Appendix A

NYCDEP Draft Technical Memorandum for Task 2.1.1,
New York City Water Quality Data and
Montrose Improvement District Water Quality Data

City of New York
Department of Environmental Protection

Capital Project No. WM-30
Contract No. CAT-37
Catskill and Delaware Water Treatment

DRAFT

Technical Memorandum For:

Task 2.1.1
Water Quality Regulations and New York City Water Quality Data

August 1995

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Water Quality Regulations and New York City Water Quality Data

1.0 Introduction

The objectives of this water quality review for the New York City Catskill and Delaware reservoir systems are to:

- Identify areas where existing data is insufficient or not available, and develop a supplemental monitoring program to address these areas.
- Review recent as well as anticipated changes to water quality standards and regulations.
- Understand how the water quality changes through each system, as well as historically.
- Combining the above, determine anticipated treatment challenges and compliance issues, including confirmation of the locations and processes for the pilot plant studies.

Prior to assessing the adequacy of the water quality chronology, a review of regulatory initiatives was undertaken to assess how the requirements of pending and anticipated regulations may affect treatment of the Catskill and Delaware systems.

2.0 Regulatory Initiatives and Direction

The City's Catskill and Delaware surface water supplies are governed by three current and three proposed federal water quality regulations. The promulgated regulations include:

- *Surface Water Treatment Rule (SWTR)*: requires filtration of all surface water supplies unless certain avoidance criteria can be met; requires improved disinfection for all systems; and lowers the maximum contaminant level (MCL) for turbidity.
- *Total Coliform Rule (TCR)*: establishes a MCL based on the presence or absence of coliform bacteria; requires greater vigilance for secondary disinfection and addresses distribution system water quality issues.
- *Lead and Copper Rule (LCR)*: establishes action levels for lead and copper; requires increased sampling, and optimization of corrosion control treatment.

The proposed regulations include:

- *Information Collection Rule (ICR)*: an 18-month data collection program for microbial and disinfection by-product parameters which will form a database for use by EPA in developing future regulations.
- *Disinfectants/Disinfection By-Products Rule (D/DBPR)*: proposes lower limits for DBPs such as trihalomethanes (THMs) and haloacetic acids (HAAs); requires optimization of organic

precursor removal; in turn, these could require use of alternative disinfectants or other significant changes in current treatment practices.

- ***Enhanced Surface Water Treatment Rule (ESWTR)***: expected to include more stringent removal/inactivation requirements for pathogens which are linked to source water microbial quality; could require treatment for *Cryptosporidium*.

There are a number of other water quality regulations not discussed herein which address compounds that are either absent, not detectable, or not of regulatory significance for New York City's surface water supplies (synthetic organic compounds, inorganic compounds, radionuclides, etc.). DEP is presently in compliance with all applicable portions of Subpart 5-1 of the State Sanitary Code which is under the jurisdiction of the New York State Department of Health.

3.0 Key Regulatory and Compliance Issues

The key compliance issues for the Catskill and Delaware supplies are based on source water quality and current and potential water quality regulations. The overall issues are:

- *Disinfection*. Compliance with Ct requirements of the SWTR, and future Enhanced SWTR, must be balanced against lower THM and other DBP standards to be established under the D/DBPR. In addition, utilities must be cognizant of the maximum residual disinfectant levels (MRDLs) proposed by the D/DBPR. The Enhanced SWTR may also include an inactivation requirement for *Cryptosporidium*.

- *Disinfection By-Products*. Although Stage II TTHMs/HAA5s standards of 40/30 μg/L have been discussed, this phase of the D/DBPR is subject to renegotiation in light of the results of the ICR monitoring program. It will also be important to consider the requirement to optimize precursor removal prior to primary disinfection.

- *Filtration*. The concern over *Cryptosporidium* and the likely link between source water pathogen concentrations and treatment levels of the Enhanced SWTR makes optimizing particle reduction critical. Also, the enhanced coagulation provision of the D/DBPR is expected only to pertain to conventional treatment and not to direct filtration.

- *Washwater Recycle*. Given the philosophy behind the Enhanced SWTR, the relationship between parasite accumulation and breakthrough and the level of washwater treatment must be established.

- *Microbial Regrowth*. Biologically-stable effluent is particularly important for any treatment alternatives which include ozone. This will include keeping AOC/BDOC at low levels, minimizing free ammonia, checking heterotrophic plate counts (HPCs), and optimizing corrosion control.

- *Others*. While not a health concern, controlling taste and odors is also important. Taste and odors may be affected by changes in treatment processes, especially disinfection. Optimizing

treatment processes to enable lower disinfectant residuals will be important. Reducing iron and manganese is also important for aesthetic reasons.

4.0 Review of Historical Water Quality Data

The City has a tremendous historical record documenting the quality of its Catskill and Delaware water supply systems. This information was reviewed to determine if it is sufficient to evaluate and confirm treatment options for the pilot studies, and, ultimately, the full-scale treatment facility. A supplemental monitoring program is also recommended.

4.1 Reports and Data Reviewed

The following NYCDEP water quality-related reports were reviewed:

- *Progress Report for the Initial Study, Pilot Program, and Conceptual Design for Treatment of Catskill and Delaware Water*, December 31, 1993, and subsequent quarterly progress reports (April 1994, August 1994, October 1994, January 1995, April 1995).

- *Results of Bench-Scale Testing and Outline for Pilot Plant Research for Treatment of the Catskill and Delaware Water Supplies*, April 30, 1994.

- *Water Quality Surveillance Monitoring Report, 1993*, Prepared by the Division of Drinking Water Quality Control, June 1993.

- Keypoint Database, 1987 - 1994
  - Delaware District at Shaft 9 (DEL9) and Shaft 10 (DEL10)
  - East of Hudson District at Catskill Alum Plant (CATALUM), Catskill Lower Effluent Chamber (CATLEFF), Shaft 17 (DEL17) and Shaft 18 (DEL18)

- Pathogen monitoring results from NYC's source waters from Shaft 18 (DEL18) and the Catskill Aqueduct Lower Effluent Chamber (CATLEFF) from June 1992 through December 1994.

While the entire database was examined, particular attention was focused on the specific locations cited above as they provide an understanding of the change in the quality of the water as it travels through the reservoir system. The influence of intermediate reservoirs, such as West Branch and Kensico, were a major focus, as this could determine the need to conduct pilot tests both upstream and downstream of these locations.

4.2 Adequacy of Existing Data and Sampling Program

The existing water quality reports and data provide a tremendous background on parameters directly affecting treatment (e.g., turbidity, TOC) as well as parameters indicative of the condition of the reservoir supply system (e.g., nutrient levels such as nitrogen and phosphorous), which, ultimately also affect treatment.

We believe that the records and on-going sampling program are adequate for overall characterization of the supplies as well as understanding how water quality relates to the potential

sites for a filtration plant(s). These assessments are presented in Section 5.0. There are a few areas where additional monitoring would be valuable to provide a baseline upon which to compare the results from the pilot testing program.

