

**DRAFT**  
**Diamond Lake Management Plan**  
**Oregon Department Fish and Wildlife**  
**Umpqua Watershed**  
**2009**

**Introduction:**

Diamond Lake is a natural lake located about 80 miles east of Roseburg in the Cascade Mountains. Originally fishless, the lake has been stocked with rainbow trout (*Oncorhynchus mykiss*) since 1910. Although Diamond Lake lacks adequate spawning habitat to sustain a trout population, the lake is very productive and once trout are introduced the growth rates and survival of the trout are exceptional. Consequently Diamond Lake has been recognized for decades as a premier fishery. Unfortunately this fishery and the lake's ecosystem have been disrupted twice by the invasion of tui chub (*Gila bicolor*). Rotenone was used in 1954 and 2006 to eradicate the chub and restore the fishery and the quality of the lake. The *Diamond Lake Restoration Project Final Environmental Impact Statement (FEIS)* which was adopted in 2004 was used to select a treatment for the lake and recommend post-treatment activities. Per the FEIS, after treatment the ODFW would develop an ecologically sound stocking strategy and new management plan when sufficient information was available for managing the fishery. According to the FEIS (2004) the decision process would take into consideration, "the environmental, biological, economic, and community values of the people of Oregon."

Diamond Lake has operated under various management plans and management directives since 1990. The 1990 plan (635-500-0703) was for hatchery production under the Basic Yield alternative of Oregon's Trout Plan. The plan noted that the lake averaged 100,000 angler trips per year, had an average harvest of 2.7 trout per trip, and was annually stocked with about 400,000 fingerling trout. As the fishery declined due to the increasing chub population, management directives allowed the department to switch to an experimental stocking program which used various legal and trophy sized stocks of trout to try to maintain the fishery. Angler numbers dropped to a low of 6,000 and averaged only 22,400 trips per year from 1994 – 2006 prior to treatment. Post-treatment, the lake has been under a modified stocking strategy per the FEIS. This 2009 plan would fulfill the agreement to develop a management plan. This proposed plan could modify the existing plan and would still be for option (1)(c) of OAR 635-007-0525--"manage for hatchery fish," under the Basic Yield alternative (635-500-0115).

**Overview:**

Diamond Lake sits in the Cascade Mountain Range at an elevation of 5,191 feet and is part of the Umpqua National Forest. Diamond Lake is fed by three perennial and six intermittent streams and is approximately 3.5 miles long and 1.5 miles wide. It drains to the North Umpqua River via Lake Creek and Lemolo Reservoir. Diamond Lake's water level and flow into Lake Creek is managed by a weir at the mouth of the outlet. The old weir was replaced in 2005 in preparation for drawing the lake down for the 2006

treatment. The ODFW has a water right for Diamond Lake and is responsible for maintaining the water level of the lake. During the summer, Diamond Lake stores 5,800 acre-feet of water (permit R-7734, S-4367, S-7800).

Diamond Lake is surrounded by gently sloping forested terrain except for the steep, rocky shoreline on the north end of the lake and the marshy portion of the southern shoreline. Diamond Lake is managed by the U.S. Forest Service (USFS) as a “Special Management Area: MA-2.” Consequently, the area is managed for concentrated developed recreation such as resort use, camping, picnicking, boating, fishing, interpretation, and winter sports. A special use permit allows a main resort and marina on the northeast end of the lake and a pizza parlor/store on the south end. There are also three campgrounds around the lake and five boat ramps (Figure 1). On the west side of the lake there are approximately 100 private cabins leased by the USFS as summer homes.

