TECHNICAL SPECIFICATION

DRAINAGE AND PRIMARY TREATMENT FACILITIES

DEP 34.14.20.31-Gen.

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DESIGN AND ENGINEERING PRACTICE

USED BY

COMPANIES OF THE ROYAL DUTCH/SHELL GROUP

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The information set forth in these publications is provided to users for their consideration and decision to implement. This is of particular importance where DEPs may not cover every requirement or diversity of condition at each locality. The system of DEPs is expected to be sufficiently flexible to allow individual operating companies to adapt the information set forth in DEPs to their own environment and requirements.

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1. INTRODUCTION

1.1 SCOPE

This DEP is a revision of and supersedes the document 'Drainage and Primary Treatment Systems' published under the same DEP number in May 1986. This DEP outlines the minimum requirements for the design and engineering of drainage networks and primary treatment facilities.

This DEP is intended to provide the user with a specification which will improve standards for good design and engineering practice for drainage and primary treatment facilities, whilst emphasizing the importance of integrating these facilities with water/effluent masterplanning.

Guidelines for operational management (maintenance, housekeeping and inspection) are included so that the engineer can allow for these aspects during the design stage.

The importance of well designed, constructed and managed drainage and primary treatment facilities cannot be overstressed, in terms of safety and environmental care. Shortcomings in drainage and primary treatment systems and management can have significant impact on the environment (e.g. pollution of soils, ground water, public waters and air) and can result in the making of significant unnecessary additional expenditure.

Although this DEP is mainly intended for new construction projects, it is equally applicable for any revamp work and/or upgrading works on existing facilities.

1.2 DISTRIBUTION, INTENDED USE AND REGULATORY CONSIDERATIONS

Unless otherwise authorised by SIPM, the distribution of this DEP is confined to companies forming part of the Royal Dutch/Shell Group or managed by a Group company, and to Contractors nominated by them (i.e. the distribution code is "C" as defined in DEP 00.00.05.05-Gen.).

This DEP is primarily intended for oil refinery, chemical plant and gas plant application. However, the basic principles are equally applicable to onshore exploration and production facilities and supply/marketing installations.

If national and/or local regulations exist in which some of the requirements may be more stringent than in this DEP, the Contractor shall determine by careful scrutiny which of the requirements are the more stringent and which combination of requirements will be acceptable as regards safety, environmental, economic and legal aspects. In all cases the Contractor shall inform the Principal of any deviation from the requirements of this DEP which is considered to be necessary in order to comply with national and/or local regulations. The Principal may then negotiate with the Authorities concerned with the object of obtaining agreement to follow this DEP as closely as possible.

1.3 DEFINITIONS

1.3.1 General definitions

The **Contractor** is the party which carries out all or part of the design, engineering, procurement, construction, commissioning or management of a project or operation of a facility. The Principal may undertake all or part of the duties of the Contractor.

The **Manufacturer/Supplier** is the party which manufactures or supplies equipment and services to perform the duties specified by the Contractor.

The **Principal** is the party which initiates the project and ultimately pays for its design and construction. The Principal will generally specify the technical requirements. The Principal may also include an agent or consultant authorised to act for, and on behalf of, the Principal.

The **Purchaser** is the party which buys materials, equipment and/or services for its own use or on behalf of the owner.

The word **shall** indicates a requirement.

The word **should** indicates a recommendation.

1.3.2 Specific definitions

Primary treatment is water purification based on the difference in density of the polluting substance and the medium, the former being removed either by rising or settling.

Secondary treatment is water purification based on chemical and/or biological action or enhanced gravity separation.

The word **'oil'** in this DEP is synonymous with the word "hydrocarbon".

1.3.3 Abbreviations

AOC	:	Accidentally Oil Contaminated
COC	:	Continuously Oil Contaminated
API	:	American Petroleum Institute (separator)
CPI	:	Corrugated Plate Interceptor
PPI	:	Parallel Plate Interceptor
LLOD	:	Last Line of Defence
FFU	:	Flocculation-Flotation Unit
BOD	:	Biological Oxygen Demand

Variations to the above are allowed to suit specific instances, e.g. for chemical plants.

ACC	:	Accidentally Chemical Contaminated
CCC	:	Continuously Chemical Contaminated

1.4 CROSS-REFERENCES

Where cross-references to other parts of this DEP are made, the referenced section number is shown in brackets. Other documents referenced by this DEP are listed in (15.).

2. WATER/EFFLUENT MASTERPLANNING

The importance of a proper conservation and protection of the environment has led to an increased awareness of the possible ecological consequences of industrial activities. In light of this, the quality of the effluent discharged by the petrochemical industry is expected to be subject to a continuously increasing pressure for improvement.

In recent years, refinery effluent specifications in many countries have become much more stringent, with sharpening limitations on oil, suspended solids and BOD, and additional emphasis on other contaminants, such as ammonia, nitrates and trace elements.

In conformance with Group policy guidelines for the environment and in particular with the strategy "Shell Companies shall pursue in their operations, progressive reductions of emissions, effluent and discharges of waste materials that are known to have a negative impact on the environment, with the ultimate aim of eliminating them", guide emission/discharge limits are used. These guide values on effluent discharge limits result from an assessment of the environmental impact of the contaminates, expected legislative developments, and the status of the best demonstrated available technology. The guide values have been established to serve as a yardstick against which to measure current effluent treatment performance and all future investment and/or expansion schemes for water effluent treatment.

For MF, the guide values focus on today's most critical specifications (Oil, Suspended Solids and BOD). Guidelines are also laid down for the discharge quantities of ammonia, phenols and aromatics. Specifications excluded are on fluorides, nitrates and chlorinated hydrocarbons, although these should be addressed in future designs.

It is stressed that MF guide values on effluent specifications cannot be achieved with primary treatment facilities only, thus where these specifications are mandatory secondary and tertiary treatment facilities will be required.

In many instances it may not be necessary to replace the standard effluent treatment facilities in order to achieve guide discharge values. Upgrading and extending existing networks with new techniques may turn out to be the most economical and appropriate route.

The proper phasing of upgrading proposals and extensions to existing facilities with correctly planned investments will ultimately enable guide values to be achieved at the required time.

Water effluent masterplanning aims for a cost effective investment in effluent collection networks and effluent treatment facilities, an essential element of this being the integration of surface water drainage and other refinery effluents. Masterplanning takes into account all water/effluent streams, resulting in a coherent plan that can be implemented in phases and enabling priority setting of individual effluent/water projects. It also provides the means for anticipating future environmental legislation on the discharge of effluents in an environmentally acceptable manner.

A water effluent masterplan integrates the following main topics:

1) Surface drainage and primary treatment facilities;
2) Process water integration;
3) Secondary treatment facilities;
4) Sludge handling and disposal.

This DEP deals only with the surface drainage networks and primary treatment facilities and their relation with the other treatment facilities as an integral part of the water effluent masterplan.

A typical integrated flow scheme for a masterplan is shown in Figure 1.

3. EFFLUENTS

Dependent upon source, type and level of contamination, effluents shall be classified into various categories. Each category shall be used to define the required drainage network and treatment facility.

The segregation of all effluent streams shall start at the source.

3.1 EFFLUENT SOURCES

The following sources of effluents shall be considered:

- rainwater
- fire fighting water
- wash/flush water
- cooling water blowdown / filter backwash
- tank bottom drains
- equipment drains
- sampling points
- desalter drains
- accidental process spillages
- maintenance operations (e.g. exchanger bundle pulling)
- domestic sewers
- ships' ballast water

3.2 EFFLUENT CLASSIFICATION

Effluents shall be classified as belonging to one of the following categories:

- Entirely oil-free water
- Accidentally Oil Contaminated (AOC)
- Continuously Oil Contaminated (COC) with high oil contamination and low BOD
- Continuously Oil Contaminated (COC) with high oil contamination and high BOD
- Cooling water return/blowdown
- Domestic sewage
- Oil drip/drain 'non-hazardous' service (atmospheric)
- Oil drip/drain 'hazardous' service, as specified by the Principal.
- Process water effluents

3.3 EFFLUENT ROUTING

Effluents shall be routed by means of drainage networks to selected treatment facilities and/or discharge points.

The selection of the routing of drainage networks shall be determined in conjunction with the plant layout requirements. Typical destinations for effluents are as follows;

a) Non-process effluents

  - Oil free: direct to public water without treatment.
  - AOC: to a controlled discharge facility.
  - COC: to either a pre-separator, followed by an oil separator (e.g. CPI) or via a buffer tank to secondary treatment.
  - Once through cooling water : to a controlled discharge facility.
  - Domestic sewage: to a sewage treatment plant.
  - Oil drips/drain effluents ('non-hazardous'): to collection sumps and recovery.

b) Process effluent networks

  - Process effluents from selected processes: to dedicated treatment facilities;
  - Oil drips/drain effluent ('hazardous'): to dedicated treatment facilities.

c) Chemical effluent networks

- Chemically polluted effluent streams: to dedicated secondary treatment facilities as specified by the Principal.
- Effluent streams contaminated with acids: to a neutralization pit located as near as possible to the source of effluent discharge. The discharge routing of these effluents shall be determined in consultation with the Principal.
- Effluent streams containing solids, emulsifying agents, and contaminates that tend to flocculate upon dilution, shall not be combined with COC networks. These streams shall be treated and disposed of separately in consultation with the Principal.

For a diagrammatic summary of typical effluent classification and routing, see Figure 2.

4. CATCHMENT AREAS

A catchment area is defined as an area in which a number of effluent streams have a common discharge point.

For calculation and identification purposes catchment areas shall be numbered and may be further divided into sub-catchment areas.

Typical areas within a refinery which can be identified as sub-catchment areas are:

ON PLOT areas: e.g. process and utilities areas.

OFF SITES: e.g. roads, pipetracks, tank farms, administration areas, depots and loading areas.

5. DRAINAGE NETWORKS

Each network shall be capable of collecting and handling the design flows of the specific effluents and shall be selected to achieve optimum segregation of the different effluent categories.

The most efficient and practical routing of the networks to the 'end-of-pipe' treatment facility shall be taken.

Networks common in refinery service shall be considered in two main categories, namely:

a) Non-process drainage networks

- Oil free;
- AOC;
- COC for high oil and low BOD effluents;
- COC for high oil and high BOD effluents;
- Cooling return/blow down;
- Domestic sewage;
- Oil drips/drain collection (for 'non-hazardous' service, atmospheric).

b) Process water effluent drainage networks *

- Desalter drains
- Process equipment drains
- Oil drips/drains collection (hazardous service, usually pressurized)
- Acidic effluent streams
- Heavy emulsion streams

* For chemical plants read "chemically polluted effluent drainage networks".

5.1 OFF PLOT NETWORKS

5.1.1 Tank compounds

All surface water run offs within a tank compound (rain water, fire fighting water used for cooling) shall be collected and discharged by means of surface drain channels to an AOC network outside the tank compound bunded area.

A sand trap shall be provided at the discharge point of the drain channels within the bunded area.

A fire trap between the compound area and the external AOC network shall be provided by means of a sump within the compound area, a liquid filled discharge pipe under the bund wall and a sump at the tie-in with the external AOC network.

Each compound shall have a dedicated discharge line which shall be valve controlled. The valve shall be located outside the bunded area and shall be easily accessible for operation purposes. A tank compound shall not be drained via an adjacent tank compound.

The decision whether or not a tank compound surface and bund walling should be made impermeable, should be dictated by local rules and regulations.

It should however be noted that the applicable run-off factor will be affected by the selection of the surface finishes.

A typical arrangement of tank compound drainage is shown in Figure 3.

5.1.2. Tank bottoms drainage

Tank bottoms shall be drained via a separate closed system drainage network of steel piping and routed to a COC network.

The connection of the drainage network to the COC system shall be kept flooded.

The bottom drain of each tank shall discharge into the network through a funnel.

Directly under the funnel a valve shall be installed for the purpose of shutting off the funnel from the system when the tank is not being drained. Where a branch of the system leaves the tank compound, an isolating valve shall be installed at the outside of the bunded area.

The drainage network may be located above or below ground but should be underground in areas where freezing conditions can be expected.

A typical arrangement of a tank bottom drain funnel is shown in Figure 4.

For typical details of a pipe passing through a bundwall, see Standard Drawing S 12.002.

Tank bottom drainage network routings shall be determined as follows:

Tank bottoms with high oil contamination and low BOD content (e.g. crude tank bottom drains): to a CPI and the non-process stream of secondary treatment.

Tank bottoms with high oil contamination and high BOD content (e.g. product/slops tanks): to a dedicated CPI and the process stream of secondary treatment.

Separate drainage networks shall be considered for the collection and treatment of tank bottoms rich in H_2S (e.g. routing to sour water collection system) and tank bottoms containing lead.

The capacity of the drainage network for tank bottom drain systems shall be designed based on the following ;

- for a crude oil tanks : 100 m^3/hr.
- for a product tanks : 50 m^3/hr.

The sizing of the CPI's to treat the effluents from tank bottom drains shall consider the draining of any one crude tank at any one time and the draining of any two product tanks at any one time.

This design condition should not be taken as occurring together with any other specified intermittent operation which loads the CPI or effluent treatment facility.

It is however essential to determine operational procedures to arrive at economical design criteria which satisfy operational flexibility whilst not resulting in oversized CPI and effluent treatment plant designs.

5.1.3 Impounding basins

The requirements for impounding basins are specified in DEP 34.18.51.10-Gen.

Where pumping facilities are required to pump out any rainwater accumulated in the basins, the discharge of these pumps shall be to the AOC drainage network.

5.1.4 Pipetrack drainage

All pipetracks surface finishes shall have a free run-off towards a pipetrack drain channel and shall be constructed with a minimum slope of 1:200. to one side.

The high point of the pipetrack finished level shall be 250 mm below the top of the pipe sleepers.

For wide pipetracks a central high point should be provided with surface finishes sloping to both sides to drain channels.

To prevent pollution of the subsurface soil, the surface finish of pipetracks in areas where spills or leakages can be expected should be provided with a hard surface layer. This will facilitate cleaning, maintenance and washdown operations in the event of a spill having occurred.

Recommended surface finishes for pipetracks are as follows:

Pipetracks containing light product lines: concrete blinding
Pipetracks containing heavy product lines: gravel or stone chippings

The design of open drain channels at pipetracks shall comply with the requirements of section 6.4.

For typical details of pipetrack drainage, see Figure 5.

5.2 ON PLOT NETWORKS

5.2.1 New designs

For onplot drainage networks, two main segregated systems shall be considered:

5.2.1.1 AOC network

The AOC drainage network shall comprise a 'sump free' paved area with surface water run-offs being collected in perimeter drain channels and routed via underground headers to end-of-pipe treatment.

To satisfy the requirements for the fire fighting water design condition it is necessary to provide additional catch basins located such that accidental spills or spills which could be on fire, can be quickly collected in the underground system.

The design rules for the selection of the location and number of these additional catch basins are as follows:

In plant areas with light product pumps (C4 service and lighter), catch basins shall be provided such that accidental spills will not travel more than 15 metres over the surface of the paved plant area (see area A, Figure 6.).

The maximum catchment area to be served by one catch basin shall not exceed 600 m^2.

The design capacity of the catch basin and underground pipe shall be minimum 250 m^3/hr.

The paved areas for all other process areas shall be laid out such that the maximum catchment area served by a catch basin shall not exceed 1200 m^2 (see area B, Figure 6.).

The segregation of the paved catchment areas can be achieved by optimum selection of the high points in the paving construction. Paving slopes shall wherever possible be directed away from equipment to reduce the risk of further spill contamination or escalation of fire. Paving slopes around catch basins serving an area of 600 m^2 shall be at least 1:100 and for other areas the slope should be a least 1:200.

The relationship between the high point of paving and adjacent plant roads shall comply with the requirements of DEP 34.13.20.31-Gen.

For the fire fighting and spray water quantities, see Table 2 (Section 8.7.1).

In the event that no actual data on fire fighting quantities is available the design flow for the on plot underground system for a paved area of 600 m^2 shall be taken as 250 m^3/hr, and for a paved area of 1200 m^2 as 500 m^3/hr.

The main perimeter drain channels at the edge of the plant area shall be provided with heavy duty grating covers and shall slope to collection sumps located at a maximum of 50 m centres. These sumps shall in turn discharge to the main underground headers located under the surface drain channels.

All on-plot and perimeter underground drainage piping shall be liquid filled.

5.2.1.2 Oil drip/drain collection network for 'non-hazardous' service.

i) drips/drains for hydrocarbons with a high viscosity and low solidification point, e.g. bitumen/wax: Collection should take place at the source via trays or buckets, in which these materials will solidify. Trays and buckets shall then be placed in a collector sump or vessel, fitted with steam coil. The collector sump/vessel shall be located within the process plant area such that easy access for inspection and maintenance can be achieved.

ii) drips/drains for hydrocarbons which remain in the fluid state (e.g. do not evaporate or solidify): Collection of flange leakages, pump seals, pump baseplates, sample points and drainage from equipment should take place by means of an atmospheric drainage system comprising, pipes (with funnels) and/or channels, both sloping to a collection sump or vessel. All connections in the system shall be liquid-sealed by means of turned-down elbows. The collection sumps shall be connected by means of liquid-filled underground drain pipes to a main collection sump or vessel located at or near the battery limit of the plot area. All funnels and pipe ends (connections) shall be provided with flanges to allow pressure cleaning/testing per section. The collected hydrocarbons shall, wherever possible, be returned to slops or re-processing. In the event that the on-plot collection sumps are gas sealed, consideration shall be given to venting provision to a safe area.

For typical details of a drip/drain system, see Figure 7.

iii) drips/drains for hydrocarbons which will easily evaporate at ambient temperature: no special drainage requirements are necessary.

5.2.2 Existing plants

For existing plant areas the drainage networks may comprise individual networks for AOC, COC and cooling water effluents. For Shell designs the AOC and COC systems will normally be of a 'liquid-filled' design incorporating horizontally laid underground pipes interconnected by sumps. The AOC systems will generally discharge to a holding basin or oil trap and the COC systems to an interceptor whose effluent would normally be directed to the AOC network tieing in to the network upstream of the end facility.

Points which shall be taken into consideration for upgrading exercises on existing plants are as follows;

a) Upstream network capacities are often under-designed for the fire fighting design condition.
b) COC networks generally allow ingress of rain water, often resulting in overloading of interceptors under peak flow rainfall conditions.
c) Inadequate segregation of networks often exists. At-source segregation can result in savings on Capex investment on downstream facilities.
d) Both AOC and COC network capacities can be taken into consideration when checking loadings due to the fire fighting design condition.
e) Existing oil traps and holding basins are vulnerable to contaminated effluent carry-over under peak flow conditions.

6. NETWORK COMPONENTS

6.1 SUMPS, CATCH BASINS AND MANHOLES

Sumps or catch basins shall be located such that they collect surface water from the surrounding areas.

Manholes shall be located at intersections of main drainage lines for inspection and/or maintenance purposes, but in general shall not be designed to collect surface water run-offs.

Existing plants

For extensions or modifications to existing on-plot areas the following design parameters shall apply:

Drainage sumps for paved on-plot areas shall form an integral part of either the AOC or COC networks. Sump locations within these areas shall be determined such that proper segregation is assured between the networks.

A drainage sump located in paved surfaces shall serve an area of paving of maximum 400 m^2, with a maximum distance between sumps of 50 m. The level difference between the top of a sump and the high point of the 20 x 20 m paved area shall be 100 mm.

New plants

For new process areas the design aim is to achieve improved surface water run-off and provide better segregation of effluents at source, thus reducing the risk of contaminating cleaner effluent streams with dirtier streams.

In line with this aim the following design parameters shall apply to new process areas:

The number of sumps shall be kept to a minimum while satisfying the requirements for spill run-off and distance between each sump as laid down in section 5.2.1.

The safety distance between open sumps and the burners in furnace/ boiler areas shall be at least 7.5 m.

Offsites

Sumps which are interconnected by piping of diameter 900 mm and larger shall be located at a maximum distance of 100 metres apart.

Sump sizes

Square sumps shall have minimum internal plan dimensions of 800 x 800 mm.

