Diffusers and pollution discharge to receiving waters

Environmental Hydraulics

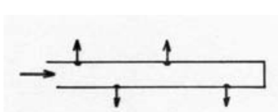
Diffusers

Small flow rates: discharge through pipe end (one jet)

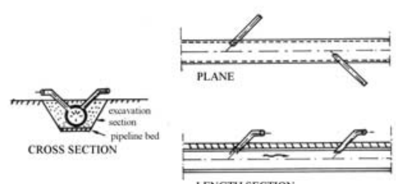
Large flow rates: discharge through diffuser arrangement (a series of jets)

Figure 1
Outfall Diffuser

Figure 2
Outfall Without Diffuser



Simple diffuser

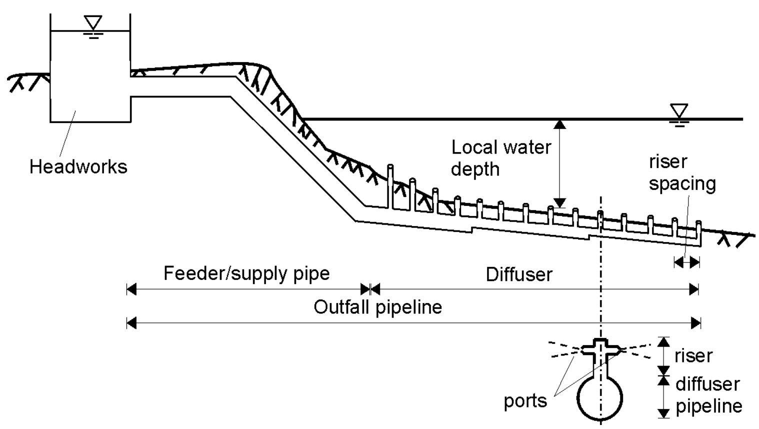


Definitions

Outfall: underwater pipeline that discharges wasterwater into a receiving water

Diffuser: a section of the outfall (usually the most seaward portion) with relatively small holes or ports

Outfall and Diffuser System



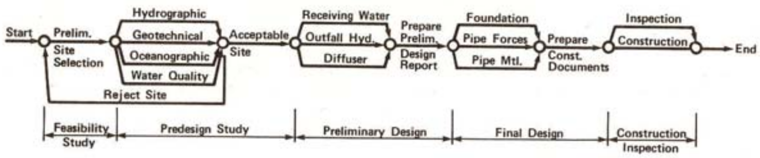
Outfall Design Process

Major components of design process:

- **site selection**
- **outfall hydraulics**
- **dilution and mixing**
- **diffuser port design**
- **pipe design**
- **pipe support system**
- **construction methods**

Four Design Stages

- **feasibility study**
- **predesign**
- **preliminary design**
- **final design**



Site Selection

Discharge point normally located close to treatment plant etc.

Outfall siting criteria:

- bottom topography and surf zone
- physical oceanography
- water quality
- underwater soils and geology

Bottom Topography and Surf Zone

- Hydrographic survey required
- Desirable to locate the diffuser on a relatively flat slope
- Try to achieve equal discharge from each diffuser port.

Difficult to penetrate the surf zone (breaking waves). Problems during construction and long-term structural integrity.

Physical Oceanography

Parameters to measure:

- **water mass movement (currents):**
  - Eulerian and Lagrangian measurements
  - recordings over appropriate period (cover all relevant conditions)
- **salinity and temperature**
  - needed to determine density (stratification)
- **diffusion**
  - dye, tracer studies
- **wave height and period**
  - important for design

Water Quality

Predict changes in the water quality due to pollution discharge.

→ **Determine existing water quality (monitoring program for baseline condition)**

Parameters of interest for domestic sewage outfall:

- dissolved oxygen
- pH
- conductivity/salinity
- temperature
- oil and grease
- fecal coliform bacteria
- nutrient content
- heavy metals
- BOD/COD

In water column and benthic area.

