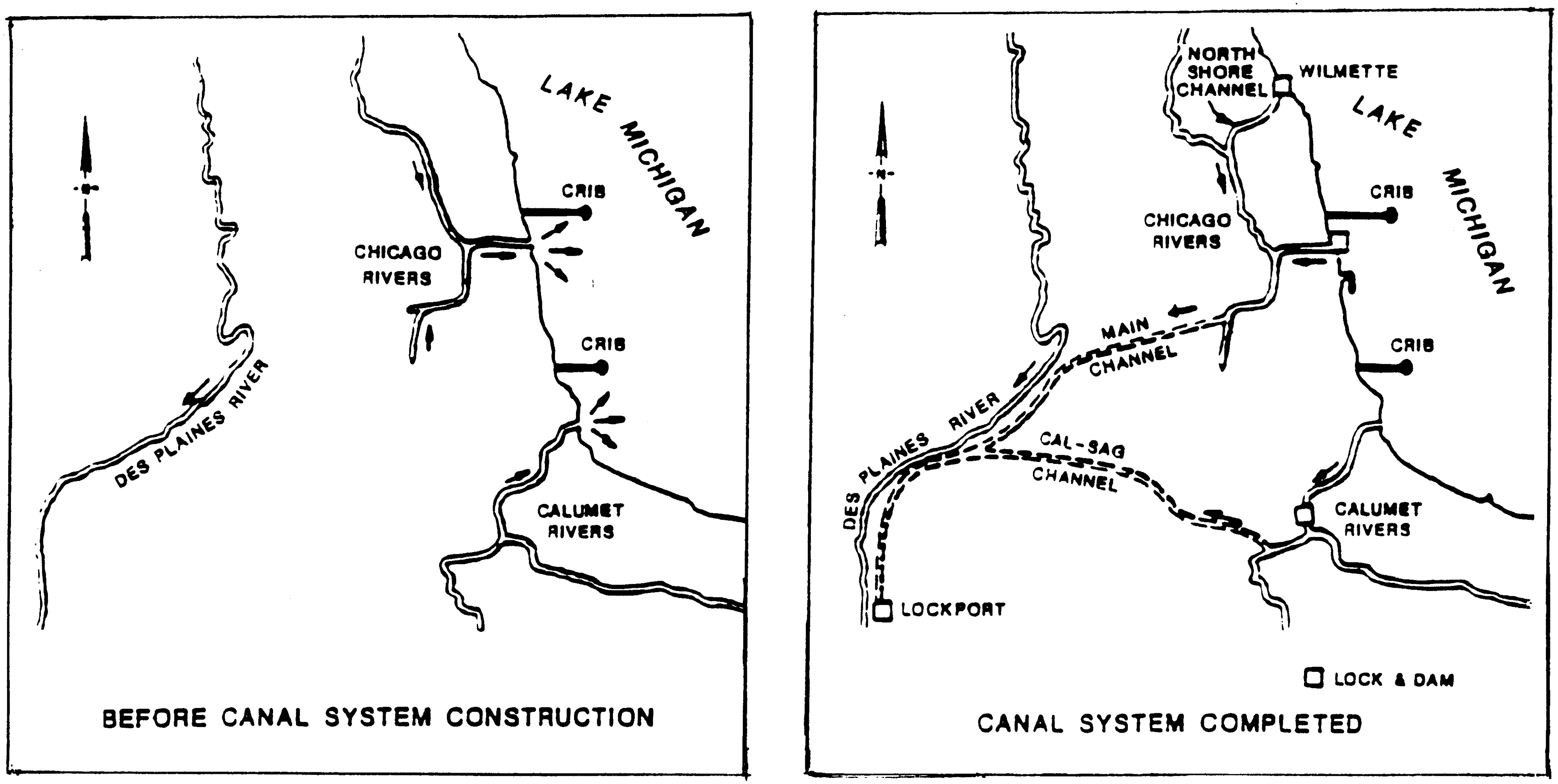
As a solution to the sanitation and flooding problems construction of the Chicago Sanitary and Ship Canal (CSSC) was undertaken. This construction allowed the flow direction of the Chicago River to be reversed (Figure 1). Construction of the Chicago Sanitary and Ship Canal was completed in 1900 by the Metropolitan Water Reclamation District of Greater Chicago (MWRDGC) (formerly Metropolitan Sanitary District of Greater Chicago, MSDGC). The Sanitary and Ship Canal followed the course of the older I and M Canal. This canal is much larger than the I and M canal and can handle the Chicago River flow as well as increased shipping. The Chicago River Controlling Works was constructed at the mouth of the Chicago River. The lock regulates the amount of Lake Michigan water allowed to pass into the river and restricts river flooding from entering Lake Michigan.

Between 1907 and 1910 the MWRDGC constructed a second sanitary canal called the North Shore Canal. It extended from Lake Michigan at Wilmette in a southerly direction 6.14 miles to the north branch of the Chicago River. The Wilmette Controlling Works regulates the amount of Lake Michigan flow allowed down the channel.

Construction of a third canal, the Calumet Sag Canal, was completed in 1922. The canal connects Lake Michigan through the Grand Calumet River, to the Sanitary and Ship Canal. This canal was constructed to carry sewage from South Chicago, Illinois and East Chicago, Indiana. The O'Brien Lock and Dam located on the Calumet River, regulates the flow of Lake Michigan waters down the canal.

Figure 1

Development of the Chicago Canal System



BACKGROUND OF LAKE MICHIGAN DIVERSION ACCOUNTING

The Lake Michigan diversion accountable to Illinois is limited to 3,200 cfs over a forty year averaging period. During the forty year period, the average diversion in any annual accounting period may not exceed 3,680 cfs except in any two accounting periods in which the average diversion may not exceed 3,840 cfs as a result of extreme hydrologic conditions. During the first 39 year period, the maximum allowable cumulative difference between the calculated diversion and 3,200 cfs is 2,000 cfs-years. These limits apply to the period beginning with WY81.

Prior to the 1983 accounting report, diversion accounting was done by the MWRDGC in the form of monthly hydraulic reports. As required by Supreme Court Decree, the diversion was calculated by deducting non-diversion flows from the Lockport record measured by MWRDGC and adding those diversion flows not discharging to the Chicago Sanitary and Ship canal. All of the deductible flows could not be measured, therefore MWRDGC used flow records from gaged areas to get typical flow values and then extrapolated to arrive at the total deduction.

The State of Illinois contracted with NIPC, to revise the diversion accounting calculations. At the same time, the State of Illinois moved from monthly hydraulic reports to annual accounting reports. NIPC adapted computer models of the diverted Lake Michigan and the Des Plaines River watersheds, previously developed for studies in Northeastern Illinois under Section 208 of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500), to calculate those flows that could not be measured. Like MWRDGC, NIPC deducted non-diversion flows from the Lockport record and added those flows not discharged to the canal to calculate the Lake Michigan diversion. However, NIPC modeled both the gaged and ungaged areas to calculate much of the deduction and addition flows. Then computational budgets were developed around each of the gaged areas to verify the models. The budgets aid in identifying problem areas in the procedure. The procedure developed by NIPC is a significant improvement over the previous approach because of the more rigorous approach and because of the verification provided by the budgets.

As required by Supreme Court Decree, a three member technical committee is convened every five years to evaluate the diversion accounting program to ensure that the accounting is accomplished using the best current engineering practice and scientific knowledge.

The first technical committee was convened during the period when diversion accounting was done by MWRDGC. The committee was primarily concerned with the rating of the various components at the Lockport facility, the primary diversion measurement location (Espey et al, 1981). In response to the Committee's concerns, the Corps' Waterways Experiment Station (WES) revised the ratings of the two sets of Lockport sluice gates (Hart and McGee, 1985).

In response to the Committee's concerns, the State of Illinois installed an acoustic velocity meter (AVM) at Romeoville five miles upstream of Lockport. The AVM is a highly accurate flow meter that proved to provide better flow measurements than the MWRDGC reported Lockport flows and the new Corps rating curves. The AVM became operational 12 June 1984. However, USGS did not publish the AVM flows until 1 October 1985. Because of significant equipment problems with the AVM, a replacement AVM was installed in November 1988.

To provide flows during periods of malfunction, various regression analyses were done to relate the MWRDGC reported Lockport flows to the AVM flows. Several sets of equations were proposed by the Corps of Engineers, the USGS, Harza Engineering Co., and the Second Technical Committee. The report, Chicago Sanitary and Ship Canal at Romeoville Acoustical Velocity Meter Backup System, was completed September 1989 (USACE, 1989). That report documents the many efforts taken by various parties to develop useful regression equations. The regression equations that were ultimately used to estimate missing AVM flows from WY86 through WY91 were developed by the USGS in a report titled "Comparison, Analysis, and Estimation of Discharge Data from the Two Acoustic Velocity Meters on the Chicago Sanitary and Ship Canal at Romeoville, Illinois." This report is contained in the Lake Michigan Diversion Accounting WY93 Annual Report.

The second technical committee reviewed the NIPC hydrologic and hydraulic computer models and agreed that the approach was consistent with what was required by the decree (Espey et al, 1987). However, the committee felt that some of the parameters used in the models were out of date and in need of revision. To address the committee's concerns, the Corps hired a consultant (C. B. Burke Engineering, Ltd.) in September of 1988 to review and update the modeling parameters. The final report (Burke, 1990) concerning the updating of modeling parameters was submitted to the Corps in October 1990.

The Water Resources Development Act of 1986 gave the Corps of Engineers the full responsibility for computation of the Illinois Lake Michigan diversion as of 1 October 1987. When the Corps' new responsibility became effective, the WY84 diversion accounting report, developed by NIPC, had not been certified. As a result, the Corps was responsible for the WY84 and all subsequent reports.

NIPC completed the WY84 diversion accounting report in April of 1987. It was subsequently reviewed by the Corps. The Corps found the report to be adequate with two exceptions. First, the 1984 accounting was completed with the modeling parameters questioned by the second technical committee. Second, MWRDGC reported Lockport flows, adjusted using the WES rating curves, were used rather than AVM flows. The Corps, knowing that the modeling parameters required updating and that AVM flows for the period prior to installation could be calculated accurately using regression equations, refrained from certifying the WY84 report until these issues were resolved.

NIPC completed the WY85 diversion accounting report in December of 1988 and the report was reviewed by the Corps. Like the WY84 report, the WY85 accounting was done with the modeling parameters questioned by the second technical committee. Additionally, NIPC used the AVM flows published by the U.S. Geological Survey (USGS) in their WY85 Water Resources Data for Illinois report. Since the publication of the WY85 USGS report, more reliable equations have been developed for calculating flows when the AVM was malfunctioning. These equations are periodically reviewed and updated as necessary.

Upon completion of the analysis of the modeling parameters by Christopher B. Burke Engineering, LTD, the WY84 and WY85 diversion flows were recalculated using the revised modeling parameters and the Romeoville AVM flows. The diversion flows were certified by the Corps of Engineers and transmitted to all interested parties in the Lake Michigan Diversion Accounting 1989 Annual Report (USACE, 1990).

The computation of Illinois' diversion from Lake Michigan for WY86 was undertaken as a joint effort between NIPC (under contract to the Corps of Engineers) and the Corps of Engineers. The computation of Illinois' diversion from Lake Michigan for WY87 through WY90 was performed solely by the Corps of Engineers. The WY86 through WY89 Diversion Accounting Reports are contained in the Lake Michigan Diversion Accounting Annual Report covering WY90 through WY92 (USACE, 1994).

DIVERSION ACCOUNTING PROCEDURES

The Lake Michigan diversion accountable to the State of Illinois is calculated by measuring the flow in the Chicago Sanitary and Ship Canal at Romeoville and deducting flows that do not constitute Lake Michigan diversion and are not accountable to the State of Illinois. Finally, additions are made to the Romeoville record for diversions that are not discharged to the canal. The deductions include groundwater water supply pumpage whose effluent is discharged to the canal, runoff from the Des

Plaines River watershed that is discharged to the canal, Lake Michigan water supply pumpage from Indiana that is discharged to the canal, and water supply pumpage from Lake Michigan used for Federal facilities that is discharged to the canal. The additions to the Romeoville record include flows diverted from the canal upstream of Romeoville, and Lake Michigan water supply whose effluent is not discharged to the canal. This procedure represents the accounting method required by the Supreme Court Decree.

The diversion accounting results are presented as a series of columns that are listed in Table 1. Column 1 through Column 3 compute the total flow in the Sanitary and Ship Canal. Column 4 through Column 7 presents the deductions from the canal system flows with the total deduction being presented in Column 8. Column 9 presents the additions to the canal system record. Column 10 is the computed Lake Michigan diversion accountable to Illinois and is equal to the canal system flow minus the deductions plus the additions. Columns 11 through 13 are independent flow estimates for the three sources of diversion: water supply pumpage from Lake Michigan, runoff from the diverted Lake Michigan Watershed, and direct diversion through the lakefront structures. Column 11 through Column 13 are not used in the diversion calculation but are included as another estimate of the diversion for verification of the accounting flows in Column 10. The sum of Column 11 through Column 13 should theoretically equal the flow in Column 10.

In addition to the diversion calculations presented in the 13 columns, 14 computational budgets are prepared as input to the diversion calculation and to verify the estimated flows that cannot be measured. A summary of these budgets is presented in Table 2. Budgets 1 and 2 do not compare simulated to measured flows but are summations of critical water supply pumpage data. Budget 3 through Budget 6 partition stream gage records into runoff and sanitary/industrial discharge components to estimate a portion of the runoff from the diverted watershed that is used as input to Column 12, "Runoff from the Diverted Lake Michigan Watershed." Budget 7 through Budget 13 compare simulated to measured flows at MWRDGC facilities. These budgets are for verification of the diversion accounting procedures and give an indication of the accuracy of the diversion accounting models. Budget 14 compares canal system inflows and outflows. It is used primarily as a verification of modeling results as well as an indicator of the accuracy and completeness of measured/reported flows.

