LAKE MANAGEMENT PLAN

Region	Area	D.O.W. Number	County	D.O.W. Lake Name	Lake Class	Acreage
1	Park Rapids	29-0185	Hubbard	Big Sand	22	1,635 GIS 465 littoral

LONG RANGE GOALS:

- Maintain or improve the quality of fishing for walleye by attempting to maintain a population with a mean catch per effort (CPE) index of at least 8.5 per gill net lift and a proportional stock density (PSD) index of 30 to 60. Attempt to maintain a relative stock density (RSD) of preferred length (20") walleye of at least 20 and an RSD of memorable length (25") walleye of at least 3.
- Walleye abundance should be balanced with abundance of preferred forage, yellow perch, by attempting to maintain a perch population with an average CPE index of at least 12 per gill net lift.
- Maintain related fish communities
- Protect or enhance desirable aquatic and riparian habitats (water quality, aquatic and riparian vegetation, and shoreline substrate).

OPERATIONAL PLANS:

- Conduct targeted gill net sampling about every three years (2017, 2023, 2026...), or as needed to evaluate management efforts. Monitor the walleye spawning run during sucker egg take operations on years of targeted gill net sampling, if possible within time and manpower constraints. Targeted fall electrofishing should be conducted annually to evaluate natural reproduction of walleye and to provide a baseline for comparisons with other lakes, if feasible within time and manpower constraints. , within a 5 year window of MPCA Watershed Assessments, to assess other fish populations. Include vertical gill net (VGN) sampling to better evaluate cisco, spring electrofishing to better assess smallmouth and largemouth bass populations, nearshore sampling to calculate an Index of Biotic Integrity (IBI), and additional targeted sampling to provide information about physical and chemical characteristics of the lake and its watershed that can be used to monitor long term habitat trends.
- Monitor the special 20 to 28 inch walleye slot length limit regulation using results of gill netting, spawning run monitoring, and fall electrofishing. If significant negative effects occur, recommend modification or rescind the regulation.
- Monitor winter fishing pressure by conducting aerial fish house counts.
- Maintain free and adequate public water access to Big Sand Lake.
- Work with educators, groups, agencies, individuals or news media to provide aquatic education opportunities. Efforts may include presentations, news releases, personal contacts or special projects.
- Provide recommendations on permit applications that will minimize impacts to aquatic resources associated with projects in Big Sand Lake, its tributaries, or its watershed.
- Encourage, support and assist efforts of local, state or federal groups or agencies to improve water quality, and maintain or improve fisheries habitat in Big Sand Lake.

MID RANGE OBJECTIVES:

- Evaluate population characteristics (abundance, size and age structure, and growth) of walleye, yellow perch, northern pike, smallmouth bass, largemouth bass, black crappie and tullibee (cisco). Continue to refine definitions of desirable levels of abundance and size structure for managed fish species.
- Continue to evaluate the extent of natural reproduction and recruitment of walleye.

POTENTIAL PLAN:

- Use fee title purchase or easements to protect additional lands in the watershed of Big Sand Lake to maintain or improve lake water quality. Priority should be given to riparian lands adjacent to known spawning areas, sensitive shorelands, or other critical aquatic habitat.

SUBTOTAL $ Costs would depend on extent and value of projects

<table>
<tr><td colspan="2">**NARRATIVE:** (Historical perspectives - various surveys; past management; social considerations; present limiting factors; survey needs; land acquisition; habitat development and protection; commercial fishery; stocking plans; other management tools; and evaluation plans)

(see following)</td><td>FOR CENTRAL OFFICE USE ONLY

Entry Date: | Year Resurvey:
Stock Species-Size-Number per Acre
Schedule: | Year Beginning
Population Manipulation
YES NO Year</td></tr>
<tr><td>Primary Species Management:

Walleye</td><td>Secondary Species Management:
Yellow perch, Northern pike, Smallmouth bass, Largemouth bass, Black crappie, Tullibee (Cisco)</td><td>Development
YES NO Year</td></tr>
<tr><td>Area Supervisor’s Signature:</td><td>Date</td><td>Creel or Use Survey
YES NO Year</td></tr>
<tr><td>Regional Manager’s Signature:</td><td>Date</td><td>Other:
Year</td></tr>
</table>

Big Sand Lake is located 2.5 miles north of Dorset, in central Hubbard County. Big Sand Lake has a GIS measured surface area of 1,635 acres, a maximum depth of 135 feet, is 28% littoral (465 acres), and has been assigned to lake class 22. Big Sand is part of the Mantrap chain of lakes. The Sand River flows through Big Sand, entering from Emma Lake at the north end, and flowing from the south end of the lake, into Ida and then Little Sand Lake. Small to medium sized boats can navigate upstream through Emma and Lower and Upper Bottle Lakes, or downstream through Ida to Little Sand and with good conditions through Shallow to Belle Taine.

PAST MANAGEMENT:

Minnesota fishing lakes can be grouped based on similar physical and chemical characteristics. Groups of lakes have similar fish communities. Big Sand Lake has been grouped in lake class 22. Lakes in this classification are often characterized by populations of walleye, yellow perch, pumpkinseed or rock bass. Largemouth bass, northern pike, black crappie, bluegill, brown bullhead, yellow bullhead, black bullhead, white sucker, tullibee (cisco) or bowfin may also be found in some of these lakes.

