Preserving Lake Kinneret (Sea of Galilee, Israel) as a strategic water resource in a changing climate

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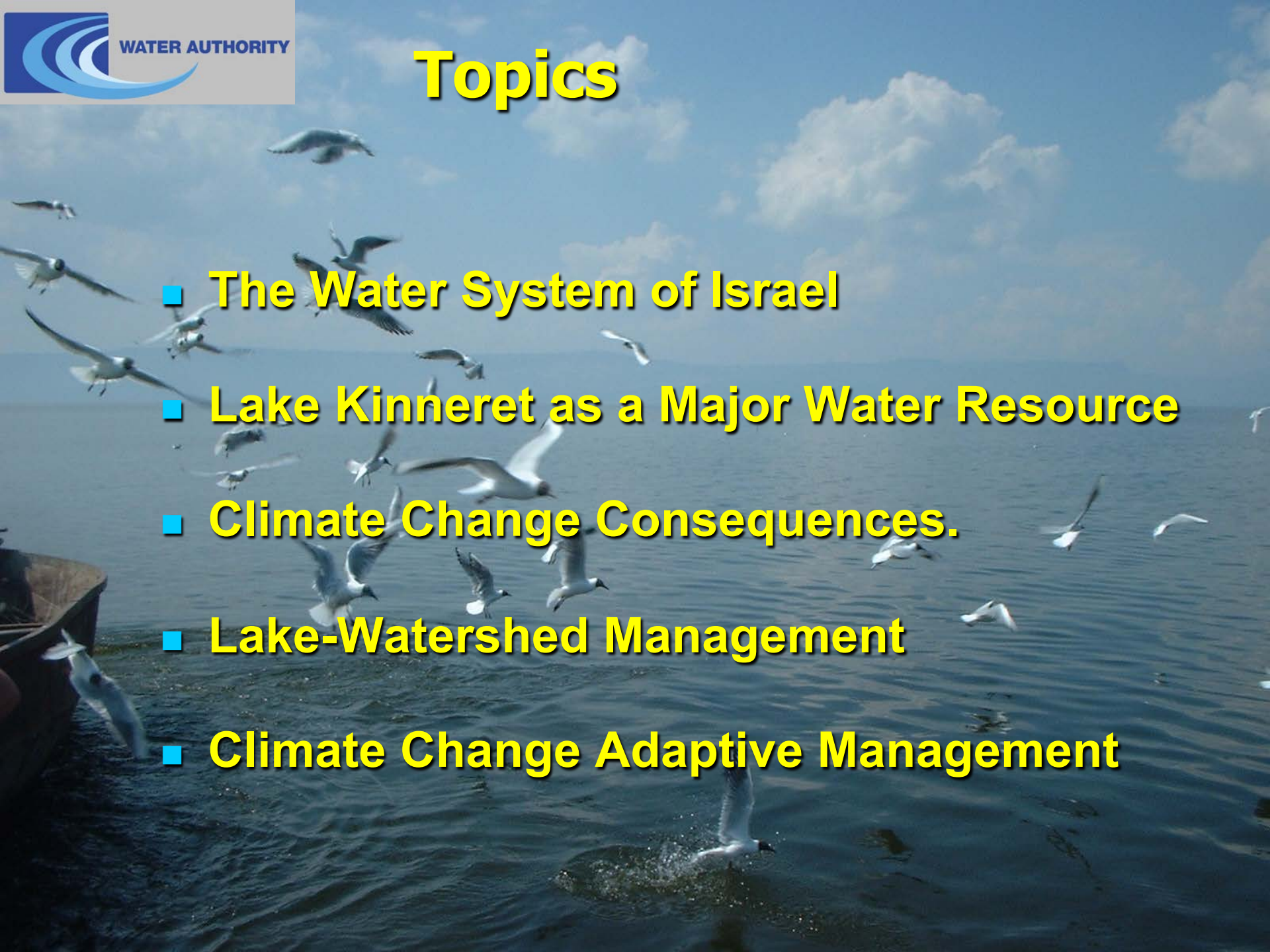
Acknowledgment:
Prof. Sharon Megdal
Mr. Conrad Plimpton

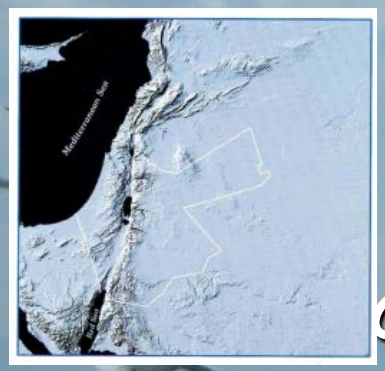


Topics

- The Water System of Israel
- Lake Kinneret as a Major Water Resource
- Climate Change Consequences.
- Lake-Watershed Management
- Climate Change Adaptive Management

Water Resources of Israel

WATER AUTHORITY



Western Galilee and Karmel Cost
100 ~~139~~

Costal Aquifer
275 ~~295~~

Mountain Aquifer
280 ~~316~~

(0.96)
1180 ~~1500~~ MCM/y (Until ~~1980~~)
1.2 MAF/y 1995 - 2016

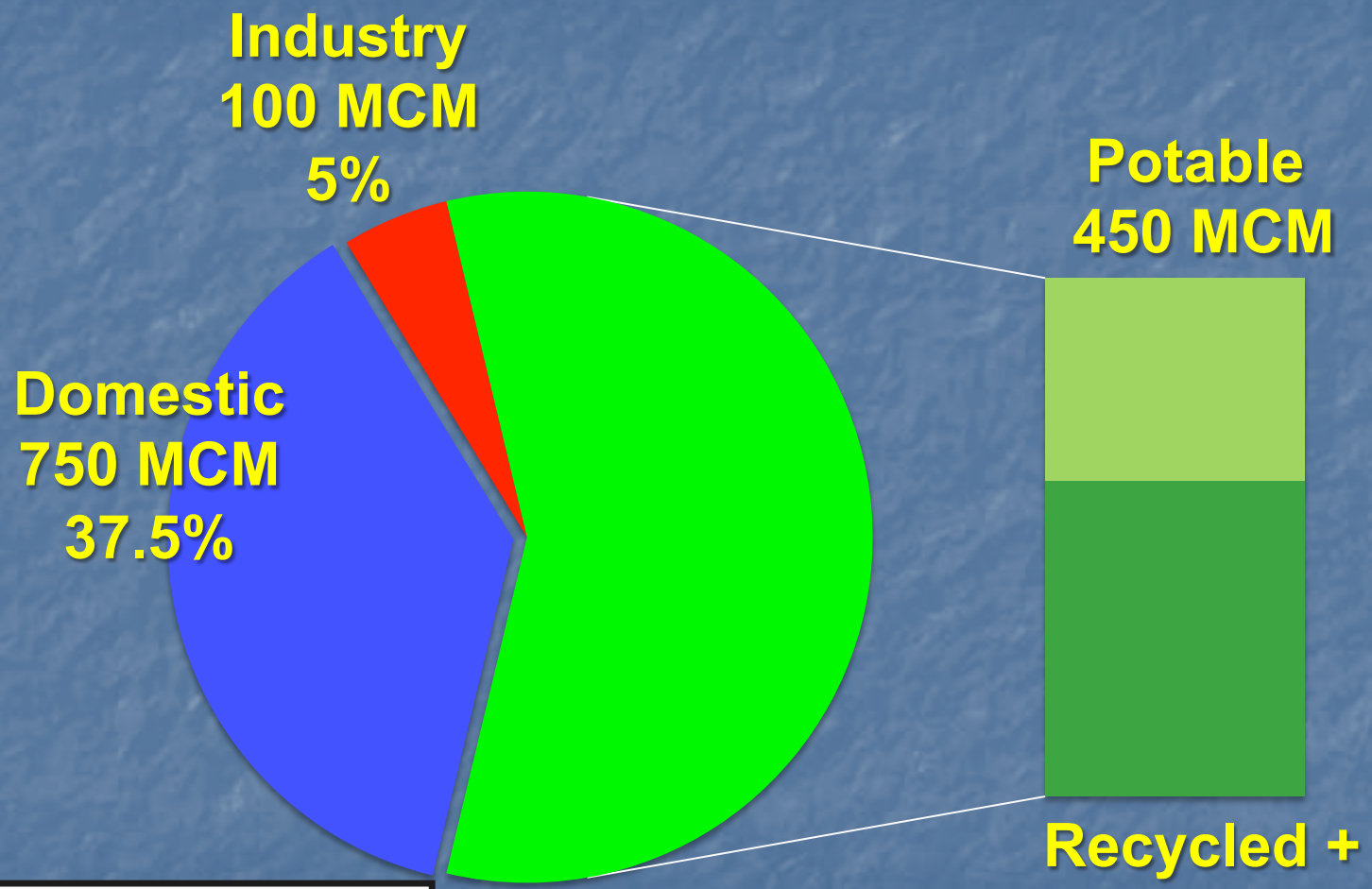
Kinneret Basin
~~550~~ 350

Eastern Basins
~~130~~ 110

The Climate Change is here!

Negev and Arava
~~70~~ 65

Annual Consumption in Israel



Total: 2,000 MCM/y

(1.6 MAF/y)

