

NUMERICAL ASSESSMENT OF THE PERFORMANCE OF SKIMMING WELLS UNDER VARIABLE DESIGN AND OPERATIONAL PARAMETERS IN THE LOWER INDUS BASIN, PAKISTAN

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ABSTRACT

Aim of the study

This study aimed to evaluate skimming well technology for sustainable abstraction of groundwater in the Lower Indus Basin, Pakistan. It focused on how well design and operating conditions affect saltwater upconing and pumped water salinity to identify optimal configurations for the sustainable extraction of freshwater.

Materials and methods

Using the MODFLOW-MT3D model, simulations tested single- and multi-strainer wells under varying discharge rates (5.7–8.5 l/s), penetration depths (30–60%), and pumping durations (up to 6 hours/day). The model assessed freshwater–saltwater interface movement and resulting groundwater salinity over a four-year period.

Results

Higher discharge rate (8.5 l/s) caused greater saltwater upconing (~19 m). Multi-strainer wells reduced upconing and produced lower salinity (<950 mg/l) compared to single-strainer wells. The study recommends 4-strainer wells, with a 30–40% penetration depth, and up to 6 hours of daily operation for sustainable abstraction of freshwater.

Keywords: Lower Indus Basin, MODFLOW-MT3D, pumped water salinity, skimming wells

INTRODUCTION

Water is one of the most vital resources on Earth, with an estimated total volume of 1.4 billion km³, of which 97% is saline and only 3% is freshwater (Faheem et al., 2023). Groundwater stored in confined and unconfined aquifers constitutes about 12.6 million km³, representing nearly 30% of global freshwater (Faheem et al., 2023). Its availability depends on recharge processes influenced by physiography, lithology, drainage, land use, soil, rainfall, and geology (Apollonio et al., 2018). Aquifers formed by unconsolidated sediments or frac-

tured rocks provide favourable conditions for storage and flow (Murmu, 2023).

Globally, about 12,666 km³ of groundwater is recharged annually, with 986 km³ (7.78%) extracted for agriculture, domestic, and industrial use (Giordano et al., 2010; Villholth, 2016). Groundwater supports 67% of irrigation, 22% of domestic, and 11% of industrial water demand worldwide (van der Gun, 2012), contributing to over 40% of food production (Foster et al., 2015). In South Asia, more than one billion farmers rely on groundwater for irrigation (Villholth et al., 2009; Canbaz et al., 2025), and around 20% of global

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irrigation depends on groundwater extraction (Wada et al., 2012; Eshniyazov et al., 2021). It also supplies potable water to about 2.5 billion people (Xiao et al., 2022). However, rising populations, urbanization, and food demand have intensified groundwater exploitation, raising concerns over depletion and quality deterioration (Villholth, 2016; Asgharina and Petroselli, 2020).

In Pakistan, groundwater sustains agriculture, domestic, and industrial sectors (Lytton et al., 2021). The country is the fourth user of groundwater globally, withdrawing about 62, 000 km³ annually, which supplies roughly one-third of the national water demand (Farid et al., 2022). Groundwater provides nearly 70% of the required water for domestic and industrial use, and meets half of agricultural needs in the Indus Basin (Bhatti et al., 2015). However, excessive abstraction has led to aquifer depletion and declining water quality (Bhatti et al., 2017).

Fresh-saline aquifers with freshwater lenses overlying saline water are widespread (Kashyap et al., 2020). Deep, high-capacity wells can trigger saltwater upconing, whereby saline water rises into freshwater zones (Saravanan et al., 2014; Aslam et al., 2014). The extent of this depends on pumping rate, penetration, aquifer properties, and recharge (Dahri et al., 2011). Skimming wells—partially penetrating single- or multi-strainer wells—can extract freshwater, while limiting saline intrusions (Lytton et al., 2021; Zardari et al., 2015). Proper design and operation that takes into account discharge, well depth, strainers, and pumping duration, are essential (Aslam et al., 2014; Saeed and Ashraf, 2005; Asghar et al., 2002, 2004).

Numerical groundwater models such as MODFLOW and MT3D simulate the flow of groundwater and the transport of solutes (Harbaugh, 2005; Bedekar et al., 2016). Studies using MODFLOW-MT3D show that higher discharge rates, greater penetration depths, and longer operation periods increase salinity, while multi-strainer wells yield higher-quality water (Akhtar et al., 2022; Alam and Olsthoorn, 2013; Aslam, 2015). Wells with 30–60% penetration, 4–28 l/s discharge, and 4–8 h/day operation time can sustainably skim groundwater with salinity below 1,000 mg/l (Dahri et al., 2011; Kashyap et al., 2020).

