Fundamental of Environmental Engineering

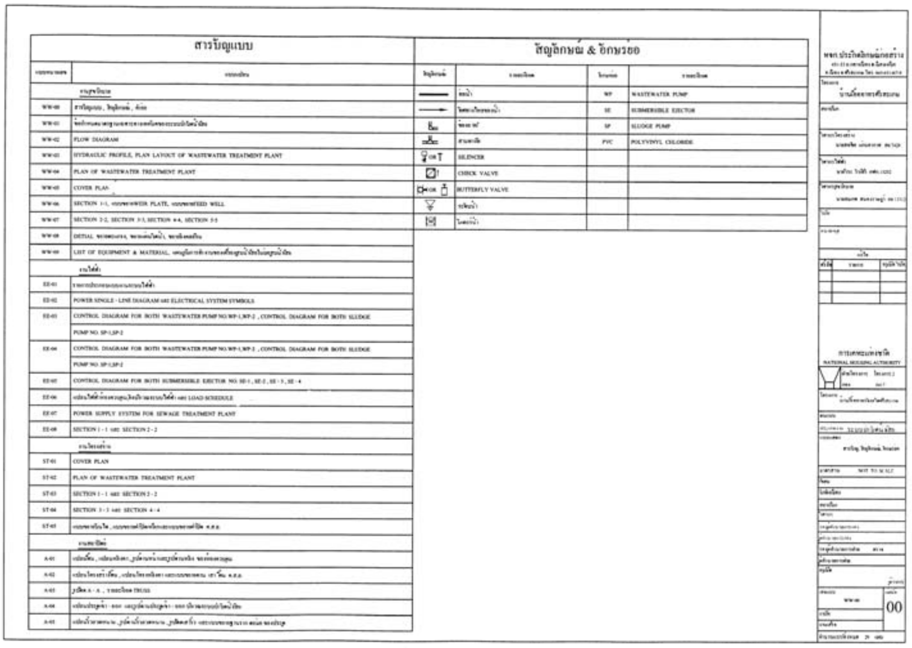
Chapter 0: Engineering Basics

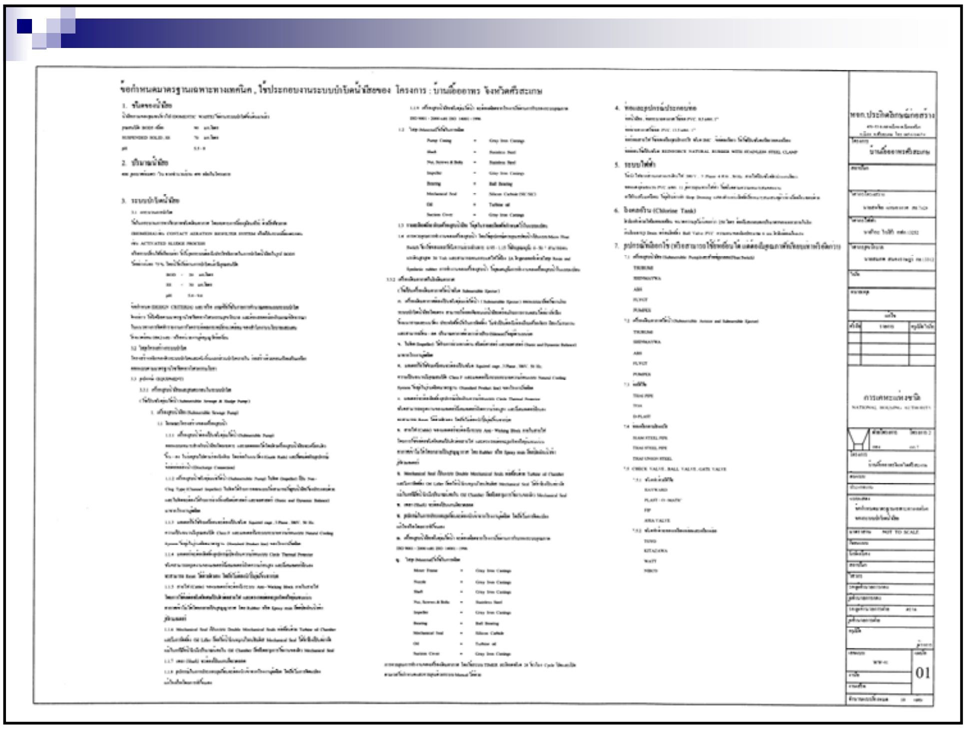
Engineering Basics

- Engineering Drawing*
- Engineering Mechanics: Static and Fluid*
- Engineering Materials
- Computer*