4.3 Additional Water Quality Data Requirements

We have identified additional water quality parameters and/or sampling locations where we believe supplemental information is needed. This request for supplemental information has been forwarded to the DEP as well as the New York State Department of Health. The information requested is summarized below.

4.3.1 Source Water Quality Data

- ***Routine Water Quality Monitoring Data*** prior to 1987, for parameters of the same type (turbidity, color, temperature, pH, alkalinity, TOC, ammonia nitrogen, iron, manganese, total coliform and fecal coliform) and frequency as that contained in the limnology database, hydrology database, and keypoint database. The sample locations would be the same as listed in Section 4.1.

- ***Upper Aqueduct Pathogen Sampling Results***. We currently have data for DEP's pathogen monitoring program at Shaft 18 on the Delaware Aqueduct (DEL18) and the Catskill Aqueduct Lower Effluent Chamber (CATLEFF). These two monitoring locations provide useful data should a filtration plant be located downstream of Kensico Reservoir. However, there are also filtration plant sites under consideration upstream of Kensico Reservoir along both the Catskill and Delaware Aqueducts.

  Therefore, we have requested data from all upstream pathogen monitoring sites, including, if possible, the Rondout Reservoir chlorination facility to sample upper Delaware water (upstream of West Branch Reservoir), Shaft 17 to sample lower Delaware water (downstream of West Branch), and the Ashokan Reservoir chlorination facility to sample upper Catskill Aqueduct water.

- ***Storm Event Information.*** DEP records of storm events, especially for Kensico and Ashokan Reservoirs, as they related to water quality.

- ***Hudson River Water Quality Data.*** To be able to evaluate alternative operational scenarios, such as the injection of Hudson River water into the New York City water supply system, data for baseline water quality parameters such as turbidity, color, pH, alkalinity, temperature, TOC, ammonia, dissolved oxygen, iron, manganese, chloride, and sulfate is requested. We believe data has been collected under the Hudson River Study by another DEP consultant. In case that data is not adequate, we have requested data from NYSDOH for the Poughkeepsie plant (see below).

4.3.2 *Distribution System Data*

- ***Assimilable Organic Carbon*** data from various points within the New York City distribution system to provide a baseline upon which to compare the results from the pilot testing program.

- ***Disinfection By-Product*** data for trihalomethanes (THMs), haloacetic acids (HAAs) and any other potentially-regulated DBPs (e.g., cyanogen chloride, chloral hydrate (CH), chloropicrin (CP), aldehydes, etc.). Sample locations of interest begin immediately downstream of primary disinfection at Hillview Reservoir as well as locations within the City's distribution system.

- ***Inorganic parameters*** (lead, copper, pH, temperature, alkalinity, iron, manganese, calcium, hardness and/or other parameters indicative of stability of the water in the distribution system)

4.3.3 *Operational Records and Water Quality Data from Other Water Treatment Plants Along the Catskill and Delaware Aqueducts*

To determine how the aqueduct water quality may affect treatment plant operation/performance, we have requested data for some of the existing filtration plants along both aqueducts and on the Hudson River. A request has been forwarded to NYSDOH to obtain water quality and operational records for the period 1975-1995 for the following systems:

- Marlborough (Delaware Aqueduct tap)
- New Windsor (Catskill Aqueduct tap)
- New Castle (Catskill Aqueduct tap)
- Westchester Joint Water Works (Kensico Reservoir)
- Westchester County Water District #2 (Kensico Reservoir)
- City of Poughkeepsie (Hudson River)

5.0 Water Quality Characterization

5.1 *Overview*

The water from the Catskill and Delaware systems is generally of high quality due to the upstream locations of the source water reservoirs. The water quality is characterized by low turbidity, alkalinity, organic content, pathogen and mineral concentrations. The following discussion addresses:

- Key water quality parameters
- Catskill Reservoir system water quality
- Delaware Reservoir system water quality
- Downstream of Kensico—mixed Catskill and Delaware water quality
- Other comparisons—Ashokan and Rondout source reservoirs
- Conclusions

5.2 *Key Water Quality Parameters*

The remaining discussion will focus on those source water characteristics as listed below that have potential to impact treatment process selection and locations for pilot testing:

Water Quality Parameter	Treatment Significance
Temperature	Disinfectant stability, disinfection inactivation requirements (Ct), filtration performance, disinfection by-product formation kinetics, biological regrowth
pH	Coagulation, disinfectant stability, disinfection inactivation requirements (Ct), disinfection by-product formation kinetics, corrosion control
Alkalinity	Coagulation, corrosion control
Iron	Oxidant and disinfectant demand
Manganese	Oxidant and disinfectant demand
Turbidity	Oxidant demand, coagulation, need for clarification process, filtration performance
Color	Oxidant demand, coagulation, filtration performance
Nitrogen (ammonia)	Oxidant and disinfectant demand, need for biological filtration
Total Organic Carbon	Oxidant and disinfectant demand, coagulation, disinfection by-product formation kinetics, biological stability
Microbial Parameters (Total and Fecal Coliform, *Giardia*, *Cryptosporidium*)	Disinfection inactivation requirements (Ct)
Algae	Need for clarification process, filtration performance, taste and odor
Reservoir Nutrient Levels (N and P)	Algae levels (see above)
Biodegradable Organic Matter (BDOC, AOC)	Biological regrowth

Historical water quality results from the keypoint database are summarized in Tables 1 and 2. Table 1 provides minimum, maximum and average values over the entire period from 1987 to 1994. Table 2 summarizes maximum values for individual years from 1987 to 1994. Both tables focus on key water quality parameters affecting treatment as well as indicators of long-term trends.

The tables furnish an overall summary of water quality, maximum values indicative of worst case occurrences, and changes in water quality over time. Both tables are organized according to location to assess any changes occurring throughout the aqueducts, the impact of reservoirs, and the most significant influences on downstream water quality. Results are discussed first for each system separately, and then for mixed water quality downstream. Detailed plots were prepared showing seasonal and yearly trends by location, and provide the basis for the following discussion. These plots are included in the appendix.

