Marseille CMI December 12-14, 2016
Mediterranean Regional Technical Meeting

Dealing with water scarcity through PPPs for desalination and Non-Revenue Water reduction

Cyprus Experience with Desalination and Non-Revenue Water Reduction

Nicos Neocleous
Acting Chief Water Officer
Water Development Department
Ministry of Agriculture, Rural Development and Environment
Republic of Cyprus

Bambos Charalambous
NRW and Water Utility Specialist
World Bank Consultant

15 December 2016

WORLD BANK GROUP

CENTER for MEDITERRANEAN INTEGRATION | CENTRE pour l'INTÉGRATION en MÉDITERRANÉE
مركز التكامل المتوسطي

Outline of Presentation

WATER SITUATION IN CYPRUS

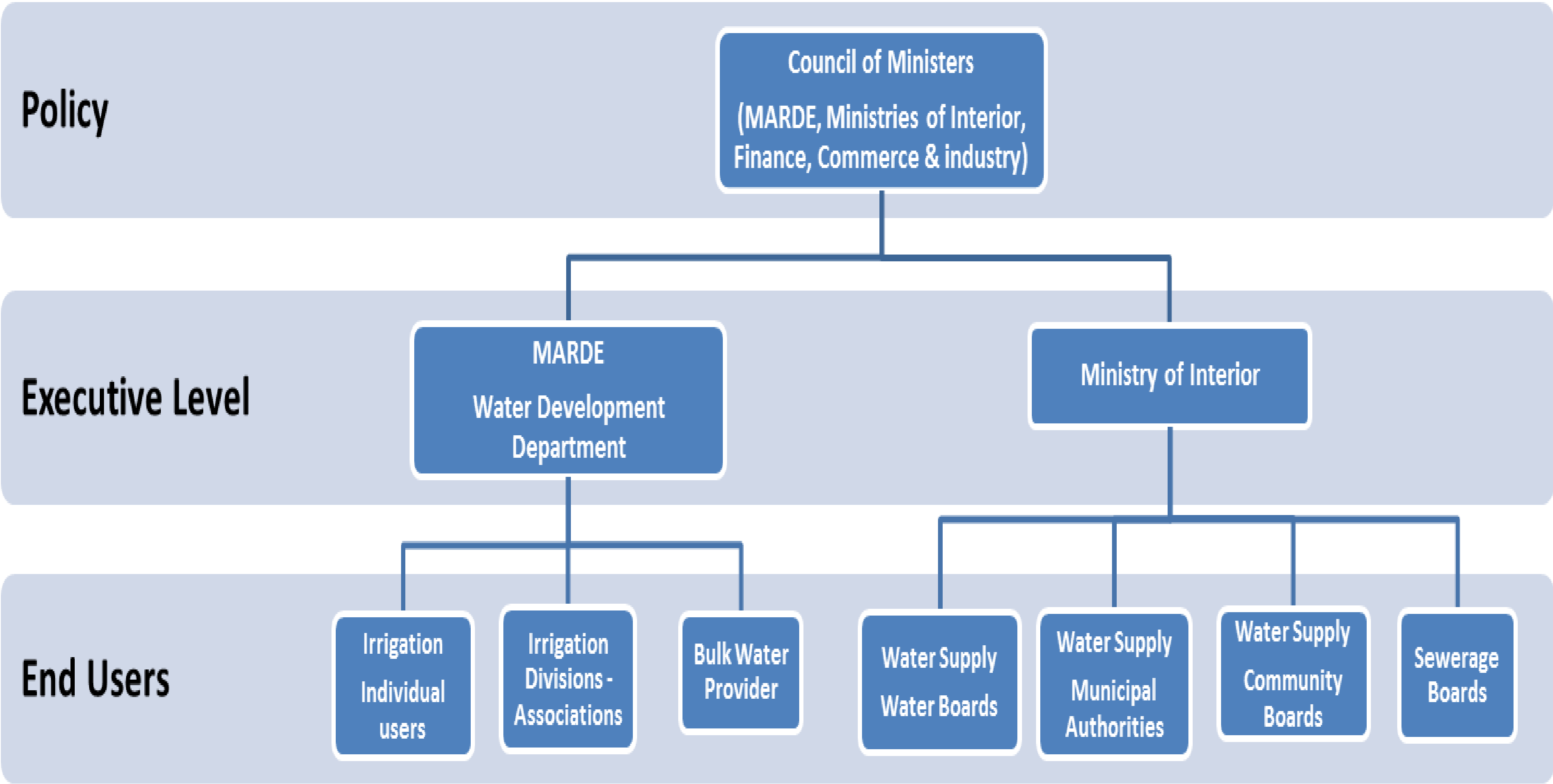
EXPERIENCE WITH DESALINATION

NON-REVENUE WATER REDUCTION

THOUGHTS ON NEXT STEPS

WATER SITUATION IN CYPRUS

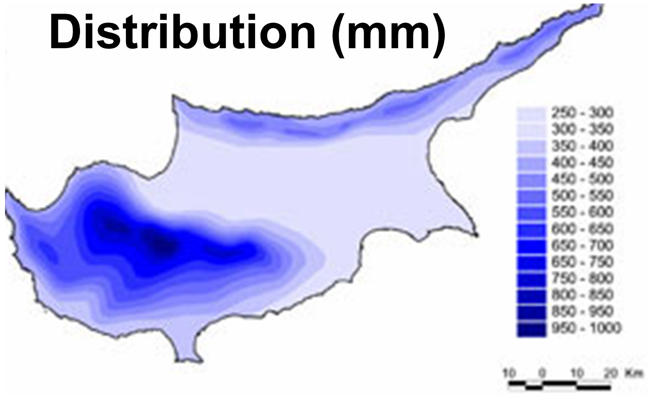
Institutional and Administrative Structure of the Water Sector in Cyprus



Water Situation in Cyprus

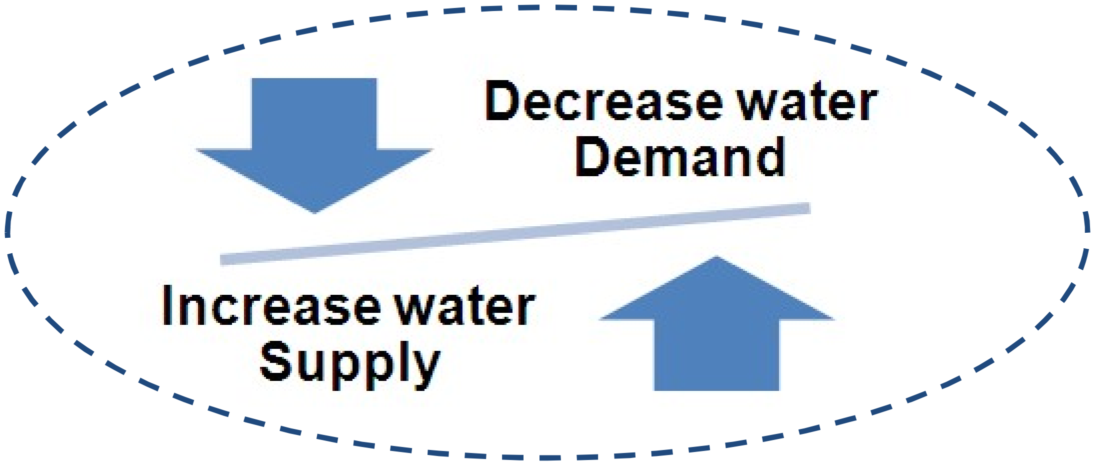
- Water scarcity has always been a very serious problem for Cyprus
  - Cyprus and Malta are the “water poor” countries of Europe
- Semi-arid climate
- Limited water resources
  - Depend mainly on rainfall
  - Scarce & expensive to exploit
- Unevenly distributed rainfall
- Frequent occurrence of droughts
- Many small catchments, but no perennial flow

