Special Study Title: Comparison of methods to determine the mass of sludge in secondary clarifiers

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What is the problem being addressed by the study?

Alternatives to taking core samples of secondary clarifier solids are being sought to address challenges faced by operators with taking clarifier core samples and measuring clarifier solids concentrations (CSC method). Challenges include available time to take and analyze samples at large treatment plants with many clarifiers and clarifiers that are difficult to access (covered, deep, no walkways).

What are you trying to show by doing the study?

Alternative methods to the CSC method can be used to get an estimate of the secondary clarifier sludge mass.

How will you do the study?

A desktop evaluation of existing data will be done to compare the CSC and alternative methods of determining secondary clarifier sludge masses. Two data sets will be used – one from a treatment plant that has circular clarifiers and another with a rectangular clarifier.

Approach

- Collect data from the two different types of clarifiers, and include data that has a range of sludge depths (e.g. one to six feet), settling characteristics (i.e. SVI) and %RAS (RAS flow ÷ plant flow)
    - Circular clarifiers: Elora WWTP (squircular). Elora is an extended aeration treatment plant with one aeration basin and two clarifiers in service.
    - Rectangular clarifiers: Barrie WWTP. Pure oxygen activated sludge with six clarifiers in service. All six clarifiers are sampled for clarifier mass by taking core samples from each clarifier and combining in a composite sample. A special study was done in Fall 2020 on clarifier 6 to test a more robust method of clarifier sampling.
- Assume the sludge mass using CSC measurements represents the actual clarifier mass and compare that mass to the mass of sludge calculated by the alternative methods.
- Alternative methods to examine:
    - Measured RAS concentration and sludge blanket depth
    - Estimated RAS concentration and sludge blanket depth
    - 30-minute settled sludge concentration and sludge blanket depth
- Provide the special study results to ODT members for their feedback

Calculations

Clarifier mass by CSC:

$$Clarifier\ mass\ (kg) = CSC\left(\frac{mg}{L}\right) \div 1000 \times clarifier\ volume\ (m^3)$$

Clarifier mass by RAS concentration:

$$Clarifier\ mass\ (kg) = RAS\left(\frac{mg}{L}\right) \div 1000 \times sludge\ depth(m) \times clarifier\ area\ (m^2)$$

Predicted RAS concentration:

$$RAS_{predicted}\left(\frac{mg}{L}\right) = \frac{(100+\%RAS)}{\%RAS} \times MLSS\left(\frac{mg}{L}\right)$$

$$\%RAS = \frac{RAS\ (m^3)}{Plant\ flow\ (m^3)} \times 100$$

Clarifier mass by 30-minute settled sludge concentration (SSC30):

$$SSC30\left(\frac{mg}{L}\right) = 10^6 \div SVI\left(\frac{g}{mL}\right)$$

$$Clarifier\ mass\ (kg) = SSC30\left(\frac{mg}{L}\right) \div 1000 \times sludge\ depth(m) \times clarifier\ area\ (m^2)$$

Results and Conclusions:

Write down the study data and any conclusions.

Results: Circular clarifiers using Elora data

Circular clarifiers using Elora data

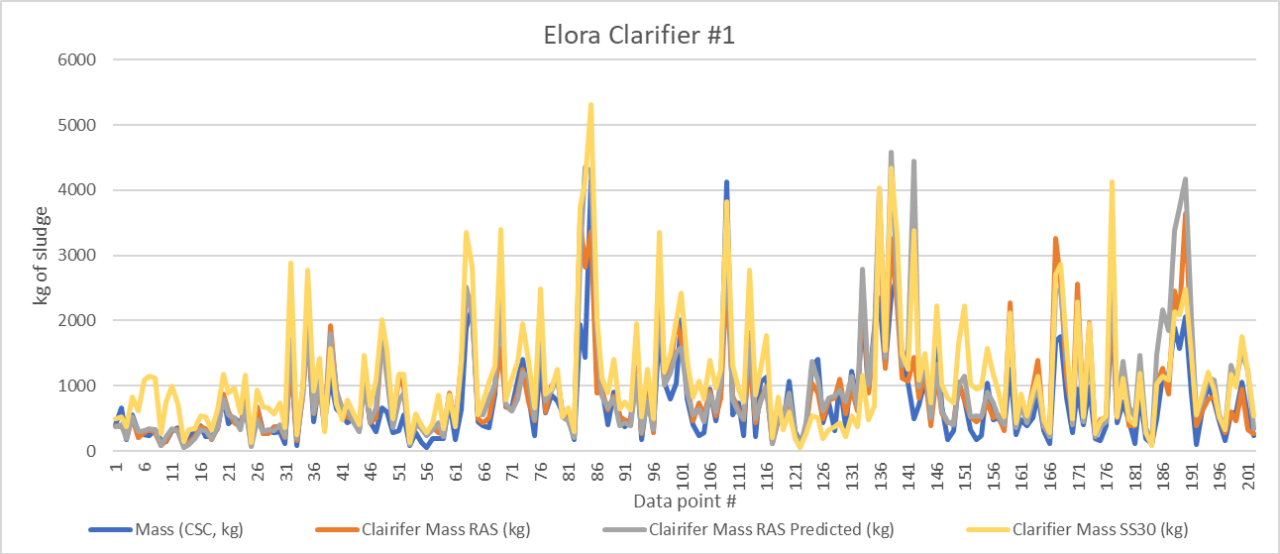
- One year of data analyzed (November 2018 – October 2019)
- Data from clarifier #1 showed the greatest variation in sludge depth of the two clarifiers in service during this time period.
    - Had to assume the flow to both clarifiers is equal as there are no flow meters to each clarifier. However, there is evidence that clarifier #1 receives more flow than clarifier #2 by visual observation and clarifier #1 consistently has more sludge than clarifier #2. This assumption impacts the calculation of %RAS to the clarifiers.
    - Assumed any error in the flow split to the clarifiers was the same at all flow rates.
    - RAS sample for TSS is taken where RAS enters aeration so it is a combined concentration from #1 and #2 clarifiers. RAS concentrations from each clarifier are likely different because of uneven flow splitting.
- Data points were not used when the sludge depth was recorded as zero

