FLASH FLOOD FORECASTING SYSTEM FOR LAI NULLAH BASIN (A CASE STUDY OF MARCH 19, 2007 RAINFALL EVENT)

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Abstract:

Two to six hours convective storm nowcasting hydro-meteorological model MIKE 11 is currently in use at the National Weather Forecasting Centre Islamabad for providing pre-alerts and warnings from flash floods in local stream known as Lai Nullah. Forecasters use this regularly updated (every 10 minutes), automated weather product as guidance in anticipating flash flood hazards for the stream. This system, which combines runoff and point rainfall recorded data, produces 2 to 6 hour precipitation rate and accumulation forecasts every 10 minutes for both meteorological and hydrological purposes; accurate warning for flash floods are a primary goal in the use of this tool.

On 20th march 2007, after 5 hours of intermitant showers from 2200 (19th Mar) till 0300 PST 20th morning, the system intensified and produced heavy rainfall over the catchments of the local stream termed as Lai Nullah. Consequently, the stream rose to alert level and necessary warnings were issued. The model reported corresponding alerts well and confidence on the system was established.

Introduction:

Pakistan is a disaster prone country. The country is frequently faced with a number of natural hazards that threaten to affect the lives and livelihood of its citizens like floods, earthquakes, landslides, cyclones, and droughts.

Recent advancements in science and technology have encouraged a remarkable growth in the development of reliable Early Warnings for most of natural hazards. These early warnings carry many potential benefits for reducing risks from natural hazards.

On 23rd July 2001, during the 10 hrs of extremely heavy rains in some what cloud burst proportion, the ridges of the twin cities were completely saturated by torrential rains. The heaviest rains ever recorded in the one hour were between 11am to 12 noon amounting to 181 mm. The local stream “called Nulla Lai” and all of its contributory streams, rose to such heights that the phenomenon will be remembered as the "2001 flash Flood." The Nullah Lai made a clean sweep of all surrounding buildings and some road bridges which crossed it. It was the worst flash flood ever experienced in the twin cities. There were other flash floods In the past. But most old timers say that those were "insignificant" compared to the current one.

After the devastating flash floods of July 2001 in Lai Nullah, a project was initiated for the improvement of flood forecasting and warning system for Lai Nullah basin. The

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project has been completed in March 2007. Under this project six rainfall measuring stations and two water gauging stations were installed and integrated through telemetry system for near real-time monitoring of hydro-meteorological conditions and input the data to hydrological model named Mike11 for flood risk analysis and flood forecasting (Annex-1).

The Hydrological Model MIKE11

It is an integrated model developed by Denmark Hydrological Institute (DHI) Water & Environment for river management. It is an industry standard for simulating flow and water level, sediment transport in rivers, reservoirs and other inland water bodies. It is comprehensive hydro-meteorological tool with a wealth of capabilities. It provides a versatile and comprehensive approach in river hydrodynamics. The flexibility and speed ensures a complete and efficient design for all aspects of river system.

Key Features:

MIKE11 consists of a hydro-dynamic core module and a number of add-on modules, each simulating a certain phenomena in the river system. The modular structure offers great flexibility because;

- Each module can be operated separately.
- Data transfer between modules is automatic.
- Complex physical processes can be coupled.
- Updation and expension of exixting modules with new ones is simlle.

For flash flood forecasting of Lai Nullah basin, two core modules; MIKE11-RR (Rainfall-Runoff Module) and MIKE11-HD (Hydrodynamic module) have been tuned as per climate and Terrain of the basin.

Computation of Rainfall and runoff are very important aspects in modeling river system. For this basin, Unit Hydrograph model (UHM) is being used as it is one of the most suitable model for short term and flood runoff simulation. The unit hydrograph is the unit pulse response function of a linear hydrologic system.