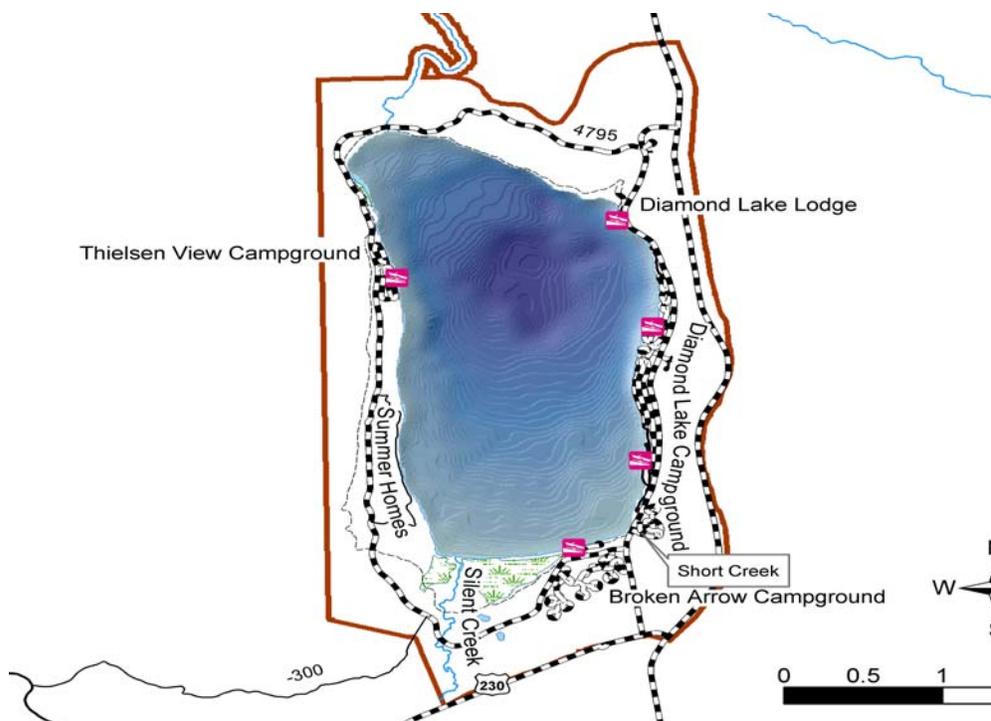


Figure 1. Diamond Lake and associated recreational use areas (FEIS 2004).

### **Fishery Economics:**

Diamond Lake is categorized as a high use destination recreation area of significant economic benefit to southern Oregon by the United States Department of Agriculture (USDA). Open to camping and fishing from late April through October, then snowmobiling, cross country skiing and tubing during the winter, the area attracts a variety of recreational users. From 1962 – 1978 the lake attracted 70,500 to 139,500 angler trips per year and averaged 109,800 trips. After chub were discovered and the water quality and trout growth/survival declined, angler numbers dropped to a low of 6,000 and averaged only 22,400 trips per year from 1994 – 2006. The experimental

stocking program that was implemented during this time to attract anglers was expensive and focused on the release of legal and trophy-size trout. The 2004 FEIS noted that the reduction of angler trips caused a loss of \$4.9 million in annual sales and \$1.4 million in labor income in the area (Douglas, Jackson and Klamath counties).

The first year post-treatment (2007), Diamond Lake attracted 72,085 angler trips and generated an estimated \$3.76 million dollars in sales and \$2.57 million in labor income in the area based on the 2006 value of the dollar. In 2008, due to a late ice off (Memorial Day weekend), high gas prices and road closures due to fire, the number of angler trips decreased to 41,330. The 2004 FEIS had predicted stabilizing at 100,000 angler trips per year. Given the current economy and current angler participation rates, angler trips may range from 65,000 to 85,000 per year. This would still have positive impact on the local economy.

### **Lake Ecology and Tui Chub Impacts:**

Since 1910, when trout stocking began in Diamond Lake, tui chub populations have exploded twice and were subsequently eradicated in 1954 and 2006. During chub invasions, trout survival and growth rates declined. Monitoring conducted between 2001 and 2006, while the chub population was expanding, showed an increase in blue-green algae *Anabaena spp.* phytoplankton cells, an increase in pH, high internal nutrient loading, a decrease in water clarity, and a decrease in benthic organisms. The lake was listed on the Oregon DEQ 303 (d) list for not meeting water quality standards. *Anabaena* blooms led to human health concerns that initiated three health advisory “no water contact” closures and two warnings. At times pH exceeded 9.5 which was above the 6.5 to 8.5 levels preferred by salmonids. High phosphorous levels and internal nutrient loading was believed to be caused by the sheer number of tui chub in the lake—over 95 million. The chub also grazed heavily on the phytoplankton, zooplankton, and benthic organisms—disrupting natural food webs and depleting the food resources of the lake. The pounds of benthic organisms per acre dropped from a 1955 to 1979 average of 115.4 lbs/ac (range 54.7 – 188.0) to less than 25 lbs/ac between 2004 and 2006. Trout growth rates declined to the point that fingerling stockings were no longer a viable option for maintaining a fishery. The condition factor (ratio that relates fish length and weight to indicate the relative “plumpness”) of the trout dropped from an average of 1.43 during 1960 to 1991 (range 1.23 – 1.89), to 1.04 from 1992 – 2004 (range 0.87 – 1.23).

During September 2006, all fish were eradicated from Diamond Lake during the rotenone treatment. Approximately 34 tons of chub were removed from Diamond Lake prior to treatment and 17.4 tons of fish were removed post-treatment in an attempt to minimize some of the potential nutrient loading caused by decaying fish carcasses. Eradicating the chub lowered the internal nutrient loading occurring in the lake.