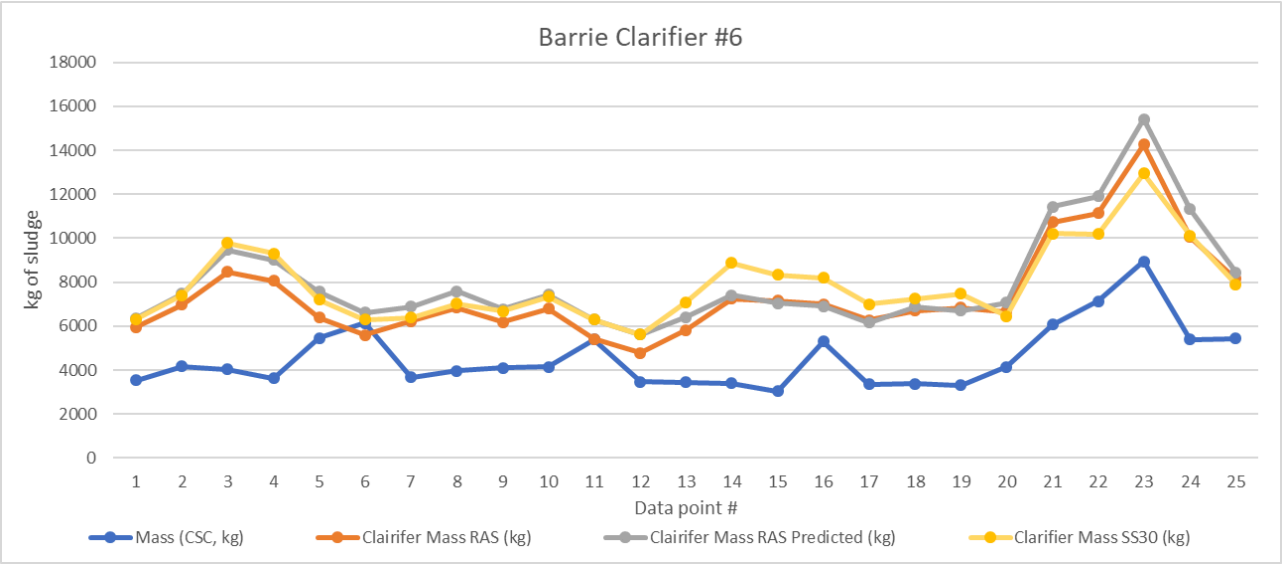
Rectangular Clarifiers using Barrie data

- Three weeks of data (October – November 2020) from clarifier #6, and one year of data for the composite CSC sample from all six clarifiers (May 2020 to April 2021)
- Each clarifier has two cells.
    - Clarifier #6 had six samples taken, three from each cell along the length of the clarifier. The three samples were composited together. Data trends show the composite samples for each cell were nearly equal so the data presented in this study is an average of the two composite samples.
    - All six clarifiers are sampled for clarifier mass by taking core samples from each clarifier and combining in a composite sample.
- Assumed sewage flow is split evenly to all clarifiers, so flow to a clarifier = plant flow ÷6.

Figures 1-4 assess the ability of indirect methods of measuring clarifier mass (RAS concentration, predicted RAS concentration and SSC30) to accurately determine clarifier mass.

Figure 1: Sludge mass calculated by CSC, RAS concentration, predicted RAS concentration and SSC30.





