Trend of Flood Peaks in Godavari Basin

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Abstract:

River Godavari is the largest peninsular rivers and third largest in India draining about 10% of the Geographical area of the country. CWC has started Hydrological Observation at various Stations in Godavari Basin from 1964 onwards and the Flood Forecasting started from the year 1975. The peak levels at various Flood Forecasting stations yearwise were taken for analysis of trend for the years for which data was available in CWC. The trend analysis has been done using linear trend lines as well as moving averages for 3 year period. The results of the study are given in detail with graphical outputs in this paper.

1.0 Godavari Basin and its flood problem

1.1 Godavari River System

The Godavari basin lies in the Deccan Plateau and is situated between latitude 16°16' N and 22°43' N and longitude 73°26' E and 83°07' E and is roughly triangular in shape and the main river itself runs practically along the base of the triangle.

The river Godavari, the largest of the peninsular rivers, and third largest in India, drains about 10% of India's total geographical area. The catchment area of the river is 3,12,812 sq. km and is spread in the States of Maharashtra (48.6%), Telangana (19.4%), Madhya Pradesh (10%), Chhattisgarh (10.9%), Orissa (5.7%), Andhra Pradesh (4.0%),and Karnataka (1.4%).

The river Godavari rises at an elevation of 1,067 m in the Western Ghats near Triambak Hills in the Nasik district of Maharashtra. After flowing for about 1,465 km., in a generally south-east direction, through Maharashtra and Andhra Pradesh, it falls into the Bay of Bengal.

The Godavari receives the waters of the Dharna on its right bank about 64 km from its source and about 30 km lower down the Kadana joins it from the left. The combined waters of the Pravara and the Mula that rise in the hills of Akola join the river from its right bank about 217 km downstream of its source. About 338 km further downstream, while still in Maharashtra, the river receives the combined waters from the Purna and Dudhna rivers and after a further 138 km at the border of Maharashtra and Telangana, the waters of the Manjira River join it from the south. At this point, the Godavari flows at an elevation of about 329 m.

The river Pranhita, conveying the combined waters of the Penganga, the Wardha and the Wainganga, which drain the southern slopes of the Satpura range, falls into Godavari about 306 km downstream of its confluence with the Manjira. 48 km lower, the waters of the Indravathi river join the Godavari. Both the Pranhita and the Indravathi are major rivers in their own right. The last major tributary is

the Sabari from Orissa that falls into the Godavari, 30 km downstream of Bhadhrachalam.

The largest tributary of Godavari is the Pranhita with about 34.9% coverage of drainage area. The Pravara, Manjira and Maner are notable right bank tributaries covering about 16.1%, the Purna, Pranhita, Indravathi and Sabari are important left bank tributaries, covering nearly 59.7% of the total catchment area of the basin. The Godavari in the Upper, Middle and Lower reaches make up for the balance of 24.2%. The particulars of the catchment area, length, elevation of the source points of the river and its tributaries in the order of their occurrence along the length of the main river are given in the following Table.

Table -1

Important Tributaries of Godavari

Sl. No.	Name of the River System	Elevation of Source (m)	Length of Tributary (km.)	Catchment Area (sq.km.)
1.	Pravara	1,050	208	6,500
2.	Purna	838	374	15,600
3.	Manjira	823	686	30,800
4.	Maner	533	225	13,100
5.	Pranhita	640	721	1,09,100
6.	Indravathi	914	535	41,700
7.	Sabari	1,372	418	20,400
8.	Main Godavari including minor tributaries	1,067	1,464	75,600

1.2 Physiography of the Basin

Except for the hills forming the ridge around the basin, the entire drainage basin of the river comprises rolling and undulating country - a series of ridges and valleys interspersed with low hill ranges. Large flat areas of the type characteristic of the Indo - Gangetic plains are scarce, except in the delta.

The western edge of the basin is an almost unbroken line of 129 km. formed by the Sahyadri range of the Western Ghats, forming a barrier of 600 to 2100 m height. It has the heaviest rainfall and the dampest climate in the basin. Hardly 50 to 60 km east of the Ghats lie the sparsely cultivated and undulating plains of the Deccan, with a dry climate.

The interior of the basin is a plateau, the greater part of which is at an elevation of 300 to 600 metres. Its general slope is eastwards, great undulating plains, divided from each other by flat topped ranges of hills, are the characteristics of this plateau. The hillsides are marked by conspicuous wide terraces except in the southern parts where the hills are frequently crowned with great 'tors' or rounded hummocks of bare rock, the result of ages of weathering.

The northern boundary of the basin comprises a series of table-lands varying from 600 to 1200 metres in elevation, which have withstood the effects of ages of denudation better than the terrain to the north and south of them. To the south,

lie great stretches of plain at an elevation of more than 300 m, interspersed with and surrounded by hill ranges, some bare and rocky, but generally covered with forests or scrub jungle.

The delta of the Godavari, formed by deposits at the mouth of the river over the ages, consists of a wide belt of river borne alluvium. The process of silting at the mouth of the river is still continuing and the delta is gradually extending into the sea.

1.3 Rainfall Pattern

The Godavari basin receives its maximum rainfall during the south-west monsoon. The monsoon currents strike the West Coast of the peninsula from the west and south-west, meet the Western Ghats or Sahyadri Range which present almost an uninterrupted barrier ranging from 600m to 2100m in height. Before surmounting this barrier the currents deposit most of their moisture on its windward side of Konkan and a small portion of Madhya Maharashtra, and then sweep across the interior of the peninsula on a south-westerly course. Rainfall is governed largely by the orography of the area, which leads to variation in the amount of precipitation. In crossing the Western Ghats, the monsoon winds lose a large part of their moisture. The monsoon currents follow the eastward slope of the country from the crest of the Western Ghats that form the watershed. Conditions in the interior are, therefore, somewhat unfavourable for heavy precipitation except in association with the depression from the Bay of Bengal. The north-east part of the Godavari basin also receives some rain in association with monsoon depressions, which move west-north-west across the Orissa coast.

The Western boundary of the Godavari River is about 129 km in length in the high rainfall zone in the Western Ghats. The annual rainfall is around 3,000 mm along this boundary and reduces rapidly to 1000 mm up to a line running approximately from Chitradurga through Sangli and Pune and east of this line it further reduces to less than 600mm upto a line connecting Kurnool, Raichur, Bijapur and Ahmednagar. East of this line the rainfall again gradually increases to about 900 mm towards the coast. There is an area of about 10,360 sq.km, including portions of Aurangabad and Ahmednagar districts of Maharashtra which is having an annual rainfall of less than 600 mm. The area is lying 100 km East of the Western Ghats and in width varying from about 80 km in the South to about 97 km in the North.

