NATIVE FISH RESTORATION IN THE NORTH CREEK DRAINAGE: 2019 ACTIVITIES

Michael J. Hadley
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February 2020

Utah Division of Wildlife Resources
Southern Region

Introduction

North Creek is one of the primary tributaries of the Escalante River and drains the southwest slope of Boulder Mountain (Figure 1). North Creek and its tributaries upstream of North Creek Reservoir contain up to 15.5 miles (25 km) of potential trout habitat. This upper drainage is found within the Dixie National Forest (DNF) Escalante Ranger District. Tributaries that are known to sustain trout include White Creek and Twitchell Creek. Limited historic surveys have found no fish in West Fork North Creek, though more extensive sampling is needed to fully assess its suitability as fish habitat. North Creek is seasonally dewatered below North Creek Reservoir and surveys by both Utah Division of Wildlife Resources (UDWR) and DNF have found that this reach provides only seasonal or intermittent habitat for trout. Stream temperature and flash floods from side canyons limit trout occupation in lower North Creek, while native speckled dace are abundant. Eleven lakes, reservoirs, and ponds in the headwaters of the basin also sustain trout populations (Fig. 2). Stocking of nonnative trout – including rainbow, cutthroat, and brook trout – was documented as early as the 1940s in the North Creek drainage and likely occurred even earlier. Over time, nonnative trout expanded and replaced native Colorado River cutthroat trout (CRCT) throughout much of the drainage. Stocking of fertile rainbow and brook trout continued in several of the lakes into the mid 2000s.

General plans for CRCT restoration and conservation in Utah were formalized in the state's conservation agreement and strategy (Lentsch and Converse 1997), followed by a rangewide agreement and strategy in 2006 (CRCT Conservation Team 2006, CRCT Coordination Team 2006). Benefits of and needs for CRCT restoration and conservation in the Escalante River drainage were identified by UDWR in a drainage management plan (Ottenbacher and Hepworth 2003). BCT conservation efforts in the Lower Colorado River Geographic Management Unit (GMU) – which encompasses the Fremont and Escalante river drainages – are coordinated and completed by a cooperative interagency team, with representatives from UDWR, Fishlake National Forest (FNF), DNF, Bureau of Land Management (BLM), and Trout Unlimited (TU). This team acts as a subset of the range wide CRCT Conservation Team.

Remnant CRCT were first discovered in the Lower Colorado River GMU in the mid 1980s, in East Fork Boulder Creek (Hepworth et al. 2001, 2002). This discovery prompted extensive searches for CRCT throughout the Escalante River drainage, eventually yielding an additional six populations between 1990 and 2011 (Hadley et al. 2014). One of those was discovered in North Creek tributary White Creek in the late 1990s (Hepworth et al. 2001). The White Creek population was isolated from nonnative trout by a natural cascade barrier and was found to be genetically pure (University of Montana unpublished analysis 2001, Evans et al. 2013). Two fish passage barriers were constructed in lower White Creek in 2000 and nonnative trout were removed from the lower 0.3 mile (0.5 km) of stream in 2001. Nonnative trout were discovered in and removed from the reach between the constructed barriers during the mid 2000s, prompting a retrofitting of the lower barrier with a concrete splash pad that removed the plunge pool and prevented reinvasion.

CRCT were transferred from the east and west forks of Boulder Creek to Dougherty Basin Lake in the North Creek drainage from 1997 to 1999 to establish a wild brood population that would support the conservation and restoration of CRCT in southern Utah, as well as provide fish for sport fish stocking. The Boulder Creek populations were identified as pure CRCT both by meristic and genetic analyses (Behnke 1992, Shiozawa and Evans 1994, Hudson

and Davis 2002, Thron and Miller 2002, Shiozawa and Evans 2011). The brood established in Dougherty Basin Lake and the connected Tall Four Reservoir has produced fertilized CRCT eggs since 1999. This two-lake system is isolated from the rest of the North Creek drainage by sinkholes and subsurface flow. Efforts to improve the genetic diversity of the Dougherty Basin brood began in 2014 with the introduction of CRCT from remnant populations in White Creek and Pine Creek, as well as additional transfers from Pine Creek in 2017 and 2018 (Hadley 2019). Spawning efforts have documented contribution from each of these transferred groups to the brood, though the White Creek population has contributed far less due to limited numbers of CRCT available for transfer. The Pine Creek remnant was identified as pure CRCT by Toline et al. 1999, Evans and Shiozawa 2005, and Evans et al. 2013.

As a joint effort of the Boulder Mountain Sport Fish Enhancement Project and CRCT conservation, nonnative trout were removed from Twitchell Creek and it headwaters lakes – Long Willow Bottom and Round Willow Bottom reservoirs – in 2001 and 2002 (UDWR 2000, Hadley and Hepworth 2013). One fish barrier was constructed in lower Twitchell Creek to prevent reinvasion from North Creek, while a natural barrier acts as security in the case of passage over the constructed barrier. The reach between the two barriers was treated again in 2006 to remove brook trout that had bypassed the constructed barrier. The barrier was also retrofitted with a concrete splash pad. CRCT produced by the Dougherty Basin brood were introduced to Twitchell Creek after 2002 and are stocked annually – along with sterile tiger trout – in the headwater reservoirs. The stream has maintained self-sustaining CRCT population for over 15 years (Hadley et al. 2014).

Beginning in the late 2000s, rainbow and brook trout stocking in the North Creek lakes was converted to triploid fish. This change was intended to help facilitate a potential future restoration of CRCT in North Creek. Focus on CRCT expansion in the Boulder Creek drainage delayed any further efforts in North Creek for over 10 years. The Boulder Creek project was indefinitely postponed in 2019, however, allowing for a shift in CRCT conservation to other drainages. North Creek was considered a high priority for restoration due to the presence of an assumed barrier (North Creek Reservoir dam), the Dougherty Basin brood, two current CRCT populations, and the previous shift to sterile sport fish stocking. North Creek and its headwaters represent up to 10 mi (15.7 km) of additional CRCT habitat and would provide a location for further combination of CRCT remnants from White Creek, Boulder Creek, and Pine Creek. This report summarizes preliminary efforts to restore CRCT in North Creek conducted in 2019.

Methods

Pathogen Testing

Thirty brook trout were collected from North Creek just upstream of its confluence with Twitchell Creek in May 2019 and submitted to the Fisheries Experiment Station (FES) for testing of infection by *Myxobolus cerebralis*, the parasite that causes whirling disease. Such testing is regularly conducted prior to native trout restoration.

Barrier Evaluation

The North Creek Reservoir dam, spillway, and outlet were inspected visually during summer 2019 to determine their suitability as barriers to upstream fish passage.

Brook Trout Removal

Besides North Creek itself, three other waters in the drainage are known to harbor self-sustaining populations of brook trout – Dougherty Basin Lake, Blue Lake, and Upper Barker Pond. The latter two waters were treated with rotenone in 2019 to remove fertile brook trout. Blue Lake is a 1.6-acre natural lake fed by multiple seeps and springs, with no outlet (Fig. 2). Upper Barker pond is a historic beaver pond covering 0.2 acre. Some of the spring sources for this pond presumably are fed by the sinkholes that drain Tall Four Reservoir. The outlet of Upper Barker Pond feeds into Barker Reservoir. The springs and inlet streams of both waterbodies provide ample spawning habitat for brook trout.

Liquid rotenone (5% active ingredient) was applied to target waters in Upper Barker Pond and its tributary springs on August 12 and September 16, 2019, with a target concentration of 1.5 parts per million (ppm). Rotenone was applied to the pond using backpack sprayers and to spring sources with 7-gal (4-hr charge) drip barrels (Fig. 3). Drips were reduced and combined for the second treatment because no fish were observed in the spring channels during the first. The grassy portions of the spring inlets were also sprayed. Rotenone applied by drip stations was subtracted from the total needed to treat the pond volume to avoid elevating concentration over 1.5 ppm and overwhelming the detox station.

Potassium permanganate ($KMnO_4$), an oxidizing agent, was applied to toxic waters at a constant rate using an auger-hopper system to deactivate the rotenone below Upper Barker Pond. The detox station was set just upstream of Barker Reservoir and well below a head cut barrier that would prevent reinvasion of the pond (Fig. 3). Sentinel fish (brook trout electrofished from the stream prior to the treatment) were placed in a live cage upstream of the detox station to monitor rotenone arrival.

Liquid rotenone was applied to Blue Lake and its tributary springs on August 13, 2019, with a target concentration of 1.5 ppm. Rotenone was applied to the lake using backpack sprayers and to spring sources with 7-gal (4-hr charge) drip barrels (Fig. 4). Spray crews used a raft to apply to areas not reached from shore. The grassy portions of the spring inlets and lakeshore were also sprayed. Rotenone applied by drip stations was subtracted from the total needed to treat the lake volume to avoid elevating concentration over 1.5 ppm. Because the lake has no outlet, detox was not necessary.

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FES reported no evidence of *M. cerebralis* in the brook trout collected from North Creek.

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Due to the historic high snowpack of 2019, North Creek Reservoir spilled over for most of the summer, allowing for observation of water activity over the spillway. The spillway and outlet were determined to be suitable barriers to upstream fish passage.

Brook Trout Removal

Table 1 lists personnel that participated in the treatments of Upper Barker Pond and Blue Lake, with assigned tasks. Rotenone was applied to Upper Barker Pond during the afternoon of August 12. Limited numbers of brook trout were observed dying in the pond just a few hours after application started at about 1:00 pm. A total of 0.48 gal (62 ounces; 1.83 L) of rotenone was applied (Table 2) by six crew members – 26 oz by drip stations and 36 oz by sprayers.

