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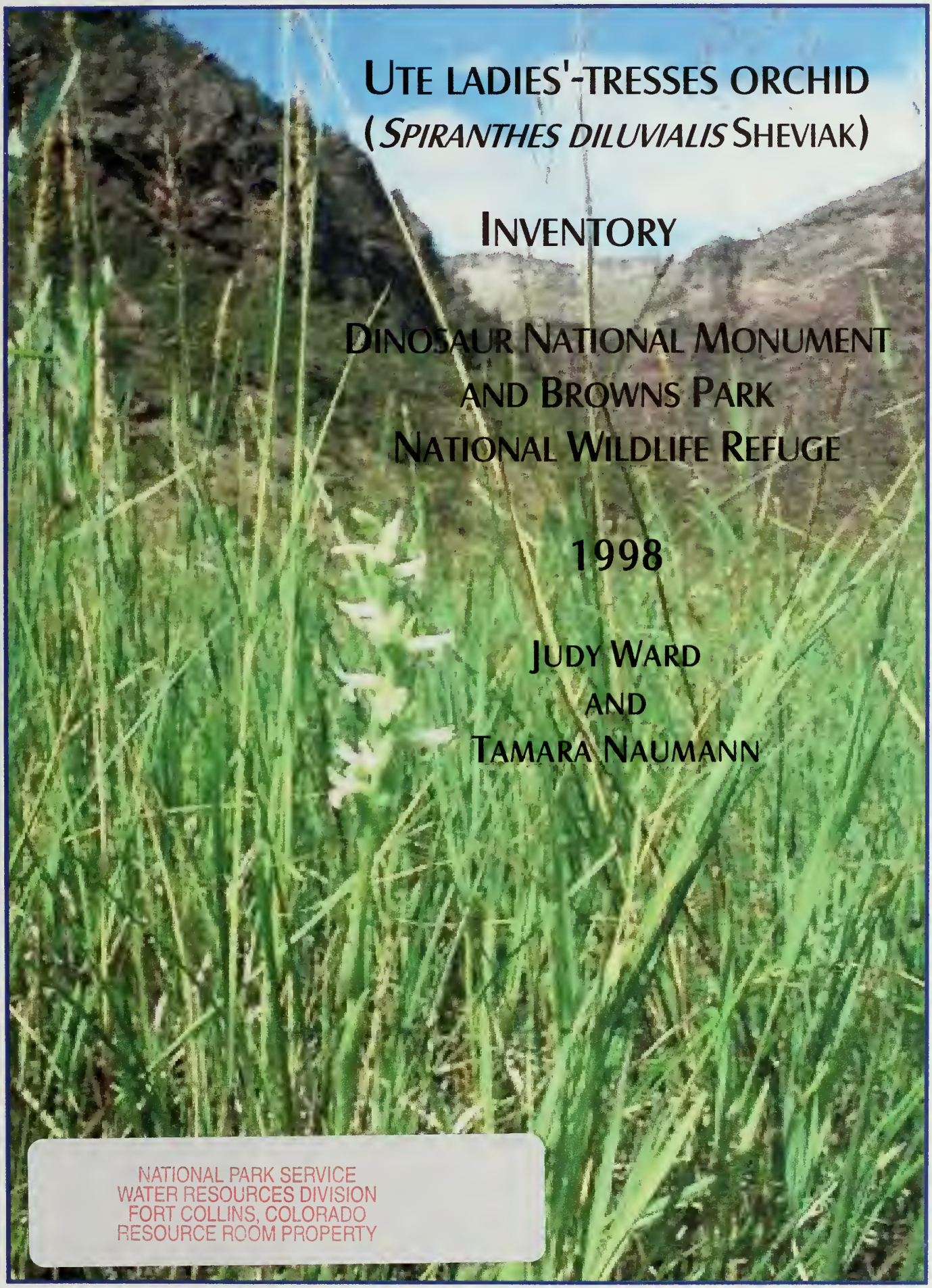

Ute ladies'-tresses orchid (*Spiranthes diluvialis* Sheviak)

Inventory

Dinosaur National Monument and Browns Park National Wildlife Refuge

1998

Judy Ward
and
Tamara Naumann

NATIONAL PARK SERVICE
WATER RESOURCES DIVISION
FORT COLLINS, COLORADO
RESOURCE ROOM PROPERTY

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Executive Summary
Dinosaur National Monument & Browns Park National Wildlife Refuge
1998 Ute ladies'-tresses Survey

Results

- Federal threatened Ute ladies'-tresses orchid (*Spiranthes diluvialis*) occurs along the upper Green River in Browns Park on BLM land and on Browns Park NWR.
- It also occurs in Lodore Canyon, Island Park, and downstream of Split Mountain Canyon in Dinosaur National Monument.
- Within these reaches, *Spiranthes* appears primarily to occupy geomorphic surfaces that developed after Flaming Gorge Dam closure.
- Several possibly relictual subpopulations were observed in habitat that is not currently appropriate for *Spiranthes* establishment, both in Lodore Canyon and in Island Park.

Interpretation

- *Spiranthes* probably did not occur as extensively as it does now in Lodore Canyon prior to closure of Flaming Gorge Dam. This possibility is suggested by pre-dam absence of suitable habitat in Lodore Canyon and present lack of suitable habitat in Whirlpool and Split Mountain Canyons.
- In contrast, *S. diluvialis* probably occurred more extensively in Browns Park and Island Park than it does now. The best evidence for this is:
  - *Spiranthes*' apparent range-wide habitat preference for mesic, early mid-seral floodplain features. These features were more abundant in pre-dam Browns Park and Island Park.
  - Range-wide observations suggest that the species is predominantly water dispersed. [i.e., it came from upstream]
  - Occurrences at Trailer Draw, Lower Disaster and Pot Creek in Lodore Canyon and on Bobby Island in Island Park suggest the possibility that these areas could have supported *Spiranthes* prior to dam closure. Secondary channels associated with islands appear to be the most likely pre-dam habitats.

Implications

- *Spiranthes diluvialis* populations in Browns Park, Lodore Canyon, Island Park, and downstream of Split Mountain could be affected by changes in Flaming Gorge Dam operations.
- More information is needed to assess the risk and/or potential benefit to this listed species from changes under consideration for the benefit of endangered Colorado River fish.
- If it is determined that the proposed changes may adversely affect *Spiranthes* in Lodore Canyon, then Browns Park and Island Park are the most likely mitigation areas.
- The focus of research efforts in 1999 should be expanded geomorphic mapping in Browns Park and below Split Mountain, refinement of correlations/associations between *Spiranthes* and geomorphic surfaces in Lodore and Island Park, and relationship between vegetation succession and fluvial processes. [i.e., parameters that will contribute toward meaningful risk assessment]

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0.0 Purpose

The purpose of this report is to summarize and convey results of an inventory conducted for threatened Ute ladies'-tresses orchids (*Spiranthes diluvialis* Sheviak) on the Green and Yampa Rivers in Dinosaur National Monument and Browns Park National Wildlife Refuge during the summer of 1998. This inventory was undertaken to increase understanding of the orchid's presence and distribution along the Green River below Flaming Gorge Dam. Information currently available is insufficient for adequate assessment of potential impacts to *S. diluvialis* from changes in Flaming Gorge dam operations, changes which have been proposed for the benefit of endangered Colorado River fish. Funding for this project was provided by the U.S. Bureau of Reclamation..

The specific objectives of the 1998 inventory were to:

1. Document the location and distribution of *Spiranthes diluvialis* in Brown's Park NWR, and Lodore Canyon, Whirlpool Canyon, and Split Mountain Canyon in Dinosaur National Monument. Conduct reconnaissance surveys in selected portions of Yampa Canyon.
2. Estimate the number of individuals in each occurrence and characterize the occupied area.
3. Document associated species on occupied sites.
4. Document invasive non-native species (tamarisk, perennial pepperweed, and Russian knapweed) in occupied habitat.

1.0 Protocol Development for 1998 Survey

1.1 Lodore Canyon

The protocol employed for *Spiranthes* inventory in Lodore Canyon was developed in consultation with Utah State University fluvial geomorphologist Dr. John Schmidt. River channel geometry, hydrology, and depositional and erosional patterns strongly influence presence and distribution of *Spiranthes diluvialis*. We sought Dr. Schmidt's expertise in interpreting the nature of the geomorphic surfaces inhabited by *S. diluvialis* in Lodore Canyon, particularly with regard to deposit age and flood plain evolution. This consultation took place on the Green River between Gates of Lodore and Split Mountain on July 20-23, 1998.

We began our discussions at Lower Disaster Falls (RM 236.6 and RM 236.3), a site known to support a large number of orchids. This site includes an old secondary channel downstream from a significant tributary debris flow and a series of low terraced benches formed by lateral waves on the shoreline. Schmidt identified two discrete geomorphic units occupied by *S. diluvialis* at Lower Disaster Falls; these are described by Grams (1997) as *post-dam flood plain* and *intermediate bench.* Grams' analysis indicates that both surfaces post-date Flaming Gorge dam (see Appendix 2 for Grams' complete description of these surfaces).

Grams (1997) states that in Lodore Canyon (above the confluence with the Yampa River), "post-dam flood plain is the level that is inundated annually in the present streamflow regime. The average elevation is 0.8 ± 0.3 m above baseflow water surface.... [It] forms a very distinct and typically flat surface that is inundated by the post-dam mean annual flood of $143 m^3 s^{-1}$ (5053 c.f.s.)." He describes the intermediate bench in Lodore as "a flat surface that typically occurs as a strip adjacent to and lower in elevation than..." an older (pre-dam) surface he terms the *cottonwood-box elder terrace*. "The intermediate bench averages 1.9 ± 0.7 m above baseflow water surface.... High-water marks on the intermediate bench in Lodore Canyon indicate that this surface was inundated by the 1983 flood, which peaked at $388 m^3 s^{-1}$ (13,700 c.f.s.)."

