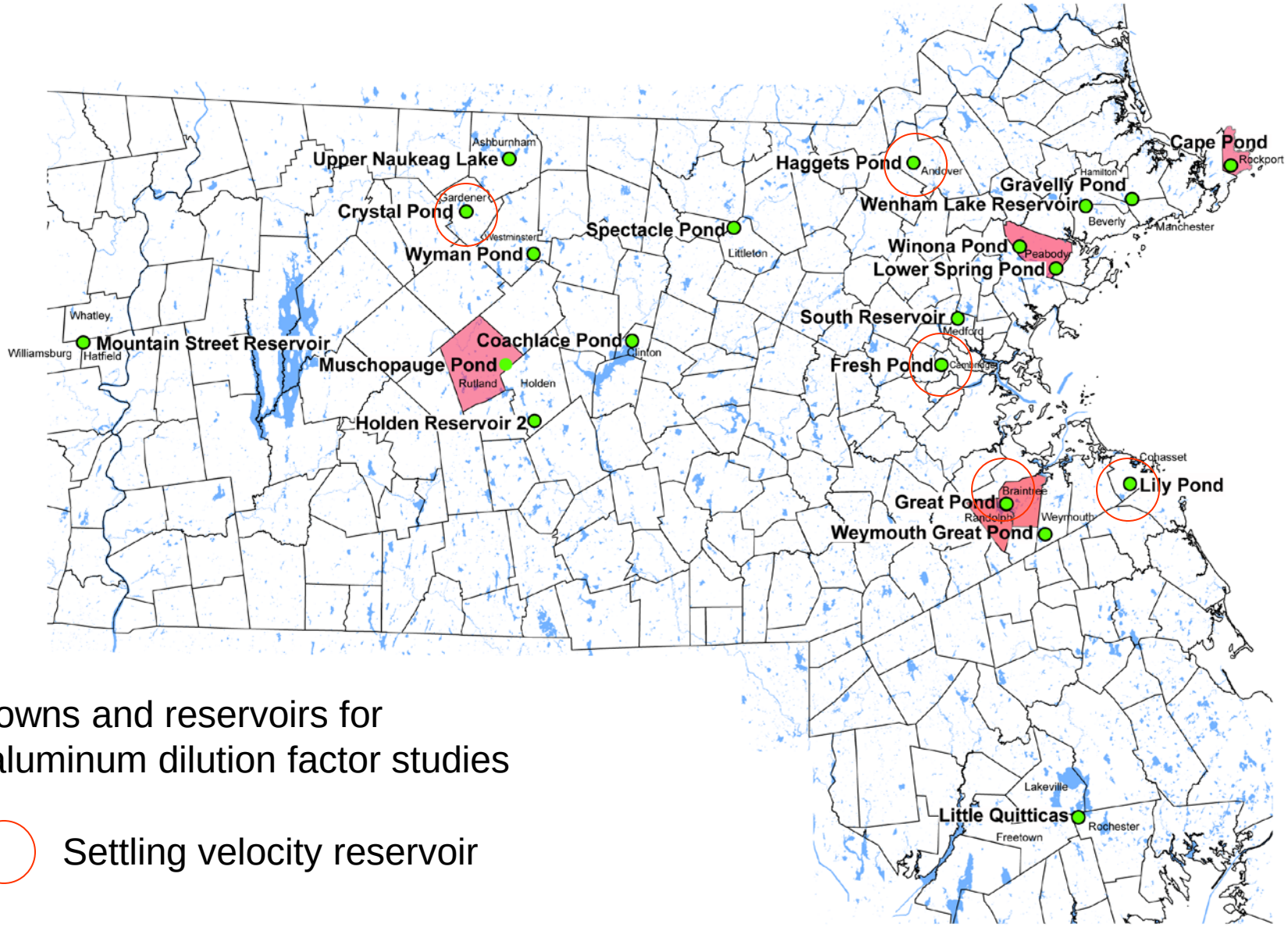
jacolman@usgs.gov



Towns and reservoirs for aluminum dilution factor studies

Settling velocity reservoir

Project Objectives

- Develop a method for computing dilution factors for the discharge of aluminum-containing filter backwash wastes into reservoirs.
- Compute dilution factors for all (about 21) of the aluminum effluents from PWS treatment plants that discharge into Massachusetts PWS reservoirs.