Application of $KMnO_4$ began at 1:00 pm on August 12. Sentinel fish set above the detox station indicated that lethal concentration of rotenone arrived at 3:15 pm, 2.25 hours after application began. Detox operations continued until 1:30 pm on August 13. The oxidizer was applied at a mean rate of 24.8 g/min for 23.75 hours. An estimated 77.8 lbs (35.3 kg) of $KMnO_4$ were applied at the detox station (Table 2).

A second application of rotenone was conducted in Upper Barker Pond on the afternoon of September 16, 2019. No fish were observed after this treatment, indicating that the initial treatment in August was successful in removing brook trout. Once again, 0.48 gal of rotenone was applied (Table 2) by three crew members, though only 20 oz of the total was applied by drips this time because the number of drip stations was reduced. Detox operations began at 12:30 pm and rotenone arrived there at about 2:00 pm about 3 hours after rotenone application began. $KMnO_4$ was applied at a mean rate of 22.7 g/min for 23.5 hours, until 12:00 pm on September 17. An estimated 70.5 lbs (32.0 kg) of $KMnO_4$ were applied at the detox station during the second treatment (Table 2).

Rotenone was applied to Blue Lake during the morning of August 13. Brook trout were observed dying in the lake within a couple hours after application started at 7:40 am. A total of 3.0 gal (11.4 L) of rotenone was applied (Table 2) by six crew members – 0.3 gal by drip stations and 2.7 gal by sprayers. Electrofishing in the main inflow stream found no fish upstream of Drip 3, which allowed for the elimination of all drips above that station (Fig. 4). The lake level had also dropped since the reconnaissance survey, so Drips 7 and 8 were combined where the seep channels met. No complications were experienced during the treatment.

Discussion

Activities conducted in 2019 helped to complete preliminary work for future native fish restoration the North Creek drainage. These activities primarily focused on eliminating two of the last three known refuges of fertile brook trout in the headwater lakes. Following successful eradication, a limited number of tiger trout were stocked in Upper Barker Pond in fall 2019 to provide sport fish opportunity. It is also recommended that a small number of CRCT be transferred from Pine Creek to the pond in 2020 in order to assess the spring sources' suitability for cutthroat spawning. Blue Lake will be treated a second time in June 2020, after which tiger trout will be stocked annually.

The documented presence of fertile brook trout upstream of Barker Reservoir in 2019 increases the likelihood that fertile fish may still be found in some of the North Creek lakes, despite the switch to triploid stocking more than a decade ago. Brook trout should be collected from Barker, Lower Barker, and Joe Lay reservoirs in 2020 and tested for ploidy. Inlet streams of Lower Barker and Joe Lay reservoirs should also be electrofished to collect more fish. Based on the results of these tests, further CRCT restoration activities in the North Creek drainage may include treatment of up to three of these lakes. Nonnative fish removal is not anticipated to resume until 2021, at the earliest.

Brook trout have maintained a low-density population in Dougherty Basin Lake for many years. Unfortunately, trapping efforts during recent years have found an increase in brook trout abundance, possibly from just one or two strong cohorts (Hadley 2019). A limited effort was made to catch, by angling, and remove brook trout from Dougherty Basin Lake during September 2019. Numerous brook trout were both caught and observed during this effort. The brood operation at Dougherty Basin makes chemical removal of this population unfeasible at this

time, though their persistence poses a threat to both the brood itself and the North Creek drainage. Although Dougherty Basin is isolated from North Creek and its tributaries, fertile brook trout can still be illegally transferred by anglers to other connected waters. The best way to avoid this type of invasion is to completely remove fertile fish from the area. Attempts will be made to mechanically remove brook trout from Dougherty Basin Lake in the coming years, with the goal of reducing density and potential competition with CRCT brood. Chemical removal may be possible in the future due to the development of a captive CRCT brood (Hadley 2019), though implementation would depend on the need for replacing brood with wild egg takes at Dougherty Basin.

Another small pond located between Upper Barker Pond and Tall Four Reservoir was known to contain fertile brook trout in the mid 2000s. This pond was filled by overflow from Tall Four, then drained through sinkholes and subsurface flow to Upper Barker Pond. Observation of the pond in 2019 found no fish, but did find evidence of the pond being dry in recent years. Young aspens and terrestrial grasses were prevalent in the pond bottom, indicating that the basin had only recently been flooded. This condition is likely explained by a sinkhole that formed in the shoreline of Tall Four Reservoir during the last 10 years. The hole apparently allowed water to bypass the outlet pond, yet still reach the springs feeding Upper Barker Pond. Although the hole was seen as a detriment to Tall Four by dropping the water level multiple feet and reducing CRCT habitat, it actually served a beneficial purpose as well by eliminating brook trout from the outlet pond. The hole was plugged by concrete in fall 2018, which allowed Tall Four Reservoir and the outlet pond to fill completely in spring 2019.

While the North Creek project has so far focused on CRCT, other native fish species should also be considered for restoration. Speckled dace are common in North Creek below North Creek Reservoir, despite conditions that limit trout. This population should provide ample fish for transfer upstream of the reservoir following nonnative fish removal. Mottled sculpin may also be restored from nearby populations in Boulder Creek. More extensive surveys should be conducted in the lower reaches of North Creek to assess current occupation by nonnative trout and potential habitat for additional native species (sculpin, flannelmouth sucker, roundtail chub).

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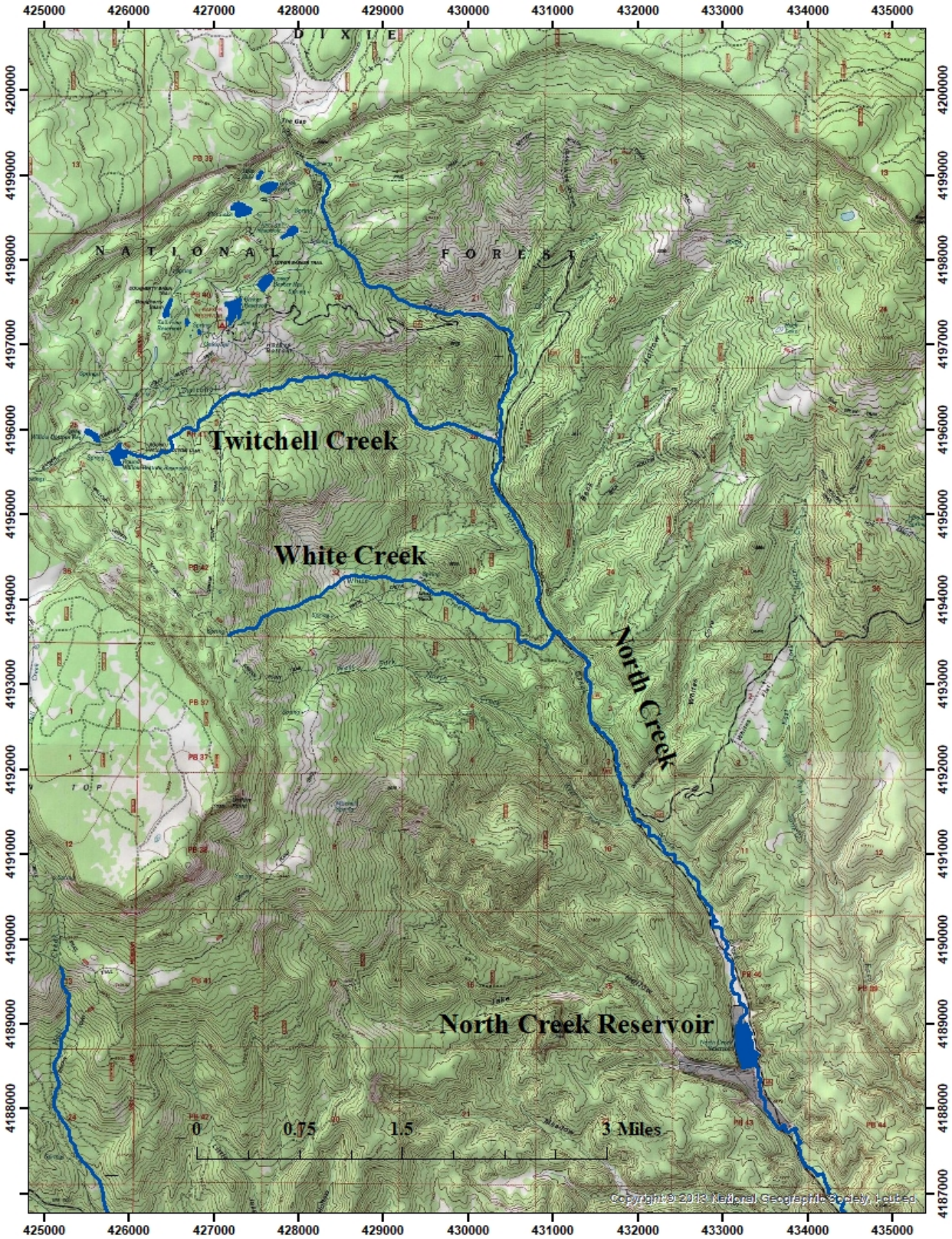

Figure 1. North Creek drainage.