The hydrodynamic module (MIKE11-HD) is the core of MIKE11. It provides library of computational methods for steady and unsteady flow in branched and looped channel networks. HD module of the model simulates the river flow. One dimensional version of governing equations for momentum transfer and continuity of fluid flow are basic equations for MIKE11 – HD. To solve these equations, dynamic wave model option is applied for simulation of flood events. The surveyed data of the Lai Nullah basin is used for input as cross section data for modeling.

Antecedent Events on 20th March 2007 and Precipitation Analysis:

The heavy rainfalls that produce flash floods are the result of high rainfall rates that persist. Similarly, even a moderate rainfall rate can result in threatening rainfalls if it persists long enough. A rainfall that is concentrated within a single, "flashy" drainage basin may be vastly more dangerous than when the same meteorological event is

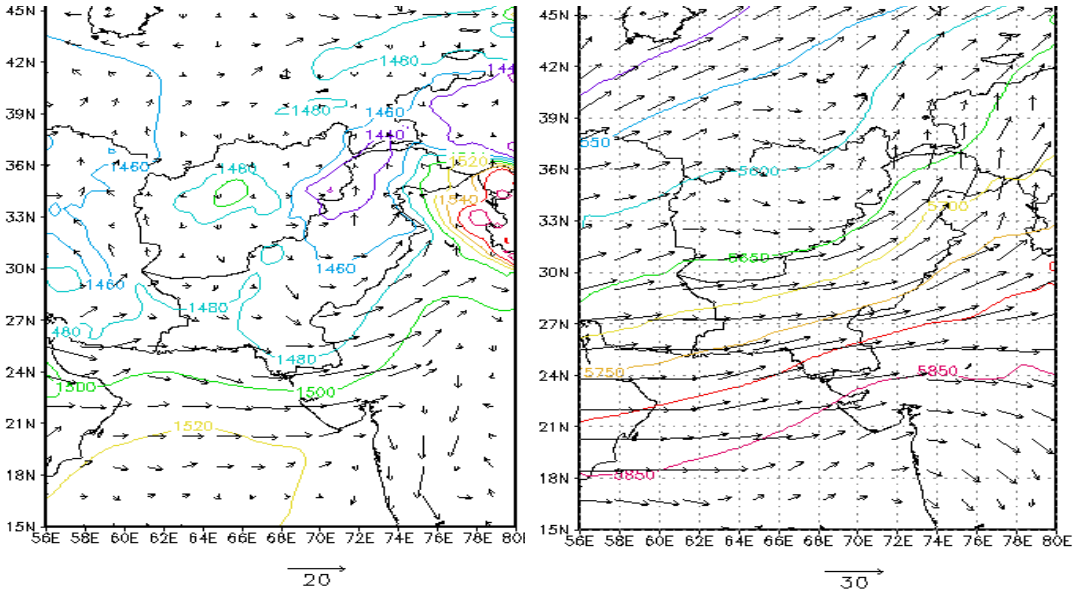
distributed among several basins, or within a basin with a large capacity to absorb rainfall.

On March 20th, the system precipitated with moderate intensity for more than six hours resulting in flash flood situation in Lai Nullah.

The following narrative briefly describes the rains that culminated in alarming level flash flood.

Cloudy skies greeted residents of twin cities on Monday, March 19, 2007. After many days of warm, dry weather, cooler temperatures were a welcome change. Skies remained cloudy into the early afternoon, but in mid afternoon the sun broke through. Cloud masses began to bubble upwards forming towers of billowing dark-bottomed cumulus clouds over the foothills of Margalla hills. The development continued till late evening. Thunder began to rumble, and by 2100 PST, the first torrents of moderate rain poured down in the northwest and another core of heavy rain fell farther northwest in Golra.

Fig. 1 Weather Charts at 850 hpa and 500 hpa on 20th March, 2007 at 00Z



Quickly the storm expanded southward, and sheets of rain splashed onto most of the catchment area of the Lai Basin. Thunder crashed and storm clouds spread eastward and southward out across Margalla hills. This first round of thunderstorms was quite typical of late Spring.

