WYOMING GAME AND FISH DEPARTMENT

FISH DIVISION

ADMINISTRATIVE REPORT

TITLE: Instream Flow Studies on Clear Creek

PROJECT: IF-3094-07-9301

AUTHOR: Paul D. Dey and Thomas C. Annear

DATE: August 1994

ABSTRACT

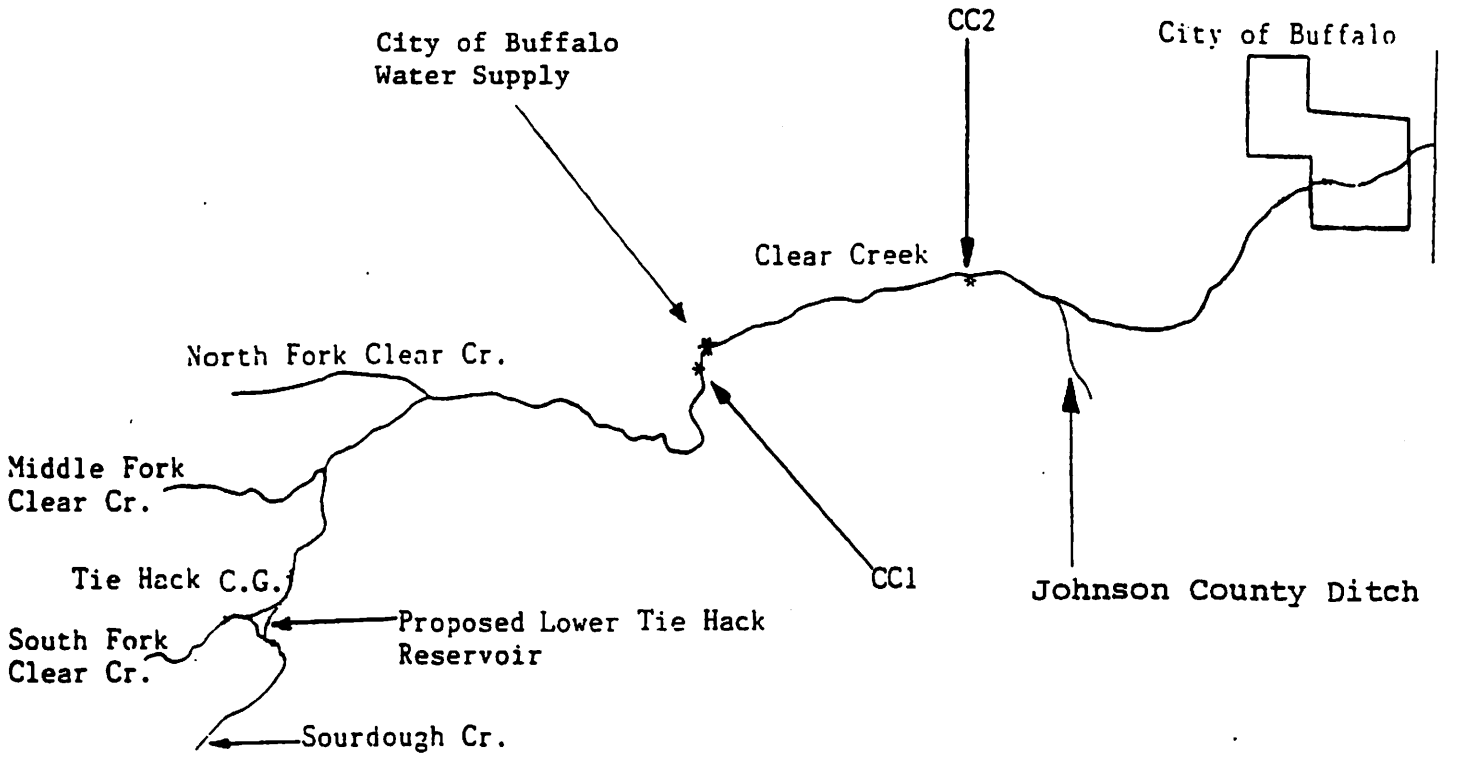
Data collected in earlier studies (Vogt 1989, Appendix 1) were used to determine instream flows needed to maintain the trout fishery in the Class 2 section of Clear Creek. The Class 2 reach was divided into two contiguous sections based on differences in the fishery, geomorphology and hydrology. Separate instream flow recommendations were developed for each section.