Rectangular sumps shall have minimum internal plan dimensions of 800 x 600 mm. The maximum depth for a minimum size sump is 1.5 m.

The minimum internal plan dimensions of sumps deeper than 1.5 m shall be increased proportionally to allow access for maintenance and inspection.

The internal plan dimensions for a sump shall not be less than the largest pipe size plus 500 mm.

For a summary of recommended sump sizes, see Figure 8.

The bottom of each sump shall be at least 200 mm below the bottom of the lowest connected pipe. Pipe ends shall be flush with the inside sump wall to allow the installation of self-skimming buckets.

Self-skimming buckets should be considered for installing in sumps serving a COC drainage network to reduce oil accumulation and subsequent evaporation within the sumps.

For a typical self-skimming sump, see Figure 9.

Where the requirement for closed (sealed) sumps and/or manholes is unavoidable, ventilation shall be provided to prevent accumulation of hydrocarbon vapours in the sump. The ventilation shall be provided by means of a pipe of minimum diameter 50 mm routed to a safe area.

6.2 FLOW DIVERSION SUMPS

Flow Diversion Sumps may be considered upstream of a primary treatment unit.

Their design purpose being to divert any peakflow loadings (Q_{rain} or Q_{fire}) in excess of the design capacity of the relevant treatment unit.

Flow diversion can be achieved by means of two free weirs with differential heights or alternatively, by means of one free weir and flow throttling.

Although flow throttling is considered to give better 'diversion' results, higher hydraulic losses may result, and checks shall be carried out on the effects of these losses on the upstream networks.

See Figure 10 for further details.

6.3 UNDERGROUND PIPING

To prevent the propagation and accumulation of hydrocarbon vapours and/or fire through an underground drainage network, underground pipes shall be laid horizontally and designed such that they are kept flooded (liquid-filled) at all times. A minimum liquid head of 50 mm, measured from the inside top of the pipe, shall be maintained.

For 'dry areas' (e.g. Middle East) this minimum head should be increased to 100 mm.

Underground piping in drainage service should have a minimum diameter of 200 mm.

Piping used in oil drip/drain service shall have a minimum diameter of 100 mm.

The minimum depth of underground piping shall be determined from the following.

- Minimum depth for burial, from the structural load bearing capacity of the pipe.
- Minimum depth required to avoid interference from other underground services (e.g. cables, foundations)
- Minimum depth shall be 1.5 m, or deeper if required by the above.

Underground piping shall not be installed underneath spread footings or foundations.

Drainage piping through foundations (e.g. ground beams) shall be installed with pipe sleeves.

6.4 OPEN CHANNELS

The size of open drain channels shall be determined by hydraulic calculation for the actual design condition applicable.

Open drain channels designed for transporting hydrocarbon contaminated effluents shall 'run dry' after a rain or fire condition.

The cross sectional profile of open drain channels may be rectangular or hydraulically shaped.

A slope of 1:300 shall be used where practical, although for oil free networks slopes of up to 1:1000 may be used if construction methods can be executed which avoid low spots and possible ponding.

Open channels may be constructed in-situ or by utilising precast sections.

The minimum width of rectangular channel shall be 300 mm, and the minimum depth for all channels shall be 150 mm.

Large open channels (greater than 900 mm wide) shall be provided with a central dry weather flow channel.

No piping and/or pipe supports shall be installed directly over or across open channels.

Open channels shall be covered with galvanized grating only at those places where operator/maintenance access is required.

Open channels located at the toe of an embankment shall be provided with a 'walking strip' (minimum 350 mm wide) for maintenance access.

For typical details of open drain channels, see Figure 5.

6.5 FIRE AND SAND TRAPS

Fire traps and sand traps shall be installed at road crossings and/or fire breakers within pipetracks.

The minimum requirements for fire trap sumps shall be the same as those specified for the drainage sumps. The minimum distance between two interconnecting fire trap sumps shall be 9 m and the connecting underground pipe shall always be liquid-filled.

Sand traps shall be provided upstream of a fire trap and at the lowest point in an open drain channel system where this enters a sump. Sand traps shall have the same width as the drain channel, shall have a minimum length of 2 m and shall have a minimum depth of 0.5 m.

Typical details of a sand/fire trap together with the recommended level difference between drain channel inverts and sand trap overflow are shown in Figure 5.

Fire trap design shall comply with the following additional requirements with respect to compound drainage networks;

- The location of the (outlet) valve sump shall be such that safe access is possible even under fire-fighting conditions.
  Where a tank compound drainage valve discharges directly into an open channel a splash wall shall be provided.

- The lowest invert of the open drain channel inside the tank compound at the sand trap shall always be 50 mm higher than:

  a) the invert level of the drain outside the tank compound receiving the tank compound discharge.
  b) the static water level of the liquid-filled system serving also the tank compound drainage.

7. MATERIALS

Drainage networks and components should be of leak-proof design. System tightness shall be controllable and measurable, even after a long period of operation.

7.1 UNDERGROUND PIPING

Whereas pipe material selection may be influenced by the degree of application of the above requirements and in many instances influenced by local material availability, the following shall apply wherever possible.

Glass Reinforced Epoxy (GRE) material should be used for hydrocarbon contaminated drainage networks and shall comply with DEP 31.38.70.24-Gen. and DEP 31.38.70.37-Gen.

The minimum allowable pressure rating for GRE piping used in underground drainage service should be 8 bar (ga) and the design and installation shall be carried out in accordance with DEP 31.38.70.24-Gen.

Carbon steel pipe may be used for drip/drain systems as a cost effective alternative to GRE. In this event consideration shall be given to the external protection of the pipes by the application of appropriate coating and pipe material selection shall be in accordance with DEP 31.38.01.12-Gen.

The use of reinforced concrete pipes should be considered in instances where pipe diameters of greater than 900 mm are required for design purposes.

For specific applications relating to chemical sewers, material selection shall be based on the requirements laid down in DEP 31.38.01.12-Gen. and DEP 30.10.02.13-Gen.

Piping for domestic sewer systems and rainwater downpipes from buildings shall be PVC, ABS or an equivalent approved material.

The following general design parameters shall apply to the design of underground drainage piping :

- Pipe connections and materials shall be selected such that the underground sumps and pipes and sewers in plant areas and tank farms areas can easily be installed and will not give rise to leakage or collapse due to e.g. settlement of subsoil, shock loads of aggressive oils/chemicals released accidentally or during plant shutdown (polluted effluent), cleaning of pipes by rodding, the use of low-pressure steam of 3.5 bar and/or the insertion of high pressure jetting water of approximately 10 bar.
- GRE and carbon steel pipes passing through concrete walls of sumps and concrete basins shall be provided with a puddle flange around the pipe, cast in the wall.
- In instances where differential settlement or differential expansion between pipe and sump can be expected, a flexible connection shall be applied.
- All possible chemical components of the effluent shall be identified. Adequate protection is required against continuous erosion, corrosion and attack by aggressive chemicals.

7.2 SUMPS

Sumps shall be constructed in-situ from reinforced concrete or precast units.

The use of prefabricated GRE sumps may be considered for offsite areas. In these areas the structural load bearing capacity of the sumps should at all times be checked against vehicle wheel loadings from plant traffic. Manufacturers shall be consulted for available sump sizes, material specification and structural capacities.

7.3 NEUTRALIZATION FACILITIES

All reinforced concrete pits, drain channels and sumps in neutralization service shall be designed and constructed in accordance with the requirements of DEP 30.48.60.12-Gen.

8. DESIGN PARAMETERS FOR DRAINAGE NETWORKS

8.1 GENERAL

The following minimum requirements shall be applicable to designs in order to achieve functional drainage networks.

8.1.1. Maximum and minimum velocities

The maximum velocity of hydrocarbon contaminated effluents in an underground drainage system shall not exceed 0.9 m/s. This velocity will generally prevent dispersion of oil by turbulence.

This velocity may be exceeded only under the fire fighting design condition.

Higher velocities are permitted in systems which are primarily designed for deballasting systems and cooling water networks, to avoid uneconomical pipe sizes. Designs should aim for uniform stable flows (e.g. large radius bends, no tee junctions etc.)

Velocities of less than 0.3 m/s shall be avoided in order to prevent a premature separation and consequent accumulation of oil/sediment within the drainage network. For a COC drainage network with low and often intermittent design flows it is recommended to provide a minimum constant flow through the system (e.g. diversion of cooling water to the upstream sumps).

8.1.2 Effluent temperature

The maximum effluent temperature within any drainage network shall not exceed 45 °C.

8.1.3 The use of concrete and steel

All concrete and steel used in the construction of drainage and primary treatment systems shall comply with the requirements of DEP 34.19.20.31-Gen.

8.1.4 Design flow

Drainage networks shall be designed for the maximum flow resulting from the greater of the following load combinations:

Rainfall (Q_{rain}) + any other known contributing continuous 'dry weather flow'.

Fire water (Q_{fire}) + any other known contributing continuous 'dry weather flow'.

8.2 CONTROLLED FLOODING

Temporary storage of effluent in pipetracks is allowed, provided that the safety and environmental requirements are met. The maximum allowable effluent level during any surcharging condition shall not be higher than 150 mm below the top of the pipe sleeper.

Flooding is not permitted in any other area.

8.3 RAINWATER PEAKFLOW/ACCUMULATED FLOW

Peakflow calculations will determine the design of drainage collection systems and the capacity (throughput) of treatment facilities.

Accumulated rainfall calculations will determine the design of buffer volumes and controlled discharge facilities.

8.3.1 Rainwater peakflow design parameters

Specific meteorological data is required to achieve functional and economical designs for rainwater peakflows. Rainfall 'Intensity-Frequency-Duration' curves shall form the basis of any hydraulic calculations.

Calculations for establishing the run-off values shall be carried out using established and proven methods. One method most frequently used is the Rational Method:

$$Q_{rain} = C\ i\ A$$

where Q_{rain} = quantity of rainwater run-off in m^3/hr

C = run-off coefficient

i = design rainfall intensity (m/hr) based on the time of concentration (T_c)

A = catchment area under consideration in m^2.

The Rational Method assumptions and design parameters are as follows:

1) The maximum run-off resulting from a particular rainfall intensity occurs if the duration of rainfall is equal to or greater than the time of concentration (T_c). The time of concentration is defined as the time required for water to flow from the most distant point of the catchment area under consideration to the point of flow measurement (investigation).
2) The maximum run-off resulting from a particular rainfall intensity, whose duration is equal to or greater than the time of concentration, is directly proportional to the rainfall intensity.
3) The frequency of occurrence of the peak discharge is the same as that of the rainfall intensity from which it was calculated.
4) The peak discharge per unit area decreases as the drainage area increases, and the intensity of rainfall decreases as its duration increases.
5) The coefficient of run-off remains constant for all storms on a given watershed.
6) The method may only be applied for surface water run-off by gravity for an area not larger than approximately 40 hectares (400,000 m^2). For areas greater than 40 ha, the total area should be sub-divided into smaller catchment areas. For each individual catchment area, the Rational Method may then be applied.

8.3.2 Accumulated rainfall design parameters

Accumulated rainfall data is generally available in the form of tables from local weather stations, indicating rainfall 'depths' in mm for a range of durations and recurrence periods. These tables can be plotted as graphs indicating the accumulated rainfall for given time periods. These graphs can be used to establish required buffer/storage volumes which govern the requirement for controlled discharge facilities (see Figure 11).

8.4 RUN-OFF COEFFICIENT

The permeability of surface finishes and in some instances the evaporation of rainwater affect the quantity of rainwater which enters a drain system.

Table 1 lists some typical run-off coefficients which have been selected for drainage network design for various types of surface finishes.

TABLE 1 RUN-OFF COEFFICIENTS

a	Plant area/utility area (paved) Evaporation/percolation coefficient (see note below)*	1.0
b	Manifold and pump slab areas	1.0
c	Roads and road shoulders Brick roads/tiled areas	0.95 0.75
d	Pipe tracks (general) Pipe track concrete finish	0.50 0.90
e	Bundwalls (average) Bundwalls with seepage prevention	0.55 0.90
f	Tank roofs	1.0
g	Tank compounds areas (unpaved) Tank compound areas with seepage prevention Grassed areas (sandy soil, flat) Grassed areas (clayey soil, flat)	0.3 0.9 ≈ 0.1 ≈ 0.5

* Note: For densely built up plant areas where significant heat is generated by equipment and plant piping, this run-off coefficient may be reduced to 0.7.

8.5 RAINFALL INTENSITY

Rainfall data shall be obtained in the form of rainfall 'intensity-duration-frequency' curves which define the rainfall intensities and durations for given storm recurrence periods.
(For typical curves, see Figure 12)

For drainage network designs, curves representing a 'one in two year storm' return period shall be used.

8.6 TIME OF CONCENTRATION/ENTRY/FLOW

The time of concentration (T_c) shall be used to determine the applicable rainfall intensity which, when used in the Rational Formula, will determine the peak flow values at the point of measurement in the system.

The time of entry or 'overland flow' (T_e) shall be taken as the time required for one rain droplet to enter a drain channel or sump in the drainage network. The time of overland flow within typical refinery areas normally varies between 5 and 25 minutes. Figure 13 shows typical T_e values for various surface slopes and finishes.

The time of flow (T_f) shall be taken as the time required for the effluent to flow through the drainage network or an element thereof.

For open drain channels and for non-liquid-filled pipes, the time of flow (T_f) is the time required for the effluent to flow through the relevant channel length, i.e. length divided by the velocity.

For liquid-filled pipes the time of flow should be taken as the time required for the system to reach stable flow conditions and is referred to as T_{df}. Typically, this value can vary between 2 and 5 minutes.

Thus, for drainage networks the following T_c values should be used:

a) For open drain channels and for non-liquid-filled pipes:

$$T_c = T_e + T_f$$

b) For liquid-filled pipes only:

$$T_c = T_e + T_{df}$$

c) For a combination of liquid-filled pipes and open drain channels the overall network calculations should be simplified using the formula:

$$T_c = T_e + T_f$$

For calculating storage volumes, e.g. buffering capacity of a controlled discharge facility, a T_C value of 30 minutes should be used for typical refinery areas. The Principal should be consulted when selecting T_c values as these can be critical to the sizing of drainage networks and controlled discharge facilities, can impact investment costs, and can influence the downstream discharge characteristics.

8.7 FIRE FIGHTING WATER (FFW)

8.7.1 General design parameters

Reference is made to the DEP 80.47.10.30-Gen. and DEP 80.47.10.31-Gen.

The quantity of fire fighting water to be collected and discharged through a drainage network shall be determined based on the assumption that there will only be one major fire at any one time.

Fire fighting water quantities shall where possible be determined from actual data and scenarios prepared by the responsible Safety Officer. For studies and front end designs, the typical data indicated in Table 2 can be used as a minimum.

TABLE 2 INDICATIVE FLOW RATES FIRE FIGHTING WATER/SPILL CONTROL

AREA	INTENSITY [l/min/m^2]	MAX FLOW [m^3/hr]	SPILL CONTROL [m^3]
PLANTS			
process	6.8	500	100 m^3 of oil
offplot general	see section 8.7.2	-	4 hrs FFW
offplot tankage	see section 8.7.2	-	bunded area
jetties/loading	see section 8.7.2	-	kerbed area
LNG			
process	24	1750	10
storage	Note 1)	-	-
jetties/loading	10	750	1
LPG			
process	24	1750	10
storage (spheres, bullets)	10	-	10
jetties/loading	10	750	1

Under the FFW design condition all available drainage networks may be used to discharge fire fighting water and the parameters governing the velocities in the individual drainage network elements are not applicable.

Normally, FFW design condition will govern design of upstream networks, whereas the rainfall design condition will govern downstream networks.

NOTE: 1) ependent upon tank construction. Principal should be consulted.

8.7.2 Off-plot areas

For all areas other than the process and utility areas and tank farms, FFW shall calculated in relation to the actual fire hydrant discharge quantities for the area under consideration.

Where no data exist or can be provided, the minimum fire fighting water quantity for any offsite area shall be 500 m^3/hr. Quantities shall be determined in consultation with the Principal or the local fire/safety officer.

In the event that no specific data are available, individual hose discharge quantities shall be taken as 60 m^3/hr.

For tank compounds the following shall apply:
Where automatic spray water systems are installed, these will be used to cool adjacent tanks in the event of a tank on fire. The discharge capacity of those systems shall be used to determine the run-off FFW quantities.
The drainage network and outlet valve shall be designed such that the water level inside the tank pit will not exceed a height of 0.3 m above the lowest tank pad during a fire fighting condition. A practical valve size is 300 mm. If the design requires a larger outlet, additional outlet valves should be selected rather than increasing the valve diameter.

Special attention shall be paid to the quantity of water resulting from spray water systems applied at LNG/LPG facilities. Resultant run-off quantities may be considerably higher than those specified for refinery designs.

8.7.3 Buffering of contaminated fire fighting water

Contaminated FFW shall not be discharged directly to public water. Buffering facilities shall be provided to retain fire fighting water to allow inspection and analysis for decision making with respect to treatment requirements.

FFW buffering facilities shall, where practical, be an integral part of the controlled discharge facility for rainwater effluents. Separate or dedicated buffering facilities for FFW should only be considered in areas of low and infrequent rainfall.

8.8 INDIRECT FLOWS

The design of drainage networks shall consider the maximum use of indirect flows to reduce end-of-pipe treatment capacity.

Indirect flows can be achieved by buffering of rainwater at defined areas during a rain storm and releasing the buffered effluents only after treatment of the direct run-off effluents has been completed.

Typical drainage networks which shall incorporate an indirect flow design are as follows:

1) AOC networks within tank compounds.

   The buffering of rainwater shall be achieved by keeping the valve controlled outlet of the tank compound closed during a rainstorm. Sequential release of buffered rainwater shall take place within a maximum period of 6 hours after a given storm. The compound shall have adequate buffer volume such that the level of buffered rain shall not reach the level of the underside of the tank base.

2) COC networks for:

   Tank bottom drains from crude tanks, product tanks and slops tanks
   Ballast water tanks
   Filter backwash water
   Jetty head loading arm areas

Operational practices will determine the frequency of the intermittent run-offs with respect to tank bottom draining, ballast water and filter backwash discharges.

Dedicated buffer tanks shall be selected to achieve optimal minimum loading on the end-of-pipe treatment facilities.

Jetty heads shall be provided with collection sumps or vessels to buffer COC effluents resulting from rainwater. The buffer and associated effluent pump capacity shall be carefully selected to minimise downstream treatment capacity.

9. HYDRAULIC CALCULATIONS

9.1 GENERAL

Hydraulic calculations shall be prepared to achieve an economical and effective drainage network design. All drainage piping, sewers and open drain channels shall be designed in accordance with accepted standard formulae and calculation methods, including sump influences (losses), weir overflow losses, and friction coefficients which take into account the anticipated future condition of the drainage network.

Although there are many 'empirical' formulae which can be used, the formulae given in (9.2), should be used in order to simplify and standardize the design method and presentation.

The design of drainage networks should be based on gravity flow where the installed depth of the underground pipes relates directly to the weir level at the main outlet point, e.g. treatment facility (see Figure 14). At locations where the available positive head is insufficient to achieve a gravity flow condition, pumping facilities shall be provided. In such instances, the Archimedes type of screw pumps should be used.

9.2 HYDRAULIC GRADIENTS

The hydraulic gradient (I) can be determined by using Chezy's formula:

$$I = \frac{V^2}{C^2 R}$$

where V = velocity [m/s]
C = Chezy coefficient [$m^{0.5}$/s]
R = hydraulic radius, or hydraulic mean depth [m]
I = hydraulic gradient or incline [m/m']

R is the relationship between the amount of liquid being conveyed and the contact area between this liquid and the inside of the channel.
R = cross sectional area of flow divided by the wetted perimeter

The Chezy coefficient can be calculated using the simplified Colebrook-formula:

$$C = 18 \log_{10}\left(\frac{12\ R}{k}\right)$$

where C = Chezy coefficient [$m^{0.5}$/s]
R = hydraulic radius [m]
k = Nikuradse wall roughness factor [mm]

The value k is independent of the diameter of the drainage pipeline. Table 3 gives k values for various materials. Note that for GRE material the influence of the boundary layer in the calculations of the Chezy coefficient has been taken into account. The influence of the boundary layer can be disregarded for k values of 0.5 mm and greater.