In the Lower Indus Basin (LIB), thin freshwater lenses overlying saline aquifers increases the region's vulnerability to upconing. While past studies (Ullah,

1999; Aslam 2015) highlighted the potential of skimming wells, evaluation under varied design and operational parameters remains limited. This study uses MODFLOW-MT3D to assess the impact of well design, penetration depth, discharge rate, and operational duration on water quality in the LIB. It aims to develop site-specific guidelines for sustainable freshwater abstraction, minimizing saltwater intrusion and ensuring long-term aquifer health.

MATERIALS AND METHODS

Study area description

The LIB in Sindh (Fig. 1) spans a gross command area (GCA) of 6.247 million hectares (Mha), with 5.488 Mha used for cultivation. The region has an arid, hot climate and receives only 100–200 mm of annual rainfall. Major crops include rice, cotton, sorghum, millet, wheat, oilseeds, sugarcane, and fruits.

Irrigation in the LIB is supplied by 15 canals fed by the Guddu, Sukkur, and Kotri Barrages. The Guddu Barrage commands 1.13 Mha through the Pat Feeder, Desert, Begari Feeder, and Ghotki Feeder canals; the Sukkur Barrage supplies 3.03 Mha via the Northwest, Rice, Dadu, Khairpur West, Khairpur East, Rohri and Nara canals; and the Kotri Barrage serves 1.18 Mha through the Kalri, Pinyari, Fuleli, and Lined canals.

Groundwater is essential for irrigation in the LIB. As shown in Table 1, only 10% (0.612 Mha) of the area contains fresh groundwater (total dissolved solids, TDS, $\leq 1,000$ mg/l), while 76% (4.751 Mha) has saline water (TDS $> 3,000$ mg/l), and 14% (0.884 Mha) is marginal (Dahri et al., 2011). Groundwater meets about 20% of Sindh's irrigation demand (Lytton et al., 2021; Young et al., 2019). Freshwater can be found mainly along the Indus River's left bank in Ghotki, Khairpur, and Rohri. Canal shortages and unregulated pumping have worsened secondary salinization (Lytton et al., 2021).

The unconfined alluvial aquifer of the LIB comprises deep saline groundwater of marine origin, overlain by a variable freshwater layer recharged from the Indus River, canals, irrigation return flow, and rainfall (Table 2). Freshwater thickness decreases with distance from the recharge zones, typically occurring at depths of 30–60 m.

The Lower Indus alluvium forms a highly transmissive, unconfined aquifer that exceeds 180 m in

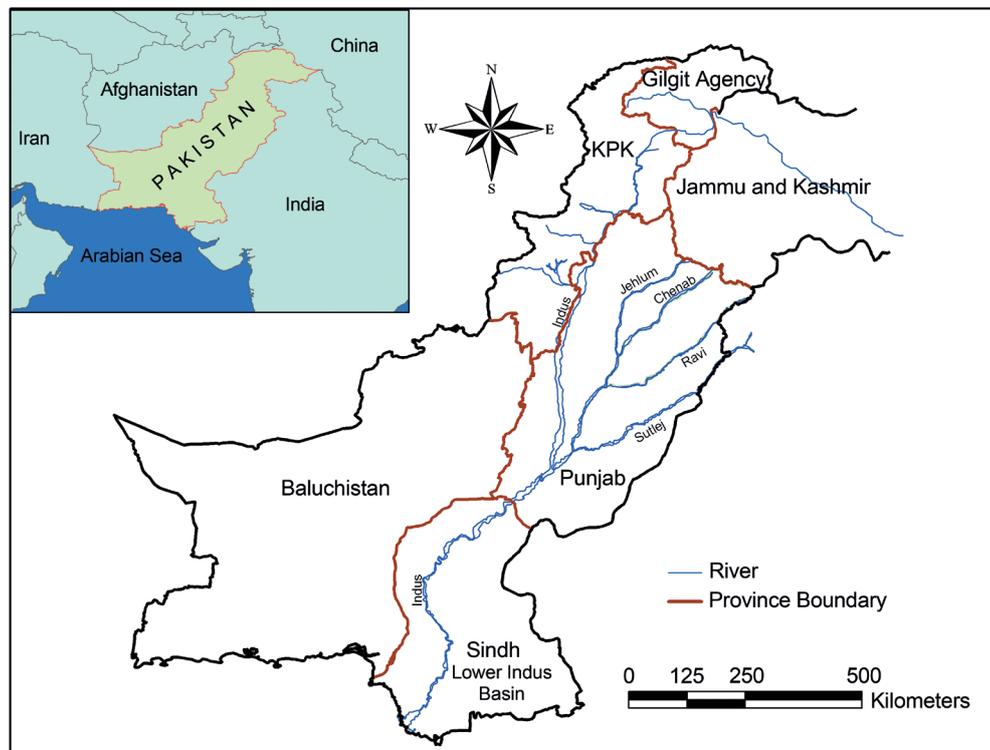


Fig. 1. Location map of the LIB (Sindh) (Source: own elaboration)

