10th International Riversymposium & Environmental Flows Conference
Brisbane September 2007

Environmental Flow Hydrology using Flow – Stressor Response Methodology

Ken Haumann

PDNA – South Africa

PDNA
PD NAIDOO & ASSOCIATES

Environmental Flow Hydrology

A brief overview of current methodology being used in South Africa for the determination of Ecological Water Requirements

Environmental Flow Hydrology

PDNA
PD NAIDOO & ASSOCIATES

Acknowledgements

– SA Dept of Water Affairs & Forestry

– IWR Source to Sea
  - Prof. Denis Hughes – Univ. of Grahamstown

– PD Naidoo & Associates

PDNA
PD NAIDOO & ASSOCIATES

Environmental Flow Hydrology

Some Definitions

- EFR : Environmental Flow Requirements
- IFR : Instream Flow Requirements
- EWR : Ecological Water Requirements
- EC : Ecological Category
- PES : Present Ecological State
- WRYM : Water Resources Yield Model
- SPATSIM : Spatial Time Series Simulation Model

PDNA
PD NAIDOO & ASSOCIATES

Environmental Flow Hydrology

Environmental Water Requirements

Hydrology :

- **Drought flows** – minimum flow requirements
- **Maintenance flows** – requirements for maintaining habitat and biological cycles
- **High flows** – system resetting flows required for river geomorphology, riparian vegetation and river flushing

PDNA
PD NAIDOO & ASSOCIATES

Environmental Flow Hydrology

FLOW – STRESSOR RESPONSE METHODOLOGY

Provides a basis for determining drought and maintenance flow requirements by relating the stress response of particular biological drivers (fish and invertebrates) to a range of flow velocities and depths.

This methodology is restricted to the determination of low flow requirements. High flows are determined using the Building Block Methodology and are driven by a combination of biological trigger events as well as geomorphological and riparian vegetation requirements

PDNA
PD NAIDOO & ASSOCIATES

Environmental Flow Hydrology

While the following methodology is a simplified overview of the process, there is a comprehensive and continuous interaction between the hydrologist and the ecological specialists throughout the process.

Environmental Flow Hydrology

PROCEDURE

- Establish the present ecological state (PES) based on the specialist assessments in terms of an ecological category (EC) (range : A to F – from pristine {A}, to totally impacted {F})

- Establish the amount of stress that invertebrates and fish experience for a range of flow conditions. (stresses range of 0 to 10 for a range flows)

- Determine a likely range of ECs for each site. (eg. If PES=Class C/D, may consider scenarios to achieve Classes C and D)

PDNA
PD NAIDOO & ASSOCIATES

Environmental Flow Hydrology

At each EWR site field assessments are carried out at relevant season intervals for;

- flow measurements (needed for calibration of flow modelling)
- riparian vegetation assessments (provided indicators for bank and floodplain vegetation requirements)
- geomorphological assessments (to determine habitat formation and maintenance flow requirements)
- invertebrate assessments (to determine drought and maintenance flow requirements)
- fish assessments (to determine drought and maintenance flow requirements)
- Water quality assessments

PDNA
PD NAIDOO & ASSOCIATES

Environmental Flow Hydrology

For each EWR site, flows are determined from hydrological records and operational limitations;

- the Virgin Flows (i.e. natural flows with no demands or artificial alteration in the catchment)
- the Present Day Flows (modelled using a simulation model {WRYM or other}, by applying present day water demands and operating rules onto the virgin flows in order to simulate present day conditions)

Environmental Flow Hydrology

PDNA
PD NAIDOO & ASSOCIATES

SPATSIM (Spatial Simulation Time Series Model)

- Desktop Reserve Model. Using regional parameters, generates monthly time series of flows to match the EC requirements.
- Flow-Stress Response Model. Generates distribution curves of ecological stresses to the selected flow time series.

