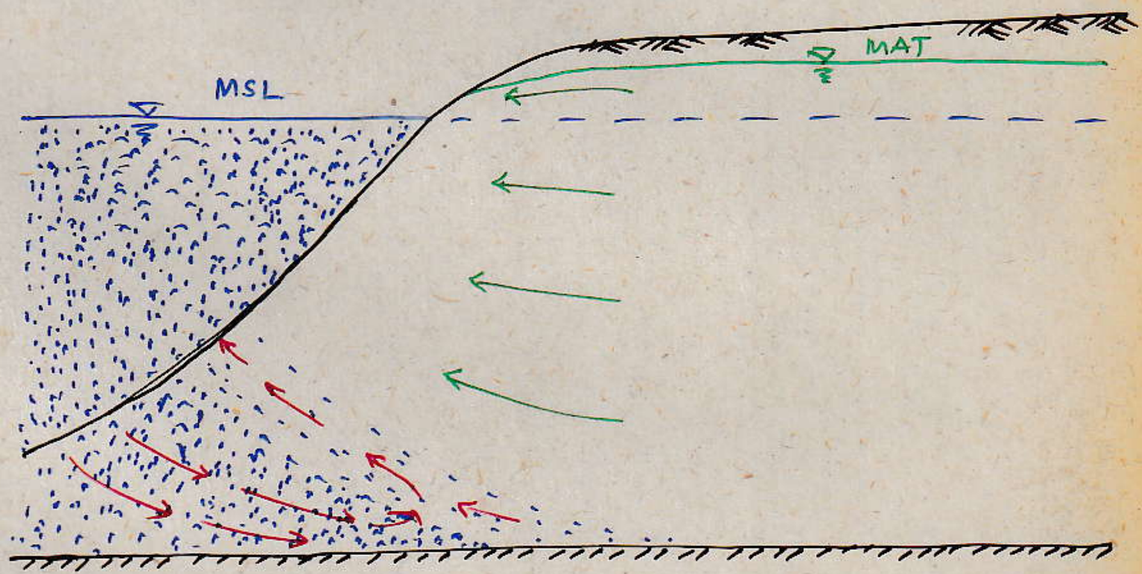
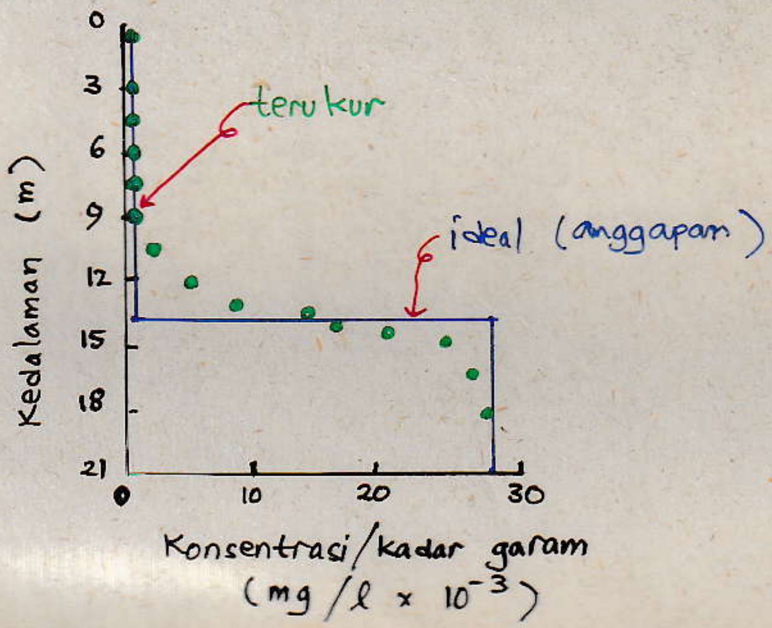
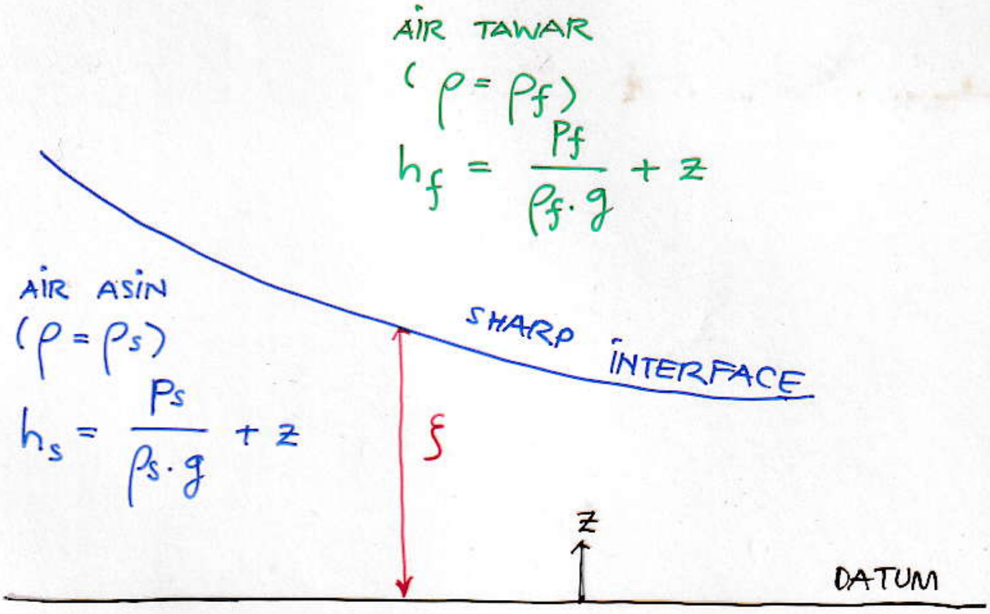
INTRUSI AIR ASIN

