Assessment of Internal Loading of Total Phosphorus in a Northern Everglades Canal Using a Simple Mixing Model

Keywords: Everglades, Eutrophication, Internal Loading

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The Arthur R. Marshall Loxahatchee National Wildlife Refuge includes one of three areas in South Florida designated to maintain water storage, provide flood control, and provide a refuge for the remnant Everglades ecosystem. In the 1950s and 1960s the refuge was surrounded by perimeter canals and hydrologically isolated from its watershed by levees. Stormwater runoff, primarily from the Everglades Agricultural Area, is pumped into the perimeter canal where it may flow to discharge structures or mix into the rainwater-dominated interior wetland. The pumped stormwater has elevated concentrations of both Cl and P. Data collected primarily by the South Florida Water Management District were analyzed in this study using a simple mixing model to provide a preliminary graphical assessment of P internal loading within the perimeter canal. This technique is analogous to the use of mixing plots or concentration-salinity diagrams in estuarine systems to identify presence of sources and sinks of constituents during seaward mixing. Rather than salinity, Cl is here used to estimate the fraction of each water sample originating in pumped inflow to the canal. This analysis supports the hypothesis that there is an internal P loading source within the canal. It is conjectured that the internal canal P source results from groundwater advection of re-mineralized P in sediment pore water. Recent studies have documented a large pool of P in the highly organic sediments deposited in the perimeter canal since construction. Relationship of internal loading to canal stage and discharge are examined.

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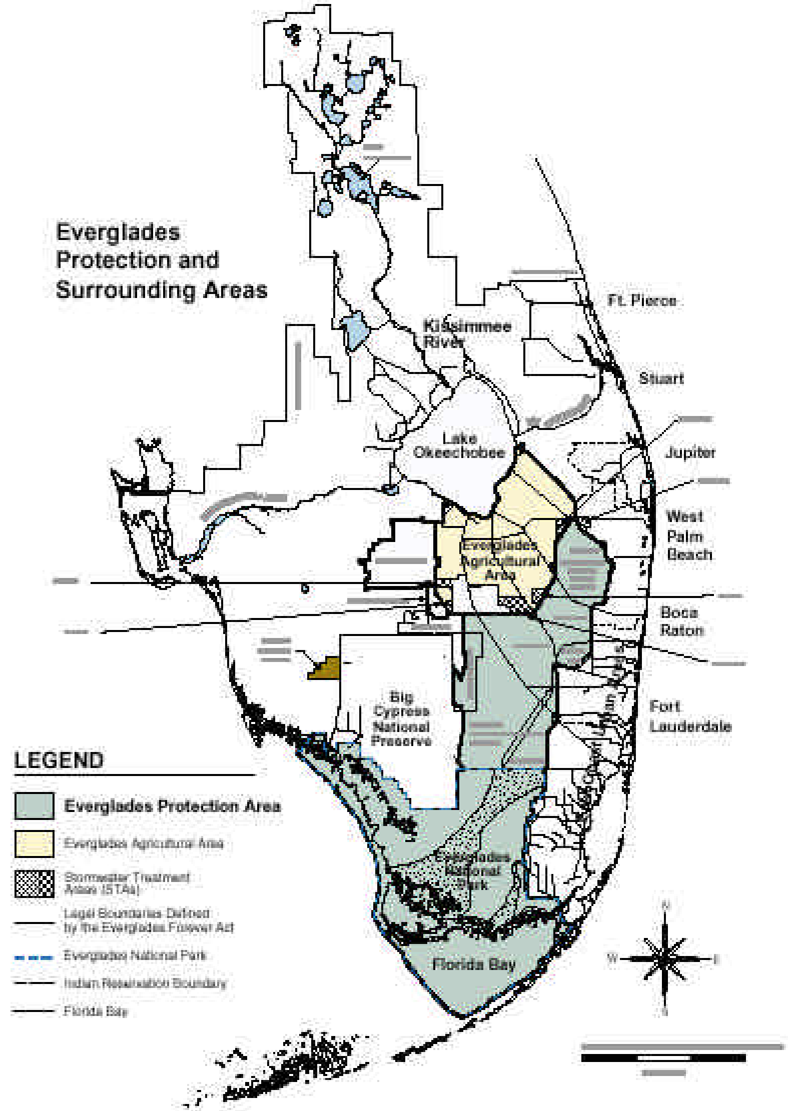
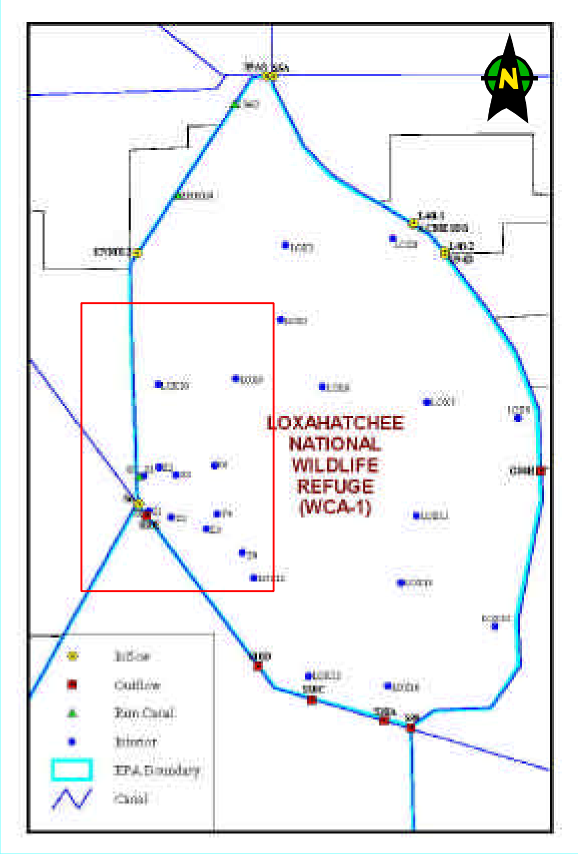
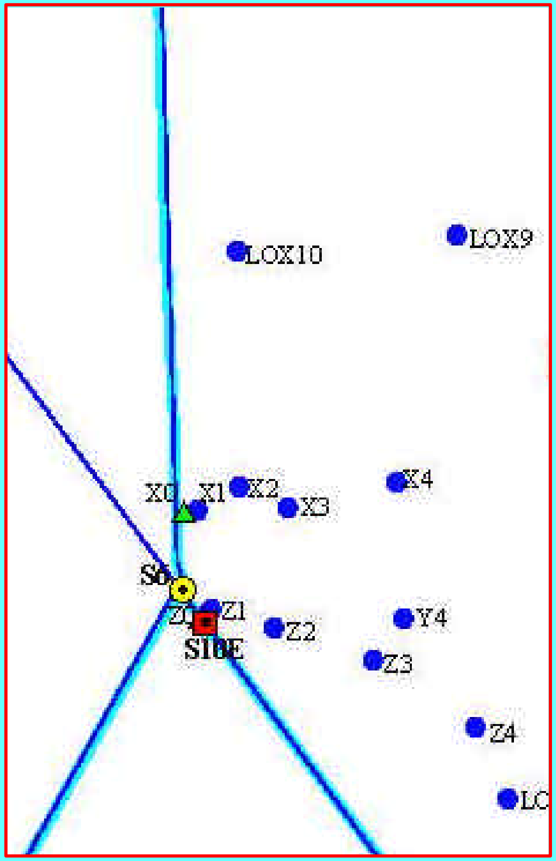
South Florida and the “Everglades Protection Area”



Source: *2001 Everglades Consolidated Report*, South Florida Water Management District

