

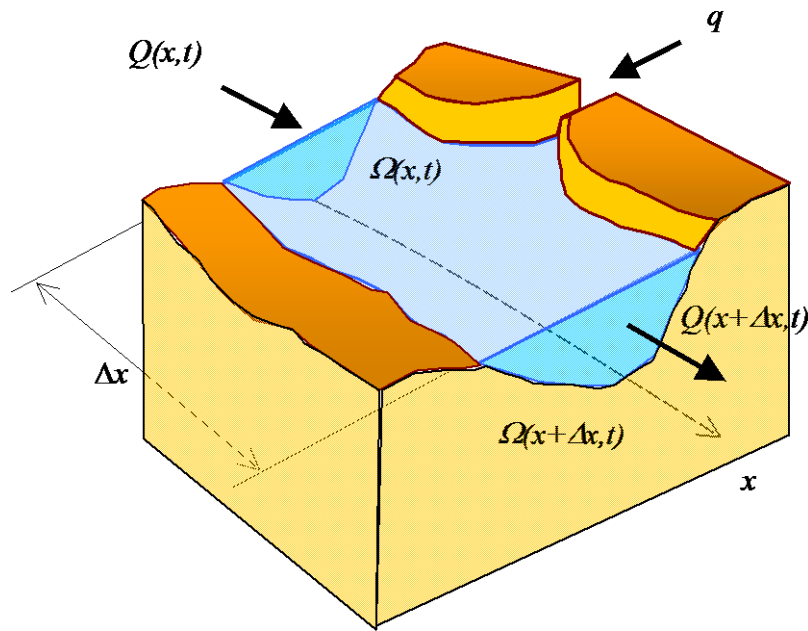
CURSOS SUPERFICIALES (Ríos y Estuarios)

- **Modelo unidimensional**
- **Modelo bidimensional**

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ANÁLISIS UNIDIMENSIONAL (ECUACIONES DE SAINT VENANT)



$$\frac{\partial \Omega}{\partial t} + \frac{\partial Q}{\partial x} = q$$

$$\frac{\partial U}{\partial t} + U \frac{\partial U}{\partial x} + g \frac{\partial z}{\partial x} + g I_f = -\frac{q}{\Omega} (U - u_L)$$

$$I_f = \frac{n^2 U^2}{R^{4/3}}$$

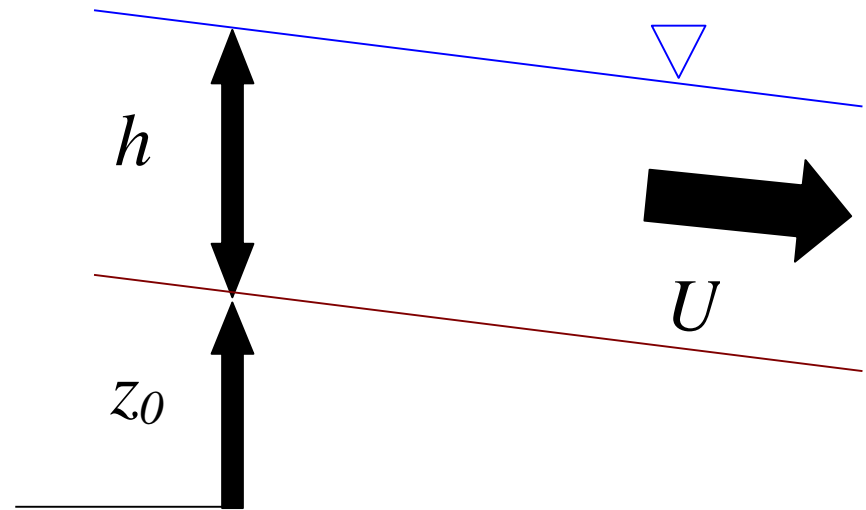
RUGOSIDAD (n)

| Tipo de curso de agua | Rango de valores normales |
|---|----------------------------------|
| Canal alineado o artificial | |
| Cemento | 0.011/0.013 |
| Concreto | 0.013/0.027 |
| Canal excavado o dragado | |
| Tierra, alineado y uniforme | 0.018/0.027 |
| Tierra, sinuoso y lento | 0.025/0.040 |
| Cortes de roca | 0.035/0.040 |
| Cursos naturales menores (ancho < 30 m) | |
| En planicie | 0.030/0.100 |
| Montañosos | 0.040/0.050 |
| Planicie de inundación | |
| Pasturas | 0.030/0.035 |
| Áreas cultivadas | 0.030/0.040 |
| Arbustos | 0.050/0.100 |
| Árboles | 0.040/0.120 |
| Cursos naturales mayores (ancho > 30 m) | 0.025/0.100 |