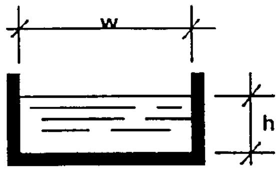
TABLE 3 NIKURADSE WALL ROUGHNESS FACTOR "k" FOR VARIOUS MATERIALS

MATERIAL	k (mm)
concrete	2
steel (non corroded)	0.5
steel (corroded)	5
GRE	0.2 (Includes influence of boundary layer)

9.2.1 Open channels

For a rectangular drain channel, R is given by :

$$R = \frac{(h \ w)}{2h + w}$$



C values for open drain channels, based on the Colebrook formula, are shown in Figure 15.

If precast drain channels are used, Manufacturer's design charts may be used to establish I, V and C.

All reference documentation shall be enclosed in any design packages prepared.

9.2.2 Liquid-filled pipes

For 100% liquid filled drainage pipes, Chezy's formula can be simplified as follows:

(1) $$I = \frac{V^2}{C^2 \ R}$$

For liquid filled drainage pipes, the hydraulic radius (R) will be:

(2) $$R = \frac{\pi D^2 / 4}{\pi D} = \frac{D}{4}$$

V is derived as follows:

(3) $$V = \frac{Q}{\pi \ (D^2 / 4)}$$

Inserting (2) and (3) into (1) gives:

$$I = \frac{64 \ Q^2}{\pi^2 \text{ x } D^5 \text{ x } C^2}$$

The relationship between I and Q can be written as:

$I = \alpha \text{ x } Q^2$

where I = incline (slope) [m/m']

Q = flow [m^3/s]

$$\alpha = \frac{64}{\pi^2 \ D^5 \ C^2}$$

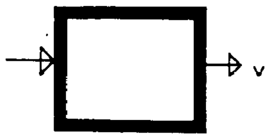
α is related to the pipe material. The α factors are shown in Table 4, using C values calculated with Colebrook's formula.

TABLE 4 "C" VALUES AND "ALPHA" VALUES FOR LIQUID FILLED PIPES (based on Chezy-formula)

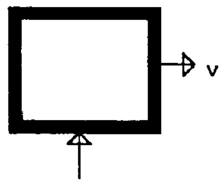
Diameter	GRE k = 0.2 mm		Concrete k =2 mm		Steel k = 0.5 mm		Corroded steel k = 5 mm	
(m)	c	alpha $*10^{-3}$	c	alpha $*10^{-3}$	c	alpha $*10^{-3}$	c	alpha $*10^{-3}$
0.10	57.2	198 403.47	39.2	422 650.13	50.0	259 312.5	32.0	632 991.41
0.15	60.3	23 454.36	42.3	47 636.18	53.2	30 198.59	35.2	69 011.59
0.20	62.6	5 173.04	44.6	10 192.73	55.4	6 596.52	37.4	14 467.73
0.25	64.3	1 604.42	46.3	3 093.20	57.2	2 031.65	39.2	4 327.94
0.30	65.8	617.13	47.8	1 170.00	58.6	777.24	40.6	1 619.31
0.35	67.0	275.34	49.0	515.00	59.8	345.25	41.8	706.62
0.40	68.0	136.92	50.0	253.23	60.8	171.06	42.8	344.99
0.50	69.8	42.65	51.8	77.48	62.6	52.97	44.6	104.37
0.60	71.2	16.46	53.2	29.49	64.0	20.35	46.0	39.39
0.70	72.4	7.36	54.4	13.05	65.2	9.07	47.2	17.30
0.80	73.4	3.67	55.4	6.44	66.3	4.51	48.3	8.50
0.90	74.3	1.99	56.3	3.46	67.2	2.43	49.2	4.54
1.00	75.2	1.15	57.2	1.98	68.0	1.40	50.0	2.59
1.10	75.9	0.70	57.9	1.20	68.8	0.85	50.8	1.56
1.20	76.6	0.44	58.6	0.76	69.4	0.54	51.4	0.99
1.30	77.2	0.29	59.2	0.50	70.1	0.36	52.1	0.64
1.40	77.8	0.20	59.8	0.34	70.6	0.24	52.6	0.44
1.50			60.3	0.23	71.2	0.17	53.2	0.30
1.60			60.8	0.17	71.7	0.12	53.7	0.21
1.70			61.3	0.12	72.2	0.09	54.2	0.16
1.80			61.8	0.09	72.6	0.07	54.6	0.12
1.90			62.2	0.07	73.0	0.05	55.0	0.09
2.00			62.6	0.05	73.4	0.04	55.4	0.07

9.3 SUMP LOSSES AND WEIR LOSSES

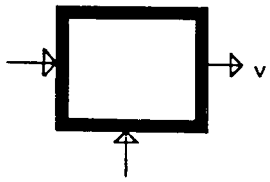
Sump losses can be determined by using the following simplified formulae:



$$P = 0.3\frac{V^2}{2g} = \frac{V^2}{66}$$

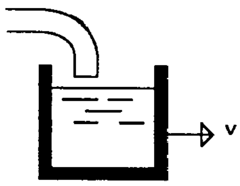


$$P = 1.5\frac{V^2}{2g} = \frac{V^2}{13}$$



$$P = (0.3 + 0.6)\frac{V^2}{2g}$$

$$P_{max} = \frac{V^2}{2g} = \frac{V^2}{20}$$



$$P = \frac{V^2}{2g} = \frac{V^2}{20}$$

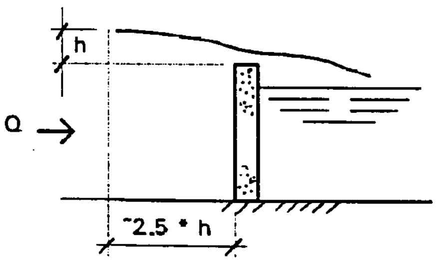
Where:

V = velocity (m/s)
P = sump head loss (m)
g = acceleration due to gravity (m/s^2)

Weir overflow losses can be determined by using the following simplified formulae:

The liquid depth over a weir may be calculated as follows:

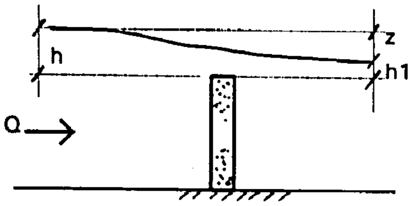
a) Free weir



$$Q = 1.84 L h^{3/2}$$

or $$h = \left(\frac{Q}{1.84\ L}\right)^{2/3}$$

b) Submerged weir



$$Q = \left(1.84\ L\ z^{3/2}\right) + \left(2.8\ L\ h_1 \sqrt{z}\right)$$

where Q = flow [m^3/s]
L = length of the weir [m]
h = liquid depth over the weir [m]
z = liquid depth over the weir [m]

9.4 ACCUMULATION OF HYDROCARBONS IN SUMPS

Sumps within hydrocarbon contaminated liquid filled drainage networks will accumulate hydrocarbons. The liquid levels within the sumps, when calculated on the basis of water, shall be converted into levels corresponding to a density of 850 kg/m^3 (due to the difference in density between water and hydrocarbons). Only the height of the liquid above the invert of the drainage pipe shall be used. For areas where controlled flooding is not allowed, the converted levels shall remain at least 0.15 m below the top of the sump.

9.5 COMPUTER PROGRAMS

Computer programs used for design purposes shall take into account that the design of underground piping networks as required by this DEP are principally laid horizontally and liquid filled.

Programs and calculation methods proposed by contractors shall be subject to review and approval by the Principal.

10. PRIMARY TREATMENT FACILITIES

Primary treatment facilities are separators which, like any settling facility, provide an environment in which suspended solids can be settled coincidentally with the separation of oil in the influent. Flow rate, oil gravity and effluent temperature are factors affecting their design. They are facilities which will separate free oil from waste water but will not separate soluble substances, nor will they break emulsions.

10.1 DESIGN PRINCIPLES

In an ideal separator, the principles governing design may be expressed mathematically and although there is a practical limitation to separator effectiveness due to the varying factors involved, the following design rules should be followed for new designs or in assessing the performance of existing designs.

For oil separation, the removal of an oil droplet of given size shall be equal to or greater than the "overflow rate". The overflow rate being the flow rate through the separator divided by its surface area.

Thus the rising velocity of an oil globule expressed as V_r can be determined using Stokes' Law, as follows:

$$V_r = \frac{g}{18\mu} * \frac{(\delta_w - \delta_o)}{\gamma}$$

where V_r = rising velocity of oil globule (m/s)
μ = diameter of oil globule (m)
δ_w = density of influent at the design temperature (kg/m^3)
δ_o = density of oil in the influent at the design temperature (kg/m^3)
γ = absolute viscosity of influent at the design temperature (Pa.s)
g = acceleration due to gravity (m/s^2)

Where possible, all physical properties of the influent should be determined by measurement.

10.1.1 Comparison of typical primary treatment facilities for refinery duty

It should be noted that the efficiency of oil removal and hence the actual effluent quality in milligrams per litre at the outlet of a primary treatment facility is influenced by factors which cannot always be controlled or measured. Table 5 is indicative of typical facilities in refinery service for stable flow conditions and for well maintained and well operated facilities. The surface area indications are based on an average throughput of between 100 and 120 m^3/hr.

TABLE 5 COMPARISON BETWEEN SEPARATOR TYPES

Separator type	Design basis	Effluent quality	Surface Area
API	150 microns	80 to 100 ppm oil	270 m^2
PPI	100 microns	50 to 80 ppm oil	45 m^2
CPI	50 to 60 microns	25 to 50 ppm oil	30 m^2

10.1.2 Area classification

Primary water treatment facilities shall be considered as hydrocarbon containing equipment and their location shall be subject to the minimum safety distances noted as follows:

- Distance to the edge of public roads: 30 m
- Distance to the edge of main roads: 15 m
- Distance to a fixed source of ignition: 15 m

Prevailing winds should be taken into consideration when choosing the location and orientation of the treatment facility.

10.1.3 Design considerations

Designs of treatment facilities should consider the following:

- hand railing and grating for operator safety and access
- easy access to skimmers, pumps and filters
- proper ventilation for depressed locations
- perimeter lighting
- surface drainage of surrounding paved area
- kerbs around pump foundations
- water supply for flushing and/or pump seal cooling
- maintenance access for gulley sucker, vacuum truck, mobile crane
- signboard with unit number and capacity
- level instrument with high-level alarm in oil collection sump

Covers shall not be used on separators without the approval of the Principal.

10.2 PRE-SEPARATORS

A pre-separator (pre-sedimentation basin or sludge trap) shall be provided upstream of a gravity separator where heavily polluted influent streams are present, its primary function being to allow the settling of solids which would otherwise impair the performance of the downstream separator basin.

The pre-separator should be integral with the separator basin and comprise a concrete basin with retention baffle, overflow weir and a sedimentation zone.

The pre-separator design should incorporate the following features:

- Sludge removal (e.g. sloping basin floor).
- Distribution walls for equal flow distribution where required upstream of a CPI with two parallel bays.
- Flow diversion provisions for maintenance/repair of the downstream treatment facility.
- Skimming facilities.
- Residence time for the average flow should be around 15 min, subject to the inflow (feed) composition.
- Recommended overflow rate under maximum flow conditions is 10 mm/s.

A typical arrangement of a pre-separator is shown in Figure 16.

10.3 API (AMERICAN PETROLEUM INSTITUTE) SEPARATOR

API separators should not be used for new designs.

An API separator is the simplest form of interceptor, the separating chamber simply consisting of an open rectangular basin.

The standard API separators existing in many old refineries comprise an inlet section and oil-water separation chambers and are based on the following design parameters:

- Maximum horizontal velocity within the oil separation channel is 0.015 m/s, or 15 times the rising velocity (whichever is the smallest).
- The minimum depth-to-width ratio is 0.3.
- The depth of the oil separation channel is 0.9 m to 2.4 m maximum.
- For calculating purposes, a sediment layer of 0.30 m on the bottom of the entire oil trap has been taken into consideration.
- The width of the oil separation channel is 1.8 m to 6 m maximum.
- The approach channel and transition part have been constructed in two bays in order to facilitate its cleaning and repair when required.
- Flight scrapers may be installed to gently move the sludge to the sludge collection pit and oil to the oil skimming device.
- Covers may have been installed to avoid odour hindrance or to prevent the formation of algae.

A standard lay-out of an API separator is shown in Figure 17.

10.4 PPI (PARALLEL PLATE INTERCEPTOR)

A PPI is a gravity separator and, although it is more efficient than the conventional API separator, it should not be used for new designs.

The standard PPIs which exist at some refinery locations are generally based on a standard capacity of 50 m^3/hr per bay for dry weather flows and 100 m^3/hr under rainfall design conditions.

Within a PPI the combined surface area of the plates is significantly higher than the surface area of the conventional API separator, resulting in a lower overflow rate and therefore a better oil removal efficiency.

Standard Drawings for PPIs are being withdrawn. If information is required on PPIs for maintenance and inspection purposes the Principal should be contacted.

10.5 CPI (CORRUGATED PLATE INTERCEPTOR)

The CPI shall be used for the treatment of COC effluents.

Specially designed corrugated plate packs increase the efficiency of oil removal way above the levels achieved in PPIs of similar capacity.

The separation of oil from water takes place between the plates based on countercurrent flow, i.e. the effluent flows downward whereas the oil will flow upward to the surface.

The following design parameters shall be applied to CPI design:

- CPIs should be installed as close as possible to the source of the pollution, i.e. the interceptor for a processing area shall be placed inside or near the battery limit.
- The drainage network for tank bottoms shall have either an independent interceptor or shall be connected to the nearest interceptor of a processing/utility area.
- The CPI shall be constructed in accordance with the principles indicated on Standard Drawing S 14.021 and other drawings mentioned thereon.
- The plate packages shall be installed at an angle of 45 or 60 degrees. 60 degree angled packs should be used in situations where the effluent to be treated contains heavy suspended solids.
- Standard packs are available with the distance between plates of 20 and 40 mm. The 40 mm distance between plates is recommended for highly viscous streams containing heavy suspended solids where no pre-separator is specified upstream.
- A minimum constant effluent throughput of 5 m^3/h per plate pack or 10 m^3/h per bay should be applied for good operation.

The maximum allowable flows are related to the plate distance of the plate packs and the loading condition.

Loading condition	Plate distance [mm]	Max. flow per plate pack [m^3/hr]
Normal dry weather flow	20	30
	40	15
Rain and normal flow	20	60
	40	30

CPIs with a capacity greater than 540 m^3/hr shall be designed with a back-to-back arrangement of bays, comprising a flow diversion sump at the inlet and independent outlets. The design shall incorporate provisions to facilitate cleaning and repair.

Process effluent streams (e.g. Desalter drains) and effluent streams containing high levels of BOD shall be treated in a separate CPI than those streams for non-process waters.

A typical arrangement for a 2 Bay CPI is shown in Figure 18.

10.6 OIL-TRAPS

Oil traps are facilities designed to trap and retain floating oil, caused primarily by a spillage and entering an AOC network. They have very low separation capacity and no controlled discharge provisions. Oil traps shall not be considered for new designs.

The standard oil trap as constructed in many refineries, consists of an approach channel, a transition part and a final weir section. Their design is generally based on the following parameters:

- An approach channel of minimum length 60 metres.
- Maximum velocity within the approach channel is 0.25 m/s under normal conditions and 0.45 m/s during maximum rainfall conditions.
- For the final weir section the maximum velocities are 0.20 m/s and 0.35 m/s respectively.
- For the maximum velocities underneath the baffle the values are 0.08 m/s and 0.15 m/s respectively.
- For calculation purposes, a sediment layer of 0.30 m on the bottom of the entire oil trap is taken into consideration.
- The underside of the baffle wall is a minimum of 0.60 m below the water level in the oil trap.
- The approach channel and transition part are constructed in two bays in order to facilitate its cleaning and repair when required.

The standard drawings for oil traps are being withdrawn; the Principal should be contacted for information regarding maintenance and inspection.

10.7 OIL-HOLDING BASIN

Oil-holding basins are designed to function as an oil separator, their main purpose being to retain large accidental spillages of up to 100 m^3.Their design principles are similar to those of an API separator, with higher horizontal effluent velocities.

Holding basins shall not be considered for new designs.

The standard holding basins existing in many refineries are located at the end of an AOC drainage network, near or at the property fence or boundary. Their design is based on the following parameters:

- Maximum velocity of effluent through the holding compartment does not exceed 0.05 m/s under normal conditions and 0.075 m/s during maximum rainfall.
- The velocity underneath the baffle is not greater than 0.15 m/s.
- For calculating purposes, a sediment layer of 0.30 m on the bottom of the entire holding basin is taken into consideration.
- The optimum overflow rate is 0.005 m/s.
- Theoretical design water depth is 1.20 m.
- The underside of the baffle wall is a minimum of 0.60 m below the water level in the holding basin.

The standard drawings for oil holding basins are being withdrawn; the Principal should be contacted for information regarding maintenance and inspection.

10.8 WATER RETENTION OR OBSERVATION BASIN

The requirement in design for a water retention or observation basin shall be specified by the Principal.

These basins shall be located downstream of all other primary and secondary treatment facilities and facilitate sampling of final effluent quality before it is discharged to public water.

10.9 CONTROLLED DISCHARGE AND SPILL CONTROL

10.9.1 Controlled discharge

Prevention of uncontrolled discharges is essential for proper refinery operations within existing and new plants.

Controlled discharge facilities shall be installed as a means of controlling the discharge of rainwater and fire fighting water effluents, their function being to allow inspection and testing of effluent quality before a decision is taken to discharge to public water or to route back for further treatment.

A controlled discharge facility or "last line of defence" (LLOD) shall incorporate the following design features:

- A first flush compartment designed to cater for the quantity of first flush which is expected to occur as a result of the 'first rain' after a relatively dry period.
- A peak overflow or peak overflow compartments designed to cater for a specific quantity of rainfall after the first flush.
- Provision for the handling of dry weather flows.
- Facilities for the pumping of contaminated effluents to secondary treatment.
- Facilities for discharging 'clean' effluents to public water.
- Skimming facilities in the first flush compartment.

The volume of a controlled discharge facility shall be calculated to retain a specific quantity of effluent resulting from the more onerous of the following two design conditions:

1. AOC run-offs resulting from the rainfall design condition.
2. AOC run-offs resulting from potentially contaminated FFW.

For the rainfall design condition the combined first flush and peak overflow compartment design capacity shall be based on the run-off calculated from the applicable Time of Concentration (T_c) for the actual site area under consideration.

Further consideration shall be given to the expected recurrence of rainfall after the design storm, and the requirement to empty the controlled discharge facility before the next rainfall occurs. This data design condition, known as the "accumulated flow", should be determined from actual meteorological data has a integral role in the sizing of a controlled discharge facility and pumping capacity to secondary treatment (see Figure 11).

In areas of low rainfall where effluent discharge specifications are stringent, the economical merits of sizing the first flush basin to accommodate the total first flush should be justified in consultation with the Principal.

In areas of high rainfall the resultant size of the first flush and peak overflow compartments to accommodate the first flush rainwater quantity will often lead to high capital expenditure, and all design proposals should be undertaken in consultation with the Principal.

For the FFW design condition the combined capacity of the first flush and peak overflow compartments shall satisfy the retention capacity required for potentially contaminated FFW effluents resulting from a fire duration of a given period. This period shall be determined in consultation with the Principal.

The pumping capacity to transfer contaminated effluent from the controlled discharge facility to secondary treatment should be based on the available intake capacity of the secondary treatment facility, whilst considering the need to sufficiently empty the controlled discharge facility before the next first flush.

Designs should wherever possible incorporate the principle of gravity flow to public water. An emergency overflow shall be provided from the peakflow compartment to prevent the controlled discharge facility flooding in the event that the design flow run off from the site area is exceeded. e.g. in the event that a storm occurs which exceeds the design storm.