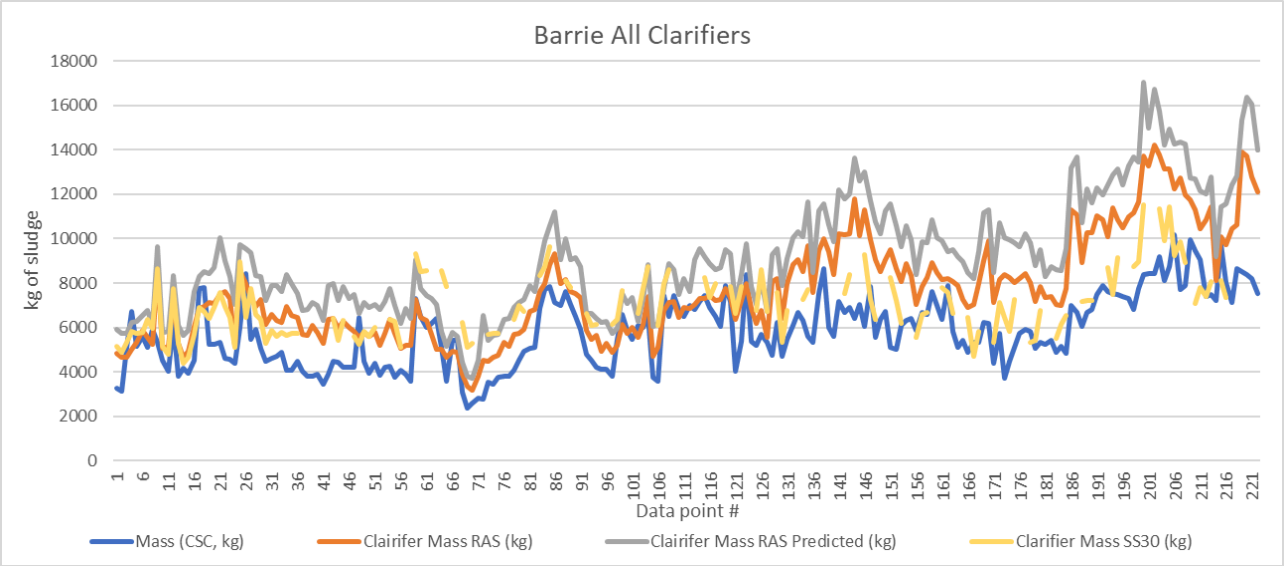
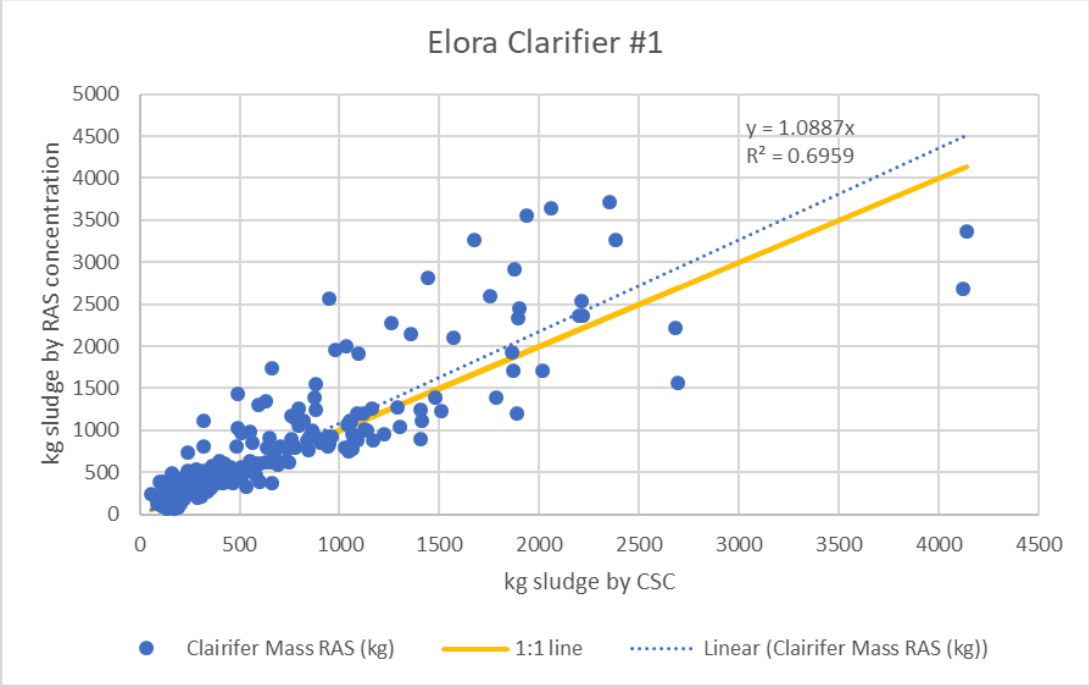
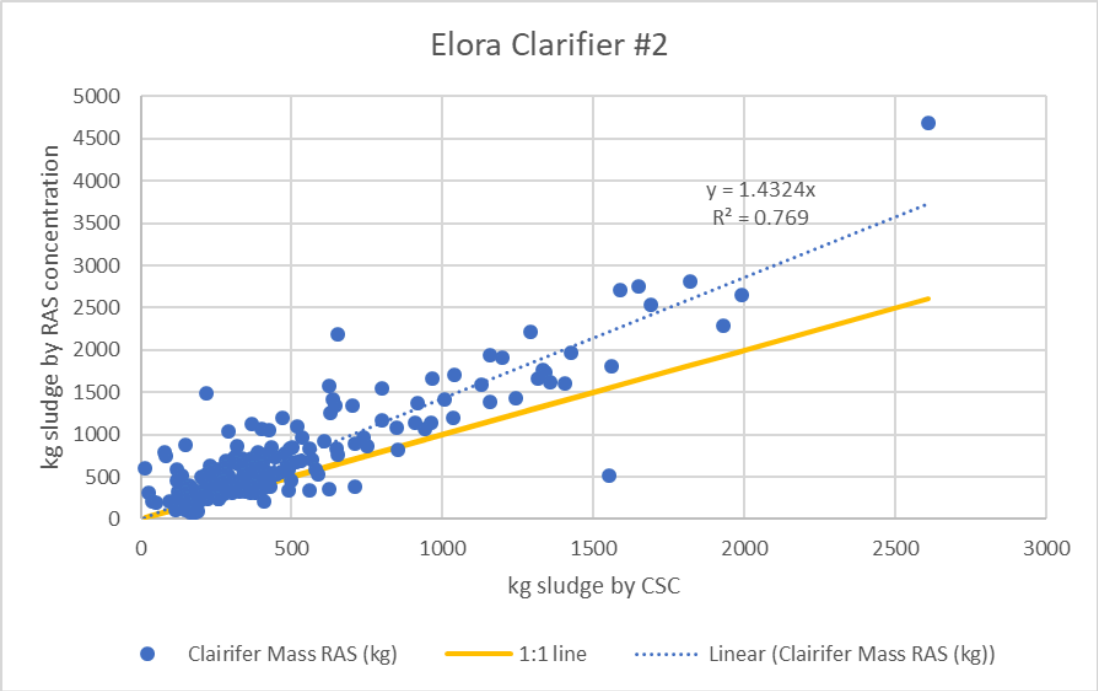


