TELEMETRY SYSTEMS IN CHANNELS

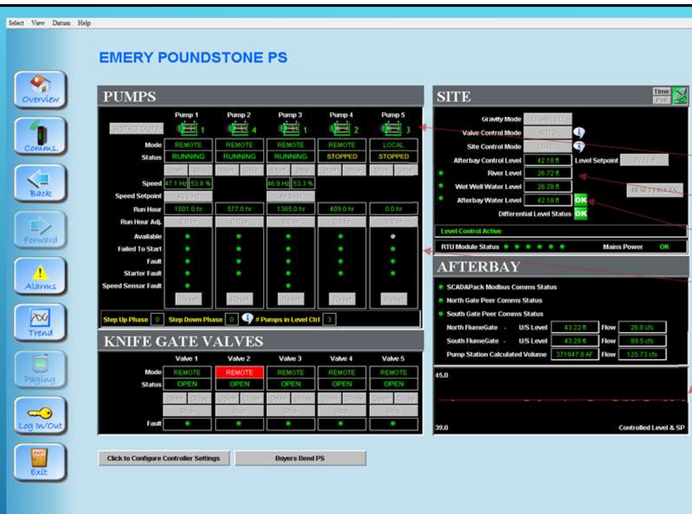
Jordon Navarrot
Reclamation District 108

- Irrigated Lands 48,000 acres
- Sacramento River Supply 232,000 acre-feet
- Earthen Canals 84 miles
- Concrete Lined Canals 35 miles
- Pipelines 4 miles
- Drains 301 miles
- Levees 90 miles

RECLAMATION DISTRICT 108

- Constructed in 2008
- 300 cfs capacity
- Fish screen

POUNDSTONE PUMPING PLANT



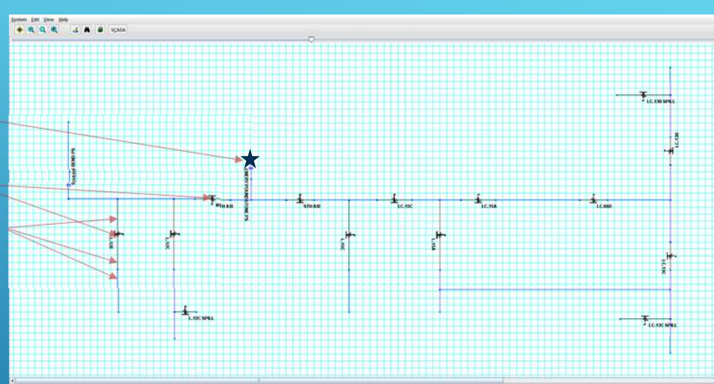
- Pump status
- River Elevation
- Canal Elevation
- Alarms
- Trending

POUNDSTONE PUMPING PLANT - HMI

- Solar powered
- Mechanically driven
- Radio communicaiton

RUBICON FLUMEGATE

- Poundstone Pumping Plant
- Rubicon FlumeGates
- Lateral Deliveries

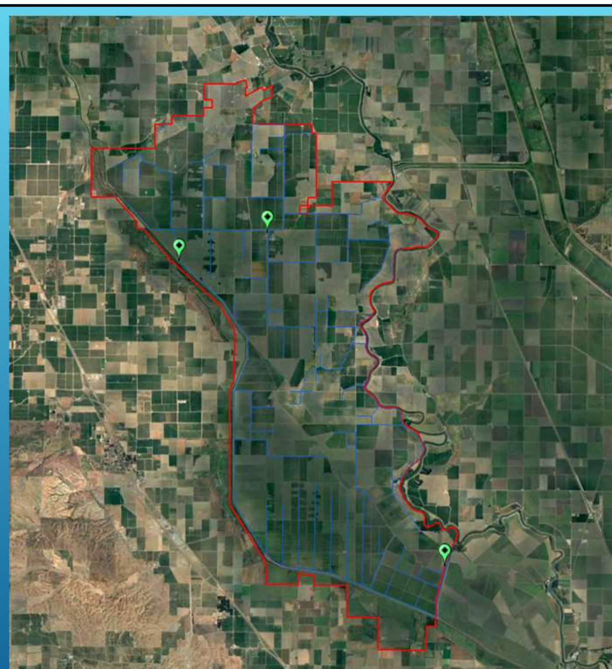


RUBICON – SYSTEM DIAGRAM

- Screw gate in canal
- Weir box in field
- Portable velocity sensor

FIELD DELIVERY

- Three reuse pumping stations drain water back in to field-delivery canals
- Reuse totals 60,000 acre feet annually, accounting for nearly 1/3 of the districts total use

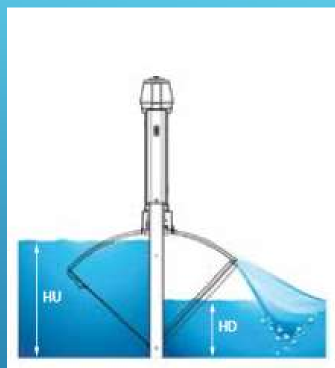


REUSE

SYCAMORE SLOUGH REUSE FACILITY

- Rubicon
- Telemetry
- Remote Tracker

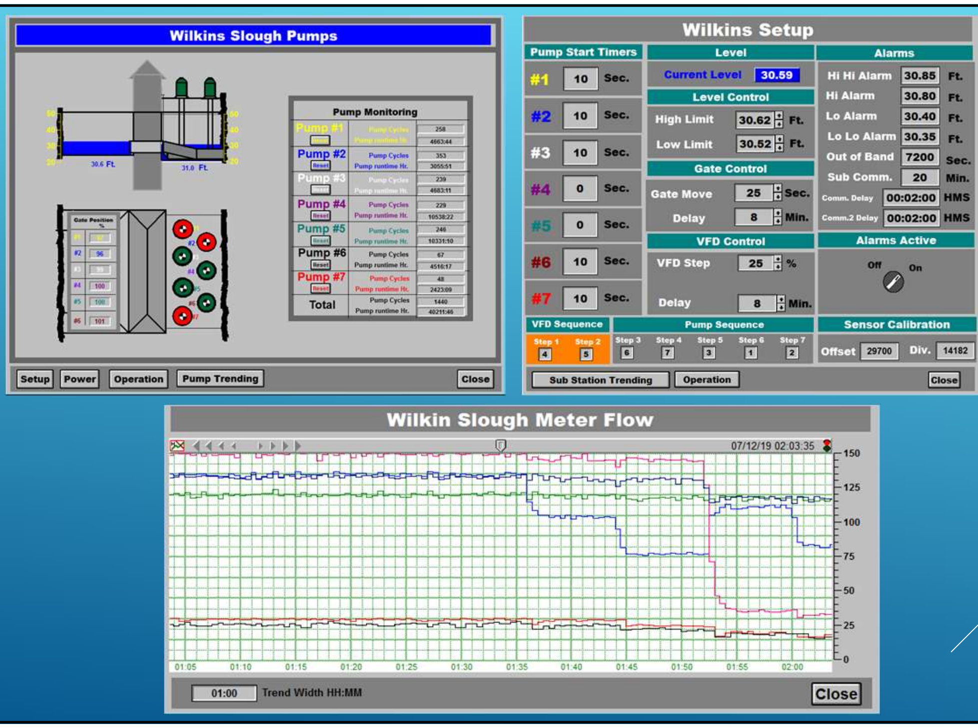
TECHNOLOGIES IN DETAIL



Control objective		Gate action
Local	Position	Moves to a desired set-point and stays there
	Flow	Maintains a constant flow regardless of upstream or downstream levels
	Upstream level	Maintains a desired level in the pool immediately upstream
	Downstream level	Maintains a desired level in the pool immediately downstream

RUBICON – FLUMEGATE CAPABILITIES

WILKINS SLOUGH PUMPING PLANT



Introduced in State Senate January 9, 2015 (following drought)

Everyone must file annual use reports

For Diverters >1000 AF/yr - hourly monitoring required on measurement devices.

Devices must meet 15% accuracy requirement(10% if installed after 1/1/16)

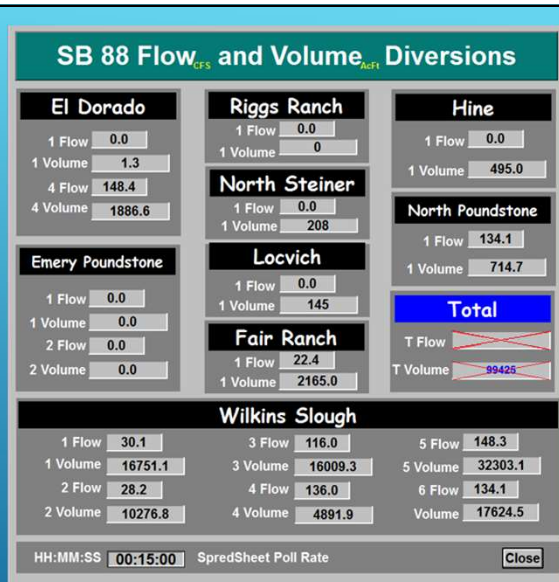
Effective Jan. 1 2020:

Sites must have telemetry

Data must be posted to a public website

SENATE BILL 88 (SB 88)

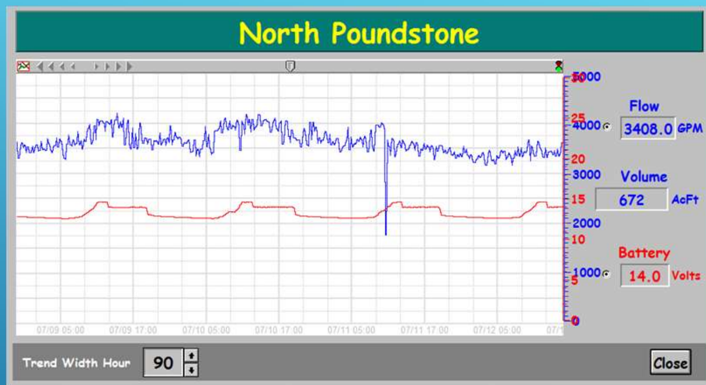
- As of 2019:
  - 100% compliant with 2017 and 2018 objectives
  - 90% completion of 2020 telemetry requirements
    - Still working on data transmission from Rubicon



SB 88
ALL DISTRICT DIVERSIONS HMI

- Local meter-head for USBR reading
- 4-20 ma output for communicating flow rate

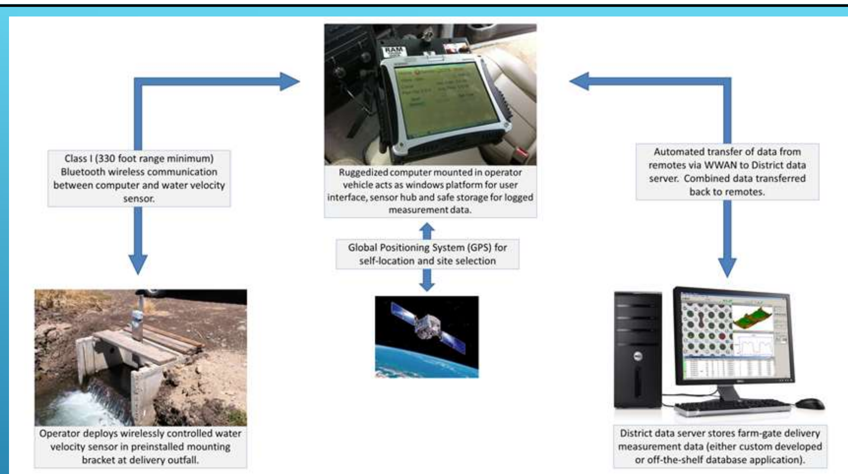
SB 88
SINGLE PUMP DIVERSION HARDWARE



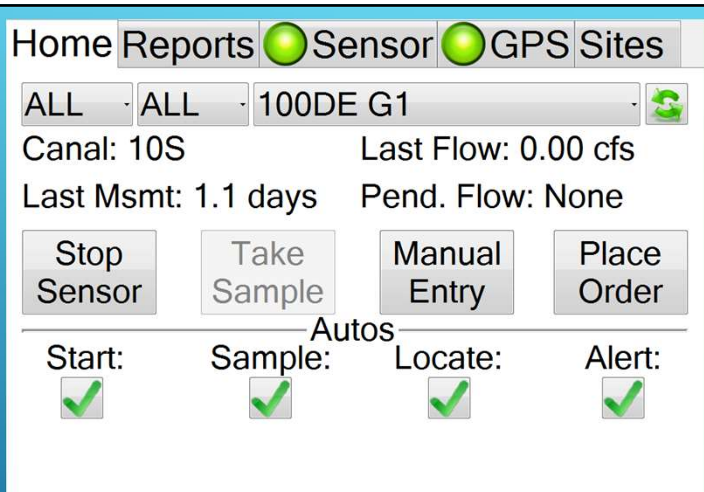
SB 88
SINGLE PUMP DIVERSION HMI

- California Water Commission adopted July 11, 2012
- Requires Agencies over 25,000 acres to:
- Measure the volume of water delivered to customers with sufficient accuracy
  - Existing device must be +/- 12%
  - New or replacement device must be:
    - +/- 5% using laboratory certification
    - +/- 10% using field verification
- Adopt a pricing structure for water customers based at least in part on quantity delivered

FIELD LEVEL MEASUREMENT – SB X7-7

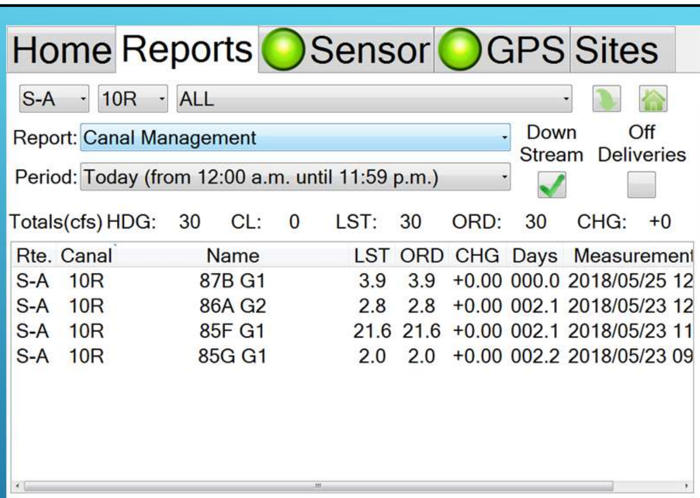


REMOTE TRACKER



- GPS automatically populates measurement site within 300 feet of designated location
- Bluetooth connects Remote Tracker device to Toughbook
  - 40 second flow sample

LAPTOP MEASUREMENT INTERFACE



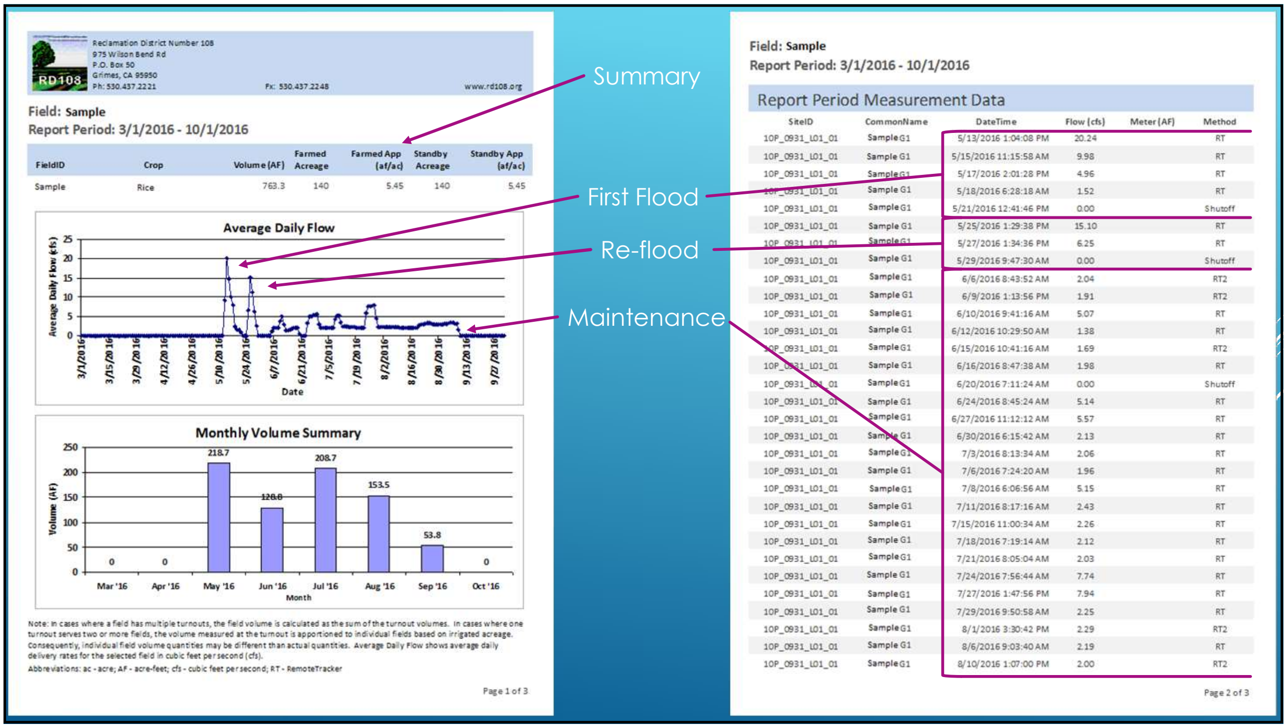
- Instantaneous access to district-wide delivery flow

LAPTOP MEASUREMENT INTERFACE

- All field measurements download to Water Information System(WIS) computer daily for review
- Volumes computed at WIS transfer to Water Accounting Database when invoices are created

FIELD LEVEL MEASUREMENT

REMOTE TRACKER SOFTWARE



Reclamation District Number 108
975 Wilson Bend Rd
P.O. Box 50
Grimes, CA 95950
Ph: 530.437.2221 Fx: 530.437.2248 www.rd108.org

Field: Sample
Report Period: 3/1/2016 - 10/1/2016

FieldID	Crop	Volume (AF)	Farmed Acreage	Farmed App (af/ac)	Standby Acreage	Standby App (af/ac)
Sample	Rice	763.3	140	5.45	140	5.45

Note: In cases where a field has multiple turnouts, the field volume is calculated as the sum of the turnout volumes. In cases where one turnout serves two or more fields, the volume measured at the turnout is apportioned to individual fields based on irrigated acreage. Consequently, individual field volume quantities may be different than actual quantities. Average Daily Flow shows average daily delivery rates for the selected field in cubic feet per second (cfs).
Abbreviations: ac - acre; AF - acre-feet; cfs - cubic feet per second; RT - RemoteTracker

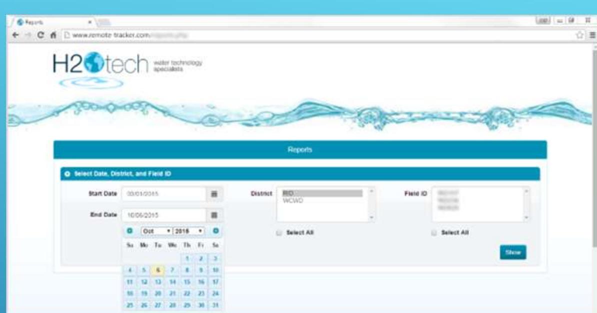
Page 1 of 3

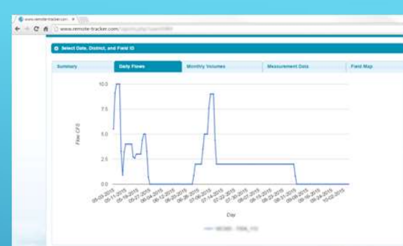
Field: Sample
Report Period: 3/1/2016 - 10/1/2016

Report Period Measurement Data

SiteID	CommonName	DateTime	Flow (cfs)	Meter (AF)	Method
10P_0931_L01_01	Sample G1	5/13/2016 1:04:08 PM	20.24		RT
10P_0931_L01_01	Sample G1	5/15/2016 11:15:58 AM	9.98		RT
10P_0931_L01_01	Sample G1	5/17/2016 2:01:28 PM	4.96		RT
10P_0931_L01_01	Sample G1	5/18/2016 6:28:18 AM	1.52		RT
10P_0931_L01_01	Sample G1	5/21/2016 12:41:46 PM	0.00		Shutoff
10P_0931_L01_01	Sample G1	5/25/2016 1:29:38 PM	15.10		RT
10P_0931_L01_01	Sample G1	5/27/2016 1:34:36 PM	6.25		RT
10P_0931_L01_01	Sample G1	5/29/2016 9:47:30 AM	0.00		Shutoff
10P_0931_L01_01	Sample G1	6/6/2016 8:43:52 AM	2.04		RT2
10P_0931_L01_01	Sample G1	6/9/2016 1:13:56 PM	1.91		RT2
10P_0931_L01_01	Sample G1	6/10/2016 9:41:16 AM	5.07		RT
10P_0931_L01_01	Sample G1	6/12/2016 10:29:50 AM	1.38		RT
10P_0931_L01_01	Sample G1	6/15/2016 10:41:16 AM	1.69		RT2
10P_0931_L01_01	Sample G1	6/16/2016 8:47:38 AM	1.98		RT
10P_0931_L01_01	Sample G1	6/20/2016 7:11:24 AM	0.00		Shutoff
10P_0931_L01_01	Sample G1	6/24/2016 8:45:24 AM	5.14		RT
10P_0931_L01_01	Sample G1	6/27/2016 11:12:12 AM	5.57		RT
10P_0931_L01_01	Sample G1	6/30/2016 6:15:42 AM	2.13		RT
10P_0931_L01_01	Sample G1	7/3/2016 8:13:34 AM	2.06		RT
10P_0931_L01_01	Sample G1	7/6/2016 7:24:20 AM	1.96		RT
10P_0931_L01_01	Sample G1	7/8/2016 6:06:56 AM	5.15		RT
10P_0931_L01_01	Sample G1	7/11/2016 8:17:16 AM	2.43		RT
10P_0931_L01_01	Sample G1	7/15/2016 11:00:34 AM	2.26		RT
10P_0931_L01_01	Sample G1	7/18/2016 7:19:14 AM	2.12		RT
10P_0931_L01_01	Sample G1	7/21/2016 8:05:04 AM	2.03		RT
10P_0931_L01_01	Sample G1	7/24/2016 7:56:44 AM	7.74		RT
10P_0931_L01_01	Sample G1	7/27/2016 1:47:56 PM	7.94		RT
10P_0931_L01_01	Sample G1	7/29/2016 9:50:58 AM	2.25		RT
10P_0931_L01_01	Sample G1	8/1/2016 3:30:42 PM	2.29		RT2
10P_0931_L01_01	Sample G1	8/6/2016 9:03:40 AM	2.19		RT
10P_0931_L01_01	Sample G1	8/10/2016 1:07:00 PM	2.00		RT2

Page 2 of 3

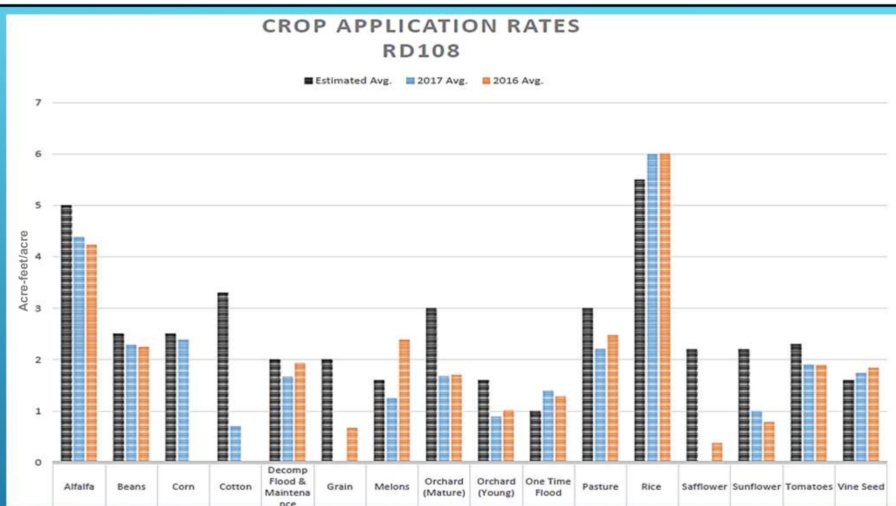




- View real-time water measurement data on a computer or mobile device

FIELD LEVEL MEASUREMENT

GROWER ACCESS TO MEASUREMENT DATA



- Adjust crop-duty charge
- Compare irrigation practices
- Understand geographical differences

WATER MEASUREMENT REPORT

DATA WITH A PURPOSE

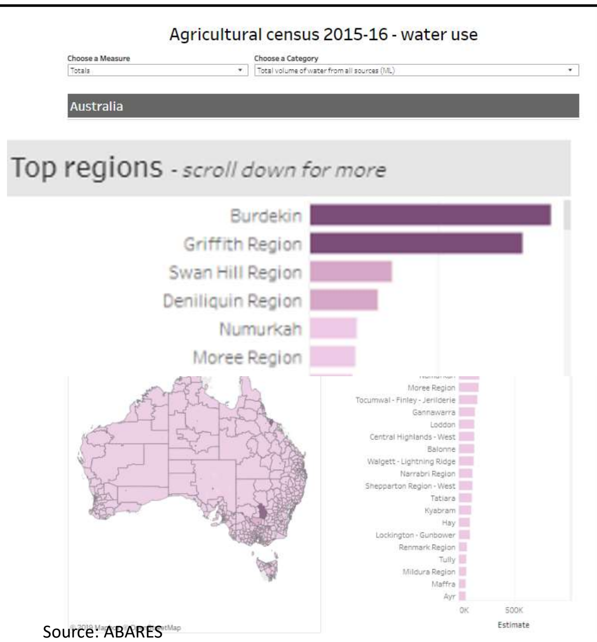
- Rubicon
- Telemetry
- Remote Tracker

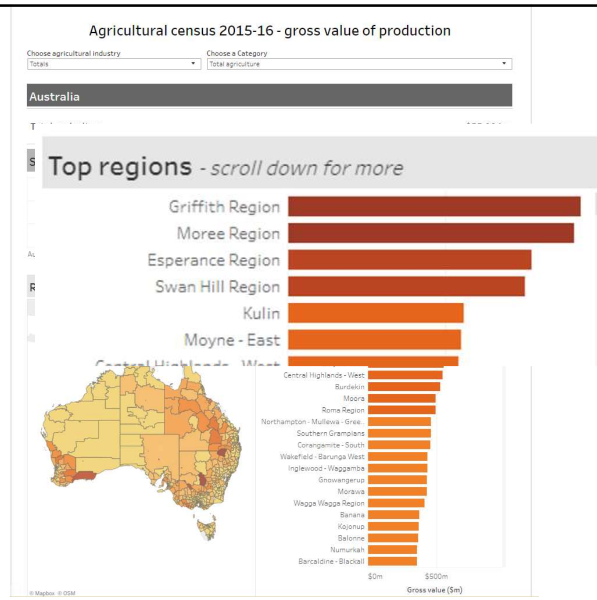
QUESTIONS?

Water Irrigation Efficiency
Dr Rose Brodrick, CSIRO Agriculture and Food, Australia

Managing irrigation water is key to future of food and agriculture

- **70% of water used globally for Agriculture**
- **40% of area used for Agricultural production is irrigated**
- **Average water use efficiency of 38%**
- **The challenge… improving this!**





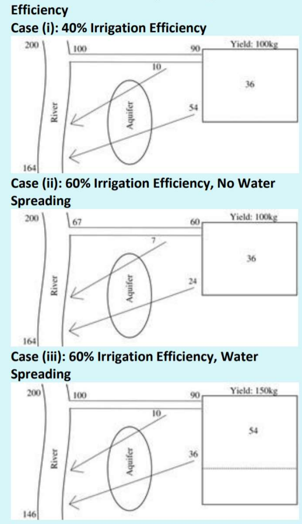
Source: ABARES

Water productivity

- Water productivity has improved 100% in last 60 years!
- Crop water productivity (yield per unit water applied) improvements have been often been driven by yield gains
- Opportunities to improve efficiency through scheduling irrigations to maximise yield – to close the yield gap.
- Lack of confidence in decision making in variable conditions
- Often reliant on experience rather than definitive data to make decisions.

en

Figure 3: **Effects of Changes in Irrigation Efficiency**

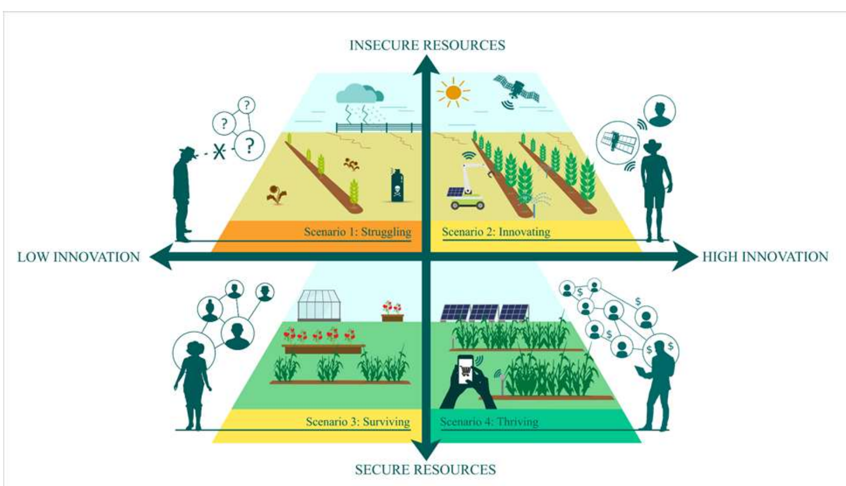


Source: Scheierling et al. 2014.

A 'climate of change'

- increased variability
- decreased water availability
- rising costs of production
- regulatory constraints
- competing land use
- climate change/carbon markets
- digitally driven agriculture
- Social licence to farm

How do we remain productive in the face of changing and uncertain futures

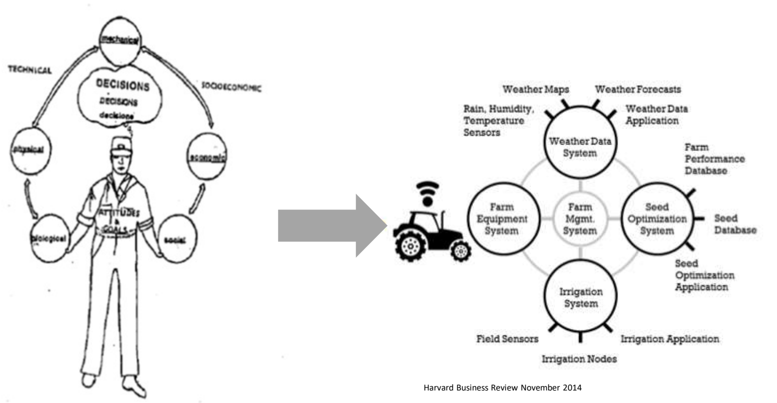


Strategies to adapt to change

- **Increase/maintain yields**
- **Improve production/system efficiencies**
- **Improve the return for Crops/Reduce Costs**
  - **Adaptive Integrated Management**
  - **Harness understanding of existing variability**

APEC CHILE 2019

Irrigation decision making in a complex and CHANGING system



Harvard Business Review November 2014

- Improvements in water productivity over time have been at the whole-farm level not at the crop level
- Often reliant on experience rather than definitive data to make decisions.
- "Solutions" have often been complex and difficult to implement and situation specific
- Can we develop a simple integrated solution that can be tailored to the system?

Irrigation decision making

- Timing is critical to maximise crop yield and quality.
- Differences in soil type, regional climate, water availability, system capacity, attitude to risk and the amount of data collected means that any irrigation management tools must be able to be tailored to the system.
- Decisions are often difficult when situations are considerably different from normal, such as when extreme weather events occur.

Irrigation Scheduling

- **Efficient Scheduling – putting the right amount on at the right time**
- **Weather, soil and plant based methods of determining crop water use**

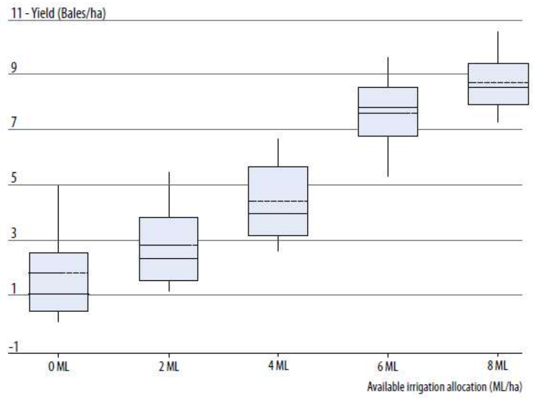
Table 6.2: Optimum deficits for irrigation: vegetative growth, photosynthesis and boll growth.

Age	Deficit for	Irrigation	Minimum Ψ_l uncovered	Relative % reduction		
Days	%	mm	MPa	Vegetative Growth	Photo-synthesis	Boll Growth
61 – 90	50	67 - 77	- 1.8	45	12	Nil
91 - 120	60	93 - 108	- 2.2	82	24	Nil
121 - 160	40	72	- 2.2	82	24	Nil

Source: Hearn & Constable (1984).

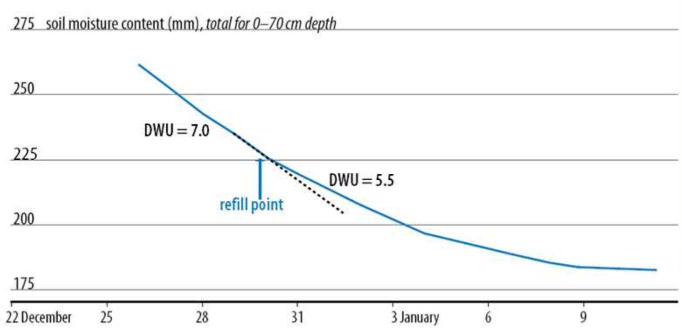
Aim is to reduce variability and optimise yield and water use efficiency

Figure 3.2.3 – CottBASE predicted yield for different irrigation allocations for an example farm at Narrabri .



Irrigation Decision Making Tools and Technologies have often been complex and not integrated

Figure 2.10.3. Setting the refill point by observing the decline in crop daily water use (DWU)



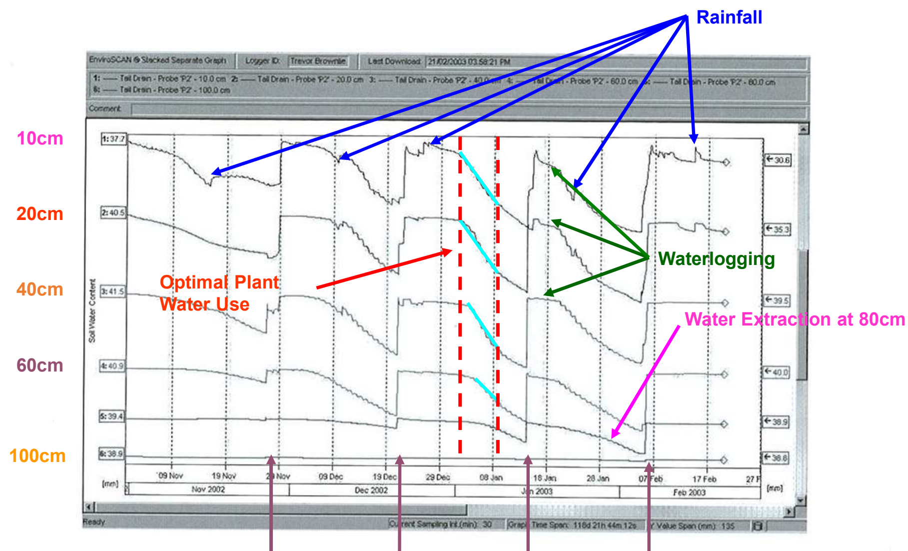


Figure 11. Stacked soil moisture graph

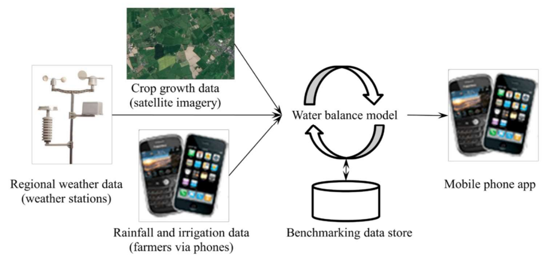
Irrigating to meet plant requirements

- **More water early can change root development and conditioning of the plant to water stress**
- **Efficient Scheduling – putting the right amount on at the right time**
- **Earlier is not necessarily better – depends on demand from plant and climatic conditions**
- **Aim is to keep the plant functioning at it's biological optimum temperature, balancing vegetative and reproductive growth, keeping in mind soil condition and climatic conditions**

EASY?

A range of options in the 'Toolkit'

- Visual Plant Symptoms
- Shovel
- Weather data (ETc)
- Calendar
- Crop models
- Sensors (Soil and Plant based)



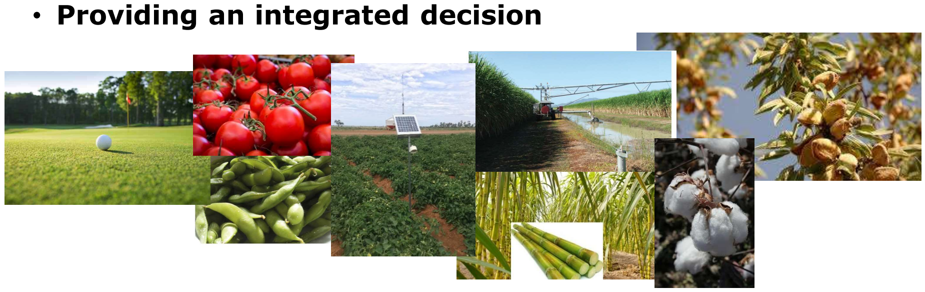
APEC CHILE 2019

WaterWise

More efficient irrigation timing through sensing plant water stress

https://research.csiro.au/digiscape/digiscapes-projects/waterwise/

- addressing the challenges of irrigating high value irrigated crops with limited water
- using sensors, models and analytics develop a blueprint to serve an industry quickly
- Providing an integrated decision



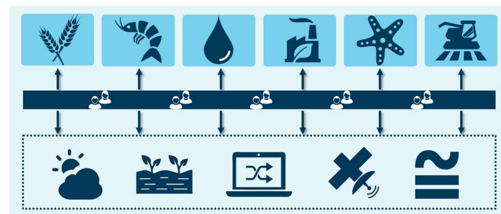
APEC CHILE 2019

Multidisciplinary Teams

- Systems agronomists
- Data Analysts
- Social Scientists
- Climate Scientists
- Software Engineering
- User Experience testing
- Sensor optimisation
- Uncertainty analytics
- Hardware development
- Technical Support

Digiscape Future Science Platform

Harnessing the digital revolution for Australian farmers & land managers



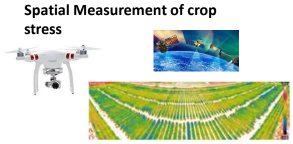
APEC CHILE 2019

WATERWISE

Quantifying crop stress and the need for Irrigation

Novel Continuous Plant based sensing for stress Quantification

Spatial Measurement of crop stress



Current and future weather

Advanced Analytics

Senaps-LAND

Image Analysis

Improved Weather Forecasts

Underpinning Physiology

UX expertise

Blueprint for other high value crops

Prototype "APP" for engagement and demonstration

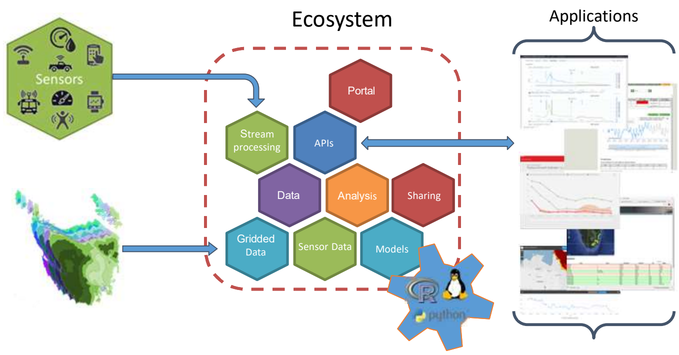
https://waterwise.io

Partner for implementation

APEC CHILE 2019

Senaps: sensor data staging system

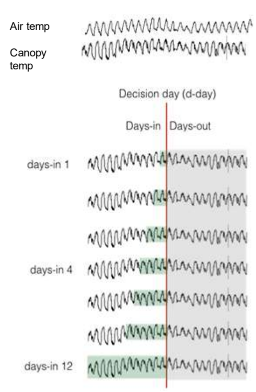
- **Sensor data management, access control**



Digiscape | Andrew D. Moore

APEC CHILE 2019

Prediction



Prediction of Canopy Temperature

- **Predict when to irrigate**
- **End of season water needs**
- **Error checking and patching data**
- **Self calibrating sensors**

APEC CHILE 2019

Prototype for grower feedback

- **WaterWise V2**
  www.waterwise.io

WaterWise Approach in new crop

- **1st Year:**
  - Asking the farmer who make the decisions in target crops
  - What are the issues
  - What information would be helpful?
  - Sensor deployment for information and learning about how farmers currently irrigate
- **2nd Year:**
  - More intensive sensor deployment, yield and water monitoring
  - Biochemistry for crop
  - Develop irrigation and predictive algorithms
- **3rd Year +**
  - Test the algorithms
  - Get feedback from farmer partners
  - Fine tune and tailor to system

Grower Interviews
(User Experience/Human Centre Design)

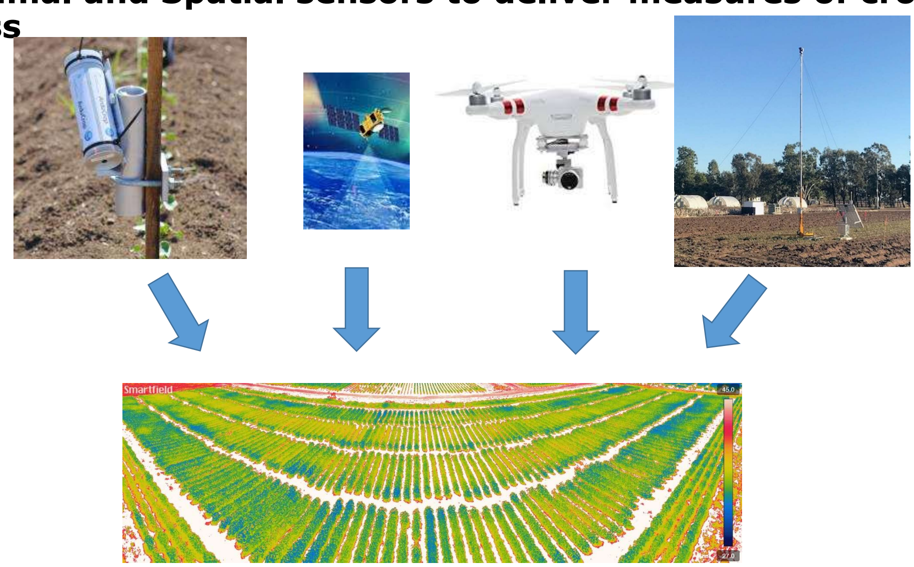
"A lot of farming is about looking back to see whether we made the right decision, and if we didn't, it is about understanding what we should do next time".

"You don't want the crop to be stressed, but it is like your children, you tend to be over protective. So you tend to give them more water than they actually need".