Outfall Hydraulics

Determine design flows, pipe diameters for outfall and diffuser section, and port size and spacing.

Discharge through a gravity system, if possible. Pumping sometimes required.

Diffuser Hydraulics

Size and spacing of diffuser ports determined through iterative hydraulic calculations considering:

- **design flows**
- **pipe diameter**
- **pipe slope**
- **frictional resistance**
- **effluent density**
- **receiving water density**
- **discharge depth**
- **operating head**

Guidelines for Diffuser Design

<u>Flow distribution</u>: uniform distribution between ports

<u>Velocity in diffusers</u>: velocity high enough to prevent deposition of sludge, grease etc

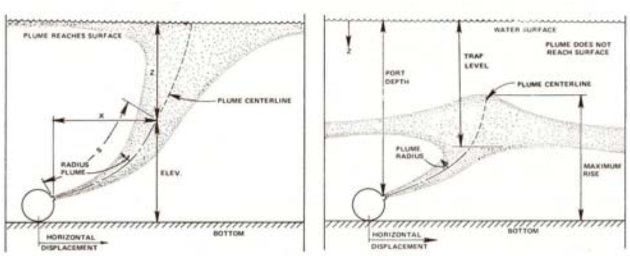
<u>Prevention of seawater intrusion</u>: full flow in all ports to avoid seawater intrusion

Dilution and Mixing

A diffuser changes a point source to a line source.

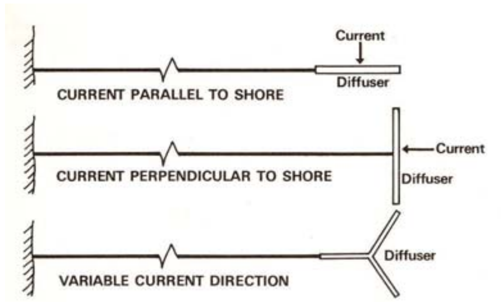
Mixing is due to:

- **kinetic energy (initial discharge velocity)**
- **buoyant forces (density difference between effluent and receiving water)**
- **receiving water currents**



Diffuser Port Design

Orientation: determined by flow direction of receiving water currents



Diffuser should be located perpendicular to the net current to maximize dilution.

Port types: two basic types, pipe wall port and riser tube

Holes in the wall of the pipe

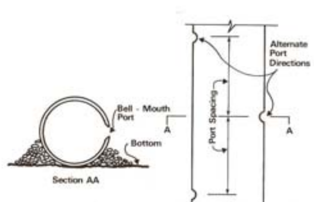


Figure 7
Pipe Wall Port Diffuser

Tubes project upward from the pipe

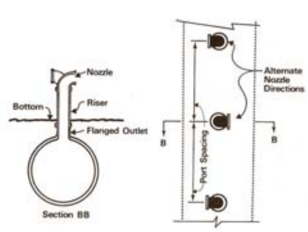


Figure 8
Riser Port Diffuser

Pipe Design

The following pipe design components should be considered:

- foundation requirement
- pipe forces
- hydraulic flow properties
- corrosion resistance
- pipe material selection
- pipe anchoring
- construction method

Pipe Forces

The pipe must resist both external and internal forces.