Engineering Drawing

- Flow diagram (process)
- Hydraulic profile (level)
- Plan lay-out (area)
- Sections (details)
- Isomatic view (3-D)




ข้อกำหนดมาตรฐานเฉพาะทางเทคนิค , ใช้ประกอบงานระบบบำบัดน้ำเสียของ โครงการ : บ้านเอื้ออาทร จังหวัดศรีสะเกษ
1. ชนิดของน้ำเสีย
2. ปริมาณน้ำเสีย
3. ระบบบำบัดน้ำเสีย
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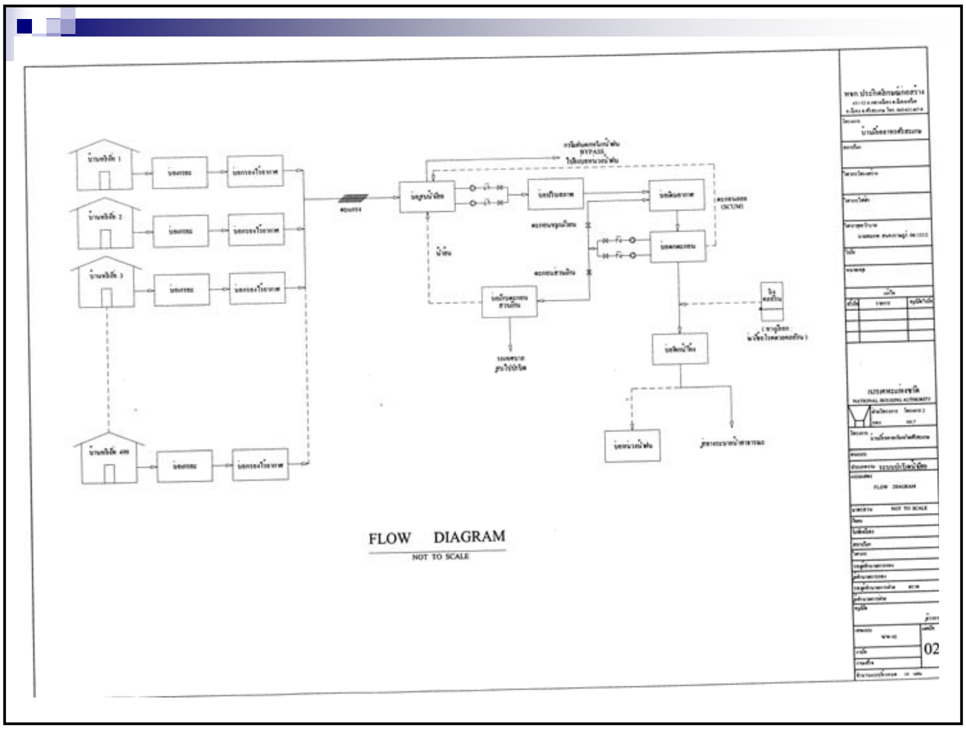
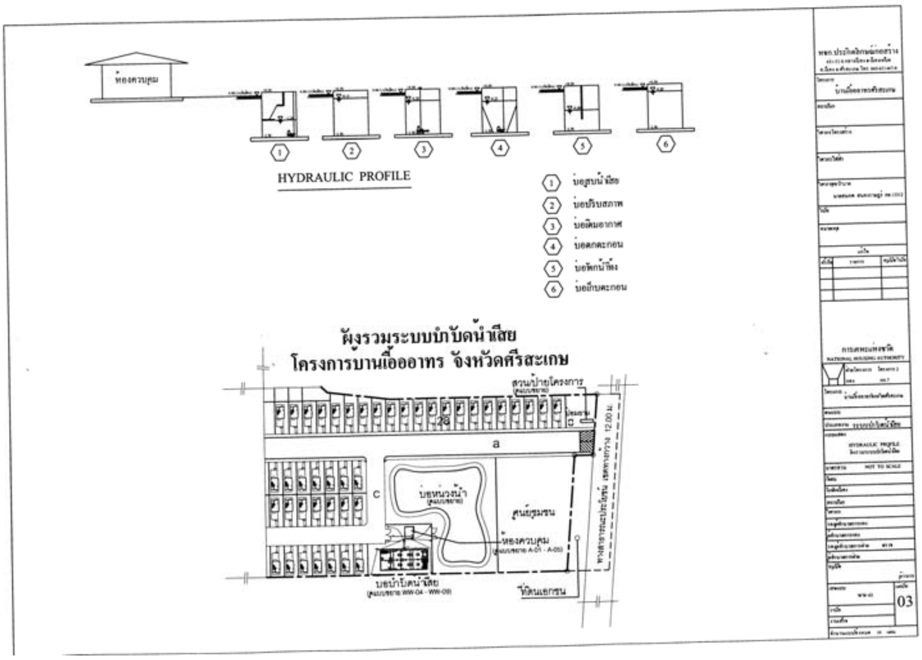