A risk analysis shall be undertaken to justify any controlled discharge facility design which will not accommodate the design flow conditions and which may lead to a degree of uncontrolled discharge of effluents to public water. This analysis should take into account the effects and frequency of uncontrolled discharges of effluent on the receiving public water.

A typical arrangement of a controlled discharge facility is shown in Figure 19.

10.9.2 Spill control

Hydrocarbon leaks and spills are often the cause of soil and groundwater pollution, effluent water pollution and contribute in general to unwanted atmospheric emissions and the formation of waste and sludge.

Hydrocarbon leaks which result from loss of product containment due to failure of equipment, corrosion or mechanical damage, are related to the integrity of the equipment and as such are not covered in this specification.

Specific requirements for spill control should be determined in conjunction with the Principal. Factors to be considered include:

- the probable size of a spill, which can be estimated by realistic failure scenarios;
- the resulting impact on the environment and related potential liabilities;
- the pollution as a result of a fire.

11. OIL RECOVERY

11.1 GENERAL

The recovery of floating oil from effluents shall be given due attention in the design of drainage and primary treatment facilities. Maximum oil recovery with minimum water ingress will drastically reduce slops system investment and operating costs.

The recovery of floating oil separated from water at gravity separators shall be carried out by means of skimming devices installed at interceptors and basins.

The selection of type and location of the skimming device required shall take into account the following factors:

- Type of treatment facility (e.g. CPI, API, First flush basin).
- The degree of floating oil expected at the surface.
- The economics of the costs of skimming devices against the oil recovered.
- The advantages or disadvantages of manual versus automatic operation.
- Operation and maintenance access.

11.2 OIL SKIMMERS

Fixed pipe skimmers should only be used when the water level in an interceptor is constant at all times.

Rotating trough skimmers with hand wheel operation should be used in interceptors where the fluctuation in water level does not exceed 75 mm. These skimmers shall not be operated during 'rain' conditions. The trough shall always be kept in an upright position when unattended.

Rotating disc or drum skimmers should be used where continuous oil skimming operation is necessitated. These skimmers are available for fixed level and floating application. The fixed level application can accommodate a variation in water level of 0 to 100 mm.

Continuously operating disc or drum skimmers shall be powered by hydraulic or pneumatic power packs.

Floating skimmers should be considered for continuous/non-continuous operation where high fluctuations in the water level are expected.

A typical application for a rotating trough skimmer (hand wheel operated) is shown in Figure 20.

11.3 OIL SUMPS

Oil sumps which are intended to collect skimmed oil and/or oil from oil drip systems shall incorporate the following design features.

- Material of construction shall be reinforced concrete. The use of pre-fabricated GRE sumps may be considered after consultation with the Principal.
- A trash rack or bar screen shall be installed at the entry point of an open drain channel to the sump.
- The sump bottom shall be sloped to facilitate sediment or sludge removal.
- Sumps of depth greater than 2 m and having vertical centrifugal cantilever type pumps, shall be provided with access for inspection purposes (manhole and step irons). Access shall be possible without removal of pumps.

11.4 OIL PUMPS (SLOPS PUMPS)

Oil recovered from primary treatment facilities and/or oil drip systems shall be collected and pumped to a slops system, or collected for reprocessing. The location of the pumps shall be adjacent to or above the oil sump, dependent on the type of pumps selected.

Pump should be vertical centrifugal cantilever type and carefully selected to suit the expected viscosity of the oil slops. The designer should note that where manual skimming operations are present low viscosity slops with high water content may be present.

Oil sump capacity shall be determined on the basis of a minimum pump running time of 9 to 10 minutes, and pump capacities shall be selected based on the capacity or design of the downstream facility.

The level control of the pump and installed spare shall be set for automatic start and stop.

The installed spare should have a HH-on level control and the LL control of both pumps shall be protected by a low level alarm and switch off.

A typical arrangement and line up of vertical centrifugal pumps at an oil collection sump is shown in Figure 21.

12. OTHER FACILITIES

12.1 LNG/LPG FACILITIES

The general design principles with respect to drainage and primary treatment for LNG/LPG facilities are similar to those laid down for general refinery design.

It should be noted however that the contamination level of the effluent streams will be lower than those expected in refineries and the maximum selection and use of oil free streams in designs is encouraged.

Surface water effluents from liquefied gas processing, storage and loading areas shall be classified as AOC water and as such shall not be allowed to drain to public water without provision of controlled discharge.

The use of oil drip/drain systems and COC systems shall be determined in conjunction with the Principal.

Potential liquefied gas spills shall be drained away from equipment as quickly as possible to a safe distance where the liquefied gas shall be allowed to evaporate in a collection basin or open ditch (liquid gas trap). Spills shall not be allowed to enter any closed drainage network, and to prevent ingress of liquefied gas entering the underground flooded drainage network, gas seals shall be constructed at the connection of gas traps to the underground drainage system.

The selection of the number of gas traps shall be in consultation with the Principal.

Paved areas of liquefied gas processing, storage and loading facilities shall be divided into sub-catchment areas of approximately 30 m x 40 m The areas shall be finished with concrete paving sloping at 1:100 towards the perimeter drain channels.

The provision of fire deflection walls between critical equipment shall be determined in consultation with the Principal.

Liquid gas trap design shall have a retention volume of minimum 10 m^3 unless stated otherwise by the Principal.

Typical drainage layouts for processing and storage areas are shown in Figure 22 and Figure 23, with typical gas trap details shown in Figure 24.

The FFW run-off quantities as indicated in Table 2 (Section 8.7.1) shall be applicable to each sub-catchment area unless other specific data is available.

12.2 CONDENSATE FACILITIES

For areas in which condensates are handled or stored, the drainage networks shall be provided in line with the requirements for refinery service.

Condensate drains shall not discharge into open surface drain channels and shall be routed either for recovery or to a COC drainage network.

12.3 CHEMICAL PLANTS

The drainage networks of chemical complexes shall comply with the requirements laid down for refinery service.

In instances where petrochemical installations are situated on a common site it is permitted to route the AOC drainage networks from the chemical plant to the downstream section of the refinery network utilising a common controlled discharge facility.

All COC streams for chemical service shall have independent networks and treatment facilities. The necessity of CPIs on chemical plant drainage networks and the further treatment of chemically contaminated effluent streams shall be determined in consultation with the Principal.

12.5 GAS TREATMENT FACILITIES

The drainage network design for gas treatment facilities shall comply with the requirements laid down for refinery service.

In view of the low risk of encountering heavy pollution (except during line cleaning) the drainage system can be considered primarily as being AOC.

A COC network and oil drip/drain collection networks shall be installed only if specifically required by the Principal.

A collection basin or vessel of approximately 100 m^3 volume shall be installed, preferably at a location near the pig receiving station, where all effluents from line cleaning activities can be discharged. The testing of effluents and their further handling or treatment shall be determined in consultation with the Principal.

The collection basin shall have adequate protection against any aggressive effluents expected.

Direct discharge of line cleaning effluents to the drainage network is not allowed.

12.6 JETTIES

No provision of surface water drainage is required for jetty approaches or approach trestles if these have no manifold facilities or sources of leakages.

12.6.1 Crude oil and oily product berths

Jetty heads or quays with crude oil and oily product loading facilities shall be provided with dedicated kerbed areas around loading arms, metering stations and manifolds. These kerbed areas shall drain, by means of sloped concrete paving or hard piping, to a collection sump or vessel mounted in the jetty deck or integral with the deck.

The effluent classification of the kerbed area shall be considered as COC and subsequent treatment of the effluent should take place either by;

- discharging to onshore treatment facilities (e.g. CPI) or
- allowing primary separation of oil and water to take place in the collection sump

In the event of the latter, the collection sump shall be provided with an emergency overflow to public water.

To minimise the requirement for COC drainage systems, consideration may be given to the use of dedicated oil drip/drain systems at isolated points.

12.6.2 LPG/LNG berths

Jetty heads and quays for liquefied gas service shall be provided with two separate drainage systems, namely:

- An AOC system for the deck areas having loading arms and manifolds in gas service, and
- A COC system for the deck areas having condensate or gasoil loading arms.

The AOC system shall comprise a kerbed area around the loading arms and manifolds draining to a liquid gas trap located at a safe distance downwind of the facilities.

The gas trap shall incorporate a submerged baffle and overflow weir and shall have the capacity to retain a minimum of 1 m^3 of liquefied gas, thus enabling controlled evaporation of liquid phase of the gas. The discharge capacity of the AOC system shall be designed to handle the governing design rainfall or FFW flows.

The COC system shall be designed in accordance with the requirements outlined for the crude berths.

13. OPERATIONAL MANAGEMENT

13.1 GENERAL

The Principal's standards and permits, and possibly legislative regulations, require periodic measurements/control and registration of the effluent discharge quality (quantity). These measurements will provide the Principal and, when required, the authorities, with an insight of the water/effluent treatment facility's performance versus the applicable standards. Good performance of the upstream drainage networks and primary water treatment facilities will form an essential contribution to achieving the required effluent standards.

13.2 MAINTENANCE, HOUSEKEEPING AND INSPECTION

Preventive maintenance and good housekeeping shall be practised at the 'source' of all drainage networks, and shall continue through the systems and treatment facilities up to and including the outfall to public waters. Regular maintenance, housekeeping and inspection activities shall be considered as a safety and environmental care item.

The responsibility for housekeeping and maintenance of drainage networks, treatment facilities and any other related disposal activities shall be assigned to plant personnel or departments qualified and trained for these particular duties. The overall coordination shall be allocated to a supervisor, who shall maintain a complete records of the overall networks and treatment facilities updating these as necessary to include as-built situations.

Records shall be maintained of all cleaning and other related activities (spill control), to establish upgrading and cleaning/maintenance schedules.

The table below gives ann indicative schedule for the inspection/maintenance of drainage networks and primary water treatment facilities. The frequency of the these activities should be adjusted where necessary as a result of inspection findings.

Sumps, manholes and self-skimming buckets	6 monthly
Channels and underground piping	6 monthly
Pre-separator oil skimming	daily
Inspection for sludge cleaning	3 monthly
Oil skimming of the oil traps/interceptors	daily
Inspection for sludge cleaning	6 monthly
Last Line of Defence:	as and when required
First flush basin; oil skimming control of effluent quality	
sampling and subsequent discharge route selection	after every major rainstorm
Peak overflow basin	oil skimming when required (use floating vacuum skimmer), sampling and discharge route selection
Tank compound (valve controlled)	every 6 months and after every major rainstorm

Drainage networks should be tested once a year under simulated fire conditions, i.e. 500 m^3/h water supply, including spray water system discharge (subject to the type of plant, see Table 2, Section 8.7.1), at the upstream section of each catchment area.

13.3 COST CONTROL/RECOVERY

Consideration shall be given to the implementation of a dedicated cost control/recovery system applicable to drainage systems and primary treatment.

Departmental costs for the activities outlined under Section 13.2 could be recovered by considering a chargeable basis for the number of connections and/or discharge quantities/quality from the individual plants to the treatment facilities. The merits of the system would be:

- proportional contribution from dirty/clean areas;
- direct feedback to custodian for corrective action;
- awareness of cost and possible savings.

Application of the above can be extended to the costs for cleaning services, e.g. vacuum trucks, gulley suckers, high pressure trucks, sludge handling.

14. MISCELLANEOUS

14.1 THE INSTALLATION OF UNDERGROUND PIPES

Underground pipes for drainage systems shall be installed in accordance with the following:

- Site preparation and earthworks required for drain installation shall comply with the appropriate requirements laid down in DEP 34.11.00.11-Gen.
- All pipes shall be laid in a straight line between manholes/sumps.
- The installation sequence shall commence at the downstream end of the system.
- Trenches should not be excavated too far in advance of the pipe laying, and should be backfilled as soon as possible after each section of line has been installed.
- Surface material should be set aside for use in subsequent reinstatement. All excavated material should be stacked at least 0.5 m from the edge of the trench and the size of the spoil bank should not endanger the stability of the trench sides.
- Excavated material not suitable for backfilling and/or surplus material shall be disposed of at a location approved by the Principal.
- Temporary supports to the installed pipes shall be provided where necessary.
- All pipe joints, connections, bedding, laying and backfilling shall be carried out in accordance with the Manufacturer's specifications.

14.2 TESTING

All underground drainage systems shall be tested for watertightness.

Testing may be performed on completed sections of a network before the network as a whole has been completed.

Smoke or air tests shall not be permitted.

Testing shall be carried out by qualified personnel only.

Joints shall be left exposed until completion and acceptance of the tests by the Principal.

14.3 REHABILITATION OF EXISTING LINES

Leaking underground systems shall be rectified to prevent soil pollution.

Replacement of leaking sections or the use of relining is permitted.

The methods proposed for rectification shall be approved by the Principal.

The hydraulic capacity of replacement sections shall be checked.

14.4 DEMOLITION

The method proposed for the demolition of underground drainage systems and primary treatment facilities shall be chosen in close consultation with the Principal.

15. REFERENCES

In this DEP, reference is made to the following publications:

NOTE: Unless specifically designated by date, the latest edition of each publication shall be used, together with any amendments/supplements/revisions thereto.

SHELL STANDARDS

Index to DEP publications and standard specifications	DEP 00.00.05.05-Gen.
Non-metallic materials - Selection and application	DEP 30.10.02.13-Gen.
Design and installation of chemical-resistant linings for concrete structures	DEP 30.48.60.12-Gen.
MF piping classes	DEP 31.38.01.12-Gen.
Design and installation of glass-fibre reinforced epoxy and polyester piping	DEP 31.38.70.24-Gen.
Requirements for glass-fibre reinforced epoxy and polyester pipes and fittings	DEP 31.38.70.37-Gen.
Site preparation and earthworks	DEP 34.11.00.11-Gen.
Roads, paving, surfacing, slope protection and fencing	DEP 34.13.20.31-Gen.
Minimum requirements for the construction and maintenance of tank foundations, bund walls and drainage systems for small storage installations	DEP 34.18.51.10-Gen.
Reinforced concrete foundations and structures	DEP 34.19.20.31-Gen.
Requirements for fire protection in onshore oil and gas processing and petrochemical installations	DEP 80.47.10.30-Gen.
Active fire protection systems and equipment for onshore facilities	DEP 80.47.10.31-Gen.

STANDARD DRAWINGS

NOTE: The latest revisions of Standard Drawings are identified in DEP 00.00.06.06-Gen.

Bund wall - typical details	S 12.002
Corrugated plate interceptor - construction, start up and operation	S 14.021