Internal force: pressure from water flow

External forces: waves, currents, impact from foreign bodies

External Forces on Pipes

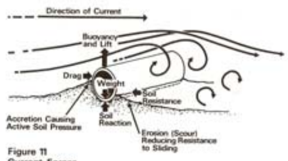


Figure 11
Current Forces

Current

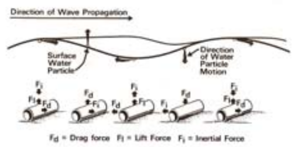


Figure 12
Wave Forces

Waves

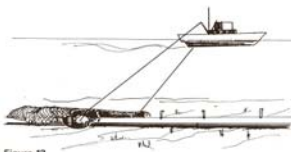
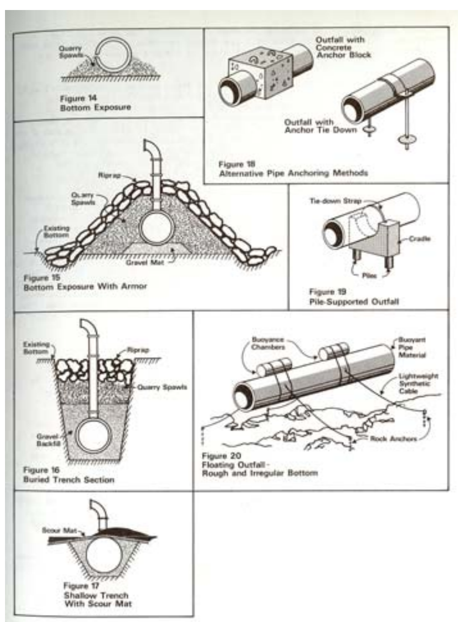


Figure 13
Impact Forces

Impact forces



Pipe Support System

- bottom exposure
- bottom exposure with armor
- buried trench section
- pile-supported system
- semi-floating outfall

Construction Method

Three different zones: onshore, surf, and offshore.

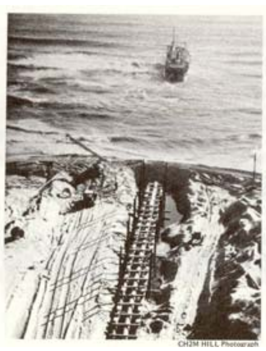
Commonly used construction methods:

- **barge lay**
- **trestle lay**
- **string float**
- **bottom pull**

Barge lay

Trestle lay

String float



Bottom pull

String float

Effect on Dilution of the Diffuser Number

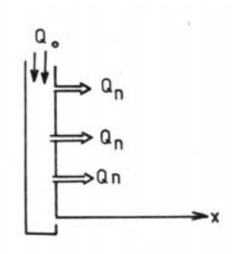
Incoming flow rate: Q_o

Opening area: A_o

n openings => $A_n=A_o/n$

Diameter for opening: $D_n = \frac{D}{\sqrt{n}}$

Flow rate from opening: $Q_{on}=Q_o/n$



Flow rate after distance *x* in one jet:

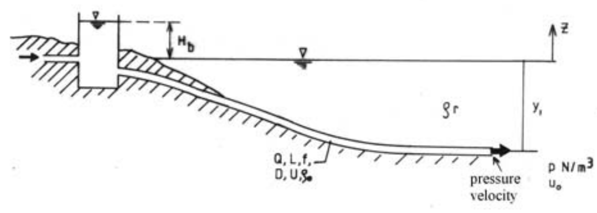
$$Q_n(x) = 0.32 Q_{on} \frac{x}{D_n} = 0.32 \frac{Q_0}{n} \frac{x\sqrt{n}}{D} = \frac{0.32 Q_0}{\sqrt{n}} \frac{x}{D}$$

Flow rate after distance *x* in all jets:

$$Q(x) = n Q_n(x) = 0.32\sqrt{n}\,\frac{x}{D}$$

Dilution increases with a factor $\sqrt{n}$

Effect of Density on Required Energy for Discharge to Receiving Water



Energy equation (reservoir to just outside pipe exit):

$$H_b = -y_1 + \frac{p}{\rho_0 g} + \frac{u_0^2}{2g} + f \frac{L}{D} \frac{u^2}{2g}$$

Pressure at pipe exit (hydrostatic pressure):

$$p = y_1 g \rho_r$$

Yielding:

$$H_b = -y_1 + \frac{y_1 \rho_r}{\rho_0} + \frac{u_0^2}{2g} + f\frac{L}{D}\frac{u^2}{2g} = y_1\frac{\rho_r - \rho_0}{\rho_0} + \frac{u_0^2}{2g} + f\frac{L}{D}\frac{u^2}{2g}$$