1. PENDAHULUAN

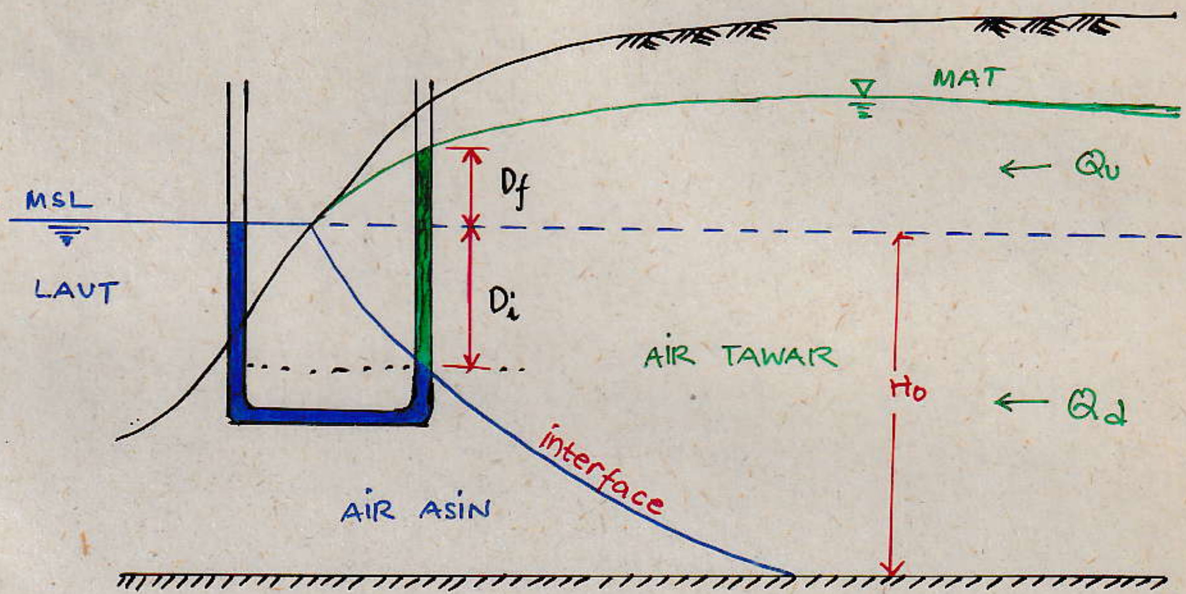




Air tawar ⟩ - Tercampur (miscible)
Air asin ⟩ - Terpisah (immisible)



2. PENYELESAIAN GHYBEN - HERZBERG



KONDISI KESEIMBANGAN STATIS:

$$D_i \cdot \rho_s = (D_f + D_i)\,\rho_f$$

$$(\rho_s - \rho_f)\,D_i = \rho_f \cdot D_f$$

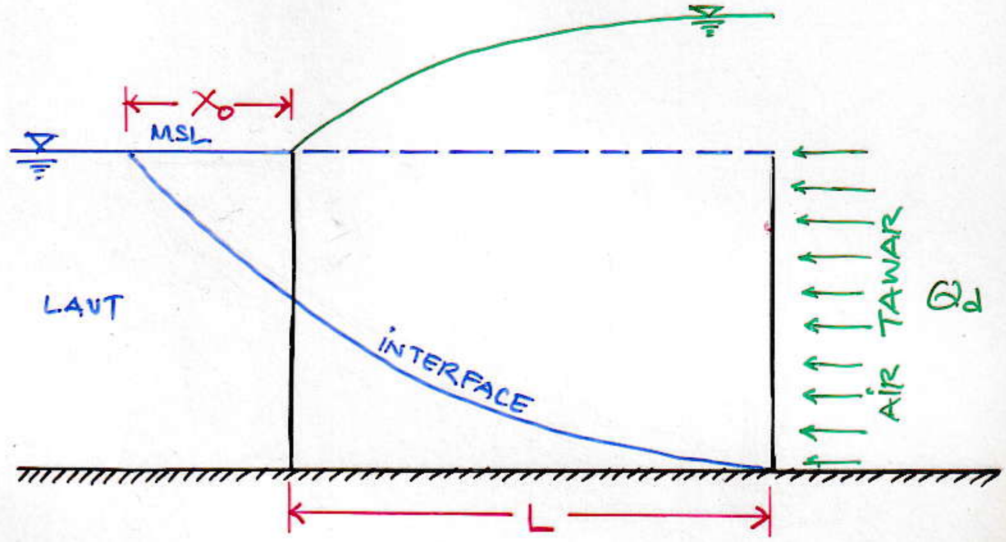
$$\boxed{D_i = \frac{\rho_f}{\rho_s - \rho_f}\,D_f}$$

Air laut $\rightarrow \rho_s = 1.025$

Air tawar $\rightarrow \rho_f = 1$

$$D_i = \frac{1}{1.025 - 1}\,D_f \;\Rightarrow\; D_i = 40\,D_f$$

3. PENYELESAIAN GLOVER



Persamaan tempat kedudukan interface :

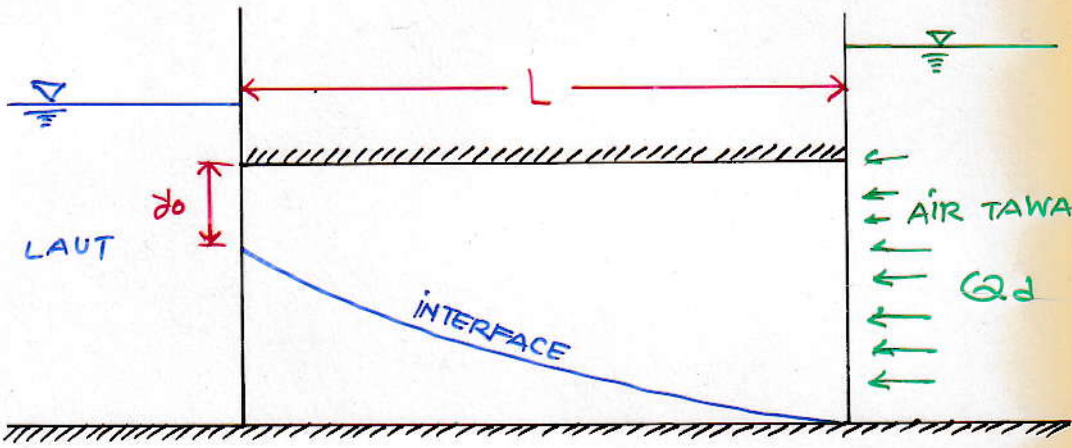
$$D_{i(h)} - \frac{2Q_d}{\alpha K}x - \left(\frac{Q_d}{\alpha K}\right)^2 = 0$$

$$\alpha = \frac{\rho_s - \rho_f}{\rho_f}$$

$$D_{i(h)} = 0 \Rightarrow x = x_0$$

$$x_0 = -\frac{Q_d}{2\alpha K}$$

4. PENYELESAIAN HENRY



$$y_0 = 0{,}741 \frac{Q_d}{\alpha K}$$

PRINSIP PENYELESAIAN :