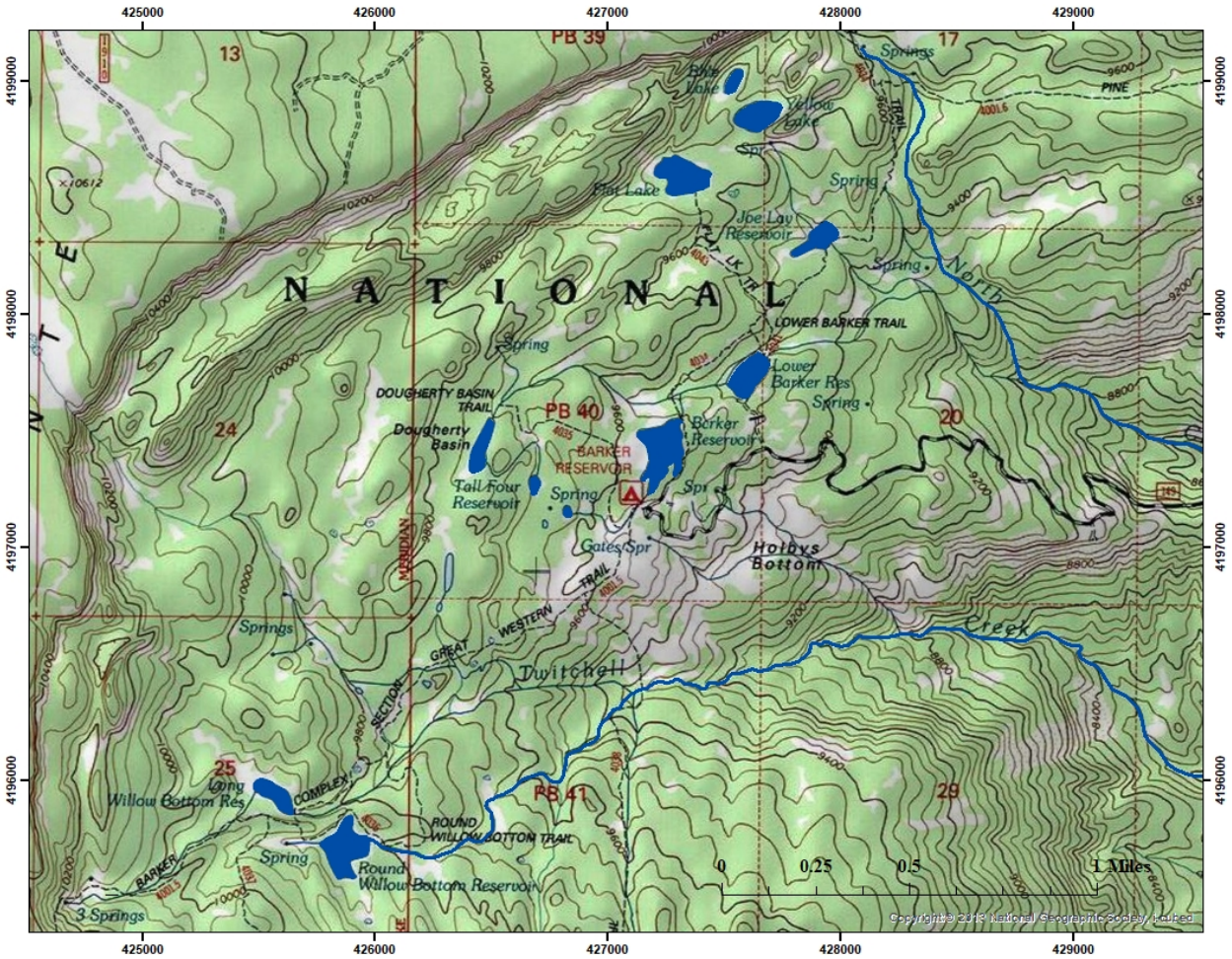

Figure 2. Lakes, reservoirs, and ponds of the North Creek headwaters.

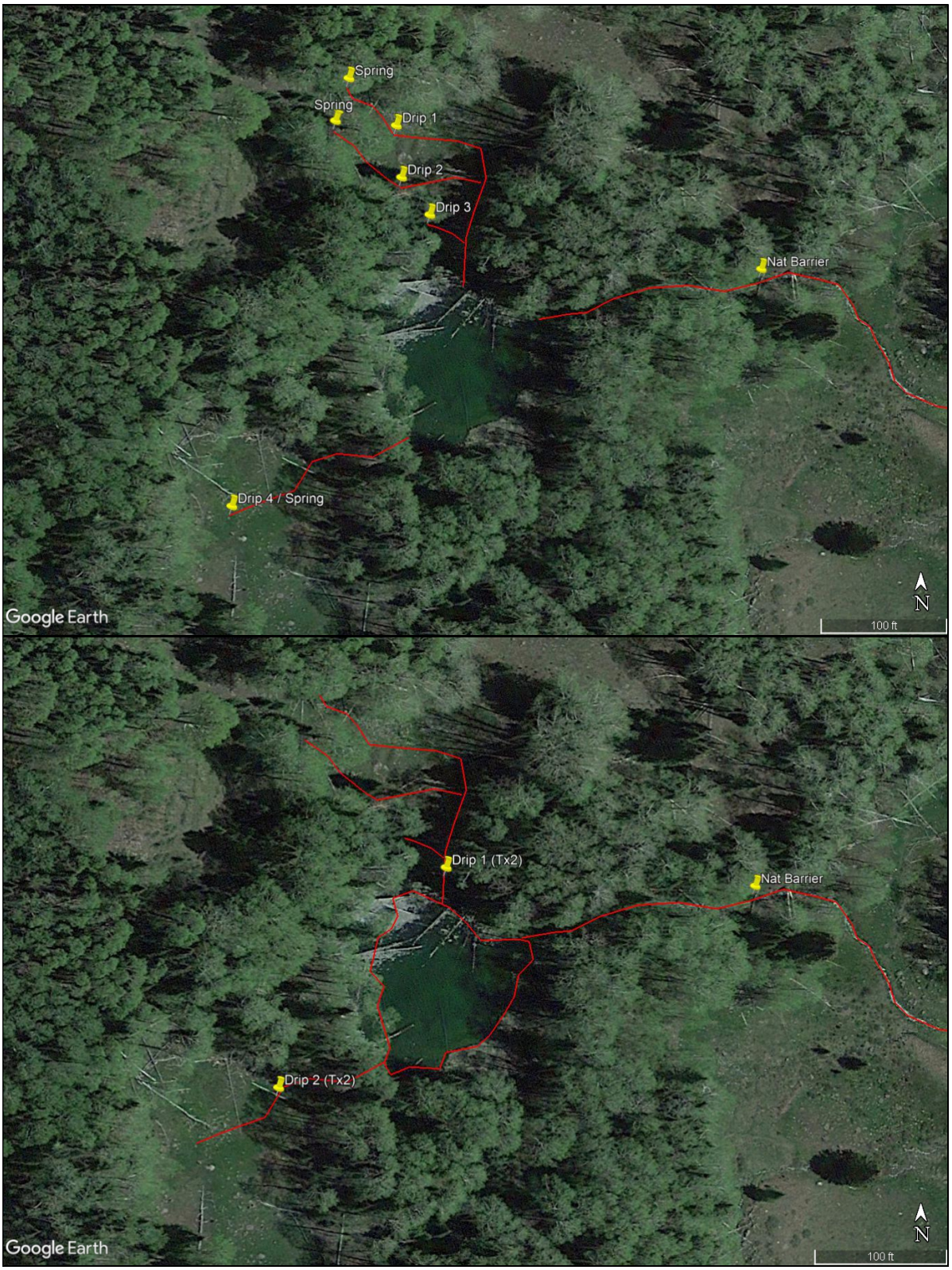

Figure 3. Rotenone drip stations set in Upper Barker Pond spring sources on August 12 (top) and September 16 (bottom), 2019.

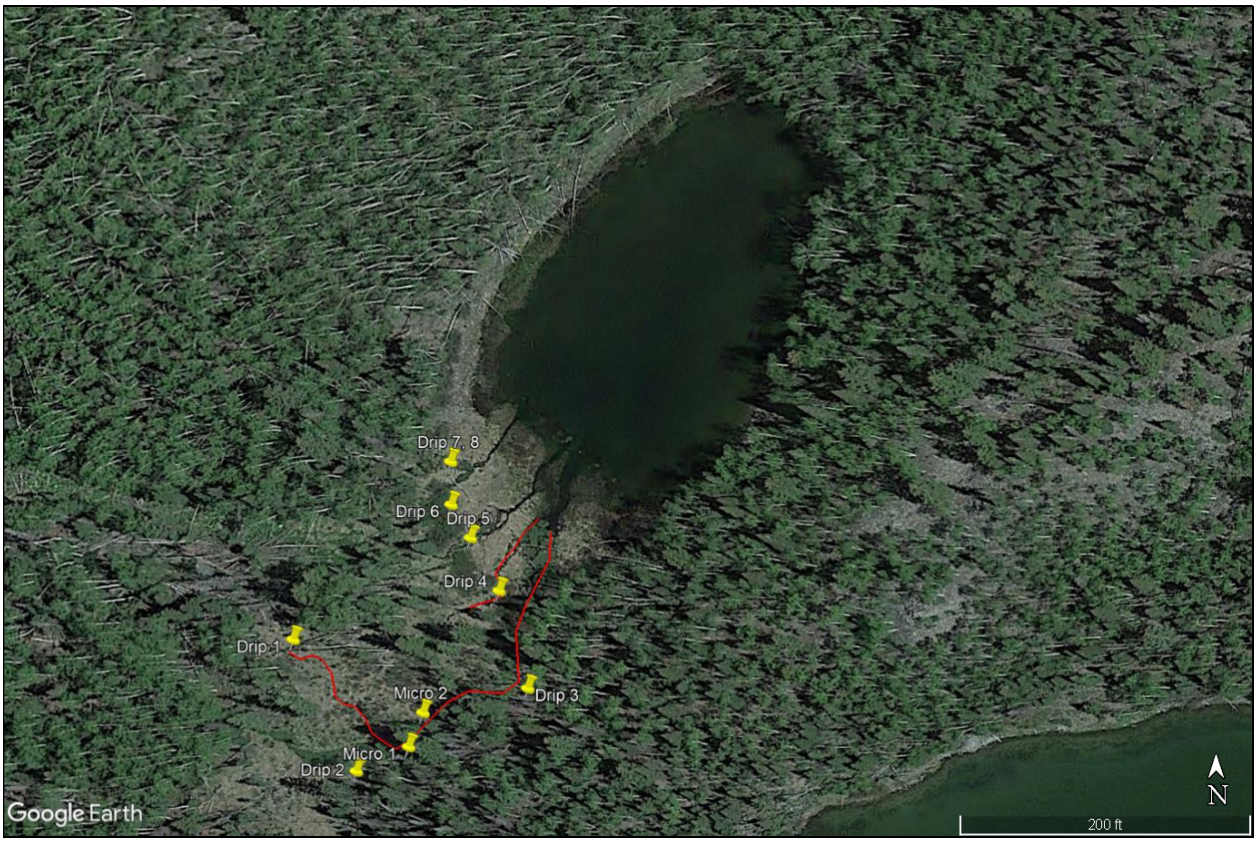

Figure 4. Rotenone drip stations set in Blue Lake spring sources on August 13, 2019.

