LAKE MICHIGAN DIVERSION ACCOUNTING

WATER YEAR 1984 and WATER YEAR 1985

REPORT

U.S. Army Corps of Engineers, Chicago District
Lake Michigan Diversion Accounting Section
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LAKE MICHIGAN DIVERSION ACCOUNTING
WATER YEAR 1984 & 1985 REPORT

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INTRODUCTION

The Corps of Engineers is responsible for monitoring the measurement and computation of the diversion of Lake Michigan water by the State of Illinois. The measurements and computations for Water Year 1983 (WY83), WY84 and WY85 (1 October 1984 through 30 September 1985) were performed 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 performed by NIPC. This report represents the final Lake Michigan diversion accounting for both WY84 and WY85.

BACKGROUND

Prior to the 1983 accounting report, diversion accounting was performed by the MWRDGC in 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 sanitary and ship canal. Because not all of the deductible flows could be measured, 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 refine the diversion accounting calculations and at the same time the state moved from monthly hydraulic reports to annual accounting reports. NIPC adapted previously developed computer models of the majority of the diverted Lake Michigan watershed and the Des Plaines River watershed 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 water budgets were developed around each of the gaged areas to verify the models. The budgets aid in identifying problem areas in the procedure. The computer models adapted by NIPC for diversion accounting were developed in conjunction with studies in Northeastern Illinois under Section 208 of the Federal Water Pollution Control Act Amendments of 1972 (PL 92-500). 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 water 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 performed according to the best current engineering practice and scientific knowledge.

The first technical committee was convened during the period that the diversion accounting was performed by MWRDGC and 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). Also 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 which 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.

Through the life of the AVM there have been periods when the equipment malfunctioned. To provide flows during periods of malfunction, various regression analyses were performed to relate the MWRDGC reported Lockport flows to the AVM flows. The report presenting the most current regression equations was completed September 1989 (USACE,1989).

The second and most recent 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 Water Resources Development Act of 1986 gave the Corps of Engineers full responsibility for computation of the Illinois Lake Michigan diversion as of 1 October 1987. At the time that the 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 1988 and it was subsequently reviewed by the Corps. The Corps found the report to be adequate with two exceptions. First, the 1984 accounting was performed 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 performed 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.

Upon completion of the analysis of the modeling parameters by Burke, the WY84 and WY85 diversion flows were recalculated using the revised modeling parameters and Romeoville AVM flows. This report represents the Corps' WY84 and WY85 diversion accounting and certification of the WY84 and WY85 Illinois diversion.

AUTHORITY

Under the provisions of the U.S. Supreme Court Decree in the Wisconsin, et al v. Illinois et al, 388 U.W. 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 gives 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.

REPORT ORGANIZATION

The Diversion Accounting is presented first which includes a description of the accounting procedure, revisions made to the WY84 and WY85 accounting originally performed by NIPC, and final the WY84 and WY85 accounting results. Then a discussion of the diversion accounting results is presented in which the accounting components are discussed in detail and accounting verification is discussed. Subsequent to the component and verification discussions, potential improvements to the accounting system are reviewed. Finally a summary of the accounting and discussions is presented. Monthly summaries of the WY84 and WY85 diversion accounting are included in this report and daily values of the accounting are included as Appendix B1. The NIPC WY84 diversion accounting report is included as Appendix B2. The NIPC WY85 diversion accounting report is included as Appendix B3.

DIVERSION ACCOUNTING

The WY84 and WY85 accounting reports were initially prepared by the Northeastern Illinois Planning Commission. However, because of the use of modeling parameters questioned by the second technical committee and because of the lack of use of AVM derived flows in WY84 and the outdated regression equations used in WY85, the Corps of Engineers recalculated the diversion for the two years. In the following paragraphs, a general description of the accounting procedure is given followed by a discussion of the differences between the NIPC report and this report. The results of the accounting are then presented.

ACCOUNTING PROCEDURE

The Lake Michigan diversion accountable to the state of Illinois is calculated by measuring the flow in the Sanitary and Ship Canal at Romeoville near Lockport and deducting flows that do not constitute Lake Michigan diversions and diversions that 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.

Formerly the diversion accounting was based on the Lockport record. However on 12 June 1984, the AVM at Romeoville Illinois became operational and beginning with WY84, the diversion accounting will be based on the Romeoville record.

The diversion accounting results are presented as a series of columns which are listed in table 1. The first three columns compute the flow in the Sanitary and Ship Canal. Columns 4 through 8 present the deductions from the Canal system flows and Column 9 presents the additions to the Canal system record. Column 10 presents those diversion flows which are for Federal purposes and are a deduction from the Canal system record. Column 11 is the computed Lake Michigan diversion accountable to Illinois and is equal to the canal system flow minus the deductions plus the additions. Columns 12 through 14 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. Columns 12 through 14 are not used in the diversion calculation but are included as another estimate of the

TABLE 1

COLUMN FUNCTIONS

COLUMN	DESCRIPTION
1	Romeoville Gage Record
2	Diversion Above Gage
3	Total Flow Through Canal
4	Ground Water Pumpage from Lake Michigan Watershed in Illinois
5	Groundwater Pumpage from Des Plaines River Watershed
6	Water Supply Pumpage from Indiana Reaching Canal
7	Runoff from Des Plaines River Watershed Reaching Canal
8	Total Deduction from Romeoville Gage Record
9	Lake Michigan Pumpage not Discharged to the Canal
10	Federal Facilities Lake Michigan Withdrawals Discharged to the Canal
11	Total Diversion
12	Pumpage from Lake Michigan Accounting to Illinois
13	Runoff from the Diverted Lake Michigan Watershed
14	Direct Diversion Through Lake-Front Control Structure

diversion for verification of the accounting flows in column 11. The sum of columns 12 through 14 should theoretically equal the flow in column 11.

In addition to the diversion calculations presented in the 14 columns, 13 water budgets are prepared as input to the diversion calculation and to verify the estimated flows that cannot be measured. Many of the budgets compare simulated to measured flows. These verification budgets give an indication of the accuracy of the diversion accounting and indicate changes in the watershed when measured and simulated flows begin to diverge. Budgets 1 through 3 do not compare simulated to measured flows but are summations of critical water supply pumpage data. Budgets 4 and 9 through 11 also do not compare simulated to observed flows but are streamgage records at several sites tributary to the Sanitary and Ship Canal. These budgets are used to calculate a portion of the runoff from the diverted watershed which is used as input to Column 13 "Runoff from the Diverted Lake Michigan Watershed". Budgets 5 through 8 and budget 12 compare simulated and measured flows at MWRDGC Water Reclamation Plants (WRP) that discharge to the canal system and at a pump station that is tributary to one of the WRPs. Budget 13 compares canal system inflows and outflows. The budgets are listed in table 2 and a discussion of the budget balances is presented in a subsequent section of this report. The accounting procedure is described in detail in the Lake Michigan Diversion Accounting Manual of Procedures, (NIPC, 1985).

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 3840 cfs as a result of extreme hydrologic conditions. During the first 39 year period, the maximum allowable cumulative difference between the calculated diversion and 3200 cfs is 2,000 cfs-years. These limits apply to the period beginning with WY81.

ACCOUNTING REPORT REVISIONS

The WY84 and WY85 diversion accounting performed by NIPC was reviewed extensively and all aspects of the diversion were recalculated. As a result of the review and recalculation, the accounting report has been revised. The revisions are the result of concerns expressed by the second technical committee and concerns of the Corps. The revisions are discussed below. The first two revisions, updating of the computer modeling parameters and updating of the Lockport flows, affect the calculated diversion. The third revision, reinstitution of the Upper Des Plaines pump station budget, impacts the verification of the simulation models. The final revision, reorganization of the diversion accounting calculation column functions, is a formatting change.

TABLE 2

WATER BUDGETS

Budget	Description
1	Lake Michigan Water Supply
2	Groundwater Supply Lake Michigan Watershed
3	Groundwater Supply Des Plaines Watershed
4	North Branch Chicago River at Touhy Avenue
5	Northside Water Reclamation Plant
6	Upper Des Plaines Pump Station
7	West - Southwest Water Reclamation Plant
8	Calumet Water Reclamation Plant
9	Little Calumet River at State Line
10	Thorn Creek at Thornton
11	Little Calumet River at South Holland
12	Lemont Water Reclamation Plant
13	Lockport Powerhouse and Controlling Works

Computer Modeling Parameter Revisions

The second technical committee, assigned to review and evaluate Lake Michigan Diversion Accounting, found that information from studies concerning the hydraulics of the MWRDGC service area, more recent than NIPC's data, had not been included in the diversion accounting models. The committee also found that some areas known to be served by separate sewers were identified as combined sewer areas. To address the committee's concerns, the Corps entered into a contract with C.B. Burke Engineering Ltd to review the drainage areas in the Des Plaines River watershed and the assumptions concerning the amount of runoff entering the sewers.

Burke reviewed the most recent reports that were developed in conjunction with design of the Chicago Tunnel and Reservoir Plan (TARP) and reviewed MWRDGC sewer atlases to identify combined and separate sewer areas. In the Des Plaines River watershed, 20 square miles of area previously identified as having combined sewers were found to contain separate sewers.

Burke also reviewed flow monitoring data and Upper Des Plaines pump station data to evaluate the estimates of surface and subsurface runoff entering the sewers. Subsurface runoff entering the sewers is termed infiltration while surface runoff entering the sewers is termed inflow. Infiltration and inflow together are termed I/I. Burke confirmed that in combined sewer areas all surface and subsurface runoff enters the sewers. However it appears that more runoff enters the separate sewers than was originally estimated by NIPC. The flow monitoring data indicated that more than 100% of the available subsurface runoff was required to properly calibrate to the observed infiltration. This indicated a deficiency with the runoff generating model which was not updated by Burke. Instead, the hydraulic model parameters, which sum the runoff components, were revised to compensate for the deficiency. The percentage of area producing and contributing subsurface runoff was increased from 45% to 100%. The amount of impervious surface runoff entering the sanitary sewers was increased from 2.5% of the surface area to 5% of the surface area to adequately model the inflow entering the sewers. The revised percentages were applied to each of the simulated areas in both the diverted Lake Michigan and Des Plaines River watersheds and in each of the MWRDGC water reclamation plant service areas. The results of the analysis and justification for changes in the runoff percentages is presented in the report I/I Study and Diversion Accounting Model Modification (Burke, 1989).

The change in modeling parameters, discussed above, impacts the calculated diversion. It primarily impacts the deduction for Des Plaines watershed runoff discharging to the canal. In the Des Plaines watershed, only runoff that enters the sewer system is

discharged to the canal. Runoff not entering the sewer system or overflowing out of the sewer system during high flows, discharges directly to the Des Plaines River which drains to the Illinois waterway, downstream of Romeoville. Designating areas previously thought to be served by combined sewers as area having separate sewers reduces the simulated runoff entering the sewer system while increasing the percentage of flow entering the separate sewers increases the simulated runoff entering the sewer system. The net affect of these offsetting revisions was to increase the WY84 Des Plaines watershed deduction by 18 cfs and the WY85 deduction by 19 cfs.

In the Corps' review of the WY84 accounting it was discovered that 28 square miles of drainage area in the western portion of the Lake Michigan watershed was included in the calculation of the Des Plaines watershed deduction. Excluding this area from the calculation decreased the WY84 and WY85 deductions by 28 cfs.

Lockport/AVM Flows

Prior to 1984, flows recorded by MWRDGC at the Lockport facility were used in the diversion calculation. In response to the first technical committee's concern for the inaccuracy of the MWRDGC flows, WES revised the rating curve for the sluice gates located at the power house. They also revised the rating curve for the controlling works sluice gates located approximately two miles upstream of the power house. WES found that the MWRDGC rating curves for both sets of sluice gates were over reporting flows.