Table 1

Description of the Diversion Accounting Columns

Column No.	Description
1	Chicago Sanitary and Ship Canal (CSSC) at Romeoville AVM Gage Record
2	Diversion from the CSSC above the Romeoville AVM Gage
3	Total Flow Through the CSSC
4	Groundwater Pumpage Discharged into the CSSC and Adjoining Channels
5	Water Supply Pumpage from Indiana Reaching the CSSC
6	Runoff from the Des Plaines River Watershed which Reaches the CSSC
7	Lake Michigan Pumpage by Federal Facilities which Discharge to the CSSC and Adjoining Channels
8	Total Deduction from the CSSC Romeoville AVM Gage Record
9	Lake Michigan Pumpage Which is not Discharged into the CSSC
10	Total Diversion Accountable to the State of Illinois
11	Pumpage from Lake Michigan Which is Accountable to State of Illinois
12	Runoff from the Diverted Lake Michigan Watershed
13	Direct Diversions Through Lake Front Control Structures Which is Accountable to the State of Illinois

Table 2

Description of the Diversion Accounting Computational Budgets

Budget No.	Title	Description
1	Diverted Lake Michigan Pumpage	This budget sums Lake Michigan water diverted by the State of Illinois in the form of municipal and industrial water supply. The results of this budget are used in Column 11.
2	Groundwater Discharged to the CSSC	This budget sums groundwater pumpages that are discharged to the CSSC. The results of this budget are used in Column 4.
3	North Branch Chicago River at Niles, IL	This budget performs a simple separation of stream flow into sanitary and runoff portions. The results this budget are used in Budget 14 and Column 12.
4	Little Calumet River at the IL-IN State Line	This budget performs a simple separation of stream flow into sanitary and runoff portions. The results this budget are used in Budget 14 and Column 12.
5	Thorn Creek at Thornton, IL	This budget performs a simple separation of stream flow into sanitary and runoff portions. The results this budget are used in Budget 14 and Column 12.
6	Little Calumet River at South Holland, IL	This budget performs a simple separation of stream flow into sanitary and runoff portions. The results this budget are used in Budget 14 and Column 12.
7	MWRDGC Northside Water Reclamation	This budget performs hydrologic and hydraulic simulation of the service basin tributary to the MWRDGC Northside Water Reclamation Facility. The simulations estimates the runoff from portions of the Lake Michigan and Des Plaines River watersheds within the Northside service basin that is diverted to the CSSC in the form of inflow-infiltration. The budget provides an internal verification of the accounting procedures. The results of this budget are used on Budget 14 and Columns 6 and 12.

Table 2 (cont)

Description of the Diversion Accounting Computational Budgets

Budget No.	Title	Description
8	MWRDGC Upper Des Plaines Pumping Station	This budget performs hydrologic and hydraulic simulation of the MWRDGC Upper Des Plaines Pumping Station. This budget provides a calibration point to verify models of the Des Plaines River watershed
9	MWRDGC Mainstream TARP Pumping Station	This budget performs hydrologic and hydraulic simulation of the MWRDGC Mainstream TARP Pumping Station. The results of this simulation are used in Budgets 10 and 14 and Columns 6 and 12. The budget also provides internal verification of the accounting procedures.
10	MWRDGC Stickney Water Reclamation Facility	This budget performs hydrologic and hydraulic simulation of the service basin tributary to the MWRDGC Stickney Water Reclamation Facility. The simulations estimates the runoff from portions of the Lake Michigan and Des Plaines River watersheds within the Stickney service basin that is diverted to the CSSC in the form of inflow-infiltration. The budget provides an internal verification of the accounting procedures. The results of this budget are used in Budget 14 and Columns 6 and 12.
11	MWRDGC Calumet TARP Pumping Station	This budget performs hydrologic and hydraulic simulation of the MWRDGC Calumet TARP Pumping Station. The results of this simulation are used in Budgets 12 and 14 and Columns 6 and 12. The budget also provides internal verification of the accounting procedures.

Table 2 (cont)

Description of the Diversion Accounting Computational Budgets

Budget No.	Title	Description
12	MWRDGC Calumet Water Reclamation Facility	This budget performs hydrologic and hydraulic simulation of the service basin tributary to the MWRDGC Calumet Water Reclamation Facility. The simulations estimates the runoff from portions of the Lake Michigan and Des Plaines River watersheds within the Calumet service basin that is diverted to the CSSC in the form of inflow-infiltration. The budget provides an internal verification of the accounting procedures. The results of this budget are used in Budget 14 and Columns 6 and 12.
13	MWRDGC Lemont Water Reclamation Facility	This budget performs hydrologic and hydraulic simulation of the service basin tributary to the MWRDGC Lemont Water Reclamation Facility. The simulations estimates the runoff from portions of the Des Plaines River watershed within the Lemont service basin that is diverted to the CSSC in the form of inflow-infiltration. The budget provides an internal verification of the accounting procedures. The results of this budget are used in Budget 14 and Column 6.
14	Chicago Canal System	This budget performs a water balance of the Chicago Canal System which includes the CSSC and adjoining channels. This budget provides a verification point for the accounting procedures.

REVISIONS TO THE LAKE MICHIGAN DIVERSION ACCOUNTING PROCEDURES

The primary revision implemented for the WY90 diversion accounting was the incorporation of the new 25-gage precipitation network into the runoff simulation models. The 25-gage precipitation network replaces the previous 13-gage network. The new precipitation network has solved many of the problems associated with the old network, such as poor exposure and distribution patterns. The Illinois State Water Survey, ISWS, installed and maintains the precipitation network for the Corps of Engineers. They also collect the data and adjust it if necessary. A description of the new 25-gage precipitation network can be found in the ISWS report titled "Installation and Operation of a Dense Raingage Network to Improve Precipitation Measurements for Lake Michigan Diversion Accounting: Water Year 1990" (ISWS, 1991). That report is contained in the Lake Michigan Diversion Accounting WY93 Annual Report.

In addition to the installation and use of the new 25-gage precipitation network was the subsequent modifications to the hydrologic runoff models and hydraulic sewer routing models. These models were revised in order to reflect the changes in the precipitation network. Many of the model changes were accomplished by Rust Environment and Infrastructure under contact with the Corps of Engineers. Their work culminated in a report titled "Diversion Accounting Update for the New 25-Gage Precipitation Network" (Rust,1993). That report is also contained in the Lake Michigan Diversion Accounting WY93 Annual Report.

Rust's work involved review and correction of map delineations of combined sewer special contributing areas, delineation of precipitation gage assigned areas for the 25-gage network, land-use/land-cover delineations, modifications to the hydraulic sewer routing model to reflect the revised precipitation network and land cover assignments, and an assessment of the model parameters used in the hydrologic runoff model, Hydrologic Simulation Program - Fortran (HSPF).

The Corps of Engineers modified the hydraulic sewer model, Special Contributing Area Loading Program (SCALP), in separate sewer areas in order to incorporate changes in the precipitation network. Since actual boundaries have not been mapped for those areas some assumptions as to the location of the separate sewer areas were made. This was necessary since effective areas have been applied for the separate sewer areas in the SCALP model. These assumptions will continue until a further study can be accomplished that will reflect actual boundaries for these separately sewered areas.

A study was also done by the Corps to improve the response of the HSPF hydrologic runoff models. Input on parameter improvements were received from NIPC and Rust. The study resulted in some minor parameter modifications to the HSPF runoff model to correct for past inconsistencies and improve parameter accuracy.

It will be shown later in the report that the effect of the new 25-gage precipitation network, improvements and updates in the land cover delineations, and modifications to the hydrologic and hydraulic models has resulted in improved water balances at the primary calibration points, the four MWRDGC water reclamation plants as well as the Upper Des Plaines pumping station.

ACCOUNTING RESULTS

The WY90 diversion accounting monthly summary is presented in Table 4. Table 4 shows the total WY90 Lake Michigan diversion accountable to the State of Illinois is 3,531.2 cfs (Column 10). This is 331.2 cfs greater than the 3,200 cfs average specified by the Decree. The 40 year running average (Table 3), rounded to the nearest cfs, beginning with WY81 is 3,452 cfs and the cumulative deviation from the 3,200 cfs average is -2,520 cfs-years. The negative cumulative deviation indicates a water allocation deficit. The maximum allowable deficit is 2,000 cfs-years. Tabular data on daily diversion flows is presented in Appendix A.

Table 3

Status of the State of Illinois' Diversion from Lake Michigan Under the 1980 Modified U.S. Supreme Court Decree

Accounting Year	Certified Flow, cfs	Running Average, cfs	Cumulative Deviation, cfs
1981	3,106	3,106	+ 94
1982	3,087	3,097	+ 207
1983	3,613	3,269	- 206
1984	3,432	3,309	- 438
1985	3,472	3,342	- 710
1986	3,751	3,410	- 1,261
1987	3,774	3,462	- 1,835
1988	3,376	3,451	- 2,011
1989	3,378	3,443	- 2,189
1990	3,531	3,452	- 2,520

Table 4

Lake Michigan Diversion Accounting – WY 1990

Summary of Diversion Flows (cfs)

LAKE MICHIGAN DIVERSION ACCOUNTING WY 1990	ROMEOVILLE GAGE RECORD	DIVERSIONS ABOVE THE GAGE	TOTAL FLOW THROUGH THE CANAL	GROUNDWATER PUMPAGE DISCHARGED INTO THE CANAL	WATER SUPPLY PUMPAGE FROM INDIANA REACHING THE CANAL	RUNOFF FROM THE DES PLAINES RIVER WATERSHED REACHING THE CANAL	LAKE MICHIGAN PUMPAGE BY FEDERAL FACILITIES DISCHARGED TO THE CANAL	TOTAL DEDUCTION FROM THE ROMEOVILLE GAGE RECORD	LAKE MICHIGAN PUMPAGE NOT DISCHARGED TO THE CANAL	TOTAL DIVERSION ACCOUNTABLE TO THE STATE OF ILLINOIS	PUMPAGE FROM LAKE MICHIGAN ACCOUNTABLE TO THE STATE OF ILLINOIS	RUNOFF FROM THE DIVERTED LAKE MICHIGAN WATERSHED	DIRECT DIVERSION ACCOUNTABLE TO THE STATE OF ILLINOIS
MONTH	1	2	3	4	5	6	7	8	9	10	11	12	13
OCT 89	2856.5	0.5	2857.0	85.4	27.9	72.0	1.9	187.2	103.4	2773.2	1742.2	305.7	462.0
NOV 89	2654.6	0.6	2655.2	90.3	27.4	98.3	2.0	218.0	97.0	2534.3	1666.2	481.4	65.5
DEC 89	2231.2	0.6	2231.8	76.0	27.6	28.7	1.8	134.1	99.9	2197.6	1687.9	135.5	48.8
JAN 90	2883.4	0.7	2884.0	111.4	27.3	183.0	2.1	323.8	95.9	2656.2	1689.2	829.2	51.6
FEB 90	3254.2	0.7	3254.8	121.8	27.7	284.2	1.7	435.4	97.5	2916.9	1644.7	1241.8	44.5
MAR 90	3966.8	0.7	3967.5	112.4	27.5	302.9	1.8	444.5	97.9	3620.9	1636.3	1404.8	57.7
APR 90	2933.2	0.6	2933.9	88.7	27.6	141.3	1.7	259.3	97.3	2771.9	1661.6	626.9	87.7
MAY 90	5491.1	0.7	5491.7	116.8	28.2	371.4	2.0	518.3	106.0	5079.4	1686.6	2013.5	252.9
JUN 90	3882.3	1.1	3883.4	107.6	28.6	191.5	2.2	329.9	114.6	3668.1	1867.8	676.1	650.5
JUL 90	4657.7	1.2	4658.9	99.5	28.7	301.5	1.9	431.6	121.6	4348.9	1964.7	818.7	894.6
AUG 90	5224.7	1.0	5225.7	129.0	28.7	223.2	2.5	383.4	126.4	4968.7	1901.7	1526.9	943.7
SEP 90	4736.8	0.9	4737.7	86.5	28.2	75.6	2.1	192.4	110.9	4656.2	1906.6	300.0	1790.2
AVERAGES	3748.5	0.8	3749.3	102.3	27.9	191.6	2.0	323.8	105.7	3531.2	1754.7	872.9	449.6

COMPUTATIONS:

1. COLUMN 3 EQUALS THE SUM OF COLUMN 1 AND COLUMN 2.
2. COLUMN 8 EQUALS THE SUM OF COLUMN 4 THROUGH COLUMN 7.
3. COLUMN 10 EQUALS COLUMN 3 MINUS COLUMN 8 PLUS COLUMN 9.

(light shading) DEDUCTIONS FROM THE ROMEOVILLE GAGE RECORD

(dark shading) ADDITIONS TO THE ROMEOVILLE GAGE RECORD

NOTES:

1. ALL VALUES ARE ROUNDED TO THE NEAREST TENTH.
2. MATHEMATICAL COMPUTATIONS BETWEEN COLUMNS UTILIZE UNROUNDED VALUES.
3. AVERAGE VALUES FOR WY90 WERE COMPUTED USING DAILY VALUES.

DISCUSSIONS OF RESULTS

The following is a discussion of the column functions and computational budgets. The discussion of the column functions describes the purpose of each column as well as some observations on the WY90 values in the columns. The discussion of the computational budgets presents the purpose of each budget and the results of the budget flow balances. The results of the computational budgets are used in the diversion calculations where seven budgets are used to verify the diversion simulation models. The columns are discussed first followed by the discussion of the budgets.

COLUMNS

The first ten columns display the components of the diversion calculation and include the Romeoville flow as well as the various deductions and additions to the Romeoville record. The final three columns display the three diversion components (Lake Michigan pumpage accountable to Illinois, runoff from the diverted watershed, and direct diversion through the lakefront control structures) and the sum of the three columns should theoretically equal the Romeoville based diversion calculation. A comparison of the sum of these three columns to the calculated diversion (Column 10) is presented in the discussion of Column 11 through Column 13.

COLUMN 1: CHICAGO SANITARY AND SHIP CANAL (CSSC) AT ROMEOVILLE, USGS AVM GAGE RECORD

The discharge at Romeoville for WY90 is 3,748.5 cfs. For days when the AVM was inoperable, the flow at the Romeoville site was calculated from regression equations.

