Hydraulic Model for Niger Basin Management

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- Model Niger : Stakes, construction and calibration steps of model, current structure of Model
- Model Exploitation : scenarios elaboration and simulation, Results
- outcomes : optimization
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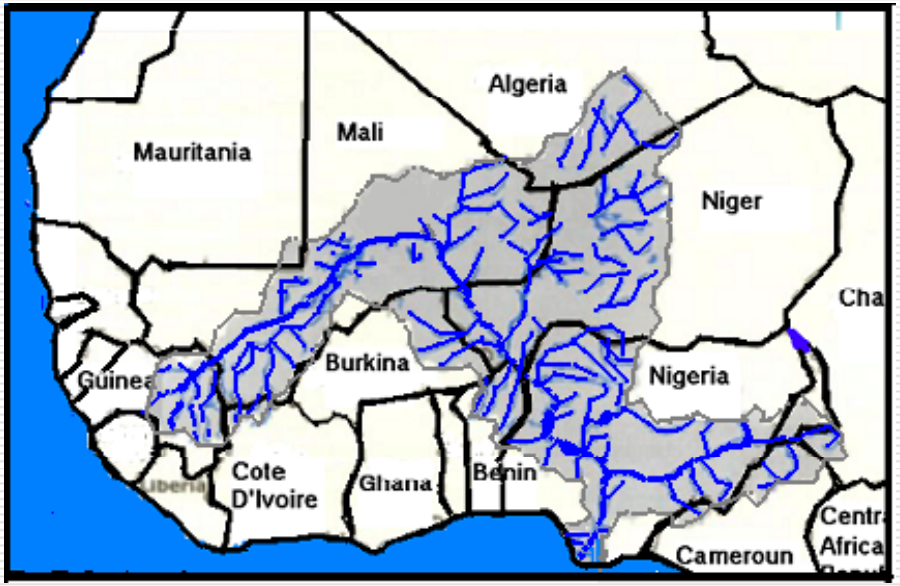
- Perspectives : at regional (ES/NBA) and local (country) levels

GENERALITIES

- Types of models
  - hydraulic Model : require watershed geometry, topography (cross section profile), dynamic equations (momentum and continuity)
  - hydrologic Model : rainfall-runoff relation, hydrologic balance equation
  - IWRM Model : Mike Basin

BASIN PRESENTATION



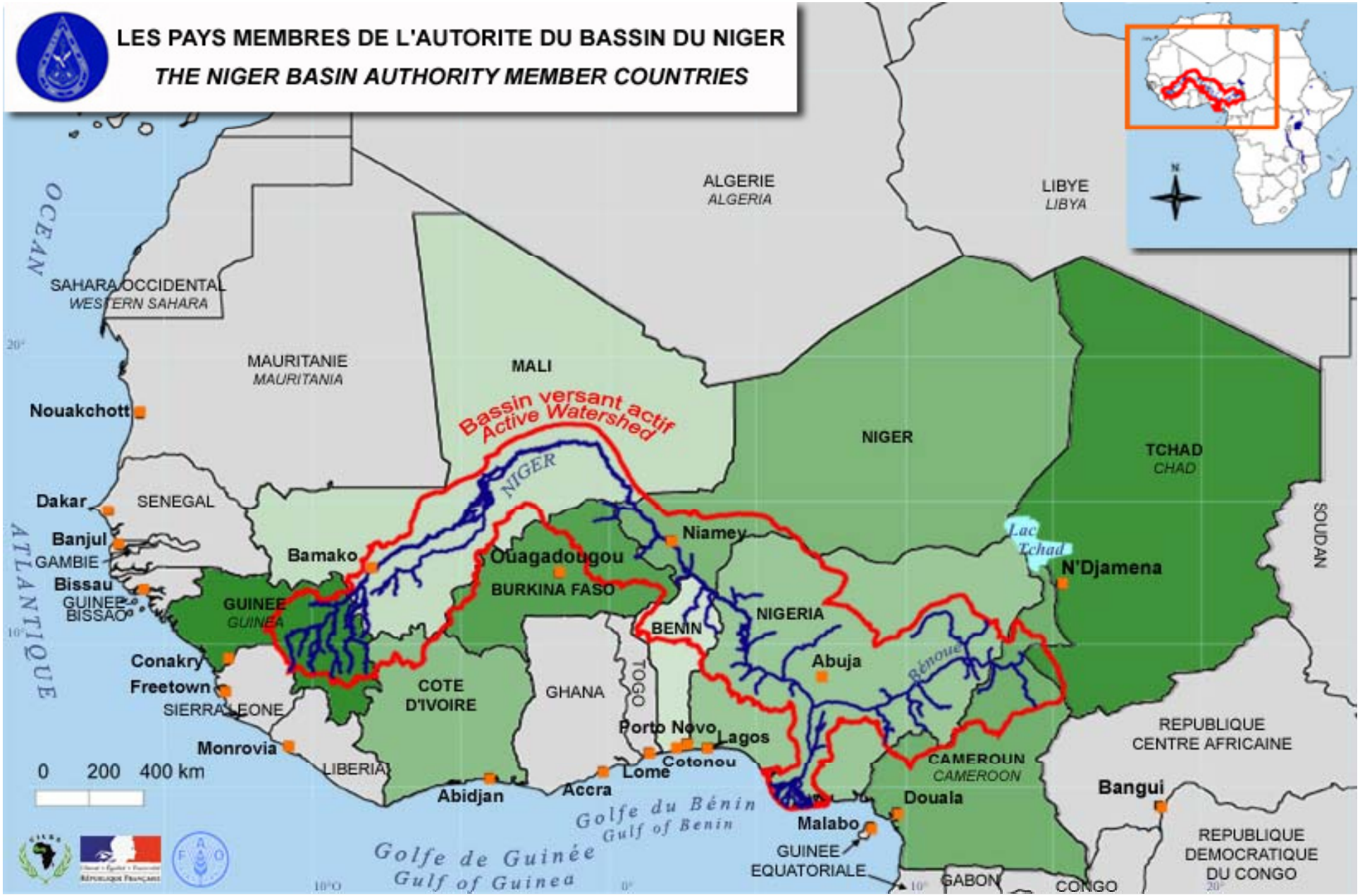
- Length of the river = 4200 km
- 9th largest world river
- 3rd largest river in Africa
- Theoretical Catchment Area = 2 million km²
- Active Catchment Area = 1.5 million km²
- Mean Annual Flow = 160 Billions m^3

Basin Area distribution

- Ten countries sharing the basin Algeria :0.5%, Benin: 2%; Burkina Faso:2% Cameroon:4%; Chad :1%; Cote D'Ivoire :1% Guinée: 6%; Mali:25 %; Niger:21%; Nigeria: 31.5%;

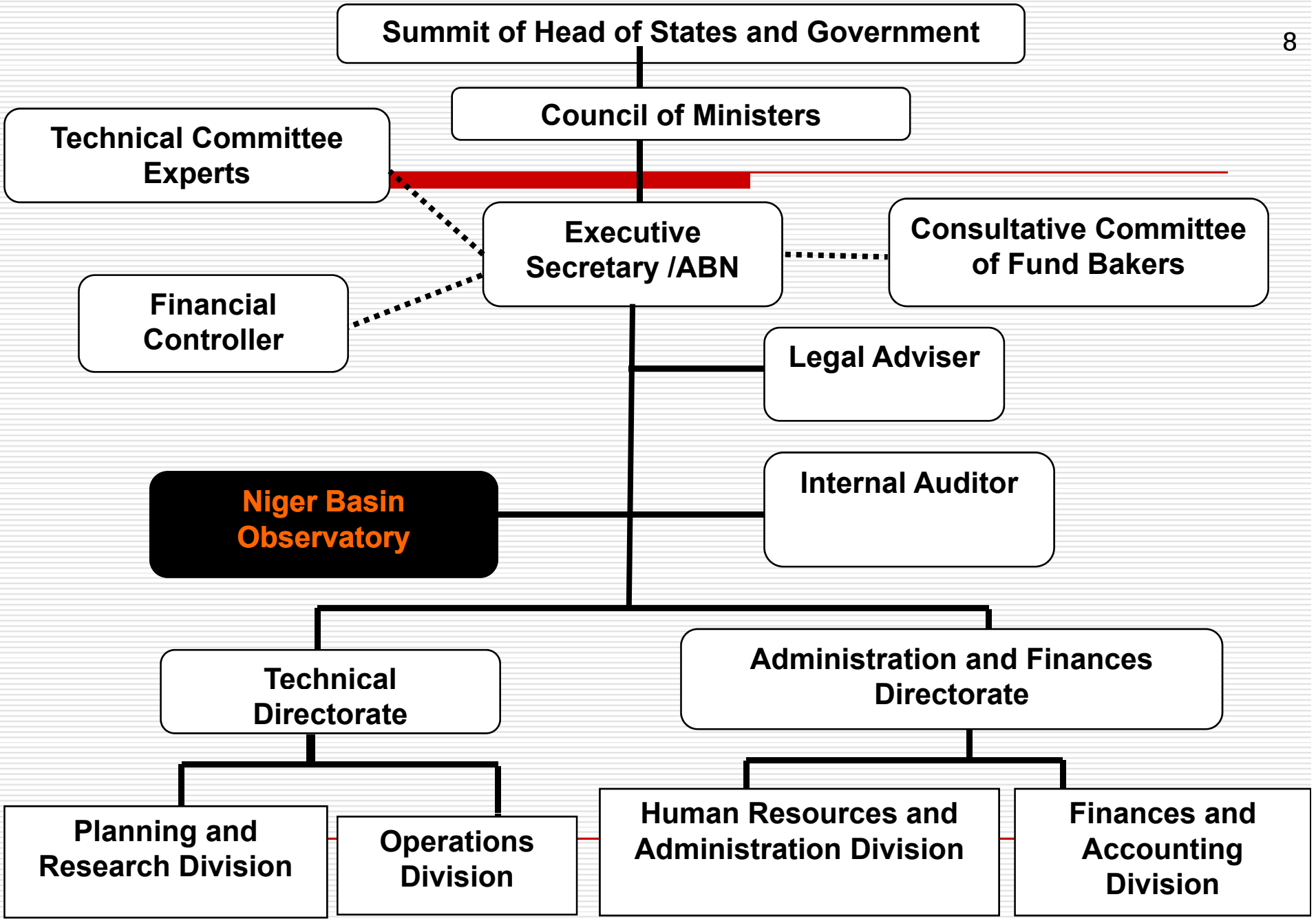
NIGER BASIN AUTORITY

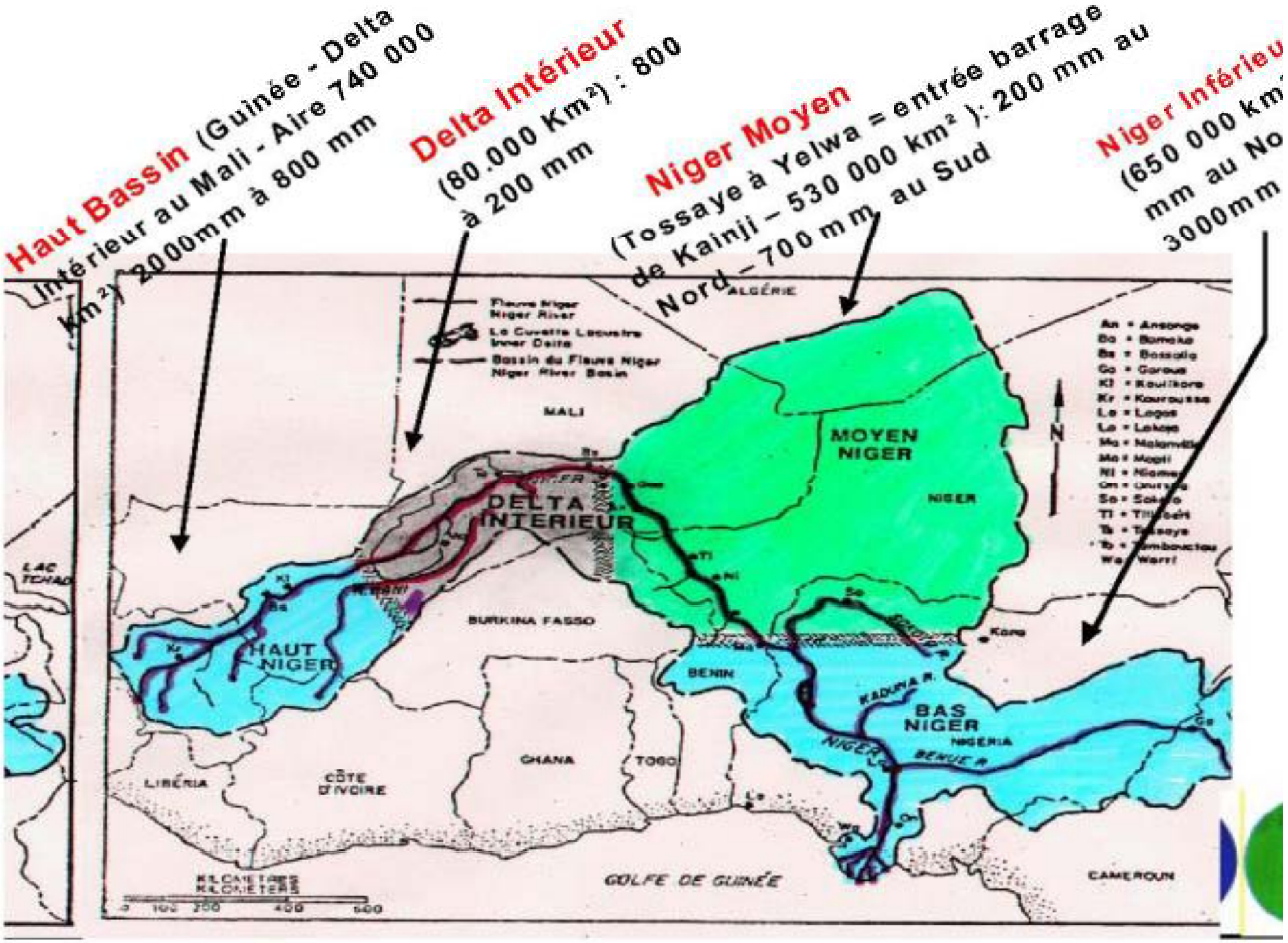
- Created by the nine countries sharing the active watershed (except Algeria) november 1980 (Faranah,Guinea) issued from the reform of river commission created in 1964
- The Executive Secretariat of NBA located in Niamey, Rep. of NIGER



Guinée (6%) ; Côte d'Ivoire (1%) ; Mali (26%) ; Niger (23%); Nigeria (33%)
Burkina Faso (4%) ; Bénin (2%) ; Cameroun (4%) ; Tchad (1.0%) ;

Chart of Niger Basin Authority




Haut Bassin (Guinée - Delta Intérieur au Mali - Aire 740 000 Km²) : 2000mm à 800 mm
Delta Intérieur (80.000 Km²) : 800 à 200 mm
Niger Moyen (Tossaye à Yelwa = entrée barrage de Kainji – 530 000 km²): 200 mm au Nord – 700 mm au Sud
Niger Inférieu (650 000 km² mm au No 3000mm
Fleuve Niger Niger River
La Cuvette Lacustre Inner Delta
Bassin du Fleuve Niger Niger River Basin
ALGÉRIE
MALI
MOYEN NIGER
NIGER
DELTA INTERIEUR
HAUT NIGER
BURKINA FASSO
BENIN
BAS NIGER
NIGERIA
GHANA
TOGO
CÔTE D'IVOIRE
LIBÉRIA
LAC TCHAD
GOLFE DE GUINÉE
CAMEROUN
KILOMETERS
KILOMETERS
0 100 200 400 600
An = Ansongo
Ba = Bamako
Bs = Bassatia
Go = Goroua
Kl = Koulikoro
Kr = Kourousse
Lo = Lagos
La = Lokoja
Mo = Molomdio
Mp = Mopti
Ni = Niamey
On = Onitsha
So = Sokoto
Tl = Tillabéri
Ta = Tossaya
Tb = Tombouctou
Wa = Warri
N
Kano
KADUNA R.
NIGER
BENUE R.