WATER AUTHORITY

Israel National Water System

Halutza settlements

Nahariya
Haifa
Krayot
Karmiel
Hagalil
Kiryat Shmona
Banias
Dan
Golan Heights
Yoshan Reservoir
Kfar Giladi
Birkat-Ram 7 million m³
Nagit Kfar Blum Reservoir 1.36 million m3
Zemer Works
Einan Reservoir
Ein Aviv Works
Rosh Pina
Ayoun Station
Alonei Habashan Wells
Dalton Reservoir 2.5 million m³
Safed
Dvash Reservoir
Sha'abania Reservoir
Revaya Reservoir
Bnei Israel Reservoir
Kursi Station
Golan Heights
Gihon Amud
Sapir Station
Hayarden Canal
Shomrat Reservoir-New 3 million m³
Eshkol Reservoir
Haifa recycled effluents
Filtration Plant
Bet Netofa Canal
Line*108
Tiberias
Hatzor Station
Meitzar
140+
Nazareth
Golani
Sharona Reservoir 3.2 million m³
Maagan Michael (9.5)
Oren-Hadera
Nitsanim Zvi A Reservoir 2 million m³
Maayan Zvi B Reservoir 2 million m³
Kfar Baruch Reservoir 5 million m³
Menashe Tunnel
Menashe Station
Afula
Maale Hakishon Reservoir 12 million m³
Hof Hacarmel Station
Nahalel Menashe plants for capturing flood water for running to ground water
Hadera (127)
Bilkat Hanadiv Reservoir 1.8 million m³
Bet Hashita Reservoir 2.5 million m³
Eastern Reservoir 5 million m³
Line*108
Haviva Reservoir 2.6 million m³
Netanya Recycled effluents
Netanya
Hefer Recycled effluents
Tel Yitzhak Reservoir 2.3 million m³
Ramat Hakovesh Reservoir 1.4 million m³
Neve Yarak Station
Merkaz Hashomron
T.T.A regulation station
Ariel
Tapuach Junction
Ma'ale Efraim
Givatayim
Ramat Gan
Holon
Bat Yam
Tel Aviv-Yaffo
Dan Bnei Brak Line
Kfar Daniel Reservoir 3.5 million m³
Sorek (150)
Rishon le Zion
Shafdan Sewage Treatment and Reclamation Plant
Yarkon West Line
Givat Brenner Reservoir 0.6 million m³
Palmachim (45) (90 = future)
(Ghrmarim) Hafetz Haym Reservoir
Yarkon East Line
Pedaya Pools
Fourth Line to Jerusalem
Heller Station
Shoeva Station
Ramallah
Bitunia Pool
Jerusalem
Fifth Line to Jerusalem
Kalya
Bethlehem
Og Reservoir 3.5 million m³
Ashdod (100)
Granot Pool A
Granot Pool B
Granot Gat
Mei Gadot Reservoir 3.5 million m³
Hafetz Haym Reservoir 1.35 million m³
Menachem Reservoir 3.5 million m³
Shimshon Reservoir 3.5 million m³
Ashkelon (120)
Lahat
Ashkelon Reservoir 2 million m³
Yoga Pool 100.000 m3
Zohar Lake 8 million m³
Kiryat Gat
Makhtzeva Pool
Amatzia
Kiryat Arba Hebron
Almog Station
Simcha Station
Sde Yoav Reservoir 1 million m3
Nachal Oz Reservoir 3.6 million m³
Tekuma Pool B 100.000 m³
Mafsakh Reservoir 100.000 m³
Tekuma Pool A 200.000 m³
Titrach Pool
Be'er Sheva Pool
Shoket Pool and Station
Neve Zohar (3)
Arad Pool
Yatir Station
Desalination of drinking water for Hotels at the Dead Sea
Ye'elim Pool and Station
Arad
Be'er Sheva
Rehovot Reservoir
Avrahami Station
Magen Reservoir 100.000 m³
Lev Hanegev Reservoir 50.000 m³
Tze'elim Reservoir 100.000 m³
Mivtachim Pool
Tze'elim Pool
Hevel Shalom Reservoir 4 million m³
Titrach Reservoir 2 million m³
Mevo'ot Yerushalayim Reservoir 3.7 million m³
Rotem Plain
Efeh Wells
Dimona Pool 150.000 m³
Dimona
Tazfit Pool

Sea Water Desalination in Israel

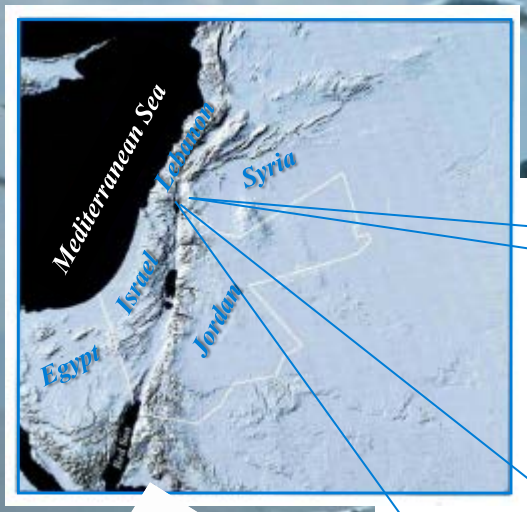
Overall in 2017 = 580 MCM/Y
(0.47 MAF/y)

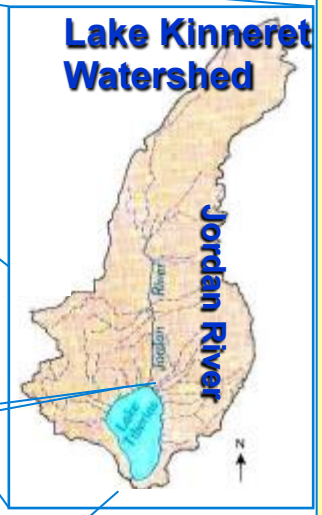
Sea Water Desalination in Israel

Overall in 2017 = 580 MCM/Y
Potential capacity = 650 MCM/y

WATER AUTHORITY

Lake Kinneret (Sea of Galilee)





Lake Kinneret and its Watershed

- The only freshwater lake in Israel.
- The lowest in the world.
- Supplies 20% of Israel's potable water
- Lake Area: 167 km^2
- Lake Max Depth: 44 m
- Lake Max Volume: 4.3×10^9 m^3
- Average Salinity: 280 mg/L Cl
- Stratification: Monomictic
- Watershed Area: 2730 km^2
- Main Landuse: Agriculture
- Main Water inflow: Jordan River 70%

WATER AUTHORITY

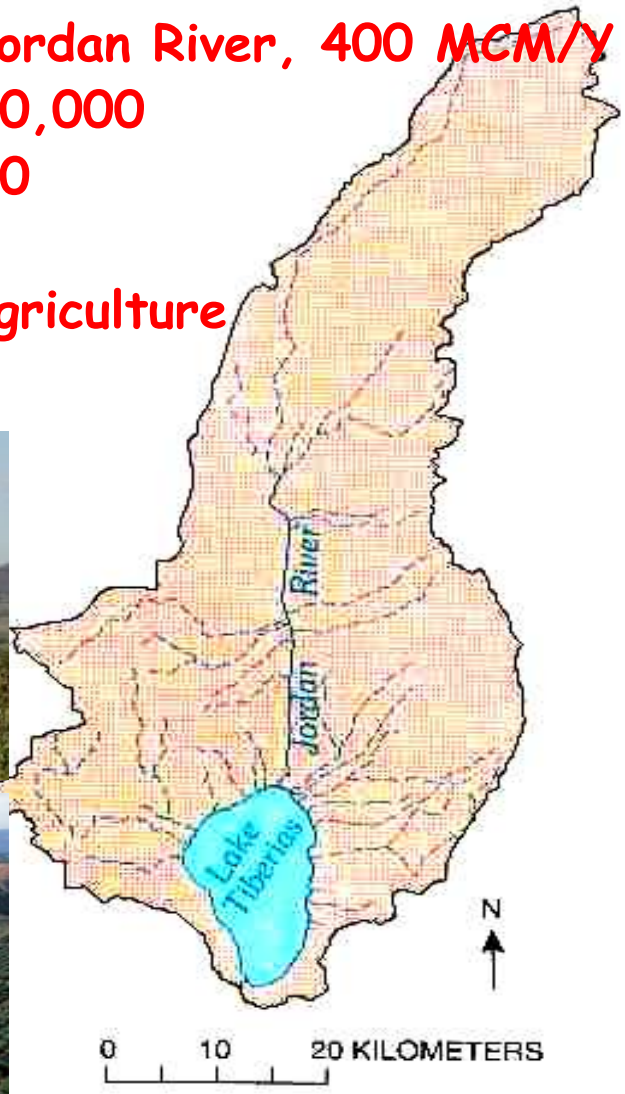
Lake Kinneret Watershed

- Area: 2730 km^2
- Country: 75% in Israel, 25% in Lebanon
- Rain fall: 300-1000 mm/Y
- Main River: Jordan River, 400 MCM/Y
- Residents: 220,000
- Settlements: 180
- Cities: 4
- Primary Use: Agriculture

Point Pollutant Sources
- Sewage overflow
- Fish ponds overflow
- Dairy farm drainage
- Fuel stations
- Army Bases

Non Point Sources
- Agricultural drainage
- open Grazing areas

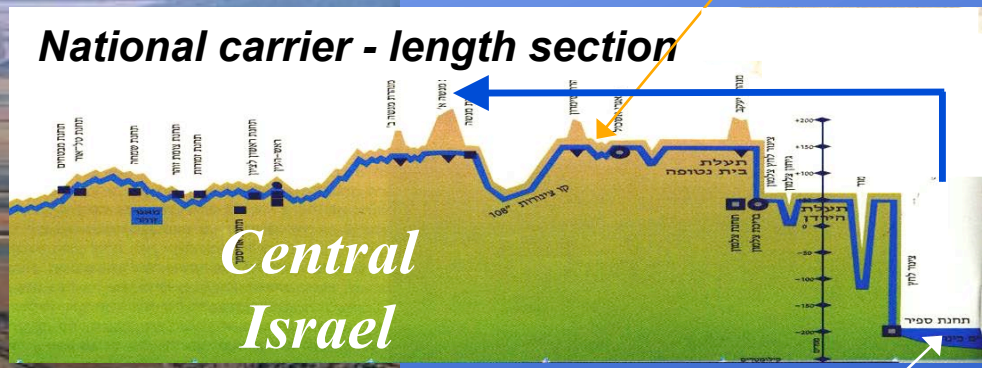
The Main Pollutants
- Nutrients: N & P
- Fecal Coli
- Pesticides & Herb.
- Oil and Fuel residues
- Salt