BYPASS
FLOW DIAGRAM
NOT TO SCALE
02


ห้องควบคุม
HYDRAULIC PROFILE
1 บ่อสูบน้ำเสีย
2 บ่อปรับสภาพ
3 บ่อเติมอากาศ
4 บ่อตกตะกอน
5 บ่อพักน้ำทิ้ง
6 บ่อเก็บตะกอน
ผังรวมระบบบำบัดน้ำเสีย
โครงการบ้านเอื้ออาทร จังหวัดศรีสะเกษ
สวนป้ายโครงการ
บ่อหน่วงน้ำ
ศูนย์ชุมชน
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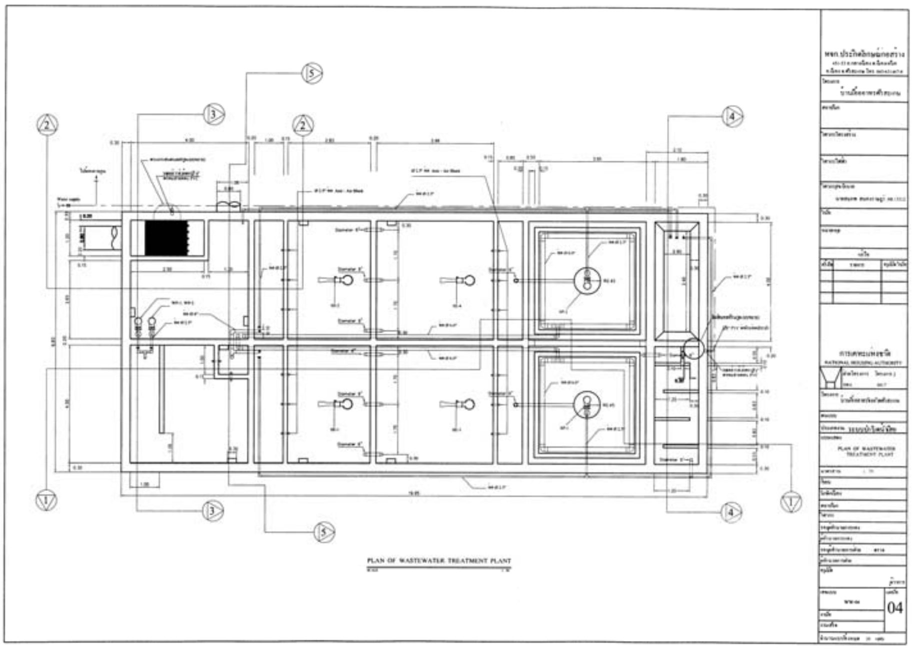
PLAN OF WASTEWATER TREATMENT PLANT
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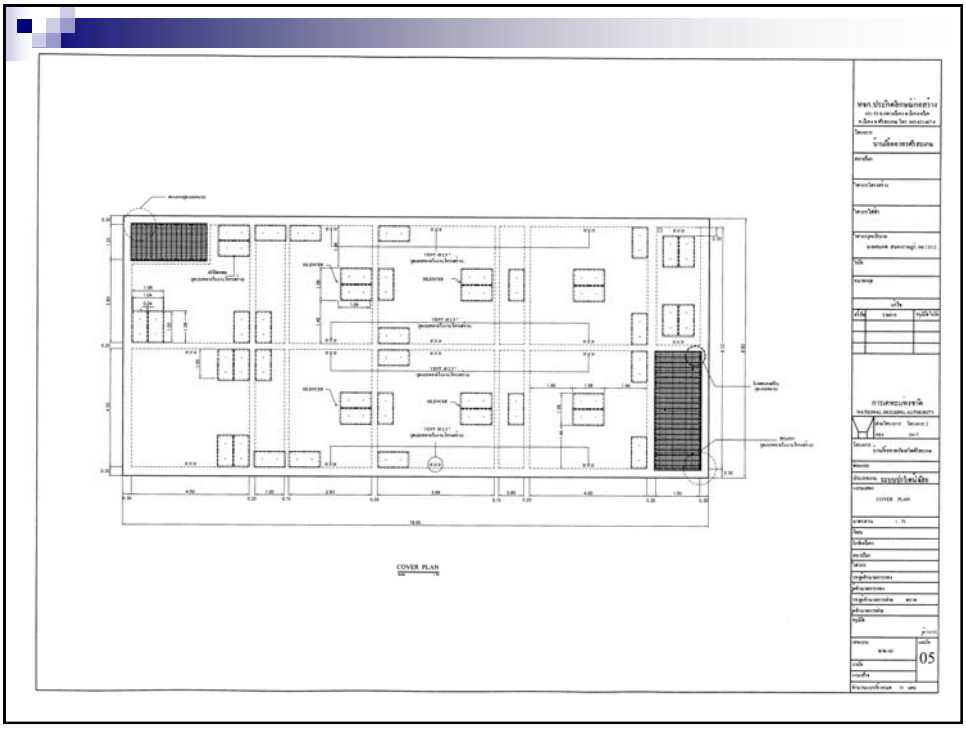
COVER PLAN
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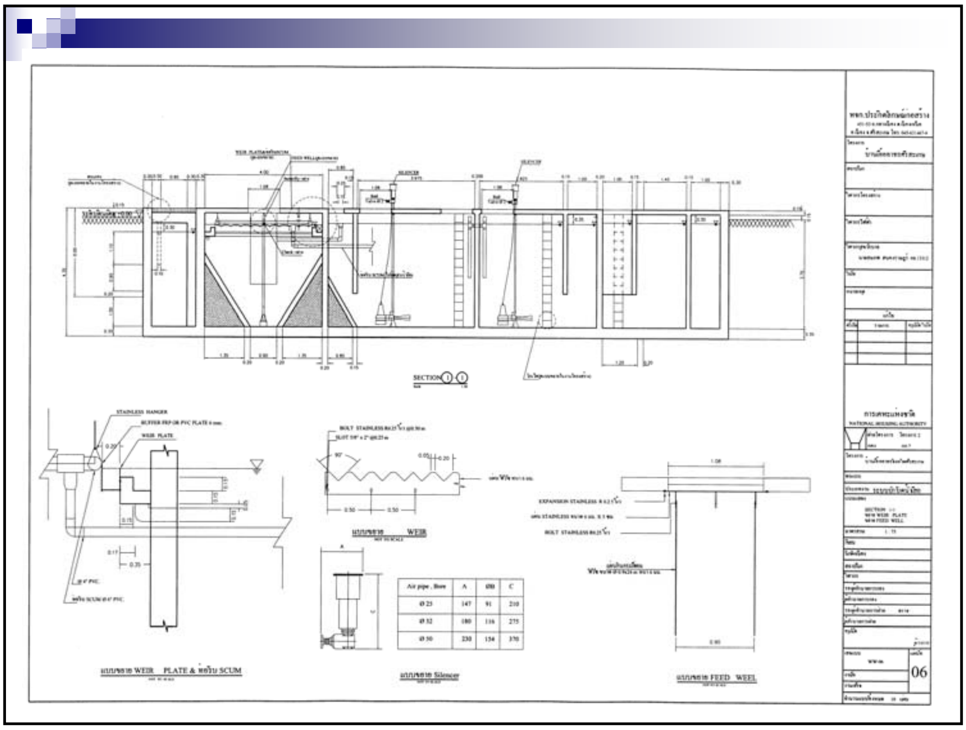
SECTION
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06

