Water Sustainability using the Pond-In-Pond Treatment System with Reuse

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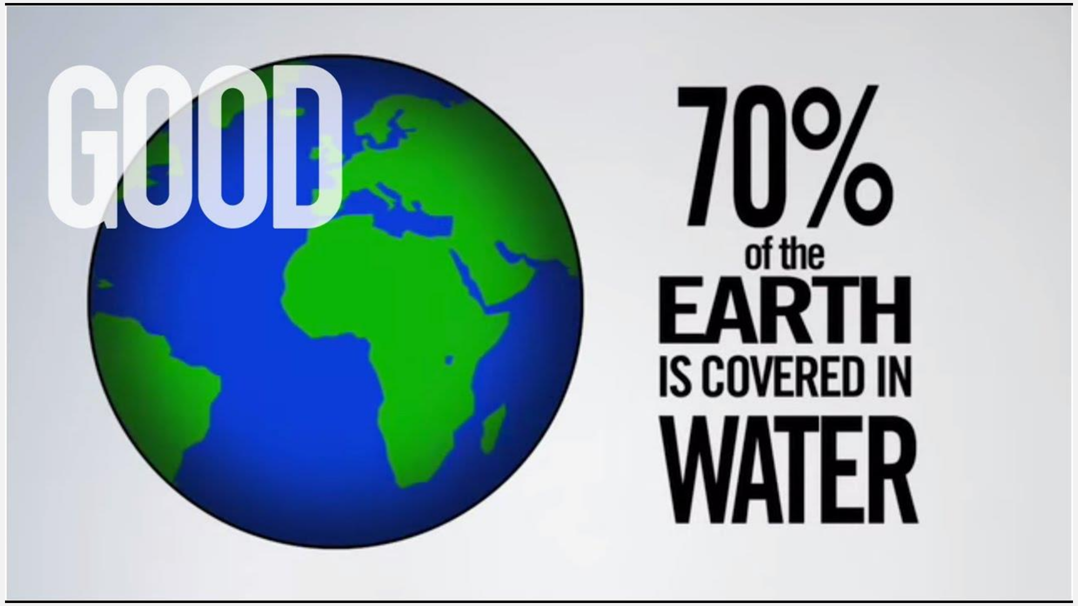
Should We Even Care?



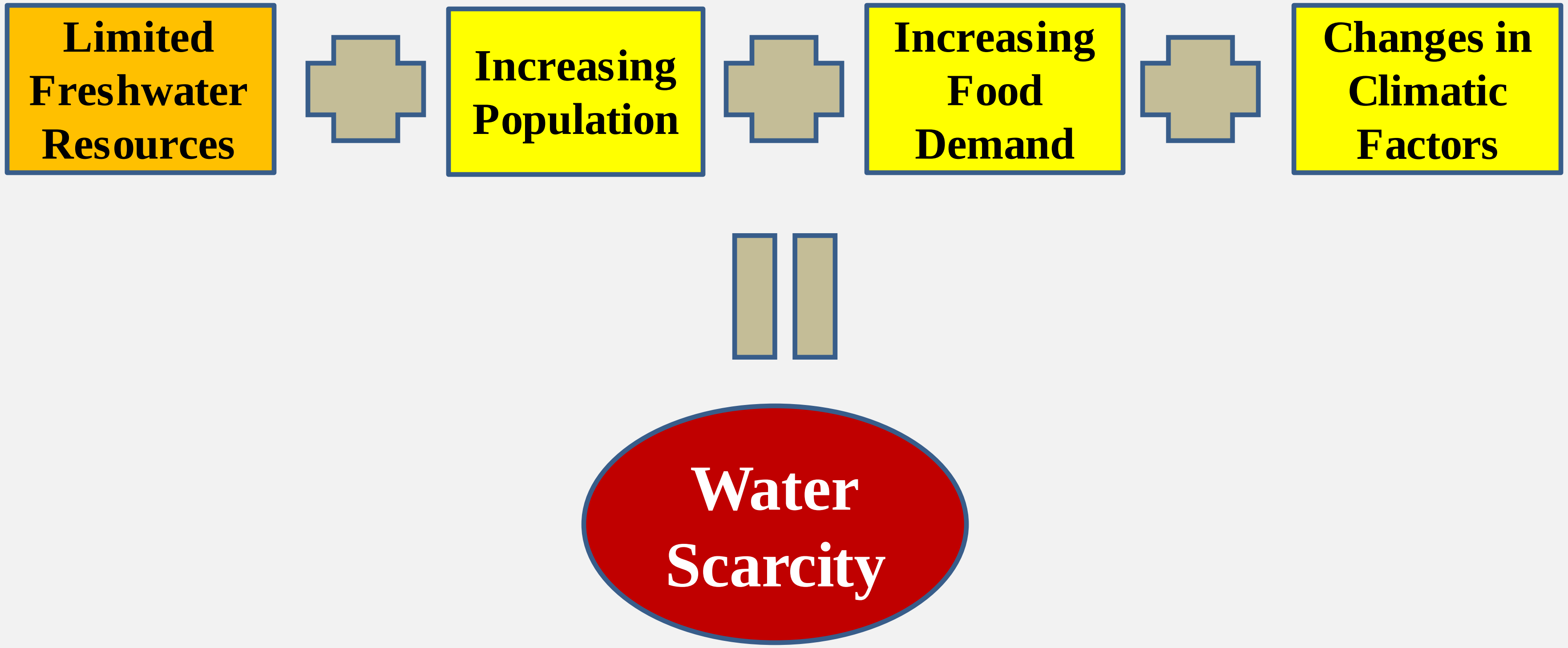
- Earths total water vol. **~ 1.4 billion km^3**
- Current global water demand ~ 4600 km^3 per year
- Projected global water demand ~ 6000 km^3 per year by 2050
- Simple math tells even if we use only 5%, we have at least next 20,000 years of water supply

Our Water Resources

The total usable freshwater supply for ecosystems and humans is -

- Less than 1% of all freshwater resources, and **only 0.01%** of all the water on earth

Water Resources: Global Concerns



- By 2025, 1.8 billion people will be living in countries or regions with absolute water scarcity (<500 m^3/capita/year), and two-thirds of the world's population could be living under water stressed (<1700 m^3/capita/year) conditions

