BIRGANJ METROPOLITAN CITY
SECONDARY TOWNS INTEGRATED URBAN ENVIRONMENTAL IMPROVEMENT PROJECT (STIUEIP)
PROJECT IMPLEMENTATION UNIT (PIU)
BIRGANJ, PARSA, NEPAL

Ref. No. : 156/074/075

Date: 30 Nov 2017

To,
Mr. Chakrawarti Kantha
Project Director
Project Coordination office
Babarmahal, Kathmandu

O/C

Sub: - **Submission of Operation and Maintenance Manual**

Dear Sir,

PIU has received Operation and Maintenance Manual for Sewerage and Drainage System for STIUEIP, Birganj from Consultant (SMEC and Associates). While PIU is reviewing the report; you are requested for having feedback in relation to submitted report.

2 copies of **Operation and Maintenance Manuals** are attached herewith.

CC to:

1. Mayor, Birganj Metropolitan City

Regards

Shailendra Shrestha
Project Manager

Project Manager

Ph. No.: 00977-51-525426,51-531900, Fax No. : 51-525120
e-mail : stiueip.birganj@gmail.com, stiueip.birganjnew@gmail.com

SMEC in association with BRISBANE CITY ENTERPRISES PVT LTD BDA CEMAT

Ref. No.: DSC/074/075-93 Date: 24 November 2017

To,

Mr. Shailendra Shrestha
Project Manager, STIUEIP
Project Implementation Unit
Birgunj Metropolitan City
Birgunj.

Sub: Operation and Maintenance Manual

Dear Mr. Shrestha,

Please find enclosed three copies of Operation and Maintenance Manual for Sewerage and Drainage System for STIUEIP, Birgunj for your information and review.

With thanks.

Sincerely yours,

SMEC in association with BCE/BDA/CEMAT

Nagendra Jha
Team Leader, DSC
STIUEIP, Birgunj

Birgunj Metroplitan City
STIUEIP
Birgunj
Reg. No. ९८६/०६६/०६५
Date ..२०७४/८/१७..

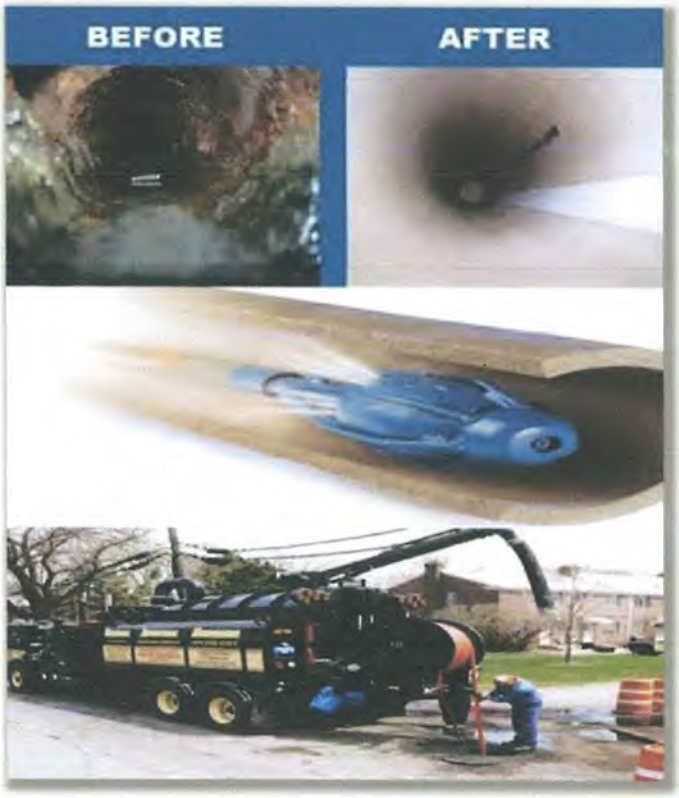
in association with

Brisbane City Enterprise Pty Ltd – Australia
Building Design Authority – Nepal
CEMAT Consultants – Nepal

OPERATION AND MAINTENANCE MANUAL

Sewerage and Drainage System

Secondary Towns Integrated Urban Environmental Improvement Project (STIUEIP), Birgunj, Nepal



FINAL REPORT

Birgunj Metropolitan City, Nepal

November 2017

SMEC

in association with

Brisbane City Enterprise Pty Ltd – Australia
Building Design Authority – Nepal
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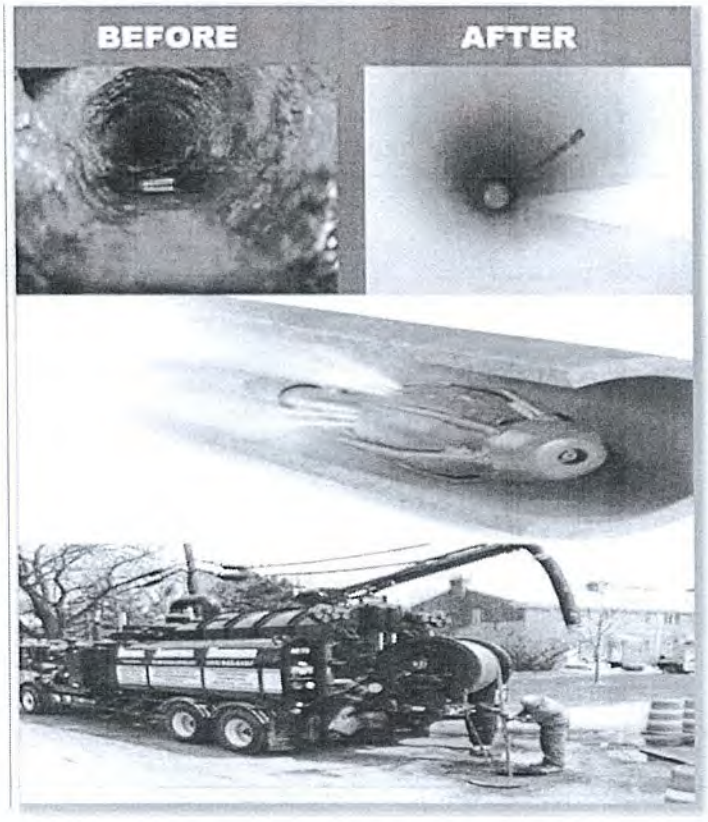
OPERATION AND MAINTENANCE MANUAL
Sewerage and Drainage System

Secondary Towns Integrated Urban Environmental Improvement Project (STIUEIP), Birgunj, Nepal



FINAL REPORT

Birgunj Metropolitan City, Nepal

November 2017

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1. GENERAL

Sanitary sewer collection systems are designed to remove waste water from homes and other buildings and convey it to a wastewater treatment plant. The collection system is a critical element in the successful performance of the wastewater treatment process. Under certain conditions, poorly designed, built, managed, operated, and/or maintained systems can pose risks to public health, the environment, or both. Effective and continuous management, operation, and maintenance, as well as ensuring adequate capacity and rehabilitation when necessary, are critical to maintaining collection system capacity and performance while extending the life of the system.

In order to understand and subsequently plan comprehensive solutions, it is imperative to evaluate the existing collection and disposal system of the pertaining to sewerage and storm water drainage. This section of the report will cover main features of the existing collection system along with associated key issues which are hindering efficient operation and maintenance.

1.1 Existing Drainage and Sewerage System

There are neither public centralized sewerage network systems for sewage collection nor sewage treatment plants for sewage disposal in Birgunj. The open drains have been used for waste water collection and disposal. The on-site sanitation with septic tank and soak pits has been adopted for the sewage disposal from settlements. About 51% households have modern toilets, additional 24% households have ordinary toilets but 25% households do not have any toilets. Though most of the houses have septic tanks, but very few have soak pits. As such, the septic tank effluents from most houses are directly discharged into the open road-side storm water drains. The municipality does not have facilities for the collection and disposal of septic tank solids. Generally the private operators provide these kinds of services and they have been found to dispose the solids in the road-side drains or on the vacant land. As reported in the Birgunj Initial Environment Assessment, the town is seriously short of public toilets. Based on a copy of the Birgunj Facilities map, there are only seven public toilets in the city. Most of the residents living in settlements belong to slum and squatter areas without toilet facilities have to sort to defecating either in the open fields or in open drains. Most of the existing public toilets have not been maintained after their constructions.

Due to the flat topography the city suffers inundation and flooding frequently during the monsoons from the two rivers, the Sirsiya in the west and Singha in the east part of the city.

1.2 Storm Water System

Details of the existing system: Birgunj municipality has only storm drainage system. A field Inventory Survey was carried by DSC to find out the details of the existing drainage network system in the Birgunj Municipal area. During the Inventory Survey the drainage networks all over the urban municipal area was taken into consideration. During the survey works the type of drains, its physical condition, direction of flow, its size (breadth and width), location of the discharge point and its existence either on one side or on both side of the road was recorded.

The earthen drains on the side of black topped road or along the gravel road within the municipal urban area were not measured during the inventory survey. The length of the drains was measured with the help of available soft drawing. No measurement could be made for the main drain MD1 as it has wider in section, structures over it at few locations and some length spread on surface (downstream of Khetan Campus). The total length of the drain was found to

be about 71.3 km. The length of Brick Masonry (BM) drains, RCC drains and main drain MD1 were found to be 56.5 km, 9.9 km and 4.9 km respectively.

In Birgunj, there is an acute lack of appropriate drainage system. The existing system in several locations in place does not function well. The natural surface drainage system is altered due to unplanned filling of allotments and road causing conversion of natural wetland into urban settlement. At the moment, the drainage network system is severely stressed and causes flooding along major streets under severe rainfall events in the area prone to flooding. An effective comprehensive drainage system is visibly vital, that enhances the environment for economic growth and sustaining quality living conditions to the residents of Birgunj.

The new design concept: In order to achieve the key objectives and address the project drivers, an attempt has been made to emanate a comprehensive drainage system that would alleviate flooding and public health risks within the project area (Birgunj Metropolitan City). The existing land-use plans have been used to set the horizon for assessing the future system performance although the anticipated future development for Birgunj was unknown. The proposed drainage system concepts are estimated to cater for **1 in 2 years return period storm event**. The following sections describe the proposed drainage system and retention sites per Outfall. The entire Birgunj has been divided into 6 groups or catchments, starting from the north leading to the south. The different Catchment areas are divided in accordance to the potential outlet points to the two rivers, Sirsiya river and Singha river, flowing along the both sides of Birgunj. The total area covered in Birgunj is about 927.87 ha. In all 6 sections have been selected as potential outlet for the storm water drainage. Out of the 6 outlets, the out lets 3, 9 and 10 drains out its flow to the Sirsiya river whereas, the remaining 3 outlets 6, 7 and 8 drains out its flow to the Singha river. The surface water drains and sewer are dimensioned in order to limit flooding based on the design assumption. It is usually impracticable to avoid flooding from the occurrence of very sever storm. The locations of the six out lets are shown in the Fig.1 and the summarized findings which present the total flow at each catchment is presented in Table 1-1.

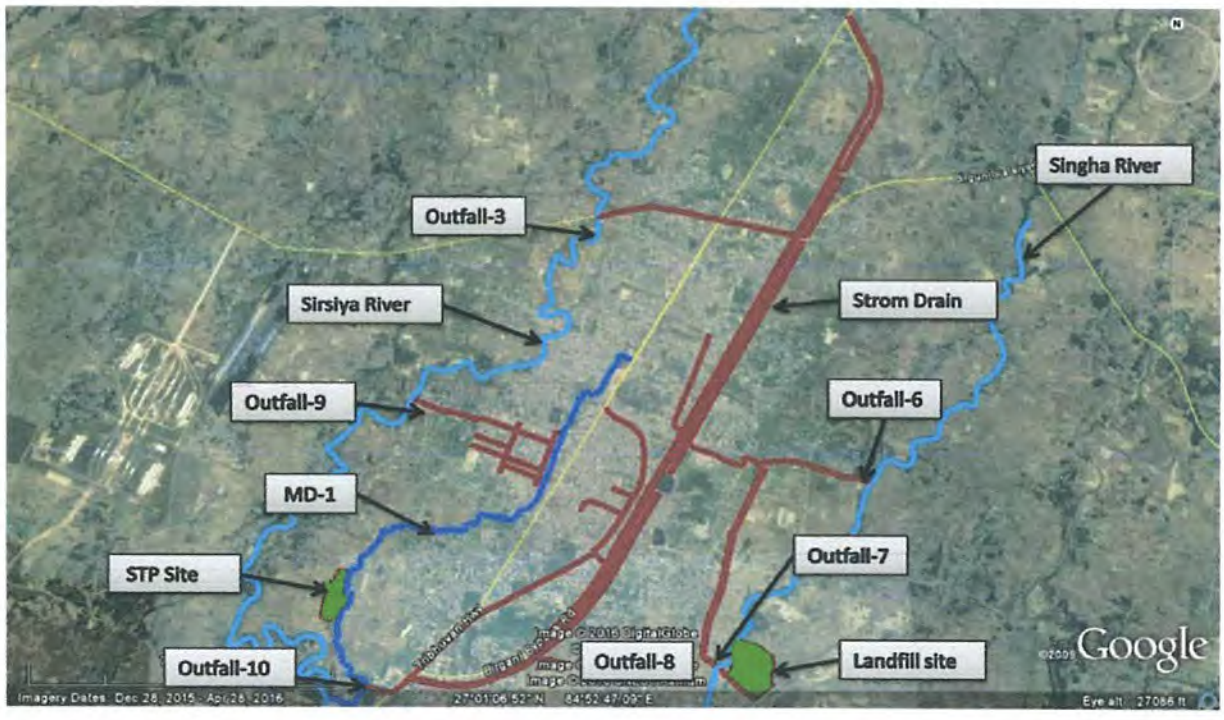


Figure 1: Outfall Locations of Storm Drains

Table hereafter summarized the findings which presents the total flow at each catchment.

Table 1: Outfall area and Flows for Storm Drains

Outfall No.	Ward No.	Main Drain	Area Covered in ha.	Flow in m3/s
3	16,17,18	Diversion 4	171.90	6.03
6	10,15,18	Diversion 12	160.20	5.81
7	19	Diversion 13	46.40	2.30
8	4,6,9,19	Diversion 13A	88.10	7.25
9	1,3,7,8,11,12,13	MD1	149.40	3.81
10	1,2,3,4,5	Rect. Drain	115.30	5.16

The total length of the newly constructed storm drains under STIUEIP project is about 47.379 km out of which, the length of Reinforced Concrete Drain (RCC) is 27.00 km, length of Brick Masonry Drain is 17.691 km and length of Stone Masonry Drain (for rehabilitation work of MD1) is 2.688 km.

1.3 Sewerage System

The Sanitary sewer has been constructed which mainly consists of network of sewer lines of main and branch and sewer. This system serves the area west of Tribhuwan Rajpath (main city road). It is a gravity collection system having total length 7.856 km with 4.856 km main sewer line and 3.00 km branch sewer line. The diameter of the pipe varies from 200 mm diameter to 800 mm diameter. High Density Polythene Pipe (HDPE) has been used up to 250 mm diameter whereas, from 300 mm diameter to 800 mm diameter, Reinforced Concrete Hume pipe has been used.

2. SYSTEM IMPROVEMENT, OPERATION AND MAINTENANCE (SIOM) PROGRAM

The System Improvement, Operation and Maintenance (SIOM) Program incorporate many of the standard operation and maintenance activities that are routinely implemented by the Authority/Agency (Birgunj Municipality) with a new set of information of management requirements in order to:

- Better manage, operate, and maintain the collection systems
- Investigate capacity constrain edare as of the collection system
- Proactively prevent Sanitary Sewer Overflows (SSOs)
- Respond to Sanitary Sewer Overflows (SSO) events

The SIOM approach helps the owner, or operator provide a high level of service to customers and reduce regulatory noncompliance. SIOM can help utilities optimize use of human and material resources by shifting maintenance activities from "reactive" to "proactive" –often leading to savings through avoided costs due to overtime, reduced emergency construction costs, changes in financial performance goals, and fewer law suits. SIOM programs can also help improve communication relations with the public, other municipal works and regional planning organizations.

It is important to note that the management the municipality of Birgunj, should ensure that the SIOM program is established as a matter of policy. The program should not be micro-managed, but an understanding of the resources required of the operating staff to implement and maintain the program is necessary.

The SIOM planning frame work covers operation and maintenance (O&M) planning, capacity assessment and assurance, capital improvement planning, and financial management planning. Information collection and management practices are used to track how the elements of the SIOM program are meeting performance goals, and whether overall system efficiency is improving.
On a periodic basis, utility activities should be reviewed and adjusted to better meet the performance goals. Once the long-term goal of the SIOM program is established, interim goals may be set.

An important component of a successful SIOM program is periodically collecting information on current systems and activities to develop a "snapshot-in-time" analysis. From this analysis, the management of the Municipality evaluates its performance and plans its SIOM program activities. An example for maintenance program could be:

Inspection Routine inspections shall consist of walking the entire length of the drainage, documenting obstructions, trash, debris or any other issues that may cause flooding including the condition of any manmade structures. Open brick drains-monthly in general; weekly in market areas. Covered brick drains-monthly with drains opened in February. Brick linings drains-monthly. All drains following first heavy rainfall in year.

Cleaning Open brick drains-as required. Covered brick drains-in February when opened Brick linings drains and culverts- January to February prior to rains. All drains-as revealed by inspection. The inspections will also show where repairs are required and where encroachment into the drain and deliberate blocking of the drain is taking place. Appropriate action to enforce the regulations must be initiated immediately. The cleaning of permanently closed brick drains and small culverts is difficult and time consuming. New drains should have removable covers to facilitate cleaning. Whereas, the responsibility of cleaning and conservancy of drains fall under

the conservancy section under Municipality, operation and maintenance of drains of the Municipality involve the services in the following areas.

- Conservancy (Cleaning of drains)
- Mosquito killing
- Solid waste management
- Structural maintenance of drains

Maintaining the value of the investment is also important. Collection systems represent major capital investments for communities and are one of the communities 'major capital assets. Equipment and facilities will deteriorate through normal use and age. Maintaining value of the capital asset is a major goal of the SIOM program. The infrastructure is what produces sales and service. Proper reinvestment in capital facilities maintains the ability to provide service and generate sales at the least cost possible and helps ensure compliance with environmental requirements for ongoing investment in the collection system and treatment facilities to ensure design capacity while maintaining existing facilities and equipment as well as extending the life of the system.

The performance of wastewater collection systems is directly linked to the effectiveness of its SIOM program. Performance characteristic sofa system with an inadequate SIOM program include frequent blockages resulting in overflows and backups. Other major performance indicators include pump station reliability, equipment availability, and avoidance of catastrophic system failures such as a collapsed pipe.

The SIOM program is what the municipality should use to manage its assets; in this case, the collection system itself. The SIOM program consists of a set of best management practices that should be applied over the entire lifecycle of the collection system and treatment plant. These practices include:

- Designing and constructing for O & M;
- Knowing what comprises the system (inventory and physical attributes);
- Knowing where the system is (maps and location);
- Knowing the condition of the system (assessment);
- Planning and scheduling work based on condition and performance;
- Repairing, replacing, and rehabilitating system components based on condition and Performance;
- Managing timely, relevant information to establish and prioritize appropriate SIOM activities;
- Training of personnel.

2.1 Collection System Management

Collection system management activities form the backbone for operation and effective maintenance activities. The goals of a management program should include:

- Protection of public health and prevention of unnecessary property damage;
- Minimization of infiltration, inflow and exhilaration, and maximum conveyance of wastewater to the wastewater treatment plant or final disposal point;
- Provision of prompt response to service interruptions;
- Efficient use of allocated funds;

- Identification of and remedy solutions to design, construction, and operational efficiencies;
- Performance of all activities in a safe manner to avoid injuries.

Without the proper procedures, management and training systems, O&M activities may lack organization and precision, resulting in a potential risk to human health and environmental contamination of surrounding water bodies, lands, dwellings, or groundwater. The following sections discuss the common elements of a robust collection system management program.

2.1.1 Organization Structure

Well-established organizational structure, which delineates responsibilities and authority for each position, is an important component of a SIOM program for a collection system. This information takes the form of an organizational chart or narrative description of roles and responsibilities, or both. The organizational chart should show the overall personnel structure, including operation and maintenance staff.

Additionally, up-to-date job descriptions should be available. Job descriptions should include the nature of the work performed, the minimum requirements for the position, the necessary special qualifications or certifications, examples of the type of work, lists of licenses required for the position, performance measures or promotion potential. Other items to note in regard to the organizational structure are the percent of staff positions currently vacant, on average, the length of time positions remain vacant, and the percent of collection system work that is contracted out.

The inclusion of job descriptions in the organizational structure ensures that all employees know their specific job responsibilities and have the proper credentials.

2.1.2 Training

The commitment of management to training is key to a successful program. It is important to recognize training as a budget expense item. USEPA guideline for the typical amount of funding for training is three to five percent of the gross budget for the collection system. However, in large collection systems or those undergoing extensive construction this percentage may be considerably lower and in systems with a high turnover, training costs may be higher due to orienting new employees. Other changes, such as incorporation of new technology, will have a short-term impact on training costs.

It is recommended that the Municipality of Birgunj should generally provide training in the following areas:

- Routine line maintenance (may be on-the-job training only)
- Safety during confined space entry (every system should also have a strict policy and permit program)
- Traffic control (where applicable)
- Record keeping
- Pump station O&M
- Electrical and instrumentation (may be a combination of form a land on-the-job training)
- Public relations and SSO/Emergency response
- Pump station operations and

- Pipe repair; bursting or cured in place pipe(CIPP); or closed circuit TV and trench/shoring (where these activities are not outsourced).This is very specialized and may not be possible to apply these techniques in Nepal at this time.

2.2 Collection System Operation

For better collection system operation, management of the Municipality of Birgunj should implement following tasks:

2.2.1 Monitoring

The management of the collection system may be responsible for fulfilling some water quality or other monitoring requirements. Responsibilities may include:

- Monitoring discharges into the collection system from industrial users;
- Monitoring to determine the effects of SSOs on receiving waters.

The Municipality of Birgunj should maintain written procedures to ensure that sampling is carried out in a safe, effective and consistent manner. The procedures should specify at a minimum the following:

- Sampling location(s)
- Sample volumes, preservatives and holding times
- Instructions for the operation of any automatic sampling and/or field monitoring (e.g., H or dissolved oxygen) equipment
- Sampling frequency
- Sampling and analytical methodologies
- Laboratory QA/QC

Records should be maintained of sampling events. These records should at a minimum include the following:

- Date, time and location of sampling
- Sample parameters
- Date delivered to the laboratory

2.2.2 Safety

The purpose of the program is to define the principles under which the work is to be accomplished to make the employees aware of safe working procedures and to establish and enforce specific regulations and procedures. The program should be in writing (e.g., procedures, policies and training courses) and training should be well documented.

The purpose of safety training is to stress the importance of safety to employees. Safety training can be accomplished through the use of manuals, meetings, posters and a safety suggestion program. One of the most common reasons for injury and fatalities in wastewater collection systems is the failure of victims to recognize hazards. Safety training cuts across all job descriptions and should emphasize the need to recognize and address hazardous situations. Safety programs should be in place for the following areas:

- Confined spaces;
- Chemical handling;
- Biological hazards in wastewater;
- Trenching and excavations;
- Electrical and mechanical safety;
- Pneumatic or hydraulic systems safety;
- Traffic control and worksite safety;
- Material Safety Data Sheets (MSDS).

The Municipality should have written procedures which address all of the above issues and should make available to employees. In addition to training, safety programs should incorporate procedures to enforce the program. For example, this could include periodic tests or "pop"quizzes to monitor performance and/or compliance and follow-up on safety related incidents.

The Municipality should maintain all of the safety equipment necessary for system staff to perform their daily activities and also undertake any emergency repairs.

Each field crew vehicle should have adequate health and safety supplies. If the reviewer has access to the municipal vehicles to municipal vehicle storage, he might choose to check actual vehicle stocks, not just supplies in storage.

2.2.3 Emergency Preparedness and Response

The Municipality should have a comprehensive plan in place for dealing with both routine and catastrophic emergencies. Routine emergencies include situations such as overflowing manholes, line breaks, localized electrical failure, and power outages at the pump station at the wastewater treatment plant. Catastrophic emergencies include floods, earthquakes, other natural events or widespread electrical failure. Ideally, this plan is written, reviewed, and adjusted as needed at periodic intervals.

The plan should utilize the most current information on the collection system. For larger systems, a structured analysis or risk assessment should be made of the collection system, treatment plant and the community. The risk assessment should identify areas where the collection system is vulnerable to failure and determine the effect and relative severity to collection systems operations, equipment and public safety and health of such a failure. The risk assessment should concentrate on such factors as topography, weather, sewer system size and other site-specific factors which reflect the unique characteristics of the system. Once the areas of vulnerability are known, the collection system owner or operator should have appropriate plans in place to ensure collection system operations continue for the duration of the emergency.

The Municipality should track emergency situations to be come better prepared for future emergencies and to assist with reporting and maintaining compliance with emergency-related requirements. Typical components of an emergency program may include:

- General information regarding emergencies, such as telephone numbers of collection system personnel, fire department and ambulance;
- Vulnerability analysis that identifies the various types of emergencies that could occur, such as natural disasters, power outages or equipment failures;
- Emergency response procedures;
- Methods to reduce risk of emergencies;

- Responsibilities of staff and management;
- Continuous training.

Procedures for emergency response plans should be understood and practiced by all personnel in order to ensure safety of the public and the collection system personnel responding. It is important to keep detailed records of all past emergencies in order to constantly improve response training, as well as the method and timing of future responses. The ability to deal with emergencies depends on the knowledge and skill of the responding crews, in addition to availability of equipment. The crew should be able to rapidly diagnose problems in the field under stress and select the right equipment needed to correct the problem. If resources are limited, consideration should be given to contracting other departments or private contractors to respond to emergency, situations.

2.2.4 Disposal / Lift Stations

Proper operation, maintenance and repair of pumping stations typically require special electrical, hydraulic and mechanical knowledge. Pumping station failure may damage equipment, the environment or endanger public health.

Part of the O&M manual will contain procedures in writing for the following:

- Are pumps operated manually or automatically ? If manually, how frequently ?
- Are wet well operating levels set to limit pump starts and stops ?
- Is there a procedure for manipulating pump operations (manually or automatically) during wet weather to increase in-line storage of wet weather flows ?
- Is flow monitoring provided ? How the collected data is used ?
- Does the pump station have capacity-related overflows ? Maintenance related overflows ? Is overflow monitoring provided ?
- Is there a history of power outages ? Is there a source of emergency power ? If the emergency power source is a generator is it regularly exercised under load ?

2.3 Equipment and Collection System Maintenance

The Municipality should have a well-planned, systematic and comprehensive maintenance program. The goals of a maintenance program should include:

- Prevention of overflows;
- Maximization of service and system reliability at minimum cost;
- Assurance of infrastructure sustainability (i.e., ensure all components reach their service life).

