EFFECTS OF PROPOSED EMERGENCY WITHDRAWALS FROM THE HUDSON RIVER BY THE CITY OF NEW YORK ON SALT-FRONT MIGRATION IN THE HUDSON RIVER ESTUARY--

Legal Testimony Given Before Judge Susan DuBois

By Daniel C. Hahl

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ILLUSTRATIONS

CONVERSION FACTORS AND ABBREVIATIONS

For use of readers who prefer to use metric (International System) units, conversion factors for inch-pounds terms used in this report are listed below:

Multiply inch-pound unit	By	To obtain metric unit
inch (in.)	0.0254	meter (m)
foot (ft)	0.3048	meter (m)
statute mile (mi)	1.6093	kilometer (km)
nautical mile (nt mi)	1.8532	
U.S. gallon (gal)	3.7850	liter (L)
cubic ft (ft^3)	0.8283	cubic meter (m^3)
	Flow	
cubic foot per second (ft^3)	0.0283	cubic meter per second (m^3/s)
ton	0.9070	metric ton (t)
pound (lb)	0.4535	kilogram (kg)
million gallons per day (Mgal/d)	1.5499	cubic meter per second

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Abstract

Withdrawal of water from the Hudson River at Chelsea, N.Y., for an emergency water supply of 100 Mgal/d (million gallons per day) for New York City may affect the position of the salt front in the estuary. Hydraulic characteristics of the estuary indicate that the proposed point of water withdrawal is within the zone of freshwater and saltwater mixing (transition zone). At the point of withdrawal, the chloride concentration fluctuates from 20 mg/L (milligrams per liter) to 700 mg/L, and, even at the lowest 3-day average inflow above Chelsea on record, the river discharge was 14 times greater than the proposed water-withdrawal rate.

The overwhelming effect of natural driving forces, expressed in the tidal movement of water and in the large fluctuations in chloride concentration within the transition zone, should completely mask the effects of withdrawal of 100 Mgal/d pumpage at Chelsea.

INTRODUCTION

The City of New York built the Chelsea Pump Station on the Hudson River estuary in the mid-1960's to provide 100 Mgal/d (million gallons per day) of potable water to meet emergency needs during water shortages (fig. 1). The subsequent advent of environmental laws required that an Environmental Impact Statement (EIS) be approved for continued operation of the pumping station. In response, the New York City Department of Environmental Protection filed for a water-supply permit persuant to Environmental Conservation Law, Article 15, for drought-emergency operation of the Hudson River pumping plant at Chelsea; the permit application included an EIS.

Environmental conservation groups and local county governments challenged several points in the EIS. Daniel Hahl of the U.S. Geological Survey submitted, on request, the following statements as prefiled direct testimony for a hearing conducted by Judge Susan J. DuBois, Administrative Law Judge for the New York State Department of Environmental Conservation, on May 3-6, 1988, in New York City. The testimony deals with: (1) the hydraulic characteristics of the Hudson River estuary; (2) the magnitude of natural fluctuations in chloride concentration of the estuary in the vicinity of the Chelsea Pump Station; and (3) the magnitude of the proposed withdrawal rate in relation to the river's natural inflow above Chelsea.