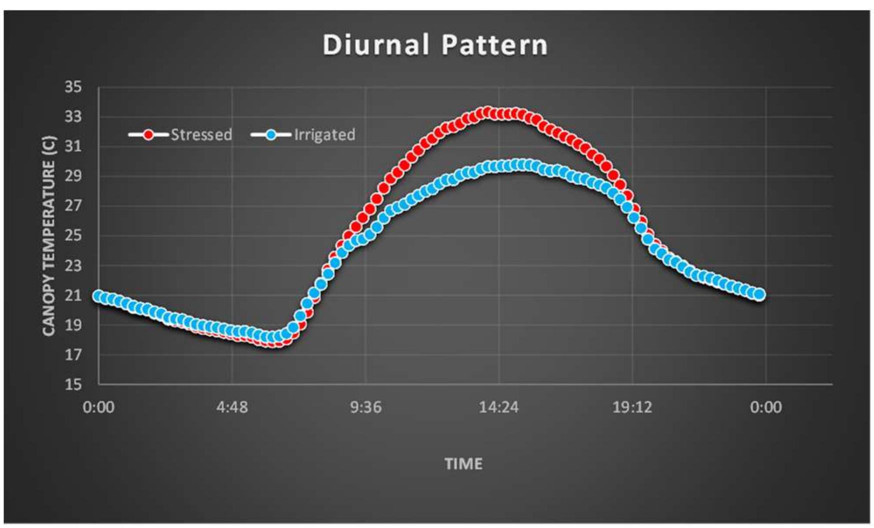
"It (WaterWise) might reduce the number of irrigations. Or on the contrary, people might realise that they should be irrigating more often".

- Perfect tool would be easy to use and integrated.
  - soil moisture,
  - canopy temperature
  - weather forecast
- Scenario Analysis – including the costs/consequence of different decisions
- Record keeping

Proximal and Spatial sensors to deliver measures of crop stress



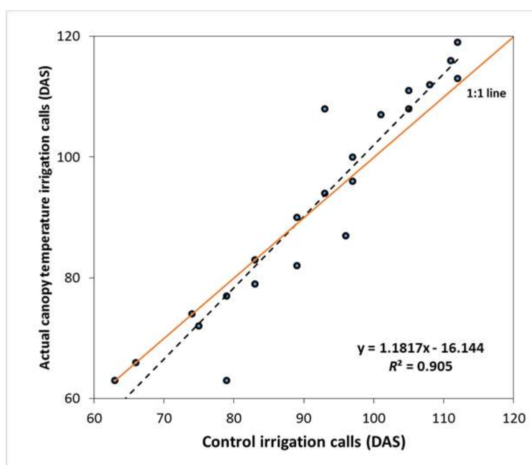
Physiology – temperature tells us a lot!!



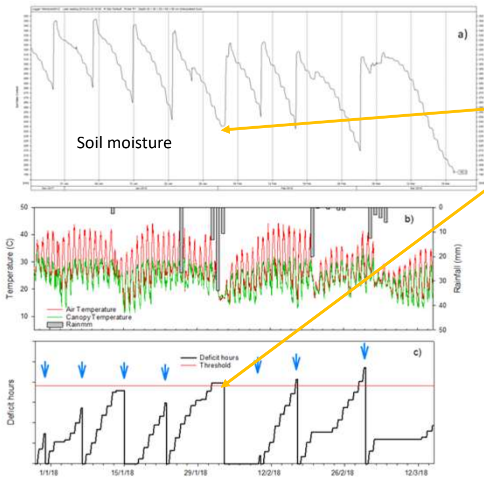
Could we irrigate crops as well as existing best irrigators?

Experiment	Yield	No. of Irrigations
Narrabri 13/14	The Same	The Same
Emerald 13/14	The Same	The Same
Narrabri 14/15	The Same	The Same
Emerald 14/15	The Same	The Same
Moree 14/15	The Same	One Less
Emerald 15/16	The Same	One Less

Comparing the timing of irrigation calls compared to grower practice



DAS – Days after sowing



Grower experience

Grower delayed irrigation using CT and captured rain saving an irrigation

Benefit to cotton producer estimated to be $60 USD/ha.

Based on achieving a 10% water saving 1/3 years with a yield gain of 3% every second year.

Outcomes

- **Quantitatively thus confidently providing irrigators with means to optimise water use, yield, and quality of the target crop.**
- **Water savings**
- **Improving regional economies**
- **Provide stability to industries and regional communities exposed to variable and changing climates.**

No simple answers to complex problems but we can simplify what we deliver to the user

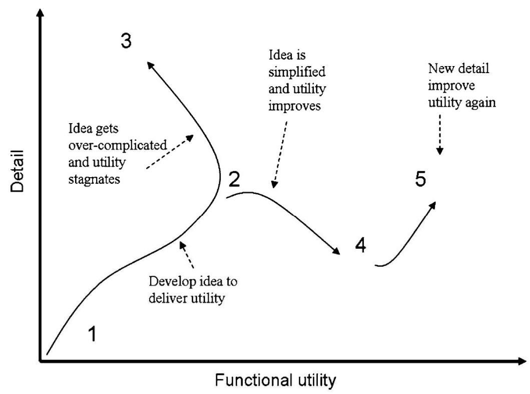
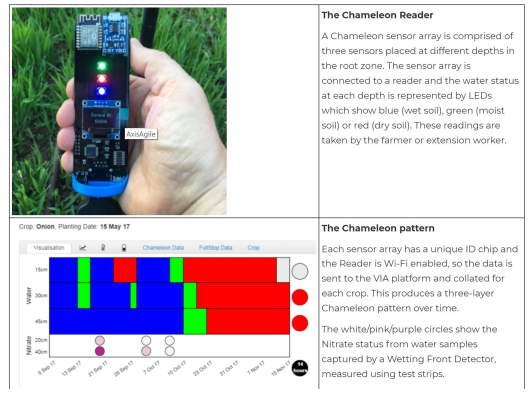


Fig. 2 The simplicity cycle [adapted from Ward (2005)]



Learning tools and shared knowledge – not just cool tech

APEC CHILE 2019

There are many ways to improve crop water productivity

- **Weeds, nutrition and disease**
- **Selection of cultivars or crop type**
- **Cultivation**
- **Bed and field formation and drainage**
- **Use of cover crops or films**
- **Changing planting time**

- **Focus on what are the issues and what tools or knowledge could be applied.**
- **Learning and simplicity – listening and talking to growers can be the fastest way to improvements on farm.**

APEC CHILE 2019

APEC
CHILE 2019

Efficients and Sustainable Use of Water for Agriculture under the New Climates Scenarios

HIDROCIENCIAS
COLEGIO DE POSTGRADUADOS
CAMPUS MONTECILLO

Sustainable Irrigation system with porosus emitters

Abel Quevedo Nolasco
& equipo

APEC
Santiago de Chile
July 24, 25 & 26 - 2019

By Gravity- Gravedad

Water supply systems for plants

Sistema de suministro de agua para las plantas

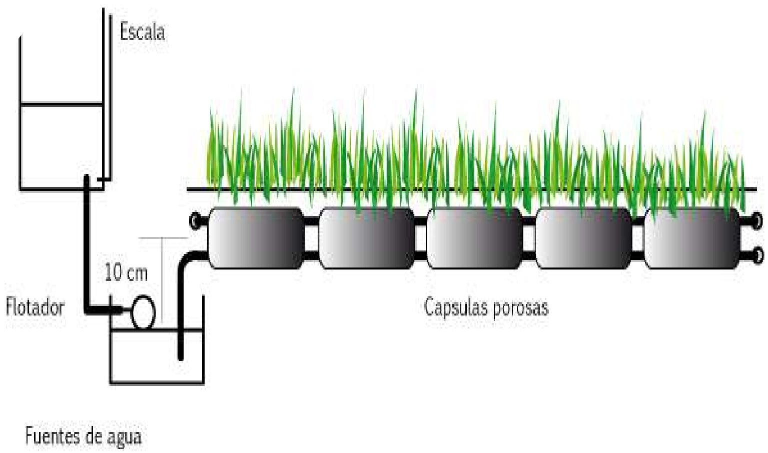
Located -Localizado

Sprinkler / Aspersión

By Subirrigation Subirrigación

Irrigation by porous emitters

Riego por emisores porosos



Suction	Succión
Marinolas	Marinolas
Capillarity	Capilaridad
Sustainable	Sustentable
Auto watering	Auto regables
Porous emitters	Emisores porosos

APEC CHILE 2019

Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco

1918

Livingston seems to have been the first to use auto-irrigators.

Livingston parece ser el primero en usar autoirrigadores.

It consisted of one or more porous cylindrical capsules buried in the soil contained in a pot, filled with water and connected to a source of water supply, located at a lower level.

Consistía de una o varias capsulas porosas cilíndricas enterradas en el suelo contenido en una maceta, se llenaban con agua y se conectaban a una fuente de abastecimiento de agua, situada a un nivel más bajo.

APEC CHILE 2019

Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco

1975

Olguín (1975) commented that the application of water is more efficient and the operation of the irrigation system is simpler.

In addition to not requiring an external source of energy to supply the water needs of the plant.

Water is supplied in a localized manner, efficiently and continuously, which translates into higher yields per unit volume of water used.

Olguín (1975) comento que la aplicación del agua es más eficiente y la operación del sistema de riego, más sencilla.

Además de no requerir de una fuente externa de energía para abastecer las necesidades hídricas de la planta.

El agua es suministrada en forma localizada, de manera eficiente y continua, lo cual se traduce en mayores rendimientos por unidad de volumen de agua utilizada.

García (1977), in the strawberry cultivar Tioga, tested the efficiency in the use of water and the yield in a system of irrigation by suction, with three levels of fertilization and two plant densities (80,000 and 40,000 plants / ha) .

García (1977), en el cultivar de fresa Tioga, se probó la eficiencia en el uso del agua y el rendimiento en un sistema de riego por succión, con tres niveles de fertilización y dos densidades de planta (80,000 y 40,000 plantas/ha).

He found that the higher the plant density, the higher the yield.

That the method of irrigation by suction is capable of supplying the water demand of a crop as demanding as strawberry.

The water I used was eight times smaller in volume than the water used commercially (surface irrigation methods).

Encontró que a mayor densidad de planta hubo mayor rendimiento.

Que el método de riego por succión es capaz de abastecer la demanda de agua de un cultivo tan exigente como la fresa.

El agua que uso, fue ocho veces en volúmenes menores que los que usaron a nivel comercial (métodos de riego superficiales).

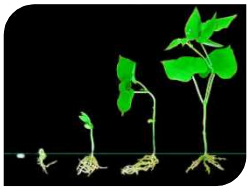
An exuberant development was observed, uncommon in the plants, which was due to the doses of fertilizers that were used, which were directly to the root through the irrigation system by suction.

Se observó un desarrollo exuberante poco común en las plantas el cual fue debido a las dosis de fertilizantes que se utilizaron, las cuales fueron directamente a la raíz a través del sistema de riego por succión.

Morales (1978) in greenhouse cultivation

Wheat (triticum aestibium),
Tomato (licopersicum sculentum) and
Beans (phaseolus vulgaris),

considered as tolerant, semitolerant and susceptible to salinity respectively.



Morales (1978) en invernadero cultivo

Trigo (*triticum aestibium*),
Tomate (*licopersicum sculentum*) y
Frijol (*phaseolus vulgaris*),

considerados como tolerantes, semitolerante y susceptibles a la salinidad respectivamente.

I determine the potentiality of the method of irrigation by suction for crops, when **using salt water**.

It was demonstrated by obtaining higher yields of dry matter, greater leaf area, lower water consumption and higher plant height than those obtained by the surface irrigation method.

Determino el potencialidad del método de riego por succión para cultivos, **al usar agua salada**.

Se demostró al obtener mayores rendimientos de materia seca, mayor área foliar, menor consumo de agua y mayor altura de planta que las obtenidas por el método de riego superficial.

Rendón (1979) found some problems:

Clogging (the pores can be sealed with salts) low uniformities and small hydraulic conductivities are the main disadvantages of suction irrigation with porous capsules.

Rendón (1979) encontró algunos problemas:

Taponamiento (Los poros se pueden sellar con sales), las bajas uniformidades y pequeñas conductividades hidráulicas son las principales desventajas que presenta el riego por succión con cápsulas porosas.

Coras (1979) tested three geometric shapes of porous capsules (conical, cylindrical and plate), providing water to the soil in different quantities because they had different hydraulic conductivity in the lettuce crop.

The highest yield of total production in lettuce corresponded to the treatments with irrigation by suction made with conical capsules.

Coras (1979) probo tres formas geométricas de cápsulas porosas (**cónica, cilíndrica y platillo**), proporcionan agua al suelo en cantidades diferentes debido a que tuvieron diferentes conductividad hidráulica en el cultivo de Lechuga.

El mayor rendimiento de producción total en lechuga correspondió a los tratamientos con riego por succión realizada con cápsulas cónicas.

Tijerina (1988) used the irrigation system by suction with porous capsules in the bean crop, with three soil moisture treatments (varying the filtering area from the number of capsules and the height of suction).

Tijerina (1988) utilizó el sistema de riego por succión con cápsulas porosas en el cultivo de frijol, con tres tratamientos de humedad en el suelo (variando el área filtrante a partir del número de cápsulas y la altura de succión).

APEC CHILE 2019

Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco

The system operated continuously throughout the crop cycle in two treatments a decrease in water potential in the soil was observed, possibly due to a plugging of the pores of the capsule, by the absorbent hairs of the roots and precipitation of the fertilizer inside. of the pores.

The analysis of the yield of grain turned out to be much superior when compared with the yields obtained by traditional irrigation methods.

El sistema opero de manera continua todo el ciclo del cultivo en dos tratamientos se observó una disminución del potencial del agua en el suelo, posiblemente debido a un taponamiento de los poros de la cápsula, por los pelos absorbentes de las raíces y precipitación del fertilizante dentro de los poros.

El análisis del rendimiento de grano resulto ser muy superior al compararlo con los rendimientos obtenidos por los métodos de riego tradicionales.

APEC CHILE 2019

Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco

Albanil (1991) in the strawberry crop, I compare the methods of irrigation by suction and traditional, in both with fertilization.

Water productivity per fruit yield unit in treatments irrigated by suction was 4.5 times higher than traditionally irrigated treatments.

Albanil (1991) en el cultivo de fresa, comparo los metodos de riego por succión y tradicional, en ambos con fertilización.

La productividad del agua por unidad de rendimiento de fruto en los tratamientos regados por succión fue 4.5 veces mayor que los tratamientos irrigados en forma tradicional.

APEC CHILE 2019

Perea (1993) developed a methodology for design, construction and laboratory evaluation of a low pressure irrigation system with porous capsules.

The total estimated cost for one hectare of irrigation was $ 1378. U.S.D.

Perea (1993) desarrollo una metodología para diseño, construcción y evaluación en laboratorio de un sistema de riego a baja presión con capsulas porosas.

El costo total estimado para una hectárea de riego fue de $1378. U.S.D.

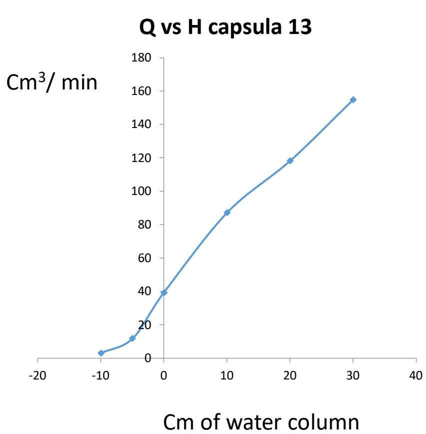
APEC CHILE 2019

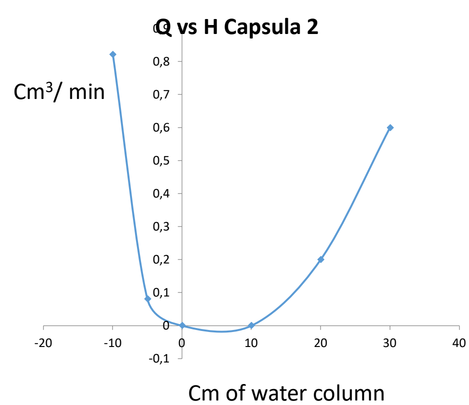
López et al. (2012), evaluated the hydraulic performance of porous capsules in terms of their hydraulic conductivity, under different loads (pressure and suction).

López *et al. (2012),* evaluarón el funcionamiento hidráulico de capsulas porosas (existentes) en términos de su conductividad hidráulica, bajo diferentes cargas (a presión y succión).

APEC CHILE 2019

Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco





APEC CHILE 2019

Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco

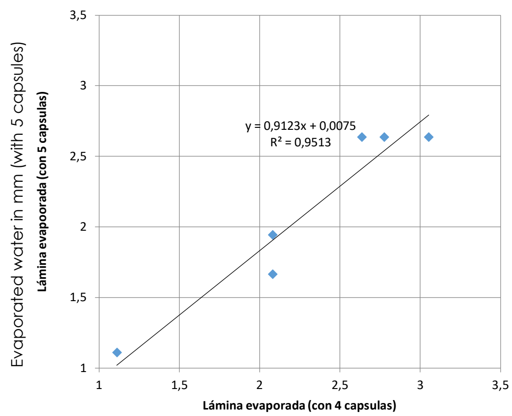
It was proposed to use commercial irrigation connectors to make the interconnections between the capsules to improve the functioning of the system

Se propuso utilizar conectores comerciales de riego para hacer las interconexiones entre las capsulas para mejorar el funcionamiento del sistema

An irrigation system was designed by sub-irrigation with porous capsules to evaluate its operation in different substrates with different particle sizes.

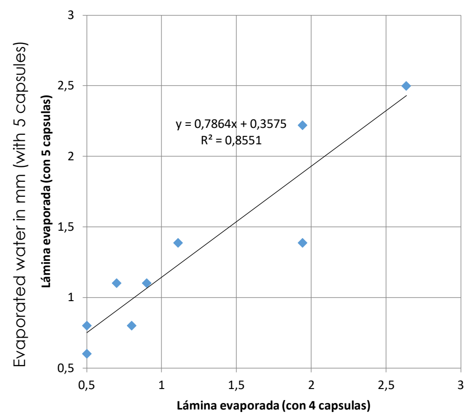
Se diseño un sistema de riego por subirrigación con capsulas porosas para evaluar su funcionamiento en diferentes sustratos con diferentes tamaños de partículas.

Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco



Evaporated water in mm (with 4 capsules)

Fine substrate (Mesh 8)

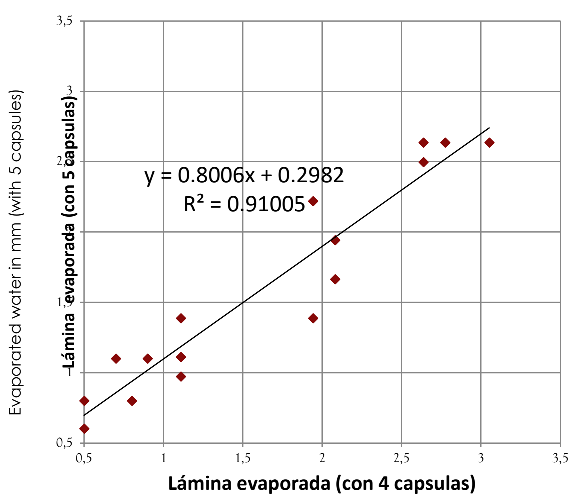


Evaporated water in mm (with 4 capsules)

Medium substrate (Between 6 and 8 mesh)

Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco

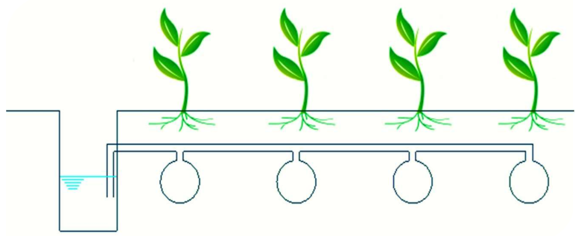
Mixture of both substrates (fine and medium)



Evaporated water in mm (with 4 capsules)

Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco

Pacheco *et al*. (2014) indicated that irrigation by suction implies a high efficiency in irrigation, assumed to reach 100%.



Pacheco *et al*. (2014) indicaron que el riego por succión implica una alta eficiencia en el riego, asumen alcanza el 100%.

Trujillo et al. (2012), evaluated the hydraulic operation of porous spherical capsules of commercial ceramic paste, in substrate (tezontle) with different particle sizes, for irrigation purposes.

Trujillo et al. (2012), evaluarón el funcionamiento hidráulico de cápsulas porosas esféricas de pasta cerámica comercial, en sustrato (tezontle) con diferentes tamaños de partículas, con fines de riego.

There is a linear relationship between the sorptivity
and hydraulic conductivity, so it is possible to design irrigation systems with porous capsules based on the sorptivity.

The smaller the size of the particles in the substrate, the greater the contact with the capsule, thus providing greater water demands.

Sorptivity. the volume of water absorbed by the unit of surface of a floor and the square root of the time during which this occurs, when the effects of gravity are negligible

Existe una relación lineal entre la sortividad y la conductividad hidráulica, por lo que es posible diseñar sistemas de riego con cápsulas porosas a partir de la sortividad.

A menor tamaño de las partículas del sustrato, existe un mayor contacto con la cápsula por lo que se abastecen mayores demandas hídricas.

APEC CHILE 2019

Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco

Some advantages /Algunas ventajas

It does not require a pumping system to operate, it only requires constant water availability.

The emitter self-regulates the water supply, if it rains it does not emit water (suction) and there is no drainage.

If the emitter is subjected to pressure, it emits water and does not self-regulate.

An irrigation system with capsules is designed according to the properties of the capsules.

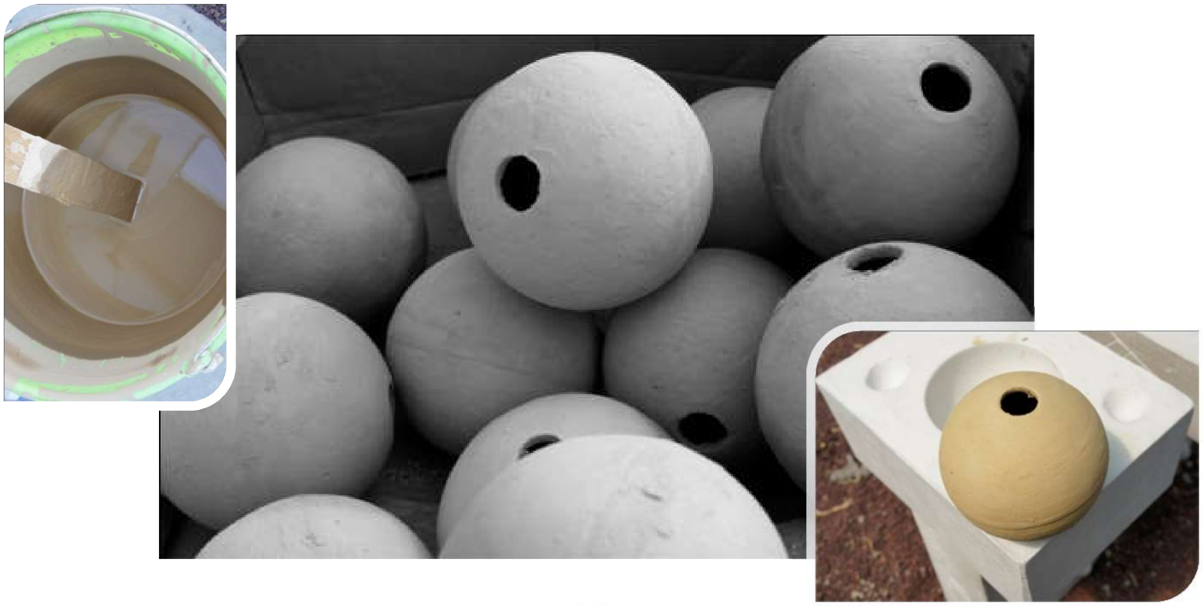
No requiere un sistema de bombeo para operar, solo requiere contar con agua disponible constante.

El emisor autorregula el suministro de agua, si llueve no emite agua (a succión) y no hay drenaje.

Sí el emisor se somete a presión emite agua y no se autorregula.

Un sistema de riego con capsulas se diseñan según la propiedades de la capsulas.

2013-2015



APEC CHILE 2019

Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco

Liquid mixture

filling process, in the mold

burned capsules

APEC CHILE 2019

Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco

Device for evaluating the porous capsule (Pressure and suction)

If you collect a substrate sample very close to the emitter with your hand.

You can feel the moisture content in the substrate. If you squeeze the sample it does not release water, but if you leave the sample, the hand is dry

Brix degrees increase

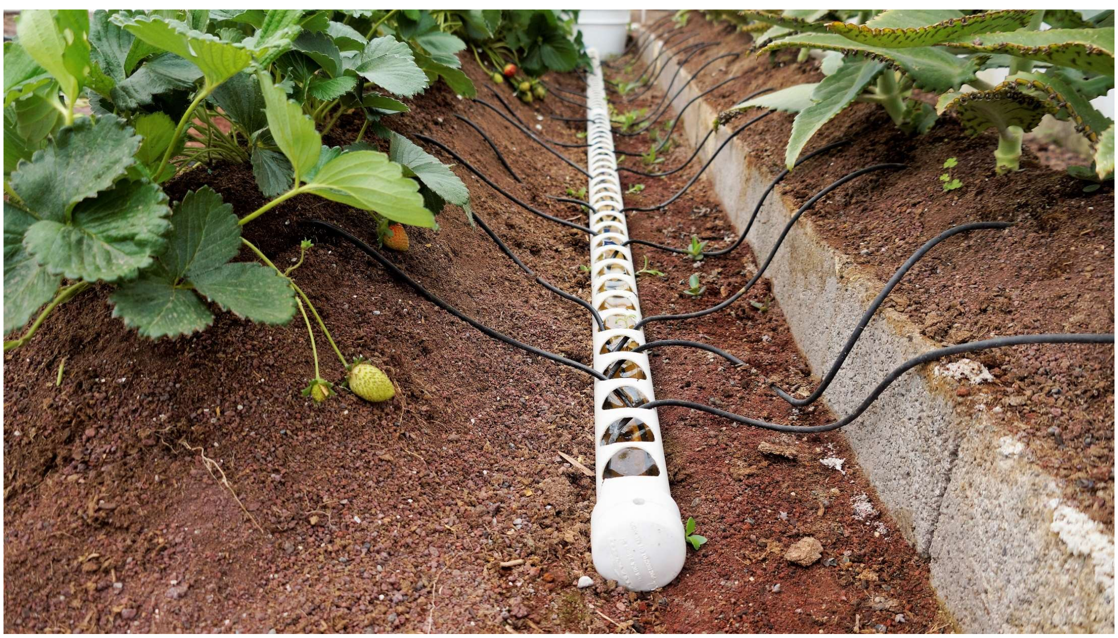
First tests with the new model ....

Primeros ensayos con el nuevo modelo….

Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco

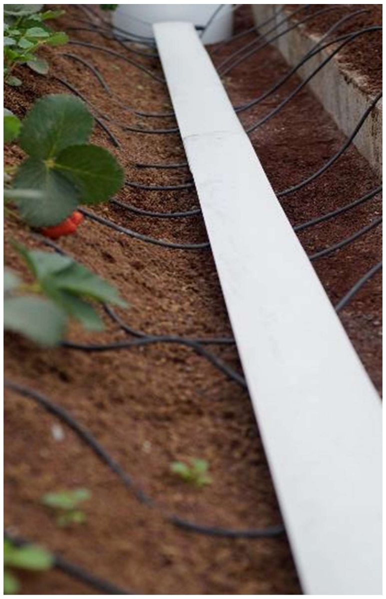
Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco

Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco



APEC CHILE 2019

Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco



APEC CHILE 2019

Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco

APEC CHILE 2019

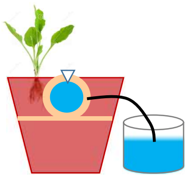
Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco

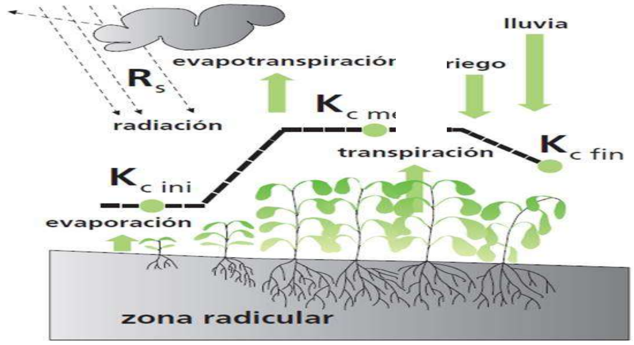
Another application

Determination of the crop coefficient (Kc) in three ornamental species (Geranium, Petunia and Gazania) by means of the irrigation system by porous capsules.

On substrates: fine and coarse

Determinación del coeficiente de cultivo (Kc) en tres especies ornamentales (geranio, petunia y gazania) mediante el sistema de riego mediante cápsulas porosas.

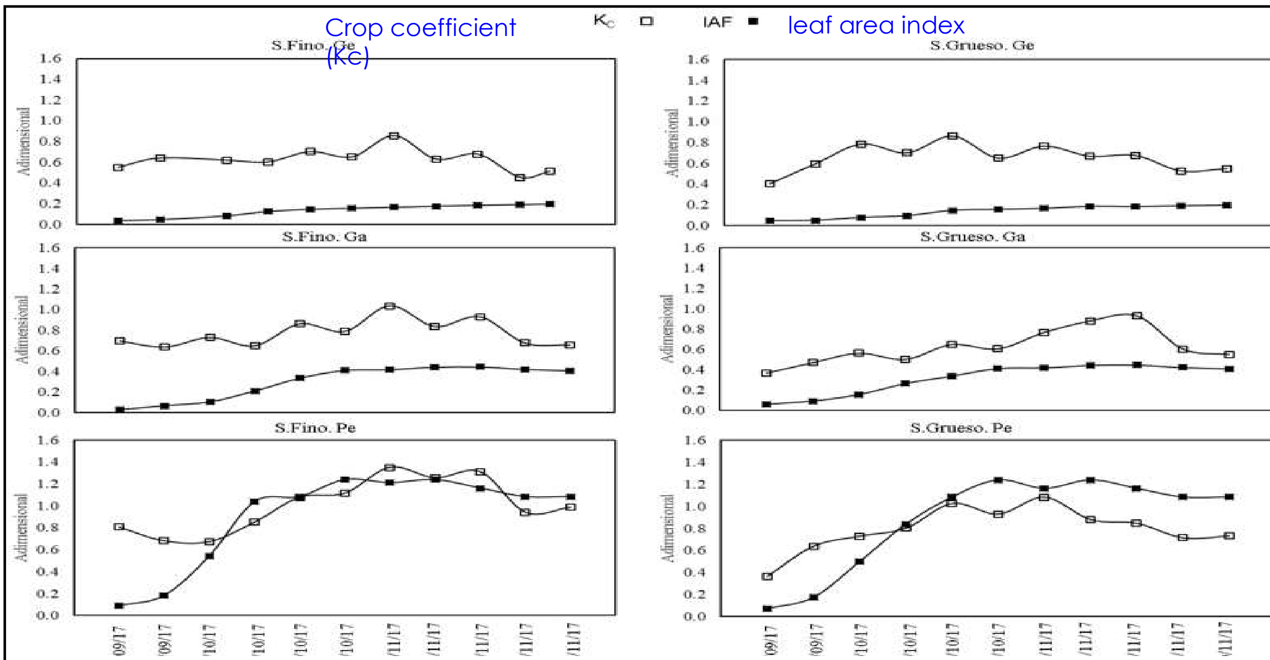




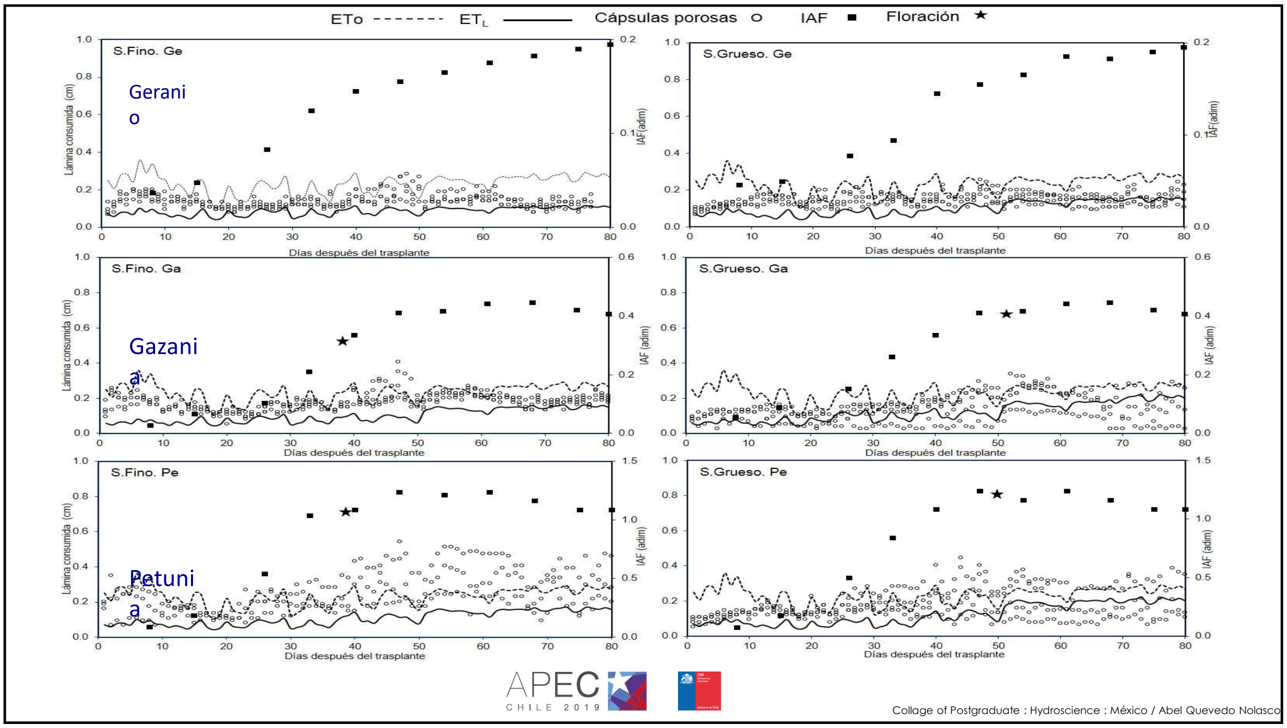
Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco

Crop coefficient (Kc)

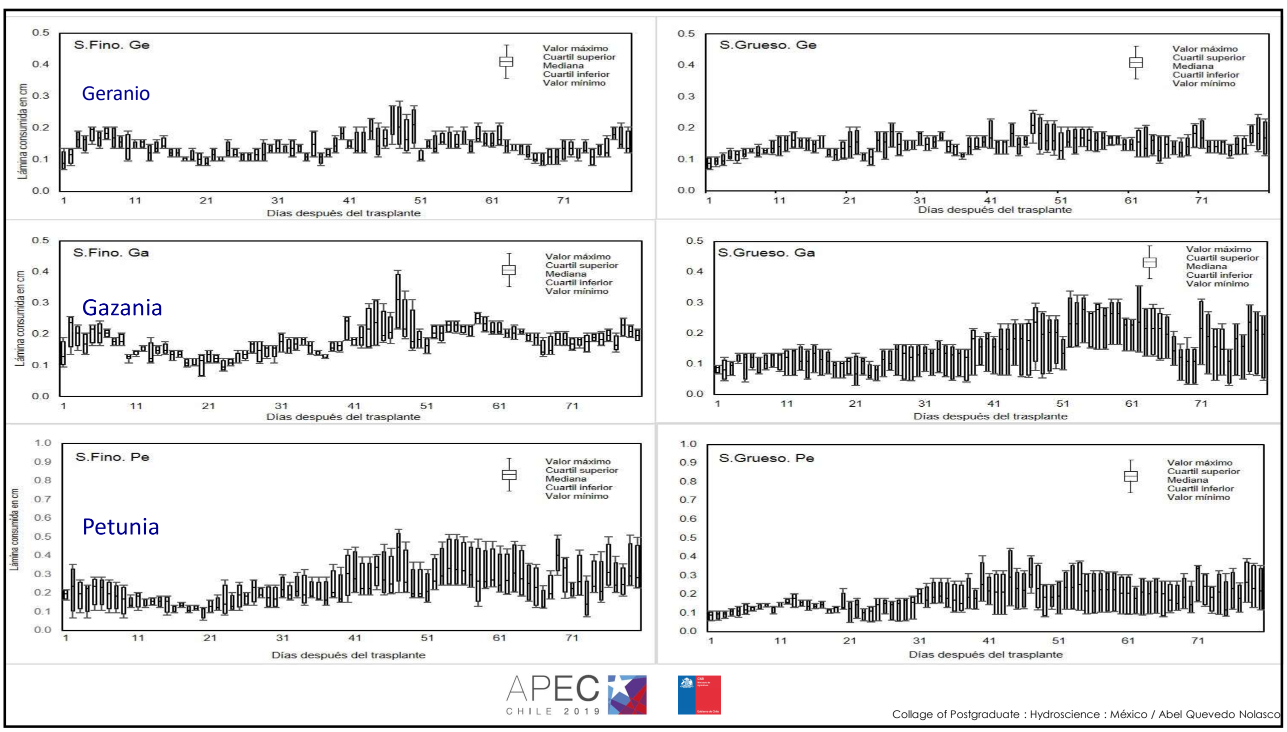
leaf area index



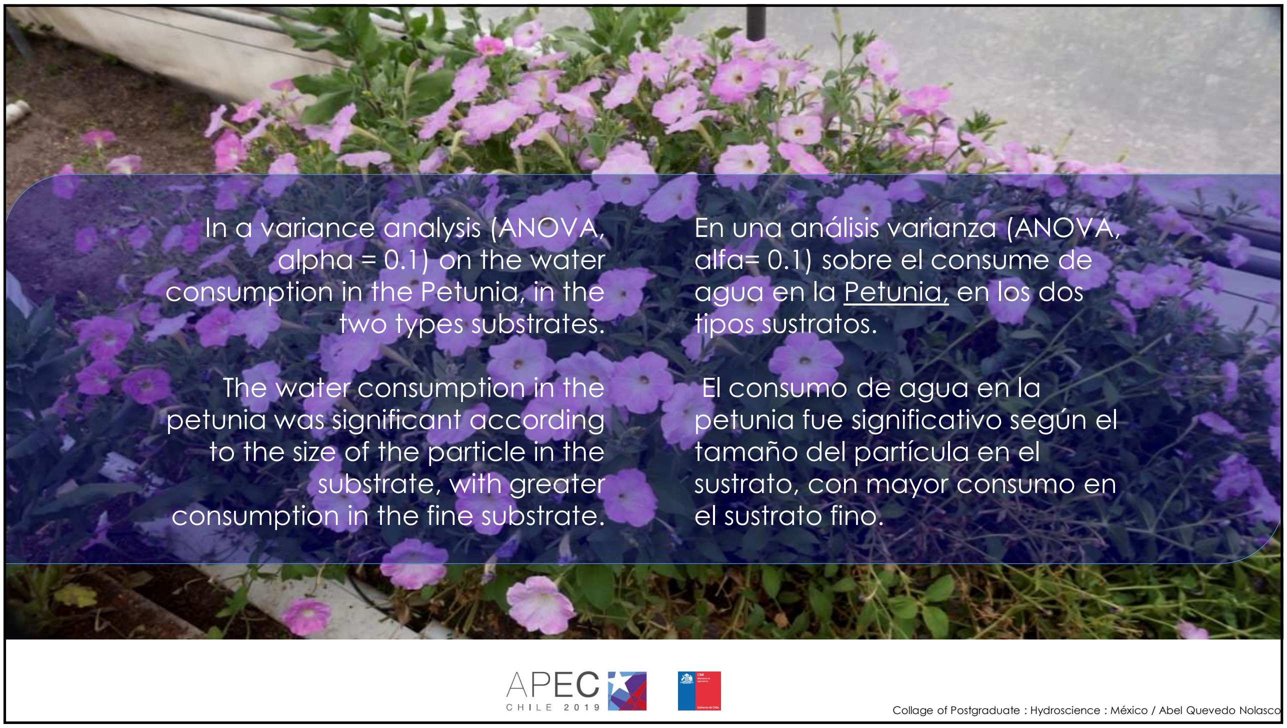
Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco



ETo ------- ETL ——— Cápsulas porosas ○ IAF ■ Floración ★
S.Fino. Ge
Geranio
S.Grueso. Ge
S.Fino. Ga
Gazania
S.Grueso. Ga
S.Fino. Pe
Petunia
S.Grueso. Pe
Lámina consumida (cm)
IAF (adim)
Días después del trasplante
APEC CHILE 2019
Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco



S.Fino. Ge
Geranio
S.Grueso. Ge
S.Fino. Ga
Gazania
S.Grueso. Ga
S.Fino. Pe
Petunia
S.Grueso. Pe
Valor máximo
Cuartil superior
Mediana
Cuartil inferior
Valor mínimo
Lámina consumida en cm
Días después del trasplante
APEC CHILE 2019
Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco

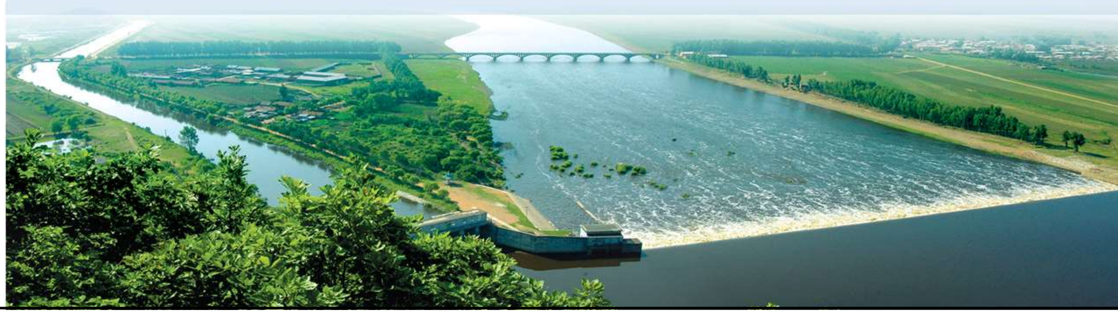

In a variance analysis (ANOVA, alpha = 0.1) on the water consumption in the Petunia, in the two types substrates.
The water consumption in the petunia was significant according to the size of the particle in the substrate, with greater consumption in the fine substrate.
En una análisis varianza (ANOVA, alfa= 0.1) sobre el consume de agua en la Petunia, en los dos tipos sustratos.
El consumo de agua en la petunia fue significativo según el tamaño del partícula en el sustrato, con mayor consumo en el sustrato fino.
APEC CHILE 2019
Collage of Postgraduate : Hydroscience : México / Abel Quevedo Nolasco

Chinese experience in water-saving irrigation

Wu Jingwei
Wuhan University, P.R.China
Chile, 2019

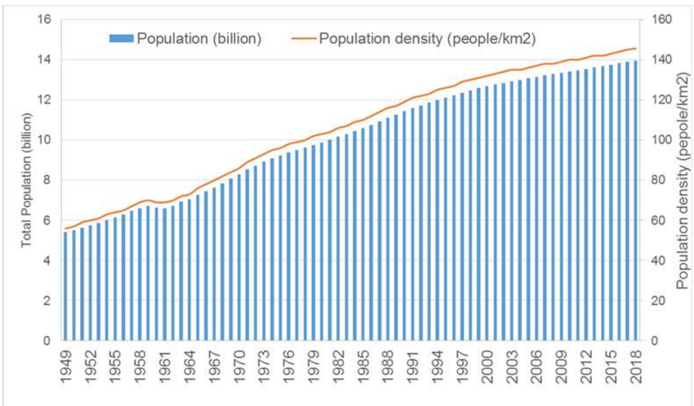
Outline

- The importance of irrigation in China
- Water-saving irrigation in the past twenty years
- Effect from water-saving irrigation practices
- Outlook for irrigation



□ The importance of irrigation in China

- China is the most populous economy in the world. (1.3958 billion in 2018)
- We need to feed ourselves and we did.

