Paper:

Japan-Egypt Hydro Network: Science and Technology Collaborative Research for Flash Flood Management

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The present paper outlines the development of a shared hydraulic and hydrology-based network between Kyoto University and three institutional research units in Egypt that seeks to bridge the gap in research, education and practice. This network base was developed the contextualized problems facing the water resources sector in Egypt. Although Sinai Peninsula, Egypt, suffers from severe water shortages, flash floods are responsible for the loss of lives and other problems. One of the JE-HydroNet (Japan-Egypt Hydro Network) outcomes is to forecast flash floods and to propose mitigation strategies in order to reduce the threat of flash floods and water harvesting. An integration of remote sensing data and a distributed Hydrological model so-called Hydro-BEAM (Hydrological River Basin Environmental Assessment Model) has been proposed for flash flood simulation at Wadi-El-Arish, Sinai. Simulation has been successfully carried out to flash flood event that hit Egypt in January, 2010. Simulation results present remarkable characteristics such as the short time to maximum peak, short flow duration, and severe damage resulting in difficulty in evacuating people from the vulnerable regions. The methodology developed to forecast flash floods considering mitigation strategies which can be applied effectively at different arid regions.

Keywords: collaborative research in science and technology, Nile River Basin, delta of Egypt, Japan Egypt Hydro Network (JE-HydroNet), Wadi El-Arish – Sinai Peninsula of Egypt, flash flood, HydroBeam

1. Introduction

The gap in education, research and practice in the hydraulics and hydrology field is recognized by many aspects. Bridging the gap can be achieved by involving practitioners in education and training, and specifically in life-long learning processes. Hydro-engineering projects are becoming more and more complex and have to be carried out in close cooperation by several experts from different disciplines and locations. Under the umbrella of the Global Center of Excellence – Sustainability/Survivability Science for a Resilient Society Adaptable to Extreme Weather Conditions (GCOE-ARS) project at Kyoto University, a joint project for research and education was established between Kyoto University and three institutional research units in Egypt, i.e., Assiut and Alexandria Universities, and the National Water Research Center, Ministry of Water Resources and Irrigation. Egypt is an arid country where the annual precipitation is only 25 mm in Cairo, and totally depends on the Nile. The water resources system of Egypt faces a number of serious problems, including the Nile River basin upstream and at Nasser Lake, downstream from the Aswan High Dam, delta, irrigation and drainage networks, coastal, and energy resources.

Furthermore, the impact of climate changes on the water resources system has become a challenge for the country. Accordingly, the main objectives of the network is to assess the vulnerability of the Nile Delta coastal zone to climate change/sea level rise and to design effective strategy based on an adaptation policy framework. Climate change adaptation strategies will be vital to countries such as Egypt. Adaptation options for Egypt's water resources, meanwhile, are closely intertwined with Egypt's development choices and procedures. Mitigating climate change will closely resonate with mitigating water scarcity and is likely to require the implementation of water demand management strategies that may require capacity building and raising awareness throughout institutions and society. Mitigation measures on the supply side include ways for improving rain-harvesting techniques, increasing the extraction of ground water, water recycling, desalination, and improving water transportation. In addition, regular review and updating of drought responses and research into improved long-term forecasting are essential to enhancing Egypt's ability to cope with prolonged drought. Egypt is suffering a water shortage that increases gradually. Away from the Nile and especially in the Eastern Desert and Sinai Peninsula, renewable water resources are limited to the very small amount of rainfall that, in some cases, causes flash floods. These flash floods in the Wadi System if properly managed, would serve the needs of the fragile communities located in the desert.

Flash floods are the result of heavy short period storms, and the velocity of floodwater depends mainly on the topography of the Wadi and soil characteristics. Flash floods cause severe damage and loss of life. They also represent a constraint on regional development, and a major source of erosion and pollution. Floodwater can, however, also be an important source of water replenishment in arid regions. The wise use of floodwater in these areas is therefore important for the sustainable management of water resources. The Belgian-Egyptian project FlaFloM (Flash Flood Manager) is designed to develop and to implement an integrated flash flood management plan for the Wadi Watier area of South Sinai. The Flash Flood Manager Project (FlaFloM) is jointly funded by the Government of Egypt (GOE) through the Ministry of Water Resources and Irrigation (MWRI) and by the European Commission (EC) through LIFE [1].

