DEPARTMENT OF SANITARY ENGINEERING

PUBLIC
WATER SYSTEM
OF THE
DISTRICT OF COLUMBIA

PREPARED IN THE
DESIGN AND ENGINEERING DIVISION

APRIL 1966

PUBLIC WATER SYSTEM OF THE DISTRICT OF COLUMBIA

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INTRODUCTORY HISTORY

Water Supply in the Nation's Capital

The development of the District of Columbia and its surrounding area, as with other cities and localities the world over, has been influenced from its very beginning by matters of water supply. Captain John Smith was probably the first white man to explore and describe the area. In reporting on his expedition to the head of navigation of the Potomac in 1608, he described it as "...fed...with many sweet rivers and springs, which fall from the bordering hills." In describing the area in 1634, Father White, a missionary to the Indians, wrote "All is high woods except where the Indians have cleared for corn. It abounds with delicate springs which are best drinks."

Major L'Enfant's original plan for the City of Washington, made in 1791, bears several notes concerning the availability of streams and springs and their possible use in supplying the proposed Federal City.

In a letter written in 1798, General Washington expressed a belief "that the water of the Potomac may, and will be brought from above the Great Falls into the Federal City, which would, in future, afford an ample supply of this object." In its first Act of Incorporation approved by President Thomas Jefferson on May 3, 1802, the City of Washington was granted, among other powers, the authority "to sink wells and erect and repair pumps in the streets." In the early growth of the new capital city, it was natural that dependence for water supply was on the many springs and the ground water supply available in shallow wells.

The principal springs which supplied the downtown part of the city were the City Spring on the north side of C Street, N. W. between 4-1/2 and 6th Streets; Caffrey's, or the Hotel Spring, at the northwest corner of 9th and F Streets, N. W.; one in the public space of 13th Street, N. W., north of Eye Street; another just to the west, near the center of Franklin Park; one located in "City Hall Park", now judiciary Square; and the Smith Spring, located within the present McMillan Reservoir. There were many other springs of considerable neighborhood importance within the old city, but it is doubtful if any of them were used to supply pipe systems.

The first instance of water having been piped through the streets for public use was in 1808, when the Corporation permitted the "inhabitants" in the vicinity of the 600 block of Pennsylvania Avenue, N. W., to convey water from the City Spring to their neighborhood. The first appropriation of public funds for a water piping project was by Act. of August 4, 1809, when the city appropriated the sum of $300.00, representing about one-third of the cost, toward construction of a pipe to convey water from Caffrey's Spring to the vicinity of Pennsylvania Avenue, N. W., between 9th and 14th Streets. There appear to have been no further water pipe extensions in the streets until 1823, when the 13th Street Spring was piped southward in 13th Street and 14th Street with branches and extensions going, in the course of several years, as far south as Ohio Avenue, west to 15th Street and east to 11th Street. The pipe lines constructed in 1808 and 1809 were of bored log construction. The 1823 work seems to have been partly of bored log pipe and partly of cast iron. Remains of the wooden pipes are still encountered in excavations in the streets.

A major factor in the protection of the ground water supply was an ordinance approved May 13, 1805, which prohibited the use of privy pits.

An Act of the City Council dated August 5, 1812, provided gneral authority "for sinking of wells and erecting of pumps, conveying of water in pipes, and fixing of hydrants, for the improvement of springs and other purposes." Under this Act, upon application of two-thirds of the residents of a neighborhood, the Mayor, if he deemed it reasonable and expedient, could cause one-half of the cost of such improvements to be assessed against the resident beneficiaries. In addition to the construction, improvement and maintenance of springs, wells and pipe lines, the city constructed large brick cisterns or reservoirs in strategic street intersections to store water for fire fighting.

In order to secure the use of the spring located in Square 249 to supply the White House and nearby government buildings, the Federal Government in 1832 purchased that square, now known as Franklin Park, and by 1834 this water was in use in the White House. A previous appropriation in 1819 for this purchase had proven insufficient and was diverted to other work. In 1833, the Smith Spring located north of Florida Avenue was purchased and the water therefrom piped to the Capitol Building. In 1837, this supply was extended by a 4-inch main along Pennsylvania Avenue nearly to 15th Street and a number of fire hydrants were erected on the avenue.

The spring water piping systems were extended and replaced from year to year. By 1850 most of the streets in the vicinity of Pennsylvania Avenue from First to 15th Streets and north as far as the springs were supplied with pipes which for the most part were used for public hydrants or "pumps", but in some cases for service pipes into private premises.

The spring waters being cooler and clearer than unfiltered Potomac water and supposedly having medicinal properties, citizens insisted upon the continued maintenance of some of the spring lines after introduction of the Potomac water and some of them were not abandoned until after 1900.

In the older City of Georgetown there seems to have been no piping of spring water but a number of wells and pumps were maintained by the city. A "company for the purpose of supplying Georgetown with water," authorized by Act of Congress approved April 13, 1814, apparently did not become active.

By the middle of the 19th century, the communties had reached a stage of development where these rudimentary methods of water supply were entirely inadequate. In the 1850 census, the population of Washington was about 40,000 and Georgetown 8,000.

In 1850 Congress appropriated $500.00 and the Corporation of Washington an additional $1,000.00, followed by $300.00 in 1851, for an examination of "the most available mode of supplying water" to the city. Prompted possibly by a fire in the Capitol on December 24, 1851, which destroyed many books of the Thomas Jefferson library, a further appropriation of $5,000.00 was made by Congress in 1852. The engineering studies under the first appropriation were made by Col. George W. Hughes. When the larger amount became available, the further studies were begun by Capt. Frederick A. Smith and upon his death, which occurred almost immediately, the project was assigned to Lieut. Montgomery C. Meigs, later for many years Quartermaster General of the Army. He is credited with the planning and, in the succeeding decade, the construction, of the structures and facilities which became known as the Washington Aqueduct. His recommended plan, which Congress accepted and immediately provided funds for commencing, included a dam and intake above Great Falls, a 9-foot diameter conduit from Great Falls to Dalecarlia, storage and settling reservoirs, at Dalecarlia and above Georgetown, together with various tunnels, bridges, gatehouses and watermains.

Construction was unduly prolonged due to the inadequacy of annual appropriations and, in the later stages, the effects of the Civil War. It was not until January 3, 1858, that water first reached the city through the new system. At first the water was from Little Falls Branch, which was impounded in the Dalecarlia Receiving Reservoir. Potomac water from Great Falls first entered the system on December 5, 1863.

The completion in 1905 of the Washington City Tunnel, McMillan Reservoir and Filtration Plant, and the Bryant Street Pumping Station, introduced filtered water and improved distribution service. Increasing population required a material addition to the system, which was completed in 1928. This included a second conduit from Great Falls, a filtration plant and pumping station at Dalecarlia, with additional transmission mains and reservoirs.

Further expansion of water supply facilities was proposed in a joint report by the District Engineer, United States Engineer Office, and the Engineer Commissioner of the District of Columbia, which was transmitted to the Congress on February 8, 1946, and subsequently published as House Document 480, 79th Congress, Second Session. This report analyzed requirements predicted through the year 2000 (including point of population saturation), established a construction program for the progressive development of facilities and cost estimates. The total estimated cost of necessary construction based on then prevailing prices was $41,427,000. Progress on this program, as modified by changing requirements and available funds, has been under way since 1946. Current construction of the projects under this plan is a part of the present Public Works Program of the District of Columbia.