Annual Rainfall Distribution (mm)

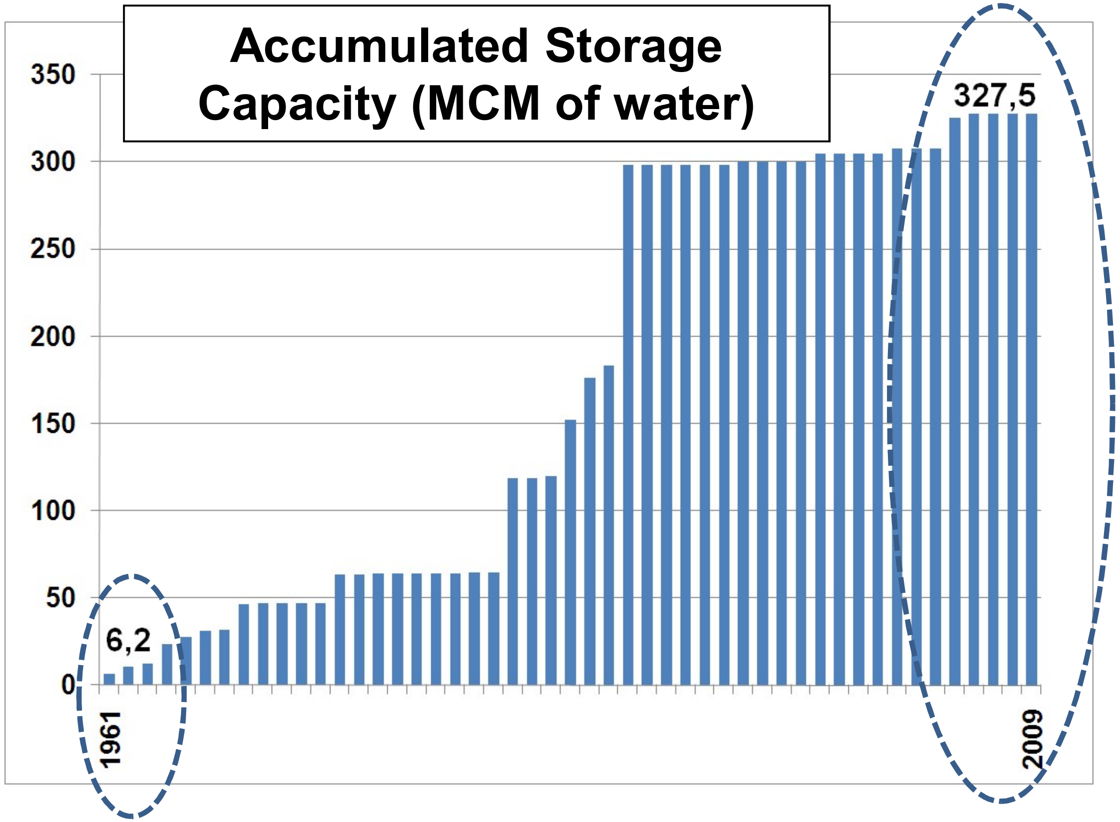


Water Management Master Plan

- Implementation embarked in the late 60s
- **Objective**: to satisfy in a sustainable way the different users of water and safeguard human & other life
- **Measures implemented**: to increase water availability and decrease water demand

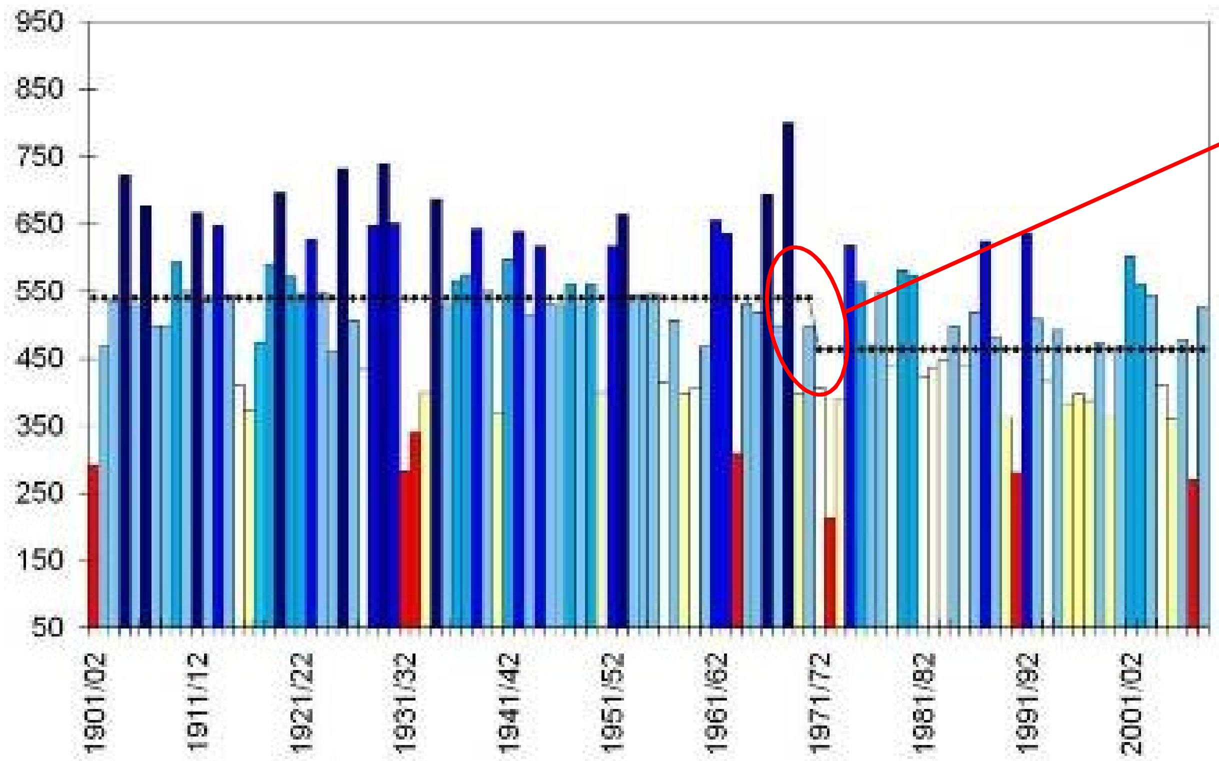


Supply Management



- Increased storage capacity through dam construction
- Drilled boreholes for domestic and irrigation purposes
- Constructed water treatment plants & recharge works

Declining Rainfall



Stepped drop of precipitation in the early 70s

LEGEND:
- Extreme wet (>130% normal)
- Wet (121-130% normal)
- Above normal (111-120% normal)
- Around normal (91-110% normal)
- Below normal (81-90% normal)
- Drought (71-80% normal)
- Severe drought ≤70% normal
- Average 1901-70 541 mm
- 1971-09 463 mm
- Normal 1961-1990= 503 mm

- Climate models predict rise in temperature and increase in the intensity and frequency of extreme drought events
- These conditions, coupled with increased water demands are worsening the water scarcity problem in Cyprus

