**Department of Electrical Engineering Assignment Date: 13/04/2020 Course Details**

**Course Title: Model Applications in Integrated Water Resource Management**

**Module: 2**

**Instructor: Total Marks: 30**

**Student Details**

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Please select two Research Papers from Impact Factor (IF) journals under the topic of “Artificial Ground Water Recharge” and

a. Discuss the major strategies proposed by researcher in order to mitigate solution b. Write the detailed review of work performed in both the researches c. Discuss how the proposed models can be useful for the implementation at different stakeholder levels in Pakistan

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*1. Abstract:*

*There are two main source of water ie surface water and ground water. The quality of surface water is detoriating day by day due to contamination whereas underground water table is depleting rapidly and if the situation continues then there will be an acute water shortage at Pakistan in the near future both for drinking purpose as well as for agriculture and industrial needs.*

*So If the available water resources of Pakistan are not managed and maintained properly and wisely than our future generation shall face the disastrous consequences. In order to avoid water scarcity in near future we would have to adopt a comprehensive and integrated water resource management strategy.*

*The main focus of this research article is to devise a comprehensive four prons strategy for ground water management. Artificial Recharge Mechanism (ARM) is one of the important element of water resource management which has been discussed in detail in this research article*

*2. Introduction*

*Water is life and life without water is impossible. Water is essential for the*



*existence of life, Agriculture and Industry. The sustainable use and management of groundwater has always remained a critical research and societal challenge, because groundwater resources are often hidden and considered hard to*

*conceptualize. Furthermore, groundwater overexploitation and pollution can remain undetected for decades or even for centuries.*

*In Pakistan, underground water is the second largest source of irrigation, because of the arid climatic conditions [1, 2]. The dependence on groundwater has significantly been increased during the past few decades to meet the food and fiber requirements of increasing population [3]. Furthermore, the surface irrigation system has high degree of conveyance and application water losses. Thus, the system operates at an efficiency of less than 40% that meets only less than 40% of the crop water requirements [4]. The dependence on irrigation water from other sources such as groundwater is indispensable for efficient productivity [5]. The growth rate of private tube wells has increased significantly at the rate of 60% in Punjab province from 1991 to 2012. About 1.20 million tube wells of capacity ranging from 0.015 to 0.056 m3/sec have been installed in Pakistan for irrigation at depth of 30–85 m , out of which 86% tube wells are installed in Punjab [6]. Due to non availability of irrigation water in the tail areas the farmers of tail ends of the distributaries and watercourses are compelled to rely upon on groundwater, particularly where canal water supplies are constrained. Without groundwater availability, not only Punjab but the whole country would face a severe water shortage that leads to food shortages as Punjab produces more than 90% of total grains [7]. However, the unchecked exploitation of groundwater has created serious problems in terms of depletion water table and saltwater intrusion that may lead to the issues of sustainability of usable groundwater resources. As a result of saline groundwater intrusion, about 200 public tube wells initially installed in the fresh groundwater zone of Punjab and Sindh provinces have been abandoned now.[8]. Shah [9] reported similar problems existed in most of the irrigated regions of the world; those were further increasing rapidly and negatively affecting agricultural productivity. Thus, the assessment of groundwater quality and quantity is important to ensure the safe use of these resources and its management on a sustainable basis.*

*The followings were the two main objectives of the current study: to develop a regional groundwater flow model and observe its future trend and to formulate a comprehensive integrated groundwater management strategy for its proficient utilization.*

*3. Literature review*

*According to a study from the U.S. Geological Survey (USGS), about 72% of Earth is covered with water and roughly 326 million cubic miles (1.332 billion cubic kilometers) water is present on our planet Earth. All this water is not useable for human or other consumption as 97% of water is salty ocean water and Only a small fraction of water (2.75%) of the total water on earth is fresh water and suitable for human consumption. As much as 70% of that is locked up as ice in glaciers and polar caps while the rest 30% is surface water, groundwater or water vapor in the air. There is a very small fraction (about 1%) of fresh water which is readily available for use. It shows that fresh water is a finite and vulnerable resource for human life present on the Earth.*