Big Sand Lake has been managed primarily for walleye with secondary emphasis on muskellunge (muskie), smallmouth bass, northern pike, or black crappie at various times. Management activities have consisted of: statewide fishing regulations; experimental regulations for walleye since 1989 and for northern pike from 1989 to 1995; whitefish and tullibee netting from 1944-55; collection of walleye eggs in the channel between Big Sand and

Emma Lakes during the 1940's and 1990's; collection of white sucker eggs in the channel between Big Sand and Emma Lakes since 1982; posting of the channel between Big Sand and Emma Lakes during the walleye and white sucker run to protect walleye spawning activity and facilitate egg take operations; closure to spearing in 1948-51; muskie designation and associated spearing closure from 1978 to 2004; stockings; improvement of angler access; and efforts to protect aquatic habitat.

From 1909 to 1943 various fish species were stocked in Big Sand Lake, including walleye, northern pike, bass, crappies, sunfish, and lake trout. From 1945 through 1950 only walleye and bass were stocked. The lake was classified as a walleye lake for management purposes in 1951, and walleye has remained the primary management species to present. No stockings were recommended in 1951 but frequent walleye stockings continued. In 1969 a muskie stocking program was initiated. The 1971 management plan recommended continued stocking of muskie fingerlings, and walleye fry were to be stocked only if natural walleye hatch rates were low for a particular year. However, both Shoepac strain muskies and walleyes were regularly stocked between 1971 and 1977. Big Sand was designated as a muskie lake in 1978, with an associated prohibition of spearing. Muskie stocking was recommended to be discontinued at this time because stocking success was poor and there was little interest in the muskie fishery. However, muskie stocking continued through 1981. Both walleye fry and fingerlings continued to be stocked through 2004. Walleye fingerlings were stocked in alternate, even numbered years from 1976 through 2004 in an attempt to better evaluate the extent of natural reproduction. However, that evaluation was confounded by stockings of walleye fry in 1977, 1979, and 1997. Fry were stocked as return for a walleye egg take operation. Walleye fingerling stocking rates were minimal, with only 0.33 pounds per littoral acre (155 pounds total) stocked in even numbered years from 1992 through 2004. Stocking evaluations suggested that natural reproduction was very successful and was likely sustaining the population, so walleye stocking was discontinued after 2004.

Experimental / Special Regulations

1990-1994 - One walleye over 20 inches and one northern pike over 24 inches in possession regulations were implemented in response to public pressure when it was felt that Big Sand Lake's walleye fishery was being overexploited. Studies conducted from 1990-92 concluded that the "one over" regulations alone were ineffective at limiting harvest of walleye or northern pike. In response to the public's desire to limit harvest, an experimental protected slot length limit, which restricted harvest of any walleye between 18 and 26 inches and allowed only one walleye over 26 inches in possession, was proposed, accepted by the public, and implemented in 1995. Northern pike reverted back to statewide regulations in 1995.

1995-1999 - 18-26" protected slot length limit, 1>26" in possession The experimental protected slot length limit for walleye was scheduled to sunset in 2000. Public input meetings were held, and results of evaluations were presented which showed some improvements in the proportion of 18-26 inch fish in the population but little improvement in walleye larger than 26 inches. It was recommended to continue the experimental regulation through 2005, continue to monitor the population during spawning runs and with population assessments, conduct angler creel surveys in 2002 and 2003 to compare fishing pressure, catch and harvest with 1990-92 information and use collected information to decide whether to modify, rescind, or make the experimental regulation permanent. The majority of the public approved of that strategy.

2000-2005 - 18-26" protected slot length limit, 1>26" in possession A special assessment using only gill nets was conducted in 2001, an open water creel survey was conducted in 2002, the walleye spawning run was monitored and a population assessment was conducted in 2004, and fall electrofishing evaluations were conducted annually. Results of those evaluations suggested that abundance of small to medium sized walleye was quite good, that angler catch rates of walleye had increased, and that natural reproduction was quite good and probably sustaining the walleye population. However, there was some evidence that walleye growth and condition had declined. It was recommended that the walleye regulation be modified by increasing the protected length range to 20 to 28 inches and the public supported that recommendation.

2005-2011 – 20-28" protected slot length limit, 1>28" in possession A population assessment was conducted in 2006, a resurvey was conducted in 2011, the walleye spawning run was monitored in 2008 and 2011, and fall electrofishing was conducted annually. Results of those evaluations suggested that abundance of medium and large walleye declined since 2004 but abundance of small walleye was higher. Abundance was still good compared to other similar lakes and higher than the regulation objective and Lake Management Plan goal. Similarly, proportions of medium and large walleye in recent spawning runs were lower and proportions of small walleye were higher. Condition of walleye improved slightly since 2005, but was still not as good as 1995 and 1998. Walleye growth rates appeared to have peaked in 2004 and declined since. Angler catch rates of walleye were lower in 2011 and may have been responsible for a decrease in fishing pressure. However harvest rate of walleye was still fairly good. That information was presented to the public, who were evenly split between whether to continue or modify/rescind the regulation. The decision was made to continue the regulation.

