THE FRAMEWORK PROGRAMME FOR RESEARCH AND INNOVATION
HORIZON 2020
FREEWAT

European Commission

EIP Water Online Market Place
Matchmaking for water Innovation
MAR Solutions - Managed Aquifer Recharge Strategies and Actions (AG128)

Evaluating processes, parameters and observations using computationally frugal sensitivity analysis and calibration methods

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Workshop
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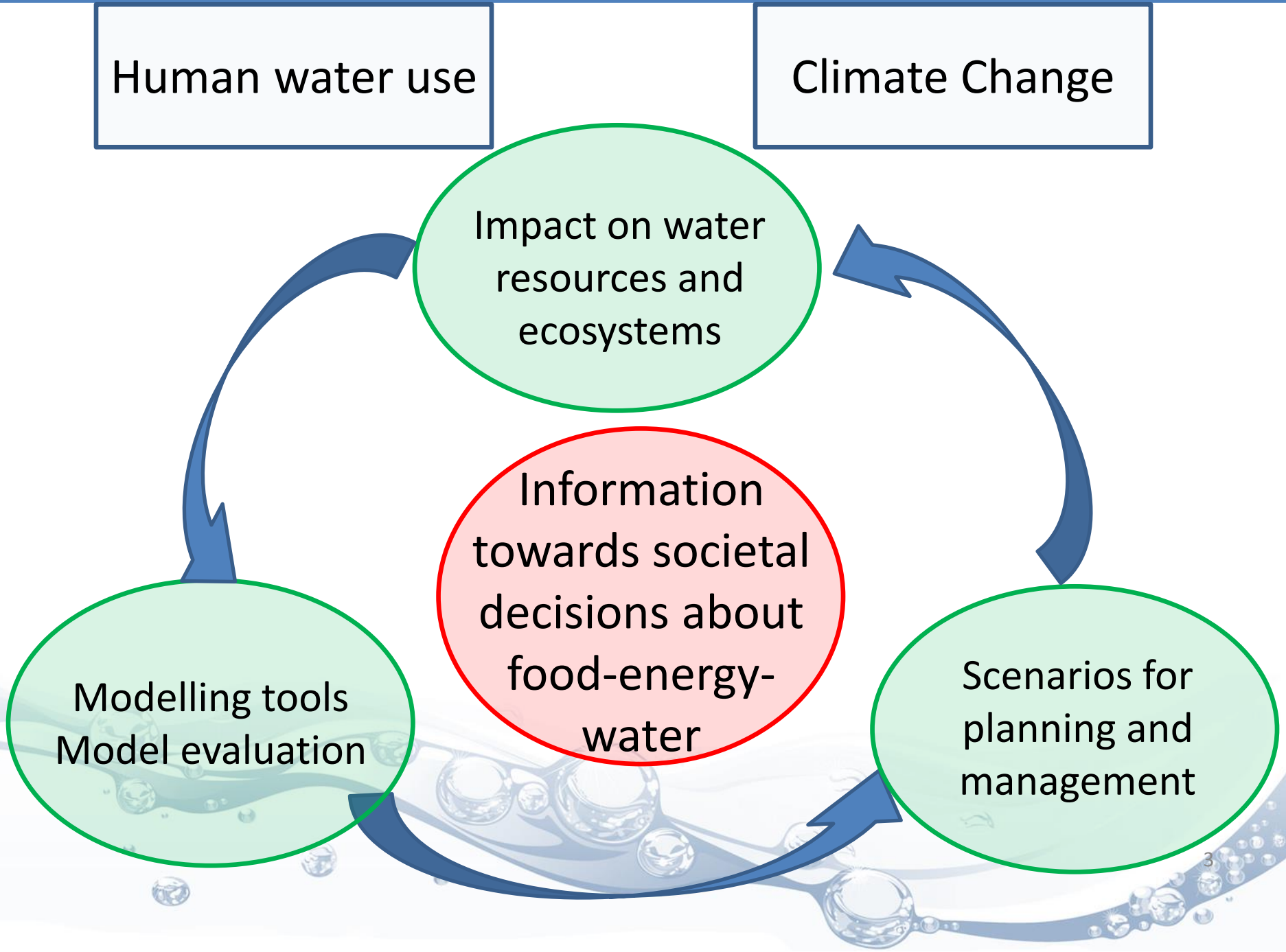
TECHNISCHE UNIVERSITÄT DARMSTADT

Outline

- Environmental models → many parameters → computationally fast methods for «model evaluation» → model testing to check consistency of processes, parameters, and goodness of fit
- Uncertainty analysis → communicate model results and uncertainty!
- Development of models to understand the systems
  - Examples from two case studies: Maggia Valley, Switzerland and Scott Valley, CA
  - **Use models to guide data collection**


Human water use
Climate Change
Impact on water resources and ecosystems
Information towards societal decisions about food-energy-water
Modelling tools
Model evaluation
Scenarios for planning and management

Modelling tools

- Integrated hydrological models wit many parameters
- Sensitivity analysis, calibration, uncertainty evaluation
  - computationally fast vs slow analyses
  - simple vs complex models

How do we use these for models for water management?

increasing model complexity to represent multiple processes and guide integration of multiple data types/obs.

Fast methods

Model development, sensitivity analysis and calibration (UCODE_2014; Poeter +, 2014)

- Need to be explored for highly non linear and non ideal problems!

Importance of observations to parameters: fit independent statistics (based on linear regression theory, Hill and Tiedeman, 2007), i.e.:

Dimensionless Scaled Sensitivity:

$$DSS_{ij} = \left(\frac{\partial y'_i}{\partial b_j} \right) \Big|_{\underline{b}} |b_j| \omega_{ii}^{1/2}$$

Can fast methods attain the needed understanding for our model development?

- Given the model as constructed
  - What parameters (and processes) are most important to the observations or the predictions of interest?
  - Which observations are most important to the estimated parameter values?
  - What new observations would be most useful to estimated parameters? to predictions?

Sensitivity Analysis

  - What parameter values produce the best fit to observations?

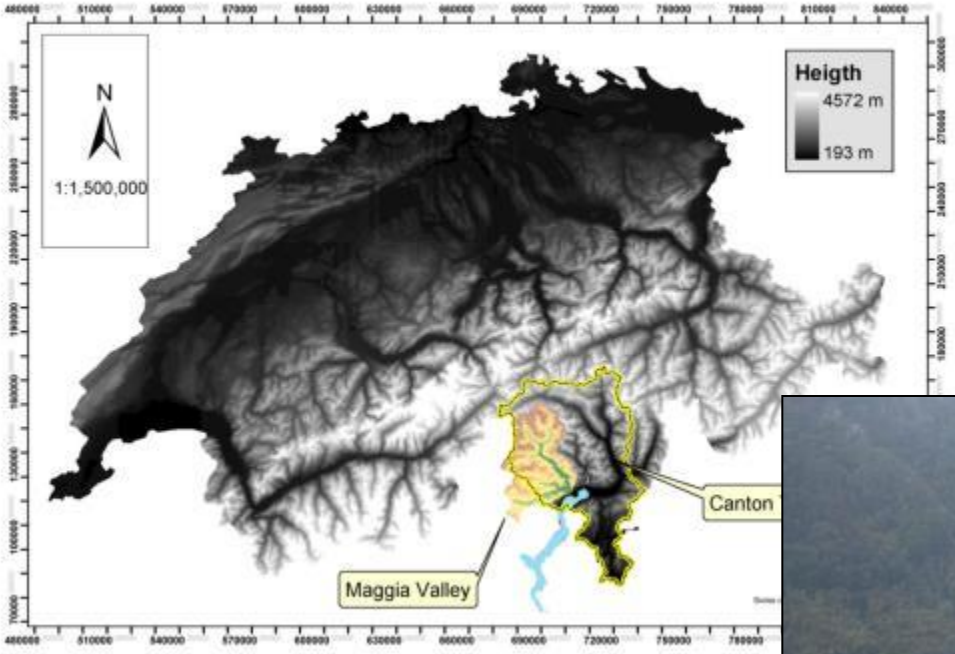
Regression

Goal of the model?

Use models to quantitatively connect

Processes-Obs-Parameters-Predictions

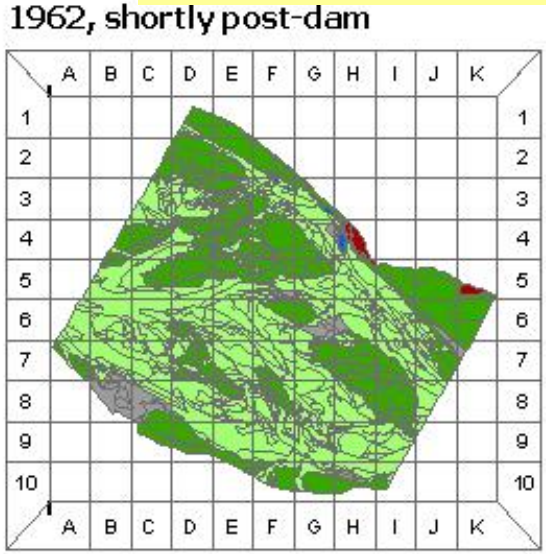
The Maggia Valley, Southern Switzerland

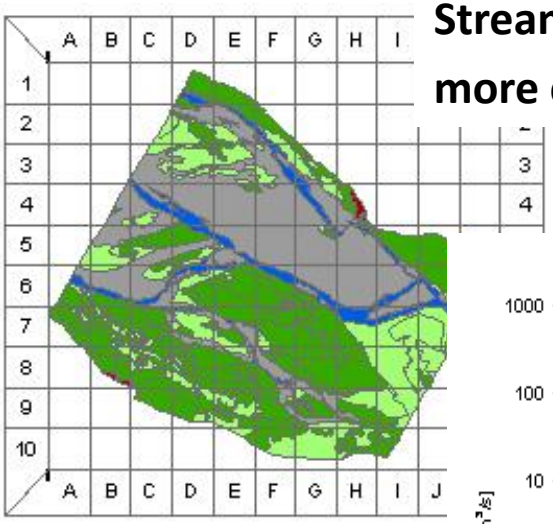


http://www.maggia.ethz.ch

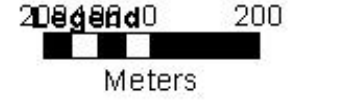
Changes in vegetation and river patterns

