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Groundwater - Surface Water Interaction Modeling in The Mampang Sub-Watershed

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Abstract. Groundwater - surface water around the banks of rivers/streams has an inseparable relationship. The interaction of the two impacts groundwater–surface water patterns in terms of quantity and quality of water. The research location is in the Mampang sub-watershed, part of the Krukut watershed area; the Krukut watershed is one of the major rivers in Jakarta. This research is to analyze the Ground Surface Water Exchange Rates (GSWER) with the aim of knowing the interaction of groundwater-surface water in the Mampang Sub-watershed. The research method consisted of collecting primary data and secondary data, SWAT simulation, SWAT-MODFLOW simulation, and GSWER value analysis. The results of the SWAT delineation of the Mampang sub-watershed with 21 sub-basins. The GSWER value for the rainy season, selected in April 2022, is the highest for the effluent system (gaining), worth - 223 m^3/day, and the highest influent system (losing), is 305 m^3/day. As for the dry season, August 2022 was chosen to be the highest for the gaining stream with a value of -83 m^3/day and for the losing stream with a maximum value of 62 m^3/day.

Keywords: *groundwater; Mampang Sub-watershed; SWAT; SWAT-MODFLOW.*

1 Background

Proper groundwater management can maintain the sustainability of groundwater in quantity and quality. Groundwater management in a groundwater area is called Groundwater Basin. Groundwater Basin is defined as an area with hydrogeological boundaries where all hydrogeological events, including the recharge, drainage, and release of groundwater, take place (Water Resources Law Number 17 of 2019). Groundwater - surface water around the banks of rivers/streams has a close relationship. The interaction of the two has an impact on groundwater–surface water patterns in terms of quantity and quality of water. This interaction is also influenced by the season; during the dry season, surface water does not supply water from runoff, so surface water from rivers gets groundwater (Gaining Stream) (Sri Harto, 2000).

Groundwater that is continuously utilized around the river can result in a decrease in the groundwater level. If the groundwater level decreases, the surface water table will enter the groundwater. When the river water experiences a decrease in the water level, the groundwater will flow slowly toward the river (Bisri, 2012).

The Mampang sub-watershed is geographically located 106°48'44" - 106°49'59" East Longitude and 6°15'4" - 6°22'17" South Latitude. The Mampang sub-watershed in the Provinces of Jakarta and Depok Province is one of the areas that will be used as water catchment. One of the problems that occur in the Mampang Sub-watershed is that it experiences floods every year. This research aims to analyze the interaction of groundwater-surface water in the Mampang Sub-watershed using a SWAT - MODFLOW simulation. The limitation of this research is that there is no river discharge data in the research area, so it requires self-measurement at a specific time and this study only discusses the interaction of groundwater - surface water in the Mampang Sub-watershed.

2 Research Method

The methods used in this study include collection of primary data and secondary data, SWAT (Soil and Water Assessment Tools) Simulation, SWAT-MODFLOW Simulation and, Value analysis of groundwater-surface water exchange rates (GSWER).

This approach uses primary data and secondary data. Primary data is data obtained from observations and measurements or self-calculations in the form of groundwater level data and river discharge data. While the secondary data is in the form of DEM maps, geological maps, hydrogeological maps, land use maps, climatological data, and aquifer parameters. SWAT-MODFLOW is a hydrological model that incorporates land surface parameters. The hydrological processes of this river have previously been simulated using SWAT, and the hydrogeological processes of groundwater were simulated using MODFLOW-NWT. For modeling groundwater in unpressured aquifers using MODFLOW-NWT.

SWAT and MODFLOW can analyze groundwater-surface water interactions quantitatively and qualitatively. The analysis of groundwater - river water interactions has been obtained by checking the groundwater and river water table elevations and the physical and chemical parameters of groundwater and river water. (Bailey et al., 2016). Rivers that interact with groundwater use two main mechanisms, namely rivers filled with groundwater (gaining streams) and rivers filling groundwater (losing streams) (Winter, 1998).

3 Discussion

3.1 Geological Setting

Based on the Geological Map of the Jakarta Sheet and the Thousand Islands (Turkandi, 1992), the geological conditions of the study site are in the Southern Region bounded by Quaternary volcanoes. Quaternary deposits consist of volcanic alluvium fans, coastal alluvium units, and rivers. The three units are finger-to-finger related (Delinom, 2015). The Quaternary deposits were formed by Pleistocene (1 – 2 million years ago) to Recent (present) rock units, with lithology in the form of volcanic fan deposits in South Jakarta (Figure 1).