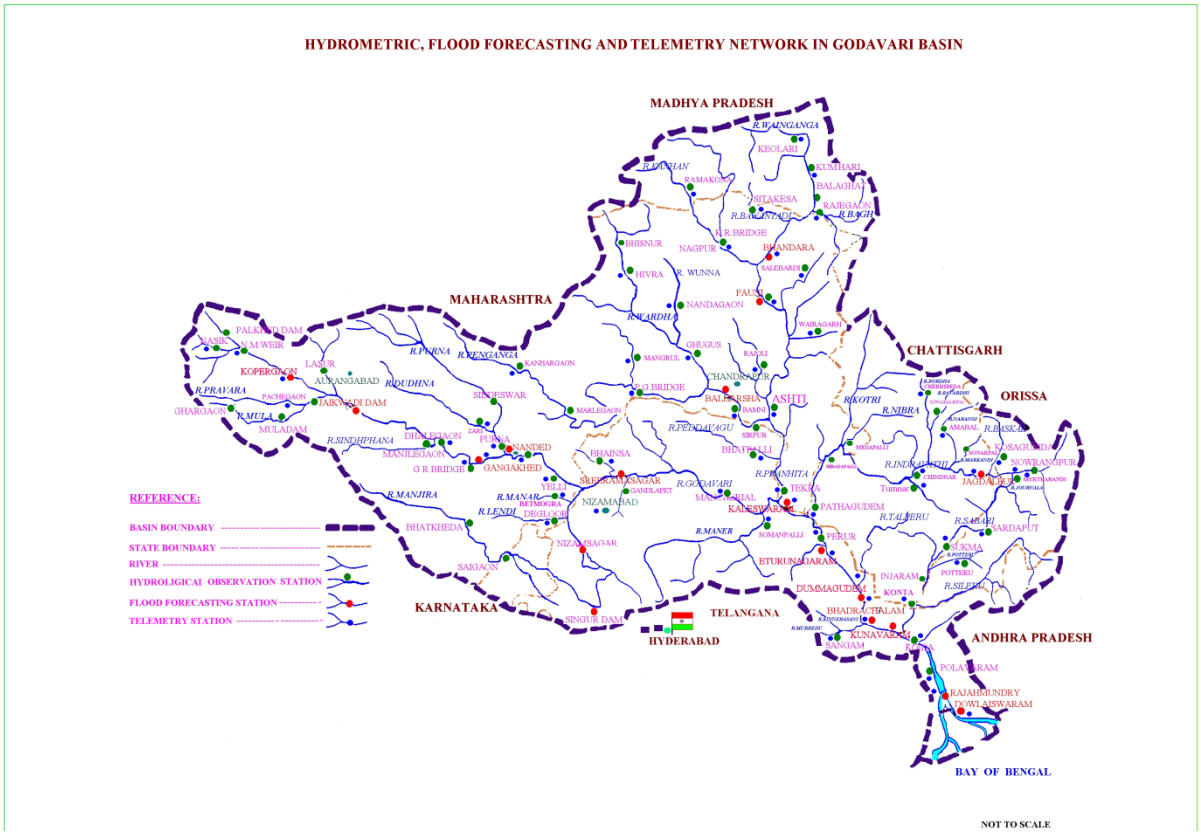
January and February are almost entirely dry in the Godavari basin, the rainfall during these two months being less than 15 mm. During the next three months, up to end of May, the rainfall varies from 20 mm to about 50 mm, in most parts of the basin. All parts of the basin receive the maximum rainfall in the period from June to September.

1.4 Flood Problem

During the monsoon, the Godavari river spills its banks in the lower reaches downstream of confluence of river Indravathi with Godavari causing floods. In Maharashtra, the problem is confined to the Nanded Town situated on the banks of the river as also to the agricultural lands on the banks of the river in Nanded

and Parbhani districts and those on the banks of the Wardha and Wainganga in the Vidharbha region.

The parts of the basin lying in Madhya Pradesh, Orissa and Karnataka have generally no serious flood problem. The flooding of deltaic areas has been prevented by construction of embankments. The major flood prone areas of Godavari basin are shown in Figure-1.



2 Flood Forecasting Activity in Godavari Basin

2.1 Beginning of Flood Forecasting Activity

Flood forecasting activity in Godavari Basin started in 1974 with the opening of a Division office of Central Water Commission at Pochampad (Sriramsagar Dam). In 1975 the Division office was shifted from Pochampad to Hyderabad for better management and communications. The first forecasts of the river stage in the Godavari were issued by this Division during 1975 monsoon for Dowlaiswaram Anicut (Sir Arthur Cotton Barrage) and are being continued since then. The year 2009 is the thirty fifth year of operation of flood forecasting activities. Presently, stage forecasts are issued on regular basis for 14 stations located on the main Godavari and its tributaries. Inflow forecasts are also issued for the four reservoirs (Jaikwadi Dam, Sriramsagar, Singur Dam and Nizamsagar) on the main Godavari and Manjira. River stage forecasts and advance warnings enable the concerned authorities to take appropriate precautionary measures to minimize loss of life and property. Reservoir inflow forecasts help in reservoir regulation. The flood forecasting network in Godavari basin is shown in Figure-1.

3 Analysis of Peak Data for various flood forecast stations

3.1 Availability of Data

There are fourteen flood level forecast stations in Godavari Basin. The availability of data yearwise for various stations is given in Table-2.

Table-2 Period of availability of Data at various FF Stations

S. No.	FF Station	Year from which data is available	Number of years of data available for study
1.	Kopergaon	1994	23
2.	Gangakhed	1995	22
3.	Nanded	1995	22
4.	Bhandara	1992	25
5.	Pauni	1992	25
6	Balharsha	1999	18
7	Kaleswaram	1989	28
8	Jagdalpur	1982	34
9	Eturunagaram	1995	22
10	Dummagudem	1979	37
11	Bhadrachalam	1978	38
12	Kunavaram	1979	37
13	Rajahmundry Railway Bridge	1983	33
14	Dowlaiswaram Barrage	1983	33

Thus it can be seen that data is available between 18 and 38 years for the stations considered for analysis. There are 3 stations in upper reaches of the river upstream of Sriramsagar reservoir, 5 stations in the middle reaches of the river upto confluence of river Indravathi and 6 stations in the downstream reaches of the river. The peak data of all these sites in different reaches is studied in the following paragraphs.

3.2 Analysis of Peak Levels in the upper reaches of river Godavari

3.2.1 Kopergaon

River Godavari at Kopergaon in Ahmednagar District of Maharashtra is the first level forecast station in Godavari Basin. This station is downstream of Nandurmadmeshwar Weir on river Godavari. The weir stores water upto its Pond level and overflows when the level is exceeded. Gates have been erected after the year 2008 and flood flow is released whenever the flow exceeds limit of storage. The peak levels attained in various years are given in the following Table-3.

Table-3 Year wise Annual Peak Level at Kopergaon on river Godavari

Sl. No.	Year	Max. Water Level recorded (m)	Average Annual Peak(m)
1	1994	492.83	491.55
2	1995	488.00	491.55
3	1996	489.55	491.55
4	1997	491.80	491.55
5	1998	492.54	491.55
6	1999	491.45	491.55
7	2000	488.50	491.55
8	2001	489.12	491.55
9	2002	489.55	491.55
10	2003	492.19	491.55
11	2004	494.44	491.55
12	2005	495.04	491.55
13	2006	498.20	491.55
14	2007	492.20	491.55
15	2008	495.04	491.55
16	2009	489.75	491.55
17	2010	489.85	491.55
18	2011	490.45	491.55
19	2012	489.15	491.55
20	2013	489.92	491.55
21	2014	490.40	491.55
22	2015	490.00	491.55
23	2016	495.60	491.55

The average peak is 491.77m for the 23 study years, The Warning Level at Kopergaon is 490.90 m which indicate that the average peak is above the Warning Level at Kopergaon. The graph showing the annual peak water levels at Kopergaon is shown in Figure-3 below:

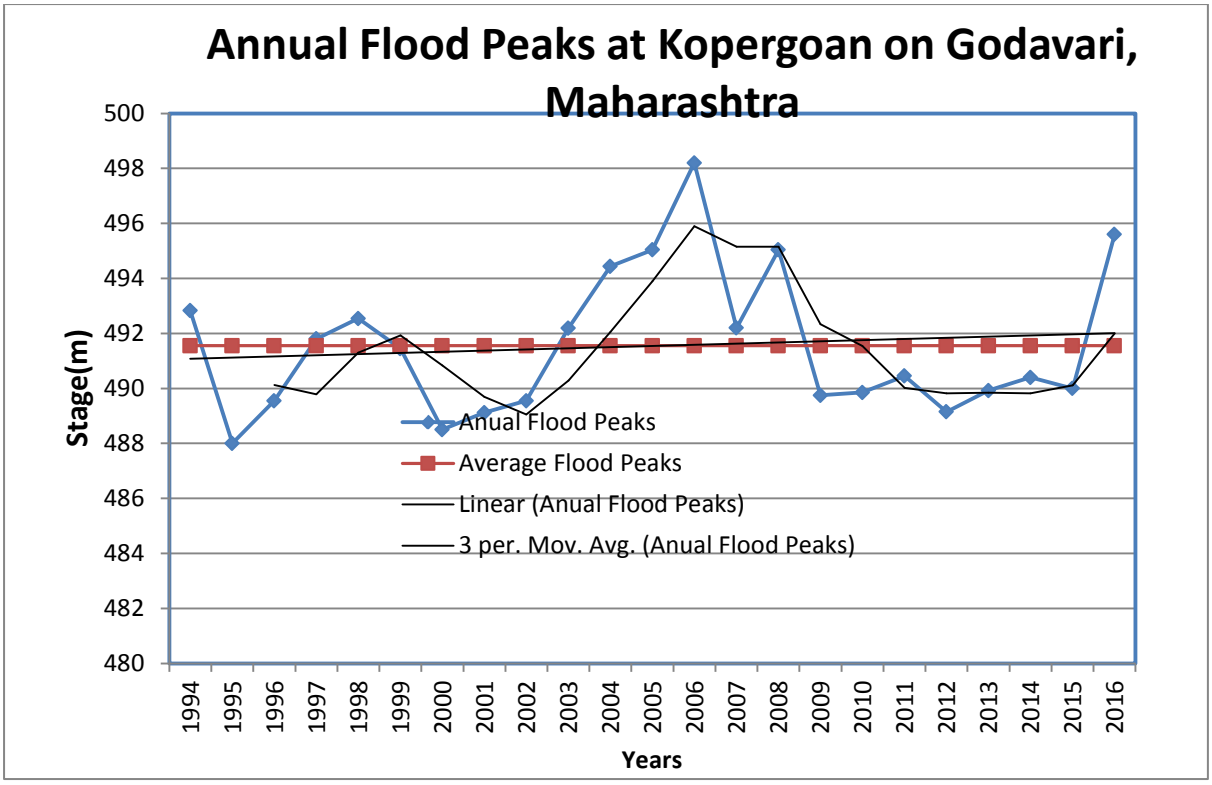


Figure-3 Annual Peak Water Levels(m) at Kopergaon on Godavari

3.2.2. Gangakhed and Nanded

The river Godavari at Gangakhed and Nanded are affected by the Storage Projects at Jaikwadi Dam on river Godavari and Manjlegaon Dam on river Sindhpana and the flood peaks at Gangakhed is pronounced only in case the upstream dams Dam release surplus water through their spillway. River Purna one of the main left bank tributary of river Godavari also contributes to the flow at Nanded. However on river Purna also two projects namely Yeldari and Siddeswar Weir store water and surpluses are released only in good monsoon years. The annual peak water levels at Gangakhed and Nanded were also analysed and the corresponding figures are shown in Figure -4 and Figure-5.

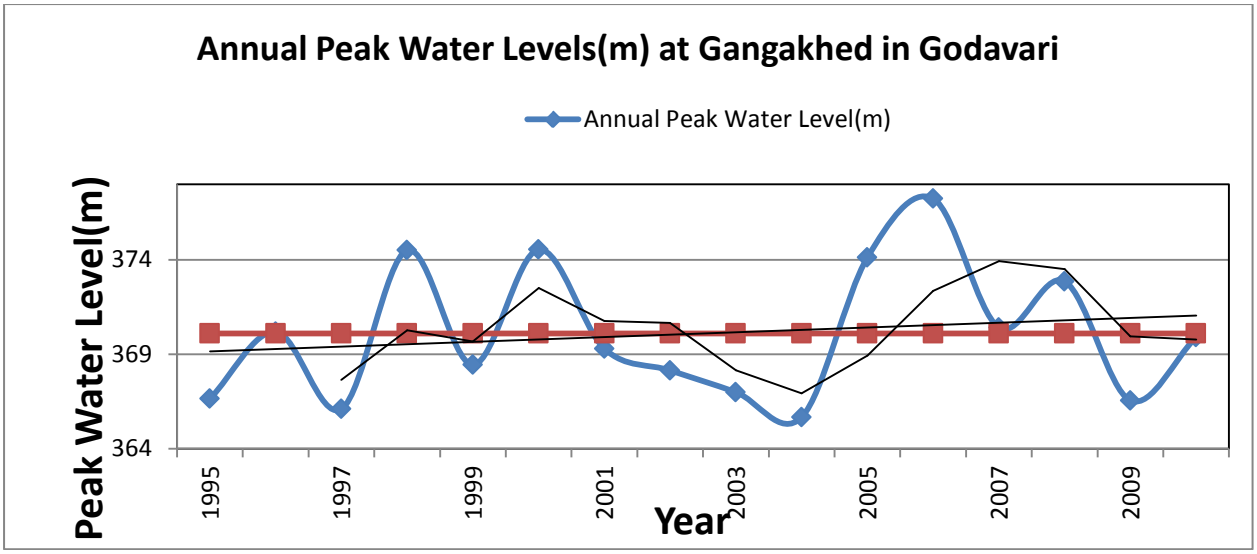


Figure-4 Annual Peak Water Levels(m) at Gangakhed on Godavari

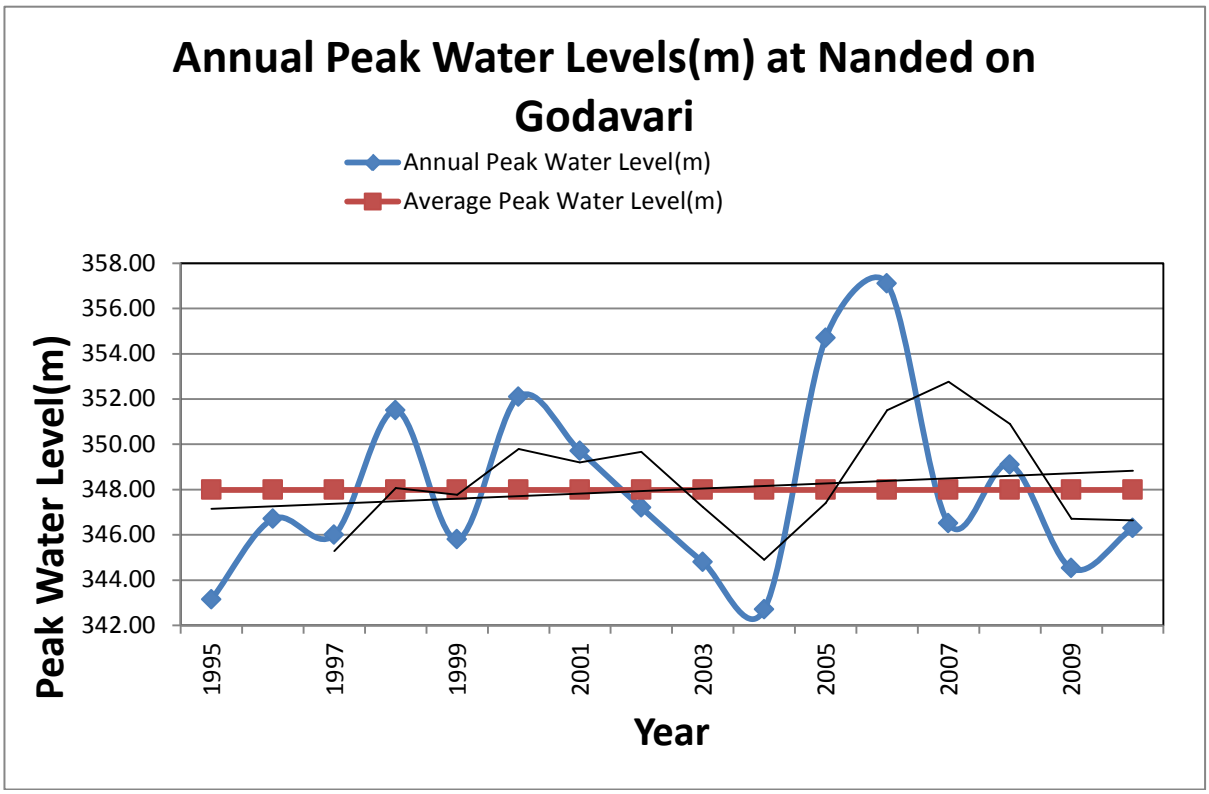


Figure-5 Annual Peak Water Levels(m) at Nanded on Godavari

3.2 Analysis of Peak Levels in the middle reaches of river Godavari

The middle reaches of river Godavari have significant free catchment areas and two major left bank tributaries namely, Pranhita and Indravathi confluences river Godavari in this reach. River Pranhita and Indravathi have almost half the total catchment area of the basin. The main rivers in this reach are river Wainganga, River Wardha, River Indravathi and the main Godavari downstream of Sriramsagar Dam. The flood forecasting stations on river Wainganga are at Bhandara and Pauni,

on River Wardha at Balharsha, on River Indravathi at Jagdalpur and on River Godavari at Kaleswaram in the middle reaches of the basin.