PDNA
PD NAIDOO & ASSOCIATES

Environmental Flow Hydrology

Stress – Flow Index

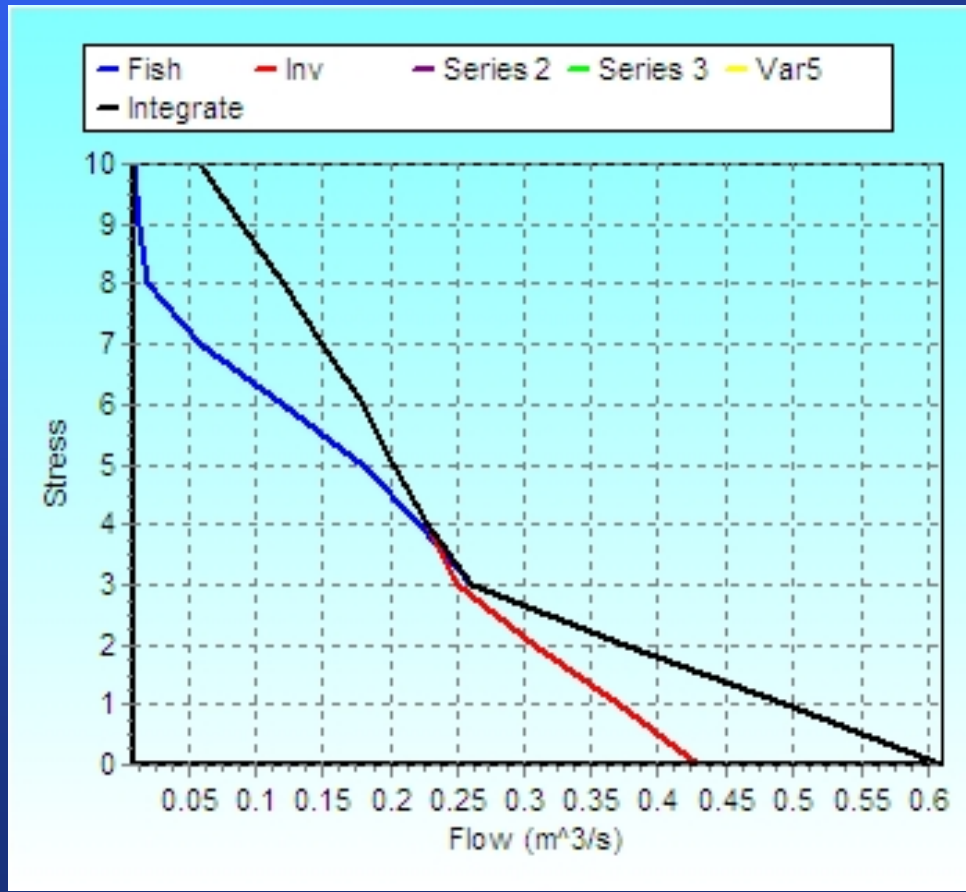
From the specialist fish and invertebrate assessments an index is developed relating the degree of stress experienced by the relevant indicator species of fish and invertebrates for a range of flows.

Stress various from 0 (no stress) to 10 (maximum stress)