What is a dilution factor?

» **For Massachusetts:**

» **Equation used to calculate the dilution factor at the outfall**

$$\text{Dilution Factor} = \frac{QR + (QP \times 1.55)}{QP \times 1.55}$$

where:

QR = Estimated 7Q10 low flow for the receiving water at the outfall, in cubic feet per second (cfs).

QP = Discharge rate, in million gallons per day (mgd)

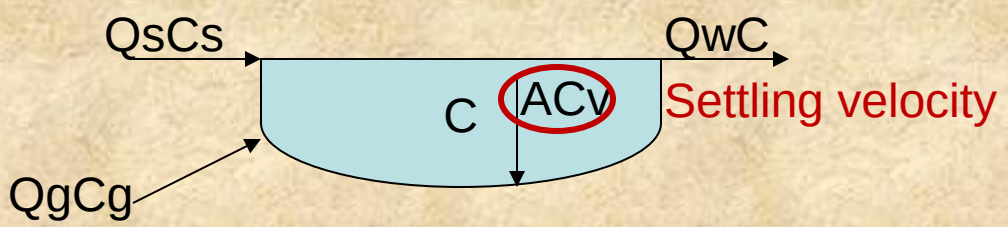
1.55 = Factor to convert mgd to cfs.

- **Used to set concentrations and flows for discharge permits.**

Could define DF by concentrations: DF = Ce/C

- **dC/dt = (QeCe+QsCs+QgCg-QwC-ACv)/V, where**

- **C is the total aluminum concentration in the reservoir,**
  Qe is the discharge of the effluent,
  Ce is the total aluminum concentration in the effluent,
  Qs is the discharge of the streams that are influent to the reservoir,
  Cs is the total aluminum concentration in the stream,
  Qg is the discharge of groundwater that is influent to the reservoir,
  Cg is the total aluminum concentration of the groundwater,
  Qw is the sum of water withdrawal for water supply and discharge downstream,
  A is the area of the reservoir,
  v is the apparent settling velocity of total aluminum in the reservoir, and
  V is the volume of the reservoir subject to mixing—typically the epilimnion volume.



To solve the differential equation, need:

- Daily inflow and concentration from streams
- Daily inflow and concentration from groundwater
- Volume of the reservoir

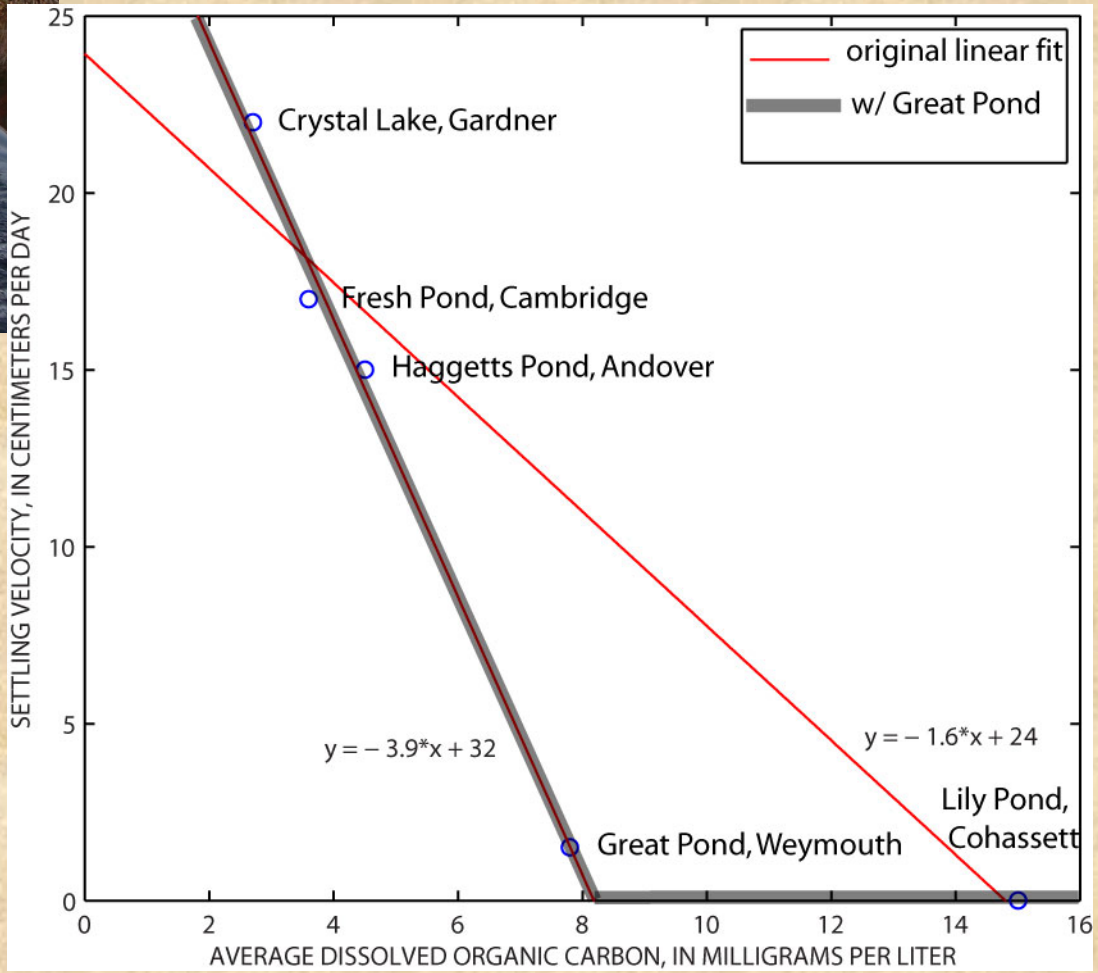
That is we need stream-flow estimators; safe yield studies.

