Consolidation of the Nile Decision Support Tool

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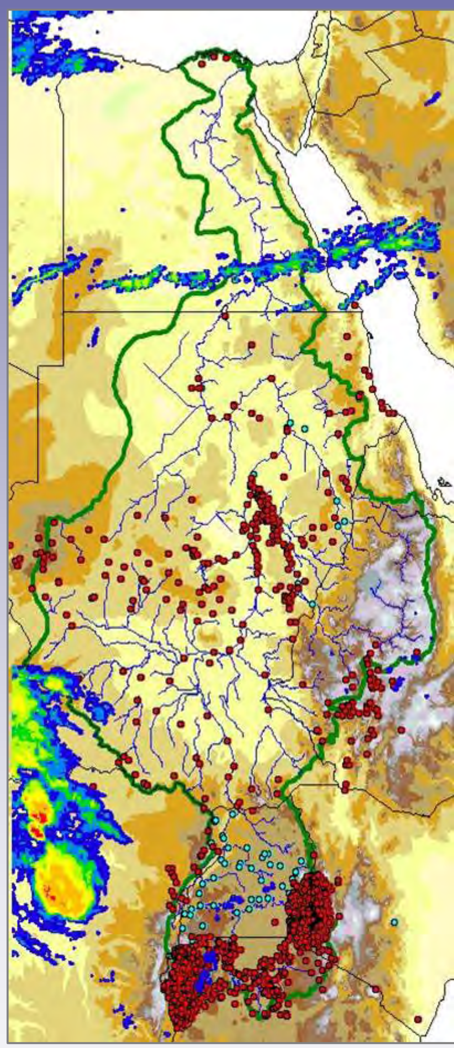

Technical Completion Report

Volume 2: Workshop Exercises & Presentations

Developed collaboratively by

The Nile Basin Nations,

The Georgia Water Resources Institute at the Georgia Institute of Technology,

and

The Food and Agriculture Organization of the United Nations

July 2007

Consolidation of Nile Decision Support Tool (Nile DST)
Technical Completion Report

Volume 2: Workshop Exercises and Presentations

Report developed by

Huaming Yao
Senior Research Engineer

Aris Georgakakos
Project Director

Georgia Water Resources Institute
School of Civil and Environmental Engineering
Georgia Institute of Technology

In collaboration with

The Nile Basin Nations

and

The Food and Agriculture Organization (FAO)
of the United Nations

Nile Basin Water Resources Project
(TF/UGA/CPA 177517-2005/AGLW)

July 2007

Acknowledgements

This report and associated software were developed by the Georgia Water Resources Institute (GWRI) at the Georgia Institute of Technology as part of the initial Nile Basin Water Resources Project (GCP/INT/752/ITA) and follow-up contract TF/UGA/CPA 177517-2005/AGLW. This project was funded by the Government of Italy and was executed for the Nile Basin nations by the Food and Agriculture Organization (FAO) of the United Nations.

The GWRI Director and project staff are grateful to the Nile Basin nations (Burundi, Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, Sudan, Tanzania, and Uganda), their focal point institutions, their Project Steering Committee (PSC) members, and their National Modelers for entrusting us to work with them in this important basin-wide project. The development of databases, models, technical reports, software, and user manuals are key but not the only project accomplishments. Even more important are the evolving contributions relating to people and the difference the project is poised to make in data and information sharing, developing a common knowledge base for policy debates, and long term capacity building.

GWRI is also grateful to the Government of Italy and to FAO and its Chief Technical Advisor, Mr. Bart Hilhorst, for sponsoring the project and for providing dependable logistical and technical support through the FAO office in Entebbe.

It is our hope that the Nile DST effort will contribute in some positive way to the historic process of the Nile Basin nations to create a sustainable and peaceful future.

Aris Georgakakos
GWRI Director
Atlanta, July 2007

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2006 Nile DST Training Workshop

Review Exercises: River & Reservoir Simulation & Mgt. Model

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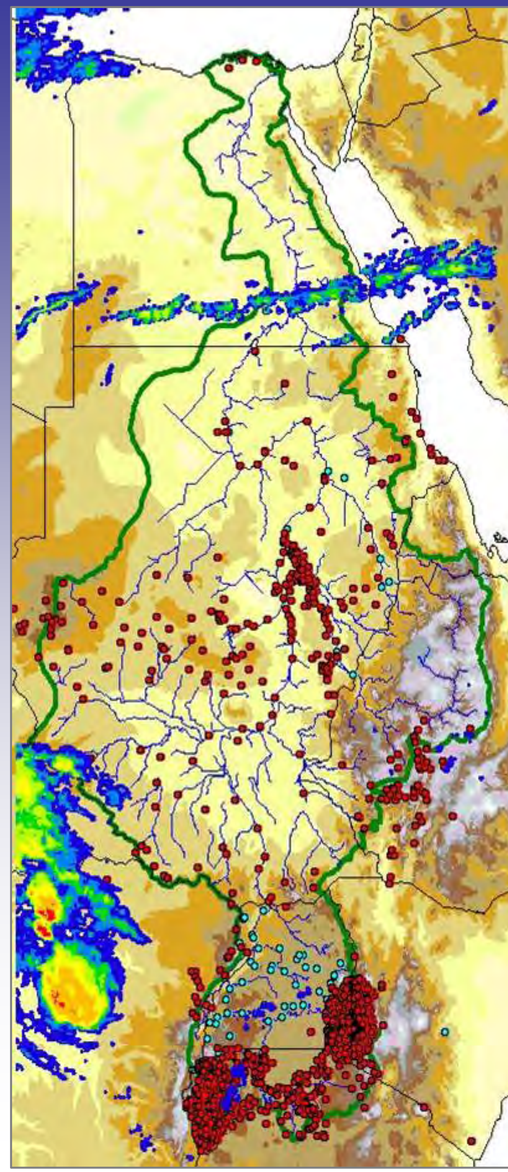

Nile DST RRSM Review Exercises

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Self Study Scope:

As we approach the 4th Nile DST Training Workshop, we would like to initiate this training event by a self study session. This session has two purposes: For the participants that have attended previous Nile DST workshops, the exercises provide an opportunity to review the Nile DST software while working on an interesting water resources assessment. For the new Nile DST workshop participants, the exercises are an opportunity to start becoming familiar with the River and Reservoir Simulation and Management Nile DST module. Since all country teams have at least one individual with sufficient prior training, we would like to request that these individuals demonstrate the Nile DST software to their new colleagues and assist them in becoming familiar with its features. Namely, we ask the experienced Nile DST users to serve as instructors for the new users during the self-study session.

Nile DST RRSM Exercise 1

1. Water Balance and Water Use Assessments

This exercise aims to determine the magnitude of the water balance terms in various Nile River reaches. The river reaches are defined as follows:

(a) Southern Nile system up to the border of Uganda and Sudan (Nimule);

(b) Nimule to Malakal upstream of the Sobat junction;

(c) Malakal (upstream of the Sobat junction) to downstream of Gebel El Aulia Dam; (Namely, before the junction of the White and Blue Niles;)

(d) Ethiopian Blue Nile up to the Sudanese border;

(e) Sudanese Blue Nile up to the junction with the White Nile;

(f) Main Nile from the Blue and White Nile junction up to the entrance of Lake Nasser (High Aswan Dam reservoir);

(g) Egyptian Nile, including Lake Nasser, to the Mediterranean Sea.

1.1 Consider first a baseline basin development scenario with existing projects and water use targets. For each one of the above-mentioned reaches, determine and graph the following quantities: (Generate one graph per river reach.)

- Average monthly and annual reach outflows over the period of record;
- Average monthly and annual reach outflows over the driest five years of the record; (Indicate the drought years;)
- Average monthly and annual reach outflows over the wettest five years of the record; (Indicate the five wettest years of record;)
- Develop quantitative measures of the outflow variability (e.g., percent difference of dry and wet periods from normal) and determine if wet and dry climatic periods occur at the same time across the various river reaches; Specify which river reaches behave similarly in this respect.

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Nile DST RRSM Exercise 1 cont'd

1.2 For the baseline scenario and each one of the above-mentioned river reaches, estimate and graph the following quantities: (Generate one graph for each river reach.)

- Average monthly and annual reach water use and losses (separately) over the period of record;
- Average monthly and annual reach water use and losses (separately) over the driest five years of the record;
- Average monthly and annual reach water use and losses (separately) outflows over the wettest five years of the record;
- Develop quantitative measures of the water use and losses variability (e.g., percent difference of dry and wet periods from normal);
- Determine the reliability of meeting water use targets in each reach;
- Compare water losses to reach outflows;

Note : Reach water losses include evaporation and other water abstractions not related to human water uses.

1.3 For the baseline development scenario and each river reach, estimate and graph the following quantities: (Generate one graph per reach.)

- Average monthly and annual reach energy generation over the period of record;
- Average monthly and annual reach energy generation over the driest five years of the record;
- Average monthly and annual reach energy generation over the wettest five years of the record;
- Develop quantitative measures of energy generation variability (e.g., percent difference of dry and wet periods from normal).

Nile Basin Water Resources GCP/INT/752/ITA

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Nile DST RRSM Exercise 2

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2. Eastern Nile Scenario Analysis

This exercise focuses on Eastern Nile including the Blue Nile, Atbara, and Main Nile reaches.

2.1 *Ethiopian Hydropower vs. Water Supply Tradeoff:* Derive the tradeoff between hydropower and irrigation in Ethiopia. Namely, include all potential hydropower and storage projects on the Eastern Nile reaches, define several incremental Ethiopian water demand target levels in the range between 0 and 20 bcm per year, run the Nile DST, and record energy generation in Ethiopia versus reliability of water supply. (Note that irrigation is needed in Ethiopia during the dry season, from October through April.) Present the tradeoff by means of two graphs. One showing the frequency curve of energy generation versus the water demand target, and a second showing the frequency curve of the water supply deficits versus the water demand target. For each Ethiopian water demand target level, perform a sensitivity on the geographic distribution of water demand targets and discuss your conclusions.

2.2 *Water Supply Tradeoffs—Ethiopia, Sudan, Egypt:* For each Ethiopian water demand target (in 2.1), derive and graph the frequency curves of the Sudanese and Egyptian water supply deficits (two graphs) and the frequency curves of the reservoir levels at Roseires, Merowe, and HAD (three graphs). Please comment on your results.

2.3 *Water Supply vs. Hydropower Tradeoff for Eastern Nile:* For each Ethiopian water demand target (in 2.1), derive and graph the frequency curves of the Sudanese and Egyptian energy generation (two graphs). Please comment on your findings.

2.4 *Coordination Schemes:* Based on your findings in 2.1, 2.2, and 2.3, select an Ethiopian demand target that represents a reasonable compromise among the Eastern Nile stakeholders, and develop a reservoir coordination strategy that improves the benefits and minimizes the costs with respect to all water uses and users. Present and discuss your results.

Nile DST RRSM Exercise 3

3. Southern Nile Scenario Analysis

This exercise focuses on the Southern Nile up to the junction with the Blue Nile.

3.1 *Lake Victoria Hydropower vs. Water Supply Tradeoff:* Derive the tradeoff between hydropower and irrigation in the Lake Victoria region. Namely, include all potential hydropower projects on the Victoria and Kyoga Niles, define several incremental water demand target levels in the range between 0 and 10 bcm per year in the Lake Victoria watershed, run the Nile DST, and record energy generation in Uganda versus reliability of water supply in the lake watershed. Present the tradeoff by means of two graphs. One showing the frequency curve of energy generation versus the water demand target, and a second showing the frequency curve of the water supply deficits versus the water demand target. For each water demand target level, perform a sensitivity on the temporal distribution of water demand targets and discuss your conclusions.

3.2 *Downstream River Flow Tradeoffs—Mongala, Malakal:* For each Lake Victoria water demand target (in 3.1), derive and graph the frequency curves of the river flow at Mongala and Malakal upstream of the Sobat junction (two graphs). Please comment on your results.

3.3 *Jonglei Canal:* For each Lake Victoria water demand target (in 3.1), determine the capacity of the Jonglei Canal that causes the frequency distribution of the Malakal flow to approach the baseline frequency distribution. Please comment on your findings.

3.4 *Coordination Schemes:* Based on your findings in 3.3, select a Lake Victoria demand target that represents a reasonable compromise among the Southern Nile stakeholders, and develop a lake coordination strategy (Victoria, Kyoga, and Albert) that further improves the frequency distribution of the Malakal flow as measured by the baseline. Present and discuss your assessment findings.

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Nile DST RRSM Exercise 4

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4. Basin Wide Scenario Analysis and Benefit/Cost Sharing Strategies

This exercise combines the results of exercises 3 and 4 and seeks to develop a basin wide shared vision development and management strategy.

4.1 *Basin Wide Assessment:* Consider the most promising Eastern and Southern Nile scenarios assessed in Exercises 2 and 3 and analyze their combined effect on Sudan and Egypt. Namely, derive the water supply deficits and energy generation frequency curves and compare them against those of the baseline.

4.2 *Preliminary Economic Assessments:* The strategic vision of the Nile Basin Initiative is to promulgate a benefit/cost sharing plan acceptable to all Nile partners. Toward this goal, the relative economic value of different water uses needs to be assessed. Let us hypothetically consider the following societal values for different water uses:

Irrigation:	$1/m^3 (roughly equal to the alternative cost of water desalination);
Hydropower:	$600/KWh (roughly equal to the alternative cost of thermal power generation);
Lake Victoria:	Value (Mill. $/Yr) = -733,500 + 650 x (Annual Average Lake Level in meters);
Lake Kyoga:	Value (Mill. $/Yr) = -520,700 + 500 x (Annual Average Lake Level in meters);
Lake Albert:	Value (Mill. $/Yr) = -46,200 + 75 x (Annual Average Lake Level in meters);
Sudd:	Value (Mill. $/Yr) = 100 x (Annual Average Flow through the Bahr El Jebel--bcm)

Using these water use value estimates, determine the benefits and costs of your most promising scenarios with respect to the baseline by country. If necessary, refine your scenarios in light of your findings, possibly using basin wide coordination management schemes.

4.3 *Benefit/Cost Sharing Strategies:* Based on your findings in 4.2, develop a plausible basin wide benefit/cost sharing proposal (including power-for-irrigation water trading and compensation terms). Present and discuss the pros and cons of your benefit/cost sharing plan. Comment on the assumptions used and the need, if any, for additional data and model capabilities.

4.4 *Report:* Prepare a report summarizing your work and conclusions.

NILE DST , Exercises 2006

By Burundi Team

Evariste Sinarinzi

and

Joachim Kagari

Nile DST RRSM Applications

- **Water Balance and Water uses assessments**

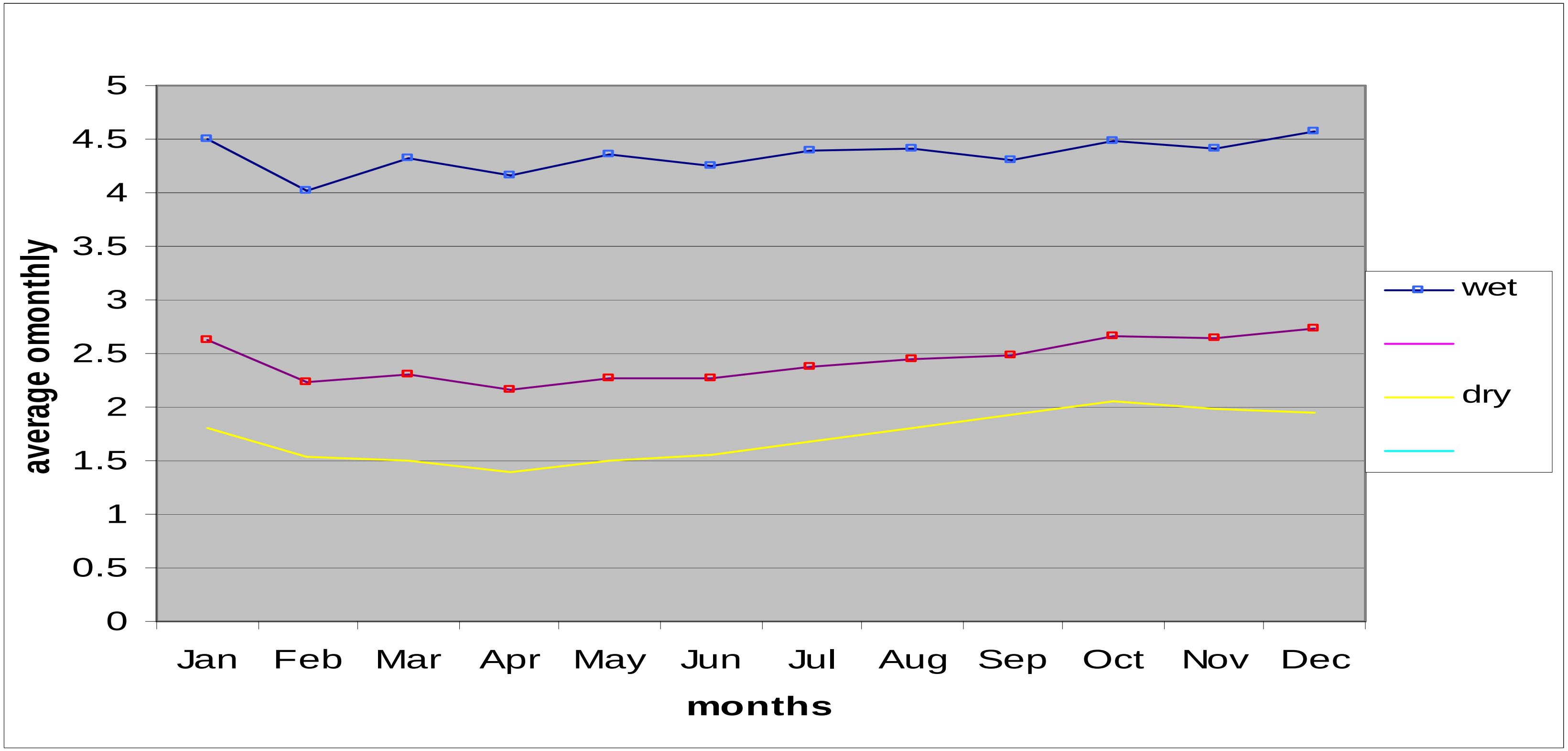
Definition of river reaches for simulation

River reach name	country	River node of simulation
LV up to Nimule	Uganda	Pakwatch
Nimule to Malakal	Sudan	Malakal
Malakal to gebel El Aulia	Sudan	Gebel El Aulia
LTana to the Border of Sudan	Sudan	Diem
Khartoum to Asuan Dam	Sudan- Egypt	Dongala
Sudanese BN up to kartoum	Sudan	Khartoum
Main Nile up to Lake Nasser	Sudan-Egypt	DSHAD

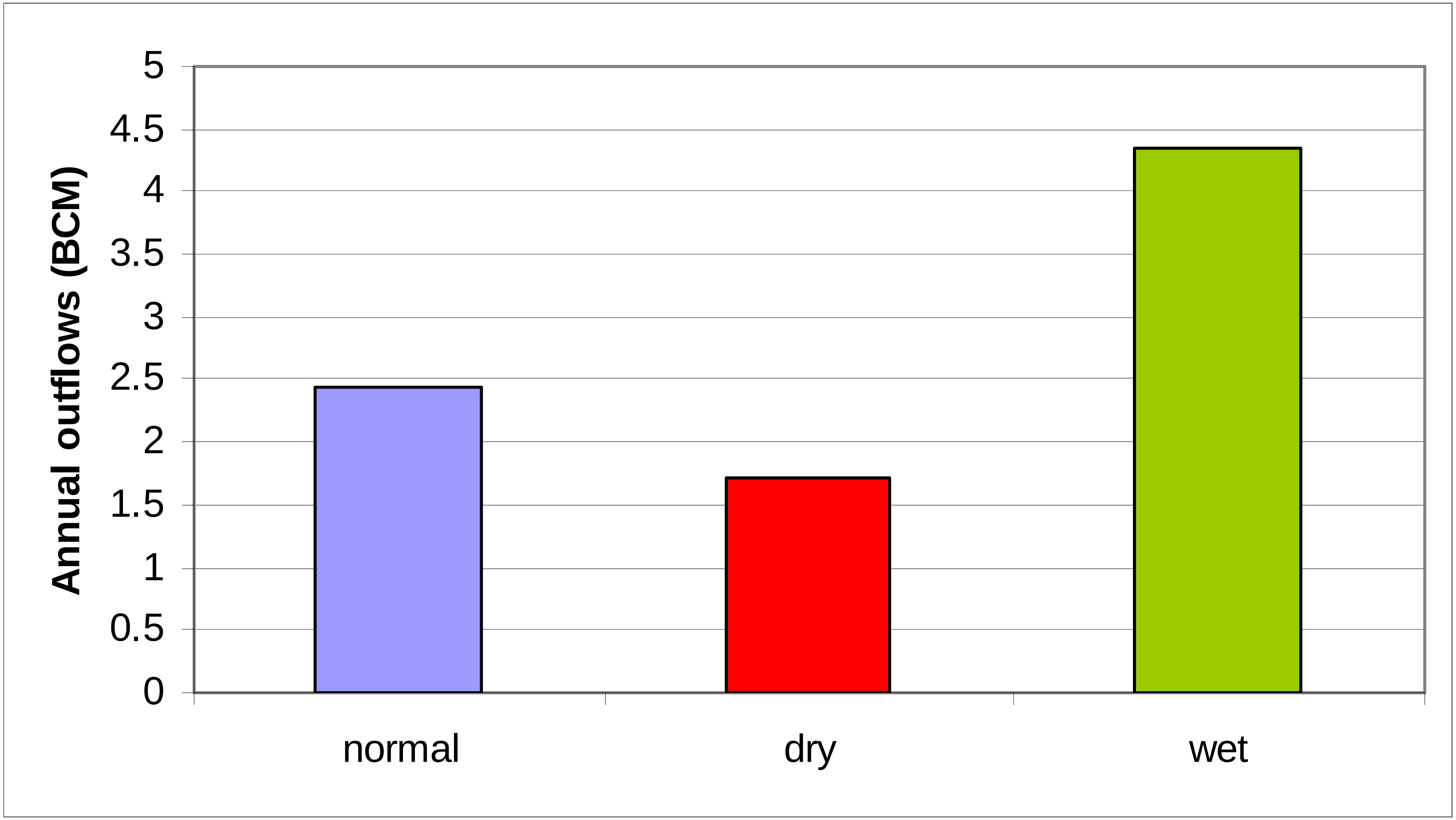
Pakwatch monthly average outflows

months	WET YEARS	DRY YEARS	NORMAL
JAN	4.502954	1.810092	2.620157
FEB	4.01163	1.542226	2.230889
MAR	4.313402	1.493605	2.298001
APR	4.155571	1.388173	2.158305
MAY	4.355749	1.496025	2.273439
JUNE	4.249275	1.559545	2.261668
JUL	4.400233	1.67217	2.37416
AUG	4.419144	1.805744	2.454788
SEP	4.300663	1.924249	2.479422
OCT	4.48329	2.06062	2.655513
NOV	4.417372	1.984139	2.645426
DEC	4.568102	1.952796	2.734824

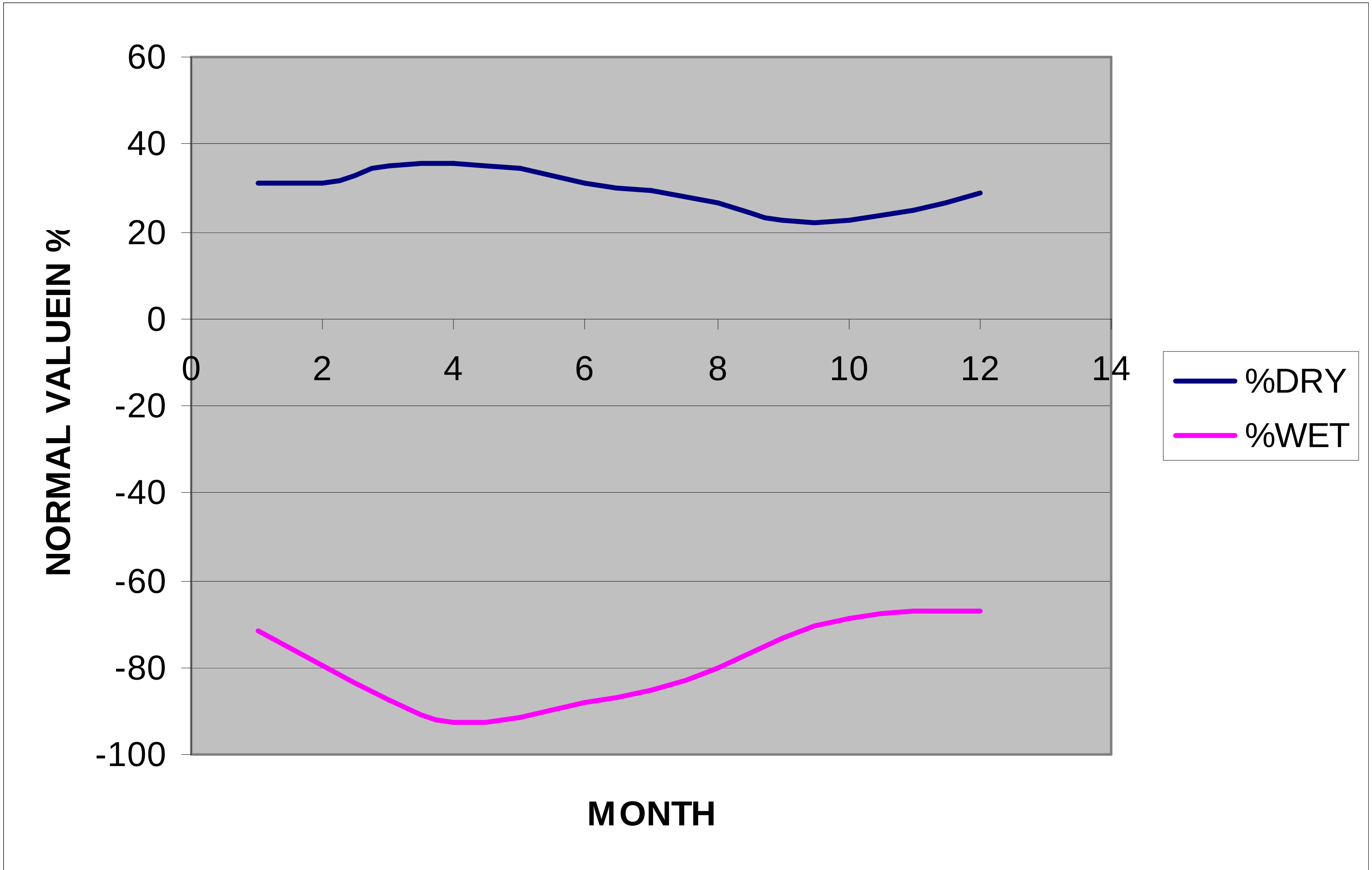
Pakwatch : Average monthly outflows



PAKWATCH: ANNUAL AVERAGE OUTFLOWS



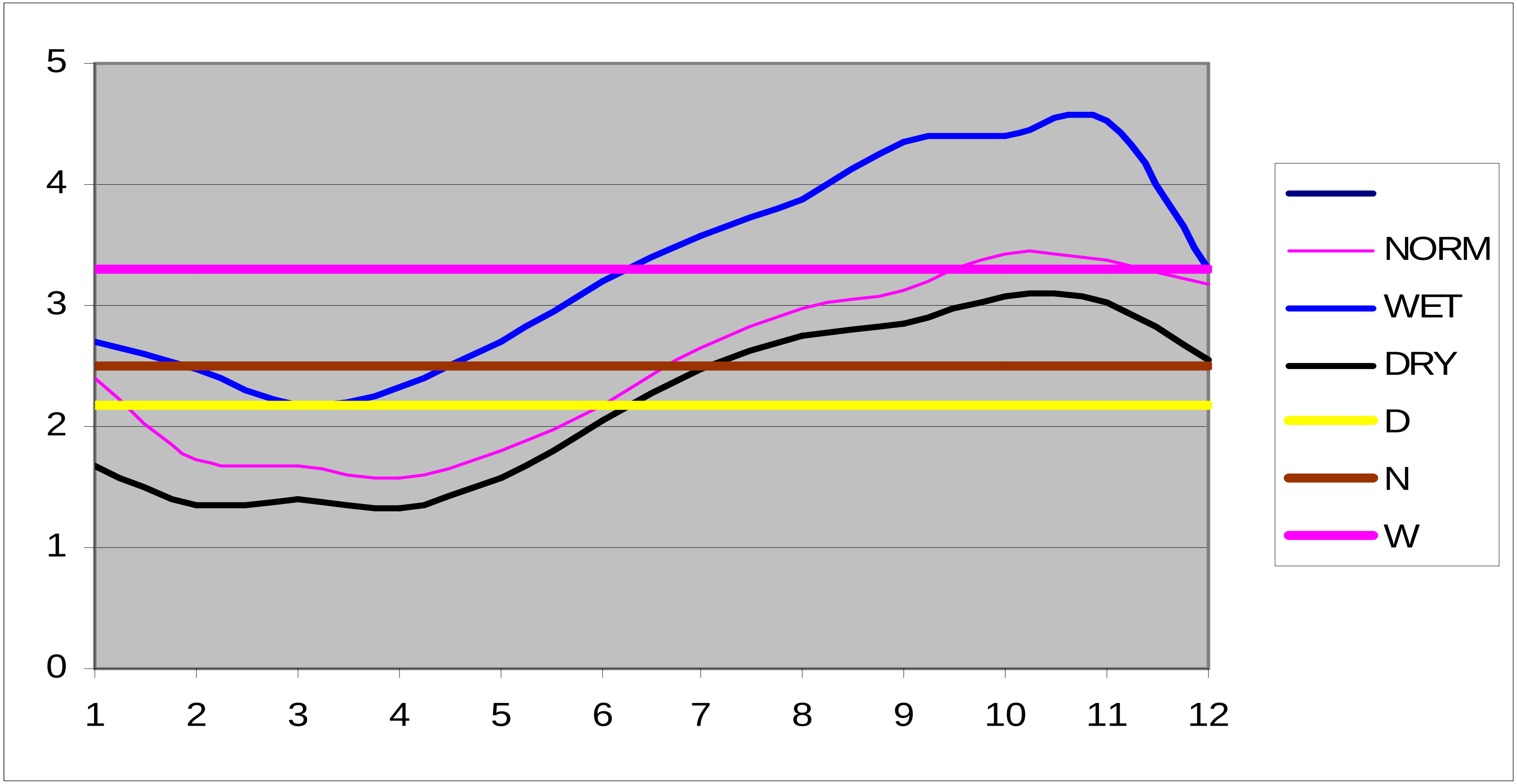
Pakwatch :Quantitative measures of outflows from the Normal



Malakal: Monthly and annual average outflows

Monthly				Annuel average		
Months	**NORM**	**WET**	**DRY**	**D**	**N**	**W**
Jan	2.40779	2.699741	1.672461	2.176132	2.506916	3.301999
FEB	1.717491	2.468466	1.34148	2.176132	2.506916	3.301999
MAR	1.679677	2.180421	1.403831	2.176132	2.506916	3.301999
APR	1.582399	2.33588	1.336342	2.176132	2.506916	3.301999
MAY	1.788797	2.705413	1.582772	2.176132	2.506916	3.301999
JUN	2.181959	3.195433	2.038782	2.176132	2.506916	3.301999
JUL	2.659635	3.567804	2.475301	2.176132	2.506916	3.301999
AUG	2.970113	3.869588	2.757401	2.176132	2.506916	3.301999
SEP	3.127938	4.360197	2.848883	2.176132	2.506916	3.301999
OCT	3.420432	4.403755	3.085391	2.176132	2.506916	3.301999
NOV	3.375525	4.534316	3.020488	2.176132	2.506916	3.301999
DEC	3.171231	3.30297	2.550454	2.176132	2.506916	3.301999

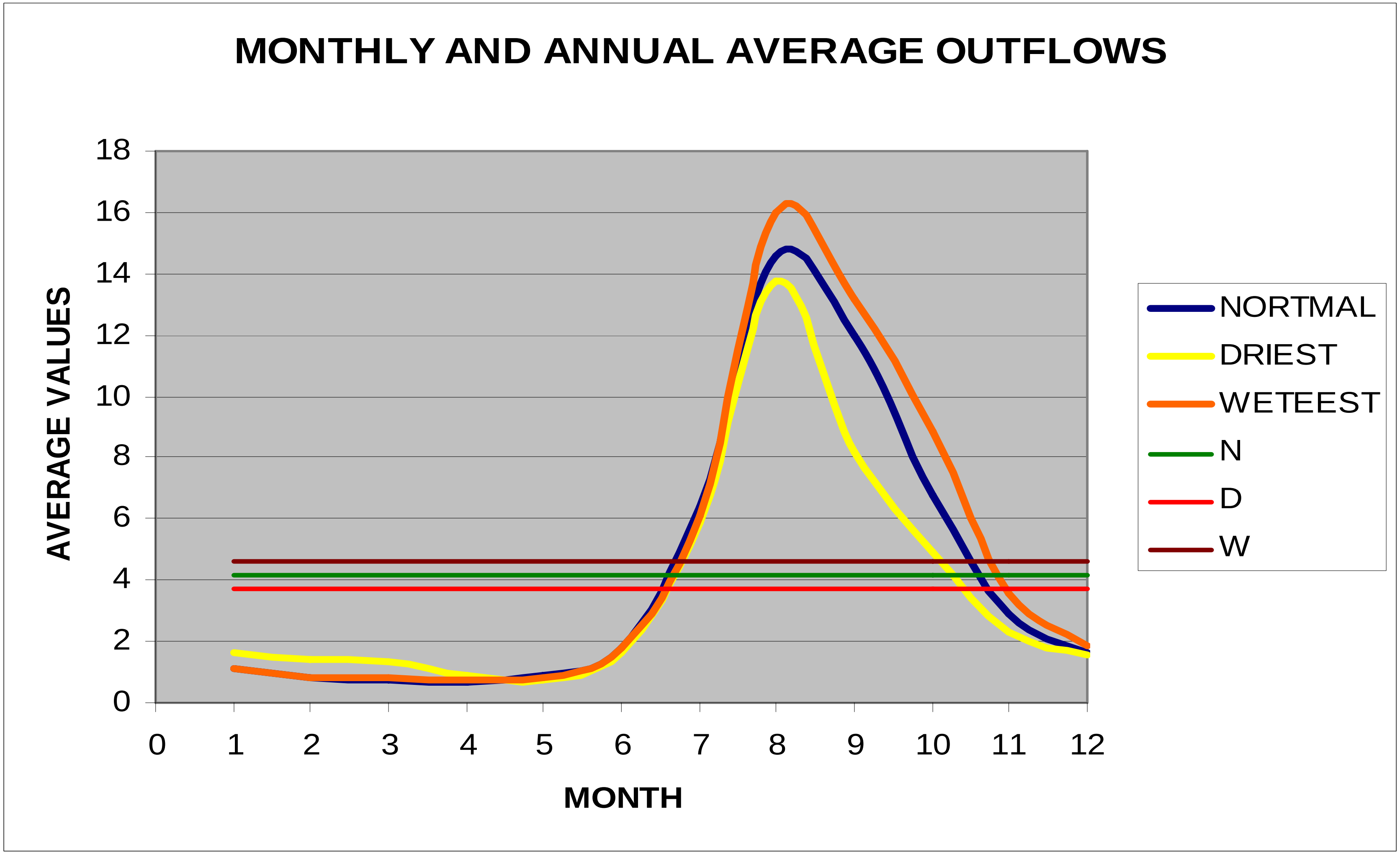
Malakal: Graph of Monthly and annual average outflows



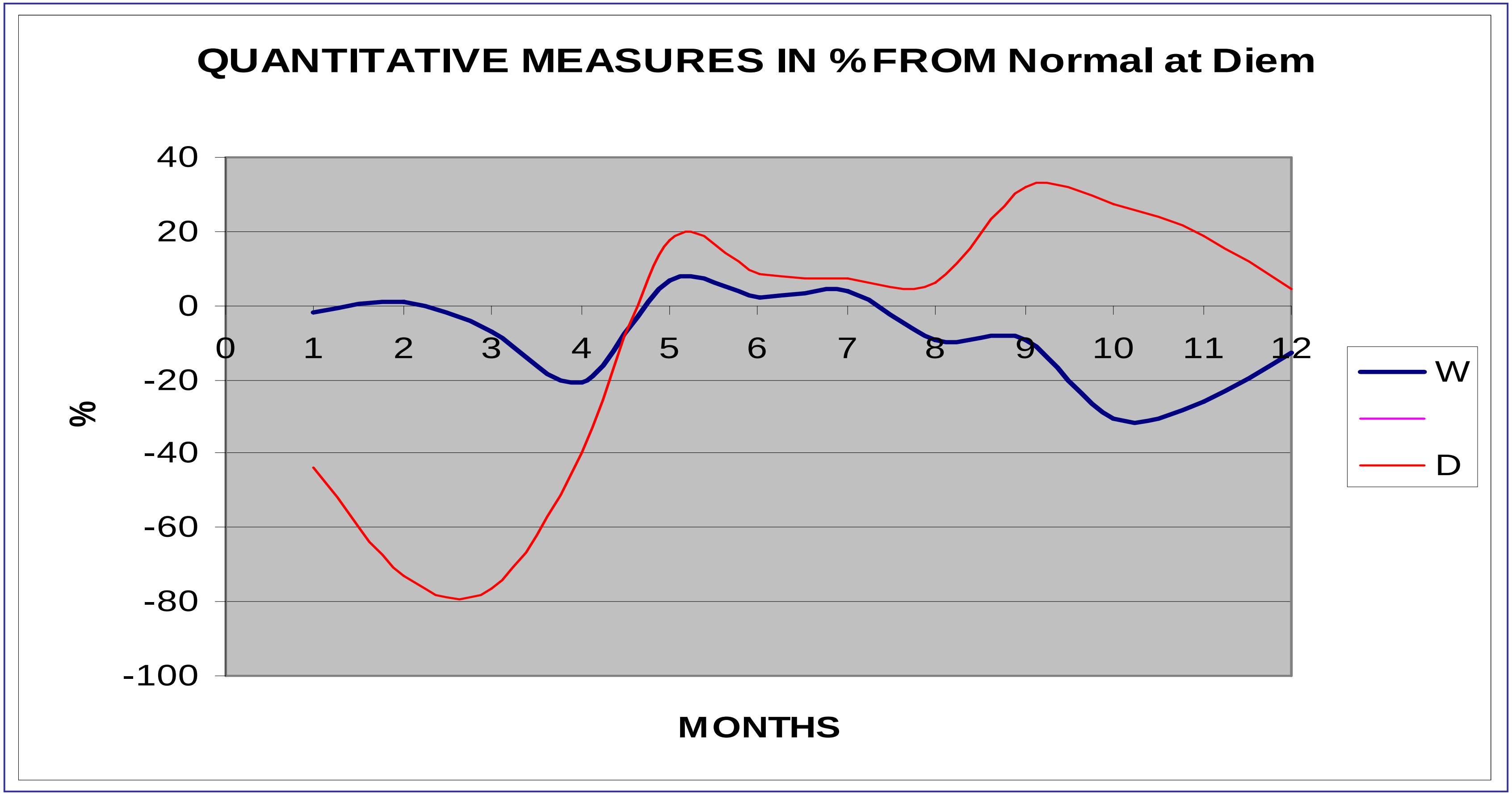
Diem: Monthly and annual Average outflows

Months	Monthly			Annuel average		
	NORM	WET	DRY	D	N	W
Jan	1.1296751	1.622427	1.147977	4.190376	3.691643	4.640721
FEB	0.7969755	1.377685	0.790565	4.190376	3.691643	4.640721
MAR	0.7389647	1.302795	0.790209	4.190376	3.691643	4.640721
APR	0.6444324	0.899243	0.777332	4.190376	3.691643	4.640721
MAY	0.8749321	0.722743	0.814487	4.190376	3.691643	4.640721
JUN	1.8065587	1.658723	1.765573	4.190376	3.691643	4.640721
JUL	6.3684877	5.910985	6.12754	4.190376	3.691643	4.640721
AUG	14.605103	13.74099	16.0099	4.190376	3.691643	4.640721
SEP	12.009064	8.19521	13.13311	4.190376	3.691643	4.640721
OCT	6.7780981	4.939357	8.841406	4.190376	3.691643	4.640721
NOV	2.8651017	2.334144	3.605564	4.190376	3.691643	4.640721
DEC	1.6671232	1.595415	1.884996	4.190376	3.691643	4.640721

Diem: Graph of Monthly and annual Average outflows



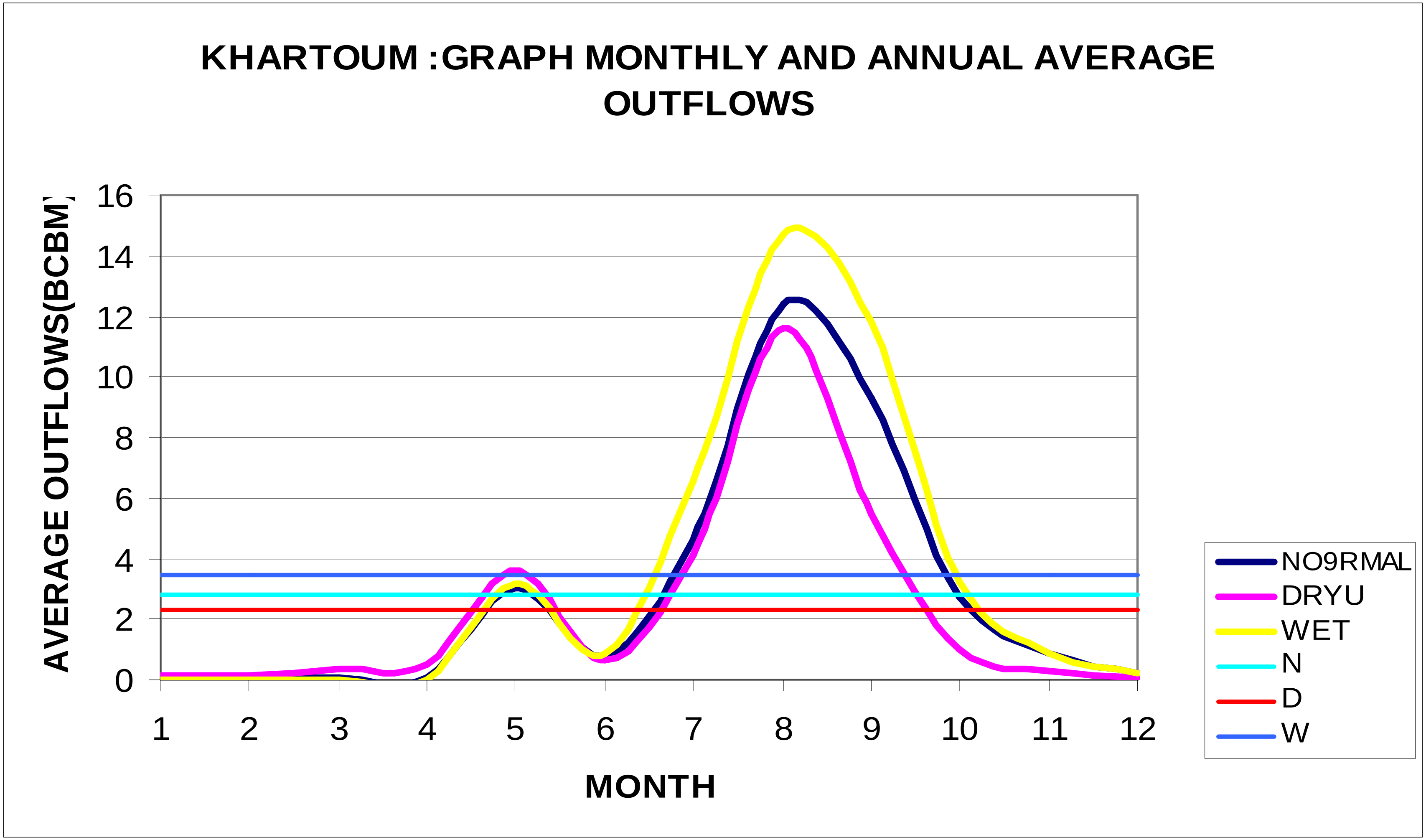
Quantitative measures in % from normal at Diem



Khartoum :Monthly and annual average outflows

MONTH	NORM YEAR	DRY YEAR	WET YEAR	N	D	W
1	0.020232	0.124454	0	2.8385749	2.33415576	3.44777216
2	0.013334	0.15897	0	2.8385749	2.33415576	3.44777216
3	0.042024	0.382066	0	2.8385749	2.33415576	3.44777216
4	0.077354	0.490829	0	2.8385749	2.33415576	3.44777216
5	3.054301	3.614514	3.18252259	2.8385749	2.33415576	3.44777216
6	0.768178	0.624736	0.865759163	2.8385749	2.33415576	3.44777216
7	4.581011	4.122293	6.530723923	2.8385749	2.33415576	3.44777216
8	12.3847	11.59628	14.67170949	2.8385749	2.33415576	3.44777216
9	9.324852	5.480848	11.79610281	2.8385749	2.33415576	3.44777216
10	2.760495	1.017621	3.255851765	2.8385749	2.33415576	3.44777216
11	0.838855	0.294496	0.889325538	2.8385749	2.33415576	3.44777216
12	0.19756	0.102767	0.181270677	2.8385749	2.33415576	3.44777216

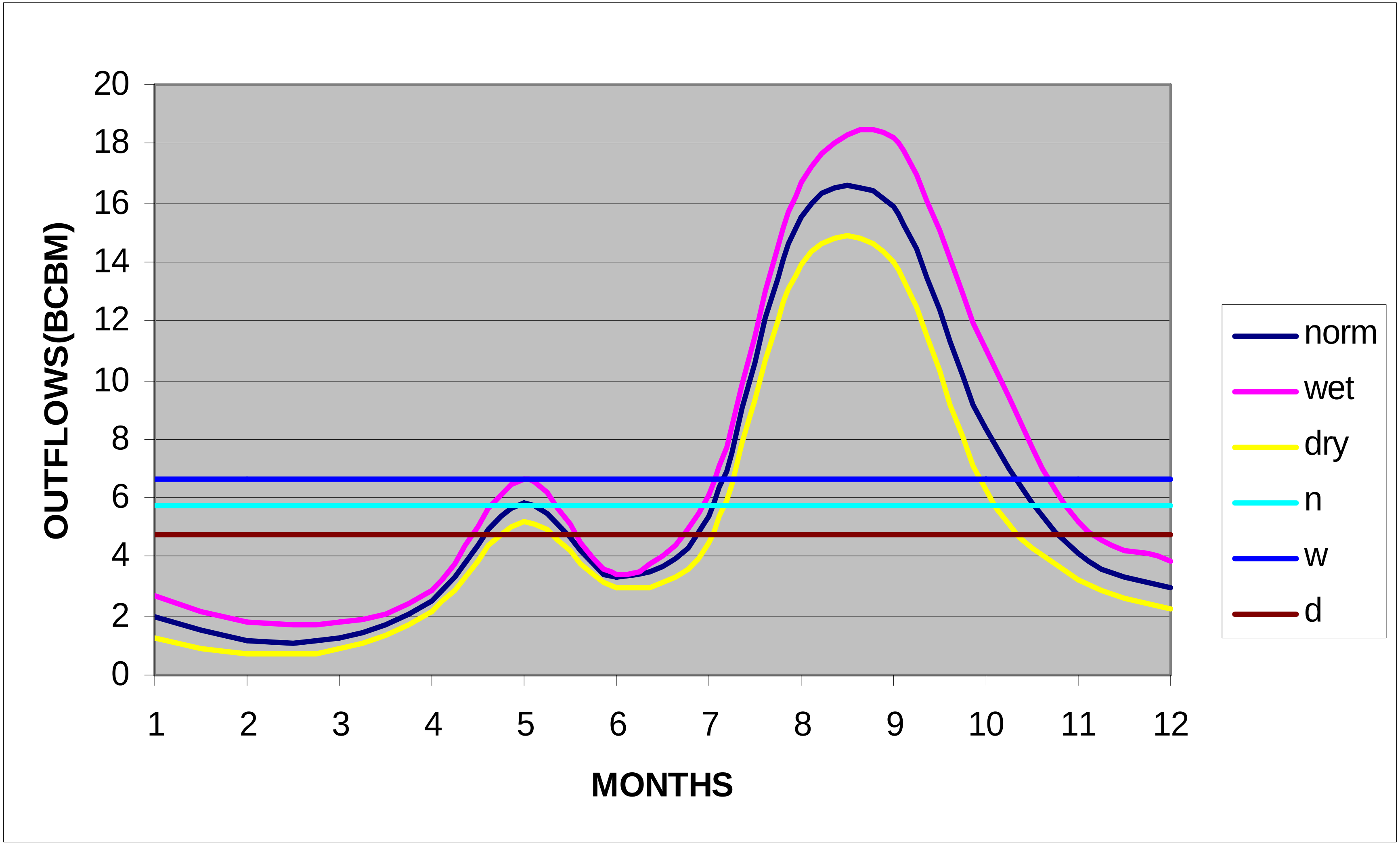
Khartoum :Graph of monthly and annual average outflows



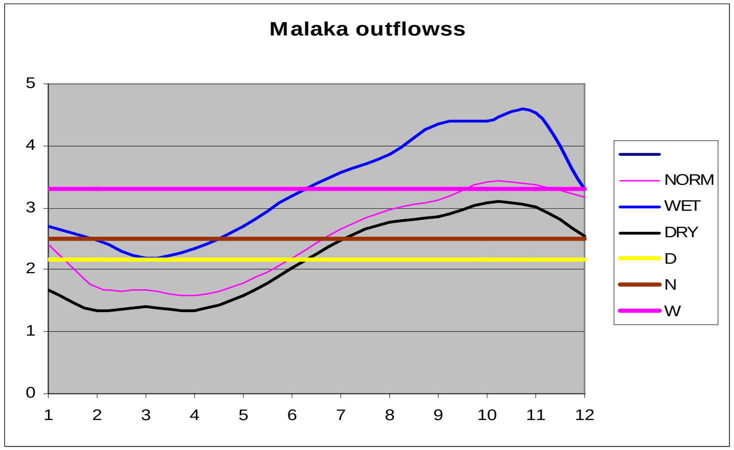
Dongala :Monthly and annual average outflows

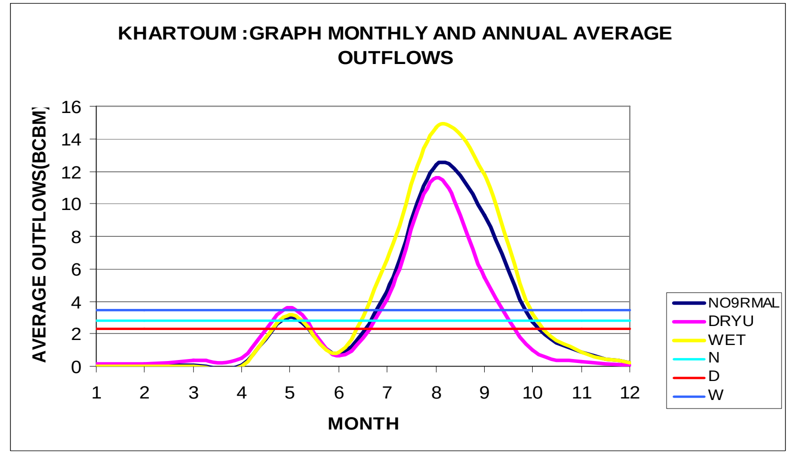
MONTH	NORM YEAR	DRY YEAR	WET YEAR	N	D	W
1	1.995317	2.675294	1.266485	5.703766	6.674848	4.779304
2	1.186387	1.810409	0.703095	5.703766	6.674848	4.779304
3	1.285173	1.788145	0.887869	5.703766	6.674848	4.779304
4	2.549349	2.839222	2.186907	5.703766	6.674848	4.779304
5	5.816221	6.601213	5.167738	5.703766	6.674848	4.779304
6	3.274336	3.408031	2.979376	5.703766	6.674848	4.779304
7	5.371541	6.084632	4.48646	5.703766	6.674848	4.779304
8	15.51581	16.64688	13.88948	5.703766	6.674848	4.779304
9	15.91709	18.17676	13.99224	5.703766	6.674848	4.779304
10	8.366619	11.03047	6.29513	5.703766	6.674848	4.779304
11	4.167039	5.163332	3.237075	5.703766	6.674848	4.779304
12	3.000298	3.873795	2.259798	5.703766	6.674848	4.779304

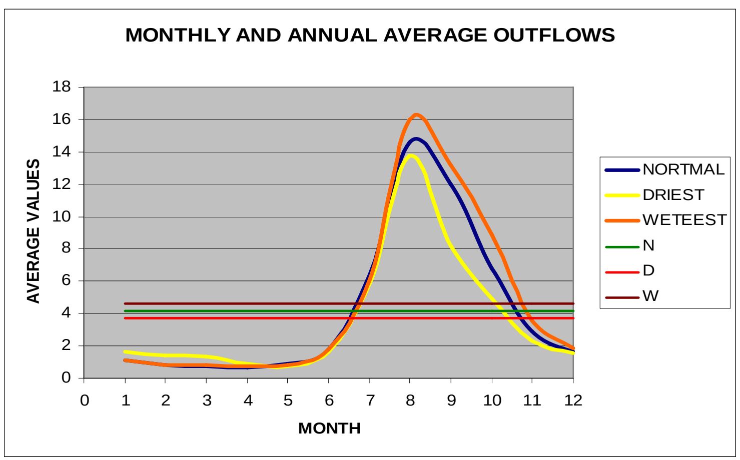
Dongala :Monthly and annual average outflows

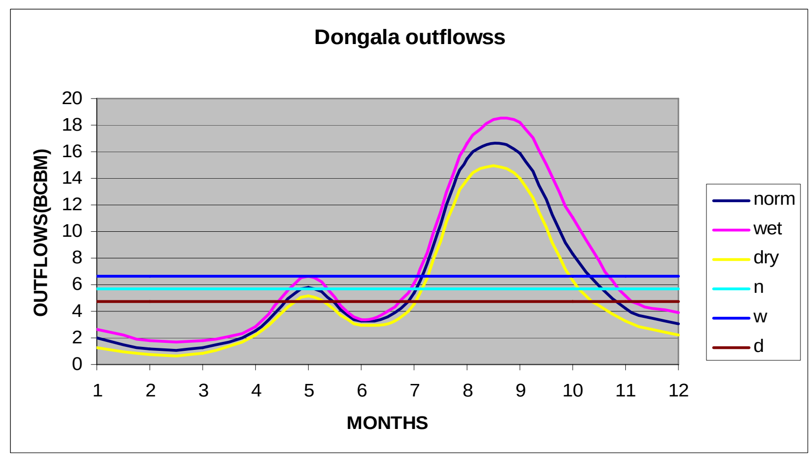


Comparison of average outflows at different river nodes.









comments

Comparison of outflows variability at the diff.
river nodes.

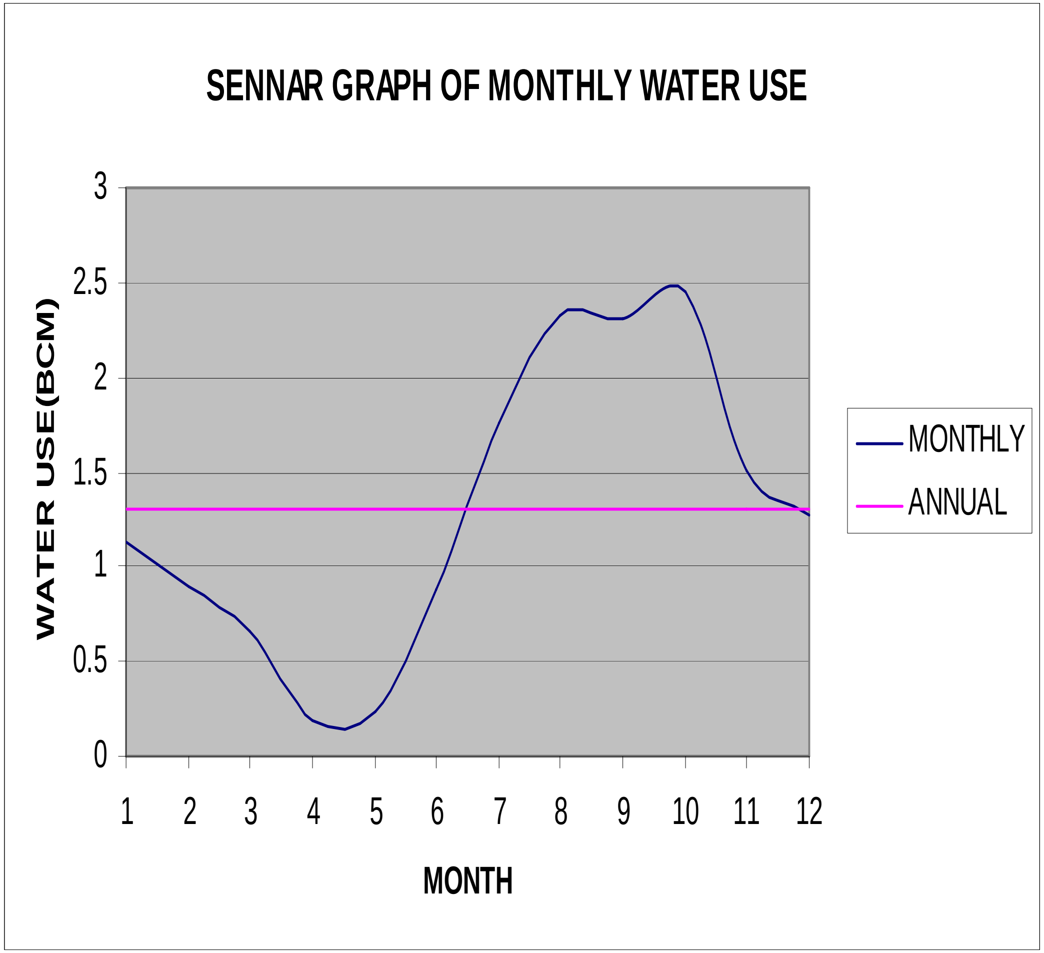
- The seasonality effect at Pakwacth is not significant .
- At Malakal, Diem ,Khartoum and Dongala nodes, the average outflows exhibit seasonal variability: low values from Jan to June.
- For diem, Khartoum and Dongala there are two peaks: one small peak in may due to short rain and one big peak due to the long rain season in the Blue Nile .

WATER USE AND LOSS COMPUTATION

Sennar: water use

MONTHS	MONTHLY	ANNUAL
1	1.134012	1.301146
2	0.891902	1.301146
3	0.66385	1.301146
4	0.192126	1.301146
5	0.232738	1.301146
6	0.880968	1.301146
7	1.754126	1.301146
8	2.31957	1.301146
9	2.314884	1.301146
10	2.446092	1.301146
11	1.504206	1.301146
12	1.279278	1.301146

Sennar: water use



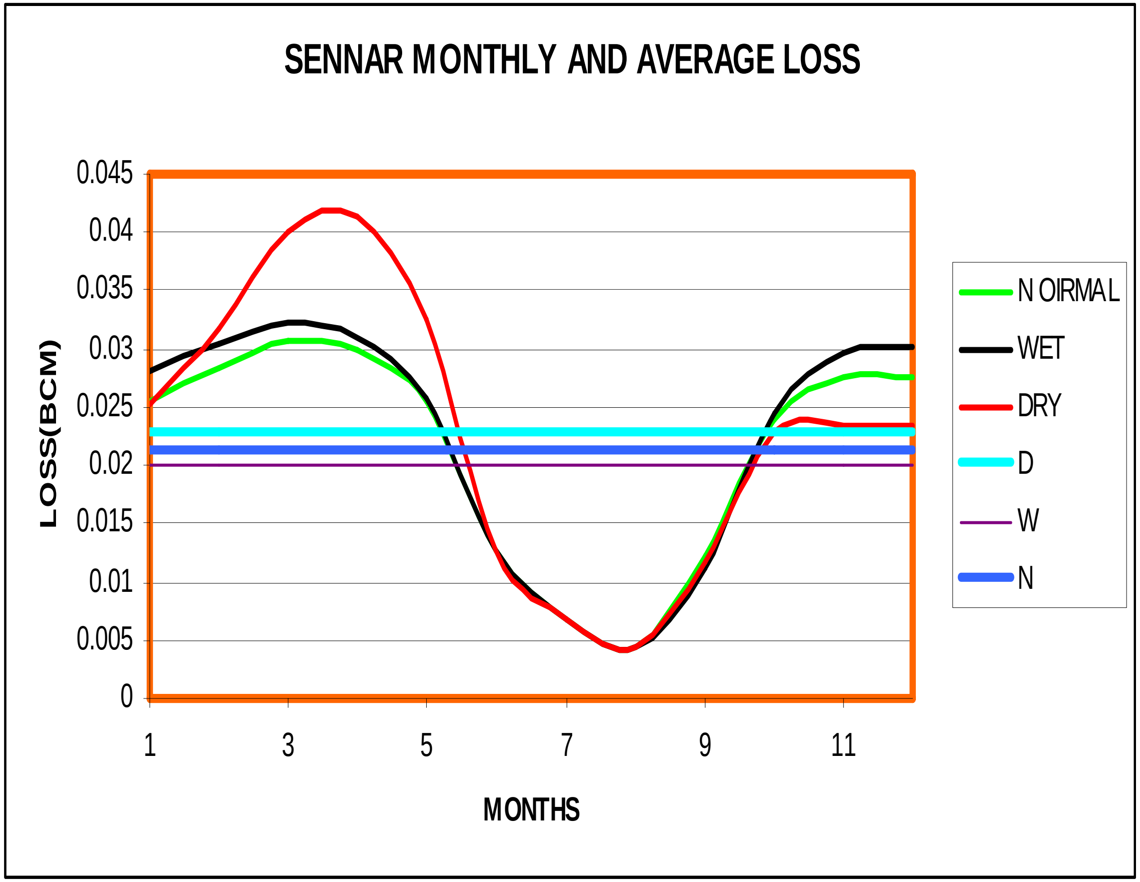
COMMENTS

- For Sennar, the average water use for normal, wet and dry years are constant quantities.
- The variability of monthly water use is high: low quantities from February to may .

SENNAR MONTHLY AND ANNUAL AVERAGE LOSS

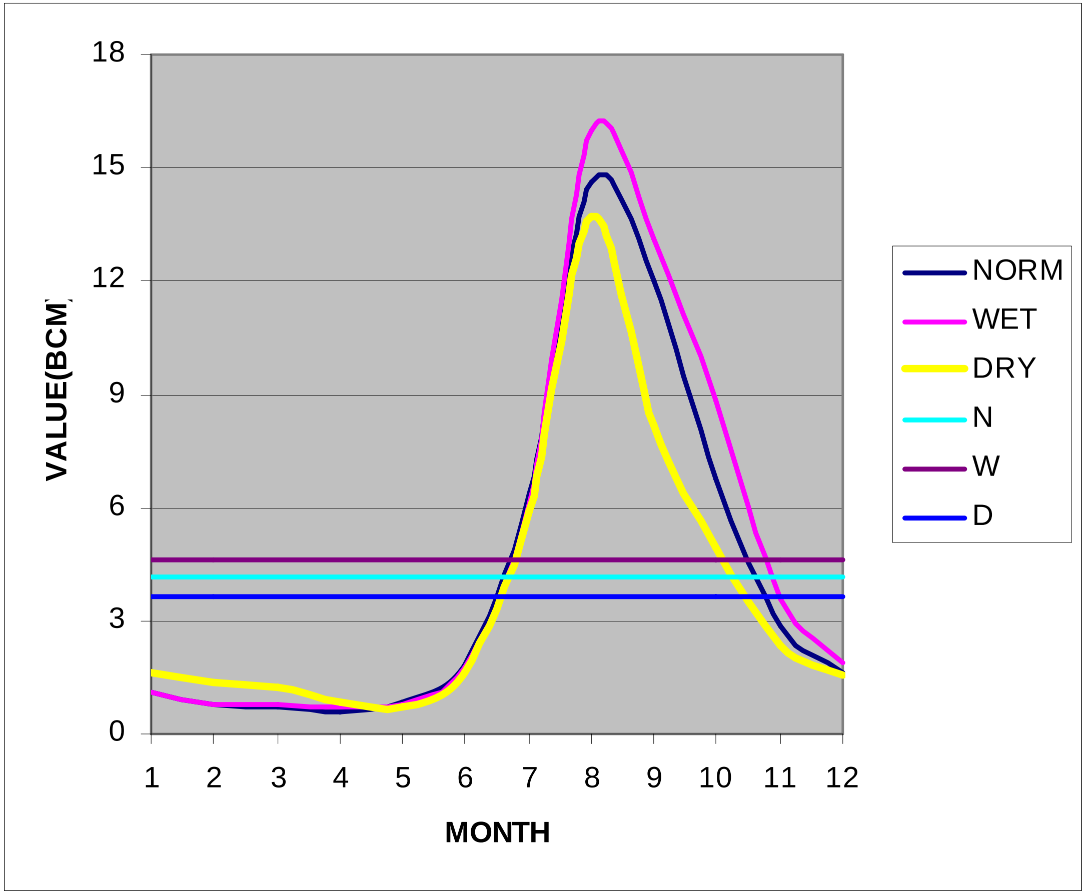
MONTHS	NORMAL YEAR	WET YEAR	DRY YEAR	D	W	N
1	0.025562	0.027963	0.025168	0.023005	0.020142	0.021266
2	0.028331	0.030489	0.031633	0.023005	0.020142	0.021266
3	0.030631	0.032129	0.039962	0.023005	0.020142	0.021266
4	0.029863	0.03087	0.041255	0.023005	0.020142	0.021266
5	0.025582	0.025875	0.032633	0.023005	0.020142	0.021266
6	0.012783	0.012783	0.012783	0.023005	0.020142	0.021266
7	0.006757	0.006757	0.006757	0.023005	0.020142	0.021266
8	0.004346	0.004346	0.004346	0.023005	0.020142	0.021266
9	0.012195	0.011071	0.011748	0.023005	0.020142	0.021266
10	0.023983	0.024514	0.022815	0.023005	0.020142	0.021266
11	0.027643	0.029628	0.023494	0.023005	0.020142	0.021266
12	0.02752	0.030198	0.023471	0.023005	0.020142	0.021266

SENNAR MONTHLY AND ANNUAL AVERAGE LOSS



- Comments:
- The loss of water is less during the rain season from may to September.
- And relatively high from October to may

SENNAR: DIFFERENCE BETWEEN OUTFLOWS AND LOSS



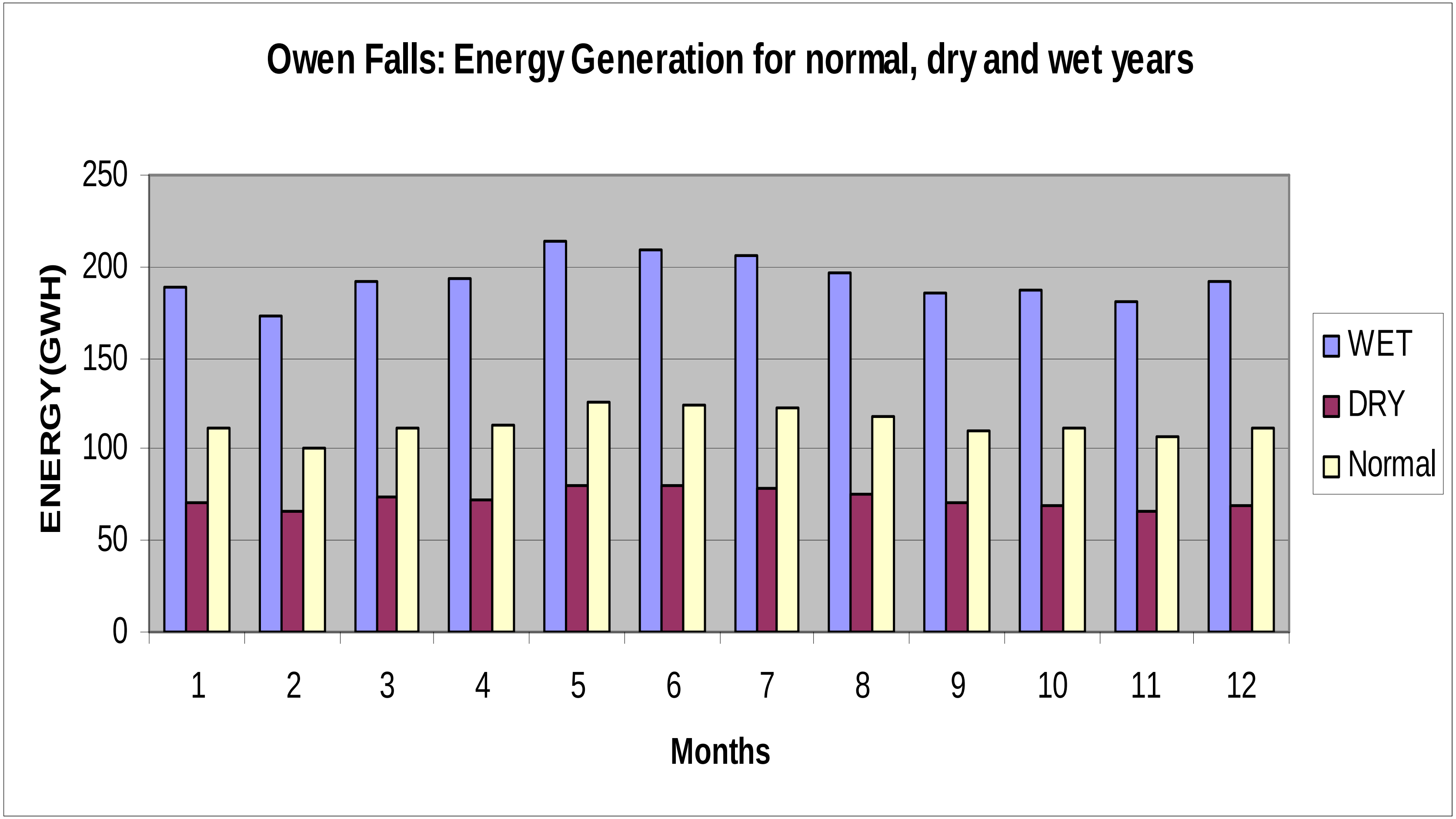
- **Comments:**
- Comparison of Loss and outflows at Diem to Khartoum river reach reveals that the loss have not significant influence on the flows.

ENERGY GENERATION

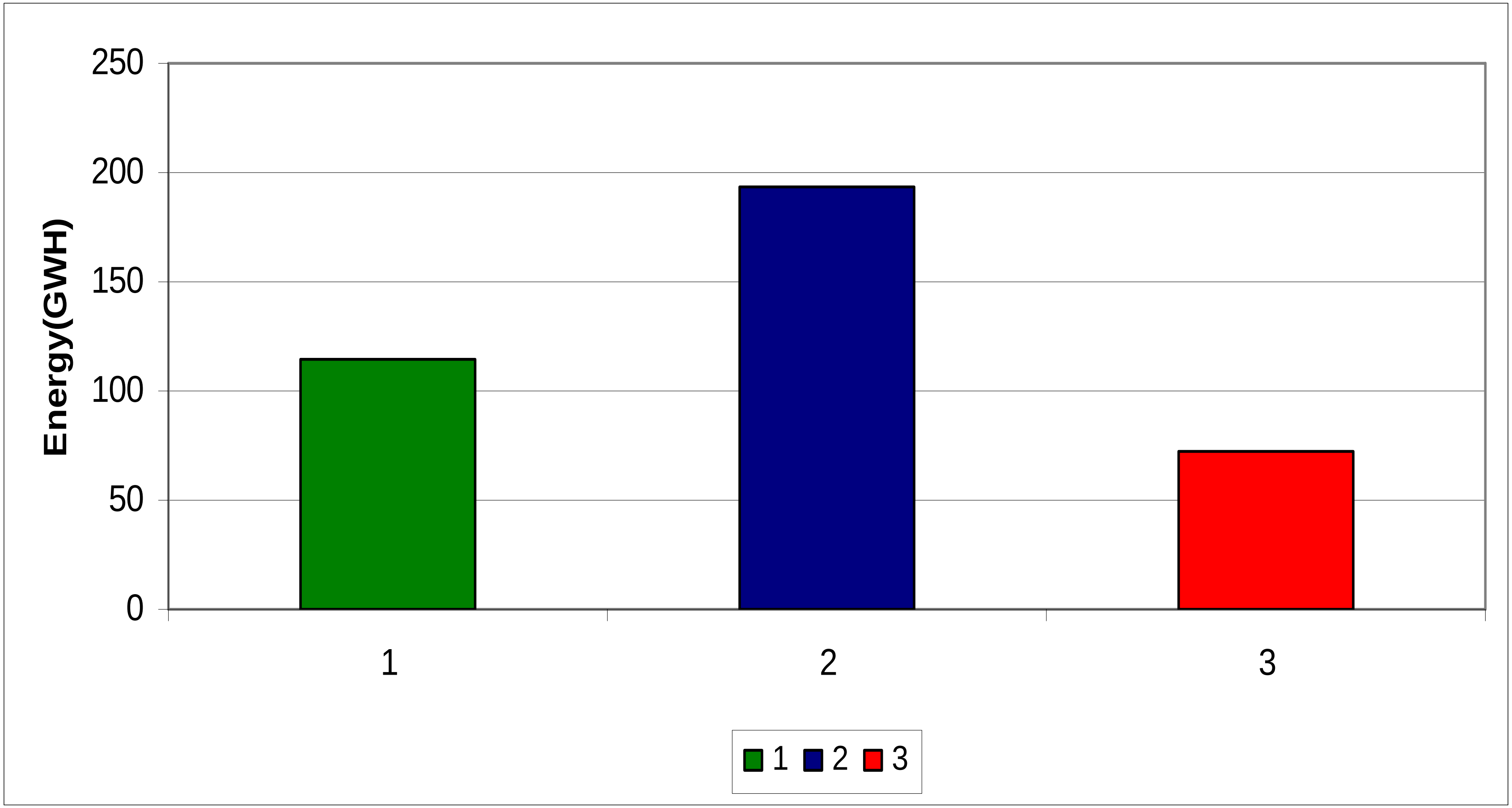
Owen Falls: Montly Average Energy Generation

Month	Max	Min	Normal
1	189.241171	71.4406506	111.725545
2	173.009055	65.2737535	101.114001
3	191.706715	73.7967865	112.119471
4	193.756466	72.748806	113.315767
5	213.140598	80.146492	125.146075
6	208.448768	79.9775635	123.775345
7	206.616621	79.2173813	123.159259
8	197.244449	74.7762047	117.565536
9	185.164881	70.0377266	110.059749
10	186.797459	68.588525	110.932608
11	180.960793	65.9524628	106.62228
12	191.19871	69.207325	111.702259

Owen Falls Energy Generation



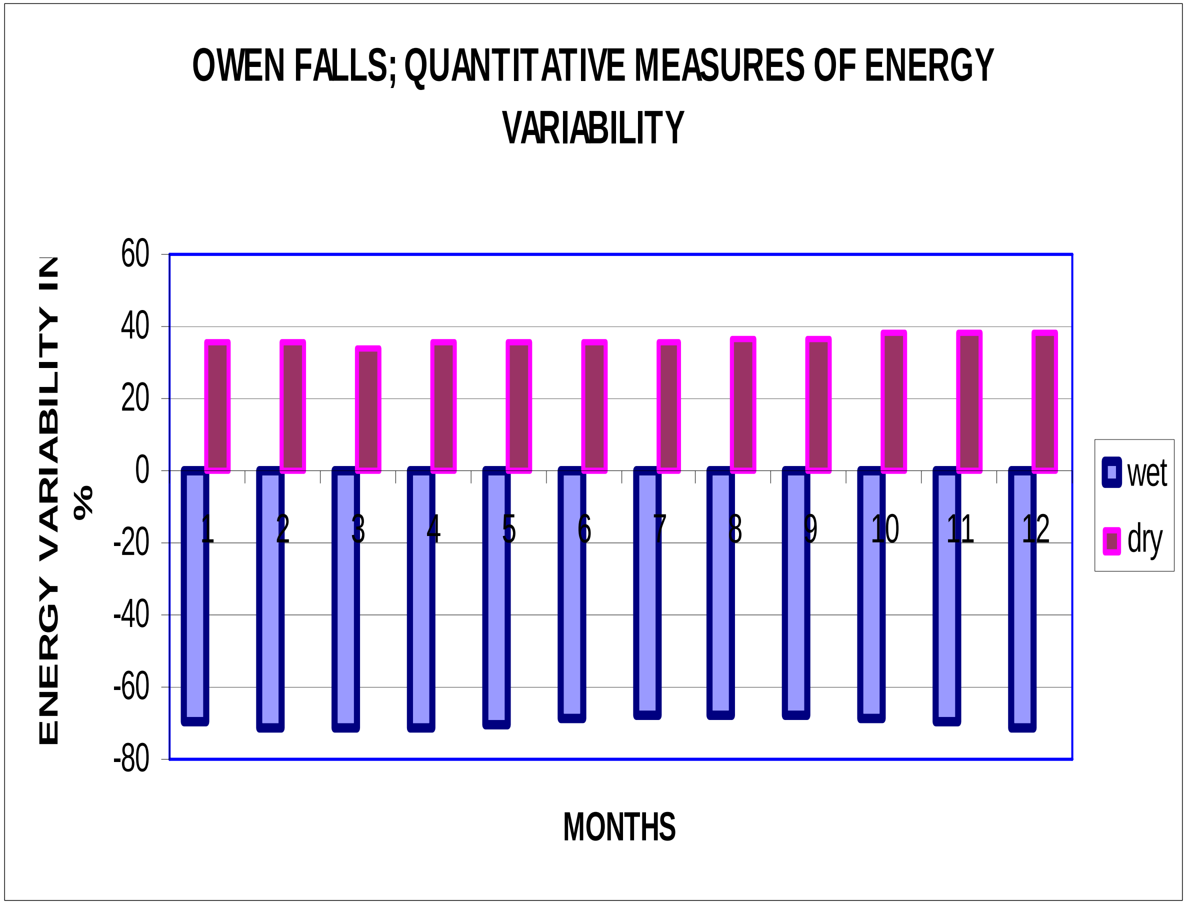
OWEN FALL: ANNUAL AVERAGE ENERGY GENERATION



OWEN FALLS: QUANTITATIVE MEASURES OF ENERGY VARIABILITY

MONTH	WET PERIOD	DRY PERIOD
1	-69.3803962	36.057013
2	-71.1029658	35.4453858
3	-70.9843194	34.1802224
4	-70.9880904	35.7999262
5	-70.3134494	35.9576464
6	-68.4089569	35.3848997
7	-67.763774	35.6789071
8	-67.7740398	36.396152
9	-68.2403261	36.363905
10	-68.3882337	38.1709973
11	-69.7213687	38.1438261
12	-71.1681676	38.043039

OWEN FALLS; QUANTITATIVE MEASURES OF ENERGY VARIABILITY

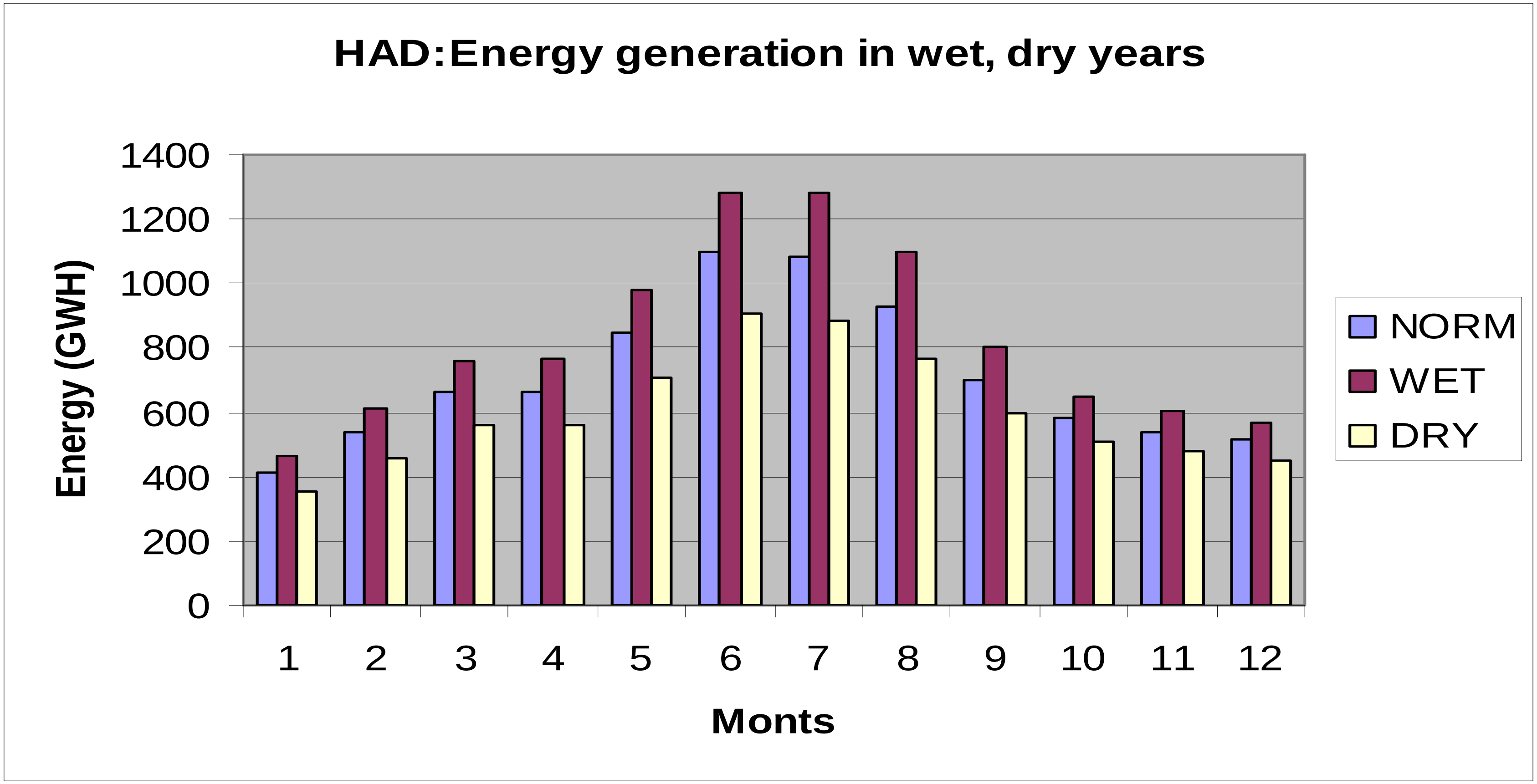


- **Comment**:
- The differences from the normal are relatively high in wet period(70%)
- Differences in % in dry period are relatively low (about 30%)

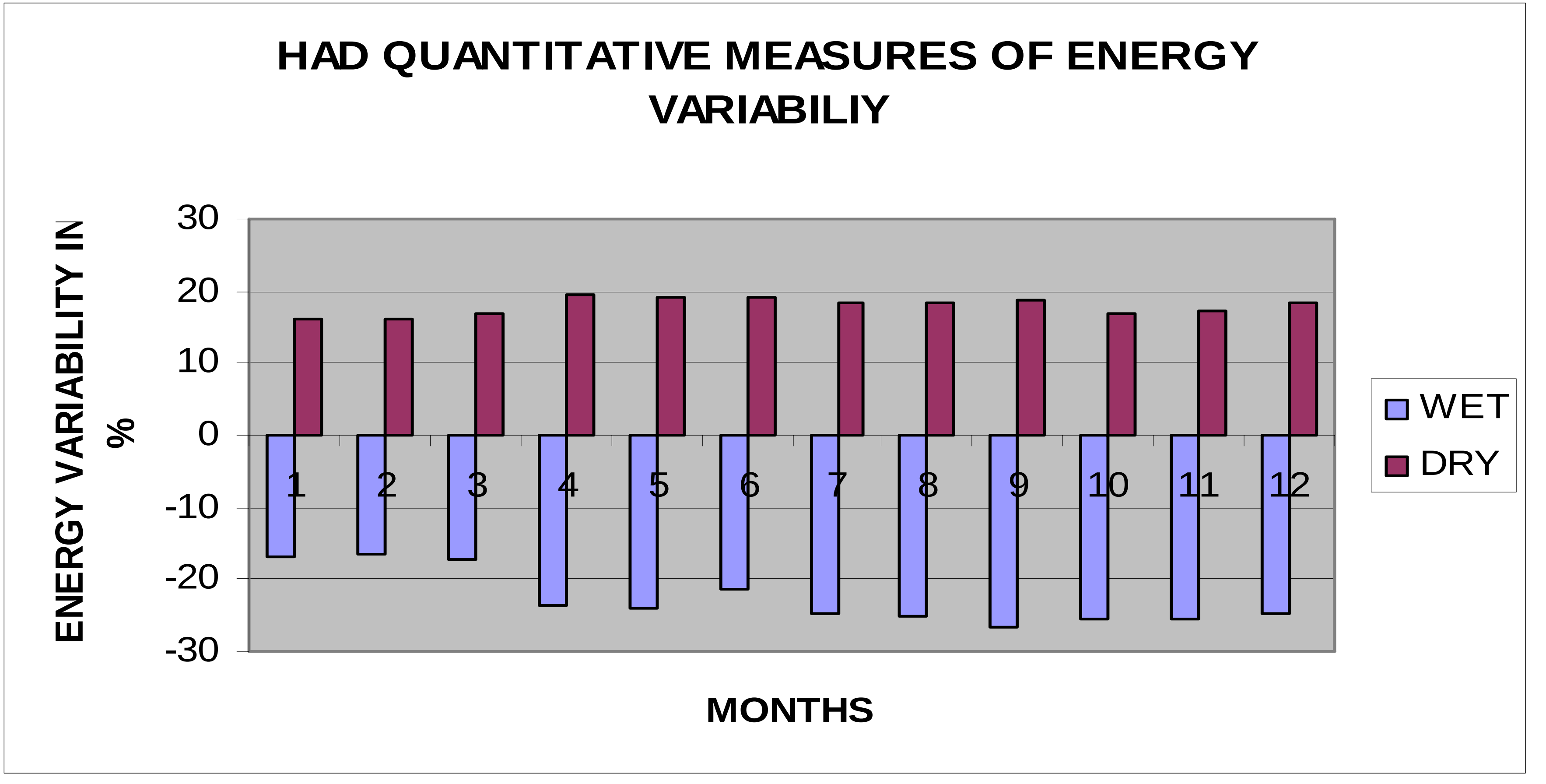
HAD: ENERGY GENERATION

Months	NORM	WET	DRY
1	410.219	461.3512	351.2159
2	538.9955	608.8401	458.4395
3	662.0719	755.3288	559.1611
4	665.9442	766.8189	558.3639
5	844.7421	980.4848	703.816
6	1096.185	1281.136	907.6881
7	1080.343	1280.795	885.592
8	931.6773	1101.221	768.1604
9	698.765	801.9955	595.2626
10	580.9016	651.5531	508.1184
11	541.3752	603.2853	475.4867
12	512.182	570.7132	449.1391

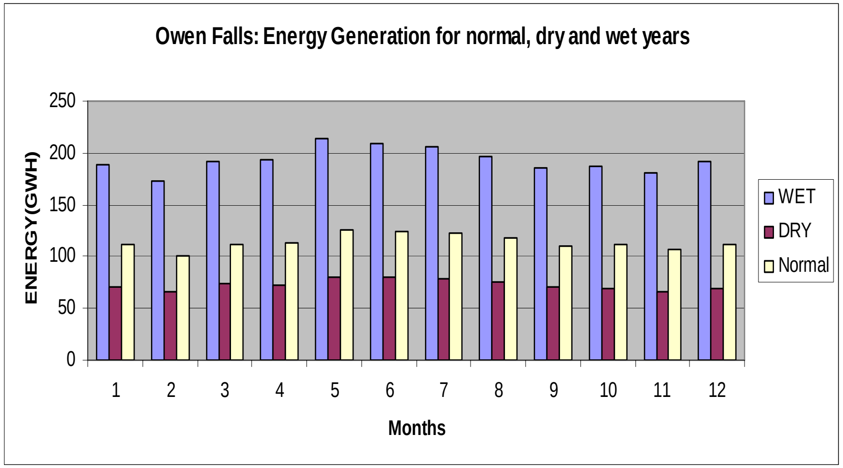
HAD: ENERGY GENERATION OF NORMAL ,DRY AND WET YEARS

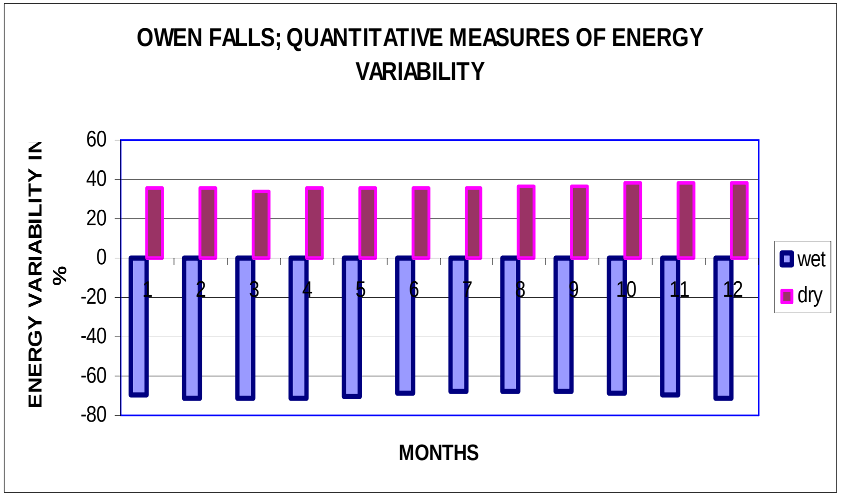


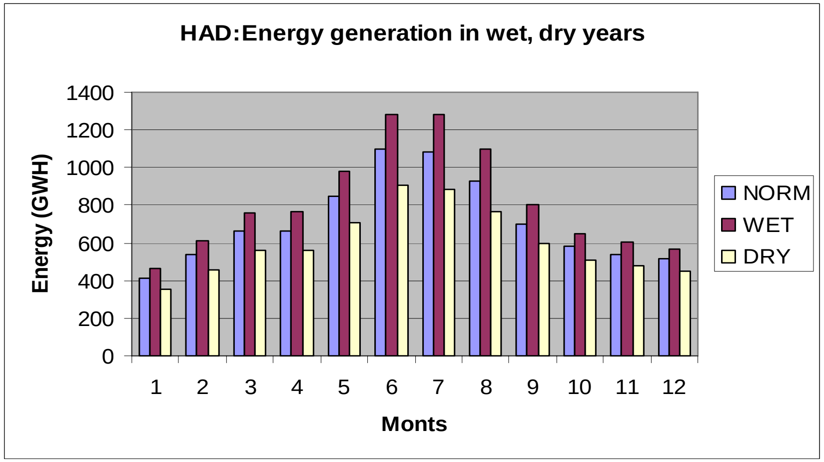
HAD: QUANTITATIVE MEASURES OF ENERGY VARIABILIY

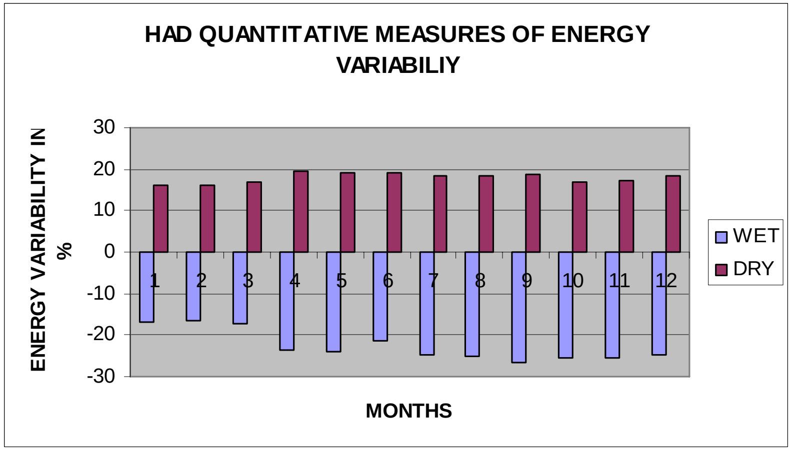


COMPARISON ENERGY GENERATION AT OWEN FALLS AND HAD









COMMENTS ON ENERGY GENERATION GRAPH.

- 1 **<u>OWEN FALLS DAM.</u>**
- *The Energy generation in wet period is twice more than in dry period.
- The quantitative measures   from the normal are higher during the wet period (> 60%) than in dry period(40%).

- **<u>2. HAD</u>**
- There difference from the normal (in %) of energy generation in wet and dry periods are not big, but begins increasing slowly from March up to November.

- **<u>3. COMPARISON BETWEEN HAD AND OWEN FALLS</u>**.
- The   energy generation at HAD is six times higher than at Owen Falls.
- HAD increases its energy production from June to September period.

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- THANK YOU

NILE DST RRSM APPLICATIONS

DRCongo PRESENTATION

By

Arly BATUMBO

Georges GULEMVUGA

SEPT – OCTOBER 2006

WATER BALANCE AND WATER USES ASSESSMENT

The river reaches are defined as follows:

Reach I : PAKWATCH – MALAKAL

with Torrents and Sobat as tributaries

Reach II : MALAKAL – KHARTOUM

with Gebel Aulia as Reservoir

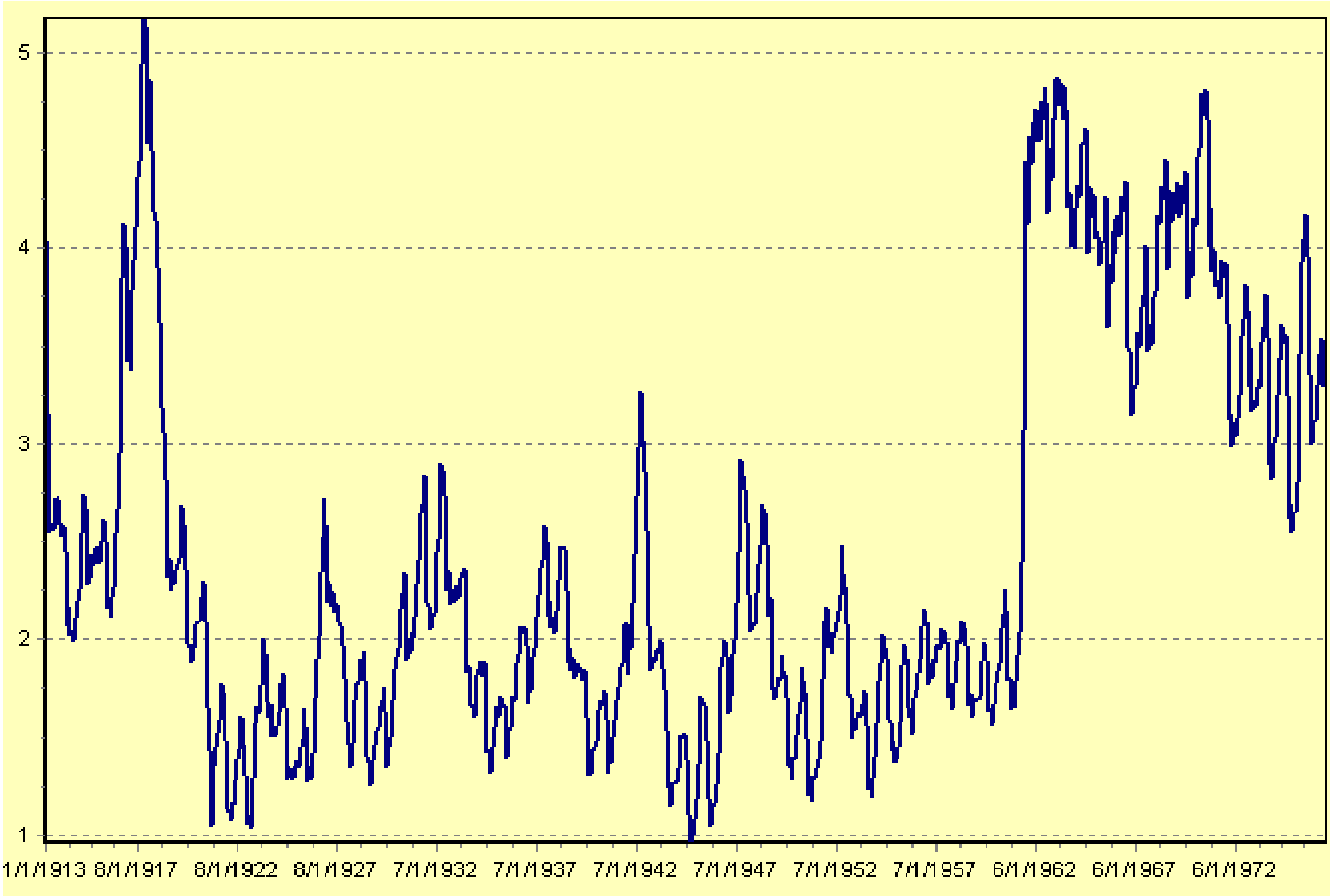
Reach III: BORDER (DIEM) – KHARTOUM

with Sennar and Roseires as withdrawals

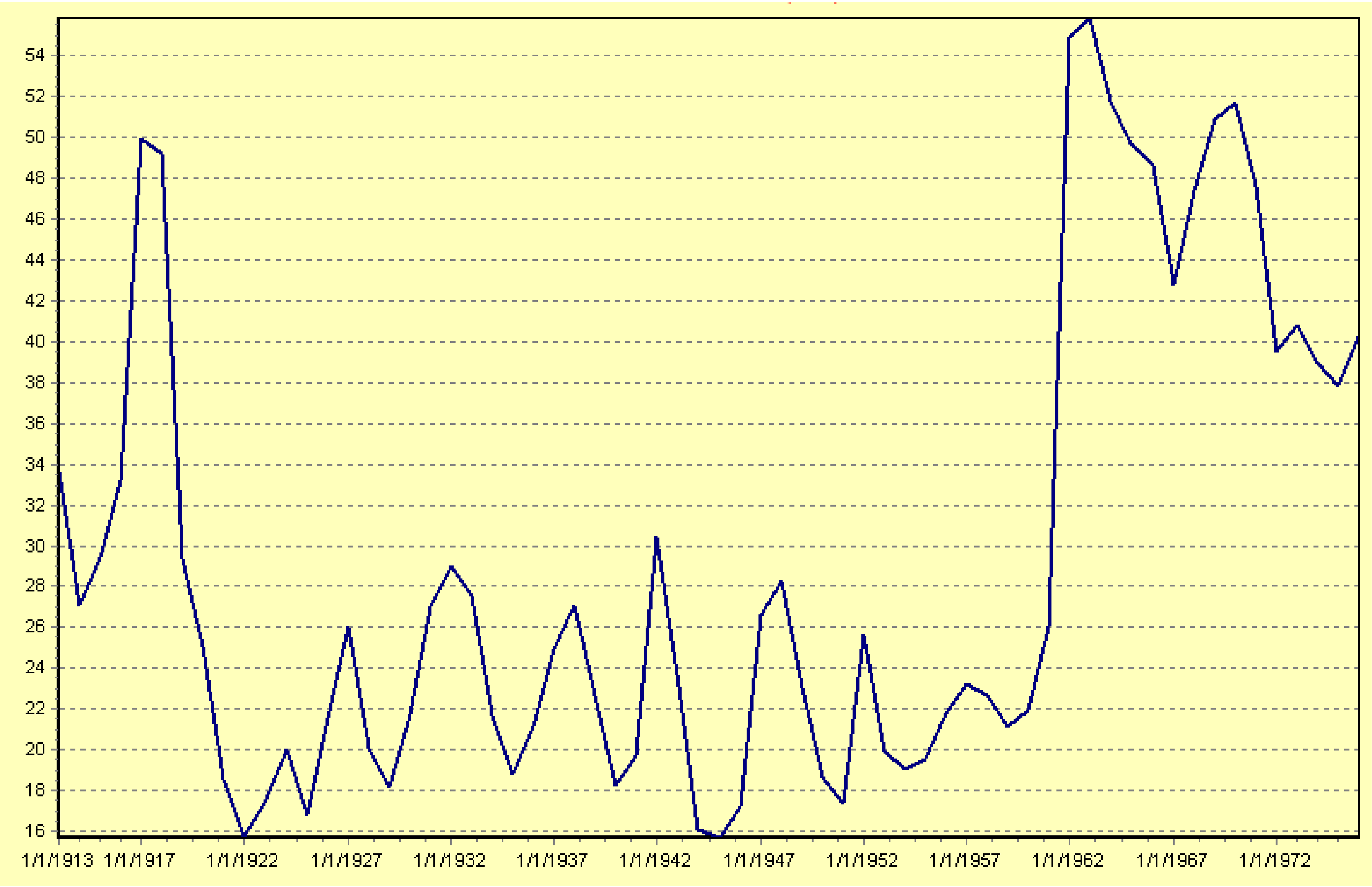
Reach IV: KHARTOUM – DONGOLA

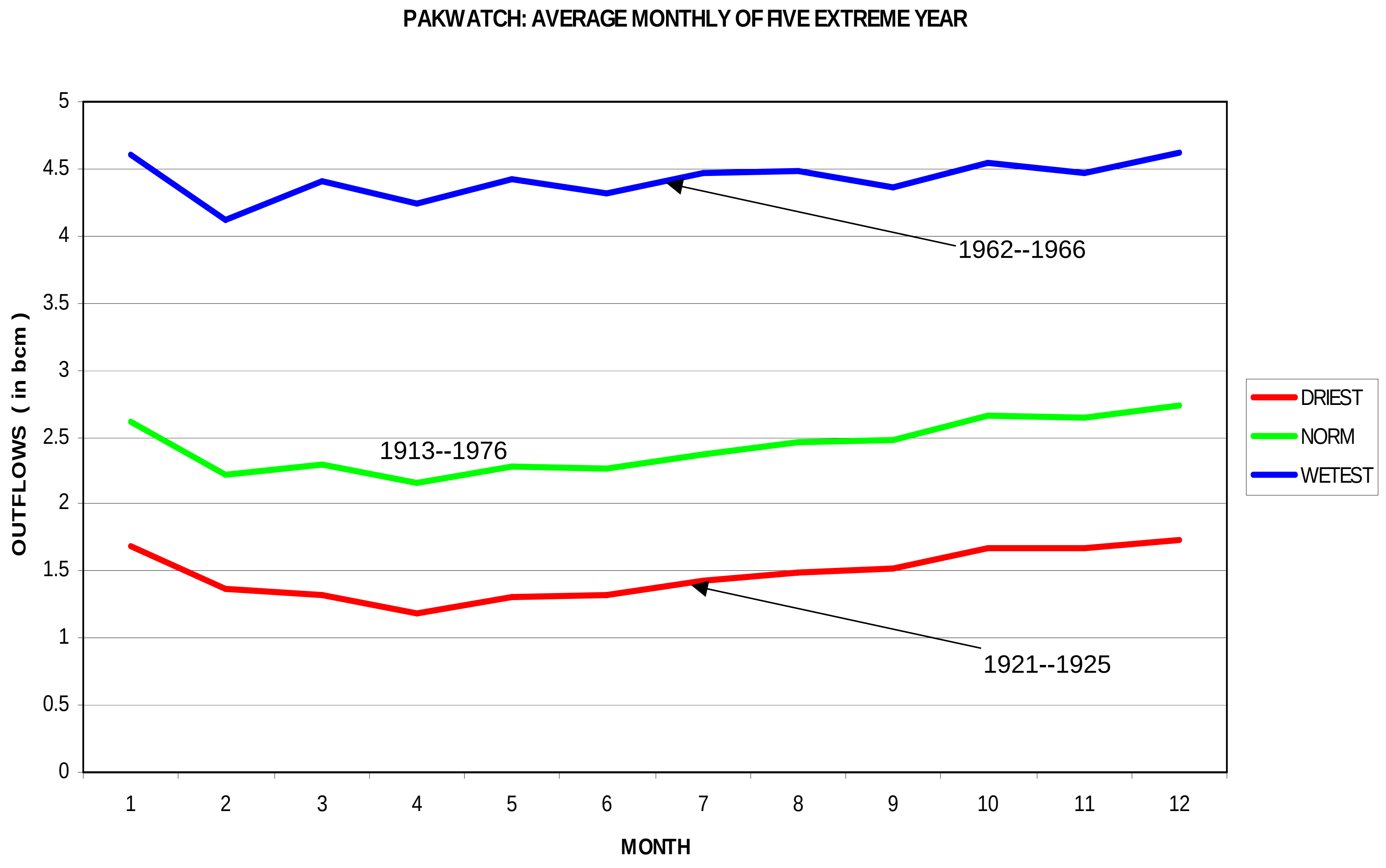
with Atbara as a tributary and Merowe as withdrawals

Pakwatch monthly outflow

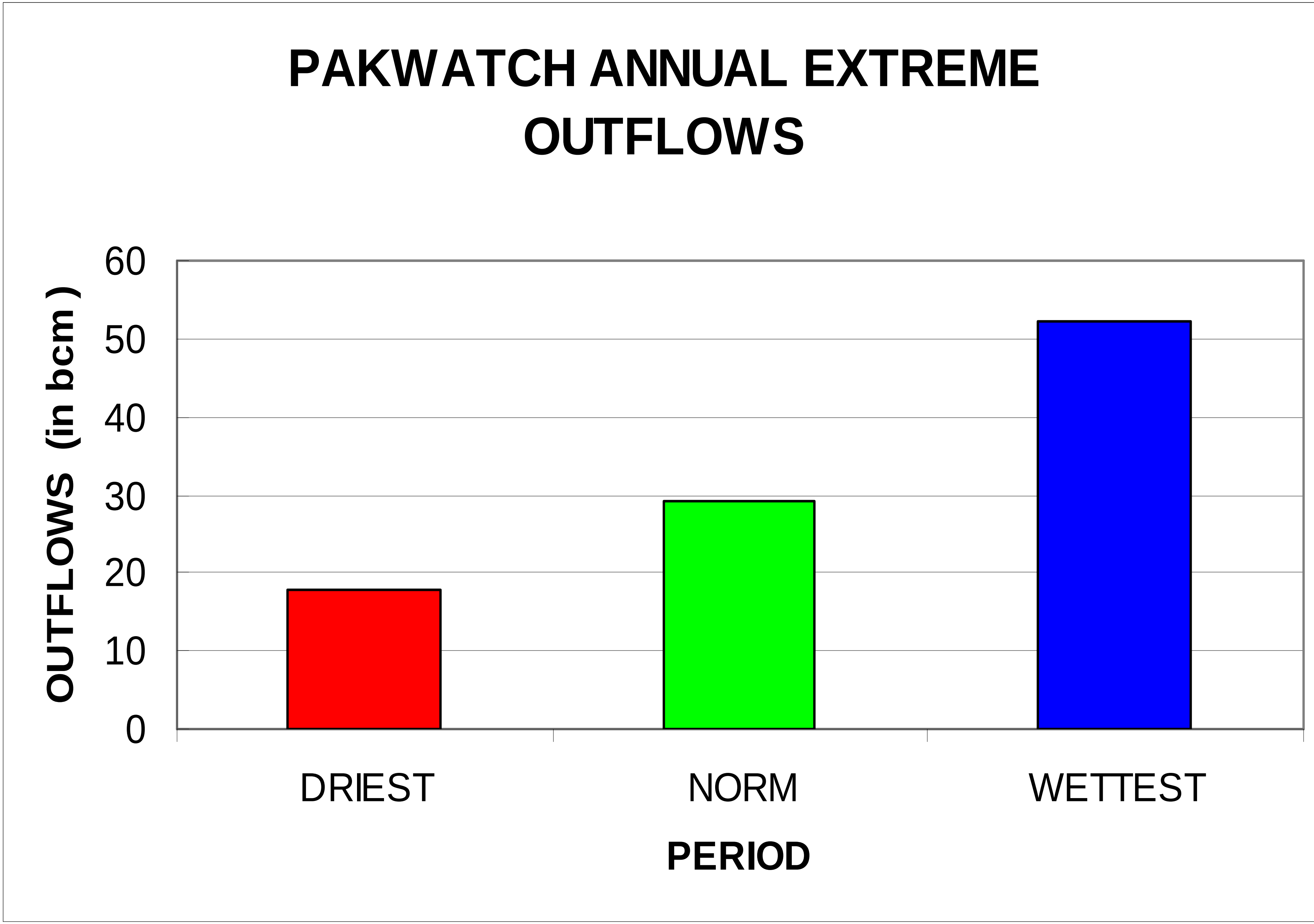


Pakwatch annual outflows





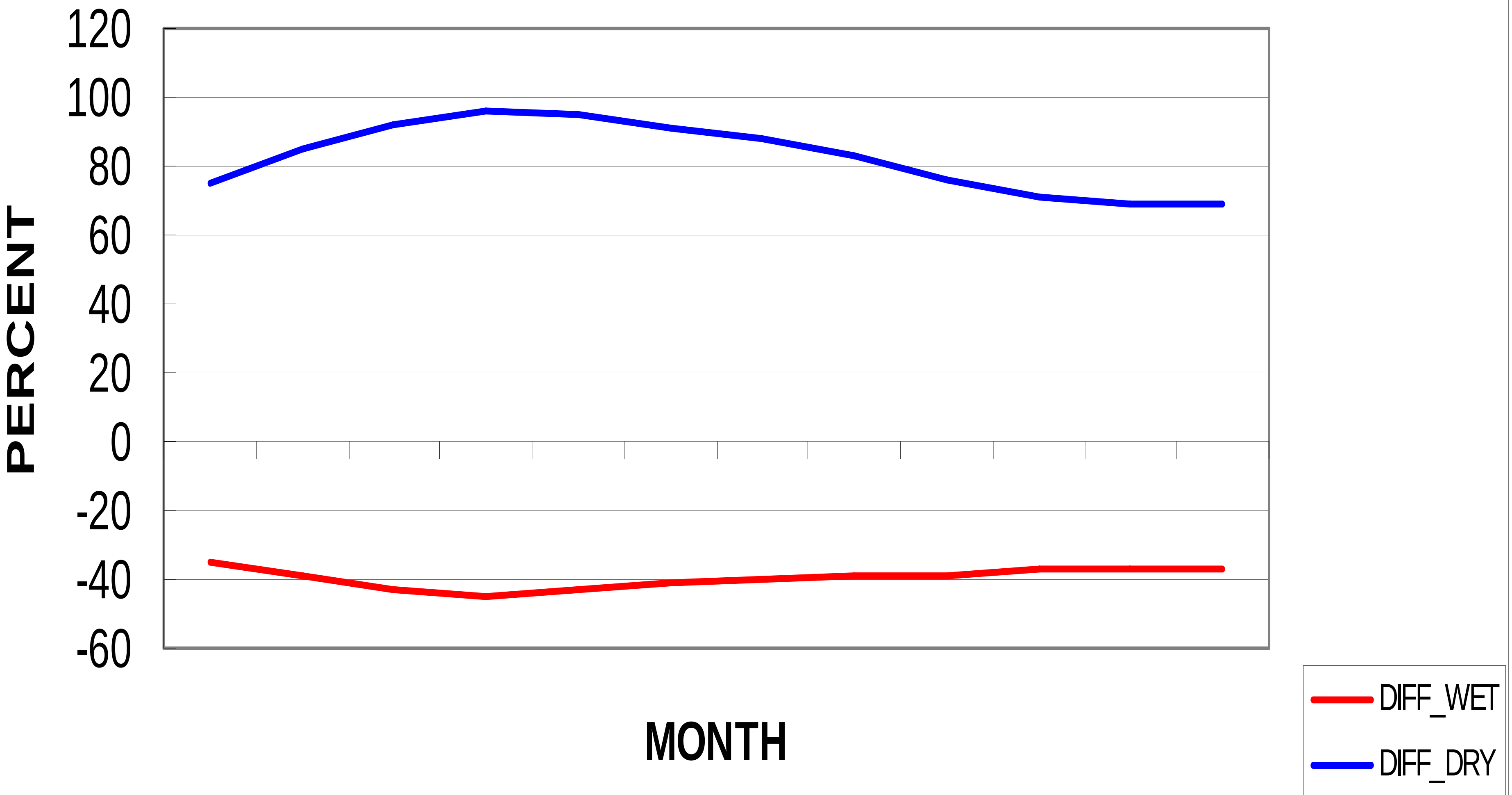
PAKWATCH: AVERAGE MONTHLY OF FIVE EXTREME YEAR
OUTFLOWS (in bcm)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
7
8
9
10
11
12
MONTH
1962--1966
1913--1976
1921--1925
DRIEST
NORM
WETEST

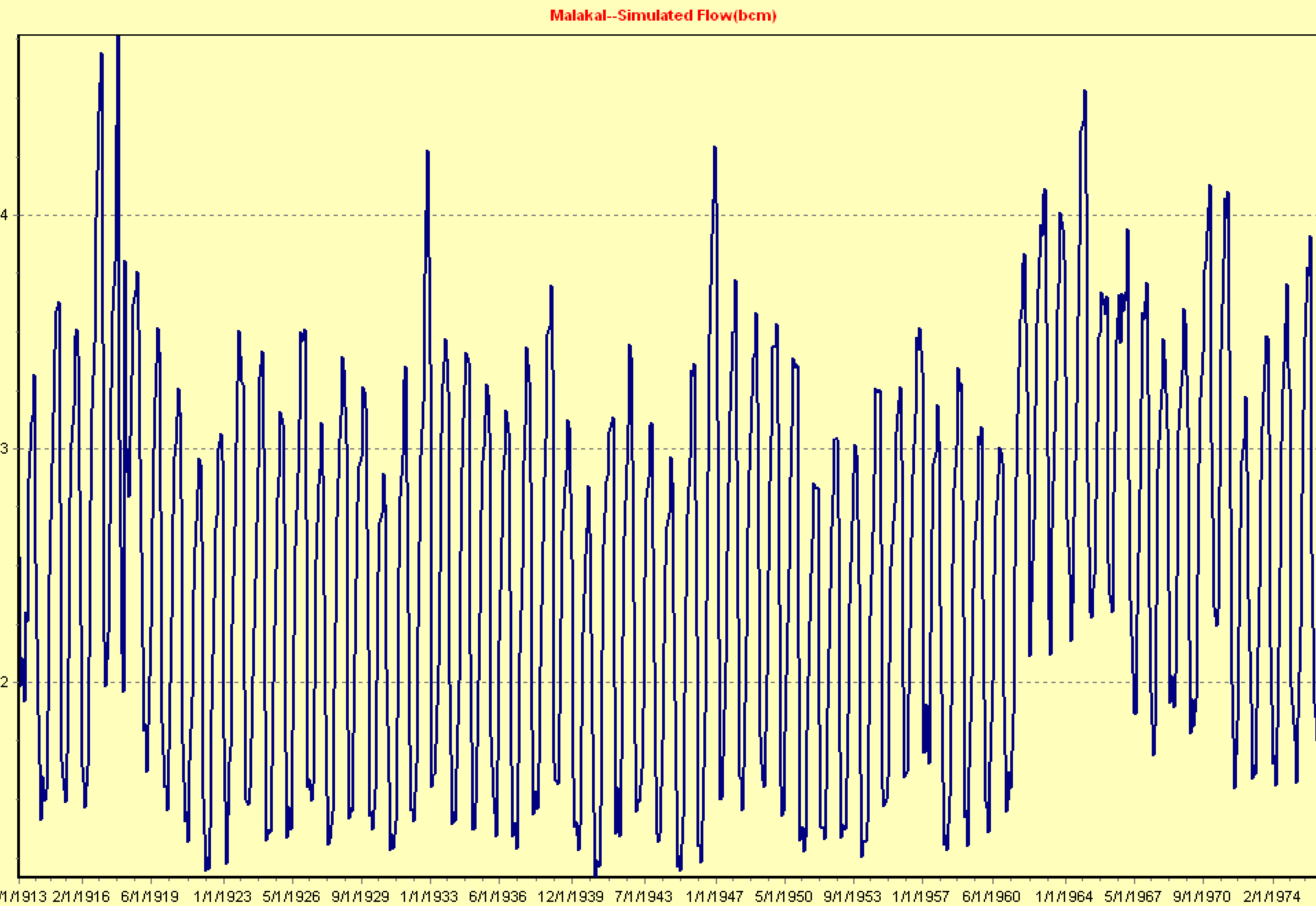

PAKWATCH ANNUAL EXTREME OUTFLOWS
OUTFLOWS (in bcm)
60
50
40
30
20
10
0
DRIEST
NORM
WETTEST
PERIOD

PKW : PERCENT DIFFERENCE OF DRY/WET PERIODS FROM NORMAL

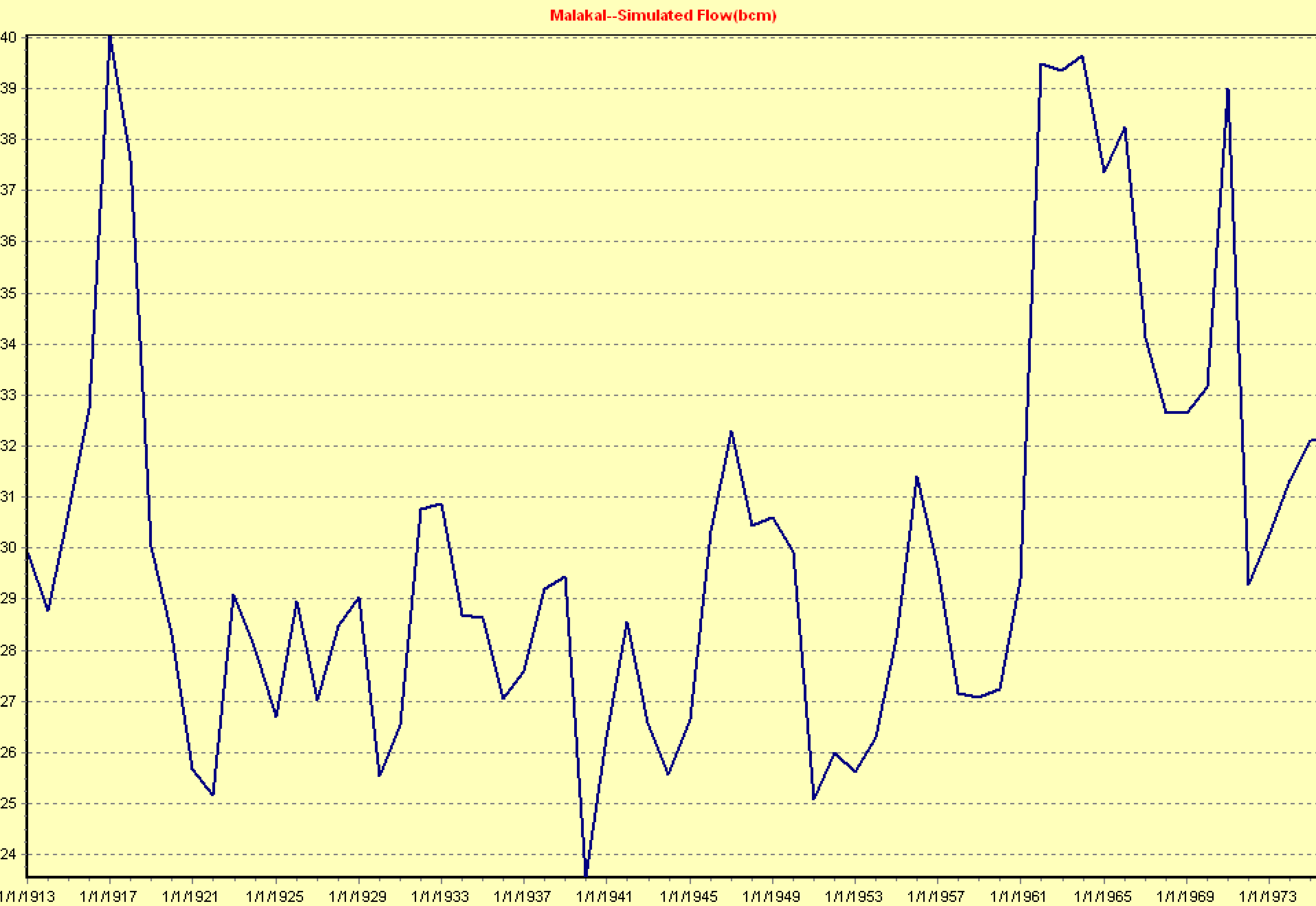
Driest : 1921 – 1925

Wettest: 1962 - 1966

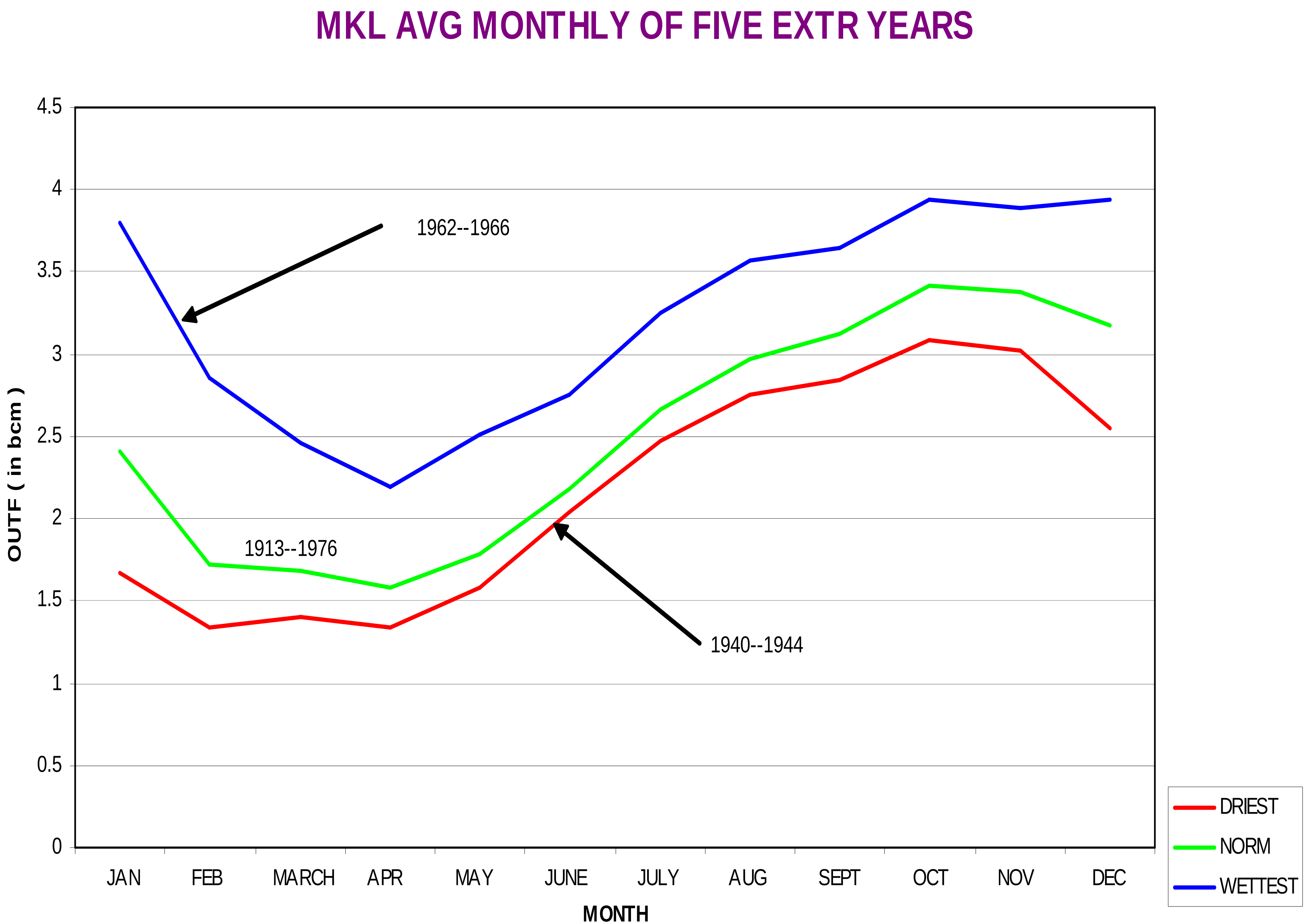




Malakal--Simulated Flow(bcm)
4
3
2
1/1/1913
2/1/1916
6/1/1919
1/1/1923
5/1/1926
9/1/1929
1/1/1933
6/1/1936
12/1/1939
7/1/1943
1/1/1947
5/1/1950
9/1/1953
1/1/1957
6/1/1960
1/1/1964
5/1/1967
9/1/1970
2/1/1974

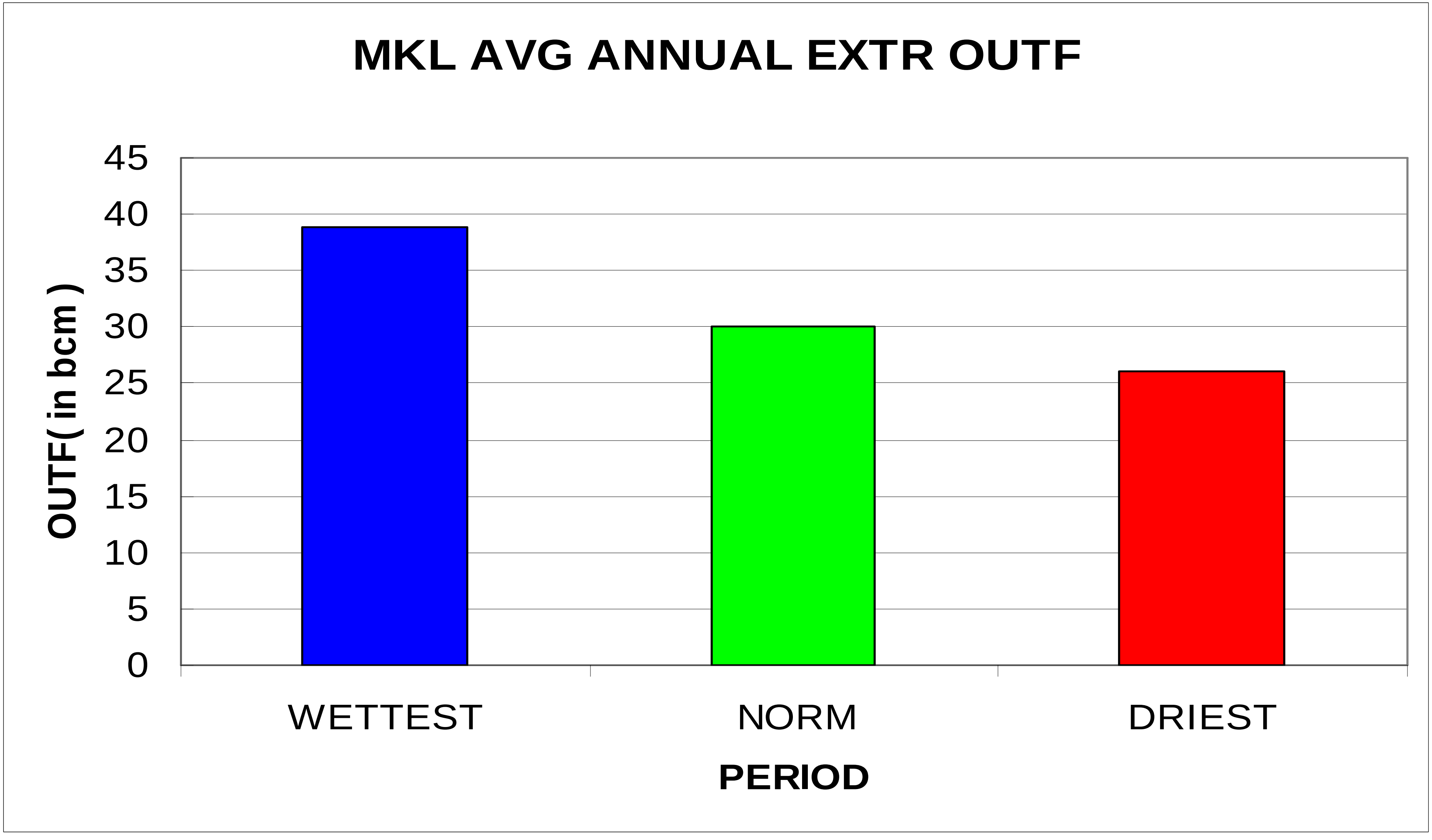


Malakal--Simulated Flow(bcm)
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
1/1/1913
1/1/1917
1/1/1921
1/1/1925
1/1/1929
1/1/1933
1/1/1937
1/1/1941
1/1/1945
1/1/1949
1/1/1953
1/1/1957
1/1/1961
1/1/1965
1/1/1969
1/1/1973



MKL AVG MONTHLY OF FIVE EXTR YEARS
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
OUTF (in bcm)
1962--1966
1913--1976
1940--1944
JAN
FEB
MARCH
APR
MAY
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
MONTH
DRIEST
NORM
WETTEST

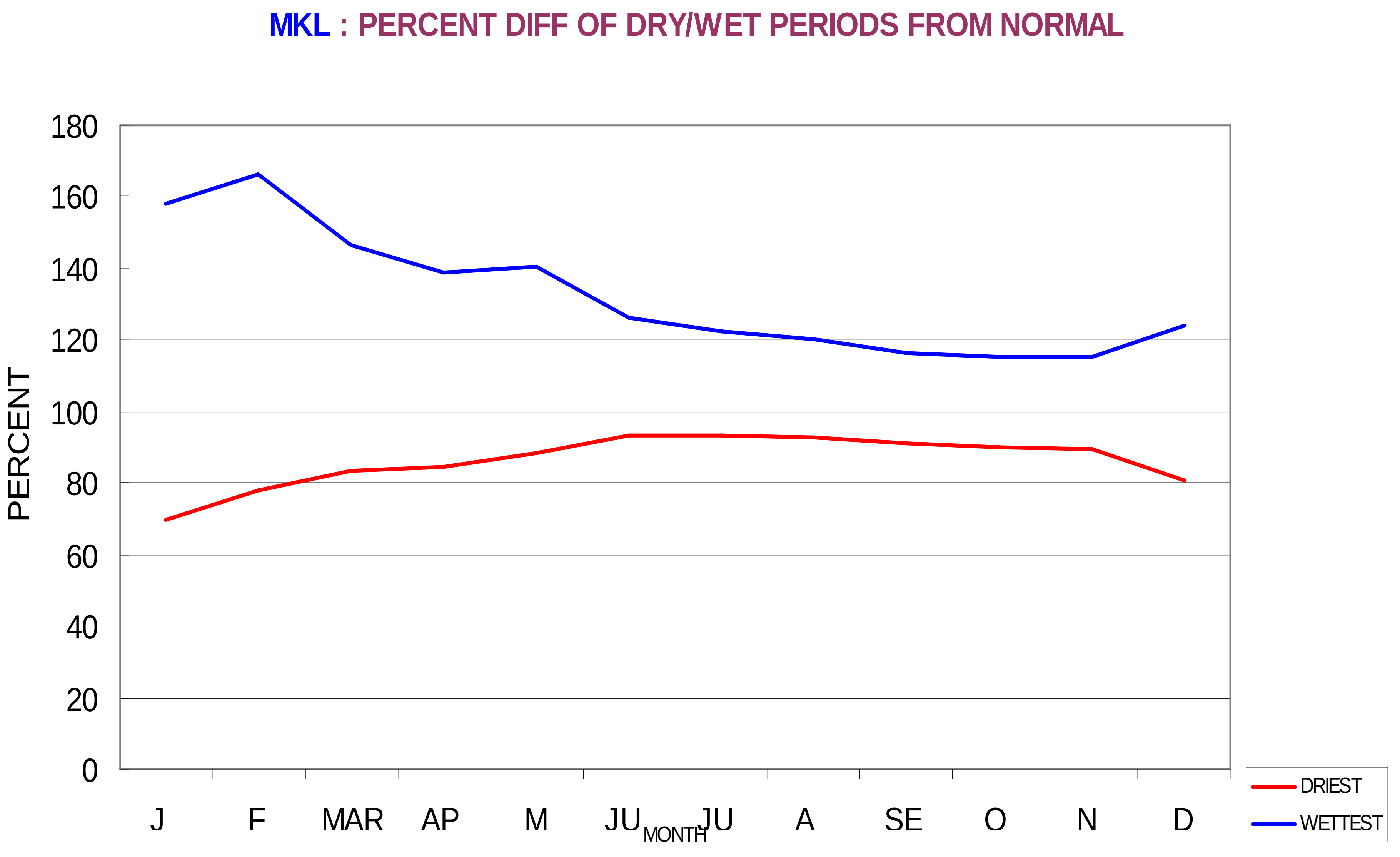
WETTEST	38.81735
NORM	30.08299
DRIEST	26.11359

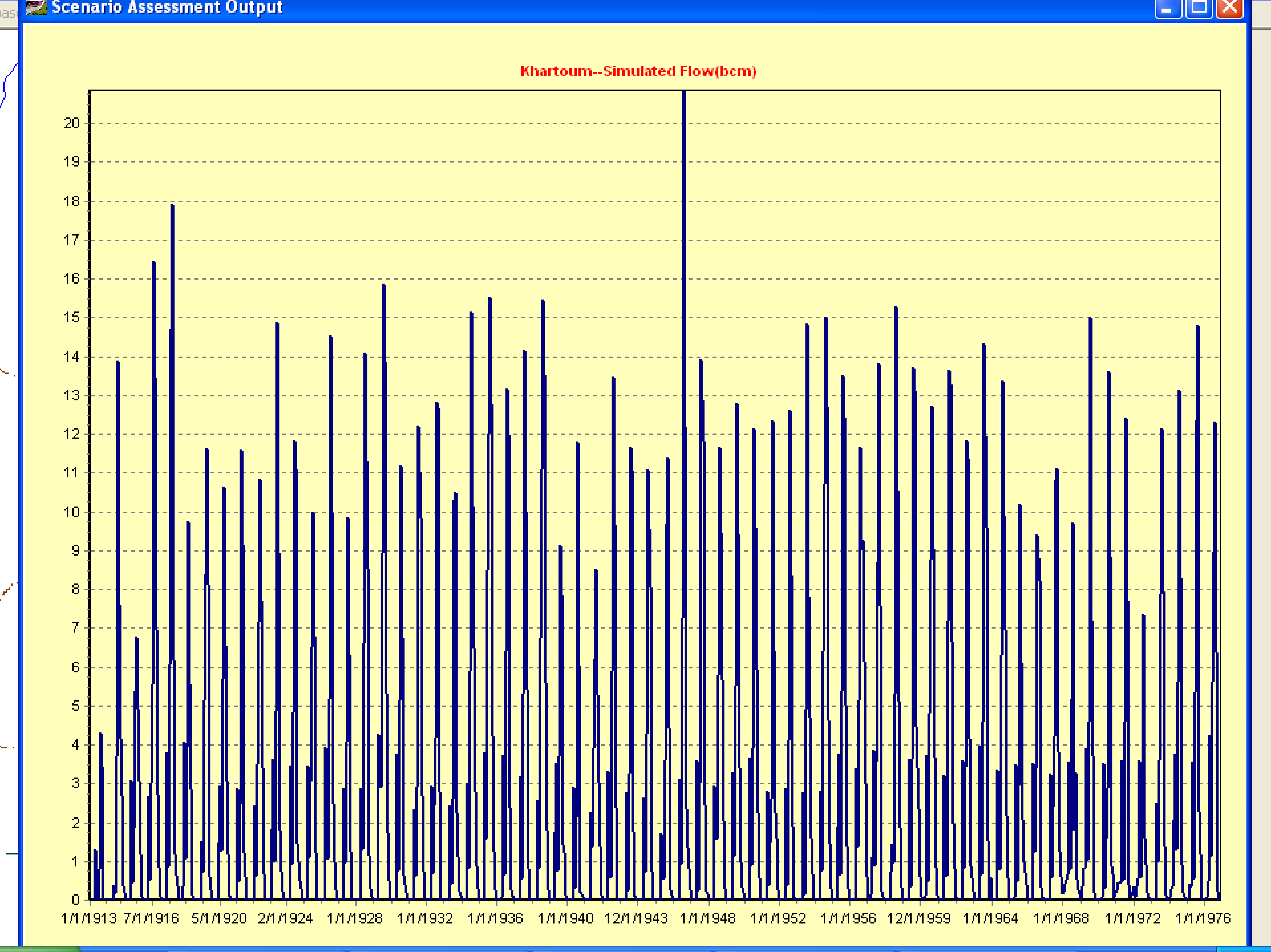


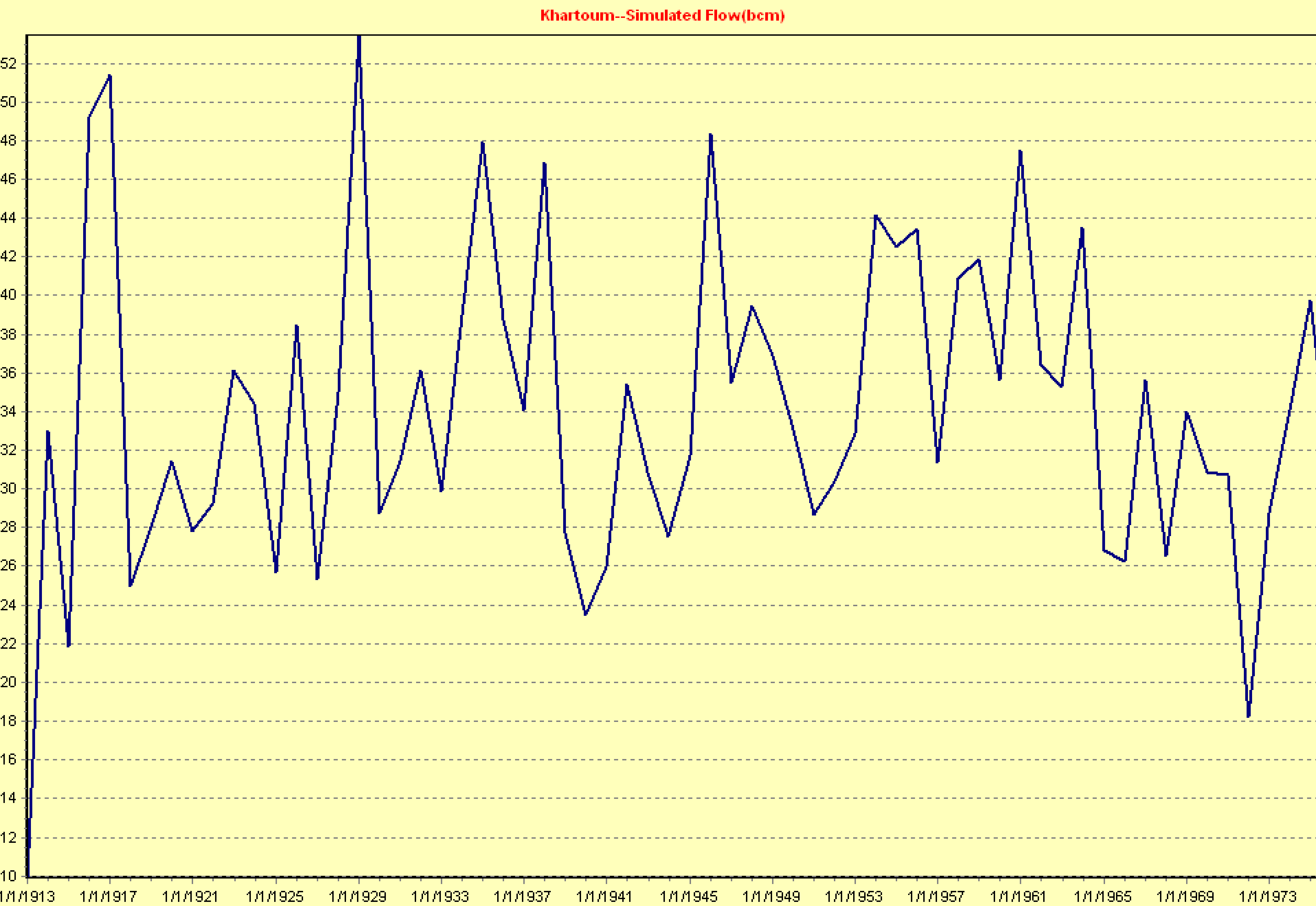
DIFF_DRIEST	DIFF_WETTEST
-30.53958829	57.97640256
-21.89303809	66.42785532
-16.42258981	46.67119215
-15.54958449	38.96254558
-11.51751854	40.38228587
-6.561854474	26.38302947
-6.930786965	22.16307116
-7.161749066	20.12228255
-8.921386015	16.47989922
-9.795265547	15.02004309
-10.51799179	15.33302659
-19.57526775	24.12667097