A.R.M. Loxahatchee National Wildlife Refuge

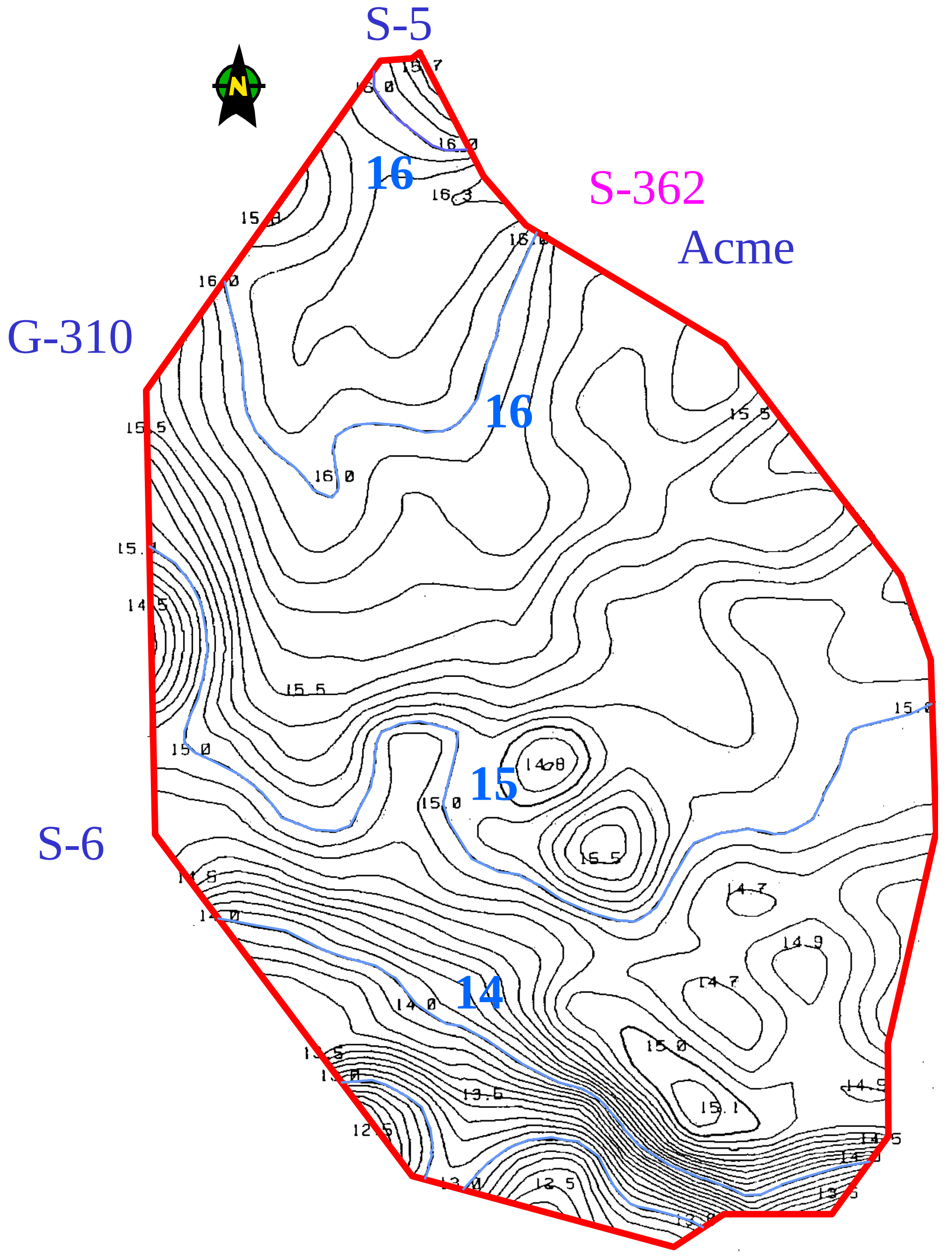


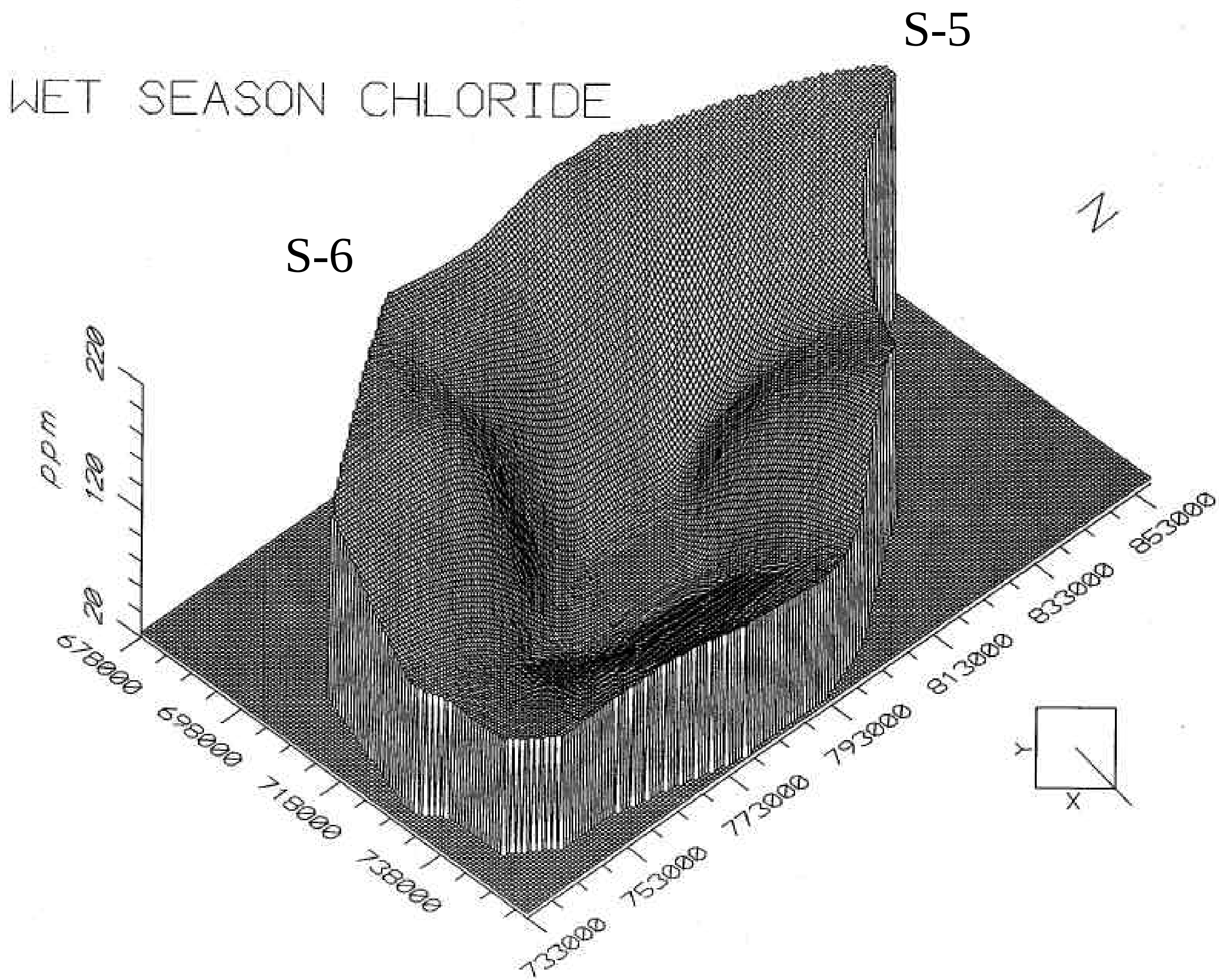


Contour plot

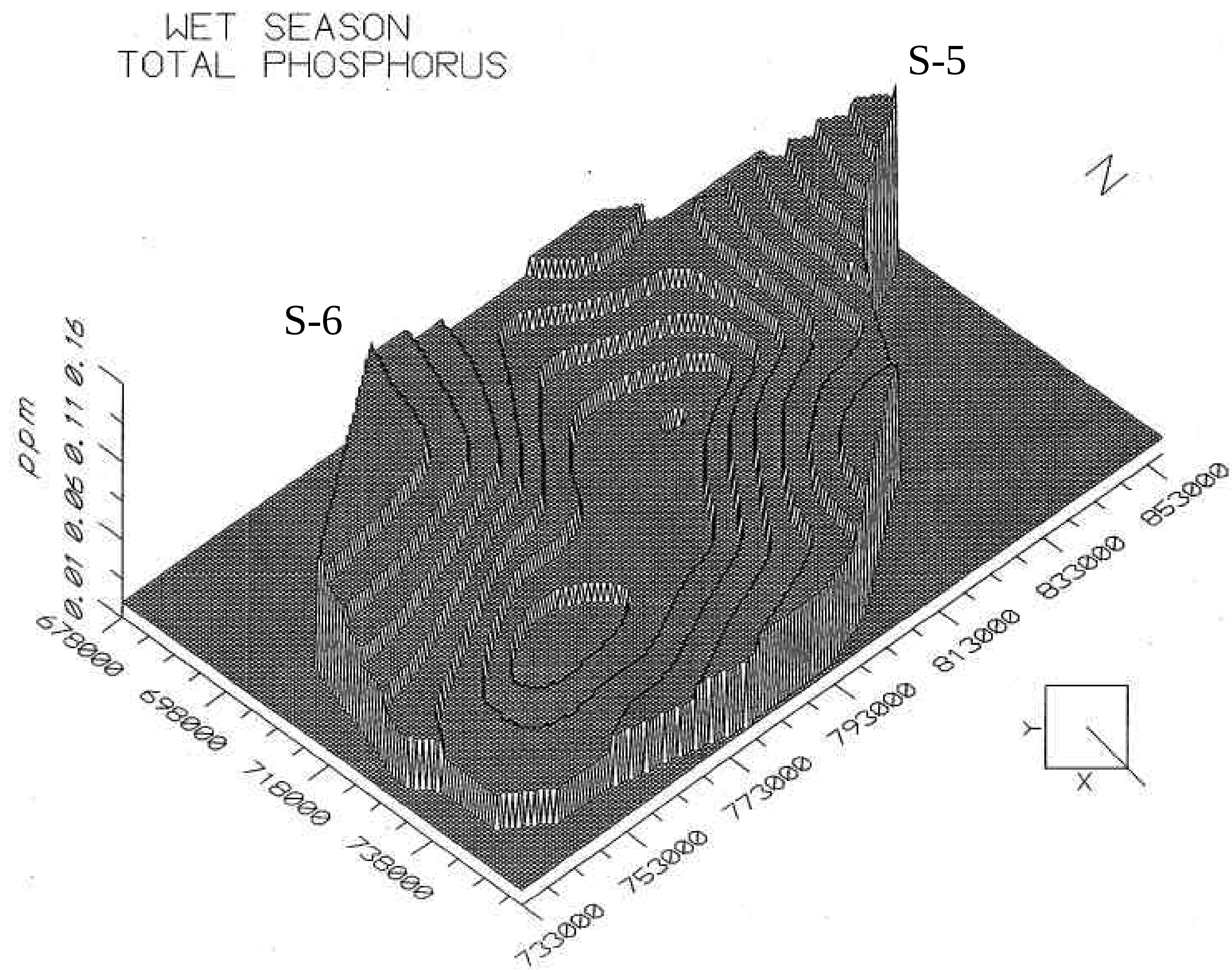
0.1 foot contour intervals