Table 1. Project personnel and assignments for the chemical treatments of Upper Barker Pond and Blue Lake.

Personnel	Assignment
August 12-13, 2019 (Upper Barker Pond and Blue Lake)	
Mike Hadley, UDWR SRO	Planning, recon, supervise, drips, spray
Mike Golden, DNF	Planning, recon, detox upper Barker Pond
MaKayla Roundy, UDWR SRO	Spray, drips
Nick Dastrup, UDWR SRO	Spray
Hunter Gilson, UDWR SRO	Spray
Clay Tyler, DNF	Spray
Kalli Tyler, DNF	Spray
Mike Jensen, UDWR SRO	Pack equipment to Blue Lake with horses
September 16, 2019 (Upper Barker Pond)	
Mike Hadley, UDWR SRO	Supervise, drips, spray
Mike Golden, DNF	Detox upper Barker Pond
Clay Tyler, UDWR SRO	Spray
Kalli Tyler, UDWR SRO	Spray

Table 2. Chemical used during 2019 treatments in Upper Barker Pond and Blue Lake.

Date and location	**Chemical and formulation**	**Application method**	**Amount of chemical used**	**Concentration / rate**
Aug 12, 2019 Upper Barker Pond	Liquid rotenone, 5% active ingredient	Drip barrels and back pack sprayers	0.48 gal (1.83 L)	~1.5 ppm total ingredient
Aug 12-13, 2019 Barker Res inlet	Potassium permanganate	Auger	77.8 lbs (35 kg)	24.8 g/min (mean)
Aug 13, 2019 Blue Lake	Liquid rotenone, 5% active ingredient	Drip barrels and back pack sprayers	3.0 gal (11.4 L)	~1.5 ppm total ingredient
Sep 16, 2019 Upper Barker Pond	Liquid rotenone, 5% active ingredient	Drip barrels and back pack sprayers	0.48 gal (1.83 L)	~1.5 ppm total ingredient
Sep 16-17, 2019 Barker Res inlet	Potassium permanganate	Auger	70.5 lbs (32.0 kg)	22.7 g/min (mean)

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Discussion

Activities conducted in 2019 helped to complete preliminary work for future native fish restoration the North Creek drainage. These activities primarily focused on eliminating two of the last three known refuges of fertile brook trout in the headwater lakes. Following successful eradication, a limited number of tiger trout were stocked in Upper Barker Pond in fall 2019 to provide sport fish opportunity. It is also recommended that a small number of CRCT be transferred from Pine Creek to the pond in 2020 in order to assess the spring sources' suitability for cutthroat spawning. Blue Lake will be treated a second time in June 2020, after which tiger trout will be stocked annually.

The documented presence of fertile brook trout upstream of Barker Reservoir in 2019 increases the likelihood that fertile fish may still be found in some of the North Creek lakes, despite the switch to triploid stocking more than a decade ago. Brook trout should be collected from Barker, Lower Barker, and Joe Lay reservoirs in 2020 and tested for ploidy. Inlet streams of Lower Barker and Joe Lay reservoirs should also be electrofished to collect more fish. Based on the results of these tests, further CRCT restoration activities in the North Creek drainage may include treatment of up to three of these lakes. Nonnative fish removal is not anticipated to resume until 2021, at the earliest.

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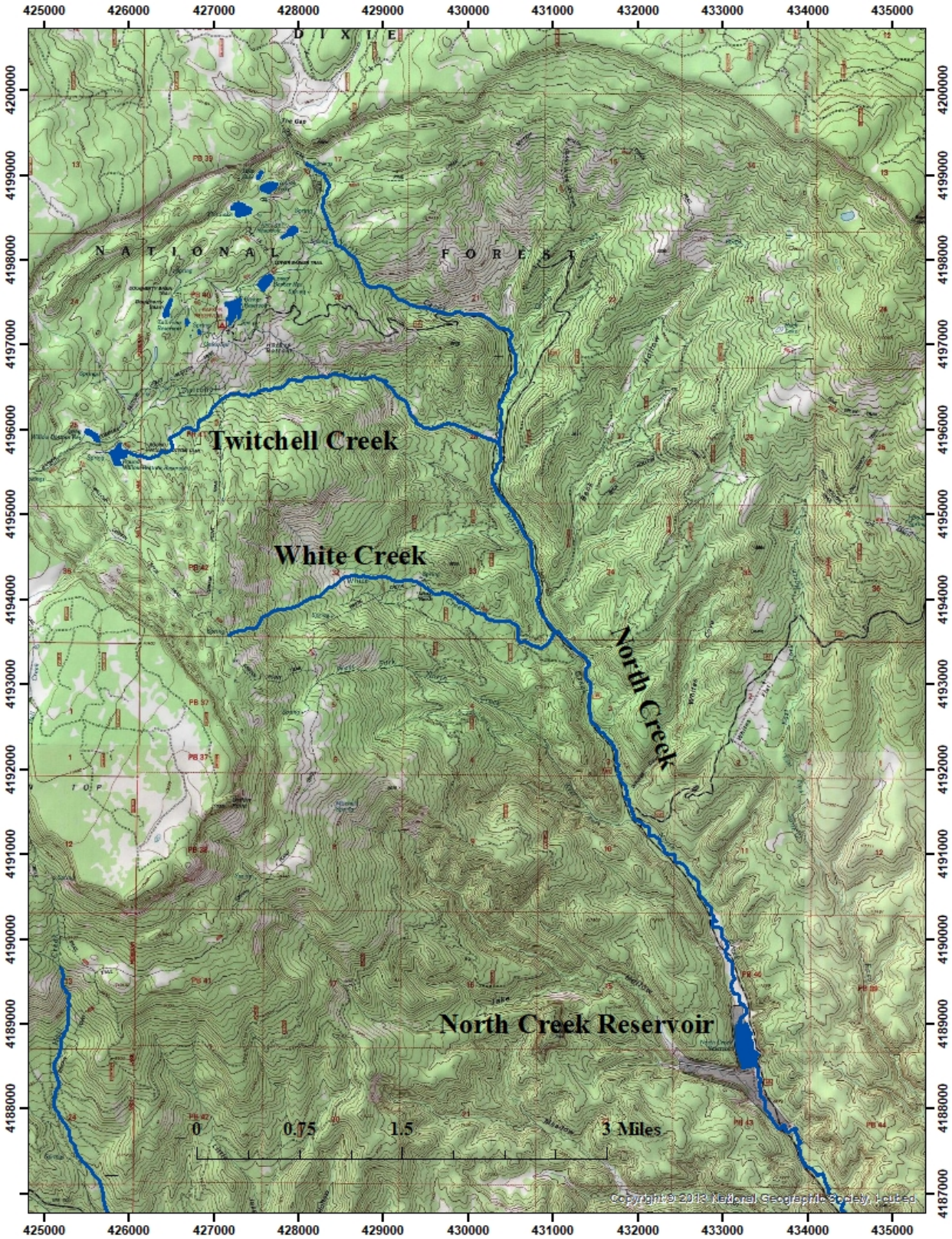

Figure 1. North Creek drainage.

