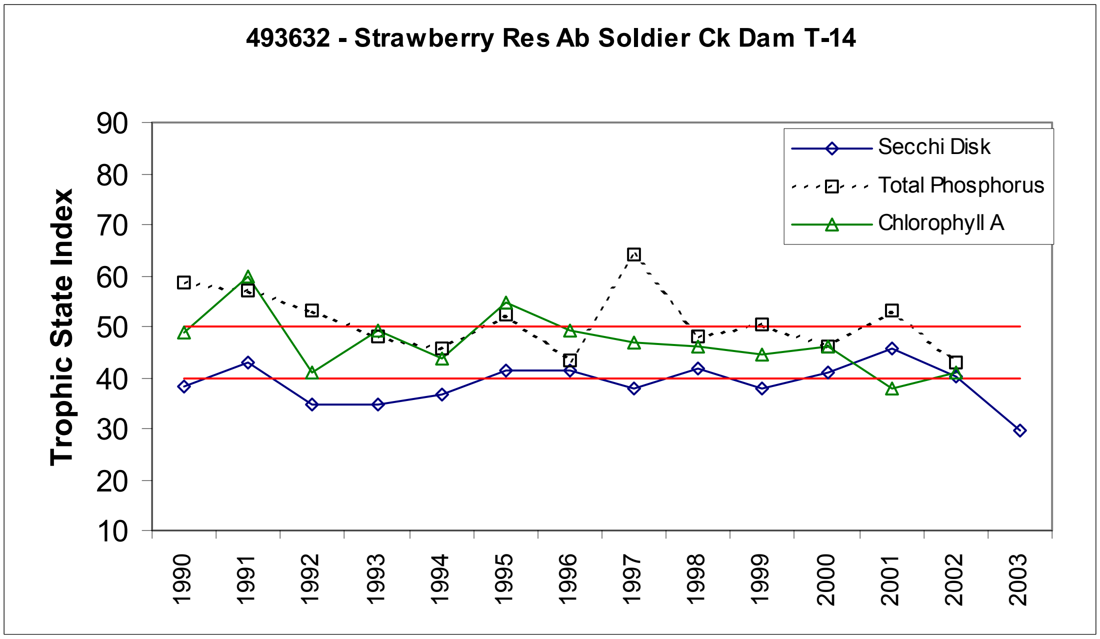
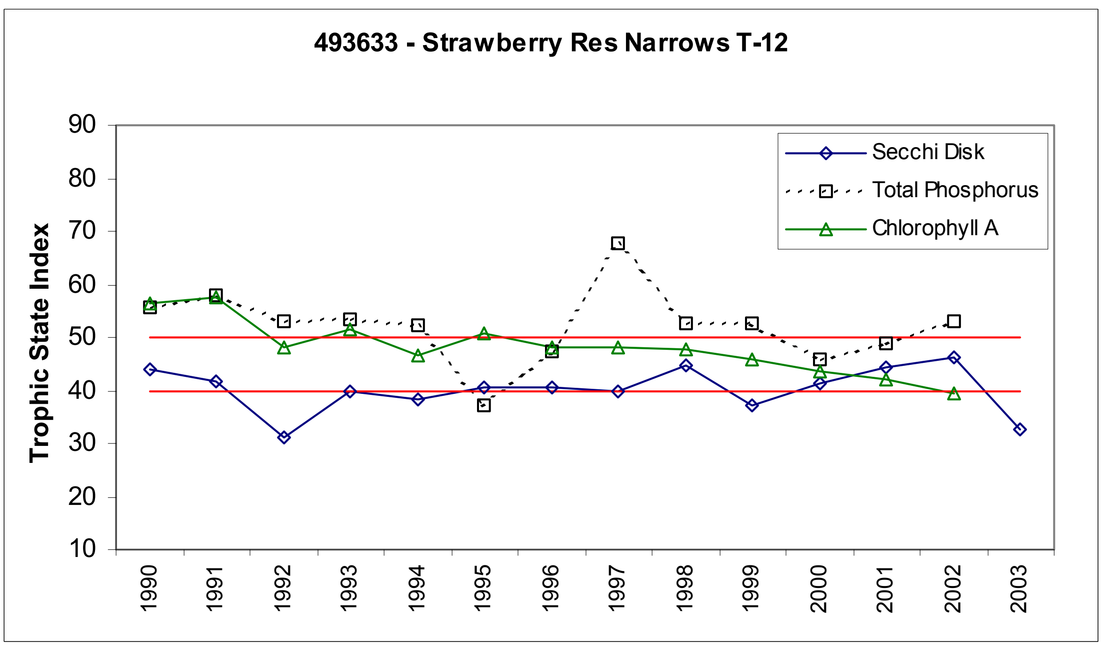
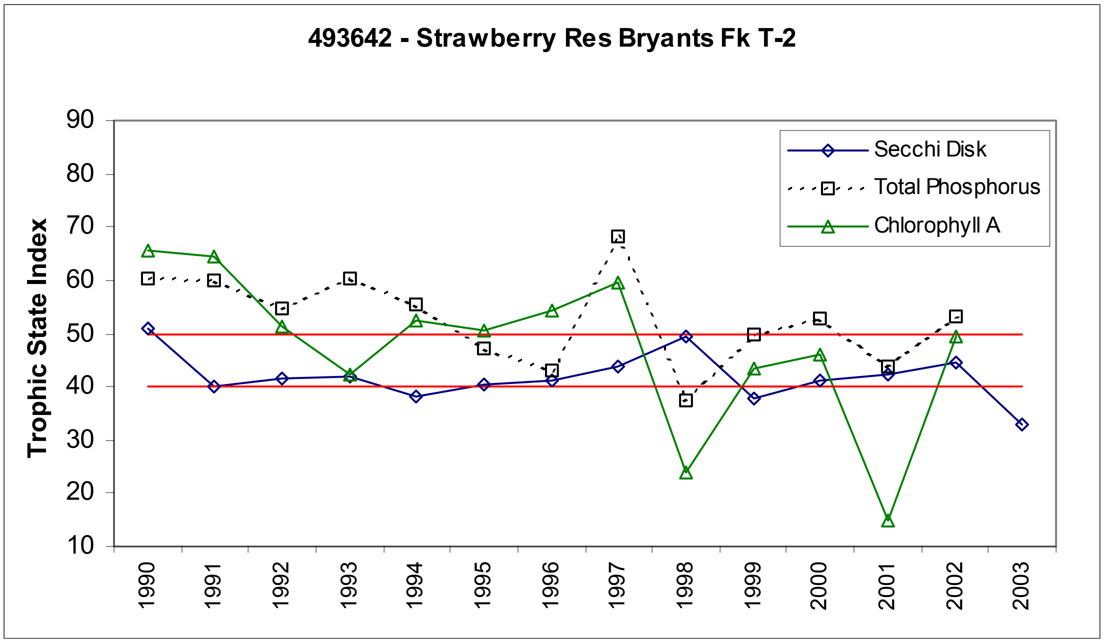
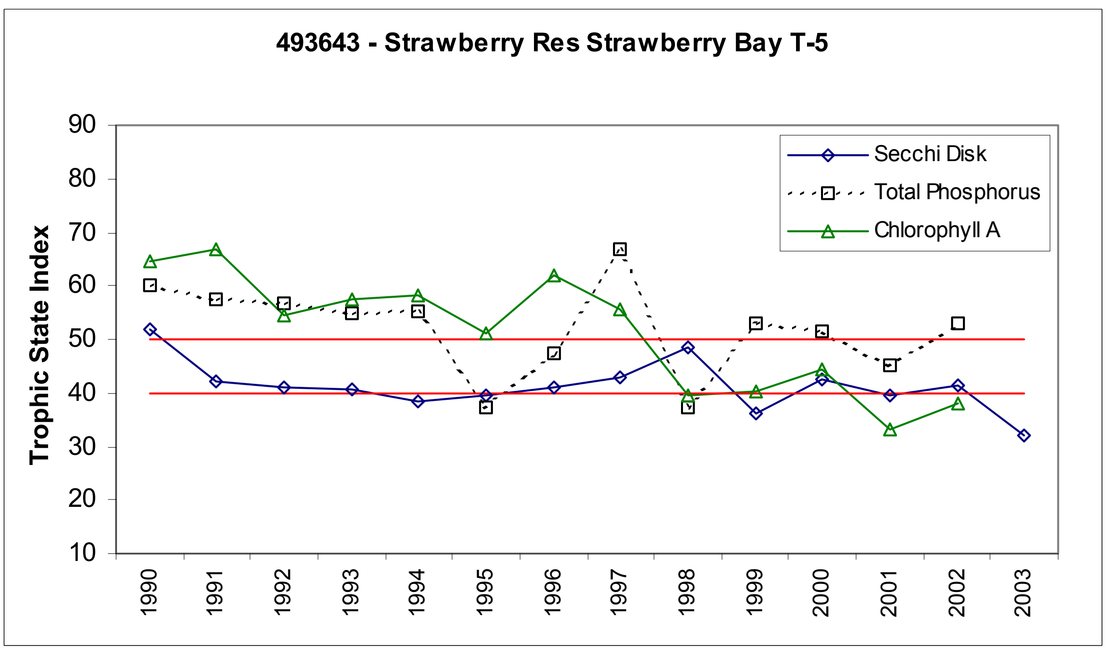
Appendix A

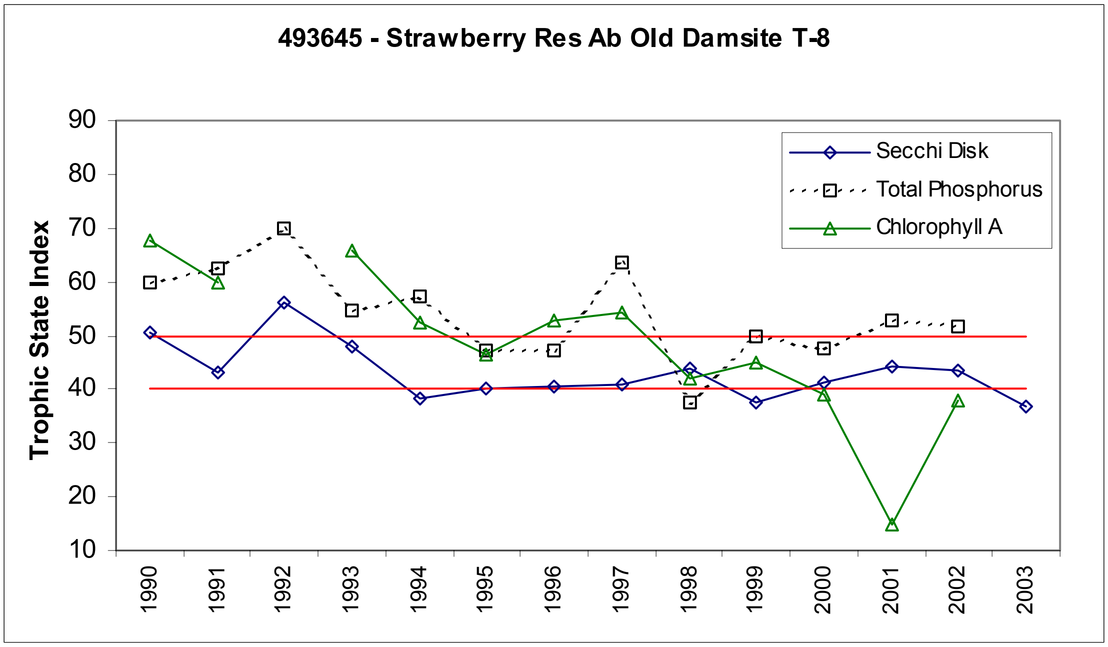
Trophic State Indices

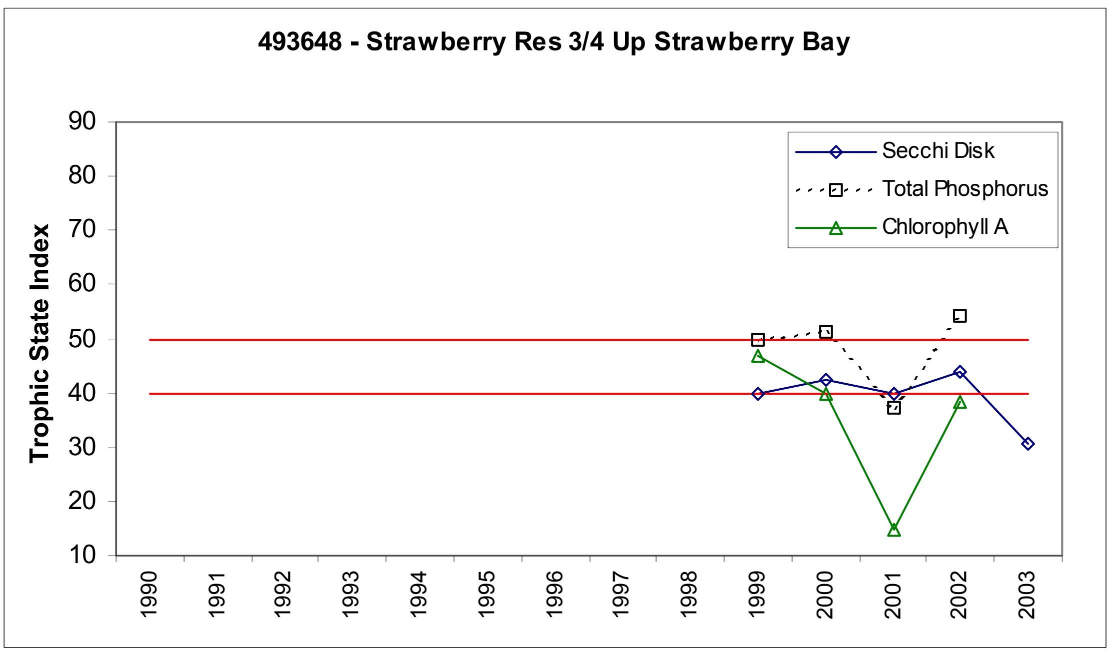

493632 - Strawberry Res Ab Soldier Ck Dam T-14
Trophic State Index
90
80
70
60
50
40
30
20
10
Secchi Disk
Total Phosphorus
Chlorophyll A
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003

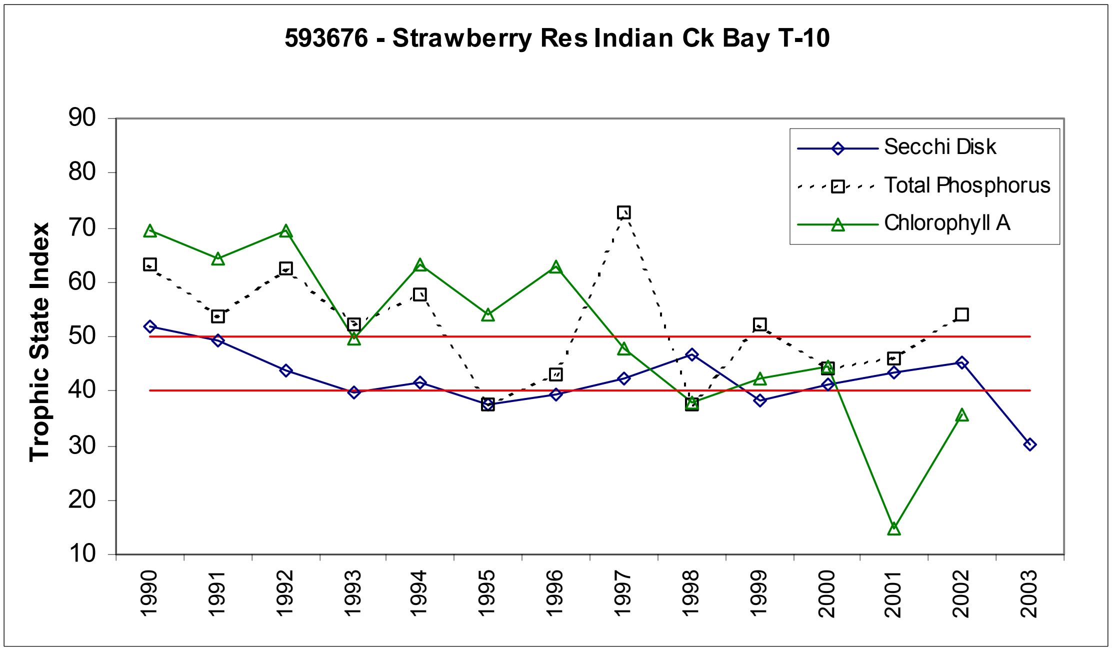

493633 - Strawberry Res Narrows T-12
Trophic State Index
90
80
70
60
50
40
30
20
10
Secchi Disk
Total Phosphorus
Chlorophyll A
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003


493642 - Strawberry Res Bryants Fk T-2
Trophic State Index
Secchi Disk
Total Phosphorus
Chlorophyll A
90
80
70
60
50
40
30
20
10
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003

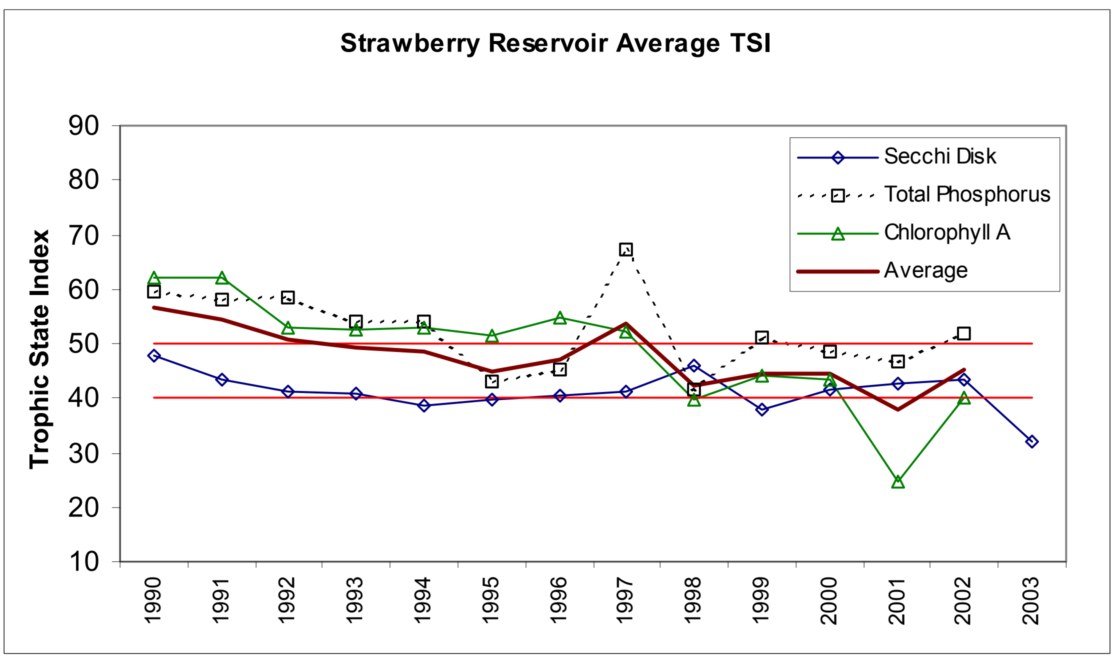

493643 - Strawberry Res Strawberry Bay T-5
Trophic State Index
Secchi Disk
Total Phosphorus
Chlorophyll A
90
80
70
60
50
40
30
20
10
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003


493645 - Strawberry Res Ab Old Damsite T-8
Trophic State Index
90
80
70
60
50
40
30
20
10
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Secchi Disk
Total Phosphorus
Chlorophyll A


493648 - Strawberry Res 3/4 Up Strawberry Bay
Trophic State Index
90
80
70
60
50
40
30
20
10
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Secchi Disk
Total Phosphorus
Chlorophyll A



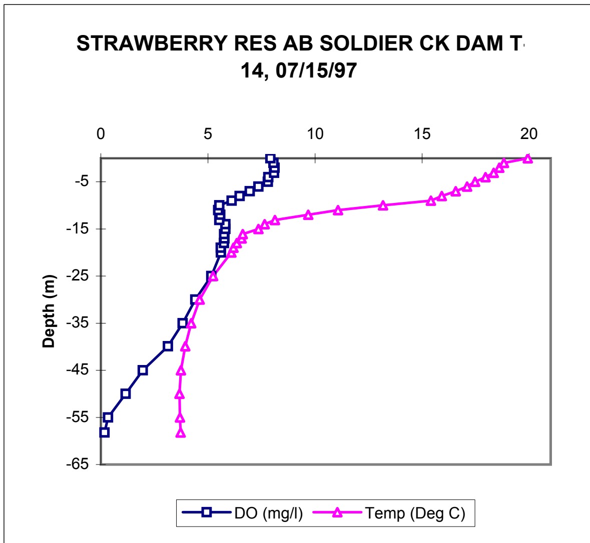
593676 - Strawberry Res Indian Ck Bay T-10
Trophic State Index
90
80
70
60
50
40
30
20
10
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Secchi Disk
Total Phosphorus
Chlorophyll A

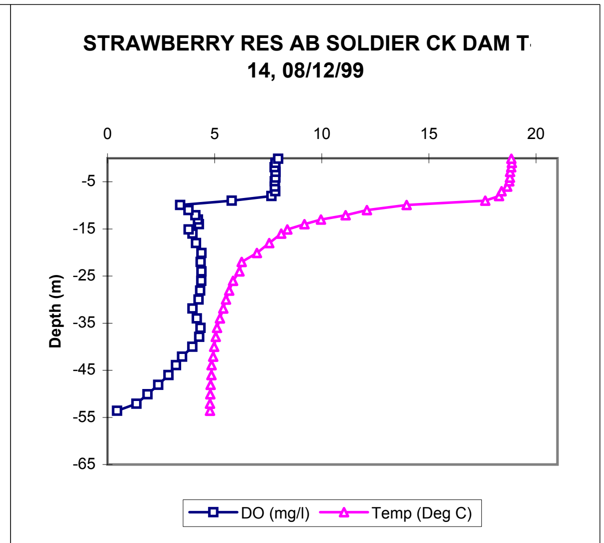


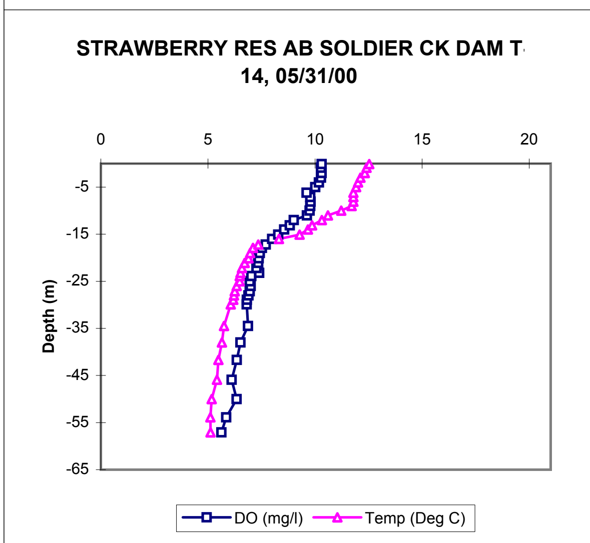
Strawberry Reservoir Average TSI
Trophic State Index
90
80
70
60
50
40
30
20
10
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
Secchi Disk
Total Phosphorus
Chlorophyll A
Average

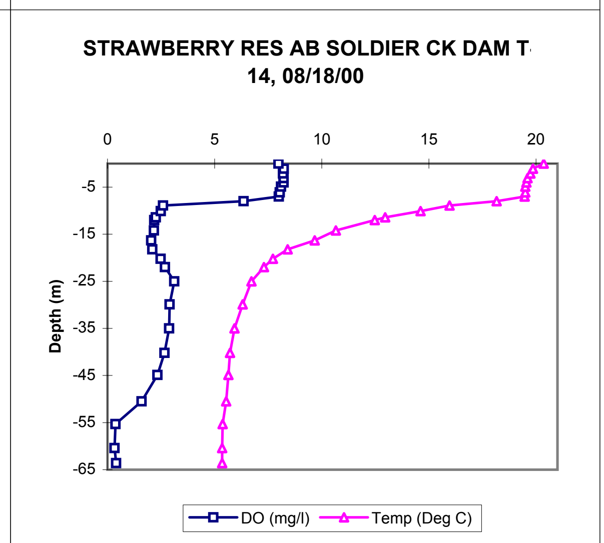
Appendix B

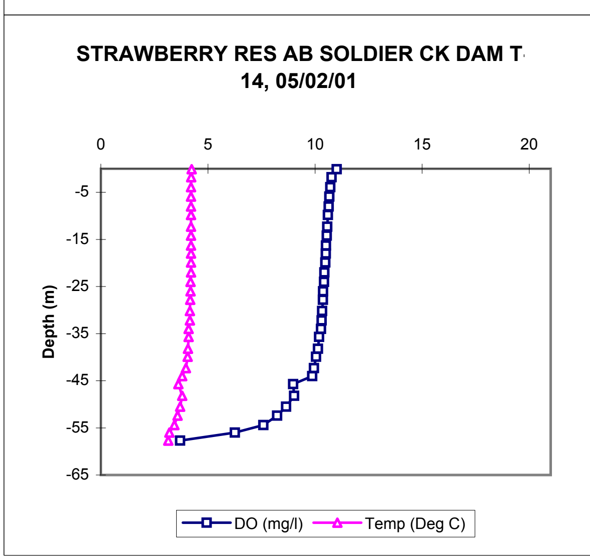
Dissolved Oxygen and Temperature Profiles

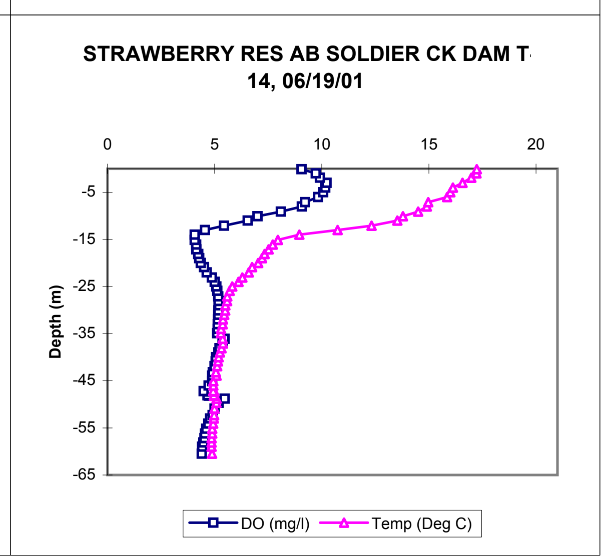

STRAWBERRY RES AB SOLDIER CK DAM T 14, 07/15/97
0 5 10 15 20
-5 -15 -25 -35 -45 -55 -65
Depth (m)
DO (mg/l)
Temp (Deg C)

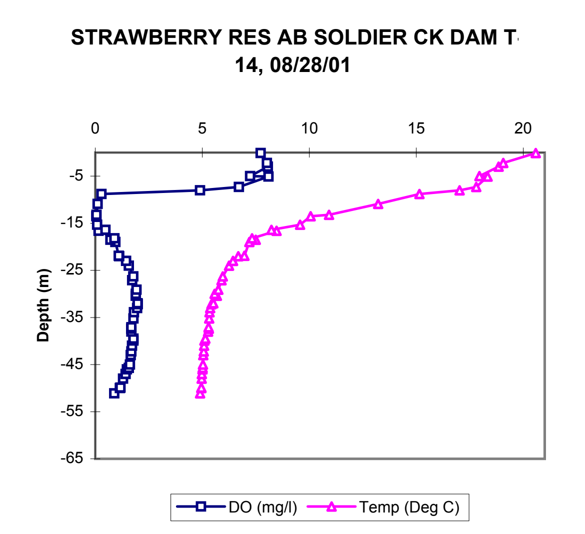

STRAWBERRY RES AB SOLDIER CK DAM T 14, 08/12/99
0 5 10 15 20
-5 -15 -25 -35 -45 -55 -65
Depth (m)
DO (mg/l)
Temp (Deg C)

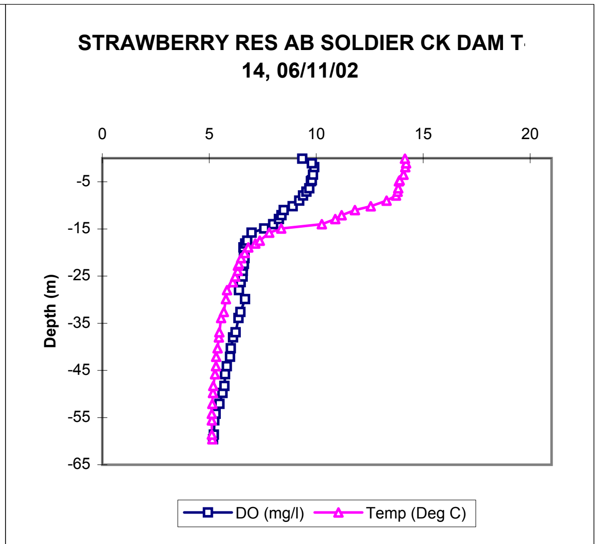

STRAWBERRY RES AB SOLDIER CK DAM T 14, 05/31/00
0 5 10 15 20
-5 -15 -25 -35 -45 -55 -65
Depth (m)
DO (mg/l)
Temp (Deg C)

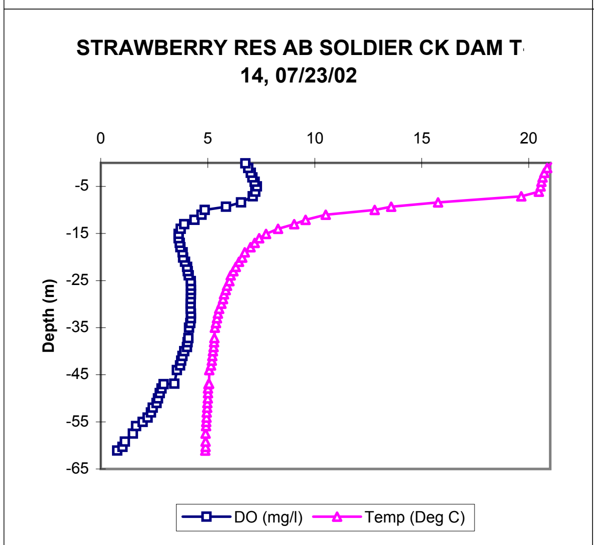

STRAWBERRY RES AB SOLDIER CK DAM T 14, 08/18/00
0 5 10 15 20
-5 -15 -25 -35 -45 -55 -65
Depth (m)
DO (mg/l)
Temp (Deg C)

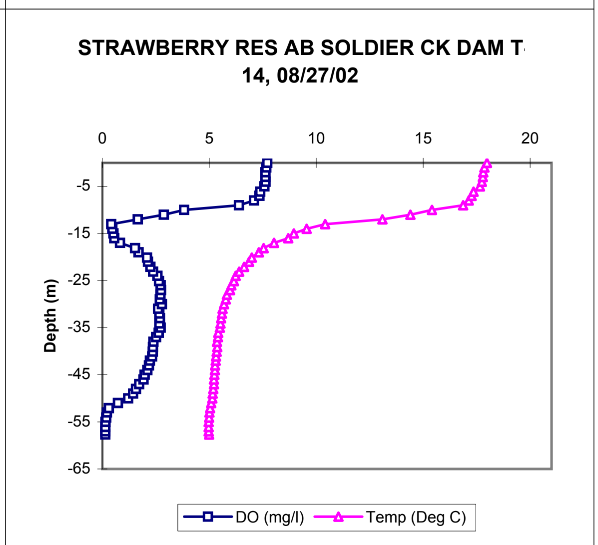

STRAWBERRY RES AB SOLDIER CK DAM T 14, 05/02/01
0 5 10 15 20
-5 -15 -25 -35 -45 -55 -65
Depth (m)
DO (mg/l)
Temp (Deg C)