During our consultation, we examined eleven more sites (Table 1). These sites were chosen for their potential to support *Spiranthes*, based on presence of typically associated species. A pattern quickly emerged suggesting a strong correlation between Grams' post-dam geomorphic surfaces and presence of *Spiranthes diluvialis* or associated species. Of 13 sites chosen for vegetation cues, 12 appeared as post-dam flood plain or intermediate bench units on Grams' maps (see Figures 1 and 2 and Appendix 3); we detected orchids on 11 of the sites at the time and later found them on the remaining two. Based on this preliminary analysis, we chose to narrow our focus to Grams' post-dam flood plain and intermediate bench geomorphic units. Aside from maximizing the return for our effort, this approach has the added advantage of enabling us to merge our *Spiranthes* inventory data with Grams' GIS database (housed at Utah State University).

Table 1: Sites Examined During Preliminary Fluvial Geomorphology Consultation.							
River Mile	River Bank	Map Unit #	Post-Dam Flood plain	Intermediate Bench	Debris Fan	*Spiranthes* Presence	Comments
236.6	Left	157,159	✓	✓		+	Lower Disaster Falls
236.3	Left	161,162	✓	✓		+	Lower Disaster Falls
235.9	Island	165		✓		+	Above Zenobia Creek
235.5	Island	174,175	✓	✓		+	
234.9	Left	186,187	✓	✓		+	Not relocated on 8/25
234.2	Island	202	✓			+	
233.0	Left	232		✓		- (+)	Not detected 7/21, but later found on 8/17
231.8	Left	259		✓		+	
231.7	Left	257,258		✓		+	
231.3	Left	265			✓	+	
229.5	Right	294	✓			+	
229.4	Right	294	✓			+	
227.4	Right	340,341		✓		- (+)	Not detected 7/22, but later found on 8/18

1.2 Echo Park, Whirlpool Canyon, Island Park-Rainbow Park, and Split Mountain Canyon

For purposes of this study, we used the same river reaches delineated by Grams; these include Lodore Canyon, Echo Park, Whirlpool Canyon, Island Park-Rainbow Park, and Split Mountain Canyon. To facilitate analysis, we further divided Lodore Canyon into sub-reaches based on geomorphic characteristics and *S. diluvialis* distribution. See Appendix 1 for a general map and description of reaches. See Appendix 3 for Grams' complete geomorphic map coverage. Prior to 1998, *S. diluvialis* was known to occur at "The Cove" river camp in Island Park (RM 214.2). We confirmed on our consultation trip that the occupied area had been mapped by Grams as a post-dam surface. The same inventory protocol was used in all reaches, though suitable habitat was encountered much less frequently below the Yampa confluence (see Results Section for a discussion).

Source: Grams, Paul E. 1997. *Geomorphology of the Green River In Dinosaur National Monument*. Unpublished Master's Thesis, Utah State University, Logan, Utah. 140 pp.

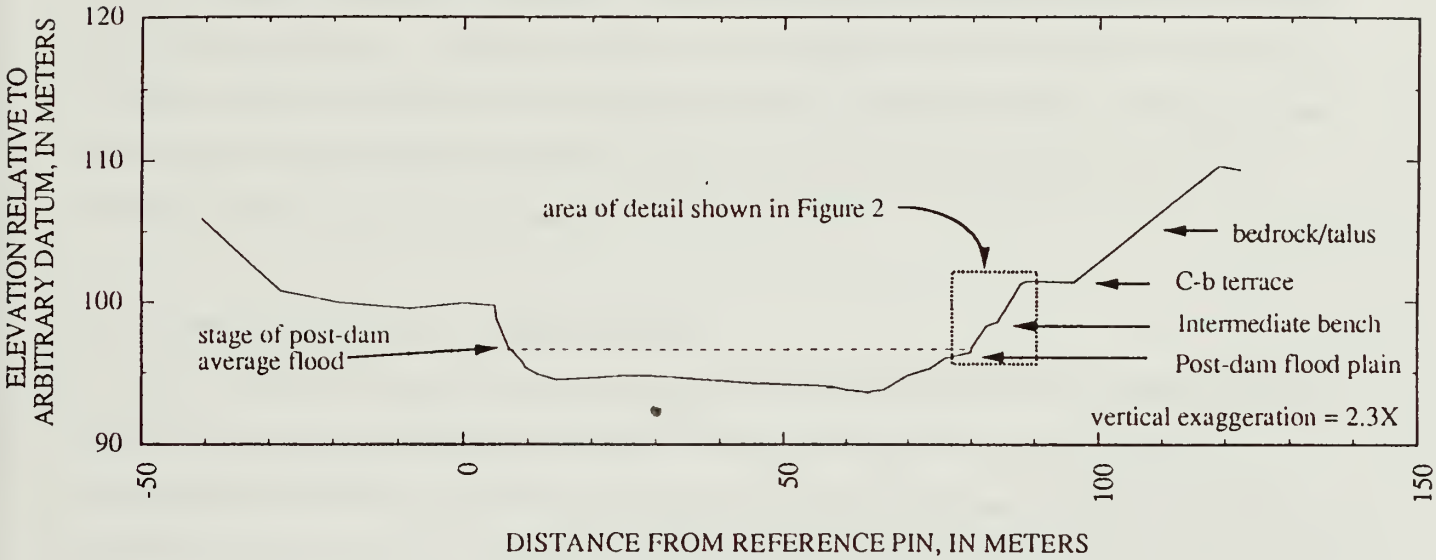

Figure 1. Example channel cross-section showing three geomorphic surfaces. View is downstream at Rkm 574.26 in Lodore Canyon. All surfaces are fine-grained sediments, and the bed of the river is sand.

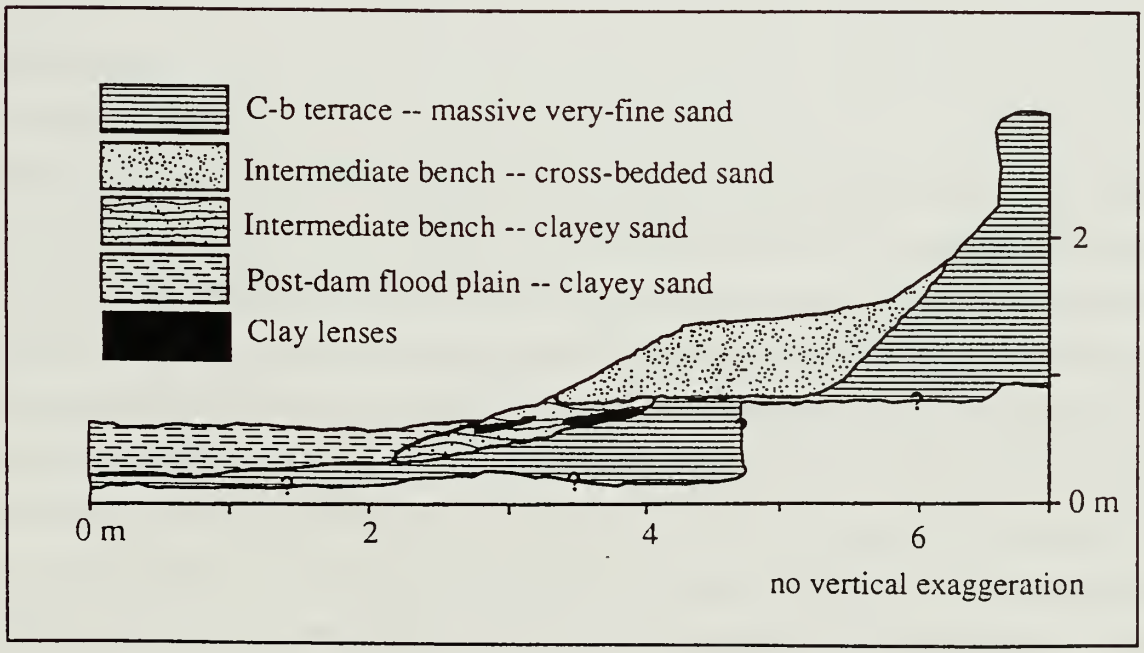

Figure 2 . Trench showing intermediate bench geomorphic surface inset into the c-b terrace and the post-dam flood plain inset into the intermediate bench. This is a detail of a segment of the cross section shown in Figure 1 . The question marks show the bottom of the excavated trench.

1.3 Yampa River Canyon

Tamara Naumann conducted a *Spiranthes* inventory during a low-water Yampa River trip from July 29 through August 1. Geomorphic maps are not available for the Yampa River in Dinosaur. The inventory occurred after the consultation trip with Dr. Schmidt, however, and attention was given to geomorphic surfaces along with vegetation in searching for potential habitat. (See Results Section for further discussion.)

1.4 Browns Park National Wildlife Refuge

The U. S. Fish and Wildlife Service, Browns Park National Wildlife Refuge is located upstream from Dinosaur National Monument in Moffat County, Colorado. Geomorphic maps are unavailable for this reach. However, the Refuge has recent color-infrared aerial photographs showing abandoned ox-bows, backwater channels, and flood plain features. Because *Spiranthes* is known to inhabit such features, we used the aerial photographs to focus our inventory efforts on the Refuge. We met with Refuge Manager Michael Bryant on July 7, 1998 to obtain staff input on likely habitat areas.