Physical Habitat Simulation (PHABSIM), the Habitat Quality Index (HQI), and a Habitat Retention method were used to derive flow recommendations. Recommendations for the reach from the North Fork Clear Creek confluence downstream to the City of Buffalo diversion are: April 1 - June 30 = 40 cfs, July 1 - September 30 = 30 cfs, October 1 - March 31 = 7.9 cfs. Recommendations for the reach from the Buffalo water diversion downstream to Johnson County Ditch are: April 1 to June 30 = 40 cfs, July 1 to September 30 = 25 cfs, October 1 to March 31 = 6.0 cfs.

INTRODUCTION

Since 1983, the City of Buffalo and Wyoming Water Development Commission (WWDC) have proposed several alternatives for developing an additional municipal water supply. Proposed construction alternatives involved reservoir development in the Clear Creek drainage. Instream flow data were collected by the Wyoming Game and Fish Department (WGFD) at several locations in the Clear Creek drainage in 1987 through 1989 to evaluate potential habitat losses and fishery enhancement opportunities associated with water development plans (Appendix 1, Vogt 1989). These data indicated that the proposed Tie Hack dam would provide opportunities for providing instream flows per state water law for maintaining fishery values.

Trout stream classifications throughout Wyoming were developed by WGFD and range from Class 1 (highest quality) to Class 5 (lowest quality). Clear Creek from the confluence of the North Fork of Clear Creek to the Johnson County Ditch is classified as a Class 2 trout stream and is managed as a wild trout fishery. Less



Scale: 1 inch = approximately 2 miles

Figure 1. Clear Creek Study Sites.

than 7% of all Wyoming stream miles are classified as Class 2 or better. This section of Clear Creek contains naturally reproducing (wild) populations of rainbow, brown and brook trout and receives no fish from department hatcheries.

Coincident with the important fishery values represented in this reach of Clear Creek, the public has expressed interest in maintaining instream flows for this fishery. For these reasons, these stream segments are considered critical.

Specific objectives included 1) determine instream flows necessary to maintain hydraulic characteristics important for fish passage through riffle areas and survival of trout and aquatic insects at all times of the year, 2) determine instream flows necessary to maintain adult trout production during the late summer months, and 3) determine instream flows necessary to maintain juvenile trout production during the spring months.

DESCRIPTION OF THE STUDY AREA

Clear Creek from the confluence of the North Fork of Clear Creek to the City of Buffalo diversion has a steep gradient, and stream habitat is dominated by cascading riffles and plunge pools. Clear Creek below the city diversion to I-25 has a more gentle gradient and contains long sections of swift-moving water characteristic of run habitat. Substrates in both reaches consist mainly of cobble and boulder.

METHODS

Study Sites

Data collected in 1989 studies were used to develop instream flow recommendations (Appendix 1, Vogt 1989). Study sites were established on Clear Creek approximately 1/2 mile upstream from the City of Buffalo diversion structure (CC1; T50N, R83W, S10) and near the abandoned Pacific Power and Light (PPL) powerplant 4 miles west of Buffalo (CC2; T50N, R82W, S 6; Fig. 1). Results obtained at site CC1 were applied to a 4.7 mile segment of Clear Creek from the confluence of the North Fork of Clear Creek to the City of Buffalo diversion structure. Results from site CC2 were applied to the 5.3 mile segment of Clear Creek between the City's diversion and the Johnson County Ditch. Based on the different fish habitat characteristics and hydrology above and below the Buffalo diversion, slightly different instream flow recommendations resulted for these reaches.

In the 1989 report (Appendix 1), the first major irrigation diversion structure below site CC2 was erroneously referred to as the Six Mile Ditch. This ditch is actually called the Johnson County Ditch and this terminology was used in this report.