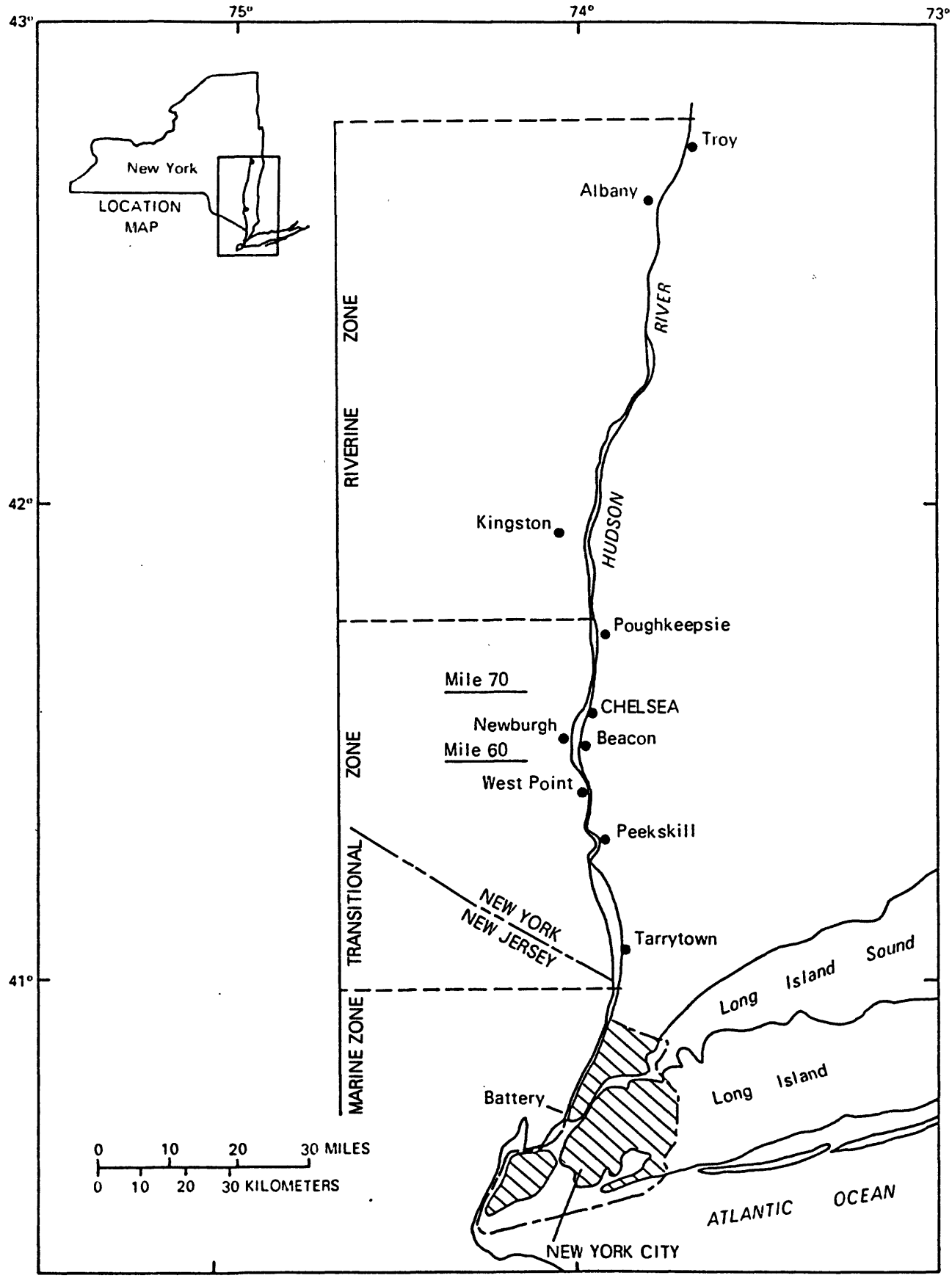

Figure 1.--Components of the Hudson River estuary.

VERBATIM HEARING TESTIMONY

Q. Please state your name and occupation.

A. My name is Daniel C. Hahl. I am the Albany, New York Subdistrict Chief of the Water Resources Division, U.S. Geological Survey, United States Department of the Interior.

Q. On whose behalf are you testifying?

A. My testimony is based on my unique knowledge related to the subject of these proceedings. As an employee of the U.S. Geological Survey I can not act as a consultant to either party. My testimony will be limited to and based upon observed data.

Q. Please summarize your educational and professional experience.

A. I received a B.S. in Chemical Engineering from the University of Utah. Since 1959, I have been employed as a Water Quality Hydrologist by the United States Geological Survey. Until 1968, I served on the staff and as a project chief of lake and river basin studies. From 1968 to 1978, I served as Project Chief for studies of 10 estuaries along the Texas coast. The study described climatic and seasonal variability in estuarine nutrients, the chemical and physical characteristics, and hydrodynamics of the estuaries. From 1978 to 1982, I was a member of a group studying the Potomac Estuary. One of my responsibilities was to document nutrient, suspended sediment, and chloride transport in the estuary. Since 1983, I have developed programs and managed an office of 32 people investigating the hydrology of water resources of eastern New York State, including the Hudson River and watershed areas for the New York City water supply.

