ATTACHMENT 1
CONDITION ASSESSMENT METHODOLOGY

The approach used for the condition assessment involves analysis of TV inspection data and maintenance information in order to establish a "condition rating" for each sewer pipe (manhole-to-manhole reach) in the system. The TV data is also used to develop preliminary estimates of costs for rehabilitation of sewers with identified defects in order to determine the most cost-effective method of repair for each pipe. The District's program for performing the condition assessment is called Pipe Condition Assessment Program or "PCAP." PCAP is contained in a Microsoft Access™ database program.

In order to prioritize the sewers for rehabilitation work, the condition ratings are considered in conjunction with other factors, called "impact factors", that reflect how "critical" each sewer is, i.e., the potential severity of the impacts should the pipe fail structurally or a blockage occur. The combination of the sewer condition rating and impact factors defines the overall "critical rating" of the sewer, which then determines its relative priority for rehabilitation.

DATA

There are two types of data used in the pipe condition assessment: TV inspection data and maintenance data. These are discussed in the following paragraphs:

Television Inspection Data

TV inspection data provides information about the condition of each sewer segment. The District's ongoing preventive maintenance program provides for TV inspection of every sewer pipe in the system once every six years. The TV data identifies the location, type, and severity of defects observed in the sewer, as well as other pertinent data such as pipe diameter, material, joint length, and the location of lateral connections.

During the TV inspection, the condition observed in the sewer is entered into a computer database while it is simultaneously being recorded on videotape. The District uses the Hansen system for recording TV inspection data. The data entered into the Hansen database is also uploaded to the District's Geobase maintenance management system for data storage and reporting purposes.

Sewer defects observed during TV inspection are categorized and identified using a pre-established set of defect codes. The general categories of defects include the following:

- Offset or separated joints
- Root intrusion
- Grease and debris
- Obstructions
- Lateral connections (type, protrusions)
- Corrosion

- Infiltration
- Sags (horizontal misalignment)
- Deflection (vertical misalignment)

The location of each defect (footage) within the sewer pipe is recorded, along with the corresponding defect code that indicates the type and severity of the defect. Comments by the TV operator can also be entered into the database; although these are not considered in the condition assessment.

Maintenance Data

Sewers in the District that have historically experienced maintenance problems, such as chronic blockages due to accumulation of grease or debris or excessive root intrusion, are placed on a scheduled maintenance program. The scheduled maintenance program includes sewer cleaning at 3-, 6-, 12-, and 24-month intervals, and root treatment at 36-month intervals. The frequency of scheduled maintenance for a sewer is an indicator of the severity of maintenance problems. Therefore, the scheduled maintenance frequency is useful as a parameter in evaluating the overall physical condition of the sewer. Sewers without chronic problems are cleaned once every six years in conjunction with the cyclic TV inspection.

CONDITION RATING

Using the TV inspection and maintenance schedule data, sewers are assigned separate ratings for structural and maintenance condition. The structural and maintenance ratings are calculated using the following formula:

$$\textbf{Condition Rating} = \frac{\text{sum (no. of defect type * points per occurrence per defect) * 100}}{\text{pipe length}}$$

Table 1 lists the pipe defect codes and the points per occurrence used for the structural and maintenance condition ratings.

A maintenance condition rating "default value" based on scheduled cleaning and root treatment frequency is also calculated for those sewers in the scheduled maintenance program. For each pipe, the maintenance condition rating calculated from the TV inspection data is compared to the default value, and the higher of the two condition ratings is used. Since each sewer is cleaned prior to TV inspection, the use of a default value ensures that pipes for which the TV data does not reflect the true extent of problem conditions in the pipe (e.g., grease deposits, debris, or roots that may have been temporarily removed by the pre-TV cleaning) are not overlooked in the condition assessment process. The default maintenance condition rating values used are as follows:

TABLE 1
PIPE DEFECT CODES AND POINTS

Defect Code			Points per Occurrence	
Hansen	Geobase	Description	Structural	Maintenance
A1	060	sag minor	1	1
A2	061	sag moderate	2	2
A3	062	sag severe	10	10
A4	039	can't get by	20	10
A5	040	camera under water	10	10
R1	026	roots minor	1	1
R2	027	roots moderate	2	2
R3	028	roots severe	5	5
C1	006	cracked bell minor	2	NA
C2	007	cracked bell moderate	25	NA
C3	008	cracked bell severe	100	NA
C4	012	cracked spigot minor	2	NA
C5	013	cracked spigot moderate	25	NA
C6	014	cracked spigot severe	100	NA
C7	009	cracked barrel minor	10	NA
C8	010	cracked barrel moderate	50	NA
C9	011	cracked barrel severe	200	NA
D1	031	grease minor	NA	1
D2	032	grease moderate	NA	2
D3	033	grease severe	NA	5
D4	034	debris minor	NA	1
D5	035	debris moderate	NA	2
D6	036	debris severe	NA	5
I1	057	infiltration minor	1	NA
I2	058	infiltration moderate	2	NA
I3	059	infiltration severe	5	NA
L1	043	lateral wye - 4"	NA	NA
L2	044	lateral wye - 6"	NA	NA
L3	045	lateral tap - 4"	1	NA
L4	046	lateral tap - 6"	1	NA
L5	047	protruding lateral minor	1	2
L6	048	protruding lateral moderate	2	4
L7	049	protruding lateral severe	5	10
L8	050	cracked lateral minor	1	NA
L9	051	cracked lateral moderate	2	NA
LA	052	cracked lateral severe	5	NA
LB	053	dead lateral	NA	NA
J1	015	joint offset minor	2	NA
J2	016	joint offset moderate	4	4
J3	017	joint offset severe	10	10
J4	018	joint separated minor	2	NA
J5	019	joint separated moderate	4	2
J6	020	joint separated severe	10	5
S0	071	start of cast iron	NA	NA
S1	054	corrosion minor	10	NA
S2	055	corrosion moderate	50	NA
S3	056	corrosion severe	200	NA
S4	072	end of cast iron	NA	NA
S5	073	start PVC	NA	NA
S6	074	end PVC	NA	NA
S7	075	deflection minor	2	NA
S8	076	deflection moderate	5	NA
S9	077	deflection severe	10	NA

Maintenance Frequency	Default Condition Rating
3 months	20
6 months	15
12 months	10
24 months	5
36 months (root control)	15

For example, for a pipe on a 6-month scheduled cleaning cycle, the default maintenance condition rating of 15 would be equivalent to 6 occurrences of severe grease in a 200-foot reach.

The individual structural and maintenance condition ratings are added together to determine the overall condition rating of the pipe. Because the defect point values are generally higher for the structural rating than for the maintenance rating, the overall condition rating is typically weighted more by the structural condition of the pipe, which is generally appropriate. However, for pipes in generally good structural condition, but with chronic maintenance problems, the overall condition rating tends to be dominated by the default maintenance rating. In general, the pipes with the highest overall condition ratings are those with extensive cracking and other structural problems such as severe sags or obstructions.

IMPACT FACTORS

Impact factors are assigned to pipes according to four categories:

- **Community Impact.** This factor reflects the "sensitivity" of the area in which the pipe is located with respect to environmental or social impacts. Sewers assigned community impact factors include those adjacent to drainage channels, streams, or wetlands, or located in the vicinity of hospitals, schools, parks, or other community facilities.

- **Construction Impact.** This factor reflects the relative difficulty of construction and maintenance due to access limitations or traffic concerns. Sewers assigned construction impact factors include those located in easements and along streets or in intersections with high traffic volume.

- **Critical Crossings.** This factor is assigned to sewers that cross highways, railroads, flood control channels, and major or critical utilities. The impact of these crossings is associated with the difficulty and cost of construction.

- **Pipe Diameter.** The diameter of the pipe is indicative of the size of the tributary area that is served by the sewer. Larger diameter pipes are assigned higher impact factors because of the larger area and number of people that would be affected should the pipe fail or be temporarily out of service. However, six-inch pipes are assigned a slightly higher factor than eight-inch pipes because of the greater likelihood of problems such as overflows or backups should a blockage occur in the sewer.

Each pipe is assigned an impact factor ranging from 0 to 2 (0 to 4 for critical crossings) for each of the above four categories. The impact factor values are shown in Table 2.