Per Capita Water Supply

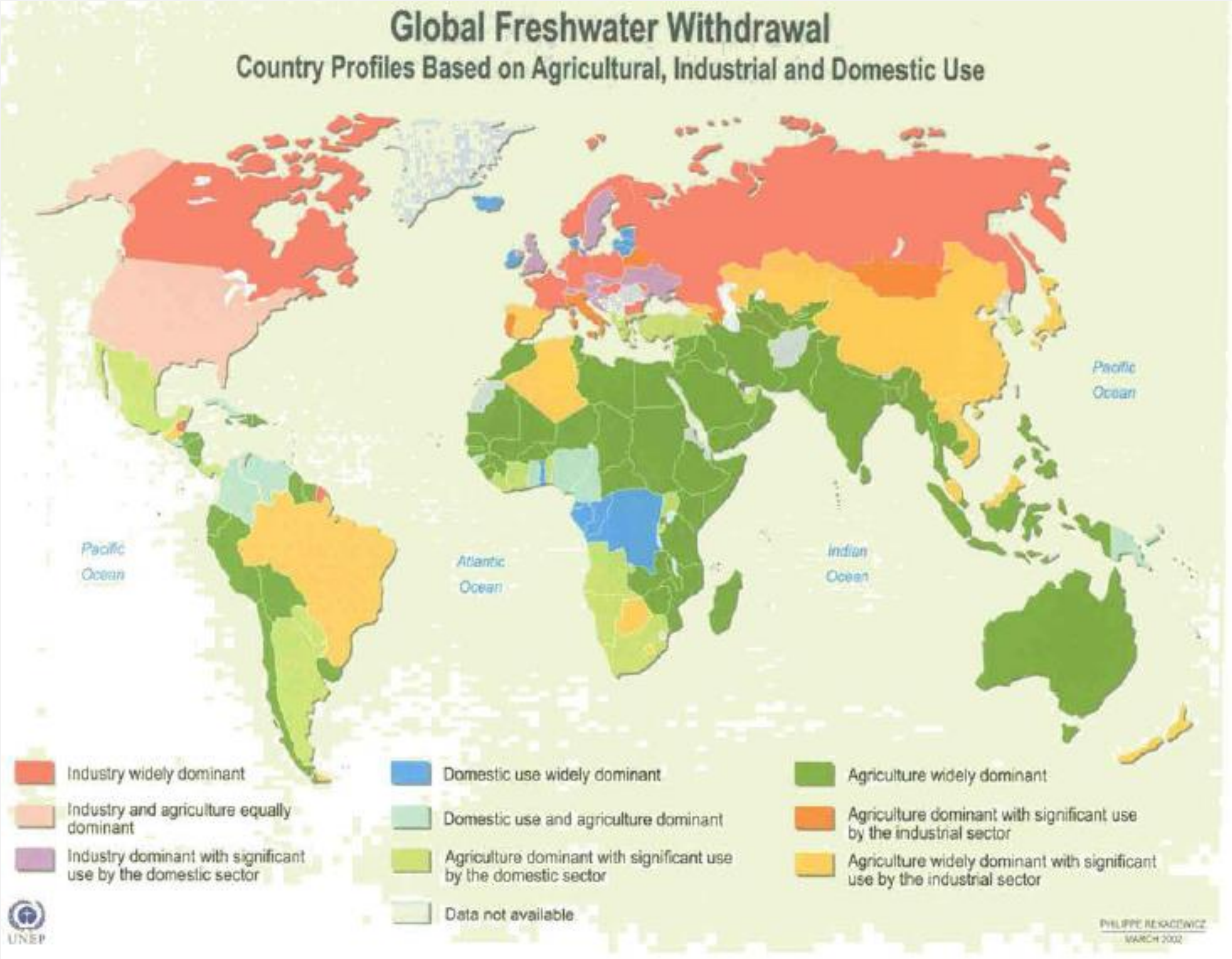
Country	Year 1991	2001	2011	2017	% Reduction since 1991
Canada	103,451	93,713	84,483	77,985	25%
United States	11,997	10,748	9,802	8,668	28%
Iraq	5,028	3,660	2,751	937	81%
Japan	3,504	3,416	3,399	3,392	3%
Ethiopia	2,004	1,733	1,323	1,147	43%
Israel	383	290	235	86	77%
Jordan	260	191	148	70	73%

