6.4.5 *Conclusions*

6.4.5.1 Since the SSDS Stage I design:

(1) Flow projection for SEKD has not changed significantly.

(2) Flow projection for Central and East Kowloon has risen substantially, especially in East Kowloon.

6.4.5.2 The substantial rise in population projected for East Kowloon could result in capacity constraints in the SSDS system if development reaches TPEDM Scenario II levels beyond 2011 and peak flows coincide at all contributing catchments.

6.4.5.3 Studies are currently being undertaken by the EPD to model the peak flows to each node of the SSDS Stage I and their effect on the overall capacity of the system. This work will show whether a real capacity constraint is likely is likely beyond 2011, in advance of further stages of the SSDS (or the Harbour Area Treatment Scheme 'HATS'). If so, the constraint would result primarily from intensified development in the existing urban area of Kowloon, not from the SEKD, and measures could be taken to alleviate the constraints through provision of additional facilities at Kwun Tong and/or To Kwa Wan on land already allocated for the purpose.

6.4.5.4 Possible extension facilities to the To Kwa Wan and Kwun Tong PTWs, as described in sections 6.4.2, 6.4.3 and 6.4.4, will be included in the SEKD projects. Implementation of such facilities is contingent upon the findings of the HATS study to be completed in 2003.

6.5 Part 2 - Sewerage Design Criteria

Preliminary designs for the proposed sewerage system have been prepared in accordance with the requirements specified in the DSD Sewerage Manual and DSD's Standard Drawings. The following additional requirements shall also be adopted in the detail design.

6.5.1 *Design Standards*

6.5.1.1 Design of the foul sewers, manholes, pumping mains, pumping stations and chambers follow the recommendations of the Drainage Services Department Sewerage Manual, DSD's Standard Drawings and the Tables for the Hydraulic Design of Pipes and Sewers (5th edition) - Hydraulics Research, Wallingford; where appropriate, these designs will comply with the provisions of the following standards:

- BS65 Specification for Vitrified Clay Pipes, Fittings and Joints;
- BS EN598 Ductile iron pipes, fittings, accessories and their joints for sewerage applications, requirements and test methods;
- BS497 Specification for manhole covers, road gully gratings and frames for drainage purposes;
- BS4772 Specification for Ductile Iron Pipes and Fittings;
- BS5911 Part 100 Specification for Unreinforced and Reinforced Pipes and Fittings with Flexible Joints;
- BS5911 Part 120 - specification for unreinforced jacking pipes with flexible joints;
- BS8005 Part 1 : Sewerage - Guide to New Sewerage Construction;
- BS8007 Design of Concrete Structures for Retaining Aqueous Liquid;
- BS8010 Section 2.1 - Code of Practice for Pipeline: Ductile Iron; and
- BS8110 Part 1 : Structural Use of Concrete - Code of Practice for Design and Construction.

6.5.2 *Velocities and Gradients*

6.5.2.1 The following velocity and gradient criteria will be used in preparing the detailed designs:

Velocity

6.5.2.2 The sewers will be sized to achieve a self-cleansing velocity of 1m/s at least once a day. The maximum velocity will be 3m/s.

Gradient

6.5.2.3 The sewers will be laid to follow the ground profile wherever possible, but at all times at a gradient steep enough to satisfy the minimum velocity criteria given above. In addition, care has been taken to ensure that pipe invert levels do not fall greater than 6 metres below ground level.

6.5.3 *Manholes*

Drops through Manholes:

6.5.3.1 Notwithstanding the requirements for increasing sewer sizes at manholes, minimum drops shall be provided in the inverts of manholes as listed in **Table 6.11** to account for losses through manholes.

Table 6.11 Drops through Manholes

Situation	Assessed Loss
Straight through	$0.15 \times \frac{V^2}{2g}$
30° bend	$0.50 \times \frac{V^2}{2g}$
60° bend	$0.95 \times \frac{V^2}{2g}$
90° bend	$1.00 \times \frac{V^2}{2g}$

Flexible Joints adjacent to Structures:

6.5.3.2 In order to accommodate differential settlement that may occur between sewers and adjacent structures (including manholes), two flexible joints shall be provided at a spacing of 0.5D + 1.0D from the structure, where D = pipe diameter.

Drop Structures:

6.5.3.3 Backdrop manholes, where required, shall be used to connect pipes at significantly different levels. These should be provided as per the Sewerage Manual and DSD's Standard Drawings.

