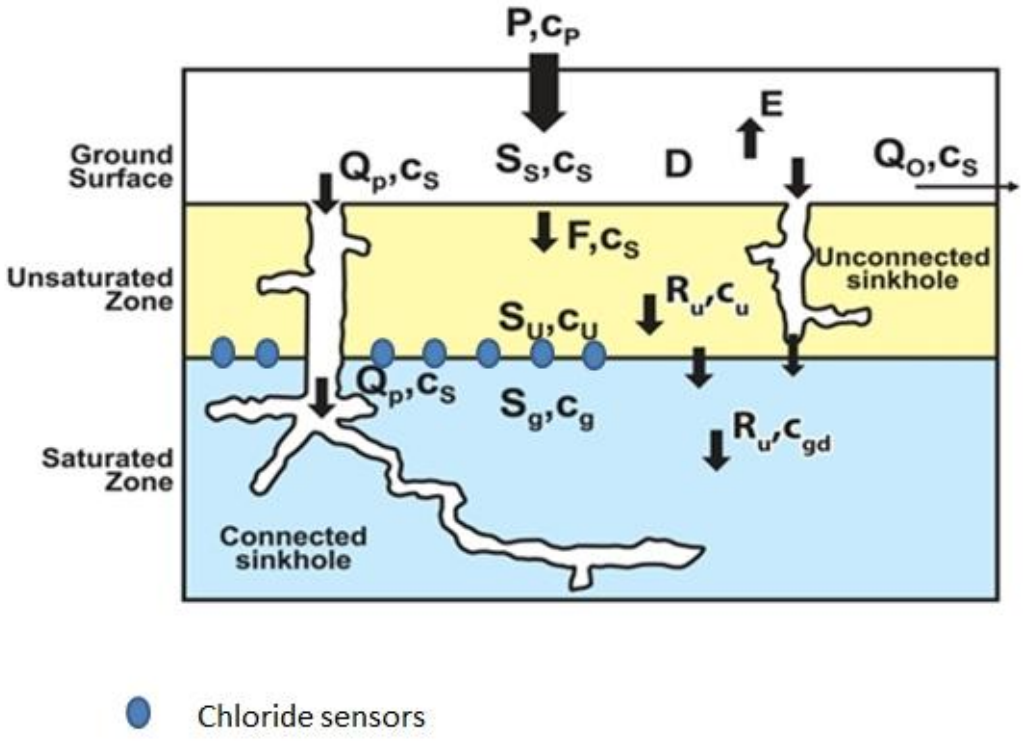
Why the Conventional CMB Fails in Karst.

To illustrate why the conventional CMB can underestimate recharge in Karst systems we use a simple diagram and explanation.



Suppose we install chloride sensors at the locations shown in the figure and suppose (for illustration) that the diffuse recharge volume is 5 Gl with an average chloride concentration of 100 mg/l. If there is no flow through the connected sinkhole then the conventional CMB applies and the average chloride concentration measured across the sensor array can be used in the calculation.

Now, consider what happens if we get an additional 5 Gl of flow through the connected sinkhole (or network of discrete connected sinkholes). Features of this flow are that it occurs through a relatively small cross-sectional area, has a concentration of Cl that is more reflective of rainfall (to illustrate in this example we use 50 mg/L) and is mostly transient flow from runoff to sinkholes (note that in our method we still seek to represent this as a long term average value, and hence total long-term chloride mass of the aquifer is not changed).

Clearly, the Cl sensors do not 'see' this contribution because they are sensing long term resident chloride concentrations. If there is transient water table rise in the sinkhole after rainfall events then the dilution effect will tend to be limited to a small zone around the sinkhole directly above the ambient water table plane in the diagram. Even if there happens to be one sensor close to the sinkhole, the average across the sensors will still tend towards the diffuse recharge value. Hence, the 5 Gl of sinkhole flow is not accounted for and the conventional CMB will underestimate recharge. This is also why increasing the number of sensors does not solve the problem.

Obviously, if the aquifer was continuously well mixed then the average chloride concentration from the two sources would be 75 mg/L (clearly lower than the diffuse recharge chloride concentration of

100 mg/L in this example) and the conventional chloride mass balance principles could be applied to account for the volume of the source that had caused this dilution. Unfortunately, most aquifers (particularly in karst) are not so obliging and at best we see lower Cl ‘lenses’ as evidence of a bimodal recharge process (possibly augmented by evidence of Cl dilution around sinkholes) .

Hence, the only way to account for this transient sinkhole recharge is to attempt a measure or estimate of the point source recharge volume and add it to the diffuse recharge term, as we have done.