Wetland River Flow Interaction

Wetland river flow interaction in the white Volta basin, Ghana

Abstract

Groundwater in the White Volta River basin plays a vital role in the economy of Ghana by acting as a major source of water for agriculture activities for communities living around. During three years of study, 12 observation wells were monitored; groundwater data were obtained from two distinct geological formations. Groundwater data obtained in conjunction with stratigraphy/topography groundwater conditions were characterize within the landscape. Groundwater condition indicates a systematic variation in response to changes geological formation and rainfall pattern with March, April, and May showing a high level of draw down. Areas along the main stream indicated a high water level with the hydraulic gradient towards the upper catchment. Nevertheless, a bidirectional flow was observed, throughout each rainfall year.

Introduction

Floodplains wetlands are formed on strips of land bordering a main course of a river, it get inundated during seasonal floods (Bridge 2005). Floodplains and its associated wetlands may extend from few to several meters along the river strip. Wetland provides a lot of environmental benefits such as habitat for wildlife, water purification, groundwater recharge and production of biomass. In some situation subsurface and surface water in wetlands sites are pumped for irrigation activities in the dry season (………………). In most developing countries not much investigation has been done in any of the river basins to catalog or create a database on the distribution and types of wetlands; though it appears to be on decline due to the destructive nature of human activities and climate change (------------). Wetland found within river basins have important ecosystem, but management practices are not available, because of lack of sufficient scientific data to support any meaningful decision making by institution involve in environment and water resources management. To deal with problems related to floodplains such as floods, water supply, floodplain irrigation, river bank erosion, and remediation of polluted surface water and groundwater, earth scientist and civil, agricultural engineers must understand rivers and floodplains (Bridge 2005).

Wetlands have a spatial and temporal complex hydrological system as a result of interaction it has with it surrounding (Mansel et al., 2000). The complexity of subsurface and surface water inteaction processes in wetland sites does not occur in any terrain but are often governed by localized groundwater flow; these flows are often governed by the regional flow process influenced by nature of the landscapes (Fares et al., 1997). In the Volta River basin recharge to subsurface water is reducing leading to low level of hydraulic heads in the aquifers (Nicola, 2005). The hydrology of wetlands in the basin is complex because some sites are characterized by temporally variable volumes and surface areas of free water. This study is an attempt to investigate the interaction between wetland and river flow using a two dimensional model –MODFLOW.

Theoretical background

Groundwater and surface water system in floodplain environment are not isolated components of the hydrological cycle, but instead interact in a variety of physiographic and climatic landscapes. Understanding the basic principles of modelling interaction between groundwater and surface water is essential for efficient and effective water resources management. Modelling wetland hydrodynamics needs to give fundamental consideration to the physics of surface flow processes (Grapes et al., 2005). Water flow in wetlands can be represented by an overall water movement often dominated slough channel flow, i.e., flow through a network of open water channels that exist between areas or patches of dense vegetation (Lewandowski 1993).

Groundwater modelling is a multifaceted task by which greater understanding of the physical, chemical and biological condition in the subsurface can be achieved. Groundwater and surface water interaction models are analytical tools for characterisation and prediction of the quantity and quality of groundwater. In attempting to understand ground water and surface water interaction most research has been on the vertical interaction of surface and groundwater. For instance, Nield et al. (1994) used a numerical model to examine groundwater flow in vertical sections near surface water bodies, such as lakes, wetlands, ponds, rivers, canals, and drainage and irrigation channels. They distinguished different flow regimes by noting the presence and nature of groundwater mounds or depressions near the edges of a surface water body and by corresponding stagnation points. Matos et al. (2002) examined aquifer heterogeneity and channel pattern on flow interactions between stream and groundwater systems. In such a study, MODFLOW, was used, to evaluate the magnitude, direction and spatial distribution of stream-subsurface exchange flows, with the underlying sediments acting as an aquifer. According to Richardson et al. (2001), exchange between groundwater and surface water infiltrating water moves along a gradient reaching an impeding layers of clay The infiltrating water moves along the hydraulic gradient until it reaches an impeding layer of fine clay and silt, which has a lower hydraulic conductivity; hence less water is transmitted per unit time. FLOWNET, FEFLOW, MIKE-SHE and other numerical models have been used to plot and visualize equal hydraulic heads and groundwater flow paths and mostly consist of equipotential lines and flow stream lines. Physical-based, process-oriented and spatially distributed models have seldom been applied to study wetlands in developing countries, since they are complex to operate and require a level of data that is hardly available in most developing countries because of cost (Bonell and Balek 1993).