6.5.4 *Septicity and Pipe Materials*

6.5.4.1 In any sewerage network, bacteria breaks down (degrades) the organic components contained in sewage. If there is a lack of oxygen during this degradation process, septic conditions could occur which results in the formation of hydrogen sulphide, which forms a health hazard. Septicity of sewage is particularly problematic when the retention time of sewage in the mains is long, and the temperature is high or the incoming sewage in the mains is already septic.

6.5.4.2 The preliminary design has been formulated to ensure that sewers are laid to size and gradient to achieve the minimum velocity of 1m/s. Therefore, these conditions should be sufficient to prevent the onset of a septic environment in the system.

6.5.4.3 Nevertheless, to mitigate corrosion problems, the following protective measures will be adopted:

- The use of rubber ring jointed vitirifed clay pipes (pipe diameters less than 600mm) and PVC lined reinforced concrete pipes (diameter exceeding 600mm); and
- The protection of exposed concrete surfaces in manholes, control structures, pumping stations, etc. using epoxy coating or plastic lining and the use of epoxy mortar for manhole benching.

6.5.4.4 For the SEKD, a section of pipeline which could provide large retention times for sewage at average flows, is the section of rising main from Pumping Station No. 4 to the To Kwa Wan PTW. Preliminary assessment indicates that the sewage retention time within the rising main could exceed one hour, which could provide result in septic conditions. However, it is recommended that the potential for generation of septic conditions be assessed at the detailed design of the scheme, to take into account the following key criteria:

- Final configuration of the rising main (length/diameter/gradient/flow);
- Slime/sewage interface (Pomeroy, 1977); and
- Sewage parameters (BOD or COD and sewage temperature).

6.5.4.5 To control septicity in rising mains, the most common method is the direct injection of oxygen into the mains. Another method, which may be considered at Pumping Station No. 4, would be to include some pre-aeration in the wet well of the pumping stations or to add controlled dosage of nitrate solution. The preferred method should be evaluated at the detailed design upon finalisation of the scheme. Nevertheless, PS4 should allow an area for oxygen injection or other alternative method. The overall cost of PS4 should allow for this facility as well.

6.5.5 *Hydraulic Calculations*

6.5.5.1 Hydraulic calculations will be carried out using the Colebrook-White equation in accordance with the DSD Sewerage Manual. Roughness values will be based on the recommendations contained in the 5th edition of the Hydraulic Research tables for slimed sewers.

6.5.6 *Bedding Details*

6.5.6.1 Bedding types used in the construction of the sewers will be dependent on the depth, pipe strength, ground and surface conditions. The design of bedding details for the pipelines will be based on the Marston theory.

6.5.6.2 Bedding types will be selected from the following based on the conditions mentioned above:

- Granular surround (Type BO);
- Concrete cradle (Type ABP);
- Reinforced concrete cradle (Type ABR);
- Concrete surround (Type AO); and
- Piled foundation for recently reclaimed land.

6.5.7 *Depths*

6.5.7.1 A minimum depth of cover of 0.9 m will be used wherever possible.

6.5.8 *Manhole Spacing*

6.5.8.1 The maximum spacing between manholes shall be in accordance with DSD's 'Sewerage Manual'.

6.5.9 *Rising Mains*

Hydraulic Calculations:

6.5.9.1 Hydraulic design for rising mains have been based on the Colebrook-White equation as described in the DSD Sewerage Manual. Roughness values for pipelines shall be determined based on the recommended values described in Table 6 of the DSD Sewerage Manual.

Velocities and Gradients:

6.5.9.2 Rising mains have been designed to achieve minimum flow velocities of 0.6 m/sec (corresponding to average dry weather flow rates), and minimum daily self-cleansing velocities of 1.0 m/sec (corresponding to peak dry weather flow rates). To restrict power requirements and energy costs, maximum velocities in rising mains should be limited to 3.0 m/sec.

6.5.9.3 Rising mains have been graded to avoid high and low points wherever possible. Slight gradients (viz. less than 0.40%) shall also be avoided to minimise the risk of air entrapment.

Pipe Materials:

6.5.9.4 Rising mains have been, wherever possible, proposed to be constructed using rubber ring jointed internally cement mortar lined ductile iron pipes and fittings in accordance with DSD's Sewerage Manual.