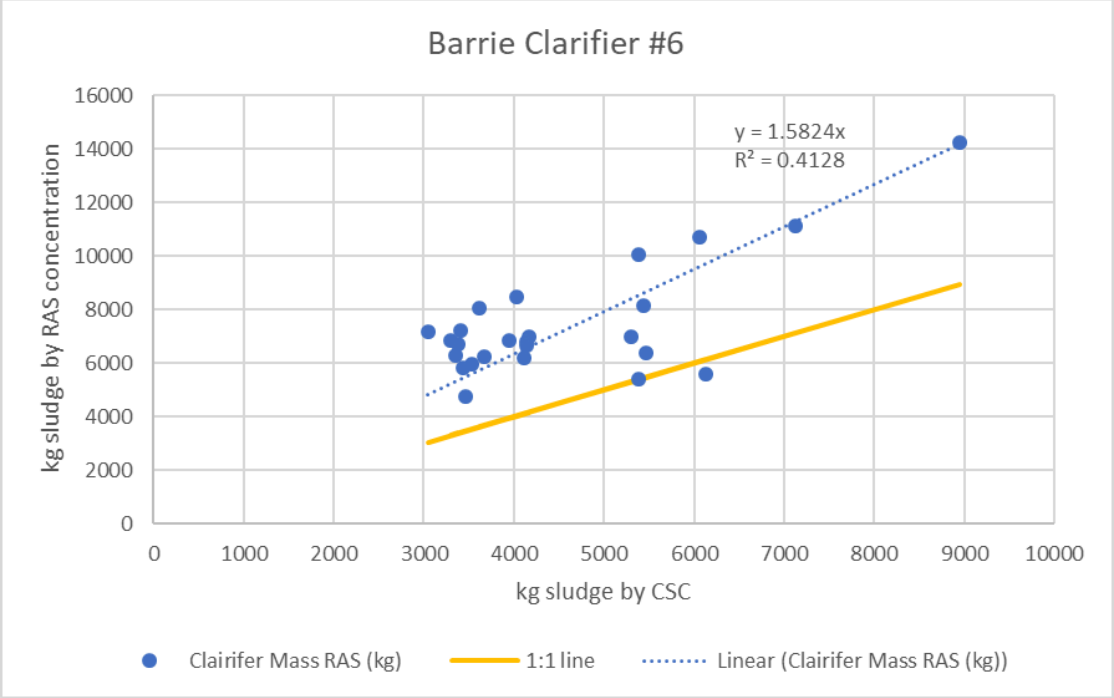
Figure 1 interpretation

- The estimated clarifier mass by RAS, predicted RAS and SS30 trend with the clarifier mass determined using sludge core samples (CSC)
- The indirect mass calculations appear consistently higher than the CSC masses, especially for the Barrie data
- The same trend is shown with Elora clarifier #2 data (data not included in the figure), but the differences between the estimated masses and actual masses are larger.

Figure 2: Sludge mass by RAS concentration versus mass by CSC




Elora Clarifier #2
kg sludge by RAS concentration
kg sludge by CSC
y = 1.4324x
R² = 0.769
Clairifer Mass RAS (kg)
1:1 line
Linear (Clairifer Mass RAS (kg))


Barrie Clarifier #6
kg sludge by RAS concentration
kg sludge by CSC
y = 1.5824x
R² = 0.4128
Clairifer Mass RAS (kg)
1:1 line
Linear (Clairifer Mass RAS (kg))