Data is entered into the Flow – stress response module in SPATSIM

Environmental Flow Hydrology

Typical Stress Index



PDNA
PD NAIDOO & ASSOCIATES

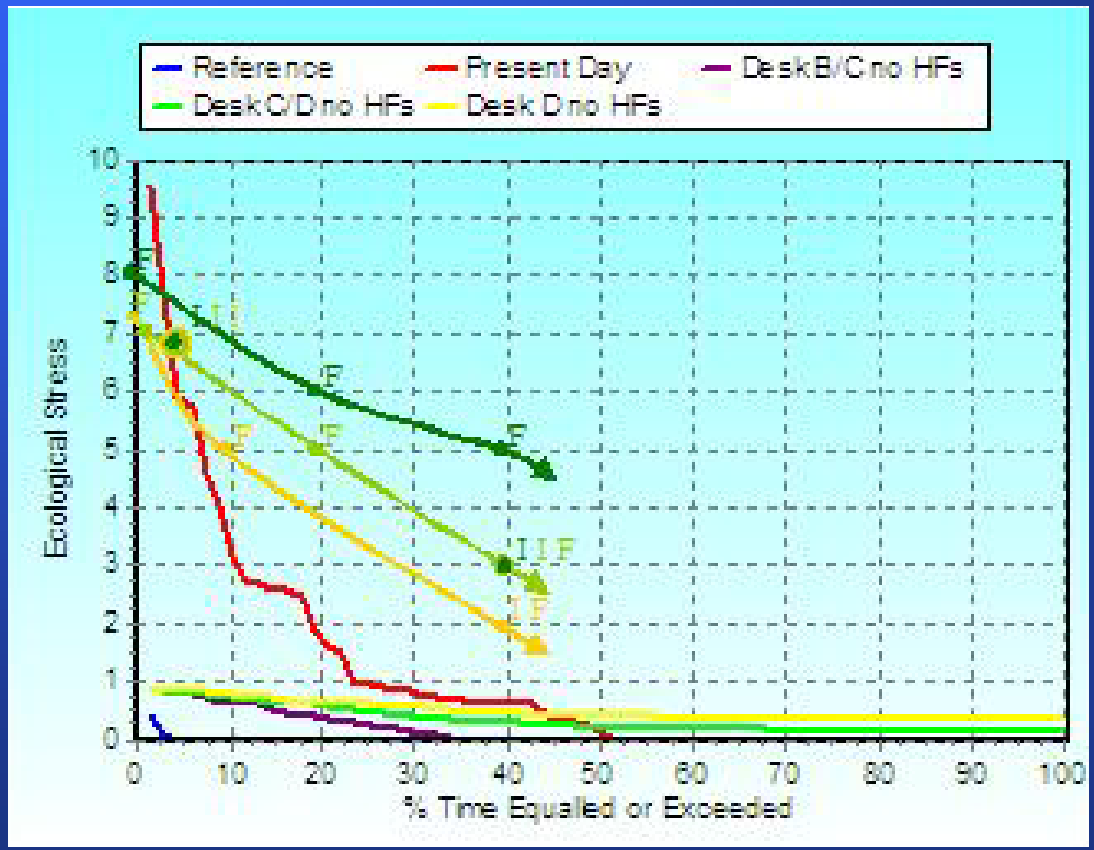
Environmental Flow Hydrology

The fish and invertebrate specialists pre-determine critical points on the desired stress distribution curve for each of the selected ecological categories for both the wettest and driest months of the year.

(i.e. at what frequency of occurence can certain stresses be tolerated.)

Environmental Flow Hydrology

Typical EC Stress Distribution Requirement (wettest month)



EC : D (dark green) ; C/D (light green) ; C (orange)