Methodologies

A Habitat Retention Method (Nehring 1979) was used to identify fisheries maintenance flows for each of the two identified Clear Creek segments. A maintenance flow is defined as a continuous flow that will maintain minimum hydraulic criteria in riffle areas within a stream segment. These criteria are

important at all times of year to maintain passage between different habitat types for all life stages of trout. These criteria are also important for maintaining survival rates of fish and aquatic macroinvertebrates during the winter that approximate rates observed under natural stream flow conditions. Data from single transects placed across riffles at sites CC1 and CC2 were analyzed with the IFG-1 computer program (Milhous 1978). These data were collected at various stream discharges at each site (Table 1). Based on extensive research on instream flow methods on Wyoming streams by Annear and Conder (1983), the maintenance flow is identified as the discharge at which two of the three hydraulic criteria are met for all riffles in the study area (Table 2). Maintenance flows apply to all times of the year except when higher stream flows are required to meet other fishery management objectives.

Table 1. Dates and discharges when instream flow data were collected.

Site	Date(s)	Discharge (cfs)
CC1	6-27-89	147
	8-09-89	84
	9-12-89	43
CC2	5-24-89	120
	8-08-89	79
	9-14-89	33

Table 2. Hydraulic criteria used to obtain an instream flow recommendation using the Habitat Retention Method.

Category	Criteria
Average Depth (feet)	Top width[1] x 0.01
Average Velocity (feet per second)	1.00
Wetted Perimeter (percent)[2]	60

1 - At average daily flow
2 - Compared to wetted perimeter at bank full conditions

The Habitat Quality Index (HQI) developed by the Wyoming Game and Fish Department (Binns and Eiserman 1979) was used to estimate potential changes in trout standing crops over a range of late summer flow conditions. This model was developed by the WGFD after several years of testing and model refinement. The model incorporates nine attributes that address chemical, physical, biological, and hydrological components of trout habitat. Results are expressed in trout habitat units (HU). One HU is defined as the amount of habitat quality which will support 1 pound of trout.

By measuring habitat attributes at various flow events as if associated habitat features were typical of average flow conditions, HU estimates can be made for a variety of stream flow scenarios (Conder and Annear 1987). Habitat attributes were measured at each site at several discharges (Table 1). To better define the potential impact of other flow scenarios on trout production, some attributes were

derived mathematically or obtained from existing gage data. Gage data were obtained from USGS gage #6318500 located on Clear Creek near site CC2.

A physical habitat simulation model (PHABSIM) developed by the Instream Flow Service Group of the U.S. Fish and Wildlife Service (Bovee and Milhous 1978) was used to examine incremental changes in amount of physical habitat available for rainbow and brown trout spawning at various discharges. This model is widely considered to reflect state-of-the-art technology for evaluating fisheries physical habitat changes with changes in stream flows and is widely used throughout North America.

The amount of physical habitat at a given discharge is expressed in terms of weighted usable area (WUA) and reflects the composite suitability of depth, velocity and substrate at a given flow. Depth, velocity and substrate data were collected at sites CC1 and CC2 at several different flow levels (Table 1) in accordance with guidelines given by Bovee and Milhous (1978). Suitability curves for brown and rainbow trout juveniles are from Bovee 1978. Weighted Usable Area for rainbow and brown trout juveniles was simulated for a range of flows at each site with calibration and modeling techniques outlined by Milhous (1984) and Milhous et al. (1984). To standardize this analysis for both species, data were converted to percent of the maximum WUA using the following formula:

$$\% \text{ MUA} = (WUA_Q / WUA_{MAX}) * 100$$

Where Q = an individual flow level
and MAX = the maximum WUA for a particular analysis

Critical fish species and life stages in Clear Creek were identified (Table 3). Critical species are defined as those species identified by WGFD as the main fishery resource for a particular stream. In the case of Clear Creek, management efforts focus on maintaining both rainbow and brown trout populations but rainbow trout have a higher priority. Therefore, PHABSIM-derived flow recommendations were based on habitat requirements of rainbow trout. Analyses indicated that brown trout habitat would be maintained at flow levels recommended for maintaining rainbow trout habitat.

