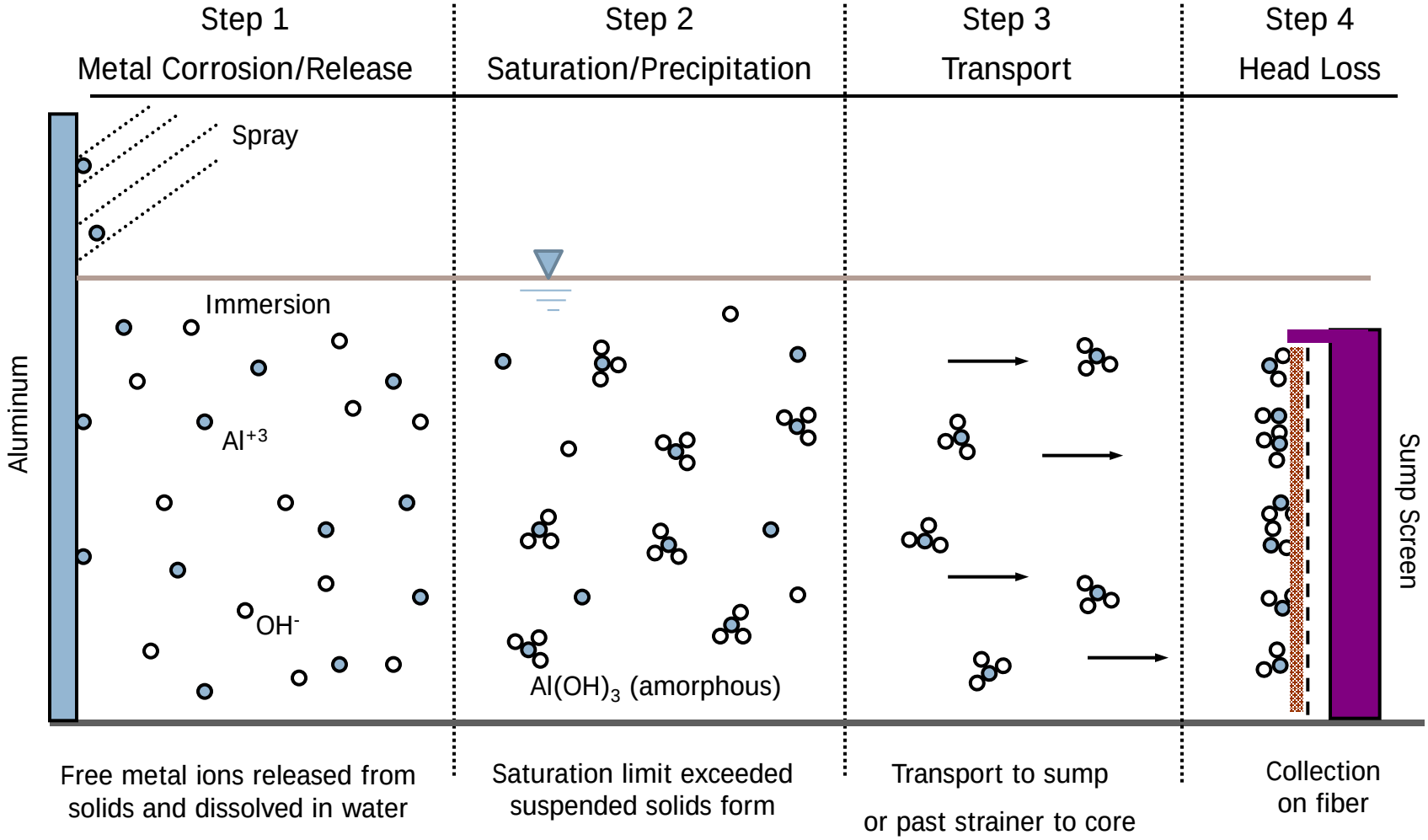
CHEMICAL EFFECTS IMPLICATIONS OF WCAP-16530-NP FOR SOUTH TEXAS PROJECT

December 1, 2011

Discussion Overview

- Conservatism in chemical effects - WCAP-16530-NP
  - Corrosion/release
  - Precipitation
- Reduction of conservatism
  - Casa Grande
  - Hypotheses of chemical effects occurrences without conservatisms
- Objectives of new chemical effects testing
- Preliminary testing ideas
- Conclusion
- Areas for requested input

