McDowell Dam Lake Management and Hypolimentic Discharge System Operation Agreement

Background:

This Agreement is between the Burleigh County Water Resource District (District) and the North Dakota State Game and Fish Department (Department).

The McDowell Dam Recreation Area was constructed for recreation purposes. It was designed by the Natural Resources Conservation Service with the Burleigh County Water Resource District acting as the local sponsor. The dam creates roughly a 56.5 acre reservoir and has a principal spillway structure that contains a low level drawdown or Hypolimentic Discharge System (HDS). This system consists of a passive low water conservation port, and a 16" asbestos concrete low water removal line with a slide gate within the principal spillway drop inlet.

The Department historically has stocked fish in the reservoir to maintain and enhance its fishery. The HDS is designed to help in maintaining water quality and the fishery within the reservoir; however, it has not been actively operated due to the small upstream watershed and limited inflows to the reservoir. The passive low level drawdown has been rendered inoperable via the closure of the conservation port and installation of flashboards to increase reservoir elevations in an attempt to maintain reservoir levels during low runoff periods.

The District supports the discharge of poorer quality water from the bottom of the reservoir, during those periods when the dam is actively spilling and when waters can be released without the potential for adversely impacts to reservoir levels. This opportunity typically occurs during the spring runoff season, though occasionally after heavy rainfall events. This agreement is intended to formally define an approach to coordinate and manage these beneficial releases.

General Intent:

The general intent of this agreement is to provide the Department the authority to operate the HDS while ensuring adequate coordination with the District and other agencies. It also defines the conditions whereby releases from the HDS can occur without adverse impacts on reservoir levels. There is value associated with these releases in the ability to maintain and/or improve water quality within the reservoir.

Releases through the HDS may only occur during those periods when water is actively spilling, and releases may not be greater than the flows that would otherwise be spilling over the principal spillway outlet. Releases through the HDS during no flow periods require formal approval by the District. These are anticipated to occur during the late summer and late winter stratification periods of each year and require consideration of the risks associated with the reduction in water levels within the reservoir that may or may not be recovered the following spring. The District is pursing the importation of water from Apple Creek to supplement runoff into the reservoir. The implementation of this project will provide increased flexibility in operating the HDS.

POINTS OF AGREEMENT:

The District and Department hereby agree to the following:

- The Department will notify the District when releases from the HDS are being considered and provide a projection as to when such releases are anticipated to commence, for what duration, and the anticipated amount of the release.

- The District may open the HDS, at its discretion, when the reservoir is at or above its full service (top of flashboards) and waters are actively spilling over the principal spillway. The District will consult with the Department prior to releases to obtain information related to water stratification within the reservoir.

- The Department may operate the HDS during periods when they feel it is beneficial to reservoir water quality, however at no time shall water levels be lowered below the top of the gate well or elevation 1725 (NGVD 1929 Datum), which is also the elevation as the concrete weir level at the bottom of the flashboards. Spring releases may occur below this level only after consultation with the District and there is justification for spring inflows to refill the reservoir.

- The Department will coordinate releases with the North Dakota Department of Health and provide any applicable notices and complete any water quality testing that may be required.

- The Department will monitor downstream conditions on both the unnamed tributary downstream of the embankment as well as on Apple Creek.

- The Department will keep records of all gate manipulations and the corresponding periods of release and provide such records to the District, upon completion of each release, to document the actions taken and waters released.

- The Department will cease all releases upon order of the District or the North Dakota Department of Health. Such order can be in the form of a phone call, email or letter.

- The District will provide access to the locked gate. Assistance may be provided through the Bismarck Parks and Recreation District, who is under contract to manage the recreation area.

- The District or their technical representative shall assist the Department in determining the quantity of water released based on the records.

- This agreement will commence on October 1, 2011 or the date at which this agreement is signed, whichever comes later, and shall remain in effect until September 30, 2016.

1. **Embankment and Dam Safety:** The District will retain authority and responsibility over the dam itself, including management of water quality, water quantity and dam safety concerns.