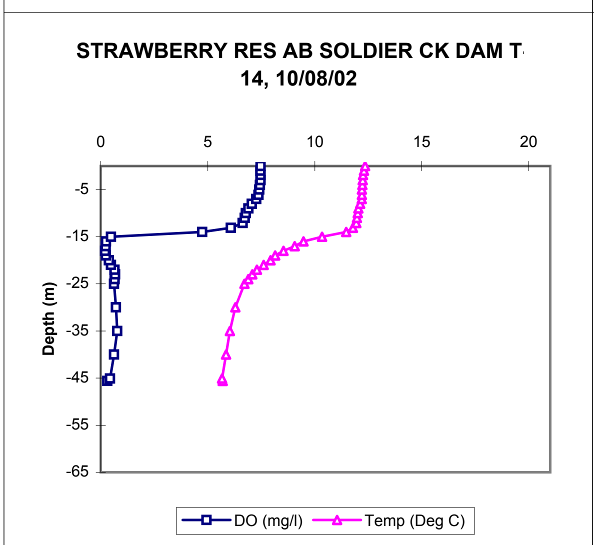

STRAWBERRY RES AB SOLDIER CK DAM T 14, 06/19/01
0 5 10 15 20
-5 -15 -25 -35 -45 -55 -65
Depth (m)
DO (mg/l)
Temp (Deg C)

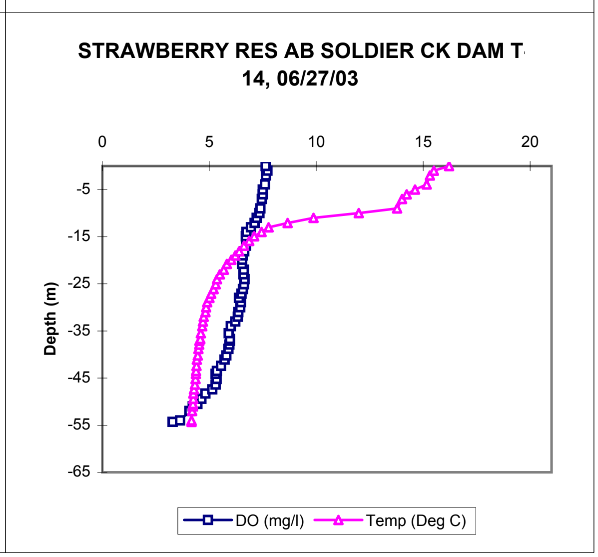

STRAWBERRY RES AB SOLDIER CK DAM T
14, 08/28/01
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES AB SOLDIER CK DAM T
14, 06/11/02
Depth (m)
DO (mg/l)
Temp (Deg C)

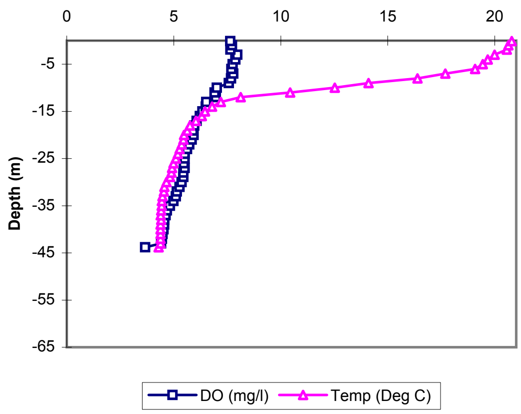

STRAWBERRY RES AB SOLDIER CK DAM T
14, 07/23/02
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES AB SOLDIER CK DAM T
14, 08/27/02
Depth (m)
DO (mg/l)
Temp (Deg C)

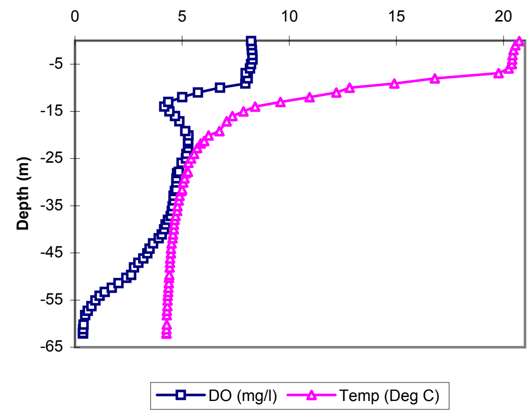

STRAWBERRY RES AB SOLDIER CK DAM T
14, 10/08/02
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES AB SOLDIER CK DAM T
14, 06/27/03
Depth (m)
DO (mg/l)
Temp (Deg C)

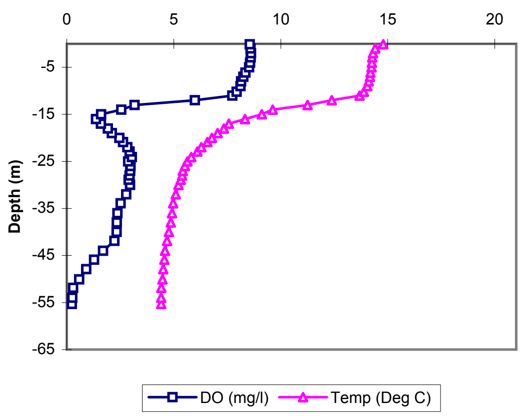
STRAWBERRY RES AB SOLDIER CK DAM T-14, 07/15/03



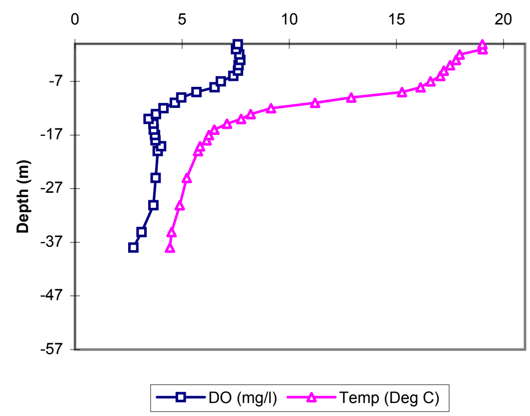
STRAWBERRY RES AB SOLDIER CK DAM T-14, 08/12/03



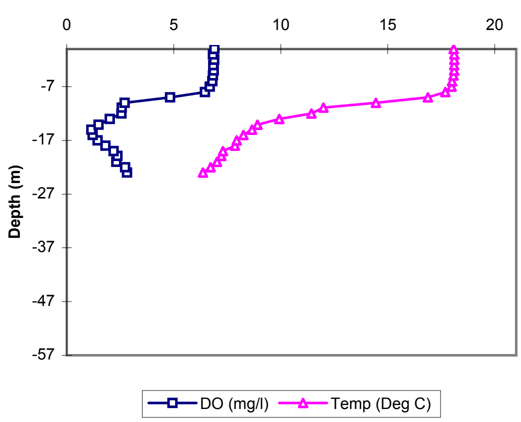
STRAWBERRY RES AB SOLDIER CK DAM T-14, 09/24/03



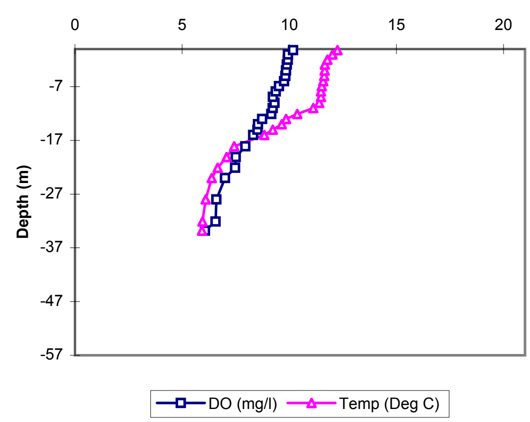
STRAWBERRY RES NARROWS T-12, 07/15/97

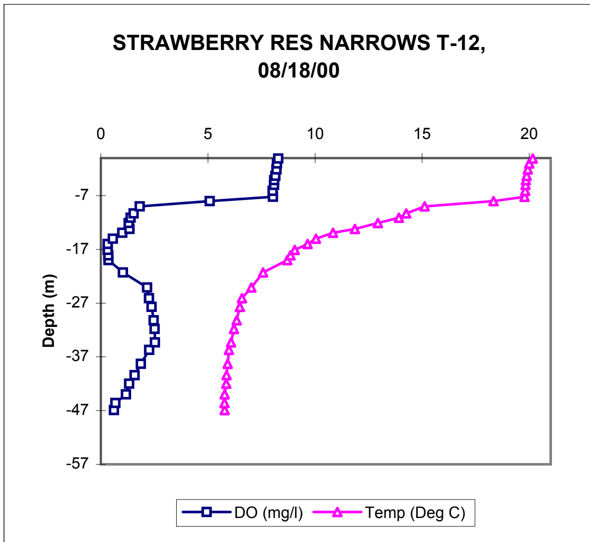


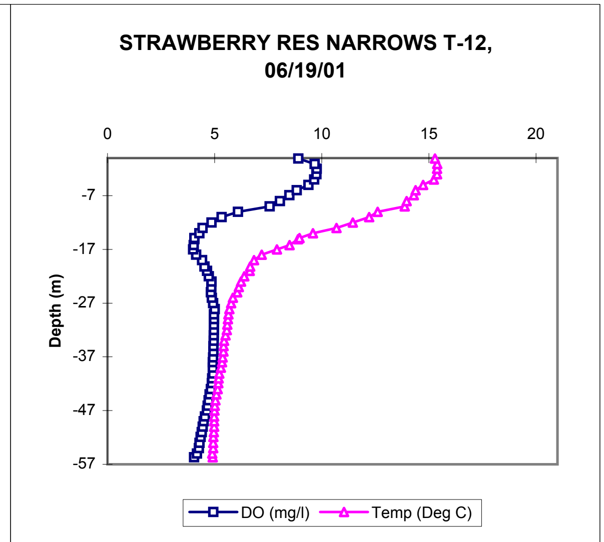
STRAWBERRY RES NARROWS T-12, 08/12/99

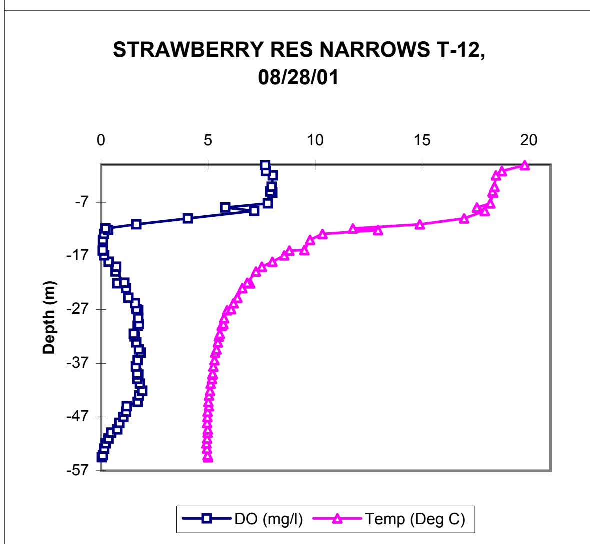


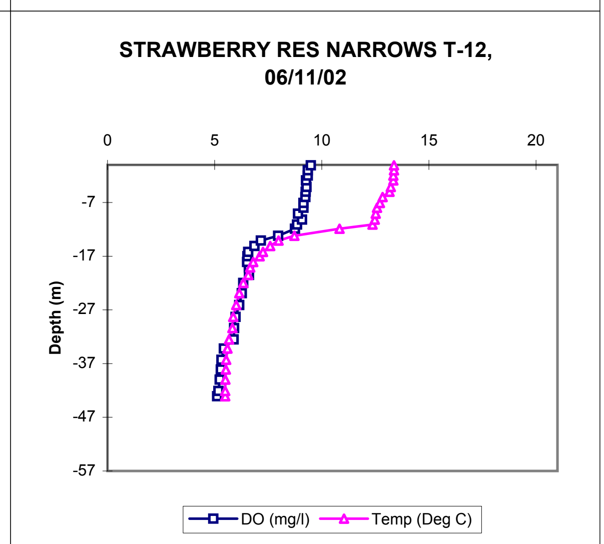
STRAWBERRY RES NARROWS T-12, 05/31/00

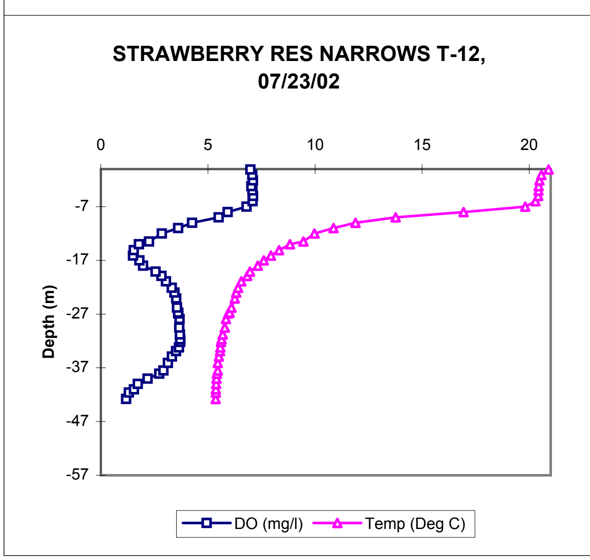


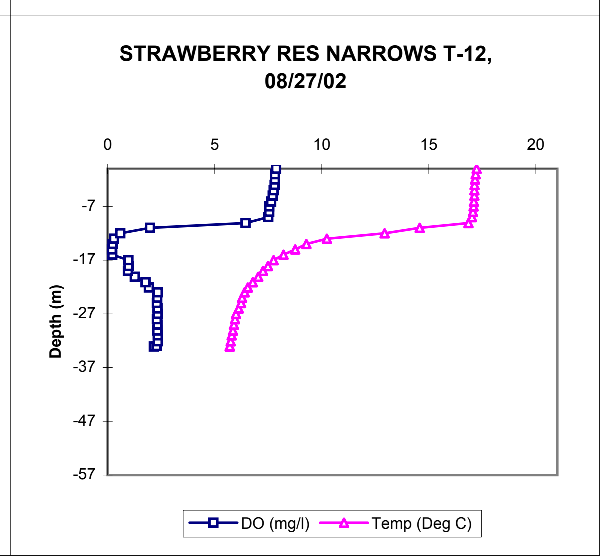

STRAWBERRY RES NARROWS T-12, 08/18/00
0
5
10
15
20
-7
-17
-27
-37
-47
-57
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES NARROWS T-12, 06/19/01
0
5
10
15
20
-7
-17
-27
-37
-47
-57
Depth (m)
DO (mg/l)
Temp (Deg C)

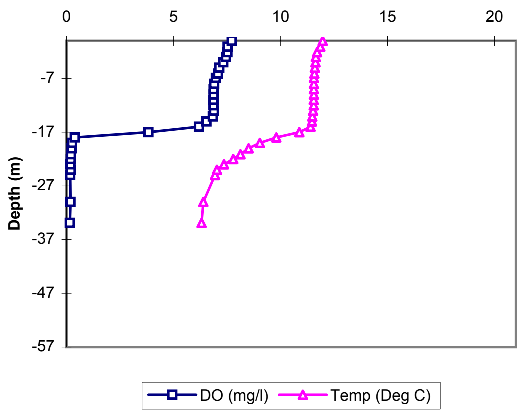

STRAWBERRY RES NARROWS T-12, 08/28/01
0
5
10
15
20
-7
-17
-27
-37
-47
-57
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES NARROWS T-12, 06/11/02
0
5
10
15
20
-7
-17
-27
-37
-47
-57
Depth (m)
DO (mg/l)
Temp (Deg C)

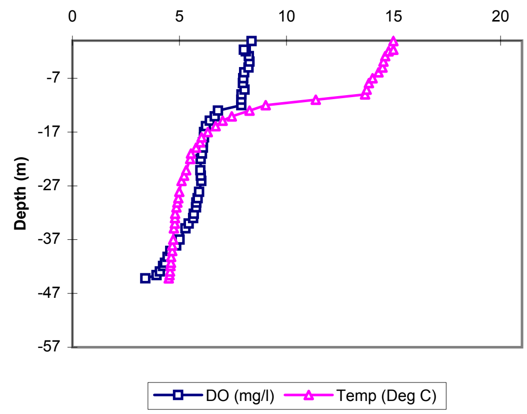

STRAWBERRY RES NARROWS T-12, 07/23/02
0
5
10
15
20
-7
-17
-27
-37
-47
-57
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES NARROWS T-12, 08/27/02
0
5
10
15
20
-7
-17
-27
-37
-47
-57
Depth (m)
DO (mg/l)
Temp (Deg C)

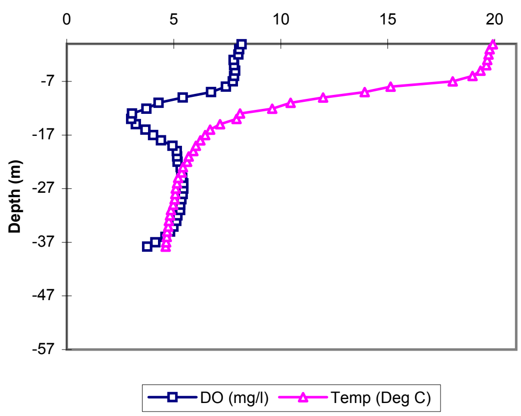
STRAWBERRY RES NARROWS T-12, 10/08/02



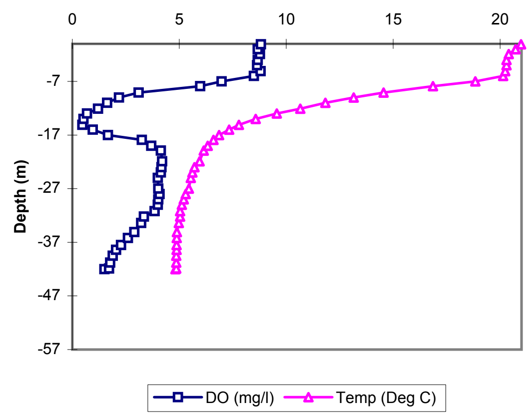
STRAWBERRY RES NARROWS T-12, 06/27/03



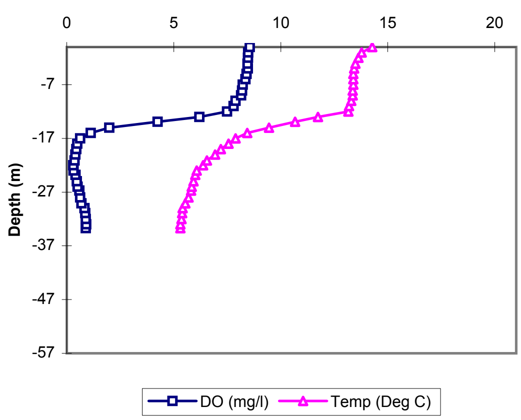
STRAWBERRY RES NARROWS T-12, 07/15/03



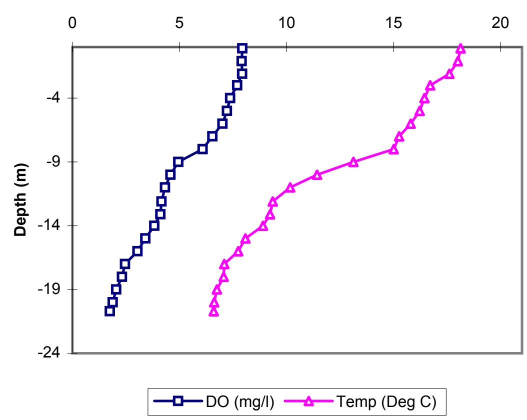
STRAWBERRY RES NARROWS T-12, 08/12/03

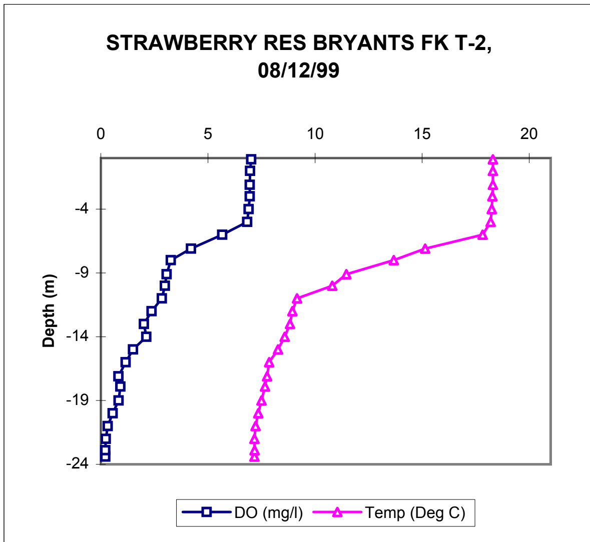


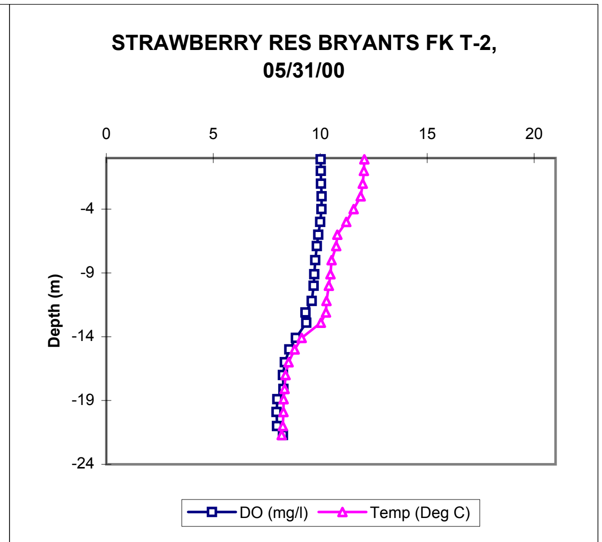
STRAWBERRY RES NARROWS T-12, 09/24/03

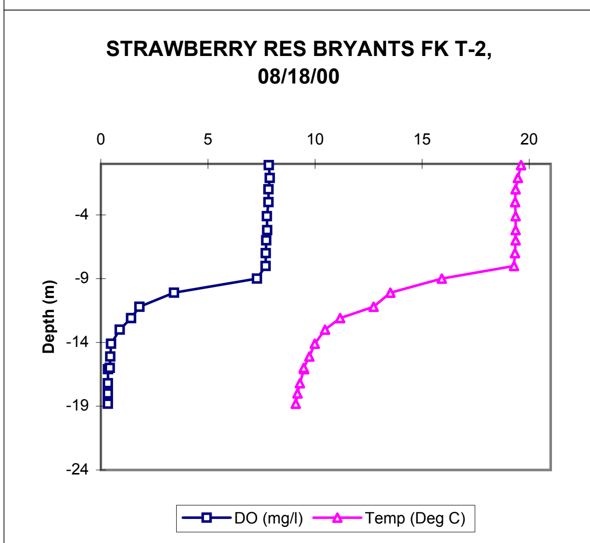


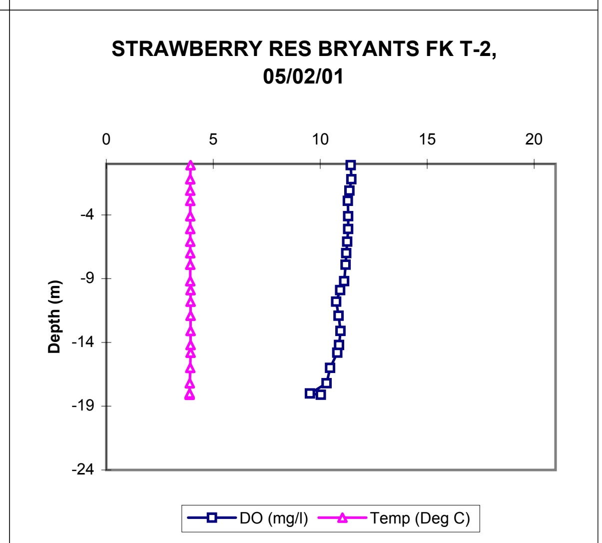
STRAWBERRY RES BRYANTS FK T-2, 07/15/97

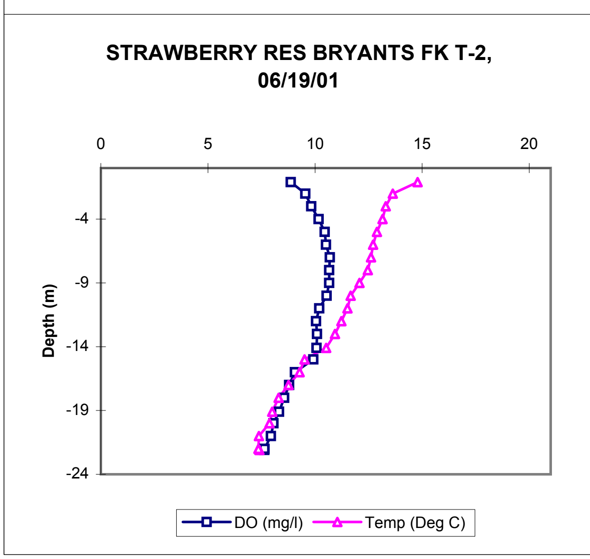


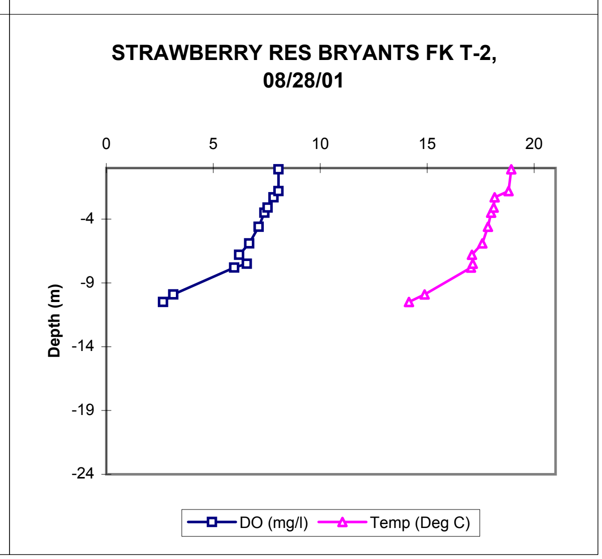

STRAWBERRY RES BRYANTS FK T-2, 08/12/99
Depth (m)
DO (mg/l)
Temp (Deg C)

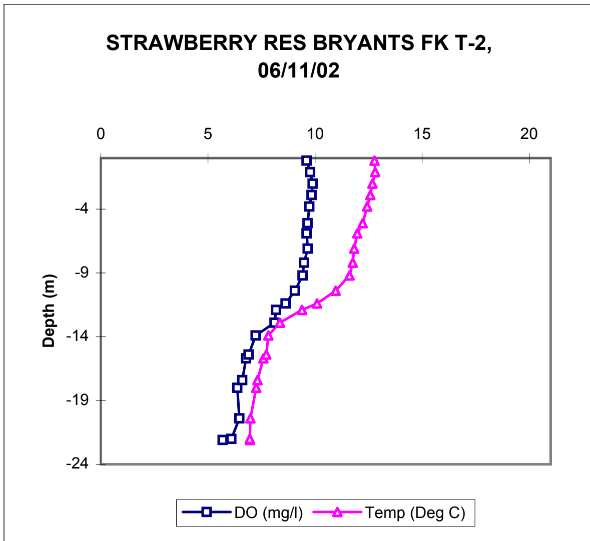

STRAWBERRY RES BRYANTS FK T-2, 05/31/00
Depth (m)
DO (mg/l)
Temp (Deg C)

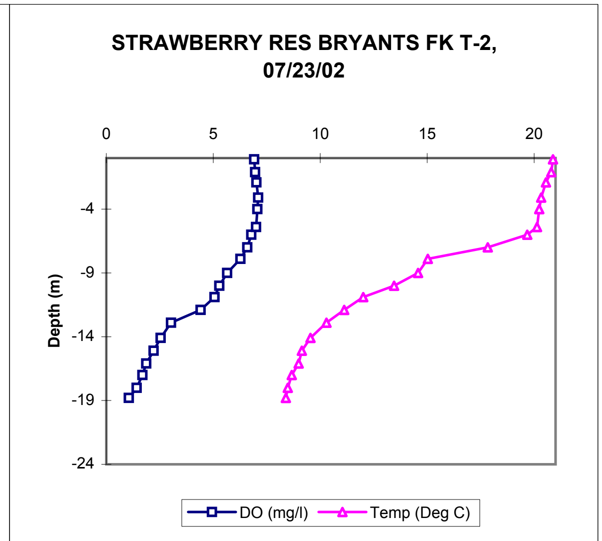

STRAWBERRY RES BRYANTS FK T-2, 08/18/00
Depth (m)
DO (mg/l)
Temp (Deg C)

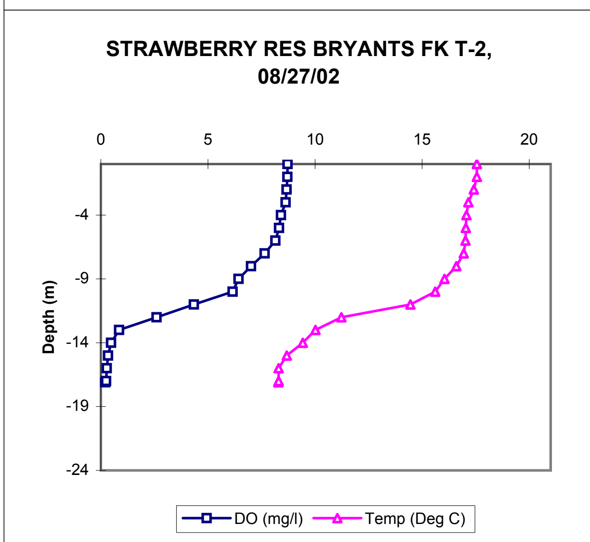

STRAWBERRY RES BRYANTS FK T-2, 05/02/01
Depth (m)
DO (mg/l)
Temp (Deg C)

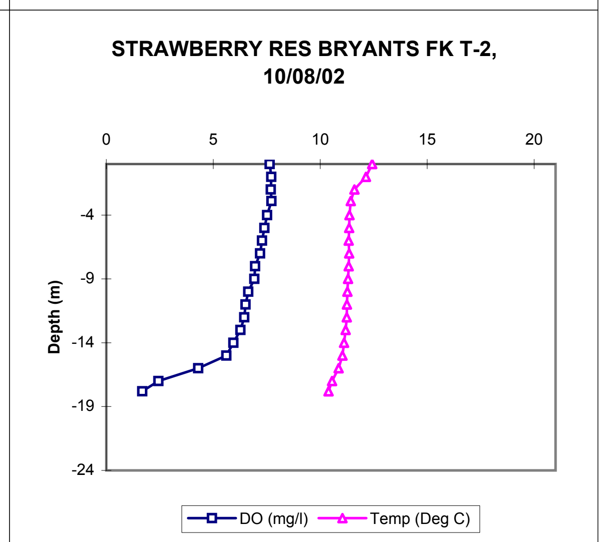

STRAWBERRY RES BRYANTS FK T-2, 06/19/01
Depth (m)
DO (mg/l)
Temp (Deg C)

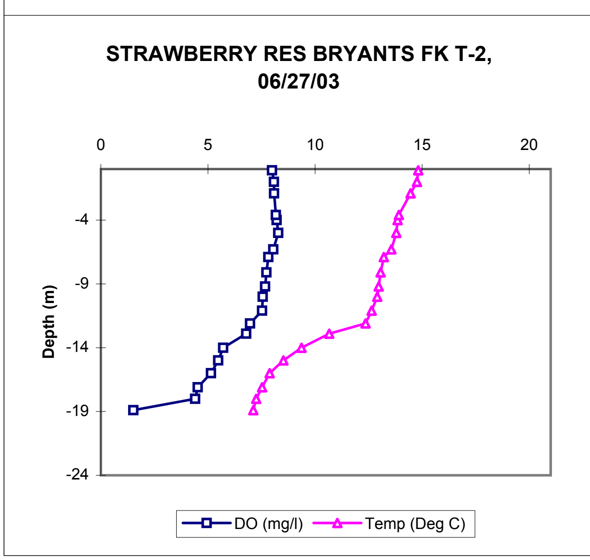

STRAWBERRY RES BRYANTS FK T-2, 08/28/01
Depth (m)
DO (mg/l)
Temp (Deg C)