3.2.1 Bhandara and Pauni

The northernmost portion of Godavari basin lies in foot hills of Satpura ranges and river Wainganga originates in Satpura ranges in the Chhindwara District of Madhya Pradesh. Bhandara and Pauni are two forecast stations in this reach of river. There are several medium projects on rivers Wainganga, Bagh, Bawanthri and they affect the flow on river Wainganga upstream in source regions. However since the region is in very heavy rainfall zone, the flow occurs frequently in this reach of the river. Major Project at Gosikhurd in between Bhandara and Pauni has restricted the flow at Pauni from the year 2009 onwards. The annual peak water levels at Bhandara and Pauni were also analysed and the corresponding figures are shown in Figure -6 and Figure-7.

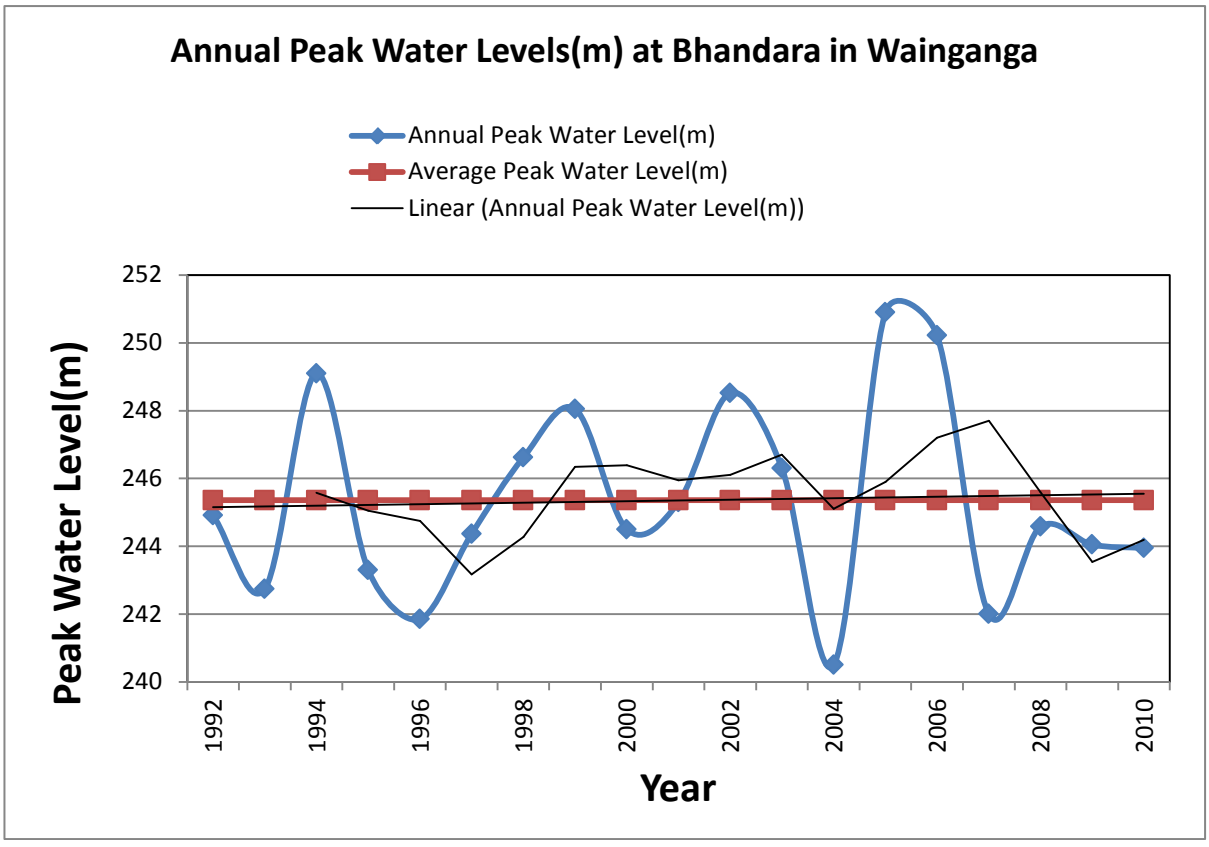


Figure-6 Annual Peak Water Levels(m) at Bhandara on Wainganga

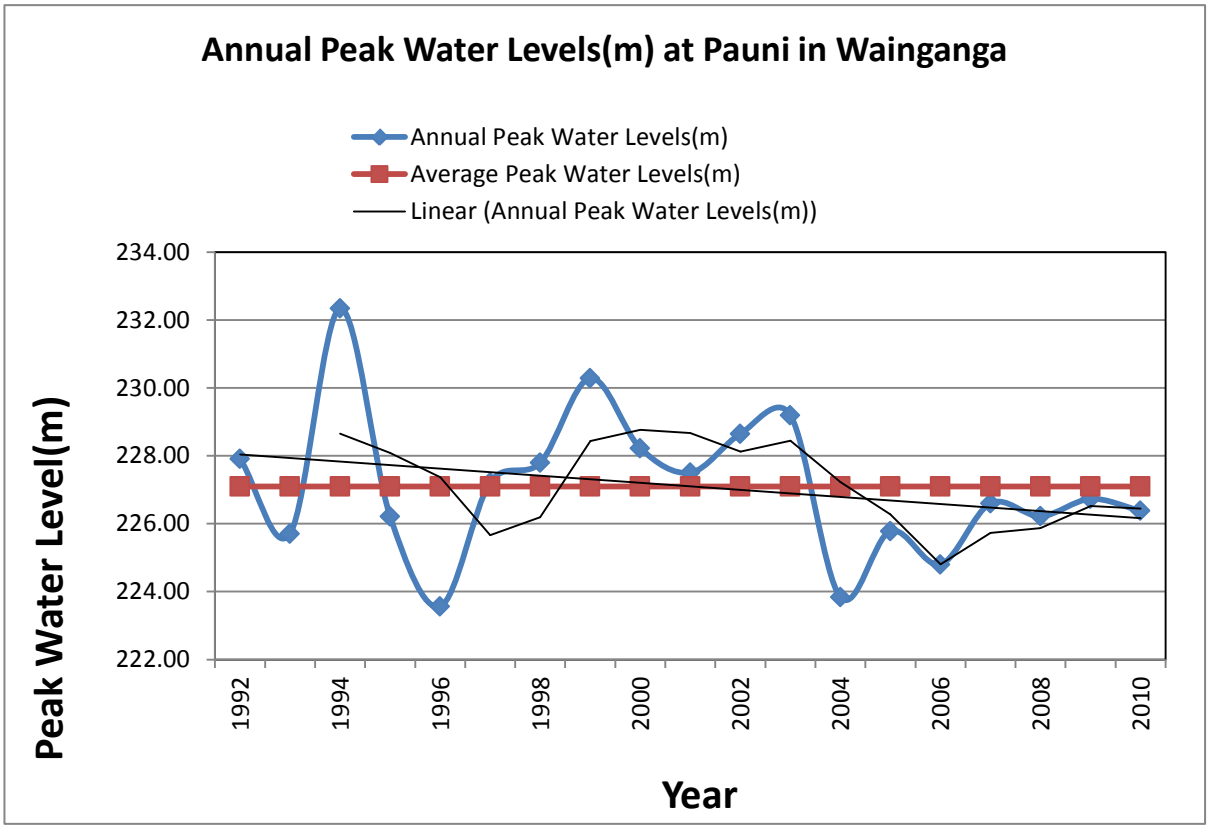


Figure-7 Annual Peak Water Levels(m) at Pauni on Wainganga

3.2.2 Balharsha

River Wardha at Balharsha is one of the flood forecasting stations in this reach of Godavari Basin. The Upper Wardha Project upstream of this stations affects the flow in this reach. The river Penganga a tributary of Wardha is having Issapur project which affects the flow on river Penganga. The river Wardha is also affected by backwater flow from Penganga at its confluence point. The annual peak water levels at Balharsha was also analysed and the corresponding figure is shown in Figure -8.

