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HYDROLOGIC AND HYDRAULIC MODELING OF THE MCCOOK AND THORNTON TUNNEL AND RESERVOIR PLANS

Chicago, Illinois

DAVID KIEL, U.S. ARMY CORPS OF ENGINEERS

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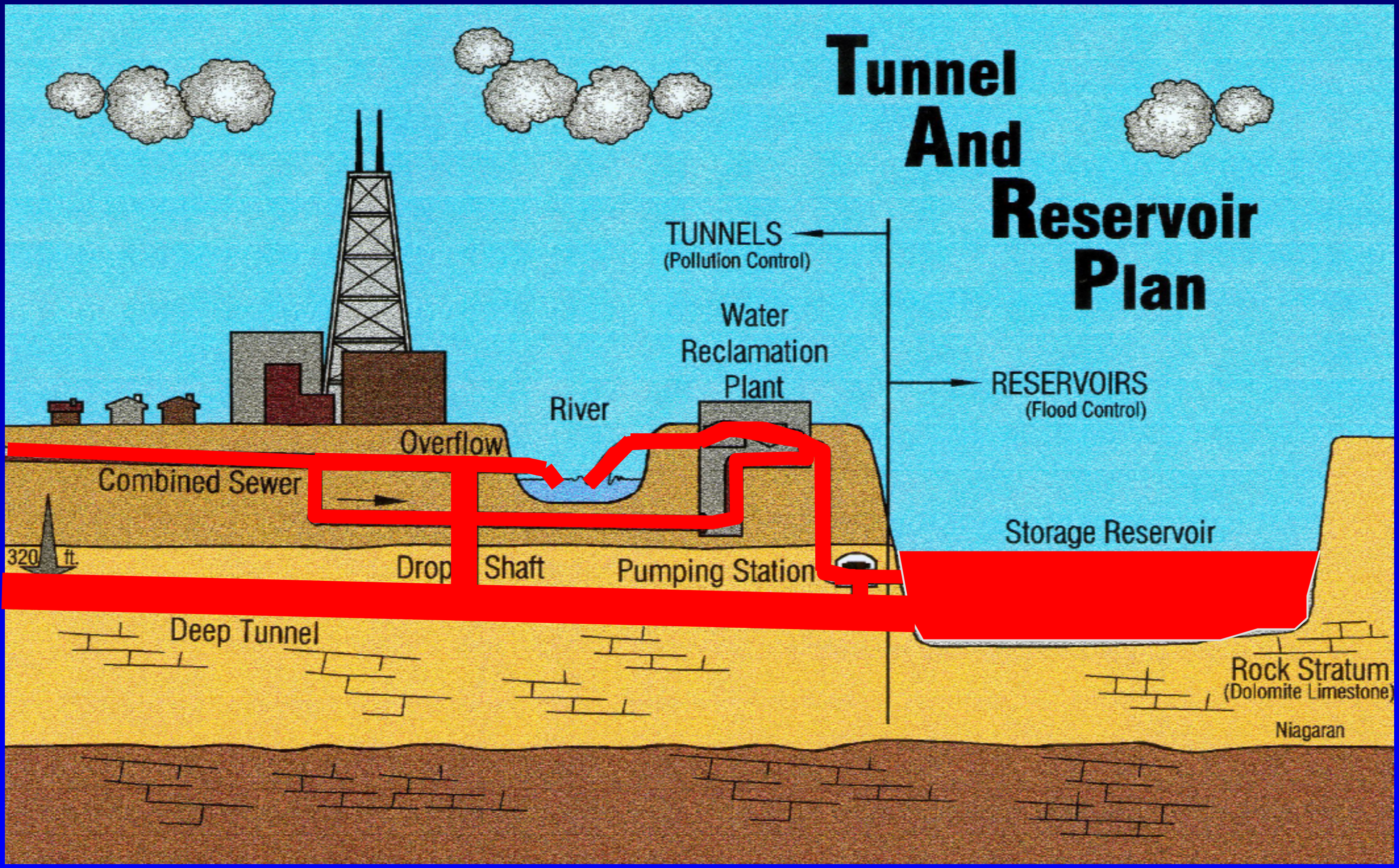

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TUNNEL AND RESERVOIR PLAN

- Reduce waterway pollution from CSOs
- Prevent backflows to Lake Michigan
- Provide storage for floodwaters
  - Reduces basement flooding from CSOs (economic justification of project)

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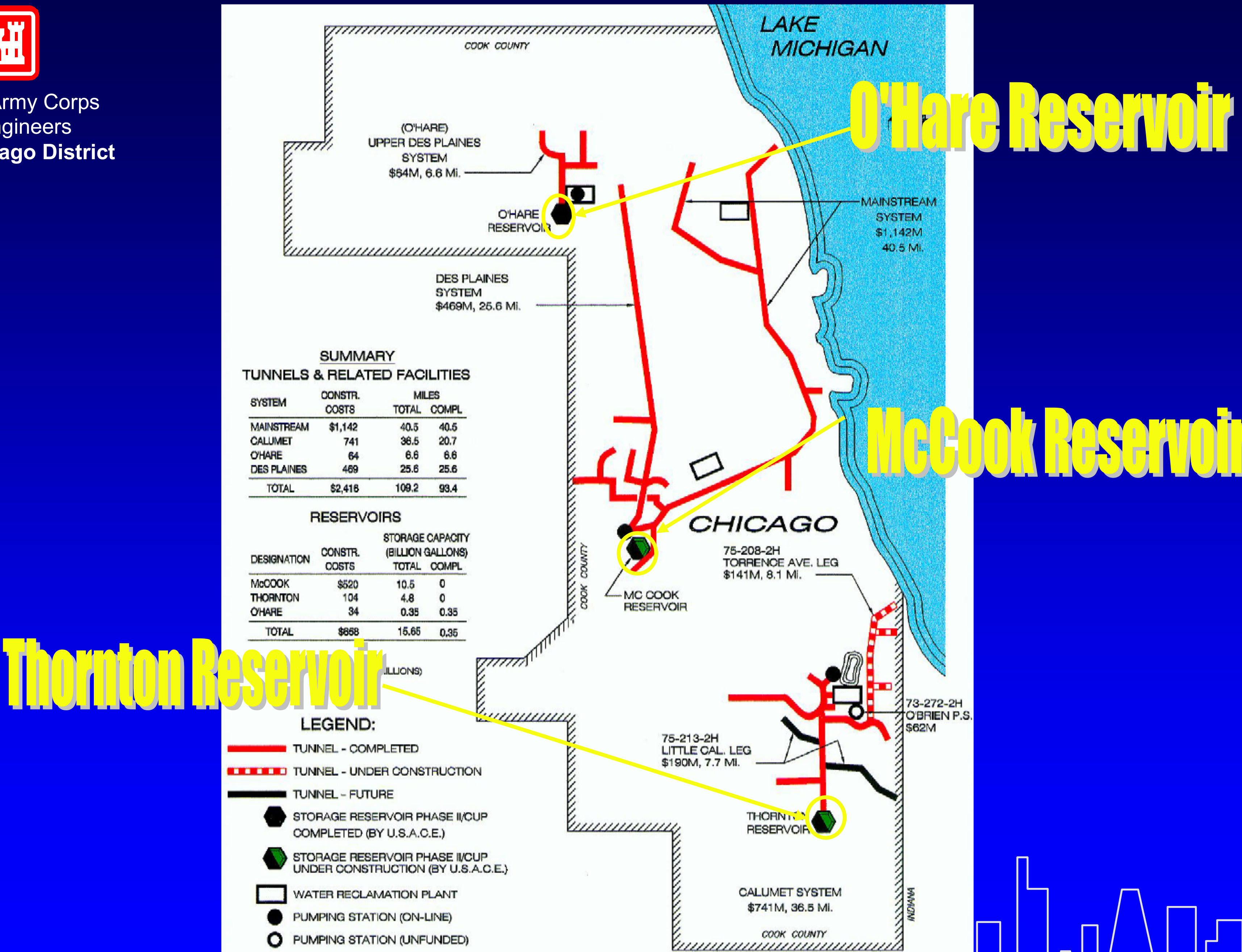
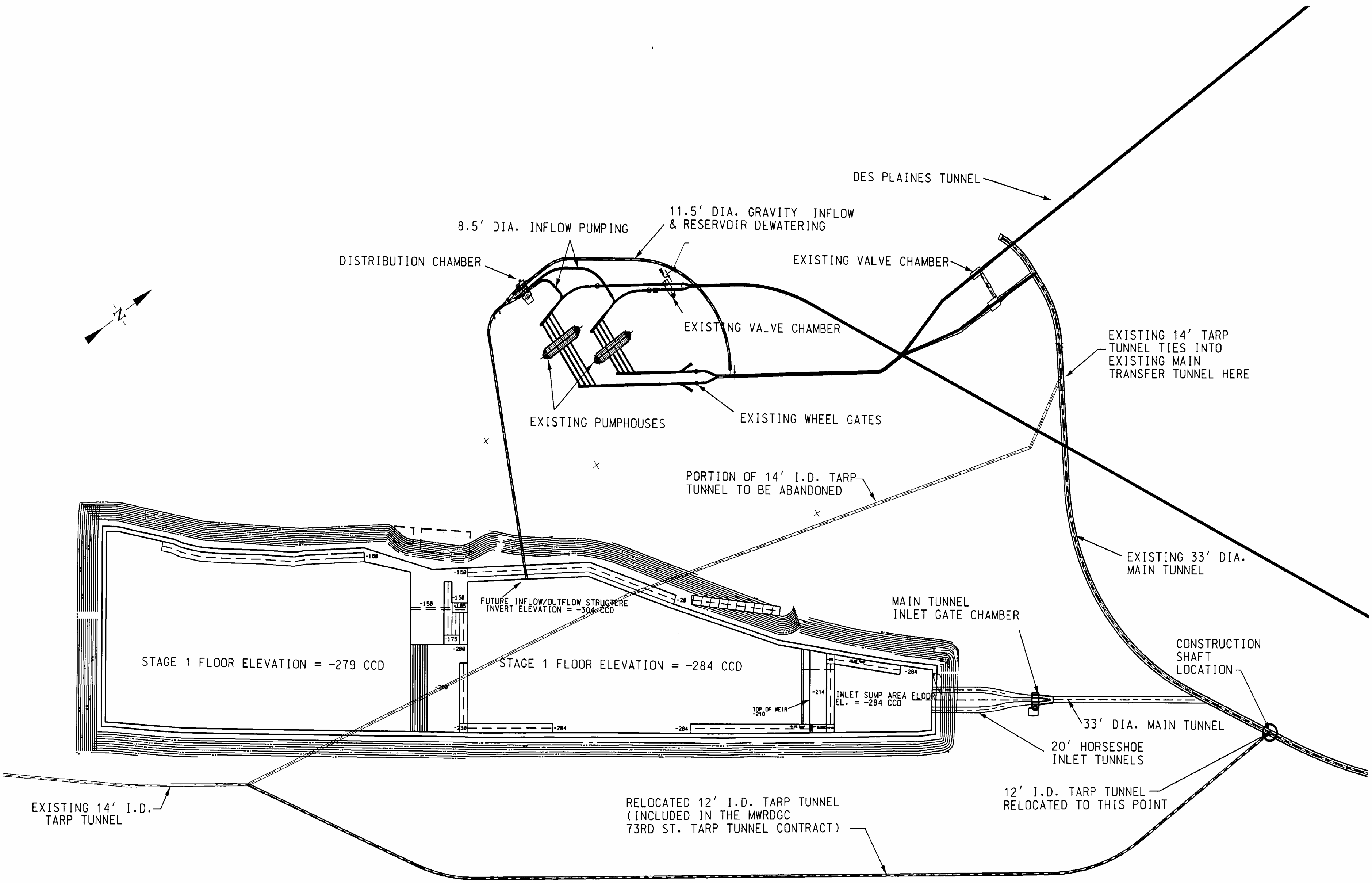
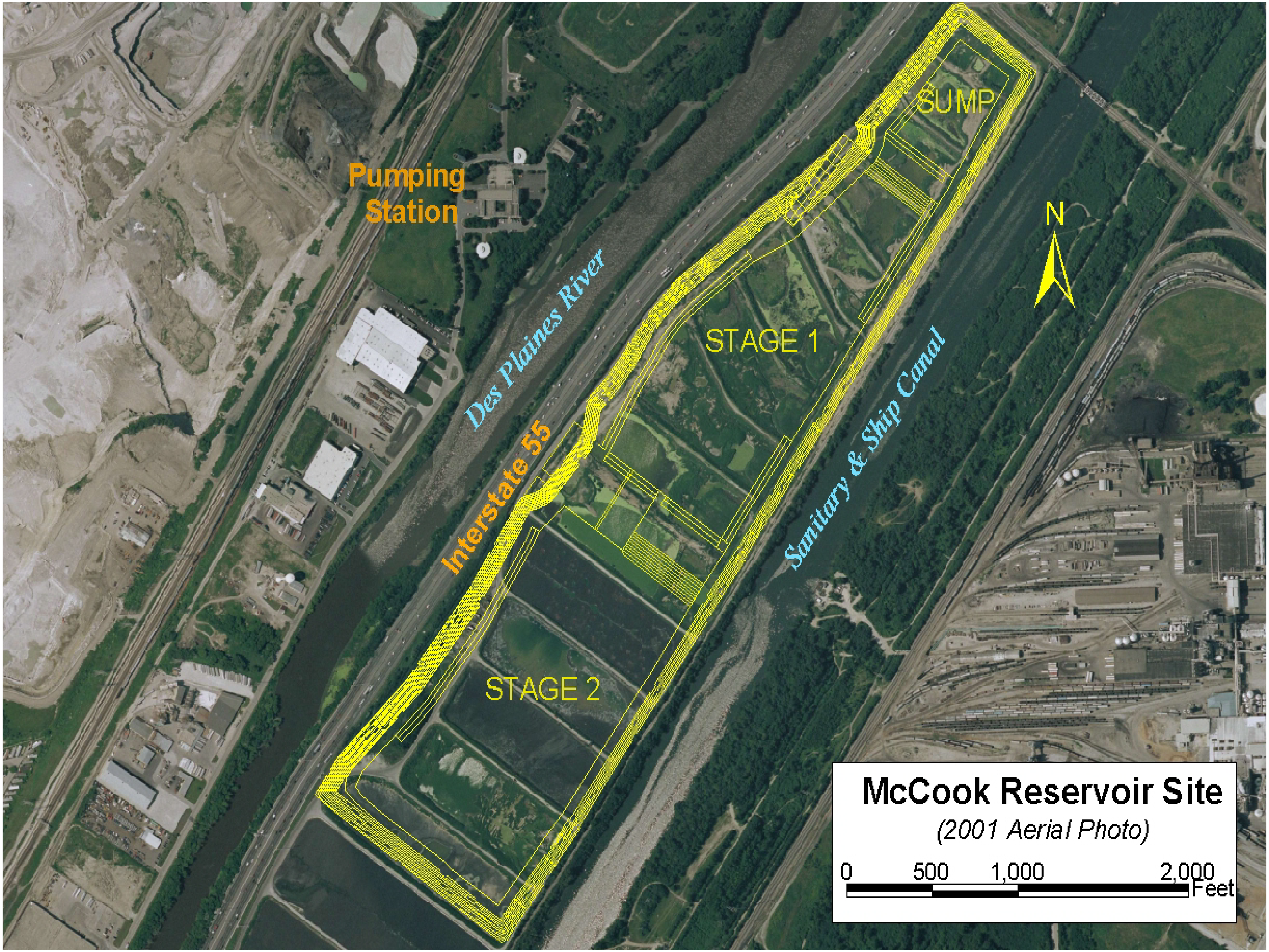