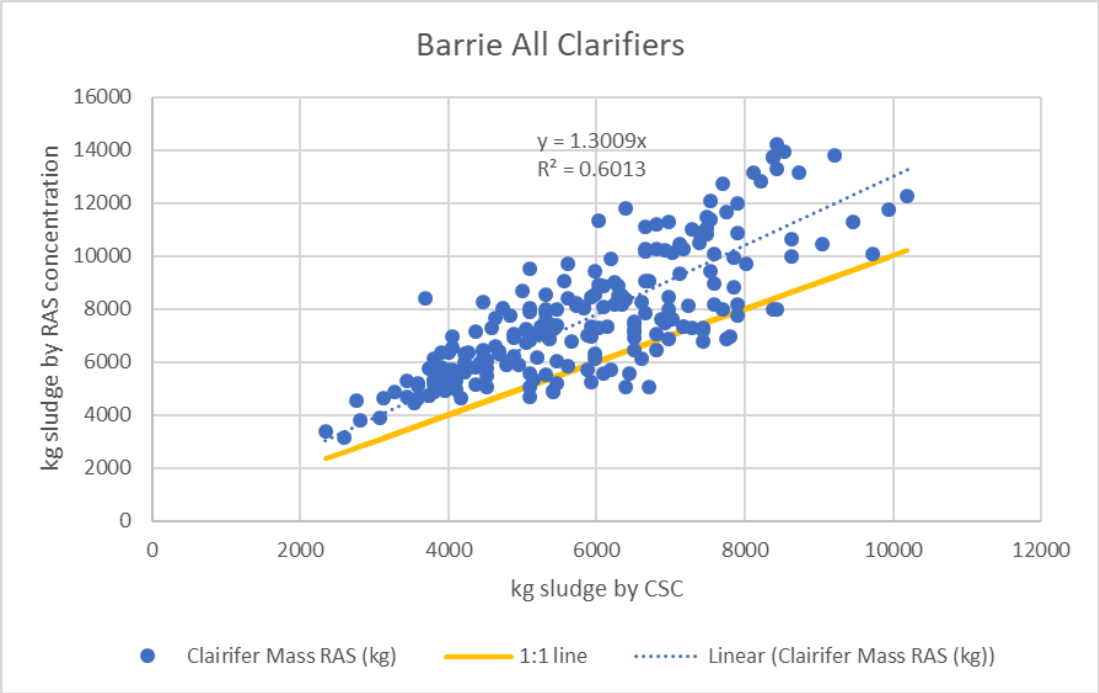
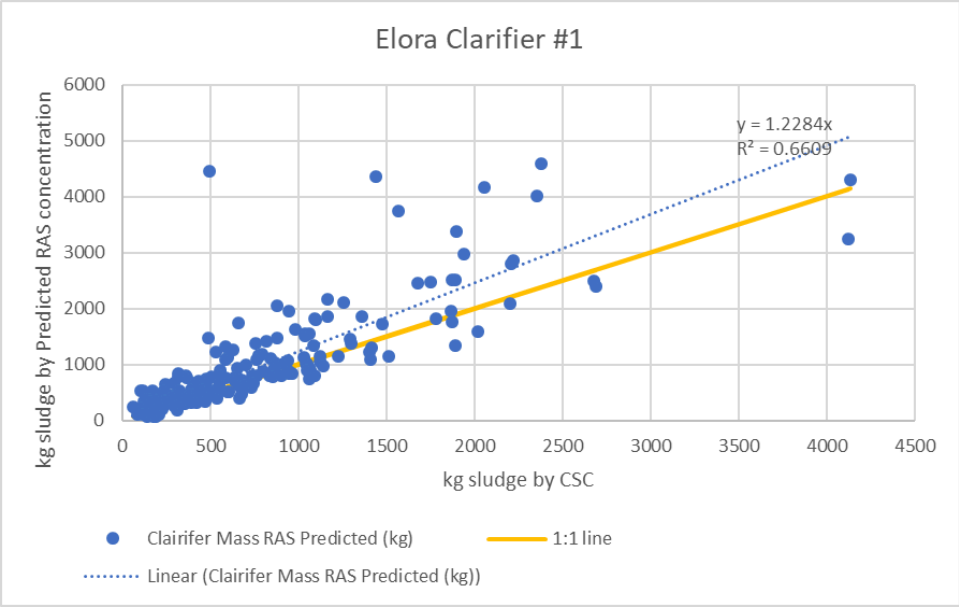
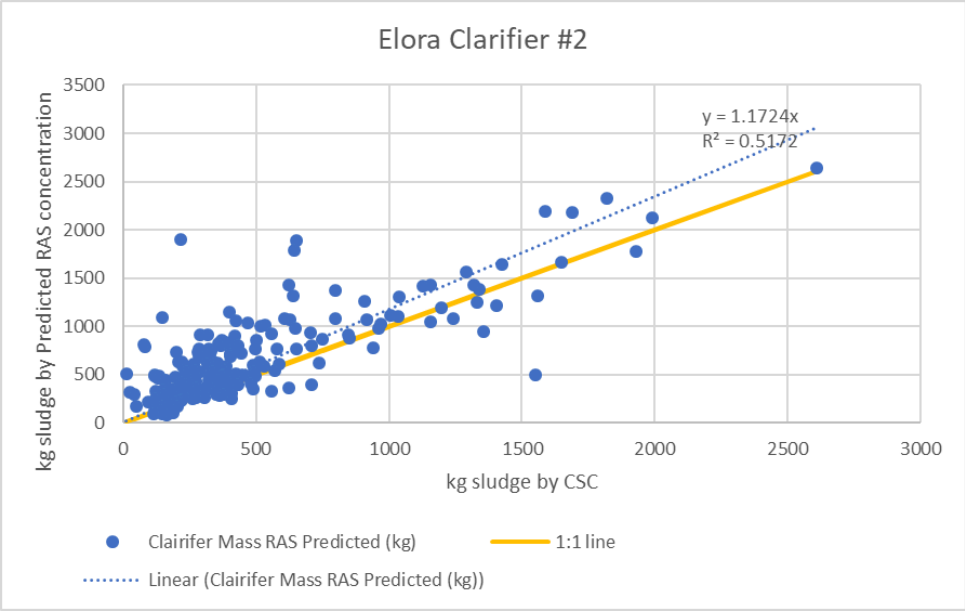