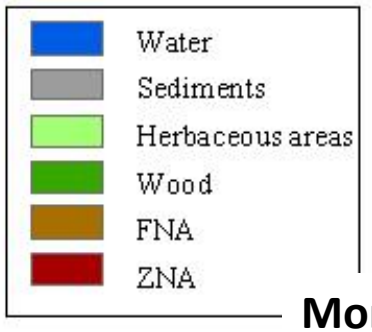
EFR started 1969, Big floods 1978 and 1987

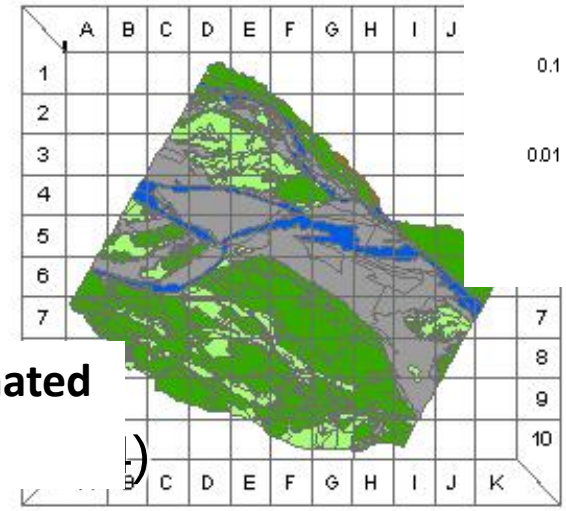




Stream becomes more channelized

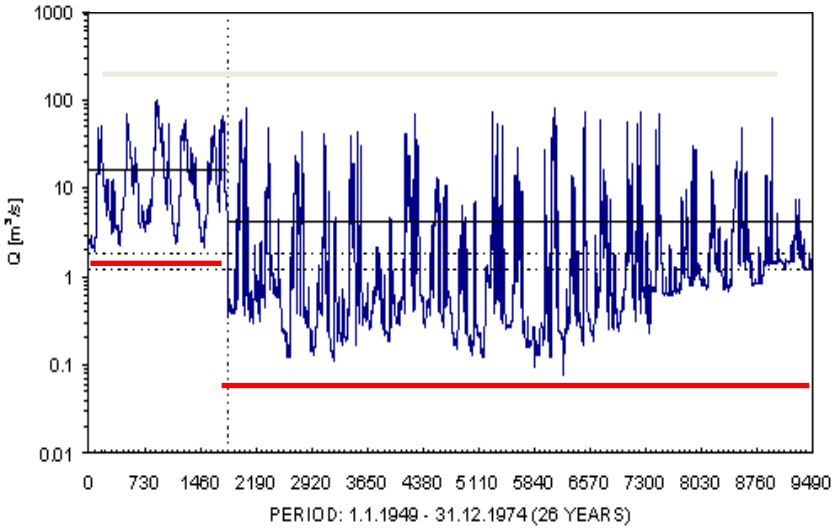






More dominated by forests

Flows from 1949-1974



As expected the significant change is in the low flows

Models: simple to complex

GROUNDWATER: MODFLOW-2000 (Harbaugh+, 2000; Hill+,2000)

- Two confined aquifers, water table approximated
- River Package (simple and fast) and SFR package
- 25m grid resolution to match DEM
- Steady state, Short execution time – few minutes

HYDROLOGICAL MODEL: TOPKAPI

TOPographic Kinematic APproximation and Integration physically based distributed rainfall-runoff model based on the integration in space and time of the non linear kinematic wave model [Todini & Ciarapica, 2002, Liu & Todini, 2002].

INTEGRATED MODEL: TOPKAPI+MODFLOW

- TOPKAPI output → distributed recharge into MODFLOW

Increasing Complexity

Which observations are impor[illegible]nd unimportant?

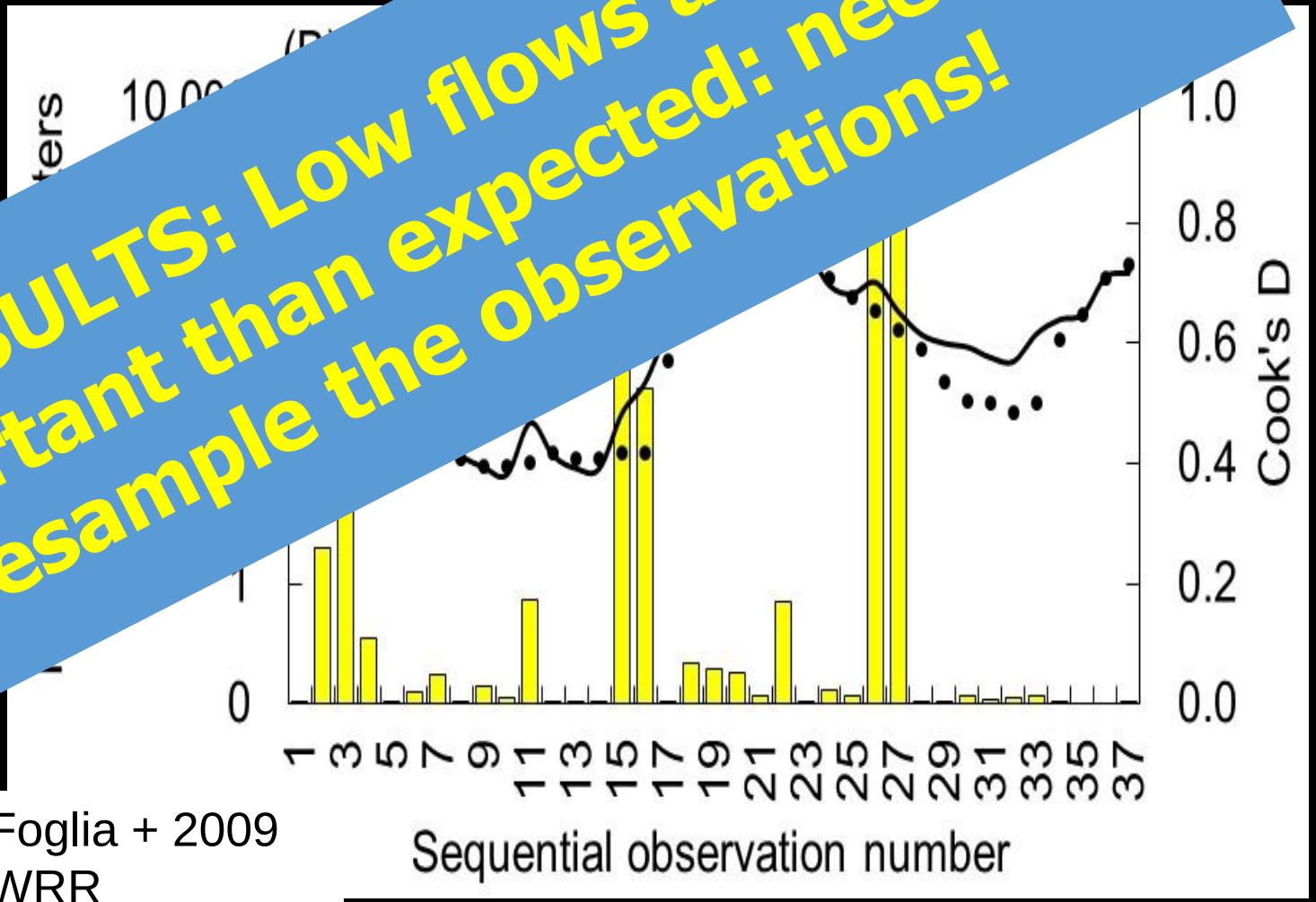
High bars indicate important parameters

Learn[illegible]

so[illegible]

[illegible]mple low flows.

→ **RESULTS: Low flows are more important than expected: need to resample the observations!**