There should then be procedures which describe the maintenance approach for various systems. In addition, there should be detailed instructions for the maintenance and repair of individual facilities. These instructions should provide a level of detail such that any qualified collection system personnel or repair technician could perform there pair or maintenance activity.

Maintenance may be planned or unplanned. There are essentially two types of planned maintenance; predictive and preventive. Predictive maintenance is a method that tries to look for early warning signs of equipment failure such that emergency maintenance is avoided. Preventive maintenance consists of scheduled maintenance activities performed on a regular basis. There are two types of unplanned maintenance; corrective and emergency. Corrective

maintenance consists of scheduled repairs to problems identified under planned or predictive maintenance. Emergency maintenance are activities (typically repairs) performed in response to a serious equipment or line failure where action must be taken immediately. The goal of the Municipality should be to reduce corrective and emergency maintenance through the use of planned and predictive maintenance. The goals of the maintenance program are:

- Identify Sanitary Sewer Overflows (SSOs) caused by inadequate maintenance
- Determine maintenance trends (i.e., frequent emergency maintenance performed as opposed to predictive maintenance);
- Identify sustainability issues (i.e., inadequate maintenance to allow system components to reach service life and/or many components nearing or at service life).

2.3.1 Maintenance Budgeting

The cost of a maintenance program is a significant part of the annual operating budget. The Municipality should track all maintenance costs incurred throughout the year, both by internal staff and contractors to ensure that the budget is based on representative costs from past years. Budgets should be developed from past cost records which usually are categorized according to preventive maintenance, corrective maintenance, and projected and actual major repair requirements. Annual costs should be compared to the budget periodically to control maintenance expenditures.

The Municipality should evaluate the maintenance budget keeping in mind the system's characteristics, such as age. Costs for emergency repairs should be a relatively small percentage of the budget; five to ten percent would not be considered excessive as per current practices in the World.

3. OPERATION & MAINTENANCE OF SYSTEM

3.1 Introduction

A systematic operation, maintenance, and rehabilitation program is an essential element in the management of a wastewater collection system. Effective inspection, cleaning, and rehabilitation are key processes for optimizing the proper functioning of a collection system.

No storm system will continue to operate satisfactorily if maintenance in particular drain cleaning is routinely neglected. There is no point in providing a new drain scheme, if analysis shows that flooding is caused by a failure to maintain an existing drain of the same or similar capacity to that which is proposed. Where problems arise from poor operation and maintenance, the focus should be on improving O&M unless it can clearly be shown that providing new facilities will contribute to solving those O&M problems. Major points to be considered are preventive maintenance and maintenance/rehabilitation. Maintenance also helps to protect the capital investment and ensures an effective and economical expenditure in operating and maintenance of a sewerage facility. Besides, it is essential to build up cordial relations with the public, whose support is essential for success of any facility

3.2 Planned Maintenance

A planned maintenance program is a systematic approach to perform maintenance activities so that equipment failure is avoided. Planned maintenance is composed of predictive and preventive maintenance. In the end, a good planned maintenance program should reduce material and capital repair and replacement costs, improve personnel utilization and morale, reduce Sanitary Sewer Overflows (SSOs) and sustain public confidence.

Examples of predictive maintenance includes scheduled cleaning of sewers, monitoring equipment for early warning signs of impending failure, such as excess vibration, heat, dirty oil, and leakage. Assessment and inspection activities can be classified as predictive maintenance. Predictive maintenance also takes into account this to recall information about the system as all systems will deteriorate overtime. A predictive maintenance program strives to identify potential problem are as and uncover trends that could affect equipment performance. Predictive maintenance offers a nearly warning. It allows collection system personnel to detect early signs of increasing rates of wear and therefore failure and thus shift a "corrective" task into a "planned" task.

The basis of a good predictive maintenance program is record keeping. Only with accurate record keeping baseline conditions can be established, problem areas identified and a proactive approach taken to repairs and replacement.

Effective preventive maintenance minimizes system costs and environmental impacts by reducing breakdowns and thus the need for corrective or emergency maintenance, improves reliability by minimizing the time equipment is out of service, increases the useful life of equipment thus avoiding costly premature replacement and avoids potential noncompliance situations. An effective preventive maintenance program includes:

- Trained personnel;
- Scheduling based on system specific knowledge;
- Detailed instructions related to the maintenance of various pieces of equipment;
- A system for record keeping;
- System knowledge in the form of maps, historical knowledge and records.

The basis of the schedule for mechanical equipment maintenance (i.e., pump station components) should be the manufacturers' recommended activities and frequencies. This schedule may then be augmented by the knowledge and experience of collection system personnel to reflect the site- specific requirements. In many systems, a relatively small percentage of the pipe generates most of the problems. Efficient use of inspection data allows the management authority to implement a schedule in the most constructive manner.

Typically, there should be a maintenance record for each piece of equipment within the collection system. These records should contain maintenance recommendations, schedule and instructions on conducting the specific maintenance activity. The records should include documentation regarding any maintenance activities conducted to date and other observations related to that piece of equipment or system. Maintenance records should be kept where maintenance personnel have easy access to them. It is necessary to examine the full series of periodic work orders (i.e. weekly, monthly, semi-annually and annually) for as election of system components (e.g., a few pump stations, several line segments).

3.3 Unplanned Maintenance

Unplanned maintenance is that which takes place in response to equipment breakdowns or emergencies. Unplanned maintenance may be:

i. Corrective maintenance
ii. Emergency maintenance.

Corrective maintenance could occur as a result of preventive or predictive maintenance activities which identified a problem situation. A work order should be issued so that the request for corrective maintenance is directed to the proper personnel.

Corrective maintenance takes resources away from predictive and preventive maintenance. When corrective maintenance becomes a predominant activity, personnel may not be able to perform planned maintenance, thus leading to more corrective maintenance and emergency situations.

Emergency maintenance occurs when a piece of equipment or system fails, creating a threat to public health, the environment or associated equipment. This type of maintenance involves repairs on short notice of malfunctioning equipment or sewers.

Types of Portable Emergency Equipment

- By-pass pumps
- Portable generator
- Air compressor (trailer-mounted)
- Sewer rodder and/or flushing machine
- Portable lights and hand tools
- Chemical spray units (for insects and rodent control)
- Truck (1-ton) and trailers
- Vacuum truck
- Repair equipment for excavation (backhoe, shoring equipment, concrete mixers, traffic control equipment, etc.)
- Confined space entry gear

Emergency crews should be geared to a 24-hour-a-day, year-round operation. Most large systems have staffed 24-hour crews; many small systems have an "on-call" system. The owner

or operator should be able to produce written procedures which spell out the type of action to be taken in a particular type of emergency and the equipment and personnel requirements necessary to carry out the action. The crews should have copies of these procedures and be familiar with them. Equipment must be located in an easily accessible area and be ready to move in a short period of time. Vehicles and equipment must be ready to perform under extreme climatic conditions if necessary.

Disposal/Lift stations should be subjected to inspection and preventive maintenance on a regular schedule. The frequency of inspection may vary from once a month to once a week as per the condition of disposal/lift stations. The basic inspection should include verification that alarm systems are operating properly, wet well levels are properly set, all indicator lights and voltage readings are within acceptable limits, suction and discharge pressures are within normal limits, that the pumps are running without excessive heat or vibration and have the required amount of lubrication and that the emergency generator is ready if needed. Less frequent inspections may include such items as vibration analysis and internal inspection of pump components.

Observations and tasks performed should be recorded in a logbook or on a checklist at the disposal/lift stations. It is important to note that how this data returns to the central maintenance data management system. At the time of the inspection, collection system personnel may perform minor repairs if necessary. If non-emergency repairs are required that are beyond the staff's training, it will probably be necessary to prepare a work order which routes a request though the proper channel is to initiate the repair action. During the review, Birgunj Municipality should check a random number of work orders to see how they move through the system. In disposal/lift stations, for critical equipment (pumps, drives, power equipment, and control equipment), there should not be much backlog.

Overall, the pumping station should be clean, in good structural condition and exhibit minimal odor. The settings of the pumps (i.e., which are operating, which are on stand-by which are not operating) should be properly documented. The operating pumps should be observed for noise, heat, and excessive vibration. The settings in the wet well should be noted (as indicated on the controls, as direct observation of the maintenance staff in the wet well is not recommended) and the presence of any flashing alarm lights. The operating staff should check the logbook and/or checklist kept at the disposal/lift station to ensure that records are current and all maintenance activities have been performed. Below is a listing o items that indicate in adequate maintenance:

- Overall poor house keeping and cleanliness;
- Excessive grease accumulation in wet well;
- Excessive corrosion on railings, ladders and other metal components;
- Sagging, worn, improperly sized or inadequate belts;
- Excessive equipment out of service for repair or any equipment for which repair has not been ordered (i.e., a work order issued);
- Pumps running with excessive heat, vibration or noise;
- Peeling paint and/or dirty equipment (the care given to equipment's outer surfaces often, but not always, mirrors internal condition);
- Check valves not closing when pumps shut off;
- In operative instrumentation, alarms and recording equipment;
- "Temporary" repairs using in appropriate materials;
- Leakage from pumps, piping or valves;
- Inadequate lighting or ineffective/in operative ventilation equipment.

3.4 Sewer System Rehabilitation

The Municipality of Birgunj should have a sewer rehabilitation program. The objective of sewer rehabilitation is to maintain the overall viability of a collection system. This is done in three ways: (1) ensuring its structural integrity; (2) limiting the loss of conveyance and waste water treatment capacity due to excessive Infiltrations/Inflows; and (3) limiting the potential for groundwater contamination by controlling exhilaration from the pipe network. The rehabilitation program should build on information obtained as a result of all forms of maintenance and observations made as part of the capacity evaluation and asset inventory to assure the continued ability of the system to provide sales and service at the least cost. The reviewer should try to gain a sense of how rehabilitation is prioritized. Priorities may be stated in the written program or may be determined through interviews with system personnel.

4. SYSTEM MAINTENANCE REQUIREMENTS

A Preventive maintenance program is important to ensure that the system continues to operate smoothly and quality service continues to be provided to the city's customers. Preventative maintenance may include visual inspections by maintenance personnel, closed circuit television (CCTV) inspections and regular cleanings.

4.1 Cleaning

Stoppages in gravity sewers usually are caused either by structural defects or by an accumulation of material in the pipe. Accumulated material can include fats, oil, grease, sediment or other materials such as solid waste. In correct lateral sewer connections into the main/trunk sewer may catch debris which then causes a further build up of solids that eventually block the sewer.

Another problem is low flow velocity. If the flow is less than approximately 1.0 to 1.4 feet per second (0.3-0.43m/s), grit and solids can accumulate leading to a potential blockage. The recommended minimum velocity is 2.0 feet per second (0.6m/s) which is the 'self-cleansing' velocity.

Repair or elimination of any defects that contribute to a build up of material in the pipe should be evaluated as part of a rehabilitation program since the defects will always be a maintenance problem.

Stoppages in gravity sewers are usually caused by:

i) Structural defect,
ii) Poor design,
iii) Poor construction,
iv) Dumping of solid waste and
v) Accumulation of material in the pipe (especially grease) or root intrusion.

There are three major methods of sewer cleaning: hydraulic, mechanical and chemical. Hydraulic cleaning (also referred to as flushing) refers to any application of water to clean the pipe. Mechanical cleaning uses physical devices to scrape, cut or pull material from the sewer.

Mechanical and hydraulic cleaning of sewers is a cost-effective method of removing material that interferes with the proper operation of the sewer. The objective is to remove all material clinging to the interior surface of the pipe so that the sewer pipe can carry full pipe flow without any restrictions that might result in blockages due to reduced pipe capacity.

Cleaning is either scheduled or unscheduled; scheduled cleaning is proactive in that cleaning is done on a preventive basis to remove material prior to a stoppage occurring. Preventive cleaning activities can be supplemented by additional cleaning on an as-needed basis in cases where predictive information such as previous history, inspection data, pipe age and material, slope or other information indicates a need for more frequent cleaning.

Scheduled cleaning is usually coordinated with planned CCTV since televising requires a clean pipe for access and visually provides a much better picture of conditions.

However, unless the cleaning schedule is adjusted to take into account the actual conditions in various parts of the collection system pipelines, routine cleaning can result in over or under maintenance of the system. In most collection systems, some sections do not require frequent

cleaning while other sections may require cleaning on a more frequent basis, such as monthly, if they are susceptible to blockages. Information from the inspection program should be used to help identify chronic problem areas in the gravity sewer system and related structures in the wastewater collection system, quantify defects and problem areas and develop a preventive maintenance sewer cleaning program based on actual conditions in a particular wastewater collection system.

Unscheduled cleaning is usually the result of a reported stoppage and is therefore reactive. When reactive maintenance is the primary form of maintenance (that is, waiting until a failure occurs before performing maintenance), it will always result in poor system performance, especially as the system ages. Normally, this type of cleaning is done on an emergency basis to clear a stoppage, restore pipe capacity to full flow and relieve a surcharging situation in the sewer that has caused a back up into homes and/or an over flow.

Specifically, if there is a problem with residents throwing food and garbage into the sewer systems. This often results in frequent blockages and the production of excessive hydrogen sulphide gas produced in the main sewer lines. In order to solve this problem regular preventative cleaning should be implemented in the main sewer lines twice per year in the dry season in March–June and October–February. It is also proposed that CCTV inspections should be implemented after cleaning has been implemented to check if the action has been completed successfully.

Various hydraulic and mechanical methods are available for main line sewer cleaning. Hydraulic cleaning methods include equipment that uses water and water velocity to clean the invert and walls of the sewer pipe. Mechanical cleaning methods use equipment to physically remove the material from the walls and invert of the sewer pipe. For more details on sewer cleaning see Appendix A.

The backbone of an effective sewer cleaning program is accurate record keeping. Accurate record keeping provides the management within formation on the areas of the collection system susceptible to stoppages such that all portions of the system can be on an appropriate schedule. The reviewer should examine the records for legibility and completeness. They should then review the database to determine if entry of the field notes is current and accurate. Sewers vary widely in their need for preventive cleaning.

4.2 Inspection and Examination for Sewer

4.2.1 Importance of Inspections and Examinations

Sewer collections systems are intended to be are liable method of conveying sewage from individual dischargers to sewerage treatment plants. Inspection and examination are the techniques used together information to develop operation and maintenance programs to ensure that new and existing collection systems serve their intended purposes on a continuing basis. Inspection and testing are necessary to do the following:

- Identify existing or potential problem areas in the collection system;
- Evaluate the seriousness of detected problems, locate the position of problems and
- Provide clear, concise, and meaningful reports to supervisors regarding problems.

Two major purposes of inspection and examination are to prevent leaks from developing in the sewers and to identify existing leaks so they can be corrected.

A designer's mistake and/or the failure in construction are directly responsible for many of the sewer failures. Due to age, deterioration of the material of the sewer by attack of hydrogen

sulphide or other chemicals, settlement of foundation sand leaking joints may result in the structural failure of the sewer. It takes a very long time from the onset of the first initial defect to the collapse of the sewer. A crack or a leaking joint will allow subsoil water and soil to enter the sewer causing cavities around it leading to slow settlement of foundation and the eventual collapse of the sewer. Very often soil with water is carried away below the bedding along the length of the sewer. The type of break often gives a clue to the cause. A shear failure due to faulty foundation or movement of earth is a clean vertical break in the pipe or barrel. Excessive loading, either internally or externally, causes horizontal breaks. Breaks caused by internal pressure gives cracks in the sewer while external overload causes the top of the pipe to crush. Regular inspection of the sewer can pinpoint the sewer that needs to be attended before there is a complete failure or collapse. For preventing the above serious instances of damages to the sewer system, the maintenance engineer should establish adequate inspection and examination programs.

4.2.2 Guidelines for Inspections and Examinations

Documents and data that can give information on the status of sewer facilities are necessary for operation and maintenance of the facilities. However, enormous time and costs are necessary for examining and inspecting the overall information on sewer facilities that extend over a wide area. It is recommended that a preliminary inspection be implemented to acquire with comparative ease documents and data that can be used to decide the facilities to be examined/inspected and from this information, it is possible to prioritize which facilities need to be examined in more detail for effective data acquisition.

The procedure is to first acquire the basic information through preliminary inspection for the examination and inspection of the facilities in this section. Preventive maintenance is required for all components of the project, including sewer network and appurtenances and treatment plants. It is necessary to carry out preventive or routine maintenance to avoid situations like clogged sewer line, overflowing manholes, structural failure of system or failure of function of STP. The preventive maintenance is always more economical and ensures reliability in operation of the assets created and emergency repairs would become very rare if preventive maintenance is carried out regularly. Sewer network requires regular maintenance in order to maintain proper hydraulic conditions. In Asian condition, wastewater from households is often not only the source causing sewerage flows, there is a tendency to connect roof water drain to the connection manholes which contribute to surcharge condition of sewers during rainfalls. The Operation and Maintenance (O&M) for drainage is similar to the O&M presented in the previous section 5 for sewerage as far as equipments and personnel are concerned. The main difference are the type and length of drains, the presence of natural channel and the more specific operations procedures related to preventive maintenance as the frequency of inspection and cleaning will be more frequent especially at the start of the rainy season and on the importance of the drain, main diversion channels/pipes and natural drains, secondary and tertiary drains.

4.3 Preventive Maintenance of System

General

A preventive maintenance program is important to ensure that the system continues to operate smoothly and quality service continues to be provided to the Municipality's customers. Preventive maintenance as the name suggests are carried out to prevent breakdown of sewer systems if it is done on regular basis and in a systematic manner. It prevents clogging of service lines, overflowing of manholes, backflow of sewage in to a house. It also prevents structural failure of sewer system. The need of emergency maintenance may not arise, if carried out in a planned manner. The success preventive maintenance depends upon three elements.

- Manpower
- Equipments
- Schedule of maintenance

The entire sewerage system or service lines are divided into sections and each section or service line is put under a gang which normally consists of a supervisor and skilled sewer men. The area for one gang will depend upon size of sewer, its depth and number of repairs to be made.

Drainage Cleaning

Preliminary inspection ⇨ section and examination

⇩

Judge from the inspection results

⇩

Decide the necessary measures (repairs, modifications)

The detailed method for conducting a preliminary inspection is described in the following section.

4.3.1 Preliminary Inspection

During the preliminary inspection of the sewerage system, subsidence, collapse, blockages and overflows on the roads on which sewers are laid, should be confirmed. Deformation or damage to facilities and deposits of sand and silt are to be confirmed during observation from the manhole. If damage or possibility of damage to the facility or if any of the abnormalities listed

below are confirmed during the preliminary inspection, the facility manager should examine and inspect the relevant locations for the following:

- Corrosion, wear, damage or cracks in the facilities;
- Water infiltration;
- Corrosion of steps, wear of covers, deformation of manhole, buried manhole;
- Abnormal odours;
- Clogging and overflowing.

The suggested period of preliminary inspection should be carried out as shown in Table 2, Table 3 and Table 4.

Table 2: Preliminary Inspection during Defect Liability Period (DLP)

Category Inspection Stages				Any other Infrastructure
Initial/first inspection	During the first 3 months of start of DLP (to expose any hidden construction defects)			
Final inspection	During the last 3 months of DLP			

Table 3: Preliminary inspection for Manholes & Sewers

Category Roads & Traffic Conditions	Manhole	Sewer
Roads subjected to heavy and mixed traffic	Once a year	Once a year
Roads 2-5m wide (6-15 feet) subject to mixed traffic	Once a year	Once a year
Roads and lanes less than 2m wide	Once a year	Once a year

Table 4: Preliminary inspection period for other facilities

Category	Inverted siphon	Force main and their appurtenance
Inspection period	Once a year	Once a year

Note:

1. Remedial measures should be implemented immediately upon finding Defects / distress / disfunction in the components of the sewerage system.

2. The above frequency of inspection should a maximum frequency and will depend on the Condition of the pipes and manhole condition from the initial inspection.

4.3.2 Type of Inspections and Examinations

In order to assess the condition of sewers inspections and examinations are necessary. There are two basic types of inspections and examinations:

- Direct
- Indirect

4.3.3 Direct Inspection and Examination

Direct inspection translates to a person walking through a sewer and physically inspecting the condition visually, although this should not be avoided once the sewer has been put into service. Even for new sewers, the inside diameter shall be more than 1.8m. All safety precautions needed for working in confined spaces shall be taken. Hitting at the side wall with a hammer or other devise shall be totally prohibited. The only purpose of a visual inspection it will be to get a visual idea of whether the pipe joints are assembled properly and if there are any visible cracks.

Special Equipment

The maintenance of sewerage system requires a number of special equipments and devices notable among them are sewer jetting machines and suction units.

Sewer Jetting Machine Sewer jetting machines are high velocity sewer cleaners. The make use of high velocity water jets to remove and dislodge obstructions, soluble grease, grit and other materials from sewerage system. It combines the functions of a Roding machine and gully emptier machine. It consists of high pressure hydraulic pump generally capable of delivering water at variable pressure up to about 80 kg/cm^2 as per standards through a flexible hose to a sewer cleaning zone. The high pressure water coming out of the holes with a very high velocity breaks up and dislodges the obstructions and flushes the materials down the sewer. The entire equipment is usually mounted on truck chassis. The truck shall consist of one tank for fresh water only.

Suction cum Jetting Machine Suction units creates vacuum for siphoning of mud, slurry, grit and other materials from sewerage system. The vacuum created is such as to siphon the materials from the deep manholes. The unit will be vehicle mounted. To achieve economy in operation of sewer cleaning, it is normal to have a combined unit of jetting and suction machine to perform both the function.

Suction Machine for Cleaning of Sewer Lines/Septic Tanks Septic tanks are constructed for onsite disposal and treatment of excreta. A septic tank is a combined sedimentation and digestion tank where the sewage is held for one or two days. During this period, the suspended solids settle down to the bottom. Further anaerobic digestion of settled solids and liquid takes place resulting in a reasonable reduction in the volume of sludge and biodegradable organic matter. The effluent of septic tanks requires secondary treatment. The dislodging of septic tanks by manual means is not advisable. Therefore best option for dislodging of septic tanks is by vehicle mounted suction machines. Normally individual's households size their septic tanks so that dislodging is required after three years.

Therefore for effective maintenance of sewer lines and regular cleaning of septic tanks, sewer jetting machine, suction and jetting machine and suction machine for septic tanks cleaning are essential equipments. The main purpose is identification of requirement of equipments after assessing the use of existing facility of sewer cleaning equipments maintained by concerned Municipal Corporation.

4.3.4 Indirect Inspection and Examination

These can be classified by a variety of methods as in Table 5.

Table 5: Classification of inspection

	Technology	Sewer type			Pipe material	Pipe diameter mm	Defect detected			
		Gravity	Forcemain	Lateral			Internal	Pipe wall	Leakage	Pipe support
Camera	Digital cameras	•			Any	150-1500	•	•	•	
	Zoom cameras	•			Any	>150	•	•	•	
	Push-camera			•	Any	300	•	•	•	
Acoustic	In-line leak detectors	•	•		Any	≥100			•	
	Acoustic monitoring Systems		•		PCCP	≥450		•		
	Sonar/ultrasonic	•	•		Any	≥50	•	•		
Electrical/ Electromagnetic	Electrical leak location	•	•	•	Non-ferous	≥75			•	
	Remote field eddy current	•	•	•	Ferrous, PCCP	≥50		•	•	
	Magnetic flux leakage	•	•	•	Ferrous	50-1400		•		
Laser	Laser profiling	•	•		Any	100-4000	•	•		
	Gamma-gamma	•	•	•	Concrete	Not yet defined				•
	logging									
	Ground penetrating radar	•	•	•	Any	Not yet defined			•	•
	Infrared thermograph	•	•	•	Any	Not yet defined			•	•
	Micro-deflection	•			Brick	Not yet defined		•		•
	Impactecho /SASW	•			Brick/ Concrete	>1800		•		

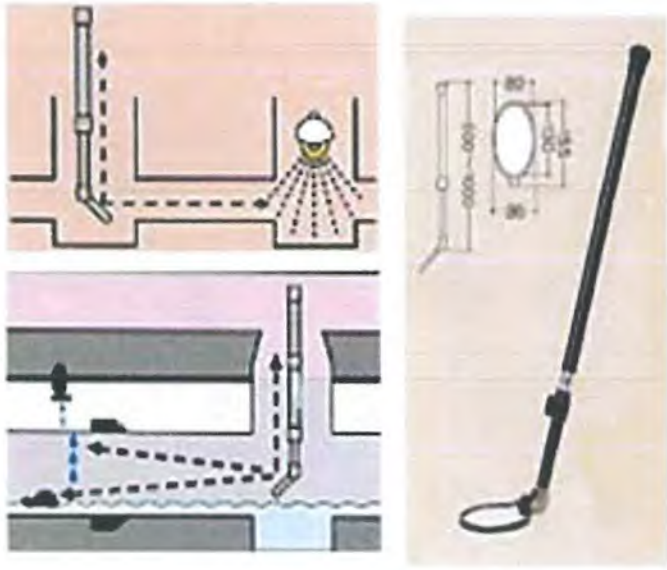
Source: EPA/600/R-09/049 May 2009

Even though there are so many technologies available as shown in Table 5 above, the technology to be chosen will depend on the affordability by the user departments. A simpler and more applicable technology compilation is as shown in Table 6 below.

Table 6: Sewer system inspection technologies considered applicable to Nepalese conditions

No.	Technology	Applicability		
		Sewer Size	Sewer Material	Sewer Condition
1	Light and Mirror	Up to 300 mm	Any	Empty
2	Closed Circuit	Any size	Any	Empty
3	Sonar Systems	Any size	Any	Fully flowing

The light and mirror is the oldest of known technologies. Two successive manholes are opened and vented sufficiently for about an hour. Thereafter along hand-held mirror secured at 45 degrees to the handle is lowered into the bottom of the manhole and a torchlight is focused on the mirror from above so that the light beam is deflected by 90 degrees to travel horizontally through the sewer pipe and the light is seen in the opposite manhole. This is easiest at twilight hours. This method indicates whether the bore of the pipe is choked or clear.



Source: http://www.sankyotrading.co.jp

Figure 2: Mirror Test and Mirror with rod blot

The closed circuit camera (CCTV) is propelled through the sewer by a remote controlled wired power supply from a van and travels through the sewer and relays the picture of the inside to a TV in the van. The sonar system is similar. A robot is sent through the sewer and item its high frequency sound waves which impinge on the pipe surface sand returns to the emitter as a reflection. By knowing the material of construction of the sewer pipe walls, this can be programmed to verify the structural condition of the wall of the sewers.

Indirect inspection is carried out by sending a camera through the sewer for taking photographs or a closed circuit television equipment (CCTV) to send pictures which can be seen on a TV Screen or recorded as video. The CCTV inspection can be used for sewer lines as small as 100 mm. Above 900 mm diameter there are limitations due to lighting problems and camera line angles.

Continual advances are being made in the range of TV cameras and also in quality. The type of camera selected should be robust for use in sewers and be able to give good quality pictures.