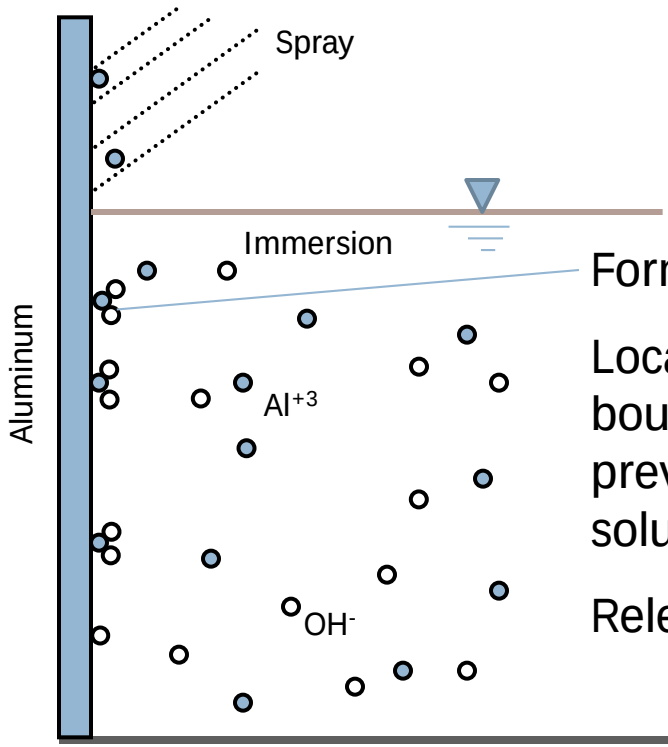
Corrosion/precipitation scenario



Conservatism: Corrosion/release

- Corrosion rates were determined in studies of relatively short duration
  - Over longer time, base metal corrodes but oxide layer forms at surface, limiting release of corrosion products into solution
- Passivation of surface by silicon and phosphate
- Contribution of soluble aluminum from un-submerged (sprayed) sources vs submerged sources
- Results in conservative estimate of soluble metal concentration