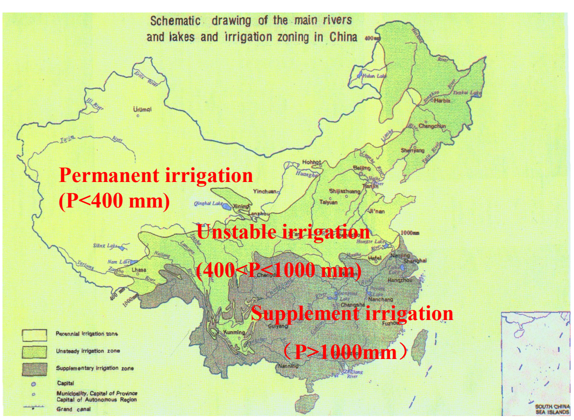


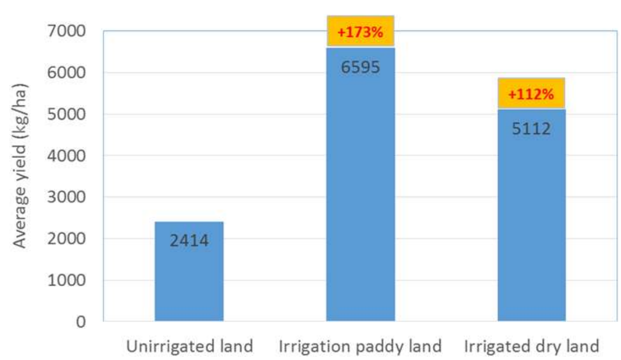
APEC CHILE 2019

□ The importance of irrigation in China

- Irrigation contributes to the **food security** of China.

✓ Irrigation is totally required for stable output.
✓ Irrigation generally increase the yield by 1-2 times in China





APEC CHILE 2019

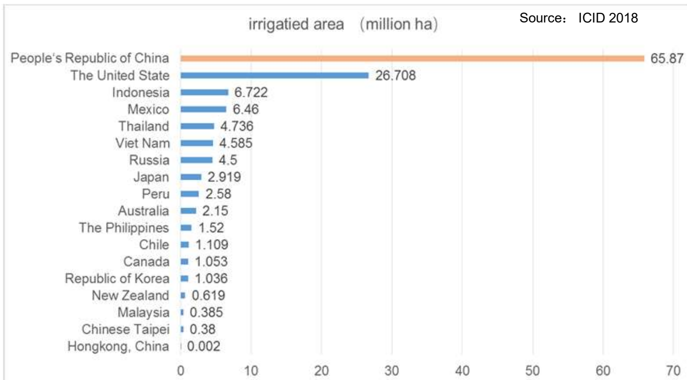
☐ The importance of irrigation in China

● **Irrigation contributes to the food security of China.**

✓ China has the most irrigated lands in the world (65.87 miilion ha in 2018).

✓ Irrigated land(about 50% of the total) produce 75% cereals and 90% cash crops

✓ 7% world arable land feed 20% world population .



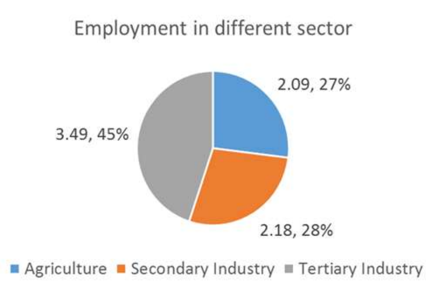
APEC CHILE 2019

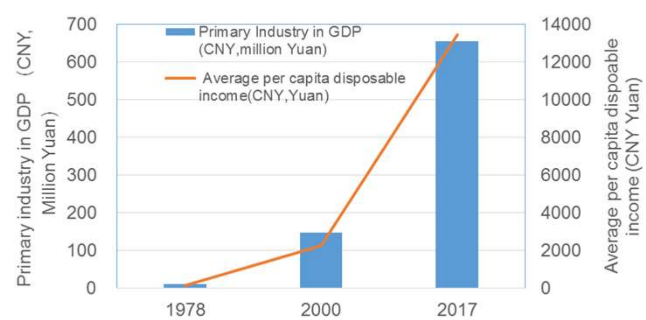
☐ The importance of irrigation in China

● **Irrigation contributes to the social development.**

✓ Irrigated agriculture employ 27% labors in 2018 and ensure the rapid development is rural development

✓ Irrigation projects provide 1/7 industrial and domestic water supply, covering 50% urban population.



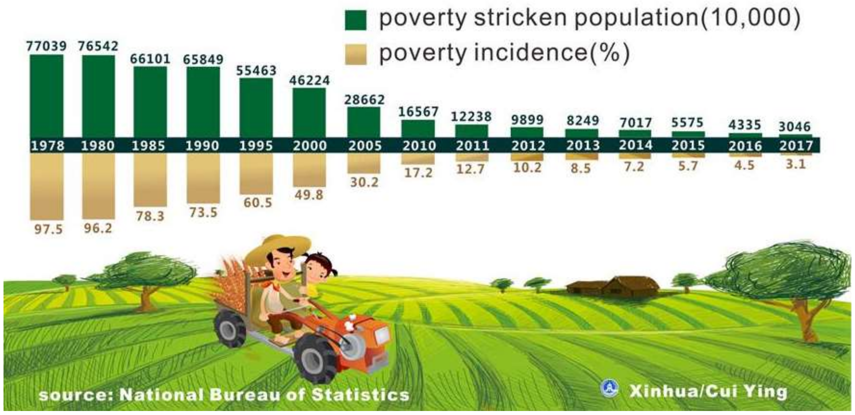


APEC CHILE 2019

◻ The importance of irrigation in China

● **Irrigation contributes to the social development.**

✓ The development in irrigation is one important measure for poverty-relief



China promises to end poverty by 2020

1% in 2018

Poverty standard:

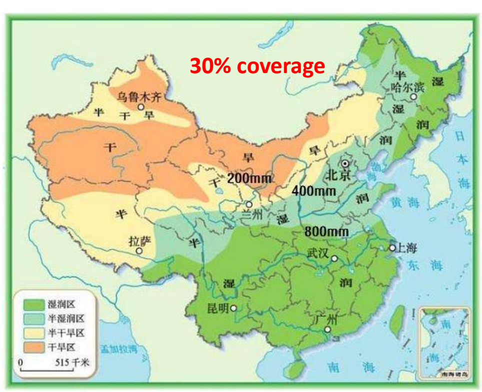
2018：Family's per capita net income
< 3535 CNY Yuan

APEC CHILE 2019

◻ The importance of irrigation in China

● **Irrigation play an important role in eco-environment protection.**

✓ Oasis irrigation in arid areas greatly improves the living environment conditions for organism (plant, animals and human).



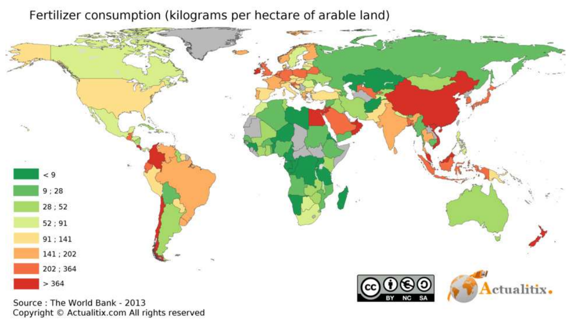
APEC CHILE 2019

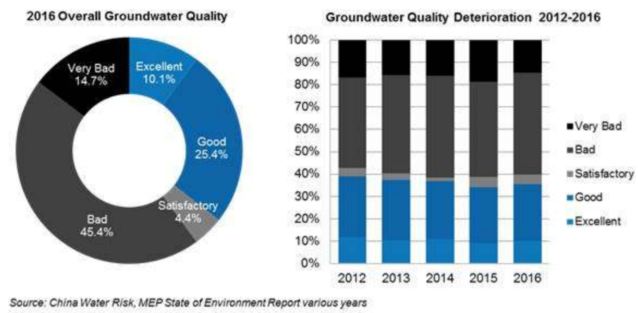
◻ The importance of irrigation in China

● **Irrigation play an important role in eco-environment protection.**

✓ The fertilizer consumption application rate is 3.7 times as the world average level

✓ The ultilization application efficiency is less than 30%, half of the world average level

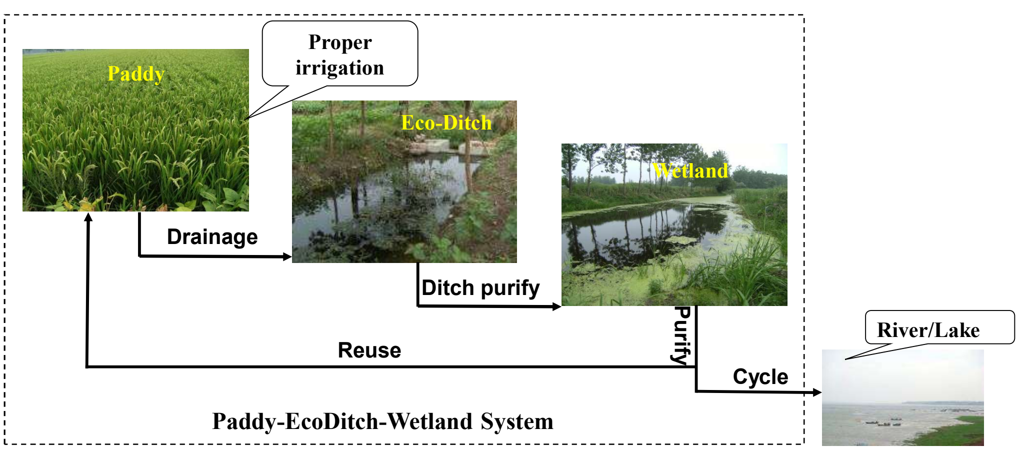




◻ The importance of irrigation in China

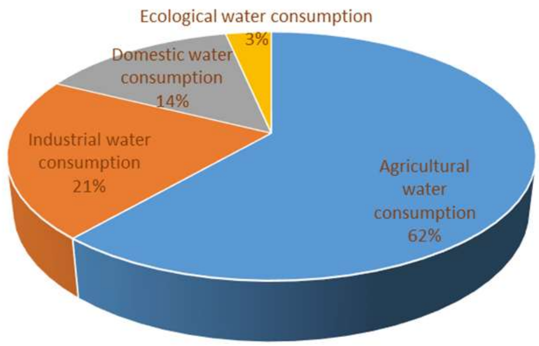
● **Irrigation play an important role in eco-environment protection.**

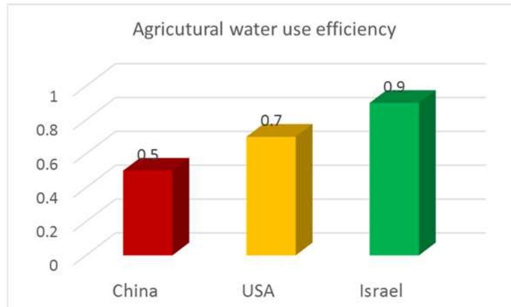
✓ Suitable irrigation and drainage management can help reduce agricultural pollution.



□ The importance of irrigation in China

- **Irrigation plays an very important role in the Water security of China.**





□ Water-saving irrigation in the past twenty years

- **Political and policy support: building a water saving society.**

✓ ***Protecting and saving water is the basic national policy***, 1983.

✓ ***Promote water-saving irrigation as a revolutionary measure***， The Third Plenary Session of the 15th CPC Central Committee， 1998

✓ ***Building a water saving society***, the 10th Five-Year Plan for Economic and Social Development of the People's Republic of ,2000

✓ Water saving is focused in the No. 1 central document since 2004

✓ Applying the Strictest Water Resources Management system, "three red line", the No. 1 central document ,2011

国家节水标志

◻ Water-saving irrigation in the past twenty years

● **Political and policy support: building a water saving society.**

✓ "Applying the Strictest Water Resources Management system, "three red line", the No. 1 central document ,2011

Table 1. Future water planning targets

	Targets	2015	2020	2030
Red line for total water use	Total water consumption must not exceed	635 billion m^3	670 billion m^3	700 billion m^3
Red line for water use efficiency	Industries will reduce their water use per US$1,600 (CNY10,000) of industrial added value	30% below 2010 figures	65 m^3	40 m^3
	Irrigation efficiency must exceed	53%	55%	60%
Red line for controlling pollution	The number of water function zones complying with the water quality standard will be more than	60%	80%	95%
	All sources of drinking water will meet set standards for both rural and urban areas		Yes	Yes
	All water function zones will comply with water quality standards			Yes

◻ Water-saving irrigation in the past twenty years

● **Law**

✓ Water Law of the Peoples Republic of China

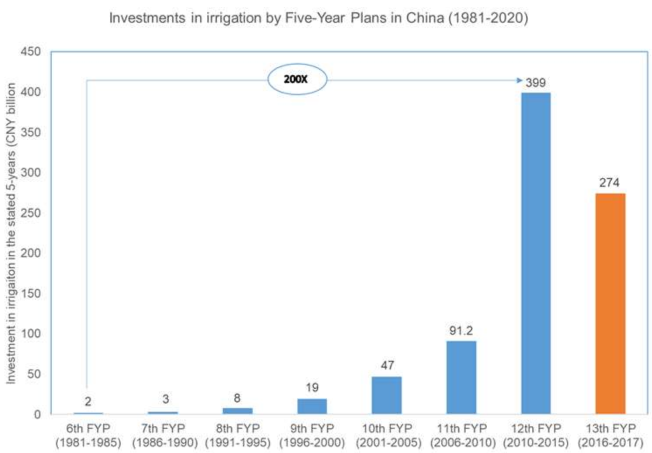
✓ Agricultural Law of the Peoples Republic of China

✓ Law of the PRC on the Popularization of Agricultural Technology

The people's governments at all levels shall implement water-saving irrigation methods and water-saving technologies, take necessary anti-leakage measures for agricultural water storage and water transfer projects, and improve agricultural water use efficiency.

☐ Water-saving irrigation in the past twenty years

● **Investment**



Investments in irrigation have been growing steadily and rapidly from the 6th Five-Year Plan period (1981–1985) to the now. The investment during the 12th Five-Year Plan (2011–2015) is about **200 times** as that during the 6th Five year Plan (1981-1985).

It is required that the local government should invest 10% of the land transfer fee in irrigation projects.

APEC CHILE 2019

☐ Water-saving irrigation in the past twenty years

● **Central government financed water-saving plans for irrigation**

✓ Water-saving and Efficiency-increasing Demonstration project (1996-2008)

- 1230 demonstration plot with a total area of 0.27 million ha

✓ Rehabilitation of large & middle-scale irrigation schemes with the objectives of increasing irrigation efficiency and productivity （1998-2020）

- 434 large-scale irrigation (Irrigated Area > 3 million mu, or 20000 hm²)
- 2157 middle-scale irrigation (Irrigated Area 667～20000hm²)
- 30 million ha effectively irrigated area is covered.

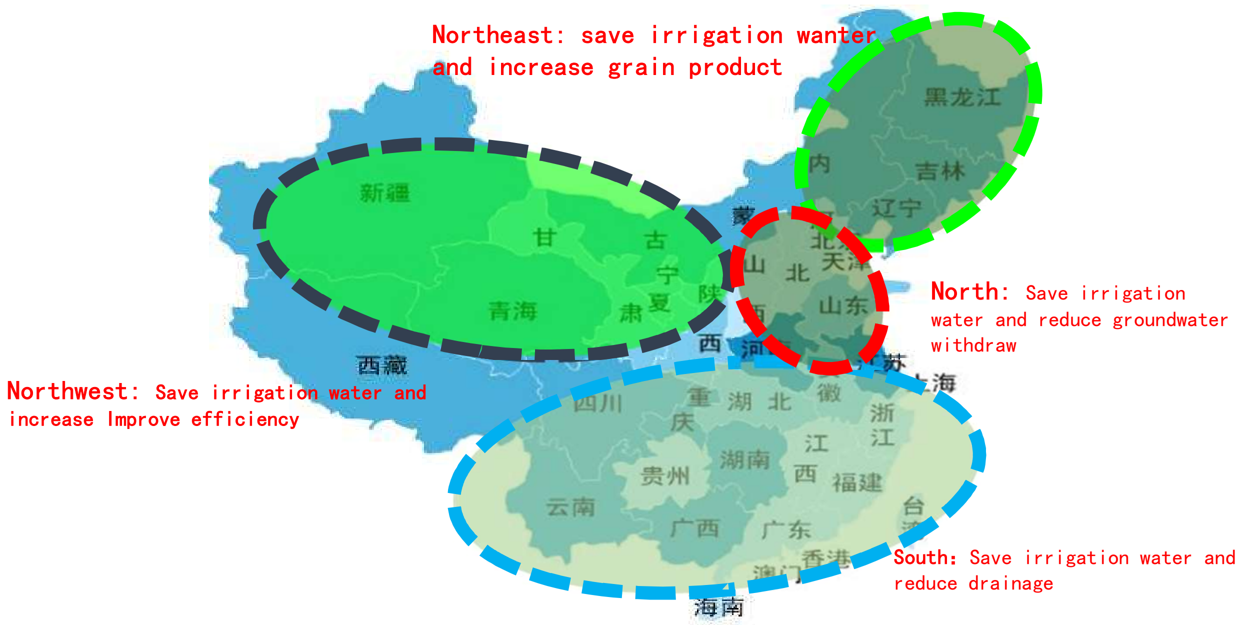
✓ National plan to increase production capacity of 100 million ton project (2009-2020)

- Arable land ≈66.7 million ha

✓ Water saving irrigation in mountainous and pastoral area project (2011-2020)

✓ High efficient water-saving irrigation project (2012-2020)

APEC CHILE 2019



□ Water-saving irrigation in the past twenty years

- **Comprehensive water-saving measures**
  - ✓ Engineering measures
  - ✓ Agronomic measures
  - ✓ Irrigation management measures
  - ✓ Economic and policy measures

◻ Water-saving irrigation in the past twenty years

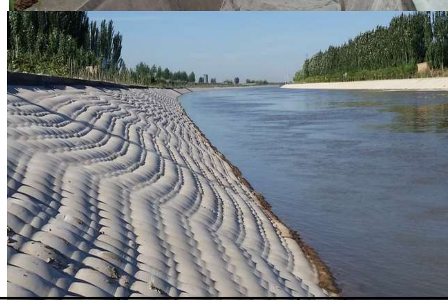
● **Comprehensive water-saving measures**

✓ Improve the efficiency in conveyancing and allocating water

Canal lining

pipe

Canal lining



Canal Control structure

◻ Water-saving irrigation in the past twenty years

● **Comprehensive water-saving measures**

✓ Improve the efficiency in field application

land leveling

Improve surface irrgation efficiency

Film cover

Improve surface irrgation efficiency

□ Water-saving irrigation in the past twenty years

● **Comprehensive water-saving measures**

✓ Improve the efficiency in field application

Sprinkle irrigation

Drip irrigation

Micro-sprinkle irrigation

Drip irrigation Under film

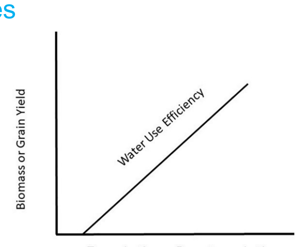
□ Water-saving irrigation in the past twenty years

● **Comprehensive water-saving measures**

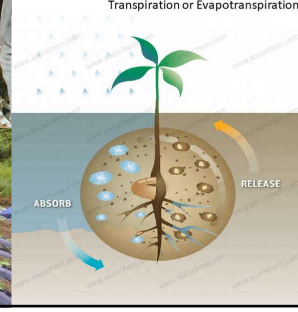
✓ Improve the efficiency agronomic measures

Sowing with partial irrigation

Coupling water and fertilizer application



super absorbent polymer(SAP)



Conserve water by land covering

◻ Water-saving irrigation in the past twenty years

● **Comprehensive water-saving measures**

✓ Improve irrigation management

Double control irrigation:
Water application rate
Total water consumption


ICS 13.060.99
P40
DB65
新 疆 维 吾 尔 自 治 区 地 方 标 准
DB 65/ 3611—2014

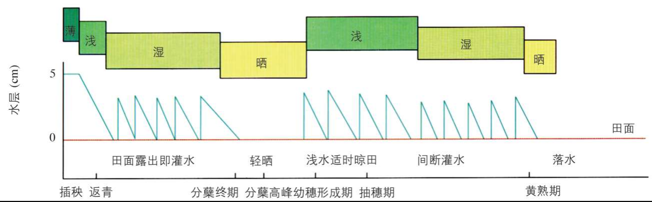
农业灌溉用水定额
Agricultural irrigation water quota

2014－03－19 发布　　2014－04－19 实施

新疆维吾尔自治区质量技术监督局　发布

Smart Irrigation:
Soil/Water/Crop Sensing
irrigation forecast
Precision irrigation

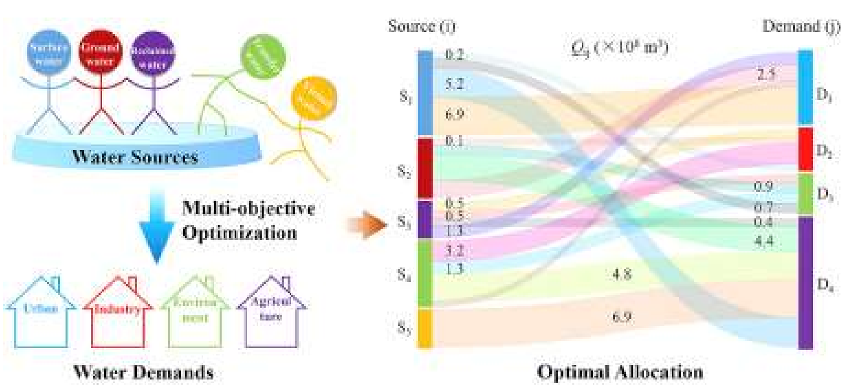
Water saving irrigation scheme



◻ Water-saving irrigation in the past twenty years

● **Comprehensive water-saving measures**

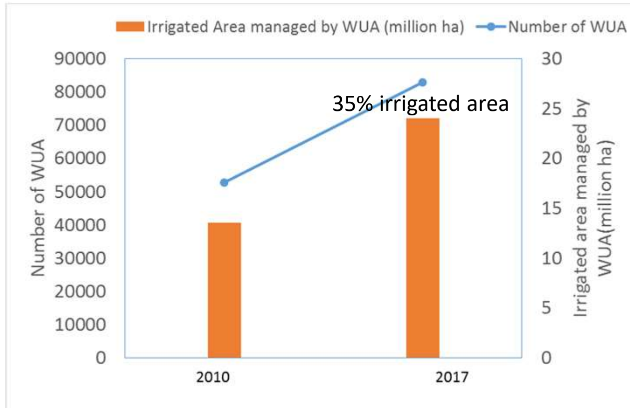
✓ Optimizing irrigation water resource



□ Water-saving irrigation in the past twenty years

● **Economic and social measures**

✓ Water user's association (WUAs)



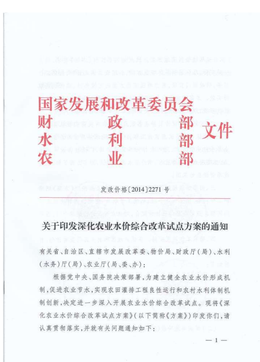
APEC CHILE 2019

□ Water-saving irrigation in the past twenty years

● **Economic and social measures**

✓ ***Water tariff reforms:*** Water tariffs in China is below the price needed to recover the full financial cost of services, and much lower compared to other economies.

2008, agricultural water tariff reform started



国家发展和改革委员会
财政部
水利部
农业部
文件

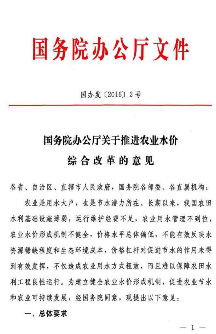
发改价格〔2014〕2271 号

关于印发深化农业水价综合改革试点方案的通知

有关省、自治区、直辖市发展改革委、物价局、财政厅(局)、水利(水务)厅(局)、农业厅(局、委、办):

根据党中央、国务院决策部署,为建立健全农业水价形成机制,促进农业节水,实现农田灌排工程良性运行和农村水利体制机制创新,决定进一步深入开展农业水价综合改革试点。现将《深化农业水价综合改革试点方案》(以下简称《方案》)印发你们,请认真贯彻落实,并就有关问题通知如下:

— 1 —



国务院办公厅文件

国办发〔2016〕2 号

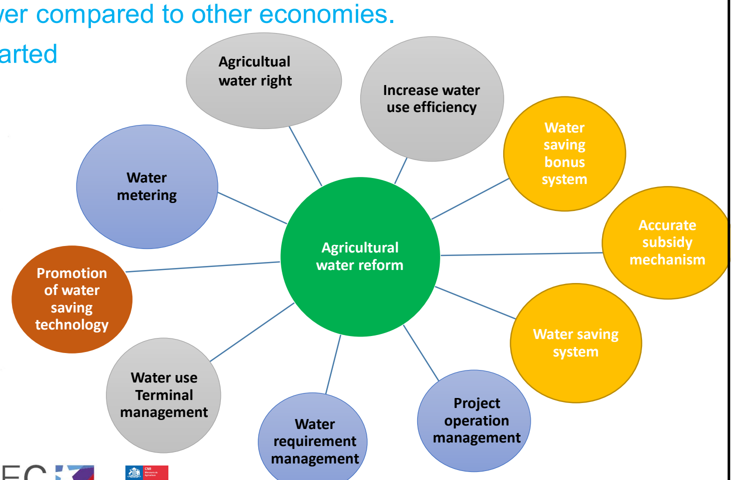
国务院办公厅关于推进农业水价综合改革的意见

各省、自治区、直辖市人民政府,国务院各部委、各直属机构:

农业是用水大户,也是节水潜力所在。长期以来,我国农田水利基础设施薄弱,运行维护经费不足,农业用水管理不到位,农业水价形成机制不健全,价格水平总体偏低,不能有效反映水资源稀缺程度和生态环境成本,价格杠杆对促进节水的作用未得到有效发挥,不仅造成农业用水方式粗放,而且难以保障农田水利工程良性运行。为建立健全农业水价形成机制,促进农业节水和农业可持续发展,经国务院同意,现提出以下意见:

一、总体要求

— 1 —



APEC CHILE 2019

◻ Water-saving irrigation in the past twenty years

● Economic and social measures

✓ ***Water right exchange***

Started in 7 provinces in July, 2014

Contents: water right identification and registration; water right exchange and related rules

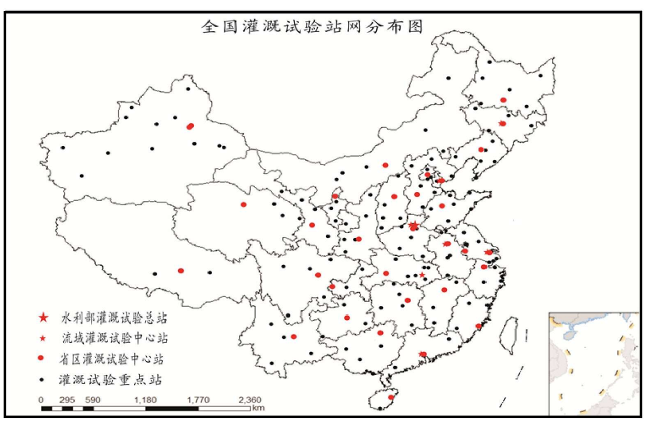
Dealer: inter-basin; upstream-downstream, regions; sectors; irrigators.

China water exchange established in 2016 and 2.774 billion m^3 water have been exchanged.

◻ Water-saving irrigation in the past twenty years

Scientific and technic support:

✓ Irrigation experimental network



附图 1 全国灌溉试验站网试验站点分布图

137 irrigation experimental stations have been built or rebuilt since 2003, providing standards for water saving

APEC CHILE 2019

◻ Water-saving irrigation in the past twenty years

Scientific and technic support:

✓ Irrigation experimental network

ICS 13.060.99
P40

DB65

新疆维吾尔自治区地方标准

DB 65/ 3611—2014

农业灌溉用水定额

Agricultural irrigation water quota

2014－03－19 发布　　2014－04－19 实施

新疆维吾尔自治区质量技术监督局　发布

APEC CHILE 2019

◻ Water-saving irrigation in the past twenty years

Scientific and technic support

✓ A series of technical standard for water-saving irrigation engineering have been set to guide water-irrigation practices

UDC

中华人民共和国国家标准　GB

P　GB/T 50363－2006

节水灌溉工程技术规范

Technical specification for water-saving irrigation engineering

2006－04－07　发布　　2006－09－01　实施

中华人民共和国建设部
中华人民共和国国家质量监督检验检疫总局　联合发布

UDC

中华人民共和国国家标准　GB

P　GB/T 50363－2018

节水灌溉工程技术标准

Technical standard for water-saving irrigation project

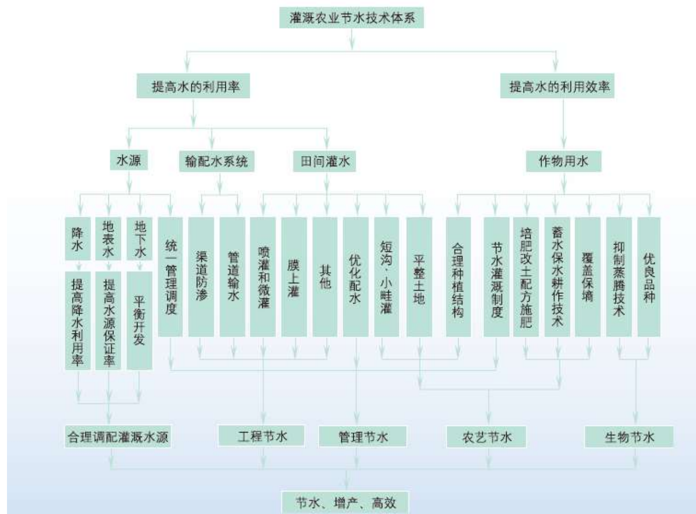
2018－03－16　发布　　2018－11－01　实施

APEC CHILE 2019

□ Water-saving irrigation in the past twenty years

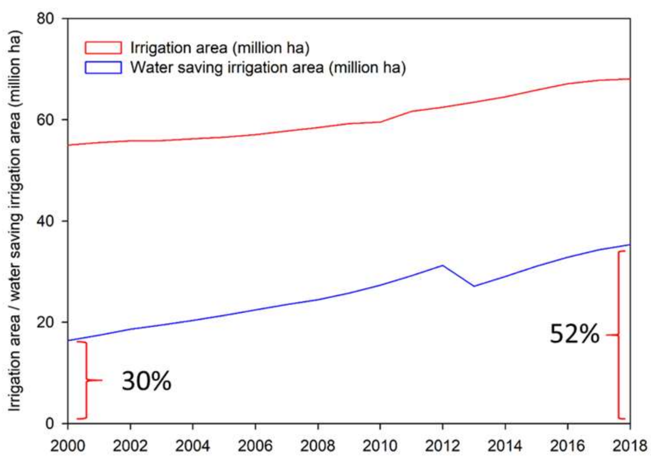
Scientific and technic support

✓ Systematic Research of irrigation water saving



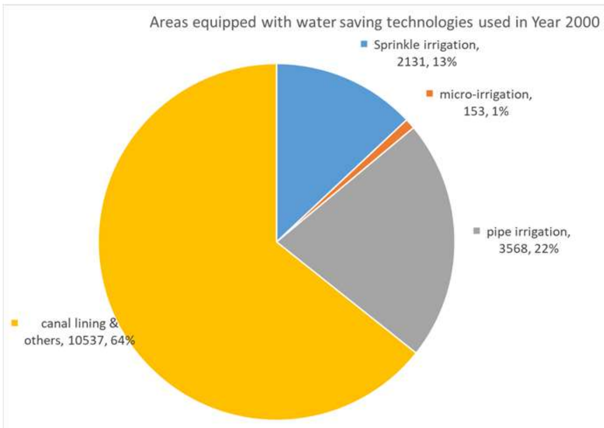
□ Effects from Water Saving Irrigation

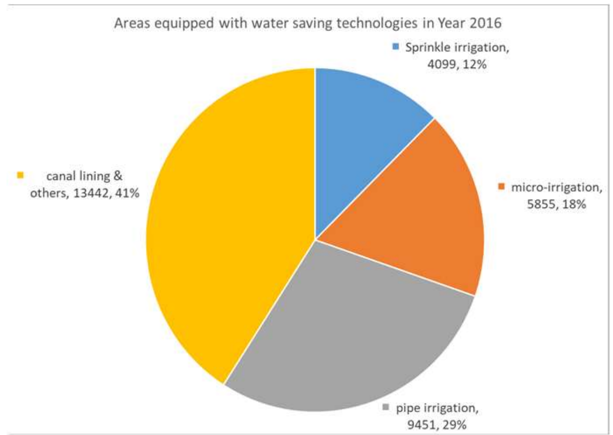
- **Irrigated area increased from 55 million ha in 2000 to 68 million ha in 2018**
- **The ratio of water-saving irrigation area increased from 30% t0 52%.**



☐ Effects from Water Saving Irrigation

- More efficient water saving technologies used

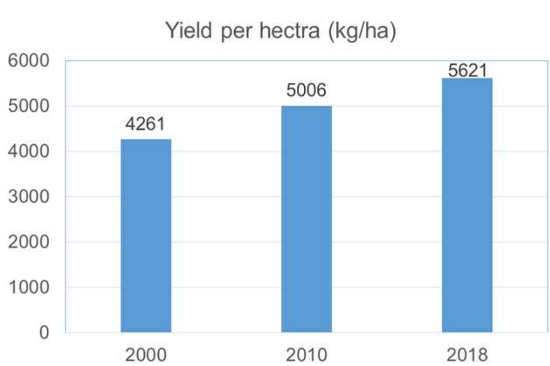


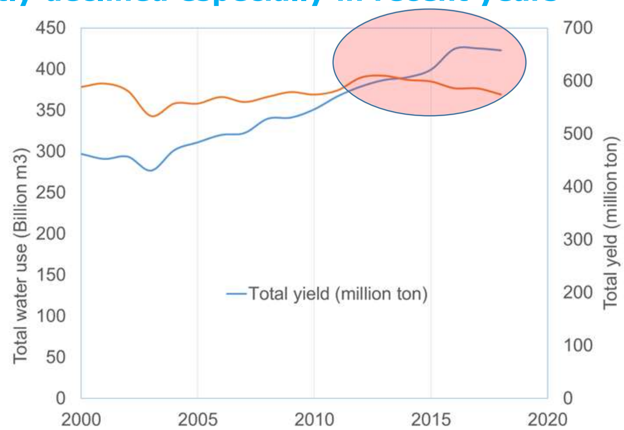


APEC CHILE 2019

☐ Effects from Water Saving Irrigation

- Unit yield: increased from 4261 kg/ha to 5621 kg/ha. **(+32%)**
- Total yield: increased from 462 to 658 million ton. **(+42%)**
- Total water use for agriculture slightly declined especially in recent years





APEC CHILE 2019

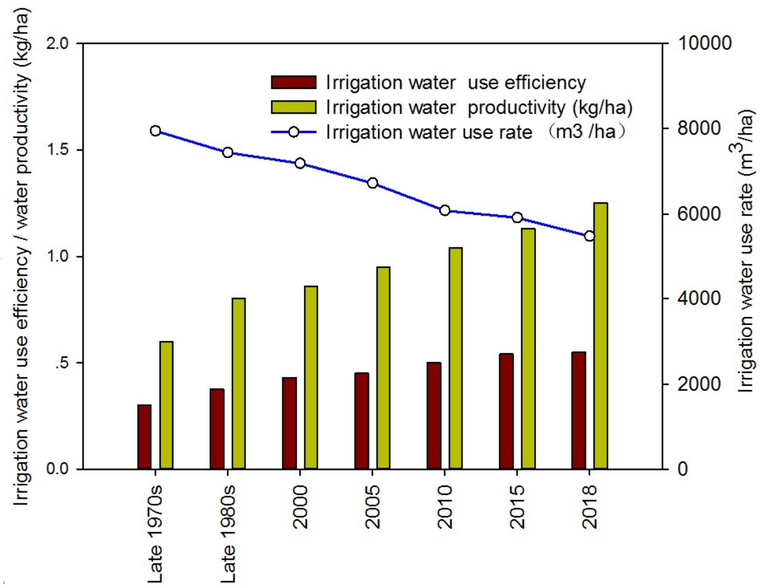
◻ Effects from Water Saving Irrigation

Year 2000→Year 2018

- **irrigation water use rate**
  7185-5475 m³/ha -24%

- **irrigation water use efficiency**
  0.43→0.554 +28%
  44 bn m³/yr water saved

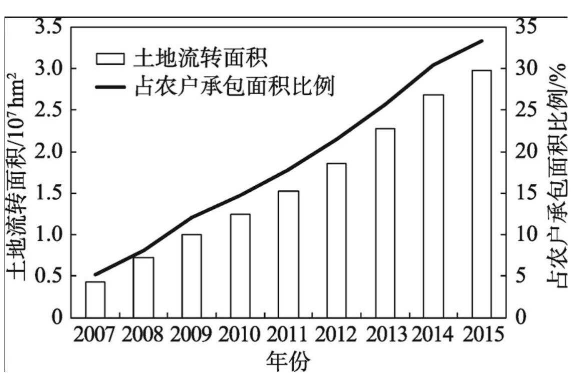
- **Irrigation water productivity**
  0.86 → 1.25 kg/m³ +45%



◻ Effects from Water Saving Irrigation

- **The increases in agricultural productivity push the transformation of traditional agriculture to modern agriculture.**

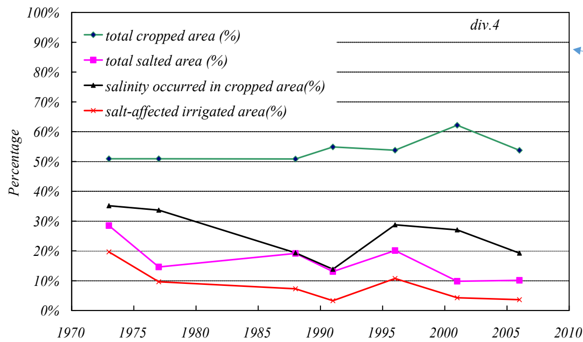
✓The percentage of transferred land is higher than 35%.

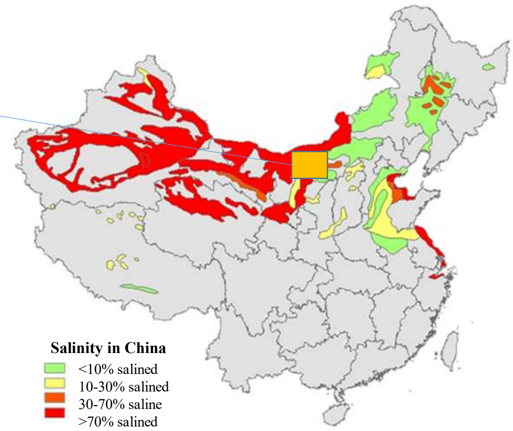


APEC CHILE 2019

◻ Effects from Water Saving Irrigation

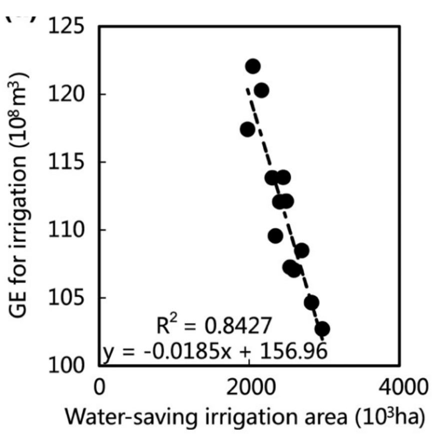
- **Help to protect water-environment.**
  - ✓ Problems due to excessive irrigation are getting better, including soil salinity and water logging

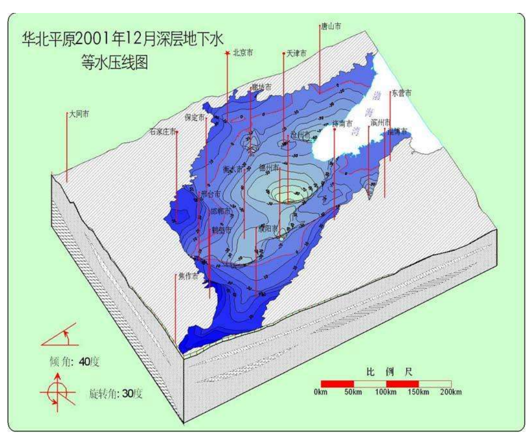




◻ Effects from Water Saving Irrigation

- **Help to protect water-environment.**
  - ✓ Over-exploited groundwater is been slightly recharged.

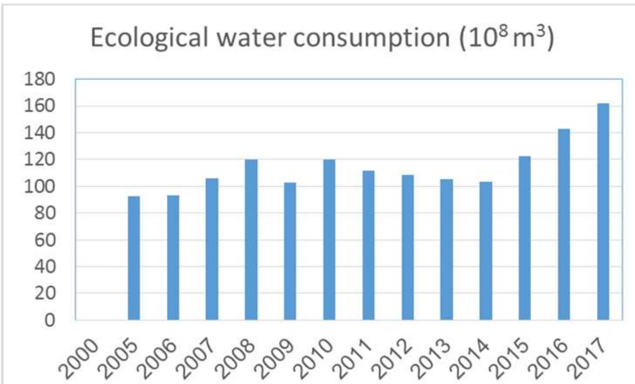




☐ Effects from Water Saving Irrigation

● **Help to protect water-environment.**

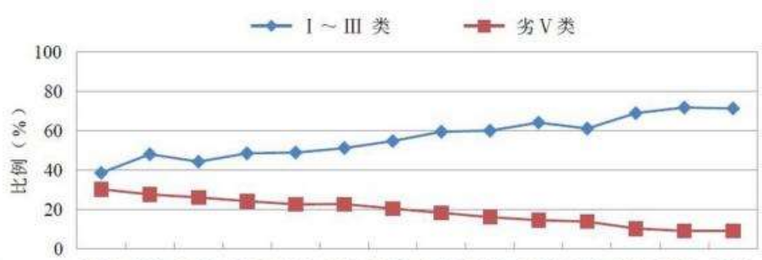
✓ Saved water has been used by ecological restoration of dried/polluted water bodies.



☐ Effects from Water Saving Irrigation

● **Help to protect water-environment.**

✓ The quality of surface water in the main rivers are getting better



年 份	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
断面数（个）	454	436	457	469	471	483	483	485	482	485	469	704	704	702
评价指标（项）	9	9	9	9	9	9	9	9	9	9	9	21	21	21

图 1 2001-2014 年中国主要河流总体水质年际变化曲线图

◻ Effects from Water Saving Irrigation

● **Help to protect water-environment.**

✓ The farmer's living environment is getting much cleaner and more beautiful

◻ Outlook for irrigation

● **Food security call for sustainable and more efficient irrigation.**

● **Water saving irrigation becomes more important as the task is more difficult.**

● **Nation water saving action plan was released in April 2019.**

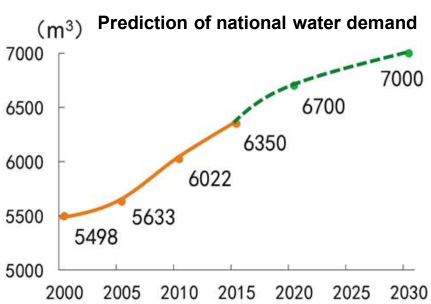
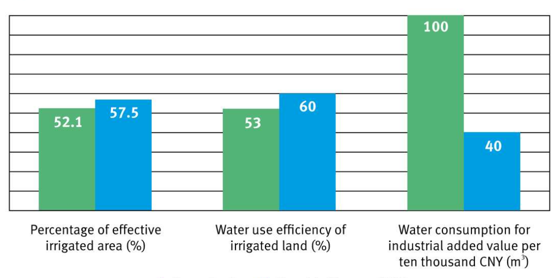


Figure 6. Indicators of water use efficiency for 2030



◻ Outlook for irrigation

● **Environment**

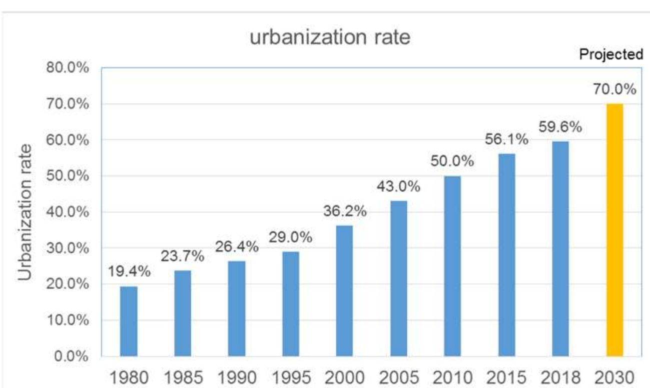
- ✓ **Sound ecological environment is the most inclusive benefits to people's wellbeing.**
- ✓ **We want both golden, silver hill and clean water, green mountains as well.**
- ✓ **More consideration will be make when water saving is applied to irrigation.**

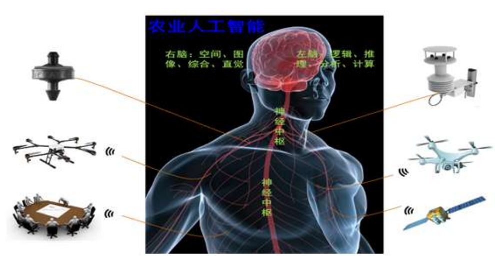
APEC CHILE 2019

◻ Outlook for irrigation

● **Modernization**

- ✓ Modernization of the State
- ✓ Urbanization





APEC CHILE 2019

Thank you very much for your attention!