Table 1
Catskill/Delaware Water Supply Systems
Water Quality Summary
1987-1994

PARAMETER / LOCATION	Temperature (oC)			pH (units)			Alkalinity (mg/L)			Fe (mg/L)			Mn (mg/L)			TOC (mg/L)		
	min	max	avg	min	max	avg	min	max	avg	min	max	avg	min	max	avg	min	max	avg
CATSKILL AQUEDUCT																		
ASHOKAN EFFLUENT	0.6	22.2	9.2	5.78	7.74	6.92	6.58	14.19	10.32	0.005	1.20	0.09	0.005	0.270	0.056	1.3	4.7	1.9
ALUM PLANT	0.0	22.8	10.0	3.95	8.59	6.59	0.01	28.80	10.85	0.03	0.25	0.08	0.005	0.120	0.037	1.1	52.5	2.0
LWR EFFLNT CHAMBER	0.0	22.8	10.0	3.45	8.06	6.64	5.20	16.20	10.59	0.01	0.13	0.04	0.005	0.080	0.028	1.3	52.5	2.0
UPPER DELAWARE AQUEDUCT																		
RONDOUT EFFLUENT	0.5	18.0	7.9	0	7.84	6.54	5.66	12.08	8.39	0.005	0.090	0.028	0.003	0.120	0.027	1.1	2.7	1.8
WBRANCH INFLUENT	0.0	20.0	8.7	5.88	7.69	6.62	0.96	15.20	9.29	0.010	1.080	0.067	0.010	2.340	0.098	1.2	4.9	1.8
WBRANCH EFFLUENT	0.0	25.0	9.6	5.94	7.77	6.63	6.00	18.40	9.96	0.010	0.150	0.047	0.010	0.090	0.030	1.2	5.8	1.9
LOWER DELAWARE AQUEDUCT																		
DEL17	0.0	24.0	10.0	5.70	7.76	6.64	0.01	17.58	10.05	0.010	0.120	0.048	0.005	0.070	0.025	1.1	52.5	2.0
DEL 18	0.0	24.0	11.1	5.64	7.59	6.72	5.20	26.90	10.73	0.005	0.100	0.038	0.005	0.070	0.025	1.1	52.5	2.0

PARAMETER / LOCATION	DO (mg/L)			NH3-N (mg/L)			Turbidity (NTU)			Color (units)			Total Coliform (CFU/100 mL)			Fecal Coliform (CFU/100 mL)		
	min	max	avg	min	max	avg	min	max	avg	min	max	avg	min	max	avg	min	max	avg
CATSKILL AQUEDUCT																		
ASHOKAN EFFLUENT	Not Available			0.000	0.100	0.030	0.3	120	2.6	3	29	9	1	320	11	1	91	3
ALUM PLANT	8	8	8	0.001	8.1	0.062	0.3	97.6	2.1	0	100	11	1	17200	37	1	77	2
LWR EFFLNT CHAMBER	Not Available			0.002	0.215	0.030	0.4	9.0	1.0	0	25	10	1	3000	32	1	103	7
UPPER DELAWARE AQUEDUCT																		
RONDOUT EFFLUENT	7.5	14.7	11.4	0.002	0.160	0.030	0.0	6.3	1.3	0	21	8	0	5800	41	0	341	2
WBRANCH INFLUENT	1.7	13.6	11.0	0.000	0.556	0.037	0.3	6.2	1.0	1	35	11	1	2400	32	1	43	4
WBRANCH EFFLUENT	10.4	14.0	11.6	0.000	0.535	0.042	0.4	15.8	1.0	0	49	11	1	31000	142	1	101	8
LOWER DELAWARE AQUEDUCT																		
DEL17	1.9	12.3	10.6	0.002	0.400	0.028	0.0	6.0	0.9	0	36	11	1	3300	42	0	120	4
DEL 18	9.6	14.0	11.6	0.002	0.620	0.032	0.3	9.0	0.9	0.7	45	11	1	6400	60	1	6500	13

Table 2
Catskill/Delaware Water Supply Systems
Annual Water Quality - Maximum Values
1987 to 1994
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PARAMETER / LOCATION	Temperature (oC)								pH (units)							
	1987	1988	1989	1990	1991	1992	1993	1994	1987	1988	1989	1990	1991	1992	1993	1994
CATSKILL AQUEDUCT																
ASHOKAN EFFLUENT	18.9	22.2	17.8	20.0	21.0	19.0	21.0	4.0	7.40	7.39	7.74	7.36	7.19	7.04	7.11	7.20
ALUM PLANT	21.1	22.8	18.9	21.7	22.0	21.0	20.0	19.0	7.09	6.93	8.59	8.01	7.38	7.27	7.59	7.34
LWR EFFLNT CHAMBER	16.7	16.7	22.8	22.0	22.0	19.0	19.0	18.5	7.04	6.93	7.69	8.06	7.65	7.79	7.59	7.49
UPPER DELAWARE AQUEDUCT																
RONDOUT EFFLUENT	12.0	15.0	17.0	16.0	18.0	16.0	15.5	14.0	7.39	7.74	7.45	7.84	7.05	7.23	7.4	7.62
WBRANCH INFLUENT	14.4	15.6	20.0	19.4	19.0	17.0	15.0	18.5	7.21	7.14	7.43	7.2	7.33	7.52	7.69	7.09
WBRANCH EFFLUENT	15.6	20.0	15.6	20.0	25.0	18.0	23.0	18.0	7.01	6.55	7.00	6.76	7.19	7.23	7.77	7.27
LOWER DELAWARE AQUEDUCT																
DEL17	16.7	14.4	16.7	21.1	24.0	21.0	22.0	18.5	7.01	6.86	7.76	7.14	7.48	7.14	7.67	7.36
DEL 18	20.6	19.4	20.0	23.3	24.0	22.0	22.0	21.0	6.99	6.97	7.27	7.39	7.38	7.59	7.41	7.53

PARAMETER / LOCATION	Alkalinity (mg/L)								TOC (mg/L)							
	1987	1988	1989	1990	1991	1992	1993	1994	1987	1988	1989	1990	1991	1992	1993	1994
CATSKILL AQUEDUCT																
ASHOKAN EFFLUENT	12.64	14.19	13.06	11.98	12.57	11.82	10.99	9.06	NA	2.06	3.15	3.58	2.03	2.425	4.69	3.10
ALUM PLANT	14.90	14.10	14.02	15.60	28.80	12.22	12.34	9.80	3.57	2.23	3.80	16.0	52.5	4.00	2.30	2.10
LWR EFFLNT CHAMBER	11.80	15.78	16.20	11.60	12.54	13.30	13.70	11.30	3.20	1.88	3.65	2.97	52.5	2.30	2.90	2.60
UPPER DELAWARE AQUEDUCT																
RONDOUT EFFLUENT	9.5	11.8	12.08	9.58	8.98	11.36	9.36	9.5	0	2.21	2.73	2.66	2.14	2.45	2.29	2.3
WBRANCH INFLUENT	11.4	13.44	15.2	11.72	13.08	12.14	10.86	11.2	2.38	1.67	3.55	3.6	2.2	2.4	4.9	2.5
WBRANCH EFFLUENT	14.7	12.1	18.3	12.6	17.2	13.1	18.4	12.0	2.92	2.04	2.98	5.83	2.6	2.5	3.0	3.0
LOWER DELAWARE AQUEDUCT																
DEL17	11.48	12.94	16.70	11.72	13.88	17.58	11.40	14.60	8.54	2.07	3.93	2.48	52.5	3.70	2.70	2.40
DEL 18	11.80	12.28	16.00	11.84	15.28	26.9	14.10	11.60	6.56	1.94	3.24	2.72	52.5	2.40	2.80	3.10