Traction of the cameras is by pulling winches, by pushing or self-traction. The former two are not used much at present. However, self-traction is suitable for use in sewers above 225 mm diameter. Other constraints in the use of self-traction are the weight of the trolley and electricity requirements. Heavy silting of sewers precludes the use of self-traction. The cameras are attached to trolleys or mounted on pair of skids or single flat trays. Inspection of the sewer by CCTV is limited to the opportiononly. The objects under scrutiny are parallel to the camera and viewing is at 40 to 50 degrees. With radial scanning head, inspection normal to the sewer wall is possible. A typical arrangement of CCTV Equipment is as shown in Figure 3.

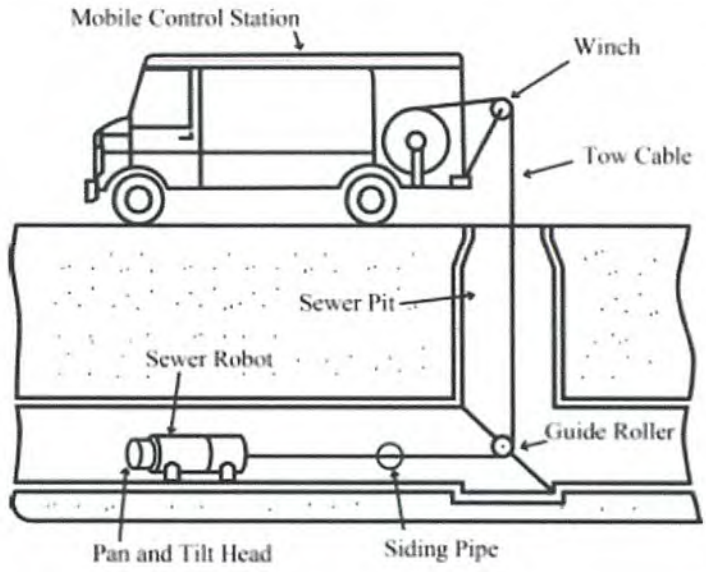


Figure 3: Typical CCTV equipment in action

A classical problem encountered in sewers laid through light forest or heavy garden areas is the roots of trees piercing through the joint sand growing there. These become like a plug and choke the sewer. This is shown in Figure 4. (Tree roots growing into joints of stone ware sewers when these are laid near light forests and heavy gardens. At right is the photo of the bunch of roots taken by a CCTV camera).

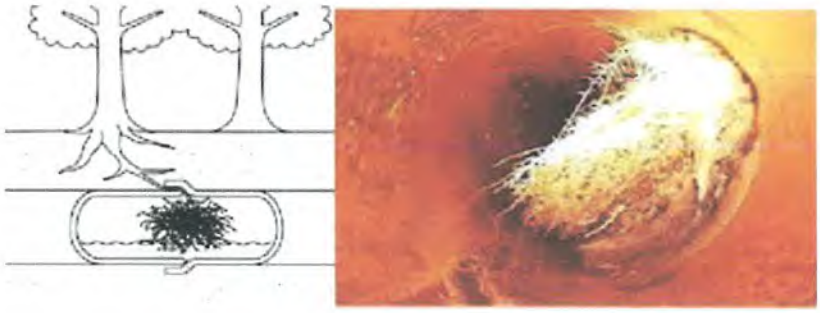


Figure 4: Tree roots and sewers

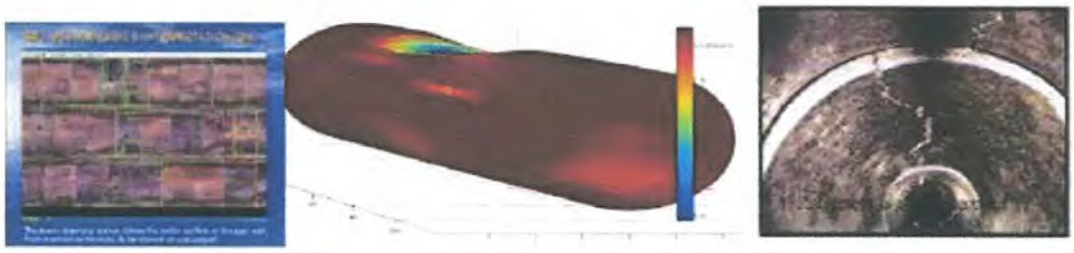


Figure 5: Photos showing structural damage and longitudinal cracked condition of the sewer

Similarly, the structural condition of old sewers like brick arch sewers and concrete pipes can be ascertained by sonar surveys which can provide the frontal image of the wall on a 360- degree vertical spiral around the horizontal axis. The seimages can be analyzed carefully. The system can also provide information on the deflection and side wall breakages of the sewer as in Figure 5. (The side wall condition shown as photographs, the structural damage to the crown of the sewer and longitudinal cracked condition of the sewer from the survey).

5. SEWER INSPECTION AND EXAMINATION

If an abnormality is detected during preliminary inspection or through notification from outside, the maintenance engineer should judge the urgency and the content of the abnormality and then make a proper inspection and study.

5.1 Visual Examination

Visual examination is an inspection through images or by sight to detect an abnormality. Visual examination includes direct visual inspection, and indirect visual in section using pole- mounted inspection camera and closed-circuit TV equipment (CCTV).

5.1.1 Manhole Visual Inspection

The visual inspection of manhole is performed by visually checking the manhole cover and its environment and observing the internal parts of the manhole. To inspect the internal parts of the manhole, the inspector should enter the manhole and check the items listed below. However, refer to Appendix B for more details of the inspection items.

- Status of internal surface of manhole
- Status of sewer on the upstream and downstream sides viewed from the man hole
- Status of the step iron steps

5.1.2 Status of Groundwater Infiltration

To inspect the internal parts of the sewer from the manhole, either a mirror or a strong light should be used for observation or a CCTV camera for inspecting conduits should be used.

5.1.3 Features of Manhole Visual Inspection

Inspection accuracy is high because the inspector actually observes and measures the abnormality personally.

Economical compared to inspection using a TV camera. The inspected results become very useful O&M data. Procedure for manhole visual inspection is shown in Figure 6.

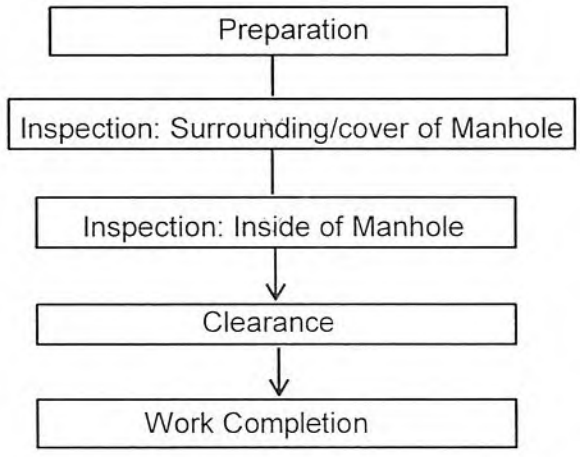


Figure 6: Procedure for manhole visual inspection

Before entering any manhole, adequate safety measures should be taken in accordance with sub-section 6.9.

5.2 Inspection Using a Pole-mounted TV Camera

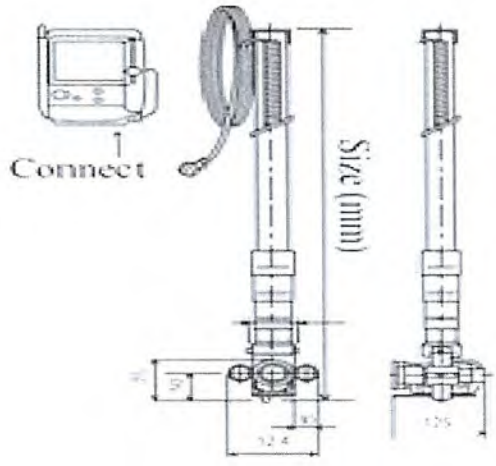
As shown in Figure 7, a pole-mounted TV camera consists of an extendable operating rod at, the front of which a camera and light are fitted. This arrangement is inserted in the manhole from the ground and the inspector on the ground observes a monitor and inspects the internal parts of the pipe through the camera. This check may also be used for pre-inspections. The method of inspection is shown in Figure 8. The features of direct visual inspection compared with the inspection by a TV camera are shown below.

Advantages

The inspection is easy and observations can be made in a short period. Moreover, the data of inspection can be recorded as images. Since the inspector works above ground, there is no chance of oxygen deficiency or accidents by falling, therefore the work is much safer.

Disadvantages

The scope of inspection is limited to the area around the mouth of the pipe. Offset in the horizontal direction or fine cracks cannot be detected. The condition of the side surfaces in the sewer pipe cannot be viewed.



Source: JASCOMA, 2007

Figure 7 : Pole-mounted inspection camera

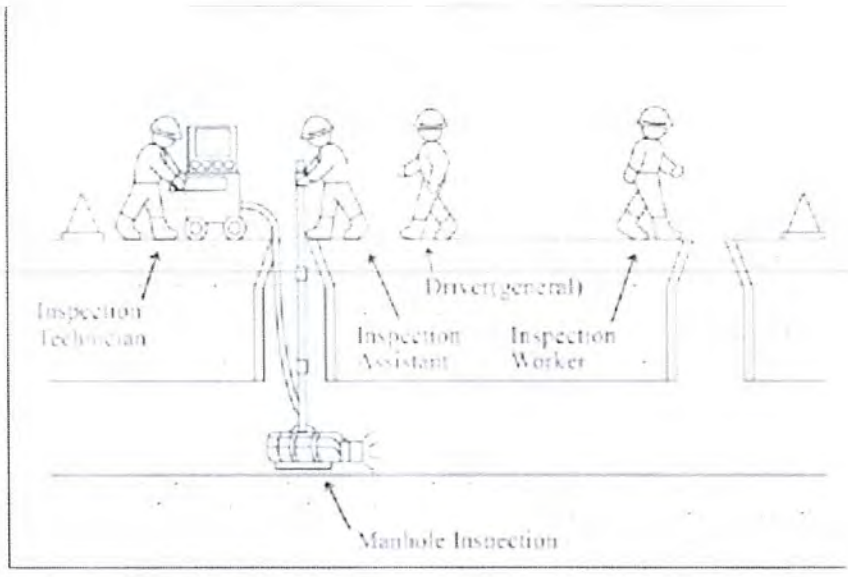


Figure 8: Illustration of pole-mounted TV camera inspection

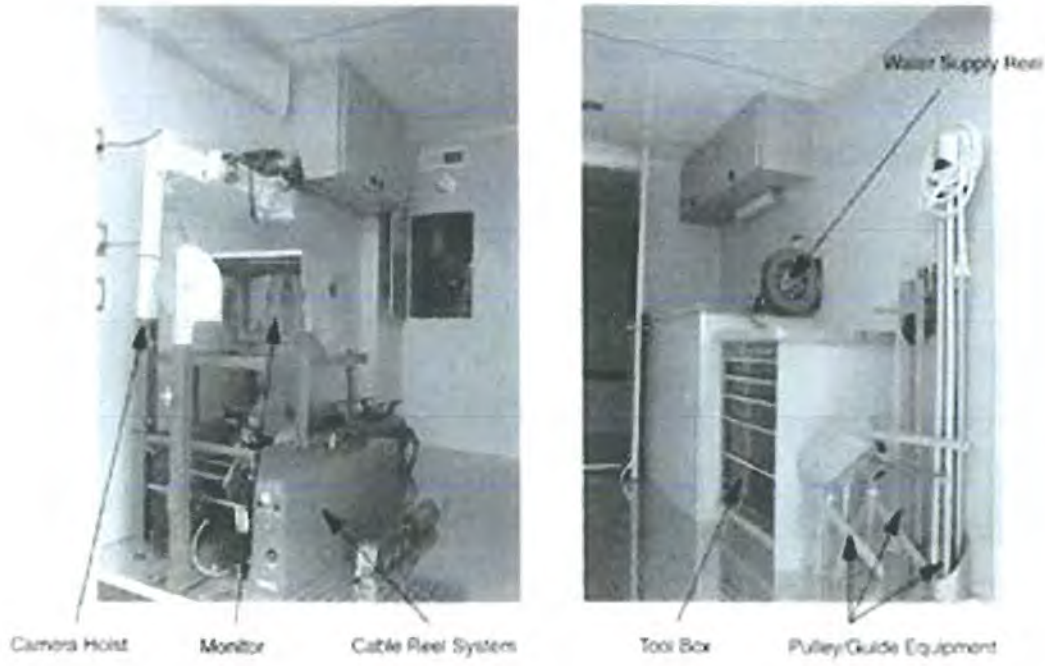
5.2.1 Inspection Using Closed-Circuit Television (CCTV)

Pipes that can be inspected by CCTV have inside diameters ranging from 150mm to 900mm, but large diameter pipes may also be inspected by CCTV.

Types of TV Camera

TV camera may be the travelling type or the towed type. Either the direct method (taking panoramic shots of the overall scene) or the side view method of taking local shots of only abnormal locations may be used. See Figure 9 for CCTV camera and vehicle on which it is loaded and Figure 10 shows an illustration of the TV inspection work.

Step Van



Source: EPA, 2003

Figure 9: Step Van CCTV system

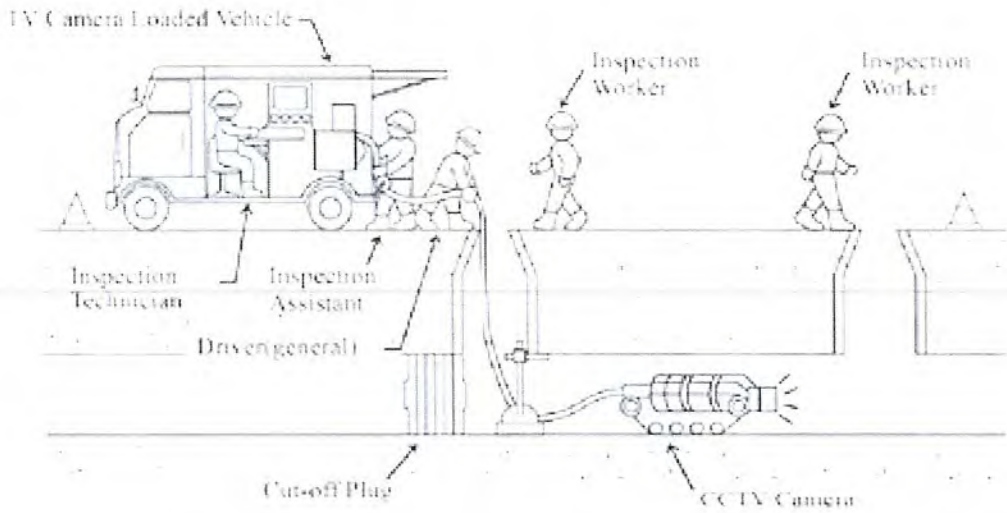


Figure 10: Illustration of CCTV camera inspection

Features of TV Camera Inspection

By merely opening a manhole at one location, inspection using the travelling TV camera is enabled. Continuous inspection up to a maximum distance of 100 to 200m (cable length) is possible.

Connections of the lateral sewer and main sewer and defective locations should be photographed by the side view method. TV camera inspection work procedure is shown in Figure 11.

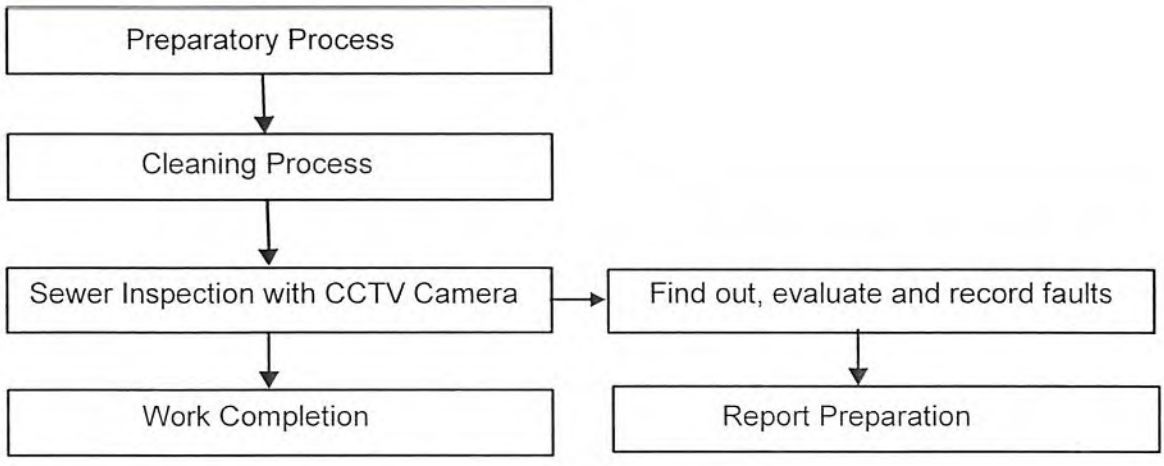
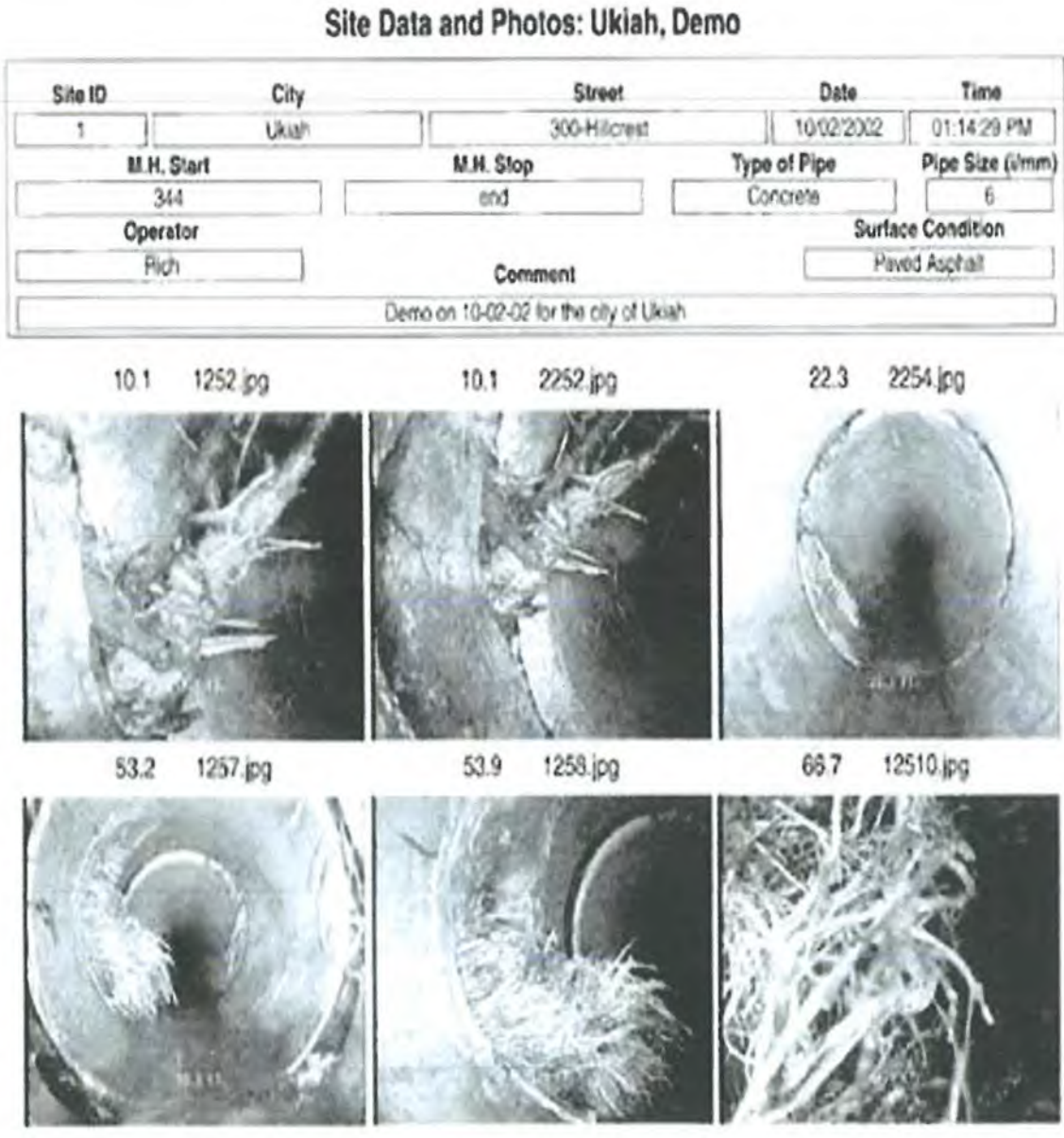


Figure 11: Work procedure for TV camera inspection

Abnormalities detected in the pipeline during the CCTV camera inspection should be recorded on video tape or as photographs, according to the judgement criteria. The inspected results should be recorded in the inspection record. Examples of forms of the inspection record are shown in Figure12 and Figure 14.



Source: EPA, 2003

Figure 12: Typical CCTVData1

Source: EPA, 2003

Figure 13: Sewer line inspection by CCTV

CITY OF PHOENIX SANITARY SEWER REPORT

SEC. #: 12-24 T.V. OPER: RENTFRO			DATE: 10-15-02	ROUTINE: ☑	
PIPE DIA: 8"	PIPE TYPE: VCP	PIPE LENGTH: 6'	EQUIP. #: 481	COMPLAINT:	
				NEW WORK:	
M.H.# 303	FLOW DIR. → 432 L.F. → T.V. DIR.	M.H.# 304	V.T. # 34	START: 000	
			COMMENTS: SEWERE CRACKED PIPE AS NOTED ROD LINE - ROOTS CLEAN LINE - SLUDGE & ROCKS	STOP: 135	
STREET: W. CAMELBACK					

STA. #:		VT
0+00	M.H. # 303	
0+16.5	TN FACT.	
0+18.5	TS TAP	
0+42.0	ROOTS @ JOINT (4)	000
0+54.0	" " (5)	010
0+72.5	PIPE CRACKED (7)	014
0+84.5	" " (6)	020
0+90.5	TN TAP	
0+92.5	TS FACT.	
1+16.5	OFF-SET JOINT 1"+	028
1+22.0	2" WATER & SLUDGE	031
1+28.0	3" WATER	033
1+34.0	C.U.W	036
1+37.0	C.O.W	039
1+52.0	PIPE CRACKED (9)	042
1+64.5	TN FACT.	
1+66.5	TS TAP	
1+90.0	OFF-SET JOINT 1"+	047
2+10.0	SLUDGE - HVY.	051
2+14.0	ROCKS - SLUDGE	055
2+20.0	LOW JOINT - 1/8" WATER	060
2+32.0	TN FACT.	
2+34.0	TS FACT	
2+69.0	ROOTS @ JOINT (1)	066
2+70.0	" " (8)	069
2+90.0	TN FACT - CRACKED (2)	072
2+93.0	TS TAP - CRACKED (3)	079
3+10.0	OFF-SET JOINT 2"+	084
3+16.0	" " " 2"+	088

STA. #:		VT
3+28.0	PIPE CRACKED (5)	092
3+40.0	" " (9)	101
3+57.5	TN FACT.	
3+59.5	TS FACT.	
3+89.0	ROOTS @ JOINT (1)	105
3+90.0	" " (7)	
3+96.0	" " (4)	
4+02.0	" " (6)	
4+08.0	" " (8)	
4+14.0	" " (5)	
4+20.0	" " (2)	130
4+32.0	MH # 304	

SERVICE REQUEST SUBMITTED
TYPE: CONST. - ROD - CLEAN
DATE: 10-17-02

INSPECTOR:

PERMIT #

Source: EPA, 2003

Figure 14: Typical Reviewed CCTV Inspection Report

5.3 Inspecting Infiltration of Water

If infiltration of water is more than the planned flow and is excessive than the sewerage plant, the pipelines and treatment facilities will be adversely affected. This also leads to an increase in the treatment costs of the wastewater treatment plant.

The cause of infiltration of water is either the pipeline is in adequate or the drain age system is inadequate. For this reason, inspection of cross connections, flow rate inspection and water proofing inspections need to be combined and the route of infiltration water should be checked. Flow rate inspections will be useful data for potential improvements and modifications of the sewer collection system.

5.3.1 Inspecting Cross Connections

Inspection has to be performed to check that stormwater equipment is not connected to the sanitary system which is totally a separate system. The scope of work is from the trunk sewers to the lateral house connections.

There are three typical methods for inspecting cross connections as follows.

a) Smoke Test

The smoke test makes use of a smoke bomb in a separate sewerage system pipeline. Across connection can be judged by checking for smoke rising from the house inlet of rain gutter. This test identifies locations where stormwater inlet or rain gutter drainage equipment is directly connected to wastewater pipe house inlet and locations where stormwater that has permeated the ground from the ground surface or gutter has indirectly permeated the sewerage pipe or house inlet. Figure 15 shows the materials to be used.

Source: EPA, 2003

Figure 15: Materials for smoke test

Features of the smoke test:

The status of connection of drain pipes in each space can be checked in a short time. Inadequacies in the house drainage facility can be quickly detected. Smoke test procedure is shown in Figure 16.

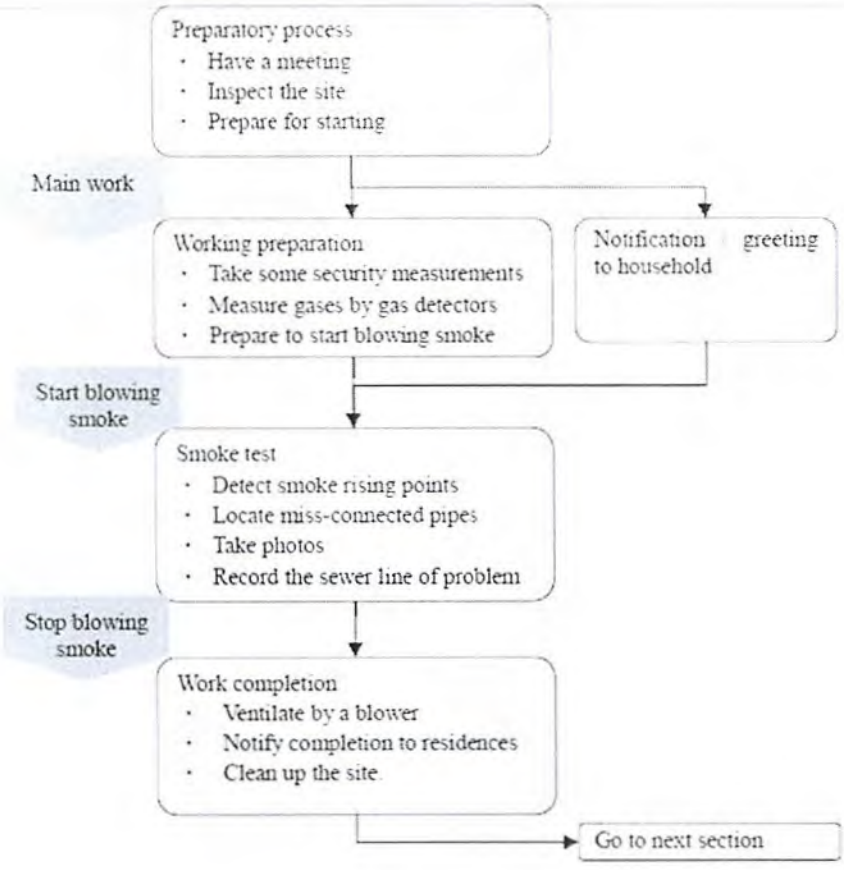


Figure 16: Work procedure of smoke test

b) Echo Sound Test

This is a method for confirming that piping facilities are correctly connected, and is also an effective method for knowing the plumbing systems and the routes of wastewater mains and lateral sewers. Ultrasonic waves are used (transmitter and receiver). Figure 17 shows the test method.