FIGURES

Figure 1 Typical Masterplan Refinery Effluent / Water Treatment

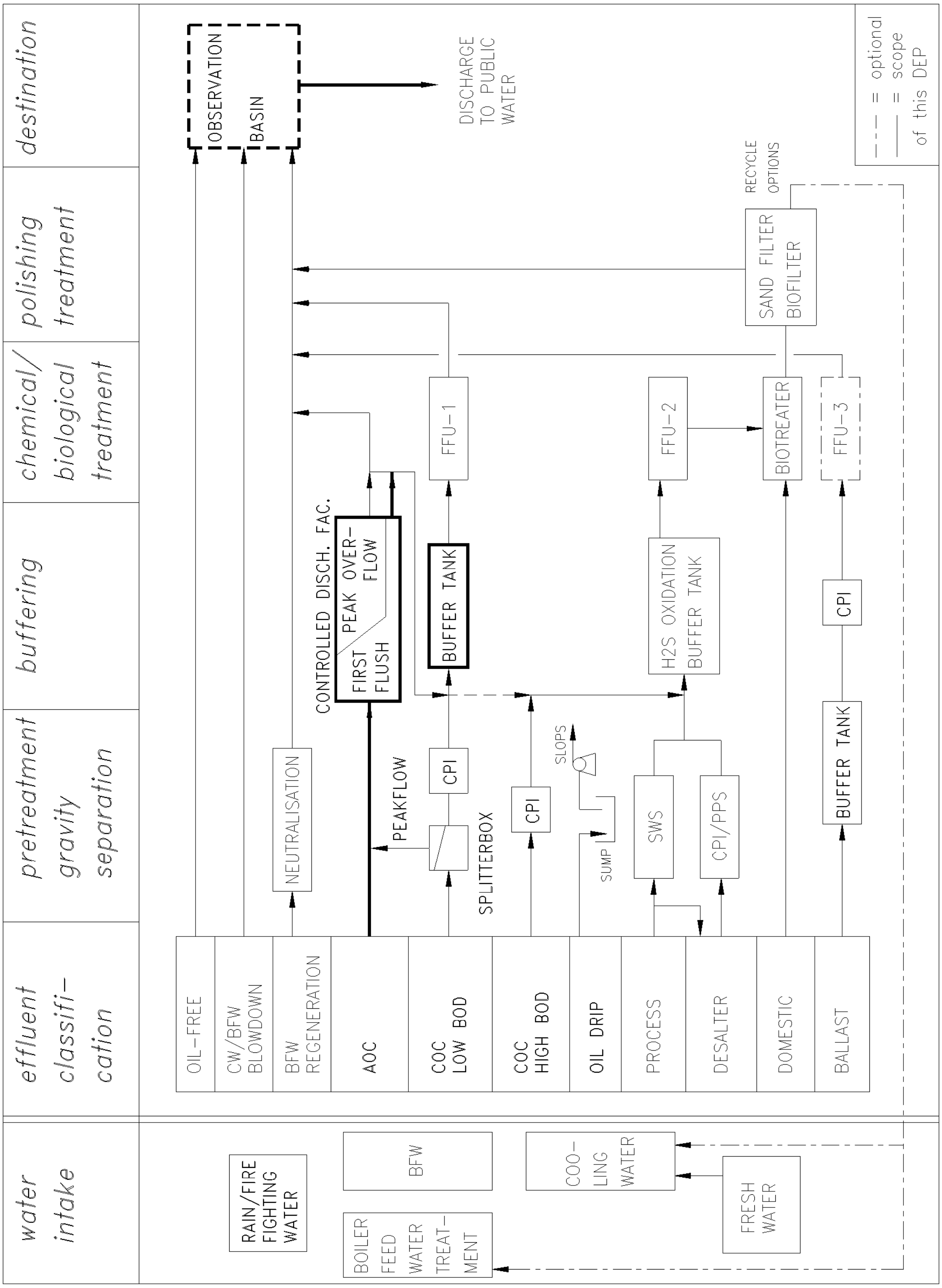


Figure 2 Effluent Classification and Routing

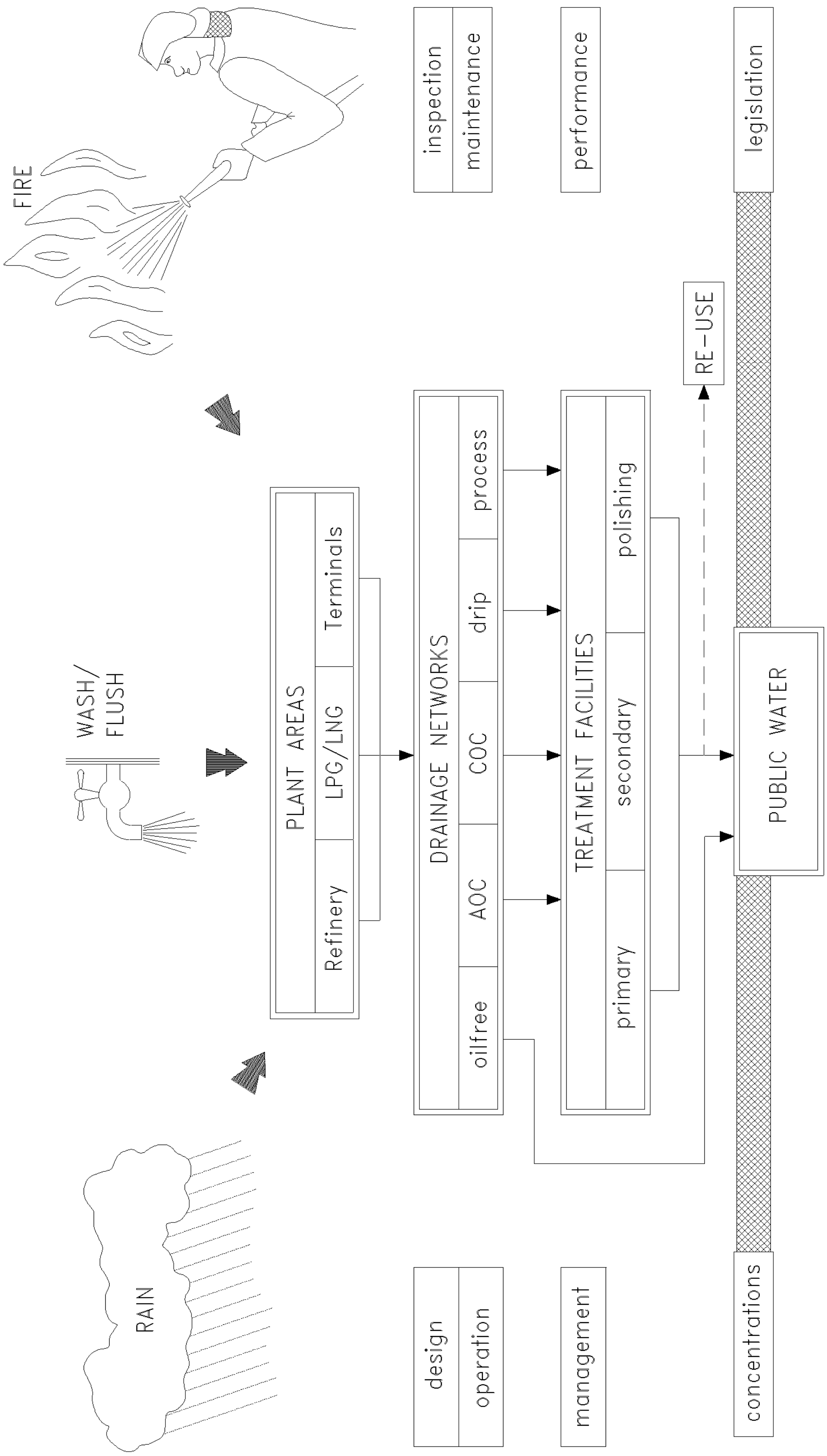


Figure 3 Typical Tank Compound Drainage

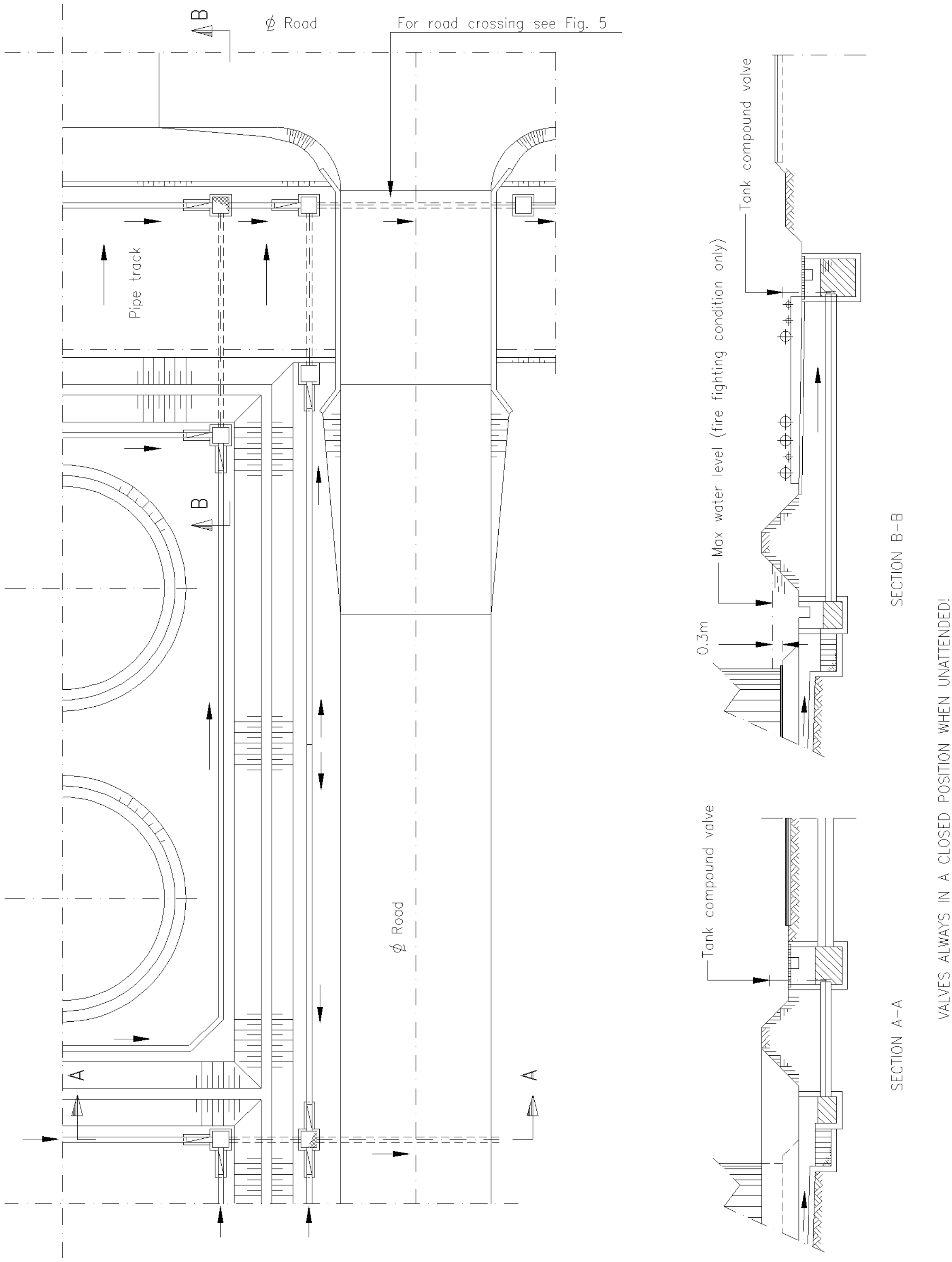
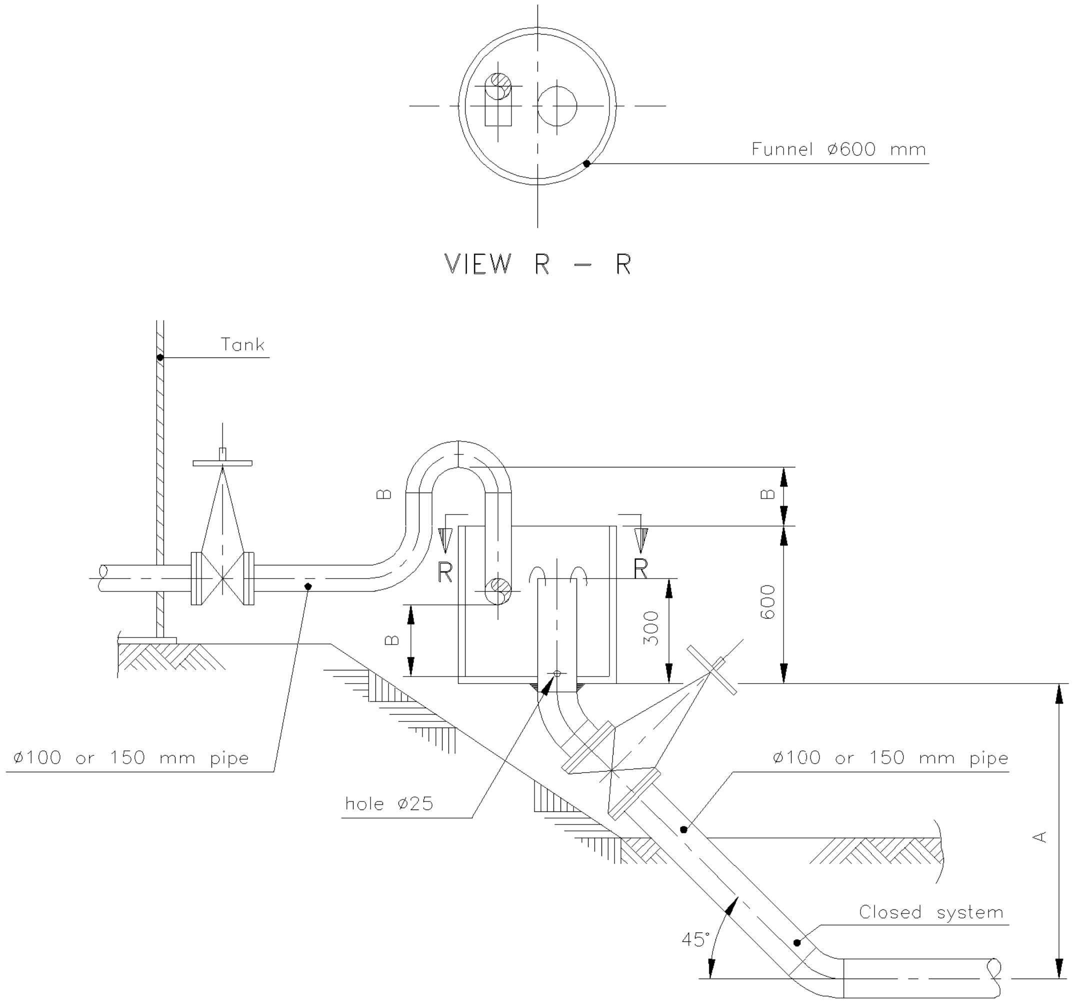


Figure 4 Typical Tank Bottom Drain Funnel



All dimensions in mm

Dimension 'A' is dependent upon pressure drop in system.
Dimension 'B' is dependent upon maximum expected settlement of tank and height of tank foundation.
For areas where freezing conditions can be expected, the drain line shall be underground as shown on the sketch.
For closed tank bottom drain systems (remote controlled) principal should be consulted.
Steam tracing for drain line should be considered for waxy/heavy emulsion service.

Figure 5 Typical Pipetrack Drainage/Sand Trap/Fire Trap Details

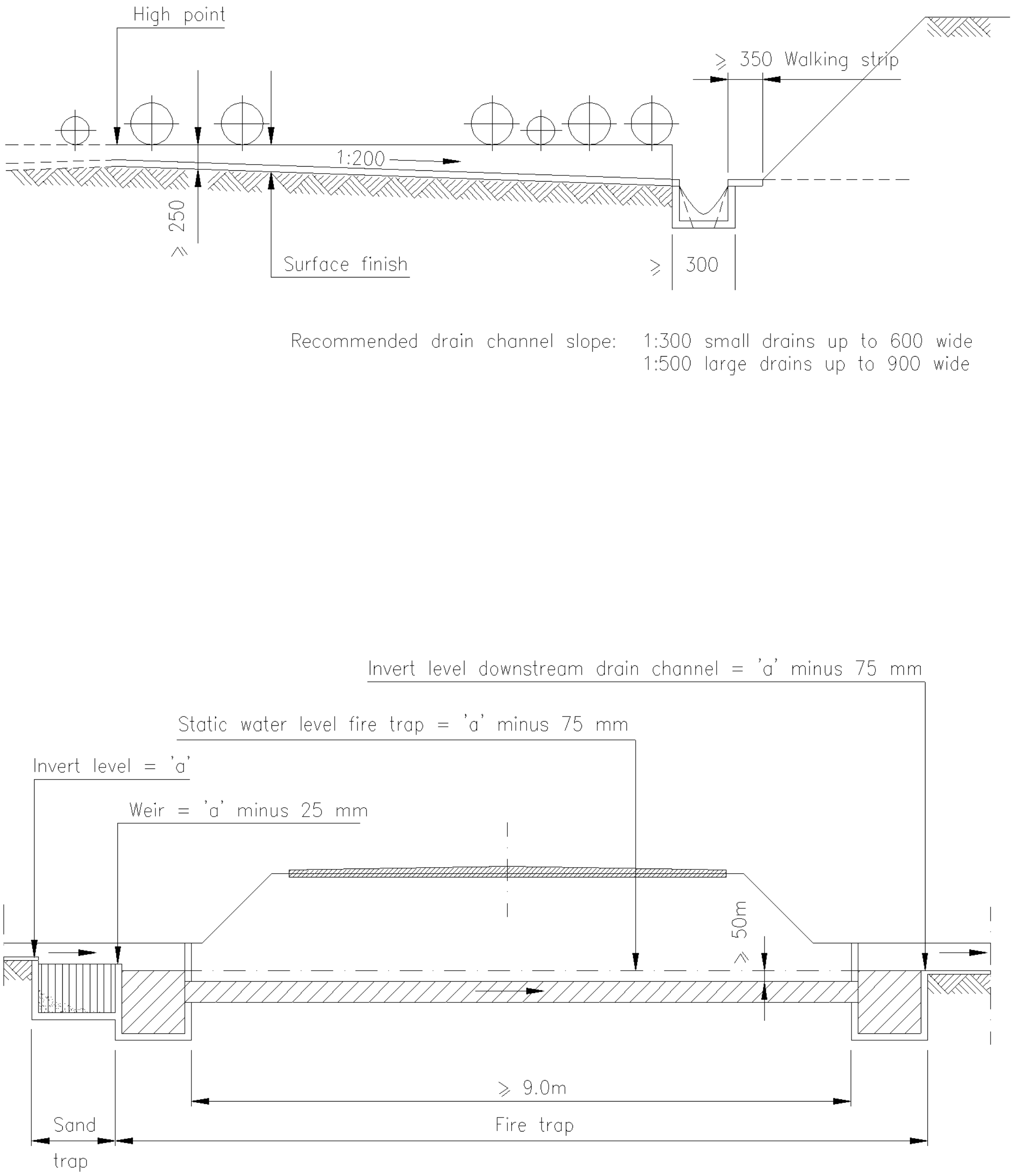


Figure 6 Typical Process Area Surface Water Drainage and Open Drip/Drain System

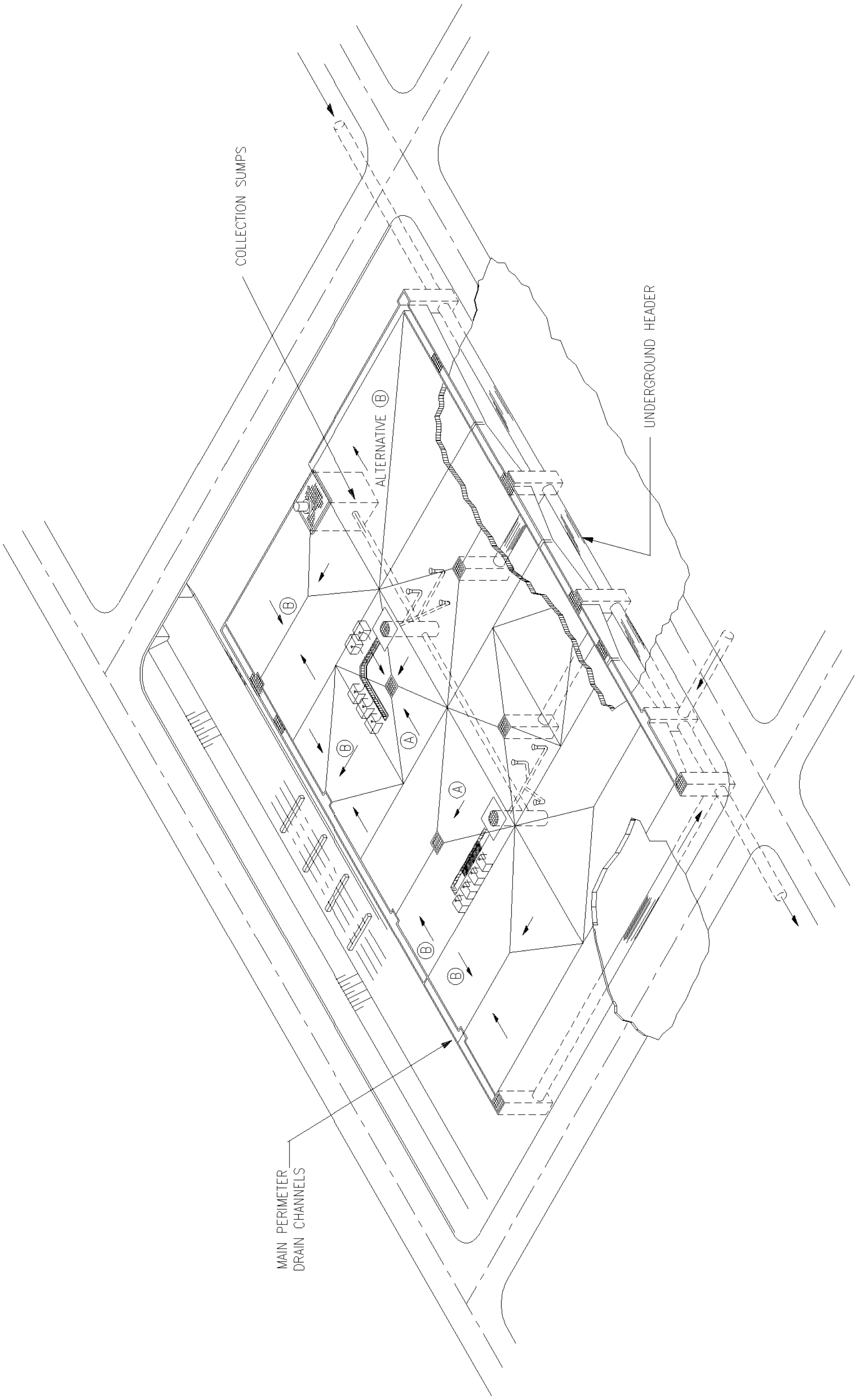


Figure 7 Oil Drip/Drain Collection System (Non-hazardous service)