### **Fishery Management: 2007 – 2008 Post-Treatment Stocking & Lake Recovery:**

Fish stocking resumed in spring of 2007. In planning for the stocking, ODFW wanted to avoid high internal nutrient loading, minimize pressure on zooplankton, and still provide an attractive fishery. To address these issues, the number of fish stocked was very conservative especially considering the number of chub which used to occupy the lake.

The number of catchable-sized trout stocked in 2007 and 2008 was approximately 85,000 (Table 1). All of the fish except the 2008 Fish Creek stock were legal to trophy sized and immediately available to anglers for harvest.

The fingerling stocking was delayed until mid-June. This provided the zooplankton community more time to rebound before receiving any grazing pressure from the fingerlings. The number of fingerlings stocked was far less than the 93 million tui chub <132 mm in length that once occupied the lake. Generally trout 125 mm or greater in length will switch from a zooplankton diet to a benthic diet. Delaying the fingerling stocking also meant that the fingerlings were already 90 – 100 mm at the time of stocking. With an estimated growth rate of two inches per month, the fingerlings would switch to a benthic diet in less than a month, further reducing grazing pressure. These growth rates were verified by creel data and trap nets set in July and October.

Table 1. Type of rainbow trout, stocking dates, size and number stocked in Diamond Lake during 2007 and 2008.

| Type of Trout      | 2007: Stocking Dates        | Number Stocked | Size (# per lb)      |
|--------------------|-----------------------------|----------------|----------------------|
| Oak Springs (53)   | 6/12 – 13/2007              | 100,010        | Fingerling (46/lb)   |
| Cape Cod (72T)     | 4/26 – 6/9/2007             | 21,619         | Legal (2.7/lb)       |
| Trout Lodge (103T) | 5/4 – 5/23/2007             | 51,075         | Legal (1/lb)         |
| Cape Cod (72T)     | 5/2 – 5/10/2007             | 3,619          | Trophy (0.2/lb)      |
| Eagle Lake (171)   | 9/18/2007                   | 6,593          | Legal (1.6/lb)       |
| Fish Creek (551)   | 6/12/2007                   | 1,547          | Legal (2.3/lb)       |
|                    | <b>2008: Stocking Dates</b> |                |                      |
| Oak Springs (53)   | 6/10/2008                   | 200,100        | Fingerling (43.5/lb) |
| Oak Springs (53)   | 8/12/2008                   | 6,005          | Legal (3.3/lb)       |
| Trout Lodge (103T) | 5/19 – 6/10/2008            | 50,942         | Legal (1/lb)         |
| Eagle Lake (171)   | 7/24/2008                   | 14,805         | Legal (3/lb)         |
| Fish Creek (551)   | 5/30 & 8/19/2008            | 7,807          | Sub-legal (4.5/lb)   |
| Oak Springs (53)   | 5/30/2008                   | 6,227          | Trophy (0.64/lb)     |

A similar strategy was used for 2008 (Table 1). Additionally, data on the benthic community, *Anabaena* cell counts, transparency, pH, zooplankton, trout growth rates & condition, plus number of angler trips became available. With the stocking noted above, and data for two years post-treatment, the following has been observed:

- During sampling in October, benthic organisms increased from <25 lbs/ac in 2004 – 2006; to 200.6 lbs/ acre in 2007 and 168 lbs/acre in 2008.
- *Anabaena* cell counts dropped from >20,000 cells/ML in 2006 to well below human health concerns in 2007 and 2008.
- Water clarity as measured by secchi disk depth readings increased from a pre-treatment mean of 1.62m in 2006, to a mean of 6.38m in 2007 and 6.35m in 2008.
- pH went from a mean of 8.5 in 2006 to a mean of 7.6 in 2008.
- The number of edible zooplankton increased post treatment.

- Trout growth rates were similar to the “heydays” of the 1960s, 1970s and 1980s. In 2007 and 2008, fingerlings started being legal sized in August, were about 11 inches long by October, and their condition factors went back up to 1.3 – 1.5.

Golden shiners (*Notemigonus crysoleucas*) were discovered in Diamond Lake during a routine trap net survey done in July 2008. The ODFW subsequently removed a total of 639 shiners during the remainder of the summer via trap nets and electro-shocking. Due to the size of the shiners captured and the lack of any young-of-the-year, it is believed the shiners were placed into the lake after the 2006 rotenone treatment. This theory is being tested by otolith (ear bone) analysis of shiners collected at Diamond Lake versus shiners sold at bait shops. If both sets of shiners have the same chemical isotopes in their otolith, it would confirm that shiners from Diamond Lake originated from bait shop stock.