SYSTEM	CONSTR. COSTS	MILES TOTAL	MILES COMPL
MAINSTREAM	$1,142	40.5	40.5
CALUMET	741	36.5	20.7
O'HARE	64	6.6	6.6
DES PLAINES	469	25.6	25.6
TOTAL	$2,416	109.2	93.4

DESIGNATION	CONSTR. COSTS	STORAGE CAPACITY (BILLION GALLONS) TOTAL	COMPL
McCOOK	$520	10.5	0
THORNTON	104	4.8	0
O'HARE	34	0.35	0.35
TOTAL	$658	15.65	0.35



GENERAL RESERVOIR LAYOUT


Pumping Station
Des Plaines River
Interstate 55
SUMP
STAGE 1
STAGE 2
Sanitary & Ship Canal
N
McCook Reservoir Site
(2001 Aerial Photo)
0 500 1,000 2,000
Feet

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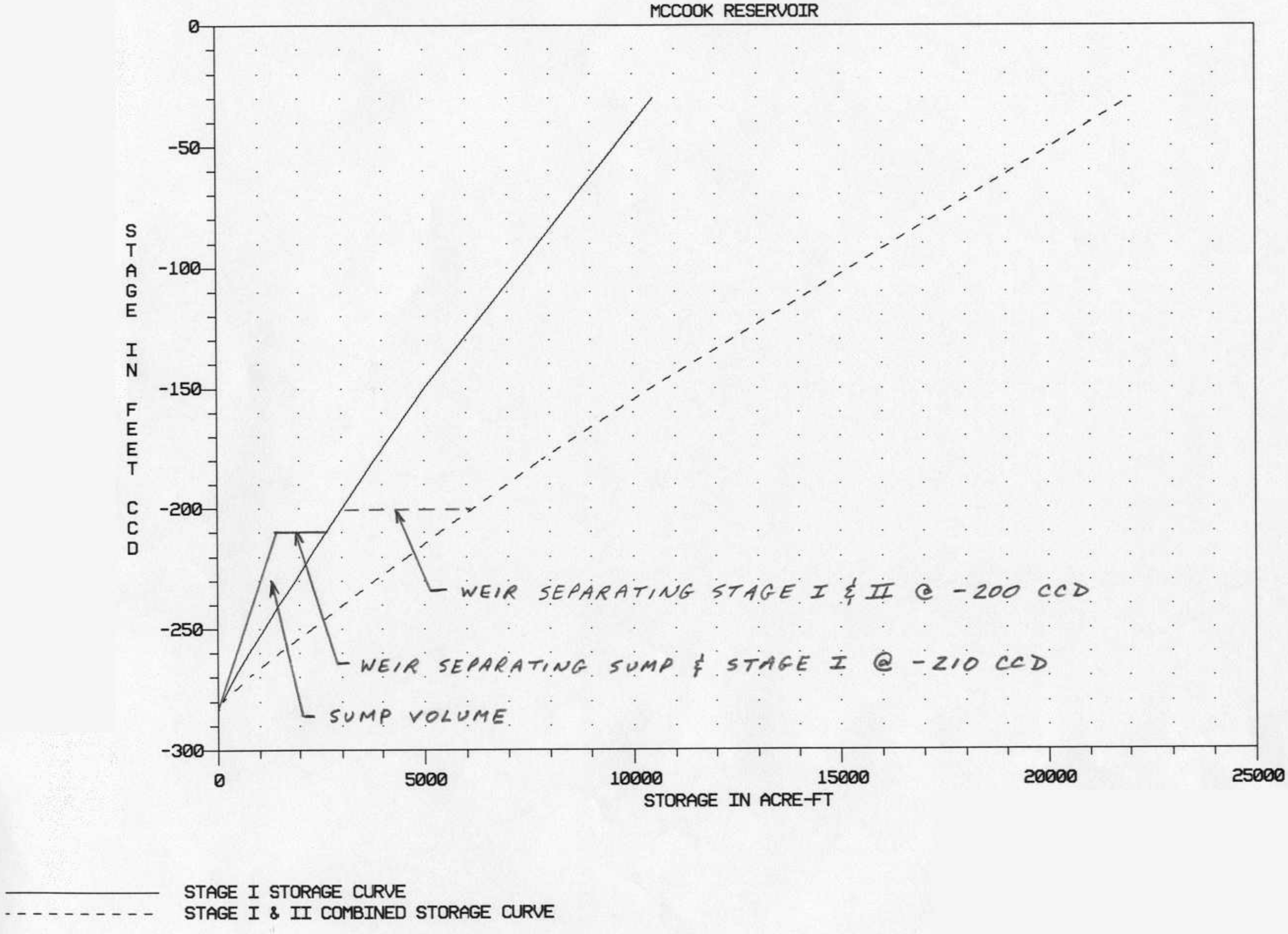
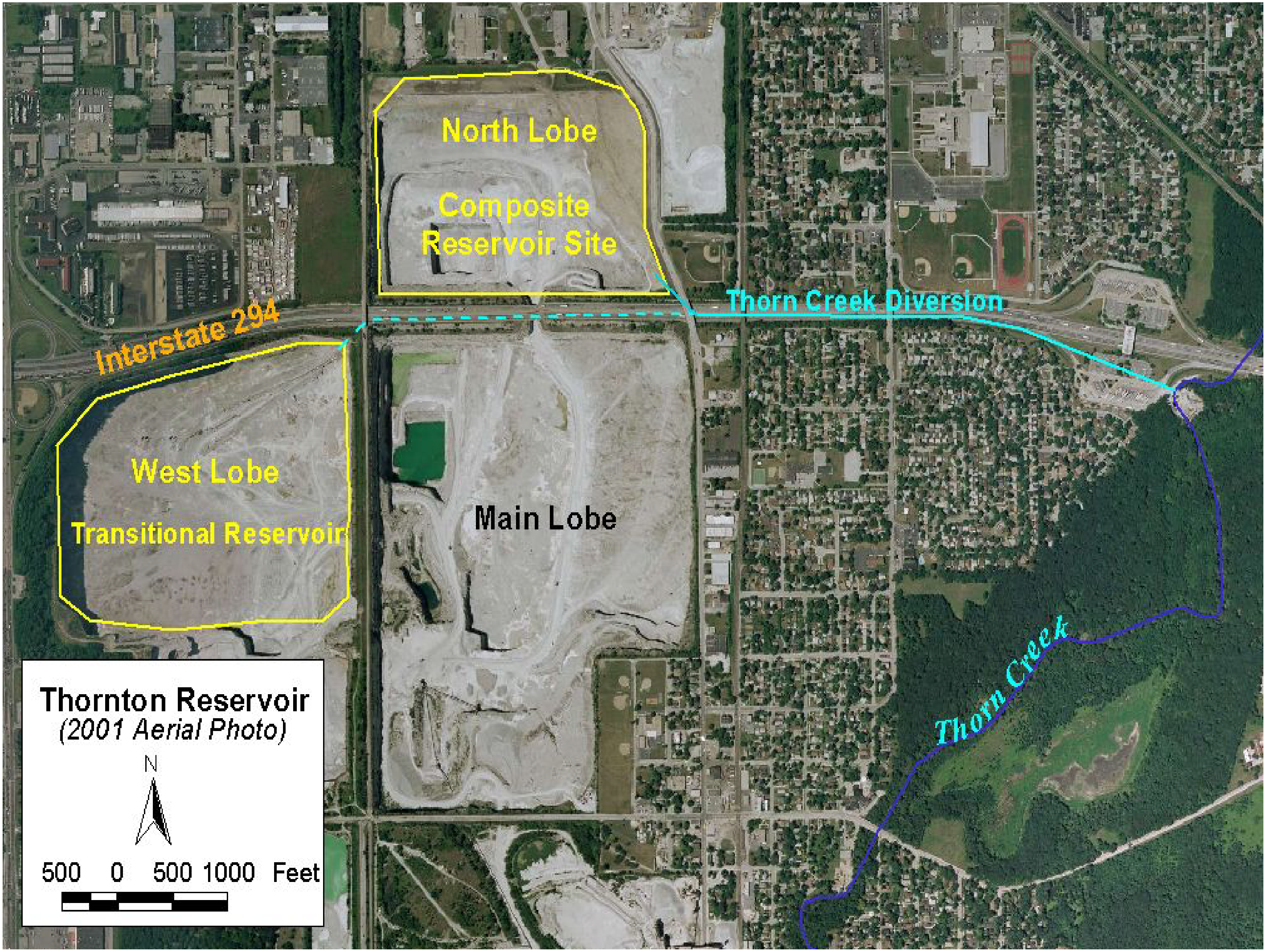
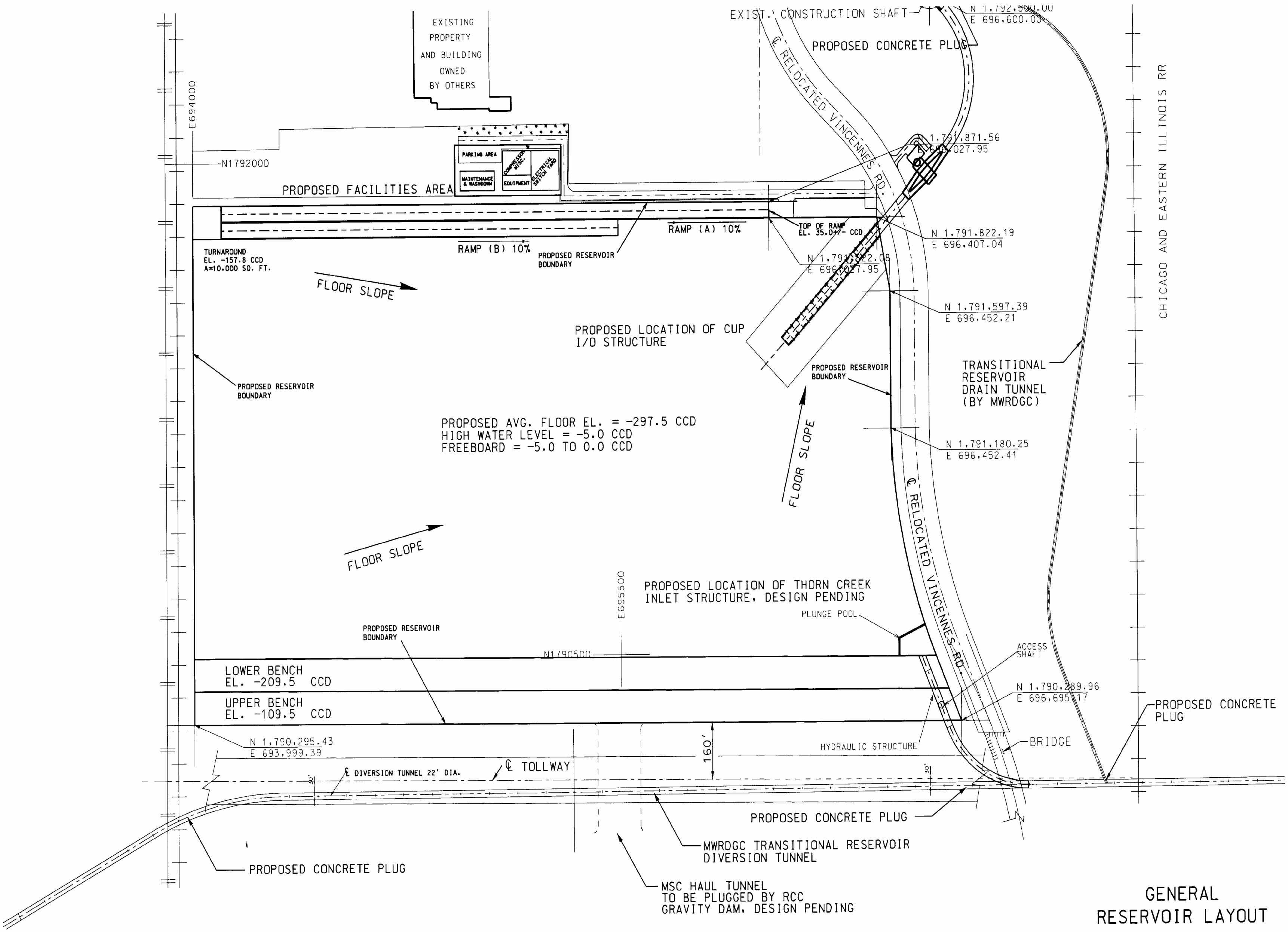
McCook Reservoir