Basic Hydraulic Principles

General Flow (Q) Characteristics

- Conveyance (water travels from points of higher energy to lower energy

- Area (A)
  - Cross-sectional area of flow
  - Prismatic channel (a channel with a consistent cross-sectional shape, slope and roughness)

- Open channel or free-surface flow
  - river
- Pressure flow (full-flow conditions)
  - Water distribution pipe

- Wetted Perimeter (P_w)
  - Defined as the portion of the channel in contact with the flowing fluid

- Hydraulic Radius (R)
  - Defined as the area divided by the wetted perimeter (unit of length)

$$R = \frac{A}{P_w}$$

For circular pipe with full-flow water

$$R = \frac{D}{4}$$

where, D is the pipe diameter

Velocity (V)

- Not constant throughout the cross-sectional area (it varies with location)
- Equal to zero where the fluid is in contact with the conduit wall

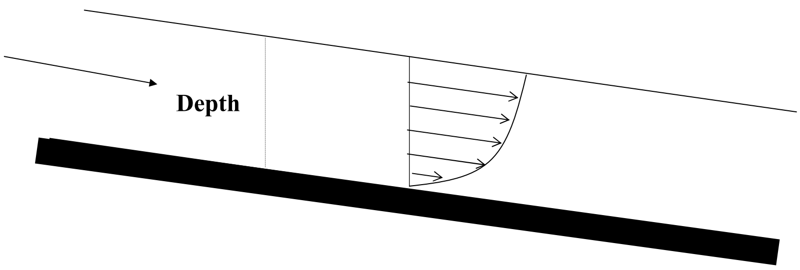


Figure 1. Velocity Distribution

$$V = \frac{Q}{A}$$

Steady Flow

- A constant flow rate (the flow velocity does not change with respect to time at a given location