Source: FAO, AQUASTAT Data, 2022

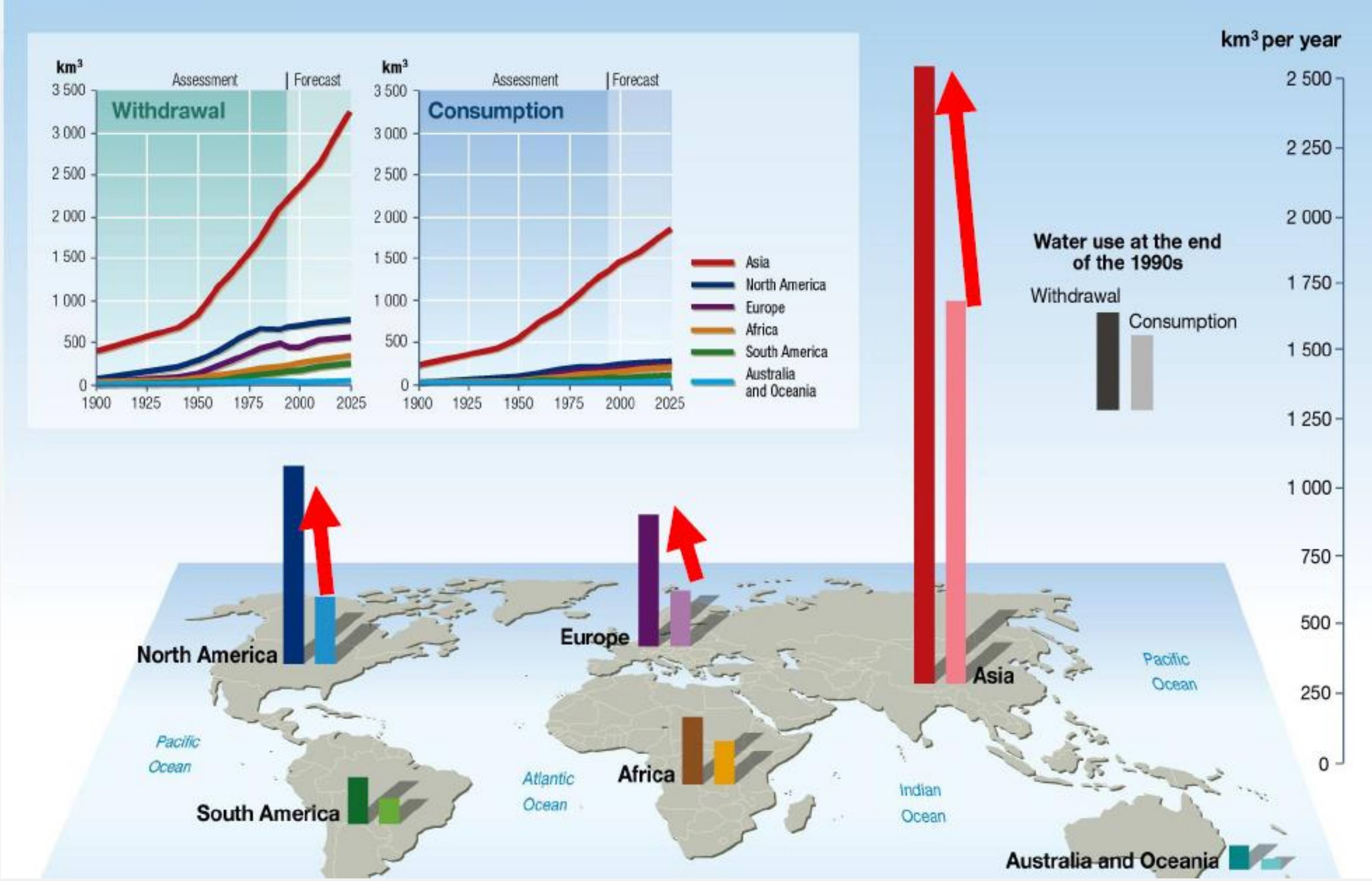
Wastewater Reuse in Agriculture

Global Freshwater Withdrawal

- Agricultural sector is by far the biggest user of freshwater, (70%)
- Second largest consumer sector is Industry (19%)
- Municipal withdrawals is 11%



Withdrawal vs. Consumption

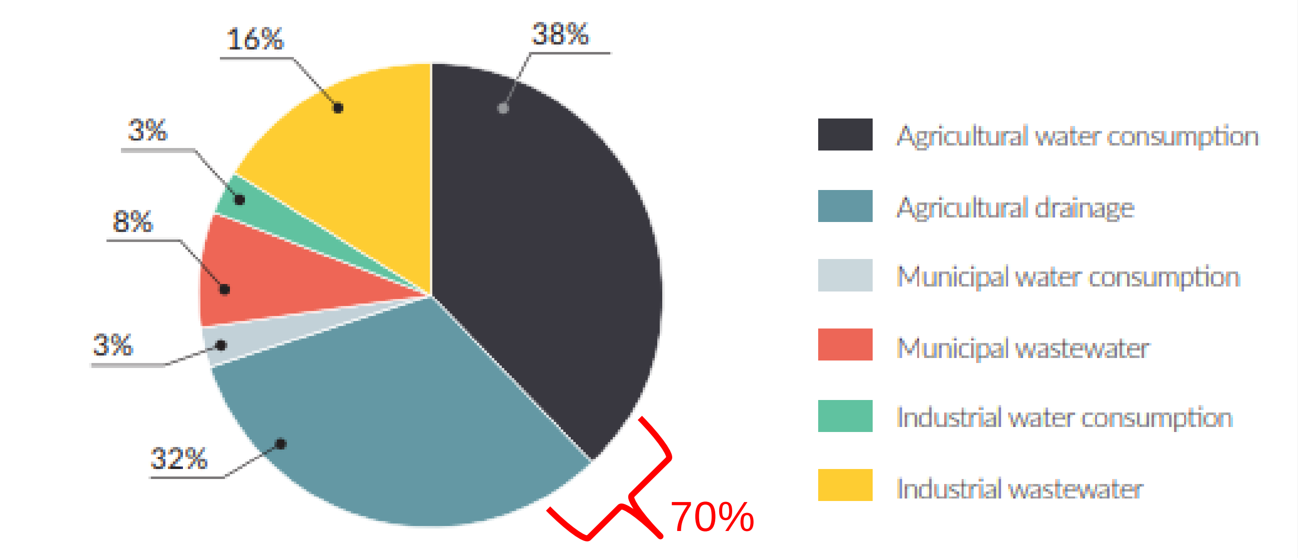


Not all quantity of water withdrawal is consumed

Wastewater

- Represents 56% of global freshwater withdrawals

- Only 6% in the US and less than 3% globally is reclaimed for beneficial use
    - In US, approximately 10 million hectares could be irrigated, representing about half of the irrigated crop area
- Increased recycle rate to 15%, freshwater could last until 2125 instead of 2030



Source: FAO

Research Objective

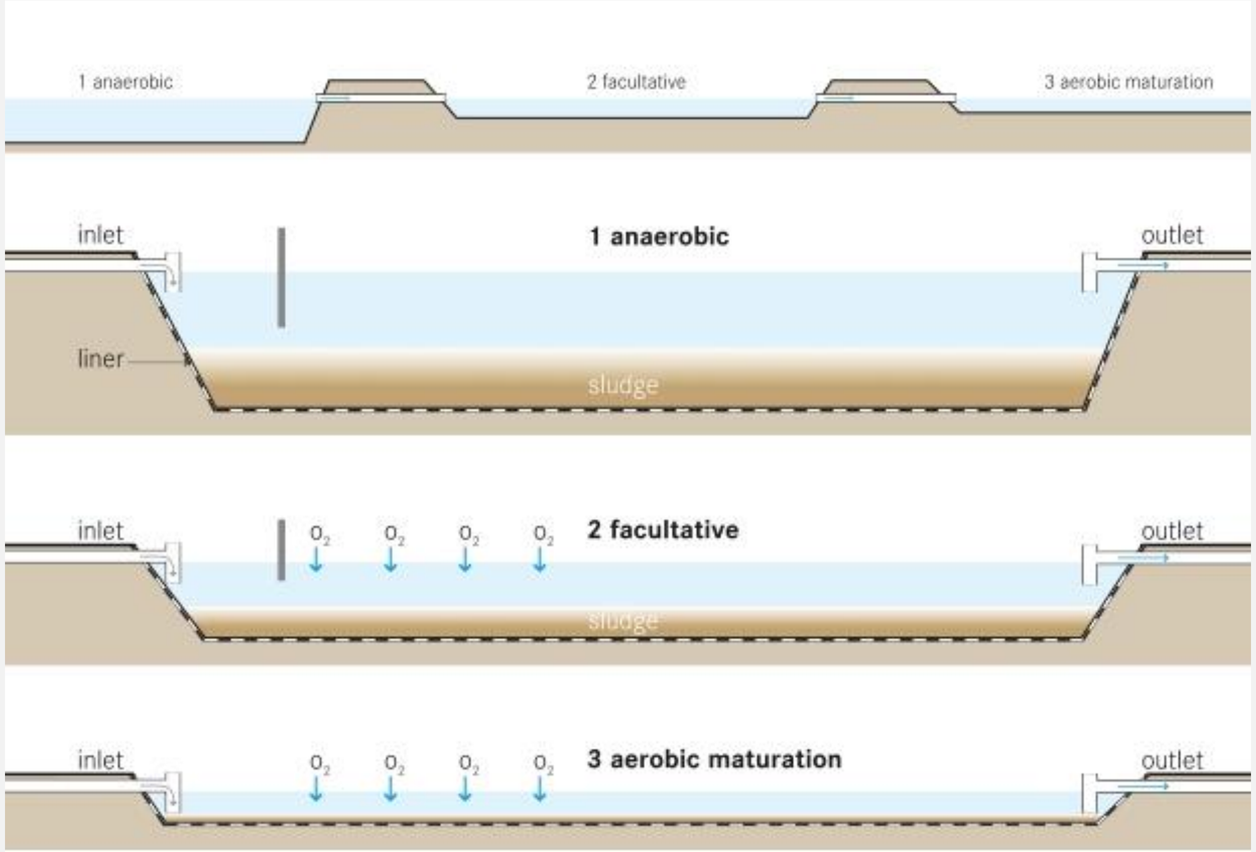
Develop a simple, low-cost adaptable wastewater treatment system that can be used for wastewater reuse in irrigation