MCCOOK RESERVOIR
STAGE IN FEET CCD
0
-50
-100
-150
-200
-250
-300
0
5000
10000
15000
20000
25000
STORAGE IN ACRE-FT
WEIR SEPARATING STAGE I & II @ -200 CCD
WEIR SEPARATING SUMP & STAGE I @ -210 CCD
SUMP VOLUME
STAGE I STORAGE CURVE
STAGE I & II COMBINED STORAGE CURVE


North Lobe
Composite
Reservoir Site
Thorn Creek Diversion
Interstate 294
West Lobe
Transitional Reservoir
Main Lobe
Thorn Creek
Thornton Reservoir
(2001 Aerial Photo)
N
500 0 500 1000 Feet



GENERAL RESERVOIR LAYOUT

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THORNTON RESERVOIR

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COMPUTER SIMULATION MODELS

- Hydrologic Simulation Program - Fortran (HSPF)
- Hydraulic Sewer Routing Model, (SCALP)
  Special Contributing Area Loading Program
- Tunnel Network Model (TNET) for TARP,
  Tunnel and Reservoir Plan
- UNET Canal Model
- PAR3D Fluid Dynamics and Water Quality Model
- First 4 Models use DSS database

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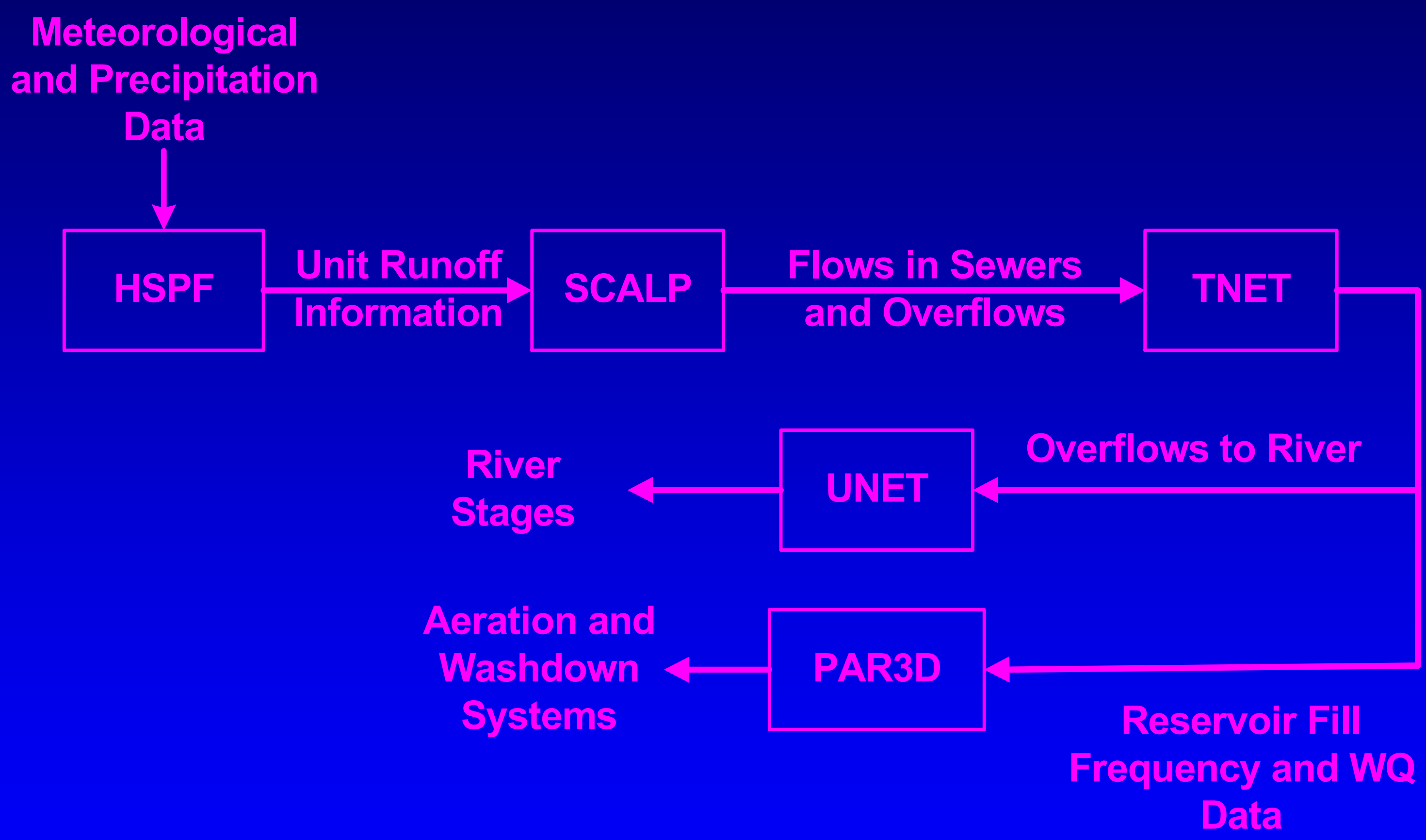
Summary of Models



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HSPF: HYDROLOGIC SIMULATION PROGRAM- FORTRAN

- Continuous simulation of rainfall-runoff process including snow accumulation and melt
- Physically based model representing:
  - interception storage above soil
  - infiltration through soil
  - storage within soil (upper and lower zones)
  - losses to deep aquifer
- 39 parameters define soil, land cover, infiltration rates, etc.

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HSPF RUNOFF COMPONENTS

- Surface Runoff
- Interflow
  - infiltration that moves laterally through soil towards stream
  - function of infiltration rate and soil moisture
- Active Groundwater or baseflow

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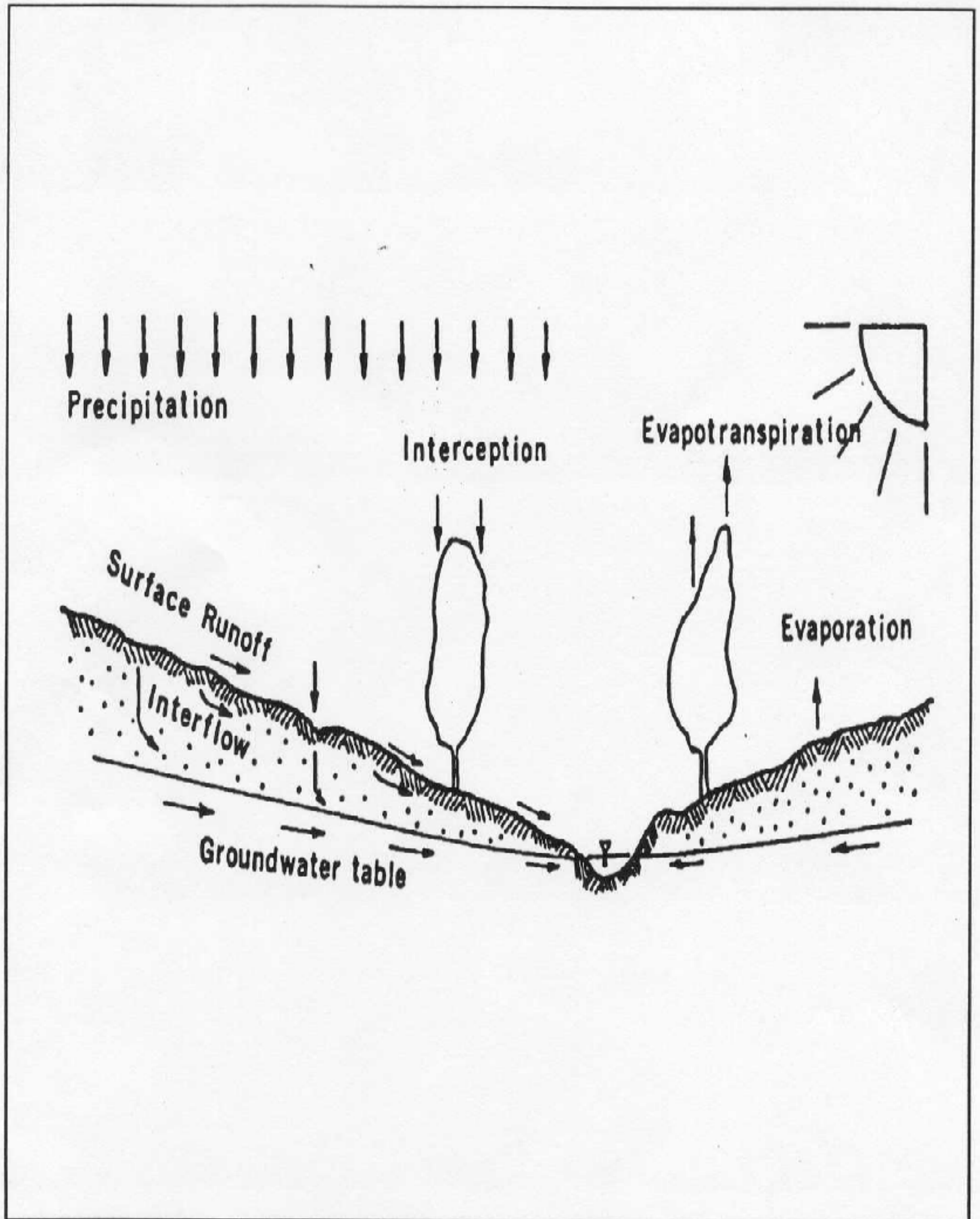

Figure 4.2(1).3-1 Hydrologic cycle

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HSPF WATER STORAGE

- Defines antecedent soil moisture at start of an event
  - interception storage
  - surface storage
  - interflow storage
  - upper zone storage
  - lower zone storage
  - active groundwater storage

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HSPF MODEL

- 13 Precipitation Gages thru WY89, 25 Gages WY90
- Theissen Polygons define 13 and 25 areas
- 3 Land Type Runs — Unit Area Runoff Output (in/hr)

3 Land Type Runs	Unit Area Runoff Output (in/hr)
- Impervious	IMPRO
- Grassland	OLFRO, SUBRO
- Forestland	OLFRO, SUBRO

- IMPRO = impervious runoff
- OLFRO = pervious surface runoff
- SUBRO = pervious subsurface runoff
  = interflow + active groundwater