Up to now, no proper protection from flash floods has been proposed for all Wadi basins in Egypt. Unfortunately, there is often a lack of data on key hydrological processes in arid areas [2]. This limits the ability to understand the flooding process and use this knowledge to minimize its threat to human health and well-being. One of the main outcomes for JE-HydroNet is to develop and implement an integrated flash flood management strategy for Wadi El-Arish, Sinai Peninsula, Egypt, based on stakeholder and practitioners participation. The main obstacle to study flash flood is clearly the lack of reliable observations in most of the flash flood prone basins, so there is an urgent necessity to develop a new methodology to simulate and forecast flash floods in arid regions. Various problems associated with forecasting flash floods caused by convective storms over semi-arid basins have been studied [3]. Hydrological models of varying complexity approaches are applied to provide detailed estimates of flow processes for ungauged regions where, providing a general analytical framework for assessing the dependence existing among spatial rainfall organization, basin morphology and runoff response [4]. Distributed hydrological modeling was performed with TOPMODEL and assessed for ungauged basins with discharge estimates of post-event surveys [5]. A spatially distributed hydrological model was also developed for flood simulation based on physical process representation [6]. A distributed hydrologic model is used in conjunction with threshold frequencies to improve the accuracy of flash flood forecasts at ungauged locations [7]. Hydrologic characteristics of flow discharge have been discussed using both one- and two-dimensional models, showing the acceptable values of the two-dimensional model [8]. Despite these models having been developed, however, arid regions still lack a distributed hydrological model for flash floods forecasting.

In order to achieve our target, the analysis of geography, geomorphology, geology, hydrology and hydraulics, vegetation, land use, flash flood history, and flash flood characteristics has been performed throughout Geographic Information System (GIS) and Remote sensing data integrated with the physical-based hydrological model. In conclusion, the methodology developed to forecast flash floods considering preventive and mitigating strategies can be used in advance for taking emergency actions for evacuating people so that their lives and property may be saved and minimized.

2. Concept of the Network, Objectives, and Road Map

Following Academic Exchange Agreements between the Disaster Prevention Research Institute (DPRI) Kyoto University (Japan) and the Faculty of Science of Assiut University (Egypt), a sincere and friendly discussions with a view to strengthening research and education, to promoting cooperation on scientific exchange and the public understanding of science and technology, have been started between Kyoto University and two other institutional research groups in Egypt. The concept of network partners and tasks is illustrated in **Fig. 1**.

This network is unique, first, in the sense that groups of international experts from very distant a priori scientific fields (hydraulics, hydrology, flash flood and hazard mapping, dam operation, coastal management, sediment management in reservoirs, and numerical and experimental modeling) initiated the Japan Egypt Hydro Network (JE-HydroNet), as well as the strong extensive knowledge and decision making responsibility of the National Water Research Center (NWRC), Ministry of Water Resources and Irrigation (MWRI). Second, a group of researchers at DPRI, Kyoto University and Assiut University have simulated flash flood and ground water problems in the delta and the hydrology of the whole Nile Basin, by using an integrated hydrological model, i.e., the Hydro-BEAM (Hydrological Basin Environmental Assessment Model) [9].

2.1. Specific Objectives of the Network and Applications

Improvement of the flexibility, availability, sustainability and environmental impacts of water resources in the Nile Delta by developing an advanced methodology for operation, monitoring, planning and management of the water resources problem by focusing on:

- Setting-up potential hazard maps with a global flash flood warning system,
- Assessing and evaluating Wadi basins during flash flood events,
- Adapting to potential climate change,

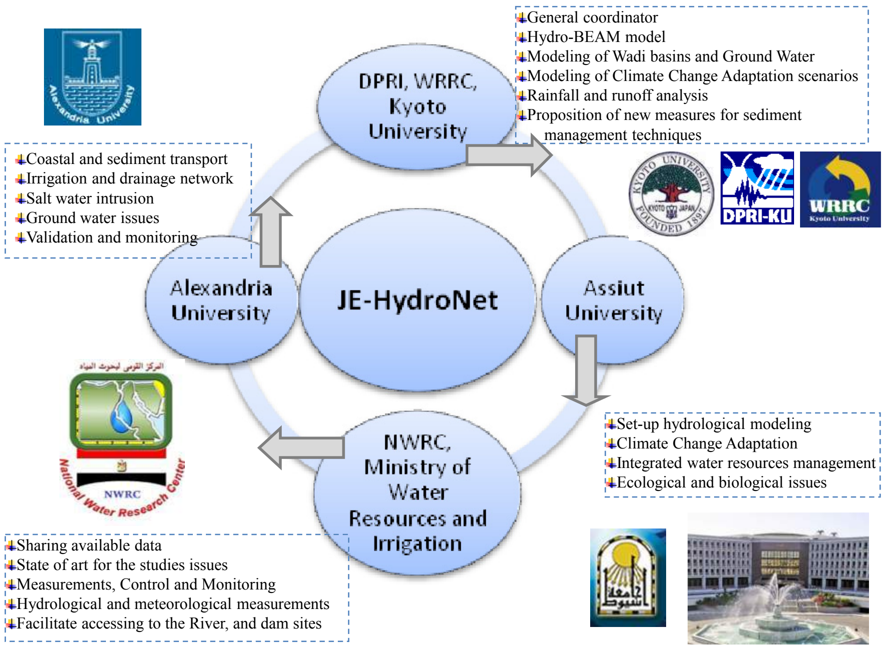

Fig. 1. Concept of network and partners main tasks.

