memo

Project Name |	Square Lake Trout Stocking Moratorium MOU	**Date** |	3-16-2017
To / Contact info |	CMSCWD Board of Managers		
Cc / Contact info |	Jim Shaver, District Administrator		
From / Contact info |	Meghan Funke, PhD		
Regarding |	Long Lake Study		

At the March 8, 2017 Board Meeting, T.J. DeBates, East Metro Fisheries Supervisor, cited a 2005 research article on spring trout stocking effects on water clarity in Long Lake as support for the proposed 3-year spring stocking of rainbow trout in Square Lake. Dr. Leif Hembre was the lead author of the Long Lake study, and also of the subsequent LCMR-funded study of Square Lake that tested whether spring trout stocking compared to autumn trout stocking would result in the same effects on the *Daphnia* population and water clarity in Square Lake as in Long Lake. This memo compares the 1996-1999 Long Lake study and the 2003-2005 Square Lake LCMR study, and highlights key differences that are relevant to the MN DNR proposed spring stocking plan for Square Lake. A comparison of the lake physical characteristics is provided in Table 1 below.

Table 1. Comparison of Long Lake and Square Lake physical characteristics

Parameter	Long Lake (15-0057)	Square Lake (82-0046)
Surface area (acres)	164	203
Littoral area (acres)	24	65
Maximum depth (feet)	80	68
Average depth (feet)	43	30
Volume (acre-feet)	6,186	5,693
Length/fetch (miles)	1.5	0.9

Table 2. Comparison of the 1996-1999 Long Lake & 2003-2005 Square Lake Studies

1996-1999 Long Lake Study	2003-2005 Square Lake Study
Report Citation	
Leif K. Hembre and Robert O. Megard. 2005. Timing of predation by rainbow trout controls *Daphnia* demography and the trophic status of a Minnesota Lake. *Freshwater Biology* 50: 1064-1080.	Leif K. Hembre. 2006. Maintaining zooplankton (*Daphnia*) for water quality: Square Lake. Funded by the Legislative Commission on Minnesota Resources (LCMR).
Trout Stocking Manipulation	
Stocking Rate: ~88 per acre **1996 & 1997**: 14,500 yearlings in autumn **1998 & 1999**: 14,500 yearlings in spring	**Stocking Rate**: ~15-25 per acre **2003-2004**: 2,000 yearlings in autumn 2003 plus 3,000 yearlings in spring 2004 **2005**: 3,000 yearlings in spring
Study Questions	
1. Does predation by rainbow trout significantly affect the demography of the lake's *Daphnia* population? 2. Does a change from autumn to spring stocking alter the nature of the trophic interactions among trout, *Daphnia*, and phytoplankton? 3. What is the appropriate stocking strategy to maximize trout survival and also maintain clear water?	• If the stocking of trout was timed correctly (i.e., spring stocking only), is the *Daphnia pulicaria* population in Square Lake able to establish itself during the winter and grow exponentially during the spring and early summer?

Table 2 (continued). Comparison of the 1996-1999 Long Lake & 2003-2005 Square Lake Studies

1996-1999 Long Lake Study	2003-2005 Square Lake Study
Monitoring Data	
Approximately monthly sampling during the open-water seasons of 1996-1999: • Secchi transparency, temperature and oxygen depth profiles, and surface water chlorophyll *a* at one point in the middle of the lake • Zooplankton distribution and density based on sonar backscattering and plankton net counts • Rainbow trout stomach contents • *Daphnia* reproductive rates based on average number of eggs per individual and water temperature • *Daphnia* mortality rates, corrected for water temperature, based on a bioenergetics analysis of rainbow trout by Hirsch & Negus (2000) that concluded each individual overwintering trout consumed 12,000 Daphnia per day	Approximately monthly sampling between April and October of 2004 and 2005: • Secchi transparency, temperature and oxygen depth profiles, and surface water chlorophyll *a* at one point in the middle of the lake • Zooplankton distribution and density based on sonar backscattering and plankton net counts • Rainbow trout stomach contents • *Daphnia* reproductive rates based on average number of eggs per individual and water temperature • water temperature, based on a bioenergetics analysis of rainbow trout by Hirsch & Negus (2000) that concluded each individual overwintering trout consumed 12,000 Daphnia per day • Rainbow trout abundance based on acoustic data (echoes) • 2004 winter and summer creel surveys

Table 2 (continued). Comparison of the 1996-1999 Long Lake & 2003-2005 Square Lake Studies