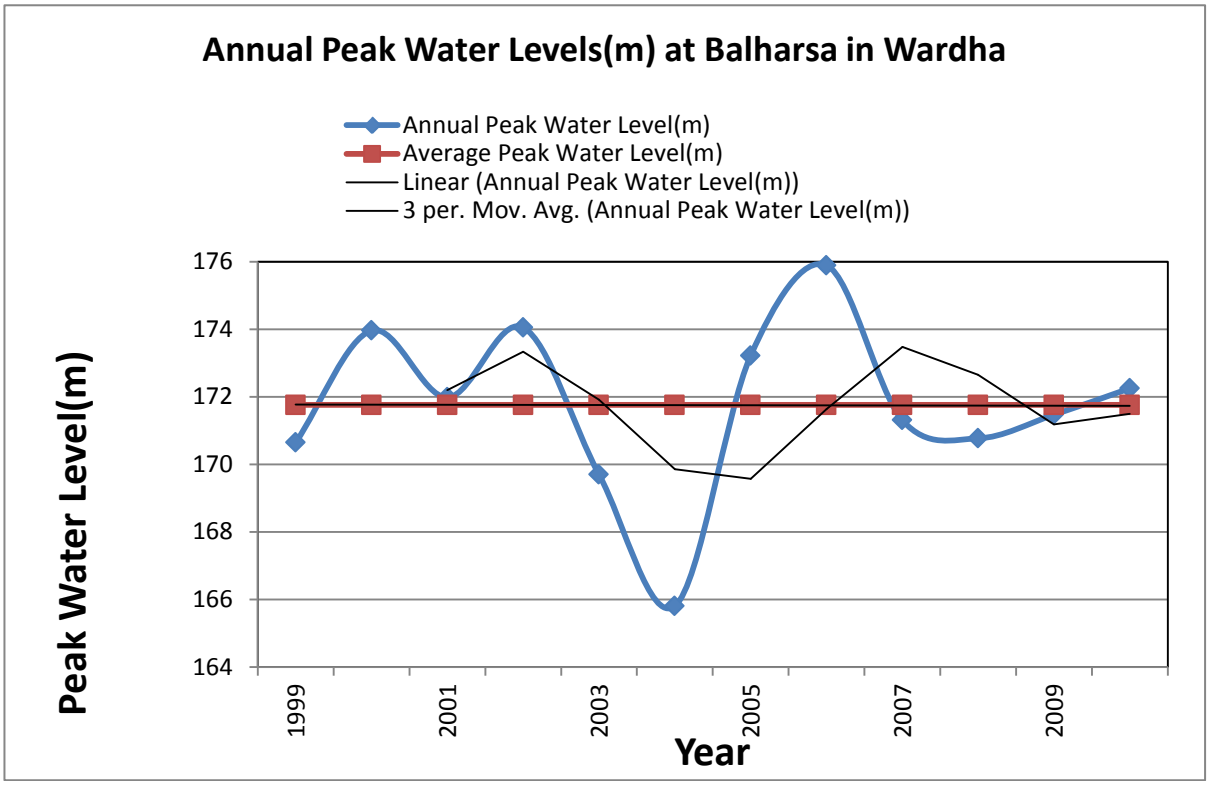


Figure-8 Annual Peak Water Levels(m) at Balharsha on Wardha

3.2.3 Kaleswaram

Kaleswaram on river Godavari is one of the flood forecasting stations in the middle reaches of river Godavari. This site is affected by major projects such as Sriramsagar Dam on main Godavari, Lower Maner Dam on river Maner, Kaddam Dam on river Kaddam and many of the upstream projects in Wainganga and Wardha. The annual peak water levels at Kaleswaram was also analysed and the corresponding figure is shown in Figure -9.

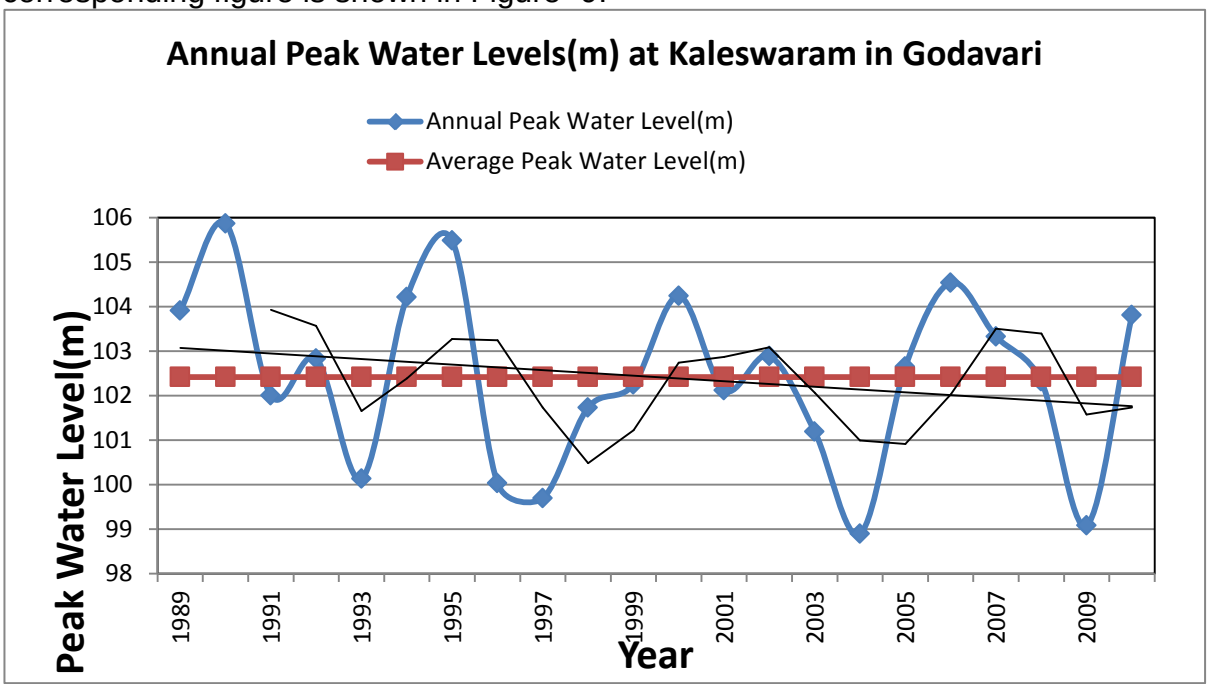


Figure-9 Annual Peak Water Levels(m) at Kaleswaram on Godavari

3.2.4 Jagdalpur

Jagdalpur on river Indravathi is one of the flood forecasting station in this reach of Godavari Basin. Major project such as the Upper Indravathi Project affects this station. The natural diversion of flow into Jourunala stream is also one of the salient features of the river Indravathi upto Jagdalpur. The annual peak water levels at Jagdalpur was also analysed and the corresponding figure is shown in Figure -10