- Ensuring sustainable integrated sediment management,
- Minimizing coastal erosion,
- Optimizing dam operation,
- Bettering the potential of young researchers: helping them enhance their effectiveness as research group leaders and increase the results they achieve with modelling and measurements,
- Allowing participants to practice and sharpen their skills in interpersonal communication,
- Analyzing problems of flash floods, climate changes, ground water modelling, sediment management and coastal problems,
- Clarifying final discussions about continuation of the project, research methodology, and exchange data and experiences methods.

Additional benefits through cooperation are:

- Regular seminars for exchanging experience,
- Research students exchanges at the Master, Ph.D. and postdoctoral levels,
- International publications;
- Solution to local problems in Egypt and the sharing of experiences with Japanese researchers.

JE-HydroNet will be implemented as a scientific network for exchanging young researchers and information among related institutions towards a consistent standardized methodology for management, and for proposing mitigation projects. An early warning system for flash floods is planned to be implemented for Wadi El-Arish. To make useful output for management decisions, a master plan on flash flood management and an emergency response plan will be developed by local authorities and the helps of Japanese counterpart as shown in **Fig. 2**. Because flash floods are particularly common in arid and mountainous regions, it is the aim of MWRI to extend the system to all high-risk zones in Egypt.

- Planning and design of flash flood control will be the responsibility MWRI, Egypt.
- The main application of the project will be protection of the city of El-Arish from flood hazards, by reducing the frequency and minimizing damages produced by flash floods.
- The project will set up an innovative system for rainfall forecasting and early warning for flash-floods in the pilot area of Wadi El-Arish.
- Based on rainfall-runoff and hydrodynamic modeling, flood-risk maps will be derived, and the best-storage options and suitable protection against flood measures will be identified.
- The project will develop a master plan for flash-flood management and an emergency-response plan with local authorities in the pilot area.
- Flood retention structures such as dry dam can be constructed using innovative updated Japanese technology and other new construction methodology such as Cemented Sand and Gravel techniques (CSG).

2.2. Description of Road Map for Cooperation

Participants expressed their views concerning the most important open question that the network should address

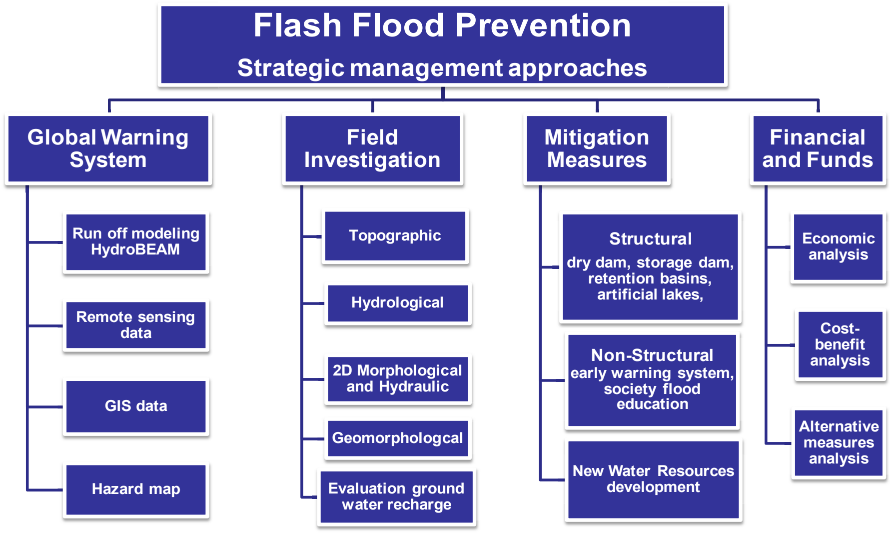

Fig. 2. Flash flood project methodology and prevention strategic management approaches.

in the near future. The following is a summary of the main points addressed:

1) Impacts of climate changes on the Nile Basin and the Delta in Egypt,
2) Integrated water resources managements including irrigation and ground water,
3) Reservoir sustainability management,
4) Coastal management,
5) Flash flood disaster management,

There was widespread understanding that we should build a data sharing website for exchanging data and starting real cooperation between groups. Some of the roadmaps for future steps are summarized as follows:

- Establishment of JE-HydroNet data sharing, and observational station for measurements,
- HydroBEAM, SiBUC, groundwater models development and provision to Egyptian researchers,
- Fund Raising and Promotion of young researchers for Ph.D. study in Japan.

