CHAPTER 2

DESIGN OF GRAVITY SEWERS

2.1 General Requirements

2.1.1 Type of System. All sewers shall be designed as separate sanitary sewers. Combined sewers are not permitted in the City and County of Honolulu.

2.1.2 Ordinance Requirements. The discharge of wastewater from industrial or commercial establishments into public sewers shall be in accordance with the requirements of Chapter 14, Articles 1 through 10, Revised Ordinance of Honolulu 1990, as amended. Compliance is required with the provisions in Section 14-1.9, which impose certain restrictions on the quantity, strength and characteristics of industrial wastewater before discharge into public sewers.

2.2 Quantity of Wastewater

2.2.1 Design Population. In general, sewer systems should be designed for the estimated ultimate tributary equivalent population. Chapter 1 Section 1.7 provides the requirement to be considered in establishing the initial and ultimate population for a proposed project.

2.2.2 Design Flows for Sewers. Design flows of existing sewers will be provided by the City. The following factors shall be used in determining the required capacities of new sanitary sewers, and the ability of the existing sewers to accommodate the new capacity.

A. Average Daily Per Capita Wastewater Flow. Sewer systems shall be designed based on 70 gallons per capita per day (gpcd) average wastewater flow, unless other current data has been established by the City.

The per capita wastewater flow is intended to be applied to equivalent populations reflecting typical residential occupancy and wastewater generation rates.

B. Densities for Residential Occupancy. Densities for residential occupancy shall be assumed to be 4 persons per single family home and 2.8 persons per apartment unit, unless other current data has been established by the City. The densities for residential occupancy shall be applied to the projected number of residential dwelling units. Duplex units shall be assumed to be equivalent to two single family homes. Where the proposed number of apartment units is unknown, typical development densities based on zoning as indicated in Section 2.2.2.C may be used.

C. Other Land Use Densities and Wastewater Flows. Other wastewater flows shall be based on land use or best available data, whichever is higher. Consideration shall be given for high wastewater generation capability for particular types of industries such as laundries and food or beverage processing plants.

The following equivalent populations in capita per acre (cpa) shall be considered for the various land uses.

1.	Business Mixed Use-Central (BMX-4)	300 cpa
2.	Business Mixed Use-Community (BMX-3)	200 cpa
3.	Community Business (B-2)	140 cpa
4.	Neighborhood Business (B-1)	40 cpa
5.	Resort	400 cpa
6.	Apartment Mixed Use-High Density (AMX-3)	450 cpa
7.	High Density Apartment (A-3)	250 cpa
8.	Apartment Mixed Use-Medium Density (AMX-2)	310 cpa
9.	Medium Density Apartment (A-2)	170 cpa
10.	Apartment Mixed use-Low Density (AMX-1)	130 cpa
11.	Low Density Apartment (A-1)	90 cpa
12.	General Industry (I-1, I-2)	100 cpa
13.	Waterfront Industry (I-3)	100 cpa
14.	Industrial Mixed Use District (IMX-1)	100 cpa

Equivalent population for major facilities such as schools and institutions and for special industries or laundries shall be based on available information and accepted industry standards.

D. Base Sanitary Flow (BSF). The portion of wastewater which includes domestic, commercial, institutional and industrial sewage and specifically excludes infiltration and inflow.

Base sanitary flow for various sources is calculated by multiplying the average daily per capita wastewater flow as specified in Subsection 2.2.2.A by the equivalent population.

E. Peak Base Sanitary Flow (PBSF). The peak base sanitary flow is obtained by multiplying the average wastewater flow by a flow factor. In the design of new sewers, a flow factor of 2.5 shall be used to obtain the maximum rate of wastewater flows. Special considerations as noted in Subsection 2.2.2.K may be considered.

Peak Base Sanitary flows from existing service areas that impact new sewer lines shall be furnished by the City.

F. Average Dry Weather Flow (ADWF). The average dry weather flow is the sum of the base sanitary flow and the groundwater infiltration rate

G. Groundwater Infiltration (GWI). The groundwater infiltration rate shall be 35 gallons per capita per day (gpcd) which was based on the average of the low nighttime flows per day for the same period as the ADWF, minus significant industrial or commercial nighttime flows.

H. Peak Dry Weather Flow (PDWF). The peak dry weather flow is the sum of the Peak Base Sanitary flow and the Groundwater Infiltration.

I. Wet weather Infiltration/Inflow (I/I). The wet weather I/I peak hourly rate shall be 3,000 gallons per acre per day (gpad).

For parks, golf courses, and similar parcels with wastewater generating facilities which occupy only a small percentage of the total parcel, the entire parcel area shall not be used to calculate the wet weather I/I. The area used to calculate the wet weather I/I may be based on 25 feet on either side of the branch sewer line or lateral within the parcel. This method of calculating wet weather I/I shall not be applicable to resorts and other higher density developments unless other appropriate methods to calculate peak flow, such as those described in Section 2.2.2.K, are used and reviewed by the City for approval.

J. Design Flow (Q_{DES}). The design flow of wastewater is the sum of the peak dry weather flow and wet weather I/I described above.

K. Special Considerations. Where appropriate for high density developments, other methods of peak flow computation, including the applicable requirements of the latest City Plumbing Code, should be considered for sizing of service laterals and nearby downstream sewers. These developments include high-rise buildings where maximum day factors may be higher and wet weather I/I factors may be lower. In such cases, consideration should be given to flows developed based on an analysis of fixture units. Special consideration should also be given to commercial and industrial discharges that may exhibit case-specific peaking factors and peak flow discharges.

Consideration shall also be given to the peak pumping rate of a wastewater pump station discharging to a service lateral or sewer.

Short-term peak flows such as those from high-rise buildings and wastewater pump stations with short pumping cycles will tend to be rapidly dampened in gravity sewers. The Design Engineer shall be responsible for assessing the nature of the flows to ensure adequate sewer capacity is provided.