Wastewater Reuse in Agriculture

- Reduce stress on freshwater resources
- Less stringent effluent quality standards thus low cost
- Public acceptance
- Readily available and produced at a proximity of demands for crop production
- Nutrient-rich water supply
    - Reduced need for commercial fertilizers

Wastewater Treatment

- Plethora of systems available for treating wastewater
- Ponding Systems - simple, low cost, low energy treatment system
- Pond types – Anaerobic, Facultative, and Aerobic
- Different design approaches



Experiences with Pond Design

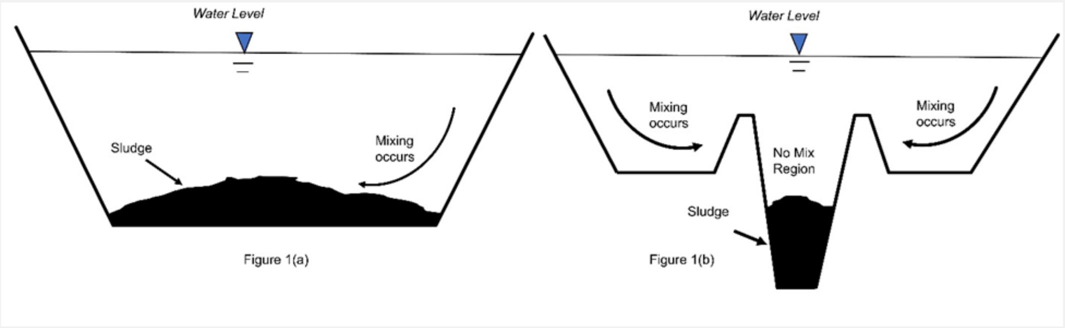
- Large land area requirements
- No agreement on the pond configuration required for optimal performance
    - Loading vs. performance
    - Pond dimensions (depth, retention time) vs. performance
    - Pond configuration (L:W ratio, baffles, I/O locations) vs. performance
- Huge variation in area requirements
- Pond-In-Pond as an alternative system for wastewater reuse

Method	Hydraulic Retention Time, days	Depth, m	Volume, m^3	Surface area, m^2
Wehner-Wilhelm	53.9	2.45	204012	83,270
Surface Area	145.7	2.45	551547	225,124
Complete mix	61.2	2.45	231533	94,503
Gloyna	67.5	2.45	255334	104,218
Plug flow	98.7	2.45	373646	152,508

Pond-In-Pond

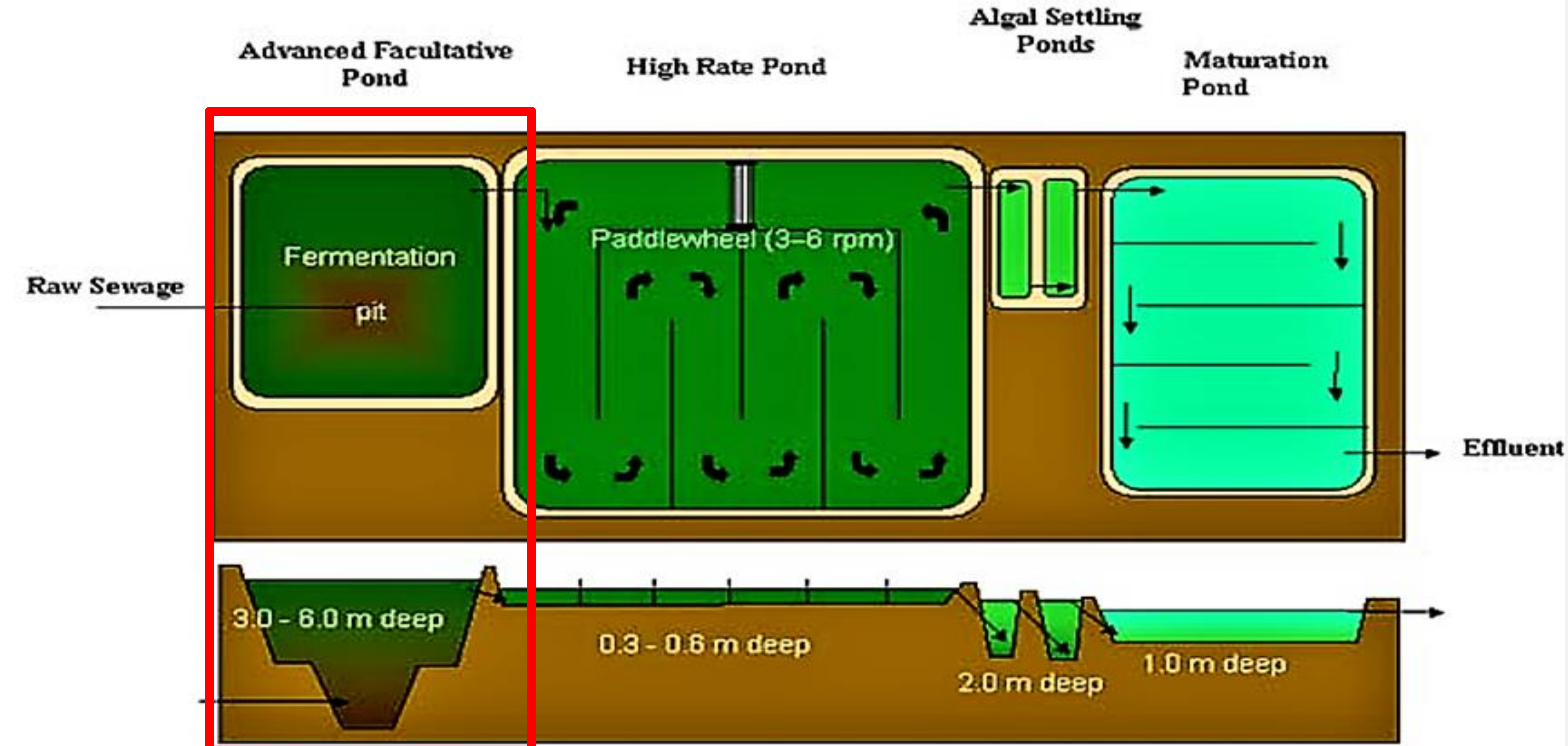
An alternative system for wastewater reuse