Lake Kinneret Uses

Water Supply – the primary use according to Israeli Water Law

Eshkol Reservoir



Lake Kinneret

WATER AUTHORITY

Lake Kinneret Uses

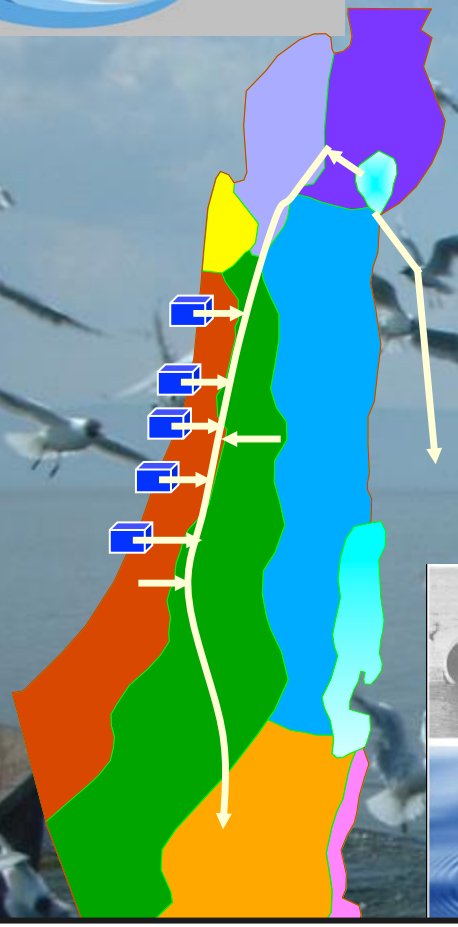
Recreation and Tourism

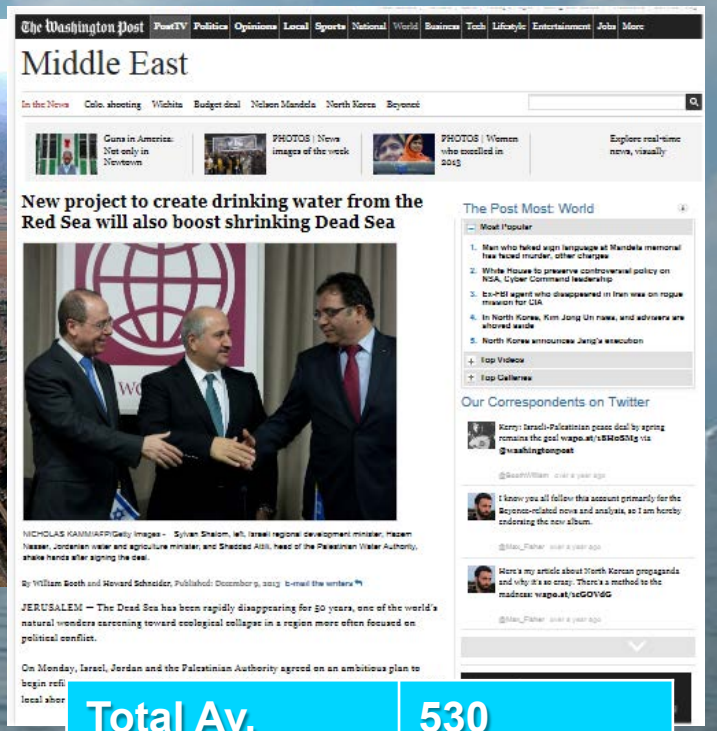
WATER AUTHORITY

Lake Kinneret Uses

Commercial Fishery – 1000 ton annual yield

Lake Kinneret as a Major Water Resource



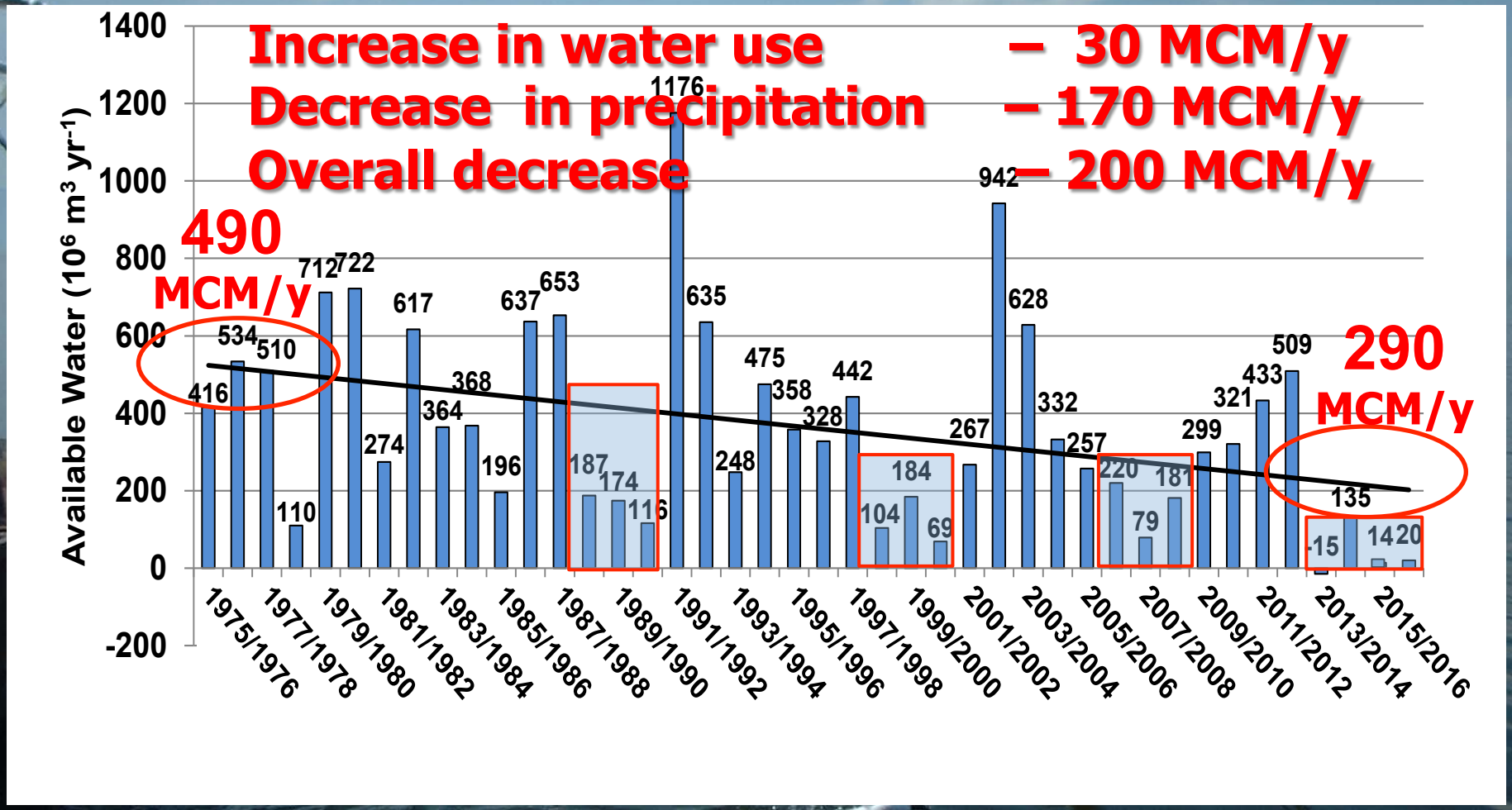


Total Av. Inflow	530 (10^6 m^3/y)
Evaporation	240
Local Cons.	50
K. Of Jordan	50
NWC	190

"Lake Kinneret Will continue to serve as a strategic water resource for Israel, desalination will enable flexible water supply"

WATER AUTHORITY

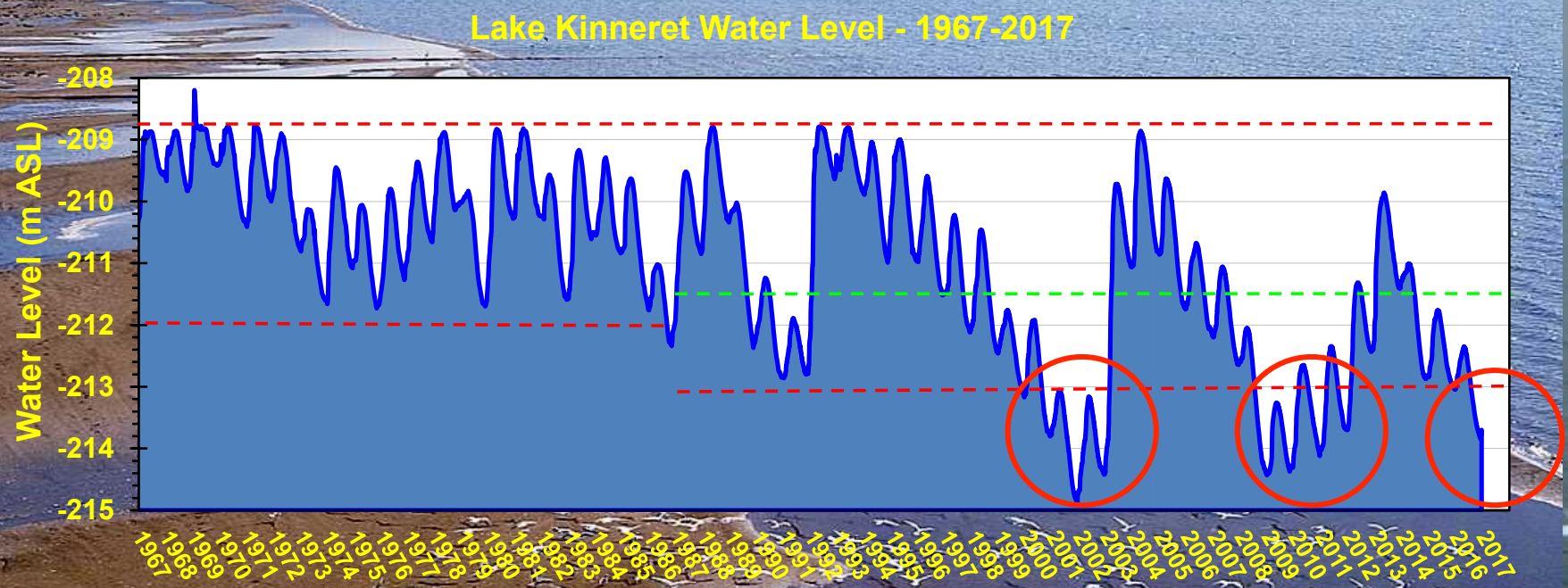
Net Inflow to Lake Kinneret (Available Water) 1975-2017