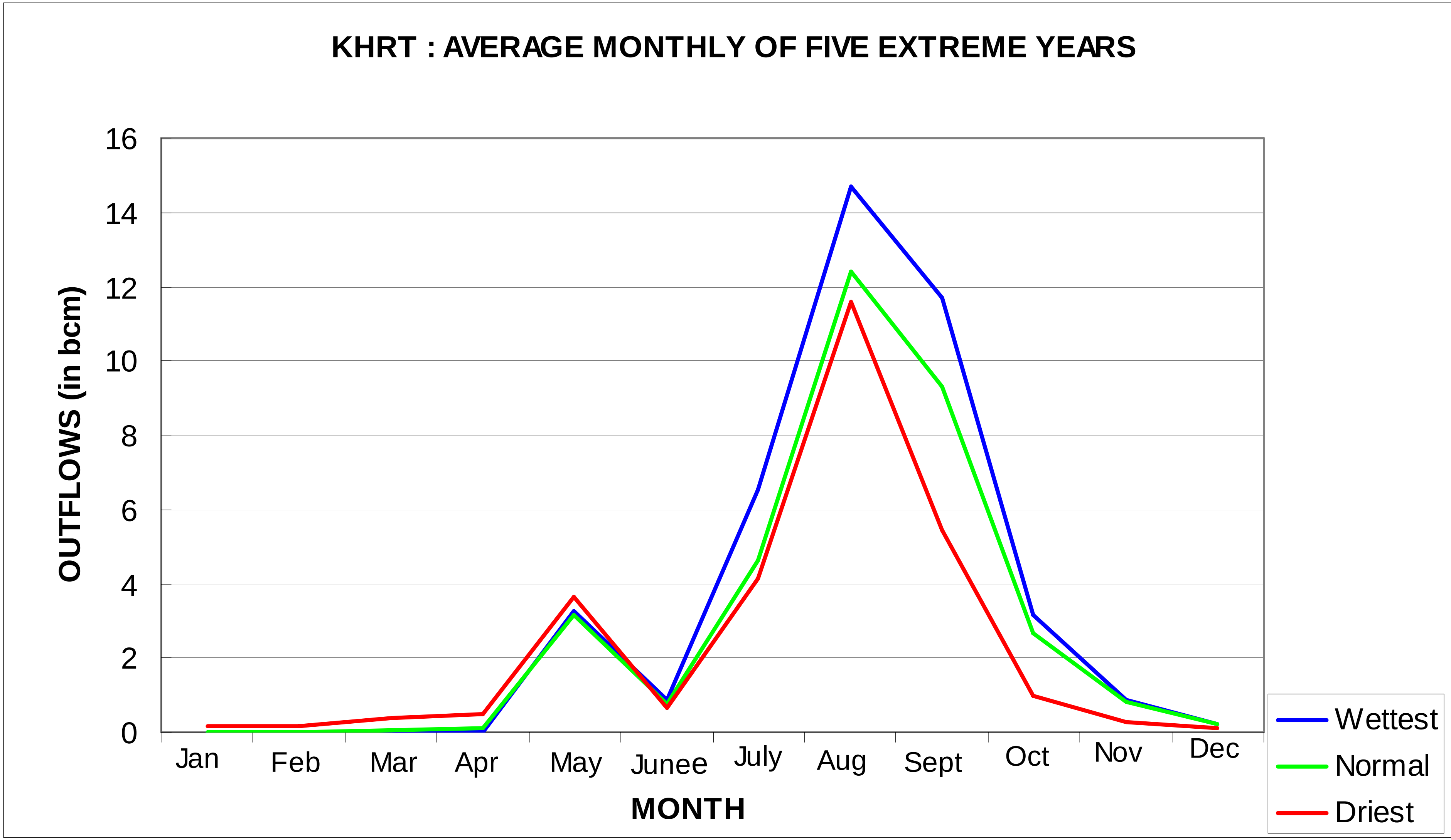
Wettest : 1962 – 1966

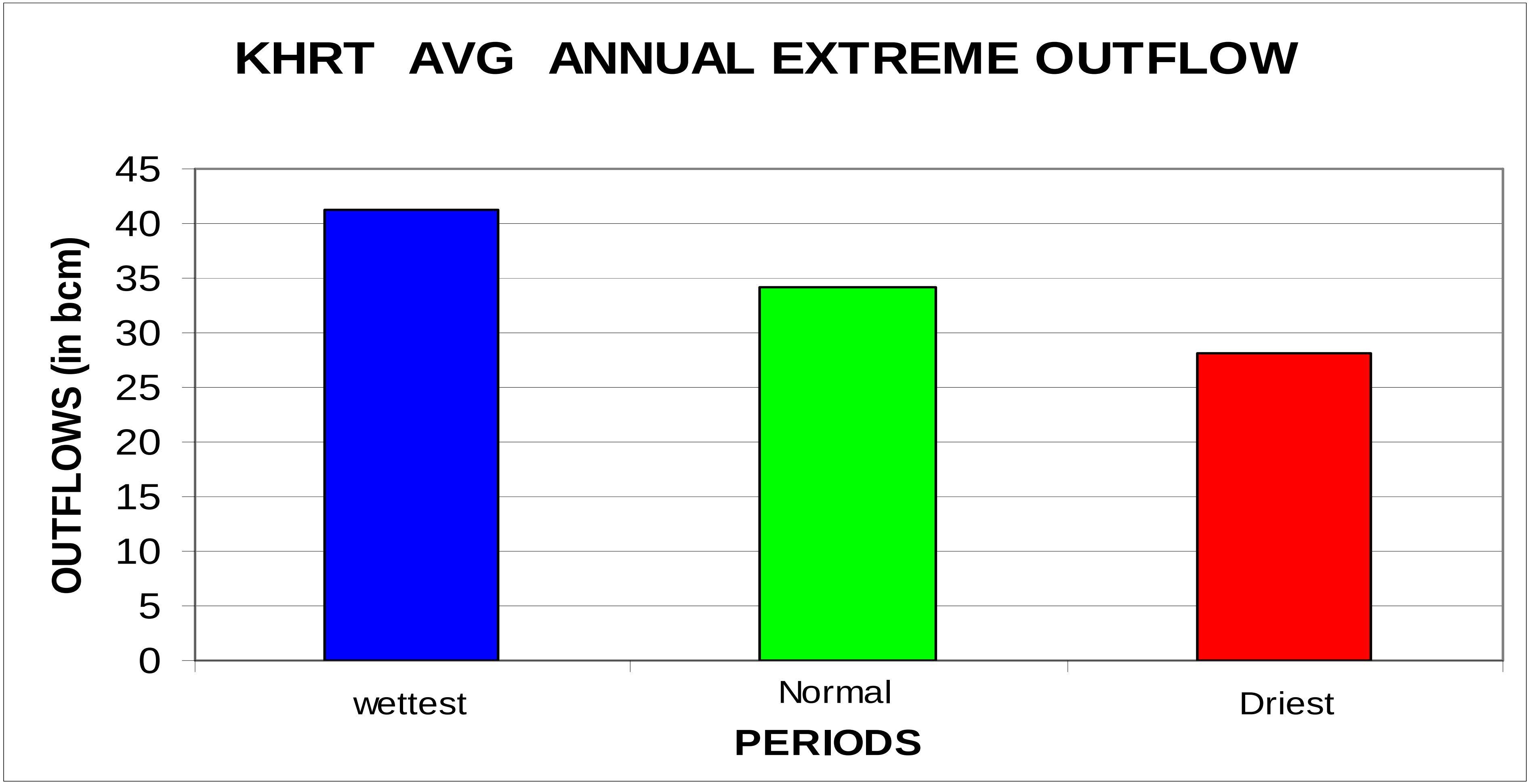
Driest : 1940 - 1944



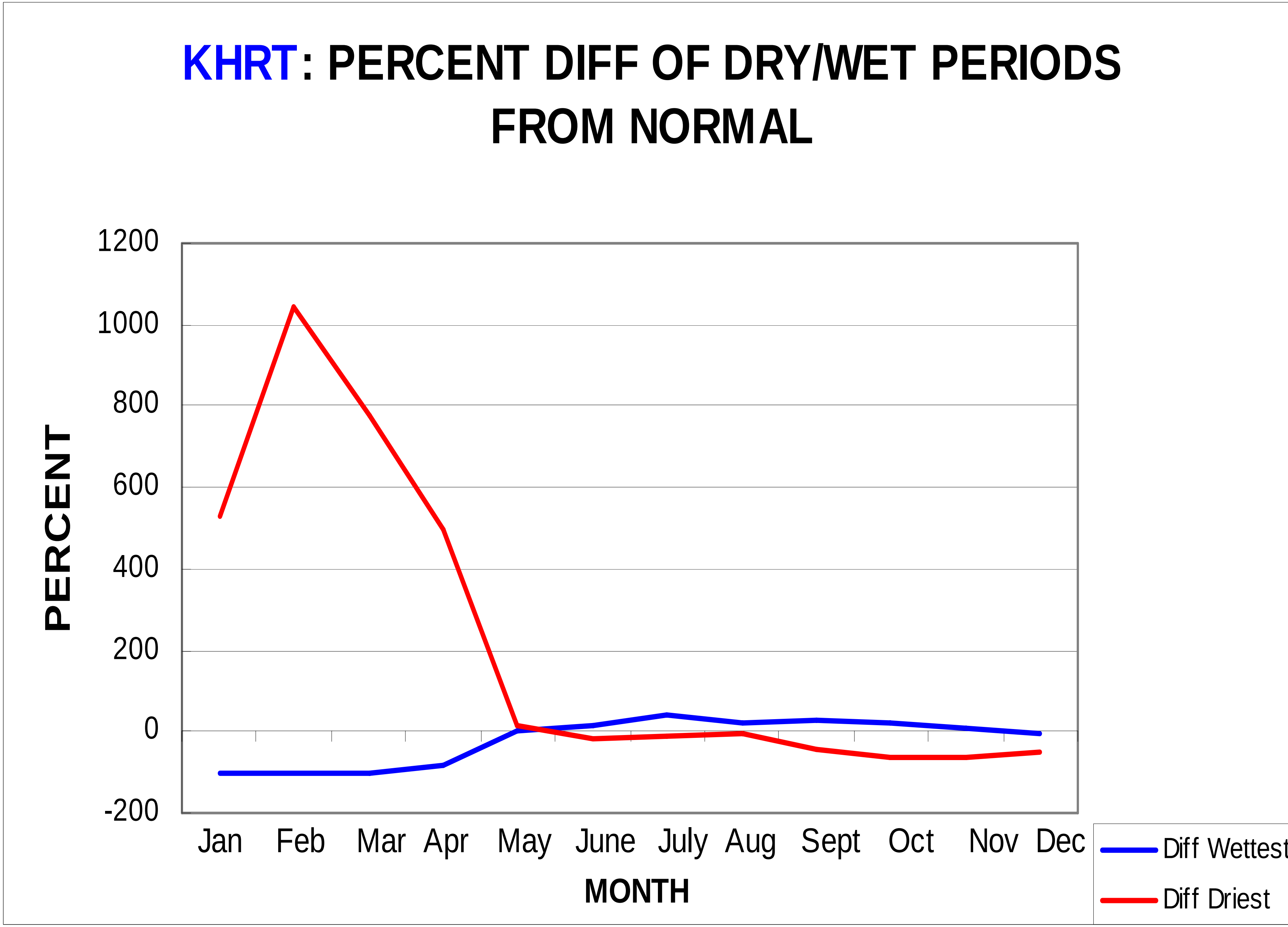

Scenario Assessment Output
Khartoum--Simulated Flow(bcm)
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
1/1/1913
7/1/1916
5/1/1920
2/1/1924
1/1/1928
1/1/1932
1/1/1936
1/1/1940
12/1/1943
1/1/1948
1/1/1952
1/1/1956
12/1/1959
1/1/1964
1/1/1968
1/1/1972
1/1/1976

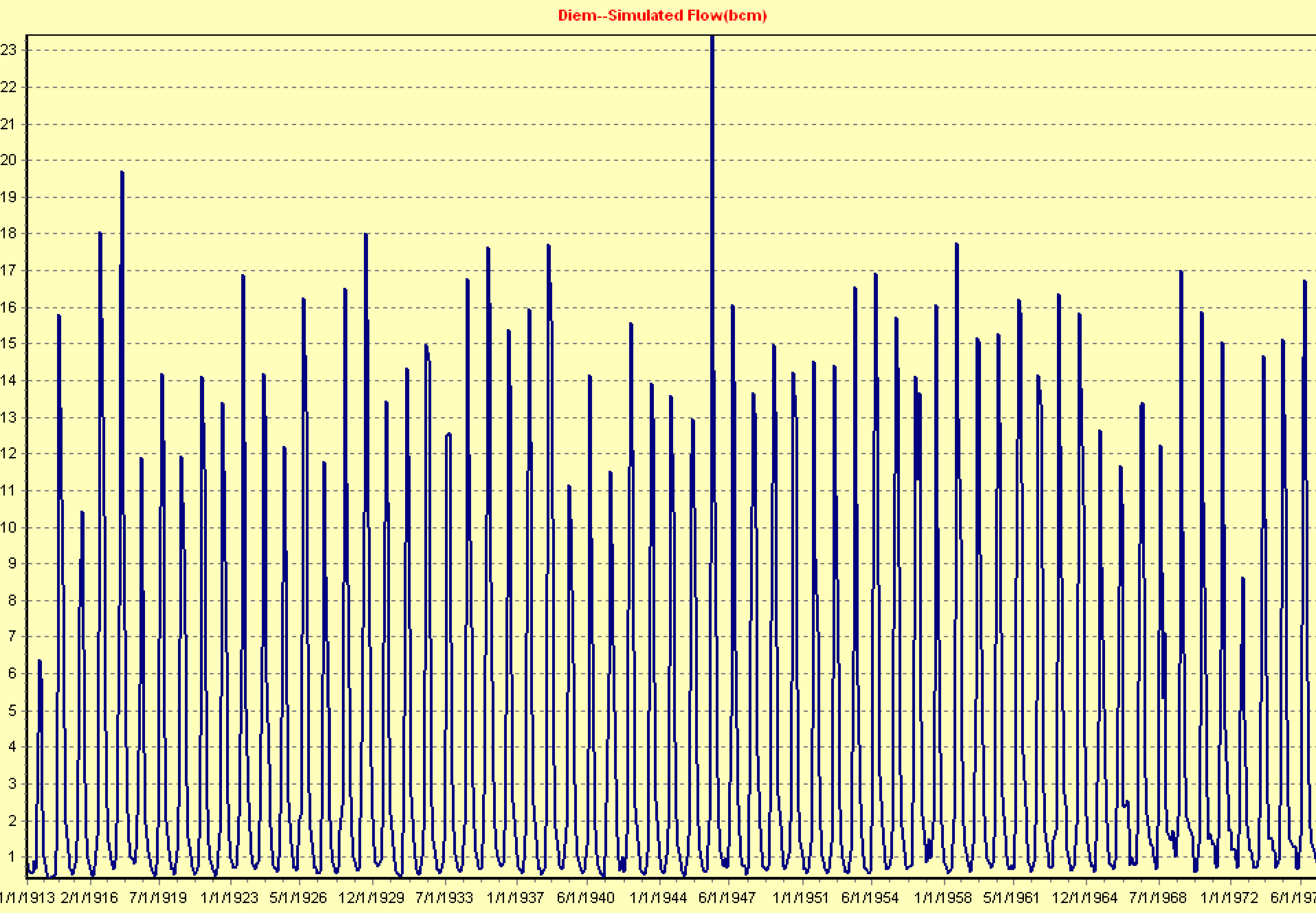

Khartoum--Simulated Flow(bcm)
52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
1/1/1913
1/1/1917
1/1/1921
1/1/1925
1/1/1929
1/1/1933
1/1/1937
1/1/1941
1/1/1945
1/1/1949
1/1/1953
1/1/1957
1/1/1961
1/1/1965
1/1/1969
1/1/1973


KHRT : AVERAGE MONTHLY OF FIVE EXTREME YEARS
OUTFLOWS (in bcm)
16
14
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
Junee
July
Aug
Sept
Oct
Nov
Dec
MONTH
Wettest
Normal
Driest

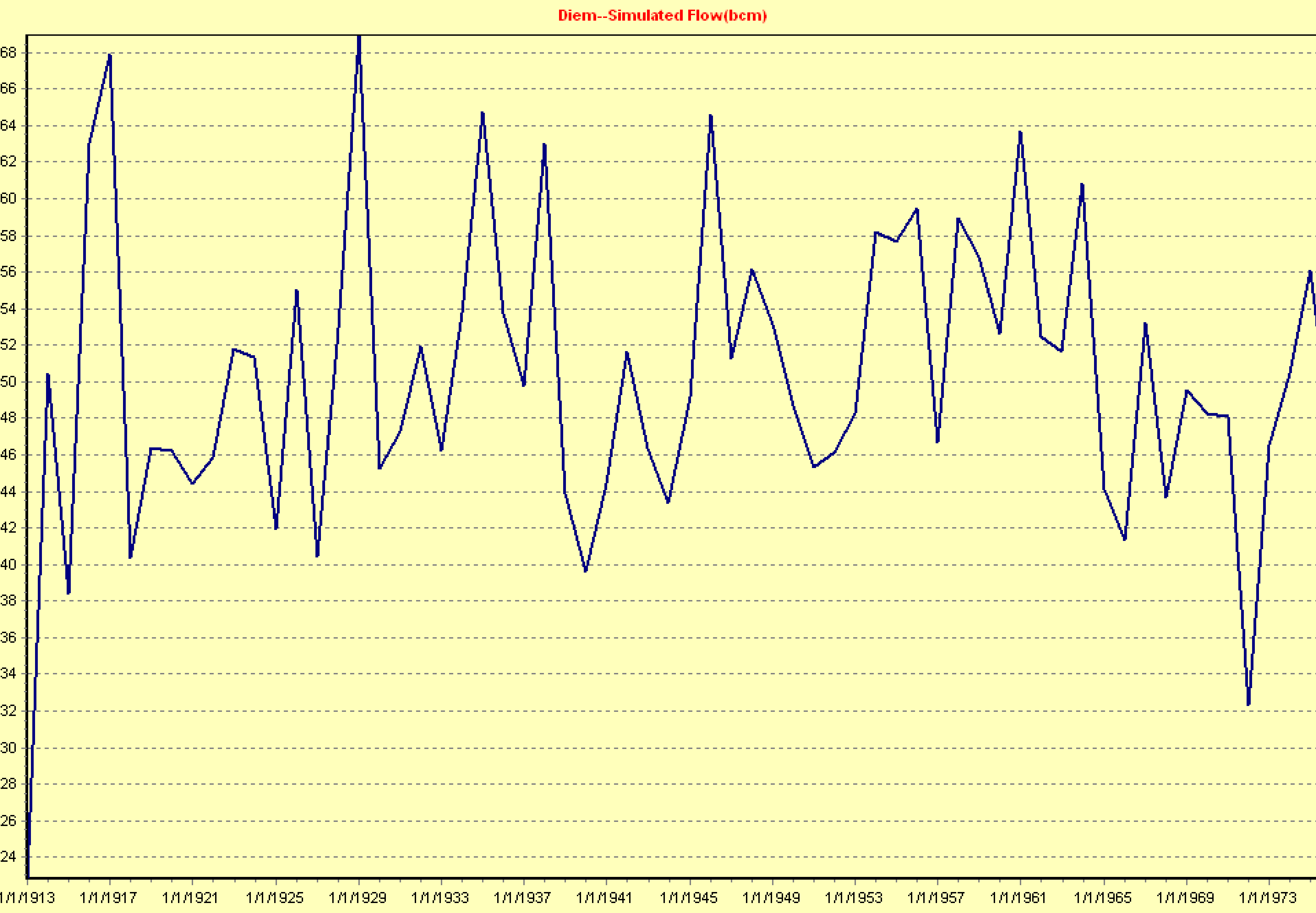


KHRT AVG ANNUAL EXTREME OUTFLOW
OUTFLOWS (in bcm)
45
40
35
30
25
20
15
10
5
0
wettest
Normal
Driest
PERIODS

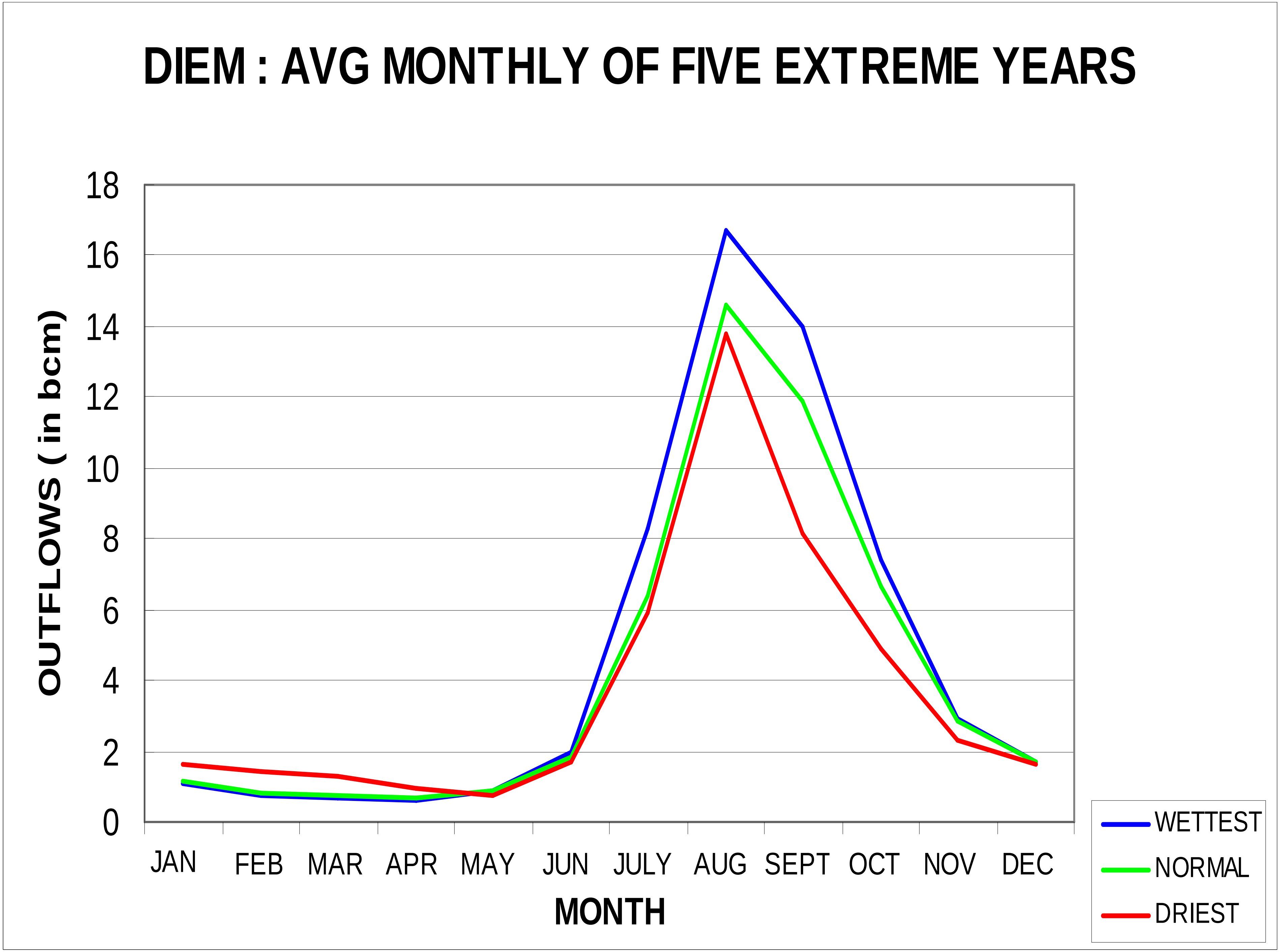

KHRT: PERCENT DIFF OF DRY/WET PERIODS FROM NORMAL
1200
1000
800
600
400
200
0
-200
PERCENT
Jan
Feb
Mar
Apr
May
June
July
Aug
Sept
Oct
Nov
Dec
MONTH
Diff Wettest
Diff Driest

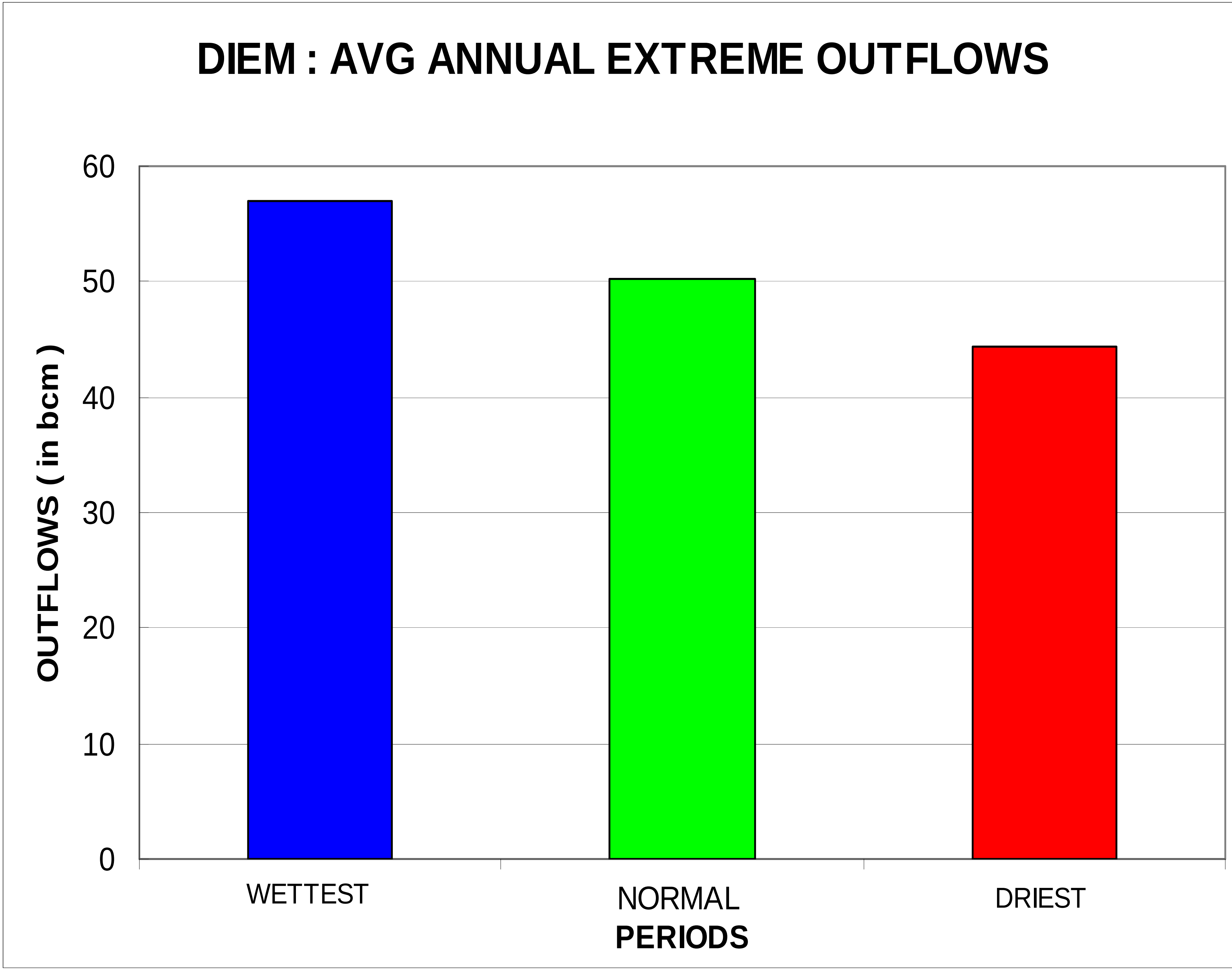


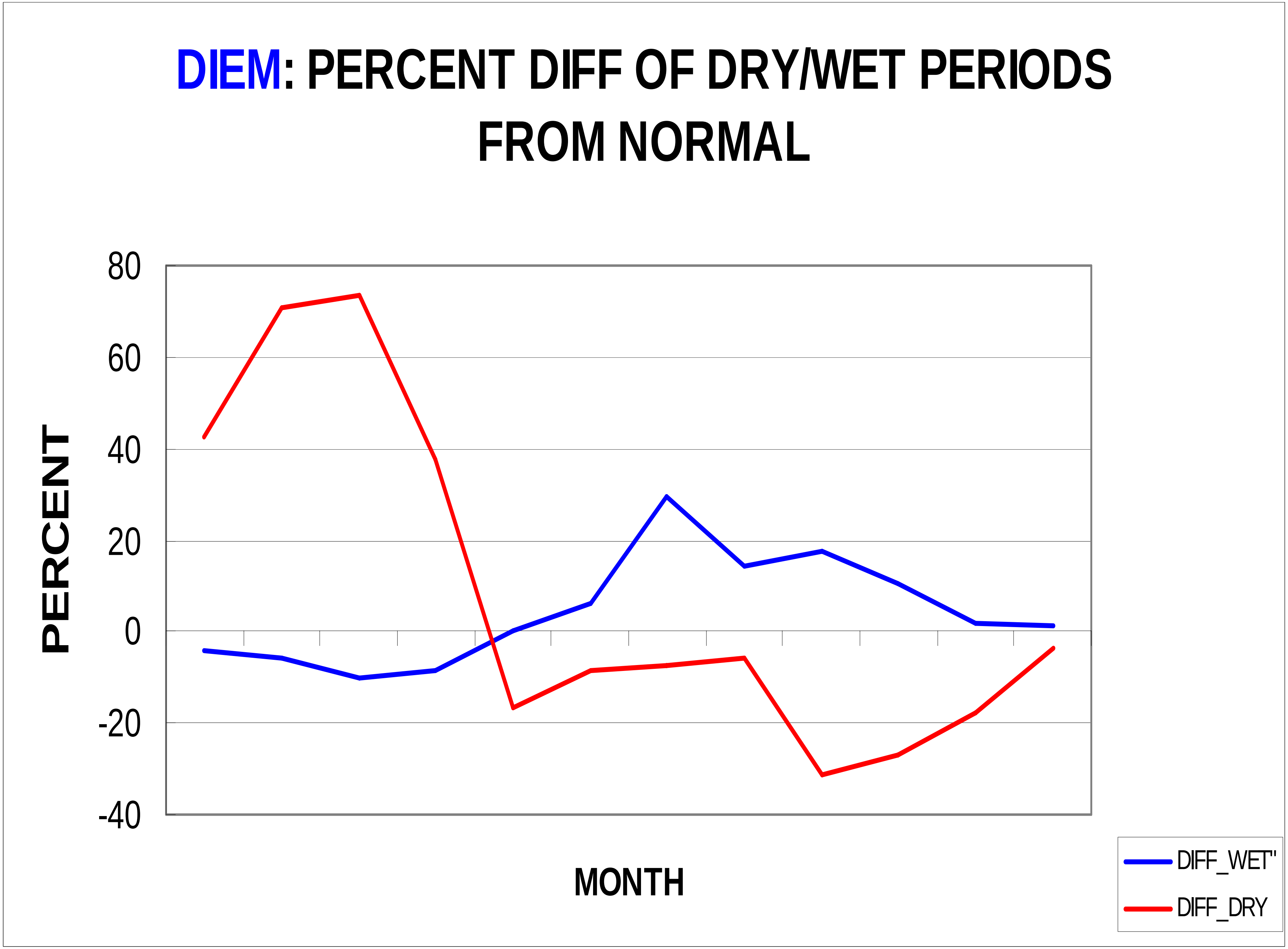
Diem--Simulated Flow(bcm)
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1/1/1913
2/1/1916
7/1/1919
1/1/1923
5/1/1926
12/1/1929
7/1/1933
1/1/1937
6/1/1940
1/1/1944
6/1/1947
1/1/1951
6/1/1954
1/1/1958
5/1/1961
12/1/1964
7/1/1968
1/1/1972

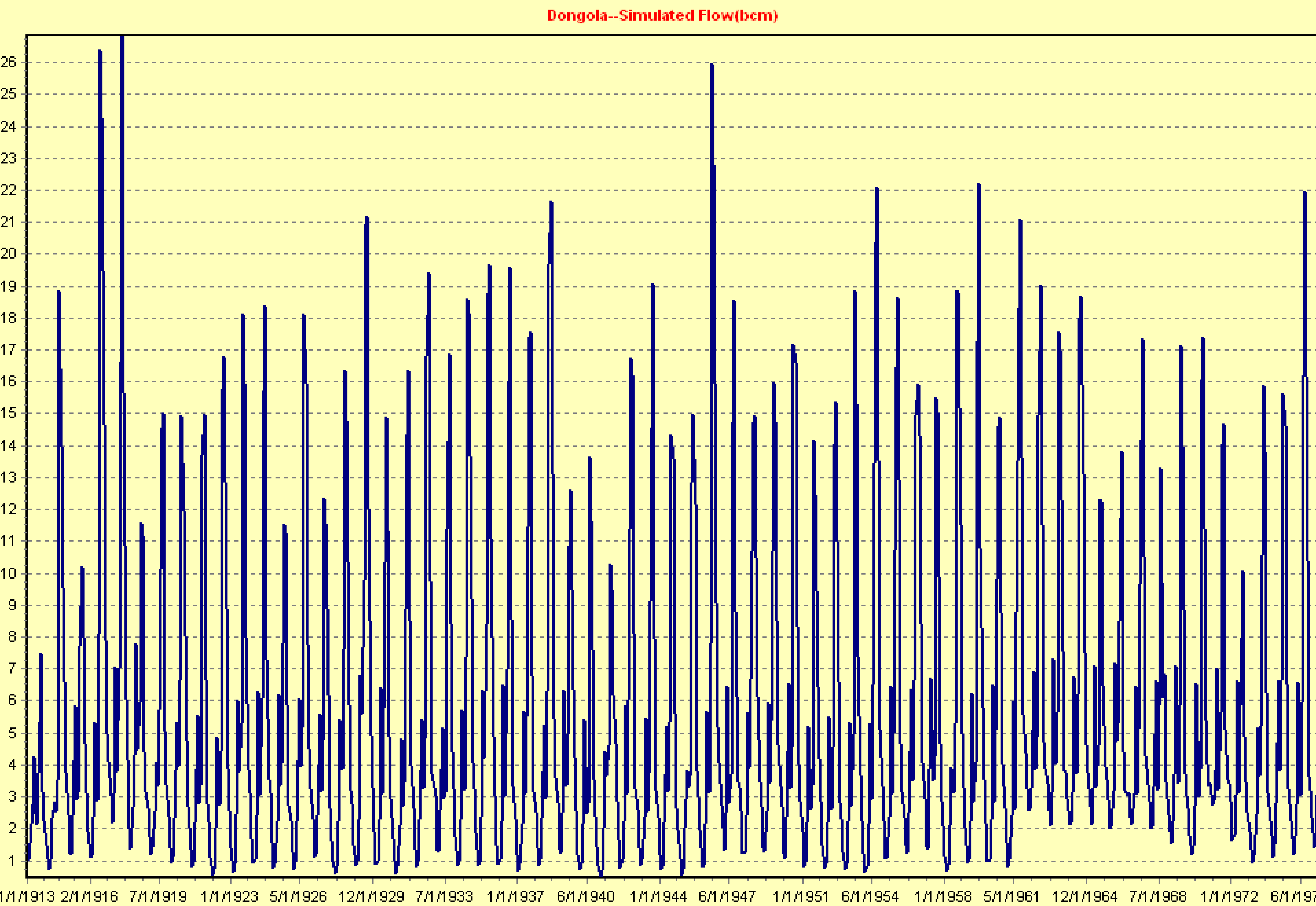


Diem--Simulated Flow(bcm)
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
1/1/1913
1/1/1917
1/1/1921
1/1/1925
1/1/1929
1/1/1933
1/1/1937
1/1/1941
1/1/1945
1/1/1949
1/1/1953
1/1/1957
1/1/1961
1/1/1965
1/1/1969
1/1/1973

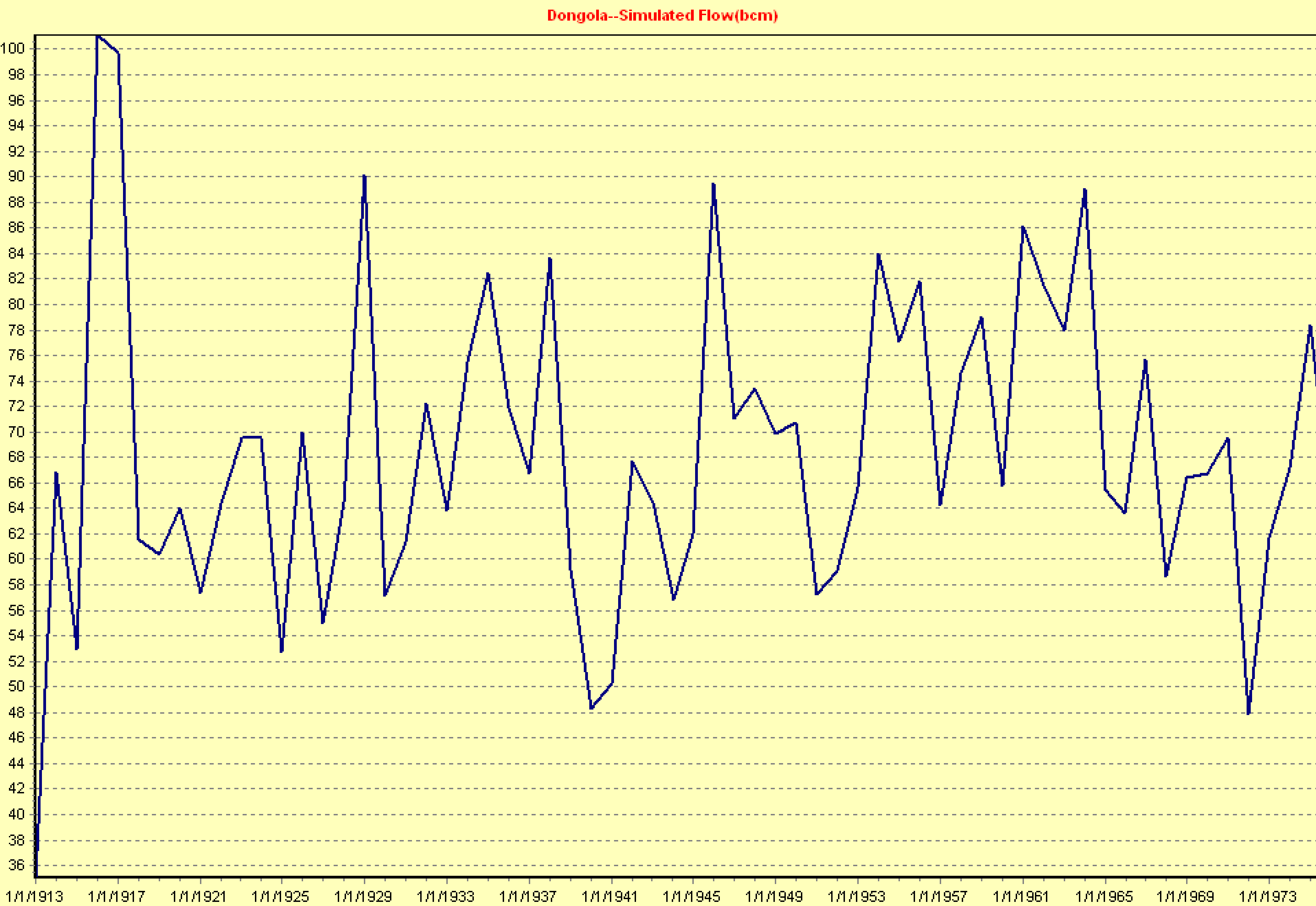

DIEM : AVG MONTHLY OF FIVE EXTREME YEARS
OUTFLOWS (in bcm)
0
2
4
6
8
10
12
14
16
18
JAN
FEB
MAR
APR
MAY
JUN
JULY
AUG
SEPT
OCT
NOV
DEC
MONTH
WETTEST
NORMAL
DRIEST


DIEM : AVG ANNUAL EXTREME OUTFLOWS
60
50
40
30
20
10
0
OUTFLOWS (in bcm)
WETTEST
NORMAL
DRIEST
PERIODS


DIEM: PERCENT DIFF OF DRY/WET PERIODS FROM NORMAL
PERCENT
80
60
40
20
0
-20
-40
MONTH
DIFF_WET"
DIFF_DRY



Dongola--Simulated Flow(bcm)
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1/1/1913
2/1/1916
7/1/1919
1/1/1923
5/1/1926
12/1/1929
7/1/1933
1/1/1937
6/1/1940
1/1/1944
6/1/1947
1/1/1951
6/1/1954
1/1/1958
5/1/1961
12/1/1964
7/1/1968
1/1/1972


Dongola--Simulated Flow(bcm)
100
98
96
94
92
90
88
86
84
82
80
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
1/1/1913
1/1/1917
1/1/1921
1/1/1925
1/1/1929
1/1/1933
1/1/1937
1/1/1941
1/1/1945
1/1/1949
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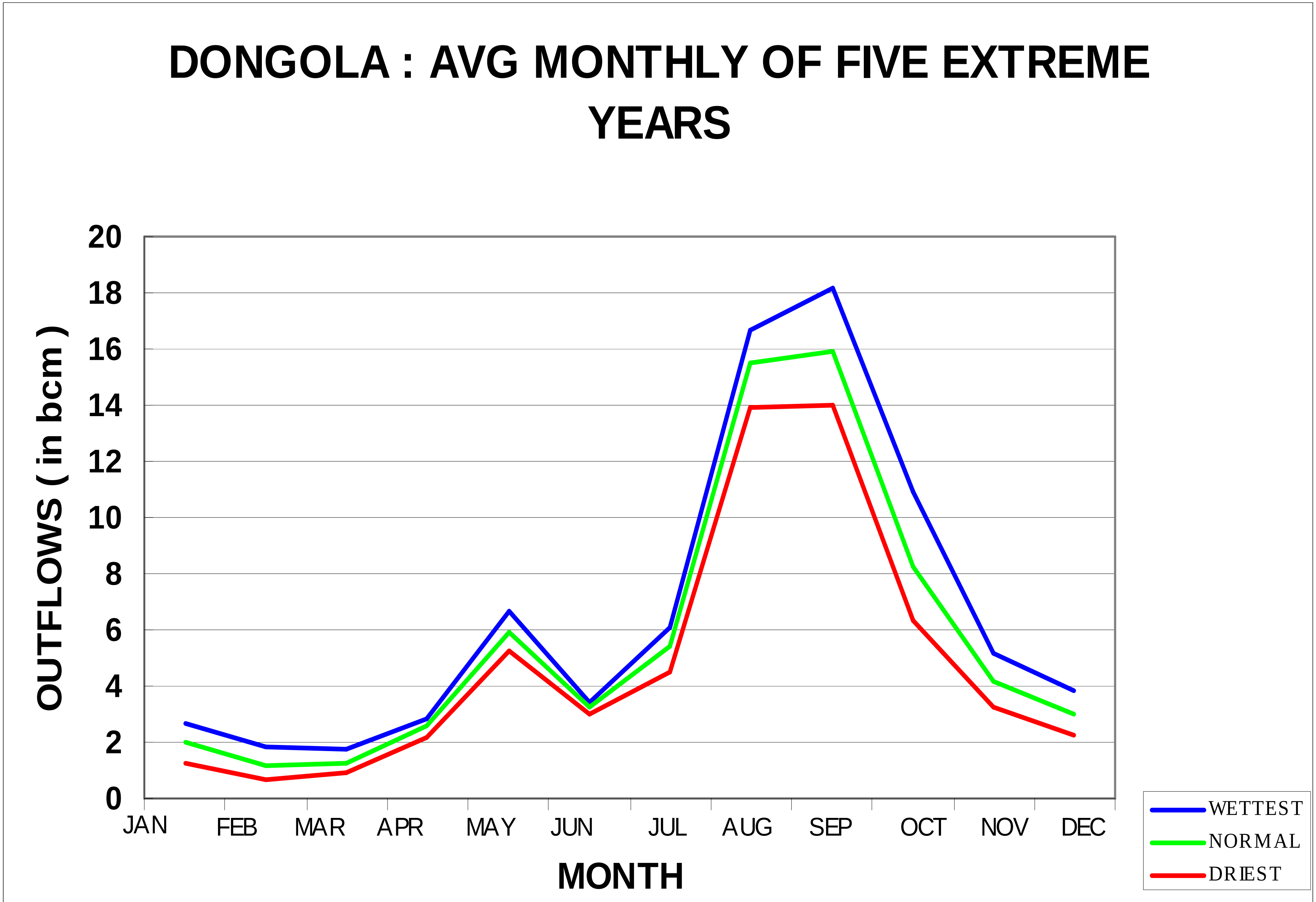
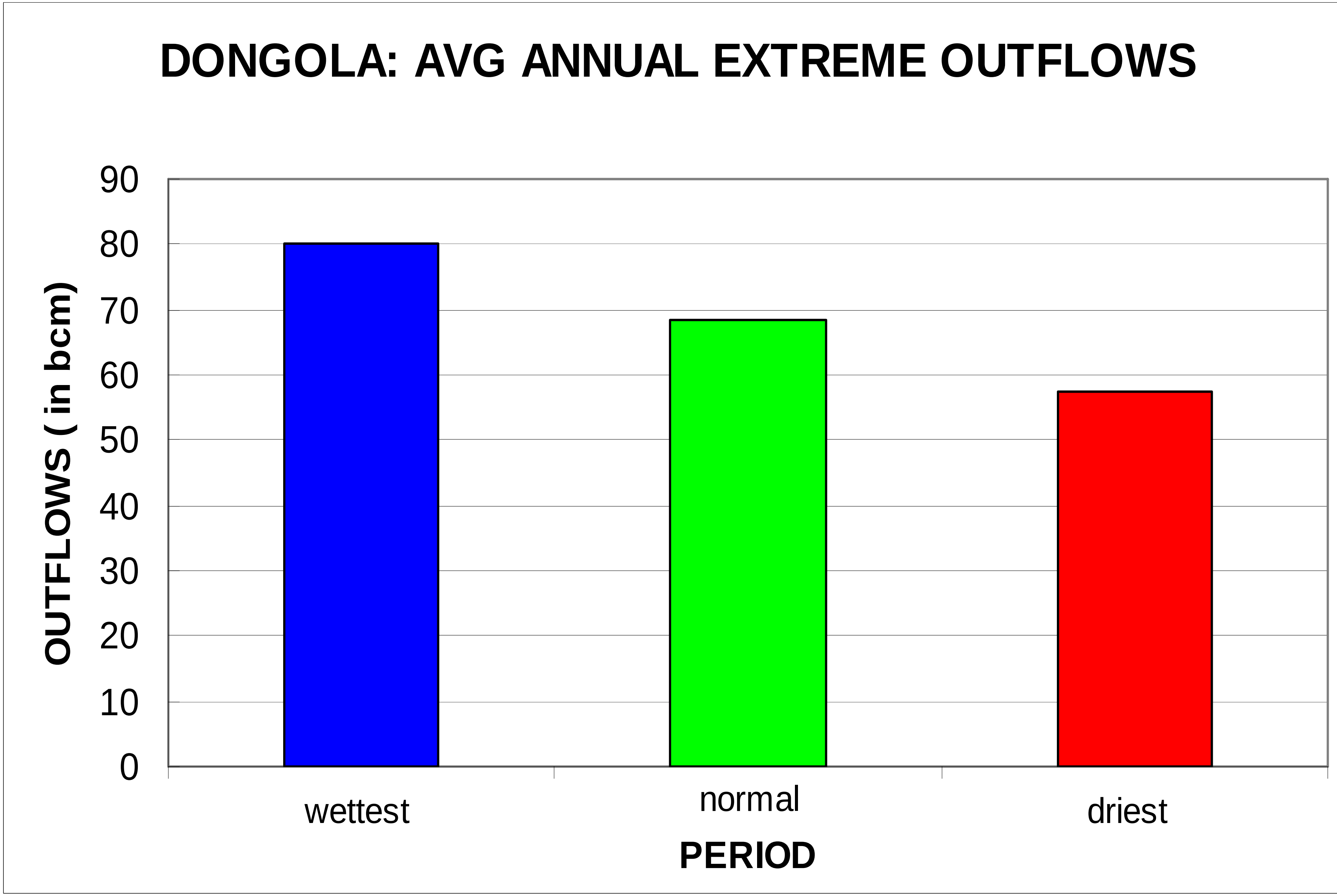
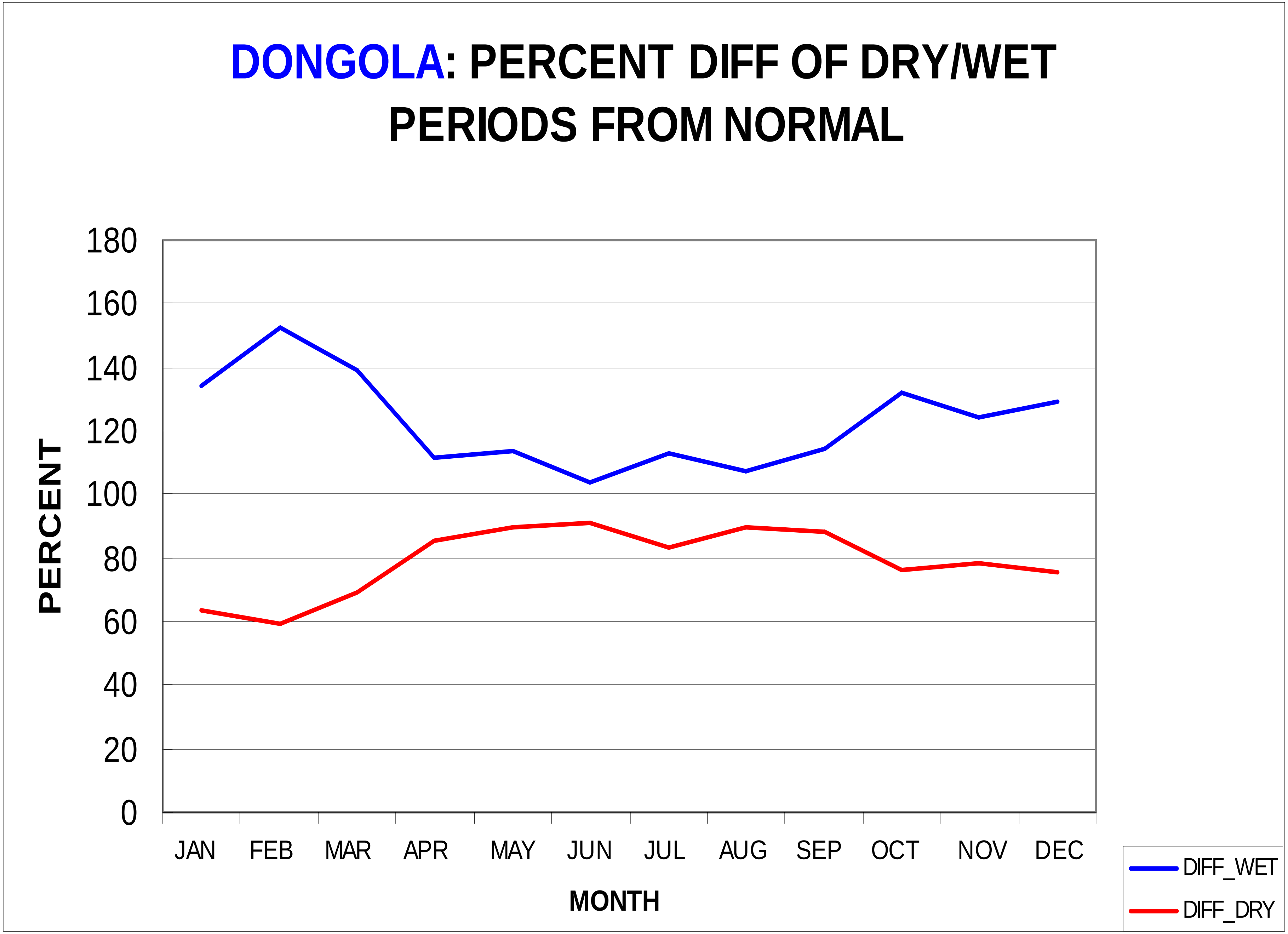
1/1/1957
1/1/1961
1/1/1965
1/1/1969
1/1/1973



DONGOLA : AVG MONTHLY OF FIVE EXTREME YEARS
OUTFLOWS (in bcm)
20
18
16
14
12
10
8
6
4
2
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH
WETTEST
NORMAL
DRIEST


DONGOLA: AVG ANNUAL EXTREME OUTFLOWS
OUTFLOWS (in bcm)
0
10
20
30
40
50
60
70
80
90
wettest
normal
driest
PERIOD


DONGOLA: PERCENT DIFF OF DRY/WET PERIODS FROM NORMAL
PERCENT
180
160
140
120
100
80
60
40
20
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
MONTH
DIFF_WET
DIFF_DRY

WATER BALANCE OF EACH REACH

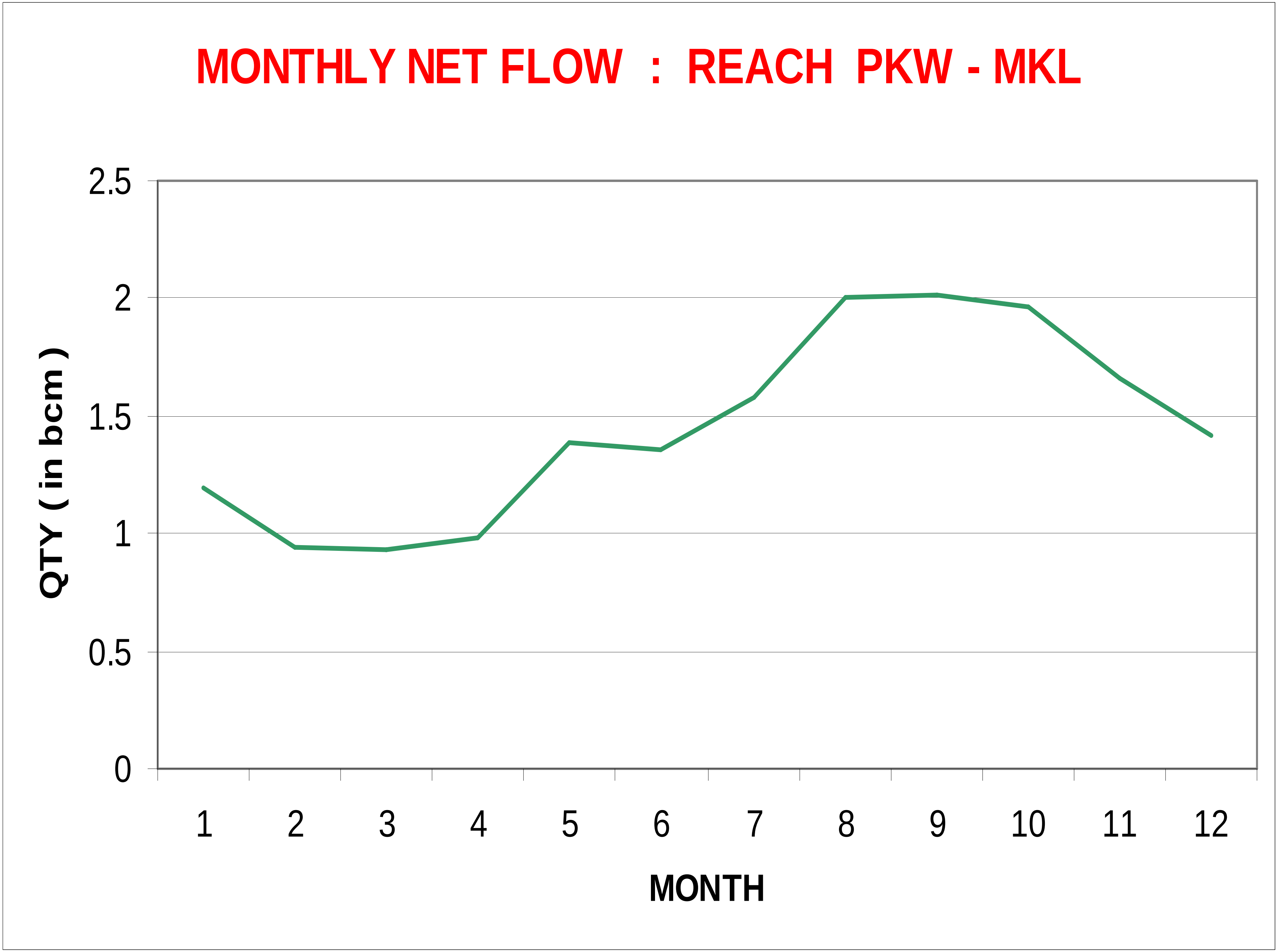
AND

THEIR LOSSES

REACH : PAKWATCH - MALAKAL

$$\text{NET FLOW} = I_{PKW} - O_{MKL} + I_{TORR} + I_{SOB}$$

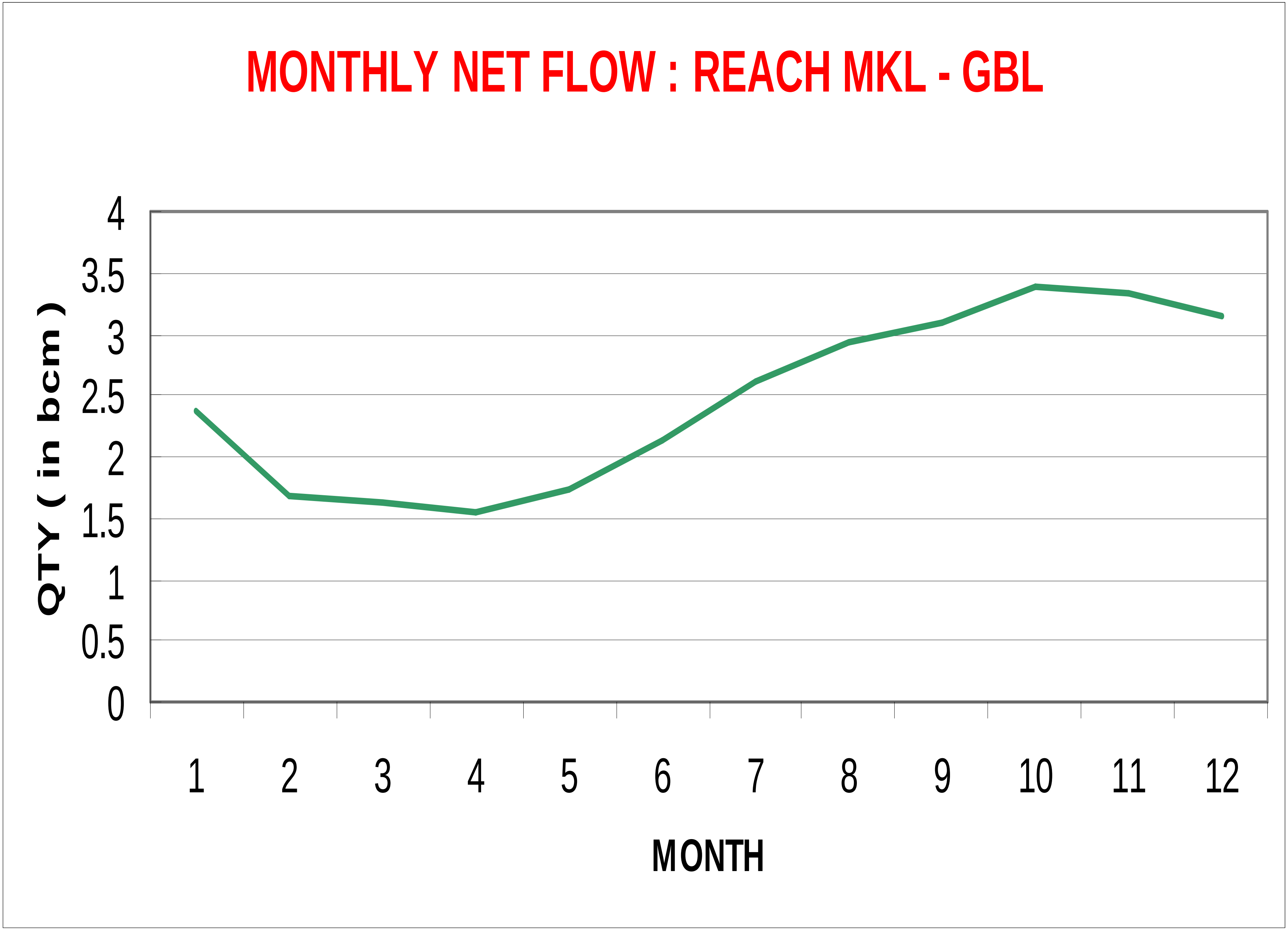
MONTHLY					
	PAK	MKL	TORR	SOBAT	NET FLOW
	2.62016	2.40779	0.026718	0.958123	1.197208
	2.22636	1.717491	0.016468	0.413886	0.939223
	2.298	1.679677	0.034678	0.273406	0.926407
	2.15831	1.582399	0.163045	0.244024	0.982976
	2.27344	1.788797	0.478438	0.421163	1.384243
	2.26167	2.181959	0.418514	0.861551	1.359774
	2.37416	2.659635	0.572533	1.292852	1.57991
	2.45479	2.970113	0.926577	1.591687	2.002939
	2.47942	3.127938	0.888743	1.770764	2.010991
	2.65551	3.420432	0.733623	1.9919	1.960604
	2.64543	3.375525	0.41476	1.975357	1.660017
	2.73482	3.171231	0.136793	1.719643	1.420029
ANNUAL					
	29.1821	30.083	4.8109	13.5144	17.4244


MONTHLY NET FLOW : REACH PKW - MKL
QTY (in bcm)
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
7
8
9
10
11
12
MONTH

REACH: MALAKAL - KHARTOUM

$NET\ FLOW = I_{MKL} - O_{GBL}$

MONTHLY			
	MKL	GEBEL	NET FLOW
	2.40779	0.047266	2.360524
	1.717491	0.042933	1.674559
	1.679677	0.04515	1.634527
	1.582399	0.042832	1.539567
	1.788797	0.042933	1.745865
	2.181959	0.040666	2.141292
	2.659635	0.04515	2.614485
	2.970113	0.042933	2.927181
	3.127938	0.04515	3.082788
	3.420432	0.023084	3.397348
	3.375525	0.048234	3.327291
	3.171231	0.034945	3.136285
ANNUAL			
	30.083	0.501277	-4.48978



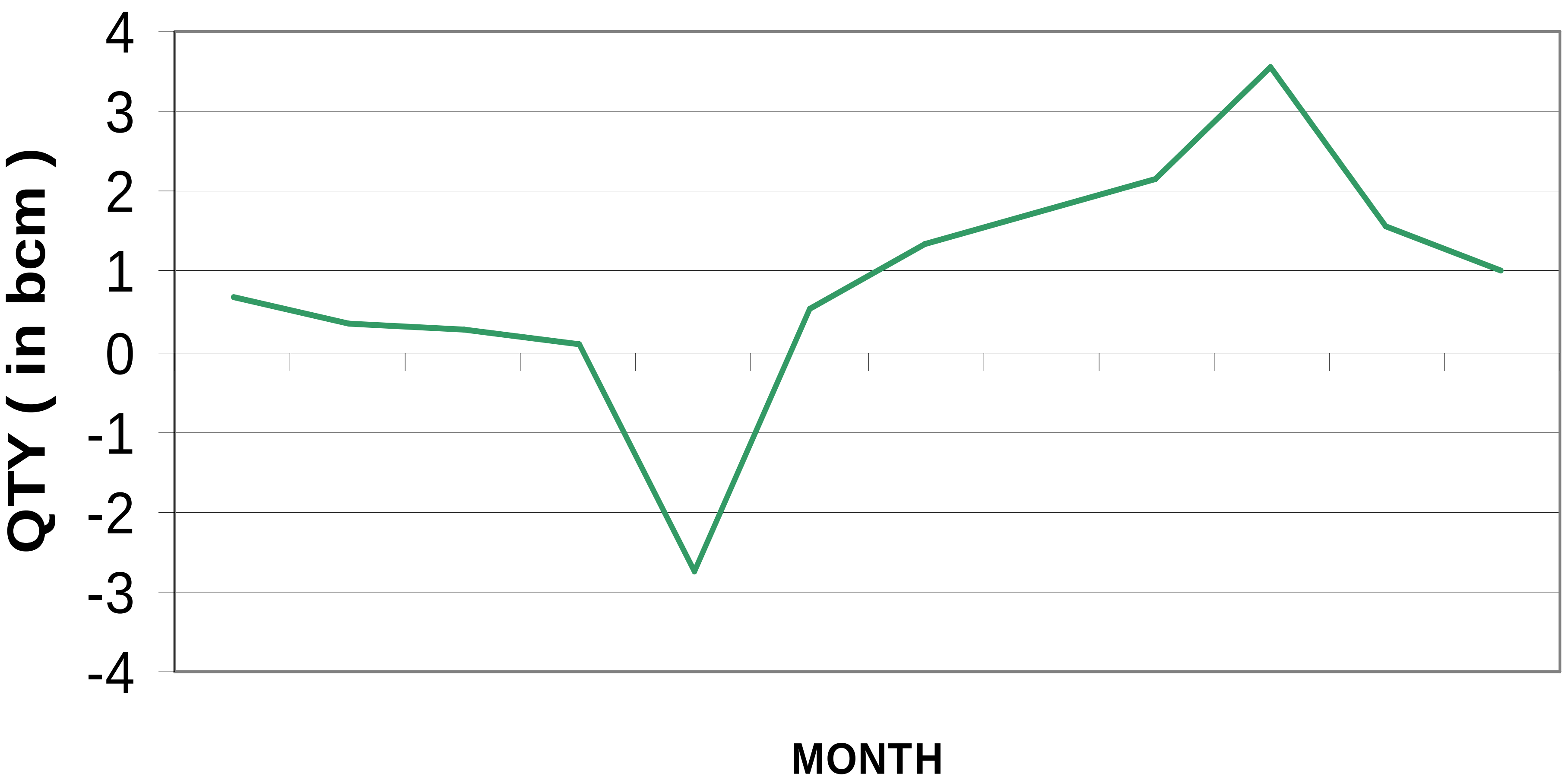
MONTHLY NET FLOW : REACH MKL - GBL
QTY (in bcm)
4
3.5
3
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
7
8
9
10
11
12
MONTH

REACH : DIEM (BORDER) - KHARTOUM

$\text{NET FLOW} = I_{DIEM} - O_{KHRT} - O_{ROSR} - O_{SENN}$

MONTHLY					
	DIEM	KHRT	ROSEIRES	SENNAR	NET FLOW
	1.15509	0.022974	0.035643	0.403435	0.693038
	0.818461	0.015146	0.035643	0.403435	0.364236
	0.762329	0.045383	0.037008	0.418884	0.261054
	0.667529	0.083841	0.041057	0.464719	0.077911
	0.894805	3.136016	0.041057	0.464719	-2.74699
	1.831966	0.783862	0.041422	0.468844	0.537838
	6.407071	4.599005	0.037426	0.423619	1.34702
	14.59921	12.40421	0.037426	0.423619	1.733957
	11.91265	9.279381	0.039766	0.4501	2.143399
	6.678476	2.686231	0.035589	0.402825	3.553832
	2.835093	0.812713	0.035589	0.402825	1.583966
	1.679644	0.202721	0.038985	0.441265	0.996674
ANNUAL					
	50.2423	34.0715	0.45661	5.168292	10.5459

MONTHLY NET FLOW : REACH DIEM - KHRT

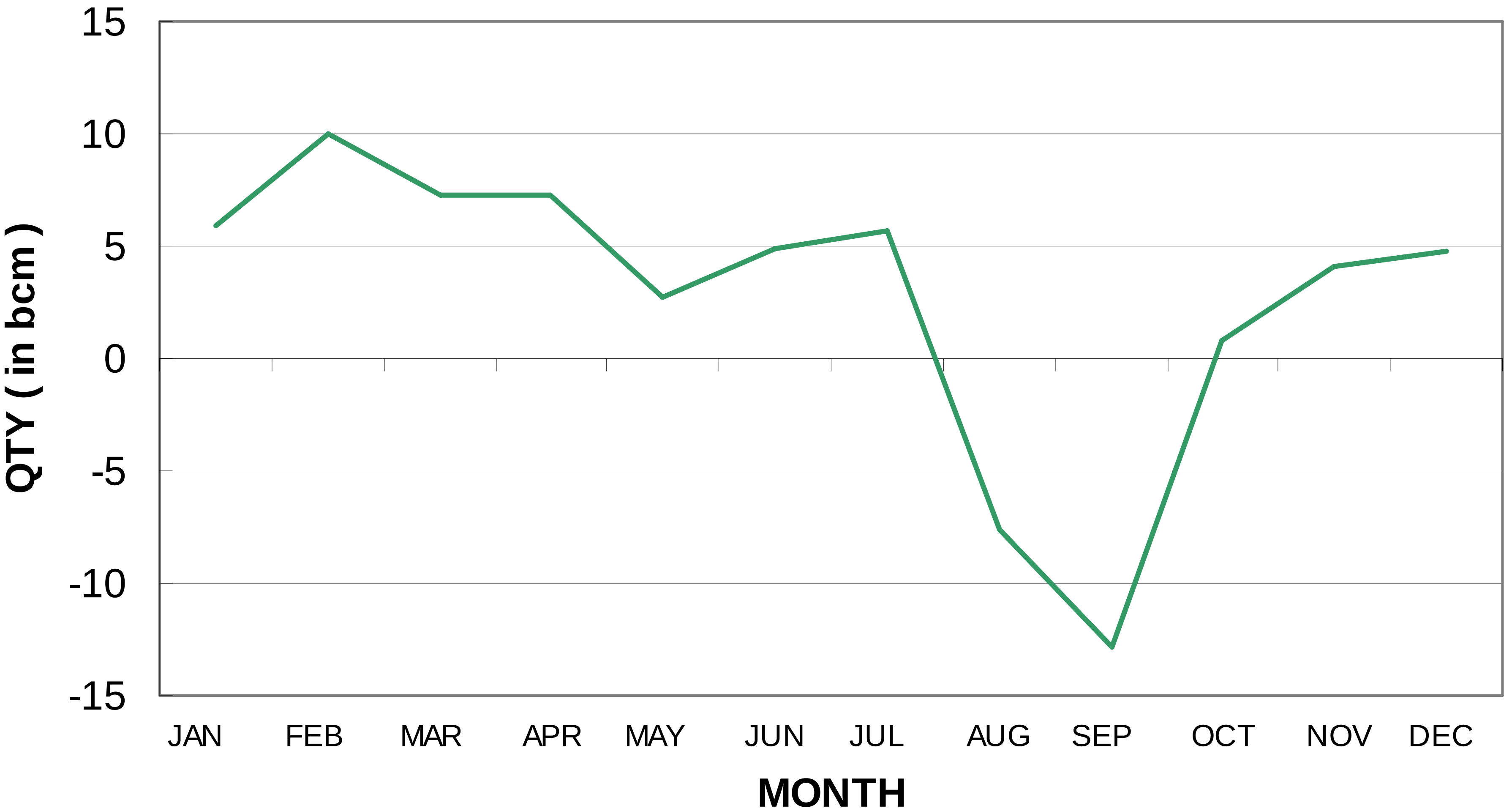


REACH : KHARTOUM - DONGOLA

$NET\ FLOW = I_{KHRT} - O_{DONG} + I_{ATB} - O_{MRW}$

MONTHLY					
	KHRT	DONGOLA	ATBARA	MEROWE	NET FLOW
	0.022974	1.9985625	9.893446	1.998562	5.919295
	0.015146	1.1880383	12.35073	1.188038	9.989801
	0.045383	1.288428	9.823918	1.288428	7.292445
	0.083841	2.5537984	12.34326	2.553798	7.3195
	3.136016	5.9032311	11.34179	5.903231	2.671348
	0.783862	3.2890844	10.62754	3.289084	4.833235
	4.599005	5.389787	11.902	5.389787	5.721433
	12.40421	15.535169	11.10655	15.53517	-7.55958
	9.279381	15.899175	9.668265	15.89918	-12.8507
	2.686231	8.2750921	14.70856	8.275092	0.84461
	0.812713	4.1335947	11.5279	4.133595	4.073428
	0.202721	3.0036826	10.54074	3.003683	4.736091
ANNUAL					
	34.07158	68.4576	135.8347	68.45764	32.99104

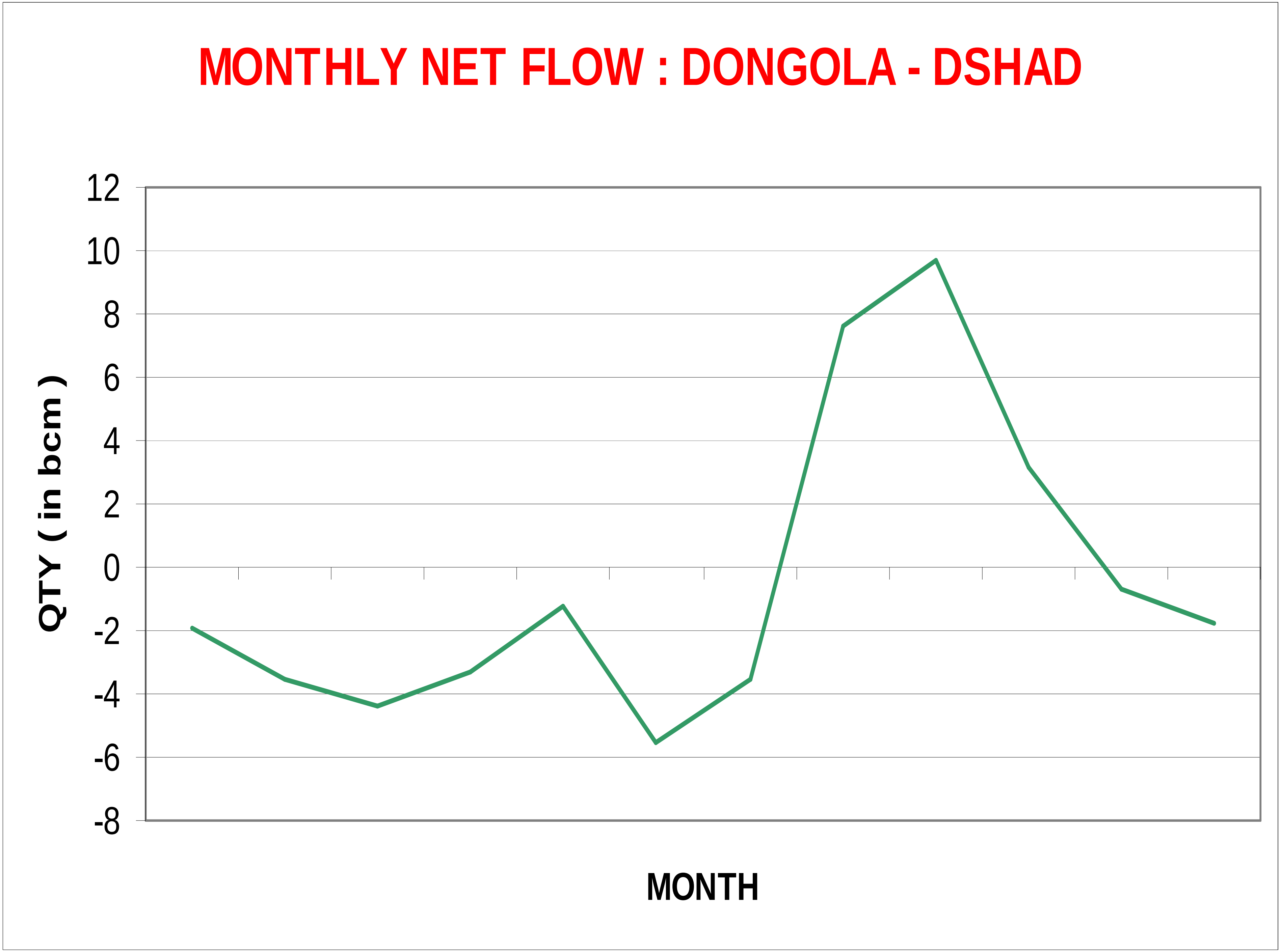
MONTHLY NET FLOW : KHRT - DONGOLA



REACH : DONGOLA - DSHAD

$NET\ FLOW = I_{DONG} – O_{DSHAD} - O_{LNSSR}$

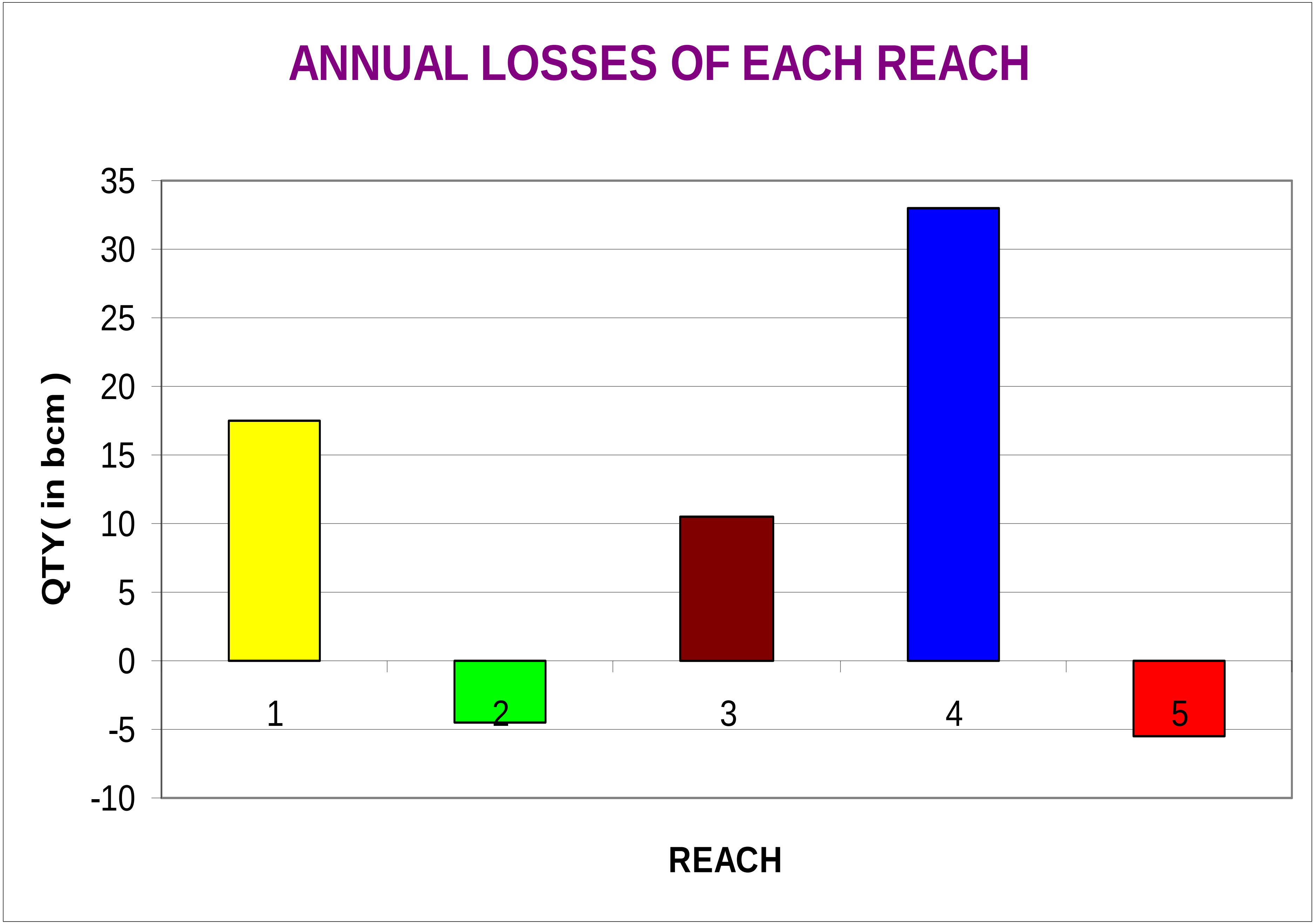
MONTHLY				
	DONGOLA	DSHAD	LAKE NASSER	NET FLOW
	1.9986	2.5474	1.3604	-1.9093
	1.188	3.3804	1.3604	-3.5528
	1.2884	4.218	1.4492	-4.3787
	2.5538	4.3124	1.5867	-3.3452
	5.9032	5.5444	1.5867	-1.2279
	3.2891	7.2594	1.5429	-5.5132
	5.3898	7.3482	1.6092	-3.5677
	15.535	6.327	1.6092	7.59893
	15.899	4.4955	1.7352	9.66843
	8.2751	3.5964	1.4994	3.17932
	4.1336	3.33	1.4994	-0.6958
	3.0037	3.1635	1.5977	-1.7575
ANNUAL				
	68.4576	55.5226	18.43649	-5.5015


MONTHLY NET FLOW : DONGOLA - DSHAD
12
10
8
6
4
2
0
-2
-4
-6
-8
QTY (in bcm)
MONTH

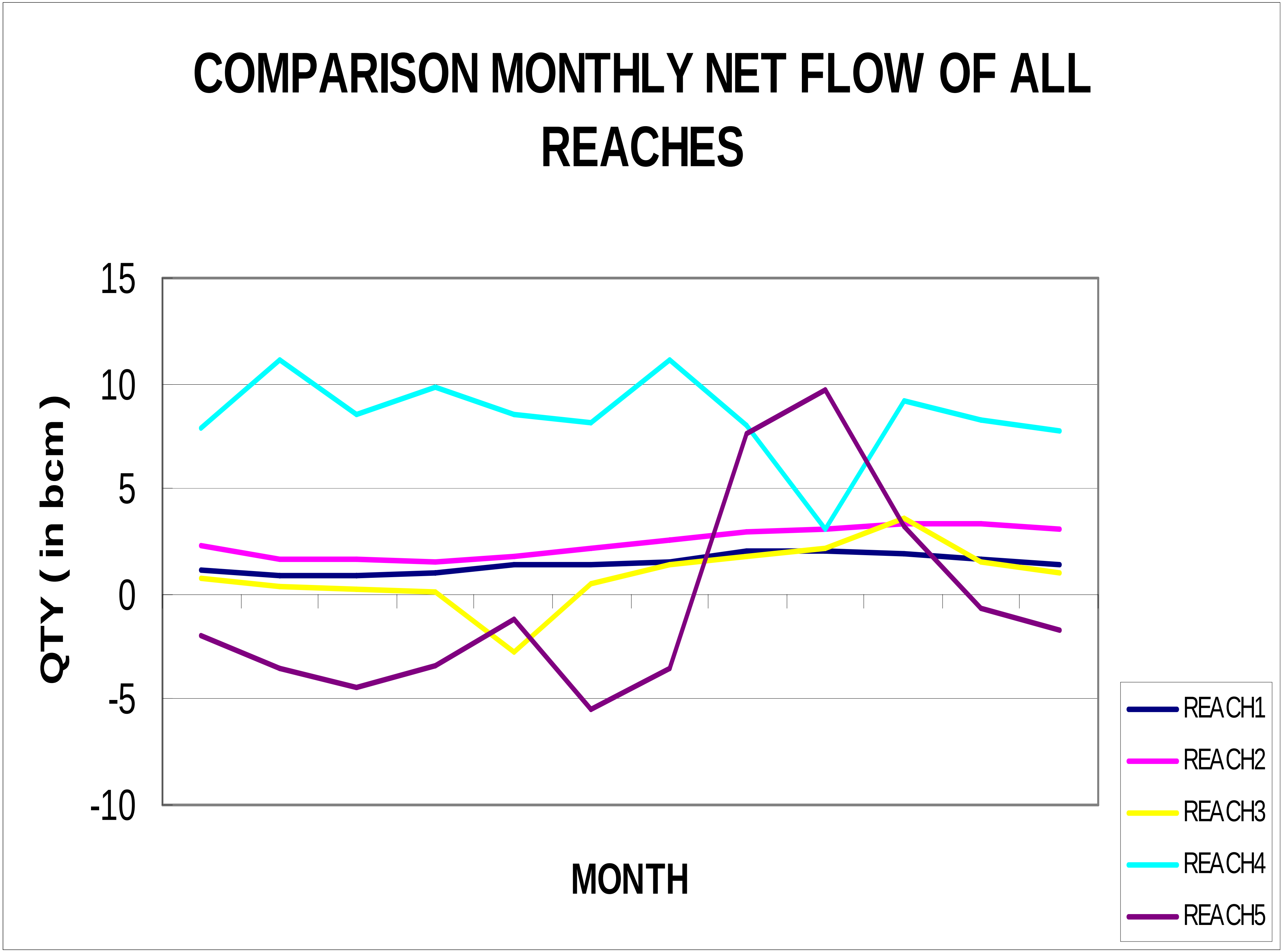
ANNUAL NET FLOW BY REACH

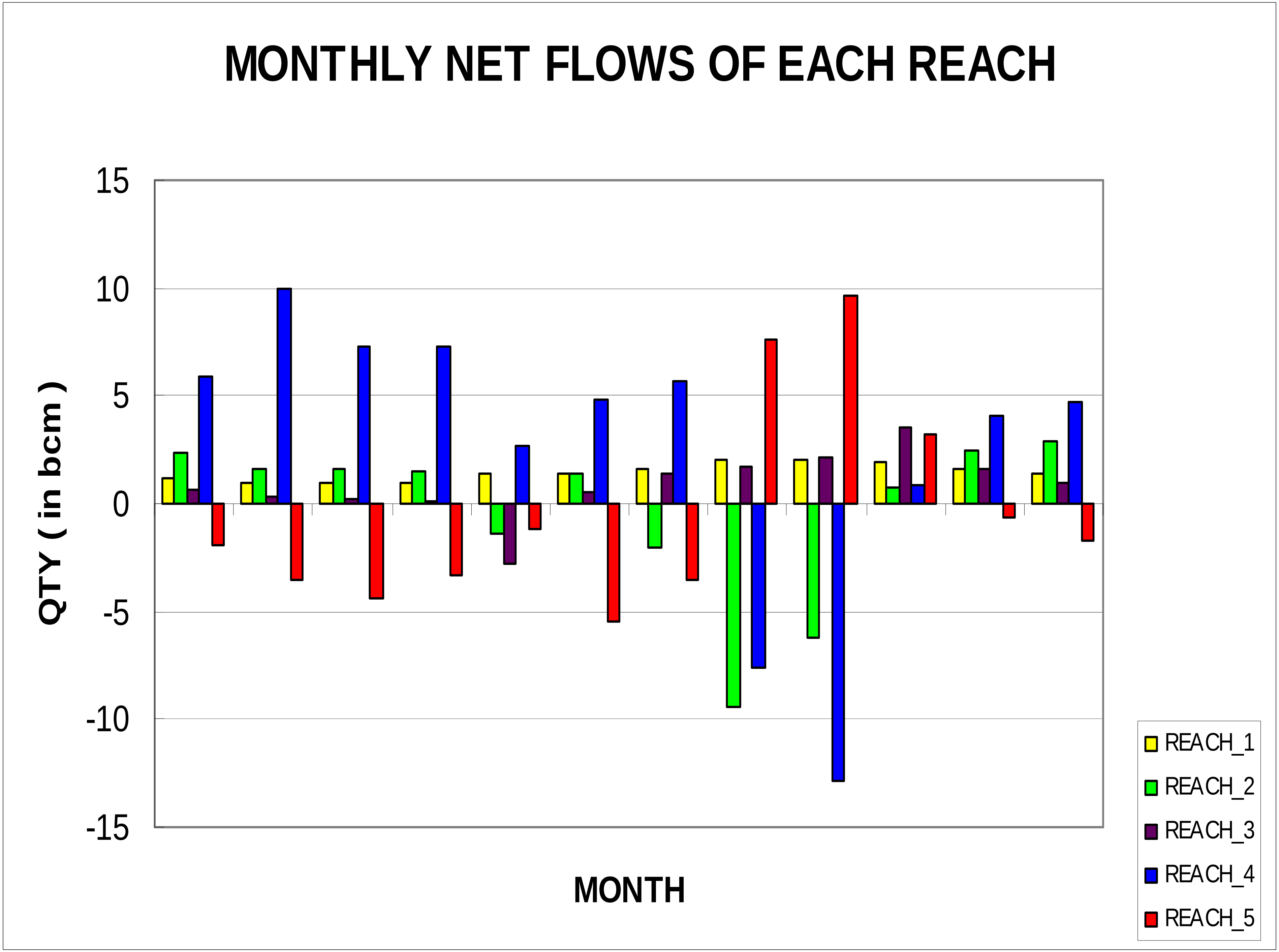
(in bcm)

REACH 1	REACH2	REACH3	REACH4	REACH5
17.4244	-4.4898	10.5459	32.9911	-5.5015


ANNUAL LOSSES OF EACH REACH
35
30
25
20
15
10
5
0
-5
-10
QTY(in bcm)
1
2
3
4
5
REACH

REACH1	REACH2	REACH3	REACH4	REACH5
1.197208	2.33755	0.693038	7.917858	-1.90933
0.939223	1.659412	0.364236	11.17784	-3.55277
0.926407	1.589144	0.261054	8.580873	-4.37873
0.982976	1.455726	0.077911	9.873299	-3.34524
1.384243	-1.39015	-2.74699	8.574579	-1.22791
1.359774	1.35743	0.537838	8.12232	-5.51322
1.57991	-1.98452	1.34702	11.11122	-3.56765
2.002939	-9.47703	1.733957	7.975587	7.598929
2.010991	-6.19659	2.143399	3.048471	9.668433
1.960604	0.711117	3.553832	9.119702	3.179325
1.660017	2.514577	1.583966	8.207022	-0.69577
1.420029	2.933565	0.996674	7.739774	-1.75752


COMPARISON MONTHLY NET FLOW OF ALL REACHES
15
10
5
0
-5
-10
QTY (in bcm)
MONTH
REACH1
REACH2
REACH3
REACH4
REACH5



MONTHLY NET FLOWS OF EACH REACH
15
10
5
0
-5
-10
-15
QTY (in bcm)
MONTH
REACH_1
REACH_2
REACH_3
REACH_4
REACH_5

COMMENTS

When we compare the different water balance of each reach, we've these conclusion :

I. The water balance of the first reach (Pkwt – Mkl) is stable every year.

II. For the second (Mkl – Gbl),the net flow decreases from November to April and get increasing from May to October.

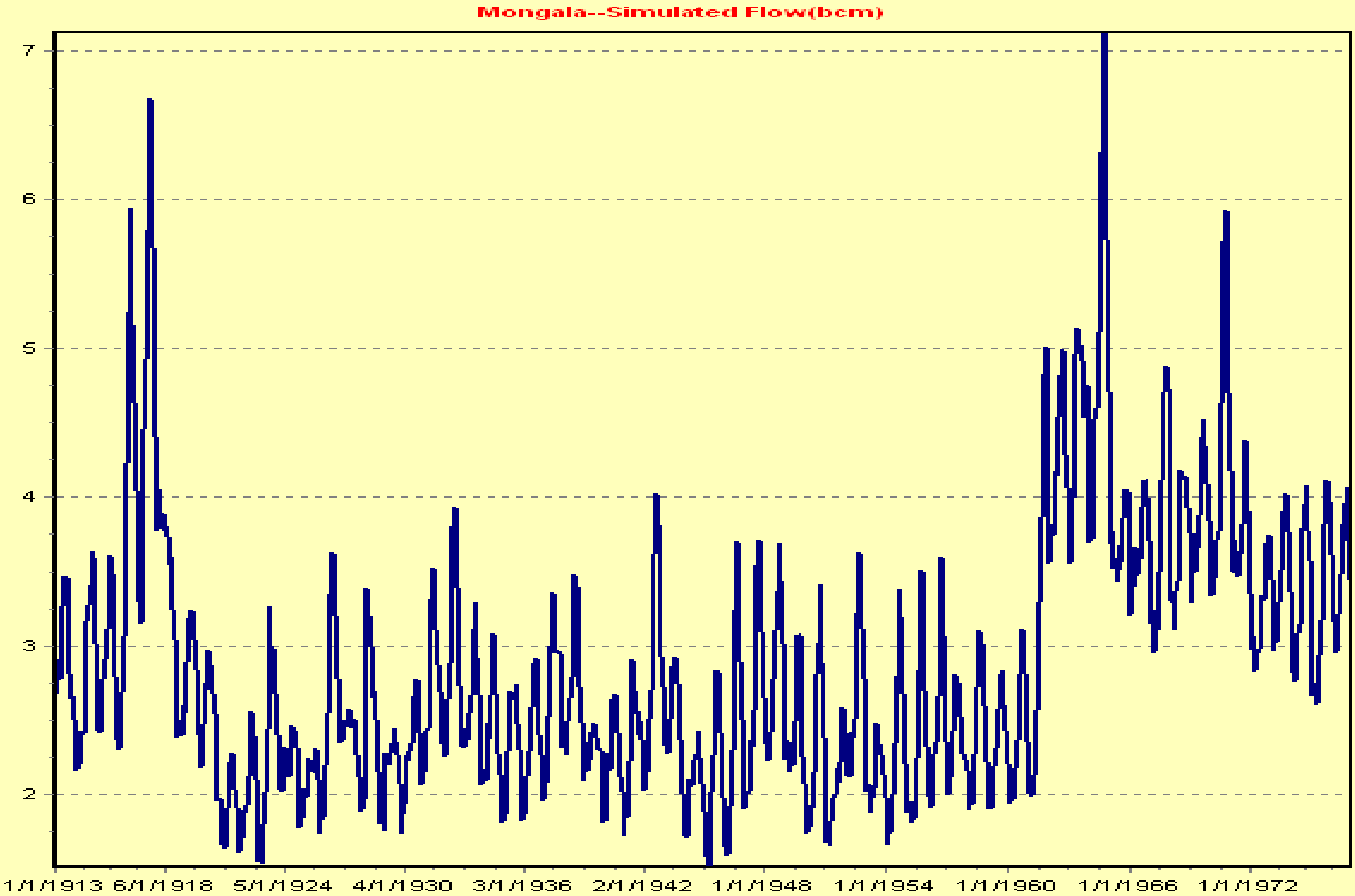
III. The 3th reach (Diem – Gbl) is characterized by a certain stability of net flow that don't exceed 5 bcm.

IV. Concerning 4th reach, it's the most has high net flow every year.

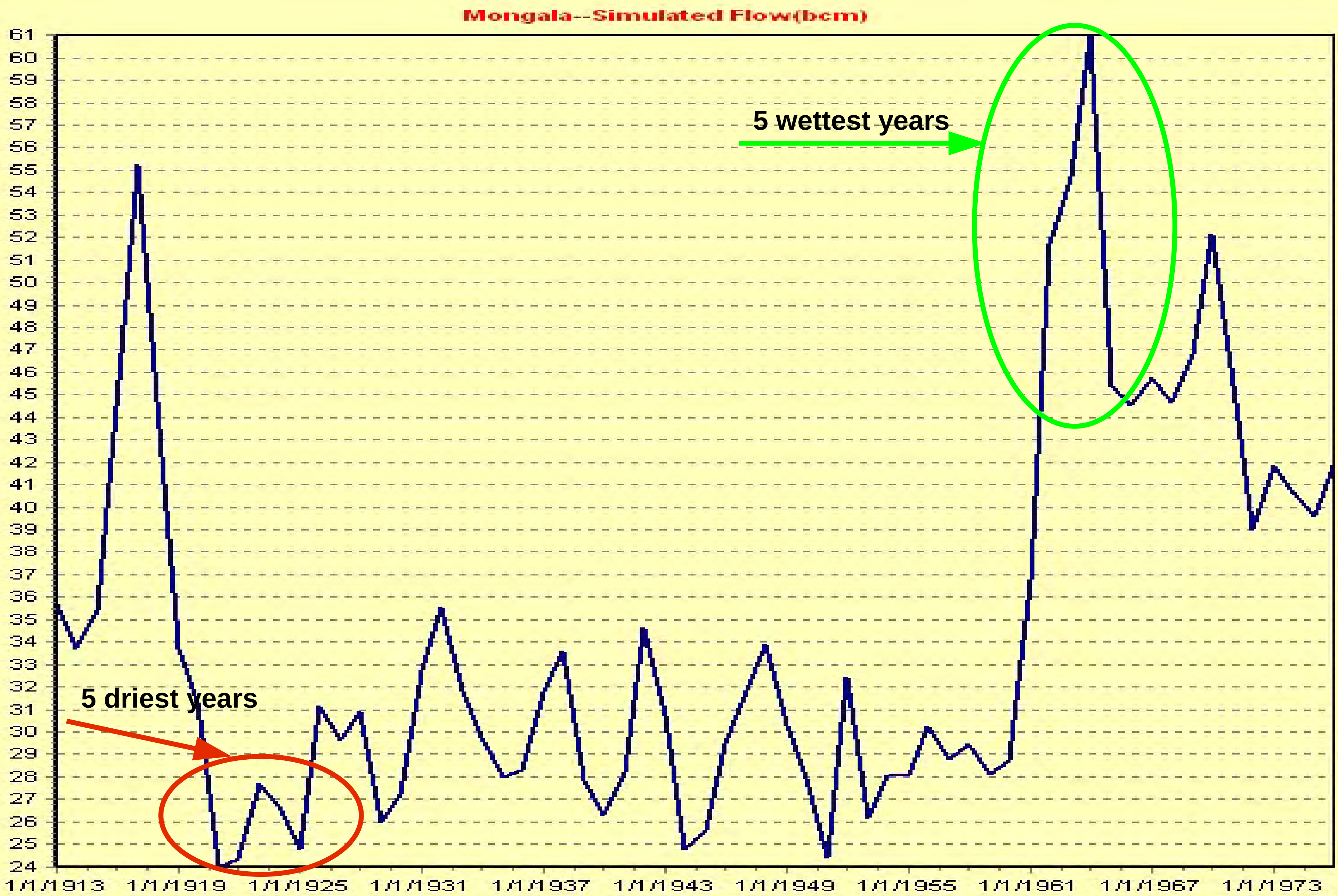
V. The net flow of the 5th is negative from Nov. to June.

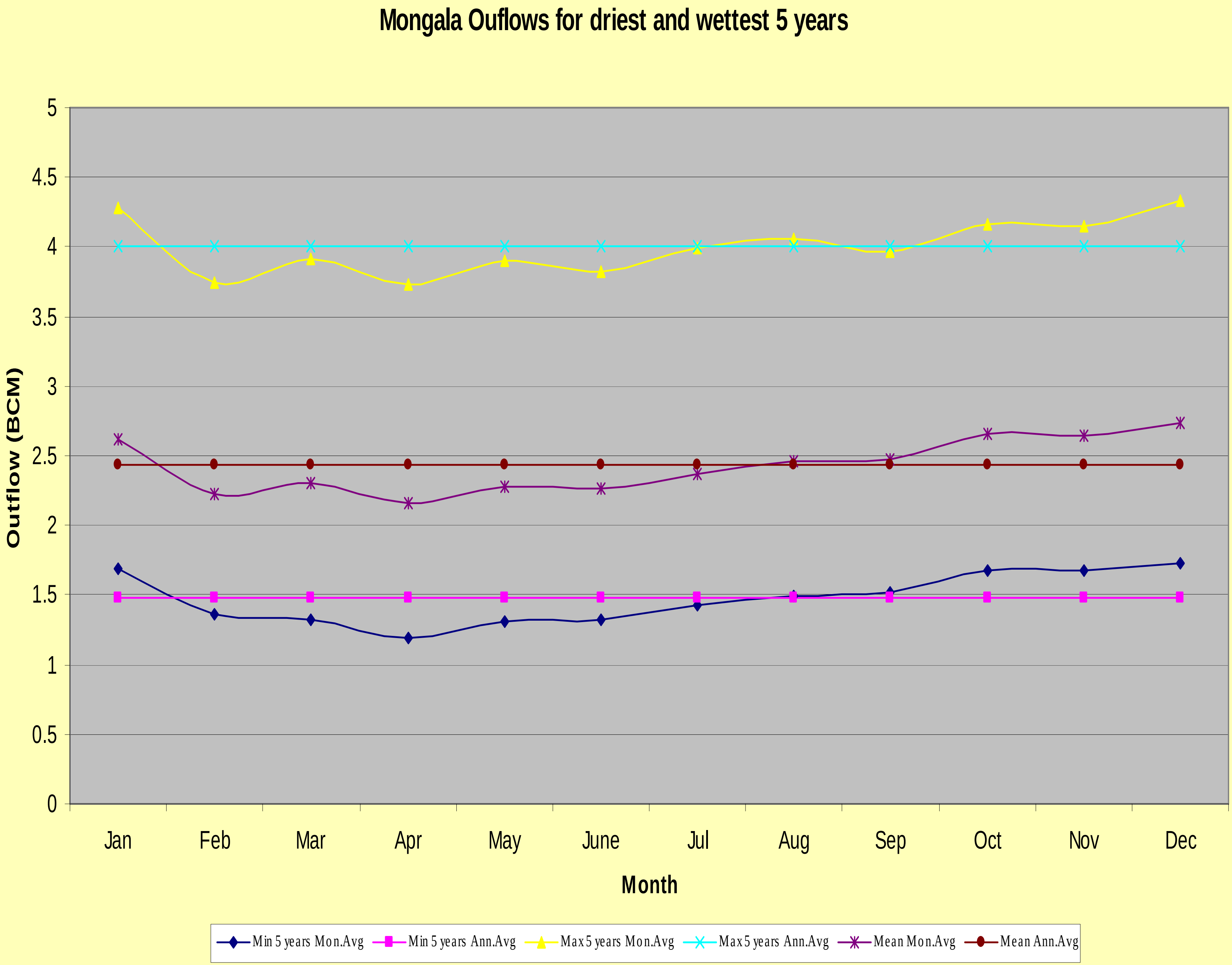
THANK YOU VERY MUCH

Monthly flow

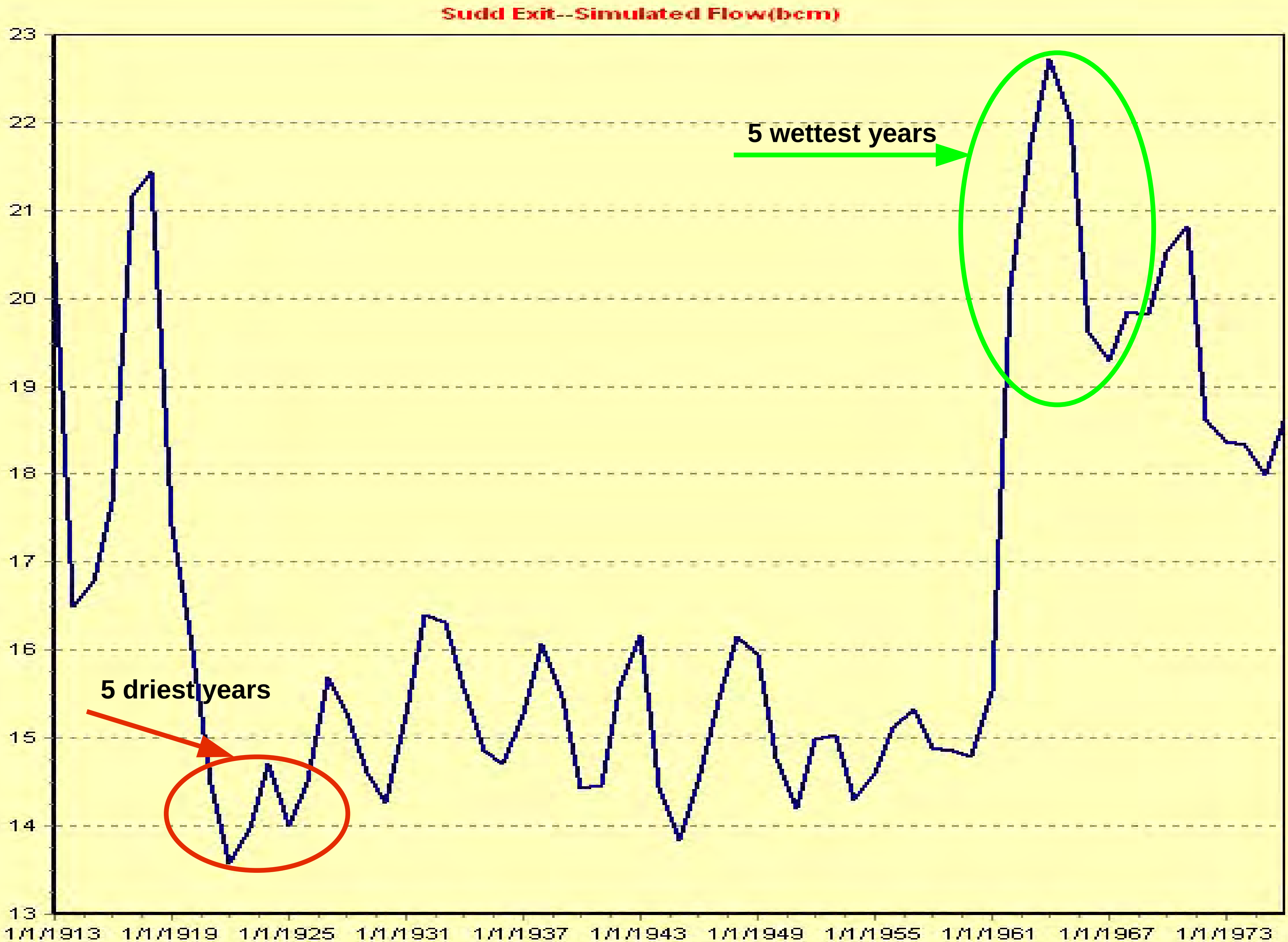


Annually time step

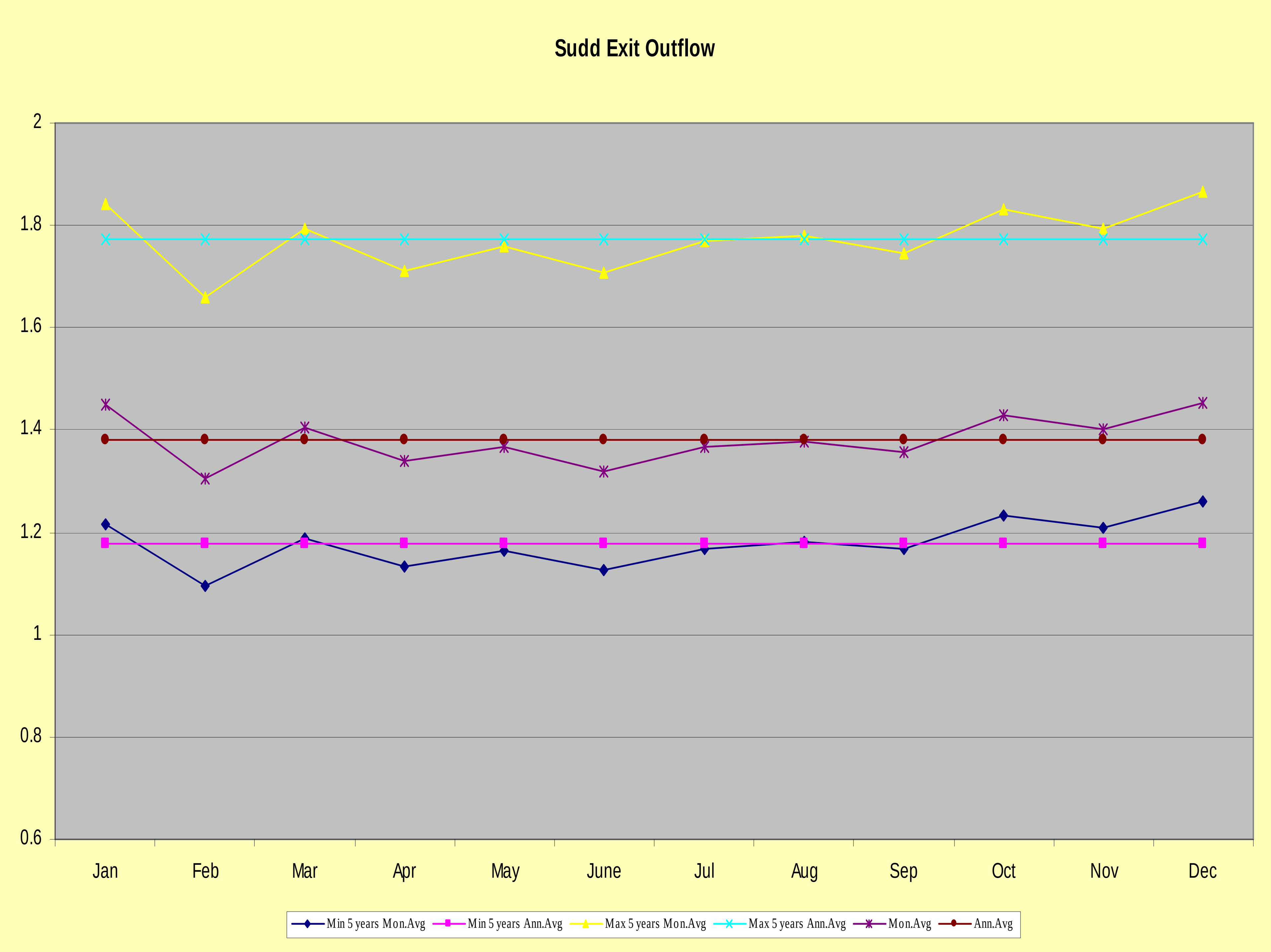



Mongala Ouflows for driest and wettest 5 years
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Outflow (BCM)
Jan
Feb
Mar
Apr
May
June
Jul
Aug
Sep
Oct
Nov
Dec
Month
Min 5 years Mon.Avg
Min 5 years Ann.Avg
Max 5 years Mon.Avg
Max 5 years Ann.Avg
Mean Mon.Avg
Mean Ann.Avg

Monthly flow

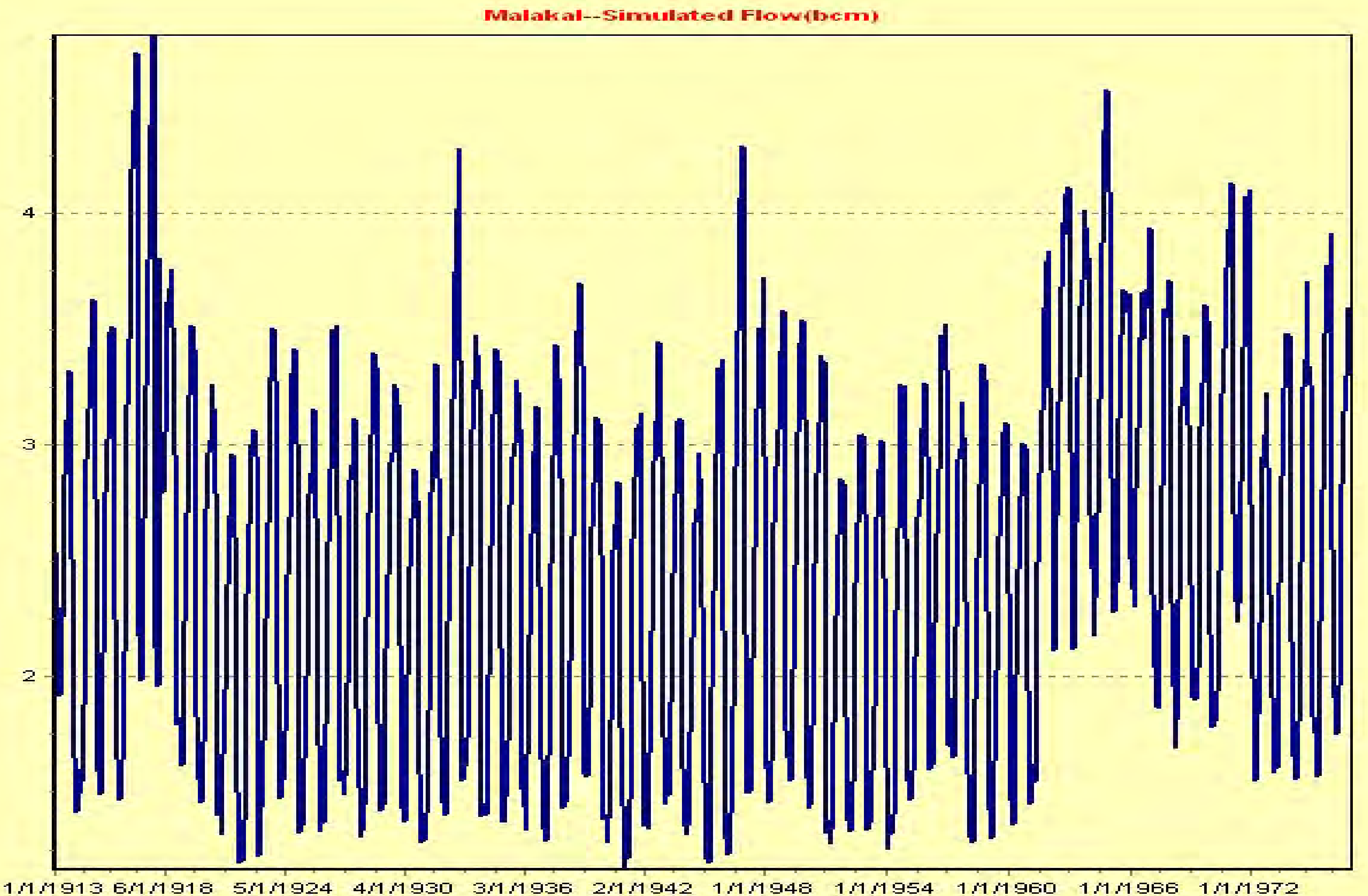


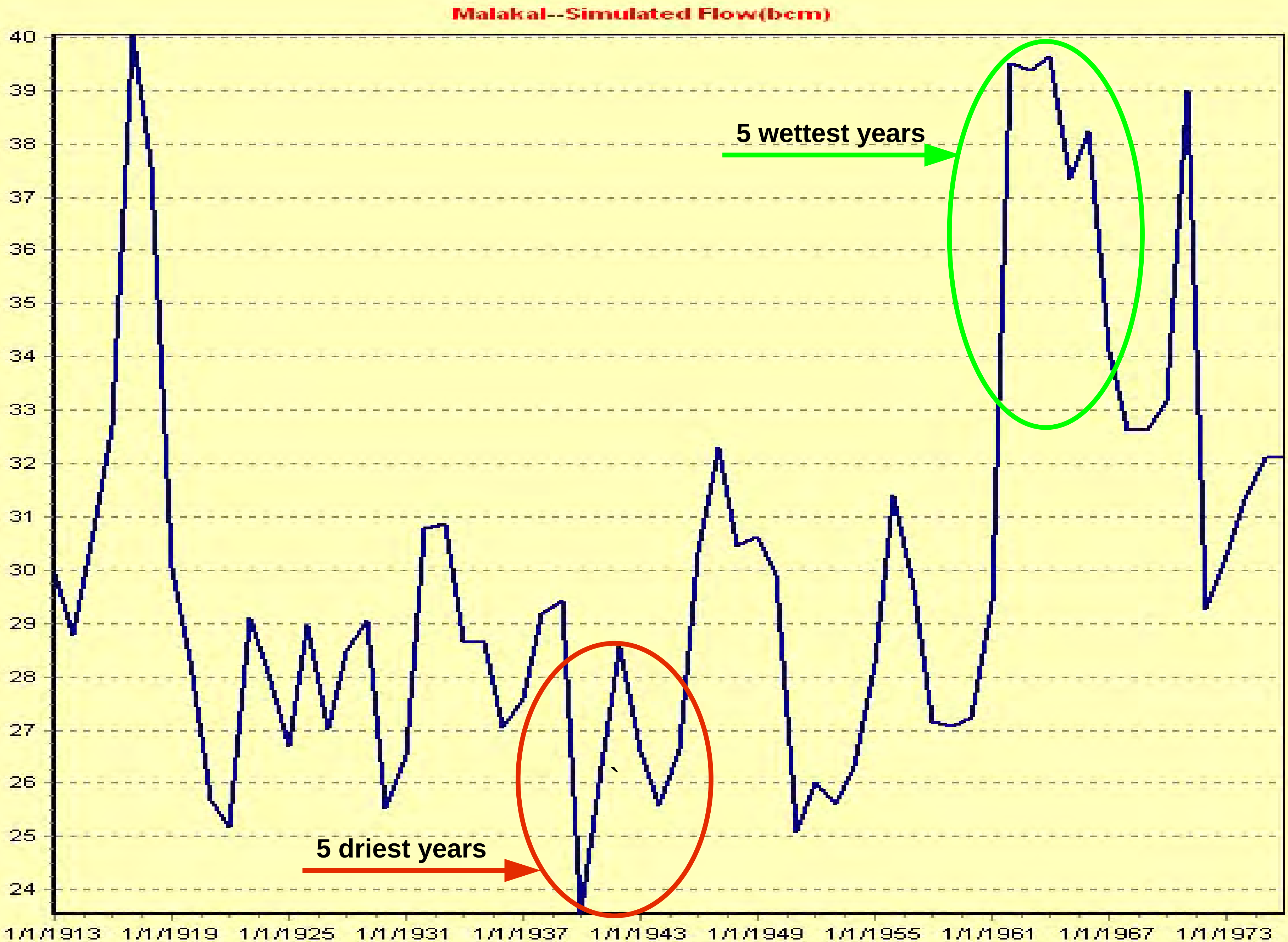
Sudd Exit--Simulated Flow(bcm)
23
22
21
20
19
18
17
16
15
14
13
1/1/1913
1/1/1919
1/1/1925
1/1/1931
1/1/1937
1/1/1943
1/1/1949
1/1/1955
1/1/1961
1/1/1967
1/1/1973
5 wettest years
5 driest years

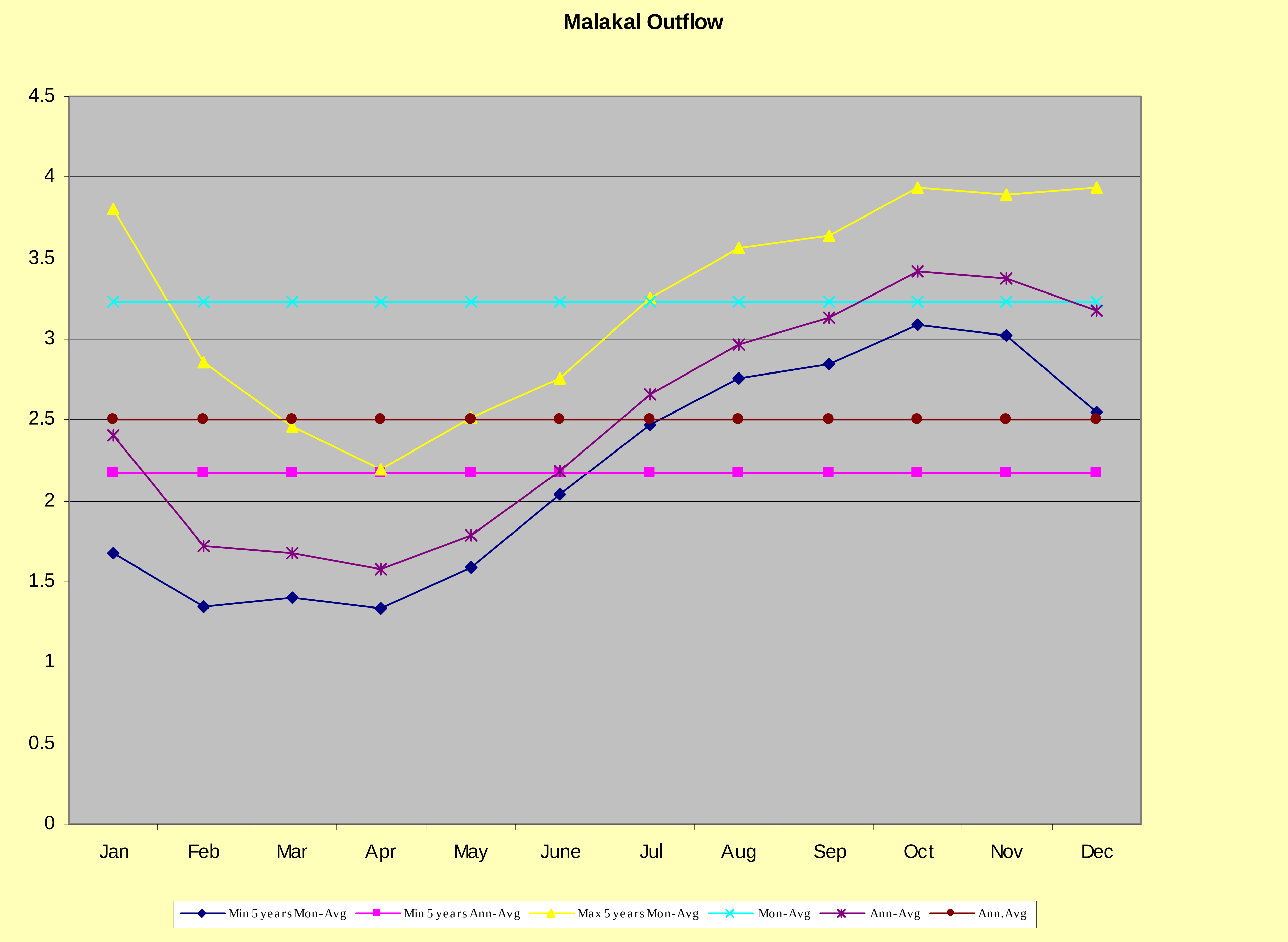


Sudd Exit Outflow
2
1.8
1.6
1.4
1.2
1
0.8
0.6
Jan
Feb
Mar
Apr
May
June
Jul
Aug
Sep
Oct
Nov
Dec
Min 5 years Mon.Avg
Min 5 years Ann.Avg
Max 5 years Mon.Avg
Max 5 years Ann.Avg
Mon.Avg
Ann.Avg

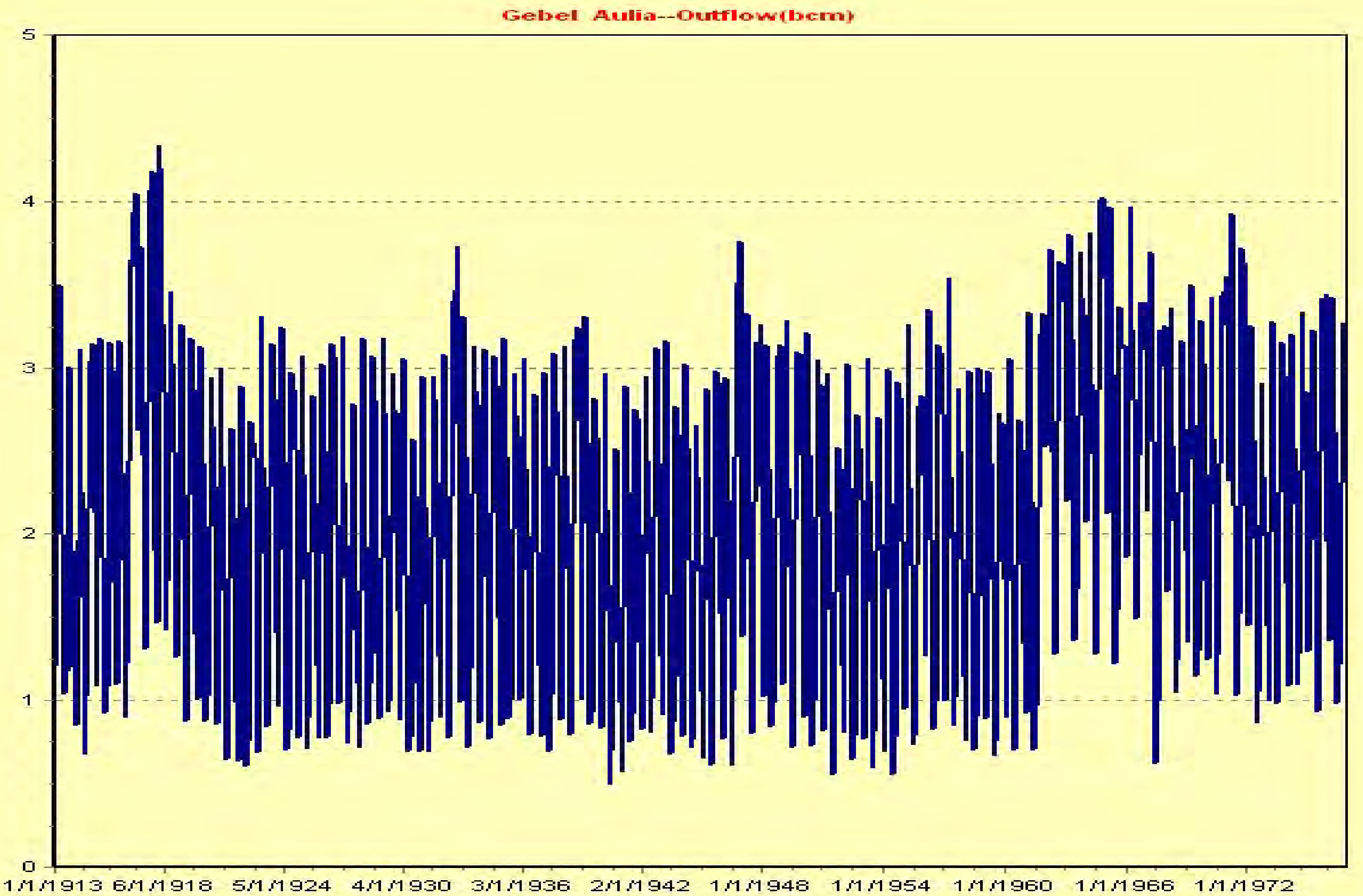
Monthly flow

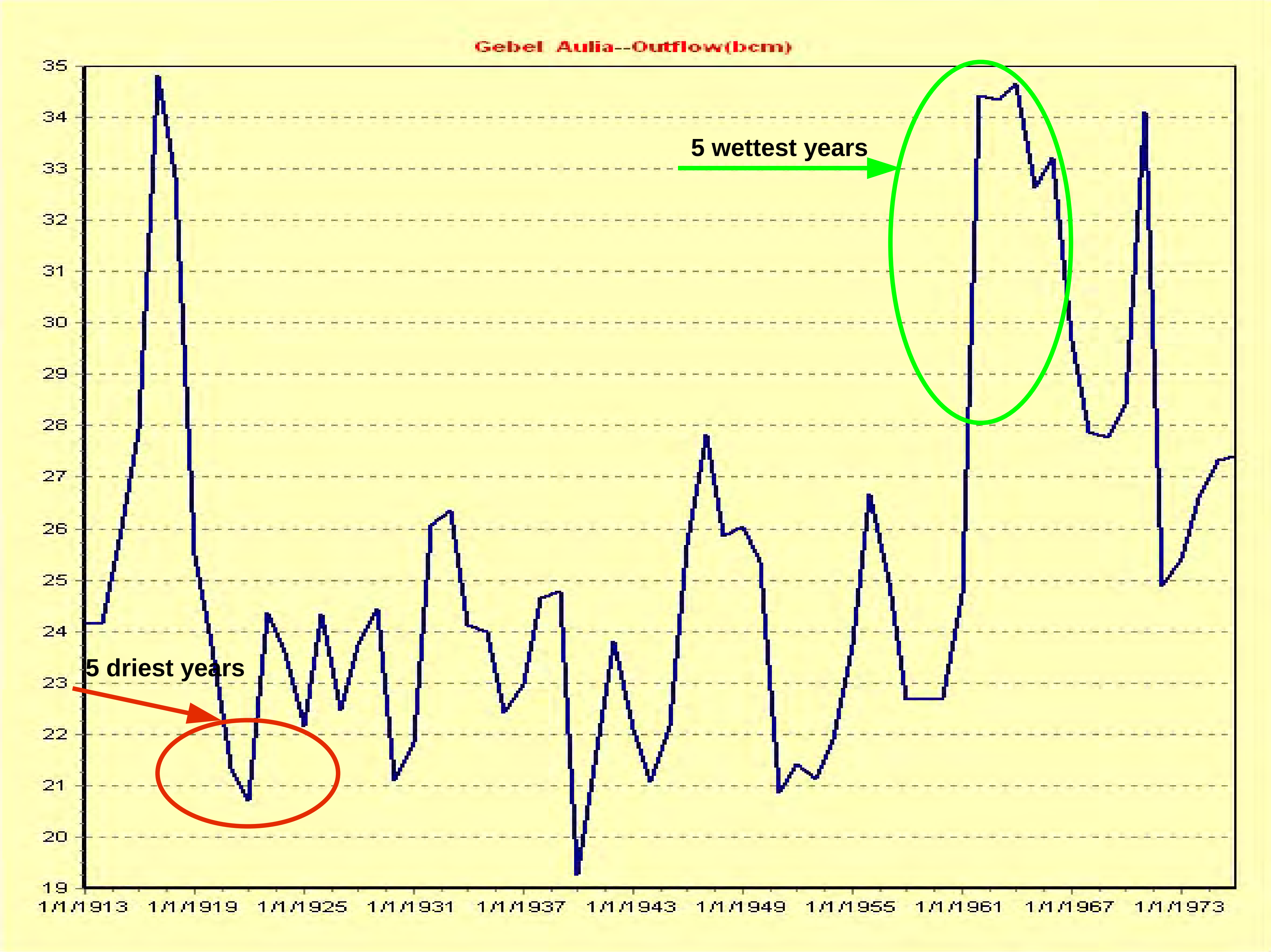


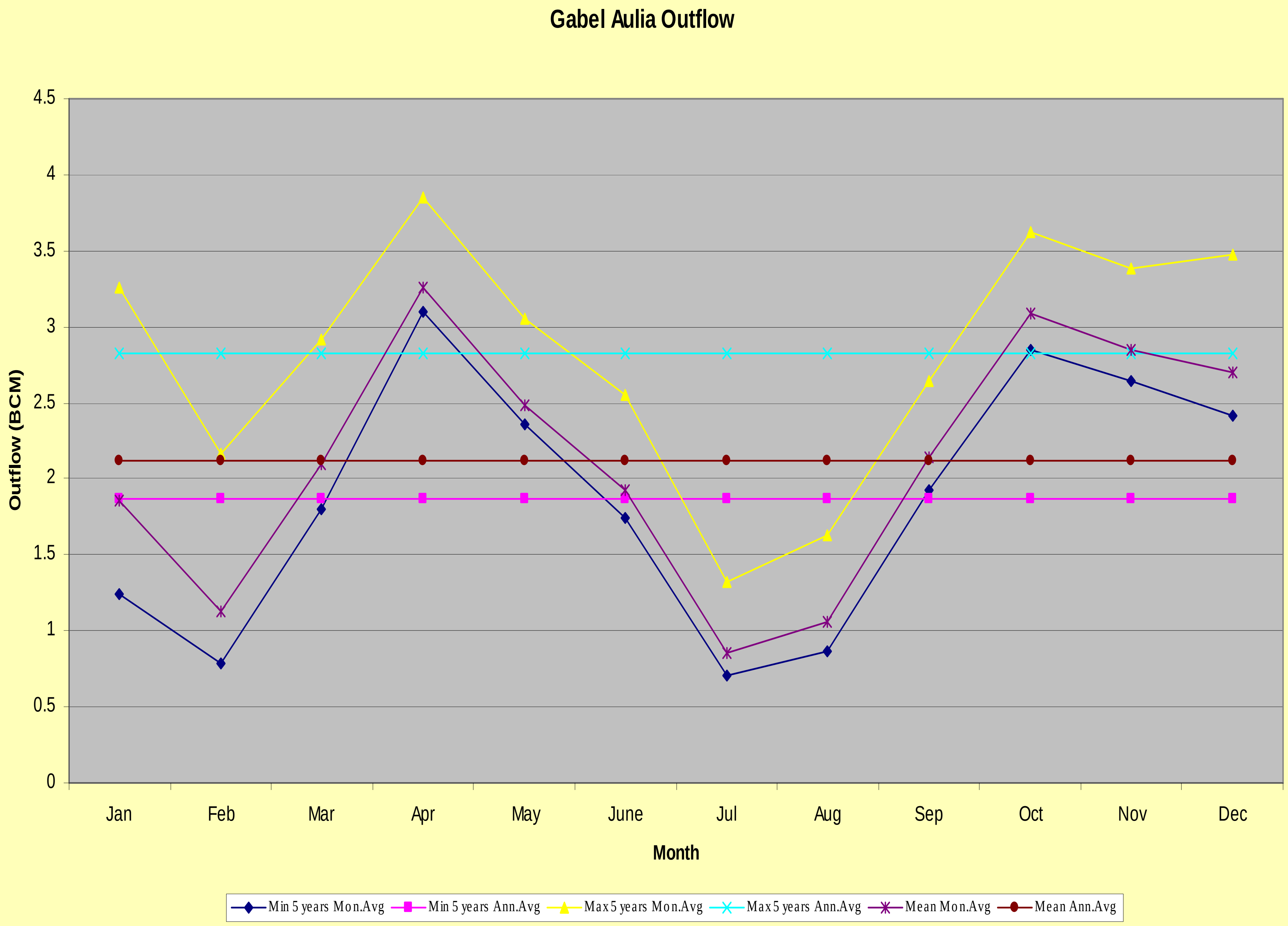

Malakal--Simulated Flow(bcm)
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
1/1/1913
1/1/1919
1/1/1925
1/1/1931
1/1/1937
1/1/1943
1/1/1949
1/1/1955
1/1/1961
1/1/1967
1/1/1973
5 wettest years
5 driest years


Malakal Outflow
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
June
Jul
Aug
Sep
Oct
Nov
Dec
Min 5 years Mon-Avg
Min 5 years Ann-Avg
Max 5 years Mon-Avg
Mon-Avg
Ann-Avg
Ann.Avg

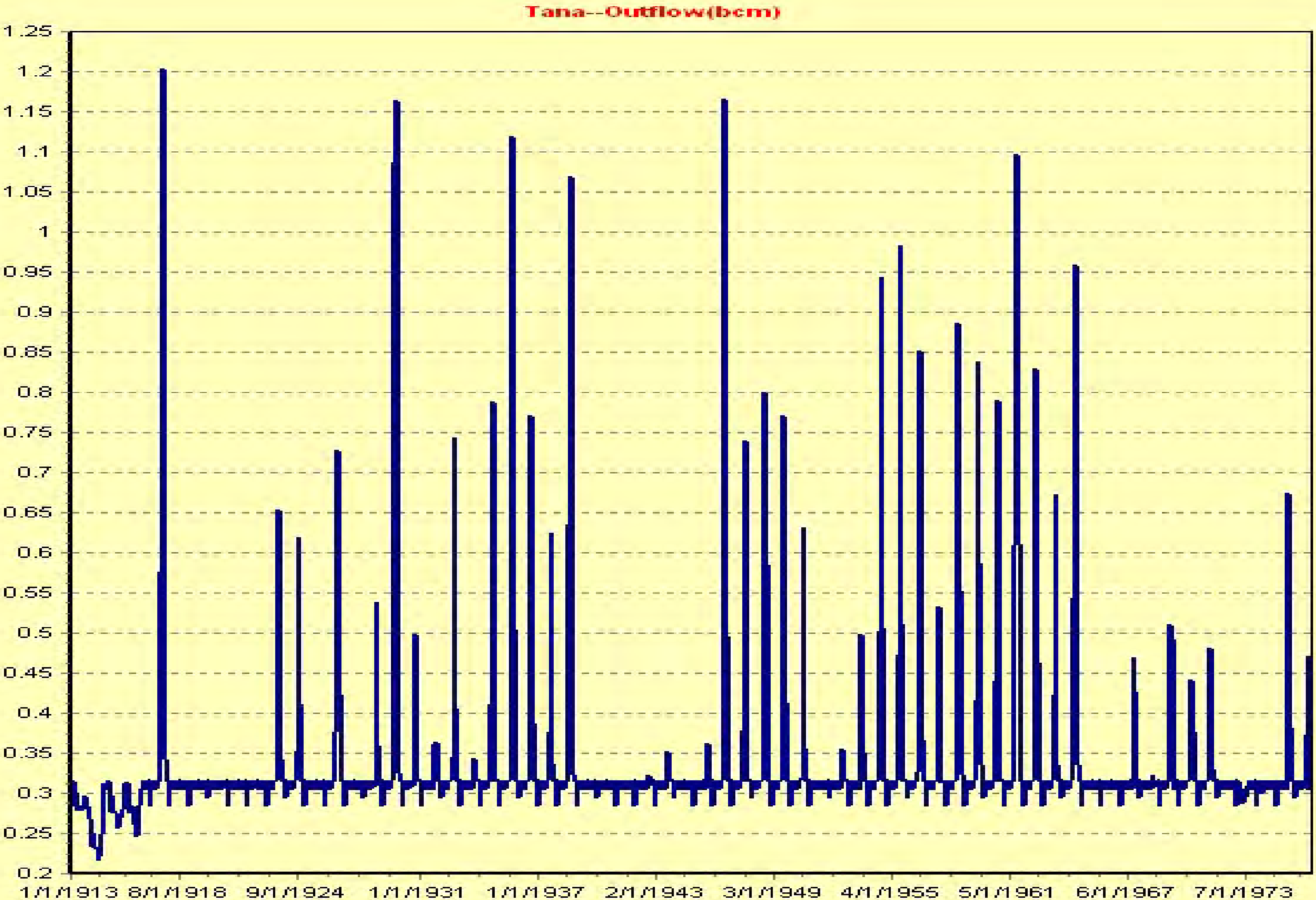
Monthly time step

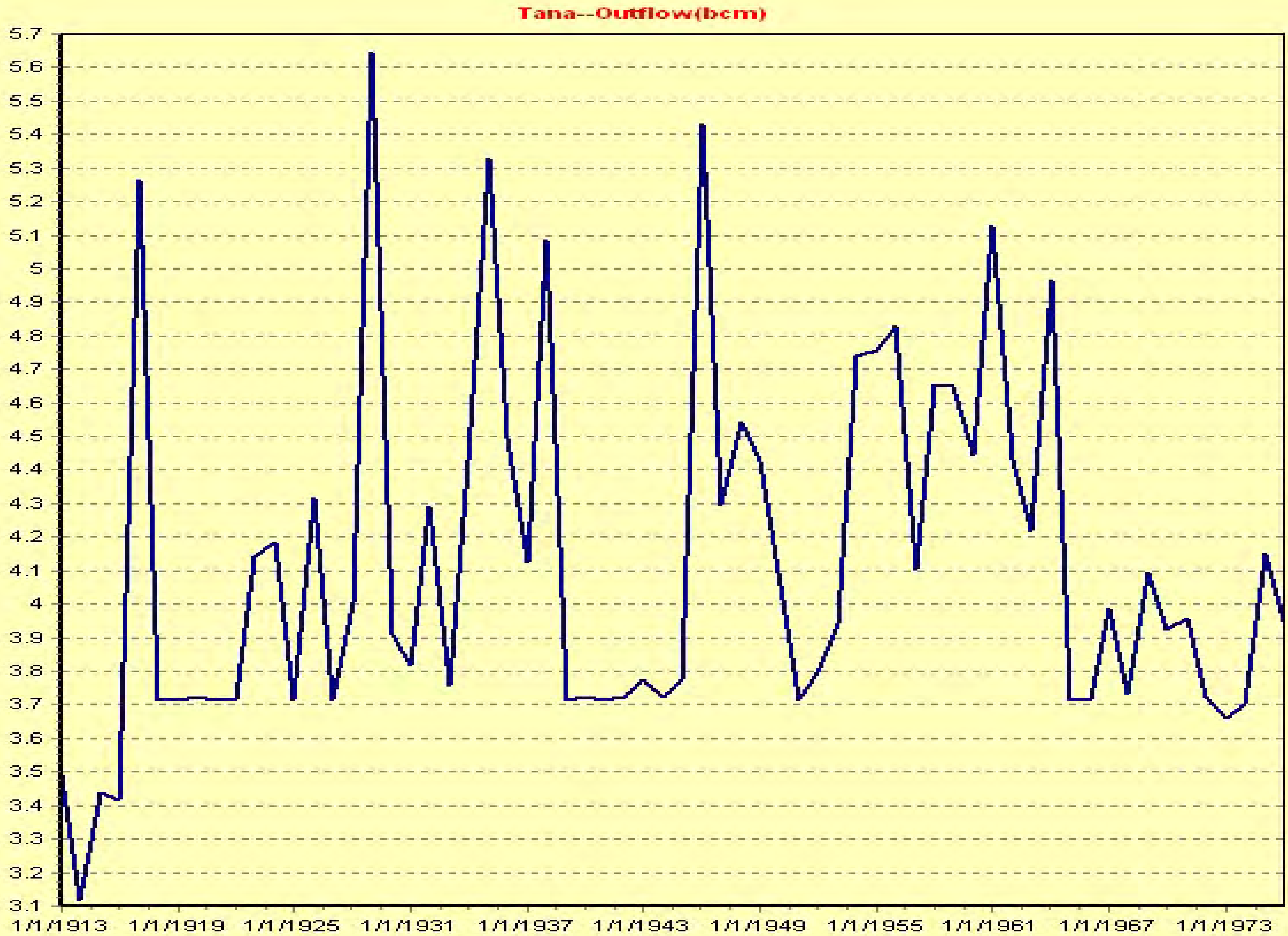



Gebel Aulia--Outflow(bcm)
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
19
1/1/1913
1/1/1919
1/1/1925
1/1/1931
1/1/1937
1/1/1943
1/1/1949
1/1/1955
1/1/1961
1/1/1967
1/1/1973
5 wettest years
5 driest years