- Estimate of settling velocity

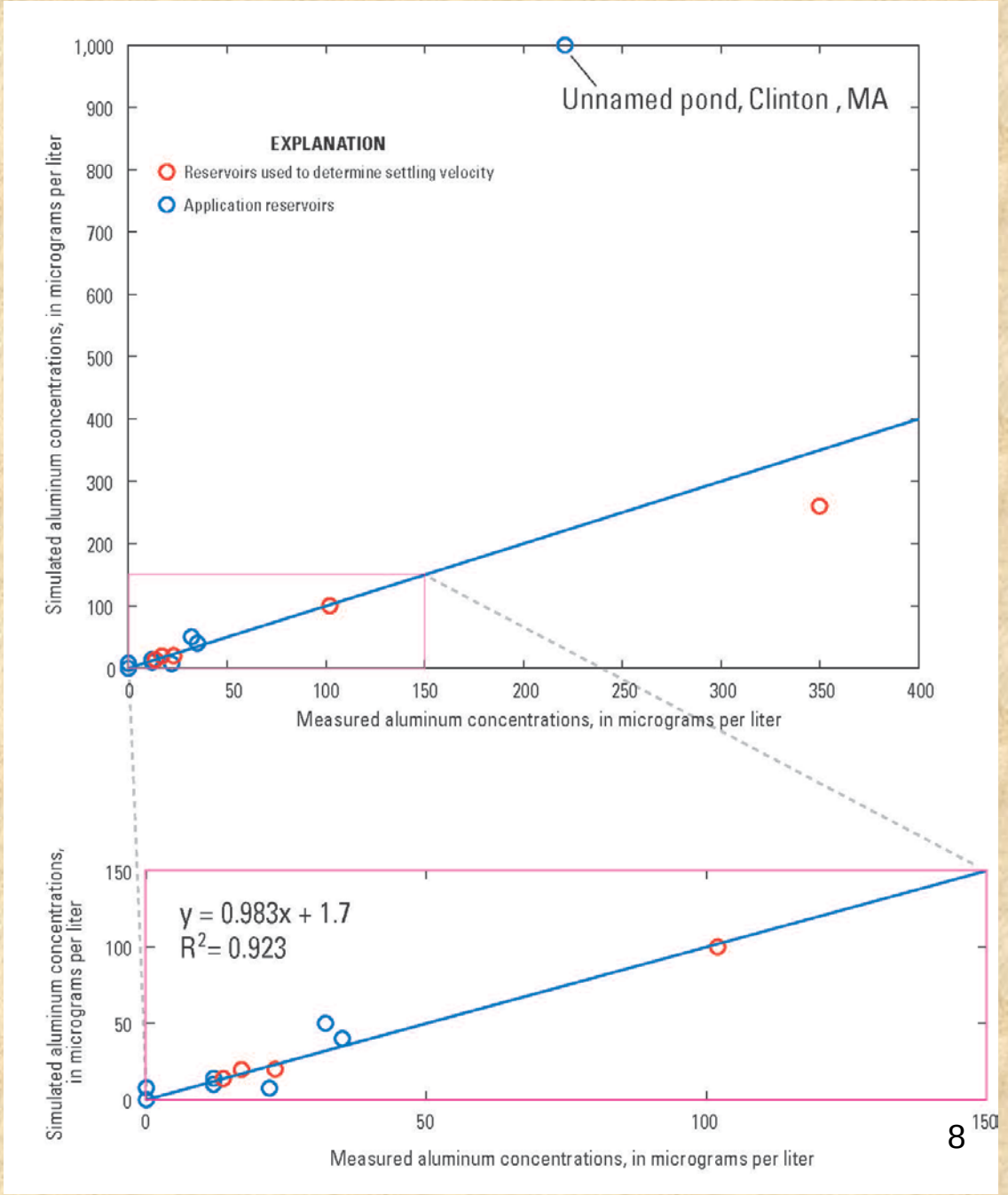
Settling velocity versus DOC

Lily Pond, Cohasset MA

Aluminum is very insoluble, <1µg/L at pH 4.7-7.0, so we could expect it to precipitate from the water and end up in the sediment. But organic carbon holds it in solution.



Predicted versus measured values of Al concentration



How difficult is the solution?

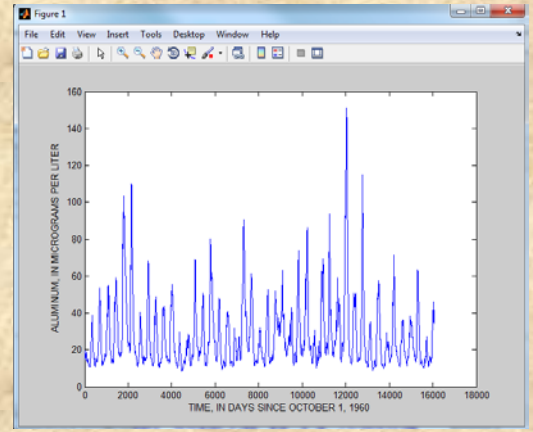
- 40 years of data because of the need for recurrence statistics.
- Excel input files used by MATLAB routine (available in the appendix) to generate Al concentration time series in the reservoir and a time series of dilution factors. 1.5 minutes of run time.