COLUMN 2: DIVERSIONS FROM THE CSSC ABOVE THE GAGE

Argonne Laboratories and Uno-ven Corporation were the only diversions from the Chicago Sanitary and Ship Canal upstream of the Romeoville gage in WY90. The average withdrawal upstream of the AVM for WY90 is 0.8 cfs.

COLUMN 3: TOTAL FLOW THROUGH THE CSSC

Column 3 is the sum of Column 1 and Column 2 and represents the total flow entering the canal system. The average canal flow is 3,749.3 cfs for WY90.

COLUMN 4: GROUNDWATER DISCHARGED TO THE CSSC AND ADJOINING CHANNELS

Column 4 is groundwater water supply pumpage by communities, industrial users, and other private users as reported by the Illinois State Water Survey (ISWS) whose effluent is discharged to the CSSC. It also includes the groundwater seepage into the TARP system that is discharged to the canal. This quantity is determined by summing all reported groundwater pumpages tributary to the canal along with the estimated groundwater seepage into the Mainstream TARP (Budget 9) and Calumet TARP (Budget 11) systems. This total is then adjusted by subtracting the groundwater normally tributary to the canal that is contained in the combined sewer overflows that discharge to the Des Plaines River and other watercourses not tributary to the CSSC. This method prevents double accounting of the combined sewer overflow portion of the groundwater supply pumpage.

Using ISWS groundwater records, groundwater pumpages were assumed to reach the CSSC and adjoining channels if they were located in the diverted Lake Michigan watershed in Illinois or if they were located within MWRDGC Water Reclamation Plant (WRP) service boundaries in which their effluent was discharged into the CSSC and adjoining channels. Groundwater seepage into the Mainstream TARP and Calumet TARP systems was determined through simulation and is discussed in Budgets 9 and 11. The groundwater constituent of combined sewer overflows is determined entirely thorough simulation.

Groundwater pumpage from the Lake Michigan watershed whose effluent is discharged to the canal is a deduction except to the extent that the groundwater sources are recharged by Lake Michigan. Current piezometric levels indicate that groundwater is discharging to the lake. Therefore, groundwater pumpage from within the Lake Michigan Watershed that reaches the canal continues to be a deduction. Research literature will be reviewed periodically to verify this assumption.

Column 4 represents a deduction from the Romeoville record and averaged 102.3 cfs for WY90. This is an increase of 20.3 cfs from WY89. Groundwater pumpage tributary to the canal is composed of 18.9 cfs of groundwater pumpage from the Lake Michigan watershed, 25.0 cfs of groundwater pumpage from outside of the Lake Michigan watershed, 52.0 cfs of groundwater seepage into the Mainstream TARP system, and 6.6 cfs of groundwater seepage into the Calumet TARP system. The total of these components is 102.5 cfs. However, the deduction from the Romeoville gage record is 102.3 cfs since 0.2 cfs of this groundwater supply pumpage was determined, through simulation, to be discharged to the Des Plaines River and other watercourses not tributary to the CSSC in the form of combined sewer overflows.

COLUMN 5: WATER SUPPLY PUMPAGE FROM INDIANA REACHING THE CHICAGO SANITARY AND SHIP CANAL

Column 5 represents the computation of Indiana water supply reaching the canal through the Grand Calumet and the Little Calumet Rivers. In the case of the Little Calumet River, a drainage divide exists east of the confluence with Hart Ditch. Therefore, flows from Hart Ditch, including virtually all dry weather flows, normally flow westward into Illinois. Under high flow conditions, the drainage divide may shift westward and a portion of the Hart Ditch flows may be diverted eastward to Burns Ditch and ultimately to Lake Michigan. However, it is believed that the occurrence in the shift in the drainage divide is infrequent and the flow that is diverted eastward is insignificant. Therefore, it is assumed that all effluent discharged into Hart Ditch and the Little Calumet River west of the divide flow westward. For WY90, total flow in the Little Calumet River was 77.3 cfs, with 4.9 cfs of that flow being determined to be Indiana water supply.

The Grand Calumet River has a summit. On one side of the summit, the flow is toward Lake Michigan. On the other side of the side of the summit, the flow is toward the Calumet Sag Channel which flows into the CSSC. However, the location of the summit is variable and highly influenced by Lake Michigan levels (USGS, 1984). Thus the calculation of this deduction from the Romeoville record is influenced by Lake Michigan levels. In the absence of a stream gaging station on the Grand Calumet River to measure westward flow into Illinois, flow is computed based on a statistical relationship of which the principal variable is lake levels. Beginning with the WY91 accounting, Grand Calumet River flow will be measured by a gage that was installed in 1990 that began officially measuring flows on 1 October 1990.

Flow in the Grand Calumet River is estimated to be in excess of 90% sanitary effluent. Therefore, it is assumed that the portion of this flow that is attributable to domestic water supply is equal to the sum of the daily water supply pumpage for East Chicago, Whiting, and Hammond (whose pumpage includes water supply for Munster, Highland, and Griffith). If the total water supply pumpage for these communities is greater than the flow in the Grand Calumet River, it is assumed that the flow consists entirely of effluent that originates from water supply.

The total Grand Calumet flow reaching Illinois in WY90 was computed as 23.0 cfs. It was determined that all of the 23.0 cfs was water supply pumpage. Therefore, the total WY90 Indiana water supply deduction, including the flow from the Little Calumet and Grand Calumet Rivers is 27.9 cfs. This is virtually the same as the Indiana water supply deduction for WY89 which was 27.8 cfs.

COLUMN 6: RUNOFF FROM THE DES PLAINES RIVER WATERSHED REACHING THE CHICAGO SANITARY AND SHIP CANAL

The WY90 average discharge of Des Plaines River watershed runoff reaching the canal (Column 6) is 191.6 cfs. This deduction is determined almost entirely through simulation. The runoff is composed of two elements, surface runoff and subsurface runoff. Surface runoff that enters sewers is referred to as inflow while subsurface runoff is referred to as infiltration. The infiltration and inflow discharged to the water reclamation plants is 97.1 cfs, the infiltration and inflow reaching the canal through combined sewer overflows is 23.8 cfs, and the runoff from the Lower Des Plaines and Summit Conduit areas is 70.7 cfs. The deduction is also influenced by the O'Hare basin flow transfer that contributed 10.9 cfs of the 97.1 cfs runoff to the water reclamation facilities during WY90. The deductible Des Plaines River watershed runoff increased 56.7 cfs from WY89 to WY90 as a result of increased antecedent soil moisture conditions, slightly greater precipitation over the Des Plaines Watershed, and changes in storm characteristics during WY90. Increased runoff may also be partially due to the improvements in the rain gage network as well as the subsequent changes to the hydrologic and hydraulic models.

COLUMN 7: LAKE MICHIGAN PUMPAGE BY FEDERAL FACILITIES WHICH DISCHARGE TO THE CSSC

Column 7 represents Lake Michigan diversions for Federal use, not chargeable to the State of Illinois, and is typically comprised of water supply pumpage used by federal facilities. Also included is emergency navigation makeup water used for federal purposes. Column 7 represents a deduction from the Romeoville record and the total amount of the WY90 deduction is 2.0 cfs.

COLUMN 8: TOTAL DEDUCTIONS FROM THE CSSC ROMEOVILLE GAGE RECORD

Column 8 is the sum of Columns 4, 5, 6, and 7 and represents the total deduction from the Romeoville record. The total deduction for WY90 is 323.8 cfs.

COLUMN 9: LAKE MICHIGAN PUMPAGE NOT DISCHARGED TO THE CANAL

This column represents water supply pumpage from Lake Michigan that is not discharged to the canal. The water supply pumpage not discharged to the canal is composed of two components:

(1) Lake Michigan water supply used by communities serviced by water reclamation facilities that do not discharge to the CSSC (104.2 cfs). This is a decrease of 2.8 cfs from WY89.

(2) The sanitary portion of combined sewer overflows attributable to Lake Michigan domestic water supply that does not discharge to the CSSC (1.5 cfs).

The communities that make up the flow in the first component are suburbs whose treated effluent is discharged to the Des Plaines River and other watercourses not tributary to the CSSC. These communities include Elk Grove Village, Hoffman Estates, Mount Prospect, Schaumburg, Hanover Park, Rolling Meadows, Streamwood, Arlington Heights, Buffalo Grove, Palatine, Wheeling, Lincolnshire, Riverwoods, Libertyville, Illinois Beach State Park, Winthrop Harbor, Zion, Waukegan, 76 percent of North Chicago, and 38.2 percent of Des Plaines. It should also be noted that the Lake Michigan water supply component of the O'Hare flow transfer is subtracted from the total Lake Michigan water supply of the above communities since (1) the O'Hare flow transfer is treated at the Northside WRP which discharges sanitary effluent that is tributary to the CSSC and (2) the entire Lake Michigan water supply component of the O'Hare flow transfer is from communities contained in the above list. The Lake Michigan water supply for these communities is measured while the sanitary portion of the CSO's is derived through simulation. Column 9 represents an addition to the Romeoville record and the total WY90 addition is 105.7 cfs. This is a decrease of 2.5 cfs from WY89 to WY90.

COLUMN 10: TOTAL DIVERSION

Column 10 is equivalent to Column 3 with the deduction of Column 8 and the addition of Column 9. The total diversion for WY90 is 3,531.2 cfs. This amount is 331.2 cfs greater than Illinois's long term diversion allocation of 3,200 cfs. The 40-year running average diversion, rounded to the nearest cfs, beginning with WY81, is 3,452 cfs and the cumulative deviation from the 3,200 cfs allocation is -2,520 cfs. The negative deviation indicates that the cumulative diversion is greater than an average of 3,200 cfs for the period.

COLUMN 11 THROUGH COLUMN 13: LAKE MICHIGAN DIVERSION COMPONENTS

Column 11 through Column 13 represent the three Lake Michigan diversion components: Lake Michigan pumpage accountable to Illinois (1,754.7 cfs), runoff from the diverted Lake Michigan watershed (872.9 cfs), and direct diversion through the lakefront structures (449.6 cfs) which also accounts for the 1.3 cfs backflow during WY90. The sum of the columns (3,077.2 cfs) should theoretically equal the total diversion as shown in Column 10 (3,531.2 cfs) with one exception. The Romeoville record receives effluent that is assumed to contain only 90% of the water supply pumpage while Column 11, Lake Michigan water supply pumpage accountable to Illinois, does not account for consumptive use. This is based on a consumptive loss (water supply pumpage that is consumed or lost prior to reaching the water reclamation facilities) estimate of 10% of the water supply pumpage (International Great Lake Diversion Consumptive Use Study Board, 1981).

Because the diversion estimate from Columns 11 - 13 is based on simulation, suspect ratings of the lakefront structures, and simple flow separation techniques, the estimate is not expected to be as accurate as the AVM based calculations. Consequently, a difference between estimates of 454.0 cfs or 12.9% is a fair balance. However, this discrepancy becomes even greater when consumptive use is accounted for in Column 11. The discrepancy in these two estimates is related to the canal system balance in Budget 14, discussed in a subsequent section, and potential sources of the discrepancy are addressed in that budget discussion.

Using the figures from these three columns, 57.0% of the WY90 Illinois diversion is attributable to pumpage from Lake Michigan for domestic water supply. Runoff from the diverted Lake Michigan Watershed accounted for 28.4% of the diversion, and direct diversion through the lakefront structures accounted for 14.6% of the diversion. Water supply from Lake Michigan actually dropped 37.2 cfs from WY89 to WY90. This is most likely due to the slight increase in basin wide precipitation during WY90. Additionally, a larger percentage of rain fell during the summer months when demand tends to be slightly higher. Due to increased antecedent soil moisture and slightly higher precipitation during WY90 there was a 164.1 cfs increase in runoff from the Lake Michigan watershed that occurred between WY89 and WY90. A more detailed breakdown of these percentages is shown in Table 5 and Figure 2.

Table 5

Breakdown of the Diversion by the State of Illinois Based on Columns 11 Through 13

Category	Flow	Percentage
Lake Michigan Pumpage by the State of Illinois	1,754.9 cfs	57.0 %
Runoff from the Diverted Lake Michigan Watershed	872.9 cfs	28.4 %
Direct Diversions		
Lockages	71.8 cfs	2.3 %
Leakages	28.3 cfs	0.9 %
Navigation Makeup Flow	46.1 cfs	1.5 %
Discretionary Flow	304.7 cfs	9.9 %