VARIOUS SURVEYS:

Big Sand Lake was mapped in 1941. An initial fisheries survey was conducted in 1951, and resurveys were conducted in 1971, 1978, 1992, 1995 and 2011. Population assessments were conducted in 1983, 1986, 1989, 1998, 2001, 2004 and 2006. A special assessment (targeted gill net sampling) was conducted in 2014. Fall electrofishing has been conducted annually since 1998 to evaluate walleye reproduction. Water samples were chemically analyzed during surveys in 1983, 1990 and 1992. The Big Sand Lake Association has participated in the Hubbard County Coalition of Lake Associations (COLA) lake water quality monitoring program since 1998. The Lake Association has monitored dissolved oxygen and temperature profiles biweekly during the open water season since 2007 and contracted for surveillance flights in 1991 and 1992 to look for Eurasion water milfoil. Lake water transparency has been recorded through the Minnesota Pollution Control Agency (MPCA) Citizen Lake Monitoring Program in 1975, and annually since 1987. Bluegill, northern pike, walleye and white sucker were tested for contaminants in 1992 and again in 2011. Those analyses resulted in consumption advisories, particularly for larger walleye and northern pike because of elevated levels of mercury.

The walleye spawning run between Big Sand and Emma Lakes was monitored in 1988 and 1990-92. Walleye were tagged in 1990-92 to estimate adult walleye population size. Open water angler creel surveys were conducted in 1990-92 to estimate fishing pressure, catch and harvest. Those studies were conducted to evaluate the 1989-95 experimental walleye and northern pike regulations. Results and recommendations are available in a MDNR Investigational Report. Walleye spawning run monitoring was conducted from 1997-2001, 2004, 2008 and 2011 during white sucker egg take operations. Open water angler creel surveys were conducted in 2002 and 2011.

Aerial fish house counts have been conducted annually since 1988 to monitor trends in ice fishing. Counts have averaged 10 with a range of 1 to 24 houses. The low numbers of houses observed in counts is a reflection of poor winter access for the general public. The highest counts were observed in 2001 through 2008 and 2010 through 2013, possibly indicating a better ability to gain access, or more interest from property owners.

Mean gill net catch rates provide the best index of walleye abundance. Average gill net catch rates of walleye have fluctuated widely, but have shown no significant long term trends of either increasing or declining over time (Figure 1). If anything, walleye catch rates have generally increased since 1983. Average catch rates of walleye in Big Sand have always been within or above the interquartile or "normal" range for lakes with similar physical and chemical characteristics (4.0 to 9.6/gill net). The long range goal of 8.5/gill net was set in 2000 at what was then the long term average of all catch rates. With sampling catch rates above

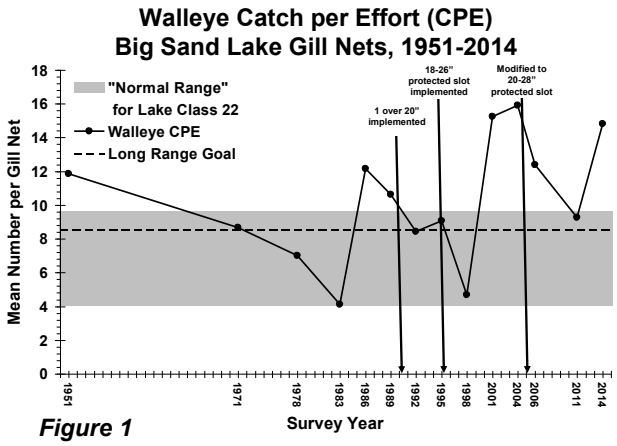

Figure 1

the goal since 2001, the average of catch rates from all Big Sand Lake samples is now 10.3 per gill net. The catch rate in 2014 was the third highest ever observed at Big Sand Lake and well above the normal range for similar lakes and the long range goal for Big Sand.

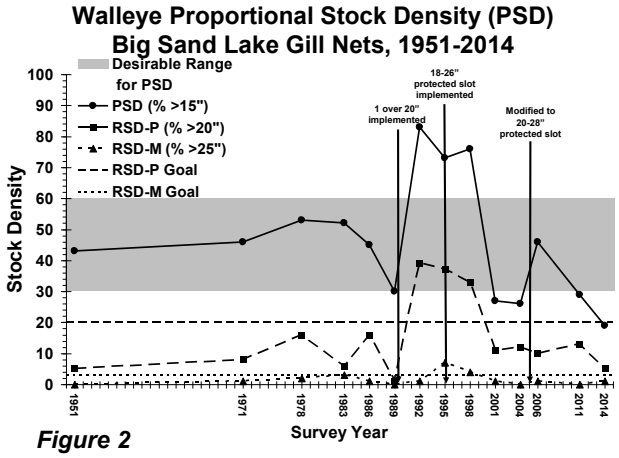

Figure 2

Proportional Stock Density (PSD) is an index of population size structure that describes the proportion of stock sized fish that are a quality size. For walleye, stock size is 10 inches and quality size is 15 inches. PSD of walleye in Big Sand Lake was within a desirable range of 30-60 in 1951 through 1989 samples (Figure 2). Big Sand walleye PSD increased to above the desirable range in 1992-98 samples, declined to slightly below desirable in 2001 and 2004, increased to within the desirable range in 2006 and has declined to near the low end of the desirable range in 2011 and below the desirable range in 2014. High PSDs are a reflection of a high proportion of large fish and fewer small fish in the sample, which may indicate poor recruitment. Low PSDs are due to a high proportion of small fish and relatively few large fish, a less desirable condition for anglers. Mid-range PSDs indicate enough small fish recruiting into the population to provide good fishing in the future, and enough large fish to provide good fishing now. The worst condition for large fish was in the 1989 sample, just before the public requested more protection of large fish. The best conditions for large fish were in 1992, 1995 and 1998 samples. However, the low proportion of small fish suggests that reproduction and/or recruitment may have been lower at that time.