F = Fish I = Invertebrates

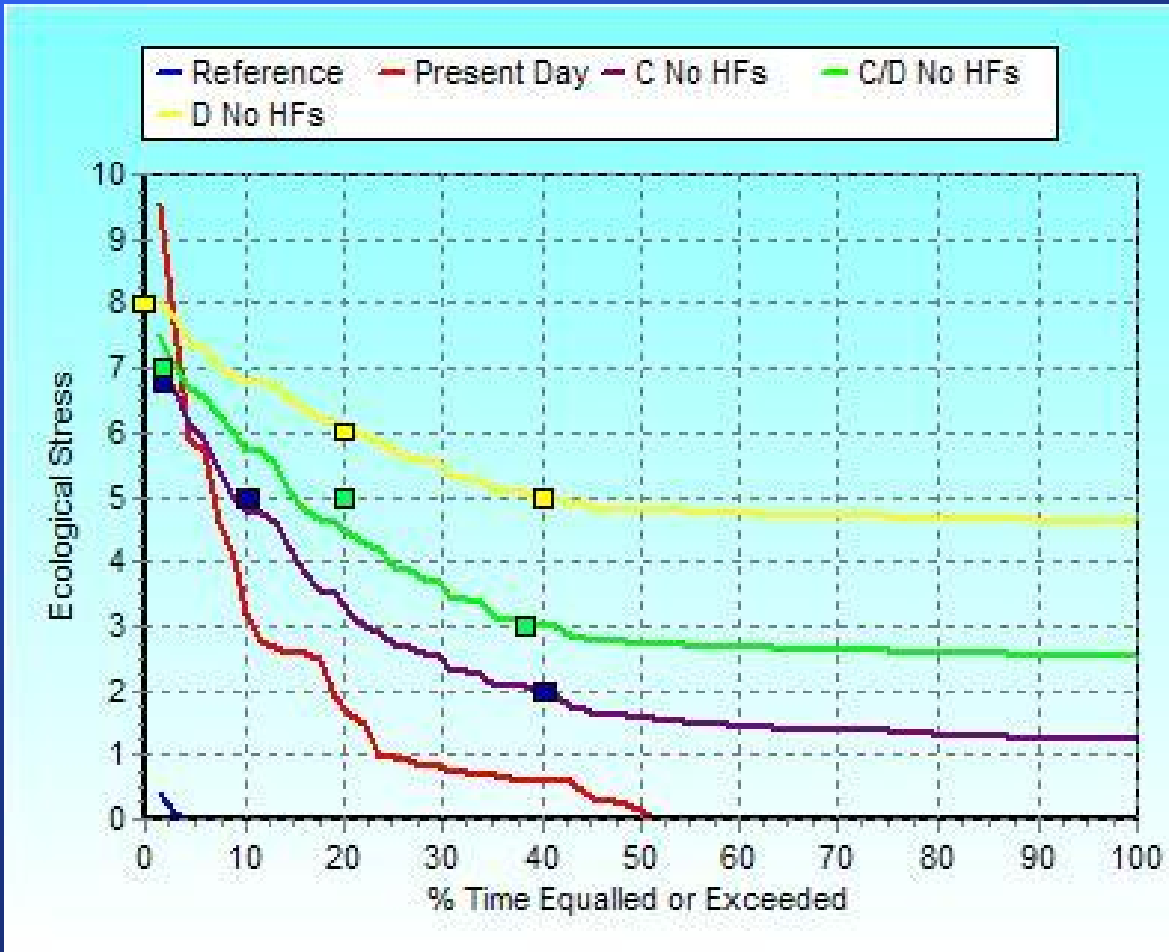
PDNA
PD NAIDOO & ASSOCIATES

Environmental Flow Hydrology

The hydrologist then uses SPATSIM Desktop Reserve and Flow – Stress Response modules to manipulate the hydrological time series of flow in order to fit each of the selected ecological categories.

Environmental Flow Hydrology

Hydrology fitted distribution curves to suit stress requirements (Wettest month)