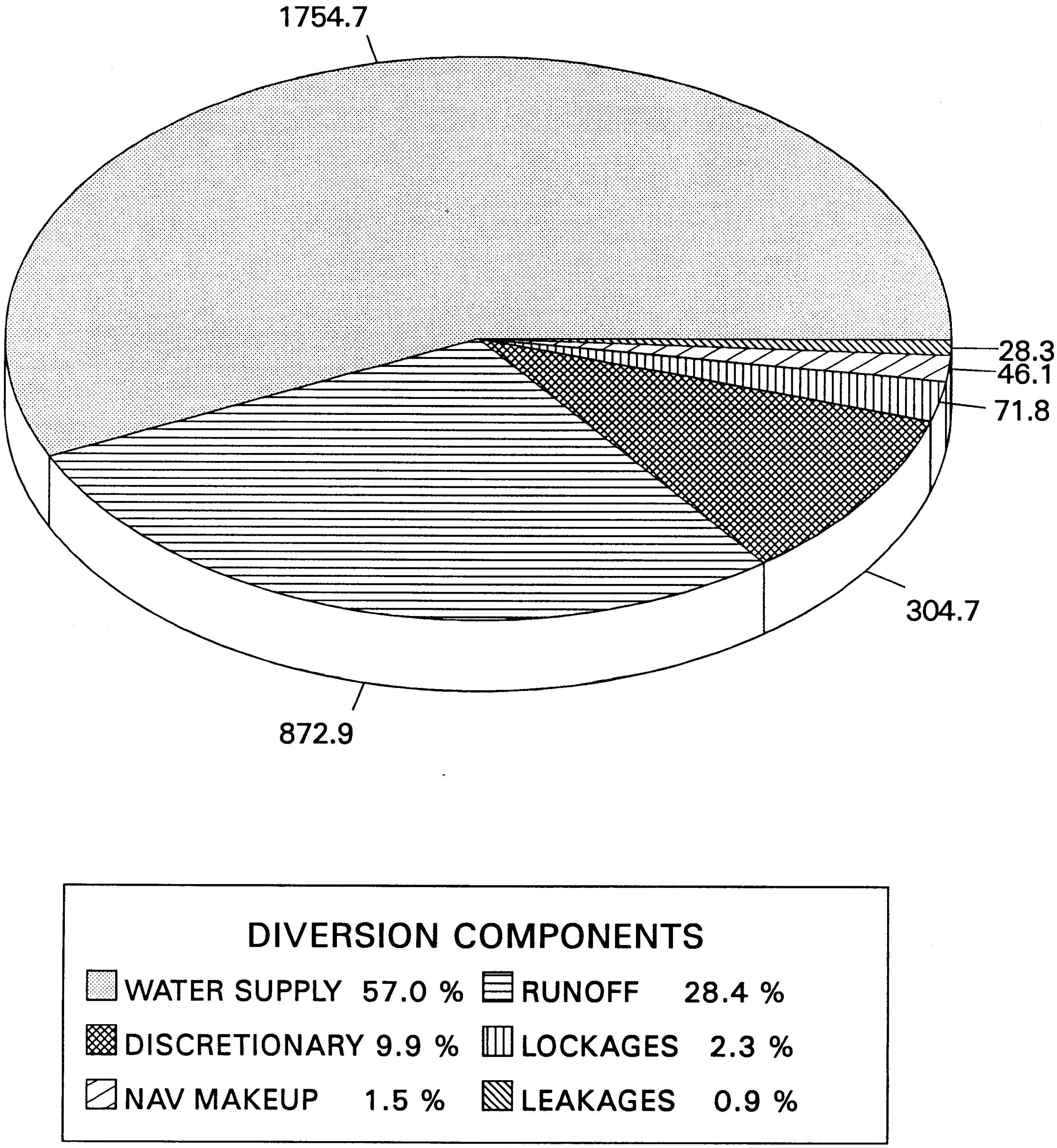
BUDGETS

The first two budgets are used to sum the water supply for the area influenced by the diversion. The following four budgets are of stream gage sites that are not simulated and are used as part of the calculation of the runoff from the diverted Lake Michigan watershed. The remaining seven budgets compare measured and simulated flows and compute Column inputs used in the diversion computations.

BUDGET 1 AND BUDGET 2: WATER SUPPLY PUMPAGE

Budgets 1 and 2 are summations of critical water supply pumpage data. Budget 1 sums Lake Michigan water supply diverted by the State of Illinois. The Lake Michigan water supply data is supplied by the state as daily values for primary users and monthly data for secondary users. Budget 2 sums groundwater pumpages in the Lake Michigan and Des Plaines River watersheds that are diverted to the Chicago Sanitary and Ship Canal. Groundwater pumpage data is recorded as a total annual withdrawal based on calendar years.

Figure 2
Component Breakdown of Illinois' Diversion
Based on Columns 11 through 13



BUDGET 1: DIVERTED LAKE MICHIGAN WATER SUPPLY

Budget 1 represents the summation of Lake Michigan pumpage accountable to the State of Illinois. For WY90, the average annual Lake Michigan pumpage accountable to Illinois is 1,754.7 cfs. This is a decrease of 37.2 cfs from WY89. As stated previously, this is most likely due to the slight increase in precipitation, especially during the summer months when demand is usually higher.

BUDGET 2: GROUNDWATER DIVERTED TO THE CHICAGO SANITARY AND SHIP CANAL

Budget 2 is groundwater water supply pumpage by communities, industrial users, and other private users, as reported by the Illinois State Water Survey (ISWS), whose effluent is discharged to the canal. This quantity is determined by summing all reported groundwater sources in the area tributary to the canal less groundwater not discharged to the canal in the form of combined sewer overflows.

Using ISWS groundwater records, groundwater pumpages were assumed to reach the CSSC and adjoining channels if they were located in the diverted Lake Michigan watershed in Illinois or if they were located within MWRDGC service boundaries in which their effluent was discharged into the CSSC and adjoining channels.

The total groundwater pumpage by communities, industrial users, and other private users whose sanitary effluent is tributary to the canal is 43.9 cfs for WY90. It was determined through simulation that 0.2 cfs of this flow never reached the canal. Instead it was discharged to the Des Plaines River or other watercourses not tributary to the canal in the form of combined sewer overflows. The total groundwater pumpage reaching the canal represents an increase of 21.0 cfs from WY89 to WY90.

In addition to groundwater supply pumpage there was also a significant amount of groundwater infiltration into the two TARP systems that ultimately reached the canal. Mainstream TARP and Calumet TARP accounted for 52.0 cfs and 6.6 cfs, respectively, of groundwater discharged to the canal during WY90. Groundwater infiltration into the Calumet TARP system was significantly less than in previous years due to changes in the simulation model during the WY89 accounting.

BUDGETS 3 THROUGH BUDGET 6: STREAM GAGING STATIONS

The stream gage budgets are used to make estimates of runoff from portions of the diverted Lake Michigan watershed. Sanitary and other point source flows are subtracted from the stream gaging record to develop the runoff estimates. The runoff estimates are used in Column 12. The flows at the stream gaging sites is also part of Budget 14, the canal system budget. Table 6 presents the estimated runoff from these budgets. It should be noted that Budgets 4 through 6 are a composite calculation of the runoff above the Little Calumet River at South Holland gage. It should also be noted that the Little Calumet River is a losing stream, i.e. it recharges groundwater. The computations in deriving runoff account for this when recharge is significant (i.e., when groundwater recharge is computed).

Table 6
Stream Gage Flow Separation

Budget	Location	Flow cfs	Sanitary cfs	Runoff cfs
3	North Branch Chicago River at Niles, IL	125.8	18.8	107.0
4	Little Calumet River at IL-IN State Line	77.3	3.9	73.4
5	Thorn Creek at Thornton, IL	118.9	16.8	102.1
6	Little Calumet River at South Holland, IL$_1$	190.2	182.0	8.2

1 Incremental Runoff

BUDGETS 7 THROUGH BUDGET 13: MWRDGC WATER RECLAMATION FACILITIES

The budgets for the water reclamation plants compare the simulated flows to the measured inflows at the MWRDGC facilities and perform verifications of the diversion accounting program. The simulated flows were developed from an estimated sanitary flow with a daily, weekly, and monthly flow variation, from hydrologic precipitation-based runoff models, and from hydraulic sewer routing models. The estimated sanitary flow input to the hydraulic simulation models is based on the population estimates for each plant's service basin. Per capita sanitary flows are determined based on the service basin's water supply minus an assumed 10 percent consumptive loss. Simulated flows were compared with recorded inflows at each facility to assess the accuracy of the simulations.

The discussion of the budgets will concentrate on the results of each simulation as the development of these models have been discussed in previous reports. A summary of the simulation results is presented in Table 7. At all four water reclamation plants and the Upper Des Plaines Pump Station the simulation results were improved. This is the result of the new 25-gage precipitation network first utilized for the WY90 diversion accounting, improvements and updates in the land cover delineations, and modifications to the hydrologic and hydraulic models .

BUDGET 7: NORTHSIDE WATER RECLAMATION FACILITY

Budget 7 analyzes the water balance at the MWRDGC Northside Water Reclamation Facility (Figure 3). The balance for WY90 of the inflow to the Northside facility is very good. The simulated to adjusted recorded inflow ratio (S/R) for the Northside WRP is 0.94, indicating that the simulated inflow volume is slightly less than the adjusted observed inflow volume. The coefficient of correlation (R) of simulated to observed flow is 0.89, indicating that the model predicted the inflow hydrograph to the Northside facility very well.

BUDGET 8: UPPER DES PLAINES PUMP STATION

Budget 8 analyzes the water balance at Upper Des Plaines Pump Station (UDPPS) (Figure 4). The pump station budget is used to verify simulated flows. Although it has no direct impact on the diversion calculation, it is intended to be used as a primary calibration point for the models that simulate the deductible runoff from the Des Plaines watershed contained in Column 6. This will be possible only after the existing measurement problems at that site are resolved. This will be discussed later in the report.

The balance at UDPPS for WY90 was reasonable. The simulated to recorded flow ratio (S/R) for the UDPPS is 1.08, indicating that the simulated inflow volume to UDPPS is greater than the recorded inflow volume. However, the daily S/R ratio shows a high degree of variability, indicating that the trends within the recorded and simulated inflow may not correspond very well. The coefficient of correlation (R) of simulated to recorded flow is 0.64, indicating the time series trends in the simulated inflow compared fairly well with the time series trends of recorded inflow. This is a significant improvement over previous years. This may be the direct result of the revised raingage network and subsequent modifications to the hydrologic and hydraulic models.

TABLE 7

WY 1990 SUMMARY OF SIMULATION STATISTICS

Budget No.->	7	8	9	10	11	12	13	14
Description	Northside WRP (1)	Upper Des Plaines Pump Station (1),(3)	Mainstream TARP Pump Station (2)	Stickney WRP (1),(4)	Calumet TARP Pump Station (2)	Calumet WRP (1),(4)	Lemont WRP (1)	Chicago Canal System Balance (1)
Mean Recorded Flow, cfs	437.3	69.2	96.4	1054.9	39.0	385.6	2.2	3269.3
Max. Recorded Flow, cfs	792.0	111.9	262.9	2038.1	129.1	593.1	8.5	17360.0
Min. Recorded Flow, cfs	333.6	20.1	19.9	608.2	2.7	263.5	1.1	1513.8
Mean Simulated Flow, cfs	411.2	74.7	101.3	1125.0	28.6	388.0	1.9	3758.3
Max. Simulated Flow, cfs	695.0	188.3	254.0	2591.7	98.7	611.9	5.4	18098.0
Min. Simulated Flow, cfs	301.6	43.6	39.5	803.6	3.0	308.9	1.2	1772.1
Mean S/R	0.94	1.08	1.05	1.07	0.73	1.00	0.86	1.15
Max. S/R	1.15	2.96	6.19	1.75	4.85	1.35	1.65	2.18
Min. S/R	0.56	0.57	0.39	0.70	0.19	0.83	0.41	0.51
Correlation	0.89	0.64	0.49	0.86	0.51	0.89	0.92	0.84

(1) Based on daily values.
(2) Based on weekly values.
(3) Does not include days with missing records.
(4) Does not include pumpage from TARP.