Corrosion/precipitation scenario

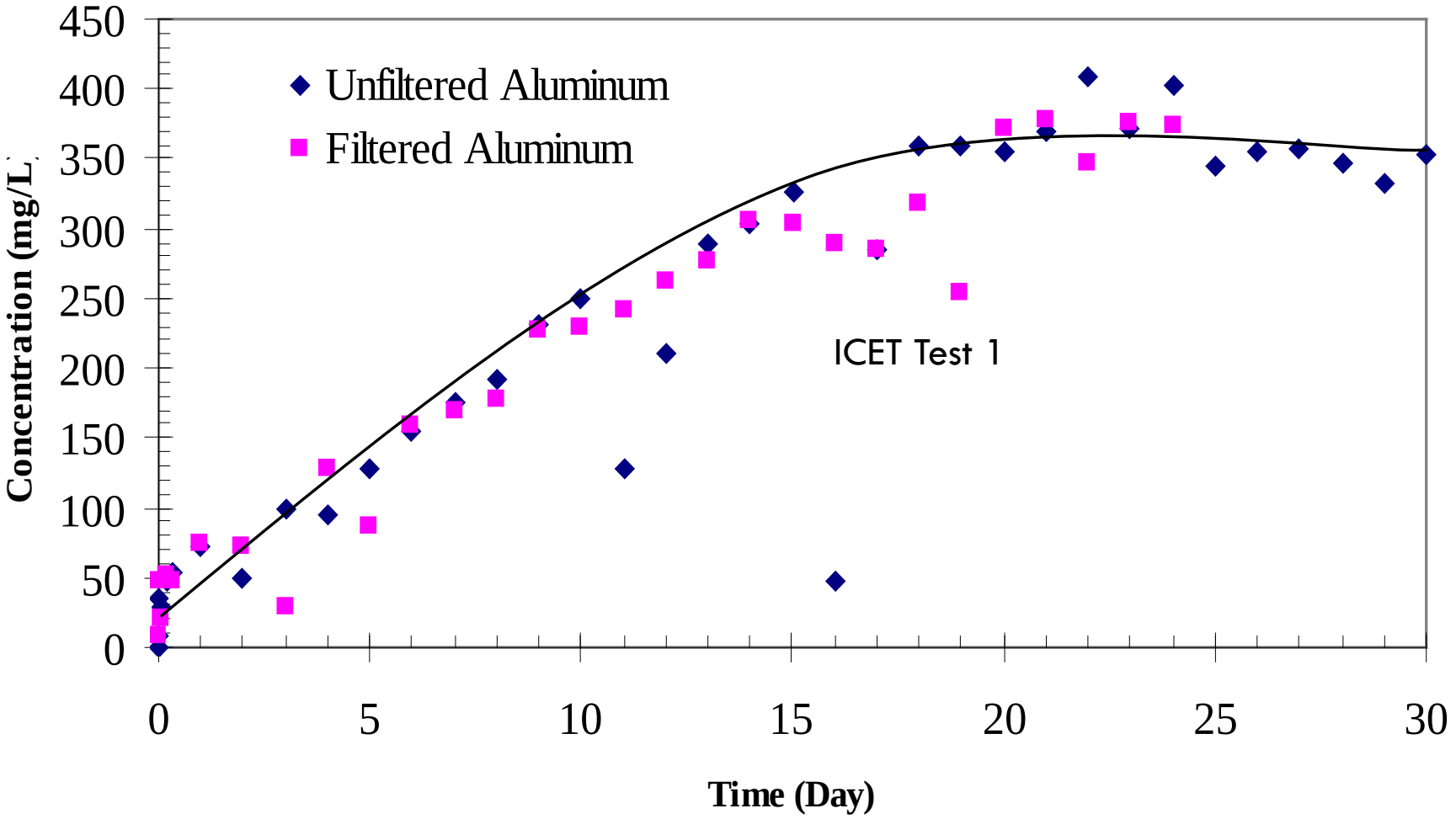


Formation of oxide layer on surface

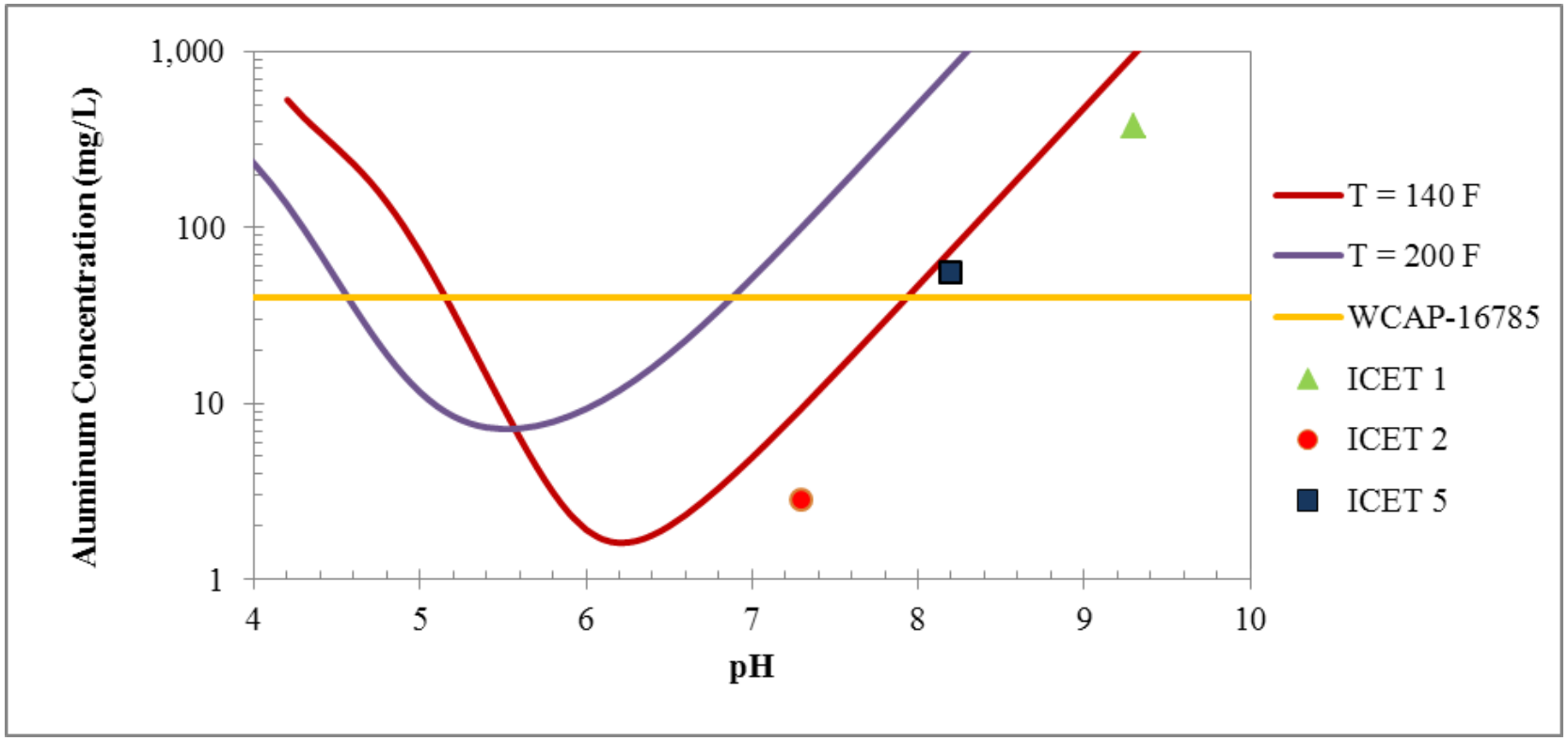
Localized higher concentration of aluminum in boundary layer causes surface precipitation, preventing supersaturation of aluminum in solution