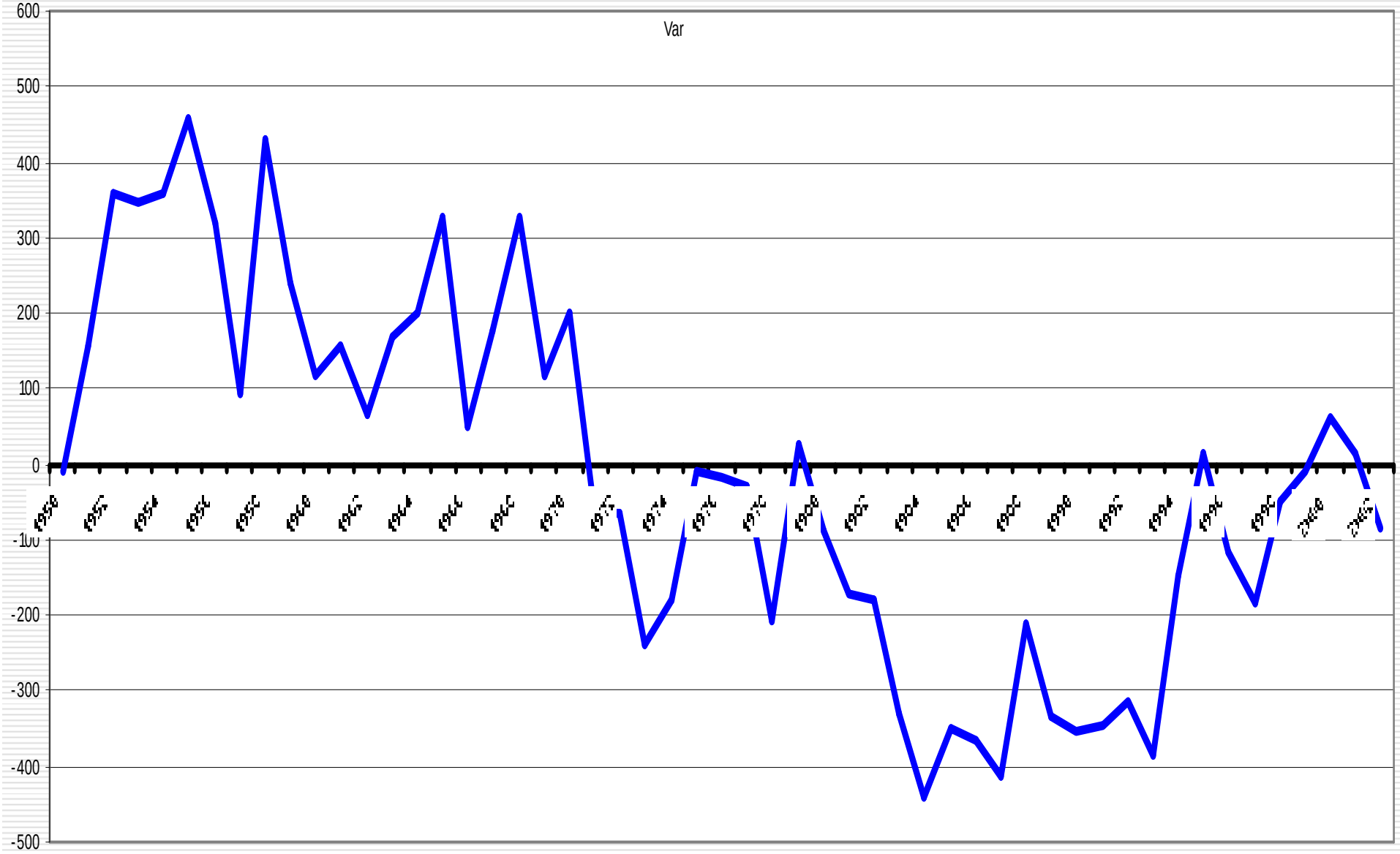
SOCIOECONOMIC SITUATION

- Population 106 Million (2005) :
  - Urban 32%
  - Rural; 68%
  - Under 15 years : 44%
  - Growth Rate 2.63%
- GNP Per Capital : 350 USD/yr
- Access to drinking Water : 52%
- Literacy rate : 35%
- Life expectancy : 50 years

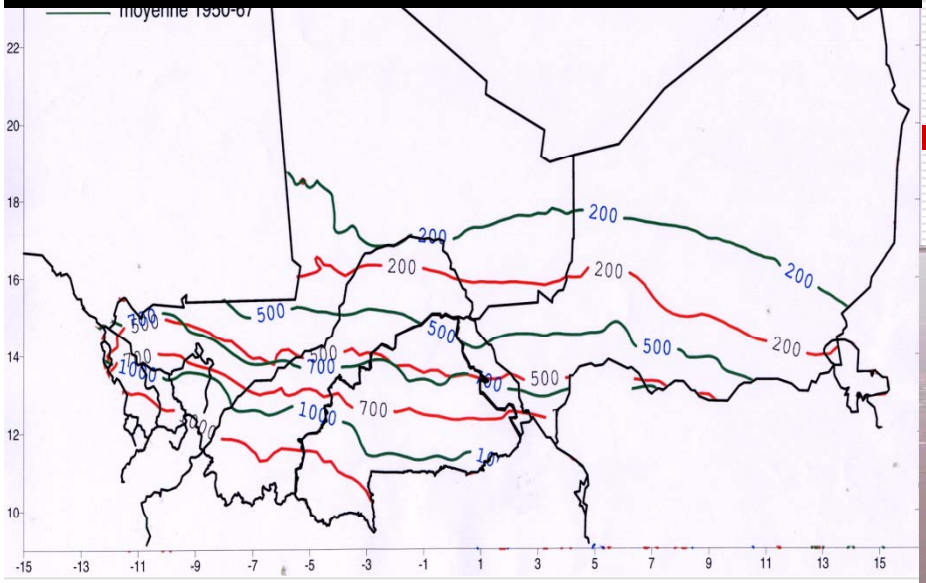
ENVIRONNEMENTAL SITUATION

- Impact of climate change : Since the last 4 decades the river Niger basin has been experiencing series of hydro-climatological changes that has resulted in the persistent drought ; continued low flow with consequences of acute water shortage and increasing water demand
- Land degradation : erosion and silting, loss of biodiversity
- Pollution : Aquatic weeds invasion

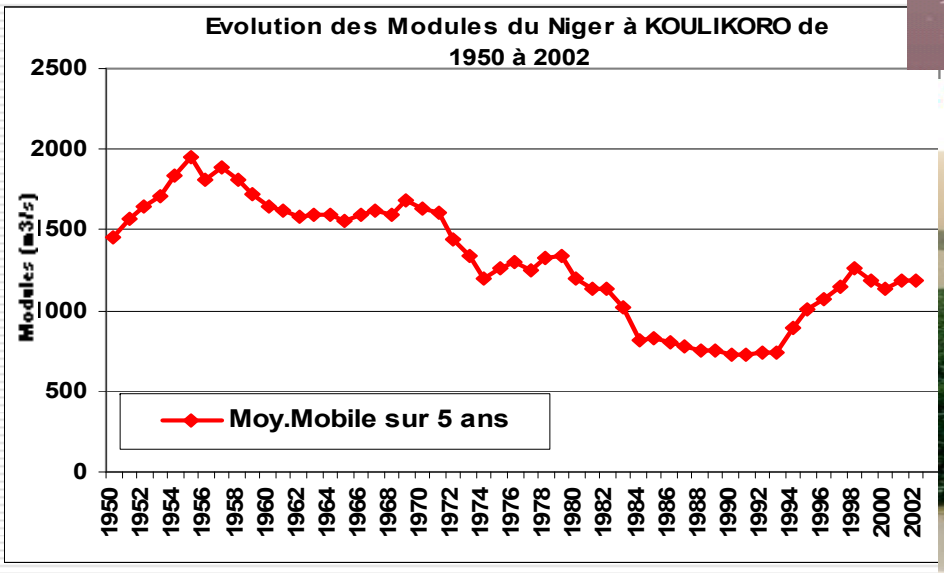
The Flow Fluctuation Pattern from the Mean in the Middle Niger at Niamey gage station 1950-2000



► Overall decrease of rainfall : 20 up to 30%, isohyets move 100 km southward



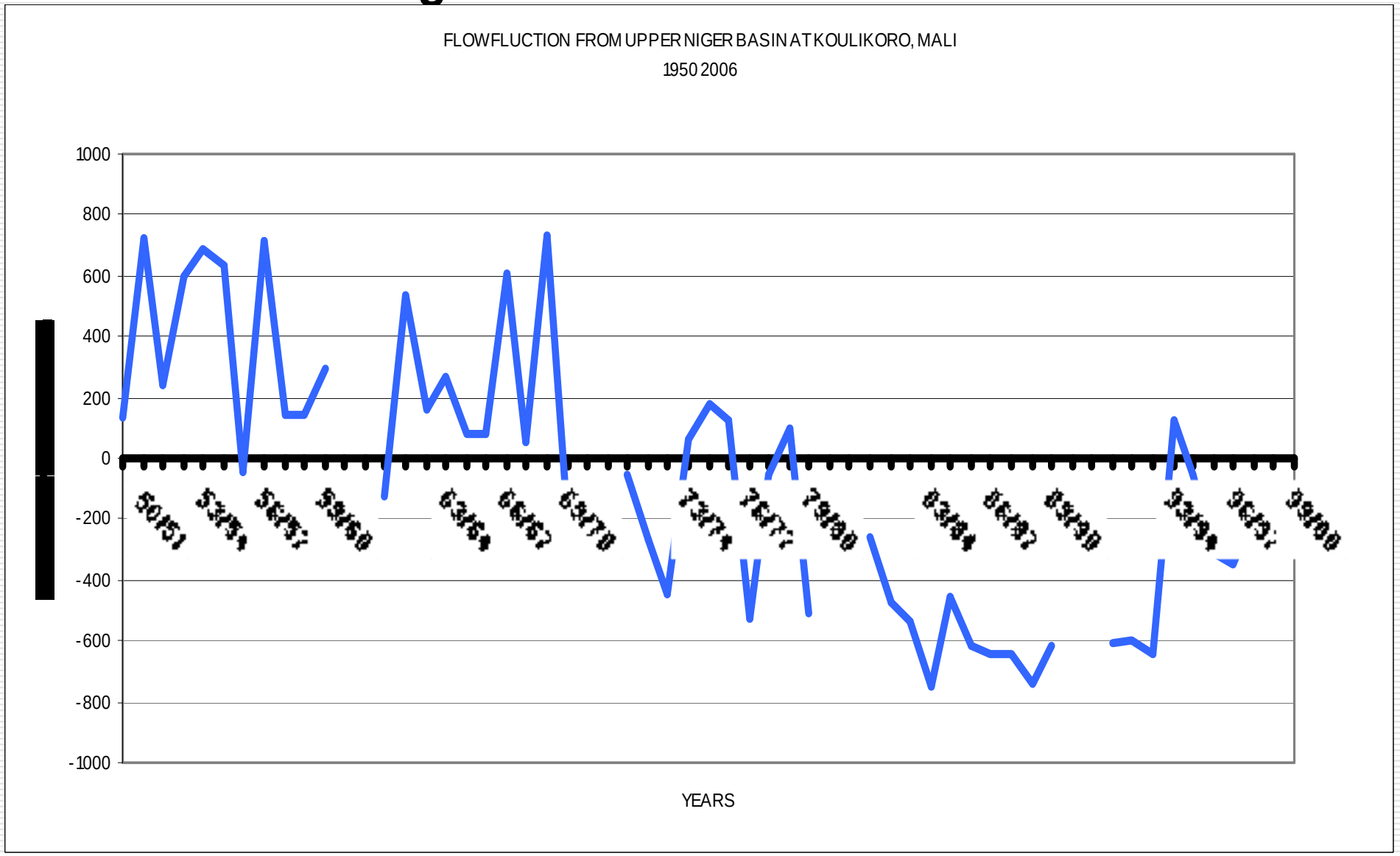
►Flow reduction : 20 up to 55%



Etat de l'eau du fleuve Niger à l' aval d'un abattoir

Cas de la Jacinthe d'eau qui entrave à la pêche, l'irrigation, la navigation, le bon fonctionnement des installations hydroélectriques, etc

The Flow Fluctuation Pattern from the Mean at the Upper Niger at Koulikoro 1950-2000



The lack of adequate hydroclimatological information and stools for planning, management and integrated development of the basin resources by the NBA member Countries were identified among the major constraints in mitigating the impact of climatic, hydrological and environmental disasters that are adversely affecting the socio-economic development in the region.

STRATEGIC ORIENTATIONS ADOPTED BY NBA

- Decisions of Summit of Head of States and Government 2002 Abuja (Nigeria) : mandated the NBA Executive Secretary to examine jointly with development partners the modalities for elaboration of " **a shared vision**" in the Niger Basin,
- International Conference of financial and technical partners and NBA Head of states in Paris, April 2004 : NBA members states signed "**Paris Declaration**" , on " the principles of management and good governance for a sustainable and shared development of Niger river basin"

STATEMENT OF SHARED VISION

- **The extraordinary session of Council of Ministers** held in Abuja in May 2005 adopted the shared vision as follows :

"**the Niger river Basin, a common space of sustainable development through an integrated management of the water resources and connected ecosystems, for the improvement of living conditions and the prosperity of the populations by 2025** »

Implementation of Shared Vision

- Studies conducted :
  - Water abstraction studies (2006)
  - Economic optimisation studies (2006)
  - Hydraulic model for water allocation/management (2007)
  - Economic module (2007)
  - Sustainable Development Action Plan (SDAP) (2007)
  - Investment Program (2008)
  - Water Charter (2008)

The Stakes

- Model of water resource management at Niger Basin scale for:
  - Put in hydraulic coherence various identified projects at basin scale,
  - Use as technical basis for SDAP studies,
  - At term: water resource management tool.

Hydraulic model for water resources management

- Carrying out a water allocation model with the support of BRLi and DHI consultants
  - Model Calibration
  - Model exploitation
  - Scenarios Simulations
  - Results Analysis
  - Performance Criteria for comparing scenarios

Gestion de la ressource en eau

MIKE BASIN

hydraulic Model for water resources management

Runoff

Diverted branch

Groundwater

many Water rights

Reservoir

Irrigation System

Intake water

Return flow

Rainfall-Runoff Model

Alimentation en eau

Irrigation System

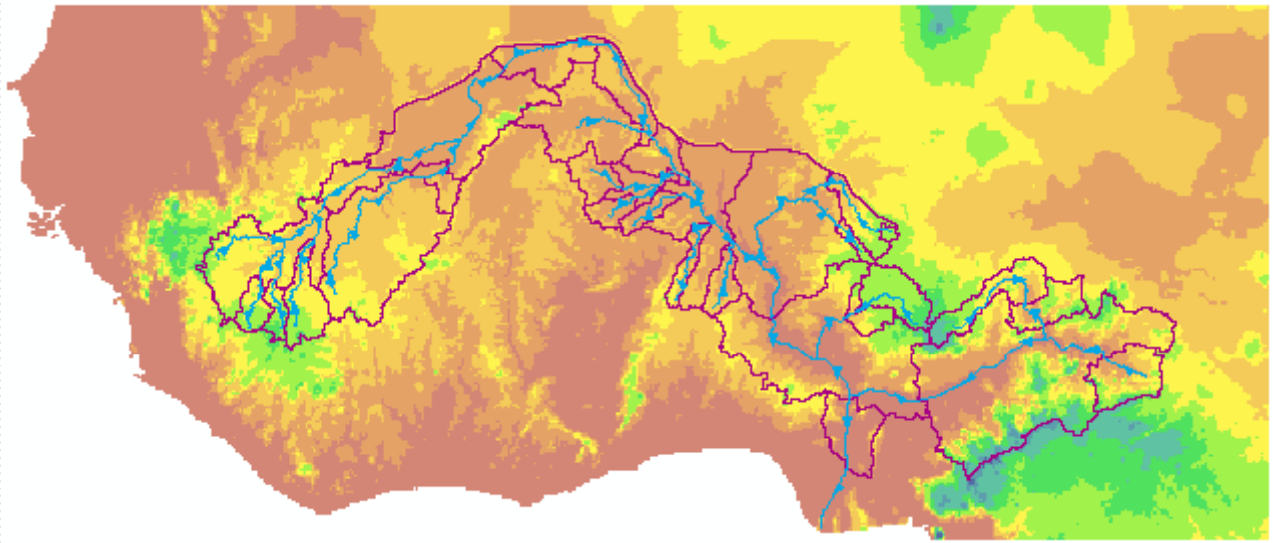
Industrial Waste water

Outlet

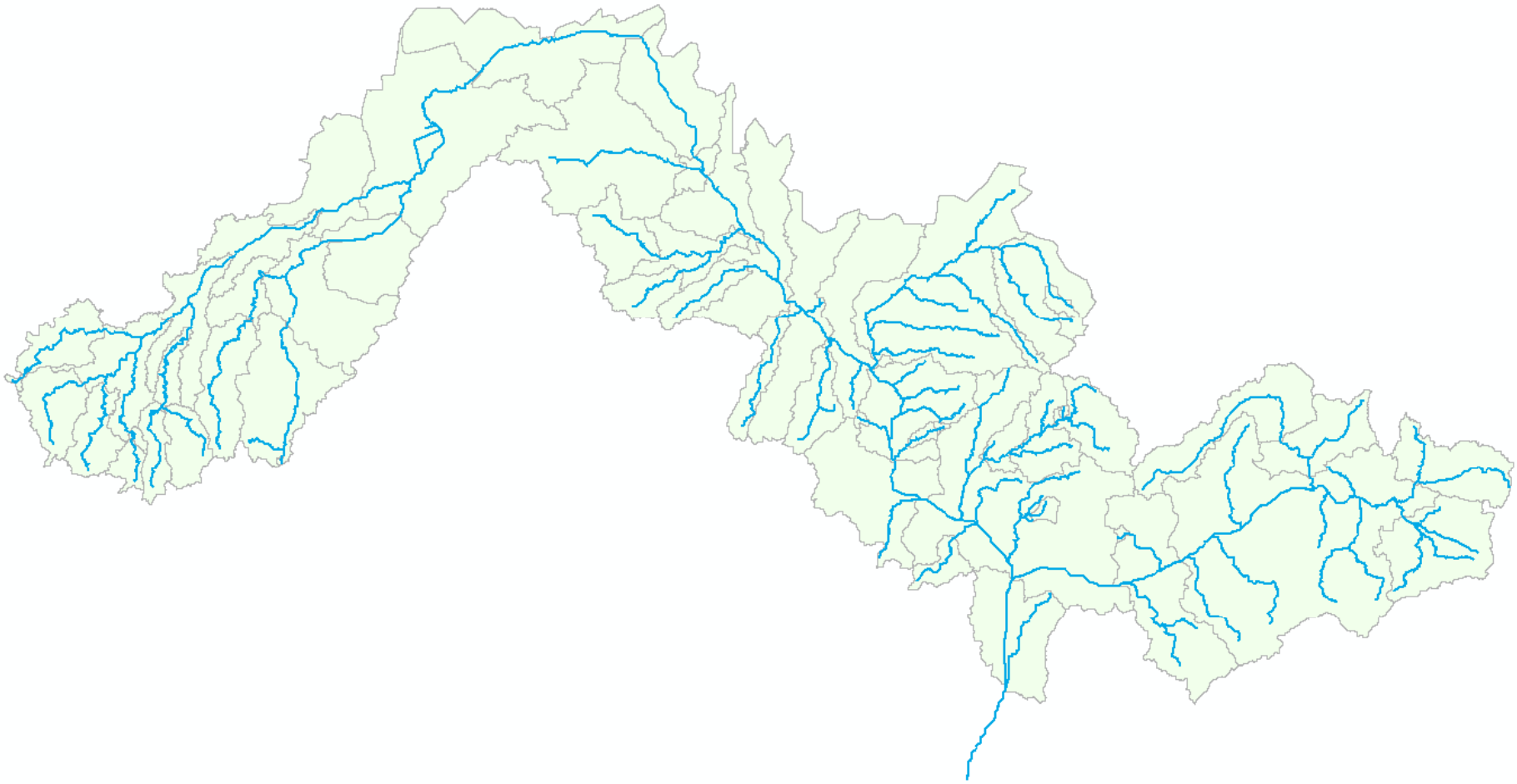
- Utilisation of surface water
- Utilisation of groundwater
- Priority rules
- Irrigation
- Natural flow
- Hydrology
- Monitoring water deficits
- Reservoir operation
- Hydroelectricity
- Utilisation for agriculture
- Flood control
- Low water Planning
- Monitoring river water quality