Because of the extremely complex hydraulics of the flow through the two sets of sluice gates, the lack of data to adequately define the flow through the sluice gates, and questions regarding the accuracy of the rating of the Lockport turbines, an AVM was installed at Romeoville. The AVM became operational 12 June 1984. To calculate flows for periods of AVM malfunction the USGS developed a set of regression equations. These equations used daily Lockport flows reported by MWRDGC to estimate daily AVM flows. The USGS equations were used to calculate WY85 flows during periods when the AVM was malfunctioning. Subsequent to the USGS equations, various other groups developed equations for the same purpose. Recently, the Corps developed regression equations (USACE, Chicago District, 1989) for the dual purpose of calculating flows for periods of AVM malfunction and for the period of Water Year 1984 prior to installation of the AVM. In the report it was found that the regression equations provide the most accurate available estimate of the Sanitary and Ship Canal flow. The equations were tested using a 144 day verification period in which the average error was 0.9% and the standard error was 3.2%. The report presenting the regression equations was reviewed by the U.S.

Geological Survey (USGS) and the Hydrologic Engineering Center (HEC), the hydrologic research group of the Corps. The USGS and HEC endorsed the equations and agreed that the equations would provide the best estimate of the Lockport flow prior to installation of the AVM at Romeoville.

The regression analyses, confirmed what was suggested by WES. The MWRDGC rating curves for the two sets of sluice gates were over reporting flows. However, the regression analysis also indicated that the MWRDGC rating curves for the Lockport turbines were significantly under reporting flows. Because of the relatively infrequent use of the sluice gates, the impact of the sluice gate rating curves over reporting flows is much less than the impact of the turbine rating curves under reporting flows. In general, the MWRDGC rating curves under report the Lockport flow. However, the amount of under reporting depends on the magnitude of the flow and which components are in operation.

In their 1984 accounting report, NIPC calculated the canal flow using the MWRDGC turbine flows and the WES sluice gate rating curves. In this update of the WY84 accounting the AVM flows at Romeoville are used for the period after 12 June 1984 and the regression flows are used for the period prior to 12 June 1984. The use of the AVM and regression equations resulted in a 314.4 cfs increase in the calculated diversion for WY84.

In their 1985 accounting report, NIPC used the Romeoville flows published by the USGS. However since the time of the USGS publication, the regression equations were updated by the Corps. In this update of the WY85 accounting, the Romeoville flows were recalculated using the updated regression equations for the periods of AVM malfunction. The use of the updated equations resulted in an increase in the calculated diversion of 0.6 cfs.

Upper Des Plaines Pump Station

NIPC had found during preparation of the 1983 accounting report that the upper Des Plaines Pump Station flow meter did not appear to be accurately recording flows. In their WY84 and WY85 accounting reports, NIPC recommended that the Upper Des Plaines pump station budget be discontinued.

During preparation of data for the modeling parameter evaluation contract, the Corps found that the pump charts for the upper Des Plaines pump station had not been digitized and weekly flow values had been used in the past. The Corps digitized the charts and compared the flows to precipitation records and to NIPC's simulated flows. The Corps found that the pump station flow meter appeared to be operating correctly. However, the meter has not received any maintenance in over 20 years and requires calibration. The calibration will either show that the meter is currently recording flows accurately or that some

adjustment to the recorded flow will be necessary. Because the meters are working properly and will be accurate after calibration, the upper Des Plaines pump station budget will continue to be used.

The pump station budget is used to verify simulated flows. However it has no direct impact on the diversion calculation. Thus use of the pump station does not result in any change to the calculated diversion for WY84 or WY85.

Column Functions

In NIPC's report, columns were included for sewer induced groundwater infiltration in Illinois and in Indiana. The U.S. Department of Justice disallowed these deductions, however, the State of Illinois continued to show these columns for informational purposes. These two columns are no longer included.

As was mentioned in previous sections, Lake Michigan water supply for Federal facilities is a deduction. In the past these deductions were included in the column entitled "Lake Michigan Domestic Pumpage not Discharged to the Canal (W/ Adj.)". For this and subsequent reports, deductions for use by Federal facilities are shown in a separate column.

ACCOUNTING RESULTS

As discussed previously, the diversion accounting is presented as a table of columns. The WY84 diversion accounting is presented in table 3 and the WY85 diversion accounting is presented in table 4. The results of the WY84 and WY85 diversion accounting as well as the difference between the present and NIPC accounting values are presented here. A detailed discussion of the values in the individual columns is presented in the discussion of accounting results section of this report.

Table 3 shows a total WY84 Lake Michigan diversion accountable to the State of Illinois of 3,431.5 cfs (Column 11). This is 231.5 cfs greater than the 3,200 cfs average specified by the Decree. The 40 year running average beginning with WY81 is 3309.4 cfs and the cumulative deviation from the 3,200 cfs average is -437.6 cfs-years. The negative cumulative deviation indicates a water allocation debt and the maximum allowable debt is 2,000 cfs-years.

Table 4 shows a total WY85 Lake Michigan diversion accountable to the State of Illinois of 3,472.5 cfs (Column 11). This is 272.5 cfs greater than the 3,200 cfs average specified by the Decree. The 40 year running average beginning with WY81 is 3,342.0 cfs and the cumulative deviation from the 3,200 cfs average is -710.1 cfs-years.

TABLE 3

LAKE MICHIGAN DIVERSION ACCOUNTING - WATER YEAR 1984

SUMMARY OF DIVERSION FLOWS (cfs)

	ROMEOVLL GAGE RECORD	DIVERSN ABOVE GAGE	TOTAL FLOW THRU CANAL	GRNDWTR PUMPAGE FROM LAKE MICH. WATRSHD IN ILLINOIS	GRNDWTR PUMPAGE FROM DES PLAINES WATRSHD	WATER SUPPLY PUMPAGE FROM INDIANA REACHNG CANAL	RUNOFF FROM DES PLAINES WATRSHD REACHNG CANAL	TOTAL DEDUCT. FROM ROMEOVLL GAGE RECORD	LAKE MICH. PUMPAGE NOT DISCHRG TO CANAL	FEDERAL LAKE MICH. WTHDRWL REACHNG CANAL	TOTAL DIVERSN	PUMPAGE FROM LAKE MICH. ACCT. TO ILLINOIS	RUNOFF FROM THE DIVERTD WATRSHD	DIRECT DIVERSN THRU LAKE CONTROL STRUCT.
DATE	1	2	3	4	5	6	7	8	9	10	11	12	13	14
OCT, 1983	3428.3	0.4	3428.7	48.5	51.2	57.0	118.1	274.8	28.1	2.5	3179.4	1526.0	546.4	756.1
NOV, 1983	3379.5	0.2	3379.7	48.5	50.7	46.2	282.6	428.0	29.4	2.5	2978.6	1484.2	1099.8	254.9
DEC, 1983	3566.4	0.3	3566.7	48.5	51.0	37.7	216.1	353.2	27.1	2.0	3238.6	1510.6	986.6	116.7
JAN, 1984	2519.8	0.2	2520.0	48.5	51.0	31.0	116.8	247.3	28.5	1.1	2300.1	1584.2	341.9	138.8
FEB, 1984	3549.9	0.2	3550.1	48.5	50.7	36.0	340.1	475.4	29.7	1.2	3103.3	1556.1	1281.5	113.7
MAR, 1984	4120.4	0.2	4120.6	48.5	50.7	43.9	348.6	491.7	30.1	1.1	3658.0	1535.4	1654.0	119.8
APR, 1984	3870.0	0.3	3870.3	48.5	50.7	58.0	385.9	543.1	29.5	1.0	3355.7	1485.6	1422.9	215.4
MAY, 1984	4091.0	0.4	4091.4	48.5	50.8	66.1	223.6	389.0	30.0	1.1	3731.4	1539.5	1207.5	422.0
JUN, 1984	4230.0	0.6	4230.6	48.5	51.0	80.2	107.8	287.5	31.2	1.1	3973.2	1817.7	545.7	1070.4
JUL, 1984	4285.5	0.8	4286.3	48.5	51.0	98.0	47.4	244.8	34.3	1.3	4074.5	1992.7	247.6	1610.1
AUG, 1984	4202.6	0.8	4203.4	48.5	51.0	91.4	73.4	264.3	34.9	1.4	3972.7	2122.6	221.0	1391.2
SEP, 1984	4246.7	0.5	4247.2	48.5	50.9	69.6	109.9	278.9	29.5	401.1	3596.7	1658.2	427.9	978.5
WY 1984	3790.6	0.4	3791.0	48.5	50.9	59.7	196.5	355.5	30.2	34.2	3431.5	1652.0	829.0	601.3

COL#3 = COL#1 + COL#2 COL#8 = COL#4 + COL#5 + COL#6 + COL#7 COL#11 = COL#3 - COL#8 + COL#9 - COL#10

COL#14: DIRECT DIVERSIONS ACCOUNTABLE TO THE STATE OF ILLINOIS

STATUS OF ILLINOIS' LAKE MICHIGAN DIVERSION
UNDER 1980 AMENDED U.S. SUPREME COURT DECREE

Accounting year	Annual Diversion (% of 3200 cfs)	40 Year Running Average	Deviation from 3200 cfs Annual	Cumulative Sum (cfs-years)
1981	3106.0 cfs (97.1%)	3106.0	+ 94.0	+ 94.0
1982	3087.0 cfs (96.5%)	3096.5	+ 113.0	+ 207.0
1983	3613.1 cfs (112.9%)	3268.7	- 413.1	- 206.1
1984	3431.5 cfs (107.2%)	3309.4	- 231.5	- 437.6

TABLE 4

LAKE MICHIGAN DIVERSION ACCOUNTING - WATER YEAR 1985

SUMMARY OF DIVERSION FLOWS

DATE	ROMEOVLL GAGE RECORD	DIVERSN ABOVE GAGE	TOTAL FLOW THRU CANAL	GRNDWTR PUMPAGE FROM LAKE MICH. WATRSHD IN ILLINOIS	GRNDWTR PUMPAGE FROM DES PLAINES WATRSHD	WATER SUPPLY PUMPAGE FROM INDIANA REACHNG CANAL	RUNOFF FROM DES PLAINES WATRSHD REACHNG CANAL	TOTAL DEDUCT. FROM ROMEOVLL GAGE RECORD	LAKE MICH. PUMPAGE NOT DISCHRG TO CANAL	FEDERAL LAKE MICH. WTHDRWL REACHNG CANAL	TOTAL DIVERSN	PUMPAGE FROM LAKE MICH. ACCT. TO ILLINOIS	RUNOFF FROM THE DIVERTD WATRSHD	DIRECT DIVERSN THRU LAKE CONTROL STRUCT.
	1	2	3	4	5	6	7	8	9	10	11	12	13	14
OCT, 1984	3699.5	0.4	3700.0	27.7	46.7	66.6	124.5	265.5	33.1	2.0	3465.6	1556.7	423.2	986.4
NOV, 1984	2904.6	0.3	2904.9	27.7	46.7	73.8	225.2	373.4	32.9	2.1	2562.3	1498.0	735.6	135.9
DEC, 1984	3017.4	0.3	3017.6	27.7	46.6	73.6	304.1	452.0	33.8	1.8	2597.7	1503.4	982.1	134.3
JAN, 1985	3165.3	0.3	3165.6	27.7	46.8	76.4	230.9	381.8	33.7	2.2	2815.3	1548.2	703.9	130.3
FEB, 1985	4056.5	0.3	4056.7	27.7	46.4	79.2	354.5	507.8	36.3	2.1	3583.2	1574.6	1694.0	173.9
MAR, 1985	4690.1	0.3	4690.3	27.7	46.3	76.8	516.5	667.4	36.3	2.0	4057.3	1548.0	2082.5	141.9
APR, 1985	3682.4	0.3	3682.7	27.7	46.7	77.7	270.8	422.9	33.3	2.2	3290.9	1547.2	903.1	251.9
MAY, 1985	3165.9	0.4	3166.3	27.7	46.7	86.5	86.7	247.7	34.8	2.1	2951.3	1704.7	373.0	418.1
JUN, 1985	3695.7	0.4	3696.1	27.7	46.7	92.2	59.2	225.8	36.5	2.3	3504.4	1861.3	352.7	841.4
JUL, 1985	4442.8	0.6	4443.4	27.7	46.7	97.1	51.2	222.7	39.7	2.7	4257.7	2013.9	430.5	1332.3
AUG, 1985	4535.7	0.4	4536.1	27.7	46.7	85.2	70.7	230.3	36.7	2.0	4340.5	1819.0	501.4	1399.9
SEP, 1985	4428.3	0.4	4428.7	27.7	46.7	82.5	60.5	217.5	36.2	1.7	4245.7	1767.3	305.2	1580.3
WY 1985	3789.4	0.4	3789.8	27.7	46.7	80.6	195.4	350.4	35.3	2.1	3472.5	1662.5	785.5	630.1