Gabel Aulia Outflow
Outflow (BCM)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
June
Jul
Aug
Sep
Oct
Nov
Dec
Month
Min 5 years Mon.Avg
Min 5 years Ann.Avg
Max 5 years Mon.Avg
Max 5 years Ann.Avg
Mean Mon.Avg
Mean Ann.Avg

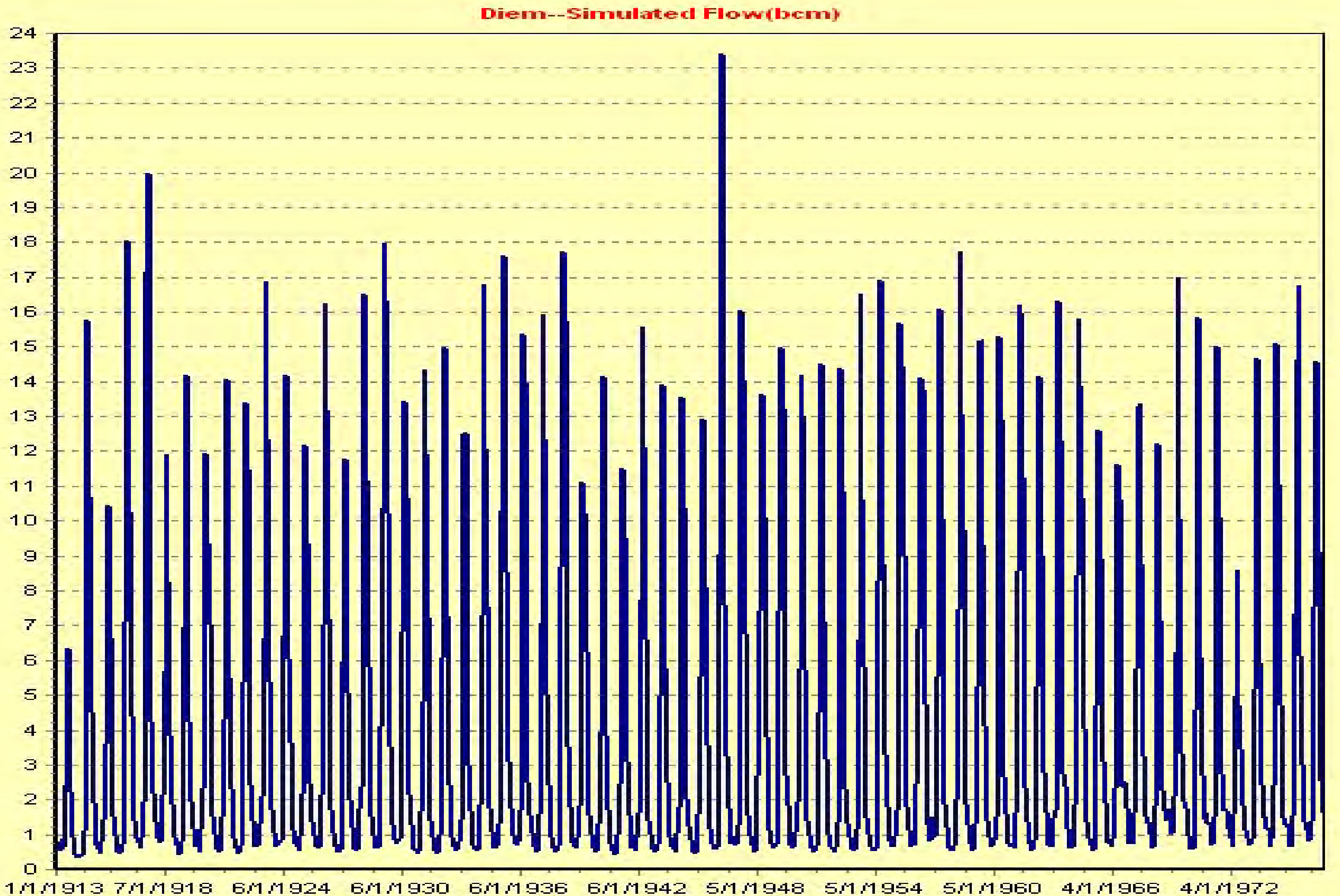
Monthly time step

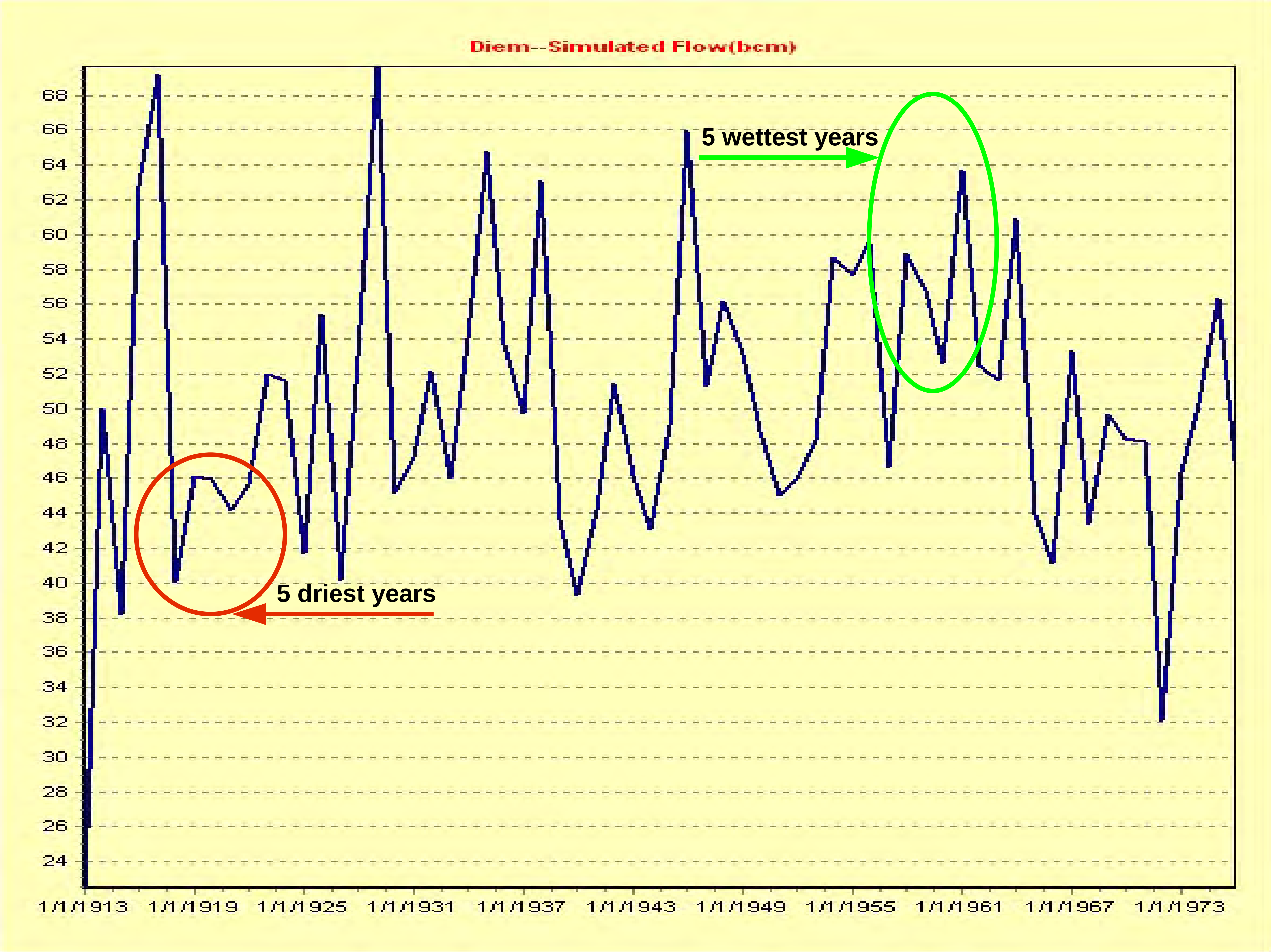




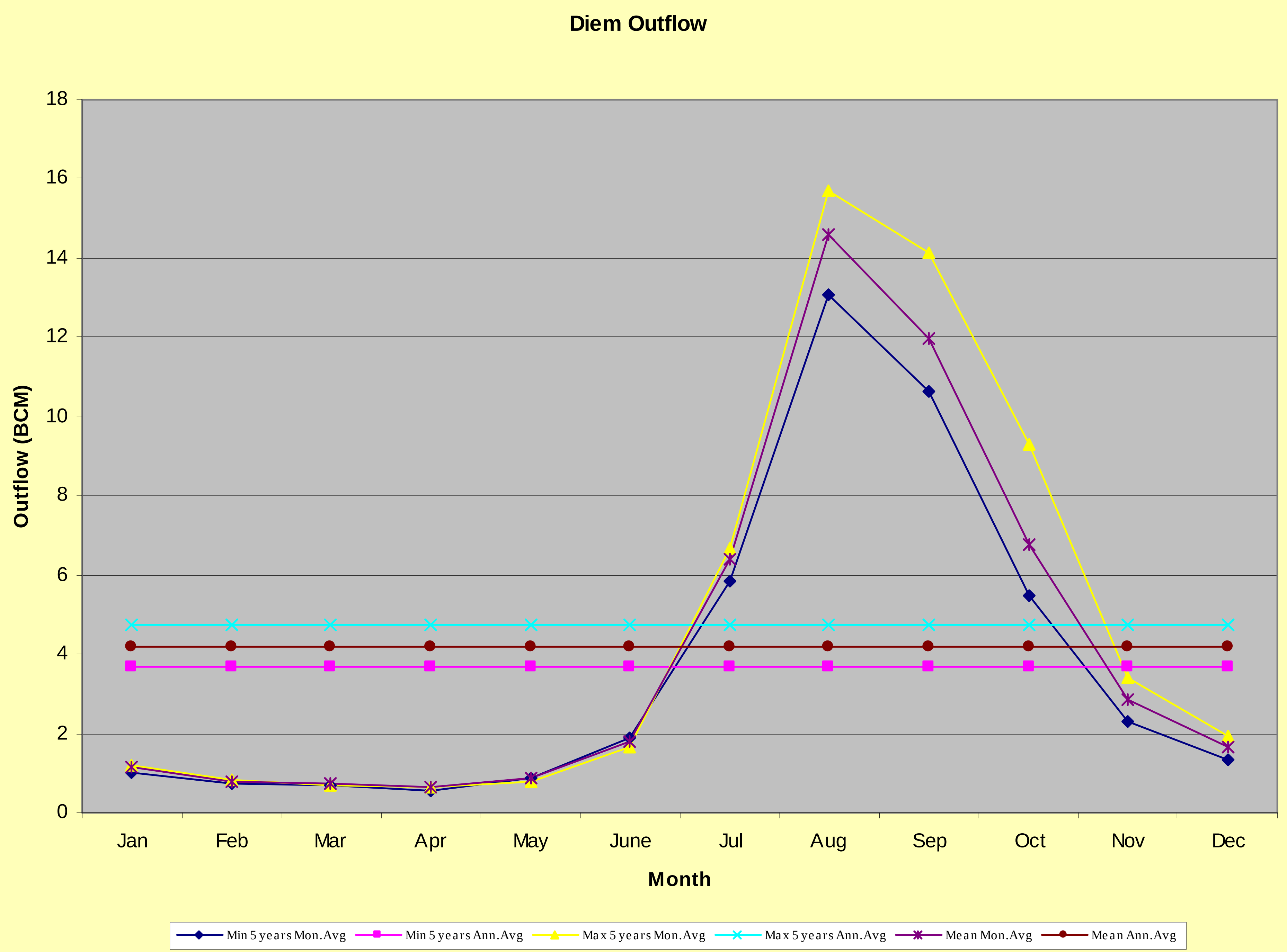
Tana--Outflow(bcm)
5.7
5.6
5.5
5.4
5.3
5.2
5.1
5
4.9
4.8
4.7
4.6
4.5
4.4
4.3
4.2
4.1
4
3.9
3.8
3.7
3.6
3.5
3.4
3.3
3.2
3.1
1/1/1913
1/1/1919
1/1/1925
1/1/1931
1/1/1937
1/1/1943
1/1/1949
1/1/1955
1/1/1961
1/1/1967
1/1/1973

Monthly time step

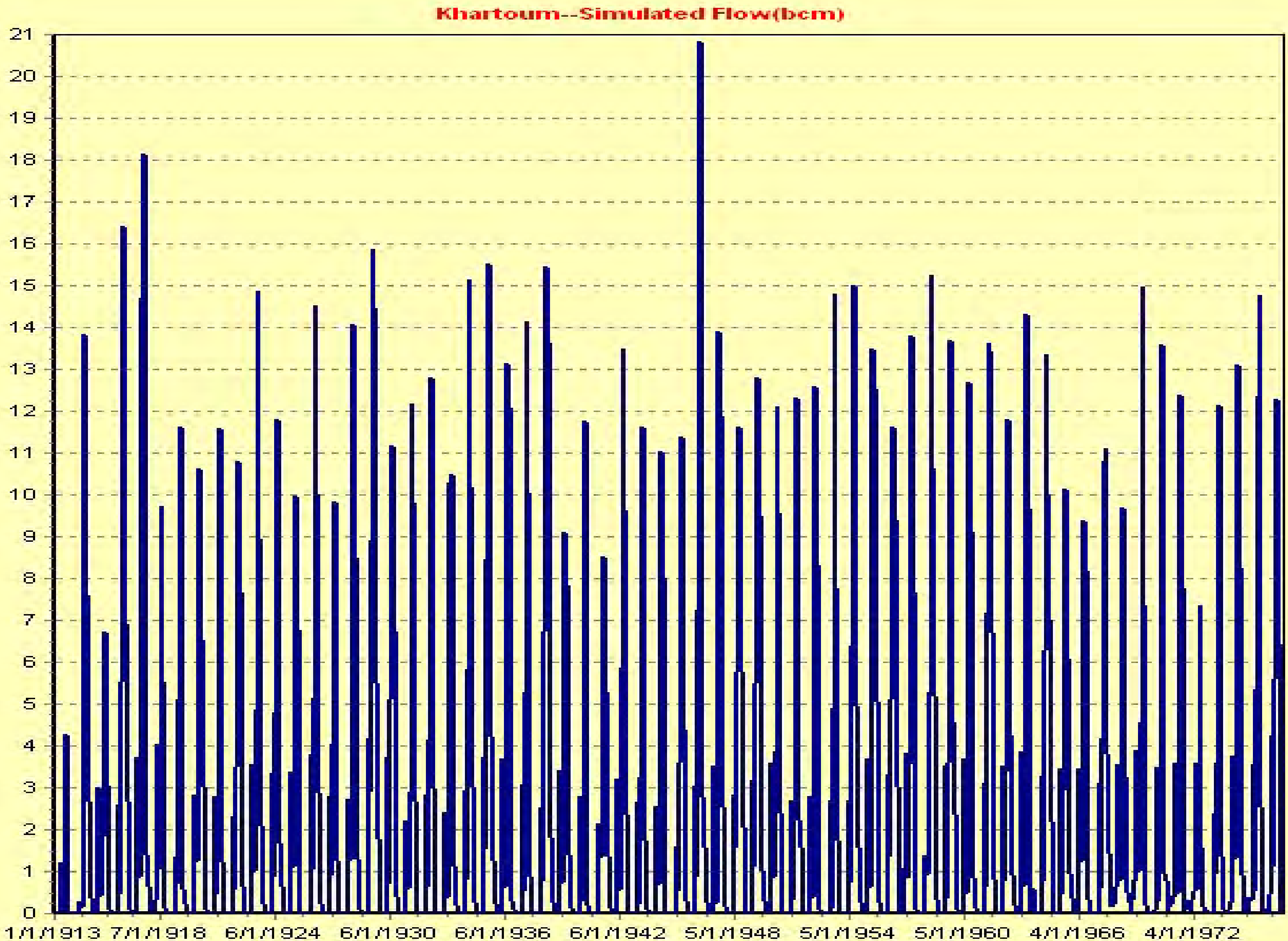


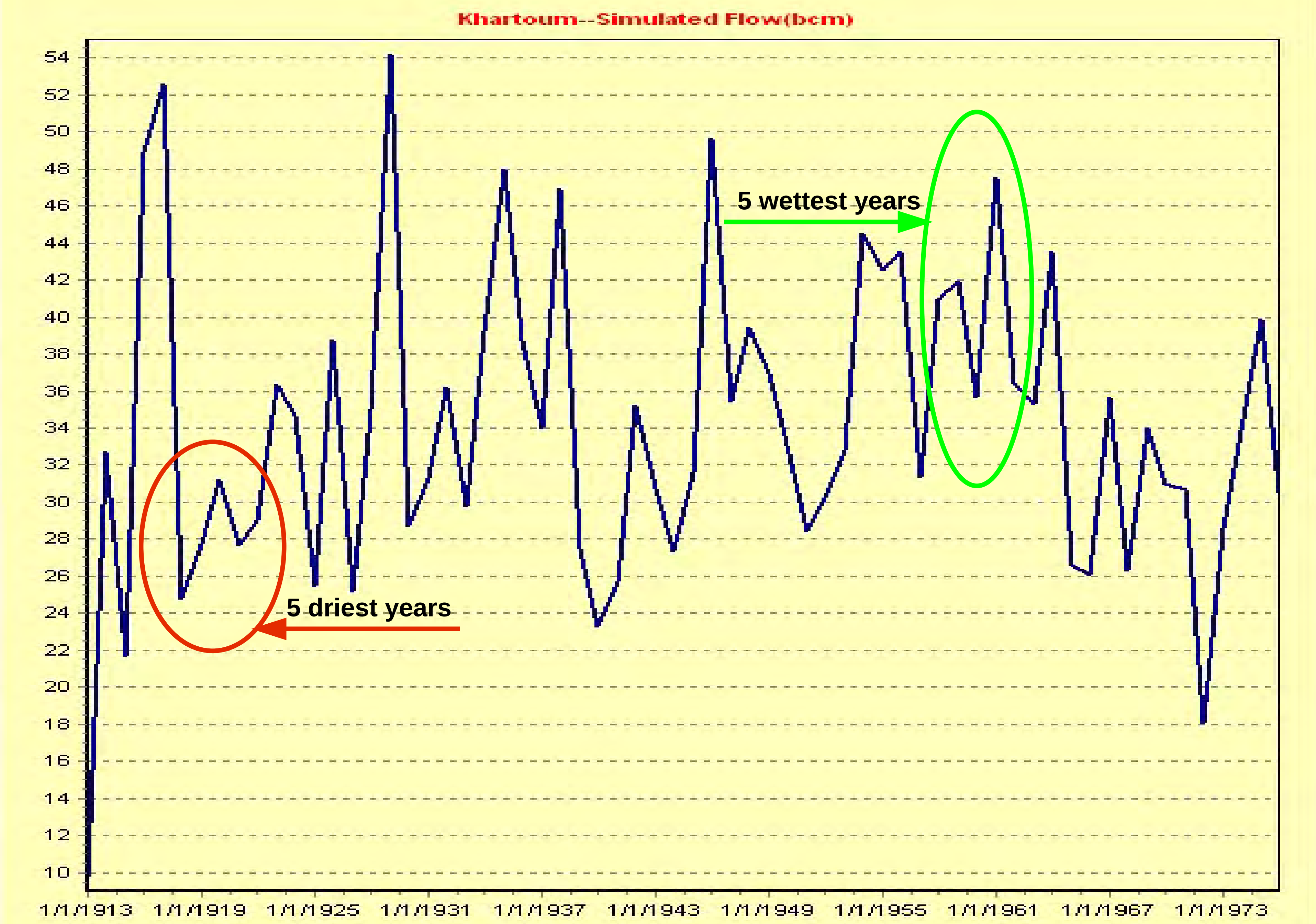


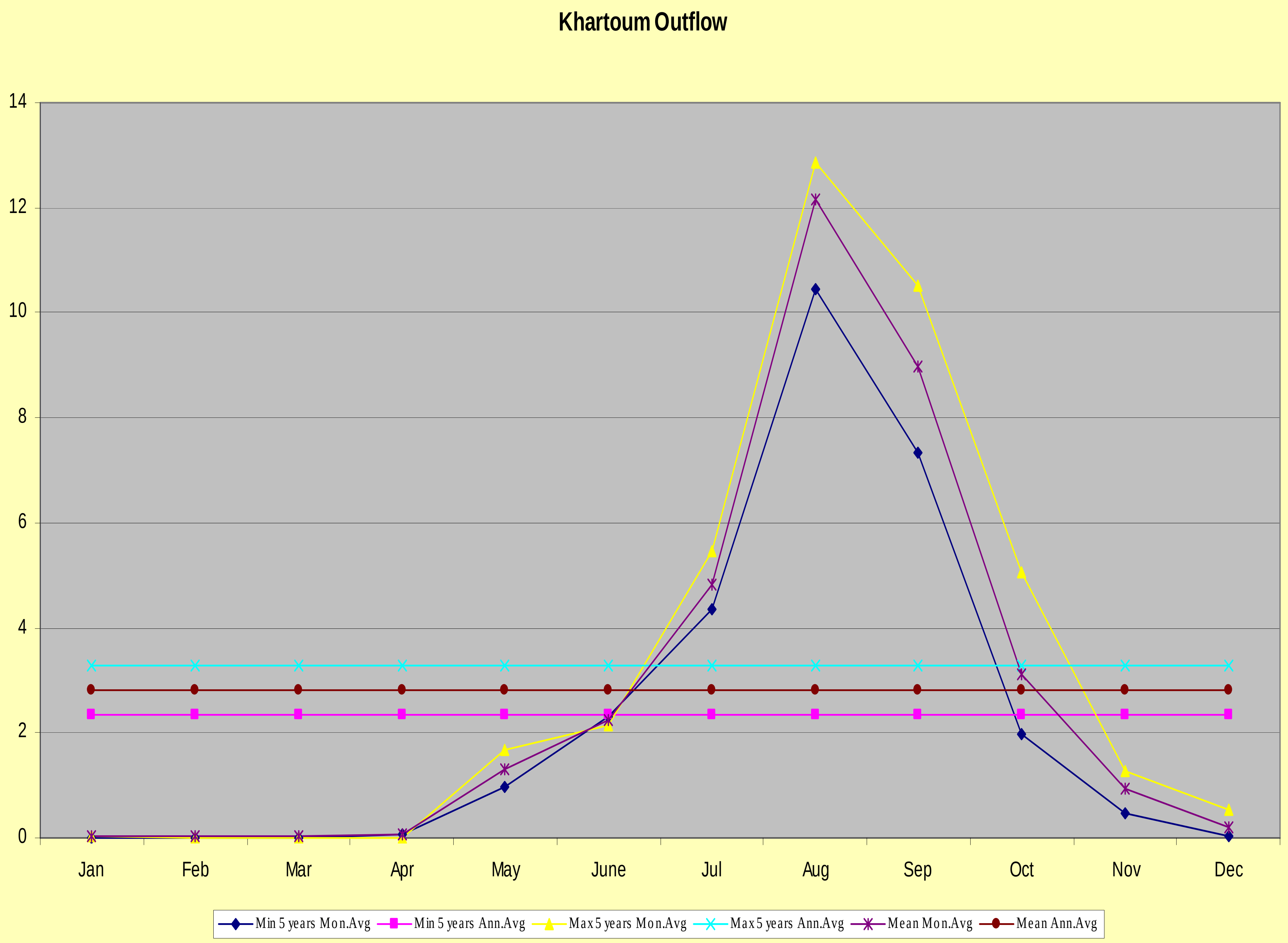
Diem--Simulated Flow(bcm)
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
1/1/1913
1/1/1919
1/1/1925
1/1/1931
1/1/1937
1/1/1943
1/1/1949
1/1/1955
1/1/1961
1/1/1967
1/1/1973
5 wettest years
5 driest years

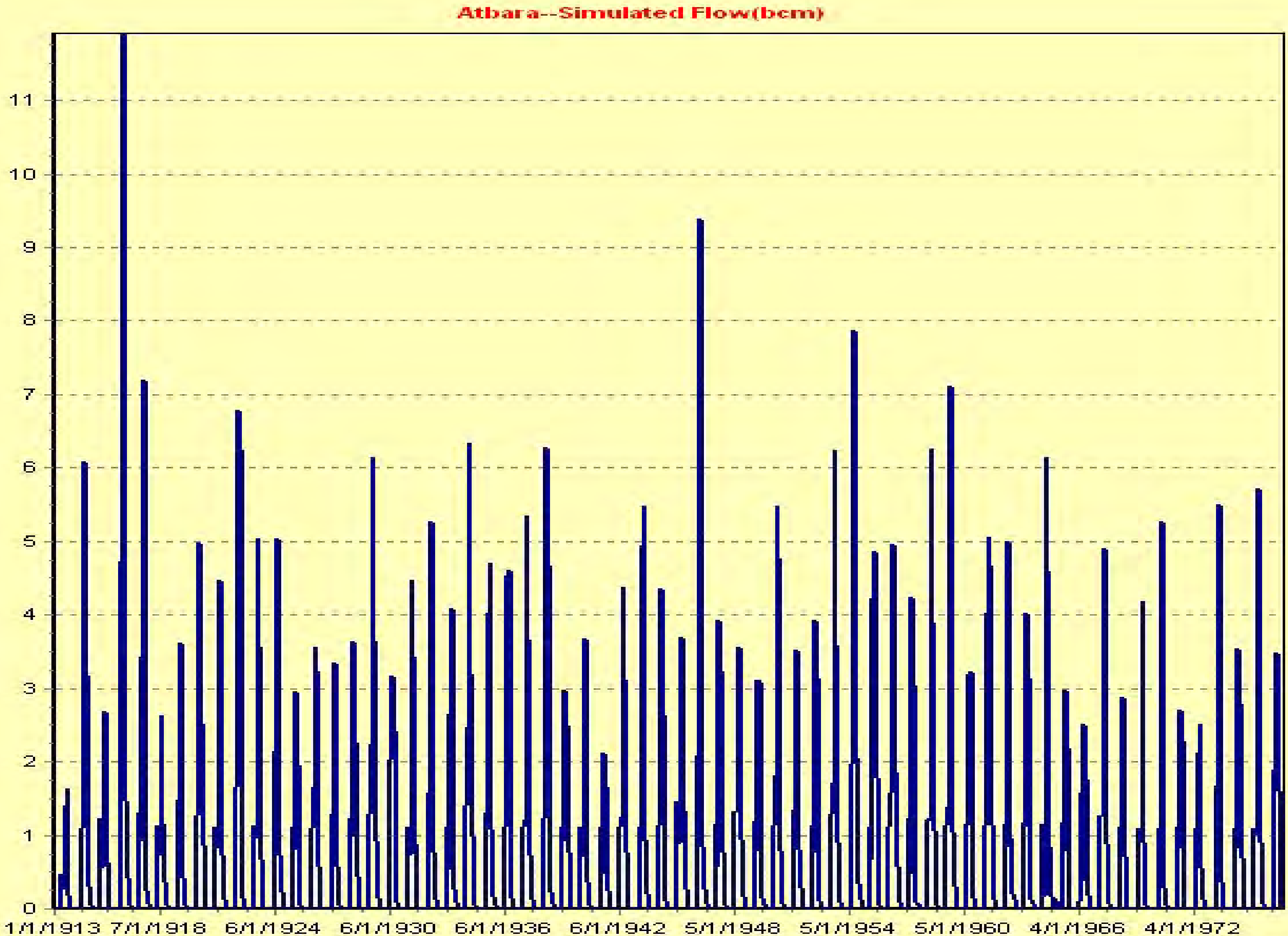


Diem Outflow
Outflow (BCM)
0
2
4
6
8
10
12
14
16
18
Jan
Feb
Mar
Apr
May
June
Jul
Aug
Sep
Oct
Nov
Dec
Month
Min 5 years Mon.Avg
Min 5 years Ann.Avg
Max 5 years Mon.Avg
Max 5 years Ann.Avg
Mean Mon.Avg
Mean Ann.Avg

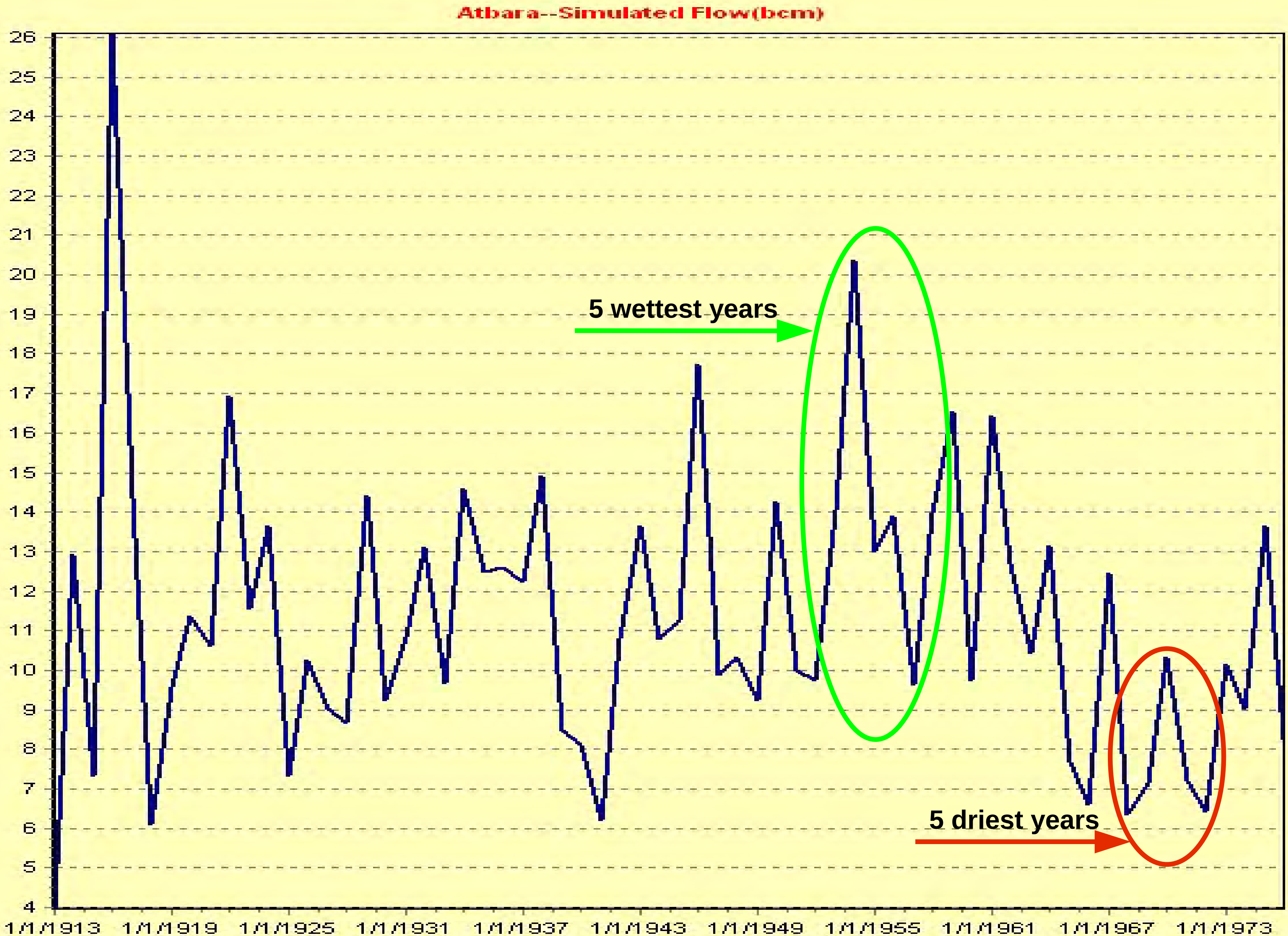

Khartoum--Simulated Flow(bcm)
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
1/1/1913
7/1/1918
6/1/1924
6/1/1930
6/1/1936
6/1/1942
5/1/1948
5/1/1954
5/1/1960
4/1/1966
4/1/1972


Khartoum--Simulated Flow(bcm)
54
52
50
48
46
44
42
40
38
36
34
32
30
28
26
24
22
20
18
16
14
12
10
5 wettest years
5 driest years
1/1/1913
1/1/1919
1/1/1925
1/1/1931
1/1/1937
1/1/1943
1/1/1949
1/1/1955
1/1/1961
1/1/1967
1/1/1973


Khartoum Outflow
14
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
June
Jul
Aug
Sep
Oct
Nov
Dec
Min 5 years Mon.Avg
Min 5 years Ann.Avg
Max 5 years Mon.Avg
Max 5 years Ann.Avg
Mean Mon.Avg
Mean Ann.Avg

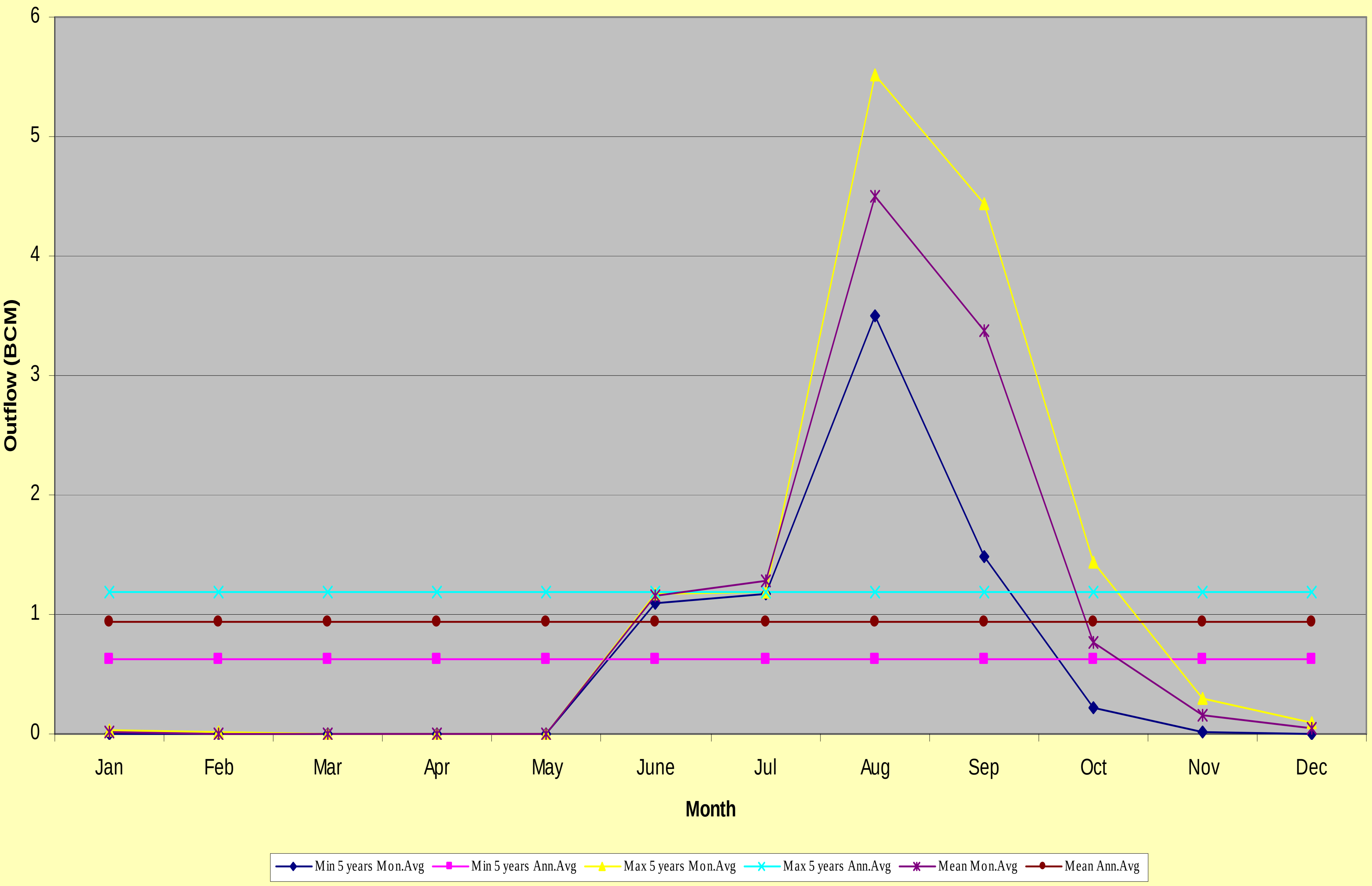


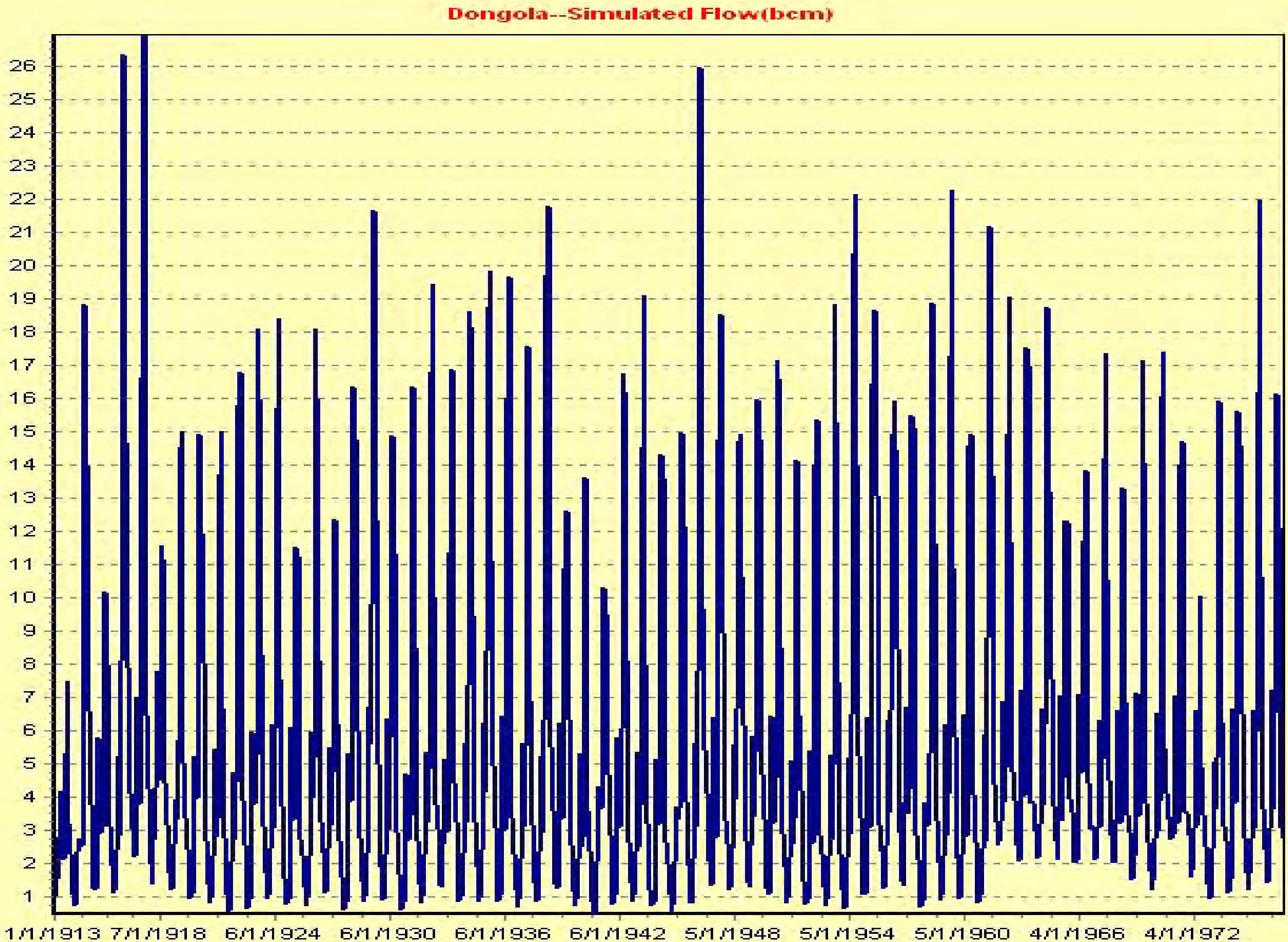
Atbara--Simulated Flow(bcm)
11
10
9
8
7
6
5
4
3
2
1
0
1/1/1913
7/1/1918
6/1/1924
6/1/1930
6/1/1936
6/1/1942
5/1/1948
5/1/1954
5/1/1960
4/1/1966
4/1/1972

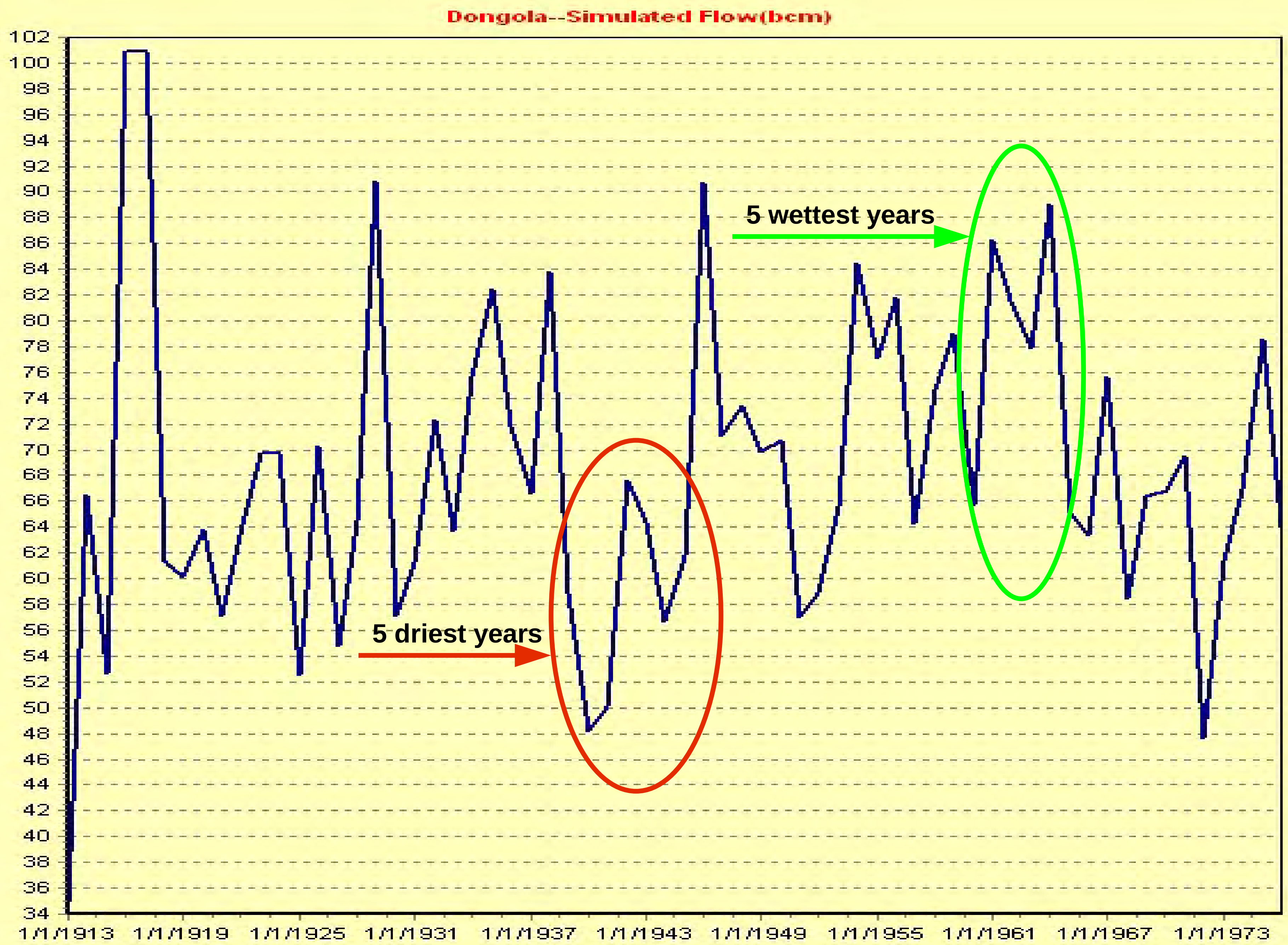


Atbara--Simulated Flow(bcm)
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
1/1/1913
1/1/1919
1/1/1925
1/1/1931
1/1/1937
1/1/1943
1/1/1949
1/1/1955
1/1/1961
1/1/1967
1/1/1973
5 wettest years
5 driest years

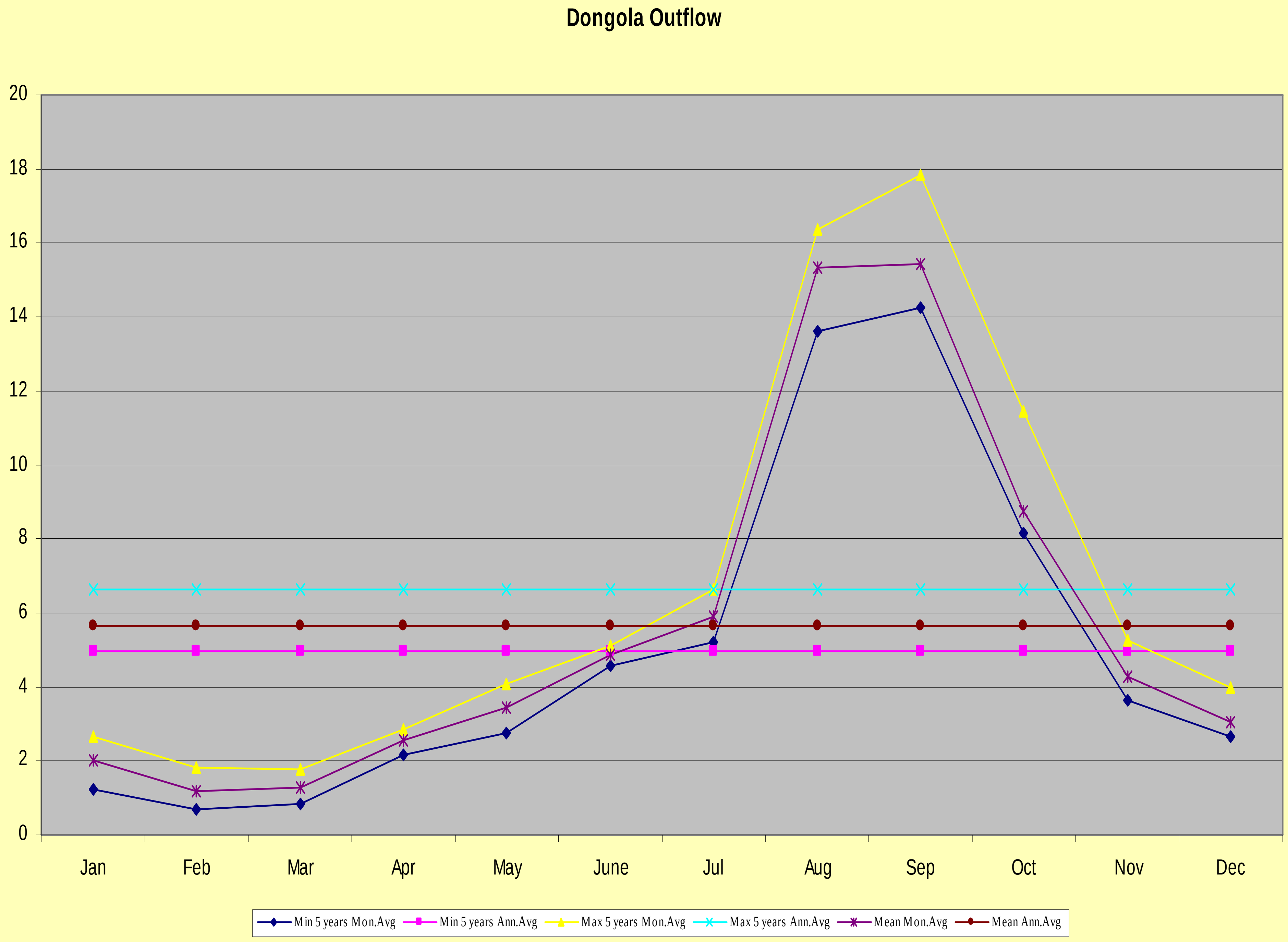
Atbara Outflows




Dongola--Simulated Flow(bcm)
26
25
24
23
22
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
1/1/1913
7/1/1918
6/1/1924
6/1/1930
6/1/1936
6/1/1942
5/1/1948
5/1/1954
5/1/1960
4/1/1966
4/1/1972



Dongola--Simulated Flow(bcm)
5 wettest years
5 driest years
102
100
98
96
94
92
90
88
86
84
82
80
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
34
1/1/1913
1/1/1919
1/1/1925
1/1/1931
1/1/1937
1/1/1943
1/1/1949
1/1/1955
1/1/1961
1/1/1967
1/1/1973

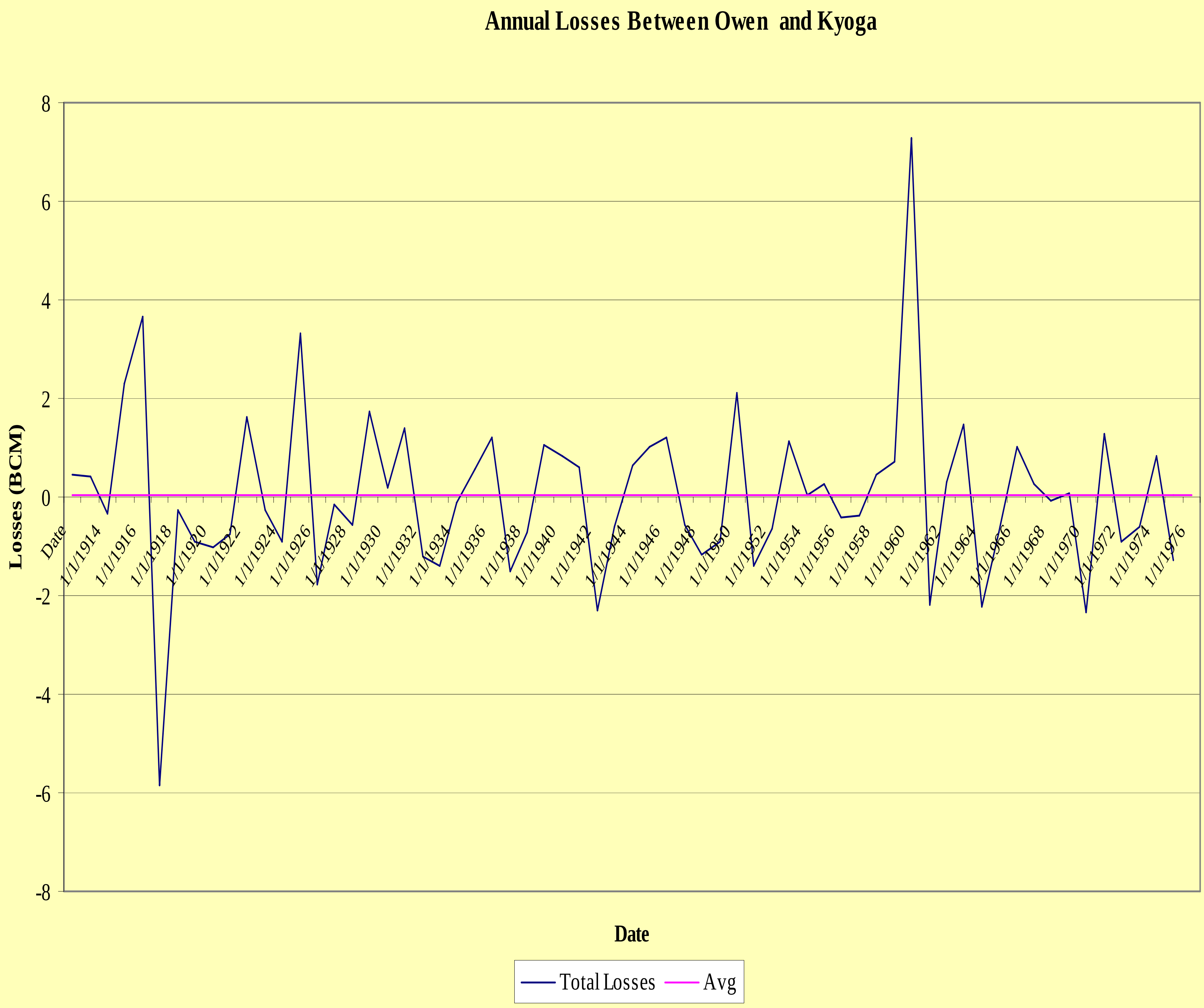


Dongola Outflow
20
18
16
14
12
10
8
6
4
2
0
Jan
Feb
Mar
Apr
May
June
Jul
Aug
Sep
Oct
Nov
Dec
Min 5 years Mon.Avg
Min 5 years Ann.Avg
Max 5 years Mon.Avg
Max 5 years Ann.Avg
Mean Mon.Avg
Mean Ann.Avg

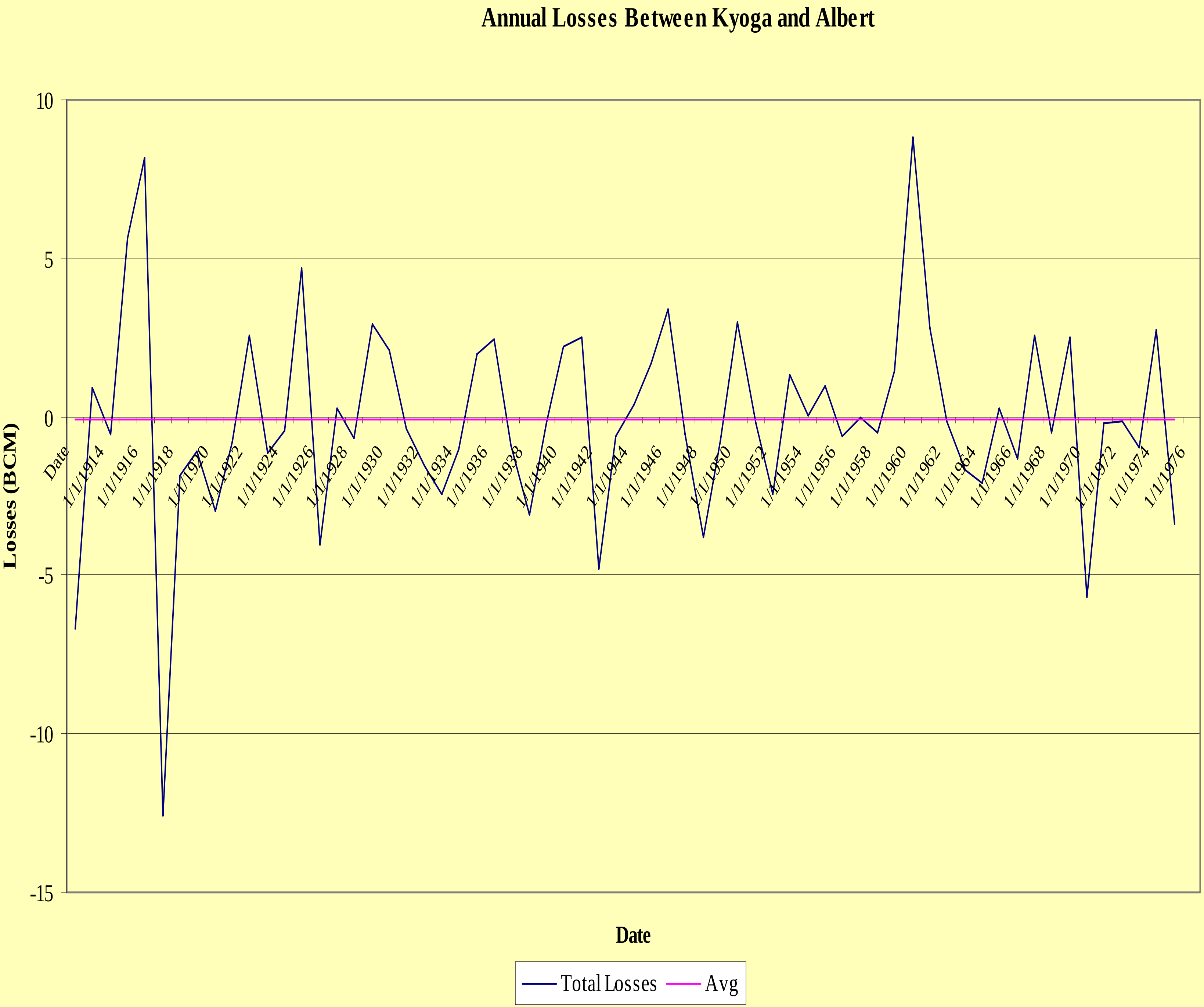
- **Percent Difference of Dry and wet periods from normal:**

	the Wettest 5 years	Wet Diff. Ratio (%)	the Driest 5 years	Dry Diff. Ratio (%)
Mongala	1964-1968	67	1921-1925	38
Sudd exit	1962-1966	28	1922-1926	15
Malakal	1962-1966	29	1940-1944	13
Gebel Aulia	1962-1966	33	1921-1925	12
Diem	1958-1962	13	1918-1922	12
Khartom	1960-1964	17	1918-1922	17
Atbara	1954-1958	25	1968-1972	34
Dongola	1960-1964	12	1941-1945	12

Water Use and Losses

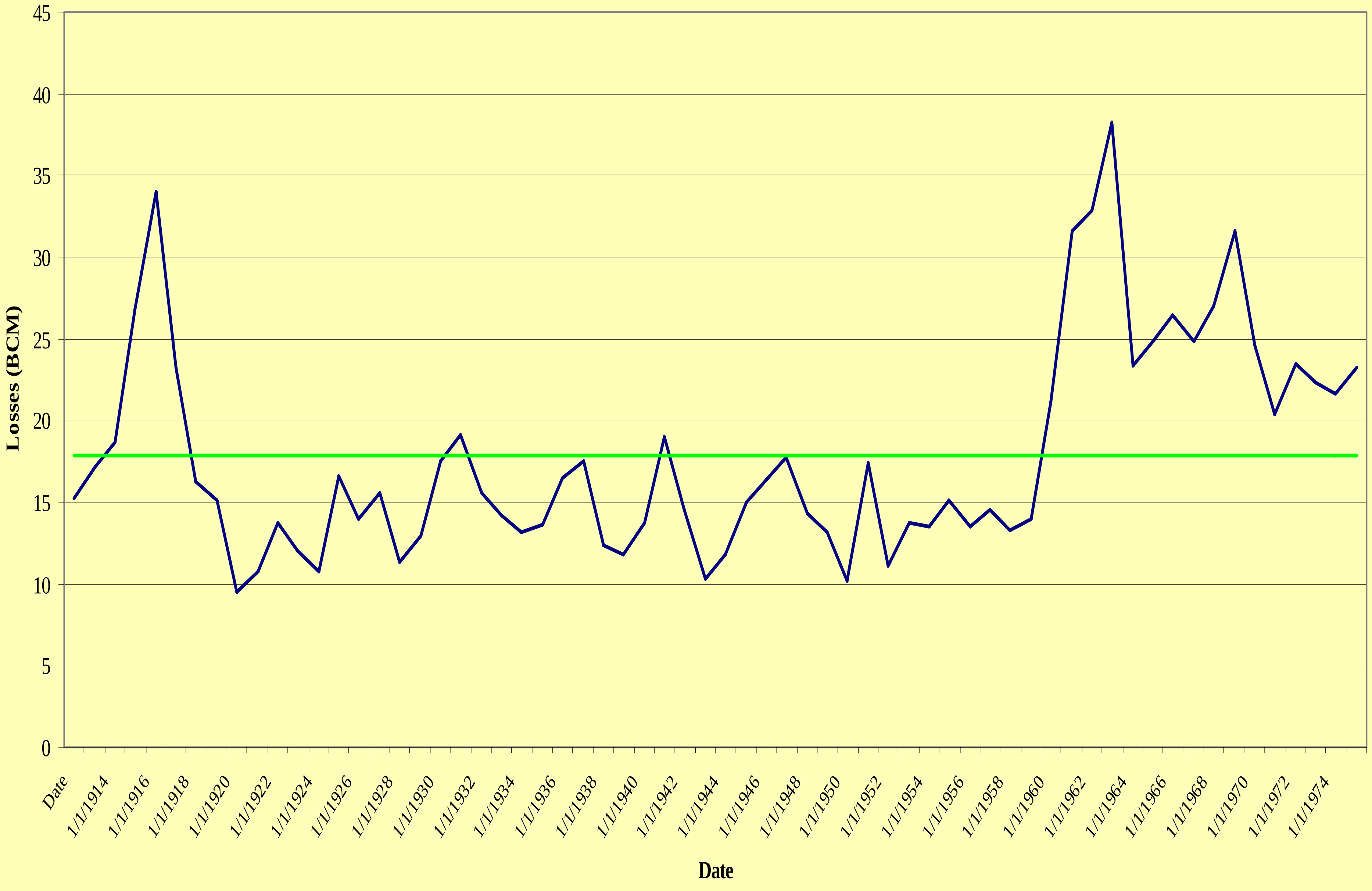


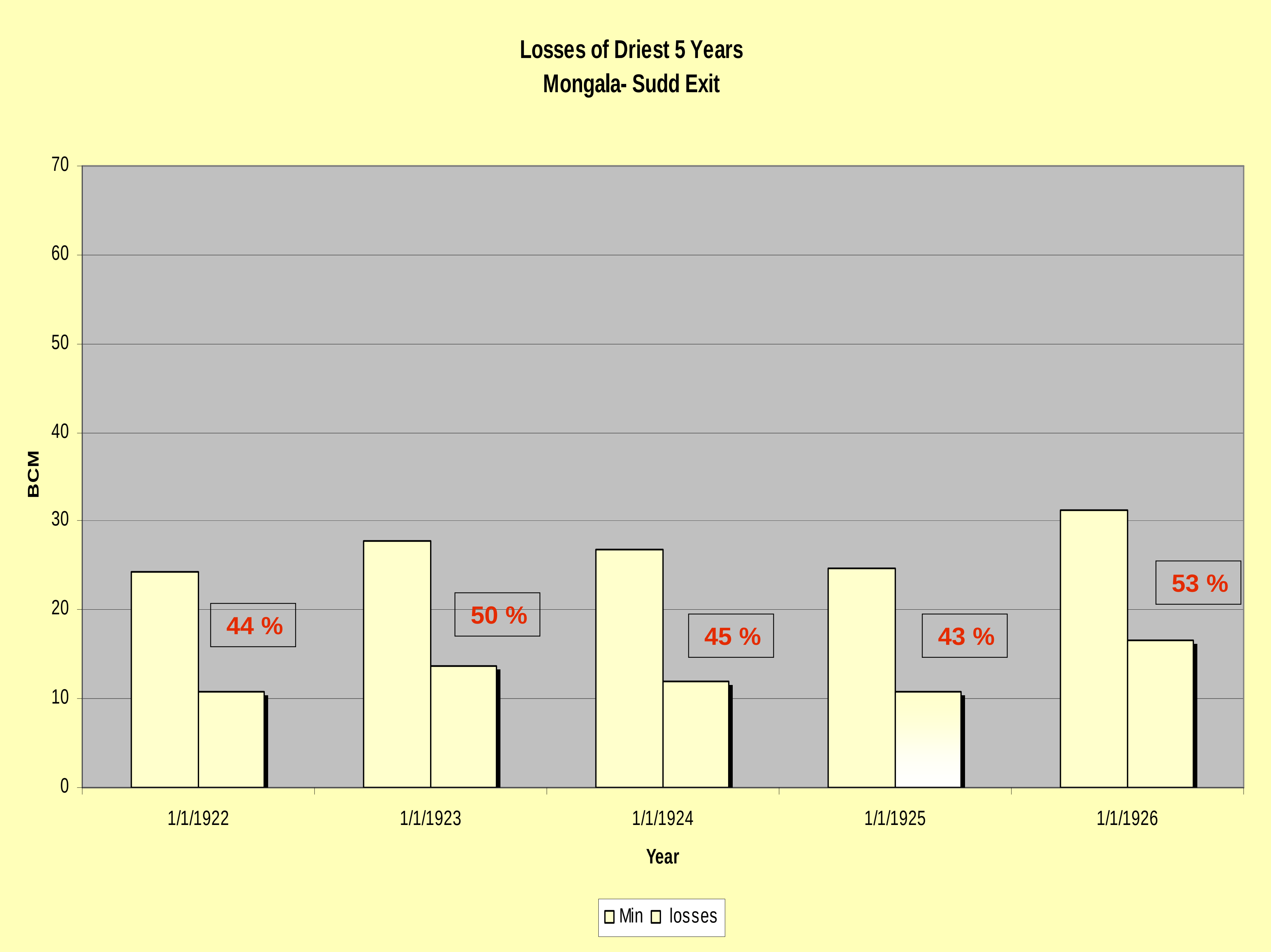
Annual Losses Between Owen and Kyoga
8
6
4
2
0
-2
-4
-6
-8
Losses (BCM)
Date
1/1/1914
1/1/1916
1/1/1918
1/1/1920
1/1/1922
1/1/1924
1/1/1926
1/1/1928
1/1/1930
1/1/1932
1/1/1934
1/1/1936
1/1/1938
1/1/1940
1/1/1942
1/1/1944
1/1/1946
1/1/1948
1/1/1950
1/1/1952
1/1/1954
1/1/1956
1/1/1958
1/1/1960
1/1/1962
1/1/1964
1/1/1966
1/1/1968
1/1/1970
1/1/1972
1/1/1974
1/1/1976
Date
Total Losses
Avg



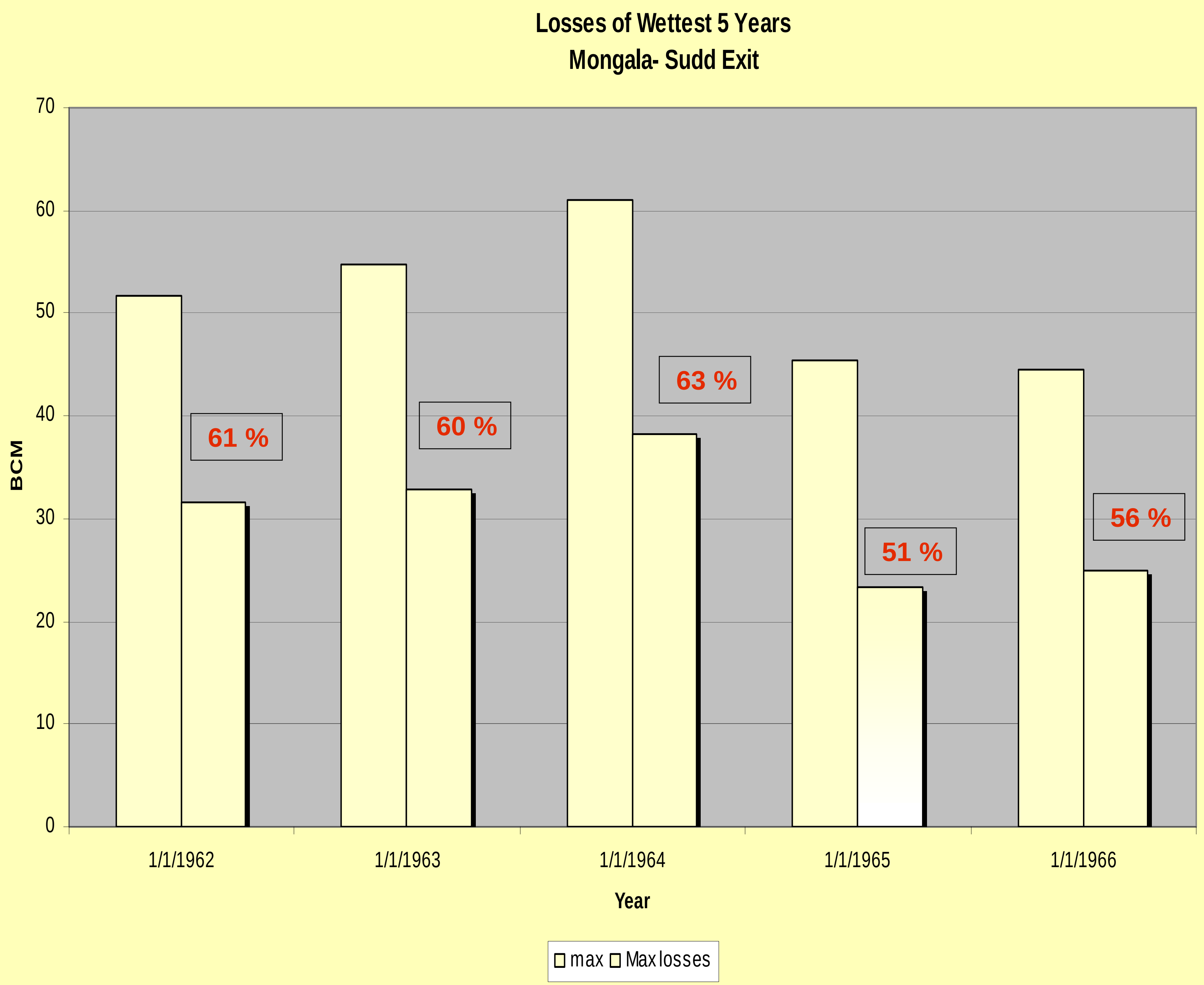
Annual Losses Between Kyoga and Albert
Losses (BCM)
10
5
0
-5
-10
-15
Date
1/1/1914
1/1/1916
1/1/1918
1/1/1920
1/1/1922
1/1/1924
1/1/1926
1/1/1928
1/1/1930
1/1/1932
1/1/1934
1/1/1936
1/1/1938
1/1/1940
1/1/1942
1/1/1944
1/1/1946
1/1/1948
1/1/1950
1/1/1952
1/1/1954
1/1/1956
1/1/1958
1/1/1960
1/1/1962
1/1/1964
1/1/1966
1/1/1968
1/1/1970
1/1/1972
1/1/1974
1/1/1976
Date
Total Losses
Avg

Annual Losses Between Mongala and Sudd Exit

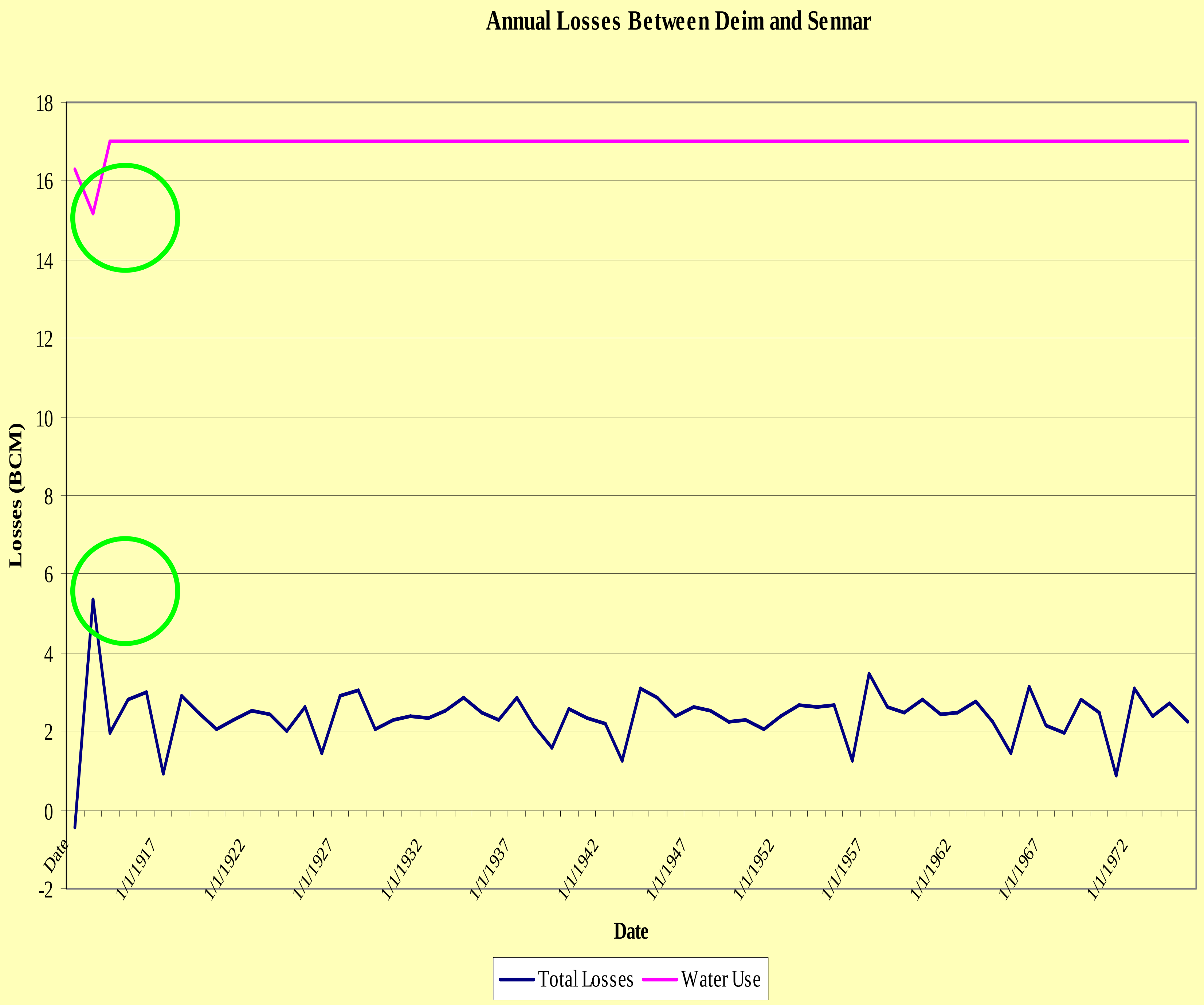




Losses of Driest 5 Years
Mongala- Sudd Exit
70
60
50
40
30
20
10
0
BCM
44 %
50 %
45 %
43 %
53 %
1/1/1922
1/1/1923
1/1/1924
1/1/1925
1/1/1926
Year
Min
losses



Losses of Wettest 5 Years
Mongala- Sudd Exit
BCM
70
60
50
40
30
20
10
0
61 %
60 %
63 %
51 %
56 %
1/1/1962
1/1/1963
1/1/1964
1/1/1965
1/1/1966
Year
max
Max losses


Annual Losses Between Deim and Sennar
Losses (BCM)
18
16
14
12
10
8
6
4
2
0
-2
Date
1/1/1917
1/1/1922
1/1/1927
1/1/1932
1/1/1937
1/1/1942
1/1/1947
1/1/1952
1/1/1957
1/1/1962
1/1/1967
1/1/1972
Date
Total Losses
Water Use

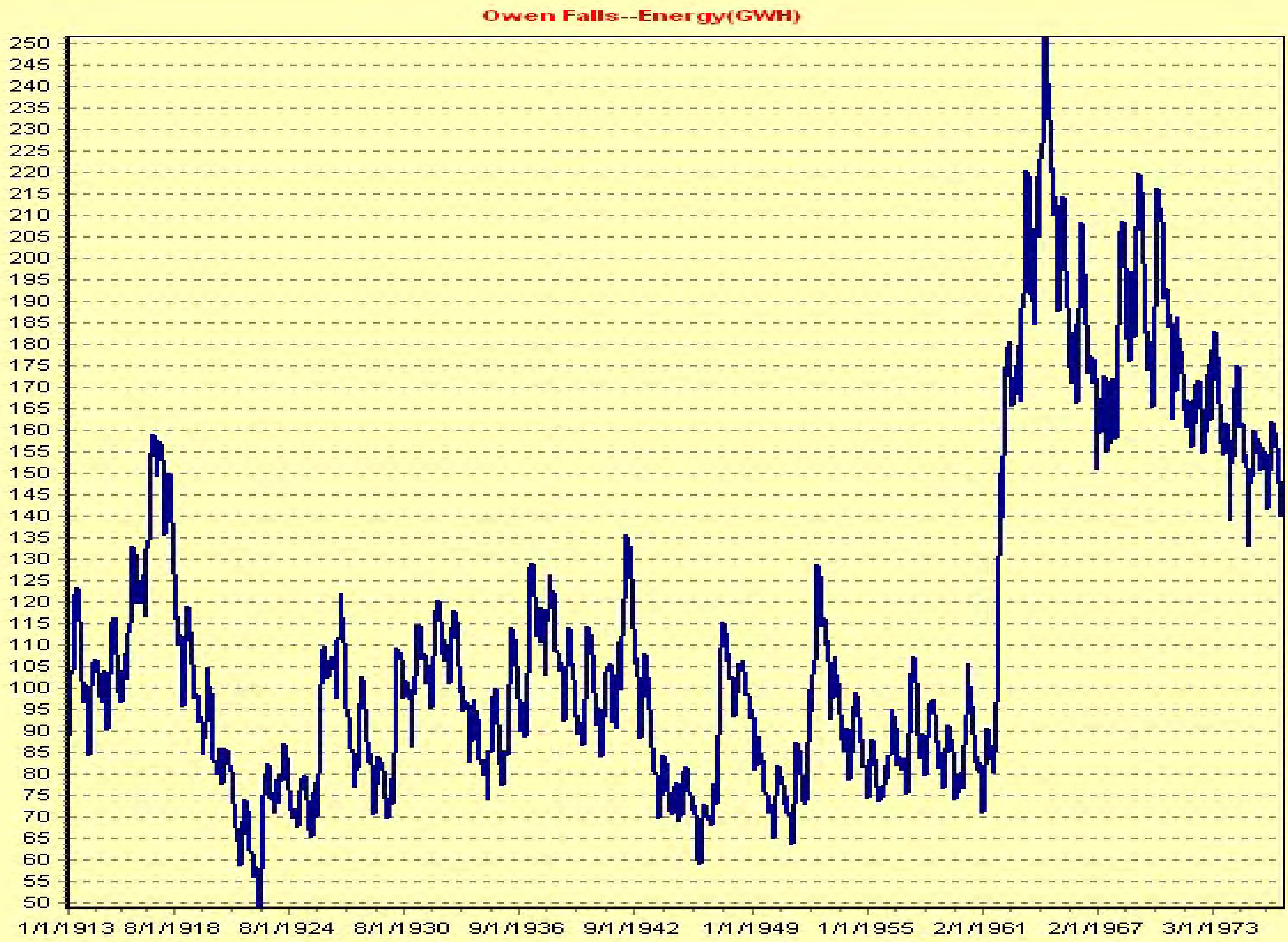
The losses through the different reaches

- There is a huge amount of water lost in the reach from Mongala station to the Sudd region Exit (more than 50 %).

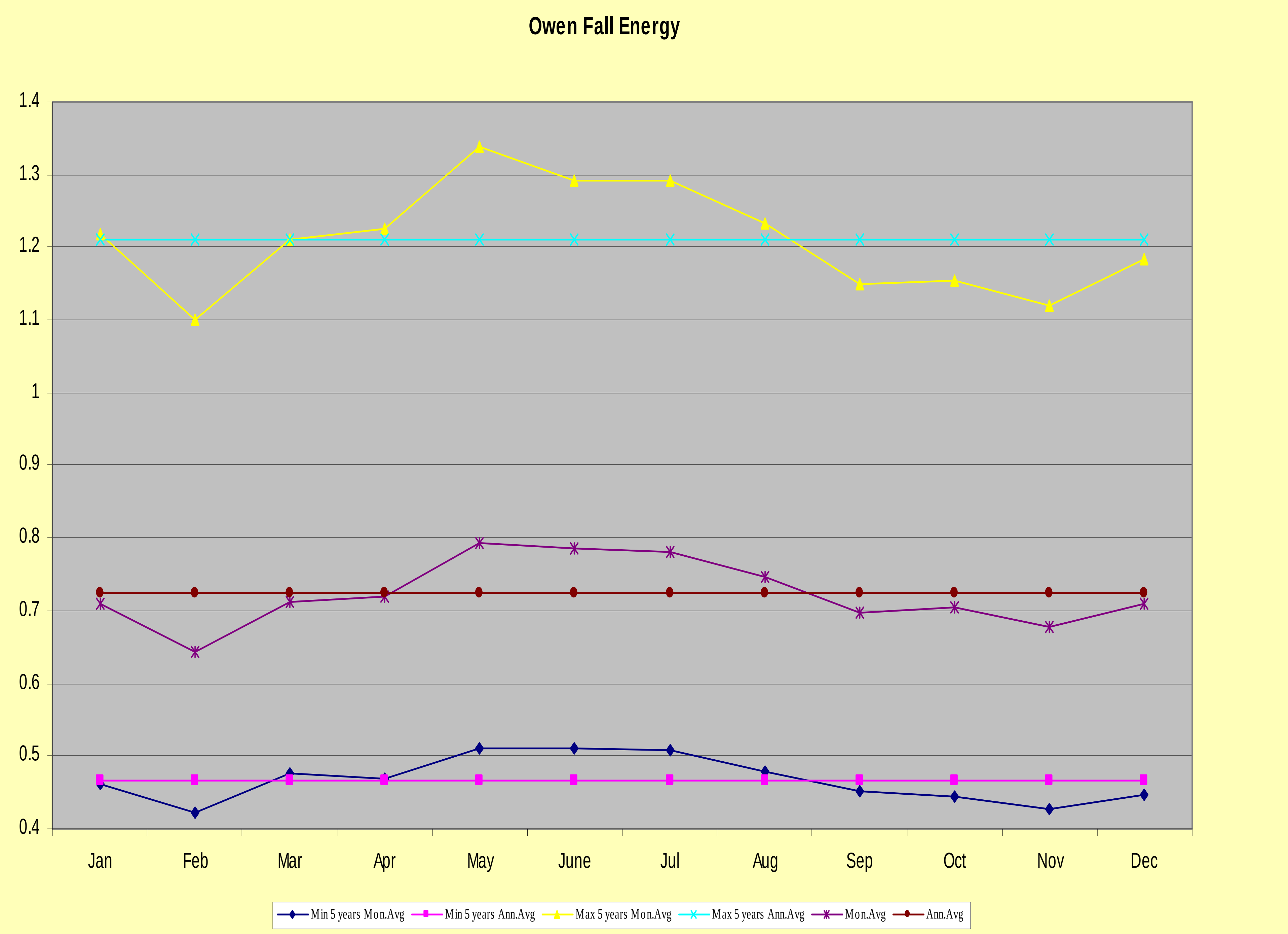
- There are no data about the Blue Nile up to Sudanese border which not enabling to find the Water Use and Losses.

- The Reach from Diem to Khartoum has experienced thought of miscalculation, the data should be revised (done).

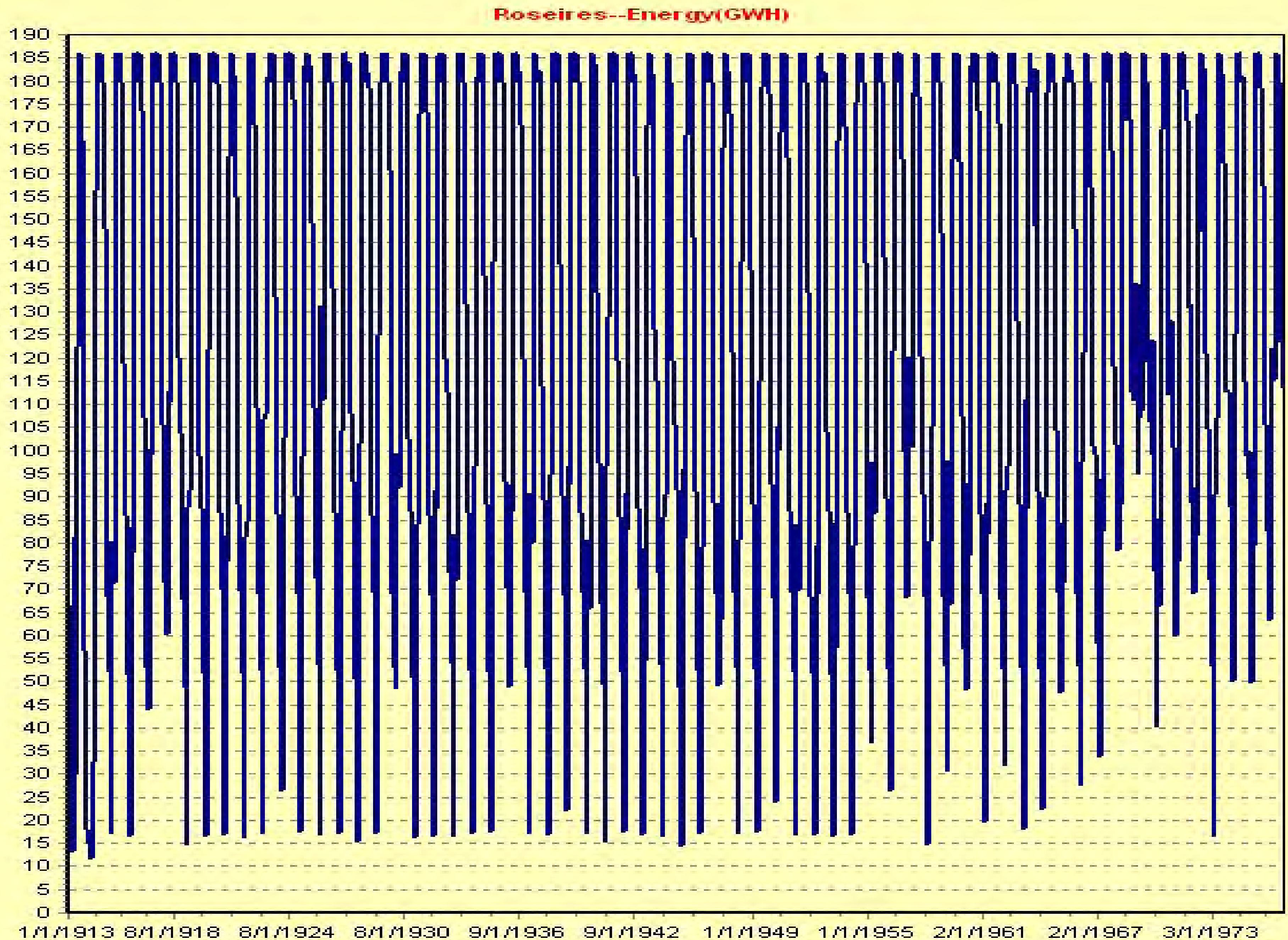
- It is difficult to determine the losses and water use separately from the different reaches due to lack of data.


Owen Falls--Energy(GWH)
250
245
240
235
230
225
220
215
210
205
200
195
190
185
180
175
170
165
160
155
150
145
140
135
130
125
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
1/1/1913
8/1/1918
8/1/1924
8/1/1930
9/1/1936
9/1/1942
1/1/1949
1/1/1955
2/1/1961
2/1/1967
3/1/1973

Owen Falls--Energy(GWH)
2,700
2,650
2,600
2,550
2,500
2,450
2,400
2,350
2,300
2,250
2,200
2,150
2,100
2,050
2,000
1,950
1,900
1,850
1,800
1,750
1,700
1,650
1,600
1,550
1,500
1,450
1,400
1,350
1,300
1,250
1,200
1,150
1,100
1,050
1,000
950
900
850
800
1/1/1913
1/1/1919
1/1/1926
1/1/1932
1/1/1939
1/1/1946
1/1/1952
1/1/1959
1/1/1966
1/1/1972



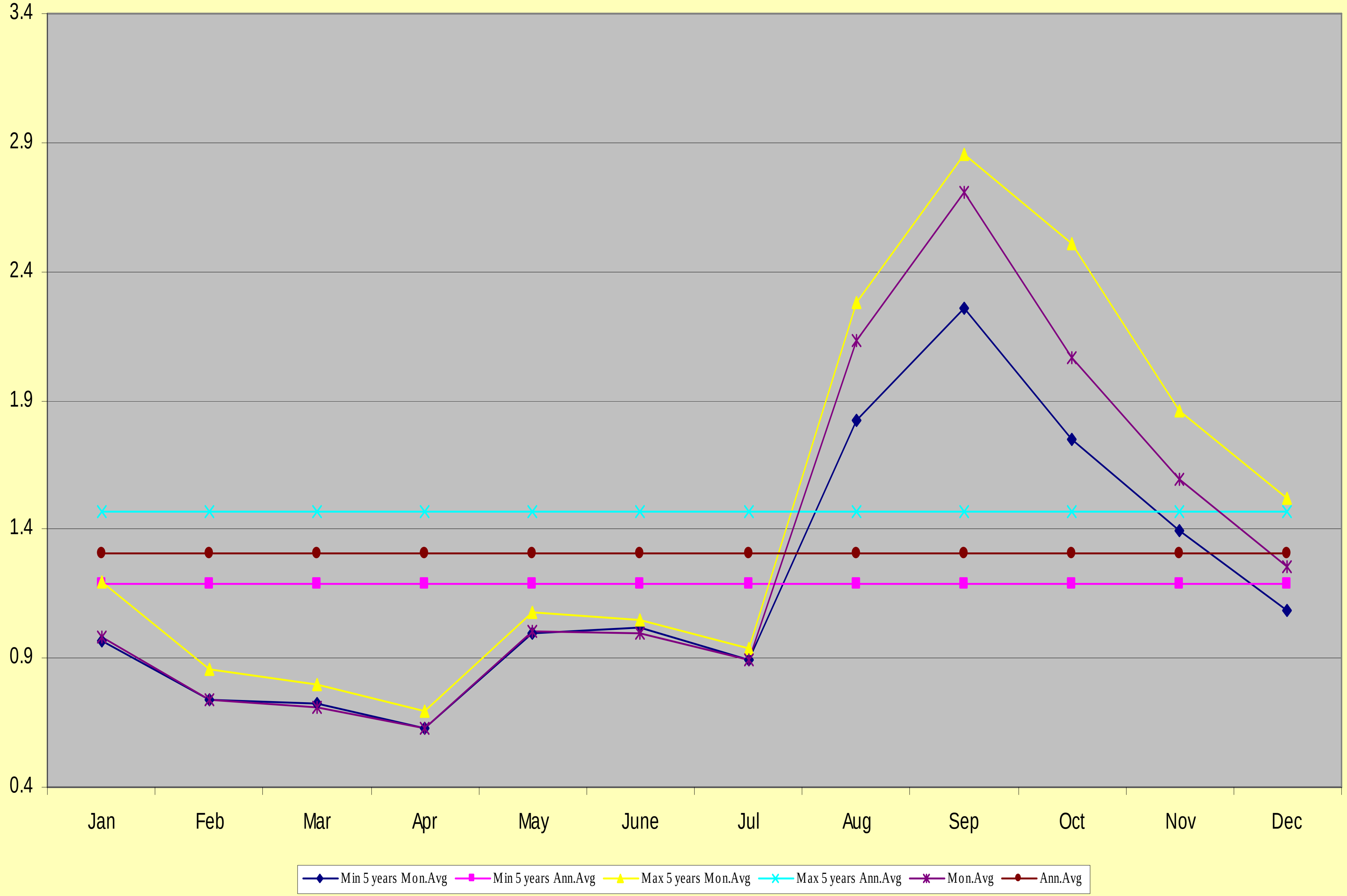
Owen Fall Energy
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.4
Jan
Feb
Mar
Apr
May
June
Jul
Aug
Sep
Oct
Nov
Dec
Min 5 years Mon.Avg
Min 5 years Ann.Avg
Max 5 years Mon.Avg
Max 5 years Ann.Avg
Mon.Avg
Ann.Avg

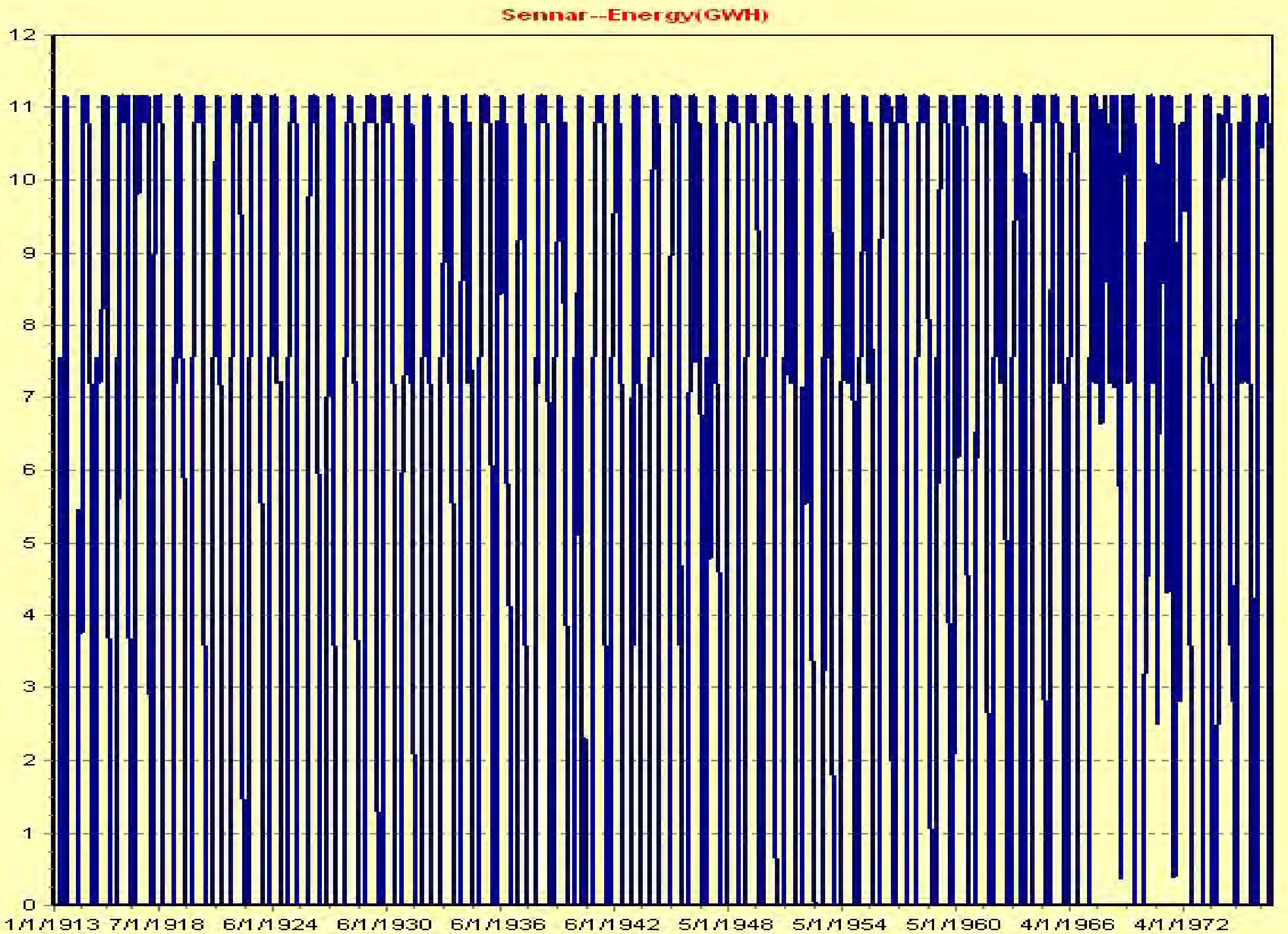


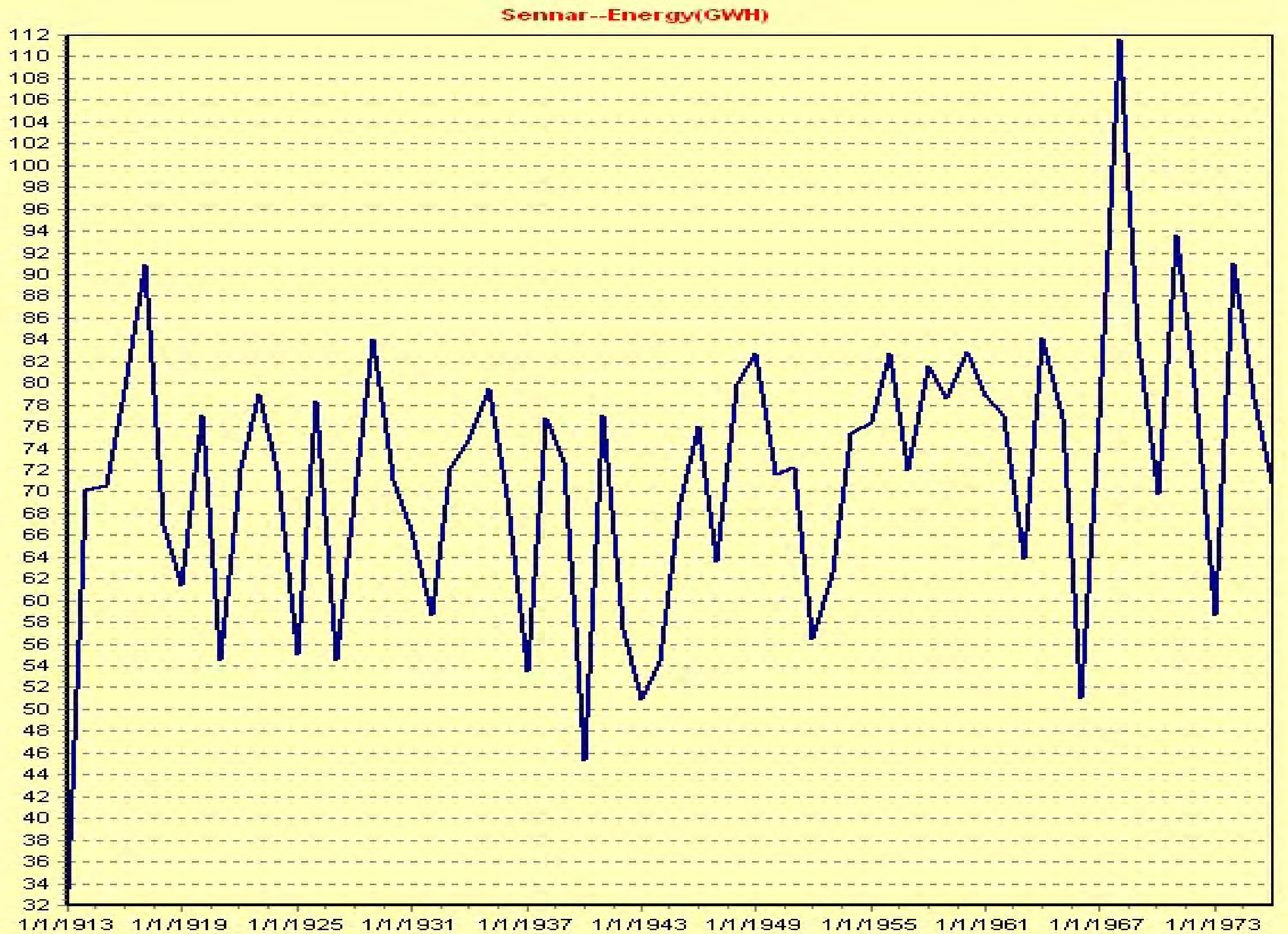
Roseires--Energy(GWH)
190
185
180
175
170
165
160
155
150
145
140
135
130
125
120
115
110
105
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
1/1/1913
8/1/1918
8/1/1924
8/1/1930
9/1/1936
9/1/1942
1/1/1949
1/1/1955
2/1/1961
2/1/1967
3/1/1973


Roseires--Energy(GWH)
1,640
1,620
1,600
1,580
1,560
1,540
1,520
1,500
1,480
1,460
1,440
1,420
1,400
1,380
1,360
1,340
1,320
1,300
1,280
1,260
1,240
1,220
1,200
1,180
1,160
1,140
1,120
1,100
1,080
1,060
1,040
1,020
1,000
1/1/1913
1/1/1919
1/1/1926
1/1/1932
1/1/1939
1/1/1946
1/1/1952
1/1/1959
1/1/1966
1/1/1972

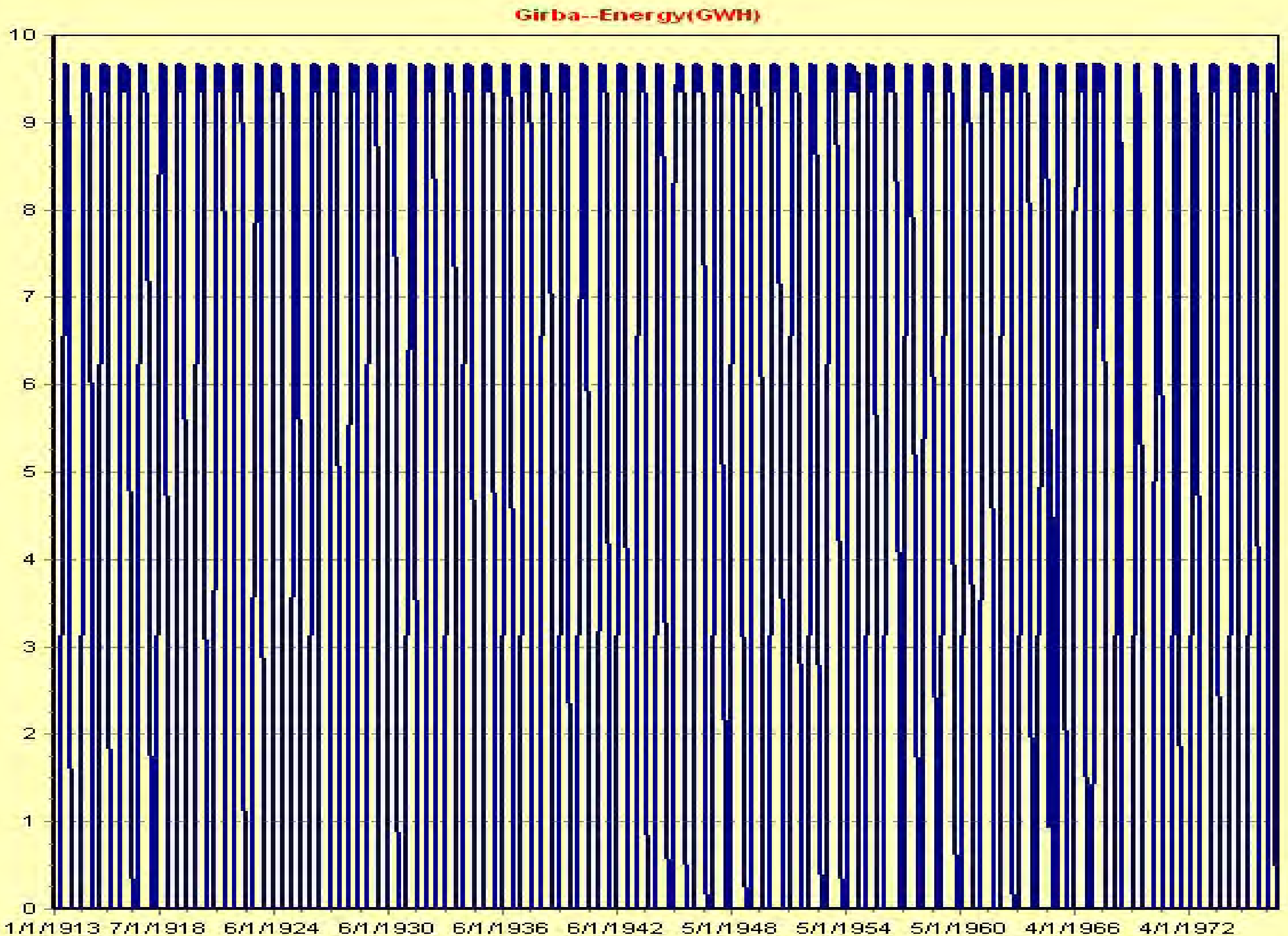
Roseires Energy



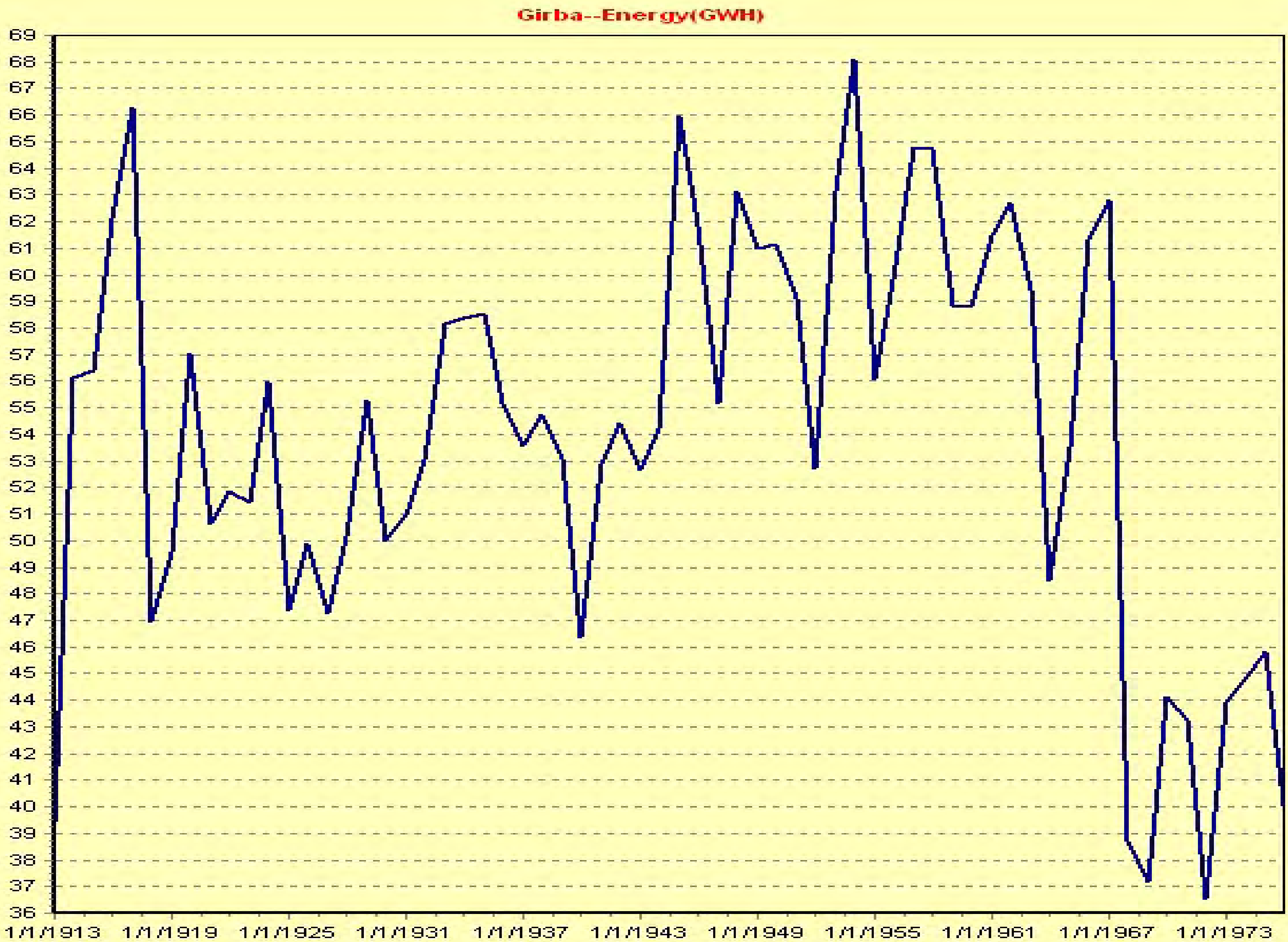

Sennar--Energy(GWH)
12
11
10
9
8
7
6
5
4
3
2
1
0
1/1/1913
7/1/1918
6/1/1924
6/1/1930
6/1/1936
6/1/1942
5/1/1948
5/1/1954
5/1/1960
4/1/1966
4/1/1972

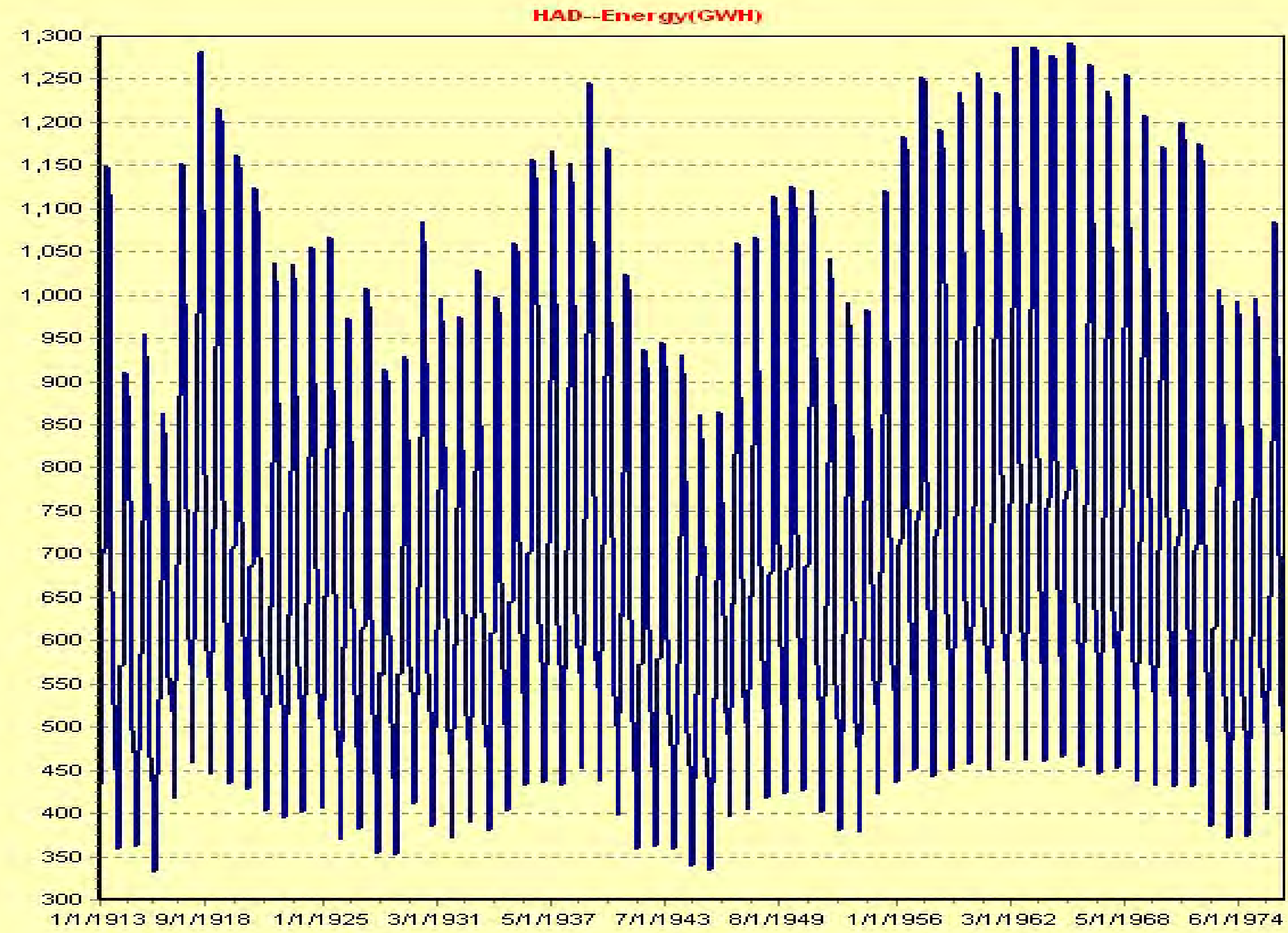


Sennar--Energy(GWH)
112
110
108
106
104
102
100
98
96
94
92
90
88
86
84
82
80
78
76
74
72
70
68
66
64
62
60
58
56
54
52
50
48
46
44
42
40
38
36
34
32
1/1/1913
1/1/1919
1/1/1925
1/1/1931
1/1/1937
1/1/1943
1/1/1949
1/1/1955
1/1/1961
1/1/1967
1/1/1973

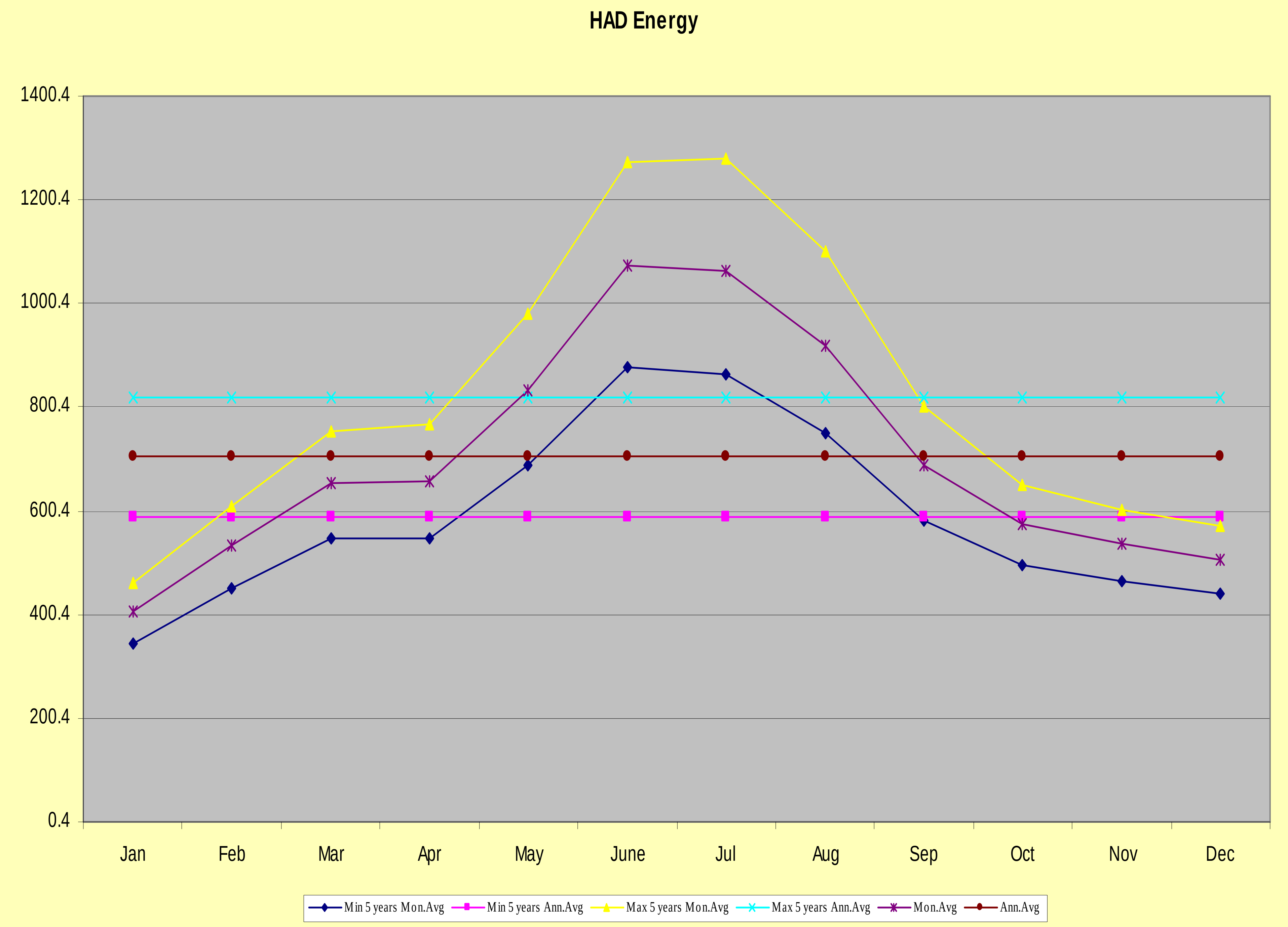


Girba--Energy(GWH)
10
9
8
7
6
5
4
3
2
1
0
1/1/1913
7/1/1918
6/1/1924
6/1/1930
6/1/1936
6/1/1942
5/1/1948
5/1/1954
5/1/1960
4/1/1966
4/1/1972


Girba--Energy(GWH)
69
68
67
66
65
64
63
62
61
60
59
58
57
56
55
54
53
52
51
50
49
48
47
46
45
44
43
42
41
40
39
38
37
36
1/1/1913
1/1/1919
1/1/1925
1/1/1931
1/1/1937
1/1/1943
1/1/1949
1/1/1955
1/1/1961
1/1/1967
1/1/1973


HAD--Energy(GWH)
1,300
1,250
1,200
1,150
1,100
1,050
1,000
950
900
850
800
750
700
650
600
550
500
450
400
350
300
1/1/1913
9/1/1918
1/1/1925
3/1/1931
5/1/1937
7/1/1943
8/1/1949
1/1/1956
3/1/1962
5/1/1968
6/1/1974


HAD--Energy(GWH)
10,000
9,900
9,800
9,700
9,600
9,500
9,400
9,300
9,200
9,100
9,000
8,900
8,800
8,700
8,600
8,500
8,400
8,300
8,200
8,100
8,000
7,900
7,800
7,700
7,600
7,500
7,400
7,300
7,200
7,100
7,000
6,900
6,800
6,700
1/1/1913
1/1/1919
1/1/1926
1/1/1933
1/1/1940
1/1/1947
1/1/1954
1/1/1961
1/1/1968
1/1/1975


HAD Energy
1400.4
1200.4
1000.4
800.4
600.4
400.4
200.4
0.4
Jan
Feb
Mar
Apr
May
June
Jul
Aug
Sep
Oct
Nov
Dec
Min 5 years Mon.Avg
Min 5 years Ann.Avg
Max 5 years Mon.Avg
Max 5 years Ann.Avg
Mon.Avg
Ann.Avg

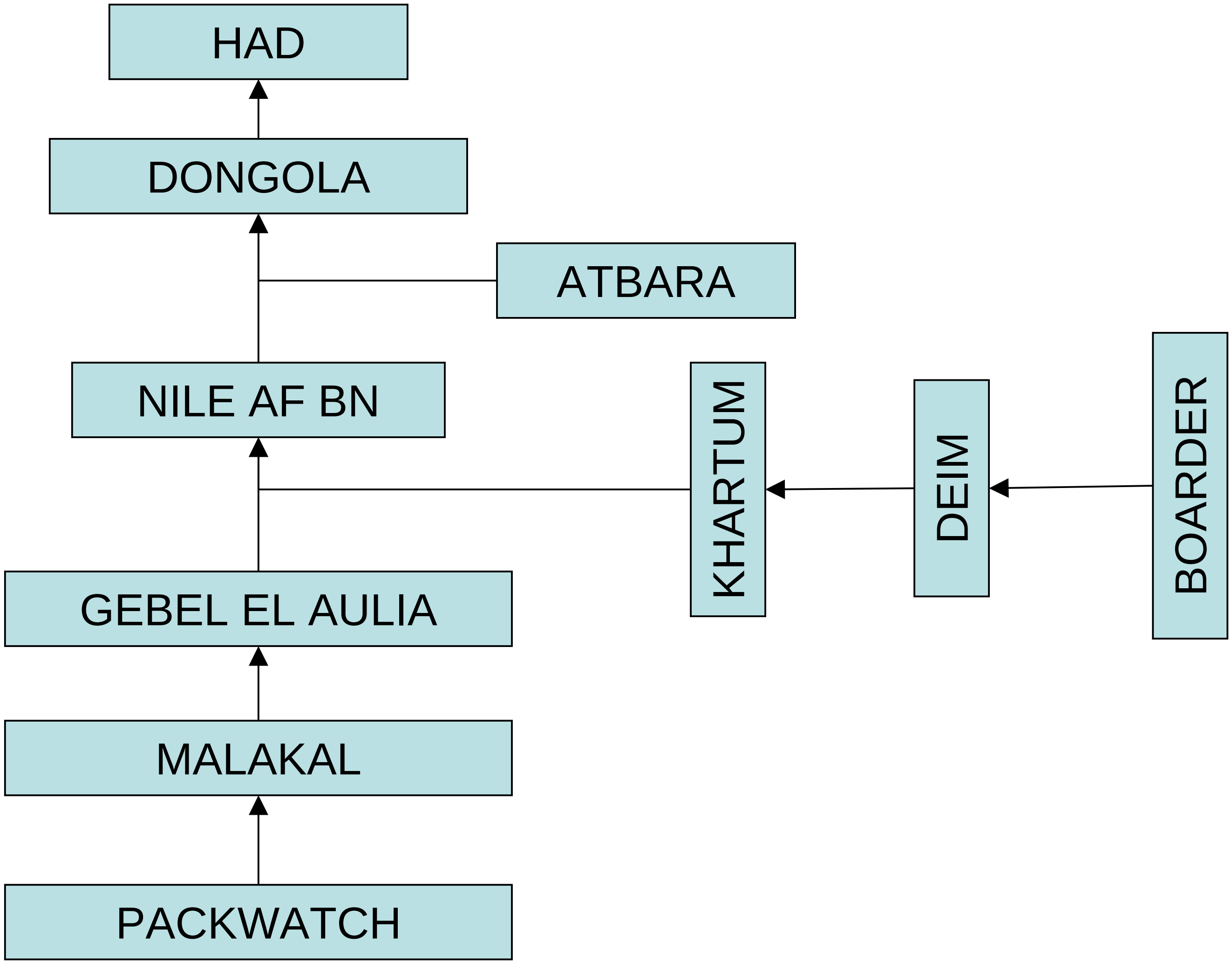
General comments

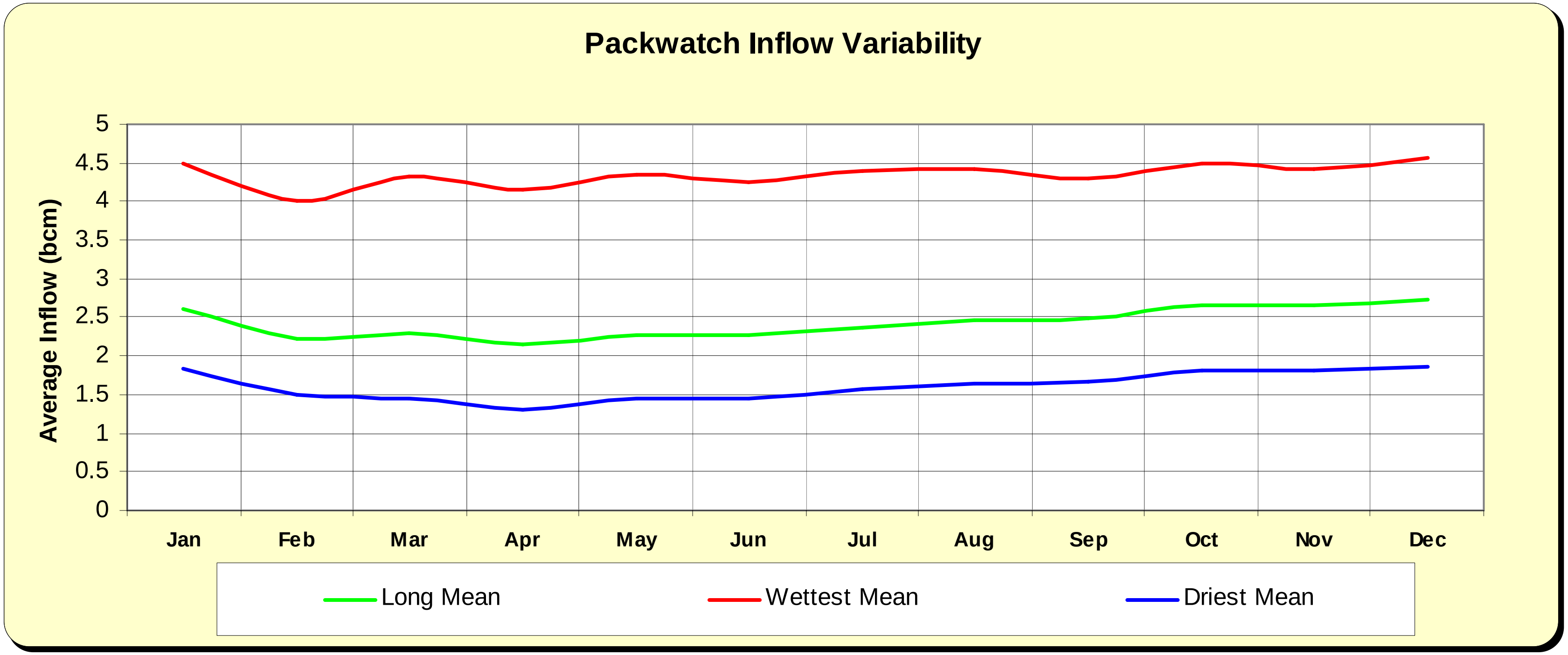
- The reach from Khartoum to Atbara river could be covered by adding two more River nodes, which should be at (Tamaniat and Hudiba). This is particularly useful after the addition of Merowe.
- The data of both the Sobat and the Blue Nile (Ethiopian side) is not available, and they should be added.
- It is advisable to complete the missed data regarding the proposed reservoirs (or at least to consider them in the future).
- For the stations which are thought to have the same behavior like (Khartoum, Atbara and Dongola) it was found that not all the outflows for these stations have the same wettest and driest years.
- It appears that both wet and dry climatic episodes affect the Ethiopian Plateau (Blue Nile) first, followed by the Equatorial Lakes (White Nile).