In addition to these major programs, the system has been continuously expanded and improved to provide more effective water service for public health, convenience and fire protection. The resulting present system and its operation are described in the following pages.

I. GENERAL

1. ADMINISTRATION:

The water supply system of the District of Columbia is divided into two separate divisions, supply and distribution.

a. Supply Division

On September 30, 1850, the Secretary of War was first made responsible for "supplying the City of Washington with pure water." Since that time, an officer of the Corps of Engineers, and later, in 1867, the Corps of Engineers, has been responsible for supplying water to the District of Columbia. The agency of the Corps of Engineers, which performs the actual function of supplying the water, is known as the Washington Aqueduct. This organization has been perpetuated since sometime prior to 1855, when it was first mentioned in a Congressional Statute. The supply system consists of the facilities required to collect the water from the Potomac River at its Great Falls and Little Falls intakes and to convey it to the District of Columbia, filter and pump a portion of it into the distribution system. This includes dams, conduits, reservoirs, filtration plants, pumping stations and transmission mains.

b. Distribution Division

The distribution division consists of elements of the Department of Sanitary Engineering of the District of Columbia Government under the Commissioners of the District of Columbia. It receives, stores, pumps and distributes the purified water furnished by the supply division. The facilities include pumping stations, reservoirs, tanks, trunk mains and service mains. The metering and billing operation for water sold to consumers, including Federal agencies, is conducted by the Department of Sanitary Engineering.

2. CONSUMERS:

Water is normally supplied to Washington, D. C., Arlington County, Falls Church, and parts of Fairfax County, Virginia. The Washington Suburban Sanitary Commission (in Maryland adjacent to Washington) has a number of connections to the Washington system. These connections are for emergency use, except for minor instances in which small areas in Maryland are regularly supplied from the Washington system. The average daily water consumption

2. CONSUMERS (Continued)

per capita in the District of Columbia for the fiscal year 1965 was 179 gallons, based on an estimated January 1, 1965 population of 815,000 (National Capital Planning Commission). The accompanying table shows water consumption by service areas of the District of Columbia for the fiscal year 1965, also, the amounts furnished to Virginia and Maryland.

3. PRESSURE AREAS:

Ground elevations in the District of Columbia vary from under 7 to 420 feet above mean sea level. To provide an average water pressure of about 50 pounds per square inch over this range in altitude, the city is divided into seven "service areas," each comprising a certain range of ground elevation. The pressure in each of these service areas is controlled to maintain a range of 30 to 90 pounds per square inch, depending upon whether a given location is near the upper or lower boundary of the service area. The Low-Service, covering the business district, is normally supplied by gravity from the McMillan Filtration Plant. Pressure is augmented by booster pumps from the Bryant Street and Dalecarlia Pumping Stations when required by demand. The First-High, Second-High and Third-High areas, consisting of progressively increasing ground elevations west of the Anacostia River, are supplied from the Dalecarlia and McMillan Filtration Plants, through the Dalecarlia and Bryant Street Pumping Stations and high service reservoirs. The Fourth-High area, serving the highest elevations in the northwest section, is supplied by pumping from the Third-High service into two elevated Fourth-High tanks, all at Fort Reno. Low-Service water supplies lower elevations east of the Anacostia River and provides pump suction for the Anacostia Pumping Station. From this station water is lifted to the Anacostia First and Second-High service areas. Arlington County and other Virginia areas are supplied from the Third-High service at Dalecarlia. Federal buildings and reservations, such as the Pentagon and Washington National Airport, are on the First-High service. District of Columbia pressure service areas are shown on page 4.

4. PROFILE DIAGRAM:

The relative elevations of existing and proposed major elements of the water supply and distribution system are shown on the "Water System Diagram," on page 5. Ground elevations supplied by the various service area pressures are shown to the same vertical scale.

WATER CONSUMPTION, FISCAL YEAR 1965

Area	Total Gallons	Average Daily Gallons
DISTRICT OF COLUMBIA		
Low Service	13,576,616,000	37,196,000
First High	15,662,340,000*	42,911,000
Second High	9,162,240,000	25,102,000
Third High	6,884,354,000	18,861,000
Fourth High	1,824,142,000	4,998,000
Anacostia		
First High	4,046,789,000	11,087,000
Second High	2,114,745,000	5,794,000
Sub Total Anacostia	6,161.534,000	16,881,000
Total District of Columbia	53,271,226,000	145,949,000
VIRGINIA		
Third High	10,788,150,000	29,557,000
MARYLAND		
Second High	56,000	------
Third High	23,132,000	63,000
Fourth High	13,643,000	38,000
Anacostia Second High	93,170,000	255,000
Total Maryland	130,001,000	356,000
GRAND TOTAL, D.C., VA. & MD.	64,189,377,000	175,862,000

	Gallons
Max. Daily Consumption, F.Y. 1965 (D.C. only) June 29,1965	215,595,000
Min. Daily Consumption, F.Y. 1965 (D.C. only) Dec. 25,1964	105,223,000
Max. Daily Consumption, F.Y. 1965 (Metro. Area) June 29,1965	263,950,000
Min. Daily Consumption, F.Y. 1965 (Metro. Area) Dec. 25,1964	132,134,000
Max. Daily Consumption of Record (Metro. Area) June, 29,1965	263,950,000
Daily District of Columbia Consumption, Per Capita (Based on National Capital Planning Commission estimate of 815,000 population).	179

*Includes Wash Water used at Dalecarlia Filter Plant — 1st High Service 621,620,000

In the Fiscal Year 1965, water consumption in the District of Columbia increased 2.09 percent over the preceding year. All services in the District of Columbia showed an increase in water consumption except Third High Service. Arlington County and Falls Church, Virginia showed an increase in consumption of 6.81 percent and 12.94 percent, respectively. The total quantity of water supplied by the District of Columbia Water System (Grand Total) showed an increase of 3.18 percent as compared to Fiscal Year 1964.