3. Flash Floods Simulation and Adaptation

3.1. Problem Statement

Ascribable to the aforementioned problems and characteristics of flash floods in arid regions, efficient integration using remote sensing data and a distributed hydrological model have been proposed for flash flood simulation in order to understand the characteristics and hydrological behaviors of flash floods. Consequently, proposing appropriate strategies of mitigation in arid regions as well as flash flood water management to overcome the scarcity of water resources in such regions is needed. The main objective of this case study application is thus to simulate flash floods at Wadi El-Arish at Sinai Peninsula, Egypt. It takes into consideration the distribution behaviors of flash floods, assessing and evaluating the contributed water flow of wadi basins during flash flood events to be utilized as a significant water resource, and proposing mitigation strategies to reduce the threat of flash floods.

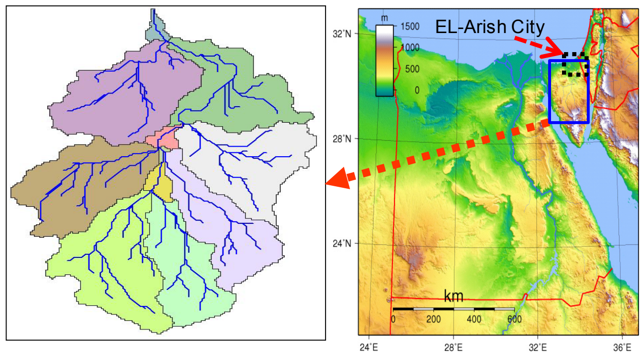

Fig. 3. Location map of Wadi El-Arish, Sinai Peninsula, Egypt.

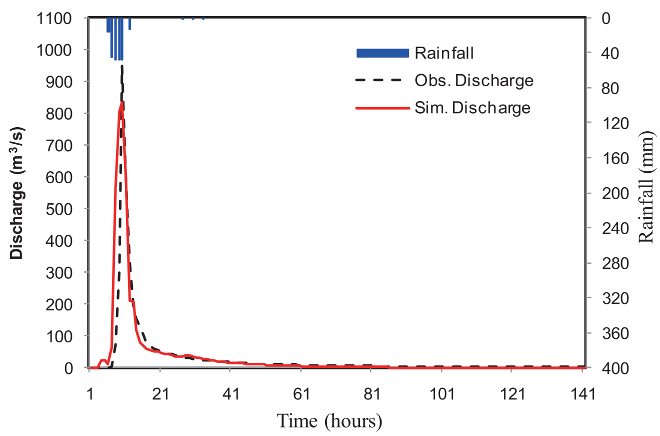

Fig. 4. Model calibration and validation at wadi Al-Khoud, Oman, during the event of (Mar. 18, 2007) [11].

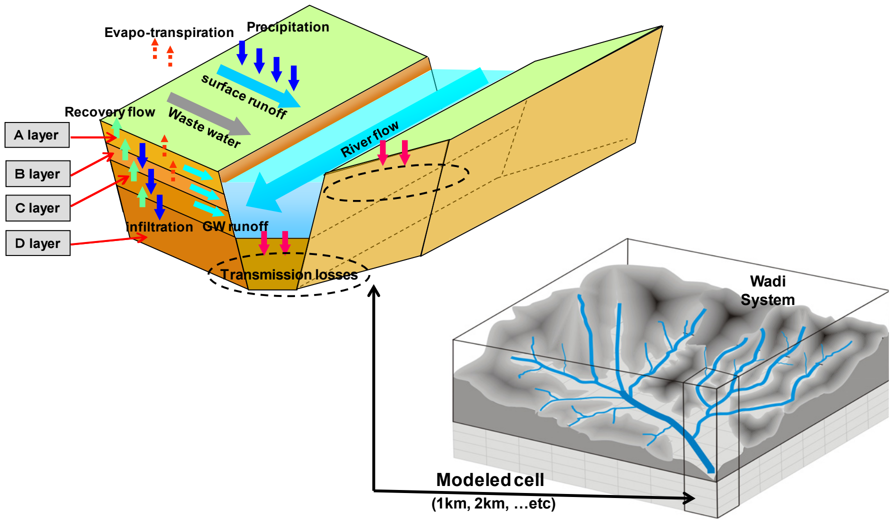

Fig. 5. Conceptual model of Hydro-BEAM [12].