Size structure indices can be further refined to the Relative Stock Density of Preferred size fish (RSD-P) and Relative Stock Density of Memorable size fish (RSD-M). Preferred size for walleyes is 20 inches and memorable size is 25 inches. RSD-P and RSD-M indices followed similar patterns as PSD. RSD-P of walleyes in Big Sand Lake fluctuated between 5 and 16 from 1951 through 1986 samples, declined to 1 in 1989, increased to 33-39 in 1992-98 samples, declined in 2001, was relatively stable, fluctuating between 10 and 13 through 2011, and declined further in 2014. RSD-M has typically been much lower. In 1995 and 1998, the proportion of 20 inch and larger fish was the highest observed in any samples. The long range goals of RSD-P $\geq$ 20 and RSD-M $\geq$ 3 were set in 2000, between the long term average and third quartile of results from all surveys for those indices up to then. RSD-P values in 1992-98 were above the goal, but values in all other samples have been below the goal. RSD-M values in 1983, '95 and '98 were above the goal, but values in all other samples have been below the goal. Those goals may have been too optimistic. The only samples that walleye size structure has been above those goals were the three samples between 1992 and 1998.

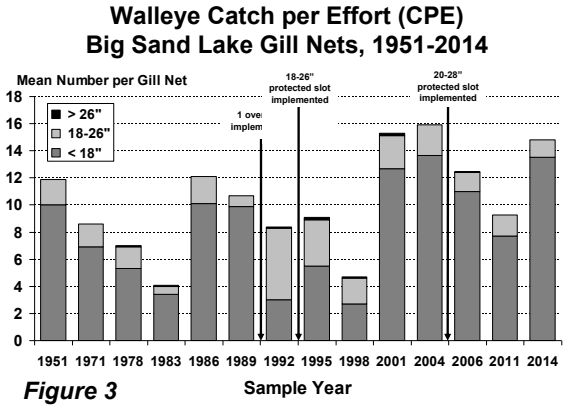

Figure 3

The abundance of 18-26 inch walleyes observed during surveys and assessments was highest in 1992, declined in 1995 and 1998 samples, was similar in 2001 and 2004, then decreased slightly in 2006 and was similar in 2011 and 2014 (Figure 3). The proportion of 18-26 inch walleyes observed during spawning run monitoring increased from 1988 through 2001, decreased in 2004 and has been similar to 1990-91 levels since then (Figure 4). In general, PSD, RSD, abundance of 18-26 inch walleye observed in sampling, and proportion of 18-26 inch walleye observed in spawning run monitoring were all higher during the period since experimental walleye regulations were implemented than they were during the period prior to experimental regulations.

Length weight relationships have been developed from samples conducted since 1995 to evaluate condition of walleye (Figure 5). Condition was best in the 1995 sample and declined through the 2004 and 2006 samples. Condition has increased since 2006, and in 2014 was as good as 1998 and 2001 samples. Mean length at age has been calculated since 1998 and was used to evaluate walleye growth rates. Growth was below average for similar lakes in 1989, increased in 1992 and was above average through 2004. Walleye growth declined and was below average in 2006 and 2011, then increase to above average again in 2014 (Figure 6).

Data from 2002 and 2011 angler creel surveys were compared to results from Big Sand creel surveys conducted in 1990, 1991, and 1992, prior to implementation of the protected slot regulation for walleye. The 2002 open water season estimate of 22,559 angler hours was 7-16% less than estimates for 1990 to 1992. Fishing pressure in 2011 was less than half that of 1990-92 or 2002. Obviously, harvest of walleye was lower in 2002 than 1990-92 due to the regulation that was intended to reduce harvest of medium sized walleye. Walleye harvest in 2002 was 25% of the average harvest estimated for 1990-92. Walleye harvest was considerably lower in 2011 because of the lower fishing pressure, but harvest rates in 2011were similar to 1990-92 and 2002. The total estimated daytime catch (harvested and released) of walleye in 2002 was 25% greater than the high estimate in 1990 and more than double the low 1992 estimate. Again, because of lower fishing pressure, the catch in 2011 was considerably lower. Walleye catch rates (number per angler hour) similarly increased in 2002 but decreased in 2011 (Figure 7). Walleye from 18-26 inches comprised an average of 41% of the catch in 1990-92, compared to 82% of the catch in 2002 and 70% of the catch in 2011. Mean catch rates of 18-26" walleye exceeded the original experimental regulation goal in both 2002 and 2011. Catch rate of walleye larger than 26 inches exceeded the goal in 2002 but was slightly lower than the goal in 2011.