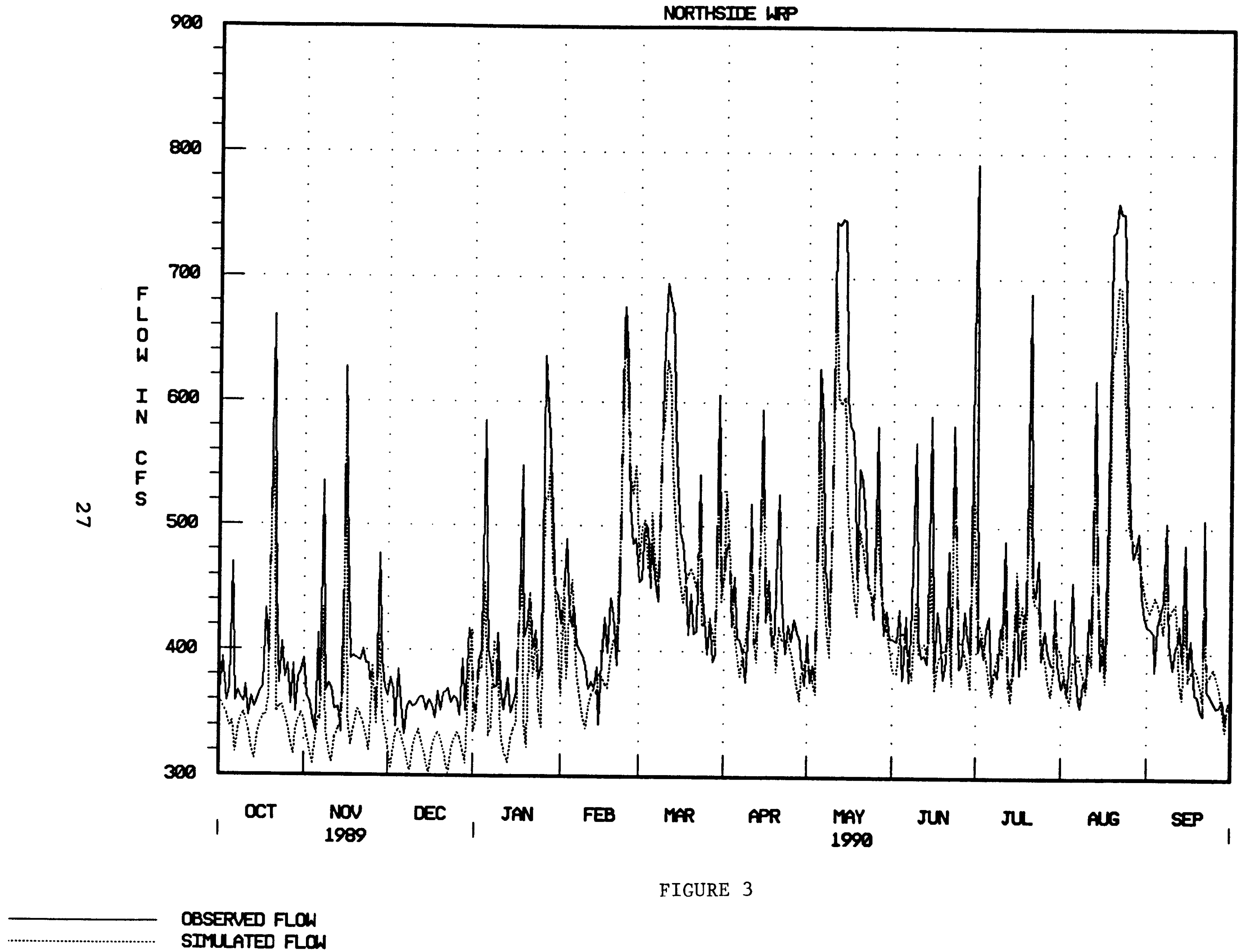


FIGURE 3

Budget 7 - Simulation of the MWRDGC Northside Water Reclamation Facility

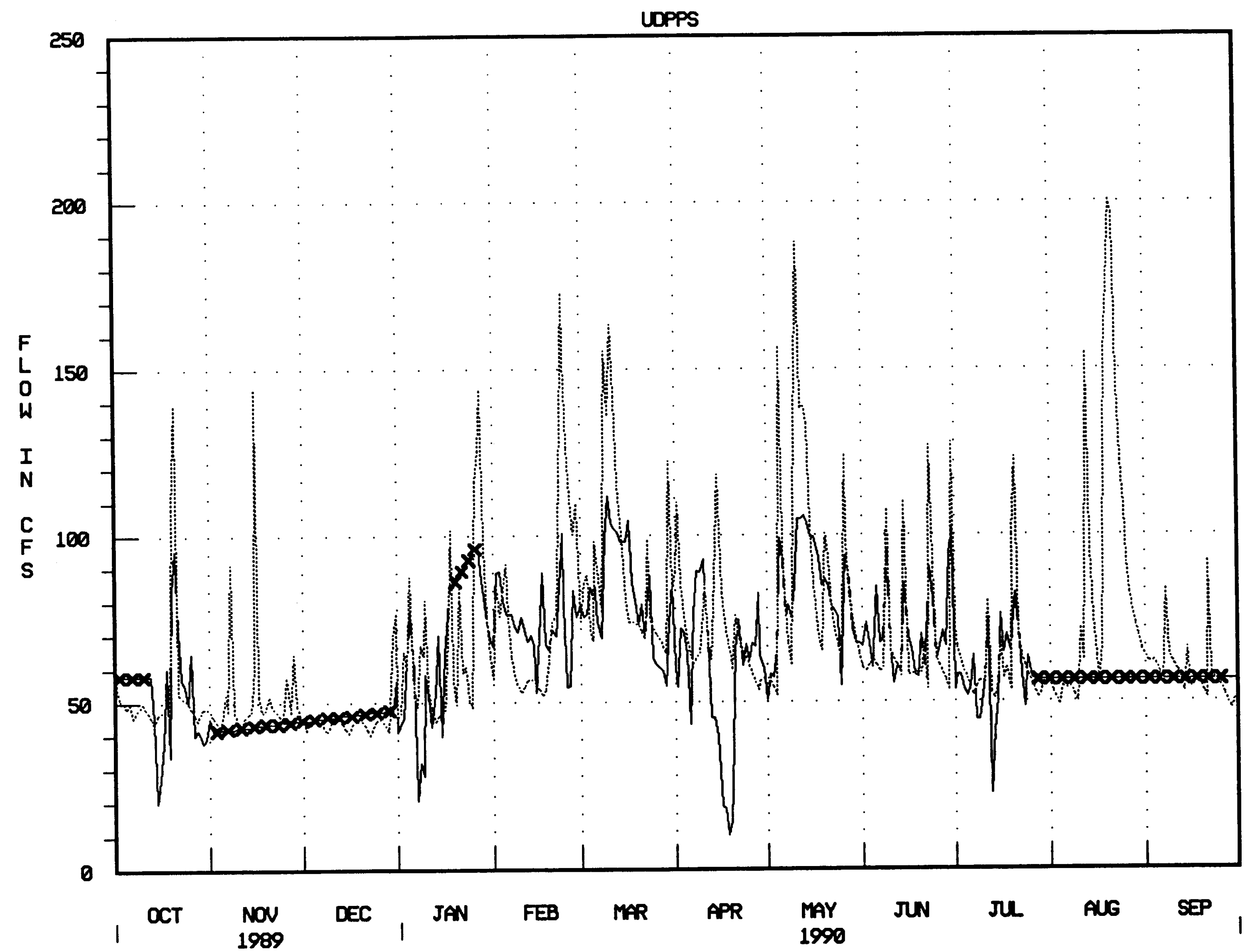


FIGURE 4

UPPER DES PLAINES PUMP STATION OBSERVED FLOW
UPPER DES PLAINES PUMP STATION SIMULATED FLOW

Budget 8 - Simulation of the MWRDGC Upper Des Plaines Pump Station

While the statistical results for WY90 at the Upper Des Plaines Pump Station have improved, this does not lead to the conclusion that flow measurement alternatives should not be investigated. This site has continued to experience its share of problems. During WY90, 145 days of records were unavailable that were attributable to meter malfunctions, problems with the recording charts which made data transformation undoable, and various other reasons. In view of the significant quantity of missing data (39.7 % missing data), the quantitative analyses of the simulation are of limited value. Second, the accuracy of the flow meters at the pump station is questionable and unmetered bypass flows are a frequent occurrence. Therefore, total flow may not be measured in storm events and the recycling of flow is possible. Further investigation of the accuracy of flow measurement at the pump station is required to verify and calibrate the simulation models that compute the deductible runoff from the Des Plaines watershed contained in Column 6.

BUDGET 9: MAINSTREAM TARP PUMPING STATION

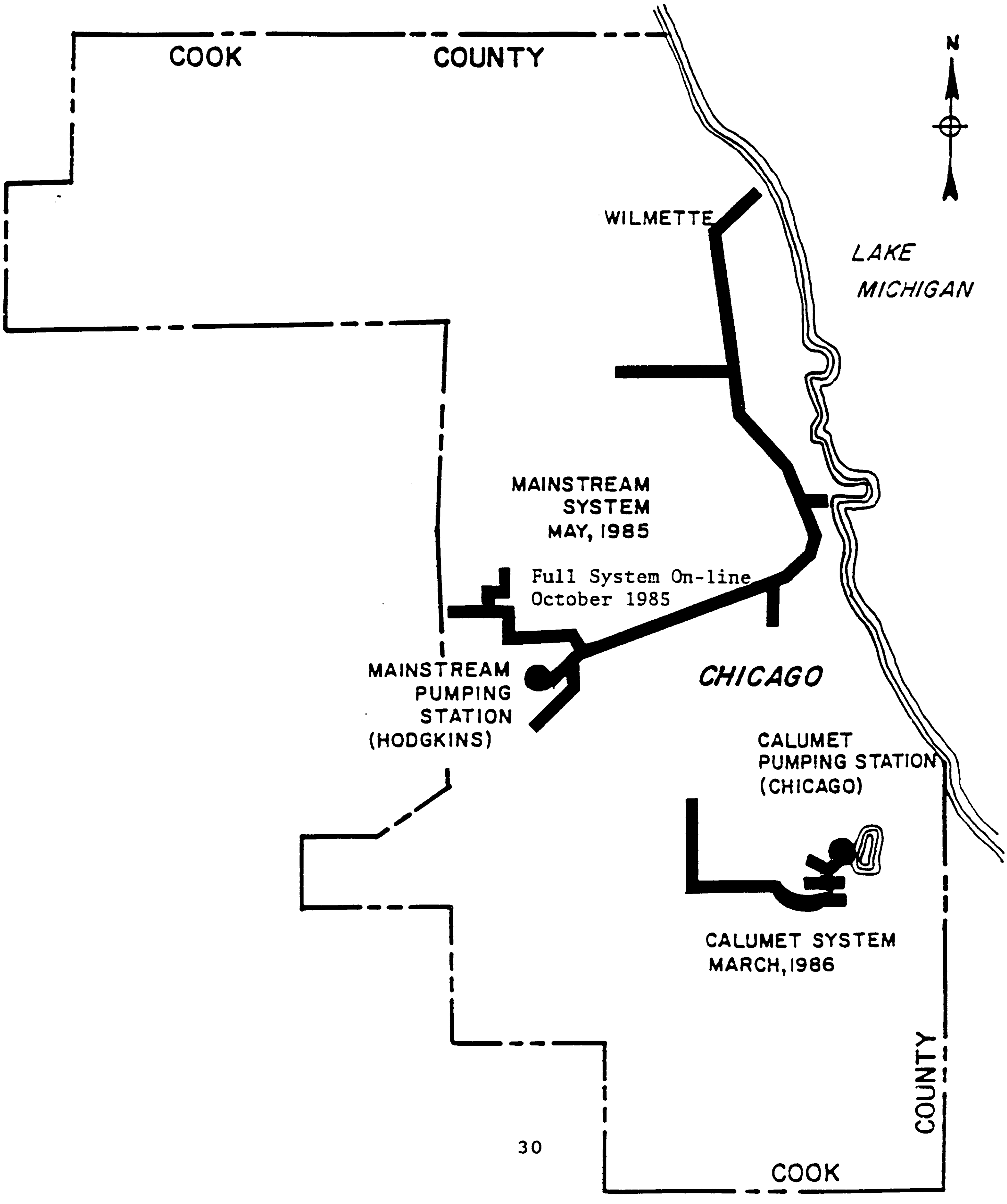
Budget 9 analyzes the water budget at the MWRDGC Mainstream TARP Pumping Station. The results of Budget 9 are used as a verification point for simulated flows. It is also used for the purpose of computing a portion of Column 6, the Des Plaines River watershed runoff deduction. The deductible portion of Budget 9 includes groundwater seepage into the TARP tunnel walls and a small amount of Des Plaines River watershed runoff captured by Mainstream TARP as overflows. Until the Des Plaines TARP segment goes on-line the Des Plaines River watershed runoff conveyed to the Stickney Water Reclamation Plant through TARP tunnels will remain very small. The modeling of Mainstream TARP is performed using the Tunnel Network (TNET) dynamic hydraulic model. A simplified map of Mainstream TARP is contained in Figure 5. A more in-depth description of Mainstream TARP and the simulation model is contained in the Water Year 1986 report which is an appendix to the Diversion Accounting Annual Report for WY90-92 (USACE, 1994).

In analyzing the balance at the Mainstream TARP Pumping Station, weekly flows were used rather than daily flows. While MWRDGC maintains daily pumpage records, days with no pumpage occur frequently. Therefore, it is not possible to compute a daily S/R ratio.

The balance for WY90 of the inflow to the Mainstream Pumping Station is fair. The simulated to recorded flow ratio (S/R) for the Mainstream Pumping Station is 1.05, indicating that the simulated inflow volume is slightly greater than the recorded inflow volume. The coefficient of correlation (R) of simulated to recorded flow is 0.49, indicating that there exists a need for

Figure 5

Map of Mainstream and Calumet TARP



improvement in the ability of the model to predict trends in the pump station flows.

From a review of the plot of the simulated versus recorded flow at the pump station (Figure 6), it appears that the model responds similarly to recorded pumpage record. However, the model is sometimes out of phase with the observed record. This could be the result of simulated pumpages occurring sooner and more frequently than actual pumpages. The model pumps normally turn on sooner and pump more frequently in order to maintain model stability during a run. Additionally, base flows appear to be overestimated in the simulation. This is probably due to overestimation of groundwater infiltration into the TARP tunnels.

In summary, it appears that the simulation of the Mainstream TARP system is reasonable. However, there is concern regarding the estimation of pumpage volume and the difference in simulated and recorded pumpage time series. A review of MWRDGC information regarding Mainstream TARP indicates that bypass flows are discharged to TARP, when available, via drop shaft 11 (DSN 11). Coordination with MWRDGC established that this is a frequent occurrence. This may account for the simulation of a pumpage volume that is less than the recorded pumpage volume. Records concerning the dates and pumpages back to TARP were not maintained for WY90. Therefore, data necessary to evaluate the impact of pumping back into TARP is not available. Therefore, it was decided that the model would not be adjusted so as to avoid double accounting of flows.

BUDGET 10: STICKNEY WATER RECLAMATION FACILITY

Budget 10 analyzes the water balance at the MWRDGC Stickney Water Reclamation Facility (Figure 7). Simulated Mainstream TARP pumpages from Budget 9 are no longer combined with simulated interceptor inflow to the Stickney Water Reclamation Facility to derive the total simulated inflow to the Stickney Facility. Instead, only simulated interceptor inflows are compared with recorded interceptor inflows to assess the accuracy of the simulation. The decision to not include TARP pumpages in the treatment plant budgets was based on the fact that the TARP systems are already analyzed in separate budgets. Including TARP pumpages in the treatment plant budgets is detrimental to the statistical results of the treatment plant budgets since the TARP models generally do not respond as well. When simulations of interceptor flows are treated separately, the response of the hydrologic runoff models (HSPF) and the hydraulic sewer routing models (SCALP) can be better isolated and not diluted by the TARP model results which are analyzed separately on their own merits and contained in their own budgets, Budgets 9 and 11.