(Richardson, et al., 1990)





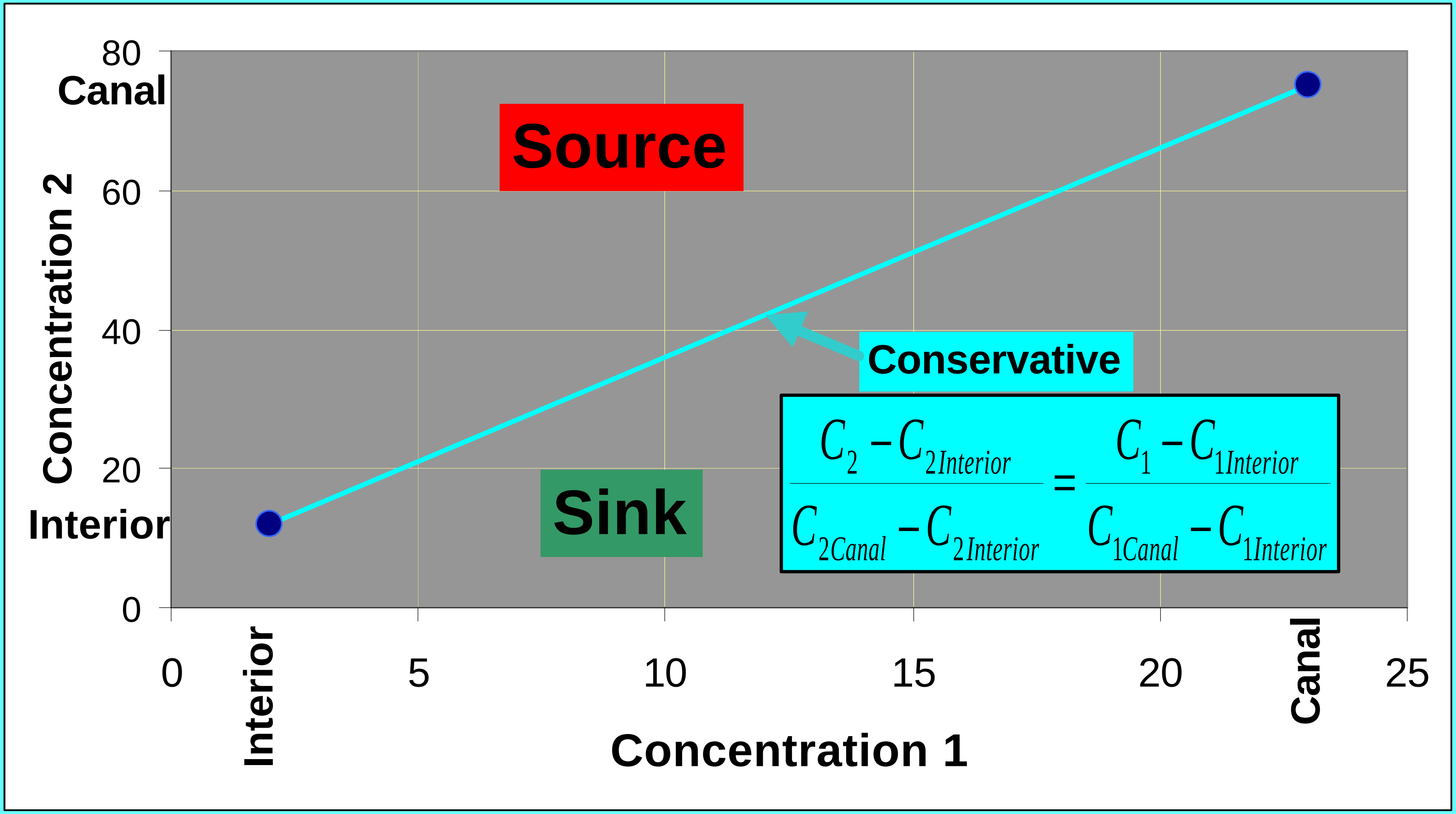
WET SEASON CHLORIDE
S-5
S-6
N
ppm
220
120
20
678000
698000
718000
738000
733000
753000
773000
793000
813000
833000
853000
Y
X