3.2. The Target Wadi Basin

Wadi El-Arish is located on the Sinai Peninsula, Egypt, it flows toward the Mediterranean Sea and its downstream part is El-Arish City, as shown in **Fig. 3**. This wadi infrequently receives flash flood water from much of northern and central Sinai which make a great threat to the life and property of El-Arish City residents. It is the largest ephemeral stream system on the Sinai Peninsula. Its catchment area is calculated to be 20,700 km^2.

3.3. Methodology

A physical-based distributed hydrological model and remote sensing data as well as a GIS technique have been integrated to simulate flash floods in arid regions. The Hydro-BEAM (Hydrological River Basin Environmental Assessment Model) which was the first developed by Kojiri, et al. [10], and was calibrated and validated at Wadi El-Khoud, Oman, (**Fig. 4**) as Hydro-BEAM-WaS (Hydrological River Basin Environmental Assessment Model Incorporating Wadi System) by Saber et al. [11] and Saber [12] to be applicable to wadi systems in arid regions. It is used as a physical-based model with GSMaP [13] as remote sensing data that was calibrated with Global Precipitation Climatology Center data (GPCC) [14] in order to overcome the lack of observations in such areas.

Hydro-BEAM consists mainly of; watershed modeling using a GIS technique, surface runoff and stream routing modeling based on using the kinematic wave model, initial and transmission loss modeling estimated by using a Soil Conservation Service (SCS) method [15] and Walter's equation [16], and groundwater modeling based on the linear storage model (**Fig. 5**).

3.4. Flash Flood Simulation

GSMaP data of precipitation has been used with Hydro-BEAM for flash flood simulation at Wadi El-Arish, Sinai Peninsula, Egypt. Simulation of the flash flood event of January 18-20, 2010 was discussed because it had a big effect on residents and their property at W. El-Arish as well as other regions upstream in the Nile River. Six outlet points have been selected based on sub-catchments of the target wadi for this simulation as depicted in **Fig. 6**. Simulation results of this event show that flash flood characteristics are highly variable from one outlet to another in terms of flow rate and time needed to reach the maximum peak within the whole watershed (**Fig. 7**).

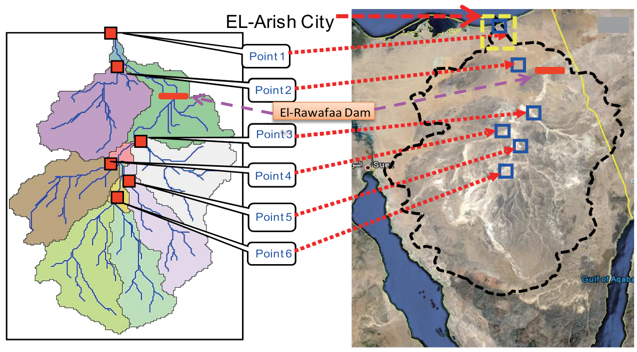

Fig. 6. Wadi El-Arish catchment, Sinai Peninsula, Egypt, in squares the target outlets for flash flood simulation and the location of El-Rawafaa Dam.

Furthermore, at the downstream outlet at W. El-Arish catchment, the flow was very severe, at 2864.84 m^3/s. At W. Abu-Tarifieh, one of the sub-catchments of W. El-Arish, discharge was calculated about 240.52 m^3/s, and the discharge of all sub-catchments was also calculated. Time to peak and flow duration in flash flood simulations have been estimated. Time to peak averaged between 8 hours in the upstream regions and 17 hours at downstream outlets, which means that time is very short. In other words, evacuating people is very difficult in such arid regions. In terms of the evaluation of sub-catchments water contribution towards W. El-Arish, the flow volume of water that can reach the downstream point of each sub-basin has been calculated (**Table 1**).