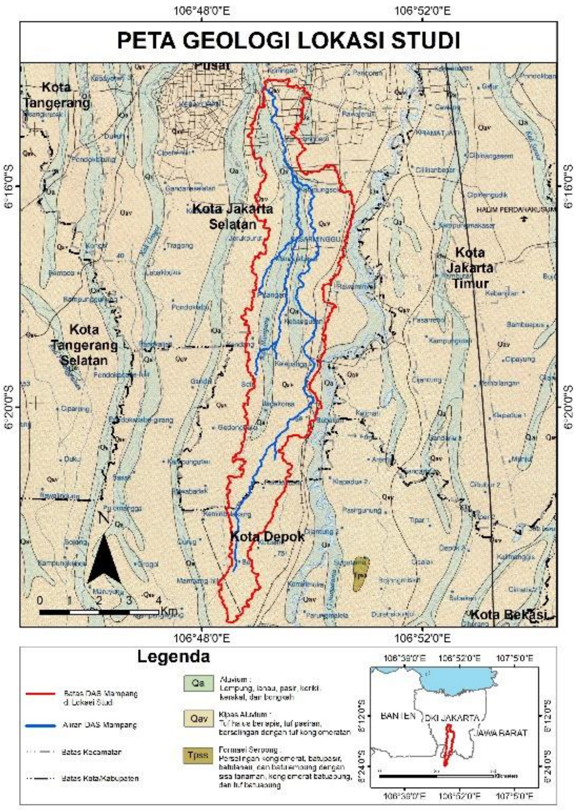


Figure 1 Geological Map of Study Location based on Geological Map of Jakarta Sheet and Thousand Islands (Turkandi et al, 1992)

3.2 Climatological data

The climate data used in this study comes from the Meteorology, Climatology and Geophysics Agency (BMKG) in 2012-2022, the average value of rainfall is 188.69 mm/month (Figure 2), the average monthly temperature value is 28, 36°C, the average solar radiation value is 13.27 %, the average relative humidity is 76%, and the average wind speed is 135.82 km/day.

Figure 2 Graph of Rainfall in Research Locations (Source BMKG,2022)

3.3 SWAT (Soil and Water Assessment Tools)

Equipment needed in operating the SWAT model using ArcSWAT 10.4.21 software on ArcGIS 10.4.12. The hydrological model in SWAT consists of the stages of watershed delineation data analysis and the formation of Hydrologic Response Units (HRU), analysis of rain data, analysis of river flow discharge, and analysis of calibration validation. The SWAT simulation has two stages, namely pre-process and process.

SWAT Pre-Process Stage include watershed delineation process to calculate the amount of accumulated flow and flow direction based on topography, HRU Overlay Process, by classifying soil types and land cover with SWAT standards and climatology gauge, data input is in *.txt format.

SWAT Process Stage, Pre-processed data is used to calculate the SWAT model. The outputs from SWAT include streamflow, groundwater flow (base flow), direct runoff, and total runoff water. SWAT simulation, at this stage, several stages of the process can be set, as follows Sub-basin contains a list of information for each sub-zone, The main channel contains summary information about what enters and leaves the channel in the watershed and HRU contains a summary of HRU information in the watershed.

After the SWAT simulation has been completed, then the calibration process is continued by comparing the SWAT discharge with the observation discharge at the same time and place. Calibration is performed with the SWAT-CUP software with the SUFI 2 (Sequential Uncertainty Fitting version 2) algorithm. After SWAT CUP is performed, the next step is using SWAT-MODFLOW.

3.4 SWAT-MODFLOW

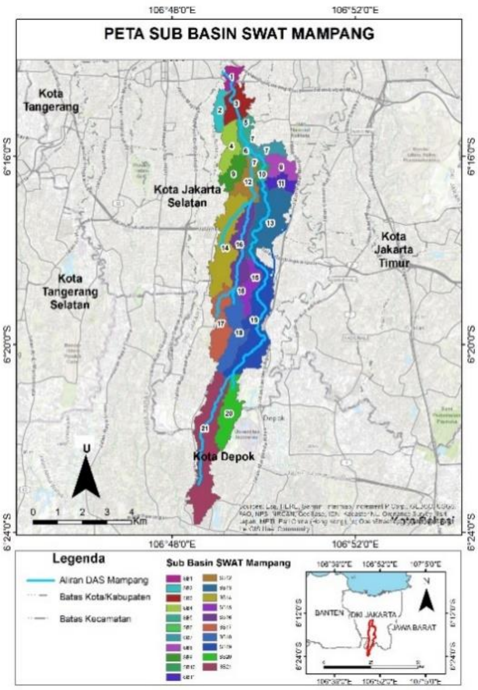
SWAT-MODFLOW is an integrated hydrological model that combines the SWAT process with spatial groundwater flow processes. The data needed in SWAT-MODFLOW are DEM data, aquifer parameters, and groundwater table elevation maps from primary data interpolated into a raster format.