Shiners were also illegally introduced into Diamond Lake in 1977 after the 1954 rotenone treatment. Shiner populations never accelerated like tui chub, and the trout fishery, benthic organism density, and trout condition factors remained healthy even after their discovery. Although it is difficult to predict whether or not shiners would have a negative impact this time, Moyle (2002) noted shiners are less successful in establishing large populations in natural lakes and streams than in reservoirs. Predation in natural situations appears to be more limiting than in reservoirs (Moyle 2002). The Eagle Lake trout were stocked into Diamond Lake in 2007 and 2008 in order to provide a piscivorous predator that could prey on shiners in the lake. Eagle Lake trout originated from California and are known to prey on tui chub; therefore it is likely that this stock of trout may prey on available shiners. Eagle Lake stock trout were stocked in Diamond Lake as part of the modified stocking plan for post-treatment invasive species prevention. The stock of trout from Fish Creek is another stock being tested in Diamond Lake to see if they have the potential to suppress shiner populations. Diet studies are in progress at Diamond Lake to evaluate level of fish predation.

### **Diamond Lake Fish Management Strategies:**

The 2009 draft Diamond Lake Management Plan proposes to maintain Diamond Lake as a Basic Yield, hatchery trout fishery but also includes new elements such as management direction for prevention of illegally introduced invasive species, and actions to limit ecological impact of invasive species if found in the lake. This Basic Yield management alternative would be a low cost, effective, family-oriented fishery similar to the successful fishery of the 1960s, 1970s and 1980s prior to the last chub invasion.

Per the OARs guiding this trout management alternative, the primary management components are:

- fingerling stocking will provide the major fish production for the lake;
- the fishery would be of a consumptive nature without special regulations, and
- the productive capacity of the waters will be maintained or enhanced.

The ODFW will use an accounting-type model to evaluate stocking rates, survival, and harvest to evaluate potential impacts and avoid internal nutrient loading or stress to the food chain. The ODFW will also look at parameters such as benthic organism densities,

pH, water clarity, dissolved oxygen (DO), fish health, and fish numbers to help maintain the lake's productivity and health.

**Implementation:** Balance stocking to meet recreational fisheries goals and lake health goals:

- Stock fingerling trout for the primary fishery production program. Adaptive management will be used for setting stocking rates but the number could range from 0 to over 400,000 fingerlings. Stocking rates or the size of trout at stocking will be based on trout harvest, trout growth rates and condition factor, and modeling outputs. Information from monitoring and evaluation of lake health parameters such as DO, pH, water clarity, and benthic organism density will also be incorporated into stocking decisions when data is available.
- Delay fingerling stocking until mid-June or later if necessitated by a late ice off.
- Allow for the option of stocking legal sized or trophy trout if desired to enhance recreational opportunity or if necessary to balance the lake's ecosystem.
- Encourage 50,000 – 100,000 angler trips per year with a harvest high enough to avoid stressing the lake's ecosystem (approximately 200,000 to 270,000 trout per year, depending on stocking numbers).
- Periodically stock predacious trout to limit the expansion of invasive fish species.
- Continue working with the Diamond Lake/SW Oregon Invasive Species Prevention Committee to conduct invasive species education, monitoring, and enforcement activities. Activities include: interpretive brochures and signs, surveys, boat checks, working with tournaments on prevention measures, and law enforcement support. Monitoring activities include trap netting, electroshocking, visual observations and public contact.

**Management Considerations:**

With a delayed stocking the fingerlings would switch to a benthic diet in less than a month, reducing pressure on zooplankton communities. Due to their fast growth rate, the fingerlings would also out-grow the size preferred by predacious fish within a month. Fish such as golden shiners will generally be less than five-inches long for over a year and thus will be more available for consumption. Unfortunately stocking the lake with predacious fish could encourage some people to illegally fish with live bait fish. To counter this, invasive species education and law enforcement efforts should continue.

By using the accounting model, stocking rates can be balanced with harvest rates to avoid stressing the lake's ecosystem. The goal is to have harvest nearly equal the number of one-year old fish available to avoid internal nutrient loading or stress to the food chain. For example data from the 1960s, 1970s, and 1980s showed that both the lake and the fish were healthy when approximately 400,000 fingerlings were stocked per year, 70% of the fingerlings survived to be one year old (280,000 trout = 92 lbs of fish/surface acre), and there were about 100,000 angler trips per year with an average harvest of 2.7 fish

(270,000 trout = 89 lbs of fish/surface acre). Approximately 280,000 fish were available and 270,000 fish harvested and the poundage of trout leftover in the lake at the end of the season was <100 lbs/surface acre. Thus by modeling the number of fish stocked, survival, harvest, and the number/pounds of fish leftover, the model can predict whether or not stocking rates need to be adjusted to reach an equilibrium.