Modeling of floodplain wetland and river interaction is both numerically and theoretically demanding and requires solving complicated numerical approximations to differential equations (Bockelmann et al. 2004; Fischer-Antze et al. 2001; Wu et al. 2000).

In most cases wetlands are generally incorporated in groundwater models as general head boundary nodes even though they can be used as constant heads (Restropo et al. 1998). The hydrologic regime of floodplain wetlands depends on the varying degree of flow in the main channel, making wetlands vulnerable to hydrologic changes resulting from flow regulation (Reid and Quinn 2004; Cloke at al. 2006). However, the nonlinear interactions among recharge, discharge, boundary conditions and changes in groundwater storage makes the solving of problems relating to recharge and groundwater development difficult, all the system parameters and their geographical distribution are not carefully accounted for (Sanford 2002).

Notably rivers interact with the floodplain wetland in three ways: 1) through direct surface runoff, 2) through sub-surface water flow, and 3) by losing water to wetlands by seepage through the river walls. The interaction between floodplain wetlands and a river sometimes vary, over a very short time frame or distance in response to rapid rises in river stage due to storm runoff. For instance the high water level in the White Volta River as in 1994 and 2007 was enough to overflow the banks and flood large areas of the floodplains causing a widespread surface recharge. Therefore, the hydraulic connection between the White Volta River and the floodplain wetland may be direct or disconnected by the intervening unsaturated zone, with rivers losing water in the form of seepage through the walls into the floodplain wetland. Important in floodplain wetland hydrological modeling within the Upper East region is to establish the contribution of shallow well development for the sustenance of dry season irrigation. This paper discusses processes involved in the use of PM-WIN (MODFLOW), to determine forms of interaction between the main White Volta River and the basin floodplain wetlands. The study is sectioned into three main parts: 1) an overview of the model; 2) discussion of the setting of the MODFLOW model, indicating the input data used; 3) discussion of model results and sensitivity analysis.

PM-WIN (MODFLOW) can simulate many of the features influencing the in-field water regime, including anisotropy and heterogeneity in hydraulic properties. In modeling floodplain wetland river flow interaction at the Pwalugu site was performed using PM-WIN (MODFLOW) was used (Chaing and Kinzelbach 1998) for the following reasons:

- MODFLOW takes account of spatial heterogeneities, vertical groundwater flow and any regional groundwater flow component.
- Leakages through heavy soils can occur at low rates and consequently become a minor component at the field scale, although the volume of leakage can be significant over the total area of the wetland.
- Irregular field boundaries and steep hydraulic gradients to the river are accommodated.
- Recharge can be distributed spatially, and recharge is assumed to be added instantaneously to the saturated zone.

- MODFLOW allows evaporation from the soil surface, hence the maximum evaporation rate is assigned to each cell when the water table equals an assigned head value and ceases below the assigned extinction depth.
- The PMWIN model is free.

Model Description

The Pwalugu floodplain wetland site is represented by an array of rectangular cells, which embody the localized values of the aquifer characteristics (Figure 1.1). The area modeled covers 7.78 km2 and comprises 8648 square cells, out of which 5693 are marked as active cells. The model for the study site is represented in two layers, and the top of the uppermost layer (Figure 1.2) corresponds to the surface of the floodplain wetland; this layer can be dried and rewetted seasonally. The thickness of the top layer varies in thickness from 6.0 m when close to river and 26 m at the eastern boarder of the study site. The second layer below has a thickness of 10 m, specified on the basis of a geological formation that limits storage and enhances transmission of water. The spatial limits of the geological formations provided no-flow boundaries to the north and west side of the river (Figure 1.1). Flow along the southern and eastern boundaries is specified as constant head. The model is specified to enable determination of whether the wetlands contribute to or receive water from the river. This depends on the head gradient between the floodplain wetland and the river. The packages river, recharge and wetting capabilities were applied during the modeling process.