Source: The Hydrological Service, Israeli Water Authority

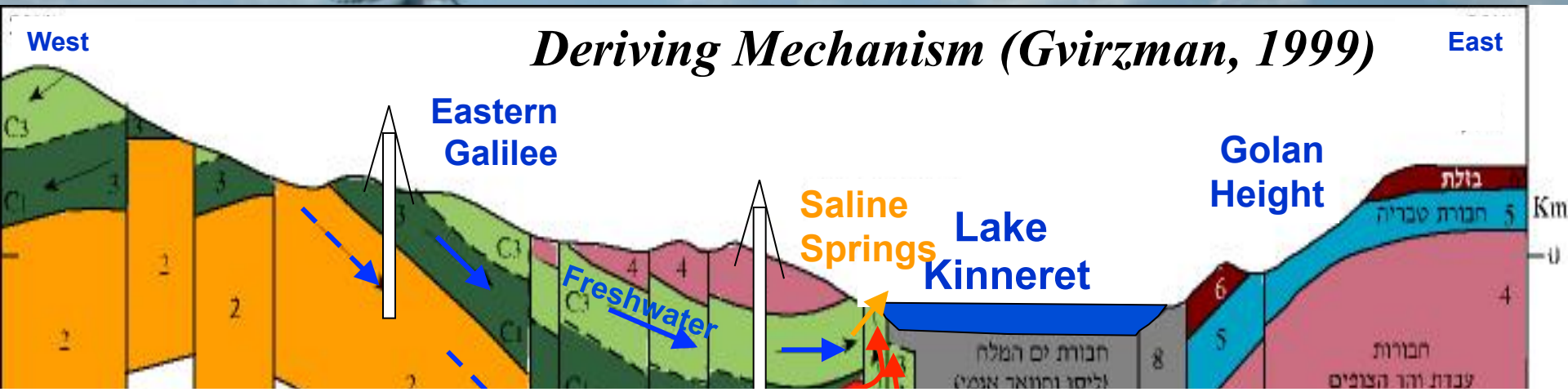
Lake Kinneret Water Level Changes

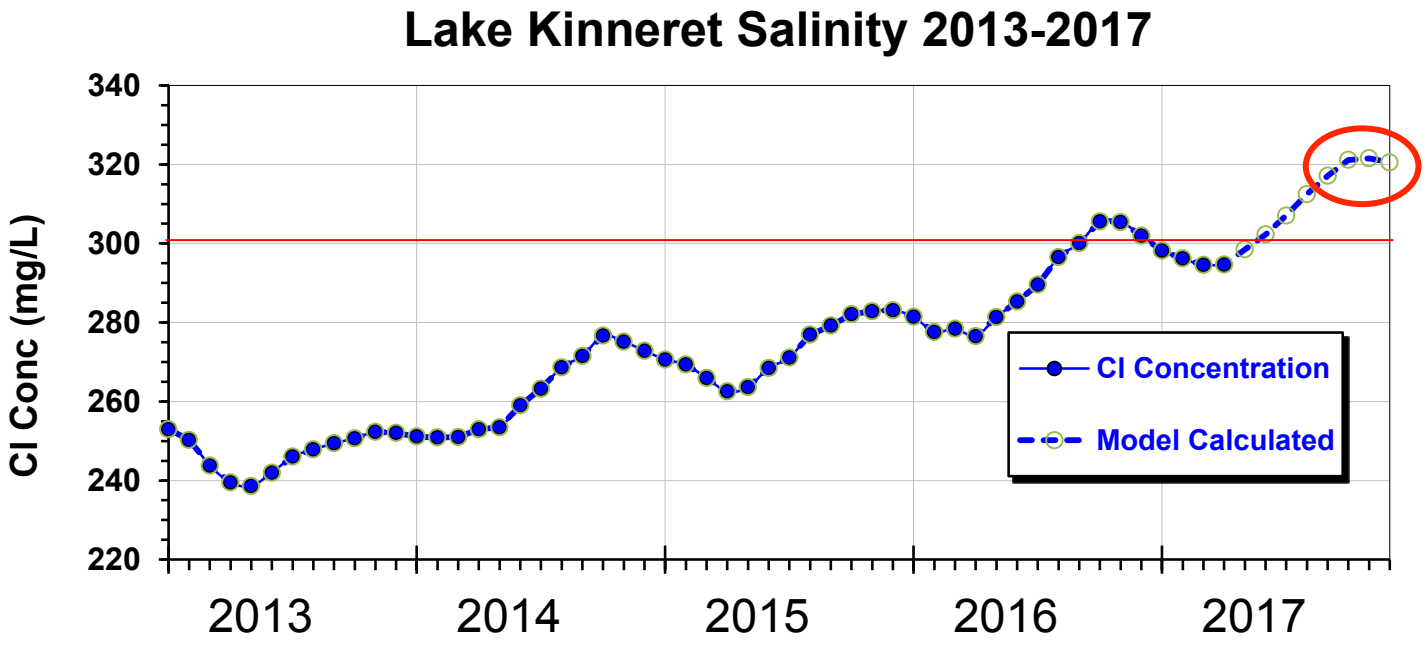
- *A Balance of the net inflow and operational outflow*
- *Red lines, drought periods and recommended green line*



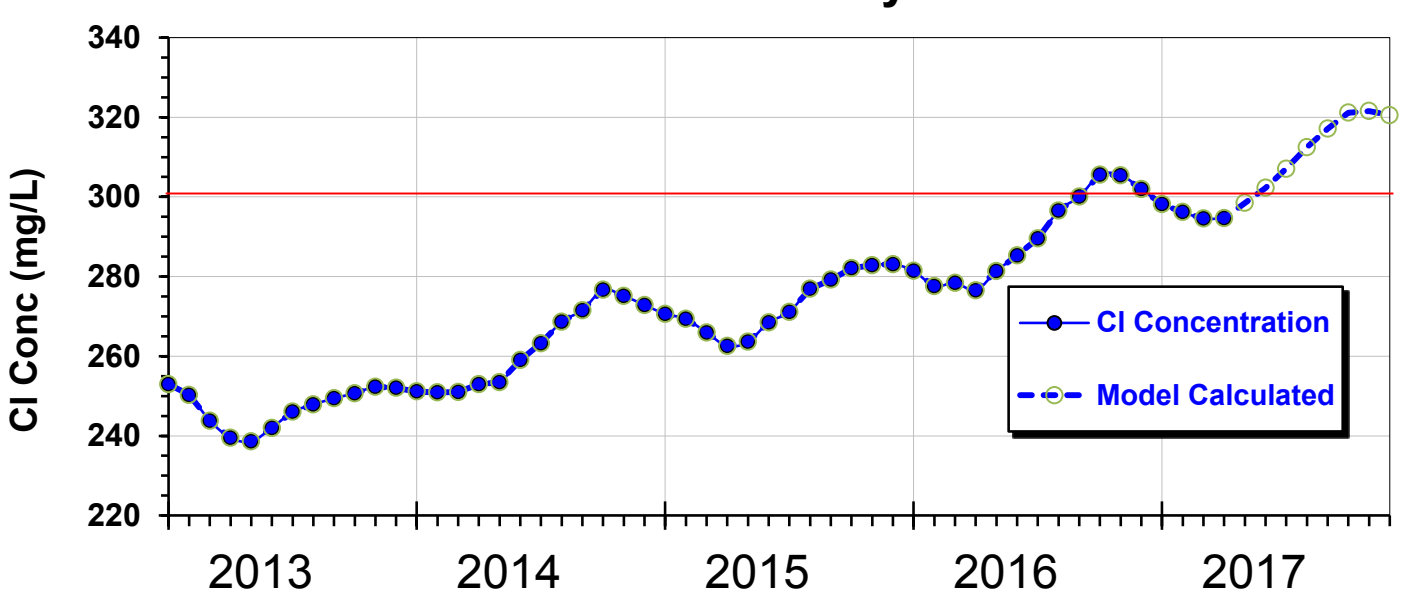
Source: The Hydrological Service, Israeli Water Authority

Lake Kinneret Salinization Process

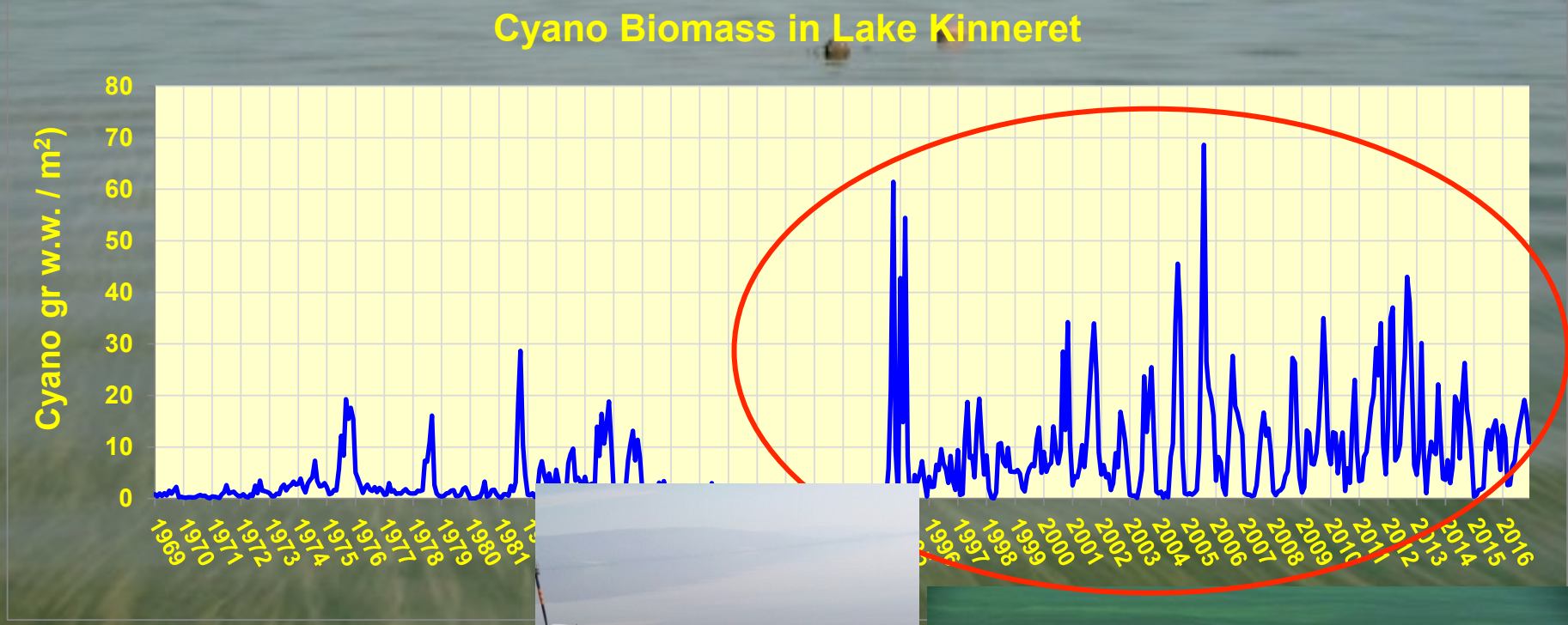




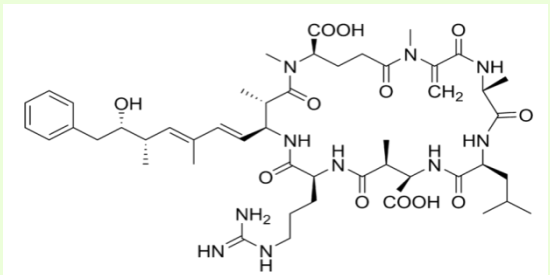
Lake Kinneret Water Quality - Salinity



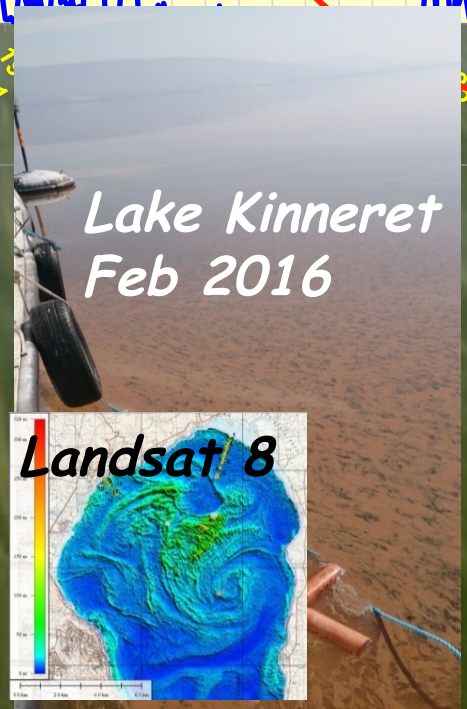
Lake Kinneret Water Quality -Cyanobacteria