COL#3 = COL#1 + COL#2 COL#8 = COL#4 + COL#5 + COL#6 + COL#7 COL#11 = COL#3 - COL#8 + COL#9 - COL#10

COL#14: DIRECT DIVERSIONS ACCOUNTABLE TO THE STATE OF ILLINOIS

STATUS OF ILLINOIS' LAKE MICHIGAN DIVERSION
UNDER 1980 AMENDED U.S. SUPREME COURT DECREE

Accounting year	Annual Diversion (% of 3200 cfs)	40 Year Running Average	Deviation from 3200 cfs Annual	Cumulative Sum (cfs-years)
1981	3106.0 cfs (97.1%)	3106.0	+ 94.0	+ 94.0
1982	3087.0 cfs (96.5%)	3096.5	+ 113.0	+ 207.0
1983	3613.1 cfs (112.9%)	3268.7	- 413.1	- 206.1
1984	3431.5 cfs (107.2%)	3309.4	- 231.5	- 437.6
1985	3472.5 cfs (108.5%)	3342.0	- 272.5	- 710.1

The changes made by the Corps as discussed in previous paragraphs affect the numbers in columns one, seven, ten, and eleven. The first column is the Romeoville (or Lockport) record as recorded by the AVM and calculated by the regression equations. As stated previously, the WY84 AVM flow is 314.4 cfs greater than the Lockport flow recorded by MWRDGC and as calculated from the WES rating curves. The recalculated WY85 Romeoville flow is 0.6 cfs greater than the NIPC WY85 Romeoville flow.

The seventh column is the runoff from the Des Plaines River watershed reaching the canal. The Romeoville deductions in this column are based on computer model simulations with the revised modeling parameters discussed previously. The change in modeling parameters caused a decrease in the WY84 deduction of 10.7 cfs and a decrease in the WY85 deduction of 10.1 cfs.

The new Column, Column 10, is the deduction for Lake Michigan water used by Federal facilities. Also included in this column, for WY84, is a deduction for an emergency diversion. On September 1-5, 1984, the Corps requested and received an emergency diversion to alleviate critically low water levels in the LaGrange Pool. This diversion averaged approximately 3,000 cfs for five days. The value of 401.1 cfs for September reflects this event. The 400.0 cfs emergency diversion for September was equivalent to an average annual flow of 32.8 cfs. The Corps recommends that this flow not be included in the 3,200 cfs allocated to the State of Illinois and, as such, it has been shown as a deduction. The total WY84 deduction in column 10 is 34.2 cfs. The WY85 deduction for federal facilities is 2.1 cfs and consists of no emergency diversions.

The eleventh column, the Total Diversion, is equal to the Romeoville record minus the various deductions plus the various additions. The conversion to the Romeoville record and the revision of modeling parameters resulted in an increase in the calculated WY84 diversion from 3,105.4 cfs to 3,431.5 cfs, a difference of 326.1 cfs. The increase in the calculated WY85 diversion is from 3,461.6 cfs to 3,472.5 cfs, a difference of 10.9 cfs.

The remaining columns were unchanged from the NIPC report but are discussed in detail in the discussion section below.

DISCUSSION OF RESULTS

The following is a discussion of the column functions and water budgets. The discussion of the column functions describes the purpose of each column as well as some observations on the WY84 and WY85 values in the columns. The discussion of the water

budgets presents the purpose of each budget and the results of the budget flow balances. The results of six of the water budgets are used in the diversion calculations and the remaining budgets are used to verify the diversion simulation models. The verification budgets compare simulated to measured flows. The columns are discussed first followed by the discussion of the budgets.

COLUMNS

The 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 is presented in the discussion of Columns 12 through 14. Table 1 is a list of the 14 columns. Tables 3 and 4 are a summary of the WY84 and WY85 diversion accounting calculations, respectively. A detailed discussion of each of the columns is presented in the following paragraphs.

Column 1 Romeoville Record

The discharge at Romeoville for WY84 was 3,790.6 cfs as measured by the AVM and calculated from the regression equations. This flow is 314.4 cfs greater than the Lockport flow reported by NIPC. NIPC reported that the WY84 flow was typical of long term averages.

The Romeoville discharge for WY85 was 3,789.4 cfs as measured by the AVM and calculated from the Corps updated regression equations. This flow is 0.6 cfs greater than the Romeoville flow reported by NIPC.

The regression equations were used to calculate the AVM flows for the period prior to 12 June 1984 (1 October 1983 through 11 June 1984) before installation of the AVM. Subsequent to installation, the AVM flows were used for the majority of the period 12 June 1984 through 20 March 1985. On 21 March 1985, the AVM transducer cables were cut by a barge. Upon repair of the cables, various system and calibration problems with the AVM equipment existed and the AVM was malfunctioning for the remainder of WY85 (21 March 1985 through 30 September 1985). Thus the regression equations were used for WY85 after 20 March.

Column 2 Diversions Above Gage

Argonne Laboratories was the only diversion of Sanitary and Ship Canal water upstream of the Romeoville gage in both WY84 and WY85. Argonne reports measured daily withdrawals and the average withdrawal for both WY84 and WY85 was 0.4 cfs.

Column 3 Total Flow Through Canal

Column 3 is the sum of columns 1 and 2 and represents the total flow entering the canal system. The average WY84 canal flow is 3,791.0 cfs and the average WY85 canal flow is 3,789.8 cfs.

Column 4 Groundwater Pumpage from the Lake Michigan Watershed in Illinois Reaching the Canal

Column 4 is the effluent whose source is groundwater water supply pumpage by communities, as reported by the State of Illinois, and the annual pumpage by industrial and other private users as reported by the Illinois State Water Survey (ISWS). Several south suburbs that previously used groundwater supplies converted to Lake Michigan water in WY84 decreasing groundwater usage 1.7 cfs (3%). Column 4 currently represents a deduction from the Romeoville record and the WY84 deduction is 48.5 cfs.

Several additional south suburbs converted to Lake Michigan water in WY85 decreasing groundwater usage an additional 20.9 cfs (43%). The WY85 deduction in column 4 is 27.7 cfs.

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. Thus groundwater pumpage from within the Lake Michigan Watershed and reaching the canal continues to be a deduction.

Column 5 Groundwater Pumpage from the Des Plaines River Watershed Reaching the Canal

Column 5 is the effluent whose source is groundwater water supply pumpage by communities and the annual pumpage by industrial and other private users (51.2 cfs) minus the water supply effluent returned to the Des Plaines River through combined sewer overflows (0.3 cfs). As in column 4, the municipal water supply is reported by the State of Illinois and the Industrial and private pumpage is reported by the ISWS. The water supply effluent discharged to the Des Plaines River through combined sewer overflows is calculated using simulation. Groundwater usage decreased 4.1 cfs (7%) due to several suburbs converting from groundwater supply sources to Lake Michigan

water. This column represents a deduction from the Romeoville record and the WY84 deduction is 50.9 cfs.

In WY85, additional communities converted to Lake Michigan water supply use. Most notable are three of the five suburbs in the O'Hare WRP service area whose flow is at least partially diverted to the Northside WRP. The O'Hare plant discharges to a tributary of the Des Plaines River while the Northside plant discharges to the canal system. Thus only a portion of the flow from these suburbs is not discharged to the canal. To complicate the calculation, one of the three suburbs receives water from both groundwater sources and Lake Michigan. Because only the groundwater portion of the flow from these communities is deductible, estimates of the proportion of the transferred flow that is sanitary effluent versus infiltration and inflow must be made. Then estimates of the proportion of sanitary flow that is groundwater versus Lake Michigan water must be made to arrive at the final deductible flow.

The total flow transferred from the O'Hare service area to the Northside service area is based on an estimate provided by MWRDGC as no measurement of the transferred flow is made. The selection of communities whose flow is transferred is based on proximity to interceptor sewers tributary to the transfer location. The proportion of transferred flow that is sanitary effluent versus Infiltration and Inflow is based on proportions in simulated areas. The proportion of sanitary flow that is from groundwater versus Lake Michigan is based on the proportions in each of the communities' overall water supply.

In WY84, the O'Hare basin transfer calculation was not as critical because all of the transferred flow was deductible (all the sanitary flow was from groundwater sources and all of the infiltration and inflow was from the Des Plaines watershed, deductible under column 7). Thus the various proportion assumptions were not necessary in WY84. The assumptions made by NIPC to calculate the WY85 flows were reasonable and because no measurements were available and no models of the area exist, the calculations were made using the best available knowledge.

Annual groundwater pumpage discharged to the canal for WY85 was 46.9 cfs and the effluent returned to the Des Plaines River in combined sewer overflows was 0.2 cfs. Groundwater usage decreased again in WY85 and the decrease was 4.2 cfs (8%). The deduction for WY85 is 46.7 cfs.

Column 6 Water Supply Pumpage from Indiana Reaching the Canal

Column 6 represents the computation of Indiana water supply reaching the canal through the Grand Calumet and the Little Calumet Rivers. 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. The location of the summit is variable and highly influenced by Lake Michigan levels. Thus the calculation of this deduction from the Romeoville record is influenced by Lake Michigan levels. The high Lake levels during WY84 caused more water supply (discharged to the Grand Calumet River from municipal treatment plants) to drain toward the Calumet Sag Channel and less to flow back toward the Lake. The total Grand Calumet flow reaching Illinois in WY84 was computed as 61.4 cfs while 54.7 cfs of that flow was determined to be water supply. The total WY84 water supply deduction including the flow from the Little Calumet River is 59.7 cfs.

Lake levels were higher in WY85 than in WY84, resulting in significantly larger computed Grand Calumet River flows reaching Illinois. The total Grand Calumet flow reaching Illinois in WY85 was computed as 105.2 cfs and 75.3 cfs of that flow was determined to be water supply. The total WY85 water supply deduction including the flow from the Little Calumet River is 80.6 cfs.

Column 7 Runoff from Des Plaines River Watershed Reaching the Canal

This column was formerly Column 8 in NIPC's accounting report. The change is a result of no longer reporting sewer induced groundwater infiltration in Indiana. Runoff from the Des Plaines River Watershed is composed of three primary components: (1) Infiltration and Inflow to combined and separate sewers that discharge to the four MWRDGC Water Reclamation Plants which discharge to the canal (110.2 cfs), (2) Des Plaines watershed runoff in combined sewer overflows that discharge to the canal (9.7 cfs), and (3) runoff from the Lower Des Plaines and Summit Conduit areas that drain directly to the canal (76.6 cfs). This column represents a deduction from the Romeoville record and the WY84 deduction is 196.5 cfs. Virtually all of this deduction is determined by simulation.