Table 1. Areas with different groundwater salinities (total dissolved solids, TDS, in mg/l) up to 105 m depth (Source: Ahmad, 1995)

Canal command	Area with TDS range of 0–1,000 mg/l (Mha)	Area with TDS range of 1,000–1,500 mg/l (Mha)	Area with TDS range of 1,500–3,000 mg/l (Mha)	Area with TDS >3,000 mg/l (Mha)	Total gross command area; GCA (Mha)
Pat		0.013	0.015	0.299	0.327
Desert		0.018	0.013	0.116	0.147
Begari	0.06	0.087	0.081	0.211	0.439
Ghotki	0.087	0.026	0.076	0.2	0.389
North West	0.044	0.016	0.054	0.398	0.512
Rice	0.005	0.003	0.036	0.175	0.219
Dadu	0.013	0.026	0.059	0.157	0.255
Khairpur West	0.078	0.022	0.05	0.021	0.171
Khairpur East	0.011	0.01	0.029	0.182	0.232
Rohri	0.314	0.11	0.14	0.631	1.195
Nara				1.018	1.018
Kalri				0.313	0.313
Lined Canal				0.236	0.236
Fuleli				0.409	0.409
Pinyari				0.385	0.385
LIB Total	0.612 (10%)	0.331 (5%)	0.553 (9%)	4.751 (76%)	6.247 (100%)

depth. The values of the key hydraulic parameters including horizontal hydraulic conductivity (Kh), vertical hydraulic conductivity (Kv) and specific yield (Sy) are summarized in Table 3.

Table 2. Shallow groundwater salinity in the LIB (Source: Ahmad, 1995)

Site	Depth (m)	Salinity (mg/l)
Kotri command		
Mohd Soth	16	430
Fuleli	16	1160
Mulla Kathar Road	19	1040
Guni Canal	22	474
Fauji Sugar Farm	22	723
Pinyari Feeder	22	1000
Jalalani	23	910
Balri	25	986
Tando Mohd Khan	29	978
Tando Mohd Khan	29	470
Gaja	29	346
Central Rohri command		
Kazi Ahmed	19	1030
Nawabshah	19	1300
Amerabad	27	352
Southern Rohri command		
Jamrao Canal	23	550
Khalan	23	670
Tando Jam	23	640
Naltari	23	480
Khesano Minor	23	1300
Ghulal Leghan	23	1290
Tando Allahyar	23	820
Fatehpur	29	590
Tando Ghulam Ali	29	820
Tando Allahyar	29	1250
Sakrand	30	1300

Table 3. Average Kh, Kv and Sy values of the LIB Aquifer (Source: Ahmad, 1995)

Canal command	Kh (m/day)	Kv (m/day)	Sy (-)
Gudu Left Bank	54.4	0.402	0.185
Khairpur	41.5	0.156	0.211
North Rohri	26.7	0.012	0.220
Central Rohri	39.7	0.441	0.002
South Rohri	22.0	0.052	–
Gudu Right Bank	50.3	–	0.132

Skimming well technology (SWT) and numerical simulations

In the LIB fresh-saline aquifers, freshwater lenses overlie saline groundwater. High-capacity (> 28 l/s) and deep tubewells can cause saltwater upconing, producing water with salinity above 1,000 mg/l (Rao et al., 2007; Saravanan et al., 2014). Properly designed skimming wells – wells that carry out partial penetration with a discharge below 28 l/s – can abstract high-quality water without triggering upconing (Saeed and Ashraf, 2005; Ashraf et al., 2012; Kori et al., 2013; Lytton et al., 2021).

Skimming wells include single-bore, multi-bore, scavenger, radial collector, and dug wells. The single- and multi-bore wells are preferred for lower cost and technical simplicity (Saeed and Ashraf, 2005). The LIB has significant potential for skimming well installation, and numerical models are essential to evaluate performance under different design and operational conditions. This study uses modelling to recommend optimal skimming well parameters for sustainable freshwater abstraction in the LIB.

Evaluation of skimming wells performance with computational models

In this study, the performance of the MODFLOW-MT3D model was validated by SWT and the results were compared with field data on aquifer properties, well characteristics, as well as the salinity of groundwater and water pumped in the Mona Reclamation Experimental Project area in the Indus Basin, Pakistan (Hafeez et al., 1986).