FLUJO UNIFORME

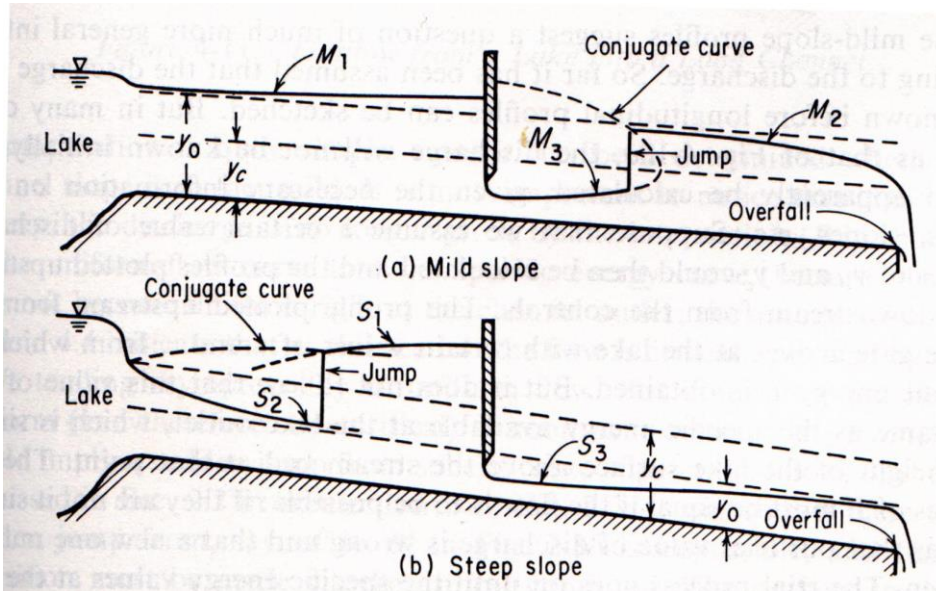
$$\Omega^2 R^{4/3} = \frac{n^2 Q^2}{I_0}$$

Relación algebraica
entre h y Q



- Régimen estacionario
- Pendiente del fondo constante
- Sin aporte lateral
- Profundidad uniforme

CURVAS DE REMANSO



$$\frac{dh}{dx} = I_0 + \frac{Q^2}{g\Omega^3} \frac{\partial \Omega}{\partial x} \bigg|_h - \frac{n^2 Q^2}{\Omega^2 R^{4/3}} \frac{1}{1 - Fr^2}$$

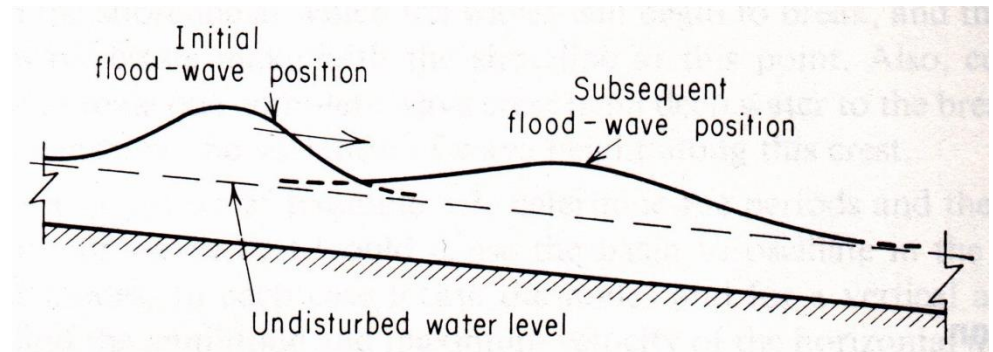
Integración numérica

- Régimen estacionario
- Pendiente del fondo variable
- Sin aporte lateral

ONDA DE INUNDACION

$$\eta(x,t) \equiv z(x,t) - z_o(x) - h_o = \frac{A}{\sqrt{4 - Fr_0^2}} \sqrt{\frac{\lambda}{2\pi gh_0 t}} \exp\left\{-\frac{2\lambda}{gh_0} \frac{(x - c_c t)^2}{(4 - Fr_0^2)t}\right\}$$