Critical life stages are those life stages most sensitive to environmental fluctuations. Population integrity is sustained by providing adequate flow for critical life stages. In many cases, Rocky Mountain stream populations are constrained by spawning and young (fry and juvenile) life stage habitat bottlenecks (Nehring and Anderson 1993). On Clear Creek, observations indicate that juvenile habitat during the spring months is likely a critical factor influencing trout populations. The spring months can be stressful to trout because energy reserves are low following winter and food is not yet plentiful. Fish energy expenditures can be relatively high in association with high flows during spring runoff and limit their distribution, growth and survival. Therefore, instream flow recommendations for April, May and June were developed based on juvenile trout requirements (Table 3). The PHABSIM system was used to derive these recommendations.

During the summer months, trout production is most directly related to growth and survival of adult fish. The HQI model was developed to determine suitability of late summer habitat for adult fish production This model was used to determine the

instream flow necessary to maintain existing levels of trout production during the months of July, August and September (Table 3).

As in many Rocky Mountain streams, survival of all life stages during winter months is a key factor influencing trout populations in Clear Creek. Winter trout survival is maintained at flow levels determined with the Habitat Retention model (see pg. 23, Appendix 1). Therefore, the Habitat Retention model was used during the low flow winter months (October through March) to determine instream flows necessary to maintain trout populations (Table 3).

Table 3. Critical species and life stages considered in development of instream flow recommendations for Clear Creek. Numbers indicate method used to determine flow requirements.

SPECIES	LIFE STAGE	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Brown trout	Adult							1	1	1			
Rainbow trout	Adult							1	1	1			
Brown trout	Juvenile				2	2	2						
Rainbow trout	Juvenile				2	2	2						
All species	All stages	3	3	3							3	3	3

1 - Habitat Quality Index
2 - PHABSIM
3 - Habitat Retention

RESULTS AND DISCUSSION

Results were separated into two sections dealing with each of the identified reaches (North Fork Clear Creek confluence downstream to the City of Buffalo diversion and Buffalo diversion downstream to Johnson County Ditch). All results and recommendations for each stream section are included under the appropriate heading.

North Fork Clear Creek confluence downstream to Buffalo Diversion

Results from the Habitat Retention model showed that flows of 7.5, 4.5, and 7.9 cfs are necessary to maintain winter survival of trout, aquatic insect production and fish passage at riffles 1, 2, and 3, respectively (Table 4). The maintenance flow recommendation derived from this method is defined as the flow at which two of the three hydraulic criteria are met for all riffles in the study site, which in this case is 7.9 cfs. The City of Buffalo has agreed to provide a maintenance flow of 7.9 cfs (O'Grady 1992, Appendix 2).

Table 4. Simulated hydraulic criteria for three riffles on Clear Creek at site CC1. Estimated bankfull discharge = 330 cfs; Estimated average daily discharge = 51 cfs.

Average Depth (ft)	Average Velocity (ft/sec)	Wetted Perimeter (ft)	Discharge (cfs)
	Riffle 1		
1.68	3.94	53.3	330.0
1.50	3.23	51.9	237.6
1.33	2.65	50.8	169.1
1.16	2.14	48.9	116.3
1.09	1.69	43.7	76.8
0.98	1.33	40.5	51.0
0.88	1.00[1]	36.9	32.1
0.83	0.86	35.3	24.4
0.52	0.43	32.0[1]	7.5[2]
0.39[1]	0.24	26.5	2.7
	Riffle 2		
1.54	4.59	47.8	330.0
1.49	4.21	47.4	288.4
1.38	3.17	44.6	188.9
1.34	2.32	39.7	119.3
1.26	1.64	36.2	72.1
1.14	1.27	35.4	51.0
1.05	1.00[1]	34.9	35.7
0.82	0.58	33.9	15.8
0.57	0.25	28.7[1]	4.5[2]
0.34[1]	0.05	15.3	0.6
	Riffle 3		
1.78	4.71	41.1	330.0
1.67	4.30	40.2	275.3
1.47	3.65	38.9	199.2
1.28	3.16	38.3	149.4
1.10	2.72	37.7	108.4
0.78	1.95	34.9	51.0
0.59	1.60	33.4	30.8
0.40	1.12	24.7[1]	11.3
0.36	1.00[1]	22.1	7.9[2]
0.34[1]	0.92	20.3	6.5