PARAMETER / LOCATION	Turbidity (NTU)								Color (units)							
	1987	1988	1989	1990	1991	1992	1993	1994	1987	1988	1989	1990	1991	1992	1993	1994
CATSKILL AQUEDUCT																
ASHOKAN EFFLUENT	120	5.1	6.8	5.3	2.7	4.0	10.0	7.4	28	18	29	15	12	15	19	15
ALUM PLANT	97.6	4.5	4.1	12.0	2.5	3.7	13.5	8.3	100	30	25	20	15	15	19	20
LWR EFFLNT CHAMBER	9.0	7.5	1.6	1.9	2.3	3.6	3.4	3.2	23	25	20	20	15	20	19	16
UPPER DELAWARE AQUEDUCT																
RONDOUT EFFLUENT	5.0	3.9	6.3	3.5	5.4	4.9	2.7	2.5	15	5	10	12	20	21	20	15
WBRANCH INFLUENT	6.2	2.5	4.9	1.7	3.0	4.2	2.7	3.2	35	25	28	20	17	20	18	27
WBRANCH EFFLUENT	3.0	1.2	1.8	2.0	2.1	1.6	3.0	15.8	20	23	30	28	21	20	22	49
LOWER DELAWARE AQUEDUCT																
DEL17	4.0	6.0	2.7	2.9	2.1	1.5	3.0	5.0	25	22	20	36	15	15	21	22
DEL 18	9.0	4.7	1.9	1.8	2.2	1.7	2.6	3.0	25	45	22	30	15	20	19	17

Table 2
Catskill/Delaware Water Supply Systems
Annual Water Quality - Maximum Values
1987 to 1994
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PARAMETER / LOCATION	Fe (mg/L)								Mn (mg/L)							
	1987	1988	1989	1990	1991	1992	1993	1994	1987	1988	1989	1990	1991	1992	1993	1994
CATSKILL AQUEDUCT																
ASHOKAN EFFLUENT	1.200	0.190	0.120	0.150	0.190	0.230	0.220	NA	0.060	0.270	0.240	0.150	0.170	0.180	0.180	NA
ALUM PLANT	NA	NA	NA	NA	0.170	0.250	0.180	0.110	NA	NA	NA	NA	0.040	0.120	0.080	0.110
LWR EFFLNT CHAMBER	NA	NA	NA	NA	0.080	0.090	0.130	0.060	NA	NA	NA	NA	0.040	0.080	0.050	0.080
UPPER DELAWARE AQUEDUCT																
RONDOUT EFFLUENT	NA	0.053	0.064	0.046	0.070	0.090	0.080	0.050	0.000	0.056	0.050	0.036	0.120	0.060	0.060	0.030
WBRANCH INFLUENT	NA	NA	NA	NA	0.120	1.080	0.070	0.060	0.000	0.000	0.000	0.000	0.080	2.340	0.060	0.040
WBRANCH EFFLUENT	NA	NA	NA	NA	0.080	0.100	0.130	0.150	0.000	0.000	0.000	0.000	0.070	0.090	0.040	0.050
LOWER DELAWARE AQUEDUCT																
DEL17	NA	NA	NA	NA	0.050	0.060	0.120	0.060	0.000	0.000	0.000	0.000	0.030	0.040	0.070	0.030
DEL 18	NA	NA	NA	NA	0.100	0.080	0.100	0.060	0.000	0.000	0.000	0.000	0.070	0.050	0.050	0.030

PARAMETER / LOCATION	DO (mg/L)								NH3-N (mg/L)							
	1987	1988	1989	1990	1991	1992	1993	1994	1987	1988	1989	1990	1991	1992	1993	1994
CATSKILL AQUEDUCT																
ASHOKAN EFFLUENT	NA	NA	NA	NA	NA	NA	NA	NA	0.048	0.100	0.080	0.060	0.060	0.060	0.060	0.030
ALUM PLANT	NA	NA	NA	NA	NA	NA	NA	8.0	0.190	0.055	0.170	0.340	0.101	0.390	0.100	8.100
LWR EFFLNT CHAMBER	NA	NA	NA	NA	NA	NA	NA	NA	0.050	0.055	0.080	0.151	0.200	0.215	0.124	0.072
UPPER DELAWARE AQUEDUCT																
RONDOUT EFFLUENT	NA	NA	NA	NA	NA	NA	14.7	13.3	0.140	0.160	0.050	0.100	0.080	0.040	0.030	0.041
WBRANCH INFLUENT	NA	NA	NA	NA	NA	NA	13.6	12.9	0.045	0.042	0.100	0.556	0.071	0.370	0.128	0.063
WBRANCH EFFLUENT	NA	NA	NA	NA	NA	NA	14.0	12.1	0.050	0.035	0.080	0.535	0.070	0.390	0.103	0.082
LOWER DELAWARE AQUEDUCT																
DEL17	NA	NA	NA	NA	NA	NA	11.60	12.30	0.170	0.050	0.090	0.075	0.400	0.070	0.280	0.063
DEL 18	NA	NA	NA	NA	NA	NA	12.80	14.00	0.085	0.056	0.091	0.065	0.092	0.470	0.620	0.080

PARAMETER / LOCATION	Total Coliform (CFU/100 mL)								Fecal Coliform (CFU/100 mL)							
	1987	1988	1989	1990	1991	1992	1993	1994	1987	1988	1989	1990	1991	1992	1993	1994
CATSKILL AQUEDUCT																
ASHOKAN EFFLUENT	150	28	170	100	58	280	320	44	30	15	27	34	36	91	76	15
ALUM PLANT	212	56	27	53	120	800	17200	150	24	54	16	15	54	77	30	13
LWR EFFLNT CHAMBER	212	104	184	320	190	3000	460	1400	103	64	81	94	66	57	52	74
UPPER DELAWARE AQUEDUCT																
RONDOUT EFFLUENT	123	42	71	327	41	5800	400	1910	31	30	48	341	32	86	11	46
WBRANCH INFLUENT	58	20	94	28	90	2400	76	66	11	2	37	20	21	13	18	43
WBRANCH EFFLUENT	800	14	140	960	255	31000	190	740	70	5	35	86	82	66	36	101
LOWER DELAWARE AQUEDUCT																
DEL17	140	302	188	590	275	3300	775	1150	27	54	74	23	68	27	51	120
DEL 18	3900	6400	160	800	270	2050	450	1800	6500	166	66	778	139	52	124	213

5.3 Catskill Reservoir System Water Quality

5.3.1 Historical Perspective

The Catskill System watersheds occupy sparsely populated areas in the central and eastern portions of the Catskill Mountains and normally provide approximately 40 percent of the daily water supply for New York City. Water in the Catskill System comes from the Esopus and Schoharie Creek subwatersheds, located approximately 100 miles north of lower Manhattan and 35 miles west of the Hudson River. The greater part of the water from these two watershed areas is stored in the Ashokan Reservoir and the balance in the Schoharie Reservoir. Water is conveyed downstream from these reservoirs via the Catskill Aqueduct.