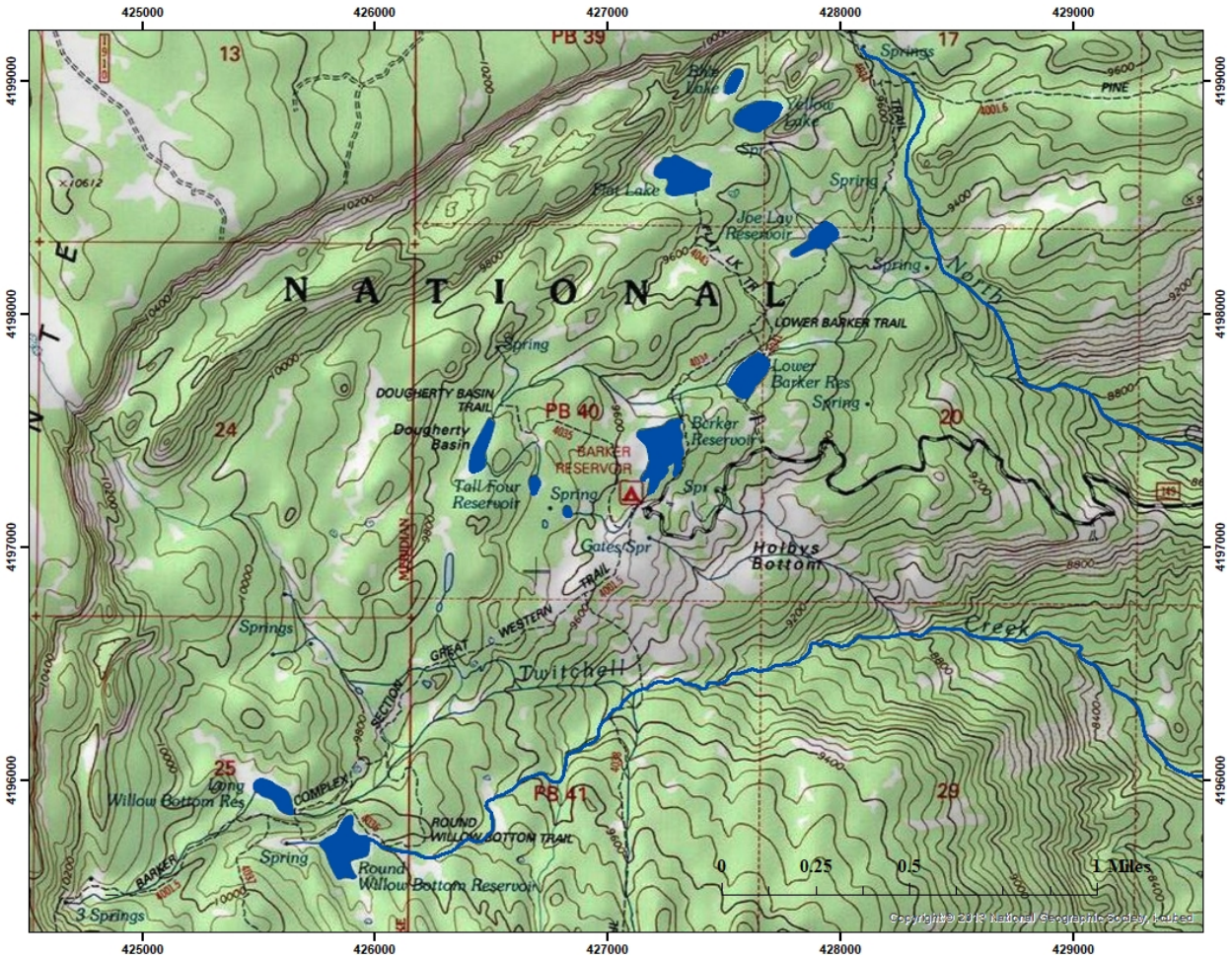

Figure 2. Lakes, reservoirs, and ponds of the North Creek headwaters.

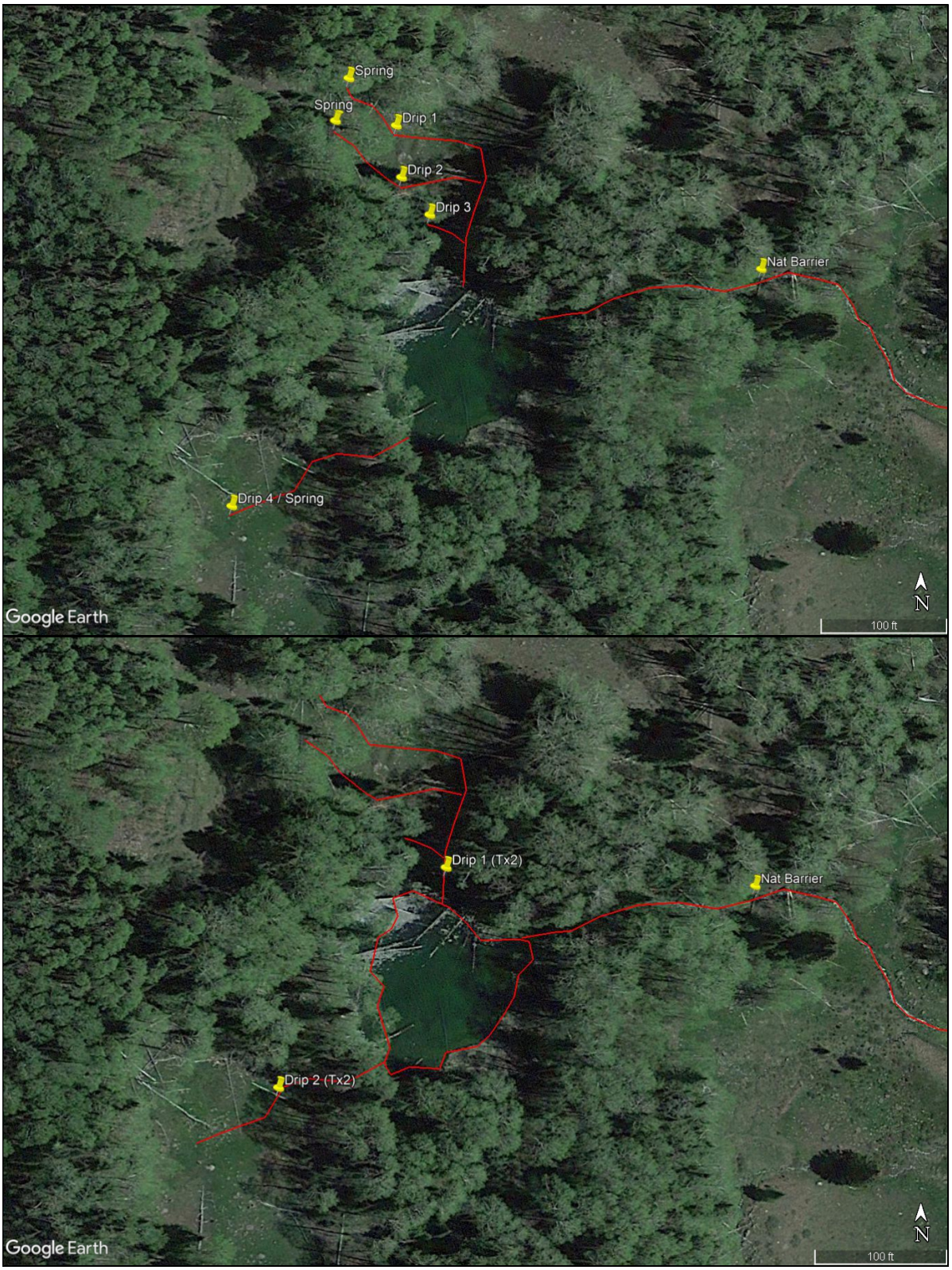

Figure 3. Rotenone drip stations set in Upper Barker Pond spring sources on August 12 (top) and September 16 (bottom), 2019.

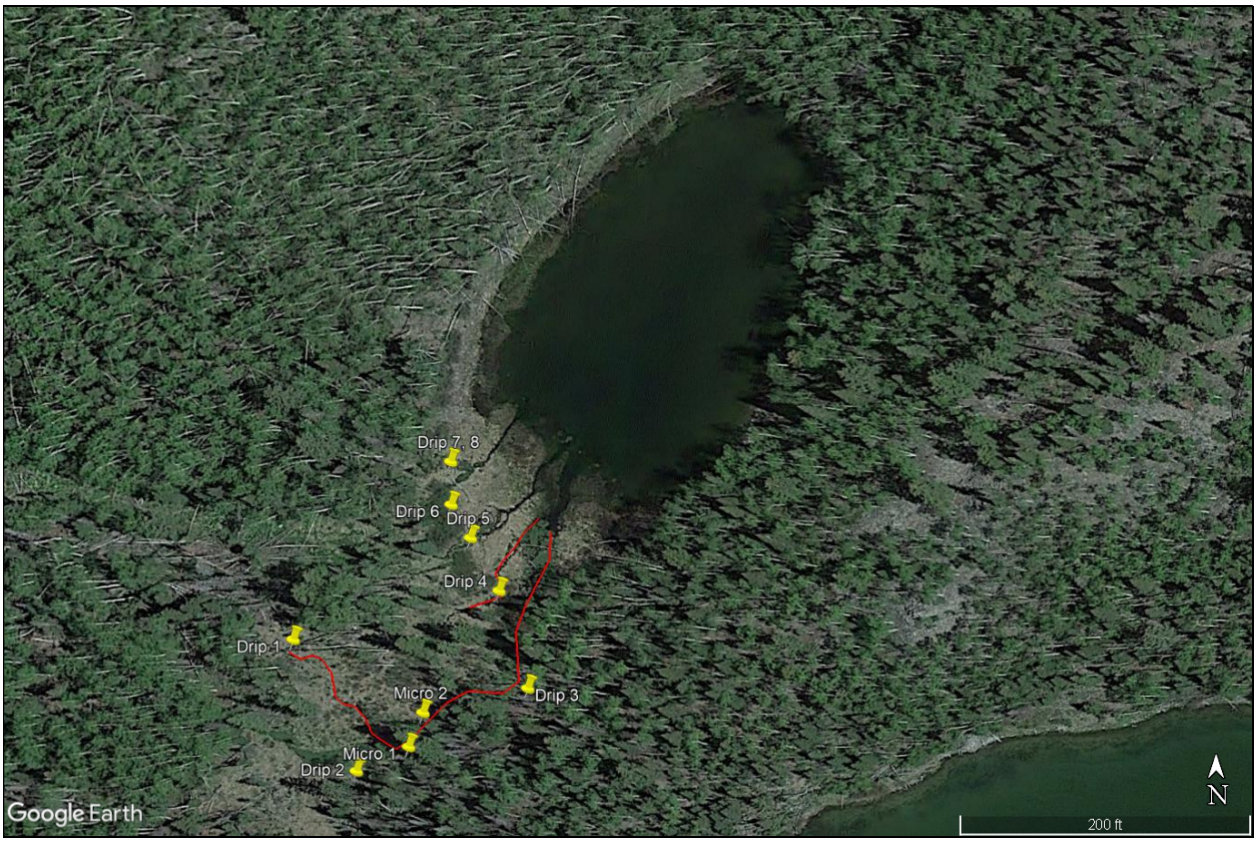

Figure 4. Rotenone drip stations set in Blue Lake spring sources on August 13, 2019.