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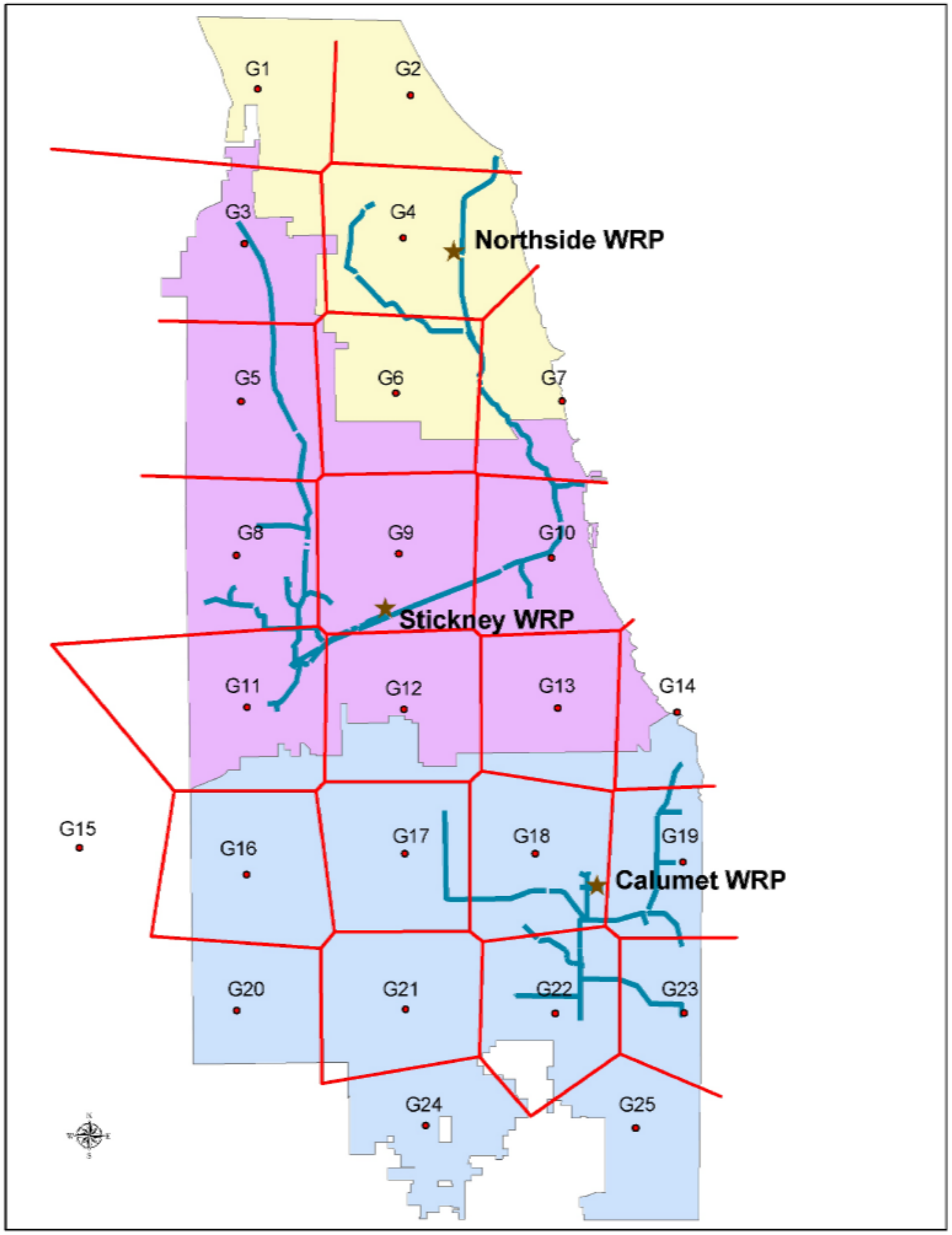

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HSPF MODEL INPUT

- Meteorologic Input
  - Precipitation (13 and 25 gages)
  - Air Temperature (4 gages)
  - Dew Point
  - Wind
  - Cloud Cover
  - Solar Radiation
  - Evapotranspiration

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HYDRAULIC SEWER ROUTING MODEL - (SCALP)

- Input is HSPF runoff output (IMPRO, OLFRO, SUBRO) from Impervious and Grassland runs
- 3 MWRDGC WRP service basins modeled
  - Stickney
  - Northside
  - Calumet

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SCALP MODEL SUBBASINS

- Each MWRDGC service basin subdivided into combined and separate sewer subareas called SCAs (Special Contributing Areas)

	Combined	Separate
• Stickney	100	3
• Northside	33	2
• Calumet	64	8

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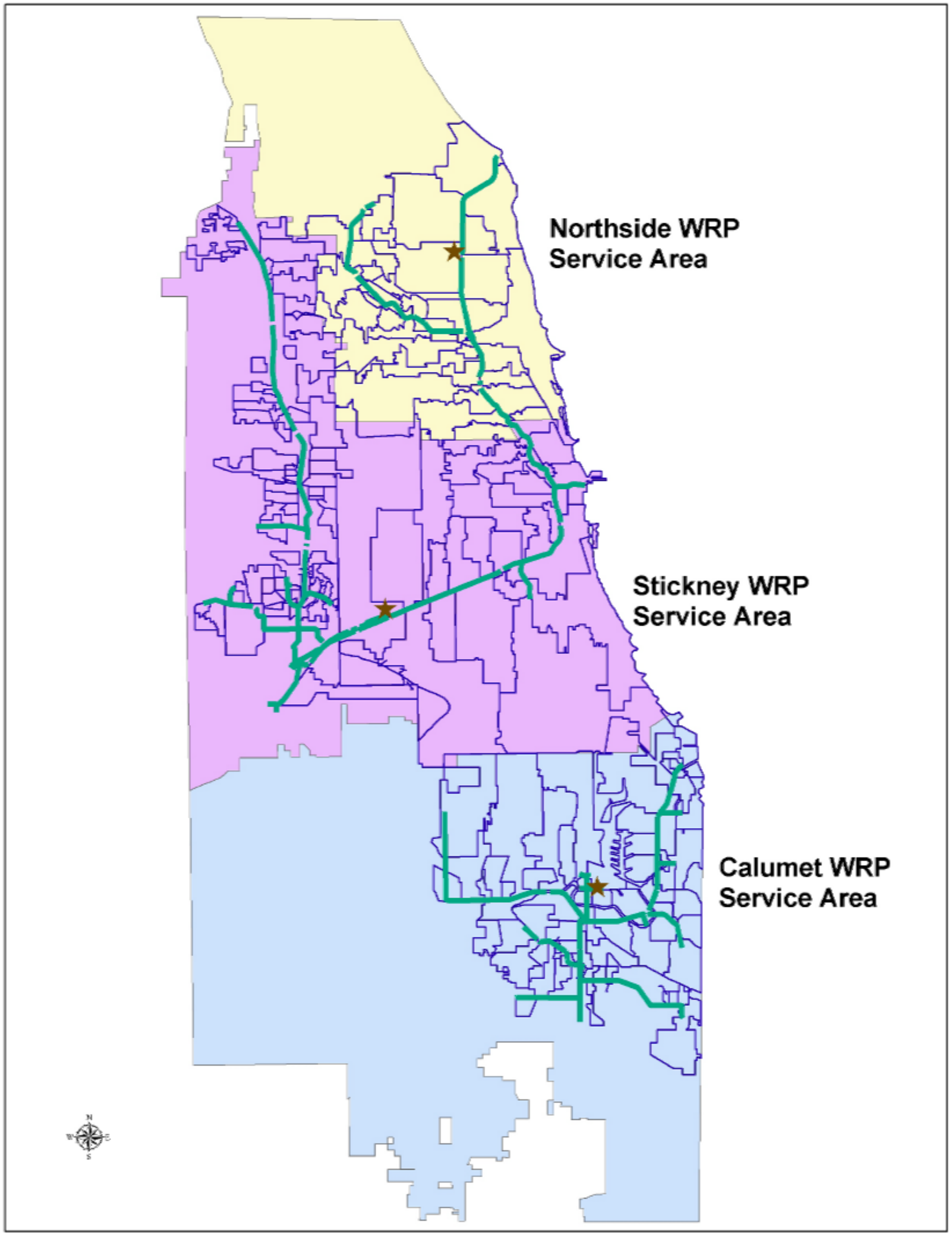

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SCALP MODEL

- Sewer flows based on linear storage routing scheme
  - Lateral sewers
  - Submain sewers
  - Main sewers
- 3 Sources of Sewer Flow
  - Wastewater (Sanitary)
  - Stormwater Surface Runoff (Inflow)
  - Stormwater Subsurface Runoff (Infiltration)

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SCALP AREA DETERMINATION

- Impervious and Grassland Area based on 161 1”=400’ Aerial Photos from 1990
- Photos subdivided into 10 landuse categories each with assumed %’s for impervious, grassland, and forestland

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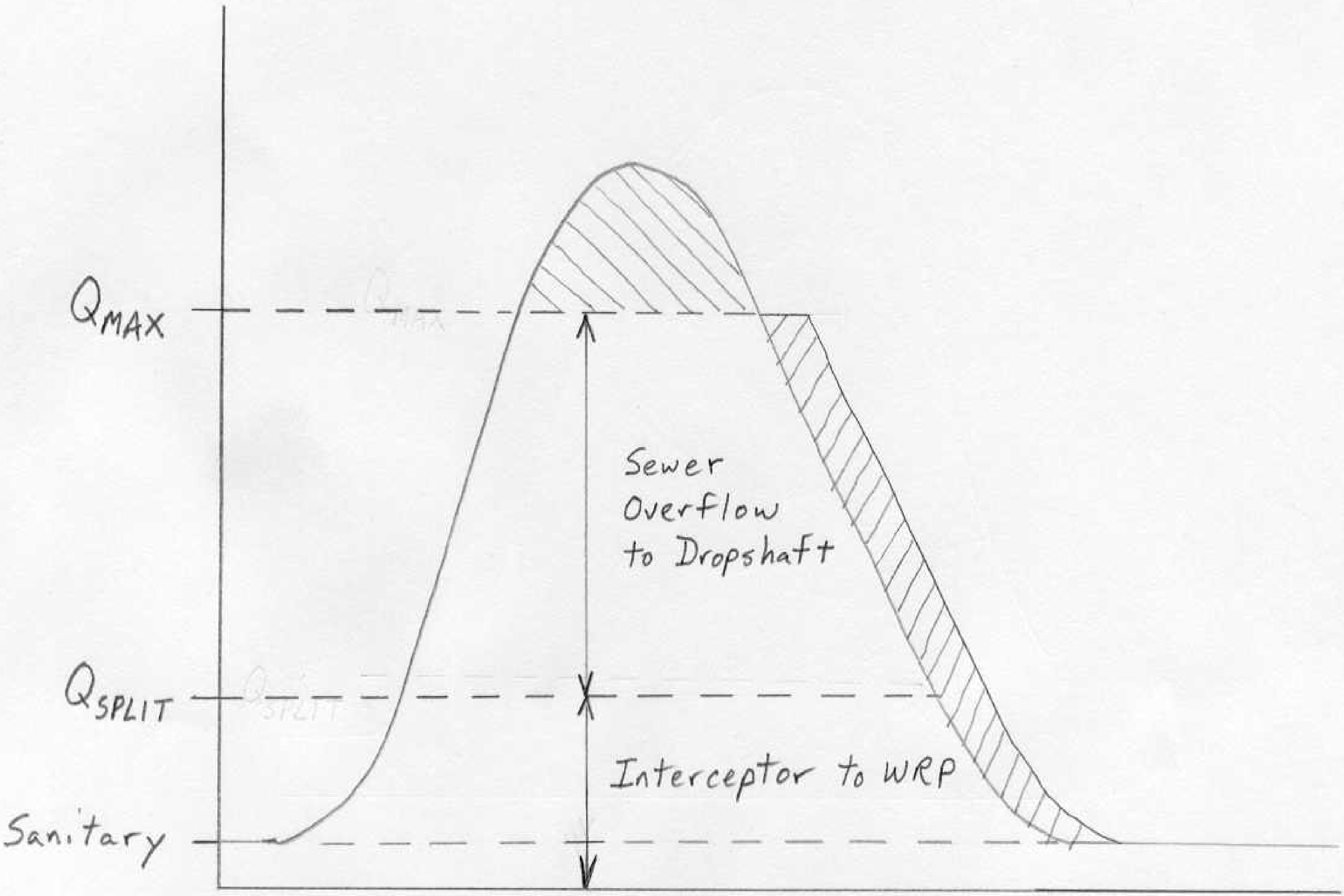
SCALP OVERFLOW SIMULATION

- Based on Q SPLIT
  - Flows in excess of Q SPLIT are overflows
- 8 Flow Outputs for each SCA
  - WRP: Inflow, Infiltration, Sanitary, Total
  - OVF: Inflow, Infiltration, Sanitary, Total
- 8 Water Quality outputs for each SCA
  - WRP: BOD, DO, TSS, Water Temperature
  - OVF: BOD, DO, TSS, Water Temperature
- Modeled interceptor flows calibrated at WRPs
- Total OVFs are routed to TARP (Tunnel and Reservoir) Tunnels as input to TNET model



Q_MAX
Q_SPLIT
Sanitary
Sewer Overflow to Dropshaft
Interceptor to WRP

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TARP TUNNEL NETWORK MODEL - (TNET)

- Modified version of UNET, the one dimensional unsteady state flow model for open channel flow developed by Dr. Bob Barkau
- TNET solves the unsteady flow equations of continuity and momentum and adds a Priesmann slot for pressurized flow forcing the open channel flow equations to correctly propagate the high celerity of the pressure waves
- Total OVFs including flow and water quality data (SCALP output) from individual SCAs are routed to TARP tunnels through drop shafts
- Model simulates operation of drop shaft gates, main inlet gate, the pumping station, WRP operations, and overflows into the canal system