Presentation by Ethiopian Trainees

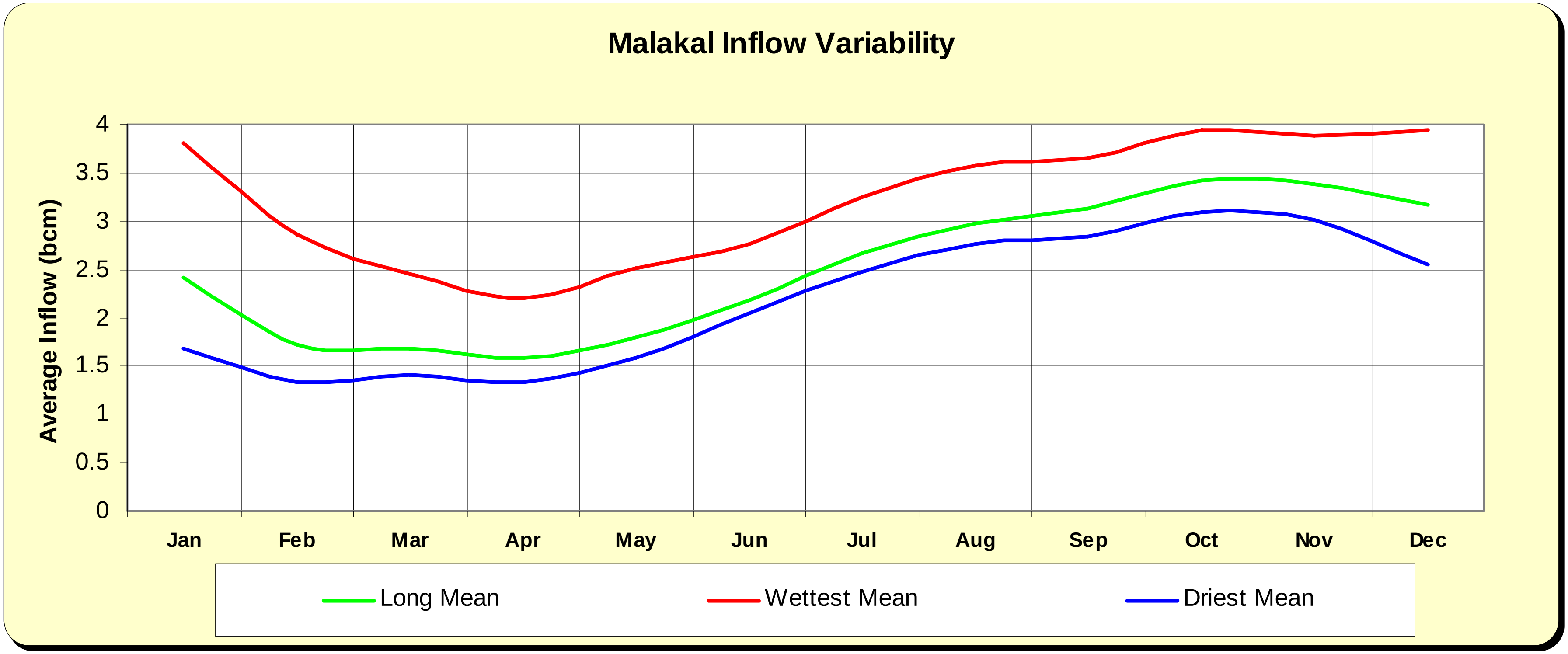
Water Balance

Nodes considered

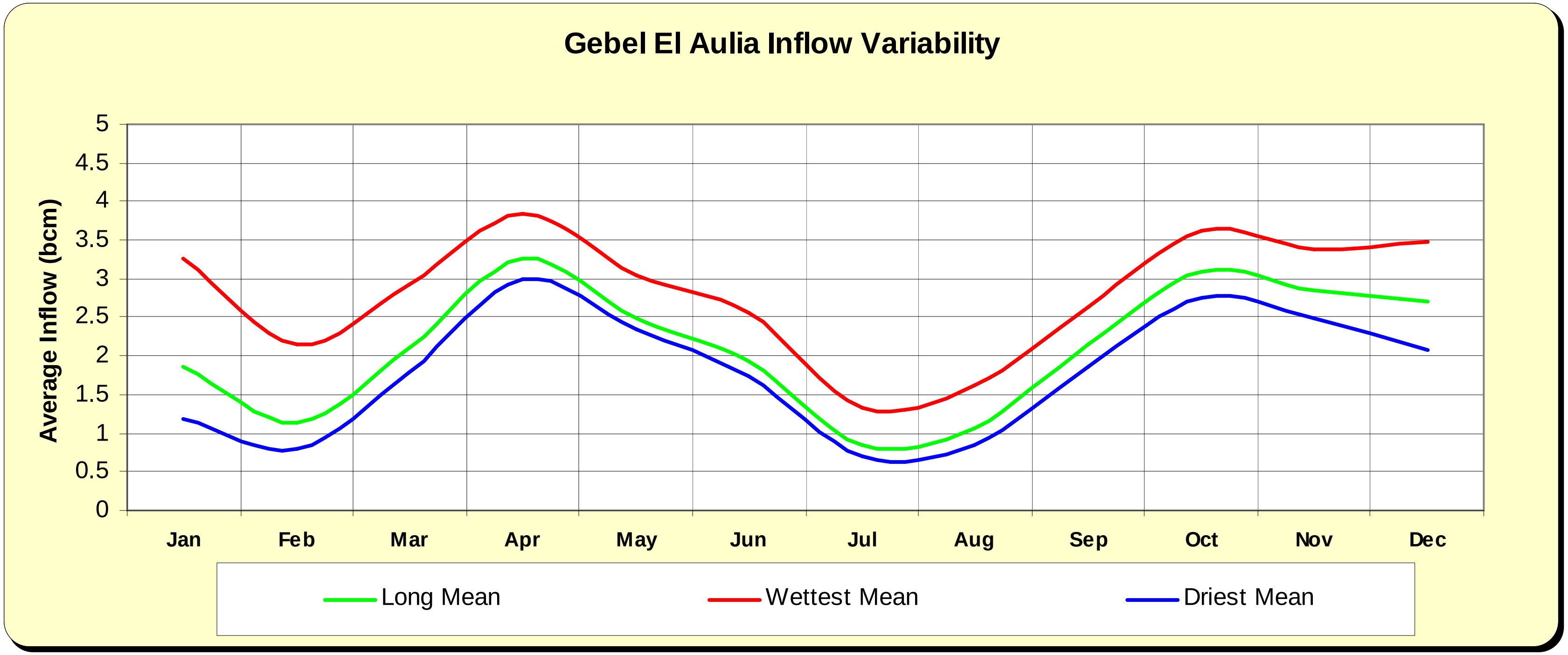




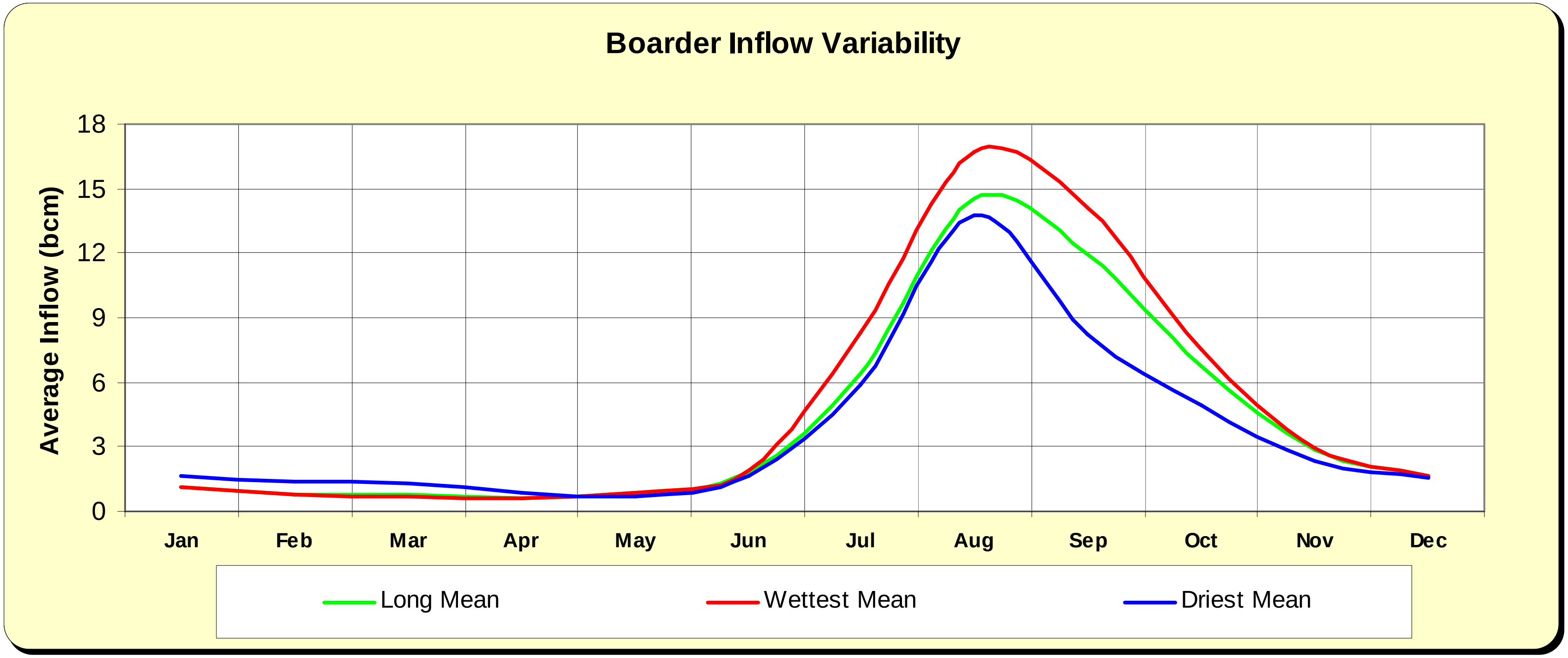
Packwatch Inflow Variability
Average Inflow (bcm)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Long Mean
Wettest Mean
Driest Mean



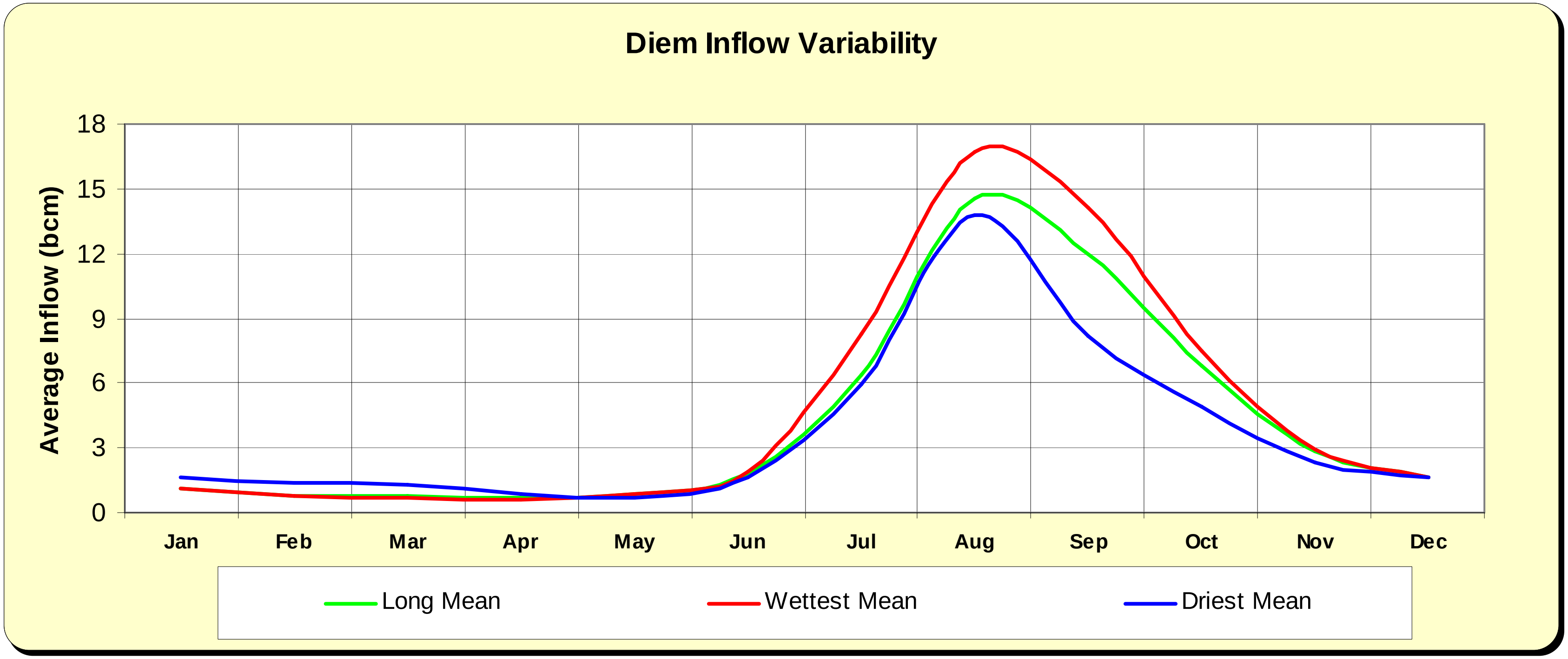
Malakal Inflow Variability
Average Inflow (bcm)
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Long Mean
Wettest Mean
Driest Mean



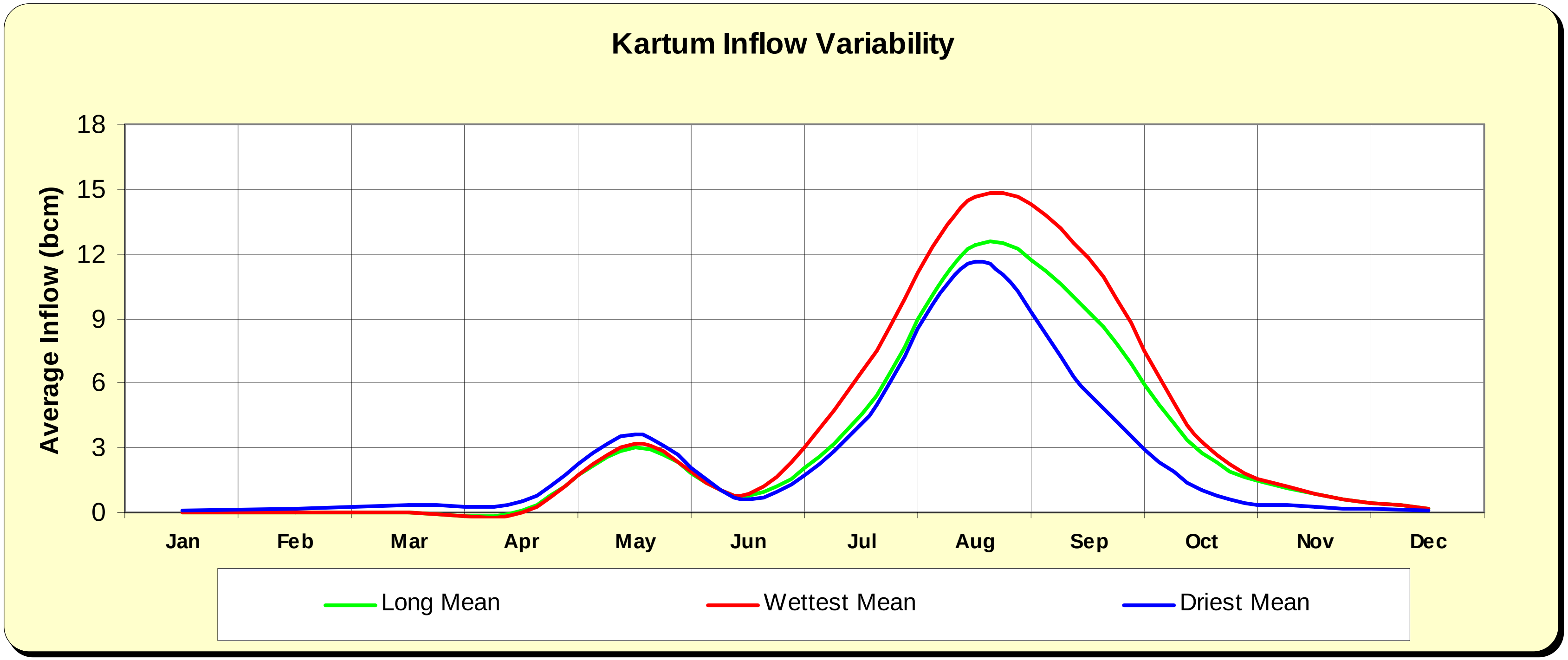
Gebel El Aulia Inflow Variability
Average Inflow (bcm)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Long Mean
Wettest Mean
Driest Mean

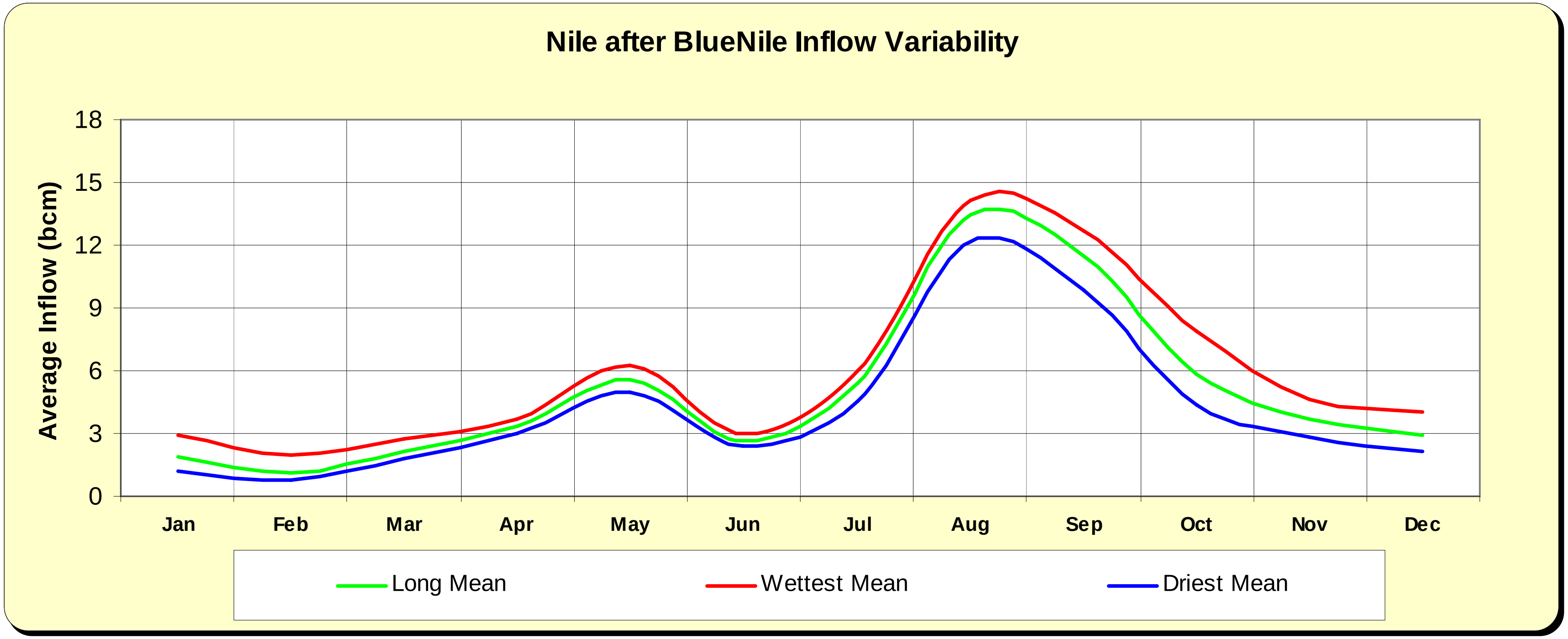


Boarder Inflow Variability
Average Inflow (bcm)
0
3
6
9
12
15
18
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Long Mean
Wettest Mean
Driest Mean

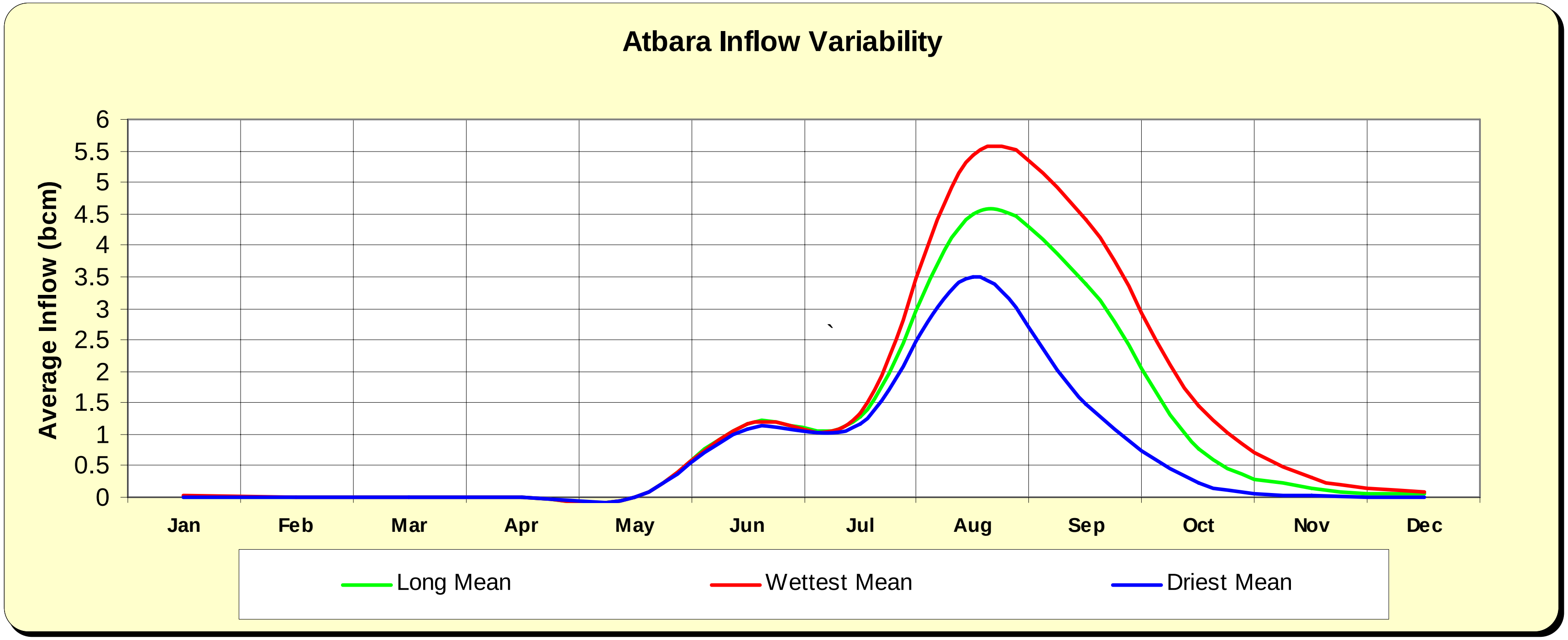


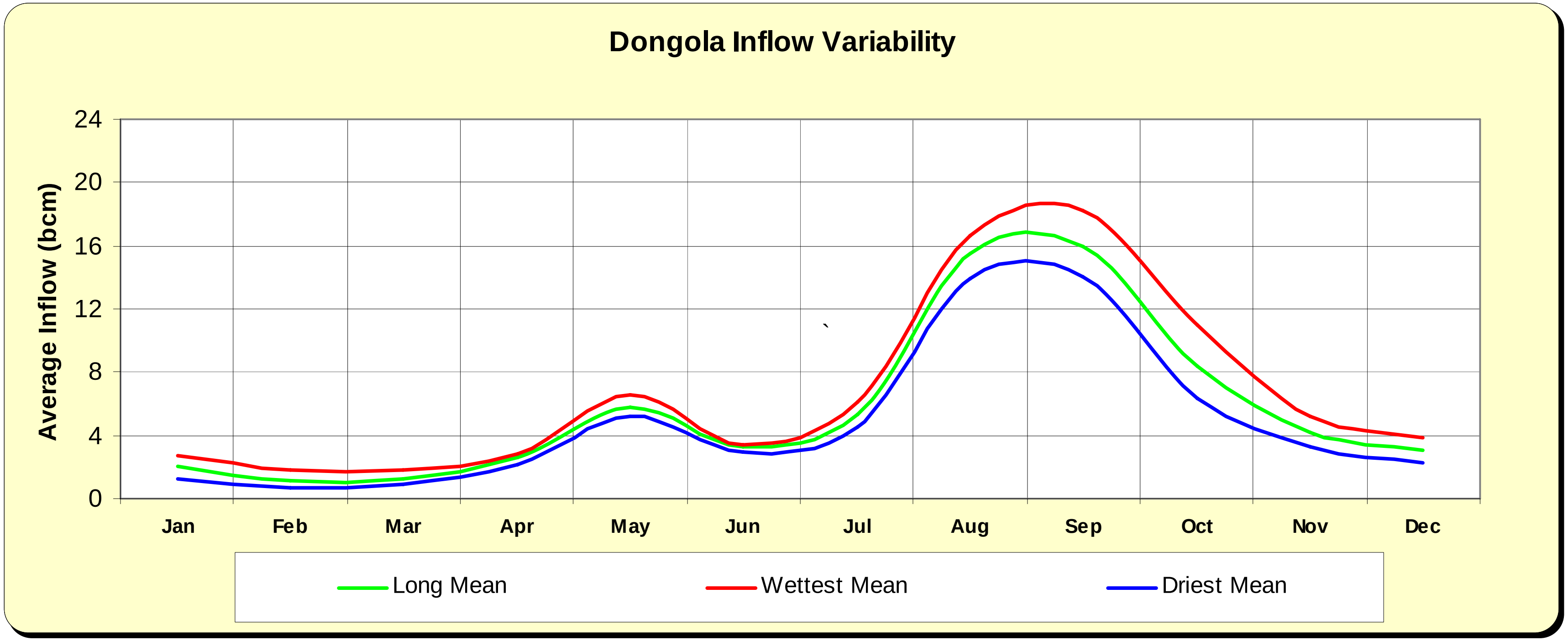
Diem Inflow Variability
Average Inflow (bcm)
18
15
12
9
6
3
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Long Mean
Wettest Mean
Driest Mean

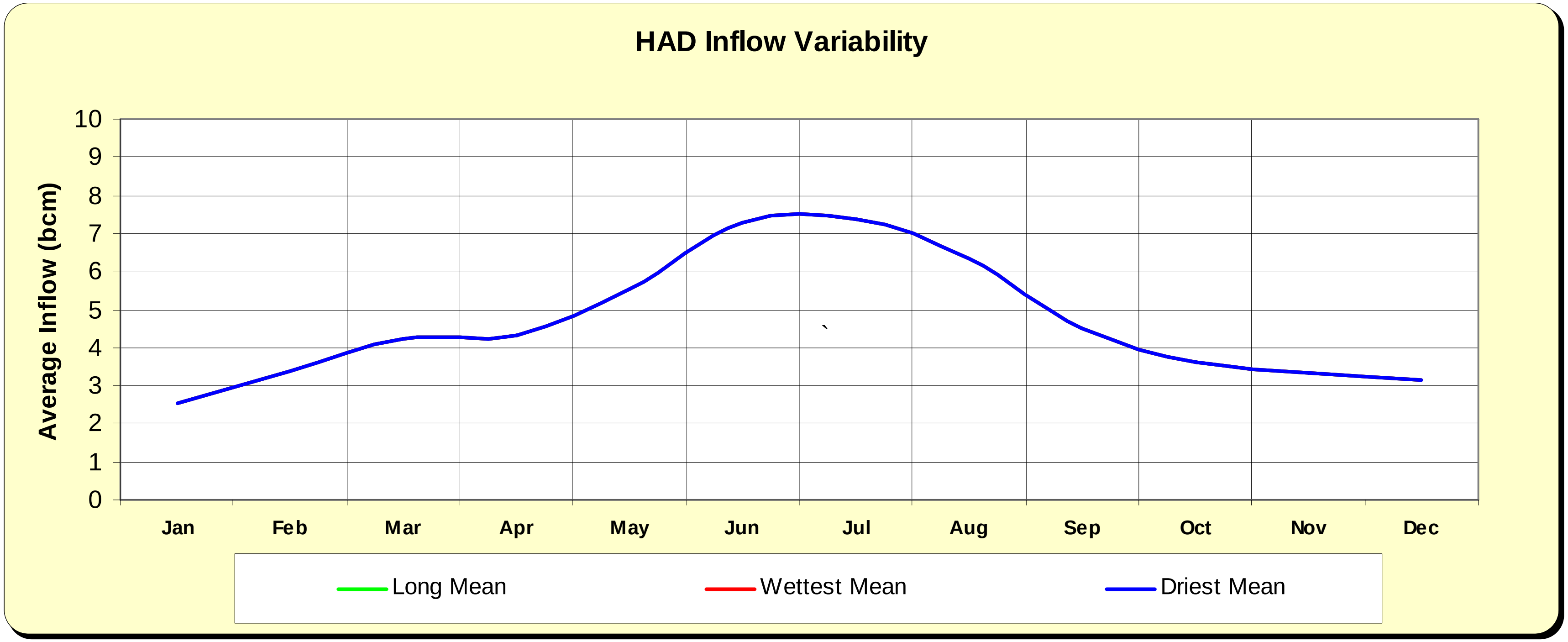

Kartum Inflow Variability
Average Inflow (bcm)
18
15
12
9
6
3
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Long Mean
Wettest Mean
Driest Mean

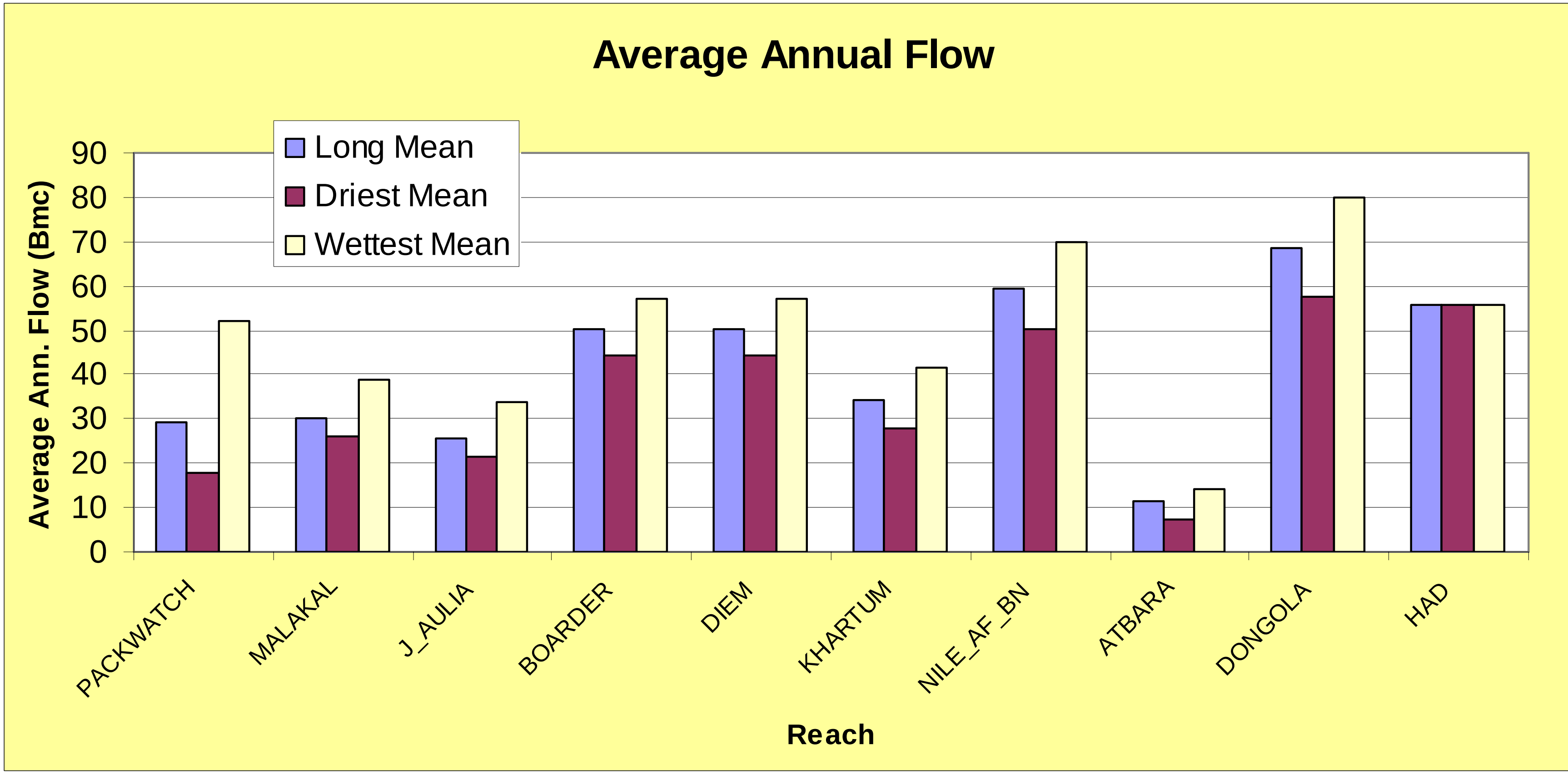


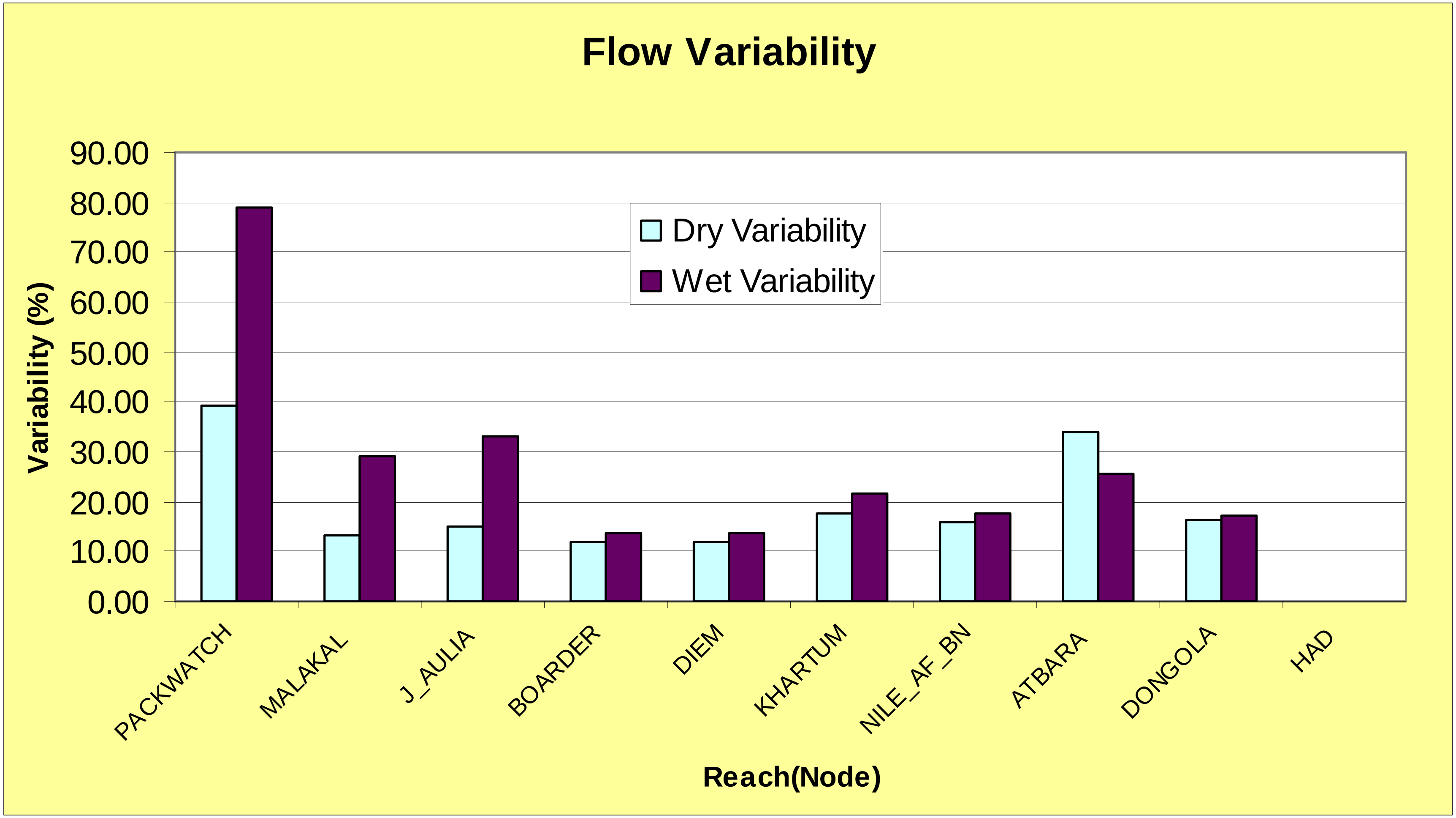
Nile after BlueNile Inflow Variability
Average Inflow (bcm)
18
15
12
9
6
3
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Long Mean
Wettest Mean
Driest Mean


Atbara Inflow Variability
Average Inflow (bcm)
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Long Mean
Wettest Mean
Driest Mean


Dongola Inflow Variability
Average Inflow (bcm)
0
4
8
12
16
20
24
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Long Mean
Wettest Mean
Driest Mean

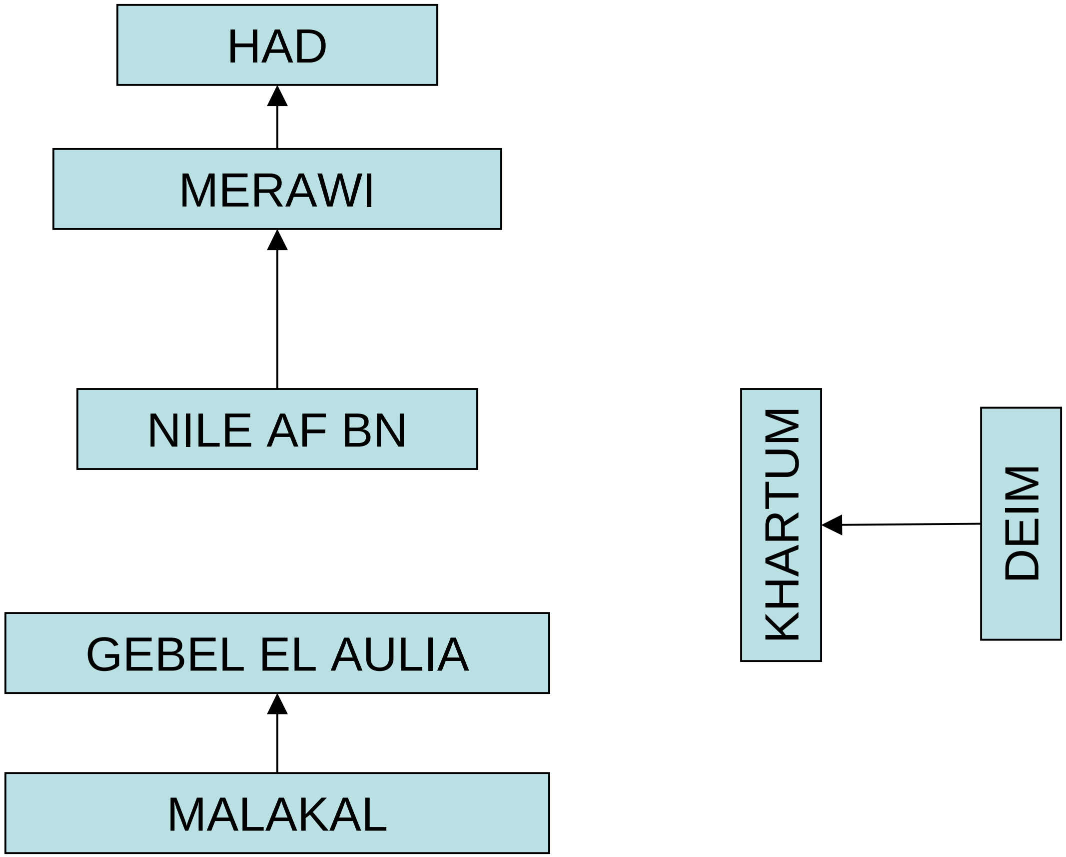

HAD Inflow Variability
Average Inflow (bcm)
10
9
8
7
6
5
4
3
2
1
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Long Mean
Wettest Mean
Driest Mean

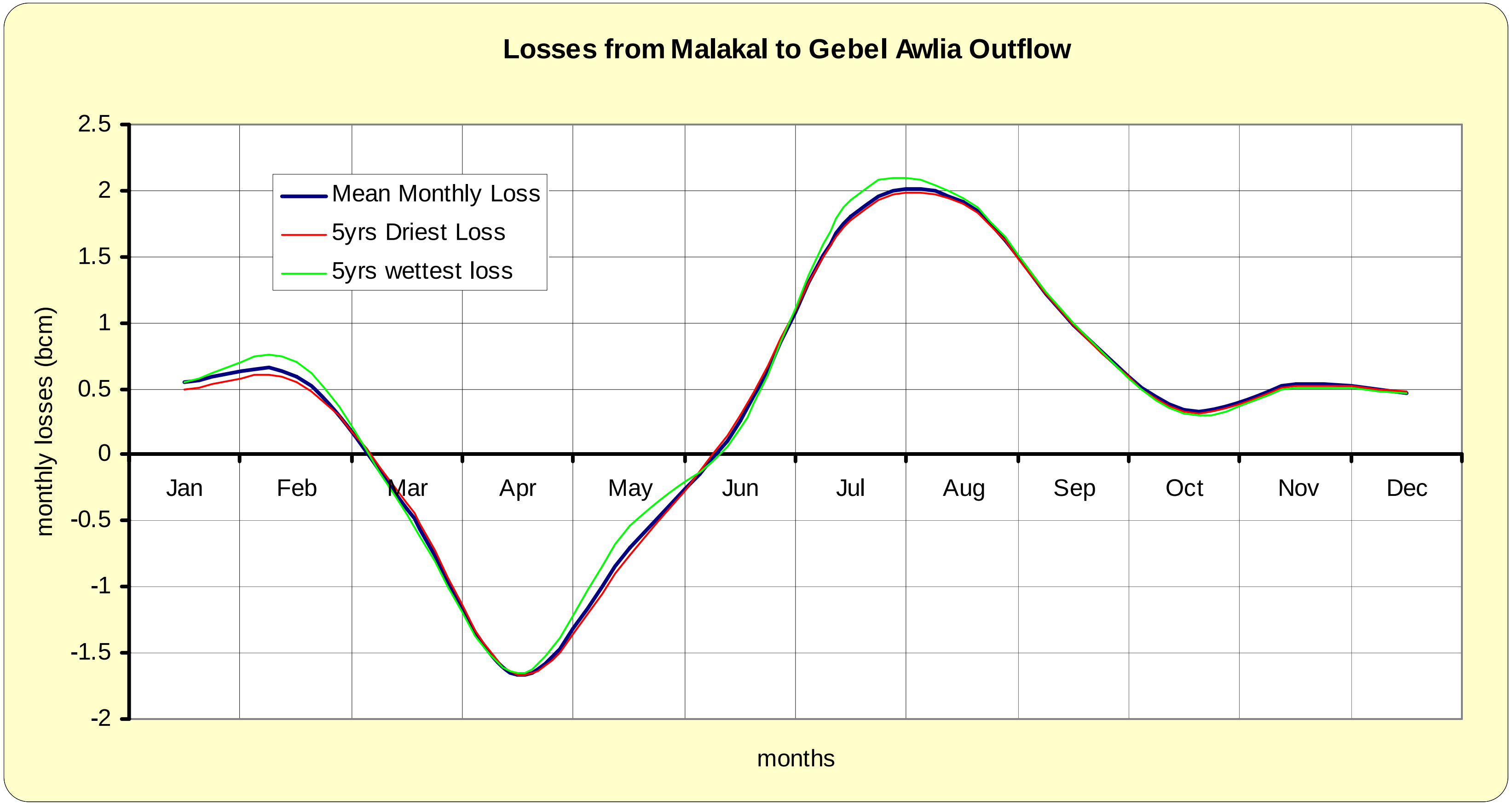

Average Annual Flow
Long Mean
Driest Mean
Wettest Mean
Average Ann. Flow (Bmc)
0
10
20
30
40
50
60
70
80
90
PACKWATCH
MALAKAL
J_AULIA
BOARDER
DIEM
KHARTUM
NILE_AF_BN
ATBARA
DONGOLA
HAD
Reach


Flow Variability
Variability (%)
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
Dry Variability
Wet Variability
PACKWATCH
MALAKAL
J_AULIA
BOARDER
DIEM
KHARTUM
NILE_AF_BN
ATBARA
DONGOLA
HAD
Reach(Node)

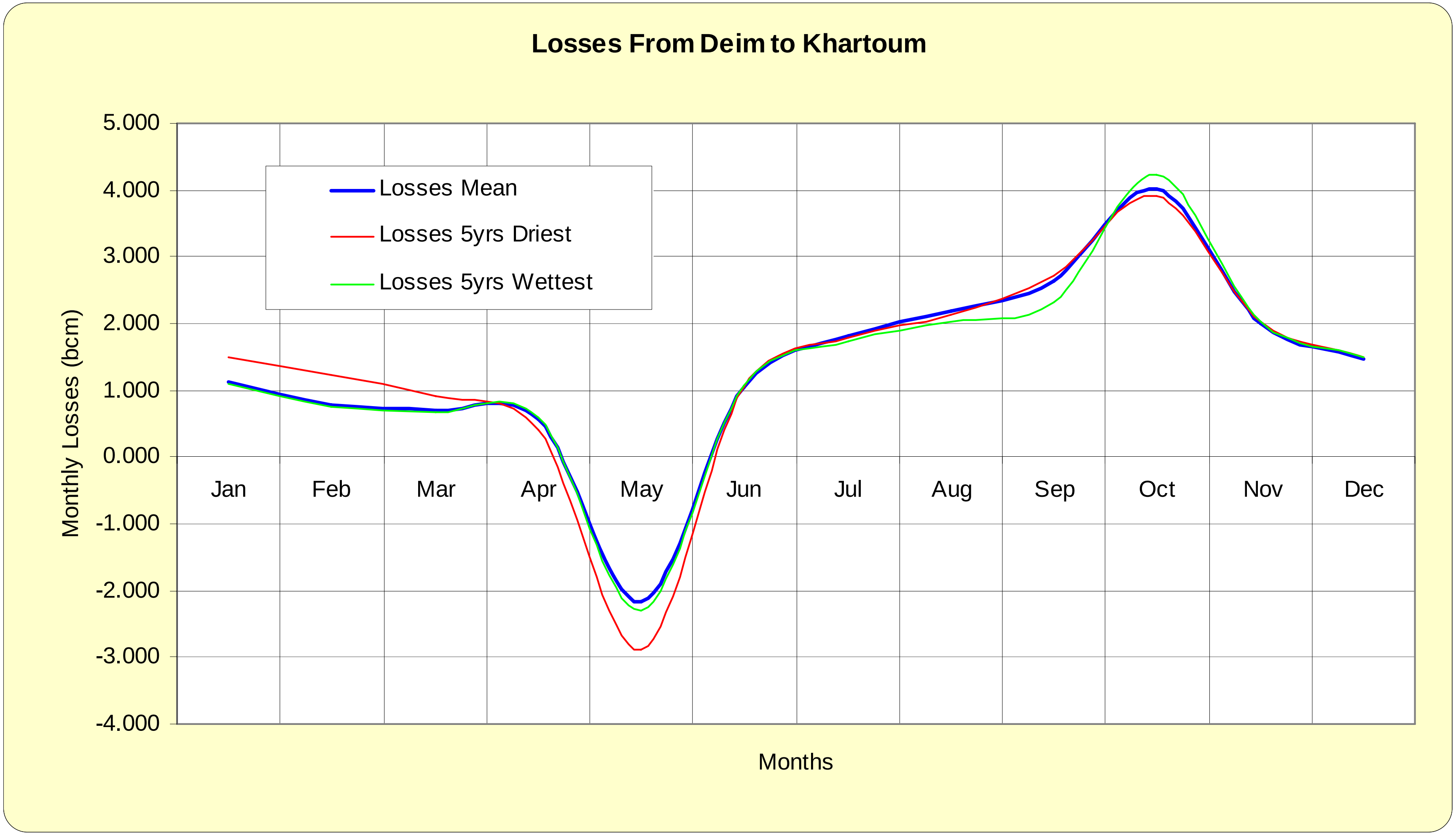
Water Losses

Reaches considered for Water Loss

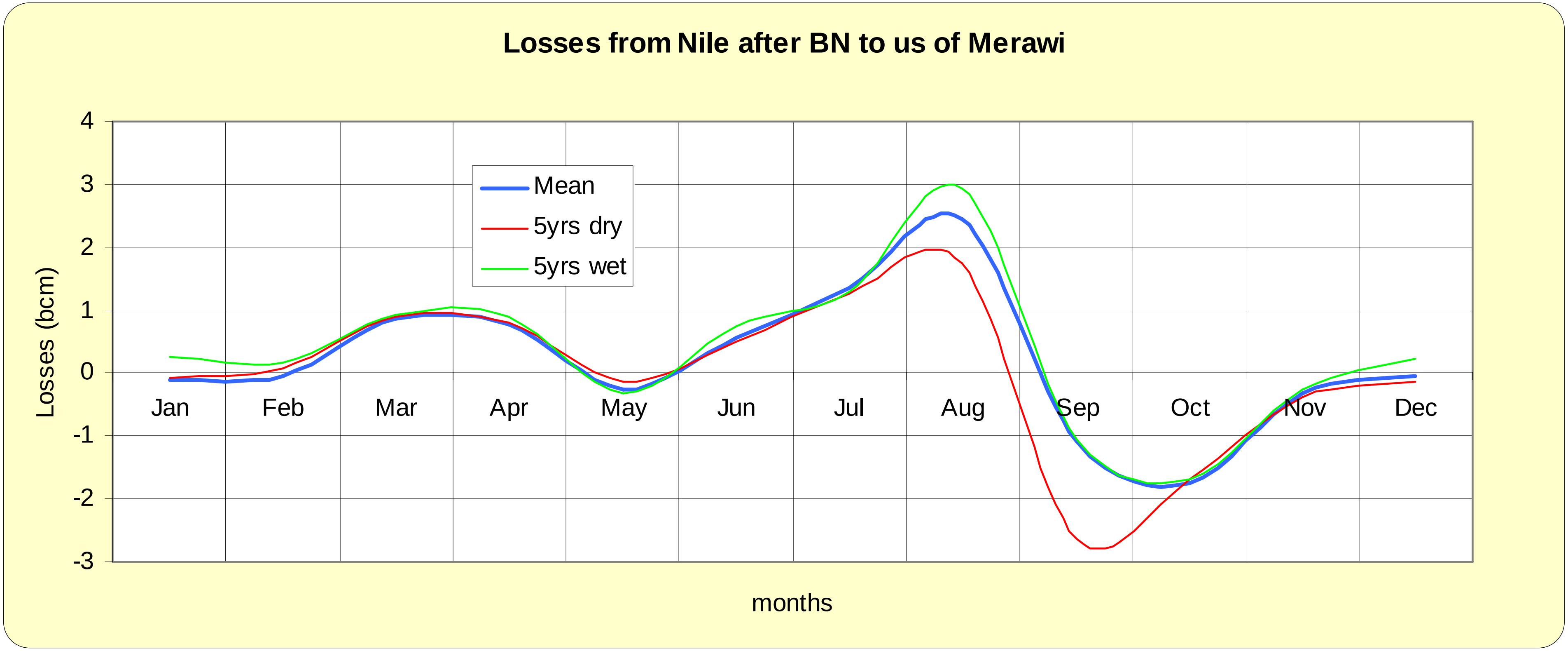




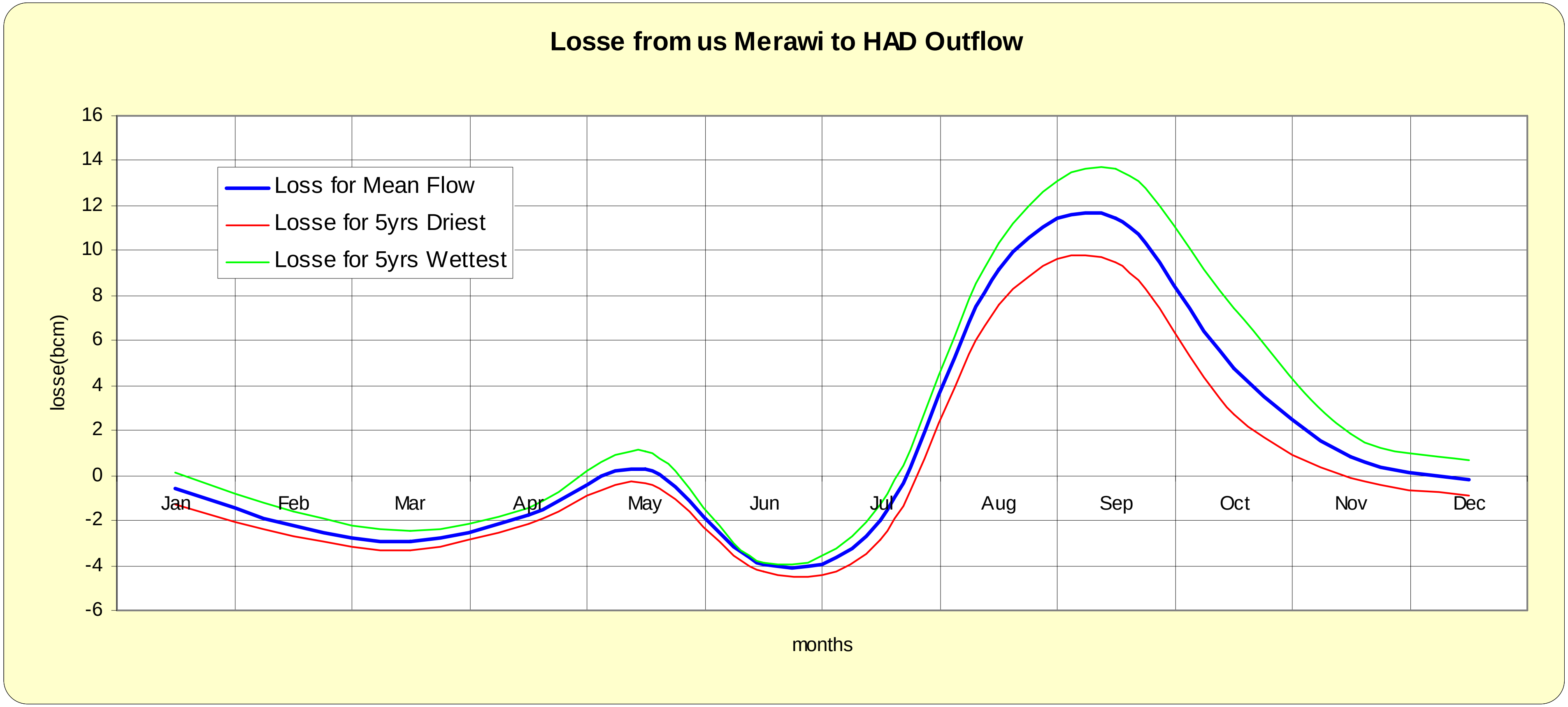
Losses from Malakal to Gebel Awlia Outflow
Mean Monthly Loss
5yrs Driest Loss
5yrs wettest loss
2.5
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
monthly losses (bcm)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
months



Losses From Deim to Khartoum
Losses Mean
Losses 5yrs Driest
Losses 5yrs Wettest
5.000
4.000
3.000
2.000
1.000
0.000
-1.000
-2.000
-3.000
-4.000
Monthly Losses (bcm)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months



Losses from Nile after BN to us of Merawi
Losses (bcm)
4
3
2
1
0
-1
-2
-3
Mean
5yrs dry
5yrs wet
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
months


Losse from us Merawi to HAD Outflow
Loss for Mean Flow
Losse for 5yrs Driest
Losse for 5yrs Wettest
losse(bcm)
16
14
12
10
8
6
4
2
0
-2
-4
-6
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
months

Nile DST Training Workshop

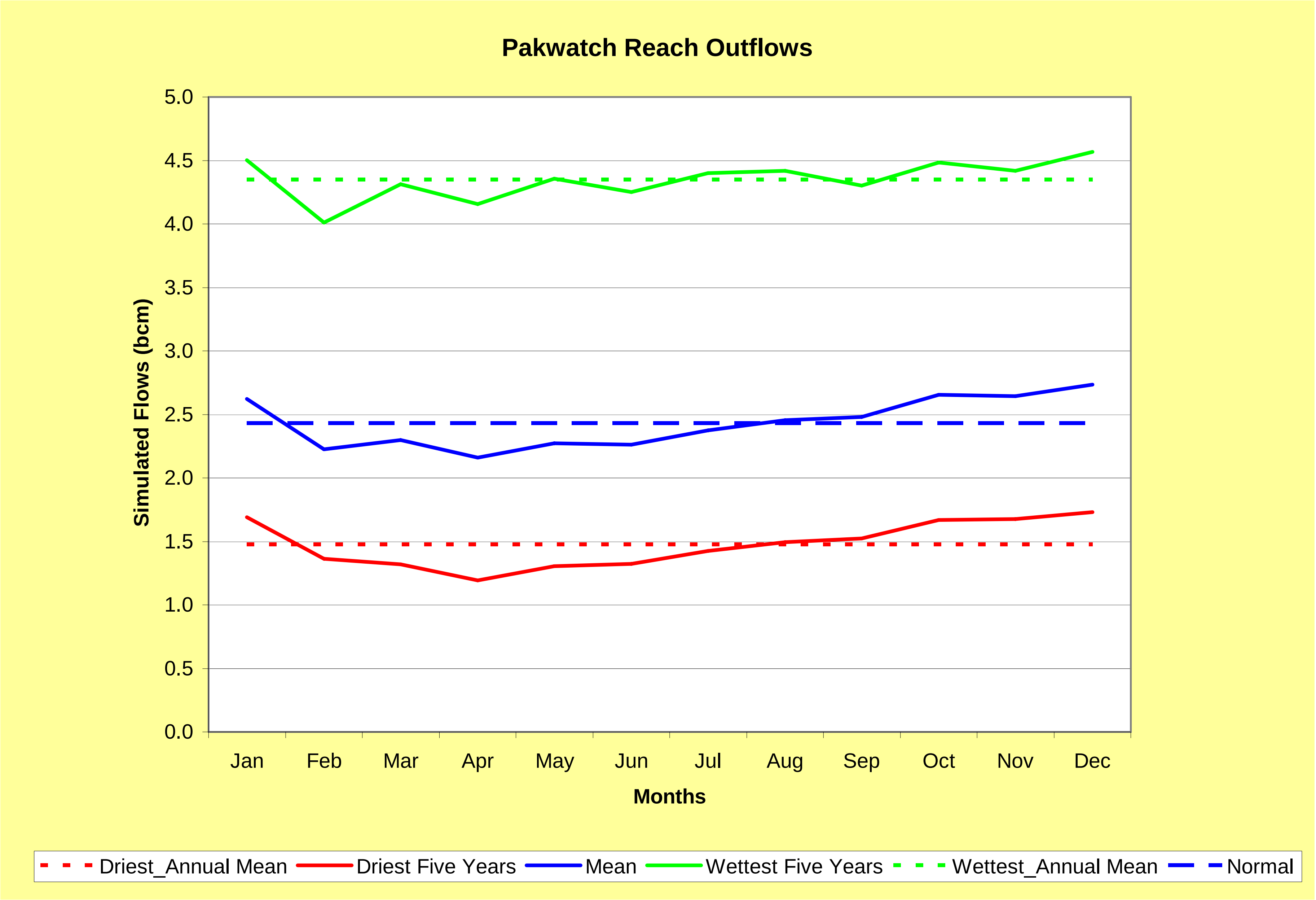
Presentation by Kenya Team

- The river reaches are defined as follows:
  - Southern Nile system up to the border of Uganda and Sudan (Nimule);
  - Nimule to Malakal upstream of the Sobat junction;
  - Malakal (upstream of the Sobat junction) to downstream of Gebel El Aulia Dam; (Namely, before the junction of the White and Blue Niles;)
  - Ethiopian Blue Nile up to the Sudanese border;
  - Sudanese Blue Nile up to the junction with the White Nile;
  - Main Nile from the Blue and White Nile junction up to the entrance of Lake Nasser (High Aswan Dam reservoir);
  - Egyptian Nile, including Lake Nasser, to the Mediterranean Sea.

MONTHLY AND ANNUAL OUTFLOWS

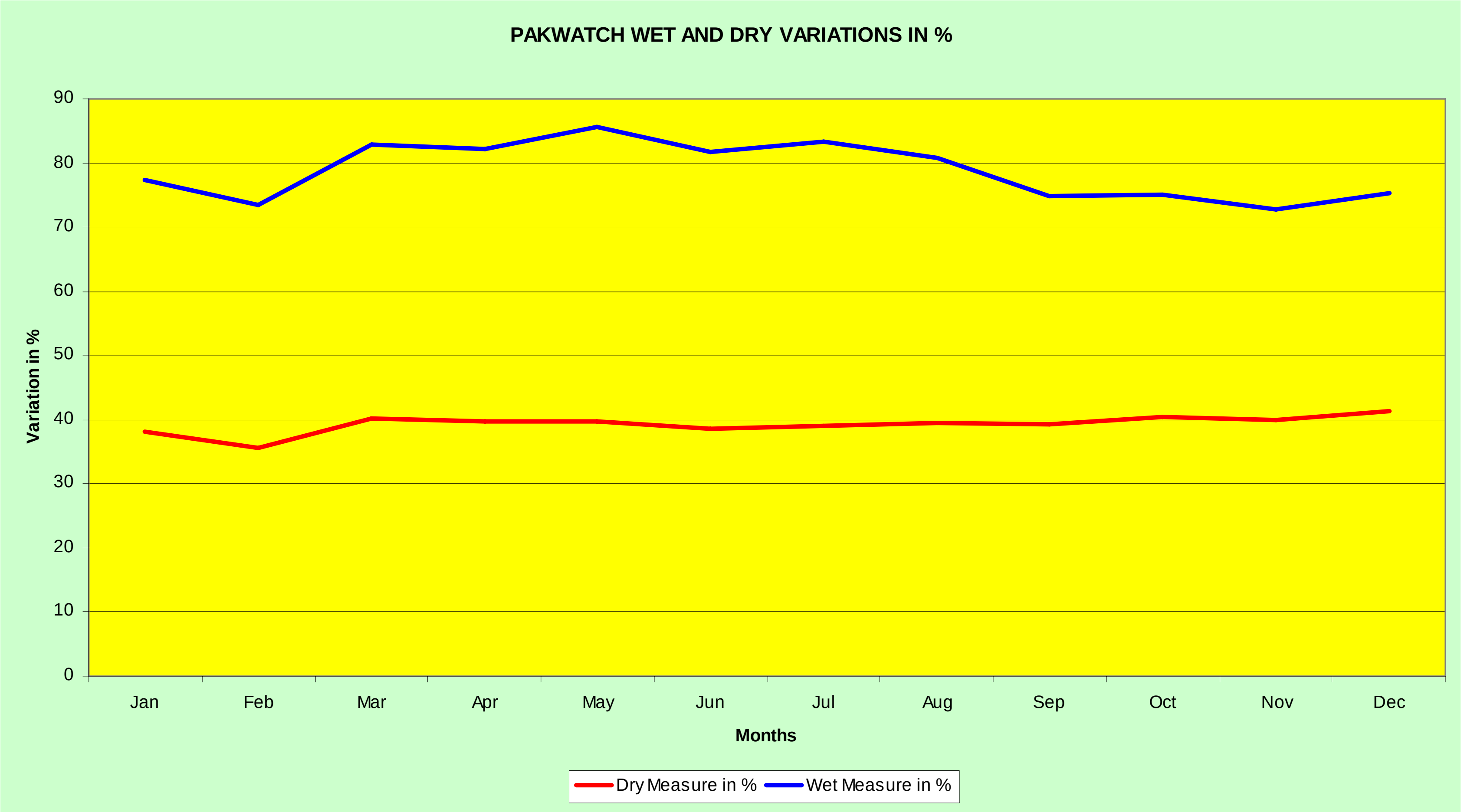
Exercise on Reach Outflows

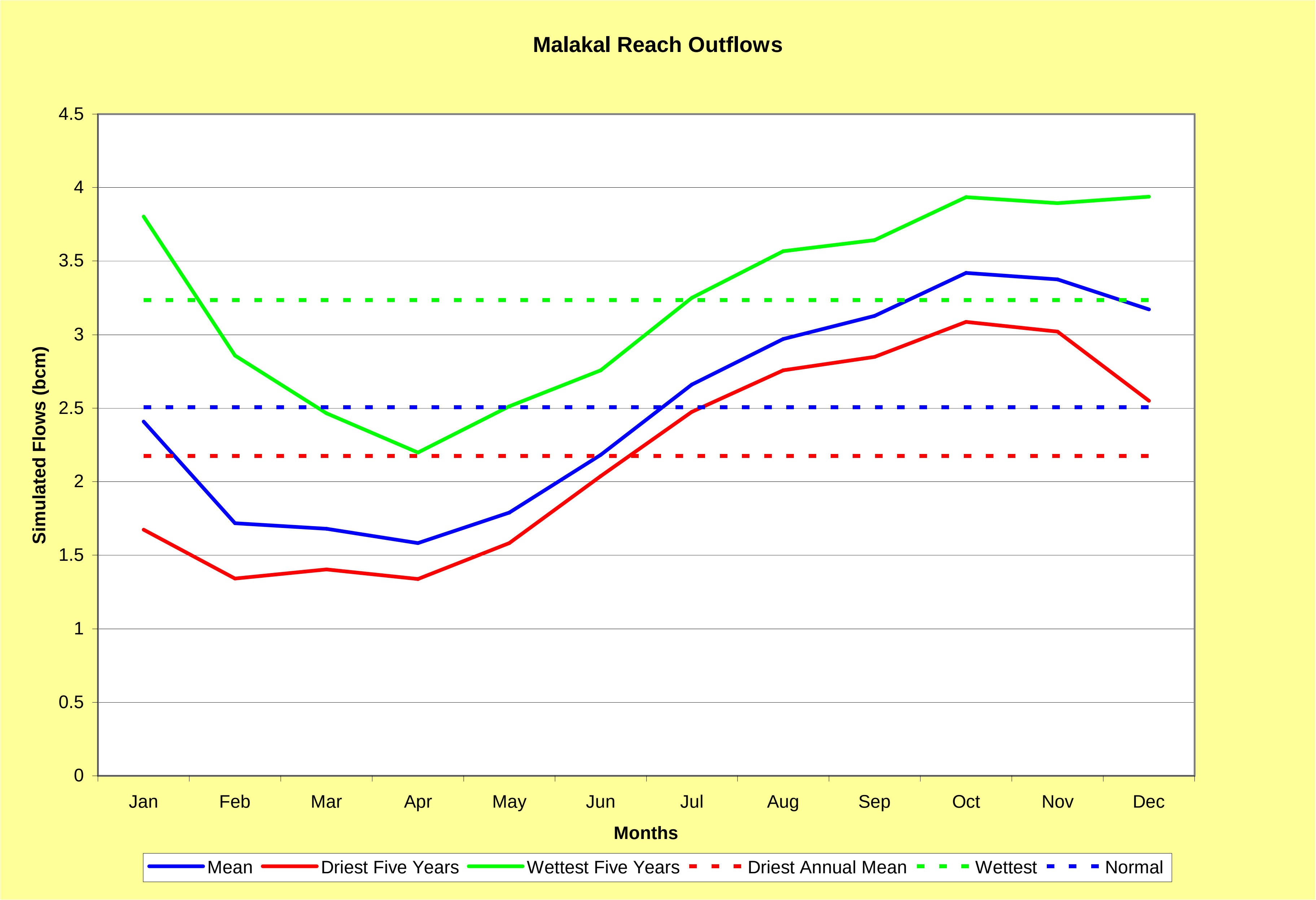
- Average monthly and annual reach outflows over the period of record;
- Average monthly and annual reach outflows over the driest five years of the record; (Indicate the drought years;)
- Average monthly and annual reach outflows over the wettest five years of the record; (Indicate the five wettest years of record;)
- Develop quantitative measures of the outflow variability (e.g., percent difference of dry and wet periods from normal) and determine if wet and dry climatic periods occur at the same time across the various river reaches; Specify which river reaches behave similarly in this respect.

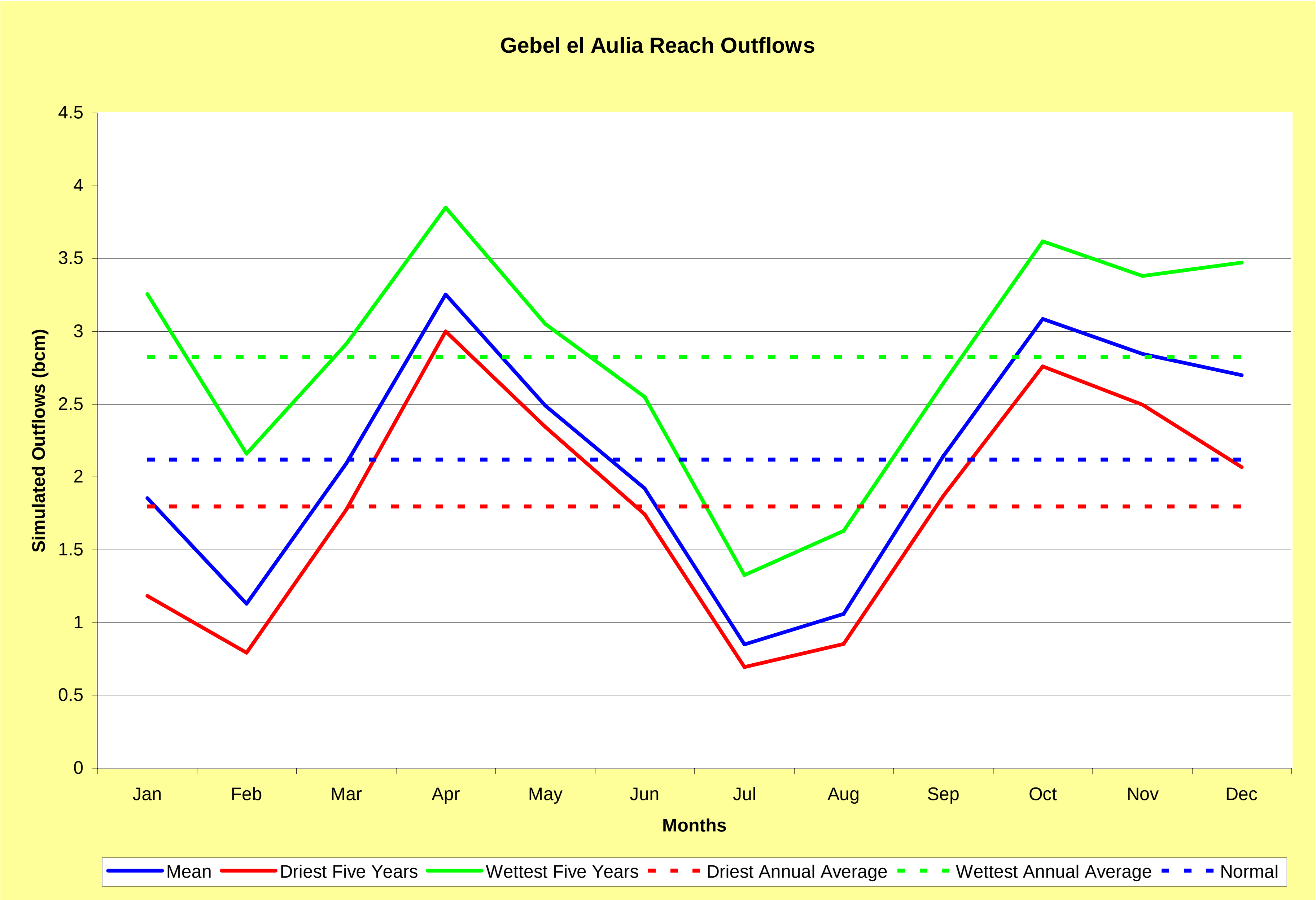


Pakwatch Reach Outflows
Simulated Flows (bcm)
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Driest_Annual Mean
Driest Five Years
Mean
Wettest Five Years
Wettest_Annual Mean
Normal

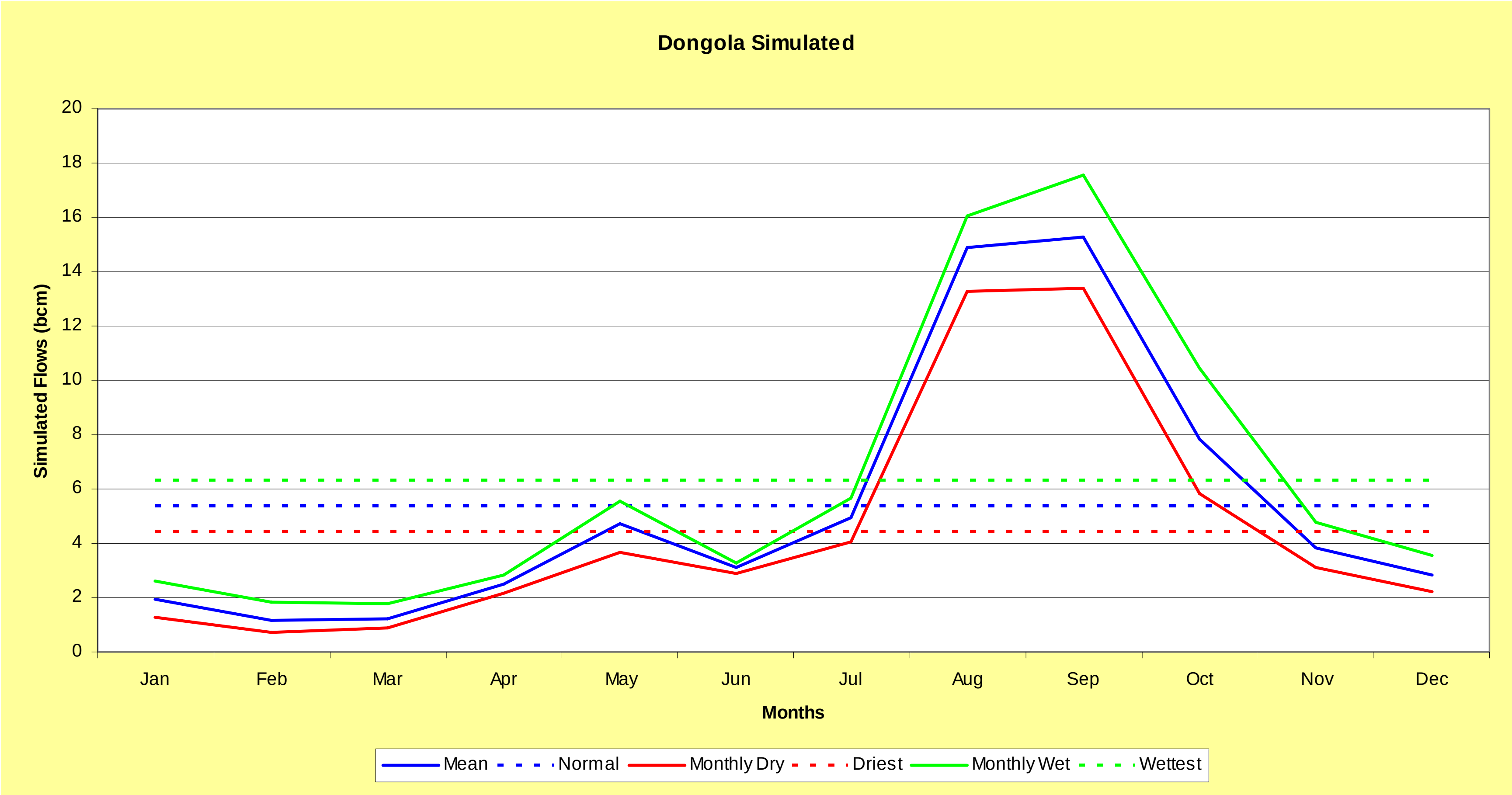
PAKWATCH WET AND DRY VARIATION



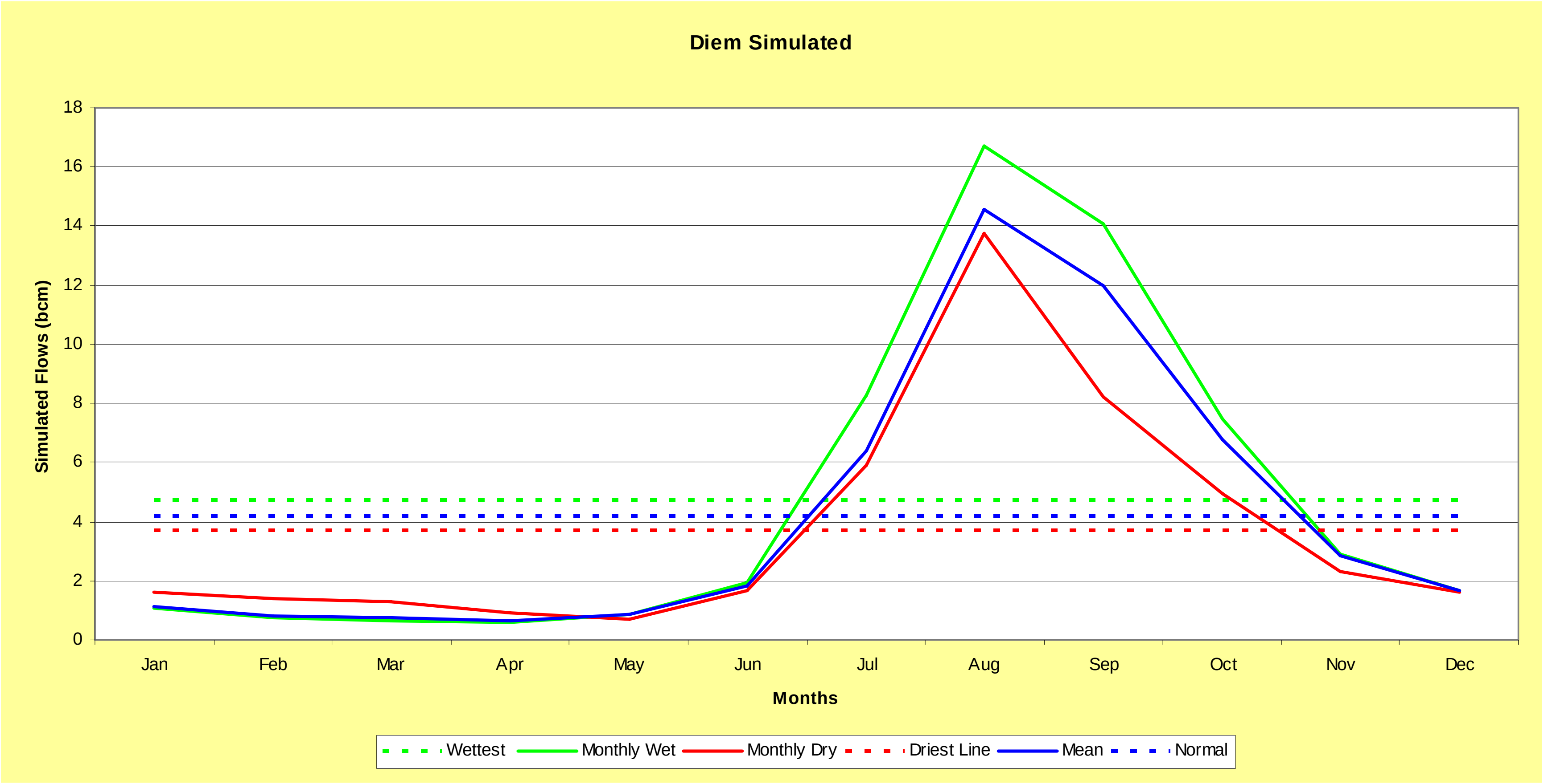

Malakal Reach Outflows
Simulated Flows (bcm)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Mean
Driest Five Years
Wettest Five Years
Driest Annual Mean
Wettest
Normal


Gebel el Aulia Reach Outflows
Simulated Outflows (bcm)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Mean
Driest Five Years
Wettest Five Years
Driest Annual Average
Wettest Annual Average
Normal

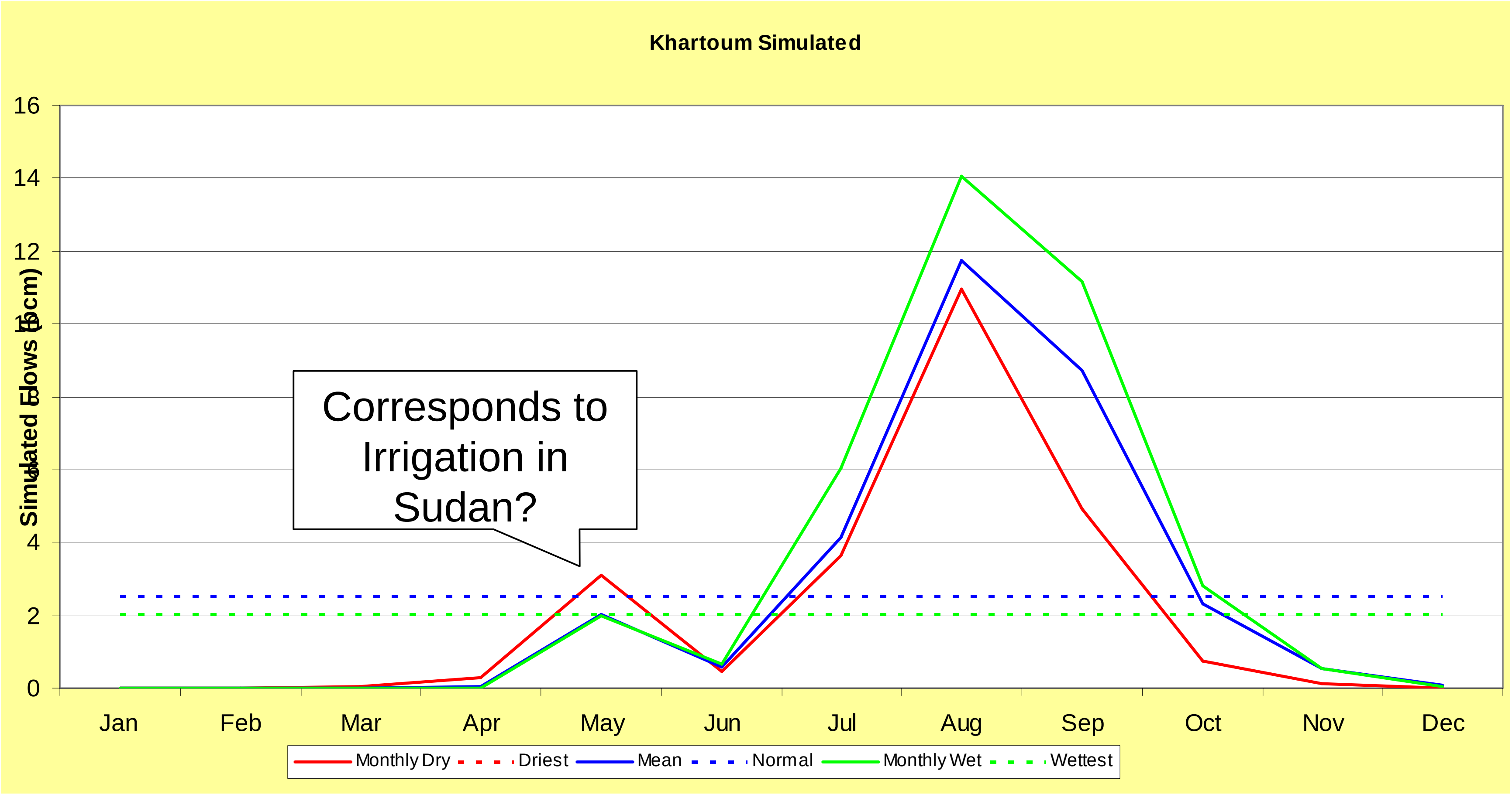
DONGOLA OUTFLOWS



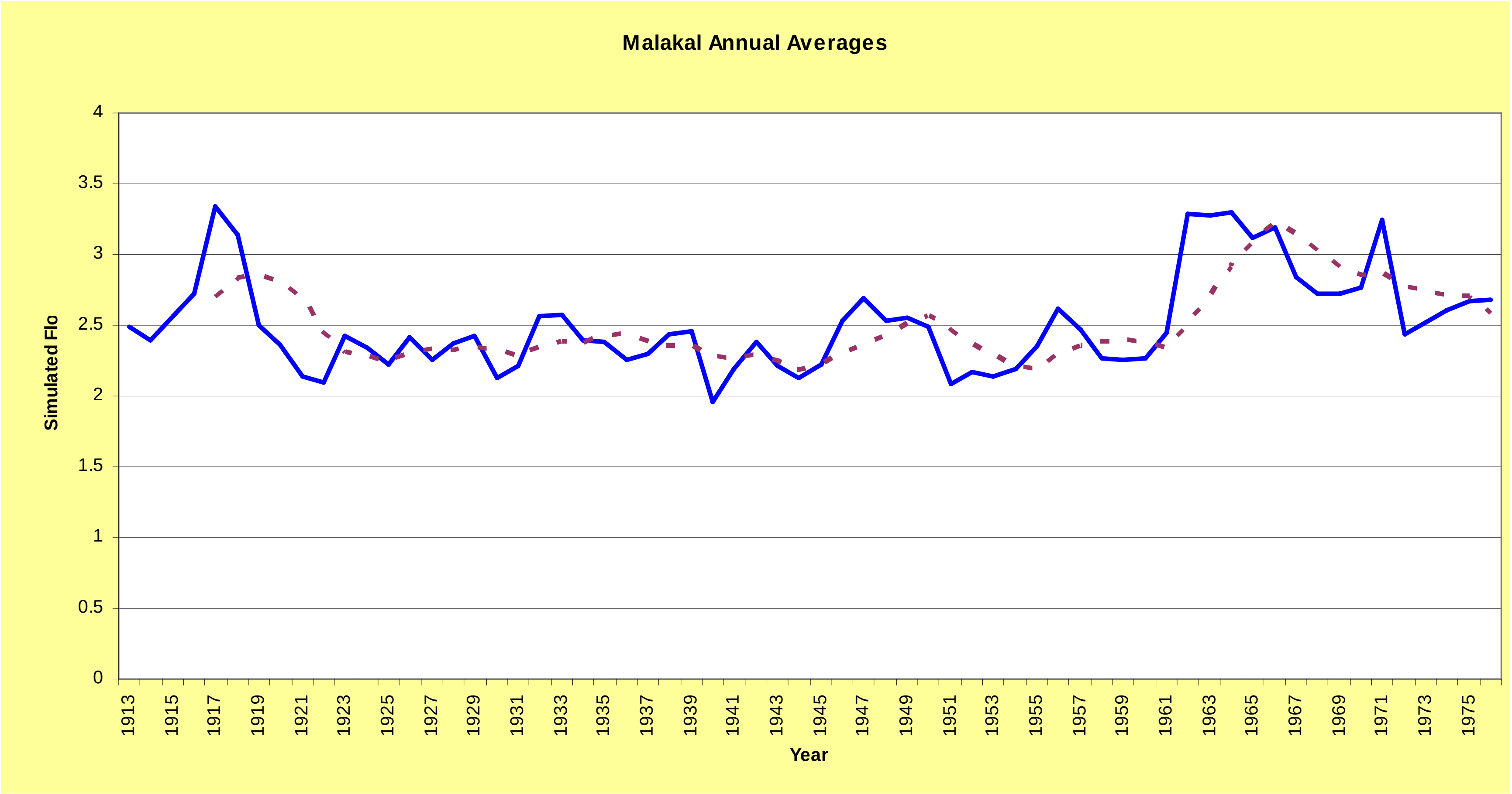
DIEM OUTFLOWS



KHARTOUM OUTFLOWS



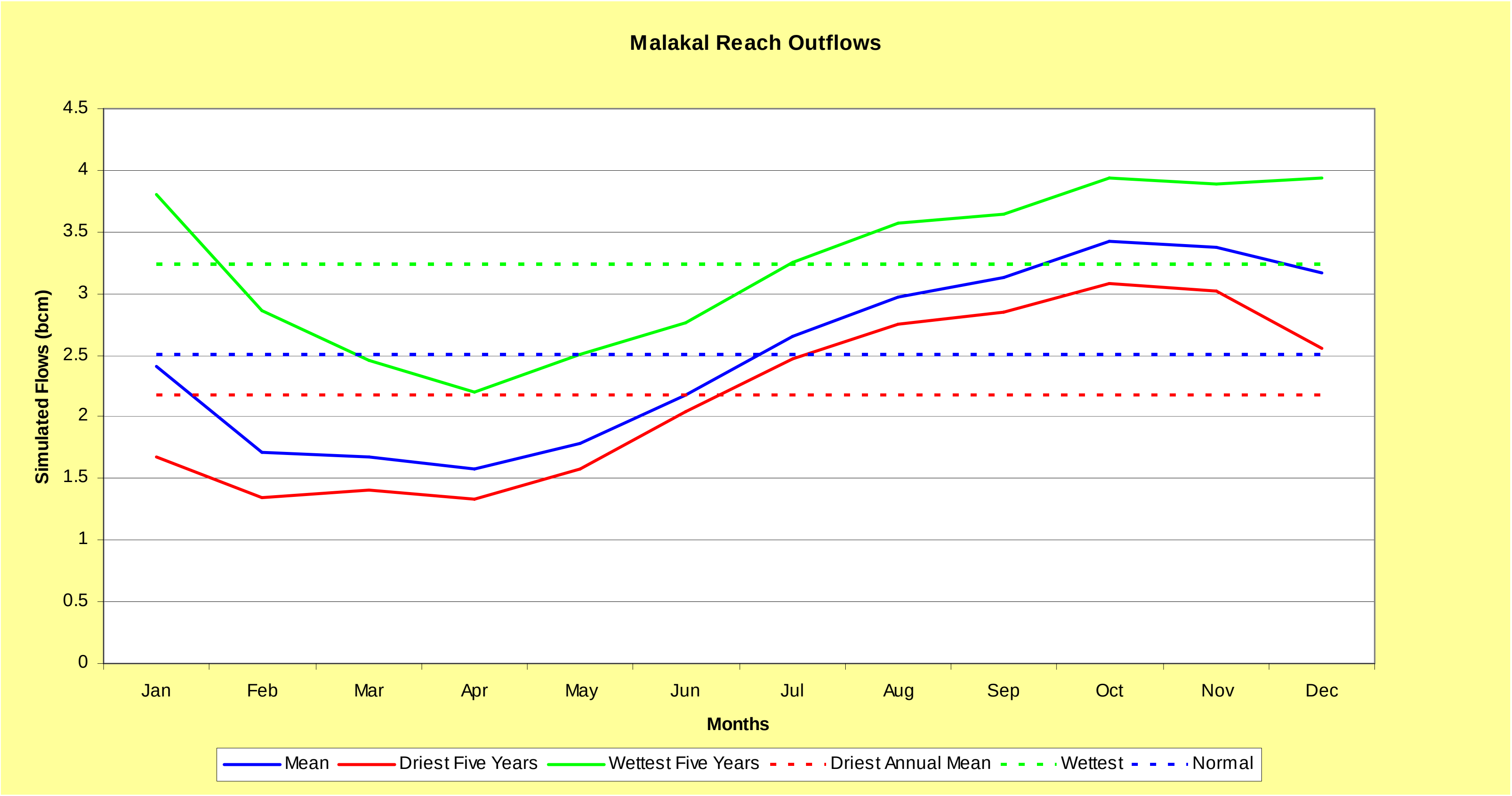
MALAKAL ANNUAL AVERAGES



DRIEST AND WETTEST FIVE YEAR PERIODS

NODE	DRIEST PERIOD	WETTEST PERIOD
Pakwatch	1921-1925	1962-1966
Malakal	1940-1944	1962-1966
Gebel el Aulia	1940-1944	1962-1966
Diem	1968-1972	1934-1938
Khartoum	1968-1972	1934-1938
Dongola	1940-1944	1960-1964

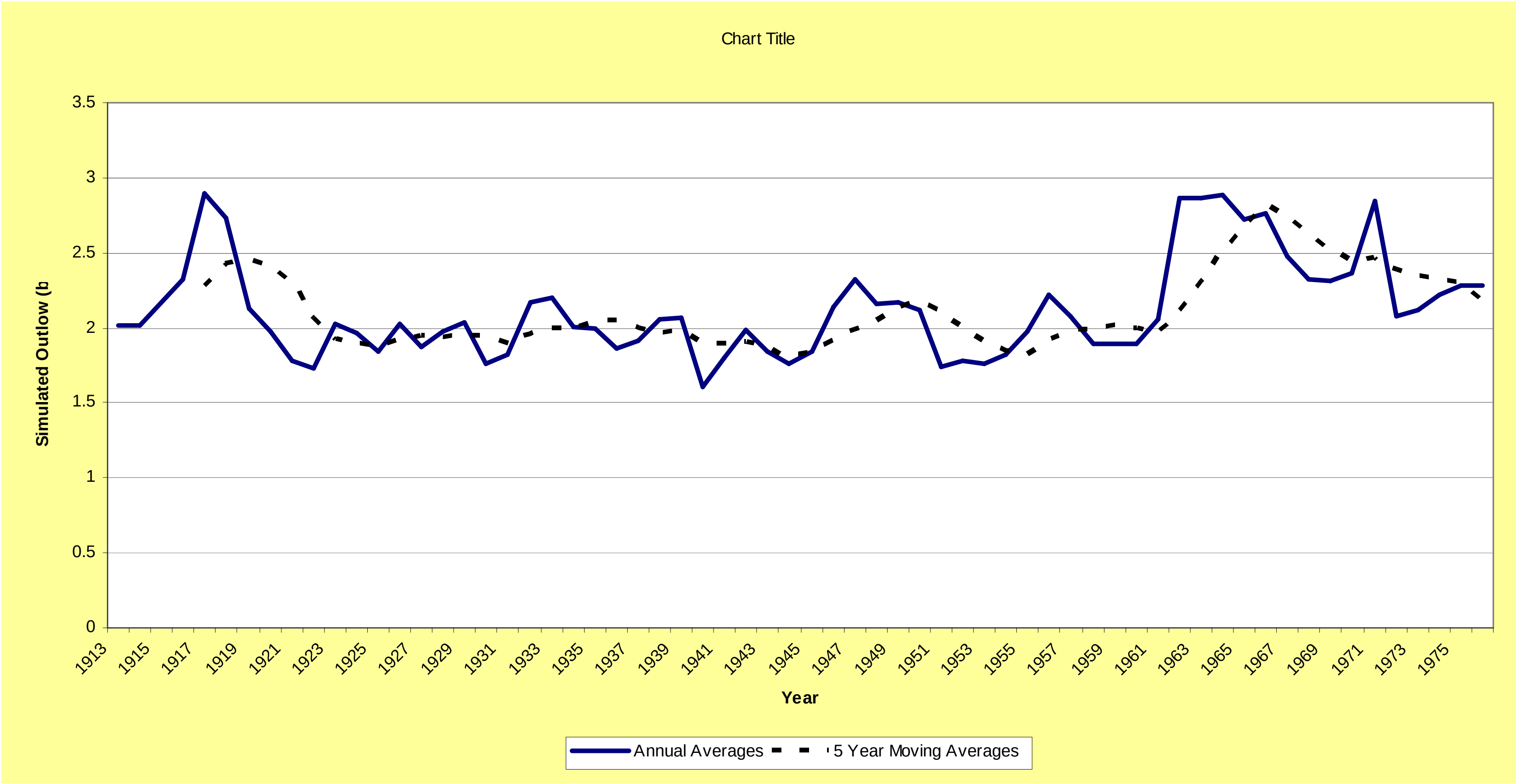
Nimule(Pakwatch) to Malakal



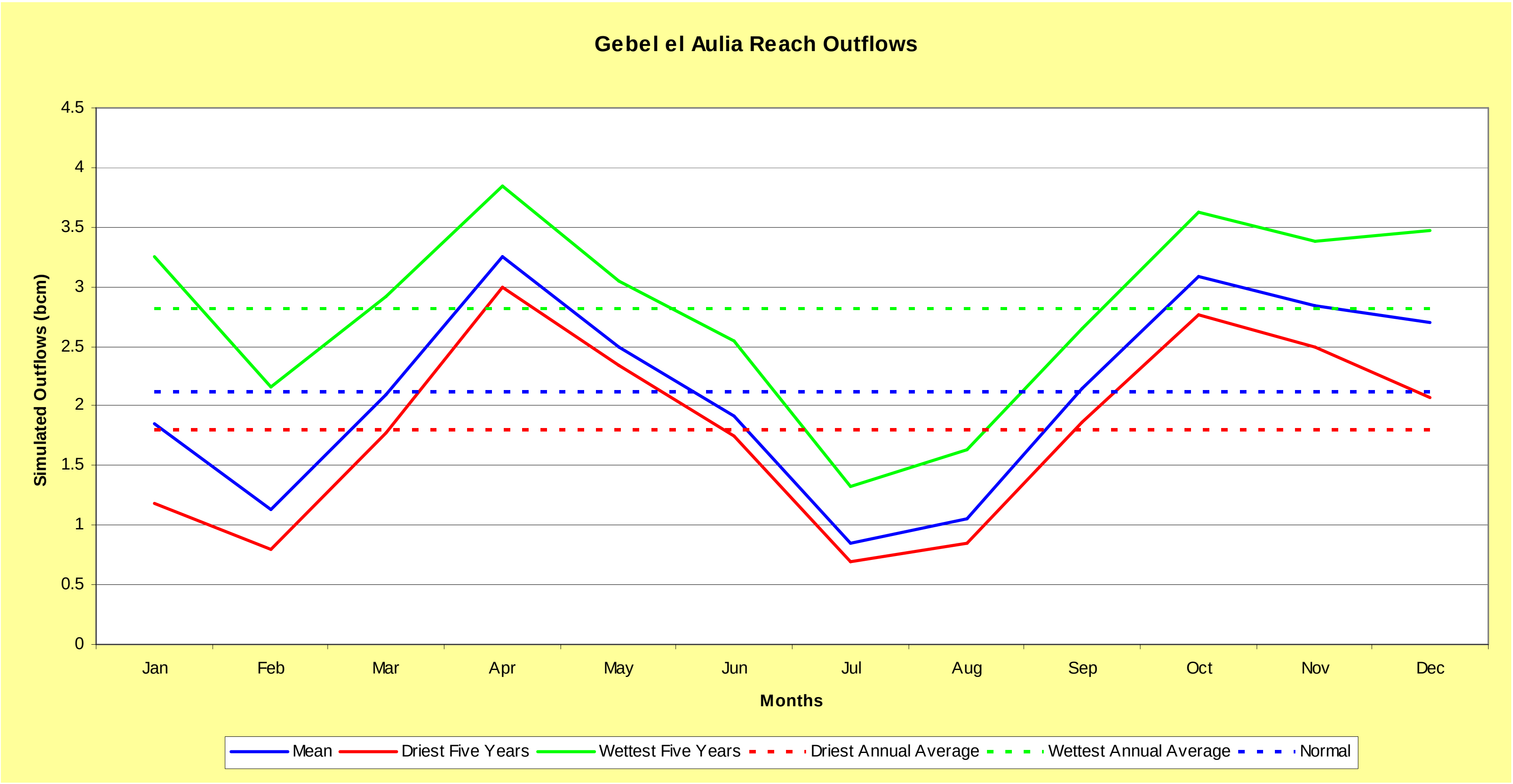
Statistical Measures (%) Pakwatch

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean Monthly Averages	2.41	1.72	1.68	1.58	1.79	2.18	2.66	2.97	3.13	3.42	3.38	3.17
Normal/All Period Mean	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51	2.51
Stats Measure Driest	29.33	15.00	11.00	9.82	8.22	5.71	7.35	8.49	11.13	13.36	14.16	24.76
Stats Measure Wettest	55.68	45.51	31.27	24.59	28.81	22.96	23.51	23.84	20.56	20.49	20.65	30.52

Annual Outflows at Gebel el Aulia



Malakal (Upstream of Sobat Junction) to Gebel el Aulia



WATER BALANCE

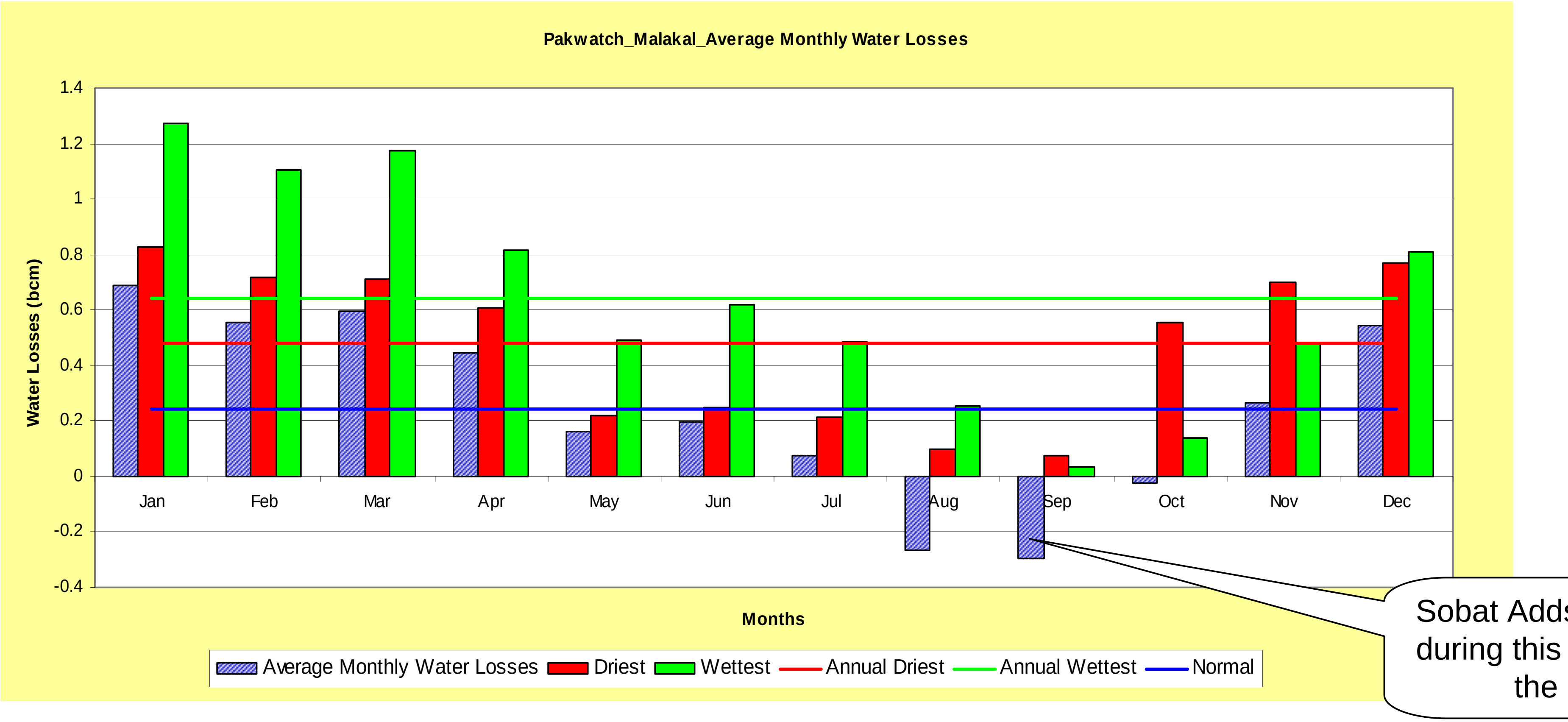
Exercise on Water Use and Losses

- Average monthly and annual reach water use and losses (separately) over the period of record;
- Average monthly and annual reach water use and losses (separately) over the driest five years of the record;
- Average monthly and annual reach water use and losses (separately) outflows over the wettest five years of the record;
- Develop quantitative measures of the water use and losses variability (e.g., percent difference of dry and wet periods from normal);
- Determine the reliability of meeting water use targets in each reach;
- Compare water losses to reach outflows;
- *Note :* Reach water losses include evaporation and other water abstractions not related to human water uses.

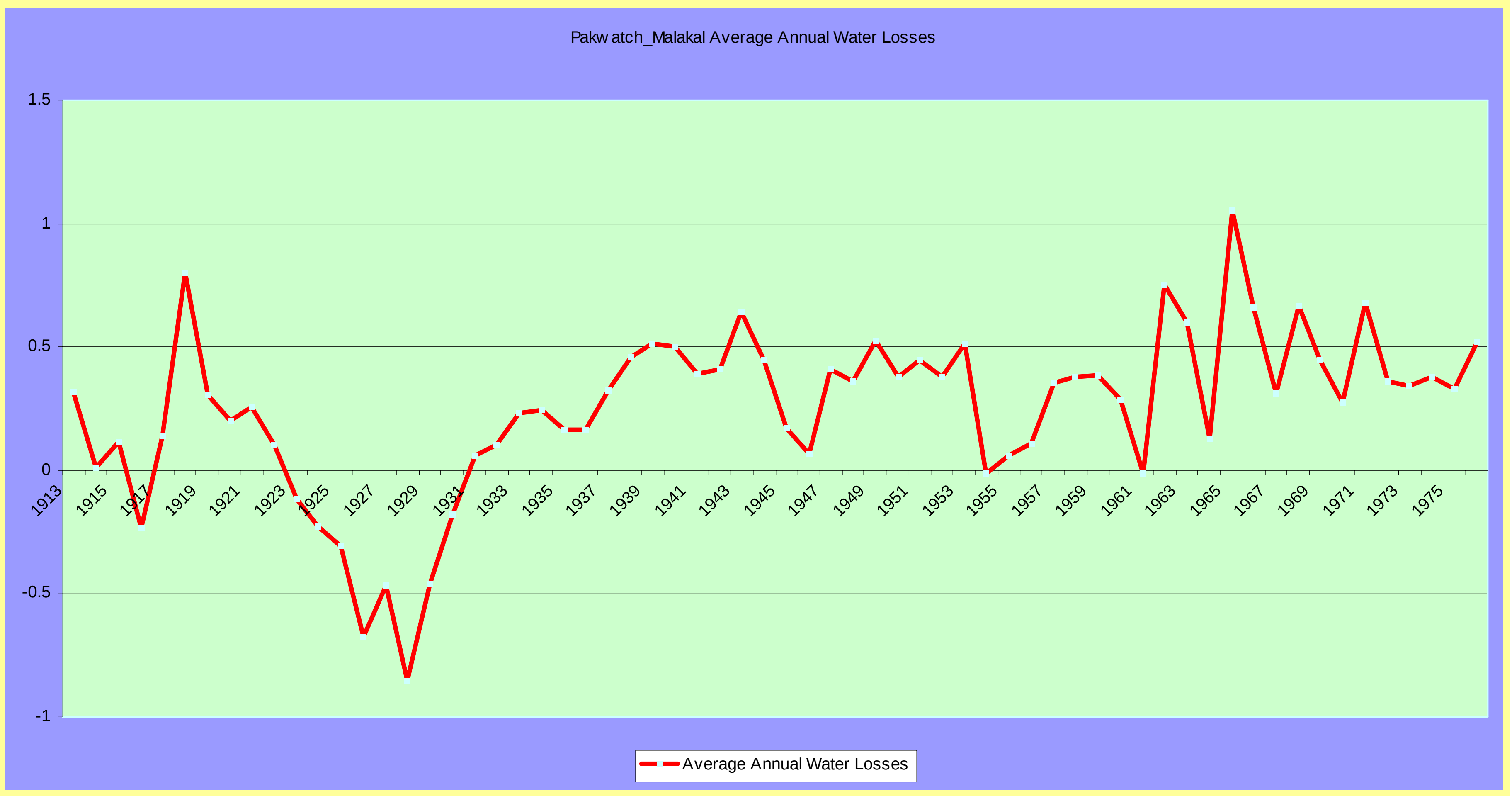
WATER LOSSES BETWEEN PAKWATCH-MALAKAL

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Loss
Monthly Dry	0.83	0.72	0.71	0.61	0.22	0.25	0.21	0.10	0.08	0.55	0.70	0.77	0.48
Driest	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	
Monthly Wet	1.27	1.10	1.18	0.82	0.49	0.62	0.48	0.25	0.04	0.14	0.48	0.81	0.64
Wettest	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	
Monthly Mean	0.69	0.56	0.59	0.45	0.16	0.20	0.07	-0.27	-0.30	-0.02	0.27	0.55	
Normal	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	

Pakwatch-Malakal Average Monthly Water Losses



Pakwatch-Malakal Average Annual Water Losses

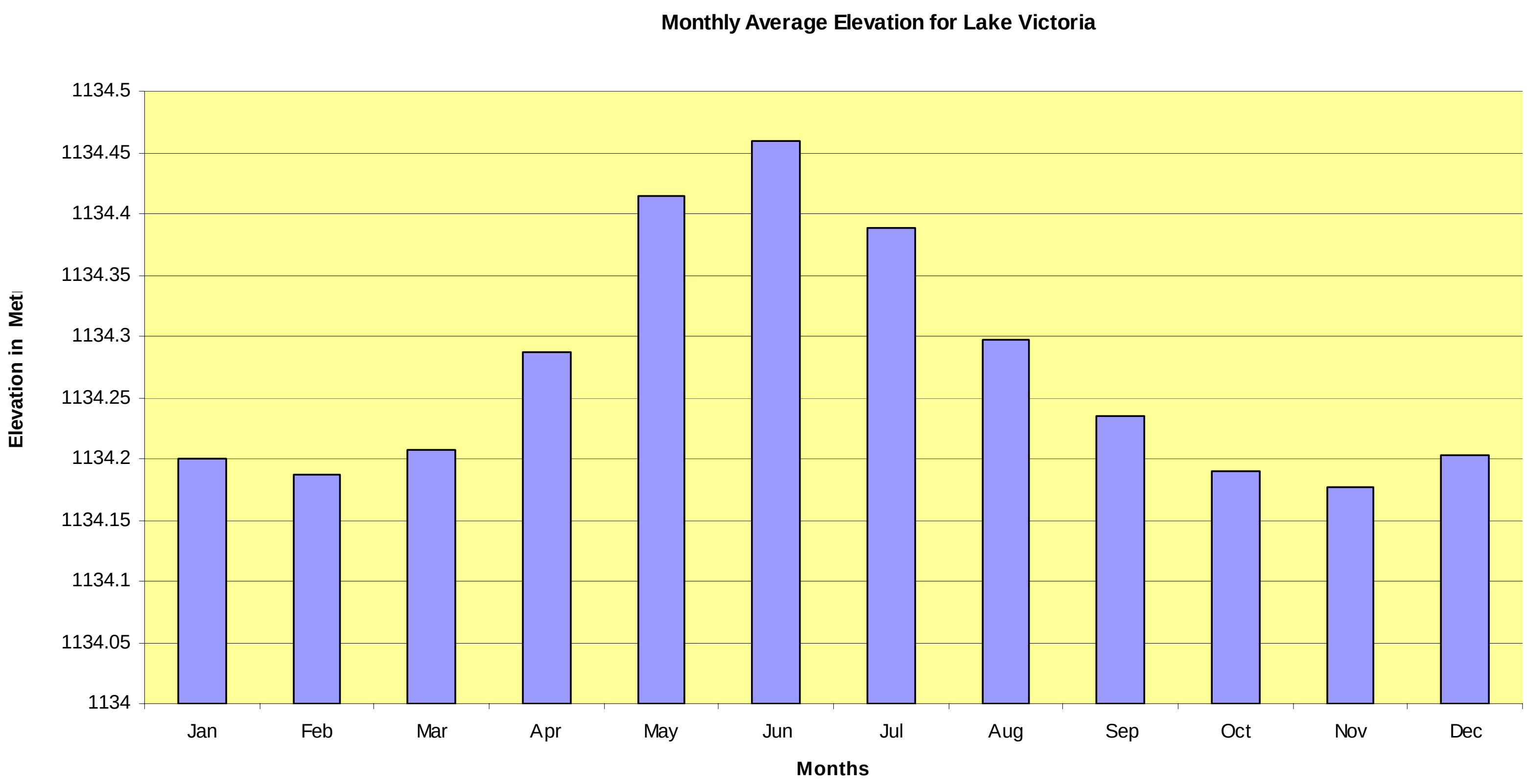


Energy Generation

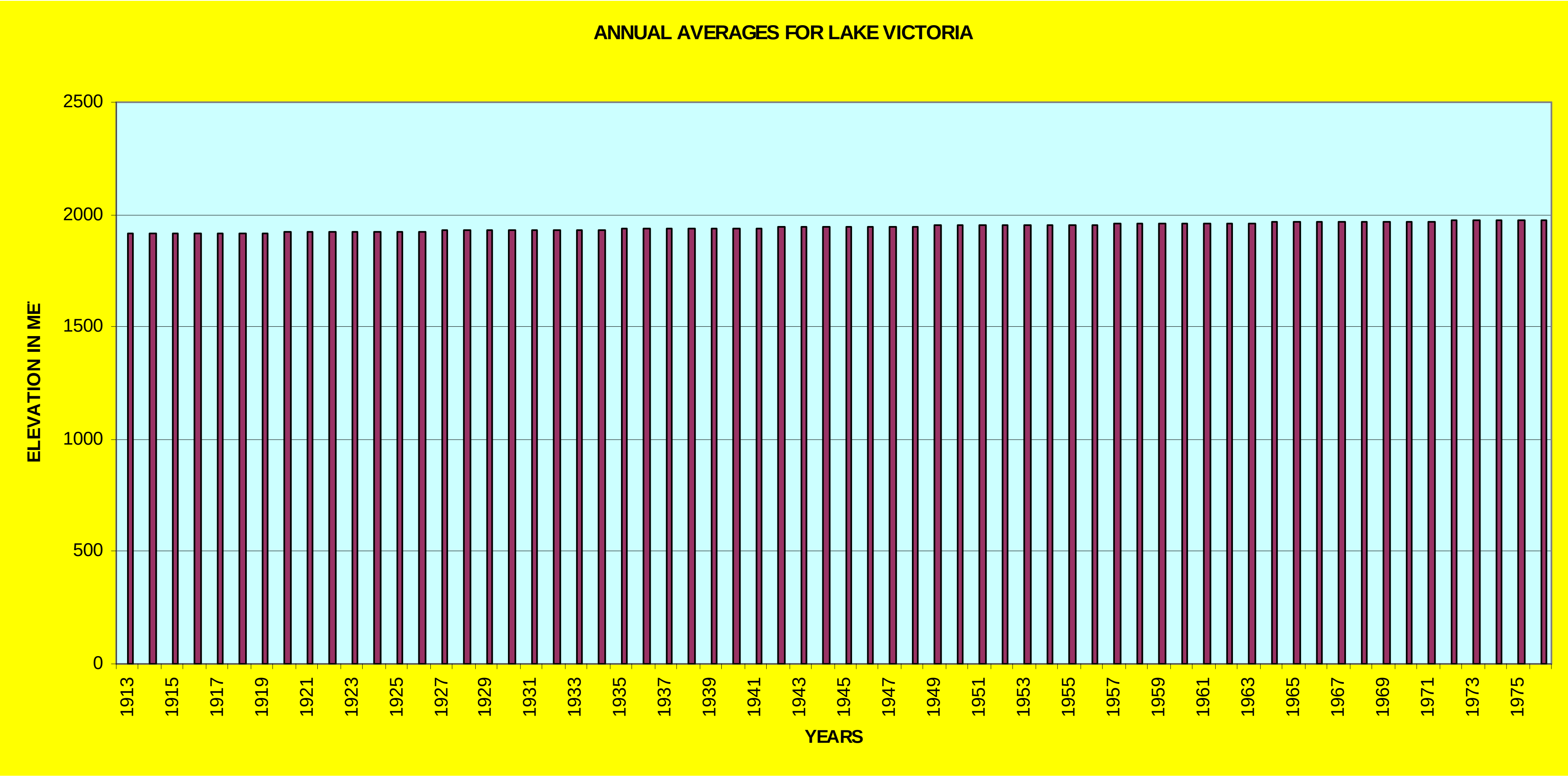
Exercise on Energy Generation

– Average monthly and annual reach energy generation over the period of record;
– Average monthly and annual reach energy generation over the driest five years of the record;
– Average monthly and annual reach energy generation over the wettest five years of the record;
– Develop quantitative measures of energy generation variability (e.g., percent difference of dry and wet periods from normal).

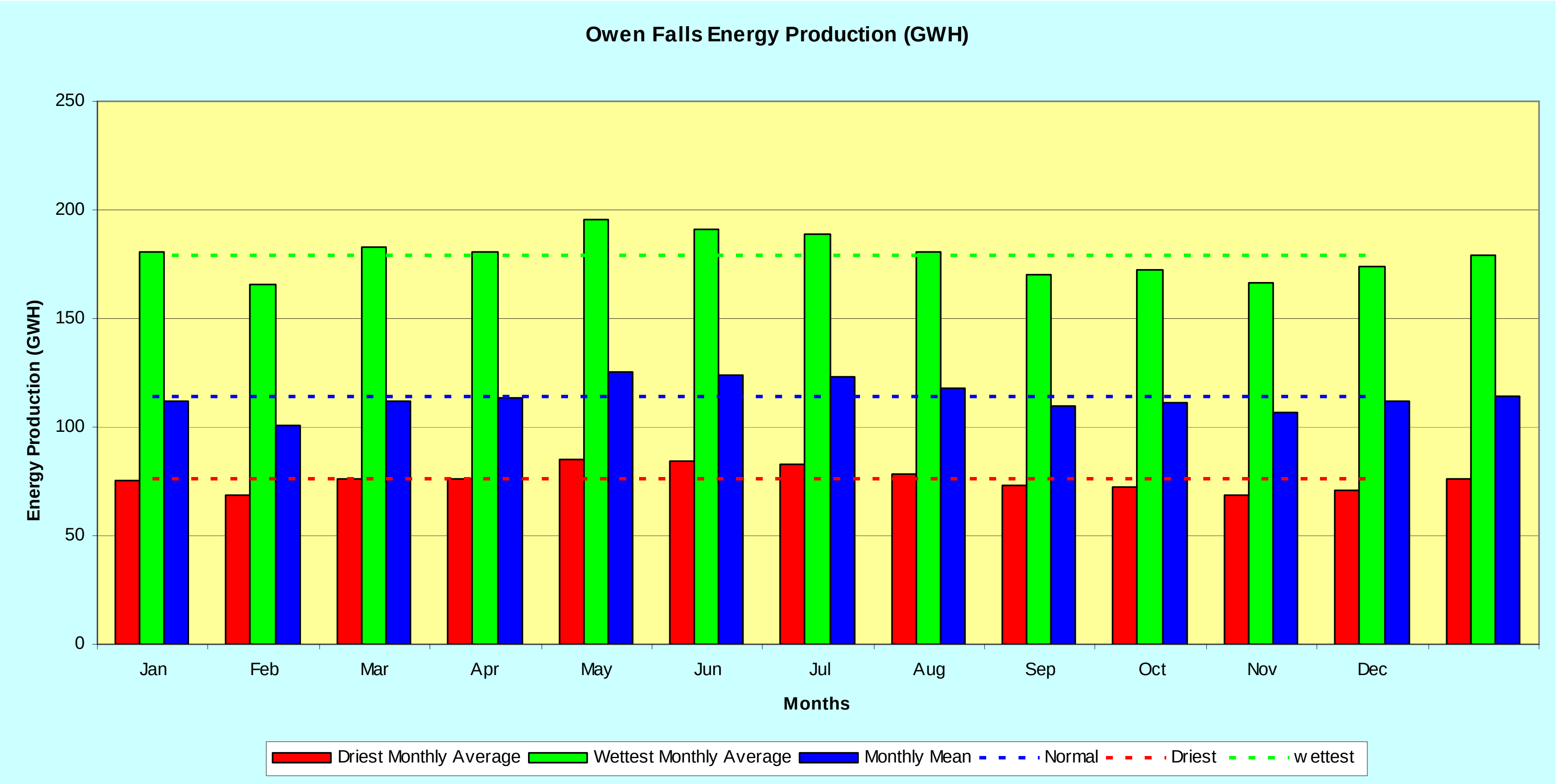
MONTHLY AVERAGE ELEVATION FOR LAKE VICTORIA



ANNUAL AVERAGE ELEVATION



OWEN FALLS MONTHLY ENERGY PRODUCTION (GWH)



Dry and Wet Statistics (Energy)

Months	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Average Annual
Driest Monthly Average	75.6	68.6	76.2	76.0	85.3	84.5	83.1	78.1	73.3	72.1	68.9	70.9	
Wettest Monthly Average	180.8	165.6	183.2	180.9	195.2	191.3	188.7	180.9	170.0	172.2	166.5	173.85	
Monthly Mean	111.7	101.1	112.1	113.3	125.2	123.8	123.2	117.6	110.1	110.9	106.6	111.7	113.9

COMMENTS

- Dongola, Diem and Khartoum have a similar outflow pattern in the period Jun-Nov
- Diem and Khartoum have wet and dry climatic conditions occurin at the same times
- The Pakwatch-Malakal reach shows a negative loss (i.e. gain) in Aug-Sep-Oct
- The Pakwatch-Malakal reach shows highest water loss around 1967, immediately after the wettest period
- Energy production at Owen Falls is highest in Jun coinciding with the period of highest elevation of L. Victoria

Nile DST RRSM Applications

Responses to exercise N1

By

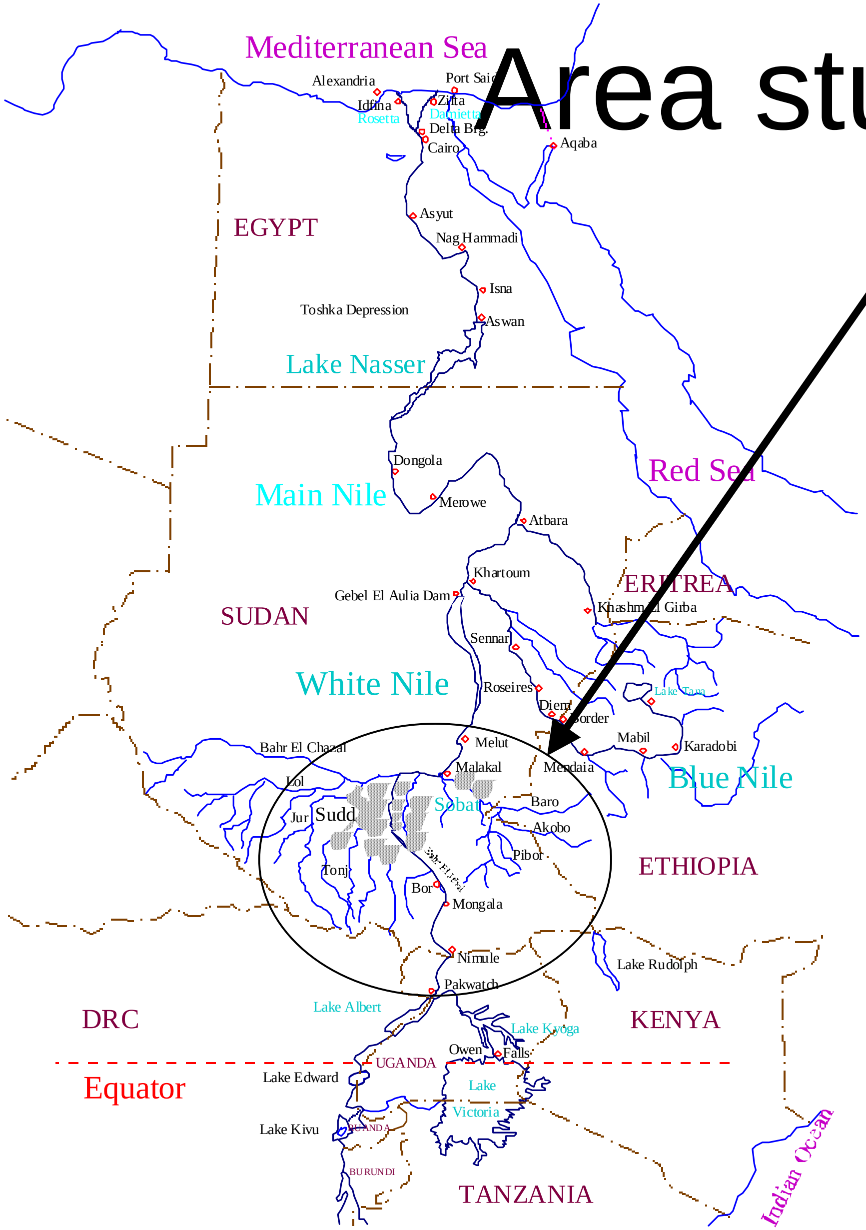
Robert Baligira and VdP Kabalisa

Rwanda

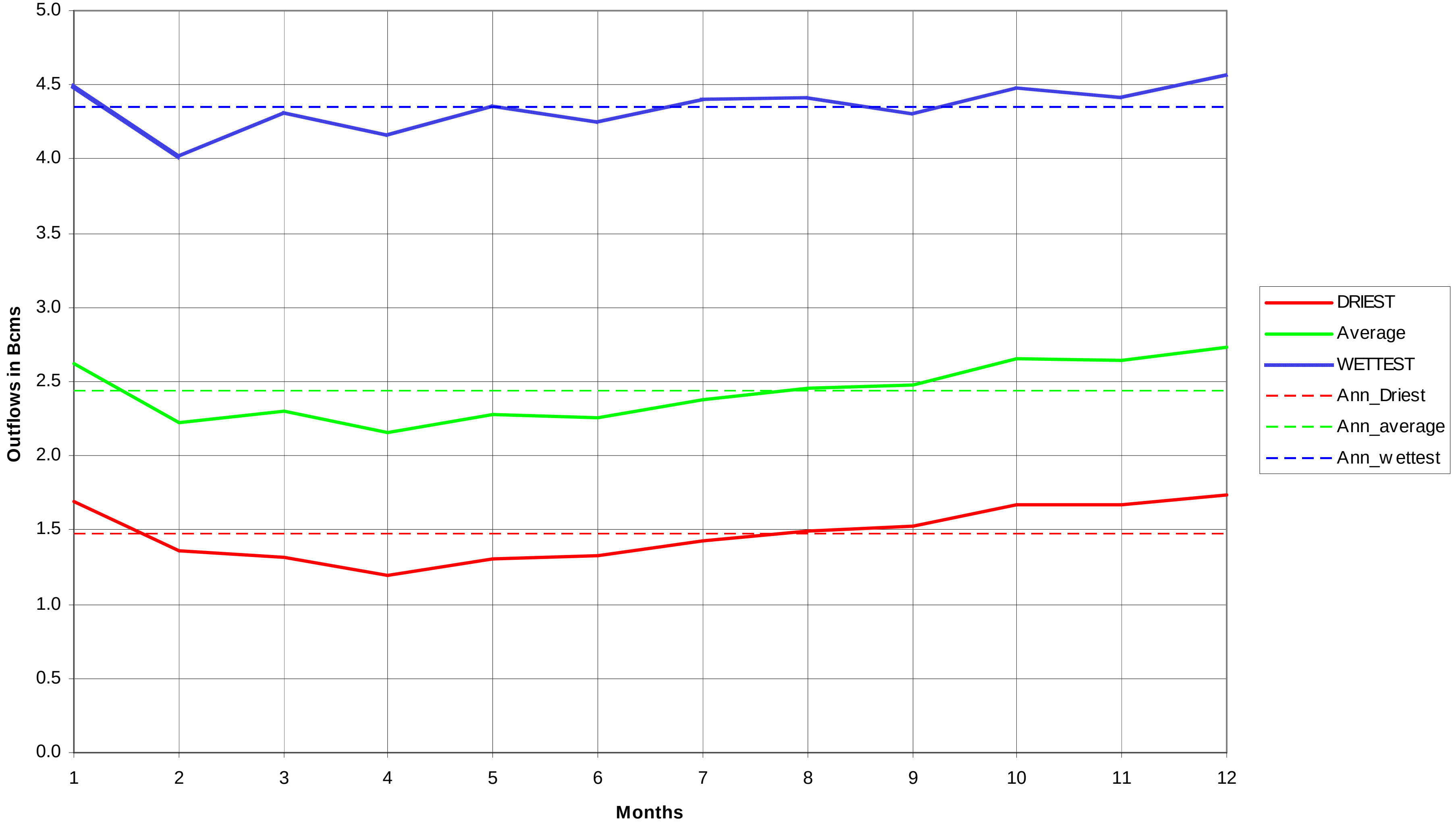
Introduction

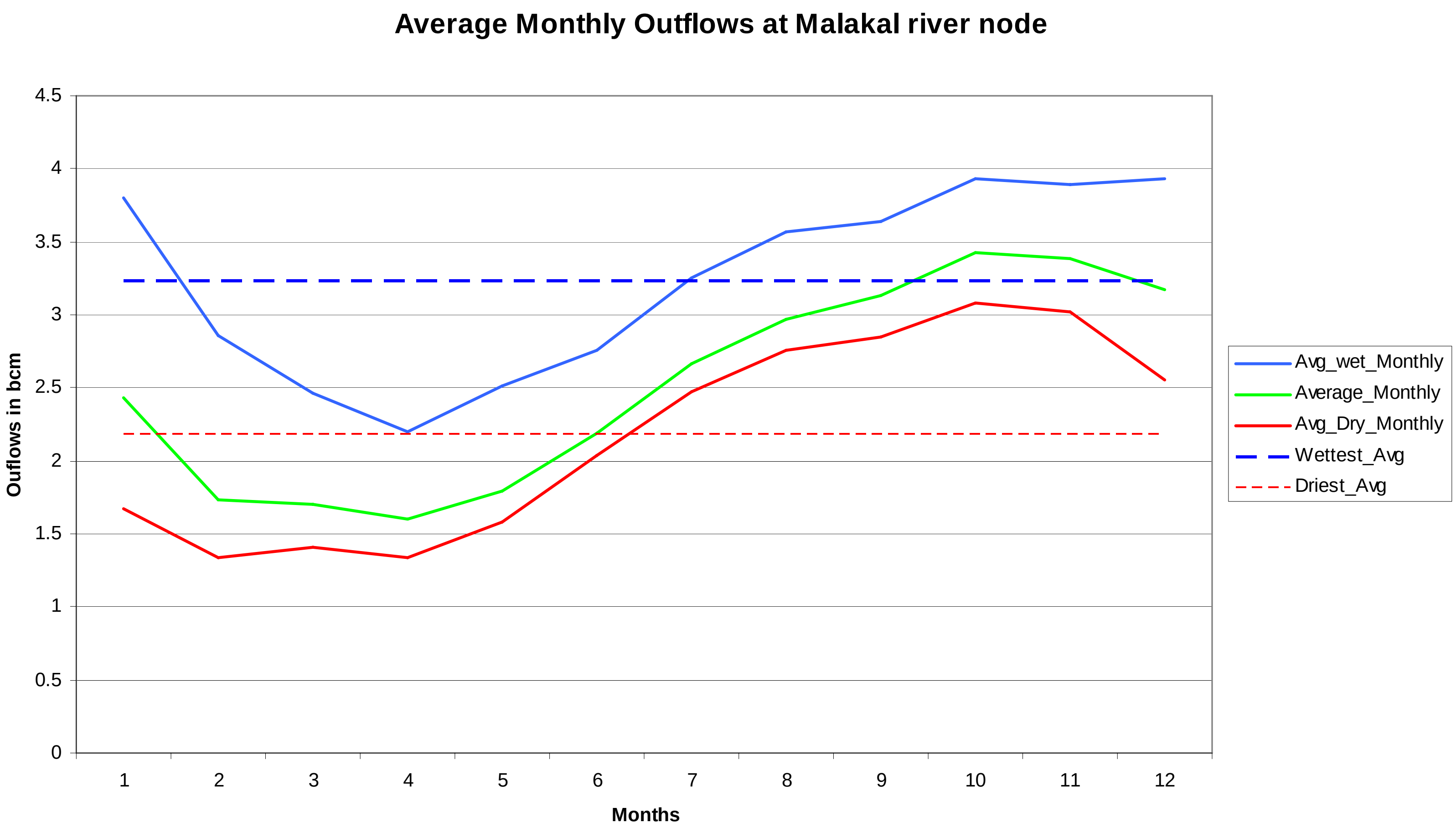
- **Scenario Assumption:**
- **Considering a baseline basin development with existing projects and water use**
- **The objective was to determine :**
  - ***The magnitude of Water Balance***
  - ***Water use and Energy generated at selected river nodes, reservoirs***

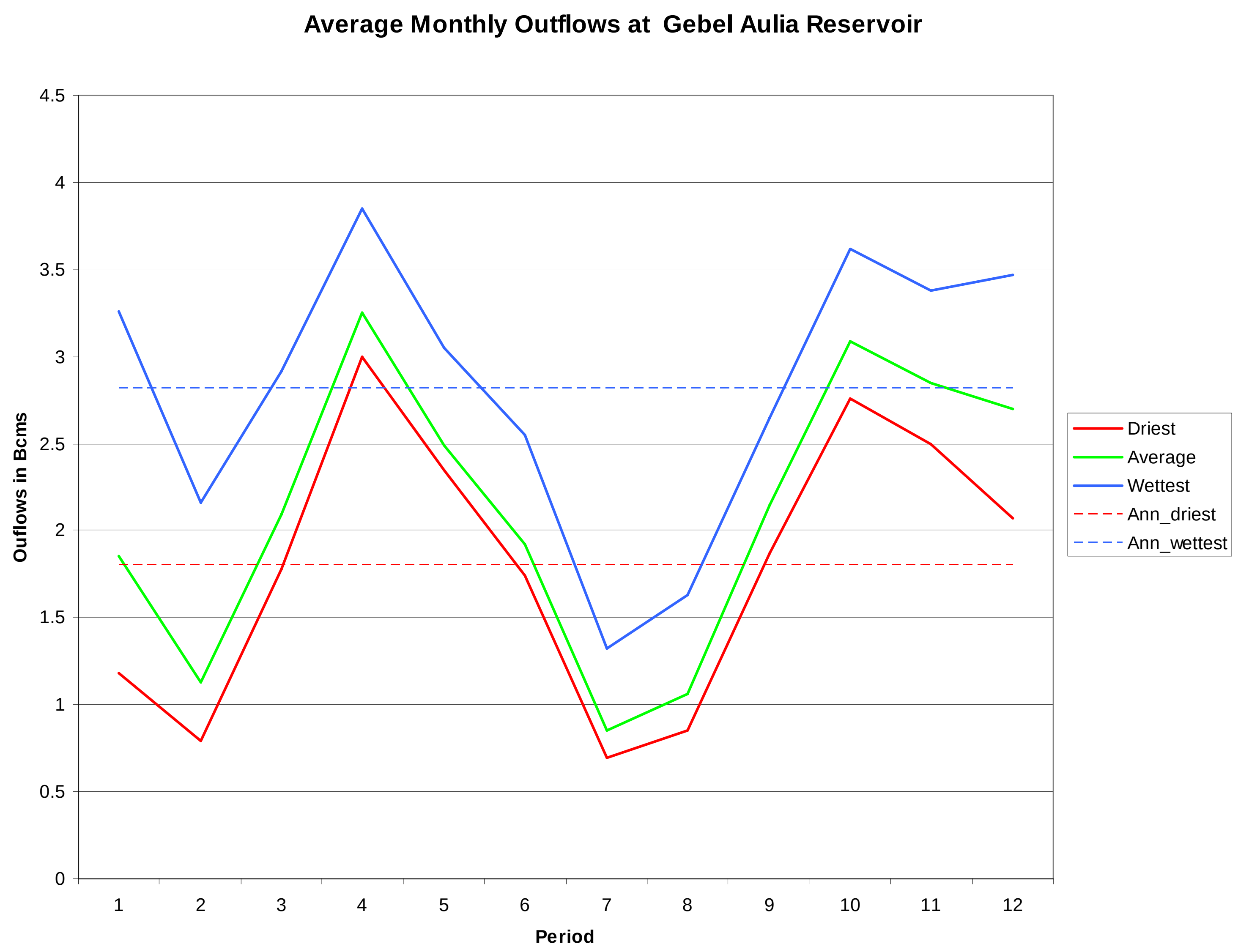
Area studied

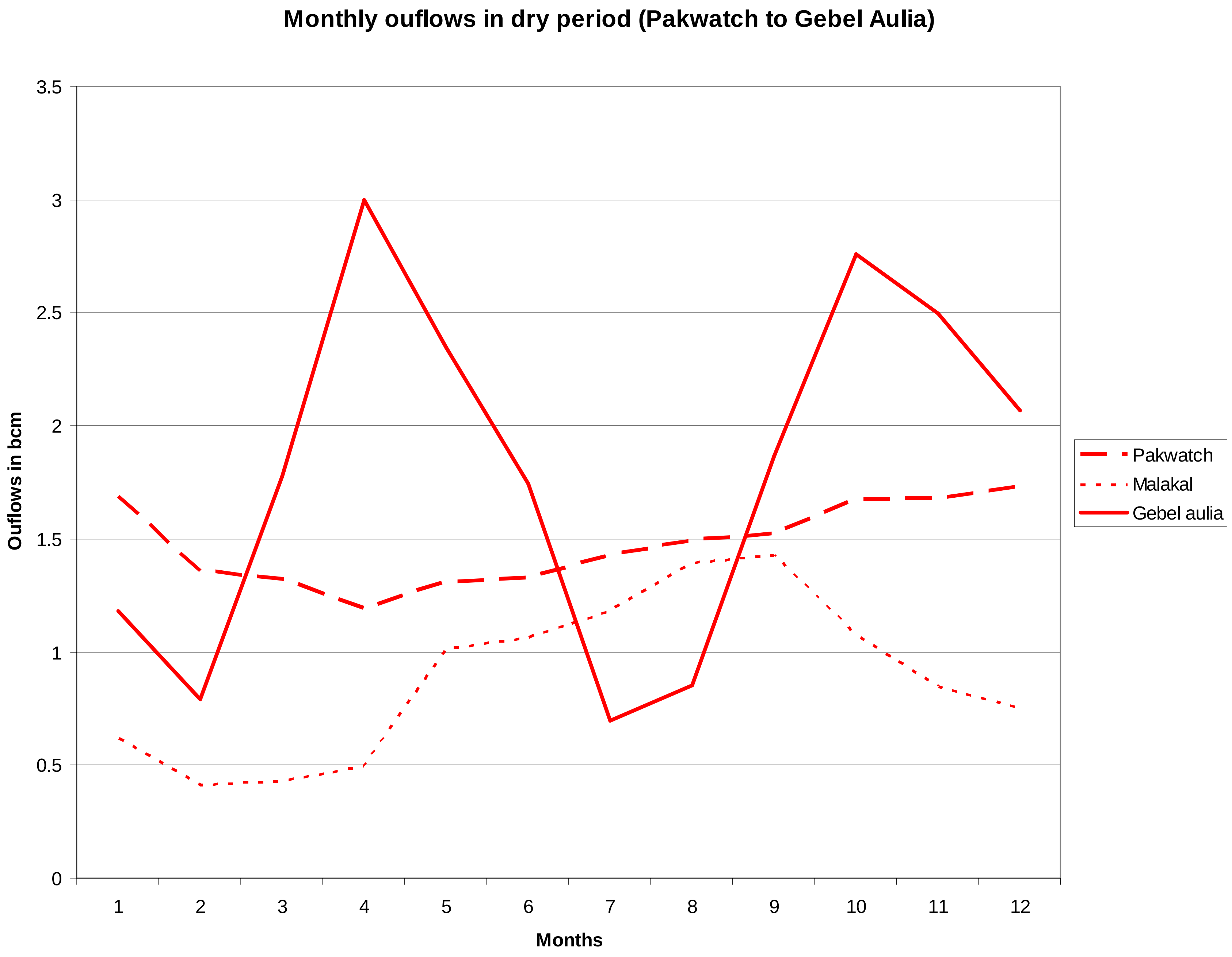


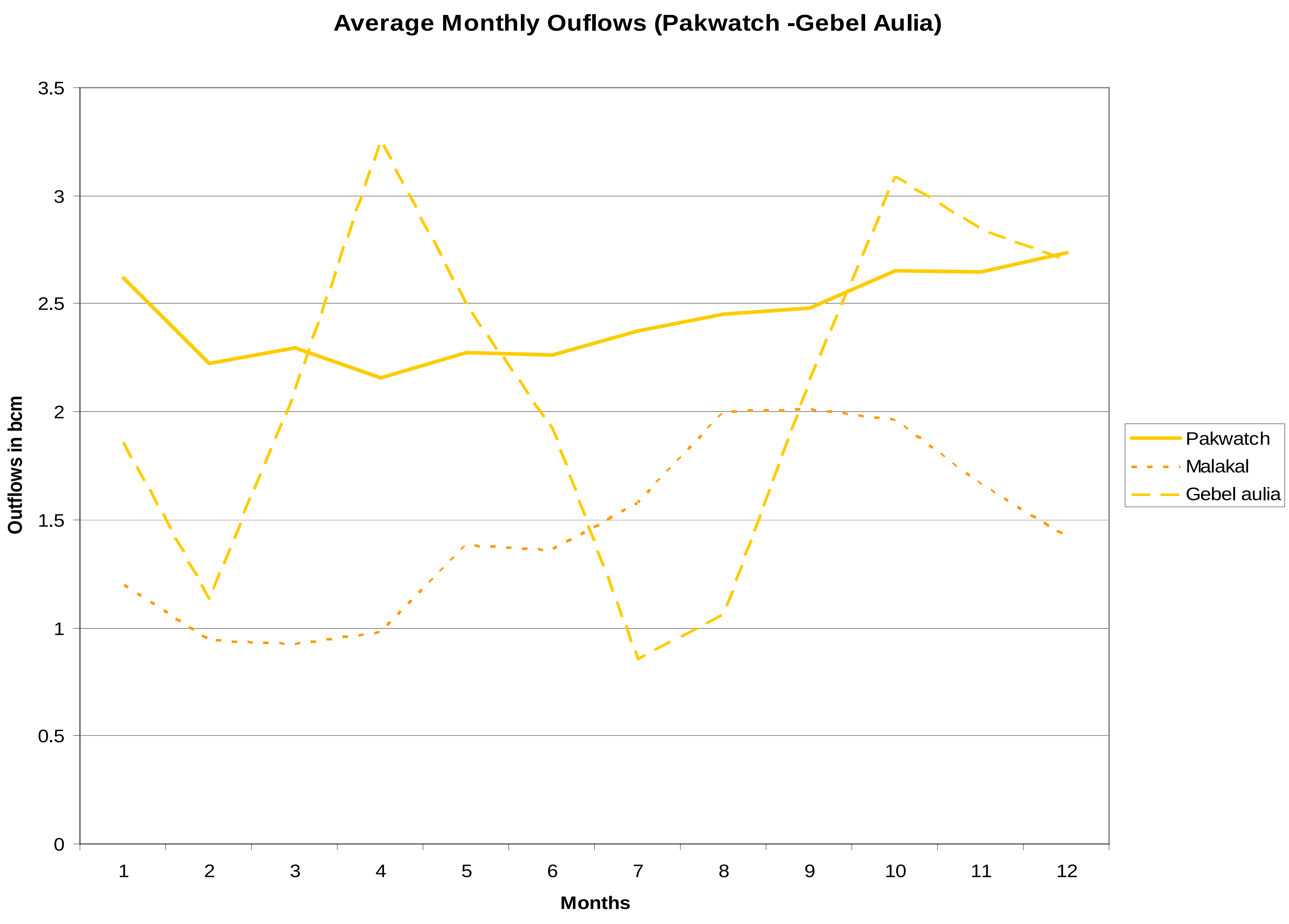
Average Monthly Outflows at Pakwatch river node

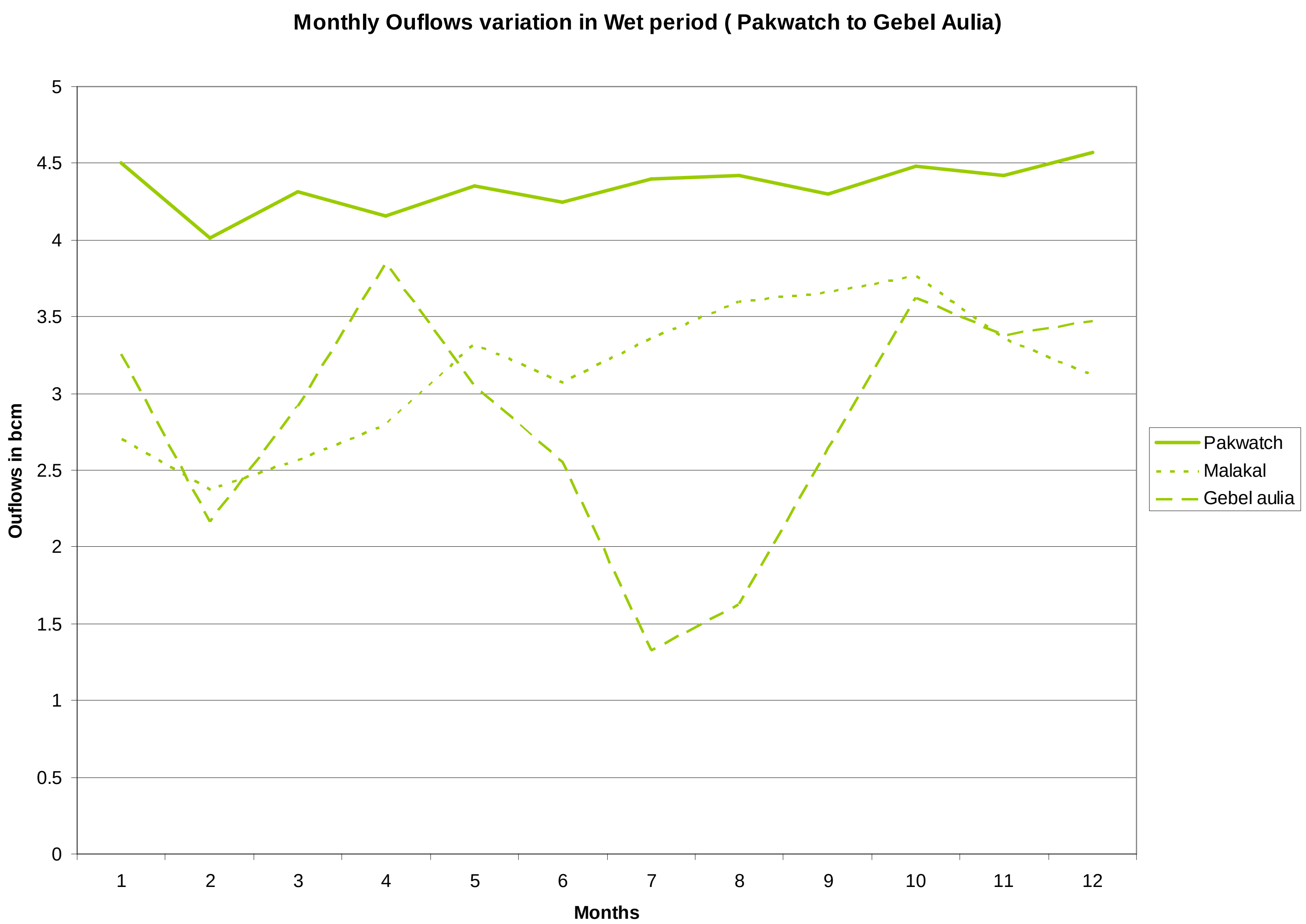



Average Monthly Outflows at Malakal river node
Ouflows in bcm
Months
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
1
2
3
4
5
6
7
8
9
10
11
12
Avg_wet_Monthly
Average_Monthly
Avg_Dry_Monthly
Wettest_Avg
Driest_Avg


Average Monthly Outflows at Gebel Aulia Reservoir
Ouflows in Bcms
Period
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
1
2
3
4
5
6
7
8
9
10
11
12
Driest
Average
Wettest
Ann_driest
Ann_wettest


Monthly ouflows in dry period (Pakwatch to Gebel Aulia)
Ouflows in bcm
3.5
3
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
7
8
9
10
11
12
Months
Pakwatch
Malakal
Gebel aulia


Average Monthly Ouflows (Pakwatch -Gebel Aulia)
Outflows in bcm
3.5
3
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
7
8
9
10
11
12
Months
Pakwatch
Malakal
Gebel aulia


Monthly Ouflows variation in Wet period (Pakwatch to Gebel Aulia)
Ouflows in bcm
Months
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
1
2
3
4
5
6
7
8
9
10
11
12
Pakwatch
Malakal
Gebel aulia

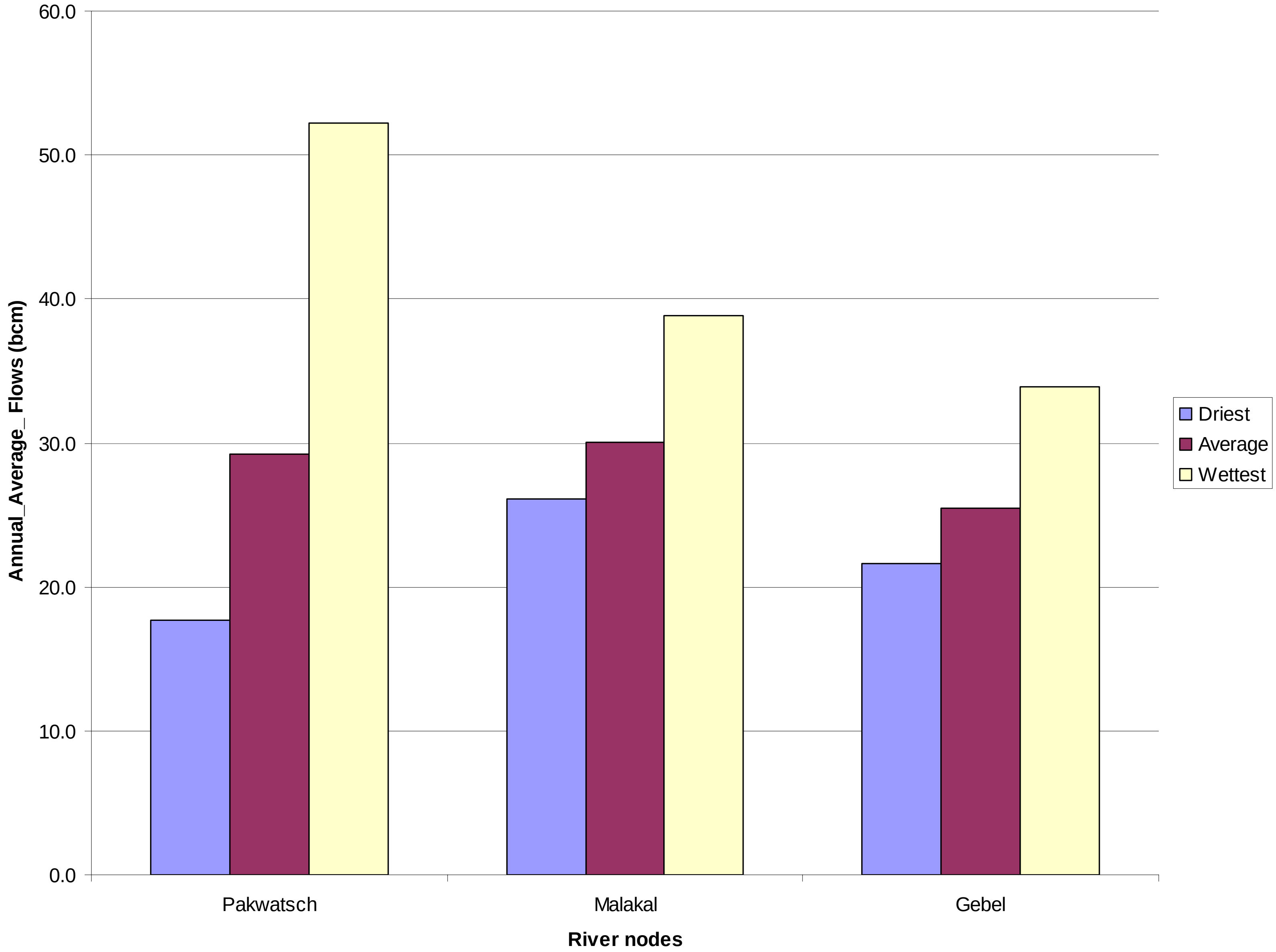
Driest and Wettest years

Gebel El Aulia Dam	Driest	Wettest
	1940	1962
	1941	1963
	1942	1964
	1943	1965
	1944	1966