2. **Relationship of Parties:** This agreement shall not be construed to create any form of any employment relationship between the District and the Department, or any person designated by the Department under the provisions of this agreement. It is the intention of the parties hereto to maintain separate and distinct organizations, and the Department through its designated employees shall at all times be acting as an independent contractor in providing services to and

for the benefit of the McDowell Dam recreational facility. The Department shall be responsible to control and supervise all of its employees and to pay compensation to or for the employees of all wages, salaries, taxes, withholding payments, fees, as well as other benefits or compensation to any pension or retirement plans. The Department shall not claim that the District is responsible for the payment of any of the foregoing payments, withholdings, contributions, or taxes in relationship to its designated employees.

Further, it is understood that this management relationship is between the District and the Department has no other responsibility to report management duties or operations, including budget and capital projects, or represent on behalf of the District unless so approved by the District or agreed to by the Department.

3. **Severability.** The unenforceability or invalidity of any provision of this contract shall not render any other provisions of this contract unenforceable or invalid.

4. **Governing Law.** This contract is to be governed by and construed according to the North Dakota Century Code and local and federal laws.

5. **Insurance**. The District and Department each shall secure and keep in force during the term of this agreement, commercial general liability for its operations. In addition, the Department shall require all subcontractors to secure and keep in force during the term of this agreement commercial general liability coverage.

6. **Indemnification and Hold Harmless**. Each party to this agreement shall be responsible for the claims, losses, damages and expenses, which may arise out of the negligent or wrongful acts or omissions of that party or that party's agents, employees, or representatives acting in the scope of their duties in this contract. Each party to this agreement agrees to inform the other in the event such party is notified of an investigation or claim arising out of the services of managing the McDowell Dam recreational facility under the terms and conditions of this contract and shall provide reasonable access to the information involving such investigation or claim. Each party shall further notify the other party of the disposition of any such investigation or claim.

7. **Attorney's Fees and Costs**. Each party shall pay its own attorney's fees and costs.

IN WITNESS WHEREOF, the parties have executed this contract as of the day, month and year written above, and each party hereby acknowledges that it has the full right and authority to enter into this contract and bind the respective party to the terms stated herein.

AGREED:

____________________________	____________________________
Gailen Narum, Chairman Burleigh County Water Resource District	Paul Bailey North Dakota Game and Fish Department
____________________________	____________________________
Date	Date

PROTOCOL AND GUIDELINES FOR:
CONSTRUCTING AND OPERATING HYPOLIMNETIC (LOW LEVEL OR BOTTOM WATER) DISCHARGE STRUCTURES IN NORTH DAKOTA
NORTH DAKOTA GAME AND FISH DEPARTMENT
FISHERIES DIVISION
DRAFTED 1994; REVISED DECEMBER 2004, MARCH 2010

This protocol and guidelines address the background, current inventory status, construction (installation/retrofitting), operations, and reporting for hypolimnetic discharge structures (HDS). Forthcoming information is intended to increase operational effectiveness and communication of results.

BACKGROUND

More than 400 dams, each capable of storing 50 or more acre-feet of water, have been constructed within North Dakota during the past several decades. Many of the reservoirs created behind these dams have been stocked with game fish, and support a considerable amount of sport fishing and associated recreational use. Currently, the North Dakota Game and Fish Department (Department) actively manages the fisheries in 127 reservoirs with a combined storage capacity of 790,000 acre-feet of water (this does not include Lakes Sakakawea and Oahe). Water quality problems in these reservoirs, as well as in the state's natural lakes, have generally deteriorated rapidly over time, primarily as a result of excessive sediment and nutrient inputs originating from intensively cultivated agricultural land and improper handling of animal wastes. Inflows carrying high amounts of sediment and/or nutrients results in excessive aquatic plants and algal growth can significantly shorten the usable life of the receiving water body. This accelerated aging is termed cultural eutrophication; it is the most evident and pervasive water quality problem in North Dakota.