L. Organization of Computation. Figure 2-1 shows the format for tabulating the results of computations for the design of sewers that shall be included in the Engineering Report submitted to the City for review.

The tabulated results are primarily intended to reflect "dampened" flows in a large tributary area. Separate calculations shall be performed for determination of design flows associated with discharges from high rises, wastewater pump stations and other sources for which actual localized upstream flows may be higher than those shown in the table.

2.2.3 Design Flows for Existing Sewers. Design flows used in the analysis of existing sewers to determine their adequacy for additional flows will be provided by the City.

2.3 Hydraulics of Gravity Sewers

All new gravity sewers shall be designed to carry the peak flow of wastewater such that 85 percent of the pipe's full flow capacity is not exceeded and to transport suspended solids in such a manner that deposits in sewers and odor nuisances are kept to a minimum.

2.3.1 Formula and "n" roughness coefficient values. All gravity sewer design shall be based on the Manning formula:

$$V = \frac{1.486}{n} r^{2/3} s^{1/2}$$

where,

V = velocity in feet per second
n = roughness coefficient, dimensionless
r = hydraulic radius in feet
s = slope of the line, feet per feet.

A minimum "n" roughness coefficient value of 0.013 shall be used for all pipes, except as noted below for rehabilitated pipes.

Lower "n" values will be permitted for rehabilitated sewers based on the City's review and approval of submitted laboratory or field testing data. The minimum allowable "n" value shall be 0.011.

Capacities shall be based on available information on the inside diameter of the sewer line. When calculating the capacity for lined pipes, the liner thickness shall be accounted for when determining the actual inside diameter of the pipe.

COMPUTATION OF WASTEWATER FLOW (SAMPLE)

Revised (7/17)

SEWER:
DISTRICT:
REFERENCE MAPS:

PAGE:
COMPUTED BY:
DATE:

SEWER LOCATION		TRIBUTARY AREA (ACRES)		TRIBUTARY EQUIVALENT POPULATION								WASTEWATER FLOW COMPUTATION									( ) Existing Sewer Study ( ) Ultimate Sewer Study				
				RESIDENTIAL				OTHER		TOTAL															
				Homes		Apartment																			
District Zone or Street	Point	Increment	Total	Increment	Total	Increment	Total	Increment	Total	Increment	Total	Base Sanitary Flow - BSF @ ____ gpcd (MGD)	Flow Factor	Peak Base Sanitary Flow - PBSF MGD)	Ground Water Infiltration - GWI @ ____ gpcd (MGD)	Average Dry Weather Flow - ADWF (MGD)	Peak Dry Weather Flow – PDWF (MGD)	Area used for Wet Weather I/I Calculation	Wet Weather I/I @ ____ goad (MGD)	Design Flow – Q_{DES} (MGD)	Pipe Diameter (in)	Slope (%)	Velocity at Full Pipe – V_{FULL} (fps)	Full Pipe Flow – Q_{FULL} (MGD)	Design Flow – Q_{DES} (MGD) / Full Pipe Flow – Q_{FULL} (MGD)	Velocity at Design Flow – V_{DES} (fps)

Remarks:

Figure 2-1

2.3.2 Minimum Velocities and Slope. Gravity sewers from 8-inches to 18-inches in diameter shall be designed to provide mean velocities of not less than 2.5 feet per second when the line is flowing full. All sewer lines larger than 18-inches in diameter shall have a minimum slope of 0.0016.

Minimum allowable slopes are as follows:

DIAMETER (inches)	MINIMUM SLOPE (feet per feet)
8 (upstream terminal)	0.0100
8	0.0052
10	0.0039
12	0.0031
16	0.0021
18	0.0018
>18	0.0016

To promote adequate scouring velocities, sewers at the upstream terminal end that are not planned to be extended within the next five years and have adequate cover, shall have a minimum slope of one percent until the equivalent population contributing to the line is greater than 40 people. Deviations from this requirement will be considered by the City on a case-by-case basis with the understanding that the Design Engineer is required to provide adequate scouring velocity at average flow in the design of new sewers.

Where the minimum slope provides adequate capacity for the design peak flow, upsizing the pipe for the purpose of reducing the slope to reduce construction costs shall not be permitted. The use of steeper sewer slopes in lieu of flat sewer slopes with a downstream drop manhole is encouraged to achieve favorable scouring velocities.

2.3.3 Maximum Velocity. The maximum velocity generally permitted is 10 feet per second. Where velocities greater than 10 feet per second are unavoidable, special provisions shall be made to protect the conduit and appurtenances against erosion and displacement by shock. Design of sewers with velocities greater than 10 feet per second shall be reviewed by the City for approval on a case-by-case basis.

2.4 General Requirements for Gravity Sewer Systems

2.4.1 Minimum Size. The minimum pipe sizes permitted for gravity sewers are as follows.

A. 8-inch diameter for mains and branch mains.

B. 6-inch diameter for lateral sewers.

2.4.2 Alignment and Grades. Sewers less than 36-inches in diameter shall be laid with constant grades and straight alignment between manholes. Curvilinear alignment of sewers 36-inches and larger in diameter shall be reviewed by the City for approval on a case-by-case basis.

No inverted siphons shall be allowed on new sewer mains.

2.4.3 Depth of Sewers. In general, sewers should be designed with sufficient depth to serve all properties within the tributary area. All properties that are not able to be served by gravity flow due to insufficient sewer depth shall be identified on the plans as requiring pumping into the gravity sewer.

Depth is defined as the vertical distance between the finished grade and the invert of the pipe. For sewers with depths greater than 15 feet, the proposed depth shall be reviewed by the City for approval based on the type and strength of pipe, pipe protection, bedding condition, soil and loading conditions, and other factors, along with supporting calculations prepared by the Design Engineer. Evaluation by the City shall consider accessibility for maintenance and repair operations.