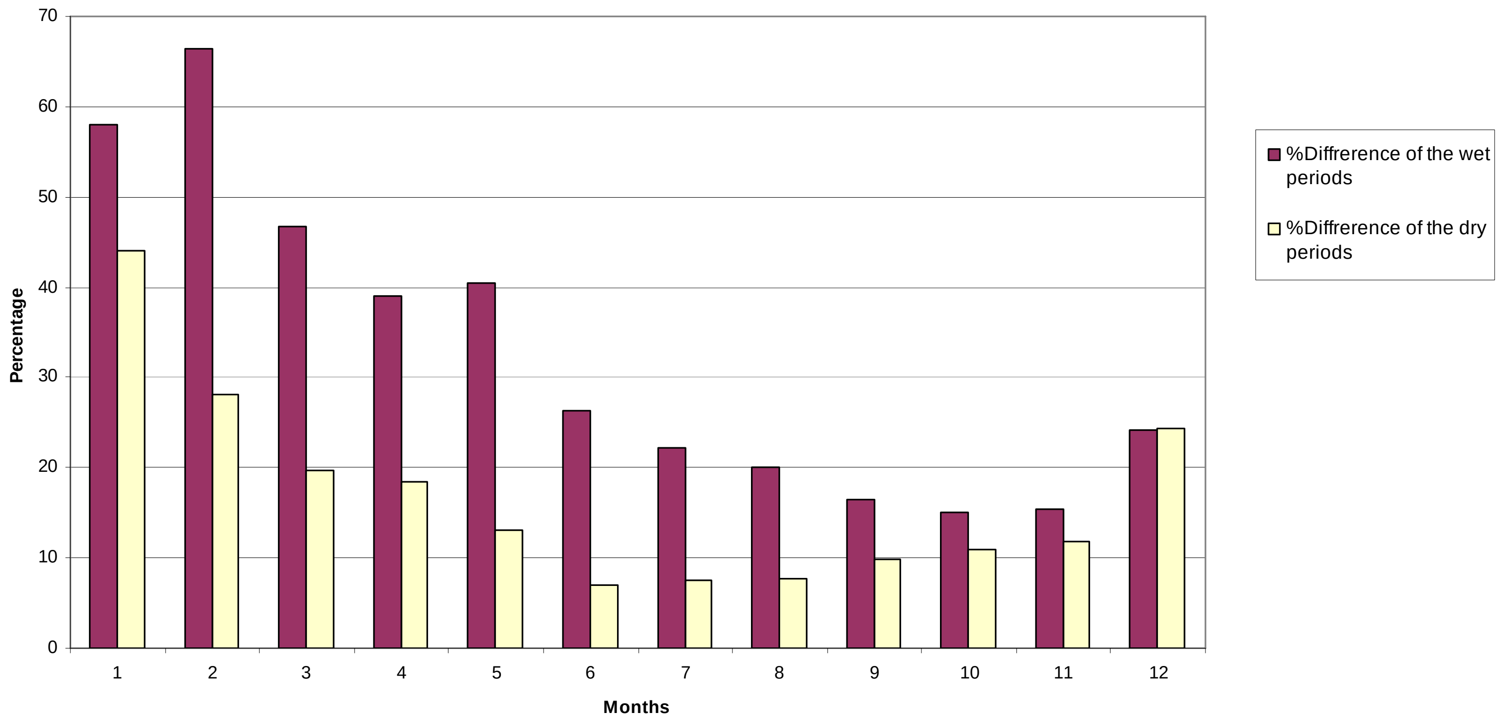
Pakwatch	Driest	Wettest
	1921	1962
	1922	1963
	1923	1964
	1924	1965
	1925	1966

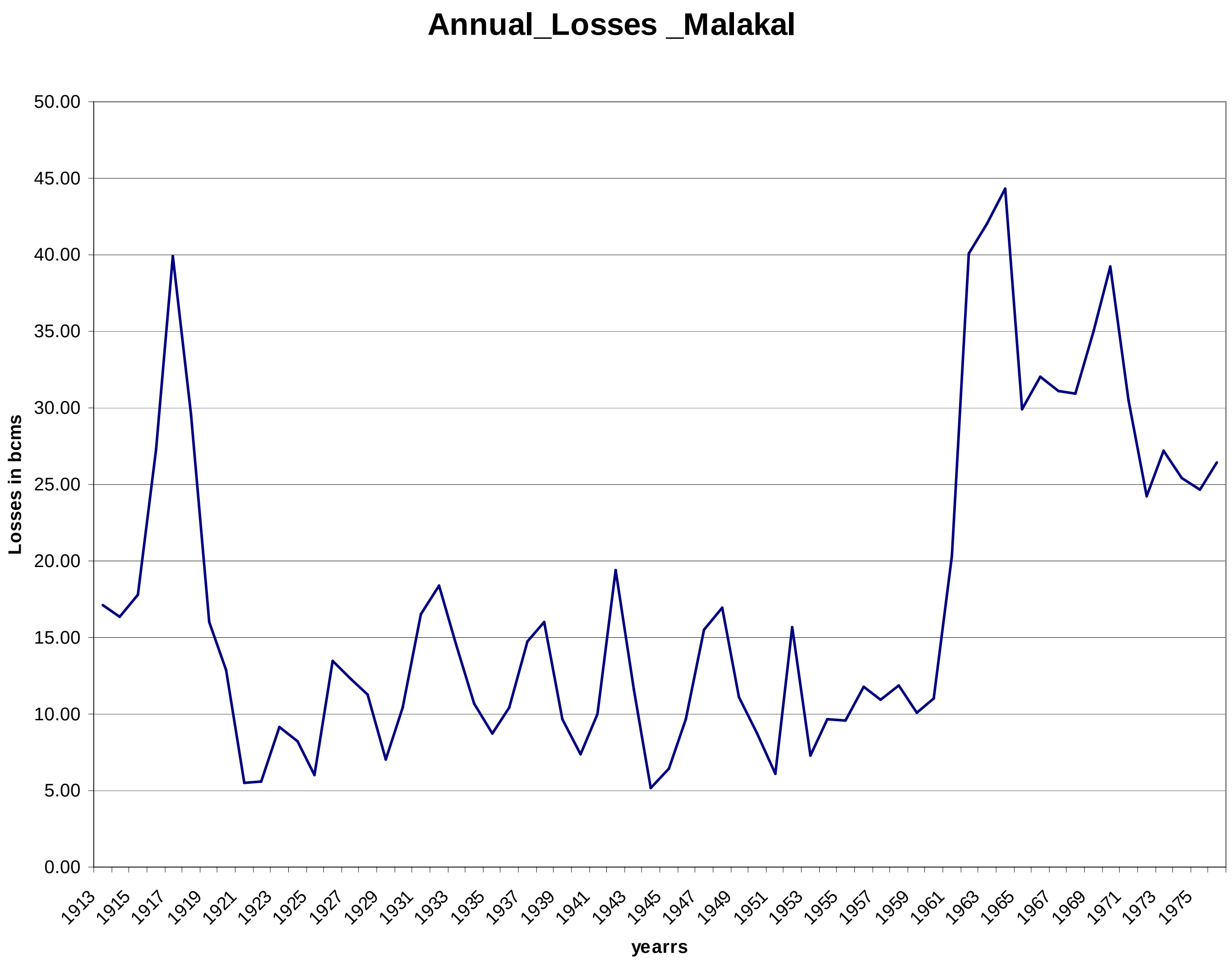
Malakal	
Driest	Wettest
1940	1962
1941	1963
1942	1964
1943	1965
1944	1966

Outflows variability
at Pakwatch, Malakal and Gebel river nodes



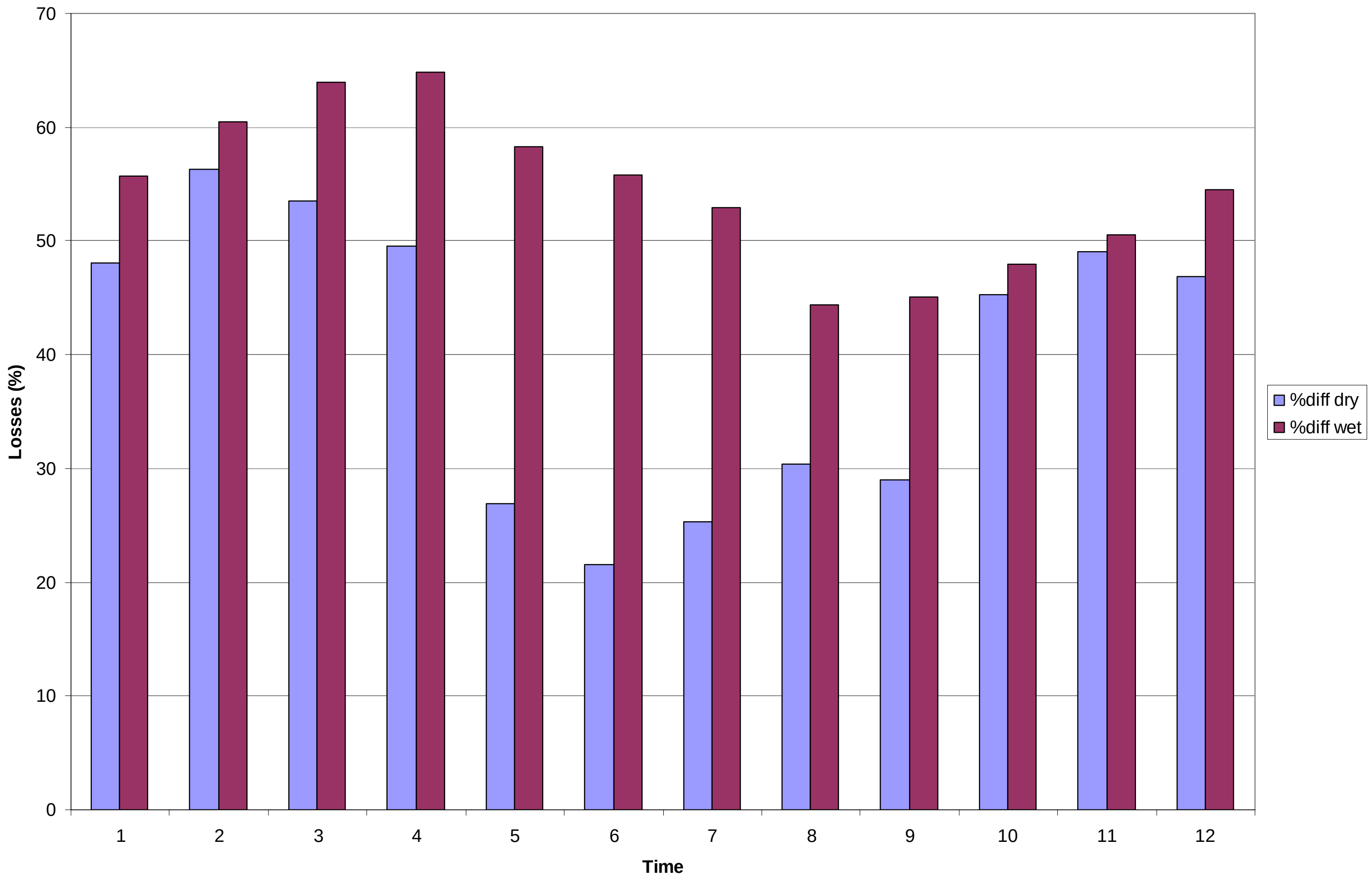
Difference from normal of water losses from Pakwatch to Malakal River during Driest and Wettest from

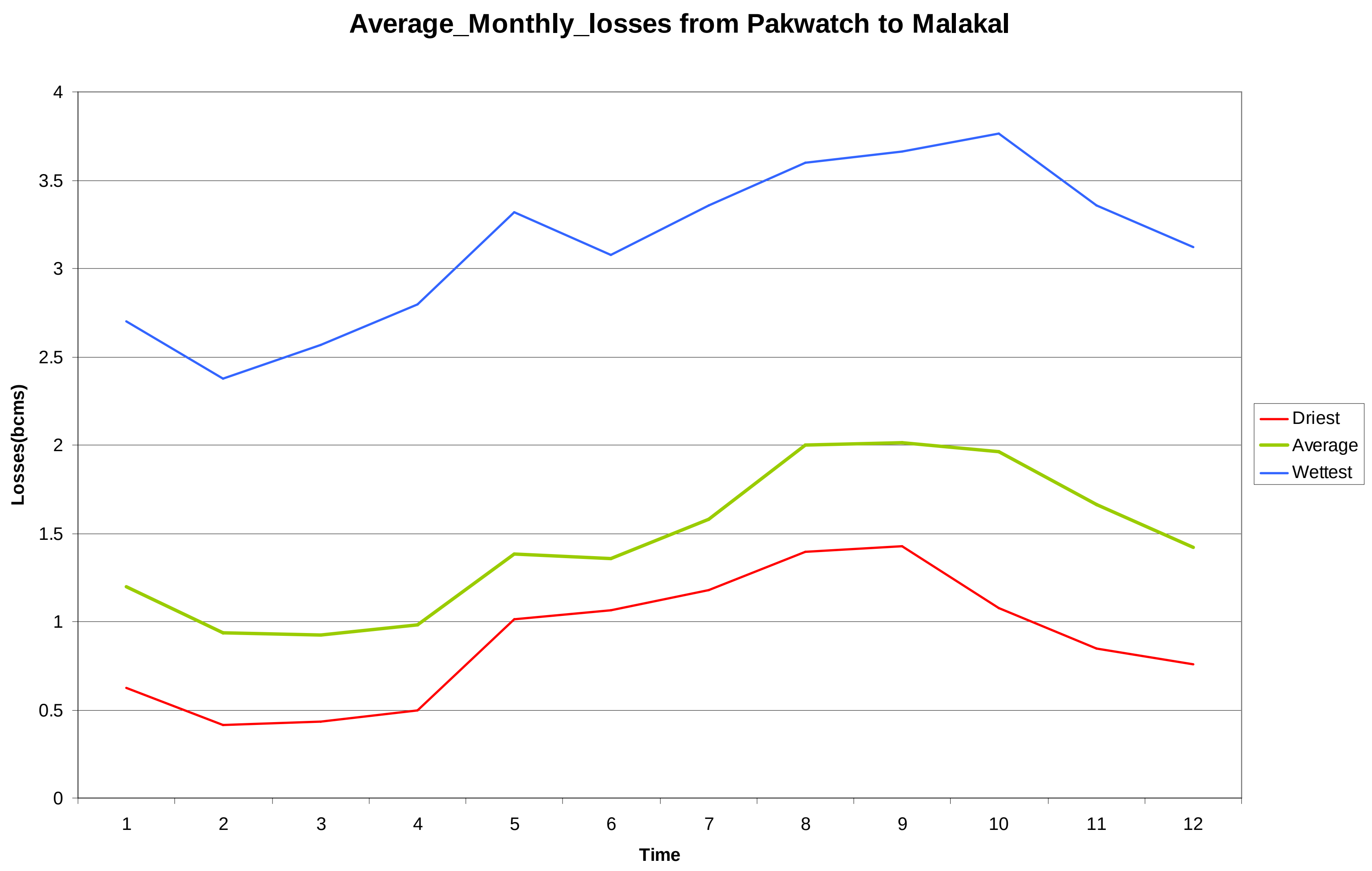




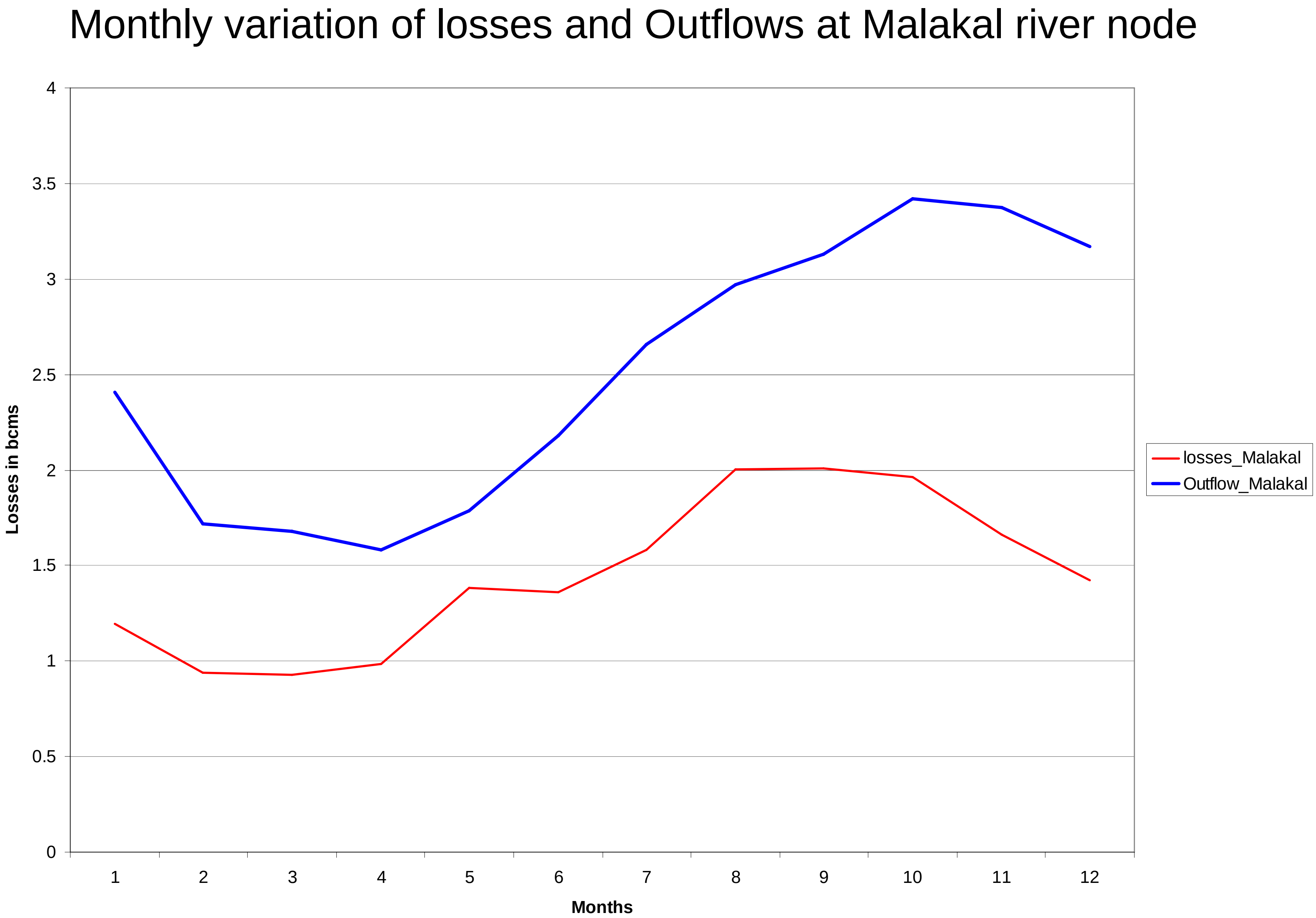
Annual_Losses _Malakal
Losses in bcms
yearrs
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
10.00
5.00
0.00
1913
1915
1917
1919
1921
1923
1925
1927
1929
1931
1933
1935
1937
1939
1941
1943
1945
1947
1949
1951
1953
1955
1957
1959
1961
1963
1965
1967
1969
1971
1973
1975

Monthly losses variability to the normal at Malakal River Node in %

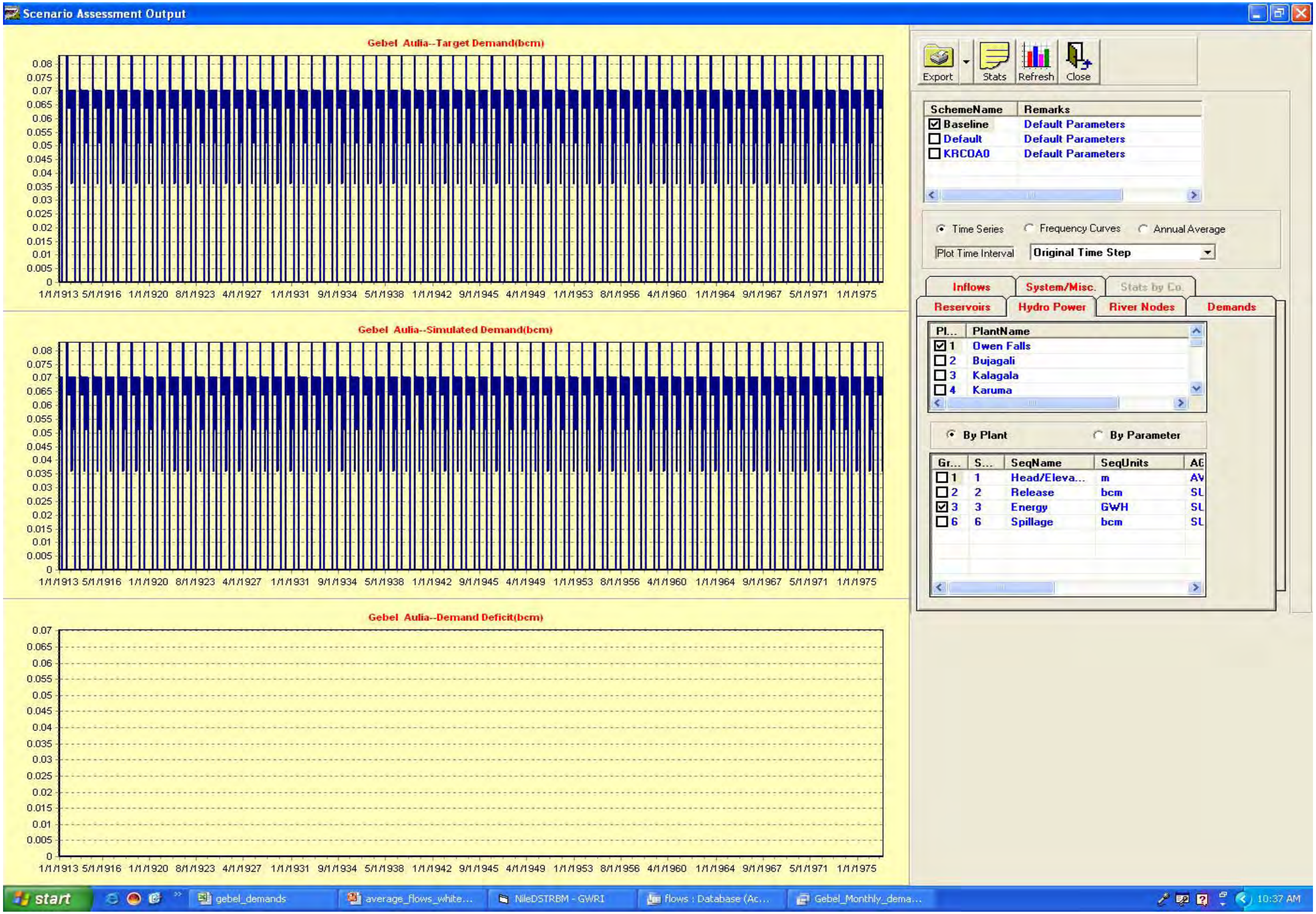




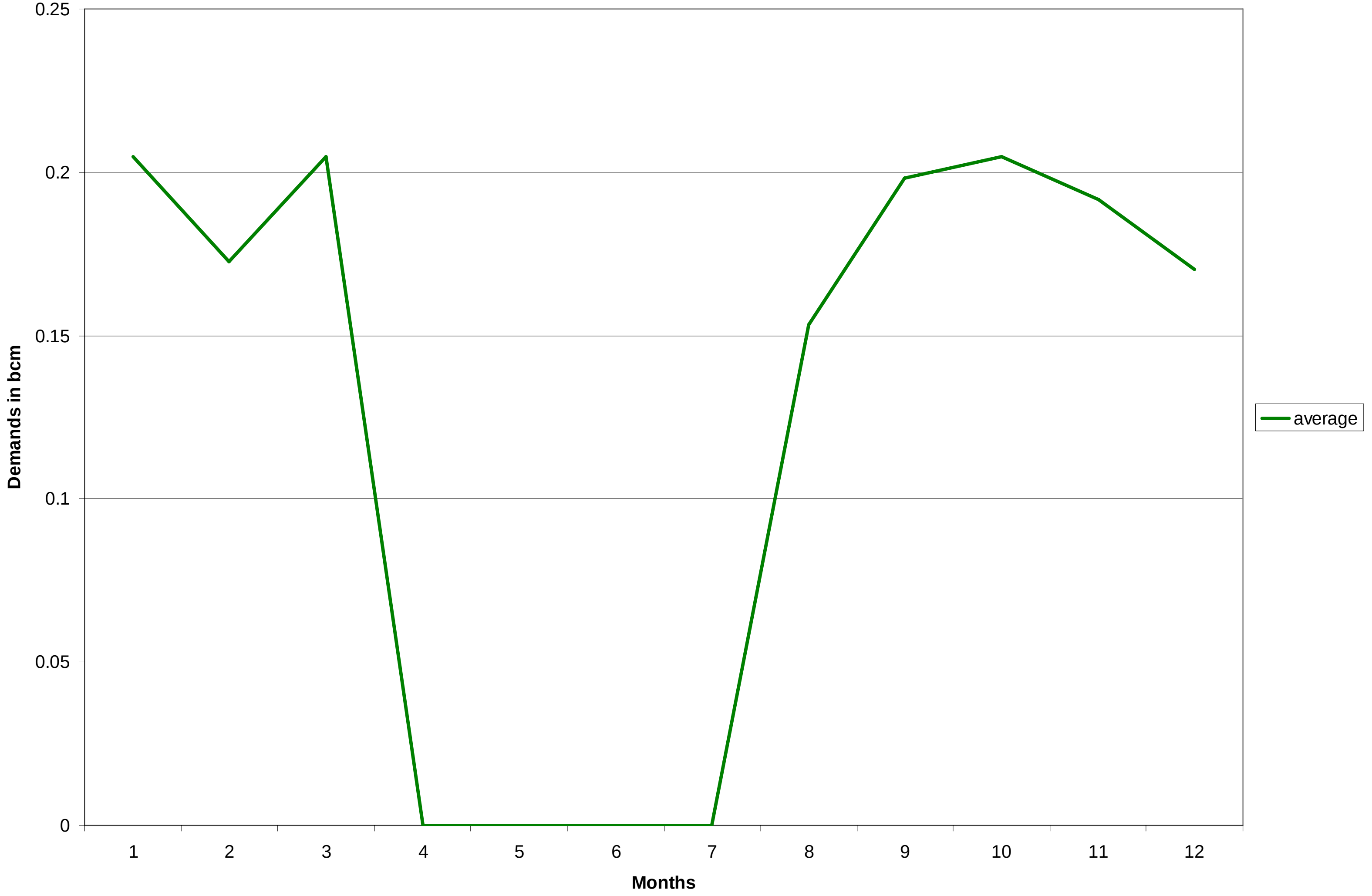
Average_Monthly_losses from Pakwatch to Malakal
Losses(bcms)
4
3.5
3
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
7
8
9
10
11
12
Time
Driest
Average
Wettest


Monthly variation of losses and Outflows at Malakal river node
Losses in bcms
Months
0
0.5
1
1.5
2
2.5
3
3.5
4
1
2
3
4
5
6
7
8
9
10
11
12
losses_Malakal
Outflow_Malakal

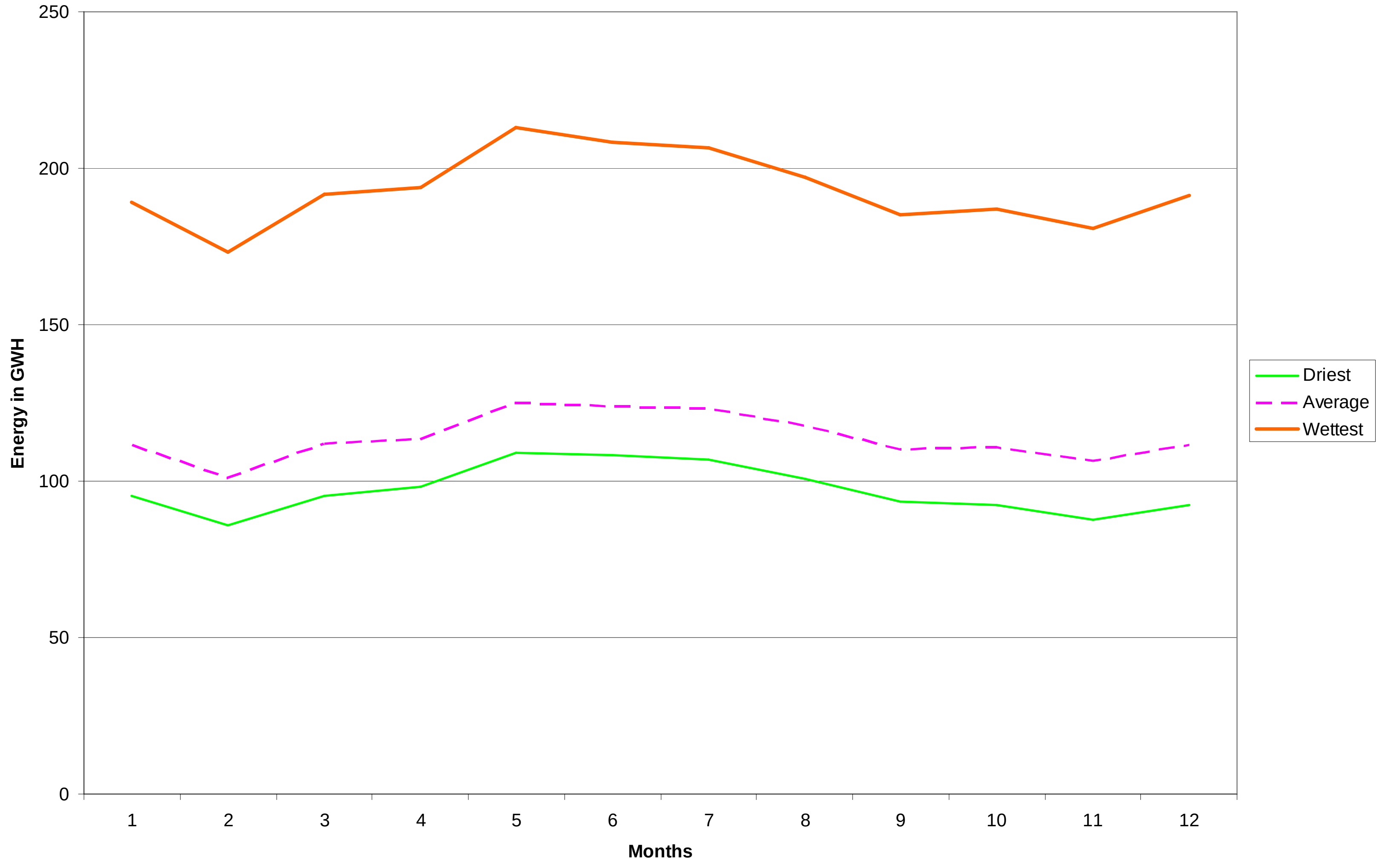
Reliability of meeting water use at Gebel El Aulia



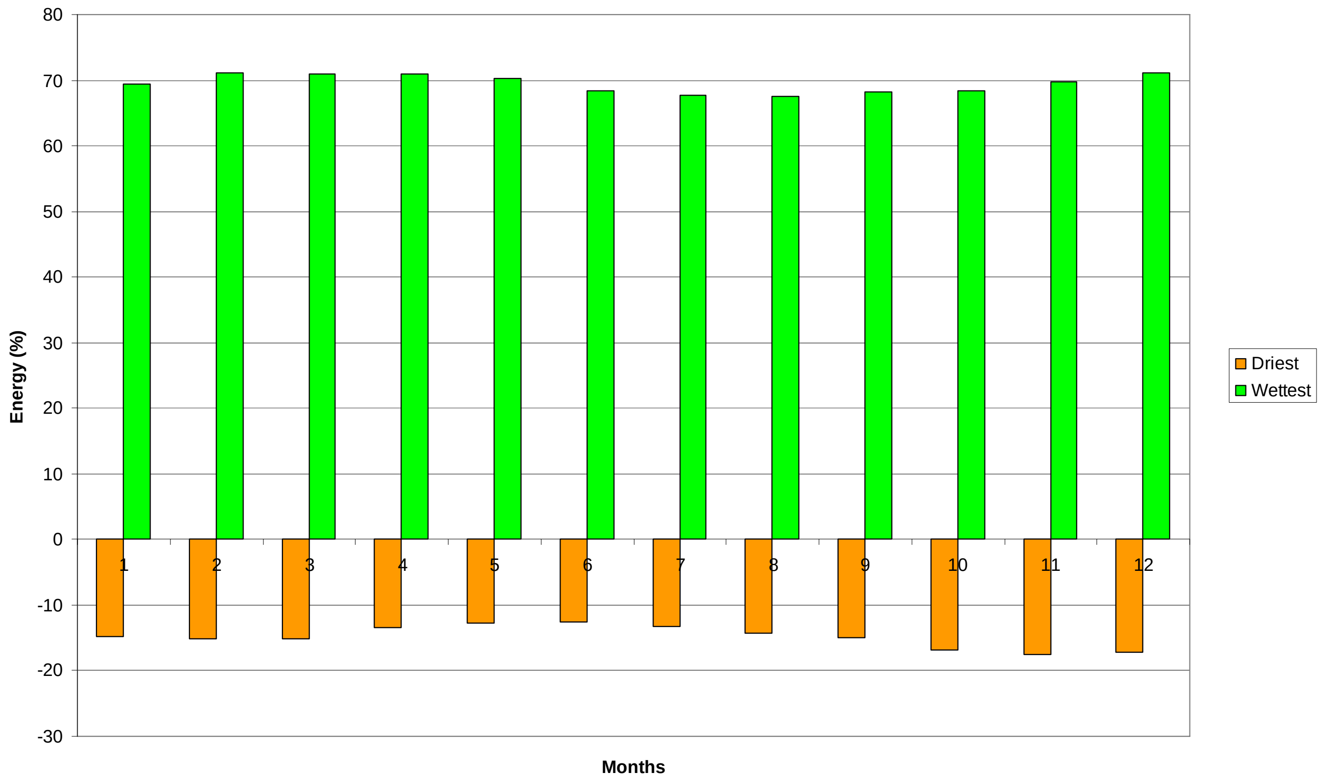
Average_Target_Demand at Gebel Aulia



Monthly Energy variability at Owen Falls



Energy variability at Owen Falls in dry and wet periods



Main Findings

- Average monthly variations of outflows tend to be uniform from Pakwatch to Gebel El Aulia with more fluctuation in Gebel El Aulia where they tend to increase from March to May and from September to October
- The variation of ouflows for the dry and wet years tend to be high at Pakwatch river node with high variation during the wet years, more internal variation at Gebel aulia
- Annual losses are varying between 5 and 43 bcm at Malakal
- Monthly losses are generally high from August to November with average values of 1 to 2 bcm
- Outflows compared to the loss at Malakal are quite high with a value of more 1.5 bcm
- At Gebel aulia, the reliabilty to meet the demand is 100%
- Average Monthly variation of energy at Owen falls is around 115 gwh with high variation in wet years where Values range around 200 Gwh

Nile DST RRSM Application

Sudan

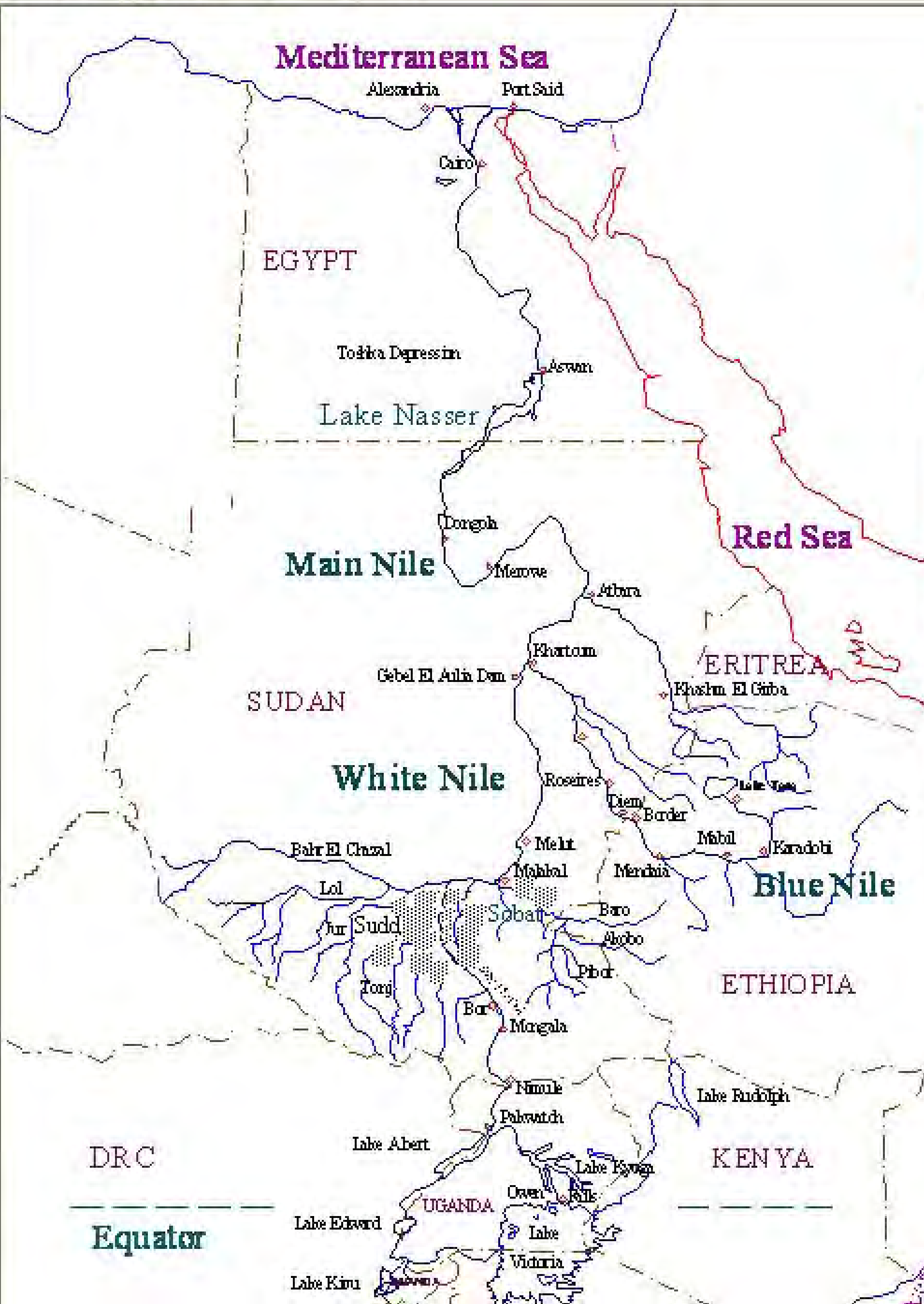
By

Ahmed M.A. Abushemila &

Younis A. Gismalla

NileDSTRBM - GWRI

Database Applications Tools Help Exit



Nile DST River Basin Management Module

Georgia Water Resources Institute

Georgia Institute of Technology

Food and Agriculture Organization of the United Nations

Nile DST RRSM Exercise 1

1. Water Balance and Water Use Assessments

This exercise aims to determine the magnitude of the water balance terms in various Nile River reaches. The river reaches are defined as follows:

(a) Southern Nile system up to the border of Uganda and Sudan (Nimule);

(b) Nimule to Malakal upstream of the Sobat junction;

(c) Malakal (upstream of the Sobat junction) to downstream of Gebel El Aulia Dam; (Namely, before the junction of the White and Blue Niles;)

(d) Ethiopian Blue Nile up to the Sudanese border;

(e) Sudanese Blue Nile up to the junction with the White Nile;

(f) Main Nile from the Blue and White Nile junction up to the entrance of Lake Nasser (High Aswan Dam reservoir);

(g) Egyptian Nile, including Lake Nasser, to the Mediterranean Sea.

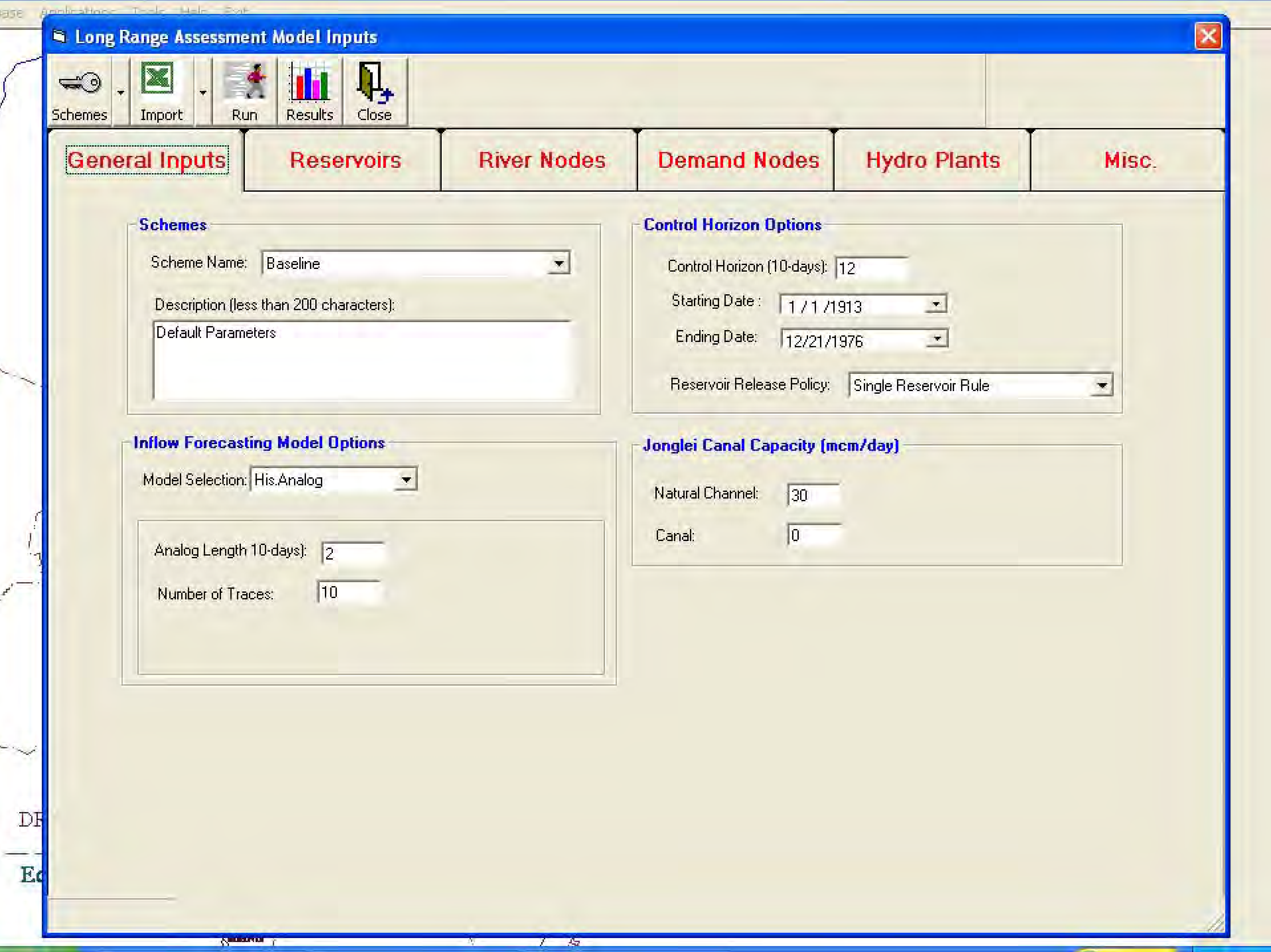
1.1 Consider first a baseline basin development scenario with existing projects and water use targets. For each one of the above-mentioned reaches, determine and graph the following quantities: (Generate one graph per river reach.)

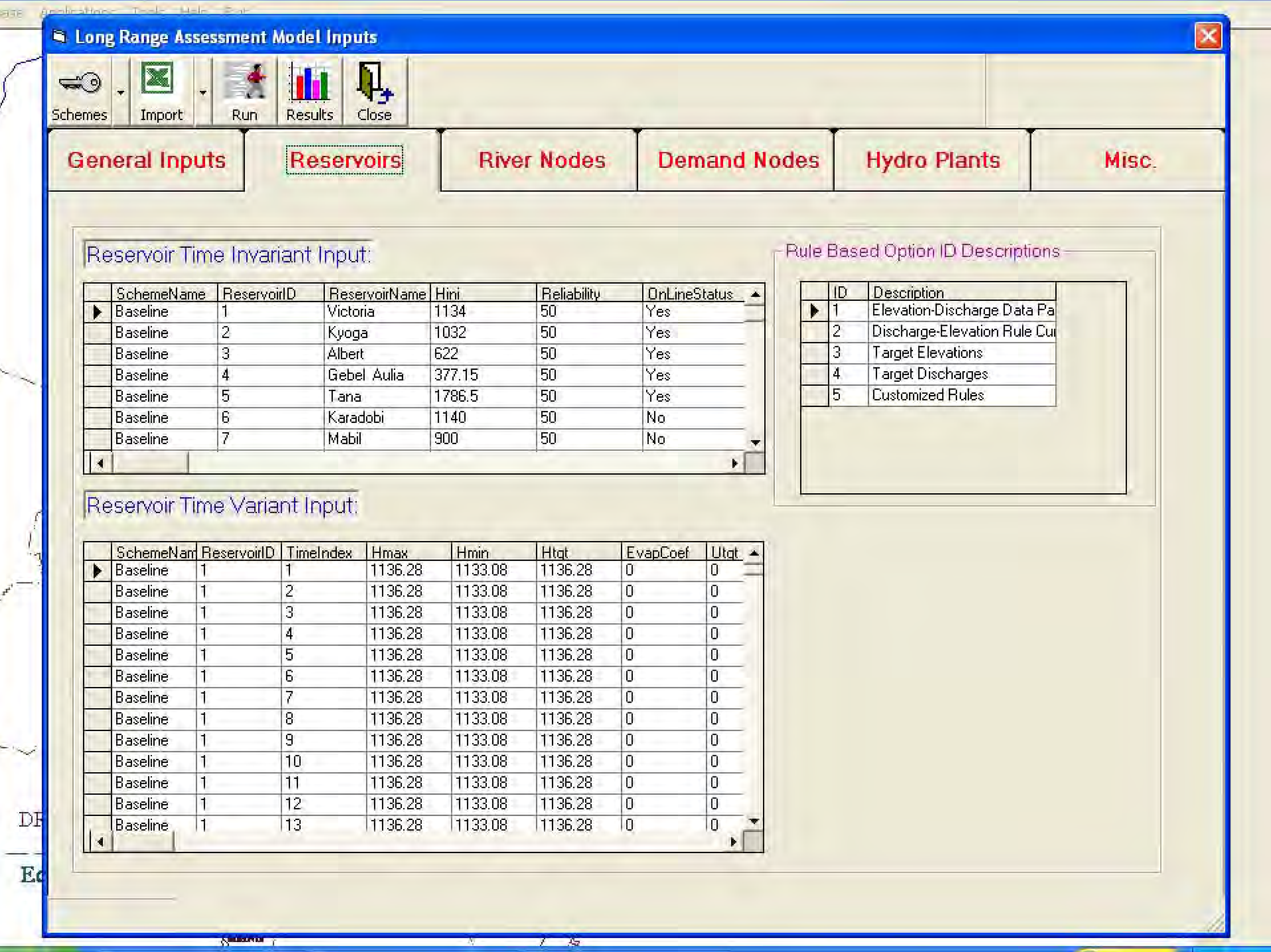
- Average monthly and annual reach outflows over the period of record;
- Average monthly and annual reach outflows over the driest five years of the record; (Indicate the drought years;)
- Average monthly and annual reach outflows over the wettest five years of the record; (Indicate the five wettest years of record;)
- Develop quantitative measures of the outflow variability (e.g., percent difference of dry and wet periods from normal) and determine if wet and dry climatic periods occur at the same time across the various river reaches; Specify which river reaches behave similarly in this respect.

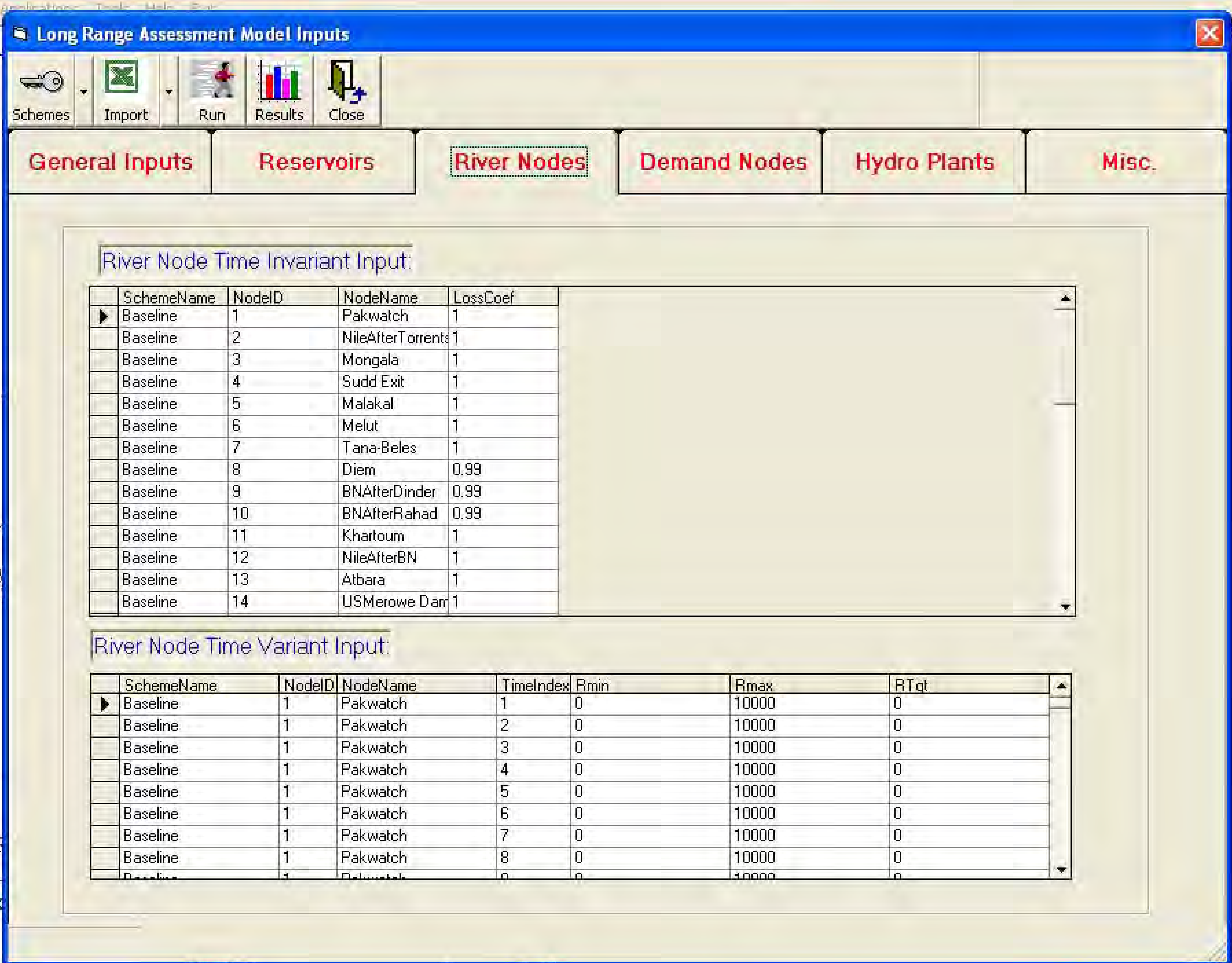
Nile DST RRSM Application

1. Water Balance and Water Uses Assessments:

The baseline basin development scenario with the existing projects and water use targets, main assumptions summarized in the following slides, is used to compute and graph the quantities in Exercise 1.1.


Long Range Assessment Model Inputs
Schemes
Import
Run
Results
Close
General Inputs
Reservoirs
River Nodes
Demand Nodes
Hydro Plants
Misc.
Schemes
Scheme Name:
Baseline
Description (less than 200 characters):
Default Parameters
Control Horizon Options
Control Horizon (10-days):
12
Starting Date :
1 / 1 /1913
Ending Date:
12/21/1976
Reservoir Release Policy:
Single Reservoir Rule
Inflow Forecasting Model Options
Model Selection:
His.Analog
Analog Length 10-days):
2
Number of Traces:
10
Jonglei Canal Capacity (mcm/day)
Natural Channel:
30
Canal:
0

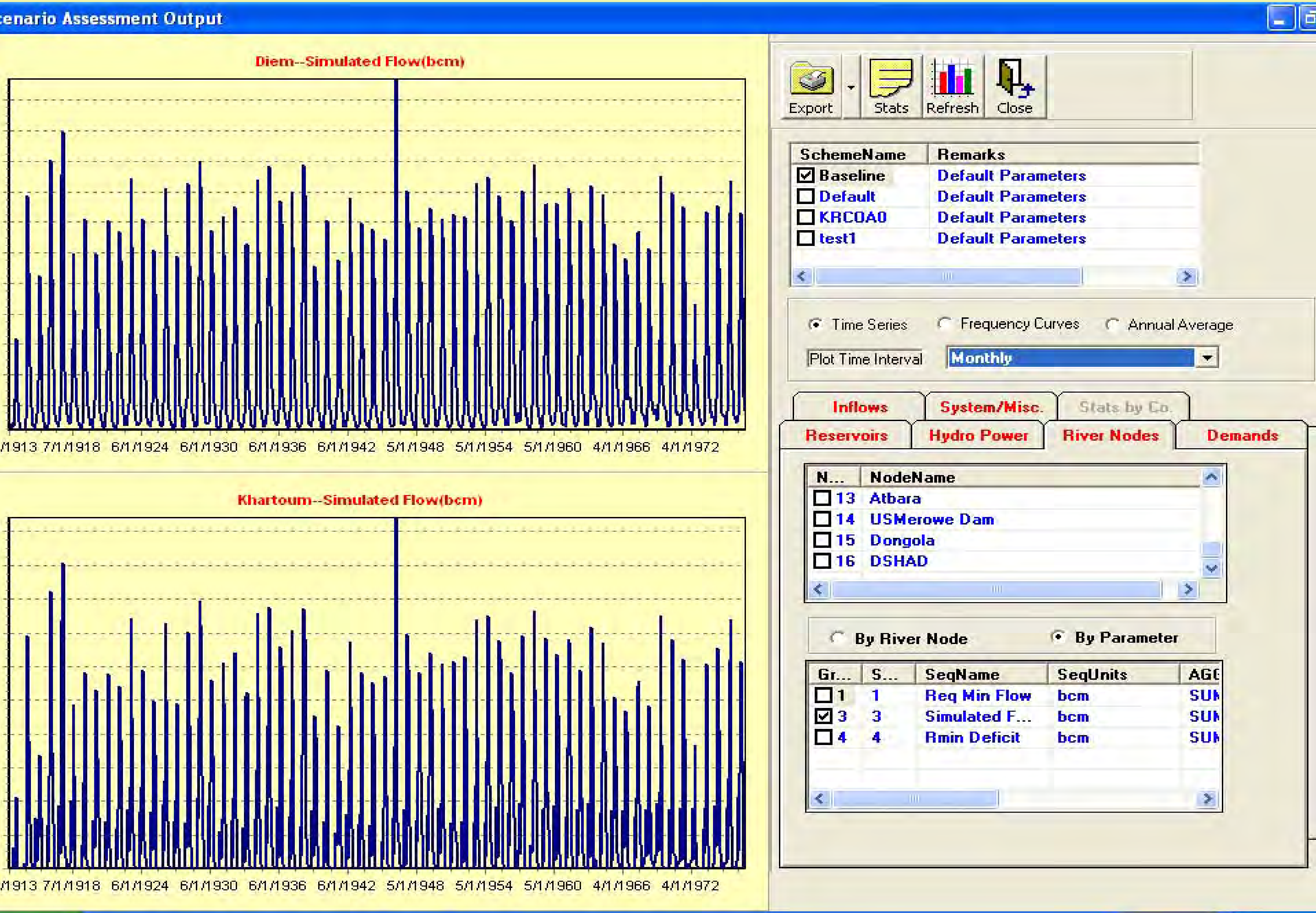

Long Range Assessment Model Inputs
Schemes
Import
Run
Results
Close
General Inputs
Reservoirs
River Nodes
Demand Nodes
Hydro Plants
Misc.
Reservoir Time Invariant Input:
SchemeName | ReservoirID | ReservoirName | Hini | Reliability | OnLineStatus
Baseline | 1 | Victoria | 1134 | 50 | Yes
Baseline | 2 | Kyoga | 1032 | 50 | Yes
Baseline | 3 | Albert | 622 | 50 | Yes
Baseline | 4 | Gebel Aulia | 377.15 | 50 | Yes
Baseline | 5 | Tana | 1786.5 | 50 | Yes
Baseline | 6 | Karadobi | 1140 | 50 | No
Baseline | 7 | Mabil | 900 | 50 | No
Rule Based Option ID Descriptions
ID | Description
1 | Elevation-Discharge Data Pa
2 | Discharge-Elevation Rule Cu
3 | Target Elevations
4 | Target Discharges
5 | Customized Rules
Reservoir Time Variant Input:
SchemeNam | ReservoirID | TimeIndex | Hmax | Hmin | Htgt | EvapCoef | Utgt
Baseline | 1 | 1 | 1136.28 | 1133.08 | 1136.28 | 0 | 0
Baseline | 1 | 2 | 1136.28 | 1133.08 | 1136.28 | 0 | 0
Baseline | 1 | 3 | 1136.28 | 1133.08 | 1136.28 | 0 | 0
Baseline | 1 | 4 | 1136.28 | 1133.08 | 1136.28 | 0 | 0
Baseline | 1 | 5 | 1136.28 | 1133.08 | 1136.28 | 0 | 0
Baseline | 1 | 6 | 1136.28 | 1133.08 | 1136.28 | 0 | 0
Baseline | 1 | 7 | 1136.28 | 1133.08 | 1136.28 | 0 | 0
Baseline | 1 | 8 | 1136.28 | 1133.08 | 1136.28 | 0 | 0
Baseline | 1 | 9 | 1136.28 | 1133.08 | 1136.28 | 0 | 0
Baseline | 1 | 10 | 1136.28 | 1133.08 | 1136.28 | 0 | 0
Baseline | 1 | 11 | 1136.28 | 1133.08 | 1136.28 | 0 | 0
Baseline | 1 | 12 | 1136.28 | 1133.08 | 1136.28 | 0 | 0
Baseline | 1 | 13 | 1136.28 | 1133.08 | 1136.28 | 0 | 0


Long Range Assessment Model Inputs
Schemes
Import
Run
Results
Close
General Inputs
Reservoirs
River Nodes
Demand Nodes
Hydro Plants
Misc.
River Node Time Invariant Input:
SchemeName NodeID NodeName LossCoef
Baseline 1 Pakwatch 1
Baseline 2 NileAfterTorrents 1
Baseline 3 Mongala 1
Baseline 4 Sudd Exit 1
Baseline 5 Malakal 1
Baseline 6 Melut 1
Baseline 7 Tana-Beles 1
Baseline 8 Diem 0.99
Baseline 9 BNAfterDinder 0.99
Baseline 10 BNAfterRahad 0.99
Baseline 11 Khartoum 1
Baseline 12 NileAfterBN 1
Baseline 13 Atbara 1
Baseline 14 USMerowe Dam 1
River Node Time Variant Input:
SchemeName NodeID NodeName TimeIndex Rmin Rmax RTgt
Baseline 1 Pakwatch 1 0 10000 0
Baseline 1 Pakwatch 2 0 10000 0
Baseline 1 Pakwatch 3 0 10000 0
Baseline 1 Pakwatch 4 0 10000 0
Baseline 1 Pakwatch 5 0 10000 0
Baseline 1 Pakwatch 6 0 10000 0
Baseline 1 Pakwatch 7 0 10000 0
Baseline 1 Pakwatch 8 0 10000 0

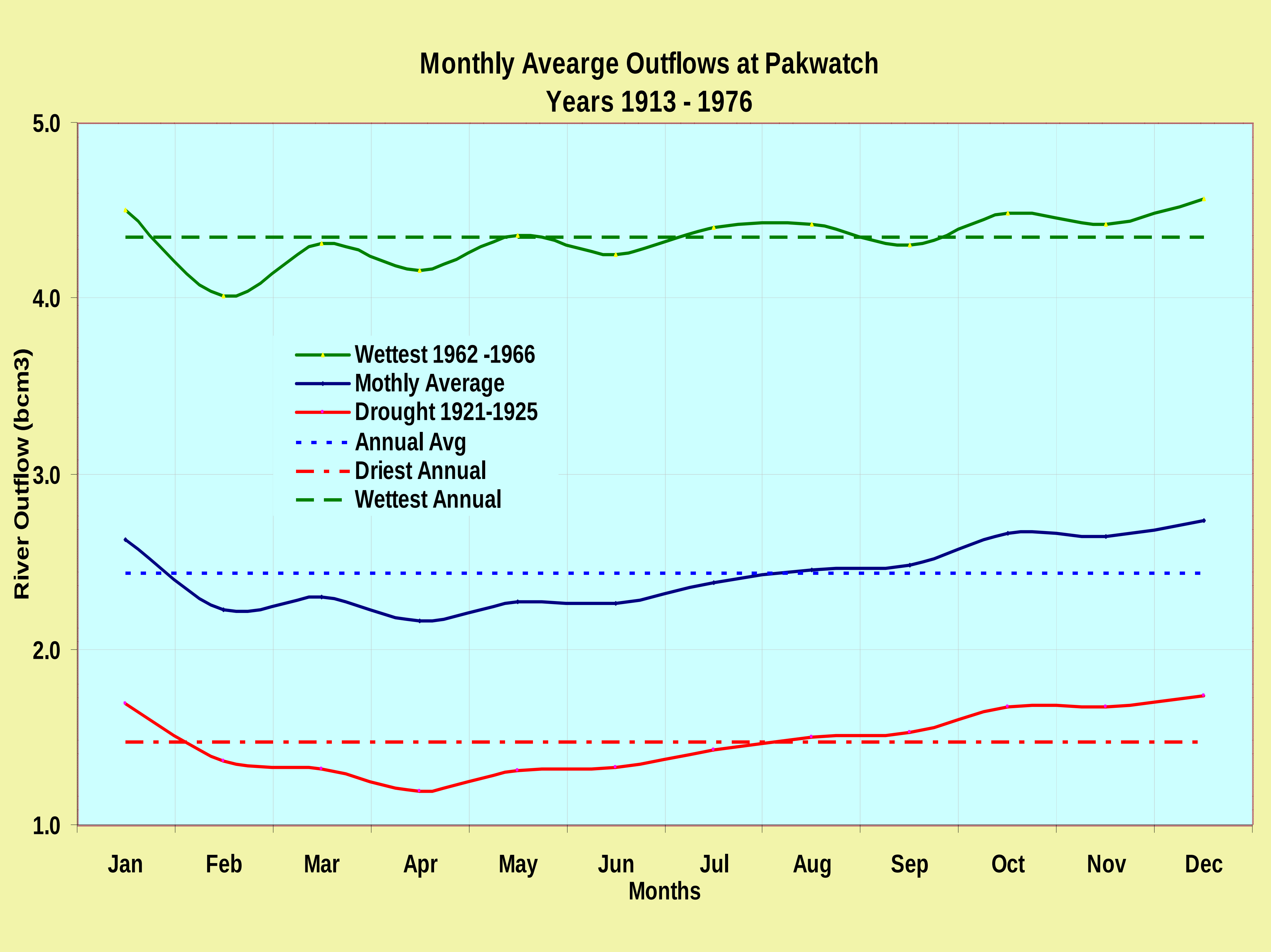
Results:

The program results are exported to Excel.

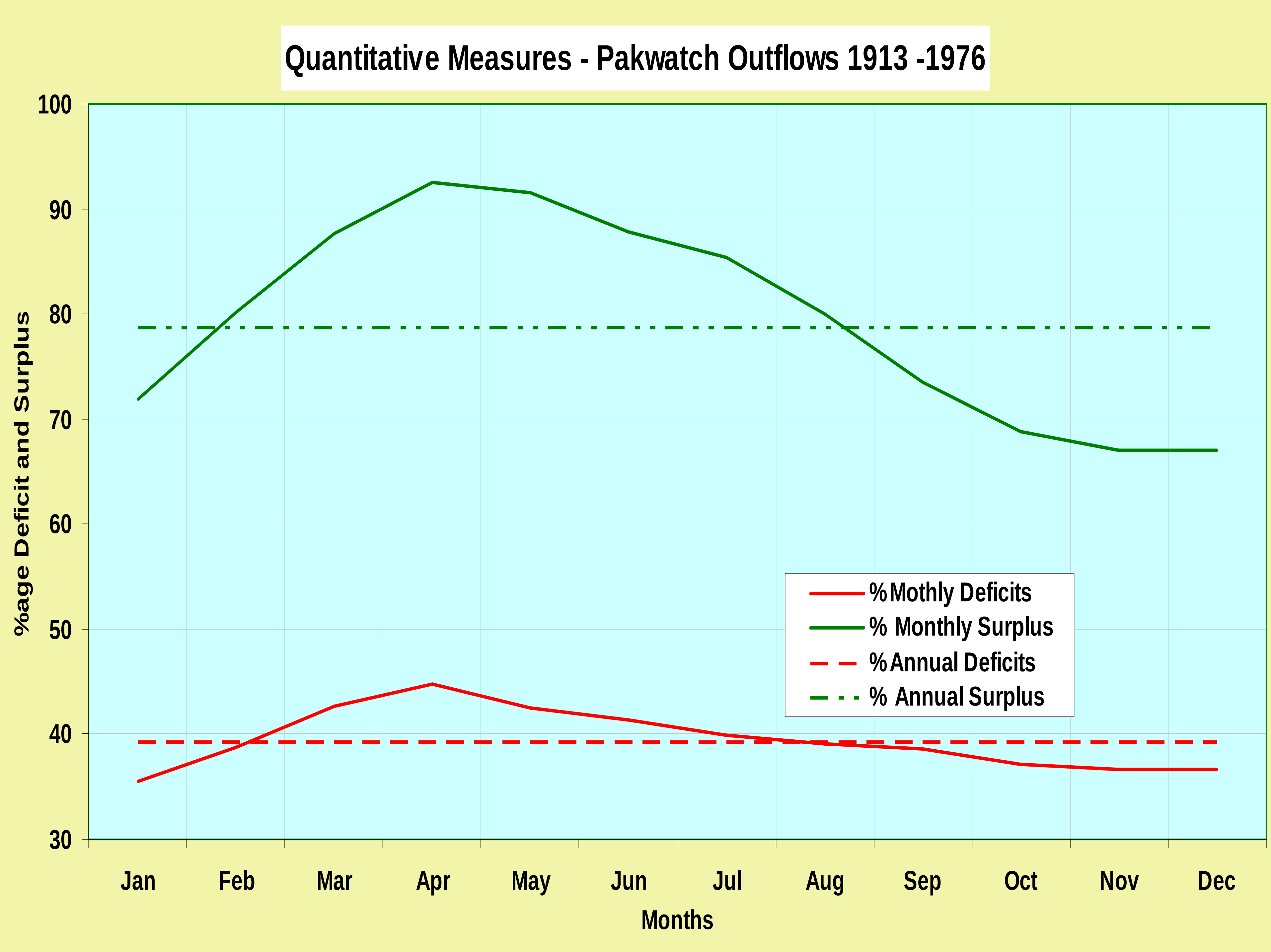
An example of the program results:

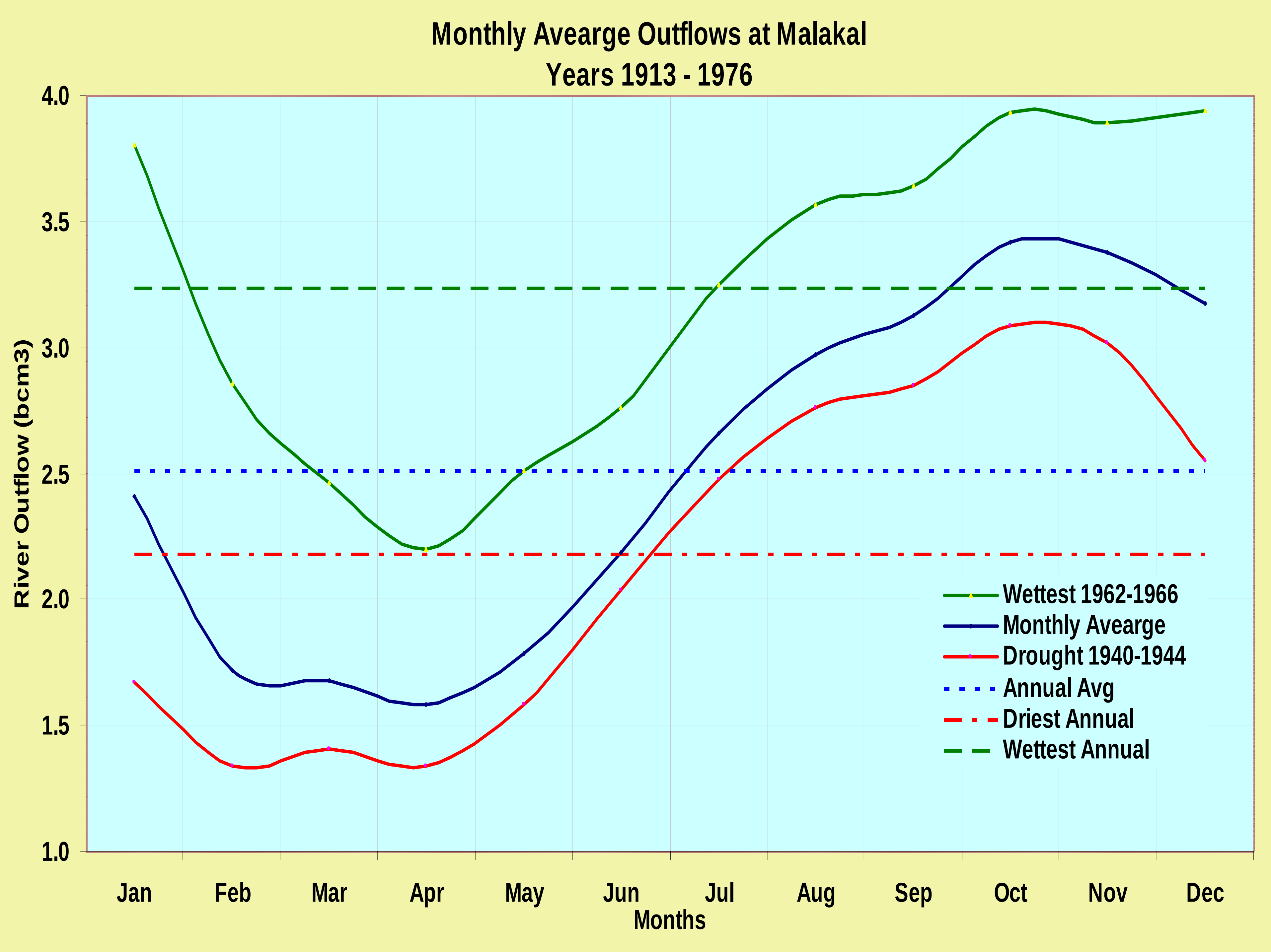


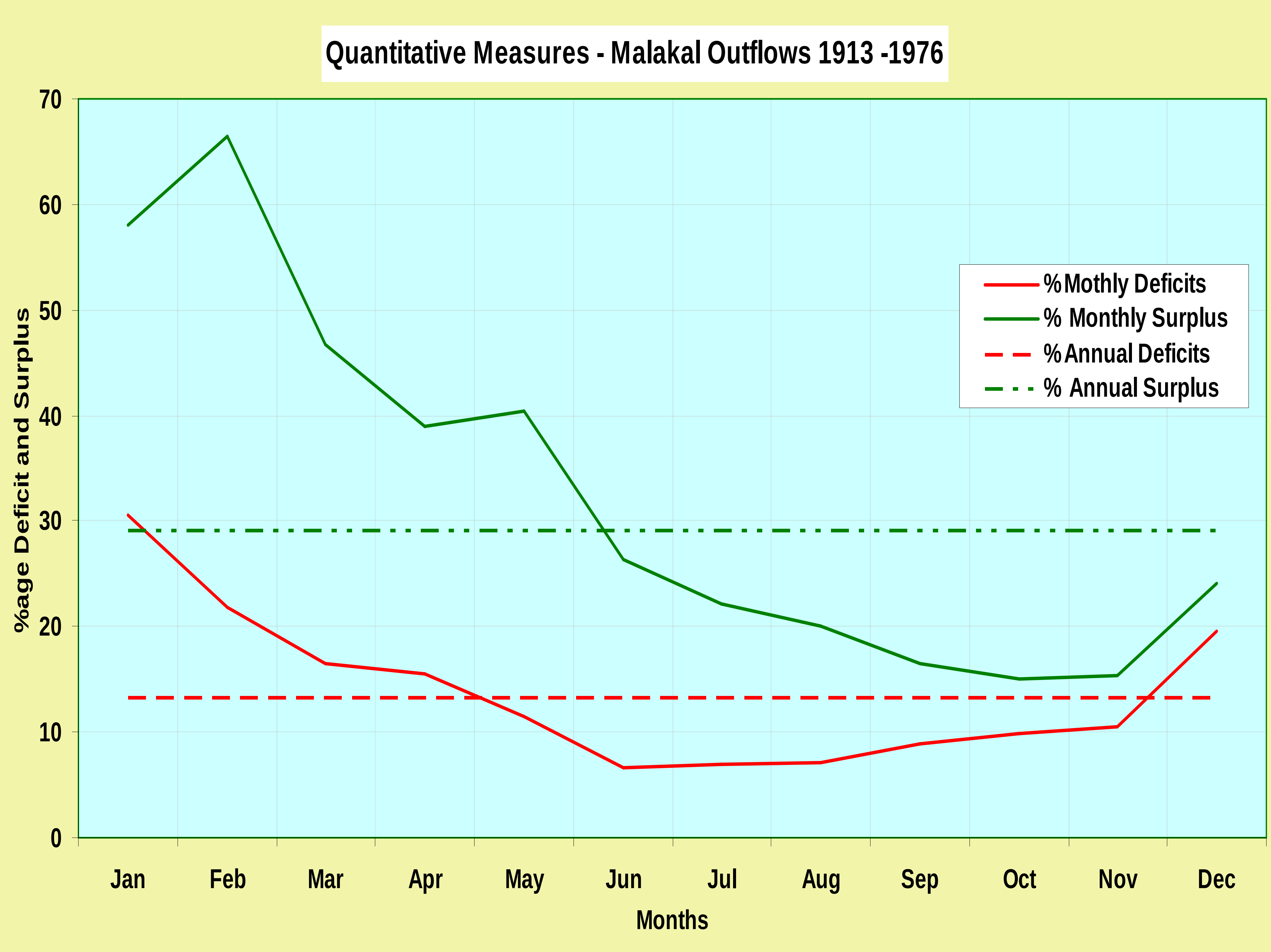
1. The White Nile System



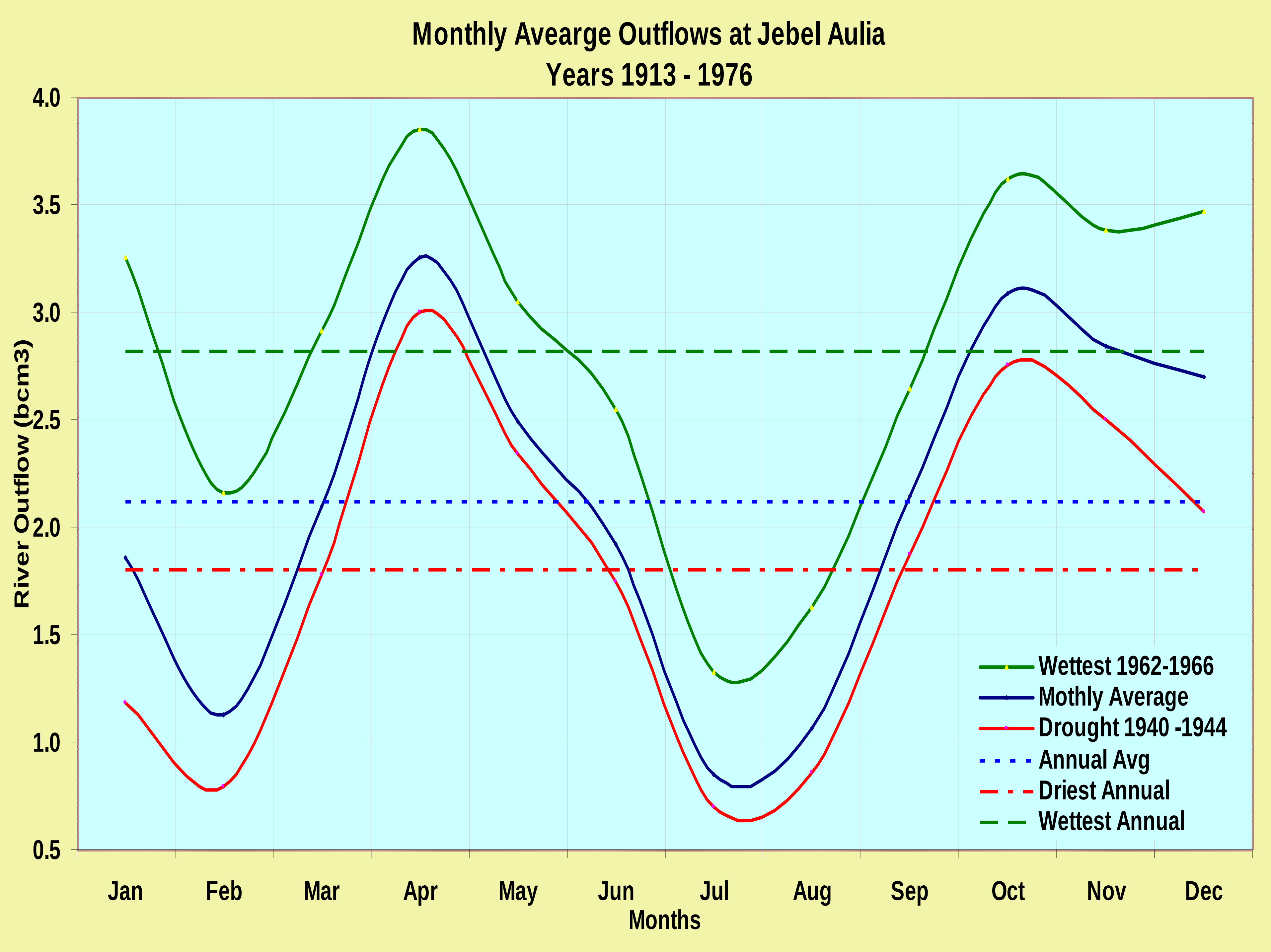
Monthly Avearge Outflows at Pakwatch
Years 1913 - 1976
5.0
4.0
3.0
2.0
1.0
River Outflow (bcm3)
Wettest 1962 -1966
Mothly Average
Drought 1921-1925
Annual Avg
Driest Annual
Wettest Annual
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

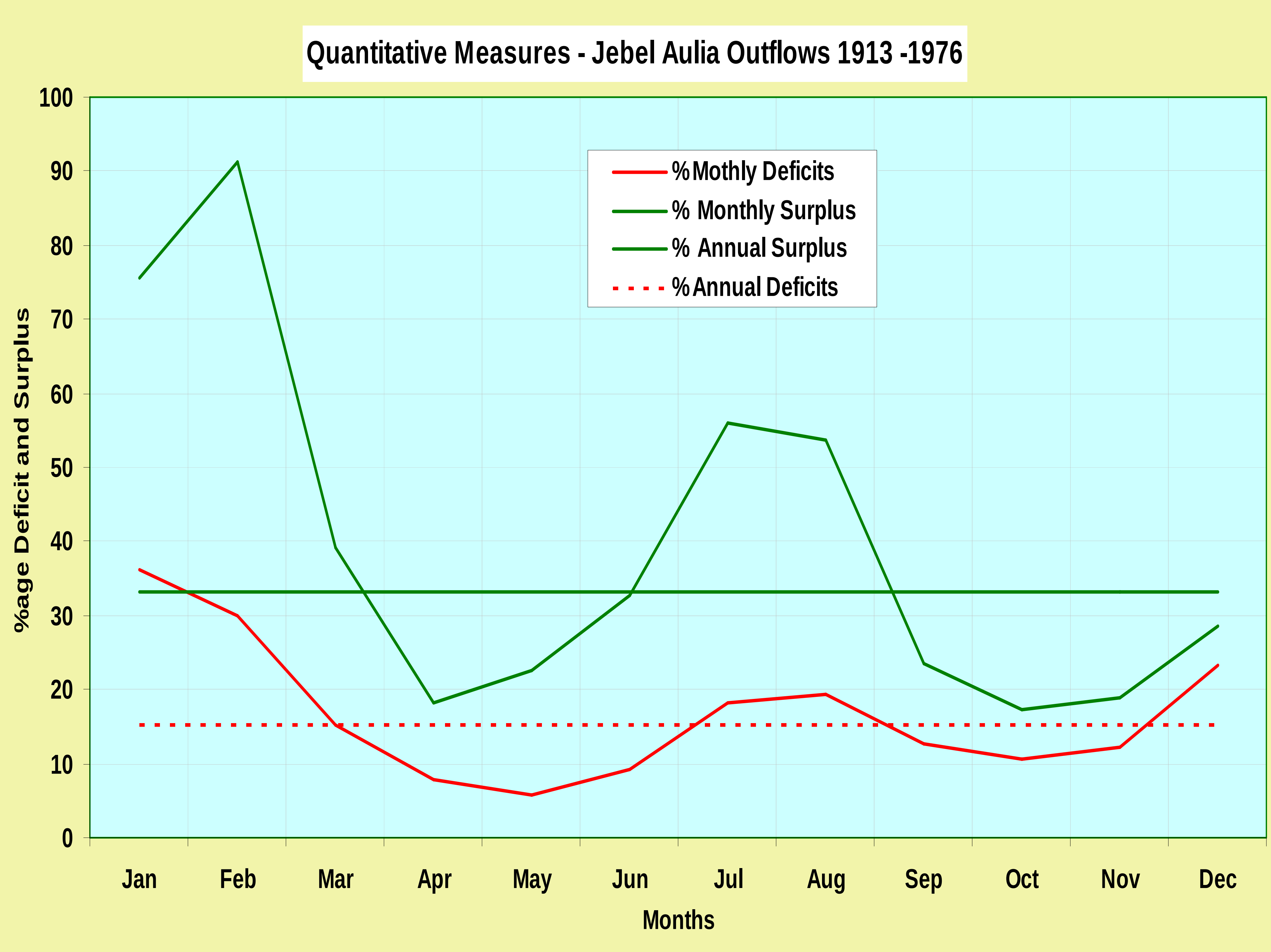

Quantitative Measures - Pakwatch Outflows 1913 -1976
100
90
80
70
60
50
40
30
%age Deficit and Surplus
% Mothly Deficits
% Monthly Surplus
% Annual Deficits
% Annual Surplus
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months


Monthly Avearge Outflows at Malakal
Years 1913 - 1976
River Outflow (bcm3)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Wettest 1962-1966
Monthly Avearge
Drought 1940-1944
Annual Avg
Driest Annual
Wettest Annual

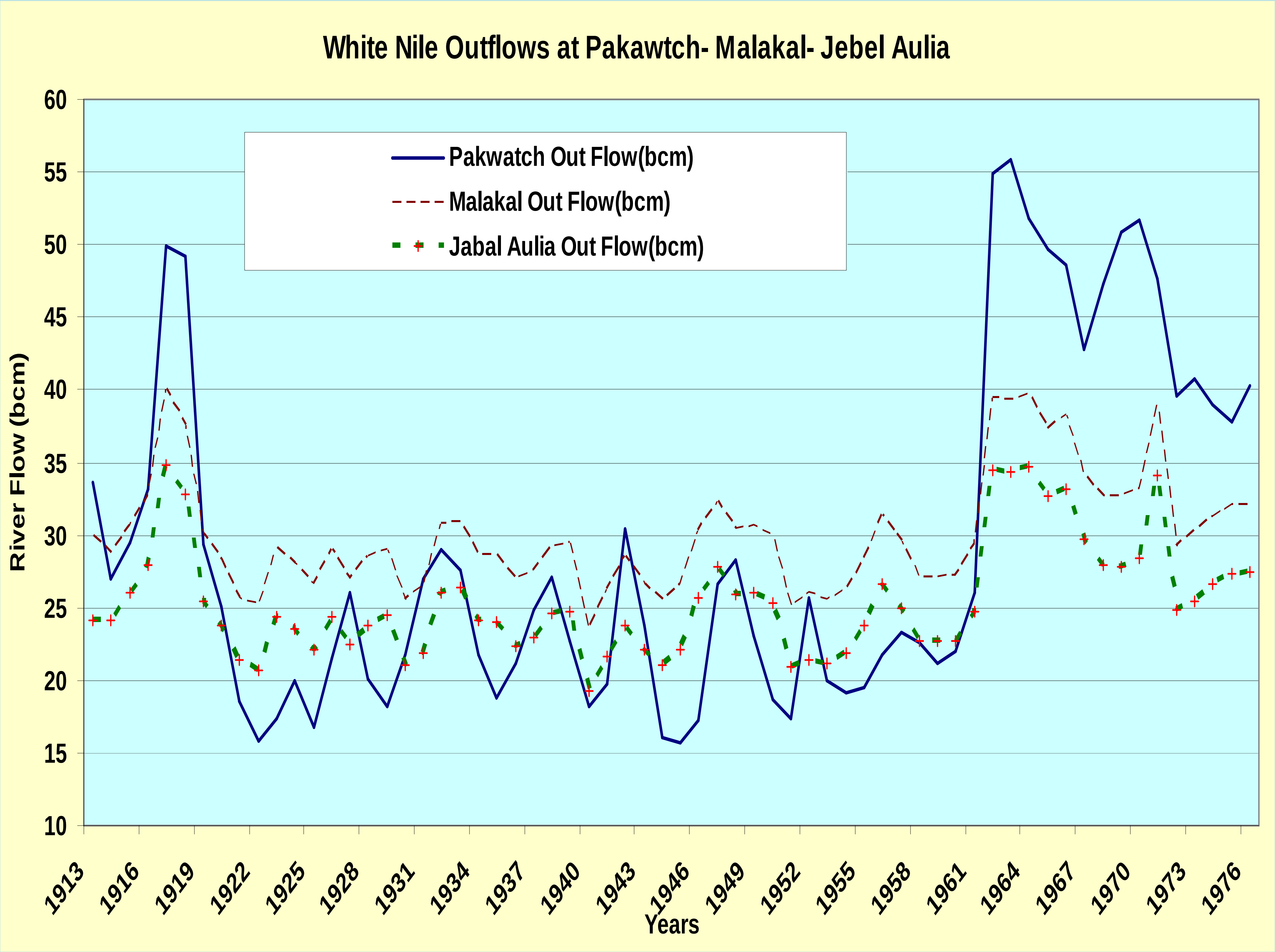


Quantitative Measures - Malakal Outflows 1913 -1976
%age Deficit and Surplus
0
10
20
30
40
50
60
70
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
%Mothly Deficits
% Monthly Surplus
%Annual Deficits
% Annual Surplus


Monthly Avearge Outflows at Jebel Aulia
Years 1913 - 1976
River Outflow (bcm3)
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Wettest 1962-1966
Mothly Average
Drought 1940 -1944
Annual Avg
Driest Annual
Wettest Annual

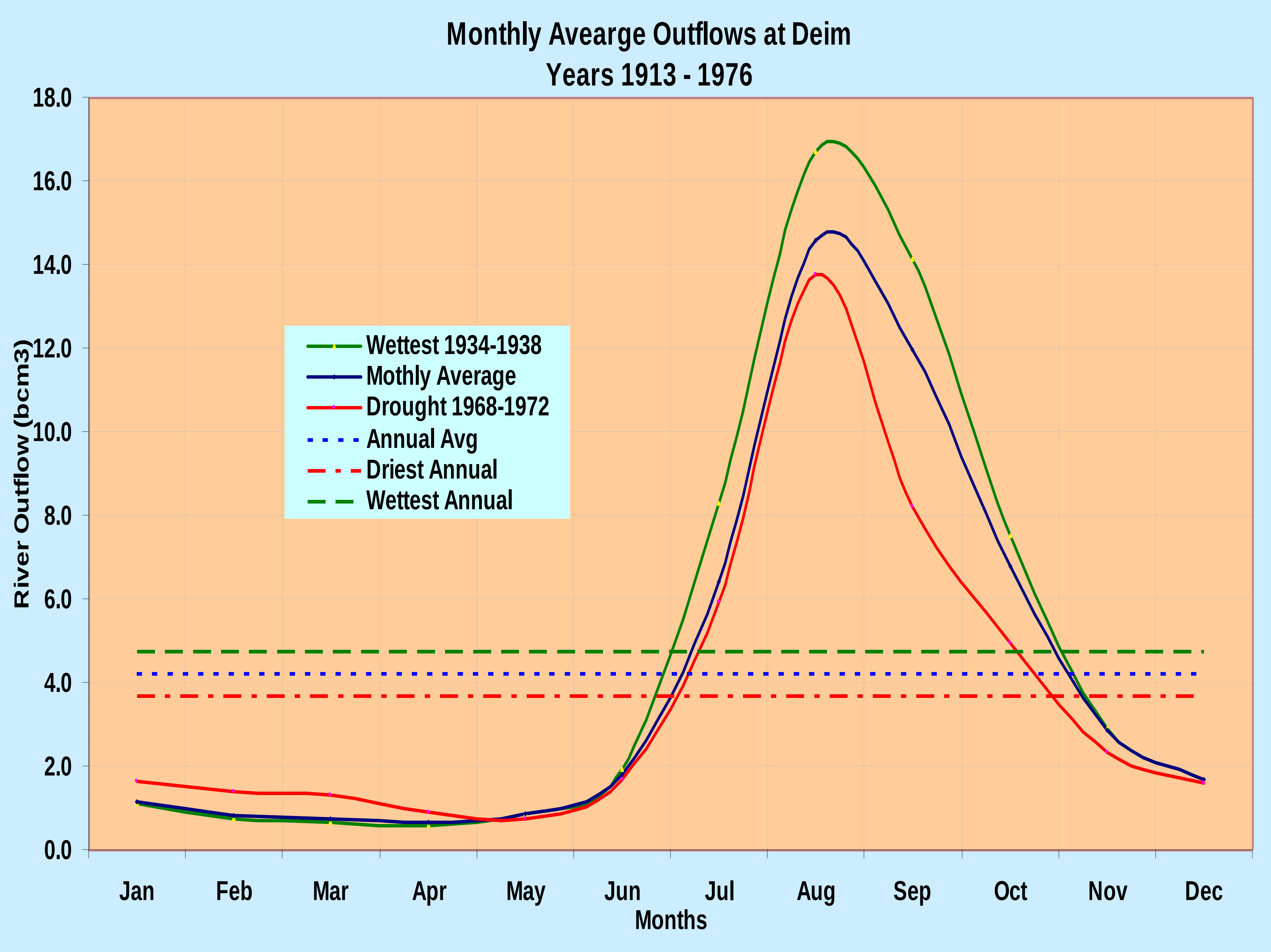


Quantitative Measures - Jebel Aulia Outflows 1913 -1976
%Mothly Deficits
% Monthly Surplus
% Annual Surplus
%Annual Deficits
%age Deficit and Surplus
0
10
20
30
40
50
60
70
80
90
100
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

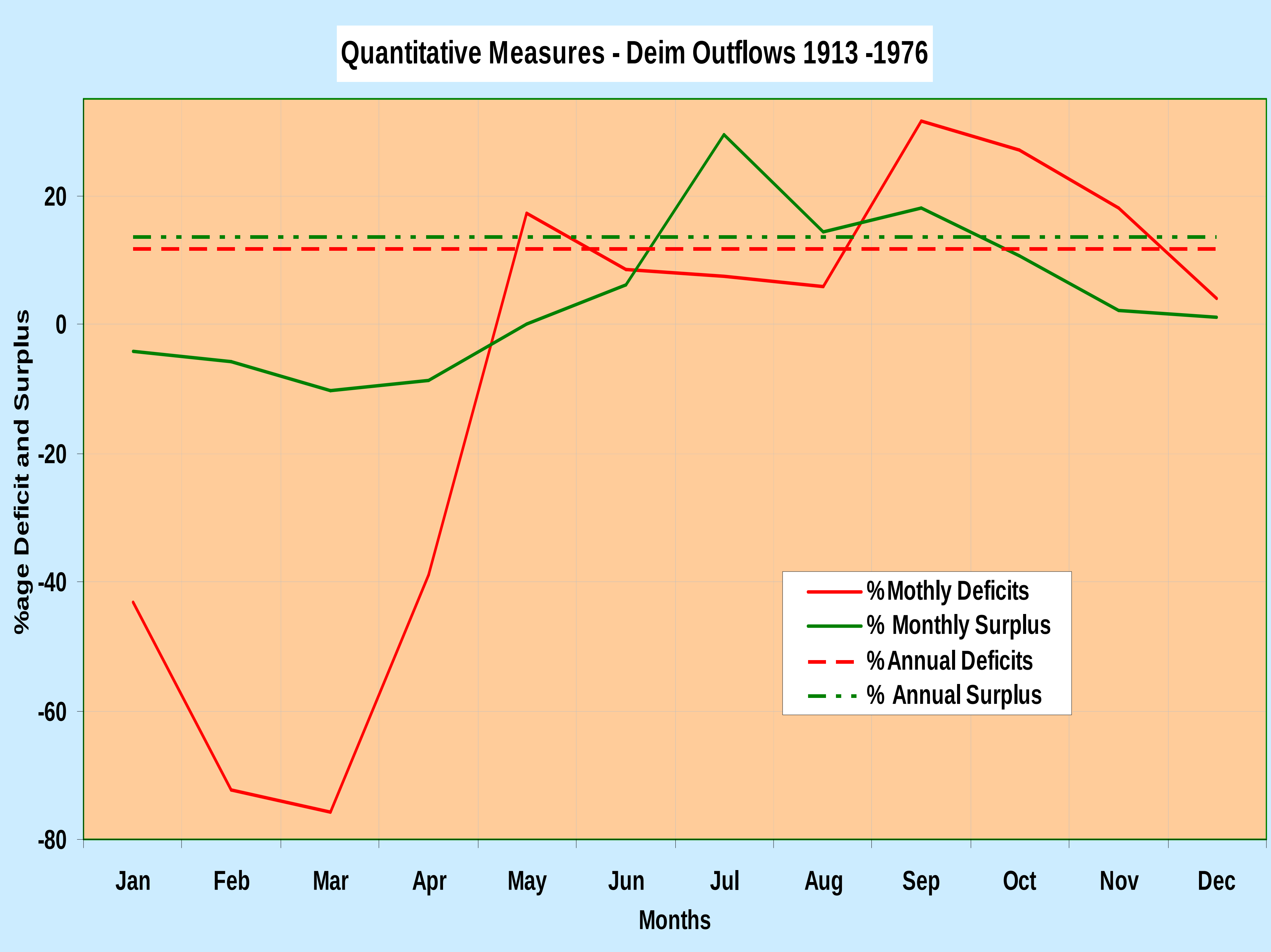


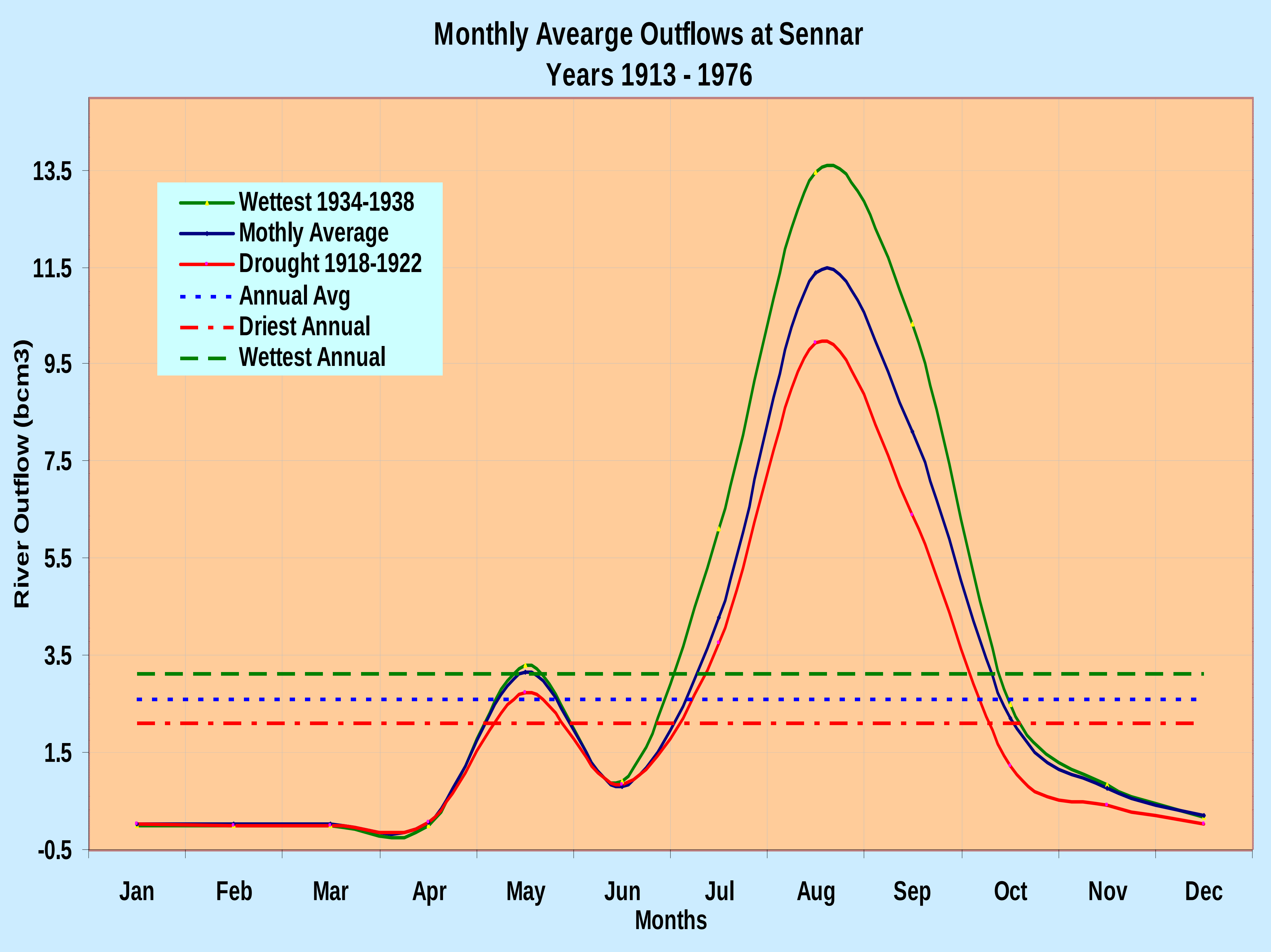
White Nile Outflows at Pakawtch- Malakal- Jebel Aulia
Pakwatch Out Flow(bcm)
Malakal Out Flow(bcm)
Jabal Aulia Out Flow(bcm)
River Flow (bcm)
Years
60
55
50
45
40
35
30
25
20
15
10
1913
1916
1919
1922
1925
1928
1931
1934
1937
1940
1943
1946
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976

2. The Blue Nile System

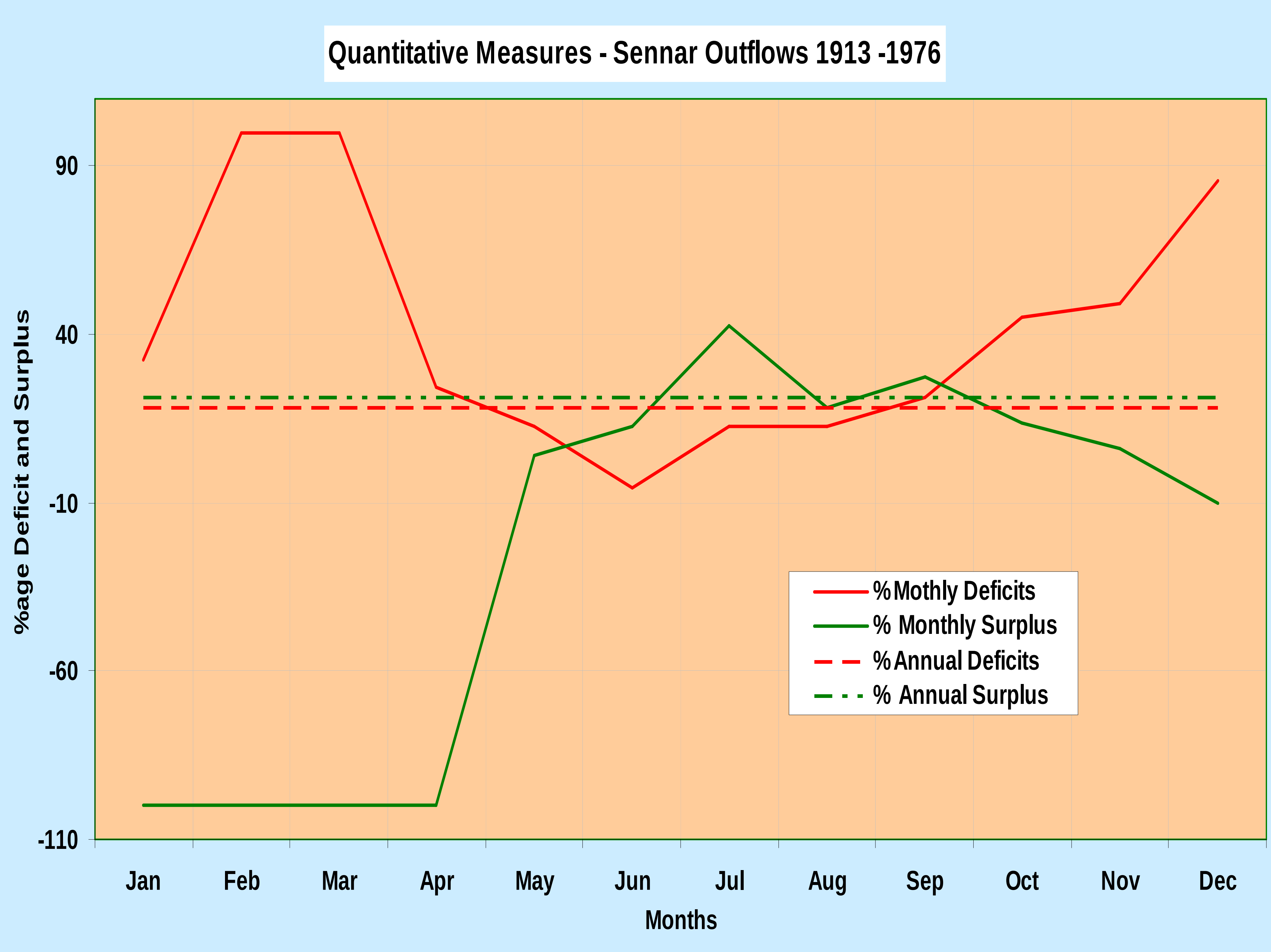


Monthly Avearge Outflows at Deim
Years 1913 - 1976
River Outflow (bcm3)
18.0
16.0
14.0
12.0
10.0
8.0
6.0
4.0
2.0
0.0
Wettest 1934-1938
Mothly Average
Drought 1968-1972
Annual Avg
Driest Annual
Wettest Annual
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

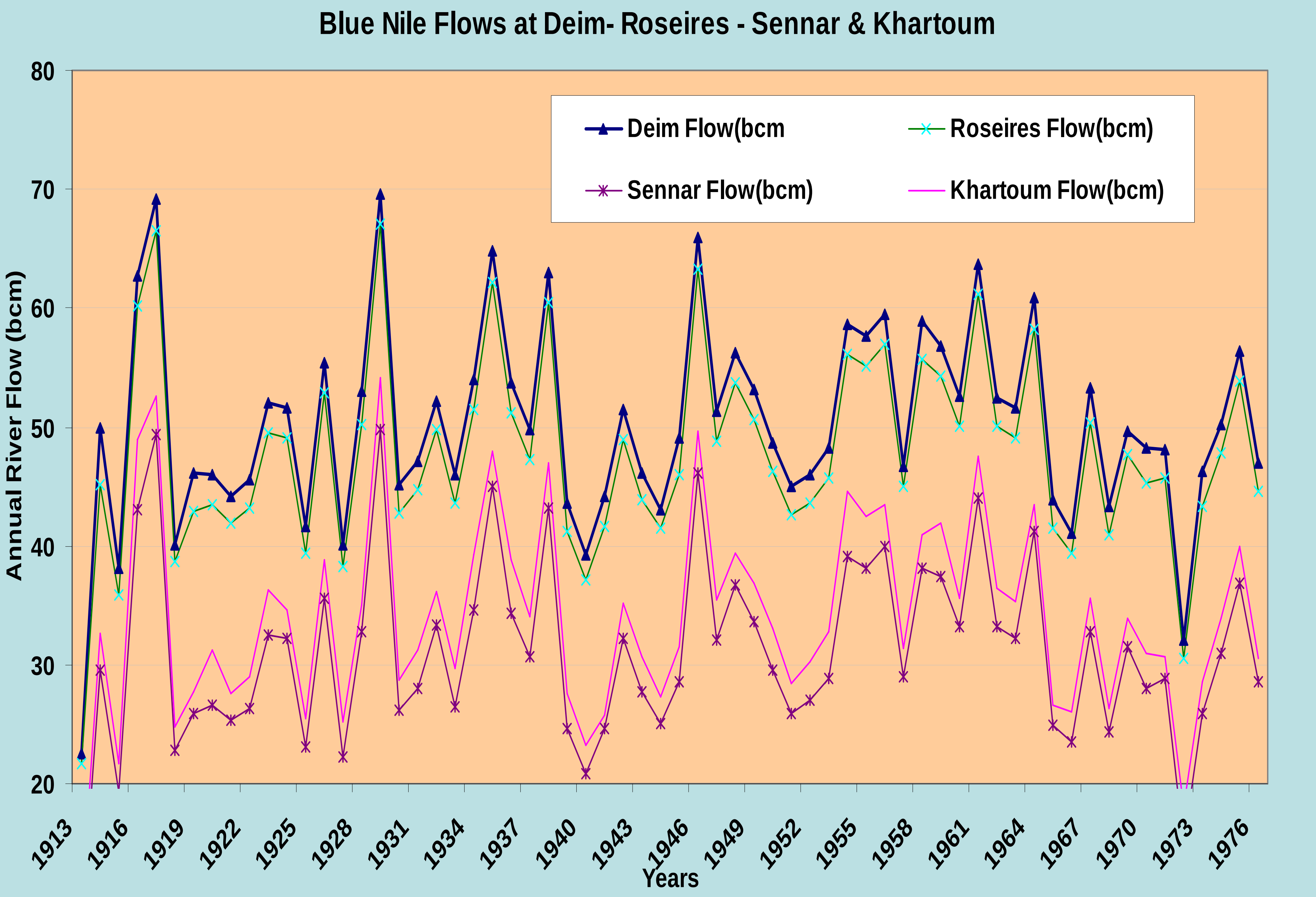

Quantitative Measures - Deim Outflows 1913 -1976
%age Deficit and Surplus
20
0
-20
-40
-60
-80
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
%Mothly Deficits
% Monthly Surplus
%Annual Deficits
% Annual Surplus



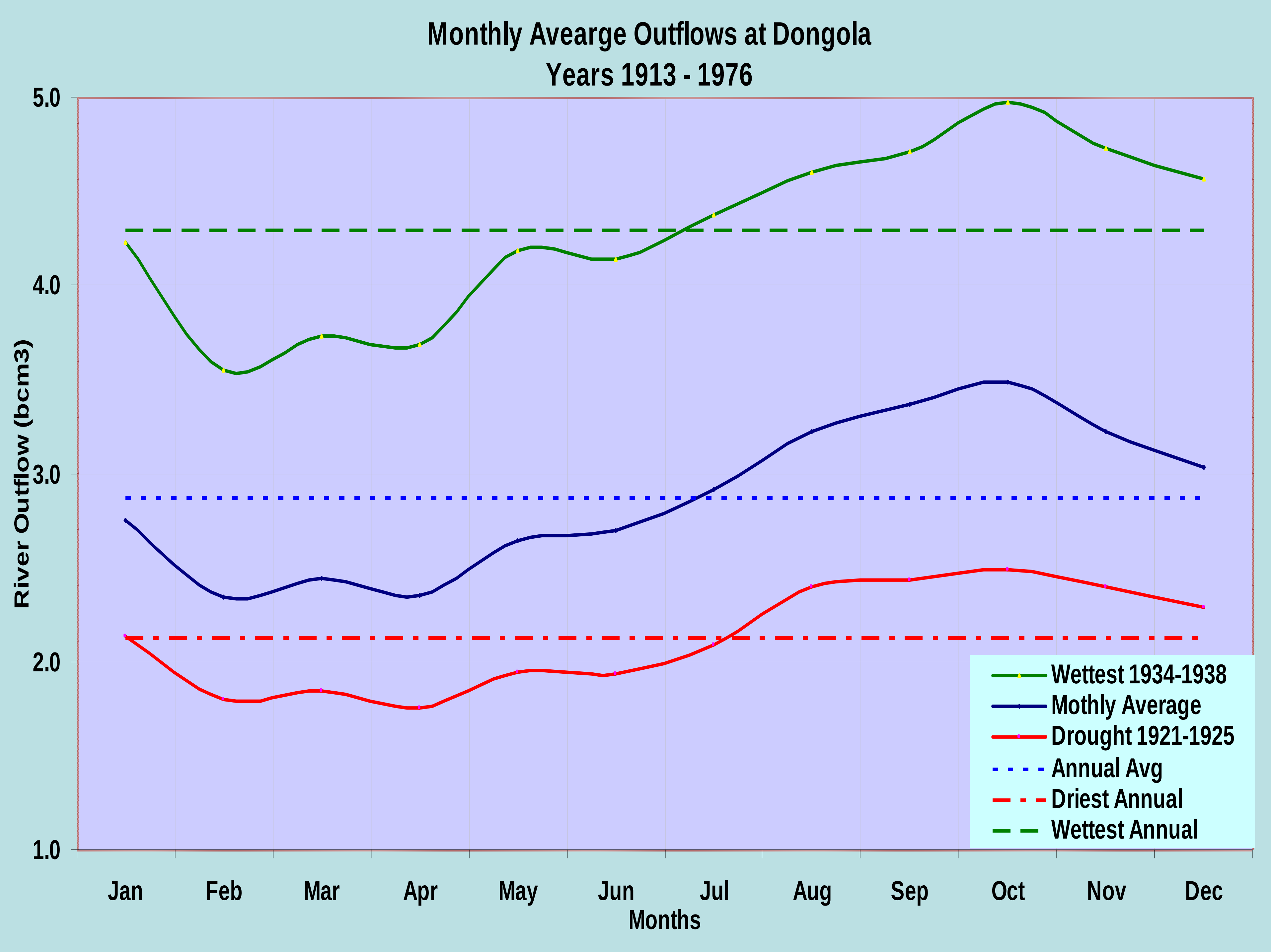
Monthly Avearge Outflows at Sennar
Years 1913 - 1976
Wettest 1934-1938
Mothly Average
Drought 1918-1922
Annual Avg
Driest Annual
Wettest Annual
River Outflow (bcm3)
13.5
11.5
9.5
7.5
5.5
3.5
1.5
-0.5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months



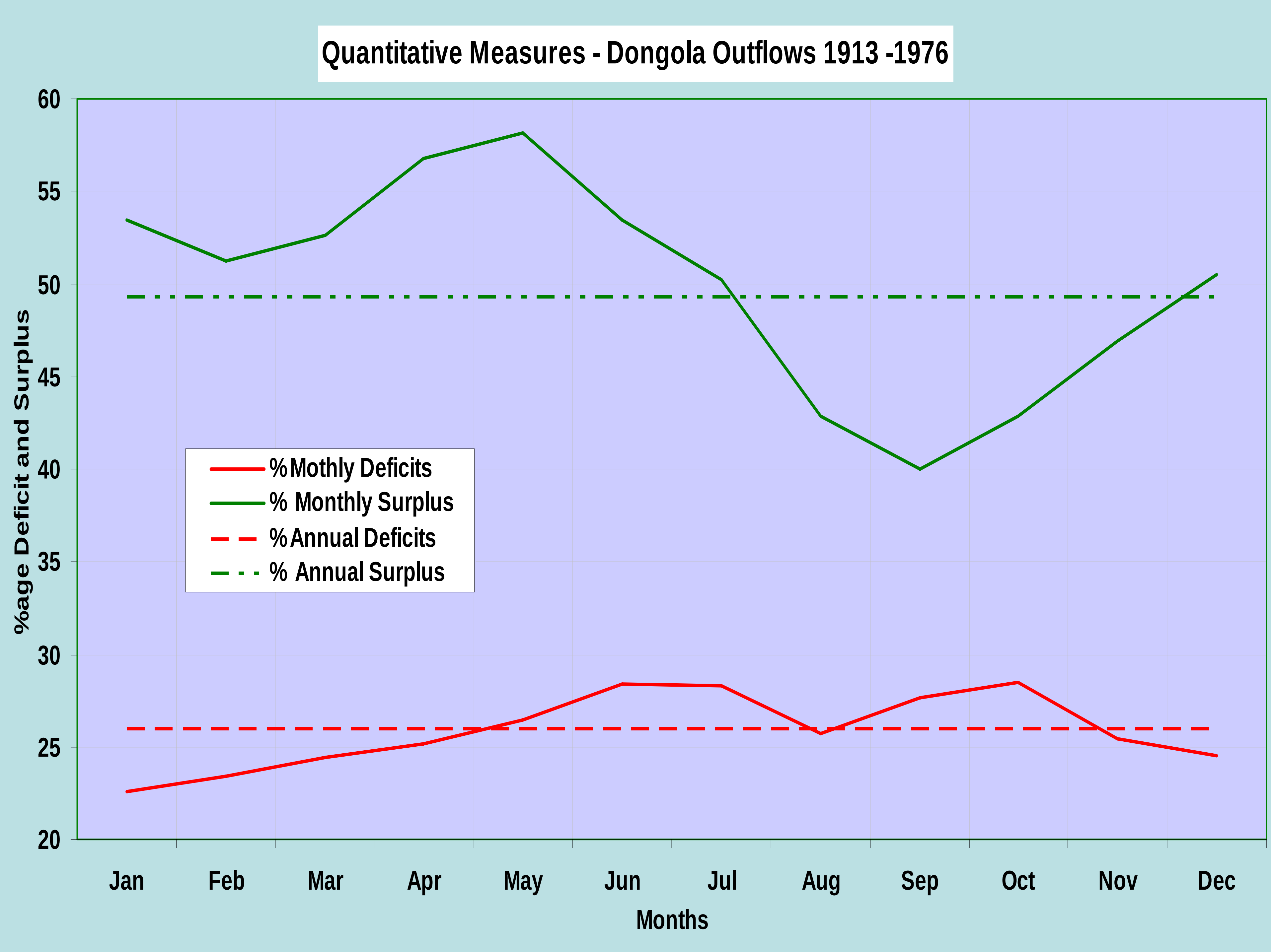
Quantitative Measures - Sennar Outflows 1913 -1976
%age Deficit and Surplus
90
40
-10
-60
-110
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
% Mothly Deficits
% Monthly Surplus
% Annual Deficits
% Annual Surplus

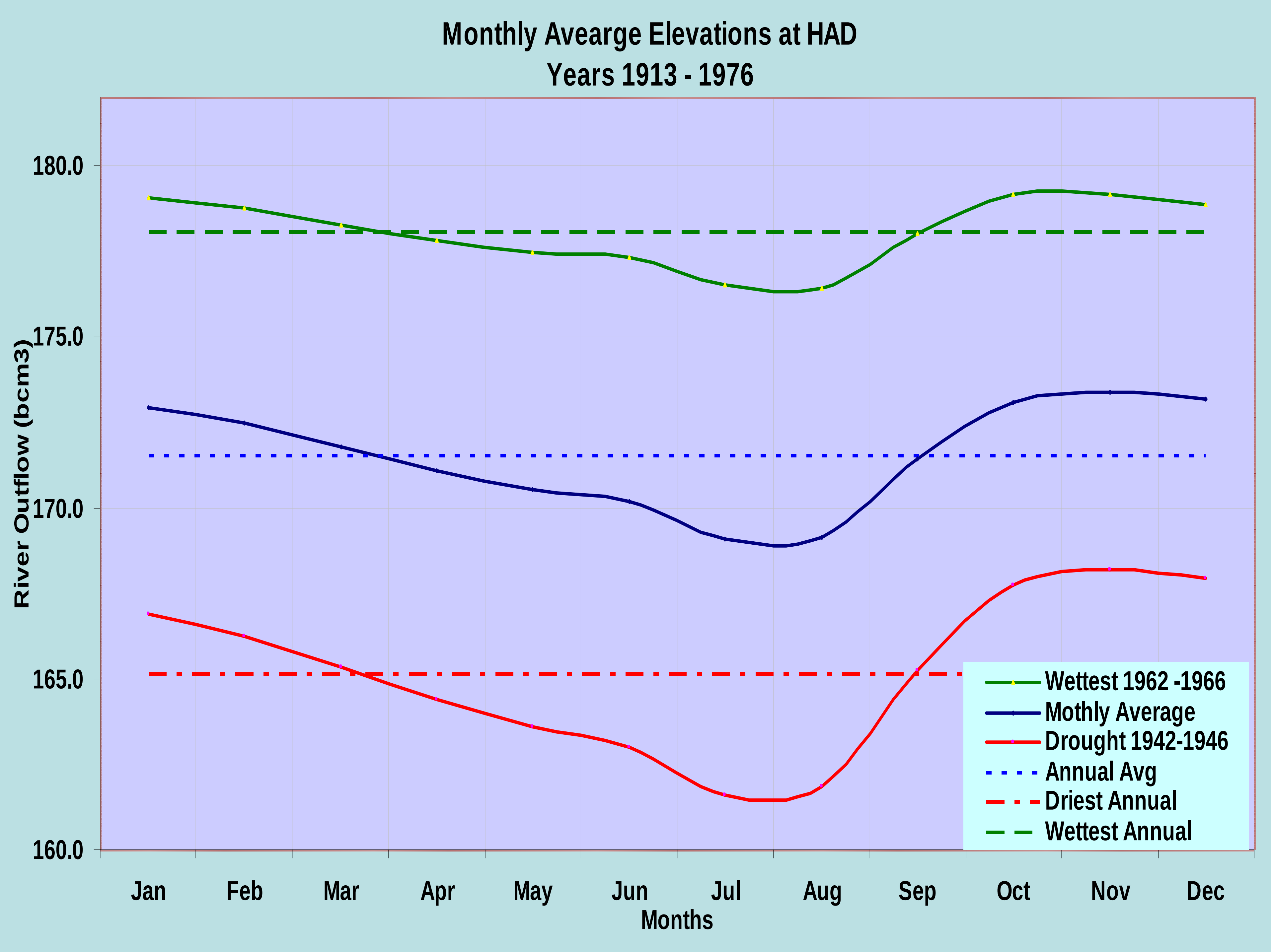

Blue Nile Flows at Deim- Roseires - Sennar & Khartoum
Deim Flow(bcm
Roseires Flow(bcm)
Sennar Flow(bcm)
Khartoum Flow(bcm)
Annual River Flow (bcm)
Years
80
70
60
50
40
30
20
1913
1916
1919
1922
1925
1928
1931
1934
1937
1940
1943
1946
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976

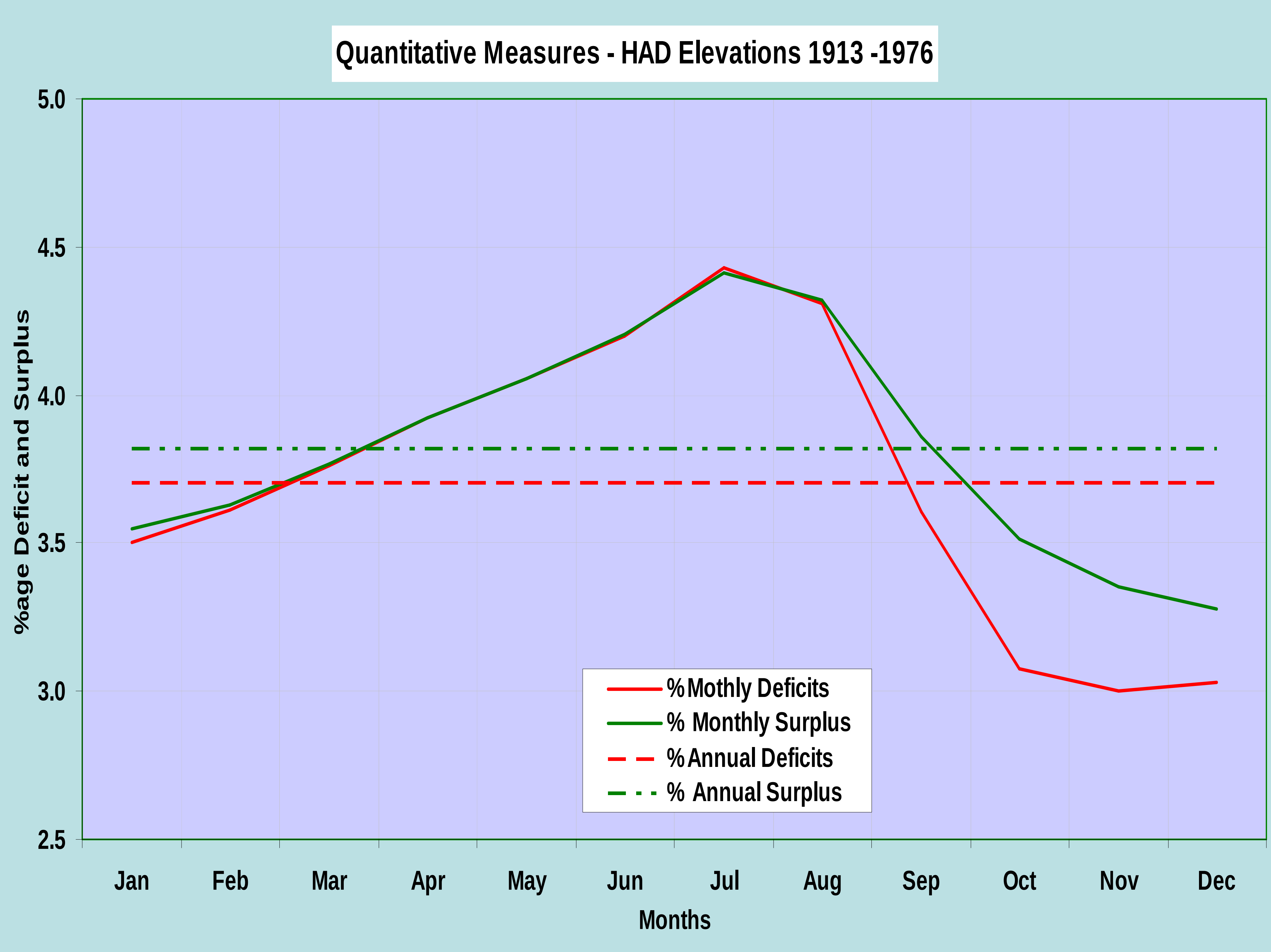
3. The Main Nile System

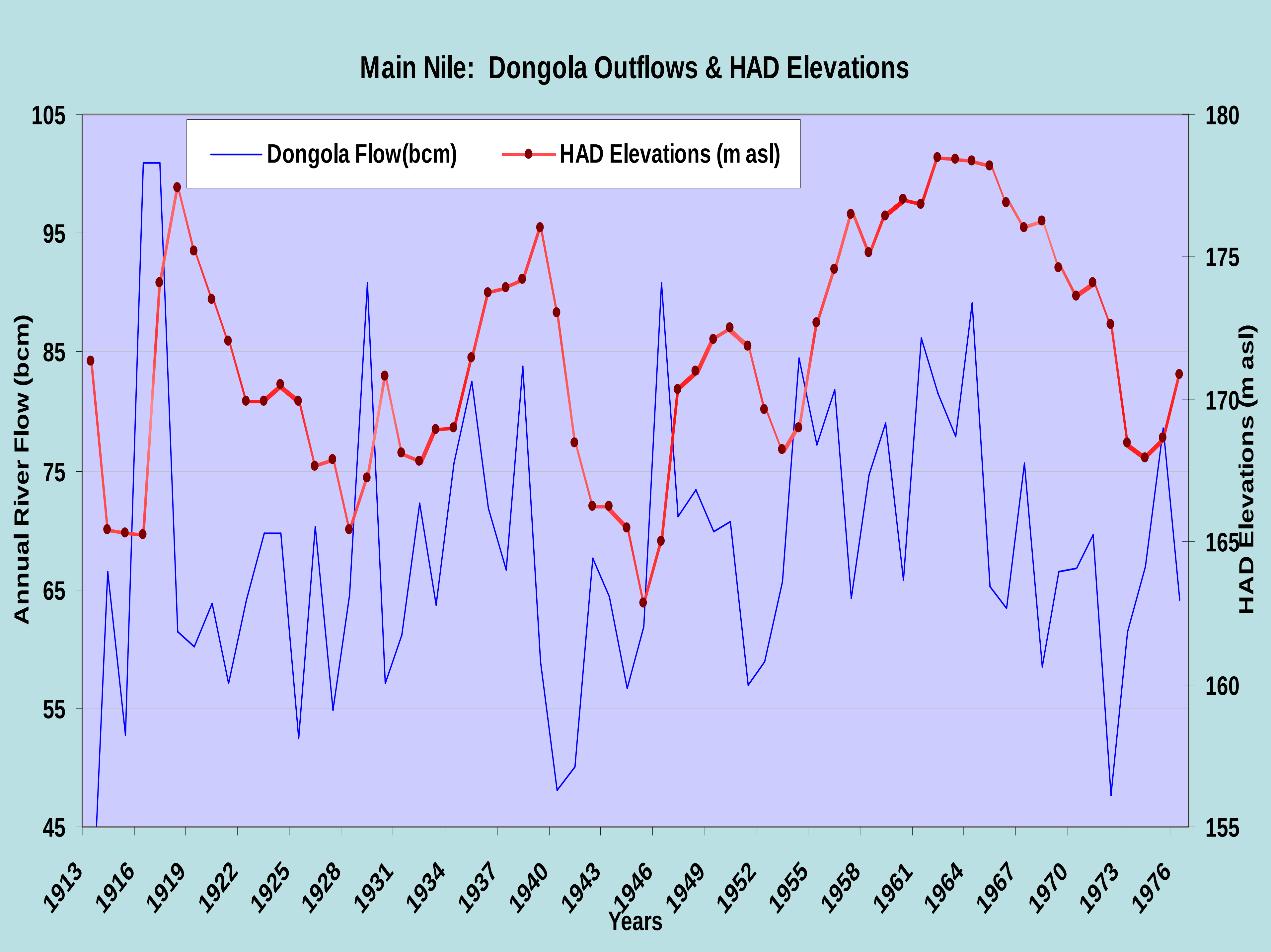


Monthly Avearge Outflows at Dongola
Years 1913 - 1976
River Outflow (bcm3)
5.0
4.0
3.0
2.0
1.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Wettest 1934-1938
Mothly Average
Drought 1921-1925
Annual Avg
Driest Annual
Wettest Annual


Quantitative Measures - Dongola Outflows 1913 -1976
%age Deficit and Surplus
60
55
50
45
40
35
30
25
20
% Mothly Deficits
% Monthly Surplus
% Annual Deficits
% Annual Surplus
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months


Monthly Avearge Elevations at HAD
Years 1913 - 1976
River Outflow (bcm3)
180.0
175.0
170.0
165.0
160.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Wettest 1962 -1966
Mothly Average
Drought 1942-1946
Annual Avg
Driest Annual
Wettest Annual


Quantitative Measures - HAD Elevations 1913 -1976
5.0
4.5
4.0
3.5
3.0
2.5
%age Deficit and Surplus
%Mothly Deficits
% Monthly Surplus
%Annual Deficits
% Annual Surplus
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months



Main Nile: Dongola Outflows & HAD Elevations
Dongola Flow(bcm)
HAD Elevations (m asl)
Annual River Flow (bcm)
HAD Elevations (m asl)
105
95
85
75
65
55
45
180
175
170
165
160
155
1913
1916
1919
1922
1925
1928
1931
1934
1937
1940
1943
1946
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
Years

Drought and Flood Periods in Different River Nodes

River	Node	Driest 5 years		Wettest 5 years	
White Nile	Pakwatch	1921	1925	1962	1966
	Malakal	1940	1944	1962	1966
	Jebel Aulia	1940	1944	1962	1966
Blue Nile	Diem	1968	1972	1934	1938
	Roseires	1918	1922	1934	1938
	Sennar	1918	1922	1934	1938
	Khartoum	1970	1974	1934	1938
Main Nile	Dongola	1921	1925	1934	1938
	HAD	1942	1946	1962	1966

Nile DST RRSM Application

1. Water Balance and Water Uses Assessments:

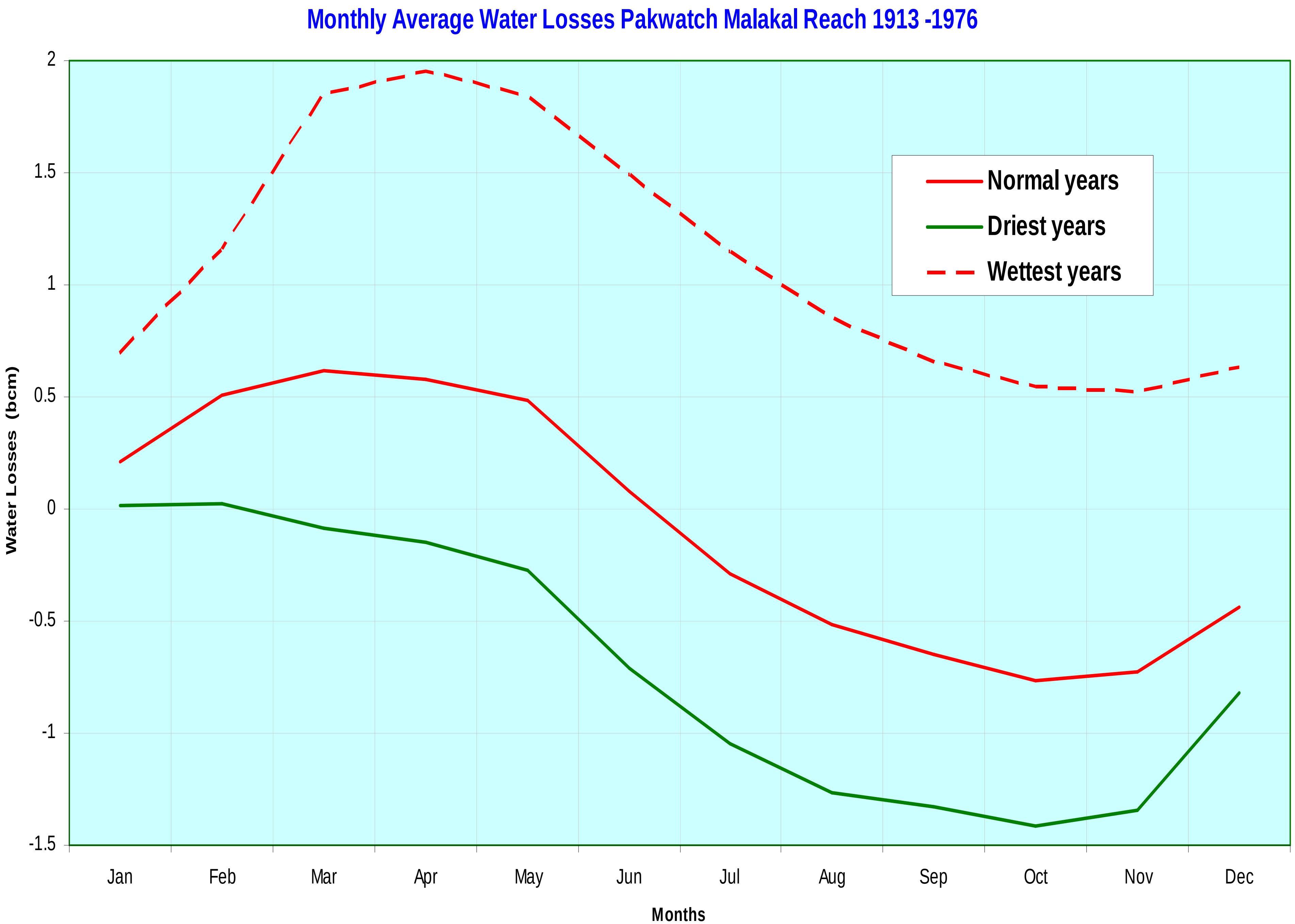
Exercise 1.2.

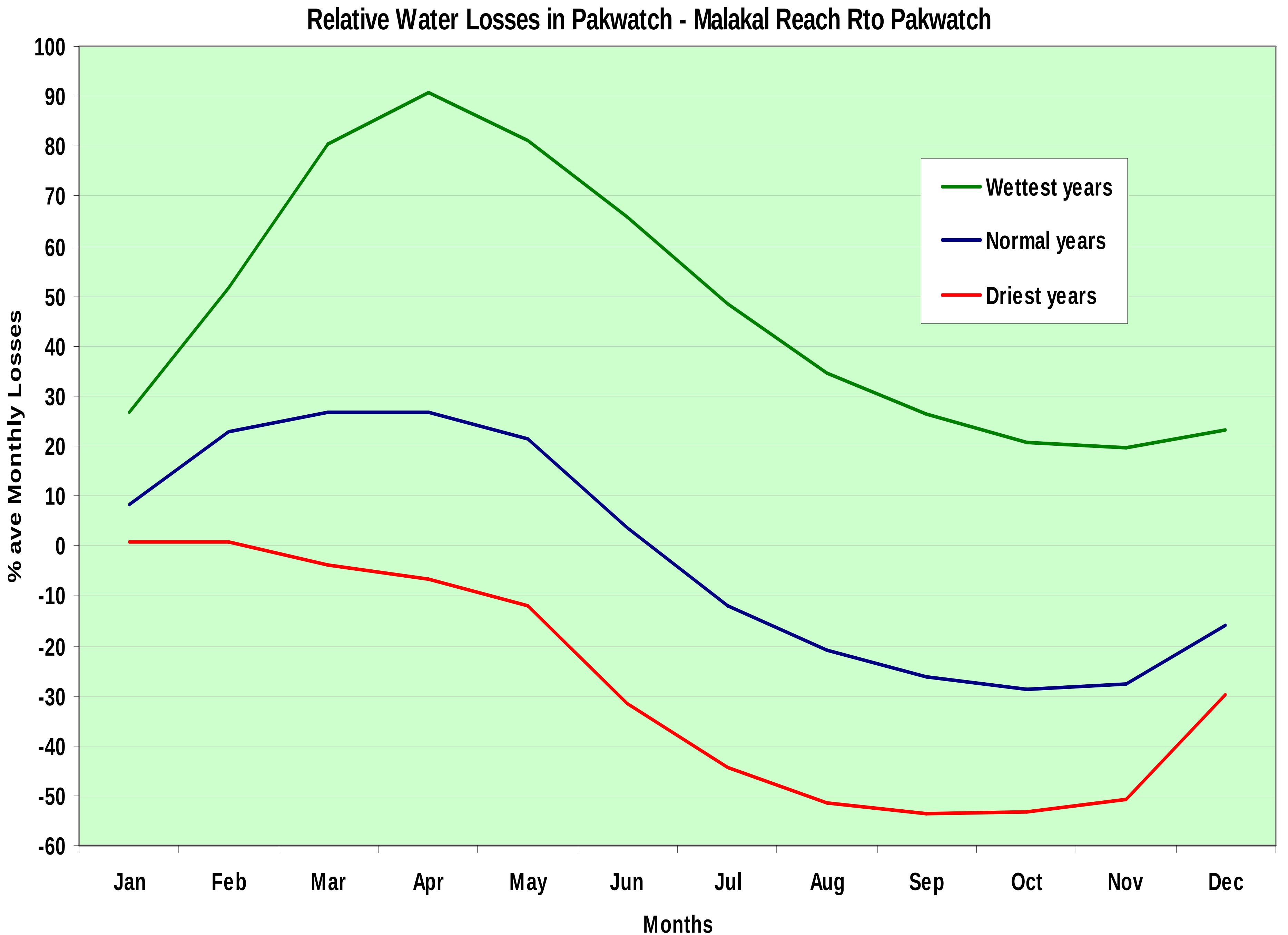
1.2 For the baseline scenario and each one of the above-mentioned river reaches, estimate and graph the following quantities: (Generate one graph for each river reach.)