DHI WATER & ENVIRONMENT

THE NIGER MODEL



Area of the study

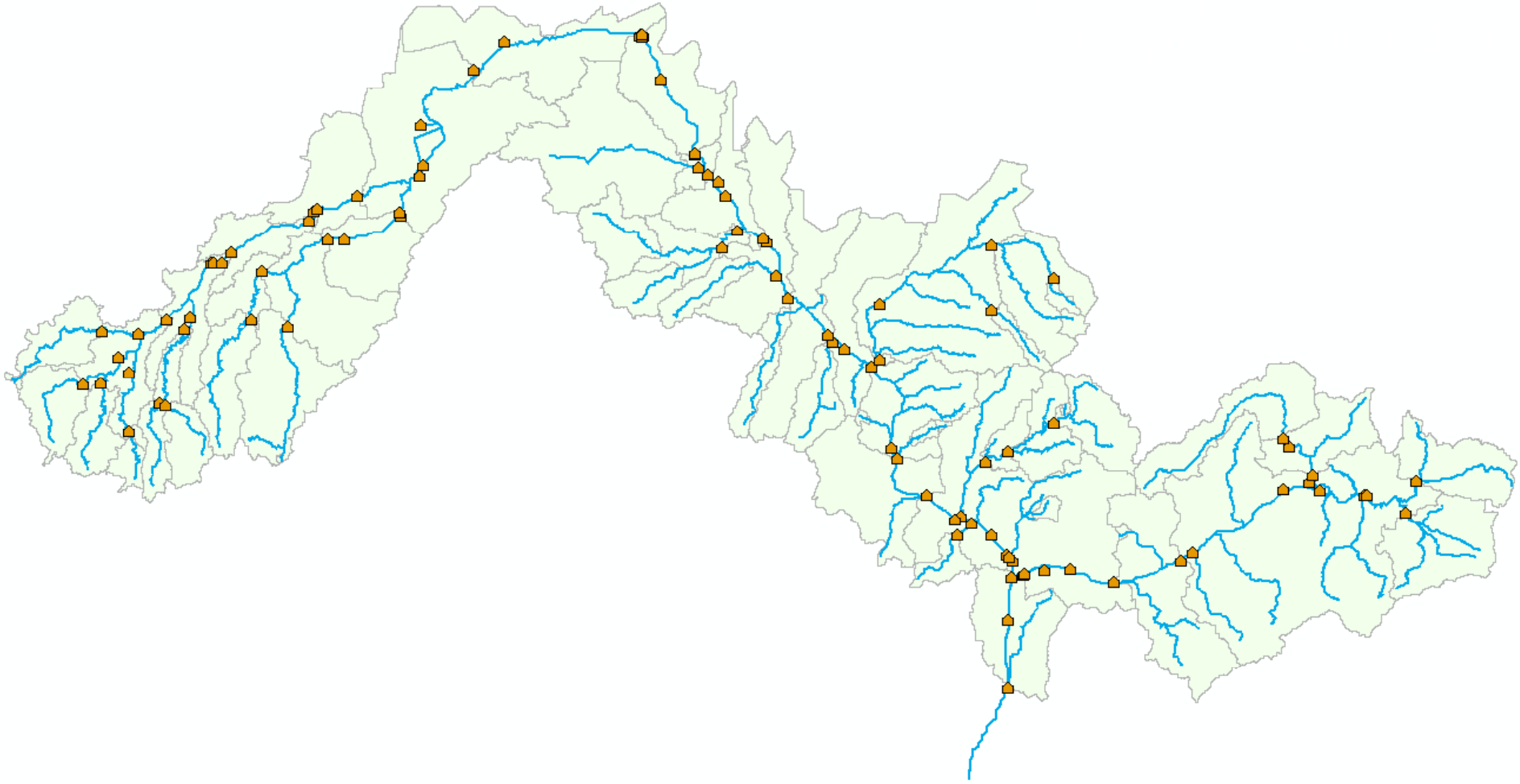


Modeling Steps (1/2)

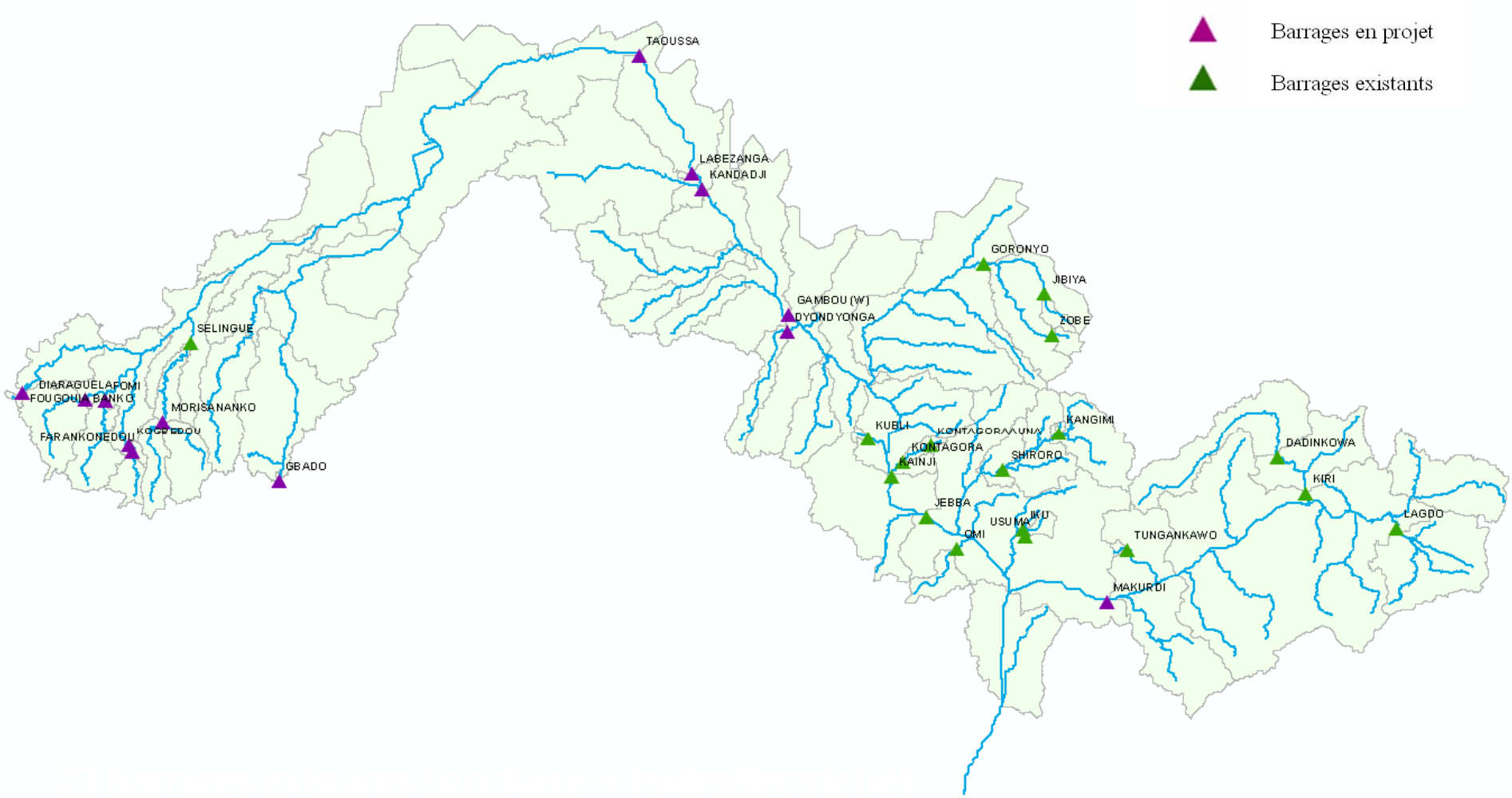
- ***Acquisition, data processing***:
  - Hydrology :
    - Quantitative and qualitative data Analysis
    - Data gap filling
  - Water Withdrawal
  - Related to existing infrastructures (geometry, management rules, uses, losses, …)
  - Related to projects

Hydrometric stations

Water abstraction Points



Existing and projected Dams



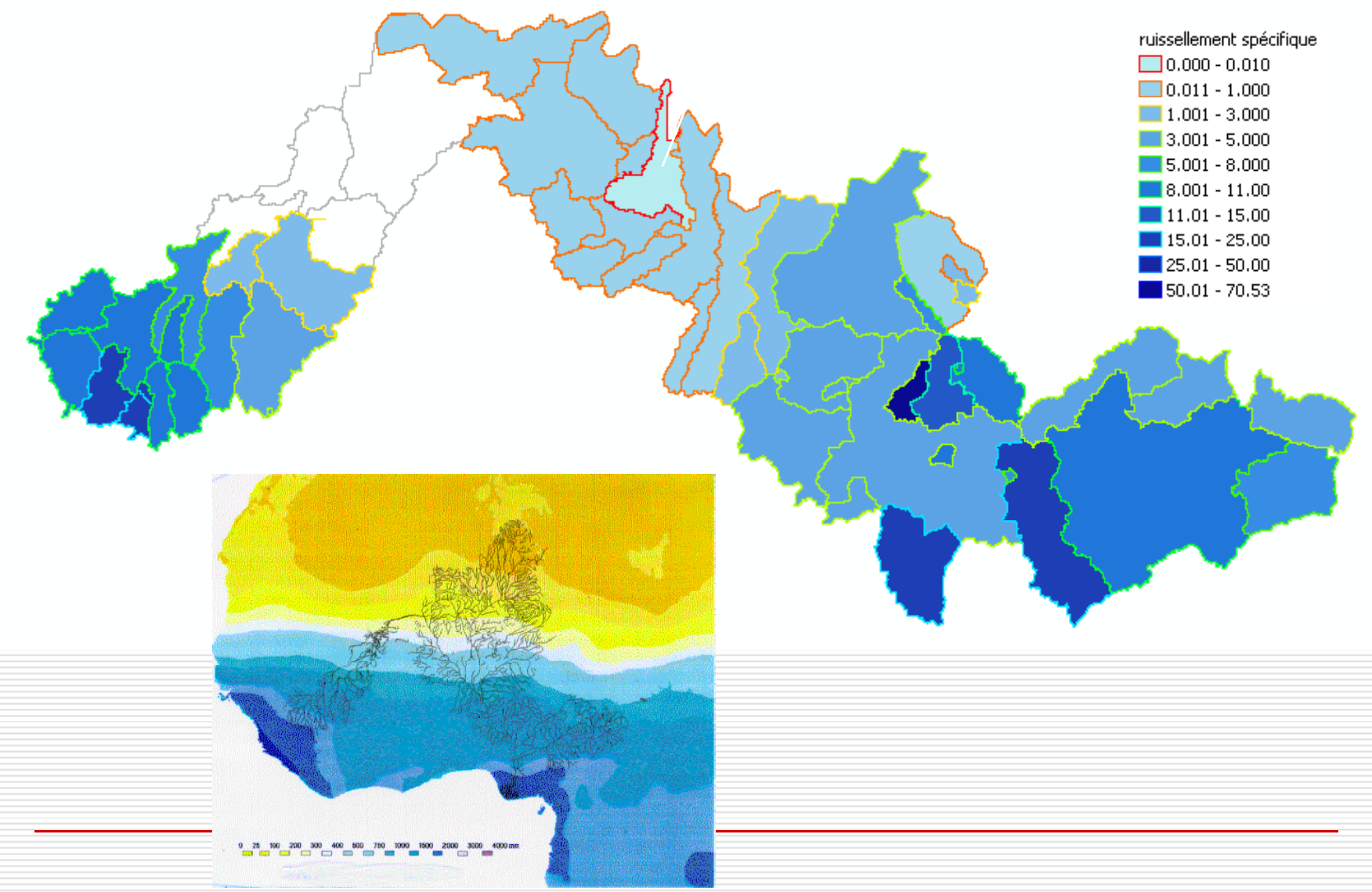
Modeling Steps (2/2)

- **Construction and calibration:**
  - Period of reference, 1966-1989
  - Elaboration of runoff time series
  - Calibration of propagation parameters
  - reference Situation (2005)

Model Calibration (1)

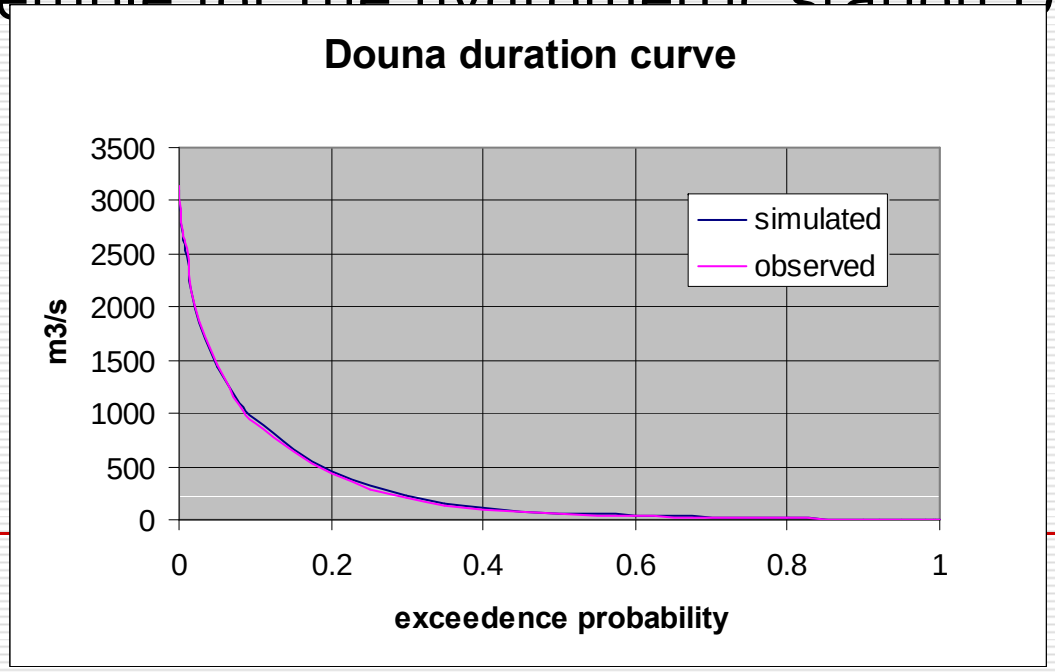
- Model calibration was made by generating runoff time series by sub-watershed along the river so that the resulting flow at each gauging station corresponds most faithfully possible to observed flow.
- Model was calibrated with data of period 1966-1989 which includes the severe drought of the beginning of year 1980s.
- .

Hydrology : specific runoff



Model Calibration (2)

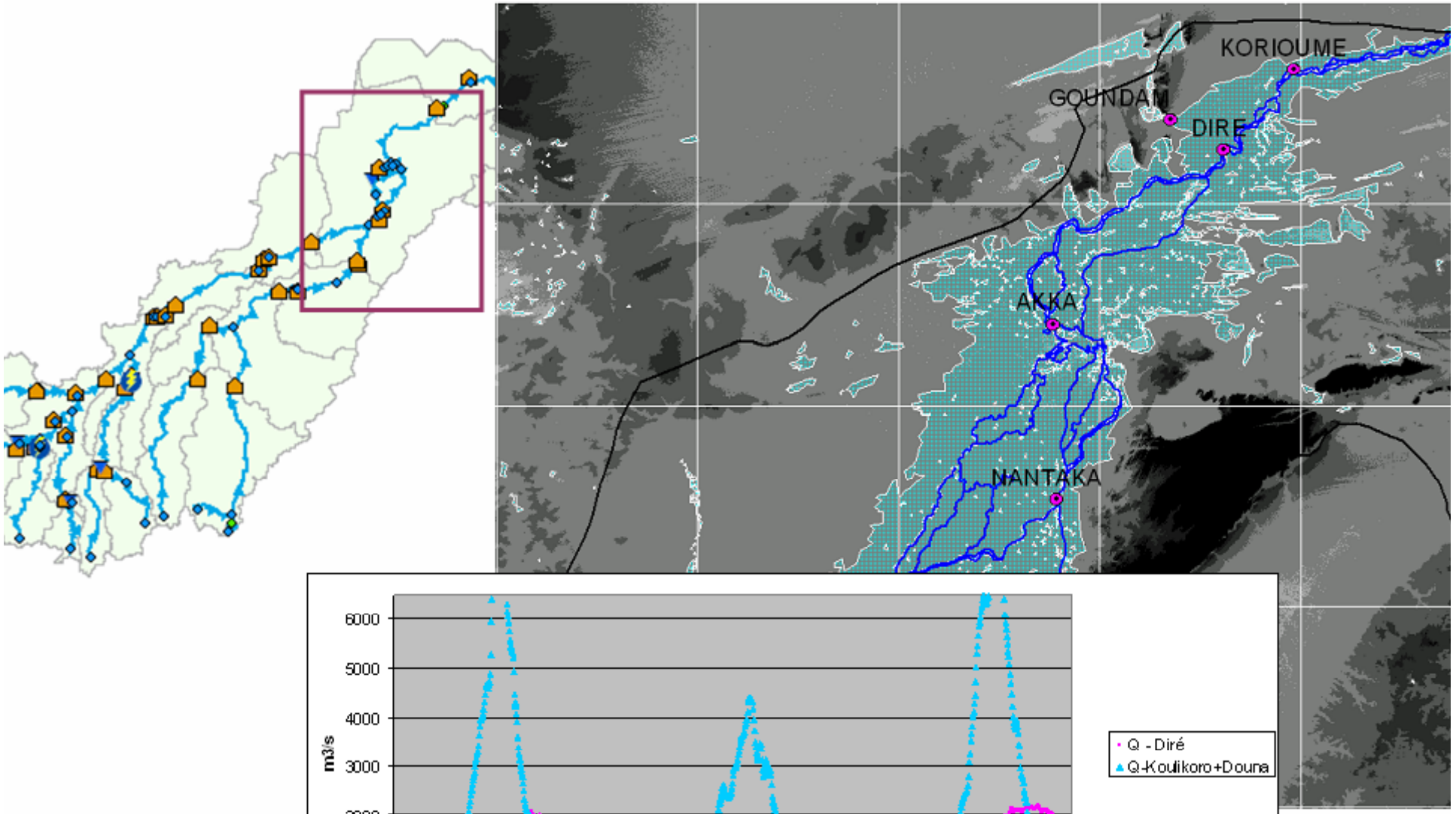
- Calibration was carried out year by year, by trying to get a good fitting of duration curves (observed and simulated data) at each gauging station, what guarantees enterely a good calibration.
  - Exemple for the hydrometric station DOUNA



Model Calibration(3)

- **Calibration of Inner Delta :**
  - To Insure Hydrological system continuity when crossing over the Delta.
  - Exam the impacts of the developments on local flooded areas : annual maximum flooded surfaces and their relations with local activities (fishery, livestock, bourgous, …..)