The WY85 volume of Des Plaines runoff reaching the canal is very similar to WY85. The infiltration and inflow discharging to the water reclamation plants was 109.1 cfs, the infiltration and inflow reaching the canal through combined sewer overflows was 9.3 cfs, and the runoff from the Lower Des Plaines and Summit Conduit areas was 77.0 cfs. The total deduction for column 7 in WY85 is 195.4 cfs. In WY85, the deduction is largely determined by simulation but it is also influenced by the O'Hare basin flow transfer as was discussed under column 5.

Column 8 Total Deduction from the Romeoville Gage Record

This column was formerly column 10 in the NIPC accounting report. The change is the result of no longer reporting sewer induced groundwater infiltration in Indiana and Illinois. 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 WY84 is 355.5 cfs and the total deduction for WY85 is 350.4 cfs.

Column 9 Lake Michigan Pumpage not Discharged to the Canal

This column was formerly column 11 in the NIPC accounting Report. 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) water supply used by communities serviced by WRPs that do not discharge to the canal (28.8 cfs) and (2) Lake Michigan water supply used by communities serviced by WRPs that do discharge to the canal but whose combined sewer overflows discharge to the Des Plaines River (1.4 cfs). The communities that make up the flow in the first component are distant northwest suburbs whose treated effluent is discharged to the Des Plaines River. The flow of the first component is measured while the flow of the second component is derived from simulation. Column 9 represents an addition to the Romeoville record and the total WY84 addition is 30.2 cfs.

In WY85, Lake Michigan the water supply used by communities serviced by WRPs that do not discharge to the canal increased to 33.7 cfs. The combined sewer overflows discharged to the Des Plaines River by communities serviced by WRPs that do discharge to the canal increased to 1.6 cfs. The total WY85 addition for column 9 is 35.3 cfs. A portion of the flow in the first category is from communities in the transferred portion of the O'Hare basin.

Column 10 Federal Facilities Withdrawals Discharged to the Canal

Column 10 is a new column whose flow was previously included in Column 9 above. Column 10 represents lake Michigan diversions for Federal use, not chargeable to Illinois and it is typically water supply used by federal facilities (1.4 cfs). The facilities are Glenview Naval Air Station, Fort Sheridan, and Hines hospital. However in 1984, the Corps of Engineers requested and received an emergency diversion to alleviate critically low water levels in the LaGrange Pool. The diversion averaged approximately 3000 cfs over a period of five days beginning at approximately noon on 5 September. The annualized amount of this diversion is 32.8 cfs. Column 10 represents a deduction from the Romeoville record and the amount of the WY84 deduction is 34.2 cfs.

In WY85 there were no emergency diversions and the entire flow was used for water supply at Federal facilities. The WY85 deduction for column 10 is 2.1 cfs.

Column 11 Total Diversion

Column 11 is equal to column 3 minus column 8 plus column 9 minus column 10. The total diversion for WY84 is 3,431.5 cfs. This amount is 231.5 cfs greater than Illinois's long term diversion allocation of 3,200 cfs. The running average diversion, beginning with WY81, is 3,309.4 cfs and the cumulative deviation from the 3,200 cfs allocation is -437.6 cfs. The negative deviation indicates that the cumulative diversion is greater than an average of 3,200 cfs for the period.

The total diversion for WY85 is 3,472.5 cfs which is 272.5 cfs greater than Illinois's long term allocation of 3,200 cfs. The running average diversion at the end of WY85 is 3,342.0 cfs and the cumulative deviation is -710.1 cfs.

Columns 12 - 14 Lake Michigan Diversion Components

Columns 12, 13, and 14 represent the three Lake Michigan diversion components (Lake Michigan pumpage accountable to Illinois, runoff from the diverted Lake Michigan watershed, and direct diversion through the lakefront structures). The sum of the columns (3,082.3 cfs) should theoretically equal the total diversion as shown in column 11 (3,431.5 cfs) with one exception. The Romeoville record receives WRP effluent which is only 90% of the water supply pumpage. This is based on a consumptive loss (water supply pumpage which is consumed or lost prior to reaching the WRP) estimate of 10% of the water supply pumpage (International Great Lake Diversion Consumptive Use Study Board, 1981). Because the diversion estimate from columns 12 - 14 is based on simulation, suspect ratings of the lakefront structures, and flow separation techniques, the estimate is not expected to be as accurate as the AVM based estimate. However a difference between estimates of 349.2 cfs or 10% is only a marginal balance. The discrepancy in these two estimates is related to the balance in budget 13, discussed in a subsequent section, and potential sources of the discrepancy are addressed in that budget discussion.

Using the figures from these three columns, approximately 54% of the WY84 Illinois diversion was attributable to pumpage from Lake Michigan for domestic water supply. Runoff from the diverted Lake Michigan Watershed accounted for 27% of the diversion and direct diversion through the lakefront structures accounted for 19% of the diversion.

The sum of columns 12 through 14 for WY85 is 3,078.1 cfs which is 394.4 cfs less than the flow in column 11 of 3,472.5 cfs. The difference between the two diversion estimates is 11% which is similar to the difference in WY84. Thus it is likely that the source(s) of the WY84 imbalance is the same as for the WY85 imbalance. In WY85, 54% of the sum of columns 12 through 14 is pumpage from Lake Michigan for domestic water supply, 26% is runoff from the diverted Lake Michigan watershed accountable to Illinois, and 20% is direct diversion through the lakefront structures. The percentages are nearly identical to those of WY84.

BUDGETS

The first three budgets are used to sum the water supply for the area influenced by the diversion and the remaining budgets compare measured and simulated flows with the exception of budgets 4 and 9 through 11. Those 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. In general, the WY84 and WY85 budget balances are quite good and are an improvement over the WY83 accounting budgets, presented in the FY85 Annual Report (USACE, 1986), and similar to the results of the NIPC accounting as discussed in the following paragraphs. A list of the budgets is given in table 2.

Budgets 1-3, Water Supply Pumpage

Budgets 1 through 3 are not comparisons of simulated and recorded flows but rather they are summations of critical water supply pumpage data. Groundwater pumpage decreased in both WY84 and WY85 due to conversion to Lake Michigan water supply by several suburbs. Groundwater pumpage from the Lake Michigan watershed decreased 3% in WY84 and 43% in WY85. Groundwater pumpage from the Des Plaines River watershed decreased 7% in WY84 and 8% in WY85. The total decrease in groundwater pumpage was 5.8 cfs in WY84 and 25.1 cfs in WY85. Illinois Lake Michigan water supply pumpage increased 2% or 38.3 cfs in WY84 and 1% or 10.5 cfs in WY85.

It is expected that in the future, the current trend of converting from groundwater sources to Lake Michigan water will continue. There are two reasons that communities are converting to Lake Michigan water. The first is that the quality of the groundwater supply of many communities is marginal. Many are forced to use bottled drinking water because of taste problems. The second reason is because of insufficient water quantity. Water levels in the wells of many western suburbs are dropping because the aquifers do not have a sustainable yield sufficient to support the greatly increasing population in those suburbs.

Budgets 5-8,12 MWRDGC Water Reclamation Plants

The budgets for the water reclamation plants compare the simulated flows to the measured inflows at the WRPs. The simulated flows were developed from an estimated sanitary flow with a daily, weekly, and monthly flow variation and from precipitation based simulated runoff. In the Burke update of the diversion accounting models, no change was made to the sanitary flow estimates, rather the changes were related to estimating the amount of runoff that enters the sewer system. The tables below compare the NIPC and revised Simulated/Recorded (S/R) ratios for the inflows to the four MWRDGC water reclamation plants and for the Upper Des Plaines pump station.

WY84

Location	Simulated/Recorded Flow Ratios		Change from Previous Estimate
	NIPC	Corps	
Northside WRP	0.92	0.97	Large Improvement
West-Southwest WRP	0.99	0.99	No Change
Calumet WRP	0.83	0.89	Large Improvement
Lemont	-	1.02	-
Upper Des Plaines P.S.	-	0.83	-

WY85

Location	Simulated/Recorded Flow Ratios		Change from Previous Estimate
	NIPC	Corps	
Northside WRP	0.96	1.00	Slight Improvement
West-Southwest WRP	1.02	1.03	No Change
Calumet WRP	0.90	0.96	Large Improvement
Lemont	-	1.16	-
Upper Des Plaines P.S.	-	0.89	-

As can be seen by examining the tables above, significant improvements over the original NIPC accounting were realized at two of the WRPs and a similar balance was achieved at a third for both WY84 and WY85. The WY84 flow weighted average S/R ratio for the three primary WRPs improved from 0.91 to 0.95. The WY85 flow weighted average S/R ratio for the three primary WRPs increased from 0.98 to 1.01 which are equally good balances. The NIPC flow weighted S/R ratio for WY83 was 0.88. Thus both the NIPC WY84 and WY85 accounting and the accounting in this report are significant improvements over WY83.

At the Northside and Calumet WRPs, significant improvements resulted from using the revised modeling parameters. The

Northside WRP balance is quite good for both years while the Calumet balance is marginal in WY84 and quite good in WY85. The increase in S/R ratio at the Calumet and Northside plants is the result of increasing the amount of runoff entering the sanitary sewers.

The annual S/R ratio at the Calumet plant is quite good for WY85. However, the daily S/R ratios vary considerably. The Calumet measured record exhibits much less variation in flow than the simulated record. The recorded Calumet daily flow variation is also much less than what is found at the other WRPs where the daily S/R ratios are generally fairly consistent. This would seem to indicate that there is storage in the Calumet system that does not exist at the other WRPs and is not properly being modeled. However, the amount of storage required to attenuate the flows would be tremendous, requiring some type of storage facility where none was known to exist. A more detailed discussion of the Calumet balance and the problems associated with it can be found in the NIPC Accounting reports in Appendices B2 and B3.

There are some apparent errors regarding the presence of combined versus separate sewers in the Calumet WRP simulation in the vicinity of the Calumet River, between the O'Brien Lock and Lake Michigan. These errors are similar to those in the Des Plaines River Watershed that were corrected by Burke Engineering, under contract with the Corps. The area in question is approximately 10 square miles and is not nearly large enough to make a significant impact on the flow balance at the Calumet WRP which serves a total area of approximately 300 square miles. This error has no impact on the diversion calculation since none of the area is in the deductible Des Plaines River Watershed.

At the West-Southwest WRP, the two balances are virtually identical for both WY84 and WY85. The balance did not change because of the offsetting impacts of increasing the runoff entering sanitary sewers and decreasing the combined sewer drainage area.

The Lemont balance is quite good in WY84. However the balance is quite bad in WY85. The reason for the large difference in balance is unknown. However, the average annual Lemont WRP flow is quite small (2 cfs) compared to the average flow at the other plants (1,100 cfs at West-Southwest). Thus the Lemont balance is not nearly as important as the other balances. NIPC did not report a balance for the Lemont WRP.

At the Upper Des Plaines pump station, the balance is marginal although it is better in WY85 than in WY84. However, the accuracy of the flow meters is suspect. Comparison of the simulated and recorded flows for the pump station indicates good agreement in terms of timing of high and low flows. Thus it appears that with calibration of the pump station meters, a better balance may result.