G - H
D - F } → DIGABUNG

↓

DISELESAIKAN DG. SYARAT BATAS GLOVER & HENRY

$$q_n = K \frac{dD_f}{dx}$$

$$Q_n = K (D_f + D_i) \frac{dD_f}{dx}$$

$$= K \alpha (1 + \alpha) D_i \frac{dD_i}{dx}$$

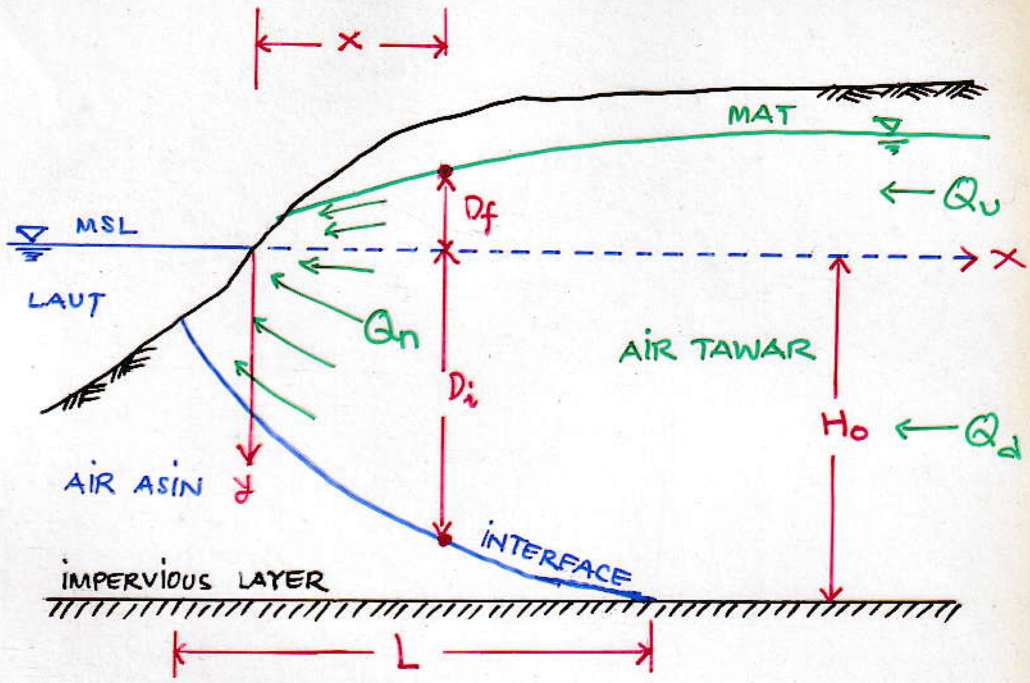
Pers. di atas diintegralkan dengan syarat batas:

(i) Di garis pantai : a) Glover → permukaan horizontal
b) Henry → permukaan vertikal

(ii) Di hulu : $x = L \Rightarrow D_i = H_0$

Hasil :

5. PENYELESAIAN DAS GUPTA & GAIKWAD



KASHEF :

$$Q_d = \alpha K \frac{H_o^2}{2L} = \frac{Q_n}{1+\alpha} = \frac{Q_u}{\alpha}$$

GHYBEN - HERZBERG :

$$D_i = \frac{D_f}{\alpha} \Rightarrow D_f = \alpha D_i$$

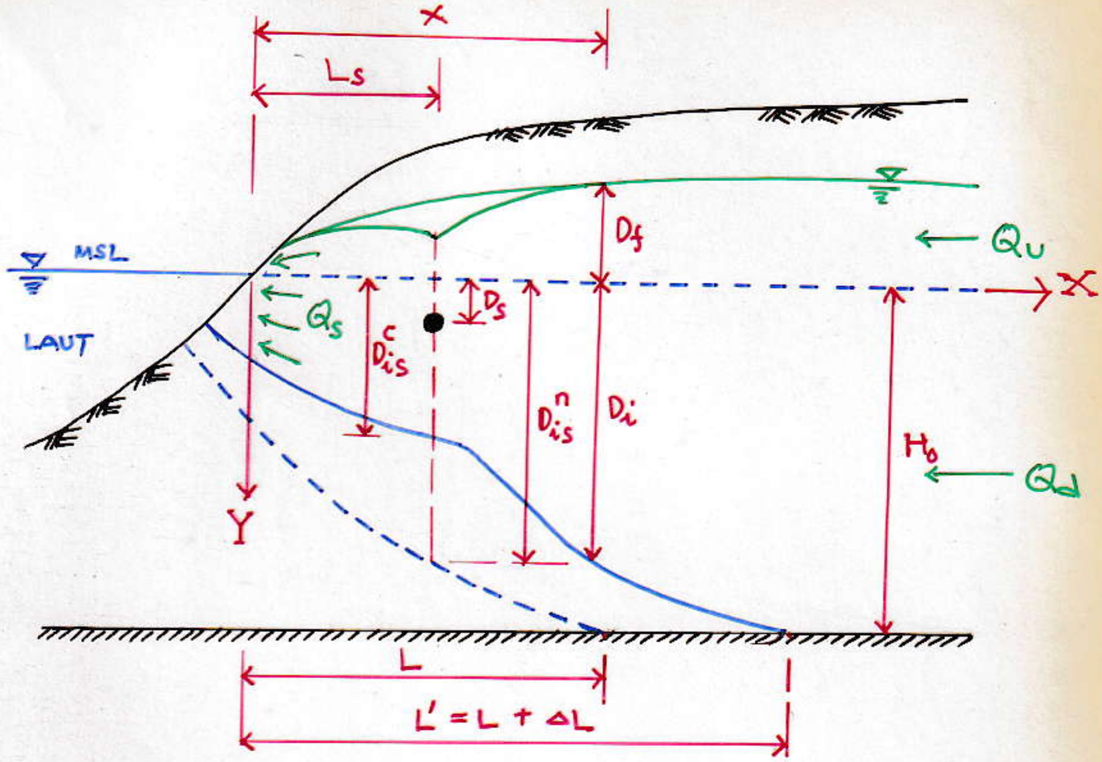
DUPUIT - FORCHEIMER :