1996-1999 Long Lake Study	2003-2005 Square Lake Study
Key Results	
• *D. pulicaria* biomass was low in the spring and increased later in the summer during 1996 and 1997 when trout had been stocked the previous autumn. • In contrast, *D. pulicaria* biomass was high in May and June and decreased later in the summer during 1998 and 1999 when trout had been stocked in spring. • Following autumn stocking, trout abundance decreased to low levels (< 16 trout per acre) by July or August. Following spring stocking, trout abundance decreased from the maxima in May to minima in October, but maintained substantially higher levels (> 16 trout per acre). • Trout were found to feed almost exclusively on *D. pulicaria*, with an average length of *Daphnia* in the stomachs of 2.1 mm and a minimum length of 1.4 mm.	• *D. pulicaria* biomass in April was an order of magnitude higher in 2005, when trout were not stocked the previous autumn, compared to 2004, when trout were stocked the previous autumn. • Counter to expectations, the large April 2005 *D. pulicaria* population declined in May and June instead of increasing as seen in Long Lake. • *D. pulicaria* biomass increased substantially in July and August of 2005, and was much larger than in 2004, but declined from August until October. • The April 2004 trout population was larger than the April 2005 trout population. In both years, the largest trout populations were observed in May after the stocking of 3,000 trout. • In 2004, the trout population appeared to decline more quickly from May to July than in 2005, but overall the population dynamics of trout were similar between the two years. • During the winter creel survey, 75% of anglers said they were fishing primarily for trout, a total of 532 fish were caught and 143 harvested, 128 rainbow trout were caught and 103 harvested. • During the summer creel survey, 59% of anglers said they were fishing primarily for trout, a total of 2,552 fish were caught and 746 harvested, 439 rainbow trout were caught and 322 harvested. • Water clarity in 2004 did not differ significantly from 2005. And in both years, water clarity was highest in spring and generally decreased through the summer and into autumn. April 2005 was exceptionally clear and more transparent than April 2004. • Surface chlorophyll a concentrations were similar in 2004 and 2005.

Table 2 (continued). Comparison of the 1996-1999 Long Lake & 2003-2005 Square Lake Studies

1996-1999 Long Lake Study	2003-2005 Square Lake Study
Key Results (continued)	
	• In winter 2004, the trout diet was mostly *D. pulicaria*, with an average length of 2.1 mm. • In summer 2005, trout fed on a mix of *D. pulicaria* and benthic Chironomid and *Chaoborus* larvae. • Contrary to the Long Lake study, on several occasions when the reproductive rates of *Daphnia* exceeded the mortality rates by trout, the *Daphnia* population decreased instead of increased. This implies that there are other relevant sources of mortality for *Daphnia*.
Key Conclusions	
• Trout predation of *Daphnia* inhibited a spring clear-water phase following autumn stocking, but not following spring stocking. • *Daphnia* mortality from trout predation was essentially irrelevant to the *Daphnia* population once it had reproductive momentum (that is to say, the reproductive rate of *Daphnia* exceeded the mortality rate). • The high reproductive rates of *Daphnia* observed in spring stocking years not only resulted in a spring clear-water phase, but also maintained the size of the trout population later into the summer.	• The harvest rate of rainbow trout was estimated to be only 9.3% based on the creel surveys. The low harvest rate could be due to either low fishing pressure and/or poor survival of the stocked trout. Harvested trout were of similar size to stocked trout indicating that growth rates were low and the trout may have been food-limited. • The period of most rapid decline in trout population from early May to early June occurred when trout harvesting by anglers was prohibited by the special regulation, supporting the idea that trout experienced mortality from a source other than angling during that period. • No evidence that the change in fisheries management from autumn and spring stocking in 2003-2004 to spring stocking only in 2005 significantly affected average water clarity or average surface water phytoplankton concentrations. • This study does not implicate rainbow trout predation as the controlling force on *D. pulicaria* population. Trout predation does contribute to *D. pulicaria* mortality but the food web of Square Lake is complex and requires a more holistic analysis of *Daphnia* predation.

Table 2 (continued). Comparison of the 1996-1999 Long Lake & 2003-2005 Square Lake Studies

1996-1999 Long Lake Study	2003-2005 Square Lake Study
Key Differences	

- Long Lake has a smaller surface and littoral area but greater maximum depth and volume than Square Lake. In general, Long Lake is longer, skinnier, and deeper than Square Lake.
- The spring stocking only manipulation in Long Lake occurred over 2 years compared to just one year in Square Lake.
- In Square Lake, the predator-prey linkage between rainbow trout and *Daphnia* is weaker and the food web more complex compared to Long Lake, because:
    - Stocking levels in Square Lake are substantially lower than in Long Lake.
    - Trout in Square Lake were not obligate predators of *Daphnia* (meaning *Daphnia* is their ONLY food source) at all times of year like they were in Long Lake.
    - In Square Lake, other sources of *Daphnia* mortality were often more important than trout-induced mortality, such as disease or predation from other species (bluegill sunfish and/or *Chaoborus* larvae).

Note that the subsequent 2012 Square Lake CWP study concluded:

- *D. pulicaria* abundances declined to very low levels (< 0.5 per liter) by late July and they were less abundant in 2010 than in 2004-2005.
- Rainbow trout ARE the primary predators of *Daphnia* in Square Lake based on a more comprehensive stomach content analysis of fish species:
    - Rainbow trout consume the most *D. pulicaria* per capita of any of the fish species examined in the study.
    - Only relatively large (> 15 cm) bluegill sunfish consume *Daphnia*, and most of the *Daphnia* they consume are the smaller-bodied species.
    - None of the species of small fish (minnows, shiners, killifish) were found to consume *Daphnia*.
    - Chaoborus larvae were scarce in 2010 compared to 2004-2005.
- An interaction between the earlier onset of summer stratification (due to climate change) and predation on *D. pulicaria* by rainbow trout during winter-early summer is responsible for the marked decline in the water clarity of Square Lake.
    - Low oxygen levels in the deeper waters began to restrict the habitat space for *D. pulicaria* in early June and severely limited their 'refuge zone' later in the summer.