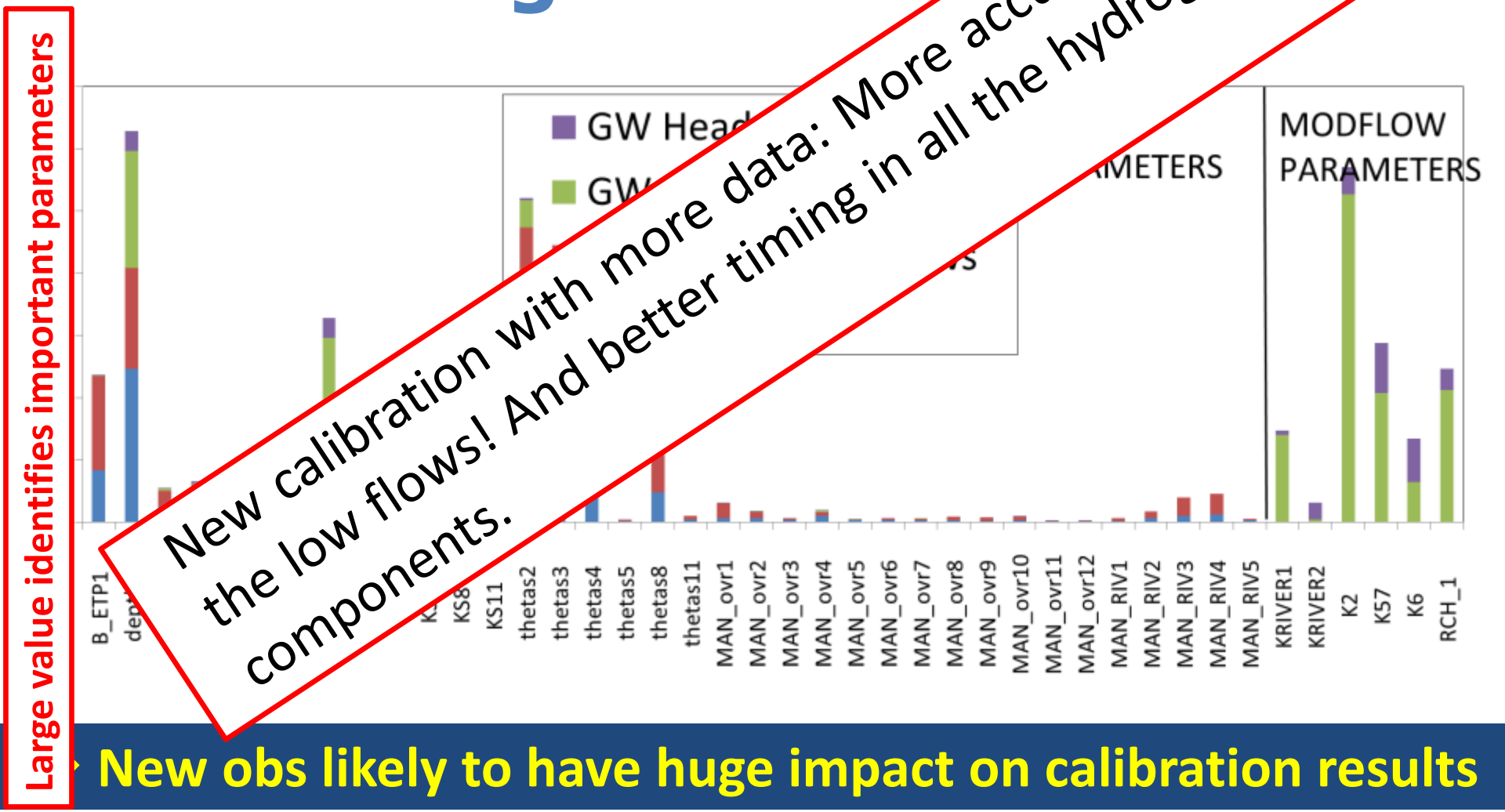


Foglia + 2009 WRR

New obs., processes, & parameters

- New Obs. - based on findings of WRR 2009 paper:
  - Increase obs from ~ 40 to 206 at all three stations
  - Improve representation of all parts of the hydrograph (low flows, flood peaks, and the rising and falling limbs).
- New Processes - Hydrological model coupled to the GW model
  - 3D GW flow + stream/aquifer interaction processes
- New Parameters (Summary)
  - 36 Rainfall/Runoff parameters
    - – ET, soil depth, conductivity, water content, Manning's n
  - 6 GW parameters
    - Recharge, aquifer and streambed conductivities

Parameter importance for t
revised integrated mod



Large value identifies important parameters

New calibration with more data: More accurate fit to the low flows! And better timing in all the hydrograph components.

- New obs likely to have huge impact on calibration results

Foglia et al., Parameter and Observation Importance in Modeling Integrated Surface-Water/Groundwater Systems , in prep.

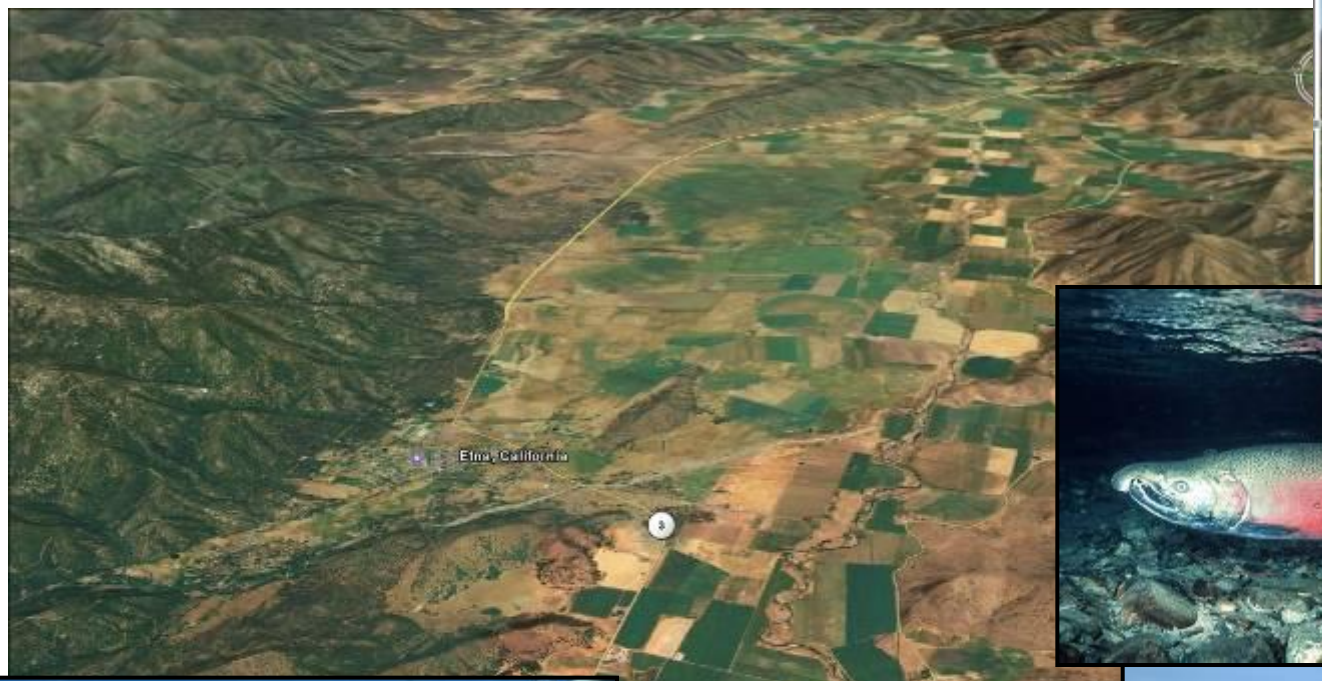
Maggia example: preliminary conclusions

(1) Low flows and high flows observations in the surface water model have similar impact on the most important parameters

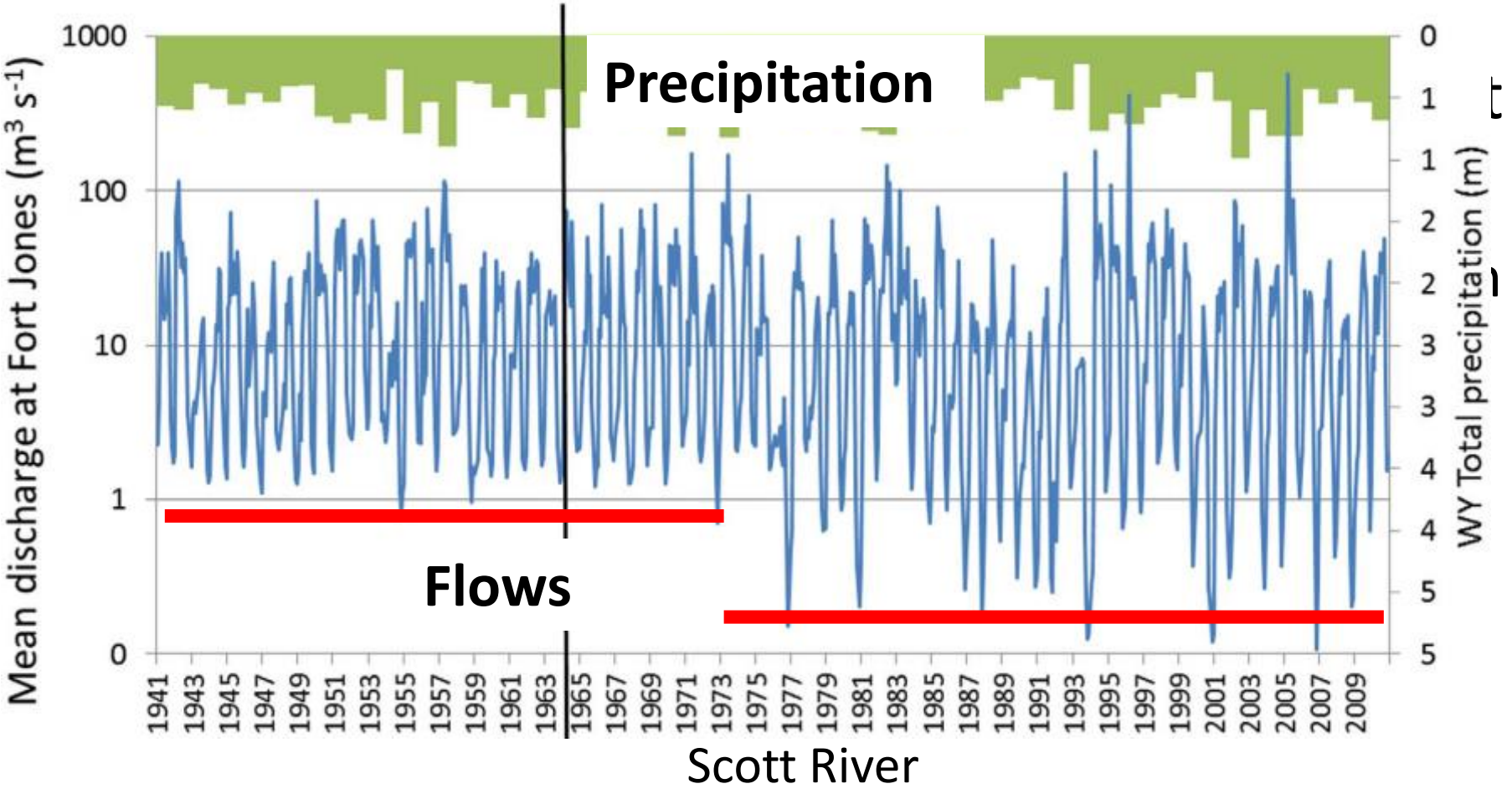
(2) Importance of properly sampling the observations (mainly SW)!!!