2.0 Methods

2.1 Lodore Canyon

Inventory in Lodore Canyon occurred between August 14-18 and August 24-28, 1998. During the first trip, from Gates of Lodore (RM 243.7) to Echo Park (RM 225), seasonal biological technicians Heath Whitacre and Judy Ward surveyed as many post-dam geomorphic surfaces as possible. The surfaces were traversed, presence or absence (+/-) of *Spiranthes diluvialis* was noted, the number of orchids observed was recorded, the proportion of each subpopulation the observed individuals represented was estimated, and significant biotic and abiotic factors affecting the orchids were noted. The estimate of the proportion observed was based on phenological state of the orchid, density of the surrounding vegetation, size and morphology of the occupied surface, and effort spent at the inventory site. The estimate of total number of orchids present at each site was calculated by taking the actual number observed as a proportion of the total. The estimates are probably conservative. Anna Arft's (1995) meticulous demographic work on the South Boulder Creek population showed the percentage of individuals flowering in a given year can vary

from as low as 23% to as high as 79%, and is influenced by site conditions (i.e., the number of orchids actually present can vary from 1.25 to 4.25 times the number observed).

The second inventory trip involved two days in Lodore Canyon and three days below the Yampa River confluence. Karen Barnett (Bureau of Reclamation), and Heath Whitacre, Lee Buschkowsky, Tamara Naumann, Judy Ward, and Ava Kahn (N.P.S., Dinosaur National Monument) conducted the inventory using the same methodology.

2.2 Echo Park, Whirlpool Canyon, Island Park-Rainbow Park, and Split Mountain Canyon

Echo Park, Whirlpool Canyon, Island Park-Rainbow Park, and Split Mountain Canyon are in Dinosaur National Monument, downstream from the confluence of the Yampa and Green Rivers at Echo Park (see general map, Appendix 1). These reaches (except for Rainbow Park) were surveyed July 26-28. 1998. Grams' geomorphic maps and vegetation cues were utilized in choosing the 11 map units surveyed in Whirlpool Canyon on August 26. In Island Park, 38 map units were chosen using geomorphic information in addition to known *S. diluvialis* distribution data. Eight map units in Rainbow Park were surveyed separately by Judy Ward on August 19. In Split Mountain Canyon, four units mapped by Grams as intermediate bench and supporting some associated plant species were surveyed on August 28. Heath Whitacre and Judy Ward surveyed several sites downstream of Split Mountain Canyon on September 10.

2.3 Yampa River Canyon

Tamara Naumann surveyed in Yampa Canyon as described in Section 1.3 above, between July 29 and August 1, 1998.

2.4 Brown's Park National Wildlife Refuge

Brown's Park National Wildlife Refuge was surveyed from August 4 to August 7. Judy Ward, Heath Whitacre, Ava Kahn, and Tamara Naumann worked with Refuge volunteers Shawn Gray, Joel Zumbalo, and Milu Carp. Tammy Wilson from the Bureau of Land Management participated on August 7. The left and right shores of the Green River, backwater channels, and old flood plain areas were accessed by canoe. The entire length of the Green River through Browns Park

National Wildlife Refuge (approximately 16 river miles) was inventoried over the four days. Locations away from the river were accessed on foot.

3.0 Results

3.1 Lodore Canyon Reach—Gates of Lodore to Yampa River Confluence

3.1.1. Lodore Sub-Reach 1—Gates of Lodore at RM 243.5 to Trailer Draw at RM 238.75

In the first 4.9 miles downstream of Lodore campground, we surveyed 26 map units and found only one orchid (Table 2). This section of Lodore Canyon is narrow, steep-walled and without significant tributary inputs to the main river channel. The post-dam surfaces are small and narrow. They are occupied by the tall annual, western goldenrod (*Solidago occidentalis*).

3.1.2. Lodore Sub-Reach 2—Trailer Draw at RM 238.75 to Limestone Draw at RM 228.5

The next section of Lodore Canyon (Lodore Sub-Reach 2, Table 2) includes a number of geological faults: Jack Springs, Ecklund, Disaster, Zenobia, and Pot Creek. These faults open up the canyon and create sizable tributaries that contribute coarse debris to the main river channel. The reach begins at Trailer (Jack Springs) Draw and continues downstream approximately ten river-miles to Limestone Draw; it contains many post-dam surfaces that are occupied by *Spiranthes*. We observed 3456 orchids in this reach and estimate the actual number to be 6097, making it the most populated reach in the Monument.

The first Lodore Canyon site with a large number of orchids is Trailer (Jack Springs) Draw (416 individuals observed, 624 estimated). Here, the orchids occur both away from the river in an abandoned side channel and on banks adjacent to the river. Both surfaces were mapped as intermediate bench by Grams. Associated species include: wild licorice (*Glycyrrhiza lepidota*), redtop (*Agrostis stolonifera*), marsh paintbrush (*Castilleja exilis*), showy milkweed (*Asclepias speciosa*), common dogbane (*Apocynum cannabinum*), Western evening primrose (*Oenothera elata*), wild rose (*Rosa woodsii*), hoary aster (*Machaeranthera canescens*), alkali muhly (*Muhlenbergia asperifolia*), common reed (*Phragmites australis*), horseweed (*Conyza canadensis*), coyote willow (*Salix exigua*), white sweet clover (*Melilotus alba*), Nuttall sunflower (*Helianthus nuttallii*), sea milkwort (*Glaux maritima*), silverweed cinquefoil (*Potentilla*

anserina), smooth scouring rush (*Equisetum laevigatum*), and Western goldenrod (*Solidago occidentalis*).

Table 2: Summary of *S. diluvialis* 1998 survey results—Dinosaur National Monument and Browns Park National Wildlife Refuge.

River Reach	Post-Dam Flood Plain & Intermediate Bench Surfaces[1]		Units Surveyed (*)		Surveyed Units Occupied (*)		*S. diluvialis* Individuals (*)	
	No. of Units	Area (m^2)					Obs.	Est.
Lodore Canyon	163	468,541	125	77%	78	62%	4054	7006
Lodore Sub-Reach 1	31	68,549	26	84%	4	15%	1	2
Lodore Sub-Reach 2	102	284,609	74 (3)	73%	62 (3)	84%	3440 (16)	6070 (27)
Lodore Sub-Reach 3	10	30,455	10	100%	5	50%	9	18
Lodore Sub-Reach 4	10	22,285	7	70%	7	100%	588	889
Lodore Sub-Reach 5	10	62,643	8	80%	0	0%	0	0
Echo Park	15	73,745	0	0%	0	--	0	0
Whirlpool Canyon	38	120,486	11	29%	0	0%	0	0
Island Park-Rainbow Park	63	761,437	45 (1)	71%	8 (1)	18%	86 (10)	178 (20)
Split Mountain Canyon	23	75,129	4	17%	0	0%	0	0
SUBTOTAL	302	1,499,338	185 (4)	61%	86 (4)	46%	4124 (26)	7157 (47)
Below Split Mountain	N/A	N/A	N/A	N/A	N/A	N/A	(30)	(150)
Yampa River Canyon	N/A	N/A	N/A	N/A	N/A	N/A	(0)	(0)
Browns Park NWR	N/A	N/A	N/A	N/A	N/A	N/A	(50)	(100)
						TOTAL	4230	7454

[1] Geomorphic surface data provided by Paul Grams, Utah State University.
* Numbers in ( ) are figures for geomorphic units other than post-dam flood plain or intermediate bench, as mapped by Paul Grams.

Compared to streambank habitat, the side channel is drier, vegetation is denser, and the habitat appears to be past the optimal seral stage for *Spiranthes* establishment. The orchids observed in this drier habitat were relatively robust (up to 2 feet tall), a condition that may be a shade-induced response to competition. The moist riverbank habitat supports shorter, less dense vegetation that indicates an earlier seral stage. The soils varied from silty sand to silty clay, mostly shallow to cobbles (about 5 inches), and moist, but not saturated.

Lower Disaster Falls supports a large number of orchids (759 observed). This area is mapped as post-dam flood plain and intermediate bench and includes an abandoned side channel that is somewhat less distinct than the one at Trailer Draw. The majority of the orchids occupy the slightly moister post-dam flood plain. Tamara Naumann estimated 2000 individuals on this site in 1997; we estimated 1518 plants in 1998 by the method described above (Section 2.1).

S. diluvialis is relatively abundant between Lower Disaster Falls and Pot Creek (approximately 1.1 river-miles). We estimate that more than 3200 orchids occur in this section, which is bisected by several geological faults and their associated tributaries. The canyon is relatively open and contains a number of active and inactive backwater channels that provide habitat for *Spiranthes*.

Spiranthes abundance drops off between Harp Falls (RM 234.2) and Hells Half Mile (RM 232). No significant geological faults or tributaries occur in this section. Near Hells Half Mile, Disaster Fault traverses the river; again we detected numerous *Spiranthes* in association with these tributary features.

Below Hells Half-Mile is a stretch containing only a few scattered orchids (RM 231.1-230.2). At RM 230.2, across from Rippling Brook, we estimated presence of 168 orchids. The individuals on this site were dispersed throughout a large area. Associated vegetation appeared shorter than at other sites, and the orchids were smaller than average (about 11inches compared with an average height of 15 inches). They were also behind in phenology (budding and flowering rather than flowering and fruiting). Scattered clusters of orchids were detected in the remainder of the reach ending at Limestone Draw (RM 228.5).

3.1.3. Lodore Sub-Reach 3—Limestone Draw at RM 228.5 to RM 227.0

Ten map units were surveyed in the 1.5-mile reach between Limestone Draw and RM 227. Only 18 orchids were estimated to occur in this reach (Lodore Sub-Reach 3, Table 2). Dense stands of tamarisk were encountered on the post-dam surfaces examined, coupled with the apparent

exclusion of *S. diluvialis*. Bedrock at river level changes from Uinta Mountain Group quartzite to Lodore Formation sandstone and shale.