Gradien hidraulik = Gradien muka air $\left(\frac{dD_f}{dx} \right)$

DARCY :

$$q_n = K \frac{dD_f}{dx}$$

6. PENGARUH PEMOMPAAN → UPCONING



DAS GUPTA & GAIKWAD:

$$D_{is}^{c} = D_s + f\,(D_{is}^{n} - D_s)$$

$$\frac{D_{is}^{c}}{H_o} = \frac{D_{is}^{n}}{H_o}\left[f + (1-f)\,\delta\right]$$

$$\delta = \frac{D_s}{D_{is}^{n}}$$

f = upconing yang diijinkan

$\simeq \frac{1}{3} - \frac{1}{2}$

Dalam bentuk non-dimensional:

$$\frac{D_{is}^{c}}{L_s} = \frac{D_{is}^{n}}{H_o}\left[f + (1-f)\,\delta\right]\frac{1}{\bar{m}}$$

$$\bar{m} = \frac{L_s}{H_o}$$

A. RUMUS DEBIT

$$\frac{Q_n}{\alpha K H_o} = \frac{1+\alpha}{\beta} m \left[\left(1 + \frac{\beta}{m^2}\right)^{\frac{1}{2}} - 1 \right]$$

$$m = \frac{L}{H_o}$$

$$\beta = \begin{cases} 1 & : \text{permukaan horizontal} \\ 0{,}55 & : \text{permukaan vertikal} \end{cases}$$

$$\alpha = \frac{\rho_s - \rho_f}{\rho_f}$$

B. RUMUS T.K. INTERFACE

$$\frac{D_i}{H_o} = \left\{ 1 - \frac{2m^2}{\beta} \left[\left(1 + \frac{\beta}{m^2}\right)^{\frac{1}{2}} - 1 \right] (1 - \bar{x}) \right\}^{\frac{1}{2}}$$

$$\bar{x} = \frac{x}{L}$$

Debit air tawar yang masuk ke laut, Q_s

$$\frac{Q_s}{\alpha K H_0} = \frac{\bar{m}(1+\alpha)}{\beta}\left\{\left[1+\beta\left(\frac{D_{is}^{c}}{L_s}\right)^2\right]^{\frac{1}{2}} - 1\right\}$$

Pertambahan panjang intrusi, ΔL

$$\Delta m = \frac{\Delta L}{H_0} = \bar{m} + \frac{\beta}{2m}\left\{\frac{1-\left(\frac{D_{is}^{c}}{H_0}\right)^2}{\left(1+\frac{\beta}{m^2}\right)^{\frac{1}{2}} - 1}\right\} - m$$

Profil (T.K.) interface :

a) $0 \leqslant x' \leqslant 1 \qquad \left(x' = \frac{x}{L_s} \right)$

$$\frac{D_i}{H_0} = \left\{\frac{\bar{m}^2}{\beta}(X-1)\left[(X-1)+2x'\right]\right\}^{\frac{1}{2}}$$

$$X = \left\{1+\beta\left(\frac{D_{is}^{c}}{L_s}\right)^2\right\}^{\frac{1}{2}}$$

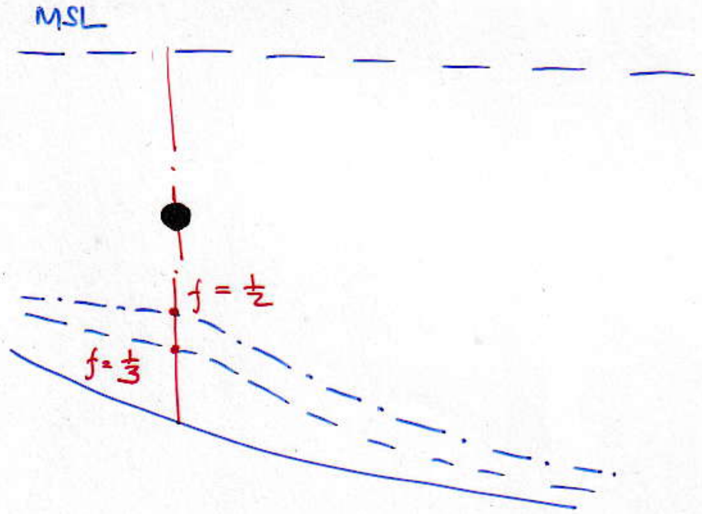
b) $1 \leqslant x' \leqslant \frac{m+\Delta m}{\bar{m}}$

$$\frac{D_i}{H_0} = \left\{\frac{2mm'}{\beta}\left[\left(1+\frac{\beta}{m^2}\right)^{\frac{1}{2}} - 1\right](x'-1) + \left(\frac{D_{is}^{c}}{H_0}\right)^2\right\}^{\frac{1}{2}}$$

RESUME

A. PERLU DIKETAHUI :

1. Kedalaman (tebal) aquifer di bawah MSL (H_0)
2. Lokasi (kedalaman) interface di (minimum) dua titik [(D_i, x_1) dan (D_i, x_2)].
4. Upconing yang diijinkan (f)



3. Lokasi pengambilan (L_s, D_s)

B. PROSEDUR HITUNGAN :

1. Hitung debit total air tawar (Q_n) dg. mengintegralkan persamaan : Q_n dg. batas integrasi kedalaman interface di dua titik.

$$Q_n = K\alpha(1+\alpha)\frac{\int_{D_{i_1}}^{D_{i_2}} D_i \, dD_i}{\int_{x_1}^{x_2} dx}$$

$$= K\alpha(1+\alpha)\frac{D_{i_2}^2 - D_{i_1}^2}{2(x_2 - x_1)}$$

2. Hitung panjang intrusi (L)

$$\frac{Q_n}{\alpha K H_0} = \frac{1+\alpha}{\beta} m \left[\left(1 + \frac{\beta}{m^2}\right)^{\frac{1}{2}} - 1\right]$$

$$m = \frac{L}{H_0}, \quad \beta \begin{cases} = 1 : \text{permukaan horizontal} \\ = 0{,}55 : \text{permukaan vertikal} \end{cases}$$

3. Hitung profil interface [$D_i(x)$]

$$\frac{D_i}{H_0} = \left\{1 - \frac{2m^2}{\beta}\left[\left(1 + \frac{\beta}{m^2}\right)^{\frac{1}{2}} - 1\right]\left(1 - \bar{x}\right)\right\}^{\frac{1}{2}}$$

$$\bar{x} = \frac{x}{L}$$

4. Hitung kedalaman kritik interface (D_{is}^c)

$$\frac{D_{is}^c}{L_s} = \frac{D_{is}^n}{H_0}\left[f + (1-f)\delta\right]\frac{1}{\bar{m}}$$

$$\bar{m} = \frac{L_s}{H_0}$$

5. Hitung debit air tawar yang masuk ke laut (Q_s)

$$\frac{Q_s}{\alpha K H_0} = \frac{\bar{m}(1+\alpha)}{\beta} \left\{ \left[1 + \beta \left(\frac{D_{is}^c}{L_s} \right)^2 \right]^{\frac{1}{2}} - 1 \right\}$$