Lake Kinneret 2001
Photo by Assaf Sukenik



Microcystin

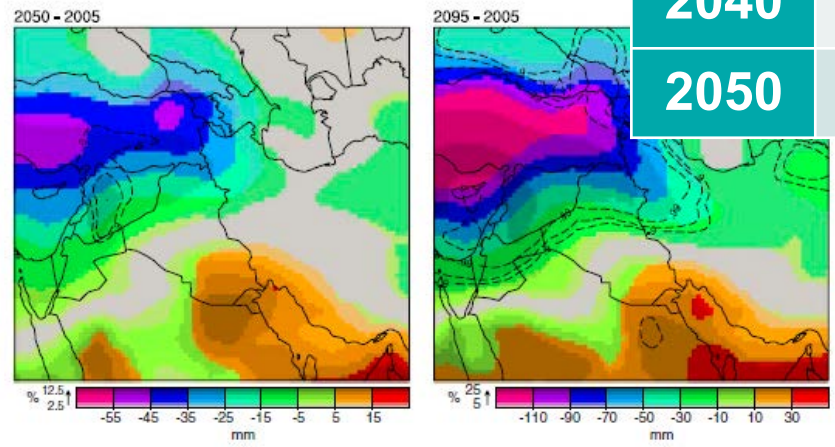


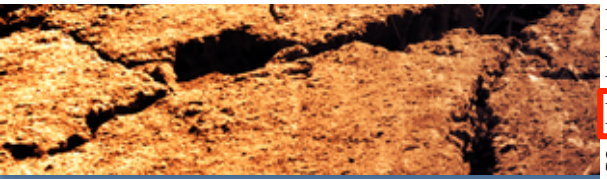
WATER AUTHORITY

Climatic Change foreseen

According to:
Rimmer et al., 2011
Evans et al., 2012
Givati and Rosenfeld, 2013

Planning Scenario Table		
Year	Av. Available Water : Climate Change only	Av. Available Water: Total impact
2017	290	290
2020	280	270
2030	260	245
2040	240	220
2050	220	195





	Echam-RegCM	Hadley-MM5	Echam-MM5	JMA Model	Ensemble
Precipitation trend 2015 -2060 (mm/year)	-7.472	-1.610	1.631	0.225	-2.229
Evaporation trend 2015-2060 (Mm^3 $year^{-1}$)	0.606	0.374	0.233	-0.051	0.411
Inflows trend 2015-2060 (Mm^3 $year^{-1}$)	-9.054	-1.953	1.943	1.438	-2.599
Solute Inflows trend 2015-2060 (Ton $year^{-1}$)	-393.820	-71.314	106.433	65.782	-0.101