APEC
CHILE 2019

Efficient and Sustainable Use of Water for Agriculture under the New Climate Scenarios

PAJAREE SINGTO
Hydrologist
Royal Irrigation Department
Thailand

24 July 2019

Presentation Outline

1. Overview
   - Overview of Thailand
   - Overview of RID

2. Climate Change in Thailand

3. Water Management in Chao Phraya Basin

Overview of Thailand

- Thailand is Land of "smile"
- Thailand is in the Southeast Asian
- 77 provinces.
- population over 68 million people
- Area 513,120 km^2
- The capital is Bangkok.
- Religion : Buddhism 94.6 %
  Islam 4.2 % and Christianity 1.1 %
- Thai Language.

About Thailand

- Thailand is located in Southeast Asia region
- Country area 51,312,000 hectares
- Agriculture area base on land-use data 23,877,800 hectares (46.5% of country area)
- Paddy field area 8,930,006 hectares (37.4% of agricultural land area)
- Irrigated paddy field area 2,792,000 hectares (31.3% of paddy field area)

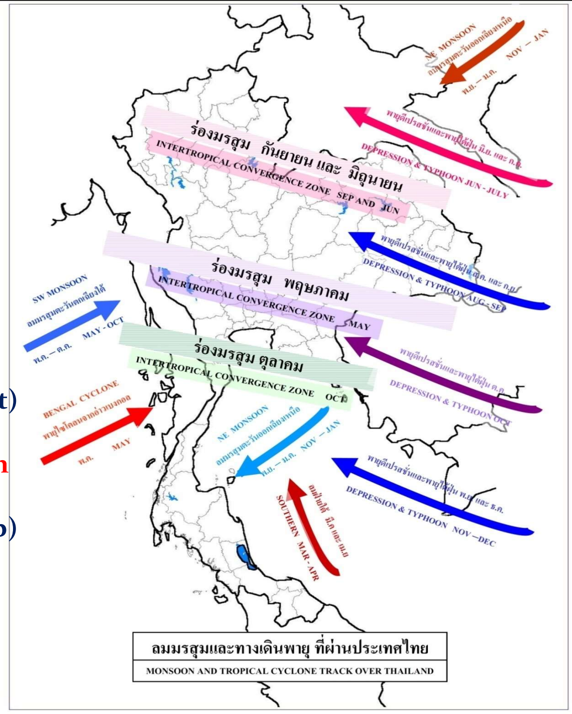
Source: Office of Agricultural Economics

Weather : "tropical wet and dry climate"

3 season
- Winter (Nov–Feb)
- Summer(Mar-May)
- Rainy (Mid May-Oct)

Except on South region 2 season:
- Rainy (Mid May-Feb)
- Summer(Mar-May)

Winter : 15-25 °C
Summer : 35-40 °C

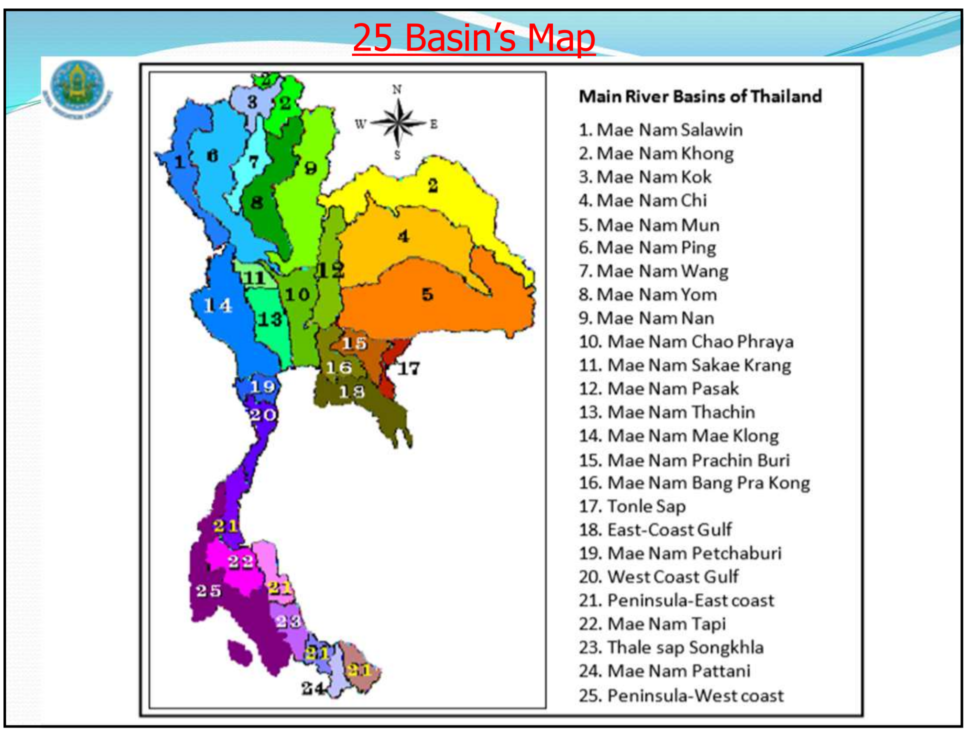


Overview of RID

Vision

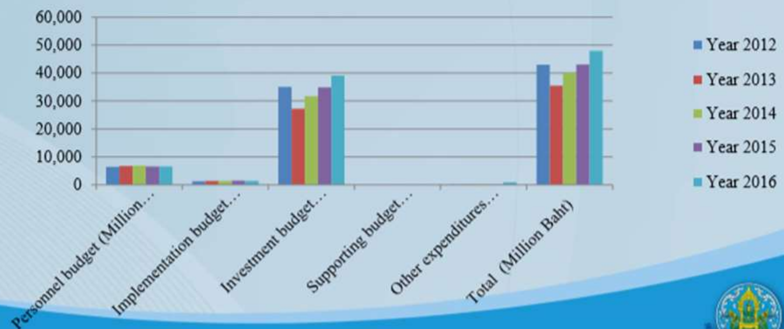
"Royal Irrigation Department is a leading organization in water resources development and integrated water management with the present irrigated area in the world top ten."


VISION & MISSION
Develop water resources & increase irrigated area
Manage water allocation (equitable and sustainable)
Prevent & mitigate water hazards
Encourage people participation (water resources mgt & development)
Royal Irrigation Department intelligent organization, emphasizes on water security, to increase the value of service within B.E.2579 (2036)


25 Basin's Map
Main River Basins of Thailand
1. Mae Nam Salawin
2. Mae Nam Khong
3. Mae Nam Kok
4. Mae Nam Chi
5. Mae Nam Mun
6. Mae Nam Ping
7. Mae Nam Wang
8. Mae Nam Yom
9. Mae Nam Nan
10. Mae Nam Chao Phraya
11. Mae Nam Sakae Krang
12. Mae Nam Pasak
13. Mae Nam Thachin
14. Mae Nam Mae Klong
15. Mae Nam Prachin Buri
16. Mae Nam Bang Pra Kong
17. Tonle Sap
18. East-Coast Gulf
19. Mae Nam Petchaburi
20. West Coast Gulf
21. Peninsula-East coast
22. Mae Nam Tapi
23. Thale sap Songkhla
24. Mae Nam Pattani
25. Peninsula-West coast

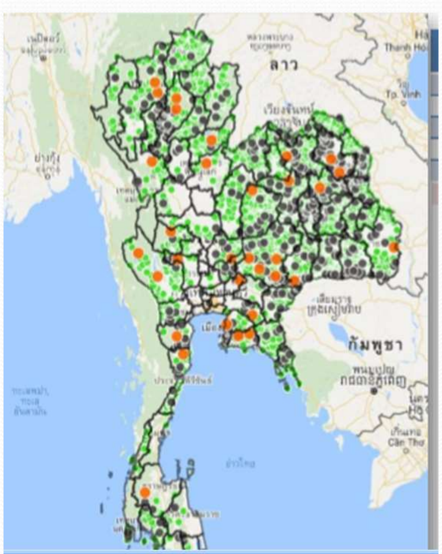
RID's Annual Budget

Budget Expenditures	Year 2012	Year 2013	Year 2014	Year 2015	Year 2016
Personnel budget (Million Baht)	6,438	6,708	6,832	6,537	6,547
Implementation budget (Million Baht)	1,300	1,392	1,392	1,498	1,309
Investment budget (Million Baht)	35,042	27,200	31,711	34,854	39,045
Supporting budget (Million Baht)	0.78	0.78	0.78	0.78	0.49
Other expenditures (Million Baht)	138	193	159	165	942
Total (Million Baht)	42,919	35,493	40,095	43,055	47,924



Royal Irrigation Department, Ministry of Agriculture and Cooperatives

Irrigation Facilities in Thailand



Project	Number of Project	Capacity (MCM)	Irrigable Area (M.ha)
Large Scale	34	73,217	2.87
Medium Scale	671	4,219	1.05
Small Scale	13,842	1,790	0.18
Pumping Station	2,557	1	0.72
Detention storage	223	451	0.01

Climate Change in Thailand

Key Risks and Adaptation in ASIA

Key issues

Asia				
Key risk	**Adaptation issues & prospects**	**Climatic drivers**	**Timeframe**	**Risk & potential for adaptation**
Increased riverine, coastal, and urban flooding leading to widespread damage to infrastructure, livelihoods, and settlements in Asia (*medium confidence*) [24.4] **"Flood"**	• Exposure reduction via structural and non-structural measures, effective land-use planning, and selective relocation • Reduction in the vulnerability of lifeline infrastructure and services (e.g., water, energy, waste management, food, biomass, mobility, local ecosystems, telecommunications) • Construction of monitoring and early warning systems; Measures to identify exposed areas, assist vulnerable areas and households, and diversify livelihoods • Economic diversification	Adapt: Exposure reduction via structures & non-structures / LU Planning / Relocation / Early warning systems, etc.		
Increased risk of heat-related mortality (*high confidence*) [24.4] **"Heat"**	• Heat health warning systems • Urban planning to reduce heat islands; Improvement of the built environment; Development of sustainable cities • New work practices to avoid heat stress among outdoor workers	Adapt: "Heat health warning systems / Urban planning / New work practices to avoid heat stress among outdoor workers		
Increased risk of drought-related water and food shortage causing malnutrition (*high confidence*) [24.4] **"Drought"**	• Disaster preparedness including early-warning systems and local coping strategies • Adaptive/integrated water resource management • Water infrastructure and reservoir development • Diversification of water sources including water re-use • More efficient use of water (e.g., improved agricultural practices, irrigation management, and resilient agriculture)	Adapt: Disaster Preparedness (Early warning, Local coping), IWRM, Water infrastructure & Reservoir development, More efficient water use, etc.		

Climate-related drivers of impacts

Warming trend · Extreme temperature · Drying trend · Extreme precipitation · Precipitation · Snow cover · Damaging cyclone · Sea level · Ocean acidification · Carbon dioxide fertilization

Level of risk & potential for adaptation

Potential for additional adaptation to reduce risk

Risk level with **high** adaptation · Risk level with **current** adaptation

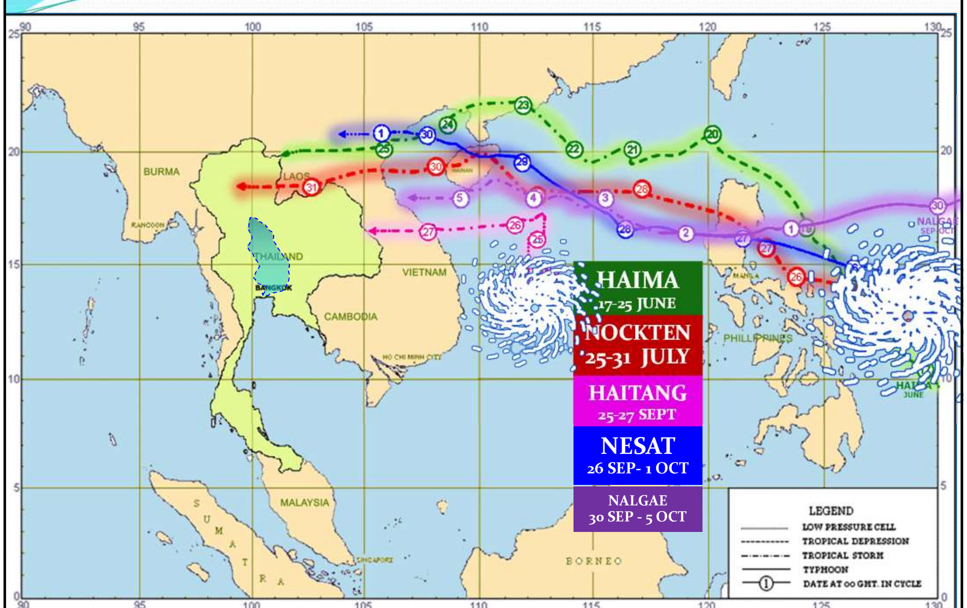
IPCC, 2014: Summary for policymakers. In: *Climate Change 2014: Impacts, Adaptation, and Vulnerability*

12

The highlight of climate change in Thailand :

- Climate change tends to drive more seriously severity disasters, especially storms, floods, and drought.
- The annual average temperature in Thailand has increased about 0.56 °C for 50 years.
- The average sea surface temperatures in the Gulf of Thailand (East coast) and the Andaman Sea (West coast) tends to increase about 0.1 °C per decade.
- Mean sea level in the Gulf of Thailand has been is increased at a rate of 3.0 to 5.0 mm per year.

TROPICAL STORMS AFFECTED THAILAND 2011



In 2011 Thailand : Extreme flooding

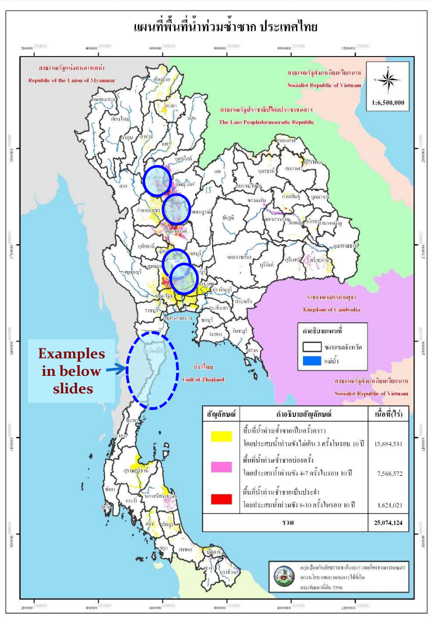
- Starting in late July and ends on 16 January 2012
- People have affected more than 12.8 million people
- the World Bank estimated losses of up to 1.44 trillion baht
- Extreme flooding cause more than 6 million hectares of land
- Farmland is expected to be damaged 0.45 million hectares

CC Key Risks in Thailand (Flood)

Sukhothai (28Jul.2017)
http://news.thaiflood.com/archives/1648

Sukhothai (28Jul.2017)
http://www.bangkokbiznews.com/news/detail/766601

Nakhon Sawan (20Oct.2017)
https://www.pptvhd36.com/news/ประเด็นร้อน/67791



Singhburi: dike break (13Oct.2017)
https://news.thaipbs.or.th/content/266894

Angthong: flow under dike (14Oct.2017)
https://www.prachachat.net/general/news-54930

Ayuthya: Sena lowland (25Sep.2016)
http://news.thaipbs.or.th/content/256074

16

In 2015-2016 Thailand has been extreme drought

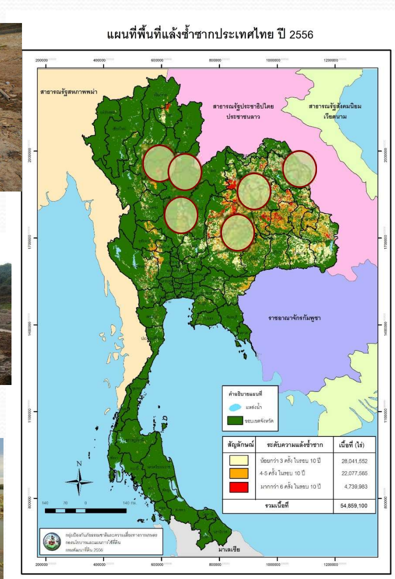
- Thailand has been affected by the El Niño years of 1982 to 1983 and a second time in 1998. The rainfall amount is less than normal

CC Key Risks in Thailand (Drought)

Sukhothai (26Feb.2014)
https://www.thairath.co.th/content/406250

Phitsanulok (20 Jan. 2016)
https://mgronline.com/local/detail/9590000006665

Nakhon Sawan (6Jul.2015)
https://www.thairath.co.th/content/509692



Nakhon Panom: from Khong Riv. (24 Mar. 2016)
https://www.thairath.co.th/content/595546

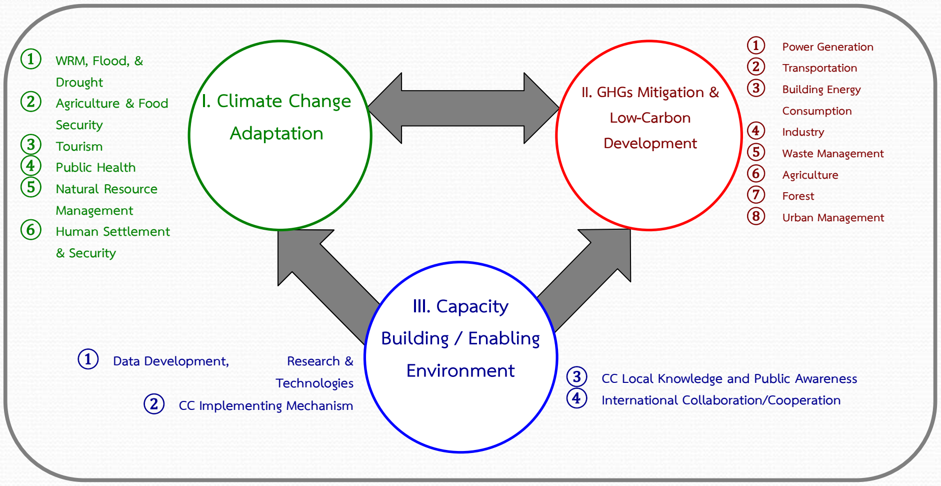
Khon Kean (23 Feb. 20xx)
http://www.khonkaenlink.info/home/news/1220.html

Korat (25 Mar. 2010)
https://www.thairath.co.th/content/72844

18

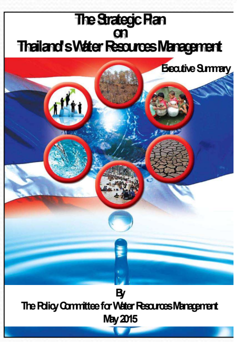
Climate Change Master Plan 2015-2050

Components



Achievements: Integrate climate change measures into national policies, strategies and planning (SDG13 Target)

The Strategic Plan on Thailand 's Water Resources Management



Situation	Trend	Water resources management direction
economic structure change to industrial structure trend	preparedness for production 2.2 An increase in income share from industrial sector 2.3 Emphasize on an increase in value chain in a production of upstream industry such as steel and petrochemical industry	2.2 Water allocation (quota) arrangement to avoid impact on other sectors
3. Agricultural production is a key for rural people's livelihoods	3.1 Change of production system to more of commercial production 3.2 Regional production mainly depending on agriculture 3.3 Higher competition in agricultural sector	3.1 Water supply provision, water development projects and an increase in efficiency of irrigation system 3.2 Change pattern of production to economic crops with high value and demand
4. Service and tourism sector	4.1 Bangkok and areas around Bangkok in the East, including areas in Northern and Southern regions will become important tourist areas.	4.1 Provide water resources in existing tourist areas having limitation and high cost of investment problems 4.2 Develop new tourist areas according to capacity in water resources provision
5. Climate change	5.1 Change of precipitation pattern to be more extreme 5.2 Impact on water supply and agricultural productivity	5.1 Accelerate provision of risk map for flood and drought, and develop efficient early warning system 5.2 Build resilience to respond and mitigate effects from flood and drought 5.3 Disseminate appropriate information and news effectively

3.1.2 Changes in resources and situation of Thailand affecting water resources management

Situation	Trend	Water resources management direction
1. Upstream and forest management	1.1 Ongoing upstream forest encroachment 1.2 Forest management and water resources development are not integrated into policy planning.	1.1 Upstream area management to mitigate overall impacts in the river basin, including flood and drought

The Strategic Plan on Thailand's Water Resources Management (May 2015) 3-2

Trend

1. Change of precipitation pattern to be more extreme
2. Impact on water supply and agricultural productivity

WRM direction

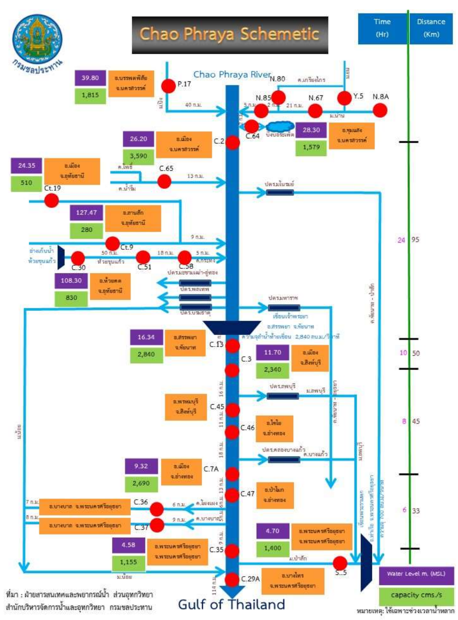
1. Accelerate provision of risk map for flood and drought, and develop efficient early warning system
2. Build resilience to respond and mitigate effects from flood and drought
3. Disseminate appropriate information and news effectively

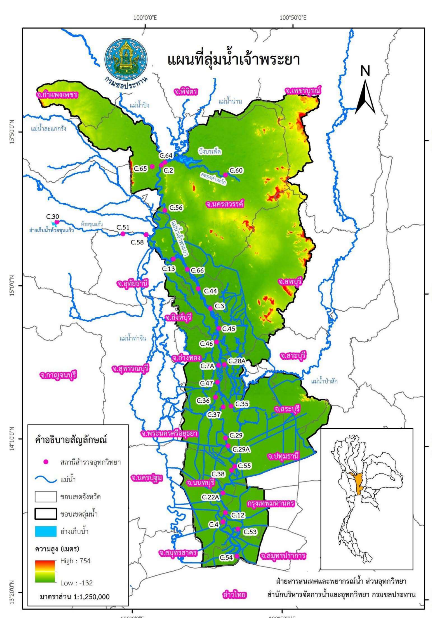
http://www.dwr.go.th/news/2/news-2-0-47295.html

ROYAL IRRIGATION DEPARTMENT (RID)
MINISTRY OF AGRICULTURAL AND COOPERATIVES

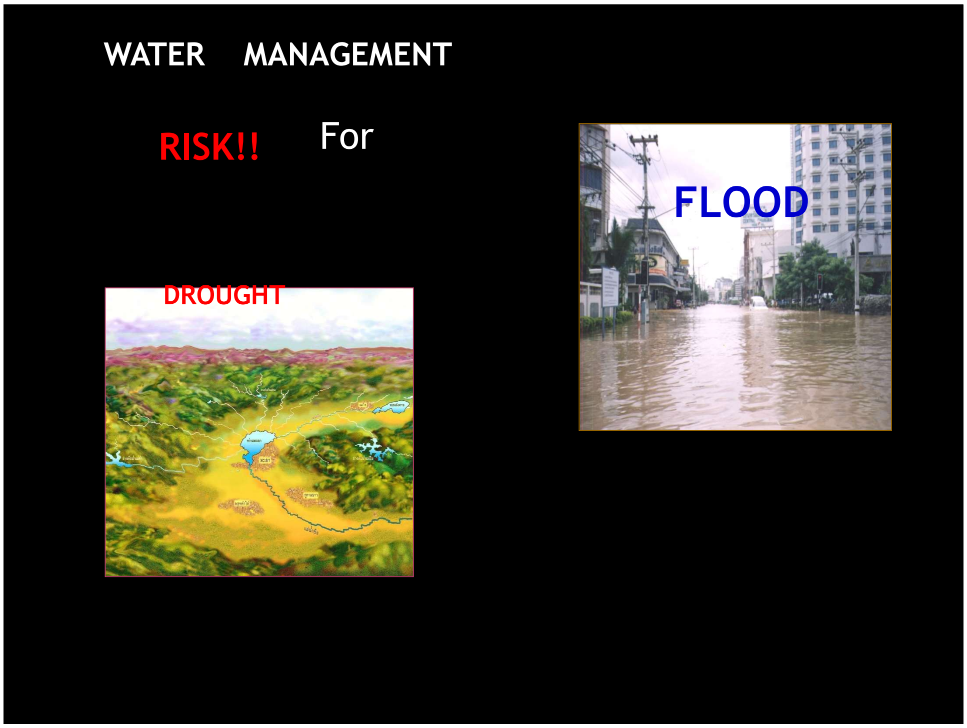
Water Management in Chao Phraya Basin

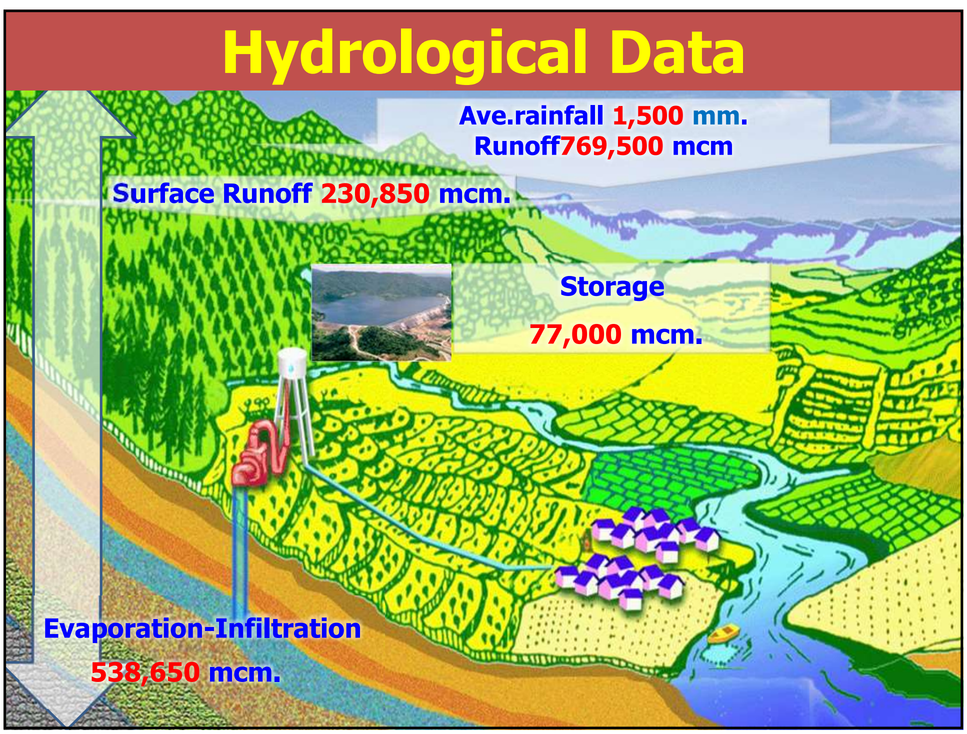
Chao Phraya Basin Map

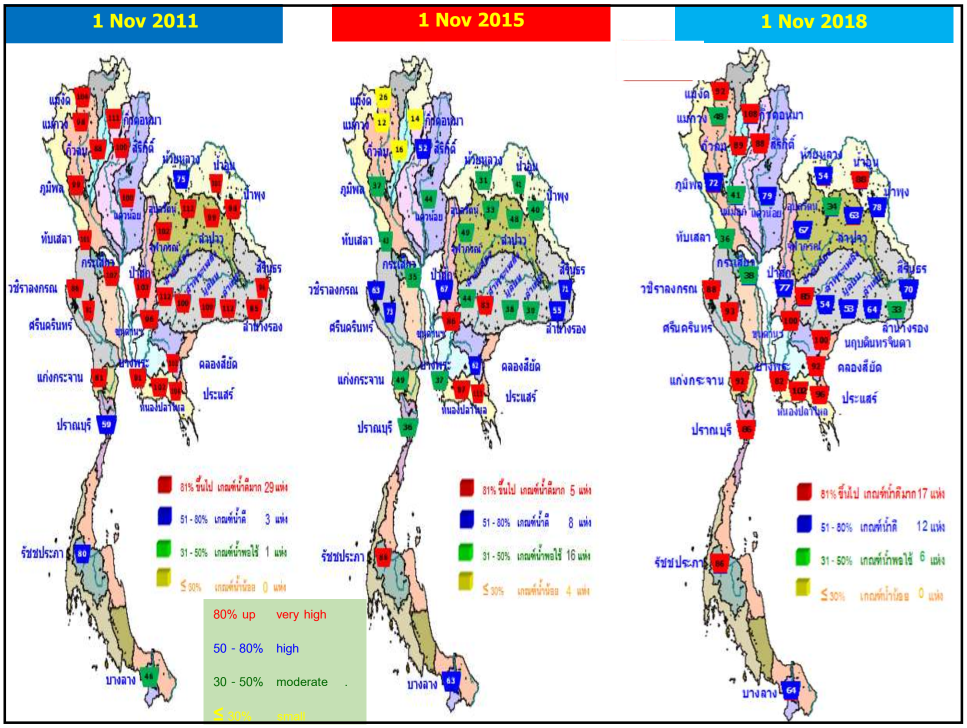


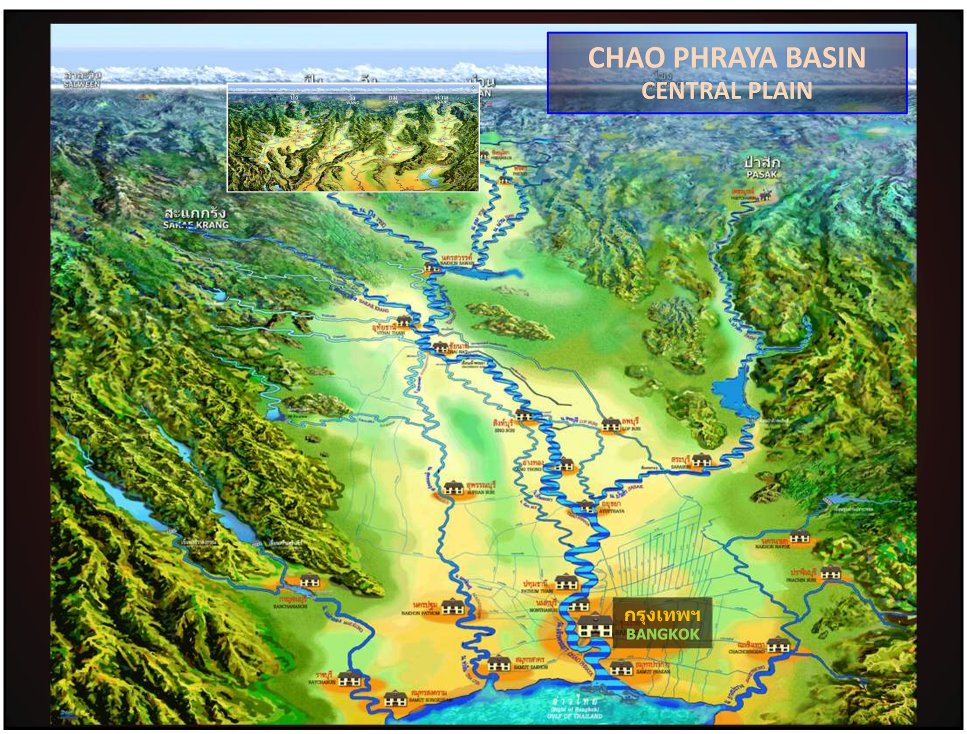


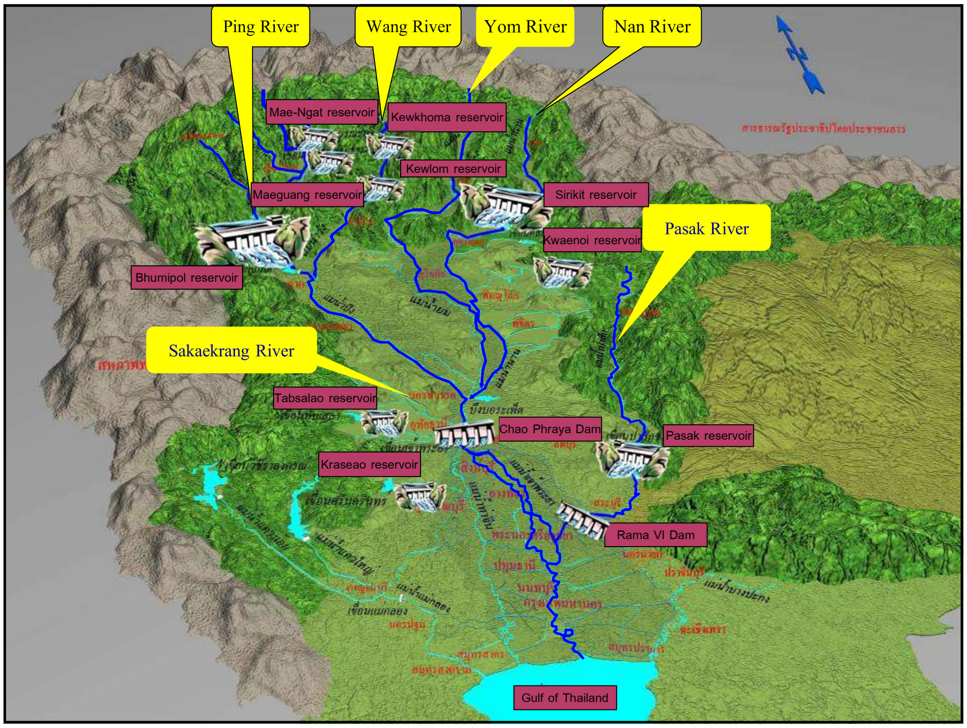
Length 372 km (231 mi), Basin size 160,400 km^2 (61,900 sq mi)

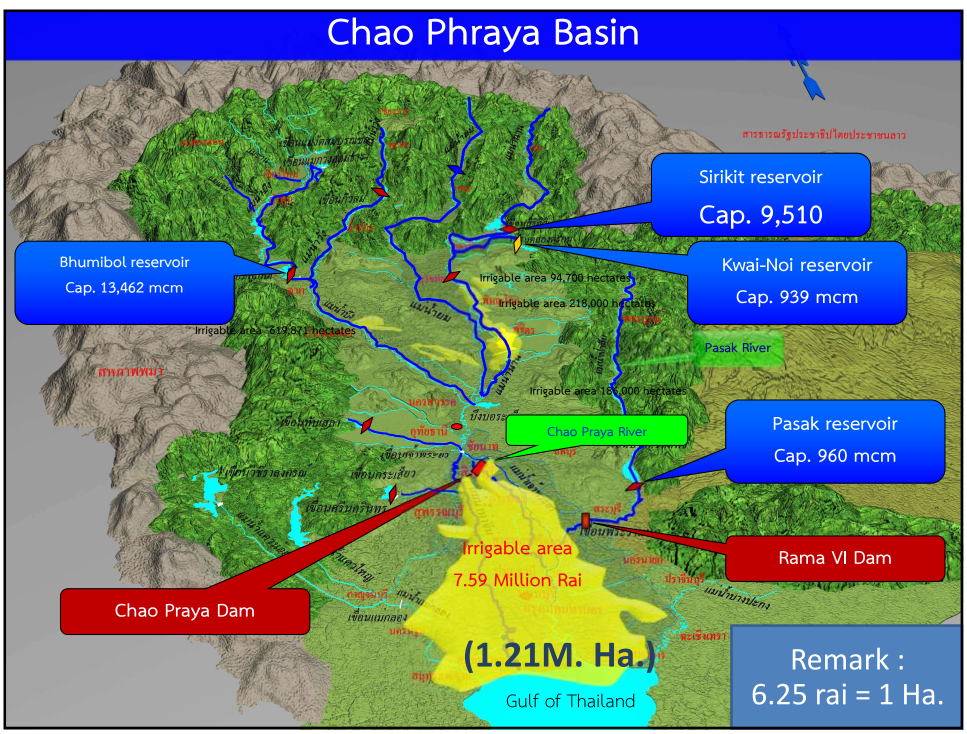

WATER MANAGEMENT
RISK!!
For
FLOOD
DROUGHT


Hydrological Data
Ave.rainfall 1,500 mm.
Runoff769,500 mcm
Surface Runoff 230,850 mcm.
Storage
77,000 mcm.
Evaporation-Infiltration
538,650 mcm.


1 Nov 2011
1 Nov 2015
1 Nov 2018
80% up very high
50 - 80% high
30 - 50% moderate


CHAO PHRAYA BASIN
CENTRAL PLAIN
ป่าสัก
PASAK
สะแกกรัง
SAKAE KRANG
กรุงเทพฯ
BANGKOK


Ping River
Wang River
Yom River
Nan River
Mae-Ngat reservoir
Kewkhoma reservoir
Kewlom reservoir
Maeguang reservoir
Sirikit reservoir
Pasak River
Kwaenoi reservoir
Bhumipol reservoir
Sakaekrang River
Tabsalao reservoir
Chao Phraya Dam
Pasak reservoir
Kraseao reservoir
Rama VI Dam
Gulf of Thailand

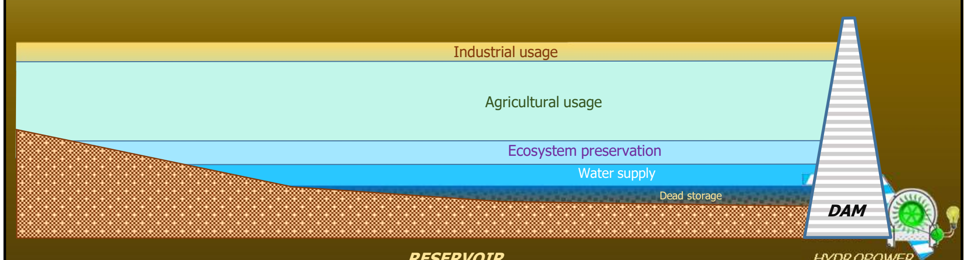

Chao Phraya Basin
Sirikit reservoir
Cap. 9,510
Bhumibol reservoir
Cap. 13,462 mcm
Kwai-Noi reservoir
Cap. 939 mcm
Irrigable area 94,700 hectares
Irrigable area 218,000 hectares
Irrigable area 619,871 hectares
Pasak River
Irrigable area 186,000 hectares
Chao Praya River
Pasak reservoir
Cap. 960 mcm
Rama VI Dam
Irrigable area
7.59 Million Rai
Chao Praya Dam
(1.21M. Ha.)
Gulf of Thailand
Remark :
6.25 rai = 1 Ha.