6. Hitung debit pengambilan (Q_p)

$$Q_p = Q_n - Q_s$$

7. Hitung pertambahan panjang interface (ΔL)

$$\Delta m = \frac{\Delta L}{H_0} = \bar{m} + \frac{\beta}{2m} \left\{ \frac{1 - \left(\frac{D_{is}^c}{H_0} \right)^2}{\left(1 + \frac{\beta}{m^2} \right)^{1/2} - 1} \right\} - m$$

8. Hitung profil intrusi (T.K. interface) → D_i

$$0 \leq x' \leq 1$$

$$\frac{D_i}{H_0} = \left\{ \frac{\bar{m}^2}{\beta} (X-1) \left[(X-1) + 2x' \right] \right\}^{\frac{1}{2}}$$

$$X = \left\{ 1 + \beta \left(\frac{D_{is}^c}{L_s} \right)^2 \right\}^{\frac{1}{2}}$$

$$1 \leq x' \leq \frac{m + \Delta m}{\bar{m}}$$

$$\frac{D_i}{H_0} = \left\{ \frac{2mm'}{\beta} \left[\left(1 + \frac{\beta}{m^2} \right)^{\frac{1}{2}} - 1 \right] (x'-1) + \left(\frac{D_{is}^c}{H_0} \right)^2 \right\}^{\frac{1}{2}}$$

$$x' = \frac{x}{L_s}$$

Nilai $K_0(x)$ dan $e_x K_0(x)$ untuk berbagai nilai x menurut Hantush

x	$K_0(x)$	$e_x K_0(x)$	x	$K_0(x)$	$e_x K_0(x)$	x	$K_0(x)$	$e_x K_0(x)$
0.010	4.721	4.769	0.10	2.427	2.682	1.0	0.421	1.145
0.012	4.539	4.594	0.12	2.248	2.535	1.2	0.319	1.058
0.014	4.385	4.447	0.14	2.098	2.412	1.4	0.244	0.988
0.016	4.251	4.320	0.16	1.967	2.309	1.6	0.188	0.931
0.018	4.134	4.209	0.18	1.854	2.219	1.8	0.246	0.883
0.020	4.029	4.110	0.20	1.753	2.141	2.0	0.114	0.842
0.022	3.933	4.021	0.22	1.662	2.071	2.2	0.0893	0.806
0.024	3.846	3.940	0.24	1.580	2.008	2.4	0.0702	0.774
0.026	3.766	3.866	0.26	1.505	1.952	2.6	0.0554	0.746
0.028	3.692	3.797	0.28	1.436	1.900	2.8	0.0438	0.721
0.030	3.624	3.734	0.30	1.373	1.853	3.0	0.0347	0.698
0.032	3.559	3.675	0.32	1.314	1.809	3.2	0.0276	0.677
0.034	3.499	3.620	0.34	1.259	1.769	3.4	0.0220	0.658
0.036	3.442	3.568	0.36	1.208	1.731	3.6	0.0175	0.641
0.038	3.388	3.519	0.38	1.160	1.696	3.8	0.014	0.624
0.040	3.337	3.473	0.40	1.115	1.663	1.0	0.0112	0.609
0.042	3.288	3.429	0.42	1.072	1.632	4.2	0.089	0.595
0.044	3.242	3.387	0.44	1.032	1.603	4.4	0.071	0.582
0.046	3.197	3.348	0.46	0.994	1.575	4.6	0.057	0.570
0.048	3.155	3.310	0.48	0.958	1.549	4.8	0.046	0.559
0.050	3.114	3.274	0.50	0.924	1.524	5.0	0.037	0.548
0.052	3.075	3.239	0.52	0.892	1.501			
0.054	3.038	3.206	0.54	0.861	1.478			
0.056	3.002	3.174	0.56	0.832	1.457			
0.058	2.967	3.144	0.58	0.804	1.436			
0.060	2.933	3.114	0.60	0.778	1.417			
0.062	2.9	3.086	0.62	0.752	1.398			
0.064	2.869	3.058	0.64	0.728	1.380			
0.066	2.838	3.032	0.66	0.704	1.363			
0.068	2.809	3.006	0.68	0.682	1.346			
0.070	2.78	2.981	0.70	0.661	1.330			
0.072	2.752	2.957	0.72	0.640	1.315			
0.074	2.725	2.934	0.74	0.620	1.300			
0.076	2.698	2.911	0.76	0.601	1.286			
0.078	2.673	2.889	0.78	0.583	1.272			
0.080	2.648	2.868	0.80	0.565	1.258			
0.082	2.623	2.847	0.82	0.548	1.245			
0.084	2.599	2.827	0.84	0.532	1.233			
0.086	2.576	2.807	0.86	0.517	1.221			
0.088	2.553	2.788	0.88	0.501	1.209			
0.090	2.531	2.769	0.90	0.487	1.197			
0.092	2.509	2.751	0.92	0.473	1.186			
0.094	2.488	2.733	0.94	0.459	1.175			
0.096	2.467	2.716	0.96	0.446	1.165			
0.098	2.447	2.699	0.98	0.433	1.154			
0.100	2.427	2.682	1.00	0.421	1.145			

Drawdown s dihitung dengan persamaan: $s = \frac{Q}{2\pi T} K_o \left(r/B \right)$

Nilai α untuk berbagai nilai p dan e menurut Huisman

p \ e	0	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45
0.1	0.54	0.54	0.55	0.55	0.56	0.57	0.59	0.61	0.67	1.09
0.2	0.44	0.44	0.45	0.46	0.47	0.49	0.52	0.59	0.89	
0.3	0.37	0.37	0.38	0.39	0.41	0.43	0.5	0.74		
0.4	0.31	0.31	0.32	0.34	0.36	0.42	0.62			
0.5	0.25	0.26	0.27	0.29	0.34	0.51				
0.6	0.21	0.21	0.23	0.27	0.41					
0.7	0.16	0.17	0.2	0.32						
0.8	0.11	0.13	0.22							
0.9	0.06	0.12								