Water Balance

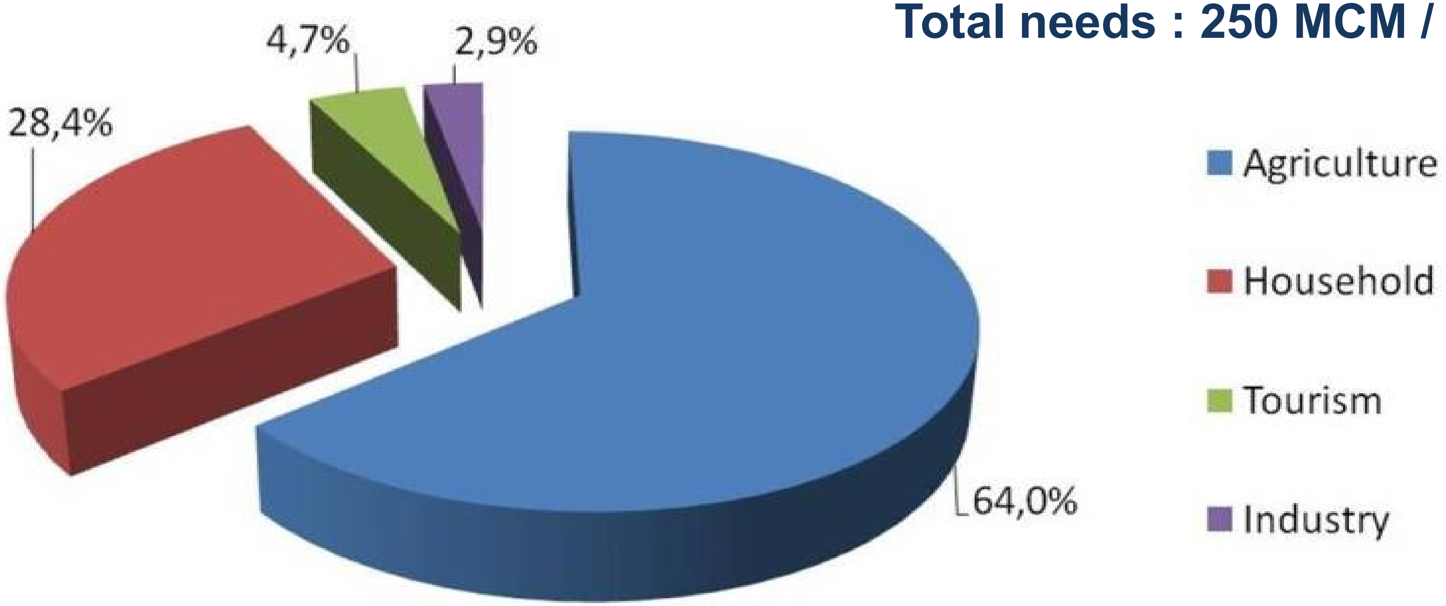
(mean values in Mm3 for period 2000-2011)

Rainfall:	476 mm
• Inflow into groundwater	201
• Outflow to the sea	62
Groundwater Balance [GW]	139
Inflow into surface storage [SW]	82
TOTAL Available (SW+ GW)	**221**
SW Releases	60
GW extraction (Pumping)	146
TOTAL Releases/ Extractions	**206**
DEMAND	**250**
DEFICIT	**– 44 (+33*+8**)**

*Desalinated **Reused

Uses of Water

Total needs : 250 MCM / year



- Above figures approximate water consumption per use
- Total water demand is higher than availability and needs particularly for irrigation are rarely satisfied
  - Since 1996, water demand for irrigated agriculture was satisfied only once, in 2004, when all dams were full

Water Resources Management

- Integrated & sustainable approach to water management
- Strategic planning
  - Long term actions to meet future demands under scarcity conditions
  - Short term actions to face a particular drought event within the existing framework

Legislative and Institutional Measures

Legislative measures

- Water Saving Law adopted in 1991

Institutional changes

- For years water legislation evolved on an ad hoc basis – Numerous complex laws with fragmented responsibilities
- In 2010 an Integrated Water Management Law (Law N. 79(I)/2010) was established giving the responsibilities of water management to the Water Development Department (WDD)

Water Saving Law 1991

Any person using a hose for the washing of pavements, or verandas, or roads or vehicles is guilty of criminal offence and could be ***imprisoned for up to 3 months*** *OR be* ***fined up to €513****, or both (Extrajudicial fine is €51)*

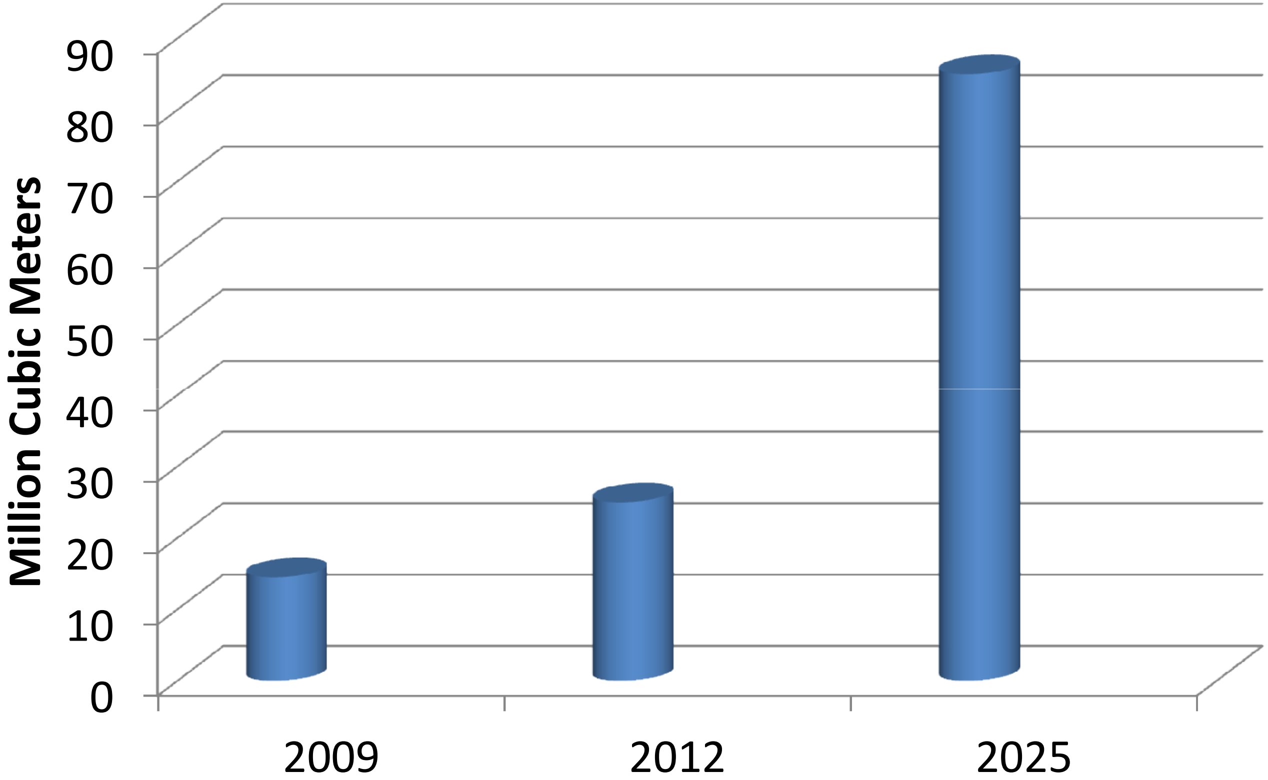
Improved Irrigation Efficiency

- Cropping patterns selected and proposed to farmers to ensure efficient utilisation of water at farm level based on water supply reliability, project economics, land resources, climatic conditions
- Water allocated to agriculture using a quota system and penalty charges for over-consumption
- Irrigation water in government schemes distributed through modern & highly efficient systems (closed pipes, drippers, sprinklers)
- Improved irrigation systems currently cover 95% of total irrigated area (annual water savings are of the order of 75 MCM)
- Conveyance efficiencies: 90-95%
- Field application efficiencies: 80-90%

Treated Waste Water Reuse

Tertiary Treatment

Irrigation of agricultural crops and recreational areas either directly or through recharge of aquifers