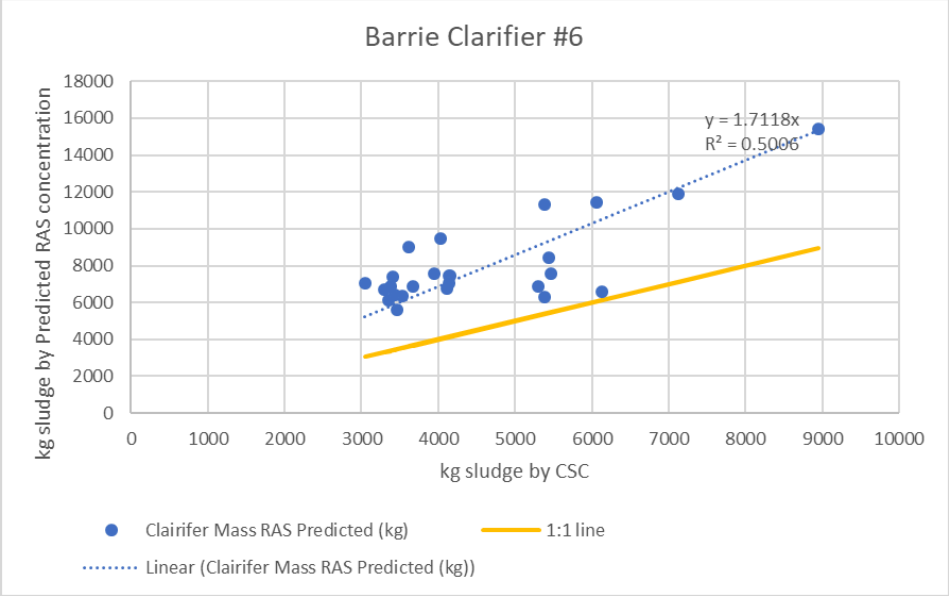
Figure 2 interpretation

- Sludge mass by RAS concentration follows the CSC mass, but tends to overpredict actual sludge mass and the correlation is modest for the Elora and Barrie clarifiers (R^2 = 0.40 – 0.77).
- RAS concentration and sludge depth is closer to actual clarifier mass for Elora Clarifier #1, than the Barrie clarifiers and Elora Clarifier #2
- The difference between the sludge mass by RAS concentration and CSC mass is greater at higher masses in terms of kilograms of sludge.

Figure 3: Sludge mass by predicted RAS concentration versus mass by CSC




Elora Clarifier #2
kg sludge by Predicted RAS concentration
kg sludge by CSC
y = 1.1724x
R² = 0.5172
0
500
1000
1500
2000
2500
3000
3500
Clairifer Mass RAS Predicted (kg)
1:1 line
Linear (Clairifer Mass RAS Predicted (kg))


Barrie Clarifier #6
kg sludge by Predicted RAS concentration
kg sludge by CSC
y = 1.7118x
R² = 0.5006
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Clairifer Mass RAS Predicted (kg)
1:1 line
Linear (Clairifer Mass RAS Predicted (kg))