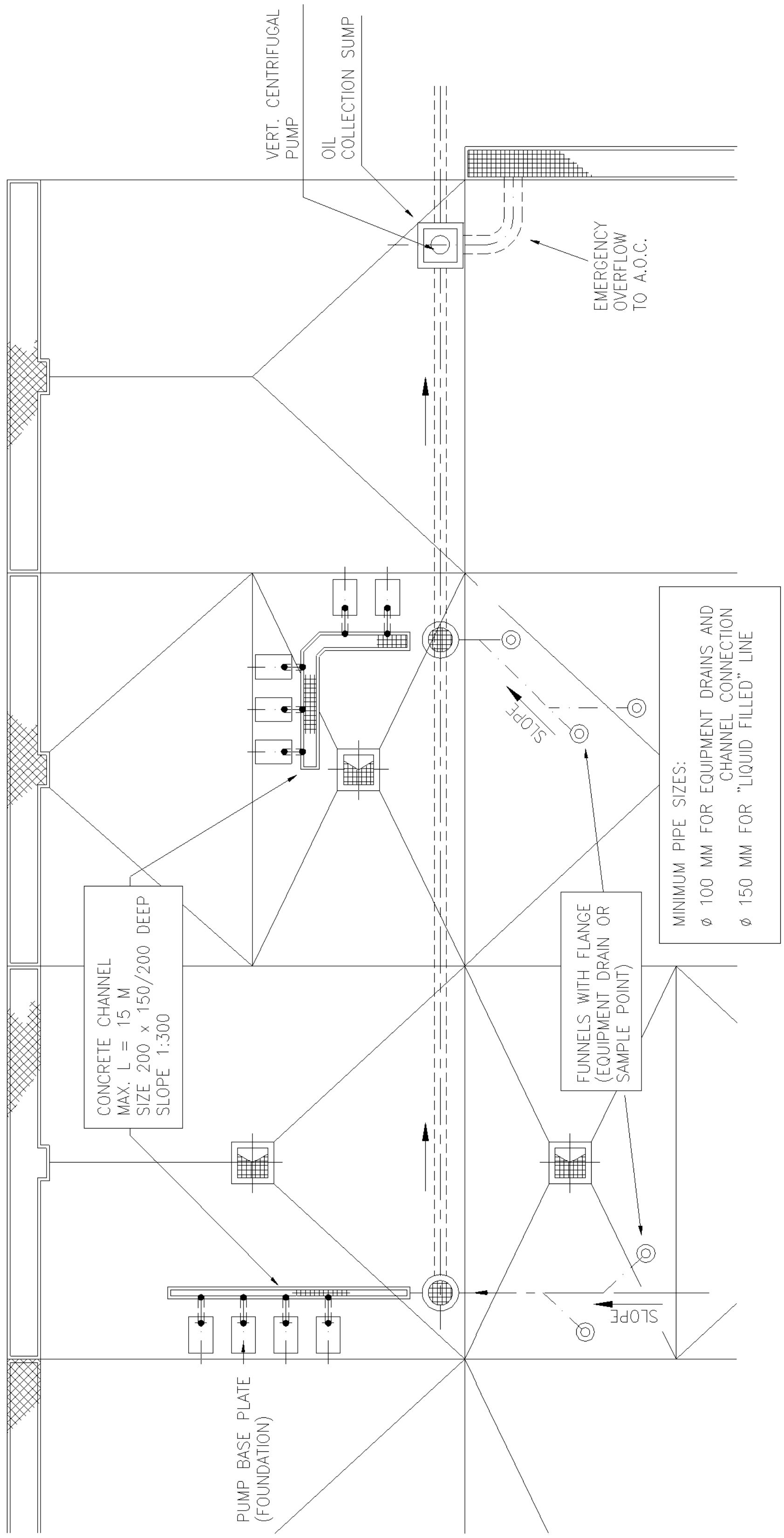


Figure 8 Typical Sump/Manhole Details

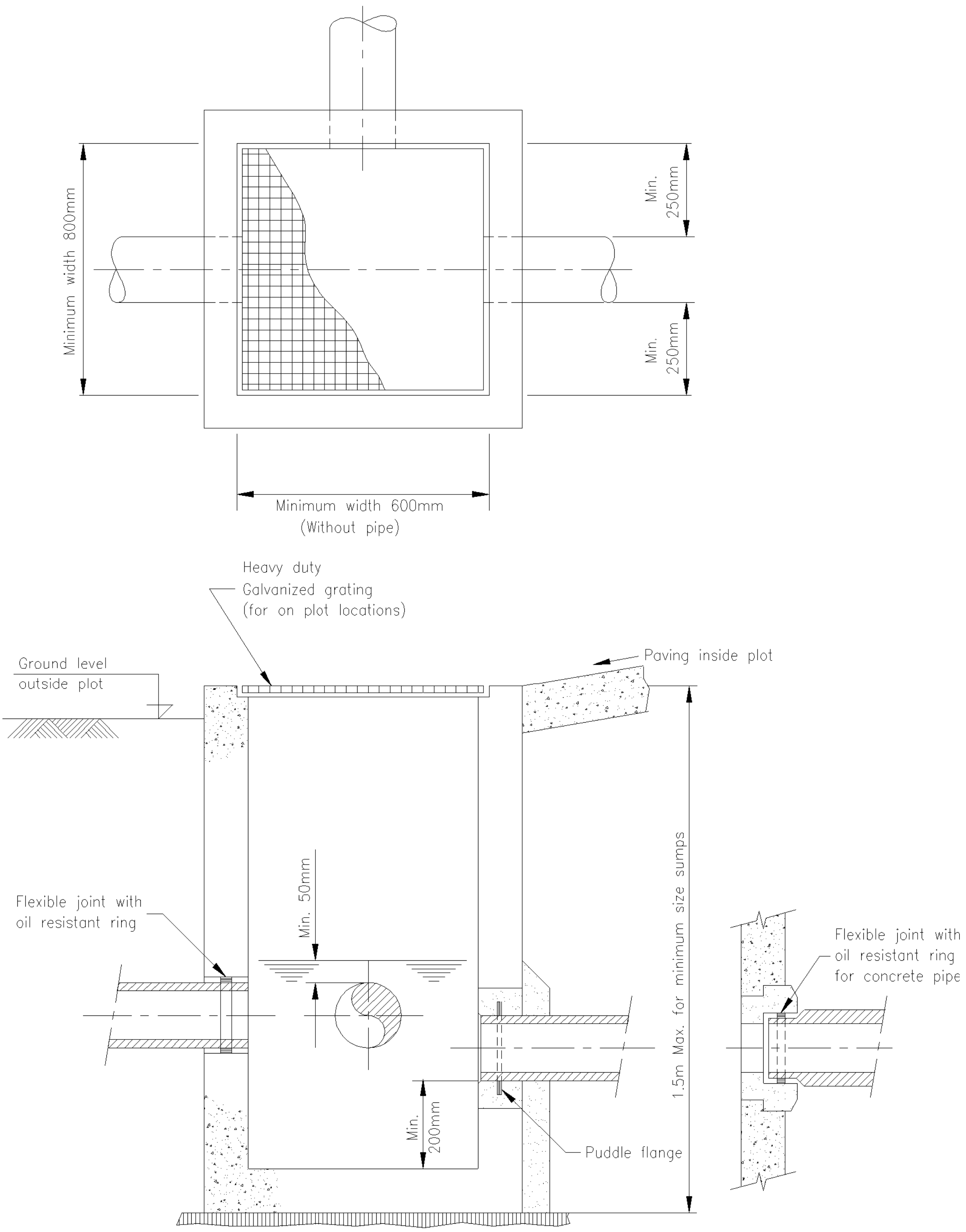


Figure 9 Self-skimming Sump

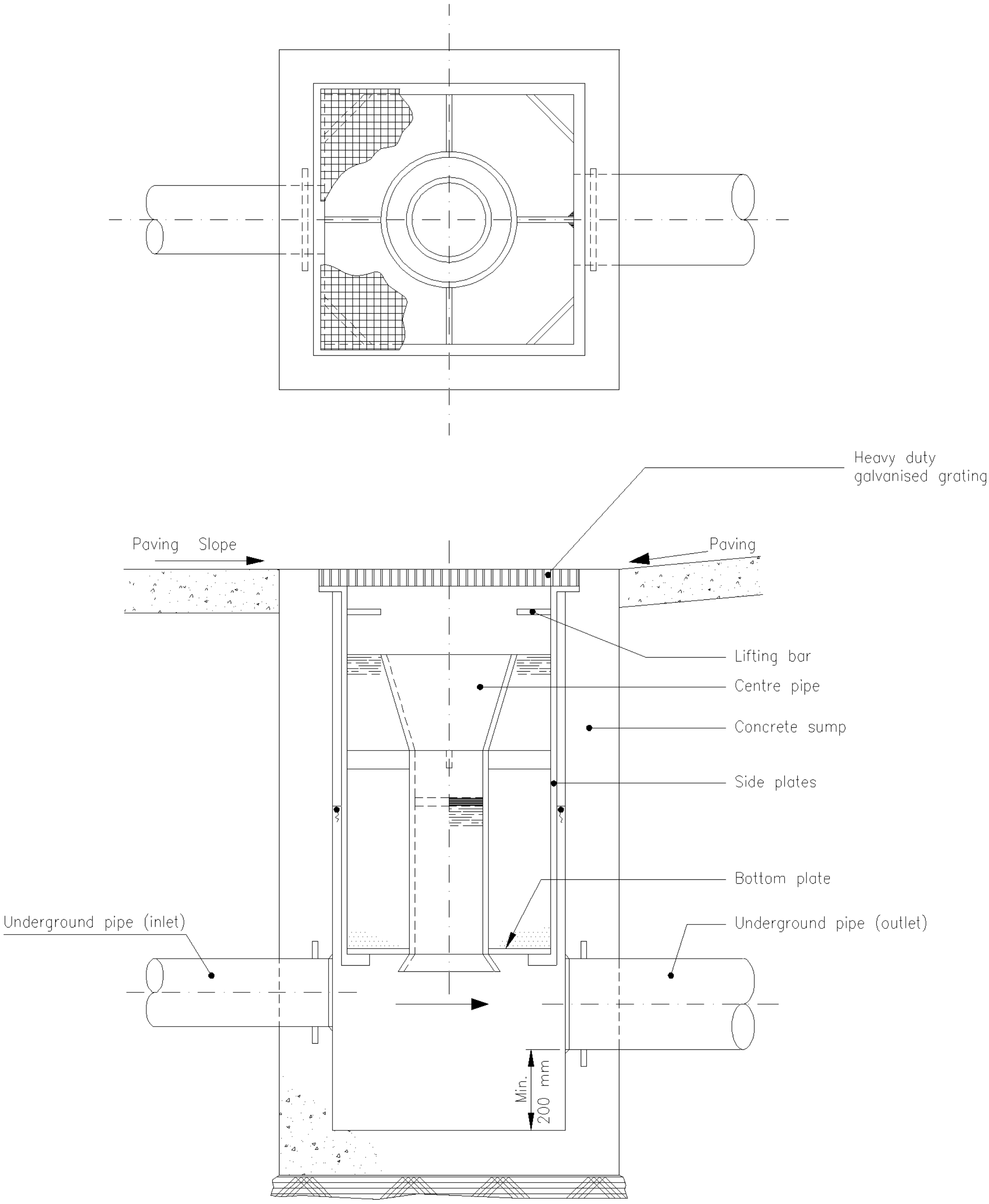


Figure 10 "Free Weir" - Flow Diversion Sump Response Curve

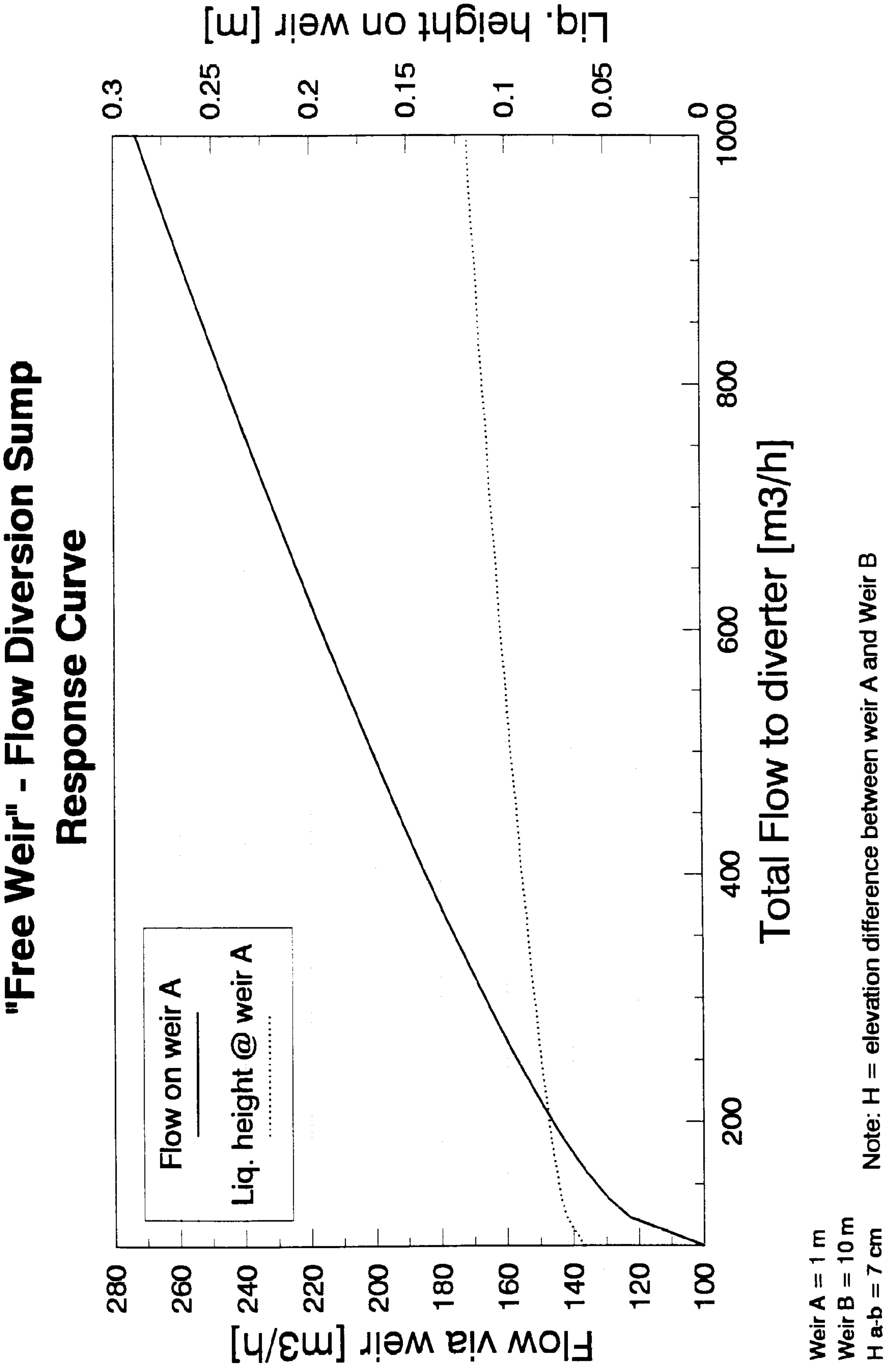


Figure 11 Accumulated Rainfall vs Intake Capacity

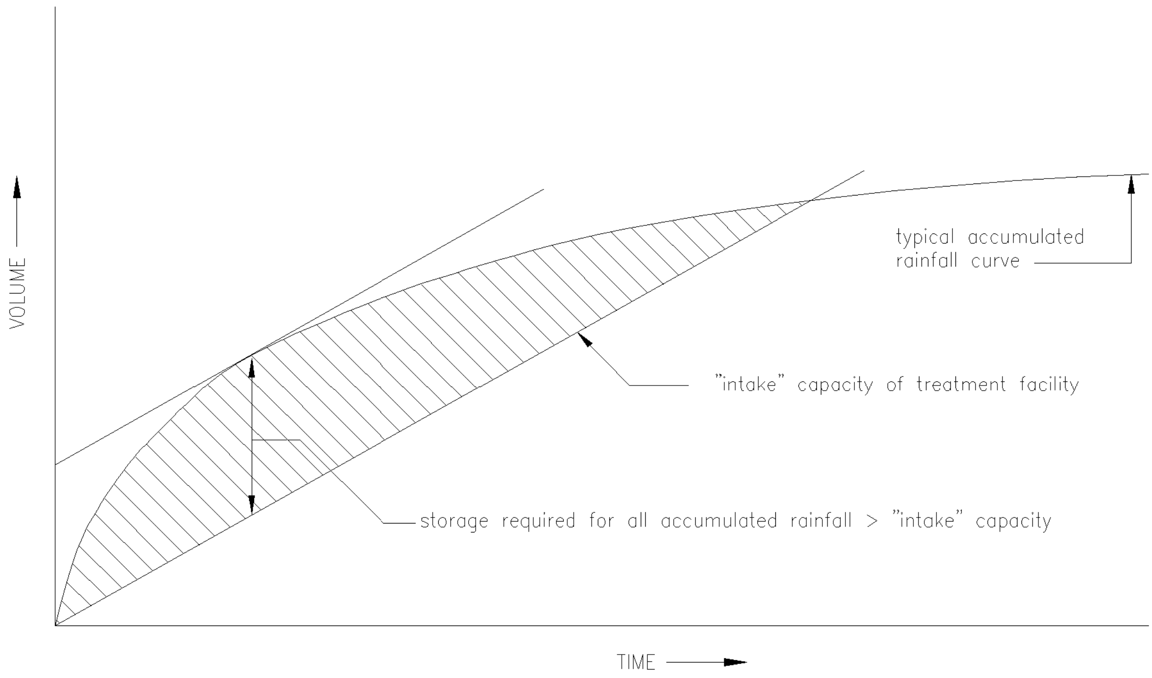


Figure 12 Rainfall Intensity/Duration Curves for Various Recurrence Periods

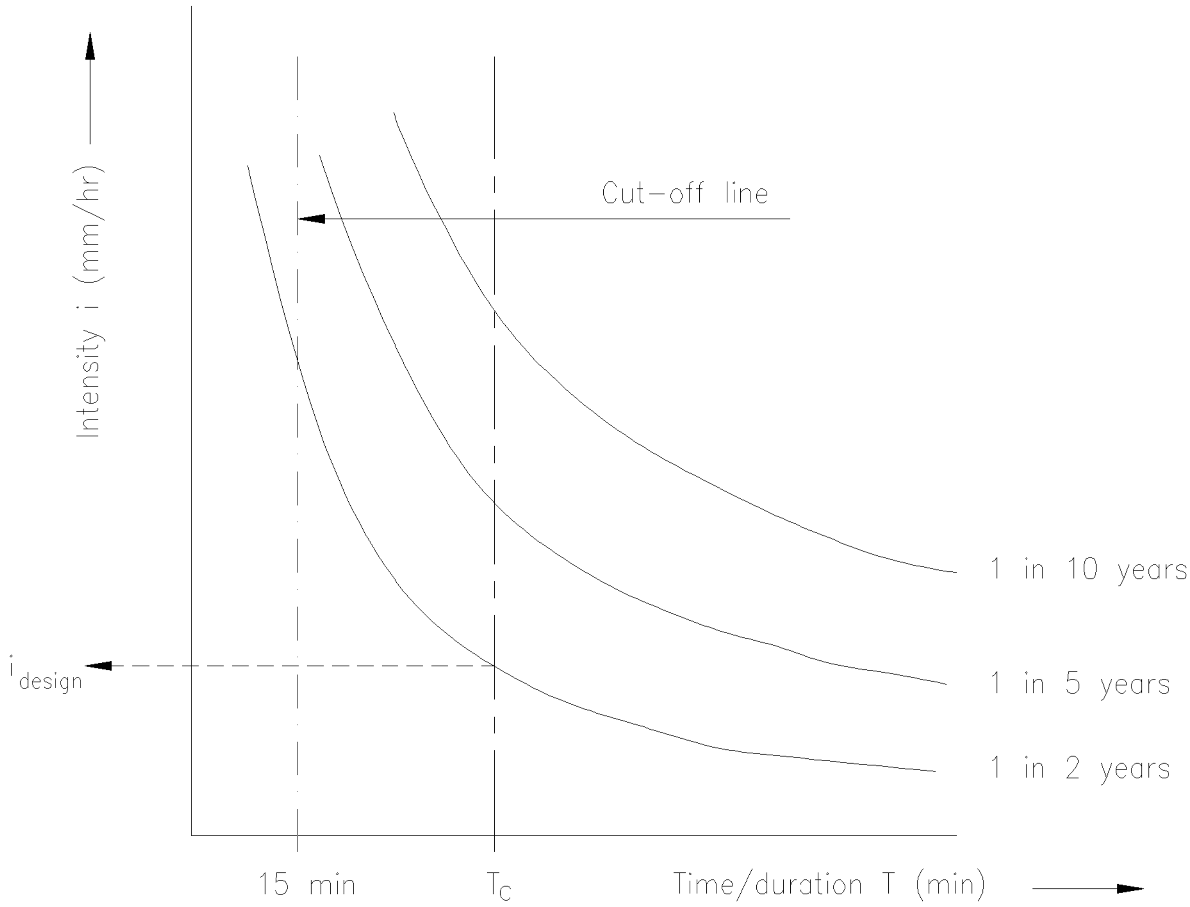
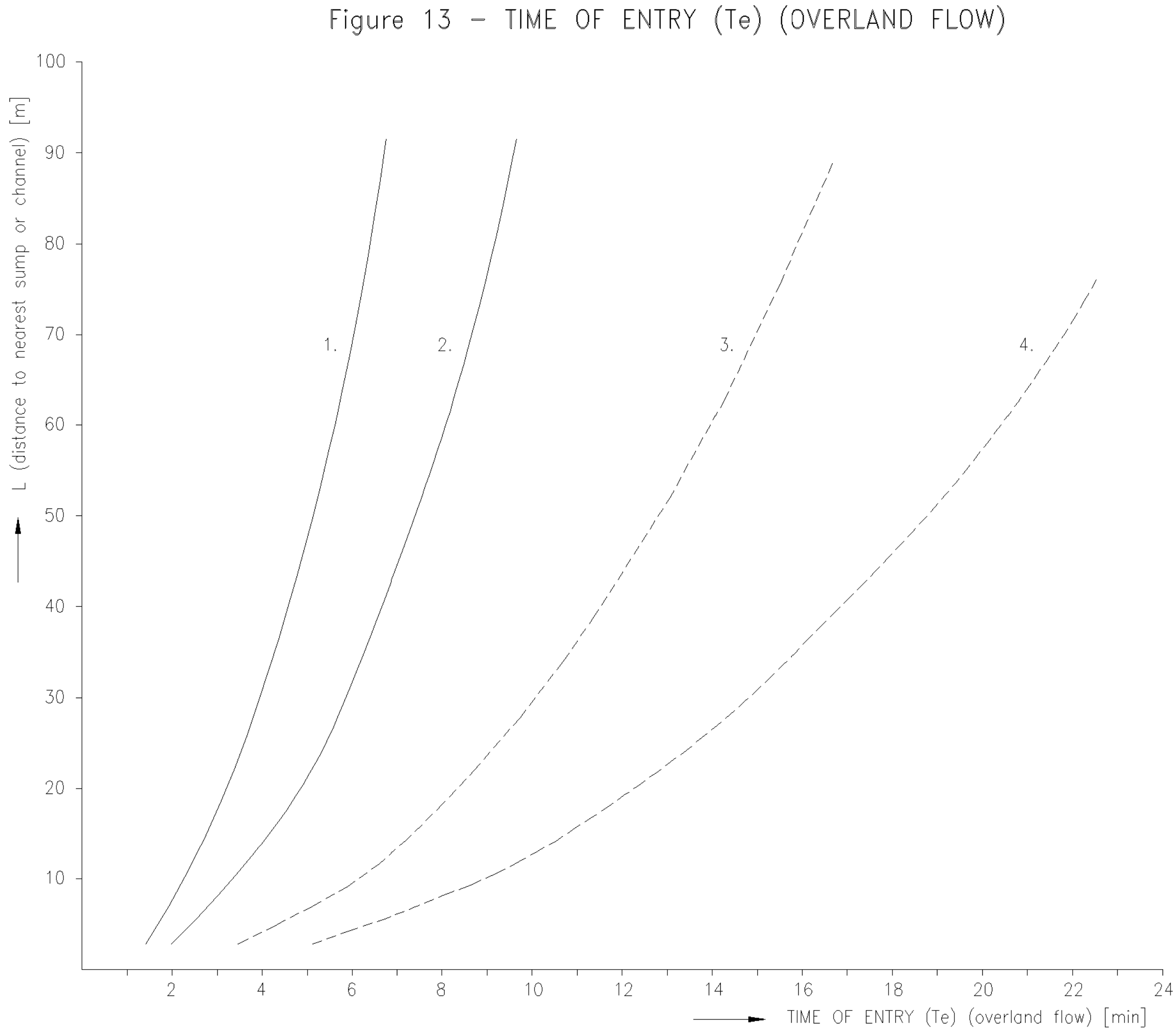
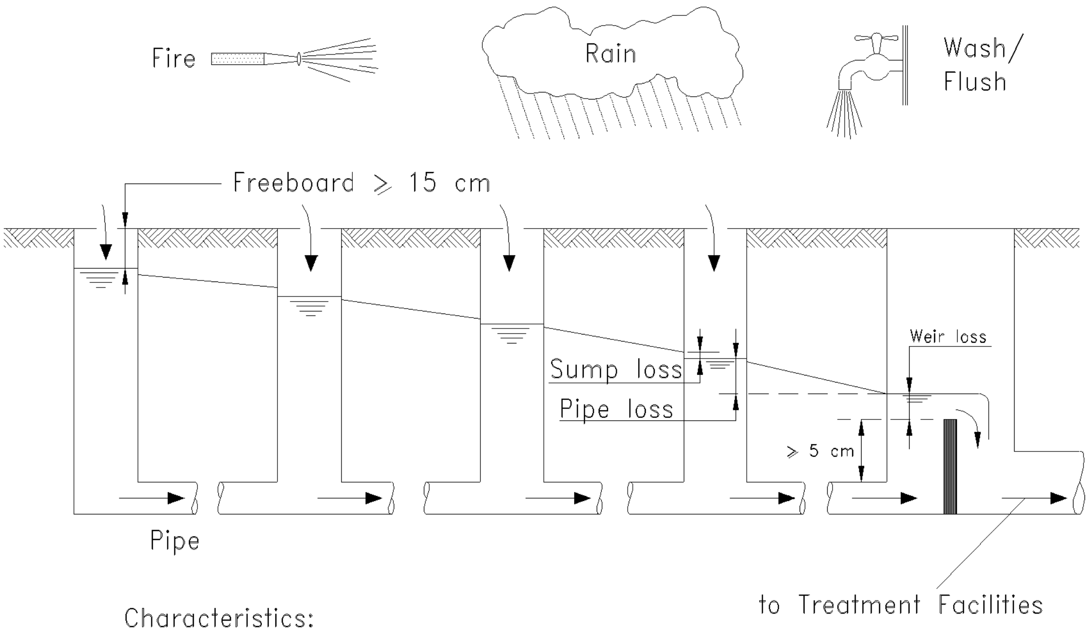

Intensity i (mm/hr)
Cut-off line
1 in 10 years
1 in 5 years
1 in 2 years
i design
15 min
Tc
Time/duration T (min)

Figure 13 Time of Entry (Overland Flow)



1. = paved surface (n = 0.02), slope 1:200
2. = paved surface (n = 0.02), slope 1:1000
3. = bare surface (n = 0.15), slope 1:200
4. = bare surface (n = 0.15), slope 1:1000

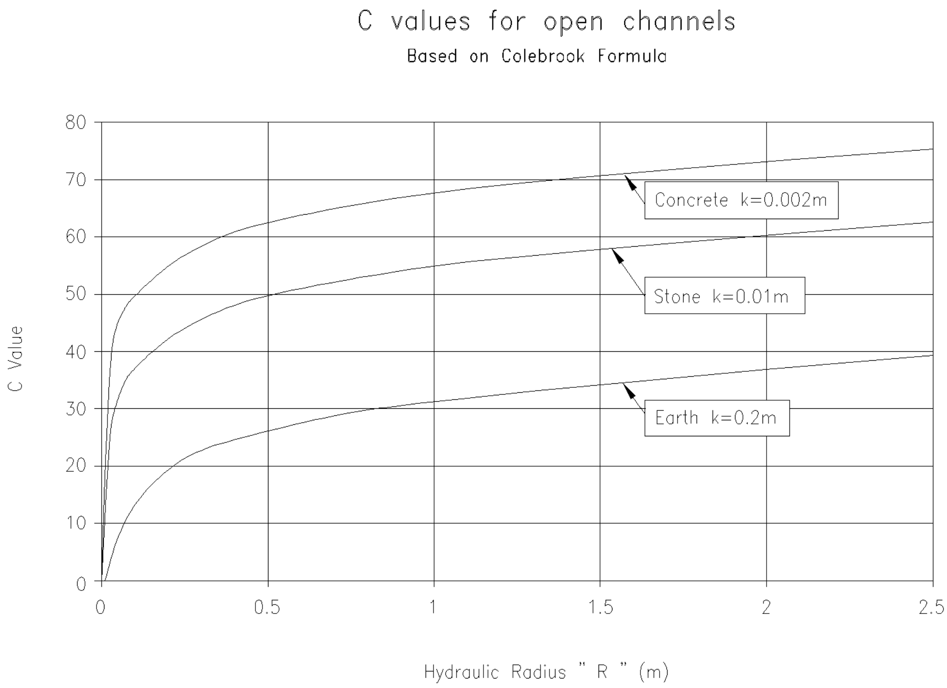
Figure 14 Schematic Layout Liquid Filled Underground Drainage Network



Characteristics:

- liquid filled system
- velocity (v) 0.3 m/s < v < 0.9 m/s
- maximum allowable effluent temperature 45 °C

Figure 15 C values for Open Channels (Colebrook)