2.4.4 Minimum Cover over Gravity Sewers. Cover is defined as the vertical distance from the finished grade to the top of the pipe. The minimum cover over all gravity sewers shall be 4.0 feet. Sewers with less than 4.0 feet cover shall be reviewed by the City for approval on a case-by-case basis.

2.4.5 Easement Widths and Access. Wherever possible, sewers shall be laid within the City's right-of-way. Sewers shall be centered within the easement, unless otherwise approved. Where new easements are necessary, the minimum widths shall be as follows:

A. Lateral and Branch Sewers: 15 feet for 6-inch and 8-inch diameter pipes.

B. Trunk and Interceptor Sewers:

1. 15 feet: 8-inch to 16-inch diameter pipes

2. 25 feet: Pipes larger than 16-inch diameter

C. Variations. The minimum widths of easements specified in Sections 2.4.5.A and 2.4.5.B may be modified by the City when unusual conditions exist. Wider easements may be required depending upon the sewer size and depth, terrain, and soil conditions.

D. Access. Easements for new sewers shall be configured and designed to allow for access by sewer cleaning and excavation equipment appropriate for the size and depth of sewers. All manholes located in easements shall be accessible by maintenance vehicles via a paved all weather access road. A gravel road designed to allow access during heavy rainfall may be acceptable and shall be reviewed by the City for approval on a case-by-case basis.

2.4.6 Manhole Location and Spacing. Manholes shall be installed at the ends of each sewer main segment, at all changes in pipe grade, size, or alignment and at all points where sewer mains intersect. Manhole locations subject to inundation and flooding shall be avoided. These locations include gutter flow areas that may extend into the pavement, and identifiable sump conditions based on topography. Manhole covers shall not be in the wheel path of the motor vehicle travel way where possible. Manhole covers shall not be located in concrete bus pads, and to the extent possible, in other concrete pavement. When manhole spacing is not controlled by the preceding limitations, the manholes shall be spaced as equally as possible, but not at a distance greater than that described below.

A. 350 feet – pipes up to and including 36-inches in diameter in roadways.

B. 250 feet – pipes up to and including 18-inches in diameter in non-roadway areas.

C. 350 feet – pipes larger than 18-inches and up to and including 36-inches in diameter in non-roadway areas.

D. 600 feet – pipes larger than 36-inches in diameter.

2.4.7 Drop Manhole and Shallow Drop Manholes. A drop manhole or shallow drop manhole shall be provided in accordance with Paragraph 2.6.3 where a sewer enters a manhole at a height of 18 inches or more above the manhole invert, or where a smooth grade transition cannot be accomplished within the manhole.

2.4.8 Sewer Laterals. Each lot shall be provided with its own lateral connection to the sewer main. Use of wye connections for laterals from two properties are no longer allowed and are prohibited. All laterals shall be installed as required below and as shown on the Standard Details.

- Laterals are to have a minimum 2 percent slope and not to exceed 100 feet in length.

- Direct lateral connection is allowed only to sewer lines up to 16-inches in diameter. Manholes shall be used for connections to lines larger than 16-inches in diameter and laterals greater than 6-inches.

- Smaller and shallower lines shall generally be used to service multiple laterals and flows should be discharged to main sewer lines at manholes.

- Laterals are to be provided with wye fittings for connection to new sewer mains. Saddles may be used for connection to existing sewer mains. All lateral connections at the sewer main shall be adequately supported to prevent structural damage to the fittings and saddles.

- To the extent possible, laterals shall be aligned perpendicular to the sewer main with a 1/8 bend right before connecting to the sewer main.

- Each lateral shall be provided with a 6-inch cleanout on the private property side of the property line, as close to the property line as reasonably possible, but not more than 5 feet from the property line as shown on the Standard Details. For laterals less than 6-feet deep, the Advanced Riser Detail may be used where feasible. The cleanout shall be accessible at all times for maintenance. A manhole may be provided in lieu of a cleanout for laterals greater than 6-inches in diameter.

When a new lateral is installed for a property, all abandoned laterals associated with the property shall be cut and plugged at the sewer line connection or removed. Abandoned laterals shall also include those laterals previously abandoned by others.

2.4.9 Chimneys. Chimneys shall not be allowed.

2.4.10 Advance Risers. Advance riser connections shall be provided for new lateral sewers 6 feet or deeper as measured from the ground surface at the property line. The advance riser shall be constructed as shown on the Standard Details. A 6-inch cleanout shall be installed at the top of the advance riser as part of the private property lateral connection work.

2.4.11 Protection of Water System.

A. Water Supply Interconnections. There shall be no physical connection between a sewer and public or private potable water supply system, non-potable water system, recycled water system, or appurtenances thereof.

B. Relation to Water Works Structures. While no general statement can be made to cover all conditions, it is generally recognized that sewers shall

be kept remote from any public water supply wells or other water supply sources and structures.

2.4.12 Clearance Requirements and Protection of Sewers and Utilities.

A. Minimum Clearance Requirements. Sewer lines shall not be laid in the same trench as other utilities. The following table includes the minimum horizontal and vertical clearances between the sewer main and other utilities.

Sewer Main Clearances		
Utility	Minimum Clearances[1]	
	Horizontal (feet)[2]	Vertical (inches)
Sewer line located above water line[3]	3	12
Sewer line located below water[4]	3	18
Non-water utility[5]	3	24
Utility pole, support, or guy wire	5	Not allowed
Non-sewer utility structure (Typical structures include manholes, meter and valve boxes, pull boxes, storm drain catch basins and vaults)	3	Not allowed

[1] The dimensions are measured from the nearest face of the sewer line to the nearest face of the other utility or concrete jacket.

[2] Sewer mains proposed to be located less than the minimum horizontal clearance from other utilities shall be reviewed and approved by the City and utility companies.