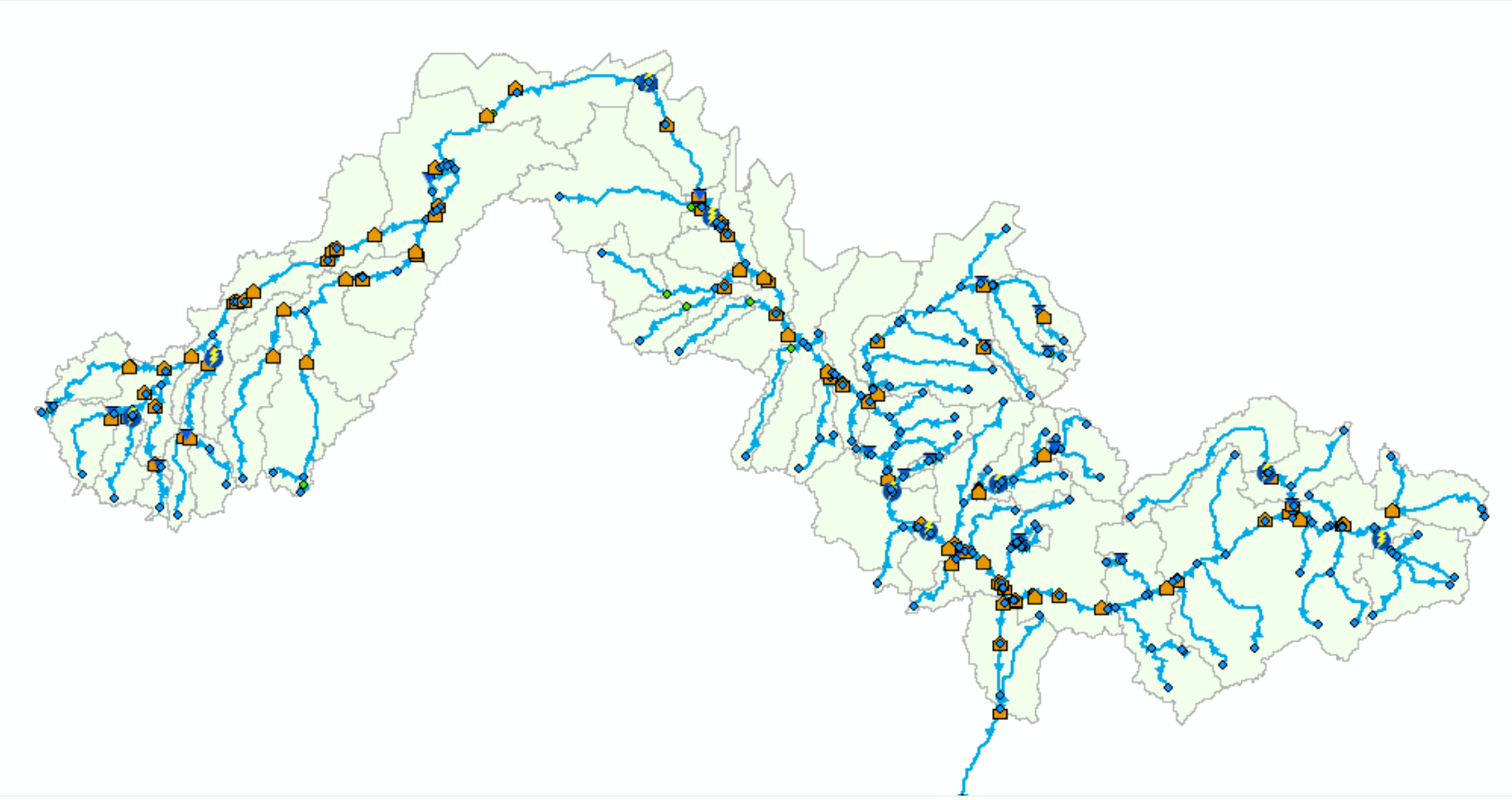
Delta Intérieur



Current Structure of Niger Model

- characteristics of Niger model
  - Basin was divided into 60 sub – catchments;
  - 445 nodes were introduced;
  - 66 hydrometric stations were used;
  - 93 withdrawal points for various utilization (drinking water, irrigation…);
  - Data from 23 existing dams were taking into account (storage dams and hydropower dams with conserved flow).

Current Structure of Niger Model



MODEL EXPLOITATION

- **reference scenarios**
  - Current Situation /current needs
  - Current Situation /Term 2015
  - Current Situation/Term 2025

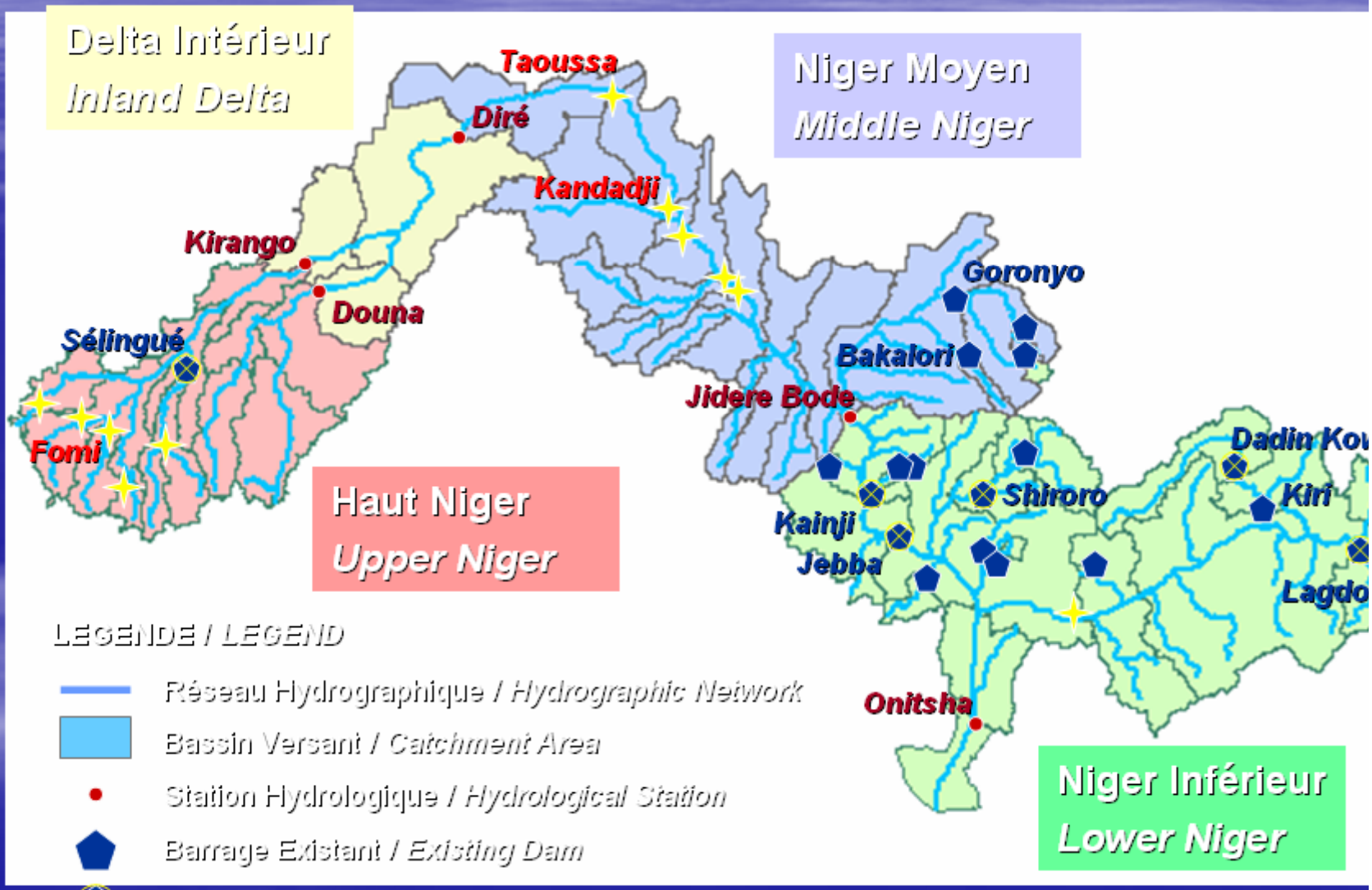
- **Developments Scenarios**

  each scenario is composed of combination elementary works

Scenarios Elaboration

- Typology:
  - Improving of existing infrastructures and irrigated perimeters management
  - New works : Fomi, Taoussa, Kandadji, Diaraguela dams
  - concerted management of shortage: priority choice by affected areas. Management rules.
- A scenario combine those three types.

THE NIGER RIVER BASIN HYDROLOGICAL DIVISIONS



Scenario development (1/2)

Development of projects and related irrigation scheme from upstream to downstream basin in the model :

- Fomi dam, + 4000 ha up to 13000 ha
- Office Niger extensions: + 40 000 ha up to + 250 000 ha.
- DIN : special analysis

Scenario development (2/2)

- Taoussa dam +28 000 up to 65 000 ha (full control), 50 000 ha (control flooding)
- Kandadji +10000 ha up to 31 000 ha (full control)
- Rehabilitation of Kainji / Jebba dams

Management rules/ management of shortage (1):

Wet season (for a dry year type 1984/85)

- Priority 1 : securing of human needs
- Priority 2 : securing livestock needs
- Priority 3 : industrial needs
- Priority 4 : irrigation for perennial or interannual crops

Wet season (for a dry year type 1984/85)

- Priority 5 : minima constraints linked to river flows: subsistence use: fishery, fodder production of decrue, minima levels for preservation of the wetlands (3 Ramsar sites in the Inner Delta …)
- Priority 6: irrigation 1 cycle of rice cultivation on minimal surface (full control)

Wet season (for a dry year type 1984/85)

- Priority 7: irrigation 1 "intermediate" cycle of crops in full control + controlled flood, with ecological constraints, navigation…
- Priority 8: (optimal) maximum irrigation
- Priority 9: optimal conservation of the ecosystems

For P1 to P9, one not turbine that downstream needs, except specific cases

Management rules/ management of shortage (2):

- Dry season (for a dry year type 1984/85)
  - Priority 1 : securing of human needs
  - Priority 2 : securing livestock needs
  - Priority 3 : industrial needs
  - Priority 4 : irrigation for perennial or interannual crops
  - Priority 5 : irrigation 1 cycle of gardening crop in dry season + cereal (except rice) on minimal surface.

Dry season (for a dry year type 1984/85)

- Priority 6: irrigation 1 cycle of rice cultivation dry season on minimal surface (full control)
- Priority 7: ecological and navigation constraints…
- Priority 8: optimal conservation of the ecosystems
- Priority 9: (optimal) maximum irrigation

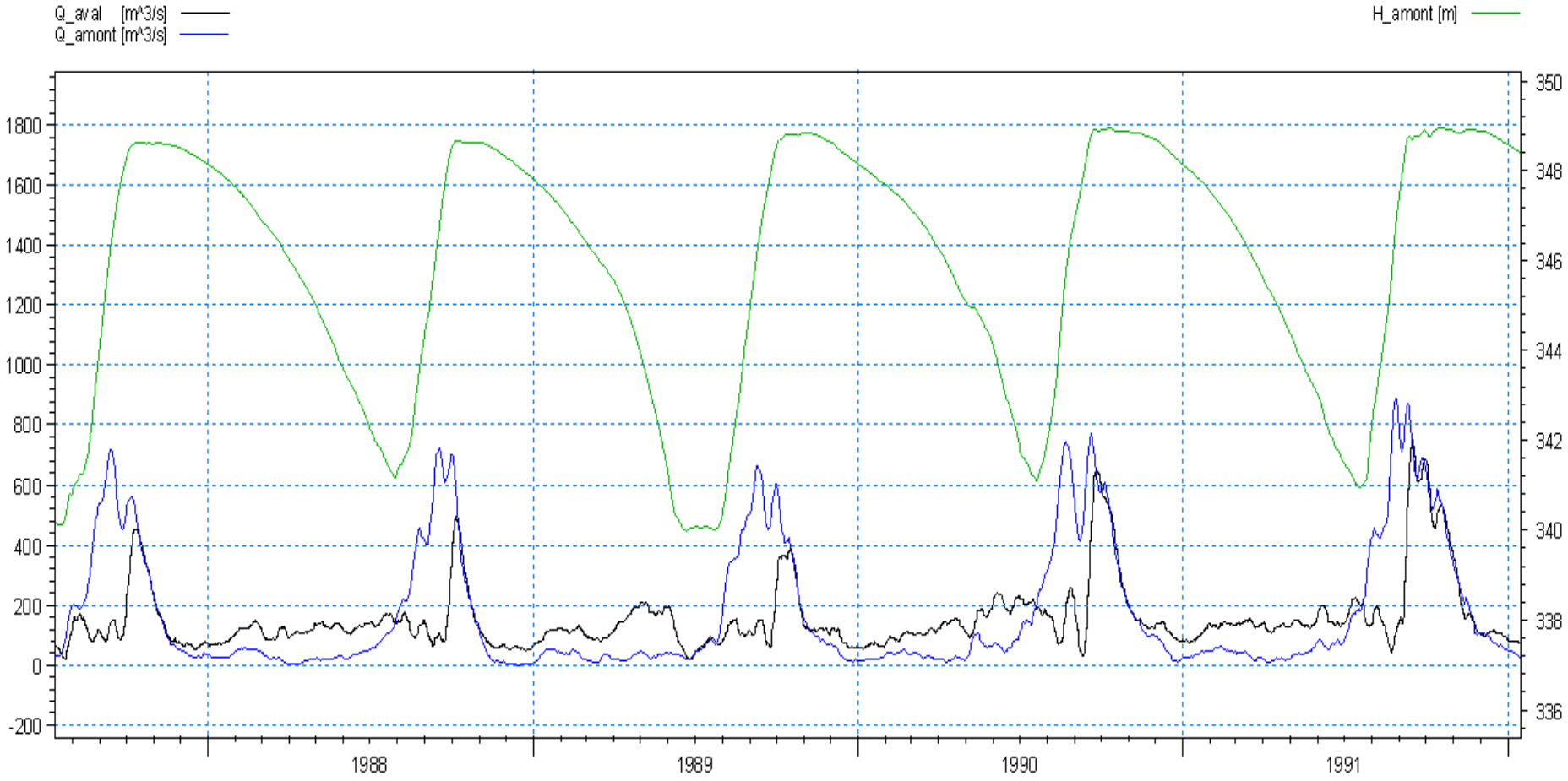
For P1 to P9, one not turbine that downstream needs, except specific cases

Model Outputs

- Information on reservoir caracteristic: water level, power generated, hydrological balance;
- Information on volume flowed at any point of hydrographic network;
- Information on needs satisfaction for any user;
- Determination regularised volumes.

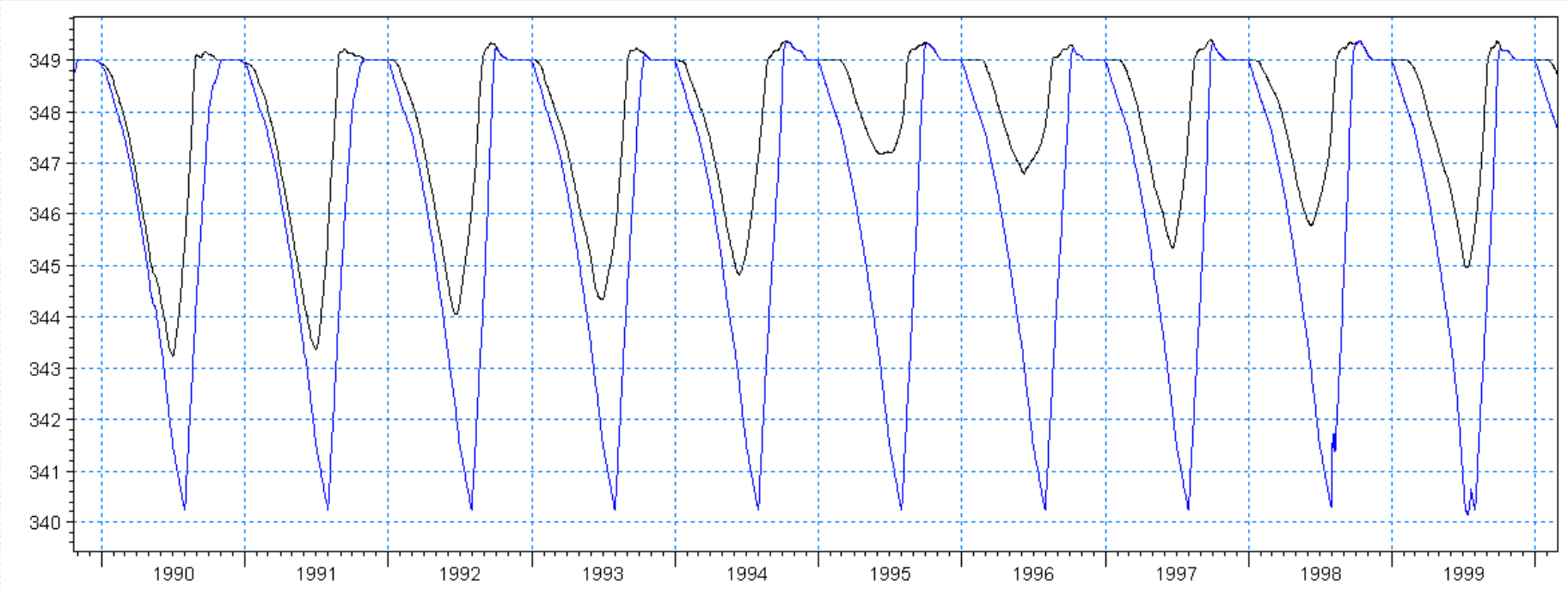
Example of output for hydraulic regulation of a dam (Mali)

Discharges upstream/downstream and water levels in the Sélingué storage



Example of output for power Optimisation

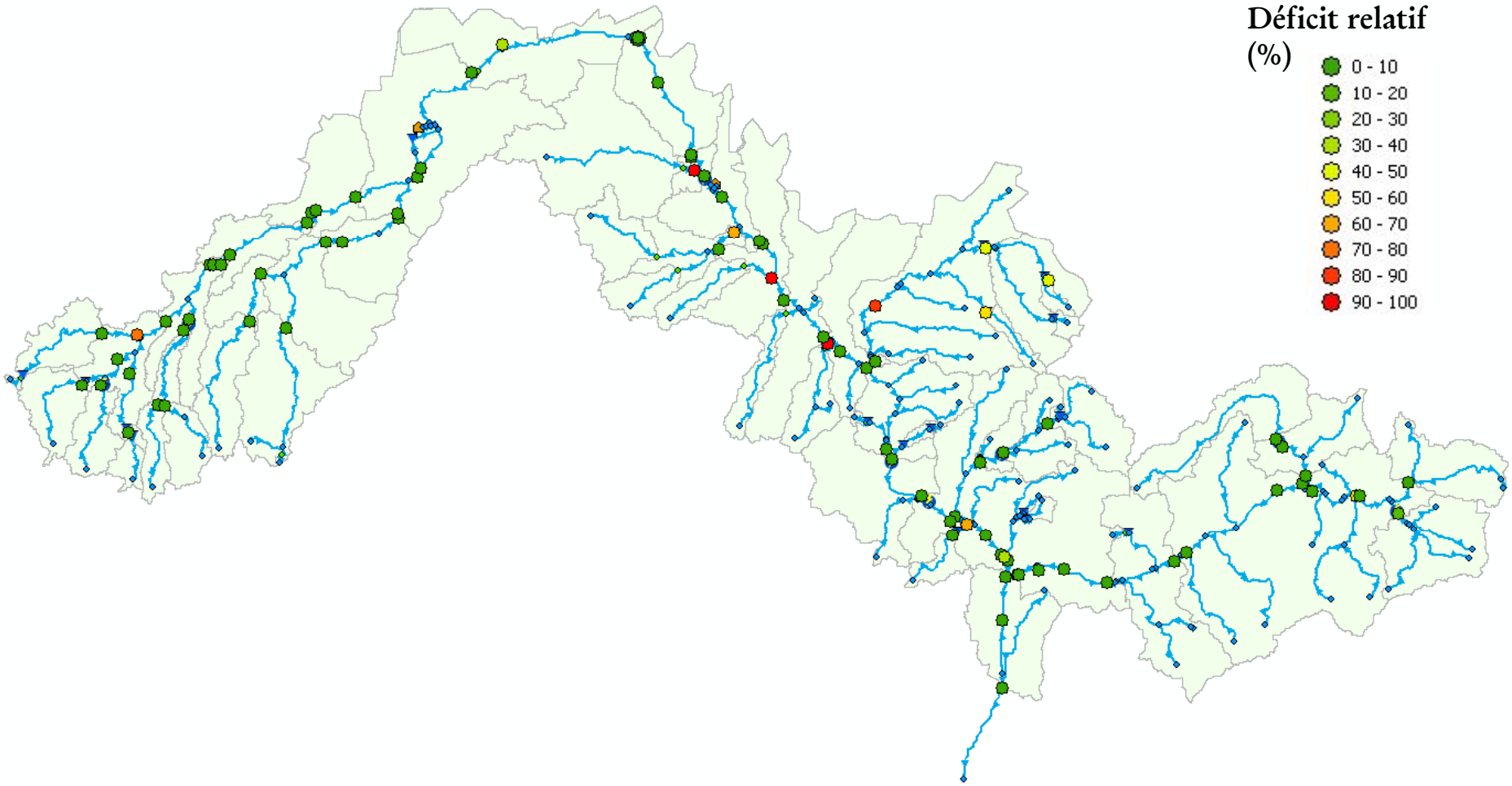
Water levels in Sélingué dam storage (Mali)