Table 1. Project personnel and assignments for the chemical treatments of Upper Barker Pond and Blue Lake.

Personnel	Assignment
August 12-13, 2019 (Upper Barker Pond and Blue Lake)	
Mike Hadley, UDWR SRO	Planning, recon, supervise, drips, spray
Mike Golden, DNF	Planning, recon, detox upper Barker Pond
MaKayla Roundy, UDWR SRO	Spray, drips
Nick Dastrup, UDWR SRO	Spray
Hunter Gilson, UDWR SRO	Spray
Clay Tyler, DNF	Spray
Kalli Tyler, DNF	Spray
Mike Jensen, UDWR SRO	Pack equipment to Blue Lake with horses
September 16, 2019 (Upper Barker Pond)	
Mike Hadley, UDWR SRO	Supervise, drips, spray
Mike Golden, DNF	Detox upper Barker Pond
Clay Tyler, UDWR SRO	Spray
Kalli Tyler, UDWR SRO	Spray

Table 2. Chemical used during 2019 treatments in Upper Barker Pond and Blue Lake.

Date and location	**Chemical and formulation**	**Application method**	**Amount of chemical used**	**Concentration / rate**
Aug 12, 2019 Upper Barker Pond	Liquid rotenone, 5% active ingredient	Drip barrels and back pack sprayers	0.48 gal (1.83 L)	~1.5 ppm total ingredient
Aug 12-13, 2019 Barker Res inlet	Potassium permanganate	Auger	77.8 lbs (35 kg)	24.8 g/min (mean)
Aug 13, 2019 Blue Lake	Liquid rotenone, 5% active ingredient	Drip barrels and back pack sprayers	3.0 gal (11.4 L)	~1.5 ppm total ingredient
Sep 16, 2019 Upper Barker Pond	Liquid rotenone, 5% active ingredient	Drip barrels and back pack sprayers	0.48 gal (1.83 L)	~1.5 ppm total ingredient
Sep 16-17, 2019 Barker Res inlet	Potassium permanganate	Auger	70.5 lbs (32.0 kg)	22.7 g/min (mean)

NATIVE FISH RESTORATION IN THE NORTH CREEK DRAINAGE: 2019 ACTIVITIES

Michael J. Hadley
Aquatic Biologist

February 2020

Utah Division of Wildlife Resources
Southern Region

Introduction

North Creek is one of the primary tributaries of the Escalante River and drains the southwest slope of Boulder Mountain (Figure 1). North Creek and its tributaries upstream of North Creek Reservoir contain up to 15.5 miles (25 km) of potential trout habitat. This upper drainage is found within the Dixie National Forest (DNF) Escalante Ranger District. Tributaries that are known to sustain trout include White Creek and Twitchell Creek. Limited historic surveys have found no fish in West Fork North Creek, though more extensive sampling is needed to fully assess its suitability as fish habitat. North Creek is seasonally dewatered below North Creek Reservoir and surveys by both Utah Division of Wildlife Resources (UDWR) and DNF have found that this reach provides only seasonal or intermittent habitat for trout. Stream temperature and flash floods from side canyons limit trout occupation in lower North Creek, while native speckled dace are abundant. Eleven lakes, reservoirs, and ponds in the headwaters of the basin also sustain trout populations (Fig. 2). Stocking of nonnative trout – including rainbow, cutthroat, and brook trout – was documented as early as the 1940s in the North Creek drainage and likely occurred even earlier. Over time, nonnative trout expanded and replaced native Colorado River cutthroat trout (CRCT) throughout much of the drainage. Stocking of fertile rainbow and brook trout continued in several of the lakes into the mid 2000s.

General plans for CRCT restoration and conservation in Utah were formalized in the state's conservation agreement and strategy (Lentsch and Converse 1997), followed by a rangewide agreement and strategy in 2006 (CRCT Conservation Team 2006, CRCT Coordination Team 2006). Benefits of and needs for CRCT restoration and conservation in the Escalante River drainage were identified by UDWR in a drainage management plan (Ottenbacher and Hepworth 2003). BCT conservation efforts in the Lower Colorado River Geographic Management Unit (GMU) – which encompasses the Fremont and Escalante river drainages – are coordinated and completed by a cooperative interagency team, with representatives from UDWR, Fishlake National Forest (FNF), DNF, Bureau of Land Management (BLM), and Trout Unlimited (TU). This team acts as a subset of the range wide CRCT Conservation Team.

Remnant CRCT were first discovered in the Lower Colorado River GMU in the mid 1980s, in East Fork Boulder Creek (Hepworth et al. 2001, 2002). This discovery prompted extensive searches for CRCT throughout the Escalante River drainage, eventually yielding an additional six populations between 1990 and 2011 (Hadley et al. 2014). One of those was discovered in North Creek tributary White Creek in the late 1990s (Hepworth et al. 2001). The White Creek population was isolated from nonnative trout by a natural cascade barrier and was found to be genetically pure (University of Montana unpublished analysis 2001, Evans et al. 2013). Two fish passage barriers were constructed in lower White Creek in 2000 and nonnative trout were removed from the lower 0.3 mile (0.5 km) of stream in 2001. Nonnative trout were discovered in and removed from the reach between the constructed barriers during the mid 2000s, prompting a retrofitting of the lower barrier with a concrete splash pad that removed the plunge pool and prevented reinvasion.

CRCT were transferred from the east and west forks of Boulder Creek to Dougherty Basin Lake in the North Creek drainage from 1997 to 1999 to establish a wild brood population that would support the conservation and restoration of CRCT in southern Utah, as well as provide fish for sport fish stocking. The Boulder Creek populations were identified as pure CRCT both by meristic and genetic analyses (Behnke 1992, Shiozawa and Evans 1994, Hudson

and Davis 2002, Thron and Miller 2002, Shiozawa and Evans 2011). The brood established in Dougherty Basin Lake and the connected Tall Four Reservoir has produced fertilized CRCT eggs since 1999. This two-lake system is isolated from the rest of the North Creek drainage by sinkholes and subsurface flow. Efforts to improve the genetic diversity of the Dougherty Basin brood began in 2014 with the introduction of CRCT from remnant populations in White Creek and Pine Creek, as well as additional transfers from Pine Creek in 2017 and 2018 (Hadley 2019). Spawning efforts have documented contribution from each of these transferred groups to the brood, though the White Creek population has contributed far less due to limited numbers of CRCT available for transfer. The Pine Creek remnant was identified as pure CRCT by Toline et al. 1999, Evans and Shiozawa 2005, and Evans et al. 2013.

As a joint effort of the Boulder Mountain Sport Fish Enhancement Project and CRCT conservation, nonnative trout were removed from Twitchell Creek and it headwaters lakes – Long Willow Bottom and Round Willow Bottom reservoirs – in 2001 and 2002 (UDWR 2000, Hadley and Hepworth 2013). One fish barrier was constructed in lower Twitchell Creek to prevent reinvasion from North Creek, while a natural barrier acts as security in the case of passage over the constructed barrier. The reach between the two barriers was treated again in 2006 to remove brook trout that had bypassed the constructed barrier. The barrier was also retrofitted with a concrete splash pad. CRCT produced by the Dougherty Basin brood were introduced to Twitchell Creek after 2002 and are stocked annually – along with sterile tiger trout – in the headwater reservoirs. The stream has maintained self-sustaining CRCT population for over 15 years (Hadley et al. 2014).

Beginning in the late 2000s, rainbow and brook trout stocking in the North Creek lakes was converted to triploid fish. This change was intended to help facilitate a potential future restoration of CRCT in North Creek. Focus on CRCT expansion in the Boulder Creek drainage delayed any further efforts in North Creek for over 10 years. The Boulder Creek project was indefinitely postponed in 2019, however, allowing for a shift in CRCT conservation to other drainages. North Creek was considered a high priority for restoration due to the presence of an assumed barrier (North Creek Reservoir dam), the Dougherty Basin brood, two current CRCT populations, and the previous shift to sterile sport fish stocking. North Creek and its headwaters represent up to 10 mi (15.7 km) of additional CRCT habitat and would provide a location for further combination of CRCT remnants from White Creek, Boulder Creek, and Pine Creek. This report summarizes preliminary efforts to restore CRCT in North Creek conducted in 2019.

Methods

Pathogen Testing

Thirty brook trout were collected from North Creek just upstream of its confluence with Twitchell Creek in May 2019 and submitted to the Fisheries Experiment Station (FES) for testing of infection by *Myxobolus cerebralis*, the parasite that causes whirling disease. Such testing is regularly conducted prior to native trout restoration.

Barrier Evaluation

The North Creek Reservoir dam, spillway, and outlet were inspected visually during summer 2019 to determine their suitability as barriers to upstream fish passage.

Brook Trout Removal

Besides North Creek itself, three other waters in the drainage are known to harbor self-sustaining populations of brook trout – Dougherty Basin Lake, Blue Lake, and Upper Barker Pond. The latter two waters were treated with rotenone in 2019 to remove fertile brook trout. Blue Lake is a 1.6-acre natural lake fed by multiple seeps and springs, with no outlet (Fig. 2). Upper Barker pond is a historic beaver pond covering 0.2 acre. Some of the spring sources for this pond presumably are fed by the sinkholes that drain Tall Four Reservoir. The outlet of Upper Barker Pond feeds into Barker Reservoir. The springs and inlet streams of both waterbodies provide ample spawning habitat for brook trout.