To obtain the most relevant understanding of flowing water quality throughout the aqueduct, key parameters are summarized in Tables 1 and 2 beginning with the entrance of Ashokan Reservoir effluent, further downstream at the alum plant, and in the lower effluent chamber after mixing with Delaware system water in Kensico Reservoir.

The general trend is one of improving quality as the water in the Catskill system travels from the source downstream and then mixes with Delaware water in Kensico Reservoir. Turbidity, used as an overall comparative measure, indicates high quality throughout the Catskill Aqueduct. Although turbidity maximums of 120 NTU were observed in the Ashokan effluent and 100 NTU at the alum plant, the average for both locations is 2 to 3 NTU. Color was fairly constant through the aqueduct at 9 to 11 units. A maximum of 100 units was observed at the alum plant.

The frequency of these turbidity spikes was examined in detail, as this could impact the processes selected for inclusion in the pilot plant studies. For example, the in-line filtration process may be capable of handling short periods of high turbidity levels, but not sustained events. Two statistical analyses were made. The first was a frequency distribution—in other words, the number of times the historical turbidity exceeded certain levels. The second was the probability that the turbidity was less than or greater than certain values.

A summary of this analysis is shown in Figure 1A beginning at the Ashokan Reservoir effluent and traveling downstream along the Catskill Aqueduct to the alum plant (CATALUM) and then ultimately to the Lower Effluent Chamber (CATLEFF). Figure 1B shows similar turbidity levels at CATLEFF and Shaft 18 (DEL18)—both locations where water leaves Kensico Reservoir.

At Ashokan Reservoir, the turbidity is nearly always greater than or equal to 0.5 NTU and generally less than 10 NTU. By the time the Catskill water reaches the Lower Effluent Chamber, the distribution shifts toward lower values, with the turbidity still usually greater than 0.5 NTU but typically less than 2 NTU. Figure 1A also shows that the incidents of turbidity events 10 NTU or higher occur 15% or more of the time at Ashokan, but less than 1% of the time at the Lower Effluent Chamber. This indicates that processes such as in-line and direct filtration are appropriate for consideration at potential filtration plant sites below, but probably not above, Kensico Reservoir.

Temperature ranges are as expected for Northeast surface water supplies, with maximum, minimum and average values of 23°C, 0°C, and 10°C, respectively. Overall no consistent changes occur through the aqueduct. On average, a pH of 6.6 to 6.9 was maintained throughout the aqueduct above Kensico Reservoir. A greater range from 3.5 to 8.5 was observed below Kensico due, most likely, to the effects of chemical addition (alum and hydrofluosilicic acid). Alkalinity is steady at 10.3 to 10.9 mg/l (as $CaCO_3$) on average; maximum values range from 12 to 27 mg/l (as $CaCO_3$). Even the maximum values indicate that the water has little buffering capacity.

Iron and manganese are low, averaging 0.04 to 0.09 mg/l and 0.028 to 0.056 mg/l, respectively, in the aqueduct. Concentrations are lower in the lower effluent chamber after mixing with Delaware water in the Kensico Reservoir. Maximum values of iron over 1987 to 1994 do not vary widely at 0.05 to 0.25 mg/l (with the exception of two discreet samples of 1.2 mg/l in 1987 at the Ashokan effluent and 1.08 mg/l in 1992 at the West Branch influent).

Organic concentrations are low, averaging about 2.0 mg/l TOC throughout the aqueduct. Ammonia concentrations are also low. The average ranges from 0.03 to 0.06 mg/l through the aqueduct. Maximum values at Ashokan and in the effluent chamber are 0.1 to 0.22 mg/l (with the exception of one discreet sample at 8.1 mg/l at the alum plant in 1994). There does appear to be a general increase in maximum values as the water travels downstream.

On average, total coliform levels are higher in water further downstream in the aqueduct at 37 CFU/100 ml compared to 11 CFU/100 ml upstream. Results for fecal coliform show a similar trend although they do not range as widely, with average levels of 7 CFU/100 ml downstream compared to 3 CFU/100 ml upstream. Fecal coliform maximum values were observed from 77 to 103 CFU/100 ml throughout the aqueduct.

Although mean coliform levels indicate high quality water, the high spikes are noteworthy. Spikes were observed at the alum plant with total coliform concentrations as high as 17,200 CFU/100 ml. The maximum level at Ashokan Reservoir upstream is several orders of magnitudes less (320 CFU/100 ml). It is likely that a corresponding spike was missed at Ashokan due to the nature of grab sampling.

5.3.2 Annual Maximum Values

To gain further understanding of the observed spikes, as well as to understand the worst case scenario from a treatability perspective, annual maximum values (Table 2) were compared to historical levels (Table 1).

In summary, there does not appear to be any significant long-term deterioration in water quality as evidenced by increasing average and/or maximum values from 1987 to 1994.

Quite frequently (except for turbidity), higher maximum values were recorded at intermediate and downstream points along the aqueduct than at the source. For example, the lower effluent chamber samples most often record some of the highest levels due to the introduction of Delaware water. Maximum turbidity values as high as 120 NTU were limited to 1987, otherwise turbidities only

increase up to 13.5 NTU at the alum plant. Color maximums were also greatest in 1987 at 100 unit, however, normal range of maximum values are 12 to 30 units.

Total coliform levels show wider ranges and spikes are evident, but trends are not indicated. The absolute high of 17,200 CFU/100 ml was recorded in 1993 at the alum plant. Otherwise, maximums ranged from 27 to 800 CFU/100 ml. Fecal coliform values ranged from 13 to 91 CFU/100 ml in 1992. Total coliform also had high values the same year. Maximum ammonia concentrations are not significant and range from 0.03 to 0. 39 mg/l with the exception of a value of 8.1 mg/l in 1994. The highest iron level was observed in 1987 at 1.2 mg/l, but generally maximums range from 0.06 to 0.19 mg/l. Manganese annual maximum values range from 0.05 to 0.18 mg/l. Maximum TOC values over 1987 to 1994 do not vary widely at 2 to 4.0 mg/l (with the exception of two discreet samples at 16.0 and 52.5 mg/l in 1990 and 1991, respectively, believed to be recorded erroneously).