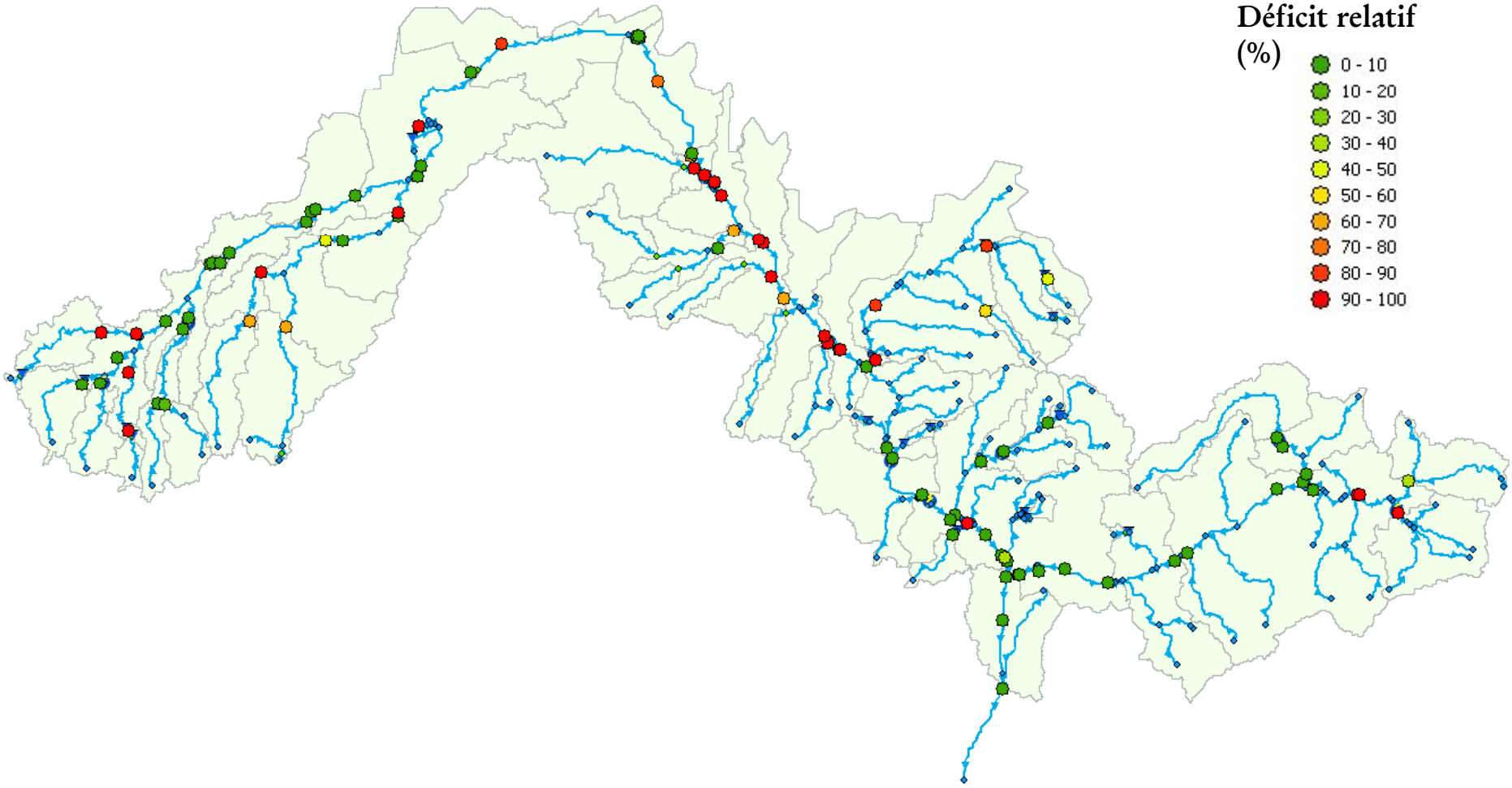
black : with management rule for downstream needs satisfaction

blue : with management rule for hydropower production optimisation

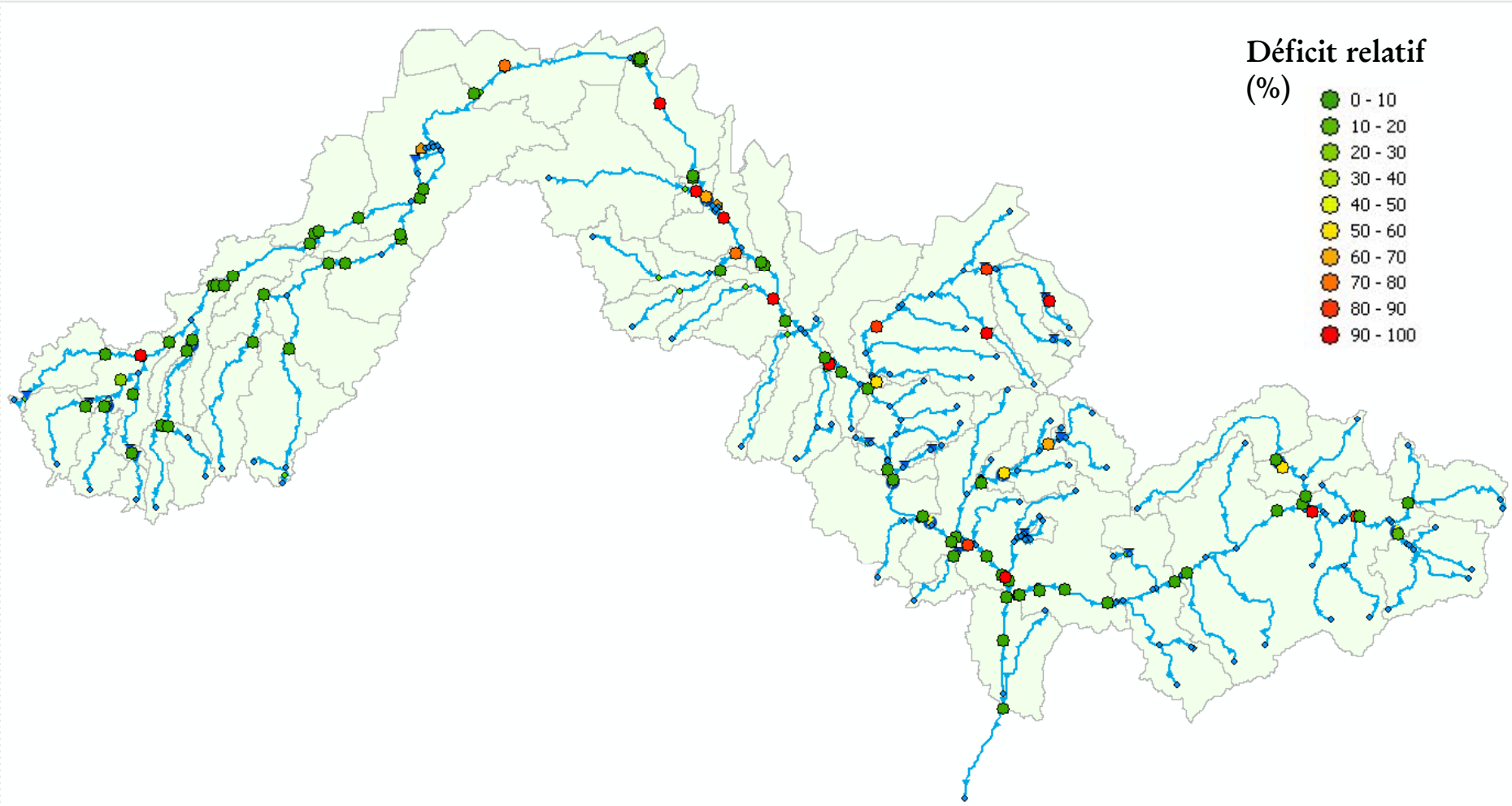
Current Situation / current needs
Reference 2005 Wet years



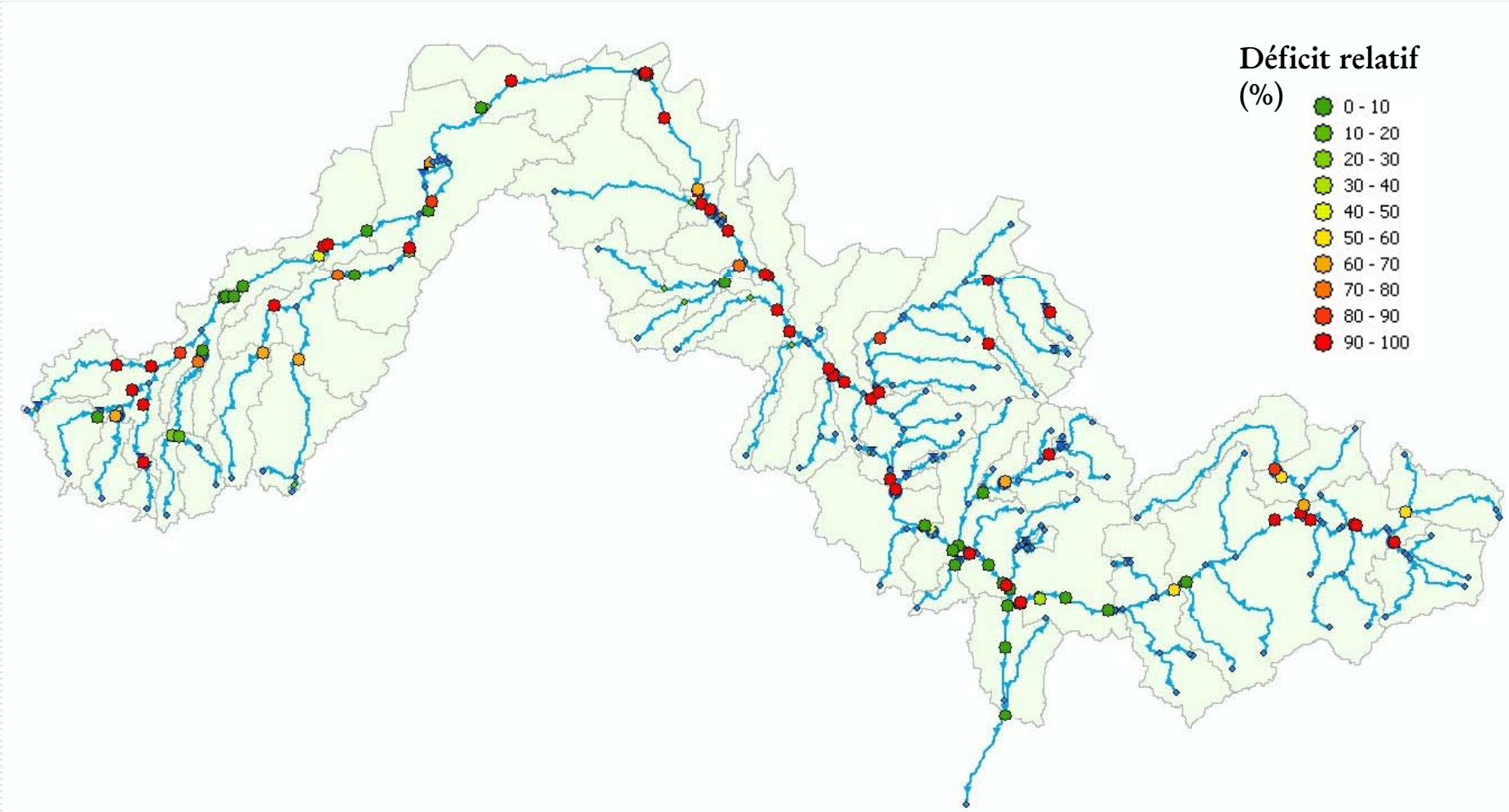
Current Situation / Current Needs
Reference 2005 dry years



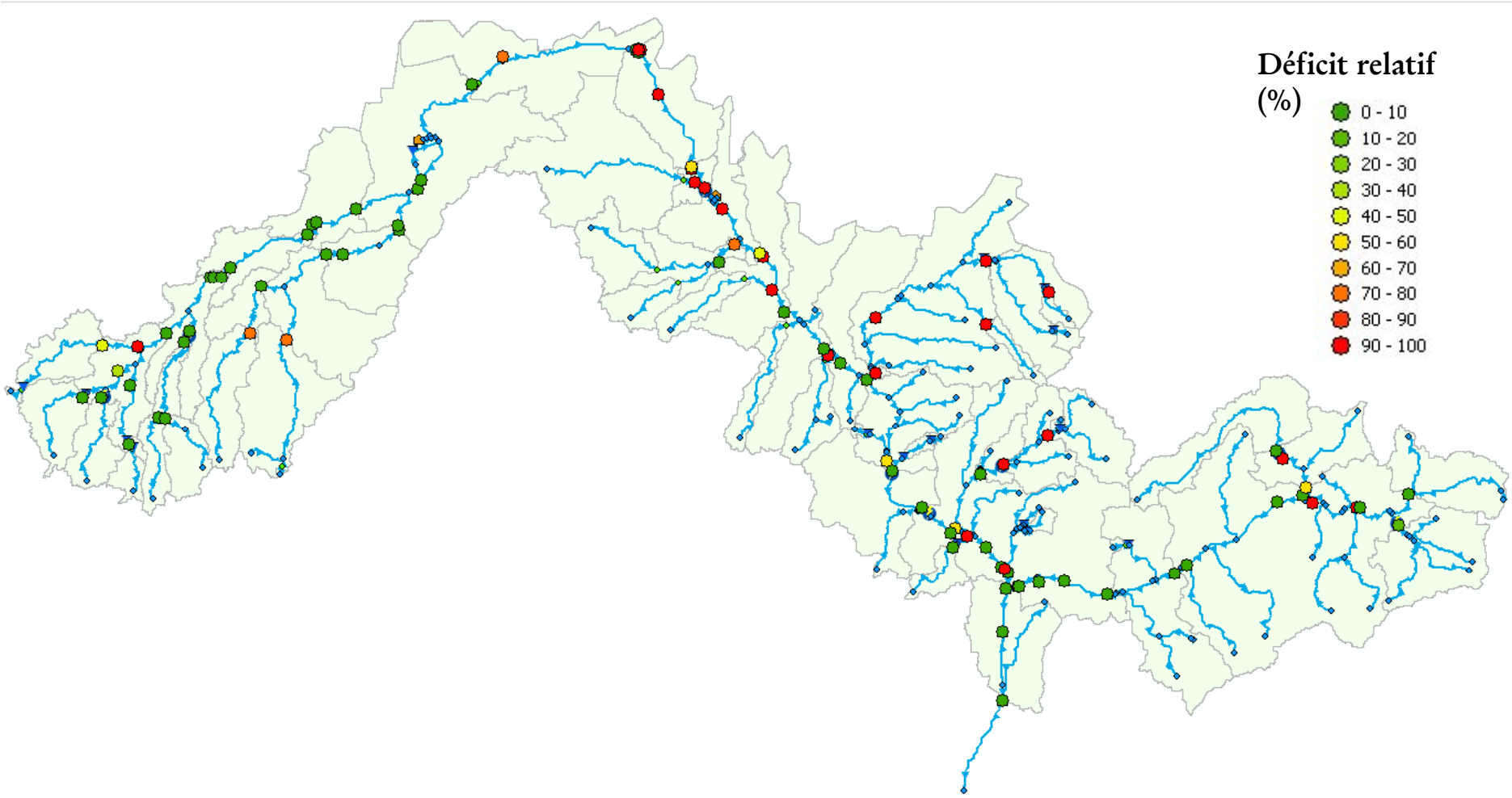
Current Situation/Needs 2015
Reference 2015 Wet years