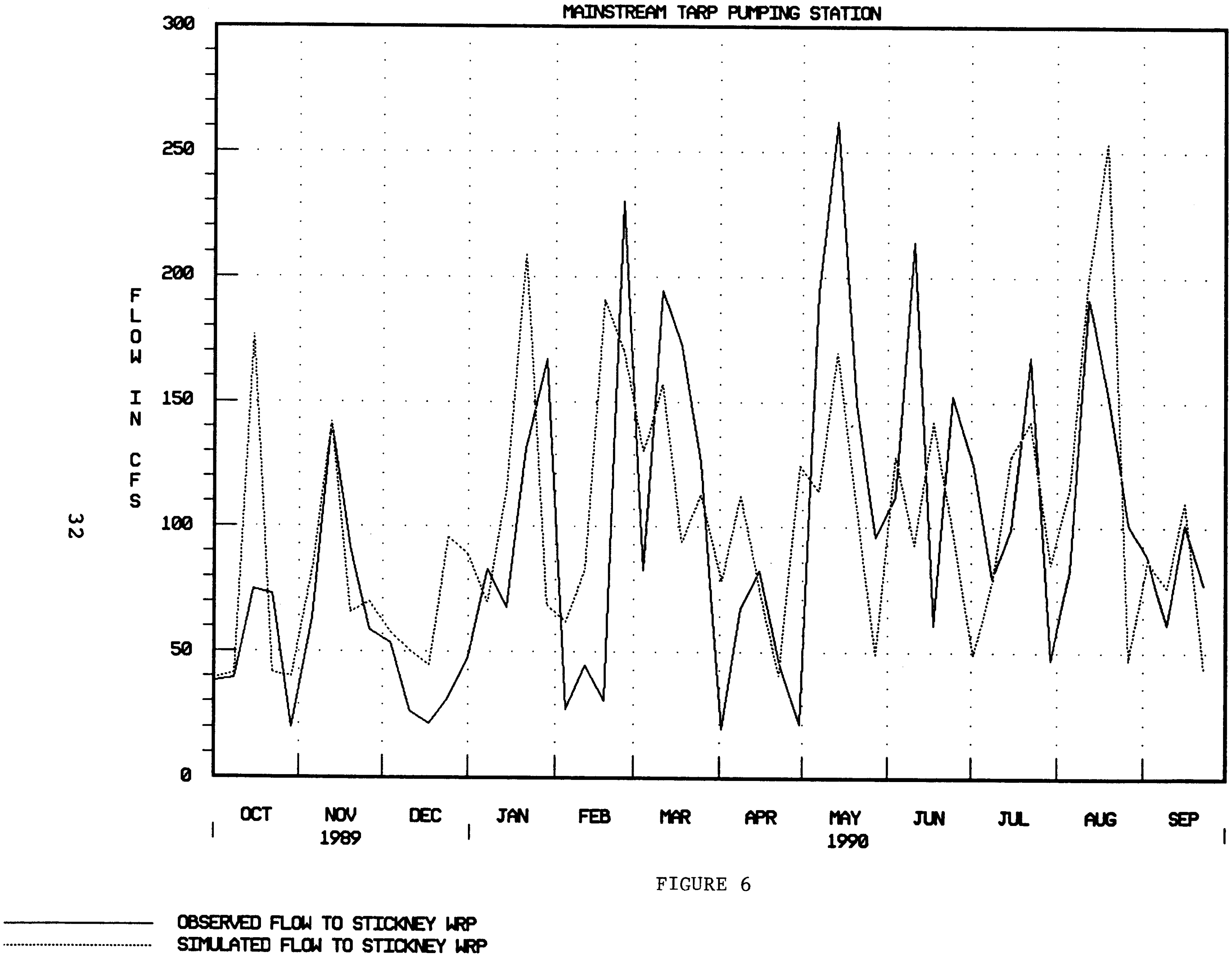


FIGURE 6

Budget 9 - Simulation of the MWRDGC Mainstream TARP Pumping Station

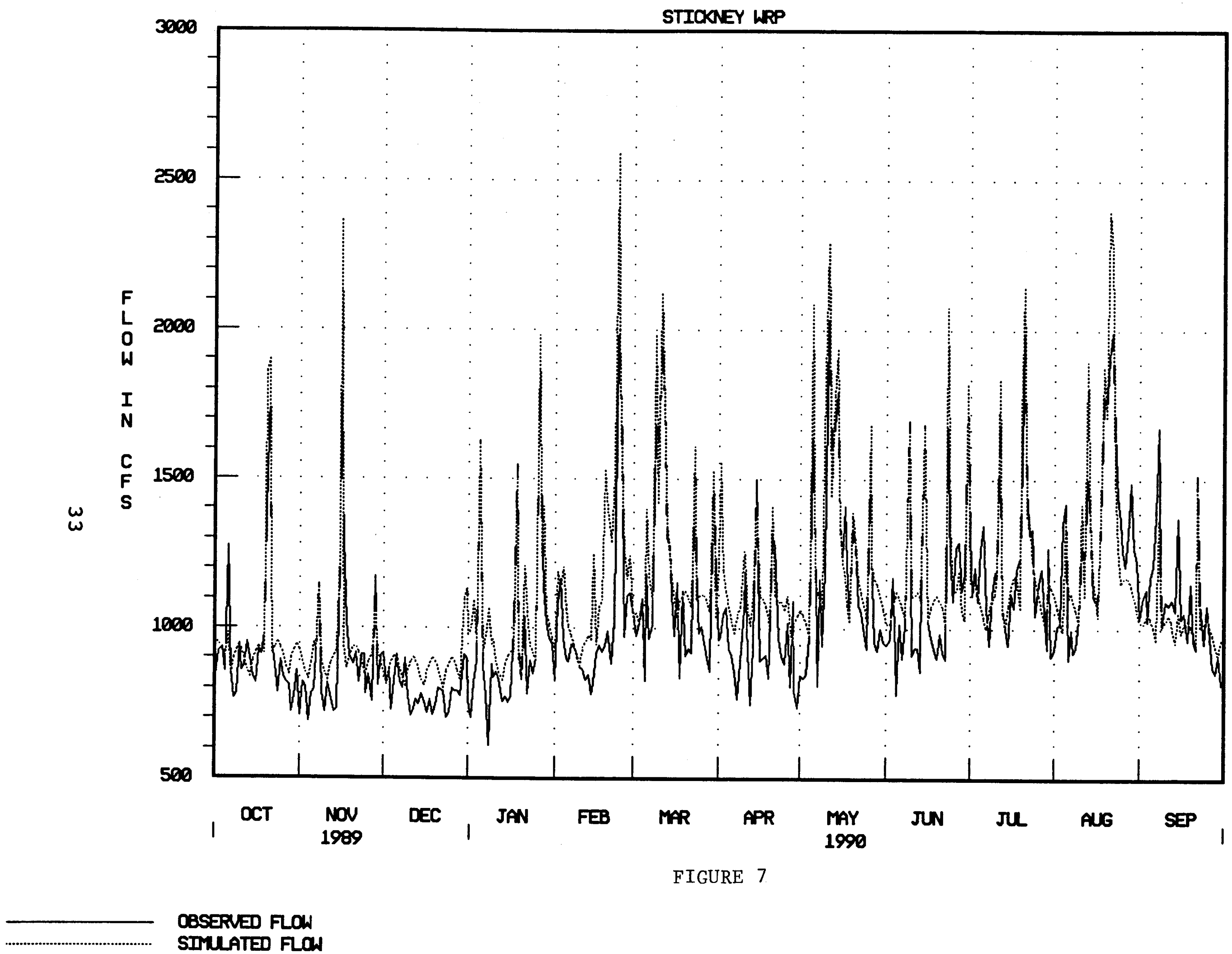


FIGURE 7

Budget 10 - Simulation of the MWRDGC Stickney Water Reclamation Facility

Overall, the balance for WY90 of the inflow to the Stickney facility is very good. The simulated to recorded flow ratio (S/R) for the Stickney is 1.07, indicating that the simulated interceptor inflow volume is slightly greater than the recorded interceptor inflow volume. The coefficient of correlation (R) of simulated to recorded flow is 0.86, indicating that the model predicted the interceptor inflow hydrograph to the Stickney facility very well.

BUDGET 11: CALUMET TARP PUMPING STATION

Budget 11 analyzes the water budget at the MWRDGC Calumet TARP Pumping Station (Figure 8). The results of Budget 11 are used as a verification point for simulated flows. The modeling of Calumet TARP is performed using the Tunnel Network (TNET) dynamic hydraulic model. A simplified map of Calumet TARP is contained in Figure 5. A more in-depth description of Calumet TARP and the simulation model is contained in the Water Year 1987 report contained in the Diversion Accounting Annual Report for WY90-92 (USACE, 1994).

In analyzing the balance at the Calumet TARP Pumping Station, weekly flows were used instead of daily flows. While MWRDGC maintain daily pumpage records, days with no pumpage occur frequently. Therefore, it is not possible to compute a daily S/R ratio.

The balance for WY90 of the inflow to the Calumet TARP Pumping Station is fair. The simulated to recorded flow ratio (S/R) for the Calumet TARP Pumping Station is 0.74 indicating that the simulated inflow volume is less than the recorded inflow volume. The coefficient of correlation (R) of simulated to recorded flow is 0.51, indicating that there was a need for improvement in the agreement between the trends of the simulated and observed Calumet TARP pumpages.

From a review of the plot of the simulated versus recorded flow at the pump station (Figure 8) it appears that the model responds similarly to the recorded pumpage record except that the recorded pumpage often lagged behind the simulated pumpages for WY90. During a review it was discovered that each of the four variable speed pumps were out of service during portions of WY90, often several at one time. Since these pumps are used during high flows (the two constant rate pumps shut off above a certain tunnel elevation) dewatering of the tunnel may have occurred over a longer time period. Consequently, simulated daily pumpages were lagged and compared to the recorded pumpages on a weekly basis in order to check if the model response would improve. It was determined that when simulated daily pumpages were lagged 3 days the coefficient of correlation improved from 0.51 to 0.65 indicating that the Calumet TARP model response was better than

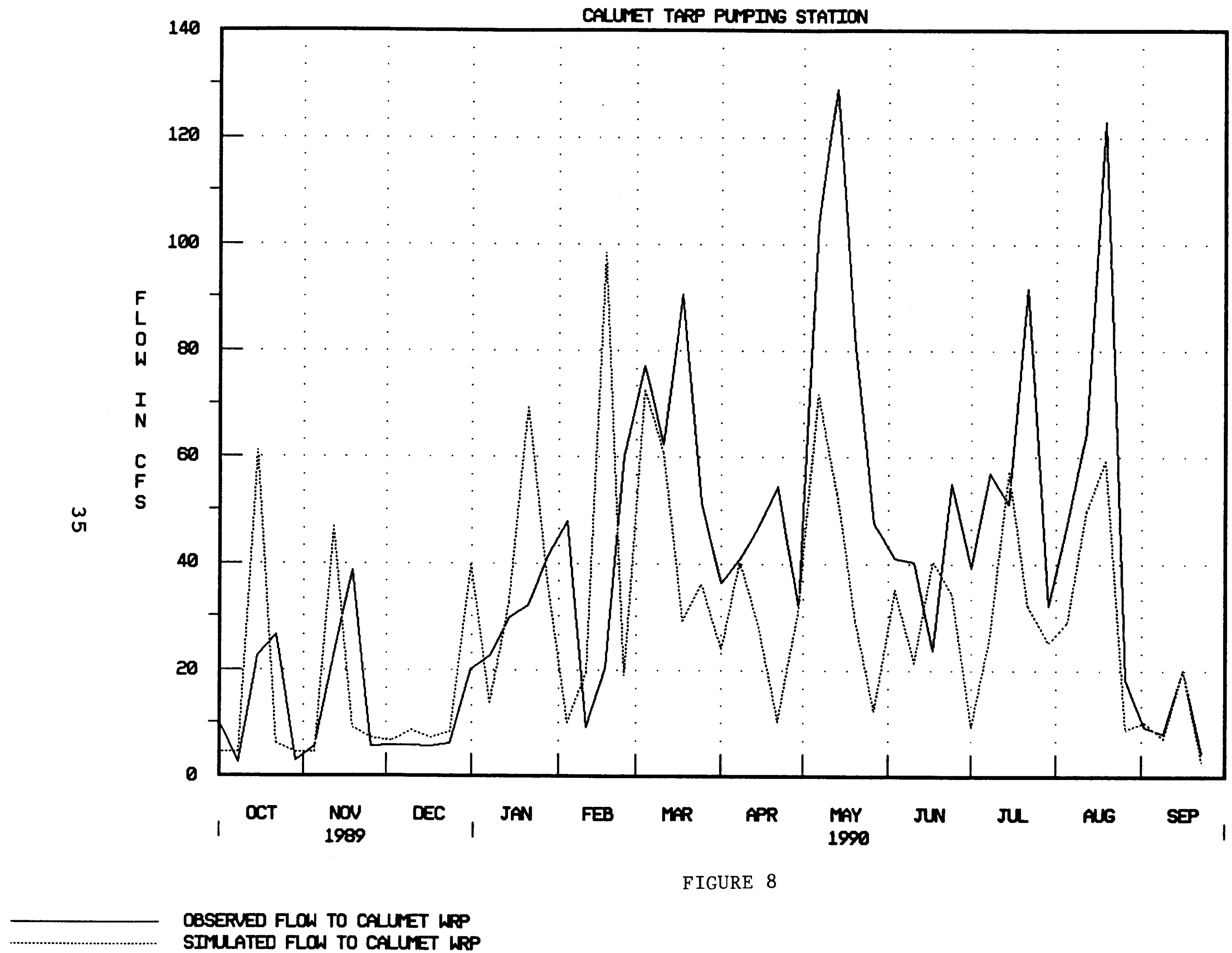


FIGURE 8

Budget 11 - Simulation of the MWRDGC Calumet TARP Pumping Station originally thought. It is due to the dynamic nature of variables like this that the successful modeling of the TARP systems is a difficult task.

Volume matching between the simulated and recorded Calumet TARP pumpages also was more difficult for WY90 as evidenced by the 0.74 S/R ratio. Because of the instability of the TARP model as well as uncertainties in the Calumet TARP system it was difficult to improve on this ratio. However, as the system is presently modeled, this does not impact the computed diversion since all Des Plaines River watershed areas whose overflows are modeled as tributary to Calumet TARP are also modeled such that "non-captured" overflows overflow to rivers that are tributary to the CSSC. Therefore, whether or not these Des Plaines River watershed runoff flows enter the tunnel or not, they are presently included in the Des Plaines River watershed runoff deduction in Column 6. This assumption will remain until separately sewered areas are modeled such that actual areas are used instead of effective areas in the hydraulic models. This will be discussed in the subsequent section on areas for improvement in diversion accounting procedures.

BUDGET 12: CALUMET WATER RECLAMATION FACILITY

Budget 12 analyzes the water balance at the MWRDGC Calumet Water Reclamation Facility (Figure 9). Simulated Calumet TARP pumpages from Budget 11 are no longer combined with simulated interceptor inflows to the Calumet Water Reclamation Facility to derive the total simulated inflow to the Calumet Facility. Instead, only simulated interceptor inflows are compared with recorded inflows to assess the accuracy of the simulation. This was revised for the same reasons as outlined previously in the discussion for Budget 10.

The annual simulated to recorded flow ratio (S/R) and the coefficient of correlation for the Calumet Water Reclamation Facility are considered very good to excellent. The S/R ratio is 1.00 indicating that the simulated Calumet interceptor flow volume matched the recorded interceptor flow volume. The coefficient of correlation was 0.89 indicating a very good correlation between simulated and recorded interceptor flows.