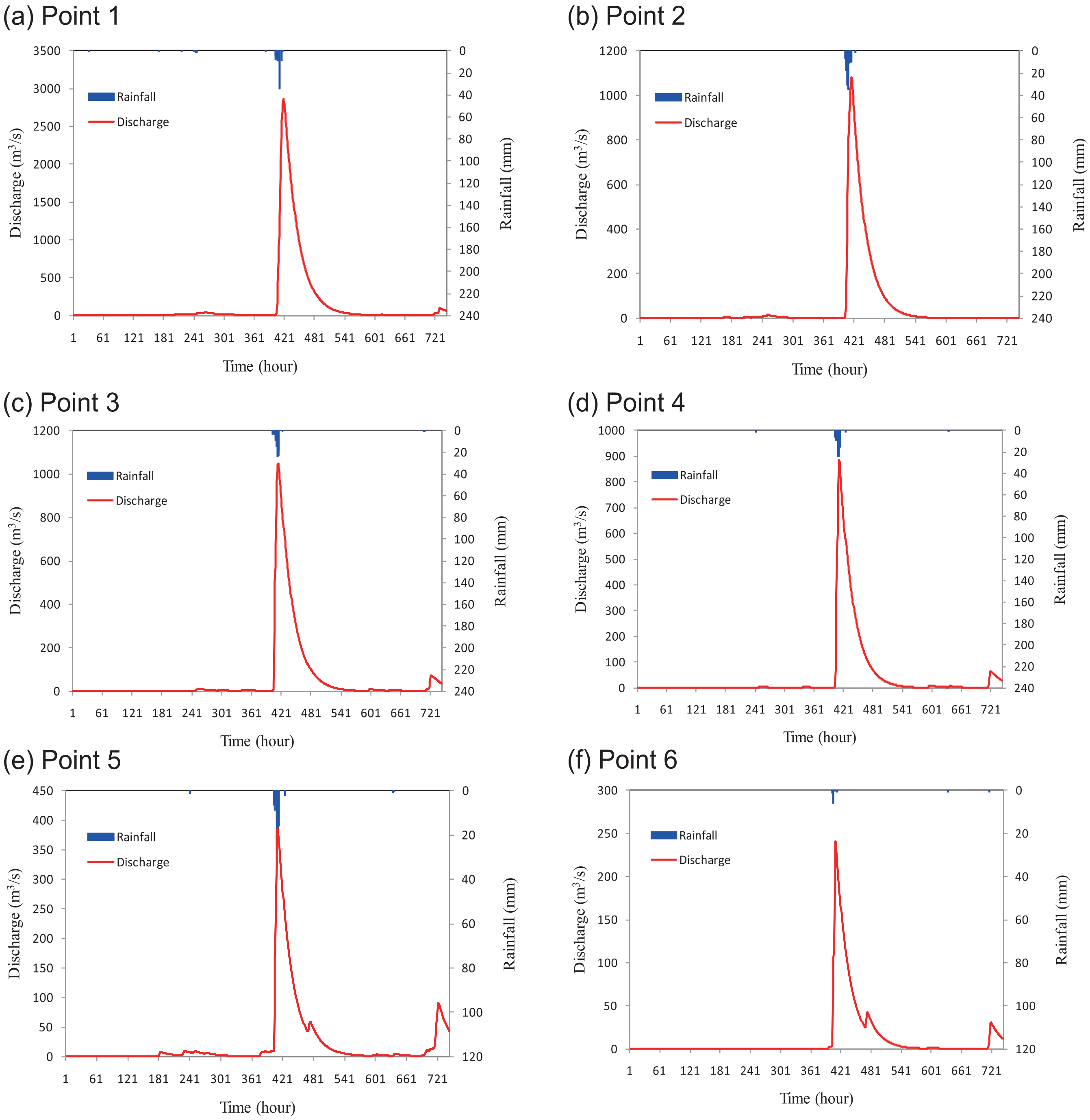

Fig. 7. Simulation of flash flood event of (Jan. 18-22, 2010) at several sub-catchment outlets of Wadi El-Arish: a) Point 1, b) Point 2, c) Point 3, d) Point 4, e) Point 5, and f) Point 6.

From distribution maps of flash floods (**Fig. 8**) at the target wadi, discontinuous flow is perfectly depicted as one of the characteristics of ephemeral streams, revealing that the proposed model depicts this important surface flow behavior in arid environments.

3.5. Flash Flood as Significant Water Resources

Water resources management is a crucial and important issue in arid regions due to the shortage of rainfall, high evaporation and transmission losses, as well as increasing population, coupled with limited water resources and attendant increases in the need for water. Flash floods are devastating and represent a big threat to human life and arid environments, but can also be utilized and managed in a proper way to make such floods useful as water resources. In this study, one of the significant targets is thus to evaluate the flash flood water as an additional water resources. The contribution of some wadi sub-basins into W. El-Arish is numerically estimated during the simulated event as listed in **Table 1**.

The water contribution from sub-catchments towards

Table 1. Simulation results of event (Jan.18-22, 2010) at W. El-Arish.