During my 29 years of professional experience conducting water-resources investigations I have acquired expertise in freshwater/saltwater mixing in estuaries; effects of precipitation on hydrology; water budgets of estuaries; river and estuary flow dynamics; and other disciplines related to the subject adjudicatory proceedings.

Q. What is the purpose of your testimony?

A. To provide an objective evaluation of the potential effect that the withdrawal of 100 Mgal/d of water through the Chelsea Pump Station, as stipulated in the draft permit, may have on the movement of saltwater in the Hudson River estuary.

Q. What are the physical characteristics of the Hudson River estuary?

A. The ability of ocean water to enter a river depends on a number of factors. Two significant factors are channel geometry and river flow. Various combinations of the two cause characteristic mixing of freshwater and saltwater. Examples can be imagined by categorical names given classes of estuaries such as fjord, drowned river-mouth, and barrier island. The Hudson River estuary is a drowned river-mouth type estuary.

Hudson River flow through the millennia has been sufficient to carry sediments into the deep ocean. This transport has (1) prevented formation of a barrier island and (2) provided continual removal of sediment from the inland channel. Therefore, the gradual sea-level rise that followed glaciation drowned the almost 160-mile-long reach from the Battery in lower Manhattan to Troy, N.Y. Thus, this reach of the Hudson is affected by tides.

Q. What are the major parts/regions of an estuary?

A. All estuaries consist of three zones: one zone always contains salty water (marine), one zone always contains fresh water (riverine) and one zone, the transition zone, is a zone of mixing of freshwater and saltwater.

Q. Please describe the location and significance of these zones within the Hudson River (as they relate to the subject proceedings).

A. The most significant zone with respect to this hearing is the transition zone (fig. 1), which extends about 55 miles south from Poughkeepsie, (at about river mile 75) as measured from the Battery to near Tarrytown (at about river mile 20). This zone is characterized by extreme changes in water quality and, hence, changes over relatively short periods of time. For example, at river mile 65, chloride concentrations usually are less than 50 mg/L (milligrams per liter); however, concentrations as high as 700 mg/L have been measured. At river mile 30, chloride concentrations are usually about 5,000 mg/L, but concentrations as low as 50 mg/L have been measured (fig. 2). The zones illustrated in figure 1 were developed from data by Giese and Barr, (1967), and U.S. Geological Survey (data on file at the New York District office, Albany, New York).

The point is that the 20- to 40-mile reach where mixing occurs migrates up and down the transition zone in response to natural forces; migration along the reach may require only a few days. Major natural driving forces that influence saltwater movement are tides, river flow, wind, and passage of large storms. Response of saltwater movement to the complex interactions of these and other driving forces is not well understood.

Q. Please define the term salt front.

A. Because the Hudson River estuary is a drowned-river estuary and receives large amounts of freshwater at the upstream end and is open to the ocean at the downstream end a unique set of physical constraints exists which causes characteristic mixing of freshwater and saltwater (Abood, 1977). Mixing in the Hudson River estuary defined by the degree of change in chloride concentration in a range from 50 mg/L to 10,000 mg/L, usually occurs in a reach 20- to 40-miles long (fig. 1). The reach in which mixing occurs is diffuse and usually contains no sharp salt-water/fresh-water interface either longitudinally or vertically. The leading edge of the reach of mixing is called the "salt front" and is conventionally defined as the location of the line where chloride concentration is 50 mg/L. The New York State Department of Health used 100 mg/L as the salt front designation during the 1985 drought.