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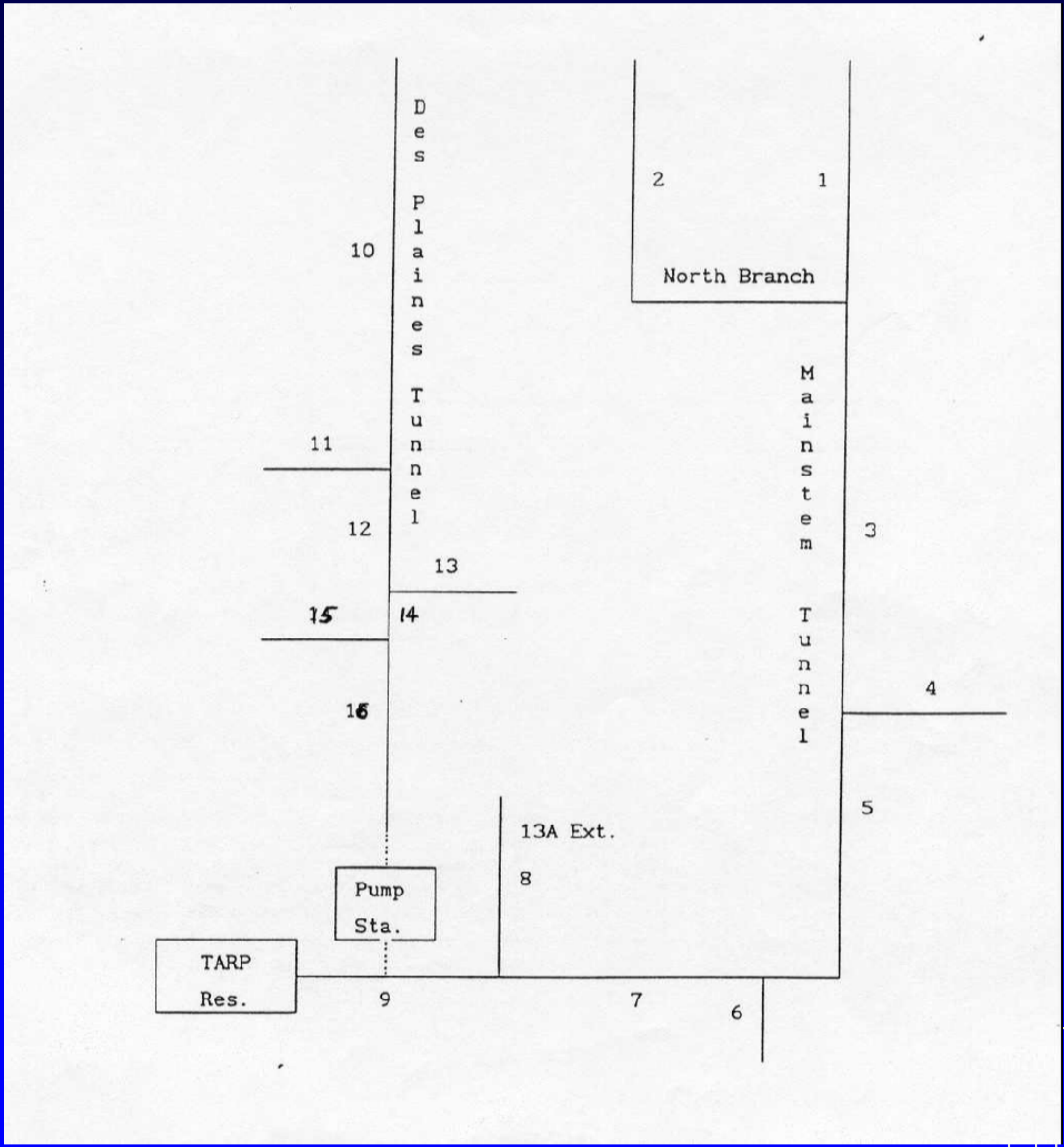

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TNET – DROPSHFTS AND SUBAREAS

- Mainstream/Des Plaines TARP (McCook)
  - 175 dropshafts, 136 subareas
- Calumet TARP (Thornton)
  - 84 dropshafts, 69 subareas

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TNET TARP MODEL

- Flow into the tunnels is controlled by dropshaft gates which are opened or closed based on MWRDGC Operation Plan
- TNET models gate openings and closings based on Index Drop Shaft(s)
- Operation of TARP pumps controlled by:
  - tunnel water surface elevation at pump
  - available treatment plant capacity (based on simulated interceptor flows from SCALP)

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TNET TARP MODEL - MCCOOK

- Dry weather WRP capacity 1900 cfs
- Maximum WRP capacity 2200 cfs sustained during event and until tunnels are pumped dry
- TNET outputs hourly data and stores them in a unique DSS pathname

  - overflows to river from each dropshaft or dropshaft grouping
  - gravity inflows to reservoir
  - pumping from tunnels to reservoir
  - pumping from tunnels to WRP
  - pumping from reservoir to WRP
  - water quality data in the reservoir
    - BOD, DO, TSS, Water Temperature

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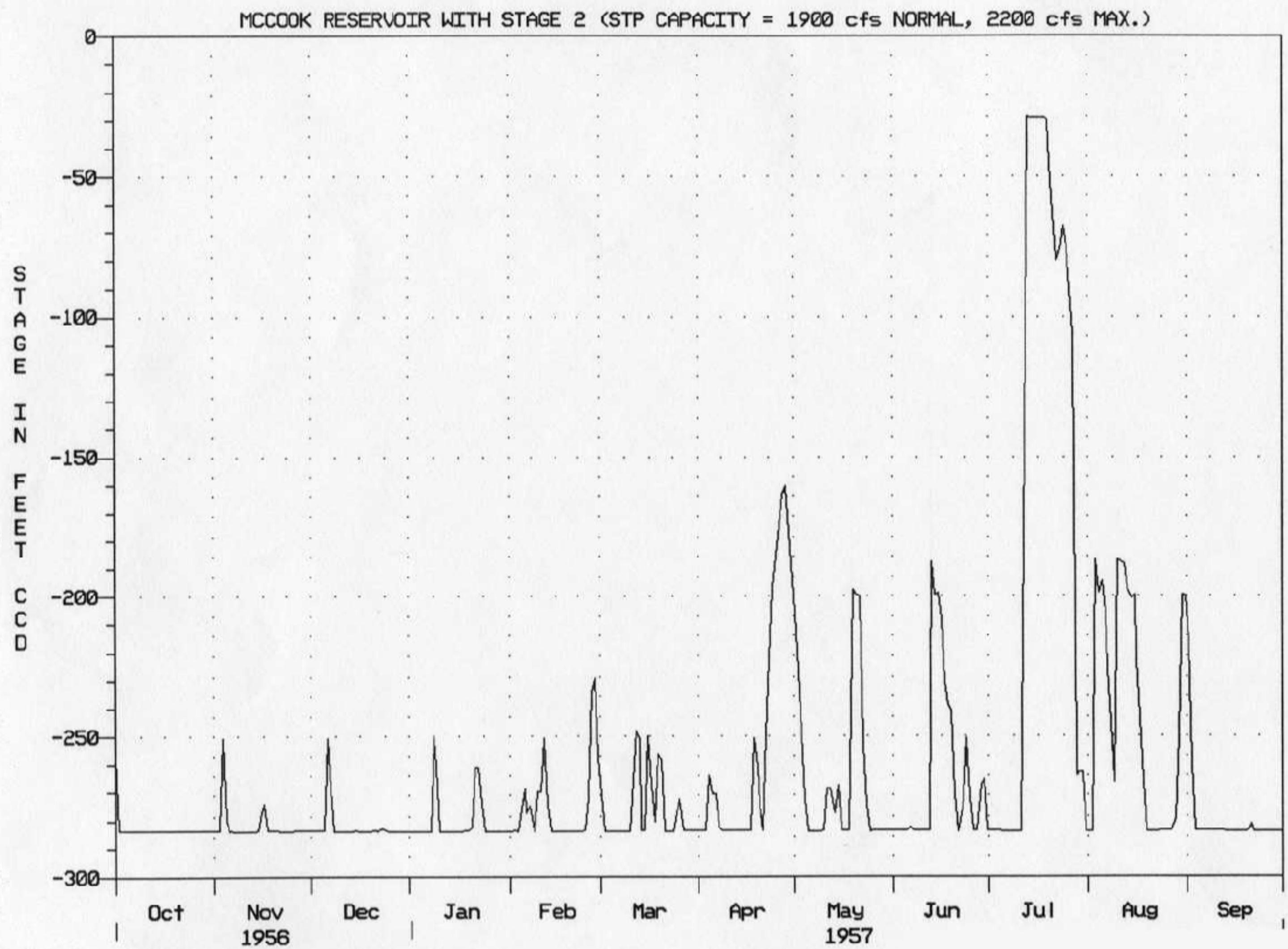
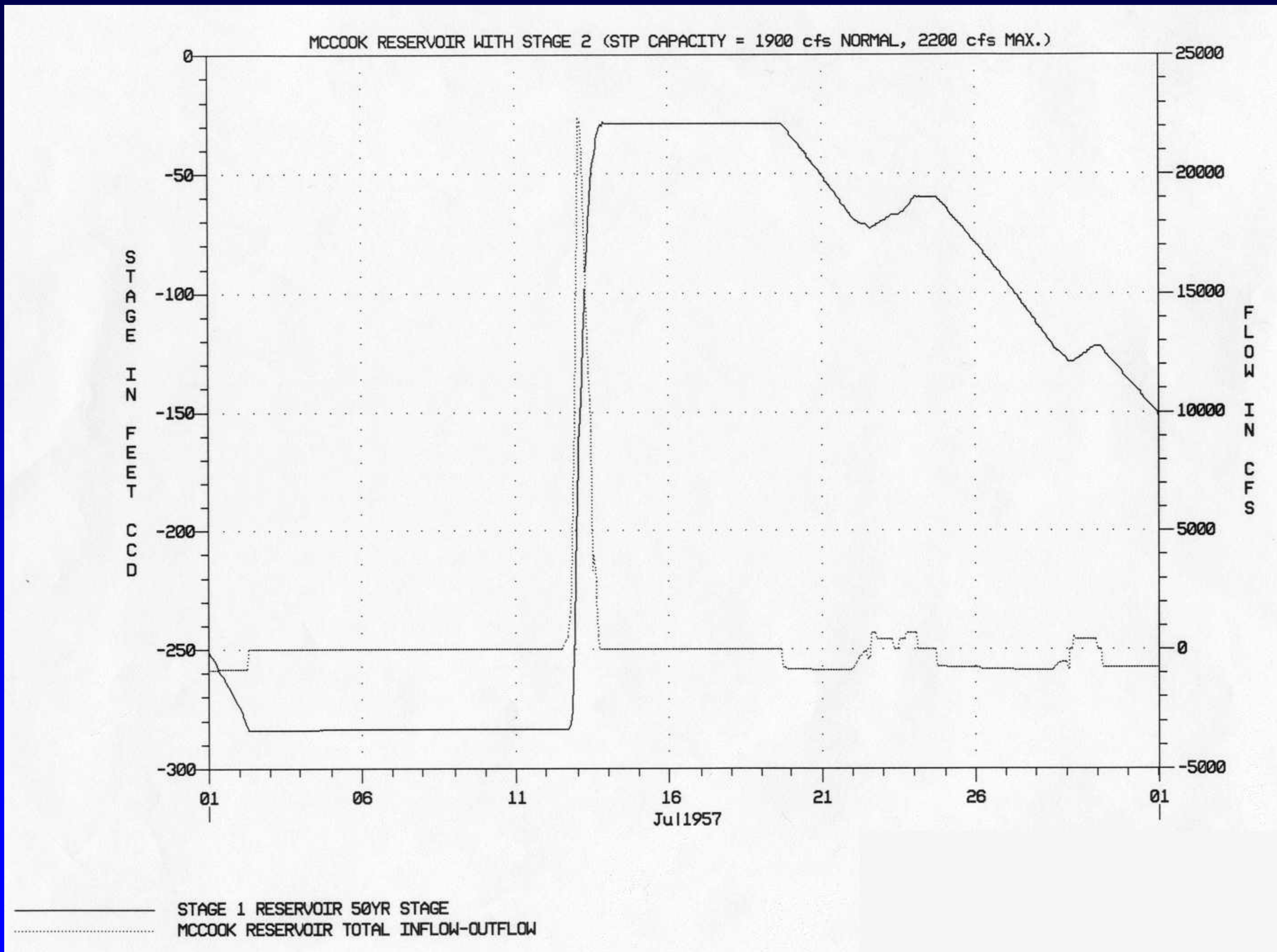
TNET – MODELED EVENTS

- 52 Year Period of Record (1949 – 2000)
- Synthetic Events
  - 1, 2, 5, 10, 20, 50, 100 and 500-Year storms
  - SPFs and PMPs for 1954 and 1957



STAGE 1 RESERVOIR MAXIMUM DAILY STAGE
STAGE 2 RESERVOIR BEGINS FILLING WHEN STAGES EXCEED WEIR @ -200 CCD
GRAVITY FLOW AND PUMPING TO RESERVOIR FOR SMALL EVENTS


MCCOOK RESERVOIR WITH STAGE 2 (STP CAPACITY = 1900 cfs NORMAL, 2200 cfs MAX.)
STAGE IN FEET CCD
FLOW IN CFS
0
-50
-100
-150
-200
-250
-300
25000
20000
15000
10000
5000
0
-5000
01
06
11
16
21
26
01
Jul1957
STAGE 1 RESERVOIR 50YR STAGE
MCCOOK RESERVOIR TOTAL INFLOW-OUTFLOW