The integration of the SWAT-MODFLOW model functions in modeling the interaction of groundwater with surface water. The output obtained from modeling on SWAT- MODFLOW in the analysis of groundwater and surface water interactions is "swatmf_out_MF_gwsw" contains the volume of exchange in units of m3/day between river water and aquifers per river grid that has been formed in the SWAT- MODFLOW modeling.

3.5 Aquifer Parameters

The aquifer parameters included in the SWAT-MODFLOW simulation are specific storage (Ss) values (Morris and Johnson, 1967) in Batu, 1998) in the form of volcanic alluvium fans, coastal alluvium units, and rivers taken as 2.3 x 10-4 ft. The specific yield value (Sy) in the form of sand medium (Morris and Johnson, 1967) is taken as 32%. The conductivity value is 0.232 m/day (Yong, 1996), and the thickness of the first layer aquifer based on the Citalang formation and the Quaternary Volcanic Deposits is 30 m (Facri, 2002). Map of groundwater elevation from primary data that has been interpolated and DEM data with a resolution of 8.3 m.

3.6 Groundwater - Surface Water Interaction (GSWER) Modeling



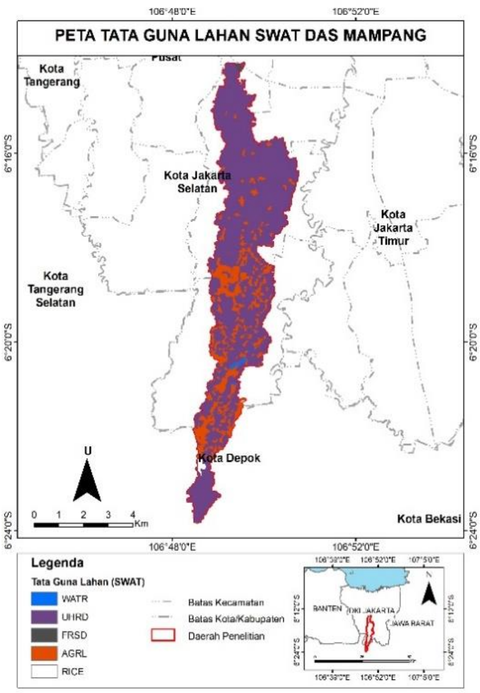


Figure 3.a Map of the Sub Basin Study Area and **Figure 3.b** Land Use Map of the Study Area

The results of the delineation form the Mampang sub-watershed with a total of 21 sub-basins with DEM data inputted into the SWAT software (Figure 3.a) and Land use is re-categorized in SWAT, which consists of Waters (WATR), Forests (FRSD), Plantations (AGRL), Rice Fields (RICE), and Settlements (URHD) with the largest land use for the Mampang Sub-watershed are Settlements and Places of Activity (Figure 3.b).

In the SWAT- MODFLOW modeling, 874 river grids were produced with the output obtained in the form *txt "swatmf_out_MF_gwsw", used as spreadsheet data and then entered into the ArcMap. The SWAT – MODFLOW simulation results and images can be graphed (Figure 4) to determine the interaction pattern between rainfall and GSWER values (Figures 5.a and 5.b). This study selected April 2022 for dry season with the smallest SWAT simulation monthly average debit value, and February 2020 for rainy season with the most significant SWAT simulation monthly average discharge value.