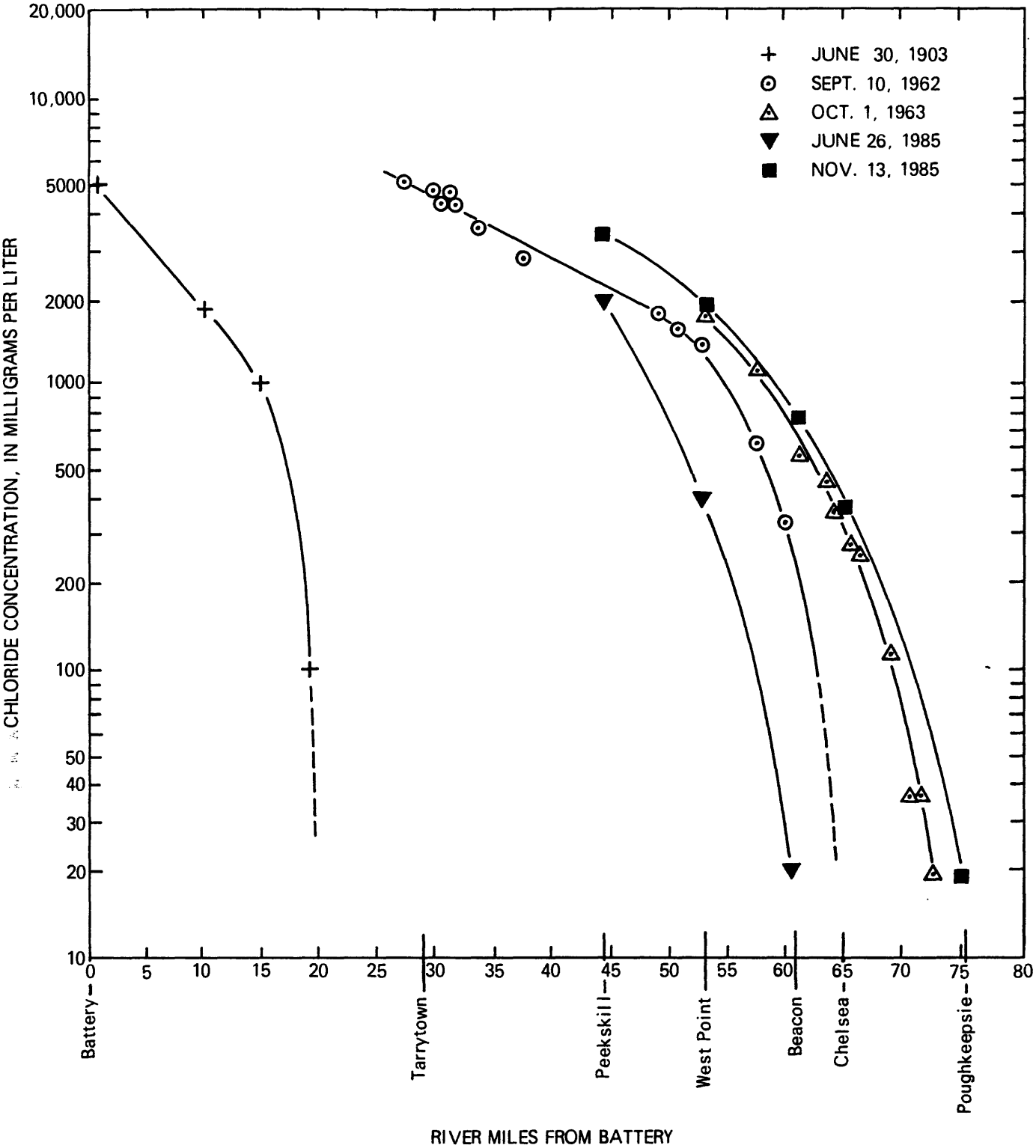

Figure 2.--Longitudinal profiles of saltwater intrusion in the Hudson River estuary. (Modified from Giese and Barr, 1967 figs. 7, 8,; includes unpublished data on file at U.S. Geological Survey office in Albany, N.Y.).

Q. What would be the significance of withdrawing 100 million gallons of water per day, under conditions stipulated in the permit, to the flow of the Hudson River?

A. The 100-Mgal/d withdrawal would not have a significant effect on the flow of the Hudson River. I reached this conclusion after performing the calculations outlined below.