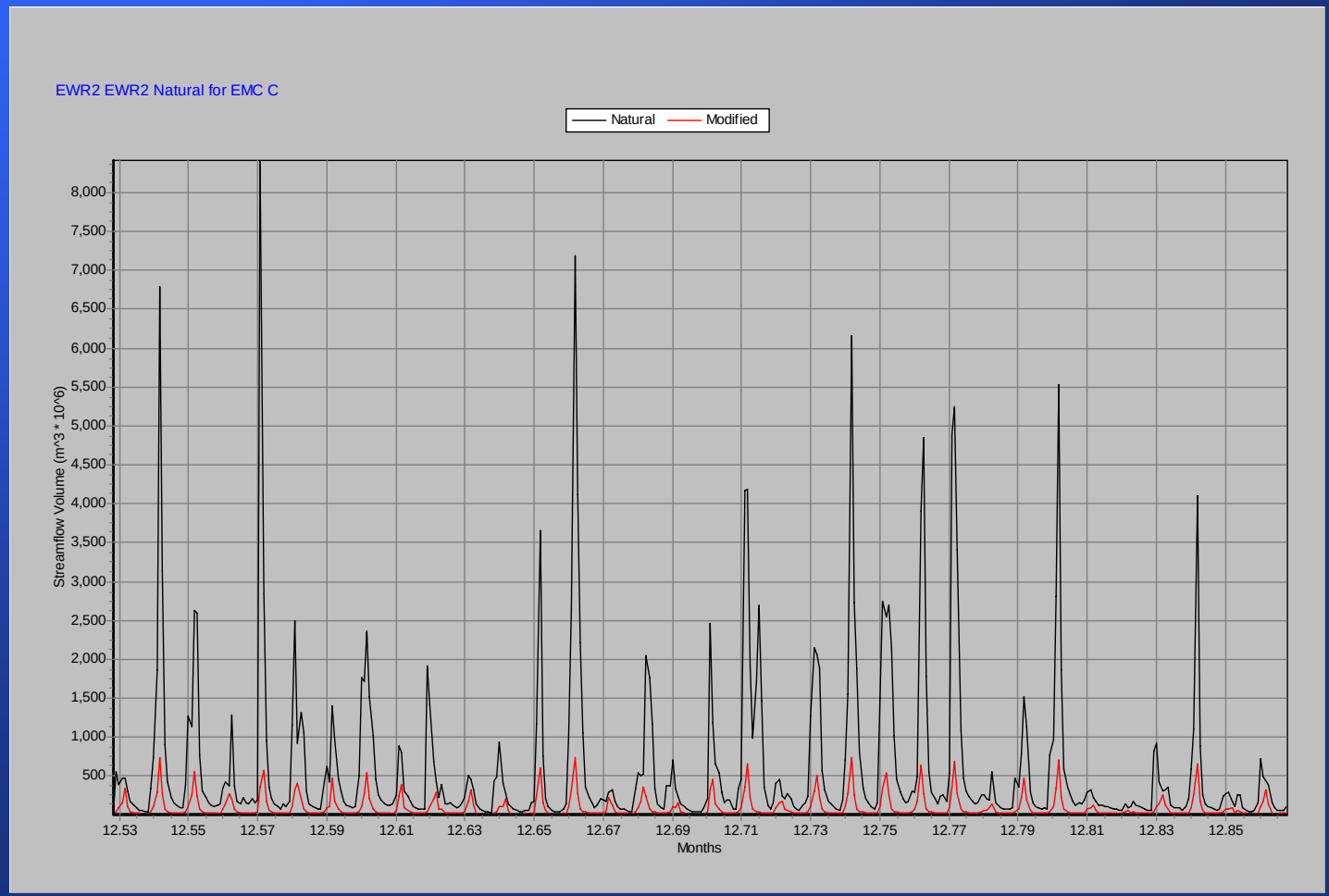
Environmental Flow Hydrology

PDNA
PD NAIDOO & ASSOCIATES

The hydrologist then adds in the high flow events that have been determined by the specialists for each EC and generates the respective EWR time series.

Environmental Flow Hydrology

Generate Environmental Flow Time Series



PDNA
PD NAIDOO & ASSOCIATES

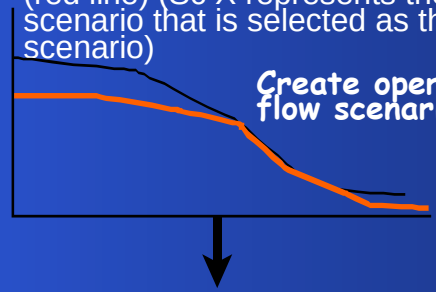
Environmental Flow Hydrology

- We have now established the range of flows that are necessary to maintain the ecological states for each EC.
- Add the EWRs for each EC to the Present Day demands in the catchment and analyse the effect on the total catchment system yield.
- Need to develop scenarios for meeting these EWRs.
  - eg. investigate supplying some of the lower priority demands in the catchment at a lower assurance level
  - Re-assess the consequences, together with the specialists, of not meeting some of ecological requirements

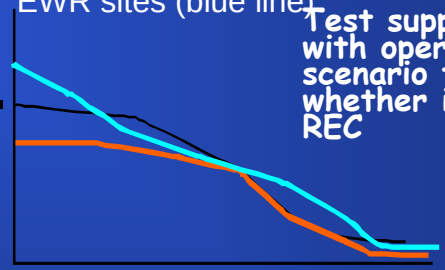
Environmental Flow Hydrology

EWR for one month set at workshop for the REC (EWR demand)