Sub-catchments of Wadi El-Arish Outlets	Location	Time to peak (hr)	Peak discharge (m^3/s)	Flow Volume (m^3)
W. El-Arish (Point 1)	33.8E, 30.7N	17	2864.84	3.54×10^8
W. El-Arish (Point 2)	33.8E, 30.4N	14	1080.38	1.26×10^8
W. Griha (Point 3)	33.9E, 29.9N	13	1050.41	1.26×10^8
W. Elbarok (Point 4)	33.7E, 29.8N	10	885.38	9.9×10^7
W. Eqabah (Point 5)	33.8E, 29.5N	7	386.66	4.5×10^7
W. Abu-Tarifieh (Point 6)	33.7E, 29.4N	8	240.52	2.7×10^7

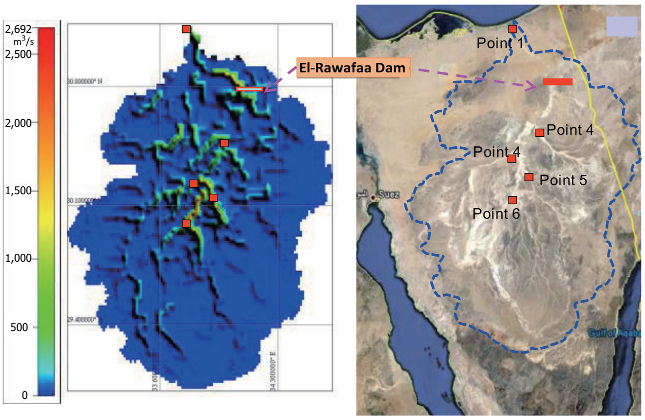

Fig. 8. Distribution maps of discharge of Jan. 2010 flash flood event at Wadi El-Arish, Sinai Peninsula, Egypt, showing discontinuous flow of discharge (red marks are the position of sub-catchments outlets of simulation).

(a) (b)

Fig. 9. (a) El-Rawafaa Dam before the flash flood, and (b) during the flash flood event in January, 2010, showing how much of the water is overflowing the dam.

W. El-Arish during flash floods has been recorded. Also, it was noted that contributed water flow volume at downstream points of wadis varies from one wadi to another, depending mainly on watershed characteristics, rainfall distribution, and hydrological conditions of these subcatchments as depicted on distributed maps of discharge (**Fig. 8**). Throughout the study of the effect of flash floods on W. El-Arish Delta aquifer, it was found that there is deterioration in groundwater levels and increasing water salinity due to exceeding of abstraction compare with recharge to the aquifer [17]. To this extent, it means that there are no reasonable strategies for how to utilize and manage the water of flash floods properly so that it is useful in the conjunctive use of surface and subsurface water to cover water demand.

3.6. Flash Flood Mitigation

Simulation results of flash flooding at W. El-Arish on the Sinai Peninsula show how much the extent of the threat of flash floods in wadi basins. It was seen from distribution maps, that flash floods are highly variable from one wadi to another, depending on rainfall events in spatial and temporal distribution, and geomorphologic and topographic conditions at wadi catchments. Remarks on the spatial variability of flash flood occurrence are illustrated in the flash flood event of January, 2010 where the most affected regions are at the middle of the catchment and around the El-Rawafaa Dam as shown in **Fig. 8**. In the real situation, the area around El-Rawafaa dam has been affected by this flash flood. The government announced that more than 14 persons were killed in Sinai Peninsula as well as thousands of people becoming homeless during this event. These results exhibit the extent of the performance of the proposed model to predict flash floods in such regions. El-Rawafaa Dam (**Fig. 9**) was constructed in 1946 at North Sinai peninsula, Egypt, for the purpose of flash flood mitigation to protect downstream regions from flash floods. Its storage capacity is about 5.8 million m^3. It is about 350 m wide and about 15 m high. It is located about 40 km away from Al-Arish City along W. El-Arish. Current simulation of the flash flood of January, 2010, shows that the water volume that reaches to El-Rawafaa Dam is more than 100 million m^3. This means that it is extensively larger than the actual capacity of the dam, and hence, severe damage occurred in this region, leaving human losses and infrastructure damages.

Based on simulation results of this event, two scenarios have been recommended. The first scenario is to construct two dams at outlets of sub-catchments (W. Griha (Point 3), and W. Abu-Tarifieh (Point 6)) as shown in **Fig. 6**, in order to reduce the flow volume of flash flood water which is expected to reach the downstream regions at the El-Rawafaa Dam shown in **Fig. 8**. In this case, water flowing towards the Mediterranean Sea without utilization, could be managed as resources for recharge to the groundwater aquifer and the threat of flash floods will be alleviated in this area. The second scenario is to construct a rechargeable dam below the El-Rawafaa dam (**Fig. 9**) where accumulated water will be used for two options, the first option is as surface water for agriculture purposes because the region below the El-Rawafaa dam is plain and can be reclaimed for cultivation purpose. The second option is to be recharged into the subsurface aquifer of W. El-Arish Delta. Accordingly, the problem of groundwater level decreasing and salt water intrusion increasing will be solved at W. El-Arish Delta and securing flash flood water will be utilized properly as a means to overcome the problem of water scarcity in such regions.