Daily input data

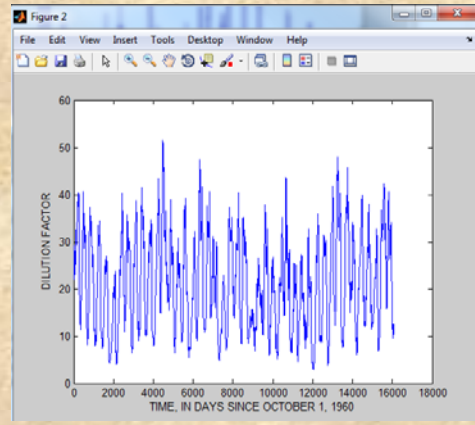
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1	day	Volume(M	Volume(L)	Area(Mi2)	Area(m2)	SpillVol(m	SpillVol(L	Qwin(mgd	Qwin(Lpd)	Qin(cfs)	Qin(Lpd)	SeriesRes	Withdrawi	Usage(Lpd	Qe(Lpd)
2	1	606.0329	2.29E+09	0.475693	1232040	2.328375	8812900	0	0	2.323723	5685165	0	1.410343	5338148	552610
3	2	604.8979	2.29E+09	0.475693	1232040	0	0	0.014132	53489.06	2.442315	5975309	0	1.410343	5338148	1135500
4	3	603.8614	2.29E+09	0.475201	1230765	0	0	0.012885	48769	2.485785	6081661	0	1.410343	5338148	1086295
5	4	602.7415	2.28E+09	0.474752	1229601	0	0	0.013898	52603.73	2.718442	6650873	0	1.410343	5338148	541255
6	5	601.9087	2.28E+09	0.474266	1228343	0	0	0.010321	39066.1	2.96539	7255052	0	1.410343	5338148	537470
7	6	601.3893	2.28E+09	0.473905	1227407	0	0	0.006433	24348.53	3.774807	9235352	0	1.410343	5338148	1086295
8	7	601.5527	2.28E+09	0.473679	1226824	0	0	-0.00202	-7662	3.911182	9569002	0	1.410343	5338148	1071155
9	8	601.1003	2.28E+09	0.47375	1227007	0	0	0.0056	21194.69	4.001512	9790003	0	1.410343	5338148	537470
10	9	600.5151	2.27E+09	0.473554	1226499	0	0	0.007239	27398.29	3.85146	9422887	0	1.410343	5338148	556395
11	10	599.8727	2.27E+09	0.4733	1225842	0	0	0.007937	30042.72	3.696927	9044812	0	1.410343	5338148	1097650
12	11	599.4388	2.27E+09	0.473022	1225120	0	0	0.005357	20275.3	4.00052	9787573	0	1.410343	5338148	1067370
13	12	599.0088	2.27E+09	0.472833	1224633	0	0	0.005306	20083.4	4.273533	10455522	0	1.410343	5338148	533685
14	13	598.8008	2.27E+09	0.472647	1224150	0	0	0.002566	9712.873	4.348425	10638751	0	1.410343	5338148	537470
15	14	598.5642	2.27E+09	0.472557	1223916	0	0	0.002918	11043.53	4.464339	10922343	0	1.410343	5338148	1105220
16	15	598.3216	2.26E+09	0.472454	1223651	0	0	0.00299	11317.54	4.468773	10933191	0	1.410343	5338148	1063585
17	16	598.0778	2.26E+09	0.472349	1223378	0	0	0.003004	11370.63	4.619888	11302905	0	1.410343	5338148	560180