The prognostic weather charts of 850 hpa & 500 hpa on 20th March, 2007 depicted the approach of well marked low over northern parts of country. Southwesterly moist flow at low level and tropical maritime flow at upper level was evident to cause frontal activity resulting in moderate to heavy rainfall over the region.

Dark clouds continued to hug the area and the temperature remained steady. The air was still, and sounds seemed to carry a long way. Around 03:00 a.m. on 20th March, the thunder rumbled, the rain intensity began to increase. For a few hours the rains

intensified. Hourly intensity ranged from 9 to 15 mm/hour. Extreme rainfall rates may have begun earlier, but the first burst to reach the recording rain gauge at Golra on the Foothills (recording site in the extreme west) began shortly before 03:00 PST. Lightning activity increased around 0600 PST as heavy rains continued to fall. Minor street flooding became increasingly more serious over the western half of the catchment as the downpours continued.

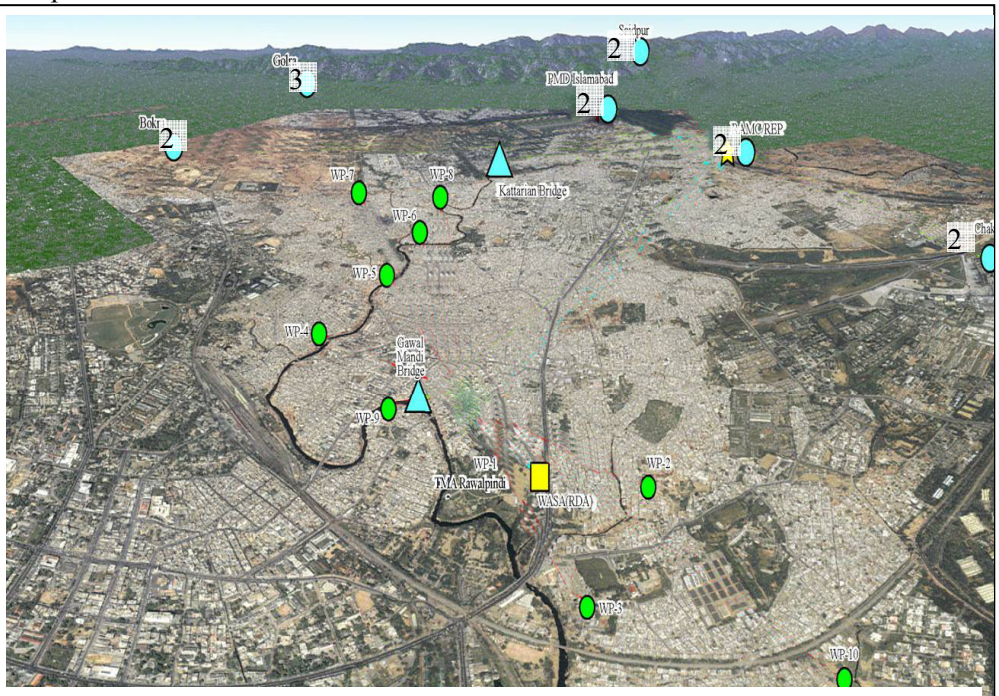


Fig-2 Precipitation Intensity (mm/hr) at 2200 PST on 19th March 2007 in the catchments of Lai Basin.

Maximum instantaneous rainfall rates exceeded 18 mm/hr at times. With these high rainfall rates falling on a surface already covered with flowing water, large volumes of water accumulated that moved downhill from approximately west to east initiating the road flooding situation (Annex 4).

The rainfall pattern from the March 20, 2007 morning storm in twin cities is shown in Fig-4. A relatively uniform rainfall gradient was observed southeastward from the storm center. This is an excellent demonstration of nearly uniform pattern in rainfall over an area which is an important characteristic of winter rainfall in this region.