- Integrates the best functions of anaerobic and aerobic pond units
- Aerobic near the surface
  - Photosynthetic oxygenation thus removing odors
- Anaerobic at the bottom
  - Complete degradation of organic matter



Example Case Study: AIWPS

Advanced Integrated Wastewater Pond Systems

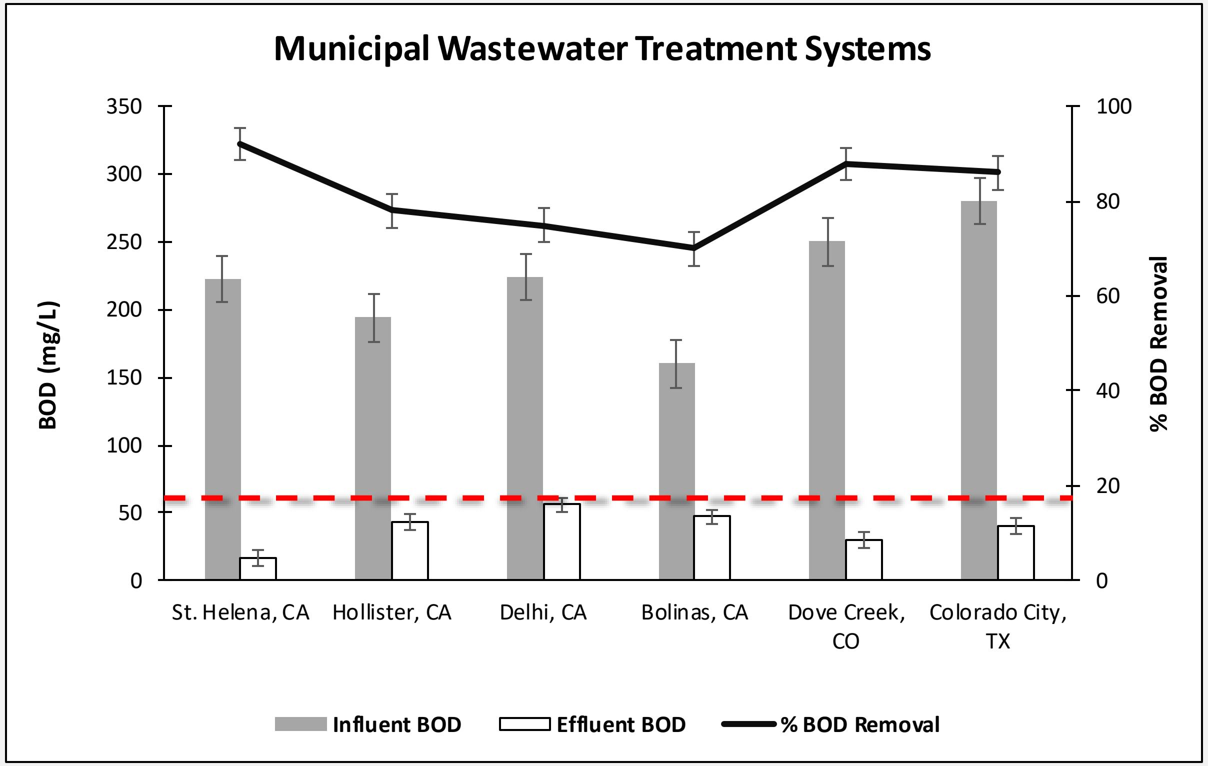


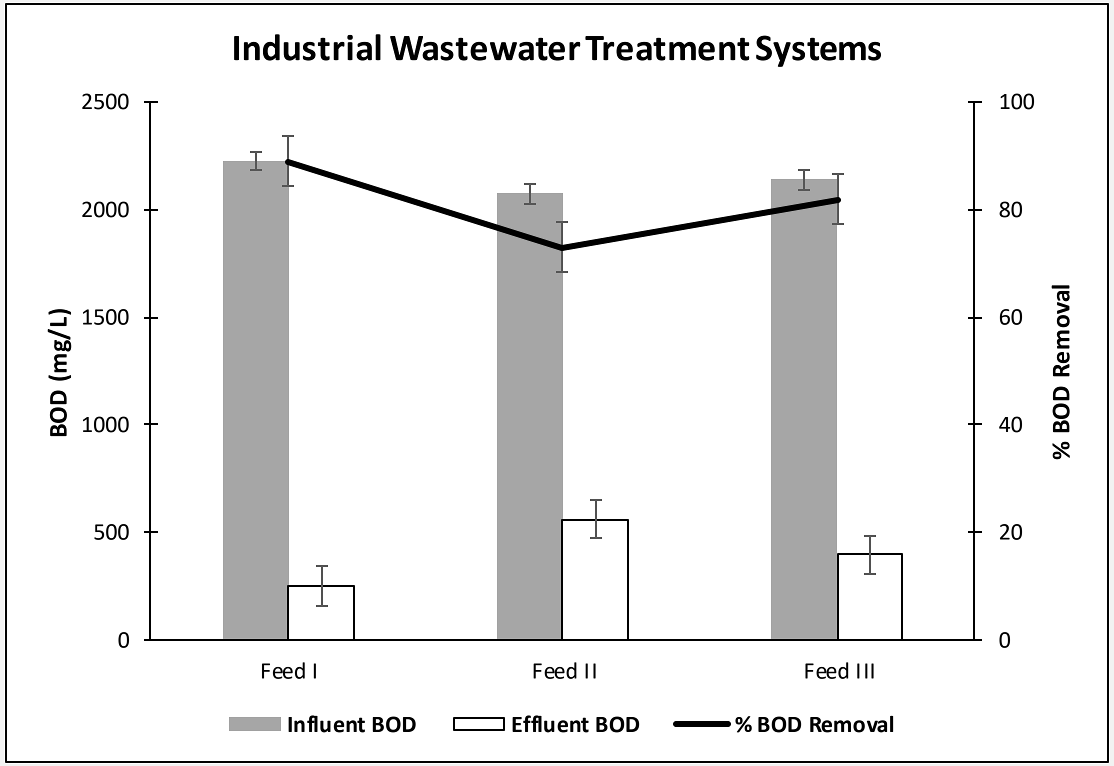
Source: Google images

AIWPS Pond Performance

System	Influent BOD (mgL^{-1})	Pond-In-Pond (PIP)			Advanced Integrated Wastewater Ponding System (AIWPS)	
		Retention time (days)	Effluent BOD (mgL^{-1})	% Removal	Effluent BOD (mgL^{-1})	% Removal
St. Helena, CA*	223	20	17	92	7	97
Hollister, CA*	194	32	43	78	7	96
Delhi, CA*	224	-	56	75	4	98
Bolinas, CA†	160	-	47	70	14	91