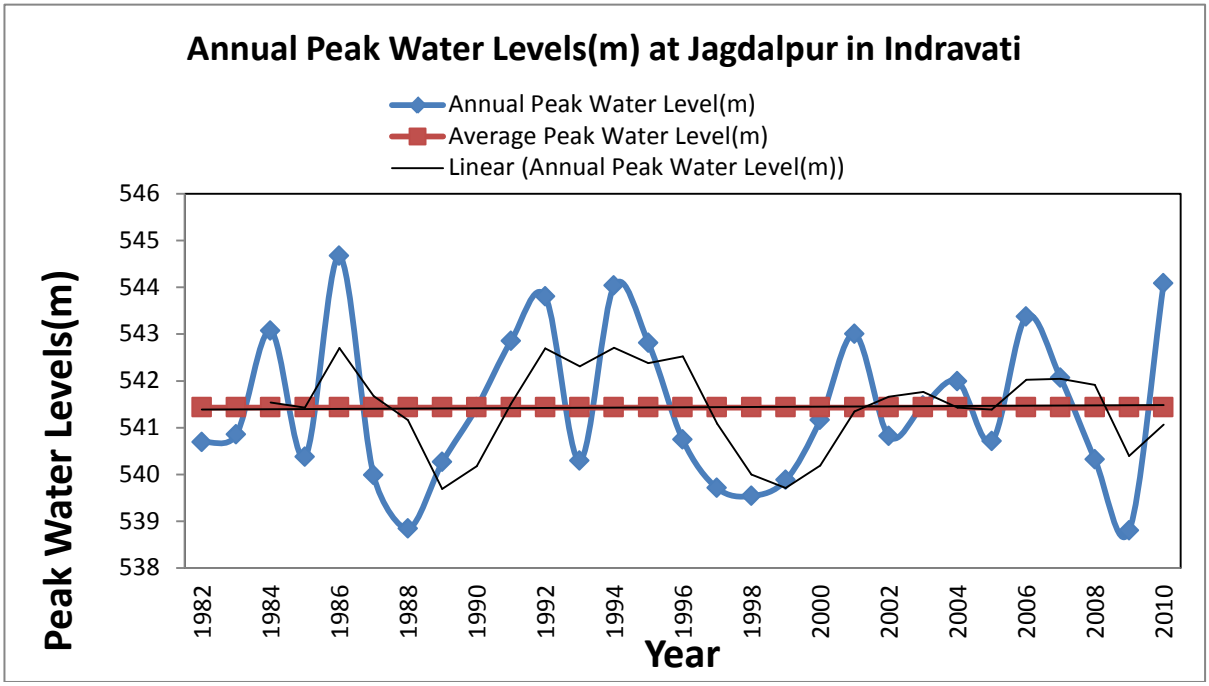


Figure-10 Annual Peak Water Levels(m) at Jagdalpur on Indravathi

3.3 Analysis of Peak Levels in the Reaches of River Godavari

The lower reaches of river Godavari also have significant free catchment areas and two major left bank tributary namely, Taliperu and Sabari and one right bank tributary Kinnersani confluences river Godavari in this reach. The flood forecasting stations this reach are Eturunagaram, Dummagudem, Bhadrachalam, Kunavaram, Rajahmundry Railway Bridge and Dowlaiswaram Barrage. The back water effect into river Sabari in case of high flood in Godavari and the constriction in the river near Papi Hills are the significant features of the river in the lower reaches.

3.3.1 Eturunagaram to Bhadrachalam Lower reaches of river Godavari

The river Godavari receives the flow of River Taliperu in the reach. The Taliperu Dam near Cherla restricts the flow. Sometimes heavy discharges from this dam also compounds to the peak level at flood forecasting stations at Dummagudem and Bhadrachalam. The annual peak water levels at Eturunagaram, Dummagudem and Bhadrachalam were also analysed and the corresponding figure are shown from Figure -11 to Figure 13.