5.3.3 Summary of Catskill System Water Quality

Catskill system water quality can be summarized as follows:

Parameter	Normal Range of Average Values, 1987-1994	Normal Range of Maximum Values, 1987-1994	Highest Value Recorded, 1987-1994
Turbidity (NTU)	1.0 - 2.5	2.5 - 12.0	120
Color (CU)	9 - 11	12 - 30	100
Iron (mg/l)	0.04 - 0.09	0.06 - 0.19	1.2
Manganese (mg/l)	0.028 - 0.056	0.05 - 0.18	0.27
Ammonia Nitrogen (mg/l)	0.03 - 0.06	0.03 - 0.39	8.1
Total Organic Carbon (mg/l)	2.0	2.0- 4.0	4.7[1]
Total Coliform (CFU/100 ml)	11 - 37	27 - 800	17,200
Fecal Coliform (CFU/100 ml)	3 - 7	13 - 91	103

[1] If values of 16.0 and 52.5 mg/l are discarded from the historical database.

5.4 Delaware Reservoir System Water Quality

5.4.1 Historical Perspective

The Delaware System, located approximately 125 miles north of lower Manhattan, normally provides approximately 50 percent of the daily water supply for New York City. Three Delaware System reservoirs collect water from a sparsely populated region on the branches of the Delaware River: Cannonsville Reservoir, Pepacton Reservoir and Neversink Reservoir. These reservoirs feed eastward through separate rock tunnels, to Rondout Reservoir where the Delaware Aqueduct begins.

To obtain the most relevant understanding of quality as the water travels downstream in the Delaware Aqueduct, parameters in Tables 1 and 2 were grouped beginning with the entrance of Rondout Reservoir effluent, further downstream at the influent (Shaft 9) and effluent (Shaft 10) of

West Branch Reservoir, at Shaft 17 (DEL17) prior to entering Kensico Reservoir, and at Shaft 18 (DEL18) as water exits Kensico Reservoir. As noted above, Kensico Reservoir combines water from the Catskill and Delaware Aqueducts.

Water throughout the Delaware Aqueduct is of very high quality. Overall, average turbidity ranged from 1.3 to 0.9 NTU in the lower aqueduct. A maximum turbidity level of 15.8 NTU was observed in the West Branch effluent. Color was on average 8 to 11 units throughout the system, with maximum values ranging as high as 49.

Temperatures were on average 7.9 to 9.6°C in the upper Delaware Aqueduct, and 10 to 11°C in the lower aqueduct. Maximum and minimum temperature values were 25°C and 0°C, respectively. pH does not range as widely in the Delaware system as in the Catskill. Delaware Aqueduct pH ranged from a low of 5.9 units to a high of 7.9 units. As the DEL18 sampling location is upstream of chemical addition (unlike CATLEFF), no depression of pH is noted in the database. Average values were 6.6 units, with no significant change throughout the aqueduct. As expected, alkalinity also does not vary widely (8.4 to 10.7 as $CaCO_3$ on average; maximum values from 12 to 27 mg/l as $CaCO_3$). The low values indicate poor buffering capacity.

Iron reached a maximum in West Branch influent of 1 mg/l but otherwise was only as high as 0.15 mg/l. Average iron levels ranged from 0.03 to 0.07 mg/l. Manganese was recorded as high as 2.34 mg/l, but on average ranged from 0.03 to 0.098 mg/l. Both iron and manganese are highest in the West Branch influent.

TOC levels are on average about 2.0 mg/l throughout the system, with maximums of 4.9 and 5.8 mg/l in West Branch influent and effluent, respectively. Dissolved oxygen was recorded more frequently for the Delaware Aqueduct than for the Catskill. On average, DO levels are high to super-saturated—11 mg/l on average, 14 mg/l at maximum. Ammonia levels are very low at about 0.03 to 0.04 mg/l on average, with a maximum of 0.62 mg/l. These higher levels are to be expected because of the greater number of wastewater treatment plant discharges in this system.

On average, total coliform levels are similar in water downstream and upstream in the aqueduct (30 to 40 CFU/100 ml upstream compared to 40 to 60 CFU/100 ml downstream. The notable exception is the effluent of West Branch Reservoir where average total coliform levels are 142 CFU/100 ml. Also with the exception of West Branch effluent, maximum total coliform levels ranged from 2,400 to 6,400 CFU/100 ml.

Results for fecal coliform show a similar trend although they do not range as widely, with average levels of 2 to 13 CFU/100 ml. Fecal coliform maximum values ranged from 43 to 341 CFU/100 ml in the upper aqueduct and 120 to 6,500 in the lower aqueduct. Both total and fecal coliform levels are notably higher in the Delaware Aqueduct than in the Catskill.

As with the Catskill, the high coliform spikes in the Delaware are noteworthy. Two locations show marked increases in downstream coliform (total and fecal) levels—West Branch effluent and Kensico Reservoir effluent (Shaft 17). A maximum total coliform level of 31,000 CFU/100 ml was reported for West Branch Reservoir effluent. The highest concentration measured in the West Branch influent

was 2,400 CFU/100 ml, suggesting deterioration within the reservoir itself. Similar observations can be made at Kensico Reservoir.

5.4.2 Annual Maximum Values

Trends in water quality in the Delaware system are not evident with time based on examination of annual maximum values. Similar to the Catskill, the annual peak values show that incidents of poor quality are infrequent. For example, the highest turbidity value recorded was 15.8 NTU in 1994, but otherwise, maximum annual values ranged from 1.2 to 6.2 NTU.

5.4.3 Impact of West Branch Reservoir

Annual maximum values were also examined to assess the impact of West Branch Reservoir on downstream water quality. Comparisons were made between the influent and effluent of West Branch at Shaft 9 (DEL9) and Shaft 10 (DEL10), respectively. The effluent of West Branch was also compared to the influent of Kensico Reservoir at Shaft 17 (DEL17) since the only difference between these points is the length of aqueduct and the operation of the system in terms of whether West Branch was being bypassed.

To further evaluate the effect of West Branch as an interim reservoir, influent and effluent turbidity, TOC, and total and fecal coliform were plotted in Figures 2A through 2C, respectively. Overall, the effluent follows similar trends as the influent. The majority of turbidity values are below 5.0 NTU, the majority of total coliform samples fall below 100 CFU/100 ml, and the majority of fecal coliform samples fall below 20 CFU/100 ml. There are random spikes of turbidity and TOC in the effluent. However, influences of the reservoir are especially evident in effluent concentrations of total and fecal coliform, particularly from 1991 onward, indicating that the interim reservoir does have occasional deleterious impact on Delaware Aqueduct coliform levels.

To substantiate whether this impact was found further downstream, West Branch effluent quality was compared to water quality at Shaft 17 at the inlet to Kensico Reservoir (Figures 3A through 3C). Peaks noted in the West Branch effluent also appear at Shaft 17 indicating that they are traveling through the aqueduct as would be expected.

In summary, turbidity and TOC do not appear to be influenced as Delaware water passes through West Branch. The primary impact of West Branch appears to be on microbial quality (total and fecal coliform).