WET SEASON
TOTAL PHOSPHORUS
S-5
S-6
ppm
0.01 0.06 0.11 0.16
678000
698000
718000
738000
733000
753000
773000
793000
813000
833000
853000
N
Y
X

Need for an alternative approach:

- Dilution from mixing in WCA-1 confounds interpretation of concentration data
- Mixing-plot uses a conservative constituent to estimate the degree that dilution causes reduced concentration
- The mixing-plot provides a graphical means to qualitatively class constituents as conservative, having a source, or having a sink

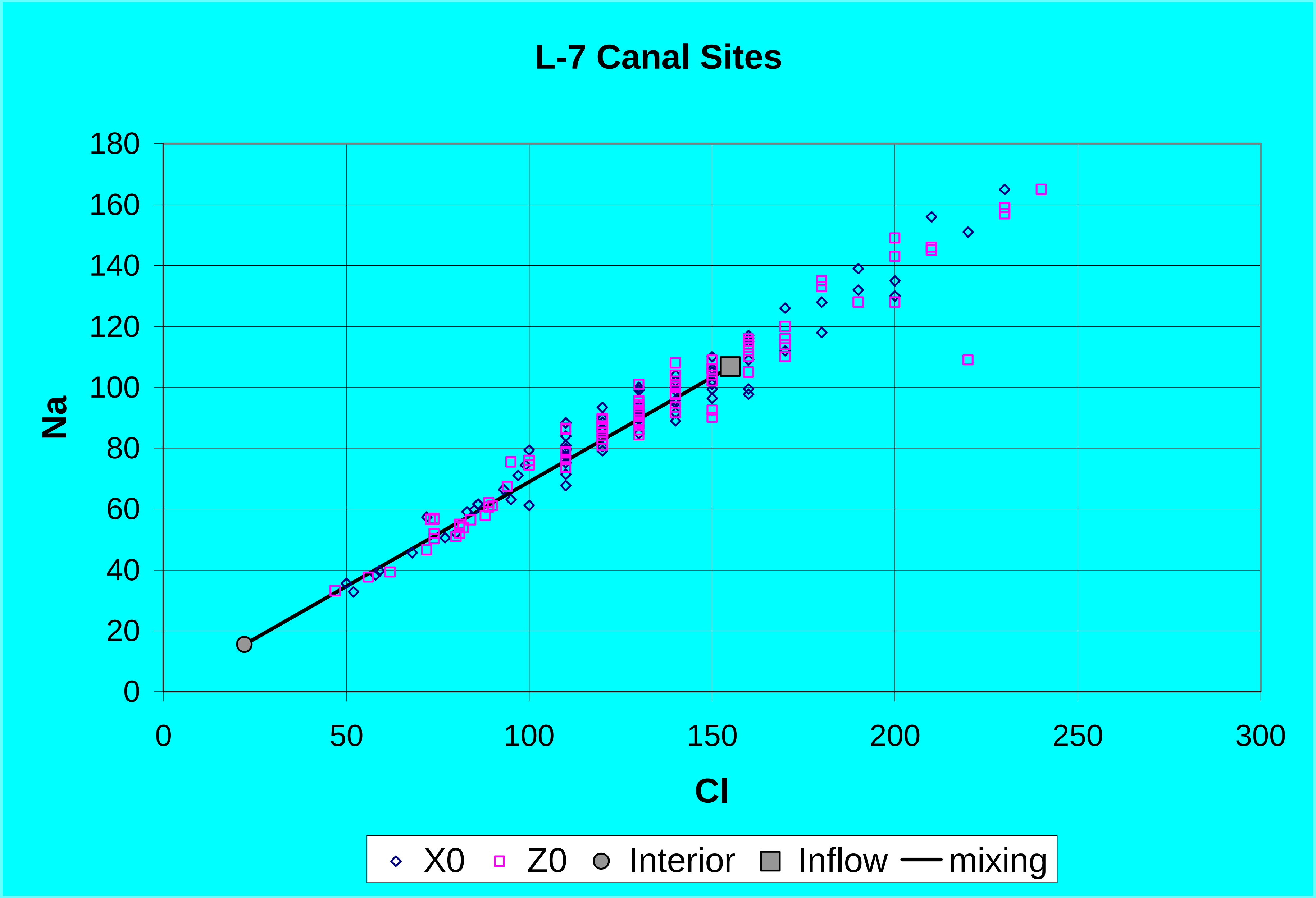
Mixing Plot


80
Canal
60
40
20
Interior
0
Concentration 2
Source
Sink
Conservative
$$\frac{C_2 - C_{2Interior}}{C_{2Canal} - C_{2Interior}} = \frac{C_1 - C_{1Interior}}{C_{1Canal} - C_{1Interior}}$$
0
Interior
5
10
15
20
Canal
25
Concentration 1