[image]

Figure 1.1 Setting of the Pwalugu floodplain wetland site

[image]

Figure 1.2 Location and transect of wetlands in the White Volta River basin

The river package (Prudic 1989) was used to represent the White Volta River in the model. The White Volta River can gain from or contribute water to the floodplain wetland depending on the river stage (Figure 1.3), riverbed conductance and adjacent floodplain aquifer water levels. The river surface elevation data are measured by the Hydrological Service of Ghana. The low level of 133.05 m was recorded in January 2005, while September 2005 had the highest reading of 140.53 m.

[image]

Figure 1.3 River gauge heights at Pwalugu Station

Riverbed conductance is a critical parameter in determining the amount of water seepage between the river and underlying aquifer (Hayashi and Rosenberry 2002). Conductance values of between 3.09 x 104m/day and 3.10 x 104m/day were assigned using the hydraulic conductivities of the observed changing bed materials consisting of alluvial deposits, metamorphosed sedimentary and granites outcrops that mostly from the riverbed. Data riverbed thickness and river width were not available to justify adjustment of riverbed conductance on a river-segment basis during the modeling process. To simulate the lateral flow interaction between wetland and river through the sediment deposits, low permeability values was assigned to the river bed to prevent leakage from the riverbed into the underlying aquifer.

A

B

C

[image][image][image]

Figure 1.4 (A) Field survey of the White Volta River (Pwalugu) (B) Cross section at Pwalugu gauging station (C) cross section at 150 m upstream from Pwalugu gauging station

The vertical and horizontal hydraulic conductivity with the floodplain wetlands are not uniform, but exhibit variability in terms of depth and direction. Two hydraulic conductivity layers were specified. For the top layer, due to spatial heterogeneity of vertical hydraulic conductivity, a range of 0.012 to 0.038 m/day was specified. A range of 0.12 m/day to 0.38 m/day was specified as the horizontal conductivity of the top layer. For the bottom layer, an arbitrary value of 0.09 m/day was specified for both vertical and horizontal hydraulic conductivities because of lack of information about the layer.

Recharge is limited to the behavior of the geological system that underlies the Pwalugu floodplain wetland site. This serves as a partitioning force that controls sub-surface recharge or water movement (Sanford 2002; Fox et al. 1998). The boundary condition in the MODFLOW groundwater model is effectively represented by specifying net bottom flux of HYDRUS-1D as a recharge flux (figure 1.5). However, in the White Volta basin it is difficult to independently obtain an accurate recharge rate and distribution data. To estimate recharge for the Bongo granite aquifer in the Volta basin, Martin (2005) used the chloride mass balance, soil moisture balance and water table fluctuation methods. Martin (2005) obtained three different recharge values of 5.9%, 12.5% and 13% of the annual rainfall respectively. Apparently, recharge measurements in the field contain some amount of uncertainty; for the MODFLOW simulation, the bottom flux from the HYDRUS-1D model was specified as the net recharge (Figure 1.5) for the Pwalugu floodplain wetland. An estimated recharge of 444 mm for 16 months (487 days) obtained from HYDRUS-1D simulation served as an input into the model. It is important to stress here that the HYDRUS-1D bottom flux as the net recharge into the subsurface; in this case, water ponding and evapotranspiration has been accounted for.

Groundwater recharge (mm)

[image]

Figure 1.5 Monthly bottom fluxes from HYDRUS-1D

Floodplain wetland and river flow interaction modeling

The PM-WIN model assisted to construct a two-dimensional transient model to quantify the temporal and spatial variation in the interaction between floodplain wetland and the White Volta River. The simulation of floodplain wetland and river flow interaction is important in estimating the flow and exchange of water between the wetland and river. An assumption made during the modeling process is that, conductivity of the riverbed is very low, thus any form of leakage from the river is a leakage into the wetland through the sub-surface. The model was run using both steady and transient mode.