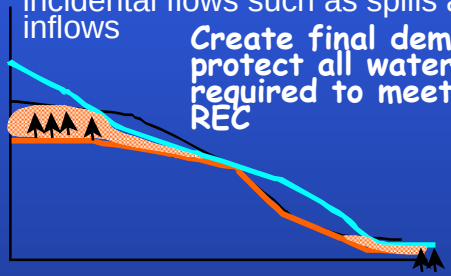
Sc X as a demand - usually less that the EWR (red line) (Sc X represents the operational scenario that is selected as the optimised scenario)



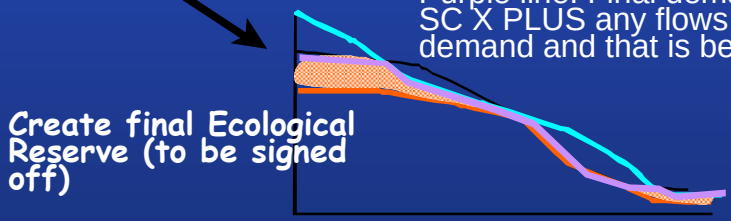
Provide supply line for testing at EWR sites (blue line)



Shaded areas: Those flows that were deleted from the EWR demand to create the scenario, but that are being supplied by incidental flows such as spills and tributary inflows



Purple line: Final demand that is signed off. It consists of the SC X PLUS any flows that form part of the original EWR demand and that is being supplied.



Note: Final Reserve line must not cross the supply line ever (check all months), but must be as close as possible to the supply line in the shaded areas

Environmental Flow Hydrology

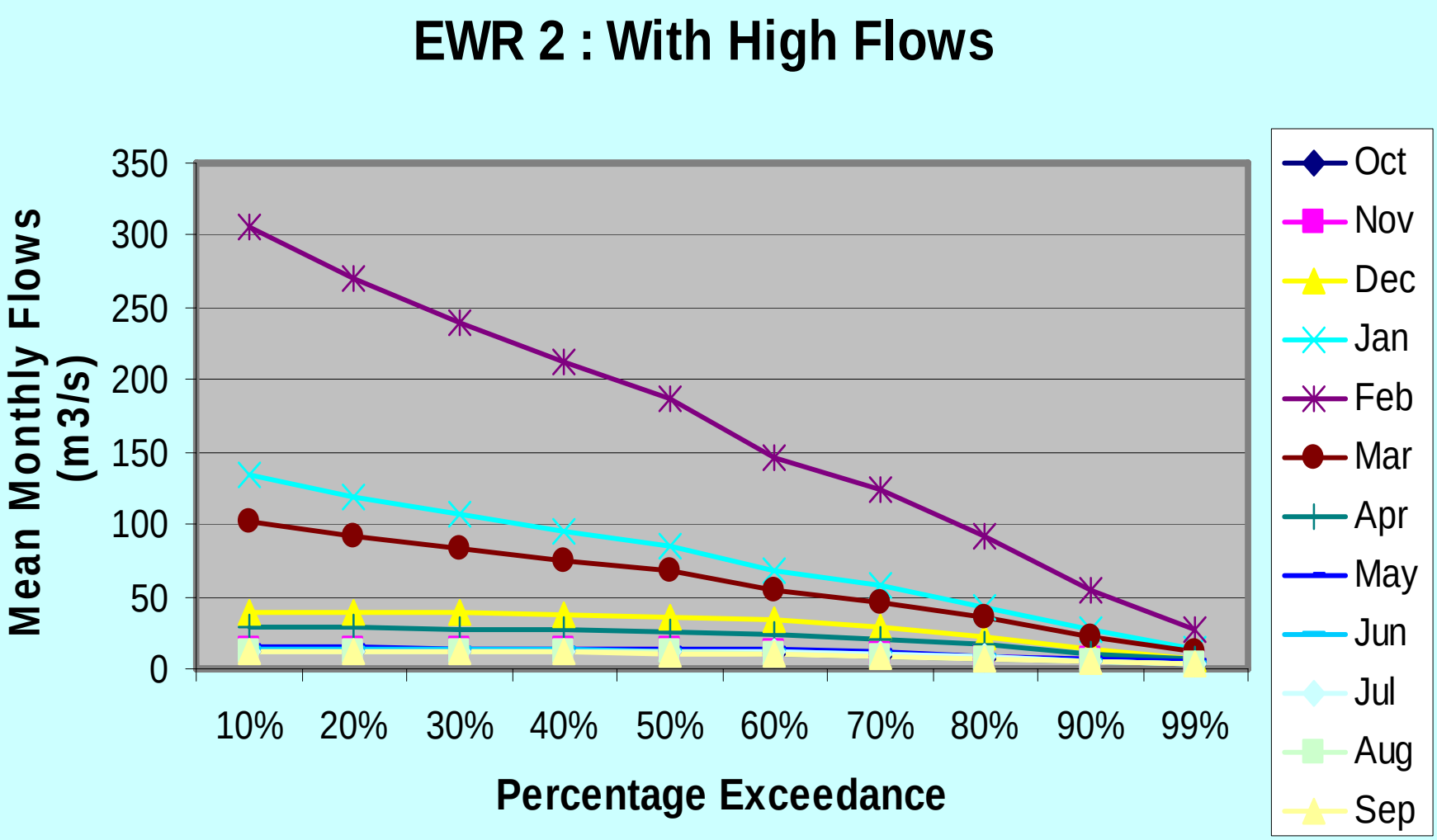
Final tabular format of results :
EWR2 with high flows