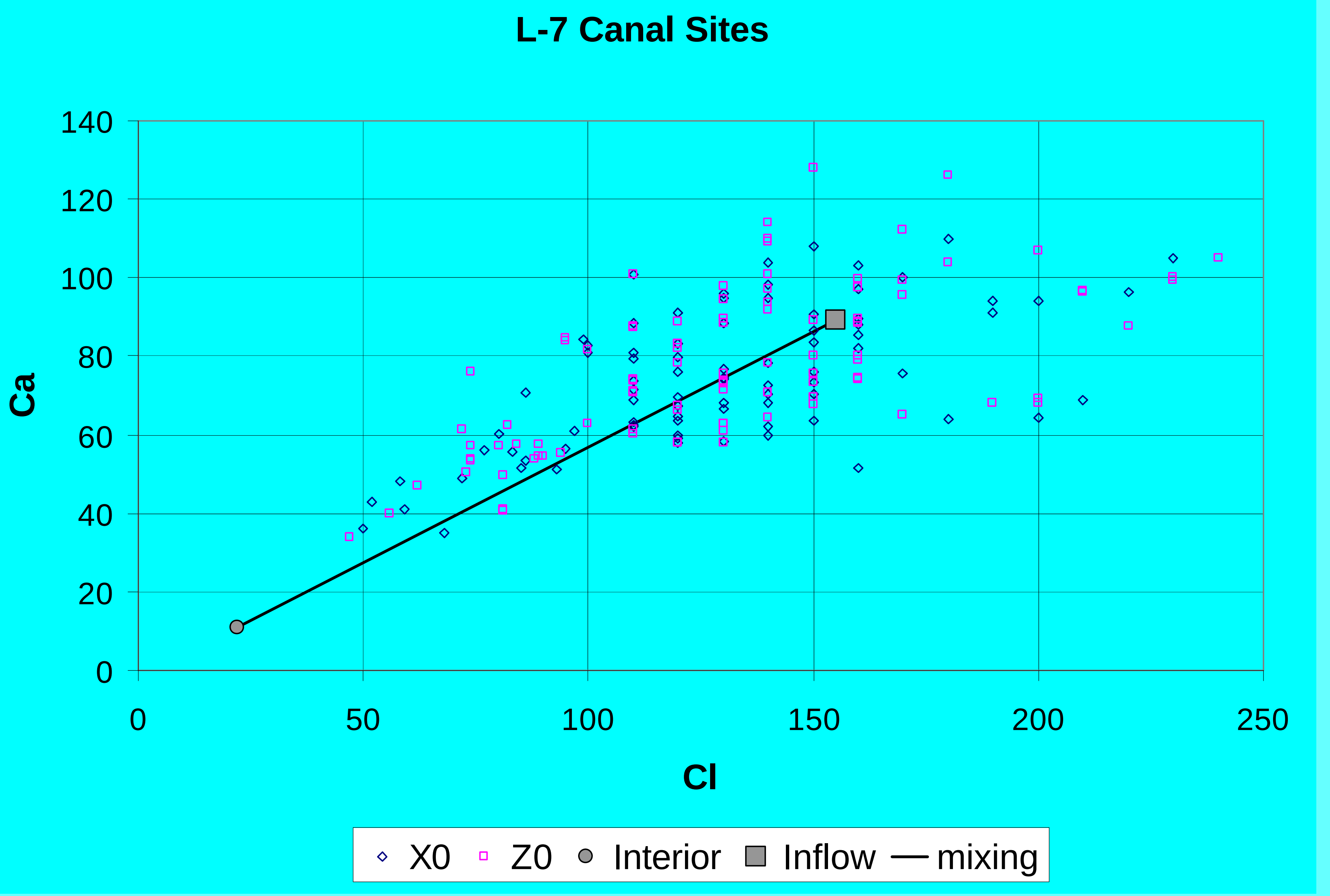
Estimated Concentrations

Inflow=median canal cond>932; Unimpacted=median sites-4 cond<228.85

SITE		Inflow	Unimpacted
Conductivity	uS/cm	1101	147
Alkalinity	mg/L	283	37
Chloride (filtered)	mg/L	155.0	22.2
Calcium (filtered)	mg/L	89.1	11.0
Sodium (filtered)	mg/L	106.8	15.5
Silica (filtered)	mg/L	21.5	5.4
Sulfate (filtered)	mg/L	61.5	1.02
Total P	mg/L	0.052	0.008
Total N	mg/L	2.71	0.98
TN/TP (mass)		53	130

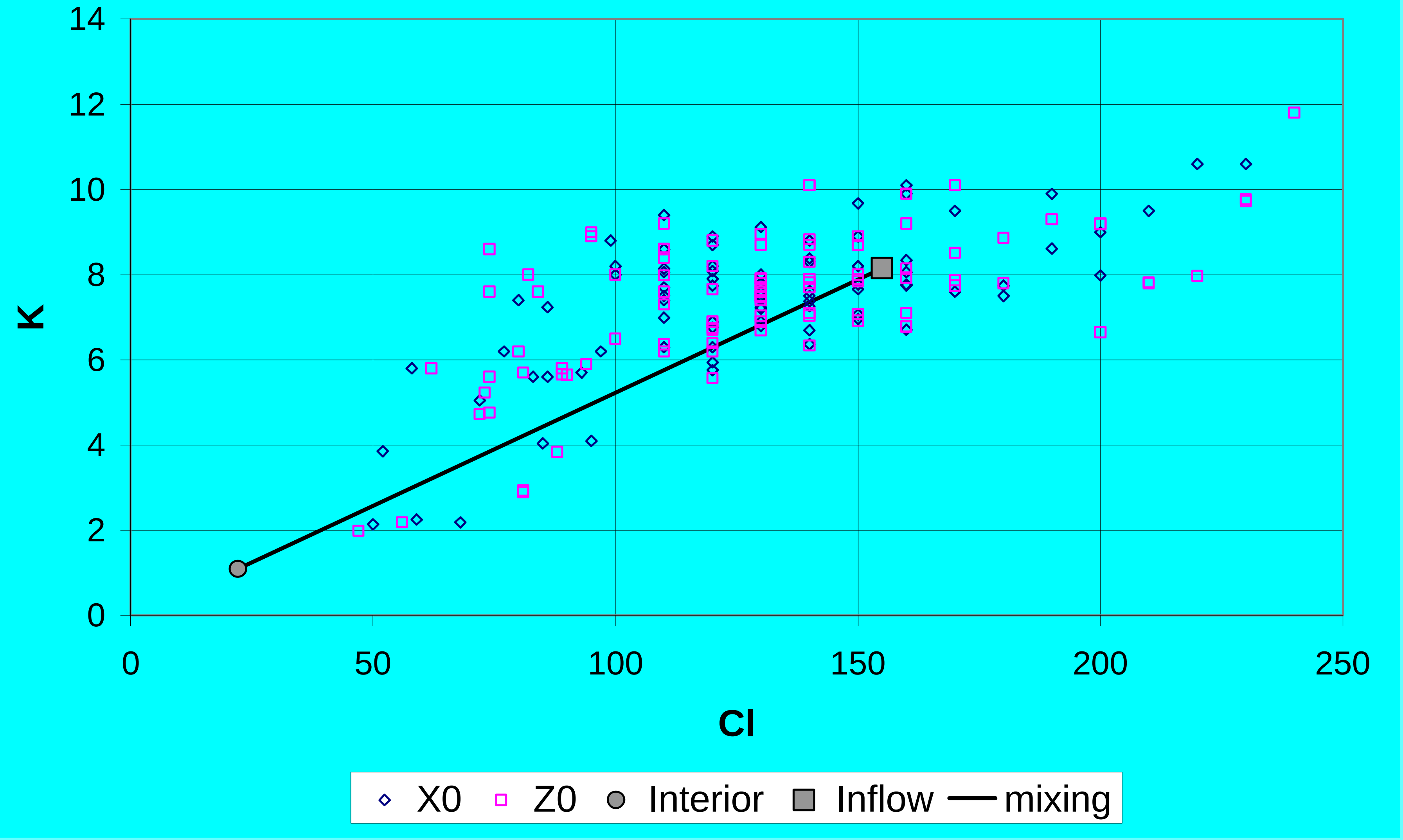


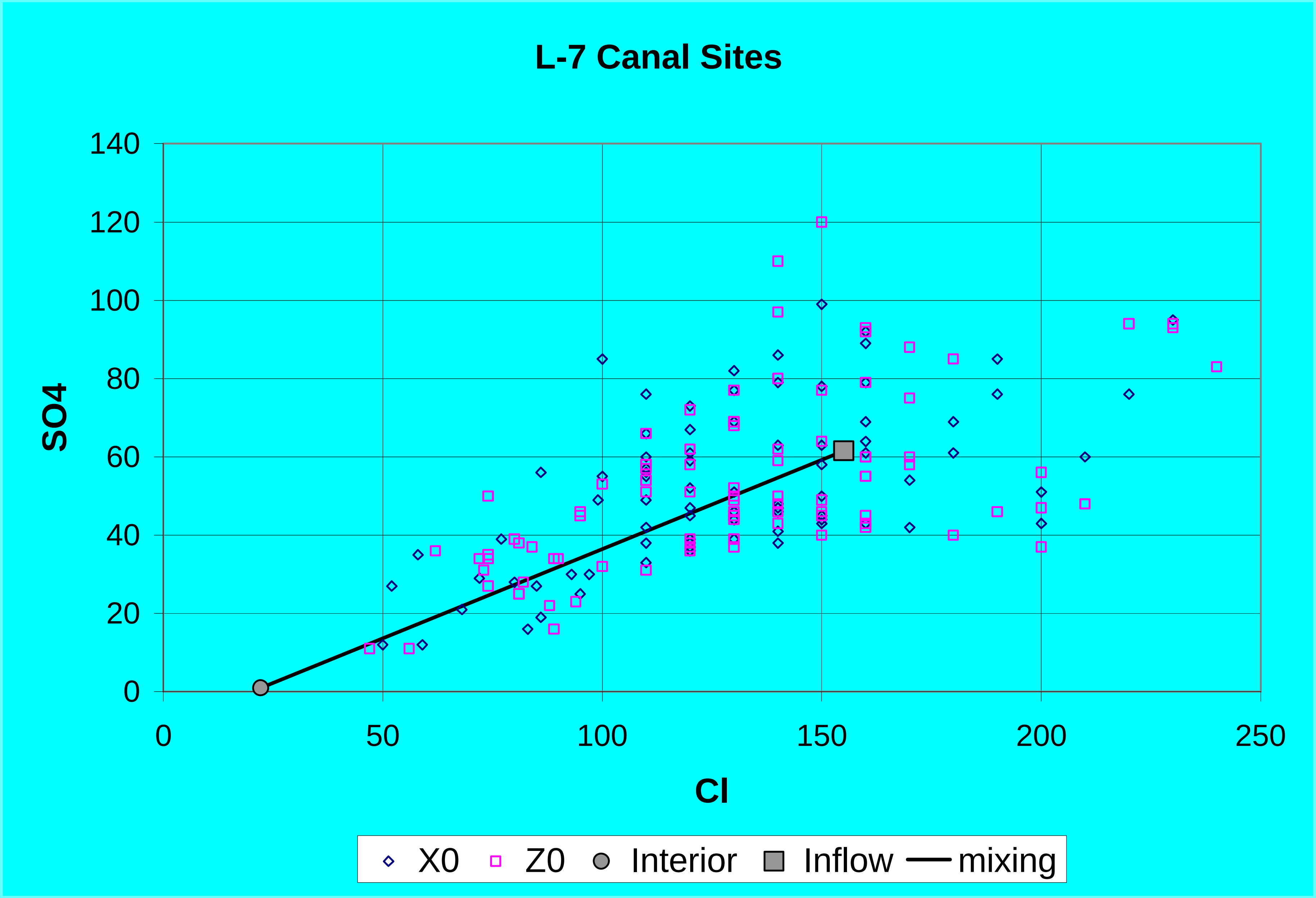
L-7 Canal Sites
Na
Cl
180
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
300
X0
Z0
Interior
Inflow
mixing