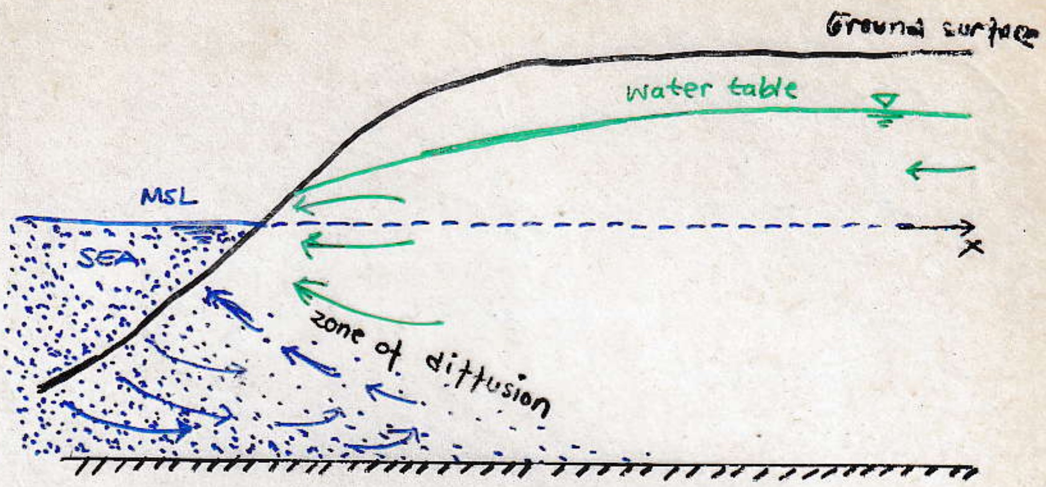
Drawdown di sumur pompa untuk sumur dengan penetrasi parsial dihitung dengan persamaan

$$s_w = s + s_{wp}$$

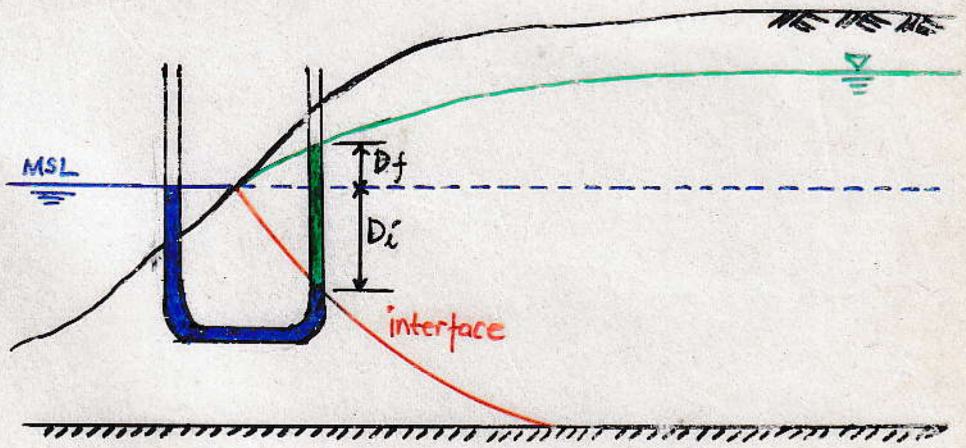
$$s_{wp} = \frac{Q}{2\pi Kb}\frac{1-p}{p}\ln\frac{\alpha l_e}{r_w}$$

Nilai W(u) untuk berbagai nilai u menurut Ferris et al.

N \ U	$N \times 10^{-15}$	$N \times 10^{-14}$	$N \times 10^{-13}$	$N \times 10^{-12}$	$N \times 10^{-11}$	$N \times 10^{-10}$	$N \times 10^{-9}$	$N \times 10^{-8}$	$N \times 10^{-7}$	$N \times 10^{-6}$	$N \times 10^{-5}$	$N \times 10^{-4}$	$N \times 10^{-3}$	$N \times 10^{-2}$	$N \times 10^{-1}$	$N \times 10^{0}$
1.00	33.96	31.66	29.36	27.05	24.75	22.45	20.15	17.84	15.54	13.24	10.94	8.63	6.33	4.04	1.82	0.219
1.20	33.78	31.48	29.17	26.87	24.57	22.27	19.96	17.66	15.36	13.06	10.75	8.45	6.15	3.86	1.66	0.158
1.50	33.56	31.25	28.95	26.65	24.35	22.04	19.74	17.44	15.14	12.83	10.53	8.23	5.93	3.64	1.46	0.100
2.00	33.27	30.97	28.66	26.36	24.06	21.76	19.45	17.15	14.85	12.55	10.24	7.94	5.64	3.35	1.22	0.0489
2.20	33.17	30.87	28.57	26.27	23.96	21.66	19.36	17.06	14.75	12.45	10.15	7.84	5.54	3.26	1.14	0.0372
2.50	33.05	30.74	28.44	26.14	23.89	21.53	19.23	16.93	14.62	12.32	10.02	7.72	5.42	3.14	1.04	0.0249
3.00	32.86	30.56	28.26	25.96	23.65	21.35	19.05	16.74	14.44	12.14	9.84	7.53	5.23	2.96	0.91	0.0131
3.20	32.80	30.50	28.19	25.89	23.59	21.29	18.98	16.68	14.38	12.08	9.77	7.47	0.22	2.90	0.86	0.0101
3.50	32.71	30.41	28.10	25.80	23.50	21.20	18.89	16.59	14.29	11.99	9.68	7.38	5.08	2.81	0.79	0.00697
4.00	32.58	30.27	27.97	25.67	23.36	21.06	18.76	16.46	14.15	11.85	9.55	7.25	4.95	2.68	0.70	0.00378
4.20	32.53	30.22	27.97	25.62	23.32	21.01	18.71	16.41	14.11	11.80	9.50	7.20	4.90	2.63	0.67	0.00297
4.50	32.46	30.15	27.85	25.55	23.25	20.94	18.64	16.34	14.04	11.73	9.43	7.13	4.83	2.57	0.63	0.00287
5.00	32.35	30.05	27.75	25.44	23.14	20.84	18.54	16.23	13.93	11.63	9.33	7.02	4.73	2.47	0.56	0.00115
5.20	32.31	30.01	27.71	25.41	23.10	20.80	18.50	16.19	13.89	11.59	9.29	6.99	4.69	2.43	0.54	0.000909
5.50	32.26	29.95	27.65	25.35	23.05	20.74	18.44	16.14	13.84	11.53	9.23	6.93	4.63	2.38	0.50	0.000641
6.00	32.17	29.87	27.56	25.26	22.96	20.66	18.35	16.05	13.75	11.45	9.14	6.84	4.54	2.30	0.45	0.00036
6.20	32.14	29.83	27.53	25.23	22.93	20.62	18.32	16.02	13.72	11.41	9.11	6.81	4.51	2.26	0.44	0.000286
6.50	32.09	29.79	27.48	25.18	22.88	20.58	18.27	15.97	13.67	11.37	9.06	6.76	4.47	2.22	0.41	0.000203
7.00	32.02	29.71	27.41	25.11	22.81	20.50	18.20	15.90	13.60	11.29	8.99	6.69	4.39	2.15	0.37	0.000116
7.20	31.99	29.68	27.38	25.08	22.78	20.47	18.17	15.87	13.57	11.26	8.96	6.66	4.36	2.12	0.36	0.0000922
7.50	31.95	29.64	27.34	25.04	22.74	20.43	18.13	15.83	13.53	11.22	8.92	6.62	4.32	2.09	0.34	0.0000658
8.00	31.88	29.58	27.28	24.97	22.67	20.37	18.07	15.76	13.46	11.16	8.86	6.55	4.26	2.03	0.31	0.0000377
8.20	31.86	29.55	27.25	24.95	22.65	20.34	18.04	15.74	13.44	11.13	8.83	6.53	4.23	2.00	0.30	0.0000302
8.50	31.82	29.52	27.22	24.91	22.61	20.31	18.01	15.70	13.40	11.10	8.80	6.49	4.20	1.97	0.28	0.0000216
9.00	31.76	29.46	27.16	24.86	22.55	20.25	17.95	15.65	13.34	11.04	8.74	6.44	4.14	1.92	0.26	0.0000125
9.20	31.74	29.44	27.14	24.83	22.53	20.23	17.93	15.62	13.32	11.02	8.72	6.41	4.12	1.90	0.25	0.00000999
9.50	31.71	29.41	27.11	24.80	22.50	20.20	17.89	15.59	13.29	10.99	8.68	6.38	4.09	1.87	0.24	0.00000719