First, for matters of convenience and consistency, I converted withdrawal information, usually presented as millions of gallons per day, to cubic feet per second by multiplying Mgal/d times 1.55. (See Appendix A). Thus, at maximum pumping capacity, the Chelsea Pump Station would withdraw 155 ft^3/s (cubic feet per second). I then established that the 3-day low inflow of the Hudson River above the Chelsea Pump Station during the greatest drought of this century was never lower than 2,110 ft^3/s and was usually about 2,500 ft^3/s. These numbers represent conditions during the 1965 drought and, compared to the withdrawal rate of 155 ft^3/s, indicate that the withdrawal represents 6 to 7 percent of the Hudson River low inflow above the Chelsea Pump Station in 1965. Conditions during the 1985 drought were not as severe, and the withdrawal rate represented less than 4 percent of river's low inflow in 1985.

Q. How did you establish the flow of the Hudson River at the Chelsea Pump Station?

A. Based upon streamflow records of the U.S. Geological Survey, I determined that the lowest 3-day average flows at Green Island (Appendix B) during the 1965 and 1985 droughts were 1,773 ft^3/s and 2,893 ft^3/s, respectively (U.S. Geological Survey, 1966, 1986). To this value, I added the inflow of tributaries to the Hudson River between Green Island and the Chelsea Pump Station (unpublished computations from USGS files). The inflow from these tributaries ranged from 6 percent to 32 percent when compared to the flow at Green Island during 1965 and 1985 (Appendix B).

Q. In layman's terms, could you provide an illustration of what the withdrawal of 155 ft^3/s of water at the Chelsea Pump Station represents in regard to the flow of the Hudson River, and the movement of the salt front within the river?

A. Yes. I can use the following analogy. My analogy compares the Cheslea withdrawal rate to the combined inflow volume of tributaries below Green Island. The Chelsea withdrawal rate of 155 ft^3/s or 100 Mgal/d usually represents less than half of the total rate of tributary inflow (Appendix B). It is important to keep in mind that the flow at Green Island is far greater than the tributary inflow, and the combined inflows of tributaries and flow at Green Island is usually 14 times that of the proposed withdrawal at Chelsea Pump Station. This relation is illustrated in figure 3.