After validation, the model evaluated various skimming well designs and operational scenarios to ensure sustainable long-term abstraction of high-quality groundwater. Simulations used representative hydrogeological conditions and salinity patterns of the LIB. The outcomes provide data-driven recommendations for optimal skimming well design and operation, supporting sustainable freshwater extraction in the region.

Model validation

To validate the MODFLOW–MT3D model for simulating skimming wells, the salinity of the drawdown and the water pumped from a 2-strainer well were reproduced and compared with field observations from the same well in the Mona Reclamation Experimental

Project area of the Indus Basin. Table 4 reveals model input data which were mainly obtained from secondary sources (Aslam, 2015). The model development and validation procedure is outlined below.

Model domain and grid layout

The study focuses on a local domain of $300 \times 300 \times 36$ m, divided into 729 block-centred finite difference cells in order to capture aquifer heterogeneity. The 36-metre-thick aquifer was split into 10 layers of varying thicknesses. The cells are defined by column (j), row (i), and layer (k), with 625 active cells and no-flow boundaries applied around the domain.

Aquifer hydraulic, solute transport, boundary conditions and well parameters

Aquifer hydraulic and solute transport parameters – including horizontal and vertical hydraulic conductivity, specific storage, effective porosity, and specific yield – were assigned to all 10 layers (Table 4), as well as longitudinal and transverse dispersivity and molecular diffusion coefficients. The initial conditions included a water table depth of 2 m, an initial head of 34 m, and boundary cells set as constant head. Groundwater salinity profiles in Table 4 defined the initial solute concentrations. A 2-strainer well, which was 9 m deep with 30 m strainer spacing, pumped continuously for 32 days at a rate of $1,223 \text{ m}^3/\text{day}$. On the model grid, the pumping cell was assigned to the second layer, reflecting the well’s depth, strainer spacing, and discharge.

Table 4. Model input data used for model validation

Aquifer physical, hydraulic and solute transport properties	
Aquifer thickness	36 m
Depth to water table	2 m
Hydraulic conductivity (Kh)	45 m/day
Hydraulic conductivity (Kv)	30 m/day
Specific storage (Ss)	0.0000033 m^{-1}
Specific yield (Sy)	0.3
Effective porosity (Ep)	0.3
Longitudinal dispersivity (α_L)	1.5 m
Transverse dispersivity (α_T)	0.15 m

Molecular diffusion coefficient (Dm)	$1.5 \text{ E-}11 \text{ m}^2/\text{day}$
Groundwater salinity at depths (m): 9, 12, 15, 18, 21, 24, 27, 30, 33 and 36	TDS (mg/l): 750, 976, 1014, 1182, 1386, 1800, 3240, 4940, 5260 and 5270
Well information	
2-strainer well depth	9 m
Strainers spacing	30 m
Well discharge	$1223 \text{ m}^3/\text{day}$ (14 l/s)
Pumping period (continuously)	32 days

Model validation simulations

A validated groundwater model reproduces natural hydrologic conditions by matching heads, drawdowns, and groundwater salinity measured in the field. In this study, the 2-strainer well used for validation operated continuously for 32 days, producing a 1.1 m drawdown. Pumped water salinity at different intervals is provided in Table 5 (Aslam, 2015).

Table 5. Observed salinity of the pumped groundwater

Time (days)	Salinity (mg/l)
1	750
5	760
10	780
15	832
20	900
32	1200

The salinity of the simulated drawdown after 32 days and the pumped water at different times were compared with the field data. The observed and simulated groundwater table drawdowns (Table 6) and salinities (Table 7) closely matched, showing similar flow and solute transport patterns. The absolute differences were minimal, ranging from 1 to 6%, which is considered acceptable. These results demonstrate that the model accurately reproduces groundwater flow (heads and drawdowns) and solute transport (salinity), thus confirming its validity for simulating skimming wells and saltwater upconing.

Table 6. Measured and simulated drawdown after 32 days of pumping

Category	Value
Measured drawdown	1.1 m
Simulated drawdown	1.0 m

Table 7. Measured and simulated salinity of pumped water

Time (days)	Measured salinity (mg/l)	Simulated salinity (mg/l)	Difference (% of measured salinity)
1	750	735	-2
5	760	772	2
10	780	830	6
15	832	867	4
20	900	906	1
32	1200	1160	-3

Model application to the LIB

This study adopted hydrogeological and groundwater salinity conditions representative for the LIB. The hydrogeological and solute transport parameters applied in the simulations are listed in Table 8, while the initial groundwater salinity profile applied in the model is presented in Table 9.