Pond Performance Summary





Pond Systems and Land Area Requirements

Waste Characteristics

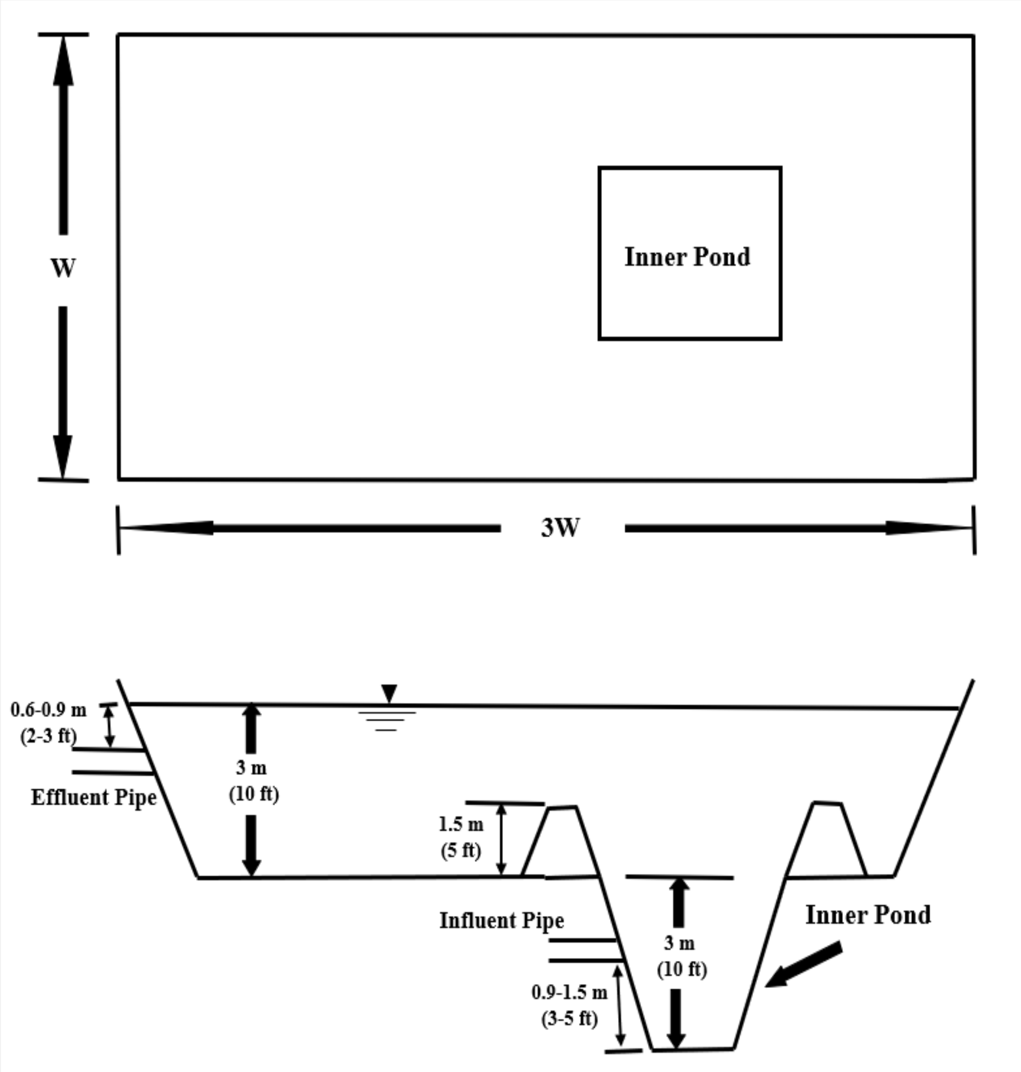
Design Flow Rate (Q):	3786 m^3/d (1 mgd)
Influent BOD_5 (C_o):	200 mg/L
Desired effluent BOD_5 (C_e):	30 mg/L
Avg. summer temperature:	25 C
Avg. winter temperature:	5 C
Avg. annual temperature:	10 C
Avg. annual rainfall:	45.7 cm (18 in)
Avg. annual evaporation:	228.6 cm (90 in)
Waste generation:	100 gpd/capita
Population @ 100 gpd/capita:	10000

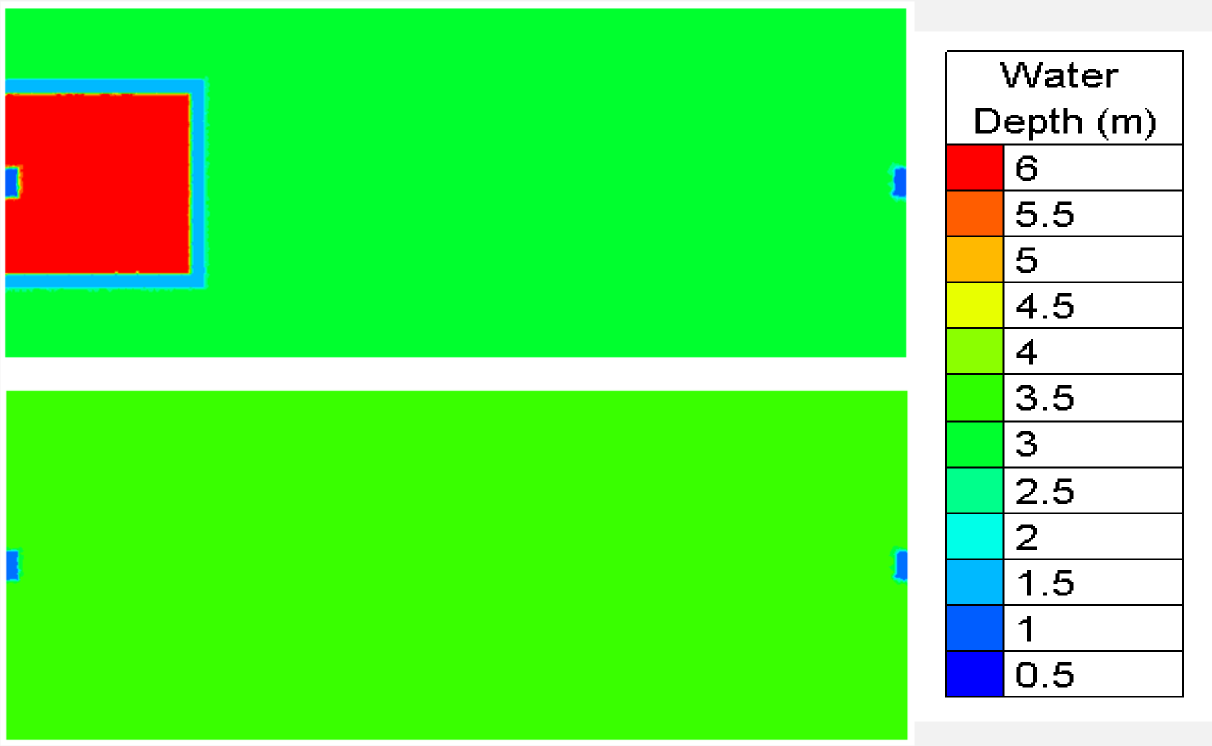
NOTE: side slope for all cases will be 2.5:1