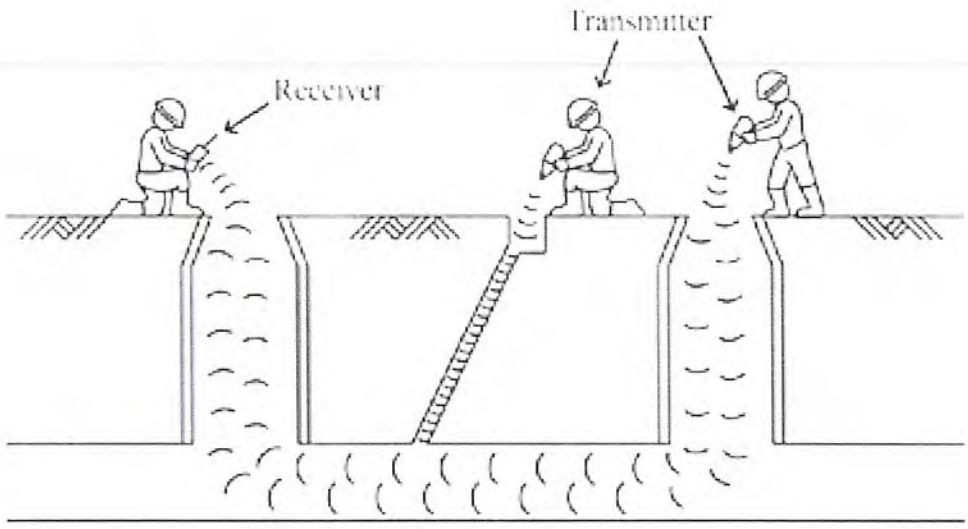


Figure 17: Illustration of echo sound test

Features of the echo sound test are as follows:

- Simple method to confirm that a pipe has been connected or not;
- Effective especially in the connections of lateral sewers;
- Cannot judge clogging or trap;
- Echo sound test procedure is shown in Figure 18.

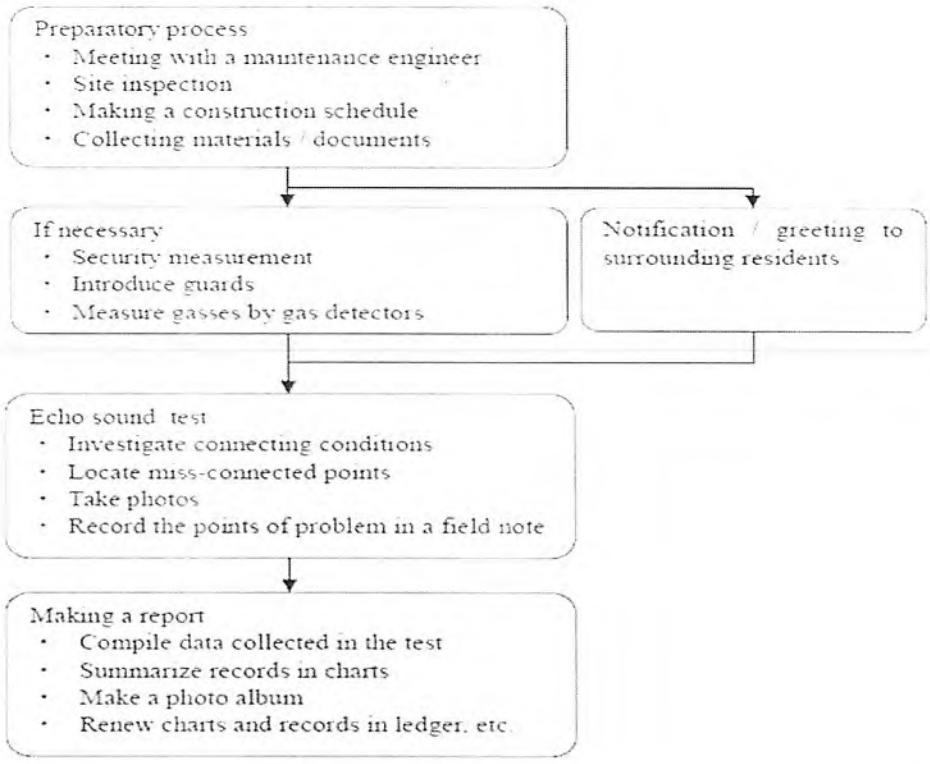


Figure 18: Echo sound test procedure

c) Dye Test

Inert fluorescent dye diluted water is made to flow from the upstream side to the treatment plan within the range of trunk sewer main, secondary line, tertiary line, lateral sewer and drainage equipment. The water flow route, leakage route and time to reach the destination point are examined. The outflow route should be checked quickly if notification of foul odour due to out flow of wastewater particularly from a masonry or pump tank is received. The method can also be used for checking the flow status in the pipe and for measuring the flow velocity. The test method is shown in Figure 19.

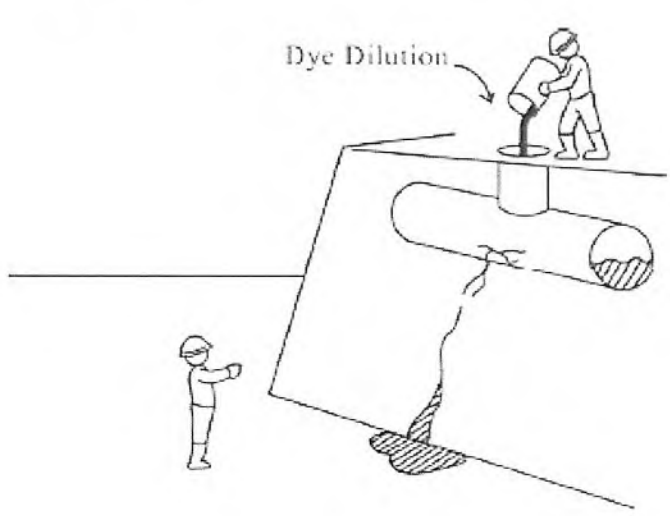


Figure 19: Drawing of Dye Test

5.3.2 Flow Rate Inspection

Inspection should be carried out at locations where possibility of infiltration is high, e.g. where groundwater level is high, at apart of a river crossing or at a part adjacent to rivers.

a) Flow Rate Measurement

Simple flow velocity meters (Palmer Bowlusflume, electro magnetic flow meter, water level gauge, ultrasonic flow meter etc.) should be installed tentatively at the mouth of the manhole for flow measurements in the piping facilities and fixed period measurements should be implemented.

b) Pumping Test

This is a method for measuring the flow rate which is used for water that has infiltrated the pipe line. The flow rate of infiltrated water into a section (space) of the sanitary system can be determined within a short time. However, the flow rate of infiltrated water varies with the variation in groundwater. Therefore, precipitation and weather at the time of measurement should be confirmed.

To drain out household wastewater from the test during inspection of each space, a cut-off plug should be installed. This should preferably be implemented during the night time when the volume of household wastewater generated is small. Figure 20 shows the pumping test. It is important to determine approximately the wastewater flow rate of each section in order to estimate the infiltration rate.

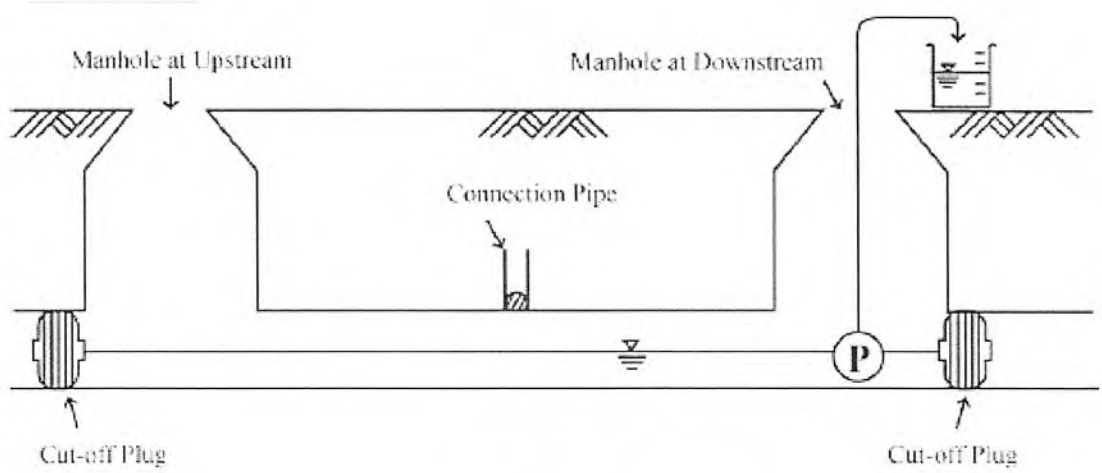


Figure 20: Pumping test

The features of measurements during pumping test are as follows:

1. The flow rate of infiltrated groundwater for each space or system can be measured within a short time;
2. The measured values differ widely depending on the variation in the groundwater level;
3. During measurements of several spaces of each system, it is difficult to isolate household wastewater late at night.

Work procedure for measurement of pumped water is shown in Figure: 21.

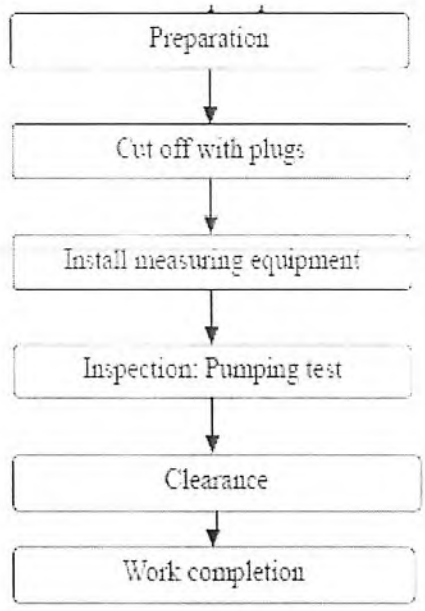


Figure 21: Work procedure of pumping test

5.3.3 Inspecting Corrosion and Deterioration

The status of deterioration or corrosion within a pipeline should inspected by using a TV camera. The materials in the piping facility are of various kinds: concrete pipe, uPVC and HDPE pipes, so the corrosion and deterioration conditions will vary.

Methods for inspecting corrosion and deterioration conditions of a sewer include the following:

- Inspection by CCTV camera of the internal pipe condition
- Crack inspection
- Neutralization test

The causes of concrete structural deterioration are mainly due to the following:

- Crack in concrete due to concentrated loads (live loads);
- Deterioration of structure due to age;
- Deterioration of concrete structures (concrete corrosion) due to sulphuric acid from the generation of hydrogen sulphide gas.

5.3.4 Concrete Corrosion

In a facility where wastewater resides for a long period, such as a rising main or an inverted siphon, the wastewater is likely to become an aerobic and dissolved sulphide gets generated, which leads to concrete corrosion because of sulphuric acid. Locations where concrete corrosion is likely to occur in sewerage piping facilities are as follows:

- Piping facilities at the discharge destination of a pressure pipe (including a manhole pump).
- Upstream and downstream ends of locations where sump discharge occurs.
- Upstream and downstream ends of locations where discharges containing hydrogen sulphide occurs.
- Locations downstream of an inverted siphon.

The following are tests of concrete pipes for hydrogen sulphide corrosion.

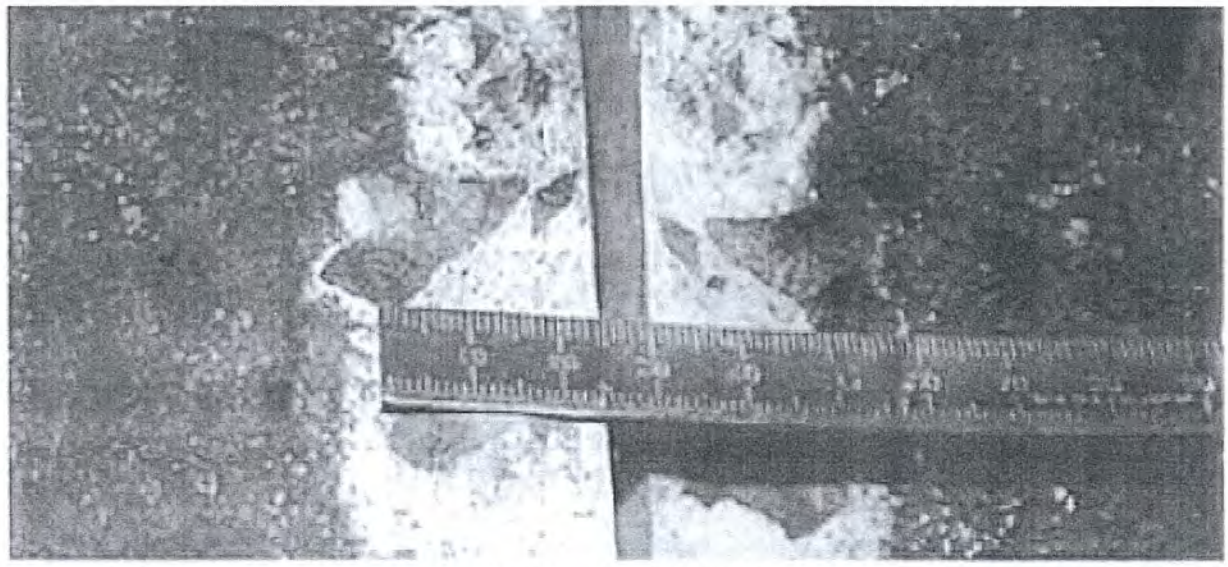
a) PH Measurement of Concrete Surfaces

For sulphuric acid corrosion of concrete, the pH on the surface of concrete is measured by pH test paper or pH meter which is placed on concrete surface directly, and the generation of sulphuric acid in the concrete structure is confirmed. When sulphuric acid is generated in a manhole, the pH of the concrete surface may indicate strong acidity with a pH of 1 to 2.

b) Neutralization test (neutralization depth test by phenolphthalein)

One of the indices for judging durability of reinforced concrete structures is the "neutralization depth." This is the method of judging alkalinity with a pH of 10 and above as un-neutralized part and uncoloured parts as neutralized parts, enabling quantitative information to be obtained easily by simple measurement.

When neutralization reaches the vicinity of the reinforcement, there inforcement is likely to be corroded easily. When corrosion of reinforcement progresses, volume expansion of corrosive products causes a crack or delamination in concrete leading to excessive loss in the durability of the structure. For details of the procedure, refer to BS-103:"Guidelines on Non-destructive Testing of Bridges".



Source: JASCOMA, 2007

Figure 22: Neutralization Test

5.3.5 Other Examinations

Special examinations to study in detail the conditions of a facility are as given below. For more details, please refer to relevant documents for each item. Various kinds of information relevant to analysis for studying gas exploration are provided as follows:

- Sewer invert elevation examinations: Understanding pipeline conditions and collating with sewerage facility records;
- Sediment examination: Check sediment material such as sand and silt which may have entered a damaged sewer or through loose joints from outside the sewer. The sand and silt may accumulate around the sewer and form voids.
- Dangerous gas detection examination: Confirming gases generated in the piping facilities, Water quality and gases encountered in a piping facility are closely related.

5.3.6 Special Precautions

When entering manholes, safety measures during the work should be adhered to and due Consideration should be given to a minimum of: wearing the proper health and safety equipment (PPE); fall protection, traffic safety, oxygen deficiency and potential poisoning due to toxic gases such as hydrogen sulphide and methane. **All employees involved in entering sewers shall be adequately trained in health and safety with the proper certification**.

For securing worker's safety, manual sewer/septic tank cleaning should be avoided because persons are likely to come in contact directly with sludge and sewage. Therefore, cleaning machinery and equipment which avoid manpower cleaning are required. Furthermore, necessary safety measures before entering manholes for cleaning should be taken.

The contamination of drinking water with sewage may occur when water supply pipe passes through sewer manholes, generally in narrow streets, especially when water supply pipe joints are enclosed in sewer manholes. Whenever water supply pipe joints leak, contamination of made nonfunctional drinking water supply can occur. As such, water supply pipelines should never been closed in a sewer manhole. If any such situation is observed, the water supply pipe should immediately be made non functional by stopping flow of drinking water. The water should be then diverted around the manhole in order to avoid water contamination to secure public health which is always a number one priority.

5.4 Judgement of Inspection and Examination Results

It is necessary to judge whether urgent repairs or modifications are necessary, or normal operation and maintenance are sufficient to ensure that the functions of piping facilities are maintained when an abnormality is detected by studies and analyses. The facility manager should make the judgment considering material of the pipe, age of the pipe, location where buried, quality of wastewater, status of groundwater, regional environment and so on.

The criteria given below may be used as judgment criteria.

- Emergency response criteria
- Judgment based on results of inspection or examination
- Testing criteria

5.4.1 Defect Repair

The Municipality of Birgunj will need to implement an effective defect repair program to handle the structural defect findings as determined by the CCTV work performed. The Municipality will need to review the findings and determine if a capital improvement project should be initiated, or if a scheduled maintenance program can be implemented for the necessary repairs. The categorization and quantification of defects is necessary to develop a budget sufficient to account for the identified repair scope and timeline of repair.

5.4.2 Standardized Defect Identification; NASSCO Methodology Overview

Implementation of a comprehensive rehabilitation program requires development of a standardized method of identifying and rating pipeline defects in a manner that facilitates proactive mediation planning. This section discusses a method that has gained increasing use in the United States of America (US) and is widely accepted elsewhere. The National Association of Sewer Service Companies (NASSCO) in the US with assistance from the Water Research Centre (WRC) developed Pipeline Assessment and Certification Program (PACP©) grading codes for sewer defects to promote the consistency ingrading/evaluating the condition of sewers. These uniform codes were developed in part to standardize pipeline conditions rating to better prioritize and plan wastewater collection system repairs.

NASSCO has two distinct "families" of defects in which a defect grade (e.g. severity rating) is applied. These include:

- Structural Defects, and
- Operational and Maintenance (O&M) Defects.

These defects are also further classified as "continuous defects" or "non-continuous" / localized. Brief descriptions follow.

5.4.3 NASSCO Structural Defects Overview

The Structural Family of defects describes various types of defects where the pipe has been damaged or otherwise defective. The following 11 groups comprise the Structural family of defects. Certain examples provided in the NASSCOPACP Manual are provided as exhibits in Appendix C.

a) Crack– Longitudinal (CL)– refer to Exhibit 3-1
b) Fracture– Longitudinal (FL)– refer to Exhibit 3-2
c) Broken (B)– refer to Exhibit 3-3
d) Hole (H)– refer to Exhibit 3-4
e) Deformation (D)– refer to Exhibit 3-5
f) Collapse Pipe (XP)– refer to Exhibit 3-6
g) Joint
h) Surface Damage
i) Weld Failure
j) Point Repair
k) Brick work

5.5 NASSCO Operational and Maintenance (O & M) Defects Overview

The O & M Family of defects describes various types of conditions that are found in sewers that may interfere with the operation of the conveyance system. The following 5 groups comprise the O&M family of defects. Certain examples provided in the NASSCOPACP Manual are provided.

a. Deposits
b. Roots– Medium (RM)– refer to Exhibit 3-7
c. Infiltration Gusher (IG)– refer to Exhibit 3-8
d. Other Obstacles (OBZ)– refer to Exhibit 3-9
e. Vermin

There are also two additional "Families" of observations, construction related (e.g. taps, intruding seal material, line/bends, access points/clean outs etc.) and other (miscellaneous observations including camera under water/sag, water level observations etc.), which are given O&M grades for Pipe Rating Index computations.

5.5.1 NASSCO Continuous Defect Overview

A "continuous defect" is any defect which extends (or is repeated) beyond the first meter (3feet) from the camera position. Continuous defects fall into one of two categories, either truly continuous (defects that extend along the sewer without any interruption over more than 1.0 meters (three feet) or repeated continuous defects (which occur at regular intervals along the pipe). The PACP Code Matrix published by NASSCO is provided as shown in Appendix C.

5.5.2 NASSCOD Effect Condition Grading

Using the PACP Code Matrix, each sewer line observation is labeled with a PACP code then, based on this code, is assigned a condition grade from 1 to 5. Grades were assigned as specified by NASSCO criteria based on potential for further deterioration or pipe failure. Pipe failure is defined by NASSCO as when the pipe can no longer convey the pipe design capacity, and does not necessarily refer to the structural failure of the pipe. An overview of the five NASSCO grades is summarized in Table 6; (Note the time frames associated with the Codes.)

Table 6: NASSCO Grade Summary

Pipeline Grade	NASSCO Classification	NASSCO General Description	NASSCO Guideline Relating to Pipeline Failure
5	Immediate Attention	Defects requiring immediate attention	Pipe failed or will likely fail within the next five years
4	Poor	Severe defects that will become Grade 5 defects with the foreseeable future	Pipe will like fail in 5 or 10years
3	Fair	Moderate defects that will continue to deteriorate	Pipe may fail in 10 or 20years
2	Good	Defects that have not begun to deteriorate	Pipe failure unlikely to fail for at least 20 years
1	Excellent	Minor defects	Failure unlikely in the reseeable future

6. PROPOSED EQUIPMENT REQUIREMENTS

I) Large diameter high capacity Jetting Machine

There is provision in the contract for supply of Jetting cum Suction machine by the Contractor of capacity 6000l/min or more. It is a smaller capacity Jetting machine and is not efficient for cleaning larger diameter pipes and also not effective for cleaning major sewer blockages.

Since a high proportion of the sewer pipes are above 400 mm, it is proposed to purchase an additional high velocity jetter for large diameters (up to 1m). The proposed machine can also be used for small diameter pipes by changing the nozzle type. Although the newly purchased high velocity jetting machine is sufficient to clean inside surfaces within the pipe range (110 mm to 400 mm), it is recommended to buy a second machine so that two working teams can clean the sewerage system at the same time. Considering the future aspect when the new sewer line connection will be added due to addition of new branch line based on sewerage treatment plant capacity. The proposed jetting machine should have the following performance specs:

Jetting flow rate	: 600-1000l/min
Pressure at truck	: 200 bar
Final pressure at nozzle	: 100-120 bar
Hose size (min.)	: 32 mm (1.25 inches).

II) Suction Machine

There is provision in the contract for supply of suction machine by the Contractor of capacity 4000l/min or more. It is a smaller capacity suction machine and is not efficient to suck up the silt and sludge at manhole location and also within the pipes.

It is recommended to purchase one set of machine with larger capacity of high jetter velocity. The smaller machine should be capable to clean the sewer pipe of smaller diameter whereas, the larger machine should be used to clean the sewer pipe of bigger diameter. In this way two teams can clean the sewerage system at the same time. In addition, the larger machine has a greater capacity to suck more material which would be beneficial to the project. The details of the specifications required are shown in Appendix D. The proposed suction machine should have the following performance specifications:

Larger machine:

Pump- max free flow : 2500 m^3/hr at 3300 rpm; 1800 m^3/hr at 2500 rpm
Pump- flow at 60% : 2010 m^3/hr at 3300 rpm: 1430 m^3/hr at 2500 rpm Max vacuum 93%
Tank capacity : 9000 liters

III) Mechanical Rodder

It is also proposed to purchase a power rodder for emergency blockages for smaller pipes less than 300 mm in diameter. The power rodder can be purchased with numerous accessories to unplug grease, sludge, hard objects and roots etc. Different heads can be attached to the power driver depending on the type of blockage and size of pipes. The following mechanical rodders and related accessories are recommended:

1. Root cutters;
2. "Diamond Lateral Core Drills (6") or similar drillbit used for drilling hard objects;
3. "Diamond" Lateral Core Drills (8") or similar drillbit used for drilling hard objects;
4. Various power auger heads and sizes.

The diamond lateral core drills are used for hard objects like hardened soil, concrete or steel or other softer material like sludge and clay. For recommended details see company flyer Appendix - D.

IV) Plugs

Inflatable Plugs are used for blocking the flow upstream and downstream of the working area. The plugs can be used when the jetting machine suction machine or CCTV camera is used so that the flow is minimized through the working area. The plugs range in size from 4 inches (0.11m) to 36 inches (0.91m). For typical detail see company flyer Appendix D.

V) CCTV Camera

There is provision in the contract for supply of Drain Camera by the Contractor. It is also worth noting that in the future an additional CCTV camera may be purchased which consists of a camera mounted on a four wheels' miniature vehicle which can maneuver within a 300mm manhole or greater. This will prevent a man enter a confined space entry situation. The CCTV camera is controlled from the surface and the video is displayed on a computer showing the pipe condition. The CCTV camera may be purchased in the future depending on the project needs, the project budget and if adequate suitable training is provided.

Note:
It is worth mention that at the initial stages of the project for the first 3 years it is suggested to use more simple inspection techniques such as the direct visual approach, light and mirrors and the proposed CCTV camera on a pole. Later as the municipality gets more familiar with the inspection and cleaning equipment more sophisticated equipment can be ordering depending on the needs of the project at the time.