Additional volumes of water for agricultural use

WORLD BANK GROUP

CENTER for MEDITERRANEAN INTEGRATION | CENTRE pour l'INTÉGRATION en MÉDITERRANÉE
مركـــز التكامـــل المتوسطـــي

Education and Awareness Campaigns

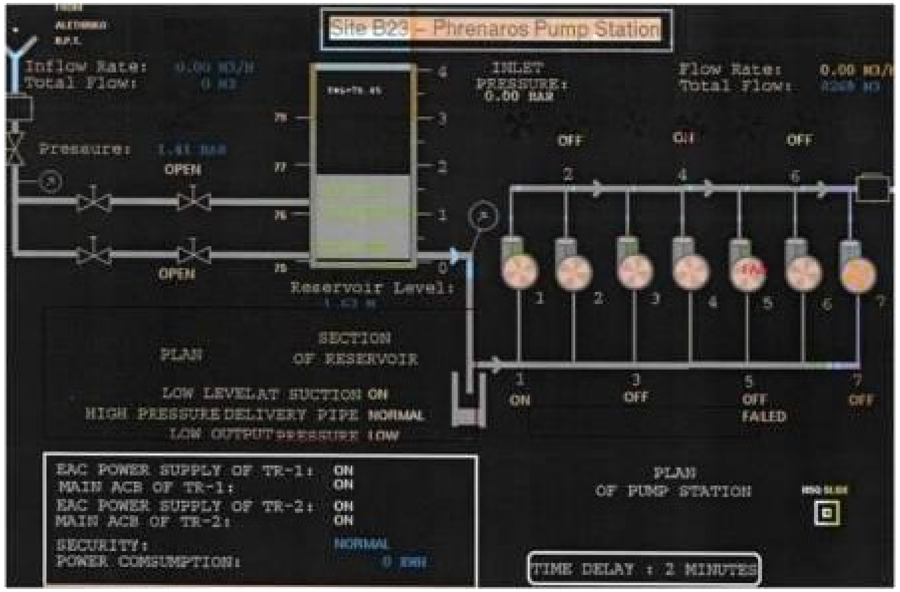
- Public awareness campaigns
- Weekly television and radio programs for the farmers
- Establishment of Water Week
- School visits
- School drawing and essay competitions
- Distribution of information on water saving
- Daily updated web-site with information on water issues

Water Pricing and Metering

- Metering applied to all water uses
- Water billing is based on actual consumption metered at each individual water supply point
- Charges usually comprise a fixed and maintenance charge and a series of block charges (rising block tariffs)
- For irrigation water, charges are established on a volumetric basis and are uniform for all schemes

Leakage Reduction in Distribution Networks

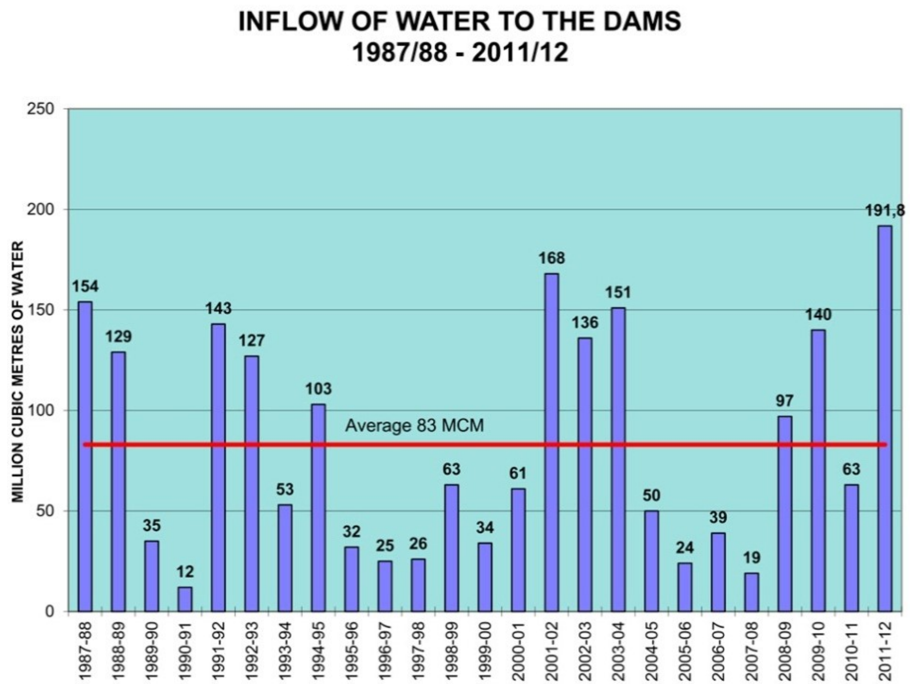
- A systematic effort is made to reduce water losses
  - Efficient conveyance and distribution systems
  - Leakage detection methods
  - Real time tele-monitoring and tele-control on most important projects to optimise operation & maintenance
- Domestic water supply networks in rural areas are gradually being replaced / improved
  - A €75 million budget has been allocated between 2001-2009



…Available Fresh Water Reduced….

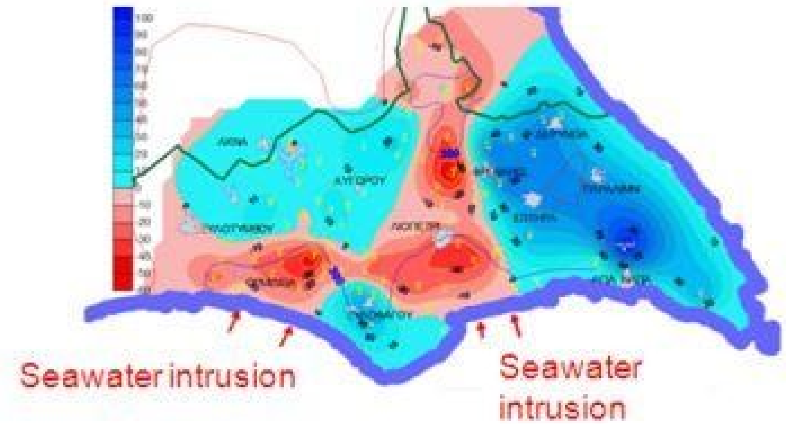
- Climate change caused a drop of 20% in precipitation resulting to a 40% reduction in surface runoff
- Experienced more frequent occurrence of extreme drought events
- Rapid increase in population and tourist arrivals

Inflow of Water to the Dams (MCM)



….Groundwater Deteriorated…

- Groundwater resources have been the most obvious & easily accessible sources of water for many years
- In the attempt to meet the increasing water demand or to mitigate drought effects, they have been heavily over-pumped:
  – Led to seawater intrusion into coastal aquifers
  – Deteriorated both quality and quantity



In 1997 Desalination was Introduced

EXPERIENCES WITH DESALINATION

Public-Private Partnerships (PPP)

- By developing partnerships with private-sector entities, the governments can use the private sectors' knowledge, experience and financing capacity to improve the quantity and quality of basic public services.
- Such Public-Private Partnerships, if properly designed and implemented, can present a number of advantages.
- In Cyprus all desalination plants operate under **B**uilt, **O**wn – **O**perate, **T**ransfer (BOOT) Contracts, where private companies using their own funds, undertake the design, construction and operation of the Plants over a fixed period.
- The Government has the obligation to buy a minimum quantity of desalinated water each year over that fixed period.