3.1.4. Lodore Sub-Reach 4—RM 227.0 to RM 226.0

We estimated 889 orchids on seven post-dam surfaces in the one-mile reach between RM 227 and RM 226 (Lodore Sub-Reach 4, Table 2). The occupied surfaces are not invaded by tamarisk, in contrast with adjacent upstream and downstream areas. This reach is not appreciably wider than the upstream reach, although the river curves sharply toward the west through the section; *Spiranthes* inhabits the outside bank of the curve. The opposite riverbank is infested with tamarisk. River-level bedrock changes to Madison Limestone overlain by Quaternary alluvium in this reach.

3.1.5. Lodore Sub-Reach 5—RM 226 to the Yampa River Confluence at RM 225

The post-dam surfaces in the section of Lodore Canyon immediately above the confluence with the Yampa River (Lodore Sub-Reach 5, Table 2) are heavily infested by dense tamarisk. We surveyed eight post-dam map units, none of which appeared to support orchids. The channel is influenced by the Yampa River in flood throughout this section. Bedrock changes to Weber Sandstone.

3.2 Below the Confluence

3.2.1. Echo Park Reach—Yampa River Confluence at RM 225 to Whirlpool Canyon at RM 222.5

No formal surveys were conducted in this reach. The river channel is low gradient and heavy tamarisk infestations occur on the banks and on sand bars. Echo Park is strongly influenced by the Yampa River.

3.2.2. Whirlpool Canyon Reach—RM 222.5 to Island Park Entrance at RM 214.5

Eleven map units in Whirlpool Canyon were surveyed on August 26, 1998. *Spiranthes* was not detected on any of the sites (Echo Park Reach, Table 2). Active channel deposits (Grams, 1997) and post-dam flood plain surfaces in Whirlpool Canyon are either unvegetated or they are vegetated by very simple early successional plant communities. Early seral species include:

sedges (*Carex* spp.), wiregrass (*Juncus balticus*), common spikerush (*Eleocharis palustris*), orange sneezeweed (*Helenium autumnale*), and prairie cordgrass (*Spartina pectinata*).

Intermediate bench surfaces are inundated more frequently in Whirlpool Canyon than they are in Lodore Canyon because of the addition of Yampa River flows. In Whirlpool, these surfaces are occasionally inhabited by some of the species typically associated with *Spiranthes*. For example, at Jones Hole, we found redtop (*Agrostis stolonifera*), wild mint (*Mentha arvensis*), silverweed cinquefoil (*Potentilla anserina*), Western evening primrose (*Oenothera elata*), and wild licorice (*Glycyrrhiza lepidota*). At other sites, these surfaces supported wild licorice, coyote willow (*Salix exigua*), and young tamarisk.

The cottonwood-box elder (c-b) terraces in Whirlpool Canyon are too dry for *Spiranthes* occupation; scouring rush (*Equisetum* spp.), large tamarisk, and sagebrush (*Artemisia tridentata*) are frequent inhabitants. Grams (1997) characterizes c-b terraces below the Yampa confluence as 4.2 ± 0.9 m above baseflow water surface (see Appendix 2).

3.2.3. Island Park-Rainbow Park Reach—The Cove river camp at RM 214.5 to Split Mountain Canyon Entrance at RM 207.0

Forty-six (46) map units were surveyed in the Island Park-Rainbow Park Reach. This is a low gradient open reach characterized by complex flood plain features, some of which are active and some of which appear to be inactive. Nine units support an estimated 198 orchids (Island Park-Rainbow Park Reach, Table 2).

Spiranthes was discovered near The Cove river camp in 1997. On August 26, 1998, we estimated 13 individuals at that site.

Across the river at RM 214.1, where we estimated 46 individuals, the orchids occur with a different suite of associates than we encountered in Lodore Canyon, including: prairie cordgrass (*Spartina pectinata*), coyote willow (*Salix exigua*), Western goldenrod (*Solidago occidentalis*), and wild licorice (*Glycyrrhiza lepidota*). The orchids occupy a slight depression approximately

one meter above and three meters lateral distance from the water (flows recorded at Jensen gauge on August 26 were 3300 c.f.s.). As we walked along the depression, we saw marsh paintbrush (*Castilleja exilis*) and redtop (*Agrostis stolonifera*), two common associates in Lodore Canyon. Near the downstream end of the site, coyote willow density increased and *Spiranthes* presence dropped off.

This somewhat unusual habitat was encountered again on a small island on river-left (RM 214) where 96 orchids were estimated. Here, the associated plants are: wild licorice (*Glycyrrhiza lepidota*), meadow horsetail (*Equisetum arvense*), common scouring rush (*Equisetum hyemale*), common dogbane (*Apocynum cannabinum*), common reed (*Phragmites australis*), coyote willow (*Salix exigua*), Canada wild rye (*Elymus canadensis*), marsh paintbrush (*Castilleja exilis*), and silverweed cinquefoil (*Potentilla anserina*). Most of the orchids are arranged along a subtle sand berm associated with driftwood, indicating a high water mark. This sand berm appears to be on the same topographic level as the occupied site near The Cove river camp (upstream) and the next site, which is located on the downstream end of the same debris fan complex

Associates of the estimated 20 orchids at the downstream edge of The Cove debris fan complex include: coyote willow (*Salix exigua*), tamarisk, red osier dogwood (*Cornus stolonifera*), comon scouring rush (*Equisetum hyemale*), common dogbane (*Apocynum cannabinum*), Western goldenrod (*Solidago occidentalis*), common reed (*Phragmites australis*), and wild licorice (*Glycyrrhiza lepidota*). Coyote willow (*Salix exigua*) occurs nearby and is possibly moving into the area occupied by orchids.

The final site in Island Park containing an estimated 20 orchids is a bench on the backside of Bobby Island. This bench was mapped as a cottonwood-boxelder terrace by Grams. It supports a narrow band of suitable habitat between willows and tamarisk/ cottonwoods. This habitat is rather high above baseflow water level and appears isolated from the channel behind Bobby Island. We observed evidence that the channel carries water during high flows, but no indication that the orchids are ever inundated.

Other side channels in Island Park (notably at RM 211.7) contained marginally suitable habitat occupied by a number of associates, including redtop (*Agrostis stolonoifera*), alkali muhly (*Muhlenbergia asperifolia*), wild mint (*Mentha arevensis)*, and horsetail or scouring rush (*Equisetum* spp.). However, we found no orchids.

The riverbanks along the main channel in Island Park do not appear to support suitable *S. diluvialis* habitat. Near the water (at approximately baseflow level), banks are covered with prairie cordgrass (*Spartina pectinata*). Above the cordgrass are wild licorice (*Glycyrrhiza lepidota*), false Solomon seal (*Smilacina stellata*), horsetail or scouring rush (*Equisetum* spp.), and showy milkweed (*Asclepias speciosa*); higher still are wild rose (*Rosa woodsii)* and three-leaf sumac (*Rhus trilobota*).

Habitat potential on the islands in Island Park varies depending on elevation above baseflow level. Lower islands range from unvegetated to densely vegetated with coyote willow and young tamarisk. Dense tamarisk/willow stands do not support a diverse graminoid understory. Wild mint (*Mentha arvensis*), silverweed cinquefoil (*Potentilla anserina*), and sea milkwort (*Glaux maritima*) do occur amongst willows and tamarisk. The surfaces on islands that are higher appear older and drier. These islands support upland vegetation along with older stands of coyote willow, Fremont cottonwood and tamarisk.

Nine map units were surveyed in Rainbow Park on August 19, 1998. None of the sites yielded orchids or suitable habitat. A number of apparently recent surfaces are either unvegetated or covered by tamarisk seedlings. Above these surfaces, Western goldenrod (*Solidago occidentalis*) and Nuttall sunflower (*Helianthus nuttallii*) are interspersed with young tamarisk. A side channel at river-mile 208.8 appeared the most likely to support potential orchid habitat. The vegetation along the channel was very early seral, however, and the banks were overgrown with tamarisk and coyote willow.

3.2.4. Split Mountain Canyon Reach—RM 207.0 to approximately Inglesby Rapid at RM 202.0

In Split Mountain Canyon, we surveyed four sites on August 28, 1998 (Split Mountain Canyon Reach, Table 2). None of these sites appeared to support *S. diluvialis*. The plant communities along the riverbanks were early seral with very little diversity, indicating frequent inundation and possible scouring and/or deposition of sand. At river-mile 205.5, the zone nearest the water (at approximately 3300 c.f.s.) contained prairie cordgrass (*Spartina pectinata)*, wild licorice (*Glycyrrhiza lepidota)* and some Western evening primrose (*Oenothera elata*). At river-mile 204.9, we traversed a side channel, which is active at higher water, where we observed bur ragweed (*Ambrosia acanthicarpa*), and witchgrass (*Panicum capillare*) growing amongst the cobbles. We did not identify any suitable orchid habitat in Split Mountain Canyon.

3.2.5. Below Split Mountain Reach—RM 200.0 to RM 198.5

Two known *Spiranthes diluvialis* locations were surveyed on September 10, 1998, below the outlet of Split Mountain Canyon. The first is a tributary drainage adjacent to the south flank of Split Mountain east of the Green River at RM 199.4. Between the first two secondary drainages coming south off Split Mountain, we counted 13 orchids. Within the immediate area we also observed Jones reedgrass (*Calamagrostis scopulorum*) and more familiar associates including: redtop (*Agrostis stolonifera*), marsh paintbrush (*Castilleja exilis*), and Western evening primrose (*Oenothera elata*). The orchids occur on a bank, two feet above the stream bottom and on the bank edge amongst helleborine (*Epipactis gigantea*). The *Spiranthes* here were mostly past flowering and we were not able to conduct a thorough search. We estimate that we saw perhaps 20 percent of them and that as many as 65 may be present.