[3] All sewer mains crossing over a water line shall be jacketed with a reinforced concrete jacket. Vertical clearance in the table is measured from the nearest surface of either concrete jacket

[4] All sewer mains crossing under a water line shall be jacketed with a reinforced concrete jacket if less than the vertical clearance in the table and conform to a minimum of 6-inches from concrete jacket faces.

[5] Sewer lines located less than 24 inches vertically from non-water utilities shall be jacketed with a reinforced concrete jacket.

Clearance and other requirements that may be imposed by the specific utilities shall also be considered. The more stringent requirement shall generally govern. Deviations from any clearance requirements shall be brought to the attention of the respective utilities, and the necessary approvals and/or special design or construction requirements shall be incorporated into the contract documents prior to construction.

Utilities shall not be located within 12 inches of sewer manholes. Concrete thrust blocks for water lines shall not place any pressure on sewer pipes or manholes.

B. Concrete Jackets. For sewer mains where the minimum vertical clearance between the sewer main and other utility cannot be met, or where the minimum depth of cover from finished grade to the top of pipe is less than 4 feet, the sewer line shall be jacketed with reinforced concrete as shown on the Standard Details. The concrete jacket lengths shall be as follows:

1. Sewer main located above other utility: Minimum 5 feet beyond the other utility, from the outside face on both sides of the point of crossing.

2. Sewer main located below other utility: Minimum 3 feet beyond the other utility, from the outside face on both sides of the point of crossing.

The concrete jacket shall begin and terminate at bell ends of the sewer pipe to facilitate replacement of the pipe outside of the jacket. A minimum 6 inch clearance shall be provided from the nearest face of the concrete jacket to the nearest face of the crossing utility or non-sewer structure. When recommending the use of concrete jackets, the ability for the subgrade to bear the weight of the concrete jacket shall be considered.

C. Alignment. Sewer lines shall cross other utilities as close to perpendicular as possible. Skew angles of less than 75 degrees shall be avoided.

2.4.13 Root Intrusion. Sewers and laterals shall not be installed within the anticipated drip line of trees and shrubs at full maturity. The sewer joints located up to 5 feet beyond the anticipated drip line of trees and shrubs at full maturity shall be wrapped with a geotextile fabric with herbicide per Standard Detail and Standard Specification to help prevent roots from entering the pipe joints. The anticipated spread of trees and shrubs at full maturity shall be indicated on the plans.

2.4.14 Redundant Facilities. When directed by the City, the design shall consider alternatives to control spills or overflows, including the installation of control structures to be used during emergencies for flow diversion.

2.5 Gravity Sewer Requirements

2.5.1 Pipes. Pipe materials shall be appropriate for specific local conditions such as septic or industrial wastewaters which are corrosive, high temperature discharges, poor soil characteristics, high external loadings, abrasive solids, and high water table conditions.

All sewers shall safely carry all superimposed loads. Proper allowance for loads on the sewer shall be provided based on the width and depth of the trench.

The following materials have been accepted and approved by the City for use in open trench pipe construction of gravity sewers system within the limitations described above.

A. Vitrified Clay Sewer Pipe (VCP), ASTM C-700, Extra Strength. Use only for gravity lines from 6-inches to 24-inches in diameter.

B. Polyvinyl chloride (PVC) Plastic Pipe. AWWA C-900 and C-905, minimum DR 18. Use only for gravity sewer lines from 6-inches to 30-inches in diameter.

C. Fusible Polyvinyl Chloride (FPVC). AWWA C-900 and C-905, DR 18. Use only for gravity sewer lines from 8-inches to 30-inches in diameter.

D. Glass Fiber Reinforced Polymer Mortar Pipe (RPMP). ASTM D-3262. Use only for gravity sewer lines in sizes from 18-inches to 60-inches in diameter.

E. Polymer Concrete Pipe (PCP). ASTM D-6783. Use only for gravity lines in sizes from 18-inches to 60-inches in diameter.

The allowable pipe diameters for the acceptable (✓) pipe materials are summarized in the table below.

Nominal Pipe Diameter, (inch)	Vitrified Clay Pipe (VCP)	Polyvinyl Chloride Pipe (PVC)	Fusible PVC (FPVC)	Glass Fiber Reinforced Polymer Mortar Pipe (RPMP)	Polymer Concrete Pipe (PCP)
6*	✓	✓	-	-	-
8	✓	✓	✓	-	-
12	✓	✓	✓	-	-
15**	✓	-	-	-	-
16	-	✓	✓	-	-
18	✓	✓	✓	✓	✓
21**	✓	-	-	✓	✓
24	✓	✓	✓	✓	✓
27**	✓	-	-	✓	✓
30	-	✓	✓	✓	✓
36	-	-	-	✓	✓
42	-	-	-	✓	✓
48	-	-	-	✓	✓
54	-	-	-	✓	✓
60	-	-	-	✓	✓

* Laterals only

** Must provide justification for special use

The same nominal diameter pipe shall be used for point repairs on existing sewers that are of diameters not shown in the table above (i.e. 10-inch). For such cases, use of ASTM D3034 PVC SDR 26 pipe will be allowed on a case-by-case basis as approved by the City. Use of a different pipe size with reducers is not allowed.

2.5.2 Joints. All joints shall be designed such that no visible infiltration or exfiltration is observed during post-construction inspection. All joint gasket materials shall be suitable for sewer service and exposure to fats, oils, and grease. All joints within easements or located within 5 feet of the anticipated drip line of the trees and shrubs shall be wrapped with geotextile root barrier.

A. PVC pipe. PVC pipes shall have elastomeric-gasket type joints compatible with AWWA C-900 and C-905 pipes. The pipe shall not be deflected at the pipe joints.

B. Flexible gasketed joints shall be used for rigid gravity sewers such as vitrified clay, reinforced polymer mortar, and polymer concrete pipes.

C. Fusible PVC pipe. Joining pipe sections in fusible PVC pipe shall be made using butt-fusion equipment designed for the specific purpose of permanently connecting PVC C-900 and C-905 pipes.