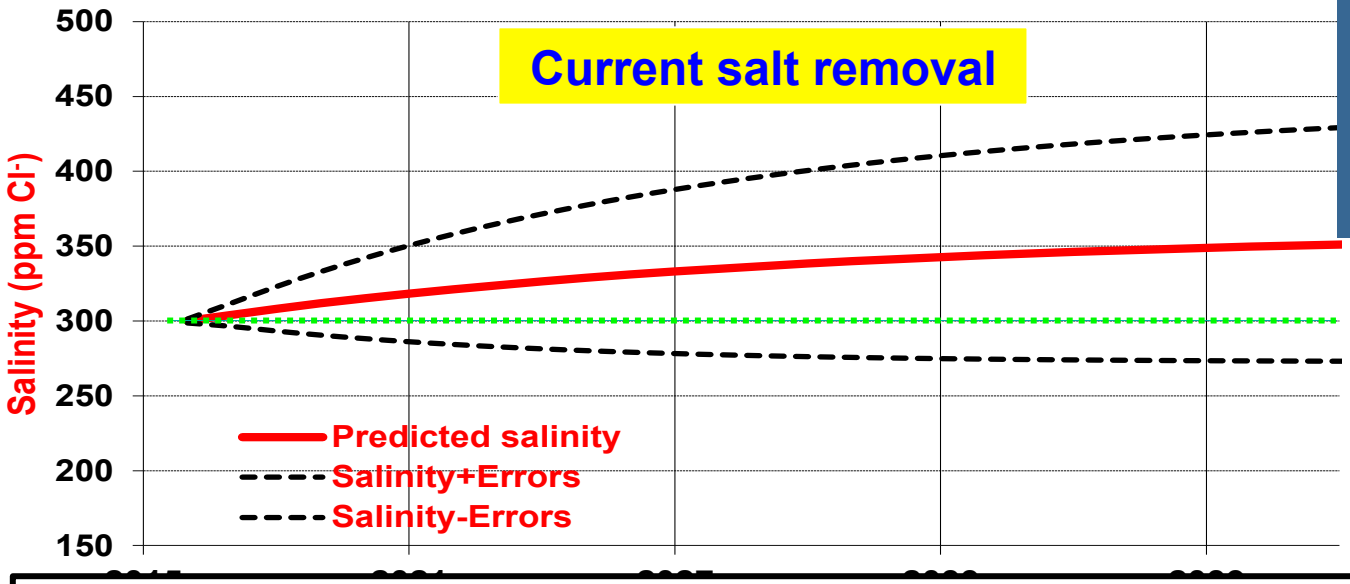
Salinity Prediction Model

30 years run

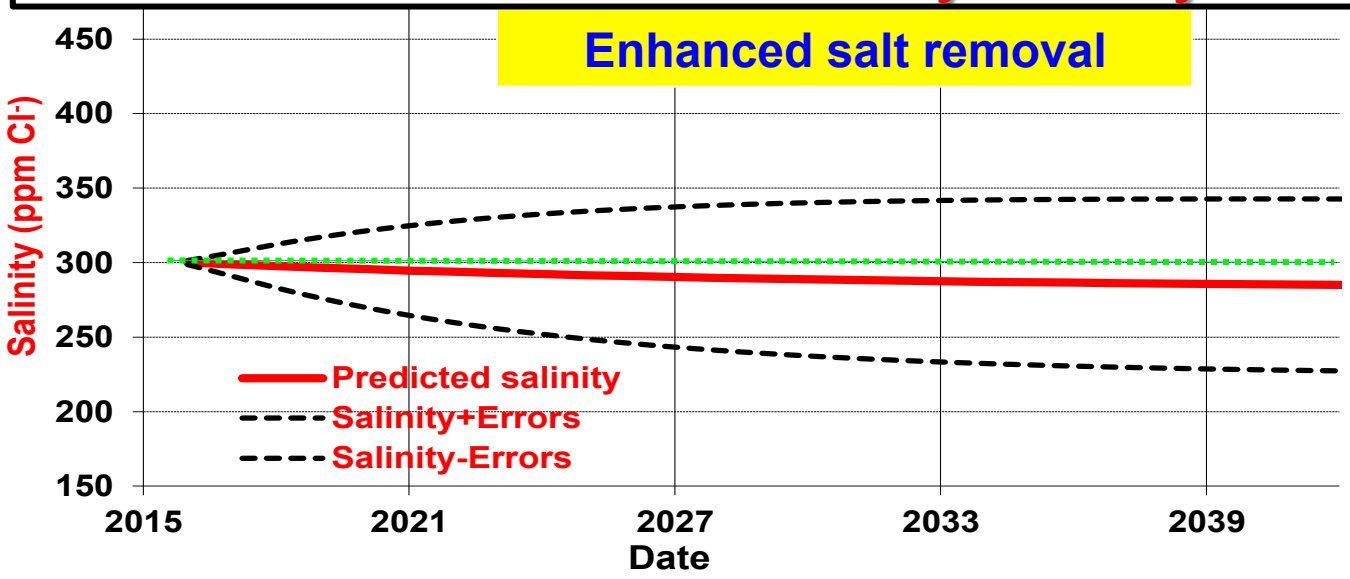
Inflow – 490 MCM/y

Evap. – 240 MCM/y

Net Infl. – 250 MCM/y



Future Available Water of 250 MCM/y - Salinity will be restraint



Source:
Dr. Alon Rimmer,
Lake Kinneret Lab

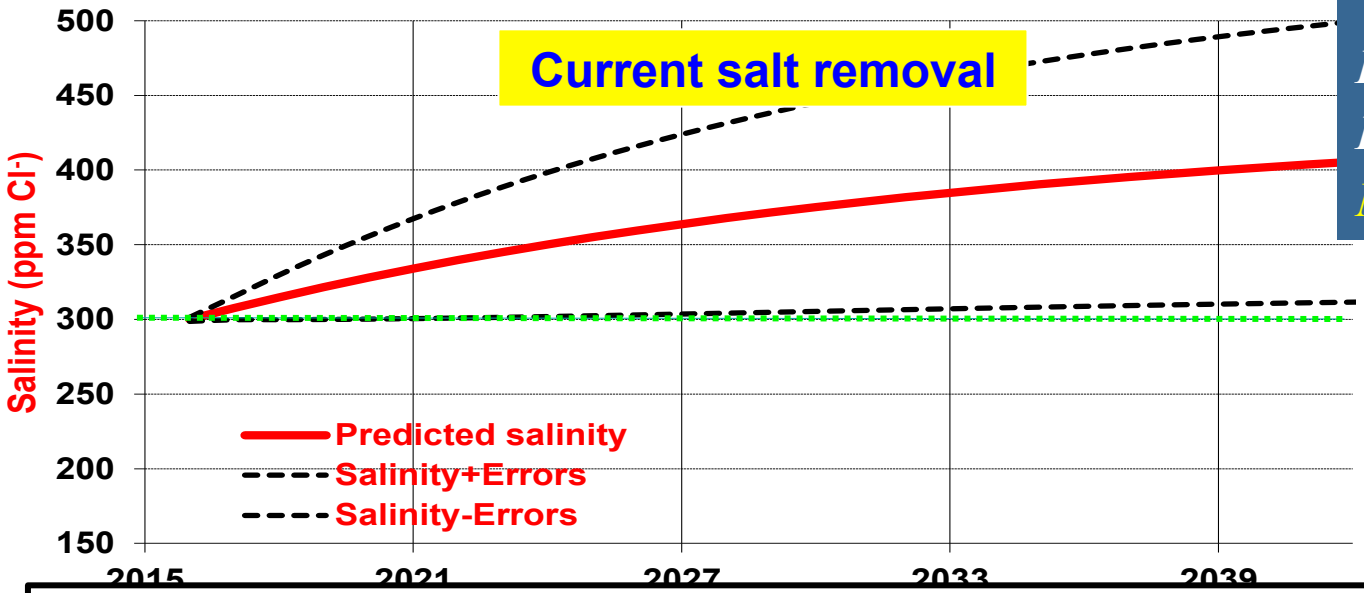
Salinity Prediction Model

30 years run

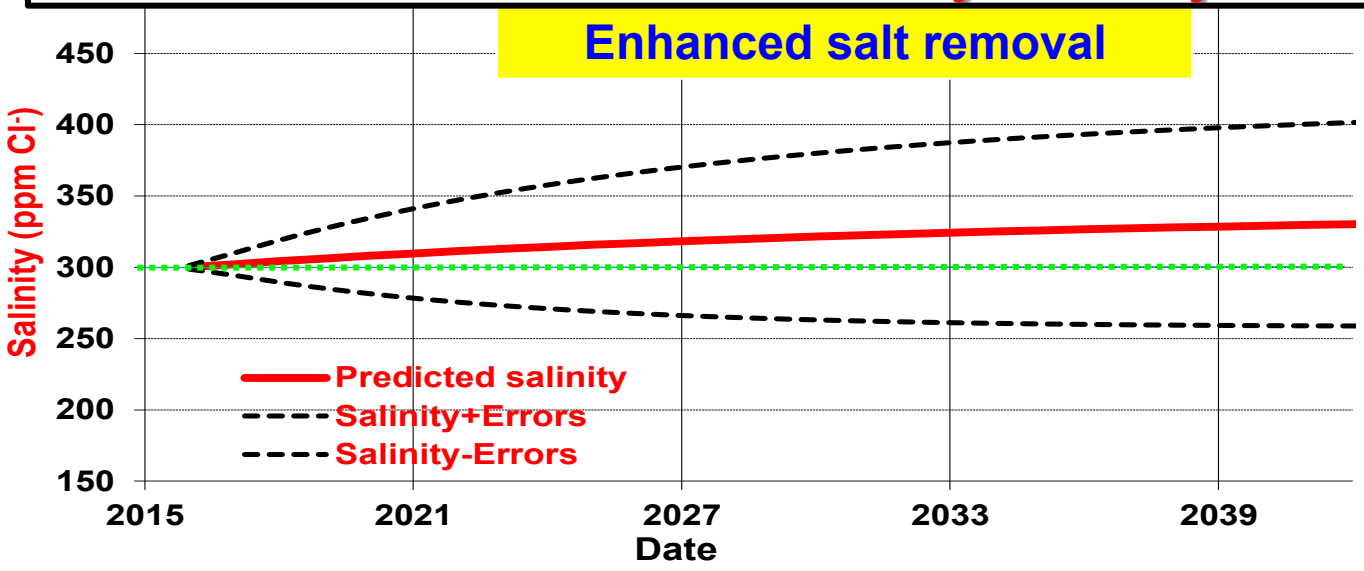
Inflow – 440 MCM/y

Evap. – 240 MCM/y

Net Infl. – 200 MCM/y



Future Available Water of 200 MCM/y - Salinity will NOT be restraint

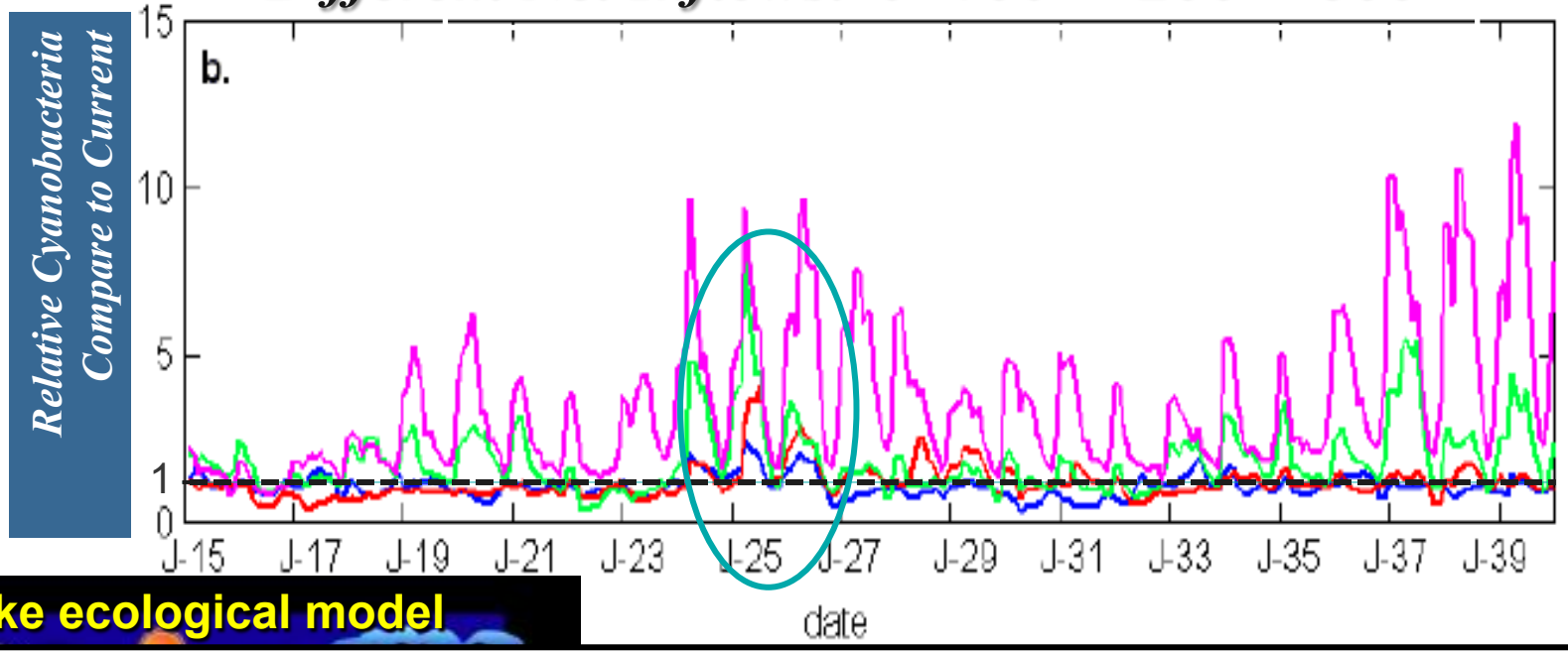


Source:
Dr. Alon Rimmer,
Lake Kinneret Lab

Ecological Prediction Model

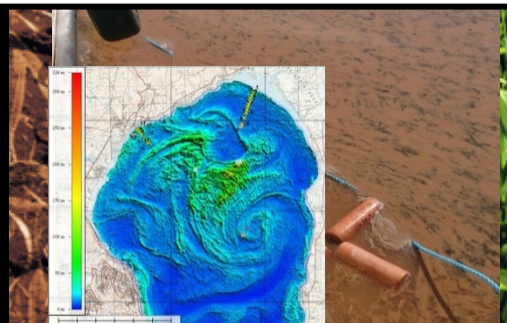
25 years run

Different Net Inflows: *0* *100* *200* *300*



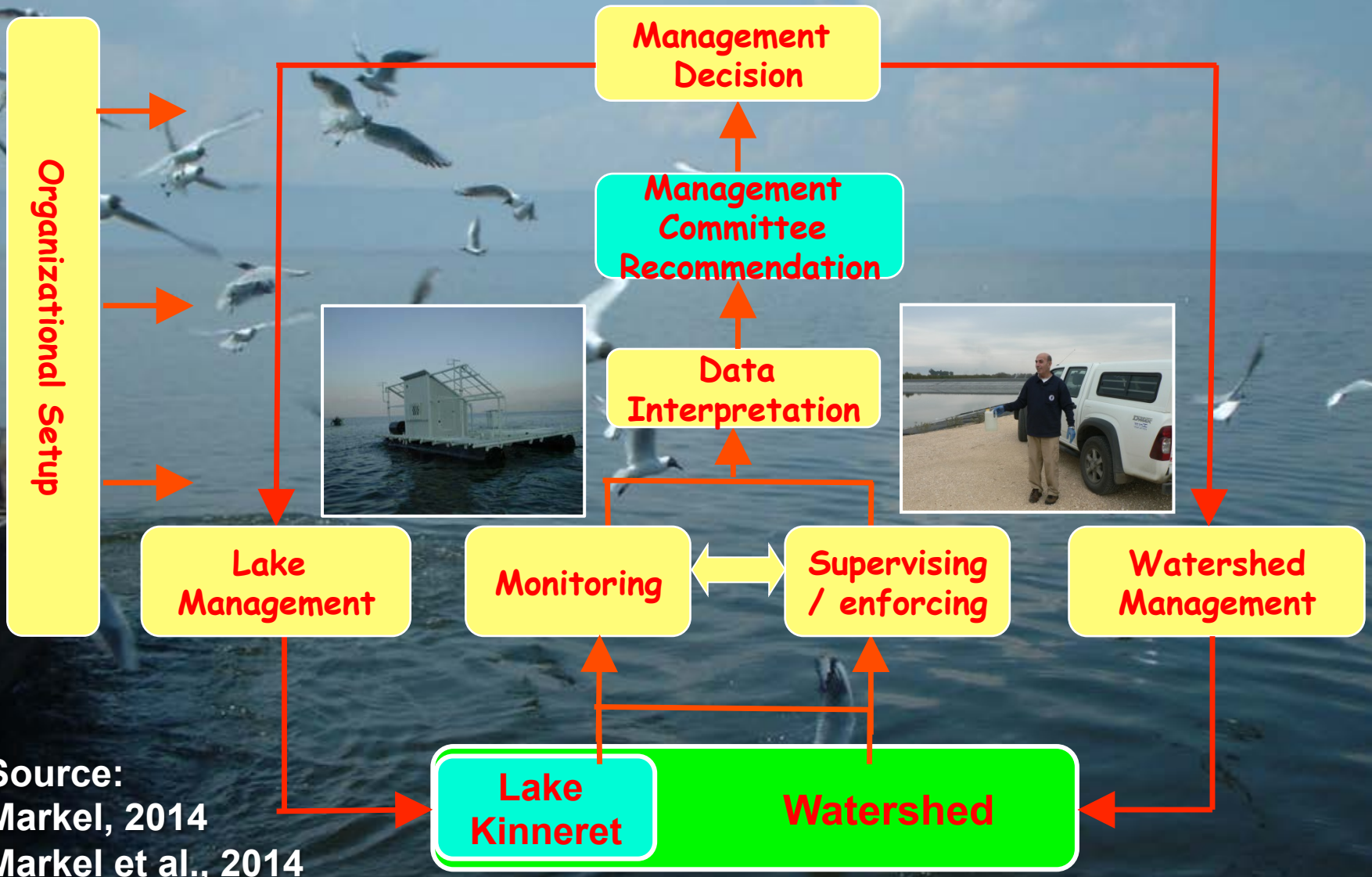
Lake ecological model

Future Available Water of below 200 MCM/y – sever algal blooms



Source:
Dr. Gideon Gal,
Lake Kinneret Lab

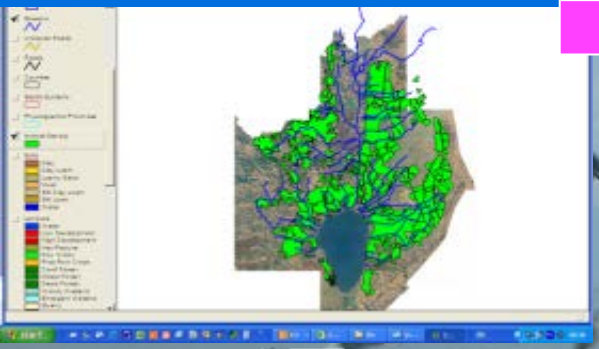
Challenge and solution:
Lake - Watershed Management