The second site is located on river-left at RM 198.9; it consists of a side channel that is inundated during high flow periods. Near the entrance of this back channel, we observed arrowleaf (*Sagittaria cuneata*) near pools of standing water. We found *S. diluvialis* on the banks further back in the channel. The orchid habitat was similar to that in Lodore Canyon, but fewer species were present. We counted 17 individuals and estimate that there are 85 present in this side channel (See Table 2).

The orchids observed at these two sites were mostly past flowering on September 10. The fruit capsules were empty—apparently no seeds were produced at either site.

3.3 Yampa River Canyon

The survey of Yampa Canyon, conducted July 29 through August 1, 1998, failed to identify any suitable orchid habitat and no orchids were observed. The geomorphic surfaces proximate to the river resemble those in Whirlpool and Split Mountain Canyons, i.e. too high above baseflow levels to provide the hydrologic conditions necessary for orchid establishment and persistence. The most likely areas are inhabited by common three-square (*Scirpus pungens*), wild *licorice (Glycyrrhiza lepidota*), silverweed cinquefoil (*Potentilla anserina*), water ladysthumb *(Polygonum amphibium*), and prairie cordgrass (*Spartina pectinata*).

3.4 Brown's Park National Wildlife Refuge—Approximately from the Colorado-Utah Border at RM 261 to the Lodore Boat Ramp at RM 243.5

We spent four days surveying Browns Park National Wildlife from August 4 through August 7, 1998. During this work, we recognized three discreet landforms associated with the river: steep cut-banks, lower sub-banks, and relatively new islands. The river edge was characterized by steep cut-banks. These cut-banks are four to six feet above the water (Flaming Gorge flows were 2900 c.f.s. during the survey period). The upper surfaces, which likely correspond to Grams' cottonwood-box elder terrace, are drier than optimal for *Spiranthes* and heavily infested by weeds, most notably perennial pepperweed (*Lepidium latifolium*). On some of these high banks, we found lower depressions indicative of abandoned side channels. These depressions contain only a few species and appeared to be dry.

Below the steep cut-banks, newer sub-banks appear to be forming one to two feet above the water surface (at approximately 2900 c.f.s.). These riverbank features likely correspond to Grams' post-dam flood plain units (note that geomorphic maps are not available for this area). On the lower sub-banks we found redtop (*Agrostis stolonifera*), smooth scouring rush (*Equisetum laevigatum*), marsh paintbrush (*Castilleja exilis*), sea milkwort (*Glaux maritima)*, and

Western evening primrose (*Oenothera elata*). These plants are strongly associated with *S. diluvialis* in Lodore Canyon and may indicate some availability of habitat on the Refuge.

In addition to the high cut-banks, and the newer sub-banks, numerous islands exist in Browns Park. These islands support disturbance-tolerant plants, including coyote willow (*Salix exigua*), common reed (*Phragmites australis*), horsetail (*Equisetum* sp.), rushes (*Juncus* sp.), sedges (*Carex* sp.), cattails (*Typha* sp.), bulrush (*Eleocharis* sp.), and young tamarisk.

The aerial photographs we examined indicated a side channel between RM 250 and RM 249. On the downstream side, this channel contained water backed up from the main channel. The area supported many associates and appeared to be potential orchid habitat. We did not find any orchids, however. Further from the main channel, the habitat looked less optimal with dense patches of coyote willow and abundant barren patches on drier surfaces.

On August 7, we found *S. diluvialis* in the lower part of the Refuge. Twenty-six individuals were counted on a sub-bank surface at RM 247.8. Refuge intern Milu Carp revisited this site on August 31, when she counted 49 individuals. These orchids are associated with redtop (*Agrostis stolonifera*), marsh paintbrush (*Castilleja exilis*), wild licorice (*Glycyrrhiza lepidota*), sea milkwort (*Glaux maritima*), coyote willow (*Salix exigua*), Western goldenrod (*Solidago occidentalis*), meadow sowthistle (*Sonchus uliginosus*), Torrey rush (*Juncus torreyii),* and wild mint (*Mentha arvensis)*. All of these plants had been observed upstream on similar surfaces. The most distinctive difference between this site and the unoccupied surfaces upstream was the presence of visible cobbles partially covered by a thin layer of sand. A mile downstream at RM 246.8 on river-left, we counted one individual in a small patch of habitat. Between these two sites, we estimated 100 individuals (Browns Park NWR Reach, Table 2).

4.0 Discussion

The complex ecology and distribution of *Spiranthes diluvialis* make effective conservation management difficult. *Spiranthes* occurs in scattered, isolated populations ranging from central Colorado to northern Washington (Hartman, 1997). Very often, it occupies riparian and flood

plain habitats situated in transition areas where rivers or streams flow from confined reaches into unconfined (or less confined reaches), at the base of mountain ranges, for example. Active flood plains allow for establishment of "new" surfaces that may provide suitable "temporary" habitat for *S. diluvialis* if they remain stable for some period of time after formation.

S. diluvialis is thought to have arisen from multiple hybridization events between the ancestral parents of two congener species, *Spiranthes romanzoffiana* and *S. magnicamporum* (Arft 1992, 1995). During the glacially active Pleistocene period, the ancestral parents *of S. romanzoffiana* and *S. magnicamporum* were most likely in contact and interbreeding, giving rise to fertile offspring—*S. diluvialis* (Sheviak, 1984, Arft 1995). The putative parents are now separated. *S. romanzoffiana* usually occurs above 8000 feet along mountain streams and lakes; *Spiranthes magnicamporum* is found in moist areas in the Great Plains (Arft, 1995).

The present-day rarity of suitable habitat in the arid intermountain region is thought to be one of the reasons *S. diluvialis* is rare and scattered across the western United States (Sheviak 1984). In addition to the hydrologic needs of the orchid, the density of surrounding vegetation and plant succession influence the orchid's abundance and distribution. *S. diluvialis* will be crowded out of a site in which the surrounding vegetation becomes tall and dense. The orchid is shade-intolerant and is found amongst low vegetation containing herbaceous and graminoid components. It appears tolerant of periodic inundation, but frequent sediment deposition and/or scouring may reset the successional stage, thereby eliminating *Spiranthes* or precluding its establishment. Its most natural successional position can perhaps be described as early mid-seral.

Along a river channel, periodic floods are natural disturbances that may either reset the stream-side vegetation to an early successional stage by scouring away or depositing sediment or arrest succession at an early mid-seral stage by inundation. Flow characteristics directly affect the establishment and persistence of *Spiranthes* populations by influencing topographic and hydrologic characteristics of the river channel and riverbank surfaces and their associated vegetation.

4.1 Lodore Canyon

Downstream from Flaming Gorge Dam, regulated flows have created two distinct surfaces in Lodore Canyon since dam closure in December of 1962 (Grams, 1997). The post-dam flood plain is a distinct and typically flat surface that is inundated annually by power plant capacity flows of approximately 4600 cubic feet per second. The intermediate bench is another distinct and relatively flat post-dam surface that was inundated in the 1983 flood; it is distal to the post-dam flood plain and approximately one meter above it in elevation (see Appendix 2 for a more complete description).

One hundred twenty-five (77%) of Grams' 163 post-dam flood plain or intermediate bench map units were surveyed in Lodore Canyon; 78 of these are occupied by *Spiranthes* (62%). Orchids were documented on three (3) additional sites in Lodore Canyon that Grams had not identified as post-dam surfaces, however, we believe they would meet his criteria as such. Between the Yampa River confluence and the outlet of Split Mountain Canyon, *S. diluvialis* was observed on only eight (13%) of the 60 post-dam surfaces examined *Spiranthes diluvialis* is not distributed randomly along the river channel; it's presence is somewhat predictable in Lodore Canyon, based on its apparent affinity for geomorphic surfaces that have formed since dam closure. Below the Yampa River confluence, this relationship is notably less striking. The large annual floods contributed by the Yampa River exert a significant influence on channel morphology of the Green River and appear to dampen the processes that have formed post-dam *S. diluvialis* habitat in Lodore Canyon.

The strong correlation between the distributions of post-dam surfaces and orchids in Lodore Canyon, coupled with absence of such correlation below the Yampa River confluence, suggests that Lodore Canyon did not provide significant habitat for *S. diluvialis* prior to dam closure. If flowing water is the primary dispersal mechanism for *S. diluvialis* seeds (as we believe), a relatively recent downstream migration is implied. Browns Park is the most probable pre-dam source area, in our opinion, as it is 1) upstream, 2) nearby, 3) characterized by complex flood plain topography (i.e., habitat), and 4) it represents an unconfined reach below a confined reach.

Although we believe pre-dam Lodore Canyon did not contain much suitable habitat, several areas within the canyon could have supported orchids. Secondary channels at Trailer Draw, Lower Disaster and Pot Creek are the most likely pre-dam habitat areas; they would be good choices for placement of monitoring plots designed to capture changes in response to reoperation.

Within Lodore Canyon, the distribution of *S. diluvialis* appears to be strongly influenced by the presence of debris fan complexes associated with tributary canyons. Tributary canyons are usually formed by faults. The main canyon is less confined and channel morphology is more complex in reaches containing abundant large debris fans. In reaches where these features are common (Trailer Draw to Limestone Draw), the orchid is relatively abundant. In steep-walled (more confined) reaches with few tributary inputs (Gates of Lodore to Trailer Draw), the orchids are rare (See maps, Appendix3 and Table 2 on page 7).