It was difficult to evaluate the extent of natural reproduction of walleye and the contribution of stocking, because there were relatively few years that walleye were not stocked in the lake prior to 2004. Comparisons of mean gill net catch rates of year classes of walleye from non-stocked years appeared to be higher (23%) than stocked years at the same age. However, sample sizes were small. Fall electrofishing has been conducted annually since 1998 to evaluate

Walleye Proportional Length Distribution
Big Sand Lake Spawning Run Monitoring 1988-2011

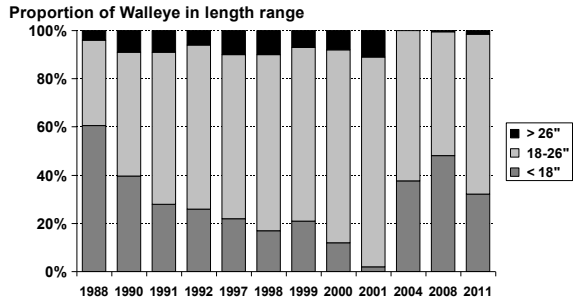

Figure 4

Walleye Relative Weight (Wr)
Big Sand Lake, 1995-2014

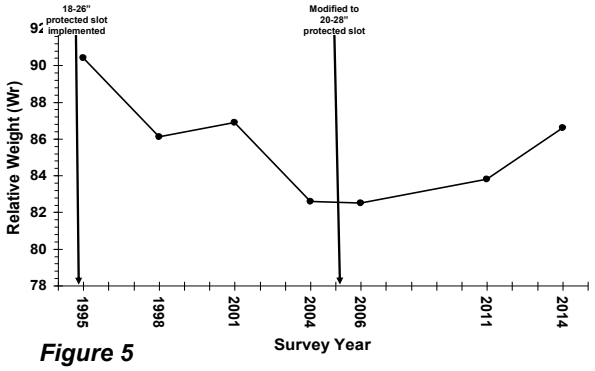

Figure 5

Walleye Mean Length at Age
Big Sand Lake, 1989-2014

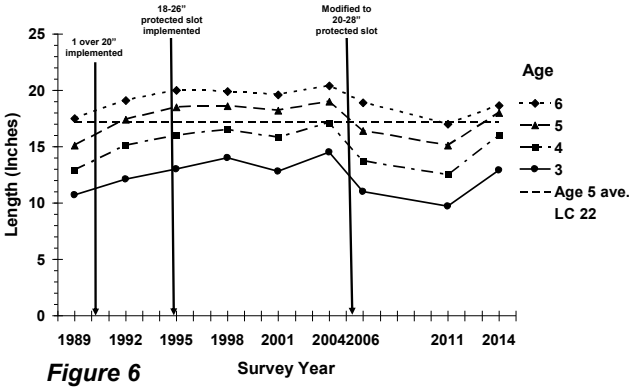

Figure 6

Walleye Catch Rates (Number per Angler Hour)
Angler Creel Surveys Big Sand Lake 1990-92, 2002, 2011

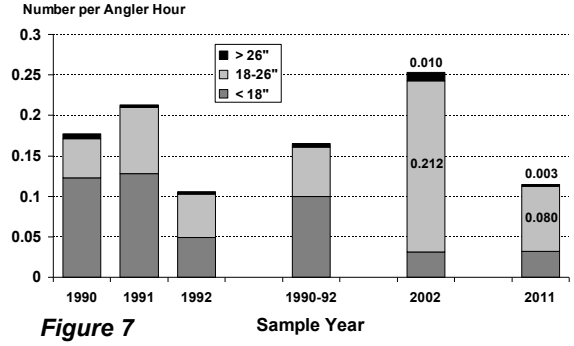

Figure 7

Goal: 0.061/Hr. 18-26" and 0.004/Hr. >26"

abundance of young of the year (YOY) walleye and the extent of natural reproduction. Fall electrofishing catch rates of YOY walleye have fluctuated widely (Figure 8). A good electrofishing catch rate of YOY in 1999 corresponds to the very high abundance of the 1999 year class in the 2001 gill netting assessment. No walleyes were stocked in Big Sand in 1999. YOY catch rates in other years also correspond quite closely with year class strength in subsequent gill net samples suggesting that natural reproduction was contributing more to the walleye population in Big Sand than stocking. Gill net catch rates of walleye have remained high and electrofishing catch rates of YOY walleye have shown an increasing trend since walleye stocking was discontinued in 2004.