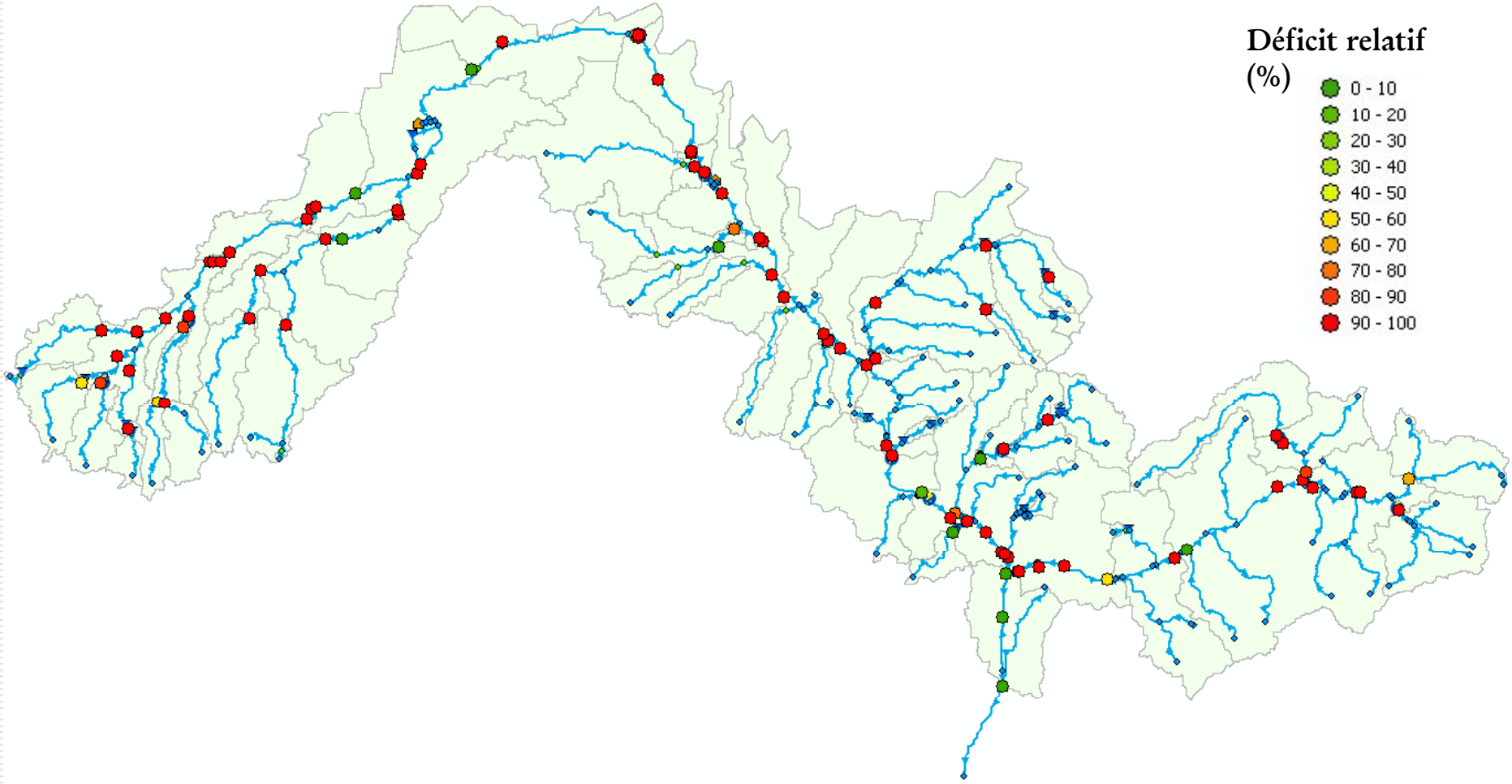
Current Situation / Needs 2015
Reference 2015 dry years



Current Situation/Needs 2025
Reference 2025 Wet years



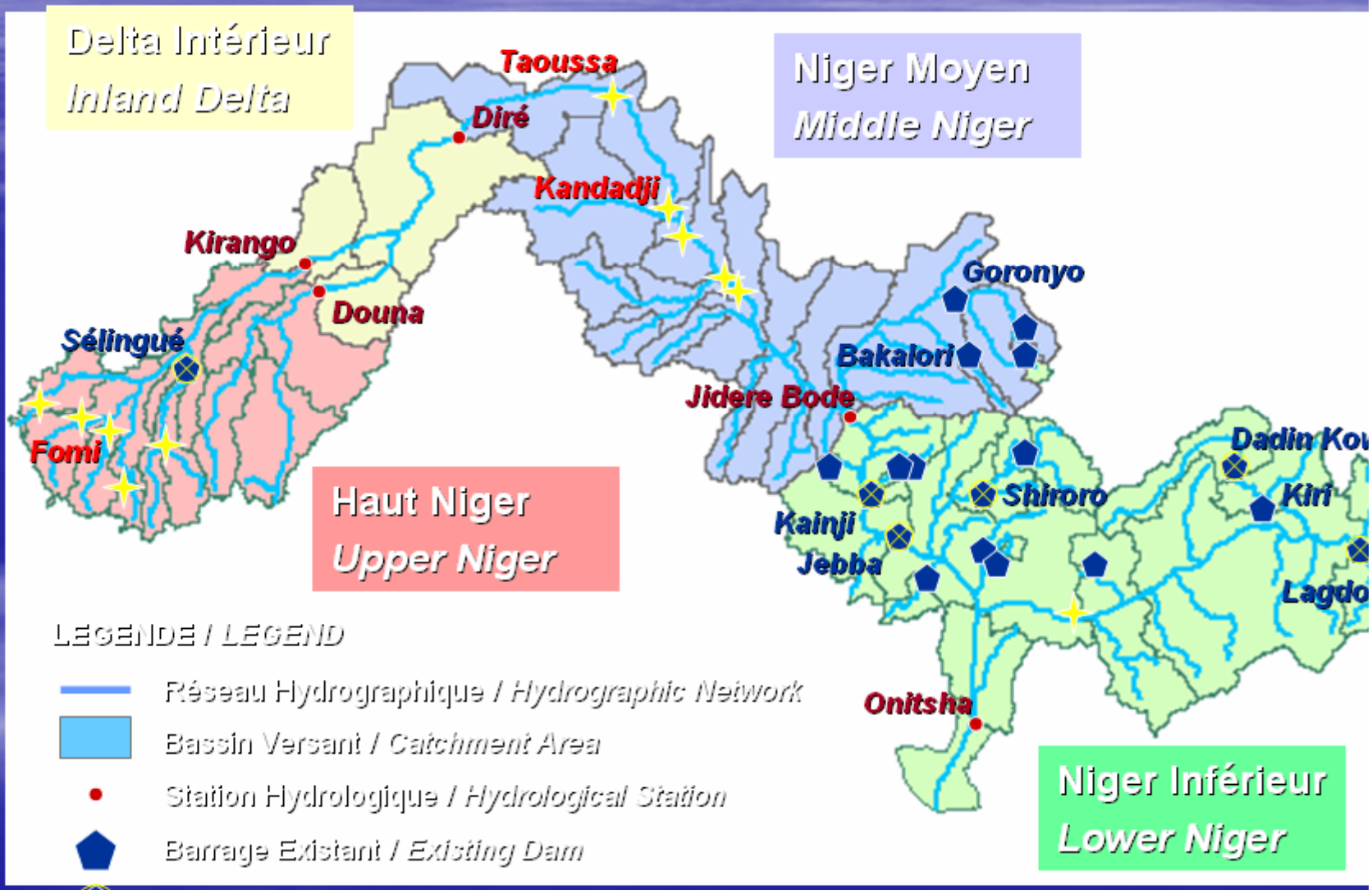
Current Situation/ Needs 2025
Reference 2025 dry years



List of 5 scenarios retained

	Fomi	Diara-guéla	Taoussa	Kandadji	Rehabilita-tion of Kainji	Improve-Ment of current manageme nt
SA optimized					*	*
1 : FO	*				*	*
2 : TA-KD			*	*	*	*
3 : FO-TA	*		*		*	*
4 : FO-TA-KD	*		*	*	*	*
5 : FO-DI-TA-KD	*	*	*	*	*	*

THE NIGER RIVER BASIN HYDROLOGICAL DIVISIONS



OUTCOMES REACHED

- Optimisation of 5 scenarios :
  - Optimisation of agricultural needs satisfaction, Optimisation of hydropower production
  - Optimisation of integrated management rules of infrastructures
  - Respect of objective flows/levels in the river: environmental flows, flood peak transparency.

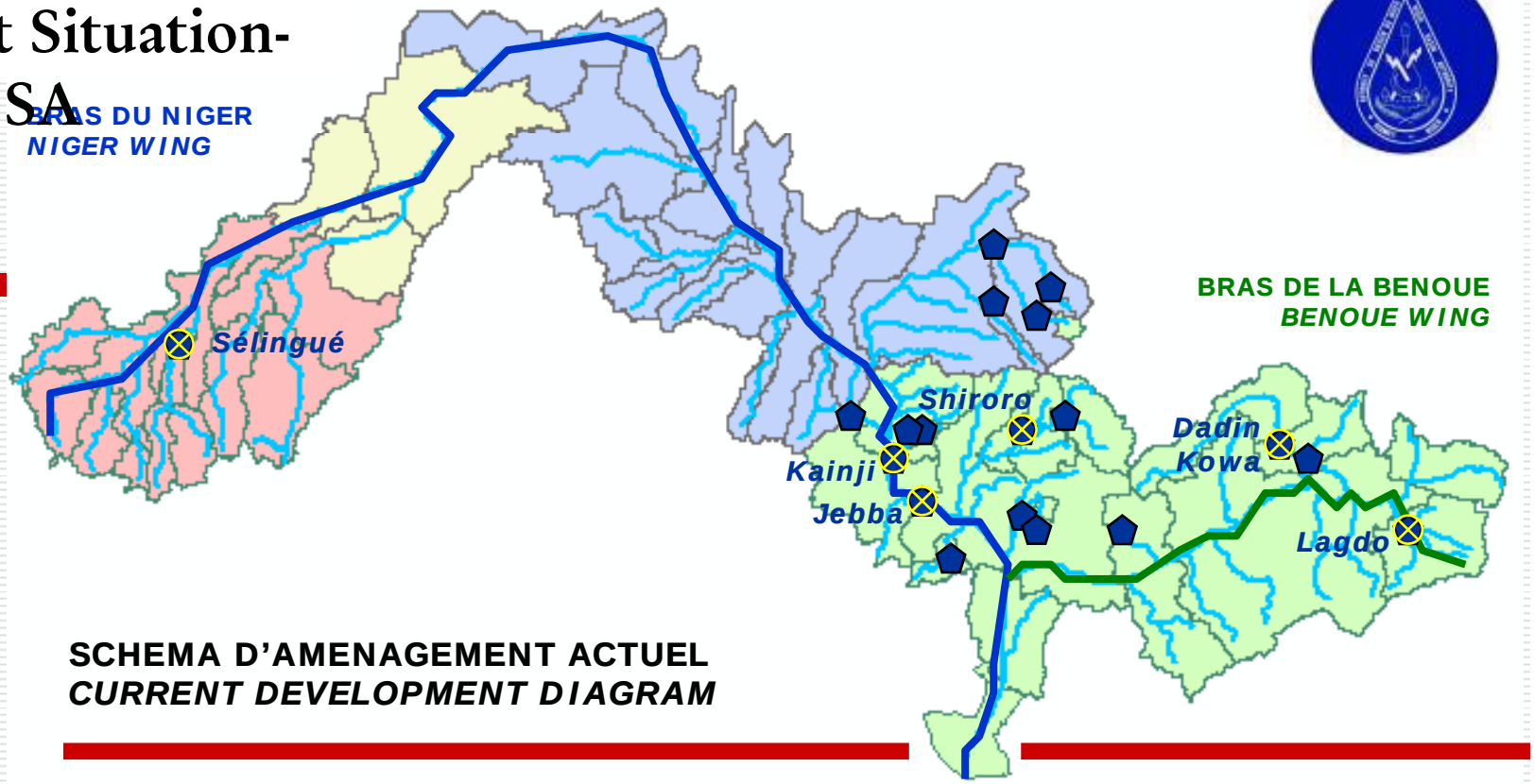
Synthetic outputs Table of 5 scenarios

Scenario	SAbis	Abis	FO	TA-KD	FO-TA	FO-TA-KD	FO-DI-TA-KD
Satisfaction level reached	1	2	4	2 upstr. / 8 downstr.	6	8	10
Overall average Production hydropower (GWh/y)	8316	8382	7904	7225	7256	7105	7014
Respect of environmental flows	No (downst. DIN)	No (downst. DIN)	Yes	No (Diré-Taoussa) / yes	Yes	Yes	Yes
Area Reduction in the Inner Delta (% in average)	0%	3%	14%	7%	14%	14%	19%
Irrigated area (x1000 ha)	460	610	715	380 / 1420	920	2130	2330
~~AEP/Cheptel~~	current 2005 satisfied	current 2005 satisfied	Term 2025 satisfied	Term 2025 satisfied	Term 2025 satisfied	Term 2025 satisfied	Term 2025 satisfied

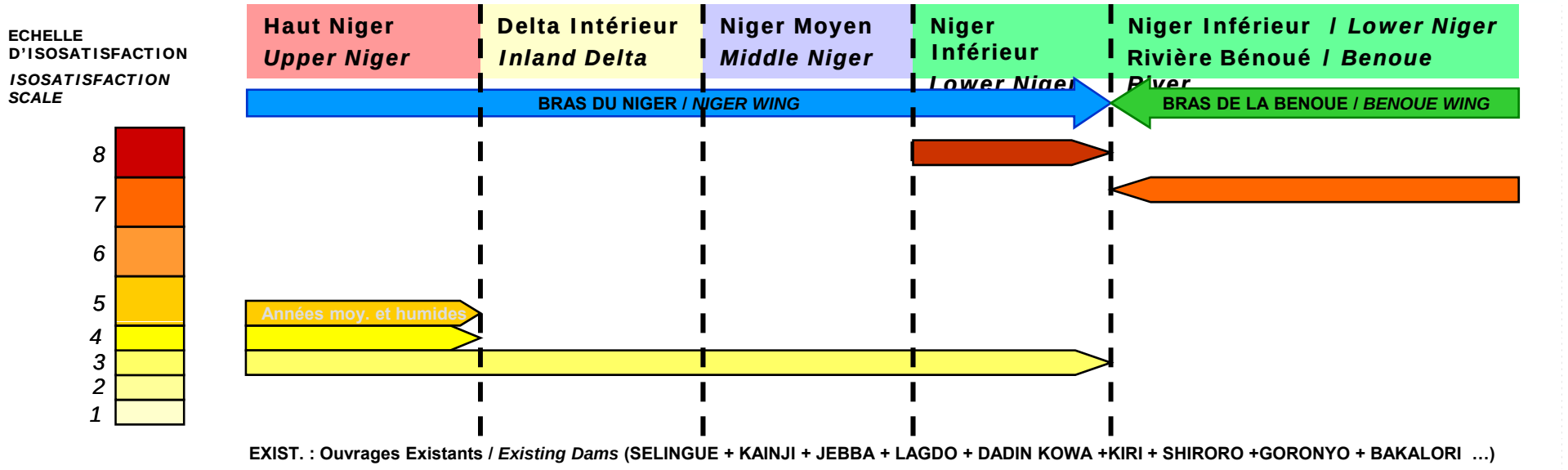
Development scenario adopted by NBA

April 30th, 2008 the summit of NBA Head of States and Government adopted development scheme of Fomi, Taoussa and Kandadji

Current Situation-SA

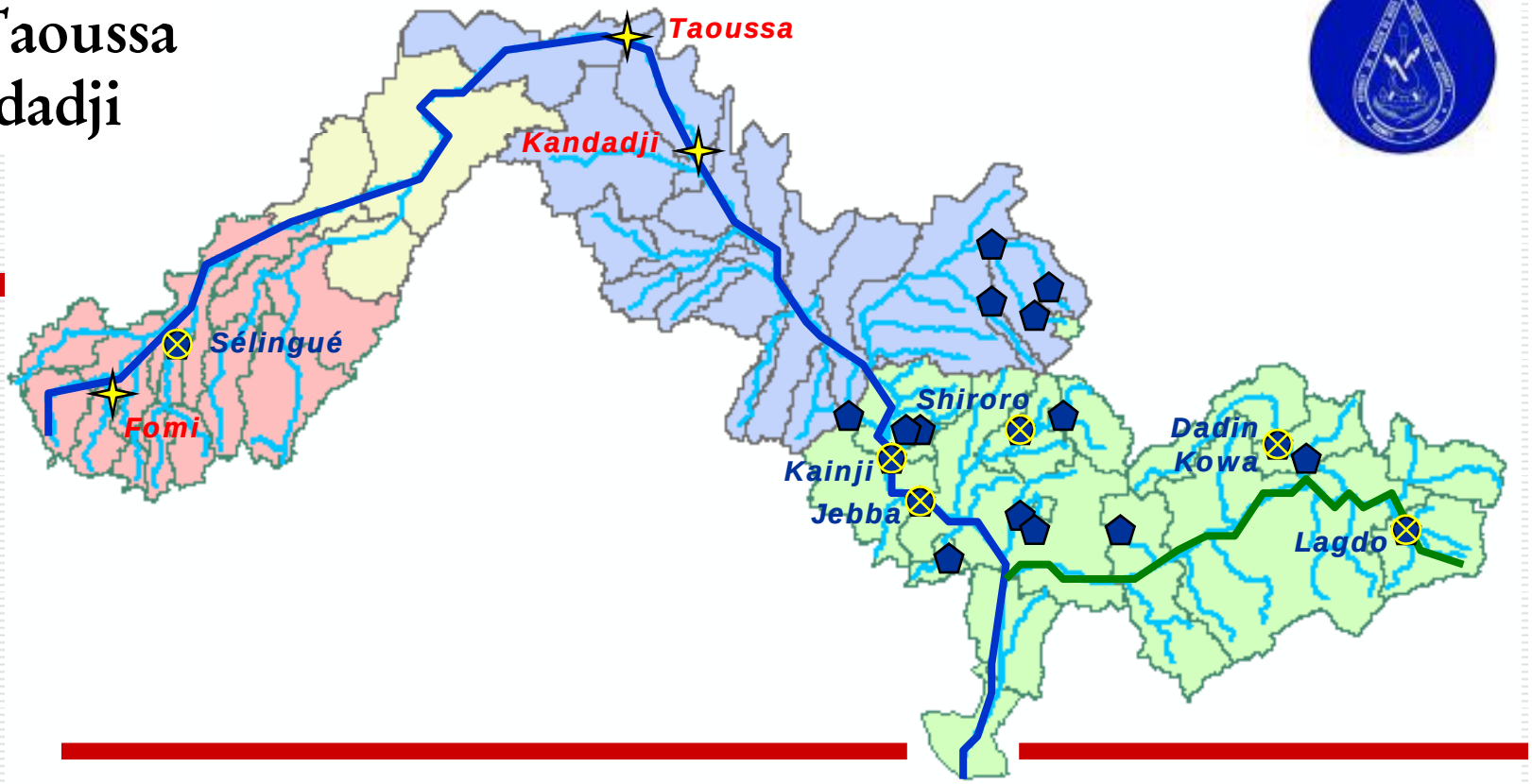


SCHEMA D'AMENAGEMENT ACTUEL
CURRENT DEVELOPMENT DIAGRAM



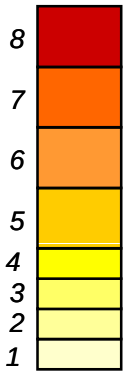
EXIST. : Ouvrages Existants / *Existing Dams* (SELINGUE + KAINJI + JEBBA + LAGDO + DADIN KOWA +KIRI + SHIRORO +GORONYO + BAKALORI …)