To first calibrate model parameters a steady state flow simulation was performed to obtain a tolerable distribution of initial hydraulic head. The vertical and horizontal hydraulic conductivity values of the top layer were adjusted to get good fit for conductivities of the layers. For the bottom layer, no value was set for both vertical and horizontal hydraulic conductivity, because the hydro-geological information was not available (Table 1.1). In addition, effective porosity, specific storage, storage coefficient and specific yield of the sub-surface were adjusted to fit the level of fluctuation occurring within the floodplain wetland. The adjustment of the conductivities and other parameters shifted the error of discrepancy between observed and modeled values to an appreciable level.

Studies have shown that in attempting to understand and to measure any hydrological process in an environmental setting, there are many different parameter sets within a chosen model structure that may be acceptable in reproducing the behaviour of that system (Feyen et al. 2004; Restrepo et al. 1998). There is seldom an “optimal” model that can generate simulated results at an acceptable limit of accuracy, rather it is more important to consider multiple possibilities for simulating in an acceptable range (Beven 2001; Beven 2009). To simulate results within an acceptable range, there should be sufficient interactions among components of a system, unless the detailed characteristics of these components can be isolated and calibrated independently, many representations may be equally acceptable. Therefore, searching for optimal parameter representation may not be possible, because it is statistically likely that the description of the system may be wrong. One justification for using multiple parameter sets to simulate a hydrological process that is non-linear stems from the fact that there are uncertainties associated with the use of models in prediction, because there are many acceptable model structures or acceptable parameter sets scattered throughout the parameter space (Beven 2009). Diekkrüger (2003) argued that nonlinear systems are particularly sensitive to their initial and boundary condition; hence any form of dynamics in these conditions may be important in controlling the observed response. It suggests that predictions of all acceptable models should include an assessment of prediction uncertainty. Uncertainty in hydrological models stem from the fact that they are not the true reflection of the processes involved, because condition and data for running the models are not error free. Hence, there is a need to find optimum parameters that are efficient and sensitive parameters to model (Beven, 2009; Hill 1989). Sensitivity analysis is carried out when initial parameterization is complete.

Sensitivity analysis was performed to quantify relative changes in model output in response to changes in input parameter values. This process was carried out after model had been specified, and its benefits include: 1) a check on the model logic and robustness of the simulation, 2) identification of the importance of specific model parameters and corresponding effort that must be invested in data acquisition for different parameters. Dimensionless and dimension scaled are the two main types of sensitivity analysis performed in MODFLOWP. These types of sensitivity analysis mentioned above have been discussed in detail in the works of Hill (1998).

As noted the main sources of uncertainty in modeling Pwalugu floodplain wetland site are the spatial distribution of the horizontal hydraulic conductivity, vertical hydraulic conductivity, specific storage and specific yield. While acknowledging the anisotropic nature of the aquifer deposits of the sub-surface deposit, however, anisotropy of horizontal hydraulic conductivity (HK_1), specific storage (SS_4) and specific yield (SY_3) were assumed at the scale of interest for the aquifer parameters. The implication is that uncertainty as a result of spatial variability of conductivity of the top layer is not accounted for in the present study. Van Leeuwen et al. (1999) showed that variability in vertical conductance of a confining clay layer strongly affects flow and shape of the capture zone. In the present study, variability is partly accounted for by the spatial variation of the thickness of the top layer.

Sensitivity analysis of horizontal hydraulic conductivity (HK_1), vertical hydraulic conductivity (VK_10), specific storage (SS_4) and specific yield (SY_3) determined which of the parameters had greatest effect on the simulated heads. MODFLOWP was used to generate sensitivities by perturbing the control parameters, during the simulation for 487 days on a daily time steps basis. The number of runs was 19 using 96 observations. Out of the 96 observations 30 had a residual greater or equal to zero, while the remaining 66 had residuals less than zero.