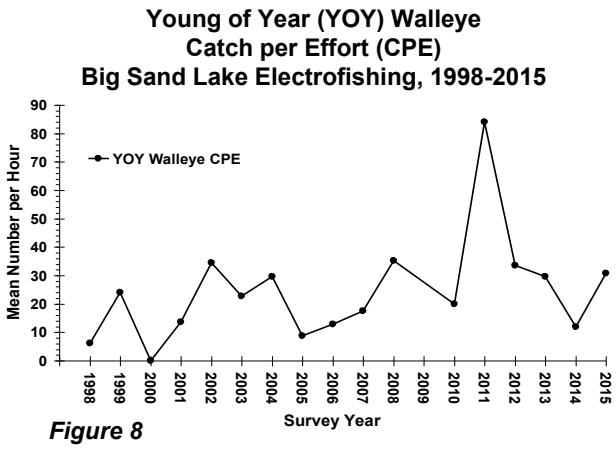

Figure 8

Gill net catch rates of yellow perch in Big Sand Lake peaked in 1989 and have fluctuated, but generally declined since then (Figure 9). Generally, catch rates of perch were higher than the interquartile or "normal" range for similar lakes (7.1 to 33.9/gill net) in 1989, lower than the interquartile range in 2011 and 2014, and within the normal range in all other years. The long range goal of 12/gill net was set in 2000 at the first quartile of all catch rates to that point. Catch rates of perch were below the management goal in 1951, higher than the goal in 1971 through 2004 samples, and below the goal since 2004. Size structure of perch in Big Sand Lake has also fluctuated but generally declined, with no perch larger than 10 inches collected in just the last three samples. In general, perch have been larger sized than most other lakes in the Park Rapids area, but most perch in Big Sand are still small enough that they may not be of interest to anglers. Although Big Sand perch may not provide much of a fishery, they are an important source of forage for predator fish species like walleyes. While walleye in Big Sand Lake are probably also seeking alternative prey like tullibee, it is still important to maintain an adequate perch population.

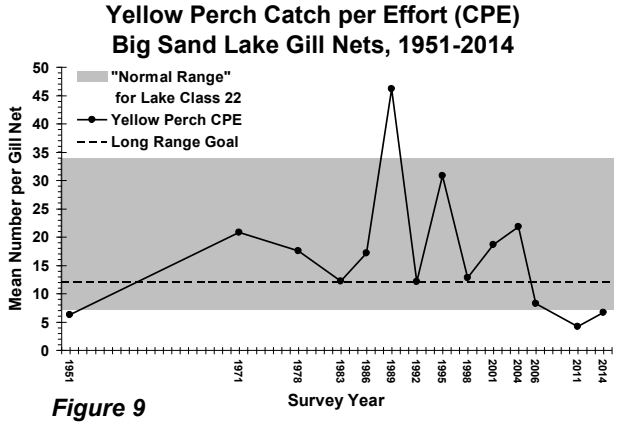

Figure 9

The abundance of northern pike in Big Sand Lake has generally been increasing since the first sample in 1951, but hasn't fluctuated much and still remains low compared to other, similar lakes. Catch rates of northern pike have ranged from 0.1 to 3.6/gill net in Big Sand compared to 3.0 to 7.9/gill net in other lakes with similar physical and chemical characteristics. When enough pike were collected to estimate PSD, the size structure of the northern pike population was usually well above the desirable range of 30-60 and generally increased over time. Proportions of preferred (28 inches and larger) and memorable (34 inches and larger) size northern pike have also been good. Proportions of 28 inch and larger northern pike have generally increased, but proportions of 34 inch and larger pike have not. Low abundance and higher size structure is probably an indication of limited natural production, and probably reflects limited spawning habitat for northern pike.

Both largemouth and smallmouth bass have been collected with gill nets and trap nets during the course of population assessments and lake surveys, but those gears do not do the best job of sampling bass. Judging from net catch rates it appears that abundance of both bass species has fluctuated, but generally increased over time. Gill net catch rates for both species peaked at historic high levels in 2011and declined slightly in 2014. Spring electrofishing may be included in future years when lake surveys are conducted to better assess smallmouth and largemouth bass, if feasible within time and manpower constraints.

Both gill net and trap net catch rates of black crappie declined from 1951 to 1971, remained at very low levels through 2006, then increased in 2011. Gill net catch rates of crappie declined again in 2014. From 1971 through 2006, catch rates of crappie were generally below the normal range for similar lakes. In 2011, crappie catch rates increased to the upper end of the normal range. Too few crappies have been collected in most samples to be able to estimate PSD, or describe size structure of the population.

Trap net catch rates provide the best index of bluegill abundance. Bluegill trap net catch rates in Big Sand were low through 1998, but have steadily increased since then. Bluegill abundance has been at record levels for Big Sand Lake since 2004, but still within the normal range for other similar lakes. Sizes of bluegill have historically been small. There have been very few bluegill sampled larger than a preferred size of eight inches and none larger than 10 inches.

Gill net catch rates of rock bass have increased dramatically and have been well above the interquartile range for similar lakes since 1998. One of the most common complaints of anglers during the 2011 creel survey was about the abundance of rock bass and how they were interfering with fishing for walleyes. That may have been one reason for the much lower fishing pressure and walleye catch rates in 2011 than in previous angler creel surveys.

Tullibee (cisco) can provide an alternate, high protein, source of forage for predator fish species like walleye. Special deep water gill net sets were used to sample and report abundance of tullibee in 1972 and 1978. Catch rates in those samples were higher, but not comparable to standard gill netting conducted in other samples. Catch rates of tullibee during standard gill netting have fluctuated widely, and probably aren't a good indication of tullibee abundance. Anecdotal reports from anglers in the early 2000s suggested that they were not seeing schools of tullibee on the surface of the lake in the evening that they had been seeing in prior years. Vertical gill nets (VGN) were used to evaluate Big Sand tullibee in 2015. That was the first time this sampling method has been used at Big Sand, so there is no historical information to compare to. The catch rate of tullibee sampled by VGN at Big Sand was low compared to other lakes where that sampling method has been used. Young of the year tullibee comprised 68% of the sample, so the catch rate of adult tullibee was particularly low. The length frequency distribution indicated that several year classes of tullibee were present.