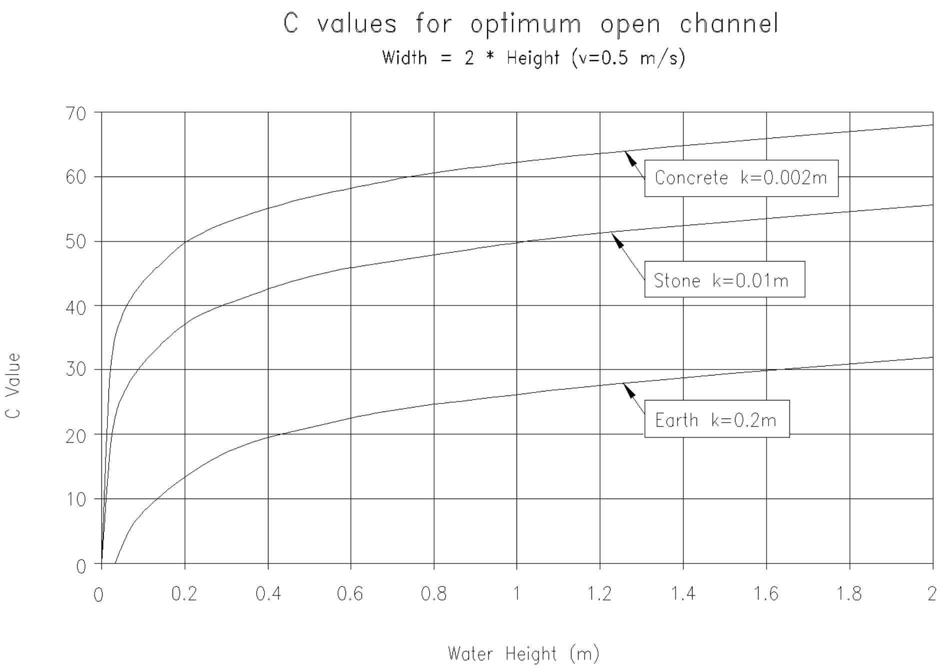


Figure 16 Typical Layout of Pre-Separator

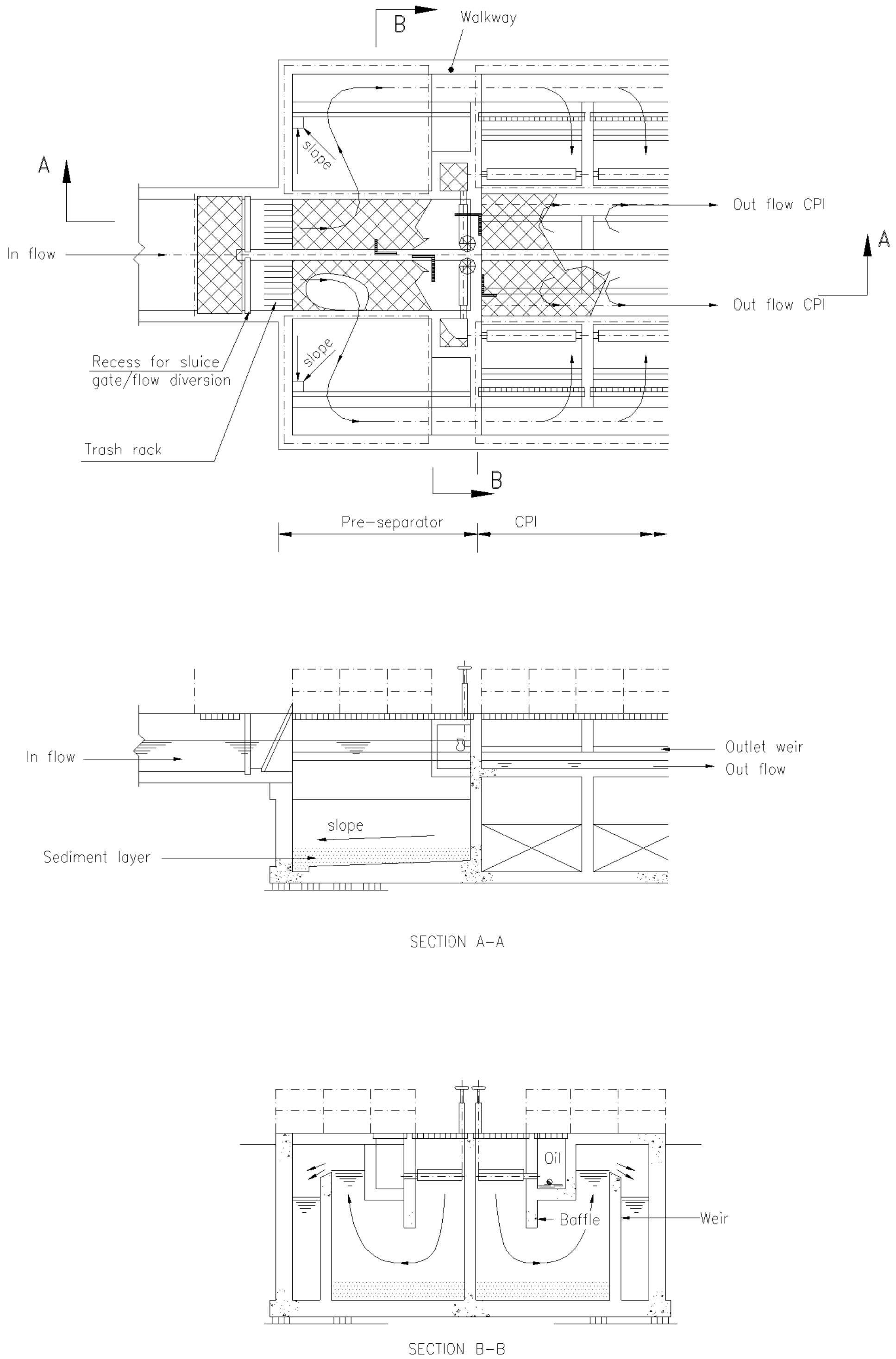


Figure 17 Typical API Separator

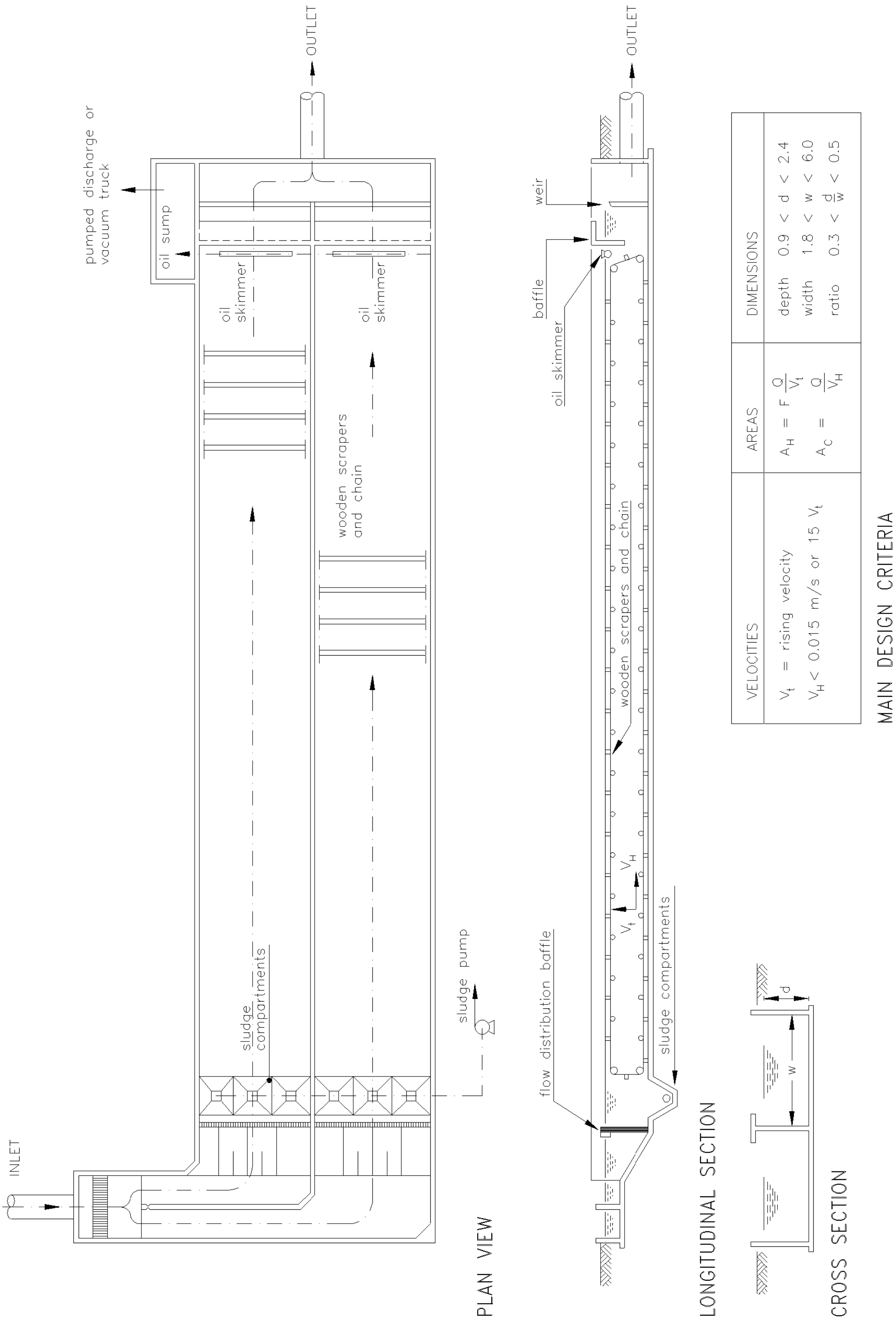


Figure 18 Typical 2 Bay Corrugated Plate Interceptor

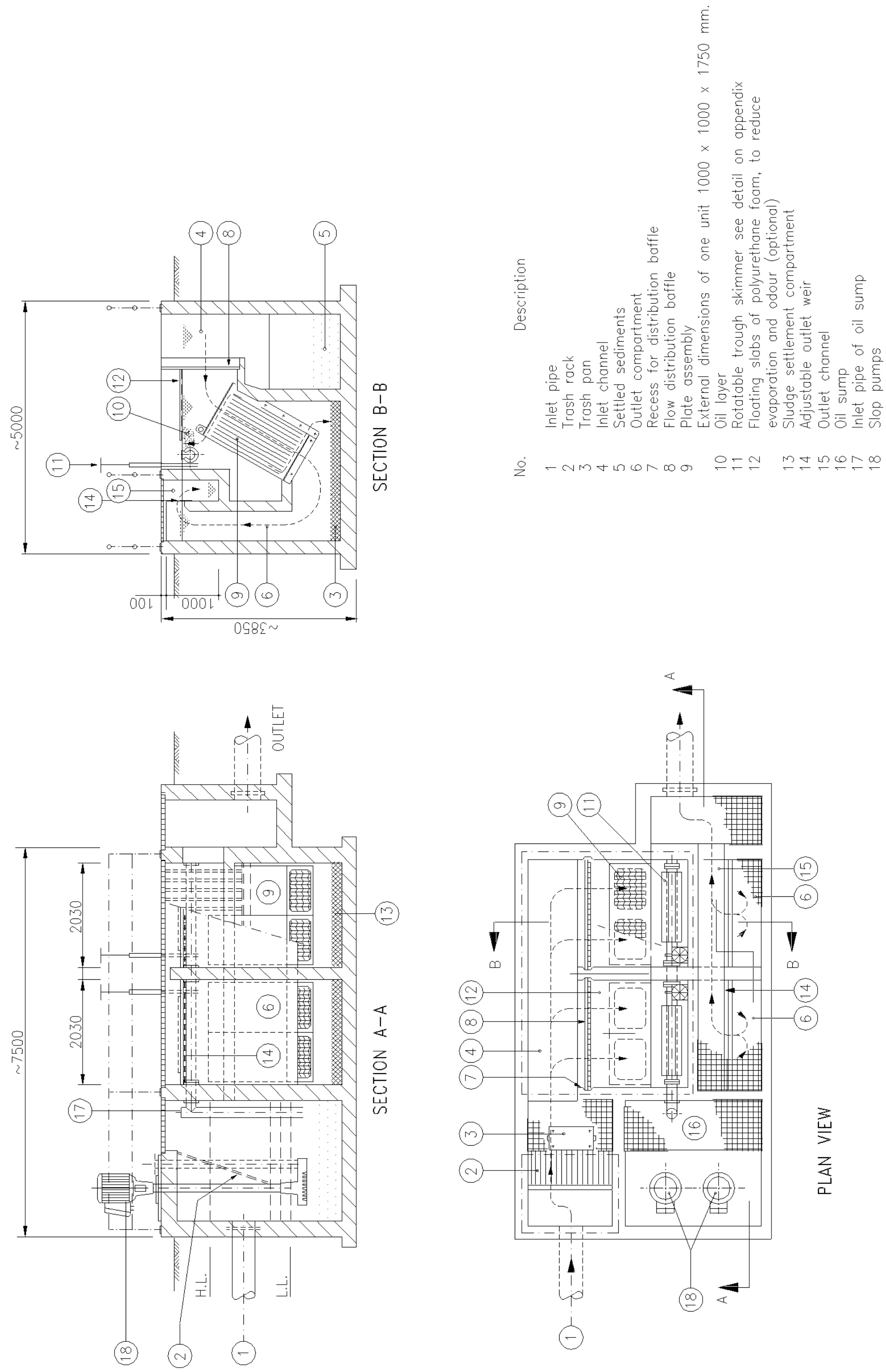
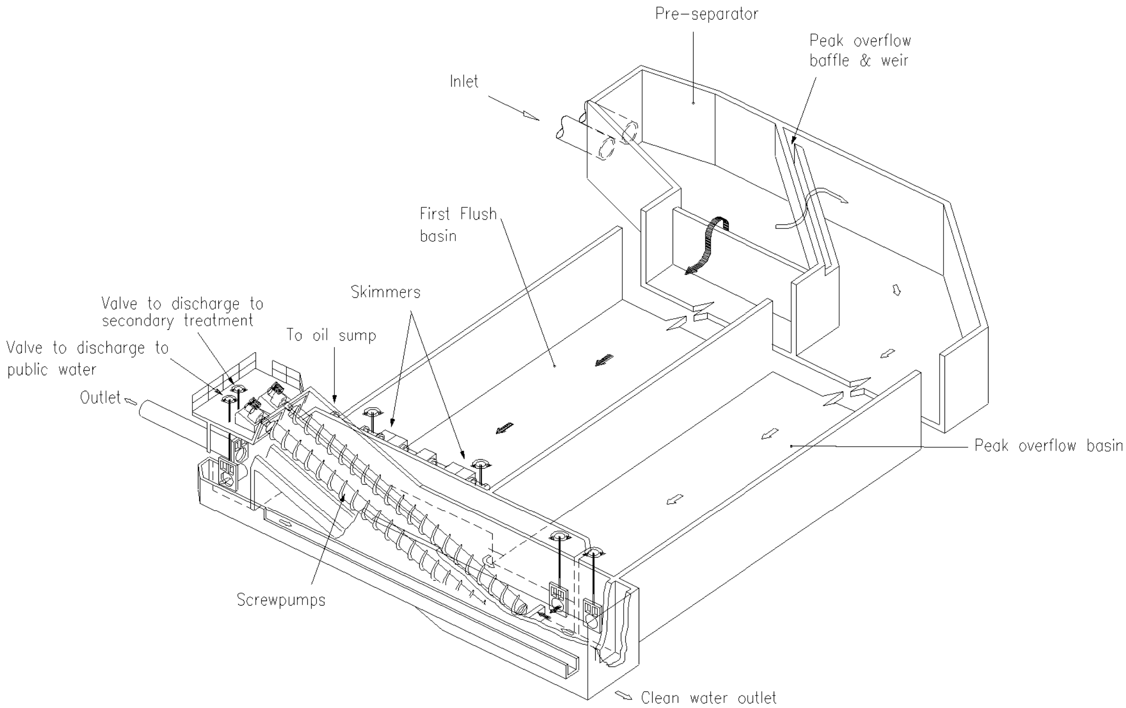


Figure 19 Typical Controlled Discharge Facility



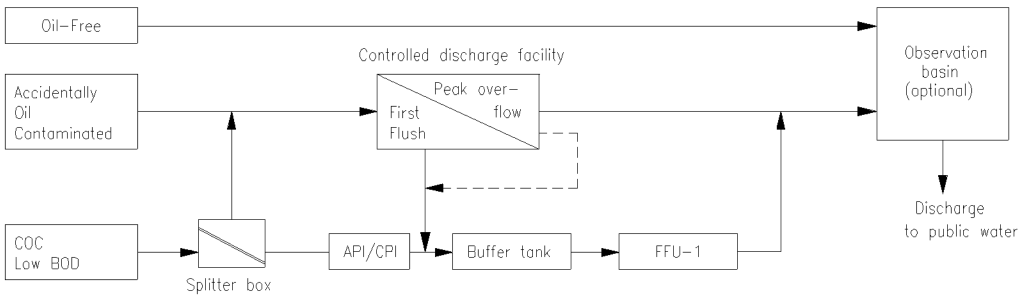


Figure 20 Typical Handwheel Operated Rotating Trough Skimmer