Liquid rotenone (5% active ingredient) was applied to target waters in Upper Barker Pond and its tributary springs on August 12 and September 16, 2019, with a target concentration of 1.5 parts per million (ppm). Rotenone was applied to the pond using backpack sprayers and to spring sources with 7-gal (4-hr charge) drip barrels (Fig. 3). Drips were reduced and combined for the second treatment because no fish were observed in the spring channels during the first. The grassy portions of the spring inlets were also sprayed. Rotenone applied by drip stations was subtracted from the total needed to treat the pond volume to avoid elevating concentration over 1.5 ppm and overwhelming the detox station.

Potassium permanganate ($KMnO_4$), an oxidizing agent, was applied to toxic waters at a constant rate using an auger-hopper system to deactivate the rotenone below Upper Barker Pond. The detox station was set just upstream of Barker Reservoir and well below a head cut barrier that would prevent reinvasion of the pond (Fig. 3). Sentinel fish (brook trout electrofished from the stream prior to the treatment) were placed in a live cage upstream of the detox station to monitor rotenone arrival.

Liquid rotenone was applied to Blue Lake and its tributary springs on August 13, 2019, with a target concentration of 1.5 ppm. Rotenone was applied to the lake using backpack sprayers and to spring sources with 7-gal (4-hr charge) drip barrels (Fig. 4). Spray crews used a raft to apply to areas not reached from shore. The grassy portions of the spring inlets and lakeshore were also sprayed. Rotenone applied by drip stations was subtracted from the total needed to treat the lake volume to avoid elevating concentration over 1.5 ppm. Because the lake has no outlet, detox was not necessary.

Results

Pathogen Testing

FES reported no evidence of *M. cerebralis* in the brook trout collected from North Creek.

Barrier Evaluation

Due to the historic high snowpack of 2019, North Creek Reservoir spilled over for most of the summer, allowing for observation of water activity over the spillway. The spillway and outlet were determined to be suitable barriers to upstream fish passage.

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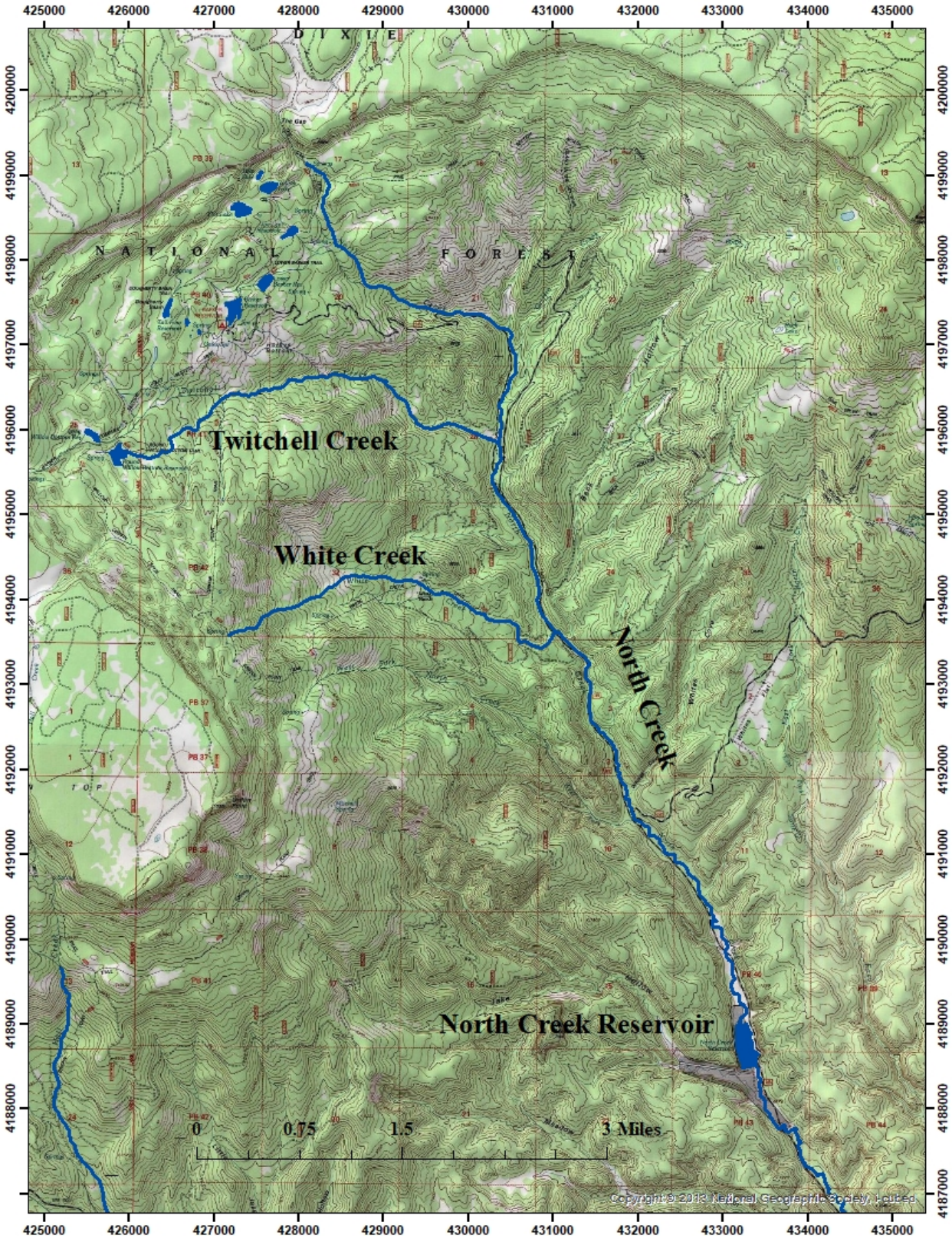

Figure 1. North Creek drainage.

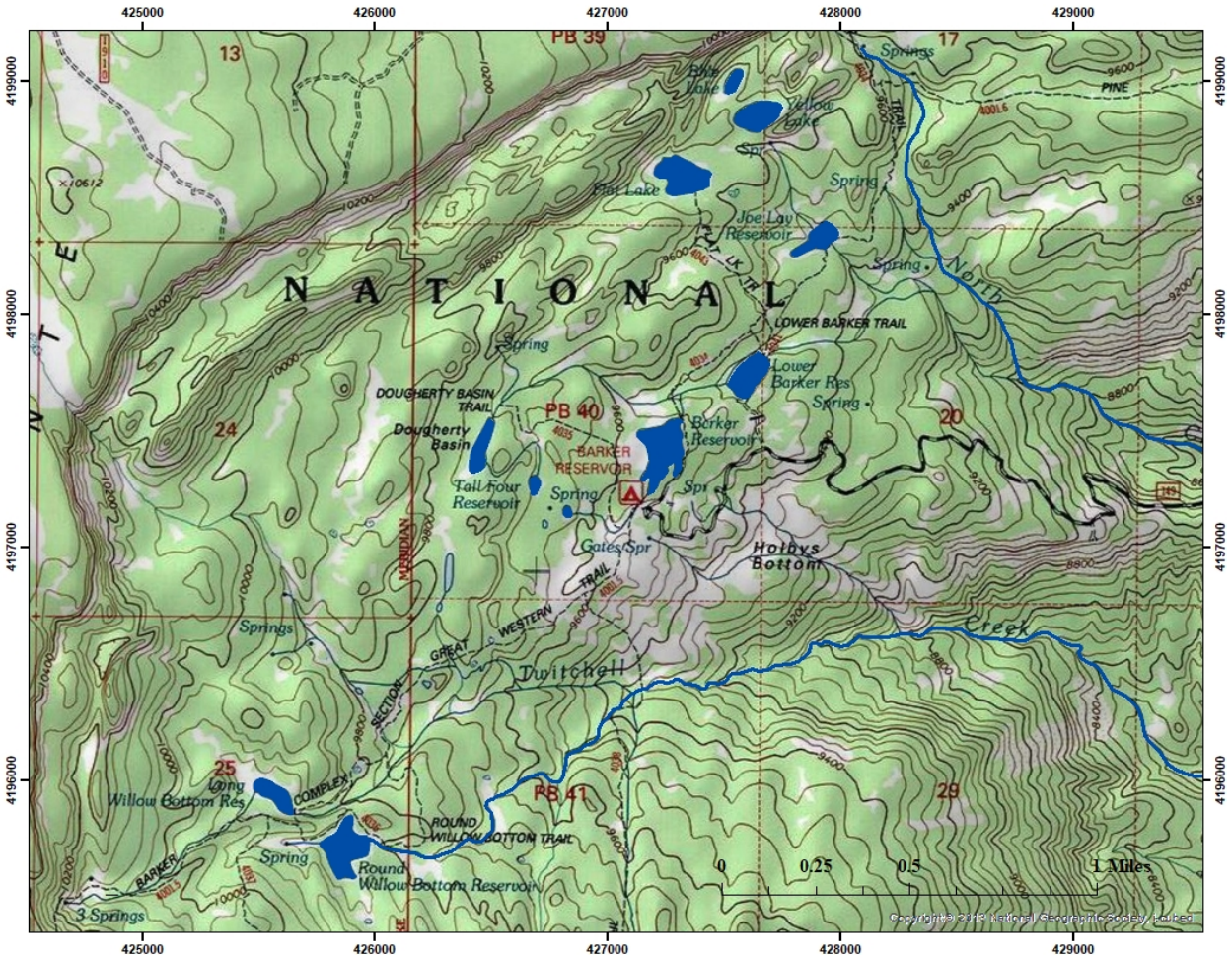

Figure 2. Lakes, reservoirs, and ponds of the North Creek headwaters.