Spiranthes' apparent tolerance of periodic inundation is illustrated by our observations near Rippling Brook (a tributary canyon at RM 230.5). The population at this site is estimated at 168 individuals. On August 17, 1998, we noted these plants and the surrounding vegetation were developmentally behind, compared with many of the other plants we'd seen. Peter Williams (personal communication) had observed this site several days before and indicated it was inundated. This inundation does not appear to harm *S. diluvialis* and may keep competing vegetation in check.

The role of invasive species in Lodore Canyon is not understood. Dr. David Cooper (Colorado State University) is conducting research that may illuminate this question. We observed a substantial increase in tamarisk below Limestone Draw, coupled with a decrease in *Spiranthes* abundance. The reaches between Limestone Draw and the Yampa River confluence are characterized by lower gradient with fewer fan-eddy complexes than the reach between Trailer Draw and Limestone Draw (Martin and Grams, 1998). The river-level bedrock changes several times in the lower reaches, in contrast to the upper reaches, which are all underlain by Uinta Mountain Group quartzite. The substantial population of *Spiranthes* (estimated at 889 individuals) observed between RM 226 and RM 227 is enigmatic. We know that within this reach

the river abruptly changes orientation to east-west from predominantly north-south; *S. diluvialis* primarily occupies areas that have not been usurped by tamarisk; the orchids appear to be confined to the outside bend in the river. Perhaps Dr. Cooper's tamarisk research will help explain our observations. Perhaps the fluvial dynamics on such a prominent outside bend result in periodic inundation, while the low gradient precludes significant scouring.

4.1 Below the Confluence

4.2.1. Echo Park

Echo Park is so strongly influenced by the unregulated Yampa River that we do not believe it presently contains suitable *Spiranthes* habitat. The frequency and magnitude of high Yampa flows, combined with regulated Green River flows are not conducive to creation of surfaces that remain stable long enough for *Spiranthes* to become established in Echo Park.

4.2.2. Whirlpool Canyon

The difference in stage height between high and low flows in Whirlpool Canyon is markedly greater than in Lodore Canyon. The resulting post-dam surfaces mapped by Grams in Whirlpool Canyon are distinctly different in character from the post-dam surfaces he mapped in Lodore. Areas immediately above base-flow level are subject to annual inundation and frequent deposition and/or scouring. As water levels drop, these surfaces are become vegetated by early seral species. Higher on the riverbanks, a few species that are typical associates of *Spiranthes* are present, for example wild licorice (*Glycyrrhiza lepidota*). Such plants may indicate the appropriate point on the hydrologic gradient, but low species diversity on these sites suggests a point that is too early in vegetation succession for *Spiranthes* occupation. The frequency and magnitude of inundation on these sites may reset successional processes frequently enough to preclude *Spiranthes* establishment. These surfaces may also be too dry by July and August, when *Spiranthes* is still actively growing—a result of greater stage height differences below the confluence. Still higher on the riverbanks, surfaces may remain stable enough over periods of time, but they are likewise too dry for *Spiranthes*, typically supporting more upland species. Whirlpool Canyon does not appear to have any habitat that is both stable and moist enough for *Spiranthes diluvialis*. Areas around Jones Hole campground appeared to have the greatest potential for orchid habitat.

4.2.3. Island Park-Rainbow Park

As the river passes the Island Park Fault and enters Island Park, the gradient flattens out and the canyon opens up. Historically, the river meandered across a complex flood plain before entering Split Mountain Canyon, forming new channels and abandoning old channels. This large flood plain may have supported a sizeable *Spiranthes* population, however, the only evidence for this is a tiny relictual group of orchids stranded on a bit of cottonwood-box elder terrace on the back side of Bobby Island. The ten-or-so orchids we observed there are barely visible in a thin strip sandwiched between encroaching tamarisk, coyote willow and Fremont cottonwood. If this small number of individuals indicates the historic elevation of *Spiranthes* occupation, then most of the pre-dam habitat in the Island Park-Rainbow Park reach is now too dry to support the species.

Geomorphic complexity of the flood plain in the Island Park-Rainbow Park reach has been reduced (Schmidt and Grams, 1998) since Flaming Gorge dam was built. Now the river is hydrologically isolated from its former flood plain. The unregulated Yampa River provides sufficient variability to create a new flood plain within this reach; it is lower in elevation and less complex than the pre-dam flood plain. We found a number of orchids on post-dam surfaces near the entrance to Island Park. This may indicate some capacity for the orchid to shift in response to changes in flood plain elevation.

The surfaces that are currently within the appropriate hydrologic zone often support dense stands of coyote willow (*Salix exigua*). Within the understory of these stands are wild mint (*Mentha arvensis*), sea milkwort (*Glaux maritima*), and silverweed cinquefoil (*Potentilla anserina*), all of which are associated with *S. diluvialis* in Lodore Canyon. These species seem to have the same moisture requirements as the orchid. Perhaps they are better able to live amongst the willow because they are shade-tolerant; it is just as likely that coyote willow is actively increasing its dominance in this type of habitat, both in Island Park and in Browns Park (Gecy, 1998). We may be viewing this process in a transitional stage that could be somewhat misleading. Fluvial processes involved in the apparent increase in coyote willow dominance below Flaming Gorge

dam are not well understood. Invasive species (tamarisk and perennial pepperweed) are also a factor in this reach.

The abandoned channel behind Tree Island appears to be suitable (if not optimal) *Spiranthes* habitat. It may have been occupied at one time, and simply have progressed beyond *Spiranthes*' successional tolerance limits. Of all the areas in Dinosaur National Monument, Island Park and Rainbow Park probably offer the greatest potential for mitigation and/or restoration activities, if such become necessary as part of Flaming Gorge Dam reoperation (see discussion re: Browns Park, below). The Tree Island channel would be a good choice for establishment of monitoring plots to assess hydrologic and fluvial geomorphic responses to operational changes at Flaming Gorge.

4.2.4. Split Mountain Canyon

Channel features and riverbank vegetation in Split Mountain Canyon are similar to those observed in Whirlpool Canyon. As in Whirlpool Canyon, we found no orchids in the Split Mountain Canyon reach. Historic photos of Lodore Canyon show similar channel morphology, and lead us to the conclusion that most of the orchids presently inhabiting Lodore Canyon represent a post-dam, downstream migration from a source area (most likely Browns Park).

4.2.5. Below Split Mountain Canyon

We found orchids at two sites downstream of Split Mountain boat ramp on September 10, 1998. The first site is a tributary drainage joining the Green River at RM 199.4. The second site is a backwater channel of the Green River at RM 198.9. We estimated 150 orchids between these two sites. The individuals we saw were mostly past flowering. The fruits were hollow and appeared to contain no viable seed. We wondered if the lack of seed production might indicate a lack of available pollinators. Because *Spiranthes* offers only pollen, pollinators that require nectar must acquire it from surrounding plants flowering at the same time (Sipes and Tepedino, 1995). If no other synchronously flowering plants are nearby to offer nectar, *Spiranthes* pollination will suffer. We did note presence of plants that flower in the same period as the orchid, including

Western evening primrose (*Oenothera elata*), marsh paintbrush(*Castilleja exilis*),and sweet clover (*Melilotus* sp.).

4.3 Yampa River Canyon

The situation in Yampa River Canyon is very much like Whirlpool Canyon and Split Mountain Canyon. No plants and no suitable habitat were observed. There are, as yet, no confirmed records of *S. diluvialis* anywhere in the Yampa River drainage. Likely tributaries were also surveyed in 1998, with the same results. This effort did, however, yield a new record of another rare orchid, the alcove bog orchid (*Habenaria zothecina*).

4.4 Browns Park National Wildlife Refuge

Browns Park is an open alluvial valley between Dinosaur National Monument and Red Canyon. The Green River exits Red Canyon at RM 283 in Utah (approximately seven river miles below Flaming Gorge Dam). It traverses Browns Park, entering Colorado at RM 261. Browns Park National Wildlife Refuge is situated at the lower end of Browns Park, between the Colorado-Utah border and Dinosaur National Monument (RM 243.5, Gates of Lodore). Prior to construction of Flaming Gorge Dam, the Green River created and maintained an active flood plain on the floor of Browns Park. This river-flood plain connection and associated processes and functions have been greatly diminished by regulation of the river since 1962. The historical interplay of river and flood plain likely produced and maintained suitable habitat for *Spiranthes diluvialis* in Browns Park. *S. diluvialis* typically inhabits riparian/flood plain areas below the juncture where rivers or streams flow from confined reaches into unconfined reaches. The presence of suitable historical habitat is strongly suggested by examination of color infrared aerial photographs of the National Wildlife Refuge. The area was once a large complex flood plain, which has become a dry upland habitat type—a response to hydrologic isolation of the river from its former flood plain.

Several *Spiranthes* populations are extant in Browns Park, including those near Indian Crossing Campground (RM 274), Taylor Flats Bridge (RM 273.5), and Browns Park Waterfowl Management Area (RM 271), all of which are in Utah (Gecy, 1998). Our 1998 survey turned up two additional sites on the Browns Park NWR in Colorado, where we estimated population size

at 150 individuals. The upper Browns Park population was estimated at 500 individuals by Gecy (1998).

The presence of a large pre-dam population of *S. diluvialis* in Browns Park is further suggested by the presence of 7,000+ individuals downstream in Lodore Canyon, on geomorphic surfaces that were formed after dam closure, as discussed above.