Preliminary results → important directions for future work

Agriculture and fish:
the Scott Valley example



Motivation

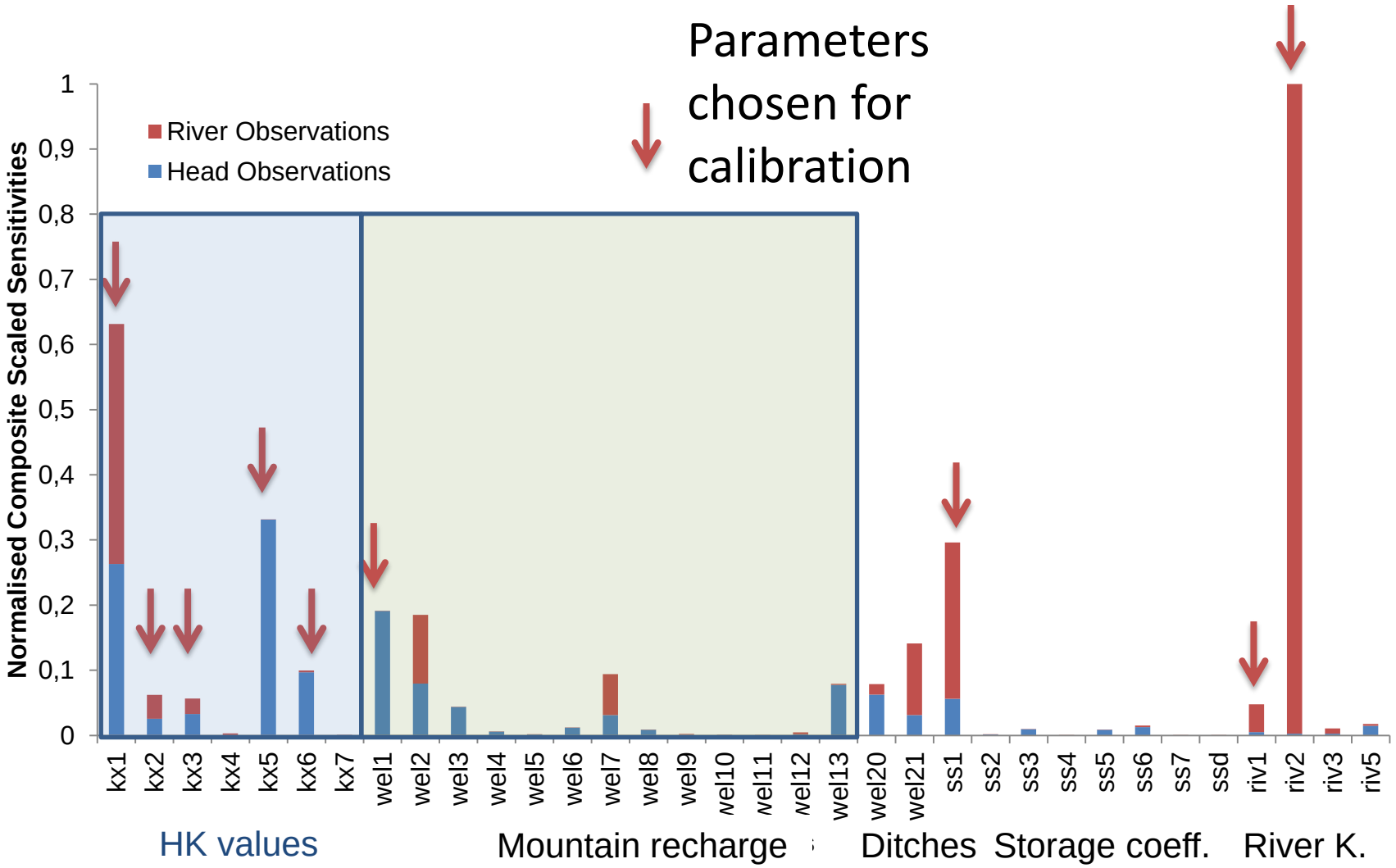


- **Many groups of stakeholders involved: farmers, fishery and native americans**

Importance of observations to parameters (using CSS): RIV model

With heads and GW/SW fluxes as observations

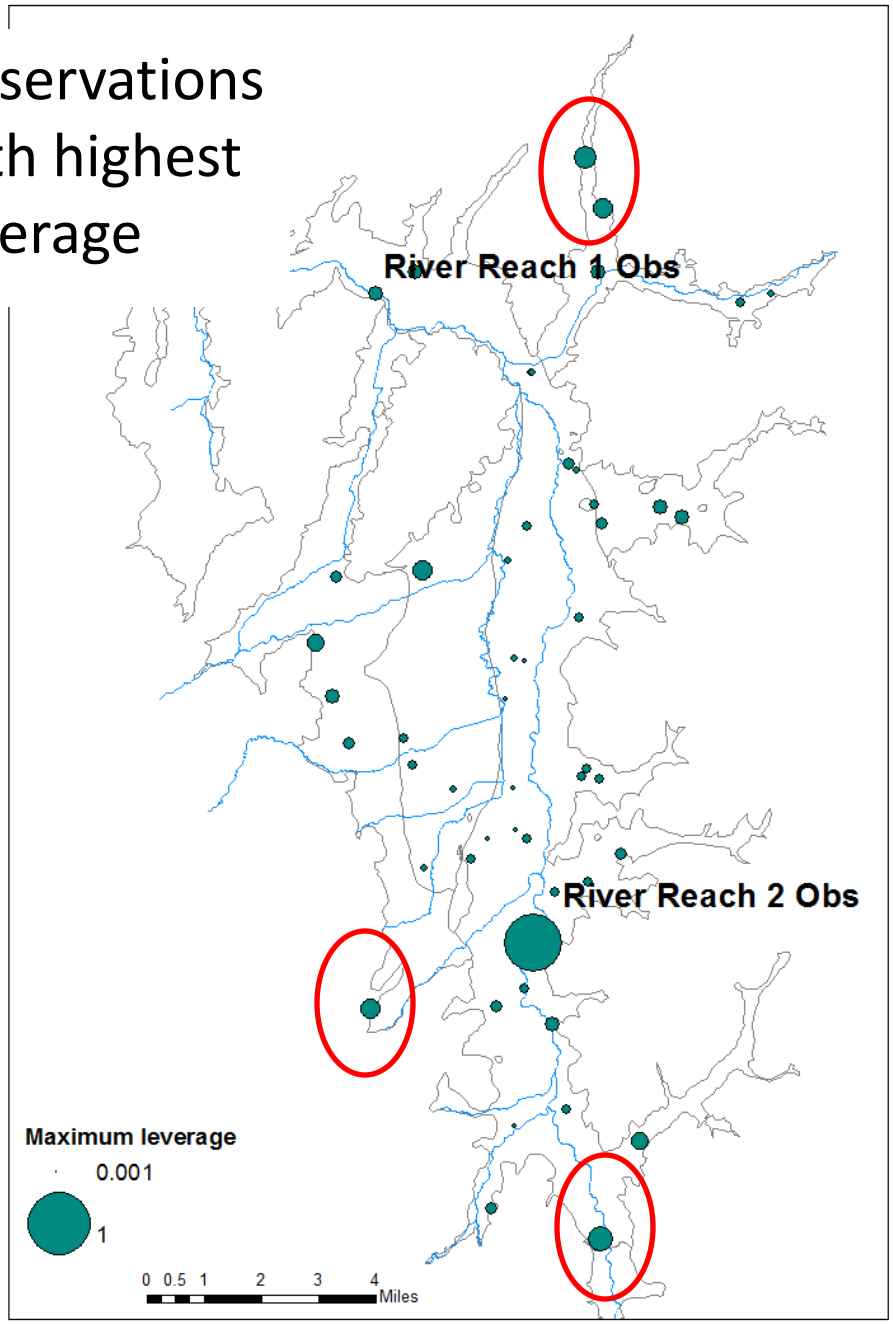
Large value identifies important parameters



Importance of observations: leverage

Observations have High leverage if they they have the **POTENTIAL** to offer new information based on type, time or location.

20 Observations with the highest leverages: among these the two river gain/loss obs



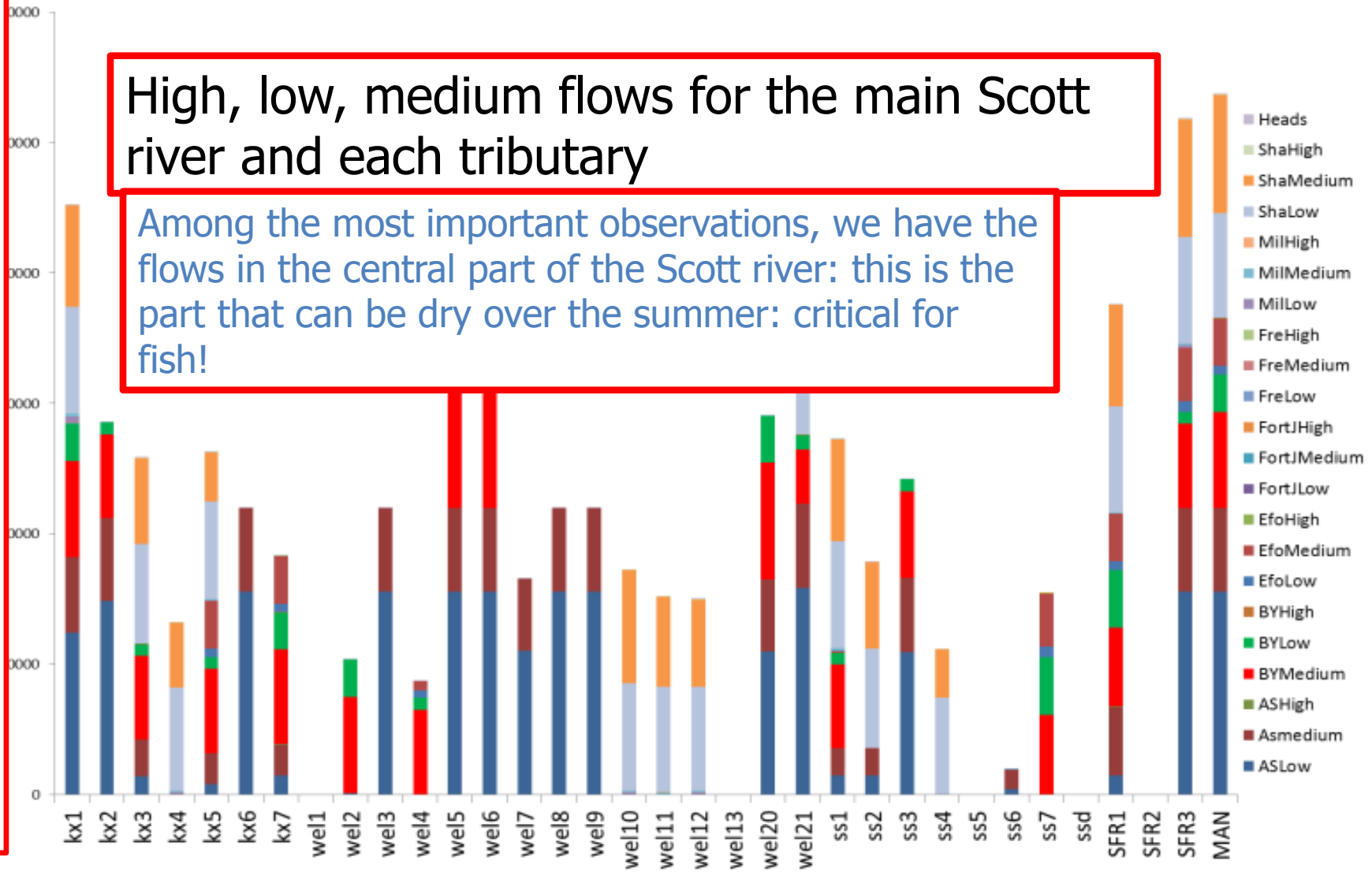
Increase model complexity: From RIV to SFR model

SFR-related

Large value identifies important parameters

High, low, medium flows for the main Scott river and each tributary

Among the most important observations, we have the flows in the central part of the Scott river: this is the part that can be dry over the summer: critical for fish!