*The Fallen Mark formula suggests that water availability under 1000 cubic meters/capita/ year limits the economic growth and health of the population, where Pakistan already stands at this moment and when it goes under 500 cubic meters threshold, it’s a real constraint to the life calling it an “Absolute Scarcity”. As per report of world bank and Asian development Bank the year 2025 has been marked as the year when Pakistan shall be water stressed country if it doesn’t mend its ways soon. Unfortunately, there is no comprehensive, integrated water resource management due to which the available surface and ground water is being wasted ruthlessly.*

*There are wide spatial and temporal variations in groundwater quality in the Indus basin, which is due to the pattern of groundwater movement in the aquifer [10]. zones of fresh groundwater is generally available near the main rivers , canal and tributaries on account of high recharge of fresh seepage water. But, then, the quality of groundwater changes to unfit as laterally away from the rivers [5, 11]. The continuous and unchecked excessive & intensive use of groundwater for irrigation is adding plenty of salts causing secondary salinization because groundwater generally has more salts than canal water. Bakhsh and Awan [12] reported that application of groundwater having total dissolved solids (TDS) of 1000 mgL−1 up to a soil depth 370 mm changed the top 300 mm depth of non saline into a saline soil that effect negatively the crop productivity. In many agricultural areas of Pakistan, the usage of poor quality tube well water for irrigation is considered as one of the major causes of salinity and, consequently, lower food productivity [13]. According to an estimate in Pakistan, the secondary salinization degraded the crop land which reduced the production potential of major crops by 25%, valued at an estimated loss of US $250 million/year [14]. Low quality water and soil salinity can affect plant growth and soil structure in several ways, directly and indirectly [15].*

*Groundwater in Pakistan, being in Indus Basin aquifer, is running out on fast pace. The World Bank and the Asian Development Bank have already categorized it as a water-stressed country, likely to face an acute water shortage over the next five years due to the lack of surface water availability for irrigation, industry and human consumption. If this trend continues, the ground water table will come under severe pressure. As per report of world bank and Asian development Bank (ADB ) Pakistan shall face extreme water shortage in 2025 when its annual per capita availability of water shall decline to 800 cubic meters/capita/year, which is far below than the threshold figure of 1000 cubic meter/capita/year.( Fallen Mark formula )*

*Hence its need of the days that all the stack holder and the Govt should take this issue seriously and take all those steps to conserve , preserve and manage this God gifted natural resources judiciously to avoid water crisis in future. If we failed to formulate and implement an effective water management policy, it will lead to a disaster.*

*Therefore, there is a need to give attention to the management of this valuable resource base at all levels from policy makers to actual users of water.*

*In 1950, Pakistan was rated by international agencies as a water abundant country. In 1951, annual water availability in Pakistan per capita stood at 5650 m3 which was more than 5 times the threshold value of 1000 m3/capita/annum.*

*In 1992, the UN Fund for Population stated that Pakistan was a water stressed country with only 1700 m3/capita/annum of the commodity available. In 2003, Pakistan’s per capita availability of water declined from threshold value. Currently Pakistan is a water scarce country with alarmingly reduced availability around 940 m3/capita/annum, which is critically less than the threshold value. The country’s per capita annual water availability is poised to drop further if there is no paradigm shift in the prevalent water infrastructure.*

*Owing to lurking water crises, the World Bank and the Asian Development Bank (ADB) has placed Pakistan in red zone categorizing it as water-stressed country which is likely to face an acute water shortage over the next five years due to the lack of water availability for irrigation, industry and human consumption. If the downward trend prevails, it is likely that ground water table will nosedive more and in the result per capita availability will touch 800 cubic meters by 2020.*

*Moreover, the United Nations has lined up Pakistan among the “water hotspots” of Asia-Pacific Region, saying that the country faces major threats of increasing water scarcity, high water utilization, deteriorating water quality and climate change risk.*

*India has 1,600 cubic meters of water per person per year while major European countries have up to twice as much ranging from 2,300 cubic meters in Germany to 3,000 cubic meters in France.145 is the approximate number of million acre feet (MAF) of surface water annually available to Pakistan on average by nature. The Indus river and its tributaries; Jhelum, Chenab, Ravi, Sutlej and Beas collectively known as “Indus water basin” is Pakistan’s pivotal source of fresh surface water that forms the backbone of the Pakistani economy, supplying water to the largest irrigation system of the world, that not only provides 90% of dietary needs and contributes 25% to the GDP also. Out of 145 MAF, on average, 102 MAF is diverted for the irrigation system. System losses (evaporation, seepage, conveyance) equal to 12 MAF annually. Surface water going to the sea is 145-(102+12) = 31MAF annually.*