Water management during dry season in Thailand

The water management is based on available water of beginning season. Priorities of water allocation are applied as follows:

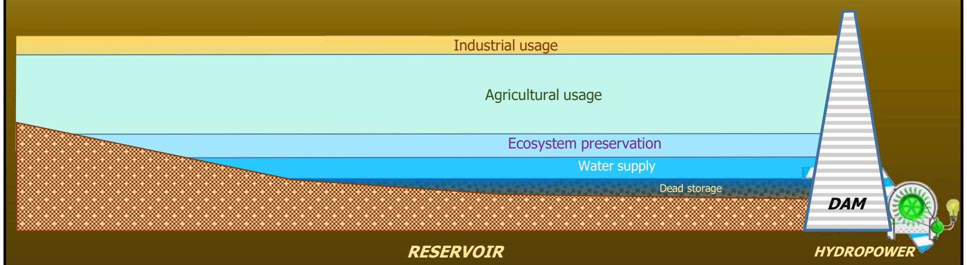
1. **Water allocation for consumption (in dry season)**
2. **Water allocation for ecosystem (in dry season)**
3. **Water reservation for beginning of rainy season**
4. **Water allocation for agriculture**
5. **Water allocation for industry**

STORAGE ALLOCATION PRIORITY



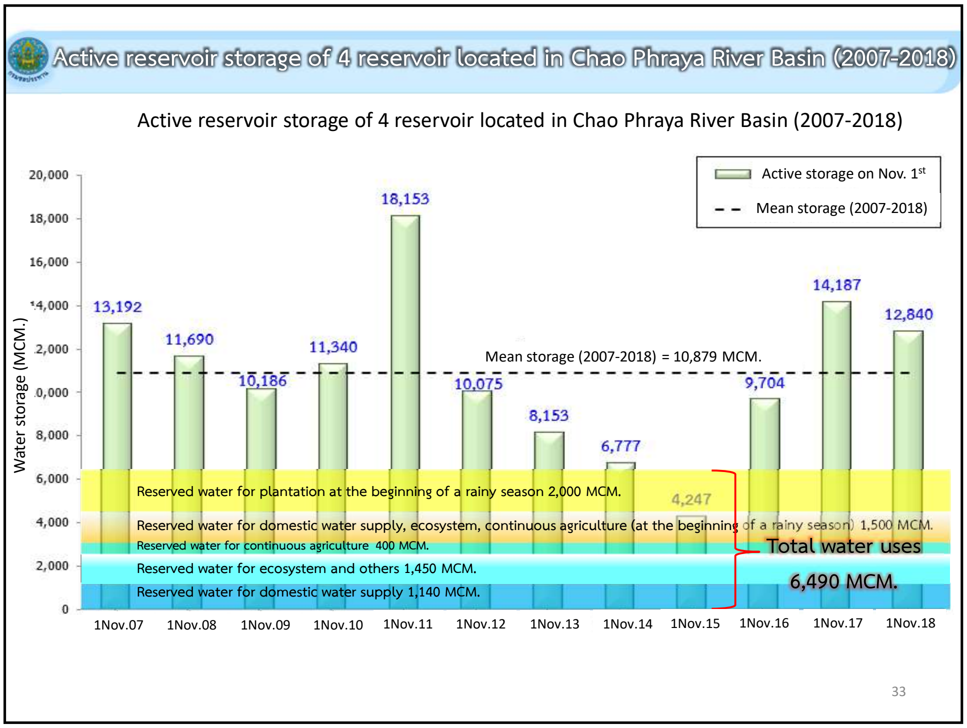
Industrial usage | Agricultural usage | Ecosystem preservation | Water supply

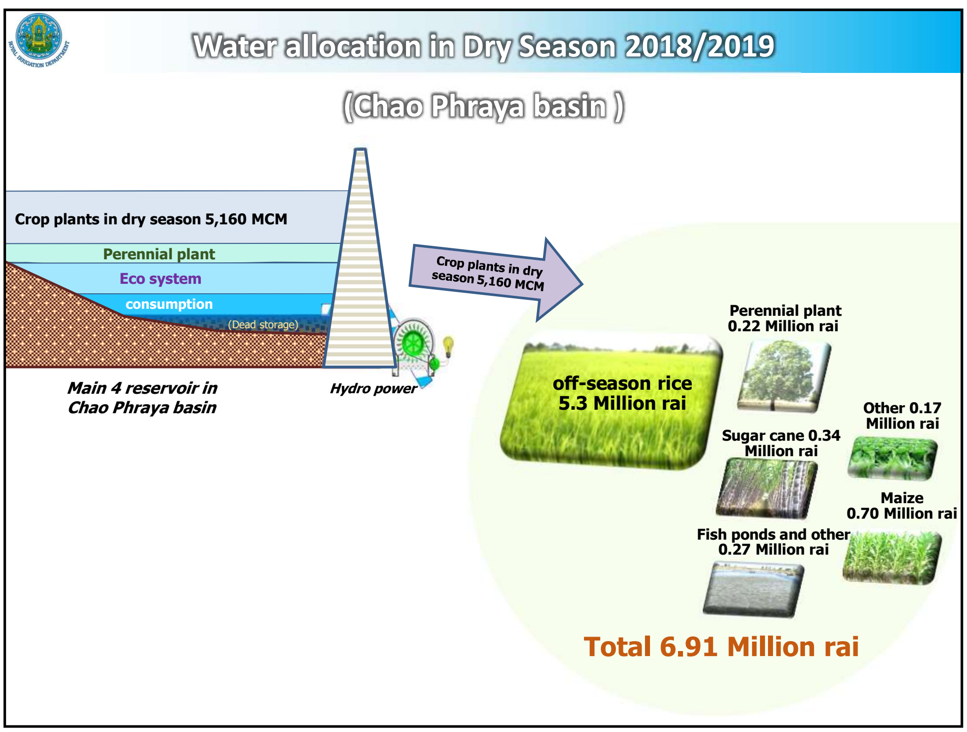
STORAGE ALLOCATION PRIORITY



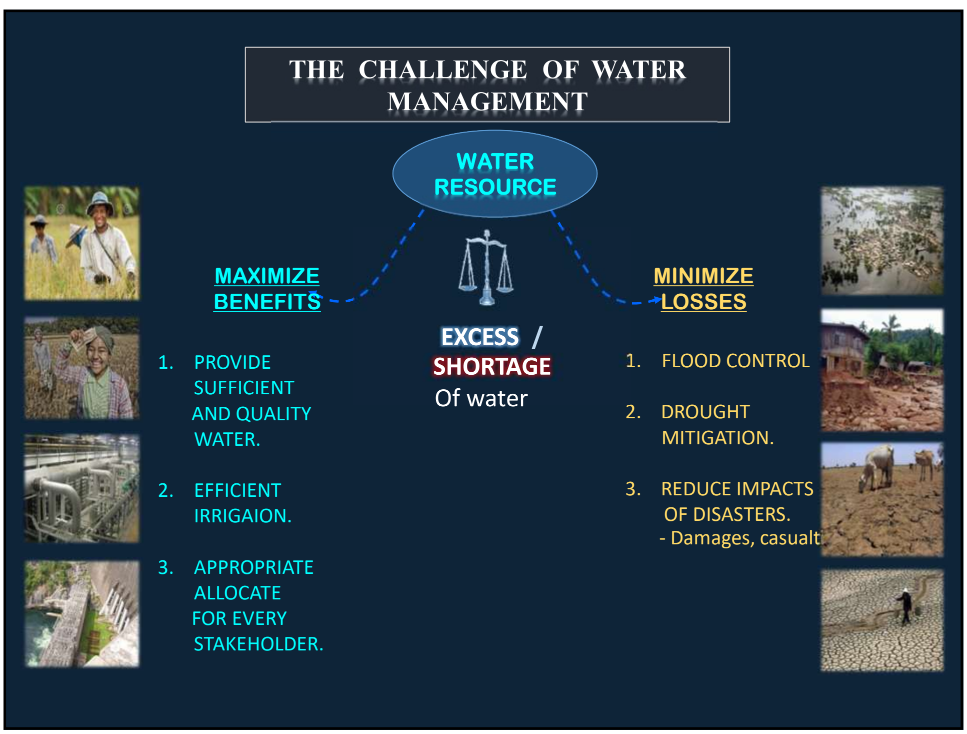
Industrial usage | Agricultural usage | Ecosystem preservation | Water supply

The minimum criteria for water reserved storage in Chao Phraya basin


Active reservoir storage of 4 reservoir located in Chao Phraya River Basin (2007-2018)
Active reservoir storage of 4 reservoir located in Chao Phraya River Basin (2007-2018)
Active storage on Nov. 1st
Mean storage (2007-2018)
Water storage (MCM.)
Mean storage (2007-2018) = 10,879 MCM.
13,192
11,690
10,186
11,340
18,153
10,075
8,153
6,777
4,247
9,704
14,187
12,840
Reserved water for plantation at the beginning of a rainy season 2,000 MCM.
Reserved water for domestic water supply, ecosystem, continuous agriculture (at the beginning of a rainy season) 1,500 MCM.
Reserved water for continuous agriculture 400 MCM.
Reserved water for ecosystem and others 1,450 MCM.
Reserved water for domestic water supply 1,140 MCM.
Total water uses
6,490 MCM.
1Nov.07
1Nov.08
1Nov.09
1Nov.10
1Nov.11
1Nov.12
1Nov.13
1Nov.14
1Nov.15
1Nov.16
1Nov.17
1Nov.18
33


Water allocation in Dry Season 2018/2019
(Chao Phraya basin)
Crop plants in dry season 5,160 MCM
Perennial plant
Eco system
consumption
(Dead storage)
Main 4 reservoir in Chao Phraya basin
Hydro power
Crop plants in dry season 5,160 MCM
Perennial plant 0.22 Million rai
off-season rice 5.3 Million rai
Other 0.17 Million rai
Sugar cane 0.34 Million rai
Maize 0.70 Million rai
Fish ponds and other 0.27 Million rai
Total 6.91 Million rai


THE CHALLENGE OF WATER MANAGEMENT
INCREASE INCOME
WATER RESOURCE
DECREASE LOSSES

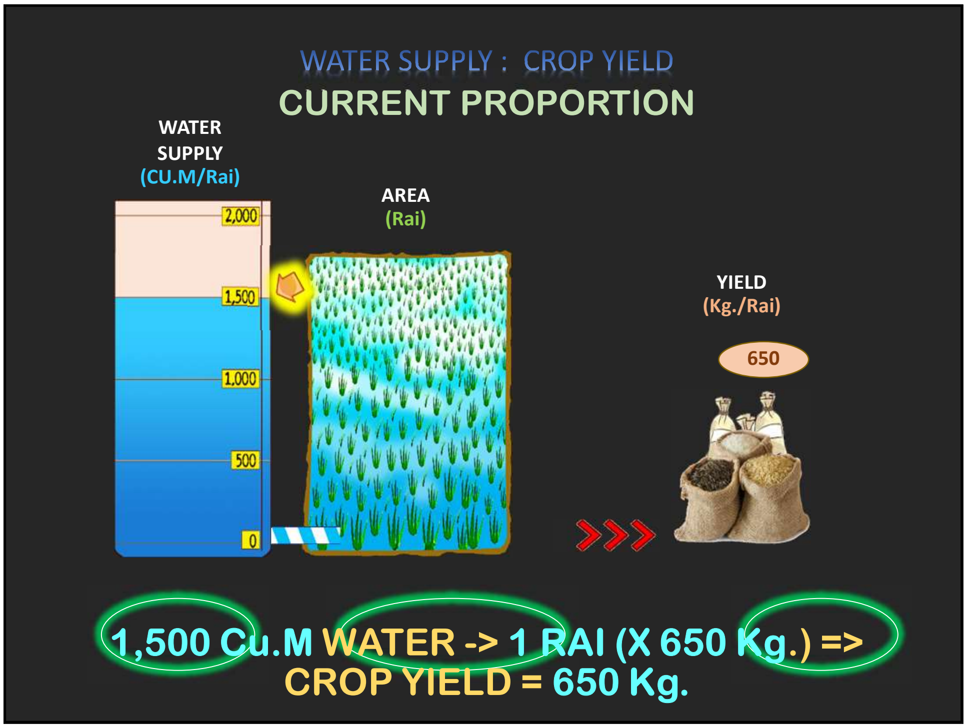

THE CHALLENGE OF WATER MANAGEMENT
WATER RESOURCE
MAXIMIZE BENEFITS
1. PROVIDE SUFFICIENT AND QUALITY WATER.
2. EFFICIENT IRRIGAION.
3. APPROPRIATE ALLOCATE FOR EVERY STAKEHOLDER.
EXCESS / SHORTAGE Of water
MINIMIZE LOSSES
1. FLOOD CONTROL
2. DROUGHT MITIGATION.
3. REDUCE IMPACTS OF DISASTERS.
- Damages, casualt

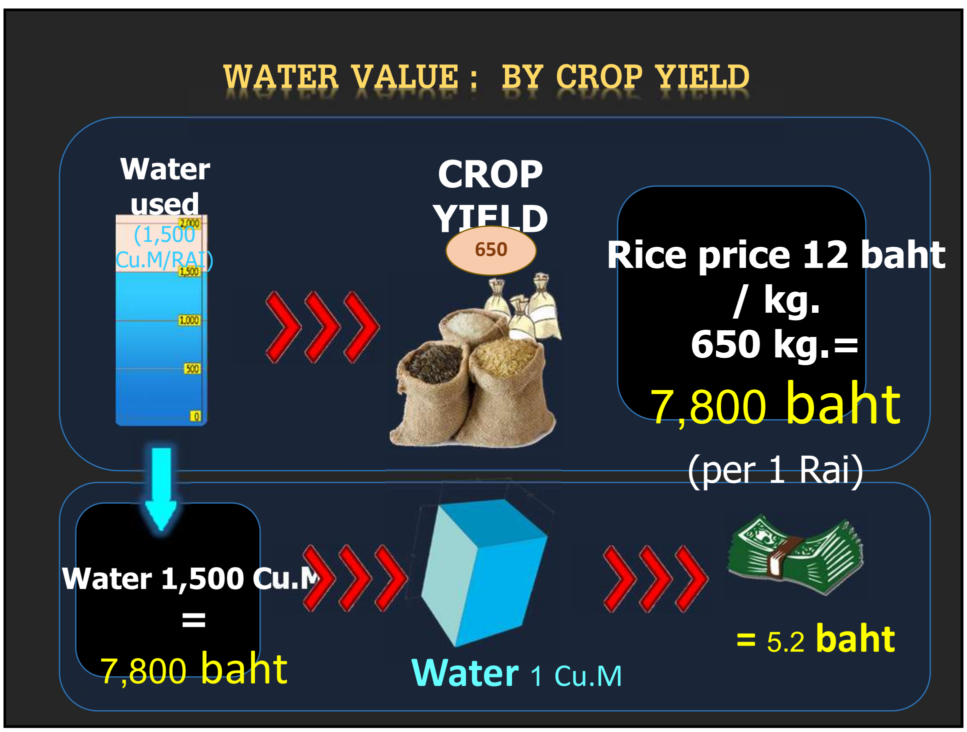
CASE 1 RESERVOIR CAPACITY GREATER THAN AVERAGE ANNUAL INFLOW

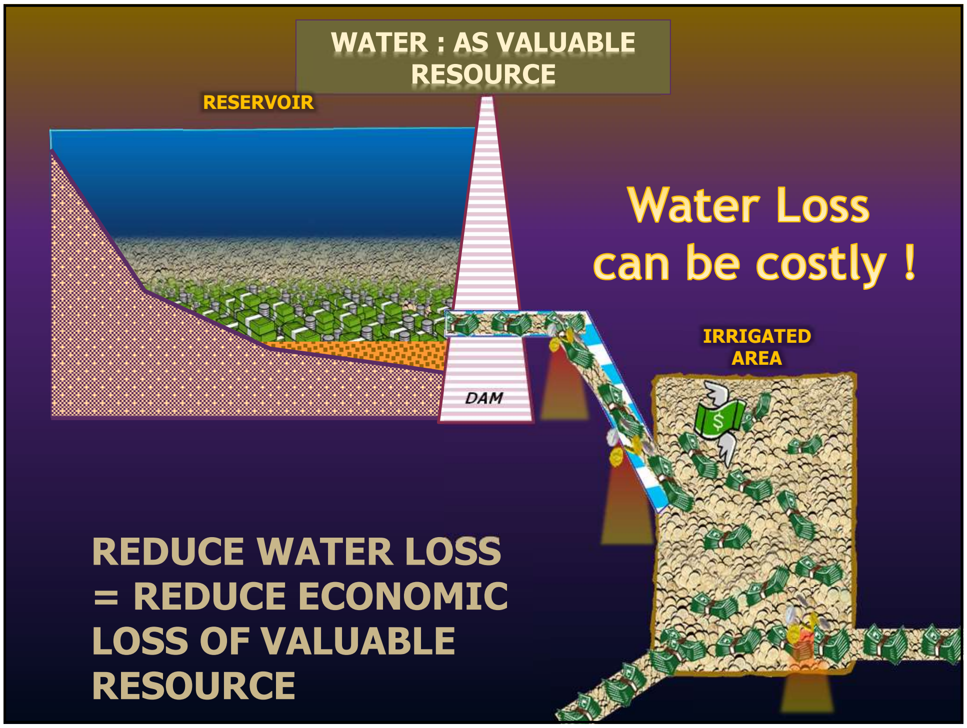
- Reserve water for in season crop (wet season)
- Reserve water for water shortage situation due to climate variability

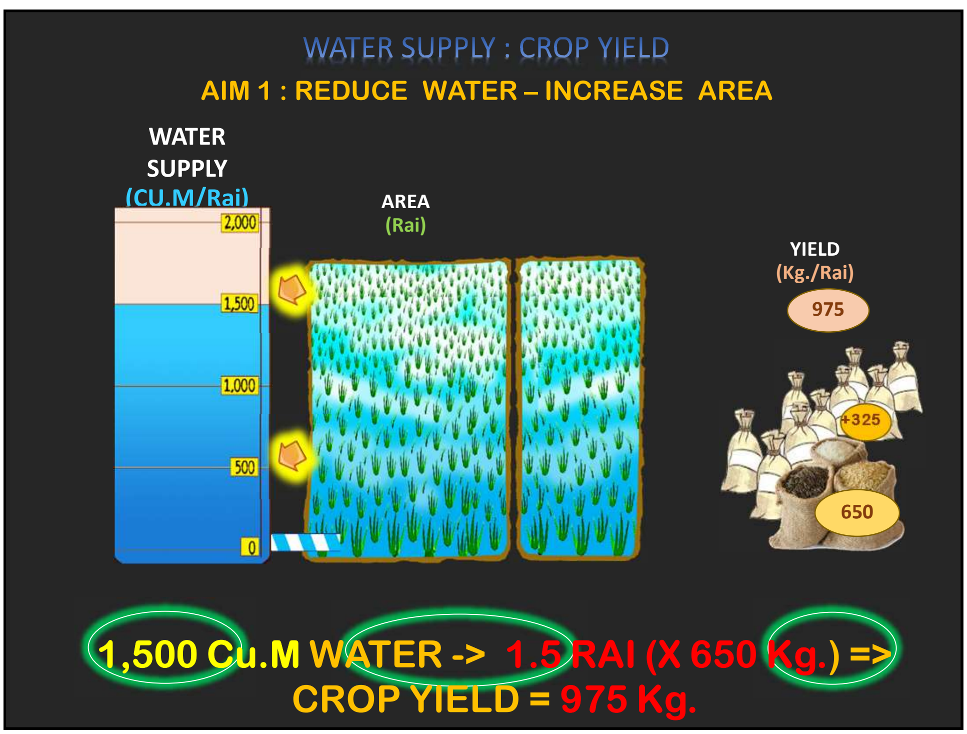
TARGET

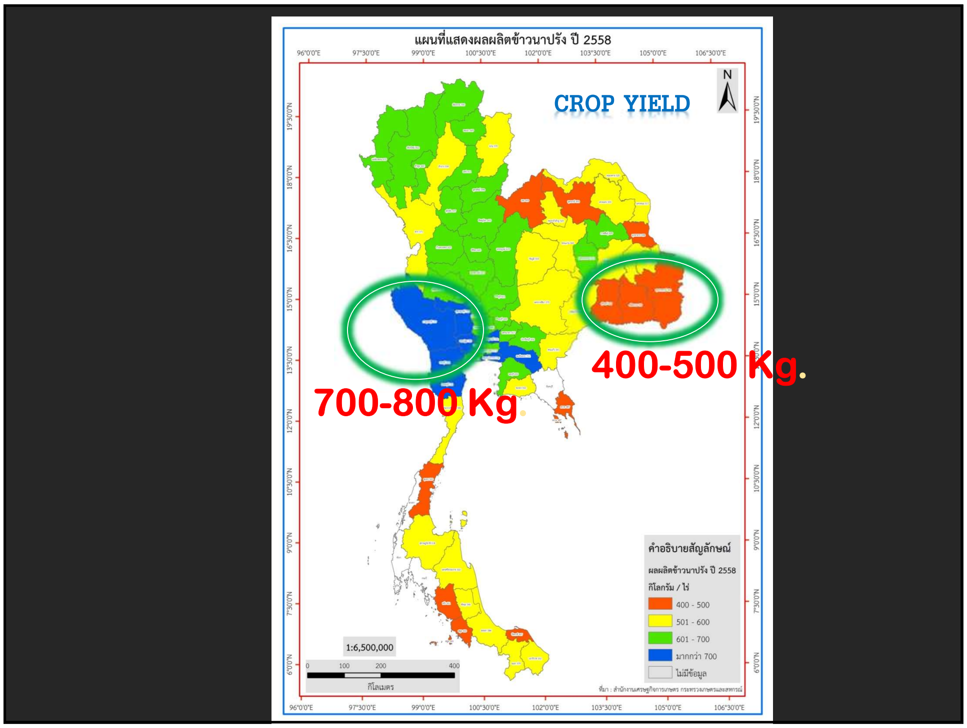
- Increase Irrigation Efficiency
- Increase Rice Yield

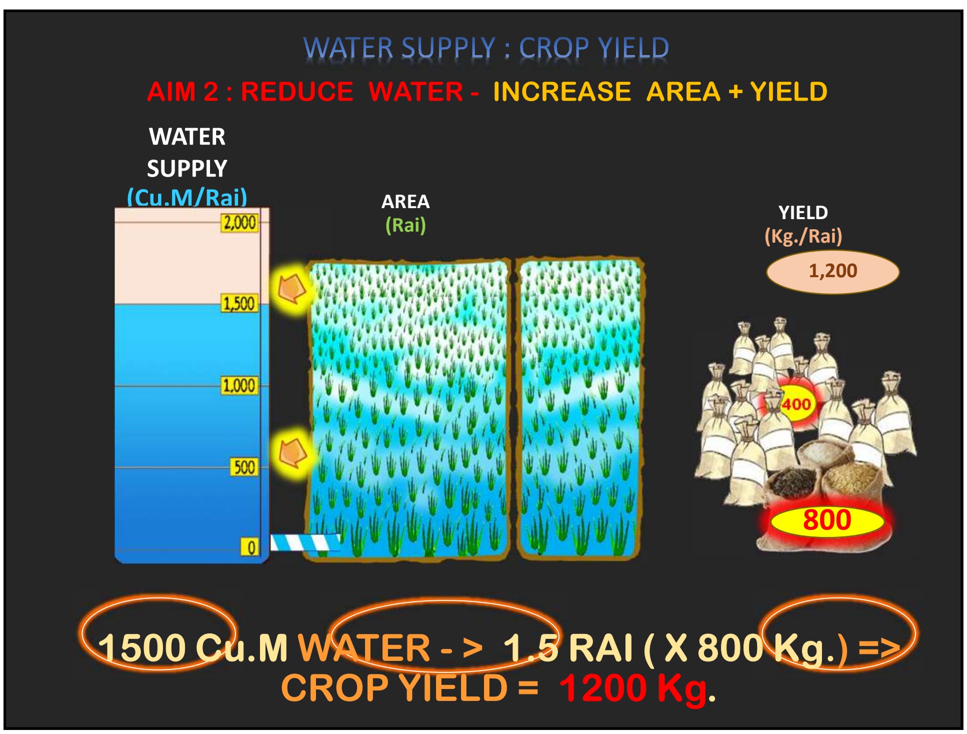

WATER SUPPLY : CROP YIELD
CURRENT PROPORTION
WATER SUPPLY (CU.M/Rai)
2,000
1,500
1,000
500
0
AREA (Rai)
YIELD (Kg./Rai)
650
1,500 Cu.M WATER -> 1 RAI (X 650 Kg.) =>
CROP YIELD = 650 Kg.

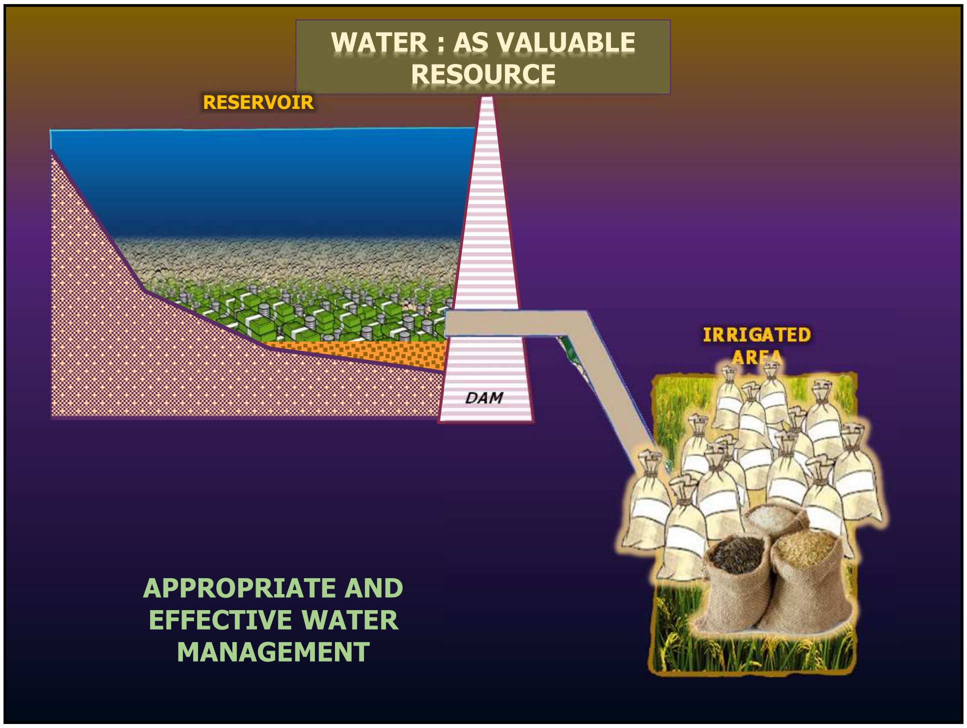

WATER VALUE : BY CROP YIELD
Water used
(1,500 Cu.M/RAI)
CROP YIELD
650
Rice price 12 baht / kg.
650 kg.=
7,800 baht
(per 1 Rai)
Water 1,500 Cu.M
=
7,800 baht
Water 1 Cu.M
= 5.2 baht


WATER : AS VALUABLE RESOURCE
RESERVOIR
DAM
Water Loss
can be costly !
IRRIGATED AREA
REDUCE WATER LOSS
= REDUCE ECONOMIC
LOSS OF VALUABLE
RESOURCE


WATER SUPPLY : CROP YIELD
AIM 1 : REDUCE WATER – INCREASE AREA
WATER SUPPLY
(CU.M/Rai)
2,000
1,500
1,000
500
0
AREA
(Rai)
YIELD
(Kg./Rai)
975
+325
650
1,500 Cu.M WATER -> 1.5 RAI (X 650 Kg.) =>
CROP YIELD = 975 Kg.


แผนที่แสดงผลผลิตข้าวนาปรัง ปี 2558
CROP YIELD
700-800 Kg.
400-500 Kg.
คำอธิบายสัญลักษณ์
ผลผลิตข้าวนาปรัง ปี 2558
กิโลกรัม / ไร่
400 - 500
501 - 600
601 - 700
มากกว่า 700
ไม่มีข้อมูล
1:6,500,000
กิโลเมตร


WATER SUPPLY : CROP YIELD
AIM 2 : REDUCE WATER - INCREASE AREA + YIELD
WATER SUPPLY (Cu.M/Rai)
2,000
1,500
1,000
500
0
AREA (Rai)
YIELD (Kg./Rai)
1,200
400
800
1500 Cu.M WATER - > 1.5 RAI (X 800 Kg.) =>
CROP YIELD = 1200 Kg.



Off-season crop statistics

off-season paddy field

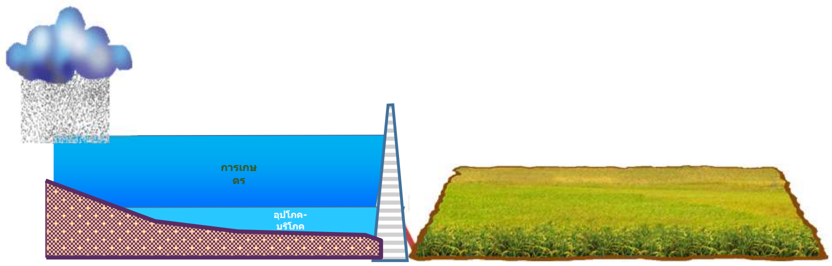
year	ปริมาตรน้ำต้นฤดู (ล้านลบ.ม.)	วันที่ เริ่มต้น	วันที่ สิ้นสุด	พื้นที่เพาะปลูก (ไร่) ตามแผน	พื้นที่เพาะปลูก (ไร่) ปลูกจริง	การใช้น้ำ (ล้านลบ.ม.) ตามแผน	การใช้น้ำ (ล้านลบ.ม.) ใช้จริง	การใช้น้ำเฉลี่ย (ลบ.ม. / ไร่)
2007	231.230	25 ม.ค. 2550	7 มิ.ย. 2550	62,082	62,082	93	51.21	824.93
2008	183.847	7 ก.พ. 2551	6 มิ.ย. 2551	36,145	36,145	54	40.81	1,128.95
2009	263.000	15 ม.ค. 2552	20 พ.ค. 2552	85,277	85,277	128	73.80	865.44
2010	208.640	14 ม.ค. 2553	18 พ.ค. 2553	73,042	73,042	110	81.39	1,114.32
2011	242.840	13 ม.ค. 2554	24 พ.ค. 2554	78,092	78,092	117	103.69	1,327.73
2012	280.440	5 ม.ค. 2555	4 พ.ค. 2555	91,572	91,572	137	136.92	1,495.18
2013	-	-	-	-	-	-	-	

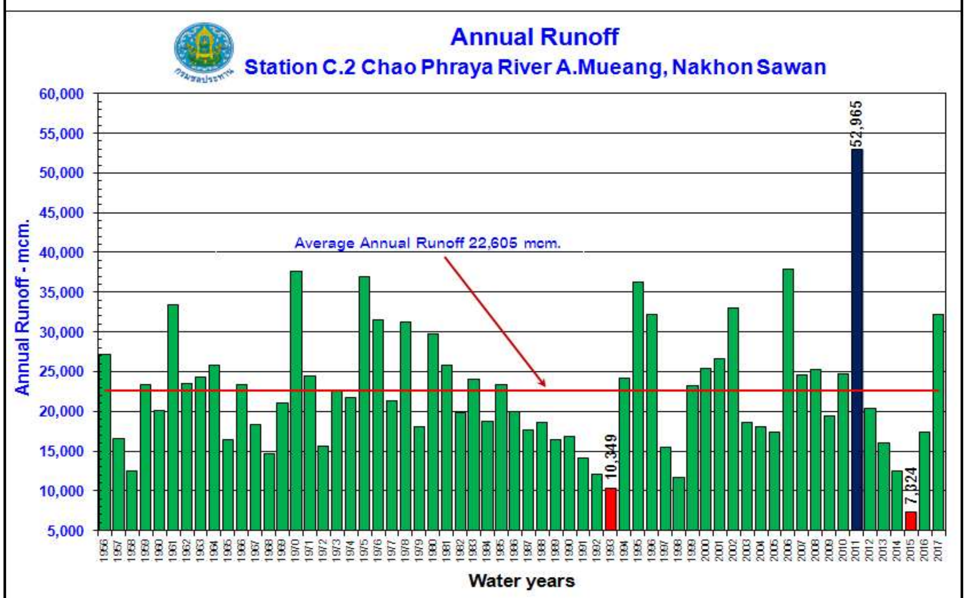
Plan to use water 1,500 m^3 / Rai

Average actual water usage 1,135 m^3 / Rai

CASE 2 RESERVOIR CAPACITY LESS THAN AVERAGE ANNUAL INFLOW

- Flood monitoring





Types of Floods in Chaopraya Basin Thailand

Types of Flood in **Chaopraya Basin**

1 Overbank flow inundation

2 Flash flood

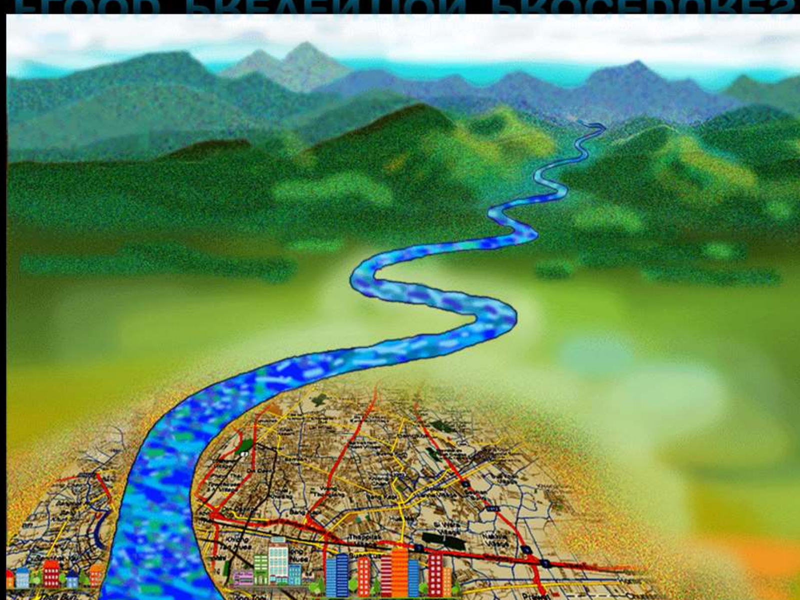
How ?

To Reduce Flood

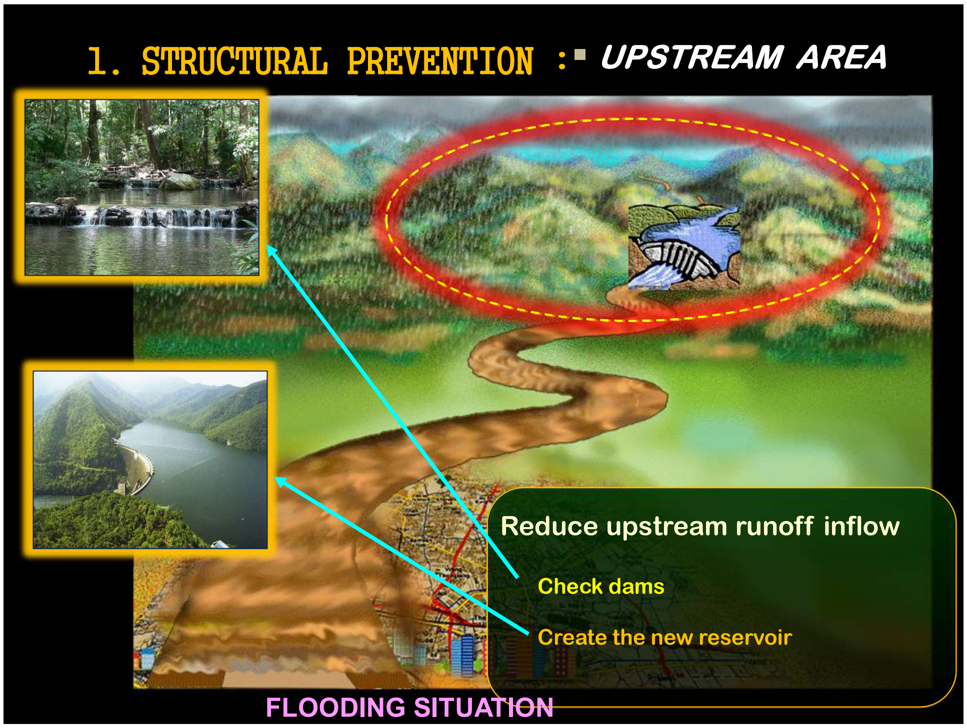
FLOOD PREVENTION PROCEDURES

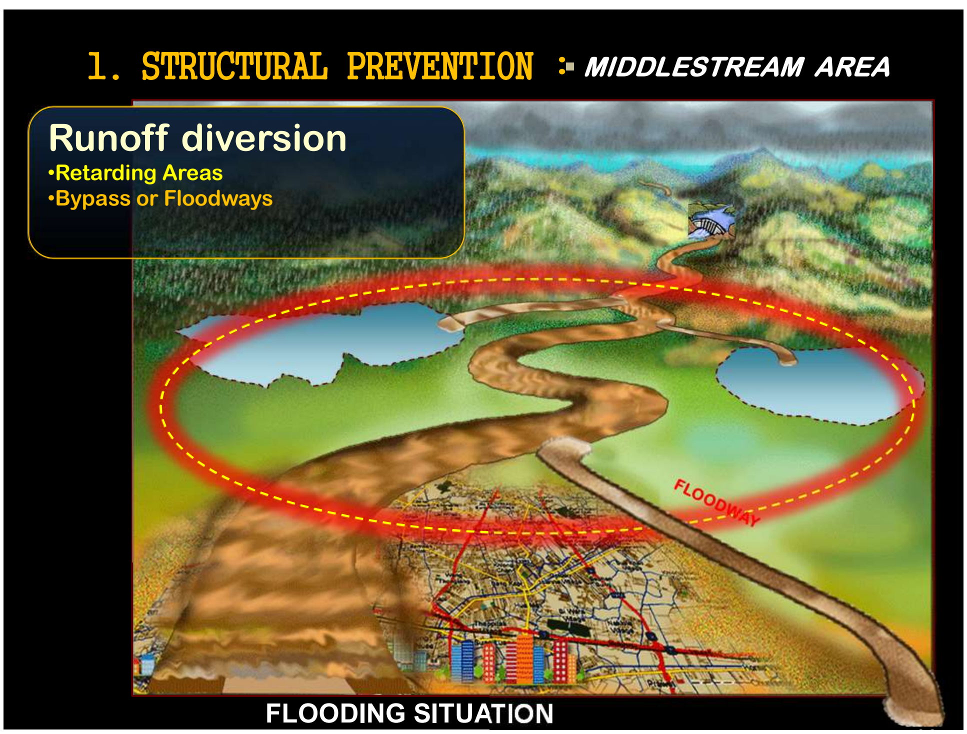
1. STRUCTURAL PREVENTION
   - Dams, reservoirs and retarding areas.
   - Bypass, floodway.
   - Dredging or enlarging channels.
   - River embankment, levee .
2. NON-STRUCTURAL PREVENTION
   - WATER MANGEMENT
   - FLOOD MONITORING AND WARNING

FLOOD PREVENTION PROCEDURES



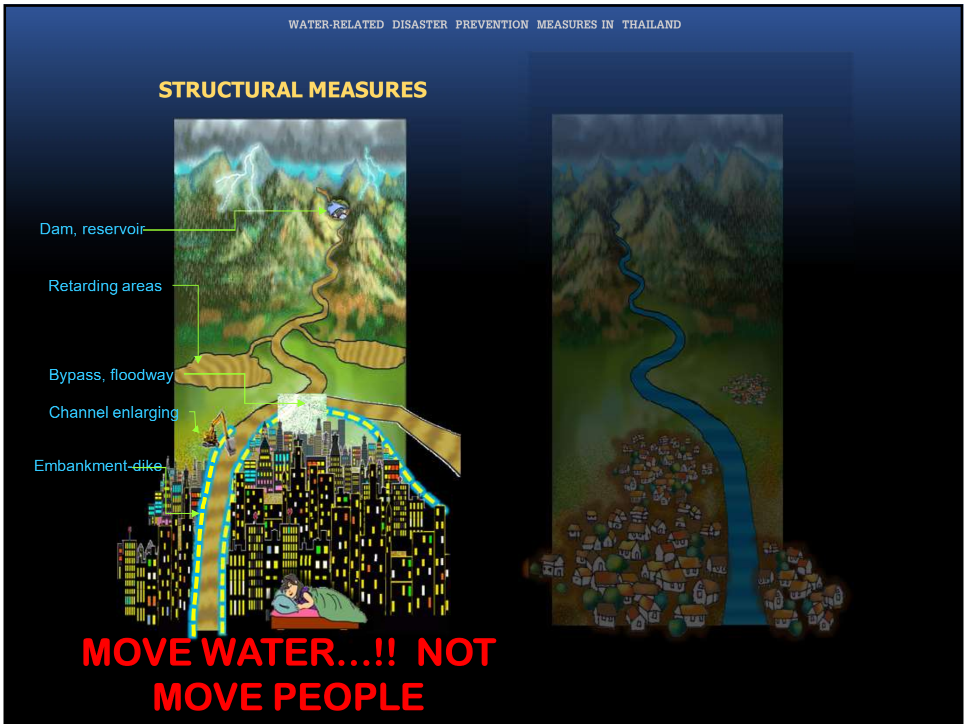
NORMAL SITUATION

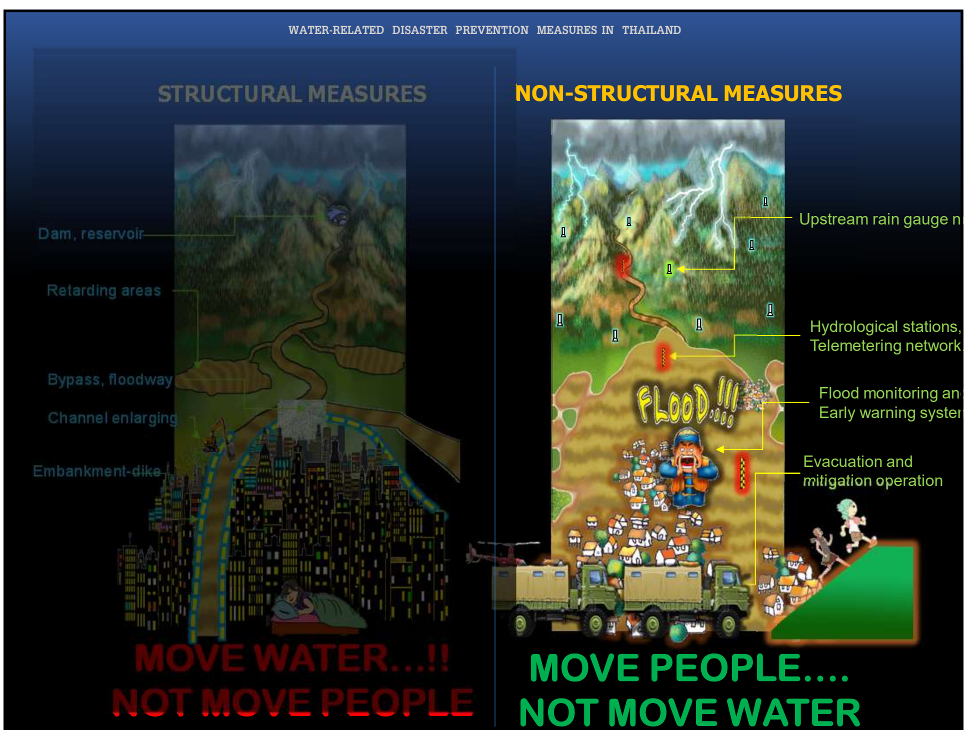

1. STRUCTURAL PREVENTION : UPSTREAM AREA
Reduce upstream runoff inflow
Check dams
Create the new reservoir
FLOODING SITUATION

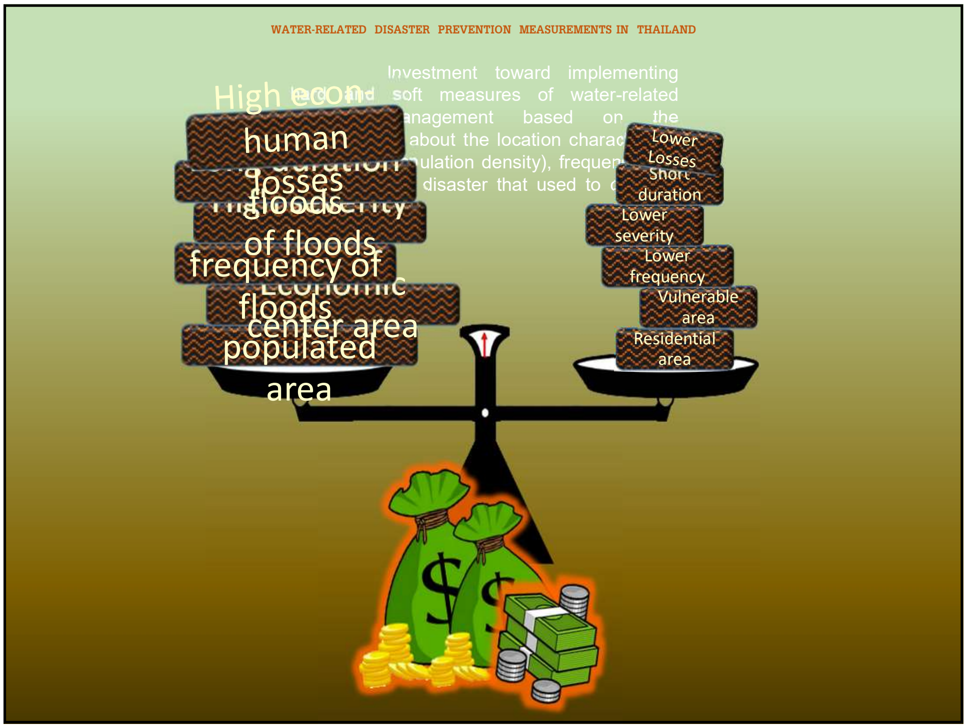

1. STRUCTURAL PREVENTION : MIDDLESTREAM AREA
Runoff diversion
•Retarding Areas
•Bypass or Floodways
FLOODWAY
FLOODING SITUATION

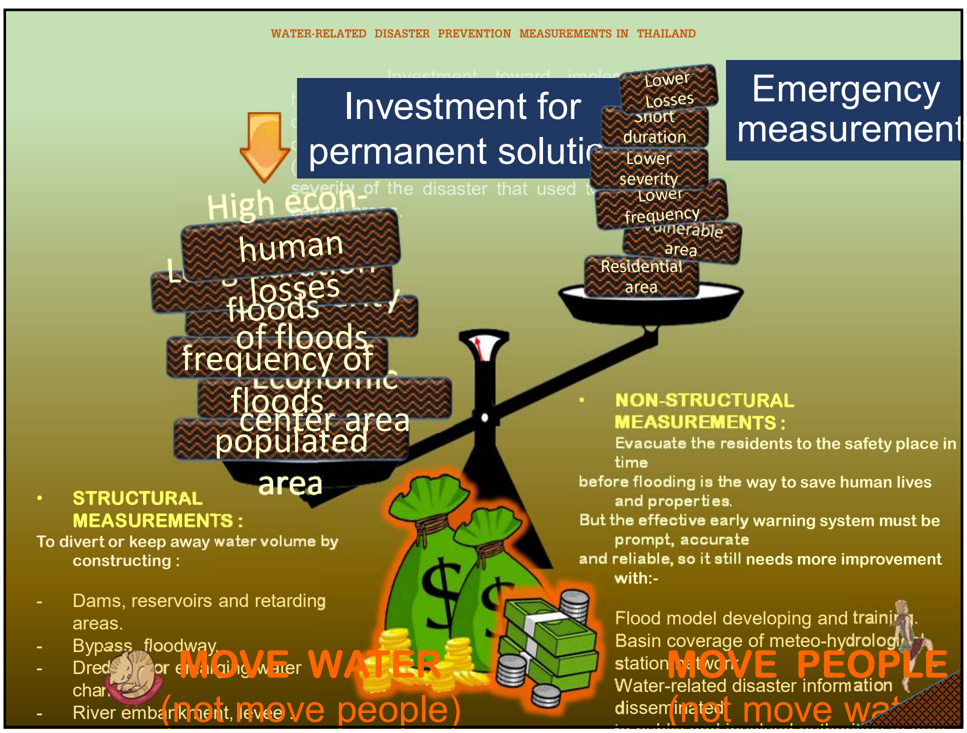

1. STRUCTURAL PREVENTION : ▪ DOWNSTREAM AREA
Specific vulnerable area protection
River embankment for economic and City areas
FLOODING SITUATION