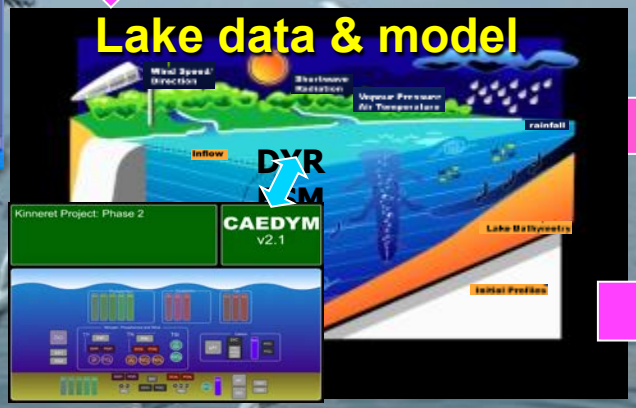
Source:
Markel, 2014
Markel et al., 2014

Integrated Lake-Watershed Management

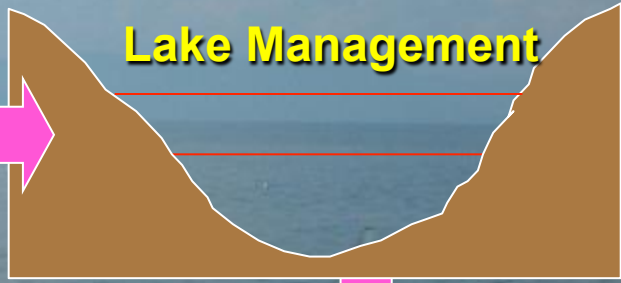
Watershed data & model



Lake data & model

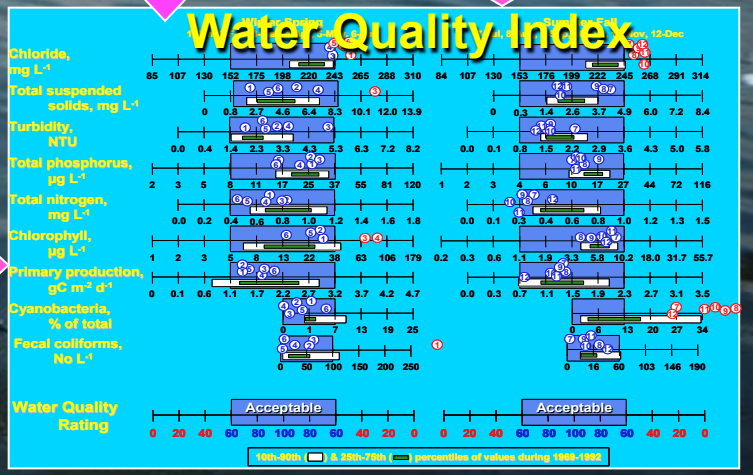


Lake Management



Watershed Management

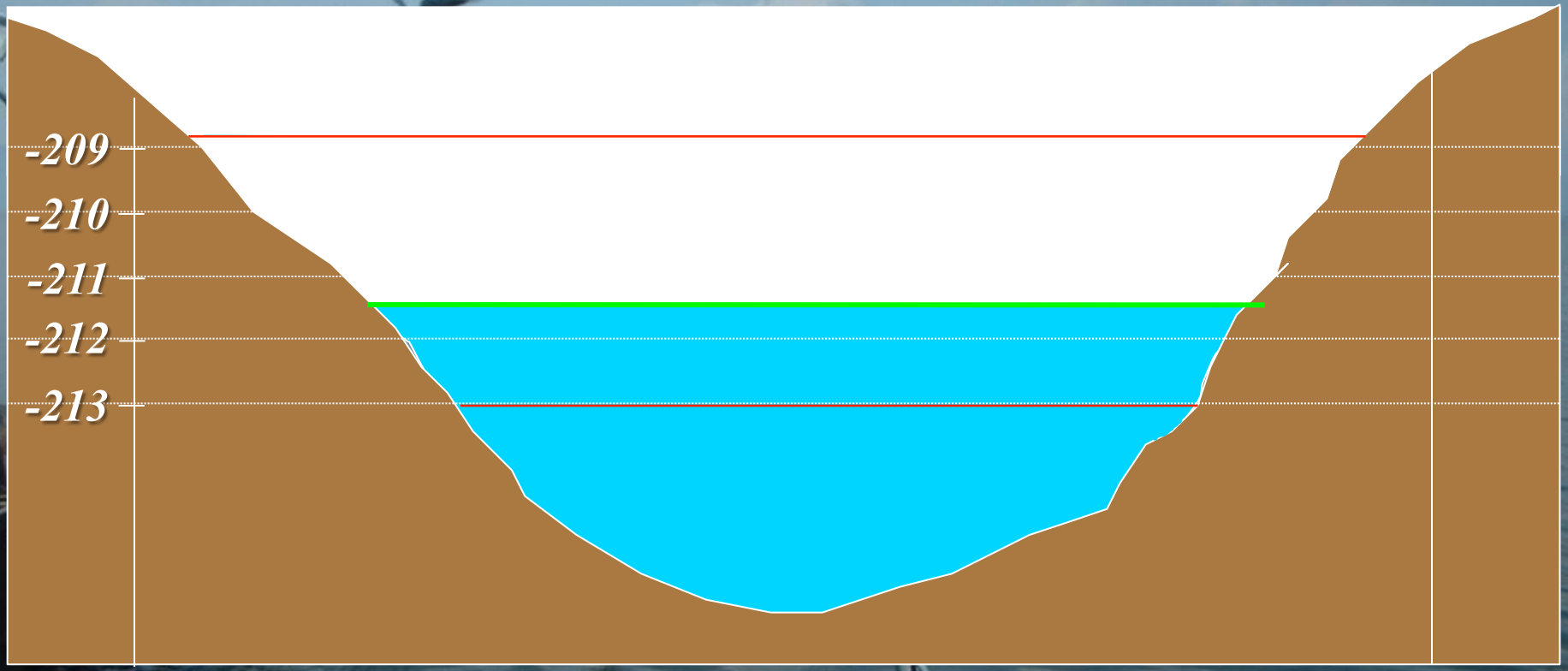
Water Quality Index



Source:
Markel, 2014
Markel et al., 2014
Markel et al., 2006

Lake Water Level Management:

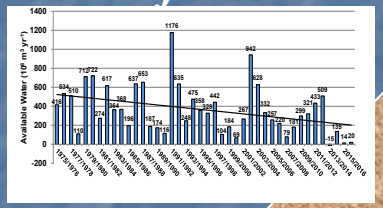
Between the Red lines and a constant minimum (Green Line)



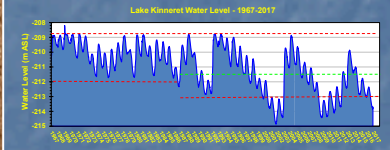
What is low water exchange?

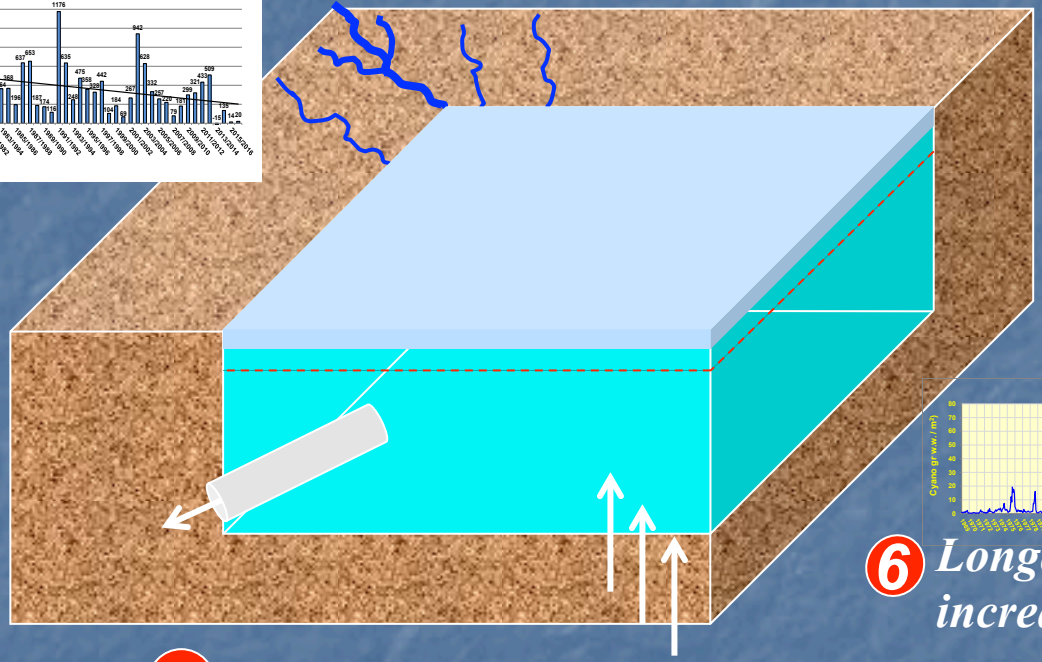
1 *Continuous precipitation shortage*

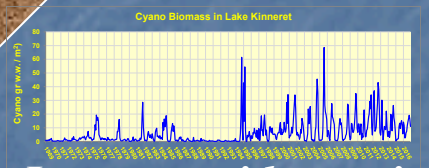
2 *Decrease of water inflows*



3 *Decrease in water level*







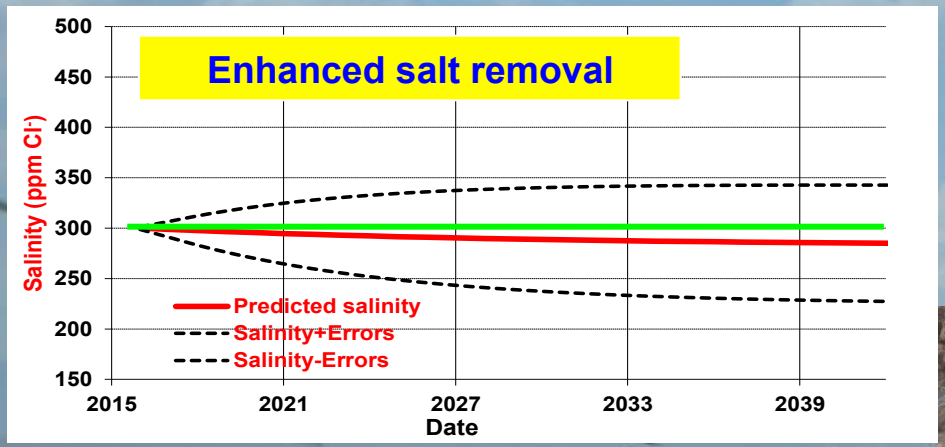
6 *Longer residence time increase salinity and cyanobacteria*