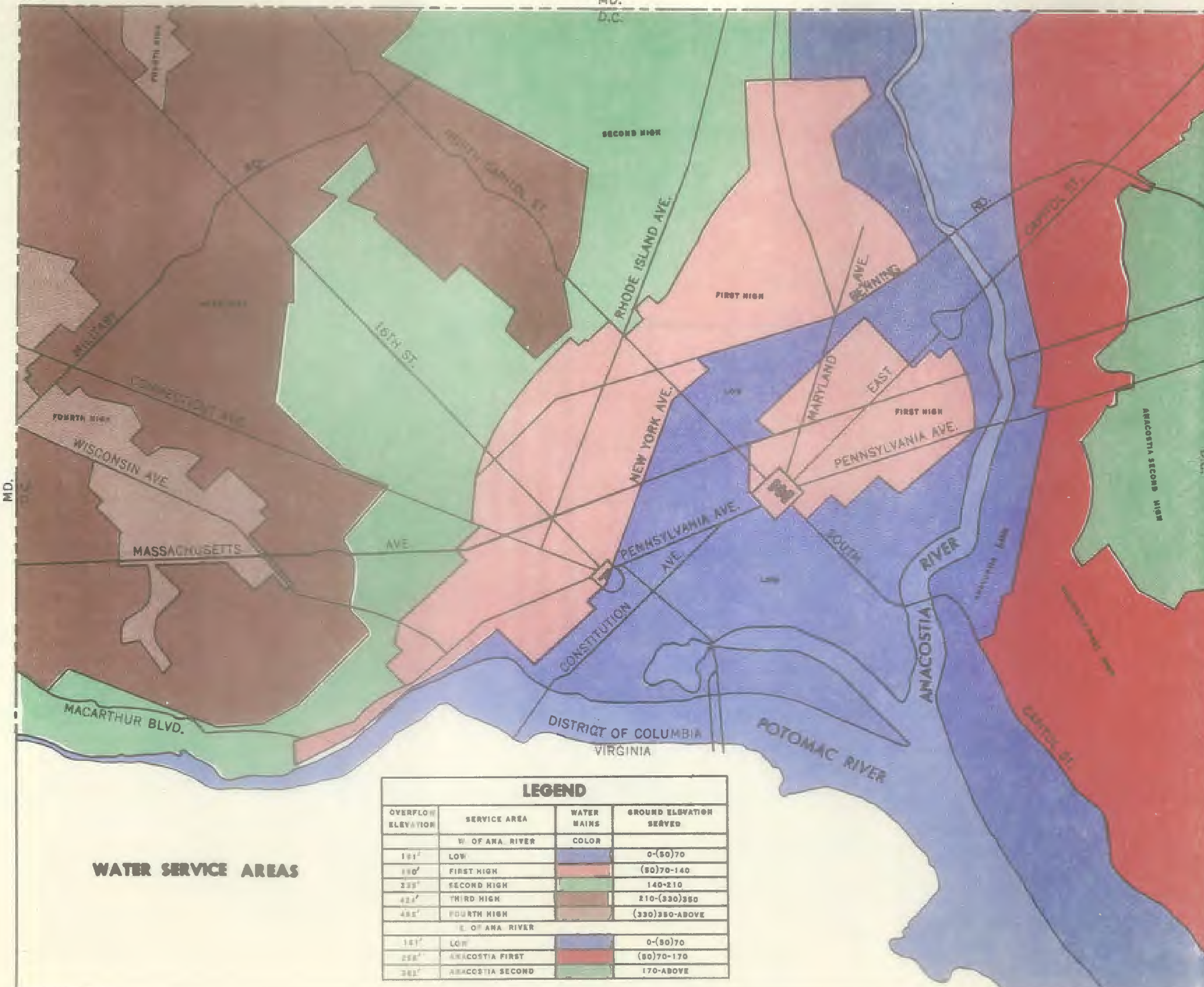
WATER SERVICE AREAS
MD.
D.C.
SECOND HIGH
FIRST HIGH
FOURTH HIGH
LOW
ANACOSTIA SECOND HIGH
SOUTH CAPITOL ST.
RHODE ISLAND AVE.
16TH ST.
MILITARY
RD.
CONNECTICUT AVE.
WISCONSIN AVE.
MASSACHUSETTS
AVE.
NEW YORK AVE.
MARYLAND
AVE.
BENNING
EAST
PENNSYLVANIA AVE.
CONSTITUTION
SOUTH
CAPITOL ST.
ANACOSTIA
RIVER
POTOMAC RIVER
DISTRICT OF COLUMBIA
VIRGINIA
MACARTHUR BLVD.
LEGEND
OVERFLOW ELEVATION
SERVICE AREA
WATER MAINS COLOR
GROUND ELEVATION SERVED
W. OF ANA. RIVER
LOW 0-(50)70
FIRST HIGH (50)70-140
SECOND HIGH 140-210
THIRD HIGH 210-(330)350
FOURTH HIGH (330)350-ABOVE
E. OF ANA. RIVER
LOW 0-(50)70
ANACOSTIA FIRST (50)70-170
ANACOSTIA SECOND 170-ABOVE

PLATE I

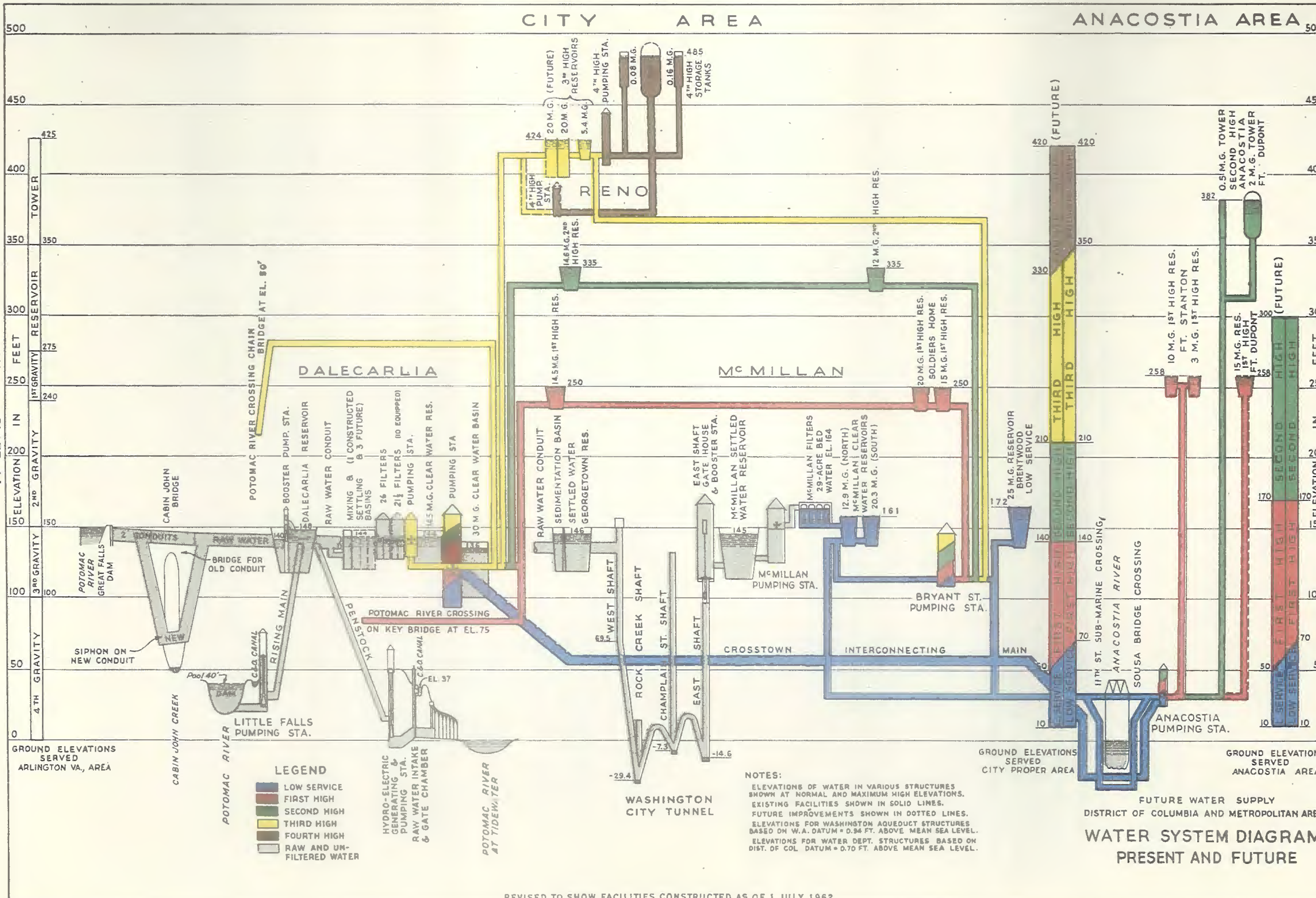

PLATE PREPARED BY MODIFICATION OF DRAWING SHEET NO. 26 TO ACCOMPANY REPORT DATED AUGUST 15, 1945, BY CORPS OF ENGINEERS WAR DEPARTMENT