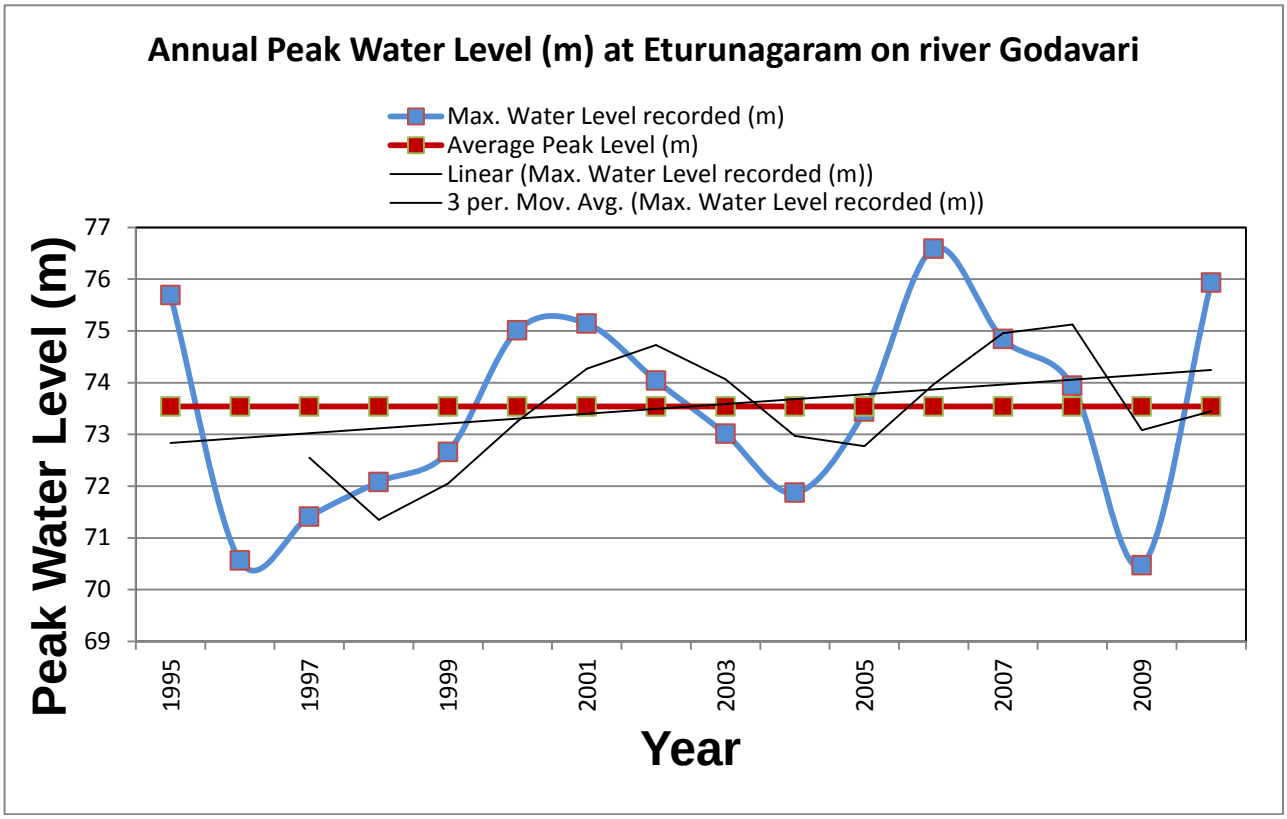


Figure-11 Annual Peak Water Levels(m) at Eturunagaram on Godavari

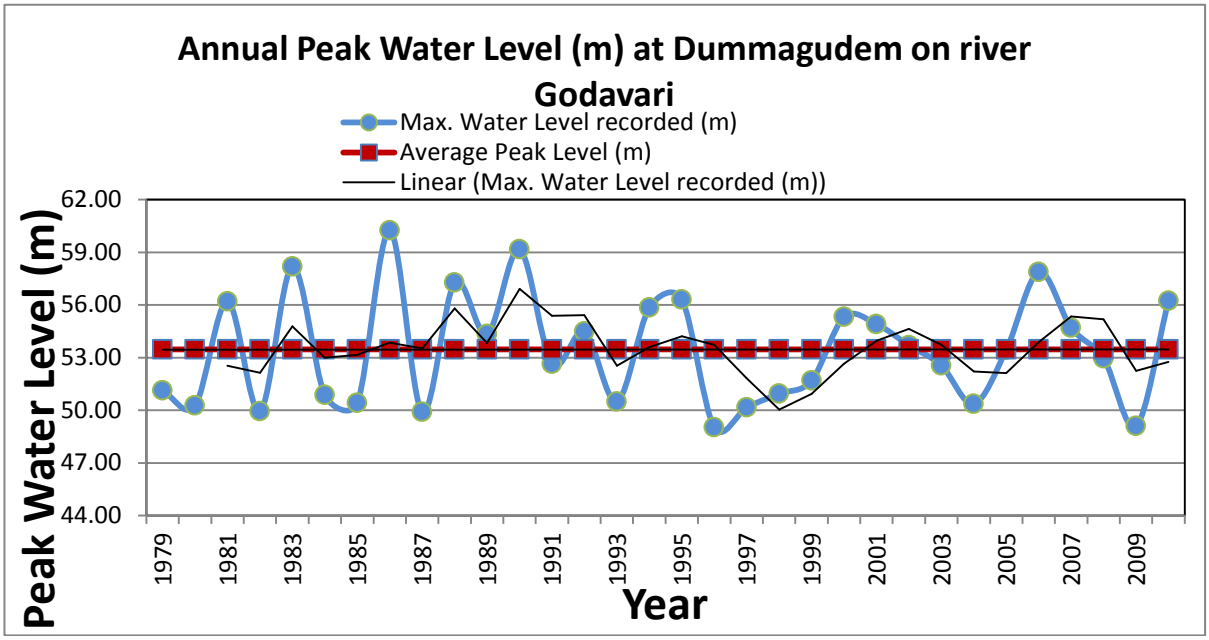


Figure-11 Annual Peak Water Levels(m) at Dummagudem on Godavari

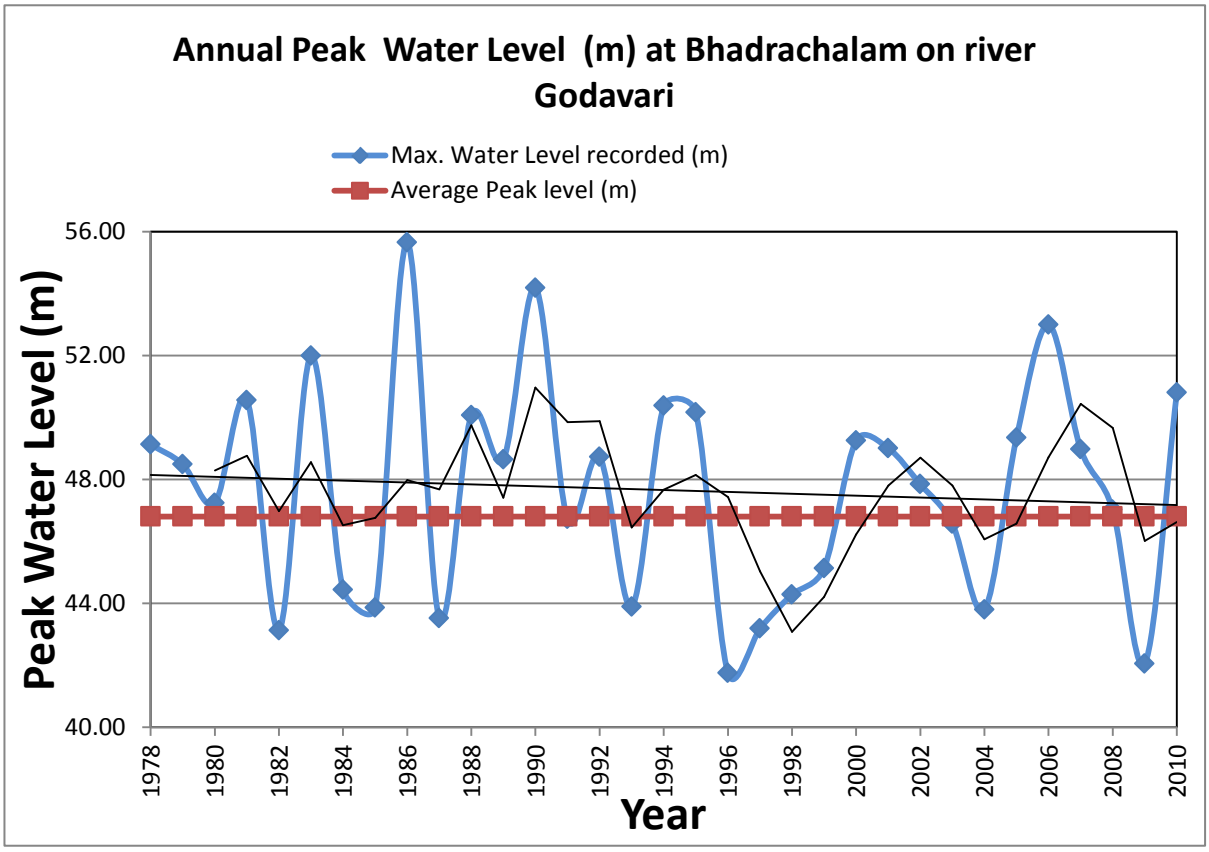


Figure-12 Annual Peak Water Levels(m) at Bhadrachalam on Godavari

3.3.2 Kunavaram to Dowlaiswaram reach of river Godavari

The river Godavari receives the flow of River Sabari in the reach. The Kinnersani Dam restricts the flow. Sometimes heavy discharges from this dam also compounds to the peak level at flood forecasting stations at Kunavaram. The annual peak water levels at Kunavaram, Rajahmundry Railway Bridge and Dowlaiswaram were also analysed and the corresponding figure are shown from Figure -14 to Figure -16.