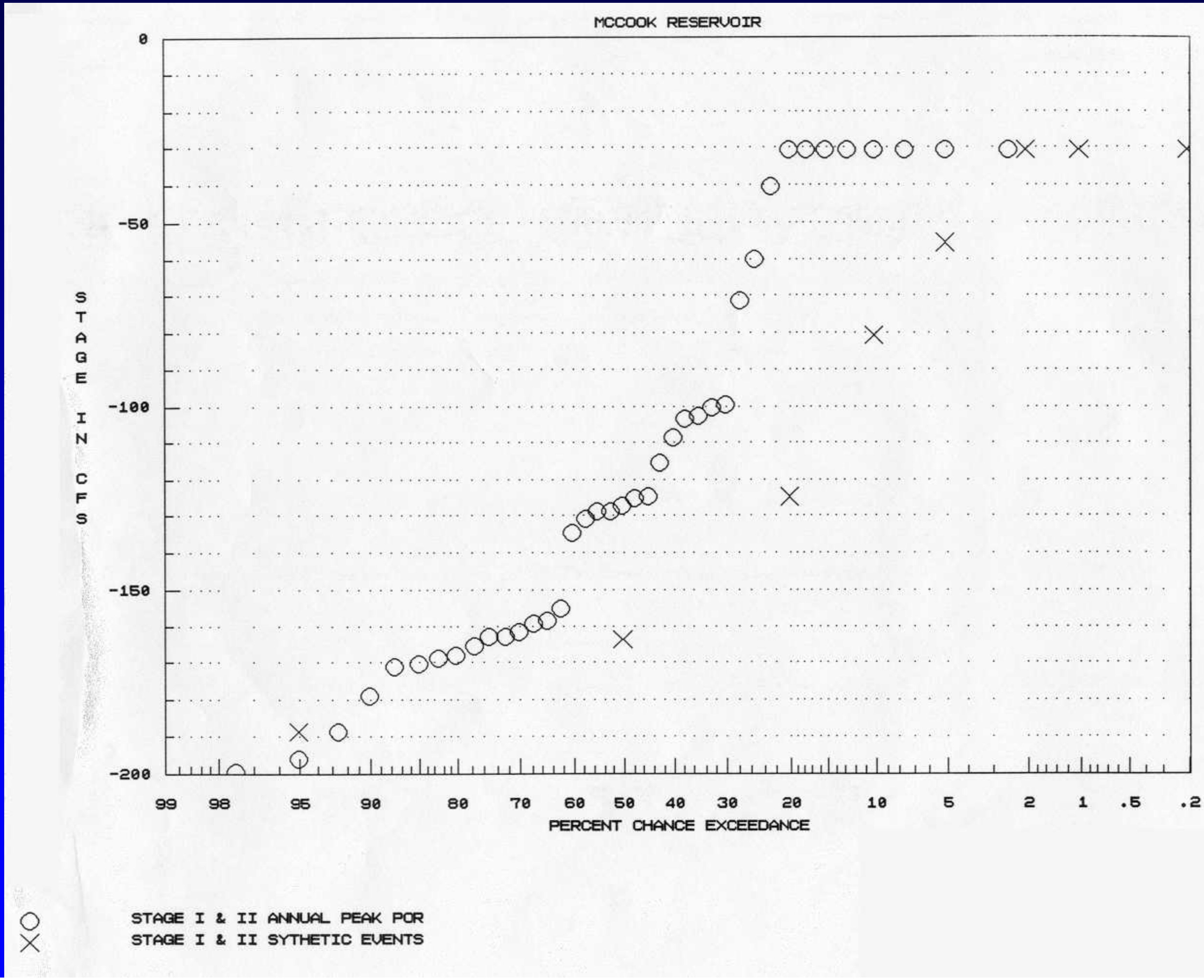

MCCOOK RESERVOIR
STAGE IN CFS
0
-50
-100
-150
-200
99
98
95
90
80
70
60
50
40
30
20
10
5
2
1
.5
.2
PERCENT CHANCE EXCEEDANCE
STAGE I & II ANNUAL PEAK POR
STAGE I & II SYTHETIC EVENTS

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Table A-7
Summary of CUP McCook
Period of Record Stages
Stage I Reservoir

Target Elevation Exceeded (ft. CCD)	Number of Specific Events	Maximum Event Duration (days)	Average Event Duration (days)	Total Days Exceeded (days)	Percent of Time Exceeded (%)
-30	10	13	8.1	81	0.6
-40	11	13	8.1	89	0.6
-60	13	24	10.3	134	0.9
-80	14	25	12.1	170	1.2
-100	17	34	12.0	204	1.4
-120	28	48	10.2	286	2.0
-140	42	49	9.4	395	2.7
-150	47	51	10.0	468	3.2
-160	52	51	10.2	532	3.6
-180	94	52	8.1	765	5.2
-200	259	53	5.4	1403	9.6
-220	308	60	5.8	1784	12.2
-240	361	66	6.1	2208	15.1
-260	491	67	5.7	2807	19.2
-280	803	74	5.0	4048	27.7
-283	869	74	4.9	4290	29.4

Stage II Reservoir

Target Elevation Exceeded (ft. CCD)	Number of Specific Events	Maximum Event Duration (days)	Average Event Duration (days)	Total Days Exceeded (days)	Percent of Time Exceeded (%)
-200	112	53	8.8	986	6.7
-220	138	60	8.7	1204	8.2
-240	153	66	9.4	1440	9.9
-260	191	67	9.4	1791	12.3
-270	213	67	9.5	2013	13.8
-275	222	68	9.8	2185	15.0

Note: The period of record spans 40 years, from 01JAN1949 to 31DEC1988. The stage-storage curve used for this analysis was developed in July 1998. Any later revisions are not reflected.
The Stage I reservoir target elevation extends to only -283 and The Stage II reservoir target elevation extends to only -275 Because the model leaves some water near the reservoir floor for computational stability.
The Stage I and Stage II reservoirs will respond the same above elevation -200 CCD.

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UNET CANAL MODEL

- Simulates the operation of the canal system including operations at Lockport (including drawdowns) as well as backflows to Lake Michigan
- Input is TNET TARP model overflow output
- Input also includes stream gage records (recorded for POR, simulated for synthetic events), and simulated ungaged area inflows
- Calibrated at Lockport

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PAR3D MODEL

- PAR3D – computational fluid dynamics model used to model fluid dynamic and water quality related processes for the water in the reservoir.
- Developed by Dr. Bob Bernard of the Coastal and Hydraulics Laboratory at WES, the Corps of Engineers Waterways Experiment Station
- Processes modeled include: gas transfer from the water surface and from bubbles, biochemical oxygen demand, sediment oxygen demand, and sedimentation.

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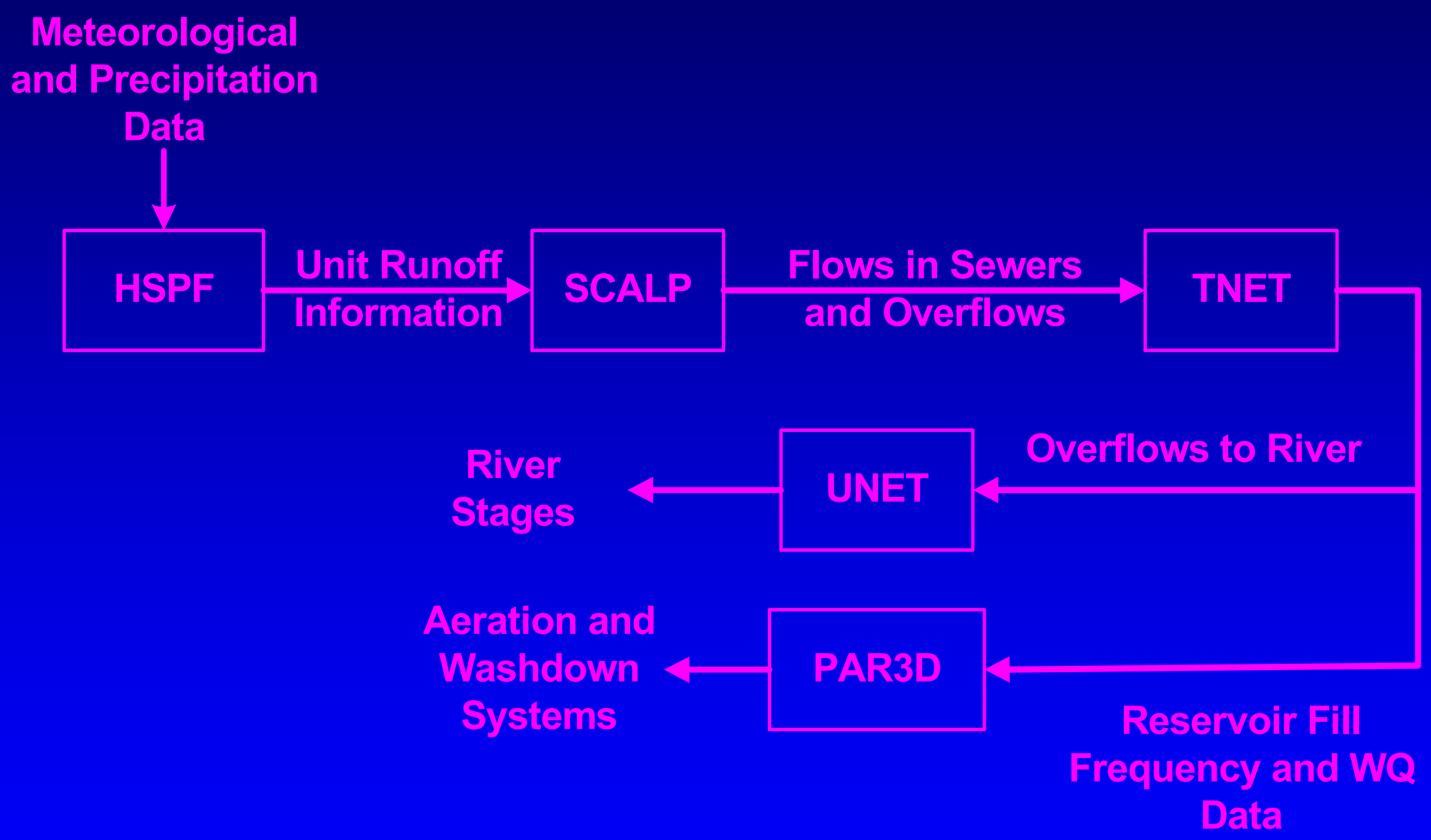
Summary of Models



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WES PHYSICAL MODELS

- Main Tunnel inlet gates, inlet tunnels, sump, weir structure, stage 1 reservoir floor (1:40)

- Distribution Chamber (1:12)
  - gravity inflow gates and conduits for Des Plaines tunnel gravity inflow

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WES PHYSICAL MODELS

- Main Tunnel inlet gates, inlet manifold, sump, weir structure, stage 1 reservoir floor
  - 1:40 model to determine:
    - Velocities on the sump and stage 1 reservoir floor for aeration design and rock protection plan
    - Stepped weir loadings and adequacy of design for energy dissipation
    - Pressures in the gate chamber, inflow conduits, and inlet manifold
    - Adequacy of inlet conduit and manifold wrt flow conditions, air entrainment, air/water surging through vents

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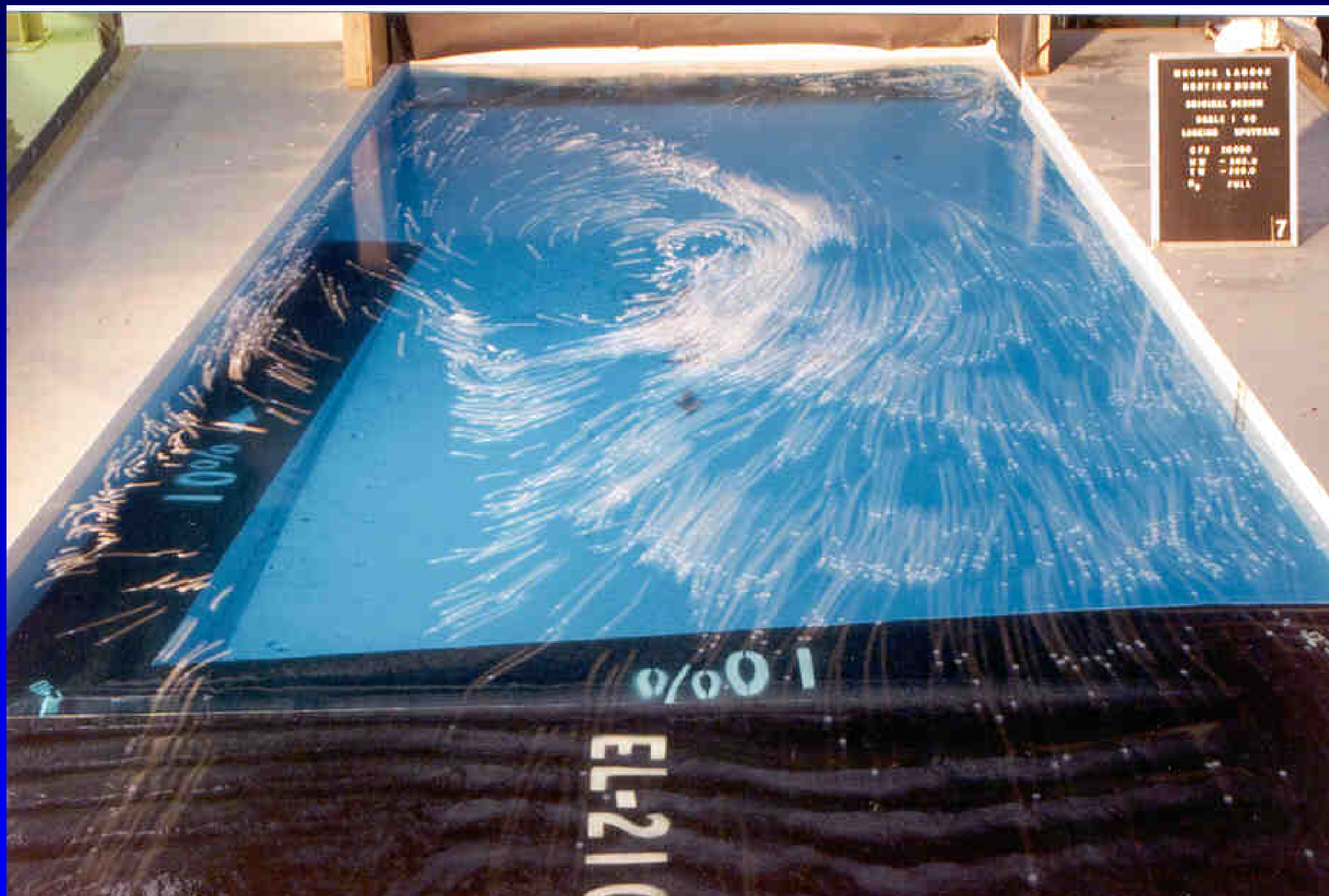