SOCIAL CONSIDERATIONS:

Big Sand Lake and its fishery are an important feature and recreational attraction for the Park Rapids area and surrounding communities. The lake and its fishery have the potential to contribute substantially to local and state economies. Angler creel surveys conducted during open water fishing seasons in 1990-92 estimated an average of 28,002 angler hours per season. An angler creel survey conducted in 2002 estimated 25,570 angler hours and a creel survey in 2011 estimated 11,771 hours.

There were 2 resorts with 24 cabins observed on Big Sand Lake in both 1995 and 1998. There were 176 homes/cabins observed in 1995, and 180 homes/cabins counted in 1998. This amounts to a 2% increase of cabins/homes in three years. Shoreline development was not reported in 2001. There were 188 cabins/homes reported in 2004 for another 4% increase in development during the 6 years between 1998 and 2004. There were 197 homes/cabins observed in 2011 for another 5% increase in development during the most recent 7 years. The number of cabins/homes observed in 2011 results in 24.9 cabins/homes per shoreline mile, which is in the 92nd percentile of 103 lakes in the Park Rapids area where shoreline development has been recorded.

A trap has been erected in the channel between Big Sand and Emma Lakes in some years, and eggs have been collected and fertilized from white suckers during the spring spawning run. Those eggs are hatched, and the resulting fry are used as forage in the muskie rearing program at Park Rapids. Sizes of walleye encountered during the sucker spawn take operation have sometimes been monitored.

PRESENT LIMITING FACTORS:

Development on Big Sand Lake and within its immediate watershed has resulted in removal of aquatic and riparian vegetation and probably increased contribution of nutrients to the lake. Removal of native vegetation also increases the risk of erosion, both on the land and shoreline, and resulting siltation and sedimentation. Loss of vegetation, and the resulting loss of habitat and degraded water quality could negatively affect fish populations, reduce recreational opportunities, and reduce the aesthetic quality of the lake. In particular, emergent vegetation like bulrush provides spawning habitat for black crappie, bluegill and largemouth bass and seasonally flooded vegetation provides spawning habitat for northern pike. Removal of aquatic vegetation will have the greatest negative impacts on these species.

Abundance or quality of various fish species may be limited by habitat or other fish populations. For example, natural reproduction/recruitment, abundance, growth, condition or sizes of walleye may be dependent on environmental conditions, habitat or other fish populations. Anglers and property owners have reported fewer tullibee in the lake since the early 2000s. Lower tullibee abundance may be a result of higher walleye abundance or an environmental catastrophe like high water temperatures and/or low dissolved oxygen levels resulting in a fish kill. Big Sand and Little Sand Lake Associations purchased equipment in 2007 and share it to monitor temperature and dissolved oxygen profiles during the open water season. Data is being evaluated for rate of hypolimnetic DO decline, trends, or quality of habitat for tullibee.

Yellow perch abundance has also declined since 1989. Evidence of slower growth and poorer condition of walleye in recent surveys may be related to increased abundance of walleye and/or changes in forage if tullibee or perch have declined. Increases in abundance of other predators like smallmouth bass, largemouth bass or rock bass may prey on young walleye or compete with older walleyes for similar foods. That could also result in low abundance, growth, condition or sizes of walleye.

Northern pike reproduction and recruitment is probably dependent on the amount of seasonally flooded vegetation and marsh areas, which provide suitable spawning habitat. The amount of habitat in Big Sand Lake for pike production appears to be minimal, but adequate. Although pike abundance is low, high recruitment of pike can result in an abundance of small fish, poor growth, and poor size structure. In addition, there is often a negative relationship between northern pike and walleye. If northerns were more abundant, it would probably result in a smaller size structure of pike, and might result in lower abundance, growth, condition or sizes of walleye. The somewhat small proportion of shallow, littoral area may limit production and abundance of "shoreline" species like black crappie, bluegill or largemouth bass. Increased fishing pressure and harvest in recent decades may affect abundance, size, or age structure of game fish populations.

SURVEY NEEDS:

Gill net sampling should be conducted about every three years (2017, 2020…). The walleye spawning run should be monitored in conjunction with white sucker egg take operations on years of gill net sampling. Targeted fall electrofishing should be conducted annually to sample young of the year walleye and evaluate natural production, and to provide a baseline for comparisons with other lakes, if possible with fiscal and manpower constraints. Standard lake surveys should be conducted about every nine to twelve years to provide information about other fish populations. Spring electrofishing should be included to better evaluate largemouth and smallmouth bass, vertical net sampling should be included to better evaluate cisco, nearshore sampling should be included to calculate an Index of Biotic Integrity (IBI), and additional targeted sampling should be included to provide information about physical and chemical characteristics of the lake and its watershed that can be used to monitor long term habitat trends.

Citizen volunteers should be encouraged to continue collecting water quality information on a regular basis. At a minimum, lake water transparency (secchi disk) should continue to be monitored through the MPCA Citizen

Lake Monitoring Program. Periodically, water samples should be tested for chlorophyll-*a* and total phosphorus to look for long term trends. If possible, dissolved oxygen and temperatures should continue to be monitored to evaluate any trends in oxygen depletion or changes in habitat suitability for species like tullibee.