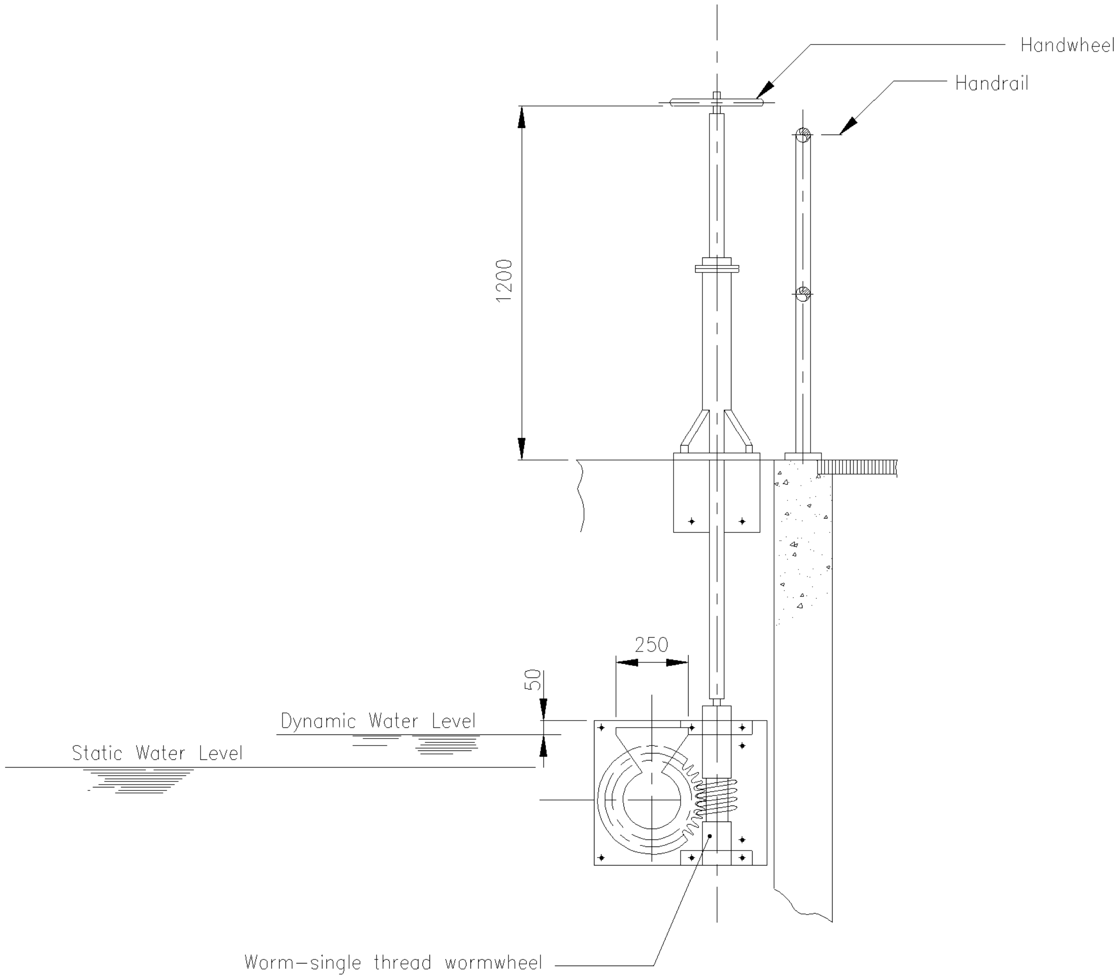


Figure 21 Typical Arrangement Vertical Centrifugal Pumps at Oil Sump

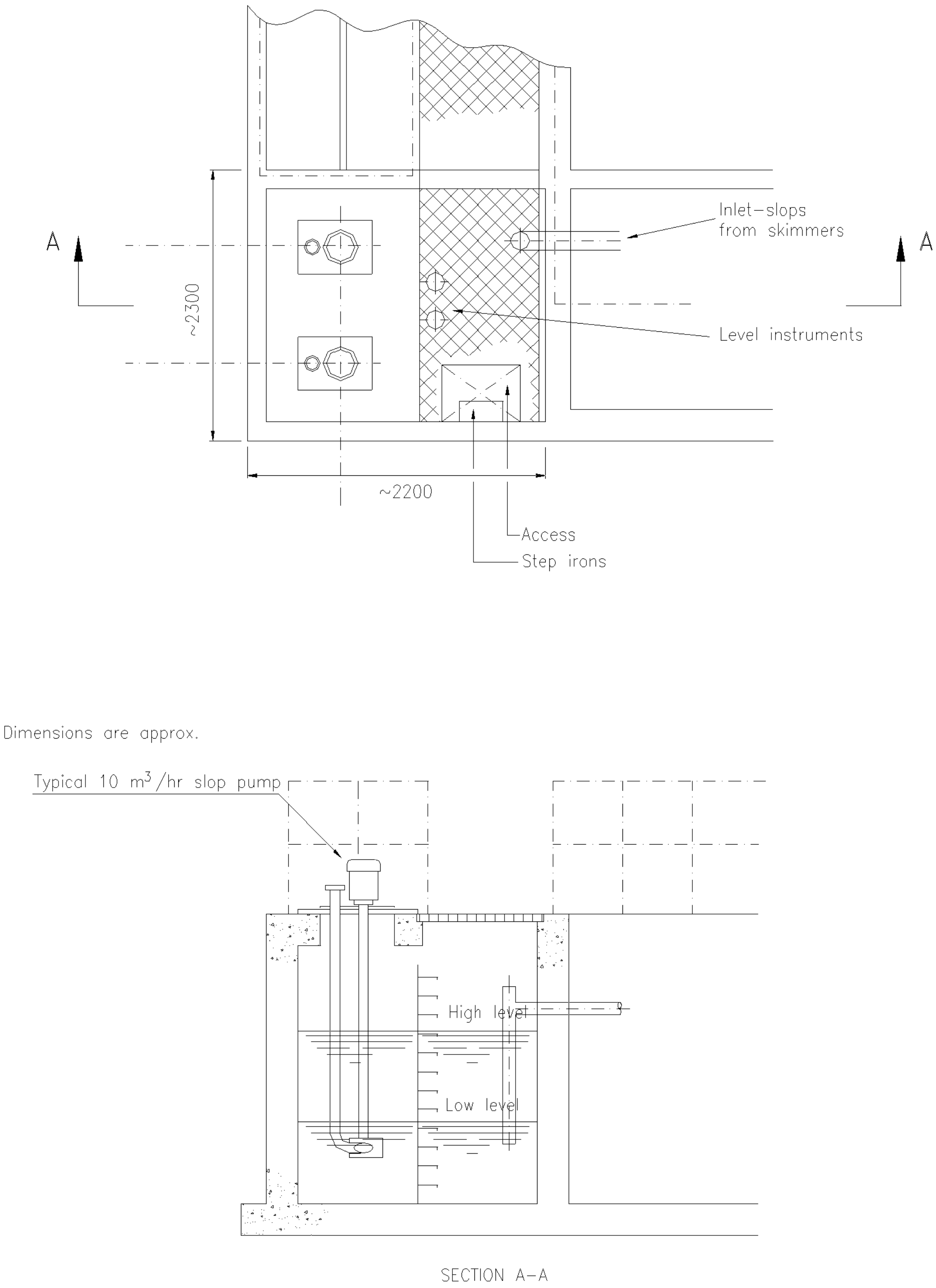
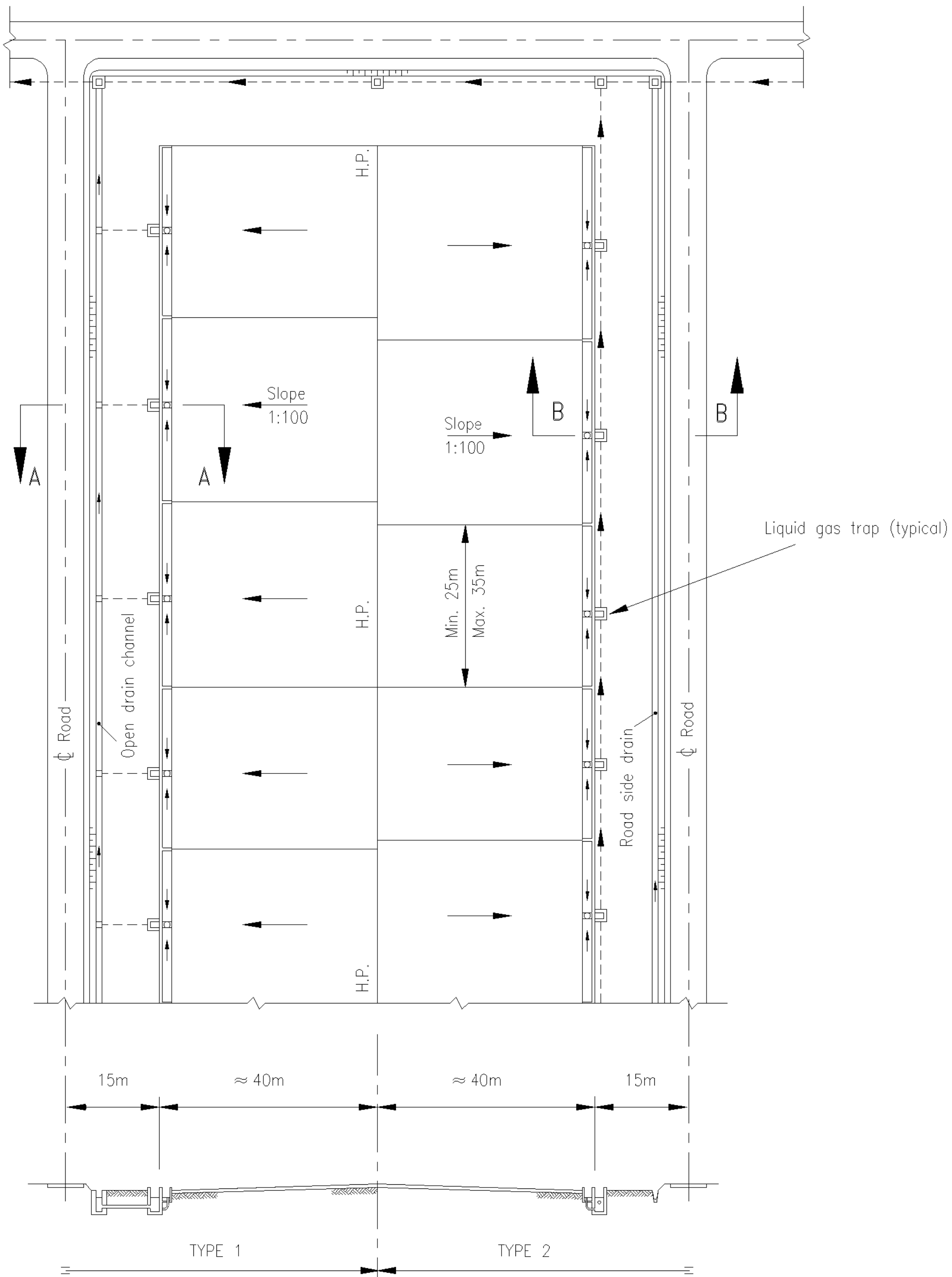


Figure 22 Typical Drainage Layout of Liquefied Gas Process Areas



TYPICAL CROSS SECTION

(For sections 'A-A' and 'B-B' see Figure 24)

Figure 23 Typical Drainage Layout of LPG Storage Areas

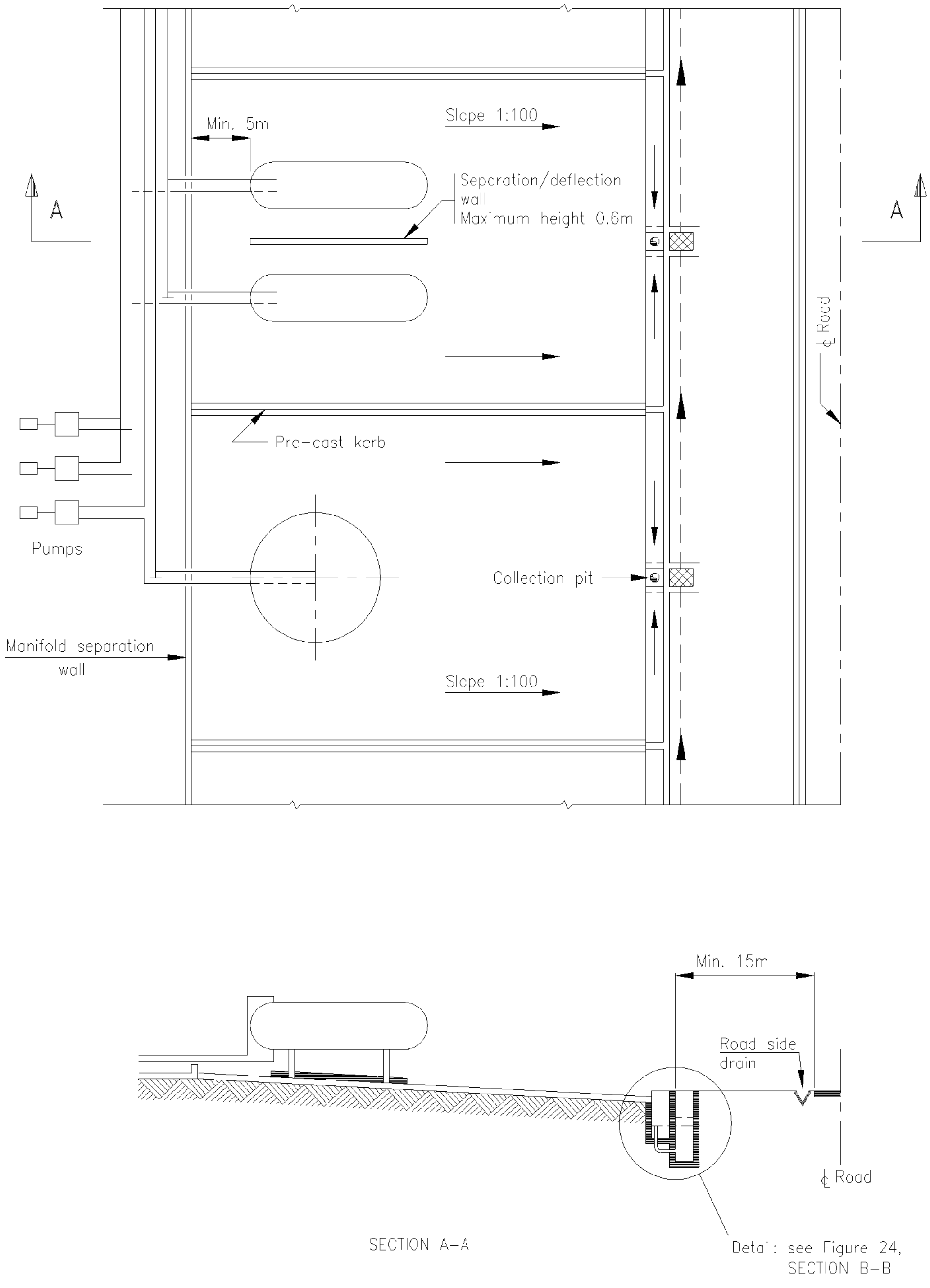


Figure 24 Typical Liquid Gas Trap