4. Conclusion

This paper has attempted to weave together ideas drawn from research and education, and from practice in supporting the development of an international hydro network. Among several proposed topics presented has been a case study of flash flood management. We need a more focused research approach on collaboration and measurement development in areas of interest that are underpinned by complex relations to a variety of work-related practices. We need much more data and field measurement stations for validation and accurate simulations.

The JE-HydroNet was formed with the aim of bringing together leading researchers from various disciplines and institutional units that are active in the area of water resources in Egypt, together with people from industry who are responsible for practical implementations in Japanese companies. The network helps us better understand problems facing the Nile River System and Delta of Egypt and how these various groups of researchers are related to one another. It reminds us how, together, they can contribute to design and implementation better improving of flexibility, availability, sustainability and environmental impacts of water resources in the Nile Delta by developing advanced methodology for operating, monitoring, planning and managing the water resources problem. This initiative represents an exciting opportunity for creating an inclusive and dynamic research group of interest that bridges the gap in guidance research and practice. It will enable us to examine ways in which learning about guidance is created and shared (beliefs, concepts, ideas, theories, actions) as well as providing a potentially powerful engine for assisting in the search for new understanding of effective guidance that benefits all groups.

Integration using remote sensing data and the distributed Hydrological model of Hydro-BEAM has been proposed for flash flood simulation at W. El-Arish, Egypt. GSMaP has been compared with monitored data of GPCC, revealing that an overestimated or underestimated systematic seasonal bias is occurring. Simulation has been carried out on the flash flood event of Jan., 2010. The simulated results present remarkable characteristics such as that the time to peak is very short, resulting in difficulty to evacuate people from the vulnerable regions. Additionally, distribution maps of flash floods corresponding to rainfall data show that there is high variability in the occurrence of flash floods in space and time in terms of wadi characteristics and the time of a flash flood event.

The output of this study is summarized as follows: i) Simulation of flash floods has been successfully achieved at wadi sub-basins of W. El-Arish, ii) A commendable contribution of wadi sub-basins as water resources towards W. El-Arish during flash floods has been recorded, and iii) In proposing mitigating strategies for flash flood risk reduction at W. El-Arish, results have exhibited that flow volume reaching to the El-Rawafaa dam is higher than the dam's capacity, resulting in failure of the dam, the loss of human lives, and the occurrence of infrastructure damage.

In conclusion, the methodology developed to forecast flash floods proposing mitigation strategies and water resources management has been accomplished. Consequently, taking emergency actions for evacuating people in advance can be done so that lives and property may be saved and minimized. Further studies concerning flash flood simulation and mitigation in arid regions, will be considered in our next step based on detailed field works and observations.

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• "Study on Measurement of Fine Sediment Discharge Process during Sediment Flushing Operation using PIV," JSCE Annual Journal of Hydraulic Engineering, Vol.51, pp. 1075-1080, 2007 (in Japanese).

Academic Societies & Scientific Organizations:
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Selected Publications:
• "Hydrological Modeling of distributed Runoff Throughout Comparative Study Between Some Arabian Wadi basins," JSCE Annual J. of Hydraulic Eng., Vol.54, pp. 85-90, 2010.
• "A physical-Based Distributed Hydrological Model of Wadi System to Simulate Flash Floods in Arid Regions," J. of Hydro-Environment Research (Accepted, final process).

Academic Societies & Scientific Organizations:
• The Japan-Egypt Hydro Network on the Nile River System and the Delta of Egypt (JE-HydroNet)
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2011-present Associate Professor, Civil Engineering Department, German University in Cairo – GUC, Egypt

Selected Publications:
• "LSPIV implementation for environmental flow in various laboratory and field cases," Journal of Hydro-environment Research, Vol.5, No.4, pp. 263-276, 2011.
• "Channel formation in large shallow reservoirs with different geometries during flushing," J. of Environmental Technology, Vol.30, No.8, pp. 855-863, 2009.

Academic Societies & Scientific Organizations:
• The Japan-Egypt Hydro Network on the Nile River System and the Delta of Egypt (JE-HydroNet)
• The Syndicate of Engineers, Egypt
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• Member of Editorial Board, Journal of Water Sciences Research