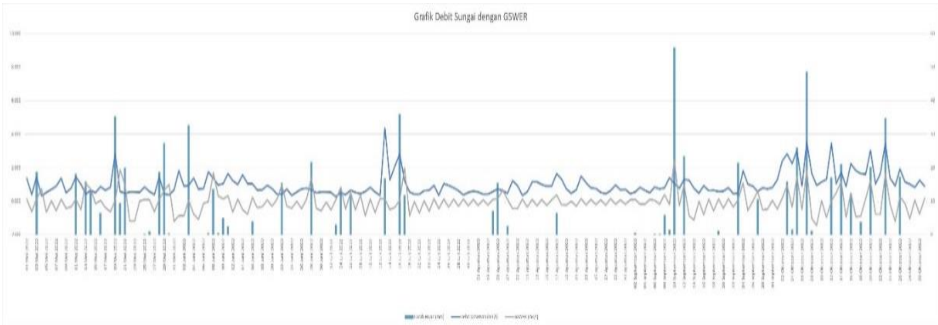


Figure 4 GSWER Graph and Rainfall During Observations in 2022

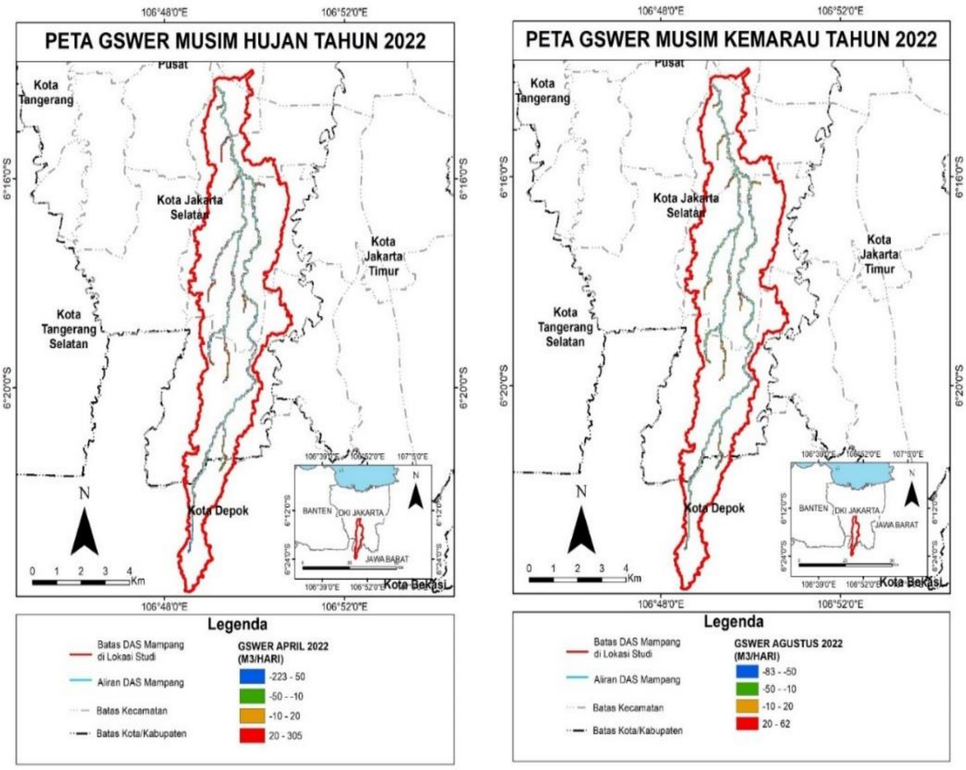


Figure 5.a GSWER Map for April 2022 and **Figure 5.b** GSWER Map for August 2022

4 Conclusions

Based on research results in SWAT modeling, the SWAT delineation results for the Mampang Sub-watershed with 21 sub-basins were obtained, and the SWAT - MODFLOW modeling obtained the river Grid results totaling 874 so that the GSWER value in the rainy season can be analyzed; in April 2022, the highest for a gaining stream is worth - 223 m^3/day and the highest losing stream is 305 m^3/day. The GSWER value in the dry season in August 2022 is the highest for gaining streams worth - 83 m^3/day; for losing streams, the highest is worth 62 m^3/day. From these results, there is a GSWER value for both gaining streams and losing streams occurring during the rainy and dry seasons. In some river segments, there is a change in the system from gaining stream to losing stream during the dry season, which is caused by a decrease in the groundwater level and also groundwater extraction at the location point.

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References

[1] Bisri, M. Studi Tentang Pendugaan Air Tanah, Sumur Air Tanah Dan Upaya Dalam Konservasi Air Tanah, 2012

[2] Bailey, R.T, Wible, T.C., Arabi, M., Records, R.M., dan Ditty, J.: Assessing regional-scale spatio-temporal patterns of groundwater–surface water interactions using a coupled SWAT-MODFLOW model, Hydrological Processes, 30, 4420 – 4433. 2016

[3] Delinom, Robert M. Ancaman Bawah Permukaan Jakarta: Tak terlihat, Tak Terpikirkan dan Tak Terduga. LIPI Press 2015

[4] Lambok M Hutasoit, Agus Mochamad Ramdhan dan Muhammad Fachri, Stratigrafi dan Hidrostratigrafi Cekungan Air Tanah Jakarta, 2002

[5] Morris, D.A. and A.I. Johnson. Summary of hydrologic and physical properties of rock and soil materials as analyzed the Hydrologic Laboratory of the U.S. Geological Survey. U.S. Geological Survey Water-Supply Paper1839-D, hal 42. 1967

[6] Sri Harto, BR. *Hidrologi: Teori, Masalah, Penyelesaian.* Yogyakarta: Nafiri Offset, 2000

[7] Turkandi, T. Sidarto, DA And Purbohadi W, MM. Peta Geologi Lembar Jakarta dan Kepulauan Seribu, 1992

[8] Undang – Undang Republik Indonesia Nomor 17 tahun 2019 tentang Sumber Daya Air

[9] Winter, T.C., Harvey, J.W., Franke, O.L., dan Alley, W.M.: Groundwater and surface water: a single resource, *USGS Circular 1139*, Denver, Colorado,1998
[10] Yong, R.N., Interim report: Development of groundwater management strategies in the coastal region of Jakarta, Indonesia, 1992.