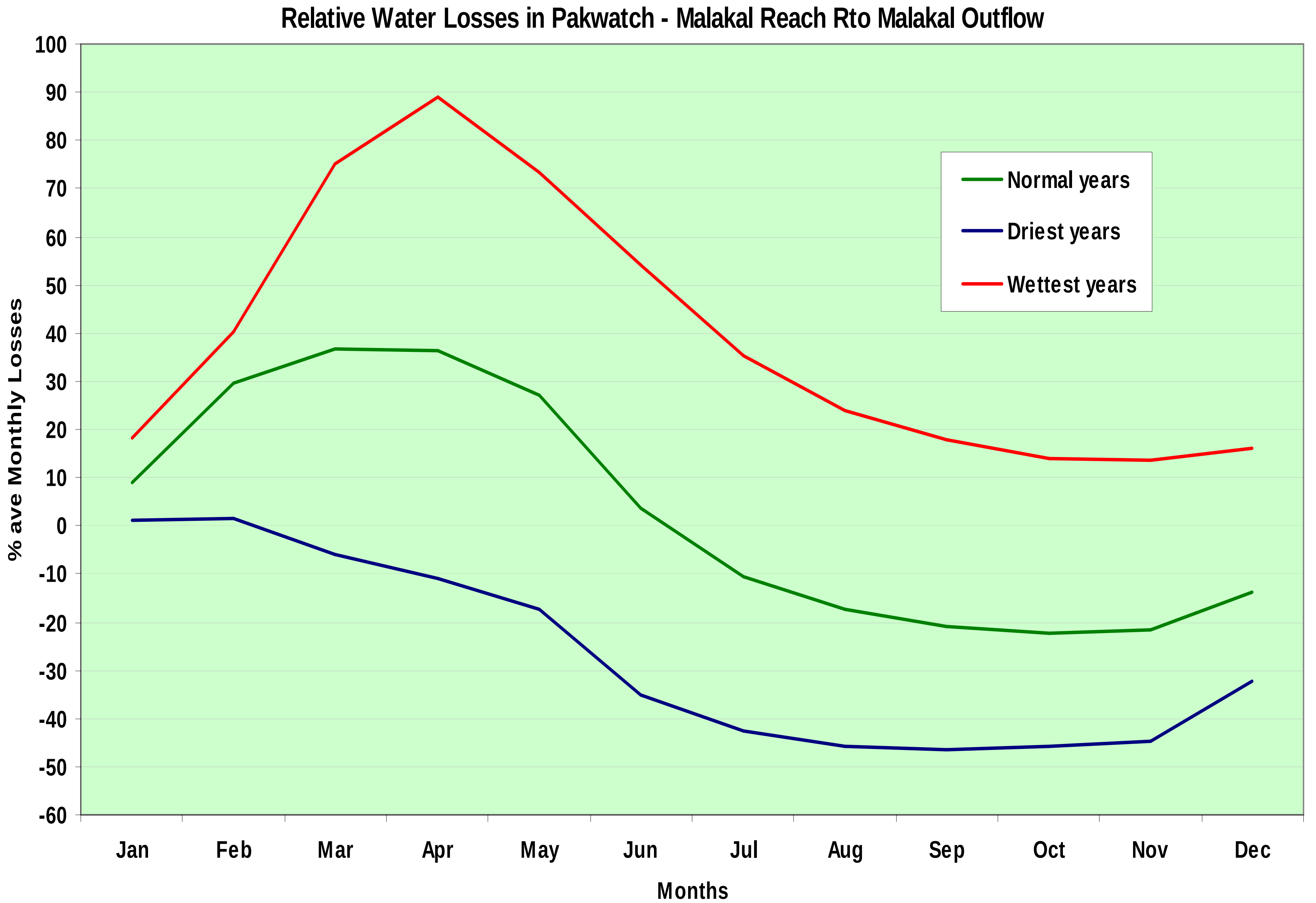
- **Average monthly and annual reach water use and losses (separately) over the period of record;**
- **Average monthly and annual reach water use and losses (separately) over the driest five years of the record;**
- **Average monthly and annual reach water use and losses (separately) outflows over the wettest five years of the record;**
- **Develop quantitative measures of the water use and losses variability (e.g., percent difference of dry and wet periods from normal);**
- **Determine the reliability of meeting water use targets in each reach;**
- **Compare water losses to reach outflows;**

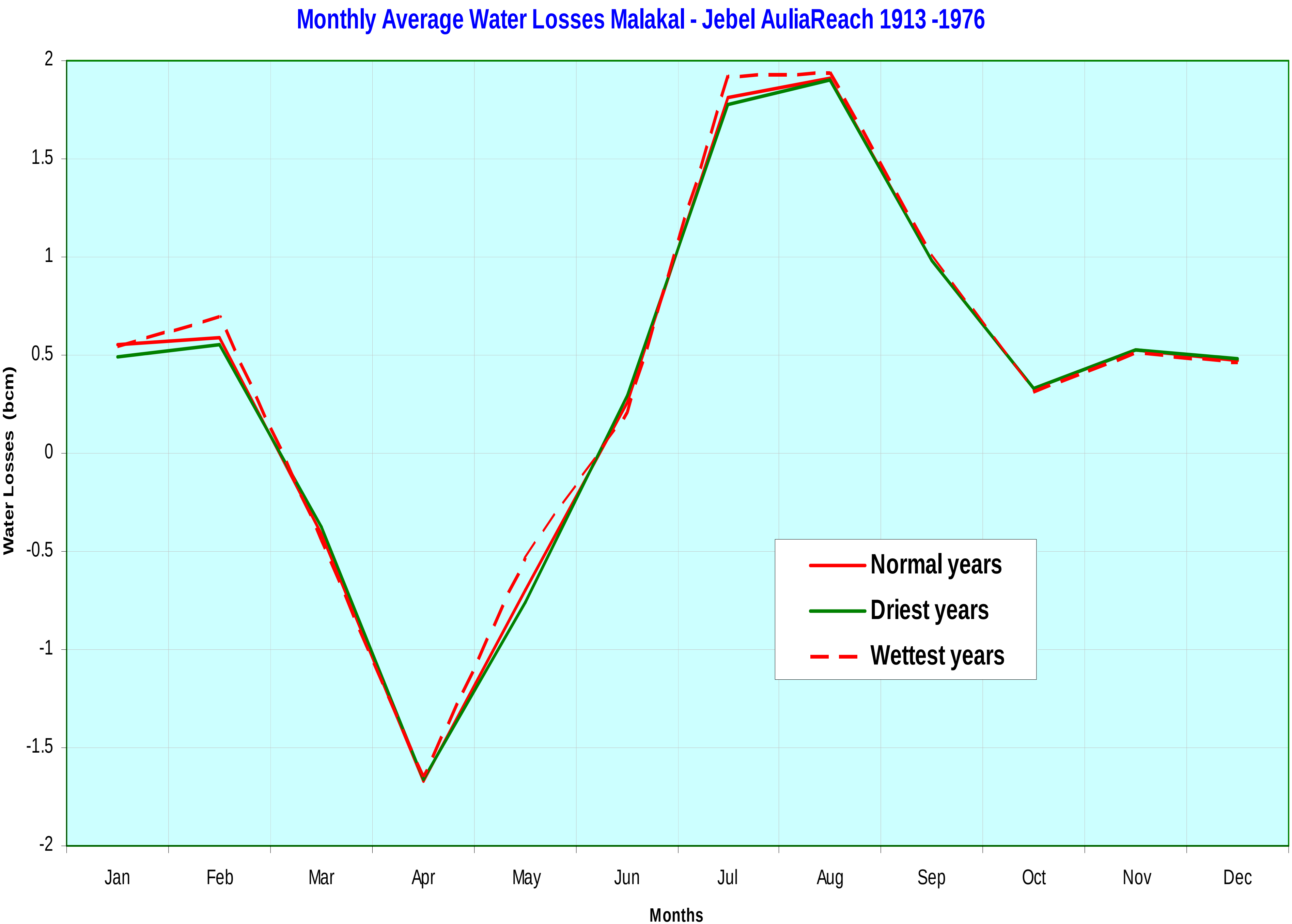
Note : **Reach water losses include evaporation and other water abstractions not related to human water uses.**

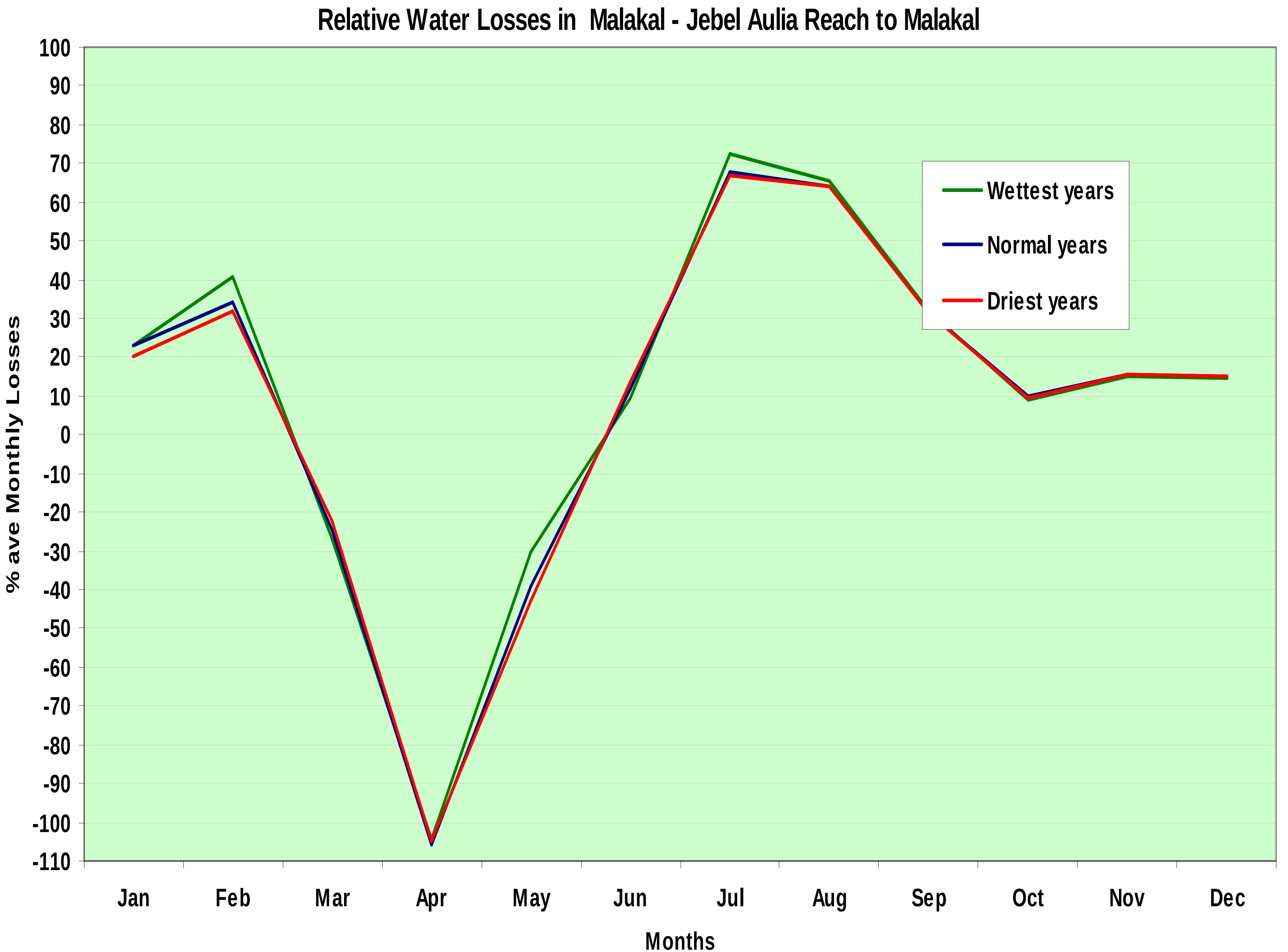
1. The White Nile System


Monthly Average Water Losses Pakwatch Malakal Reach 1913 -1976
Water Losses (bcm)
2
1.5
1
0.5
0
-0.5
-1
-1.5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Normal years
Driest years
Wettest years

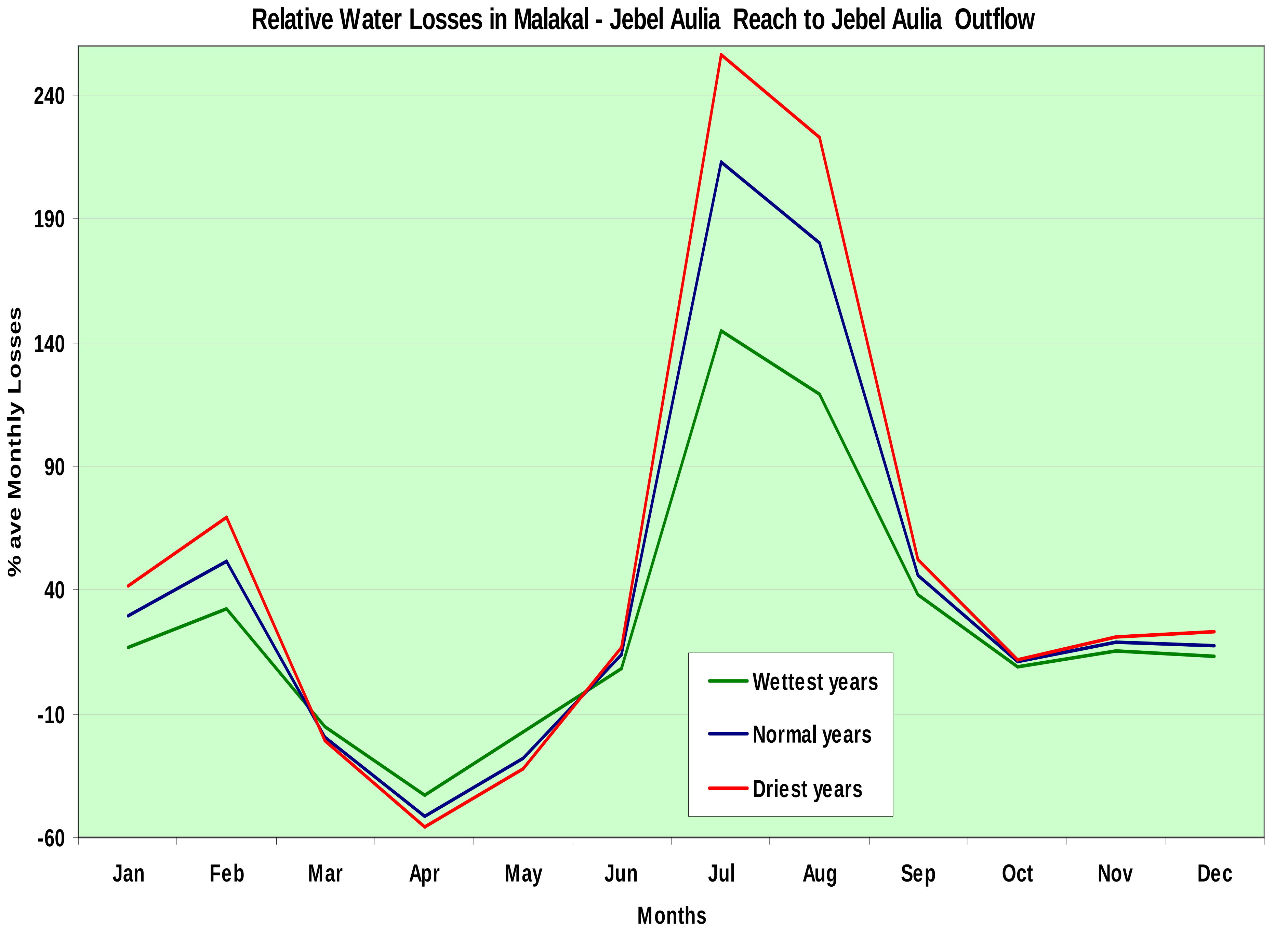

Relative Water Losses in Pakwatch - Malakal Reach Rto Pakwatch
% ave Monthly Losses
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Wettest years
Normal years
Driest years


Relative Water Losses in Pakwatch - Malakal Reach Rto Malakal Outflow
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
% ave Monthly Losses
Normal years
Driest years
Wettest years
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

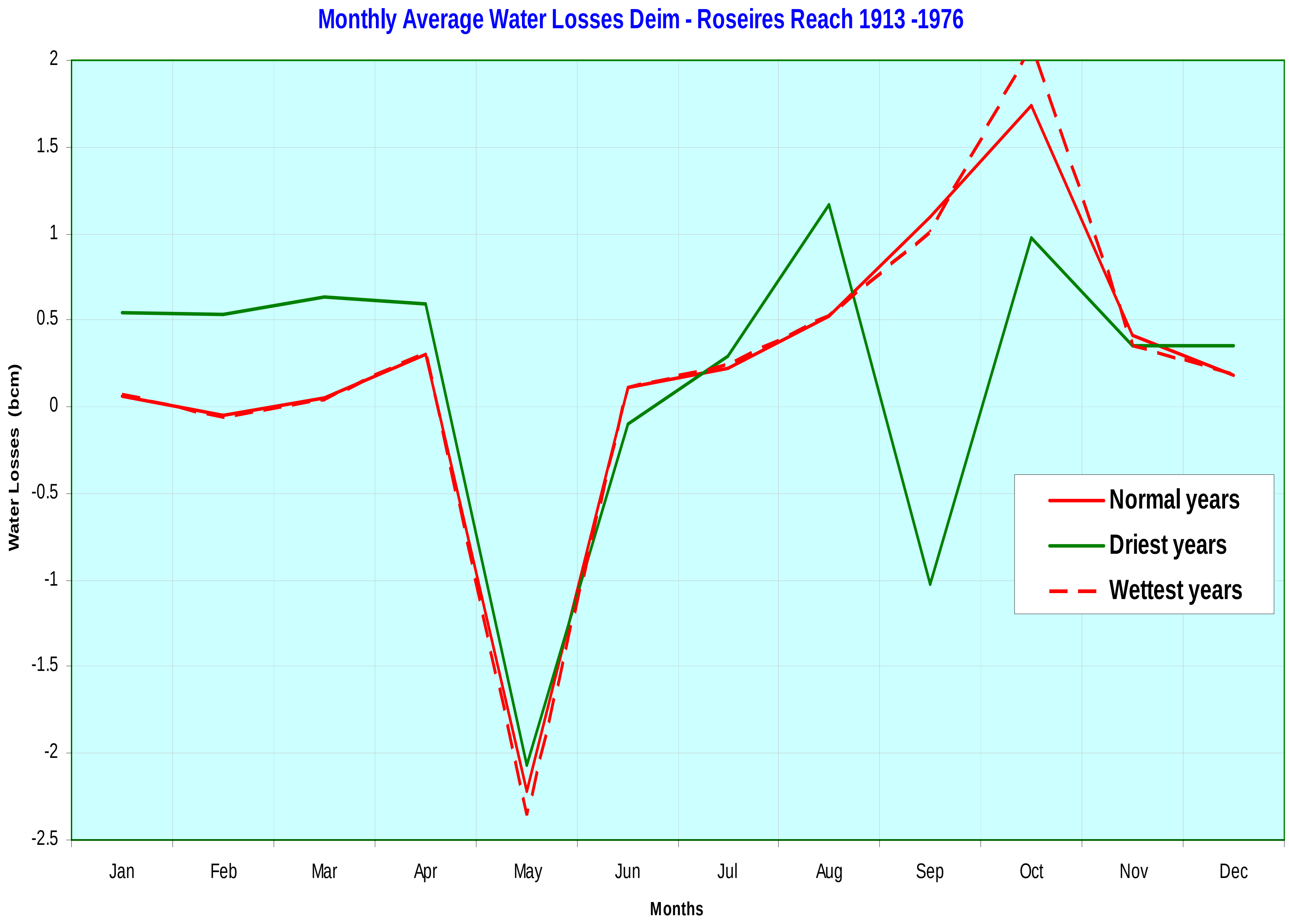

Monthly Average Water Losses Malakal - Jebel AuliaReach 1913 -1976
Water Losses (bcm)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Normal years
Driest years
Wettest years

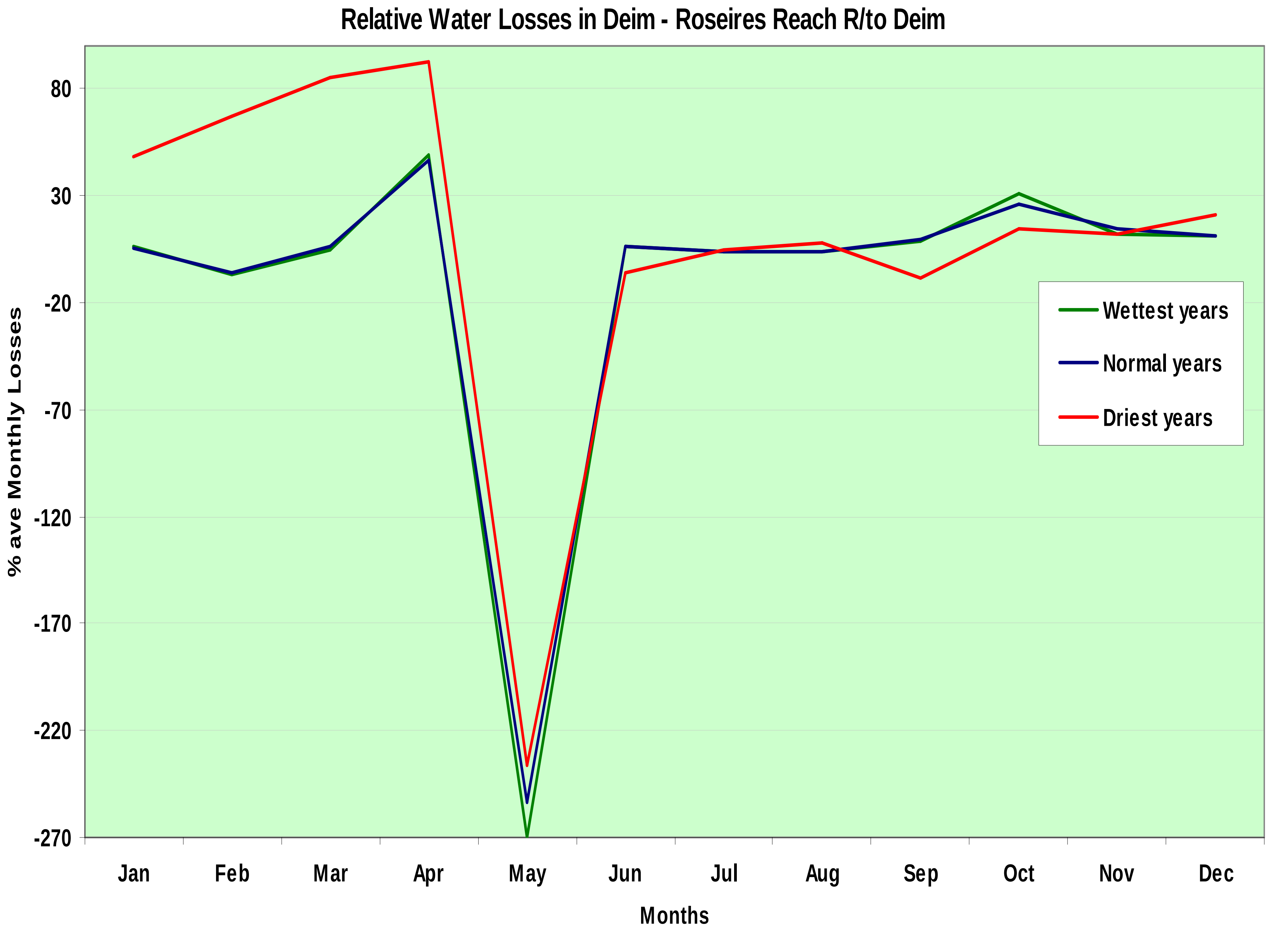


Relative Water Losses in Malakal - Jebel Aulia Reach to Malakal
% ave Monthly Losses
100
90
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Wettest years
Normal years
Driest years

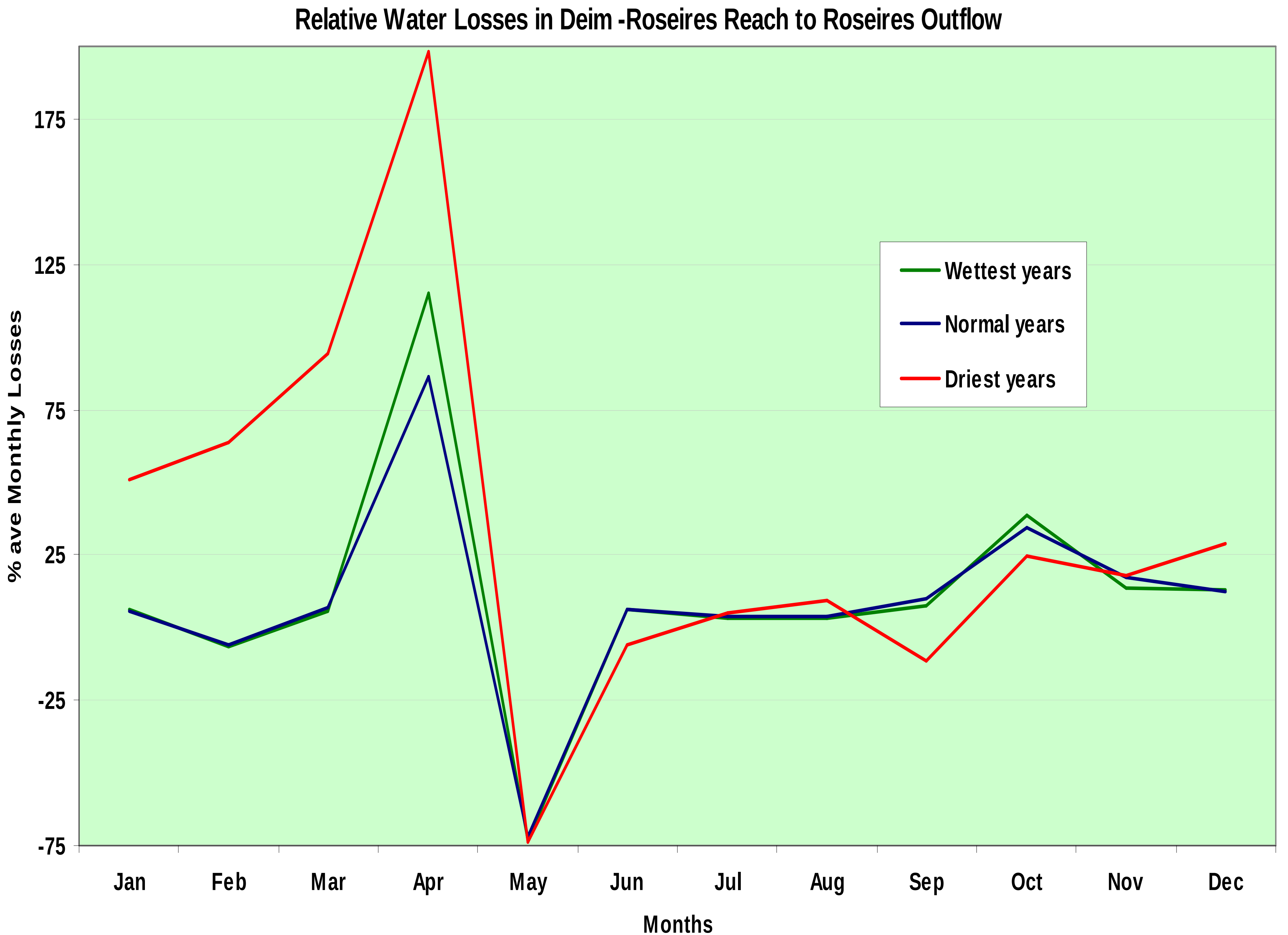

Relative Water Losses in Malakal - Jebel Aulia Reach to Jebel Aulia Outflow
% ave Monthly Losses
240
190
140
90
40
-10
-60
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Wettest years
Normal years
Driest years

2. The Blue Nile System

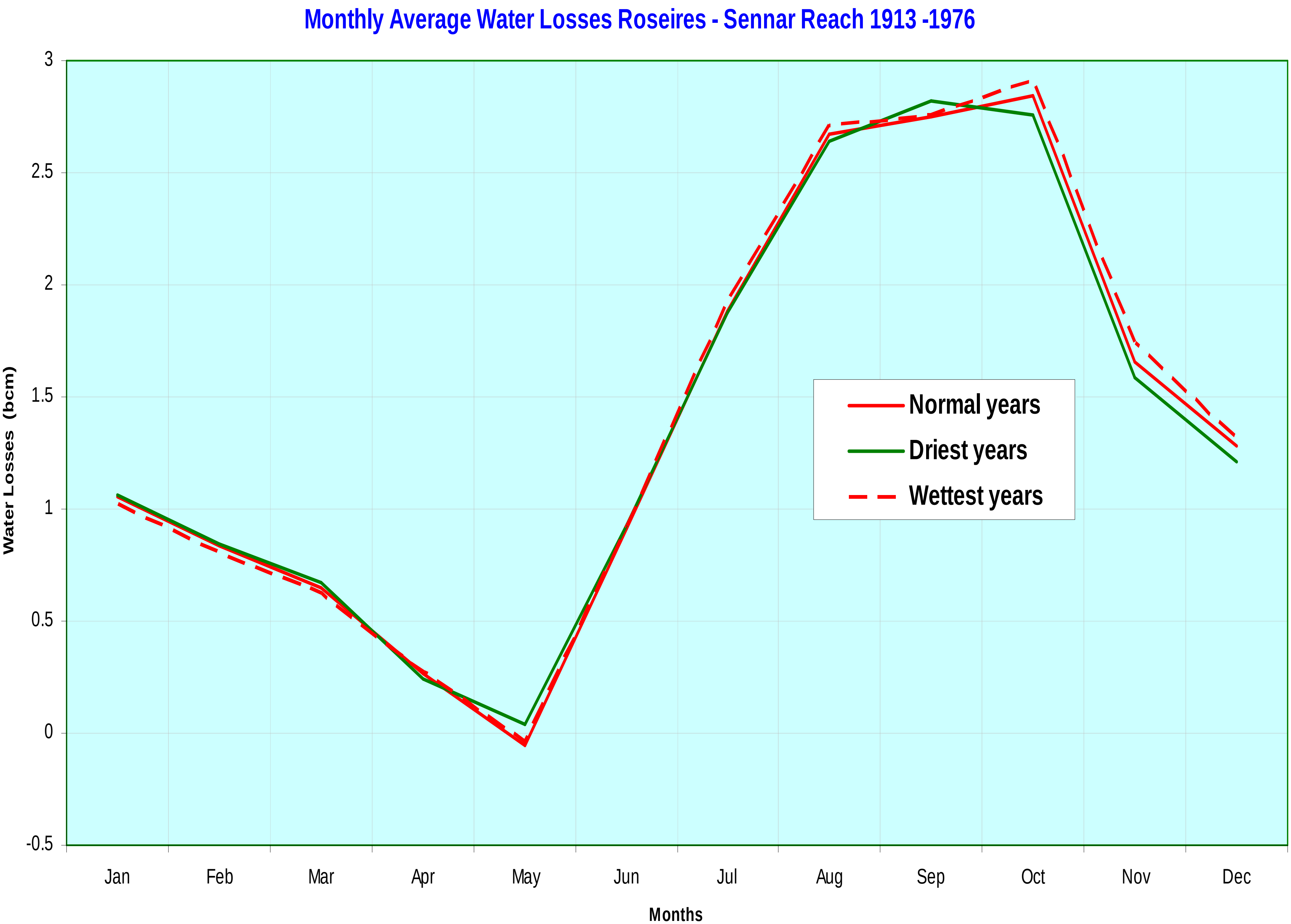

Monthly Average Water Losses Deim - Roseires Reach 1913 -1976
Water Losses (bcm)
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-2.5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Normal years
Driest years
Wettest years



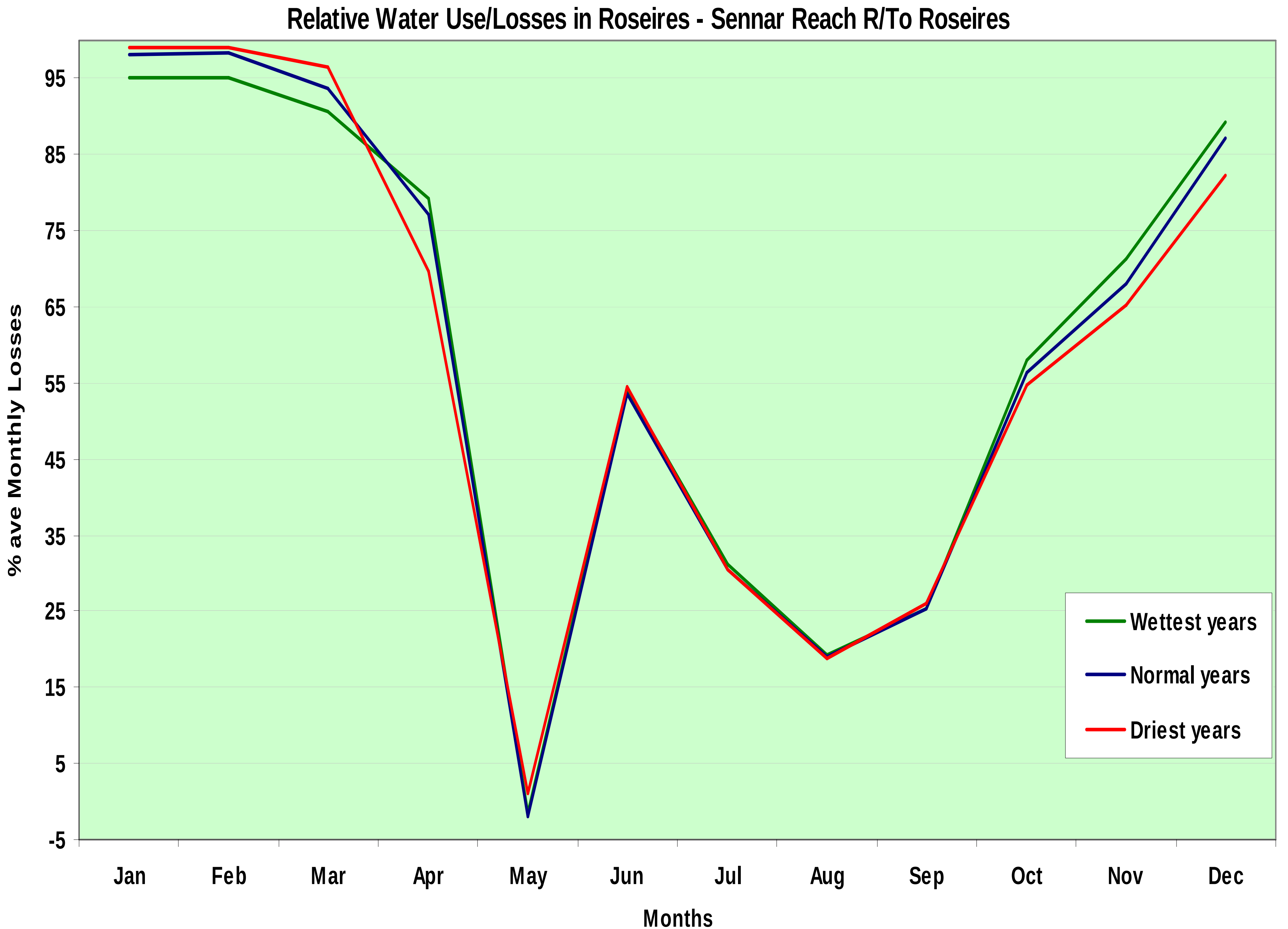
Relative Water Losses in Deim - Roseires Reach R/to Deim
80
30
-20
-70
-120
-170
-220
-270
% ave Monthly Losses
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Wettest years
Normal years
Driest years



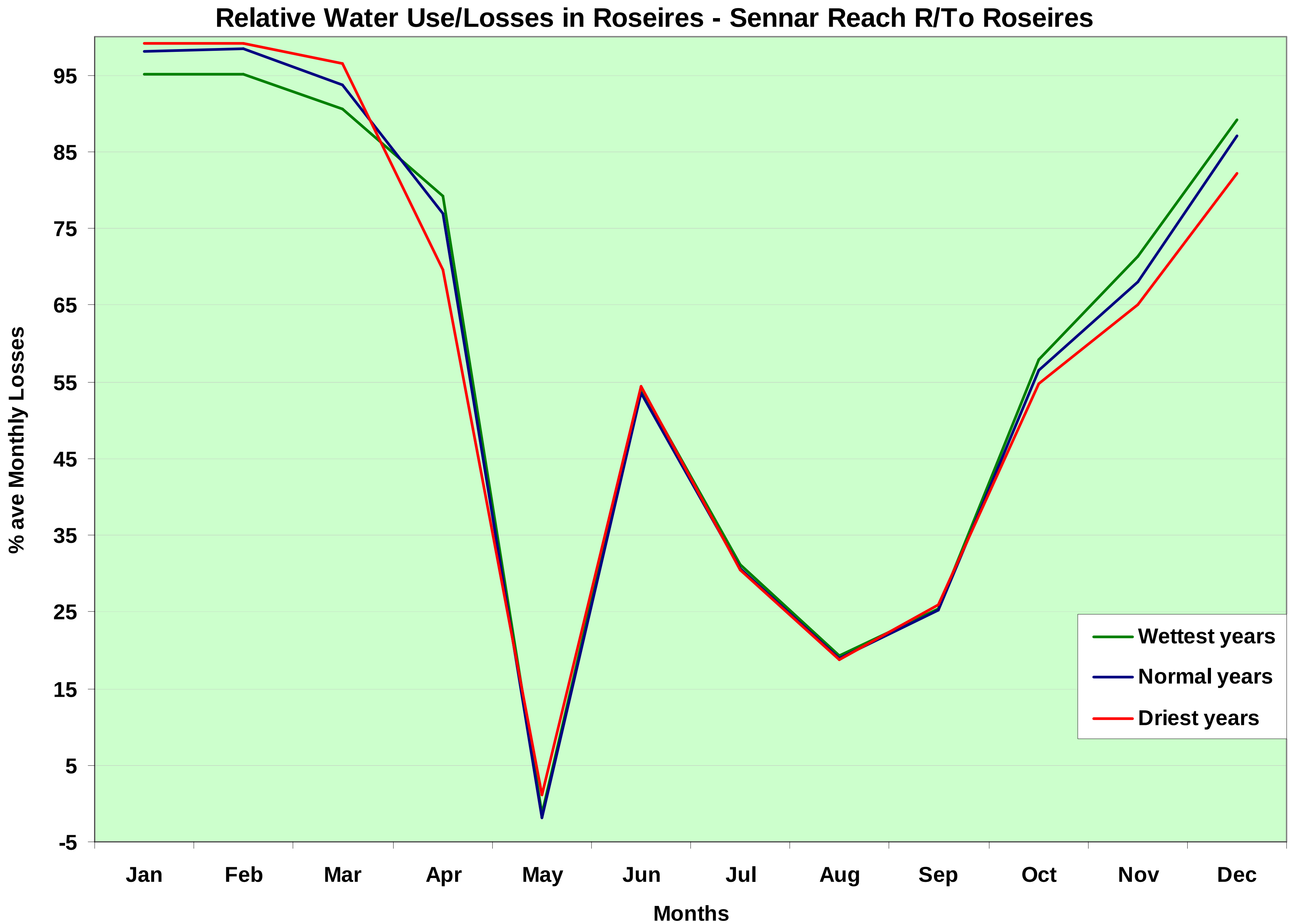
Relative Water Losses in Deim -Roseires Reach to Roseires Outflow
175
125
75
25
-25
-75
% ave Monthly Losses
Wettest years
Normal years
Driest years
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months



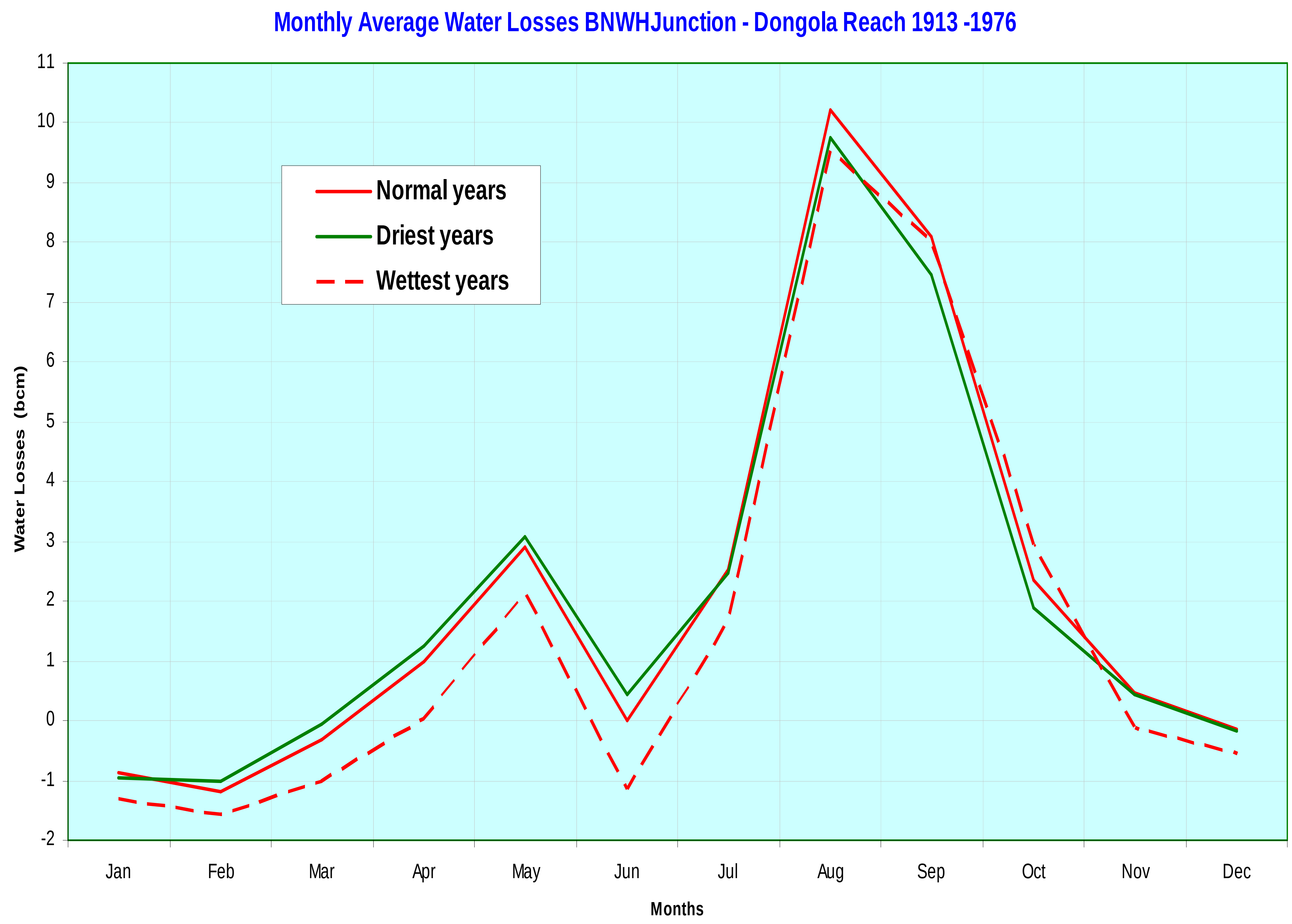
Monthly Average Water Losses Roseires - Sennar Reach 1913 -1976
Water Losses (bcm)
3
2.5
2
1.5
1
0.5
0
-0.5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Normal years
Driest years
Wettest years

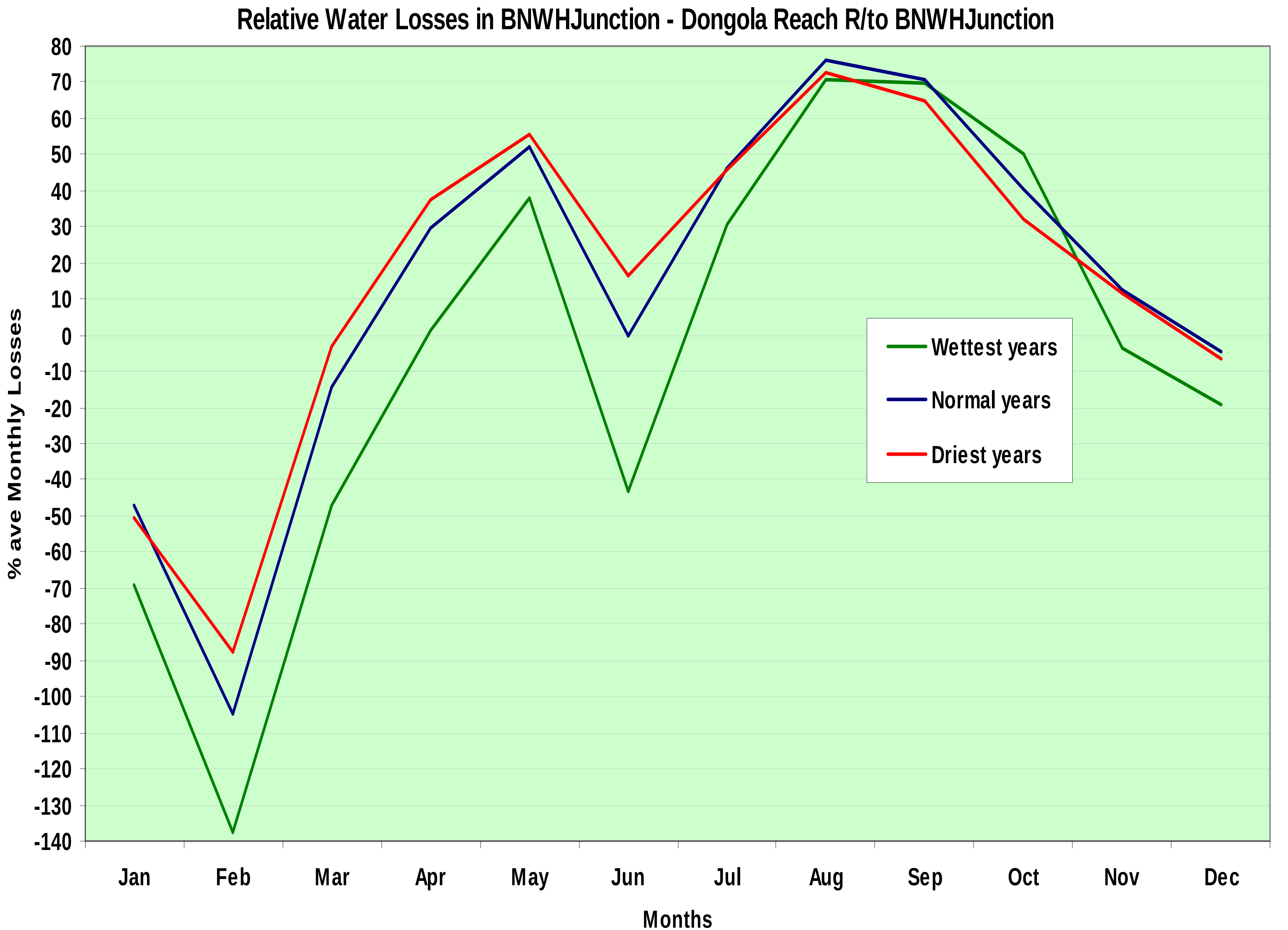


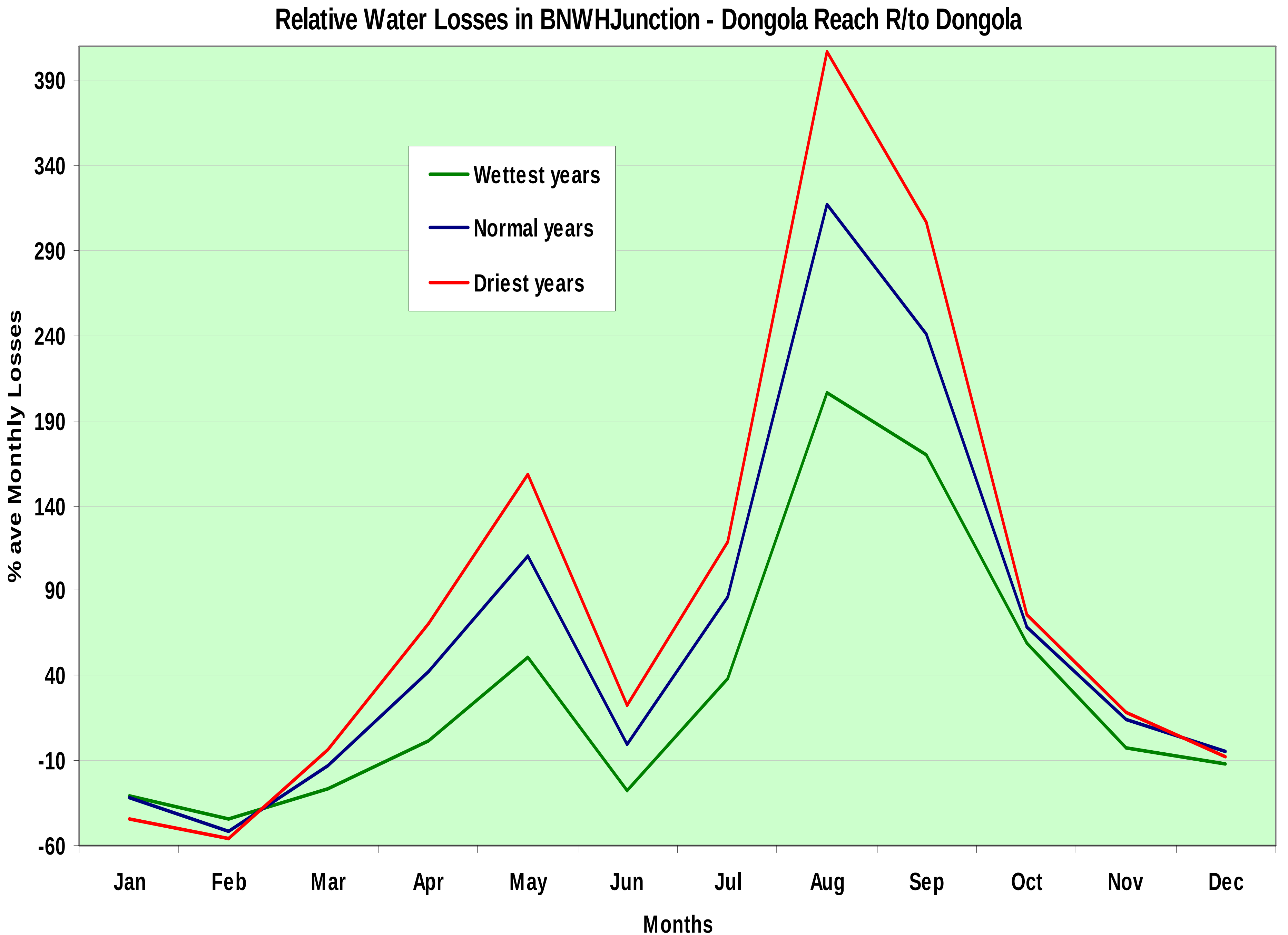
Relative Water Use/Losses in Roseires - Sennar Reach R/To Roseires
% ave Monthly Losses
95
85
75
65
55
45
35
25
15
5
-5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Wettest years
Normal years
Driest years


Relative Water Use/Losses in Roseires - Sennar Reach R/To Roseires
% ave Monthly Losses
95
85
75
65
55
45
35
25
15
5
-5
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Wettest years
Normal years
Driest years

3. The Main Nile System


Monthly Average Water Losses BNWHJunction - Dongola Reach 1913 -1976
Normal years
Driest years
Wettest years
Water Losses (bcm)
11
10
9
8
7
6
5
4
3
2
1
0
-1
-2
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

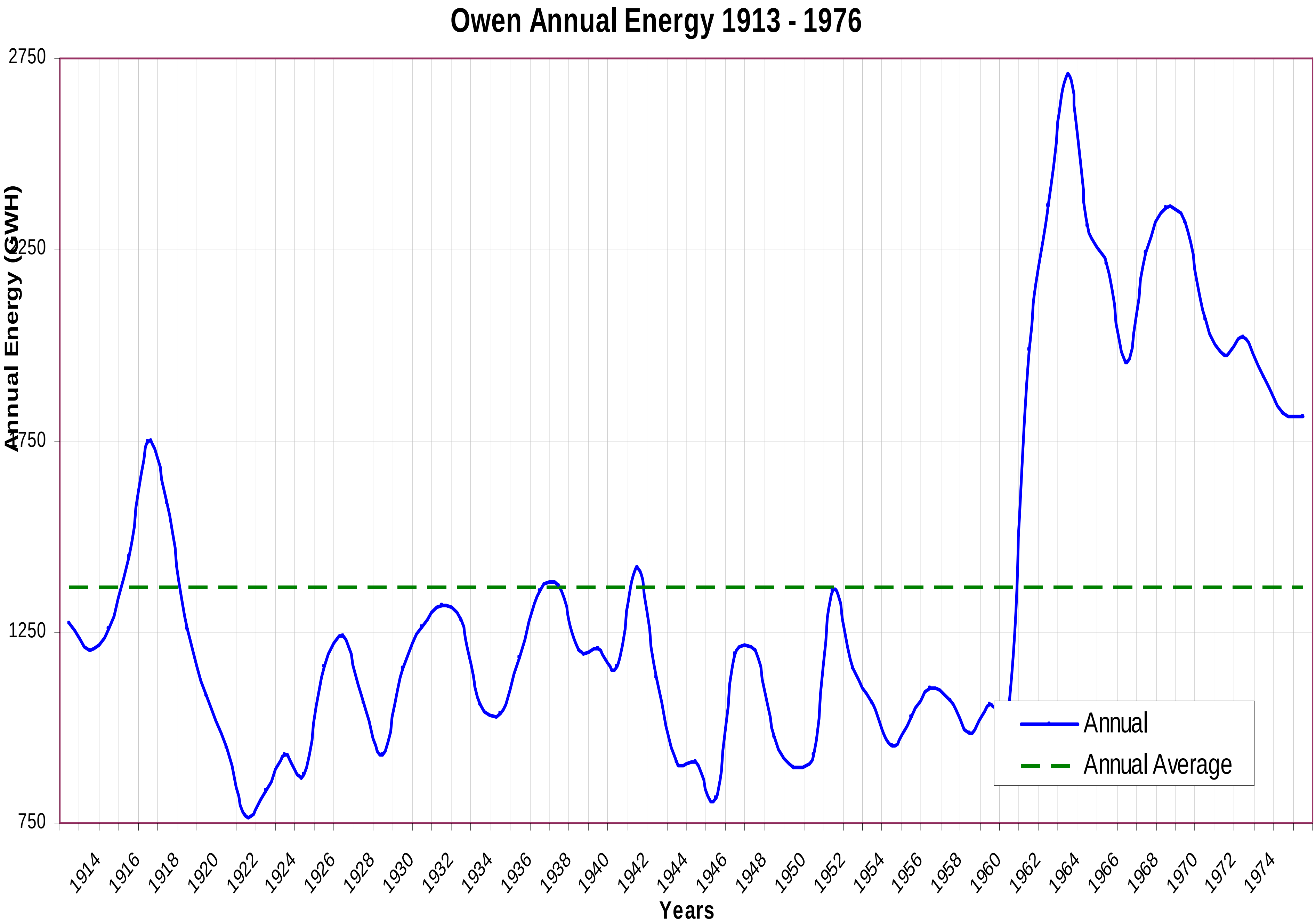

Relative Water Losses in BNWHJunction - Dongola Reach R/to BNWHJunction
80
70
60
50
40
30
20
10
0
-10
-20
-30
-40
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
% ave Monthly Losses
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Wettest years
Normal years
Driest years



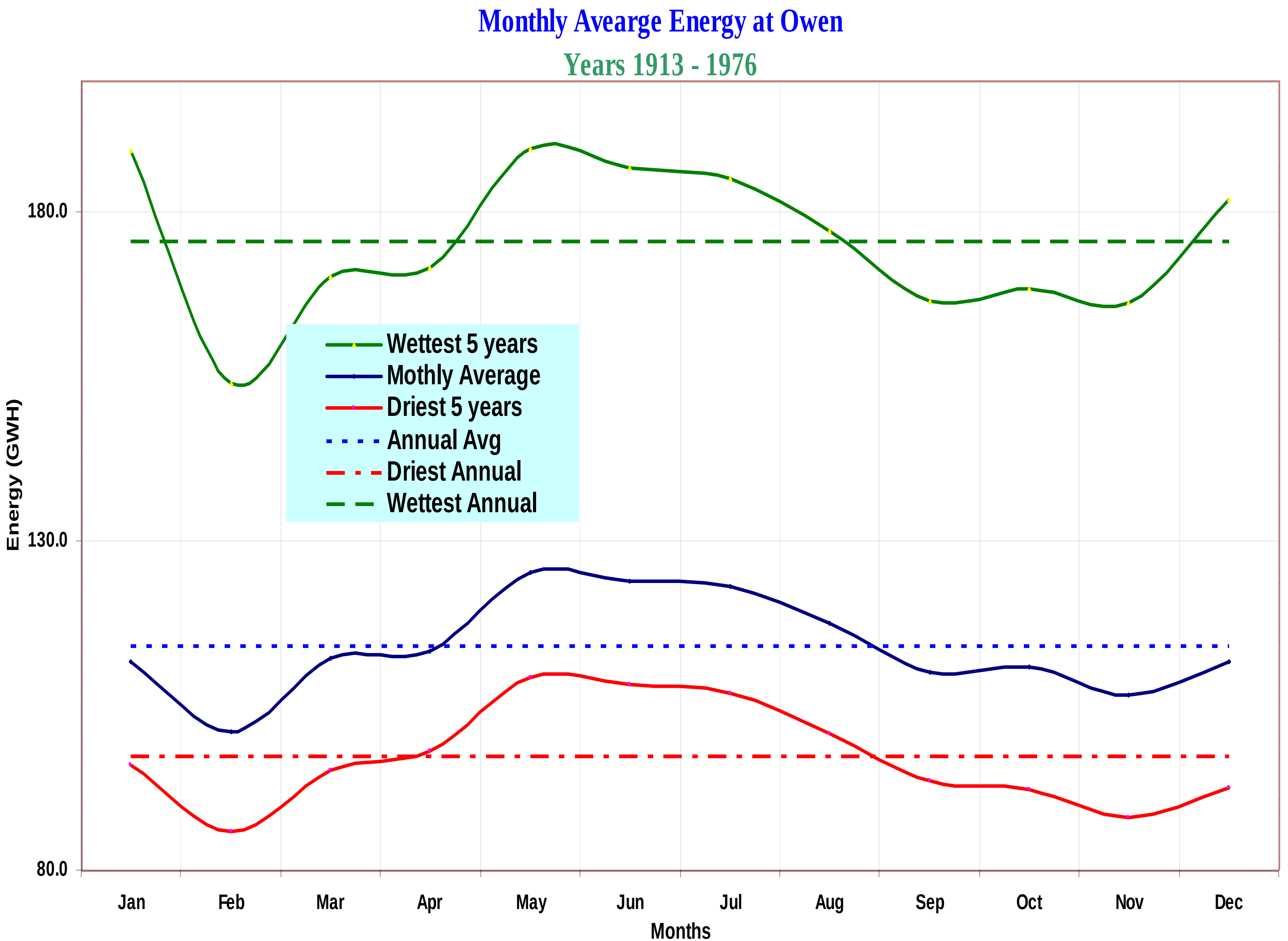
Relative Water Losses in BNWHJunction - Dongola Reach R/to Dongola
Wettest years
Normal years
Driest years
390
340
290
240
190
140
90
40
-10
-60
% ave Monthly Losses
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

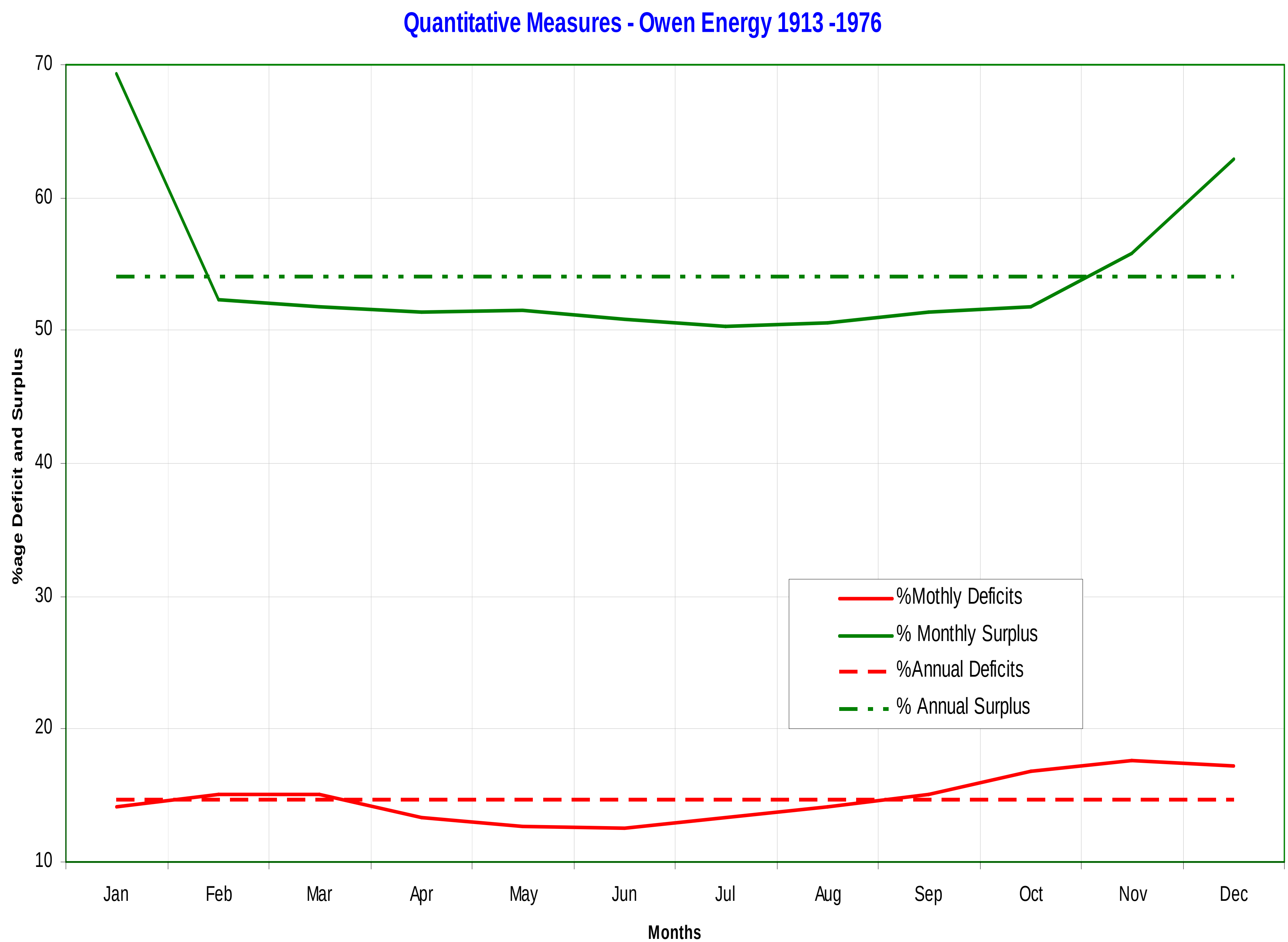
Exercise 1.3

- **Hydropower Generation**

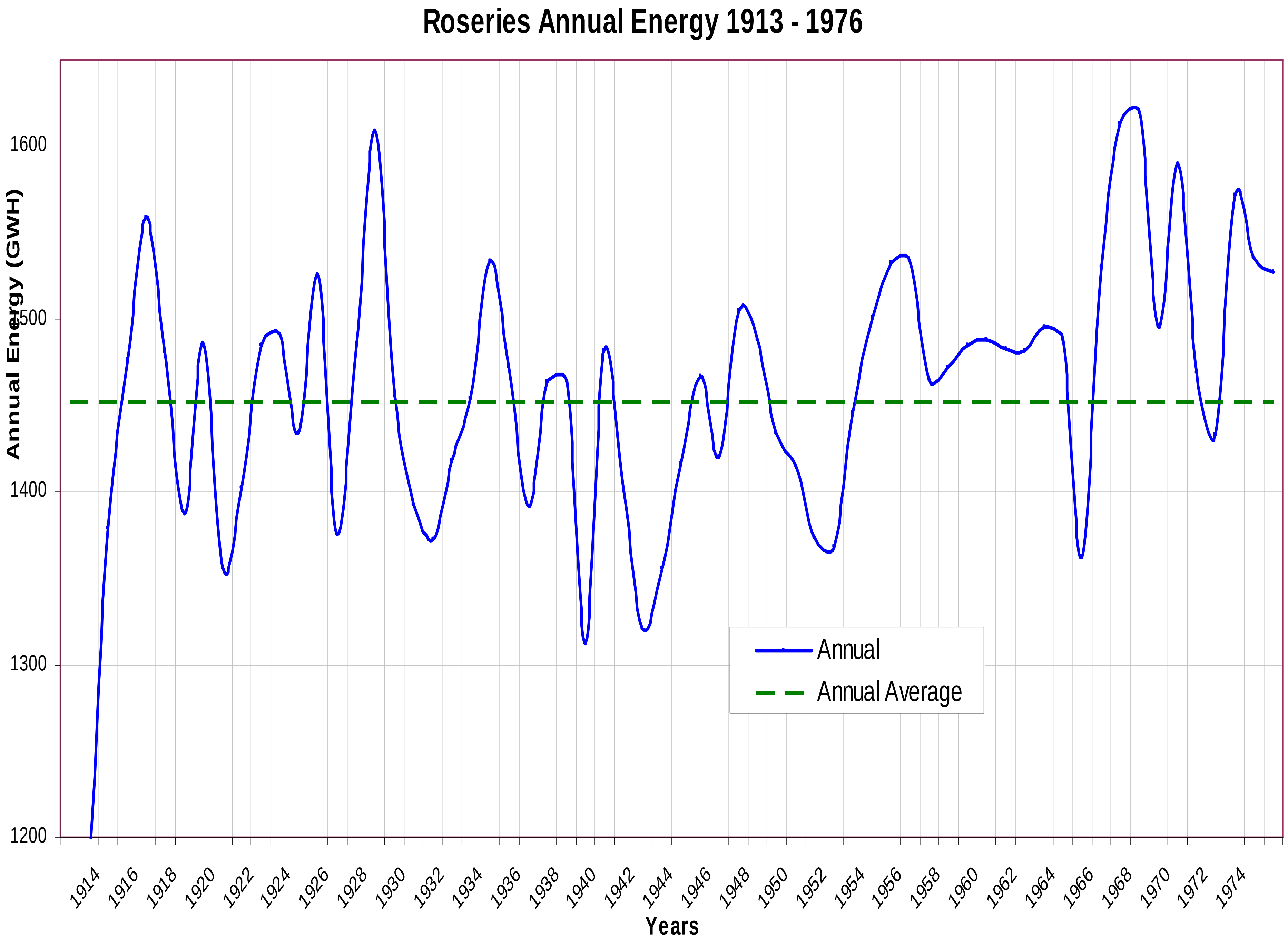


Owen Annual Energy 1913 - 1976
2750
2250
1750
1250
750
Annual Energy (GWH)
1914
1916
1918
1920
1922
1924
1926
1928
1930
1932
1934
1936
1938
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
Years
Annual
Annual Average

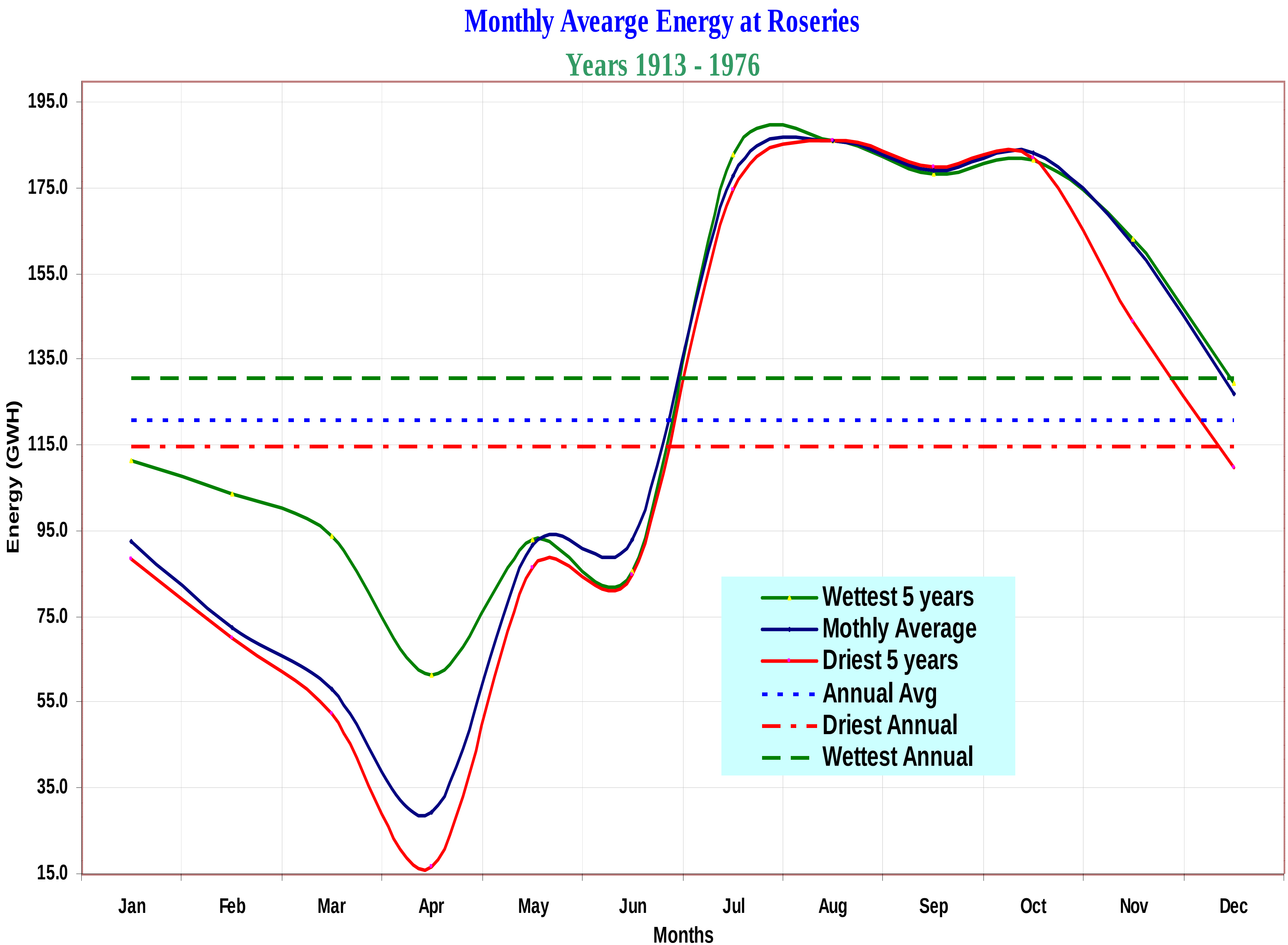

Monthly Avearge Energy at Owen
Years 1913 - 1976
Wettest 5 years
Mothly Average
Driest 5 years
Annual Avg
Driest Annual
Wettest Annual
180.0
130.0
80.0
Energy (GWH)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months

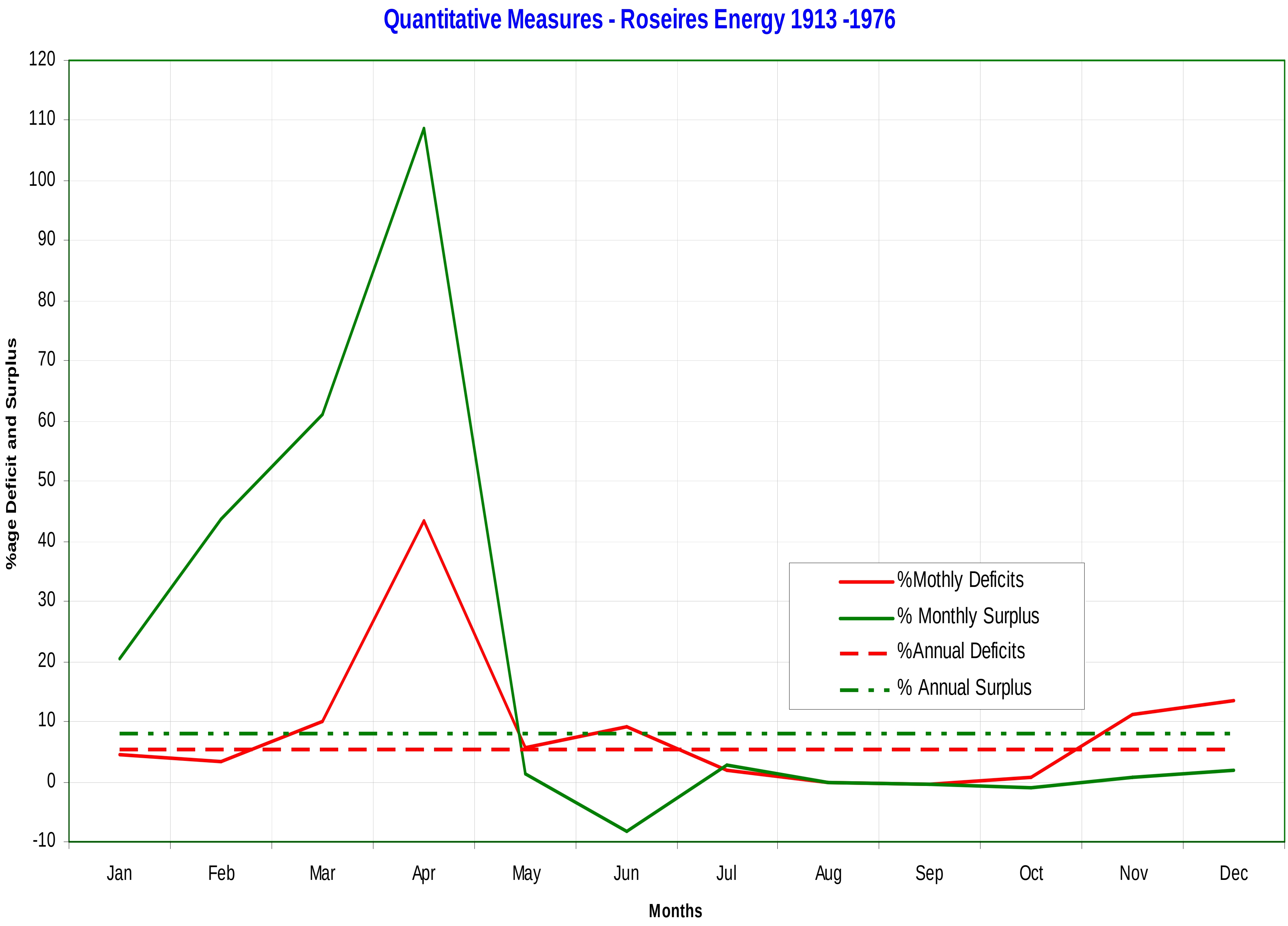


Quantitative Measures - Owen Energy 1913 -1976
70
60
50
40
30
20
10
%age Deficit and Surplus
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
%Mothly Deficits
% Monthly Surplus
%Annual Deficits
% Annual Surplus



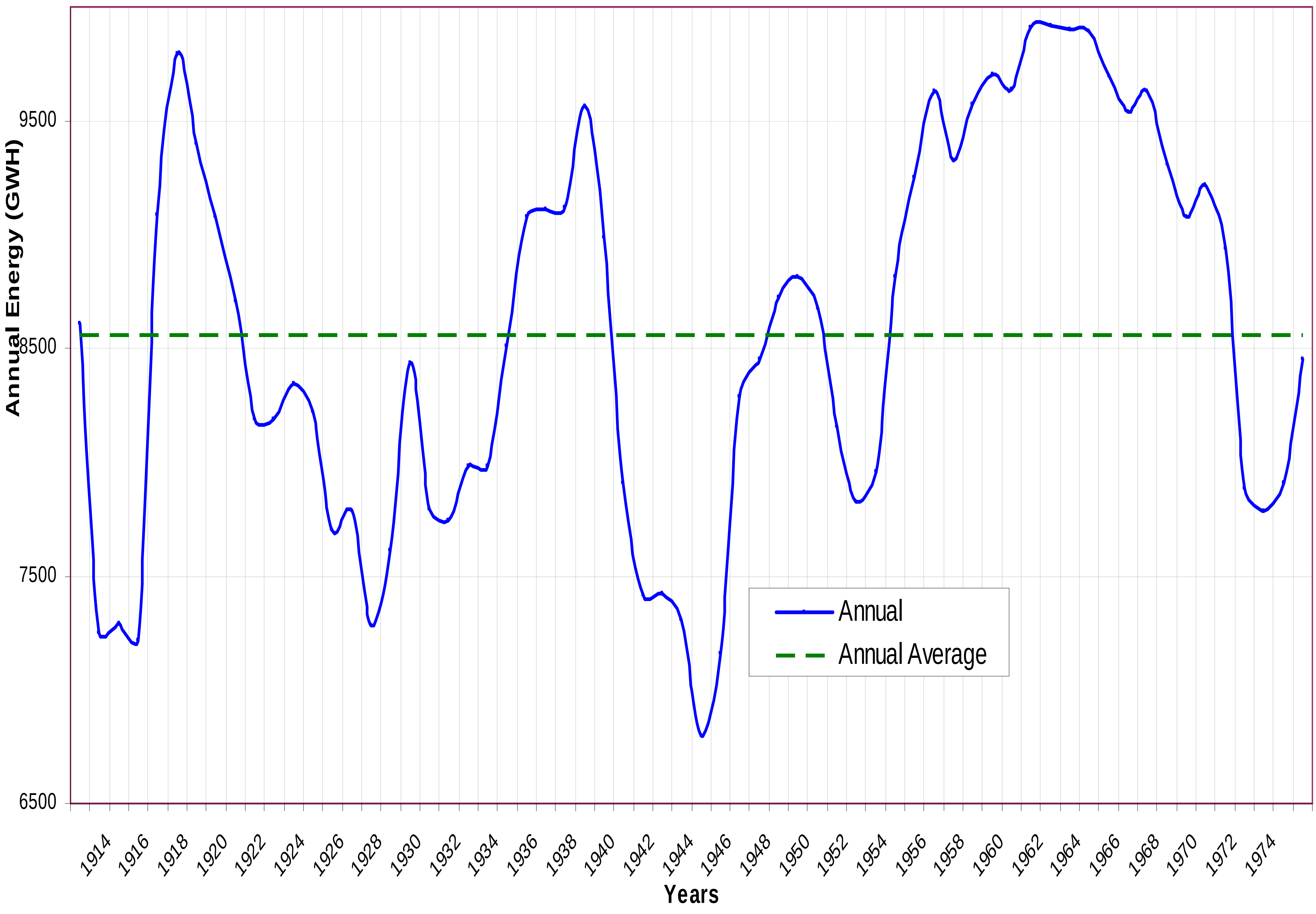
Roseries Annual Energy 1913 - 1976
Annual Energy (GWH)
1600
1500
1400
1300
1200
1914
1916
1918
1920
1922
1924
1926
1928
1930
1932
1934
1936
1938
1940
1942
1944
1946
1948
1950
1952
1954
1956
1958
1960
1962
1964
1966
1968
1970
1972
1974
Years
Annual
Annual Average

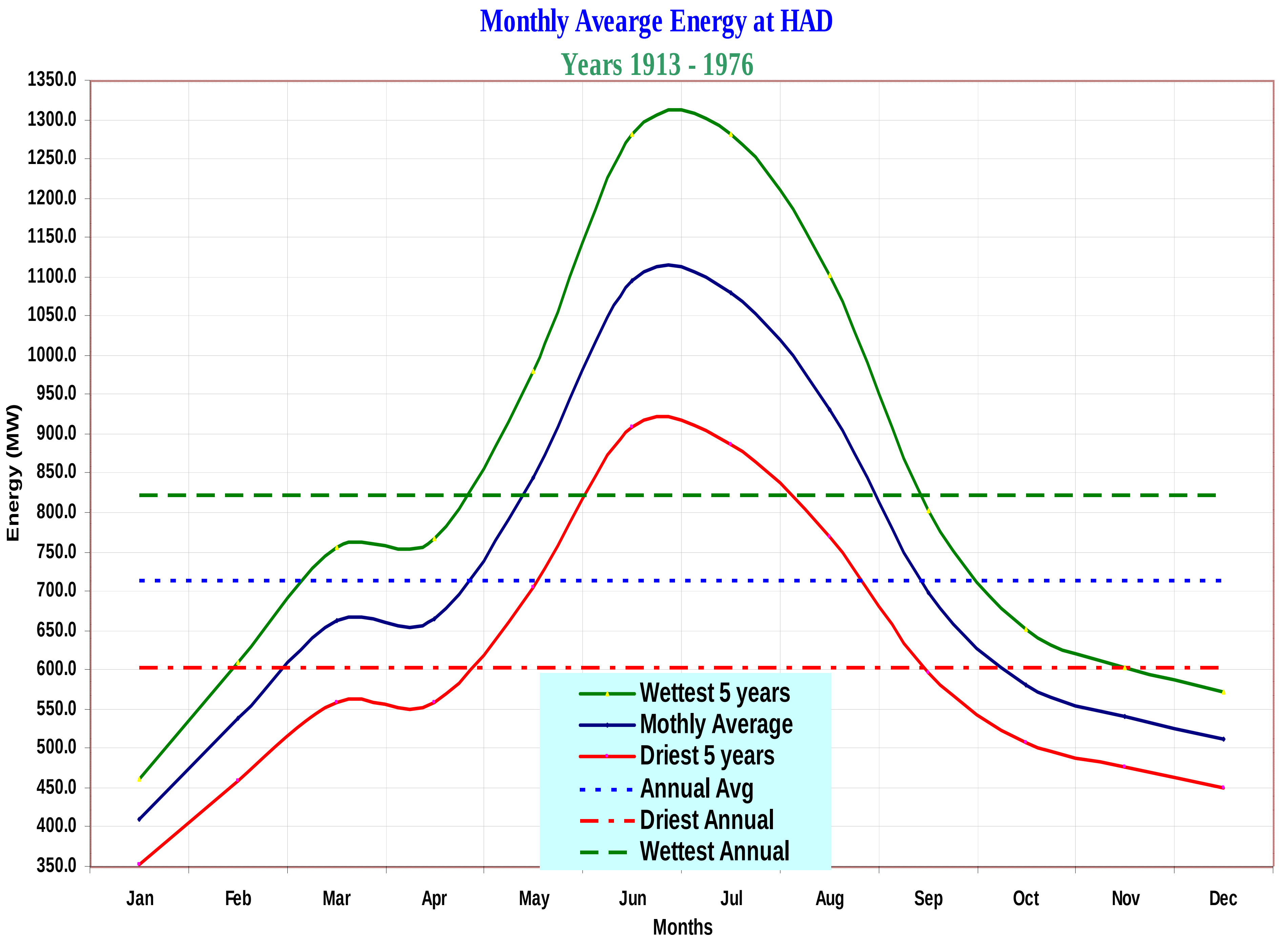

Monthly Avearge Energy at Roseries
Years 1913 - 1976
195.0
175.0
155.0
135.0
115.0
95.0
75.0
55.0
35.0
15.0
Energy (GWH)
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Wettest 5 years
Mothly Average
Driest 5 years
Annual Avg
Driest Annual
Wettest Annual



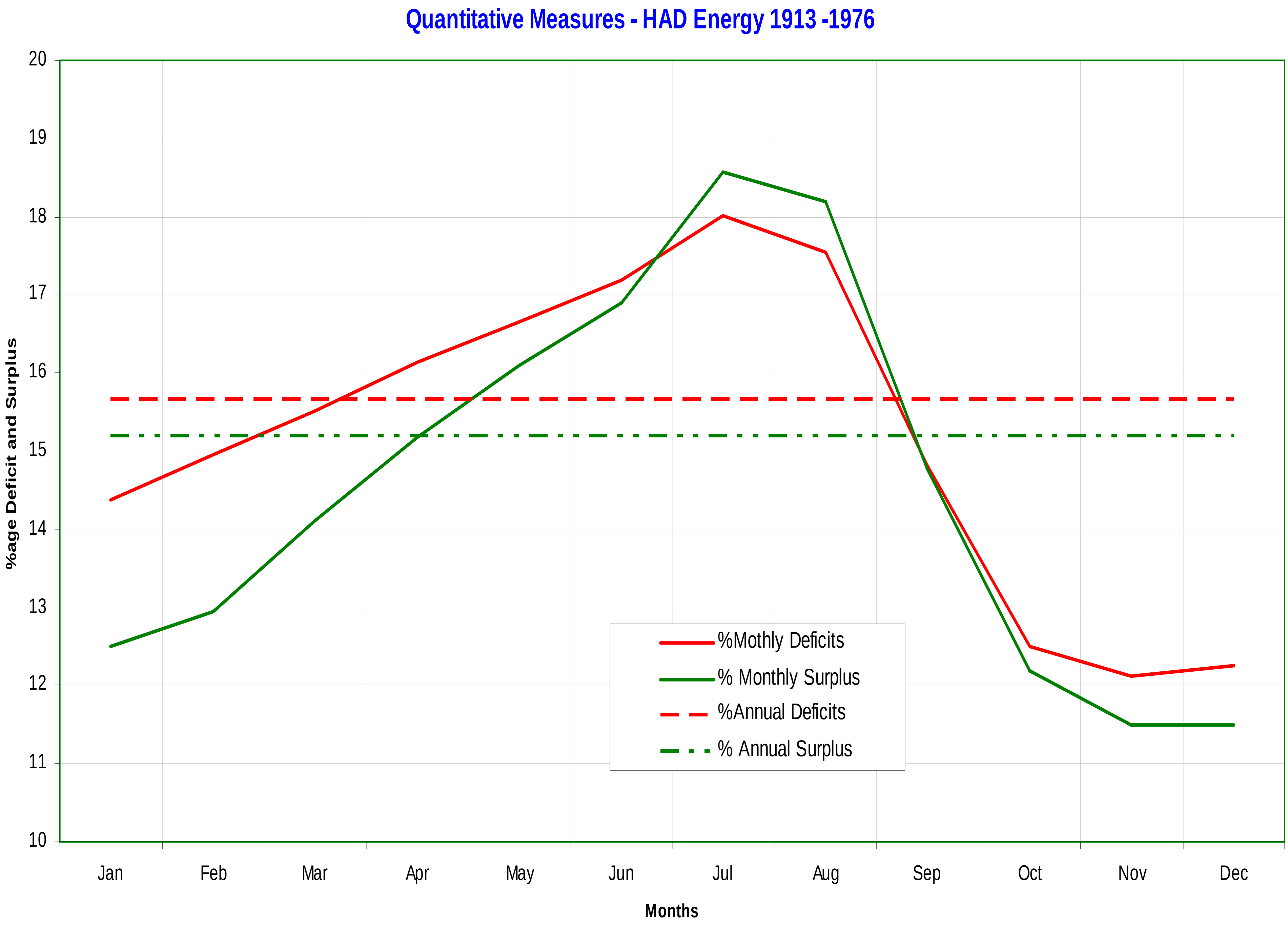
Quantitative Measures - Roseires Energy 1913 -1976
%age Deficit and Surplus
120
110
100
90
80
70
60
50
40
30
20
10
0
-10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
%Mothly Deficits
% Monthly Surplus
%Annual Deficits
% Annual Surplus

HAD Annual Energy 1913 - 1976





Monthly Avearge Energy at HAD
Years 1913 - 1976
Energy (MW)
1350.0
1300.0
1250.0
1200.0
1150.0
1100.0
1050.0
1000.0
950.0
900.0
850.0
800.0
750.0
700.0
650.0
600.0
550.0
500.0
450.0
400.0
350.0
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
Wettest 5 years
Mothly Average
Driest 5 years
Annual Avg
Driest Annual
Wettest Annual


Quantitative Measures - HAD Energy 1913 -1976
%age Deficit and Surplus
20
19
18
17
16
15
14
13
12
11
10
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Months
%Mothly Deficits
% Monthly Surplus
%Annual Deficits
% Annual Surplus

Thank you

COUNTRY: TANZANIA

EXERCISE 1

Water Balance and Water Uses Assessments

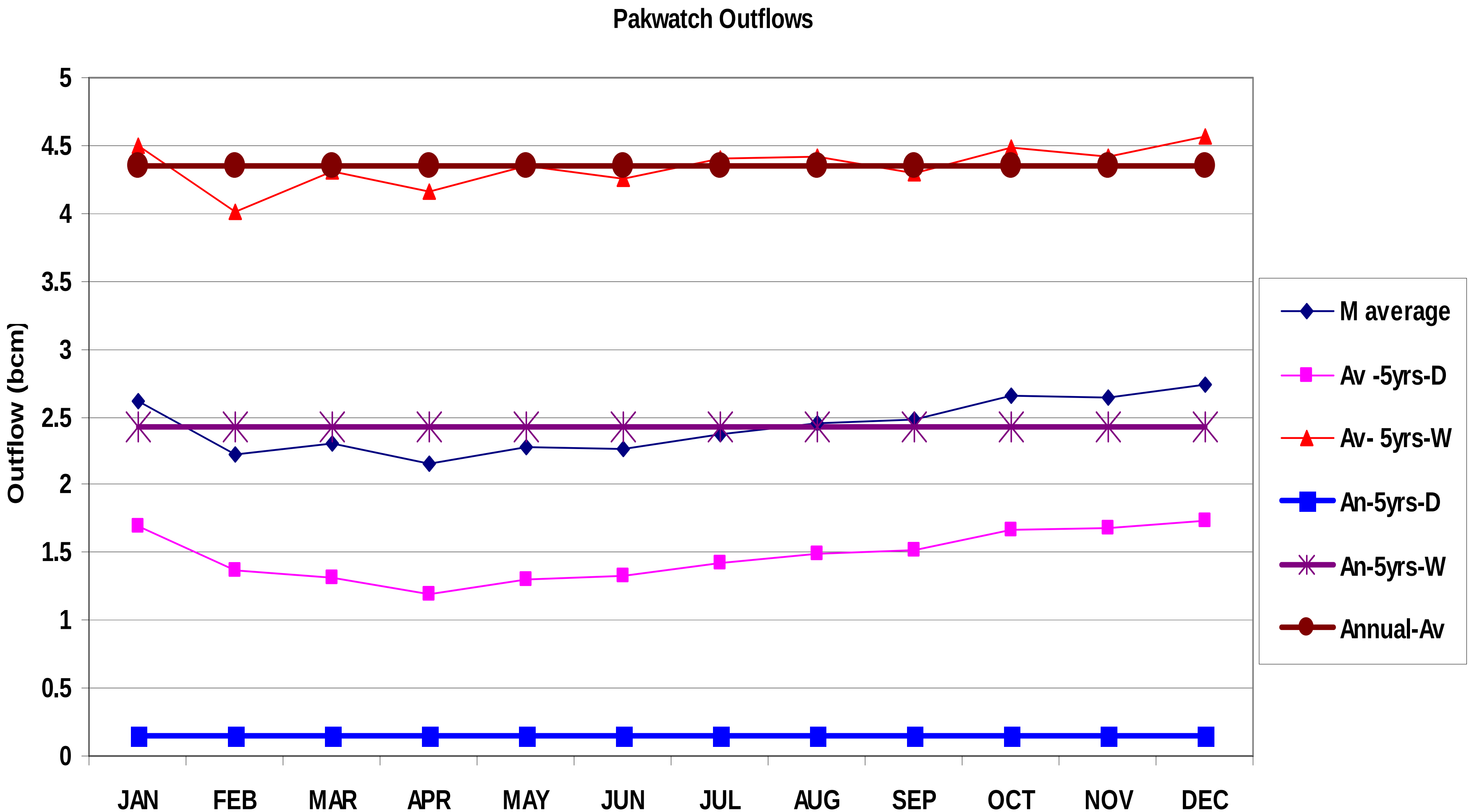
Team Members

Mr. Hamza Sadiki

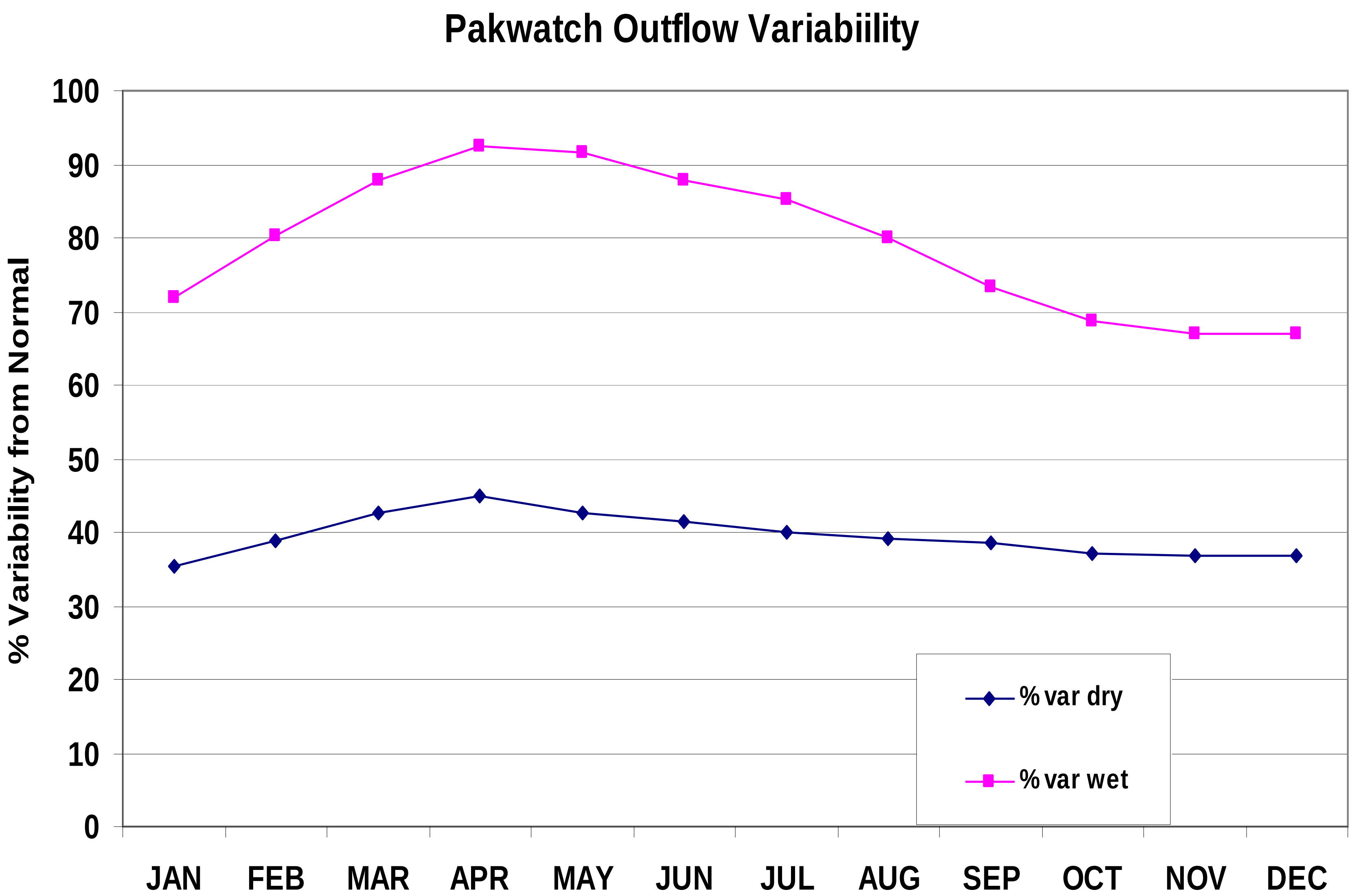
Dr. George Lugomela

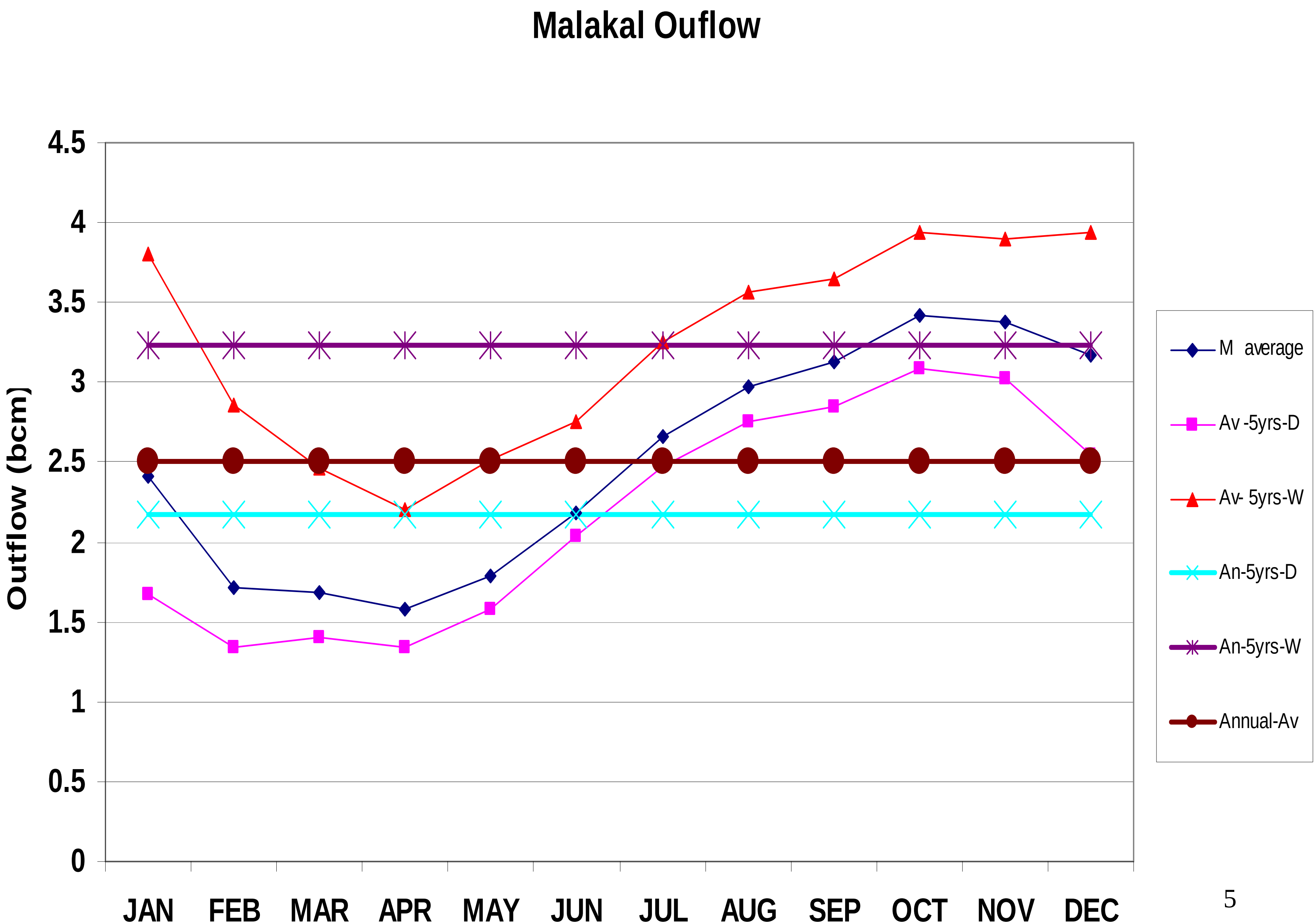
EXERCISE 1.1: SUMMARY

SN	RIVER REACH	RIVER/RESERVIOR NODE	DRIEST 5 YEARS	WETTEST 5 YEARS
1	Southern Nile up to Uganda/ Nile Border (Nimule)	Victoria	1921 - 1925	1962 - 1966
2	Nimule to Malakal u/s Sobat junction	Pakwatch	1921 - 1925	1962 - 1966
3	Malakal to d/s of Gabel el Aulia Dam (before White and Blue Niles junction)	Malakal	1940 - 1944	1962 - 1966
4	Ethiopian Blue Nile to Sudanese border	Gabel El Aulia	1940 - 1944	1962 - 1966
5	Sudanese Blue Nile to White Nile junction	Border/Diem	1913 - 1917	1929 - 1933
6.	Main Nile from B & W Nile junction to HAD	Khartoum	1934 - 1938	1968 - 1972
7.	Egyptian Nile incl. HAD to Mediterranean Sea	Dongola	1940 - 1944	1960 - 1960

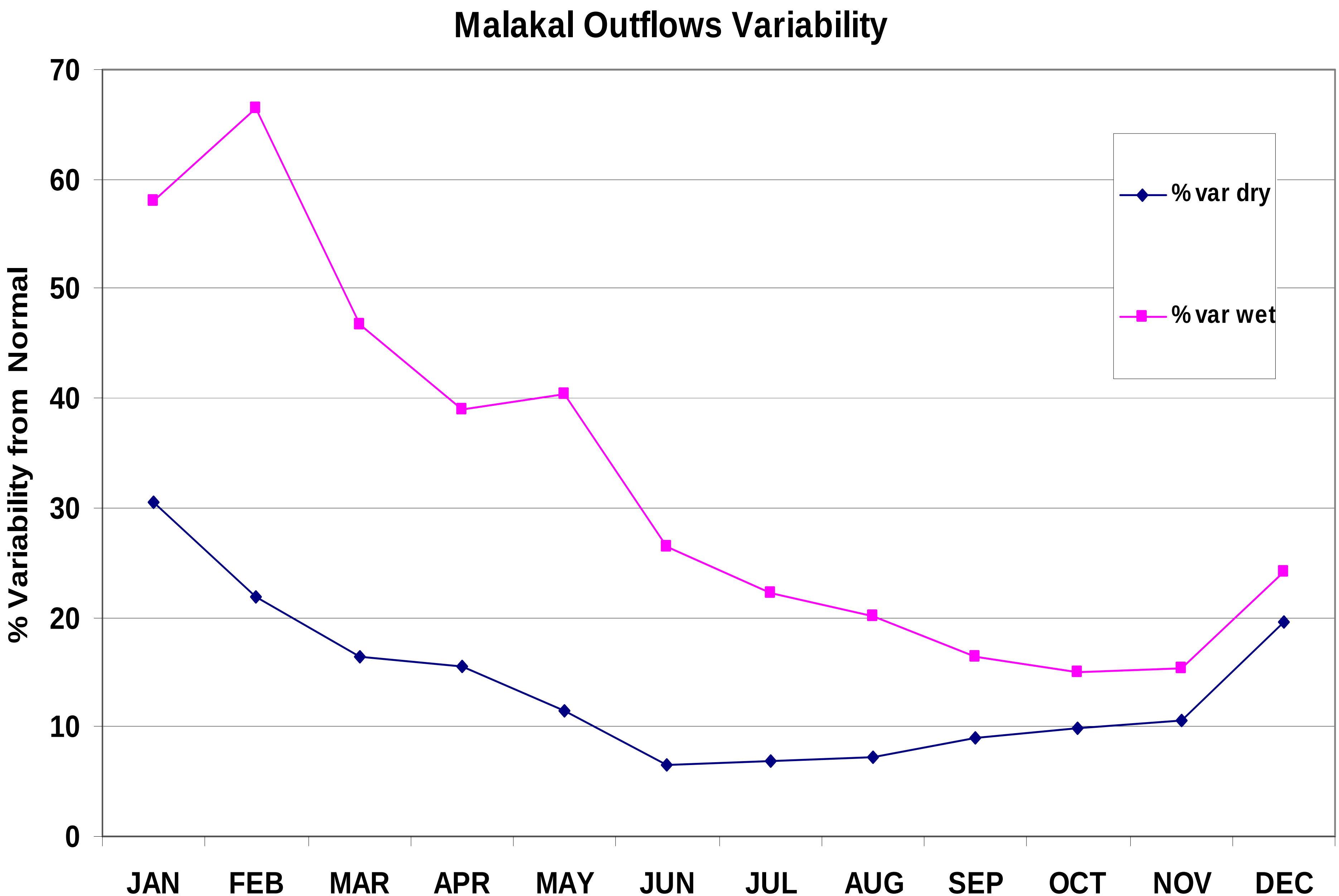


Pakwatch Outflows
Outflow (bcm)
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
M average
Av -5yrs-D
Av- 5yrs-W
An-5yrs-D
An-5yrs-W
Annual-Av

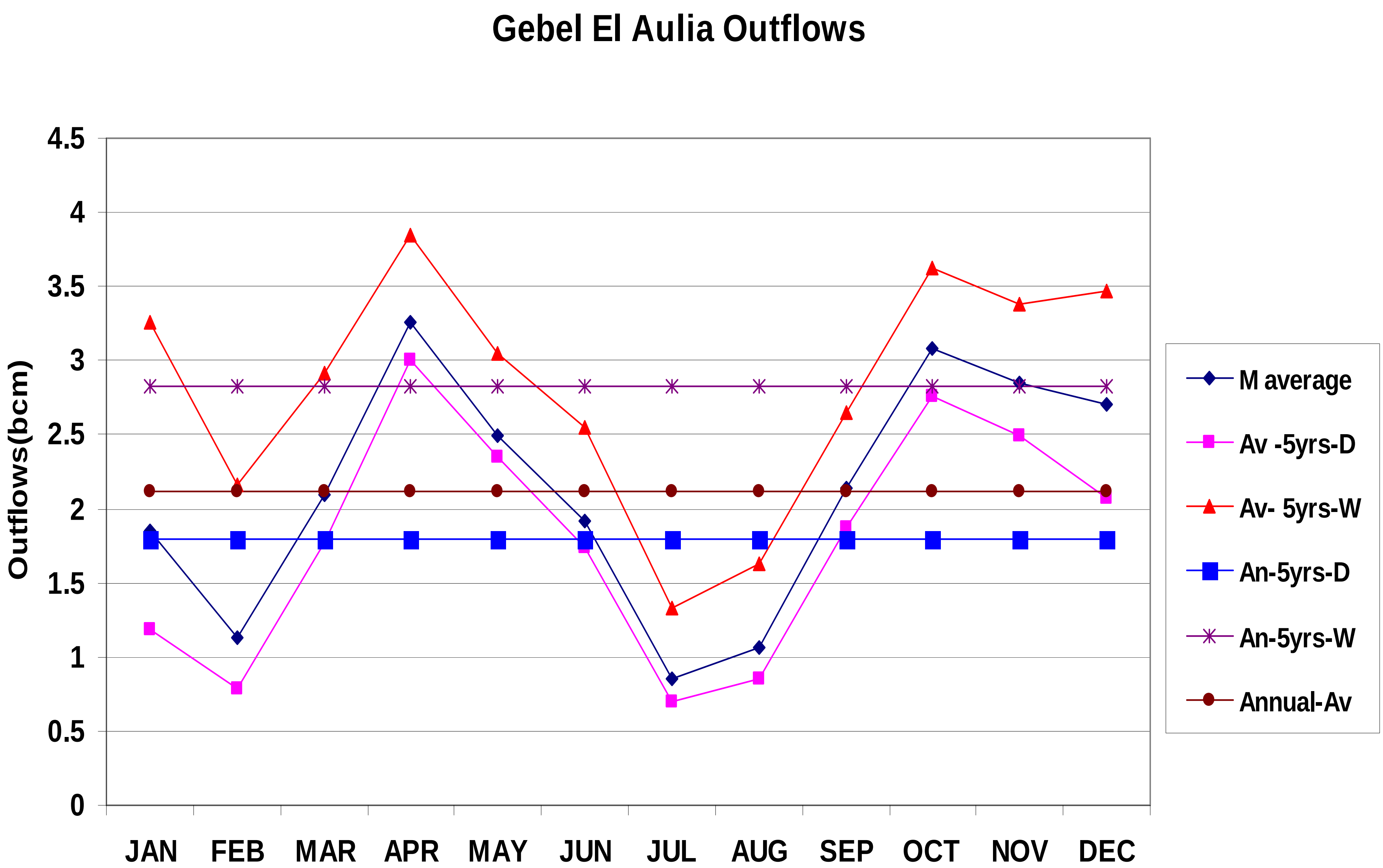

Pakwatch Outflow Variabiility
% Variability from Normal
100
90
80
70
60
50
40
30
20
10
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
% var dry
% var wet



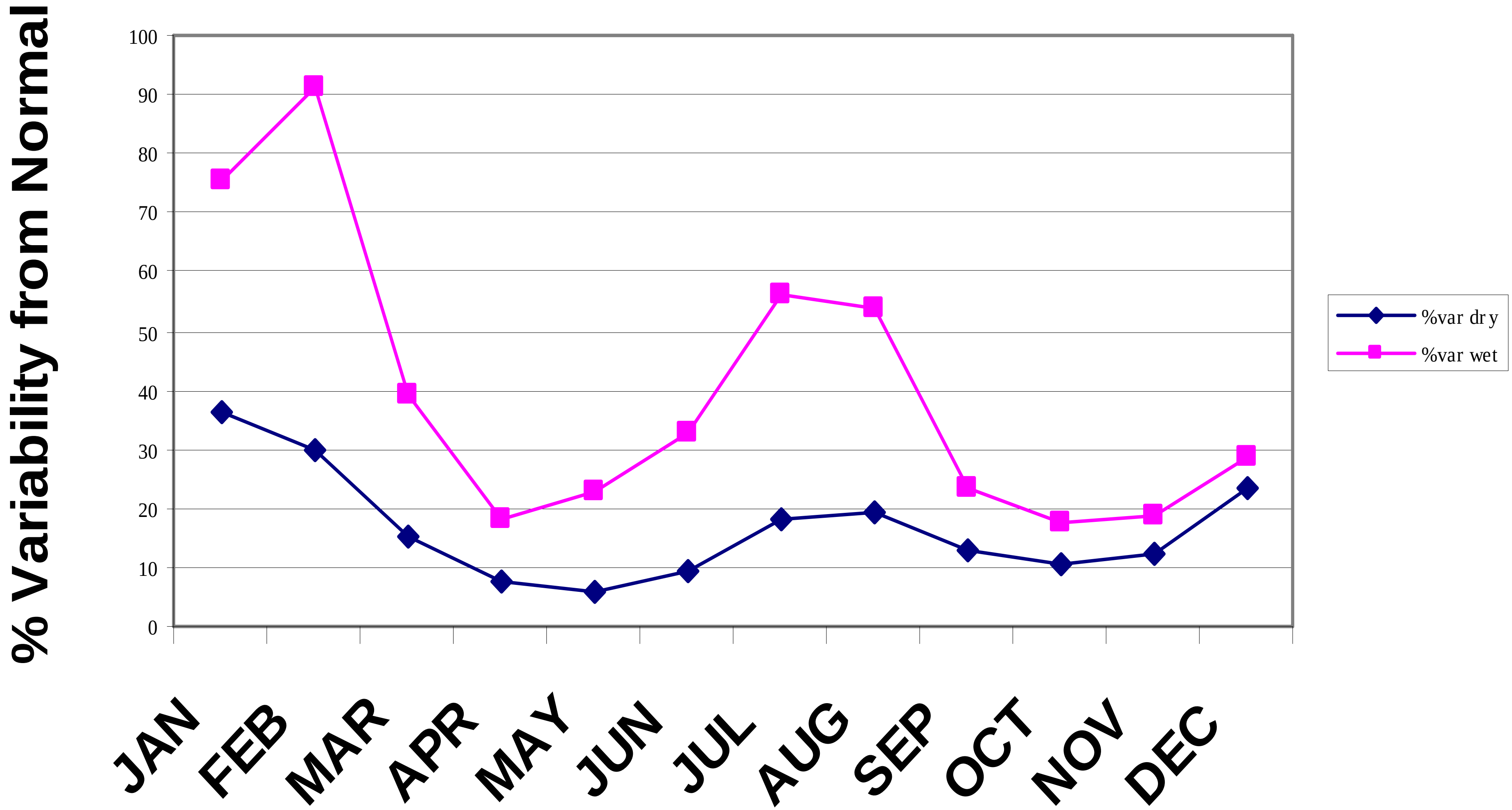
Malakal Ouflow
Outflow (bcm)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
M average
Av -5yrs-D
Av- 5yrs-W
An-5yrs-D
An-5yrs-W
Annual-Av

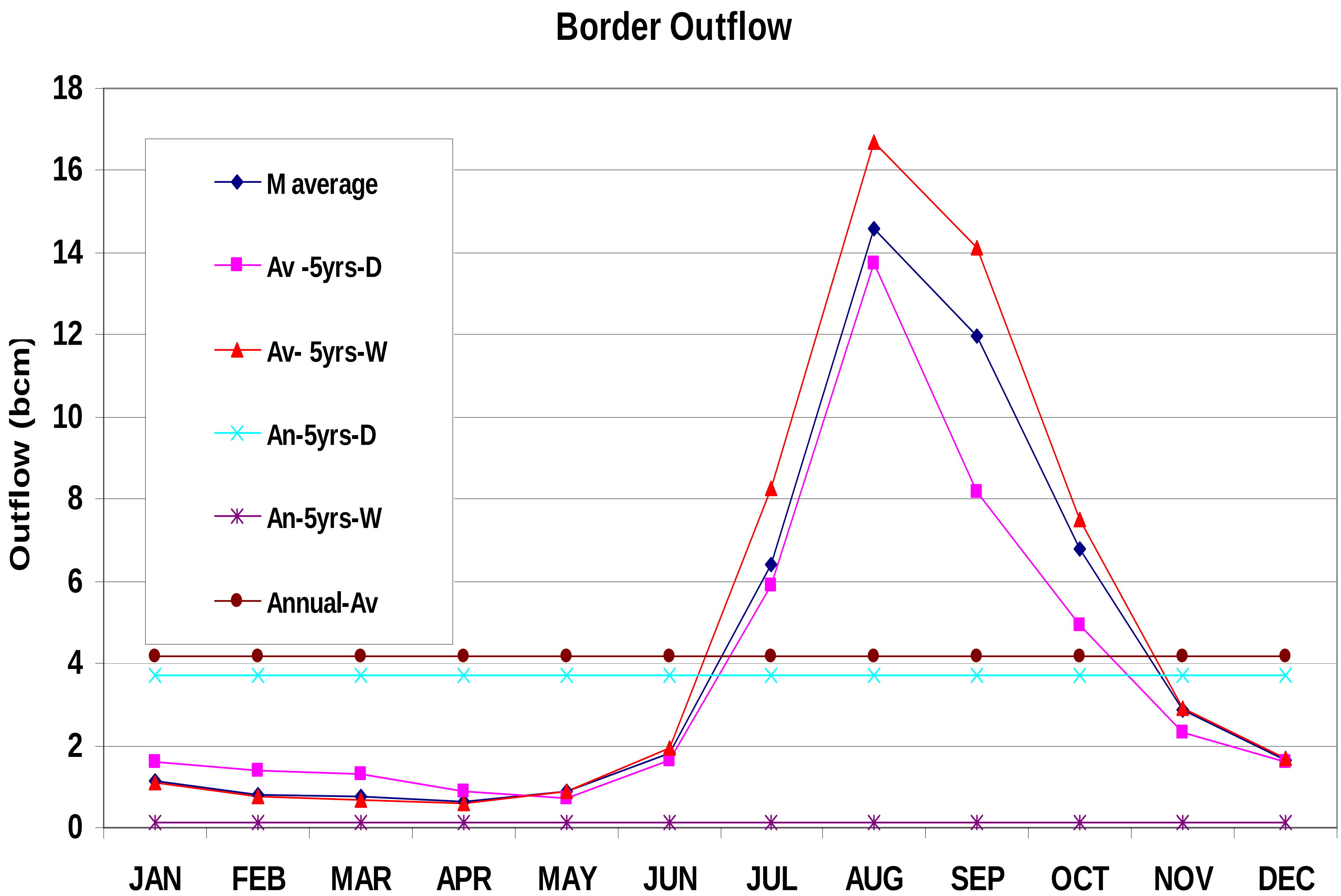


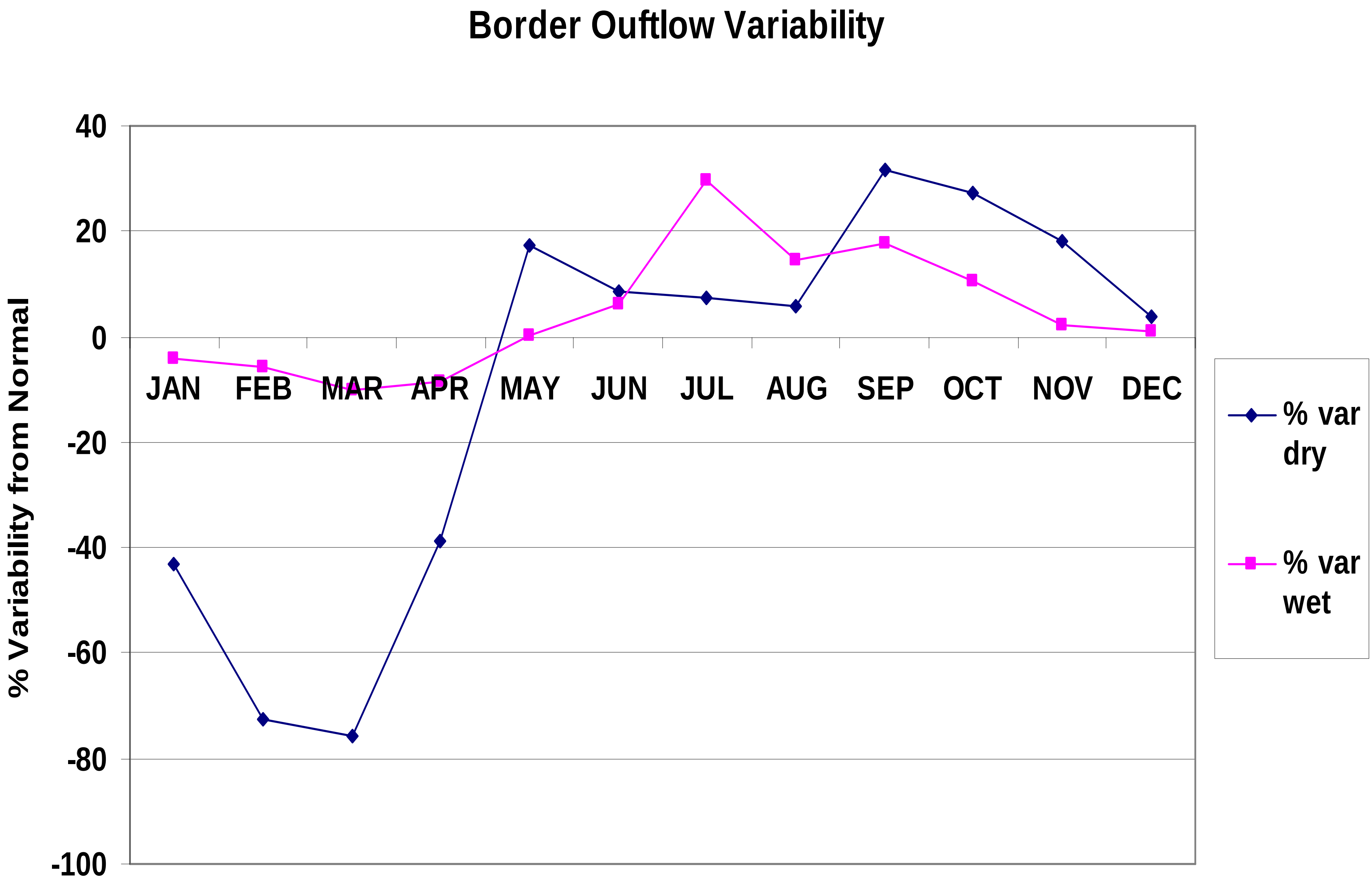
Malakal Outflows Variability
% Variability from Normal
70
60
50
40
30
20
10
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
% var dry
% var wet


Gebel El Aulia Outflows
Outflows(bcm)
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
M average
Av -5yrs-D
Av- 5yrs-W
An-5yrs-D
An-5yrs-W
Annual-Av

Gebel el Aulia Outflow Variability

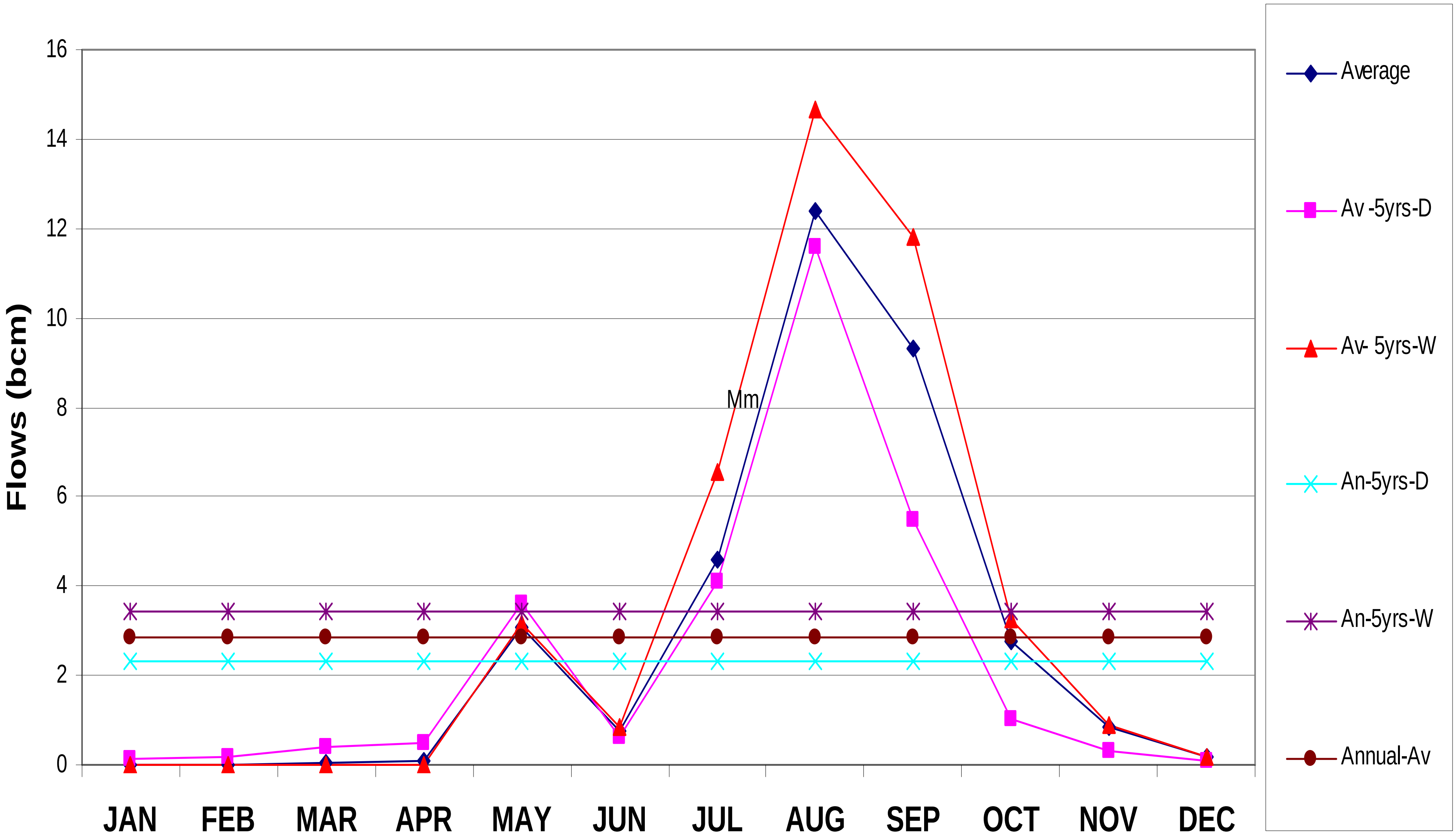


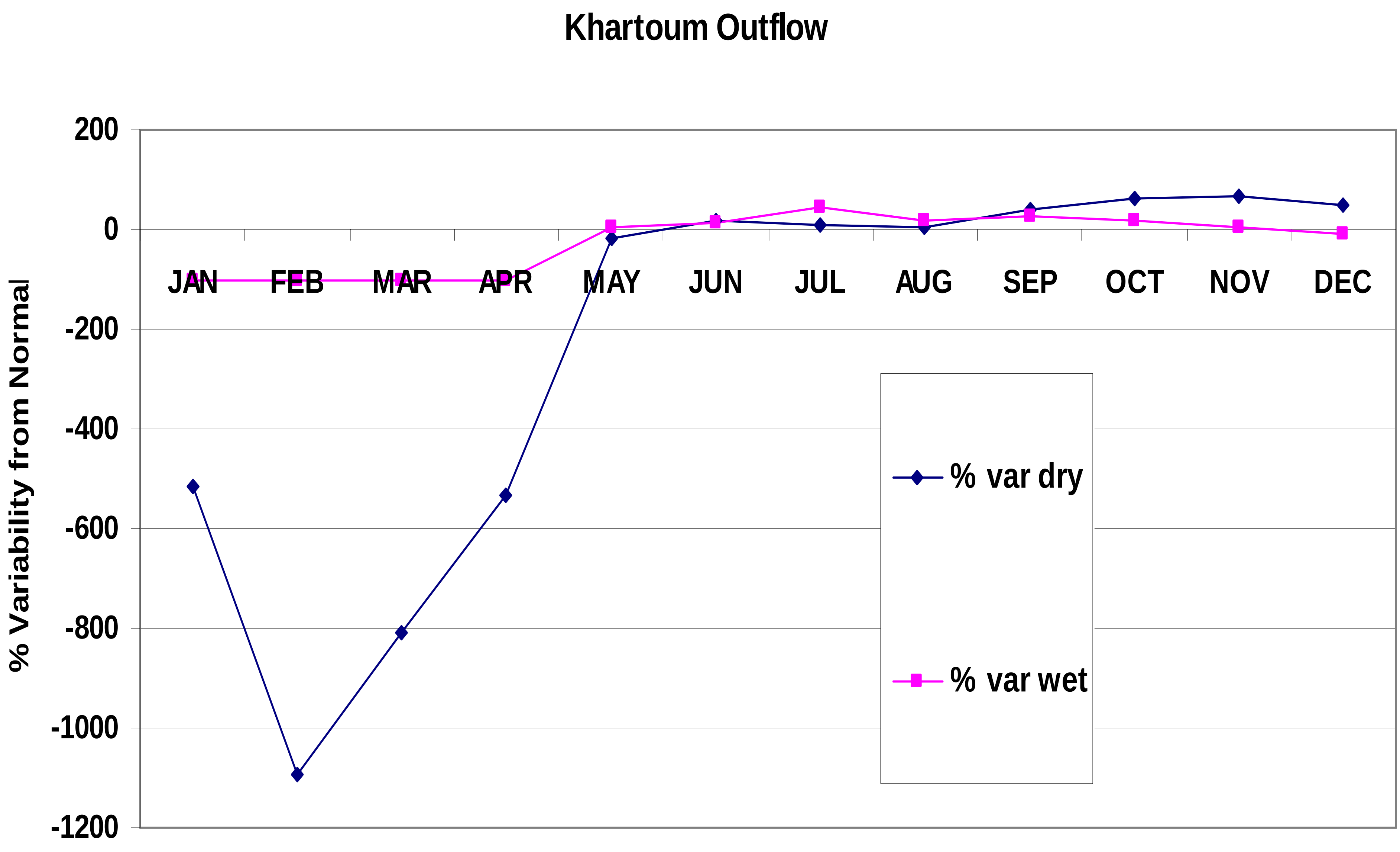

Border Outflow
Outflow (bcm)
18
16
14
12
10
8
6
4
2
0
M average
Av -5yrs-D
Av- 5yrs-W
An-5yrs-D
An-5yrs-W
Annual-Av
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC



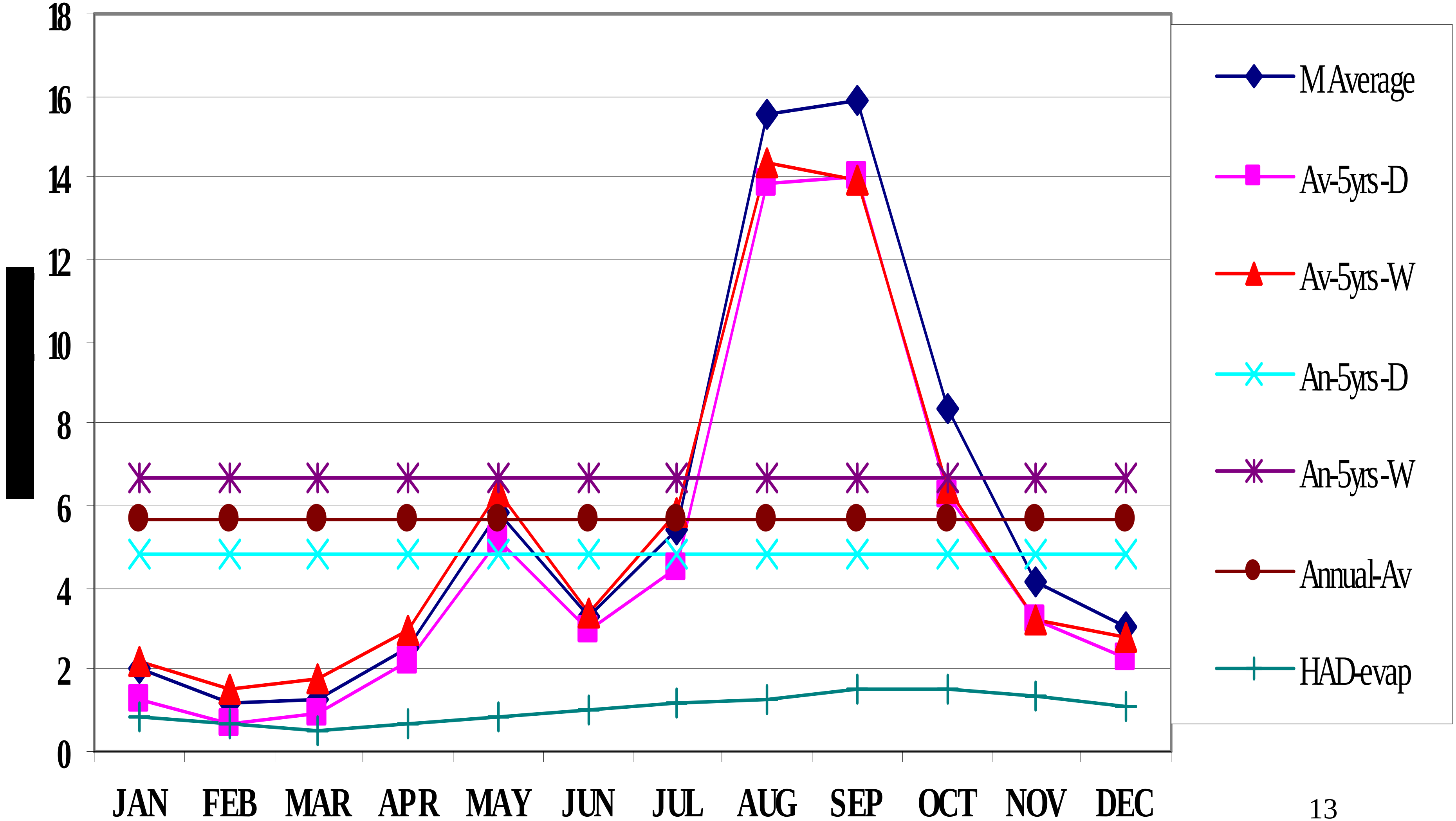
Border Ouftlow Variability
40
20
0
-20
-40
-60
-80
-100
% Variability from Normal
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
% var dry
% var wet

Khartoum Outflows

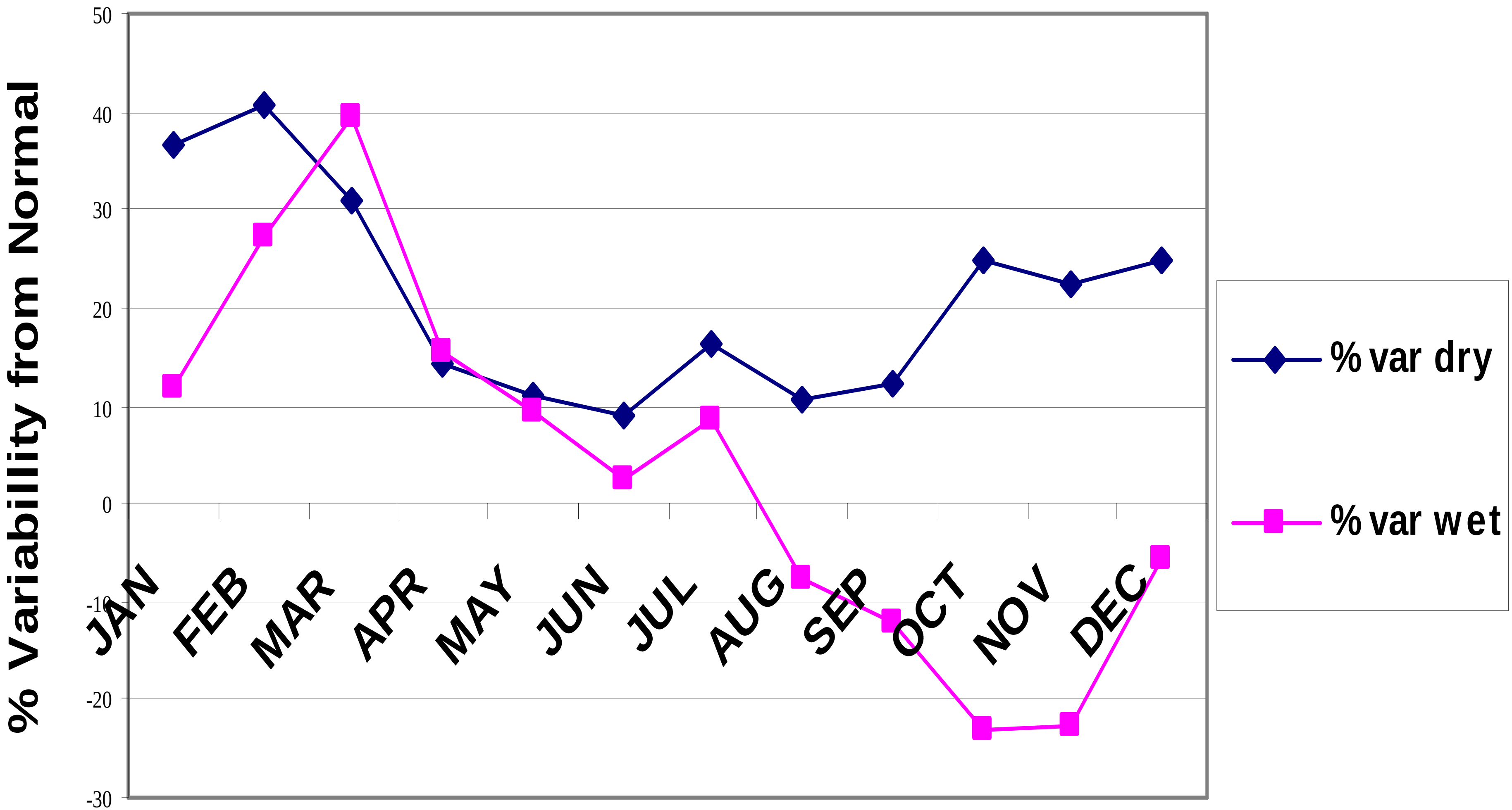



Khartoum Outflow
200
0
-200
-400
-600
-800
-1000
-1200
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
% Variability from Normal
% var dry
% var wet