Solución cerrada

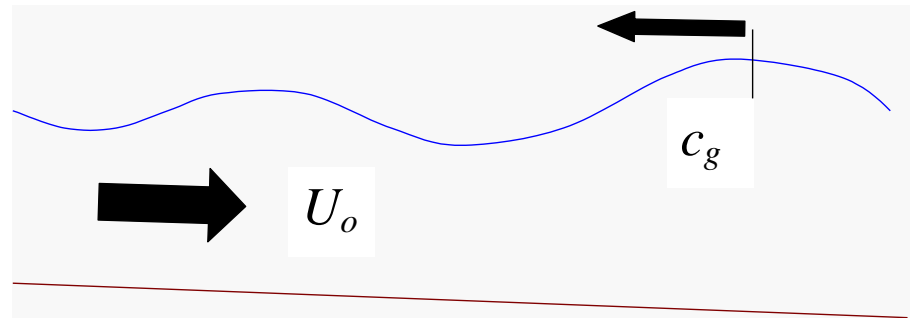


- Canal cuasi-prismático, ancho
- Pendiente del fondo constante
- Flujo de base uniforme
- Sin aporte lateral
- Onda de pequeña amplitud

ONDA DE MAREA

$$\eta(x,t) \equiv z(x,t) - z_o(x) - h_o = a_0 \exp\left(-\frac{\Psi \xi}{|c_g|}\right) \cos\left(\omega\left(t - \frac{\xi}{|c_g|}\right)\right)$$

Solución cerrada

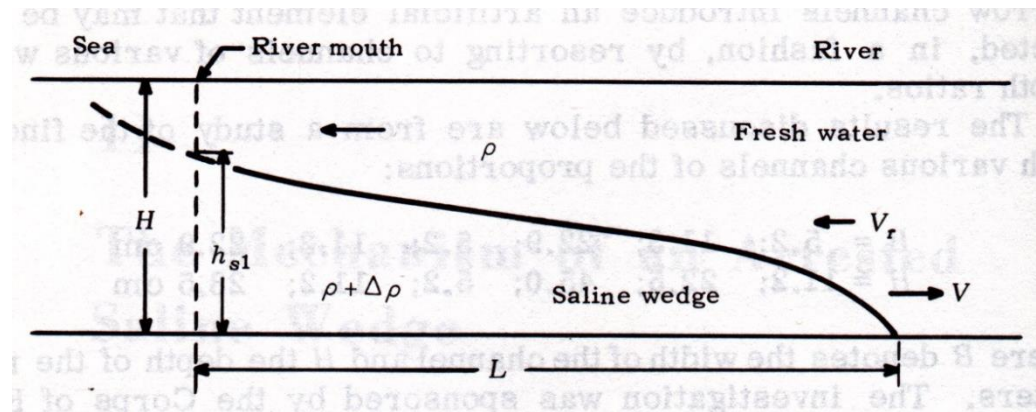


- Canal cuasi-prismático, ancho
- Pendiente del fondo constante
- Flujo de base uniforme
- Sin aporte lateral
- Onda de pequeña amplitud

ESTRATIFICACION SALINA (modelo de 2 capas)

$$x(a_1) = \frac{2h}{f_i} \left\{ \frac{1}{5Fr_0^2} - 2 + 3Fr_0^{2/3} \left(1 - \frac{2}{5} Fr_0^{2/3} \right) \right\}$$