TABLE 2
IMPACT FACTORS

Condition	Impact Factor (IF) [a]
Community Impact	
Hospital	2
School	1
Creek, Marsh, Drainage Channel	2
Construction Impact	
Easement	1 - 2
Traffic	1 - 2
Critical Crossings	
Freeway	4
Railroad	4
Hetch Hetchy	4
Flood Control Channel or Creek	3
Major Buried Utilities	2
Major Overhead Utilities	1
Pipe Diameter	
6-inch	0.5
8-inch	0
10- to 12-inch	1
15- to 30-inch	1.5
> 30-inch	2

[a] 0 = default value (minimal impact)

Based on the individual impact factors, the overall total impact factor for the pipe is:

$$\text{Total IF} = 1 + \text{sum(IF)} / 10$$

where sum(IF) is the sum of the four individual impact factors. Since the maximum value for sum(IF) is 10, the Total IF is a value ranging from 1 to 2. The Total IF is then multiplied by the condition rating to determine the critical rating for the sewer. Therefore, at most, the impact factors can serve to double the rating of a sewer that would otherwise be assigned based on its physical condition alone.

REHABILITATION METHODS AND COSTS

Three alternative methods of rehabilitation are considered for the preliminary assessment of rehabilitation needs and costs. These are methods along with their associated cost calculations are:

- **Spot Repair** (N1*S1)+ L*R*(50/FR)+ L*H*(50/FH)
- **Rehabilitation** (N2*S2) + (L*US)+ (NL*UL) + L*H*(50/F)
- **Replacement** (L*UR) + (NL*UL) + L*H*(50/F)

where:

N1: number of spot repairs (required for severe defects only)
S1: spot repair unit cost ($/ea)
R: root treatment unit cost ($/ft)
H: cleaning (hydroflushing) unit cost ($/ft)
FR: current root treatment frequency (years)
FH: current cleaning frequency (years)
F: default cleaning frequency (6 years)
L: sewer length (ft)
N2: number of spot repairs required prior to rehabilitation (Codes A2, A3, A4, A5, J2, J3, S8, S9)
S2: spot repair unit cost in conjunction with rehabilitation ($/ea) (Note: S2 is less than S1 based on the assumption that the contractor is already mobilized for the rehabilitation work.)
US: rehabilitation unit cost ($/ft) - based on an average cost for sewer lining (slip-lining or cured-in-place pipe)
NL: number of laterals
UL: lateral connection unit cost ($/ea)
UR: sewer replacement unit cost ($/ft)

The unit costs used for the rehabilitation cost calculations are presented in Tables 3 through 5. Note that the unit costs for rehabilitation (lining) and replacement assume some "economy of scale", i.e., that rehabilitation or replacement projects would typically include several thousand feet of sewers in general proximity to each other. Rehabilitation or replacement of isolated manhole-to-manhole sewer reaches would typically be somewhat higher in cost.

TABLE 3
CLEANING AND SPOT REPAIR UNIT COSTS

Item	Unit Cost [a]
Hydroflushing	$0.42/ft
Root Treatment	$1.16/ft
Spot Repairs (S1)	$3,300 ea

[a] Costs based on information provided by USD staff.

TABLE 4
REHABILITATION UNIT COSTS

Existing Pipe Diameter (in.) [a]	Unit Cost ($/ft.) [a]
6	90 [b]
8	90
10	100
12	110
15	120
18	130
21	140
24	150
27	160
30	170
36	200
Spot Repairs	$1,500 each
Lateral Reinstatement	$1,000 each

[a] ENR 6500. Costs do not include engineering, administration, or contingencies.

[b] For purposes of comparing rehabilitation (lining) to other alternatives, the cost for rehabilitation of 6-in. pipe is assumed to be the same as for 8-in. pipe. However, if rehabilitation is determined to be the least cost method, then the budget cost will assume replacement of the 6-in. sewer with 8-in. pipe.

TABLE 5
REPLACEMENT UNIT COSTS

Replacement Pipe Diameter (in.)	Unit Cost ($/ft.) by Pipe Depth [a]		
	0-9 ft.	10-15 ft.	>15 ft.
8	130	160	200
10	140	170	210
12	140	180	230
15	150	185	230
18	160	205	260
21	180	230	290
24	210	260	330

27	230	290	360
30	250	315	390
36	290	360	450
42	330	415	520
48	380	470	590

Lower Lateral Replacement (performed as part of sewer replacement project): $1,200 per lateral

(a) ENR = 6500. Includes mobilization, traffic control, shoring, dewatering, manholes, and pavement restoration (for trench section). Costs do not include engineering, administration, or contingencies.