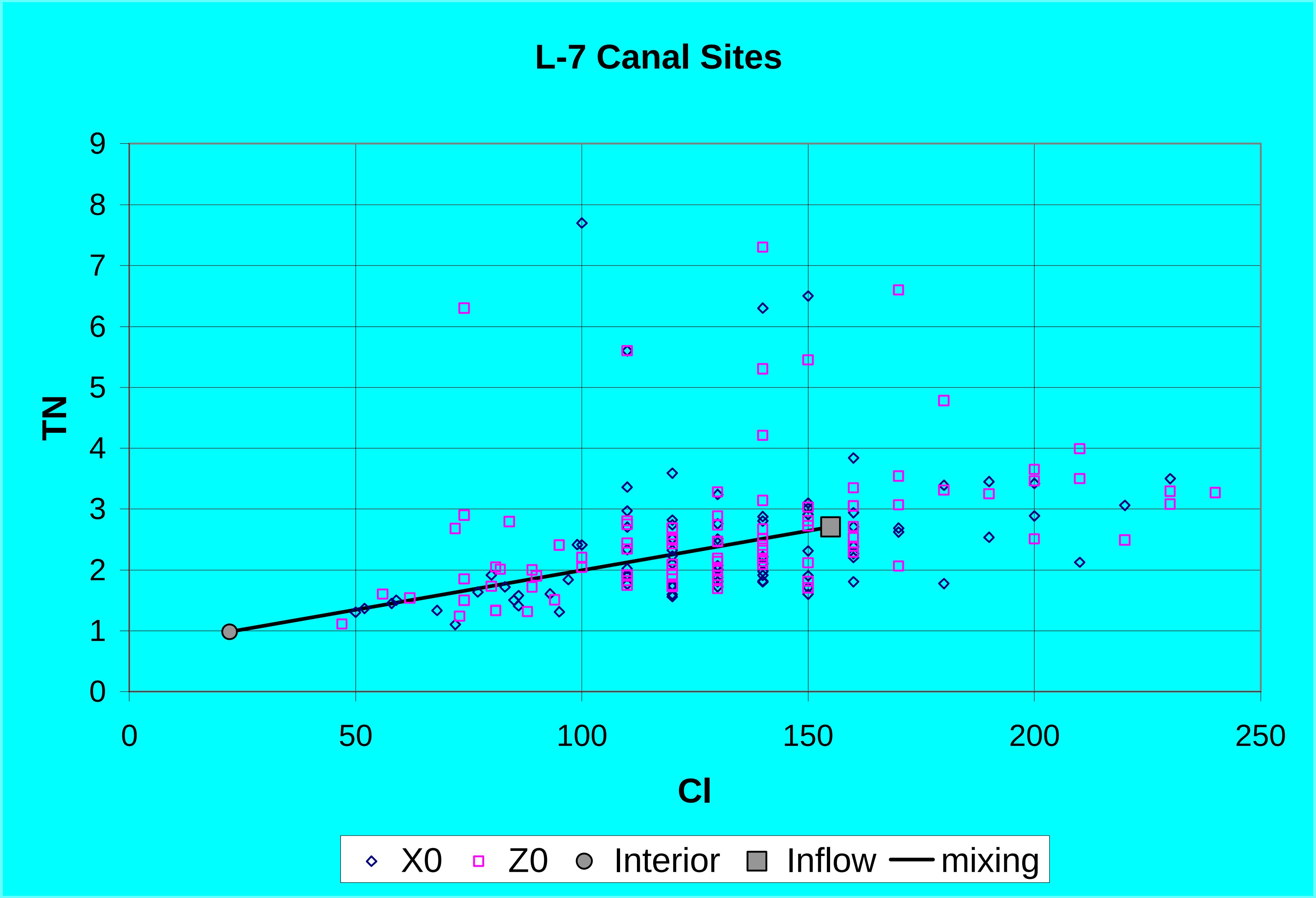
L-7 Canal Sites
Ca
140
120
100
80
60
40
20
0
0
50
100
150
200
250
Cl
X0
Z0
Interior
Inflow
mixing