5.4.4 Summary of Delaware System Water Quality

The water quality of the Delaware system can be summarized as follows:

Parameter	Normal Range of Average Values, 1987-1994	Normal Range of Maximum Values, 1987-1994	Highest Value Recorded, 1987-1994
Turbidity (NTU)	0.9 - 1.3	1.8 - 4.5	15.8

Parameter	Normal Range of Average Values, 1987-1994	Normal Range of Maximum Values, 1987-1994	Highest Value Recorded, 1987-1994
Color (CU)	8 - 11	15 - 30	49
Iron (mg/l)	0.03 - 0.07	0.06 - 0.12	1.0
Manganese (mg/l)	0.025 - 0.098	0.05- 0.09	2.34
Ammonia Nitrogen (mg/l)	0.03 - 0.04	0.07 - 0.15	0.62
Total Organic Carbon (mg/l)	2.0	2.5 - 3.5	5.8
Total Coliform (CFU/100 ml)	30 - 60	75 - 1000	6,400
Fecal Coliform (CFU/100 ml)	2 - 13	20 - 100	6,500

5.5 *Downstream of Kensico—Mixed Catskill and Delaware Water Quality*

Both the lower effluent chamber of the Catskill Aqueduct (CATLEFF) and Shaft 18 of the Delaware Aqueduct (DEL18) are locations of mixed water from Kensico Reservoir. As already observed, water quality is generally high for both aqueducts and does not vary significantly. Comparing water quality values over the period 1987 to 1994 between the Catskill effluent chamber and Shaft 18 should be representative of the same water with the exception that the intakes are at slightly differing locations and both aqueducts have historically intermittently bypassed Kensico as required for supply (yield) or water quality. The only noteworthy differences are generally higher coliform levels at Shaft 18 on average and maximum.

Pathogen monitoring results downstream of Kensico were examined in light of EPA's proposal to link source water pathogen levels to the necessary level of treatment (under the Enhanced Surface Water Treatment Rule). The City presently conducts pathogen monitoring at Shaft 18 (DEL18) and the Catskill Aqueduct Lower Effluent Chamber (CATLEFF). The data examined was collected between June 1992 through December 1994.

Under the current SWTR, all systems must provide 3-log removal/inactivation of *Giardia* cysts and 4-log inactivation of viruses, regardless of their source water quality. Although states are encouraged by the *Guidance Manual* to require higher levels based upon source water quality, in practice states have required only the minimum levels regardless of source quality. Under the Enhanced SWTR proposal, EPA is considering a requirement whereby surface waters with poorer quality source waters would be required to remove microbiological contaminants above the minimum levels currently required by the SWTR. EPA is also evaluating several options for defining (calculating) the source water pathogen density which would then be used to determine the needed level of treatment. The four calculation options under consideration are: (1) arithmetic mean; (2) geometric mean; (3) 90th percentile; and (4) maximum measured value. All four methods were examined using the City's historical pathogen database. The results of this analysis is presented below. In calculating the various pathogen concentrations, it was assumed that the results reported below the detection limit were actually at the detection limit.

Source Water Pathogen Density[1]								
Calculation Method	*Giardia* (cysts/100 L)				*Cryptosporidium* (oocysts/100 L)			
	DEL18		CATLEFF		DEL18		CATLEFF	
	Total	Confirmed	Total	Confirmed	Total	Confirmed	Total	Confirmed
Arithmetic Mean	1.24	0.94	1.26	1.03	1.48	0.98	1.43	0.99
Geometric Mean	0.72	0.59	0.73	0.61	0.80	0.61	0.81	0.60
90th Percentile	3.24	2.79	3.39	2.91	3.61	2.79	3.32	2.91
Maximum measured value	8.23	5.26	9.25	7.70	15.01	5.26	17.30	5.62

[1] *Based on 114 samples at DEL18 and 113 samples at CATLEFF.*

The results indicate that future treatment levels could vary significantly, up to 4-log *Giardia* inactivation/removal and 3 to 5-log *Cryptosporidium* inactivation/removal in some cases, depending on the method of calculation.

In summary:

- When compared to upper Catskill water, Kensico Reservoir has a positive impact on turbidity, no impact on TOC, and a negative impact on microbial quality as indicated by total and fecal coliform.
- When compared to upper Delaware water, Kensico Reservoir has little or no impact on turbidity or TOC, and a negative impact on coliform levels.

5.6 *Other Comparisons - Ashokan and Rondout Source Reservoirs*

Upstream Delaware source water at Rondout was compared to upstream Catskill source water at Ashokan. Overall, Rondout has:

- Lower average turbidity levels (1.3 NTU compared to 2.6 NTU)
- Similar average total organic carbon levels (1.8 - 1.9 mg/l)
- Higher average total coliform levels (41 versus 11 CFU/100 ml); comparable average fecal coliform levels (2 to 3 CFU/100 ml)
- Similar average ammonia levels (0.03 mg/l)

- Slightly lower average iron and manganese (Mn at 0.03 vs 0.056 mg/l; Fe at 0.028 vs. 0.09 mg/l)

- Lower temperature (maximum and average).

5.7 Conclusions

There is a slight overall improvement in water quality (namely, turbidity) in both the Catskill and Delaware systems as water travels downstream through the aqueduct and intermediate reservoirs (Kensico and West Branch). The notable exceptions to this trend are bacteria levels (total and fecal coliform). In the Catskill system in particular, turbidity spikes dampen between Ashokan and the effluent of Kensico. A similar effect is seen for the Delaware system between Rondout and Kensico, but to a much lesser extent due to the lower initial turbidity levels. TOC remains unchanged in both systems at an average of 2.0 mg/l. There is a general increase in ammonia levels downstream, most notably between Rondout and Kensico, but also observed between Ashokan and Kensico. All other water quality parameters show no significant trends relative to location along the aqueduct system.

6.0 Confirmation of Pilot Testing Locations and Treatment Processes

The historical water quality data, combined with the knowledge of anticipated regulatory requirements, allows the characterization of the Catskill and Delaware supplies in terms of anticipated treatment challenges and compliance issues. The purpose of this section is to confirm:

- Which treatment technologies can reasonably be expected to meet the minimum water quality goals, and, therefore, should be included in the pilot plant studies, and

- The appropriate locations for pilot testing.

The treatment technologies planned to be used and the initially proposed pilot locations are described in the *Phase I Pilot Testing Protocols* (January 31, 1995, Filtration Avoidance Item #202a).

The December 1993 EPA Determination stipulates that the DEP must conduct pilot testing studies at the same time as engineering evaluations of the most appropriate location for a future filtration plant. In that regard, the Phase I pilot testing locations must be sufficiently flexible to accommodate the results of the concurrent siting and engineering studies. These concurrent studies are also part of this project, and are being conducted under Subtasks 2.2 and 2.3. In Phase II of the pilot testing program, the filtration plant site(s) will be better known, and the treatment process investigations will be able to focus on optimization at one or two locations.