GHYBEN-HERZBERG APPROXIMATION



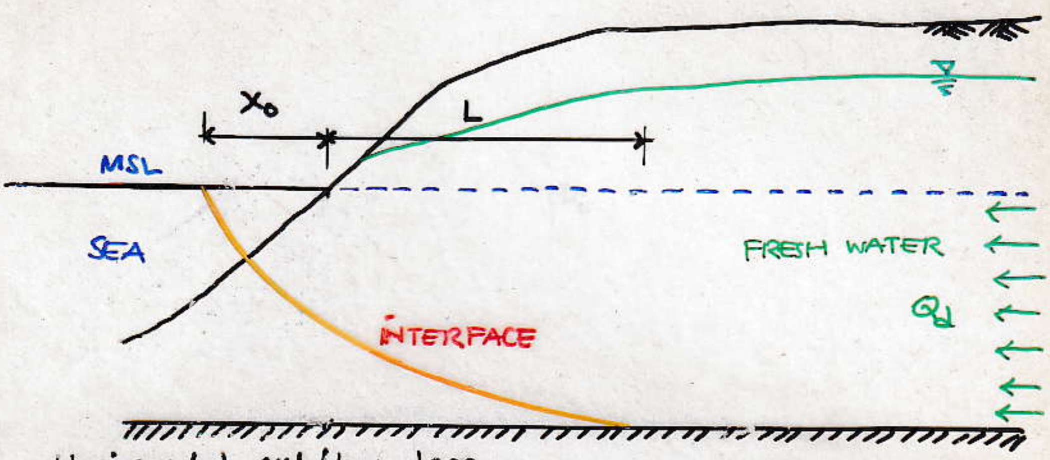
$$D_i \cdot \rho_s = (D_f + D_i)\,\rho_f$$

$$(\rho_s - \rho_f)\,D_i = \rho_f \cdot D_f$$

$$D_i = \frac{\rho_f}{\rho_s - \rho_f}\,D_f$$

$\rho_s = 1{,}025$, $\rho_f = 1$ ⟩ $\boxed{D_i = 40\ D_f}$: keadaan keseimbangan statik

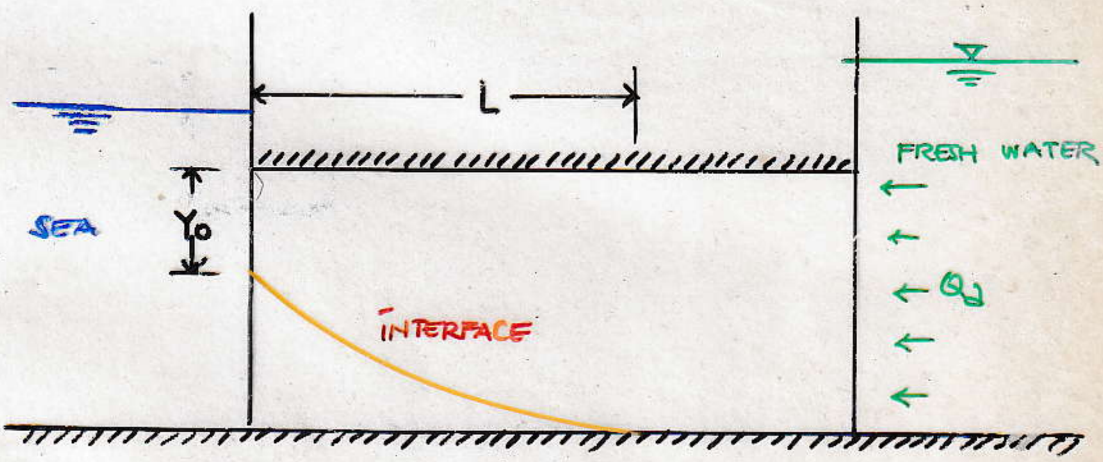
GLOVER'S SOLUTION



Horizontal outflow face :

$$X_0 = -\frac{Q_d}{2\alpha K}$$

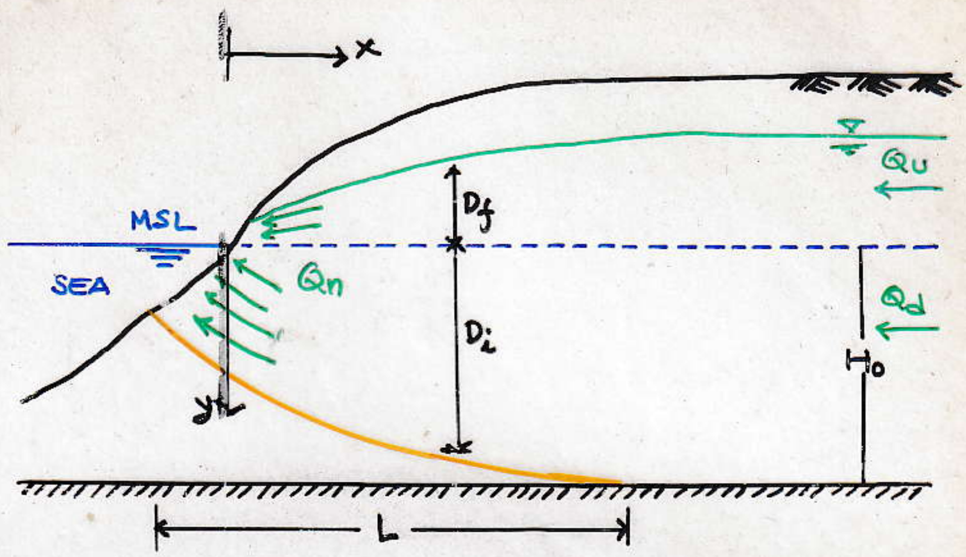
HENRY'S SOLUTION



Vertical outflow face :