PLATE 11

II. COLLECTING SYSTEM

5. SOURCE:

The Potomac River, the third largest stream on the Atlantic seaboard, is the source of water for Washington, D.C. The water supply intakes are located at Great Falls, Maryland, about 10 miles northwest of the District of Columbia boundary, and at Little Falls, Maryland, approximately 1-1/2 miles upstream from Chain Bridge. At Great Falls the river has a drainage area of 11,460 square miles, which is slightly less than the combined areas of the States of Maryland and Rhode Island. The average discharge is 7,100 mgd.* at Great Falls, Maryland. The maximum water consumption, at present, including that of parts of Maryland and Virginia supplied from Washington purification plants, utilizes about 3 per cent of the average flow and about 50 per cent of the low-water flow of 506 mgd.* which latter occurred on August 25, 1930, the lowest single day's flow of record. The supply of water from the Potomac River, therefore, is barely adequate for needs of Washington and its environs, provided flow is not diverted or utilized for other purposes.

6. DAMS AND INTAKES:

a. Great Falls

The diversion dam at Great Falls is a rectangular-shaped masonry structure, reinforced with riprap upstream. It is 2,877 feet long, 8 feet wide at top, and 10 to 15 feet in height for the greater part of its length. The twelve inch high flashboards on top of the dam maintain the surface of the intake pool at an elevation of 151.5 feet above mean sea level. Two screened intake structures feed the raw-water conduits.

b. Little Falls

In June 1959, the Washington Aqueduct completed construction of a 1,500 foot diversion dam, intake works and a pumping station at Little Falls on the Potomac. This facility provides an additional independent raw water supply. A rising tunnel, 10 feet in diameter and 4,560 feet long, discharges into the Dalecarlia Reservoir. This remotely operated intake structure and pumping station has an installed capacity of 450 mgd., and a future installed capacity of 600 mgd. A 36-inch reinforced concrete pipeline was built into the upstream face of the dam to serve areas in Virginia. A fish ladder was constructed over the dam at Snake Island.

* million gallons per day.

7. CONDUITS:

Two conduits (known as the Old Conduit and the New Conduit) conduct river water by gravity to the Dalecarlia Reservoir. The Old Conduit, a part of the original system completed in 1863, traverses the nine miles between Great Falls and the Dalecarlia Reservoir, with an additional two miles of conduit linking the Dalecarlia and the Georgetown Reservoirs. This conduit is circular, nine feet in diameter, of two or three rings of brick or cement-rubble masonry. The slope is about nine inches per mile for the entire length. Included are a number of tunnels, culverts, and bridges. Building a conduit of this magnitude and flatness of grade makes it one of the remarkable engineering feats of its time. The conduit is under slight pressure at the upper end. The maximum capacity is 106 mgd. The New Conduit, completed in 1926, parallels the old conduit between Great Falls and Dalecarlia. It is horseshoe shaped 10' x 10' in section, unreinforced concrete. Its hydraulic gradient is approximately the same as that of the old conduit. At Cabin John Bridge, a steel, concrete-encased, concrete-lined, inverted siphon is used in lieu of the bridge crossing of the old conduit. The maximum capacity is 127 mgd. Three interconnections with the old conduit permit repair of a section of either conduit without placing an entire conduit out of service. MacArthur Boulevard, originally Conduit Road, was constructed in 1870 between Great Falls and Washington to provide access to the old conduit and intake facilities in Maryland.

8. DALECARLIA RESERVOIR AND BOOSTER PUMPING STATION:

The receiving reservoir is an earth-embankment, riprap-revetment, settling and storage reservoir, 46 acres in area, with a usable capacity of 60 million gallons. It is located at the northwest District boundary in the valley of Little Falls Branch. A dam across the northern neck of the reservoir creates a fore-bay at the effluent of the raw-water conduits. A remote-controlled booster station lowers the water level in the fore-bay and raises the level in the reservoir proper. This induces greater flow in the conduits by increasing the head differential and, also, increases the head between the reservoir proper and the Dalecarlia Filter Plant, the Georgetown Reservoir, and the hydroelectric plant. The booster station consists of three main pumps, each of 108 mgd capacity against a head of 8 feet, and a single unit of 21 mgd capacity, all electrically driven. Water from Little Falls Pumping Station is pumped directly to the main Dalecarlia Reservoir.

9. GEORGETOWN RESERVOIR:

The Georgetown Reservoir is an earth-embankment, riprap-revetment, sedimentation and storage reservoir, 42 acres in area, with a usable capacity of 55 million gallons. This reservoir, originally intended only for use as a

9. GEORGETOWN RESERVOIR (Continued):

storage and distribution reservoir when the water supply was unfiltered, is now used as a sedimentation basin for the water destined for the McMillan Filter Plant. Coagulant is added to the water in the conduit at Dalecarlia, where sufficient turbulent energy is generated during flow to Georgetown to accomplish mixing of the chemicals and flocculation. The floc formed in transit settles in the two sections of the reservoir which have paved floors. These sections are drained and cleaned periodically. Clarification continues during passage through the third section of the reservoir, then the effluent from the reservoir passes through the Washington City Tunnel to the McMillan Reservoir. A conduit, 7 feet in diameter, bypasses the reservoir for emergency use.

10. WASHINGTON CITY WATER TUNNEL:

The Washington City Tunnel is four miles long extending from the West Shaft at Georgetown Reservoir to the East Shaft at McMillan Reservoir. It is horseshoe shaped in section, 9' x 9.8', and constructed of brick and rubble masonry, except for four hundred feet of flanged cast-iron pipe under Rock Creek. The end shafts are 12 feet in diameter. Two intermediate shafts, 6 feet in diameter, are at Rock Creek and Champlain Street. The entrance to the tunnel at the bottom of the West Shaft is at Elevation + 70' and the discharge end is at Elevation — 14'. The lowest point in the tunnel is at Elevation — 29' which is under Rock Creek. The original gravity-flow capacity was 75 mgd. The capacity has been increased to 150 mgd by the installation of a pump in the East Shaft.

11. MCMILLAN RESERVOIR AND EAST SHAFT PUMPING PLANT:

The East Shaft Gatehouse of the tunnel is located at the southwest corner of the McMillan Reservoir. The East Shaft Pumping Plant consists of one vertical, adjustable-blade impeller pump with capacity of 150 mgd. This pump increases the head differential between the east and west terminals of the tunnel, thus increasing the rate of flow. The reservoir is earth embanked and revetted with riprap, with an area of 38 acres and a usable capacity of 100 mg. This facility is used as a storage reservoir. The water from the East Shaft Gatehouse is introduced to the reservoir at its northwestern end through a circulating conduit. This provides good water distribution and allows for additional settlement during passage through the reservoir to the pump intakes in the east bay.