Symptoms of advanced eutrophication include excessive growth of aquatic plants and algae, rapid loss of storage volume, noxious odors, tainted fish flesh and domestic water supplies, dissolved oxygen depletion, development of undesirable fish populations, loss of carrying capacity for fish (see Appendix A), and serious or even complete fish kills. Advanced eutrophication can and does have serious economic impacts, including lower property values, increased water treatment costs, and lost values associated with contact and non contact recreation. Fish kills, especially in late summer and winter months, occur frequently in many of North Dakota's nutrient rich lakes and reservoirs. These fish kills are usually associated with critically low dissolved oxygen (DO) concentrations combined with elevated concentrations of ammonium-nitrogen and hydrogen sulfide.

Reducing or controlling nutrient inputs into the states water bodies is often an overwhelming if not insurmountable task. The Department has a vested interest in the water quality in waters which it manages for sport fishing; fisheries supervisors have long been advocates for projects which would protect or improve water quality. One management action that offers promise in terms of improving in-lake water quality and reducing fish kills is the discharge of anoxic water through a hypolimnetic discharge structure (HDS). In some but not all instances, carefully timed discharge of nutrient-rich, oxygen-poor bottom waters through an embankment via a HDS has lessened the volume of anoxic bottom waters, the buildup of toxic concentrations of ammonium-nitrogen or hydrogen sulfide, and thus the frequency and severity of fish kills. HDS have been installed in a number of embankments as a routine feature for decades; some of the original HDS have been operated intermittently for decades. A considerable number of service spillways which were originally constructed without HDS have also been modified to incorporate these systems. There are also a few waters in North Dakota in which pump systems have been installed and are operated to remove hypolimnetic waters.

The first and most thorough assessment of the effectiveness of a HDS in North Dakota was undertaken over a several year period in the 1970's at Brewer Lake (Comita 1981). Study results indicated that timely discharges of bottom water through a properly designed system progressively reduced the anaerobic pool over a three year period. Comita detailed the following benefits to the lake: 1) the likelihood of a fish kill occurring was greatly reduced or even eliminated, during both winter and summer periods. The discharge of the anoxic water lessened or even totally eliminated accumulation of lethal concentrations of ammonium-nitrogen, which often causes the kills, 2) the evacuation of anoxic waters allows a greater proportion of the lake to be utilized or available for fish, and 3) the anoxic waters are highly concentrated with nutrients, nitrogen and phosphorous in particular. Reduction in nutrients translates into less available to support algae populations. Cooke et al. (1993) also report that hypolimnetic withdrawal is an obvious and proven alternative to accelerate recovery in stratified lakes where little improvement has followed wastewater diversion or advanced wastewater treatment because of high internal loading. They reported that the effectiveness of hypolimnetic withdrawal depends on the magnitude and duration of total phosphorous transport from the hypolimnion, and that a low frequency of hypolimnion volume exchange and a low rate of replacement of the hypolimnetic volume may limit the effectiveness of this technique. They summarized that the advantages of hypolimnetic withdrawal are threefold: 1) relatively low capital and operational costs, 2) evidence of effectiveness in a large portion of cases, and 3) potentially long term and even permanent effectiveness.

Since Comita's work in the 1970's, there has been some additional data collected by Department personnel that further supports the beneficial uses of a HDS. Fryda (2001) provided documentation regarding improved DO conditions in Arroda Lakes after the HDS was operated (Appendix B). Also, a review of data collected before and after HDS operations at 19 reservoirs during the summer months from 1997-2003 indicated that the median water column DO concentration increased from 2.5 ppm (pre) to 4.6 ppm (post).

HDS are typically operated to achieve in-lake water quality benefits. However, other operational purposes may include the following: lowering the water elevation to facilitate dam maintenance or repair, help lessen peak water levels due to an anticipated high runoff event, help control submergent or emergent vegetation, facilitate installation or modification of various development projects (e.g. boat ramps, etc.), lower the cost and increase the effectiveness of eradication projects, satisfy the demand of downstream water needs, or lessen the number of fish lost in association with high flows through the service or emergency spillways.