The cost for each method of rehabilitation also includes a factor that reflects the cost for sewer maintenance over an assumed 50-year pipeline life. For spot repair, it is assumed that sewers that require scheduled maintenance (cleaning or root treatment) would continue to require maintenance at the same frequency in the future. After rehabilitation or replacement, it is assumed that maintenance would be required only at the default frequency of once every six years and that no root treatment would be required.

For each pipe, the method with the lowest cost is identified as the "best method" for that pipe. The best method cost can then be used for budgeting sewer rehabilitation needs. Note that the final "best method" cost for six-inch pipes for which rehabilitation (lining) is indicated as the best method is based on replacement of the sewer with an eight-inch diameter pipe. Pipes with no severe defects typically require no repair and are therefore indicated for preventive maintenance (PM) only.

COMPUTER DATABASE

The condition assessment methodology described above was programmed into a computerized database system. The program uses Microsoft Access™ and operates on a PC computer. To develop the database, the data from the District's Geobase system was downloaded to PC format and reformatted for import into the database. The data downloaded into the database includes inventory information (pipe upstream and downstream manhole numbers, cleaning section number, street location, diameter, length, slope, and material); maintenance schedules; and TV inspection data summarized by the number of occurrences of each defect type. The database does not include the detailed footage location for each defect or the comments recorded by the TV operators. Impact factor information, as described above, was added to the database for use in calculating the critical ratings, along with pipe design flow and capacity for those sewers that are included in the District's SNAP model.

The database program allows the user to edit, add, or delete inventory, maintenance schedule, TV inspection, and impact factor data, as well as to modify the pipe defect point values and rehabilitation unit costs. The program generates several types of output reports. The three principal reports used for the pipe condition assessment are:

- **TV Inspection Summary.** This report summarizes the number of defects for each sewer for eight general classifications of defects (cracks, joints, corrosion, sags, grease/debris, roots, obstructions, and other), separated into minor and moderate/severe categories.

- **Condition Rating Report.** This report lists the maintenance schedules and calculated condition and critical ratings for each sewer. Pipes that do not have TV inspection data are listed but not rated.

- **Rehabilitation Cost/Priority Report.** This report lists the impact conditions for each sewer and presents the calculated costs (based on the TV inspection data) for each of the three methods of rehabilitation, and it identifies the "best method" and associated cost for each pipe

Reports can be generated for the entire basin or for portions of the basin as specified by cleaning section number, upstream manhole map grid, or street. The Condition Rating and Rehabilitation Cost/Priority Reports provide the option to list the pipes in decreasing order of condition or critical rating.

LIMITATIONS OF THE DATABASE PROGRAM

The database program provides an efficient means of assessing the condition of the thousands of sewers in the District's system. It can be used to develop preliminary estimates of rehabilitation needs and priorities without the need for a time-consuming, labor-intensive review of the detailed data. However, there are certain limitations that need to be considered when using the program. Some of these limitations are discussed below.

- Some pipes in the system may be missing from the database. Without a detailed comparison of the individual database records with the sewer block maps, it is not possible to readily identify the missing pipes. However, over time, any missing or incomplete information will likely be discovered and corrected.

- Some sewers have not been TV inspected or do not have TV inspection data stored in the database. The program does not generate condition ratings or rehabilitation cost estimates for these pipes. Sewers on scheduled maintenance programs, but without TV inspection data also are not rated by the program.

- Some problems observed during TV inspection may not be coded as individual defects but entered as comments (e.g., "moderate grease last 20 feet"). Similarly, multiple defects (e.g., multiple sags, roots, grease, etc.) may not all be coded individually. Since the database program condition rating and cost calculation algorithms are based on the *number* of defects recorded by the TV inspection, the program may underestimate the severity of the sewer condition or underestimate the repair cost in these cases.

- The length of a sag (or camera under water) is not considered, only the number of times the sag or occurrence of the camera under water is recorded as an individual defect code. The same limitations apply as for multiple defects described above.

- Some severe defects that were identified during TV inspection may have already been repaired. The data does not reflect these repairs unless the sewer was re-televised or the database has been specifically edited to identify and delete these defects.

- If all lateral connections are not coded, the program may underestimate the cost for lining or replacement, since these methods require reinstatement of the lateral connections. Underestimation of the number of laterals may result in the program indicating that lining is less costly than spot repair.