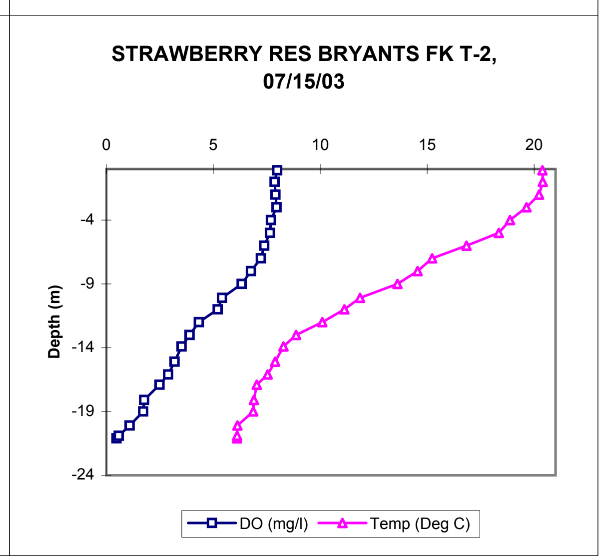

STRAWBERRY RES BRYANTS FK T-2,
06/11/02
Depth (m)
DO (mg/l)
Temp (Deg C)

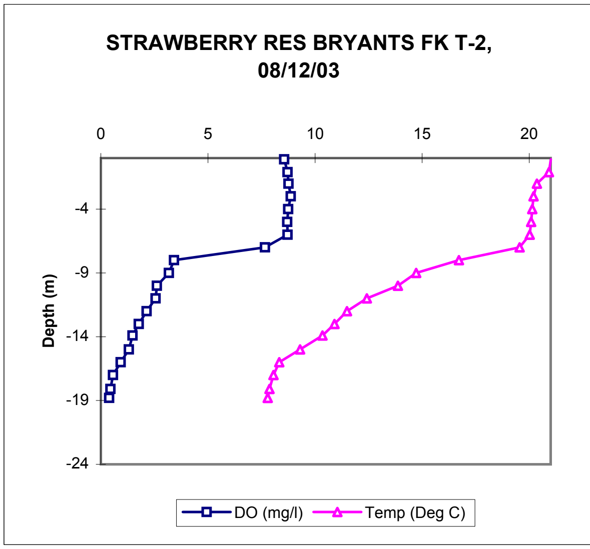

STRAWBERRY RES BRYANTS FK T-2,
07/23/02
Depth (m)
DO (mg/l)
Temp (Deg C)

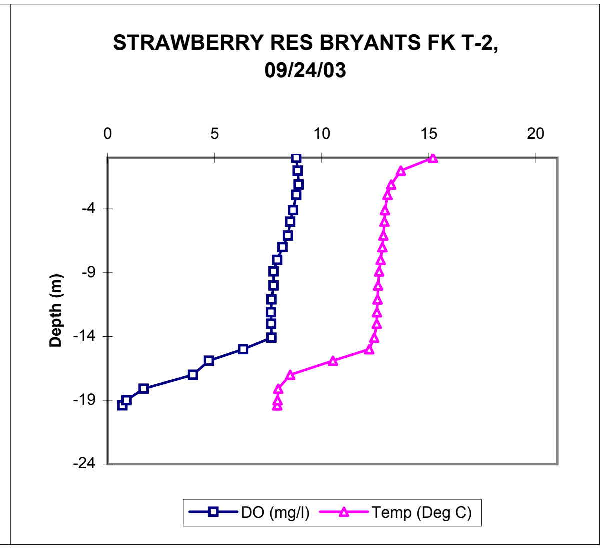

STRAWBERRY RES BRYANTS FK T-2,
08/27/02
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES BRYANTS FK T-2,
10/08/02
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES BRYANTS FK T-2,
06/27/03
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES BRYANTS FK T-2,
07/15/03
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES BRYANTS FK T-2, 08/12/03
0
5
10
15
20
-4
-9
-14
-19
-24
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES BRYANTS FK T-2, 09/24/03
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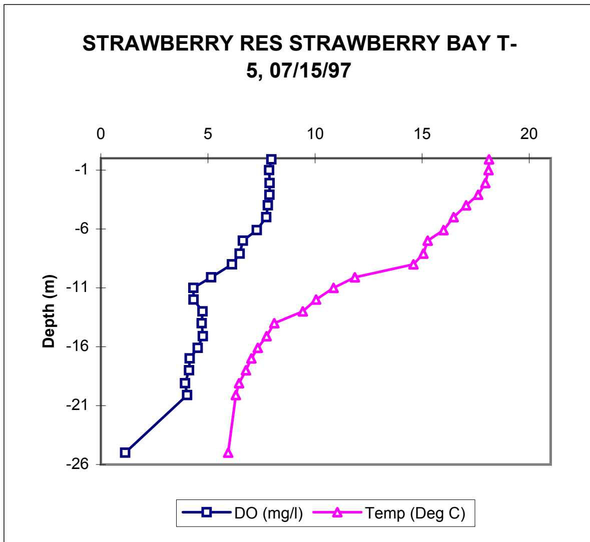
20
-4
-9
-14
-19
-24
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES STRAWBERRY BAY T-5, 07/15/97
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-1
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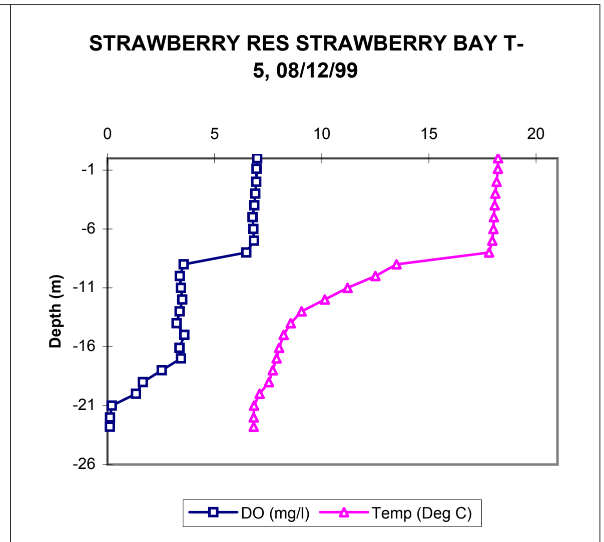
-21
-26
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES STRAWBERRY BAY T-5, 08/12/99
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-1
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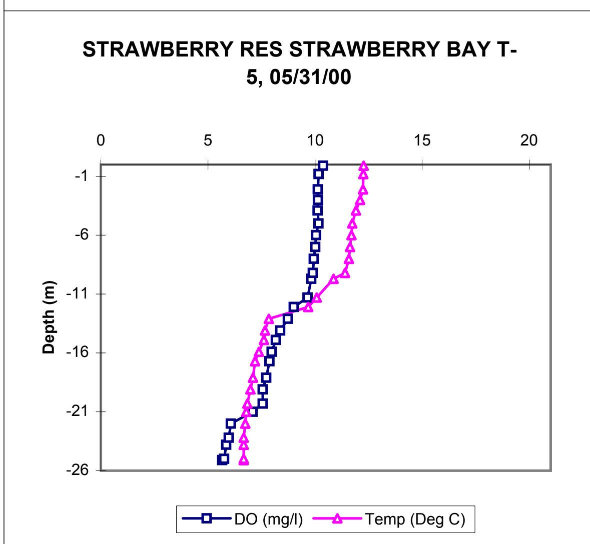
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES STRAWBERRY BAY T-5, 05/31/00
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-1
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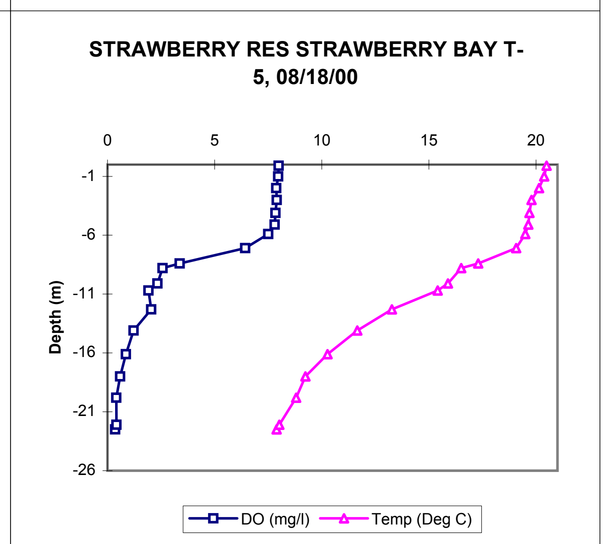
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES STRAWBERRY BAY T-5, 08/18/00
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-1
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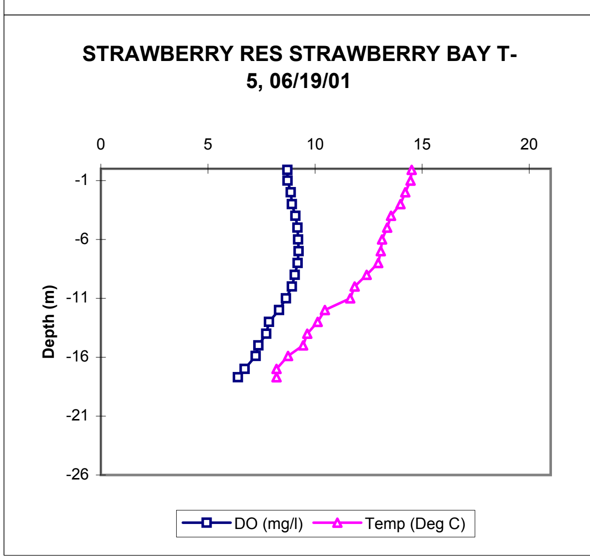
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES STRAWBERRY BAY T-5, 06/19/01
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-1
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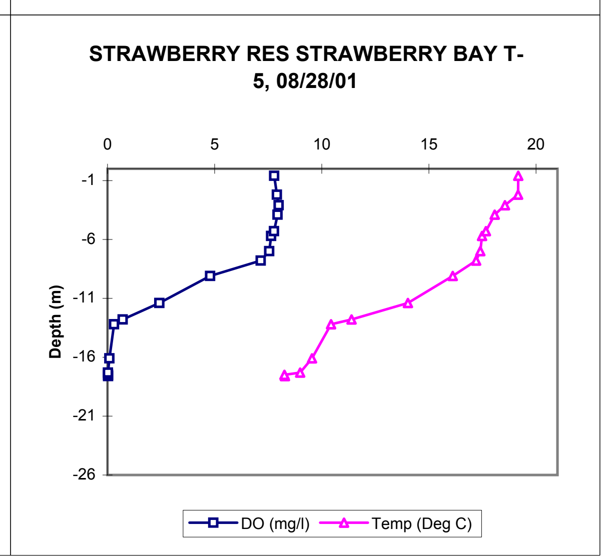
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES STRAWBERRY BAY T-5, 08/28/01
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-1
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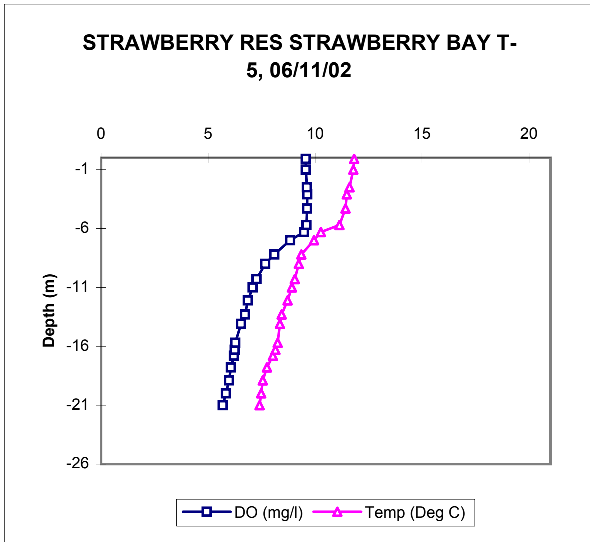
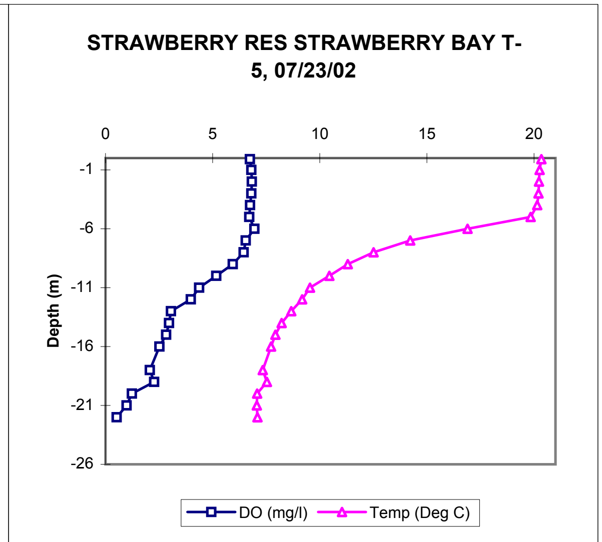
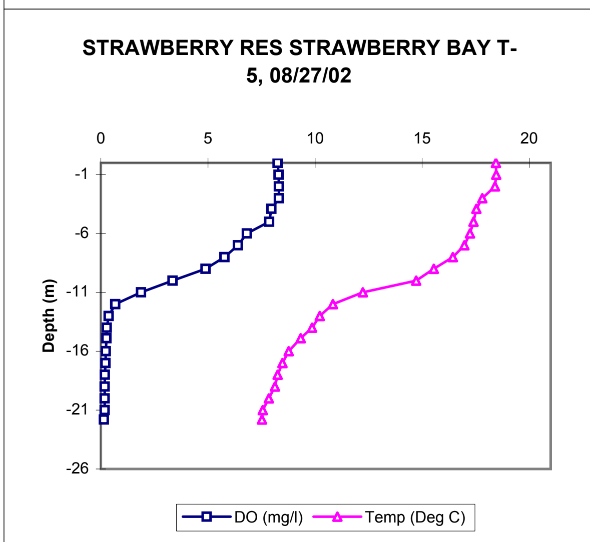
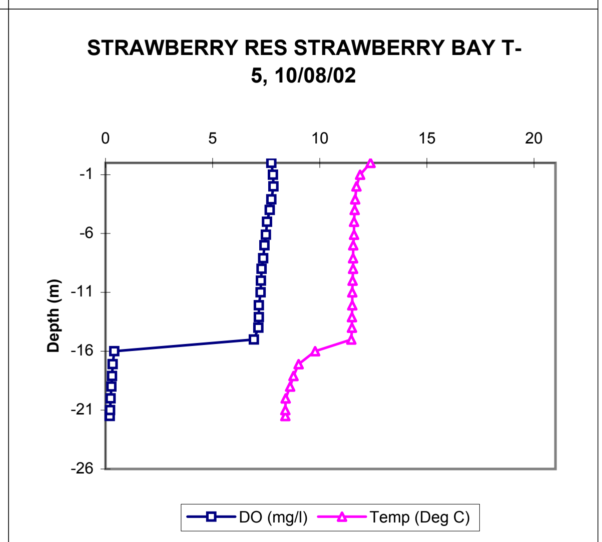
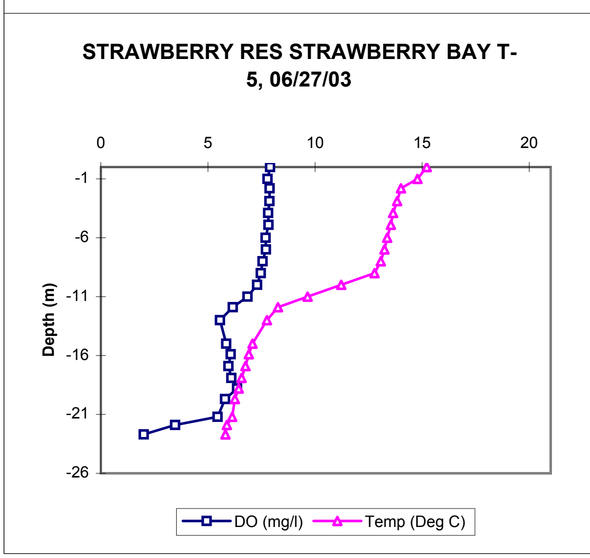
-16
-21
-26
Depth (m)
DO (mg/l)
Temp (Deg C)

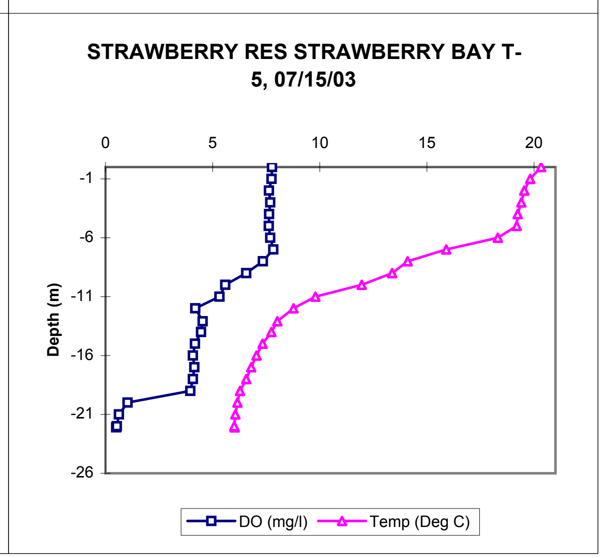

STRAWBERRY RES STRAWBERRY BAY T-5, 06/11/02
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES STRAWBERRY BAY T-5, 07/23/02
Depth (m)
DO (mg/l)
Temp (Deg C)

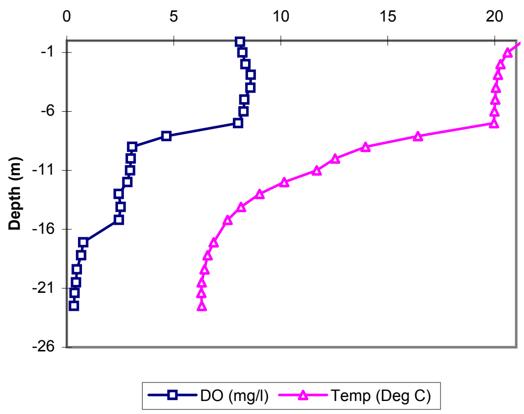

STRAWBERRY RES STRAWBERRY BAY T-5, 08/27/02
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES STRAWBERRY BAY T-5, 10/08/02
Depth (m)
DO (mg/l)
Temp (Deg C)

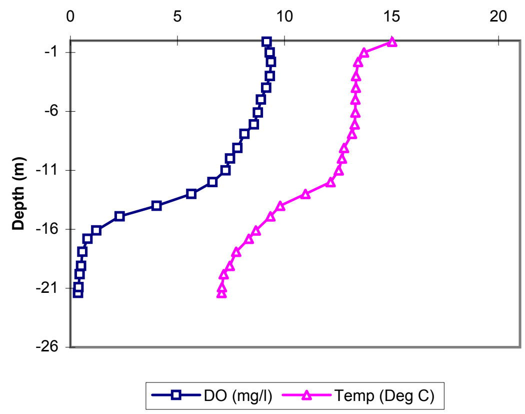

STRAWBERRY RES STRAWBERRY BAY T-5, 06/27/03
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES STRAWBERRY BAY T-5, 07/15/03
Depth (m)
DO (mg/l)
Temp (Deg C)

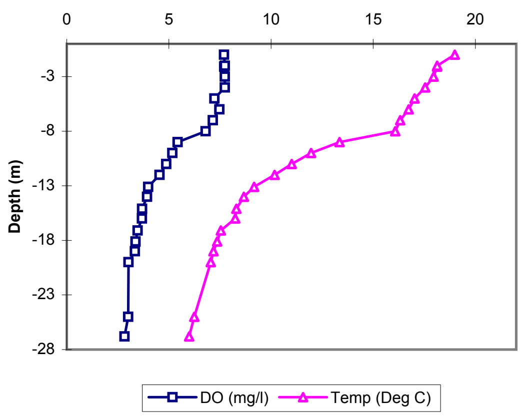
STRAWBERRY RES STRAWBERRY BAY T-5, 08/12/03



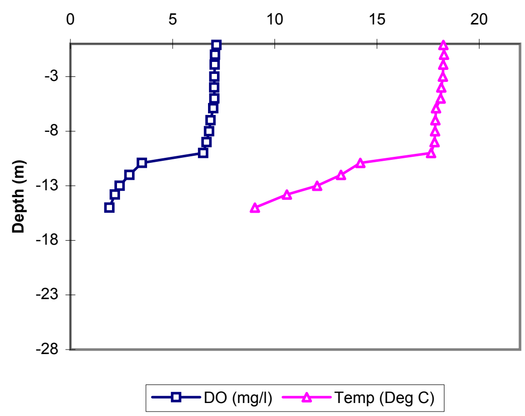
STRAWBERRY RES STRAWBERRY BAY T-5, 09/24/03



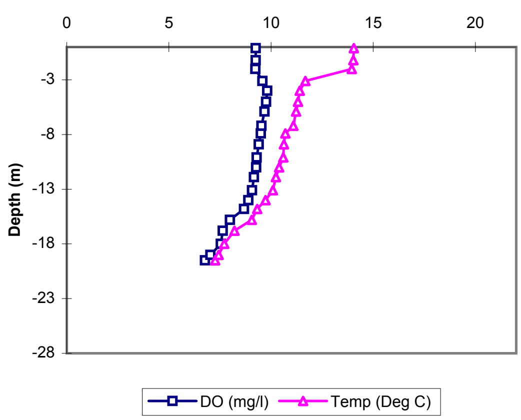
STRAWBERRY RES AB OLD DAMSITE T-8, 07/15/97



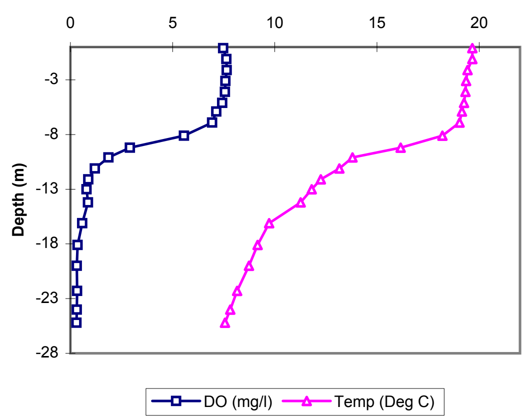
STRAWBERRY RES AB OLD DAMSITE T-8, 08/12/99