Lower Des Plaines Runoff

The WRP and Upper Des Plaines pump station budgets, discussed above, provide a measured verification for each of the flow simulations with the exception of the simulation of runoff directly to the canal from the lower Des Plaines watershed. This simulation consists of lower Des Plaines watershed overland flow directly to the canal system and combined sewer overflows to the canal. Prior to WY83, the lower Des Plaines runoff was calculated using the Hart Ditch streamflow gage at Munster, IN with a small adjustment for the difference in drainage area between the two watersheds. WY83 was the first year in which the new accounting procedure was used. In the 1985 Annual Report, certifying the WY83 Diversion Accounting Report, a comparison of the calculated lower Des Plaines watershed runoff and the measured Hart Ditch runoff was made to verify the calculated flow. A similar comparison for WY84 and WY85 is discussed below.

In WY84 the average runoff from the lower Des Plaines watershed, including infiltration and inflow to the WRPs, was 103 cfs while the average runoff from the Hart Ditch watershed was 87 cfs. The difference appears primarily to be the result of 6.8 inches of additional precipitation that fell on the lower Des Plaines watershed (34.9 inches for the Hart Ditch and 41.7 inches for Lower Des Plaines).

In WY85 the average runoff from the lower Des Plaines watershed, including infiltration and inflow to the WRPs, was 102 cfs while the average runoff from the Hart Ditch watershed was 74 cfs. However, the total annual precipitation was virtually the same for the two watersheds (36.0 inches for Hart Ditch and 37.2 inches for lower Des Plaines). In WY85 the difference in runoff between the watersheds appears to be the result of precipitation timing rather than precipitation amount. The Hart Ditch watershed had more precipitation during the summer months when evaporation is high while the lower Des Plaines watershed had more precipitation during the spring months when evaporation is low and the soil is saturated.

The two watersheds are similar in geology, land use, and hydrology and should have similar long term runoff characteristics. However because the watersheds are over 25 miles apart, the runoff at any particular time is not likely to be the same. This is evidenced by the difference in precipitation between the two watersheds in WY84. The Hart Ditch watershed (as represented by the Park Forest, IL rainfall gage) experienced 34.9 inches of precipitation while the lower Des Plaines watershed (as represented by the Midway, IL rainfall gage) experienced 41.7 inches of precipitation. Because of the difference in localized precipitation between the watersheds, the Hart Ditch comparison does not provide any substantial insight on the accuracy of the lower Des Plaines runoff simulation.

Lower Des Plaines watershed runoff is calculated from the same runoff parameters as areas of similar land use in simulations verified by the WRP budgets. Thus the lower Des Plaines runoff calculation is indirectly verified by the WRP budgets. Because the Hart Ditch watershed does not provide a good verification and because the lower Des Plaines watershed runoff is indirectly verified by other budgets, the Hart Ditch verification will no longer be used.

Budgets 4, 9-11 Stream Gaging Sites

The stream gage budgets are not used to compare simulated to recorded flows but rather 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 13. The flow at the stream gaging sites is also part of Budget 13, the canal system budget.

Budget 13 Canal System

Budget 13 compares the inflows and outflows to the canal system. 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 at Lockport, backflows through the lakefront structures, and withdrawals upstream of Lockport by Argonne National labs. The individual components are presented in table 5 for WY84. The table indicates that the inflows are 431.1 cfs (11%) less than the outflows which would indicate that there are unreported inflows to the canal system. The NIPC report indicated a difference between inflows and outflows of approximately 100 cfs. Virtually the entire discrepancy between the current difference and the NIPC difference is the result of using the measured AVM flow and regression equations rather than using the MWRDGC reported Lockport outflows. Because of the higher accuracy of the AVM and regression equations, the 431.1 cfs difference is more indicative of actual conditions.

The canal balance for WY85 is presented in table 6. The table indicates that the inflows are 503.8 cfs (13%) less than the outflows. The canal flow balance is somewhat worse than in WY84.

Review of the data indicates that the difference between inflows and outflows is not well correlated with any of the expected parameters such as direct diversion, stormwater runoff, or Romeoville flow. However, the average WY85 Lake Michigan stage near the lake front structures was +2.2 feet Chicago City Datum (CCD), 0.6 feet higher than the average WY84 stage of +1.60

TABLE 5
Water Year 1984
SUMMARY OF FLOW COMPONENTS ABOVE ROMEOVILLE (Budget 13)

INFLOWS TO THE CHICAGO SANITARY AND SHIP CANAL	
Lake Controlling Structures (Measured)	
Wilmette	38.8
CRCW	278.6
O`Brien	283.5
Streamflows (Measured)	
North Branch at Touhy	140.8
Little Calumet at South Holland	215.7
MSDGC Treatment Plants (Measured)	
Northside	420.2
West - Southwest	1,162.7
Calumet	358.6
Adjustment for Interlake - Riverdale	-2.5
Lemont	2.0
Other Point Sources (Measured)	5.4
Summit Conduit (Estimated)	9.7
Grand Calumet Streamflow (Estimated)	61.3
Combined Sewer Overflows in Ungaged Watershed (Simulated)	212.3
Direct Runoff in Ungaged Watershed (Simulated)	140.5
COE Emergency Nav. Make - up (Estimated)	32.8
TOTAL	**3,360.4**
OUTFLOWS FROM THE CHICAGO SANITARY AND SHIP CANAL	
Argonne Withdrawal (Measured)	0.4
AVM @ Romeoville Recorded Flow	3,790.6
Lake Controlling Structures (Measured) Backflows	0.5
TOTAL	**3,791.5**
DIFFERENCE BETWEEN INFLOWS AND OUTFLOWS	**-431.1**

TABLE 6
Water Year 1985
SUMMARY OF FLOW COMPONENTS ABOVE ROMEOVILLE (Budget 13)

INFLOWS TO THE CHICAGO SANITARY AND SHIP CANAL	
Lake Controlling Structures (Measured)	
Wilmette	26.8
CRCW	306.2
O'Brien	297.2
Streamflows (Measured)	
North Branch at Touhy	107.7
Little Calumet at South Holland	180.8
MSDGC Treatment Plants (Measured)	
Northside	438.8
West - Southwest	1,115.9
Calumet	336.9
Adjustment for Interlake - Riverdale	-2.5
Lemont	1.8
Other Point Sources (Measured)	6.1
Summit Conduit (Estimated)	11.7
Grand Calumet Streamflow (Estimated)	105.3
Combined Sewer Overflows in Ungaged Watershed (Simulated)	209.3
Direct Runoff in Ungaged Watershed (Simulated)	145.1
TOTAL	**3,287.1**

OUTFLOWS FROM THE CHICAGO SANITARY AND SHIP CANAL	
Argonne Withdrawal (Measured)	0.4
AVM @ Romeoville Recorded Flow	3,789.6
Lake Controlling Structures (Measured) Backflows	0.9
TOTAL	**3,790.9**
DIFFERENCE BETWEEN INFLOWS AND OUTFLOWS	**-503.8**

feet CCD and the canal flow imbalance increased 73 cfs from WY84 to WY85. The 0.6 foot difference is significant considering that the top of an 1,100 section of the Chicago harbor wall was at 3.0 feet CCD prior to WY87. This makes wind, wave, and barometric set-up of the lake likely to significantly increase the amount of overtopping of the wall. Prior to WY87, there was also significant leakage through the harbor wall and the leakage rate was likely related to the difference in water level across the wall. The impact of lake level on wall overtopping and leakage is further illustrated by examining the last four months of WY85 in which the lake stage varied between 2.6 and almost 2.9 feet CCD. During this period the difference between canal inflows and outflows varied between 615 cfs and 815 cfs. In WY87, the wall was raised and repaired which virtually eliminated the overtopping and leakage. The amount of the leakage and overtopping is difficult to estimate because both lake levels and weather conditions contributed to the problem and not enough is known about the condition of the wall or wave heights and wind setup at the time of the problem to make any estimates.

While it appears that the condition of the harbor wall and the high lake levels contributed to a large portion of the canal flow imbalance, it is unlikely that the leakage and overtopping was as much as 400 cfs or 500 cfs. During development of the WY87 accounting report, which is scheduled for transmittal with the 1991 Annual Report, the impact of the overtopping and leakage should be quite evident.

Other possible sources of the canal flow imbalance include underreporting of the lakefront flows through the sluice gates and locks and 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. Unaccounted flows could include unreported groundwater discharges to the canal.

ACCOUNTING IMPROVEMENTS

As a result of reviewing and calculating the WY84 and WY85 diversion accounting, a number of areas of potential improvement have become evident. The following paragraphs discuss those areas where improvement is needed.

O'Hare WRP Flow Transfer

A portion of the O'Hare WRP service area (tributary to the Des Plaines River) is diverted to the Northside WRP (tributary to the Canal system). The water supply in the diverted area was entirely from groundwater sources during WY84. Thus the total basin transfer was a deduction from the Romeoville record for that year. 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 was provided by MWRDGC. At the current time, the amount of the transfer is somewhat suspect as it is only estimated.

In WY85, a portion of the diverted service area converted from groundwater supply sources to Lake Michigan water, thus, the full basin transfer was no longer a deduction. A determination of the deduction required not only an estimate of the amount transferred but also an estimate of the sanitary effluent portion of the transfer. It also required an estimate of the Lake Michigan water portion of the effluent. 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.

Indiana Flow Deduction

The flow in the Grand Calumet River drains both to the Lake via Indiana Harbor and to the Calumet Sag Channel. When lake levels are high a larger portion of the flow drains to the Calumet Sag. The Grand Calumet River flow calculation is based on a regression equation relating Lake Michigan stages and measured flows in Hart Ditch to the Grand Calumet River flow. A number of current meter measurements were made on the Grand Calumet and those observations were used to develop the regression equation.

The majority of the flow in the Grand Calumet River, draining to Illinois, is water supply effluent. The Lake level influences the portion of the effluent that drains to Illinois and the portion that drains back to the lake. The water supply deduction is equal to the total water supply pumpage discharged to the 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.

This procedure is adequate and is the only method currently available to calculate the Indiana deduction. However, with additional flow measurements and/or a more detailed review of the hydraulics of the Grand Calumet river, a superior method of calculating the deduction could be developed.

Calumet WRP Balance

The Calumet WRP balance was discussed in the previous section where it was noted that although the annual S/R ratio was reasonable, the simulated flows exhibit much more fluctuation than the recorded flows. While the simulated flow fluctuations at the Calumet plant are similar to those at the other WRPs, the recorded Calumet flow fluctuations are much less than at the other WRPs. The problem may be related to flow measurement at the

plant. Personnel at MWRDGC need to be consulted on this issue to determine the source of the problem.

The portion of the Calumet WRP service area in the vicinity of the Calumet River needs to be investigated to correct errors regarding the presence of combined versus separate sewers.

Upper Des Plaines Pump Station

A review of the Upper Des Plaines pump station and its flow record indicates that the flow meters at the station are operating but need calibration. Upon calibration of the pump station meters, the pump station budget could become one of 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. All of the runoff draining to the pump station is from the Des Plaines watershed, is deductible, and is from somewhat similar land cover as the remaining deductible Des Plaines watershed. Thus the characteristics of the Upper Des Plaines watershed may be the gaged area most representative of the total deductible Des Plaines watershed. Calibration and use of the Upper Des Plaines Pump Station record is being reviewed at this time.

Canal System Balance

As discussed previously, the canal system balance indicated that the total inflows were 10% to 13% less than the outflows. A portion of the imbalance appears to be the result of overtopping and leakage through the Chicago Harbor wall. The wall was repaired at the beginning of WY87 and the diversion accounting for that time should provide valuable insight on the magnitude of the overtopping and leakage. Flow meter measurements at the lake front direct diversion points need to be made to determine if the rating curves for the sluice gates and locks need updating or if leakage is still significant. Reconnaissance missions should also be made to determine if there are any unreported discharges that are being made directly to the canal.