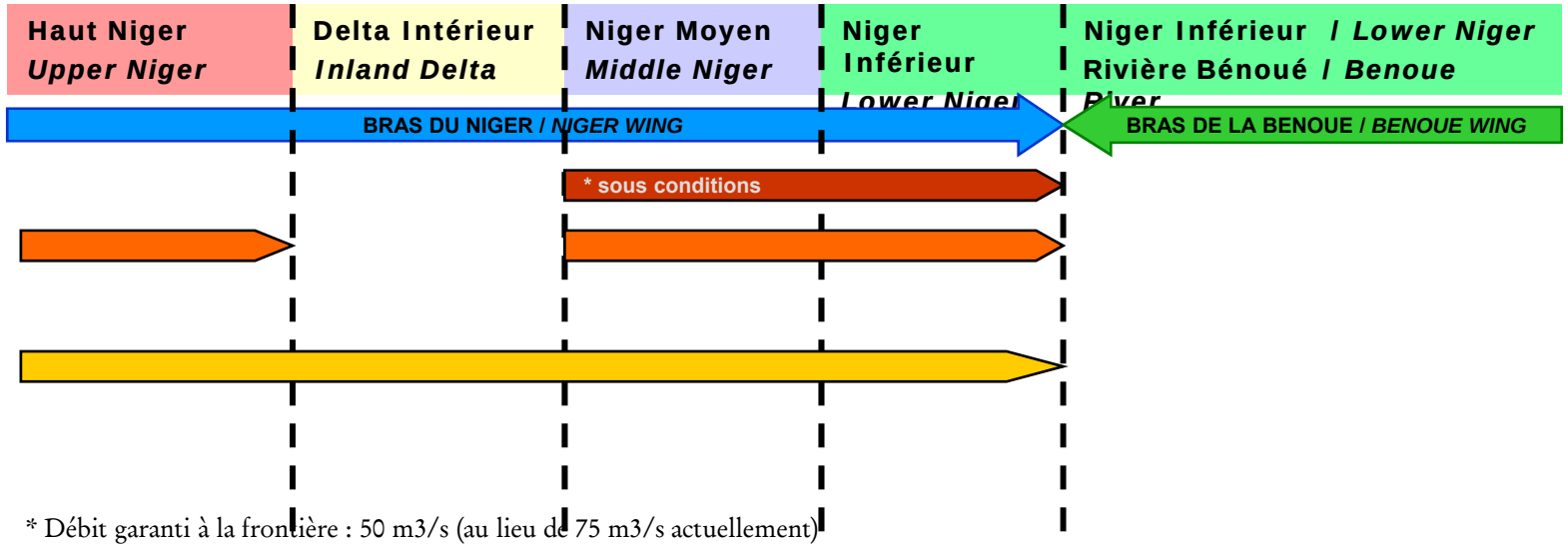
Fomi + Taoussa + Kandadji



ECHELLE D'ISOSATISFACTION

ISOSATISFACTION SCALE

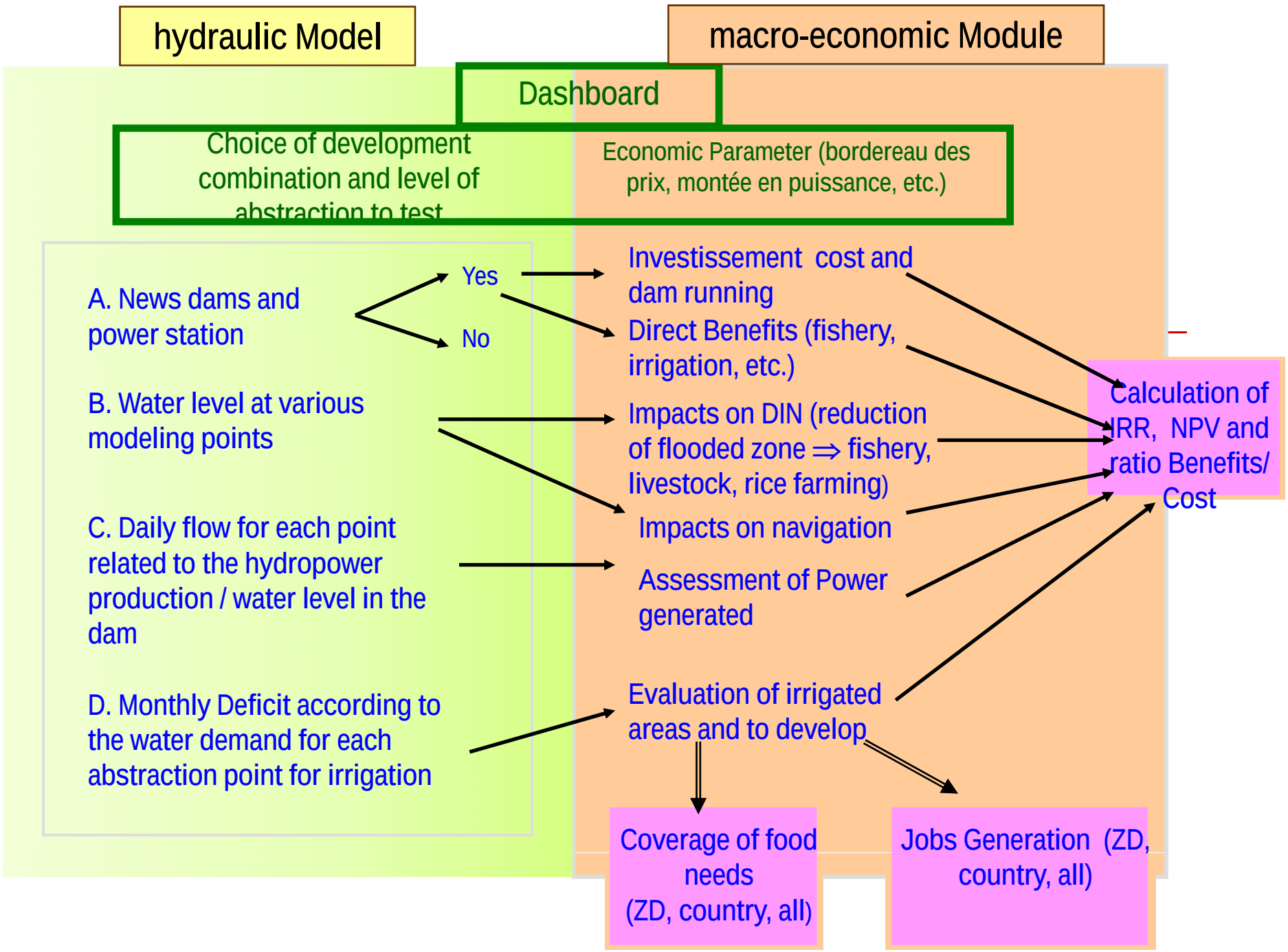




* Débit garanti à la frontière : 50 m3/s (au lieu de 75 m3/s actuellement)
Débit à Niamey atteint 52 m3/s en 1984

HYDRO-MACROECONOMIC DASHBOARD (1)

- objectives:
  - Characterise hydraulic scenarios in economic terms :
    1. monetaries : irrigated agriculture , hydropower production, fishery, navigation, inner delta (fishery, livestock, agriculture), environmental benefits
    2. non monetaries : coverage food needs, jobs creation


hydraulic Model
macro-economic Module
Dashboard
Choice of development combination and level of abstraction to test
Economic Parameter (bordereau des prix, montée en puissance, etc.)
A. News dams and power station
Yes
No
B. Water level at various modeling points
C. Daily flow for each point related to the hydropower production / water level in the dam
D. Monthly Deficit according to the water demand for each abstraction point for irrigation
Investissement cost and dam running
Direct Benefits (fishery, irrigation, etc.)
Impacts on DIN (reduction of flooded zone ⇒ fishery, livestock, rice farming)
Impacts on navigation
Assessment of Power generated
Evaluation of irrigated areas and to develop
Calculation of IRR, NPV and ratio Benefits/ Cost
Coverage of food needs (ZD, country, all)
Jobs Generation (ZD, country, all)

HYDRO-MACROECONOMIC DASHBOARD(2)

- Outcomes :
  - Support to Sustainable Development Action Plan (SDAP) elaboration
  - Support to financial programming of SDAP (Investment Program)

PERSPECTIVES (1)

- Aid decision support tool :
  - Anticipate emergencies and deficits
  - Plan realisations
  - strategic management of hydraulic works, in particular within the framework of management committees for these works : management of shortage, conflicts management, flooding prevention …..

PERSPECTIVES (2)

- Use of tool at local scale (country):
  - Utilisation of Dashboard to launch simulation related to a sub-basin jointly with Observatory.
  - Development of tactical management tools for hydraulic structures issue from the global Model Niger.

PERSPECTIVES (3)

Model linked to a technical environment technique

- Back to Hycos network and its database
- Linked to Database «abstractions »
- Gridded with the computerized forecasting system….

BIBLIOGRAPHY

- FINAL REPORTS OF HYDRAULIC MODEL FOR ALLOCATION AND MANAGEMENT OF NIGE BASIN WATER RESOURCES, CONSULTANCIES Offices DHI- BRLi


THANKS YOU FOR YOUR ATTENTATION

- Le fleuve Niger, long de près de 4200 km (3ème d'Afrique et le 9ème du monde), draine une superficie de l'ordre de 2 100 000 km², soit un tiers de la superficie totale de la région Ouest africaine. Le bassin topographique du fleuve Niger est en partage entre l'Algérie, le Bénin, le Burkina, le Cameroun, la Côte d'Ivoire, la Guinée, le Mali, le Niger, le Nigeria, et le Tchad

- La partie hydrologiquement active de ce bassin couvre près de 1 500 000 km² avec un potentiel jusque-là peu exploité. Elle concerne hormis l'Algérie, les neuf autres pays suscités

- Ce bassin comporte cinq grandes zones hydro écologiques qui sont :

- - le Niger supérieur d'une superficie d'environ 740 000 km², de pluviométrie moyenne variant entre 800 et 2000 mm, va de sa source dans le village de Koubikoro (Guinée) jusqu'à Kémacina (Mali) ;

le Delta intérieur d'une superficie d'environ 80 000 km², avec une pluviométrie annuelle variant entre 200 et 800 mm, s'étend sur un rectangle orienté Sud-Ouest /Nord-Est sur une longueur de 450 km, une largeur de 125 km entre Kémacina et San au Sud et Tombouctou au Nord (Mali) ;

le Niger moyen d'une superficie d'environ 530 000 km², où la pluviométrie varie entre 200 et 700 mm, va de Tombouctou (Mali) à Malanville (Bénin) ;

- le Niger inférieur et le Delta maritime d’une superficie d’environ 650 000 km², de pluviométrie variant entre 700 et 3 000 mm, s’étendent de Malanville jusqu’à l’embouchure du fleuve au Nigeria.

Mike Basin (2)

- Le concept du modèle s'affranchit de la topographie, réseau hydrographique simplifié, pas possible d'identifier les zones d'inondation, pas de calcul de hauteur d'eau
- modèle de bilan aux nœuds,
- propagation simplifié de débit d'un nœud à un autre
- Modèle pour simulation d'allocution et non simulation d'écoulement (modèle hydraulique)
- Données d'entrée : ruissellement, si pas de d'infos à une station hydro on utilise le modèle pluie/ débit pour générer les ruissellements (module NAM)
- Traitement de l'aspect qualité de l'eau (Module qualité de l'eau)

River Basin Management in GIS

- **The easy-to-use, yet comprehensive water resources model**
- **GIS** - the only water resources software that lets you do all modeling in ArcGIS 9
- **simple** - minimal data requirements, simple process models
- **powerful** - all relevant elements and operation logic can be modeled
- **fast** - lots of time-saving features in the user interface, fast simulations
- **easy** - no numerical instability, no need to be a hydraulics expert

River Basin Management in GIS

- **accurate** - no restrictions on time step length, realistic reservoir modeling
- **impressive** - results as maps in ArcGIS, HTML tables, animations, databases
- **expandable** - just add rainfall-runoff, water quality, and/or groundwater as you go
- **open** - link to Excel, customization or advanced rules with Visual Basic or .Net
- **valuable** - built-in non-linear optimization of any model input
- **a standard** - hundreds of users world-wide, consulting and research applications

1. Les méthodes de simulation basées sur la propagation simplifiée

- **Sans routine** : l'eau qui entre le système en amont d'un nœud est instantanément disponible à ce nœud s'il n'ya pas d'extraction ou de perte.
- **Muskingum**: cas de propagation des ondes de crue , Géométrie du cours d'eau
- **Translation de l'onde** : pas d'atténuation de l'onde , le qe est stocke puis poussé et remplacé par le qe suivant durant un pas de temps constant
- **Réservoir linéaire :** propagation , pas besoin de topo

Méthode Muskingum

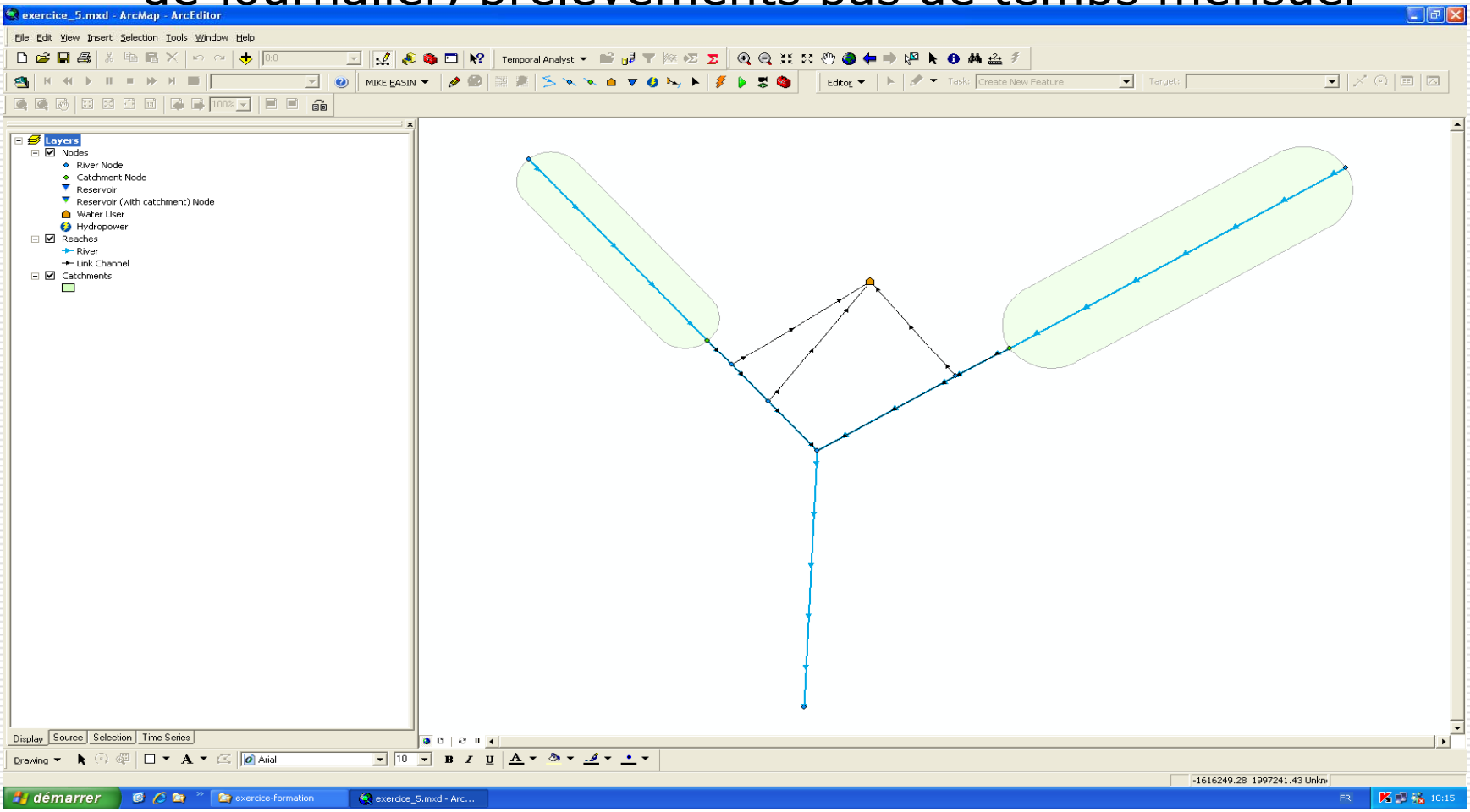
- Cette méthode est basée sur un concept simple qui consiste à écrire que le volume d'eau stocké dans un bief est proportionnel à une moyenne pondérée des débits observés au même instant des 2 extrémités du bief
- $V = K(\beta.Qe + (1- \beta).Qs$
- V(vol stocké dans le bief), Qe (débit entrant),Qs (débit sortant), K (temps de propagation dans le bief), β (terme ans dimension lié à l'amortissement de la crue dans le bief, coefficient d'atténuation).