Unsteady Flow

- A non-constant flow rate

Laminar Flow

- Predictable streamline (the paths of single fluid particles)

Turbulent Flow

- Unpredictable streamline
- Eddy formation

Reynolds Number

Reynold's Number (Re)

- Sir Osborne Reynolds (England, 1842-1903) found that fluid flow at low velocities is manifestly different from flow at high velocities
- Defined as (the 1st and 2nd Newton's law)

$$Re = \frac{\text{Inertia force}}{\text{vicous force}} = \frac{ma}{\tau A}$$

where, τ is the shear stress and A is the area

For full-flow pipe with a diameter of D,

$$Re = \frac{v_{avg} D}{\nu}$$

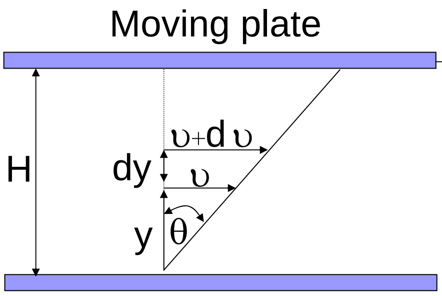
where, v_{avg} is the average velocity,

ν is the kinematic viscosity

Show how to get:

For full-flow pipe with a diameter of D,

$$Re = \frac{v_{avg} D}{\nu}$$



$$F = \tau A = \mu \frac{v_{avg}}{H} A$$

$$\tau \propto \frac{d\theta}{dt} = \frac{\frac{dx}{dy}}{dt} = \frac{\frac{dx}{dt}}{dy} = \frac{d\upsilon}{dy}$$

where, $\frac{d\theta}{dt}$ is the rate of angular deformation,

x is the horizontal distance of movement and H is the thickness

For newtonian fluid,

$$\tau = \mu \frac{d\upsilon}{dy}$$

For full-flow pipe with a diameter of D

$$\mathrm{Re} = \frac{ma}{\tau A} = \frac{m\frac{v_{avg}}{t}}{\mu \frac{v_{avg}}{H} A} = \frac{mv_{avg}}{\mu \frac{L}{H} A} = \frac{Hmv_{avg}}{\mu V} = \frac{\rho D v_{avg}}{\mu}$$

where, L is the length and V is the volume

For a general form in term of R (hydraulic radius),

$$\mathrm{Re} = \frac{\rho D v_{avg}}{\mu} = \frac{4Rv_{avg}}{\nu}$$

Rule of thumb:

For flow in pipes,

Re < 2,000	**Laminar**
2,000 < Re < 4,000	**Transition**
Re > 4,000	**Turbulent**

For flow in open channels,

Re < 500	**Laminar**
500 < Re < 2,000	**Transition**
Re > 2,000	**Turbulent**

Example:

A rectangular concrete channel is 3 m wide and 2 m high. The water in the channel is 1.5 m deep and is flowing at a rate of 30 m³/s. Determine the flow area, wetted perimeter, and hydraulic radius. Is the flow laminar or turbulent? Given: ν is 1x10⁻⁶ m²/s

$$A = 3.0\text{m} \times 1.5\text{m} = 4.5\text{m}^2$$

$$P_w = 3.0\text{m} + 2 \times 1.5\text{m} = 6.0\text{m}$$

$$R = \frac{A}{P_w} = \frac{4.5\text{m}^2}{6.0\text{m}} = 0.75\text{m}$$

$$V = \frac{Q}{A} = \frac{30\text{m}^3/\text{s}}{4.5\text{m}^2} = 6.67\text{m/s}$$

$$Re = \frac{(4 \times 6.67\text{m/s} \times 0.75\text{m})}{(1.00 \times 10^{-6}\text{m}^2/\text{s})} = 2 \times 10^7 \qquad \text{(turbulent)}$$

In hydraulic applications, energy values are usually converted into units of length.

Pressure head: $\frac{p}{\gamma}$

Elevation head: z

Velocity head: $\frac{V^2}{2g}$

where, p is the pressure, γ is the specific weight, z is the elevation and V is the velocity

Energy Equation (Bernoulli's Equation)

$$\frac{p_1}{\gamma} + z_1 + \frac{V_1^2}{2g} + H_G = \frac{p_2}{\gamma} + z_2 + \frac{V_2^2}{2g} + H_L$$