1 - Minimum hydraulic criteria met

2 - Discharge at which 2 of 3 hydraulic criteria are met

HQI analyses at site CC1 indicate that at existing average late summer flow conditions (35 cfs; from data presented in Goodwin and Hickman 1993), Clear Creek from the confluence of the North Fork of Clear Creek to the City of Buffalo diversion supports approximately 135 HUs per acre (Fig. 2). The analysis indicates that this number of HUs is maintained at a range of average late summer flows of between 30 and 45 cfs. At flows less than 30 cfs and greater than 45 cfs, the number of HUs in this stream reach is reduced from existing levels.

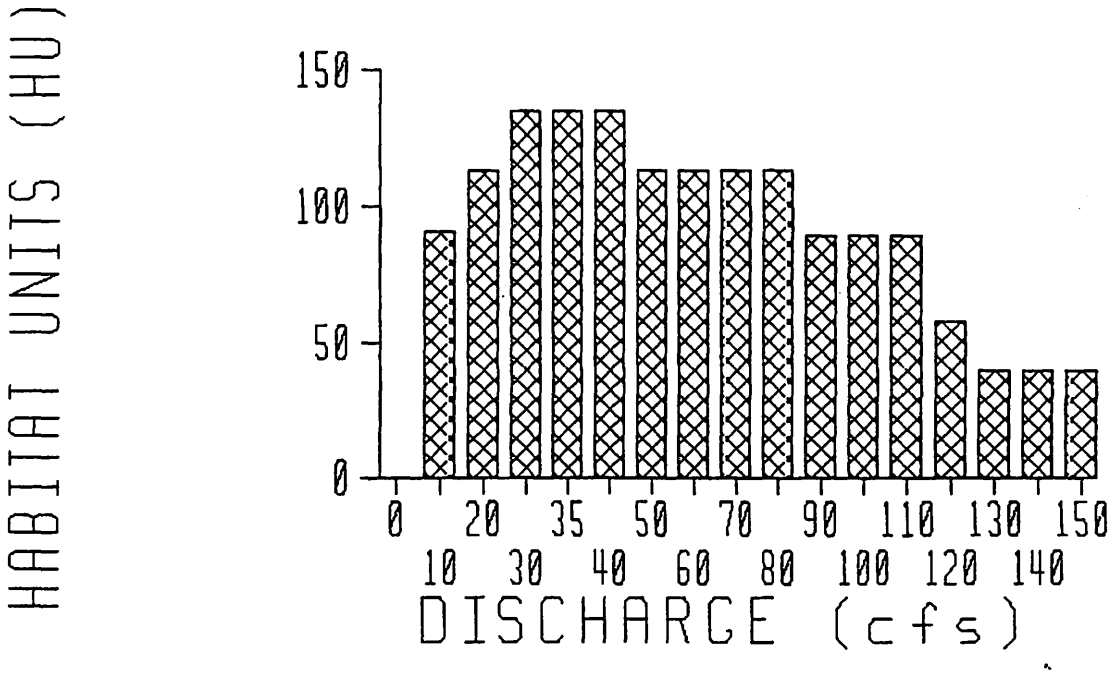


Figure 2. Number of potential trout habitat units at several late summer flow levels in Clear Creek (CC1).

Based on the results from the HQI analysis, a late summer flow of 30 cfs is the minimum stream flow that will maintain existing levels of trout production between July 1 and September 30 and will meet or exceed the hydraulic criteria addressed by the Habitat Retention Method.