HAD Inflows and Evaporation



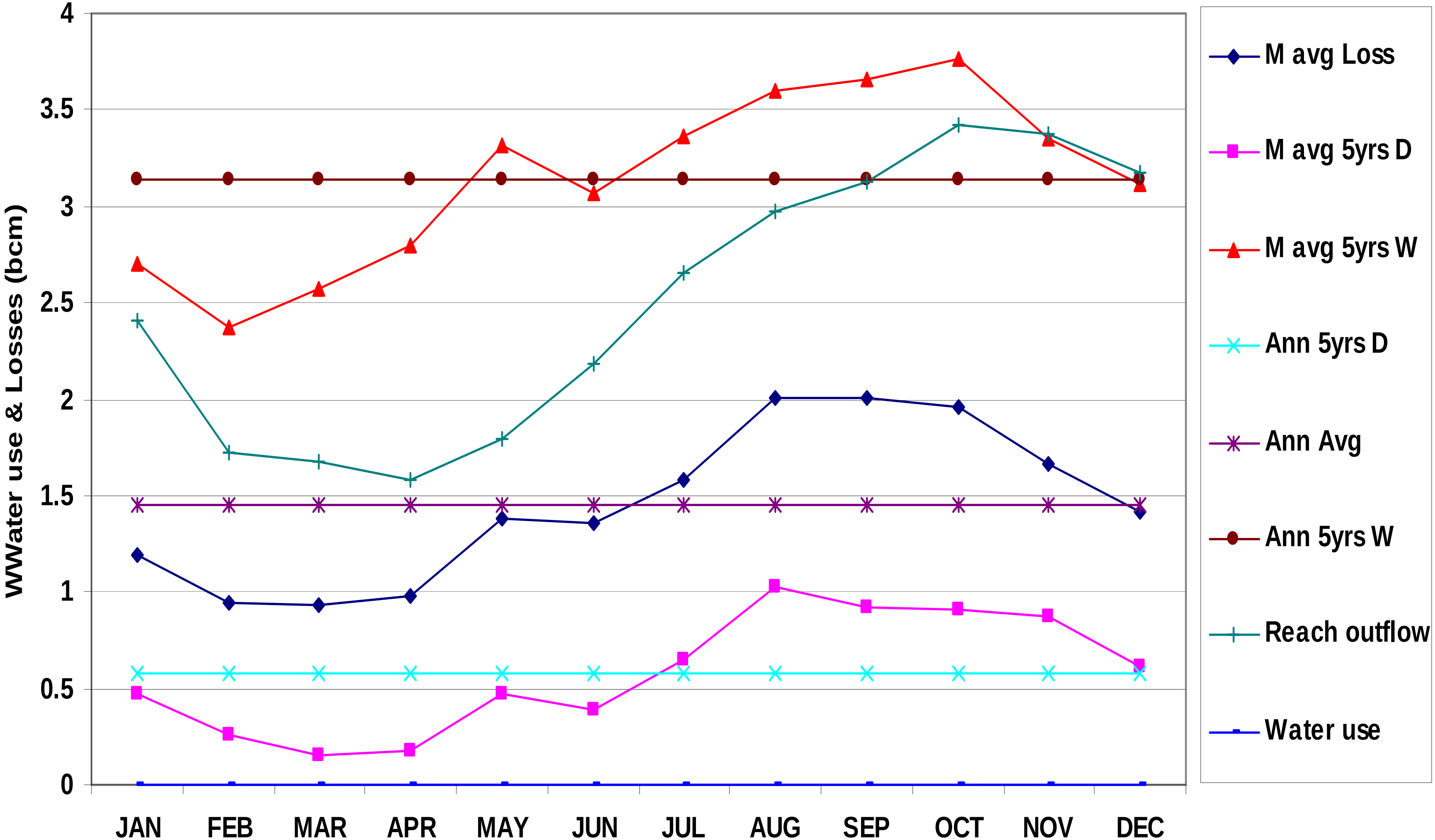
HAD Inflow Variability

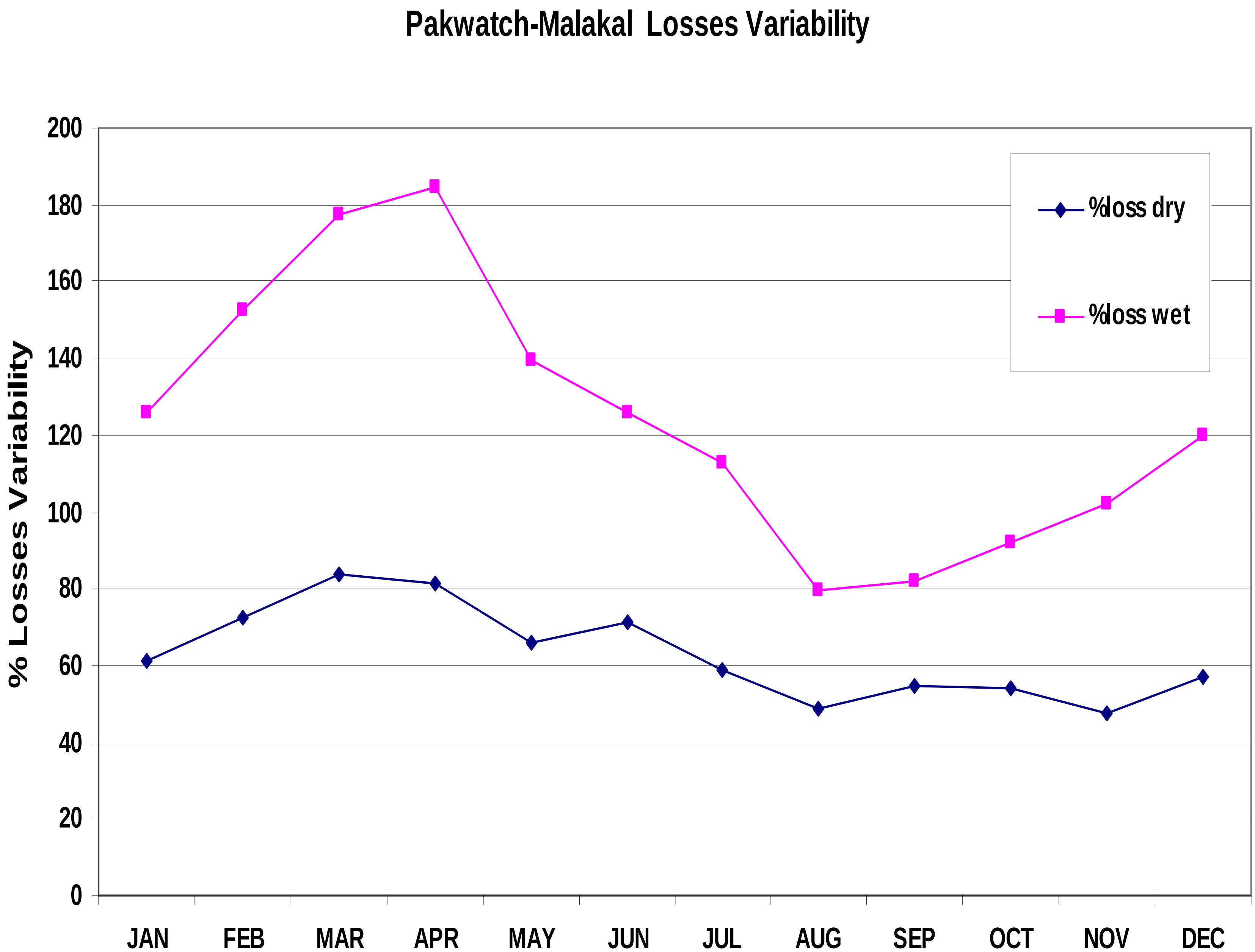


EXERCISE 1.2

Estimation of Water Uses and Losses

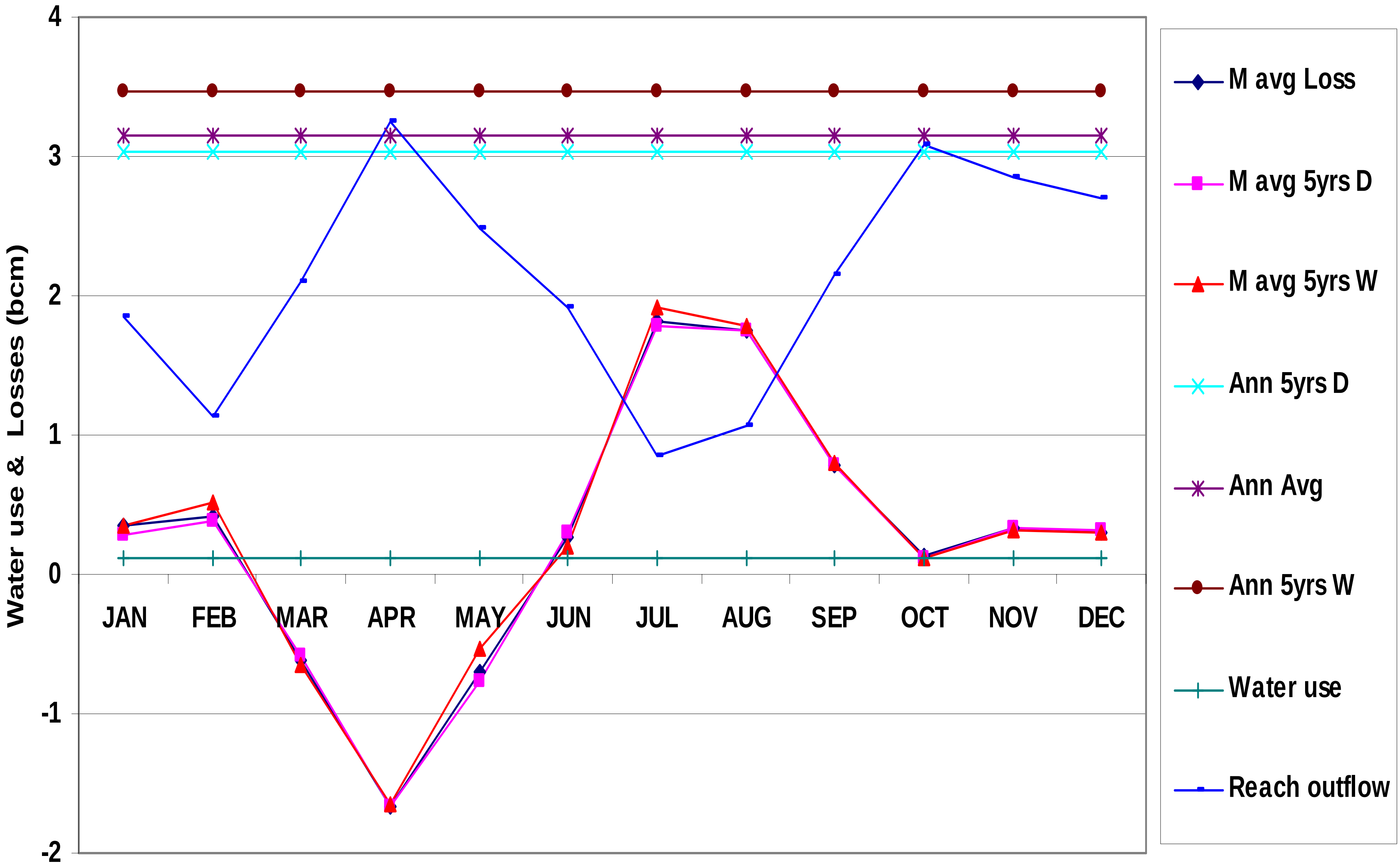
Pakwatch-Malakal Water use & Losses



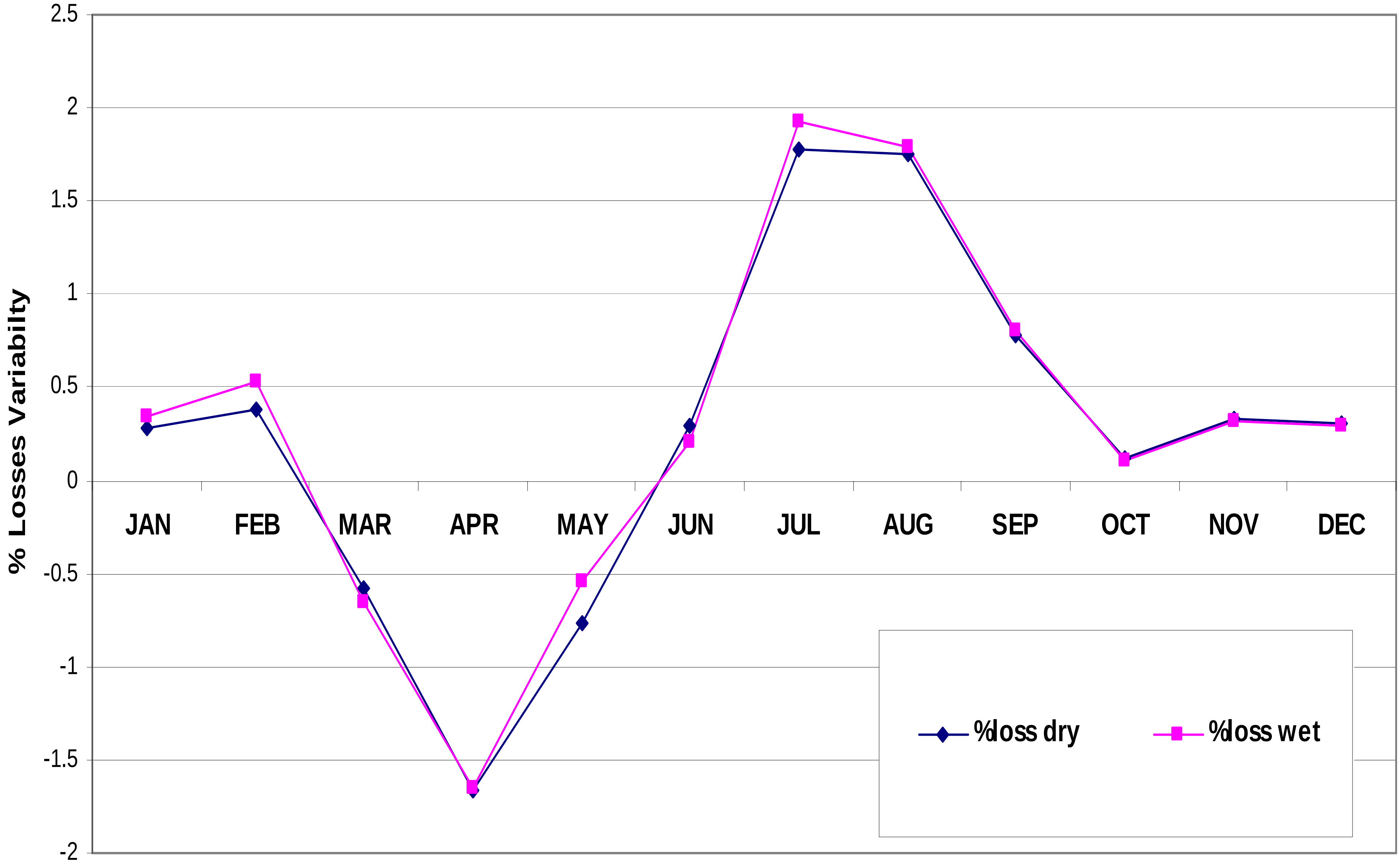


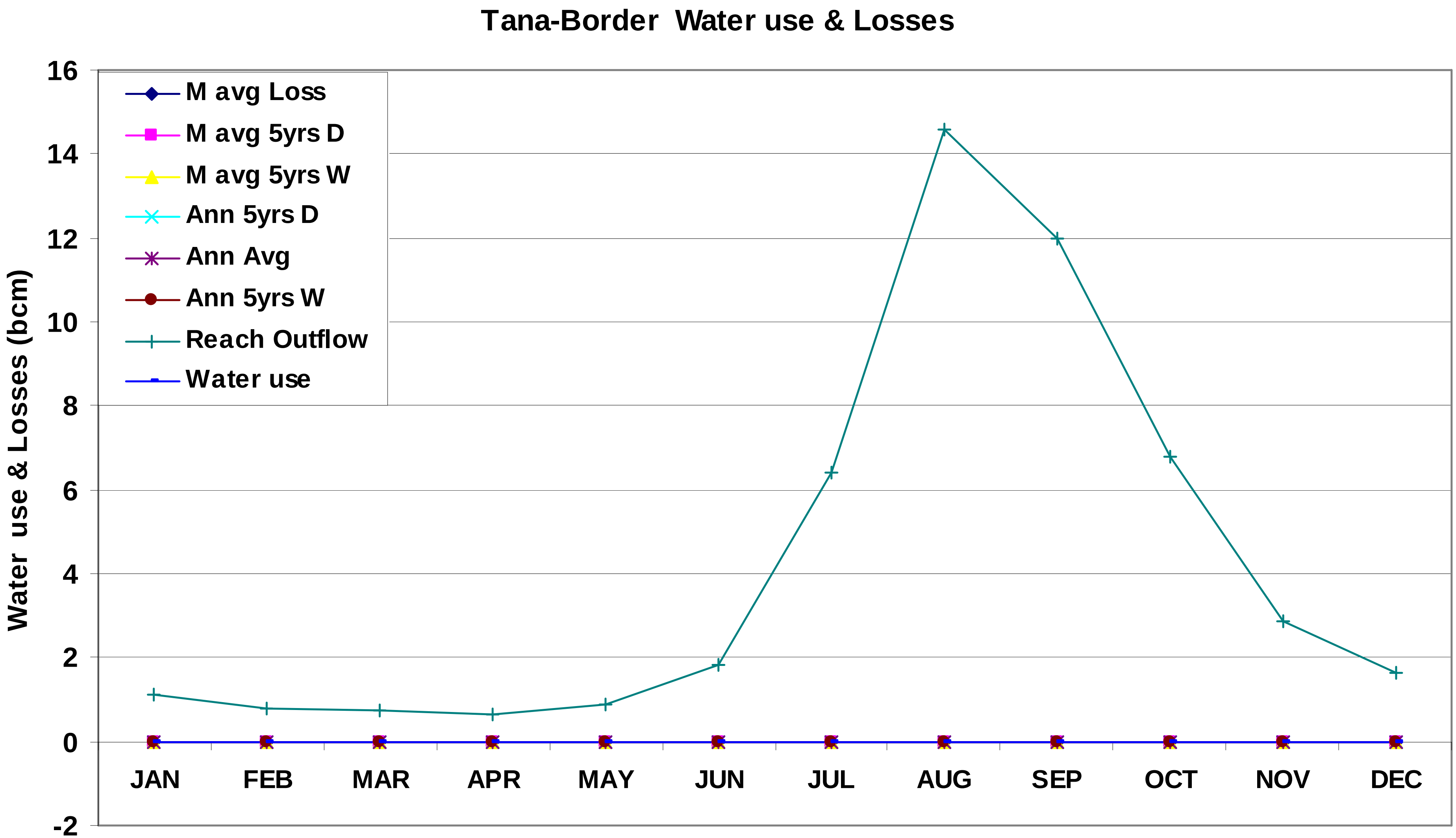
Pakwatch-Malakal Losses Variability
% Losses Variability
200
180
160
140
120
100
80
60
40
20
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
%loss dry
%loss wet

Malakal-Gebel Aulia Water use & Losses

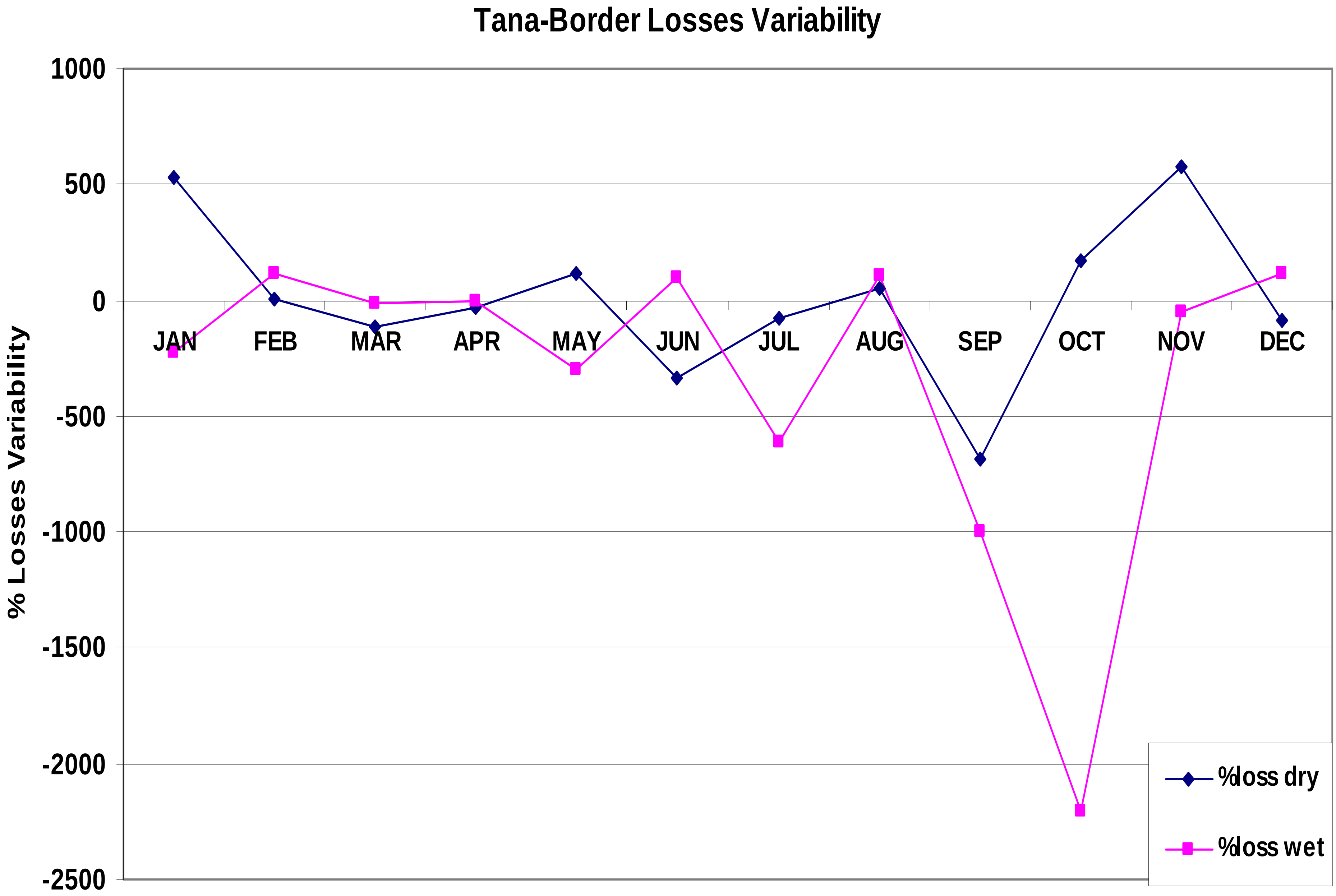


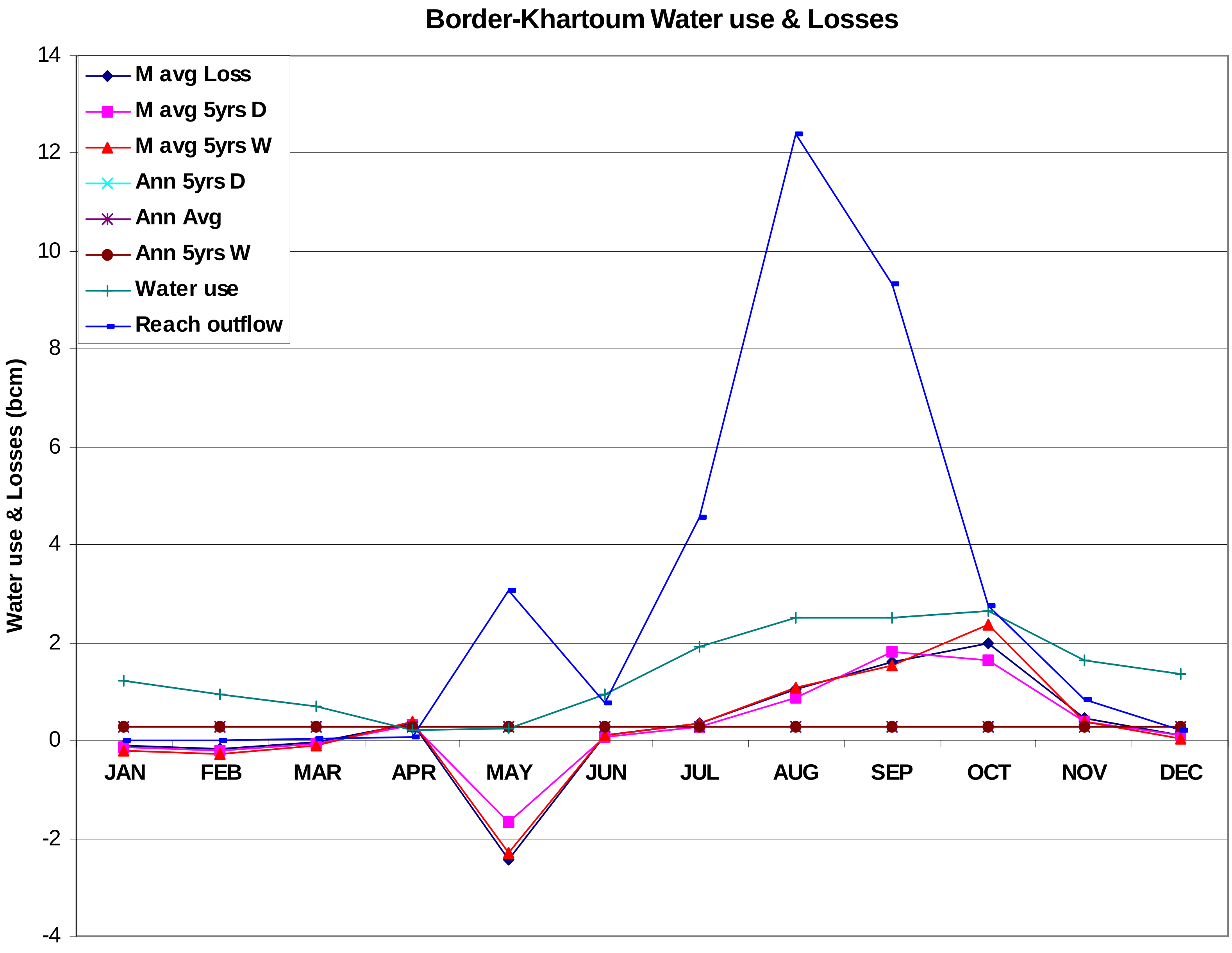
Malakal-Gebel Aulia Losses Variabiility

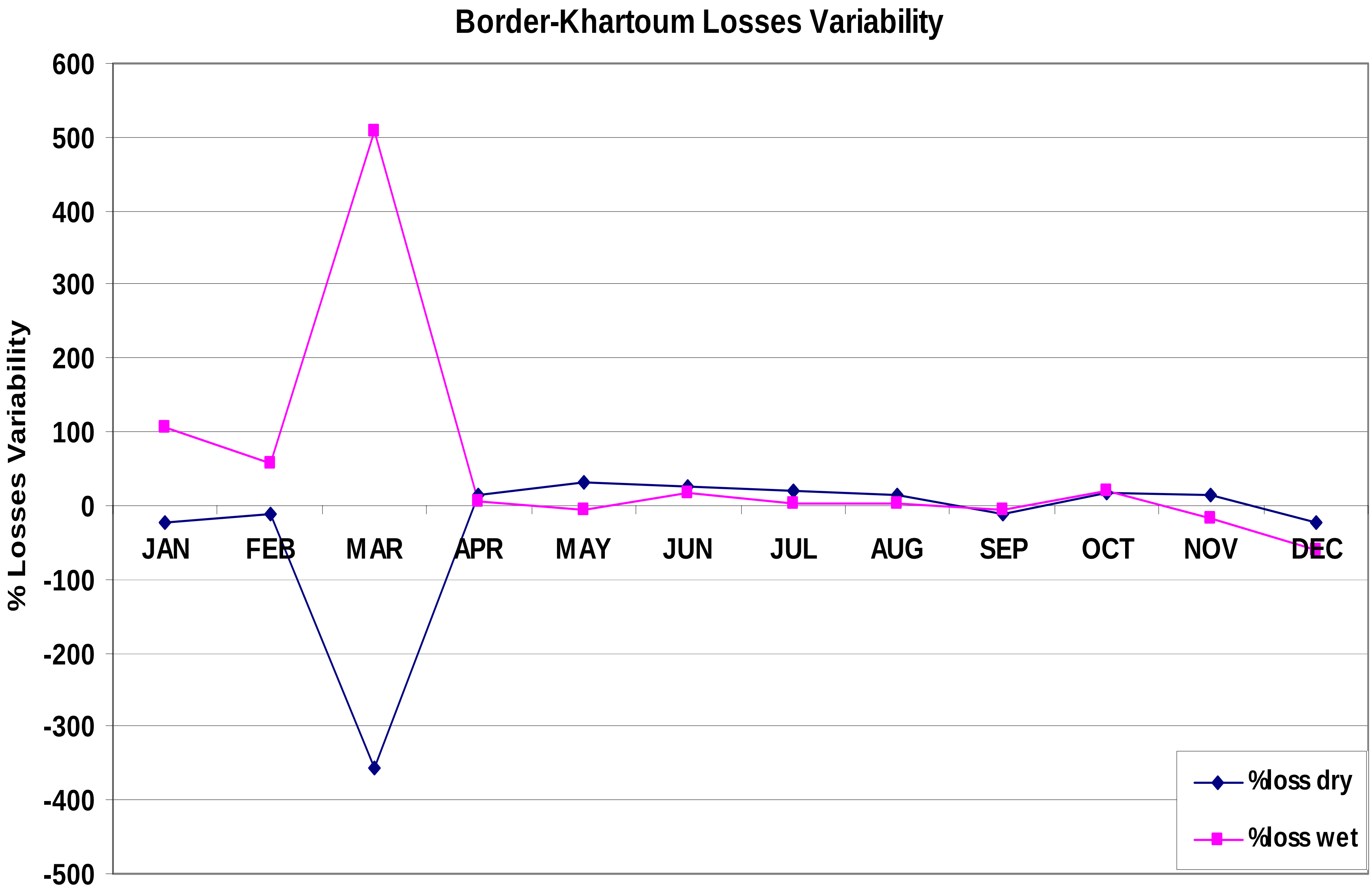


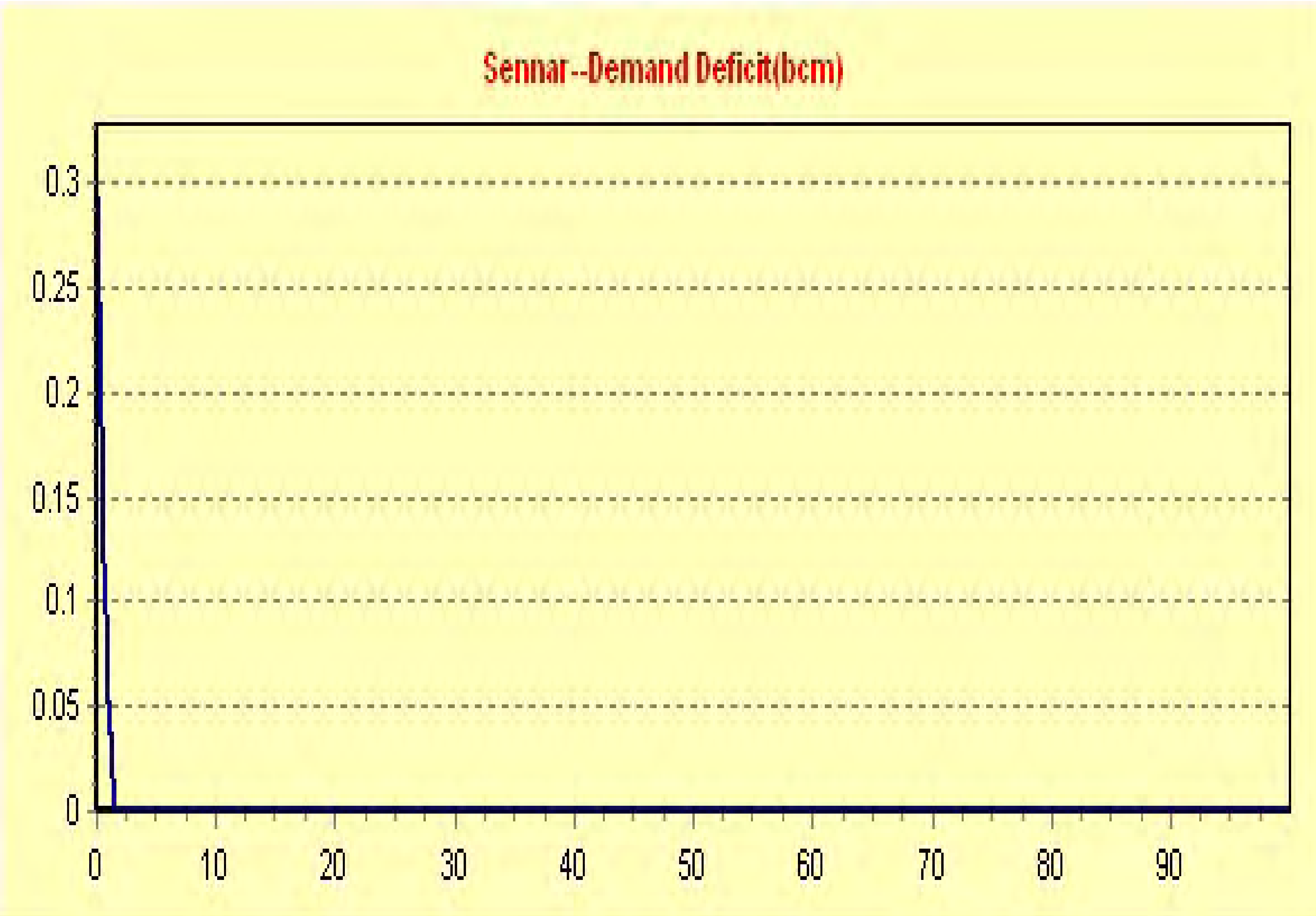


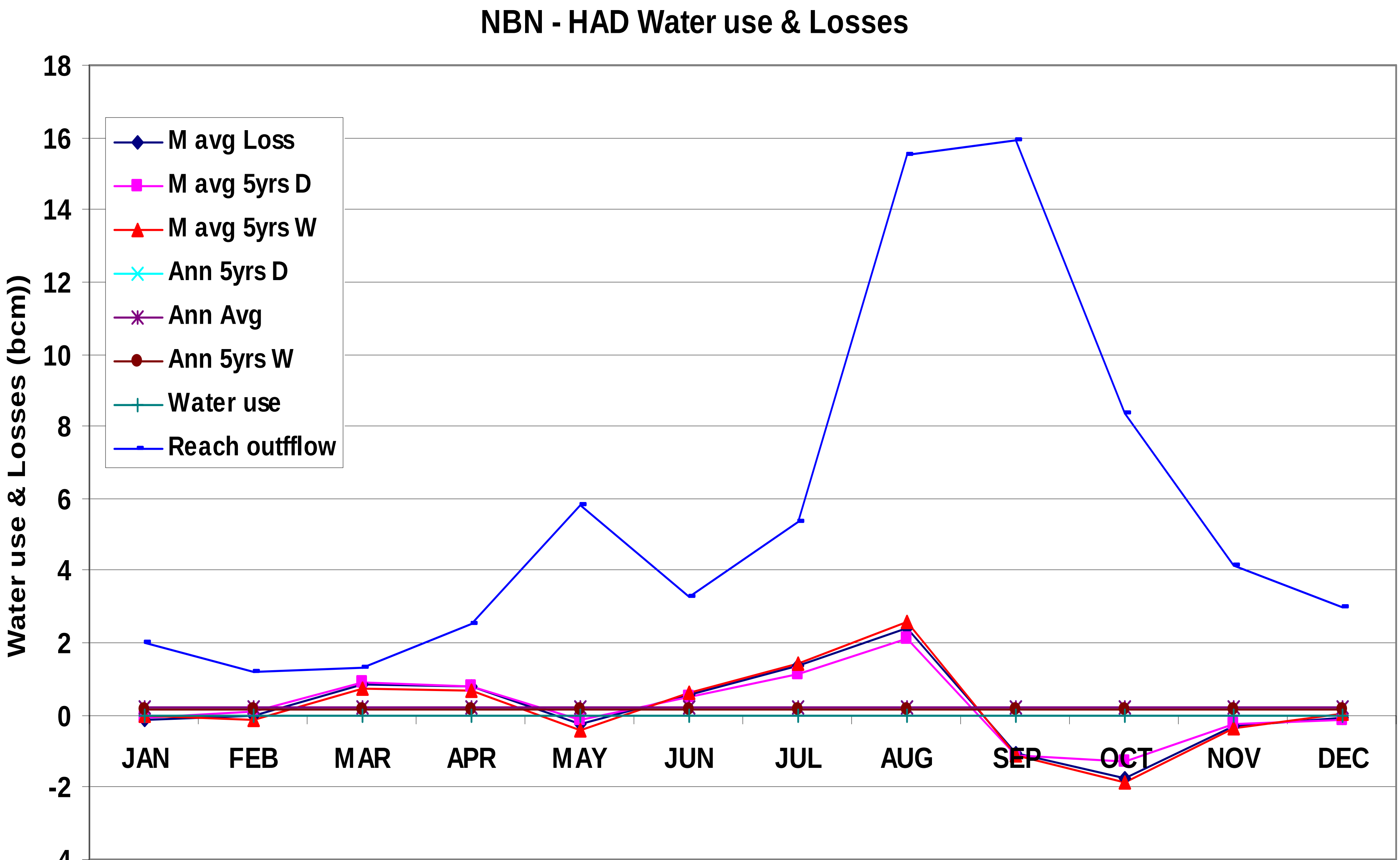
Tana-Border Water use & Losses
Water use & Losses (bcm)
16
14
12
10
8
6
4
2
0
-2
M avg Loss
M avg 5yrs D
M avg 5yrs W
Ann 5yrs D
Ann Avg
Ann 5yrs W
Reach Outflow
Water use
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

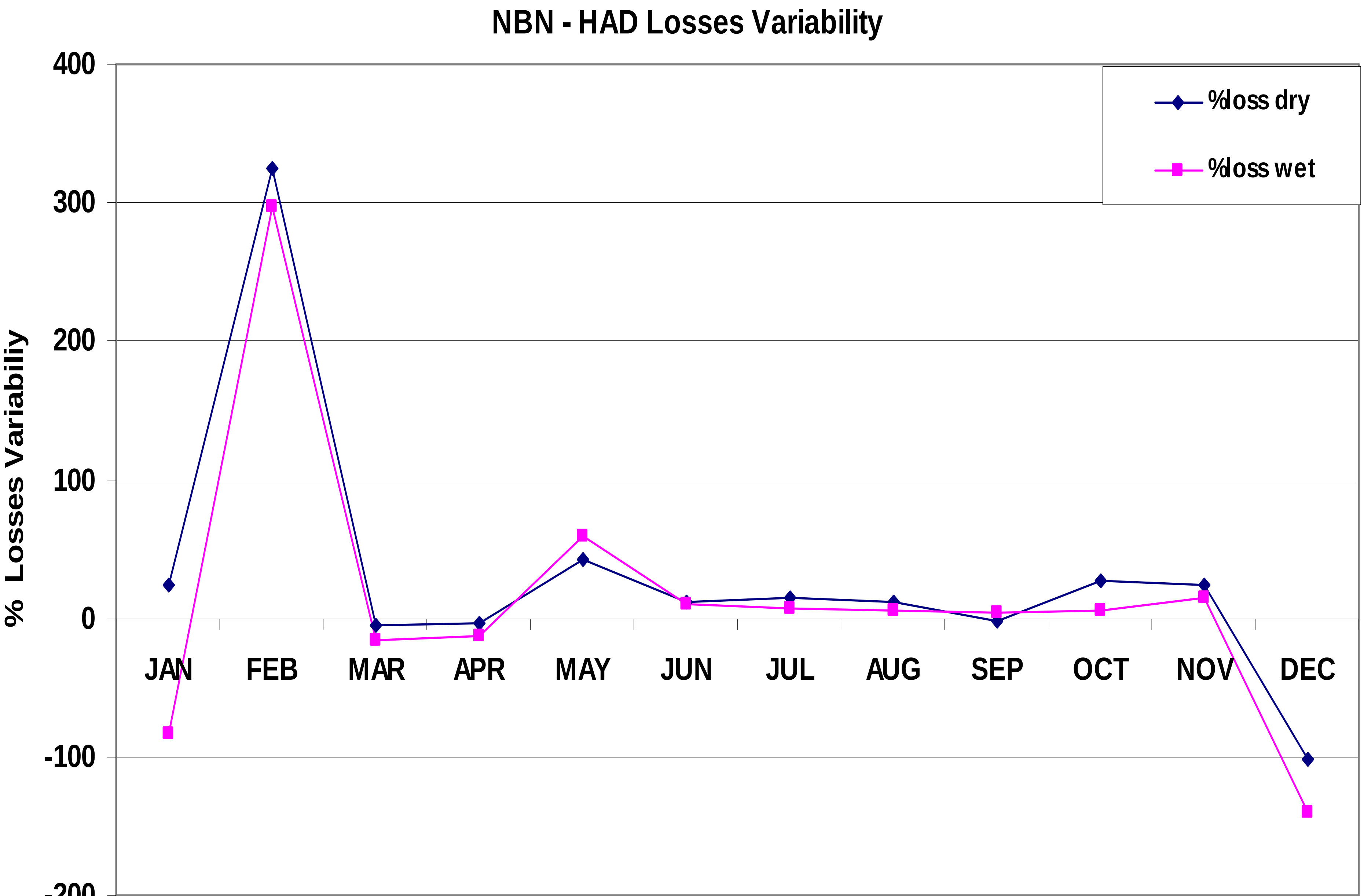

Tana-Border Losses Variability
1000
500
0
-500
-1000
-1500
-2000
-2500
% Losses Variability
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
%loss dry
%loss wet


Border-Khartoum Water use & Losses
Water use & Losses (bcm)
14
12
10
8
6
4
2
0
-2
-4
M avg Loss
M avg 5yrs D
M avg 5yrs W
Ann 5yrs D
Ann Avg
Ann 5yrs W
Water use
Reach outflow
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC


Border-Khartoum Losses Variability
% Losses Variability
600
500
400
300
200
100
0
-100
-200
-300
-400
-500
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
%loss dry
%loss wet

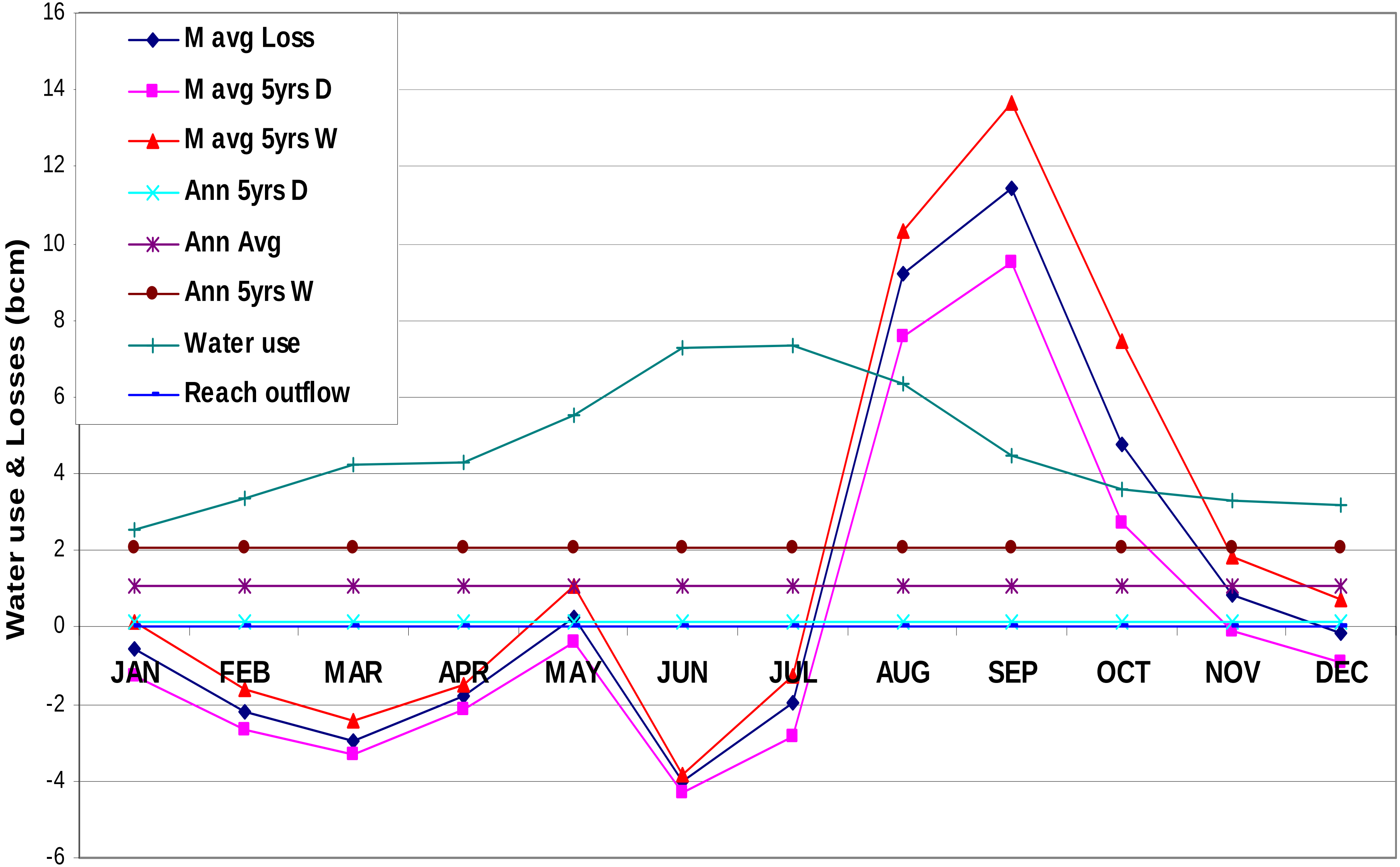

Sennar --Demand Deficit(bcm)
0.3
0.25
0.2
0.15
0.1
0.05
0
0
10
20
30
40
50
60
70
80
90

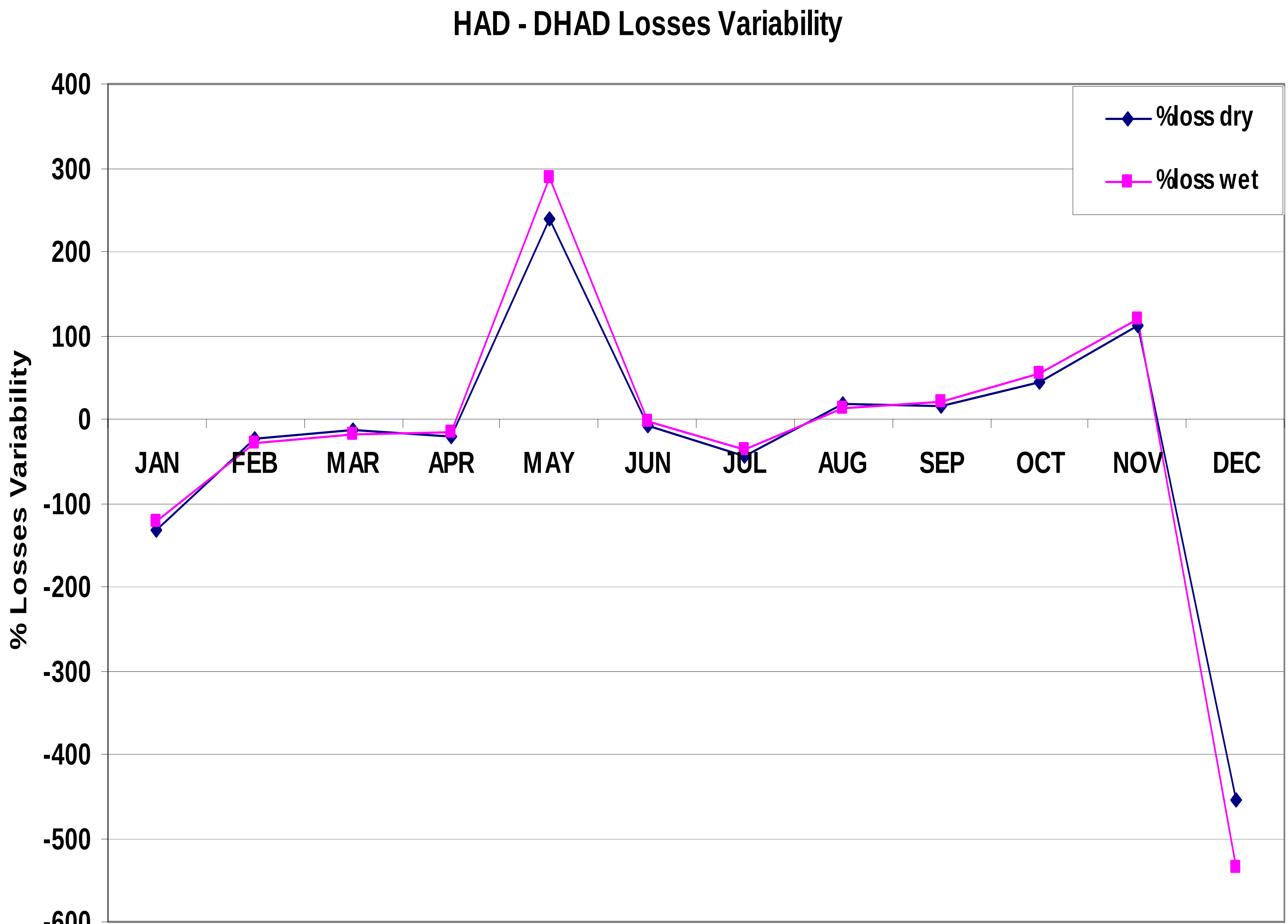

NBN - HAD Water use & Losses
Water use & Losses (bcm))
18
16
14
12
10
8
6
4
2
0
-2
-4
M avg Loss
M avg 5yrs D
M avg 5yrs W
Ann 5yrs D
Ann Avg
Ann 5yrs W
Water use
Reach outfflow
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC



NBN - HAD Losses Variability
400
300
200
100
0
-100
-200
% Losses Variabiliy
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
%loss dry
%loss wet

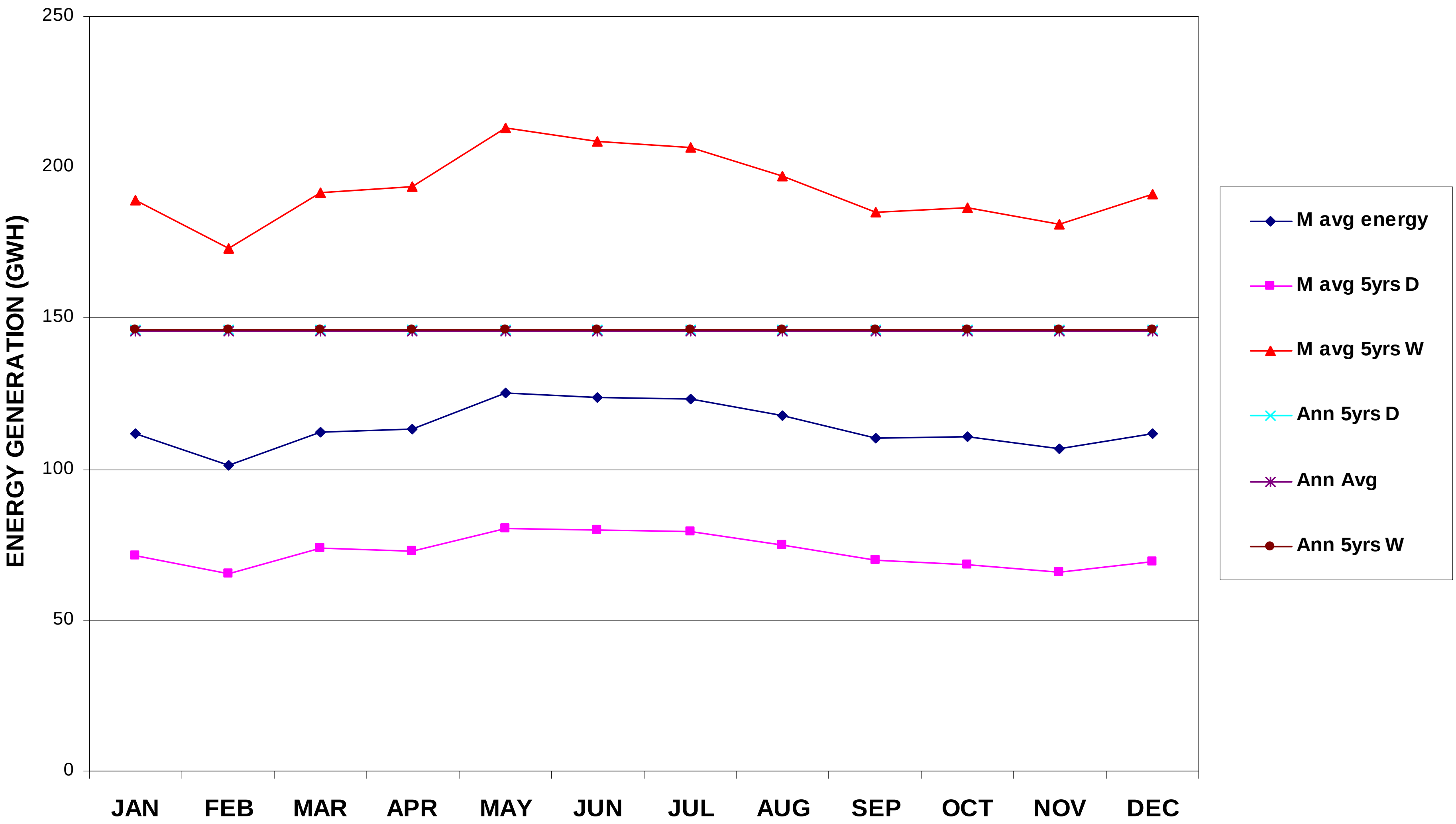
HAD - DHAD Water use & Losses

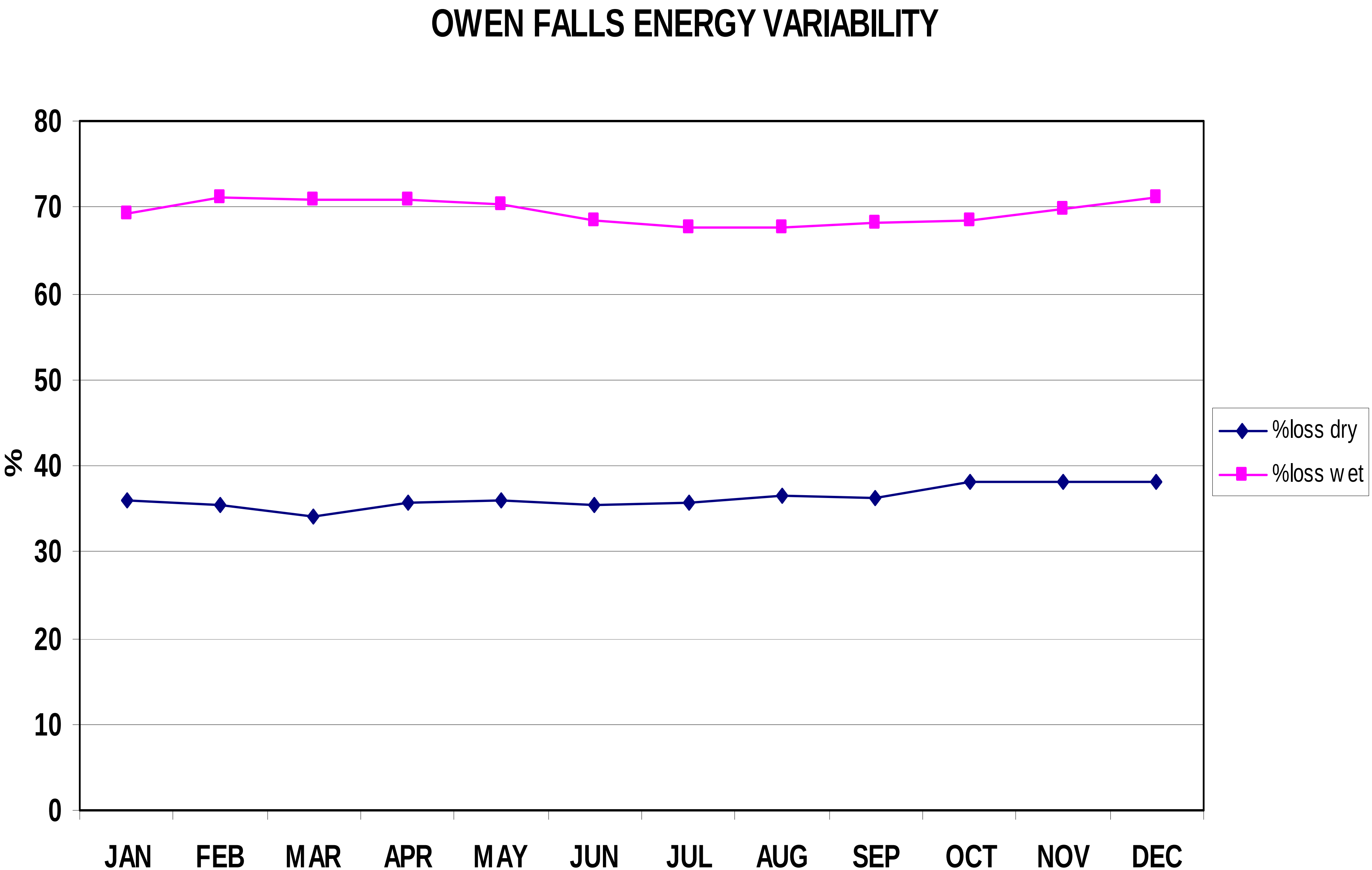


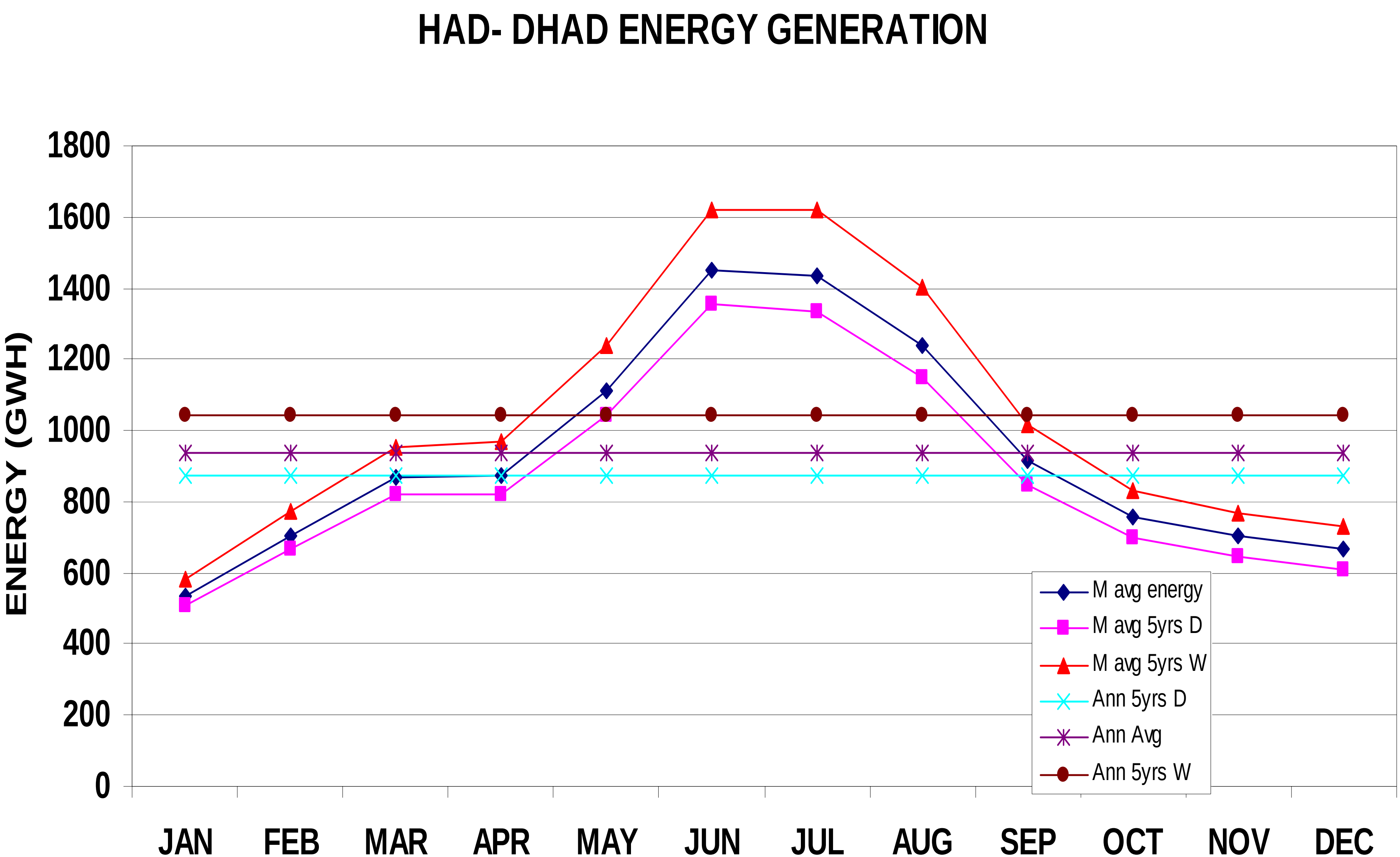

HAD - DHAD Losses Variability
%loss dry
%loss wet
% Losses Variability
400
300
200
100
0
-100
-200
-300
-400
-500
-600
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

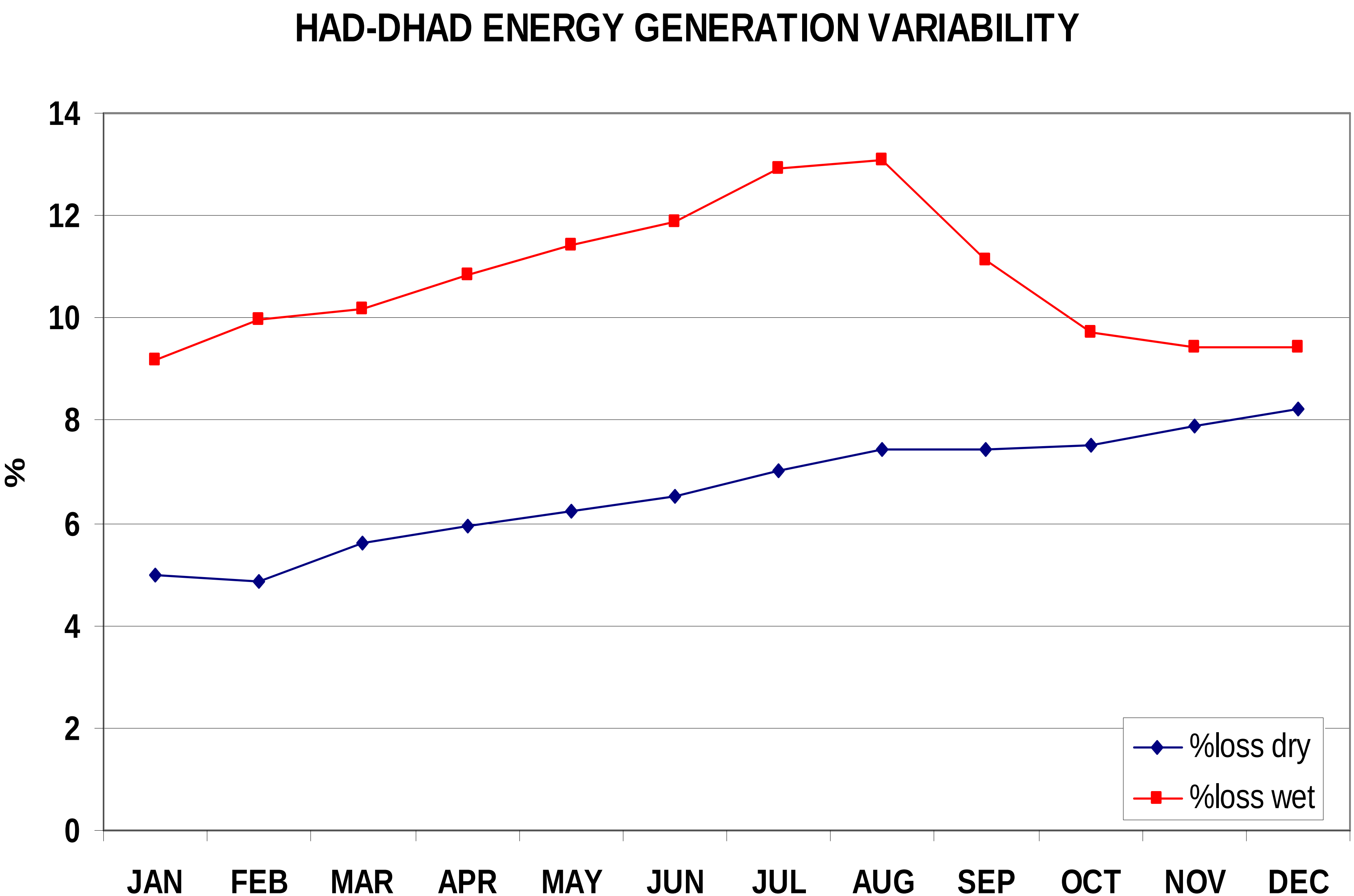
Energy Generation

OWEN FALLS ENERGY GENERATION

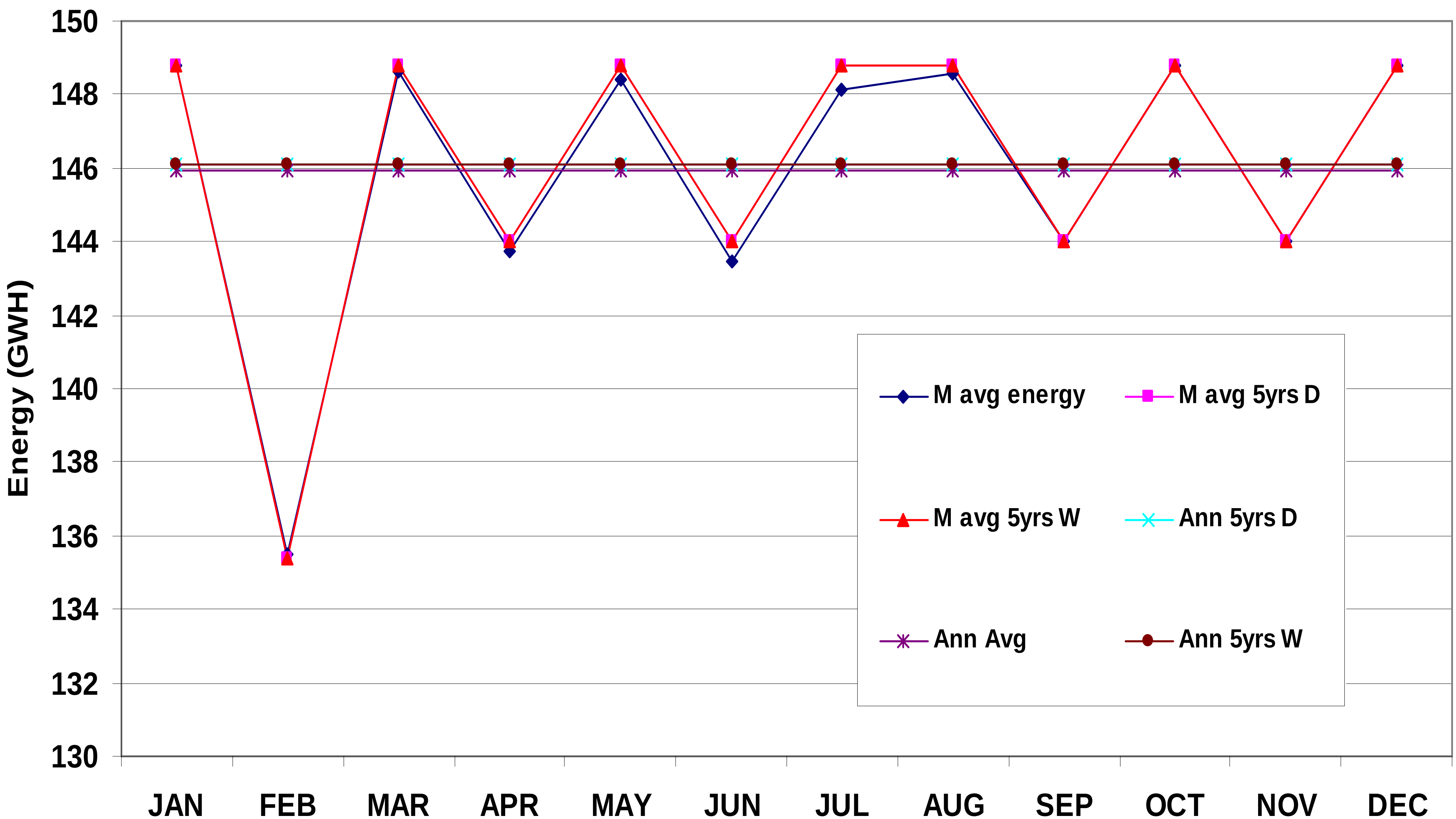


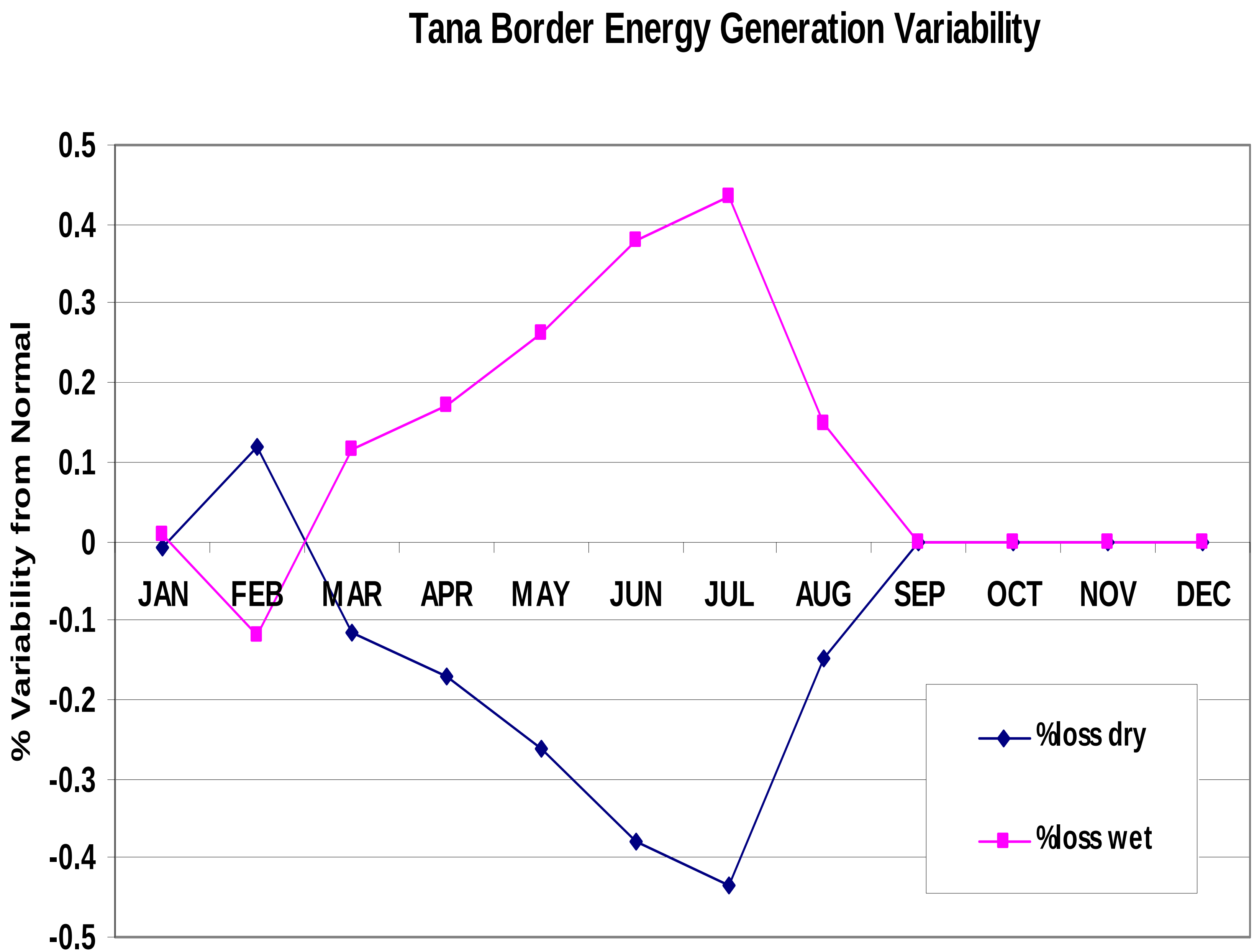

OWEN FALLS ENERGY VARIABILITY
80
70
60
50
40
30
20
10
0
%
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
%loss dry
%loss wet


HAD- DHAD ENERGY GENERATION
ENERGY (GWH)
1800
1600
1400
1200
1000
800
600
400
200
0
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
M avg energy
M avg 5yrs D
M avg 5yrs W
Ann 5yrs D
Ann Avg
Ann 5yrs W


HAD-DHAD ENERGY GENERATION VARIABILITY
%
0
2
4
6
8
10
12
14
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
%loss dry
%loss wet

Tana Border Energy Generation

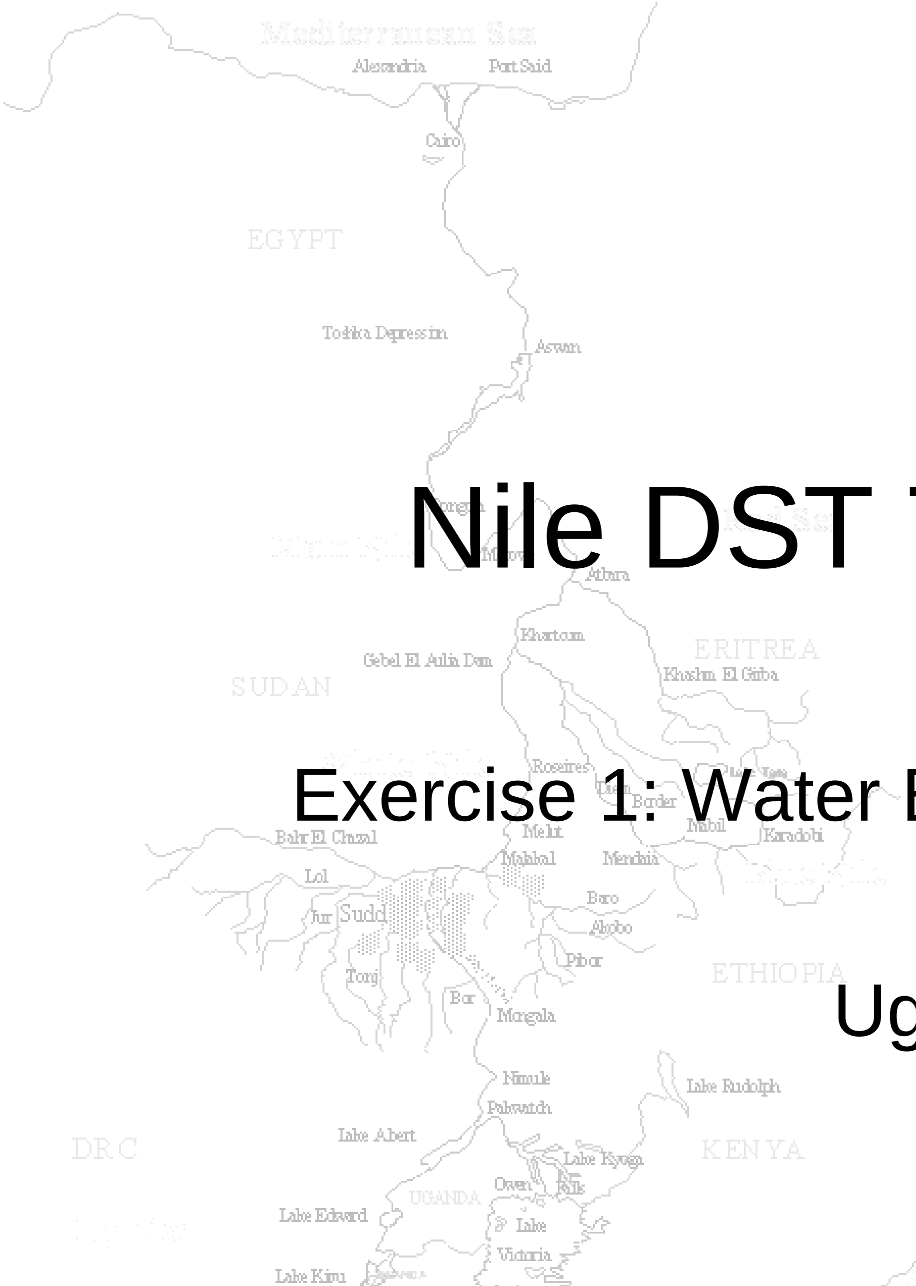


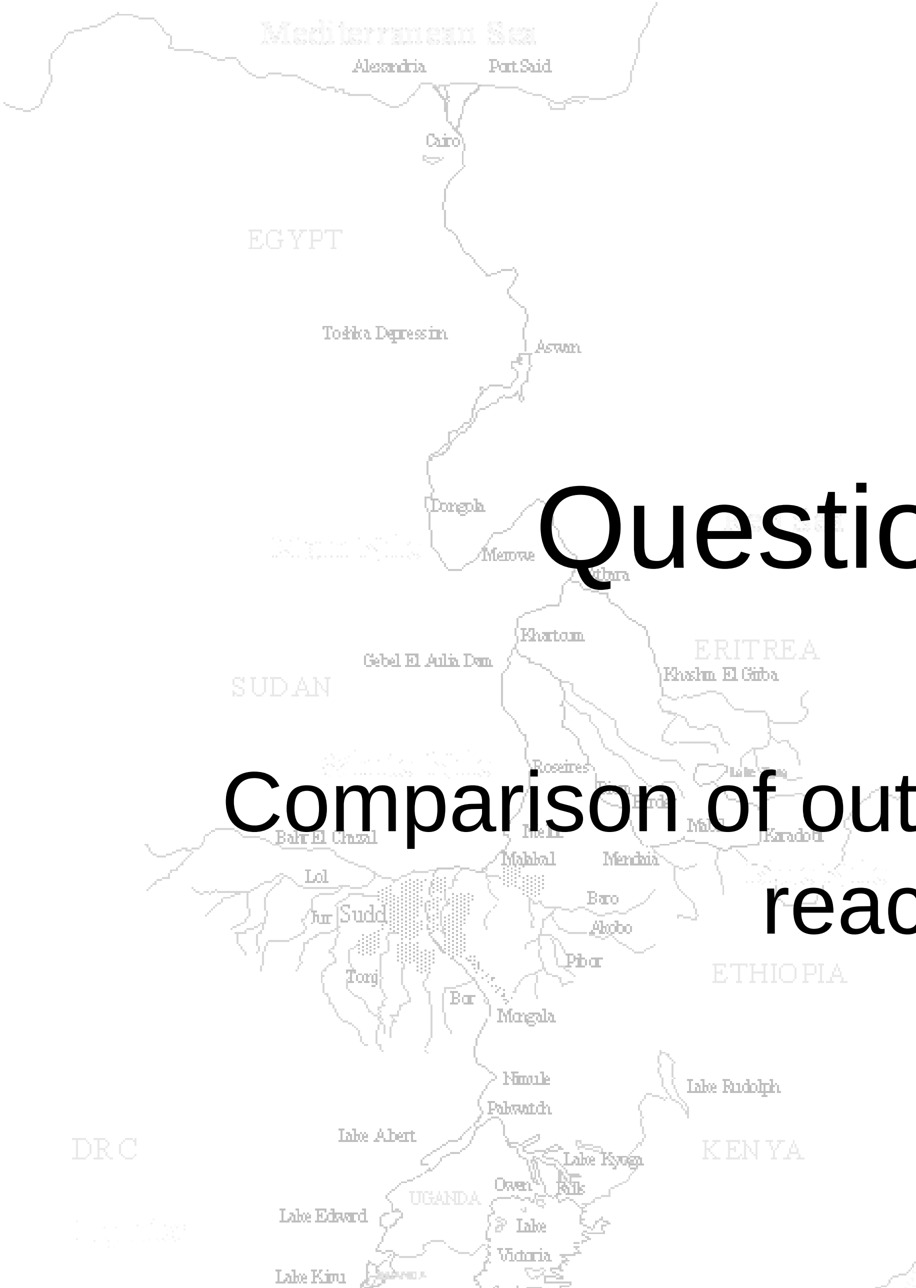

Tana Border Energy Generation Variability
% Variability from Normal
0.5
0.4
0.3
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
-0.5
JAN
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
%loss dry
%loss wet

Nile DST Training

Exercise 1: Water Balance Assessments

Uganda





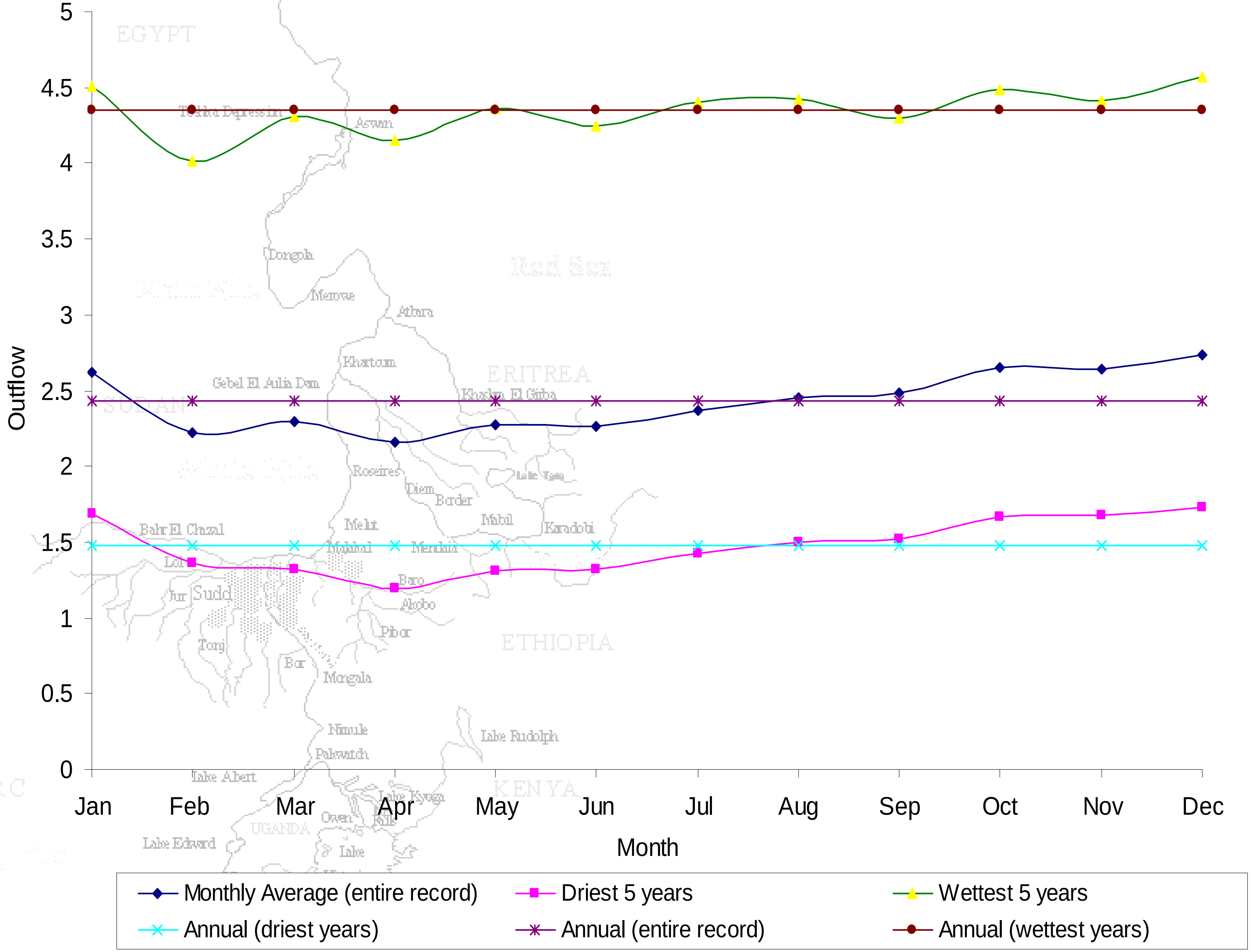
Question 1.1

Comparison of outflows from each reach

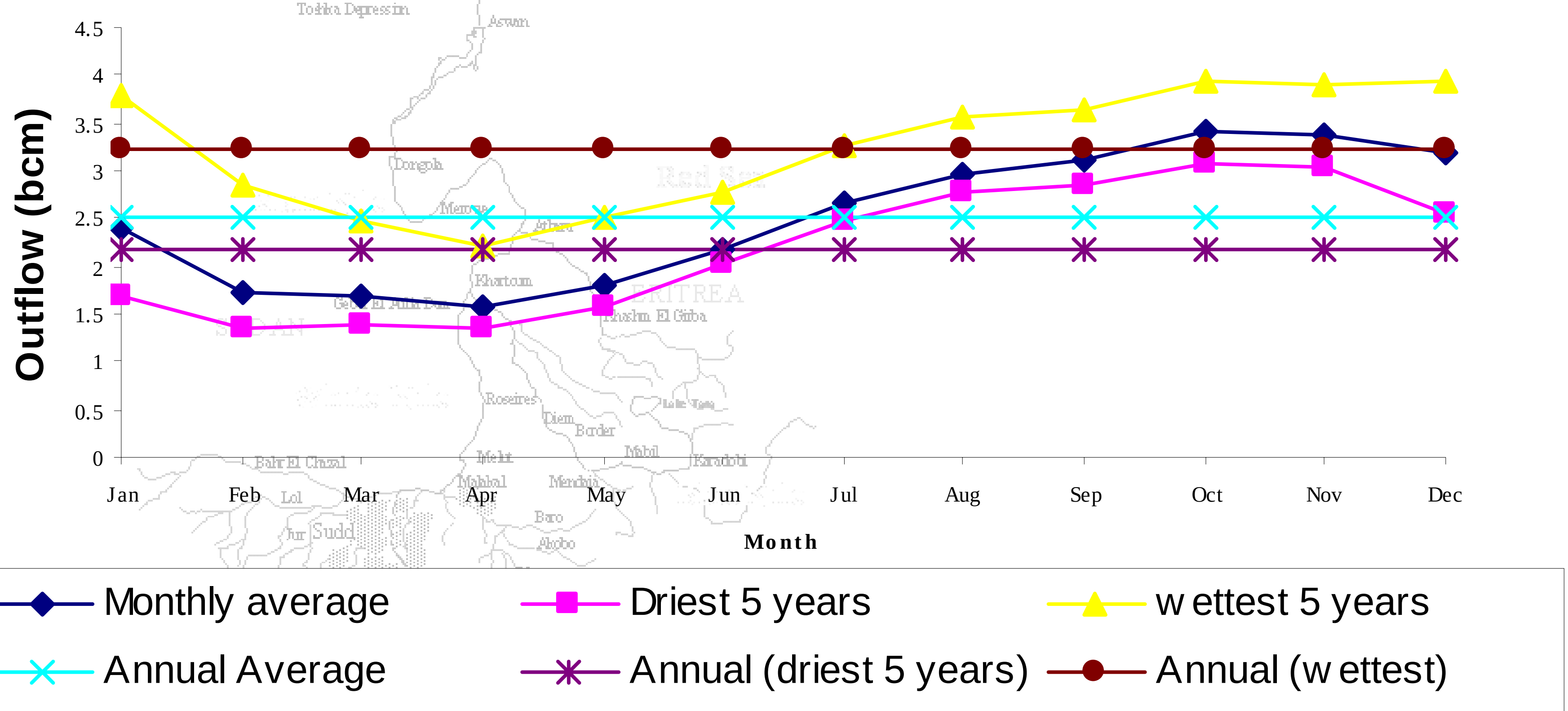
1.Defination of Reaches

- A- L. Victoria - Pakwach
- B- Pakwach – Malakal
- C - Malakal to Gebel El Aulia
- D – Blue Nile – Sennar
- E - Diem – Khartoum
- F – Khartoum – Dongola
- G – Dongola - DSH

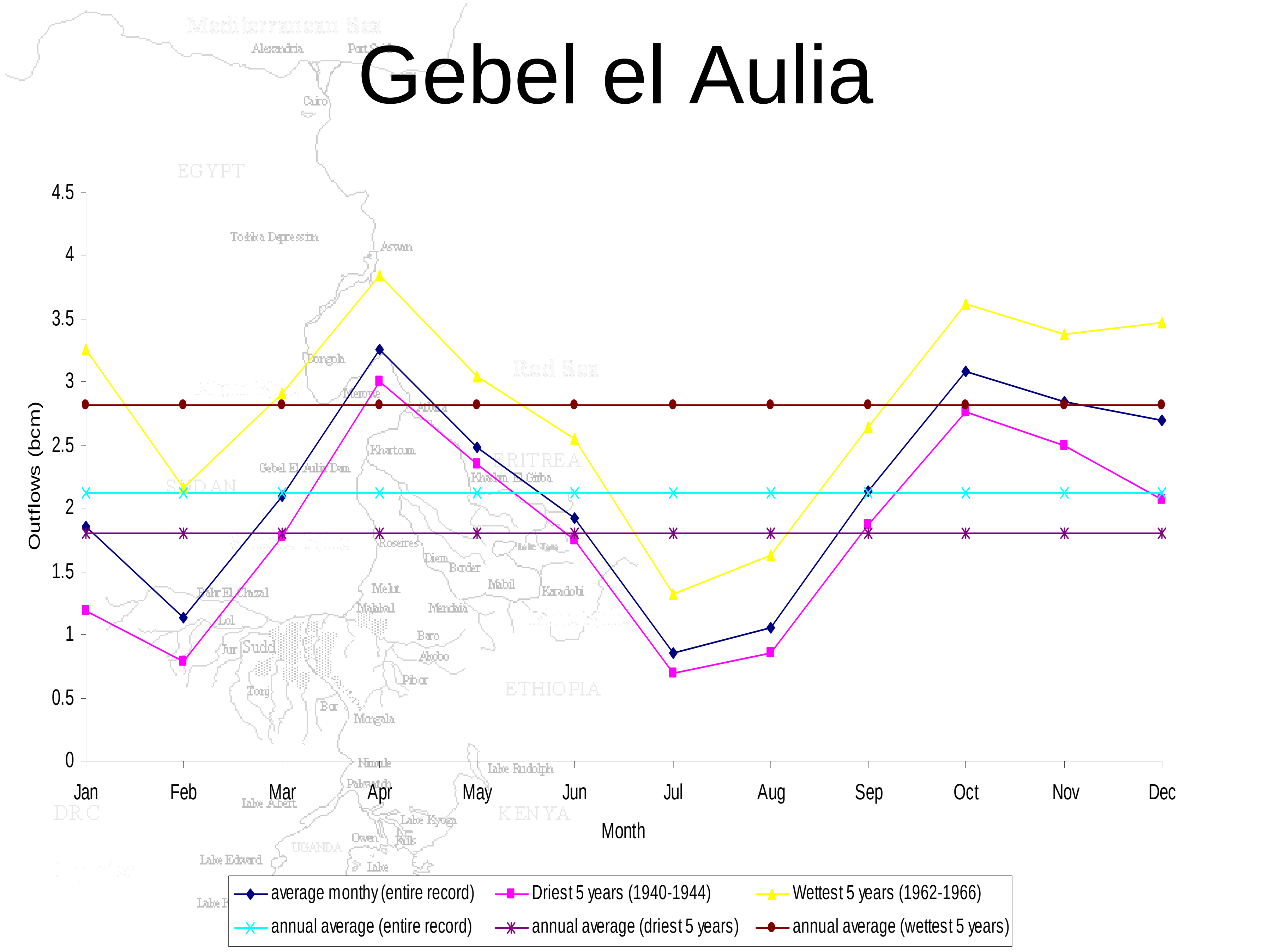
Pakwach outflows



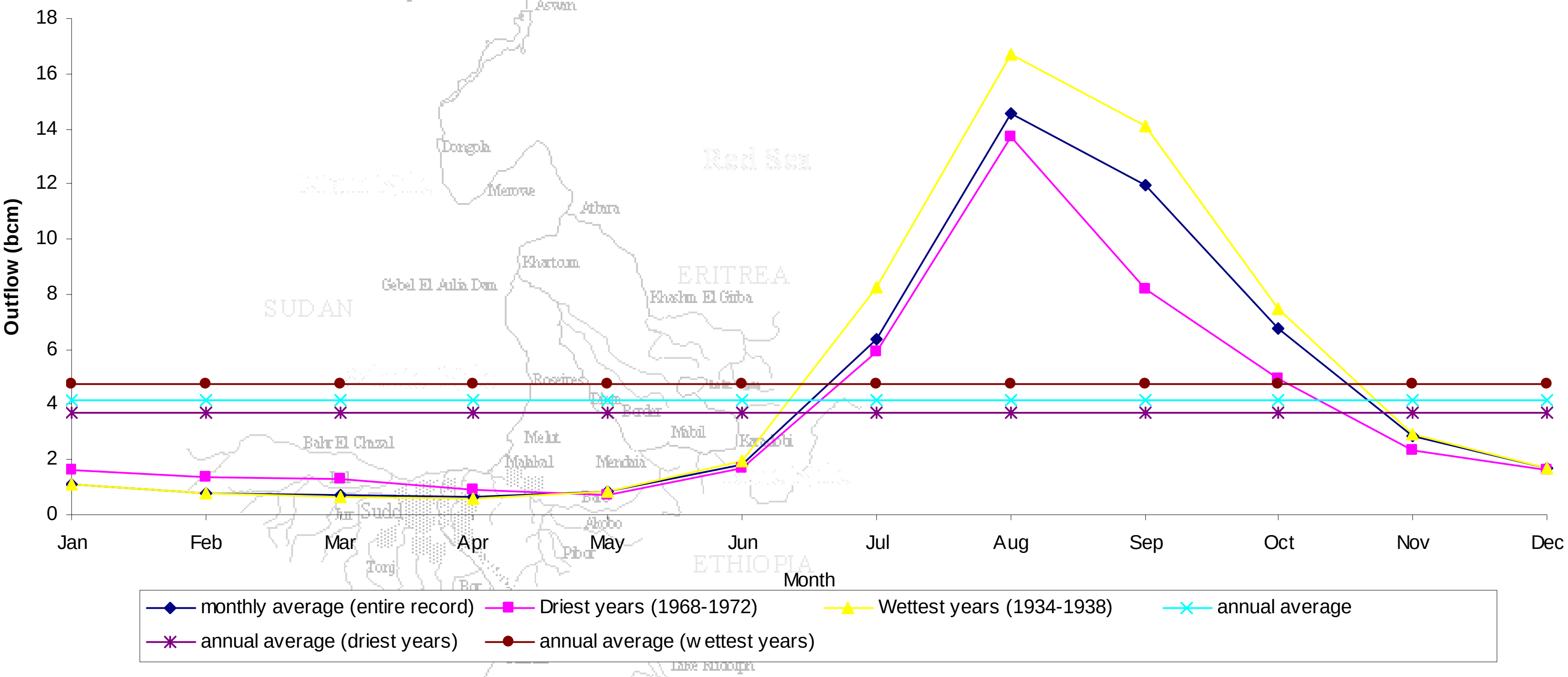
Malakal outflows



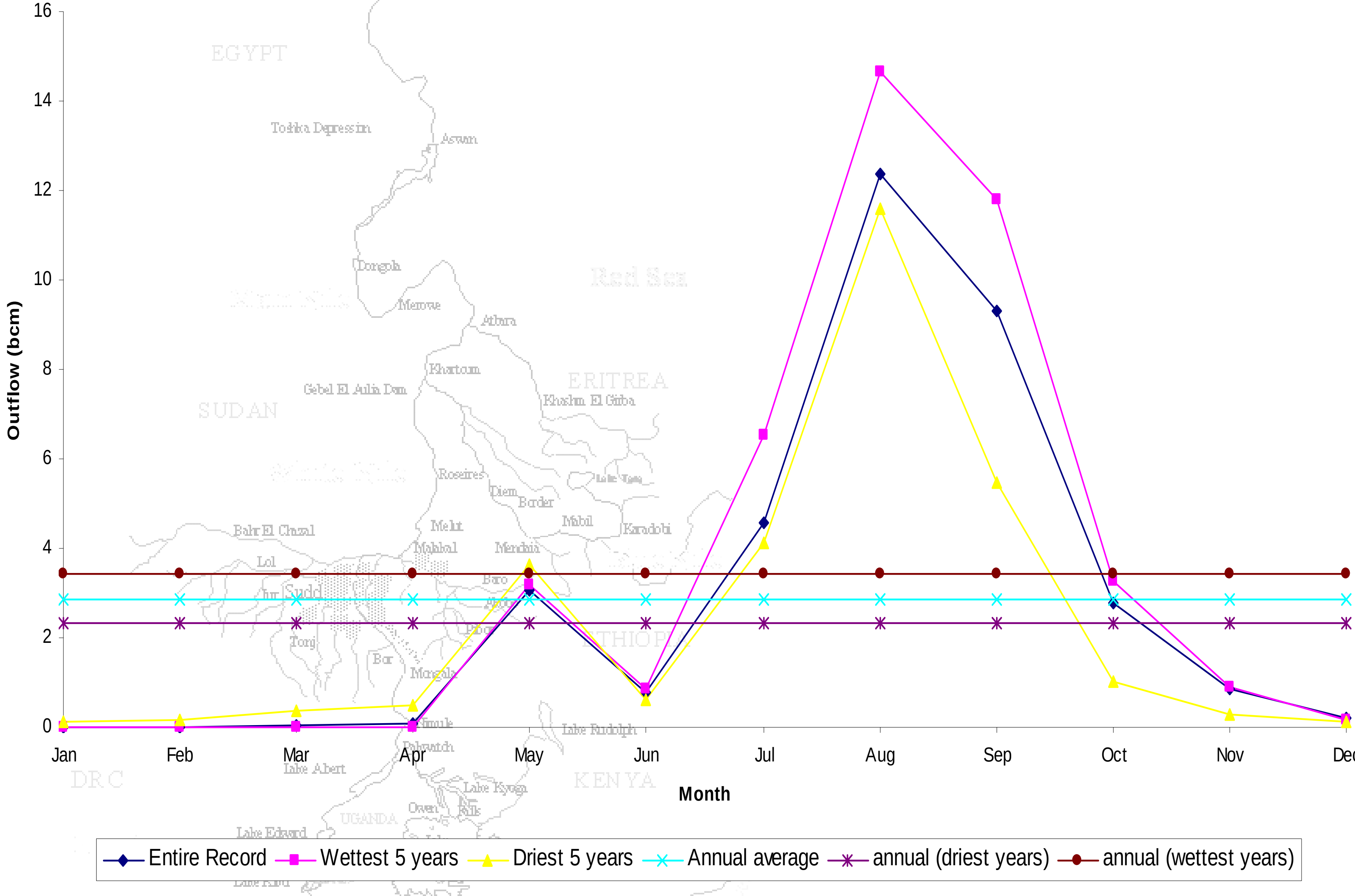
Gebel el Aulia



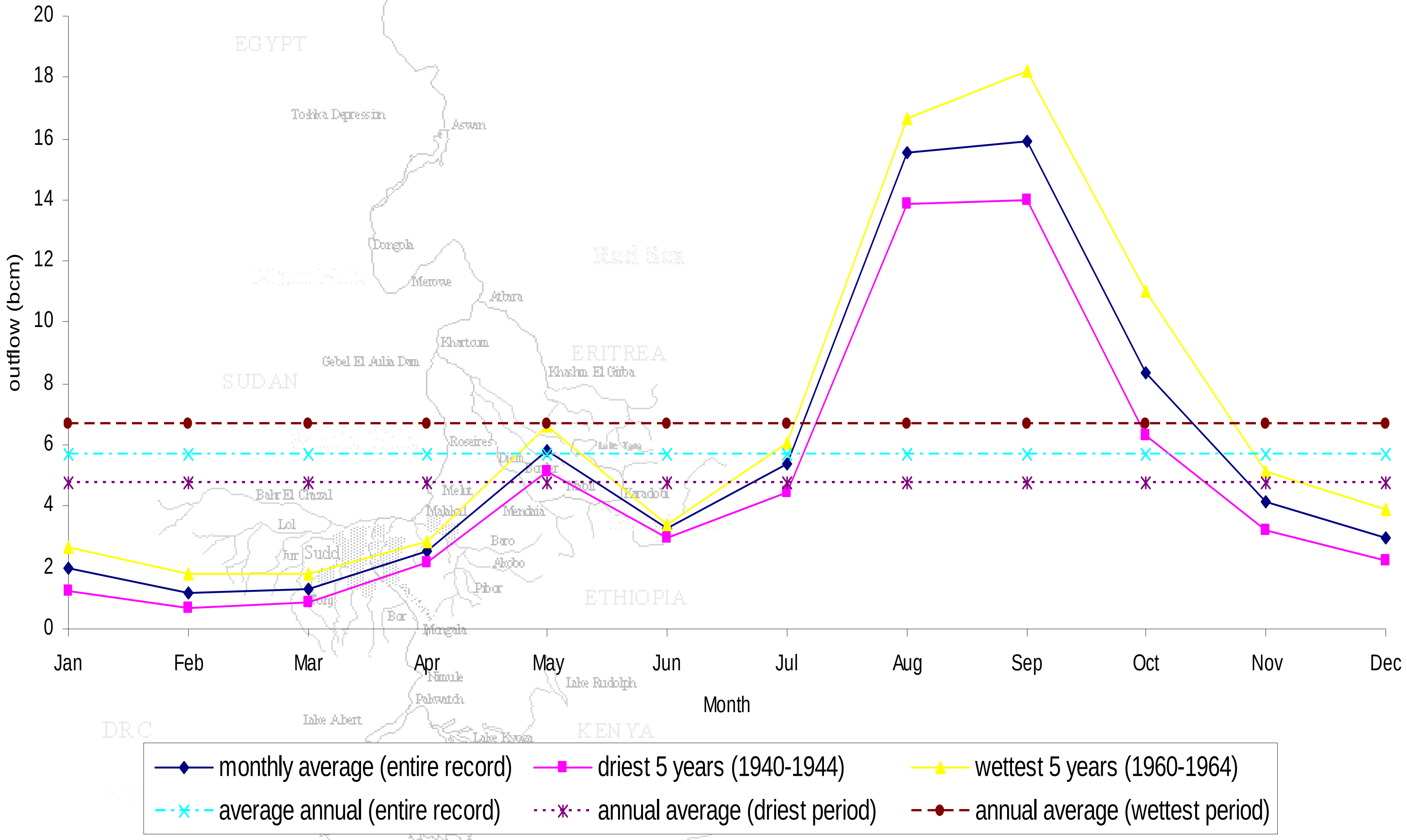
Diem outflows



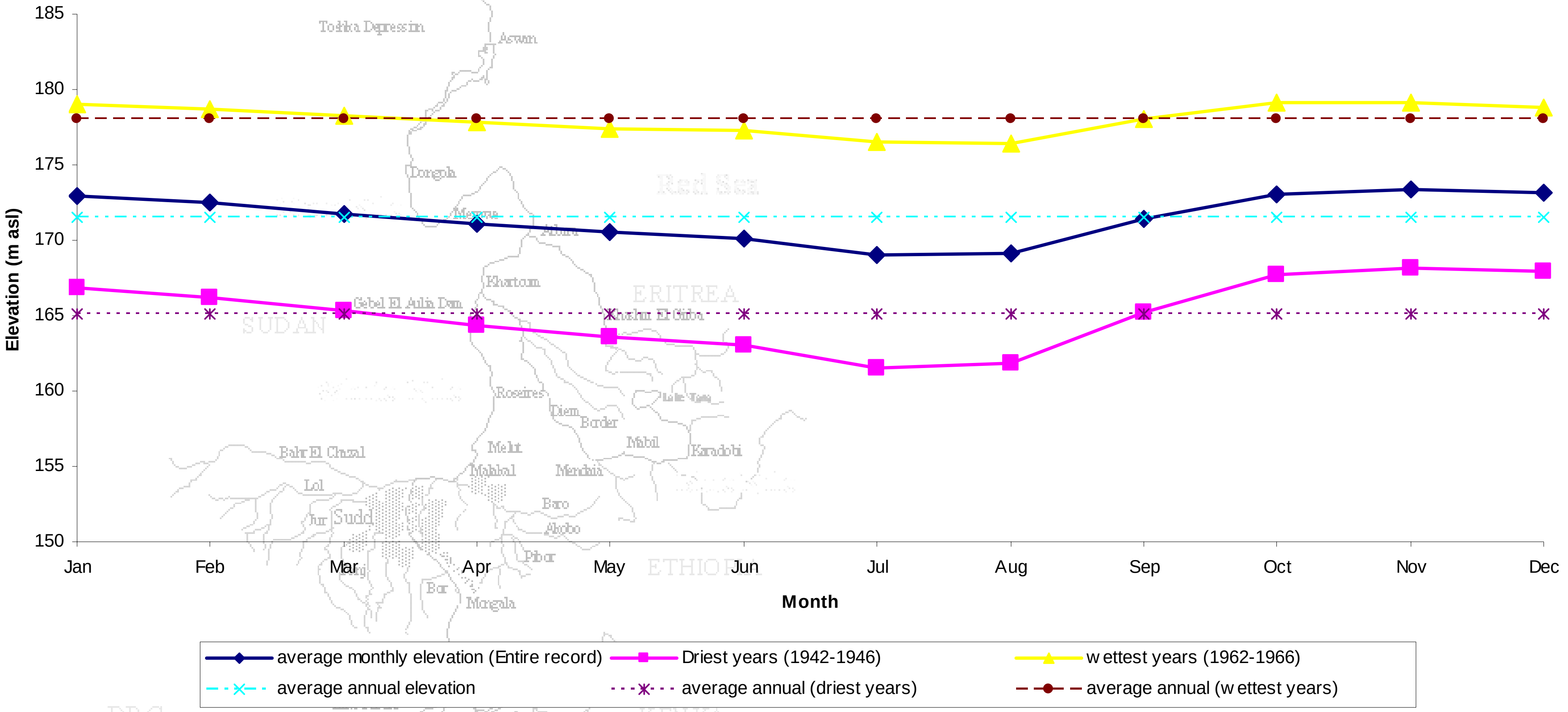
Khartoum outflows

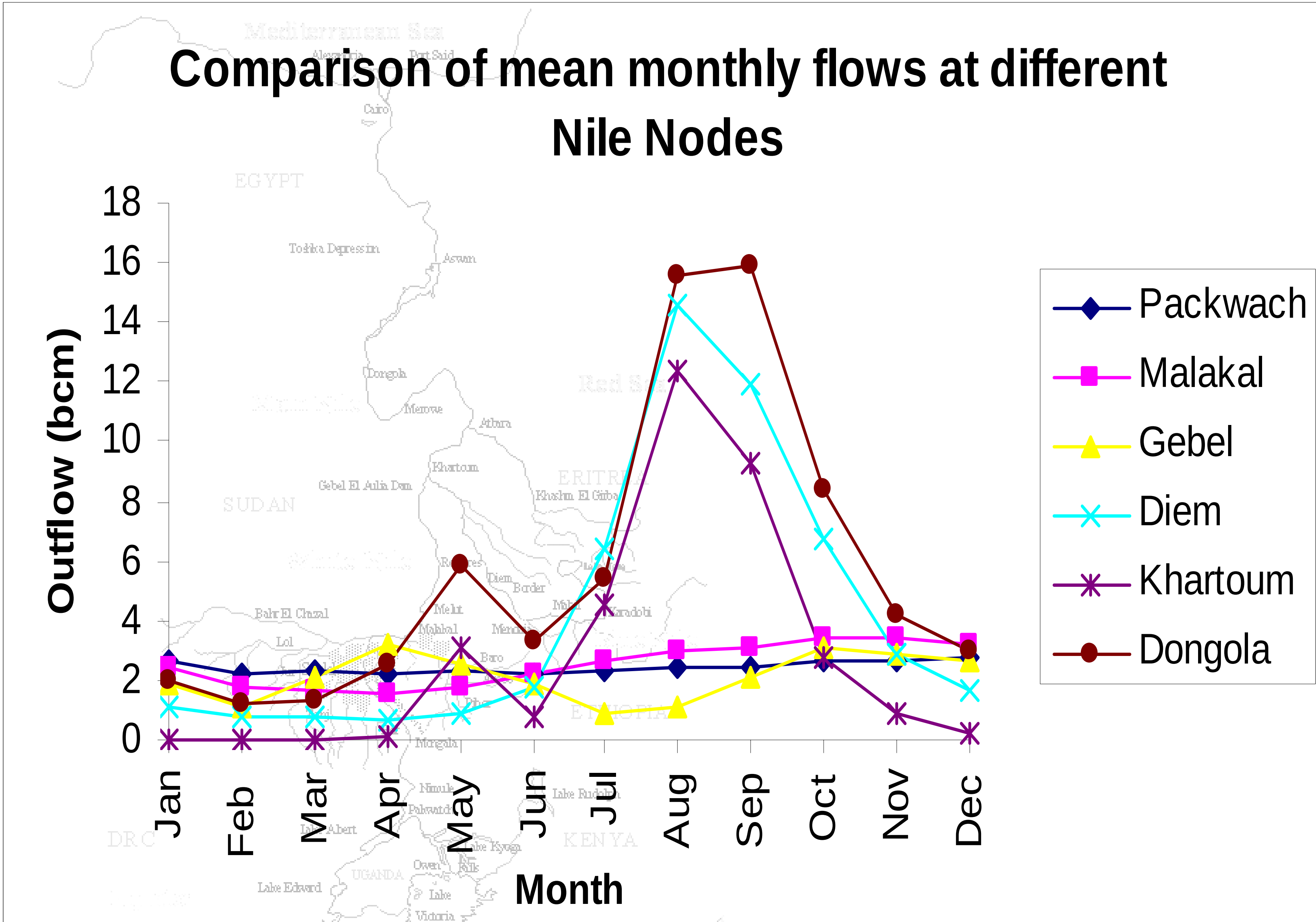


Dongola outflows



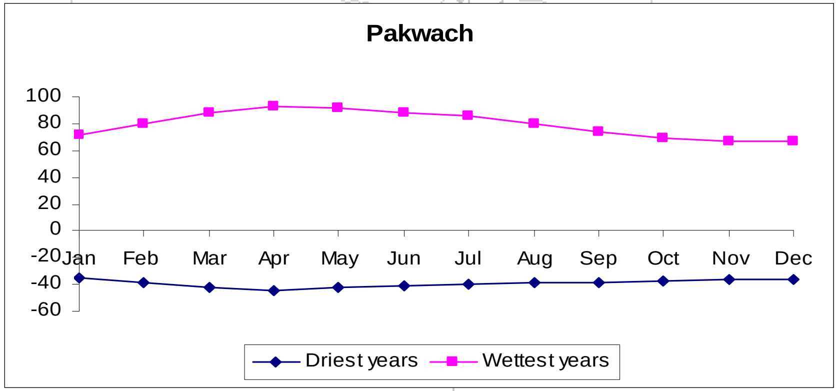
HAD Elevation

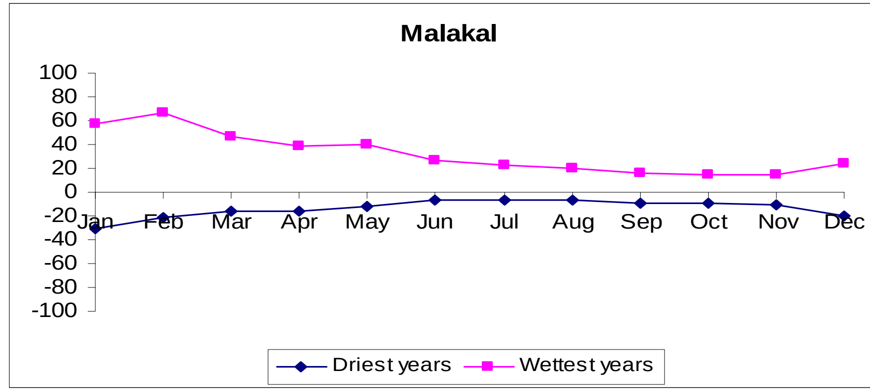


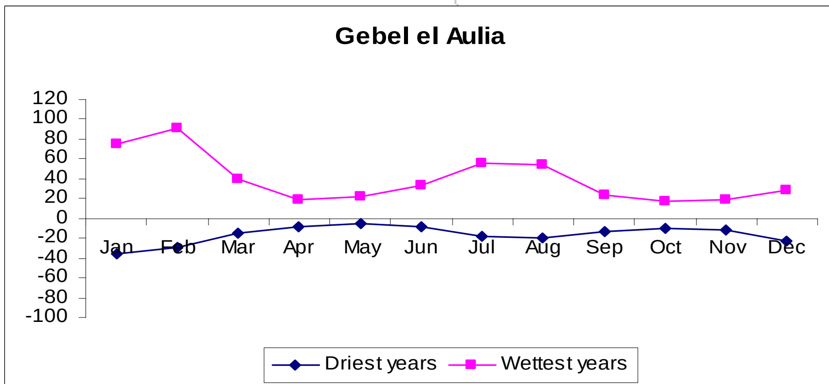


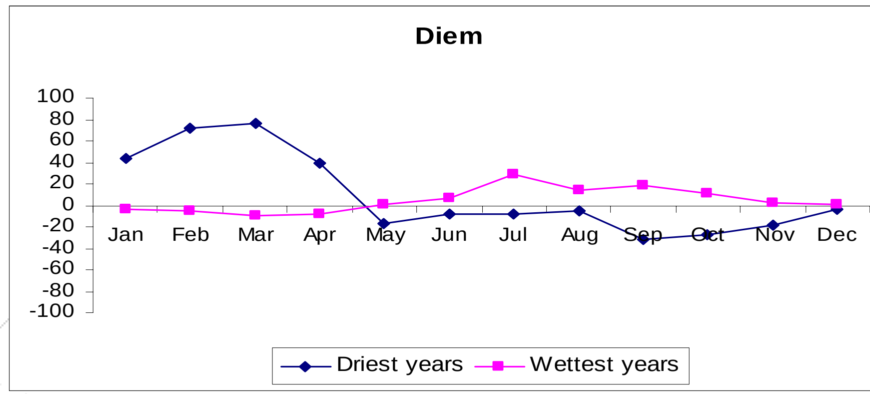
Comparison of mean monthly flows at different Nile Nodes
Outflow (bcm)
0
2
4
6
8
10
12
14
16
18
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Packwach
Malakal
Gebel
Diem
Khartoum
Dongola

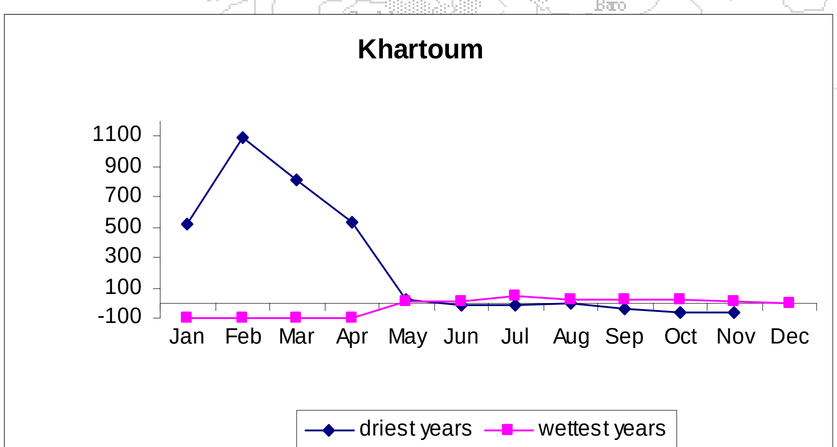
Percentage deviation of driest and wettest years from mean at different nodes

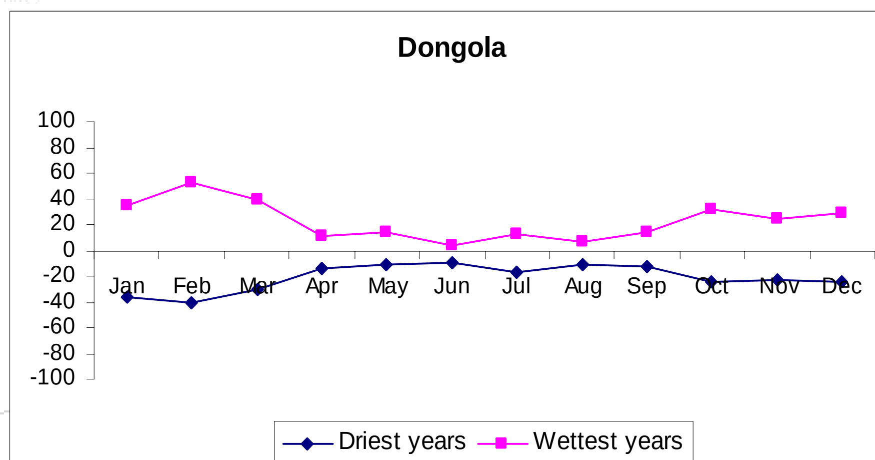








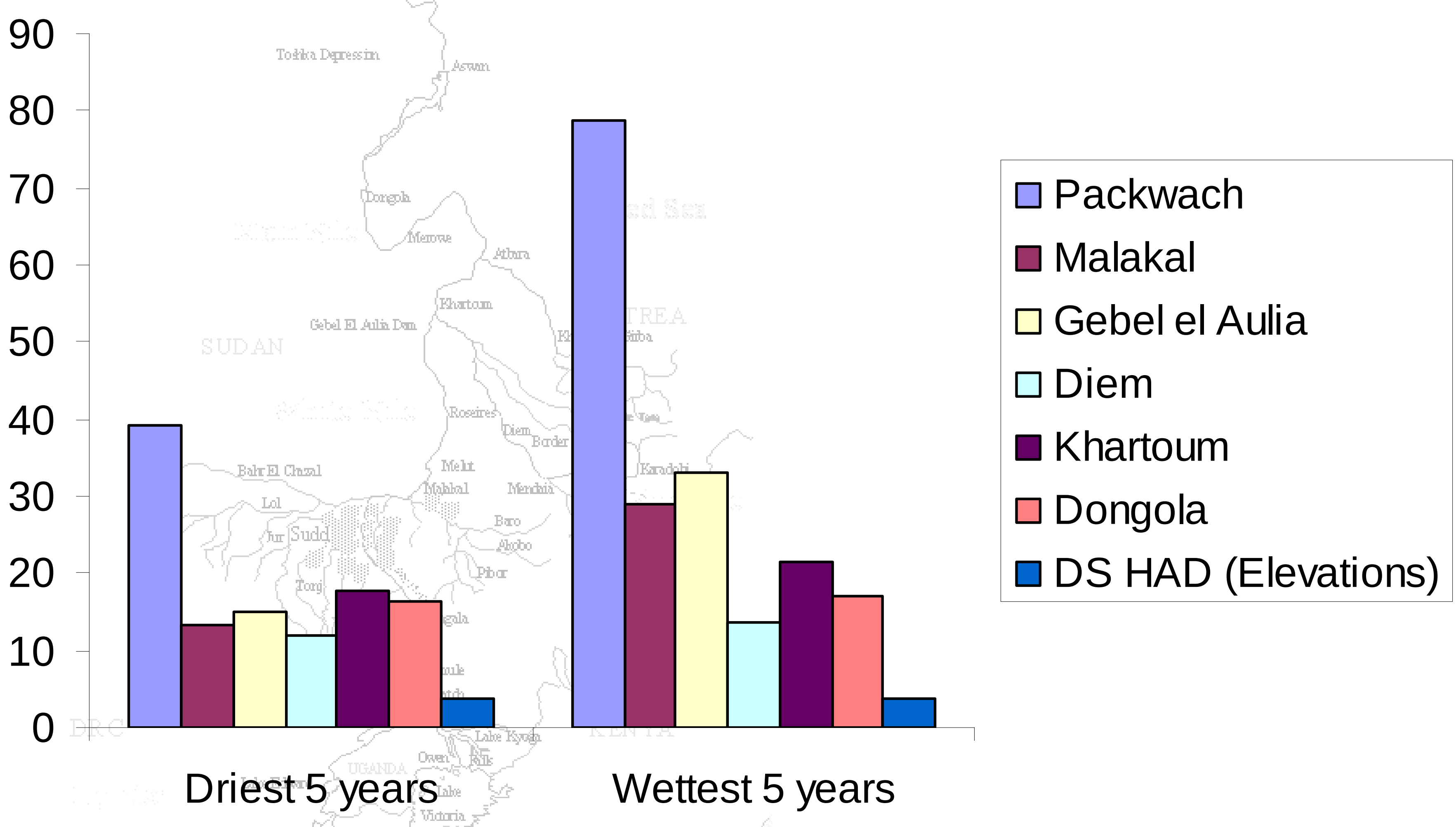


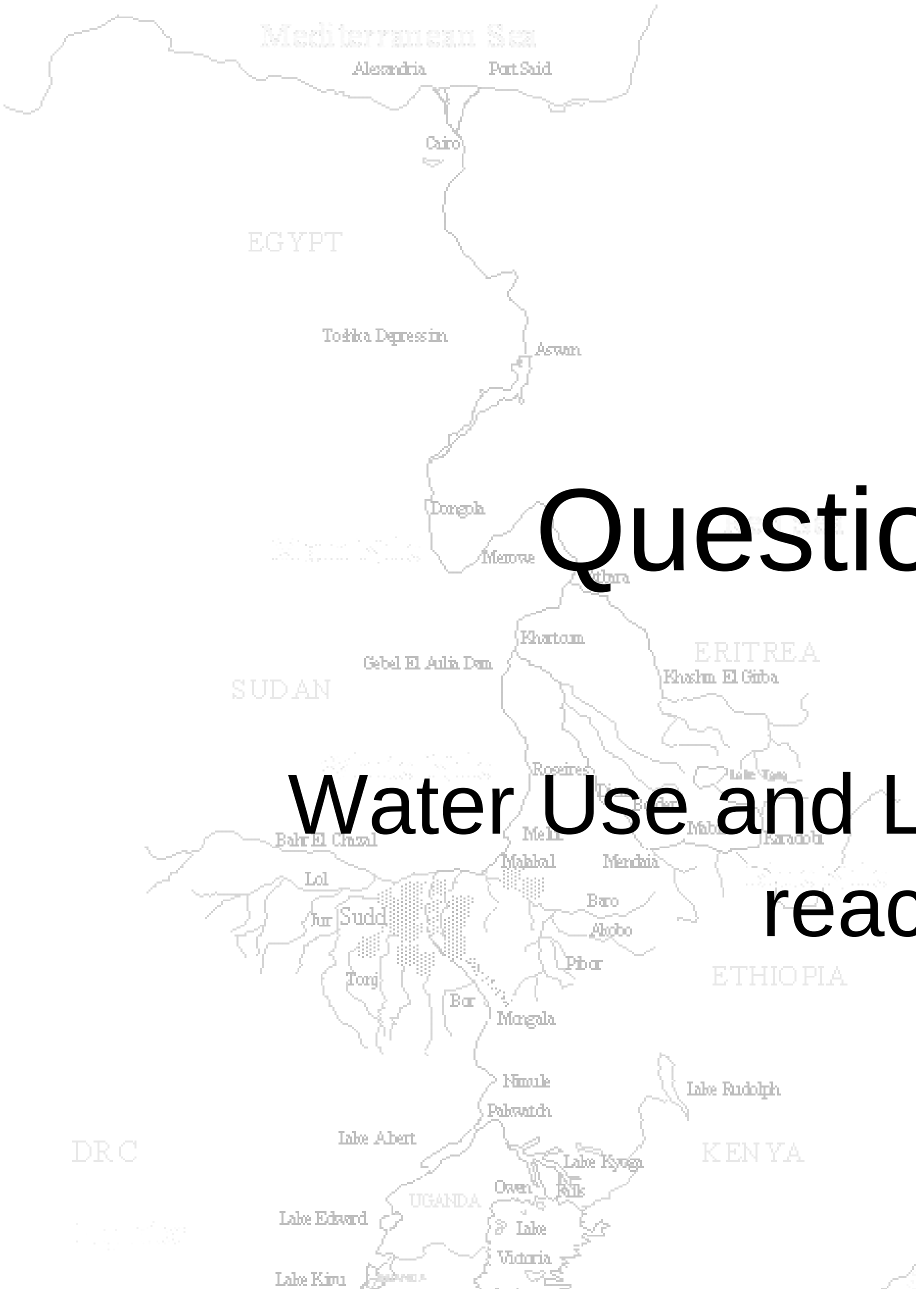


Occurrence of Wet and Dry periods within the Basin and variability from Normal

Stn	Event Occurrence		Deviation from Normal	
	Wet	Dry	Wet	Dry
WNile - Pakwach	62-66	21-25	78.8%	-39.3%
Pakwach - Malakal	64-68	40-44	21.0%	-13.2%
BNile - Diem	34-38	68-72	13.6%	-11.8%
Diem - Khartoum	34-38	68-72	21.5%	-17.8%
Khartoum - Dongola	60-64	40-44	17.0%	-16.2%
Victoria	62-66	21-25	69.7%	-35.4%
Malakal – Gebel	62-66	40-44	33.1%	-15.1%
Diem - Sennar	58-62	18-22	19.8%	-18.2%
Dongola - Dhd	72-76	-	-	-

Percentage deviation of outflows from annual averages



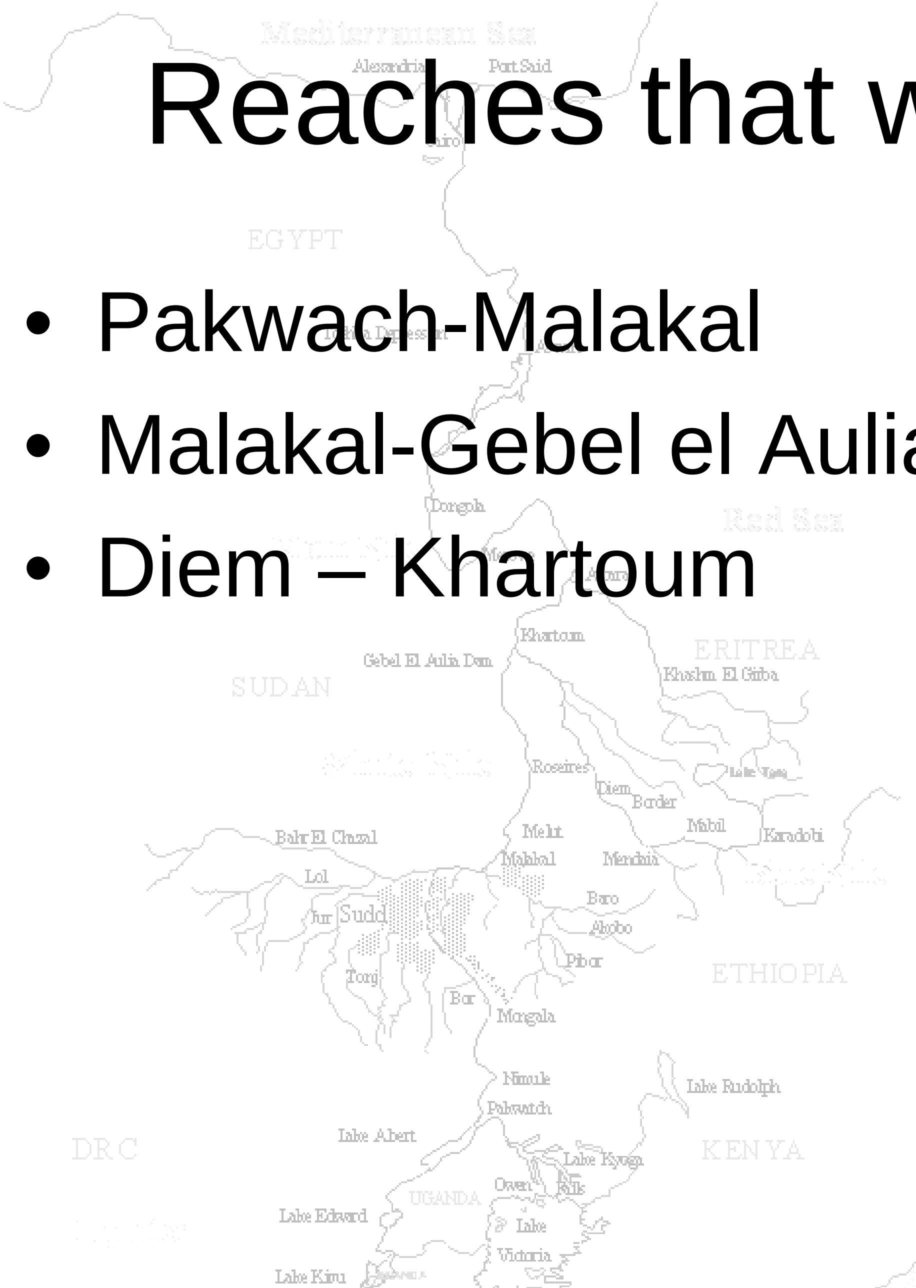


Question 1.2

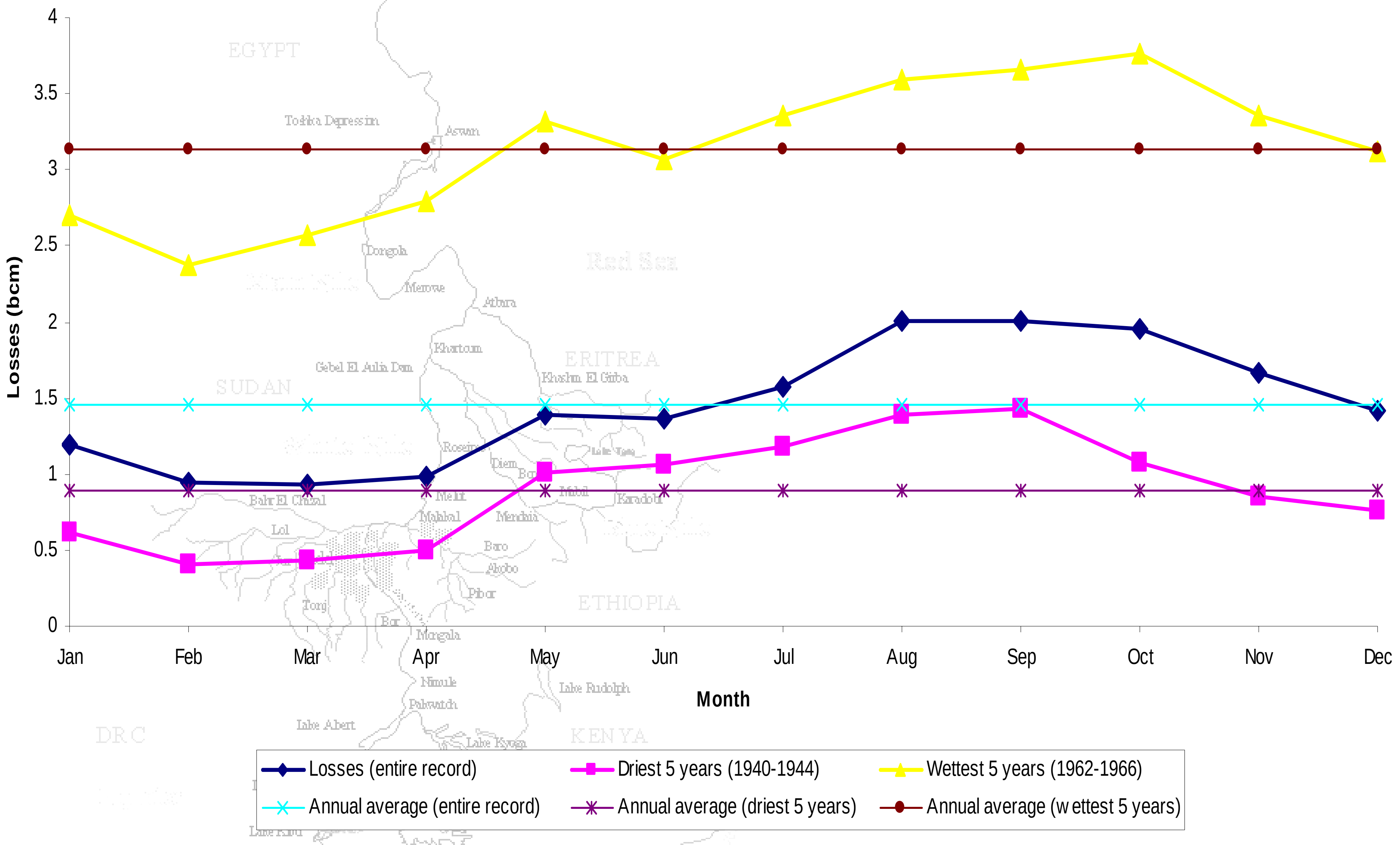
Water Use and Losses in each reach

Reaches that were included

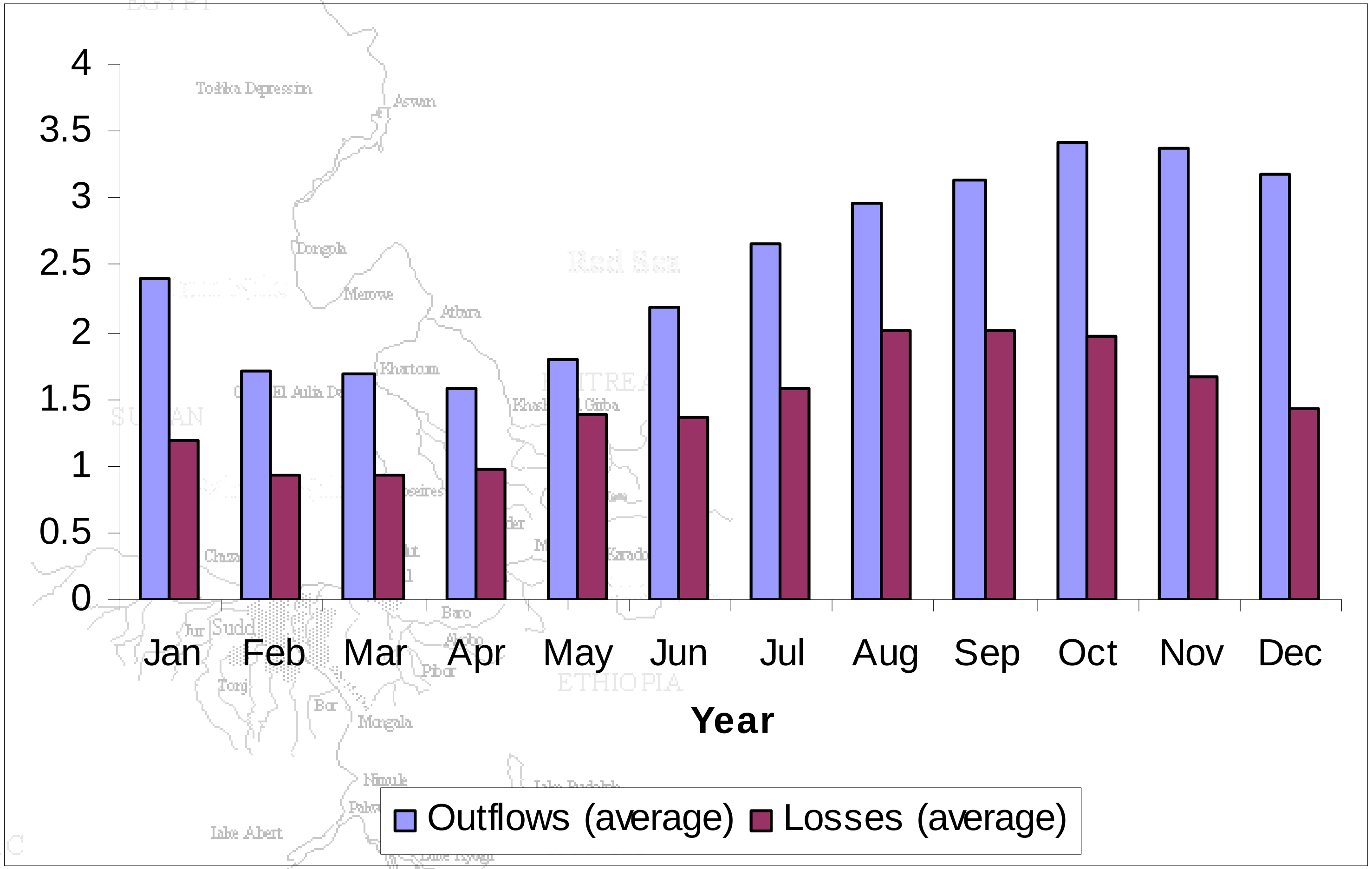
- Pakwach-Malakal
- Malakal-Gebel el Aulia
- Diem – Khartoum



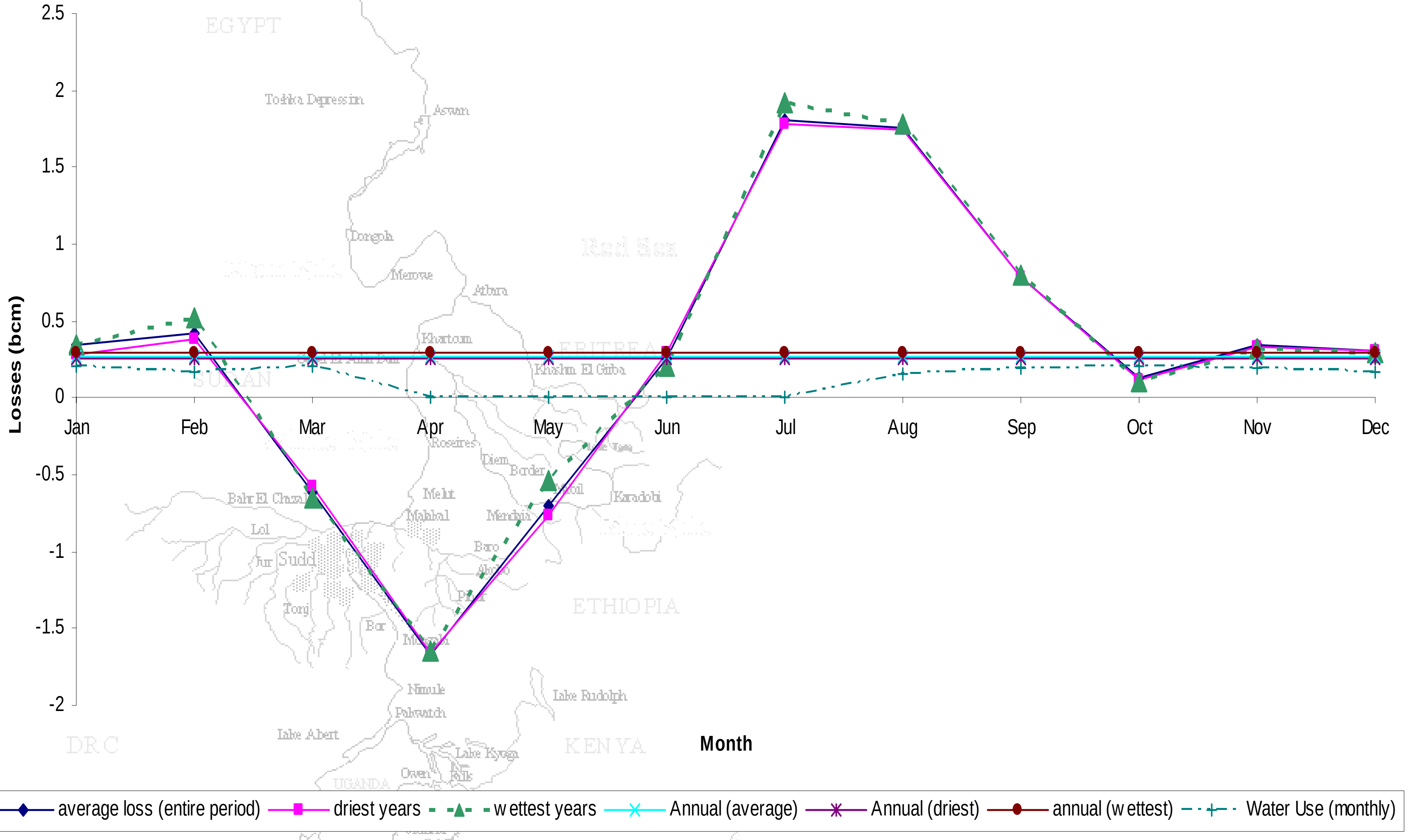
Losses in the Pakwach-Malakal reach



Comparison of losses and outflows from the Pakwach-Malakal reach

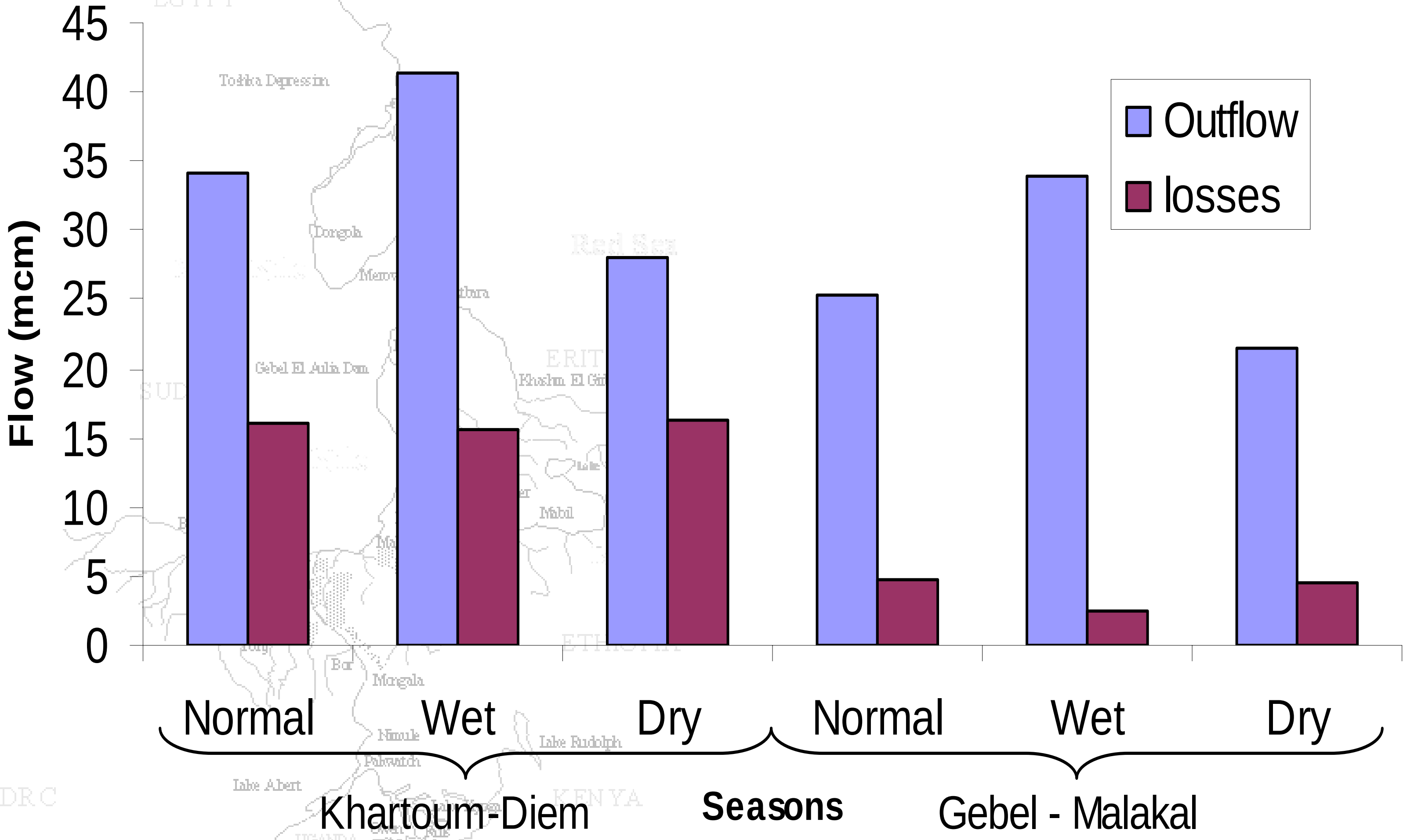


Losses and water use in the Malakal-Gebel el Aulia reach

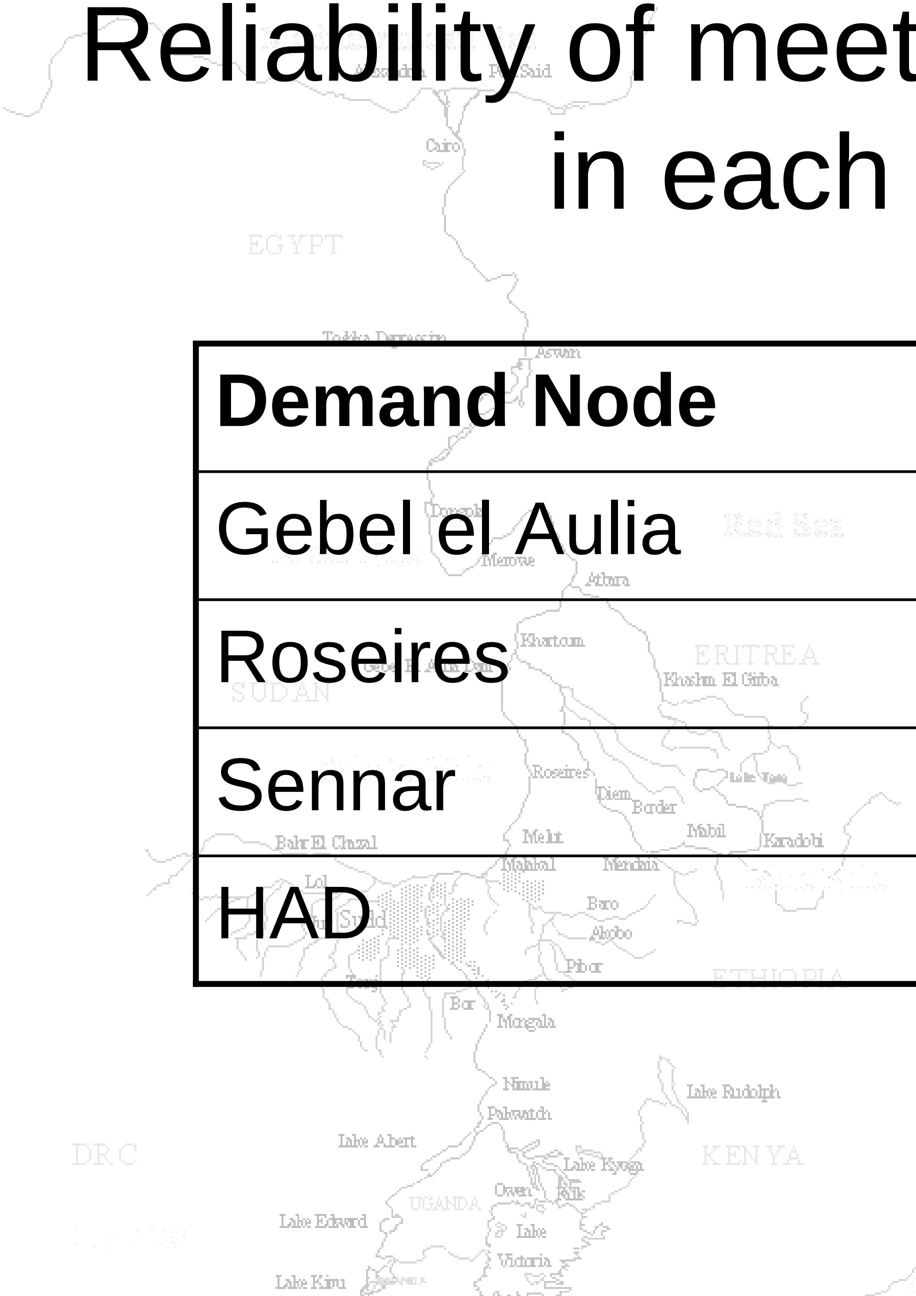


1.2.f

Comparison of water losses to reach outflows



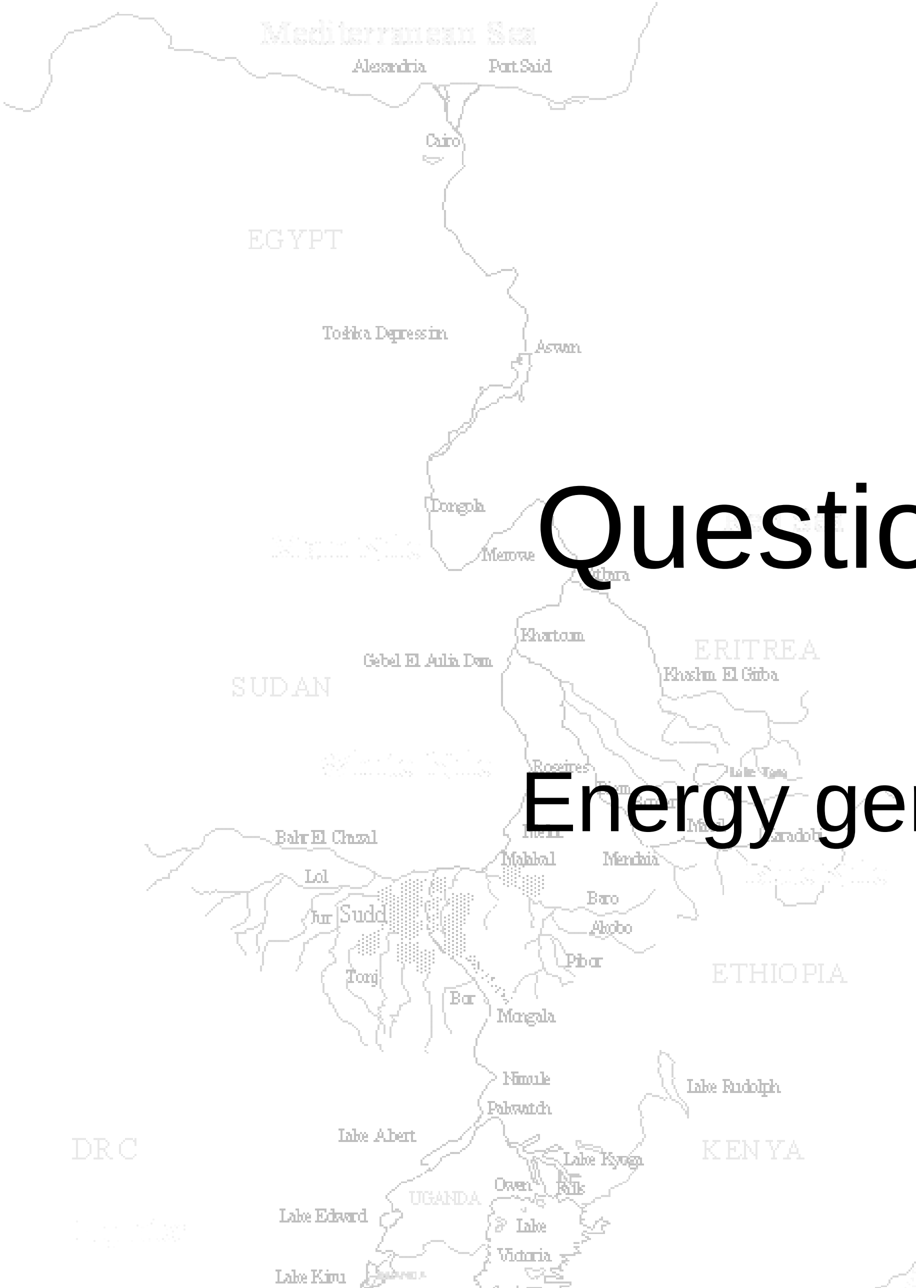
Reliability of meeting the demand in each reach