Precipitation Data

The runoff simulation models used to perform the diversion accounting are driven by precipitation and other meteorologic data. In performing the WY83 diversion accounting, NIPC discovered problems with the precipitation data related to shielding of the rain gages by buildings and other obstructions. To address this problem, the Illinois State Water Survey (ISWS) was contracted to assess the problem and adjust the precipitation data. The ISWS also adjusted the WY84 and WY85 data used in this report. To resolve the problem, a precipitation gage network of

25 gages was installed by the ISWS under contract with the Corps. However, no data will be available from the network until WY90. Prior to WY90, the precipitation data will be adjusted as in the past.

SUMMARY

The diversion accounting performed by NIPC with the adjustments for AVM flows and runoff parameters presented in this report were performed with the most current available data and the best current engineering practice and scientific knowledge.

The Lake Michigan Diversion Accountable to Illinois for WY84 was 3,431.5 cfs which is 231.5 cfs greater than the long term allocation of 3,200 cfs. The sources of the Illinois diversion were approximately 54% Lake Michigan water supply, 27% runoff from the diverted Lake Michigan watershed, and 19% direct diversion through the lakefront structures.

The Lake Michigan Diversion Accountable to Illinois for WY85 was 3,472.5 cfs which is 272.5 cfs greater than the long term allocation of 3,200 cfs. The sources of the Illinois diversion were approximately 54% Lake Michigan water supply, 26% runoff from the diverted Lake Michigan watershed, and 20% direct diversion through the lakefront structures.

Improvements in the water reclamation plant balances resulted from updating the model simulation parameters and the balances were all within 3% with the exception of the Calumet WRP which had an 11% imbalance in WY84. The improved balances indicate that the diversion calculations based on the updated simulation models should be more accurate.

The flow measurement and modeling of the Calumet WRP needs to be investigated. The flow at the Calumet plant appears to behave very much differently than the flow at the other major water reclamation plants, indicating that a metering problem may exist.

The Upper Des Plaines pump station flow meters have not been maintained and/or calibrated in 20 years. Calibration of the meters is required to restore their accuracy. Subsequent to calibration, the pump station should become a valuable verification site for the simulation models.

The Hart Ditch and lower Des Plaines watersheds are a sufficient distance apart to experience different rainfall events. Thus, the comparison of measured Hart Ditch flow and simulated lower Des Plaines watershed runoff does not provide a good verification of the Lower Des Plaines simulation. The Hart Ditch comparison will no longer be used.

The error in the canal system budget is probably partially related to overtopping and leakage through the Chicago Harbor wall. However further investigation is needed. The balance should improve somewhat in WY87 after the wall was repaired and an indication of the amount of leakage and overtopping may become evident during development of the WY87 accounting report.

The O'Hare basin transfer requires further investigation to determine the best procedure for estimating the flow transfer and the proportions of sanitary effluent and infiltration and inflow.

The calculation for the Indiana flow deduction could benefit from flow measurements and further investigation of the Grand Calumet River hydraulics.

A precipitation gage network was required to accurately measure the rainfall in the simulated area. The network, installed during WY89, will eliminate the need for adjustments to the precipitation data and reduce the uncertainty associated with the rainfall data.

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APPENDIX B3

NORTHEASTERN ILLINOIS PLANNING COMMISSION

LAKE MICHIGAN DIVERSION ACCOUNTING

WATER YEAR 1985 REPORT

LAKE MICHIGAN DIVERSION ACCOUNTING

FOR WATER YEAR 1985

Prepared by

THE NORTHEASTERN ILLINOIS PLANNING COMMISSION

For

THE ILLINOIS DIVISION OF WATER RESOURCES

December, 1988

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LAKE MICHIGAN DIVERSION ACCOUNTING FOR WATER YEAR 1985

I. Introduction

The 1985 water year accounting for the State of Illinois' diversion of Lake Michigan water is the result of a major effort by the state to improve the accounting procedure which began with the 1983 water year report. Previous accounting procedures had relied on estimation techniques which met the directives of the U.S. Supreme Court decree but did not attempt to cross check measured and estimated values. The current accounting procedure also meets the directives of the U.S. Supreme Court decree and at the same time, through a system of water budgets, checks whether the water entering key points in the diverted watershed system balances with the total water leaving those points. A comparison of previous accounting procedures to the current procedure is contained in the 1983 report (COE, 1986).

A. Budgets

A total of 12 water budgets are prepared using both measured and estimated data, the latter obtained from simulation of the hydrologic response of the major sewer systems and ungaged watersheds. Originally, there were 13 budgets but Budget 6 was dropped in water year 1984 due to the uncertainty of the flow measurement at the Upper Des Plaines Pumping Station. The remaining 12 water budgets are the starting point for the analysis of data collected to prepare the diversion accounting report. These budgets are discussed in detail in the Lake Michigan Diversion Accounting Manual of Procedures (NIPC, 1985). In balancing against the most important flow budget, Lockport Powerhouse and Controlling Works, over 85 percent of the flow data was measured and less than 15 percent estimated.

Table 1 shows the budgets used in the accounting procedure. Budgets 1 through 3 are not true budgets, in the sense that inputs are measured against outputs, but rather are summations of

critical water supply pumpage data by user. Further, Budgets 4,9,10, and 11 do not independently balance inputs versus outputs. These budgets are used to estimate stormwater runoff at stream gages by subtracting sanitary and point source flow from the streamflow record. Budgets 5,7,8,12 and 13 compare measured and estimated inputs against measured output. At the Metropolitan Sanitary District of Greater Chicago (MSDGC) treatment plants (Budgets 5,7,8 and 12) this is actually a balancing of estimated inputs versus measured inputs to the treatment plants, since plant effluent is not measured.

Table 1: Water Budgets

No.	Name	Tributary to Nos.
1	Lake Michigan Water Supply	4-11, 13
2	Groundwater Supply Lake Michigan Watershed	4-11, 13
3	Groundwater Supply Des Plaines Watershed	5-8, 12, 13
4	North Branch Chicago River at Touhy Avenue	13
5	Northside Treatment Plant	13
6	Upper Des Plaines Pumping Station (Not used in Water Year 1984)	7
7	West-Southwest Treatment Plant	13
8	Calumet Treatment Plant	13
9	Little Calumet River at State Line	11
10	Thorn Creek at Thornton	11
11	Little Calumet River at South Holland	13
12	Lemont Treatment Plant	13
13	AVM Gage at Romeoville	-

B. The Accounting Report

Following the preparation of these budgets, their components are used to compute the accounting report. Table 2 is the accounting report for the 1985 water year.

Table 2: Diversion Accounting Report for
Water Year 1985

ILLINOIS DIVISION OF WATER RESOURCES DIVERSION ACCOUNTING REPORT
FOR THE PERIOD FROM: OCTOBER, 1984 TO: SEPTEMBER, 1985
ALL DATA ARE PRESENTED IN CUBIC FEET PER SECOND (CFS)

DATE	ROMEO-VILLE RECORD	DIVERSN ABOVE GAGE	TOTAL FLOW THROUGH CANAL (1+2)	GRNDWTR PUMPAGE FROM LAKE MICH. WATRSHD IN ILLNOIS	GRNDWTR PUMPAGE FROM DES PLAINES WATRSHD	WATER SUPPLY PUMPAGE FROM INDIANA REACHNG CANAL	SEWER INDUCED GRNDWTR PUMPAGE FROM DIVERTD WATRSHD IN * INDIANA	RUNOFF FROM DES PLAINES WATRSHD REACHNG CANAL	SEWER INDUCED GRNDWTR PUMPAGE FROM DIVERTD WATRSHD IN * ILLNOIS	TOTAL DEDUC-TIONS FROM LOCK-- PCRT RECORD **	LAKE MICH. DOMEST. PUMPAGE NOT DISCHRG TO CANAL (W/ADJ)	TOTAL DIVERSN ***	PUMPAGE FROM LAKE MICH. ACCTBLE TO ILLNOIS	RUNOFF FROM DIVERTD WATRSHD	DIRECT DIVERSN THROUGH LAKE CONTROL STRCTRS
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
OCT1984	3690.5	0.4	3700.0	27.6	46.8	66.7	1.2	131.3	32.6	272.4	31.1	3458.6	1556.7	409.6	1016.8
NOV1984	2907.5	0.3	2907.8	27.6	46.7	73.8	1.4	225.7	92.8	373.8	30.7	2564.7	1498.0	718.5	148.8
DEC1984	3017.4	0.3	3017.6	27.6	46.7	73.7	1.3	323.4	88.4	471.4	31.7	2577.9	1503.4	941.2	137.5
JAN1985	3165.3	0.3	3165.5	27.6	46.8	76.3	1.8	223.3	78.0	374.1	31.2	2822.6	1548.2	725.2	131.9
FEB1985	4022.0	0.3	4022.2	27.6	46.4	79.2	0.8	401.2	113.0	554.4	34.8	3502.7	1574.6	1715.3	175.5
MAR1985	4790.3	0.3	4790.6	27.6	46.4	76.8	2.2	560.8	78.2	711.6	34.2	4113.1	1548.0	2083.6	145.0
APR1985	3695.3	0.3	3695.6	27.6	46.8	77.7	0.1	260.6	-16.9	412.8	30.5	3313.3	1547.2	900.6	278.3
MAY1985	3222.7	0.4	3223.1	27.6	46.8	86.5	-0.0	86.0	-6.6	246.9	32.3	3008.5	1704.7	346.9	483.5
JUN1985	3701.3	0.4	3701.7	27.6	46.8	92.3	0.2	58.9	4.4	225.6	33.9	3509.9	1861.4	353.1	918.7
JUL1985	4359.4	0.6	4360.0	27.6	46.8	97.2	0.2	61.0	5.7	232.6	36.8	4164.2	2013.9	434.1	1419.7
AUG1985	4553.5	0.4	4553.9	27.6	46.8	85.2	0.7	77.8	16.8	237.4	34.6	4351.1	1819.0	491.0	1487.2
SEP1985	4336.9	0.4	4337.3	27.6	46.8	82.5	0.5	60.3	10.9	225.2	34.2	4146.2	1767.3	308.0	1642.8
MEAN	3706.0	0.4	3709.1	27.6	46.7	80.7	0.9	205.5	41.1	360.5	33.0	3461.6	1662.5	778.6	668.6

(* SEWER INDUCED GROUNDWATER PUMPAGE (COLUMNS 7 AND 9) NOT INCLUDED AS A DEDUCTION PER U.S. JUSTICE DEPT. OPINION)
(** COLUMN 10=COLUMNS 4+5+6+8) (*** COLUMN 12=COLUMNS 3-10+11)

NORMAL END FOR THIS JOB

STATUS OF ILLINOIS' LAKE MICHIGAN DIVERSION
UNDER 1980 AMENDED U.S. SUPREME COURT DECREE

Accounting Year	Annual Diversion (% of 3,200 cfs)	40 Year Running Avg.	CFS - Years	
			Annual	Cumulative Sum
1981	3106 cfs (97)	3106	+ 94	+ 94
1982	3087 cfs (96.5)	3096	+113	+207
1983	3613 cfs (113)	3269	-413	-206
1984	3105 cfs (97)	3228	+ 95	-112
1985	3462 cfs (108)	3275	-262	-374

II. Observations

Observations obtained from the 1985 water year results follow. There was a significant diference between estimated and recorded components during the year (13% discrepancy versus 3% in water year 1984 and 10% in water year 1983).

A. Record at Romeoville

The 1985 water year represents the first usage of the acoustic velocity water at Romeoville for Lake Michigan diversion accounting. The use of this gage is expected to yield significantly more accurate measurements of discharge on the Sanitary and Ship Canal. The record developed by the MSDGC at Lockport will no longer be used for diversion accounting.