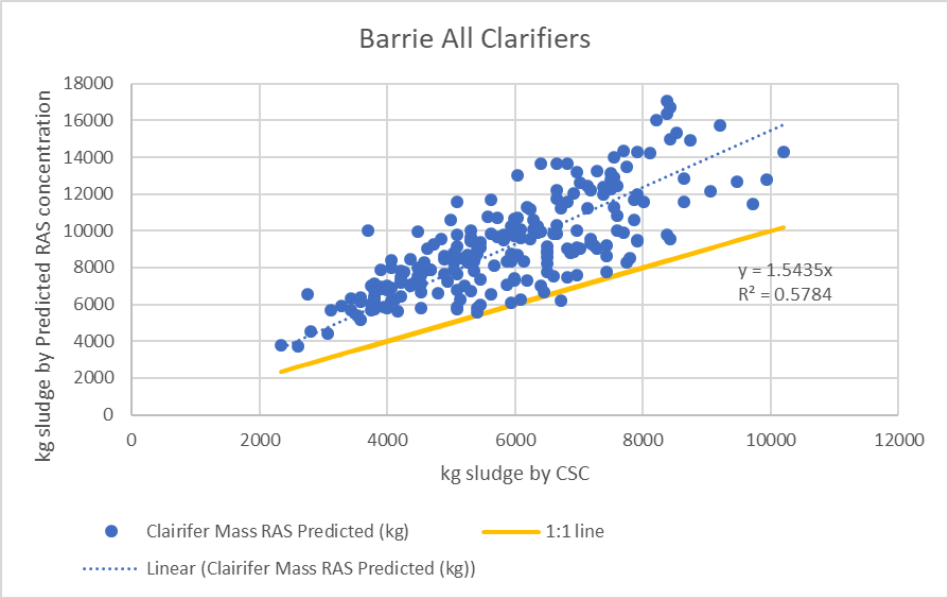
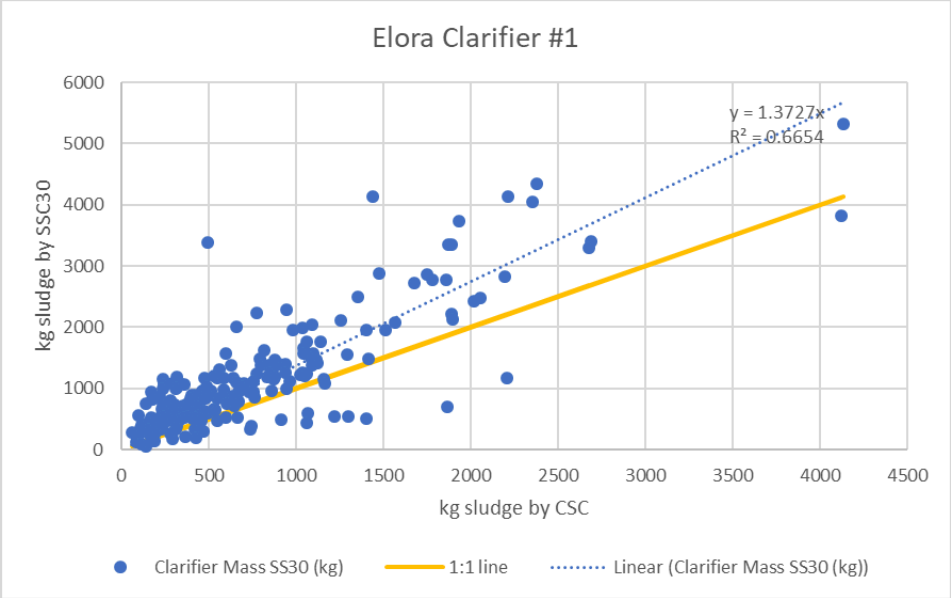
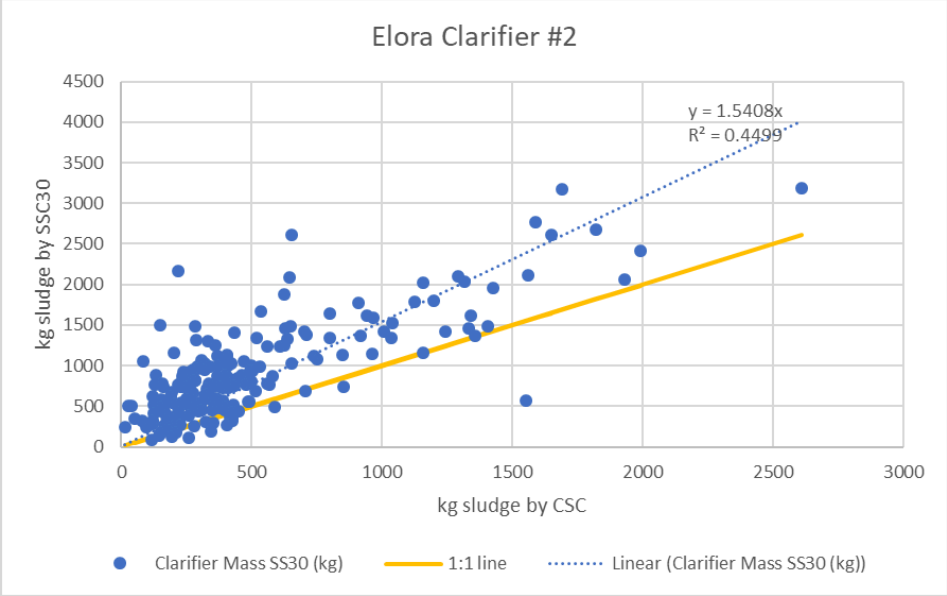


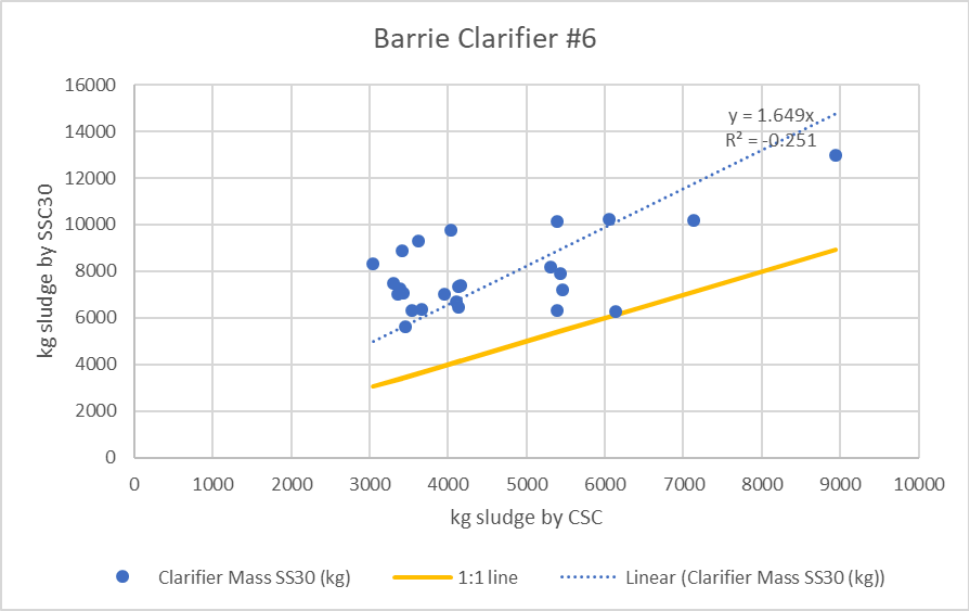
Figure 3 interpretation

- Sludge mass by predicted RAS concentration follows the CSC mass, but tends to overpredict actual sludge mass.
- The correlation between the actual mass and the predicted mass is the lowest among the methods ($R^2 = 0.50 - 0.66$), which overall is lower than the RAS concentration and blanket depth method.
- The difference between the sludge mass by predicted RAS concentration and CSC mass is greater at higher masses in terms of kg of sludge
- The predicted RAS depends on the %RAS and there is uncertainty in the %RAS calculation because of possible uneven flow splitting among clarifiers.