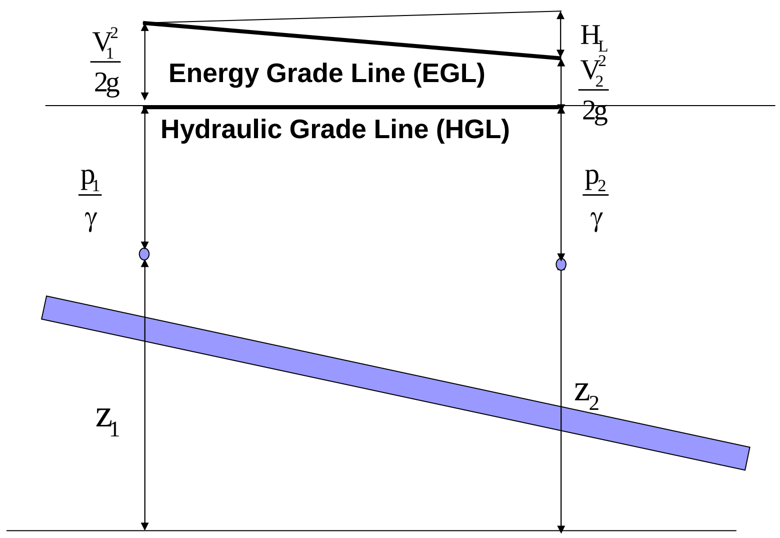
where, H_G is the head gain and H_L is the head loss

Hydraulic Grade

- The sum of the pressure head and elevation head

Energy Grade

- The sum of the hydraulic grade and the velocity head



Energy & Hydraulic Grade Line Profile

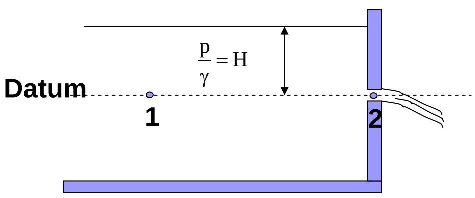
Head Loss

1. Major loss due to internal friction between fluid particles traveling at different velocity such as flow in pipe etc.

2. Minor loss due to localized areas of increased turbulence and disruption of the streamlines such as valve, fitting and a change section shape etc.

Example:

For the structure in the figure below, derive the orifice equation for an orifice of area A.



Soln:

$$\frac{p_1}{\gamma} + z_1 + \frac{V_1^2}{2g} + H_G = \frac{p_2}{\gamma} + z_2 + \frac{V_2^2}{2g} + H_L$$

$$V_2 = \sqrt{2g(H - H_L)}$$

$$AV_2 = Q = A\sqrt{2g(H - H_L)}$$

Apply an orifice coeficient (C)

$$Q = CA\sqrt{2gH}$$

Friction Losses

Some equations that are used to approximate the friction losses associated with the velocity of a liquid flow through a given section:

- **Manning's equation**
- **Chézy's (Kutter's) equation**
- **Hazen-Williams equation**
- **Darcy-Weisbach (Colebrook-White) equation**

A generalized friction equation:

$V = kCR^{x}S^{y}$

where, V is the mean velocity, C is the flow resistance factor, R is the hydraulic radius, S is the friction slope, x and y are the exponents, and k is the factor to account for empirical constants

Typical Applications:

- **Manning's equation is the commonly used for open channel flow.**
- **Chézy's (Kutter's) equation is widely used in sanitary sewer design and analysis.**
- **Hazen-Williams equation is most frequently used in the design and analysis of pressure pipe systems.**
- **Darcy-Weisbach (Colebrook-White) equation is commonly used in the design and analysis of pressure pipe systems.**

Basic Hydrology

Rainfall Characteristics:

- Depth or volume of rainfall during a specified time interval (or its average intensity over that time interval)
- Duration of the rainfall
- Area over which the rainfall occurs
- Recurrence interval of a rainfall amount (return period or frequency)
- Temporal and spatial distributions of rainfall within the storm

Return Period and Frequency

The probability that a storm event of a certain magnitude will occur in any given year.

For example, a five-year return period (20% probability) represents a storm event that is expected to occur once every five years on average.

Frequency or exceedance probability is simply the inverse of the return period.

Runoff Volume

- Watershed Area

- Rain Abstraction
  - Interception (vegetation)
  - Depression Storage (pond etc.)
  - Infiltration (rainwater infiltrates into the ground)
  - Evaporation (not typically considered in stromwater conveyances)

Determining Runoff Volume

A general form (conceptual idea)

$D_r = D_p - D_{li} - D_i - D_s - D_e$ for $D_p > D_{li}$ and $D_r > D_s$

$D_r = 0$ for $D_p \leq D_{li}$ or $D_r \leq D_s$

where, D_r is the total depth of runoff, D_p is the total depth of precipitation (rainfall), D_{li} is the total initial loss (interception), D_i is the total depth infiltrated after initial losses, D_s is the total depression storage depth, and D_e is the transpiration and evaporation losses (often ignored for short-duration stormwater events)

Therefore,

Volume of runoff $(V_r) = D_r \times A$

where, A is the contributing drainage area

Computing Peak Runoff Flow Rate

- The first level is a peak flow calculation to determine the maximum runoff flow rate at a given point resulting from a storm event (designing storm sewers and culverts).