18	17	598.1894	2.26E+09	0.472243	1223104	0	0	-0.00137	-5202.52	4.121455	10083451	0	1.410343	5338148	567750
19	18	598.1264	2.26E+09	0.472292	1223230	0	0	0	0	4.118387	10075946	0	1.410343	5338148	1146855
20	19	598.0446	2.26E+09	0.472264	1223159	0	0	0	0	4.355986	10657249	0	1.410343	5338148	1082510
21	20	600.1004	2.27E+09	0.472229	1223067	0	0	-0.02541	-96183.7	3.380109	8269691	0	1.410343	5338148	541255
22	21	603.9518	2.29E+09	0.47312	1225376	0	0	-0.04789	-181253	2.324211	5686359	0	1.410343	5338148	609385
23	22	603.227	2.28E+09	0.474791	1229702	0	0	0.009001	34069.95	2.527904	6184708	0	1.410343	5338148	1116575
24	23	602.4846	2.28E+09	0.474476	1228888	0	0	0.00921	34859.75	2.63635	6450028	0	1.410343	5338148	1097650
25	24	604.0877	2.29E+09	0.474154	1228054	0	0	-0.01994	-75458.1	2.162877	5291643	0	1.410343	5338148	560180
26	25	606.0329	2.29E+09	0.47485	1229855	4.544845	17202230	-0.02396	-90697.7	1.16085	2840107	0	1.410343	5338148	563965
27	26	604.9336	2.29E+09	0.475693	1232040	0	0	0.013688	51810.95	1.030085	2520182	0	1.410343	5338148	1112790
28	27	603.4725	2.28E+09	0.475217	1230805	0	0	0.018152	68705.64	1.082314	2647963	0	1.410343	5338148	1071155
29	28	602.0912	2.28E+09	0.474583	1229164	0	0	0.017124	64815.66	1.19816	2931388	0	1.410343	5338148	541255
30	29	601.0155	2.27E+09	0.473984	1227612	0	0	0.013314	50392.31	1.368721	3348679	0	1.410343	5338148	522330
31	30	600.0697	2.27E+09	0.473517	1226404	0	0	0.011689	44243.73	1.567807	3835759	0	1.410343	5338148	1116575
32	31	599.4402	2.27E+09	0.473107	1225342	0	0	0.007774	29423.19	1.757881	4300790	0	1.410343	5338148	1093865
33	32	600.1683	2.27E+09	0.472834	1224635	0	0	-0.009	-34069	1.838194	4497282	0	1.295868	4904862	579105
34	33	606.0329	2.29E+09	0.47315	1225452	5.262859	19919920	-0.07224	-273440	0.762508	1865532	0	1.295868	4904862	556395
35	34	604.4137	2.29E+09	0.475693	1232040	0	0	0.020146	76251	0.460295	1126148	0	1.295868	4904862	1135500

=>

Simulated Al conc.