Estimate Cost of the O & M Equipment

Table 7: Estimate Cost of the O&M Equipment

Equipment	Total Estimated Capital Costs (NRs.)
High velocity Jetting Equipment	14,000,000
Suction Equipment	8,300,000
Power Rodders and various power auger heads	1,800,000
Plugs	1,380,000
Pumping Water Facilities and related infrastructure	2,000,000
Total	27,480,000

Note:

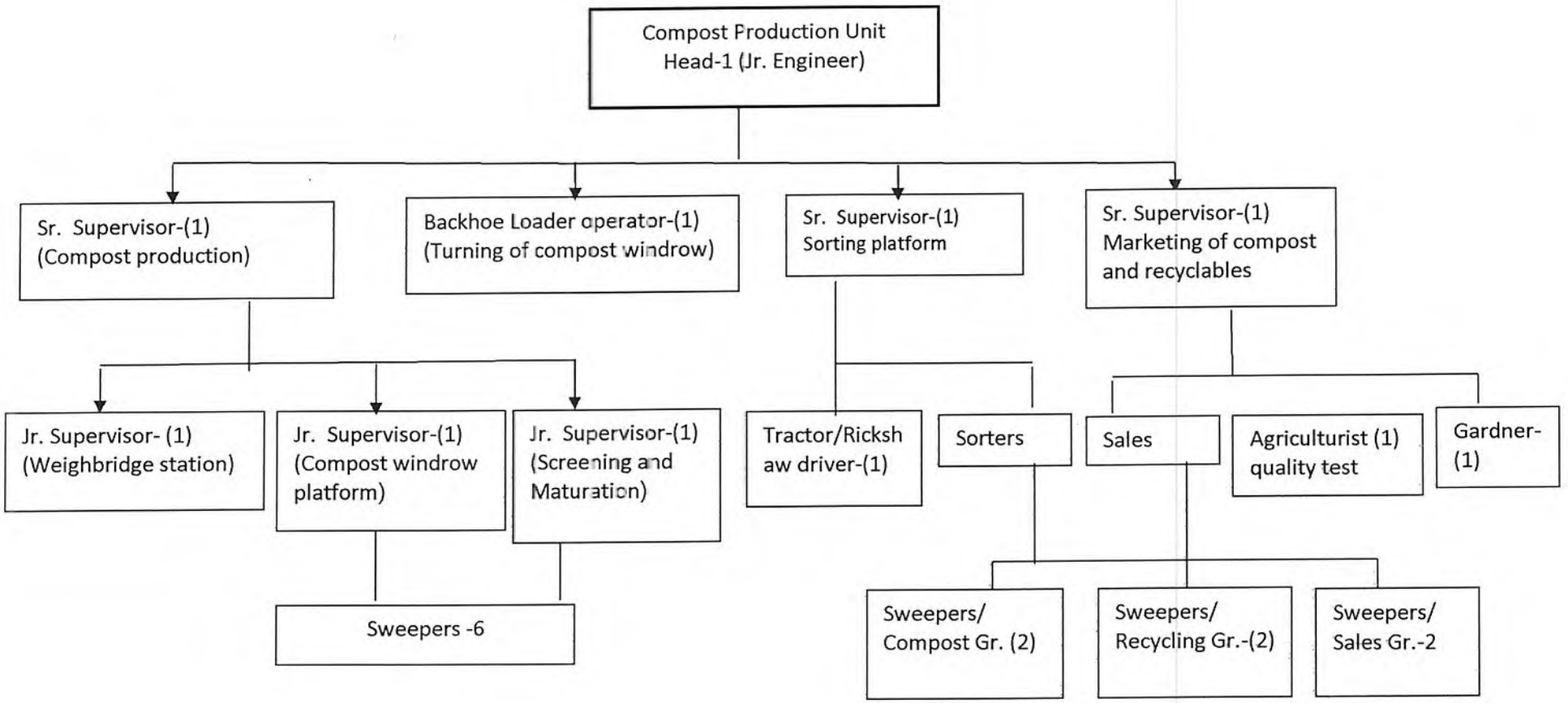
i) The above cost does not include manpower training or O&M of cleaning equipment;
ii) The opinion of probable costs is within +35% / -35%.

6.1 Proposed Staff Requirement

The proposed sanitary sewer pipes will require regular preventative maintenance as well as reactive maintenance for approximately 4.856 km of trunk / main sewer lines and approximately 3.00 km for branch sewer line. Additional staff shall be required to manage, operate and maintain the proposed system. It is also proposed that state of the art machinery shall be used for preventive, corrective and emergency maintenance of the systems therefore, staff for new categories in addition to present staff shall be required. The proposed sewerage system at Birgunj being a smaller system, it is proposed that one team of workers will inspect and/clean the sewers. The following staff requirements are proposed for the sewerage system:

1) Provide sufficient managerial and technical staff and a Labour force to provide adequate operation and maintenance of the sewerage system as shown in the organogram Figure 23. The organogram is flexible in that more positions and staff can be added depending on the system requirements:

Table 2: Manpower and Organization of Compost Production Unit



Note

- At weighbridge station, source separated & compostable waste is selected and its record is kept for reporting
- ( ) - number of employees;
- Total staffs are 23; 1 management staffs, 10 technical staffs and 12 sweepers
- This unit employs more staffs when incoming waste load is high

Table 1: Manpower in Landfill Site Operation

S.N.	Working area	manpower	Number reqd.	number to be deputed
1	**In-charge of ISWM Site**	Engineer	1	1
2	**Equipment operator**	Dozer operator	1	1
3		Payloader/Backhoe loader driver	1	1
4		Compactor operator	1	-
5		Driver (Tractor and tipper driver)	1	1
6		Rickshaw pullers (two Rickshaws)	2	1
7	**Weighbridge operation**	Weighbridge supervisor/ junior engineer (in-charge of weighbridge station)	1	1
89		Clerk / computer operator	1	1
10		Gate keepers	2	2
11	**Landfill cell operation**	Waste receiver/ spotter at landfill platform (Junior supervisor)	2	2
12		Waste filling supervisors (junior engineer)	1	1
13	**Leachate Stabilization pond**	Leachate pond technician	1	-
14	General works	Electrician	1	1
15		Labourers	2	1
		Sub-total	17	14
16	Workshop and Equipment service center	Senior Mechanic	1	1
17		Dozer mechanic (experience)	1	1
18		Electrician	1	-
19		Tireman	1	1
20		Washers/cleaners	2	1
21		Plumber	1	1
22		painter	1	-
		Sub-total	8	5
		Grand Total	25	19

ORGANOGRAM
(proposed)
FOR OPERATION AND MAINTENANCE

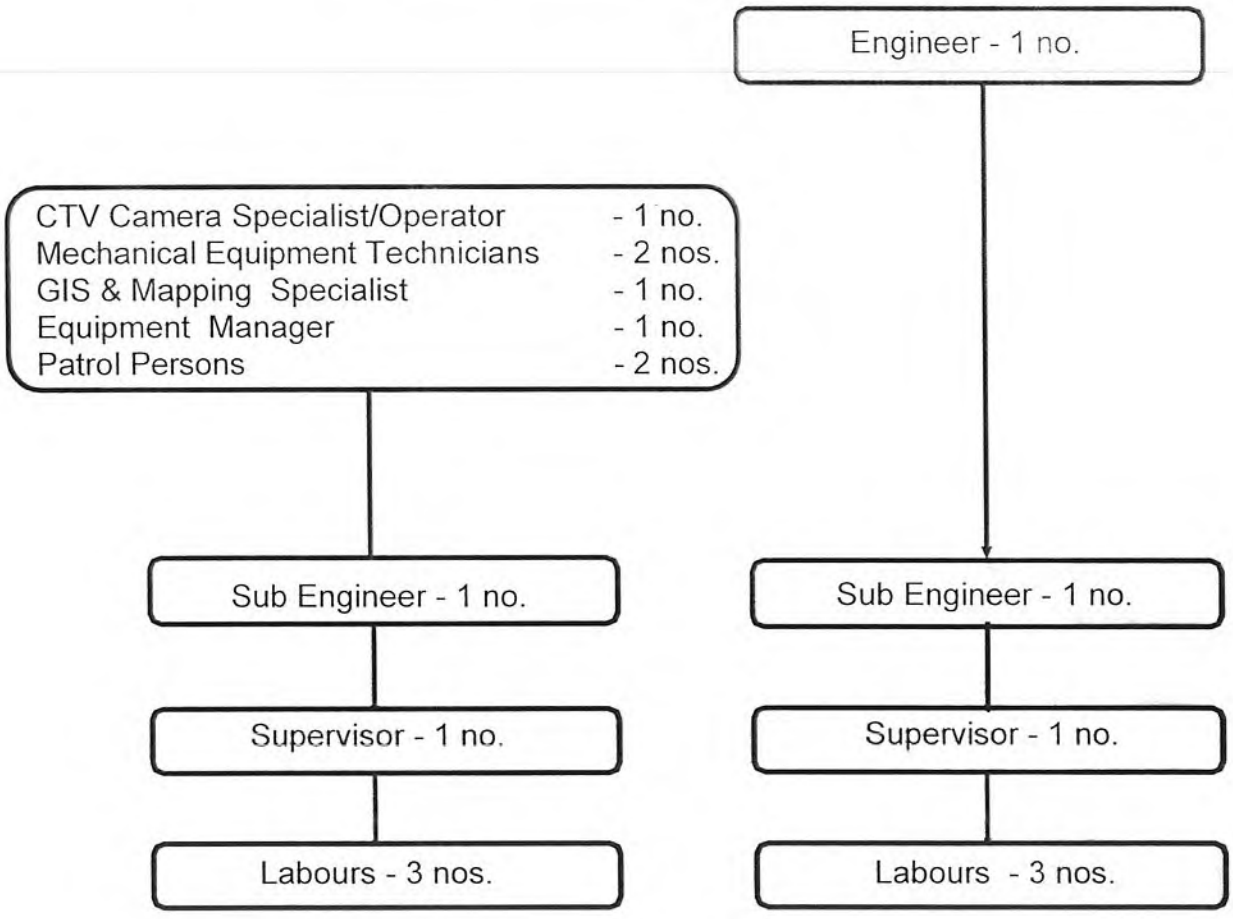


Figure 23: Organogram proposed

2) The senior staff of the Municipality of Birgunj will have enhanced duties for the proposed project which should be as a minimum of the following:

- Planning of new projects, taking into consideration the existing as well as future needs;
- Design of new sewerage and drainage projects through consultants;
- Arrangement of training sessions for capacity building of higher (i.e., engineers, sub engineers and specialists such as CCTV camera specialist/operator, mechanical technician etc.) as well as lower field staff (i.e. supervisors and laborers.);
- Planning of preventive maintenance program to best manage, operate and maintain sewerage and drainage system and build on the recommendations of this manual;
- Purchasing new maintenance equipment when required;
- Planning SSO emergency response plans.

The existing manpower structure should be increased and their knowledge enhanced to carry out the above mentioned work.

3) In order for the O&M project to be successful, all staff should be appropriately trained. The training session should be tailored be to the job requirements. (See section 6.5 for details on training).

4) Patrol persons may be required to enforce regulations for the sewerage system. The main regulations that the patrol persons will enforce will be that residents do not throw garbage or toxic substances into the sewerage system or cause any will full damage to the infrastructure. The patrol persons should also check that there are no cross connections between storm and sanitary sewers.

The following is a brief description of the qualification required for the new specialty technical positions of the project.

- **GIS Expert**

For coordinated mapping of the sewerage system a BSc or preferably a MSc in GIS science will be required.

- **CCTV Camera Analyst/Operator**

The position will serve as a utility technician with expertise in reviewing CCTV of sewer mains and laterals related to the sewer collection system. Basic qualification for this category is at least a diploma as a Sub Engineer in Mechanical/Electrical specialization.

- **Mechanical Technician Supervisor/Operator of Cleaning Equipment**

Coordinates and supervises work crews engaged in repairing, cleaning and maintaining sanitary sewer lines. He should be properly trained to operate respective machine and also be able to train the lower staff. Basic qualification for this category is at least a diploma as a Sub-Engineer in Mechanical / Electrical specialization.

6.2 Proposed Desilting/Cleaning Schedule

As noted, a good preventive maintenance O&M program is based on a routine operating procedure that assures that each component of the system is inspected and necessary maintenance performed at appropriate intervals. It is proposed that Municipality of Birgunj should observe the following schedule/program for desilting activities:

1. Pre-monsoon (during March, April and May) and post-monsoon (during October to February) grand desilting program of the trunk, secondary, tertiary and laterals should be implemented. The sewer cleaning will be implemented using at least two high velocity cleaners for preventative maintenance and mechanical rodding for plugged or semi-plugged sewer for pipes with diameters less than 300 mm. Mechanical rodding can also be used for cleaning and preventative maintenance as a supplement to high pressure jetting. It is devised that routine preventative cleaning should commence from the upstream point in the catchments at the house connections laterals to the main trunk sewers and ultimately to the WWTP.

Below are the assumptions for calculating the average inspections and cleanings per year:

- Total length of pipe to be cleaned: main sewer line and branch sewer line. Total length is approximately 8 km.
- Number of maintenance cleaning teams: 1
- Distance to be cleaned per day per teams: 250m
- Number of days of cleaning and inspection per year: = 40 (5 days per months for 8 months)
- Using these assumptions all the pipes will be inspected and cleaned on average once per year.

Therefore, one team with two sets of maintenance equipment to clean and inspect once per year on average is probable. The above estimate is an approximation. The actual working days in the field and the average pipe length cleaned and inspected per day will depend on the field conditions.

2. As mentioned the cleaning program will be conducted twice per year but different sections of the system will be cleaned more often than others depending on the condition of the sewer pipes. For example, the new sewerage system that exhibits no operating problems such as backups, surcharges, odors etc. will require less frequent inspections than twice per year, while those with chronic problems will require more frequent inspection and maintenance activities. The frequency of maintenance activities will depend on the nature of the problem. For example, secondary sewer lines with low slopes that silt up more frequently may require cleaning 3 or 4 times a year. Areas where chronic root problems occur that may require cutting or chemical treatment may require more frequent attention. Surcharging manholes (i.e. by passing manhole lids) should be inspected either during or immediately after any significant precipitation event. Below in Table 8 is a recommended frequency of cleanings by NASSCO/PACP based on the O&M condition of the pipes in terms of blockages, where 1 is the most favourable condition and 5 is the worst condition. Table 8 will need to be completed by the Engineer after completing a condition assessment of the sewerage system.

3. Sewer cleaning may also have to be carried out after receipt of complaints from the public from different areas. Immediate response to all sewer/drainage related complaints should be adhered to follow by prompt correction of the defective condition where applicable.

Table 8: Sanitary Sewer Recommended Frequency CCTV Inspection

Sanitary Sewer Cleaning Priority			Recommended Frequency	
NASSCO PACP O&M Grade	Recommended Length of Pipe to be cleaned per year[1]	Actual length of pipe cleaned per year based	Minimum interval for cleaning (months)	Maximum interval for cleaning (months)
4.1–5			3	9
3.1–4			9	15
2.1–3			15	24
1.1–2			24	36
<1			36	48

Note: The O&M and structural condition of the sewer will be based mainly on the CCTV inspections or other direct or indirect method where applicable.

6.2.1 Low 'Self Cleansing' Velocity in Secondary Pipes Require Frequent Inspection and Cleaning

One of the main problems of the sewer system is due to the flat slopes particularly in the secondary/branch lines which generally range in slope from 0.1% - 0.7% which means that the velocity of flow in the pipes will be low. If the flow is less than 0.3 - 0.43 m/s (1.0 to 1.4 feet per second), grit and solids can accumulate leading to a potential blockage. The recommended minimum velocity is 0.6m/s (2.0 feet per second) which is the minimum 'self-cleansing' velocity. The secondary lines have a total pipe length of 2845 meters of which 1835 meters has a calculated velocity **below 0.6 m/s**. This represents 64.60% of the total pipe length in the secondary lines of the sewer system. Therefore these pipes will probably have to be cleaned more frequently than the pipes with a 'self-cleansing' velocity of greater than 0.6 m/s. **The number of cleanings will be based on the inspections so these pipes with low flow velocities should be inspected more often.** There are no trunk/main lines in the design with a velocity less than 0.6 m/s. (See Appendix E for pipes in the design with calculated low flow velocities).

6.3 CCTV Inspection Schedule

The sewer line CCTV schedule will need to be adjusted on an annual basis as the condition of the sewer system will change overtime. CCTV information should be cataloged in the Municipality of Birgunj GIS data base for pre and post cleaning results. Review of CCTV comparative information will allow the Municipality to track their success and make adjustments to the maintenance schedules as necessary.

In addition to the cleaning activities the Municipality of Birgunj should implement aproactive CCTV program to monitor the status of existing defects and identify accelerated deterioration to schedule repairs. An annual CCTV program targeted to monitor existing and identify new NASCOPACP Structural Grade 4 and 5 defects is recommended. Initial re-televising efforts should focus on those portions of the system (i.e. manhole to manhole segments) that exhibit NASSCO Level 4 and 5 structural defects. Each manhole to manhole segment should be rated based on average defect Grade value (i.e. Total Grade value of defects divided by total defects observed). These sites should be revisited at least annually until the defects are stabilized, eliminated or reduced to a Level 3 or less. A map of the NASSCO Level 1 through 5 should be developed by the Engineer. Recommended annual total distance in Table 9 should be based on the maximum recommended frequency. Table 9 will need to be completed by the Engineer after completing a condition assessment of the sewerage system. The assessed values determined and recorded on the table will allow the Municipality to develop an annual CCTV program.

Table 9: Sanitary Sewer Recommended Frequency CCTV Inspection

Sanitary Sewer CCTV Priority			Recommended Frequency	
NASSCO PACP Structural Grade	Recommended Length of pipe to be cleaned per year	Actual length of pipe cleaned	Minimum interval for inspection (months)	Maximum interval for inspection (months)
4.1–5			6	9
3.1–4			9	15
2.1–3			15	24
1.1–2			24	36
<1			36	48

In view of above, a work program should be devised with the specific objective to have a trouble free operation of the sewerage system.

6.4 Manhole Accessibility Field Review Schedule

Accessibility to the sewer system is required in order to evaluate and maintain the system. A primary initial objective of the O&M program will be to evaluate the accessibility of each manhole in the system. Follow up accessibility reviews are suggested as part of annual road paving programs and review/issuance of grading and building permits as these activities are significant contributors to in accessibility problems. The Municipality should visit each manhole structure located in the system to verify the following:

- The manholes are accessible.
- The tops of the manholes are not buried or paved over.
- The manhole lids have not been displaced, removed or damaged.

Any change in status of the manhole accessibility should be noted and a photograph of the manhole location should be taken. If corrective action is required, the supervisor should schedule the field maintenance personnel to correct the issue.

6.4.1 Manhole Physical Survey Schedule

The municipality should internally inspect each manhole in the system every two years. A physical inspection of each manhole will assist in proactively identifying defects in the system before they deteriorate to the point of failure. The goals of the physical survey are to:

- Prevent the premature failure of the structures.
- Identify collection system maintenance needs.
- Identify any system surcharging/by passing.
- Maintain each manhole structure in aproactive manner.

Personnel working on the survey program should be properly trained regarding confined space entry. Each manhole inspection should be recorded on a manhole physical survey; a typical example is shown in Figure 24 below or another example as shown in Appendix B. This form should be filled out by the personnel completing the inspection and submitted to the supervisor for cataloging when the survey is complete. The inspector should take photographs of any areas that require repair. All deficiencies should be noted and ranked for repair scheduling.

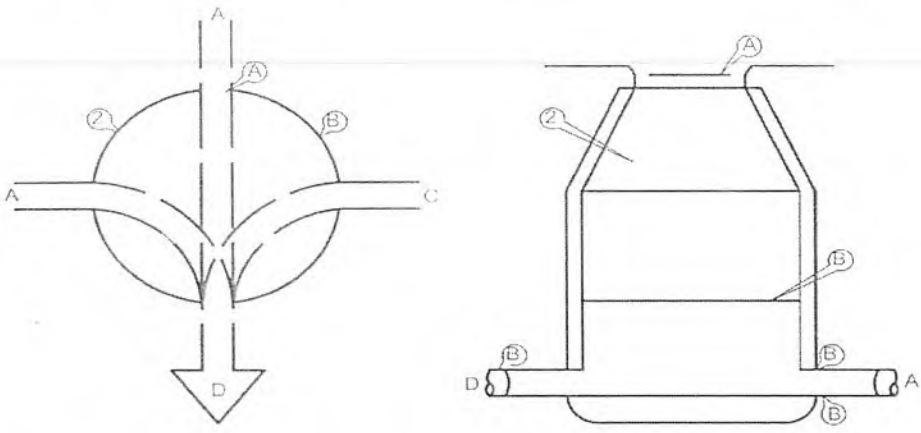
Each survey form should be considered as the initiation of a work order. The form should describe in some level of detail the nature of the repairs required. If the repairs are within the capabilities of the Municipality, the form should include as an attachment a listing of materials needed to complete the repair. If the repairs are beyond the capabilities of the crew and require outside contract, the form should include a brief scope description. Site accessor traffic concerns that may be present should be identified.

Manhole Inspection Report

MH No.: 6822 Date: 7-20-02 Inspector: JE

Elevation: Depth to Invert: 9'-7" Cleanliness: Ok

Type Construction: CONC.CAST Street References: 34 AVE & AITKIN



Defects:

(Cover, frame, grout, steps, shelf, pipes, or channels)

1. MH Ring Depressed ¼"
2. Diagonal Crack Barrel
3. Seal Failler at Joint - 1 GPM Leak
4. Seal Failler at Pipe Crack - 2 GPM Leak
5.
6.
7.
8.

(USE REVERSE SIDE FOR ADDITIONAL DEFECTS TO BE NOTED.)

	Pipe Size		Length to MH#	EST. Flow	Type Flow
A.	8	275	6823	2"	SOAPY
B.					
C.					
D.	8	320	6821	2"	

Remarks: (Include need for repairs)
Audible Leak(s) in pipes near manhole depression ring may indicate drop joint or breaks in line.

Figure 24: Example of a Typical Form for the Inspection Record

6.5 Training of Staff

For improved management, operation and maintenance of the existing and proposed sewerage and drainage system, training to the management, office and field staff of Birgunj Municipality is essential. Training sessions should be planned according to each category of staff in order to

keep them updated with recent development in their fields and to enhance their professional abilities.

Initially it is essential that following training of the staff should be conducted on regular basis:

- Health and safety training (HSE);
- Confined space entry training;
- Training on use of personnel protective equipment (PPE);
- Operation and maintenance training of new sewer cleaning and related equipment such as, high velocity cleaners power rodders and CCTV cameras.

One of the problems of training in Nepal is that the above courses are very rare or they do not exist at all, particularly in operation and maintenance training for high-tech equipment. The technology of a centralized sewer system and high tech sewer equipment is new in Nepal so training courses will have to be developed over time. First of all, it would be a good idea to investigate if any local individuals or companies specialize in the training courses. If qualified personnel or companies do not exist in Nepal, then training experts should be procured from India or overseas.

There is a possibility that local or foreign suppliers or manufacturers may have connections with suitable training experts in the operation and maintenance of their equipment and health and safety training, confined space entry etc. It is recommended to investigate securing suitable qualified training personnel. In that case, a contract may be written to supply the equipment with the addition of providing suitable training. All course curriculums of the above mentioned courses should be tailored to meet all the technical and managerial needs of the project. A suitable contract can be written up with an appropriate training component after the purchase of the equipment.

It is also strongly encouraged that after the start-up of the sewerage system and the purchase of the new equipment including the hiring of the new staff from the municipality, the training should be completed on site in Birgunj. In addition to regular training it is recommended that the professional trainers should train the staff for about a two months during the project implement phase for 'on the job training'.

It is essential that whenever new high tech equipment is ordered, the municipal technical staff should be trained by suitable well qualified professions. Local professions are the preferred choice if available due to the cost effectiveness. It is also recommended that the staff should have on going training to meet the ever changing project demands.

6.6 Public Relations and Public Opinion Related to Sewerage Works

Improving public awareness is important because the public can play a key role in improving in collection system performance. The public is a key stakeholder that should have an opportunity to identify its concern and expectations regarding the performance of collection systems and potential public health and environmental risks. Meeting the public and directly answering their questions on sewerage problems is the solid foundation of goodwill. Mostly official's in-charge of sewerage system feel hesitant to meet the public because they do not have the funds to rectify the defects pointed out by the public. Only when the public are met directly, the system draw backs will come to light and a basis for calculating the budget allocations can be known. Only then engineers in the field can carry out the remedies needed.

6.6.1 Complaint and Responses

Most local bodies have launched the internet based complaint recording by the public. It will also be good to publish on the web the complaints received and actions taken up to solve them. Otherwise the public will be kept ignorant of the problems.

6.6.2 Community Participation

The public are also responsible to maintain the system. They must not put solid wastes, solid vegetables, meat, plastics and paper into the system. The fact regarding throwing unwanted material into the sewerage and drainage systems should be well advertised by many local agencies. Educating the public through well thought out campaigns is essential for avoiding dumping unwanted material into the sewers, that will help with the long term O&M of the systems.

6.6.3 Operation and Maintenance Wastewater User Group Formation

It is highly recommended to formulate several wastewater O&M user groups (WUG) with the community of Birgunj. The WUG would be the main link between the Municipality and the community wastewater (sewerage and drainage) users. It is recommended that the WUG consist of representatives from the community of wastewater users and the local government. The number of WUGs should be decided by the Municipality in consultation with the community of users to find the optimum number of groups. The function of the WUGs is to work with the community of users to identify problems within the sewerage and drainage networks and educate the community in the proper operation and maintenance for household sewerage connections and drainage systems. The education process should consist of the following:

a) Avoid throwing any waste into the sewerage and systems that would cause potential blockages such as paper, plastic, food, solid objects like furniture, bottles, hardware and toxic substances.
b) Cleaning and maintaining individual laterals from the house connections
c) Report any broken or ineffective pipes and household connections and blockages
d) Ensure that sewerage and drainage repairs should be completed in a timely and efficient manner

One of the main advantages of WUGs is to share some of the responsibilities of the sewerage and drainage systems between the Municipality and the resident users which will inspire the users to feel ownership of their wastewater system. If the resident users feel ownership of the system, they are more like to look after it.

It is also a possibility that the WUG can expand and also include a component for a water user group in the future. This should be discussed between the Municipality and the resident water and wastewater users.

6.7 Traffic / Public Safety Arrangements

It is suggested that before starting any flushing, cleaning, desilting etc. of sewers/drains, the following traffic/public safety arrangements should be made:

- A suitable time should be arranged when the traffic volume is at a minimum or is relative low.
- Traffic hazards are to be minimized by diverting traffic to alternate routes.
- Traffic is to be diverted by putting signboards at proper locations, so that the traffic passing can take alternate routes well in advance.

- When working during the night hours reflective cones, triangles and signs must be placed at proper locations to inform the public well advance at the points of maintenance.
- Ensure a safe working area by installing adequate barricades at the specific working area.
- During night time sufficient lighting in the working area is maintained using light beams of a vehicle or generator or other source.

6.8 Timing of Sewer Rehabilitation or Cleaning During Low Flow Conditions

The optimum time to do pipe cleaning or pipe rehabilitation is during low flow conditions. This usually occurs between 1:00 AM and 5:00 AM in the morning during dry flow conditions. It is imperative to complete any sewer rehabilitation or maintenance during dry flow conditions (not during wet weather flows). For dry flow low flow condition, the quantity of water to be diverted will be minimized. When implementing any pipe rehabilitation, it is important to monitor the flow of the sewer over several days or weeks to estimate the quantity of flow for sewer water diversion.