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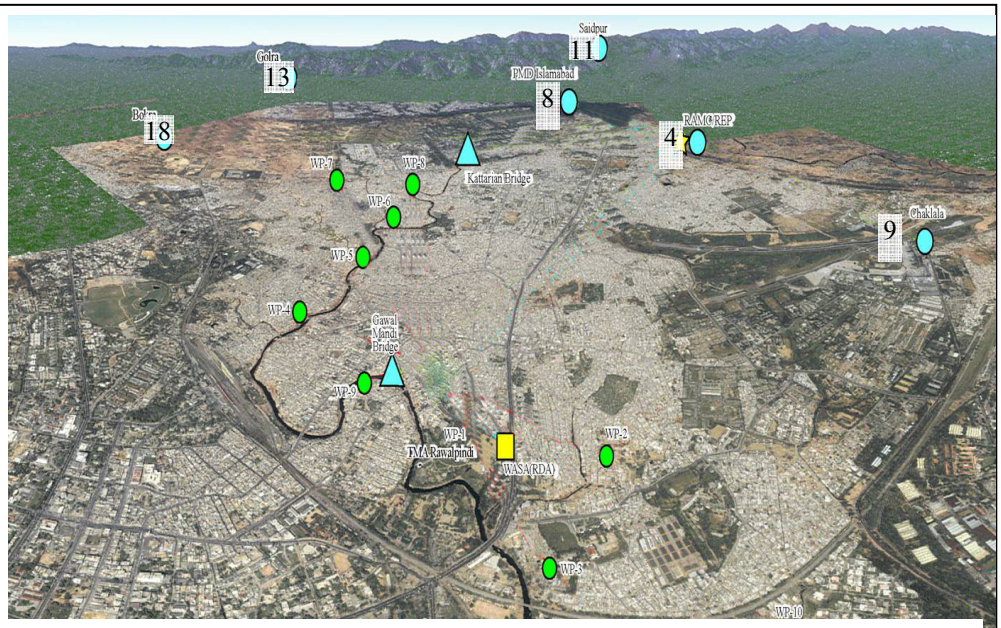

Fig-3 Precipitation Intensity (mm/hr) at 0800 PST on 20th March 2007 in the catchments of Lai Basin

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The core of the heaviest rains was immediately east of the Margalla hills at

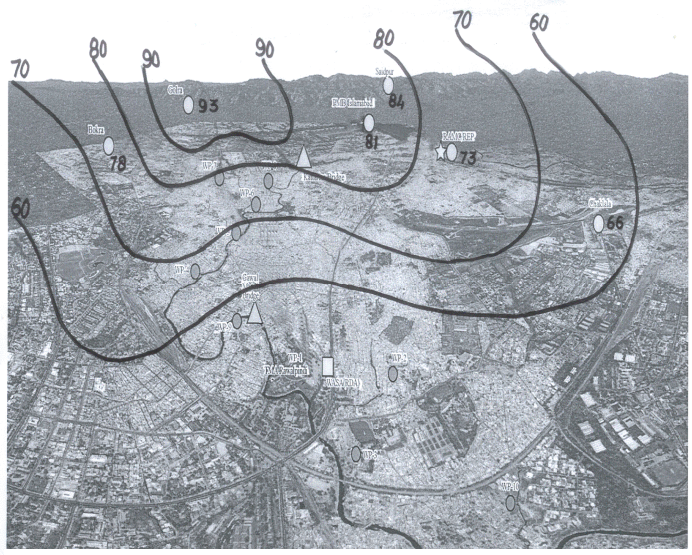

Fig-4 Analysis of precipitation amounts recorded in catchments of Lai Basin on March 19-20, 2007

Golra that marks the beginning of the foothills and serves as the western bank of catchment of Lai Basin. The band of heaviest rains reached northward from the storm center toward the towns of Golra and Saidpur and remained oriented parallel to the foothills. This positioning strongly suggests that topography played an important and perhaps controlling role in positioning this storm. South of Margalla, the rainfall diminished and spread out, but a secondary rainfall maximum was observed in the Chaklala.