Table 8. Model input parameters for the LIB

Model domain	300 m × 300 m
# rows	27
# columns	27
# layers	10
Aquifer thickness	60 m
Horizontal hydraulic conductivity	22 m/day
Vertical hydraulic conductivity	0.9 m/day
Specific yield	0.13
Effective porosity	0.13
Specific storage	0.000003 m ⁻¹
Hydraulic head	58.5 m
Longitudinal dispersivity	1.8 m
Transverse dispersivity	0.36 m
Simulation period	4 years

Table 9. Groundwater salinity profile used in groundwater model of the LIB

Layer number	Layer thickness (m)	Salinity (mg/l)
1	2.5	500
2	4	500
3	4	500
4	3	500
5	3	700
6	3	700
7	4.5	850
8	6	1000
9	15	2000
10	15	3500

For single – and four-strainer wells with 4.5 m horizontal spacing, twelve scenarios (Table 10) were evaluated for each well type. These scenarios examined the effects of well penetration depth (Pw), defined as a percentage of fresh groundwater layer thickness [$Pw = (\text{well depth}/\text{fresh groundwater layer thickness})100$], well discharge (Qw), and operational time (Ot) on pumped water salinity, assessing skimming well performance under different depth, discharge, and operational conditions in the LIB.

Table 10. Different evaluation scenarios on SWT for the LIB

Scenario no.	Well penetration depth (Pw) (%)	Well discharge, Qw (l/s)	Operation time (Ot) (h/day)
1-strainer well			
1	30	8.5	6
2	40	8.5	6
3	60	8.5	6
4	30	5.7	6
5	40	5.7	6
6	60	5.7	6
4-strainer well			
7	30	8.5	6
8	40	8.5	6
9	60	8.5	6
10	30	5.7	6
11	40	5.7	6
12	60	5.7	6

RESULTS

Saltwater upconing analysis

The rise of the freshwater–saltwater interface caused by a single-strainer well was analysed with regard to discharges of 8.5 and 5.7 l/s. Each discharge operated for 6 h/day, with well penetration depths (P_w , expressed as a percentage of the aquifer thickness) of 30%, 40%, and 60% (Fig. 2a and 2b). As shown in Figures 2a and 2b, increasing P_w led to an upward movement of the interface. At $P_w = 30\%$ and 40%, pumping at 8.5 l/s resulted in an interface rise of approximately 19 m, whereas pumping at 5.7 l/s caused a slightly lower rise of about 18.5 m. When $P_w = 60\%$,

the interface rose to approx. 19.5 m and 19 m, respectively. These results confirm that higher well penetration depths, and higher pumping rates accelerate saltwater upconing, heightening the risk of elevated salinity in the pumped water.

Figure 2c compares the interface response between single- and four-strainer wells at 8.5 l/s, 6 h/day, and $P_w = 30\%$. The single-strainer well led to an interface rise of about 19 m, while the four-strainer configuration limited the rise to approximately 18.5 m. The distribution of extraction across multiple strainers reduces localized upconing, thereby maintaining lower salinity levels and supporting more sustainable groundwater abstraction.