PHABSIM analyses were conducted at site CC1 to determine the relationship between discharge and WUA for rainbow and brown trout juveniles. WUA was simulated for flows ranging from 30 to 300 cfs. WUA for rainbow and brown trout juveniles is maximized at discharges of 40 cfs and 30 cfs, respectively (Fig. 3). Since rainbow trout have precedence over brown trout, the recommended instream flow for juveniles is 40 cfs. At this flow level, brown trout still have 98% of maximum WUA (Fig. 3).

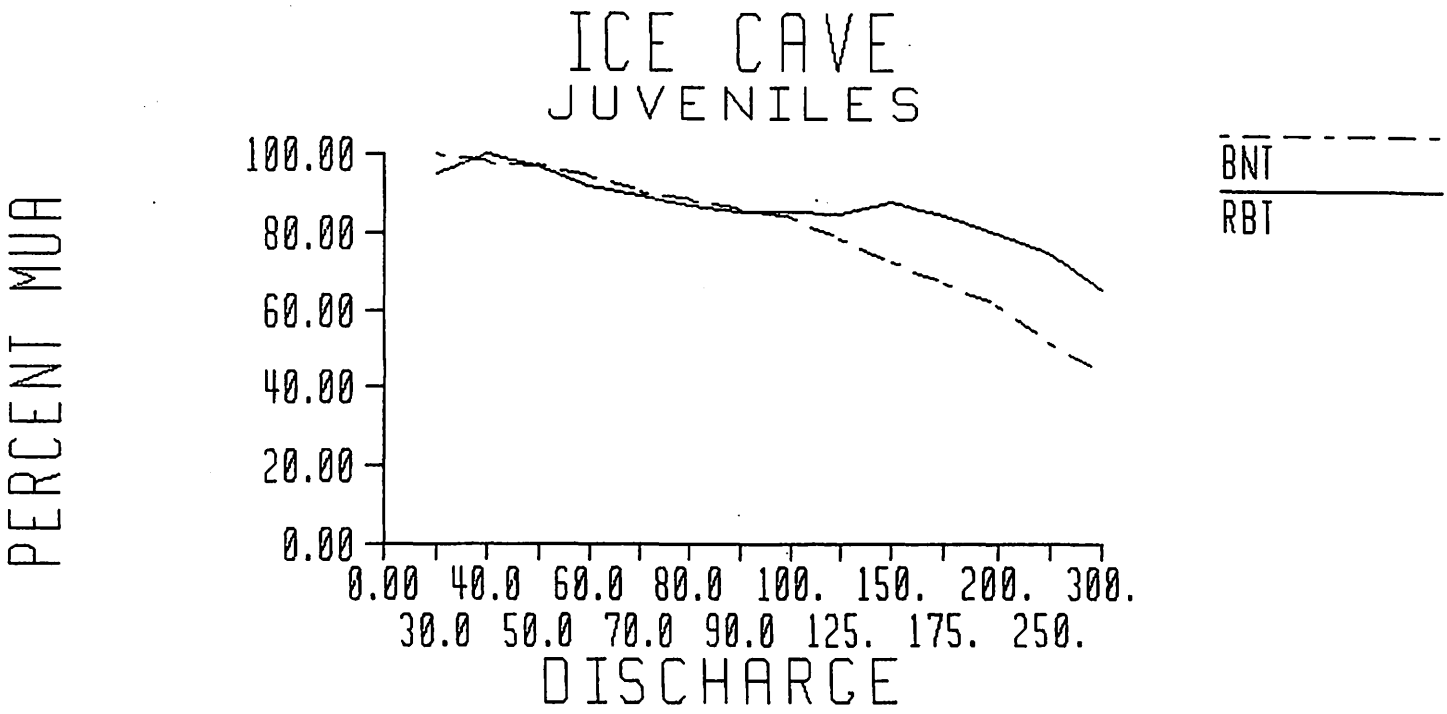


Figure 3. Percent of maximum usable area (MUA) for brown trout (BNT) and rainbow trout (RBT) juveniles at site CC1 (Ice Cave).