Use the model evaluation to plan data collection

- More head observations do not seem to be critical

- Fluxes in the river are critical, especially in the summer, when flows are dominated by baseflow.

  - Mapping of dry reaches in the summer (already planned)
  - More summer streamflow measurements along the main Scott river

How do we use these info for our model for water management?

Our goal: proper simulation of summer low f

- Seasonality well represented
- Low flows generally simulated accurately → worst low flows results for the very dry 2001
- High flows still underestimated → some water in the valley is still missing, need to improve watershed model and mountain recharge?

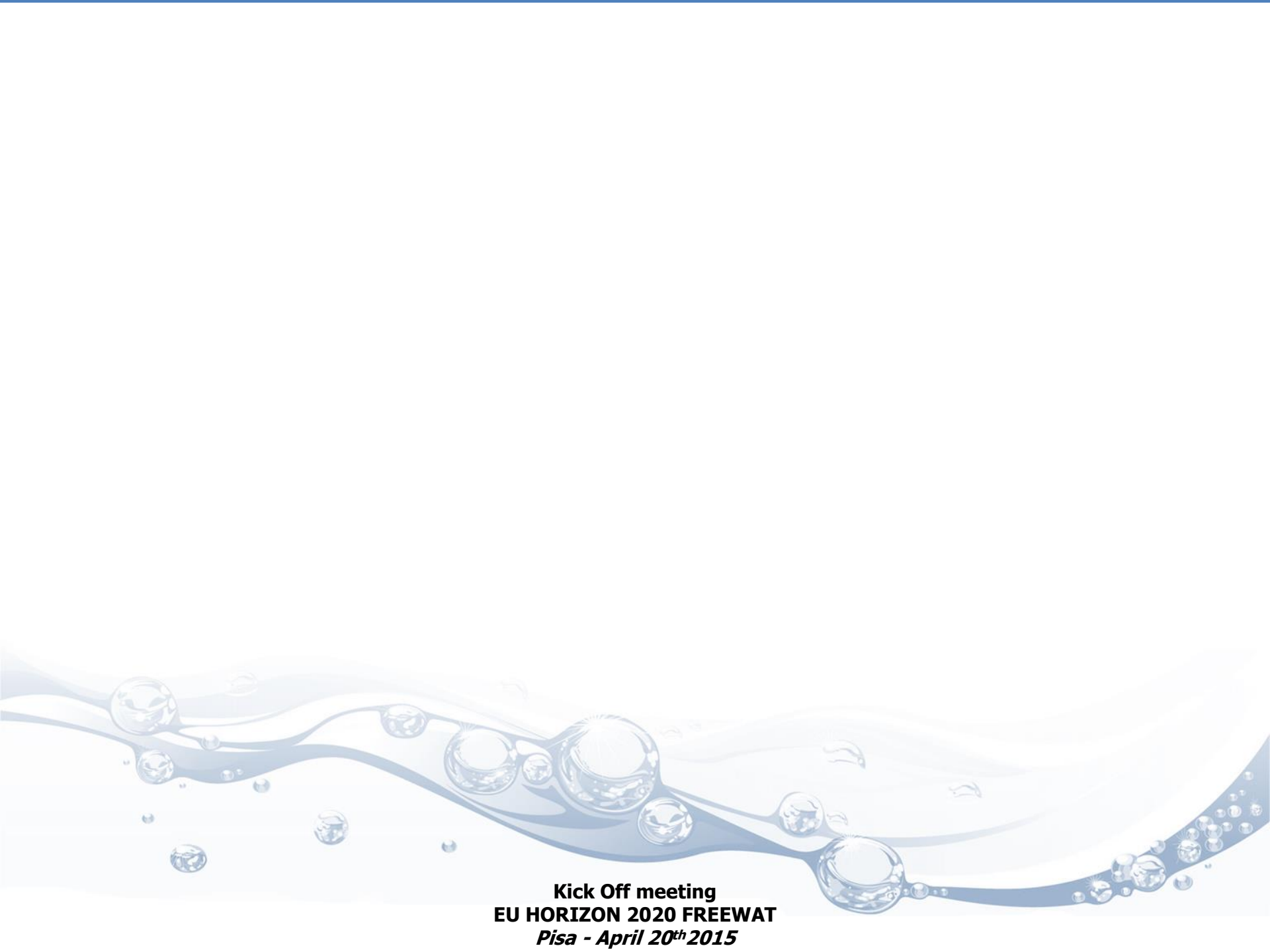
Now use the model to design scenarios!

Conclusions

- Models: simple vs. complex

- Proper model evaluation
  - Adding complexity is justified when supported by the available data
  - Evaluate parameter-processes-observations

- Importance of using model to guide data collection and to design management scenarios



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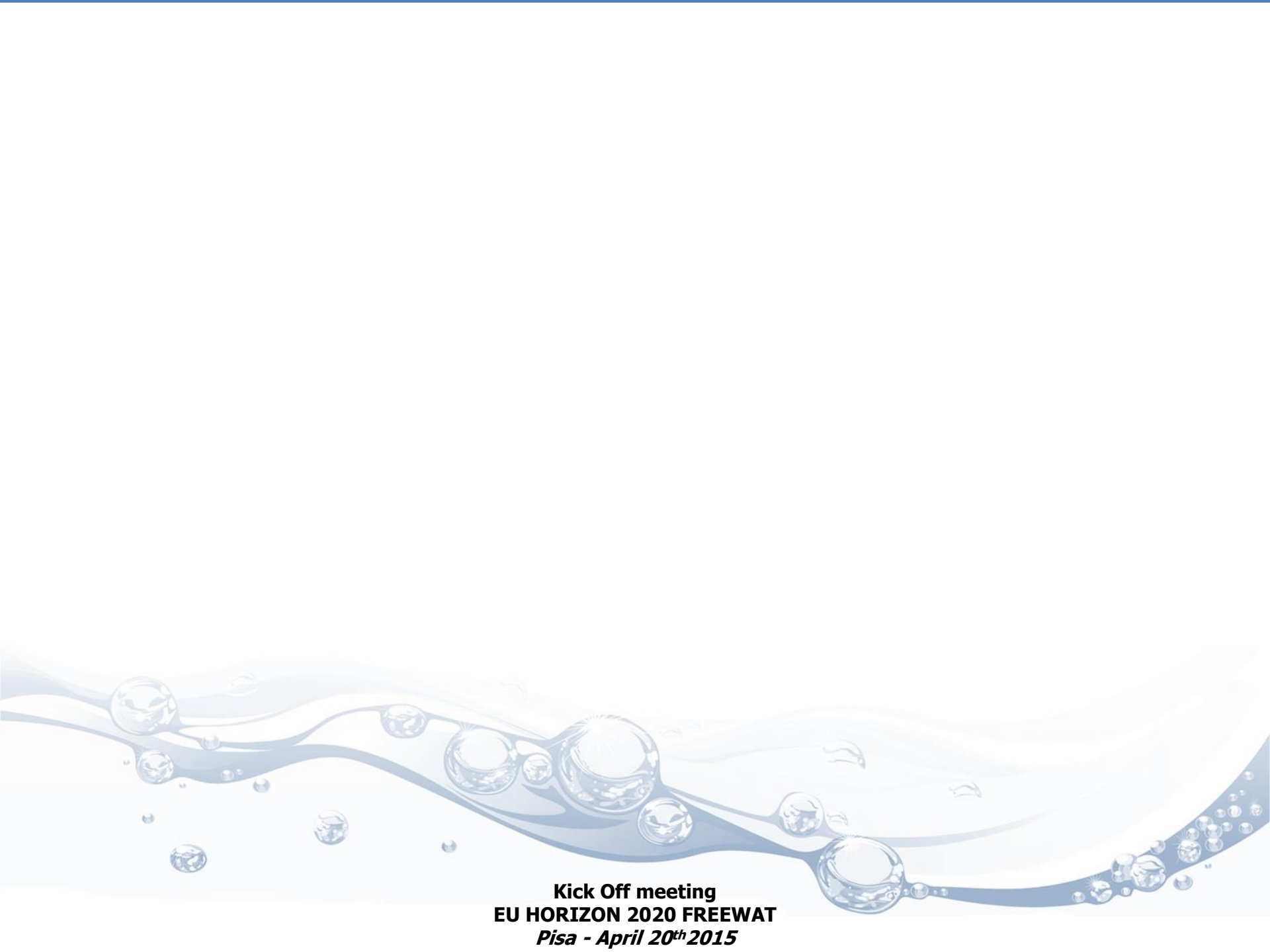