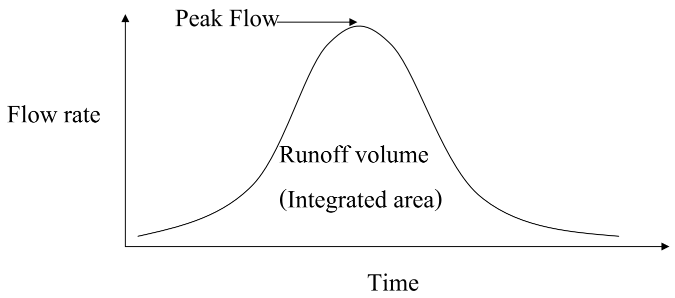
- The second level (more complex) consists of a generation of a runoff hydrograph, which provides information on flow rate versus time and runoff volume.

Techniques for Peak Runoff Flow Rate Calculation:

- Time of concentration (t_c)
  - 5 to 10 minutes recommended for a small watersheds such as a parking lot
- The Rational Method
- NRCS Peak Flow Estimation

Hydrograph

A hydrograph represents the flow rate as it varies over time at a particular location within a watershed. The integrated area under the hydrograph represents the total hydrograph volume of water.



Computer Applications for Environmental Engineering

"Computers are devices that process numbers and other information according to a collection of programmed rules" (Bloomfield, 2001)

Make our lives easier or more frantic?

Computing System

- Hardware (computer equipment)

- Software (the programs that describe the steps that we want the computer to perform)

Computer Hardware

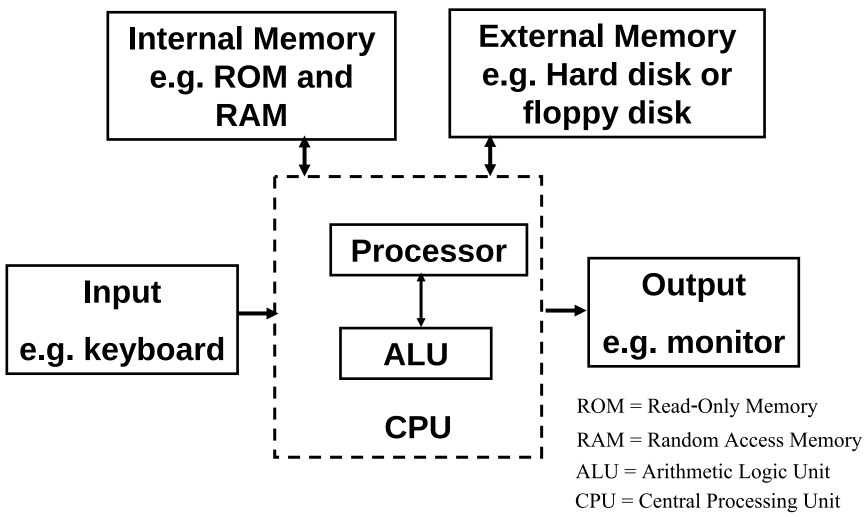


Figure 1. Internal Organization of a Computer (Etter, 1996)

Type of Computer

- Microcomputer e.g. PC
- Minicomputer e.g. workstation
- Mainframe e.g. workstation
- Supercomputer

System Pattern

- Stand-Alone
- Network
  - Local Area Network (LAN)
    - Ethernet
  - Remote
    - MODEM (MOdulator/DEModulator)

Computer Software

- Operating System

- Software Tools

- Language Compilers

Computer Software

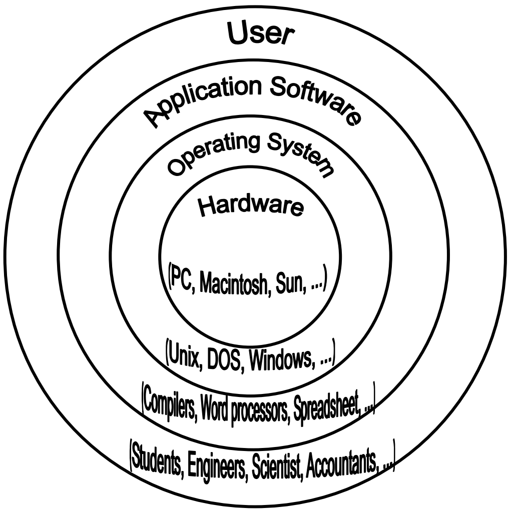


Figure 2. Software Interface to the Computer (Etter, 1996)

Operating System (OS)

- Usually come with the computer hardware.