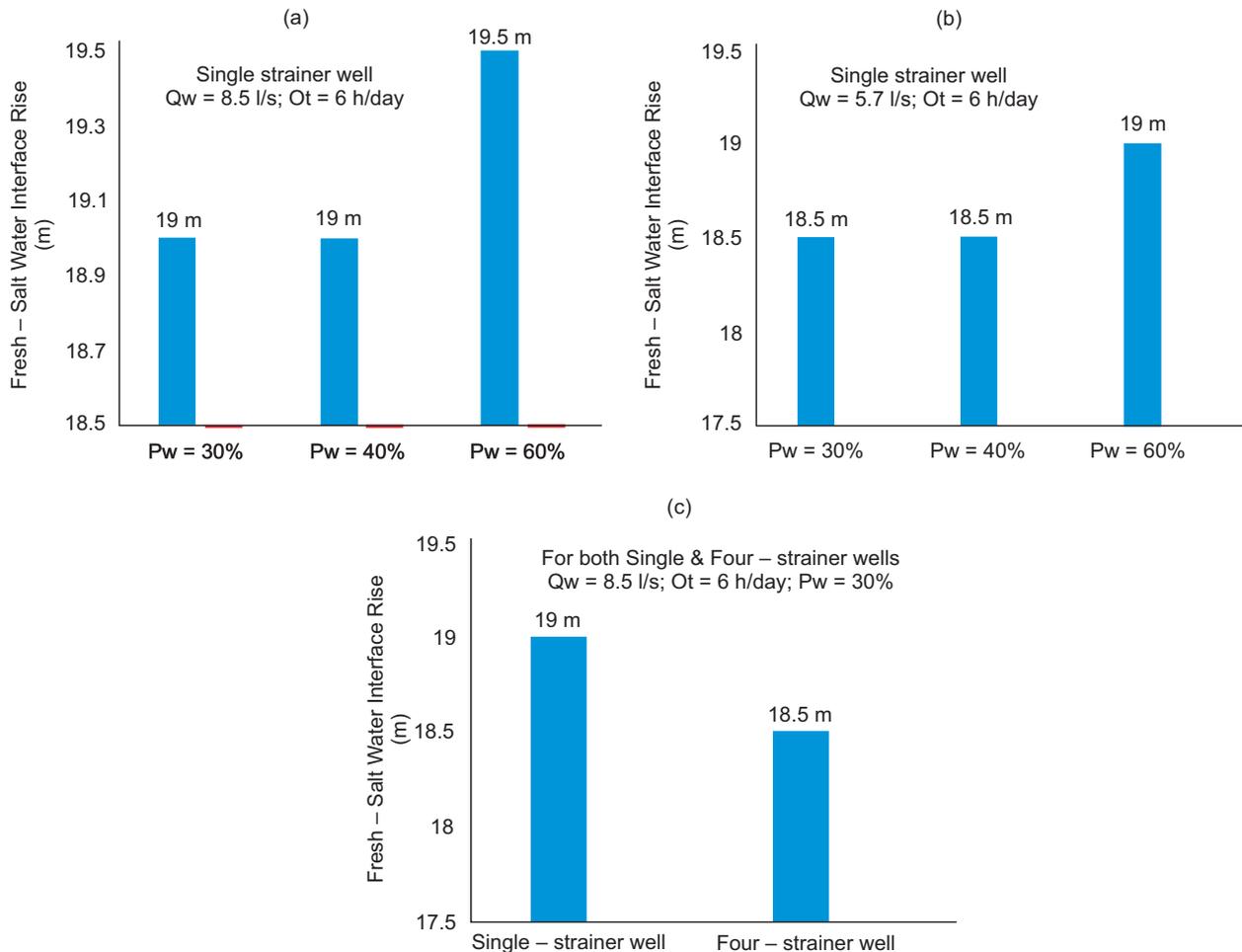


Fig. 2. Interface rise at the end of the fourth year for: (a) single strainer well, $Q_w = 8.5$, $O_t = 6$ h/day, $P_w = 30\%$, 40% and 60%; (b) Single strainer well, $Q_w = 5.7$ l/s, $O_t = 6$ h/day, $P_w = 30\%$, 40% and 60%; (c) single and 4-strainer wells, $Q_w = 8.5$ l/s, $O_t = 6$ h/day, $P_w = 30\%$ (Source: own elaboration)

Assessment of salinity of the pumped water

Figure 3 (a–d) illustrates the four-year evaluation of salinity of the pumped water for single- and four-strainer wells operated at discharge rates of 8.5 l/s and 5.7 l/s for 6 hours per day, under well penetration depths (Pw) of 30%, 40%, and 60%.

For single-strainer wells (Fig. 3a–b), salinity increased progressively over time, with higher Pw producing steeper growth. At 8.5 l/s, final salinity values after four years have reached approximately 575, 625, and 978 mg/l for Pw = 30%, 40%, and 60%, respectively. Similarly, at 5.7 l/s, the salinity rose to around 571, 626, and 954 mg/l. Despite these increases, salinity remained below the 1,000 mg/l threshold, suggesting that long-term pumping under these conditions remains viable, particularly when $Pw \leq 40\%$.

For four-strainer wells (Fig. 3c–d), salinity levels were consistently lower due to reduced localized upconing and improved vertical distribution of extraction. At 8.5 l/s, the salinity reached about 555, 624, and 946 mg/l for Pw = 30%, 40%, and 60%, respectively, while at 5.7 l/s, the corresponding values were approximately 540, 608, and 932 mg/l. In all cases, the rate of salinity increase over the four-year period was notably smaller than in single-strainer configurations.

Overall, the results confirm that multiple strainers, moderate pumping rates, and lower Pw values are effective in mitigating saltwater upconing, ensuring that salinity remains below critical limits and supporting sustainable long-term well operation.