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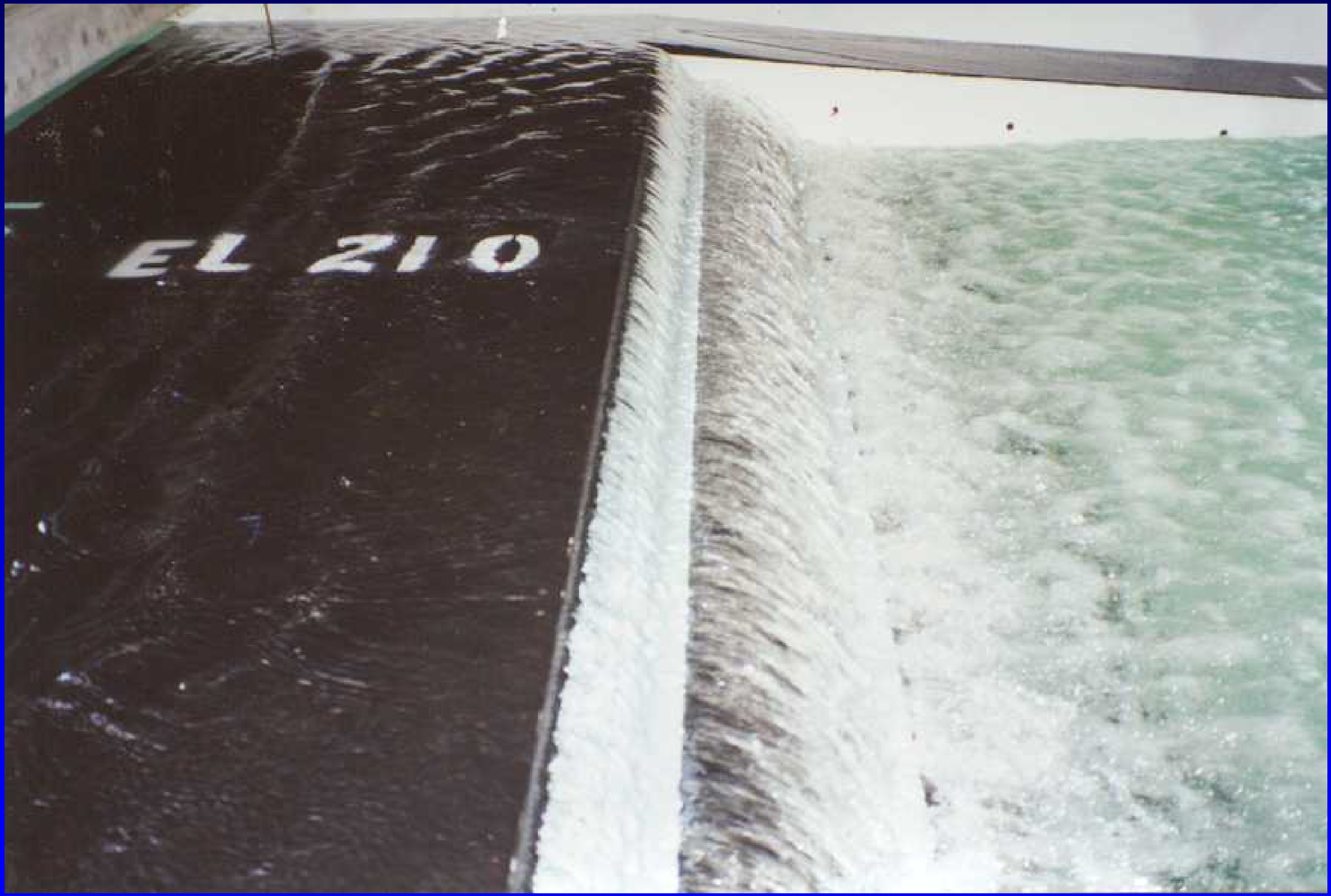

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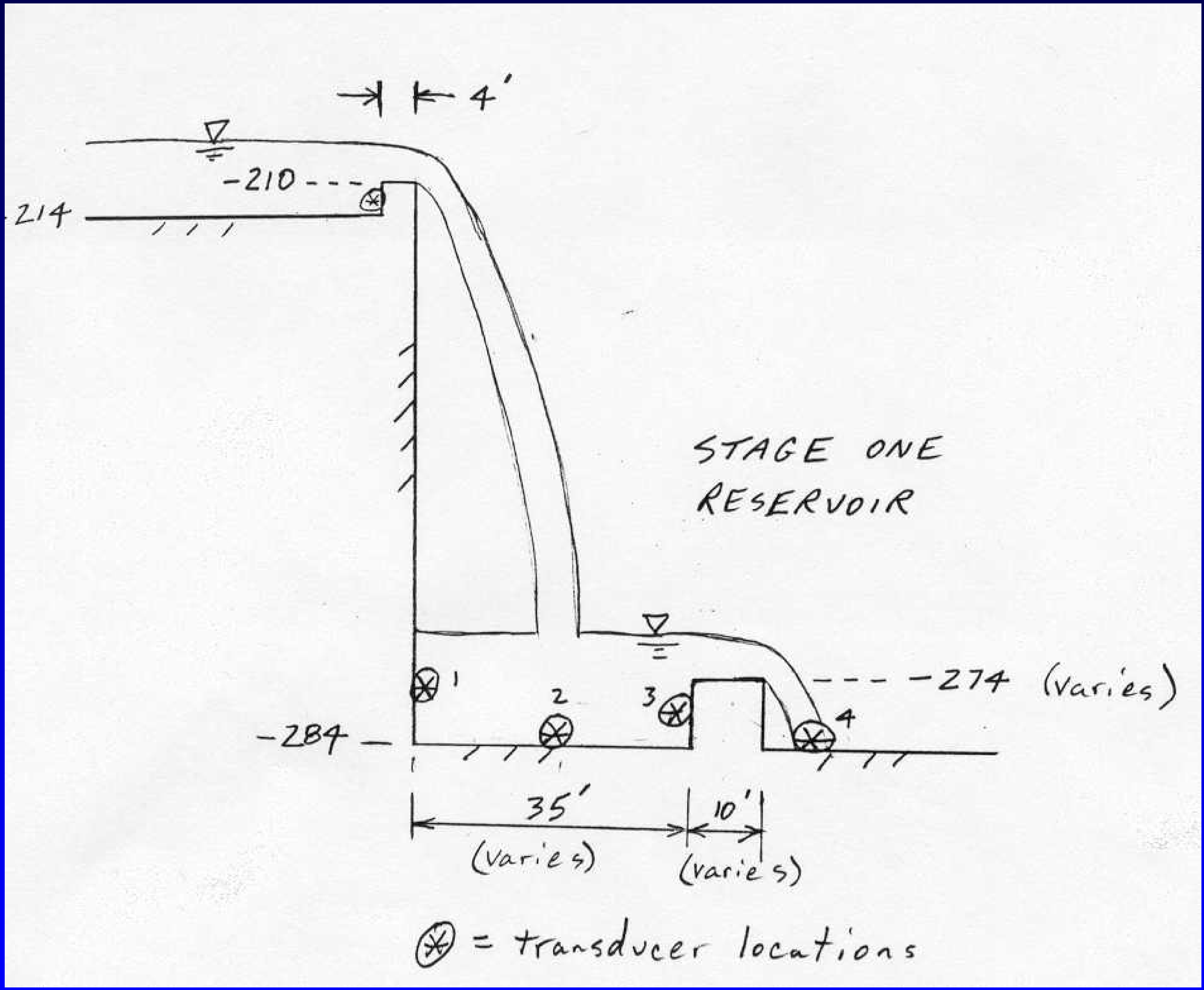

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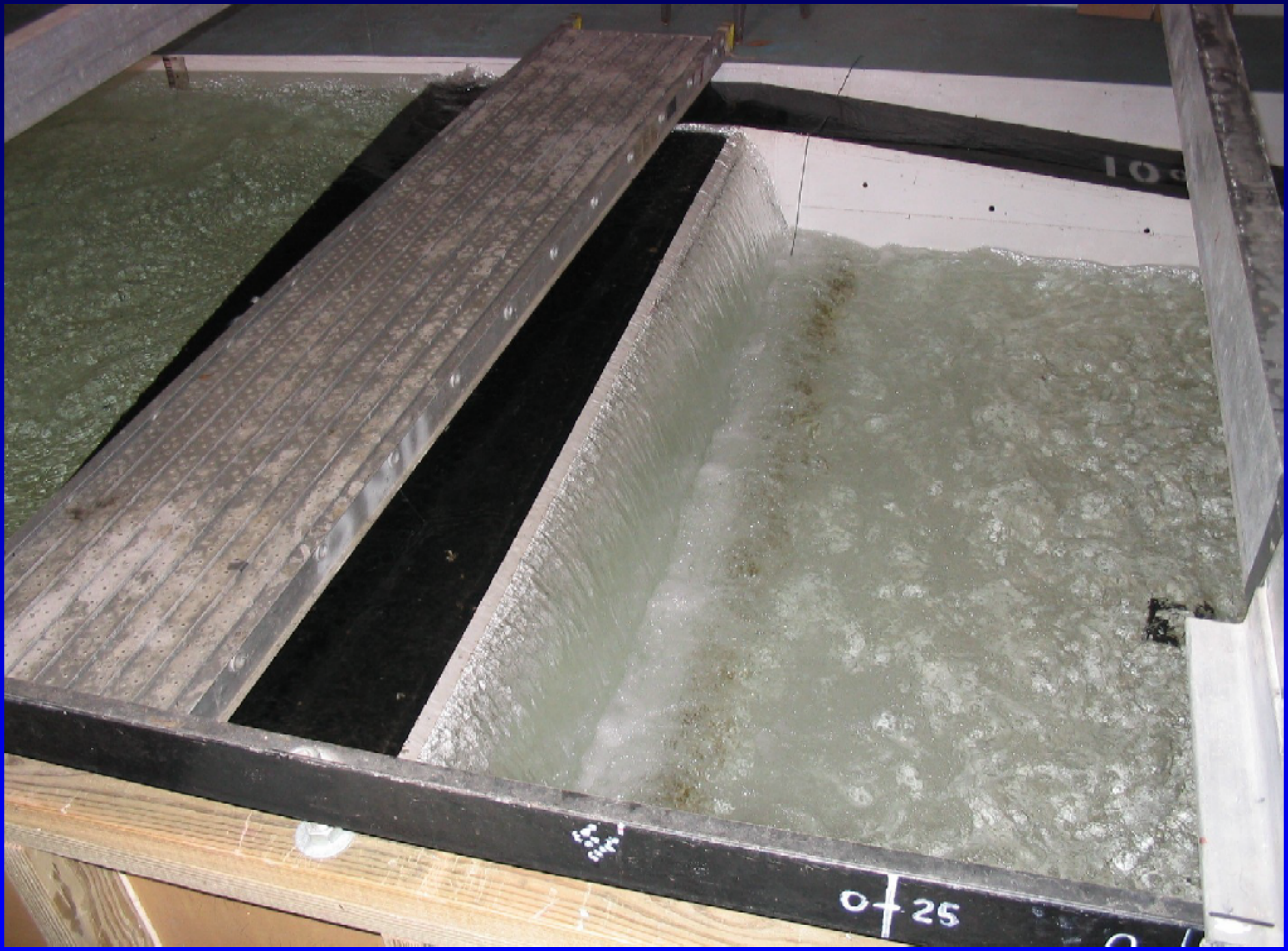