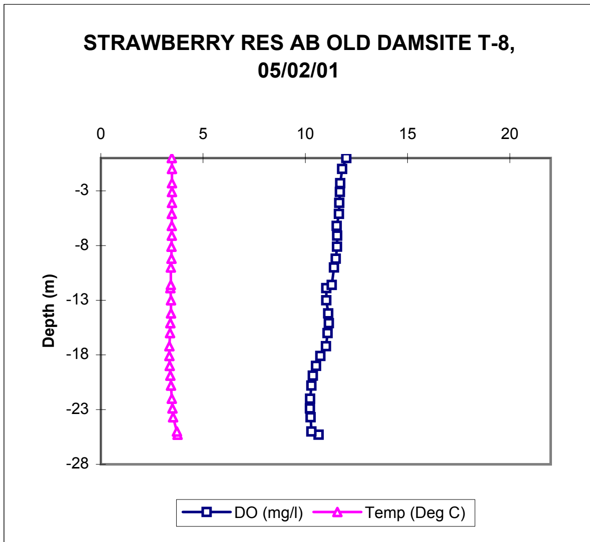


STRAWBERRY RES AB OLD DAMSITE T-8, 05/31/00



STRAWBERRY RES AB OLD DAMSITE T-8, 08/18/00




STRAWBERRY RES AB OLD DAMSITE T-8, 05/02/01
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-3
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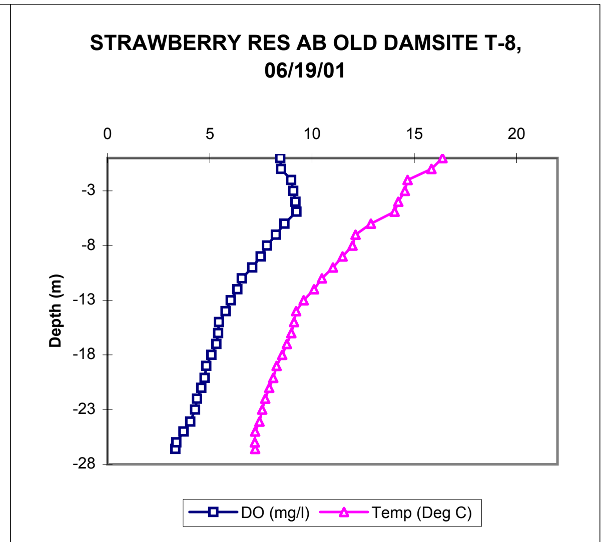
-13
-18
-23
-28
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES AB OLD DAMSITE T-8, 06/19/01
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-18
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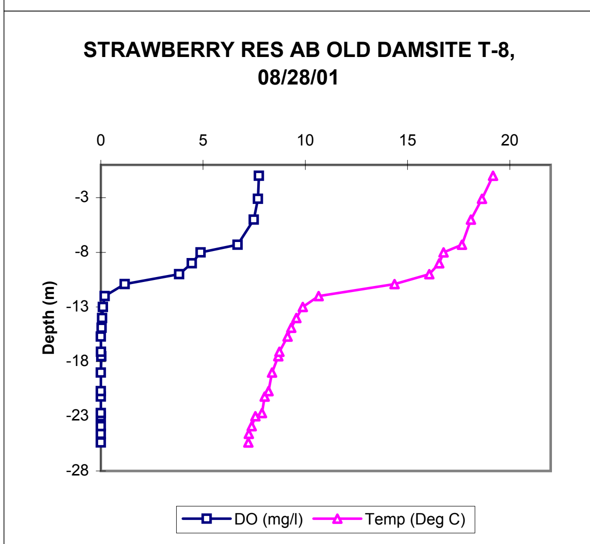
-28
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES AB OLD DAMSITE T-8, 08/28/01
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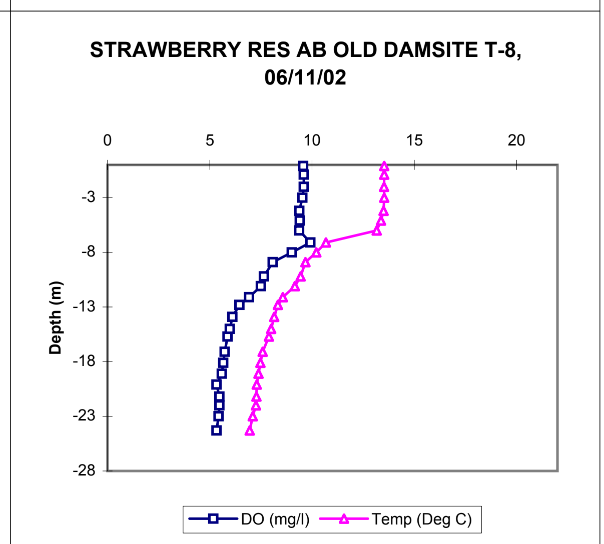
-23
-28
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES AB OLD DAMSITE T-8, 06/11/02
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-3
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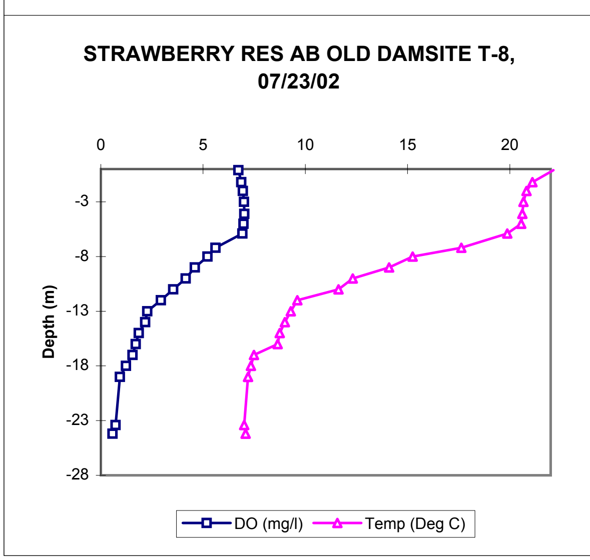
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES AB OLD DAMSITE T-8, 07/23/02
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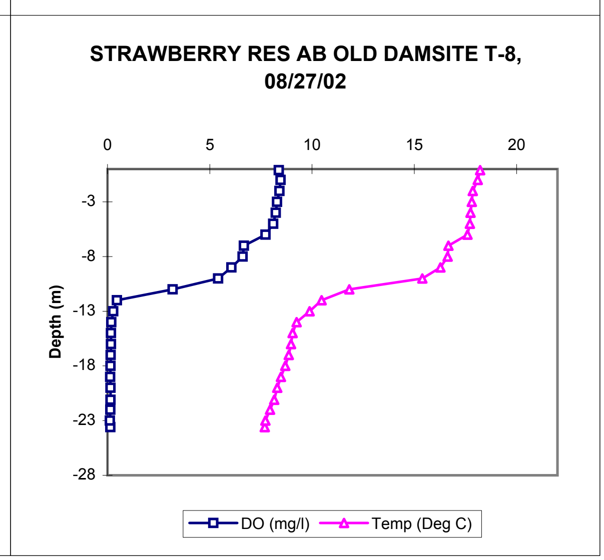
-18
-23
-28
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES AB OLD DAMSITE T-8, 08/27/02
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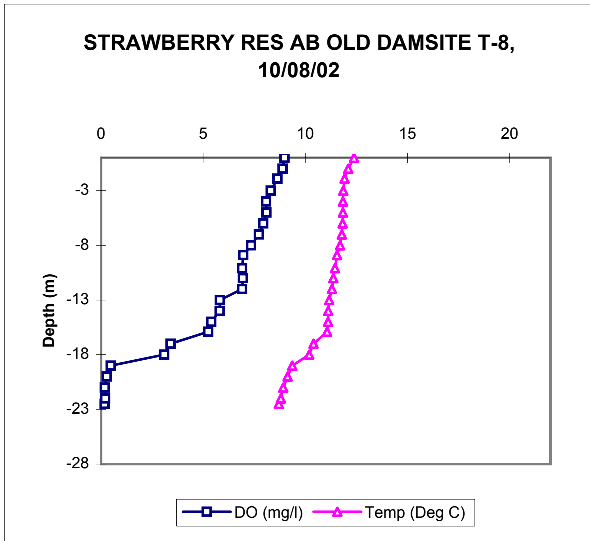
-28
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES AB OLD DAMSITE T-8, 10/08/02
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-3
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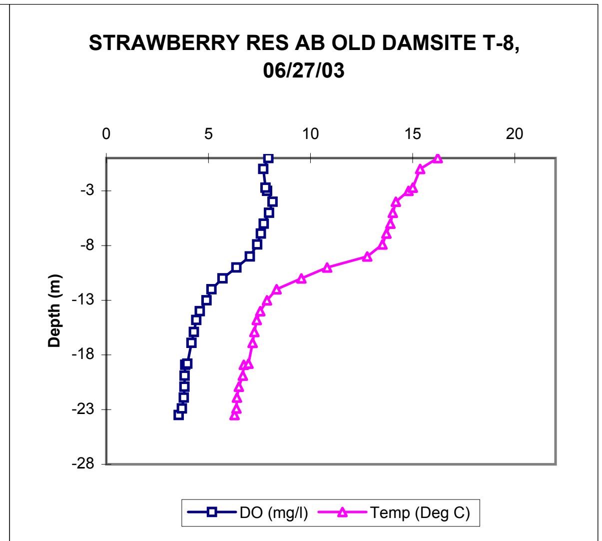
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES AB OLD DAMSITE T-8, 06/27/03
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-3
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-13
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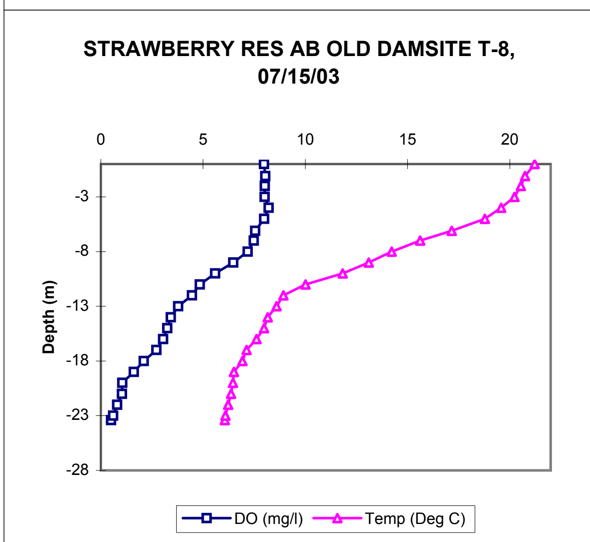
-28
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES AB OLD DAMSITE T-8, 07/15/03
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-3
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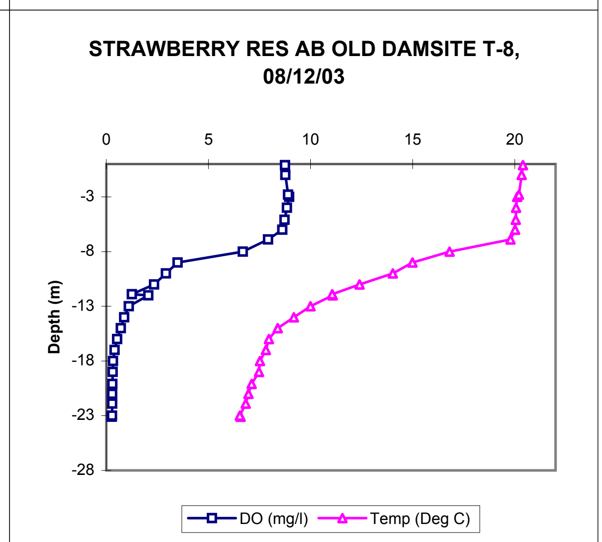
-13
-18
-23
-28
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES AB OLD DAMSITE T-8, 08/12/03
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-3
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-18
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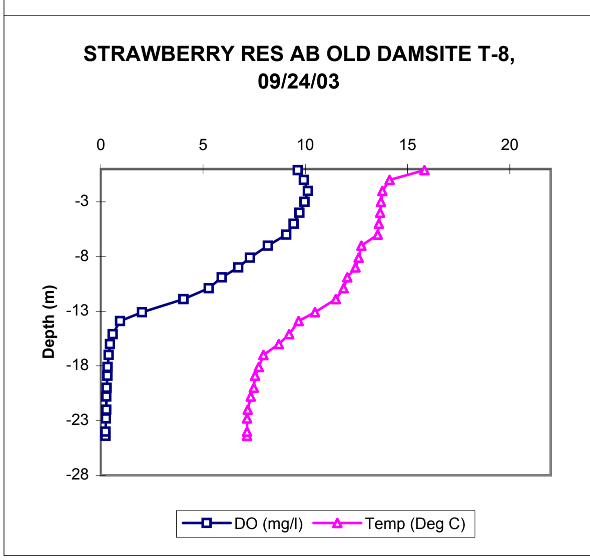
-28
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES AB OLD DAMSITE T-8, 09/24/03
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-3
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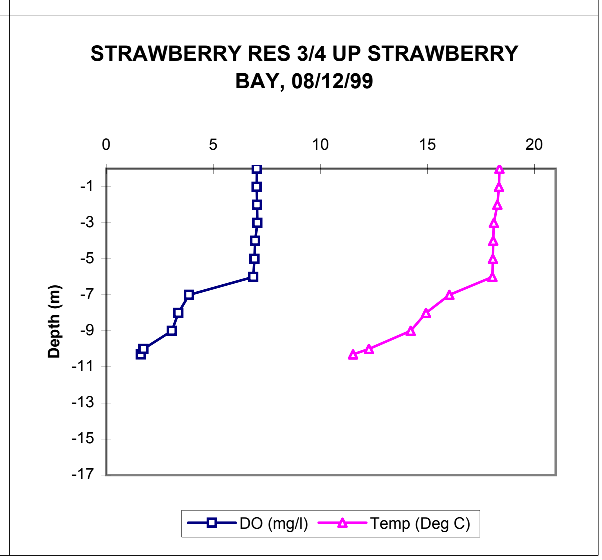
-13
-18
-23
-28
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES 3/4 UP STRAWBERRY BAY, 08/12/99
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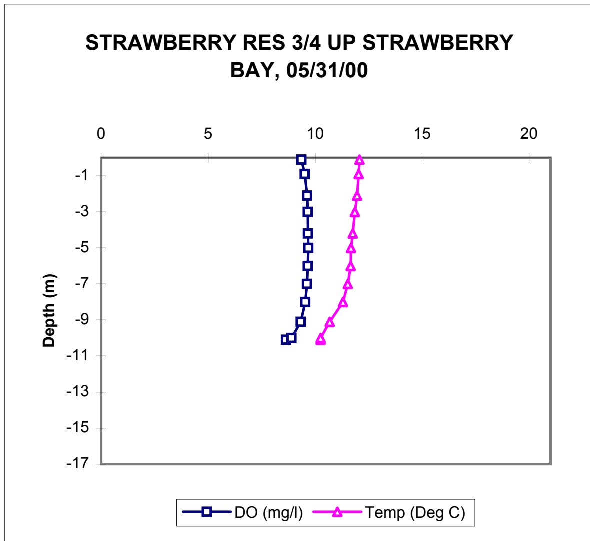
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES 3/4 UP STRAWBERRY BAY, 05/31/00
0
5
10
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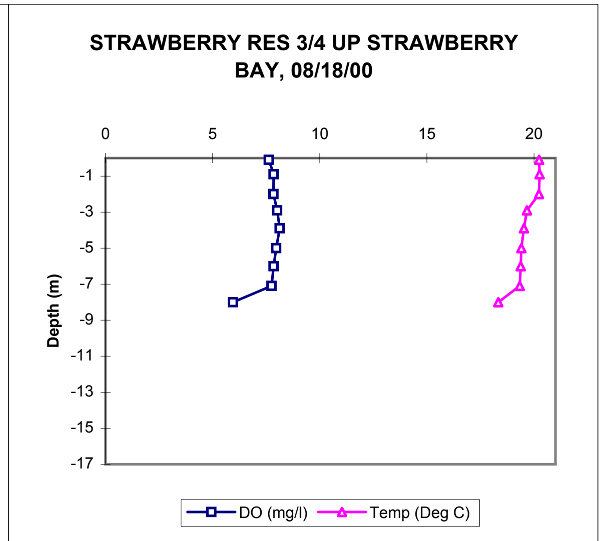
-5
-7
-9
-11
-13
-15
-17
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES 3/4 UP STRAWBERRY BAY, 08/18/00
0
5
10
15
20
-1
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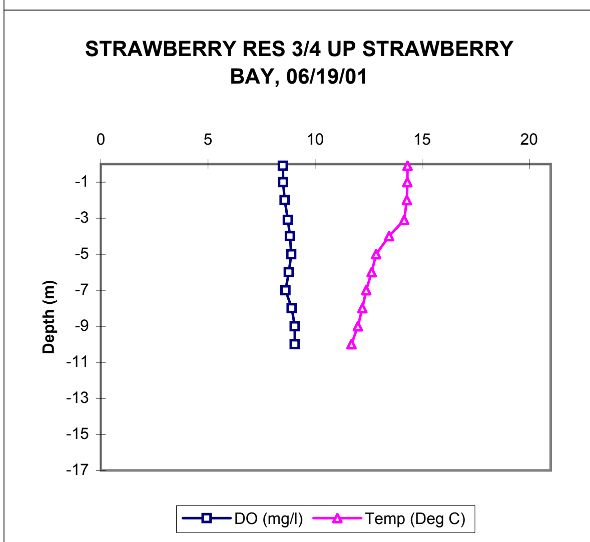
-11
-13
-15
-17
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES 3/4 UP STRAWBERRY BAY, 06/19/01
0
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10
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-11
-13
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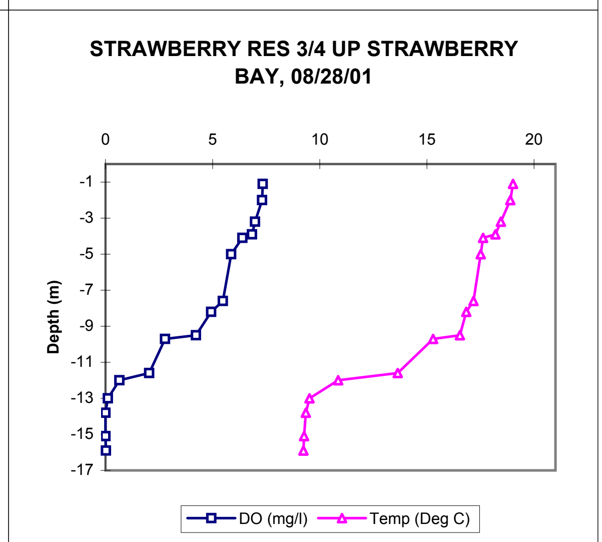
-17
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES 3/4 UP STRAWBERRY BAY, 08/28/01
0
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-11
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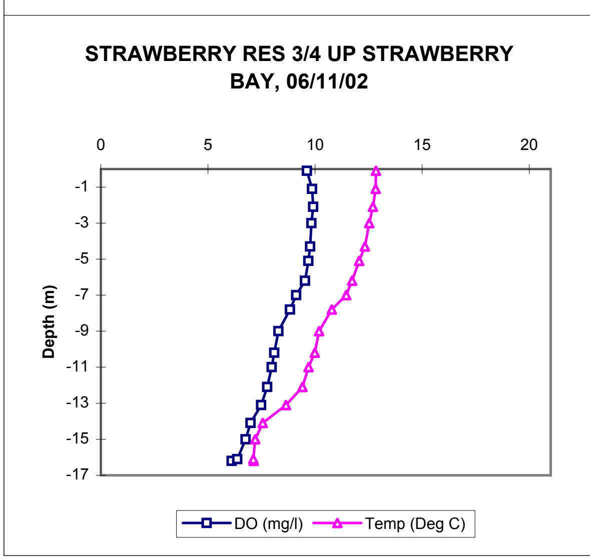
-17
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES 3/4 UP STRAWBERRY BAY, 06/11/02
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5
10
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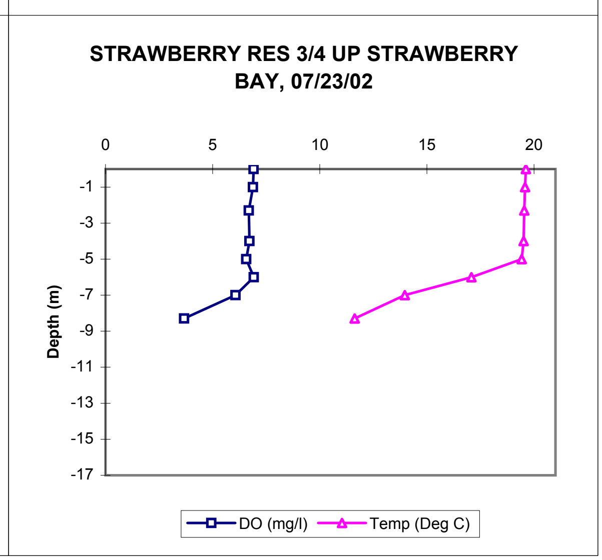
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES 3/4 UP STRAWBERRY BAY, 07/23/02
0
5
10
15
20
-1
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-7
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-11
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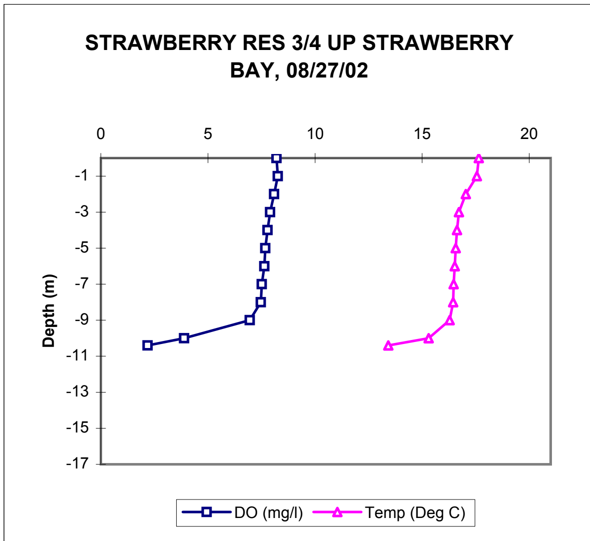
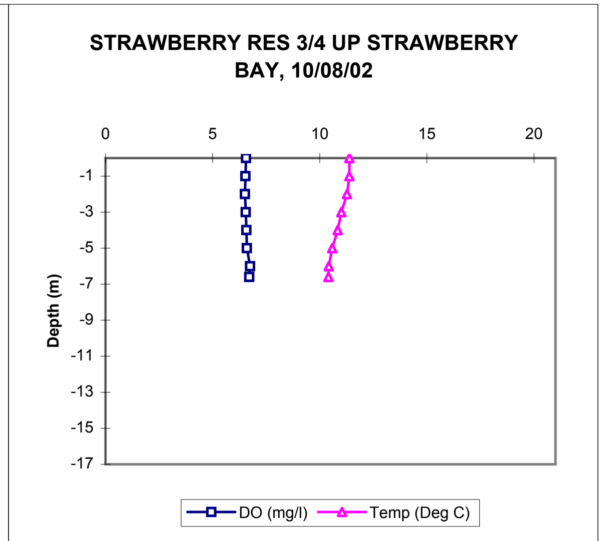
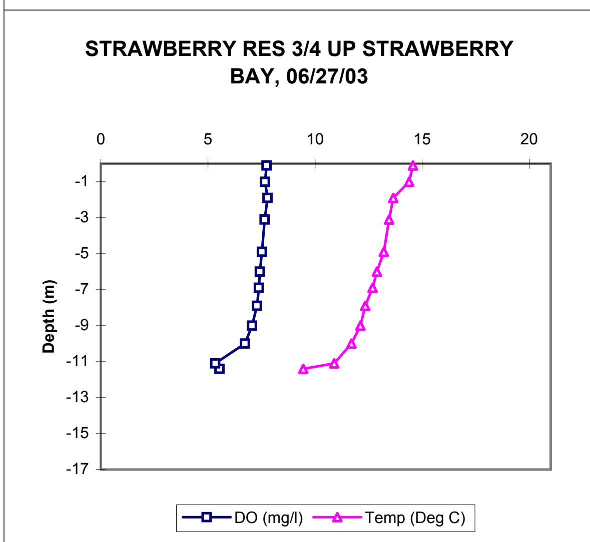
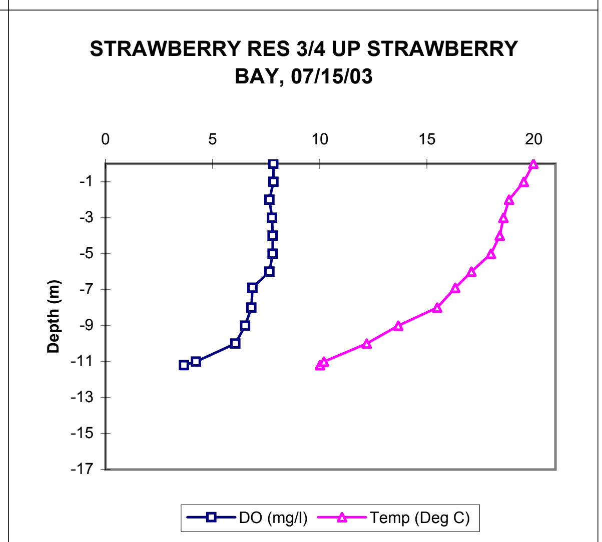
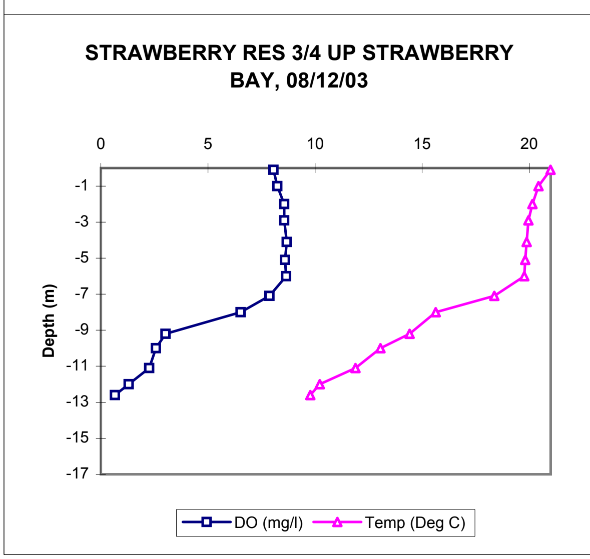
-15
-17
Depth (m)
DO (mg/l)
Temp (Deg C)

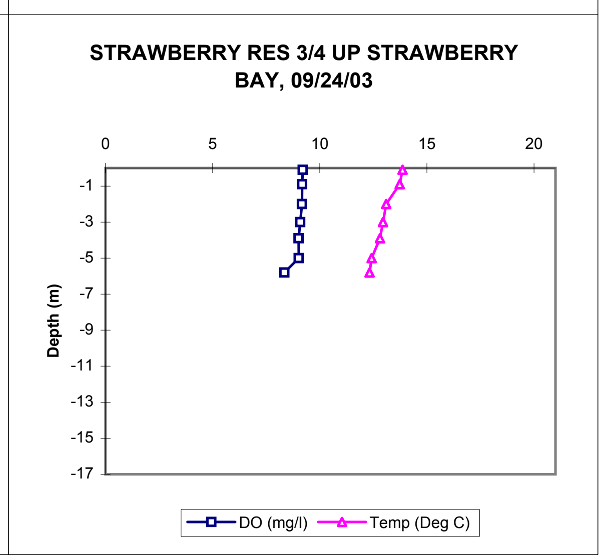

STRAWBERRY RES 3/4 UP STRAWBERRY BAY, 08/27/02
Depth (m)
DO (mg/l)
Temp (Deg C)

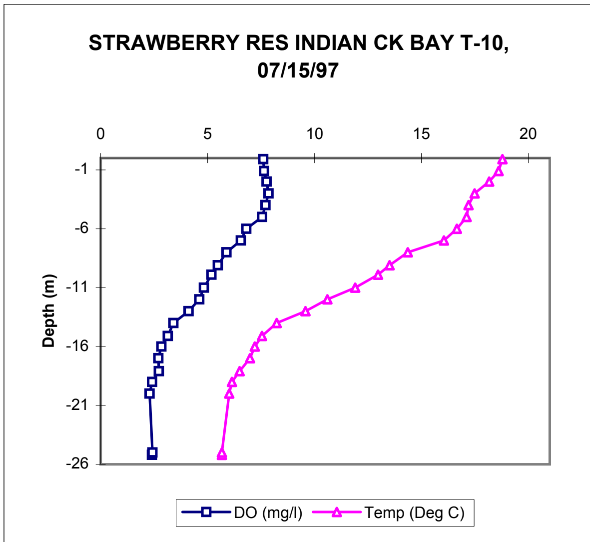

STRAWBERRY RES 3/4 UP STRAWBERRY BAY, 10/08/02
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES 3/4 UP STRAWBERRY BAY, 06/27/03
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES 3/4 UP STRAWBERRY BAY, 07/15/03
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES 3/4 UP STRAWBERRY BAY, 08/12/03
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES 3/4 UP STRAWBERRY BAY, 09/24/03
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES INDIAN CK BAY T-10, 07/15/97
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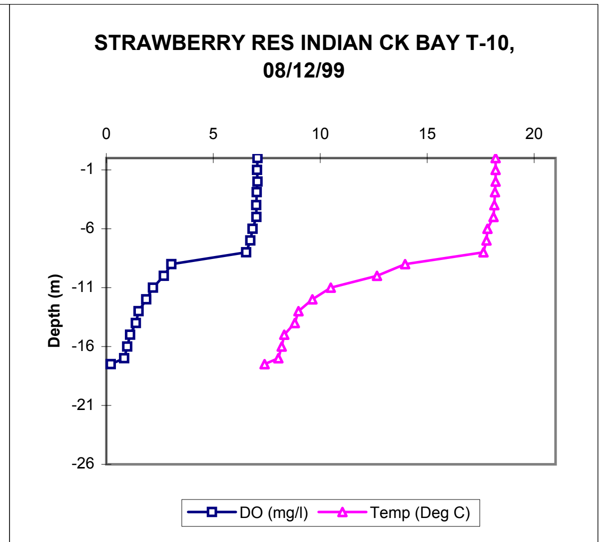
20
-1
-6
-11
-16
-21
-26
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES INDIAN CK BAY T-10, 08/12/99
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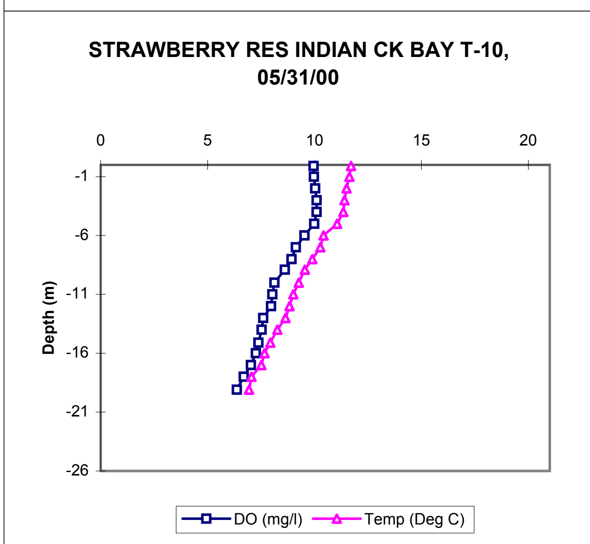
5
10
15
20
-1
-6
-11
-16
-21
-26
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES INDIAN CK BAY T-10, 05/31/00
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20
-1
-6
-11
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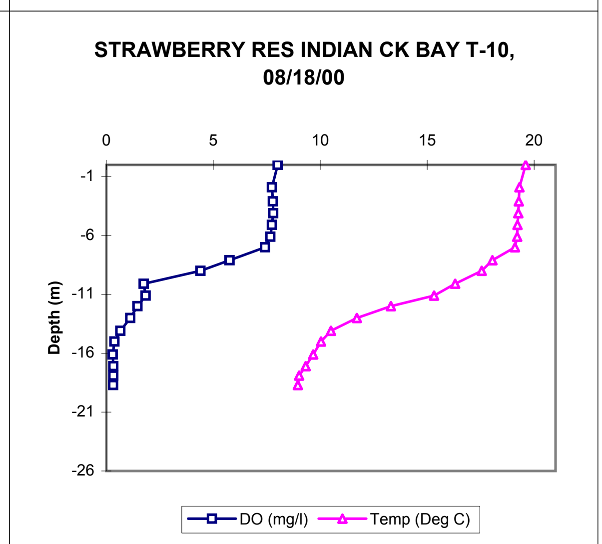
-21
-26
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES INDIAN CK BAY T-10, 08/18/00
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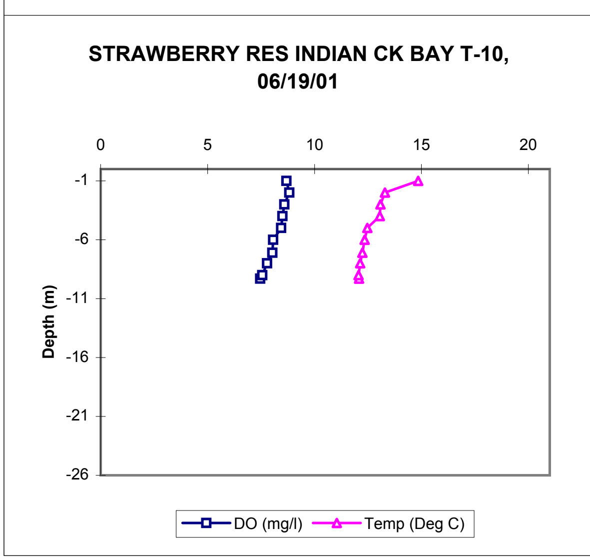
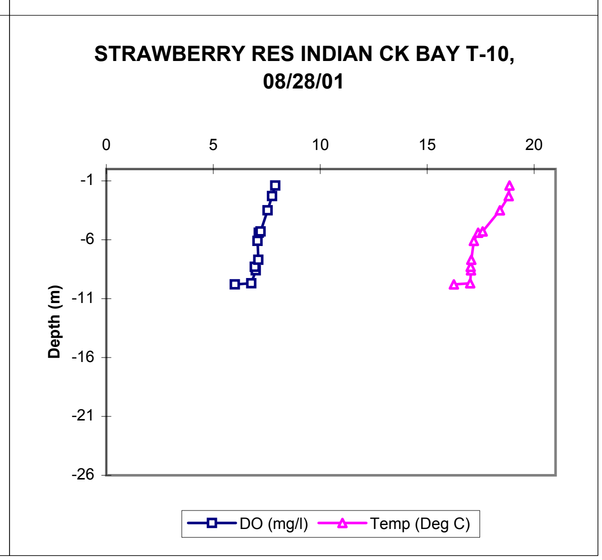
-26
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES INDIAN CK BAY T-10, 06/19/01
0
5
10
15
20
-1
-6
-11
-16
-21
-26
Depth (m)
DO (mg/l)
Temp (Deg C)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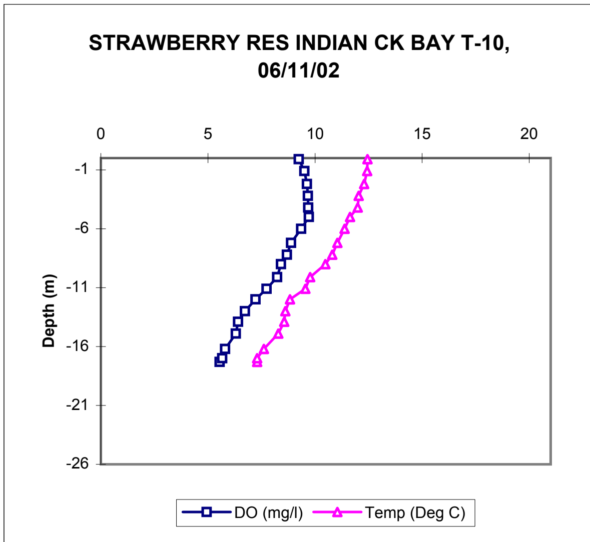
Depth (m)
DO (mg/l)
Temp (Deg C)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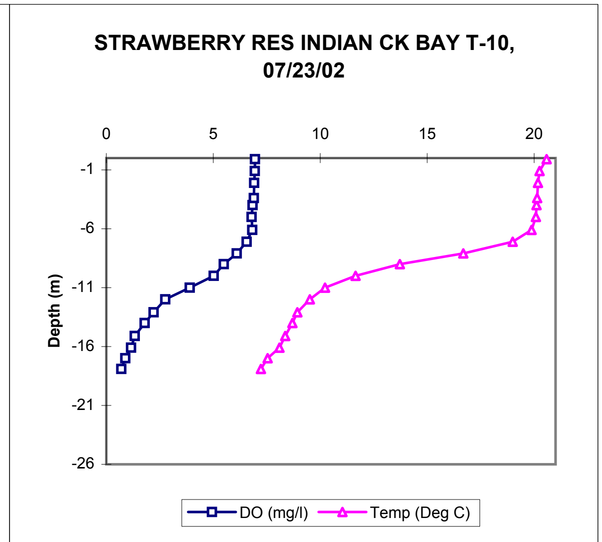
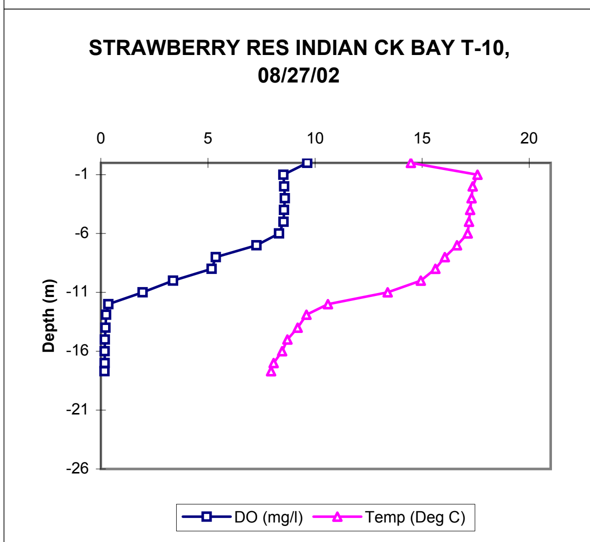
Depth (m)
DO (mg/l)
Temp (Deg C)