Desalination Plant – Main Components

- Sub-sea conveyors for sea water collection (500m at Dhekelia and 1km at Larnaca) and sub-sea conveyors for brine rejection (500m at Dhekelia and 1.3km at Larnaca).
- Sea water pumping station.
- Ground conveyors to transfer sea water to the desalination plant and reject brine to the sea.
- Desalination Plant
  - Pre-treatment
  - Reverse osmosis
  - Post-treatment
- Treated / desalinated water reservoir
- Treated / desalinated water pumping station

Desalination Plant – Contractual Obligations

- The Contractor produces desalinated water of a specified quality and quantity and delivers it to the Water Development Department's storage reservoirs
- The water quality is checked every 2 hours. Additional quality test are carried out on a daily and weekly basis
- The Water Development Department is obliged to receive a specified minimum quantity every 3 months
- Payments to the Contractor are made every 3 months
- The Contractor submits 3-monthly reports on:
  - Quantities of water delivered
  - Quantities over and above the minimum 3-monthly quantity
  - Volume of water which did not comply to the specification
  - Quantities which were not delivered by the Contractor for reasons beyond his direct control

Pricing of Water Purchased

- **The Unit Price** is made up of four components:
  - C: Capital Expenditure
  - OM: Operation and Maintenance
  - E: Energy
  - SOM: Standby Operation and Maintenance

- **Different Unit Prices** are applied:
  - Unit Price for operation: C + OM + E
  - Unit Price for Stand-by : C + SOM
  - Unit Price for additional quantities: OM + E

Operational Conditions

- The Water Development Department has the option to purchase the desalination plant before the end of the Contract
- The Contractor will indemnify the Water Development Department for quantities of water which he was not able to deliver
- The Contractor has the option to produce and deliver the above quantities within the next 3-montly periods
- If he fails to do this a penalty is imposed
- The penalty is equal to the current purchase price of desalinated water times the quantities of water which were not delivered.
- The penalty is applied once a year.

DESALINATION PLANTS (1/3)

	DHEKELIA	LARNACA	DHEKELIA REFURBISHMENT	DHEKELIA EXTENTION
CONTRACT TYPE	BOT	BOT	BOT	BOT
START OF PRODUCTION	1st April 1997	12th July 2001	20th May 2007	18th July 2008
PERIOD	10 Years	10 Years	20 Years	
CAPACITY	40.000 m^3/day	52.000 m^3/day	40.000 m^3/day	50.000 m^3/day
MINIMUM DAILY PRODUCTION (m^3)	-	46.500 m^3	36.000 m^3	45.000 m^3
MINIMUM YEARLY PRODUCTION (m^3)	-	**16.972.500 m^3**	**13.140.000 m^3**	**16.425.000 m^3**
CONTRACT PRICE	€0.92/m^3	€0.68/m^3	€0.64/m^3	€0.82/m^3 *
ADJUSTED PRICE (ELECTRICITY TARRIFF AND LABOR INDEX)	-	-	€1.31/m^3	

* For the extra 10.000 m3/day

WORLD BANK GROUP

CENTER for MEDITERRANEAN INTEGRATION | CENTRE pour l'INTÉGRATION en MÉDITERRANÉE
مركز التكامل المتوسطي

DESALINATION PLANTS (2/3)

	MONI	GARYLLIS	PAFOS	LIMASSOL
CONTRACT TYPE	BOOR	BOT	BOOR	BOT
START OF PRODUCTION	22nd December 2008	2009	22nd November 2010	1st July 2012
PERIOD	3 Years	5 Years	3 Years	20 Years
CAPACITY	20.000 m^3/day	13.000 m^3/day	30.000 m^3/day	40.000 m^3/day
MINIMUM DAILY PRODUCTION (m^3)	18.000 m^3/day	11.700 m^3	27.000 m^3/day	36.000 m^3
MINIMUM YEARLY PRODUCTION (m^3)	**6.570.000 m^3**	**3.482.592 m^3**	**9.855.000 m^3**	**1.140.000 m^3**
CONTRACT PRICE	€1.39/m^3	€0.29/m^3	€1.219/m^3	€0.8725/m^3
ADJUSTED PRICE (ELECTRICITY TARRIFF AND LABOR INDEX)	-	€0.35/m^3	€1.70/m^3	€1.27/m^3

DESALINATION PLANTS (3/3)

	LARNACA REFURBISHMENT	VASSILIKOS
CONTRACT TYPE	BOT	Purchase contract
START OF PRODUCTION	Summer 2014	Summer 2013
PERIOD	25 Years	20 Years
CAPACITY	60.000 m^3/day	60.000 m^3/day
MINIMUM DAILY PRODUCTION (m^3)	54.000 m^3/day	54.000 m^3/day
MINIMUM YEARLY PRODUCTION (m^3)	**19.710.000 m^3**	**19.710.000 m^3**
CONTRACT PRICE	€0.59/m^3	€0.813/m^3
ADJUSTED PRICE (ELECTRICITY TARRIFF AND LABOR INDEX	€0.82/m^3	€1.10/m^3

Desalination Plants at 2016

DESCRIPTION	DHEKELIA EXTENSION	LARNACA REFURBISHMENT	LIMASSOL	VASSILIKOS
CONTRACT TYPE	BOOT	BOOT	BOOT	Purchase Contract
START OF PRODUCTION	18 July2008	Summer 2014	1 July 2012	Summer 2013
PERIOD	20 Years	25 Years	20 Years	20 Years
CAPACITY	60.000 m3/day	60.000 m3/day	40.000 m3/day	60.000 m3/day
MINIMUM DAILY PRODUCTION	54.000 m3	54.000 m3	36.000 m3	54.000 m3
MINIMUM YEARLY PRODUCTION	19.710.000 m3	19.710.000 m3	1.140.000 m3	19.710.000 m3
PURCHASE PRICE OF WATER	€0.69/m3	€0.59/m3	€0.87/m3	€0.81/m3
ADJUSTED PRICE FOR 2016 (ELECTRICITY TARIFF AND LABOR INDEX)	€0.83/m3	€0.47/m3	€0.92/m3	€0.77/m3

Cost of Desalination

Cost based on two reverse osmosis plants

DESALINATED WATER PRODUCTION		
DHEKELIA (1997-2007) (m^3)	LARNACA (2001-2007) (m^3)	TOTAL (m^3)
122.985.322	112.083.355	234.798.677

DESALINATED WATER COST		
DHEKELIA (1997-2007) (€)	LARNACA (2001-2007) (€)	TOTAL COST (€)
137.812.166	80.196.431	218.008.597

SUMMARY

- Power Consumption:
  4.52 kWh / m3
  OR
  135.000.000 kWh/year
  Approximately for both desalination plants
- Energy Cost:
  €11.500.000 / year

Desalinated Water Production

YEAR	TOTAL COST/YEAR (M €)	PRODUCED QUANTITY (M.C.M.)
2008	65,28	32,6
2009	63,56	49,6
2010	62,36	52,8
2011	74,98	48,7
2012	49,98	17,6
2013	35,24	10,7
2014	36,92	32,8
2015	43,83	38,1
2016	39,27	62,6
TOTALS	**471,4**	**345,5**

Desalination Pros and Cons

Pros	Cons
■ Coverage of drinking water needs of large urban and tourist areas – Dependence on rainfall eliminated ■ Availability of additional quantities of surface water for other uses – Irrigation – Environmental Flows – Recharge of heavily over-pumped aquifers ■ Economic and social benefits ■ Safety and reliability of drinking water supply	■ Energy-consuming process – Emission of Greenhouse gasses ■ Slight impact on the Marine Environment – Increased salinity at the point of brine rejection ■ High production cost

Desalination Plants

- The inevitable choice to built Desalination Plants in Cyprus has proved particularly beneficial for the agriculture and salvation for the water supply of urban areas.
- Nevertheless building Desalination Plants is not panacea.
- The environmental impact, mainly because of the emission of greenhouse gases, should not leaves us indifferent at times where our planet struggles for survival.