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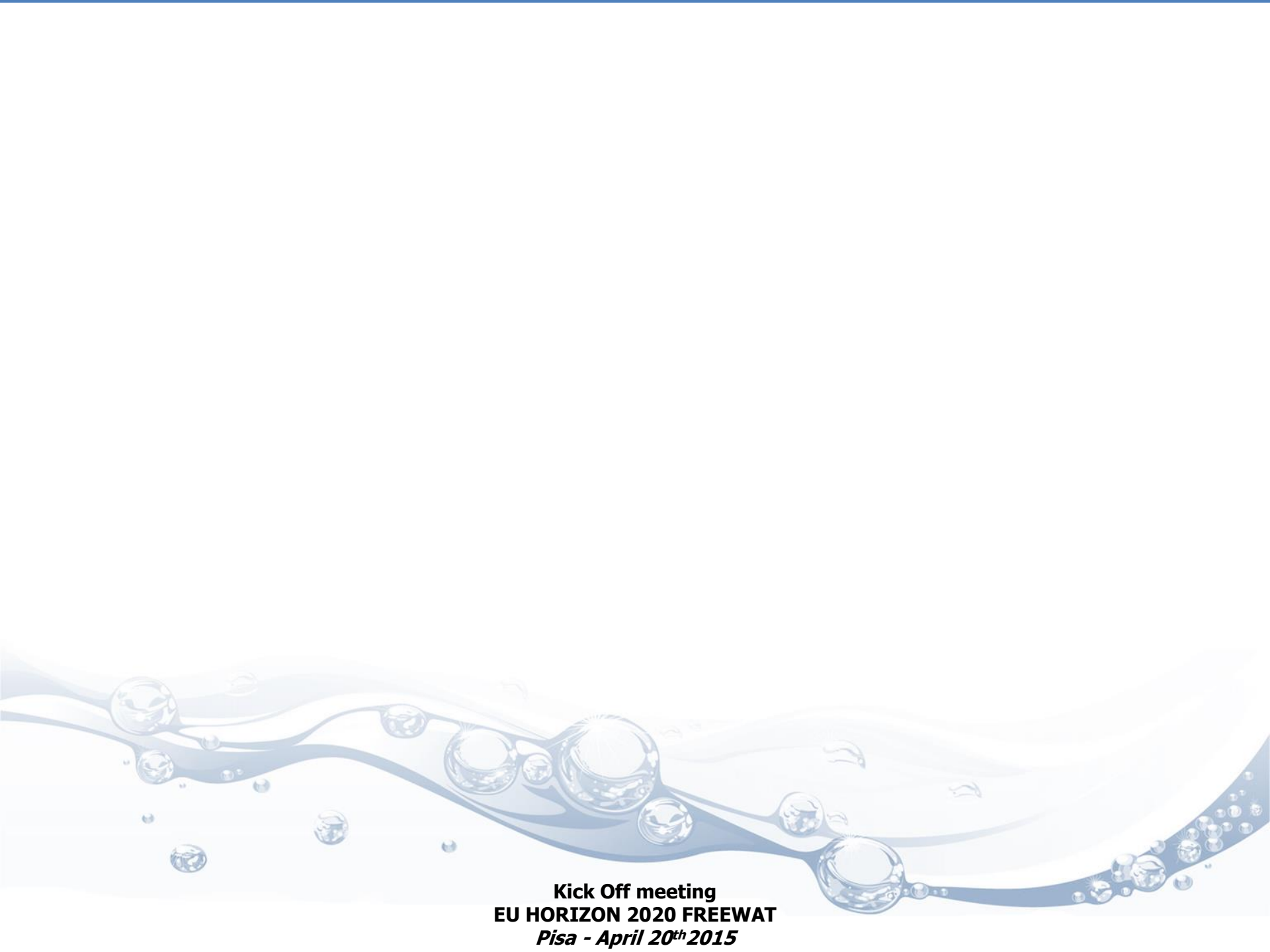

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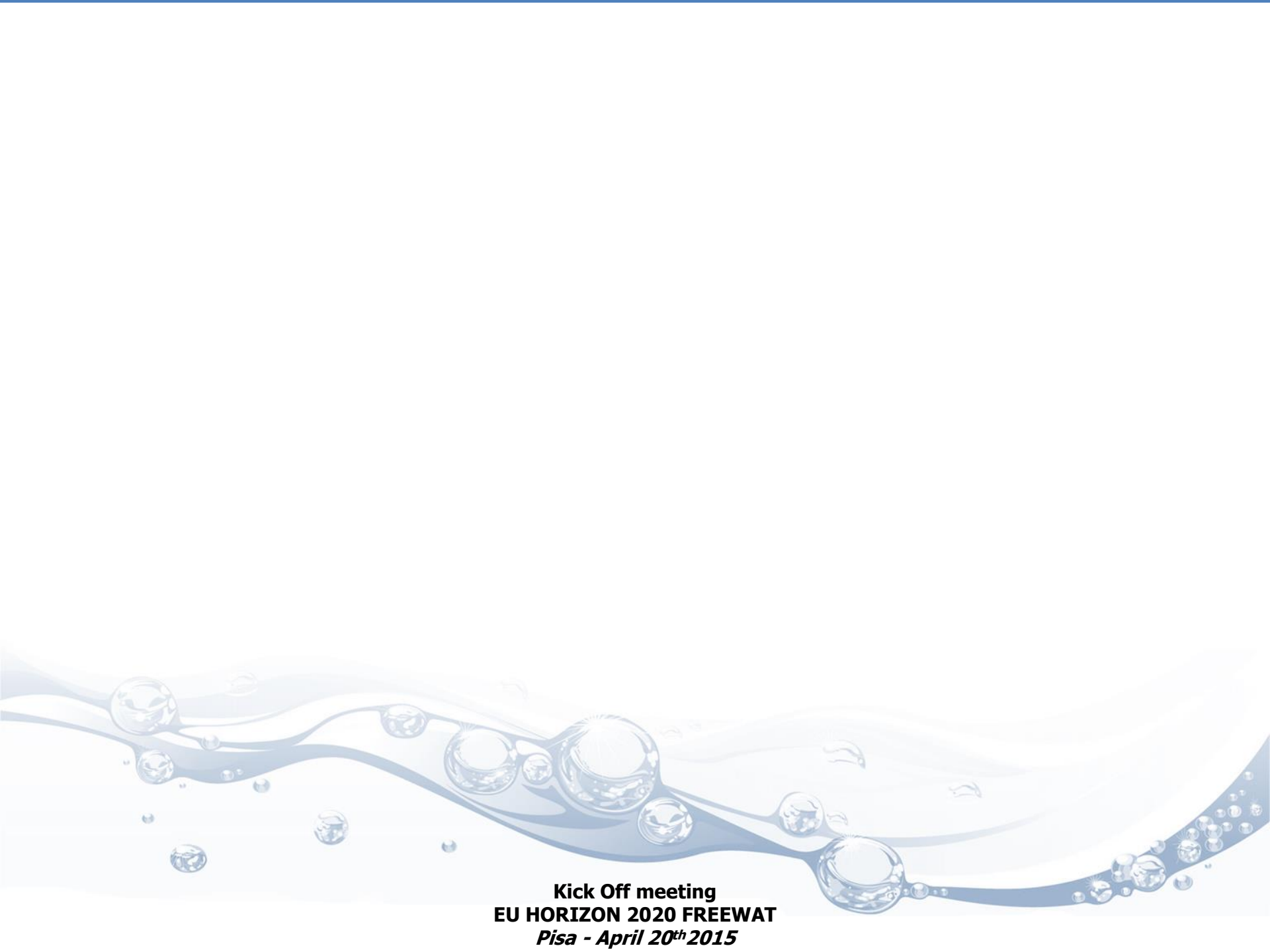

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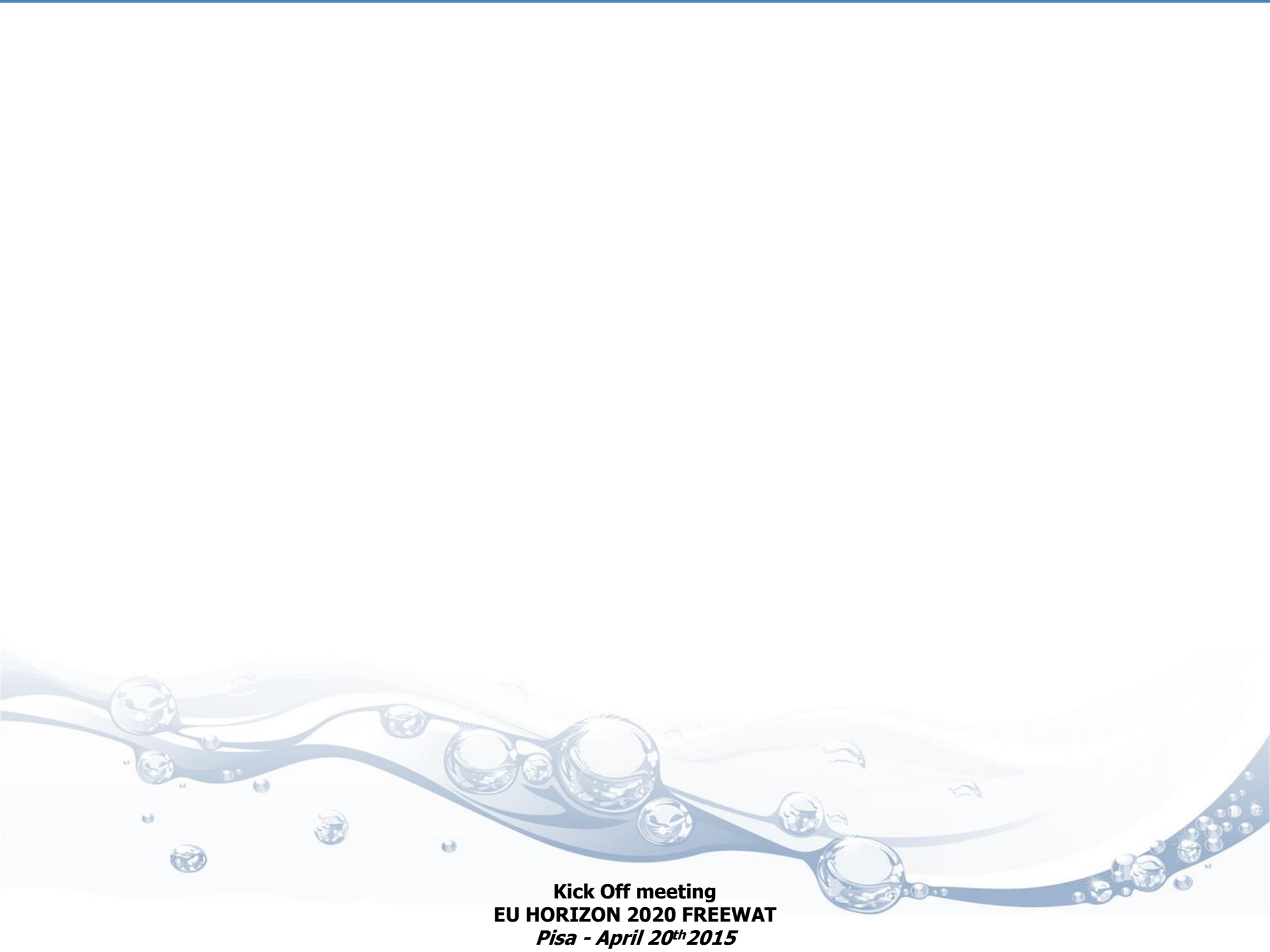