4 *Decrease in water pumped from the lake*

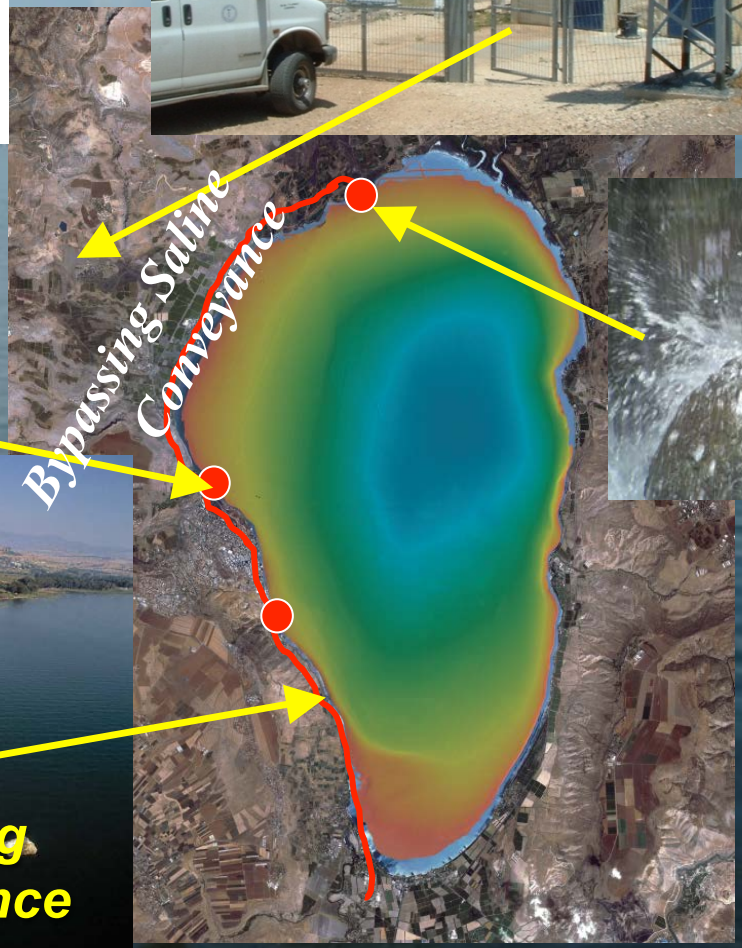
5 *Saline Springs continue to charge into the lake*

WATER AUTHORITY

Salinity Control



Eastern Galilee Drills



Capturing & Diverting Submarine Spring

Lake-Watershed Management

- *Lake Management:*
  - *Fishery Management*
  - *Costal Management*

- *Watershed Management:*
  - *Sewage reuse for irrigation*
  - *Removal of any fecal source (N/P)*
  - *Treating also diffuse pollution sources*

WATER AUTHORITY

Lake Fishery Regulation

- *Stocking of St. Peter's fish and Grey Mullet*
- *Extracting excess Sardines from the lake.*
- *Preventing overfishing and Illegal fishing.*

Coastal Management

- Keeping the precautionary principal by:
  - Removing Coastal vegetation only under permit.
  - Using permitted machines to reduce soil destruction.

Halukim-Lavnon Beach, July 2012. Photographed by: Doron Markel

Watershed Manag.: Sewage

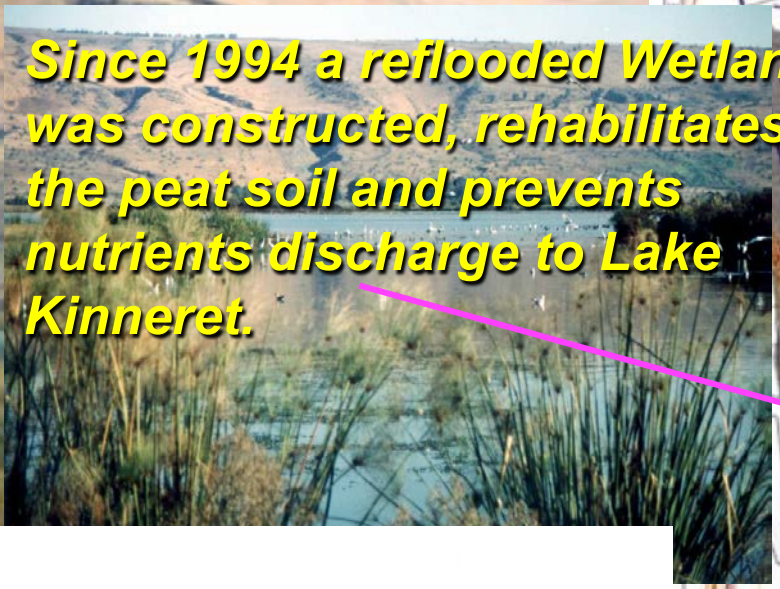
Watershed Manag.: Dairy Farms

1. Winter Roofing

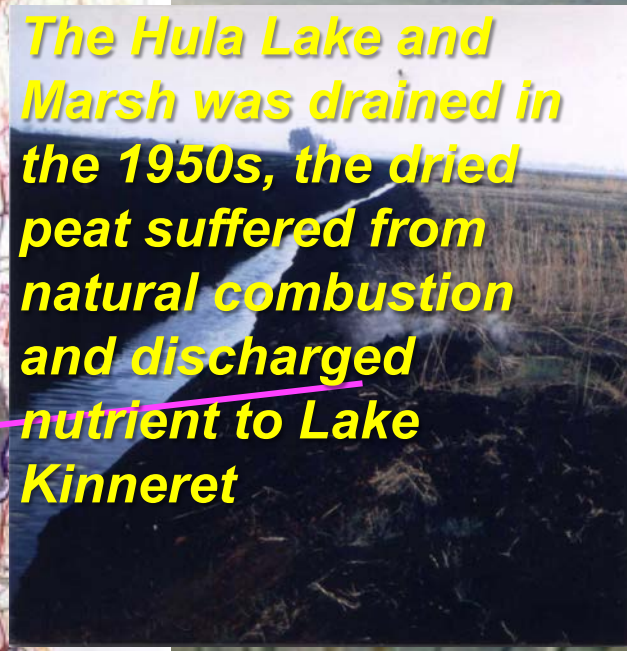
2. Liquid manure to treatment plants

3. Solid manure to compost production

Watershed Manag.: The Hula Project



Since 1994 a reflooded Wetland was constructed, rehabilitates the peat soil and prevents nutrients discharge to Lake Kinneret.



The Hula Lake and Marsh was drained in the 1950s, the dried peat suffered from natural combustion and discharged nutrient to Lake Kinneret

Historic Hula Lake and Marsh

Increasing Inflow to Lake Kinneret

WATER AUTHORITY

Hula 10

Hula 7
Hula 11

Horshat Tal 1

Hermonit 1

Shamir Wells

Gomme 2

Limiting Agricultural Consumption

Importing Outsource water to Kinneret Basin

Supply from Lake Kinneret to the Galilee

Artesian Wells

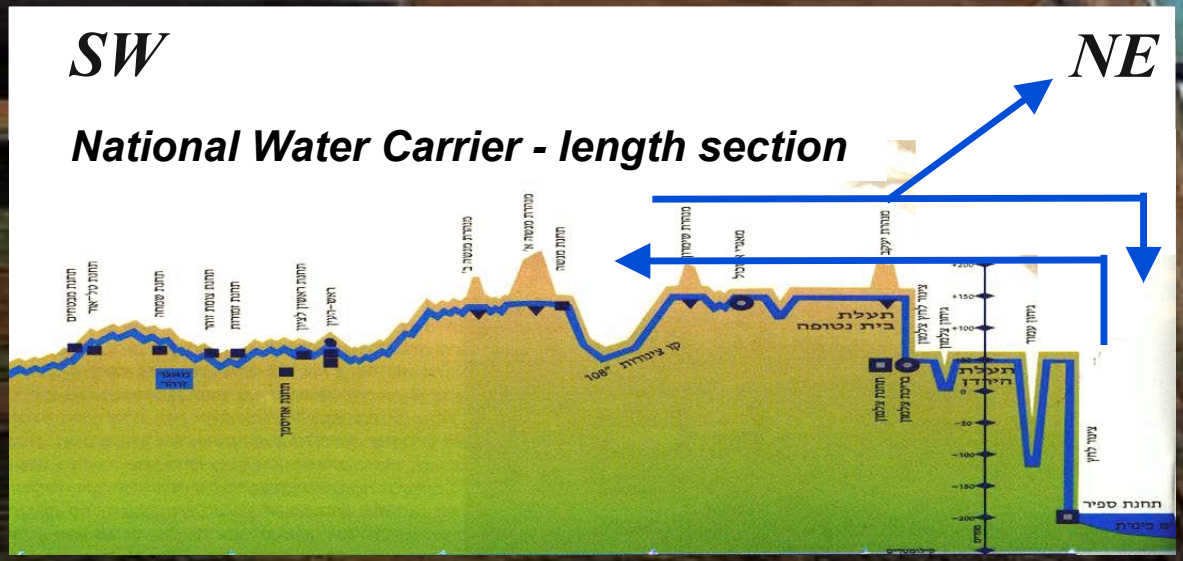
- Existed Wells
- Planned Wells

Supply from Lake Kinneret to the Golan Height

Enhancing water exchange in the lake by:
Adding 10-20 MCM/y in the short term
Adding 50-100 MCM/y in the long term

WATER AUTHORITY

Reversing the direction of the NWC



Summary

- Lake Kinneret - an important Israeli water resource, a strategic one.
- Water inflow has decreased (climate change), lower in the future .
- Low water exchange - endangering W.Q. (salinity ,cyanobacteria).
- The management plan based on data and models includes:
  - Stabilizing Water Level fluctuations.
  - Increasing removal of saline inflows.
  - Enhancing lake fishery and costal management.
  - prevention pollution in the watershed, increasing N/P.
  - Increasing water inflow by various means, including reversing the NWC northward.

WATER AUTHORITY

Summary

- Lake Kinneret is an important water resource in Israel and must remain a strategic one.
- Water inflow to Lake Kinneret decreases due to climatic change, and might be even much lower in the future .
- Operation of the lake with low inflow amount even if the water level was stable (low water exchange) might lead to increase salinity and cyanobacteria blooms.
- Therefore the enhanced management plan includes:
  - Increased removal of saline inflows.
  - Enhanced lake fishery and costal management.
  - Intensified prevention of pollution in the watershed.
  - Increase water inflow and water exchange by various means.

WATER AUTHORITY

Summary

- Integrated Lake - Watershed Management is needed in order to preserve the water quality and the ecological balance of Lake Kinneret.
- Management should be based on Monitoring, data and models, which enable knowledge and understanding the complexity of the system.
- Different Lake and watershed management activities are implemented in Lake Kinneret, allowing the preservation of the lake as a major water resource, despite the hydrological constrains.