Desalination Plants

- Furthermore the production cost, which is not recovered, at times where the oil price is unstable, should have us seriously concerned.
- It is therefore imperative to continuously seek of ways to increase the efficiency of the existing desalination technologies in such a way so as to reduce the energy consumption, and
- To seek for new methods to produce drinking water by utilizing renewable energy sources.

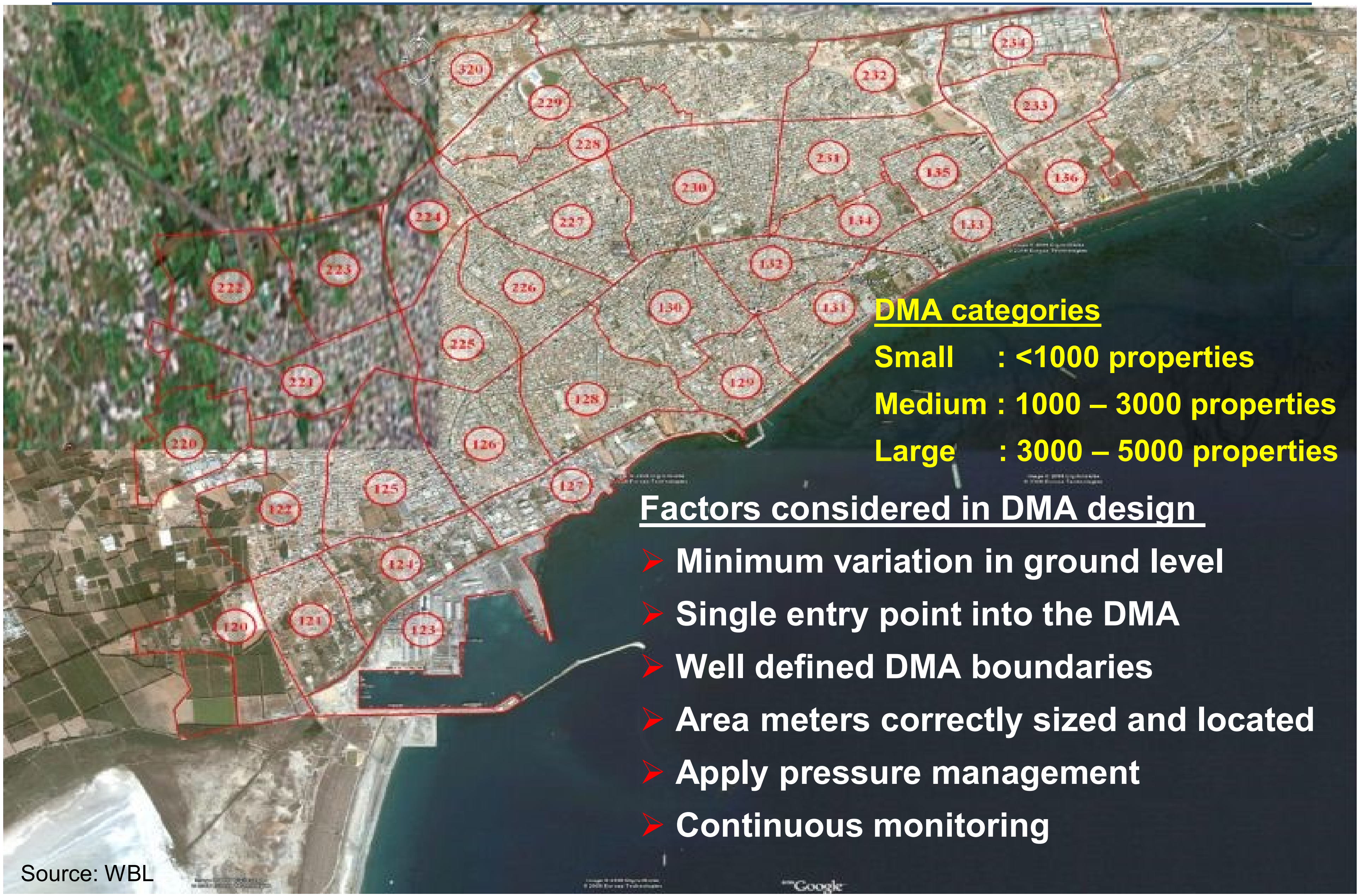
NON-REVENUE WATER REDUCTION

Potable water volumes supplied – 2012

Continuous 24x7x365 potable water supply – coverage is 100% in all areas

Service providers	Population served	Mm^3	%	m^3/ Inhab/year	NRW rate (%)
Water Board of Nicosia	220 000	21.5	27	98	23
Water Board of Limassol	170 000	12.7	16	75	24
Water Board of Larnaca	70 000	5.6	7	80	28
Municipal Water Supply Departments	160 000	18.3	23	114	35
Community Boards	185 000	21.5	27	116	40
TOTAL	**805 000**	**79.5**	**100**	**99**	**31**

Network Management



Source: WBL

DMA categories

Small : <1000 properties

Medium : 1000 – 3000 properties

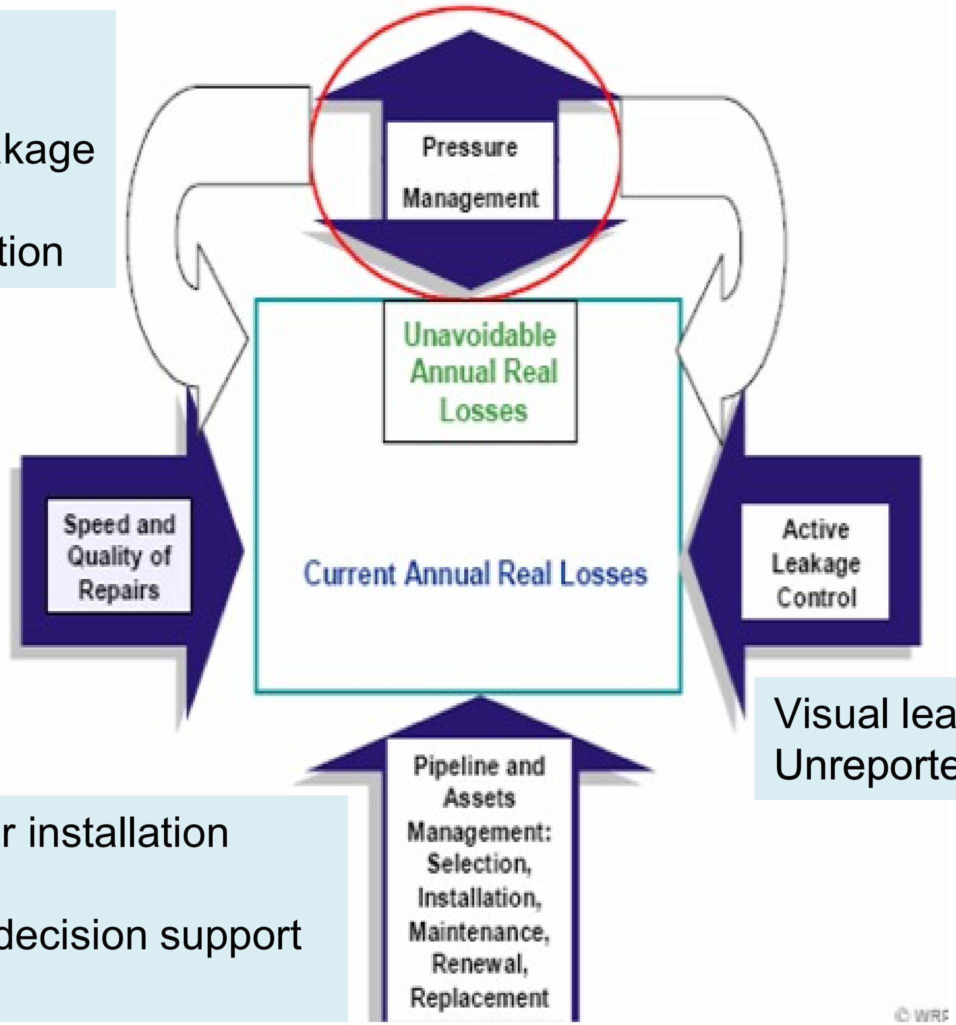
Large : 3000 – 5000 properties

Factors considered in DMA design

- **Minimum variation in ground level**
- **Single entry point into the DMA**
- **Well defined DMA boundaries**
- **Area meters correctly sized and located**
- **Apply pressure management**
- **Continuous monitoring**