Pipe Depths, Bedding and Anchoring:

6.5.9.5 A minimum cover of 0.9 metre shall be used for the design of rising mains within road reserves. Reduced cover requirements may be applied in special circumstances (e.g. where the pipeline alignment is through an area which is not subject to vehicular loading). Crossing of buried utilities shall normally be effected by passing beneath the service. Oblique crossings shall be avoided wherever possible.

6.5.9.6 Pipe bedding types will depend on depth, pipe strength, ground conditions and surface conditions, and shall be designed in accordance with the procedure set down in the CE Manual.

6.5.9.7 In-situ reinforced concrete thrust or anchor blocks shall be provided at all vertical and horizontal changes in direction of 11.25° or more.

Thrust Blocks:

6.5.9.8 Thrust blocks for all rising mains shall be designed in accordance with the requirements stated in DSD's Sewerage Manual (Part 2) "Pumping Stations and Rising Mains" – 2000, and the CIRIA Report No. 128 "Guide to the Design of Thrust Blocks for Buried Pressure Pipelines".

Air Valve and Washout Chambers:

6.5.9.9 Where high points are unavoidable, sewage air valves would be installed within covered chambers. Washout valves shall be provided at all low points and shall be arranged to discharge into a collection chamber for emptying by a vacuum tanker.

6.5.9.10 Odourous emissions from the air valves under normal operations would be minimal and at slow rates. It is recommended that the locations of air valves should be examined in the detailed design stage to allow buffer distance between air valves and nearby sensitive receivers. For locations where air valves have to be located in close proximity to sensitive receivers, an activated carbon filter should be installed after the air valves to mitigate potential odour emissions.

Termination Chambers:

6.5.9.11 A sealed termination chamber shall be provided at the connection of a rising main to a downstream sewer or pipeline, comprising an internal overflow weir set at a level above the rising main soffit to ensure the main remains full when not pumping.

Inverted Siphons:

6.5.9.12 Inverted siphons have not been used.

6.6 Design Constraints

6.6.1.1 There were several constraining factors to take into account when designing the gravity sewer system for the SEKD. The two main issues were the presence of drainage culverts of considerable size, and the allowable maximum depth at which the gravity sewer pipes could be laid.

6.6.1.2 Due to the presence of a large number of drainage culverts over which the sewerage system has to cross, it was most practical to divide SEKD into distinct catchment areas that are bounded by these main drainage culverts. The flows from within each catchment travel through a gravity system to the boundary where it is pumped via a short rising main into the next catchment. Ultimately sewage is pumped from the boundary of SEKD to the receiving PTWs at To Kwa Wan and Kwun Tong.

6.6.1.3 Designs to limit the invert depth of the sewerage system to a maximum of six meters below ground level has produced a need for slightly larger pipe sizes to convey the required flows. Increasing the pipe diameters was seen as being more advantageous than adding additional pumping stations as the additional heads required were in the order of one meter.

6.6.1.4 Construction of rising mains within SEKD will be relatively easy given there are few existing utilities within SEKD. Rising mains which are constructed outside of SEKD in the hinterland to convey the sewage to the TKWPTW or KTPTW are significantly harder to construct due to the presence of existing utilities which will have to be avoided. The most difficult rising main to construct is expected to be the twin 1,050mm dia rising main leading from PS 4, through Ma Tau Kok, to TKWPTW. Investigation of the route and construction techniques for constructing this rising main have been carried out. Several pipeline routes have been investigated for constructability including existence of major utilities and traffic loading. The preferred route option is shown on **Drawing Nos. 22936/SW/018, 39-41 and 75-77**. Trenchless pipelaying technologies such as pipe jacking are recommended to minimise complications with working around existing utilities. The proposed locations for open trenching and pipe jacking are shown in the longitudinal sections of the rising main on **Drawing Nos. 22936/SW/075 to 077**. The longitudinal sections also show major utilities.

6.6.1.5 Sewage generated in catchments furthermost from the PTW is pumped through several pump stations, which are connected in series, before its eventual discharge at one of the PTW. The catchments which are being developed first include catchments 1 and A1 which are furthest from TKWPTW where the wastewater is being discharged. Because the sewage has to pass through pump stations 1A, 1, 2 and 4 before it is discharged at the treatment plant, all this infrastructure has to be constructed before the first residents move into catchments 1A and A.