The composite rainfall pattern shows that rainfall totals exceeded 90 mm in Golra and 78 mm rain was recorded at Bokra site; the upstream localities of Lai Baisn . Simulation from the MIKE11 model predicted that water level may rise to pre-alert warning level (Annex-II). Accordingly, Pre-Alert warning was issued to mitigation authorities. The measured water level is appended as annex-III. After 0900 PST, intensity of rainfall weakened, Weather surveillance radar network and satellite imagery also depicted the decay of the weather system over the area. Therefore, no evacuation alarm was issued.

Conclusions:

Accurate warning for flash floods is a primary goal in the use of this tool. The heavy rainfalls that produce flash floods are the result of high rainfall rates that persist. Similarly, even a moderate rainfall rate can result in threatening rainfalls if it persists long enough. Near Real-time availability of data and its processing capabilities are essential elements in predicting flash floods. The flood Warning System for lai Nullah Basin is highly robust in term of real-time monitoring of storm precipitation intensities (10 min, 30 min, 60 min) and combining runoff and point rainfall recorded data to simulate stream flow and accumulation forecasts every 10 minutes for both meteorological and hydrological purposes. As such the system is a useful tool for flash flood mitigation purposes.

Recommendation:

To increase the accuracy and lead time of flash flood forecasts and warnings, the NWS should continue to implement new technologies and techniques including (a) the Flash Flood Monitoring and Prediction program at all Weather Forecast Offices, (b) data assimilation systems that integrate radar and other operational datasets into coupled hydro-meteorological and hydrological models, and (c) data fusion systems.

References:

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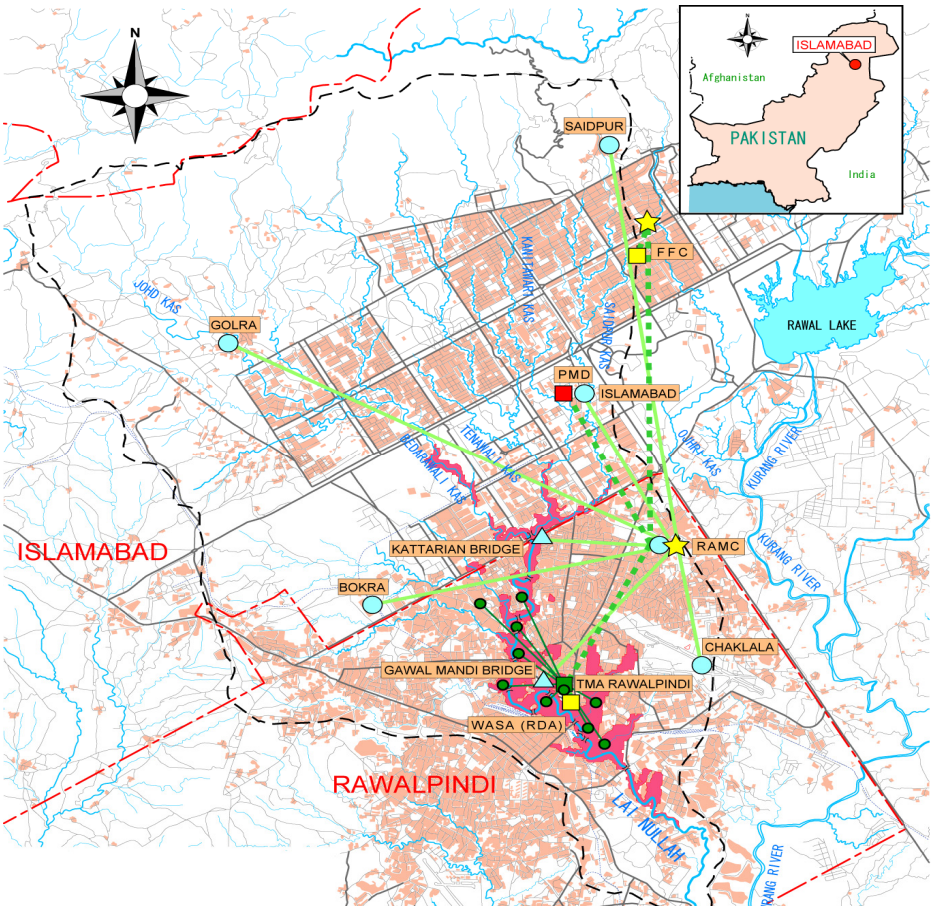
Bae, D. H., K. P. Georgakakos, and S. K. Nanda. 1995. Operational forecasting with real-time databases. ASCE Journal of the Hydraulics Division, 121, 49-60.