2. NON-STRUCTURAL PREVENTION : FLOOD MONITOR AND WARNING
HYDRO
FLOOD WARNING !
FLOODING SITUATION

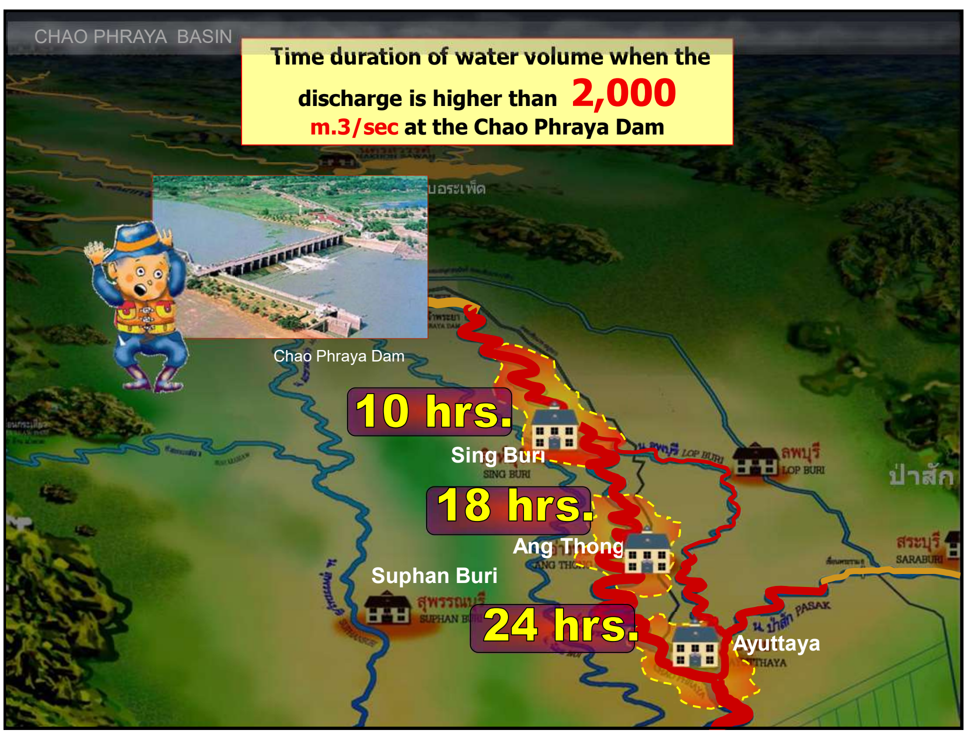

WATER-RELATED DISASTER PREVENTION MEASURES IN THAILAND
STRUCTURAL MEASURES
Dam, reservoir
Retarding areas
Bypass, floodway
Channel enlarging
Embankment-dike
MOVE WATER…!! NOT MOVE PEOPLE

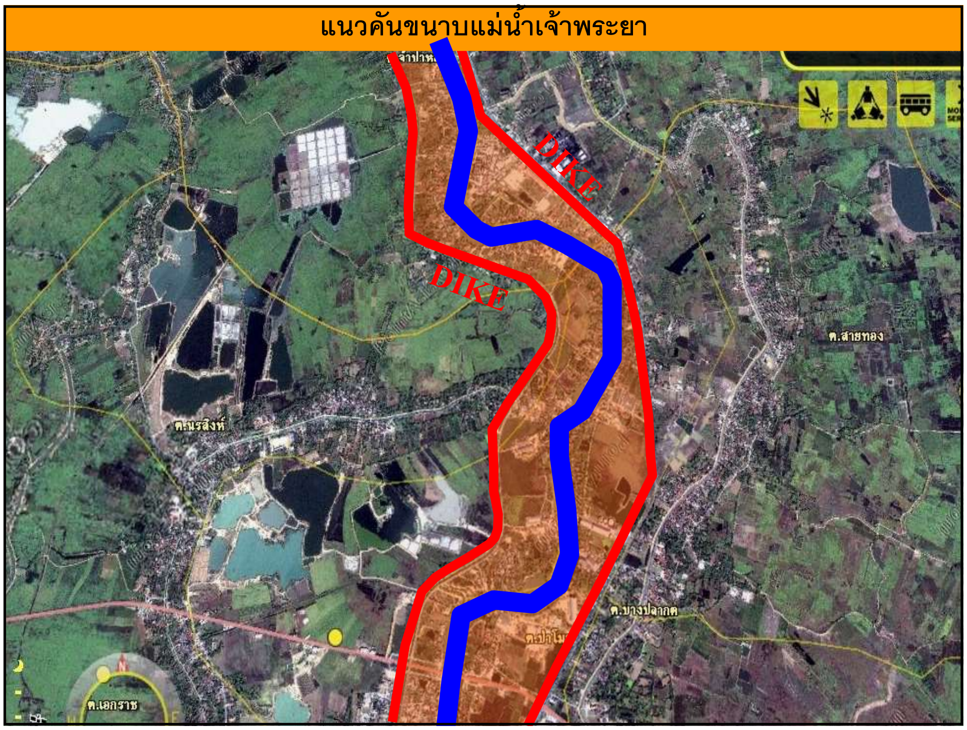

WATER-RELATED DISASTER PREVENTION MEASURES IN THAILAND
STRUCTURAL MEASURES
Dam, reservoir
Retarding areas
Bypass, floodway
Channel enlarging
Embankment-dike
MOVE WATER…!!
NOT MOVE PEOPLE
NON-STRUCTURAL MEASURES
Upstream rain gauge n
Hydrological stations,
Telemetering network
Flood monitoring an
Early warning syster
Evacuation and
mitigation operation
FLOOD!!!
MOVE PEOPLE….
NOT MOVE WATER


WATER-RELATED DISASTER PREVENTION MEASUREMENTS IN THAILAND
Investment toward implementing
soft measures of water-related
disaster that used to
human
losses
floods
of floods
frequency of
floods
center area
populated
area
Lower
Losses
Short
duration
Lower
severity
Lower
frequency
Vulnerable
area
Residential
area

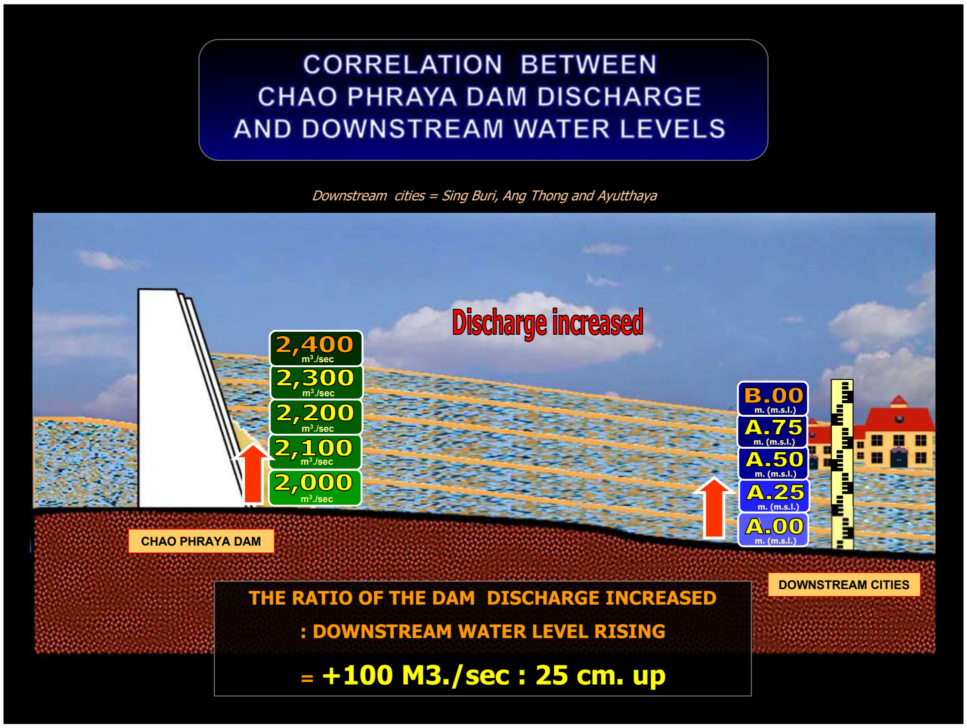

WATER-RELATED DISASTER PREVENTION MEASUREMENTS IN THAILAND
Investment for
permanent solutio
Emergency
measurement
High econ-
human
losses
floods
of floods
frequency of
floods
center area
populated
area
Lower
Losses
Short
duration
Lower
severity
Lower
frequency
Vulnerable
area
Residential
area
STRUCTURAL MEASUREMENTS :
To divert or keep away water volume by constructing :
- Dams, reservoirs and retarding areas.
- Bypass, floodway
- River embankment, levee
MOVE WATER
(not move people)
NON-STRUCTURAL MEASUREMENTS :
Evacuate the residents to the safety place in time
before flooding is the way to save human lives and properties.
But the effective early warning system must be prompt, accurate
and reliable, so it still needs more improvement with:-
Flood model developing and training.
Water-related disaster information
MOVE PEOPLE

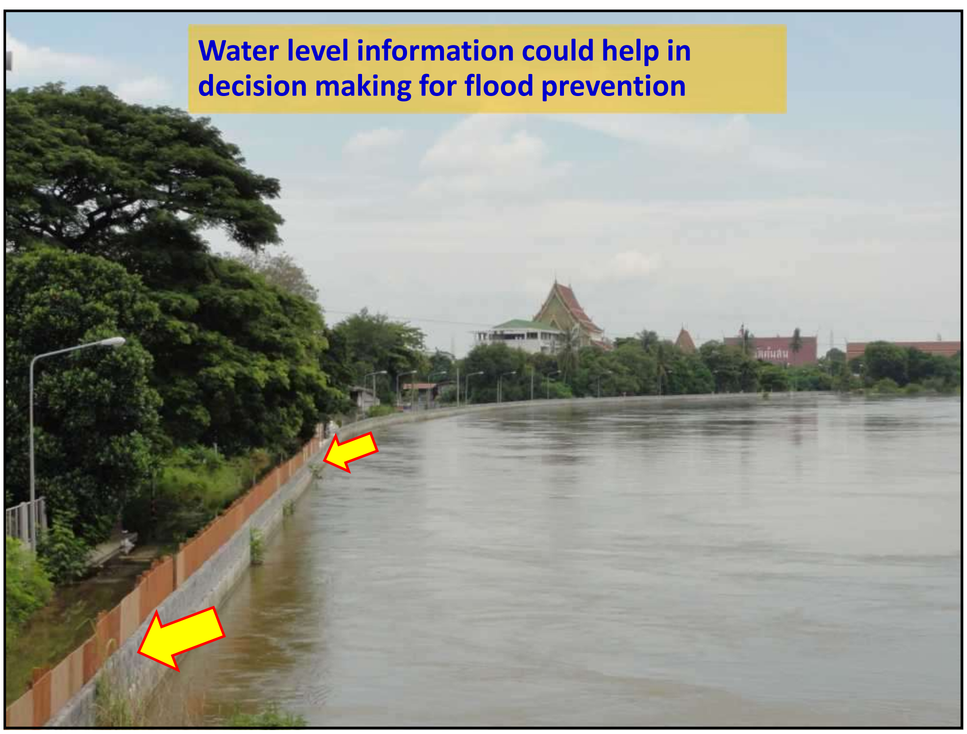

3. MODEL APPLIED TO CHAO PHRAYA BASIN
CHAO PHRAYA DAM
SAPPHAYA DISTRICT , CHAINAT

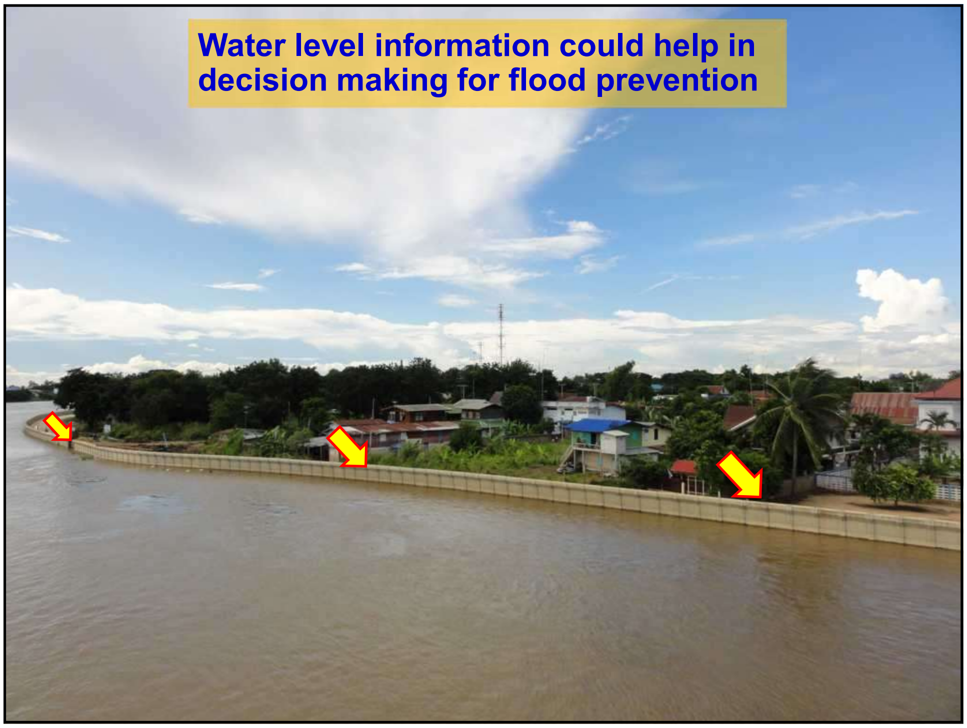

CHAO PHRAYA BASIN
Time duration of water volume when the discharge is higher than 2,000 m.3/sec at the Chao Phraya Dam
Chao Phraya Dam
10 hrs.
Sing Buri
18 hrs.
Ang Thong
Suphan Buri
24 hrs.
Ayuttaya
ลพบุรี
LOP BURI
ป่าสัก
สระบุรี
SARABURI
สุพรรณบุรี

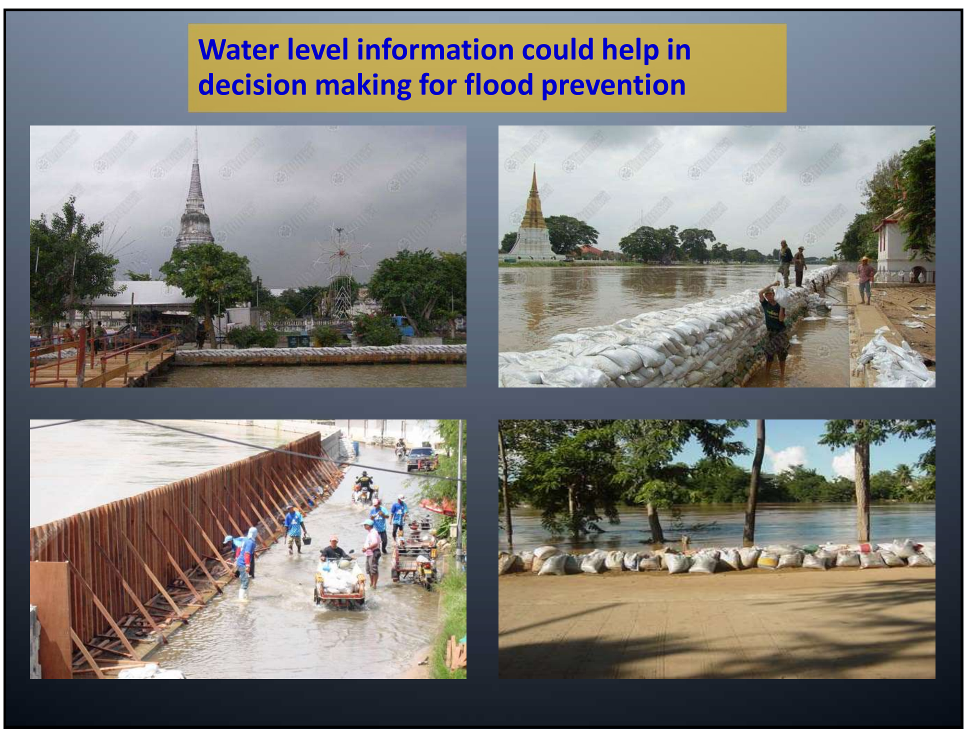

แนวคันขนาบแม่น้ำเจ้าพระยา
DIKE
DIKE

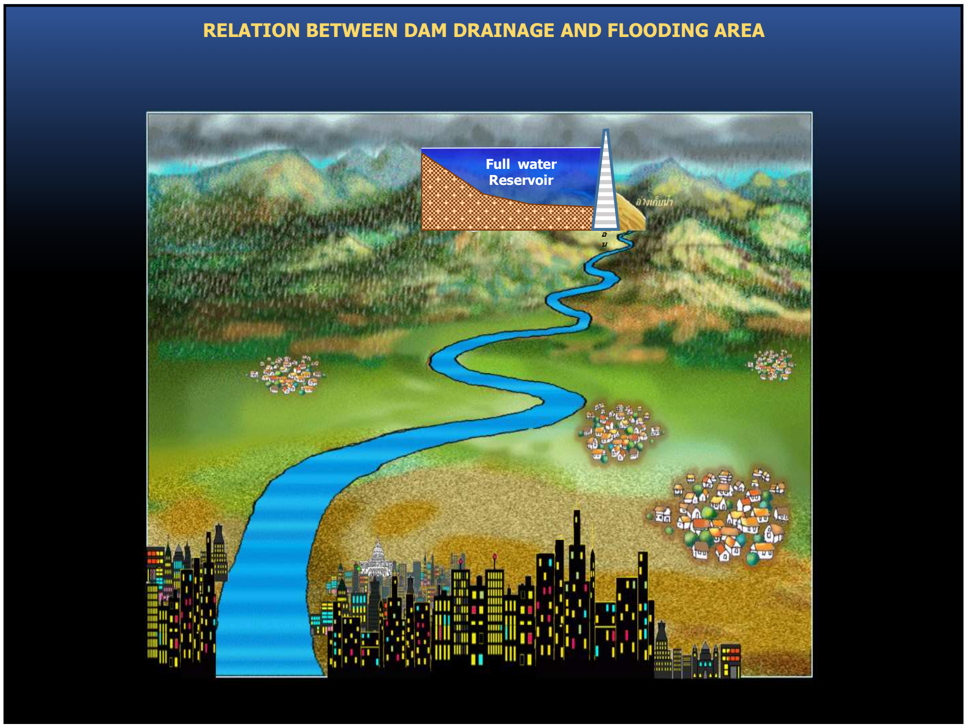

Irrigation area
DIKE
River bank
Chaopraya river

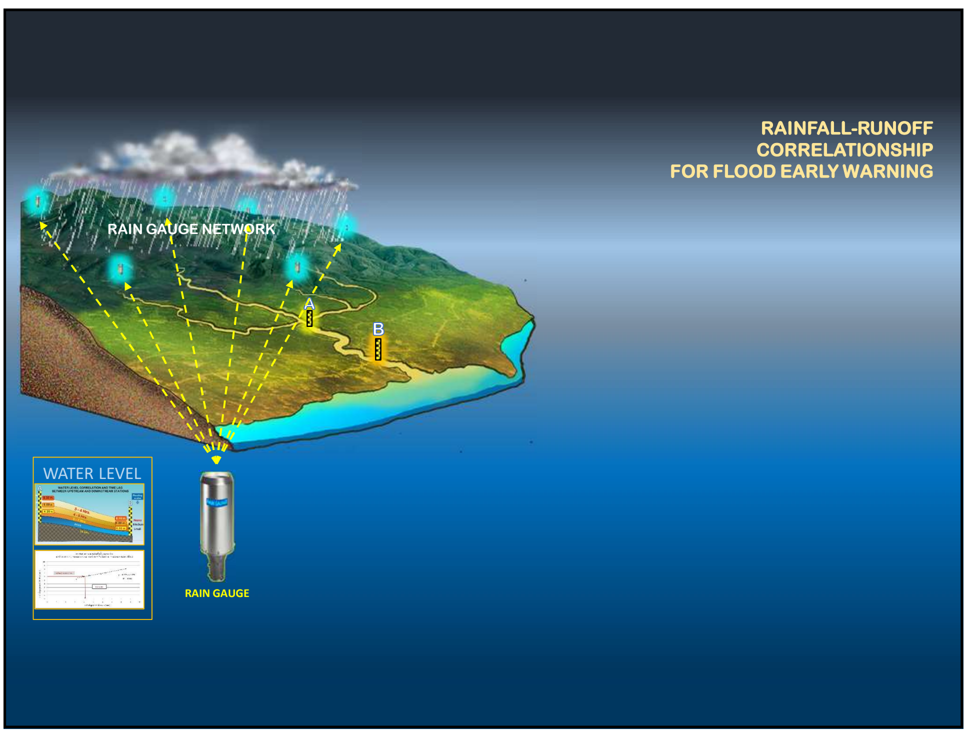

CORRELATION BETWEEN
CHAO PHRAYA DAM DISCHARGE
AND DOWNSTREAM WATER LEVELS
Downstream cities = Sing Buri, Ang Thong and Ayutthaya
Discharge increased
2,400 m³./sec
2,300 m³./sec
2,200 m³./sec
2,100 m³./sec
2,000 m³./sec
B.00 m. (m.s.l.)
A.75 m. (m.s.l.)
A.50 m. (m.s.l.)
A.25 m. (m.s.l.)
A.00 m. (m.s.l.)
CHAO PHRAYA DAM
DOWNSTREAM CITIES
THE RATIO OF THE DAM DISCHARGE INCREASED
: DOWNSTREAM WATER LEVEL RISING
= +100 M3./sec : 25 cm. up

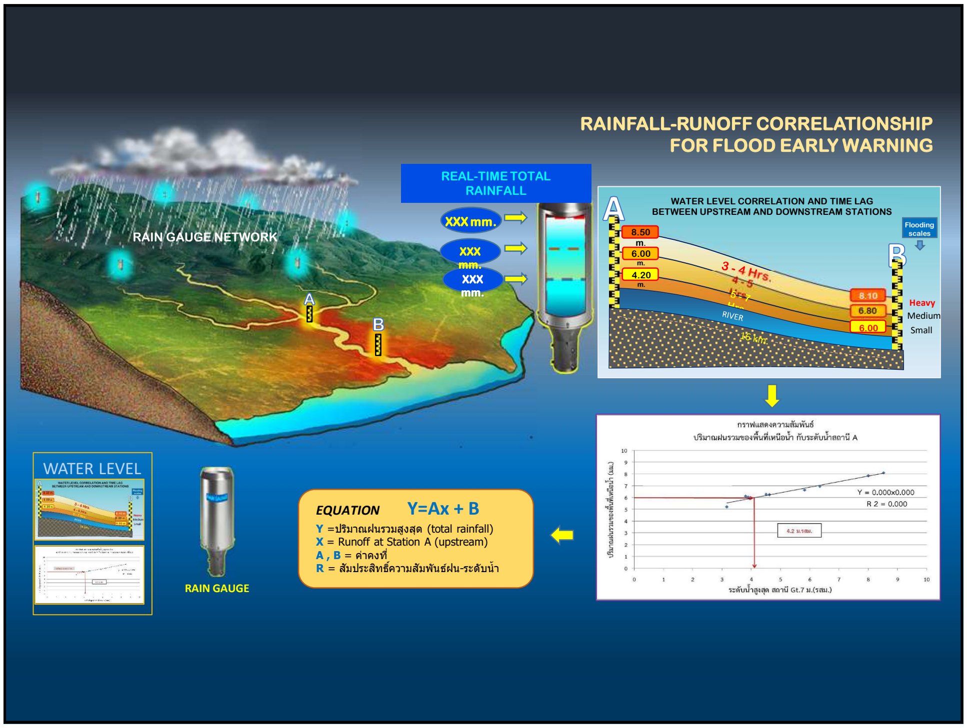

Water level information could help in
decision making for flood prevention


Water level information could help in
decision making for flood prevention


Water level information could help in
decision making for flood prevention


RELATION BETWEEN DAM DRAINAGE AND FLOODING AREA
Full water
Reservoir

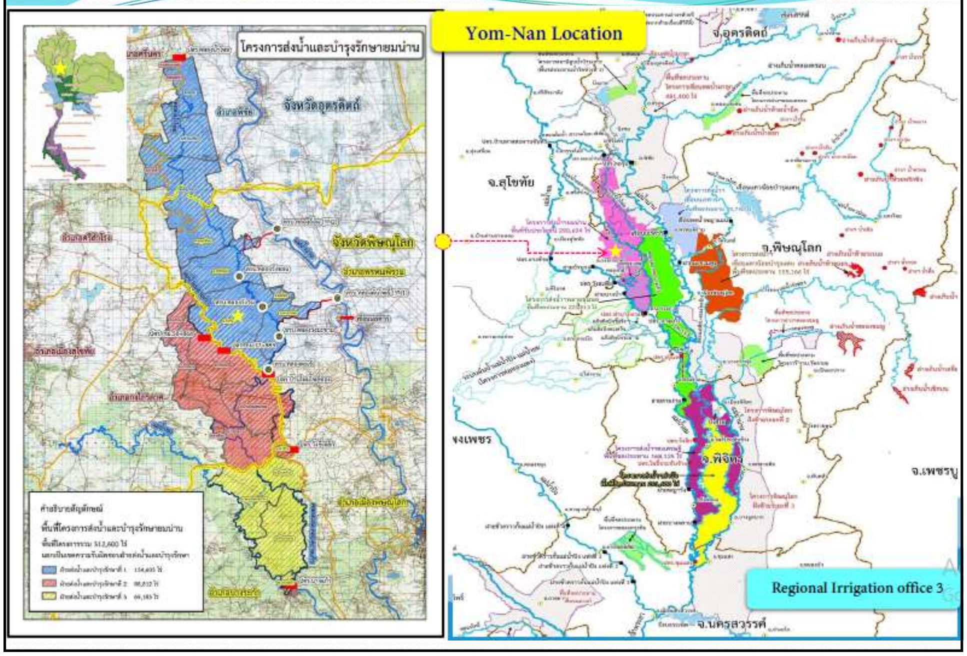

RAINFALL-RUNOFF
CORRELATIONSHIP
FOR FLOOD EARLY WARNING
RAIN GAUGE NETWORK
A
B
WATER LEVEL
RAIN GAUGE



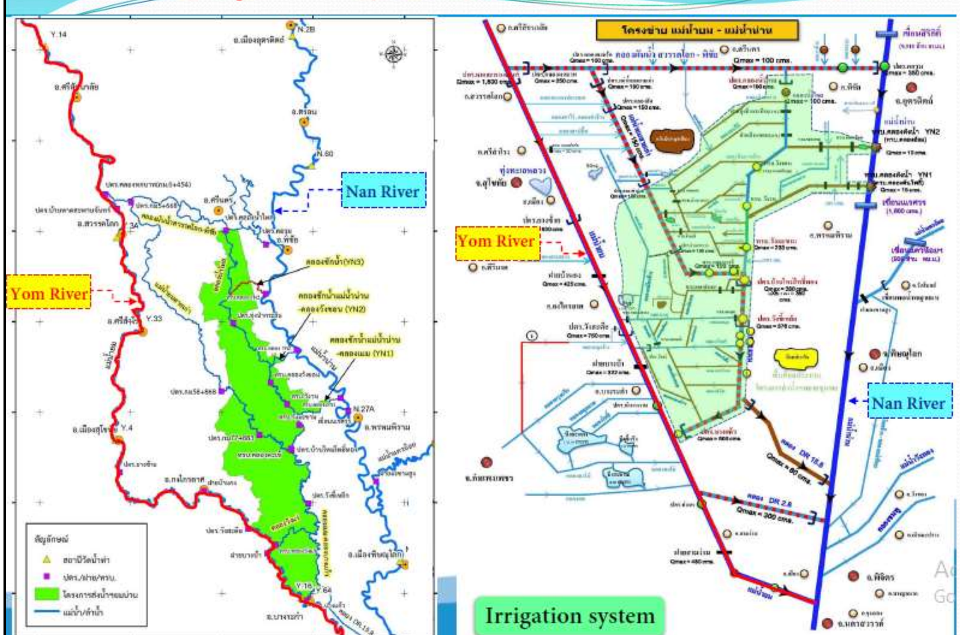
BEST PRACTICE WATER MANAGEMENT

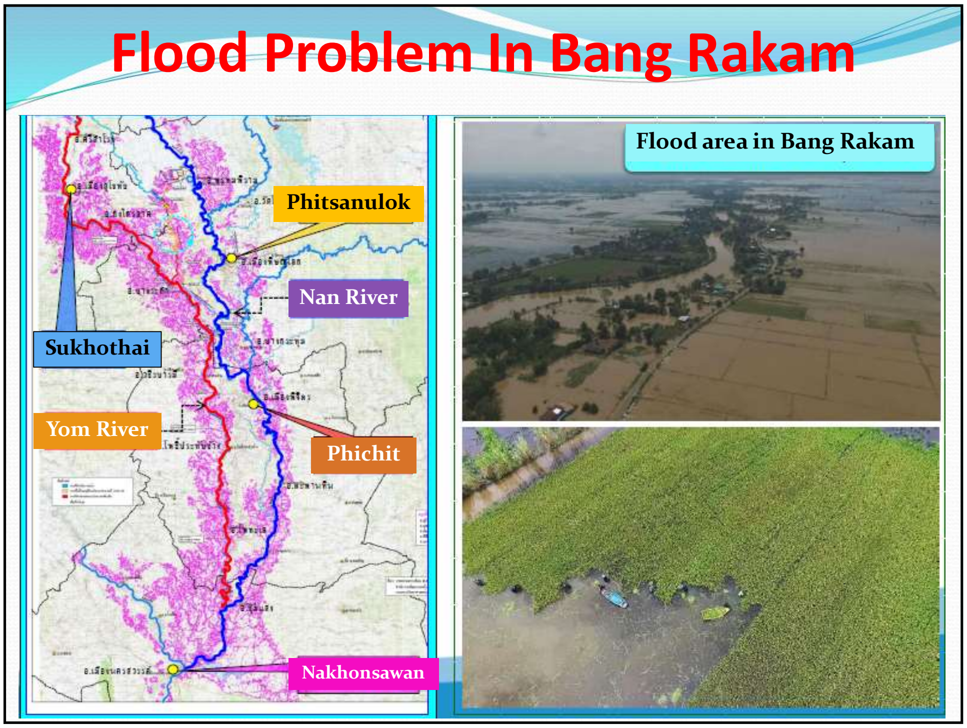
Case 1 : Bang Rakam Model

YOM – NAN Project



Irrigation system at Yom – Nan Project

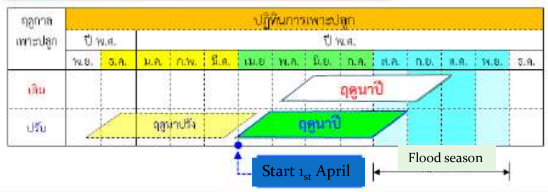



Flood Problem In Bang Rakam
Phitsanulok
Nan River
Sukhothai
Yom River
Phichit
Nakhonsawan
Flood area in Bang Rakam


Water Management in rainy season
การบริหารจัดการน้ำ
“ ฤดูฝน ”
แม่น้ำน่าน
แม่น้ำยม
ปตร.คอรุม
อ.ศรีสำโรง
อ.เมืองสุโขทัย
อ.กงไกรลาศ
อ.วัดโบสถ์
อ.พรหมพิราม
อ.เมืองพิษณุโลก
อ.บางระกำ
ปตร.บางแก้ว
ปตร.DR.2.8

2 principles for water management in Bang Rakam model

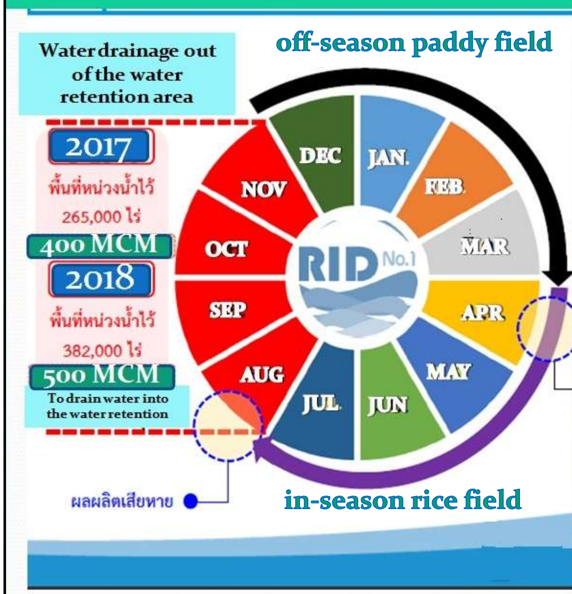
1 Adjust the planting calendar



2 Using rice fields harvested to support detention storage area

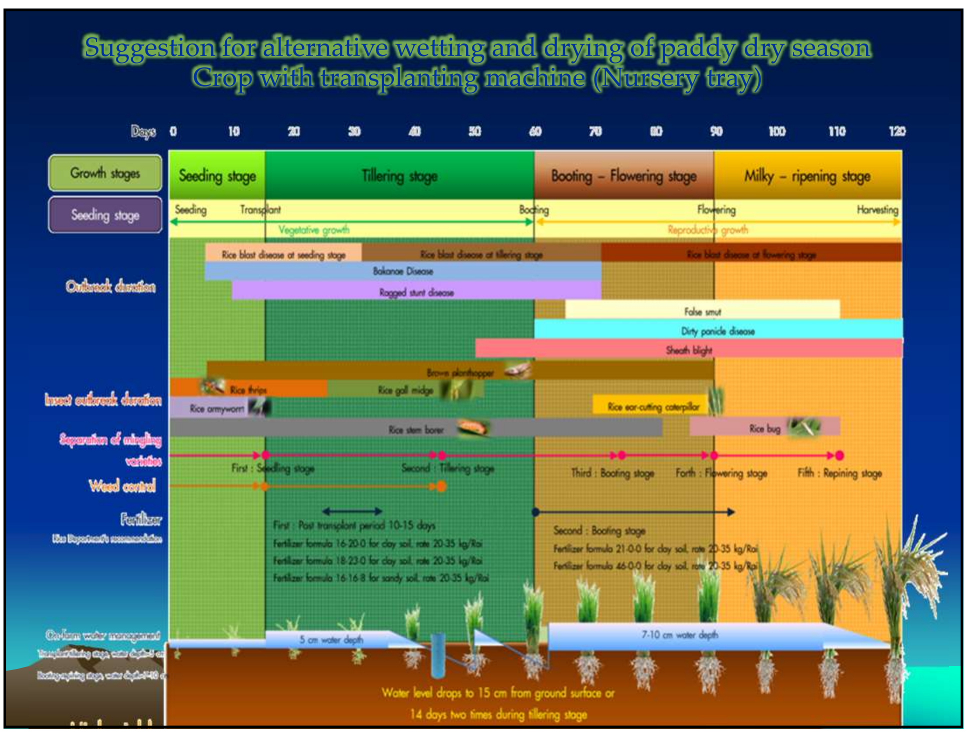
หลักการ 2 ข้อ

Water Management Plan of Bang Rakam Field

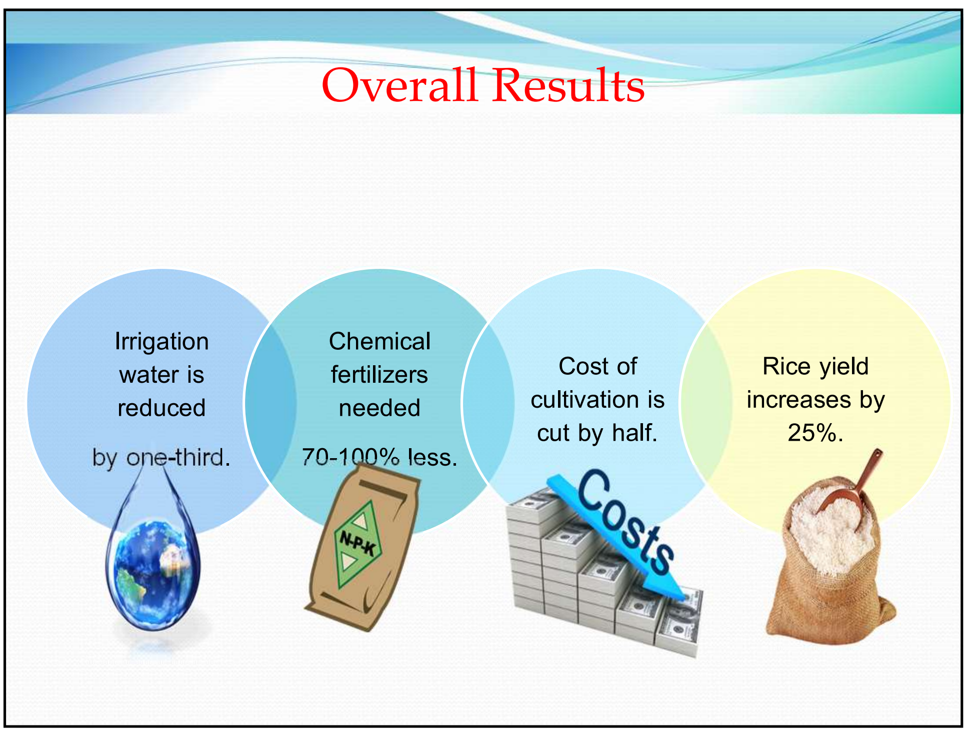


- The beginning of in-season rice farming season 20-31 March 2017 : To distribute water into water allocation system for farmers in order to start the cultivation on 1 April 2017
- Control and prevention of agricultural area10 May – 15 August 2017 : To manage water and prevent flood in order to avert impacts and farmers can harvest crops before rainy season.
- To drain water into the water retention field 15 August – 31 October 2017 : To prepare for retention areas for flooding from Yom and Nan River Basins and other sub-river basin as well as abundant rain volume served as temporary natural water retention areas and water can be retarded at the 400 million cubic meters. of maximum level.
- Water drainage out of the water retention area 1-25 November 2017 : To drain water out of the water retention area to start the off-season rice farming season of farmers under the cropping calendar of Royal Irrigation Department.

BEST PRACTICE WATER MANAGEMENT
Case 2 : alternative wetting and drying of paddy dry season Crop




Rice quality
Profit+ cumulated capital
Yield
Quality of life
Unity of community
5 increases
and
reduces 5
Water
Seed
Labor
Chemical fertilizer
Chemical substance


Overall Results
Irrigation water is reduced by one-third.
Chemical fertilizers needed 70-100% less.
Cost of cultivation is cut by half.
Rice yield increases by 25%.
N-P-K
Costs

Future Extension

- Thailand has the irrigable area using 12,500 million cubic meter of irrigation on water. In case the Integrated Smart Farming – AWDI technique is applied throughout the economy, irrigation water could be saved in dry season by 33% or more than 4,100 million cubic meter

saved in dry season

33%

or

4,100 Million cubic meter

Future Extension [2]

- According to the United Nations Framework Convention on Climate Change "Conference of Parties No.21" to which 196 economies including Thailand are signatories, there is an international commitment of keeping global warming below a 2°C increase. Consequently Thailand has to achieve 20% Greenhouse Gas Emissions (GHGs) reduction by the year 2030. The Integrated Smart Farming - AWDI technique can reduces GHGs and therefore might be a major factor to Thailand to fulfill its legal obligations. More important, perhaps this technique has proven itself to significantly contribute to making the world a healthier and more sustainable resource for future generations.

2%

Greenhouse Gas Emissions (GHGs)

healthier and sustainable resource for

future generations

Thank you so much for your Attention

Royal Irrigation Department

Thailand

CONTENT

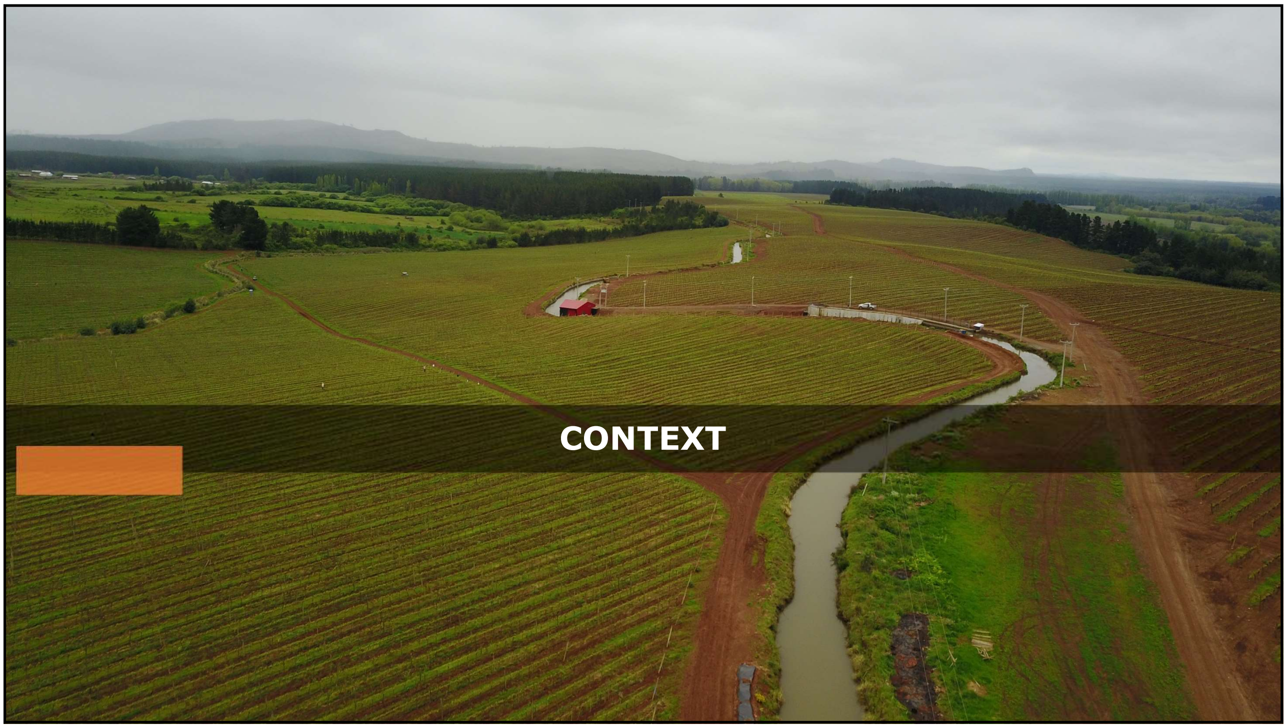
Tips:

a) Some units

1 GW: 1 Giga Watts = 1000 MW
1 MW: 1 Mega Watts= 1000 kW
1 kW: 1 kilo Watts = 1000 W

a) 1 hectares = 1 kW app.

b) 1 house = 4 to 10 kW



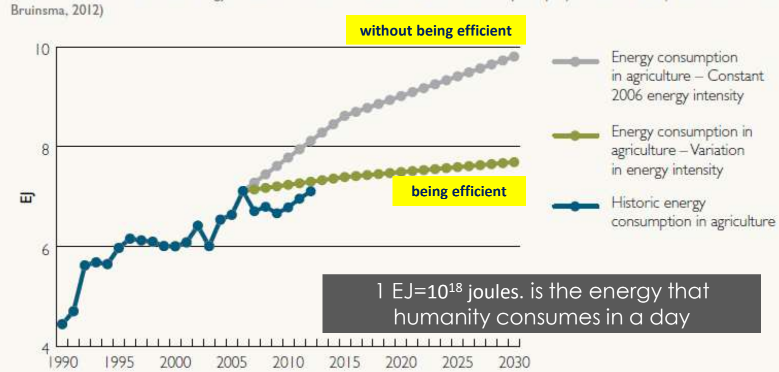
CONTEXT

CONTEXT: Energy and Agriculture

- Agriculture consumes 2% of the world's energy.
- The main energy sources in agriculture are: Electric power and fossil fuels.
- Agriculture depends on fossil fuels.