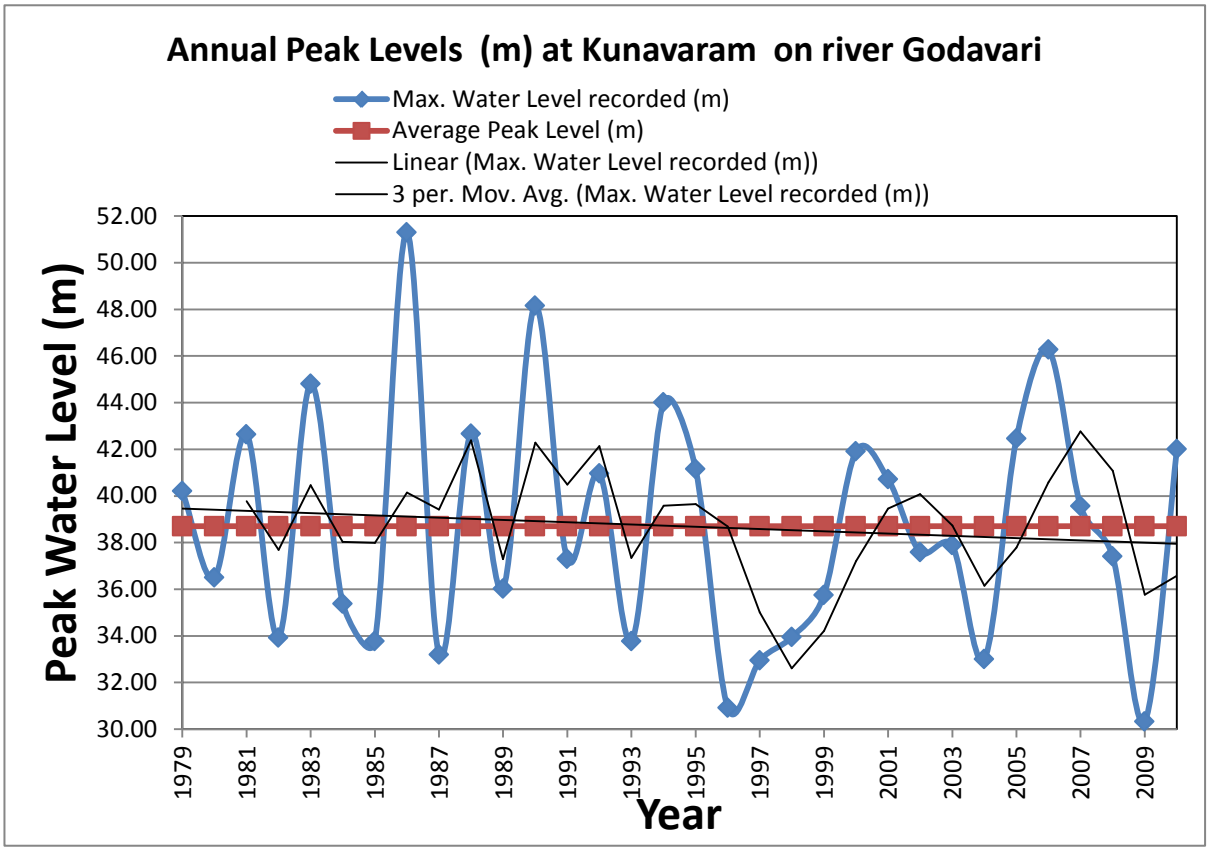


Figure-13 Annual Peak Water Levels(m) at Kunavaram on Godavari

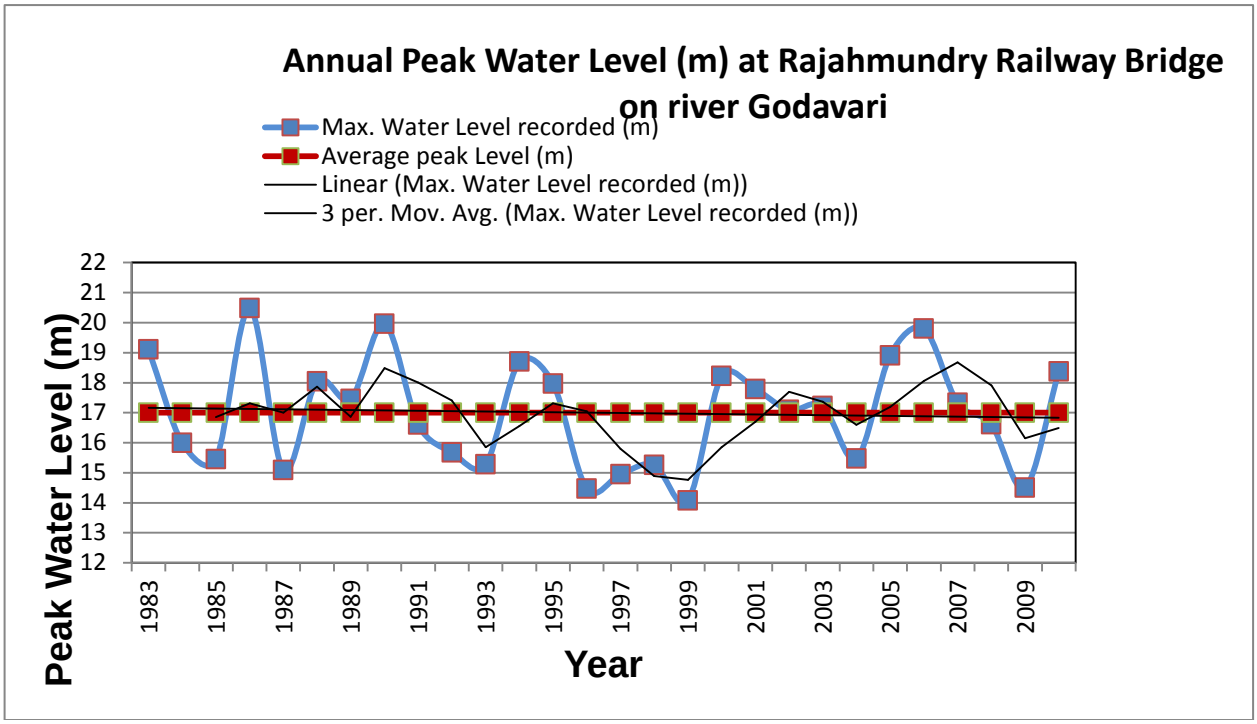


Figure-14 Annual Peak Water Levels(m) at Rajahmundry Railway Bridge on Godavari

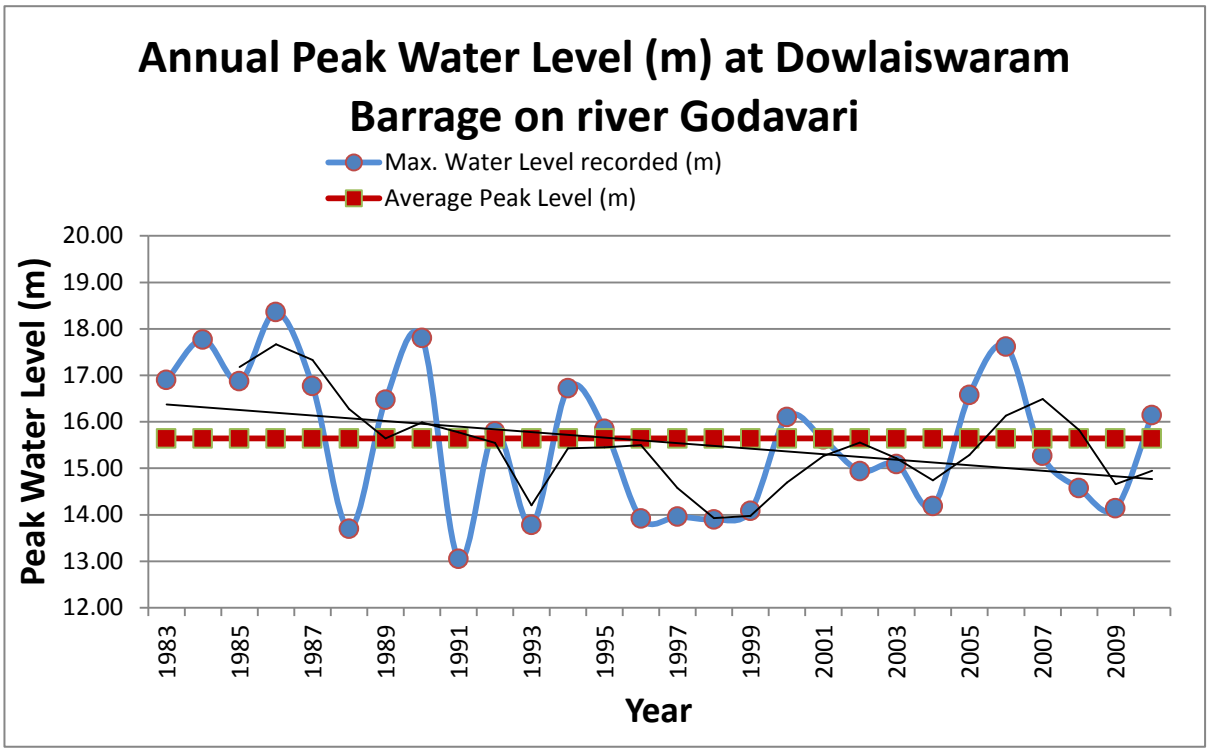


Figure-15 Annual Peak Water Levels(m) at Dowlaiswaram Barrage on Godavari

4.0 Results of the analysis

4.1 Results of the Analysis for Upper reaches of river Godavari

The linear trend line indicates a rising trend for peak levels at all the three flood forecast stations at Kopergaon, Gangakhed and Nanded. This may be mainly due to the fact that there was above normal peak levels continuously from 2004 to 2008 with high peaks in the year 2006 in all the three stations. The 3 year moving avergae indicates that there is some three year cycle at which the peaks tend to rise and fall. This indicates that there is no major variation in trend in the peak levels in the flood forecasting stations in the upper reaches.

4.2 Results of the Analysis for Middle reaches of river Godavari

The results for Wainganga reach indicates that the linear trend is almost coinciding with the average peak level and three year moving average indicates recurrence of high peaks every three years in Bhandara, while at Pauni, the trend indicates falling trend which may be explained to the structure upstream of the forecast station. The trends for Jagdalpur and Balharsha also indicate that linear

trend is almost near the average peak levels and three yearly moving average indicates recurrence of flood peaks after every cycle of rise and fall in peaks. In respect of Kaleswaram, the trend indicates a fall which may be attributed to storage structures coming up upstream of the forecast station and the restriction of flow in the downstream reaches.

4.3 Results of the Analysis for Lower reaches of river Godavari

The results of Lower reaches of river Godavari indicates that, rising trend is observed in Eturunagaram while Dummagudem to Dowlaiswaram Barrage shows a falling trend in the linear analysis. The flood peak suggests as in other reaches the recurrence of flood peaks consecutively every three year cycle with a fall and rise. This may be explained due to the fact that projects upstream of these forecast stations have moderated the flow and hence the trend in peak indicates slight fall.

4.4 Effect of Climate Change

The effect of changes in climate can be studied only after removing all trends indicative of catchment characteristics and effect of storage structures. Since most of the data in the analysis have been affected by the changes in flood regime due to increase in storage in the basin and hence no clear cut inference could be drawn about the effect of climate on peaks observed in flood forecasting stations. This analysis have to be carried out after establishment of a trend due to climate change in the meteorological regime of the catchment over the past 50 or 100 years and the effect of such a climate change has to be correlated with the effect on the hydrological regime of the catchment. Extensive data on meteorological and hydrological data have to be used for analysis to confirm trend due to climate change after removing all the cyclic trends arrived in this study, effect of changes in catchment characteristics and effect of structures on the flow regime of the river.

References:

1. Annual Flood Appraisal Reports of Godavari Basin from inception
2. Annual Appraisal Report of Central water Commission
3. Data on peaks maintained by the respective Divisional Control Rooms under Godavari Basin in Central Water Commission

Acknowledgements

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