12. <u>MCMILLAN PUMPING STATION:</u>

At this station, three vertical, adjustable-blade impeller pumps, each having a capacity of 75 mgd against a head of 27 feet, lift water from the McMillan Reservoir to the adjacent McMillan slow-sand filters. Wash water for the filters is pumped from the unfiltered reservoir by two horizontal centrifugal pumps with capacities of 1-1/2 and 2 mgd against a head of 250 feet. All pumps are electrically driven.

III. WATER TREATMENT

13. McMILLAN FILTRATION PLANT:

This plant, completed in 1905, is one of the few large, slow-sand filtration plants still in use in the United States. Originally rated at 75 mgd, plant improvements and modification of treatment operations have increased the capacity to 125 mgd. There are 29 slow-sand filter beds, with an area of one acre each with necessary sand bins, regulator houses, administrative and maintenance buildings. The filters are of groined arch, unreinforced concrete construction, with a sand dept of 20" supported by 12" of graded crushed stone. The sand has an effective size of 0.32 m.m. and a uniformity coefficient of 1.75. Filtered water is collected by an underdrain system of 6" and 12" tile pipes, laid with open joints on the filter floor, feeding a 24" tile central collector. Twenty-inch effluent pipes with propeller meters deliver the filtered water to the regulator houses. A large collector main intercepts the filtered water from the regulator houses and discharges it into the north chamber of two clear-water basins connected in series. Filters are washed after filtering approximately 1000 mg. A treaded electrically-operated mechanical unit scrapes and washes the sand, ejecting cleaned sand immediately behind the machine. The sand is raked with a tractor-drawn harrow between washings. Sand is deep-cleaned as necessary. Pre-treatment with aluminum sulphate and chlorine at Dalecarlia and subsequent sedimentation at Georgetown and McMillan Reservoirs results in turbidities as low as 2 to 3 parts per million in the water as it is applied to the McMillan filters. Fluoride is added to the McMillan raw water as it leaves Dalecarlia Reservoir. After filtration, the water is disinfected with chlorine and the pH is adjusted with hydrated lime. The two covered clear-water basins are adjacent to the filters and have a combined capacity of 33.2 mg. These basins act as a suction well for the nearby Bryant Street Pumping Station, which pumps water to the various pressure services. When Low Service is not being pumped, the basins act as a distributing reservoir for that service area.

14. DALECARLIA FILTRATION PLANT:

A rapid-sand filter plant with a rated capacity of 80 mgd was completed in 1928. Six additional filters were completed in 1951, increasing the total rated capacity to 104 mgd. With the completion of the new filter and chemical buildings early in 1964, 21 1-2 new filters were added of which 10 have been equipped and placed in operation making the total rated capacity at Dalecarlia 164 mgd. This plant receives raw water from the Dalecarlia Reservoir. Chlorine is applied to the raw water entering the plant to disinfect the water and to oxidize any organic matter which may be present. Chlorine residuals are maintained during flocculation, sedimentation, filtration and in the finished water going to the city. Aluminum sulphate in the form of a liquid solution of crystal alum is fed continuously to the raw water for removal of the suspended matter. Complete mixing of chemicals with raw water and flocculation occur in the mechanical flocculation chambers located at the influent of the sedimentation basins. Removal of the alum floc, together with the entrapped mud particles and bacteria, occurs in the sedimentation basins. There are two concrete sedimentation basins, each 335 feet long, 150 feet wide, and 12 to 17 feet deep, with around-the-end diversion walls.

A two-story flocculation-sedimentation basin was added in the fall of 1949. The water enters the two-story basin through distributing ports into the flocculation section, which is part of the lower story. Flocculation is accomplished by six rows of paddles, 14 feet in diameter, operating with axes transverse to the flow of the water. From here, the water flows through the lower sedimentation section; then, vertically, upward and back through the upper sedimentation section to the effluent channel. The capacity of the flocculation section of the basin is 1.64 mg, and the retention period is 45 minutes, with an average velocity of 2.6 feet per minute. The lower sedimentation basin is 316 feet long, 138 feet wide, and 17 feet deep. The upper basin is 460 feet long, 138 feet wide, and 15 feet deep, with a total capacity of 12.074 mg. The retention period in the sedimentation sections is 5.4 hours. These basins are flushed out 3 or 4 times per year. Construction of the second two-story flocculation-sedimentation basin was started in March, 1964 and is scheduled for completion in April, 1966.

From the sedimentation basins, the settled water flows by gravity to the rapid sand filters. Twenty-six of the filters have a rated capacity of 4 mgd. and the ten new larger filters have a rated capacity of 6 mgd., all at a design filtration rate of 2 gallons per minute per square foot of filter surface area. Both sand and crushed anthracite coal are used as filter media. The filters are cleaned by backwashing with filtered water. Rotary surface sweeps are utilized during the backwash operation.

The filtered water may be post-chlorinated, if necessary, to obtain desired residual chlorine in the finished water. Chlorine dioxide may be applied to remove objectionable tastes and odors and sulphur dioxide may be added to remove excess chlorine. Hydrated lime is added to adjust the pH and to control corrosion in the distribution system. Facilities for adding activated carbon will be constructed in 1965-66.

Fluoridation of water was begun on June 23, 1952. Fluoride residuals of approximately 1 ppm are carried in the mains. This has been determined as the optimum amount to accomplish reduction of dental caries in children.

The filtered and treated water is collected in covered concrete clear water basins. The original clear water basin at Dalecarlia has a capacity of about 10.5 mg. An additional 30 mg. covered clear water basin was completed

14. DALECARLIA FILTRATION PLANT (Continued)

in 1954, which increased the total effective storage to 40.5 mg. The new chemical building houses chemical unloading equipment, chemical storage and feed equipment, control center, and a complete waterworks laboratory. The total filtration capacity of this plant is 164 mgd.

Physical and chemical characteristics of raw and finished water are given in tabulation on the following page.

GOVERNMENT OF THE DISTRICT OF COLUMBIA

DEPARTMENT OF SANITARY ENGINEERING

COMPOSITE MINERAL ANALYSIS OF WATER BY DALECARLIA LABORATORY

Calendar Year 1965

All entries in these columns are in milligrams per litre, except for last two lines.