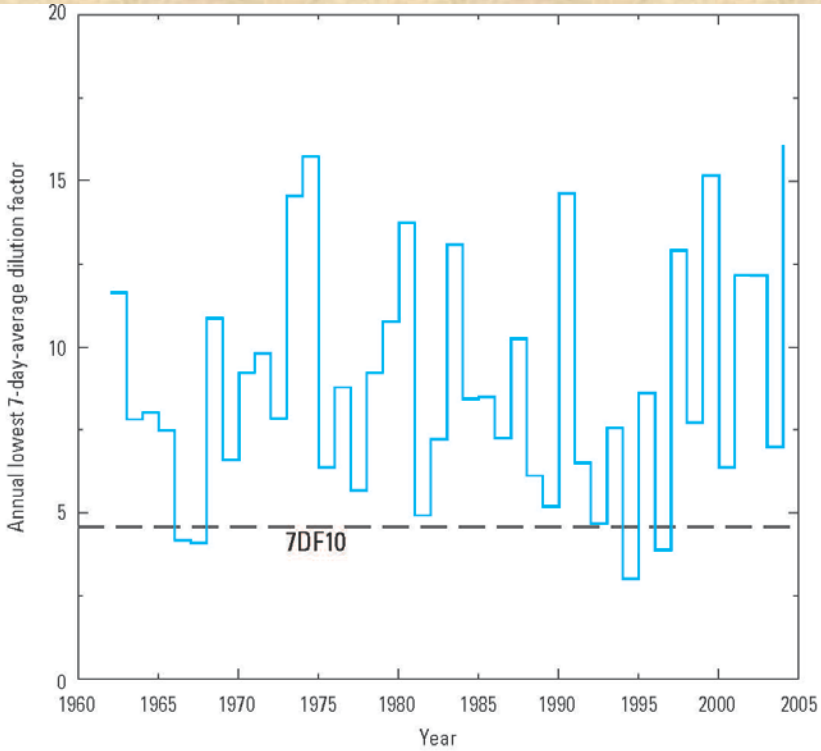


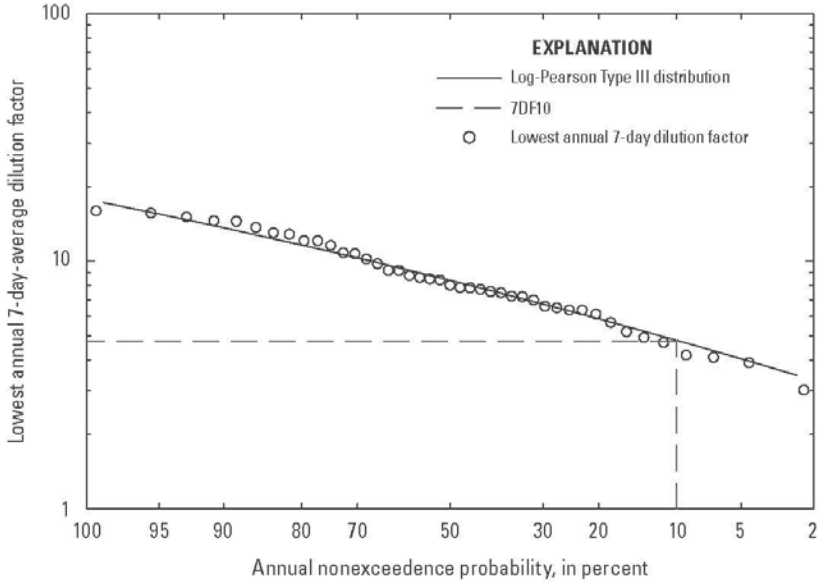
Simulated DF



With DF defined by concentrations, what happens to the 7Q10 stipulation?

- Determine the annual lowest 7-day average dilution factor
- Fit the data to a known distribution
- Select the 10th percentile non exceedance value (here equal to 4.8)





Final step

- Divide the effluent concentration used in the simulation by the 7DF10 to determine a concentration to compare to the standard
- 438/4.8= 91.3 ug/L Compare 87 ug/L standard. (Data from Quittacus Pond).
- Matching the effluent value to the standard more exactly requires an additional run at a lower effluent concentration value and interpolation.