[image]

Figure 1.6 Composite scale sensitivity (horizontal hydraulic conductivity (HK_1), vertical hydraulic conductivity (VK_10), specific storage (SS_4) and specific yield (SY_3)

The composite-scaled sensitivity (Figure 1.6) indicates the relative importance of the sub-surface parameters used in the modeling processes. During the process of model calibration, HK_1, SS_4 and SY_3 were the parameters with a high level of sensitivity, thereby influencing the interaction process between floodplain wetland and White Volta

River. VK_10 was insensitive to changes; hence it plays no role in the floodplain wetland-White Volta River flow interaction. After optimization, HK_1 was the most sensitive parameter, and any adjustment of HK_1 increased the amount of interaction between the wetland and the river.

Table 1.1 Adjusted parameters for the PM-WIN model

	Top layer	Bottom layer
Vertical conductivity	0.12 - 0.38 /day	0.9 m/day
Horizontal conductivity	4 m/day	0.09 m/day
Effective porosity	0.14 – 0.25	0.25
Specific storage	0.01	0.001
Specific yield	0.07 m3/day	0.001 m3/day
Storage coefficient	0.01	0.001

In running the steady state model, the initial hydraulic head was assumed to be the interpolated hydraulic head of the piezometers and the river in September 2004. In addition, no recharge was specified; however an equilibrated head values as initial hydraulic head for steady and transient models. The adjustment proved to be optima for running the model. The period September to October 2004 was chosen for the calibration, as detailed hydraulic head measurements were available for the period.

The transient model was run in a time varying mode with daily time steps for 487 days. The recharge specified was the bottom flux obtained from HYDRUS-1D. Inflow and outflow at the model boundaries were varied between constant and variable head until the model results were in an acceptable range. The boundary conditions specified do not represent direct recharge, but are used in conjunction with recharge to realistically represent the sub-surface water system (Sanford 2002). In running the model in the transient mode with wetting capabilities turned on, there was contribution of water flow from cells marked no-flow (inactive cells). In this situation, wetting capability was removed from the modeling process. Also, the bottom layer was disabled due to lack of data; hence it becomes a no flow boundary, thus only the top layer was used.

Results of calibration with the hydraulic conductivities and other parameters are shown in figure 1.7 as time discharge plot from six piezometers, for which the calculated head follows the pattern of the observed head. Water levels in the piezometers are always elevated in the rainy season and lower in the dry season, but PZ1 at the toe of the sloping part of the wetland is the last to dry. Data from piezometers in the Pwalugu floodplain wetland represented sections of the wetlands. The simulated curve generated shows a good fit with observations especially for PZ1, PZ2, PZ3, PZ5, PZ8 and PZ9. The rises in the hydraulic heads of the simulated hydrograph are similar and follow a pattern, while the observed hydraulic head shows some differences. The variability in the observed heads is likely to be a result of heterogeneity in the sub-surface aquifer structure.

[image][image][image][image][image][image]

Figure 1.7 Simulated and observed heads in the Pwalugu floodplain wetland

The simulation of sub-surface hydraulic head indicates a systematic variation relative to the White Volta River in response to changes in the rainfall pattern in the tropical savanna climatic zone. Over the months of September 2004, December 2004, March 2005, June 2005 and September 2005 (Figure 1.7) distinctive patterns of hydraulic heads were observed. For instance, the high hydraulic head simulated for September 2004 indicates that the floodplain wetland experienced a hydraulic head between 1 and 3 m below the topographic surface. During August and September, a ponding height of 0.50 m was measured in the field. The heterogeneity of floodplain wetland topography makes ponding uneven. In June 2005, a comparatively high hydraulic head of 4 and 6 m is simulated below the topographic surface but close to the main river course, while the further away from the river, the deeper the hydraulic heads. A bi-direction of sub-surface water flow between the White Volta River channel and the floodplain wetland system is inferred as having a temporal and spatial variation.