	POTOMAC RIVER RAW WATER SUPPLY			DALECARLIA FILTER PLANT WATER TO CITY			McMILLAN FILTER PLANT WATER TO CITY		
	AVERAGE ALL MONTHS	MAXIMUM MONTH	MINIMUM MONTH	AVERAGE ALL MONTHS	MAXIMUM MONTH	MINIMUM MONTH	AVERAGE ALL MONTHS	MAXIMUM MONTH	MINIMUM MONTH
Total Slds.	202	309	110	220	333	128	215	322	130
SiO_2	7.4	10.6	4.7	7.0	10.5	5.2	7.0	10.4	4.9
Ca.	36.8	61.1	26.5	40	61	27	40	61	27
Cl.	17.5	29.4	6.5	19.9	31.8	8.3	20.9	32.1	9.7
CO_2	1.1	1.8	0.3	1.9	3.7	0.8	2.1	4.6	0.6
F-	0.31	0.37	0.26	0.84	1.05	0.18	0.74	1.01	0.11
Fe.	0.11	0.15	0.05	0.04	0.05	0.02	0.05	0.06	0.03
HCO_3	91	148	54	88	137	54	84	133	46
Mg.	7.5	8.5	6.7	8.0	8.8	7.0	8.0	8.8	7.0
Mn.	0.04	0.06	0.02	0	0	0	0	0	0
NO_2	.010	.021	.005	0	0	0	0	0	0
NO_3	0.42	0.87	0.10	0.46	0.84	0.09	0.49	0.85	0.13
SO_4	57	91	26	68	110	30	65	104	29
Alk. $CaCO_3$	75	121	44	72	112	44	69	109	38
Total* Hard $CaCO_3$	123	181	94	134	188	108	133	187	106
N.C.H. $CaCO_3$	48	60	32	72	76	39	64	78	40
pH	8.1	8.5	7.8	7.9	8.1	7.8	7.9	8.0	7.7
Temp. °F	61	81	41	61	81	41	60	82	39

** To convert hardness to grains per gallon divide by 17.1.*

IV. HIGH SERVICE PUMPING

15. DALECARLIA PUMPING STATION:

The present Dalecarlia Pumping Station, which was completed in 1958, consists of an underground reinforced concrete sub-structure with a head-house and electric sub-stations above ground. The underground portion is 205 feet long, 101 feet wide, and 47 feet deep, or approximately the depth of a 4 story building. The fifteen vertical shaft centrifugal pumps are each connected directly to 4160 volt, 60 cycle, three phase, water-cooled synchronous electrical motors. The pumps have a combined capacity of 477 mgd. All pumping units are designed to run safely in reverse rotation, in case of power failure, at maximum runaway speed, for five minutes under heads equal to the rated heads. Three 8' x 8' finished-water suction conduits supply the pumps. These conduits draw water from the 30 mg clear-water basins located just north of the new pumping station. The pumps supply purified water to four service-level areas within the District of Columbia, and through them to metropolitan Maryland, and to Arlington County and Falls Church, Virginia. One additional pump supplies Third High water to Virginia areas only.

The station is completely air-conditioned to provide dehumidification and temperature control. The control center includes a supervisory switchboard for operational control of all major pumping units and auxiliary equipment contained in the station. It also provides for remote control of a 325 mgd raw-water booster pumping station in fore-bay of main reservoir, a 3000 kw. hydro-electric generating station, and all major pumping units and auxiliary equipment installed in the raw-water supply intake works and pumping station at Little Falls. Pump services and capacities are indicated in the following table.

TABLE III

Dalecarlia Pumping Station
Service Capacities

Service Area	Type	Hydro-Static Lift Rated Head, Feet	Pump Motor H.P.	Rated Capacity, MGD Units	Total
Low Service	Single Stage	50	500	50-50-50	150
First High	Single Stage	145	1000	35-35-35	105
Second High	Single Stage	220	900	20-20-20	60
Third High	Single Stage	300	1750	27-27-27 27-27-27	162
Third High (Va. only)	Single Stage	280	770	11	11
				Total MGD	488

16. DALECARLIA HYDRO-ELECTRIC STATION:

This station is located on the north bank of the C. & O. Canal near the Dalecarlia Filtration Plant. Water is supplied to the hydro-electric station by a 78-inch penstock from the south end of Dalecarlia Reservoir which terminates in a 28' diameter concrete surge tank. There are two vertical hydro-turbines directly connected to vertical alternating current generators. The turbines were designed for an output of 2,200 hp each with net head of 140 feet; the generators for 1,500 kw. The station is controlled from the supervisory switchboard in the operation control room at the Dalecarlia Pumping Station. This station utilizes surplus conduit flow for generation of electrical energy, thereby reducing both power demand and total power costs.

17. BRYANT STREET PUMPING STATION:

The station is located on the north side of Bryant Street between 2nd and 4th Streets, N. W., and south of the McMillan Reservoir. It is operated to take a base load and maintain predetermined minimum pressures on its pumped services. Suction is from 78", 60" and 48" connections from the McMillan clear water basins. Discharge is into transmission mains to the Low, First, Second and Third High distribution systems and reservoirs floating thereon. The Bryant Street Pumping Station has been completely rehabilitated, the project being completed in 1954. Pumps are protected from reversal on power failure by automatic stop and check valves. The control panels include switchboards, flow and pressure recorders on pump discharge lines and nearby Low Service trunk mains, and a piping diagram with position indicating signals and controls for remote operation of important valves. The following table shows pumping capacities of this station.

TABLE IV

Bryant Street Pumping Station
Service Capacities

Service Area	Type	Hydro-Static Lift Rated Head, Feet	Rated Capacity, MGD Units	Rated Capacity, MGD Total
Low	Single Stage	40	35-35-35	105
First High	Single Stage	92	35-35-35	105
Second High	Single Stage	177	25-25	50
Third High	Single Stage	268	15-15	
	Two-Stage Series	268	20	50
			Total MGD	310

18. ANACOSTIA PUMPING STATION:

This station is east of the Anacostia River. Suction is from Low Service trunk mains. Discharge is into trunk mains to the Anacostia First High distribution system and reservoirs, and the Anacostia Second High distribution system and elevated tanks. The pumps are electrically driven. This station has been rehabilitated by adding new pumps, suction and discharge lines, and extension of building. The project was completed in 1959. Pumps are protected from reversal on power failure by automatic stop and check valves. The control panels include switchboards, flow and pressure recorders on pump discharge lines and water level indicators on Anacostia storage units. Pumps, services and capacities are indicated in Table V, below.

TABLE V

Anacostia Pumping Station
Service Capacities

Service Area	Type	Hydro-Static Lift Rated Head, Feet	Rated Capacity, MGD Units	Total
Anacostia First High	Single Stage	145	8.5-11-15-15	49.5
Anacostia Second High	Single Stage	280	5-6-10-10	31
			Total MGD	80.5

19. RENO PUMPING STATION:

This station is in the high area of the northwest section. Suction is from adjacent Third High transmission main or reservoirs. Discharge is into trunk mains to the Fourth High distribution system and two elevated storage tanks, which are also located at Reno.

Pumps are all single stage. They are protected from reversal on power failure by automatic stop and check valves, excepting two small pumps which are provided with check valves. The control panels include switchboards, flow and pressure recorders on pump discharge lines, and water level indicators on Reno elevated tanks. Pumps and capacities are indicated in Table VI, on page 17.

19. RENO PUMPING STATION (Continued)

TABLE VI

Reno Pumping Station
Service Capacities

Service Area	Pump Motive Power	Hydro-Static Lift Rated Head, Feet	Rated Capacity, MGD Units	Rated Capacity, MGD Total
Fourth High	Electric and Gasoline	60	5	5
	Electric	60	5-3.5-3.5 3-1.5	16.5
			Total MGD	21.5

V. DISTRIBUTION SYSTEM

20. DISTRIBUTION RESERVOIRS AND ELEVATED TANKS:

Storage facilities are reservoirs and elevated steel tanks which are directly connected to the distribution system. This tends to equalize pressure during periods of heavy consumption and evens pumping power loads. All distribution system reservoirs are constructed of reinforced concrete and are entirely covered. Elevations and capacities of the distribution system storage facilities are indicated in the following table.