2.5.3 Corrosion Protection. All pipes shall be of corrosion-resistant material, suitable for sewer service without internal linings or coatings. All pipes shall be resistant to any external corrosion.

2.5.4 Structural Considerations and Trench Design

A. Loads Imposed by Other Utilities. Sewer lines which cross under other conduits and utilities shall be protected from extra loading as prescribed under Subsection 2.4.12. The City shall reserve the right to increase the factor of safety where determined to be justified by the City.

B. Other Imposed Loads. Consideration shall be given to all imposed loads (vehicles, retaining walls, drainage structures, building foundations, etc.) on the sewer pipes. The City shall review and approve of such conditions.

C Loads and Other Impacts Caused by Ground Movement. New sewers shall not be constructed in areas subject to significant ground movement, such as unstable hillside areas. Special design consideration shall be given to any required reconstructed sewer located in a hillside and that has experienced significant ground movement. Use of high-strength pipe, high deflection couplings, and flexible pipe shall be considered. Installation of sewer trench drains to reduce hydrostatic pressure and the risk of slope failure shall be considered and provided as recommended based on a slope stability analysis. Slope stability analyses shall be performed by the Geotechnical Engineer.

D. Geotechnical Investigations and General Trench Design. Soil conditions shall be evaluated by the Geotechnical Engineer based on analysis of available information and data obtained from borings and/or test pits. Design of the trench section, including materials selection, trench details, and installation and testing requirements shall be developed based on input from the Geotechnical Engineer. The City may permit the Design Engineer to design the trench section without the services of a Geotechnical Engineer in certain situations, such as for projects with lines less than 18 inches in diameter and shorter than 300 feet in length and where soil conditions are known to be stable based on previous soil reports for the area.

E. Pipe Foundation and Sub-bedding. Soil conditions shall be evaluated to identify the presence of unstable soils and special foundation requirements to minimize differential settlement. Appropriate measures shall be implemented to reduce the potential for pipe movement or settlement during construction and longer term differential settlement.

Where unstable soil conditions are identified by geotechnical investigations, the underlying unstable soils shall be replaced with crushed rock sub-bedding or stabilized by other approved ground improvement or

pipeline support methods to provide a suitable foundation. The determination of the depth of unstable soils to be removed shall be based on recommendations of the Geotechnical Engineer. The pipe sub-bedding shall be defined as the zone between the depth to which all unstable materials have been removed and the bottom of the pipe bedding material.

More extensive foundation improvement methods that may be applicable include ground stabilization technologies such as jet grouting, and driven or drilled shaft piles. Consideration should be given to potential differing rates of settlement for new and existing pipes with different foundation designs.

F. Pipe Bedding. The pipe bedding shall be defined as the zone between the bottom of the trench (or top of the sub-bedding) and the top of the bedding material above the pipe.

The details of the bedding material and installation shall conform to the Standard Specifications and Standard Details, unless modified by the Geotechnical Engineer and approved by the Design Engineer for inclusion in the Special Provisions.

The bedding material shall fully encase the pipe as shown on the Standard Details. Unless otherwise approved, granular bedding material shall consist of crushed basaltic rock conforming to ASTM D-448, No. 67 size. The granular bedding shall be used to help ensure that adequate densification and critical pipe support with full contact with the pipe periphery can be achieved with hand shoveling and hand tamping.

Controlled low strength material (CLSM) described in Section 2.5.4 shall be used in lieu of crushed rock pipe bedding for vitrified clay pipe to provide a higher level of pipe support.

When the pipe is located below the water table, the CLSM bedding shall be installed in a dewatered trench. Plain concrete shall not be used for pipe cradles and bedding material.

When sewer pipe beddings are compromised due to trenching of other utilities below sewer pipes, the sewer pipes shall be supported in a manner approved by the City. Backfill shall be CLSM unless otherwise justified.

For pipe construction over rock, proper bedding shall be provided to prevent point loads on the pipe.

G. Geotextile Fabric. Woven geotextile fabric shall fully envelop the crushed rock bedding and sub-bedding materials. The type of geotextile fabric shall be as recommended by the Geotechnical Engineer. The thickness, strength and permeability of the fabric shall consider the project-specific conditions, such as soil and groundwater conditions, bedding material, and need for durability to resist damage during construction (including removal of sheet piles).

H. Trench Backfill. The trench backfill shall be defined as the zone between the top of the pipe bedding and the bottom of the pavement section, top soil, building subgrade or other similar upper stratum.

Installation of backfill shall be in conformance with the Standard Specifications and Standard Details, unless modified by the Geotechnical Engineer for inclusion in the Special Provisions. The Geotechnical Engineer shall be available for consultation during construction to assess actual site conditions. Special emphasis shall be placed on specifying maximum lift thicknesses, need for evenly spreading backfill lifts, degree of compaction, number and types of compaction tests, and any disallowed methods of compaction.

Backfill below the water table shall generally be granular permeable material or other suitable materials to allow maintenance of natural subsurface groundwater flow and avoid compaction challenges in wet conditions. Where approved for use, backfill requiring compaction shall be installed in dewatered trenches. The design water table elevation shall be determined by the Geotechnical Engineer based on review of borings data and other available information.

I. Controlled Low Strength Material (CLSM). For sewers located within roadways, CLSM shall be used as the backfill material above the water table to minimize potential pavement settlement. CLSM shall be self compacting and capable of being excavated with hand tools. The mix design shall produce a uniform, flowable mixture that is essentially self-leveling when placed. The 28-day compressive strength shall be between 50 and 150 pounds per square inch (psi). Higher strength CLSM may be permitted on a case-by-case basis such as when the CLSM must be tremied.