L-7 Canal Sites

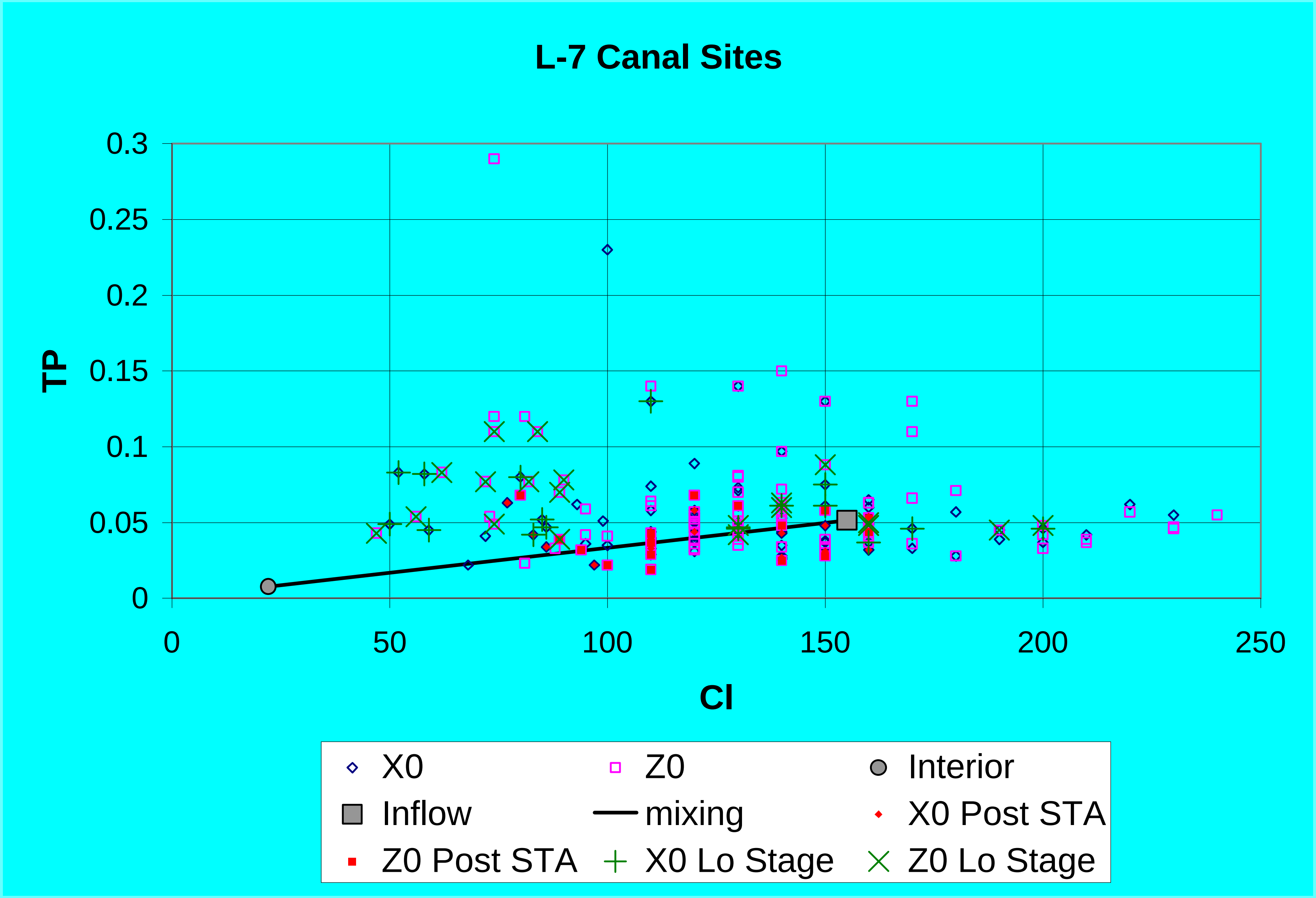


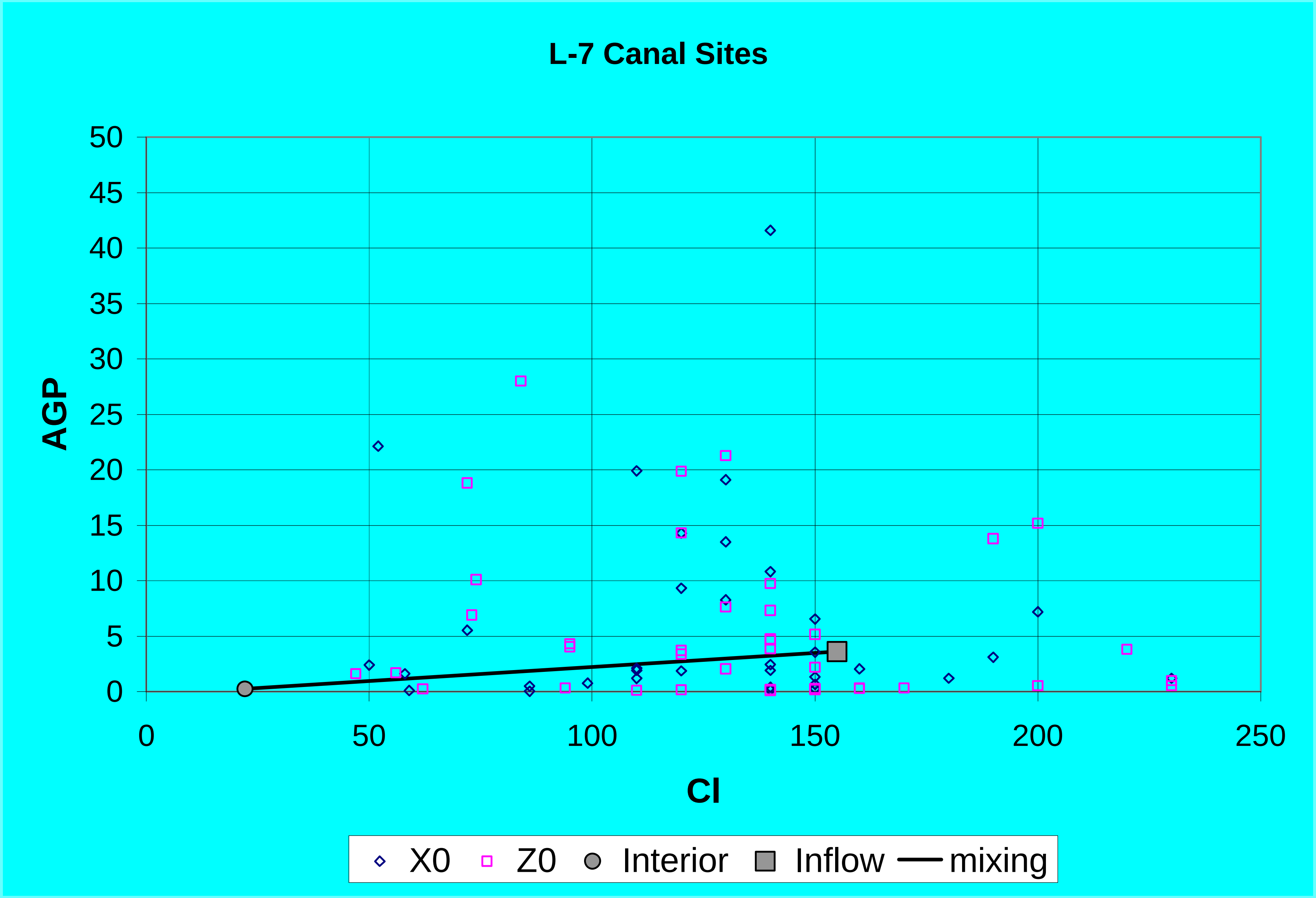


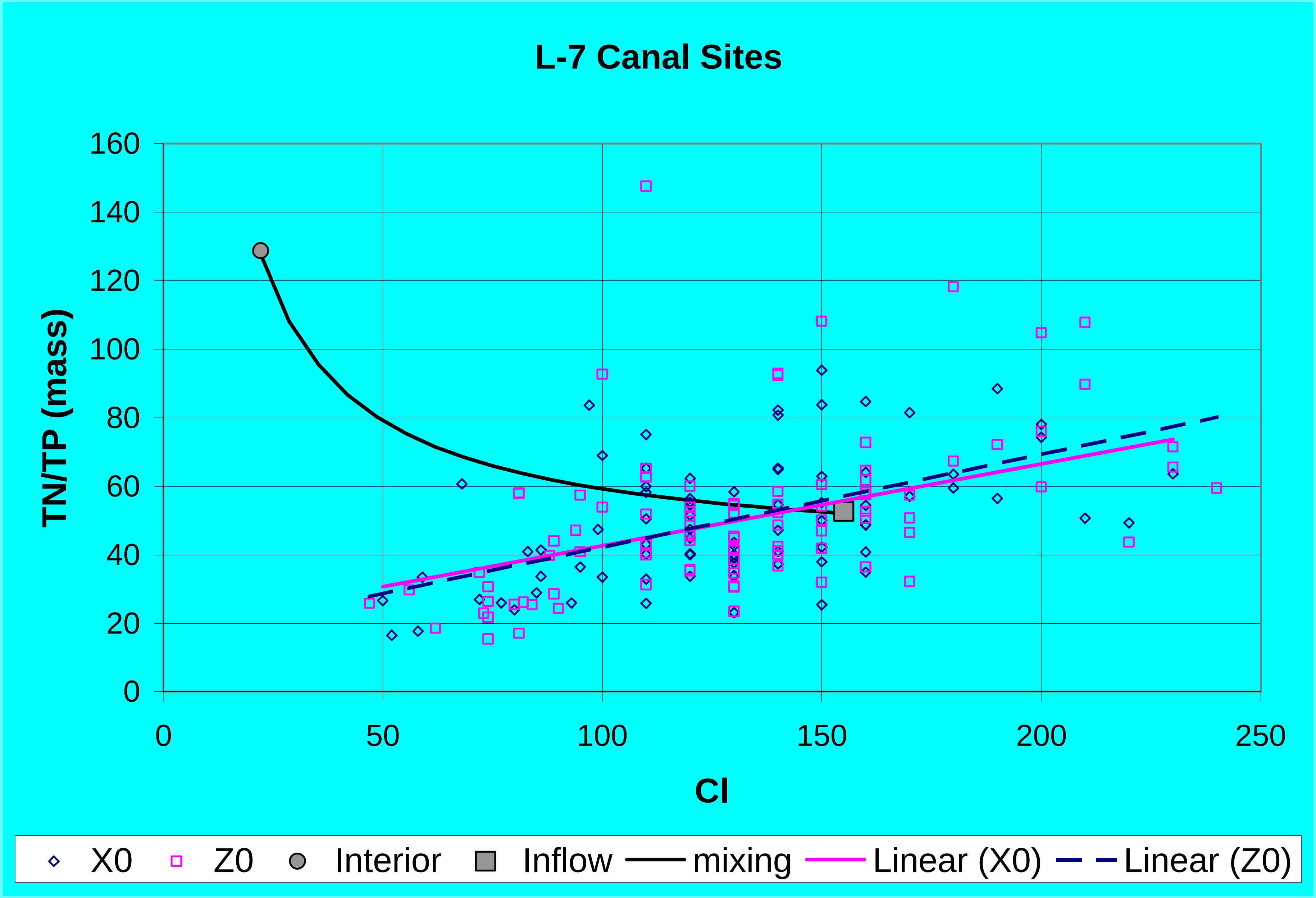
L-7 Canal Sites
SO4
Cl
0
20
40
60
80
100
120
140
0
50
100
150
200
250
X0
Z0
Interior
Inflow
mixing



L-7 Canal Sites
TN
Cl
0
1
2
3
4
5
6
7
8
9
0
50
100
150
200
250
X0
Z0
Interior
Inflow
mixing


L-7 Canal Sites
TP
0.3
0.25
0.2
0.15
0.1
0.05
0
0
50
100
150
200
250
Cl
X0
Z0
Interior
Inflow
mixing
X0 Post STA
Z0 Post STA
X0 Lo Stage
Z0 Lo Stage


L-7 Canal Sites
AGP
50
45
40
35
30
25
20
15
10
5
0
0
50
100
150
200
250
Cl
X0
Z0
Interior
Inflow
mixing



L-7 Canal Sites
TN/TP (mass)
160
140
120
100
80
60
40
20
0
0
50
100
150
200
250
Cl
X0
Z0
Interior
Inflow
mixing
Linear (X0)
Linear (Z0)

Characterization of water quality parameters

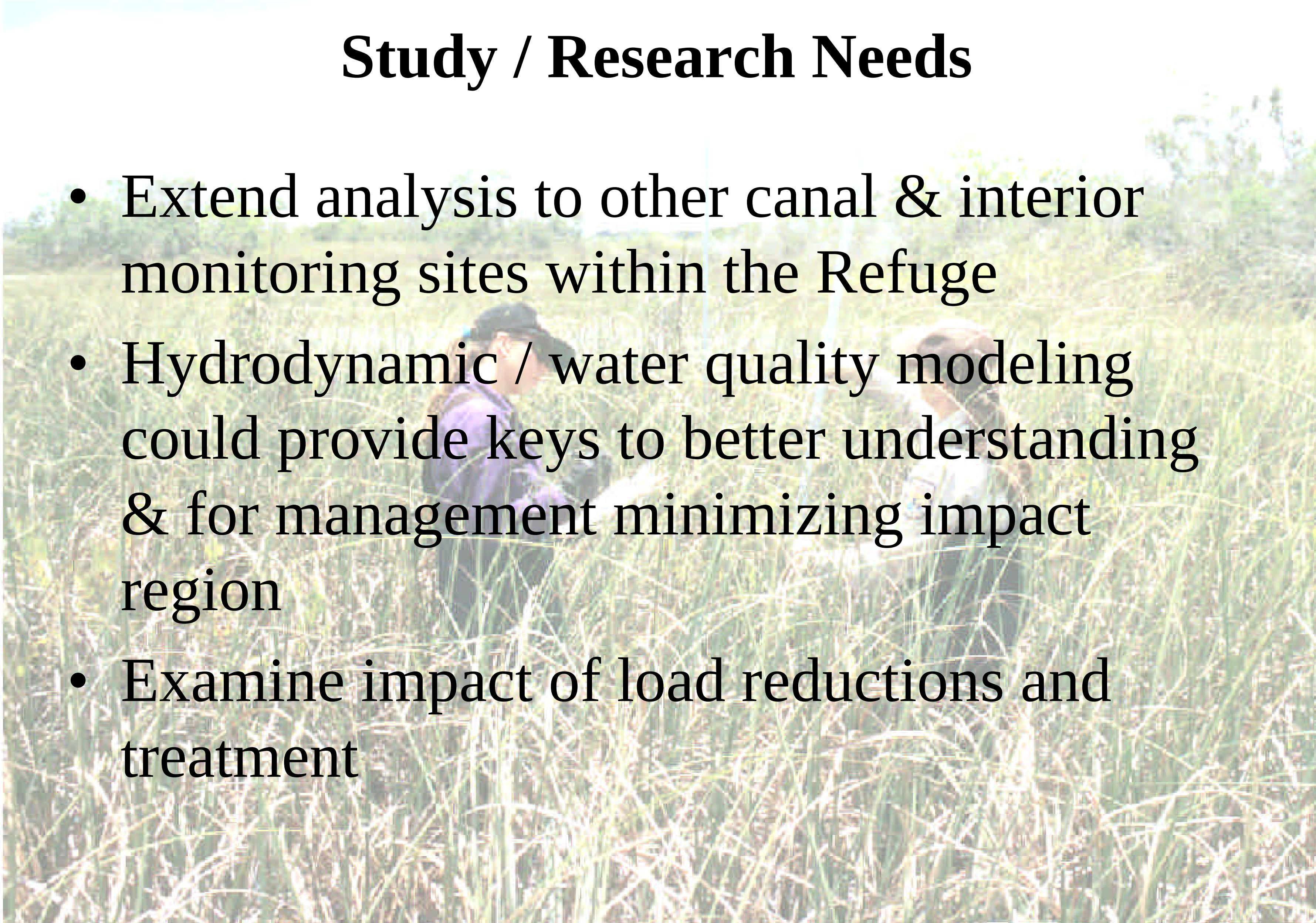
Parameter	Canal	Interior
Sodium	C	C
Calcium	+	-
Sulfate	C	-
Potassium	+	C
Silica	+/-	+/-
Algal Growth Potential	+	-
Total Nitrogen	C	-
Total Phosphorus	+	-

Conservative = C, source = +, sink = -

Conclusions

- The mixing plot method classifies source/sink
- Mixing plot lacks time-of-travel estimate
- Multi-constituent analysis increases insight into underlying processes
- In the Canal
  - No sinks identified
  - Source of TP, AGP, and Ca

Data collection
USFWS Photo by M. Bailey



Study / Research Needs

- Extend analysis to other canal & interior monitoring sites within the Refuge
- Hydrodynamic / water quality modeling could provide keys to better understanding & for management minimizing impact region
- Examine impact of load reductions and treatment

Questions?

USFWS Photo by S.D. Jewell