*An International Panel of Experts (IPOE) conducted a study in 2004-05 and suggested an annual release of 8.86 MAF of water downstream Kotri to stop the sea intrusion as well as protection against environmental hazards. In other words we are losing about (31MAF- 9MAF =22 MAF) of fresh water annually going into the sea and thereby wasting $21 Billion annually.*

*The increasing demand for water in many regions around the world has led to the implementation of more intensive water management measures to achieve more efficient utilization of limited available water supplies. The natural replenishment of groundwater occurs very slowly. If groundwater is exploited at a rate greater than that of its natural replenishment than this will cause declining groundwater levels and, in the long term, destruction of the groundwater resource.*

*As per report of Economic Survey of Pakistan (2012-13) there are more than 1.175 million tube wells in Pakistan and the estimated annual abstraction of water is about 37MAF against the annual recharge of 30MAF and thus creating an annual gap 7MAF casing 1-3ft depletion in water table,*

*The gap between extraction and natural replenishment can be filled through Artificial Recharge Methods (ARM). In the present time groundwater depletion has become a global concern, because groundwater levels on many locations are dropping due to an imbalance between extraction and natural recharge. Before devising a comprehensive ,integrated water resource management plan we should know the reason of water scarcity in Pakistan.*

*4. Challenges of ground water*

*Following are the challenges of ground water management*

 *i .Nonexistence of water resource management.*

*ii.Un checked installation of tube wells and over exploitation of ground water.*

*iii.Nonexistence of legislation for ground water.*

*iv.No aquifer recharge mechanism.*

*v.Over extraction and over pumping.*

*vi.Rapid Urbanization.*

*vii.Increase in Cropping intensity.*

*viii. Decreasing trend in storage capacity.*

*ix. Deforestation.*

*x. High growth rate of population.*

*xi .Detoriations of water quality due to contamination*

*xii. Climate change patterns.*

*xiii. Wastage of fresh water.*

*xiv. Non adoption of new technologies for irrigation.*

*5. Material and methods*

*Groundwater models are most widely used tools for efficient management of precious groundwater resources and to predict different future scenarios [16]. Different groundwater modeling codes are available, each with their own capabilities, operational characteristics, and limitations such as PMWIN, FEFLOW, SVFlux, and GWVistas. But the most extensively used three-dimensional groundwater flow model among the available models is PMWIN (Processing MODFLOW for Window) [17, 18]. Its popularity has continued, in part due to the modularity of the program, resulting ability, and user friendly interface [19]. It uses a block-centered finite-difference scheme for saturated zone. The advantages of PMWIN include numerous facilities for data preparation, easy exchange of data in standard form, extended worldwide experience, continuous development, availability of source code, and relatively low price or being freely available [20]. It is a simulation system based on the modular three-dimensional finite-difference technique for modeling groundwater flow and contamination in groundwater with a wide range of natural systems. PMWIN is used widely throughout the world and it was applied in many groundwater modeling applications [17, 23, 25].As per study a reverse tube well shall be installed and data shall be collected for one complete year and the water table shall be surrounding. This data shall be simulated and ground water pattern shall be developed for future prediction.*

*6. Discussion*

*The important question is how cope with the detoriating situation of ground water? The answer is to devise & formulate an integrated, sustainable and effective implementable water resource management policy. The issue is not so simple as the ground water conditions is multidimensional issue. A series of factor are affecting the ground water situation eg*

1. *over exploitation of ground water*
2. *less precipitation*
3. *Rapid urbanization*
4. *Deforestation*
5. *Wastage of water &Behavior change*
6. *Unchecked installation of tube wells*
7. *Population growth*
8. *Declining trend of ground water recharge*
9. *Increase in cropping intensity*
10. *Non existence of law.*

 *In order to monitor, control & regulate all these issues a regulatory authority is proposed to be established at provincial level under the umbrella of planning and development deportment. This authority shall regulate the ground water and shall engage all the stockholders of ground water for better coordination implementation of the strategy of the said policy frame work. The authority shall work in four different dimensions but in coordination with each other.*