FIGURE 2.5. Energy consumption in agriculture, forestry and fisheries: actual data to 2012 and projections to 2030.

Source: Data based on UNSD Energy Statistics Database 2015 and FAO Food Consumption projections to 2030 (Alexandratos and Bruinsma, 2012)



1 EJ=10^{18} joules. is the energy that humanity consumes in a day

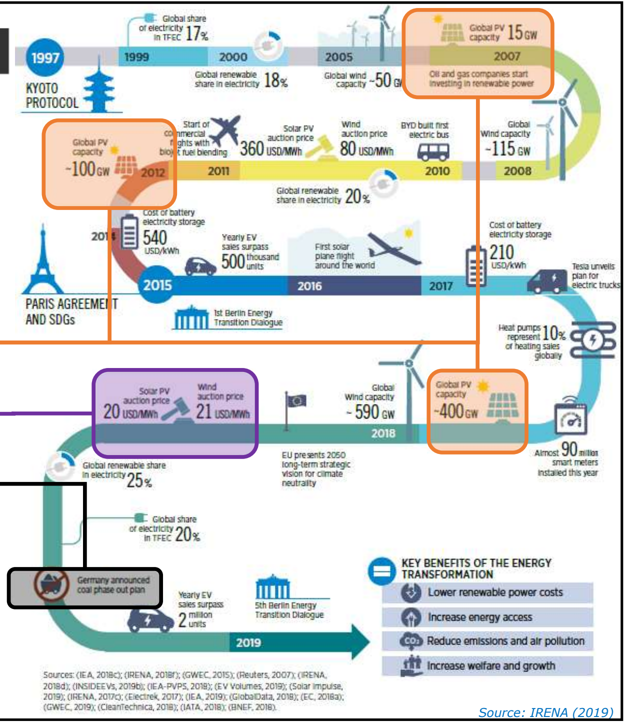
- More food means more water and energy consumption. These are closely linked.
- Reducing water consumption with the technification of irrigation has implied greater energy consumption in agriculture.
- Decrease the dependence of agriculture on fossil fuels.

Source: IEA, USDA, Servicio de información de energía, Servicio de Investigación Económica, Servicio Nacional de Estadísticas de USA año 2014 y Miranowski (2006)

CONTEXT: Energy Transformation

Last 20 years

- Lower cost for renewable energies.
- Greater access to energy.
- Energy distribution.
- Reduction of emissions and greenhouse gases.
- Greater well-being and quality of life.



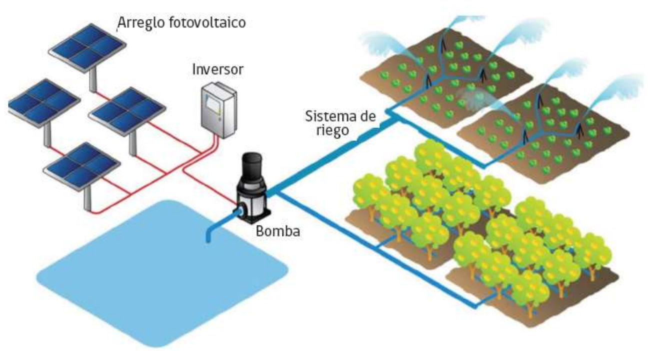
- **Increase in Renewable Energies**
- **Price of the energy to the low.**
- **Decarbonization**

Renewable energies reduce carbon and water footprint.

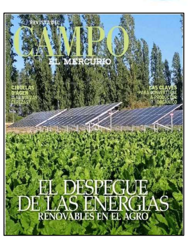
APEC CHILE 2019

Source: IRENA (2019)

CONTEXT: Renewable Energies



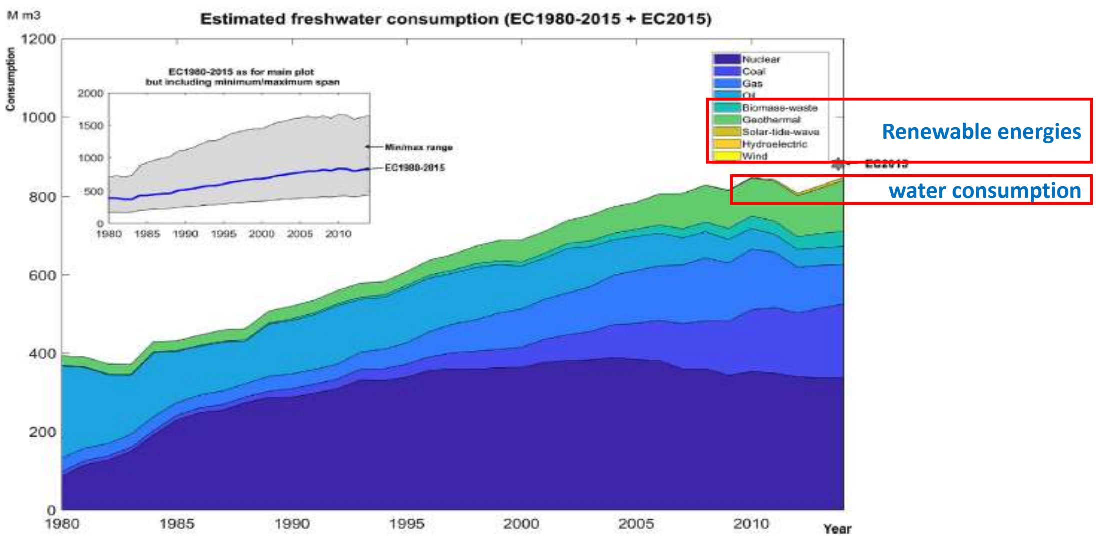
- **Improve competitiveness**
- **More resilient productive systems to the market variations.**
- **Achieve self-consumption, decentralization of Energy (DoE)**
- **Reduce electricity costs.**
- **Decrease the dependence on fossil fuels.**
- **Do not consume the water resource.**
- **Improvement in quality of life**



APEC CHILE 2019

Source: Projects in Chile, years 2018-2019

CONTEXT: Renewable against conventional water consumption



Source: Water use in electricity generation for water-energy nexus analyses: The European case (Morten Andreas Dahl Larsen, Martiun Drews, October 2018).

APEC CHILE 2019

CONTEXT: Renewable Energy

It must be:
- Accessible
- Affordable
- Simple

Photovoltaic systems.

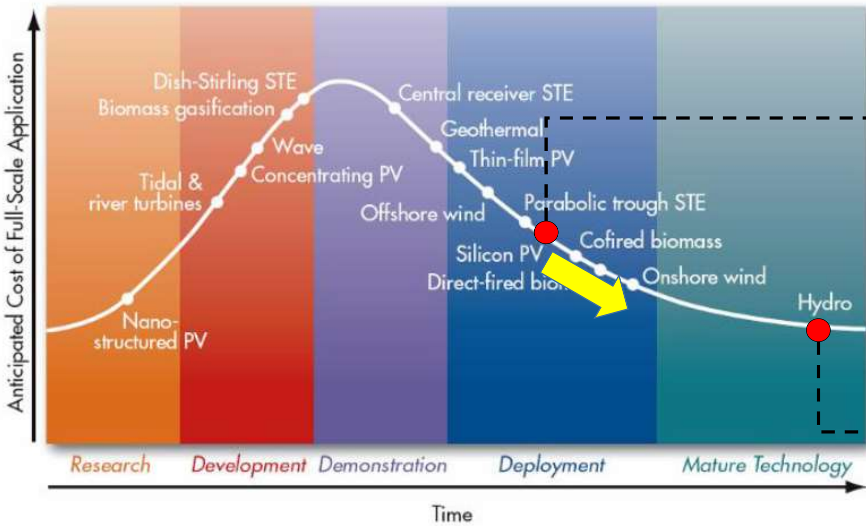
- With great potential in Chile throughout the national territory.
- Its versatility allows it to be installed on land, water and roofs.

Small hydroelectric plants (under 300 kW of capacity)

- Great potential in irrigation channels in Chile.
- Today's technology allows to use small water falls existing in the network of channels.

APEC CHILE 2019

CONTEXT: Renewable Energy on irrigation projects



Photovoltaic Systems.

Unit investment cost: >800 USD/MW

Water consumption: 4 L/MWh
For cleaning the panels

Small Hydroelectric
(under 300 kW of capacity)

Unit investment cost: >3500 USD/MW

Water consumption: 0 L/MWh

Source: Renewables: a promising coalition of Many - EPRI

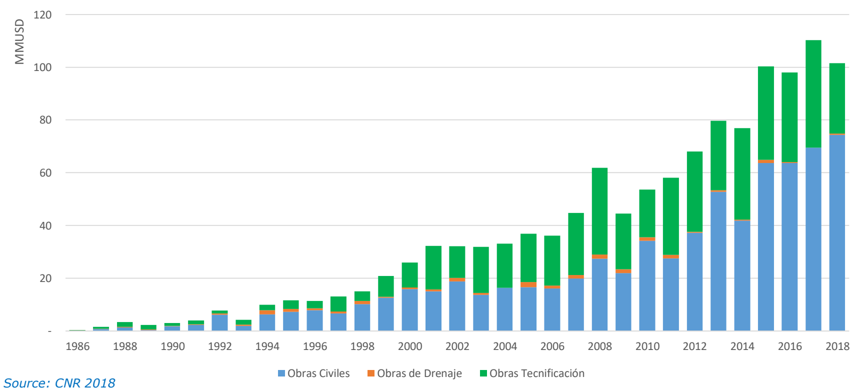
9

10

National Commission of Irrigation

MAIN OBJECTIVE: Increase and develop irrigation hectares in Chile.

Role Planner of the policies and an instrument of promotion to the efficient irrigation (Law N° 18,450).



Source: CNR 2018

Increase the irrigated and drained area of the economy.

- Increase water security.
- Increase the distribution, conduction and application of water.

Increase the competitiveness of agricultural activities.

- Improve crop production and productivity.
- Raise the income and quality of life of farmers.

11

National Commission of Irrigation

- The farmer or the organization postulates the project.
- The bonus is given by prioritizing those that have the best score according to the variables established by law.
- The private builds the project.
- When it is received by a professional who inspect the project and the investments have been credited, the State reimburses the subsidy.

Contest Results of Law Nº 18,450

- USD 1.200 millions
- 600.000 beneficiaries
- 26.000 projects
- 336.000 technified hectares

1985 - 2018

APEC CHILE 2019

12

13

PROJECTS

CO-financed projects
770 projects / 6,05 MW

PHOTOVOLTAIC SYSTEMS
756 projects / 5,6 MW

- On-grid: 373 projects, 4407 kW
- On-grid without injection: 26 projects, 41,29 kW
- Off-grid: 343 projects, 1190 kW
- No information: 14 projects, 14,81 kW

Small-Hydropower
14 projects / 0,45 MW

- On-grid: **11 proyectos**, **257,7 kW**
- Off-grid: 2 projects, 41,8 kW
- PMGD: 1 projects, 148 kW

Solar Energy per year:
7.358 MWh
4 thousand houses

Hydro Energy per year:
1.774 MWh
1 thousand houses

14

PROJECTS – DoE

The capacity of Chile is:
24.000 MW
18 million people

Decentralization of energy (DoE):
24 MW on Chile

Contribution to DoE:

RE capacity on agriculture
6 MW

25% of DoE

Whats is DoE?

Is a strategic guideline of Chile to promote self-production of energy based on renewables for the residential, public and commercial sectors.

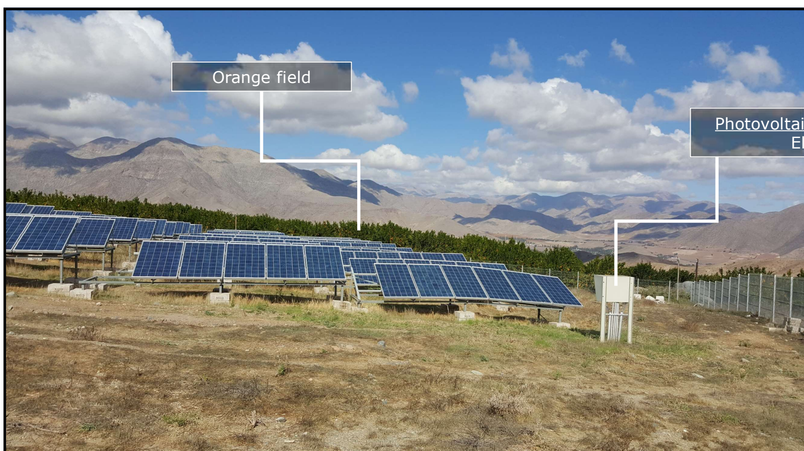
Only available for renewable energies whose installed capacity does not exceed 300 kW.

DoE Benefits:

- Most reliable and safe electrical systems.
- Better quality of service of the electric network.
- Lower production costs.
- Greater access to energy.

APEC CHILE 2019

15



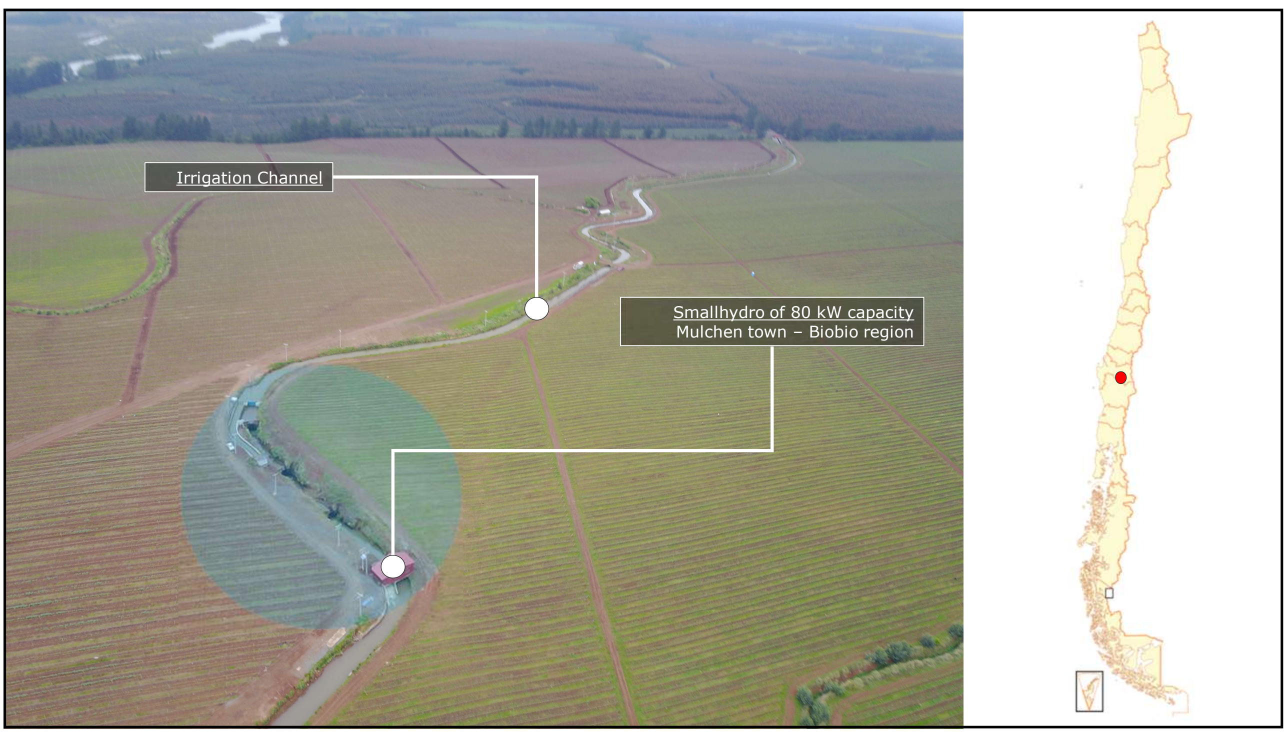
Invesment cost: 272.000 USD

PV capacity: 104 kWp

101 hectares of irrigation Surface

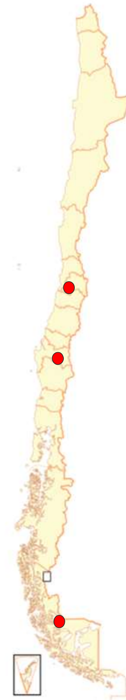
16


Pump station for
irrigation channel
Photovoltaic system of 100 kW capacity
Chimbarongo Town – O'Higgins region
Invesment cost: 329.000 USD
PV capacity: 100 kWp
500 l/second
APEC
CHILE 2019


Irrigation Channel
Smallhydro of 80 kW capacity
Mulchen town – Biobio region


Smallhydro of 12 kW capacity
San Vicente de Tagua Tagua Town -
O´Higgins region
Irrigation Channel
Invesment cost: 262.000 USD
Hydro capacity: 12 kW

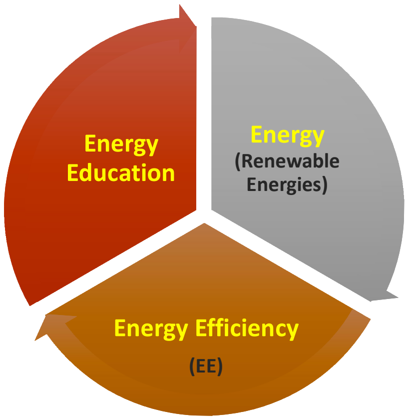

Irrigation Channel
Smallhydro of 150 kW capacity
Pelarco Town - Maule region
Invesment cost: 680.000 USD
Hydro capacity: 150 kW
PEC
CHILE 2019



APEC CHILE 2019

LINES OF WORK

LINES OF WORK



1. DIFFUSION
2. TRAINING
3. INFORMATION
4. DIRECT SUPPORT TO FARMERS
5. GOOD PRACTICES

APEC CHILE 2019

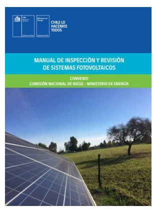
LINES OF WORK

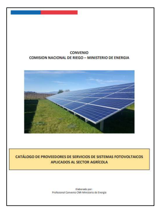
2. DIFFUSION and TRAINING

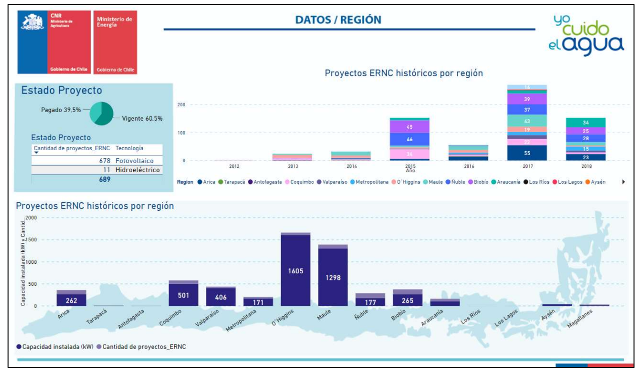
LINES OF WORK

2 • **INFORMATION**

Microhydro on irrigation projects Manual	Microhydro market characterization	Microhydro suppliers in Chile Catalog
Inspection and Review of SFV Manual	Photovoltaic suppliers in Chile Catalog	Good and Bad Practices in SFV in irrigation Guide







Available on the CNR website: http://www.cnr.gob.cl
Target audiences: Professionals, Irrigation consultants and Institutions

FINAL COMMENTS

FINAL COMMENTS

The CNR and the subsidization of irrigation projects with SFV (Law 18,450), allows to modernize and increase the agricultural competitiveness of the economy by allowing the bonus of projects with renewable energies.

Regarding of chilean farmers and its relationship with the renewables energies on agricultural application, this has had a process of assimilation and later development regarding photovoltaic parks in the energy market.

The above is due to several reasons: New technology in irrigation, Barriers, Maturation and costs.

In spite of the above, since 2012 they have been incorporated into the collective and the knowledge of farmers / irrigation consultants, resulting in a more intensive development of projects in recent years. In 2018, 171 projects were subsidized, which is equivalent to 24% of the total projects funded by the CNR.

- To date, it has achieved a bonus of 756 irrigation projects with renewable energies.
- With photovoltaic (SFV) and hydroelectric systems for over $ 20 billion in investment (MMUSD 31) and a bonus of over $ 15,700 million (MMUSD 23).
- Regarding the irrigation projects with SFV, these have installed powers vary between 0.5 to 300 kW throughout the national territory.

APEC CHILE 2019

www.cnr.gob.cl

isigenere

PIONEERS IN

FLOATING SOLAR SYSTEMS

SINCE 2008

isifloating
FLOATING SOLAR SYSTEM

Our Mission

To **preserve the world** by using existing water bodies in our planet to generate renewable **solar energy** in a more efficient way, while at the same time **protecting** scarce **water** and precious **land**.

isifloating
FLOATING SOLAR SYSTEM

FLOATING SOLAR SYSTEMS
A GREAT OPPORTUNITY
10 YEARS OF CONSTANT EVOLUTION

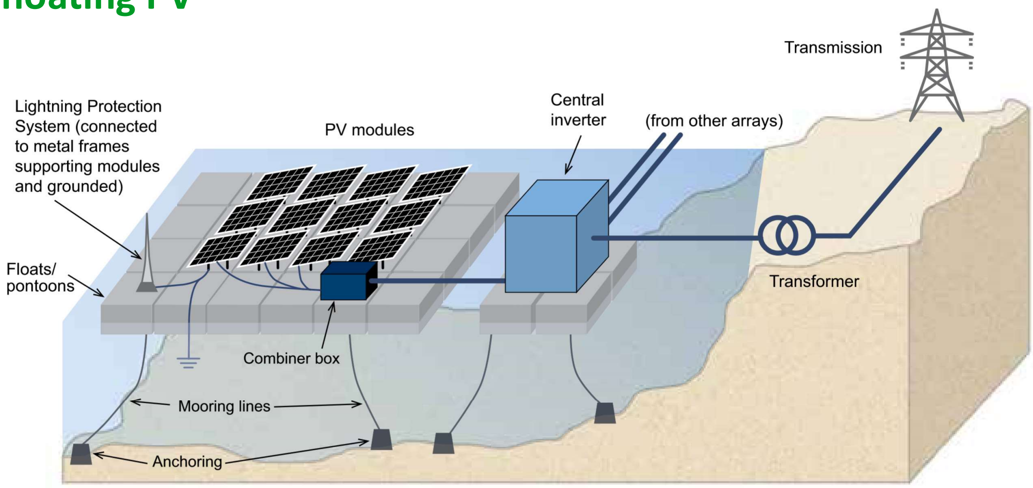
FIRST INSTALLATION
AGOST, SPAIN 2009

isifloating
FLOATING SOLAR SYSTEM

What is a floating Solar power plant?

isifloating FLOATING SOLAR SYSTEM

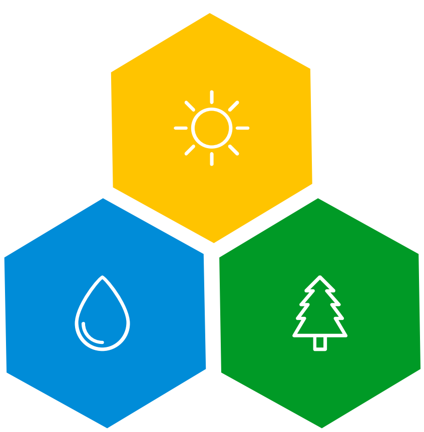
Schematic representation of a typical large-scale floating PV



Source: Solar Energy Research Institute of Singapore (SERIS) at the National University of Singapore (NUS).

isifloating FLOATING SOLAR SYSTEM

Environmental benefits



- Increases ~10-15% photovoltaic power performance compared to fixed ground solar systems thanks to cooling effect
- Produces renewable energy linked to closer power consumption

- Reduces water evaporation by ~80% as the system acts as a protective ceiling of the water
- Improves water quality, therefore reducing infrastructure maintenance costs (algae and microorganisms maintenance)

- Preserves land for agriculture, livestock or forestry. No need to use fertile soil to install a regular power plant
- Reduces visual impact and takes advantage of non productive areas like water reservoirs.

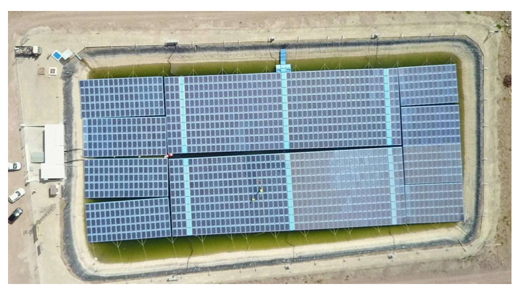
isifloating
FLOATING SOLAR SYSTEM

https://youtu.be/Meu-INAMDfE

isifloating

FLOATING SOLAR SYSTEM

Irrigation water reservoir-raft compatibility

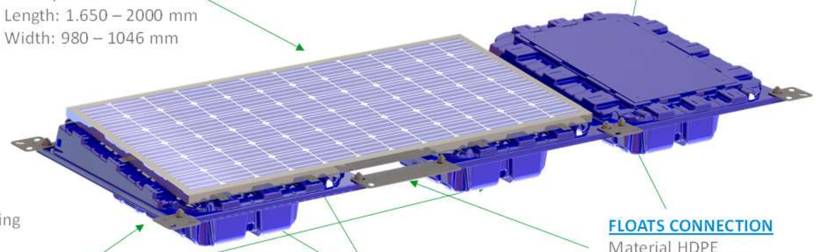


- The system is compatible with the particular geometry of any reservoir
- Rafts adapt to the changes of water level, even when it is emptied.
- Possible to install on the slopes of the irrigation reservoir
- Anchors can be fixed on every side of the raft with no need for underwater anchors.
- The lining system of the reservoir is protected from solar radiation while the HDPE material and rounded corners of the raft prevent any damage to the cover sheet.

isifloating

FLOATING SOLAR SYSTEM

Key components of Isifloating 4.0



isifloating FLOATING SOLAR SYSTEM

Key ratios of a standard 1 MW plant with 350w solar panels in Spain

Dimension	Value
Number of panels	2.858
Water area needed (mts2)	7.294
Number of floats	5.716
Manufacturing time (days)	5,0
Number of 40' containers	7
Installation time (days)	16,7
Cleaning time (days)	3,8
Water saved (m3/year)	8.752,8
CO_2 savings (kg CO_2/year)	580.870
Number of homes powered in a year	500

isifloating FLOATING SOLAR SYSTEM

Installation process (https://youtu.be/s3YFUPcqE9Y)

isifloating
FLOATING SOLAR SYSTEM

Cleaning and maintenance process (https://youtu.be/0pYtpzDVlTQ)

isifloating
FLOATING SOLAR SYSTEM

Connected to grid
C.R. Virgen de la Paz (Agost)

VALTEC Area Pro

ENERGY PRODUCTION FOR SALE
CONNECTED TO THE GRID

SITE	Irrigation water reservoir
LOCATION	Agost. Alicante. Spain
APPLICATION	Sale of energy. Financed by Caja Rural
PEAK POWER	320 Kw
FLOATS	760 units
YEAR	2009

isifloating
FLOATING SOLAR SYSTEM

Direct solar pumping.
C.R. Lorca

Región de Murcia · ferrovial agroman · cooltrade consulting · arada

MODERNIZATION OF IRRIGATION SYSTEM. ISOLATED PHOTOVOLTAIC GENERATOR SYSTEM FOR WATER SUPPLY PUMPING STATION

SITE	Irrigation water reservoir
LOCATION	Huerto Chico. La Hoya. Murcia. Spain
APPLICATION	Solar pumping
PEAK POWER	400 Kw
FLOATS	3080 units
YEAR	2016

isifloating FLOATING SOLAR SYSTEM

Self consumption pumping (PPA).
Winery Concha y Toro. Chile

SOLAER

PHOTOVOLTAIC GENERATOR SYSTEM FOR WATER SUPPLY PUMPING STATION

SITE	Irrigation water reservoir
LOCATION	San Felipe, Chile
APPLICATION	Self Consumption
PEAK POWER	230 kW
FLOATS	1532 units
YEAR	2019

isifloating FLOATING SOLAR SYSTEM

Direct solar pumping. C.R. Mérida

Hispasol Renovables ciansolar

IRRIGATION SYSTEM. ISOLATED PHOTOVOLTAIC GENERATOR SYSTEM FOR WATER SUPPLY PUMPING STATION

SITE	Irrigation water reservoir
LOCATION	Merida
APPLICATION	Solar pumping
PEAK POWER	2,5 MW (Phase 1 – 500KW)
FLOATS	15000 units (Phase 1 – 3300)
YEAR	2019

isifloating FLOATING SOLAR SYSTEM

Industries that could benefit from Isifloating solar technology

Industry	Why is floating solar good for the industry?	Water preservation needs	Energy needs	Opportunity Size
Energy	Hydroelectric systems with close access to electric grid lowering costs and possibility to complement current production	◑	●	●
Mining	Use of tailing dams to generate energy to power pump systems, heavy machinery, or electric vehicles	◑	●	●
Agriculture	Water pumping and preservation of water for irrigation purposes preserving land for agriculture or leasing the water bodies	◕	◕	◑
Fish Farming	Energy generation far from electric grid taking advantage of water	◔	●	◑
Wineries	Water pumping and preservation of water for irrigation purposes preserving land for wines	◔	◑	◑
Water management	Water preservation as it is main asset while generating renewable energy	●	◑	◕
Solar Developers	Water replaces land and less competition to lease water. Also, many times close to the water exits available capacity to connect to the grid	◔	●	◕

isifloating FLOATING SOLAR SYSTEM

Frequently asked questions

Question	Answer
1. Can the floats damage the lining system?	• No. The floats are made of HDPE and have rounded corners. It can stay directly over the lining system (on the bottom and on the slopes) with no danger of scratching it, neither during the installation nor during the operation of the system.
2. Do the anchors affect or damage the slopes?	• No. We use on shore anchors with very low horizontal charge since the panel is only at 5 degrees of inclination.
3. Does the system interfere with the work and/or infrastructure of the water reservoir?	• No. The design of the system avoids the need to enter or exit the water or the use of additional parts. There is a single access point for easy control and transit.
4. Does it affect the cleaning of the reservoir (When is it done)?	• When only part of the reservoir is covered by the system, cleaning can be made in a two step process by moving the raft to the unoccupied side. In case the whole reservoir is covered cleaning robots can be used. In cases where there is large mud accumulation the installation of the system is not recommended.
5. Can the system be removed?	• Very similar to the installation process, in case part of the system must be removed each panel and raft can be uninstalled one by one.

isifloating
FLOATING SOLAR SYSTEM

Contact us

www.isigenere.com

isifloating@isigenere.com

C/ Chapaprieta Nave 5. P.I La Casilla
03460 – Beneixama (Alicante)

www.linkedin.com/company/isigenere/

www.youtube.com/user/ISIGENERE

isifloating
FLOATING SOLAR SYSTEM

Dirección General de Aguas
Ministerio de Obras Públicas
Gobierno de Chile
División de Estudios y Planificación

Recarga de Agua Subterránea

Natural y por Gestión

Carlos Flores Arenas
Modelador Hidrológico DGA
PhD in Hydrologic Sciences UC Davis
MSc en Ingeniería Agrícola UdeC
BS Ingeniero Agrónomo UMayor

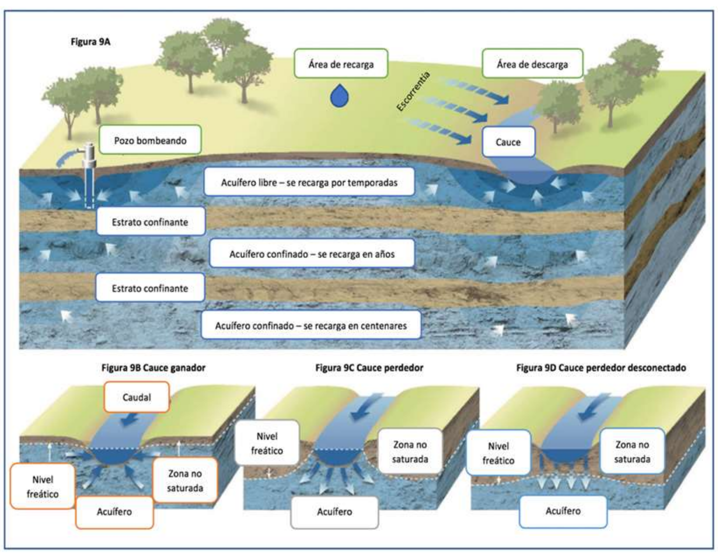
24 de Julio 2019

Contenidos

1. Interacciones entre aguas superficiales y subterráneas
2. Mecanismos de recarga de agua subterránea
   i. Natural
   ii. Por gestión
3. Experiencias en el Extranjero
4. Experiencias en Chile
5. Visión de desarrollo de obras de recarga por gestión en Chile
   I. Técnico
   II. Legal
   III. Financiero

Contenidos

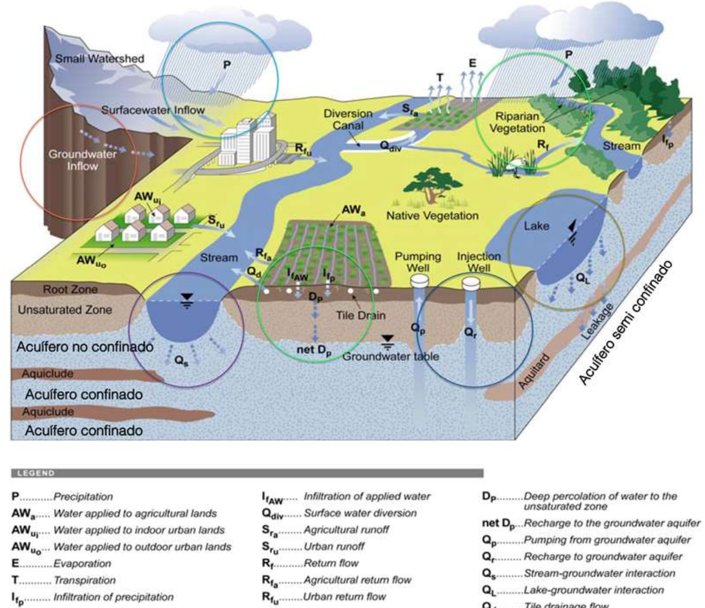
Interacciones entre agua superficial y subterránea



Procesos Hidrológicos en Recarga de Acuíferos

Recarga por

- Cauces
- Lluvia/deshielos en pie de montes
- Riego/lluvia en superficie
- Flujo subterráneo cuencas aledañas
- Planicies de inundación/ embalses/lagos
- Inyección por pozos

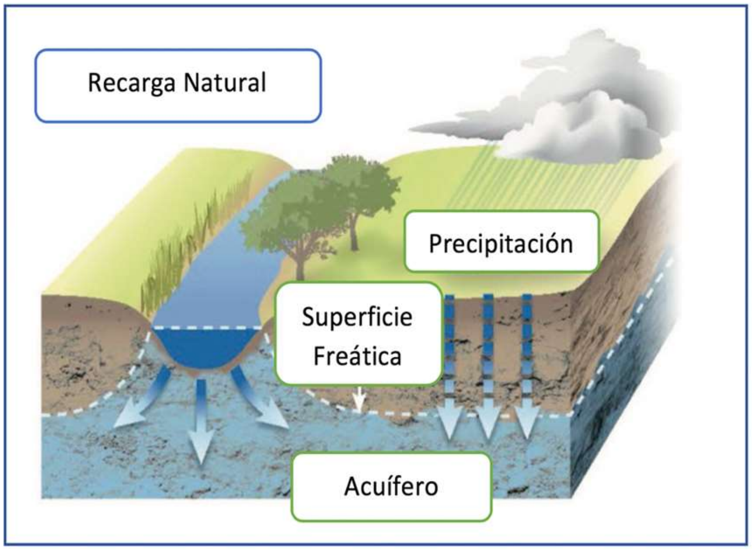


(IWFM Integrated Water Flow Model) Theoretical Documentation, 2018)

Contenidos

1. Interacciones entre aguas superficiales y subterráneas
2. **Mecanismos de recarga de agua subterránea**
   i. **Natural**
   ii. Por gestión
3. Experiencias en el Extranejero
4. Experiencias en Chile
5. Visión de desarrollo de obras de recarga por gestión en Chile
   I. Técnico
   II. Legal
   III. Financiero

Recarga natural de agua subterránea



Partición de la Recarga Acuíferos

Naturalmente:

- Cauces aportantes al agua subterránea por infiltración (50%).
- Recarga en pie de montes por efecto de precipitaciones y deshielos (20%).
- Infiltración por riego agrícola/precipitación (15%), variable según cuenca, puede llegar a más del 90% en cuencas con altas tasas de riego.
- Flujo desde cuencas aledañas (10%).
- Flujo base, i.e. caudales móviles en la zona no saturada que descargan a los acuíferos (5%).

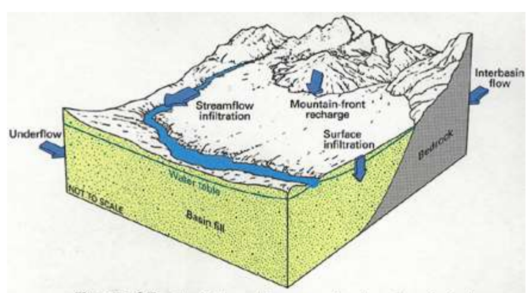
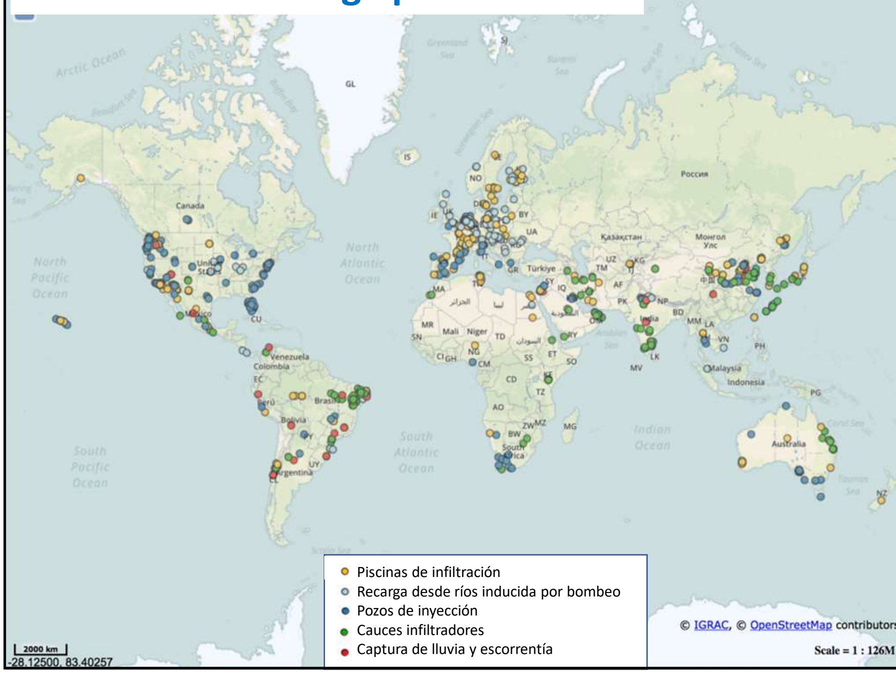


Figure 37. The Basin and Range aquifers have five principal components of ground-water recharge. Streamflow infiltration is the largest component; mountain-front recharge is the second largest.

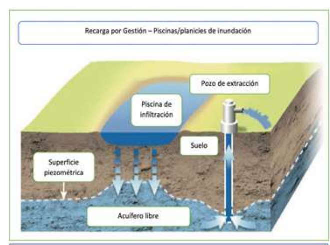
Contenidos

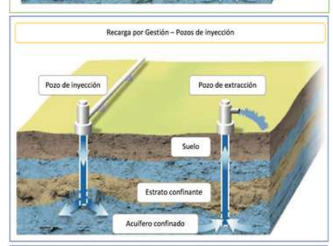
1. Interacciones entre aguas superficiales y subterráneas
2. **Mecanismos de recarga de agua subterránea**
   i. Natural
   ii. **Por gestión – Managed Aquifer Recharge (MAR)**
3. Experiencias en el Extranjero
4. Experiencias en Chile
5. Visión de desarrollo de obras de recarga por gestión en Chile
   I. Técnico
   II. Legal
   III. Financiero

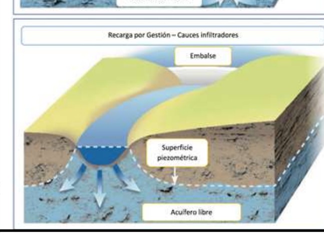
Métodos de Recarga por Gestión



Más comunes:



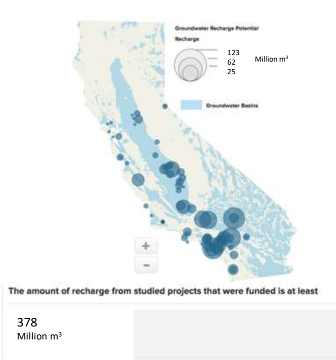


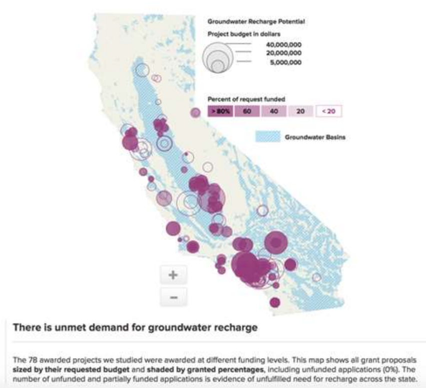


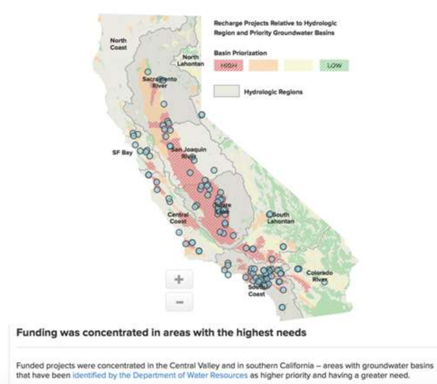
Contenidos

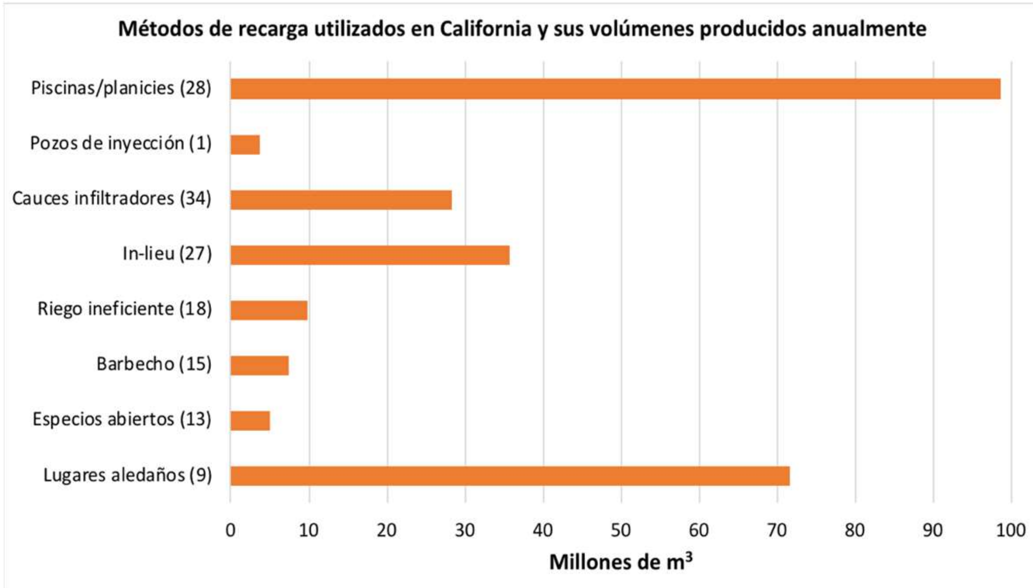
1. Interacciones entre aguas superficiales y subterráneas
2. Mecanismos de recarga de agua subterránea
   i. Natural
   ii. Por gestión – Managed Aquifer Recharge (MAR)
3. **Experiencias en el extranjero**
4. Experiencias en Chile
5. Visión de desarrollo de obras de recarga por gestión en Chile
   I. Técnico
   II. Legal
   III. Financiero

California





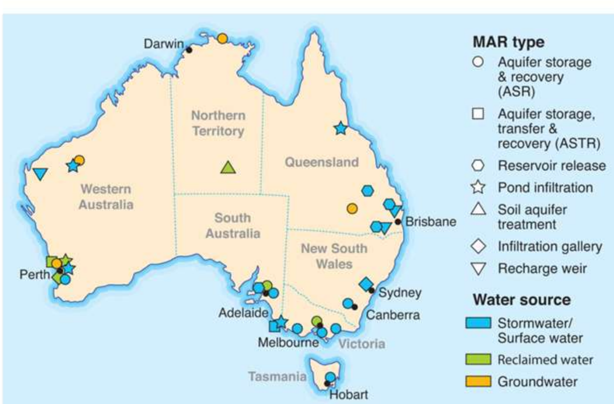


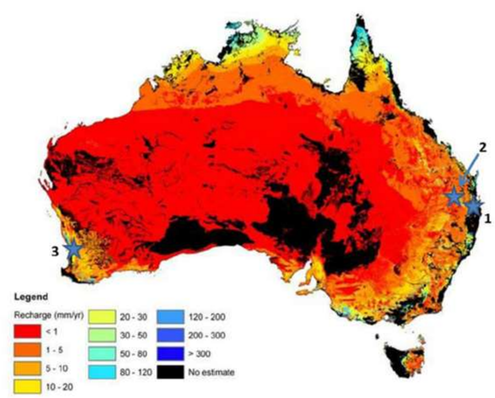


*Números en paréntesis ( ) indican casos reportados en 46 distritos de gestión hídrica en California.