Regulation of the river has severed the river from its former flood plain in Browns Park. The present river channel is deeply incised and characterized by steep sandy banks throughout most of the National Wildlife Refuge. Former flood plain features are too high and dry for *Spiranthes* establishment or maintenance. Dam-induced alterations in habitat, coupled with manipulations for waterfowl habitat management have rendered Browns Park NWR susceptible to invasion by perennial pepperweed, sweet clover, tamarisk and other aggressive non-native species. Habitat quality and availability have been diminished, as a result.

The new sediment budget imposed by the dam has created a series of low sub-banks (perhaps analogous to Grams' post-dam flood plain) at river's edge. These surfaces support many associates of *Spiranthes;* if allowed to develop they may become more hospitable to *Spiranthes*. The occupied area at RM 247.8, with an estimated 100 orchids, is one such feature. It is at the lower end of Browns Park Refuge, above the Vermilion Creek confluence. This sub-bank is wider than most and, unlike many sub-bank features encountered on the Refuge, it comprises large cobbles with a sand veneer. The population upstream (near Indian Crossing Campground) occurs in a very similar setting. Cobbles in a sand matrix are typical in occupied Lodore Canyon habitats. Could visible cobbles indicate some degree of site stability—not too much deposition, nor too much scouring?

Proximity to the dam may render Browns Park unsuitable as a mitigation/restoration area for *Spiranthes*. Without further study, this can't be determined with any confidence.

5.0 Summary

Spiranthes diluvialis occurs along the upper Green River in Browns Park on lands managed by the U.S. Fish and Wildlife Service (Browns Park NWR), U.S. Bureau of Land Management (Indian Crossing Campground and Taylor Flats Bridge), and the Utah Division of Wildlife Resources (Browns Park Waterfowl Management Area). It also occurs in Lodore Canyon, Island Park, and downstream of Split Mountain Canyon in Dinosaur National Monument (National Park Service). Within these reaches, *S. diluvialis* appears primarily to occupy geomorphic surfaces that developed after Flaming Gorge Dam closure. Several possibly relictual subpopulations were observed in habitat that is not currently appropriate for *Spiranthes* establishment, both in Lodore Canyon and in Island Park.

Typical associated species include: wild licorice (*Glycyrrhiza lepidota*), redtop (*Agrostis stolonifera*), marsh paintbrush (*Castilleja exilis*), showy milkweed (*Asclepias speciosa*), Western evening primrose (*Oenothera elata*), wild mint (*Mentha arvensis*), alkali muhly (*Muhlenbergia asperifolia*), horseweed (*Conyza canadensis*), Nuttall sunflower (*Helianthus nuttallii*), sea milkwort (*Glaux maritima*), silverweed cinquefoil (*Potentilla anserina*), common spikerush (*Eleocharis palustris*), smooth scouring rush (*Equisetum laevigatum*), meadow horsetail (*Equisetum arvense*), and Western goldenrod (*Solidago occidentalis*). Among these, redtop is not native.

S. diluvialis probably did not occur as extensively as it does now in Lodore Canyon prior to closure of Flaming Gorge Dam. In contrast, it probably occurred more extensively in pre-dam Browns Park and Island Park. The best evidence for this is:

- *Spiranthes*' apparent range-wide habitat preference for mesic, early mid-seral flood plain features; such features were more prevalent in pre-dam Browns Park and Island Park.
- A strong indication, based on range-wide observations, that the species is predominantly water dispersed (i.e., it travels downstream).
- Occurrences at Trailer Draw, Lower Disaster and Pot Creek in Lodore Canyon and on Bobby Island in Island Park suggest the possibility that these areas could have supported *S. diluvialis*

prior to dam closure; secondary channels and associated islands appear to be the most likely areas.

Spiranthes diluvialis populations in Browns Park, Lodore Canyon, Island Park, and downstream of Split Mountain Canyon could be affected by changes in Flaming Gorge Dam operations. More information is needed to assess the risk and/or potential benefit to this threatened species from the changes under consideration for the benefit of endangered Colorado River fish. If it is determined that the proposed changes may adversely affect *S. diluvialis* in Lodore Canyon, then Browns Park and Island Park offer the greatest potential for mitigation and/or restoration. The focus of research efforts in 1999 should be:

- Expanded geomorphic mapping in Browns Park and below Split Mountain and correlation with *Spiranthes* distribution,
- Refinement of correlations/association between *S. diluvialis* and geomorphic surfaces in Lodore Canyon and Island Park, with analysis of relevant formative processes,
- Identification of additional parameters that will contribute toward meaningful risk assessment.

The need for better understanding of the relationships between *S. diluvialis*, vegetation succession, and floodplain evolution stands out. The work accomplished to date merely points out the many deficiencies in the data. The work proposed for 1999 and 2000 will contribute to better understanding of the processes involved in establishment and maintenance of *S. diluvialis* populations in the upper Green River system.

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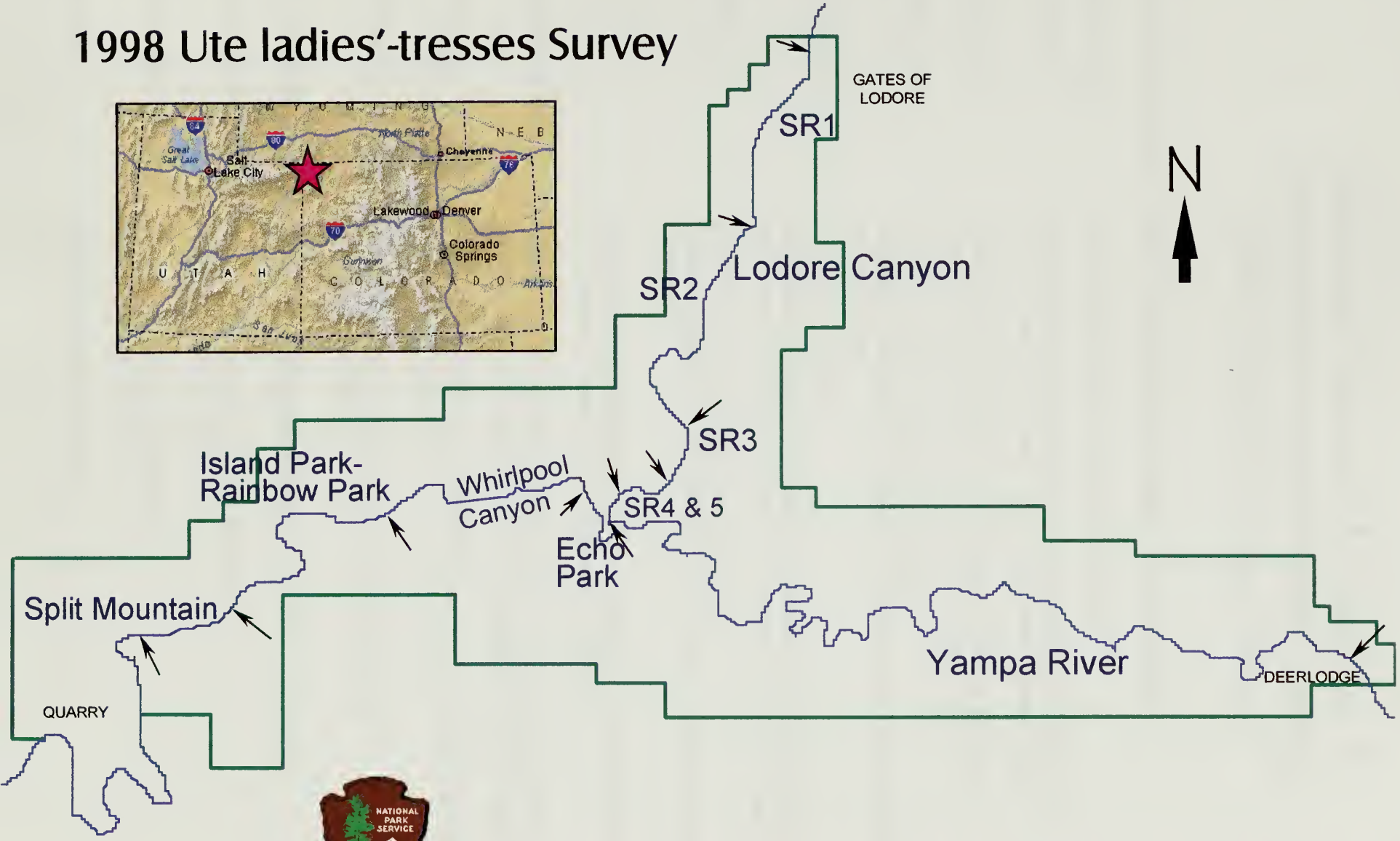
1998 Ute ladies'-tresses Survey



DINOSAUR NATIONAL MONUMENT

APPENDIX 1

Dinosaur National Monument & Browns Park National Wildlife Refuge 1998 Ute ladies'-tresses Survey

River Reaches for Which Geomorphic Maps Are Available:

Lodore Canyon	(Lodore Boat Ramp to Yampa Confluence)
■ Sub-Reach 1	(Lodore Boat Ramp @ RM243.5 to Trailer Draw @ RM238.75) Narrow, steep-walled reach with insignificant tributary inputs.
■ Sub-Reach 2	(Trailer Draw @ RM238.75 to Limestone Draw @ RM228.5) Open, faulting patterns create significant tributary inputs.
■ Sub-Reach 3	(Limestone Draw @ RM228.5 to RM227) Change in bedrock from Uinta Mtn. Group to Lodore Fm., tamarisk becomes more prevalent.
■ Sub-Reach 4	(RM227 to RM226) East-West Trending 1-mile reach w/ tamarisk on north bank, *Spiranthes* on south bank. Bedrock changes to Madison Limestone overlain by Quaternary Alluvium.
■ Sub-Reach 5	(RM226 to Yampa Confluence @ RM 225) Channel influenced by the Yampa River in flood. Bedrock changes to Weber Sandstone.
Echo Park	(Yampa River Confluence @ RM225 to Whirlpool Canyon @ RM222.5) Low gradient, strongly influenced by Yampa River.
Whirlpool Canyon	(Whirlpool Canyon Entrance @ RM222.5 to Island Park Entrance @ RM214.5) Moderate gradient confined reach, strongly influenced by Yampa River.
Island Park- Rainbow Park	(The Cove @ RM214.5 to Split Mountain Canyon Entrance @ RM207) Low gradient, wide open.
Split Mountain Canyon	(RM207 to Approximately Inglesby Rapid @ RM202) Steep gradient confined reach.