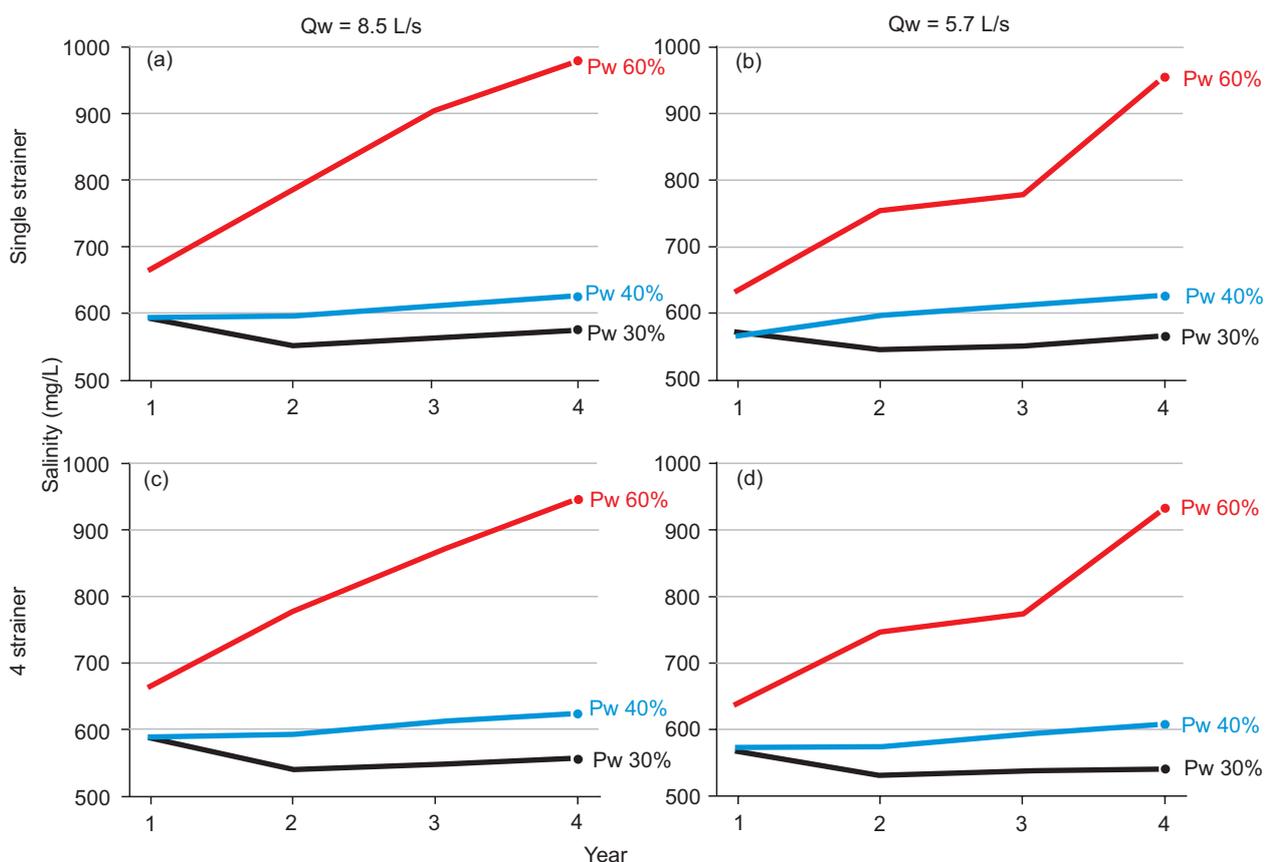


Fig. 3. Simulated salinity of pumped water over a four-year period for: (a) single-strainer well, $Q_w = 8.5$ l/s, $O_t = 6$ h/day, $P_w = 30$ –60%; (b) single-strainer well, $Q_w = 5.7$ l/s, $O_t = 6$ h/day, $P_w = 30$ –60%; (c) four-strainer well, $Q_w = 8.5$ l/s, $O_t = 6$ h/day, $P_w = 30$ –60%; (d) four-strainer well, $Q_w = 5.7$ l/s, $O_t = 6$ h/day, $P_w = 30$ –60% (Source: own elaboration)

DISCUSSION

This study highlights key findings on the performance of skimming well in the LIB. Higher discharges of 8.5 l/s cause greater saltwater upconing than discharges of 5.7 l/s, leading to an interface rise of ~19 m after four years. Multi-strainer wells consistently reduce upconing, and both types of wells (single-strainer and multi-strainer wells) with 30–60% penetration depths operating at 5.7–8.5 l/s for ≤ 6 h/day produce groundwater with acceptable quality (salinity of TDS $< 1,000$ mg/l). Multi-strainer wells at 5.7 l/s achieve the lowest salinity (< 950 mg/l), showing superior long-term performance.