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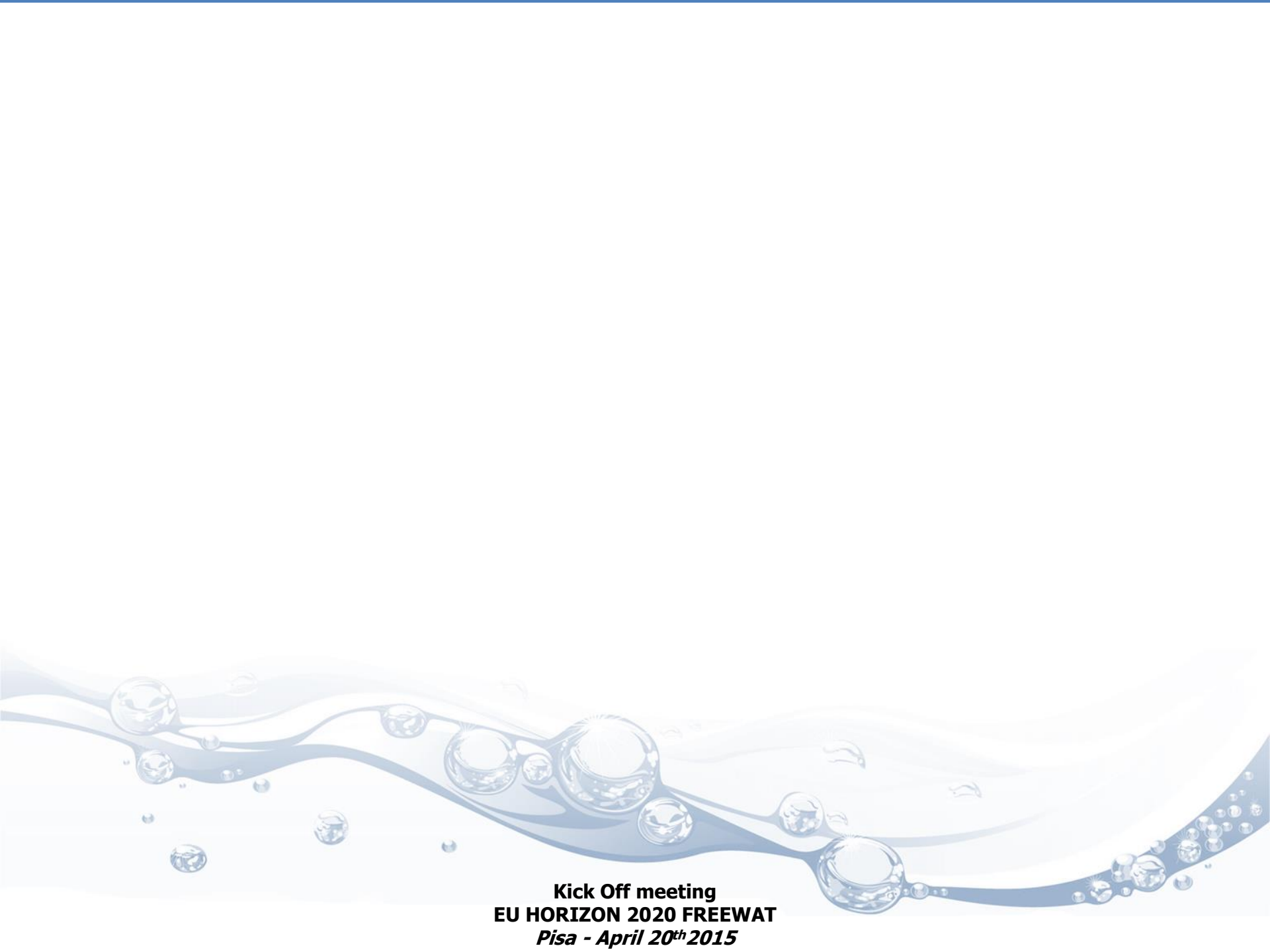

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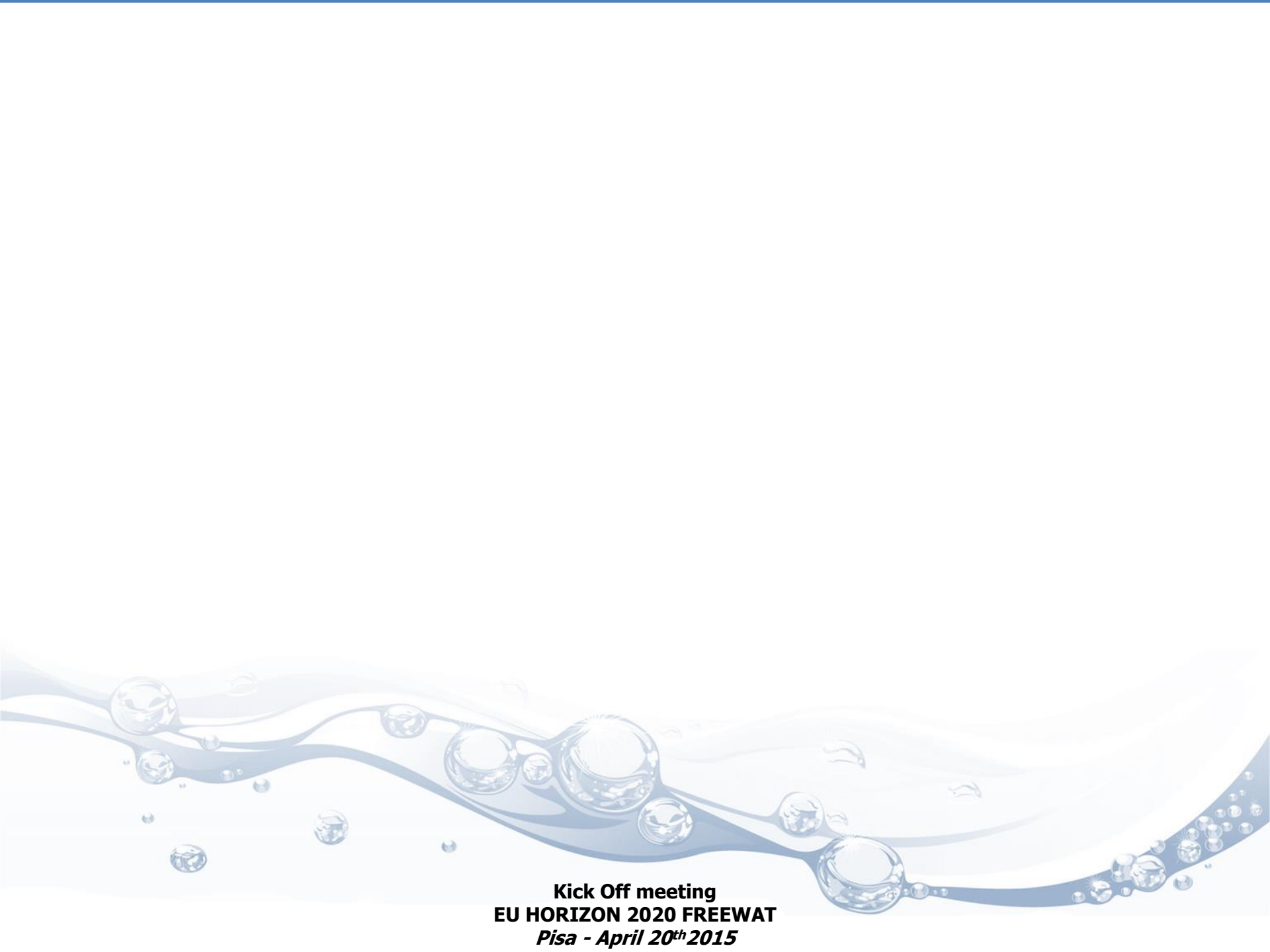