River Reaches for Which Geomorphic Maps Are *Not* Available:

Browns Park NWR	(RM261 to Lodore Boat Ramp @ RM243.5) Low gradient, unconfined.
Below Split Mountain	(RM202 to Monument Boundary) Low gradient, unconfined.
Yampa River	(Deerlodge Put-In @ RM46 to Confluence @ RM0)

points were located by parallax between foreground and background features in each photograph. In the absence of distinct foreground features, location was determined by parallax between different background features. Photographs were replicated using a Crown Graphic camera with a 135-mm lens and a 35-mm camera with a 35- to 70-mm zoom lens. Appendix B is a list of each replicated photograph, the original source of the photograph, and the type of match made. Black-and-white prints and color slides were taken of each view. Notes detailing observations were made in the field for each photograph, and measurements of change relative to stable features were made where possible. Each pair of matched photographs was examined for changes in riparian vegetation, evidence of narrowing of the active channel, the number of geomorphic surfaces adjacent to the channel, and change in substrate composition of bars and islands. This information was tabulated by photograph and summarized for each geomorphic subreach.

Historical aerial photographs were used to quantify channel changes. The use of these photos was limited to meandering reaches because the large scale and frequent shadows of early photographs make interpretations in canyon reaches inaccurate. Maps of the Echo Park and Island Park subreaches were made for 1954 and 1938, respectively. These maps were adjusted to a common scale of 1:12,000 using a zoom-transfer scope and a reflecting projector. The final maps were digitized and compared with the 1993 maps in a GIS.

Results

Geomorphology of Alluvial Deposits

Fine-grained deposits occur as four flood plain-like and terrace-like landforms that are longitudinally correlative throughout the study area. These geomorphic surfaces are the active channel deposits, the post-dam flood plain, the intermediate

bench, and the cottonwood-box elder terrace. Coarse-grained gravel deposits typically are active channel deposits but occasionally are correlative with the other three levels of fine-grained deposits.

Cottonwood-Box Elder Terrace

The cottonwood-box elder terrace (hereafter, c-b terrace) is the most continuous and extensive feature mapped in the study area and occurs in both canyon and meandering reaches. The name is derived from the cottonwood (*Populus fremontii*) and box elder (*Acer negundo*) trees abundant on this level in meandering and canyon reaches, respectively (Fig. 17). Juniper (*Juniperus osteosperma*), pinyon pine (*Pinus sp.*), sagebrush (*Artemisia sp.*), rabbit brush (*Chrysothamnus sp.*), and ponderosa pine (*Pinus ponderosa*) are also common on this surface. The soil organic layer is up to 15 cm thick and grass is the typical ground cover. The c-b terrace is a fine-grained deposit with a very flat upper surface and occasional river-parallel levees and back channels. Levees are located adjacent to the river channel and back channels are typically on the distal edge of the surface adjacent to bedrock or talus. The c-b terrace level averages 3.3 m above baseflow water surface upstream from the Yampa River confluence and 4.2 m downstream, with standard deviations of 1.0 and 0.9 m, respectively (Fig. 18).

Most exposures showing the stratigraphy of the c-b terrace are dominated by horizontally bedded fine-grained sediment, showing that this terrace formed by vertical accretion. As many as 15 distinct horizontal beds occur in a 2- to 3-m vertical exposure (Fig. 19). Individual beds range in thickness from about 1 cm to more than 50 cm, and the dominant texture of the beds ranges from clay to coarse sand. Many units are massive, but sedimentary structures commonly exist. Typically, beds are composed of medium to very-fine grained tan to brown sand with thin interbeds of coarse red sand in the upper parts of exposures and interbeds of clay lower in the exposures. Buried layers of leaf litter and other organics are also common. Some of the brownish beds are

massive, but ripple-drift cross-laminations indicating downstream transport can be found. Upward fining was observed in many bed sequences. The basal unit is typically coarse sand and upper beds are typically rippled medium- to fine-grained sand. The reddish, coarse-sand beds are believed to be slopewash deposits derived from nearby ephemeral tributaries that drain reddish Uinta Group quartzite.

Driftwood on the c-b terrace upstream and downstream from Echo Park includes sawn timbers that indicate inundation by floods that have occurred subsequent to upstream settlement in the late 1800's. U. S. Geological Survey photograph 23416 taken in 1917 (Appendix B) shows the c-b terrace completely inundated just above the beginning of Lodore Canyon. The peak discharge for that year was about 510 m^3s^{-1} which has a pre-dam recurrence interval of about 25 yr. The level of the c-b terrace downstream from the Yampa River confluence was completely inundated during the peak of the 1984 flood at 1100 m^3s^{-1}, the largest flood on record. Thus, only rare historical floods reach the level of the c-b terrace.

Intermediate Bench

The intermediate bench is a flat surface that typically occurs as a strip adjacent to and lower in elevation than the c-b terrace (Fig. 17). Mature tamarisk (*Tamarix sp.*) trees are the most common woody plant on the intermediate bench, but occasional willow (*Salix sp.*) and rare cottonwood trees can be found. Surface organic layers are thin and may consist of only 1 to 2 cm of organic duff. Horsetail fern (*Equisetum sp.*), grasses, and forbes are common ground covers. The intermediate bench averages 1.9 ± 0.7 m and 2.4 ± 0.4 m above baseflow water surface upstream and downstream from the Yampa River confluence, respectively (Fig. 18). Excavations at four sites indicate that the intermediate bench is a depositional unit inset into the c-b terrace. The inset intermediate bench is typically underlain by units of the c-b terrace (Fig. 20). Thickness of the inset varies, but is on the order of 0.5 to 1.5 m. Thus the intermediate bench

deposits must (1) postdate the c-b terrace and (2) be formed by depositional events following erosion into the c-b terrace. High-water marks on the intermediate bench in Lodore Canyon indicate that this surface was inundated by the 1983 flood, which peaked at 388 m^3s^{-1}. Downstream from Echo Park the level of the intermediate bench is typically above the stage reached by 485 m^3s^{-1}, which is the highest flow that occurred during the study period. Thus, this surface is likely inundated by flows greater than 600 m^3s^{-1} and is certainly flooded by flows of about 1,000 m^3s^{-1}.

Post-Dam Flood Plain

The post-dam flood plain is the level that is inundated annually in the present streamflow regime. The average elevation is from 0.8 ± 0.3 m above baseflow water surface upstream from the Yampa River confluence and 1.3 ± 0.4 m downstream from the confluence (Fig. 18). A primary diagnostic characteristic of this surface is the presence of young woody riparian vegetation (Fig.19). The most common species are tamarisk, willow, and cottonwood. The post-dam flood plain occurs as channel-margin deposits, eddy bars, and expansion bars. As a channel-margin deposit, it typically forms a narrow bench that is 1 to 5 m wide. On expansion bars, the post-dam flood plain usually consists of a veneer of fine-grained alluvium that forms an apron around the gravel bar, separating c-b terrace level from active gravel.

Because this surface is formed and maintained by the post-dam flow regime, its elevation differs upstream and downstream from the Yampa River confluence. The peak flow in Lodore Canyon is the same every year (Fig. 16) and has a duration of up to 8 weeks (Fig. 15). Thus the deposit associated with these flows forms a very distinct and typically flat surface that is inundated by the post-dam mean annual flood of 143 m^3s^{-1}. The post-dam flood plain downstream from the Yampa River confluence tends to cover larger areas and often occurs as a gentle slope rather than a distinct level bench.

It begins to be inundated in this reach at about 455 m^3s^{-1}, which is the post-dam 2-yr flood.

Active-Channel Deposits

Active-channel deposits consist of alluvium that is typically inundated to a sufficient depth such that bed material is mobilized frequently enough to inhibit the establishment of perennial vegetation. These deposits typically consist of bare sand, bare gravel, or debris with very little or no vegetation. Active deposits also include those that comprise the bed material of frequently inundated, nonvegetated side channels.

Longitudinal Correlation of Geomorphic Surfaces

Each level can be longitudinally correlated throughout the entire study reach, regardless of whether subreaches are debris fan dominated or meandering. The longitudinal profile of these correlated deposits generally reflects the profile of the water surface (Fig. 21). The average distance between baseflow and each deposit surface is less in meandering reaches than in debris fan-dominated reaches; and less upstream from Echo Park than downstream from Echo Park. The downstream variation in elevation for each level is less than the difference in elevation between levels. The statistical significance of the difference in elevation between the three surfaces was evaluated with 2-sample t-tests. The mean elevation of the post-dam flood plain is not greater than or equal to the mean elevation of the intermediate bench; and the mean elevation of the intermediate bench is not greater than or equal to the mean elevation of the c-b terrace, for $\alpha = 0.05$.

Individual fine-grained terraces or flood plains may extend longitudinally for as much as 1 km. The width of these deposits may be several hundred meters in meandering reaches. Deposits of the post-dam flood plain level and the intermediate