TABLE VII

Reservoirs and Elevated Tanks

Service	Location	Type	Max. Water Elevation (overflow)	Total Capacity (m.g.)
Low	Brentwood Park	Reservoir	172	25.0
First High	Foxhall Rd., N.W.	Reservoir	250	14.5
	Soldiers Home, N.W.	Reservoir	250	15.0
Second High	44th & Van Ness Sts., N.W.	Reservoir	335	14.6
Third High	Reno, N.W.	Reservoir	424	5.4
		Reservoir	424	20.0
Fourth High	Reno, N.W.	El. Tank	485	0.08
		El. Tank	485	0.16
Anacostia First High	Ft. Stanton, S.E.	Reservoir	258	3.0
		Reservoir	258	10.0
Anacostia Second High	Good Hope Rd., S.E.	El. Tank	382	0.5
	Boulevard Ave., S.E.	El. Tank	382	2.0

21. D.C. DISTRIBUTION MAINS:

The distribution system on June 30, 1965, consisted of about 1,361 miles of water mains from 2" to 78" in diameter. This is approximately equal to the distance from Buffalo, New York to Tampa, Florida. In addition the Federal Government maintains and operates 12.3 miles of transmission mains within the District of Columbia, which deliver water to the First High, Second High and Third High reservoirs. Types of pipe include cast iron, ductile iron, reinforced and pre-stressed concrete, steel, and cement-asbestos, joined with caulked lead, sulphur-base compounds, sleeve, mechanical or push-on-rubber-packed couplings and joints, and lead or rubber and steel compression joints. Cement lining for cast iron pipe was adopted in 1932 for some trunk mains, and in 1942 it was adopted as standard for all sizes. Purchase of cast iron pipe under Federal Specification was initiated in 1932. Additions to the system are constantly being made to extend service, and to provide for increasing demands through trunk main reinforcement. Design is based upon desirable objective of minimum pressures of approximately 30 to 35 psi at the curb, with limiting head loss of about 2' per 1000' of main at design flow.

TABLE VIII
Length of Pipe, Types, and Sizes, in the Distribution System
Including Private Service Mains - As of June 30, 1965
Length in Feet

Diameter (inches)	Cast Iron	Ductile Iron	Concrete	Steel	Cement Abestos	Total
2	2,058			4		2,062
3	109,678			1,188		110,866
4	155,474	489		3,910	2,533	162,406
6	1,281,344	66		13,353		1,294,763
8	3,644,568	897		24,231	2,804	3,672,500
10	9,453					9,453
12	883,077	433		7,224	2,218	892,952
16	224,822	18	1,272	5,464		231,576
18	41			4,639		4,680
20	189,851	215	17,559	6,015		213,640
22	361	255		269		885
24	69,817		14,856	18,335		103,008
30	87,449		64,313	41,146		192,908
36	73,448		37,729	29,838		141,015
42	23		14,523	92		14,638
48	46,728		46,167	30,316		123,211
54			69	14		83
60			605	293		898
66			9,494	6,318		15,812
72			218			218
75	660					660
78				428		428
Total	6,778,852	2,373	206,805	193,077	7,555	7,188,662

21. D. C. DISTRIBUTION MAINS (Continued)

The service areas are generally interconnected through closed valves at all boundary intersections, permitting flexibility in supply from higher to lower services in emergencies. Maps on 50', 100' and 200' to 1" scales, intersection valve plats on 20' to 1" scale, fire hydrant elevation and pressure cards, and detail construction notes provide records for operation. Construction records are microfilmed, in aperture cards, for reader-printer information retrieval and remote security storage.

An extensive program of renovation of older trunk mains by cleaning and lining with cement mortar is substantially complete, materially improving the hydraulic characteristics and overall performance of the distribution system. Water-waste surveys and flow surveys in trunk mains have been made, and are continuing, by pitometer measurement methods, for conservation and operating guides as well as basic data for flow analyses in the design of major system additions.

22. VALVES AND FIRE HYDRANTS:

The system contained 25,623 valves and 8,973 fire hydrants on June 30, 1965. Three and four-stem valves are used extensively, reducing the number of valves at intersections and the length of mains (and number of consumers) out of service during shutdowns. Valves from 4" to 12" in size, including three and four-stem valves of 6" and 8" size, are machined in Water Operations Division shops. Valves are set in manholes, numbered in each intersection in accordance with record plats. The valves are well distributed and maintained, affording service with minimum interruptions for repairs, extensions and connections.

Fire hydrants are principally of 4-1/2" foot-valve type, operating against pressure, with 7-1/4" barrel, one 4" and two 2-1/2" nozzles. Hydrants have automatic drain valves to prevent freezing of exposed barrel when not flowing. Fire hydrant distribution is good, affording reasonable hose lays for fire apparatus.

23. SERVICE CONNECTIONS AND METERS:

The number of District of Columbia service accounts totaled 125,728 on June 30, 1965. These are 99% metered. Modern service pipes of lead, brass or copper up to and including 2" in diameter and larger diameter service connections of cast iron, are installed by licensed plumbers at the property owners' expense, connecting to taps or valves installed in the main by the Department of Sanitary Engineering at property owners' expense.

23. SERVICE CONNECTIONS AND METERS (Continued)

Domestic meters up to and including 2" in size are furnished and installed by the Department of Sanitary Engineering. Meters for Commercial supply and all larger sizes must be supplied and installed at the expense of the property owner. Early service pipes were generally of wrought iron, black or galvanized. Lead service connections were first used in 1890. The installation of iron service connections was discontinued by the Plumbing Code of 1893, and the Code of 1926 authorized new services of brass pipe. Copper tubing was first used for services in 1933 and this practice was recognized in the Plumbing Code of 1945.

TABLE IX

Active Water Service Accounts as of June 30, 1964	
Active schedule accounts (Flat Rate)	144
Charitable schedule accounts	0
Metered (District owned meters) accounts	106,402
Metered (Privately owned meters) accounts	16,529
Metered (Charitable) accounts	471
Federal accounts (Metered and Scheduled)	816
Municipal accounts (Metered and Scheduled)	610
Fire service connections	756
Total	125,728

24. RATES:

Unmetered service connections are charged for water on the basis of fixed schedules varying according to size, occupancy or business conducted on the premises. Metered connections are charged a minimum rate of $7.50 semi-annually which covers use of 3,600 cu. ft. (26,928 gallons) of water. Water in excess of this allowance is charged at the rate of 13 cents per 100 cu. ft.

24. RATES (Continued)

Municipal agencies having service connections are not charged for the use of water; nonprofit, charitable, and church service connections are allowed basic quantities without charge, excesses are billed at the regular rate. Rates for bulk supply to Maryland and Virginia for ultimate local consumer distribution are based on production and delivery costs specifically applicable to the connection. Water rates are established by Acts of Congress. Watermains are laid by, or under contract for, the Department of Sanitary Engineering. Service watermain construction is assessed against abutting property owners at a rate of $3.00 a front foot. Exceptions apply to corner lots and parcel property.