Relación algebraica
entre x y a_1



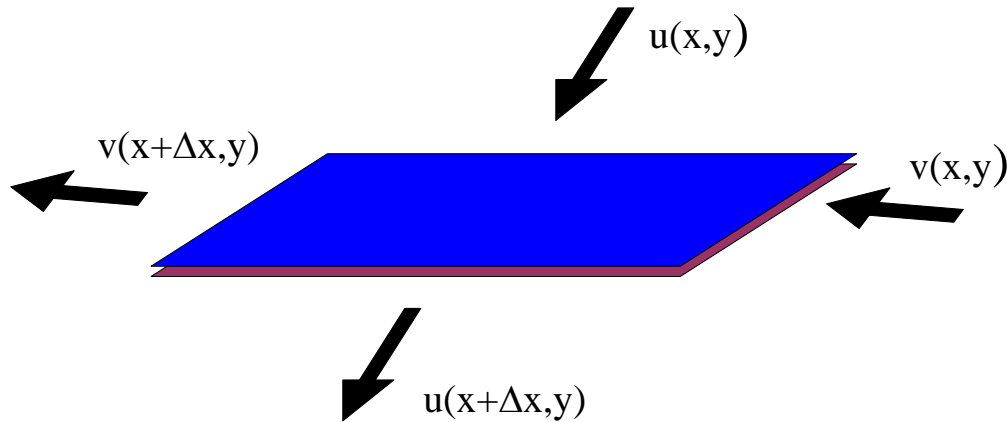
- Régimen estacionario
- Canal cuasi-prismático, ancho
- Profundidad uniforme, a dos capas
- Sin aporte lateral

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ANÁLISIS BIDIMENSIONAL

(ECUACIONES PARA AGUAS POCO PROFUNDAS)



$$\frac{\partial h}{\partial t} + \frac{\partial}{\partial x}(hu) + \frac{\partial}{\partial y}(hv) = 0$$

$$\frac{\partial u}{\partial t} + u \frac{\partial u}{\partial x} + v \frac{\partial u}{\partial y} - f_g v + g \frac{\partial(h+z_0)}{\partial x} + \frac{\tau_{fx}}{\rho h} - \frac{\tau_{sx}}{\rho h} - \frac{1}{\rho h} \frac{\partial}{\partial x}(hT_{xx}) - \frac{1}{\rho h} \frac{\partial}{\partial y}(hT_{xy}) = 0$$

$$\frac{\partial v}{\partial t} + u \frac{\partial v}{\partial x} + v \frac{\partial v}{\partial y} + f_g u + g \frac{\partial(h+z_0)}{\partial y} + \frac{\tau_{fy}}{\rho h} - \frac{\tau_{sy}}{\rho h} - \frac{1}{\rho h} \frac{\partial}{\partial x}(hT_{xy}) - \frac{1}{\rho h} \frac{\partial}{\partial y}(hT_{yy}) = 0$$

ANALISIS BIDIMENSIONAL (PARAMETRIZACION)

$$f_g = 2\omega \operatorname{sen} \phi$$

$$\frac{\tau_{fx}}{\rho h} = f_r \frac{u\sqrt{u^2 + v^2}}{h} \quad \frac{\tau_{fy}}{\rho h} = f_r \frac{v\sqrt{u^2 + v^2}}{h} \quad f_r = \frac{g}{C^2} = \frac{gn^2}{h^{1/3}}$$

$$T_{ij} \equiv \frac{\rho}{h} \int_{z_0}^{z_0+h} \left[v \left(\frac{\partial u_i}{\partial x_j} + \frac{\partial u_j}{\partial x_i} \right) - \overline{u'v'} - (U_i - u_i)(U_j - u_j) \right] dz$$

$$\frac{1}{\rho h} \frac{\partial}{\partial x} (hT_{xx}) + \frac{1}{\rho h} \frac{\partial}{\partial y} (hT_{xy}) = v_t \left(\frac{\partial^2 u}{\partial x^2} + \frac{\partial^2 u}{\partial y^2} \right)$$

$$\frac{1}{\rho h} \frac{\partial}{\partial x} (hT_{xy}) + \frac{1}{\rho h} \frac{\partial}{\partial y} (hT_{yy}) = v_t \left(\frac{\partial^2 v}{\partial x^2} + \frac{\partial^2 v}{\partial y^2} \right)$$