September 2004

[image]

Figure 1.8 Depth of hydraulic head and cross section of floodplain wetland in September 2004, December 2004, March 2005, June 2005, and September 2005

December 2004

[image]

Figure 1.8 continued

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Figure 1.8 continued

Figure 1.8 continued

Figure 1.8 continued

Table 1.2 Model fit statistics for the transient run monthly values of observed and simulated hydraulic heads

ID	Observed (m)	Simulated (m)	Root mean square error (RMSE)	Index of Agreement (IA)
PZ1	136.85	136.79	0.52	0.82
PZ2	137.53	137.00	0.45	0.89
PZ3	137.19	136.87	0.49	0.98
PZ5	136.74	137.04	0.33	0.93
PZ8	136.30	136.04	0.97	0.75
PZ9	135.95	136.47	0.55	0.89

The HYDRUS-1D bottom flux used as an input into the model resulted in a fit between the simulated hydraulic head and observed sub-surface water level fluctuation. A comparison of 6 piezometer observations and simulated hydraulic head showed some outliers with a variance of 1.62 m with a root mean square error (RMSE) of 1.28 m. Level of compatibility indicates the need to improve model calibration. Individual piezometers in the wetlands showed differences between the observed and simulated head (Table 1.2). PZ-1 located within the wetland and about 300 m away from the White Volta River gave a better fit (IA = 0.82, MAE = 0.72 m and RMSE = 0.52 m). PZ-8 in close proximity to the river shows a lower IA of 0.75, and RMSE of 0.97 m. Given the lack of spatial data, e.g., local flow pattern and hydraulic properties with depth, accurate calibration will not be feasible. Therefore, detailed data on variation in the landscape, sub-surface water level fluctuation and bottom discharge is required to develop a validated model of an accuracy required for management of floodplain wetlands in the White Volta basin.

The mass balance (table1.3) accounted for the sources of water for recharge or discharge of a hydrologic system on monthly basis. The cumulative mass balance at the end of the run period of 16 months (487 days) for the transient model demonstrate the importance of recharge as a water balance input. The monthly recharge generated suggests a significant contribution of water from wetlands into the river. At sites that do not have any form of sub-surface influence, the form of interaction between the wetland and the White Volta River resulted from overbank flow. Another important process is backwater effect, which contributes to extensive ponding leading to surface water storage as noted in the Tindama floodplain wetland.

The interaction conditions vary from season to season, with March, April and May showing the lowest leakage of 0.03 mm/day, 0.06 mm/day and 0.15 mm/day respectively, from the river into the floodplain, although the expectation is that floodplain wetland serves as a moisture buffer and supplies the river with water during the low season. However, period between July and September 2005, the recharge of floodplain wetland aquifer caused an increase in the volume of water storage in the wetlands from 992793 m3 to 1404853 m3. Interaction between the wetland and river is bidirectional, with most of the flow coming out from the river (Table 1.3), a condition that persisted in August and September. The leakage contribution of floodplain wetland to the river in August was 97.28 mm, increasing to 172 mm in November as rainfall reduced. In 2005, contribution of floodplain wetland to the river was 86.01 mm, while the river contributed 131.63 mm. The period from September 2004 to December 2005, a total simulated recharge of 444 mm from HYDRUS-1D applied to the wetland system, out of which 169.21mm leaked into the wetland from the river. Conversely, a total of 215.03 mm leaked out of the wetland system to contribute to the sustenance of the White Volta River. In this situation, floodplain wetland contributes as base flow to the White Volta River in the dry season. The total amount of water 556.75 mm moving out of the storage in the 16 month period is only for the simulation period, and becomes depleted during the dry season. The full cycle of the dynamics of hydraulic head simulation to indicate floodplain wetland and the White Volta River interaction from September 2004 to December 2009 is show in (Figure 1.9).