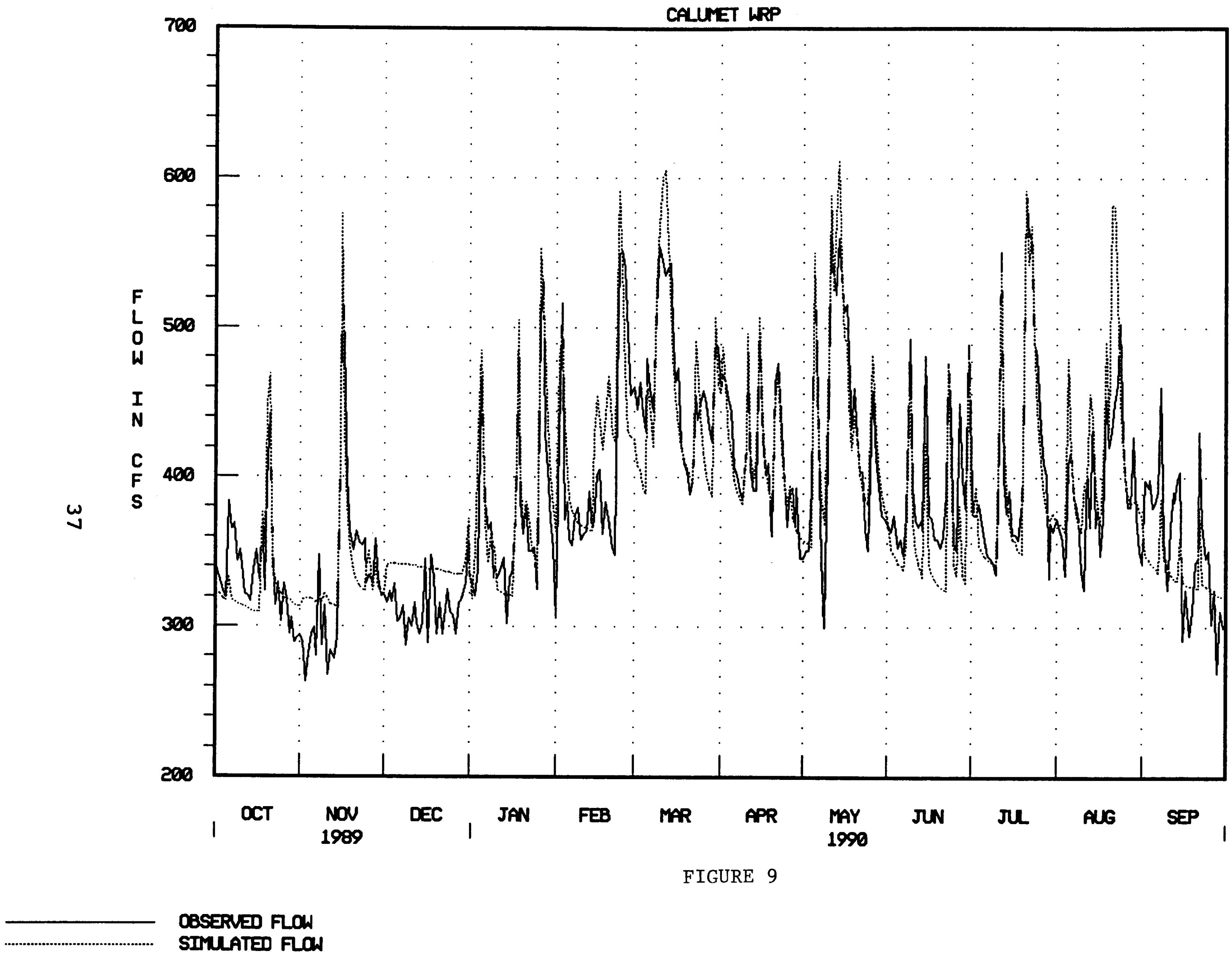


FIGURE 9

Budget 12 - Simulation of the MWRDGC Calumet Water Reclamation Facility

BUDGET 13: LEMONT WATER RECLAMATION FACILITY

Budget 13 analyzes the water balance at the MWRDGC Lemont Water Reclamation Facility (Figure 10). Overall, the balance for WY90 of the inflow to the Lemont facility is very good. The simulated to recorded flow ratio (S/R) for the Lemont is 0.86, indicating that the simulated inflow volume was somewhat less than the recorded inflow volume. The coefficient of correlation (R) of simulated to recorded flow is 0.92, indicating that the model predicted the inflow hydrograph to the Lemont facility quite well.

BUDGET 14: CHICAGO CANAL SYSTEM BALANCE

Budget 14 compares the inflows and outflows to the canal system (Figure 11). The inflow components include direct diversions through the lakefront structures, stormwater runoff discharged to the canal system, and domestic water supply whose effluent discharges to the canal system. The outflows from the canal system include the discharge past the Romeoville AVM, backflows through the lakefront structures, and withdrawals upstream of Romeoville by Argonne National labs and Uno-ven corporation. The individual components are presented in Table 8 for WY90.

Overall, the balance for WY90 between the inflows to the canal system and the outflows from the canal system is fair. The S/R (outflow/inflow) for the canal system is 1.15, indicating that the inflow to the canal system is less than the outflow from the canal system. The average measured/simulated inflow was 3269.3 cfs while the average measured/simulated outflow was 3758.3 cfs. This is a difference of 489.0 cfs (13.0%) for WY90 as compared to 480.2 cfs (13.6%) for the previous water year, WY89.

The coefficient of correlation (R) of inflow to outflow is 0.84, indicating that the time series trends of inflow to outflow are fairly well correlated. The coefficient of correlation is based on daily flows. Therefore, timing between inflows and measured outflows at Romeoville is a major issue, especially during changes in flow that occur at the beginning or end of a day. This is the result of travel time from inflow locations downstream to the Romeoville AVM site. Therefore, variability in the coefficient of correlation from year to year may be attributed to the variability in the timing of significant flow changes during a particular year.

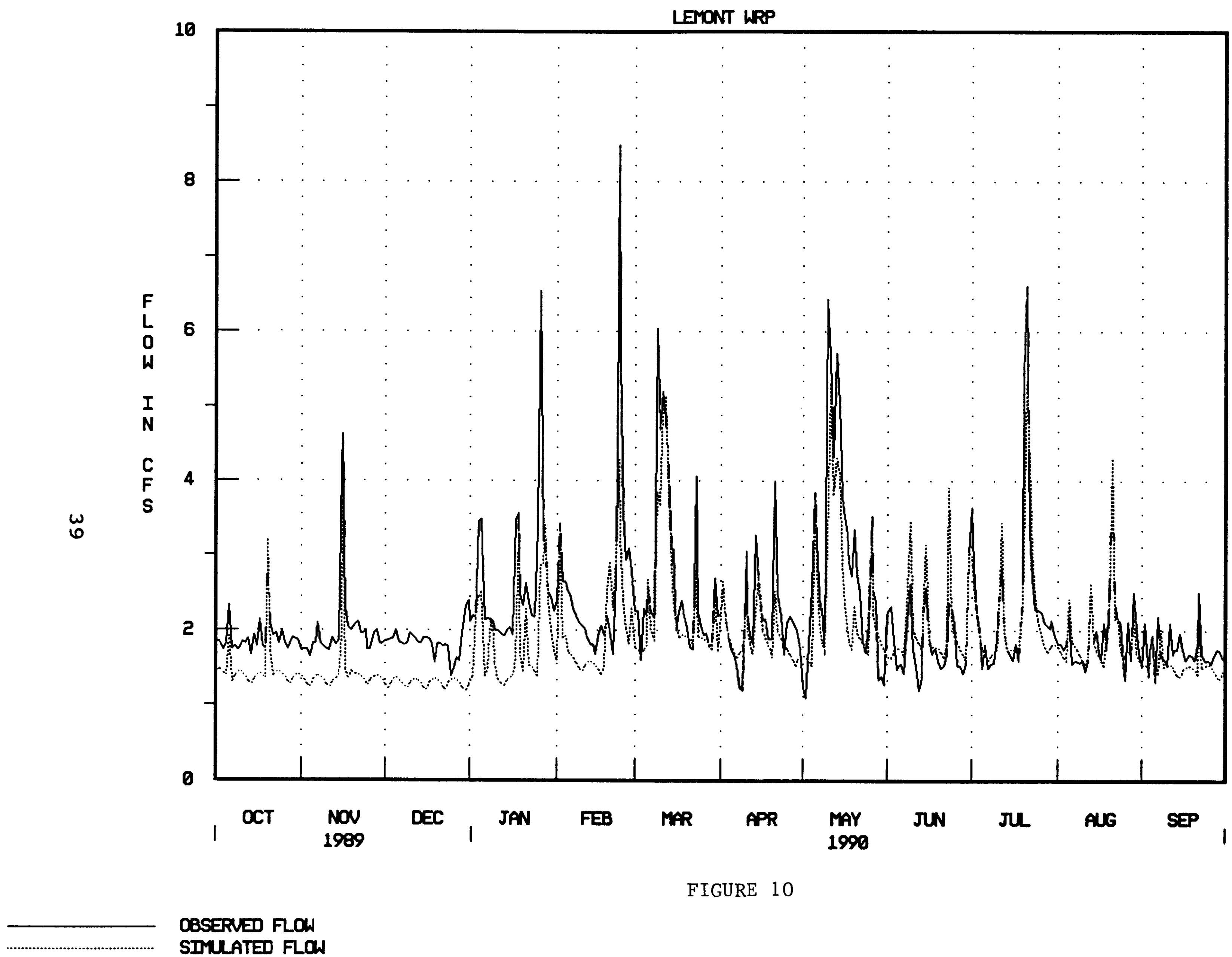


FIGURE 10

Budget 13 - Simulation of the MWRDGC Lemont Water Reclamation Facility

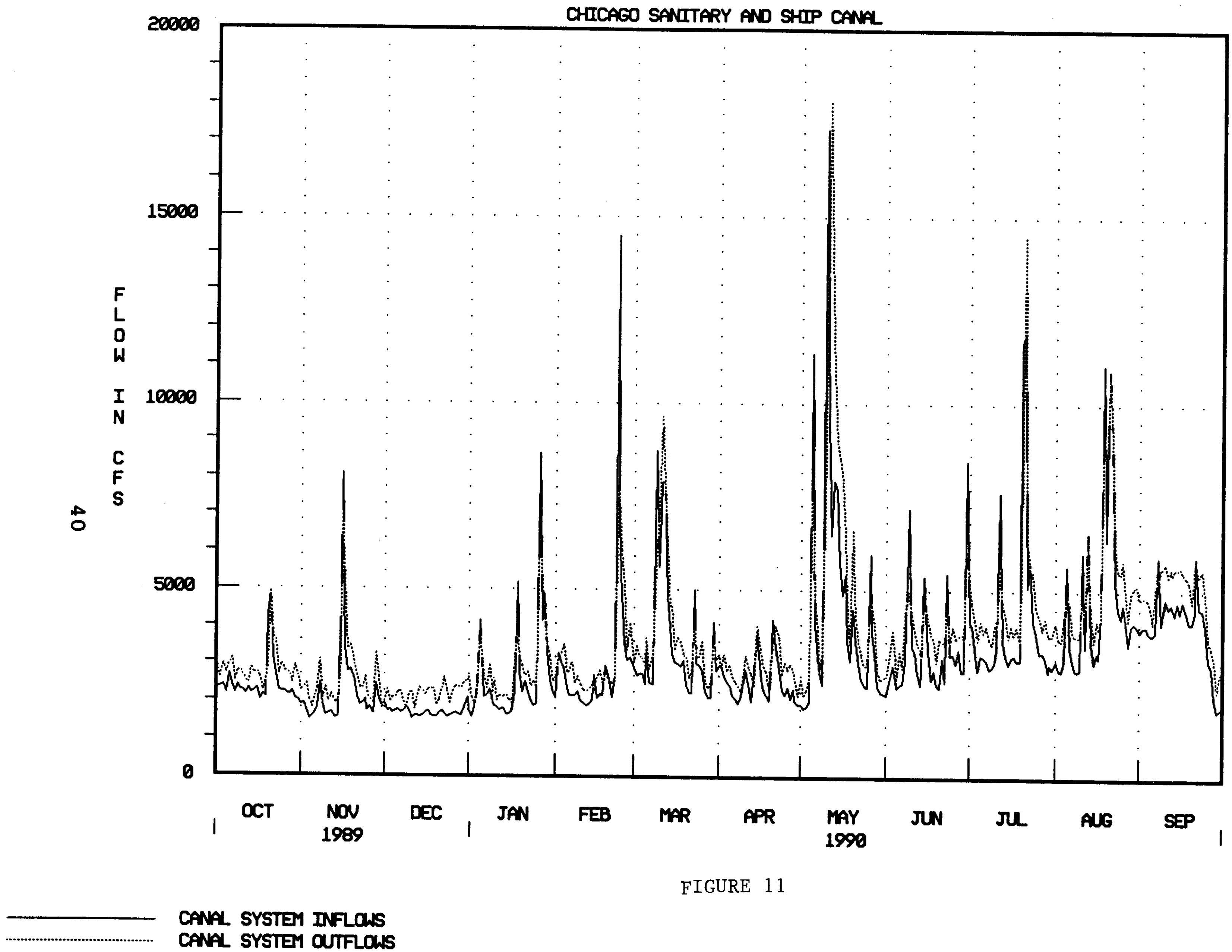


FIGURE 11

Budget 14 - Canal System Balance

TABLE 8

SUMMARY OF FLOW COMPONENTS FOR
CANAL SYSTEM BALANCE – WY1990

INFLOWS (cfs)	
Lake Controlling Structures (measured)	
– Wilmette Controlling Works	22.7
– Chicago River Controlling Works	224.7
– O'Brien Lock and Dam	203.4
Streamflows (measured)	
– North Branch Chicago River at Niles	125.8
– Little Calumet River at South Holland	190.2
Streamflow (estimated)	
– Grand Calumet River at Holman Ave.	23.0
MWRDGC Water Reclamation Facilities (measured)	
– Northside	437.3
– Stickney	1151.0
– Calumet	424.5
– Calumet TARP Pumpage to River	0.0
– Lemont	2.2
Other Point Sources (measured)	6.0
Summit Conduit (simulated)	8.4
Combined Sewer Overflows (simulated)	261.7
Direct Runoff to CSSC (simulated)	188.4
TOTAL INFLOWS (cfs)	3269.3

OUTFLOWS (cfs)	
Cal–Sag Flow Transferred to Calumet WRP as Steel Mill Blow–down	1.5
Lake Front Backflows	1.3
Argonne Laboratory	0.8
Uno–ven Corporation	6.2
USGS AVM Record	3748.5
TOTAL OUTFLOWS (cfs)	3758.3

DIFFERENCE (cfs)	–489.0

Based on the fact that the inflow is well correlated with the outflow, it appears that there is a moderately variable to constant underreported or unreported inflow. Possible sources of the canal system flow imbalance may include underreporting of the lakefront flows through the sluice gates and locks as well as unaccounted for flow sources. The underreporting of the lakefront flows could be the result of both inaccurate rating curves for the lakefront control structures and leakage through those structures. Flow meter measurements at the lakefront direct diversion points were done to assess if leakage is significant. This study (USGS, 1994) showed that lakefront leakage flows are greatly underreported. Unaccounted flows could also include unreported discharges to the canal.