25. FISCAL STRUCTURE:

The original water system was designed primarily for Federal use, and the United States provided funds for the first basic parts of the system, and for its early expansion. Later the District of Columbia provided funds from its general D. C. revenues. During the period of Federal lump sum contributions to the general D. C. revenues, allocations of such combined revenues to the water system represented original sources of both United States and District of Columbia general funds. All appropriations for operating and expanding both the supply and distribution facilities are charged exclusively to the Water Fund, established by law in 1859. All revenues derived from the sale of water, special assessments, and other miscellaneous sources, are deposited in the Water Fund, which at the present time constitutes the sole source of funds for improvements, additions, operations and maintenance of the water system. The annual budgets for the Washington Aqueduct and the Department of Sanitary Engineering for the water system are part of the municipal budget and are specifically appropriated for each fiscal year by the Congress as a part of the District of Columbia Appropriation Act. Recognizing that the construction of additional facilities under the current expansion program could not be wholly financed from current revenues, Public Law 533, 81st Congress, authorized loans up to a limit of $23,000,000 from the United States, to be repaid with interest from future Water Fund revenues. Public Law 364, 83rd Congress increased this limit to $35,000,000.

TABLE X

Cost of Water System

Cost of the District of Columbia water system developed as of June 30, 1937, (pursuant to Public Act No. 172, 75th Congress, 1st Session), revised to June 30, 1964.

Source of Funds	Washington Aqueduct	Dept. of San. Engrg.	Total
1. a. United States, reg. Appropriations . . .	$ 7,892,128.46	$ 1,027,757.67	$ 8,919,886.13
b. United States, Wks. Progress Admin.. .	---	378,547.67	378,547.67
c. United States, Army & Navy Approp.. . .	---	238,181.24	238,181.24
d. United States Lanham Act	33,703.32	207,650.80	241,354.12
		Subtotal (1)	$ 9,777,969.16
2. a. District of Columbia (100%)	$ 5,028,545.66	$ 420,635.48	$ 5,449,181.14
b. District of Columbia (incl. portion of Fed. lump-sum contribution) .	4,969,658.03	936,563.91	5,906,221.94
		Subtotal (2)	$ 11,355,403.08
3. Water Fund.	$42,205,586.94	$51,109,168.38	$ 93,314,755.32
4. Arlington, Va.	1,850.00	---	1,850.00
Grand Total	$60,131,472.41	$54,318,505.15	$114,449,978.46

ACKNOWLEDGMENT

Acknowledgment is hereby made of the assistance given by the Washington Aqueduct Division, Washington Area Office, Baltimore District Corps of Engineers, U.S. Army, for furnishing material and counsel relative to the preparation of the section pertaining to the Supply Division.

APPENDIX I

CLEANING AND LINING OF WATERMAINS

The major part of the water distribution system consists of cast iron pipe (See Table VIII). For many years this pipe was lined by dipping or painting with a bituminous solution which did not permanently protect the pipe against corrosion. Pitting occurred and tubercles accummulated, often building up to materially reduce the cross-sectional area and, therefore, the carrying capacity of the watermain. The roughness of the deposits increases the frictional resistance to the flow of water and results in hydraulic head losses.

Such mains may now be cleaned and lined in place, substantially restoring the original capacity and smoothness, and furnishing protection against further corrosion. Openings are made in the watermains for insertion and removal of hydraulically driven scrapers for cleaning, flushing, and machine application of a thin cement mortar lining, centrifugally applied. The method is also used on deteriorated steel watermains. The resulting cement mortar lining is similar in most respects to that applied at the foundry in present-day cast iron pipe, which furnisbes effective protection against corrosion.

Cleaning and lining, especially of trunk and secondary watermains, by this method effects rehabilitation of the existing system at considerably less expense than the cost of replacement or construction of additional relief watermains to restore lost capacity to the system. Beginning in 1944, the Department of Sanitary Engineering has prosecuted an extensive program, which has restored nearly all trunk and major secondary watermains, many secondaries, and a limited number of service mains.

Following is a summary of the various sizes and lengths of mains which have been cleaned and lined.

CLEANED AND LINED

June 30, 1965

TYPE OF PIPE	LENGTH
8" Cast Iron Main	3,123.00 feet
16" Cast Iron Main	14,961.67 feet
18" O. D. Steel	502.00 feet
20" Cast Iron Main	53,156.50 feet
22" O. D. Steel	1,481.00 feet
24" Cast Iron Main	24,025.00 feet
24" O. D. Steel	480.00 feet
30" Steel	5,227.00 feet
30" Cast Iron Main	59,710.00 feet
36" Cast Iron Main	59,016.82 feet
48" Steel	180.00 feet
48" Cast Iron Main	42,714.00 feet
60" Steel	175.00 feet
78" Steel	480.00 feet
Total	265,231.99 feet

CLEANED ONLY

30" Concrete Main	14,976.00 feet
Total	14,976.00 feet
Total length of pipe rehabilitated	280.207.99 feet

APPENDIX II

PITOMETER SURVEY — WATER WASTE

In the District of Columbia, the water distribution system, consisting of over one thousand miles of underground piping and over one hundred and twenty thousand service connections, must be policed to eliminate water revenue losses due to leaks and inaccurate meters. District of Columbia-owned meters in the smaller sizes (generally two-inch and smaller in connection diameter) are removed, tested and replaced on a scheduled program. The accuracy of larger meters is checked by testing them in place with portable recorders, temporarily installed.

Losses through leakage from service connections, fire hydrants and the distribution system mains are more difficult to locate. The general method employed is to divide the system into districts, limiting each district to a single feeder, measuring and recording the input over 24 hours or longer, and comparing the night-time rate with the average daily rate of consumption in that district. Leaks are traced by visual inspection of accessible facilities, by sound of underground water leaks, and by consumption comparisons.

The District of Columbia maintains a continuing program of surveys for effective leakage and unaccounted-for water control. Each year there is a project covering some section of the system. The sections are selected in a sequence which repeats at about five-year intervals in the older areas of the city, but at about twelve-year periods in newer developments where piping and plumbing are newer and leakage is less likely to prevail.

Following is a tabulation of the miles of mains tested, underground leakage and meter under-registration revealed.

PITOMETER SURVEY - WATER WASTE PROGRAM

Fiscal Year	Miles of Mains Surveyed	Underground Leakage Revealed M.G.D.	Under-Registration Private Meters M.G.D.
1944	160.6	2.358	0.185
1945	124.9	1.908	0.486
1946	157.1	1.610	0.453
1947	200.0	1.217	0.302
1948	221.4	0.287	1.000 .620*
1949	108.4		.028
1950	63.3	1.227	.055
1951	145.9	1.962	0.120
1952	158.3	1.906	None
1953A	184.8	1.562	.082
1953B	177.4	1.369	None
1955	102.2	.764	0.200
1956	106.4	.194	.027
1957	180.0	1.010	.470
1958	168.5	.335	.024
1959	162.4	.209	2.500
1960	90.5	.070	None
1961	79.5	.554	None
1962	180.3	.792	None
1963	190.0	1.000	None
1964	153.2	.437	None
1965	170.8	.354	None

* Arlington Co. Meter