- Provide an interface between the user and the hardware.

- Contain a group of programs called utilities

Software Tools

- Programs that have been written to perform common operations

For example,

Word processors (Microsoft word, Word perfect etc.)

- Help you enter and format text

- Produce professional-looking documents using a technology called desktop publishing.

Software Tools (continued)

Spreadsheet (Lotus 1-2-3, Quattro Pro, Excel etc.)

- Allow you to work with data in a grid of rows and columns.

- Include plotting capabilities.

Database management (dBase IV, Paradox etc.)

- Allow you to store and organize a large amount of data for analysis.

Software Tools (continued)

Computer-Aided Design (AutoCAD, CADKEY etc.)

- Allow you to define objects and then manipulate them graphically.

Mathematical Computation (MATLAB, MathCAD, Mathematica, Maple etc.)

- Provide very powerful mathematical commands for solving engineering or scientific problems.

- Provide extensive capacities for generating graphs.

Computer Languages

- Low-level language or machine language.
- Assembly language
- High-level language

Low-level language or machine language

- Written using two symbols, which are usually represented using the digits 0 and 1. It is also called binary language.
- Have the written instruction as sequences of 0s and 1s.
- Tied closely to the design of the computer hardware. The machine language for a SUN computer is different from the machine language for a Silicon Graphics computer.

Assembly language

- Unique to a specific computer design but its instructions are written in English-like statements instead of binary.

- Possible to be a tedious job for writing programs in assembly language because it does not have very many statements.

- Used to write real-time programs.

High-level language

- English-like commands, instructions and languages such as C, FORTRAN, Ada, Pascal, COBOL and BASIC.

- Easier than writing programs in machine language or in assembly language.

- Extensive commands and an extensive set of syntax (or grammar) rules for using the commands.

FORTRAN (FORmula TRANslation)

- Developed in the mid-1950s for solving engineering and scientific problems.

COBOL (Common Business-Oriented Language)

- Developed in the late 1950 to solve business problems.

BASIC (Beginner's All-purpose Symbolic Instruction Code)

- Developed in the mid-1960s and used as an educational tool.

Pascal

- Developed in the early 1970s and widely used in computer science programs to introduce students to computing.

Ada

- Developed in the early 1800 s.

- Developed at the initiative of the U.S. Department of Defense with the purpose of developing a high-level language appropriate to embedded computer systems that are typically implemented using microprocessors.

C

- Developed at Bell Laboratories in the late 1960s.

- Machine-independent language.

- ANSI (American National Standards Institute) standard was approved in 1989.

Executing a Computer Program

- Compilation
- Linking/loading
- Execution

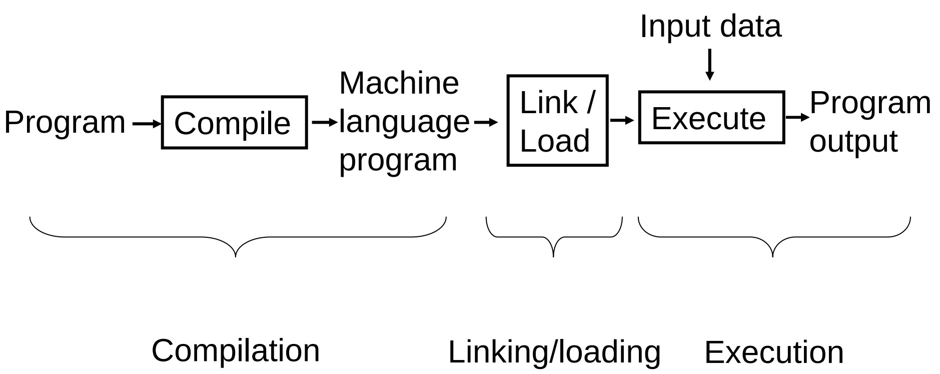


Figure 3. Program Compilation/Linking and Loading/Execution (Etter, 1996)

Compilation

- Translate a high-level language to machine language using a special program called compiler.

Compile errors

- Bugs/debugging

Source program (the original program)

Object program (the machine language version)

Linking/loading

- Link other machine language statements to the object program and then load it into memory.

Execution

- Execute the program.

Execution errors or run-time errors or logic errors

- Bugs/debugging

Software Life Cycle:

- Definition
- Specification
- Coding and Modular Testing
- Integrated Testing
- Maintenance (involve most of percentages of effort)

Software Prototypes

- Reducing the cost of software development both in time and in cost.