J. Shoring and Dewatering. Shoring and dewatering shall primarily be the responsibility of the construction contractor. The Contract Documents may include appropriate soils and groundwater information, precautionary notes, and disallowed construction practices in the contract documents to help minimize the risk of construction problems and to promote satisfactory long-term performance.

Special Provisions shall require that installation and removal of trench support systems be conducted in a manner to avoid undermining of and inflicting damage to adjacent structures, facilities, utilities, and pavements. Special care shall be required in removing sheet piles and other trench support systems to avoid affecting the slope of the newly installed sewer pipes. In areas with the potential for settlement, installation and removal of sheet piles using vibratory equipment and excessive drawdown of groundwater for dewatering shall generally be prohibited.

Special Provisions shall include requirements for preconstruction surveys and where appropriate, requirements for settlement and/or vibration monitoring during construction.

K. Trench Plug. Trench plugs shall be installed where applicable to stop or control the flow of groundwater within highly permeable trench bedding and backfill material. Trench plugs may be applicable to sewer trenches near or under a stream or other water body that may drain and divert excessive amounts of groundwater. Trench plugs may also be applicable to sewer trenches intercepting lateral ground water flow, particularly along a hillside, since the trenches may function as a subsurface drain.

The Geotechnical Engineer shall provide recommendations on the need and locations for required trench plugs and the type of material for the trench plug.

Trench drains shall be provided to reduce hydrostatic pressure created by trench plugs and CLSM backfill where the pressure may have adverse impacts. The Geotechnical Engineer shall consider the impacts of any redirection of groundwater.

2.5.5 Warning and Identification Tape. Green plastic tape, at least 6 inches wide, shall be placed in the pipe trench 2 feet above the sewer pipe. The tape shall have the words “CAUTION, BURIED SEWER LINE BELOW” printed on the tape. Warning and identification tape are only required for open trench construction.

2.6 Manhole Requirements

2.6.1 General. Gravity sewer manholes shall conform to the location, spacing and other applicable requirement in Section 2.4.6, "Manhole Location and Spacing," and other applicable requirements of these design standards. Manholes shall also conform to the Wastewater Standard Details, which include both manhole design notes and drawings.

2.6.2. Manhole Design Objectives. Manhole size, type, configuration and special design requirements can vary considerably depending on the number and size of lines to be accommodated; flow rates and velocities; line depths and soil conditions; and other factors. General manhole design objectives that shall be considered include the following:

- Promote desirable hydraulic characteristics, particularly at junction manholes, by effectively directing and transitioning flow momentum from incoming sewers to the outlet sewer in order to:
    - Minimize head losses.
    - Avoid backwater conditions, surcharging, vortexing and dead areas that can result in sluggish flow, pipe clogging and sediment accumulation.
    - Reduce turbulence that can aggravate hydrogen sulfide, corrosion and odor problems; promote erosion, and splashing wastewater on manhole benches and walls.
- Promote safe and adequate access for inspection, cleaning and maintenance operations. These operations may include use of jetting, rodding, flushing and bucket cleaning equipment; debris removal; closed-circuit television (CCTV) inspection; installation or rehabilitation of protective manhole coatings and liners; and installation of CIPP sewer liners or other sewer rehabilitation operations.

  Consideration shall be given to size of access openings, methods of entry, adequacy of bench areas and headroom, and sufficient maneuvering space to accommodate equipment.
- Provide a structurally sound structure based on live and dead loads, soil conditions, number and size of pipe penetrations, corrosion potential, and other factors.

2.6.3 Functional Types. Three basic functional types of manholes, as shown on the Standard Details, shall be used wherever applicable.

A. Plain Manhole. A plain manhole can be used where the difference in elevation between the incoming sewer and the manhole invert is less than 18 inches.

B. Shallow Drop Manhole. A shallow drop manhole shall be provided where a sewer enters a manhole at an elevation in the range of 18 inches to 5 feet above the manhole invert.

C. Drop Manhole. A drop manhole shall be provided where a sewer enters a manhole at an elevation of more than 5 feet above the manhole invert. Drop manholes shall be allowed only after other alternatives, such as steeper lines, have been evaluated and not found to be feasible. The use of drop manholes will be reviewed and approved by the City on a case-by-case basis. Drop manhole designs that do not conform to the Standard Details, including special vortex-type drop manholes, shall be reviewed by the City and approved on a case-by-case basis.

2.6.4 Manhole Diameters and Maximum Pipe Sizes. As shown in the Standard Details, standard sizes for manholes are 48-inch and 72-inch inside diameters manholes.

A 48-inch diameter manhole shall be used for pipes 24-inches or less in diameter, except where the number and size of branch lines justify the use of a larger manhole. The 72-inch inside diameter manhole shall generally be used for pipes larger than 24-inches and up to 36-inches in diameter.

Special manholes, discussed below, shall be used for pipes greater than 36-inches in diameter, and where required for smaller lines involving branch conditions.

Manholes shall have sufficient area for channelization that will allow for smooth changes in flow direction. The maximum pipe sizes for horizontal changes in direction for manholes without branch lines shall be as follows:

Manhole Inside Diameter	Maximum Size of Pipe	
	Change in Direction ≤ 45-degrees	Change in Direction > 45 Degrees and ≤ 90-degree
48”	24”	18”
72”	36”	30”

Note: Based on no branch lines. For manholes with branch lines, case-specific evaluation is required based on number, size and configuration of lines.

Manhole channelization, including the radius of the channels, shall be as described below and indicated on the Standard Details. Channelization for manhole piping configurations not addressed by the Standard Details shall be developed by the Design Engineer, shown on the construction drawings, and reviewed by the City for approval on a case-by-case basis.