*The authority shall have the following five wing*

* *Administrative and coordination wing*

*It shall administer the authority and shall devise policy matters and legislation.*

* *Regulatory wing*

*It shall implement the policy and strategy in letter and spirit.it shall have exercise the judicial powers also related to the breach of any policy matter.*

* *Research and development t wing*

*The main purpose of this wing shall be research and development work related to ground water and its conservation. New and modern technique of irrigation shall be introduced and new crop pattern shall be inve**stigated.*

*Water storage & conservation wing*

*This wing shall plan and execute new project of storage of surface water and ground water recharge*

**(Provincial Water Regulatory Authority )**

**Ground Water Resource Management Model**

 Ground Water Resource Management policy

**References**

1. Q. Javed, M. Arshad, A. Bakhsh, A. Shakoor, Z. A. Chatha, and I. Ahmad, “Redesigning of drip irrigation system using locally manufactured material to control pipe losses for orchard,” *Pakistan Journal of Life and Social Sciences*, vol. 13, no. 1, pp. 16–19, 2015.
2. A. S. Mongat, M. Arshad, A. Bakhsh et al., “Design, installation and evaluation of solar drip irrigation system at mini dam command area,” *Pakistan Journal of Agricultural Sciences*, vol. 52, no. 2, pp. 483–490, 2015
3. M. S. Shafique, F. D. Johnson, and E. W. Jackson, “Sulfurous acid generator: A technology to mitigate drought conditions,” in *National Symposium on Drought and Water Resources in Pakistan*, Lahore, Pakistan, 2002.
4. M. Arshad, A. Shakoor, I. Ahmad, and M. Ahmad, “Hydraulic transmissivity determination for the groundwater exploration using vertical electric sounding method in comparison to the traditional methods,” *Pakistan Journal of Agricultural Sciences*, vol. 50, no. 3, pp. 487–492, 2013.
5. M. N. Bhutta and L. K. Smedema, “One hundred years of waterlogging and salinity control in the indus valley, Pakistan: A historical review,” *Irrigation and Drainage*, vol. 56, no. 1, pp. S81–590, 2007.V
6. A. Shakoor, M. Arshad, A. Bakhsh, and R. Ahmed, “Gis based assessment and delineation of groundwater quality zones and its impact on agricultural productivity,” *Pakistan Journal of Agricultural Sciences*, vol. 52, no. 3, pp. 837–843, 2015
7. A. S. Qureshi, P. G. McCornick, M. Qadir, and Z. Aslam, “Managing salinity and waterlogging in the Indus Basin of Pakistan,” *Agricultural Water Management*, vol. 95, no. 1, pp. 1–10, 2008.
8. A. L. Qureshi, B. K. Lashari, S. M. Kori, and G. A. Lashari, “Hydro-salinity behavior of shallow groundwater aquifer underlain by salty groundwater in Sindh Pakistan,” in *Fifteenth international water technology conference, IWTC-15*, Alexandria, Egypt, 2011.
9. T. Shah, “Groundwater governance and irrigated agriculture,” *Tec Background Papers No. 19. Global Water Partnership Technical Committee (TEC)*, 2014.
10. A. S. Qureshi, P. G. McCornick, A. Sarwar, and B. R. Sharma, “Challenges and Prospects of Sustainable Groundwater Management in the Indus Basin, Pakistan,” *Water Resources Management*, vol. 24, no. 8, pp. 1551–1569, 2010.
11. H. Farid, Z. Mahmood-Khan, A. Ali, M. Mubeen, and M. Anjum, “Site-Specific Aquifer Characterization and Identification of Potential Groundwater Areas in Pakistan,” *Polish Journal of Environmental Studies*, vol. 26, no. 1, pp. 17–27, 2017.
12. A. Bakhsh and Q. A. Awan, *Water Issues in Pakistan And Their Remedies. In, National Symposium on Drought And Water Resources in Pakistan*, Cewre, university of engineering and technology Lahore, Pakistan, 2002.
13. M. Irfan, M. Arshad, A. Shakoor, and L. Anjum, “Impact of irrigation management practices and water quality on maize production and water use efficiency,” *Journal of Animal and Plant Sciences*, vol. 24, no. 5, pp. 1518–1524, 2014.