6.9 Safety Measures to be Taken before any Manhole Entry

All workers assigned to enter sewer manholes should be provided with proper safety equipment. Following safety equipment is recommended:

- Approved gas detector (Properly calibrated)
- Fresh air blower
- Safety harness, rope and tripod safety system
- Approved hard hat

The following guidelines may be adopted to ensure safety in manhole:

a) Oxygen content must be at least 19.5% in the 1575 confined space of the manhole measured at all levels (bottom, middle and top) Safe oxygen level is considered if it ranges between 19.5% and 21%. Nobody should enter the manhole if oxygen level is below 19.5% and more than 21%;

b) Ventilate the sewer line by opening at least two or three manholes on both sides where work is to be carried out. This is mandatory where adequate blowers for ventilating sewers are not available. The manholes should be opened at least one hour before the start of operation. The opened manhole must be properly fenced or barricaded to prevent any person specially children from accidentally falling in to the sewer. Dummy cover with BRC welded fabric or wire- net may be used;

c) Fresh air blower ventilation system should be used as far as practicable. It is desirable to operate blowers for at least 30 minutes before start and during the cleaning operation;

d) Measure gas inflammability in manholes using detector;

e) Presence of toxic gases may be tested before entry of a person in manhole/sewer line and also in between if the operations are for longer period;

f) All workers should use safety harness and lifeline before entering the sewer line. At least one support person at the top must be provided for each person entering the manhole. The person entering the manhole/sewer line must be monitored using signal/camera/CCTV etc. throughout the operation period;

g) Structural safety of manhole rungs or steps must be tested before entering the manhole. Portable aluminum ladder must be available during the work period where necessary. The portable ladder must be properly seated or fixed during use;

h) Ensure that no material or tools are located near the edge which can fall into the manhole and injure the workmen;

i) Lower all tools to the workmen in a bucket fixed with rope and pulley;

j) Lighting equipment used during sewer cleaning must be explosion and fire-proof;

k) Caution signboards must be displayed around open manholes during working period;

l) Smoking, lighting open flames or gadgets producing sparks must be prohibited inside the manhole as well as in the immediate vicinity of open manholes;

m) All workers entering the manhole must be provided with protective gear and proper equipment. Use of portable gear and equipment must be monitored strictly;

n) Gas masks for respiratory protection must be available for use by the workers. The workers must be trained to use the gas masks properly.

Note:

It must be the responsibility of the Engineer and/or Sub-Engineer to check whether all precautions have been taken at site before starting work.

6.10 Reporting Requirements

Keeping good record of previous projects as well as the present projects is vital to the success of the Operation & Regular program and formal reporting is in dispensable. The main purposes of these reports are:

a) **Functionality**
Knowledge and understanding regarding the proper functionality of the sewerage system. If property recording of information is not completed properly then it would be impossible to determine the condition of the infrastructure and what future O&M work on the system is required.

b) **Experience/Records**
To lay down experiences/records concerning operation and maintenance, to be able to learn from it. Based upon the experiences, O&M routines can be adjusted.

c) **Detect short comings and challenges**
Changes from regular patterns may indicate shortcomings, upcoming problems and challenges. If problems detected in a timely manner, the necessary actions can be taken to prevent further problems.

d) **Lesson learned**
Lesson learned from health and safety to prevent any accidents in the future.

e) **Feedback from the organization and staff**
Feedback on how the arrangements have performed and what can be improved.

Below are typical types of the minimum required recorded data for observations on a daily and monthly basis.

1) Logs

Recording logs should be used to record daily work results, which can be used in the operation and maintenance of piping facilities. A typical format for daily record is shown in Table 10.

2 Monthly Reports

Daily record should be summarized in monthly reports. A typical format of monthly report is shown in Table 11.

Table 10: Daily Report

Daily Report														Date		Weather	
Response to complaint / break down	Receipt No.	Receipt Date	Location address	Work description								Inspector		Tool Material		Remarks	
	1.																
	2.																
	3.																
	4.																
Truck cleaning	Diameter (mm)															Name of cleaned Area	Daily total
	Crew A															District	person
	Crew B																person
	Removed sand volume															System No.	M^3
	Cleaned distance																m
Manhole	Direct work	Name of place repaired		Name of drainage area		System No.	Entrusted works	Name of place repaired		Name of drainage area				System No.	Tool material	Daily total	
	Work description						Work description										

Table 11: Monthly Report

Monthly Report														Date		Weather	
Response to complaint / break down	Category	1. Lateral		2. Inlet		3. Manhole		4. Ground subsidence			5. Odour			6. Others			Total
	Number																
Trunk cleaning	Diameter (mm)																
	Direct crew																
	Entrusted crew																
	Removed sand																
	Cleaned distance																
Manhole repair	Manhole type	1	2	3	4	5	6	7	Special	Direct	Entrusted						
	Cover replaced																
	Ring replaced																
	Barrel repaired																
	Noise																

7. CONCLUSIONS AND RECOMMENDATIONS

a) The schedule of cleaning of the sanitary sewers will be implemented before and after the monsoon season i.e. from October to February and March to June each year respectively. The frequency of cleaning will be based on the NASSCO and PACP, structural defects (structural condition) and O&M condition assessment rating of 1 to 5 standards.

b) CCTV inspection frequency will be based on the NASSCOPACP Structural Grade. It is also recommended to implement CCTV inspection before and after sewer cleaning as required. The exact frequency of cleaning of each pipe is unknown at present, but will be defined after the conditions of the sewers are inspected/examined after the sewers are in operation.

c) It is recommended to purchase a large diameter capacity high velocity jetting machine and suction machines and related equipment for diameters between 400mm to 1.0m. In addition a mechanical rodders with various accessories heads will be required to effectively clean and unblock smaller diameter pipes less than 300 mm. This will probably be the case for much of the secondary lines where the low slopes will result in a minimum 'self-cleansing' velocity of below 0.6 m/s. The mechanical rodders will be a valued supplement to the high velocity jetting and suction machines. The purchase of the new equipment will greatly enhance the existing equipment purchased recently.
   It is also worth considering in the future to purchase as second vehicular CCTV camera for ease of maneuverability and to prevent health and safety incidences form an entry into the manholes. The purchase of second CCTV equipment will depend on the technology ability of the municipality, the need, training availability and cost of equipment.

d) The O&M manpower should be increased based on the sewer O&M requirements. New positions should be created as required such as GIS expert, CCTV Camera Analyst/Operator and O&M Equipment Supervisor/Operator and patrol person to enforce the sewerage regulations.

e) Appropriate staff of the Municipality should be trained in the following:
   - Health and safety training (HSE);
   - Confined spacementry training;
   - Training on use of personnel protective equipment (PPE);
   - Operation and maintenance training of new sewer cleaning and related equipment such as, high velocity cleaners power rodders and CCTV cameras.

   It is proposed that appropriate training sessions should be planned and arranged for Municipality of Birgunj staff after discussions with the Municipality office and field staff and the Consultants. It is recommended to investigate securing suitable qualified training personnel from the equipment supplier using either local or foreign training experts. In that case a contract may be written to supply the equipment with the addition of providing suitable training. On the job training is strongly recommended. The staff should have ongoing training at regular intervals as required.

f) A new health and safety plan should be implemented after proper training is provided to the staff.

g) All existing septic tanks should be maintained in case the sewerage system is interrupted for maintenance purposes or for emergency stoppages such as SSOs. Septic tank should be constructed on all new housing developments for the same reason.

h) Conduct education campaigns for all residents on the sewer line on use of the proper use system. Part of the campaigns will be to promote strongly the use of throwing garbage in the bins instead of the sanitary and storm sewers. This will help to prevent clogging. It is proposed to set up a wastewater user groups (WUG) whose members will consist of Municipality representatives and resident users to assist with O&M work.

i) All illegal cross connections between storm and sanitary sewers should be avoided.

j) Encroachments on both sides of roads at many places cause hindrances in the maintenance works. Proper arrangements including resettlement of illegal encroachments are required.

APPENDIX - A

SEWER CLEANING EQUIPMENT

INFORMATION ABOUT CLEANING EQUIPMENT

There are three major methods of sewer cleaning: hydraulic, mechanical and chemical. Hydraulic cleaning (also referred to as flushing) refers to any application of water to clean the pipe. Mechanical cleaning uses physical devices to scrape, cut or pull material from the sewer.

Mechanical and hydraulic cleaning of sewers is a cost-effective method of removing material that interferes with the proper operation of the sewer. The objective is to remove all material clinging to the interior surface of the pipe so that the sewer pipe can carry full pipe flow without any restrictions that might result in blockages due to reduced pipe capacity.

A Hydraulic Cleaning

i) High Velocity Cleaners

High-velocity cleaners are very efficient machines that provide the most flexibility with the least personnel required. A high-pressure stream of water is aimed at the surface to be cleaned. High-velocity cleaners can either be truck mounted or trailer mounted; in either case, they are designed as self-contained units for maximum efficiency.

The design of the velocity cleaning machine will vary with different manufacturers but they are essentially the same.

All tools required to route traffic, remove manhole covers and for safety of the job site are carried on the truck, as are the various nozzles and hoses required for proper operation. The removal of debris from the sewer usually requires two operators on the normal high velocity machine.

An enhancement to the high-velocity machine is the addition of a vacuum unit for removal of debris from the manhole. When sand, silt and other material are brought back to the manhole, it can be removed easily with the vacuum unit instead of manually removing it. When a vacuum unit is combined with a high-velocity cleaner on the same vehicle, it is frequently referred to as a combination machine.

Another advantage of larger high velocity cleaners is the availability of root/garbage cutters. This device is basically a flat blade that attaches to the end of the nozzle. Pressure from the high velocity stream of water spins the cutting blade causing it to cut through roots a sit passes through the sewer. With the addition no froot cutters, high velocity cleaners are capable of cleaning every type of debris from a sewer main. High velocity cleaners are the most frequently used equipment for sewer maintenance.

It is important to remove sand and gravel at the nearest downstream manhole as flushing progresses. If it is washed downstream, it can create even greater problems at pumping stations and treatment plants.

There are other devices (balls, kites, bags, parachutes, scooters, etc.) that can be used to improve performance of hydraulic cleaners, particularly in large gravity sewers where high velocity cleaners are not as effective. These devices use water pressure behind the tool to develop hydraulic water pressure and scour the pipe as the tool moves through the pipe.

Generally high velocity cleaners are the most common and efficient method for regular scheduled preventative maintenance.

The high velocity cleaning machines consist of a water supply tank, usually with a capacity of 1000 gallons or more; a high pressure water pump and an auxiliary engine for the operation of the pump. The units have a powered drum reel capable of holding at least 500 feet (150m) of hose, usually one inch (25 mm) in diameter. At the end of the hose, a nozzle is attached, which will create water velocities to do the cleaning.

The machine can be operated by one worker. A worker may need help in order to be notified when the cleaning nozzle has reached the upstream manhole and when the grit and debris are removed from the working manhole. Safety regulations usually require two workers top side when a worker is in the manhole.

Figure 1: High-Velocity Cleaners

Figure 2: results of hi-velocity cleaning of sewer

ii) Balling

This cleaning procedure is one of the least expensive methods and is quite popular in some cities. Usually balling is not the only cleaning method used by a sanitation agency, since the ball primarily removes deposits of inorganic (grit) material on the bottom of the pipe and grease build up inside the pipe. Balling can be used only in areas where the necessary water pressure behind and around the ball can be obtained without flooding homes at low elevations. Flooding can occur when the elevation of the head of water on the upstream side of the ball is higher than the plumbing fixture in a home. If many roots are in the line, a power rodding machine will

probably be needed. Power rodding and other cleaning methods will be discussed in the subsequent sections.

Balling is most commonly used in preventative maintenance programs. Under these conditions, balling is very effective in reducing the possibility of stoppages developing. The main purpose of balling is to keep the sewer clean from debris and to maintain flow velocities of two feet per second (0.61 m/s) or more. An effective balling program can be to reduce the production of hydrogen sulphide gas in collection systems, thus reducing corrosion and reduce odours.

Some sewers require cleaning by balling more frequently than others. Required frequency may vary from six months in some sluggish lines to three to five years in others. These are only typical frequencies. Many communities try to ball their entire collection every year. For the frequency of cleaning, the various sections of a collection system are based on the following:

- The desire to reduce the number and types of stoppages and complaints by analyzing records and inspecting manholes for the presence and amount of debris.
- The size of the area served by the collection system.
- Types of waste carried by the collection system, such as residential commercial or industrial.

Manpower and Equipment

At least three workers are needed for cleaning lines of twelve inches diameter. When cleaning lines located in easements off the street, additional help may be required, depending on the difficulties of the job.

Basic equipment requirements include:

- Water truck holding1,000 or 2,000 gallons.
- Tag line and a suitable reel to store it on.
- Manhole jack or roller.
- Plugs.
- Balls. These are available in sizes up to 48 inches (1200mm) for trunk lines.
- Equipment truck.
- Debris and grit trailer.
- Ladder.
- Manhole bars or hooks.
- Buckets, rope and manhole shovel.
- Hip boots and gloves.
- Waterless hand cleaner and hand towels.

Safety equipment

In some instances, water will be obtained from a fire hydrant to provide the necessary head for a balling operation. In all cases before using a fire hydrant, check the hydrant usage map and contact the agency water department. If fire hydrants are used, the following additional equipment will be needed:

- Two to two fifty meter lengths of 8.5 mm dia. fire hose
- Hydrant wrench
- Water meter
- Control valve for regulating flow at manhole
- Traffic ramp to protect hose
- Air gap device

Air gap devices are required to prevent any backflow of wastewater from the manhole into the drinking water supply. The purpose of the air gap device is to provide adequate space above the top of a manhole and the end of the hose from the fire hydrant, so no wastewater will flow out of the manhole, reach the end of the hose and be sucked back up the hose to the water supply from the fire hydrant. Suction conditions could develop, if the water supply pipe near the fire hydrant should rupture and cause a washout or any other rare condition develop that could cause a backflow through the hose.

Advantages The hydraulic action of spinning balls and high velocity water flowing around the ball dislodges debris from pipe walls and create pressure to move debris downstream. Very effective in removing large concentration of sand, grit, rock and grease from sewers.

Limitations Dangerous to use in locations with basement fixtures. There is possibility of flooding dwellings. It cannot be used effectively when sewers have badly offset joints or protruding service connection because the ball can become distorted.

B. Mechanical Cleaning Equipment

Sewers cleaning techniques described in this section rely on a mechanical action to clear the sewer. This cleaning action results from the material in the sewer being removed by the scraping, cutting, pulling or pushing action caused by a mechanical device or machine. Cleaning techniques outlined here include bucket machines, power rodders and hand rods.

i) Rodders

Power rodding machines uses a steel rod to push or pull various cleaning tools through sewers. These machines illustrated in **Figure 3 and 4** and vary in design but are equipped to store either continuous sectional rods in reel type cage in lengths up to approximately 1000 feet (305m).This reel can be rotated to give a turning action at the same time the rod is pushed in or out .Power rodders can be used for the following purposes:

- Routine preventative maintenance;
- Scheduled cleaning of roots, grease deposits and debris accumulations;
- Threading cable for balling equipment, TV inspections and bucket machines;
- Emergency use for clearing stoppages.

Although other clearing methods play an important role in maintaining the collection system, the power rodder can handle stubborn stoppages of roots, grease and debris. The power rodder is not as effective when working with deposits of solids such as sand or gravel because the tools do not have the ability to move the material. The tools are designed to cut or scrape materials from the pipe walls and are most effective on hardened grease and roots. The power rodder is called for when emergency crews cannot clear a stoppage with hand tools. This can be due to the type or size of stoppages or if the stoppage is at a distance too great for hand tools to be effective. After a sewer has been cleaned with the power rodder, it should be cleaned hydraulically to restore the line to full capacity.

Larger mechanical power rodders are equipped with a reel to carry the steel rods and an engine to provide the force to rotate, push and pull the steel rods. Power rodders are available in both truck-mounted and trailer-mounted models and a variety of different engine sizes are available for each type of unit.

Power rodders are usually less expensive than high velocity or combination machines. However, power rodders do involve more setup time than high-velocity cleaners and they normally must have drivable surfaces to operate efficiently. In extreme cases, a trailer-mounted unit can be hauled into off-road situations by using a backhoe to pull it along. Both the power rodder and the high-velocity cleaner must have well trained operators.

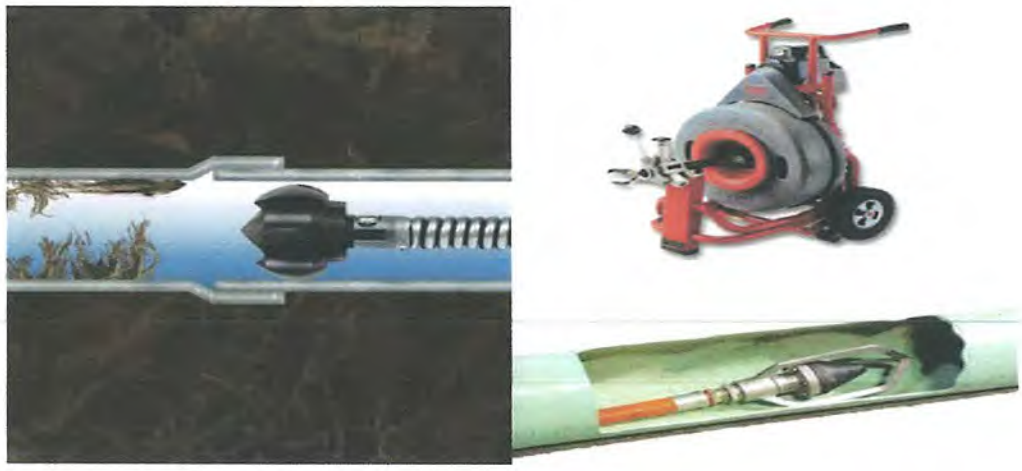


Figure 3: Power Rodders

Figure 4: Power Rodders Tools

Manpower and Equipment

Two workers are required to properly operate the power rodder but three are recommended. One worker performs the operation and an assistant is needed for close observation of the action of the rod and guide hose at the manhole. The third worker is needed to notify the operator when the cleaning tool has reached its destination when it is to be removed or when it has changed to a different tool. If a two worker crew has to enter a manhole, a foreman or someone else must be called to the job site so two workers will be at the entrance of the manhole when the third worker enters the manhole.

Tools and accessories are varied but are basic in design. Many have been developed on the basis of field reports and the industry continues to produce more effective new tools and techniques. The same basic tools are used for either the continuous or sectional power rodder. These tools basically include root saws, square bar augers, spring bade cutters, round or square bar cork screws, pick-up tools and assembly wrenches.

Advantages May be used to clear stubborn blockages of roots, grease and debris. A variety of tools can be attached to the rods.

Limitations Rods can break off inside the sewer line. Evacuation may be required to remove the broken rods. Hydraulic cleaning is generally required following power rodding. Some of the power rodding tools can damage the sewer pipes.

ii) Hand Rodding

The original method called hand rodding is the oldest and most labor intensive method of mechanical cleaning. It is very inexpensive method and provides a very effective method of cleaning in smaller systems and also in remote easements or right of way areas where large equipment cannot gain access.

Despite all of the modem equipment, it is still necessary to have hand rods available. One of the main reasons is that hand rods can be used when and where the modem methods cannot be used effectively. Hand rods are a quick and simple solution for many stoppage problems.

Manpower and Equipment

The particular job will often dictate how many workers will be needed. However, if a crew essentially doing only hand rodding, at least two workers are recommended. A three worker crew is required, if one worker has to enter a manhole. Usually rod crews or "service request" crews consist of two workers and they never enter a manhole unless they are qualified and certified to do so.

Advantages May be used to cut roots, scrape, dislodge and remove certain types of materials found in sewers. This equipment is very effective in removing emergency stoppages.

Limitations: Ineffective for removing sand and grit accumulations but may loosen material can be flushed out of the sewer. Rods have a tendency to coil and bend when used in large diameter sewers.

iii) Power Bucket Machines

Sewers are purposely designed to develop sufficient velocity to provide a self cleaning action and to convey solids through the system to the wastewater treatment plant. When deposition of solids occurs in a sewer, the consideration should be given to hydraulic cleaning methods to remove the solids from the sewer. Hydraulic cleaning techniques are used due to their simplicity, effectiveness and the costs of removing the deposited solids in comparison to other sewer cleaning techniques.

Operating bucket machines is a very labor-intensive process; therefore, power buckets are normally used only for specific cleaning purposes especially removing large amounts of debris from larger sewers.

There are instances however, when the hydraulic techniques are not the best method of removing deposited solids or roots because of the volume, size, weight or type of the material found in the sewer. This material may be concentrated in one area or spread evenly along the line. Types of deposits include silts, sand, gravel or some type of industrial solid waste. The entry of silt, sand, gravel and rocks into the collection system is often traced to some damage done either to the sewer line or manholes or a section where repairs were made to the system. Pipes or man holes may be broken by various construction projects, grade changes of streets, earthquakes or excessive loads from vehicles and heavy equipment. When a pipe breaks, large quantities of debris can enter the collection system.

When there is an indication that a sewer is failing and that sand or mud is entering the sewer, a high velocity cleaner should not be used. Nozzle action develops a negative pressure that can

hasten the collapse of a failing section of pipe. A bucket machine **(Figure 5)** can be used to remove the sand or mud when proper care is exercised. If possible, a television inspection of the pipe should be performed as quickly as possible to determine the cause of the problem and the condition of the pipe before a cleaning method is chosen.

To clean a line after a pipe breaks, the power bucket machine can be used effectively both before and after repair to remove the heavy deposited material. Next, the sewer should be cleaned hydraulically to restore it to full capacity. A damaged line must be repaired to prevent the entry of more material.

Figure 5: Bucket Machine

Manpower and Equipment

Buckets usually range in size from 6 inch (15 cm) to 36 inch (90cm) in diameter and the volumetric capacity of the buckets from 0.13 cubic feet to 8.5 cubic feet.

The bucket machine is usually trailer-mounted but can be truck trailer-mounted also. Bucket machine units must have a pintle safety hook attached to the truck that tows the trailer to the job site. Also a wire cable and shackle should be placed around the truck frame and to the frame on the bucket machine for added safety, in case the pintle hook fails.

The bucket machine units have a steel frame work on which a gas engine and a drum winch is mounted. The drum is coupled to the engine through a controllable drive train, usually a chain and belt drive combination. The drum is capable of holding1,000 feet of one-half inch steel cable and is mounted on the framework in such a position that it can be centered over a manhole. The framework includes a vertical "A" frame of sufficient height to allow the cleaning bucket to be lifted above ground level.

Two machines are needed for this operation and both are basically the same in design. At least one machine will also be equipped with an additional smaller drum capable of holding1,000 feet of one-quarter inch cable. This drum can be operated separately from the one-half inch drum. The purpose is to thread the sewer line from manhole to manhole and the other is to have a suitable cable which can be left in the line overnight. The drum therefore, is often referred to as an overnight drum.

With each bucket machine, equipment will be needed in the manhole to guide the cable into the sewer line without rubbing or cutting into the pipe. At the working machine, use a v-shaped roller of sufficient size to accommodate the size bucket being used. This roller will be held in place by means of a steel pad which in turn, is finally secured flush with the street surface by

two adjustable estabilizer legs on the machine. The companion machine may use the same method or alternately a slant jack can be used in the bottom of the manhole to over.

A variety of tools are available for use with these machines and more are being developed, making the power bucket machines usable for purposes other than bucketing of debris. Root cutters and insertion pullers can be used with bucket machine power winches.

Equipment needed other than that furnished with the bucket machines includes: sand traps, manhole shovel, debris bucket and handline, manhole rover lifter, pipe wrenches and hand tools such as crescent wrenches and pliers.

Safety equipment includes flags, cones, barricades, traffic signs, sewer gas detection equipment, safety harness, rope and other safety devices as the job setup may require.

Experience has shown that many unexpected repairs occur during the clearing operation. Extra cable swivels, cable clamps and other essential accessories should be readily available to make such repairs.

The number of workers needed to effectively conduct the clearing operation will vary but at least three are required and four workers are recommended. If traffic control dictates, flag men will also be needed.

Advantages Removes large amount of sand and debris from large diameter sewers.

Limitations May leave as much debris as it removes.

- Should be followed-up by other methods.
- Can damage sewers.
- Equipment setup is time consuming.

iv) Cable Machines

Variations of bucket machines are cable machines. Cable machines are extremely effective in larger diameter sewers where the other equipment is less effective. They operate similar to bucket machines except a winch is usually truck-mounted. The normal procedure is to pull a cable through the main line sewer from one man hole to the next, attach a cutter, brush or bucket to the cable and pull it back through the sewer to clear any grease, roots, sludge, sand or gravel from the sewer.

There are two types of cable machines. Double-drum machines allow you to operate from one man hole but require a cable to be laid over the ground surface which can cause safety concerns. Single-drum machines require set up at both manholes but all activity takes place below the surface. Cable drag operations are labor intensive and involve the longest set up time to complete the work. However, there are still specialized conditions that make this cleaning operation the best for this particular situation.

C Chemical Cleaning Methods

Several chemicals and application methods are available to kill and retard the regrowth of roots in the wastewater collection system. Methods of application include foaming, dusting and liquid application. Special equipment is required for all three application methods. If the problem is roots alone, chemical treatment is a very cost-effective method of cleaning. Grease can also be cleaned from sewers by the addition of chemicals or by bioaugmentation (addition of bacteria to speed up the breakdown of grease). Various chemicals are available; such as enzymes,

hydroxides, caustics, biocides and neutralizers for removing and/or controlling grease buildups. The effectiveness of a particular chemical depends largely on the exact nature of the problem and site specific circumstances. In most cases, these compounds tend to be an expensive method of treatment if they are applied routinely on an ongoing basis. If the grease is not removed at the source, it can create additional problems downstream at the pumping stations and treatment plants.

Specialized training must be provided for personnel who are at any time involved in the handling and application of chemicals. In addition, proper care must be taken to protect the public and the environment from any of the reaction. Proper ventilating and control of these potentially hazardous gases must be planned. Because of the extreme safety requirements and cost of the chemicals, traditional hydraulic and when applying chemicals for any reason, WASA should always notify the receiving wastewater treatment facility of the type of chemical, quantity used and time of application.

Determinants for Selecting Appropriate Cleaning Equipment

When choosing a technology for cleaning depends on numerous factors, below are some of the main factors to be considered:

- Extent of the problem such as: sewer partially blocked, fully blocked, minor sediment deposition on the sewer bottom, grease along the bottom and sides or root intrusion etc.
- Cause of the problem: Is the cause due to an engineering design flaw or due to material the effluent/ the cleaning material entering the sewer or due to a physical phenomenon.
- The reason for the cleaning: Is for an emergency stoppage or regular preventative maintenance cleaning or due to a complaint.
- Equipment/method best suited for solving the problem.
- Age of sewer pipe.
- Size of sewer pipe.
- Require Cost.
- Availability of equipment/ technology and ease of use.
- Training of staff.

Table1 shows the effectiveness of the solution for the sewer cleaning and blockage problems.

Table 1: Effectiveness of Solution

Solution to Problem	Type of Problem				
	Emergency Storages	Grease	Roots	Sand, Grit, Debris	Goods
Balling[1]		▨		▨	▨
High Velocity Cleaning	▨	▨		▨	▨
Flushing					▨
Sewer Scooters		▨		▨	
Socket Machines Scrapers				▨	
Power Rodders	▨	▨	▨		
Hand Rods	▨[3]	▨	▨		
Chemicals[2]		▨	▨		▨
Bacteria[4]		▨			

1. Kites, tires, bags, parachutes and cones are commonly used instead of
2. Balls in larger sewers (greater than 241nchdiameter with similar results.
3. Effectiveness depends on type of chemical and its intended use.
4. Power rodders and high-velocity cleaners may be faster (if available) under certain conditions.
5. Effectiveness depends on formulation of cultures.
6. The larger the size of the box in the square, the more effective the solution is for a particular problem.