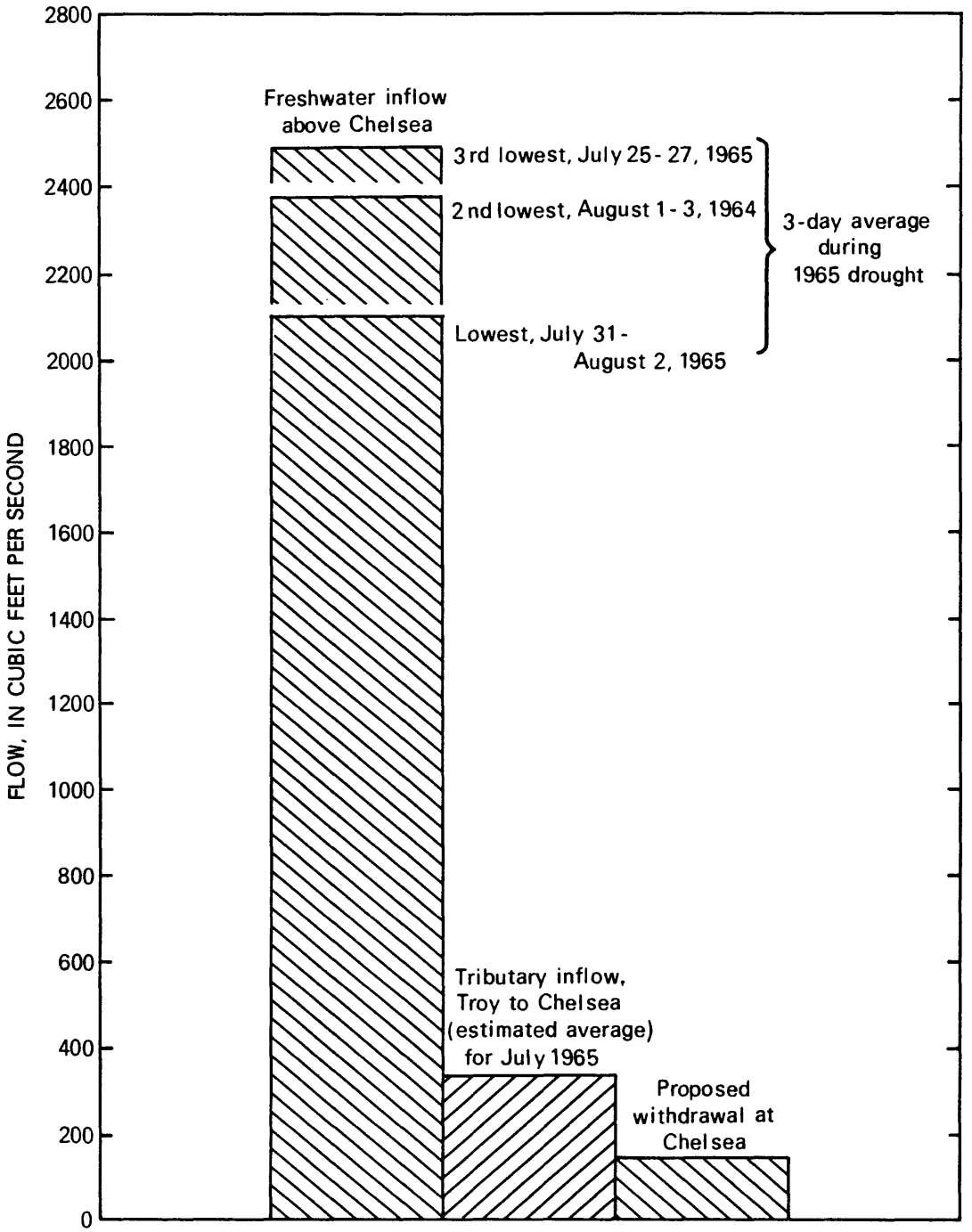

Figure 3.--Hudson River minimum 3-day average inflow above Chelsea in relation to tributary inflow and proposed withdrawal at Chelsea Pump Station.

Q. In your professional opinion, do you feel the hydraulic effect of the 155 ft^3/s (100 Mgal/d) withdrawal rate would remain within the natural hydraulic variations characteristic of the transition zone of the Hudson River estuary?

A. Yes. The distance water moves during tide cycles, the natural variation in historical chloride concentrations within the transition zone, and the large river flow during the historical drought compared to the withdrawal rate at the Pump Station will completely mask the withdrawal of 100 Mgal/d at Chelsea.

Q. Does this conclude your testimony?

A. Yes.

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APPENDIX A

COMPUTATIONAL PROCEDURES FOR CONVERTING GALLONS PER DAY TO CUBIC FEET PER SECOND.

1. Convert gallons to cubic feet:

   1 gal = 0.1337 cubic feet

2. Convert days to seconds:

   1 day = 86,400 seconds

3. Thus 1,000,000 gallons per day

$$= \frac{133{,}700 \text{ cubic feet}}{86{,}400 \text{ seconds}}$$

= 1.55 cubic feet per second

APPENDIX B

LOWEST 3-DAY PERIODS OF HUDSON RIVER FLOW AT GREEN ISLAND, N.Y., WATER YEARS 1964-65 AND 1985

[ft^3/s, cubic feet per second]

Date	Average 3-day low flow (ft^3/s)	Average tributary inflow downstream from Green Island for month (ft^3/s)	Average flow for month (ft^3/s)	Chelsea withdrawal as percent of tributary inflow	Chelsea withdrawal as percent of average monthly inflow above Chelsea
1964					
July 4-6	2,233	434	3,131	36	5
July 11-13	2,237				
July 18-20	2,203				
July 25-27	2,270				
Aug. 1-3	2,170	216	3,398	72	5
Oct. 10-12	2,187	332	2,967	47	5
1965					
July 25-27	2,150	337	3,082	46	5
July 31-Aug. 2	1,773				
Aug. 29-31	2,197	387	2,912	40	5
1985					
Aug. 4-6	3,117	1,420	4,440	11	3
Aug. 17-19	2,893				