For example, Figure 2 shows the end of season balance based on data from the number of fish stocked and harvested in 2007 and 2008. In 2009 the model values were 350,000 fingerlings stocked and 200,000 fish harvested. From 2010 on, 400,000 fingerlings were stocked per year. Harvest values inputted in the model for the “Inc. Harvest” scenario go from 200,000 fish in 2010, to 250,000 in 2011, and stabilize at a harvest of 270,000 from 2012 on, which is similar to historic harvest rates. The end of season lbs of fish/surface acre remains below 100 lbs/acre in this example. However, if the same stocking was used, but only 200,000 trout were harvested the “Stay 200,000” line exceeds 100 lbs/surface acre by 2014. Conversely, a stocking of 300,000 fingerlings per year could not sustain a harvest of 250,000 trout.

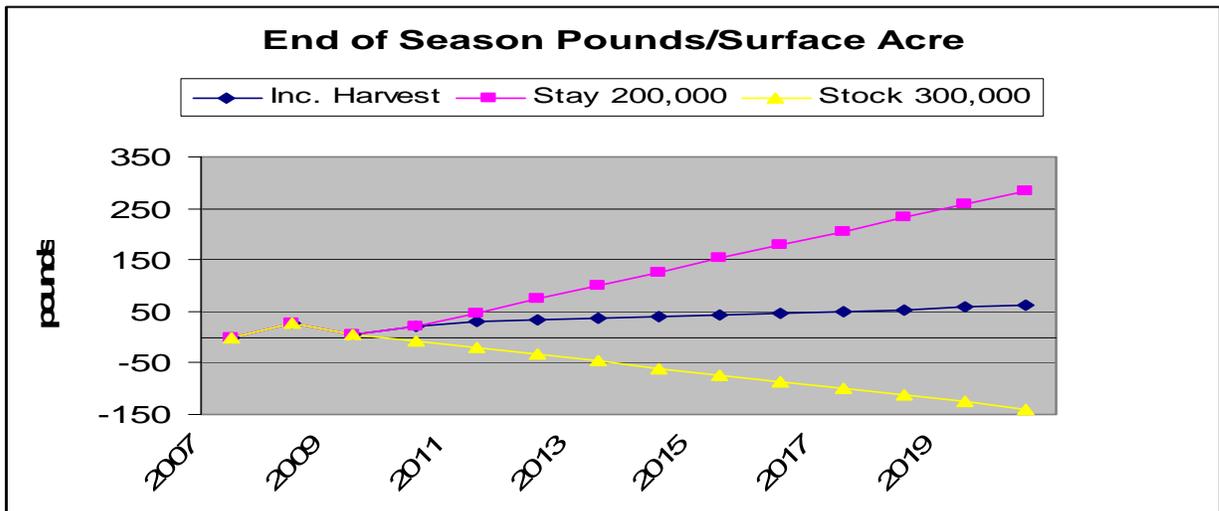


Figure 2. Accounting Model to evaluate stocking, harvest and end of season pounds of trout.

In addition to the accounting model the ODFW is also working with the Oregon Department of Environmental Quality (DEQ) and the U.S. Environmental Protection Agency (EPA) to potentially develop a biological model to help evaluate biological interactions, guide stocking and predict water quality.

**Fishery Community and Recreational Fishery Monitoring.**

ODFW will annually assess fish populations in Diamond Lake, including species composition, abundance, fish health and productivity (growth rate, condition factor). The recreational fishery will also be monitored as funding and staffing are available in order to determine harvest rates, angler catch rates, angler demographics, and angler opinions and attitudes on the Diamond Lake trout fishery.

## Summary

The 2009 Diamond Lake Management Plan seeks to balance a Basic Yield, recreational hatchery trout fishery with the ecosystem of Diamond Lake. Historically, from 1960 to 1991, the condition factor of the trout averaged 1.43, benthic density averaged 115.4/acre (1955 – 1992), the lake was known for its clarity (anecdotal) and *Anabaena* levels were below human health concerns. The growth rate of the trout during this time suggests that phytoplankton, zooplankton, and benthic communities were healthy enough to support an annual stocking of 400,000 fingerlings with a harvest of about 270,000 trout. This plan would seek to achieve a similar fishery, but provides a cautious fish stocking approach and additional conservation measures to help maintain the various trophic communities and predict conditions to continue to maintain both the fishery and the ecosystem.

## Literature Cited

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