$$Y_0 = 0,741\ \frac{Q_d}{\alpha K}$$

ALIRAN ALAM



Dupuit's assumption : $q_n = K \left(\frac{dD_f}{dx}\right)$ slope of the water table

$$Q_n = K\,(D_f + D_i)\left(\frac{dD_f}{dx}\right) \longrightarrow \text{DUPUIT}$$

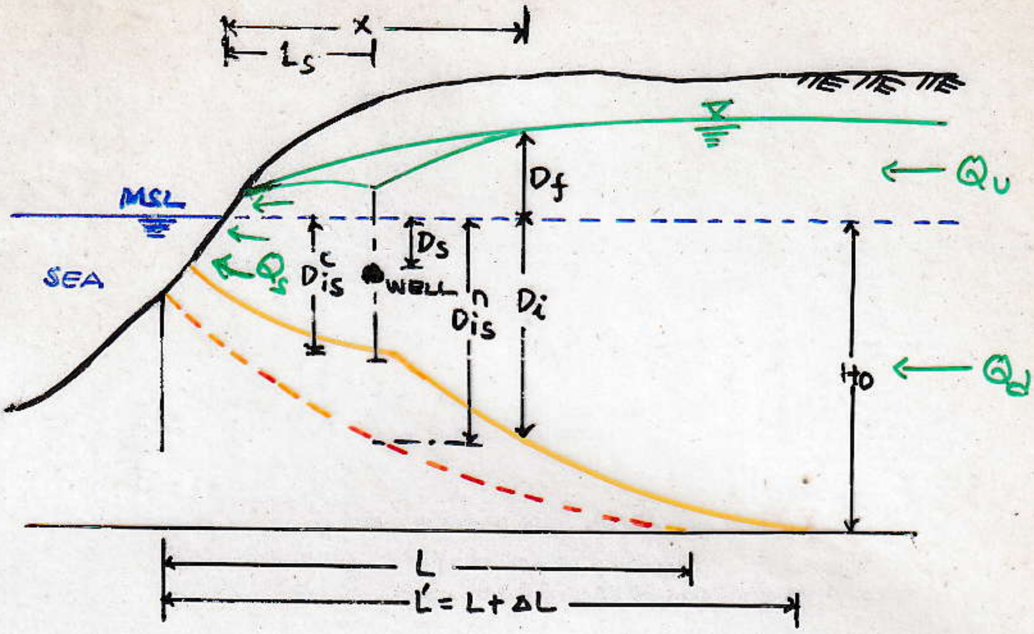
$$= K\alpha(1+\alpha)\,D_i\,\frac{dD_i}{dx} \longrightarrow \text{Ghyben-Herzberg} \qquad (6)$$

+ GLOVER / HENRY B.C

$$\frac{Q_n}{\alpha K H_o} = \frac{1+\alpha}{\beta}\, m \left[\left(1 + \frac{\beta}{m^2}\right)^{\frac{1}{2}} - 1\right] \qquad (11)$$

$$\frac{D_i}{H_o} = \left\{1 - \frac{2m^2}{\beta}\left[\left(1+\frac{\beta}{m^2}\right)^{\frac{1}{2}} - 1\right](1-\bar{x})\right\}^{\frac{1}{2}} \qquad (14)$$

PENGARUH SUMUR PENGAMBILAN



- Debit air tawar ke laut : Q_s (17)
- Pertambahan intrusi : ΔL (22)
- Profil intrusi : a) hilir sumur (23)
  b) hulu sumur (24)

- PERLU DIKETAHUI :

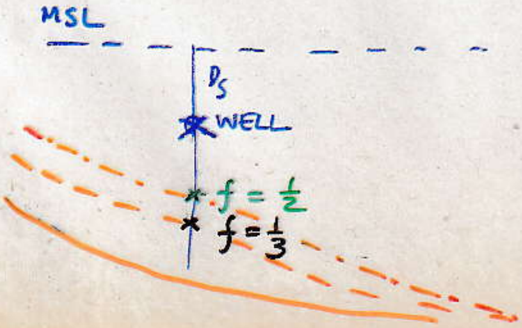
(1) Ho : Kedalaman (tebal) akuifer di bawah MSL

(2) $D_{i(1)}$, $D_{i(2)}$: Lokasi interface di 2 titik x_1 dan x_2

(3) Upconing yg. diijinkan, f.

$$D^c_{is} = D_s + f\,(D^n_{is} - D_s)$$

$$(f \simeq \tfrac{1}{3} - \tfrac{1}{2})$$



LANGKAH HITUNGAN

(1) Hitung Q_n → integrasi Pers (6) dg. batas integrasi data lokasi interface di 2 titik

$$Q_n = K(1+\alpha) \frac{\int_{D_{i_1}}^{D_{i_2}} D_i \, dD_i}{\int_{x_1}^{x_2} dx} = \frac{K(1+\alpha)}{2(x_2 - x_1)} \left(D_{i_2}^2 - D_{i_1}^2 \right)$$

(2) (a) Hitung panjang intrusi L → Pers. (11)
(b) Hitung profil intrusi $D_i(x)$ → Pers. (14)

(3) Lokasi pengambilan (L_s, D_s) } Hitung kedalaman kritik intrusi D_{is}^c
Upconing ijin f } → Pers. (16) s (19)

(4) Hitung debit air tawar yg menuju ke laut, Q_s — Pers. (9)
Debit pengambilan, Q_p — $Q_p = Q_n - Q_s$.

(5) Hitung pertambahan intrusi ΔL → Pers. (22)

(6) Hitung profil intrusi [illegible] → Pers. (23)
Pers. (24)