Australia

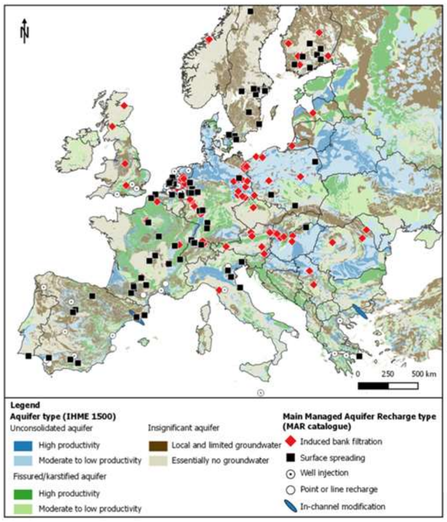
MAR: Managed Aquifer Recharge

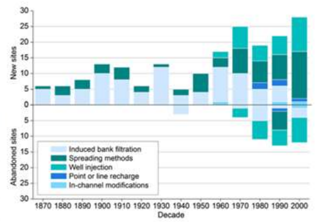


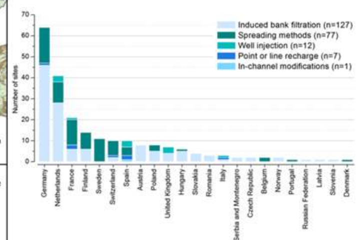


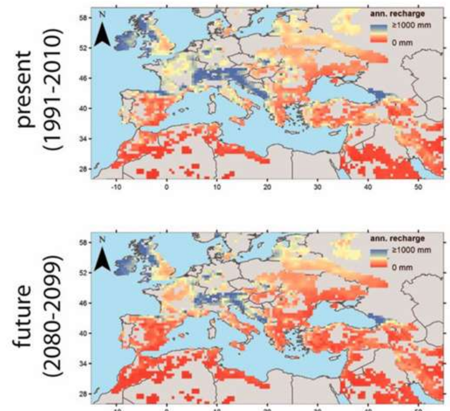
Europa

MAR: Managed Aquifer Recharge









Contenidos

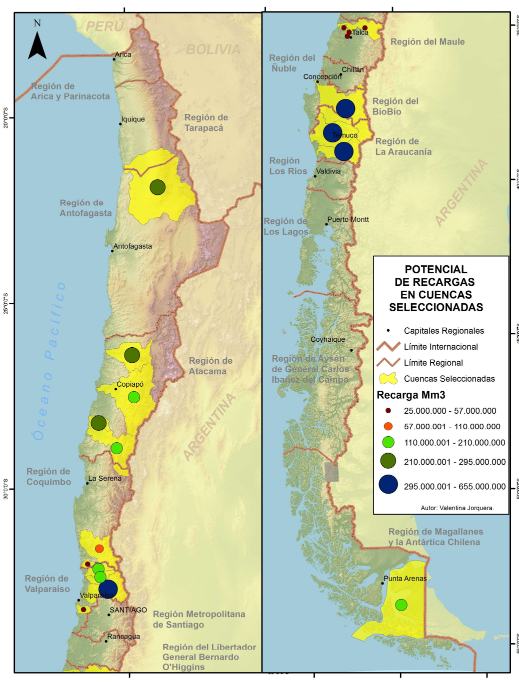
1. Interacciones entre aguas superficiales y subterráneas
2. Mecanismos de recarga de agua subterránea
   - i. Natural
   - ii. Por gestión – Managed Aquifer Recharge (MAR)
3. Experiencias en el extranjero
4. **Experiencias en Chile**
5. Visión de desarrollo de obras de recarga por gestión en Chile
   - I. Técnico
   - II. Legal
   - III. Financiero

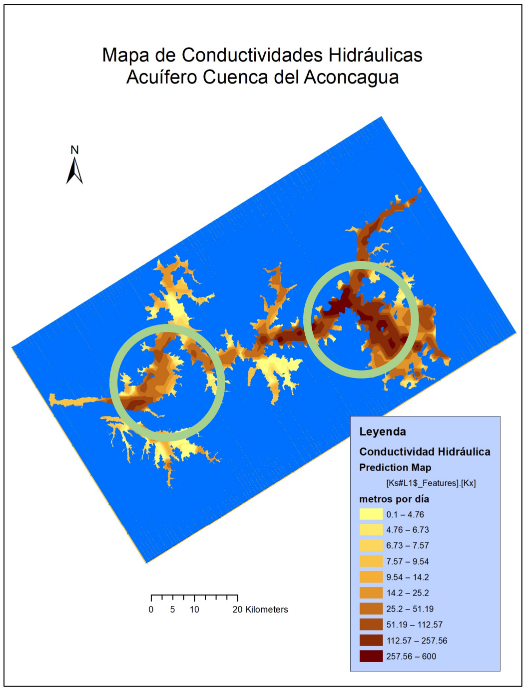
Estudios hidrogeológicos con información para realizar obras de recarga

Cuenca	Estudio
Maipo	2005.Modelación superficial para la cuenca de los ríos Maipo Mapocho. Estimación de recarga para escenario actual 2005
Aconcagua	2009. Modificación modelos DGA Visual Modflow-MOS y MOS PS
Petorca	2019. Actualización de la modelación hidrogeológica del sistema acuífero la Ligua-Petorca.
Copiapó	2013. Actualización de la modelación integrada y subterránea del acuífero de la cuenca del río Copiapó
Imperial	2016. Estudio Hidrogeológico Región de la Araucanía
Bio Bio	2012. Estudio hidrogeológico cuenca Bio Bío
Río Valdivia	2012. Estudio cuencas principales región de Los Ríos
Choapa	2017. Análisis para el Desarrollo de un Plan de GIRH en la Cuenca del Choapa
Pampa del Tamarugal	2018. Investigación de acuíferos de gran volumen y baja recarga fase II
Ligua	2019. Actualización de la modelación hidrogeológica del sistema acuífero la Ligua-Petorca.
Maule	2010. Levantamiento de información hidrogeológica para modelación cuenca del río Maule: informe final
Itata	2013. Modelación hidrogeológica cuenca Itata bajo, región del BioBío: informe final
Limarí	2013. Diagnóstico plan maestro para la gestión de recursos hídricos, Región de Coquimbo
Elqui	2013. Diagnóstico plan maestro para la gestión de recursos hídricos, Región de Coquimbo
Loa	2014. Sectorización de los Acuíferos de la cuenca del río Loa
Salar de Atacama	2019. Modelación hidrogeológica del Salar de Atacama – Proyecto Corfo
Quilimarí	2012. Investigación recarga artificial acuíferos de las cuencas de los ríos Choapa y Quilimarí Región Coquimbo
Concordia	2011. Análisis de los recursos subterráneos de la Quebrada de la Concordia
Rapel	2016. Desarrollo de un modelo para la Gestión Integrada de los recursos hídricos de la cuenca del Río Rapel
Río Bueno	2012. Estudio cuencas principales región de Los Ríos
Mataquito	2012. Estudio hidrogeológico cuenca del río Mataquito
Costeras Rapel-E.Nilahue	2013. Levantamiento hidrogeológico en cuencas pluviales costeras en la Región del Libertador Bernardo O'Higgins y Región del Bio-Bío: informe final
Costeras Elqui-Limari	2004. Aplicación de la modelación hidrogeológico valle Pan de Azúcar
Lluta	1998. Estudio hidrogeológico y modelo de simulación del valle del río Lluta
Isla de Pascua	2013. Modelo hidrogeológico Isla de Pascua
Valle Casablanca	2014. Actualización de la modelación hidrogeológica e integrada de los acuíferos de la cuenca del estero Casablanca
Aculeo	2019. Caracterización del consumo hídrico y del sistema hidrogeológico en la cuenca de Aculeo. Proyecto FIC-R
Talcahuano	2013. Levantamiento hidrogeológico en cuencas pluviales costeras en la Región del Libertador Bernardo O'Higgins y Región del Bio-Bío : informe final
Magallanes	2016. Actualización de Información y Modelación hidrológica de acuíferos de la región de Magallanes y la Antártica.
Huasco	2013. Análisis integrado de gestión en cuenca del río Huasco región de Atacama
San José - Azapa	2009. Definición de estrategias de manejo sustentable para el acuífero de Azapa, XV Región
Costeras Copiapó-Salado	2016. Caracterización de suelos y generación de información meteorológica para prevención de riesgos hidrometeorológicos cuencas Salado y Copiapó
Los Choros	2005. Modelación hidrogeológica en la Quebrada Los Choros
Totoral-Carrizal	2010. Análisis y evaluación de los recursos hídricos subterráneos de los acuíferos costeros ubicados entre los ríos Salado y Huasco, III región de Atacama
Serrano-Las Chinas	2016. Análisis de la Variación de Caudales río Las Chinas - río Serrano
Cauquenes	2013. Modelación hidrogeológica de la cuenca del río Cauquenes, región del Maule
Curepto	2013. Modelo hidrogeológico preliminar del acuífero de la cuenca del Estero Curepto
Los Puercos	2013. Modelación hidrogeológica cuenca estero Los Puercos, Región del Maule
Nilahue	2013. Modelación hidrogeológica cuenca Nilahue
Toltén	2016. Estudio Hidrogeológico Región de la Araucanía

Muestra del potencial de recarga en Chile

Estimación simulada con modelos DGA operativos, sobre la base del espacio disponible en el acuífero para recibir flujos de entrada.





Consideración:

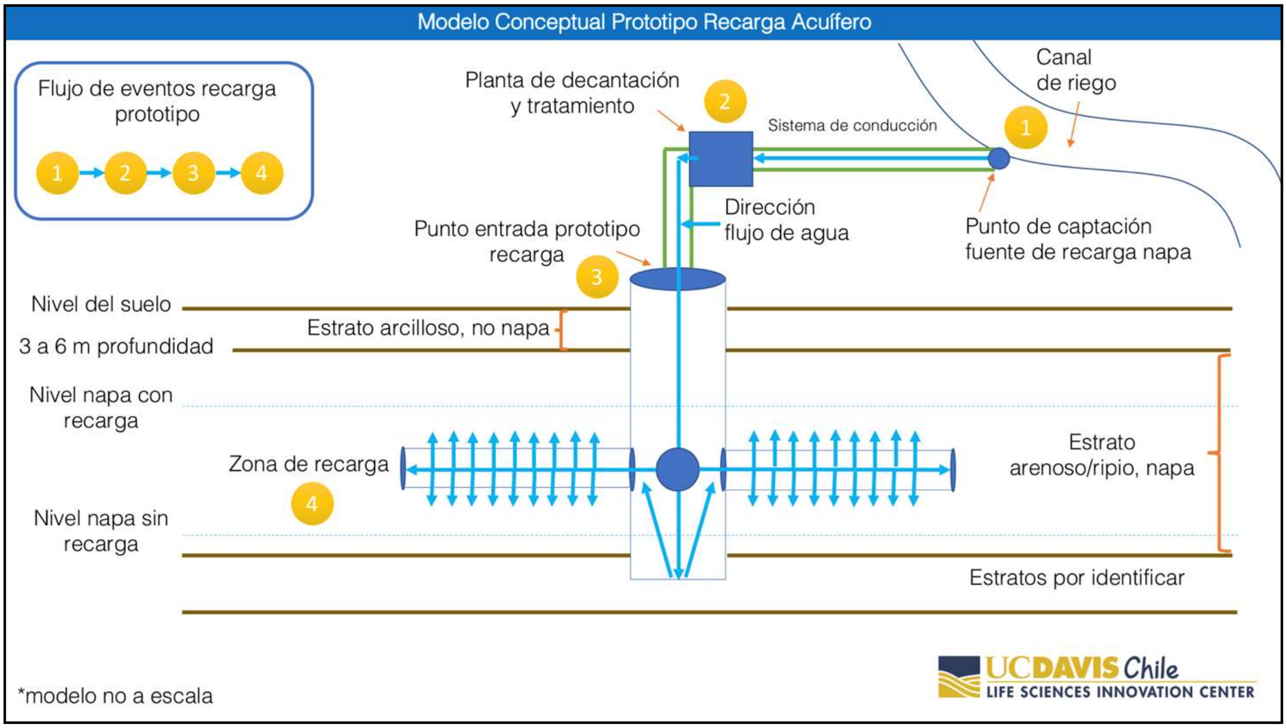
- Zonas de recarga ubicadas en áreas de mayor conductividad y potencial de recarga, equivalente a 350 Millones de m^3.

Prototipos activos de recarga de agua subterránea en Chile

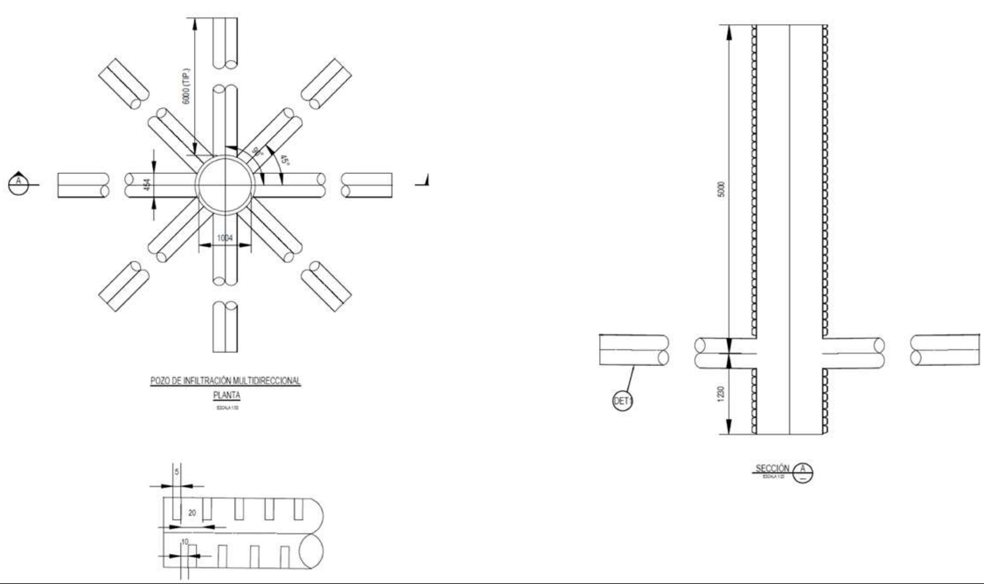
Método de recarga	Cuenca	Sector	Desarrollador	Tasa recarga (lt/s)	Almacenamiento (Millones m^3 por año)	Valor del agua ($/$m^3$)
Piscinas de infiltración	Copiapó	Piedra Colgada	Comunidad de Aguas Subterráneas CASUB	200	6,3	15
	Aconcagua	Curimón	Dirección de Obras Hidráulicas	1000	31,5	48
Cauces infiltradores	Aconcagua	Catemu	Regantes de Canales de Riego alto y abajo de Catemu	120	3,8	8
Pozos de inyección	Maipo	La Pintana	Sociedad del Canal de Maipo	50	1,5	450

Ejemplos en el Valle del Río Copiapó

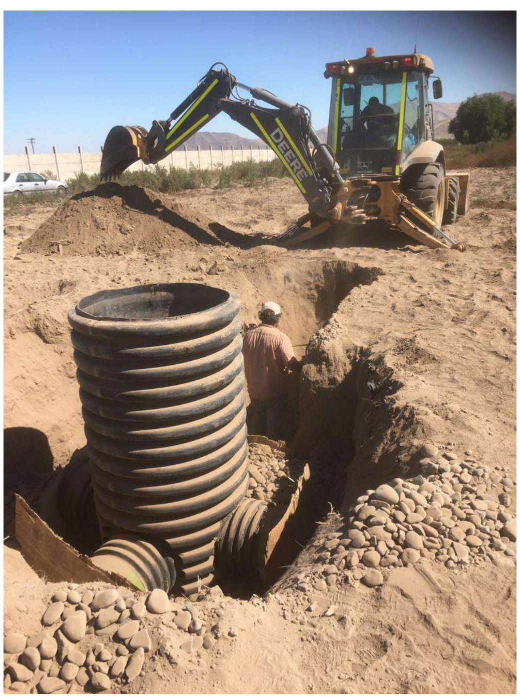
Prototipo Pozo Radial para Recarga Agua Subterránea con Uso Conjunto del Recurso Hídrico



Bosquejo Prototipo




JCB


DEERE

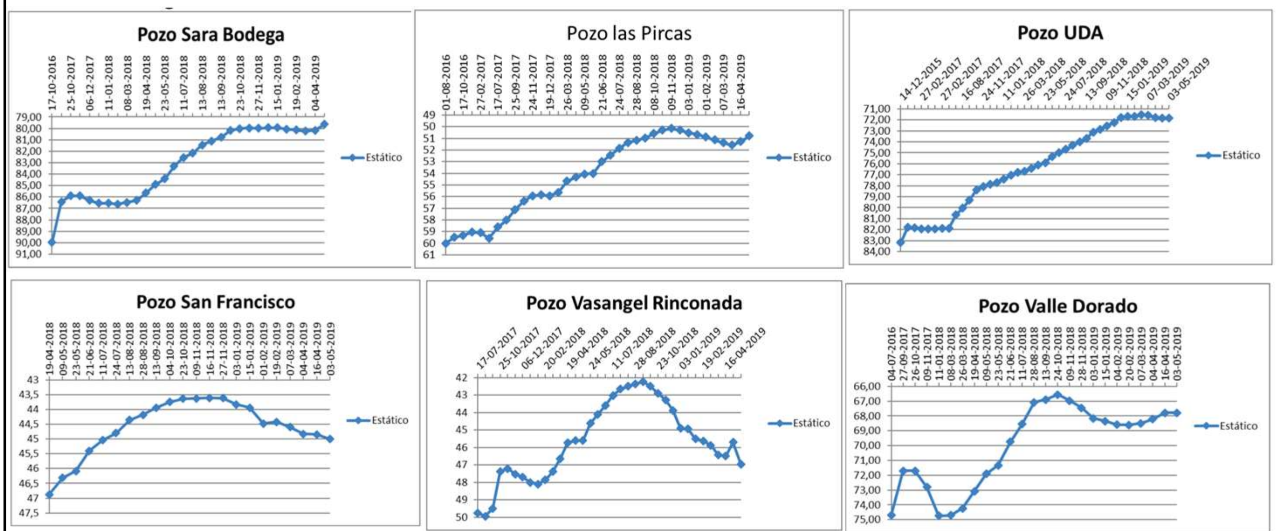
Datos Prototipo Pozo Radial de Recarga

- Origen fuente de agua: Canal de regadío
- Caudal de infiltración: 10 lt/s, escalable a otros caudales.
- Costo diseño y construcción: $7.000.000
- Costo operacional: $150.000/mes
- Costo del agua: $14/m^3$

Planicies de Inundación para Recarga Agua Subterránea con Uso Conjunto del Recurso Hídrico

Inspección en terreno DGA y MOP – Septiembre 2018

Pozos de Monitoreo Casub Copiapó – Funcionamiento Piscinas desde Agosto 2016
Profundidad de Agua Subterránea (m)



Datos Planicies de Inundación para Recarga

- Origen fuente de agua: Río Copiapó
- Caudal de infiltración: 150-200 lt/s, 5,6 millones de m^3/año
- Costo diseño y construcción: $30.000.000
- Costo operacional: $350.000/mes
- Costo del agua: $6/$m^3$

Contenidos

Marco Técnico-Operativo

Recarga de agua subterránea = Gestión conjunta aguas superficiales y subterráneas

Contenidos

Política de Promoción de Recarga de Acuíferos

- El código de aguas regula las iniciativas de recarga de agua subterránea, Artículo 66 y 67.
- Decreto Supremo N°203/2013 que "Establece las Normas de Exploración y Explotación de Aguas Subterráneas".
- Circulares:
  - Circular N° 1 del 14 de febrero de 2019, sobre las obras hidráulicas permeables, en la recarga de acuíferos.
  - Circular N°2 del 2 de abril de 2019, establece condiciones para exceptuarse de cumplir la orden de cierre de bocatomas ante peligro de grandes avenidas.

Contenidos

Oportunidades de acción y de negocio

- Estudios para determinar el marco Técnico-Operativo -> DGA
- Privados que inviertan en I+D para generar dispositivos de recarga y comercializarlos en el Mercado -> CORFO
- Sistemas de concesiones para suministrar agua por ASR, u otro -> MOP
- Fomento a la inversión privada en obras de recarga -> CNR y MOP

Modelo conceptual del negocio de recarga
(asume marco técnico-operativo favorable)

DGA Define certeza jurídica del lugar y volumen del acuífero que está sujeto al negocio

e.g. Aconcagua: 350 Millones m^3 en áreas de San Felipe y Quillota

Agente desarrollo negocio de recarga

Demanda insatisfecha en Aconcagua 1 m^3/s equivalente a 310 Millones m^3 por temporada

Posibles fuentes de agua:
- Uso de caudales excedentes en cauces
- Recargas naturales en banco de agua
- Cuotas de volúmenes superficiales de usuarios clientes
- Importación de agua desde otras cuencas para mantener stock
- Compra y tratamiento de aguas residuales

Unidades de Negocio*:
- Almacenamiento subterráneo de agua superficial en periodos húmedos, y extracción en tiempos de sequía
- Venta de volúmenes subterráneos periódicos según stock

*(incluyen conducción desde/hacia clientes y trámites administrativos/legales)

Dispositivos de recarga y conducción
- Piscinas/planicies de recarga
- Pozos de recarga
- Red de canales
- Canales, tuberías, bombas

Costo estandarizado servicio: $450/$m^3$

Clientes:
Agricultores
Industrias
Sanitarias
Mineras

Voluntad de pago: desde $1200/$m^3$

Ingreso Agente negocio recarga $750/$m^3$

Dirección General de Aguas
Ministerio de Obras Públicas
Gobierno de Chile
División de Estudios y Planificación

Recarga de Agua Subterránea

Natural y por Gestión

Carlos Flores Arenas

PhD in Hydrologic Sciences UC Davis

MSc en Ingeniería Agrícola UdeC

BS Ingeniero Agrónomo UMayor

24 de Junio2019

WASTEWATER TREATMENT AND REUSE

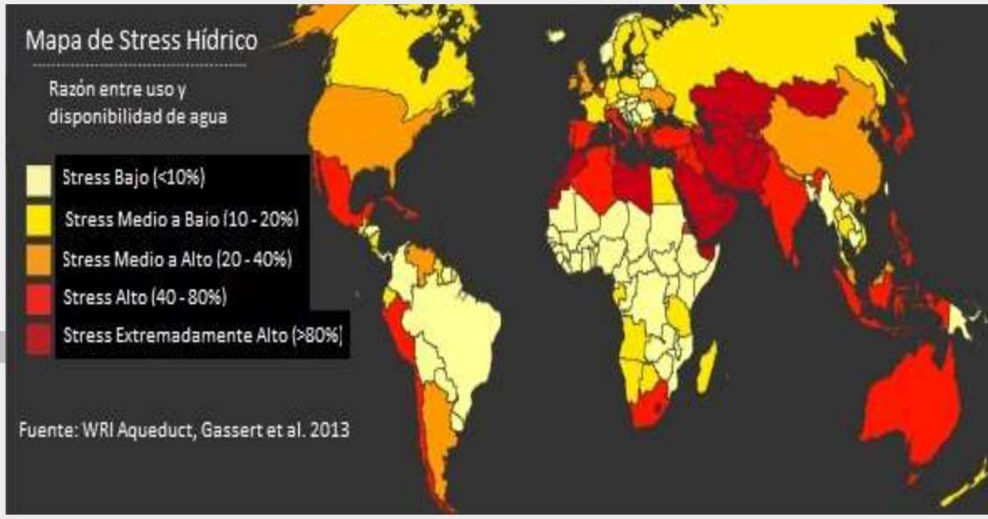
Jacobo Homsi A.

Santiago, July 2019

GENERAL.

Wastewater reuse is a global trend in developing economies as well as in developed ones, mainly determined by three factors.

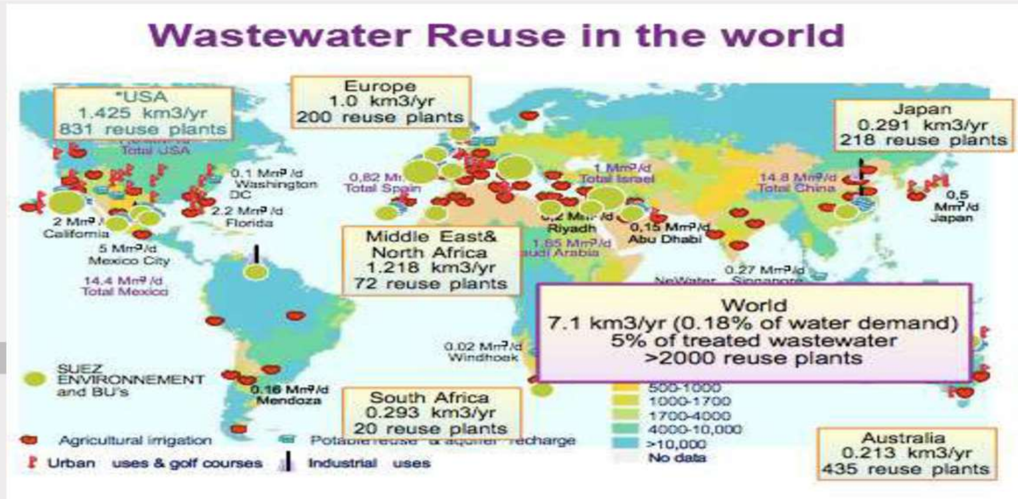
- Demand increase in a scenario with less availability.
- Increasing recognition of wastewater source importance.
- Economical considerations associated to partial return of benefits when investing in wastewater treatment.



.

Global availability of treated wastewater has appeared as resource in last decades, as a consequence of change in climatic conditions (average temperature raising, change in precipitation standards and extreme climatic events).

Reuse referenced to treated wastewater reuse, should be incorporated to integral and sustainable water management, appliable with direct benefits (reducing energy consumption and costs) allowing use of trated wastewater in local economic activities.



Source: Wastewater treatment: aims and challenges. The magazine on resource challenges and circular economy (2013); Water reuse: Overview of current practices and trends in the world with emphasis on EU states (2014)

POTENTIAL USES OF TREATED WASTEWATER.

Most common uses are assotiated to agricultural farming irrigation, parks irrigation, industrial use, groundwater recharge, energy generation, etc.

Main aspects associated to irrigation in agricultural farming are Salinity, Toxicity and microbiological quality due to pathogenic organisms present in wastewater.

CNR Ministerio de Agricultura Gobierno de Chile
APEC CHILE 2019

When considering Agricultural irrigation, type of irrigation must be strongly taken into account.

Restricted Irrigation.

Unrestricted Irrigation.

Not adverse effect on farming and soils.

No effects on animals or human health during production stages.

Suitable for aquatic life preservation.

CNR Ministerio de Agricultura Gobierno de Chile
APEC CHILE 2019

INTERNATIONAL BEHAVIOUR.

WORLD HEALTH ORGANIZATION.

Summarize epidemiologic and infectious illness transmition studies, regarding sanitary risks associated to wastewater use in irrigation, due to pathogen organisms that could survive in environment (wastewater, soils, agricultural products) that could eventually infect people.

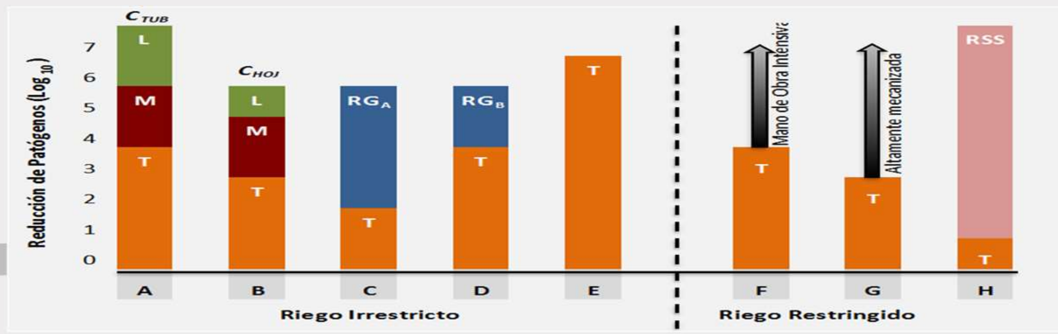
One relevant aspect, specially in agriculture is the combination of different measurements of sanitary protection in the whole chain of the process, from the water production destined to iirigation until the end consumer of the product.

There is a lot of control measurements, everyone associated to pathogen concentration reduction.

CNR Ministerio de Agricultura Gobierno de Chile

APEC CHILE 2019

Combination of sanitary protection measurements for pathogen reduction in wastewater use for irrigation.



T Tratamiento
M Mortalidad*
L Lavado de Productos
RG A Riego goteo cultivos en altura
RG B Riego goteo cultivos ras de suelo
RSS Sistema de Riego Subsuperficial
C_{TUB} Cultivos de Tubérculos (papas, zanahorias, rabanos,etc)
C_{HOJ} Cultivos de Hojas (Lechuga, apio, etc)

* Mortalidad de organismos patógenos durante el período transcurrido entre el ultimo riego del cultivo y su consumo final.

CNR Ministerio de Agricultura Gobierno de Chile

APEC CHILE 2019

STANDARDS OF DIFFERENT ECONOMIES REGARDING WASTEWATER REUSE

ISRAEL.

Israel has been developing wastewater reuse since long time ago.

Public Health Ministry has published standards regarding wastewater quality for agricultural irrigation.

Parámetro de Calidad	Categorías Específicas de Aplicación			
	A	B	C	D
DBO	60	45	35	15
DBO Filtrada	-	-	20	10
Sólidos Suspendidos	50	40	30	15
Coliformes Totales	-	-	250	12
Cloro Residual	-	-	0,15	0,5

A: Cultivos industriales, cereales y semillas
B: Forraje verde, Olivos, Nogales, Almendras y Citricos
C: Frutas y vegetales para procesamiento, vegetales que se cocinan, Frutas pelables, Canchas de Golf, Canchas de Fútbol
D: Todo cultivo sin restricción, cultivos de consumo crudo, parques municipales, prados

UNITED STATES FROM AMERICA

Wastewater reuse for irrigation in agriculture is under quality standards in more than 40 states from United States (Arizona, Nevada, California, Texas, Utah, etc.)

As an example, Public Health Department of Arizona has established maximum limits for 5 categories of crops and aquatic life preservation.

Parámetro de Calidad	Categorías Específicas de Aplicación					
	A	B	C	D	E	F
Coliformes Fecales, NMP/100 ml	1.000	1.000	1.000	1.000	2,2	1000
pH	4,5 - 9	4,5 - 9	4,5 - 9	4,5 - 9	4,5 - 9	4,5 - 9
Turbiedad, NTU	-	-	-	-	1	-
Virus Entéricos, (PFU/40 l)	-	-	-	-	-	-
Entamoeba Histolística	-	-	-	-	N.D.	-
Ascaris Lumbricoides (huevos)	-	-	-	-	N.D.	-
Tenias largas	-	-	N.D.	-	-	N.D.

A: Huertos
B: Fibras, semillas y Cultivos Forrajeros
C: Pastizales
D: Cultivos para alimentos procesados
F: Vida acuática

ENVIRONMENTAL PROTECTION AGENCY (EPA) STANDARDS (EPA/2012)

Categoría de Uso	Tratamiento	Requisitos de Calidad [1]	Requisitos de Control	Distancias de Aplicación [2]
Uso en Agricultura				
Cultivos Alimentarios El reuso de aguas servidas tratadas para riego superficial o por aspersión de cultivos alimentarios destinados al consumo humano, consumidos crudos.	Segundario[3] Filtración[4] Desinfección[5]	pH=6,0-9,0 ≤ 10 mg/L DBO ≤ 2 UNT Turbiedad Coliformes Fecales /100ml: ND Cloro Residual: 1mg/L	pH - Semanal DBO5 - Semanal Turbiedad - Continua Coliforme Fecal - Diario Cloro Residual Continuo	15m: pozos de agua potable, 30m: en suelos porosos
Cultivos Alimentarios El reuso de aguas servidas tratadas para el riego superficial de cultivos alimentarios destinados al consumo humano, procesados comercialmente.	Segundario[3] Desinfección5	pH=6,0-9,0 ≤ 30 mg/L DBO	pH - Semanal DBO5 - Semanal	90m: pozos de agua potable, 30m: areas publicas accesibles (Irrigación por aspersión)
Cultivos no alimentarios El reuso de aguas servidas tratadas para el riego de cultivos que no son consumidos por los seres humanos, incluyendo forraje, fibra y cultivos de semillas, o para irrigar pastizales, viveros comerciales y granjas de césped.		≤ 30 mg/L SST Coliformes Fecales /100ml: <200 Cloro Residual: 1mg/L	Coliforme Fecal - Diario Cloro Residual Continuo	

[1] Aplicable al punto de descarga de las instalaciones de tratamiento de las aguas servidas.
[2] Distancias para la zona de protección de la contaminación de fuentes de agua potable y de la exposición directa de personal a las aguas de reutilización.
[3] Tratamiento secundario incluye sistemas de lodos activados, filtros percoladores, biodiscos o lagunas de estabilización, cuyos efluentes no deben excederse en 30mg/L de DBO5 y SST.
[4] Filtración incluye infiltración en suelos naturales o filtración en medios granulares, o membranas.
[5] La desinfección incluye la cloración, para los efectos de destrucción, remoción o inactivación de microorganismos patógenos.

INTERNATIONAL EXPERIENCE ON WASTEWATER REUSE

EXPERIENCE IN ISRAEL

1959
Parlamento aprueba el **"Water Law"** que define el reuso de agua como un recurso a utilizar

1970
La escasez de agua ya era un tema nacional y **se comienzan a dar incentivos** para potenciar el reuso de agua.

1984
Primer sistema de reutilización de agua a gran escala

2005
Reúso de agua alcanza el 75%.
Más de 200 reservas para almacenar el agua de reuso, con reservas subterráneas en Tel-Aviv.

2011
La Autoridad del Agua elaboró el **Plan Maestro a Largo Plazo para el Sector Nacional del Agua**

2015
Reuso de aguas residuales alcanza el 85%

EXPERIENCE IN SINGAPUR

1972
First Water Master Plan.

1974
First reuse pilot plant constructed by the Water National Agency (PUB).

1998
Recovering Water from Singapur Study (NEWater) as public initiative

2000
First Plant NEWater

Source: Cisneros, B. E. J. (2008). Water reuse: an international survey of current practice, issues and needs (Vol. 20). B. Jiménez, & T. Asano (Eds.). IWA publishing.

- **NEWater** is the commercial name given to regenerated water produced by the Water National Agency.
- At the present time, **NEWater (reused water) supplies more than 30% from total water demand from Singapur.**
- **NEWater public acceptation**. By means of intensive public education and permanent searching to public acceptance, especially industries, NEWater grew constantly.
- In Singapur **all the cycle is administrated by the Public Utility Commitee**, allowing holistic approach in wastewater reuse.
- **Incentive for reuse water consumption in the public sector.**

Source : Sánchez F., Modelos de Negocio: Prospección Internacional, Fundación Chile, Seminario Aguas Residuales como nueva Fuente de Agua, Fundación Chile, Septiembre 2016.

AUSTRALIA

1994
Water Reform Program**.**

2004
National Water Commision formation **and National Water Initiative (NWI)** adoption

2007
Commonwealth Water Act

2010
"Water for the Future", long term initiative.

2011
Australian Government Productivitiy Commision regarding Urban Water Sector.

Source: Department of Agriculture and Water Resources Website; Water for the Future: Fact sheet; The Australian Government's Productivity Commission's Website

WASTEWATER REUSE IN CHILE.

BARRIERS.

STANDARDS.

1. There are no standards regarding treated wastewater use.
2. There is no legal or administrative frame (public politics, institutional leadership) associated to treated wastewater reuse.
3. Associated laws adaptation (Water Code, Santary Services Law, Environmental Law, etc.).

COMUNITY CULTURAL REJECTION.

BARRIERS.

COSTS.

Conditioned to Production points (WWTP) and Disposal points.

5% of WWTP(capacity > 500 l/s) treat 48% domestic wastewater

95% of WWTP(cap < 500 l/s) treat 32% of domestic wastewater

100% of Emisary Outfalls treat 20% domestic wastewater

WASTEWATER PRODUCTION IN CHILE

	[l/s]	[MMm3/year]
WWTP	30.125	950
Emisary Outfalls	7.930	250

TREATED WASTEWATER REUSE IN CHILE

		WW Production [l/s]	Treated WW [l/s]	%	Destination
WWTP					
	Caldera	37	37	100	Parks irrigation
	Tierra Amarilla	27	24	88	Mining
	Copiapó	312	212	68	Mining
	National	**30.125**	**273**	**< 1**	
EMISARY OUTFALLS					
	Antofagasta	850	120	14	Mining & Industry
	National	**7.930**	**120**	**< 2**	

LOCAL EXPERIENCE IN CHILE.

WATEWATER REUSE IN THE NORTHERN PART OF CHILE

SEMBCORP. SINGAPUR SANITARY ENTERPRISE THAT OPERATES IN CHILE

Planta Agua Ultrapura:
Única en Chile

sembcorp

- Sembcorp diseño, construyo y opera una moderna planta para el suministro de agua ultrapura a partir de aguas servidas a la planta de producción de litio de SQM cerca de Antofagasta.
- Tecnología es Similar a Changi NEWater.
- Luego de tratamiento en planta de Aguas Servidas: MBR para eliminar restos orgánicos, osmosis inversa para desmineralizar casi 100%, y luego remineralización.
- Planta se construyo y puso en marcha en tiempo record de 9 meses.
- Parte del agua ultrapura es luego tratada y acondicionada especialmente para uso como agua potable.
- 75-80% Tasa de recuperación
- Agua de rechazo es usada para supresión de polvo en las instalaciones del cliente.
- 2500 m^3/día

MBR Reactor

Parámetro	Valor
Aguas Servidas Antofagasta	
DBO_5	270 - 300 mg/l
Aceites y grasas	80 - 120 mg/l
Solidos Suspendidos	280 - 350 mg/l
Solidos Totales	3.500 - 4.000 mg/l
Agua Industrial	
DBO_5	15 - 25 mg/l
Aceites y grasas	15 - 20 mg/l
Solidos Suspendidos	30 - 50 mg/l
Solidos Totales	3.500 - 4.000 mg/l
Agua Ultrapura	
DBO_5	0 mg/l
Aceites y grasas	0 mg/l
Solidos Suspendidos	0 mg/l
Solidos Totales	20 - 30 mg/l

WASTEWATER REUSE IN THE CENTRAL PART OF CHILE

CANAL PROSPERIDAD (PROSPERITY CHANNEL)

GOVERNMENT OF CHILE INSTITUTIONS
AGUAS ANDINAS (SANITARY ENTERPRISE OF THE METROPOLITAN REGION)

- El Canal Prosperidad es un proyecto que beneficiará a los regantes del valle de Casablanca.
- Tiene por objetivo llevar agua de la cuenca del Maipo, desde la Región Metropolitana hasta tranques del valle de Casablanca de la V Región (Lo Ovalle, Lo Orozco, La Vinila y Los Perales.
  Se proyecta llegar hasta el lago Peñuelas para mejorar el respaldo de agua potable.
- Longitud total del canal : 183 km, con bocatoma en el río Mapocho.
- Costo estimado: 100 MM US$.
- Existe un tramo de 31 km entre Curacaví y el túnel Zapata que se ejecutó en los años 70, después de la sequía de 1968-69.

Necesidad de Recursos de Agua

- Las necesidades de los regantes alcanzan aproximadamente a **30 millones de metros cúbicos** anuales, para abastecer los embalses La Vinilla, los Perales, lo Ovalle y Lo Orozco, los que se encuentran secos desde hace 10 años.
- Además, se plantea disponer de recursos adicionales de agua para conducir al lago Peñuelas y **reforzar el abastecimiento de agua potable** de Valparaíso-Viña del Mar.
- Sin embargo, **el proyecto no dispone de derechos de agua** en la 1ra Sección del río Maipo, como tampoco en el río Mapocho.

Propuestas de aporte de Recursos AA

***1.- Entrega de Agua Tratada*:**

Las plantas La Farfana de 8,8 m³/s y Trebal-Mapocho de 6,6 m³/s de capacidad de diseño, actualmente tratan en conjunto un **caudal medio anual de 15,3 m³/s**, relativamente estable a nivel mensual.

Las alternativas de entrega de 30 hm³/año, que equivalen a un caudal de **3 m³/s** durante los meses **de junio a septiembre**, son:

A Entrega de caudales desde la PTAS La Farfana, que sería completamente gravitacional hasta la bocatoma proyectada del canal.

B Entrega desde la planta Trebal-Mapocho, que requeriría una obra de elevación de aproximadamente 15 a 20 m.

Aporte de Recursos Aguas Andinas

***2.- Entrega de Agua Cruda*:**

Aguas Andinas **posee derechos eventuales** en el río Maipo por 22 m³/s continuos, y 80 m³/s adicionales en los meses de noviembre a febrero, los que podrían conducirse hasta el Lago Peñuelas para reforzar la reserva de agua potable para el Gran Valparaíso.

- Los aportes de caudal de derechos eventuales se podrían conducir a través del canal San Carlos, Zanjón de la Aguada y otros, previa autorización de sus propietarios.
- La Sociedad del Canal de Maipo declaró su apoyo a la iniciativa y pone a disposición de la misma el Canal San Carlos, hasta su descarga en el río Mapocho, para el transporte de excedentes ocasionales de Aguas Andinas.

AGREEMENT.

The government compromises to advance in the development of a project to allow the use of part of treated wastewater coming from the wastewater treatment plants of Aguas Andinas (Metropolitan region) by means of a conduction to Casablanca valley.