Baeck, M. L., and J. A. Smith. 1998. Rainfall estimation for the WSR-88D for heavy rainfall events. Weather and Forecasting, 13, 416-436.

Technical guide on flood warning centre for Lai Nullah Basin; volume III. Feb 2007. http://www.dhisoftware.com/mike11/News/news_Flood_Mapping.htm

Annex I: Lai Basin and Telemetry Network



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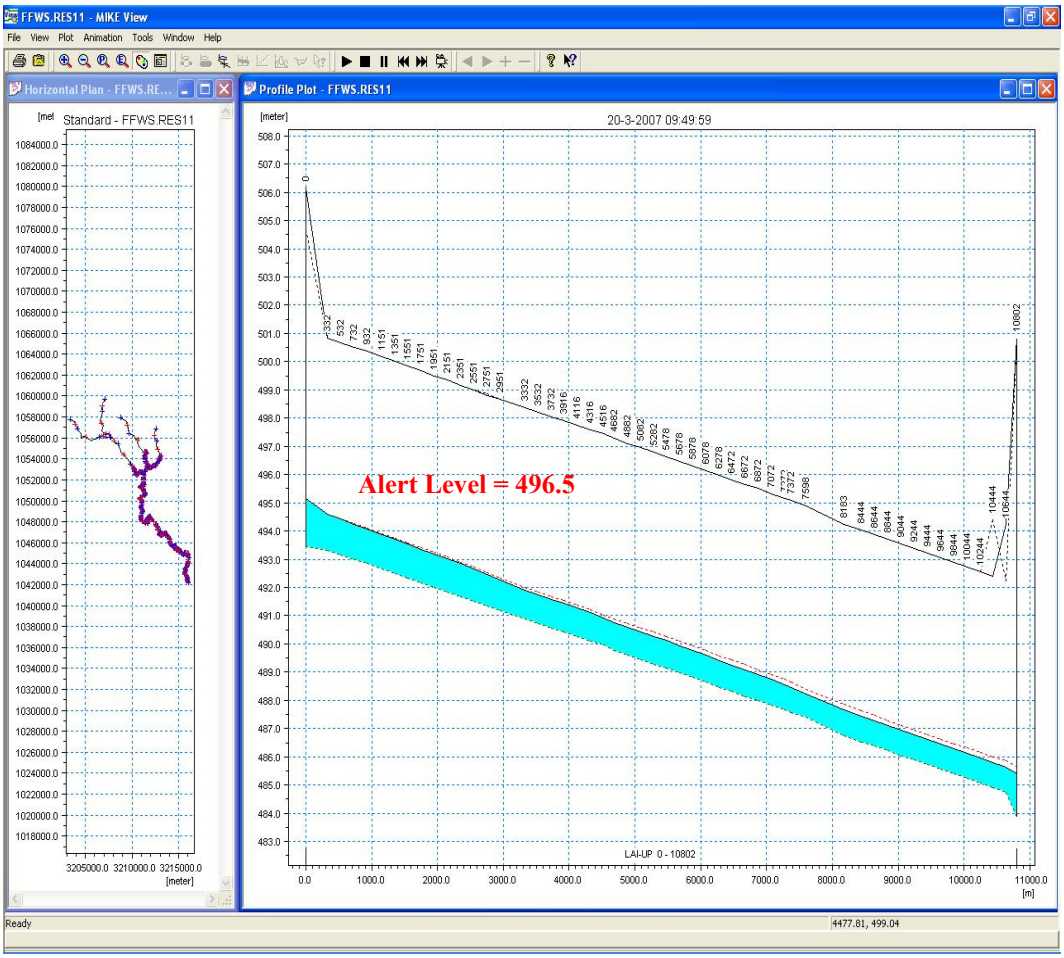
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Alert Level = 496.5
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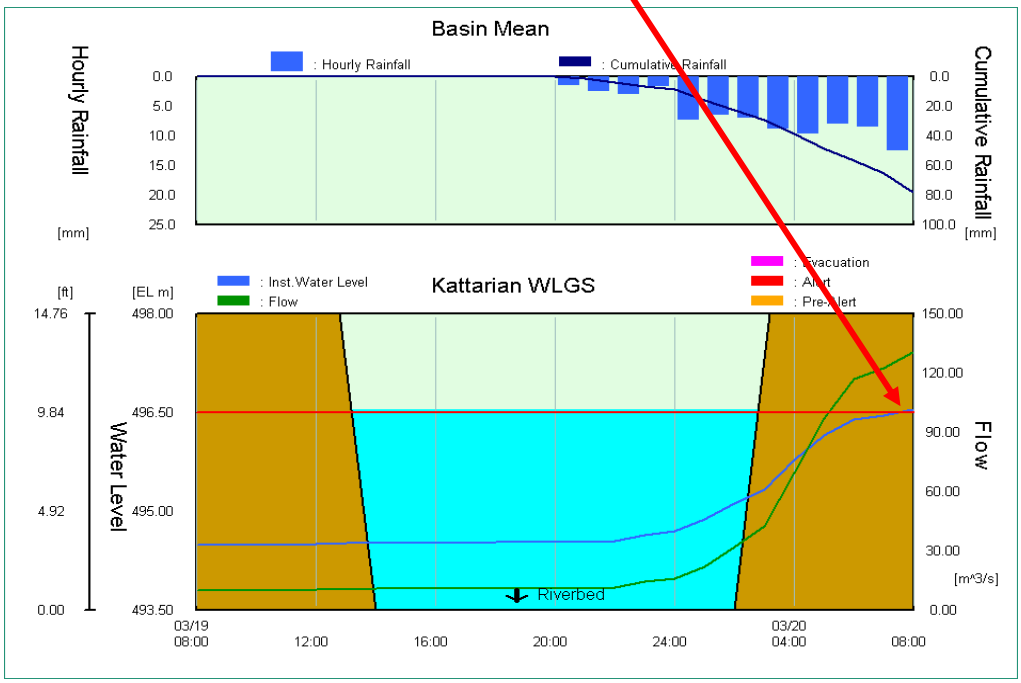
4477.81, 499.04