Physical Losses

Reduction in:
- surges and excess pressures
- burst rates and background leakage
- flow rates of all leaks
- some components of consumption



Minimize “Leak Run Time”; Use quality materials & specification; Perform quality repairs & inspection

Visual leaks
Unreported leaks

- High quality materials / Proper installation
- High standard of maintenance
- Pipeline replacement using a decision support system

Commercial Losses

All customers are metered

Water theft

- **Theft from hydrants**
- **Meter by-passes**
- **Tampering with meters**

Meter under- registration

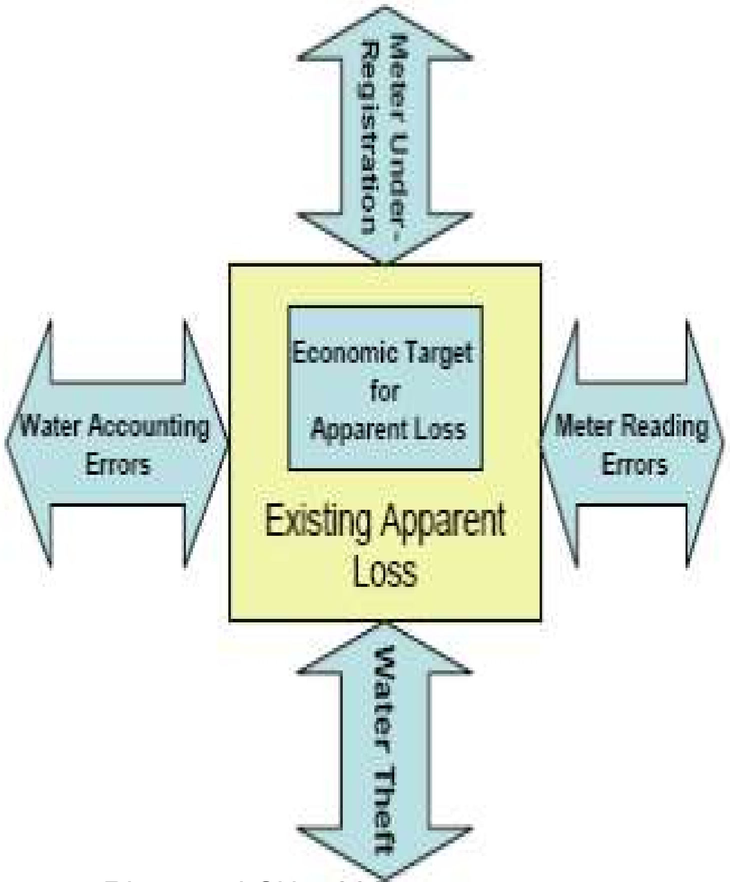
- **Improve meter accuracy**
- **Volumetric meters**
- **Certified meter test bench**

Meter reading errors

- **Hand-held devices**
- **Change meter readers' routes**
- **Check zero/low consumption**

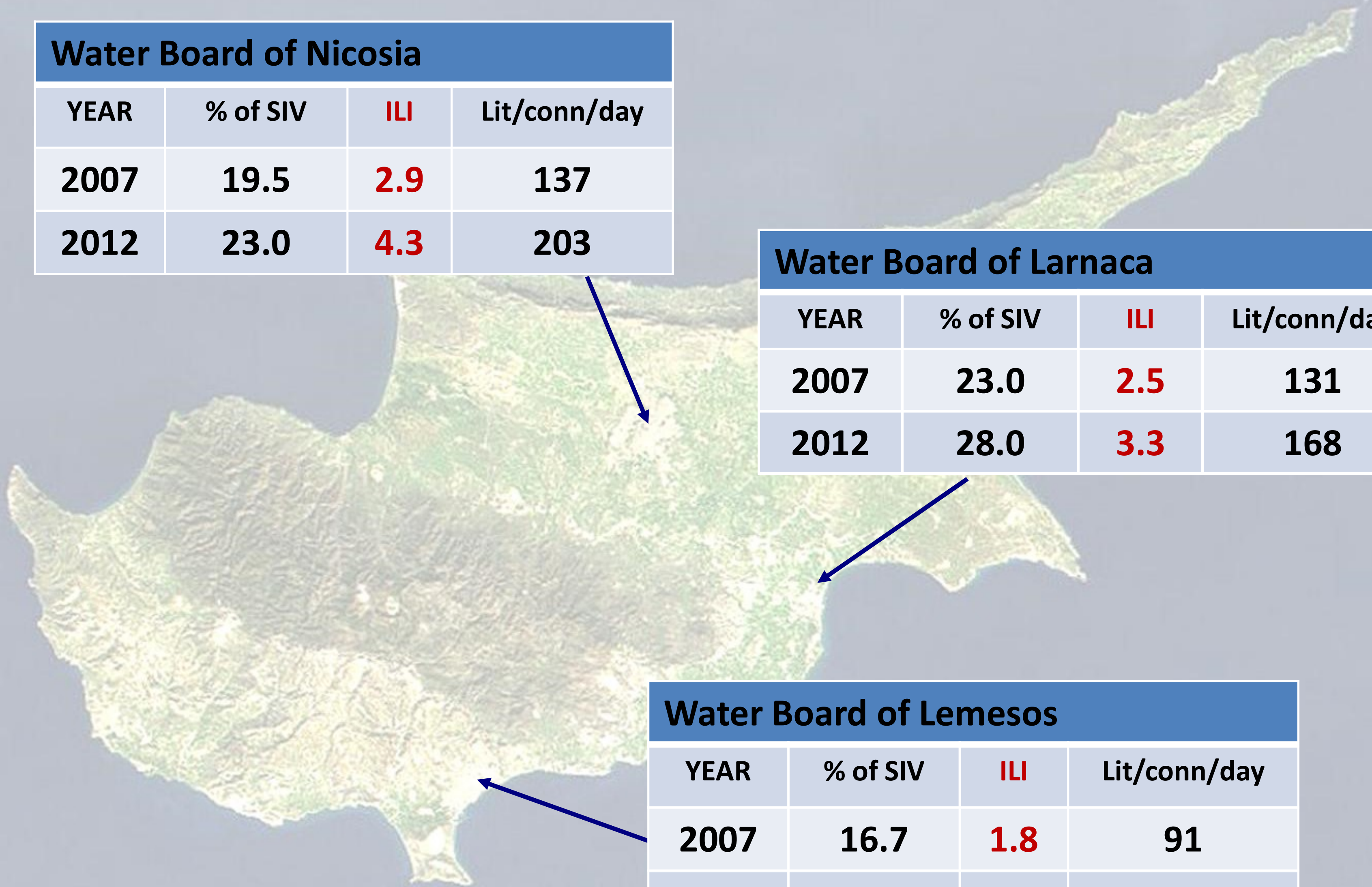
Accounting errors

- **Billing software**
- **Threshold alarms**



Source: Rizzo and Cilia, 2005

Key Performance Indicators



Water Board of Nicosia			
YEAR	% of SIV	ILI	Lit/conn/day
2007	19.5	2.9	137
2012	23.0	4.3	203

Water Board of Larnaca			
YEAR	% of SIV	ILI	Lit/conn/day
2007	23.0	2.5	131
2012	28.0	3.3	168