Release of free ions into solution is reduced

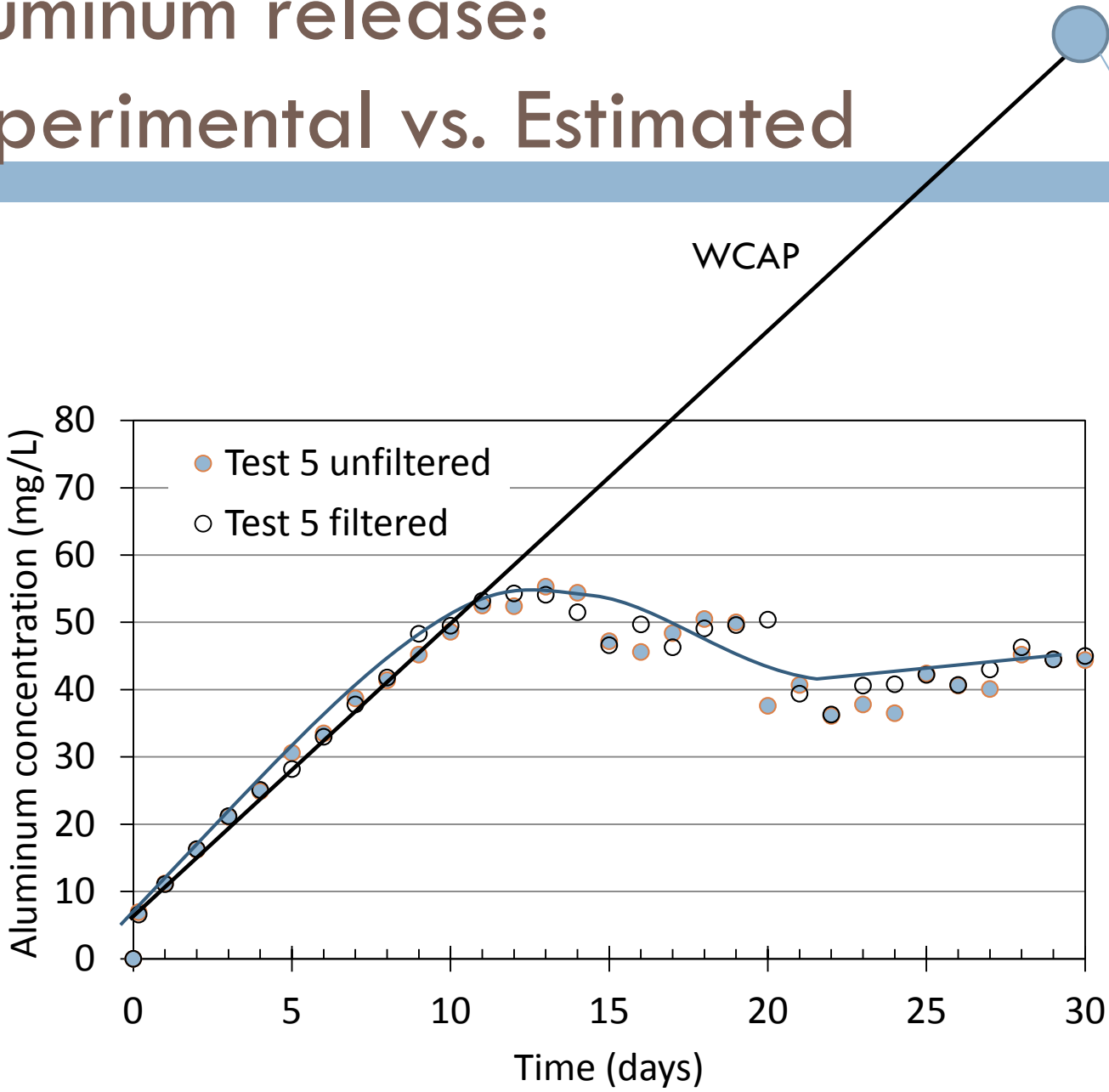
Aluminum release into solution in ICET



$Al(OH)_3$ solubility vs. Al concentration

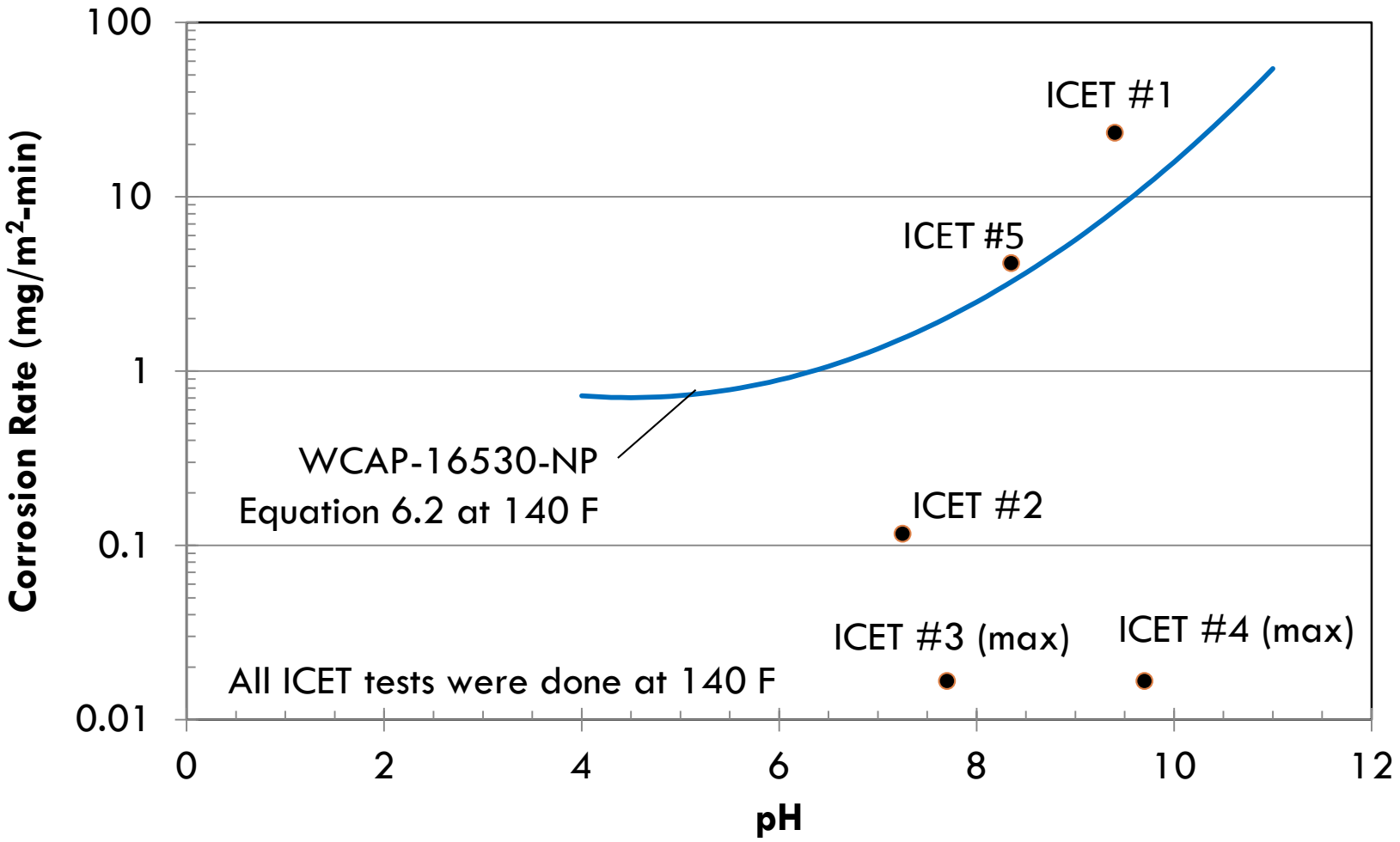


Aluminum release: Experimental vs. Estimated



Introduce this amount into strainer test in batches near time = 0

WCAP 16530 vs ICET



Passivation of Al corrosion in ICET Tests

ICET Test	pH	Al (mg/L)	Si (mg/L)
1	9.3-9.5	360	7
2	7.1-7.4	BD	45
3	7.3-8.1	BD	45
4	9.5-9.9	BD	82
5	8.2-8.5	50	4

- BD is below instrument detection limit
- Approximate concentrations at day 30 of testing

Soluble aluminum contribution: Sprayed vs Submerged sources

- Literature
  - Sprayed aluminum corrosion rate higher than submerged aluminum
- Experimental
  - Contribution of soluble aluminum from sprayed sources is negligible
- Net Effect
  - Corrosion rate may be higher but low contribution from sprayed aluminum to soluble aluminum concentration