Demand Node	Reliability
Gebel el Aulia	100
Roseires	100
Sennar	98.5
HAD	100

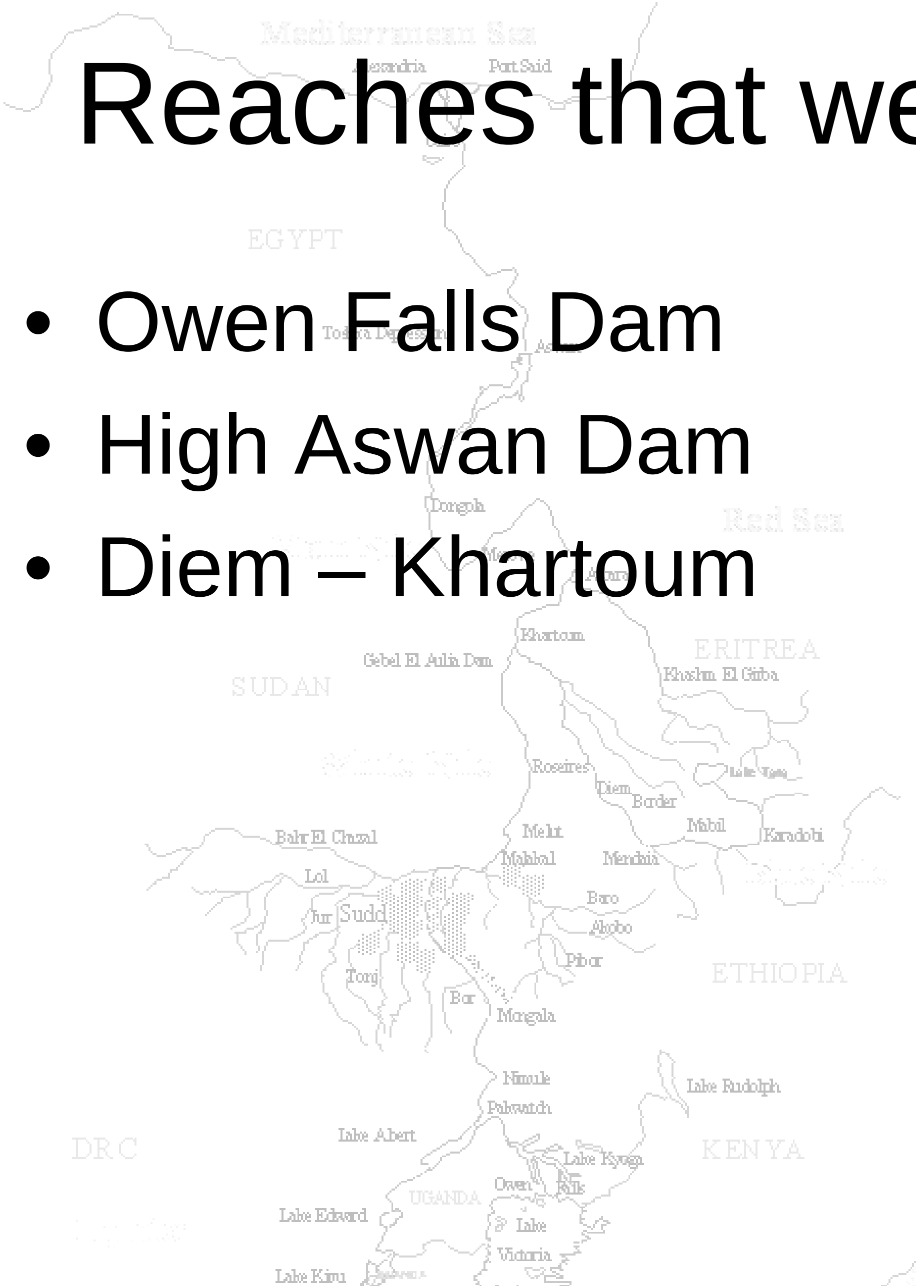
Question 1.3

Energy generation

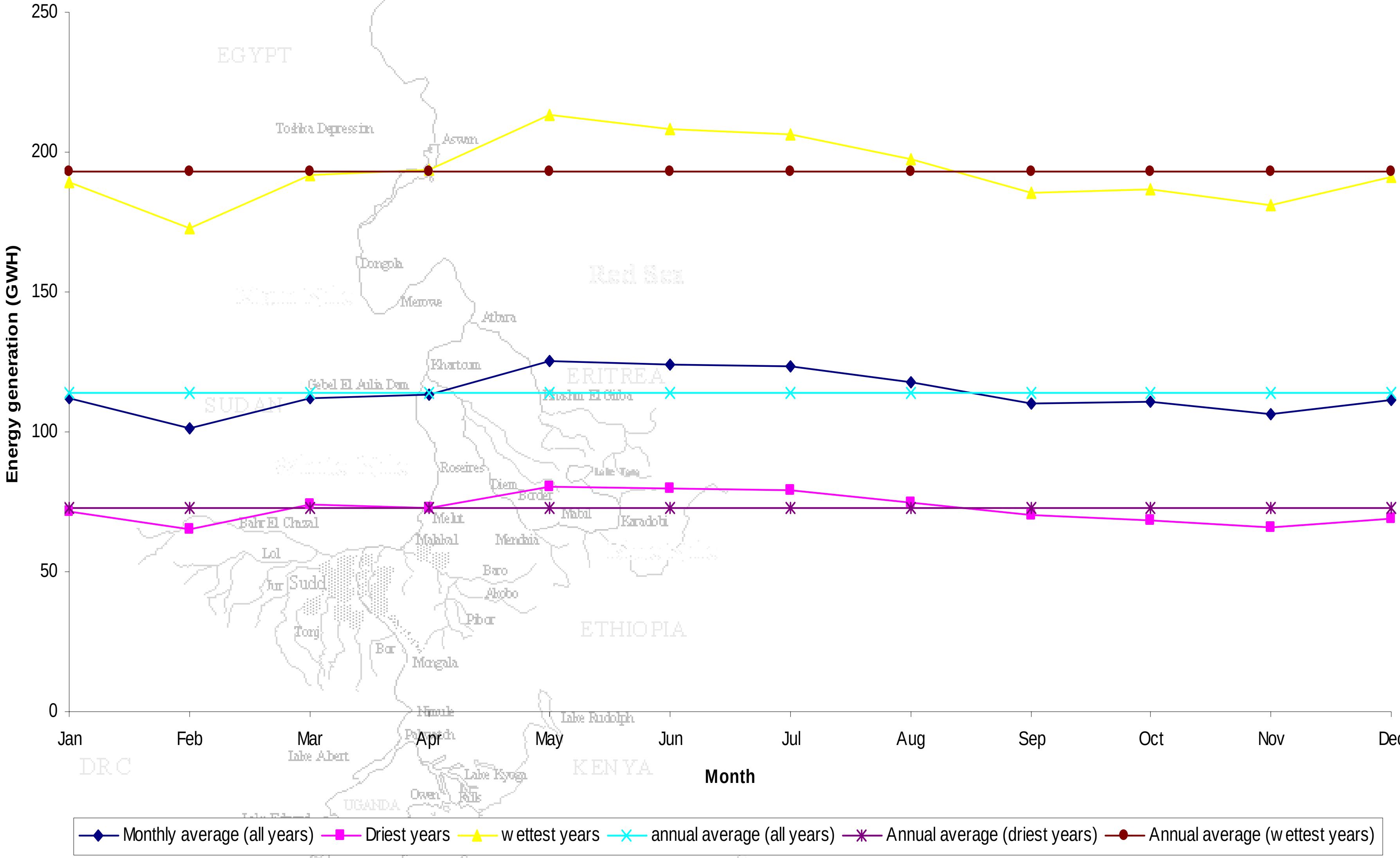


Reaches that were considered

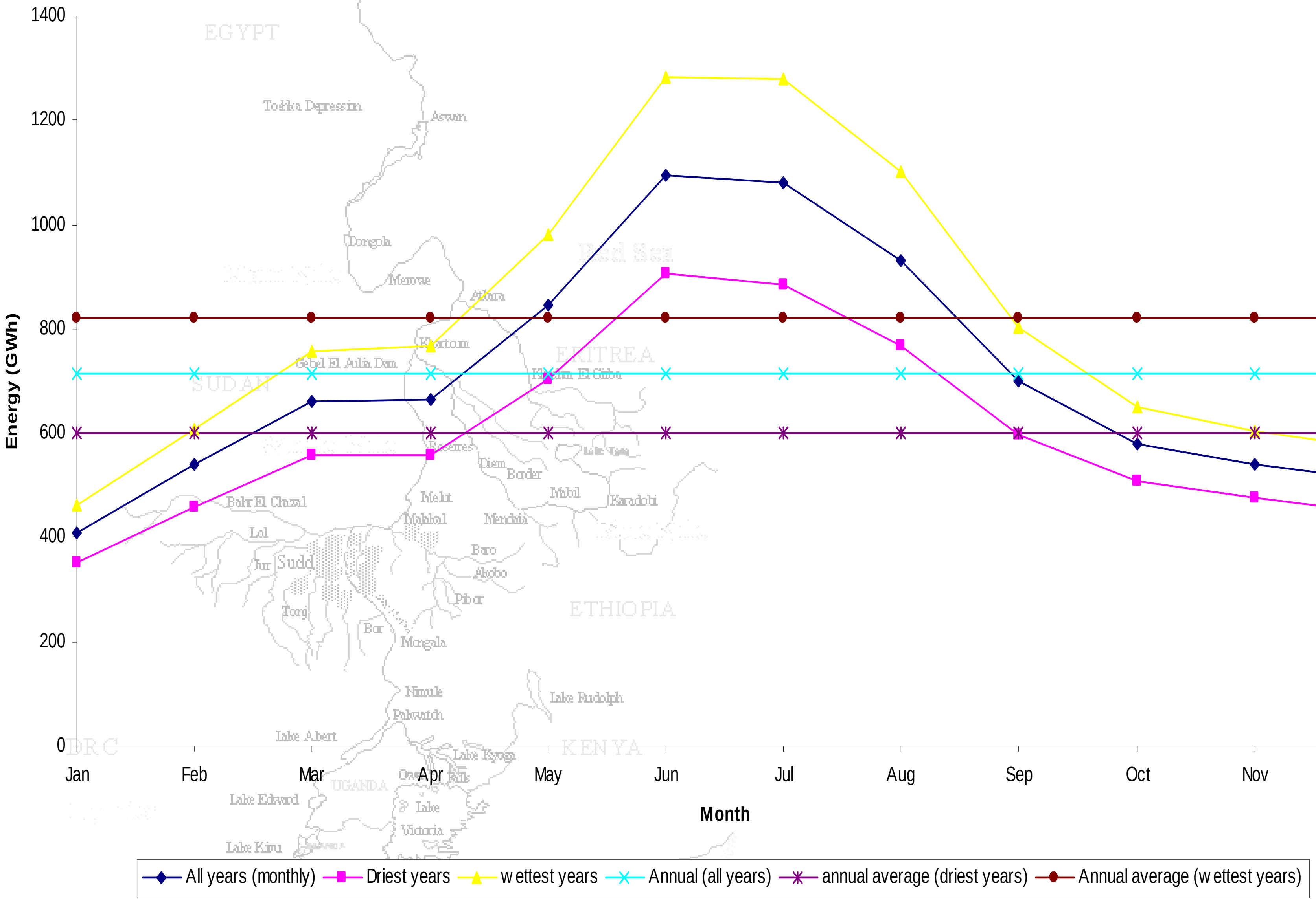
- Owen Falls Dam
- High Aswan Dam
- Diem – Khartoum



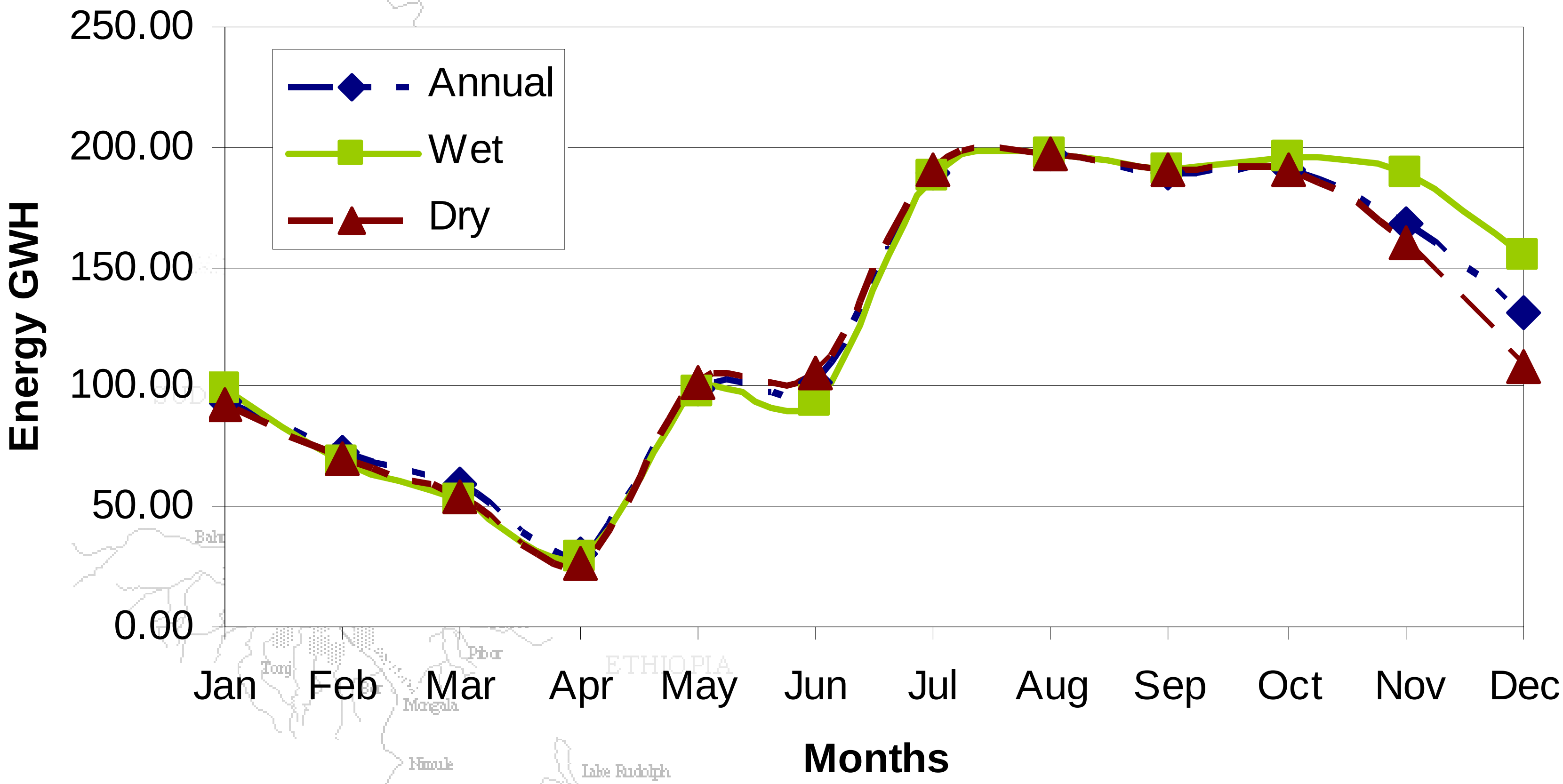
Owen Falls energy generation



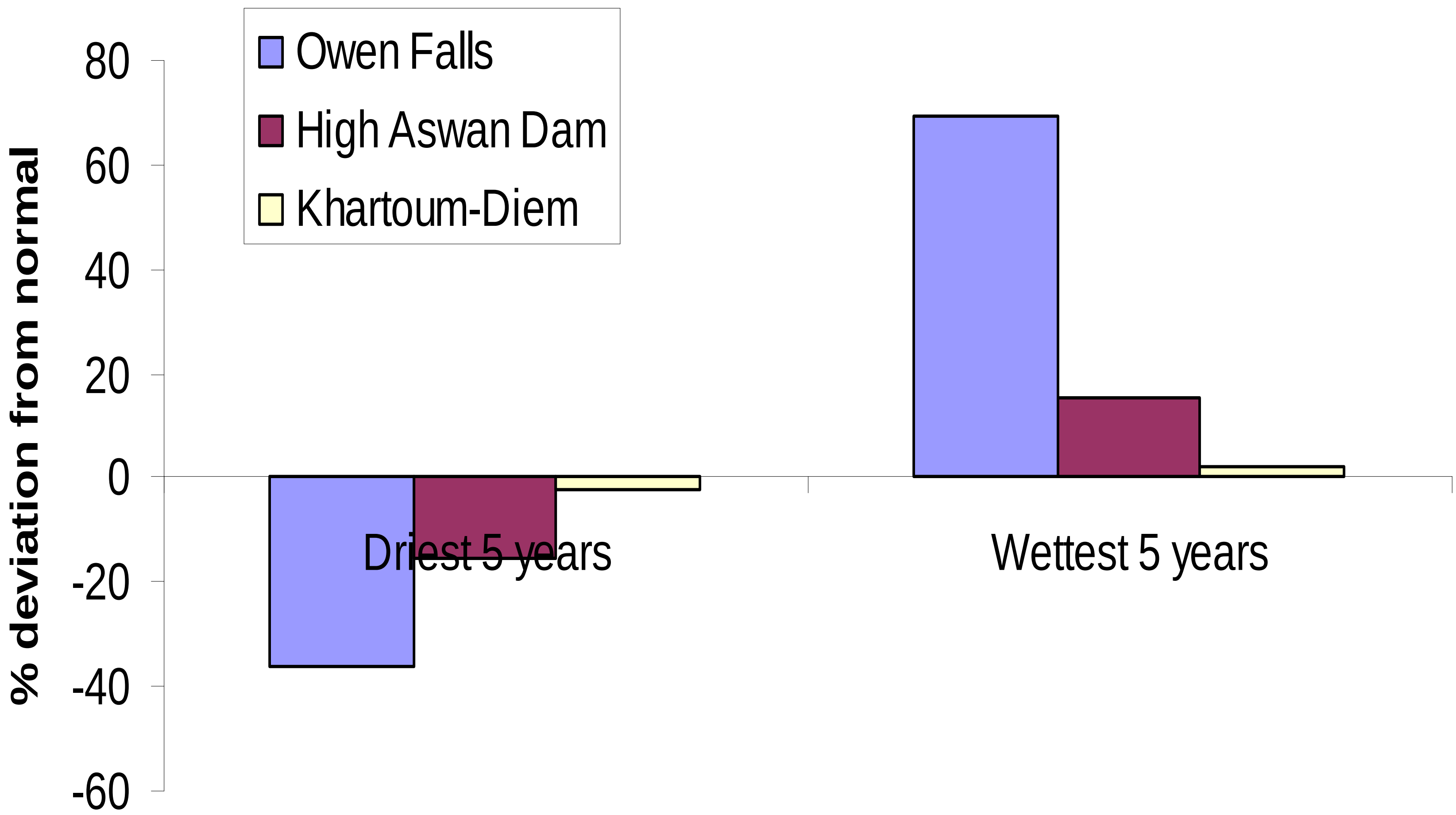
HAD energy generation



Energy Variability (Khartoum - Diem)



Deviations of annual power generation from normal

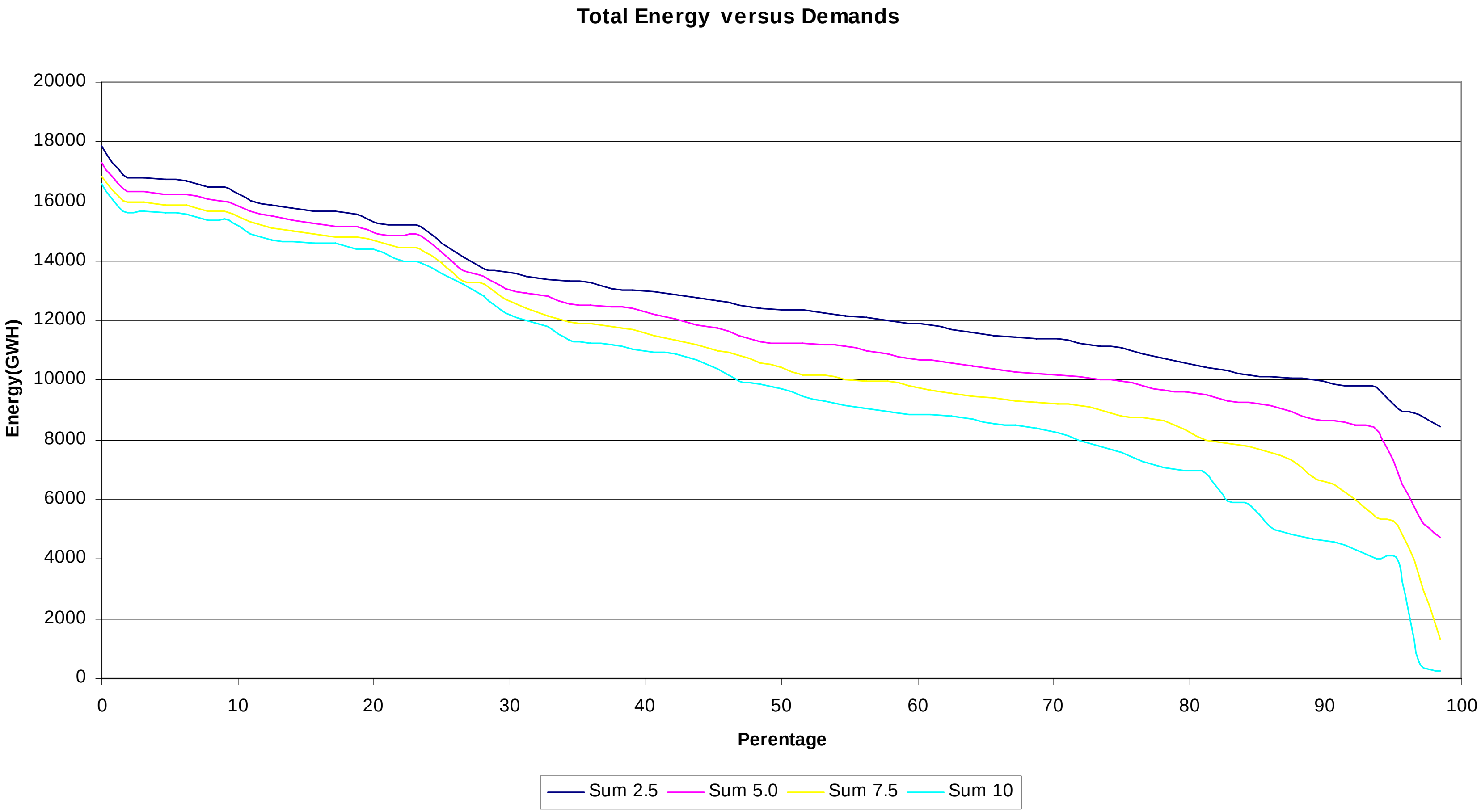


- Thank You for your attention

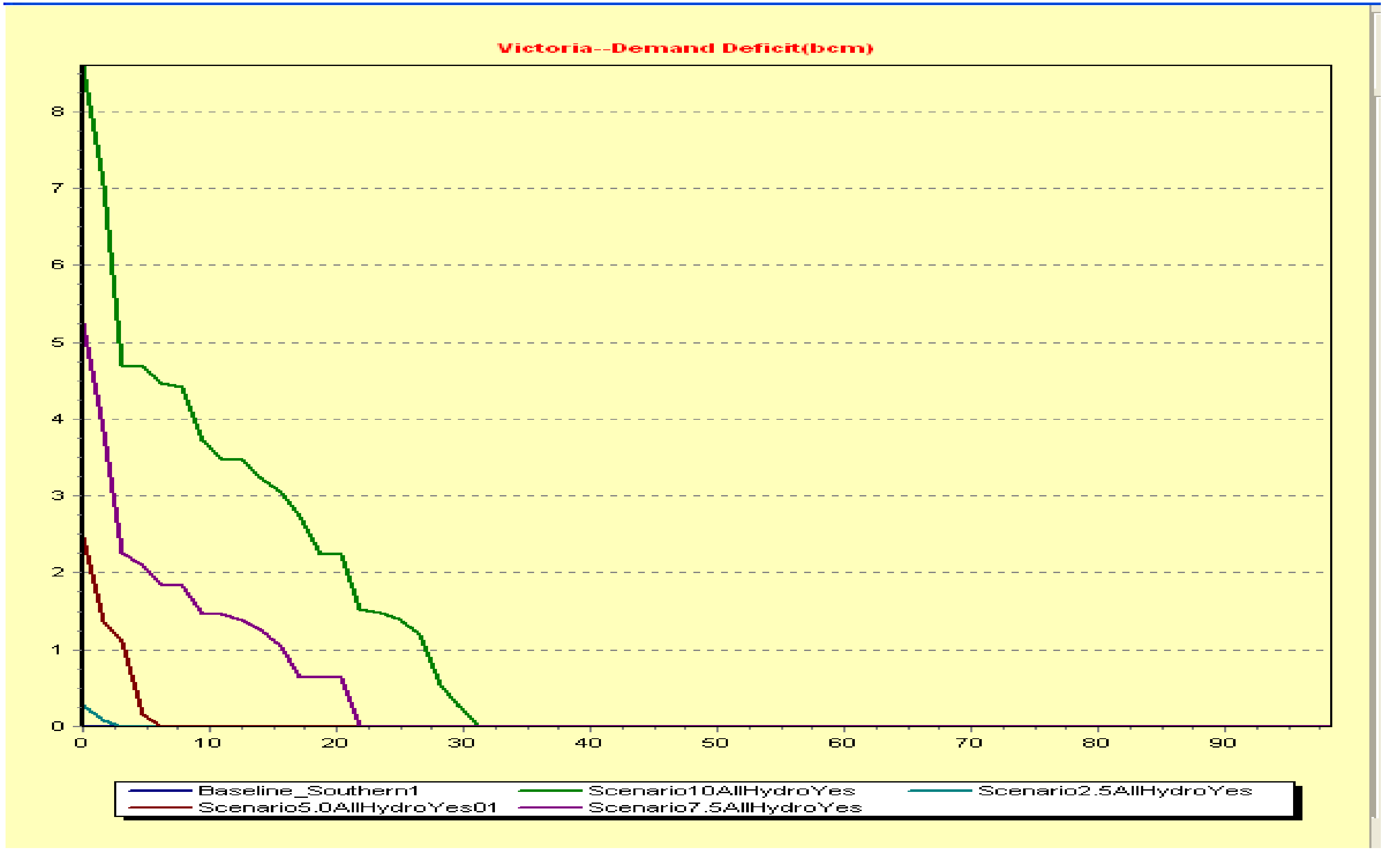
Southern Nile Scenario Analysis

Group 1 Presentation

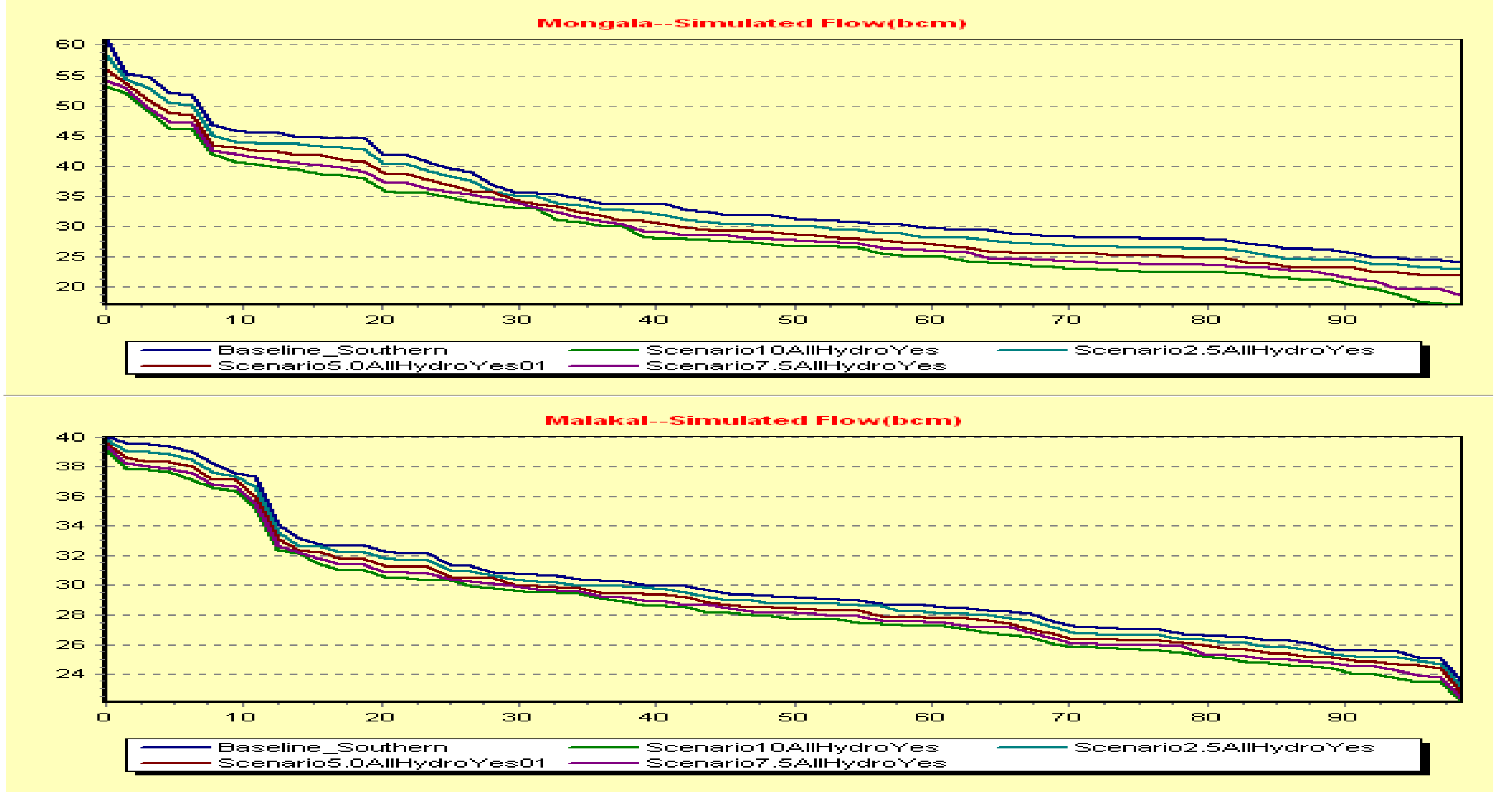
Total energy versus demands



Frequency of Demand Deficits for various Demand Targets

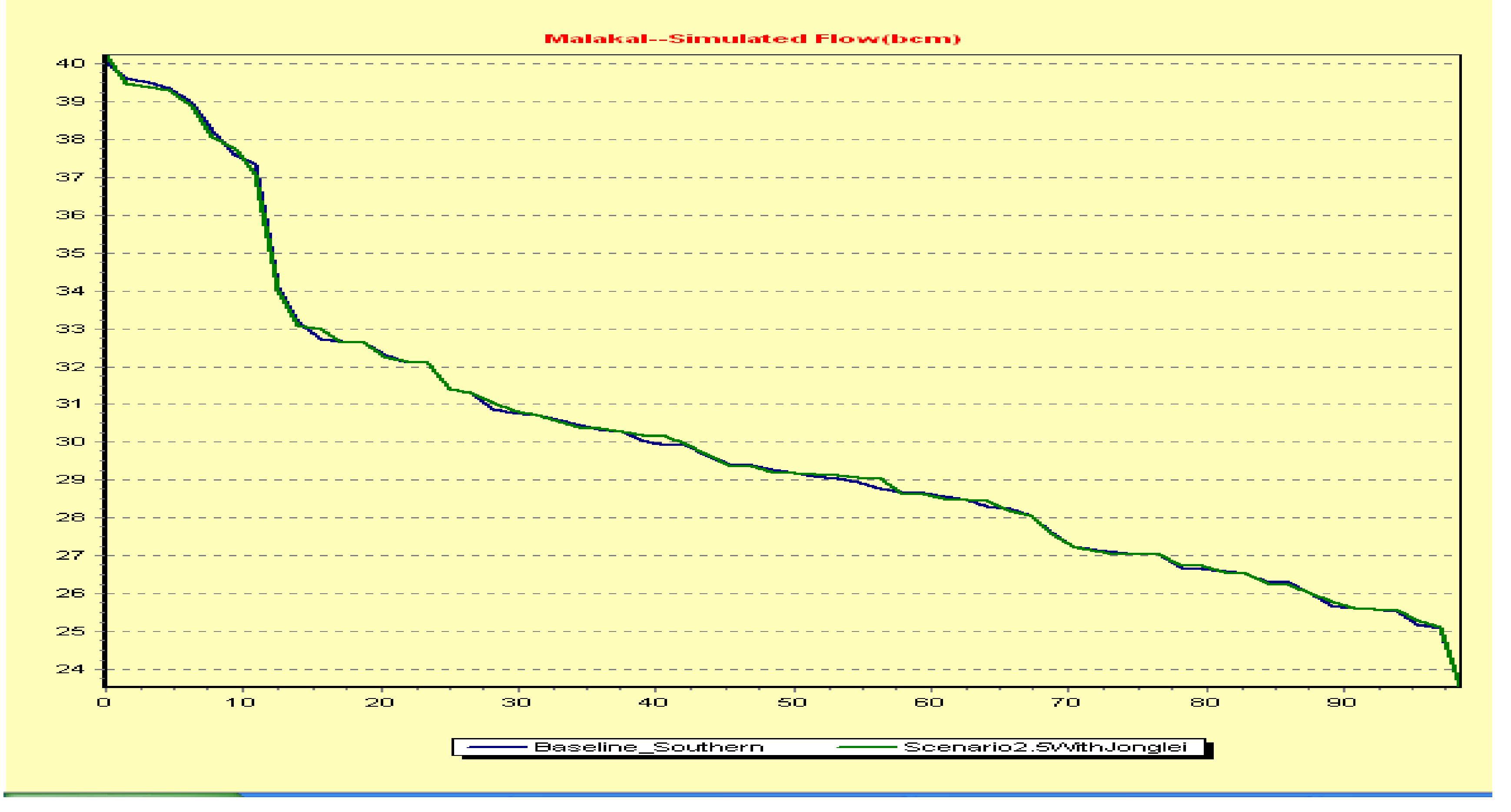


Frequency Curves at Mongala and Malakal for Victoria Demand Targets

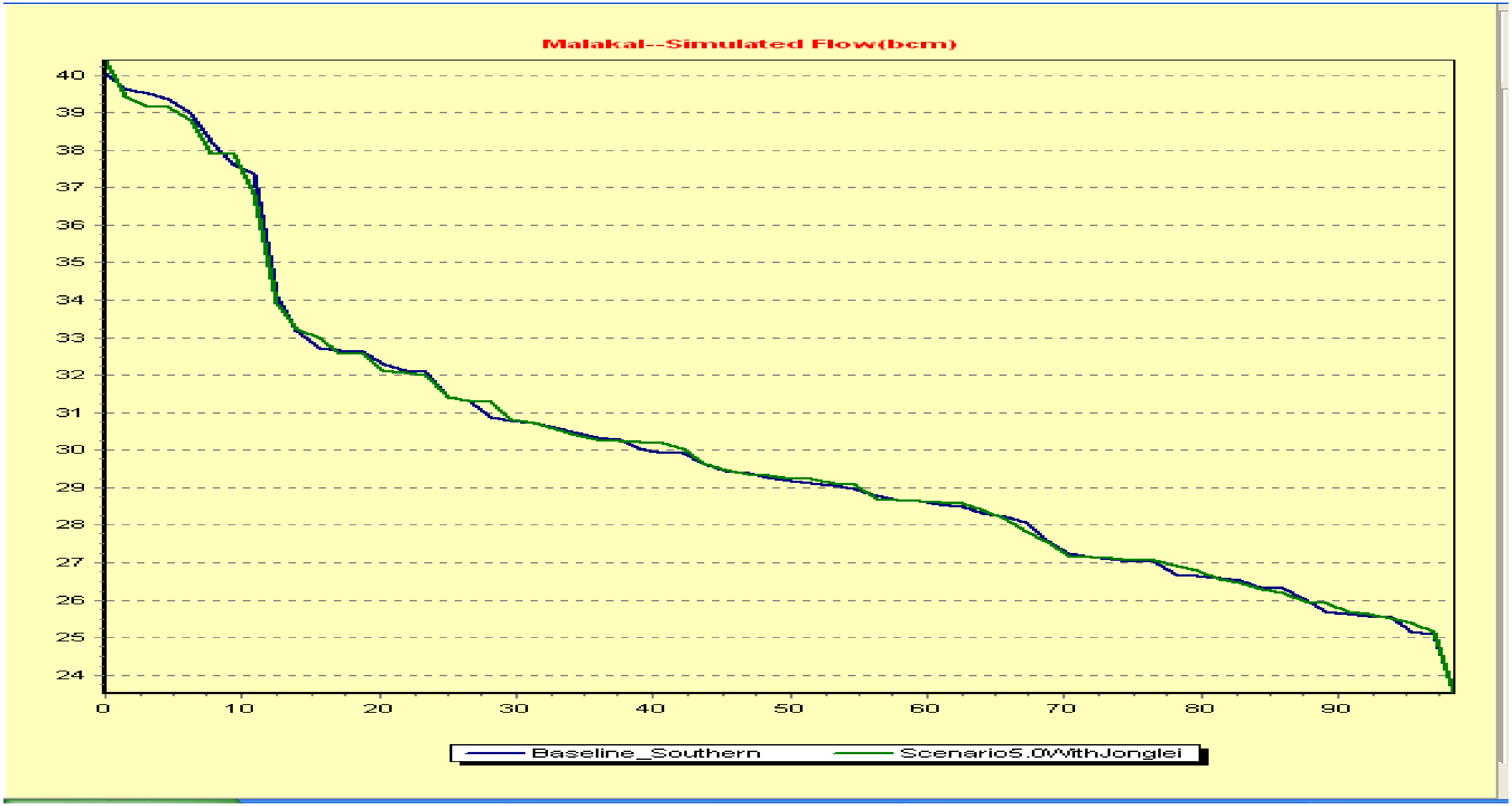


Capacity of Jonglei Canal 1.6 mcm/day

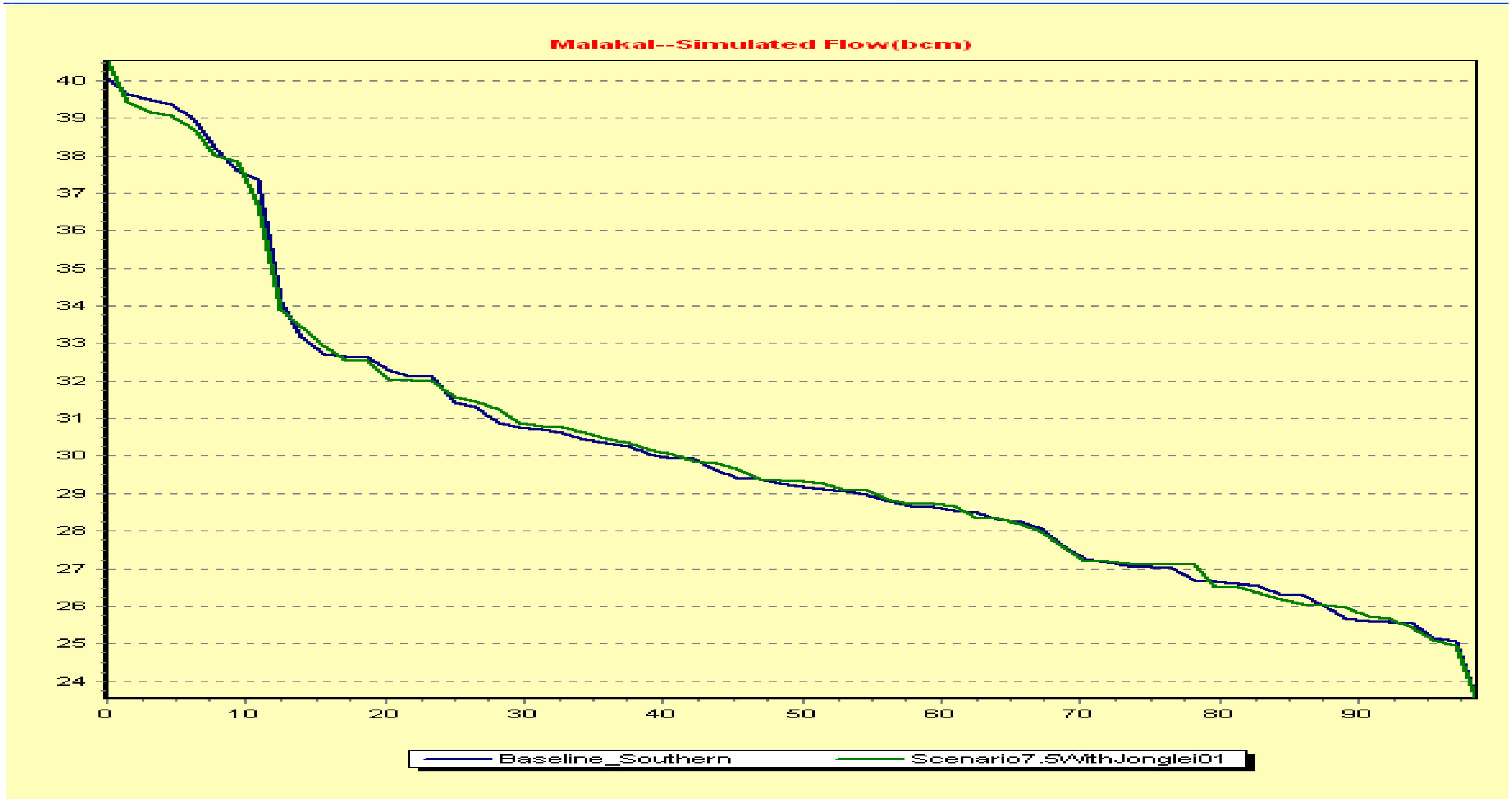
at 2.5bcm of L Victoria



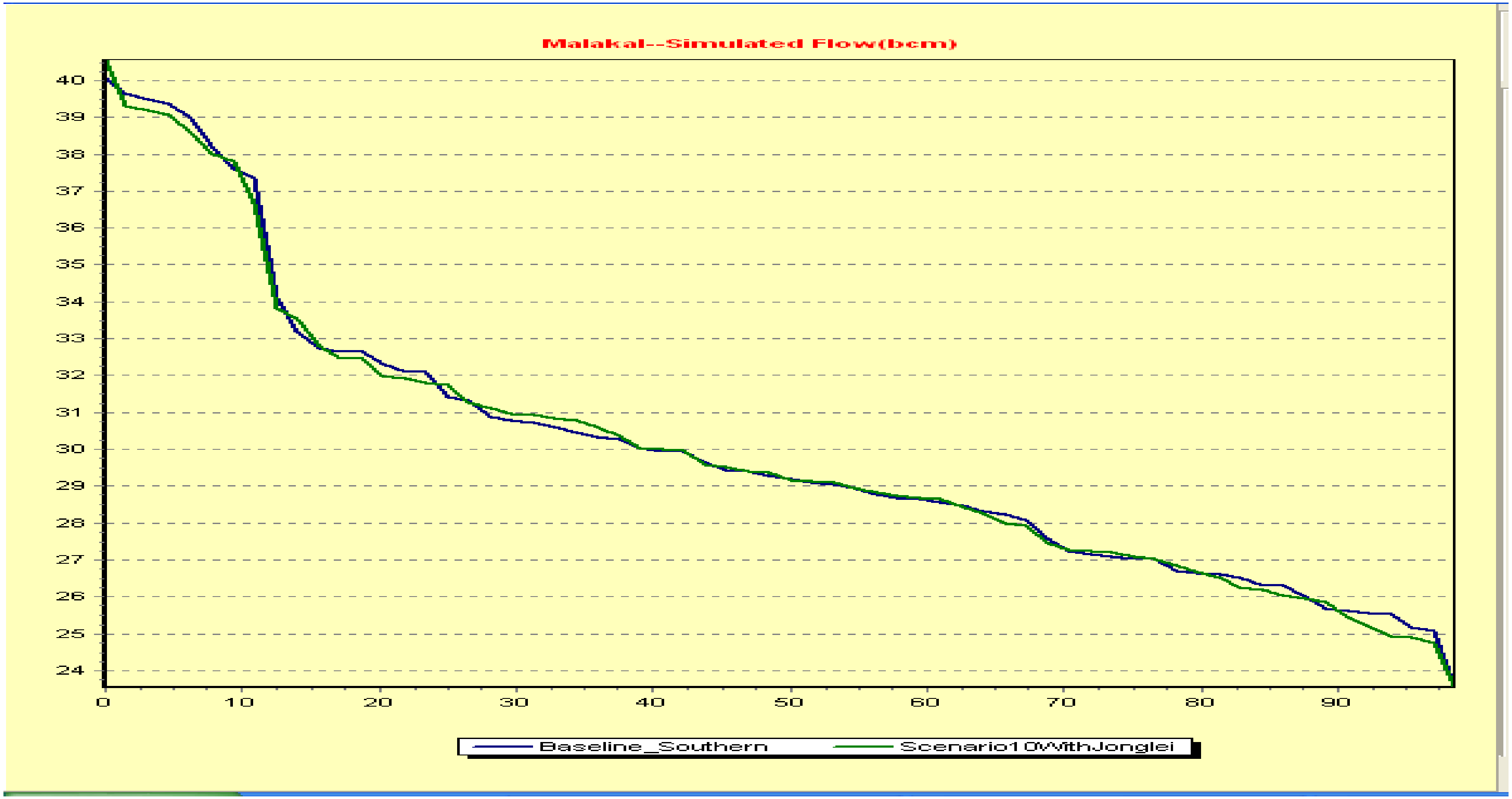
Capacity of Jonglei Canal 3.1 mcm/day at 5.0bcm of L Victoria



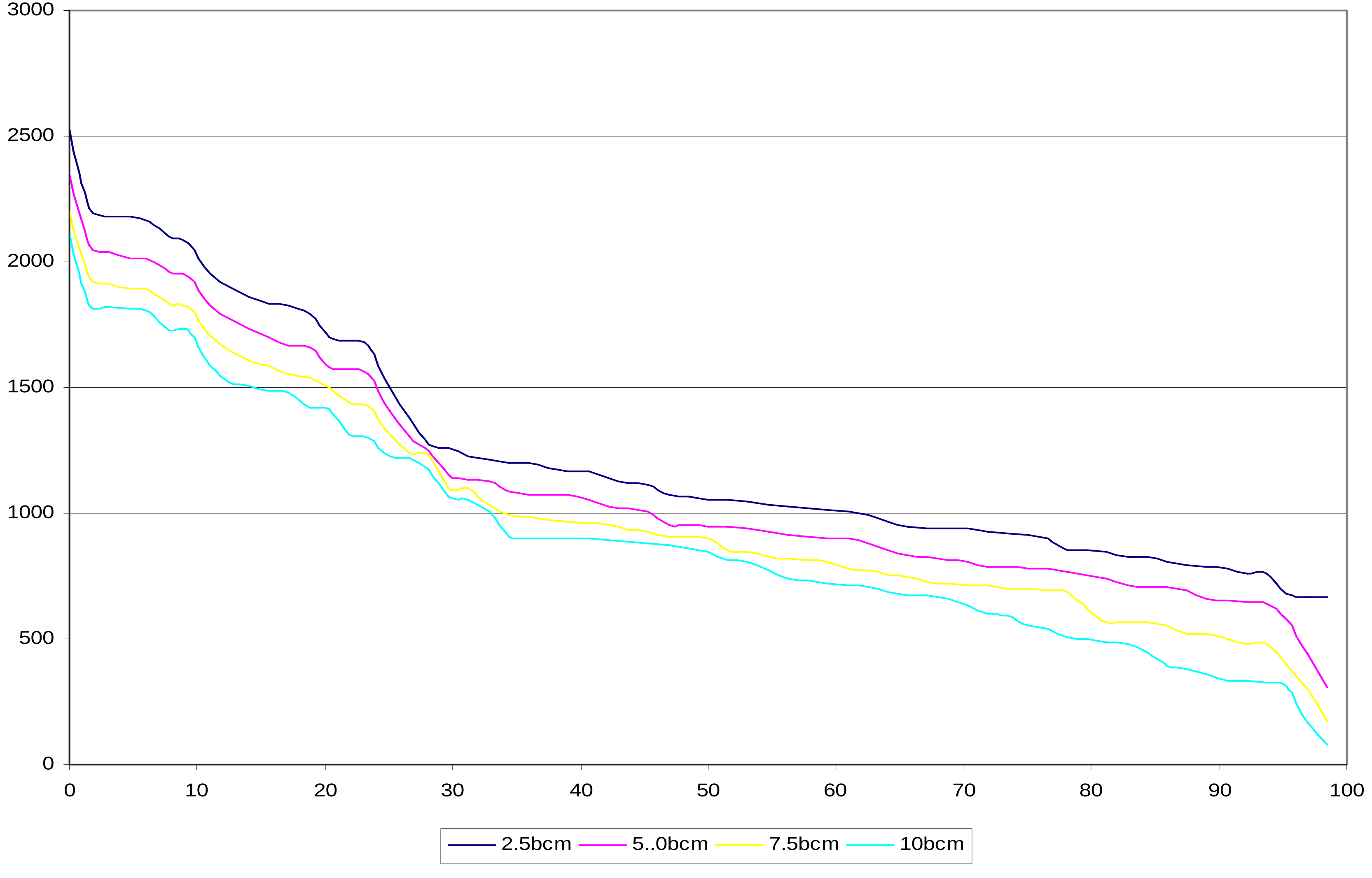
Capacity of Jonglei Canal 4.5 mcm/day at 7.5bcm of L Victoria



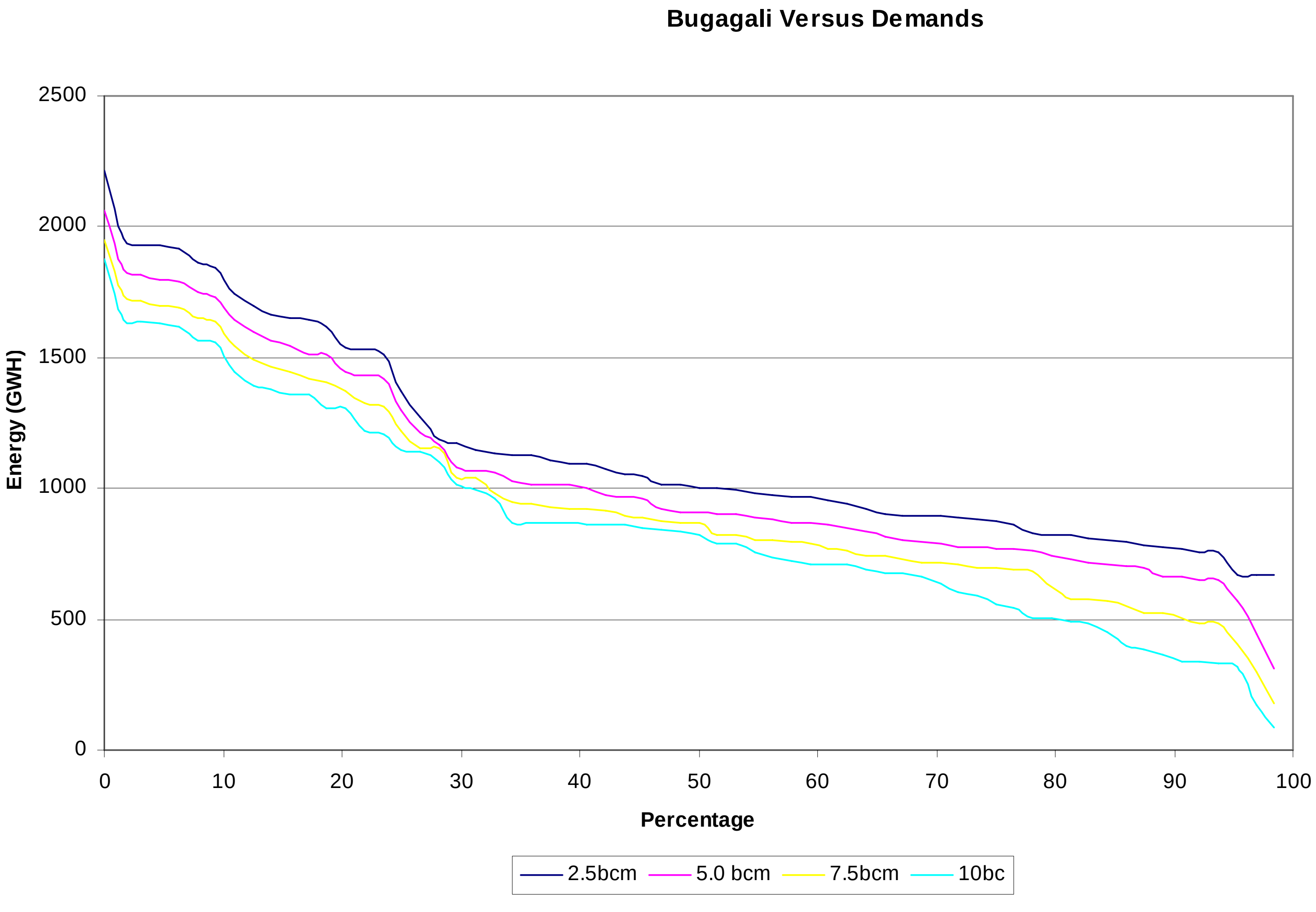
Capacity of Jonglei Canal 5.5 mcm/day at 10bcm of L Victoria



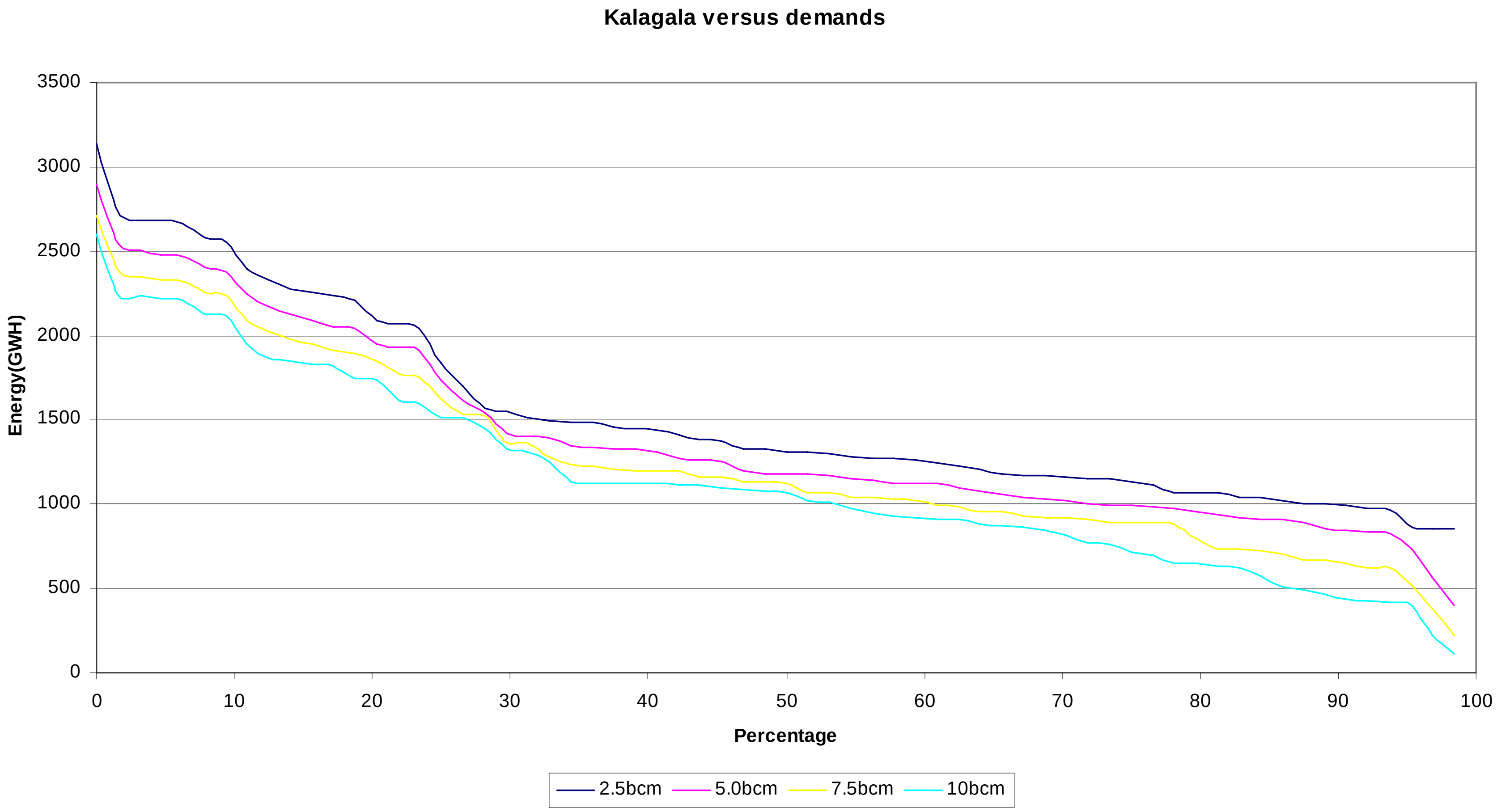
Owen falls energy versus demands



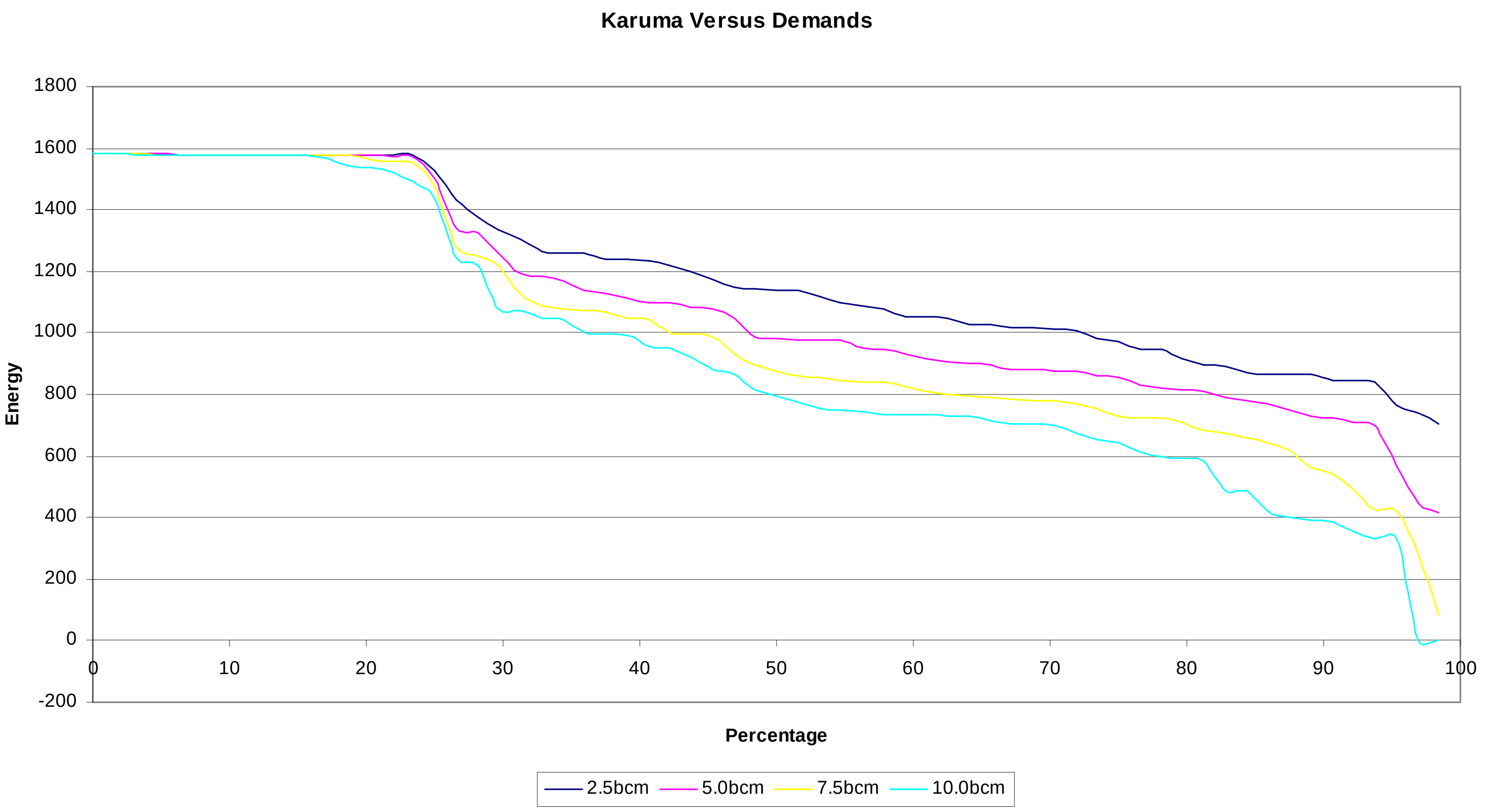
Bujagali energy versus demands



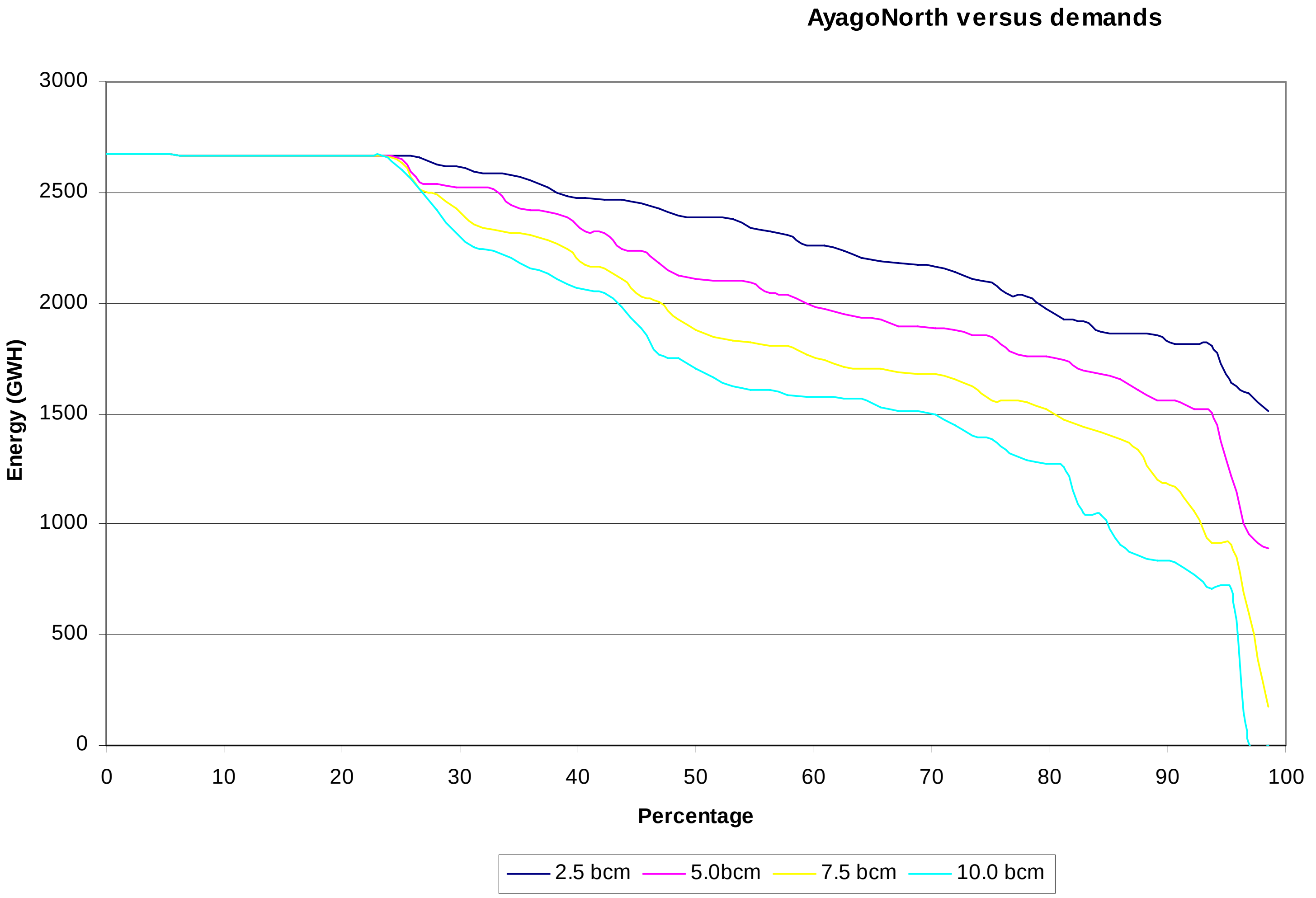
Kalagala energy versus demands



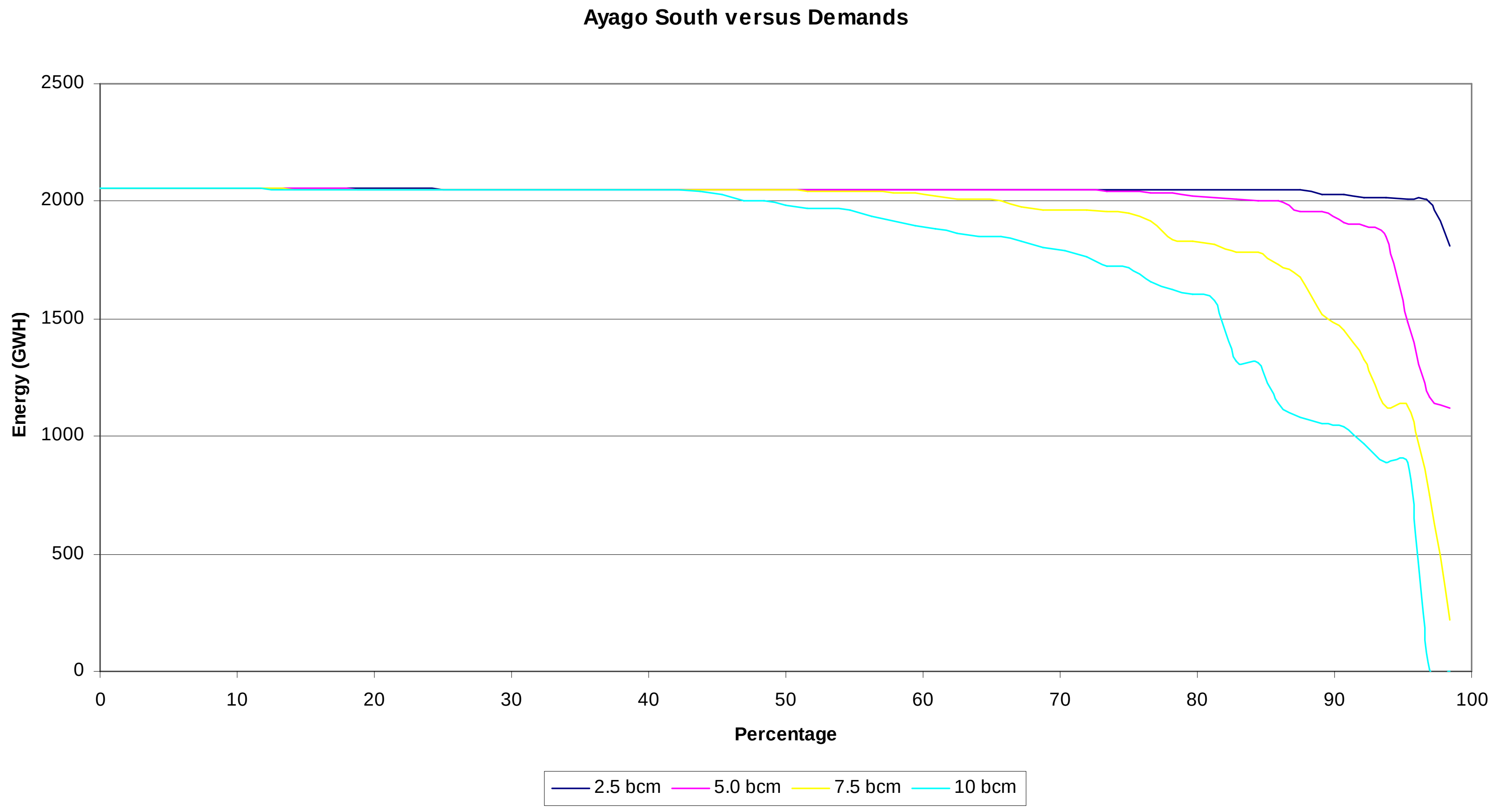
Karuma energy versus demands



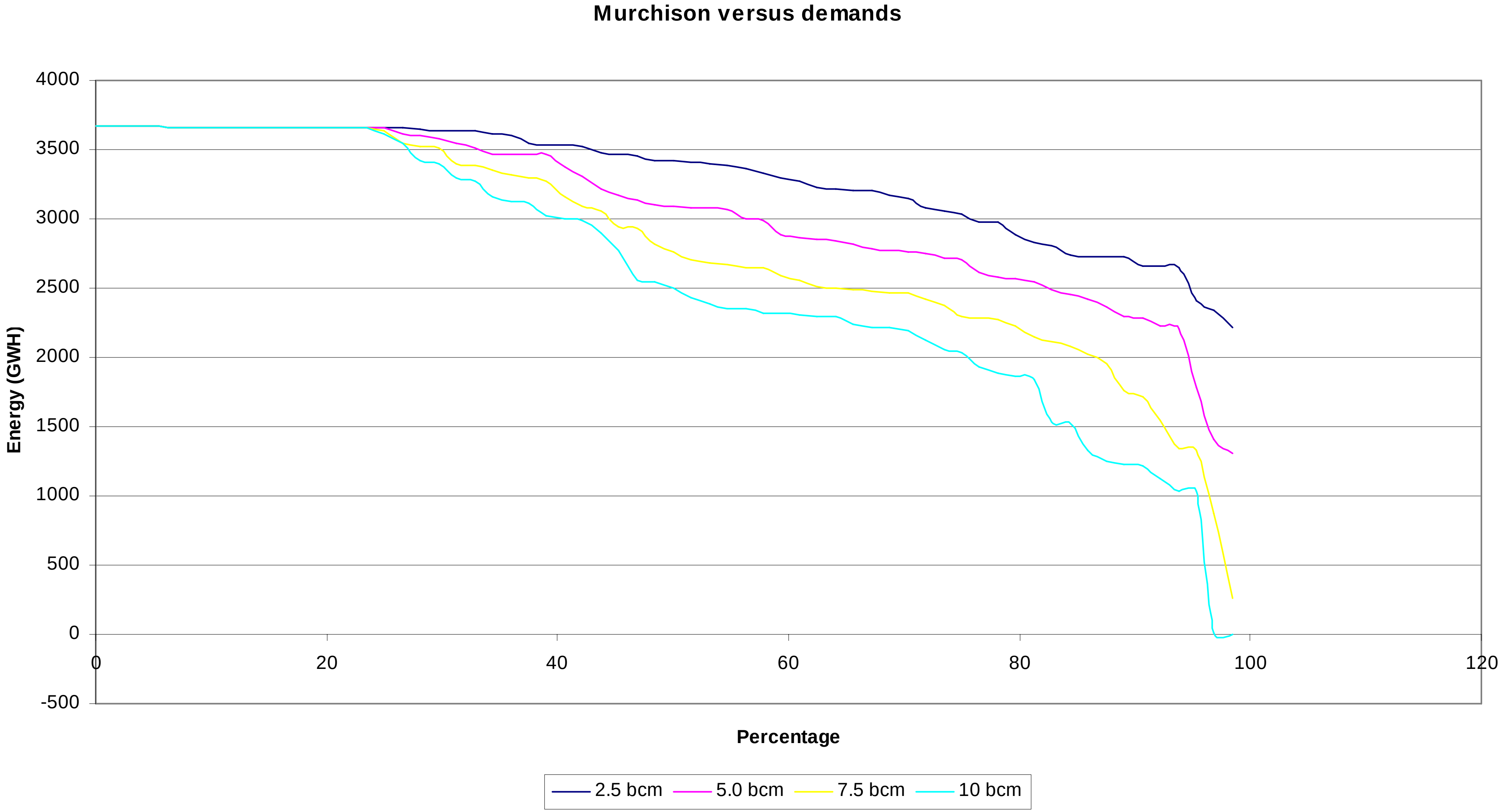
Ayago North energy versus demands



Ayago South energy versus demands



Murchison South energy versus demands



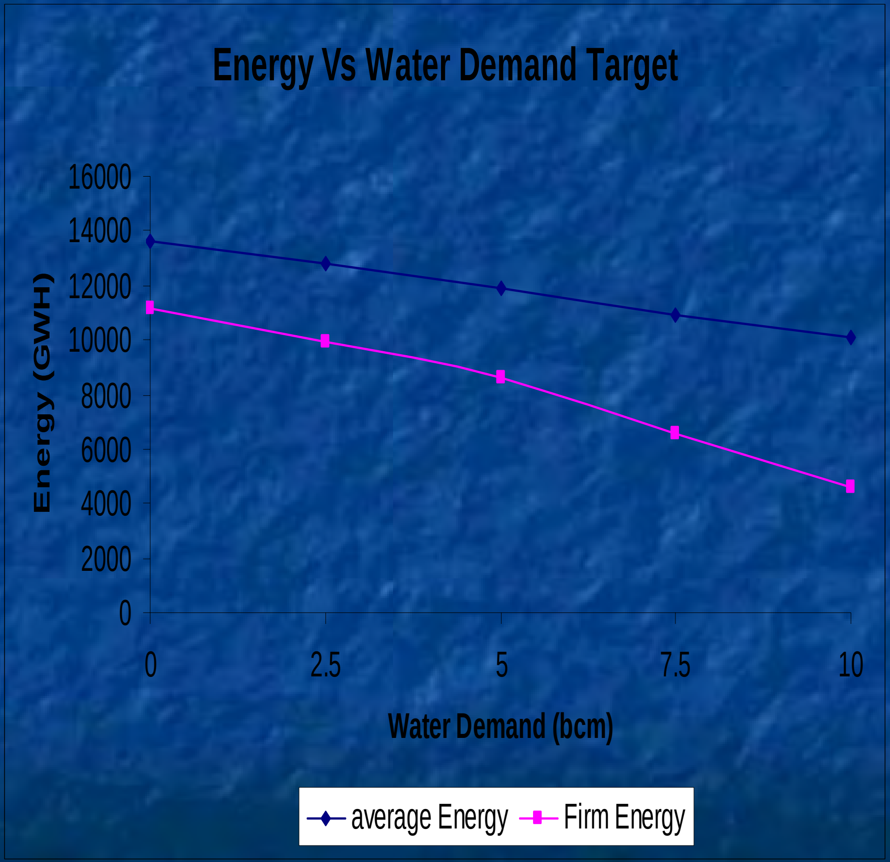
Coordination Schemes

Southern Nile

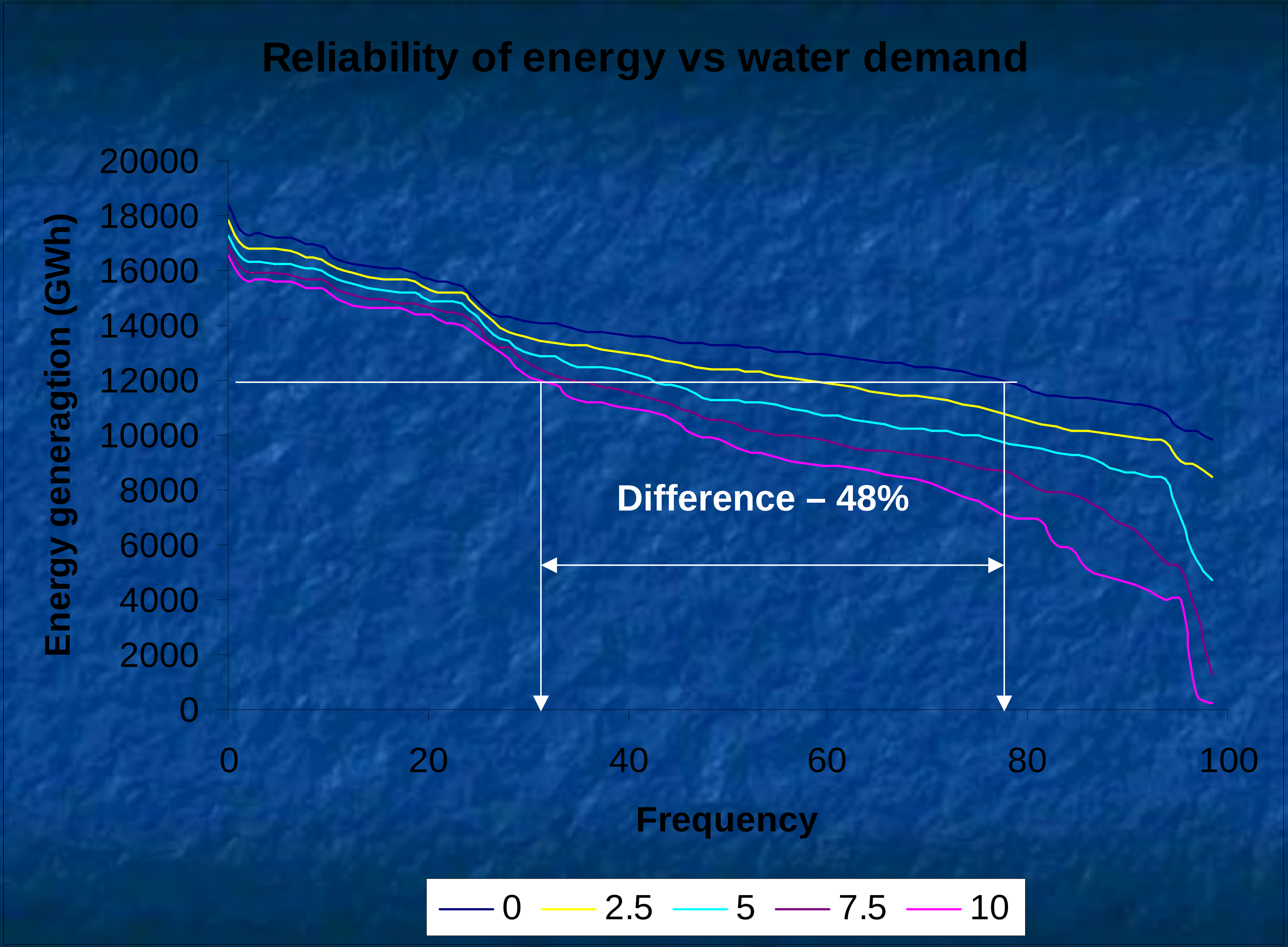
Group Members

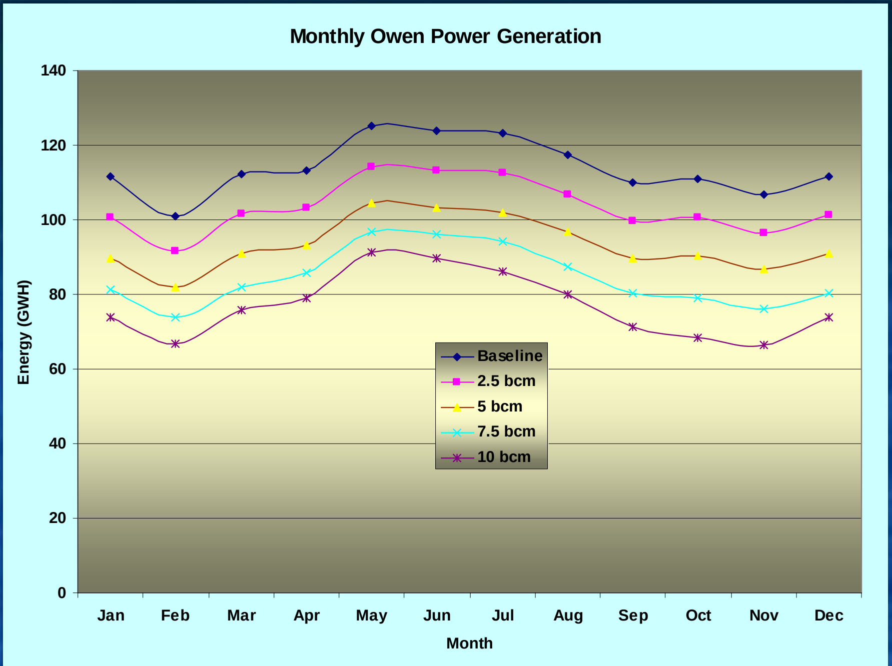
- **Burundi**
- **DR. Congo**
- **Kenya**
- **Rwanda**
- **Tanzania**
- **Uganda**

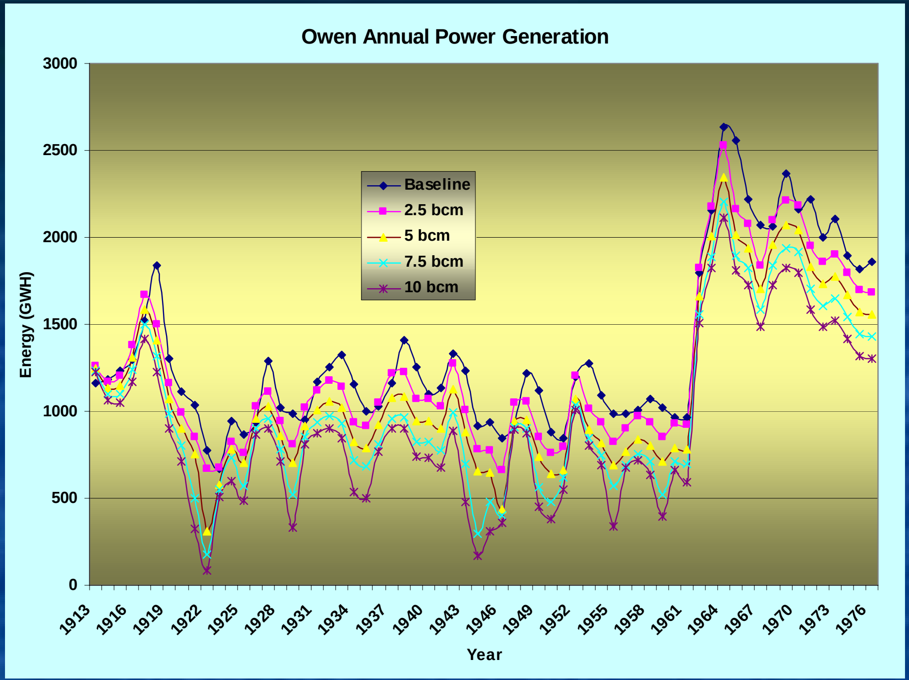
Tradeoff between Hydropower and Irrigation

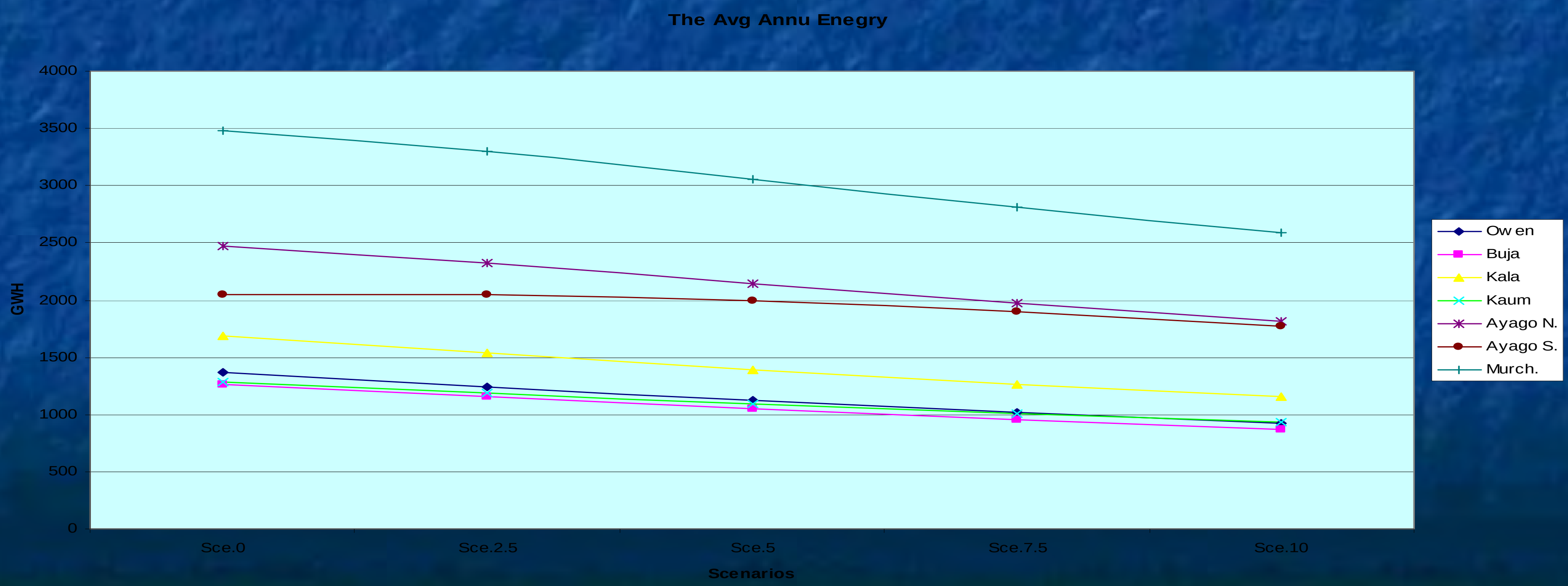


- Acceptable demand is probably 5 bcm
- Firm energy at 90%
- Firm energy sharply falls beyond 5 bcm

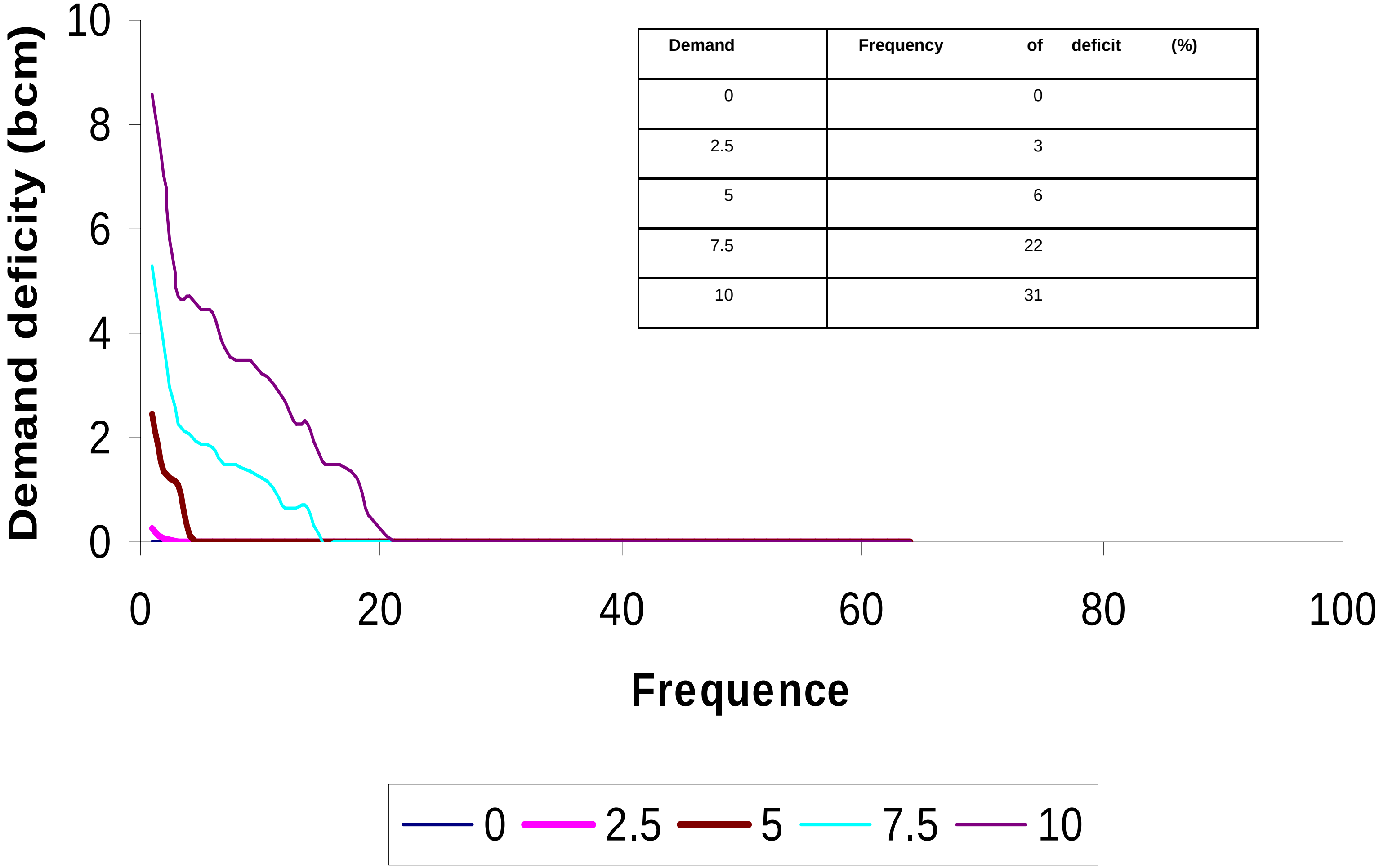

Reliability of energy vs water demand
Energy generagtion (GWh)
20000
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
0
20
40
60
80
100
Frequency
Difference – 48%
0
2.5
5
7.5
10


Monthly Owen Power Generation
Energy (GWH)
Month
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Baseline
2.5 bcm
5 bcm
7.5 bcm
10 bcm


Owen Annual Power Generation
Energy (GWH)
Year
Baseline
2.5 bcm
5 bcm
7.5 bcm
10 bcm

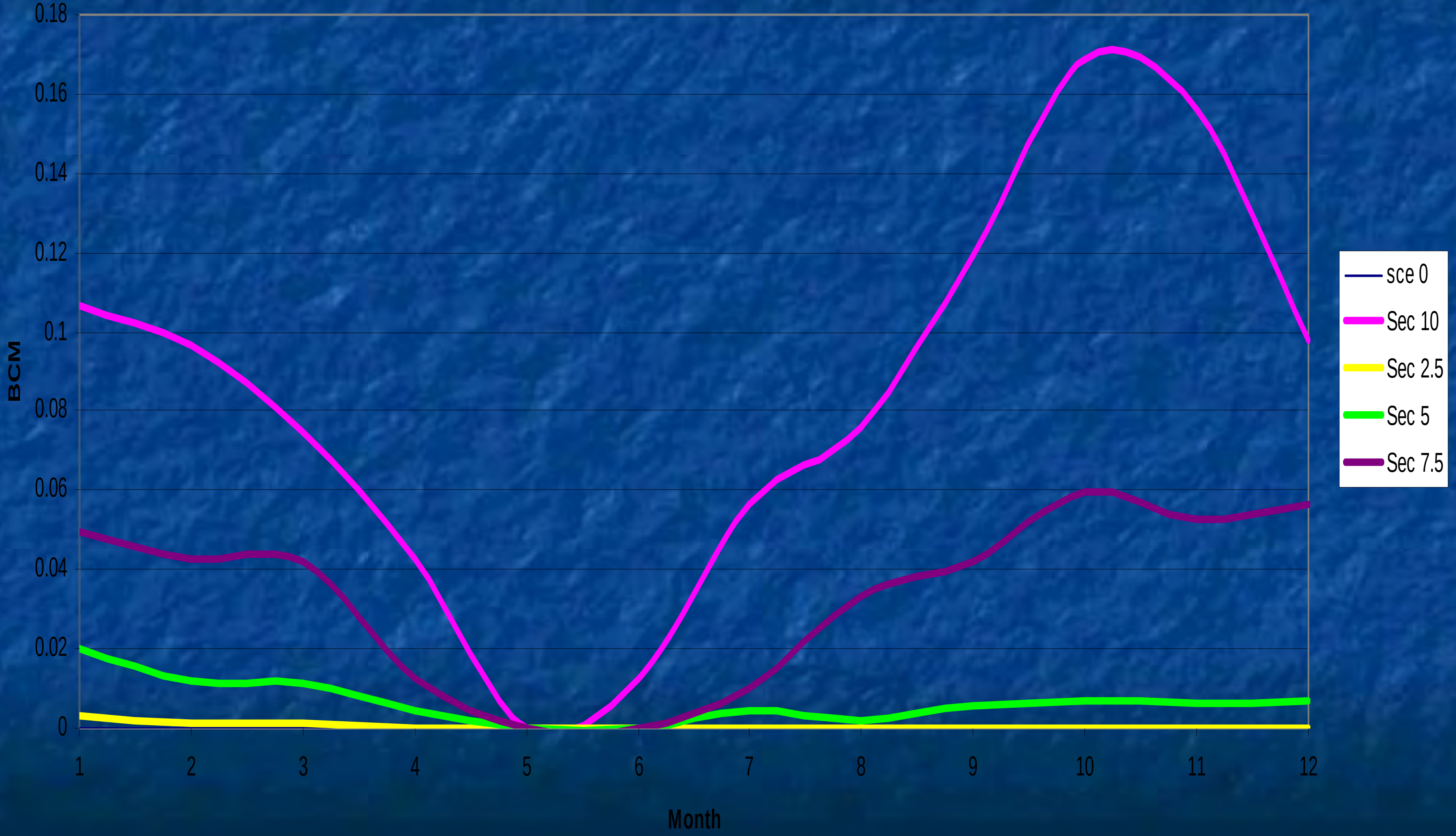

The Avg Annu Enegry
GWH
Scenarios
Sce.0
Sce.2.5
Sce.5
Sce.7.5
Sce.10
Ow en
Buja
Kala
Kaum
Ayago N.
Ayago S.
Murch.

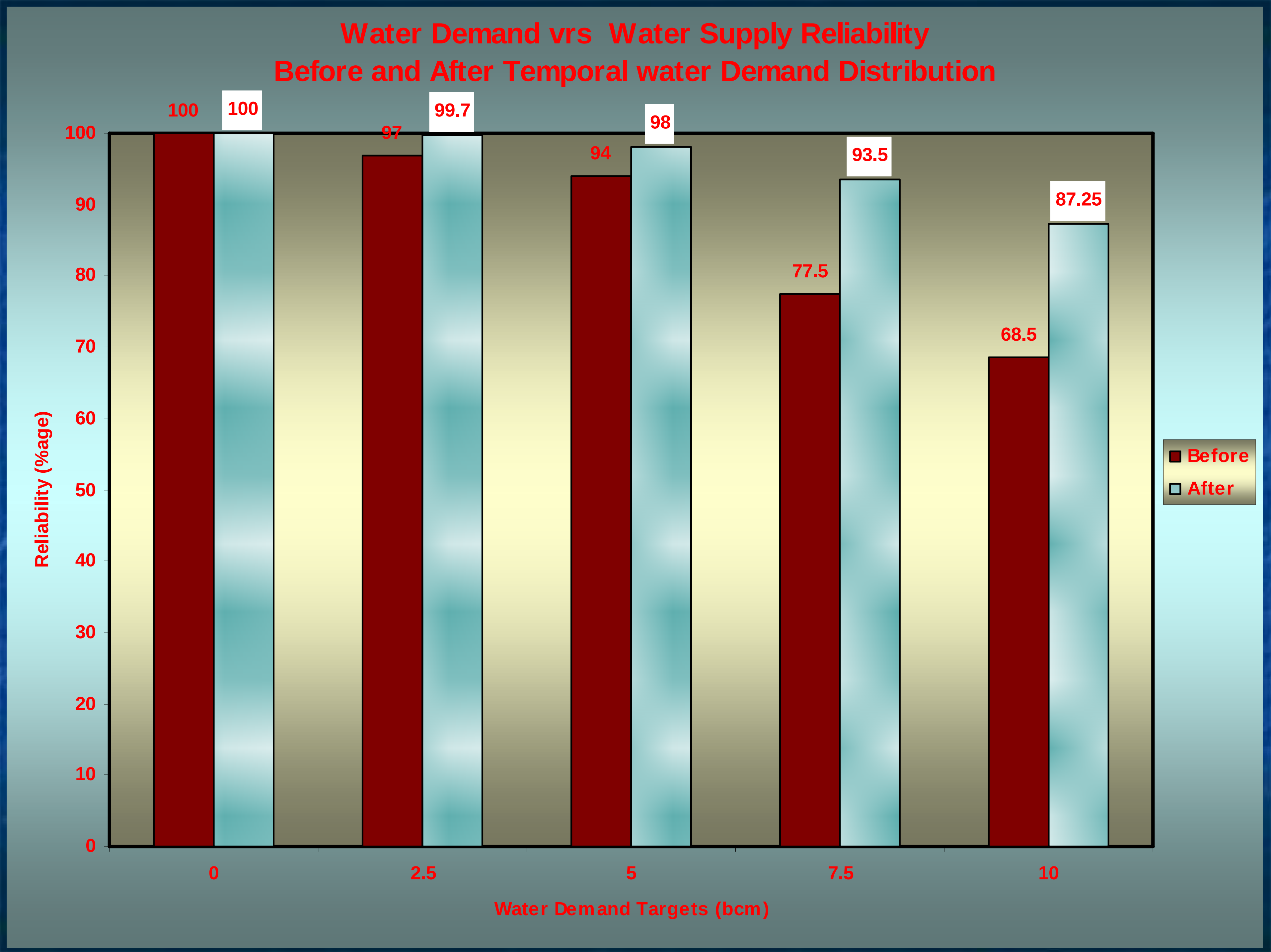
Frequence of Demand Deficit Vs Demand



Demand	Frequency of deficit (%)
0	0
2.5	3
5	6
7.5	22
10	31

Temporal Distribution of Water Demand Target





Water Demand vrs Water Supply Reliability
Before and After Temporal water Demand Distribution
100
100
97
99.7
94
98
77.5
93.5
68.5
87.25
Reliability (%age)
0
10
20
30
40
50
60
70
80
90
100
0
2.5
5
7.5
10
Water Demand Targets (bcm)
Before
After

Comments

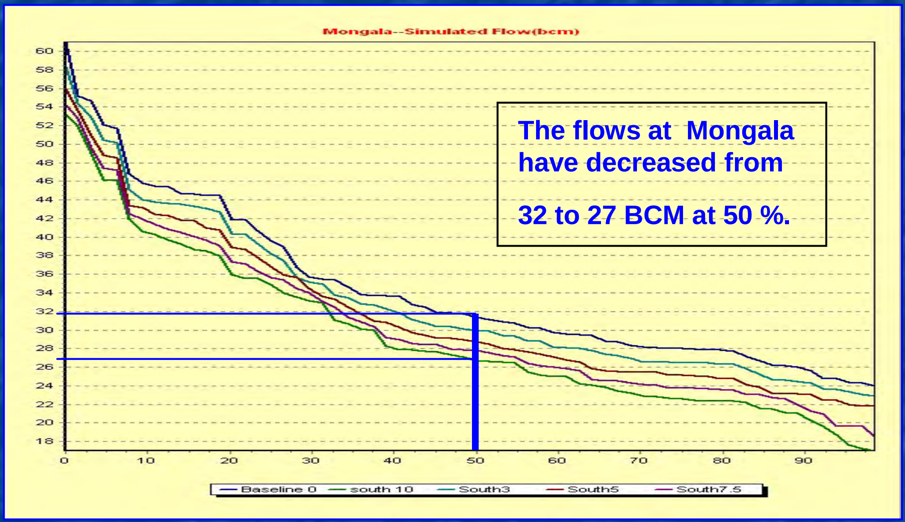
Energy Generation

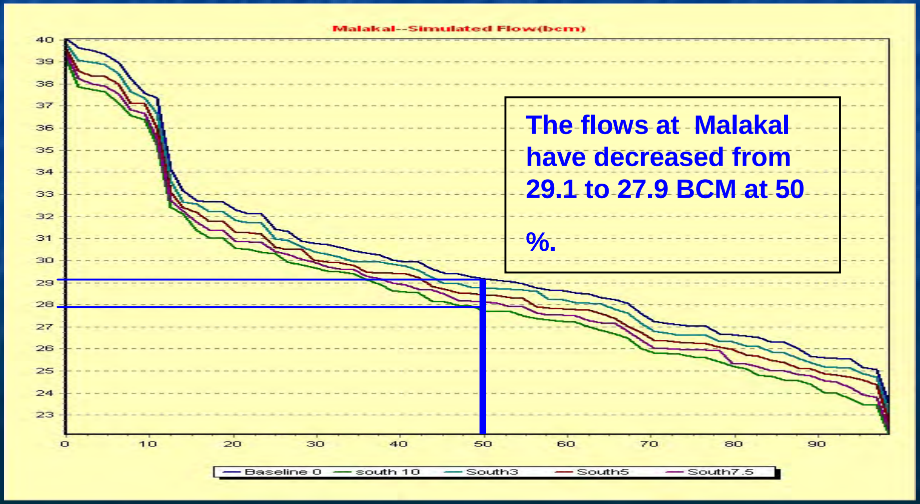
- Energy Generation in all Hydropower Plants decreases with increase in Water Demand.
- Firm energy is substantially affected for water demand >5bcm
- Monthly power generation increases during the two rainy seasons.
- Annual power generation follows the river flow pattern.

Comments cont’d

- **Regarding the Water supply Deficit, it was noted that :**
  - **It increases with the increase in water demand.**
  - **It could be met for all scenarios in May.**
  - **The reliability of water supply decreases with the increasing water demand targets.**
  - **After changing temporal water demand distribution by reducing water demand fraction during the rainy season and increasing the demand fraction for the dry period the reliability was highly enhanced.**

3.2, Frequency distribution of Mongala and Malakal flows

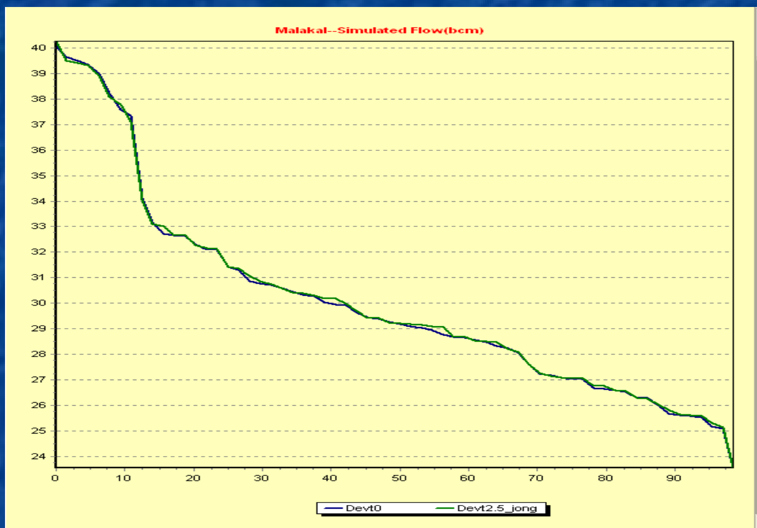


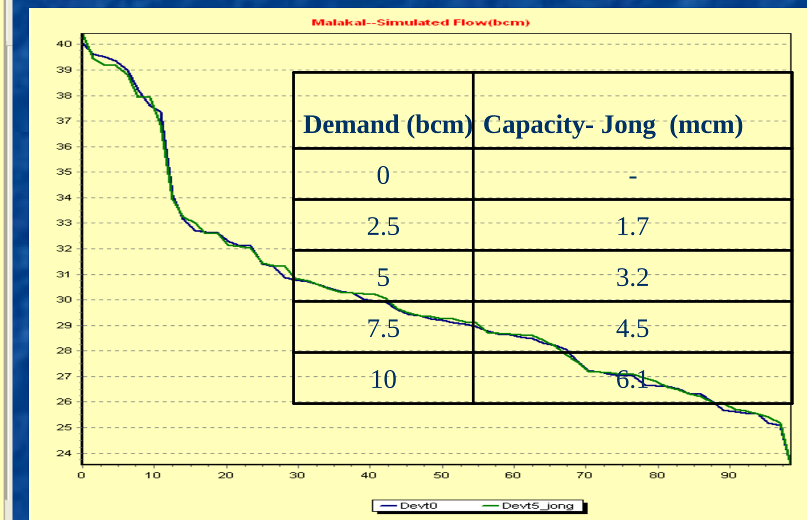


Comments

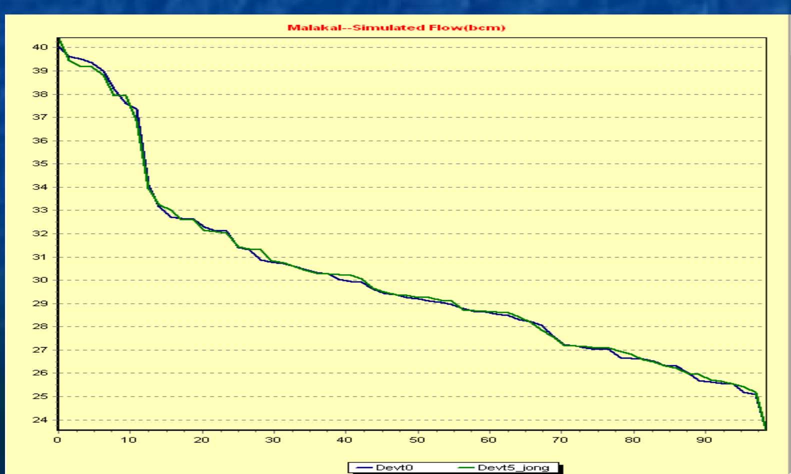
- Downward shift in the Frequency Curve
- Reduced reliability of flow as demand target increases
- Increased H_2O demand has more effect on Mongala than Malakal

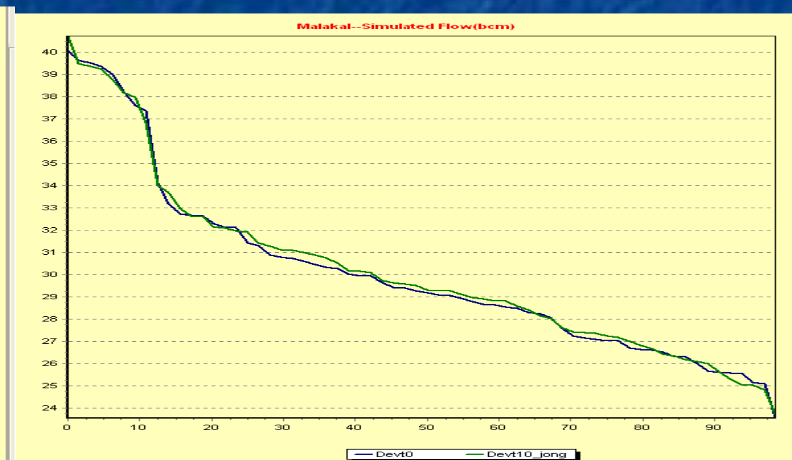
3.3 Capacity of Jonglei Canal to cause Baseline F-Dist at Malakal



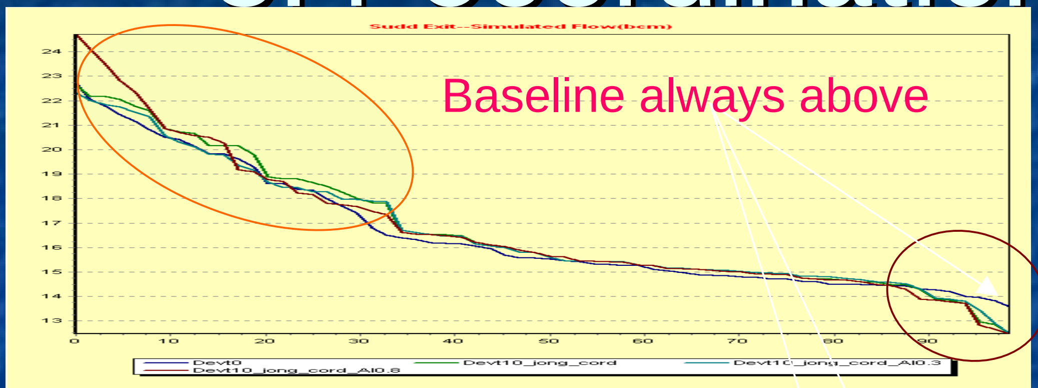


Demand (bcm)	Capacity- Jong (mcm)
0	-
2.5	1.7
5	3.2
7.5	4.5
10	6.1

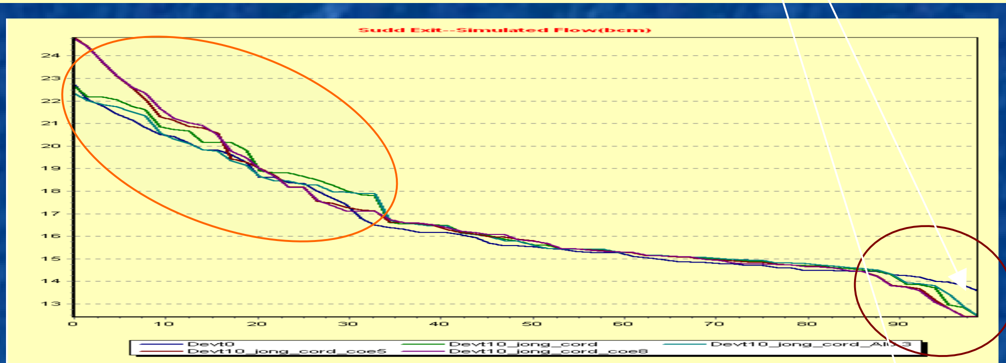




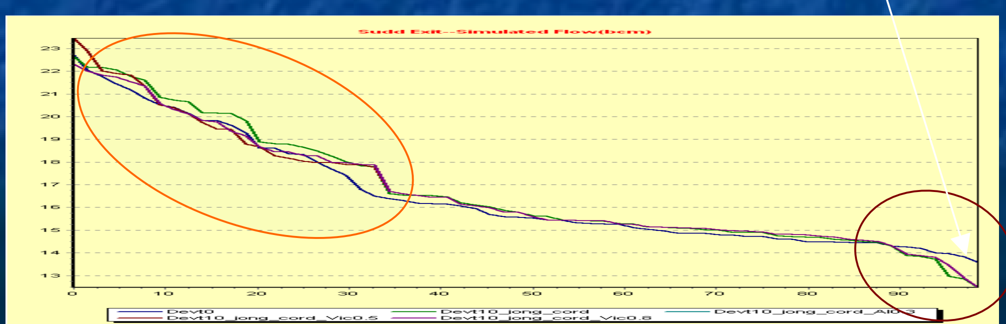
3.4 Coordination scheme



Variation of downstream reservoir (L. Albert) threshold will keeping the coordination coef. and upstream reservoir (Victoria) threshold constant



Variation of upstream reservoir (Victoria) threshold will keeping the coordination coef. and downstream reservoir (L. Albert) threshold constant



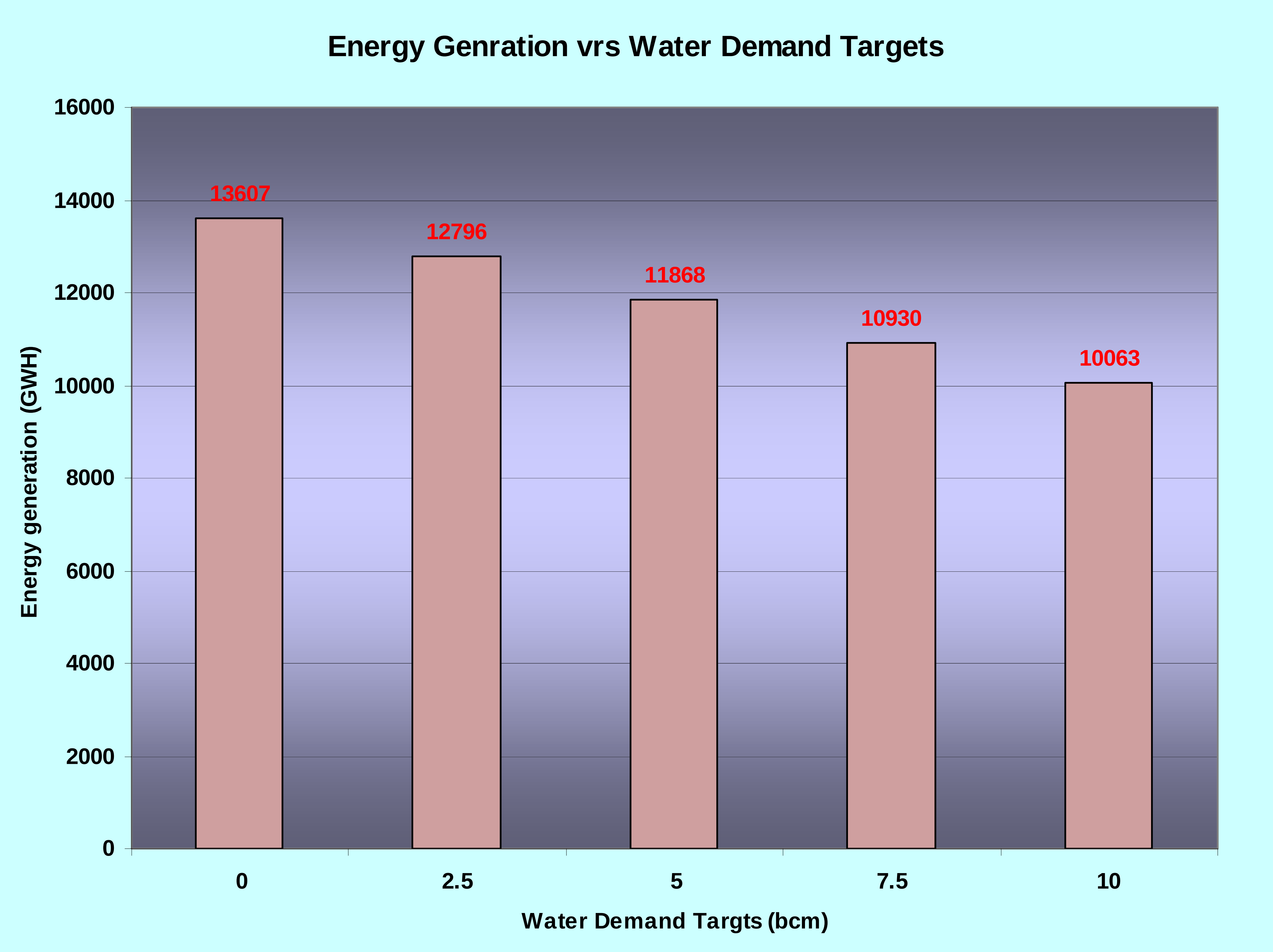
Variation of coordination coef will keeping the upstream reservoir (Victoria) threshold and downstream reservoir (L. Albert) threshold constant

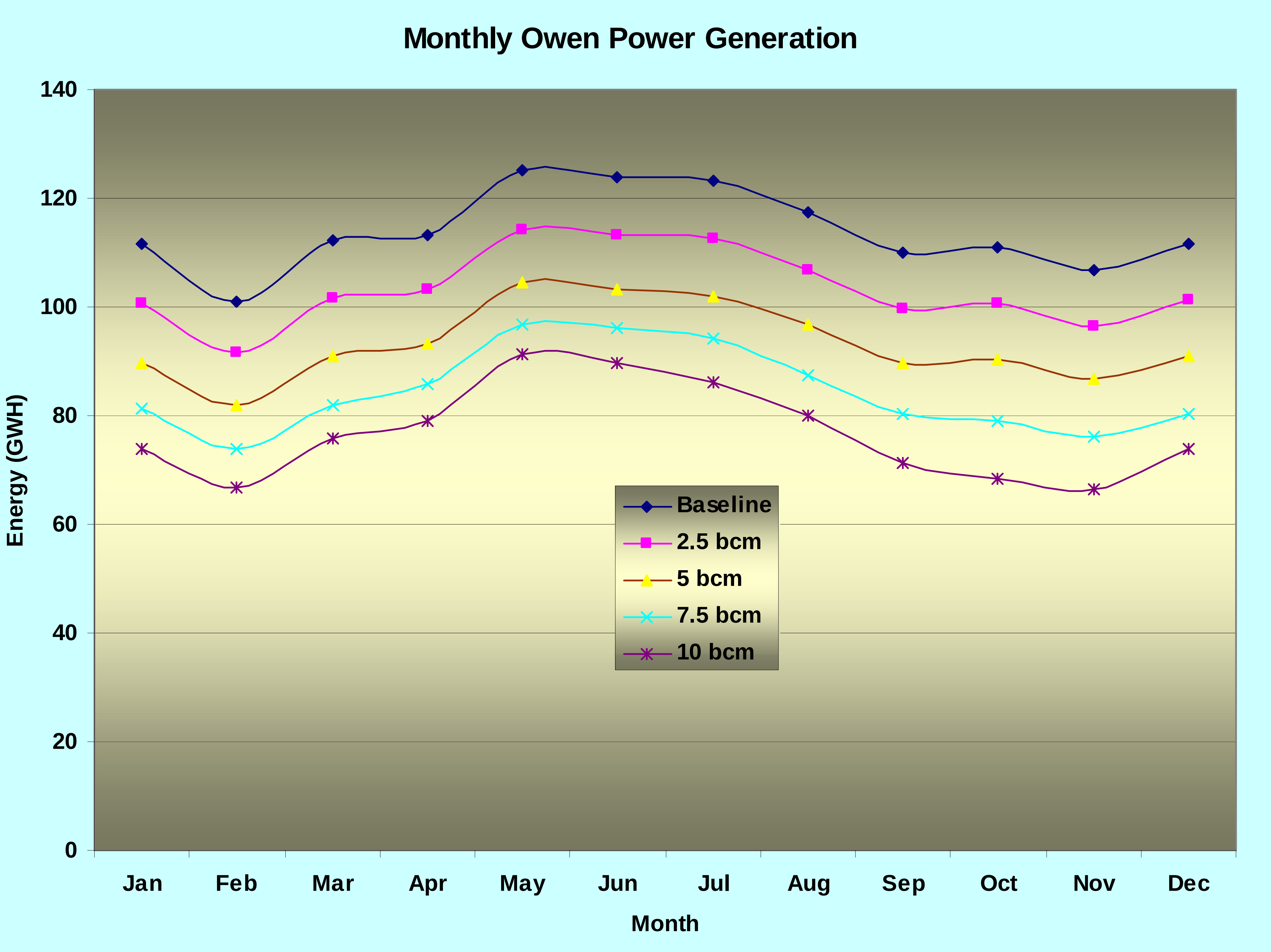
General Comments

- Firm energy is substantially affected for water demand >5bcm
- There is 50% energy variability (Max) for Water demand 0-10
- The frequency of water supply deficits increases exponentially for water demand
- The benefits accruing from constructing the Jonglei canal are insignificant for demand targets <=10 bcm
- Coordination rules did not result in significant improvement of the frequency curves of the Sudd exit in comparison to the baseline flows – esp. the baseflows

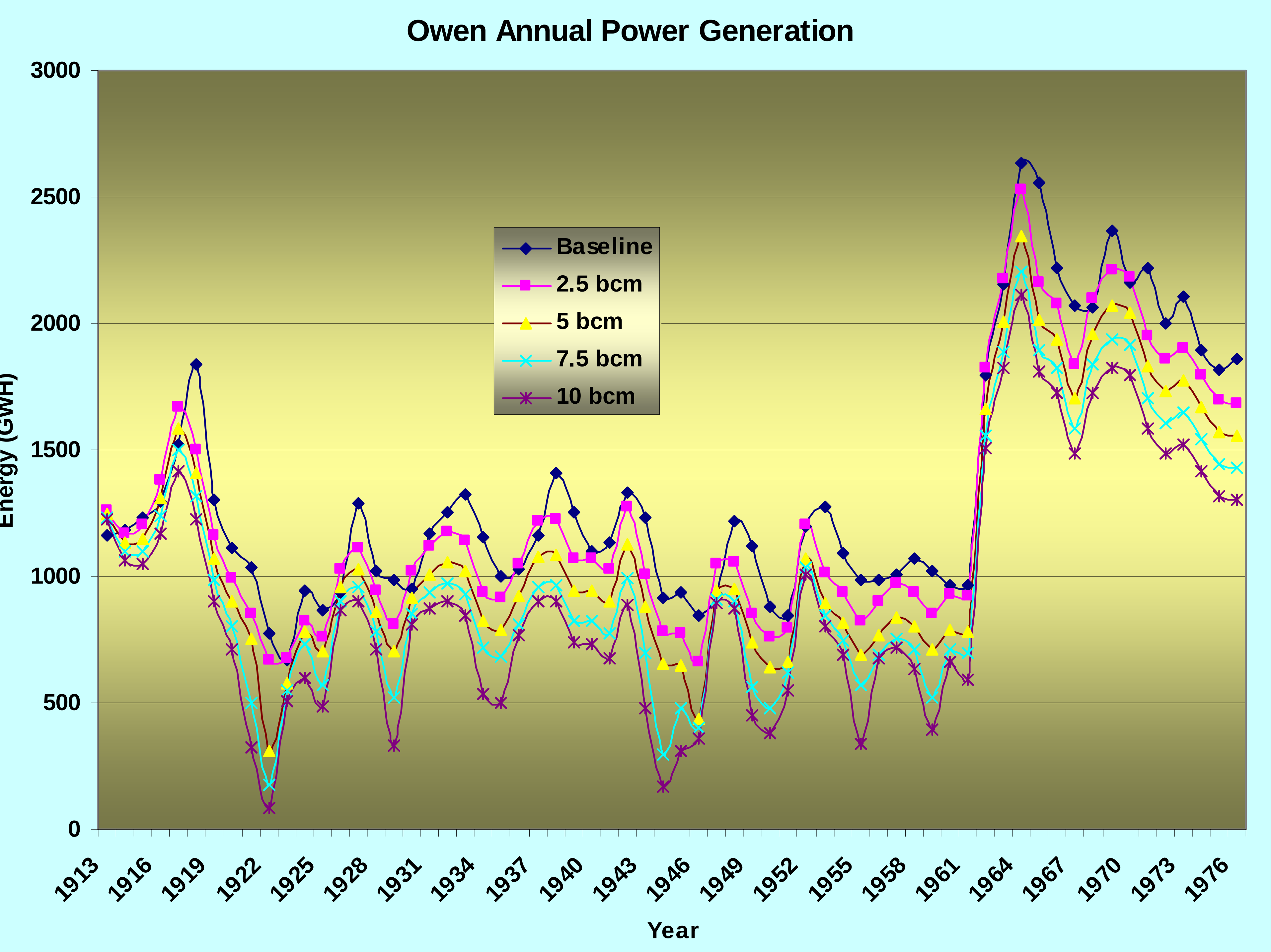
End

Group 4 Presentation

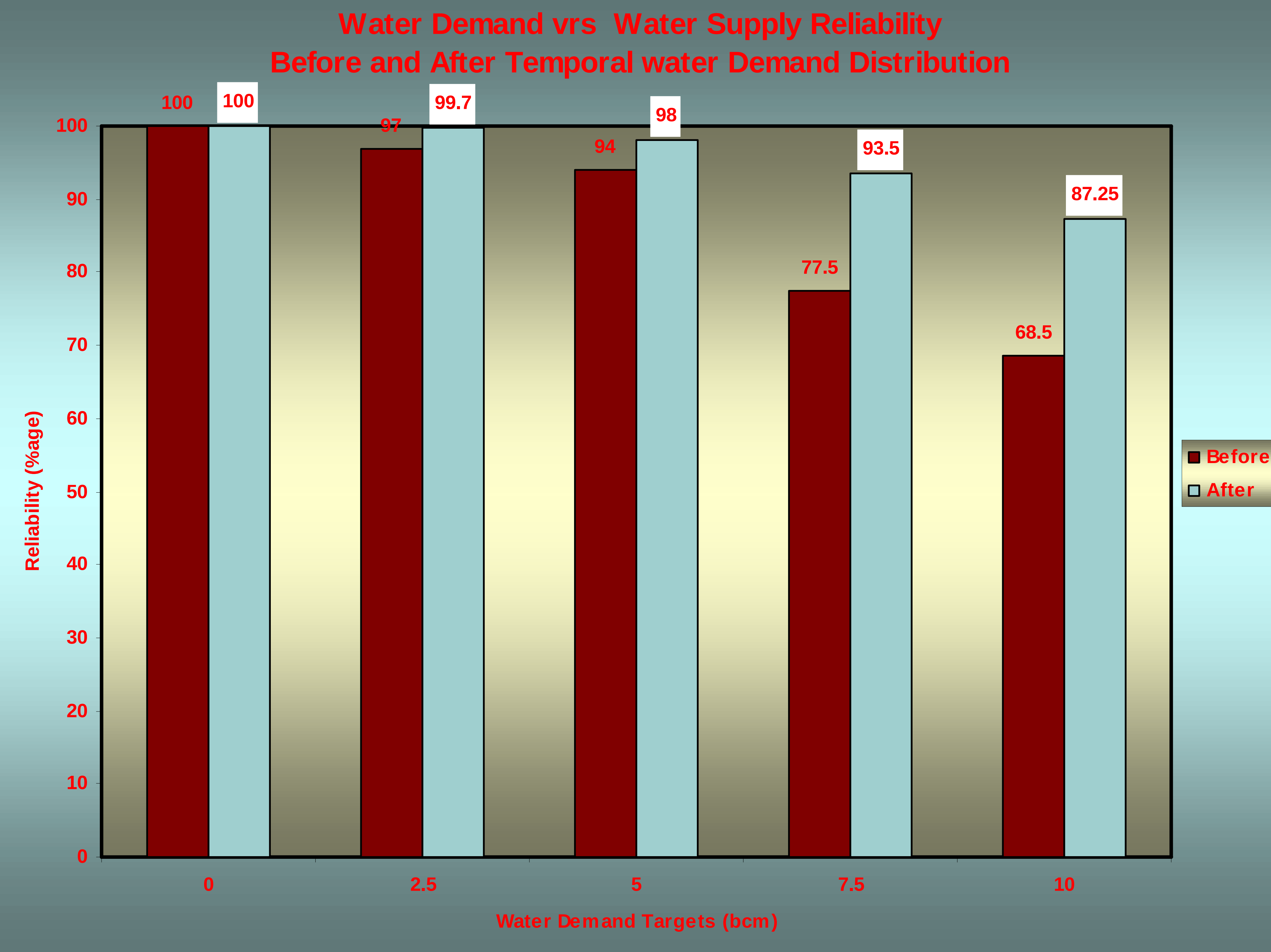

Energy Genration vrs Water Demand Targets
Energy generation (GWH)
16000
14000
12000
10000
8000
6000
4000
2000
0
13607
12796
11868
10930
10063
0
2.5
5
7.5
10
Water Demand Targts (bcm)

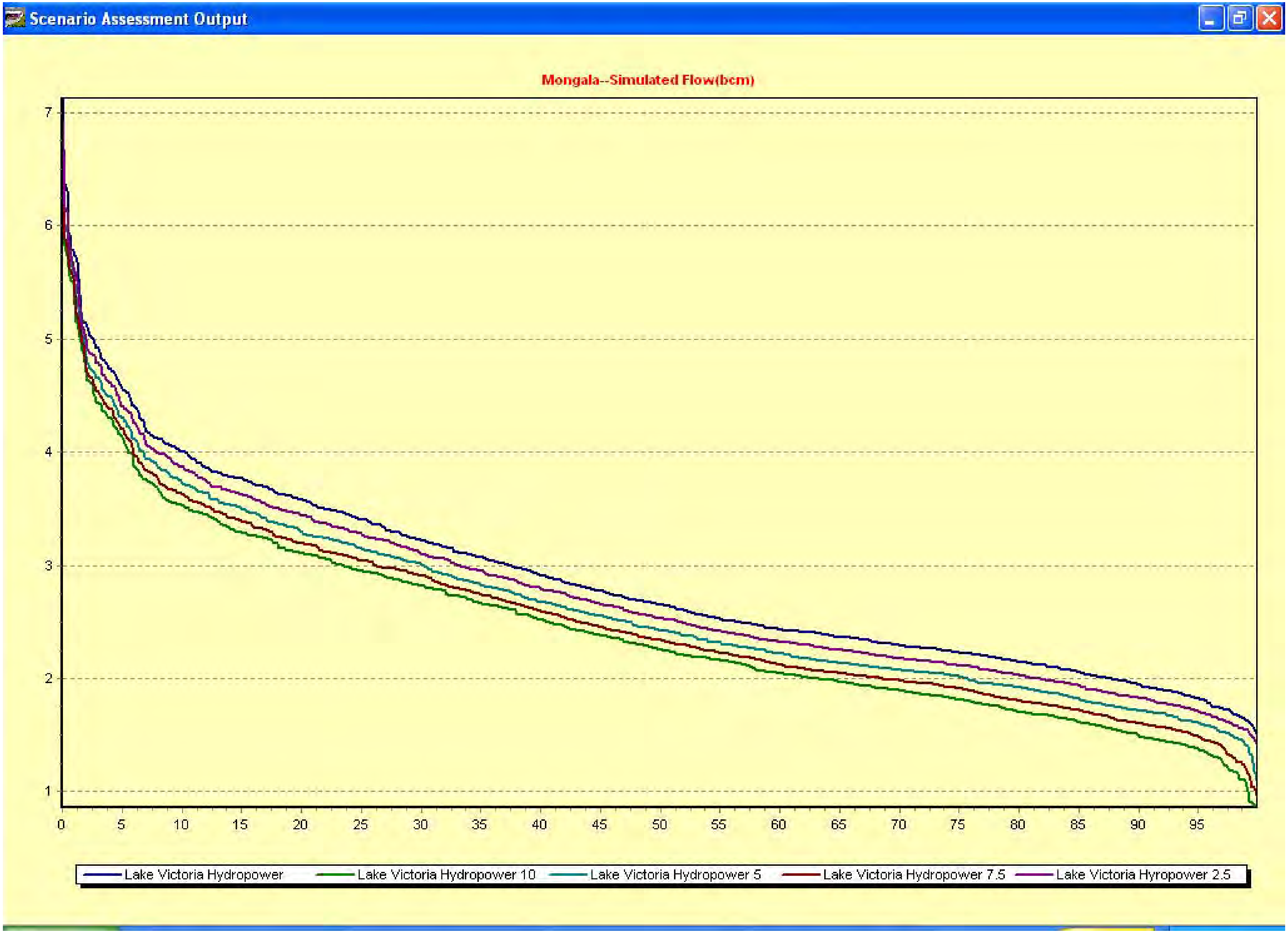


Monthly Owen Power Generation
Energy (GWH)
0
20
40
60
80
100
120
140
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Month
Baseline
2.5 bcm
5 bcm
7.5 bcm
10 bcm



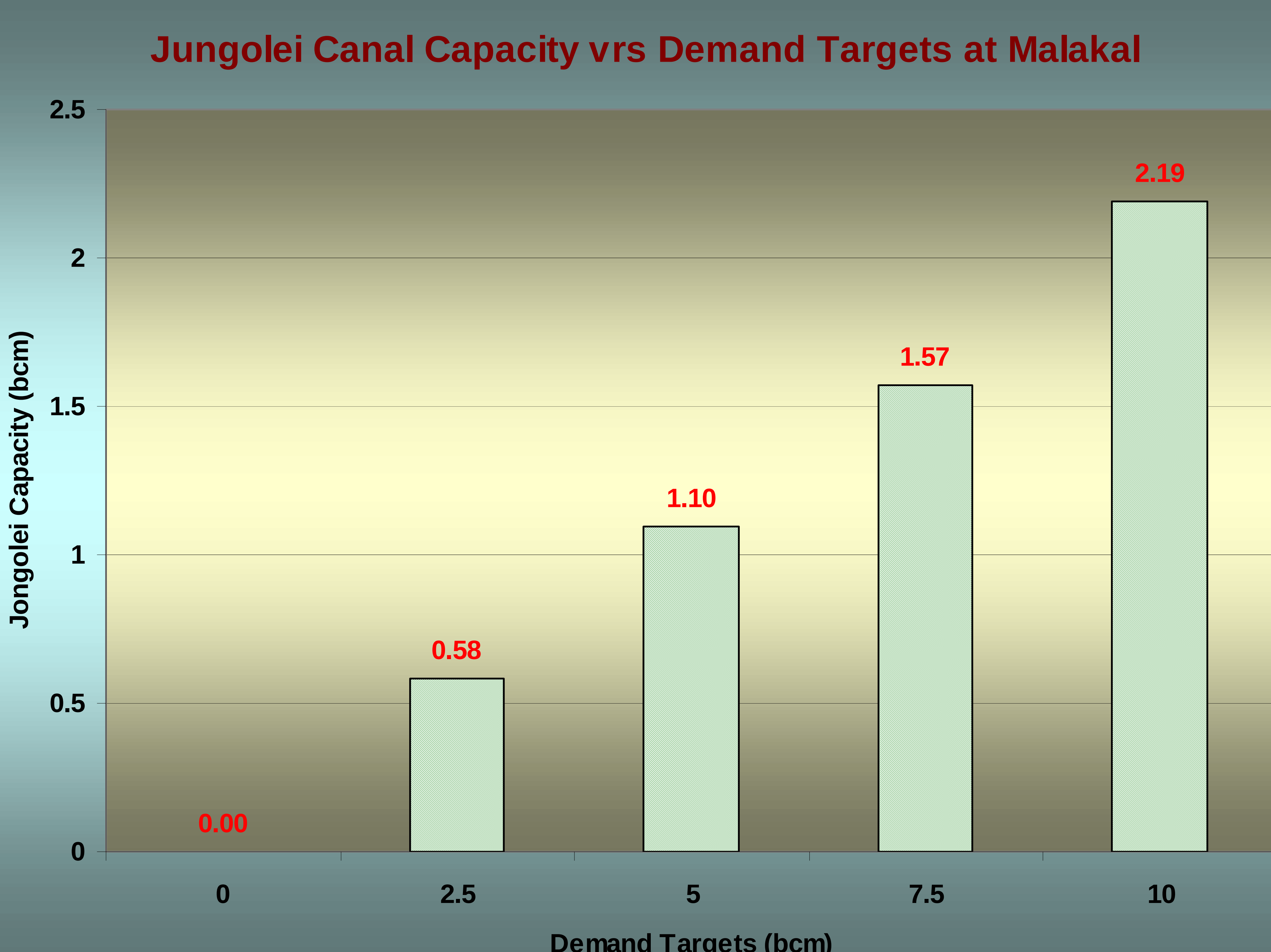
Owen Annual Power Generation
Energy (GWH)
3000
2500
2000
1500
1000
500
0
Baseline
2.5 bcm
5 bcm
7.5 bcm
10 bcm
1913
1916
1919
1922
1925
1928
1931
1934
1937
1940
1943
1946
1949
1952
1955
1958
1961
1964
1967
1970
1973
1976
Year


Water Demand vrs Water Supply Reliability
Before and After Temporal water Demand Distribution
Reliability (%age)
0
10
20
30
40
50
60
70
80
90
100
100
100
97
99.7
94
98
77.5
93.5
68.5
87.25
0
2.5
5
7.5
10
Water Demand Targets (bcm)
Before
After



Scenario Assessment Output
Mongala--Simulated Flow(bcm)
7
6
5
4
3
2
1
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
Lake Victoria Hydropower
Lake Victoria Hydropower 10
Lake Victoria Hydropower 5
Lake Victoria Hydropower 7.5
Lake Victoria Hyropower 2.5

Scenario Assessment Output
Malakal--Simulated Flow(bcm)
7
6
5
4
3
2
1
0
0
5
10
15
20
25
30
35
40
45
50
55
60
65
70
75
80
85
90
95
Lake Victoria Hydropower
Lake Victoria Hydropower 10
Lake Victoria Hydropower 5
Lake Victoria Hydropower 7.5
Lake Victoria Hyropower 2.5


Jungolei Canal Capacity vrs Demand Targets at Malakal
Jongolei Capacity (bcm)
2.5
2
1.5
1
0.5
0
0.00
0.58
1.10
1.57
2.19
0
2.5
5
7.5
10
Demand Targets (bcm)

Comments on Results:

- Energy generation decreases with increasing water demands targets.
- Monthly power generation increases during the two rainy seasons.
- Annual power generation follows the river flow pattern.

- **The reliability of water supply decreases with the increasing water demand targets.**

- **After changing temporal water demand distribution by reducing water demand fraction during the rainy season and increasing the demand fraction for the dry period the reliability was highly enhanced.**

- **Increased water demand targets reduces river flow with more effects on Mongola station than on Malakal.**

- **The Jungolei canal capacities required to balance the effect of water demands at Malakal are very low compared to the design canal capacity.**