These results align with prior studies in the Upper Indus Basin (UIB), particularly Central Punjab (Aslam et al., 2014; Aslam, 2015; Dahri et al., 2011; Saeed and Ashraf, 2005; Saeed et al., 2003; Asghar et al., 2002). In Chaj Doab, Aslam (2015) reported that single-strainer wells at 14 l/s with 30% penetration and 8 h/day showed more upconing than with 4 h/day operation, while 4-strainer wells (30% penetration, 9–14 l/s, 4–8 h/day) maintained salinity $< 1,000$ mg/l.

Similarly, Aslam et al. (2014) found that 4-strainer wells (5.7–14 l/s, 30–40% penetration depth, 4–8 h/day) in Rechna Doab consistently produced water of $< 1,000$ mg/l salinity. Dahri et al. (2011) observed linear increases in pumped water salinity as a function of discharge and operation time. Saeed and Ashraf (2005) noted that multi-strainer wells provide more sustainable, higher-quality water than single-strainer wells. Saeed et al. (2003) showed that extending pumping beyond 6 h/day increases salinity to above 1,000 mg/l, while 4–6 h/day maintains acceptable quality. Asghar et al. (2002) concluded that skimming wells with penetration depths of 60–70% and discharge rate of 10–18 l/s can operate for 8–24 h/day in unconfined aquifers with freshwater lenses 15–18 m thick.

It is important to note that this study has several limitations. Most of the hydrogeological, groundwater quality, and well data were obtained from secondary sources, which may contain inaccuracies. Primary data collection is needed for more reliable and up-to-date characterization of the aquifer. Data for validating the model were taken from another part of the Indus Basin, rather than the Lower Indus Basin, which is less

ideal. The aquifer was assumed to be homogeneous, with uniform hydraulic parameters across all layers, because detailed layer-specific data were unavailable. Saltwater upconing was analyzed using the sharp-interface approach, which is suitable for the study area but less realistic than density-dependent solute-transport modelling, which however could not be applied due to data limitations. Finally, only 1-strainer and 4-strainer wells were assessed, Future studies should evaluate additional well configurations for a more comprehensive analysis.

CONCLUSIONS

This study demonstrates that carefully designed skimming wells – particularly those with four-strainer configurations and controlled discharge rates of 5.7–8.5 l/s, moderate penetration of 30–40% of the freshwater layer, and an operation time of up to 6 hours per day – can effectively limit saltwater upconing and sustain high-quality groundwater in the LIB. Multi-strainer wells outperform single-strainer wells by reducing localized interface rise and maintaining lower salinity, even under long-term pumping conditions.

While this study assumed uniform hydrogeological conditions and fixed operational schedules, future research could consider heterogeneous aquifer properties, seasonal fluctuations, variable pumping regimes, and the impact of multiple chemical constituents in order to better reflect real field conditions.

In summary, optimizing skimming well design and operation is critical for sustainable freshwater abstraction, ensuring reliable water supply while protecting aquifer quality in the long term.

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ANALIZA NUMERYCZNA WYDAJNOŚCI STUDNI SKIMMINGOWYCH PRZY ZMIENNYCH PARAMETRACH TECHNICZNYCH I OPERACYJNYCH W DOLNYM BASENIE INDUSU W PAKISTANIE

ABSTRAKT

Cel badania

Celem niniejszego badania była ewaluacja technologii studni skimmingowych pod kątem zrównoważonego poboru wód gruntowych w dolnym basenie Indusu w Pakistanie. W badaniu położono nacisk na wpływ konstrukcji studni i warunków eksploatacji na wypływanie słonej wody oraz zasolenie pompowanej wody, aby określić najlepsze rozwiązania dla zrównoważonego wydobycia słodkiej wody.

Materiały i metody

Korzystając z modelu MODFLOW-MT3D, przeprowadzono symulacje dla odwiertów z jednym i wieloma sitami przy różnych natężeniach wypływu (5,7–8,5 l/s), głębokościach penetracji (30–60%) i okresach pompowania (do 6 godzin dziennie). Model pozwolił ocenić przemieszczanie się granicy między wodą słodką a słoną oraz wynikające z tego zasolenie wód gruntowych w ciągu czterech lat.

Wyniki

Wyższa przepustowość (8,5 l/s) spowodowała większe wypływanie słonej wody (~19 m). Studnie z wieloma sitami ograniczyły wypływanie słonej wody i zapewniły niższe zasolenie (<950 mg/l) w porównaniu ze studniami z jednym sitem. W badaniu zalecono stosowanie studni z 4 sitami, o głębokości penetracji 30–40% i maksymalnie 6 godzinach pracy dziennie, aby zapewnić zrównoważone pobieranie słodkiej wody.

Słowa kluczowe: Dolina Dolnego Indusu, MODFLOW-MT3D, zasolenie wody pompowanej, studnie skimmingowe