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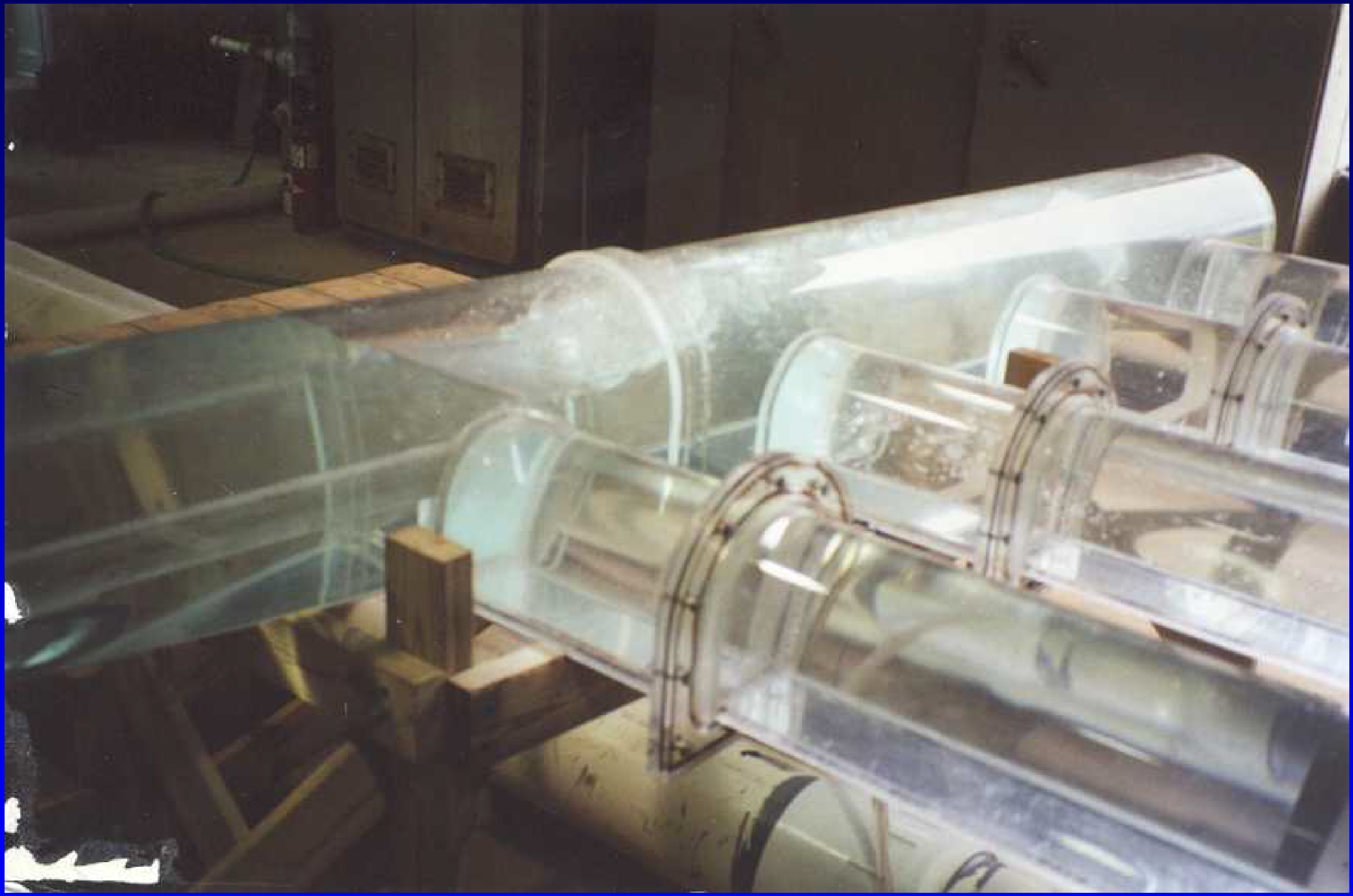

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WES PHYSICAL MODELS

- Distribution Chamber (gravity inflow gates and conduits for Des Plaines tunnel gravity inflow)
  - 1:12 model to determine:
    - Operational constraints on the bonneted slide gates wrt headwater and tailwater conditions and gate closure speeds
    - Gate loadings and pressures within the conduits
    - Cavitation potential
    - Information on the transient hydraulics in the vicinity of the bifurcations
    - Recommendations for geometric and or material changes

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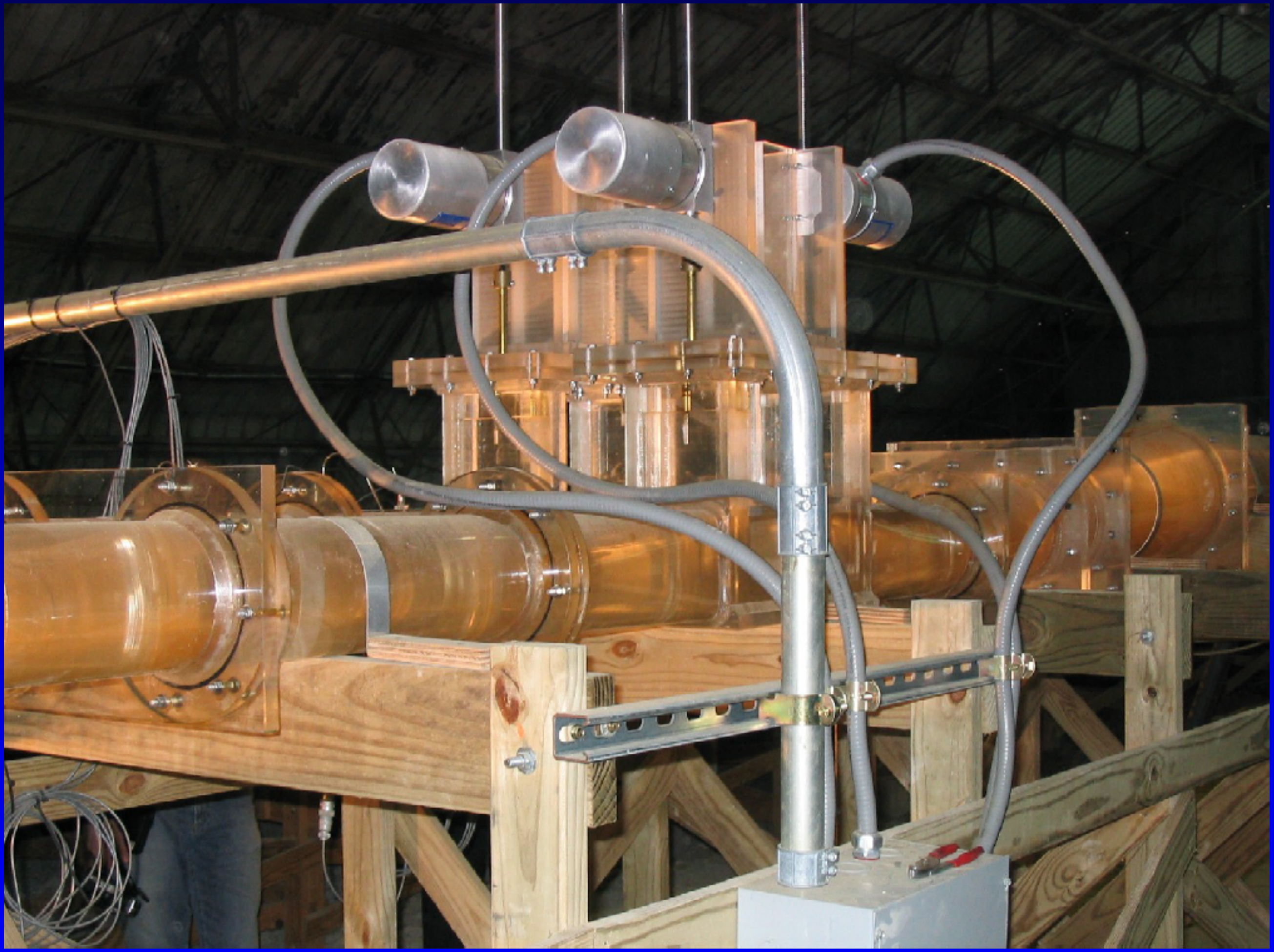

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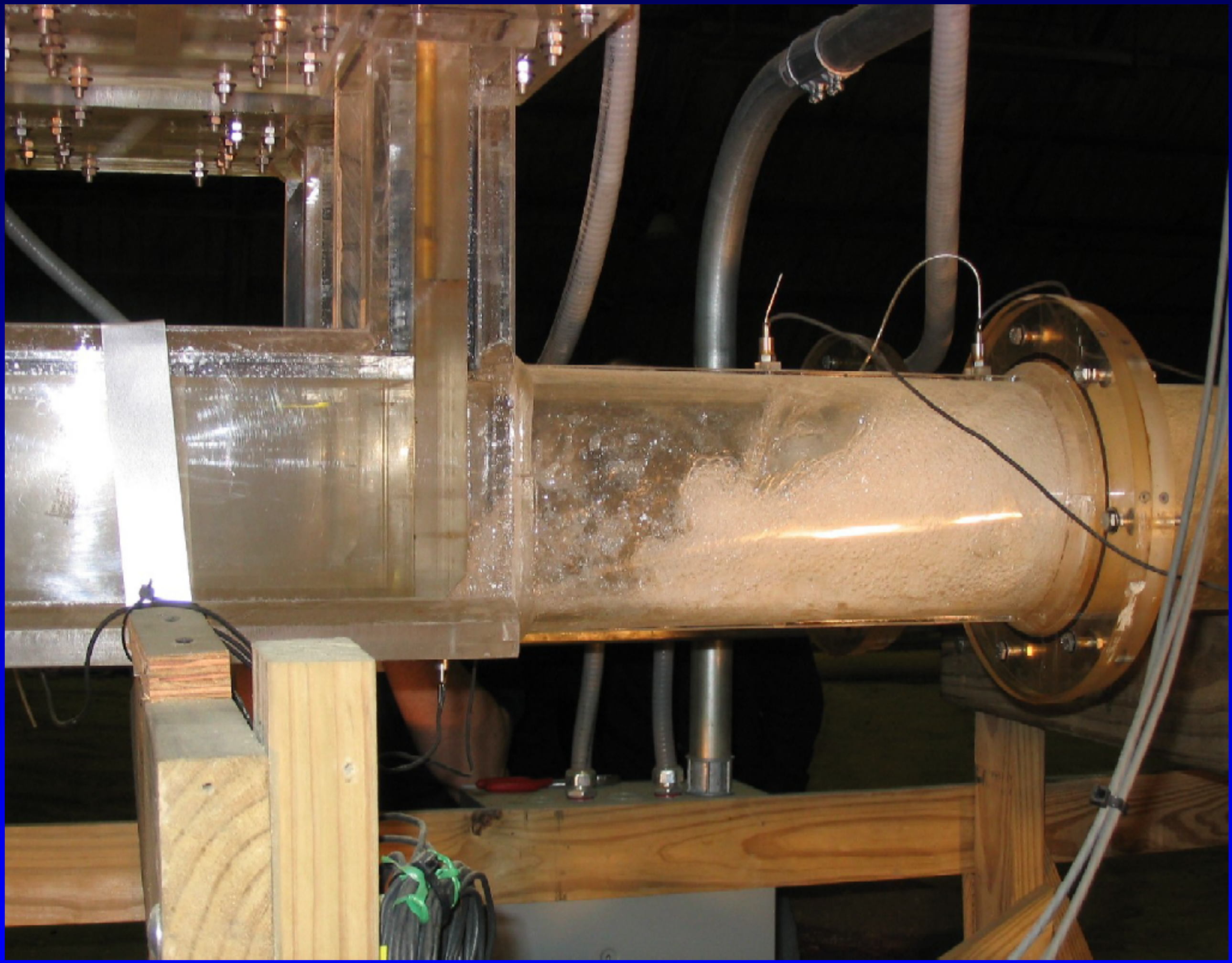

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ADDITIONAL MODELS

- MXTRANS Hydraulic Transient Model
  - University of Minnesota, St. Anthony Falls Hydraulic Laboratory
  - Applies to steady and unsteady flows including pressurized flows, free-surface flows and mixed flows
  - Based on explicit characteristic method
  - Interface between pressurized flow and free-surface flow (shock surface) is computed with the shock fitting method
  - Primarily used to determine
    - operational procedures for minimizing geysering through dropshafts
    - hydraulic loading on main gate
    - effect of main gate operation on hydraulic transients

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ADDITIONAL MODELS

- WHAMO (water hammer and mass oscillation) Hydraulic Transient Model
  - Corps of Engineers (HDC) and Camp Dresser and McKee
  - Applies to steady and unsteady fully pressurized closed conduit flows of various complexities and boundary conditions
  - Based on implicit finite difference method
  - Used to determine loadings on the distribution tunnels small gates and valves as well as surge effects resulting from various operations and mis-operations of the system (including power failures)
  - Operations investigated include pumping from tunnels to reservoir, pumping from tunnels to WRP, pumping from reservoir to WRP, and gravity inflows from Des Plaines tunnel

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QUESTIONS?