STRAWBERRY RES INDIAN CK BAY T-10, 07/23/02
Depth (m)
DO (mg/l)
Temp (Deg C)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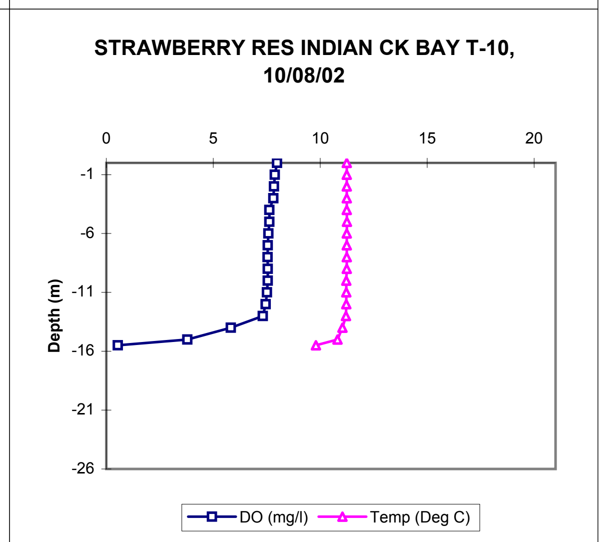
Depth (m)
DO (mg/l)
Temp (Deg C)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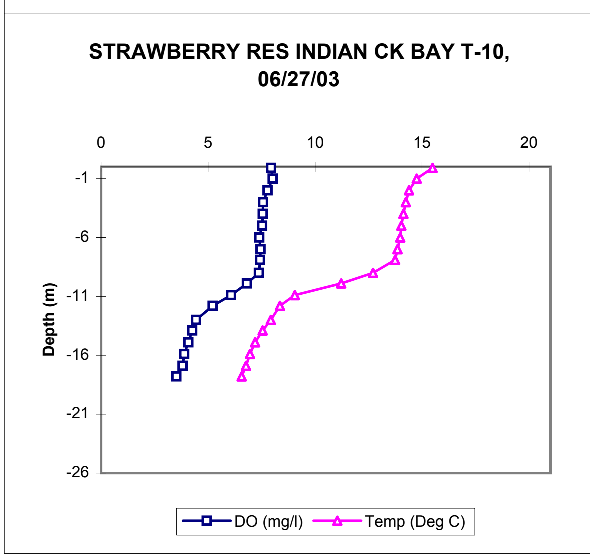
Depth (m)
DO (mg/l)
Temp (Deg C)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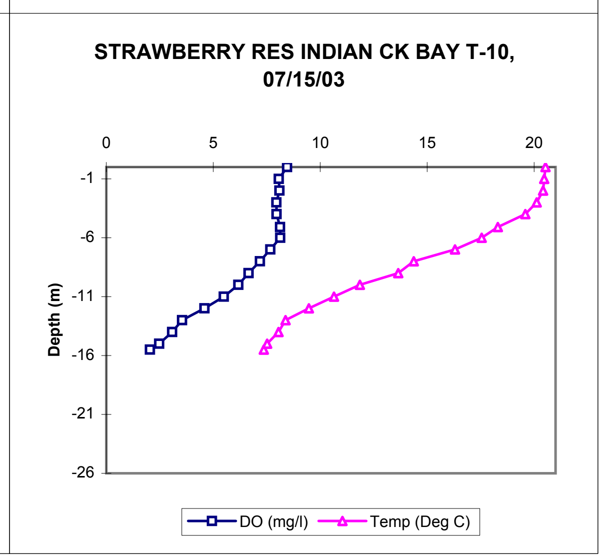
Depth (m)
DO (mg/l)
Temp (Deg C)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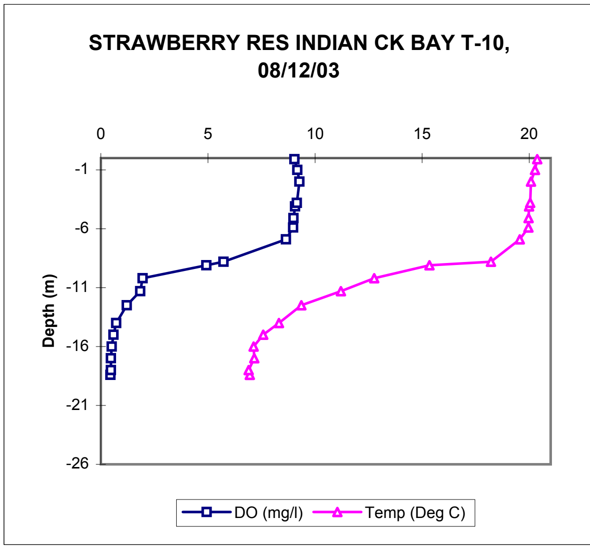
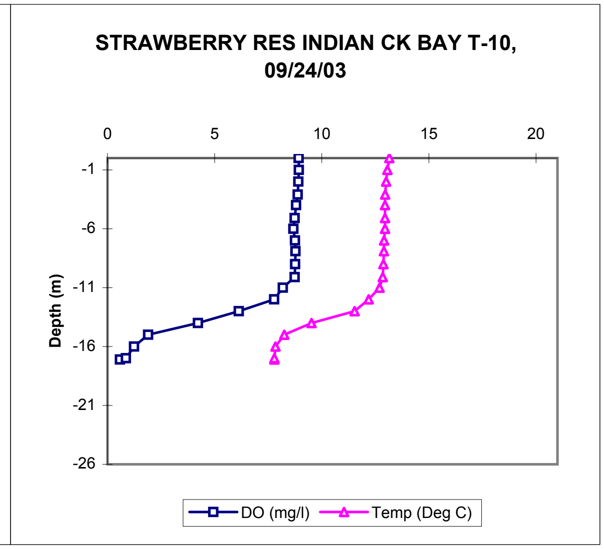
Depth (m)
DO (mg/l)
Temp (Deg C)



STRAWBERRY RES INDIAN CK BAY T-10, 08/12/03
0
5
10
15
20
-1
-6
-11
-16
-21
-26
Depth (m)
DO (mg/l)
Temp (Deg C)



STRAWBERRY RES INDIAN CK BAY T-10, 09/24/03
0
5
10
15
20
-1
-6
-11
-16
-21
-26
Depth (m)
DO (mg/l)
Temp (Deg C)

Appendix C:

Removed Data Points

Reservoir Data

Removed Data Points

Ammonia

Station	Date	Value (mg/L)	S.D. From Mean
493633-Middle	9/19/1990	0.82	5.7
593676-Bottom	9/19/1990	1.87	5.6
493642-Bottom	9/19/1990	1.78	5.5
493632-Middle	4/13/1993	0.62	5.4
493645-Middle	8/20/1991	0.78	4.8
493632-Surface	3/12/1991	0.46	4.7
493633-Bottom	9/19/1990	0.43	4.1
493645-Bottom	9/5/1990	1.63	4.0
493632-Surface	2/5/1991	0.39	3.9
493632-Bottom	3/12/1991	1.02	3.7
493645-Surface	2/5/1991	0.46	3.6
493633-Middle	8/8/1990	0.53	3.5
593676-Surface	2/5/1991	0.61	3.5
493633-Surface	8/22/1995	0.26	3.4
493633-Middle	9/19/1990	0.52	3.4
493648-Surface	10/15/1998	0.06	3.3
493642-Surface	4/17/1991	0.29	3.2
493645-Middle	8/8/1990	0.56	3.2
493632-Middle	4/11/1990	0.40	3.2
493632-Middle	3/14/1990	0.39	3.1
493643-Surface	11/7/1991	0.26	3.0

Chlorophyll A

Station	Date	Value (ug/L)	S.D. From Mean
493632-Surface	1/8/1991	90	5.8
493645-Surface	8/20/1992	190	4.9
493642-Surface	1/24/1990	113	3.8
493633-Surface	8/29/1996	44	3.6
593676-Surface	1/8/1991	134	3.2

Dissolved NO2+NO3

Station	Date	Value (mg/L)	S.D. From Mean
493645-Surface	8/19/2000	21.70	6.2
493632-Surface	8/28/2001	0.55	5.6
493643-Surface	8/19/2000	34.60	5.5
593676-Surface	3/29/1994	0.42	5.3
493645-Middle	3/29/1994	0.76	5.0
493642-Middle	8/19/2000	53.30	4.6
493642-Bottom	8/19/2000	0.60	4.4

493643-Bottom	8/19/2000	0.70	4.2
493642-Surface	5/21/1991	0.18	4.0
493633-Bottom	8/28/2001	0.77	3.9
493633-Surface	5/21/1991	0.16	3.7
493632-Bottom	6/3/1994	0.79	3.7
593676-Middle	4/17/1991	0.43	3.7
493633-Middle	8/20/1991	0.36	3.5
493642-Surface	4/17/1991	0.16	3.4
593676-Bottom	4/13/1993	0.52	3.3
493645-Middle	4/17/1991	0.52	3.2

Dissolved Oxygen

Station	Date	Value (mg/L)	S.D. From Mean
493645-Surface	1/22/1992	17.4	3.9
593676-Surface	3/17/1992	19.9	3.8
493642-Middle	1/24/1990	18.8	3.5
493632-Bottom	5/23/1990	8.7	3.1
493632-Bottom	1/24/1990	8.5	3.0

Dissolved Total Phosphorus

Station	Date	Value (mg/L)	S.D. From Mean
493642-Surface	9/5/1990	0.986	6.0
493645-Middle	8/20/1991	0.300	5.7
493633-Surface	9/19/1990	0.375	5.2
493643-Surface	9/5/1990	0.167	3.9
493642-Bottom	9/19/1990	0.277	3.8
493633-Middle	8/8/1990	0.208	3.7
593676-Bottom	9/19/1990	0.368	3.6
493643-Middle	11/7/1991	0.083	3.3
493645-Bottom	8/20/1992	0.357	3.2
493645-Bottom	8/20/1991	0.354	3.1
493632-Surface	4/13/1993	0.107	3.1
593676-Middle	8/20/1992	0.108	3.1
493643-Surface	9/19/1990	0.138	3.1
493632-Middle	11/12/1992	0.184	3.0

Secchi Disk Depth

Station	Date	Value (m)	S.D. From Mean
493632-Surface	4/17/1991	11.5	3.2
493645-Surface	4/17/1991	9.0	3.1
493645-Surface	6/27/2003	9.0	3.1

Total Dissolved Solids

Station	Date	Value (mg/L)	S.D. From Mean
493642-Surface	6/19/2001	218	3.6

Water Temperature

Station	Date	Value (Deg. C)	S.D. From Mean
493633-Bottom	9/14/1994	14.5	4.6
493632-Bottom	8/12/1999	9.8	4.3

Total Phosphorus

Station	Date	Value (mg/L)	S.D. From Mean
493645-Surface	9/7/1993	0.375	5.6
493633-Surface	7/15/1997	0.410	5.5
493645-Middle	7/15/1997	0.286	5.0
493643-Bottom	8/19/2000	0.740	4.9
493645-Middle	8/20/1991	0.248	4.1
593676-Bottom	9/19/1990	0.410	4.1
593676-Surface	11/7/1991	0.225	4.0
493642-Bottom	9/19/1990	0.330	3.9
593676-Middle	7/15/1997	0.210	3.8
493633-Middle	9/19/1990	0.250	3.7
493632-Middle	4/13/1993	0.209	3.5
493633-Middle	8/8/1990	0.235	3.4
493632-Bottom	4/13/1993	0.382	3.2
493633-Middle	11/7/1991	0.222	3.1
493645-Bottom	9/5/1990	0.382	3.0

Total Suspended Solids

Station	Date	Value (mg/L)	S.D. From Mean
493645-Surface	9/7/1993	91	6.2
493633-Surface	9/7/1993	4	5.3
593676-Surface	9/14/1994	22	4.6
493632-Surface	3/29/1994	4	4.5
493632-Surface	5/2/2001	4	4.5
493642-Surface	9/3/1997	7	4.1
493648-Surface	10/8/2002	4	3.3
493632-Middle	5/9/1995	10	3.3

Appendix D:
Friends of Strawberry Valley Presentation

Welcome

Friends of Strawberry Valley

Presentation for Strawberry Reservoir TMDL

Presentation Outline

1. Background
2. TMDL Process
3. Strawberry Reservoir Data
4. Questions

Purpose of the Presentation

- Describe the TMDL Process
- Project Status

Background

- Initially Constructed in 1922
- 8,400 Acre Reservoir
- Enlargement of the Reservoir to 17,164 Acres
- Today, Strawberry is Utah's Premier Cold-Water Fishery

Background

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PSOMAS

Background

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PSOMAS

Background

- Initially Constructed in 1922
- 8,400 Acre Reservoir
- Enlargement of the Reservoir to 17,164 Acres
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PSOMAS

TMDL Process

The Clean Water Act, Section 303(d)

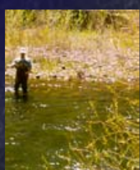
The State of Utah

The Total Maximum Daily Load (TMDL)

PSOMAS

TMDL Process

The State of Utah's Beneficial Uses for Strawberry:



- *1C - Domestic Purpose*
- *2B - Secondary for Recreation*
- *3A - Cold Water Fishery*
- *4 - Agricultural Use*

TMDL Process

The Team:

PSOMAS

USU Water Research Lab

SWCA

Dr. Sam Rushforth, UVSC

TMDL Process

What does this mean for Strawberry?

- Dissolved Oxygen (D.O.)

- Phosphorous

TMDL Process

The team has developed

10 Work Elements

to complete the TMDL Process

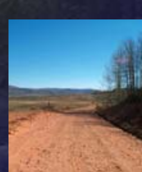
TMDL Process

***# 1* Compile, Evaluate and Validate Data…**

TMDL Process

***# 2* Identify and Characterize Point and Non-Point Source of Pollution**

- ✓ *Septic Systems*
- ✓ *Slope Erosion*
- ✓ *Grazing Allotments*



TMDL Process

***# 3* Calculate Reservoir Pollutant Loadings**

TMDL Process

***# 4* Locate Identifiable Point and Non-Point Sources of Pollution**

TMDL Process

5 Identify probable future sources of pollution

- ✓ Land Use
- ✓ Reservoir Management
- ✓ Changes in Fisheries Management

To be coordinated with Watershed Stakeholders

PSOMAS

TMDL Process

6 Prepare Project Implementation Plans

7 Quantify Reductions in Loadings from Best Management Plan (BMP) and Best Available Technology (BAT)

PSOMAS

TMDL Process

6 Prepare Project Implementation Plans

7 Quantify Reductions in Loadings from Best Management Plan (BMP) and Best Available Technology (BAT)

PSOMAS

TMDL Process

8 Use Attainability Analysis

9 Prepare TMDL Technical Report

10 Public Participation

PSOMAS

TMDL Process

8 Use Attainability Analysis

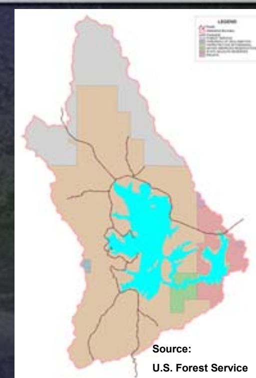
9 Prepare TMDL Technical Report

10 Public Participation

PSOMAS

Strawberry Reservoir Data

Land Ownership



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TMDL Process

8 Use Attainability Analysis

9 Prepare TMDL Technical Report

10 Public Participation

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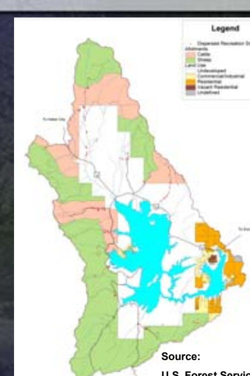
Strawberry Reservoir Data

Land Use



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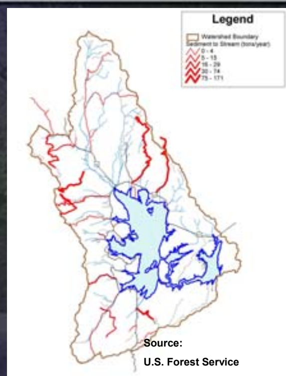
Strawberry Reservoir Data

Sediment Reaching Streams



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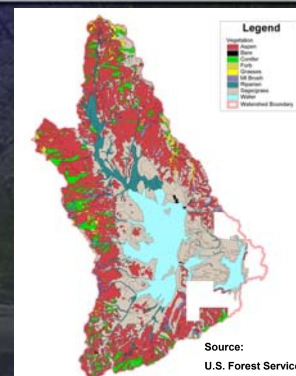
Strawberry Reservoir Data

Vegetation



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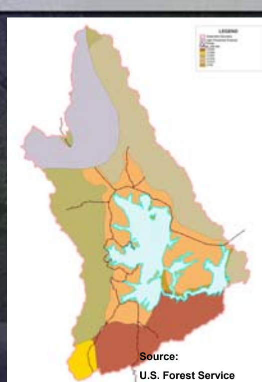
Strawberry Reservoir Data

Soil Classification



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Strawberry Reservoir Data

STORET Station Location

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Strawberry Reservoir Data

Total Suspended Solids

Strawberry Reservoir Data

Reservoir Concentration Map

Strawberry Reservoir Data

Total Phosphorus

Questions ??

Appendix E:

Detailed Hydrologic Analysis

BACKGROUND

A TMDL study is all about loads. But load equals the product of flow times concentration. Both are necessary, and it is important to have the data for both streamflows and constituent concentrations. The situation for Strawberry Reservoir is a mixed bag in this regard. The available data for Strawberry Reservoir range from very good to nonexistent. We have been able to assemble a reasonably good data set on constituent concentrations, and it is relatively extensive and consistent. The basic set of constituent concentration information is from the STORET system. There have been some data quality issues, so we have performed a quality screening of all of the data used in the analysis.

The story concerning streamflows is very different. There's a limited amount of concurrent flow data that was obtained at the time that water quality sampling took place (approximately once per month) for the STORET program. Furthermore, as with water quality sampling, flow monitoring took place in a limited season, generally May through October. With such a sampling protocol, the samplers always missed a major part of the spring runoff, which begins in late March or early April. Additionally, the annual hydrograph is "flashy". The three-month period of April through June generally represents 75% of the annual runoff volume. So we were faced with having only two spot observations per year with which to try to build a picture of the hydrologic regime at Strawberry Reservoir.

We spent a great deal of time trying to formulate an Annual Unit Hydrograph from the limited data. We were not satisfied with having to make some broad and poorly documented assumptions to do this. The results were not at all consistent with preliminary Water Budget estimates. So we put significant effort into calling around and checking out other potential sources of information. Through a stroke of luck we were able to obtain detailed records on an extensive flow monitoring program conducted by the Bureau of Reclamation between 1982 and 1991. This gave a very representative picture of the relationships between the various surface water sources to Strawberry Reservoir. Without this data set we would have had a very difficult time estimating flow patterns for the tributaries to Strawberry Reservoir.

Another factor that has complicated the hydrologic analysis is the pattern of large multiyear hydrologic variations. For example, the past five years have been one of serious drought, and flows into the reservoir have been uncharacteristically low ("super low" in fact). The decade of the 1980s showed four-fold variations in annual volumes of flow. "Normal" conditions have occurred only infrequently during the past 20 to 25 years. Defining Strawberry Reservoir hydrology has been like shooting at a moving target.

Conversely, we have good data on reservoir outflows. The Central Utah Water Conservancy District maintains daily flow records for Strawberry River outflows at the dam and outflows through the Strawberry and Syar Tunnels to the Wasatch Front.

Operationally, Strawberry Reservoir has seen a great deal of variation in the last two decades. It has been essentially in transitions throughout this period. These transitions involve both the filling of the reservoir after the most recent dam construction project, and the excursions through two periods of wetness end contrasting drought. During the last five years, Strawberry Reservoir levels have dropped 10 to 15 ft. All of these factors have contributed to an extremely difficult analytical challenge.

FLOW ANALYSIS

Approach

The objective was to find a method to estimate inflows to Strawberry Reservoir based on prevalent climatic conditions, and then to estimate normal (characteristic) and extreme flows derived from relationships to documented (official) climatological normals and extremes. Obviously, the most direct relationship would be one in which inflow would be a function of local precipitation. That is, Local Q equals a function of Local P. Ideally it is best if the precipitation data are truly characteristic of the entire local watershed.

Results – Findings

Initially, we found very little comprehensive flow data for the streams of principal interest. Subsequently, we were able to obtain detailed stream gauging results from the Bureau of Reclamation (as mentioned above). The Bureau monitored three major

Strawberry Reservoir tributaries on a continuous basis: Strawberry River, Co-op Creek, and Indian Creek. The period covered in the flow monitoring was from 1982 through 1991, but not all the streams were monitored for the entire period. We searched for contemporaneous precipitation data from some location near Strawberry. Although there have been several weather stations operated near Strawberry Reservoir in the last 50 years, none of them completely covered the period of detailed flow monitoring by the Bureau of reclamation and is still operational today. A listing of the stations and their periods of operation are included in Table 1.

Table 1 – Weather Stations near Strawberry Reservoir	
Name/Location	**Dates of Operation**
DANIELS-STRAWBERRY	1 Oct 1978 – 31 Jun 1995
EAST PORTAL	1 Jul 1948 – 31 Oct 1955
SOLDIER CREEK	1 Nov 1968 – 31 Jan 1973
STRAWBERRY DANIELS SUMM	2 Jul 1948 – 31 Dec 1948
STRAWBERRY DIVIDE	1 Oct 1978 – 31 Jun 1995
STRAWBERRY RESERVOIR EA	1 Apr 1905 – 31 Oct 1977
STRAWBERRY HIWAY STN	1954, 19 Apr 1962 – 31 Aug 1967, 1 Aug 1983 – 31 Oct 1984

In order to test our hypothesis that an acceptable precipitation-annual flow relationship could be employed, we ran a correlation analysis of Strawberry River and 8-month (Oct-May) precipitation for the Daniels-Strawberry weather station. This station was operated during the period of Bureau flow monitoring, but is no longer maintained. The results of this correlation are shown in Figure 1. The R^2 value of 0.94 is very good, and we concluded that the development of a correlation relationship method to estimate surface inflows to Strawberry Reservoir would be a worthwhile undertaking.

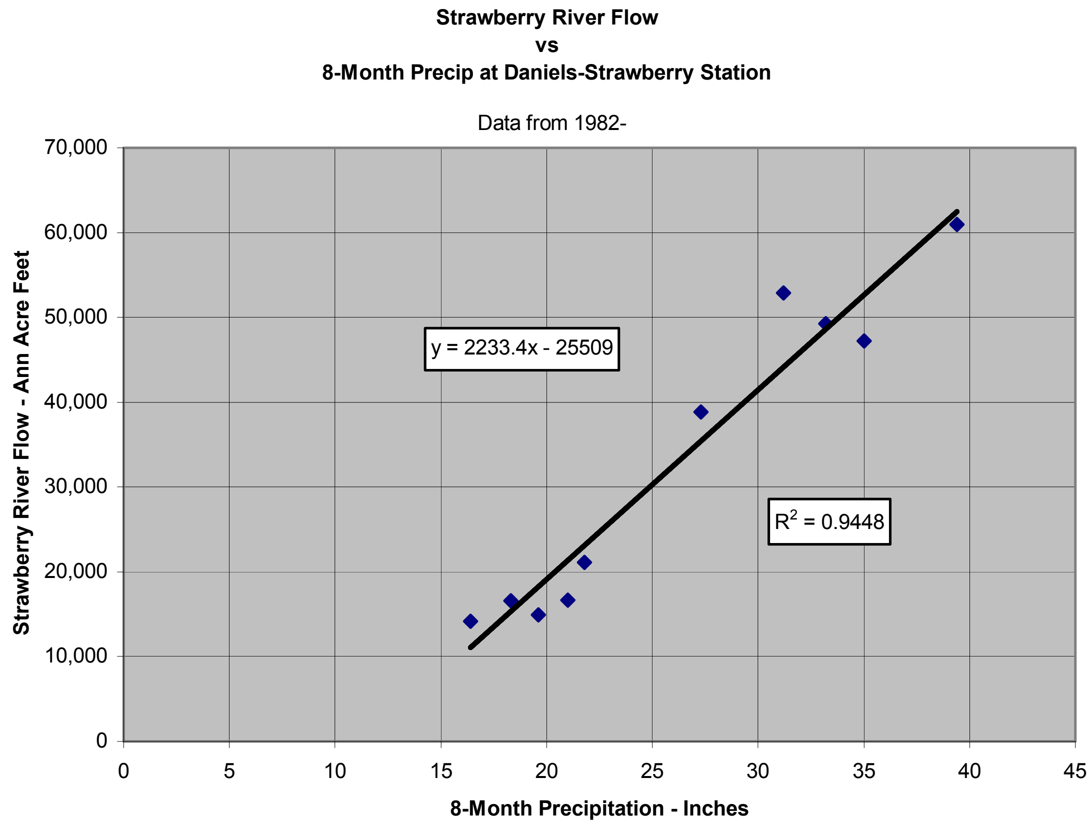


Figure 1 – Demonstration of Validity of Precipitation-Annual Flow Correlation Methodology

We had to resort to searching for surrogate precipitation data. The criteria that we used in our searched included: (1) the same time period as the flow monitoring, (2) a proximate location, (3) at a similar elevation, and (4) with a similar amounts and patterns of precipitation. There were several other mountain stations that served as candidates for the surrogate. They included Scofield Reservoir, Bryce Canyon, and Soldier Summit. However they did not match up well with respect to precipitation and certain other topographic or climatological parameters. We decided to select Heber. The Heber station has been in operation for over 100 years, and has a good and extensive record of climatological and meteorological data. Furthermore, Heber is reasonably proximate to Strawberry Reservoir, it is long-term, it has a contemporaneous record with the flow monitoring, and shows similar annual rainfall amounts (to the old Strawberry Highway station that was operated between 1962 and 1968). A comparison between the monthly and annual precipitation amounts for Heber and the old Strawberry Highway station are shown in Table 2.

Table 2 – Comparison of Normal Monthly and Annual Precipitation for Heber and Strawberry Highway Station													
Mo	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Ann
Heber	1.78	1.56	1.37	1.37	1.23	0.90	0.87	0.98	1.26	1.45	1.64	1.62	16.01
SHS	1.72	1.13	1.31	1.56	1.48	1.72	.048	1.79	0.95	0.88	1.60	1.87	16.47

We were able to develop fairly statistically significant correlation relationships between annual flow (of the surface stream) and annual precipitation (at Heber). The correlation plot for Strawberry River is shown in Figures 2. The correlations assumed linear relationships. We also examined some more good, but complex forms, but they provided only limited improvement. For the linear correlations R-squared was generally greater than 80%; not perfect, but very good.

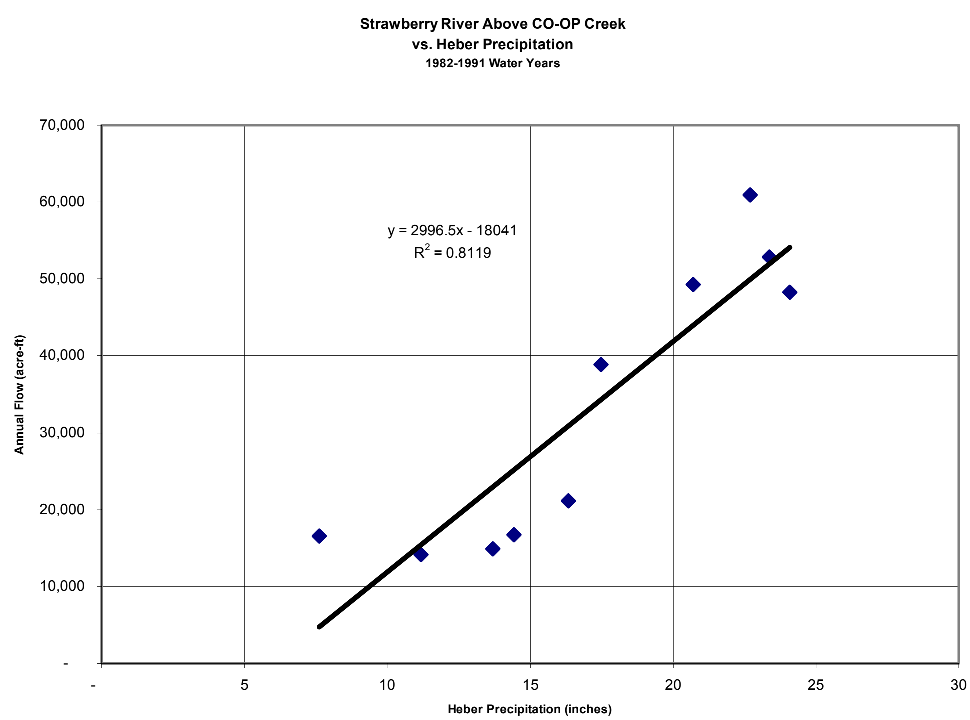


Figure 2 – Correlation Plot for Strawberry River

In order to verify the methodology, we estimated annual flows for the most recent time period, the Water Years 2000 to 2003 (October 1999 through September 2003).

VERIFICATION: Strawberry Reservoir Water Budget 2000–2003.

The rationale for performing a Water Budget of Strawberry Reservoir is that the flow-estimating method should withstand matching the requirements of a hydrological accounting of the system. The components of the Water Budget include the following:

1. Surface inflows
    a. Principal streams: Strawberry River, co-op Creek, and Indian Creek.
    b. Other streams: the other streamflows were based on estimates from the unit annual volume relationships of the principal streams (above) in units of AFY/square mile. We actually developed a separate annual flow per-unit area versus annual precipitation equation for them.
    c. Sheet flow: this was treated the same as other streams.
2. Diversion inflows. We had the daily flow data for The Ladders, obtained from the Central Utah Water Conservancy District.
3. Outflows: Strawberry River at the dam, Strawberry and Sylar tunnels. We had good daily data for these outflows from CUWCD.
4. Direct precipitation. We used the same Heber precipitation data to estimate direct precipitation on the surface of Strawberry Reservoir. The surface area of the reservoir was calculated based on the stage–area relationship provided by Central Utah Water Conservancy District.
5. Evaporation. There exists some early pan evaporation data for the Strawberry Reservoir East Portal from the years 1956 through 1977. However, this information is only characteristic and cannot be directly translated to the period in question. In order to conduct an analysis for the most recent historical period (the years 2000 through 2003 which are contemporaneous with our Water Budget interval), we had to come up with a method to estimate the appropriate

evaporation rates. The method selected is the Hargreave's evapotranspiration equation. We used contemporaneous high and low temperature data collected by the Central Utah Water Conservancy District. The evaporation estimate results, although particular to the period in question, were consistent with the early pan data. The evaporation estimates for the year 2000 are shown in Figure 3. Note that a nine-month period was selected, March through November. We assumed that the reservoir would be iced over during December, January and February.

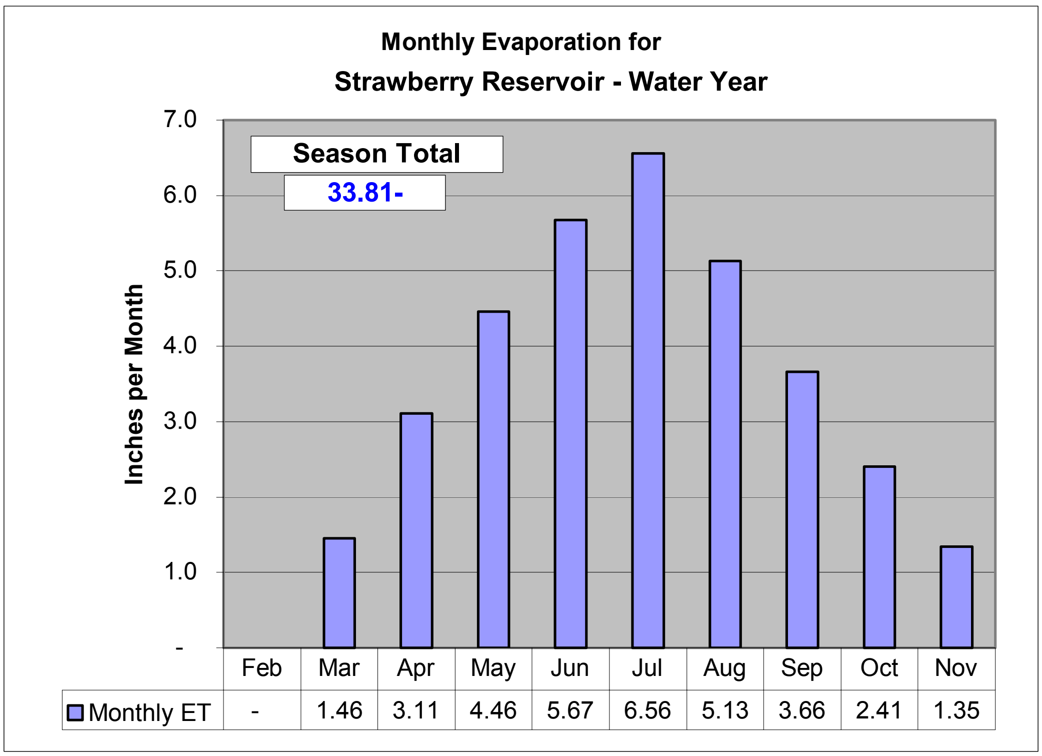


Figure 3 – Year 2000 Evaporation Estimates for Strawberry Reservoir

Results

Table 3 shows the 2000 through 2003 Water Budget for Strawberry Reservoir.