Table 3 presents Budget 13 at Romeoville and shows the significant discrepancy of 474.8 cfs between inputs and outputs. With few exceptions, the different categories of flow inputs are within a few percent of their 1984 water year values. Exceptions are Lake Controlling Structures (+11 percent), Streamflows (-23.5 percent), and Grand Calumet Streamflow (+71.5 percent). Of particular note is that the Romeoville record is 9 percent higher (312.6 cfs) than in water year 1984 even though streamflows and generally runoff and MSD treatment plant flows have dropped relative to water year 1984. This, coupled with historic high lake levels, the increase in Grand Calumet and Lake Controlling Structure flows, suggest that unmeasured leakage through lakefront structures is the cause of increased flows. Further examination of the daily inflow records versus the Romeoville gage show that the differences are present during low flow periods, suggesting a constant inflow source not dependent on hydrology such as lakefront leakage.

Table 3: Summary of Flow Components above Romeoville (Budget 13)
Water Year 1985

Lake Controlling Structures (Measured)	
Wilmette	26.8
CRCW	344.8
O'Brien	297.2
Backflows	-0.9
Streamflows (Measured)	
North Branch at Touhy	107.7
Little Calumet at South Holland	180.8
MSDGC Treatment Plants (Measured)	
Northside	420.2
West-Southwest	1115.9
Calumet	336.9
Adjustment for Interlake-Riverdale	-2.5
Lemont	2.0
Other Point Sources (Measured)	6.1
Summit conduit (Estimated)	11.7
Argonne Withdrawal (Measured)	-0.4
Grand Calumet Streamflow (Estimated)	105.3
Combined Sewer Overflows in Ungaged Watershed (Simulated)	217.6
13A Pumping Station (Estimated)	-0.3
Direct Runoff in Ungaged Watershed (Simulated)	145.1
Total	3314.0
Romeoville Recorded Flow	3788.8
Difference	474.8

B. Water Budgets at MSDGC Treatment Plants

Water balances at the MSDGC Northside (Budget 5), West-Southwest (Budget 7) and Calumet (Budget 8) treatment plants are much closer than in previous years. Estimated inputs range from 10 percent below to 2 percent above measured inputs. The overall difference is only 30 cfs, or 2 percent below measured inputs, which is significantly better than the 12 percent difference observed in 1983 and the 6 percent difference of 1984. The budgets for the MSDGC treatment plants are constructed by estimating an hourly sanitary return flow pattern and quantity and then simulating infiltration, inflow and combined sewer overflows. Sanitary return flow to the MSDGC treatment plants was assumed to be 90 percent of service area water supply pumpage. This assumption of 10 percent consumptive use agrees with conclusions developed by the #nternational Great Lakes Diversions and Consumptive Use Study Board (IGLDCUSB, 1981). This pumpage was observed to have remained about the same between 1984 and 1985. Since about 80 percent of simulated influent to these MSDGC treatment plants is sanitary flow, the estimation of influent is highly sensitive to return flow assumptions and relatively insensitive to infiltration and inflow parameters.

Overall, the simulated treatment plant influent amounts changed minimally between 1984 and 1985. Changes in recorded flows were small, ranging from -3 percent at West-Southwest to -6 percent at Calumet. The net effect of these changes on individual treatment plant flow balances for 1985 can be summarized as follows:

Treatment Plant	Simulated/Recorded Flow Ratio			Change from 1984 to 1985
	WY 1983	WY1984	WY1985	
Northside	.90	.93	.96	improvement
West-Southwest	.87	.98	1.02	same
Calumet	.90	.83	.90	dramatic improvement

At West-Southwest and Northside, the 1985 balances are quite good. At West-Southwest, there has been a continued decrease in recorded baseflow, or dry weather flow between 1984 and 1985. It is thought that this decrease may be related to elimination of waterway leakage through combined sewer flap gates. At Calumet, the 1985 balance has improved, but is still low. Recorded baseflows are significantly higher than simulated baseflows. Another observation from the Calumet reported flow record is that its response to storm events is unusual compared to the other two major MSDGC plants. Baseflows at Calumet are about 300-330 cfs and peak flows, in response to stormwater runoff, rarely rise above about 400 cfs. At Northside and West-Southwest, peak flows can be twice as high, or greater, relative to baseflows. The reasons for this situation at Calumet are unknown. Therefore, it is difficult to accurately represent the reported flow record with simulation. One possible explanation for the peculiarities in the Calumet flow record is that ongoing construction activities at the plant may result in frequent by-passes. However, such bypasses are not reflected in the bypass record reported by MSDGC. It was also suggested that extended high flows might be explained by storage in the sewer system. Considering the large volume of flow involved relative to potential sewer storage, this is not a reasonable explanation.

As was discussed in last year's report, some additional possible reasons why treatment plant budgets may not balance, assuming plant influent records are accurate, include model assumptions, recycle of river water through combined sewer overflow structures, leakage into lake front interceptors due to high lake water levels, and unreported discharges to the treatment plants. As in the 1984 balance, it does not appear that the observed discrepancy between simulated and recorded flow records at Calumet could realistically be made up by an increase in treatment plan infiltration and inflow. However, the correctness of infiltration and inflow components will be re-evaluated as additional years of data become available.

As indicated, leakage through improperly sealed gates on combined sewer overflows is a possible explanation for the difference between estimated and recorded treatment plant flows. The MSDGC feels that leakage to the plants through combined sewer overflow structures is minimal and the balances at Northside and West-Southwest now tend to support this assertion. But actual data on this phenomenon are not available. If leakage does occur, NIPC's estimate of influent does not account for it and so would be expected to be lower than the measured record.

Another possible explanation for the budget differences is unreported discharges to MSDGC plants. This explanation is unlikely because of the large difference of 110 cfs. However, if there are industries or commercial buildings using groundwater or river water whose watre supply pumpage has not been counted and who return the sewage effluent from these flows to MSDGC plants, NIPC's estimate of influent would not include them.

This remains an important issue since accurate flow balances at treatment plants can assist in the verification of estimated infiltration and inflow components, which are used in the computation of deductions.

D. Precipitation Gages

Thirteen hourly precipitation records are used to estimate flow components to MSDGC treatment plants and streamflow for ungaged watersheds. As in 1984, the Illinois State Water Survey (ISWS) was retained to review the 1985 water year data in context with historical regional data and to suggest improvements. The ISWS recommended revised precipitation event totals for the thirteen gages (Vogel, 1986).

The specific revisions which the ISWS made to the precipitation records is discussed in a separate report. Table 5 presents the actual precipitation records used for the 1985 water year.

Table 5: Monthly Precipitation (inches) - Water Year 1985

Station	October	November	December	January	February	March	April	May	June	July	August	September	Total
Glenview	3.34	2.73	3.24	1.24	2.45	4.89	1.60	2.63	2.45	3.67	4.82	2.04	35.10
O'Hare	3.15	2.64	2.92	1.48	3.46	4.73	1.49	2.79	1.97	3.75	3.90	1.82	34.10
Mayfair	3.40	3.13	3.42	1.57	2.33	5.03	1.74	3.15	1.90	3.18	4.12	2.30	35.27
Springfld	3.62	3.33	3.53	1.52	2.33	5.85	2.27	2.70	1.80	3.58	3.93	2.44	36.90
Northside	3.37	2.91	3.52	0.98	1.91	4.74	1.60	2.46	2.33	2.81	5.72	2.24	34.59
Erie	3.25	3.20	3.74	1.15	2.07	5.16	1.52	2.32	2.01	3.69	4.48	2.58	35.17
Roseland	4.21	3.59	4.12	1.90	2.92	4.67	2.51	2.74	2.28	4.64	2.93	2.84	39.35
So. Water	3.49	3.72	4.03	1.63	2.59	5.26	3.01	2.49	2.42	4.47	3.20	3.51	39.82
U of Chgo	3.78	3.09	3.82	1.58	2.71	4.26	1.65	2.62	2.68	5.51	3.10	2.50	37.30
West-SW	3.93	3.09	6.07	1.47	3.27	5.12	2.30	2.81	2.53	3.41	3.08	2.86	39.94
Midway	3.82	3.42	4.70	1.50	3.62	5.32	2.60	3.06	2.06	3.02	3.60	3.09	39.81
Calumet	4.17	3.62	4.21	1.71	2.82	4.37	2.39	2.55	2.36	4.20	3.14	3.04	38.58
Pk Forest	3.31	3.29	4.00	1.22	3.30	4.26	2.63	1.58	3.67	3.05	3.51	2.65	36.47
Average													37.11
Standard Deviation													2.09

D. O'Hare Treatment Plant Watershed Transfers

Although the O'Hare Water Reclamation Plant is now fully on line, a significant quantity of flow is still being routed from its design watershed to the Northside plant. The MSDGC has estimated this quantity at 29.4 cfs in water year 1985, but has not specified its origin within the O'Hare watershed (MSDGC, 1986). It has assumed that 12 percent of Des Plaines return flow, all of Arlington Heights, Mt. Prospect, and Prospect Heights flows, and 17 percent of Wheeling flows along with infiltration and inflow, comprise this flow. This assumption was based on proximity to the MSDGC interceptors transferring flow to Northside and an analysis of these communities' water supply pumpage versus return flows reported by MSDGC. However, the lack of any metering of this flow along with uncertainties about its origin or flow pattern suggest that further analysis or measurement of this source may be necessary. For the 1985 water year, the flows to Northside were assumed to contain the some proportion of groundwater to Lake Michigan water found in the overall municipal water supply.

E. Summit Conduit

The measured record at Summit Conduit contained many gaps due to gage malfunction in water year 1983. The location of this gage also has been criticized by previous investigators (Harza, 1981). Consequently, the available gage record was not used in water year 1984 and an estimated record was substituted. The estimating technique adds measured point source discharges to simulated runoff quantities to arrive at a record. The 5.4 square mile watershed is hydrologicly/hydraulicly complex. Contributing to this complexity are quarry dewatering operations and the existence of combined sewer overflows. A flow record exists for the quarry dewatering operation (Material Service) and for the other point source discharges from Reynolds Metals and Universal Oil Products.

There remains some lack of clarity about the quarry dewatering operation with respect to its implications on diversion accounting. A small portion of this pumpage, 0.15 cfs, was subtracted from the Summit Conduit flow in previous accounting years because this amount already had been counted as a deduction (in Column 5) as non-public groundwater pumpage reported to the ISWS. The current report continues to follow the same procedure. Though this flow is quite small, it should be verified that 0.15 cfs is still the amount reported to the ISWS by Material Service as groundwater pumpage.

III. Sewer Induced Groundwater Pumpage

Sewer induced groundwater pumpage refers to subsurface runoff (sometimes called groundwater flow or baseflow) which is induced to occur because of the presence of a very efficient underground collection system of sewers, and which would not have occurred in an unsewered, undeveloped watershed. In effect, the sewer system "pumps" this induced groundwater to wastewater treatment plants and to the river system.

Sewer induced groundwater pumpage is determined by hydrologic simulation. Subsurface runoff from pervious areas in the combined sewer watershed was compared to subsurface runoff from a pre-development pervious segment. A pre-development pervious segment could be characterized as relatively flat, poorly drained, woody and marshy. The expected hydrologic response of this pre-development "lowland/forest" segment was developed originally during a hydrologic study of the effects of urbanization (NIPC, 1976).

The estimating procedure for sewer induced groundwater pumpage is discussed in detail in the accounting manual of procedures. Very simply, the amount of induced infiltration is based on the difference in subsurface runoff between developed grassland and undeveloped lowland/forest segments.