Summary – Municipal W/W only

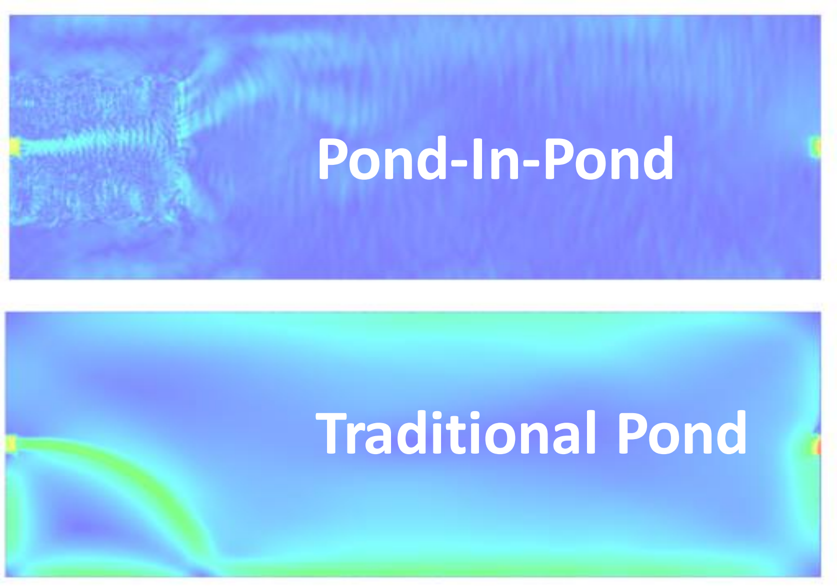
Aerobic:	13.6 ha
Facultative (W-W):	7.2 ha
Facultative (Gloyna):	8.5 ha
Anaerobic (Areal):	8.8 ha
Pond-In-Pond:	3 ha

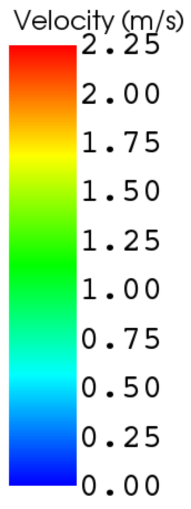
2-D Modelling of PIP

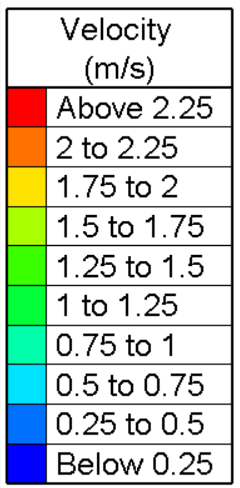




Flow Dynamics using 2-D Modelling

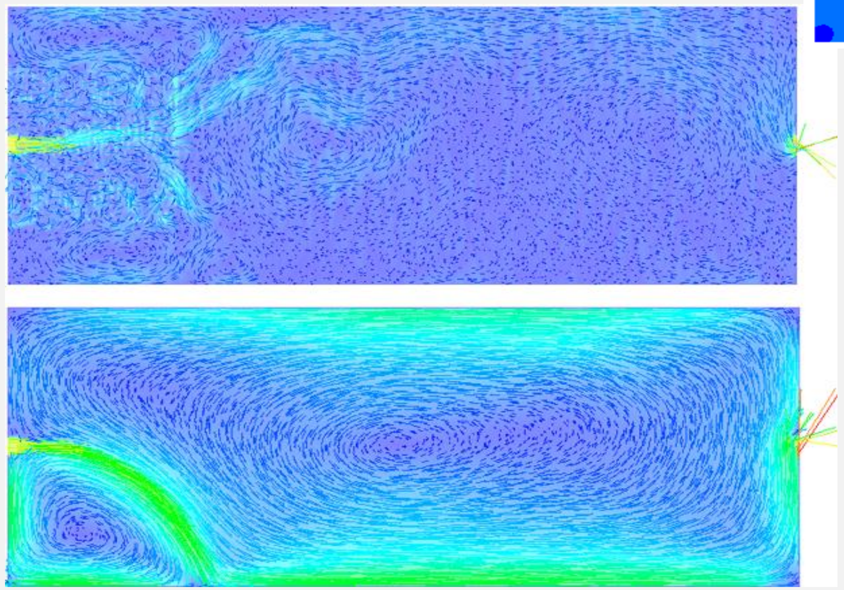






SToRM

TELEMAC-2D

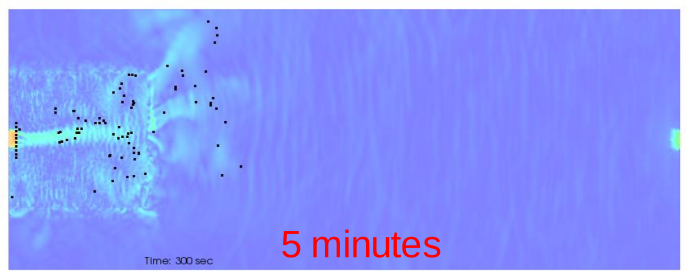


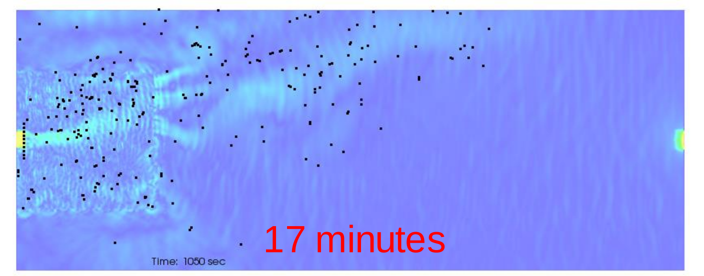
Pond-In-Pond
- **Incoming higher velocity dissipates within the inner basin**
- **More uniformly distributed flow**

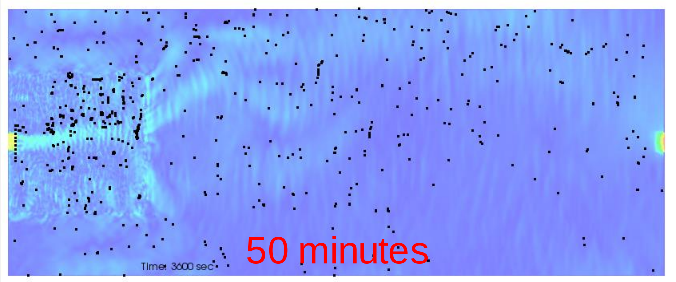
Traditional Pond
- **Incoming higher velocity propagates through the pond**
- **Channelized flow along with rotational movements**