CURRENT INVENTORY/STATUS

The Department and the State Water Commission (SWC) have cooperated in compiling a statewide inventory of HDS systems. This listing contains nearly 70 water bodies which are equipped with some type of HDS (Table 1). Less than half of the listed waters have a HDS which still exist as installed when the dam was originally constructed. The remainder of HDS are either reconstructions/modifications to original systems or installation of functional systems where none originally existed. Virtually all of the HDS function by gravity flow; there are only a couple of systems which require pumping. A few HDS have become inoperable for various reasons; where appropriate, these inoperable systems should be repaired or reconstructed (Table 1).

INSTALLATION/RETROFITTING

The SWC has taken the lead in designing and installing HDS throughout North Dakota. Funding of HDS installations has typically been split equally between the SWC, the Department and a local entity (typically the respective county Water Resources District). In addition, Department fisheries personnel have also assisted the SWC with the actual installation in most cases. Reconstruction of an existing HDS has oftentimes been based upon the results of SWC dam safety inspections which have found the HDS to be deteriorated or deficient, and their subsequent recommendations to address the deficiencies. Most new HDS within the past decade or so have been installed in conjunction with other dam maintenance work, although a few systems have been installed at the request of the Department or one or more local entities.

The currently preferred design for HDS has been to retrofit existing concrete service spillways by installing a pipe through the face of the spillway, several feet below the spillway crest, and a valve and stop log structure within the spillway. This type of design allows the HDS to function automatically whenever the valve is open and/or the top of the stop logs is lower than the surface water elevation. The advantage of this system is the manpower requirement can be greatly minimized. It is critical to properly size the intake pipe and log structure.

Since there is often a cost associated with the installation, operation and maintenance of HDS, the need for a system in any particular water body needs to be carefully considered. Since discharge of anoxic water is by far the most important function of HDS, deeper water bodies with intense stratification, as documented by water profile sampling, are the best candidates for successful use of HDS. Water bodies with a history of chronically low water levels or limited inflow are poor candidates for HDS.

OPERATIONS

HDS in North Dakota are typically operated by the respective district fisheries supervisor or their staff. Most of the larger reservoirs within North Dakota are federally owned and operated; HDS systems within these reservoirs are operated to meet the needs of various purposes for which these reservoirs were constructed. For these waters, the respective district fisheries supervisor must coordinate with the appropriate federal agency to insure that the HDS are operated in a manner which provides the most possible water quality benefits.

Several factors need to be taken into consideration when operating HDS. These include the amount of current or anticipated runoff, the amount of available “surplus” water which can be released, the presence of any anoxic water to discharge, the best timing of any release, and the impact of the nutrient rich water on downstream waters. Although discharge of hypolimnetic water that contains high concentrations of phosphorous, ammonia, hydrogen sulfide, and/or no oxygen may cause water quality problems downstream, these impacts (if any) are short-term due to agitation, etc. Furthermore, in many cases, discharged water flows downstream through dry water courses and oftentimes soaks into the ground before it actually flows into any receiving water. If the downstream receiving water contains an important fishery or is otherwise used for recreation or water supply, special precaution may be necessary to minimize adverse impacts.

From an in-lake water quality perspective, the best time to operate a HDS is during the peak periods of stagnation and chemical stratification, which in North Dakota typically occur during the late winter (from mid-February through mid-March) and again during late summer (from Mid-July through mid-August). To ensure the most effective operation of any particular HDS, fisheries staff must obtain a water quality profile at the beginning of these periods to determine the amount of anoxic water which is present. If the supervisor determines that the HDS should be operated, another water quality profile must be obtained when the HDS is subsequently shut down. In some instances, in-lake and discharge water samples could be collected and analyzed for documentation purposes.

Although HDS which discharge bottom water automatically or passively may require less time and effort to operate compared to manual systems, the automatic or passive systems seldom discharge during the most critical time periods. As a result, these systems are most effective when they can also be manually operated.