2.6.5 Special Manholes. Designs for special manholes shall conform to applicable requirements described herein and be reviewed by the City for approval on a case-by-case basis. Conceptual sketches and design data for the proposed design shall be submitted for preliminary review and acceptance before final design is initiated. The conceptual submittal shall show plan and elevation views for each special manhole used in the project. The submittal shall include information on each pipe, including the size, slope, alignment, and design average and peak flow, depth and velocity. The proposed inverts and channelization of the manhole base shall be indicated. Follow-up submittals shall include reinforcing and structural details. The proposed pipe connections shall be included to allow the City to evaluate the water-tightness and ability to accommodate differential settlement.

Special manholes may be of shapes other than round. The minimum inside wall dimension shall be 72-inches and access shafts shall have a minimum dimension of 48-inches, unless otherwise approved by the City.

Special manholes shall have minimum vertical clearance of 6.5 feet above the bench platform for maintenance activities. Bench and other requirements specified in the following sections shall be applicable.

2.6.6 Manhole Materials.

A. Cast-in-place Concrete Manholes. Cast-in-place concrete manholes may be used in all locations.

B. Precast Concrete Manholes. Precast concrete manholes may be used in all locations.

C. Glass-Fiber Reinforced Polyester (FRP) Manholes. ASTM D-3753. FRP manholes shall only be used in non-traffic areas.

D. Steel Reinforced Polymer Concrete (SRPC) Manholes. ENV Approved SRPC manholes may be used in all locations.

2.6.7 Manhole Structural Design. Manholes shall be designed in accordance with the latest version of the American Association of State Highway and Transportation Officials (AASHTO) Load and Resistance Factor Design (LRFD) Bridge Design Specification. Minimum design live load shall be HS20 unless otherwise approved by the City. Higher design live load shall be

applied as may be dictated by project requirements or when directed by the City.

Structural calculations stamped by a licensed professional structural engineer licensed in Hawaii shall be submitted for manholes that differ from those shown on the Standard Details and where the number of pipes, loading, or soil conditions justify supplemental structural analyses.

Special structural consideration shall be given in the following situations:

- Cut-out areas in the manhole wall for multiple sewer pipe penetrations may substantially reduce the load bearing capacity.
- Significant hydrostatic and buoyancy forces may result from deep manholes in high water table areas. A safety factor of 1.5 should be applied.
- Poor soils may require special foundation and subgrade treatment.

2.6.8 Manhole Hydraulic Design Requirements and Guidelines. The following requirements and guidelines are intended to enhance flow characteristics, particularly at junction manholes, to avoid undesirable hydraulic conditions such as excessive headlosses, surcharging and sluggish flow.

A. Definition of Terms.

1. Mainline and Branch Flow. Two general types of flow-through manholes are referred to herein as “mainline flow” and “branch flow.” Mainline flow is defined as the larger incoming and exiting flows in the manhole and typically represents flow in the larger sewer line. Branch flow is defined as the flow of one or more branch sewers, which is typically lower than the mainline flow. The branch sewer is generally smaller in size than the main lines but may also be the same size as the main line.

2. Flow Angle. The flow angle for lines entering and exiting the manhole shall be the angle of change between the upstream main line or branch sewer and the downstream main line exiting the manhole.

B. General Piping Configuration.

1. Pipe Crown Relative Elevations. Where different size pipes connect to a manhole, the crowns of the upstream pipes shall generally match or be higher than the crown of the downstream pipe.

2. Water Level Elevations. The water levels for the branch sewer shall generally be higher than the water levels for the mainline flow for the entire range of anticipated flows. Pipe sizes and inverts shall be selected to ensure free entry of flow from branch sewers without backwater effects caused by the main line flow. When this cannot be achieved due to practical limitations of existing sewer inverts, consideration shall be given to increasing the size of the branch sewer where feasible to prevent full flow surcharged conditions in the branch sewer. Constant surcharging and sluggish flow due to backwater shall be avoided to minimize clogging risk and maintenance effort due to grease accumulation at the pipe crowns and excessive solids deposition from low flow velocities.

3. Pipe Alignment and Angle of Entry. Inflow and outflow pipe alignments shall generally intersect at the center of round manholes. Pipes for special manholes with straight walls shall generally be aligned such that the pipe penetration is perpendicular to the wall.

4. Manholes with Pipe Junctions. Junction manholes involving multiple incoming pipes shall be designed such that the outflow occurs freely without direct adverse upstream hydraulic impacts from converging flows. Pipes shall be offset horizontally and vertically and aligned with flow redirected through channelization as necessary to minimize or eliminate undesirable or uncontrolled flow restrictions, excessive flow turbulence, or dead areas due to vortices. Requirements described below for pipe junctions shall be applicable.

2.6.9 Manhole Channels and Benches. The base of manholes shall be channelized to enhance smooth flow transitions and provided with benches to facilitate maintenance operations. Channelization shall consider the sizes, angles, slopes, flow depths, and flow velocities of the upstream and outgoing downstream sewers pipes.

A. Channel Depth. Manhole channels shall generally have side wall heights equal to 75 percent of the inside pipe diameter. Deeper channels may be considered under certain conditions, such as if full flow pipe conditions are anticipated and headlosses are significant and critical for spill avoidance. The deeper channels shall not be used unless adequate access can be provided for use of CCTV cameras and cleaning equipment.

B. Channel Shape and Transitions. Manhole channels shall generally have rounded bottoms matching inflow and outflow pipes with smooth transitions to enhance low flow hydraulics and minimize debris accumulation.

C. Channel Radius. The radius of channels shall be as shown on the Standard Details. When not shown or otherwise indicated on the Standard Details, the Design Engineer shall indicate the radius and other channelization information on the plans. The outside channel radius shall generally be tangent to the outer edge of pipes and the largest reasonable radius should be used. The inner radius of the channel shall generally be concentric to the outside radius.

D. Channel Invert Slopes and Elevations. Channels shall be provided with a smooth invert slope transition between the upstream and downstream pipes.

When the total branch flow is less than 30 percent of the total flow through the manhole (outgoing flow comprised of incoming branch and mainline flows), the inverts at the manhole wall may be based on the invert slopes of the upstream and downstream lines, and meeting the requirements described above for crowns and water surface elevations.