Particles Distribution & Retention

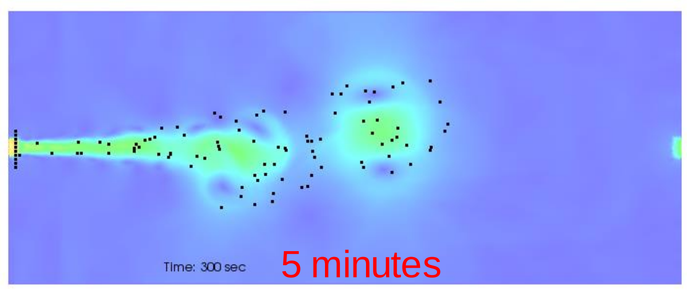
Pond-In-Pond

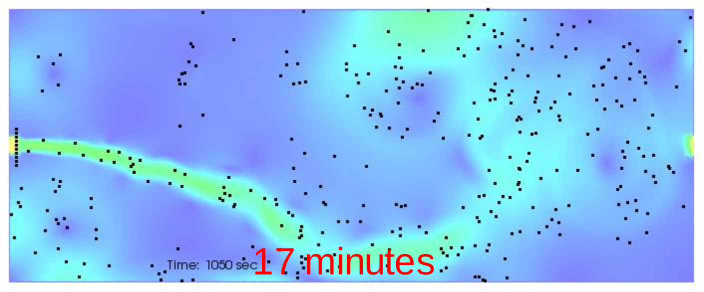


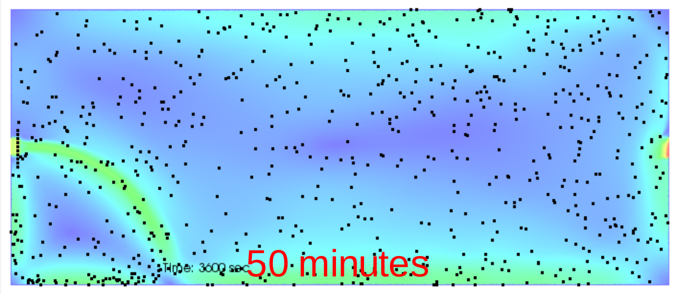




Traditional Pond







- **More particles tend to settle down in the PIP**
- **More particles tend to remain in suspension with reduced chances for particle settling**
- **Higher solids retention in PIP (~17% more)**

Summary

Simple, low cost and easy to operate

- **40-60% reduction in area requirements**
- **Minimum or no maintenance required**
- **Can operate for 20+ years without sludge removal**

Combines best functions of both aerobic and anaerobic units

- **Reduced velocity and higher retention of solids in the PIP; thus, higher treatment levels compared to traditional ponds**
- **Produce effluent within reuse standards**

Best suited for rural and small communities

- **Nearly 85% of wastewater treatment systems serve the population < 10,000**
- **Can be operated as decentralized units; avoids conveyance costs**

Future Research Prospects on PIP

Integrate CFD model with biokinetics model

- In-depth understanding of pond hydrodynamics and biological processes within the pond
- Understand Solids Retention Time (SRT) in inner ponds
  - Determine service life of PIP
  - Use of PIP for handling high strength waste

Integrate CFD model with an optimization model

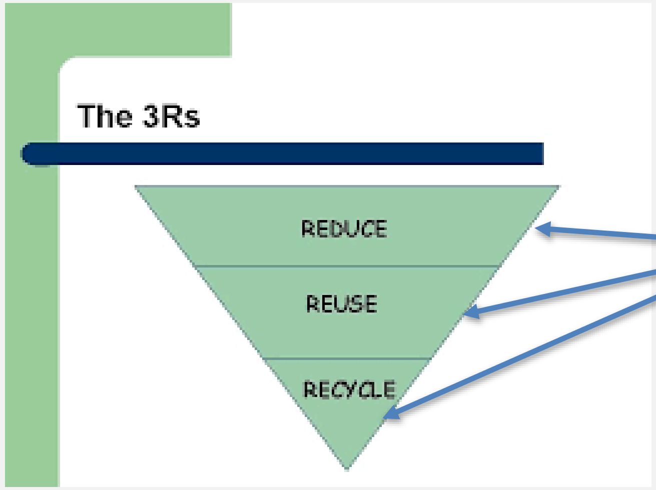
- Design optimization
- Decision support tool to test strategies for multi-objective optimization of PIP systems

Pilot study

- Data collection for other water quality parameters

Address the major societal concern of water scarcity with low-cost and effective wastewater treatment

How can we increase the life of water?



3Rs Approach

Understand and monitor the resources

Manage the available resources

Groundwater Monitoring

Groundwater Monitoring

Observed Head − MODFLOW Simulated Head = MODFLOW Residuals

Application of Kriging on MODFLOW residuals

Year	Observed head	MODFLOW Simulated head	MODFLOW Prediction Error (%)	MODFLOW + Kriging Simulated head	MODFLOW + Kriging Prediction Error (%)
1995	758.7	802.1	5.7	753.6	0.7
1996	697.6	729	4.5	689.1	1.2
1997	683	707.6	3.6	677.4	0.8
1998	694.8	733	5.5	694.6	0.0
1999	716.5	744.8	3.9	714	0.3
2000	644.7	665.5	3.2	646.5	0.3
Average error (%) in water level predictions			4.4		0.6

Application of kriging on MODFLOW residuals reduced the water level prediction error by approximately 90%

Predicted values were within 1% off from the observed values after kriging

Develop more accurate potentiometric surface maps

- **Improve monitoring and management of groundwater resources**
- **Sustainable use of groundwater resources**
- **Efficient and effective conjunctive management of surface and groundwater resources**

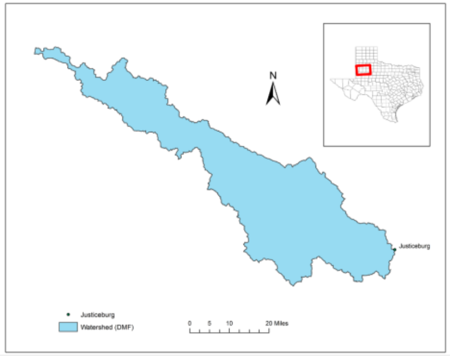
Climate-Smart-Agriculture

TARGET

- Maximize yield (Cotton)
- Optimize available water resources

SOLUTION

- Climate - Smart – Agriculture
  - Sustainable adaptation strategy



OBJECTIVES

- Develop a Watershed Model for the Double Mountain Fork (DMF) watershed.
  - Soil Water Assessment Tool (SWAT) adopted here
- Assess the impacts of future climate change on crop productivity.
  - Cotton response to future climate and adaptability study of dryland cotton production.

Dryland Cotton Production

- Over 50% of water requirement is supplied through precipitation.

Earlier shift in planting dates

- Heat units (Temperature projection)
- Increased precipitation (April – September)
- From Mid-May to Mid/End-April

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