6.1 Treatment Processes to Include in Pilot Testing Program

Based on our review of the historical water quality and DEP reports, key water quality observations with respect to treatment process selection are:

- The average turbidity in the Catskill system (1.0-2.6 NTU) is slightly higher than in the Delaware (0.9 - 1.3 NTU); higher turbidity peaks (up to 120 NTU) have been observed in the Catskill system (versus 16 NTU) than in the Delaware; the spikes present in the upper aqueducts are dampened as water travels downstream and through intermediate reservoirs; except at upstream Catskill locations, turbidity spikes in excess of 10 NTU occur less than 1% of the time.

- The organic content of the water (as indicated by TOC) remains unchanged throughout the system.

- Both systems have moderate pH (6.6) and low alkalinity (10 mg/l as $CaCO_3$) which are stable throughout the system.

The high quality of the Catskill and Delaware system water has significant impact on treatability. The low turbidity and organic content enables low coagulant doses and higher filtration rates. The low organic content yields a low oxidant demand and moderately low trihalomethane and haloacetic acid formation potential. The neutral pH and low alkalinity make it aggressive to piping materials, and generally indicates that supplemental pH/alkalinity addition will be needed for proper coagulation.

As outlined in the *Phase I Pilot Testing Protocols* (January 31, 1995, Filtration Avoidance Item #202a), the major objectives for the Phase I pilot plant program are to investigate alternative treatment process trains for each source to produce water in conformance with the requirements of the Surface Water Treatment Rule (SWTR), and future Enhanced SWTR (ESWTR) and Disinfectants/Disinfection By-Products Rule (D/DBPR). To accomplish these objectives, it was recommended that the Phase I pilot facilities be comprised of two mobile pilot plants. The first pilot plant will test conventional treatment, with the ability to bypass sedimentation for evaluation of in-line and direct filtration. The second pilot plant will test dissolved air flotation/filtration. Both pilot plants will include ozonation and alternative filter media configurations.

The major unit processes included in each pilot plants are summarized as follows:

- *Conventional/Direct Filtration:* Primary disinfection and oxidation (preozonation) - rapid mix/coagulation - flocculation - sedimentation (with bypass) - filtration (anthracite mono-media, dual media, granular activated carbon).

- *Dissolved Air Flotation/Filtration:* Preoxidation (ozone, chlorine, potassium permanganate) - rapid mix/coagulation - flocculation - dissolved air flotation - primary disinfection/intermediate ozonation (optional) - filtration (anthracite mono-media, dual media, granular activated carbon).

After review of the water quality records and system operations, we concur with these pilot plant process train selections. The rationale for these recommendations is presented in the table below.

Treatment Process	Reason for Inclusion	Variations
Direct Filtration (Coagulation → Flocculation → Filtration)	▪ High quality source water; infrequent turbidity spikes at lower Catskill and all Delaware aqueduct locations. ▪ Provides smallest building area footprint.	Preozonation. In-line and direct filtration. Alternative filter media configurations.
Dissolved Air Flotation/ Filtration (Coagulation → Flocculation → Dissolved Air Flotation → Filtration)	▪ High quality source water; occasional turbidity spikes at upper Catskill aqueduct locations. ▪ Future regulatory considerations. ▪ Potential future deterioration of source water quality. ▪ Provides intermediate building area footprint.	Pre- and intermediate ozonation. Alternative filter media configurations.
Conventional Treatment (Coagulation → Flocculation → Sedimentation → Filtration)	▪ Occasional turbidity spikes at upper Catskill aqueduct locations. ▪ Future regulatory requirements. ▪ Potential future deterioration of source water quality. ▪ Largest building area footprint for comparison purposes.	Pre- and intermediate ozonation. Alternative filter media configurations.

6.2 *Pilot Testing Locations*

6.2.1 *Original Locations Included in the Phase I Testing Protocols*

In the *Phase I Pilot Testing Protocols*, the following locations were recommended for testing and subsequently included in the testing schedule:

Shaft/Location	Representing Water Quality From
Shaft 18 (DEL18)/Valhalla	Kensico Reservoir (combined Catskill and Delaware water)
Shaft 17 (DEL17)/Valhalla	Lower Delaware Aqueduct (downstream of West Branch Reservoir)
Town of New Castle/Millwood Water Treatment Plant	Upper Catskill Aqueduct
Shaft 5A/Town of Newburgh Water Treatment Plant	Upper Delaware Aqueduct (upstream of West Branch Reservoir)

These locations were selected as follows. For all filtration plant schemes under consideration (Task 2.2), a plant is required downstream of Kensico Reservoir. Treatment plants may also be required on one or both of the upstream aqueducts. As such, there are three general locations for plants:

- A Catskill plant upstream of Kensico Reservoir along the Catskill Aqueduct,
- A Delaware plant upstream of Kensico Reservoir along the Delaware Aqueduct, and
- A plant adjacent to or downstream of Kensico Reservoir capable of treating all water.

The pilot testing locations were selected to provide water representative of each of these locations pending the results of this water quality review. The testing locations also allowed for separate testing of both segments of the Delaware Aqueduct, as the impact of the intermediate West Branch Reservoir on treatment requirements was not known at the time. A critical consideration in siting the pilot plants was to ensure that a supply of representative test water is available independently of changes in system operation due to by-passing.

6.2.2 Revised Pilot Testing Locations

Based on the water supply characterization presented above, it is recommended that piloting at the Town of Newburgh Water Treatment Plant (Shaft 5A), representing upper Delaware Aqueduct water (upstream of West Branch), be eliminated from the testing program. The reasons for this are as follows:

- The most significant water quality changes between upstream and downstream of West Branch Reservoir relate to microbial water quality (coliform) which do not have an impact on treatment process selection.
- The water quality at West Branch Reservoir effluent (Shaft 10) and Kensico Reservoir influent (Shaft 17) is nearly identical. Testing at Shaft 17 is already included in the Phase I program.
- Based upon the May 1995 Task 2 Workshop, none of the three or four most likely overall plant configurations include a plant located on the Delaware Aqueduct between Rondout and West Branch.

It is also recommended that the Phase I testing program continue to include testing at the Millwood Water Treatment Plant (upper Catskill Aqueduct water) to verify our assumptions that the somewhat higher turbidity levels seen upstream of Kensico Reservoir will have an impact on treatment (particularly in-line and direct filtration). After the first season of testing at Millwood, the need to continue pilot testing of the upper Catskill water will be re-assessed.

There are no other changes to the Phase I testing program proposed at this time.

6.2.3 Summary

In summary, the following locations are recommended for the Phase I testing based upon the water quality review and characterization:

Shaft/Location	Representing Water Quality From	Testing Period
Shaft 18 (DEL18)/Kensico Reservoir	Kensico Reservoir (combined Catskill and Delaware water)	All four seasons
Shaft 17 (DEL17)/Kensico Reservoir	Lower Delaware Aqueduct (downstream of West Branch Reservoir)	All four seasons
Town of New Castle/ Millwood Water Treatment Plant	Upper Catskill Aqueduct	Season #1 (Spring/ Summer) initially, with reassessment of need for continued testing based on initial results