The SWC has recommended that each system be operated annually for a brief time, if for no other reason than to perform a mechanical check. HDS operation as a system check is easiest during the open water period, and is most efficiently completed while obtaining standard summer water quality profiles during the late summer stagnation period.

REPORTING

Each district fisheries supervisor is responsible for collecting the pertinent water quality data in association to operating a HDS (Table 2). This information should be archived at the respective district offices. In addition, each supervisor is responsible for compiling an annual summary of operations for each of his/her respective waters (Table 3). For systems which require manual operations and are actually operated by Department fisheries staff, maintaining a record of operations is fairly simple. Each district fisheries supervisor’s annual report must also contain information regarding the operation of those systems which are operated by federal agencies or other entities. For those systems which discharge water automatically, far more effort/surveillance is needed to document/estimate the specific period when the system was actually functioning as well as the quality and quantity of water which was discharged through the HDS. Lastly, each district fisheries supervisor’s annual summary should note any problems with operation of any particular HDS so that appropriate actions can be taken to ensure the system is capable of being operated properly. This HDS summary must be attached, as a section, to the annual district fish management (electronic) report (which is to be submitted to the Fish Management Section Leader by February 1st of the following year). When all districts HDS summaries are compiled, they will be collectively forwarded to the State Water Commission.

LITERATURE CITED

Comita, Gabriel W. 1981. The Brewer Lake study, 1974-1979. A six-year study of primary productivity and the associated chemical and physical cycles in Brewer Lake. North Dakota State University, Fargo, ND.

Cooke, Dennis G., E. B. Welch, S. A. Peterson, and P. R. Newroth. 1993. Restoration and management of lakes and reservoirs, 2nd edition. CRC Press Inc., Boca Raton, FL. pp. 149-159.

Fryda, D. 2001. Winter hypolimnetic operation on East and West Arroda. Memo to file.

Greg Power, Chief of Fisheries

15 MAR 10
Date

Table 1.

Water Body	Year	Orig or Mod	Man or Auto	Full Pool Volume (A-F)	Max Water Depth (feet)	Pipe Inlet Depth (feet)	Pipe Dia.	Full Pool Head (feet)	Full Pool Disc. (cfs)	Min. Desired Design Q* (cfs)	Operating Entity
Armourdale Dam	1993	M	M	1,036	32	31	12"	12	6.25	4.8	Towner County WRD
Arroda Lake East	1970	O	M	279	37	35	12"	35	14.0	0.5	NDG&F
Arroda Lake West	1970	O	M	411	44	40	12"	40	13.7	1.2	NDG&F
Ashtabula, Lake	1951	M		70,573	45			32	230	254	Corps of Engineers
Belcourt Lake	1963	M	O	7,380	30					26.6	
Belfield Pond	1994	O	M	61	16	16	6"	8	1.91	0.25	NDG&F
Bisbee Dam	1987	M	M	2,253	28	19	8"	7	2.24	5.7	City of Bisbee/County WRD
Blacktail Dam	1991	M	M	2,413	40		12"	5	5.69	10.0	NDG&F
Bowman-Haley	1988	M	M	20,410	30	28	18"	13	20.8	69.3	Corps of Engineers
Braddock Dam	1993	M	M	430	18	18	10"	pump	1.56	1.9	Private landowner
Brewer Lake	1997	M	A	1,583	32	32	10"	6	4.59	5.5	NDG&F, Rush River WRD
Bylin Dam	1964	O	M	578	25	21	12"			2.6	Walsh County WRD
Camels Hump Lake	1968	O	M	647	36	32	12"	37	12.4	2.6	NDG&F
Carbury Dam	1982	O	M	1,171	22	21	16"	15	28.1	4.3	Boundary Creek WRD
Castle Rock Dam	1994	M	A	80	16	16	6"		1.0	1.0	NDG&F
Cedar Lake	1999	M	A	1,130	14	14	12"	6	5.73	4.2	NDG&F
Clausen Springs	1994	M	A	563	32	32	10"	6	4.23	2.25	NDG&F, Barnes CO WRD
Crown Butte Dam	1965	O		372	30	30	4"	30	0.70	1.2	NDG&F
Darling, Lake	1994	M	M	92,031	26		3-3'x4'	18	727	341	Fish & Wildlife Service