EWR2 : Mean Monthly Flows											
Month	10%	20%	30%	40%	50%	60%	70%	80%	90%	99%	Average
Oct	11.847	11.821	11.725	11.526	11.136	10.42	9.22	7.45	5.316	3.711	9.4172
Nov	14.216	14.169	14.04	13.779	13.278	12.38	10.907	8.774	6.242	4.352	11.2137
Dec	39.499	39.32	38.88	38.00	36.334	33.377	28.576	21.689	13.576	7.538	29.6789
Jan	133.427	119.098	106.794	95.861	85.356	67.853	57.658	43.29	26.604	14.266	75.0207
Feb	305.731	269.731	239.008	212.22	187.219	145.403	123.341	91.696	54.418	26.675	165.5442
Mar	101.546	91.367	82.582	74.777	67.229	54.502	46.697	35.397	21.987	11.973	58.8057
Apr	28.219	28.148	27.89	27.355	26.305	24.38	21.153	16.393	10.654	6.338	21.6835
May	14.495	14.476	14.369	14.142	13.685	12.826	11.355	9.14	6.425	4.367	11.528
Jun	13.241	13.23	13.138	12.941	12.539	11.775	10.45	8.434	5.942	4.044	10.5734
Jul	12.405	12.405	12.329	12.162	11.812	11.129	9.916	8.03	5.656	3.832	9.9676
Aug	11.708	11.699	11.619	11.448	11.098	10.434	9.282	7.529	5.362	3.712	9.3891
Sep	11.569	11.554	11.47	11.292	10.932	10.257	9.101	7.361	5.227	3.61	9.2373

Salomon Lda.

PDNA
PD NAIDOO & ASSOCIATES

Environmental Flow Hydrology



PDNA
PD NAIDOO & ASSOCIATES

Environmental Flow Hydrology

- Note that the final selection of the environmental management class needs to take into account the following:
  - The ecological category
  - Stakeholder buy-in of the consequential state of the river
  - The economic implications of not meeting water demands in the catchment
- Carry out a socio-economic analysis on the impact of implementing the EWRs.
- Carry out a stakeholder and public participation exercise to finalise operating rules for implementation of the EWRs.

PDNA
PD NAIDOO & ASSOCIATES

Environmental Flow Hydrology

Using the final selected scenario we generate the operating rules for releases in the catchment to meet the Ecological Water Requirements

(eg. Set by stochastical testing of levels of an upstream dam to meet both downstream demands and EWRs)

Environmental Flow Hydrology

PDNA
PD NAIDOO & ASSOCIATES

Thank you