The computation of sewer induced groundwater pumpage is performed for Columns 7 and 9. In water year 1985, 308 square miles of combined sewer area in the diverted watershed yielded 36.4 cfs of induced infiltration. Separately sewered areas in the diverted watershed in Illinois totalling 106 square miles, yielded an additional 4.7 cfs for a total of 41.1 cfs of induced infiltration for Illinois. Finally, sewered areas in the Indiana diverted watershed yielded 0.9 cfs. The total estimate for sewer induced groundwater pumpage is 42.0 cfs. As the result of a U.S. Department of Justice decision, sewer induced groundwater pumpage is reported by Illinois but not taken as a deduction.

IV. Diversion Accounting Report Results For Water Year 1985

The accounting report for the 1985 water year by month was shown in Table 2. Monthly reports by day are shown in Appendix A.

A. Column 1: The Record at Romeoville

The water year 1985 Romeoville discharge of 3788.8 cfs represents the second highest discharge recorded in the last 46 years (excluding 1957 when a higher diversion was authorized). Only the 1983 water year discharge of 3991.0 cfs has been higher.

It appears that the increase in discharge has resulted from a relatively constant, unmeasured flow source - most likely leakage at lakefront controlling structures exacerbated by higher lake levels.

There were two backflow events in water year 1985 during which 20.5 million cubic feet were discharged at Wilmette in March and 7.7 million gallons were discharged in August.

B. Column 2: Diversions Above Romeoville Gage

Argonne Laboratories was the only diversion of Sanitary and Ship Canal water above the gage in the 1985 water year and its withdrawal averaged just 0.4 cfs.

C. Column 3: Total Flow through Canal

This column is the sum of columns 1 and 2. Its value for water year 1985 is 3789.1 cfs.

D. Column 4: Groundwater Pumpage From the Lake Michigan Watershed in Illinois Reaching the Canal

Water supply pumpage data for communities using groundwater were combined with annual groundwater pumpage data collected by the Illinois State Water Survey (ISWS) for calendar year 1984 for industrial and other private users for the computation of this column. This column represents a deduction from the Romeoville record. Its value in water year 1985 is 27.6 cfs. Country Club Hills, Matteson, Olympia Fields, and Chicago Heights stopped using groundwater in water year 1984.

E. Column 5: Groundwater Pumpage from the Des Plaines Watershed Reaching the Canal

Again, annual community groundwater pumpage records for the 1984 water year were combined with annual ISWS groundwater usage data for industrial and other private users and adjusted by subtracting daily groundwater pumpage returned to the Des Plaines in combined sewer overflows to compute the values in this column. The average value of this column, also representing a deduction, is 46.7 cfs for the year.

Groundwater pumpage in water year 1985 decreased due to increasing Lake Michigan water usage by communities, particularly Arlington Heights, Burr Ridge and Des Plaines.

F. Column 6: Water Supply Pumpage from Indiana Reaching the Canal

This column is the computation of Indiana water supply reaching Illinois via the Grand Calumet and Little Calumet Rivers, which is deductible from the Romeoville record. The influence of high Lake Michigan levels became very pronounced in water year 1985 (annual average = 580.36 I.G.L.D. with all days above +1.0 C.C.D.). Total Grand Calumet flow to Illinois was computed at 105.2 cfs with the deduction for public water supply being 75.3 cfs. The total deduction computed for this column is 80.7 cfs with the addition of 5.4 cfs of water supply pumpage from the Little Calumet watershed in Indiana outside the Grand Calumet watershed reaching Illinois. A complete discussion of the accounting procedure is available in the Manual of Procedures (NIPC, 1985).

G. Columns 7 and 9: Sewer Induced Groundwater Pumpage

As previously discussed, sewer induced groundwater pumpage is not included as a deduction even though it is a component of groundwater. Columns 7 and 9 report the quantities of sewer induced groundwater pumpage for Indiana and Illinois, respectively. They contribute a total flow to Romeoville of about 42.0 cfs for this year, up 38 percent from water year 1984.

As in water year 1984, there are two months, April and May, in which negative values are obtained (16.9 cfs and -6.6 cfs respectively). As explained in Section III, the procedure for computing induced infiltration compares subsurface runoff from a typical post-development grassland area which is underlain with sewers, to subsurface runoff from a typical pre-development, unsewered lowland/forest area. In the long run, the post-development area yields significantly more subsurface runoff than the pre-development area as a result of increased drainage

efficiency due to sewer installation; hence, "sewer induced groundwater pumpage." The presence of sewers in the post-development area causes not only more subsurface runoff, but it also causes runoff to reach a stream, or treatment plant, more quickly than under pre-development conditions. As a result, during some periods of the year, the pre-development area may have higher subsurface runoff yields than the post-development segment due to its slower release of subsurface runoff. To avoid biasing the computation of sewer induced groundwater pumpage, these "negative" flows are included in the computation of the final number. The negative values for April and May of 1985 are examples of this situation. It is also important to note the added computational checks involved in the preparation of Column 7 and not applicable to Column 9 as detailed in the Manual of Procedures (NIPC, 1985).

H. Column 8: Runoff from the Des Plaines Watershed Reaching the Canal

The runoff from the Des Plaines watershed can be separated into five categories: (1) infiltration and inflow from the upper Des Plaines watershed to separate and combined sewers which becomes influent to the three major MSDGC treatment plants which discharge to the canal system (113.3 cfs); (2) runoff from the Des Plaines watershed which reaches the canal via combined sewer overflows (14.0 cfs); (3) direct runoff from the lower Des Plaines watershed to the canal (67.4 cfs); (4) infiltration, inflow, and combined sewer overflow from the Lemont service area (1.0 cfs); and (5) runoff from the Summit conduit watershed (9.8 cfs). The MSDGC did not report 13A Tunnel pumpage separately in water year 1985. Total 1985 water year runoff from the Des Plaines watershed was 205.5 cfs, virtually all of which is determined by simulation. Of this amount, the total runoff originating in the lower Des Plaines watershed is about 98.3 cfs.

I. Column 10: Total Deduction

Column 10 is the sum of columns 4, 5, 6, and 8. The total deduction from the Romeoville record in water year 1985 is 360.5 cfs. The portion of this amount estimated by hydrologic simulation is about 206 cfs. An additional 80.7 cfs for the Grand Calumet pumpage deduction is estimated using methods described in the manual of procedures (NIPC, 1985).

J. Column 11: Domestic Pumpage from Lake Michigan Not Discharged to the Canal, With Adjustments

This column represents a slight modification to the accounting procedure outlined in the U.S. Supreme Court decree to adjust for pumpage by federal facilities, as discussed in Section I. The total addition to the record at Romeoville from Column 11 is 33.0 cfs. This is composed primarily of pumpage by primary diverters at Waukegan, North Chicago, (minus Knollwood-Rondout), and Lake County Public Water District, and secondary diversions by Riverwoods and Lincolnshire. Also, the sanitary portion of Des Plaines River combined sewer overflows which is derived from Lake Michigan pumpage is added into the value of this column. As indicated, pumpage by federal facilities, the sanitary effluent from which reaches Lockport, is subtracted from the above. In water year 1985, the portions of the Wheeling, Buffalo Grove, and Palatine Lake Michigan water supplies, the sewage effluents derived from which reached the Des Plaines River was also added.

K. Column 12: Total Diversion

Column 12 is determined by subtracting Column 10 from Column 3 and adding Column 11. The total diversion for water year 1985 is 3461.6 cfs. This amount is 261.6 cfs more than Illinois' long term diversion allowance of 3200 cfs. It brings Illinois' 40 year running average to 3275 cfs for a cumulative sum of 374 cfs.

L. Columns 13-15: Lake Michigan Water Supply Pumpage, Stormwater Runoff, and Direct Diversion at Lake Controlling Structures

Columns 13 through 15 are not used in the computation of diversion. However, these columns represent the actual categories of diversion for which Illinois is accountable: Lake Michigan water supply pumpage by non-federal entities in Illinois, runoff from the diverted watershed and direct diversion through lake controlling structures. The sum of Columns 13 through 15 is 3110 cfs for water year 1985. The difference between this amount and the total diversion determined in Column 12 is 351.9 cfs. This difference indicates the major discrepancy in the comparison of inputs versus outputs recorded at Romeoville.

Theoretically, the sum of Columns 13 through 15 should be close to the value of diversion. This assumes that measurements of major flow components, such as Romeoville and the lake controlling structures, are accurate. One reason for expecting some difference in the two amounts is consumptive loss from water supply. The computation of diversion from the Romeoville record does not charge Illinois for consumptive loss of pumpage whose sanitary effluent reaches Romeoville; i.e., water which is withdrawn from the Lake and then consumed or lost before reaching the canal. However, this would suggest that Column 12 should be less, not greater, than the sum of Columns 13 through 15.

The major differences, from a hydrologic standpoint, between water year 1983 (difference 430 cfs), water year 1984 (difference 9.3 cfs) and water year 1985 (difference 352 cfs) as measured at Romeoville appears to be leakage at lakefront structures combined with high lake levels.

The 313 cfs increase in the record at Romeoville (1984 versus 1985 measured discharge) might be explained solely by increased leakage through lakefront structures due to high lake levels. Estimated total runoff at Romeoville decreased by 34 cfs from water year 1984 (1018 cfs) to water year 1985 (984 cfs), an insignificant amount. The principal difference between these two water years was the increase in baseflow quantity as measured at Romeoville (about a 300 cfs increase). This, coupled with the fact that major treatment plant discharges were actually down slightly, suggests another large source of constant inflow. The lakefront structures and the occurrence of record high lake levels provide a likely explanation.

V. Conclusions

A. The total water year 1985 revised measured discharge at Romeoville is 3788.8 cfs. Illinois diversion for the 1984 water year is 3461.6 cfs.

B. The estimated influent to the three major MSDGC sewage treatment plants (Northside, West-Southwest, and Calumet) using the diversion accounting procedure is about 30 cfs (2 percent) less then the amount reported by the MSDGC.

C. Significant differences were once again noted among the average precipitation amounts recorded at the NOAA gages, the MSDGC gages, and the City of Chicago gages. The ISWS was retained to investigate these differences. The ISWS confirmed problems at all of the non-NOAA gages and some of the NOAA gages. The ISWS recommendations are contained in a separate document.

D. Sanitary flow, infiltration, and inflow are still being sent from the design MSDGC O'Hare treatment plant service area to the MSDGC Northside treatment plant. These flows are not recorded, but were estimated by MSDGC to be about 29 cfs in the 1985 water year.

E. The diversion accounting procedure estimated about 42 cfs of sewer induced groundwater pumpage for the 1985 water year. Since this is essentially groundwater pumpage which would not have reached Lockport except for the presence of sewers, this should be taken as a deduction by the State of Illinois. However, the U.S. Department of Justice has found that the wording of the current decree does not allow this. Hence, it has not been included as a deduction for the 1985 accounting year.

VII. Recommendations

A. To better quantify flow balances, the following investigations are needed to determine the reasons for imbalances between estimated and recorded flow at the three major MSDGC treatment plants:

1. Quantification of sanitary return flow and infiltration and inflow quantities.
2. Evaluation of possible leakage from the Canal through combined sewer overflow structures.
3. Evaluation of possible unreported major discharges to the plant from groundwater or surface water supply return flows.
4. Lake front interceptor leakage.

In addition, explanations should be sought from MSDGC regarding some of the unusual changes in baseflows between 1983 and 1984 at the West-Southwest and Calumet plants and the unusual wet weather response at Calumet.

B. The ISWS should be retained on an annual basis to analyze and correct, where necessary, the precipitation records of NOAA, MSDGC, and the City of Chicago. If measurement of these stations cannot be improved, then the ISWS should implement their own independent precipitation network to supply data for simulation as part of diversion accounting.

C. The flow transfers from the MSDGC's design O'Hare service area to the Northside treatment plant should be metered to provide a better estimate of quantity and flow variations.

D. An evaluation of leakage at lakefront structures is needed. If problems are found, as suspected, they should be immediately corrected.

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