Table 3 - Strawberry Reservoir Hydrologic Balance for Water Years 2000-2003

All Volumes in Acre Feet	Area-SqMi	Water Year 2000	2001	2002	2003	2000-2003 Averages
Inflows						
Strawberry River	52.6	14,441	9,527	15,670	15,670	**13,827**
Indian Creek	15.0	4,641	3,498	4,926	4,926	**4,498**
Co-op Creek	14.5	3,264	2,274	3,511	3,511	**3,140**
Chipman Creek	12.8	3,364	2,419	3,600	3,600	**3,246**
Clyde Creek	6.8	1,787	1,285	1,913	1,913	**1,724**
Mud Creek	5	1,314	945	1,406	1,406	**1,268**
Trout Creek	4.6	1,209	869	1,294	1,294	**1,166**
Broad Hollow	3.8	999	718	1,069	1,069	**964**
Other Stream Inflows	29.3	7,700	5,538	8,241	8,241	**7,430**
Sheet Flow to Res.	41.9	11,011	7,919	11,784	11,784	**10,625**
Subtotals		49,729	34,993	53,413	53,413	**47,887**
The Ladders		51,243	88,621	32,825	86,098	**64,697**
Totals		100,972	123,614	86,239	139,511	**112,584**
Outflows						
Straw. & Syar Tunnels		(80,343)	(84,475)	(116,435)	(101,166)	**(95,605)**
Release From Dam		(25,751)	(17,573)	(14,247)	(14,361)	**(17,983)**
Totals		(106,094)	(102,048)	(130,682)	(115,527)	**(113,588)**
Precipitation (Heber)		14,212	11,951	14,236	13,780	**13,545**
Evaporation		(44,326)	(41,099)	(39,861)	(40,948)	**(41,559)**
Total In		**115,185**	**135,565**	**100,475**	**153,291**	**126,129**
Total Out		**(150,420)**	**(143,147)**	**(170,543)**	**(156,475)**	**(155,146)**
Calc. Delta S		(35,235)	(7,582)	(70,068)	(3,184)	**(29,017)**
Given Delta S		(37,558)	(157)	(101,047)	(20,512)	**(39,819)**
Balance Error		2,323	(7,425)	30,979	17,328	**10,801**

Note that there were large changes in storage (large drop in surface level) to contend with in making this analysis. Our four-year average estimates for inflow versus outflow (taking into account change in storage) are within 10,000 AFY, or 9%. Some possible explanations for the 9% difference are:

1. We were operating at the low end of the flow vs. precipitation correlation curves. Small changes in the correlation parameters could have measurably altered the estimated flow values at this extreme.
2. Direct precipitation on the reservoir may have been different than indicated by the Heber precipitation results.
3. The actual effective temperatures on the reservoir may have been different than those recorded by CUWCD, and the estimated evaporation could thus have been different.

However, given all the uncertainties involved, we believe that this is a reasonable closure.

Conclusions

Our conclusions are that:

Flow vs. precipitation correlation relationships are valid for purposes of estimating inflows to Strawberry Reservoir.

Further, the use of surrogate precipitation data – in this case the Heber data – produces adequate estimates of annual surface inflow to the reservoir.

Hargreaves Equation is satisfactory for estimating annual evaporation from Strawberry Reservoir.

These conclusions represent a lot of extra effort to obtain reasonable estimates of streamflows for the Strawberry Reservoir tributaries, but satisfactory estimates of pollutant loading rates could not have been obtained without such extra effort.

David W. Eckhoff

February 20, 2004

Appendix F

Seasonality and Trend Analysis

Trend analysis for nutrients, dissolved oxygen, and temperature

This section of this technical memo describes the trends in nutrients concentrations, chlorophyll A, dissolved oxygen, and temperature within Strawberry reservoir, with the objective of determining the degree to which natural forces or human modifications in the reservoir's watershed and within the reservoir itself may be changing its trophic status. In the discussion below, reference may be made to station numbers within the reservoir – a map showing those stations' locations is provided in Figure 1 for convenience.

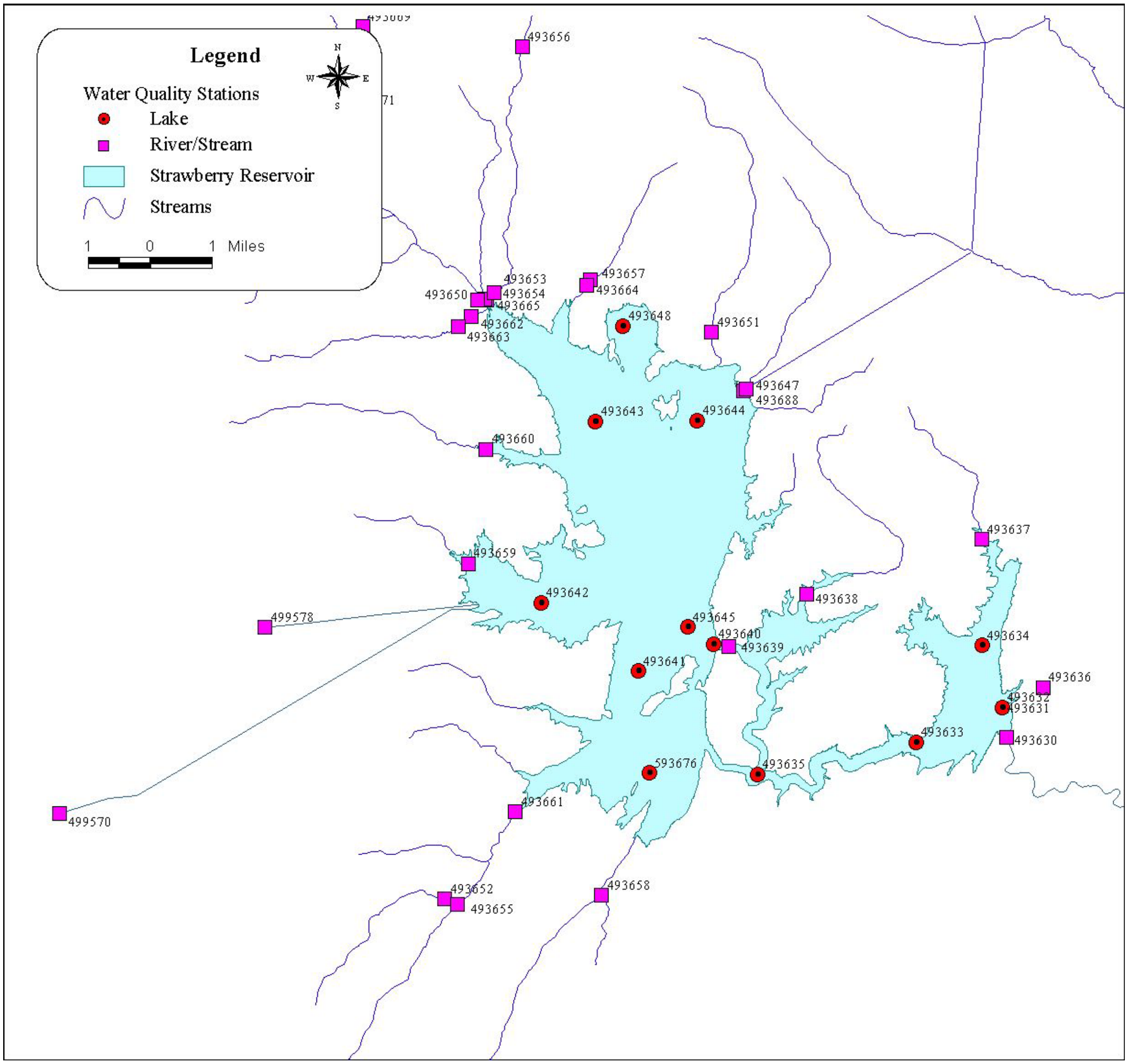


Figure 1 Map of Strawberry Reservoir showing sampling stations

There are a number of methods that may be used to analyze water quality data for trends, including parametric methods, such as least squares regression (there are several variations) and non-parametric methods such as robust regression, and Kendall's and Sen's methods, which are similar.
Many water quality data have characteristics that are unusual. In particular, they are often

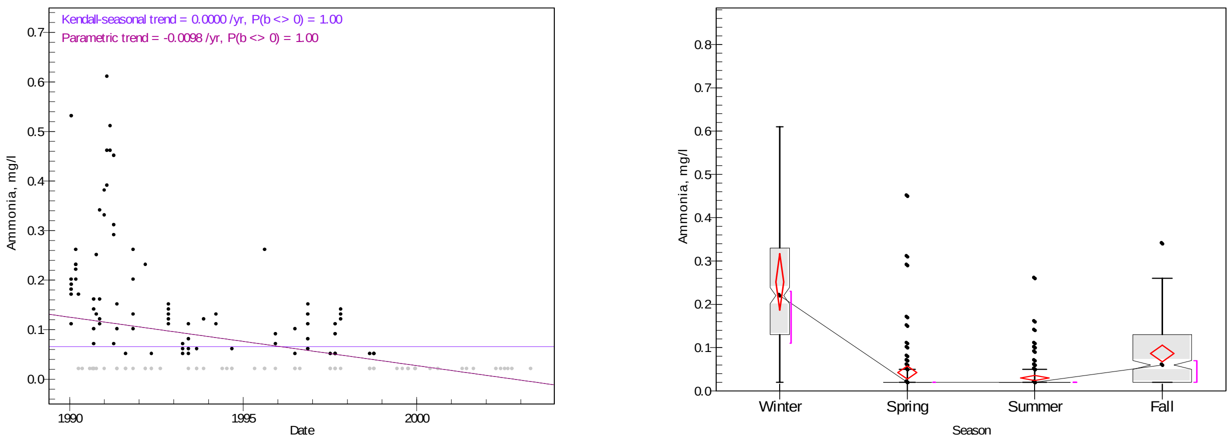
- not normally distributed – often there is skew toward higher values;
- censored – there are data that are reported as non-detected;
- seasonal in nature – data tend to follow patterns related to patterns in the environment, such as weather, runoff, seasonal human activities, etc; and
- correlated with adjacent values – higher values are often next to higher values in time, similarly with lower values.

These characteristics lead one to prefer non-parametric methods that do not require the usual statistical assumptions (errors that are normally, independently, and identically distributed with a mean of zero and constant variance) and that work in the presence of censored data. Gilbert (1987) describes an extension to the non-parametric method that works in the presence of censored data and will account for seasonality. If it is believed that there is a seasonal component (monthly, quarterly, etc.) to a data set, trends are examined for data grouped into those seasons. Within each season, data pairs for which the second member comes after the first member in time are examined to determine whether $x_2 - x_1$ is positive (upward trend), negative (downward trend), or zero (no trend). These differences are accumulated and ranked, and the median (middle) value is reported as the slope for each season. An overall seasonally adjusted slope is then found as the average of the seasonal medians.

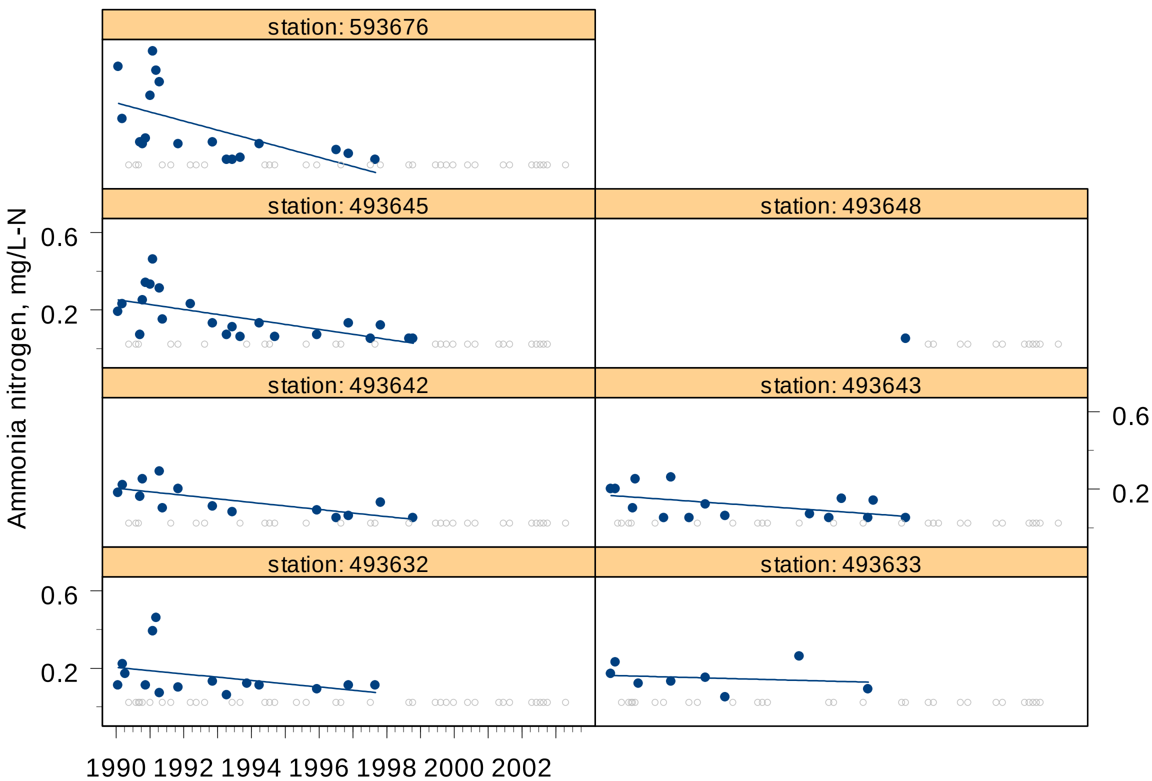
Nutrients

Nutrient data in the database consist of ammonia and dissolved $NO_2^- + NO_3^-$ nitrogen, and dissolved total and total phosphorus. Chlorophyll A data are also examined here. The raw data are shown in Figures 2 - 10 below. The data were analyzed using standard linear least squares to find the overall trend of the raw data, and by the non-parametric seasonal Kendall slope method described by Gilbert (1987), described briefly above. Appendix 1 shows the results of this analysis for all five constituents overall (all stations lumped together) and at individual stations. The analysis was done for samples obtained from near the surface (euphotic zone) and in the hypolimnion, except for Chlorophyll A, for which data were available primarily for the euphotic zone. It should be noted that Appendix 4 of this technical memo provides a description of the box and whisker plots for reference.

Ammonia (Figures 2 and 3). For most stations the ammonia data for surface samples show an overall seasonally adjusted trend of zero, primarily because of the large number of censored observations. Since the non-parametric estimates of the slope are the medians of the data pairs differences, a large number of zero slopes will dominate the overall calculation. More revealing are the results for Fall for which downward trends ranging from 0.008 mg-N/L-yr to 0.02 mg-N/L-yr are seen in six of the eight stations and overall (station 493643 with no trend had six observations for Fall and stations 493648 had none). In the hypolimnion, the overall seasonally adjusted downward trend was 0.012 mg/L-yr. In contrast to the surface samples, the major trends

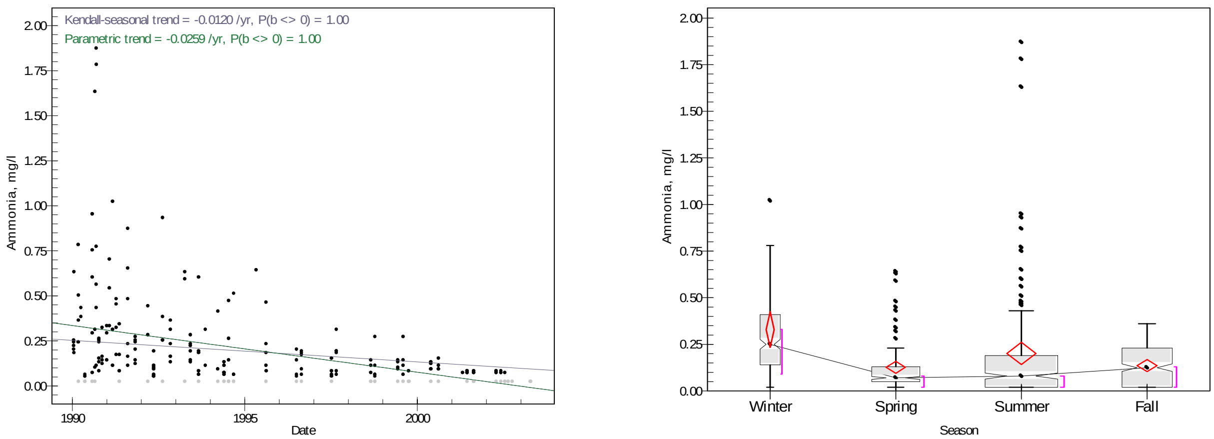


(a)

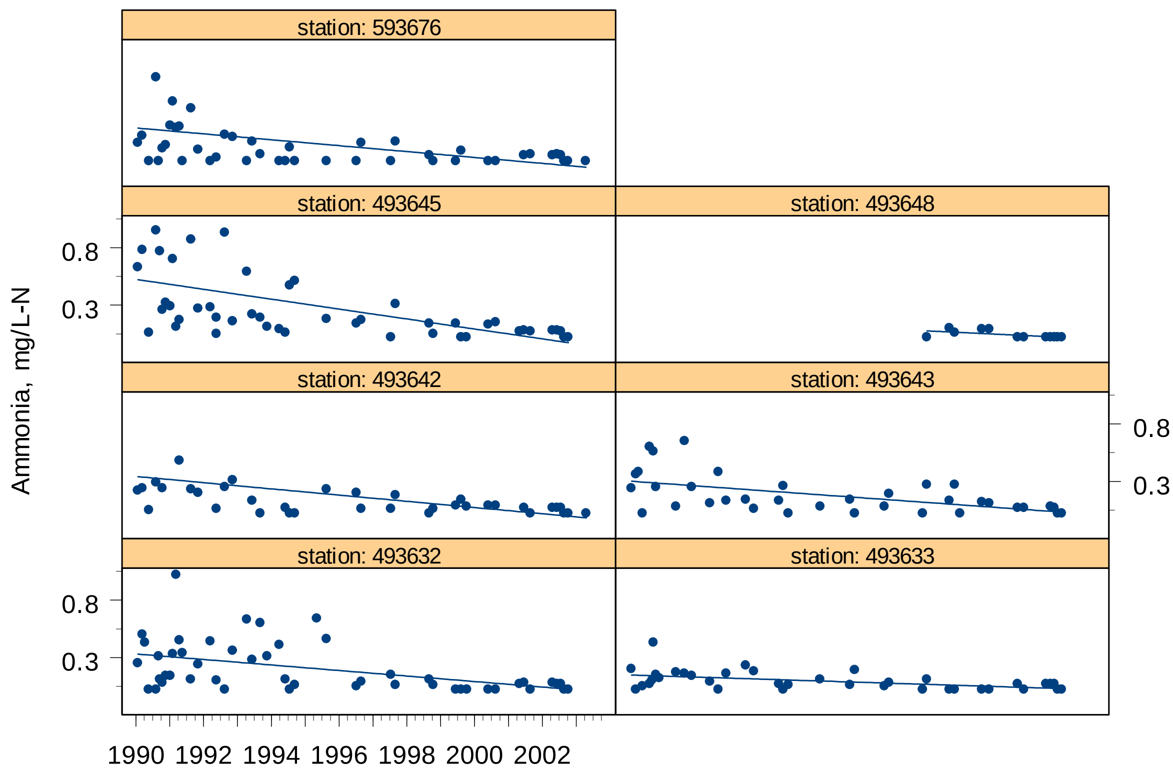


(b)

Figure 2 Surface ammonia data for Strawberry Reservoir, overall with linear regression trend and seasonal box plot (a) and time series by station with linear regression trend (b). Values below the detection limit of 0.02 mg/L are shown as open circles.



(a)



(b)

Figure 3 Hypolimnion ammonia data for Strawberry Reservoir, overall with linear regression trend and seasonal box plot (a) and time series by station with linear regression trend (b)

were seen for Summer data for the hypolimnion, ranging from 0.005 to 0.034 mg-N/L-yr. These results suggest a strong downward trend in the ammonia concentration over time.
As mentioned, the trend calculation for ammonia included a large number of observations marked as below the detection limit (MDL), or censored. In the data from 1990-1998, both uncensored and censored ammonia concentrations were observed. After 1998, all samples were reported as below the detection limit, or censored.

Dissolved NO_2^- + NO_3^- nitrogen (Figures 4 and 5). The seasonally-adjusted trend statistics for dissolved NO_2^- + NO_3^- are found in Appendix 1. In contrast to the ammonia concentrations, although there were a large number of censored observations, the dissolved NO_2^- + NO_3^- nitrogen concentrations showed no significant seasonally adjusted trend in the surface or hypolimnion samples overall or within individual seasons.

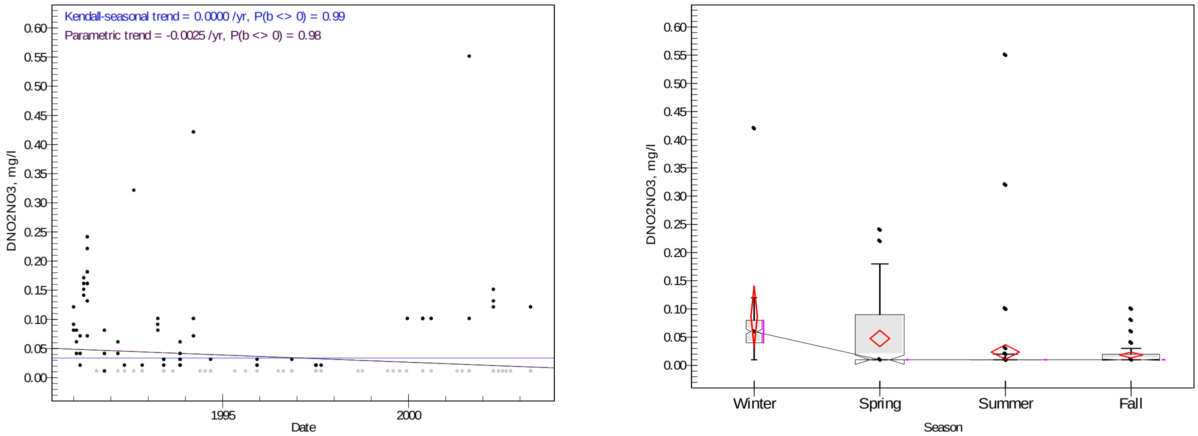
Dissolved total phosphorus (Figures 6 and 7). The seasonally-adjusted trend statistics for dissolved total P are found in Appendix 1. For the surface samples, trend results were mixed with significant trends found in the 1990-2003 data for stations 493632, 493645, and 593676 (spatially scattered throughout the reservoir) but not for remaining stations. In contrast, for the hypolimnetic samples, an overall downward trend of 0.0033 mg P/L-yr (significant at the 99.7% probability level) was found, but downward trends for individual stations were found only for stations 493633, 493645, and 593676, similar to the surface samples.

Total phosphorus (Figures 8 and 9). The seasonally-adjusted trend statistics for total phosphorus are found in Appendix 1. For surface samples, a significant overall downward trend was found in the 1990-2003 data. Some individual stations showed overall downward trends as well, as did all stations for spring and fall. For the hypolimnetic samples, a downward trend of 0.0033 mg P/L-yr (significant at the 99.7% probability level) was found for all stations, and significant trends were found for stations 493633, 493645, and 593676 individually, similar to dissolved total P.

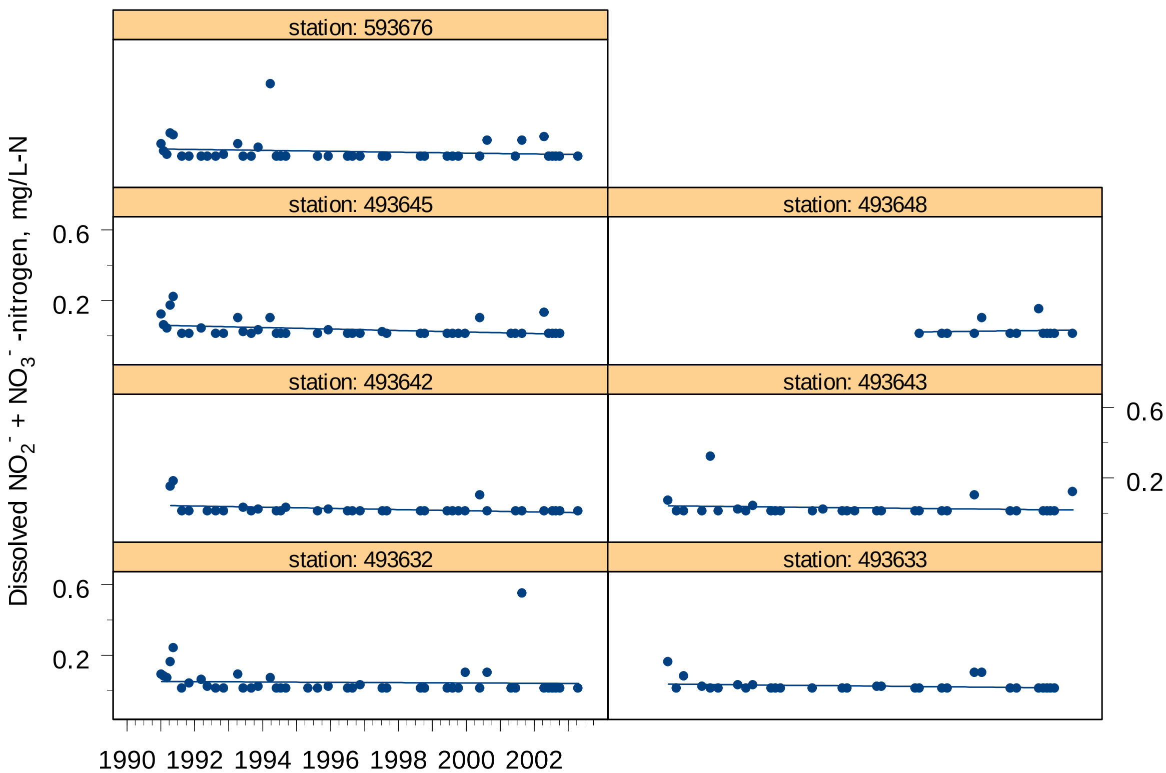
Chlorophyll A (Figure 10). The seasonally-adjusted trend statistics for Chlorophyll A are found in Appendix 1. Chlorophyll A data were primarily collected for surface samples. Significant downward trends were found in the 1990-2003 data for all stations except 493648, with only ten observations, three of which were during the summer. The downward trends are primarily found during the summer season, with significant downward trends found for all stations. A significant downward trend was found for station 593676 individually during the spring as well. No stations or seasons showed upward trends for Chlorophyll A.

Discussion

This analysis shows that the seasonally adjusted trends in all nutrient concentrations and Chlorophyll A within the lake are either decreasing or indistinguishable from zero. The positive skew commonly seen in water quality data at low concentrations and reflected in Figures 2-10, suggest that the trends manifest themselves as reductions in the variability of the data – few high concentrations are seen in the period from 1998 through 2003. This is particularly dramatic in the ammonia data in Figures 2 and 3 and for Chlorophyll A in Figure 10. In **no** cases were **increasing** trends seen for any of the parameters, seasons, or depths. This suggests that nutrient

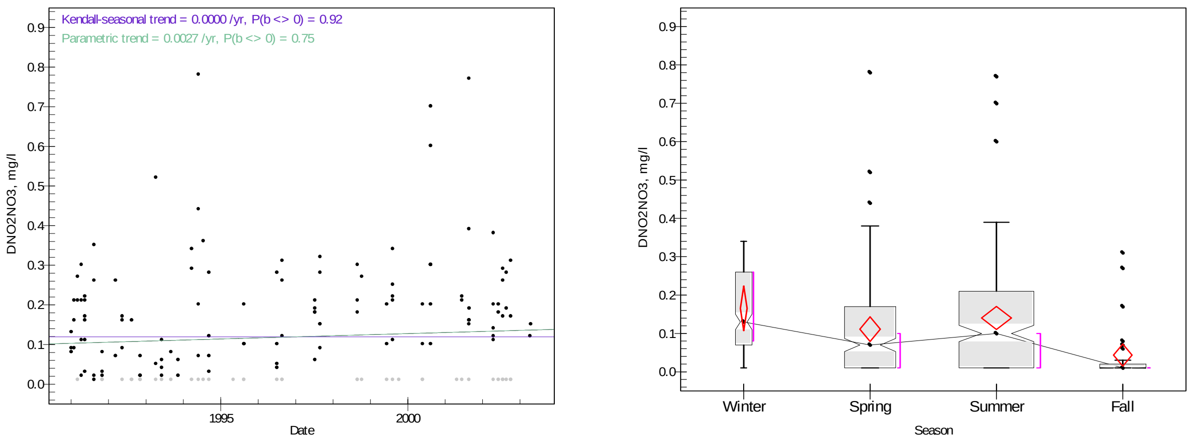


(a)

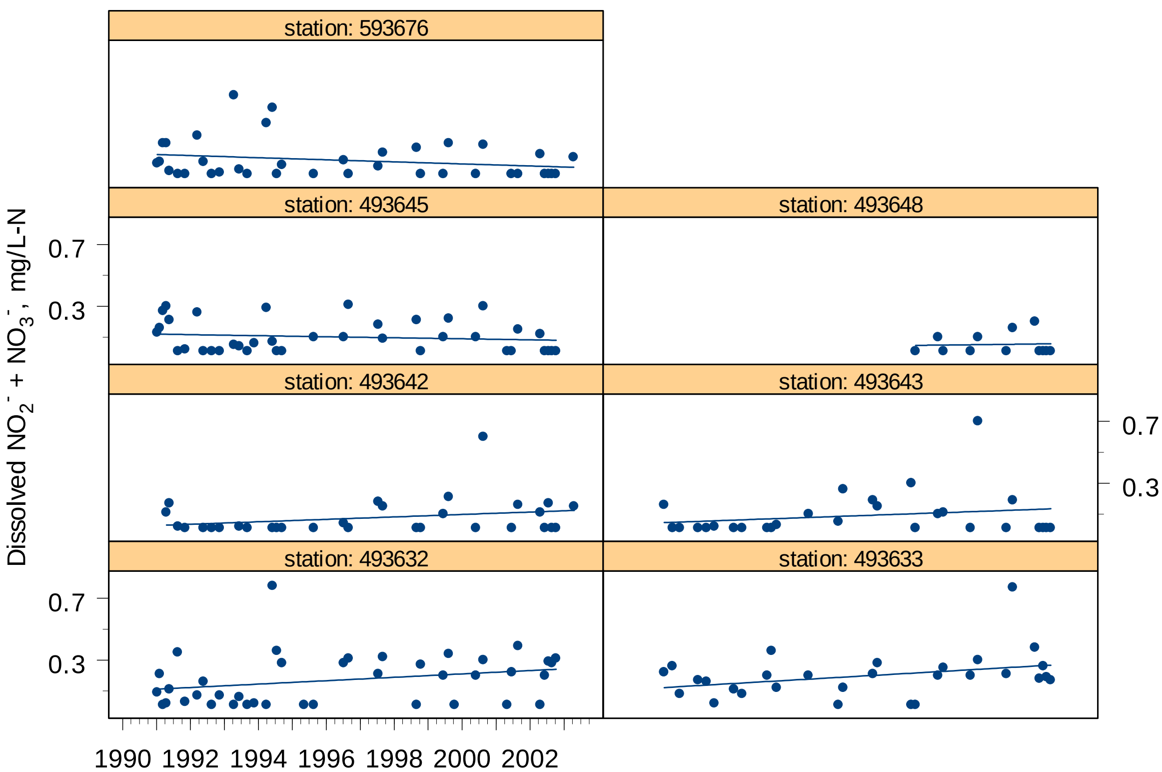


(b)

Figure 4 Surface dissolved nitrite+nitrate data for Strawberry Reservoir, overall with linear regression trend and seasonal box plot (a) and time series by station with linear regression trend (b)

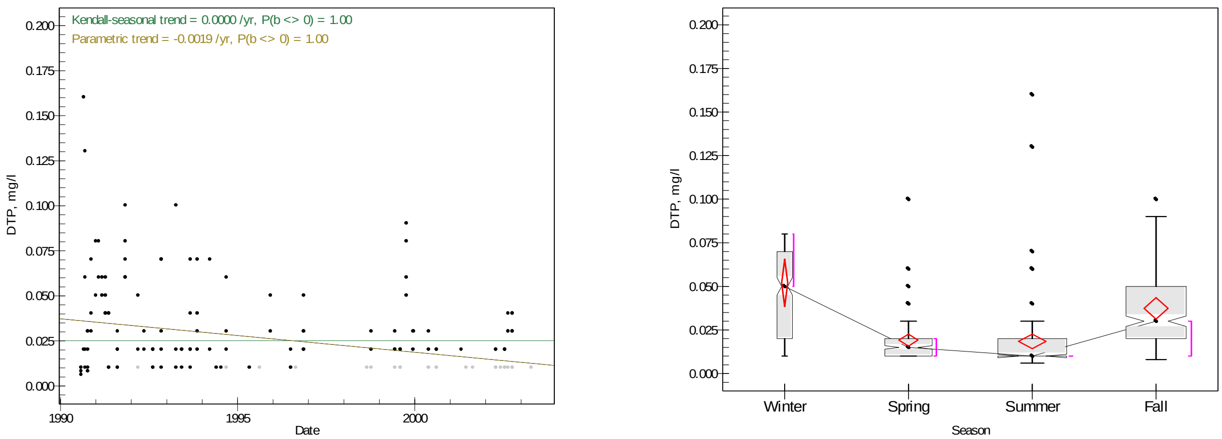


(a)