INSTREAM FLOW RECOMMENDATIONS

Based on the analyses and results outlined above, the instream flow recommendations in Table 5 will maintain the existing Clear Creek trout fishery. These recommendations apply to an approximately 4.7 mile segment of Clear Creek extending downstream from the confluence with North Fork Clear Creek (T50N, R83W, S 7) to the City of Buffalo diversion (T50N, R83W, S10).

Table 5. Summary of instream flow recommendations to maintain the existing trout fishery in Clear Creek from North Fork Clear Creek to the City of Buffalo diversion.

Time Period	Instream Flow Recommendation (cfs)
April 1 to June 30	40
July 1 to September 30	30
October 1 to March 31	7.9

This analysis does not consider instream flow needs for maintenance of channel geomorphology and trout habitat characteristics. Presently, channel maintenance flow needs are adequately met by natural runoff patterns. Following regulation, additional studies and recommendations may be appropriate for establishing instream flow needs for channel maintenance.

Buffalo Diversion downstream to Johnson County Ditch

Habitat Retention results indicate that flows of 6.2 and 6.8 cfs are necessary to maintain winter survival of trout, aquatic insect production and fish passage through riffles 1 and 2, respectively (Table 6). The maintenance flow recommendation derived from this method is defined as the flow at which two of the three hydraulic criteria are met for all riffles in the study site, which in this case is 6.8 cfs. A third riffle, included in the original analysis (Vogt 1989), was excluded from this analysis. A flow of 23.6 cfs would be necessary to maintain hydraulic criteria at that riffle. Upon further review, however, it was concluded that this flow prediction was an anomaly and the stream flow requirement at that site would be excessive at all other riffles within this segment. A more accurate maintenance flow is the 6.8 cfs defined by the other two riffles.

Table 6. Simulated hydraulic criteria for two riffles on Clear Creek at site CC2. Estimated bankfull discharge = 285 cfs; Estimated average daily discharge = 44 cfs.

Average Depth (ft)	Wetted Velocity (ft/sec)	Perimeter (ft)	Discharge (cfs)
	Riffle 1		
1.68	4.62	39.5	285.0
1.57	3.96	37.7	217.2
1.47	3.31	35.2	159.1
1.32	2.72	33.9	113.1
1.17	2.19	32.6	77.6
0.93	1.58	31.3	44.0
0.77	1.24	30.7	27.7
0.62	1.00[1]	29.9	18.1
0.42	0.62	23.7[1]	6.2[2]
0.29[1]	0.41	17.8	2.2
	Riffle 2		
1.72	4.21	42.4	285.0
1.59	3.51	40.8	210.1
1.41	2.74	38.8	139.0
1.23	2.10	36.0	88.0
1.10	1.55	33.2	52.6
1.03	1.39	32.6	44.0
0.84	1.00[1]	30.6	24.6
0.71	0.77	28.7	14.8
0.55	0.52	25.4[1]	6.8[2]
0.30[1]	0.13	10.4	0.5

1 - Minimum hydraulic criteria met
2 - Discharge at which 2 of 3 hydraulic criteria are met

The City of Buffalo has agreed to maintain an instream flow of 6.0 cfs (O'Grady 1992, Appendix 2) below the diversion using storage water from the proposed Tie Hack Reservoir at times when natural flows are less than this amount. This flow

level was identified by Vogt (1989) (Appendix 1) as an amount that would mitigate trout habitat losses caused by reservoir development. Analysis of changes in long term annual streamflow variations via the HQI model was used as the basis for this determination. In this particular instance, our department has agreed that maintenance of this flow level during the winter months will not significantly compromise trout habitat requirements that were identified by the Habitat Retention method because this flow will effect an overall positive fishery response. The impacts associated with periodic reductions in natural flows to 6.0 cfs will be more than offset by the permanent assurance that instream flows will not fall below this same threshold. In this situation, the instream flow right would be junior to the project sponsor's right and would not negatively impact project feasibility; but, could be fulfilled on a strict priority basis.