Annex III: Water Level at Katarian Bridge WLGS

Measured Date & Time	Inst. Water Depth [m]	W
Mar 19th,21:00	1.04	
22:00	1.05	
23:00	1.15	
24:00	1.21	
Mar 20th,01:00	1.38	
02:00	1.62	
03:00	1.83	
04:00	2.28	
05:00	2.66	
06:00	2.90	
07:00	2.96	
08:00	3.05	
09:00	3.16	
10:00	3.49	
11:00	3.02	

Water reached at Pre Alert Level at 0800 PST.



Annex IV: Rainfall recorded in the catchments of Lai Basin.

Measured Date & Time	Hourly Rainfall (mm)					
	Golra	Bokra	Chaklala	PMD	RAMC	Saidpur
Mar 19th, 24:00	2	1	1	2	1	2
Mar 20th, 01:00	7	6	6	9	8	9
02:00	10	5	6	4	5	4
03:00	4	8	11	8	12	10
04:00	7	10	12	10	13	9
05:00	9	10	8	11	8	11
06:00	9	8	6	7	6	8
07:00	6	7	3	13	9	12
08:00	13	18	9	8	4	11
09:00	15	5	2	4	2	7
10:00	1	1	0	0	0	2
11:00	2	0	1	2	1	5
12:00	1	12	0	0	0	1