AREAS FOR IMPROVEMENT IN THE DIVERSION ACCOUNTING PROCEDURES

As a result of reviewing and calculating the WY90 diversion accounting, and referencing the results of the WY84 through WY89 diversion accounting, a number of areas of potential improvement have become evident. The following paragraphs discuss those areas where improvement is needed.

CANAL SYSTEM BALANCE

As discussed previously, the canal system balance indicated that the total inflows were 13.0% less than the outflows. Flow meter measurements at the three lakefront direct diversion points were conducted between April and October 1993 by the USGS. The three lakefront diversion points that were measured are the Chicago River Controlling Works, O'Brien Lock and Dam, and the Wilmette Controlling Works. This study (USGS, 1994) included in the WY93 Annual Report indicated that measured leakage rates were significantly greater than the reported leakage. The underreported leakage accounts for a large portion of the flow imbalance determined in Budget 14. Additionally, sluice gate flows were also measured. Those measurements indicated that sluice gate flows were slightly underreported. Additional leakage and sluice gate measurements over a wide range of head conditions and gate settings will be required to further verify the WY93 results as well as to accurately estimate the actual discrepancy between reported and measured flows.

Another potential contributing factor in the canal system imbalance is the possibility of unreported discharges to the CSSC and adjoining waterways. Reconnaissance missions will be made in the future to determine the existence of any unreported discharges to the canal system.

It must be noted that the canal system imbalance does not directly affect the diversion computation. Its purpose is to provide a means of verification of modeled and measured flows and to indicate potential problems associated with these flows.

TUNNEL AND RESERVOIR PLAN MODELS

The TARP models should be revised such that they are more representative of actual operating conditions, if possible. Due to the model instability it was necessary to simplify or modify the gate closing and pump operation parameters. Improvements in model stability will first be required before the models can better represent operating procedures. Even after that is accomplished, representation of "actual" operating procedures may be difficult due to the TARP system operation plan not being adhered to at all times, tendencies to pump at night, down times for various pumps, changes in pump ratings, implementation of forecasting algorithms, etc.

It must be remembered that the primary purpose of the TARP models is to accurately estimate deductible components of the diversion such as the Des Plaines River watershed runoff and groundwater infiltration through tunnel walls. Currently, the Mainstream system deduction is composed almost entirely of groundwater infiltration. Until the Des Plaines tunnel goes on-line only a small percentage of the TARP pumpages at the Stickney WRP will be composed of Des Plaines River watershed runoff.

On the other hand, the Calumet TARP model requires modifications in separately sewered areas due to existing uncertainties in sanitary sewer connections as well as separate sewer area boundary delineations. These issues are being investigated and should be resolved within the next few years. As previously discussed in the Budget 11 section, all Calumet separate sewered areas within the Des Plaines River or Lake Michigan watershed are modeled such that all flows, sanitary plus runoff, are tributary to the CSSC either as interceptor or TARP flows that are conveyed to the Calumet WRP or as overflows that discharge to watercourses that are modeled as being tributary to the CSSC. Therefore, all Des Plaines River watershed runoff entering sanitary sewers within the Calumet WRP service basin is included as deductible runoff contained in Column 6, whether or not the overflows are captured by TARP or not.

It is important that low flows or dry weather flows are modeled accurately so that groundwater infiltration into the two TARP systems is properly modeled. This is important since these flows are substantial and since they constitute a deduction to the diversion. They are included in the flows of Column 4. In the Calumet TARP system there are also sanitary sewers that are connected to TARP. These sewers must be accounted for in the modeling of groundwater infiltration since they contribute to the baseflow or dry weather flows of TARP. Currently, there is some uncertainty as to the connection of these separately sewered areas. This will be investigated in the near future.

There are several other areas where the TARP models can be improved. First, modeling of dry weather flow can be improved to more accurately simulate MWRDGC operational procedures which include less frequent pumping and pumping during the night. Second, the incorporation of a pseudo-forecasting algorithm would allow the model to simulate MWRDGC dewatering procedures prior to a storm. Third, dynamic constituent (I-I versus sanitary versus groundwater) tracking can be incorporated to allow more accurate determination of the deductible components of TARP flow. Fourth, the inclusion of an algorithm to operate gaged dropshafts based on average water surface elevation in a tunnel reach would provide better simulation of "actual" operations.

Additionally, better estimates of the simulated groundwater infiltration rates for the Mainstream TARP model are necessary to better match the simulated to the recorded dry-weather flows. Procedures for accomplishing this are similar to those used for improving the simulated groundwater infiltration rates for WY89 Calumet TARP as discussed in the WY89 Accounting Report that is contained in the Lake Michigan Diversion Accounting Annual Report for WY90-92 (USACE, 1994).

UNGAGED WATERSHED MODELING

The two ungaged watersheds, the Lower Des Plaines watershed and Calumet/Cal-sag basin of the Lake Michigan watershed, are areas where runoff is not accounted for in stream gage budgets or fully accounted for in water reclamation plant budgets. The runoff generated from these areas flows to the CSSC through direct surface runoff, through storm sewers that discharge to adjoining waterways that are tributary to the CSSC, or through effluent discharge from water reclamation plants. These two areas are modeled individually by multiplying areas of land cover types by unit runoff output generated by the HSPF hydrologic models. The totals of these areas equals the actual total of a particular ungaged watershed area less any combined sewer areas that are already accounted for in water reclamation plant budgets. There is however significant portions of both ungaged watersheds that contain separately sewered areas that flow to water reclamation plants, primarily to the Calumet WRP and to a lesser extent to the Stickney and Lemont WRPs. SCALP models these sanitary sewers as collecting 5% of the impervious runoff ,inflow, and 100% of the subsurface runoff, infiltration, as suggested by Christopher B. Burke Engineering (Burke, 1990). These sanitary sewers either convey this flow to the treatment facilities or they overflow to TARP or to adjoining rivers. The problem arises from the fact that the areas used in SCALP for separately sewered areas are effective and not actual areas. To complicate matters further, a small portion of the separately sewered areas appears to fall in neither of the two ungaged watersheds, but instead within a separate watershed that is not tributary to the canal. Because of the unavailability of separate sewer boundary delineations it is impossible to know with any certainty the watershed from which those sanitary sewer inflows and infiltration flows originated. Consequently, modeling of the two ungaged watersheds (one that is part of the Des Plaines River watershed and one that is part of the diverted Lake Michigan watershed) includes those separately sewered areas that are already accounted for in the modeling of the WRPs. Since a portion of the simulated runoff for the ungaged watersheds is modeled as entering the sanitary sewers, a double accounting of flows exists. This results in a slight overestimation of the deductible Des Plaines River watershed runoff of Column 6, the estimated Lake Michigan watershed runoff of Column 12, and the inflows to the canal system balance of Budget 14.

In order to correct for the double accounting of runoff in the ungaged watersheds, a separate study is necessary to isolate those separately sewered areas that are presently modeled in SCALP. Through this study sewer boundaries would be developed for those areas and effective areas would be replaced with actual areas in the model. Then a revision of the estimated percent of HSPF unit runoffs from impervious and grassland areas that enter the sanitary sewers would need to be revised in the Lands block of the SCALP input decks. Finally, the actual separately sewered areas would be removed from the models that simulate runoff to the CSSC from the two ungaged watersheds.

MWRDGC UPPER DES PLAINES PUMP STATION

A review of the Upper Des Plaines pump station and its flow record indicates that the flow at the pump station is suspect and subject to operator error. Better flow measurement is needed at the pump station. With better flow measurement, this will become the most important balances for calibrating and verifying the simulation models of the Des Plaines watershed. In the diversion calculation, the primary use of the models is to calculate the deduction for runoff from the Des Plaines watershed discharged to the canal. Runoff from the Des Plaines watershed is deductible. The Upper Des Plaines Pump Station is the only point at which a model of inflow-infiltration can be calibrated and extrapolated to the remaining Des Plaines River watershed. Installation of better flow measurement equipment at the pump station would facilitate model calibration. Plans are currently underway with the USGS for implementation of a new measurement system during WY95.

O'HARE AND EGAN BASIN FLOW TRANSFER

A portion of the flows originating in the O'Hare and Egan Water Reclamation Plants' (WRP) service basins are transferred east to the Northside WRP. The extent of the O'Hare service area being diverted is not known and the diverted flow is not measured. Thus an estimate of the annual basin transfer is provided by MWRDGC. The total O'Hare-Egan flow transfer for WY90 was estimated by the MWRDGC to be 31.0 cfs (20 MGD).

This transfer is significant to diversion accounting in light of the fact that the O'Hare and Egan facilities discharge outside of the CSSC while the Northside facility discharges flows that reach the CSSC. Therefore, this transfer contains two components that are deductions to the flow measured in the CSSC. The two deductible components are groundwater pumpage contained in the sanitary portion of the transfer, and diverted Des Plaines River watershed runoff. These two deductible components are contained in Columns 4 and 6, respectively.

To determine the two deductible components requires an estimate of the sanitary and runoff portions of the flow transfer. Presently the sanitary and runoff portions of the flow transfer are estimated using the same constituent (sanitary, inflow, and infiltration) proportions simulated for the Upper Des Plaines Pump Station by SCALP (Special Contributing Area Program). Additionally, estimates must be made of the groundwater and Lake Michigan water components contained in the sanitary portion of the transfer. For WY90 it was estimated that the water supply for the O'Hare and Egan service basins was composed of 7.8 percent groundwater (1.6 cfs) and 92.2 percent Lake Michigan Water (18.5 cfs). The diverted Des Plaines River watershed runoff was estimated at 10.9 cfs.

For future accounting, simply measuring the basin transfer will not provide any information on the component makeup of the transfer. Thus, a review of the complex hydraulics and hydrology is necessary to determine the best procedure for estimating these flows. Several alternatives, including flow measurement and modeling are under consideration at this time. A more detailed discussion of the O'Hare and Egan basin transfer can be found in the Lake Michigan Diversion Accounting WY86 Report that is contained in the Lake Michigan Diversion Accounting WY90-92 Annual Report (USACE, 1994).

GRAND CALUMET RIVER

The flow in the Grand Calumet River drains both to the Lake Michigan via Indiana Harbor and to the Calumet Sag Channel which is tributary to the CSSC. When lake levels are high a larger portion of the flow drains to the Calumet Sag Channel. The Grand Calumet River flow calculation is currently based on a regression equation relating Lake Michigan stages and measured flows in Hart Ditch to the Grand Calumet River flow. Through current meter measurements by MWRDGC and other agencies it was determined that the accuracy of these regression equations are in question.

The Grand Calumet River flow to Illinois is important to diversion accounting because the majority of the flow in the Grand Calumet River is water supply effluent. This is a deduction to the AVM gage record and is contained in Column 5, Water Supply Pumpage from Indiana Reaching the CSSC. The Indiana water supply deduction is equal to the total water supply pumpage discharged to the Grand Calumet River if the pumpage rate is less than the calculated river flow. The deduction is equal to the river flow if the pumpage rate is greater than the river flow since under these conditions it is assumed that the river flow is composed entirely of sanitary effluent.

This procedure is the only method currently available to calculate the Indiana deduction. A stream gage has been installed for WY91 in the West Branch of the Grand Calumet River to measure flow into Illinois. This should increase the accuracy of this computation significantly. The same computational procedure for separating stream flow into sanitary and runoff will be used with the Grand Calumet stream gage record.

SUMMARY

In compliance with the modified 1980 U.S. Supreme Court decree, the WY90 diversion was computed using the best engineering technology available to date.

Overall, the simulations that comprise a significant portion of the diversion accounting computations worked well. The two most significant budgets to the diversion accounting computations, Budget 7, Northside Water Reclamation Facility, and Budget 10, Stickney Water Reclamation Facility, performed very well. Together, Budgets 7 and 10 compute the majority of the deductible Des Plaines River watershed runoff. These budgets have simulated to recorded ratios of 0.94 and 1.07 and correlations of 0.89 and 0.86, respectively. Given the complexity of the hydrologic cycle in the heavily urbanized Chicago metropolitan area, and given the number of human and other factors that cannot be adequately represented in numerical modeling procedures, the results of these two budgets are very good. Additionally, results for Budget 12, the Calumet WRP, were also very good. This budget also models a portion of the deductible Des Plaines River watershed runoff. The S/R ratio was 1.00 while the coefficient of correlation was 0.89. Areas of improvement previously outlined will be considered in order to improve the accuracy of the diversion computation.

The WY90 diversion accountable to the State of Illinois is 3,531.2 cfs. This is 331.2 cfs greater than the 3,200 cfs average specified by the Decree. The 40 year running average beginning with WY81 and rounded to the nearest cfs is 3,452 cfs, and the cumulative deviation from the 3,200 cfs average is -2,520 cfs-years. The negative cumulative deviation indicates a water allocation deficit and the maximum allowable deficit is 2,000 cfs-years.

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