Méthode de réservoir linéaire

- Distribue le flux d'un noeud amont vers un noeud aval durant un temps T après un apport et prélèvement au nœud et à partir du nœud.
- Volume sortant = (1-T/(ΔT/K))* Volume entrant + T. Stockage
- Δ Stockage= (Volume entrant- Volume Sortant) (m3)
- K : coefficient exprime le temps de propagation

2. Calcul de Débits aux noeuds

- Données d'entrée : débits spécifiques à pas de temps de journalier, prélèvements pas de temps mensuel



Mike Basin (3)

- Fonctionne sous ArcGIS : préparation de couverture de bassin versant à projeter, utilisation de toutes les fonctionnalités d'un SIG (délimitation fine de BV, direction de l'écoulement, etc.)
- Interface d'analyse de séries temporelles : reconstitutions des données, analyses et critiques des données et visualisation graphique
- Deux fichiers de BDD : fichiers de données et fichiers de résultats

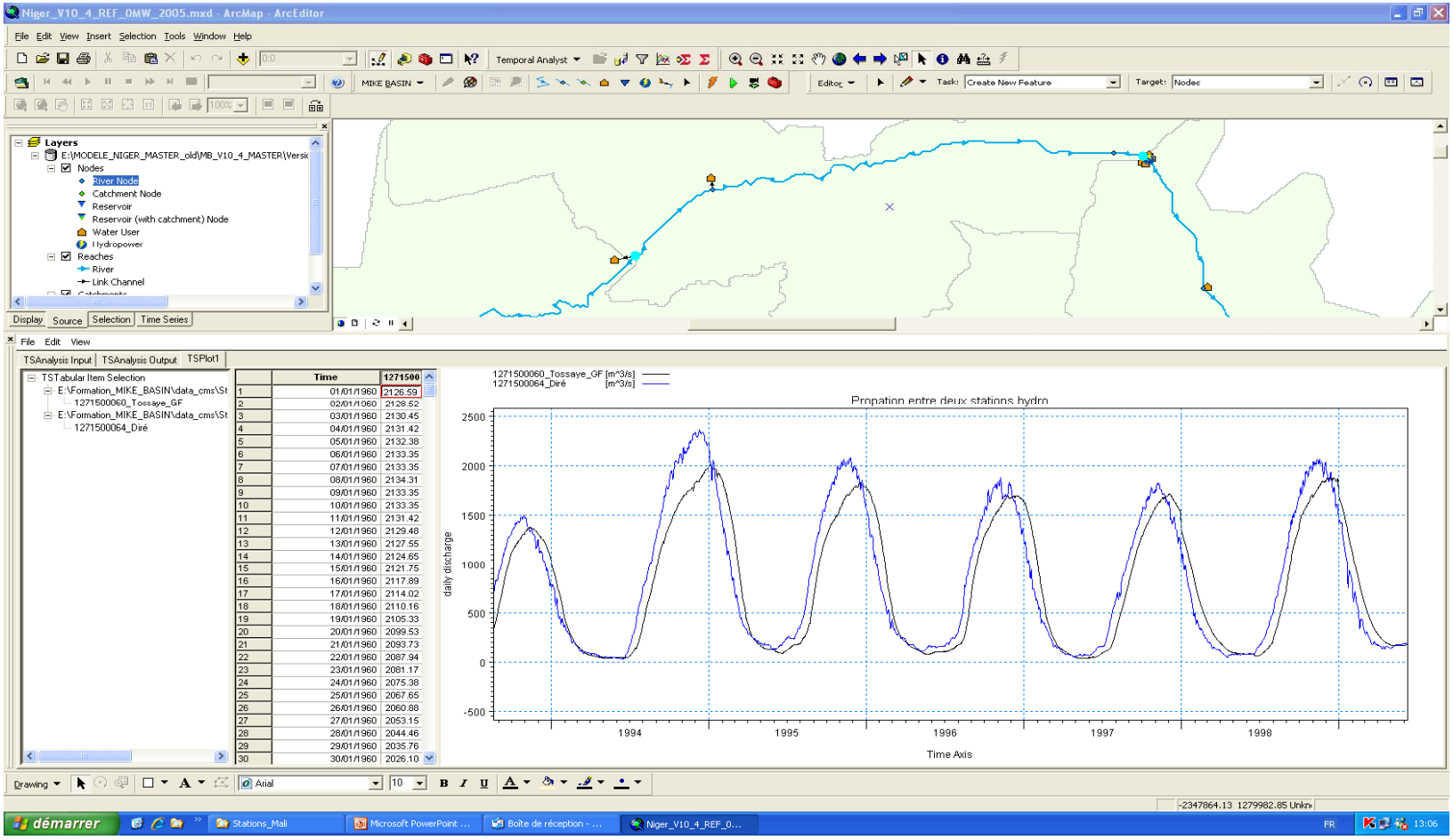
Determination du Qenv

ZD	Cours d'eau *River*	Station *Station*	Période de mesure *Periode of measurement*			VCN 10 (m3/s)			Qmin (m3/s)		
						fréquence de non-dépassement			fréquence de non-dépassement		
						1/10	2/10	5/10	1/10	2/10	5/10
Niger											
Z1	Niger	Banankoro	1967	à	2006	3	5	18	3	5	17
Z2	Niger	Koulikoro	1907	à	2006	32	35	53	31	33	49
Z2	Niger	Ké-Macina	1953	à	2006	32	26	49	31	33	49
Z4	Niger	Diré	1924	à	2006	3	5	29	3	5	27
Z5	Niger	Tossaye	1979	à	2001	4	4	6	4	4	6
Z5	Niger	Ansongo	1950	à	2006	2	3	21	2	3	24
Z5	Niger	Kandaji	1966	à	2006	4	5	14	3	4	11
Z5	Niger	Niamey	1929	à	2006	4	6	26	3	4	22
Z5	Niger	Malanville	1952	à	2000	10	15	43	7	13	39
Z8	Niger	Jebba	1914	à	1991	217	249	378	191	225	336
Z8	Niger	Baro	1980	à	2002	365	397	784	333	344	736
Z11	Niger	Lokoja	1914	à	1990	664	770	1 078	640	745	1 030
Z11	Niger	Onitsha	1955	à	2006	750	876	1 216	661	788	1 060
Affluents du Niger - *Tributaries of Niger*											
Z1	Niandan	Baro	1947	à	2006	0.4	1.3	4.5	0.4	1.0	4.0
Z3	Baoulé	Dioila	1953	à	2006	0.0	0.0	0.2	0.1	0.2	1.4
Z3	Bani	Douna	1951	à	2006	0.0	0.0	3.6	1.2	2.4	11.4
Z6	Gorouol	Alcongui	1961	à	2003	0.0	0.0	0.0	0.0	0.0	0.0
Z6	Tapoa	Campement_W	1963	à	2003	0.0	0.0	0.0	0.0	0.0	0.0
Z6	Mékrou	Kompongou	1960	à	1985	0.0	0.0	0.0	0.0	0.0	0.0
Z7	Sokoto	Kende	1989	à	1991	3.8	3.8	3.8	3.7	3.7	3.7
Bénoué - *Benue*											
Z9	Bénoué	Garoua	1930	à	1991	0.0	0.0	1.0	1.0	1.0	1.0
Z10	Bénoué	Makurdi	1955	à	2006	170	184	222	164.4	177.8	213.5
Z10	Bénoué	Umaisha	1955	à	2006	60	98	172	56.75	69.2	166.5
Affluents de la Bénoué - *Tributaries of the Benue*											
Z9	Mayo Kébi	Cossi	1954	à	1989	0.0	0.0	0.0	0.1	0.2	0.4
Z9	Taraba	Gassol	1989	à	1990	0.3	0.5	1.0	0.3	0.4	0.8
Z9	Katsina Ala	Katsina Ala	1955	à	1982	14.9	17.5	38.2	10.6	11.2	25.0

VCN30 > Q min
0,75 x Q min < VCN30 < Qmin
0,5 x Q min < VCN30 < 0,75 x Qmin
0 < VCN30 < 0,5 x Qmin

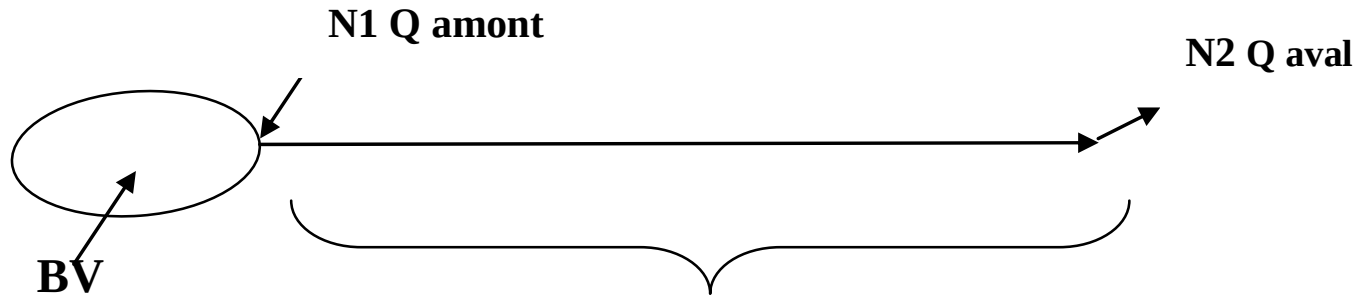
Calcul des apports intermédiaires(1)

- Cas de Propagation entre stations Amont et Aval

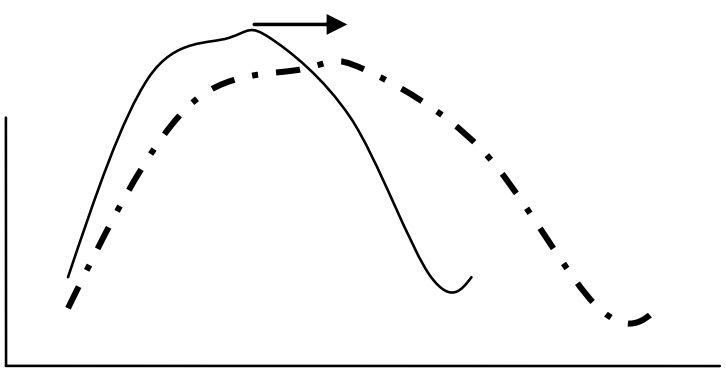


Propagation de signal

- Principe de la propagation .

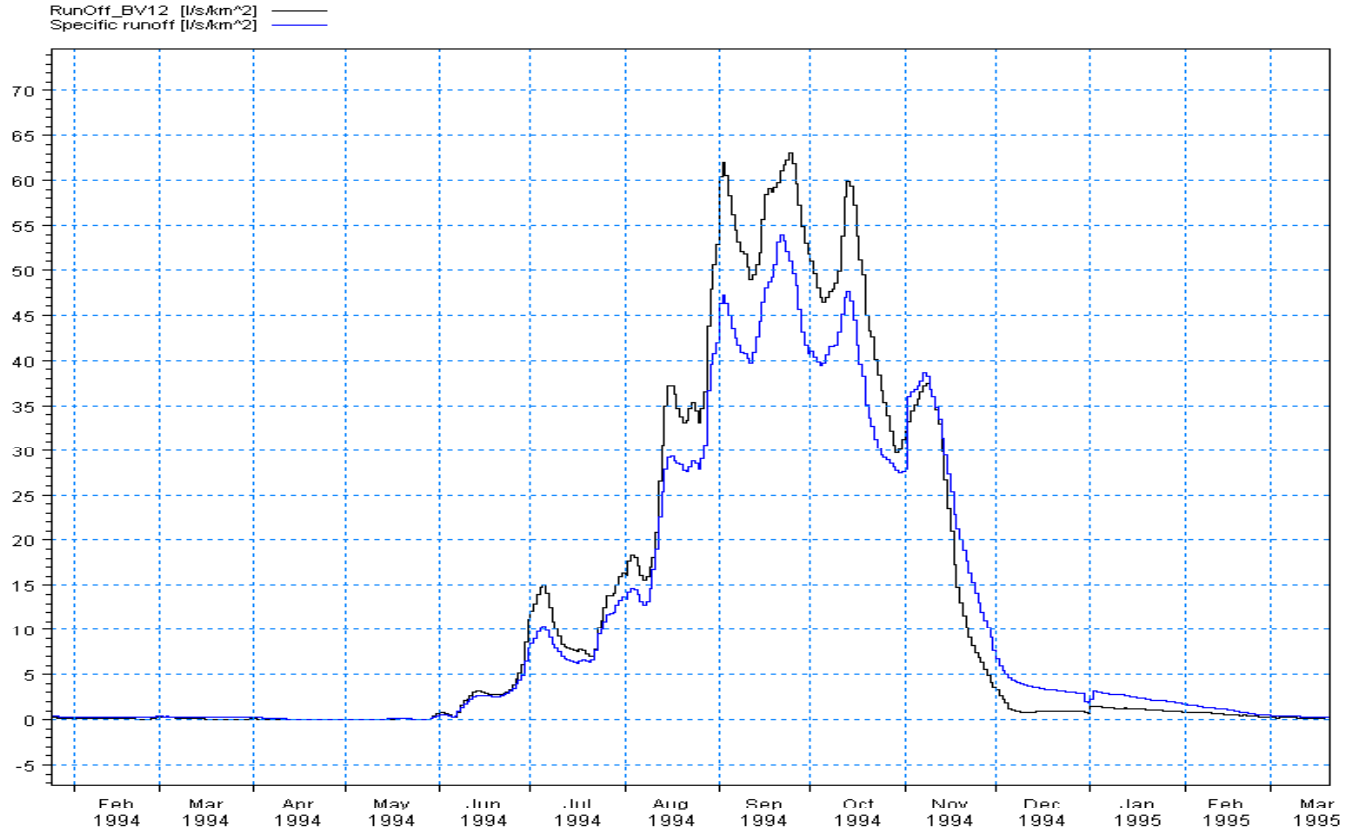


K propagation : temps de transfert du pic de l'amont sur l'aval

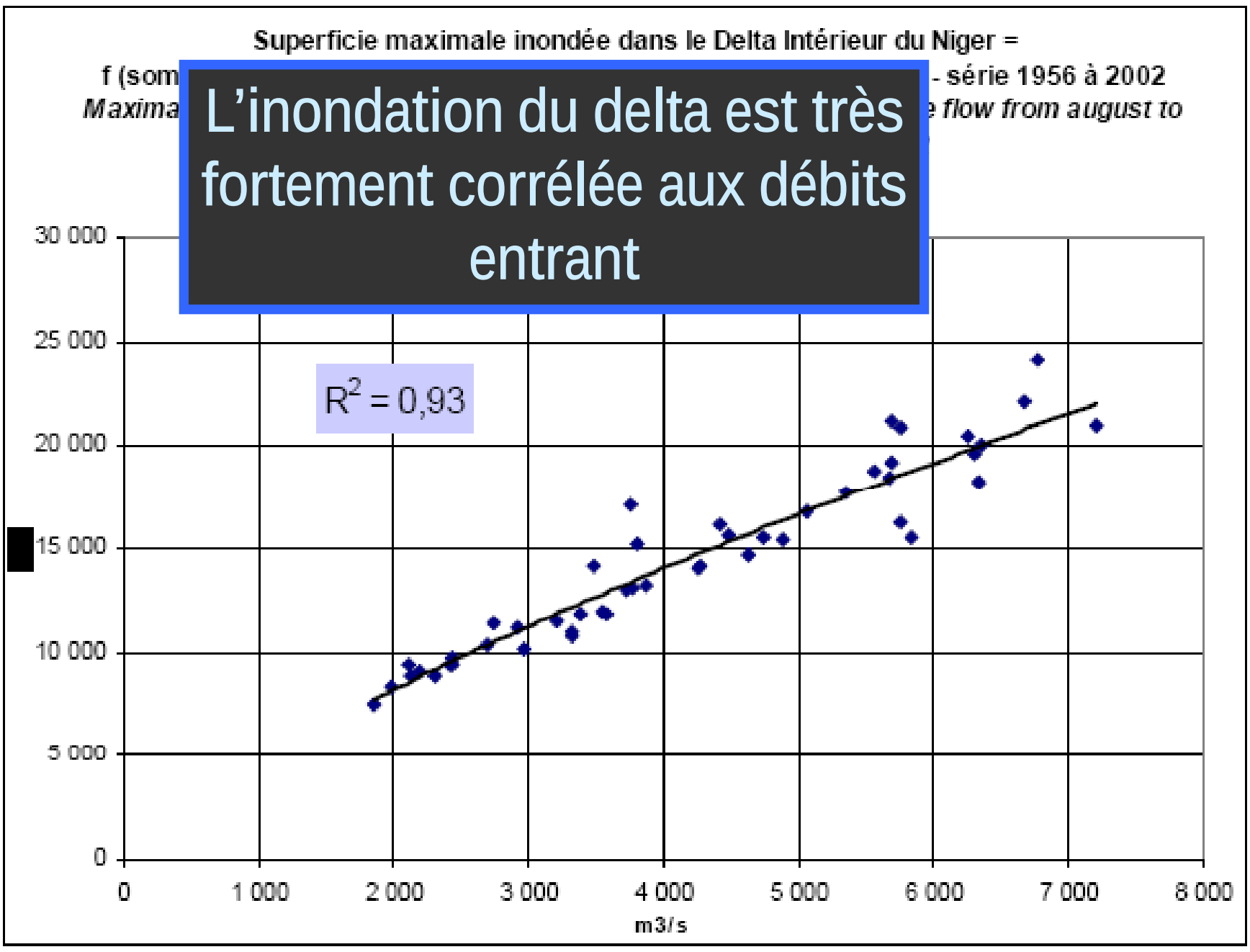


Calcul des apports intermédiaires(2)

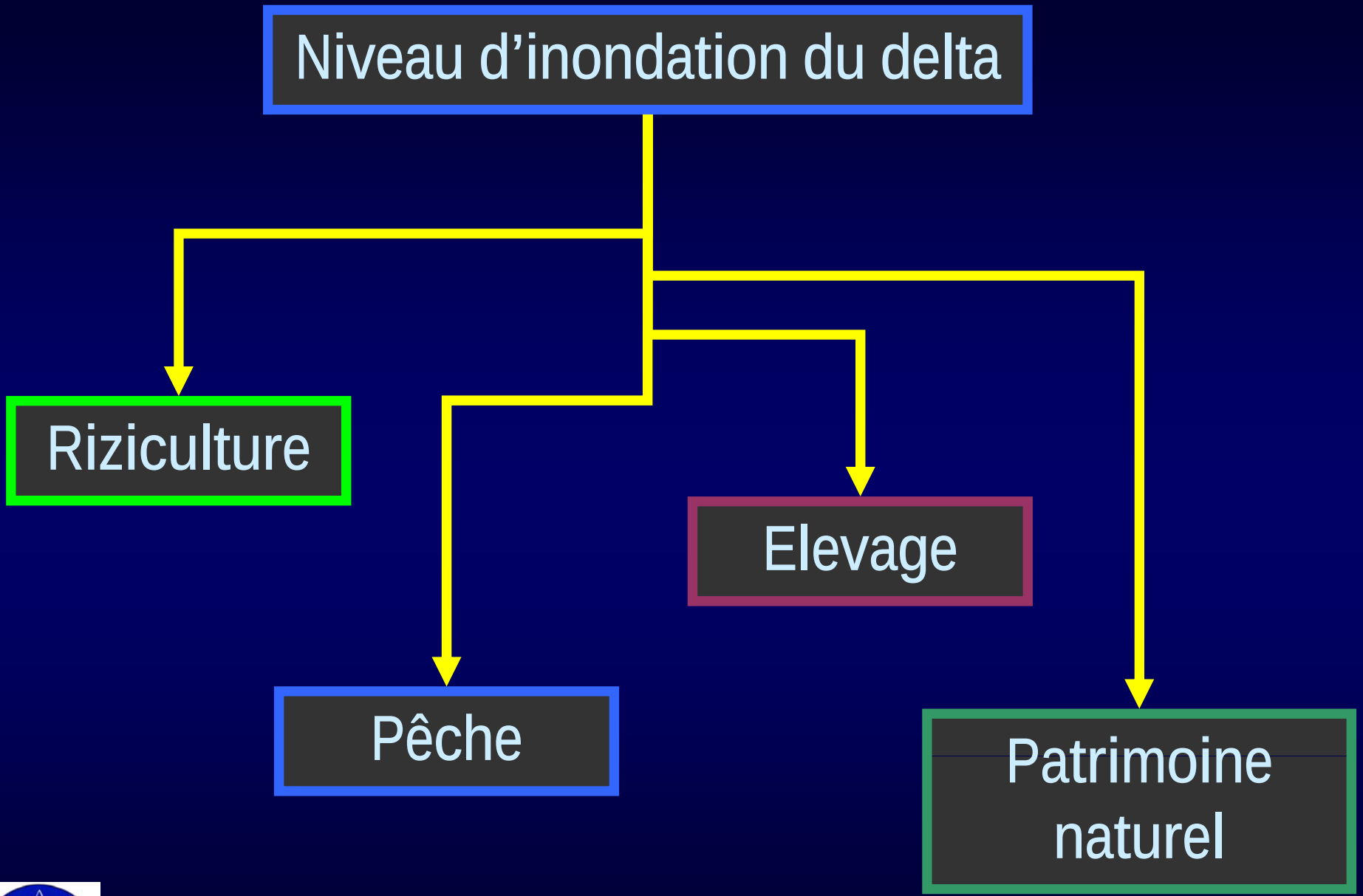
- pas de propagation entre l'amont et l'aval



L'inondation du delta est très fortement corrélée aux débits entrant



ISADES


Niveau d'inondation du delta
Riziculture
Elevage
Pêche
Patrimoine naturel

ISADES