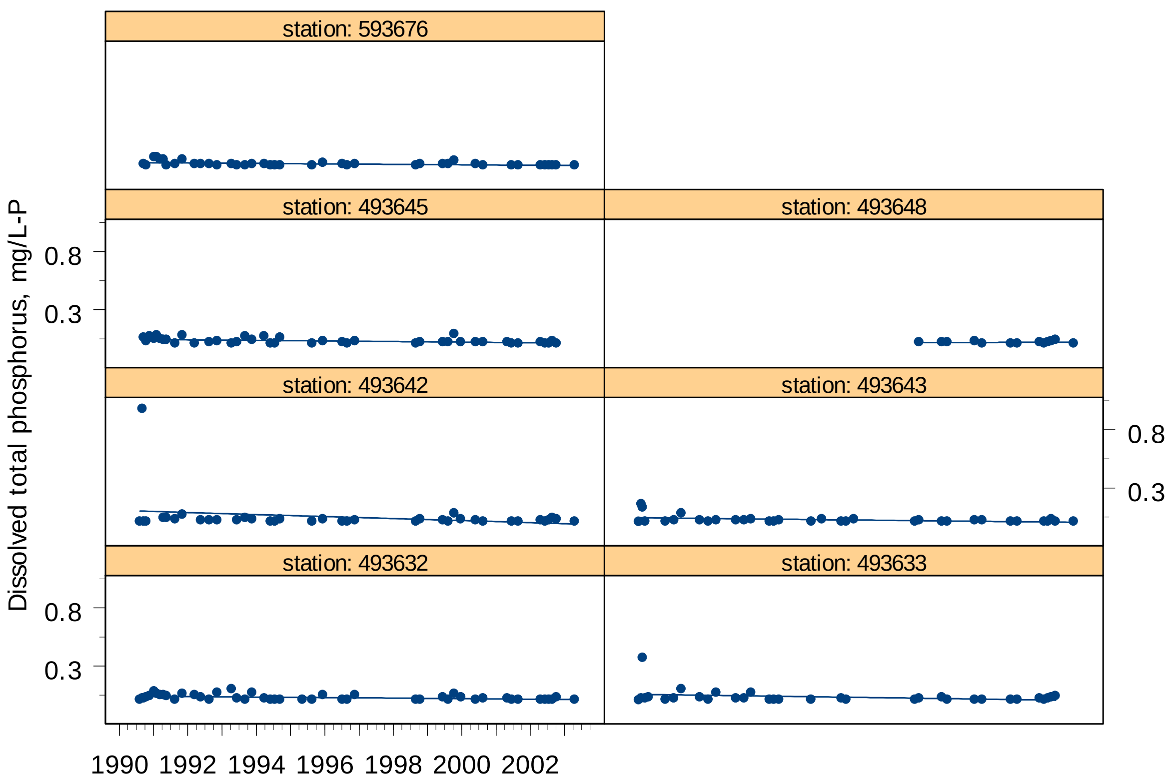


(b)

Figure 5 Hypolimnion dissolved nitrite+nitrate data for Strawberry Reservoir, overall with linear regression trend and seasonal box plot (a) and time series by station with linear regression trend (b)

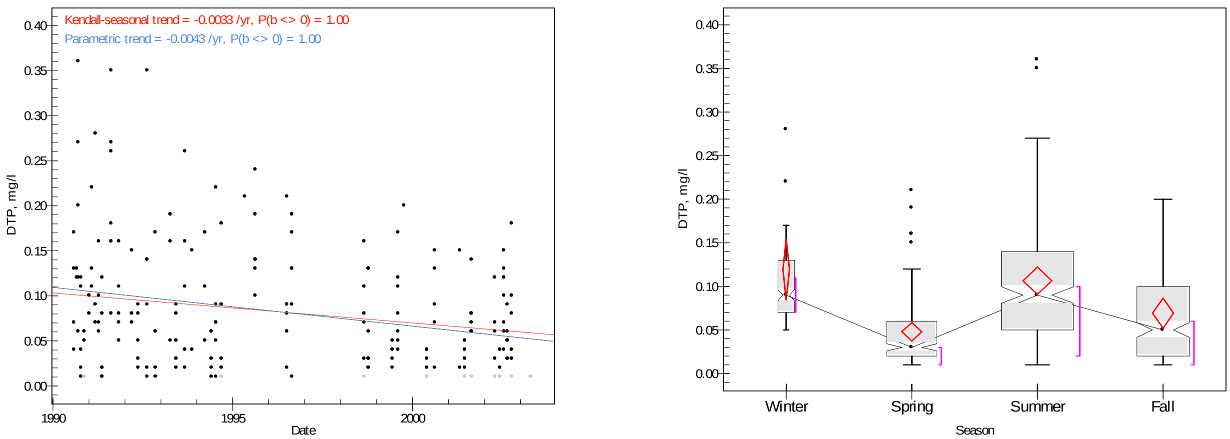


(a)

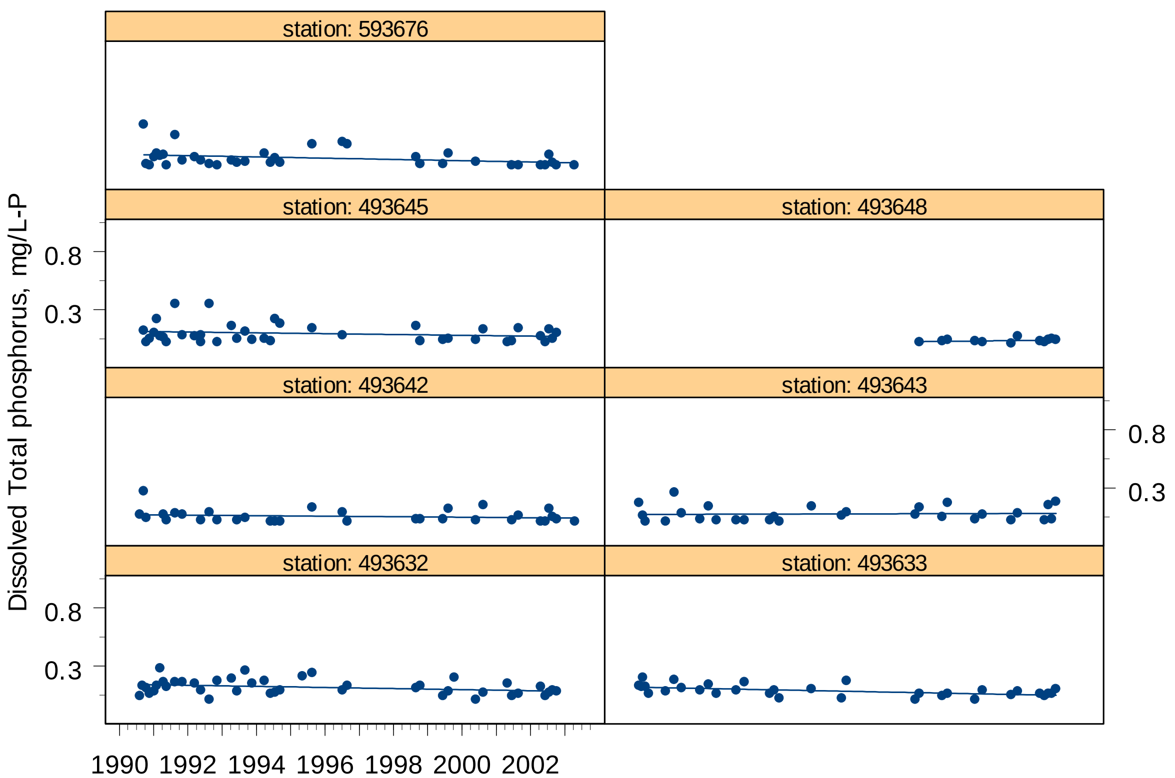


(b)

Figure 6 Surface dissolved total phosphorus data for Strawberry Reservoir, overall with linear regression trend and seasonal box plot (a) and time series by station with linear regression trend (b) (two values > 0.15 were removed for plotting purposes)

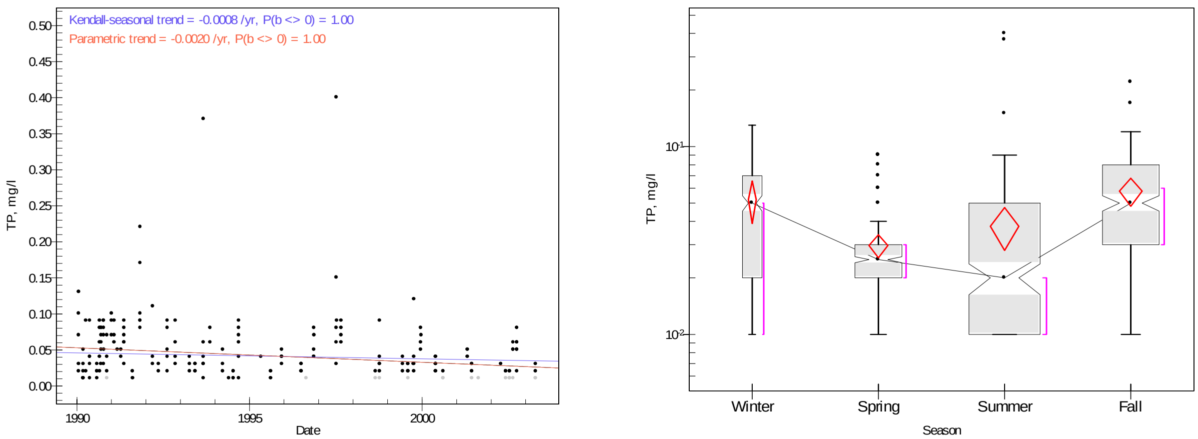


(a)

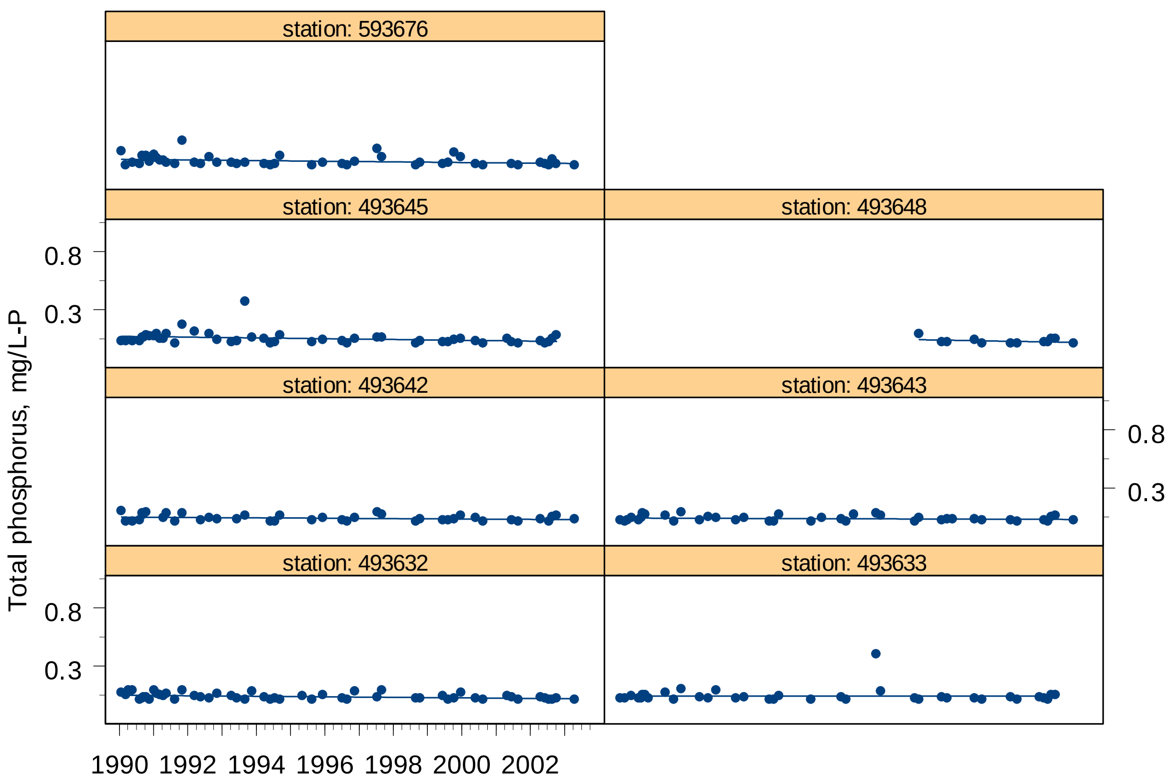


(b)

Figure 7 Hypolimnion dissolved total phosphorus data for Strawberry Reservoir, overall with linear regression trend and seasonal box plot (a) and time series by station with linear regression trend (b)

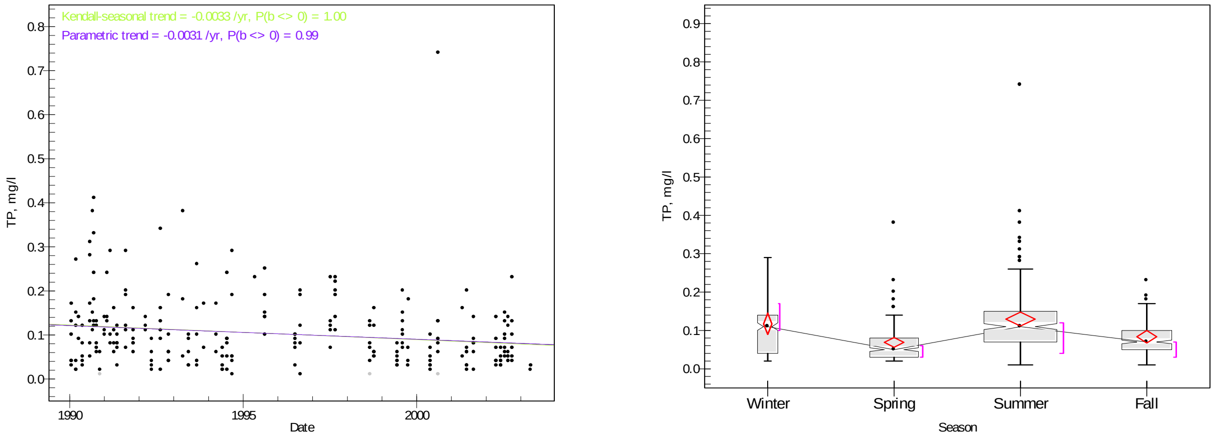


(a)

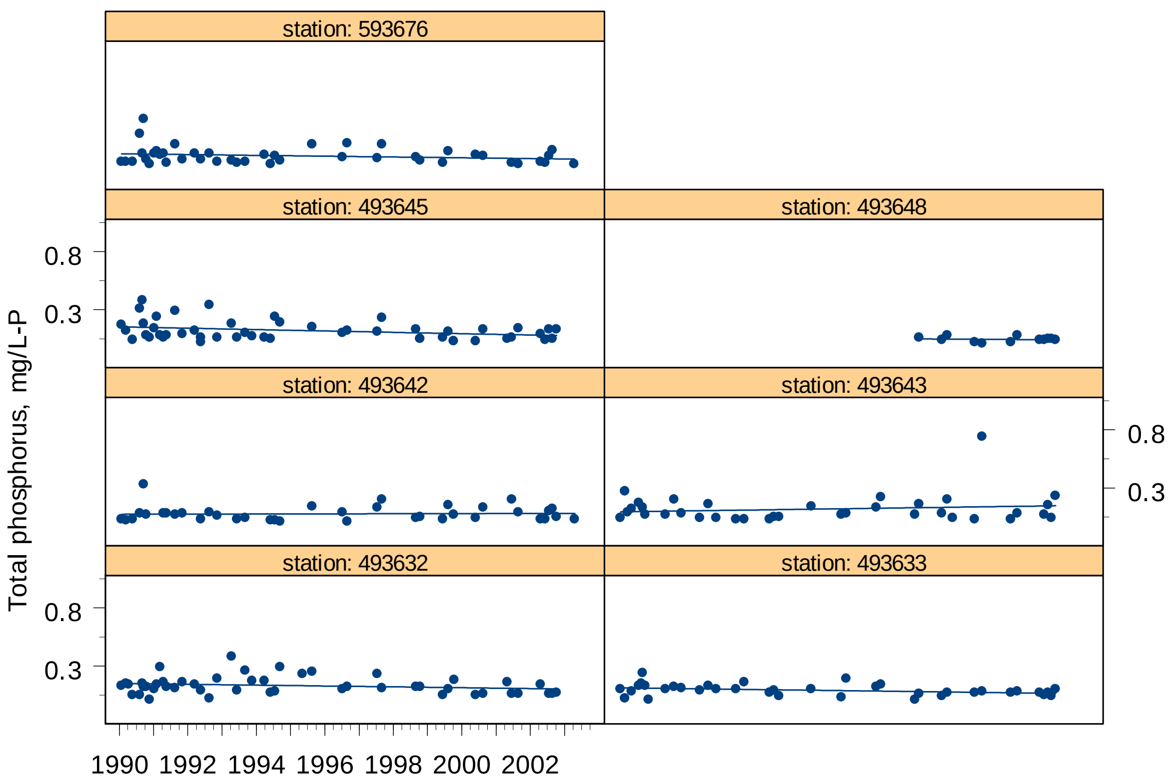


(b)

Figure 8 Surface total phosphorus data for Strawberry Reservoir, overall with linear regression trend and seasonal box plot (a) and time series by station with linear regression trend (b)



(a)

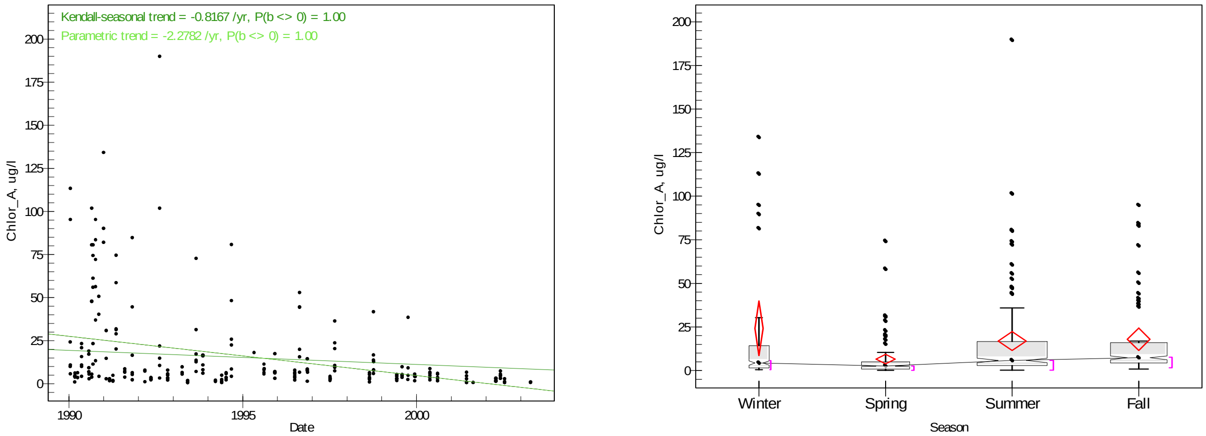


(b)

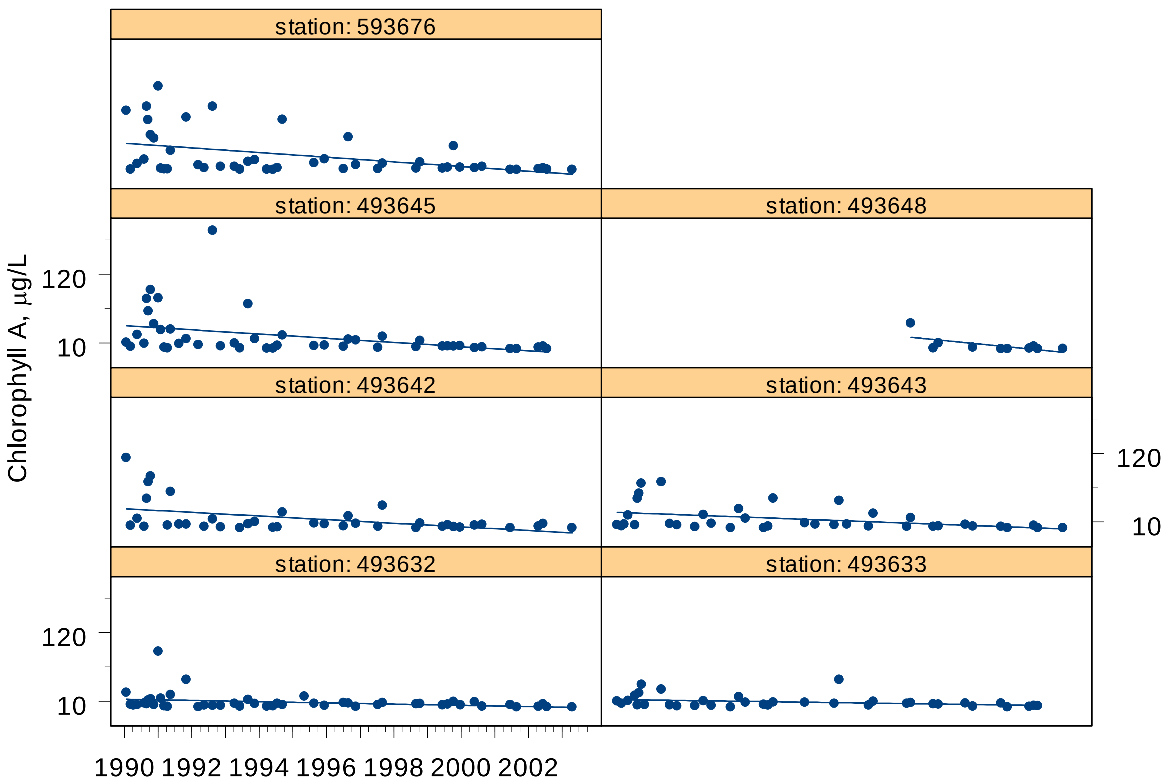
Figure 9 Hypolimnion total phosphorus data for Strawberry Reservoir, overall with linear regression trend and seasonal box plot (a) and time series by station with linear regression trend (b)

Appendix F

Seasonality and Trend Analysis



(a)



(b)

Figure 10 Surface water Chlorophyll A data for Strawberry Reservoir, overall with linear regression trend and seasonal box plot (a) and time series by station with linear regression trend (b) levels in the lake have decreased overall in the period 1990-2003, and that most of the decrease took place in the period from 1990 – 2000.

Although the trends are expressed here as linear decreases in the nutrient concentrations, those concentrations cannot continue to decrease linearly, as negative concentrations would result. First order (exponential) decreases are commonly used for processes that produce results that are inherently positive, such as a concentration. However, because of the large degree of scatter, it is unclear what form a more realistic long-term decreasing pattern would assume and the decay parameter would not be well estimated, and this analysis was not carried out here. The value of the above analysis is to indicate the trends in nutrient levels exist and that they are generally downward. The impact of these trends will be incorporated into the subsequent load reduction recommendations.

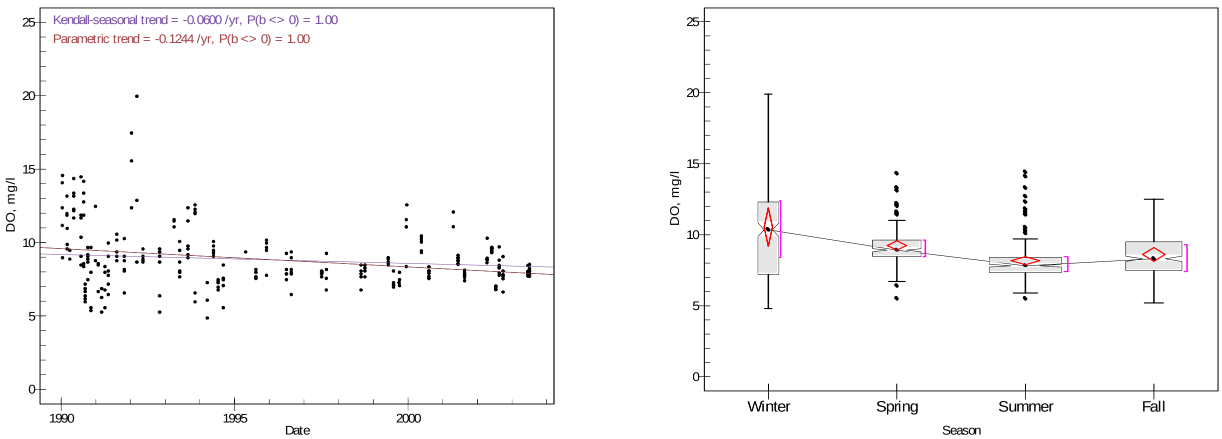
Dissolved oxygen (Figures 11 and 12)

Raw epilimnetic and hypolimnetic dissolved oxygen data were analyzed for trends for the 1990 - 2003 time period. The seasonally-adjusted trend statistics are found in Appendix 2. The raw data are shown in Figure 11 for the euphotic zone for all data and data separated by station. A similar plot is shown in Figure 12 for the hypolimnion.

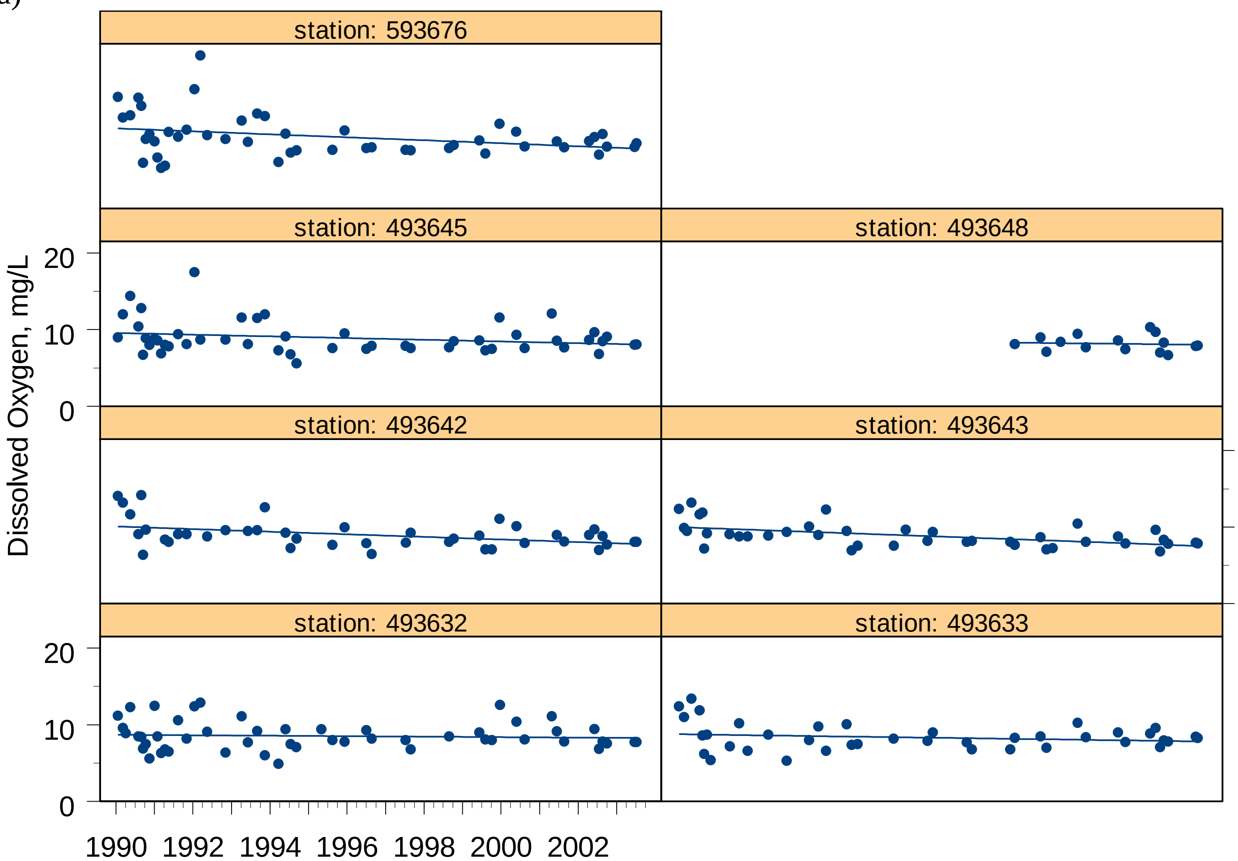
These plots suggest a downward trend in dissolved oxygen. The trend of 0.124 mg/L-yr was found to be significant at with a probability of greater than 99% using standard linear least squares regression. This trend estimate, however, is felt to be an artifact of the monitoring schedule, with more samples taken in the winter during the early portion of the time period and primarily summer samples taken toward the end. Since temperatures are higher in the summer and dissolved oxygen saturation is lower at higher temperatures, a preponderance of summer measurements would lead to a downward trend even if there were no actual change in the dissolved oxygen status in the reservoir.

This hypothesis was tested using the nonparametric seasonally adjusted trend analysis suggested by Gilbert (1987), in which the overall trend is broken down by season. The dissolved oxygen concentration in the surface measurements showed a slight downward trend over time, about 0.06 mg/L-yr, for all data, primarily in the summer for which the trend was 0.067 mg/L-yr. When examined by station, only one station is seen to have a significant trend, 493643, located at the north end of the reservoir (Figure 1), with an overall downward trend of 0.093 mg/L-year. All oxygen concentrations were above 5 mg/L in the surface water, and this trend, though, statistically significant, is not felt to be of practical significance.

For the hypolimnion, where dissolved oxygen is of critical importance, little long term change is seen with the exception of a slight **upward** trend (0.017 mg/L-yr) in dissolved oxygen over all stations, and at two individual stations toward the Soldier Creek dam (493632, 493633, 0.026 and 0.1 mg/L-yr). Though these trends are statistically significant, their values are so small as to have little practical impact, except that they are in the positive direction. Figure 13 shows the time series plots for hypolimnetic dissolved oxygen for stations 493632 and 493633, near Soldier Creek dam. These plots show significantly lower dissolved oxygen concentrations prior to 1997 than for 1997-2003. The higher values in recent years hint at improvements in the hypolimnetic dissolved oxygen. Though no conclusive evidence exists, this slight improvement may be related to the downward trends in phosphorus and Chlorophyll A in the lake (see above) with subsequent reductions in primary productivity. The changes in trophic status of the lake are discussed in more detail below.