Water Board of Lemesos			
YEAR	% of SIV	ILI	Lit/conn/day
2007	16.7	1.8	91
2012	24.0	2.8	143

Water rationing

- In 2008, Cyprus was faced with one of the most acute and prolonged droughts in 20th century
- A Drought Mitigation & Response Plan was applied in response
  - Almost 100% ban on water supply to agriculture
  - Strict restrictions on drinking water supply to households (36 hours/week)
- In 2009, situation improved and rainfall reached 105% of normal
  - Government was able to reduce household restrictions from 30% to 15% & provide some quantities of water to agriculture

Rationing measures implemented during periods of droughts with priority given to domestic sector

Kouris Dam
Apr 2004

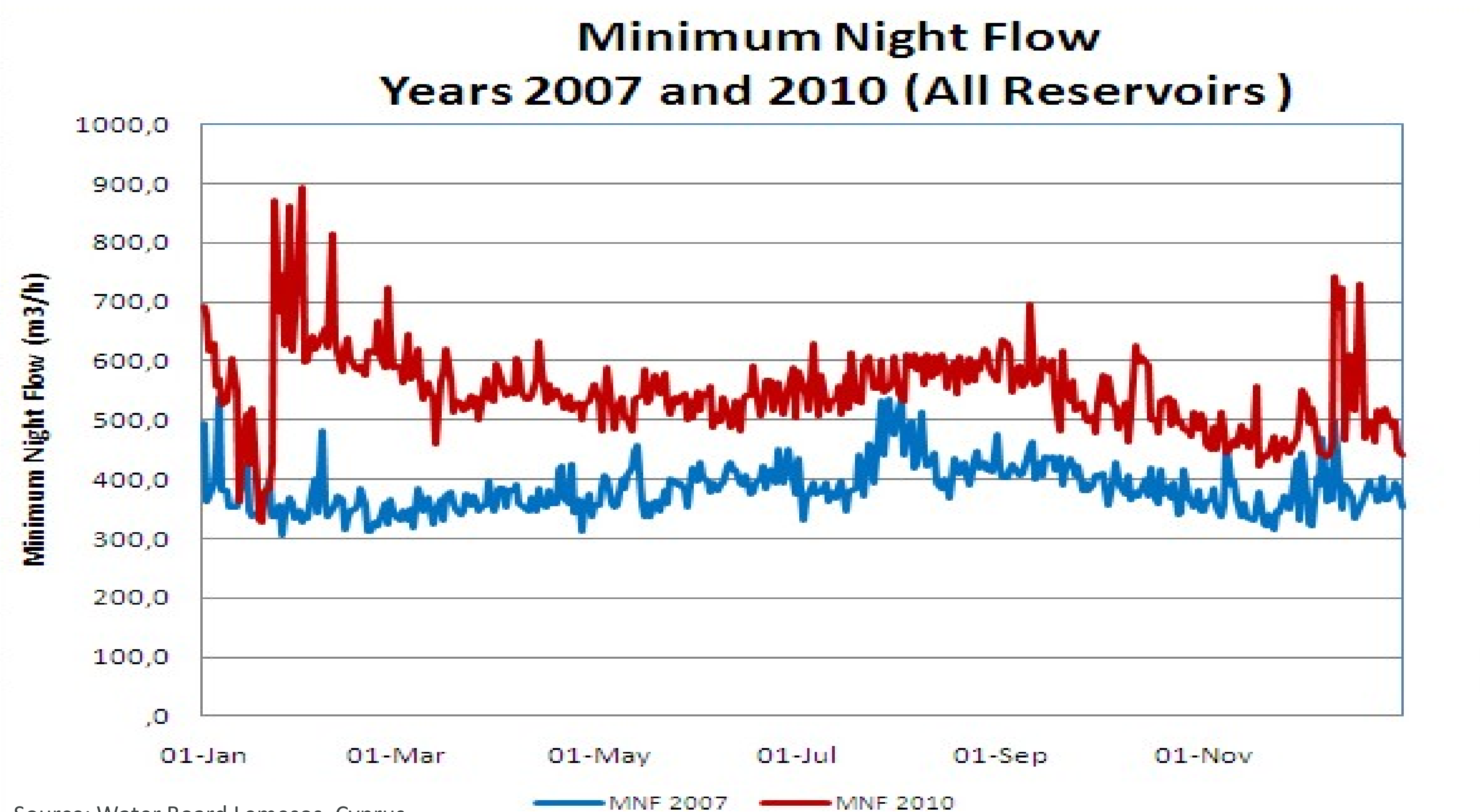
Kouris Dam
Sept 2008

WORLD BANK GROUP

CENTER for MEDITERRANEAN INTEGRATION | CENTRE pour l'INTÉGRATION en MÉDITERRANÉE
مركـــز التكامـــل المتوسطـــي

Lifeline from Athens to Lemesos in August 2008: 35.000 m^3/day

Increase in Leakage



Source: Water Board Lemesos, Cyprus

Increase in the Number of Breaks

20 DMAs: 373Km: 45%total 2008 – 2009 Intermittent Water Supply (IWS)			
Description	Number of reported breaks		
	2007 Before IWS	2010 After IWS	%increase
Mains	14 / 100km	42 / 100km	**200**
Service connections	15 / 1000 connections	30 / 1000 connections	**100**

Source: Water Board Lemesos, Cyprus

System Input vs Consumption

Year	System Input Volume	Customer Consumption
2007 Before Intermittent Supply	0% (base line)	0% (base line)
2008 Intermittent Supply	-17,5%	-9,2%
2009 Intermittent Supply	-9,1%	-8,9%
2010 After Intermittent Supply	+12,8%	-1,2%

Source: Water Board Lemesos, Cyprus

Cost of Intermittent Supply

Cost to the Water Board of Lemesos for the 2 years (2008 – 2009) of Intermittent Supply:

Loss of revenue:

- **Reduction in sales – cost of water saved: € 300.000**

Additional operational expenses:

- **Staff overtime for opening / closing valves: € 365.000**
- **Repairing additional reported breaks: € 325.000**

Additional estimated cost after Continuous Supply was established:

- **Additional leakage (2010 – 2012): € 1.700.000**
- **Estimated cost of locating leaks: € 175.000**
- **Estimated cost of repairing leaks: € 125.000**

THOUGHTS ON NEXT STEPS

Water scarcity and droughts increasing in intensity and extent

- Water scarcity and droughts is a major challenge
  - Climate change is expected to make matters worse
- There is a need to intensify efforts to prepare for and manage such water-related disasters
- Water saving & efficiency measures must be a priority
  - In some circumstances, it may be necessary to consider further approaches on the supply side
- In Cyprus, despite the many water saving & costly supply enhancement measures, the problem remains
  - Alternative options such as desalination needed to be further considered to increase water availability

Taking on the challenge

- Future presents many challenges for Cyprus
  - Rapid social changes
  - Further economic development
  - Climate change
  - Water scarcity & droughts
  - Escalating water demands in a continuously changing environment
- Necessary measures to ensure water security and resilience

Public Private Partnership

- Improving NRW using PBC (Water Boards)
- Operation and maintenance of large infrastructures using the private sector:
  - Large conveyors and pumping stations
  - Water treatment plants
  - Sewage treatment plants
- Building climate resilient utilities
- Solar Powered Desalination
- Integrated multi-objective approach for water management

Thank you

Nicos Neocleous
Acting Chief Water Officer
Water Development Department
Republic of Cyprus
Email: nicneocleous@gmail.com
Tel.: +357 99 687 608

Bambos Charalambous
NRW and Water Utility Specialist
World Bank Consultant
Email: bcharalambous@cytanet.com.cy
Tel.: +357 99 612 109