When the total branch flow is equal to or more than 30 percent of the total flow through the manhole, the invert at the outlet of the main line shall be a minimum 2.5 inches lower than the invert of the inlet of the main line. This will help to ensure that the turbulence and loss of momentum in the main line caused by the branch sewer flow will not create undesirable backwater conditions and sluggish flow in the main line.

E. Flow Direction Changes and Converging Flow Entry Angles. Maximum direction changes in sewers shall generally be 90 degrees at each manhole. Additional manholes shall generally be used for direction changes of more than 90 degrees. The use of multiple manholes for directions changes more than 90 degrees may be waived on a case-by-case basis by the City if special vortex or drop manholes can be used to redirect the flow.

As indicated in the Standard Details, channelization shall be provided to redirect branch flows into mainline flow such that the branch flow enters at an angle not exceeding 45 degrees.

Incoming branch and mainline flows shall be configured and/or channelized such that the flows do not hydraulically oppose one another and create backwater or sluggish flow conditions. Multiple or special manholes shall be used as required to stagger the location of incoming converting flows from opposing directions.

D. Benches. Provide bench widths as allowable for the applicable piping configuration. The bench top shall be sloped at approximately 2-inches per foot toward the channel. Bench top slopes may be adjusted as

required to accommodate varying pipe sizes and configurations, except slopes shall not be less than ¼" per foot to ensure positive drainage of the bench.

Benches or platforms for special manholes shall generally have a minimum width of 3.0 feet to serve as a working platform unless otherwise approved by the City.

2.6.10 Watertightness. All manhole joints shall be watertight.

2.6.11 Pipe Connections to Manholes.

Pipe connections to manholes shall be watertight through the use of watertight non-shrink grout or couplings and designed to allow differential settlement between the pipe and manhole wall through the use of flexible joints as required by the Standard Specifications and shown in the Wastewater Standard Details.

2.6.12 Corrosion Protection.

A. General. Manholes shall be of an approved corrosion-resistant material or protected internally with an approved protective coating for the following situations:

1. Manholes located within 100 feet upstream of a wastewater pump station.

2. Force main discharge transition manhole and manholes located within 1,000 feet downstream of the discharge manhole.

3. Manholes on branch sewers connected to the downstream sewers which are impacted by migrating hydrogen sulfide gas.

4. Manholes with inlet and/or outlet pipes 16-inches or larger in diameter.

5. Drop and shallow drop manholes.

6. Areas with known high levels of hydrogen sulfide gas.

B. Corrosion Protection Methods.

1. Acceptable corrosion-resistant manhole materials include fiberglass and steel reinforced polymer concrete.

2. Acceptable internal protective methods include epoxy coating, cured-in-place fiberglass lining, and prefabricated fiberglass insert. Corrosion-resistant materials and coatings/liners shall be reviewed and approved by the City on a case-by-case basis.

3. Corrosion protection materials and methods, construction/installation procedures, and testing, shall conform to applicable requirements in the Standard Specifications.

2.6.13 Manhole Appurtenances

A. Manhole Access and Cover.

Type "SA" cast iron manhole frames and covers (22-inch diameter opening) shall be used on manholes with pipe diameters of 12-inches or less. For manholes with pipes larger than 12-inches in diameter, Type "SB" manhole frames and covers (31-½ -inch diameter opening) shall be required.

Special manholes with an inside diameter greater than 6-feet or with one wall length greater than 6-feet shall be provided with two access manholes with at least one Type "SB" manhole frame and cover.

Access manhole riser shall be not less than 4 feet in diameter.

Access manhole(s) shall be located against the manhole wall. When more than one access is provided, the Type "SB" manhole frame and cover shall be located above the bench platform.

B. Inflow Inserts. Manhole cover inserts shall be used to minimize inflow through the cover. Inserts shall be as described in the Special Provisions. The inserts shall be designed to allow venting of the manhole and low rate drainage of accumulated water.

C. Manhole Rungs. No rungs shall be installed in new manholes as access to manholes shall be by safety tripod and harness in accordance with all regulatory confined space entry requirements. All rungs shall be removed prior to rehabilitation of existing manholes.

2.7 Testing and Inspection

Testing and inspection of the sewer lines and manholes shall comply with the requirements of the Standard Specifications. Testing and inspection requirements may be modified by the Design Engineer to suit site-specific and project-specific conditions and such modifications shall be included in the Special Provisions. Post-construction inspection of new sewer lines using CCTV shall be as required in the Standard Specifications.

2.8 Rehabilitation of Existing Sewers and Manholes

2.8.1 Sewer Line Rehabilitation. Acceptable trenchless pipeline rehabilitation methods include cured-in-place pipe (CIPP), slip-lining, and pipe bursting. Other methods shall be reviewed by the City for approval on a case-by-case basis.

For CIPP full length liner and slip-lining, the design shall be based on a fully deteriorated host pipe as defined by ASTM F1216, Standard Practice for Rehabilitation of Existing Pipelines and Conduits by the Inversion and Curing or a Resin-Impregnated Tube. Special attention shall be given to sealing lateral cutouts and manhole penetrations from groundwater infiltration and root intrusion. Lining or sealing of lateral wyes shall be considered.

2.8.2 Manhole Rehabilitation. Acceptable manhole rehabilitation methods include epoxy coating, cured-in-place fiberglass lining, and pre-fabricated fiberglass insert as required by the Standard Specifications and shown on the Standard Details. Other methods may be reviewed by the City for approval on a case-by-case basis.

2.9 Low Pressure Sewer System (LPSS)

The use of LPSS is discouraged and shall only be considered for individual homes or businesses that cannot be reasonably serviced by gravity sewers and may be reviewed by the City for approval on a case-by-case basis. The LPSS shall be maintained by the Owner as a private sewer up to and including the connection to the public sewer.