Water Body	Year	Orig or Mod	Man or Auto	Full Pool Volume (A-F)	Max Water Depth (feet)	Pipe Inlet Depth (feet)	Pipe Dia.	Full Pool Head (feet)	Full Pool Disc. (cfs)	Min. Desired Design Q* (cfs)	Operating Entity
Dead Colt Creek	1983	M	A	1,768	40	40	12"	39	16.9	7.4	NDG&F, Ransom CO WRD
Dickinson Dike	2003	M	M	196	20	20	6"		1.3	6.1	NDG&F
Dickinson Reservoir	1954	O	M	8,568	27	18	30"	23	60.0	33.1	BOR/City of Dickinson
Epping-Springbrook	1980	O	M	1,483	34		8"	4	2.38	5.6	NDG&F
Fish Creek Dam	1974	O	M	943	49	45	12"	8	5.73	4.8	NDG&F
Fordville Dam	1984	M	M	2,056	30	15	24"	15	86.0	7.5	Walsh/Grand Forks WRD
Froelich Dam	1987	M	M	1,819	32	30	8"	5	2.05	7.5	NDG&F
Golden Lake, South				4,102	18		15"			13.3	
Harvey Reservoir	1990	M	M	2,383	23	20	10"	5	4.38	8.4	Sheyenne R Development
Heart Butte Reservoir	1949	O	M	66,835	64		2-4'x5'		350	273	Bureau of Reclamation
Heinrich-Martin Dam	1991	M	M	267	28	28	6"	7	1.12	0.5	NDG&F
Homme Dam	1950	O	M	2,864	35	32	5'		525	10.8	Corps of Engineers
Ilo, Lake	1998	O	M	3,857	21					25.7	Fish & Wildlife Service
Indian Creek Dam	1978	O	A	2,432	28	28	12"	18	9.64	10.5	NDG&F
Jamestown Reservoir	1954	O	M	28,147	40		2-10'x10'			65.2	Corps of Engineers
Kota-Ray Dam	1983	M	M	326	27		6"	6	0.50	1.2	NDG&F
Kulm-Edgeley Dam	1975	M	A	333	29	29	12"	11	12.0	1.2	NDG&F
LaMoure, Lake	1972	M	A	5,965	37	37	16"	37	10.4	27.9	NDG&F, LaMoure Co WRD
Larimore Dam	1981	O	M	746	28	24	24"	22	76.2	2.6	Grand Forks County WRD
Lehr Dam	1988	M	M	73	24	24	4"	5	0.30	0.3	NDG&F