APPENDIX - B

MANHOLE VISUAL INSPECTION AND CLEANING INFORMATION

Manholes and Appurtenances

Because they are part of the collection system, manholes require the same inspection and attention as the rest of sewer network. When located in streets, these structures are subject to vibrations and pounding of vehicle traffic. Manholes may settle at a different rate than connected sewer creating cracks in joints. The objectives of manhole inspection are therefore, to determine the proper elevations or grades around the lid to confirm that the lid is not buried and to examine structural integrity (look for cracks) of the manhole and its functional capacity. The condition of the pipelines coming into a manhole may be known merely by observing the content and volume of flows from a specific direction.

Inspections and Examinations

Manhole inspection and examination are made by visually inspecting the condition of the cover and the internal parts. Manhole inspection should be carried out together with the inspection and examination of sewer. It is generally carried out together with the cleaning of the sewer. Before entering any manhole, adequate safety measures should be taken in accordance with safety measures during the work formulated giving consideration to traffic safety, oxygen deficiency, poisoning due to toxic gas such as hydrogen sulphide and so on.

Manhole

Damage or wear in the manhole cover obstructs passage and is a risk. The facility manager should inspect the manhole cover for damage, wear, play, non-coincidence of heights of cover and road surface, offset of manhole block and so on. Refer to Figure1, Figure 2 and Figure 3.

Figure 1: Wear of cover

Figure 2: Offset of manhole block

Figure 3: Not coinciding with height of rod surface.

Conditions inside Manhole

Manhole is an essential facility for operation and maintenance of sewer pipes. It helps operation and maintenance to be performed safely and easily. For smooth flow of wastewater through the sewer pipe, the following are to be properly inspected: scouring of sewer bottom, differential settlement, manhole block, crack inside wall, sediments and condition of mouth of connected sewer pipe.

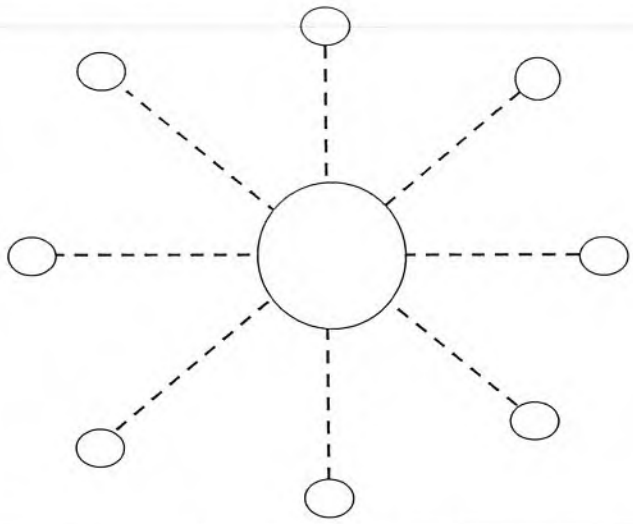
Inspection should be performed on ground, while examination should be performed by the relevant person entering the manhole and working inside. The inspection items and their descriptions are given inTable1 and Table 2 which shows an example of the form for recording inspections.

Table 1: Inspection and examination items for manhole

Item Inspected		Description of Inspection
Exterior condition	Ground surface	a) Check for crack, subsidence and cave in b) Check for overflow stream c) Check for any invaded pavement d) Check surrounding condition
	Manhole cover	a) Visual check for backlash, abraded surface and corrosion (check if any mark on external or internal surface of cover is erased.) b) Check for any malfunction of float preventive function, locking device, fall preventive function, c) etc. Others (damage on rising spacer, difference in grade of cover and grade ring, damaged grade ring, caved in manhole cover, offset, etc.)
Interior condition	Flow and sediment	a) Check for stagnant water or flow. b) Check for any accumulation of sand and soil, pieces of wood and mortar including remains of construction works and illegal disposals. c) Check for appearance of inverts such as scouring, damage, etc.
	Damage	a) Check steps for corrosion, rattling and missing items (no.). b) Check locks for damage, crack, corrosion, gap and deteriorated caulking. c) Check barrel and base or damage, rack and corrosion. d) Check for any improper joint of main sewers and laterals. e) Check for any irregular subsidence.
	Infiltration	a) Check for infiltration.
Others		a) Check inflow for unacceptable or inferior quality. b) Check for toxic gases or odour.

Table 2: Inspection record

Manhole Maintenance	Manhole No.		
Manhole Type	Type No. Specific ( )	Constructed Year	FY (_____)
		Type of Cover	Nodular graphite cast iron (flat, tapered), Gray cast iron, Concrete



Manhole	Fair / Poor
Steps	Total no.
	Fair no. Poor no.
Water depth downstream	cm

No.	Pipe diameter	Type	Depth to base	Condition

Replace cover Month / Year	M / Y /	/	/	/	/	/	/	/	/	/
Cleaning Month / Year	M / Y /	/	/	/	/	/	/	/	/	/
Inspection Month / Year Conditions	M / Y /	/	/	/	/	/	/	/	/	/
	M / Y /	/	/	/	/	/	/	/	/	/

Cover	a) Water, b) Backlash, c) Difference in level, d) Pavement hiding the manhole, e) Damaged, f) Location unknown
Interior	g) Corrosion, h) Damage base, i) Infiltration, j) Corroded steps, k) Inferior pipe joint, l) Rubbish, m) Odour
Sewer	n) Corrosion, o) Damage, p) Coupling displacement, q) Inadequate inclination, r) Infiltration, s) Roots of trees, t) Silt and mortar, u) Road subsidence

Source: JASCOMA, 2007

Cleaning

Manhole cleaning should be performed by the most appropriate work method that suits the actual conditions of the work location. In manholes, at starting point, junction manholes and manholes at sharp curve of sewers, sand and silt get deposited and environmental problems such as foul odours occur. For this reason, periodic cleaning is necessary. Moreover, when large debris flows in, it should be removed immediately otherwise, there is a possibility of an overflow accident, float-off and dispersion of cover. Manhole inspection should be generally carried out together with the cleaning of the sewer. The work on the silt and sand in the bottom part should be pursuant to cleaning of the sewer pipe while the dirt on the side wall should be cleaned by high-pressure jet washing machine.

Rehabilitation

Degradation of functions due to damage should be confirmed and necessary repairs and rehabilitation of the manhole should be carried out.

Manhole repair methods may be classified into watertight construction method, lining method, partial repair method (open-cut method) and manhole cover replacement method.

Before repairs, the objectives of the repairs should be clarified, work conditions studied and items below should be paid attention and then repairs should be carried out.

- If cover is worn out or damaged, it should be replaced immediately.
- If steps are corroded and if they need to be replaced, they should be replaced with corrosion resistant fittings.

If internal parts of manhole and sewer bottom are damaged or worn out, they should be replaced immediately.

APPENDIX - C

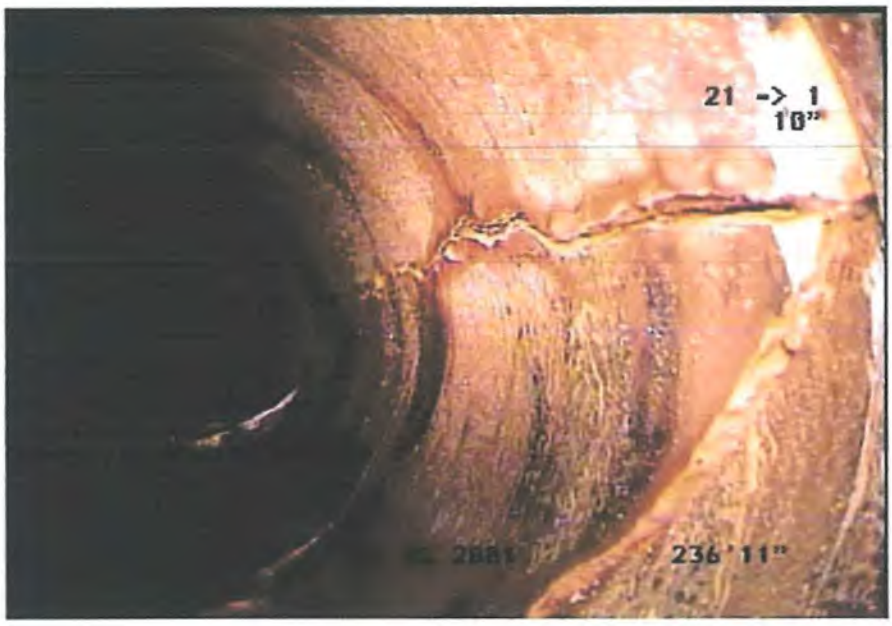
PIPE CONDITION ASSESSMENT (NAASCO STANDARDS)

Crack-Longitudinal (CL)

Distance (Feet)	Video Ref.	Code		Continuous defect	Value				Joint	Circumferential Location	
		Group/ Descriptor	Modifier/ severity		S/M/L	Inches		%		AV From	To
						1st	2nd				
1.5		CL		S01						03	
1.5		CL		S02						09	

EXHIBIT 3-1

Fracture-Longitudinal (FL)



Distance (Feet)	Video Ref.	Code		Continu OLIS defect	Value				Joint	Circumferential Location	
		Group/ Descriptor	Modifier/ severity		S/M/L	Inches		%		At/From	To
						1st	2nd				
236.0		FL								03	

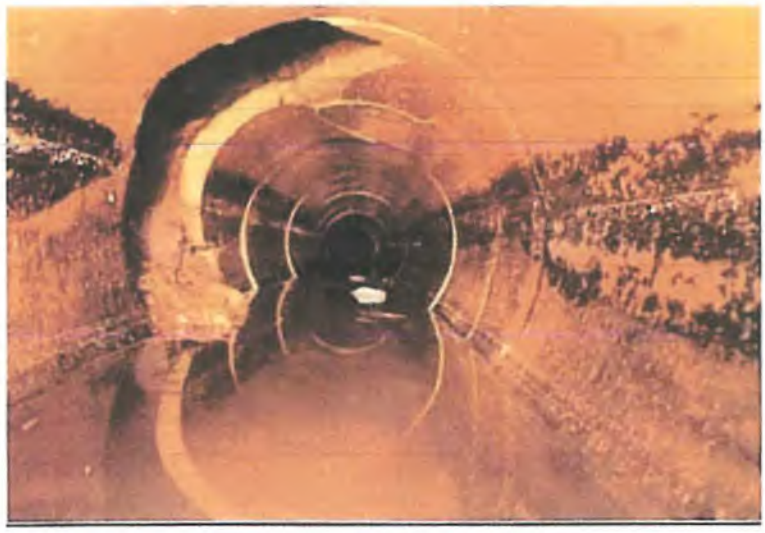
EXHIBIT 3-2

Broken (B)

Distance (Feet)	Video Ref.	Code		Continuous defect	Value				Joint	Circumferential Location	
		Group/ Descriptor	Modifier/ severity		S/M/L	Inches 1st	Inches 2nd	o/o		At / From	To
3.4		B		S01						07	03

EXHIBIT 3-3

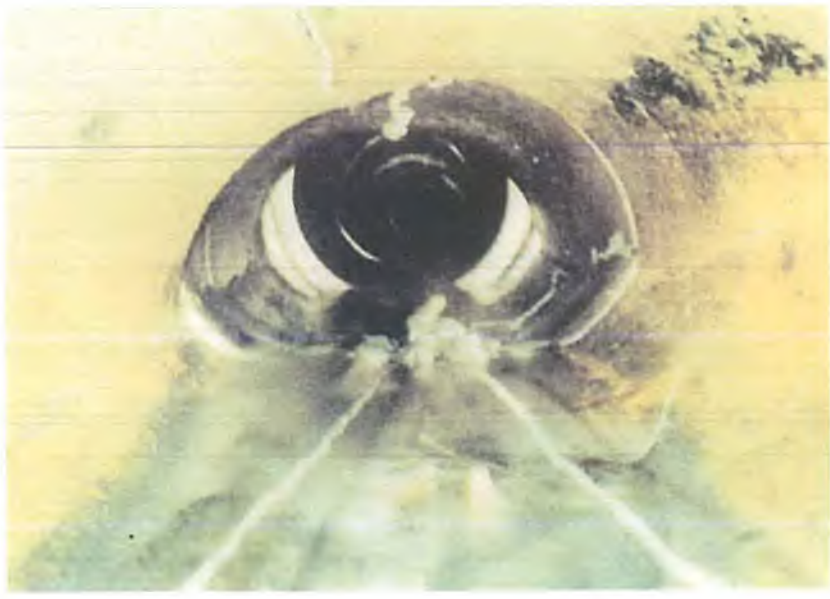
Hole (H)



Distance (Feet)	Video Ref	Code		Continuous defect	Value				Joint	Circumferential Location	
		Group/ Descriptor	Modifier/ Severity		S/M/L	Inches		%		At/From	To
						1st	2nd				
309.4		H	SV							07	12

EXHIBIT 3- 4

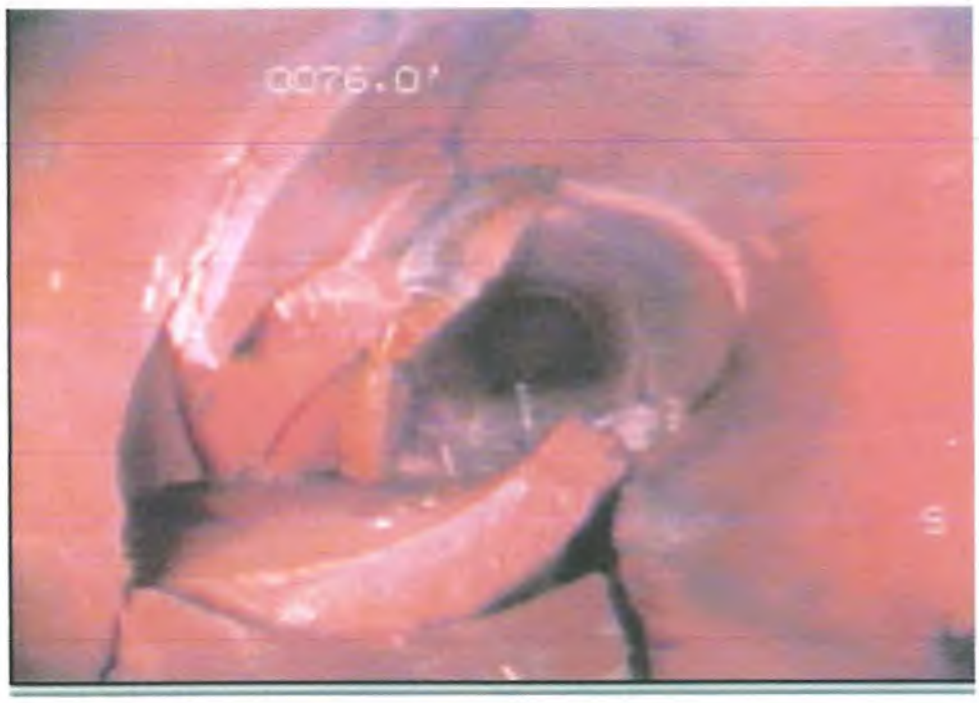
Deformation (D)



Distance (Feet)	Video Ref.	Code		Continu DUS defect	Value				Joint	Circumferential Location	
		Group/ Descriptor	Modifier/ severity		S/M/L	Inches		%		At/From	To
						1st	2nd				
30		D						20			

EXHIBIT 3-5

Collapse Pipe (XP)



Distance (Feet)	Video Ref.	Code		Continuous defect	Value				Joint	Circumferential Location	
		Group/ Descriptor	Modifier/ severity		S/M/L	Inches 1st	Inches 2nd	%		At/From	To
76.0		XP						75			
76.0		MSA									

Note: By definition Collapse means the camera is blocked and the survey abandoned. The survey abandoned code (MSA) will also be used (See Section 8).

EXHIBIT 3-6

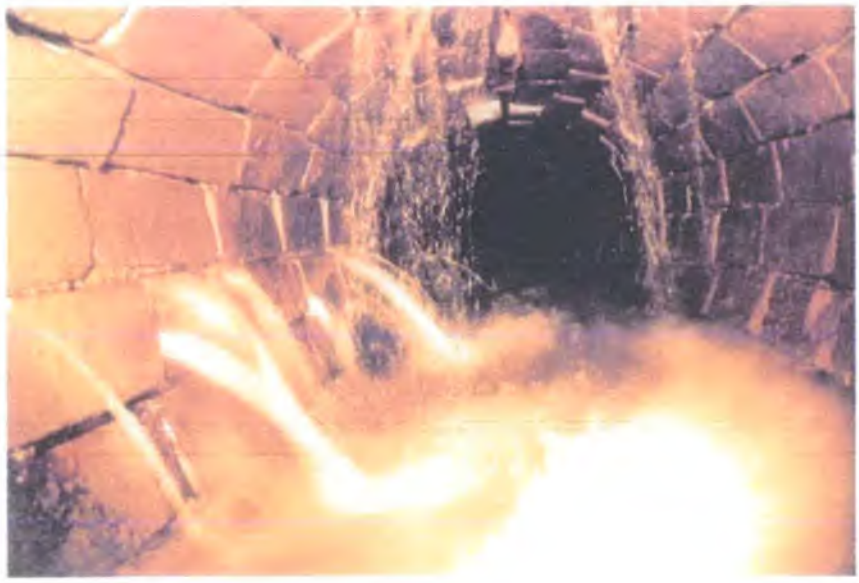
Roots-Medium (RM)

Distance (Feet)	Video Ref.	Code		Continuous defect	Value				Joint	Circumferential Location	
		Group/ Descriptor	Modifier/ severity		S/M/L	Inches		%		All From	To
						tst	2nd				
251.6		RM		S01				20	J	07	: 05

Note: Joint column used as modifier. 50% or less cross sectional area loss means Roots Medium used for coding.

EXHIBIT 3-7

Infiltration Gusher (IG)



Distance (Feet)	Video Ref.	Code		Continuous defect	Value				Joint	Circumferential Location
		Group/ Descriptor	Modifier/ severity		S/M/L	Inches		%		At/From : To
						1st	2nd			
31		IG								08 - 09

Note: Infiltration from 08 to 09 are coded "Gushers"

EXHIBIT 3-8

Other Obstacles (OBZ)

Distance (Feet)	Video Ref.	Code		Continuous defect	Value				Joint	Circumferential Location	
		Group/ Descriptor	Modifier/ severity		S/M/L	Inches		%		At/From	To
						1st	2nd				
99.3		OBZ						45		03	09

EXHIBIT 3-9

APPENDIX - D

PROPOSED SEWER CLEANING EQUIPMENT BROCHURES

TECHNICAL SPECIFICATION FOR
SUPER SUCKER MACHINE -9KL

Vehicle	16 tonner GVW cabin chassis fitted with PTO.
General	The vehicle mounted super sucker unit creating very high vacuum and capable of airlifting of dense water/sludge like mud, slurry, oil, small stones, debris, grit etc. from sewer lines, stormwater drains etc. through vacuum mode. Aspiration of dense waste/sludge from septic tanks, sewer lines, storm water drains, gullies etc. is carried out on the principle of creating high vacuum in the compartment using an exhauster/compressor which can be operated in both vacuum and pressure mode. Blowing of pressurized air/water into the chamber dislodges the sediment solids which combine with the liquefied effluent to form sludge. This is then collected into the tank by operating the system in the vacuum mode.
Construction	The unit shall consist of the following: • Tank • PTO • Suction pump • Safety devices for suction system • Accessories for suction system • Controls • Piping • Accessories • Painting Vehicle Chassis with factor fitted side PTO & Standard Sleeper Cabin
Tank	
Tank capacity	9000 liters
Construction	The Whole tank is made of steel plate of 6-mm thick and will confirm the IS 2062 standard.
	The tank is all MIG continuous welded construction.
	The tank is fitted with 2nos. anti surge baffles to provide dynamic stability to the vehicle when in motion
	A ladder will be provided on the tank for accessibility to the tank top
	Top platform on the tank
	Epoxy paint inside the tank body
	Tank to be mounted with high tensile U bolts.
	Acrylic tubing water level indicator.

	• The tank is mounted on an auxiliary frame of ISMC 150 section and to be adequately strengthens to render it • Torque resistant. The auxiliary frame shall be of an all electrically welded construction.
PTO	Power required for vacuum pump is taken from vehicle's engine through split shaft PTO. Heavy duty full torque split shaft PTO Pneumatic operated controls for PTO engagement and disengagement drive shaft.
Suction pump	
Make	Imported JUROP brand Model PVT 400
Performance	• Max free flow: 2500 m^3/hr at 3300rpm • 1800 at 2500rpm • Flow at 60% : 2010 m^3/hr at 3300 rpm • 1430 m^3/hr at 2500 rpm
Features	• Positive displacement vacuum pump with tri-lobe rotors and lateral injection cooling system. • High vacuum, low noise level, efficient cooling of all the moving parts. • Operating without oil and without wear. • Long life high temperature seals.
Safety devices	
Primary shut off valve	Ball float type primary shut off valve is provided inside the tank to prevent the water entering into the vacuum pump due to overflowing of the tank.
Secondary shut off valve	Cyclone type Ball float type secondary shut off is provided to the inlet of the suction pump to prevent water/slurry entering into the pump.
Strainer	Cleaning filter housing with SS mesh type filter fitted for protection of pump in the pump suction line.
Air Relief valve	Imported Italian make heavy-duty spring type adjustable pressure/vacuum relief valve fitted to safeguard the tank From excess pressure/vacuum creating inside the tank.
Intake cooling filter	Cleaning filter housing with SS mesh type filter fitted for protection of pump.
Exhaust silencer	Cleaning filter housing with SS mesh type filter fitted for protection of pump.
Accessories for suction system	

Tank suction hose	Heavy duty PVC hose 100mm x 15 meters long
Tank suction valve	100mm ball/knife edge gate valve
Discharge valve	100mm ball/knife edge gate valve
Level indicator	Acrylic tubing sludge level indicator
Vacuum gauge	100mm dial gauge
Quick coupler	Imported make quick coupler of sufficient diameter to connect the hose/metal pipes.
Hydraulic system	
Tank tipping	Front telescopic cylinder operated hydraulic tank tipping arrangement.
Rear door	Top hinged type with two side hydraulic cylinders operated rear door for cleaning purpose.
Hydraulic pump	Power required for hydraulic pump is to be taken from vehicle fitted PTO.
Control valve	Two spools, control valve fitted for door and tank tipping controls.
Oil tank	Oil tank with accessories like suction filter, return line filter, oil level gauge etc.
Paint	Two coat of primer Epoxy paint inside the tank. Two coat of synthetic enamel paint.