ICET Test	Submerged	Sprayed
1	-98.6	0.7
2	-0.9	0.4
3	0.6	0.4
4	0	0.6
5	-11.2	0.4

❖Mass change (g) in aluminum coupons after 30-day ICET tests

Conservatism: Precipitation

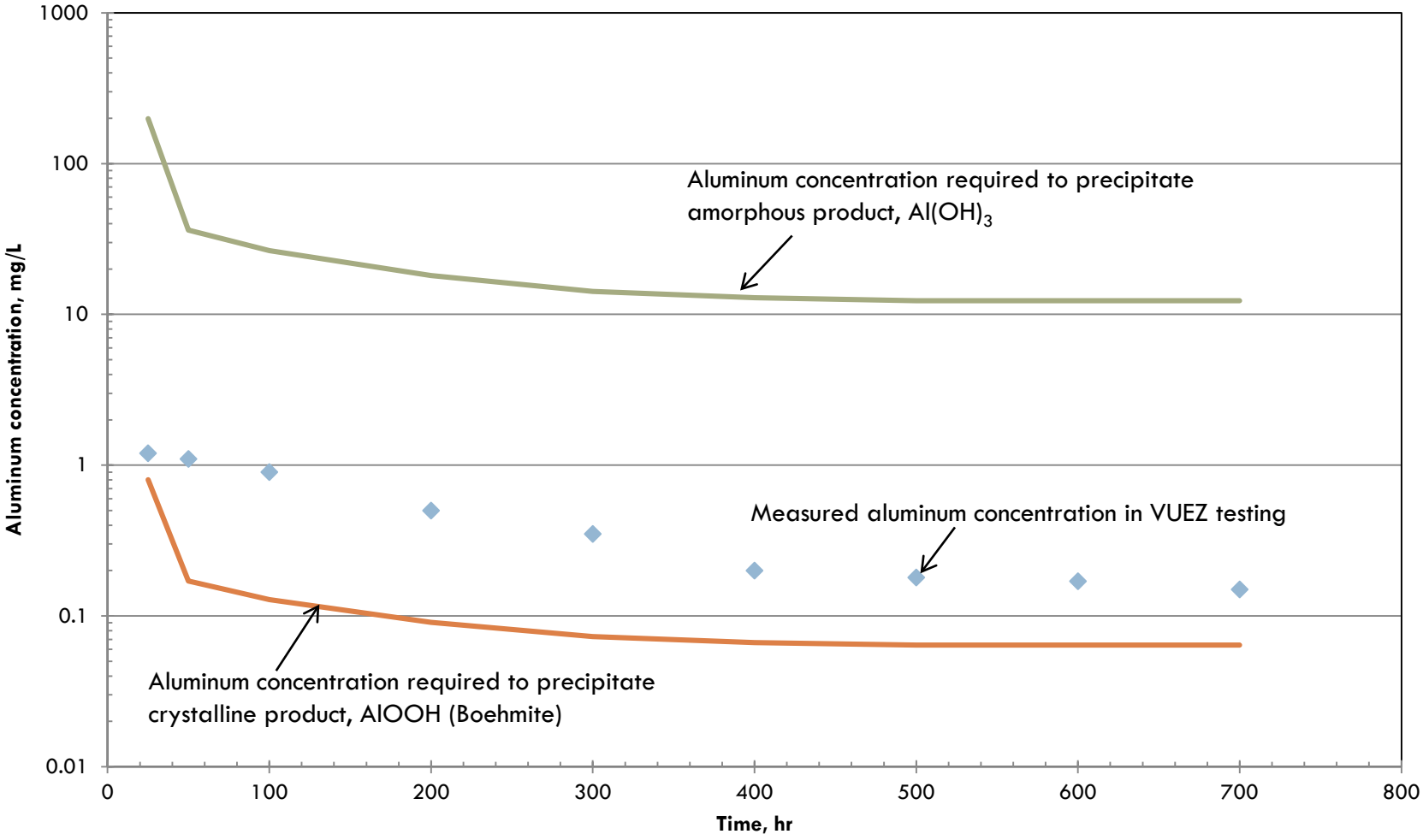
- WCAP 16530 'estimates' precipitate formed
  - $NaAlSi_3O_8$ and/or AlOOH
- Another possible form:
  - $Al(OH)_3$
- Molecular weight of precipitate determines quantity
  - STP WCAP calculation predicts 83 kg of Al in solution
    - 650 kg of $NaAlSi_3O_8$ and 36 kg of AlOOH

    OR
    - 237 kg of $Al(OH)_3$
- Quantity of precipitate is used to predict head loss
  - Over or under estimation of actual head loss

Conservatism: Precipitation

- Amorphous phase precipitate
  - Occurs in solution
  - Transported to screen
  - Assumed by WCAP-16530-NP
  - Greater head loss ?
- Mineral phase precipitate
  - Occurs on surfaces
  - Not transported
  - Occurred during VUEZ chemical effects tests
  - Less head loss ?

Amorphous vs crystalline phases



Casa Grande: Limiting excessive conservatism

- Risk assessment philosophy
- Stochastic analysis and uncertainty quantification
- Allows for educated reduction of previously demonstrated conservatism

Hypothesis of Chemical Effects at STP during a LOCA – Corrosion/Release

- The release of aluminum into solution resulting from corrosion is less than predicted by WCAP-16530-NP
  - Passivation effects
  - Formation of oxide layer
  - Aluminum exposed to spray releases less metal into solution than submerged aluminum

Hypothesis of Chemical Effects at STP during a LOCA - Precipitation

- Calcium phosphate precipitation will be minimal
- Crystalline aluminum precipitate will occur in fiber bed or on surfaces in the containment pool and not in the bulk solution
- Amorphous aluminum precipitation may occur in bulk solution when passed through heat exchanger
- Precipitation will be less due to less corrosion products in solution