Water Body	Year	Orig or Mod	Man or Auto	Full Pool Volume (A-F)	Max Water Depth (feet)	Pipe Inlet Depth (feet)	Pipe Dia.	Full Pool Head (feet)	Full Pool Disc. (cfs)	Min. Desired Design Q* (cfs)	Operating Entity
Matejcek Dam		M		2,496	40	26	24"			9.1	Walsh County WRD
McDowell Dam	1975	O	M	802	39	39	16"	32	31.8	2.8	NDG&F
McGregor Dam	1986	M	M	785	36		6"	5	1.16	2.7	NDG&F
McVille Dam	1985	M	A	317	23	20	6"	20	1.86	1.4	McVille Park Bd./Co. WRD
Mirror Lake	1985	M	M	350	15	15	8"	11	2.76	1.9	Hettinger City Park Board
Mott Watershed Dam	1969	O	M	218	18		8"	13	6.08	1.0	Hettinger County WRD
Mt. Carmel Dam	1995	M	M	4,782	31	29	12"	7	6.53	15.1	Cavalier County WRD
Nelson Lake	1974	M	M	8,792	45		2-10'x10'	37	5,500	37.8	Minnkota Power Coop.
Northgate Dam	1979	M	A	1,388	25	25	12"	14	10.9	4.8	NDG&F
North Lemmon Lake	2001	M	M	591	30	30	12”	5	4.0	2.6	NDG&F
Pheasant Lake	1991	M	M	1,212	18	18	8"	15	3.51	6.2	NDG&F
Pipestem Reservoir	1973	O	M	13,200	32		36"	27	173	34.8	Corps of Engineers
Raleigh Reservoir	1988	O	A	790	34	34	12"	21	9.5	2.5	NDG&F
Renwick Dam	1962	O	M	1,300	18	14	24"			5.0	Pembina County WRD
Sakakawea, Lake	1953	O	M		180	178	28'	178			Corps of Engineers
Schlecht-Thom Dam	1988	M	M	143	25	25	4"	5	0.32	0.6	NDG&F
Sheep Creek Dam	2003	M	A	1,155	34	34	12"		7.4	4.3	NDG&F
Short Creek Dam	1983	M	M	1,239	26		6"	26	2.67	4.3	NDG&F
Spiritwood Lake	1982	O	M	15,167	53	53	12"	pump	4.45	43.1	NDG&F, WRD, City
Stanley Reservoir	1968	O	M	1,164	12		10"			3.2	NDG&F

Water Body	Year	Orig or Mod	Man or Auto	Full Pool Volume (A-F)	Max Water Depth (feet)	Pipe Inlet Depth (feet)	Pipe Dia.	Full Pool Head (feet)	Full Pool Disc. (cfs)	Min. Desired Design Q* (cfs)	Operating Entity
Sweetbriar Dam	1965	O	A	2,671	31	30	16"	31	3.72	9.9	NDG&F
Sykeston Dam	1993	M	M	629	20	20	12"	10	6.17	1.6	Sykeston / Wells Co WRD
Tioga Reservoir	1963	O	M	777	27		12"	27	15.1	2.8	NDG&F
Tolna Dam	1992	M	M	1,610	22	22	12"	8	5.52	5.3	Nelson County WRD
Velva Sportsmens	1998	O	A	67	26	25			0.41	0.2	NDG&F
White Earth Dam	1969	O	M	1,129	25	18	10"	25	9.50	5.9	NDG&F
Whitman Dam	1974	M	M	1,620	26	15	8"	10	3.36	4.2	Nelson County WRD
Wilson Dam	1992	M	M	293	16	16	6"	7	1.21	1.1	NDG&F

* defined as the flow needed to discharge 10% of the full pool water volume in a 14-day period. 1 cfs = 1.983 A-F / day

Table 2.

INDIVIDUAL HYPOLIMNETIC DISCHARGE SYSTEM OPERATION DOCUMENTATION

Water Body:________________________________ **County:**__________________

Valve Opening Date:_________________________ **Time**:_______________am pm

Valve Closing Date:__________________________ **Time**:_______________am pm

(Total:________________hours opened; ___________________days opened)

Valve Opening:_____________________%, and/or ___________number of turns

Water Elevation, when opened:____

Water Elevation, when closed:____

Discharge Anoxic: When Opened? Yes or No When Closed? Yes or No

Purpose(s) of System Operation (Check all that apply):

______in-lake water quality benefit
______dam maintenance or repair
______anticipated F30D work activities
______aquatic vegetation management
______fish management
______other (specify)____

(Pipe Specs: Size:_____________________" Depth:_____________________')

Approximate Discharge:_____________________CFS, _______________Acre-Feet

Approx.:___________vertical feet of bottom water evacuated

Approx.:___________% of total lake volume evacuated

Comments:____

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* Attach all pertinent water quality profile documentation

Table 3. ☐

DISTRICT	WATER BODY	FULL POOL DISCHARGE (CFS)	DAYS OPERATED	VOLUME DISCHARGE (ACRE-FEET)	FULL POOL VOLUME (ACRE-FEET)	% OF FULL POOL VOLUME DISCHARGED	LOW LEVEL COMMENTS

FISH CATCH RATES – Epilimnion vs Hypolimnion

In early August 2001, three small North Dakota reservoirs were sampled to determine fish populations above and below the thermocline. All three reservoirs were also chemically stratified at the time of sampling. Fish catch rates were considerably higher immediately above the thermocline compared to below the thermocline in all three reservoirs. There was virtually no presence of fish in the anoxic waters of the hypolimnion.