APPENDIX - E

PIPES IN DESIGN WITH LOW 'SELF CLEANING' VELOCITY

(below 0.6 m/s)

Main Line Pipes with "Self Cleansing Velocity" more than 0.6 m/s

U/S MH	D/S MH	Pipe Name	Primary (P) or Secondary Line (S)	Diameter (D) (m)	Height of Water (H) (m)	Slope (I) (m)	Velocity (V) (m/s)	Pipe Material	Pipe Length (m)
SW1 MH-1a	SW1 MH-1	SW1	M	0.200	0.0813	0.647664	0.64766	HDPE	58.92
SW1 MH-1	SW1 MH-2	SW1	M	0.200	0.0813	0.647664	0.64766	HDPE	33.39
SW1 MH-2	SW1 MH-3	SW1	M	0.200	0.0813	0.647664	0.64766	HDPE	26.00
SW1 MH-3	SW1 MH-4	SW1	M	0.200	0.0813	0.647664	0.64766	HDPE	4.87
SW1 MH-4	SW1 MH-5	SW1	M	0.200	0.0813	0.647664	0.64766	HDPE	48.60
SW1 MH-5	SW1 MH-6	SW1	M	0.200	0.1265	0.776952	0.77695	HDPE	15.07
SW1 MH-6	SW1 MH-7	SW1	M	0.200	0.1265	0.776952	0.77695	HDPE	31.06
SW1 MH-7	SW1 MH-8	SW1	M	0.250	0.1652	0.79049	0.79049	HDPE	61.96
SW1 MH-8	SW1 MH-9	SW1	M	0.250	0.1652	0.79049	0.79049	HDPE	7.08
SW1 MH-9	SW1 MH-10	SW1	M	0.250	0.1905	0.81298	0.79049	HDPE	30.42
SW1 MH-10	SW1 MH-11	SW1	M	0.250	0.1905	0.81298	0.81298	HDPE	29.04
SW1 MH-11	SW1 MH-12	SW1	M	0.250	0.1905	0.81298	0.81298	HDPE	29.62
SW1 MH-12	SW1 MH-13	SW1	M	0.250	0.1905	0.81298	0.81298	HDPE	32.97
SW1 MH-13	SW1 MH-14	SW1	M	0.250	0.1905	0.81298	0.81298	HDPE	30.26
SW1 MH-14	SW1 MH-15	SW1	M	0.250	0.1905	0.81298	0.81298	HDPE	32.24
SW1 MH-15	SW1 MH-16	SW1	M	0.250	0.1905	0.81298	0.81298	HDPE	27.39
SW1 MH-16	SW1 MH-17	SW1	M	0.250	0.1905	0.81298	0.81298	HDPE	56.75
SW1 MH-17	SW1 MH-18	SW1	M	0.300	0.2352	0.664179	0.66418	RCC	34.37
SW1 MH-18	SW1 MH-19	SW1	M	0.300	0.2352	0.664179	0.66418	RCC	31.48
SW1 MH-19	SW1 MH-20	SW1	M	0.300	0.2352	0.664179	0.66418	RCC	50.86
SW1 MH-20	SW1 MH-21	SW1	M	0.400	0.2228	0.654133	0.65413	RCC	25.50
SW1 MH-21	SW1 MH-22	SW1	M	0.400	0.2228	0.654133	0.65413	RCC	32.06
SW1 MH-22	SW1 MH-23	SW1	M	0.400	0.2228	0.654133	0.65413	RCC	32.06
SW1 MH-23	SW1 MH-24	SW1	M	0.400	0.2228	0.654133	0.65413	RCC	32.75
SW1 MH-24	SW1 MH-25	SW1	M	0.400	0.2228	0.654133	0.65413	RCC	9.85
SW1 MH-25	SW1 MH-26	SW1	M	0.400	0.2353	0.667203	0.65413	RCC	61.05
SW1 MH-26	SW1 MH-27	SW1	M	0.400	0.2353	0.667203	0.66720	RCC	25.04
SW1 MH-27	SW1 MH-28	SW1	M	0.400	0.2353	0.667203	0.66720	RCC	5.10
SW1 MH-28	SW1 MH-29	SW1	M	0.400	0.2353	0.667203	0.66720	RCC	63.60
SW1 MH-29	SW1 MH-30	SW1	M	0.400	0.2353	0.667203	0.66720	RCC	27.03
SW1 MH-30	SW1 MH-31	SW1	M	0.400	0.2353	0.667203	0.66720	RCC	33.19
SW1 MH-31	SW1 MH-32	SW1	M	0.400	0.2353	0.667203	0.66720	RCC	30.71
SW1 MH-32	SW1 MH-33	SW1	M	0.400	0.2353	0.667203	0.66720	RCC	56.81
SW1 MH-33	SW1 MH-35	SW1	M	0.400	0.2353	0.667203	0.66720	RCC	40.01
SW1 MH-35	SW1 MH-37	SW1	M	0.400	0.2706	0.695915	0.69591	RCC	71.90
SW1 MH-37	SW1 MH-38	SW1	M	0.400	0.2706	0.695915	0.69591	RCC	14.59
SW1 MH-38	SW1 MH-39	SW1	M	0.400	0.2706	0.695915	0.69591	RCC	28.72
SW1 MH-39	SW1 MH-40	SW1	M	0.400	0.2706	0.695915	0.69591	RCC	62.55
SW1 MH-40	SW1 MH-41	SW1	M	0.400	0.2706	0.695915	0.69591	RCC	32.02
SW1 MH-41	SW1 MH-42	SW1	M	0.400	0.2706	0.695915	0.69591	RCC	28.77
SW1 MH-42	SW1 MH-43	SW1	M	0.400	0.2706	0.695915	0.69591	RCC	3.58
SW1 MH-43	SW1 MH-44	SW1	M	0.400	0.2775	0.70003	0.70003	RCC	63.19
SW1 MH-44	SW1 MH-45	SW1	M	0.400	0.2920	0.707082	0.70708	RCC	29.50

U/S MH	D/S MH	Pipe Name	Primary (P) or Secondary Line (S)	Diameter (D) (m)	Height of Water (H) (m)	Slope (I) (m)	Velocity (V) (m/s)	Pipe Material	Pipe Length (m)
SW1 MH-45	SW1 MH-46	SW1	M	0.400	0.2920	0.707082	0.70708	RCC	61.29
SW1 MH-46	SW1 MH-47	SW1	M	0.450	0.2833	0.712869	0.71287	RCC	30.90
SW1 MH-47	SW1 MH-48	SW1	M	0.450	0.2833	0.712869	0.71287	RCC	29.64
SW1 MH-48	SW1 MH-49	SW1	M	0.450	0.2833	0.712869	0.71287	RCC	60.52
SW1 MH-49	SW1 MH-50	SW1	M	0.450	0.2833	0.712869	0.71287	RCC	29.31
SW1 MH-50	SW1 MH-51	SW1	M	0.450	0.2833	0.712869	0.71287	RCC	31.73
SW1 MH-51	SW1 MH-52	SW1	M	0.450	0.2918	0.719079	0.71908	RCC	41.97
SW1 MH-52	SW1 MH-53	SW1	M	0.450	0.2974	0.722848	0.72285	RCC	22.93
SW1 MH-53	SW1 MH-54	SW1	M	0.450	0.2974	0.722848	0.72285	RCC	27.16
SW1 MH-54	SW1 MH-55	SW1	M	0.450	0.2974	0.722848	0.72285	RCC	34.67
SW1 MH-55	SW1 MH-56	SW1	M	0.450	0.2994	0.724157	0.72416	RCC	28.95
SW1 MH-56	SW1 MH-58	SW1	M	0.450	0.2994	0.724157	0.72416	RCC	38.15
SW1 MH-58	SW1 MH-59	SW1	M	0.450	0.2994	0.724157	0.72416	RCC	54.97
SW1 MH-59	SW1 MH-60	SW1	M	0.450	0.2994	0.724157	0.72416	RCC	31.02
SW1 MH-60	SW1 MH-61	SW1	M	0.450	0.3032	0.7265	0.72416	RCC	19.80
SW1 MH-61	SW1 MH-62	SW1	M	0.450	0.3032	0.7265	0.72650	RCC	11.28
SW1 MH-62	SW1 MH-63	SW1	M	0.450	0.3032	0.7265	0.72650	RCC	29.59
SW1 MH-63	SW1 MH-64	SW1	M	0.450	0.3074	0.72893	0.72893	RCC	63.36
SW1 MH-64	SW1 MH-65	SW1	M	0.450	0.3074	0.72893	0.72893	RCC	29.89
SW1 MH-65	SW1 MH-66	SW1	M	0.450	0.3173	0.734102	0.73410	RCC	34.99
SW1 MH-66	SW1 MH-67	SW1	M	0.450	0.3173	0.734102	0.73410	RCC	27.69
SW1 MH-67	SW1 MH-68	SW1	M	0.450	0.3173	0.734102	0.73410	RCC	54.61
SW1 MH-68	SW1 MH-69	SW1	M	0.450	0.3213	0.735967	0.73597	RCC	15.30
SW1 MH-69	SW1 MH-70	SW1	M	0.450	0.3271	0.738357	0.73597	RCC	49.87
SW1 MH-70	SW1 MH-70A	SW1	M	0.450	0.3271	0.738357	0.73836	RCC	4.05
SW1 MH-70A	SW1 MH-71	SW1	M	0.450	0.3271	0.738357	0.73836	RCC	41.72
SW1 MH-71	SW1 MH-71A	SW1	M	0.450	0.3330	0.740525	0.74053	RCC	29.47
SW1 MH-71A	SW1 MH-72	SW1	M	0.450	0.3330	0.740525	0.74053	RCC	25.78
SW1 MH-72	SW1 MH-72A	SW1	M	0.450	0.3424	0.74327	0.74327	RCC	52.73
SW1 MH-72A	SW1 MH-73	SW1	M	0.450	0.3424	0.74327	0.74327	RCC	35.57
SW1 MH-73	SW1 MH-74	SW1	M	0.450	0.3556	0.745659	0.74566	RCC	15.21
SW1 MH-74	SW1 MH-75	SW1	M	0.450	0.3443	0.769827	0.76983	RCC	52.18
SW1 MH-75	SW1 MH-76	SW1	M	0.450	0.3569	0.77197	0.77197	RCC	30.69
SW1 MH-76	SW1 MH-77	SW1	M	0.450	0.3569	0.77197	0.77197	RCC	59.51
SW1 MH-77	SW1 MH-77A	SW1	M	0.450	0.3515	0.80038	0.80038	RCC	31.07
SW1 MH-77A	SW1 MH-78	SW1	M	0.450	0.3515	0.80038	0.80038	RCC	27.20
SW1 MH-78	SW1 MH-78A	SW1	M	0.450	0.3571	0.801134	0.80113	RCC	31.17
SW1 MH-78A	SW1 MH-79	SW1	M	0.450	0.3472	0.832203	0.83220	RCC	33.86
SW1 MH-79	SW1 MH-80	SW1	M	0.450	0.3472	0.832203	0.83220	RCC	52.00
SW1 MH-80	SW1 MH-82	SW1	M	0.450	0.3472	0.832203	0.83220	RCC	37.00
SW1 MH-82	SW1 MH-83	SW1	M	0.450	0.3472	0.832203	0.83220	RCC	54.77
SW1 MH-83	SW1 MH-85	SW1	M	0.450	0.3472	0.832203	0.83220	RCC	67.59
SW1 MH-85	SW1 MH-86	SW1	M	0.450	0.3472	0.832203	0.83220	RCC	40.49
SW1 MH-86	SW1 MH-87	SW1	M	0.450	0.3522	0.833173	0.83317	RCC	55.89
SW1 MH-87	SW1 MH-88	SW1	M	0.450	0.3522	0.833173	0.83317	RCC	32.23
SW1 MH-88	SW1 MH-89	SW1	M	0.450	0.3522	0.833173	0.83317	RCC	29.94

U/S MH	D/S MH	Pipe Name	Primary (P) or Secondary Line (S)	Diameter (D) (m)	Height of Water (H) (m)	Slope (I) (m)	Velocity (V) (m/s)	Pipe Material	Pipe Length (m)
SW1 MH-89	SW1 MH-90	SW1	M	0.450	0.3522	0.833173	0.83317	RCC	65.02
SW1 MH-90	SW1 MH-91	SW1	M	0.450	0.3522	0.833173	0.83317	RCC	35.00
SW1 MH-91	SW1 MH-92	SW1	M	0.450	0.3522	0.833173	0.83317	RCC	21.64
SW1 MH-92	SW1 MH-93	SW1	M	0.500	0.3845	0.728711	0.72871	RCC	32.48
SW1 MH-93	SW1 MH-94	SW1	M	0.500	0.3845	0.728711	0.72871	RCC	52.16
SW1 MH-94	SW1 MH-95	SW1	M	0.500	0.3845	0.728711	0.72871	RCC	2.71
SW1 MH-95	SW1 MH-96	SW1	M	0.500	0.3845	0.728711	0.72871	RCC	40.74
SW1 MH-96	SW1 MH-97	SW1	M	0.500	0.3899	0.729594	0.72959	RCC	32.47
SW1 MH-97	SW1 MH-98	SW1	M	0.500	0.3899	0.729594	0.72959	RCC	32.92
SW1 MH-98	SW1 MH-99	SW1	M	0.500	0.3899	0.729594	0.72959	RCC	29.31
SW1 MH-99	SW1 MH-100	SW1	M	0.500	0.3899	0.729594	0.72959	RCC	27.15
SW1 MH-100	SW1 MH-101	SW1	M	0.500	0.3899	0.729594	0.72959	RCC	43.47
SW1 MH-101	SW1 MH-102	SW1	M	0.500	0.3899	0.729594	0.72959	RCC	17.86
SW1 MH-102	SW1 MH-103	SW1	M	0.500	0.3928	0.729975	0.72997	RCC	21.31
SW1 MH-103	SW1 MH-104	SW1	M	0.500	0.3928	0.729975	0.72997	RCC	37.02
SW1 MH-104	SW1 MH-105	SW1	M	0.500	0.3928	0.729975	0.72997	RCC	35.73
SW1 MH-105	SW1 MH-106	SW1	M	0.500	0.3928	0.729975	0.72997	RCC	40.60
SW1 MH-106	SW1 MH-107	SW1	M	0.500	0.3928	0.729975	0.72997	RCC	28.67
SW1 MH-107	SW1 MH-108	SW1	M	0.500	0.3928	0.729975	0.72997	RCC	8.36
SW1 MH-108	SW1 MH-109	SW1	M	0.500	0.3928	0.729975	0.72997	RCC	27.72
SW1 MH-109	SW1 MH-110	SW1	M	0.500	0.3928	0.729975	0.72997	RCC	19.34
SW1 MH-110	SW1 MH-111	SW1	M	0.500	0.3928	0.729975	0.72997	RCC	32.66
SW1 MH-111	SW1 MH-112	SW1	M	0.500	0.3928	0.729975	0.72997	RCC	36.02
SW1 MH-112	SW1 MH-113	SW1	M	0.500	0.3928	0.729975	0.72997	RCC	26.06
SW1 MH-113	SW1 MH-114	SW1	M	0.500	0.3928	0.729975	0.72997	RCC	27.61
SW1 MH-114	SW1 MH-115	SW1	M	0.500	0.3928	0.729975	0.72997	RCC	27.45
SW1 MH-115	SW1 MH-116	SW1	M	0.500	0.3928	0.729975	0.72997	RCC	24.78
SW1 MH-116	SW1 MH-117	SW1	M	0.800	0.5186	0.963265	0.96327	RCC	7.64
SW1 MH-117	SW1 MH-117a	SW1	M	0.800	0.5732	0.986599	0.98660	RCC	54.08
SW1 MH-117a	SW1 MH-118	SW1	M	0.800	0.5732	0.986599	0.98660	RCC	40.96
SW1 MH-118	SW1 MH-119	SW1	M	0.800	0.5732	0.986599	0.98660	RCC	17.91
SW1 MH-119	SW1 MH-120	SW1	M	0.800	0.5732	0.986599	0.98660	RCC	44.06
SW1 MH-120	SW1 MH-121	SW1	M	0.800	0.5732	0.986599	0.98660	RCC	12.98
SW1 MH-121	SW1 MH-122	SW1	M	0.800	0.5732	0.986599	0.98660	RCC	14.18
SW1 MH-122	SW1 MH-123	SW1	M	0.800	0.5732	0.986599	0.98660	RCC	18.82
SW1 MH-123	SW1 MH-124	SW1	M	0.800	0.5732	0.986599	0.98660	RCC	12.95
SW1 MH-124	SW1 MH-125	SW1	M	0.800	0.5732	0.986599	0.98660	RCC	39.51
SW1 MH-125	SW1 MH-126	SW1	M	0.800	0.5817	0.989234	0.98923	RCC	24.44
SW1 MH-126	SW1 MH-127	SW1	M	0.800	0.5817	0.989234	0.98923	RCC	10.57
SW1 MH-127	SW1 MH-128	SW1	M	0.800	0.5817	0.989234	0.98923	RCC	40.36
SW1 MH-128	SW1 MH-129	SW1	M	0.800	0.5817	0.989234	0.98923	RCC	44.78
SW1 MH-129	SW1 MH-130	SW1	M	0.800	0.5817	0.989234	0.98923	RCC	6.90
SW1 MH-130	SW1 MH-131	SW1	M	0.800	0.5817	0.989234	0.98923	RCC	49.68
SW1 MH-131	SW1 MH-132	SW1	M	0.800	0.5817	0.989234	0.98923	RCC	18.28
SW1 MH-132	SW1 MH-133	SW1	M	0.800	0.5817	0.989234	0.98923	RCC	26.44
SW1 MH-133	SW1 MH-134	SW1	M	0.800	0.5817	0.989234	0.98923	RCC	19.31

U/S MH	D/S MH	Pipe Name	Primary (P) or Secondary Line (S)	Diameter (D) (m)	Height of Water (H) (m)	Slope (I) (m)	Velocity (V) (m/s)	Pipe Material	Pipe Length (m)
SW1 MH-134	SW1 MH-135	SW1	M	0.800	0.5817	0.989234	0.98923	RCC	26.65
SW1 MH-135	SW1 MH-136	SW1	M	0.800	0.5853	0.990249	0.99025	RCC	31.19
SW1 MH-136	SW1 MH-137	SW1	M	0.800	0.5853	0.990249	0.99025	RCC	11.12
SW1 MH-137	SW1 MH-138	SW1	M	0.800	0.5853	0.990249	0.99025	RCC	15.51
SW1 MH-138	SW1 MH-139	SW1	M	0.800	0.5853	0.990249	0.99025	RCC	32.64
SW1 MH-139	SW1 MH-140	SW1	M	0.800	0.5853	0.990249	0.99025	RCC	8.22
SW1 MH-140	SW1 MH-141	SW1	M	0.800	0.5853	0.990249	0.99025	RCC	23.08
SW1 MH-141	SW1 MH-142	SW1	M	0.800	0.5853	0.990249	0.99025	RCC	28.21
SW1 MH-142	SW1 MH-143	SW1	M	0.800	0.5853	0.990249	0.99025	RCC	16.93
SW1 MH-143	SW1 MH-144	SW1	M	0.800	0.5853	0.990249	0.99025	RCC	47.61
SW1 MH-144	SW1 MH-145	SW1	M	0.800	0.5853	0.990249	0.99025	RCC	1.35
SW1 MH-145	SW1 MH-146	SW1	M	0.800	0.5853	0.990249	0.99025	RCC	10.79
SW1 MH-145	SW1 MH-147	SW1	M	0.800	0.5853	0.990249	0.99025	RCC	49.18
							Total		**4814.26**

Branch Line Pipes with "Self Cleansing Velocity" more than 0.6 m/s

U/S MH	D/S MH	Pipe Name	Primary (P) or Secondary Line (S)	Diameter (D) (m)	Height of Water (H) (m)	Slope (I) (m)	Velocity (V) (m/s)	Pipe Material	Pipe Length (m)
SW19 MH-1	SW19 MH-2	SW19	BL	0.200	0.0804	0.618890	0.61889	HDPE	29.30
SW19 MH-2	SW19 MH-3	SW19	BL	0.200	0.0804	0.618890	0.61889	HDPE	26.09
SW19 MH-3	SW19 MH-4	SW19	BL	0.200	0.0804	0.618890	0.61889	HDPE	15.01
SW19 MH-4	SW19 MH-5	SW19	BL	0.200	0.0804	0.618890	0.61889	HDPE	41.50
SW19 MH-5	SW19 MH-6	SW19	BL	0.200	0.0804	0.618890	0.61889	HDPE	57.70
SW19 MH-6	SW19 MH-7	SW19	BL	0.200	0.0804	0.618890	0.61889	HDPE	32.30
SW19 MH-7	SW19 MH-8	SW19	BL	0.200	0.0804	0.618890	0.61889	HDPE	7.03
SW19 MH-8	SW19 MH-9	SW19	BL	0.200	0.0804	0.618890	0.61889	HDPE	50.30
SW19 MH-9	SW19 MH-10	SW19	BL	0.200	0.0804	0.618890	0.61889	HDPE	47.10
SW19 MH-10	SW19 MH-11	SW19	BL	0.200	0.0804	0.618890	0.61889	HDPE	49.30
SW19 MH-11	SW19 MH-12	SW19	BL	0.200	0.0804	0.618890	0.61889	HDPE	35.70
SW19 MH-12	SW19 MH-13	SW19	BL	0.200	0.0804	0.618890	0.61889	HDPE	6.60
SW19 MH-13	SW19 MH-14	SW19	BL	0.200	0.0804	0.618890	0.61889	HDPE	38.80
SW19 MH-14	SW19 MH-15	SW19	BL	0.200	0.0804	0.618890	0.61889	HDPE	41.90
SW19 MH-15	SW1 MH -37	SW19	BL	0.200	0.0804	0.618890	0.61889	HDPE	20.75
SW20 MH-1	SW20 MH-2	SW20	BL	0.200	0.0777	0.608407	0.60841	HDPE	47.77
SW20 MH-2	SW20 MH-3	SW20	BL	0.200	0.0777	0.608407	0.60841	HDPE	45.23
SW20 MH-3	SW20 MH-4	SW20	BL	0.200	0.0777	0.608407	0.60841	HDPE	44.29
SW20 MH-4	SW1 MH -18	SW20	BL	0.200	0.0777	0.608407	0.60841	HDPE	35.73
SW24 MH-1	SW24 MH-2	SW24	BL	0.200	0.1029	0.624319	0.62432	HDPE	37.88
SW24 MH-2	SW24 MH-3	SW24	BL	0.200	0.1029	0.624319	0.62432	HDPE	30.51
SW24 MH-3	SW24 MH-4	SW24	BL	0.200	0.1029	0.624319	0.62432	HDPE	35.92
SW24 MH-4	SW24 MH-5	SW24	BL	0.200	0.1029	0.624319	0.62432	HDPE	36.60
SW24 MH-5	SW24 MH-6	SW24	BL	0.200	0.1029	0.624319	0.62432	HDPE	13.66
SW24 MH-6	SW24 MH-7	SW24	BL	0.200	0.1029	0.624319	0.62432	HDPE	17.58
SW24 MH-7	SW24 MH-8	SW24	BL	0.200	0.1029	0.624319	0.62432	HDPE	11.35
SW24 MH-8	SW24 MH-9	SW24	BL	0.200	0.1029	0.624319	0.62432	HDPE	26.54
SW24 MH-9	SW24 MH-10	SW24	BL	0.200	0.1029	0.624319	0.62432	HDPE	32.88
SW24 MH-10	SW24 MH-11	SW24	BL	0.200	0.1029	0.624319	0.62432	HDPE	32.82
SW24 MH-11	SW24 MH-12	SW24	BL	0.200	0.1029	0.624319	0.62432	HDPE	33.75
SW24 MH-12	SW1 MH -8	SW24	BL	0.200	0.1029	0.624319	0.62432	HDPE	28.02
							Total		**1009.90**

Branch Line Pipes with "Self Cleansing Velocity" less than 0.6 m/s

U/S MH	D/S MH	Pipe Name	Primary (P) or Secondary Line (S)	Diameter (D) (m)	Height of Water (H) (m)	Slope (I) (m)	Velocity (V) (m/s)	Pipe Material	Pipe Length (m)
SW9 MH-1	SW9 MH-2	SW9	BL	0.200	0.0375	0.461644	0.46164	HDPE	60.00
SW9 MH-2	SW9 MH-3	SW9	BL	0.200	0.0375	0.461644	0.46164	HDPE	40.00
SW9 MH-3	SW9 MH-4	SW9	BL	0.200	0.0375	0.461644	0.46164	HDPE	20.00
SW9 MH-4	SW9 MH-5	SW9	BL	0.200	0.0375	0.461644	0.46164	HDPE	20.00
SW9 MH-5	SW9 MH-6	SW9	BL	0.200	0.0508	0.551742	0.55174	HDPE	40.00
SW9 MH-6	SW9 MH-7	SW9	BL	0.200	0.0508	0.551742	0.55174	HDPE	40.00
SW9 MH-7	SW9 MH-8	SW9	BL	0.200	0.0508	0.551742	0.55174	HDPE	40.00
SW9 MH-8	SW9 MH-9	SW9	BL	0.200	0.0508	0.551742	0.55174	HDPE	1.72
SW9 MH-9	SW9 MH-10	SW9	BL	0.200	0.0508	0.551742	0.55174	HDPE	58.28
SW9 MH-10	SW9 MH-11	SW9	BL	0.200	0.0508	0.551742	0.55174	HDPE	44.63
SW9 MH-11	SW1 MH -93	SW9	BL	0.200	0.0508	0.551742	0.55174	HDPE	47.93
SW10 MH-1	SW10 MH-2	SW10	BL	0.200	0.0160	0.350948	0.35095	HDPE	79.95
SW10 MH-2	SW10 MH-3	SW10	BL	0.200	0.0160	0.350948	0.35095	HDPE	26.25
SW10 MH-3	SW1 MH -79	SW10	BL	0.200	0.0160	0.350948	0.35095	HDPE	44.70
SW11B MH-1	SW11B MH-2	SW11B	BL	0.200	0.0233	0.445415	0.44541	HDPE	40.00
SW11B MH-2	SW11B MH-3	SW11B	BL	0.200	0.0233	0.445415	0.44541	HDPE	38.19
SW11B MH-3	SW11B MH-4	SW11B	BL	0.023	0.0233	0.445415	0.44541	HDPE	40.00
SW11B MH-4	SW1 MH -77A	SW11B	BL	0.023	0.0233	0.445415	0.44541	HDPE	34.29
SW11B MH-5	SW11B MH-6	SW11B	BL	0.023	0.0233	0.445415	0.44541	HDPE	20.00
SW11B MH-6	SW11B MH-7	SW11B	BL	0.023	0.0233	0.445415	0.44541	HDPE	39.88
SW11B MH-7	SW11B MH-8	SW11B	BL	0.023	0.0233	0.445415	0.44541	HDPE	40.01
SW11B MH-8	SW1 MH -77A	SW11B	BL	0.023	0.0233	0.445415	0.44541	HDPE	28.28
SW15 MH-1	SW15 MH-2	SW15	BL	0.200	0.0296	0.516193	0.51619	HDPE	45.10
SW15 MH-2	SW15 MH-3	SW15	BL	0.200	0.0296	0.516193	0.51619	HDPE	31.44
SW15 MH-3	SW15 MH-4	SW15	BL	0.200	0.0296	0.516193	0.51619	HDPE	19.20
SW15 MH-4	SW1 MH -53	SW15	BL	0.200	0.0296	0.516193	0.51619	HDPE	18.11
SW22 MH-1	SW22 MH-2	SW22	BL	0.200	0.0879	0.475477	0.47548	HDPE	45.22
SW22 MH-2	SW22 MH-3	SW22	BL	0.200	0.0879	0.475477	0.47548	HDPE	40.09
SW22 MH-3	SW22 MH-4	SW22	BL	0.200	0.0879	0.475477	0.47548	HDPE	27.93
SW22 MH-4	SW22 MH-5	SW22	BL	0.200	0.0879	0.475477	0.47548	HDPE	39.96
SW22 MH-5	SW22 MH-6	SW22	BL	0.200	0.0879	0.475477	0.47548	HDPE	39.29
SW22 MH-6	SW22 MH-7	SW22	BL	0.200	0.0879	0.475477	0.47548	HDPE	34.70
SW22 MH-7	SW22 MH-8	SW22	BL	0.200	0.0879	0.475477	0.47548	HDPE	27.76
SW22 MH-8	SW22 MH-9	SW22	BL	0.200	0.0879	0.475477	0.47548	HDPE	28.95
SW22 MH-9	SW22 MH-10	SW22	BL	0.200	0.0879	0.475477	0.47548	HDPE	26.46
SW22 MH-10	SW22 MH-11	SW22	BL	0.200	0.0879	0.475477	0.47548	HDPE	27.72
SW22 MH-11	SW22 MH-12	SW22	BL	0.200	0.0879	0.475477	0.47548	HDPE	34.16
SW22 MH-12	SW22 MH-13	SW22	BL	0.200	0.0879	0.475477	0.47548	HDPE	32.71
SW22 MH-13	SW1 MH -6	SW22	BL	0.200	0.0879	0.475477	0.47548	HDPE	34.32
SW22AMH-1	SW22A MH-2	SW22A	BL	0.200	0.0879	0.475477	0.47548	HDPE	45.22
SW22A MH-2	SW22A MH-3	SW22A	BL	0.200	0.0879	0.475477	0.47548	HDPE	40.09
SW22A MH-3	SW22A MH-4	SW22A	BL	0.200	0.0879	0.475477	0.47548	HDPE	27.93
SW22A MH-4	SW22A MH-5	SW22A	BL	0.200	0.0879	0.475477	0.47548	HDPE	39.96
SW22A MH-5	SW22A MH-6	SW22A	BL	0.200	0.0879	0.475477	0.47548	HDPE	39.29
SW22A MH-6	SW22A MH-7	SW22A	BL	0.200	0.0879	0.475477	0.47548	HDPE	34.70
SW22A MH-7	SW22A MH-8	SW22A	BL	0.200	0.0879	0.475477	0.47548	HDPE	26.00
SW22A MH-8	SW22A MH-9	SW22A	BL	0.200	0.0879	0.475477	0.47548	HDPE	28.95
SW22A MH-9	SW22A MH-10	SW22A	BL	0.200	0.0879	0.475477	0.47548	HDPE	26.46
SW22A MH-10	SW22A MH-11	SW22A	BL	0.200	0.0879	0.475477	0.47548	HDPE	27.72
SW22A MH-11	SW22A MH-12	SW22A	BL	0.200	0.0879	0.475477	0.47548	HDPE	34.16
SW22A MH-12	SW22A MH-13	SW22A	BL	0.200	0.0879	0.475477	0.47548	HDPE	32.71
SW22A MH-13	SW1 MH -2	SW22A	BL	0.200	0.0879	0.475477	0.47548	HDPE	34.32
							Total		1834.75