HABITAT DEVELOPMENT AND PROTECTION:

Water sampling since 1994 at the primary site on Big Sand Lake showed increases in secchi depth measurements and decreases in Total Phosphorus concentrations and mean Trophic State Index, all of which indicate improving water quality. Increases in secchi depth measurements at other sites on the lake during different time periods also indicated improving water clarity. The lake is considered oligotrophic based on all those measurements. The Watershed Restoration and Protection Strategy (WRAPS) Report prepared for the Crow Wing River Watershed identified Big Sand as a particularly high value, sensitive lake. Small changes in nutrient loading are likely to result in large changes in water clarity. The WRAPS report recommended protecting natural water infiltration and water level fluctuations, nutrient management, and increasing forest acreage in the watershed with conservation easements or acquisition as strategies to reduce phosphorus loading and maintain or improve existing water quality of Big Sand Lake.

The MN DNR Fisheries Habitat Plan used watershed disturbance as a surrogate of lake water quality. Modeling by DNR Fisheries Research staff suggests that total phosphorus concentrations increase significantly over natural concentrations in lakes with watershed land use disturbances greater than roughly 25%. Disturbed land includes urban development, agriculture, and mining. Those types of land use may contribute up to 15 times more phosphorus to surface waters than undisturbed lands. The plan suggested that watersheds with at least 75% of their area publicly owned or in conservation easements are reasonably protected from future disturbance and watershed degradation. The plan goes on to suggest that watershed that are less than 25% disturbed but also less than 75% protected need additional protection to avoid future water quality degradation. Less than 25% of Big Sand Lake's watershed is disturbed, but less than 75% of the lake's watershed is currently protected by public ownership or conservation easements suggesting that protection efforts may be the most appropriate watershed management strategy to maintain or improve water quality.

MN DNR Ecological and Water Resources staff identified sensitive shorelands around several lakes in Hubbard County, including Big Sand, based on surveys of aquatic plants and target animal species. Those surveys were incorporated into a model that also included lakeshore areas used by focal species, areas of high biodiversity, and critical and vulnerable habitats. Efforts should be made to protect those sensitive shorelands, to identify important spawning areas or other critical aquatic habitat on Big Sand Lake and to protect those areas from further development or habitat degradation.

Fisheries personnel will continue efforts to inform and educate the public about the value of riparian and aquatic habitats (water quality, vegetation and substrates), and the need to protect or restore them. Efforts of local, state or federal groups, agencies or individuals to maintain or improve water quality or fisheries habitat in Big Sand Lake will continue to be encouraged, supported and assisted. Aquatic plant management and work in protected waters permit applications will be reviewed, and recommendations will be provided to minimize loss or degradation of riparian and aquatic habitats. In particular, existing or prospective lakeshore property owners should be advised of the benefits of riparian and aquatic vegetation as habitat and shoreline protection. They should be encouraged to maintain existing or restore destroyed vegetation. They should be given options to obtain access to open water or to reasonably use lakeshore property, but still maintain as much vegetation as possible. Fisheries personnel will also work with developers of private land or planning and zoning authorities whenever possible, to provide recommendations and define guidelines for aquatic plant management or protection of sensitive habitat.

LAND ACQUISITION:

Big Sand Lake has a county owned public access site with ramps and remote but adequate parking. This access is

located adjacent to Big Sand's outlet channel, which stays open during much of the winter. As a result, it has been difficult for the general public to gain access to the lake for winter ice fishing. An adjacent property was recently acquired that may allow moving the access ramp further away from the outlet channel and may allow other improvements to the access. Additional land acquisition may also be considered in the future to satisfy increased recreational demand or to ensure accessibility for shore fishermen, elderly or disabled. Any improvements in access should be weighed against anticipated negative effects of increased use.

Consideration should be given to acquiring property, acquiring conservation easements or using cost-share programs to protect additional lands in Big Sand Lake's watershed in order to maintain or improve lake water quality. Priority should be given to protecting riparian areas that will also maintain or improve physical habitat in the lake. High priorities will be identified spawning areas, sensitive shorelands, and other critical habitat, to protect them from development or further degradation, or to improve habitat in those areas. The highest priority will be to protect large tracts of privately owned undeveloped shoreline that meet those criteria. Consideration might also be given to acquiring property or easements, or using cost-share programs to protect marginal land and critically eroding areas, or to provide vegetative buffer strips along the lakeshore or tributaries if necessary.

Big Sand Lake has been identified as a tullibee refuge lake and was included in a program to acquire conservation easements in the watershed and maintain them as private forest lands in order to protect water quality. That program received legislative funding, but few landowners applied.

STOCKING PLANS:

No additional stockings are warranted at this time.

EVALUATION PLANS:

Fisheries sampling information will be used to evaluate population characteristics (abundance, relative abundance, size structure, age structure, growth or condition) of walleye, northern pike, smallmouth bass, largemouth bass, black crappie, yellow perch, tullibee and other forage fishes. Fisheries sampling information will also be used to build a more complete database, allow better comparisons of species' population characteristics over time, and might aid with evaluation of community interactions. Results will be used to evaluate and adjust management efforts, if necessary to achieve desirable levels of abundance and size structure for managed fish species and forage fishes at minimum costs. Targeted fall electrofishing will be used to evaluate natural reproduction of walleye. Walleye spawning run monitoring will be used to as another means to evaluate changes in size structure of adult fish. Periodic collection of information about physical and chemical characteristics of the lake and its watershed can be used to monitor and evaluate long term habitat trends.