14. G. Haider and G. Hussain, “Problems associated with ground water utilization and their management in scarp areas. In proceedings of the workshop on membrane biophysics and salt tolerance in plants, Faisalabad,” Pakistan, 2001.
15. V. Ezin, R. Delapena, and A. Ahanchede, “Physiological and agronomical criteria for screening tomato genotypes for tolerance to salinity,” *Electronic Journal of Environmental, Agricultural and Food Chemistry*, vol. 9, no. 10, p. 1641, 2010.
16. WAPDA, Hydrogeological data of Rechna Doab. Volume-I, publication No. 25. Project planning organization (N.Z) Water and Power Development Authority (WAPDA), 27-E/I Gulberg III, Lahore, 1978.
17. A. N. Al-Fatlawi, The application of the mathematical model (MODFLOW) to simulate the behavior of groundwater flow in Umm er Radhuma unconfined aquifer. Euphrates Journal of Agriculture Science, vol 3, article 1, no. 1, 2011.
18. S. Khan, T. Rana, H. F. Gabriel, and M. K. Ullah, “Hydrogeologic assessment of escalating groundwater exploitation in the Indus Basin, Pakistan,” *Hydrogeology Journal*, vol. 16, no. 8, pp. 1635–1654, 2008.View at: [Publisher Site](https://doi.org/10.1007/s10040-008-0336-8) | [Google Scholar](https://scholar.google.com/scholar_lookup?title=Hydrogeologic%20assessment%20of%20escalating%20groundwater%20exploitation%20in%20the%20Indus%20Basin,%20Pakistan&author=S.%20Khan&author=T.%20Rana&author=H.%20F.%20Gabriel&author=&author=M.%20K.%20Ullah&publication_year=2008)
19. G. Schoups, C. L. Addams, and S. M. Gorelick, “Multi-objective calibration of a surface water-groundwater flow model in an irrigated agricultural region: Yaqui Valley, Sonora, Mexico,” *Hydrology and Earth System Sciences*, vol. 9, no. 5, pp. 549–568, 2005.View at: [Publisher Site](https://doi.org/10.5194/hess-9-549-2005) | [Google Scholar](https://scholar.google.com/scholar_lookup?title=Multi-objective%20calibration%20of%20a%20surface%20water-groundwater%20flow%20model%20in%20an%20irrigated%20agricultural%20region:%20Yaqui%20Valley,%20Sonora,%20Mexico&author=G.%20Schoups&author=C.%20L.%20Addams&author=&author=S.%20M.%20Gorelick&publication_year=2005)
20. W. A. Jehangir, A. S. Qureshi, and N. Ali, Conjunctive water management in the Rechna doab: an overview of resources and issues. Working paper 48. International water management institute Lahore, Pakistan, 13, 1, 2002.
21. M. D. Ahmad, Estimation of net groundwater use in irrigated river basins using geo-information techniques: a case study in Rechna doab, Pakistan (Ph.D. Thesis), Wageningen University, Wageningen, 2002.
22. M. Arshad, Contribution of irrigation conveyance system components to the recharge potential in Rechna Doab under lined and unlined options. PhD Thesis, Faculty of Agricultural Engineering and Technology, University of Agriculture, Faisalabad-Pakistan, 2004.
23. C. Zheng, MT3D-A modular three-dimensional transport model for simulation of advection, dispersion and chemical reactions of contaminants in groundwater systems. Report to the u.s. Environmental protection agency, ADA, Oklahoma, 1990.
24. W. H. Chiang and W. Kinzelbach, “Processing Modflow: a simulation system for modeling groundwater flow and pollution. User's manual,” User's manual. U.S. Department of the interior, U.S. Geological survey, 1998.View at: [Google Scholar](https://scholar.google.com/scholar_lookup?title=Processing%20Modflow:%20a%20simulation%20system%20for%20modeling%20groundwater%20flow%20and%20pollution.%20User%27s%20manual&author=W.%20H.%20Chiang%20&author=W.%20Kinzelbach)
25. P. A. Domenico and F. W. Schwartz, *Physical and chemical hydrogeology*, John Wiley, New York, USA, 2nd edition, 1990

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