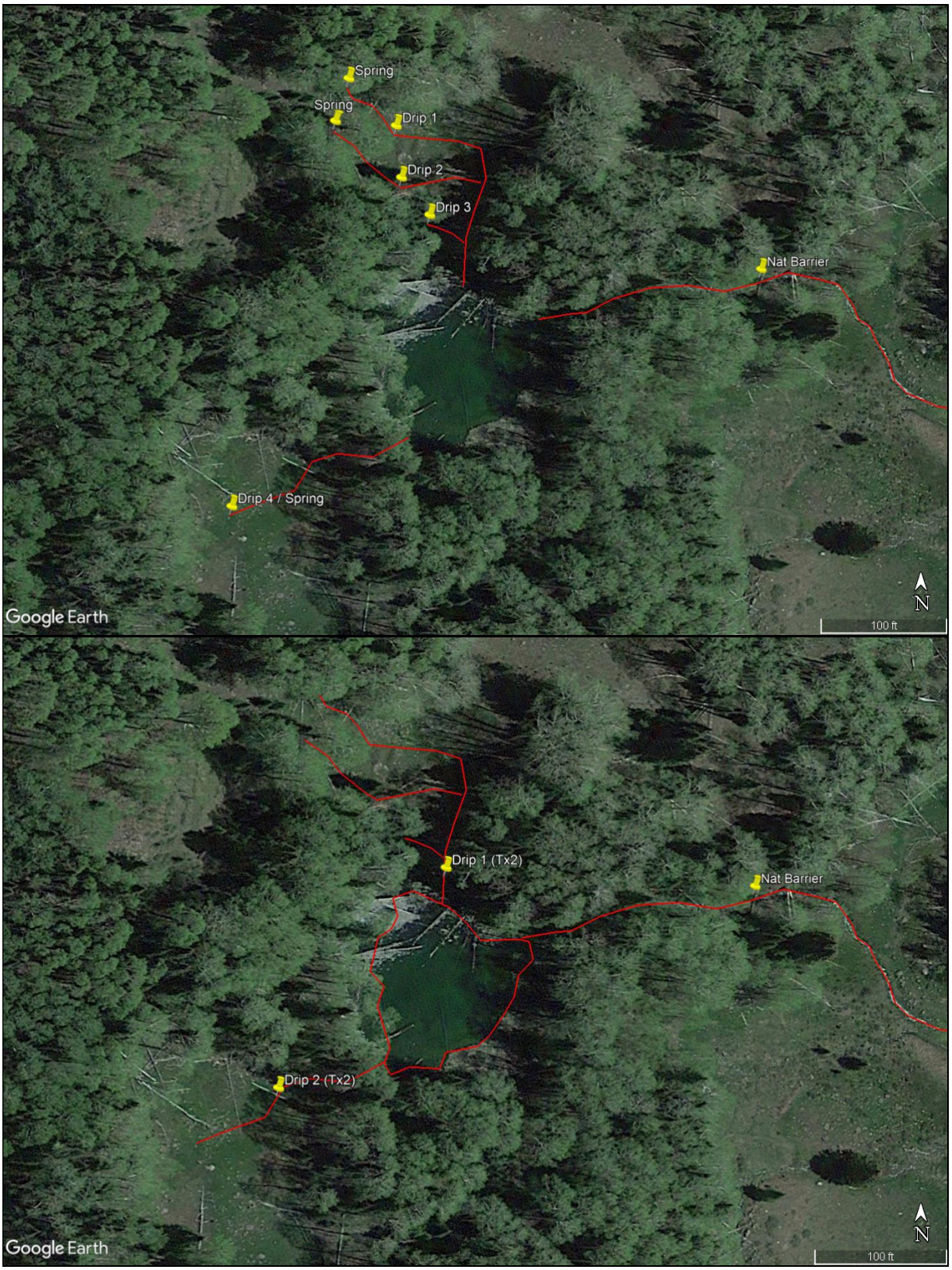

Figure 3. Rotenone drip stations set in Upper Barker Pond spring sources on August 12 (top) and September 16 (bottom), 2019.

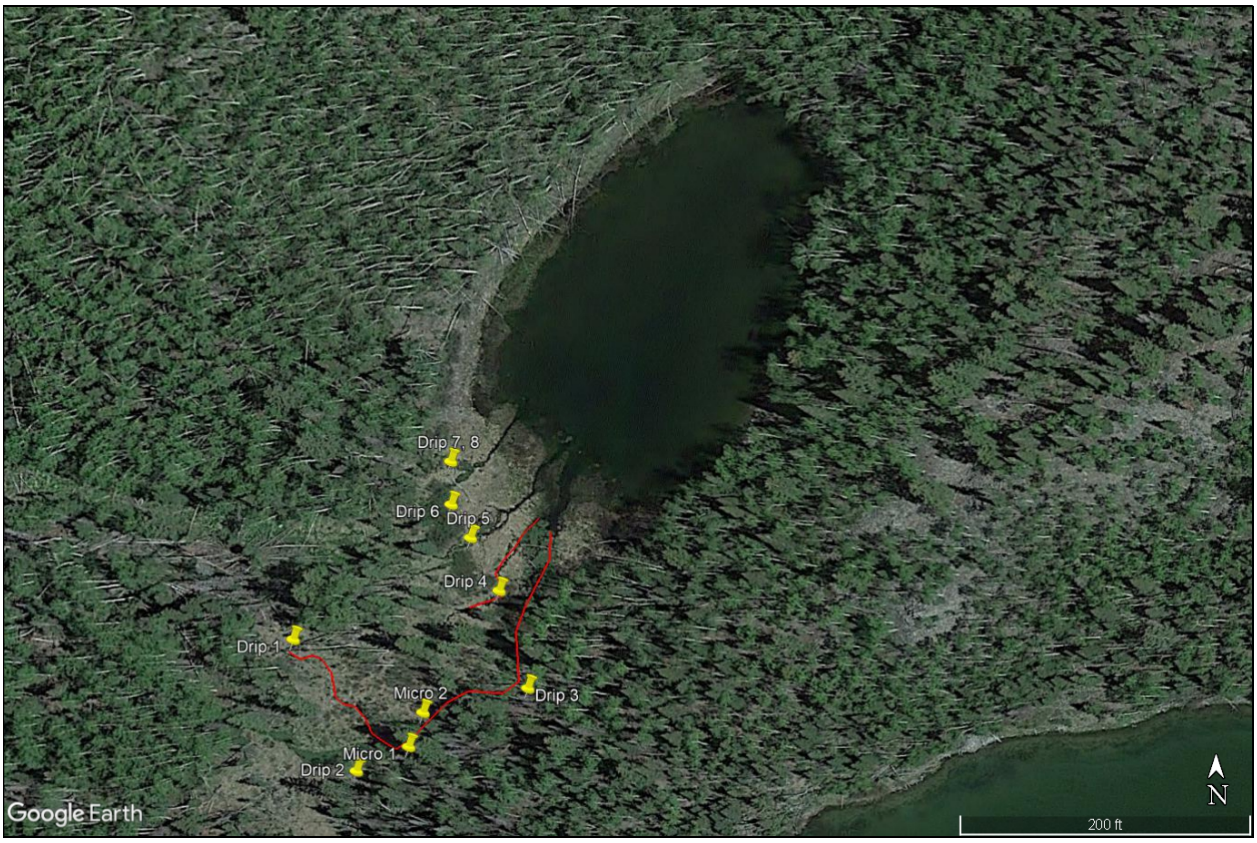

Figure 4. Rotenone drip stations set in Blue Lake spring sources on August 13, 2019.

Table 1. Project personnel and assignments for the chemical treatments of Upper Barker Pond and Blue Lake.

Personnel	Assignment
August 12-13, 2019 (Upper Barker Pond and Blue Lake)	
Mike Hadley, UDWR SRO	Planning, recon, supervise, drips, spray
Mike Golden, DNF	Planning, recon, detox upper Barker Pond
MaKayla Roundy, UDWR SRO	Spray, drips
Nick Dastrup, UDWR SRO	Spray
Hunter Gilson, UDWR SRO	Spray
Clay Tyler, DNF	Spray
Kalli Tyler, DNF	Spray
Mike Jensen, UDWR SRO	Pack equipment to Blue Lake with horses
September 16, 2019 (Upper Barker Pond)	
Mike Hadley, UDWR SRO	Supervise, drips, spray
Mike Golden, DNF	Detox upper Barker Pond
Clay Tyler, UDWR SRO	Spray
Kalli Tyler, UDWR SRO	Spray

Table 2. Chemical used during 2019 treatments in Upper Barker Pond and Blue Lake.

Date and location	**Chemical and formulation**	**Application method**	**Amount of chemical used**	**Concentration / rate**
Aug 12, 2019 Upper Barker Pond	Liquid rotenone, 5% active ingredient	Drip barrels and back pack sprayers	0.48 gal (1.83 L)	~1.5 ppm total ingredient
Aug 12-13, 2019 Barker Res inlet	Potassium permanganate	Auger	77.8 lbs (35 kg)	24.8 g/min (mean)
Aug 13, 2019 Blue Lake	Liquid rotenone, 5% active ingredient	Drip barrels and back pack sprayers	3.0 gal (11.4 L)	~1.5 ppm total ingredient
Sep 16, 2019 Upper Barker Pond	Liquid rotenone, 5% active ingredient	Drip barrels and back pack sprayers	0.48 gal (1.83 L)	~1.5 ppm total ingredient
Sep 16-17, 2019 Barker Res inlet	Potassium permanganate	Auger	70.5 lbs (32.0 kg)	22.7 g/min (mean)