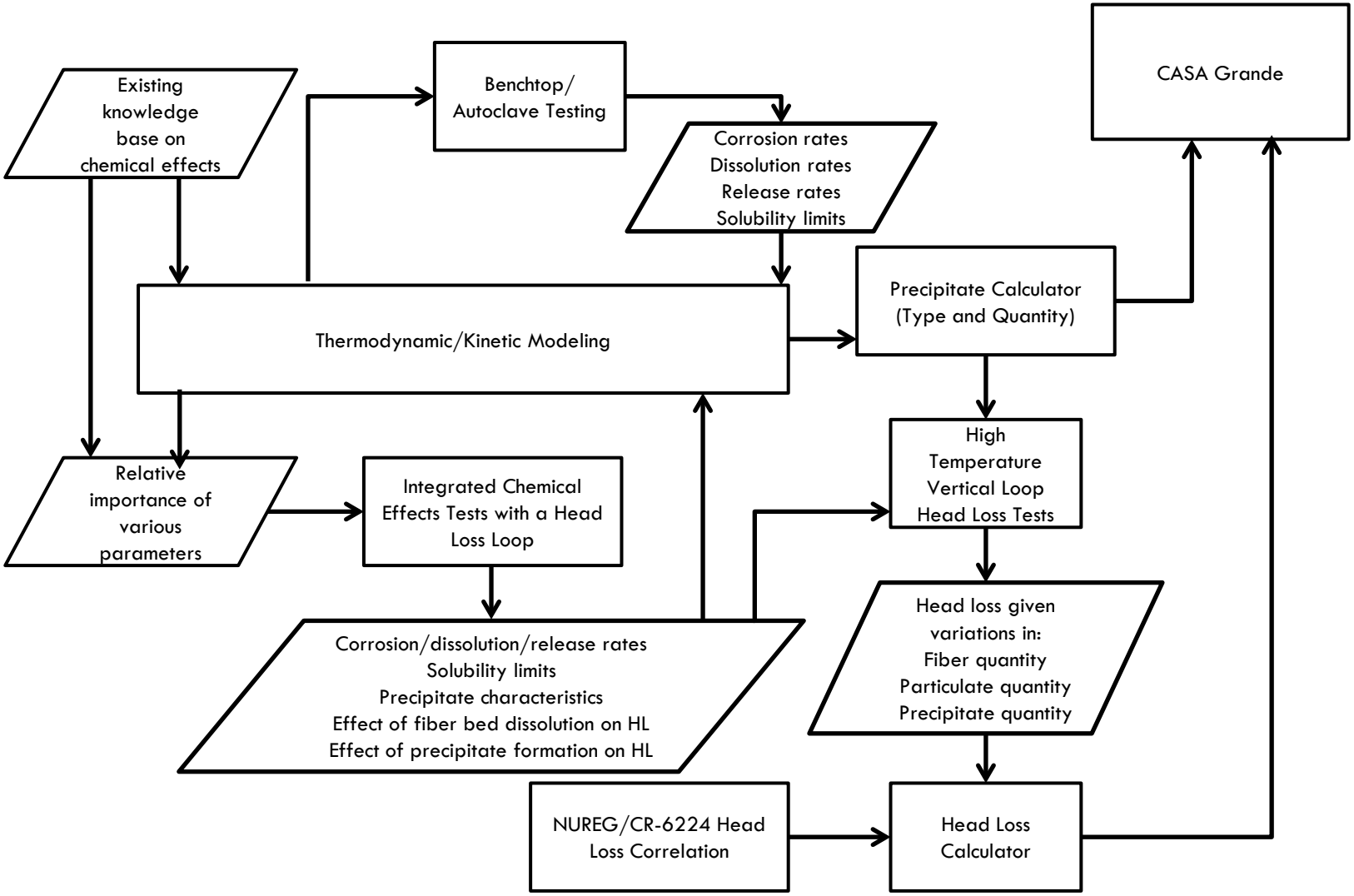
Hypothesis of Chemical Effects at STP during a LOCA - Overall

- Little or no impact of chemical effects on the STP plant
  - Reduced release of aluminum into solution, thus smaller quantity of precipitation
  - Crystalline precipitation onto the fiber bed with possibility of amorphous precipitation in solution due to heat exchanger exposure

Objectives for new chemical effects tests

- Determine the significance of chemical effects on the resolution of GSI-191 at the STP plant without excessive conservatisms
- Generate data that can be used to develop a model of system of equations that will provide input to Casa Grande
  - Equations predicting concentrations of Al, Si, Ca, and PO_4 in solution as a function of pH, temperature, pool volume, spray duration and quantities of materials in containment
  - Equation predicting incremental increase in head loss as a function of soluble Al, Si, Ca, and PO_4 concentrations, pH and temperature