		Temp. Average (C°)		Diss. Oxygen (ppm)		Total Fish CPUE	
LAKE	DATE	EPI.	HYPO.	EPI.	HYPO.	EPI.	HYPO.
McDowell Dam	8/6/01	26.5	17.0	4.5	0.1	0.96	0
Sweetbriar Dam	8/6/01	25.0	23.0	6.3	0.7	2.88	0.13
Armourdale Dam	8/6/01	26.0	20.0	8.5	0.1	0.65	0

Appendix B

interoffice
MEMORANDUM

To: File
From: Dave
Date: March 12, 2001
Subject: Winter hypolimnetic operation on East and West Arroda.

On February 12, hypolimnetic drawdowns were opened on East Arroda and West Arroda reservoirs. The valve was opened six turns on West Arroda and five turns on East Arroda. Each drawdown was left open for 48 hours and closed on February 14. At the time of closing, the water level on West Arroda had dropped approximately .5 meters while the level of East Arroda appeared unchanged. Due to the considerable drop in water elevation at West Arroda, the valve should only be opened five turns in the future.

Both reservoirs showed substantial improvement in dissolved oxygen (DO) profiles after operation of the hypolimnetic drawdowns (figures 1 and 2). In order to evaluate the duration of these improvements, a profile was taken on West Arroda 15 days after closure of the valve. Although DO levels had declined, the amount of hypoxic water in the reservoir was still considerably less than before operation of the hypolimnetic drawdown (figure 1). Hypolimnetic drawdown appears to be a viable method of improving the water quality of the Arroda Reservoirs.

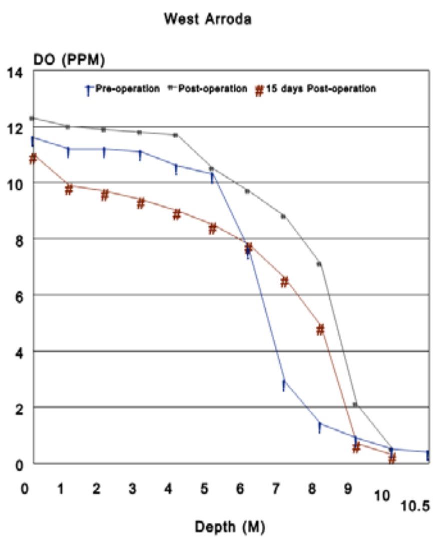

Figure 1. Dissolved oxygen profiles for West Arroda.

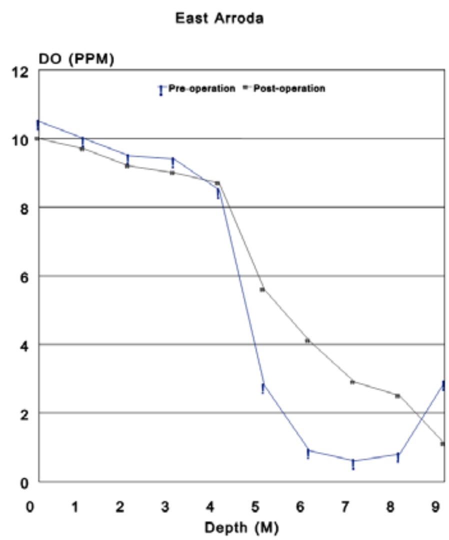

Figure 2. Dissolved oxygen profiles for East Arroda.