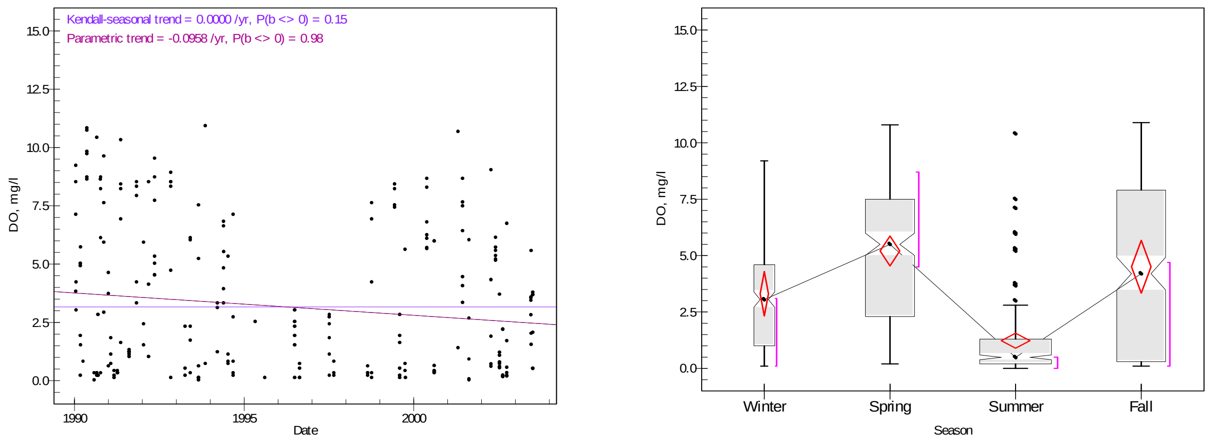


(a)



(b)

Figure 11 Surface dissolved oxygen data for Strawberry Reservoir, overall with linear regression trend and seasonal box plot (a) and time series by station with linear regression trend (b)



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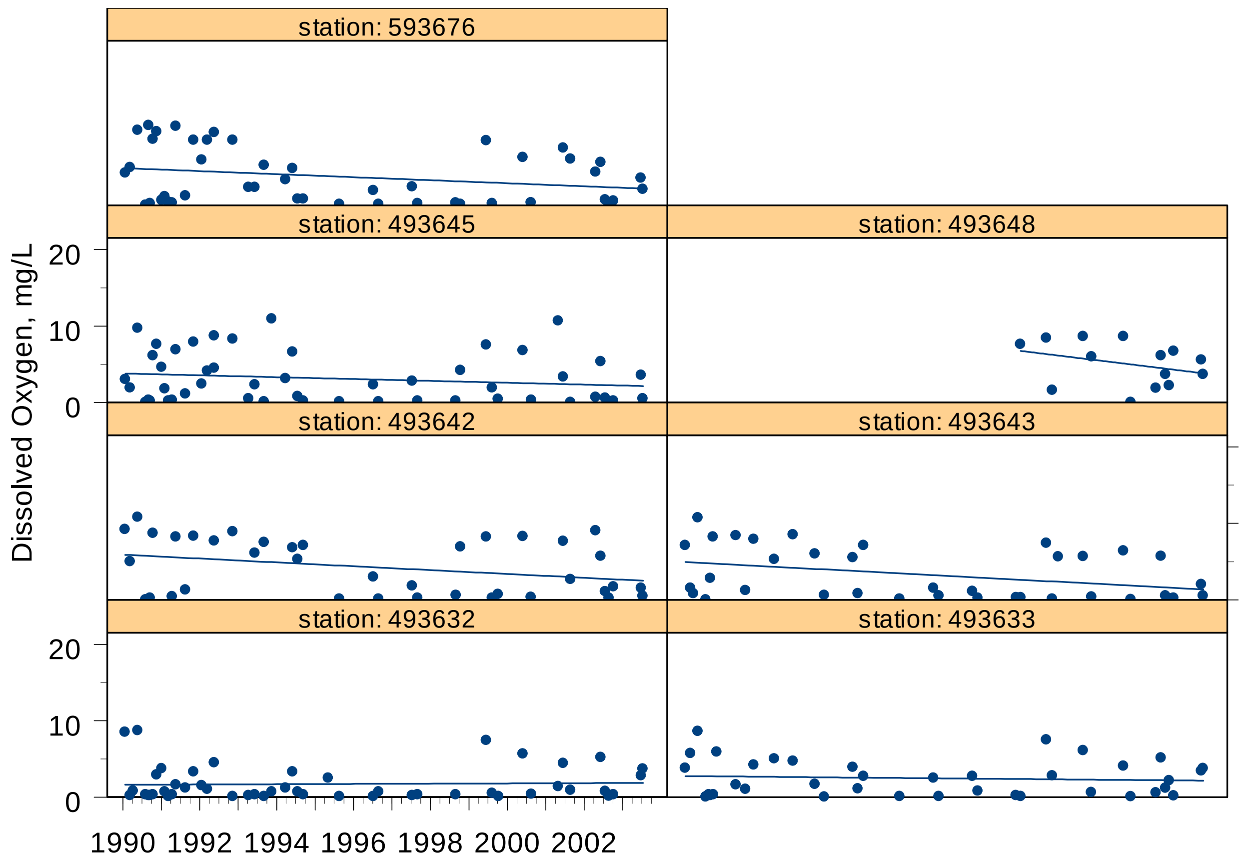
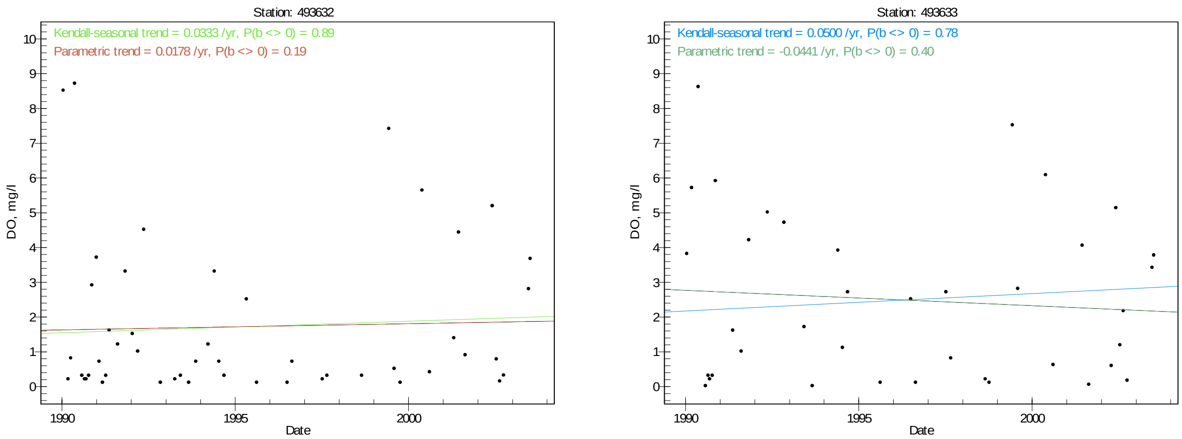
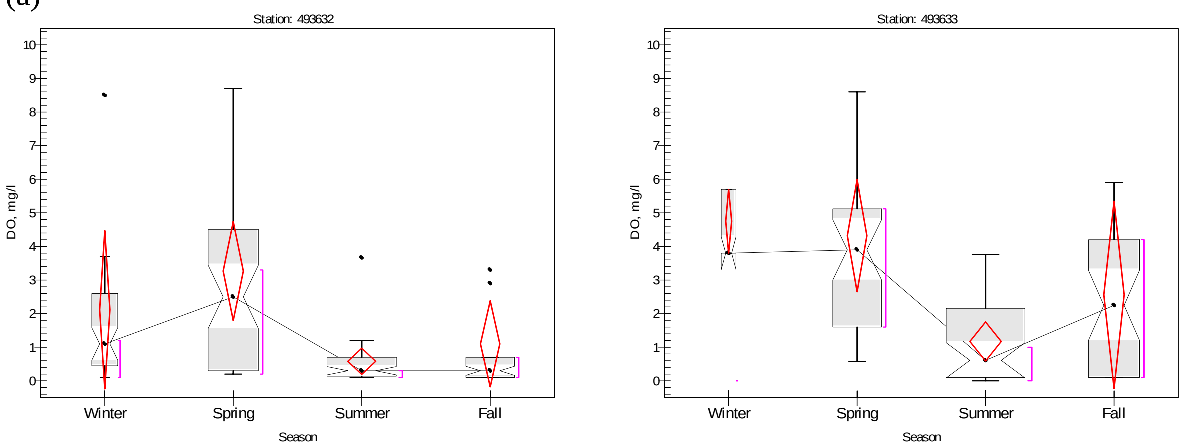


(b)

Figure 12 Hypolimnion dissolved oxygen data for Strawberry Reservoir, overall with linear regression trend and seasonal box plot (a) and time series by station with linear regression trend (b)



(a)



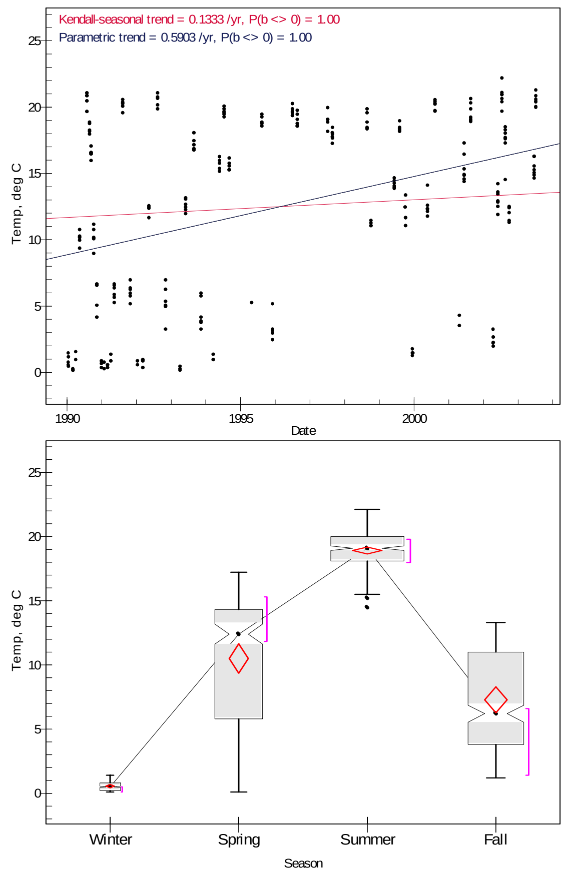
(b)

Figure 13 Time series (a) and seasonal box plots (b) of hypolimnetic dissolved oxygen, Stations 493632 and 493633, 1990-2003

We note that there are important differences in the trends estimated by standard linear regression and for the non-parametric Kendall seasonal-adjusted method. In particular, the hypolimnetic dissolved oxygen shows a **downward** trend using the ‘standard’ method, and a slight **upward** trend using the Kendall method. As discussed, these differences are primarily due to the sampling schedule for dissolved oxygen, with a preponderance of summer measurements (low DO) in later year. The importance of seasonal adjustment for seasonally-varying data cannot be overstated.

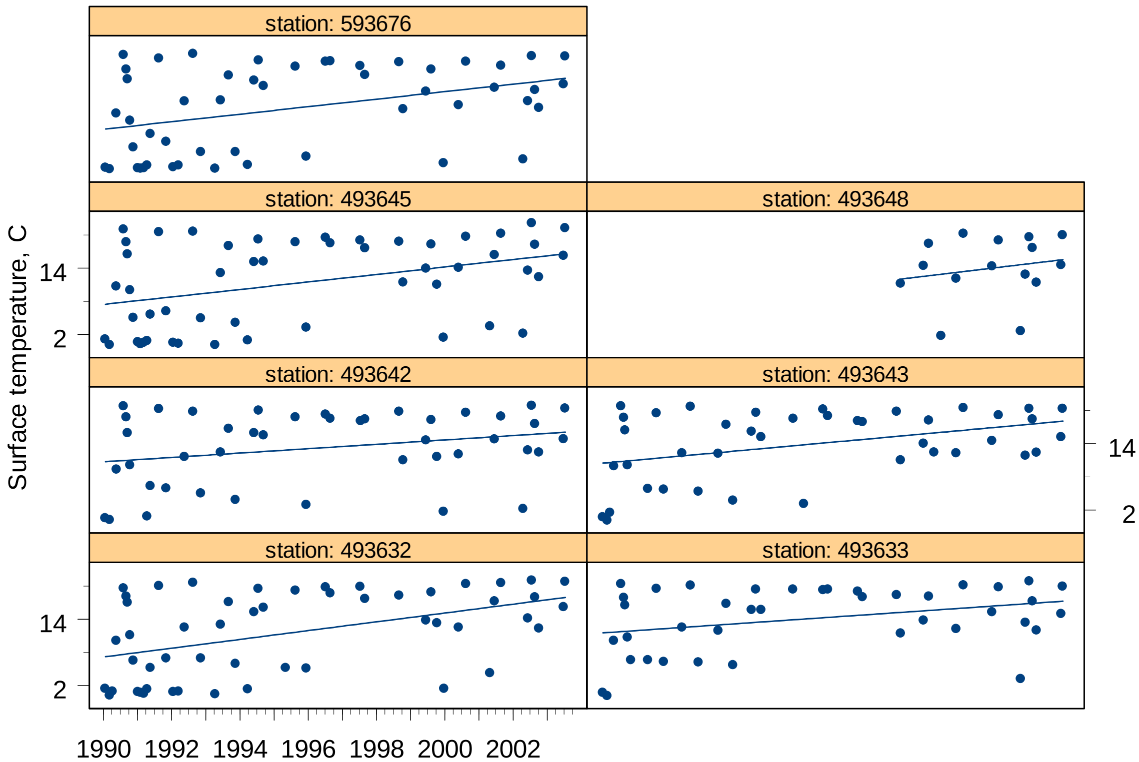
Temperature (Figures 14 and 15)

Raw surface water temperature data are shown in Figure 14 a) for all stations, and b) for individual stations. Although there appear to be upward trends in the temperature from 1990-2003, these trends are felt to be artifacts of the times of year during which the measurements were obtained, with most observations taken in the summer after 1992. The seasonally adjusted trend was estimated using the Kendall Seasonal Trend analysis described in Gilbert (1987). The seasonally adjusted slopes by station for the surface temperature are provided in Appendix 3. Trends that are statistically different from zero are in bold in the tables found there. The primary observation from these results is that for all data lumped together (292 observations), there is no trend overall. However, significant positive trends are found in the winter, spring, and summer temperatures, but for most individual stations (50 or fewer observations) there is no trend in the seasonally adjusted temperature. Trends in the hypolimnetic temperature are opposite those in the surface water – generally downward, particularly for those stations in the northern portion of the reservoir.

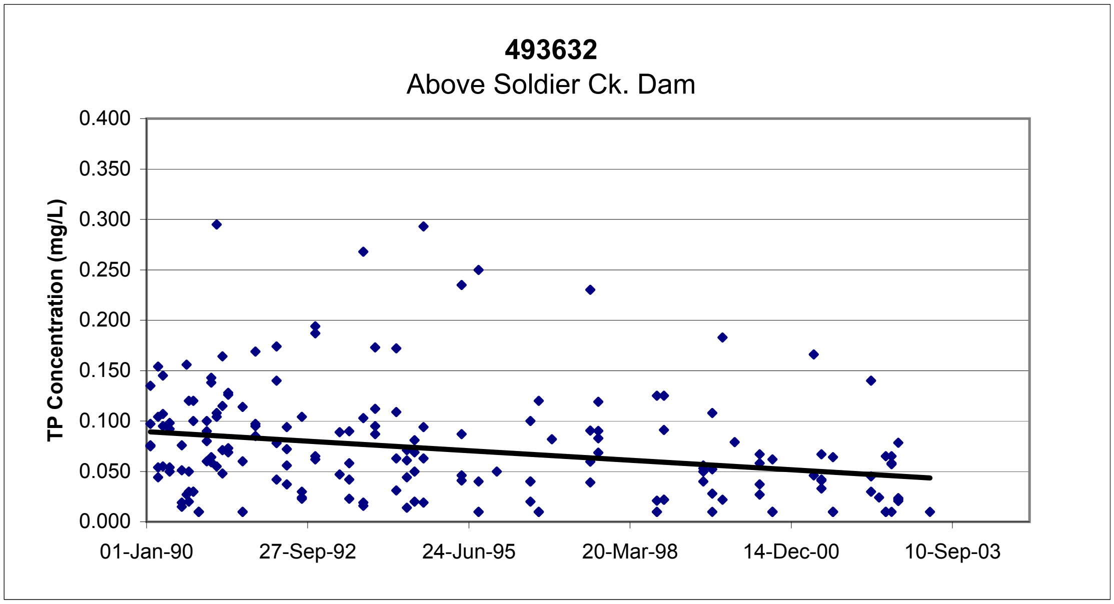


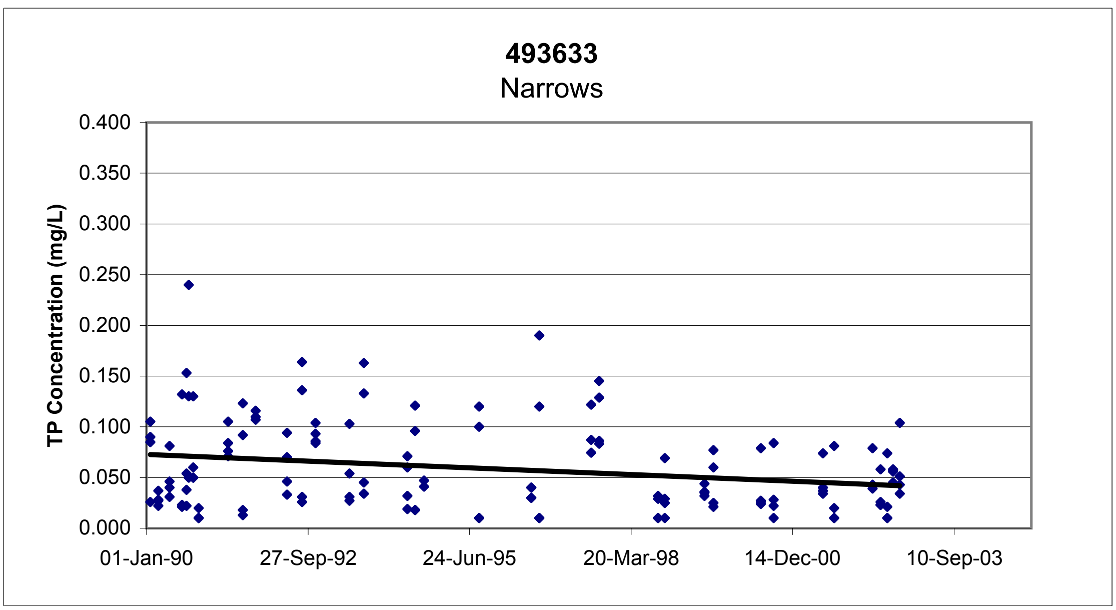
Kendall-seasonal trend = 0.1333 /yr, P(b <> 0) = 1.00
Parametric trend = 0.5903 /yr, P(b <> 0) = 1.00
Temp, deg C
Date
Temp, deg C
Winter
Spring
Summer
Fall
Season

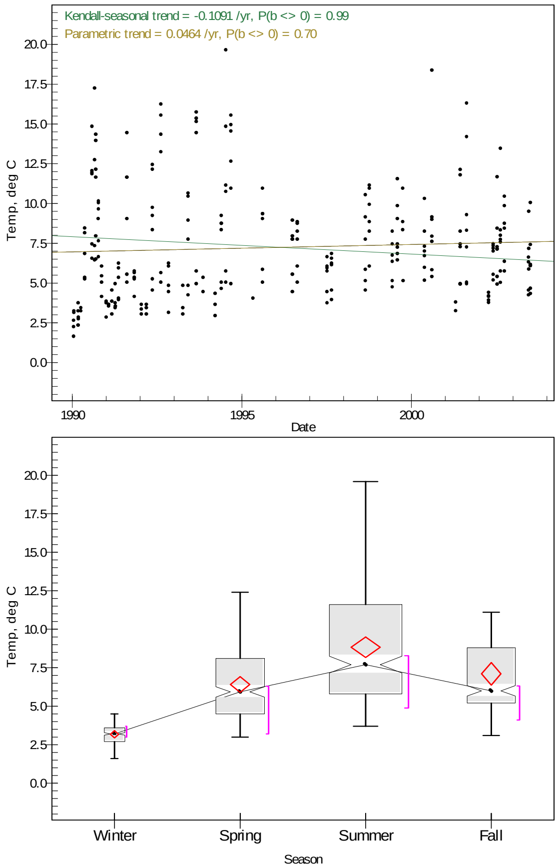
(a)



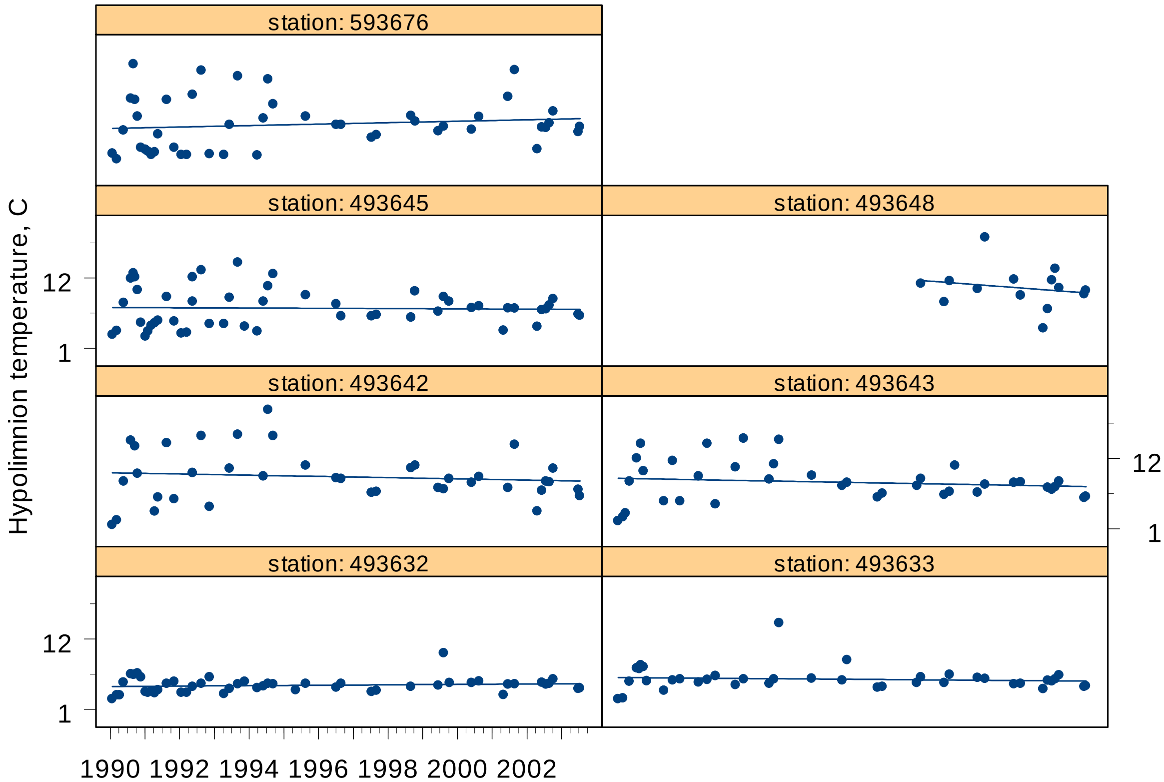
(b)
Figure 14 Surface water temperature data for Strawberry Reservoir, overall with linear regression trend and seasonal box plot (a) and time series by station with linear regression trend (b)


493632
Above Soldier Ck. Dam
TP Concentration (mg/L)
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
01-Jan-90
27-Sep-92
24-Jun-95
20-Mar-98
14-Dec-00
10-Sep-03


493633
Narrows
TP Concentration (mg/L)
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
01-Jan-90
27-Sep-92
24-Jun-95
20-Mar-98
14-Dec-00
10-Sep-03


Kendall-seasonal trend = -0.1091 /yr, P(b <> 0) = 0.99
Parametric trend = 0.0464 /yr, P(b <> 0) = 0.70
Temp, deg C
Date
Temp, deg C
Winter
Spring
Summer
Fall
Season

(a)



(b)

Figure 15 Hypolimnion temperature data for Strawberry Reservoir, overall with linear regression trend and seasonal box plot (a) and time series by station with linear regression trend (b)

Appendix G

Public Comments Received

Response To Comments

Received From: US Forest Service, Uinta National Forest
Received On: April 5, 2005

Comment Heading	Response To Comment
Short-Term Water Quality Impacts for Long-Term Improvement	In TMDL document, we reference previously completed studies, which include recommendations, conclusions, goals, and implementation plans. Responsibilities and issues for implementing specific BMPs within the watershed are contained within the referenced documents. We have also added a statement to this effect in Section 6.1.1 in reference to the BMPs listed in Table 6-1.
Sheet Flow to Reservoir	Areas within the watershed have been referred to as "sheet flow" if they are not part of a concentrated drainage. Such watershed areas may or may not have runoff that would typically be characterized as "sheet" flow, but simply are not included the other drainages. With respect to the loading rates associated with such areas, we concur that loading rates are likely lower, however, insufficient data exist to validate such an assumption. Assuming that the higher loading rate also applies to these areas is conservative, resulting in greater protection of the reservoir.
Co-op Creek	In TMDL document, we reference previously completed studies, which include recommendations, conclusions, goals, and implementation plans. The 2004 Forest Service Strawberry Watershed Restoration Report is specifically referenced, which contains these recommendations for Co-op Creek.
Load Allocations	The table and discussion in the report that

Comment Heading	Response To Comment
	covers load reductions has been revised to reflect your concerns. Small load reductions have been identified for those tributaries that have exhibited elevated phosphorus concentrations. Load reductions have not been identified for tributaries that are below the indicator value for phosphorus.
The Ladders	The table and discussion in the report that deals with load reductions has been revised to reflect your concerns. Load reductions have not been identified for tributaries that are below the indicator value for phosphorus.
Stream Recommendations and Watershed BMPs.	The "Livestock Forage Restrictions" section has been modified to be consistent with the 2003 Forest Plan.

United States Department of Agriculture **Forest Service** **Uinta National Forest** **88 West 100 North P.O. Box 1428 Provo, Utah 84603 801 342-5100**

File Code: 2530-3
Date: April 5, 2005

Mr. Carl Adams
Utah Department of Environmental Quality
Division of Water Quality
P.O. Box 144870
288 North 1460 West
Salt Lake City, UT 84114-4870

Dear Mr. Adams:

My staff enjoyed meeting with you and Amy Schmitt on March 29, 2005, to discuss the Draft Strawberry Reservoir TMDL document. We appreciate the spirit of cooperation you displayed at that meeting, and look forward to working with you and your staff in our ongoing efforts to improve and/or protect water quality in water bodies, including Strawberry Reservoir, on the Uinta National Forest. This letter serves as a follow-up to the March 29th Strawberry Reservoir TMDL meeting. As discussed in the meeting, we strongly support efforts to improve water quality in Strawberry Reservoir, but also have some concerns regarding the Draft TMDL. These concerns are discussed below.

<u>Short-Term Water Quality Impacts for Long-Term Improvement</u>
The Forest would like to see some explanation of the application of the TMDLs, and responsibilities of the land owners/managers and water users in enacting the TMDL. At the March 29th meeting, you indicated that the TMDL process is a long-term commitment and that in order to improve long-term water quality, some projects may involve short-term negative impacts. We feel this is important, and should be clearly stated in the TMDL documentation.

<u>Sheet Flow to Reservoir</u>
Sheet flow derived Total Phosphorous (TP) and Total Suspended Solids (TSS) loads were estimated using correlation of watershed area and loading from April through September in years 1982 through 1991 for STORET sites on Strawberry, Coop, Clyde, Trout, and Indian Creeks. We have concerns that the data represented by these STORET sites do not reflect conditions found on most of the "sheet flow" lands. Average elevations for the "sheet flow" areas are substantially lower than those used to correlate land area, and land management/use activities that may influence TP and TSS also differ considerably.

The Forest would recommend re-analyzing TP yields in the "sheet flow" lands. The method for calculating annual TP yield may be skewed through not accounting for lower average elevation and precipitation of the "sheet flow" areas, generally consisting of valley bottom slopes and low relief drainages. The water yield of approximately 21,000 acre-feet/year from this land is suspect due to the correlations based on watersheds with higher precipitation and much larger watershed area. In addition, much of the "sheet flow area" is comprised of Strawberry Project lands, lands which have not been grazed in over a decade and lands with limited areas of disturbance. Due to the factors discussed above, we are somewhat concerned that the TP and TSS levels estimated for these lands may be higher than actual, and therefore, TMDLs based on these projections may be impractical or impossible to ever reach.

A "sheet flow area" map would also be helpful showing the lands adjacent to the Reservoir that contribute sheet flow TP and a summary table showing acres.

Co-op Creek

Although quite a bit of restoration/rehabilitation work has been completed in this watershed in the past, Co-op Creek still exhibits some of the highest concentrations of TP and bank erosion in the valley. We recognize that Co-op Creek has relatively small flows, and that this Creek only contributes approximately 6% of reservoir phosphorous concentrations, but feel the TMDL report should recognize this drainage has the potential and need for substantial improvement. In 2004, the USDA Strawberry Watershed Restoration Report lists this watershed as the second highest potential for riparian restoration within the Strawberry watershed. Opportunities to reduce erosion/ sedimentation exist in the form of restoration of riparian vegetation, stream stabilization, and slope stabilization /vegetation establishment within the gorge.

Load Allocations

Load allocations and associated reductions are listed in Table 5-2 on page 87 of the Draft TMDL report. All streams on the Forest are slated for a 10% reduction regardless of their input into the system. The Forest strongly feels that reductions should be based on actual TP concentrations that are above an estimated background level. Using this method will focus land management and implementation of Best Management Practices (BMPs) for reductions on watersheds contributing excess TP and TSS, and not "penalize" watersheds and uses/users of those watersheds that are supporting beneficial uses and meeting state standards (e.g., Indian Creek). The Draft TMDL report is inconsistent in this matter. As discussed below, the Ladders is exempted from reductions because its water quality meets state standards, but Indian Creek is not. As we agreed during the meeting, limits for all load sources are needed to ensure that future management practices do not increase TP and TSS in these areas as well.

The Ladders

The Ladders (Sections 1.3.10, 4.3.1 and 5.4 -- Draft report pages 5, 70 and 88), is the largest contributor of TP at 4,100 lbs/year, but does not have a reduction in the Draft TMDL report. Although the Draft report does state the Ladders has an average TP concentration of 0.02 mg/L, the water inflow (approximately 45% of reservoir volume) does make a significant addition of TP to the Reservoir. Because the Ladders accounts for 27% of the TP input into the Reservoir, the study should include or consider reductions of TP levels from this source. An investigation into where the Phosphorus originates would help determine if reductions could be made. In any case, this pollutant source should be treated similar to other tributaries with "good" water quality (see discussion above).

Stream Recommendations and Watershed BMPs.
Livestock Forage Restrictions lists BMP descriptions under two different bullets as "not to exceed...." based on 30 percent slopes (page 6, Table 1-4). These BMPs are not consistent with the Uinta National Forest 2003 Forest Plan (2003 LRMP). The Description for Livestock and Forage Restrictions should either reference or summarize the standards and guidelines used in the 2003 Forest Plan. The National Forest Management Act requires that livestock grazing on the Forest be conducted in a manner that is consistent with the Forest Plan. The standards and guidelines in the Forest Plan were general measures designed to achieve a variety of resource objectives including those pertaining to wildlife habitat, soil productivity, water quality and plant community. Since the focus of the TMDL report is on water quality, some of the utilization standards may not be directly pertinent to this issue. Those most directly pertaining to water quality include: S&W-3 and S&W-4 (2003 LRMP, pages 3-8 to 3-9), Graze-1 (page 3-25), and Graze-5 through Graze-12 (page 3-27).

The Uinta National Forest is committed to working with your agency and others in continuing to improve water quality in the Strawberry River Basin. If you have any further questions or concerns, please contact Jeremy Jarnecke at 801-342-5110.

Sincerely,

Peter W. Karp

PETER W. KARP
Forest Supervisor

cc: Julie K King, William Ott, Pam Gardner, Reese Pope, Robert A Davidson, Jeremy Jarnecke