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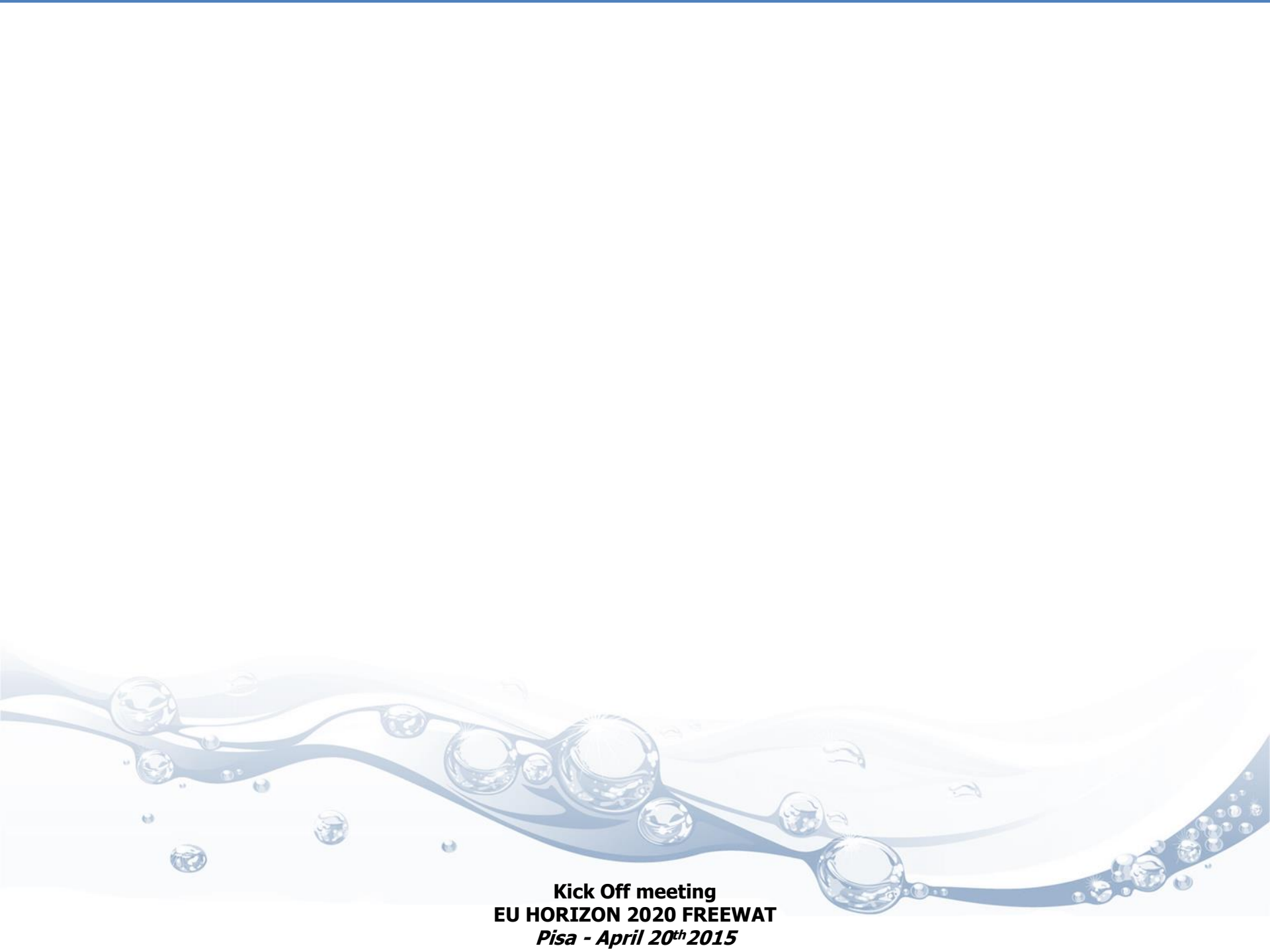

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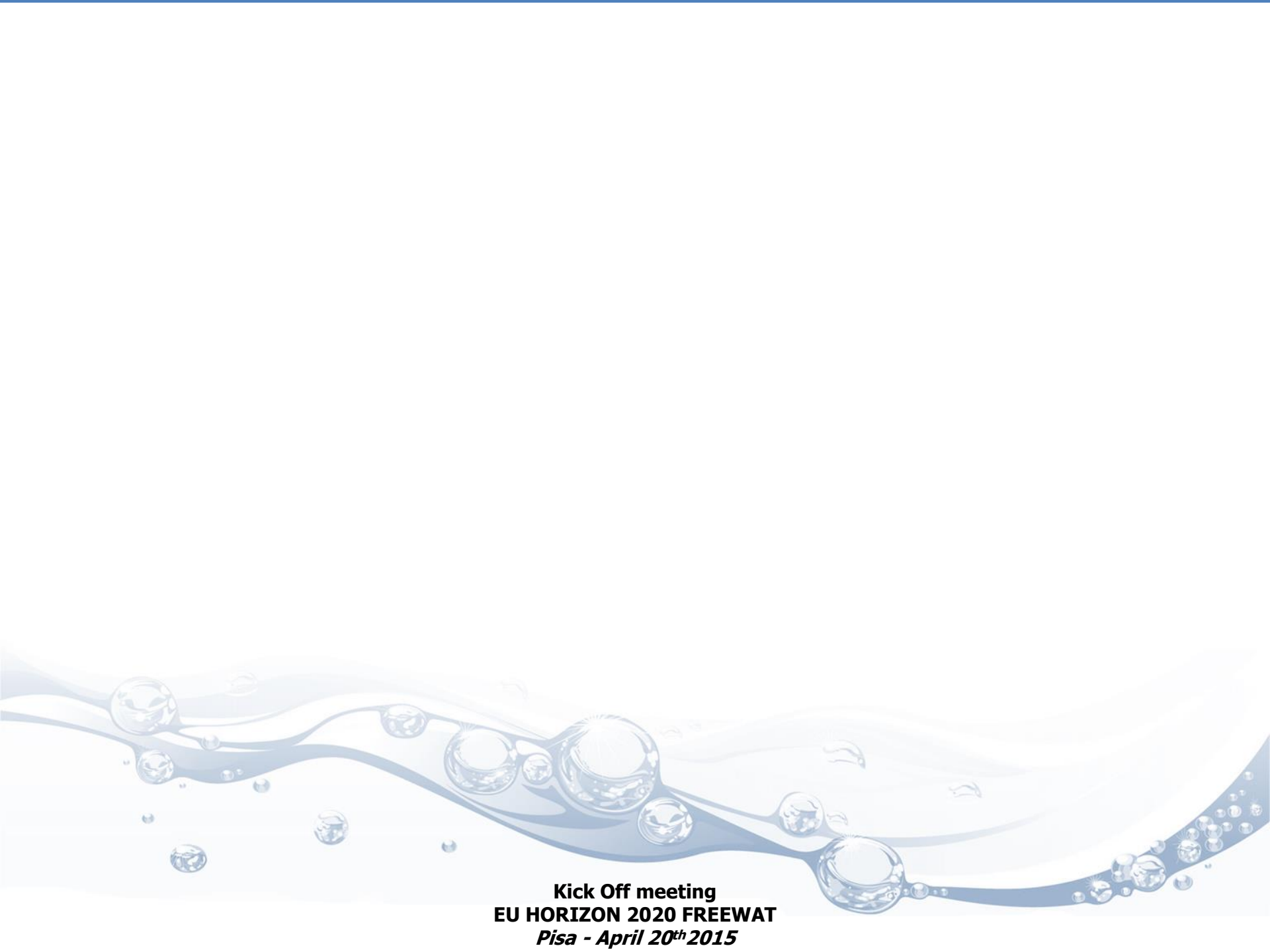

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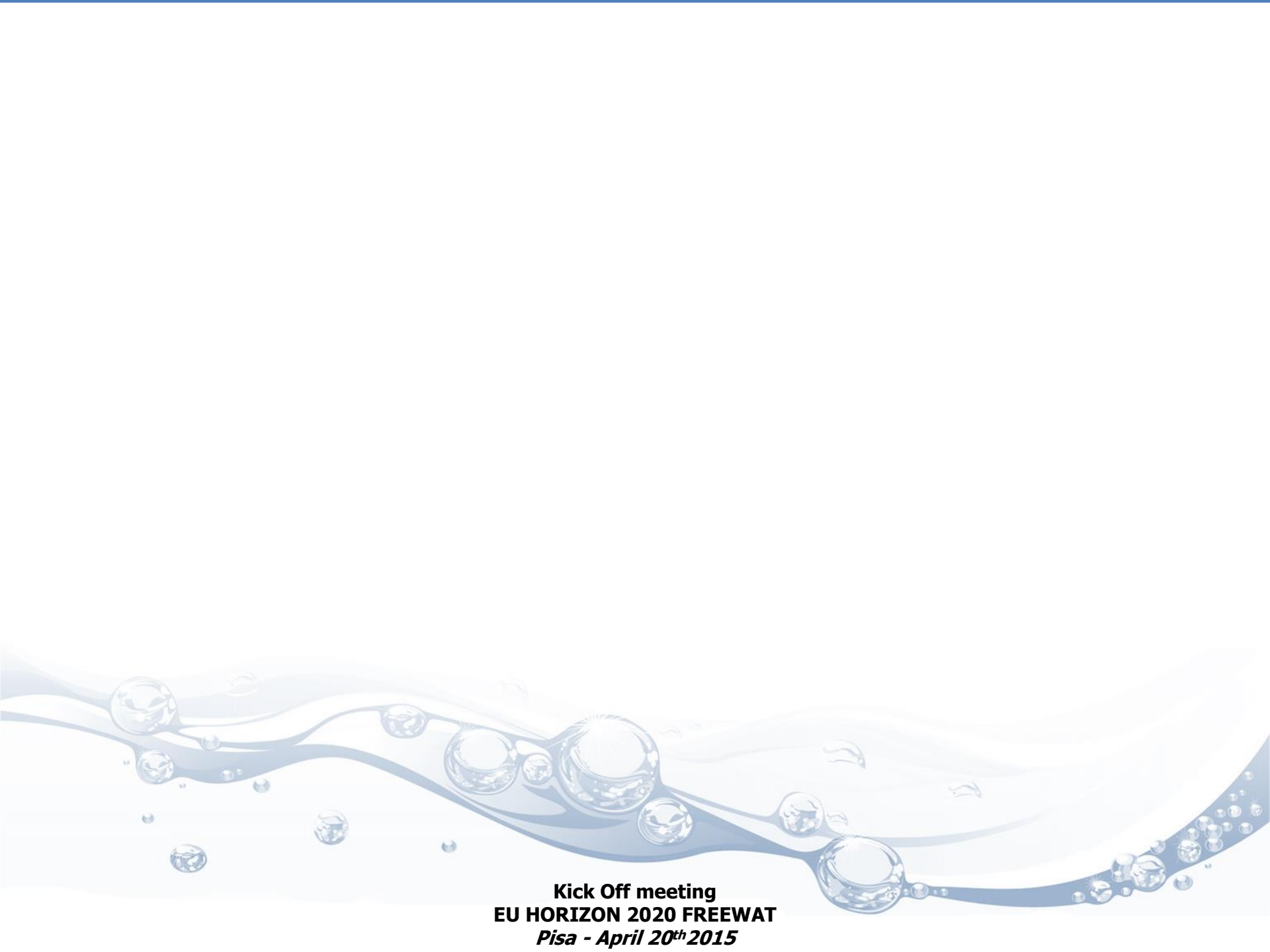

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