Path to reach objectives



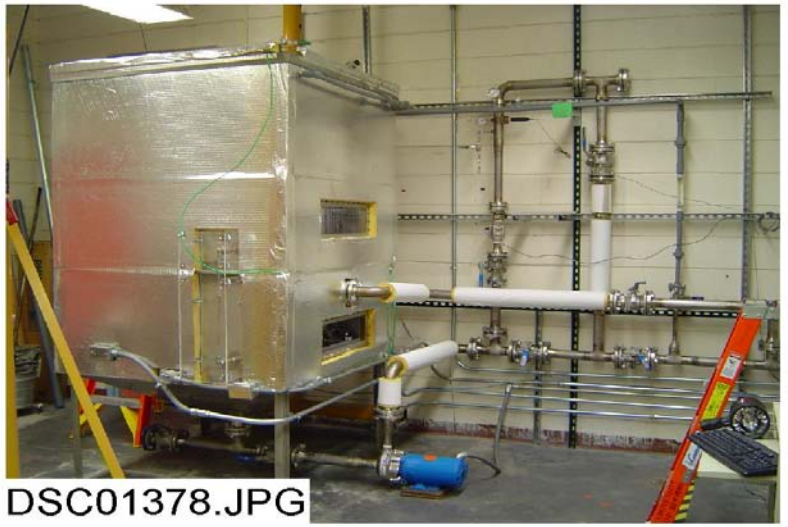
Preliminary testing ideas

- ICET Tank Tests
  - 30-day test integrated corrosion/head loss tests
    - "Blank Test"
      - Examine fiber bed dissolution and associated headless in buffered/borated water only
    - Medium break LOCA
    - Large break LOCA
  - Shorter term test
    - Effects using NaTB as buffering agent at STP
    - Examine contribution from spray metals under different spray conditions
    - Force precipitation for identification purposes
      - Will allow for more accurate head loss correlation
- Batch Tests
  - Clarify the composition of precipitates that form
  - Impact of variable concentrations of silicon
  - Flow rate effects on formation of aluminum oxide scale

Experimental Apparatus

ICET Tank

- 250 gallons
- Racks and capacity for all materials present in STP containment
- Recirculation loop to provide required turbulence and mixing in tank
- RWST chemistry at the STP plant would be simulated in the tank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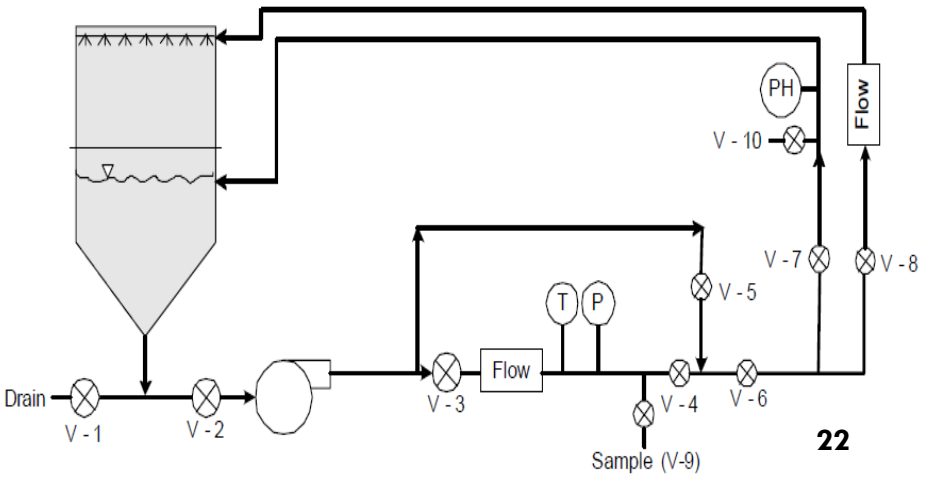

Modifications to ICET Tank

- Head loss loop, using pre-formed fiber debris beds
- Heat exchanger loop
- Scaling parameters to STP
  - Ratio of materials (aluminum, etc) to pool volume
  - Recirculation time through screen / hydraulic residence time
  - Water velocity through fiber bed
  - Hold up time at lower temperature before re-introduction into pool
- Declining temperature profile similar to LOCA
- Flow variations to simulate plant evolutions

Conclusion

- Casa Grande is a tool for reducing conservatism
  - Will include chemical effects
- Overall hypothesis for non-conservative scenarios
  - Little or no impact of chemical effects on the STP plant
- Testing to prove hypotheses
  - 30-day testing
  - Short term test
  - Batch tests
  - Modified ICET tank

Areas for discussion

- Use of pre-formed fiber beds
- Orientation of fiber bed: vertical or non-vertical
- Use of multiple beds in parallel
- Use of two beds in series with an intermediate heat exchanger