Figure 4: Sludge mass by SS30 concentration versus mass by CSC


Elora Clarifier #1
y = 1.3727x
R² = 0.6654
kg sludge by SSC30
kg sludge by CSC
0
1000
2000
3000
4000
5000
6000
0
500
1000
1500
2000
2500
3000
3500
4000
4500
Clarifier Mass SS30 (kg)
1:1 line
Linear (Clarifier Mass SS30 (kg))


Elora Clarifier #2
y = 1.5408x
R² = 0.4499
kg sludge by SSC30
kg sludge by CSC
0
500
1000
1500
2000
2500
3000
3500
4000
4500
0
500
1000
1500
2000
2500
3000
Clarifier Mass SS30 (kg)
1:1 line
Linear (Clarifier Mass SS30 (kg))



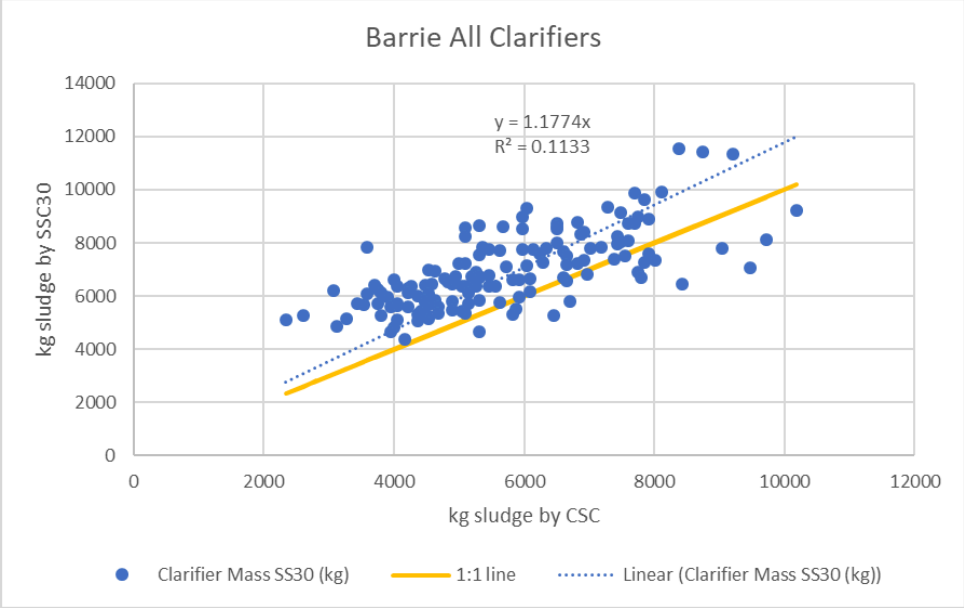


Figure 4 interpretation

- Sludge mass by SSC30 concentration follows the CSC mass, but tends to overpredict actual sludge mass and the correlation is modest
- The correlation between the actual mass and the predicted mass is the lowest among the methods ($R^2 = 0.11 - 0.66$)
- The difference between the sludge mass by SSC30 and CSC mass is greater at higher masses in terms of kg of sludge

Conclusions

- Methods used to predict secondary clarifier mass correlate with the actual clarifier mass, but these methods tend to over predict clarifier sludge masses for the data sets examined.
- Since there is a correlation, it may be possible to estimate clarifier mass using an alternate method to CSC using a correction factor (e.g. multiply clarifier sludge mass by RAS concentration and blanket height by 0.8).
- The prediction of clarifier mass with the measured RAS concentration and sludge blanket depth is the best method among the methods assessed for the data sets examined
- Errors in sludge mass estimates are higher at higher clarifier masses. Therefore, the RAS concentration method may not be applicable if a treatment plant tends to have high sludge masses in the clarifiers.
- Potential sources of error include:
    - Uneven flow splitting to the clarifiers. This would affect the predicted RAS concentration as an assumption is made that plant flow is evenly distributed to the clarifiers. Predicted RAS depends on the calculation of %RAS, which depends on knowledge of the proportion of plant flow to a clarifier.
    - RAS concentrations are not taken from individual clarifiers. Often RAS concentrations are combined samples from more than one clarifier. For example, RAS from all clarifiers my go into a chamber before being returned to aeration basin(s) and the RAS concentration is measured where it returns to the aeration basin.
    - The sludge blanket depth measurement may not represent the actual sludge blanket height.

How will you use the results?

For example, changes to plant procedures based on study results, and/or follow-up studies.

- Share the analysis in this special study with ODT members for their feedback
- Recommend that caution should be used when estimating clarifier mass using an alternative to measuring actual clarifier sludge mass (CSC method). Operators that want to use and alternative method should do a special study to evaluate the applicability of the method.
    - The study would be to collect clarifier core samples and asses how well the alternative method agrees with the actual clarifier masses.
    - Data should be taken at a range of clarifier sludge masses, %RAS, blanket depths and SVI as these parameters may impact results.
    - The RAS concentration from each clarifier being studied should be measured separately, ideally.
    - If an alternate method is used, it is recommended to periodically check the method against the CSC method.