Table 1.3 Cumulative mass balance

2004	2005	Sept. 2004-Dec.2005	
IN:	mm	mm	mm
Storage	36.23	61.76	171.87
River leakage	2.31	131.63	169.21
Recharge	159.67	221.11	421.64
Total In	198.21	414.50	762.72
OUT:			
Storage	141.33	338.57	556.75
River leakage	58.91	86.01	215.03
Total out	200.24	424.58	771.78
In - Out	-2.03	-10.07	-9.06

During the rainy season between June and September 2005, the hydraulic head in the Pwalugu floodplain wetlands increased from an average of 137.79 m to 139.43 m, but started declining from October 2005 where the hydraulic head was 138.38 m. The extent, depth, frequency, timing and duration of water ponding at the surface of the wetlands are important parameters controlling the extent of soil moisture for the sustenance of the river. For instance, ponded water in the Pwalugu wetland to a depth of 0.50 m measured during fieldwork in August 2005 results from a complex and variable combination of groundwater upwelling and accumulation of rainfall on the saturated surface. Saturation of the entire wetland was rarely achieved in 2004, because of frequent breaks in rainfall pattern with longer dry spells. In addition, the geological formation within the study area is Voltaian sandstone. The formation is a poor water retention system, and water stored during the rainy season is not readily transmitted to other parts of the system.

The internal conceptualization of Pwalugu floodplain wetland is based on a semi-confined one-layer system with differing hydraulic characteristics. However, the interaction between the White Volta River and floodplain wetlands takes place in one of these three basic ways: 1) rivers gain water from inflow of groundwater through the riverbed, 2) river lose water to groundwater by outflow through the riverbed or both, or 3)river gain in some reaches and lose in others. The manner of interaction between the Pwalugu floodplain wetland and the White Volta River depends upon the processes controlling the recharge, floodplain morphology and hydraulic properties of the system. In this setup, the amount of water delivered to the water table is controlled by the geological formation. Another issue of concern is the estimation of spatial distribution of recharge, and this can only be estimated if accurate information on the magnitude and distribution of aquifer properties is available.

A correlation of 0.78 is established between the weighted residuals and weighted simulated values (Figure 1.12), although they are assumed to be independent of each other. Conversely, the model was found to have well identified parameters; however the model results were sensitive to the values of input parameters. Therefore, the application of the MODFLOW model will be more reliable for decision making.

Conclusions

The hydrology of the wetlands found in the basin is complex characterized by spatial and temporal variability of their volume and surface area.

The White Volta River catchment is experiencing climatic, hydrologic and vegetation changes. This research was conducted to examine the essential role floodplain-wetlands play in stream flow within the White Volta basin, in order to ensure good management and a sustainable level of water resource usage. This research shows that changes in floodplain-wetland characteristics have ramifications on surface water flow.

Data collected for the study are derived from field measurements, field observation and laboratory analysis.

The hydraulic connection between the White Volta River and floodplain wetland varies temporally and spatially because of intervening unsaturated zones. To establish the form of interaction that goes on between the main river and floodplain wetlands within the White Volta basin, PM-WIN(MODFLOW) was specified using lower boundary discharge from the HYDRUS-1D model as estimated groundwater recharge. This input quantifies the temporal and spatial variations in the interaction between floodplain wetland and stream flow. Prior to simulation, parameters were calibrated to obtain a tolerable distribution of initial hydraulic head. The calibration process reduced the error of discrepancy from -0.69 to 0. The HYDRUS-1D bottom flux used as an estimate of groundwater recharge gave a better fit between the simulated hydraulic head and observed sub-surface water level fluctuation. This level of compatibility gives indications that the model calibration needs to be improved.

The simulation of the sub-surface hydraulic head of the wetland indicates a systematic variation relative to the White Volta River in response to changes in the rainfall pattern. The interaction conditions vary from season to season with March, April, and May showing the least leakage (estimated values of 0.03mm/day, 0.06mm/day and 0.15 mm/day, respectively) from the river into the floodplain, although the expectation is that floodplain wetlands serve as a moisture buffer and supply the river with water during the low season. Nevertheless, the interaction between the wetland and the river as simulated is bidirectional. With most of the flow coming out from the river, this condition persists in the months of August and September.

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