Therefore, an instream flow filing of 6.0 cfs will be made for the winter period (rather than the 6.8 cfs identified by Habitat Retention). If the Tie Hack project is not completed, the fishery should be allowed to benefit from all naturally available streamflows, as it does under existing, natural conditions, up to the 6.8 cfs identified by the Habitat Retention method. In such a case, a supplemental filing for 6.8 cfs will be completed.

HQI analyses at Site CC2 indicate that at existing average late summer flow conditions (from Goodwin and Hickman 1993) Clear Creek from the Buffalo City diversion to the Johnson County Ditch supports approximately 59 HUs per acre (Figure 4). The analysis indicates that over the range of flows simulated, HUs are maximized at 59 HUs per acre at late summer flows of between 25 and 35 cfs. At flows less than 25 cfs and greater than 35 cfs, the number of HUs in this stream reach is reduced from existing levels.

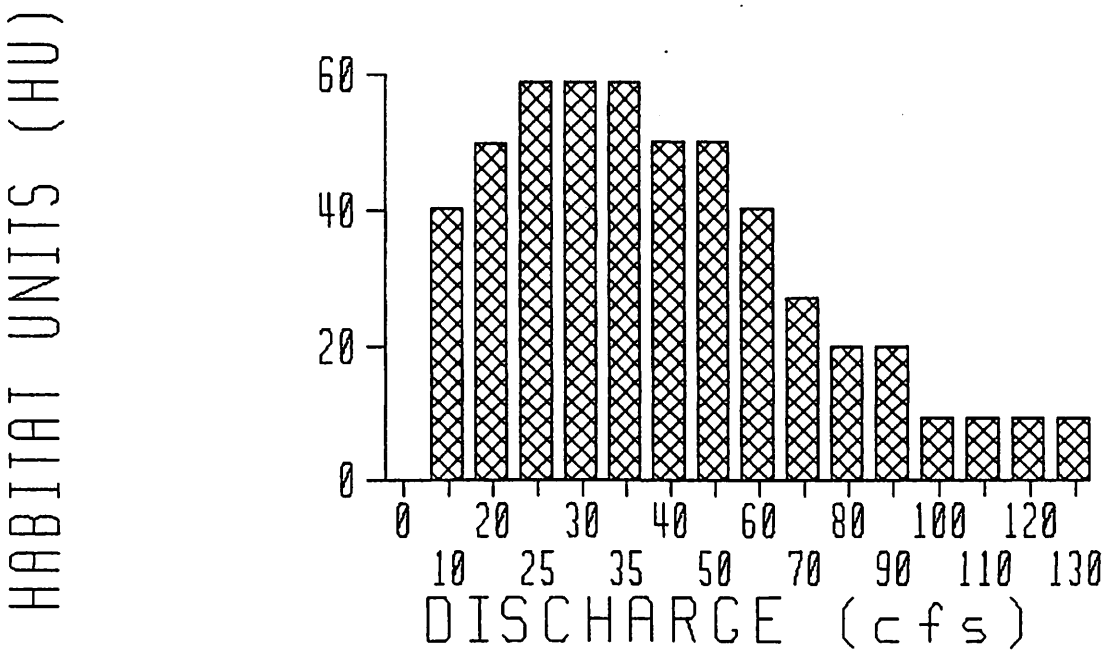


Figure 4. Number of potential trout habitat units at several late summer flow levels on Clear Creek (CC2).

Based on the results from the HQI analysis, an instream flow of 25 cfs will maintain existing levels of trout production between July 1 and September 30 and will meet or exceed the hydraulic criteria addressed by the Habitat Retention Method.

The relationship between discharge and WUA for rainbow and brown trout juveniles was analyzed at site CC2 using the PHABSIM model. Weighted Usable Area was simulated for flows ranging from 10 to 400 cfs. Weighted Usable Area for rainbow and brown trout juveniles is maximized at discharges of 40 cfs and 20 cfs, respectively (Fig. 5). Since rainbow trout have precedence over brown trout, the recommended instream flow for juveniles is 40 cfs. At this flow, brown trout still have 94% of maximum WUA (Fig. 5).

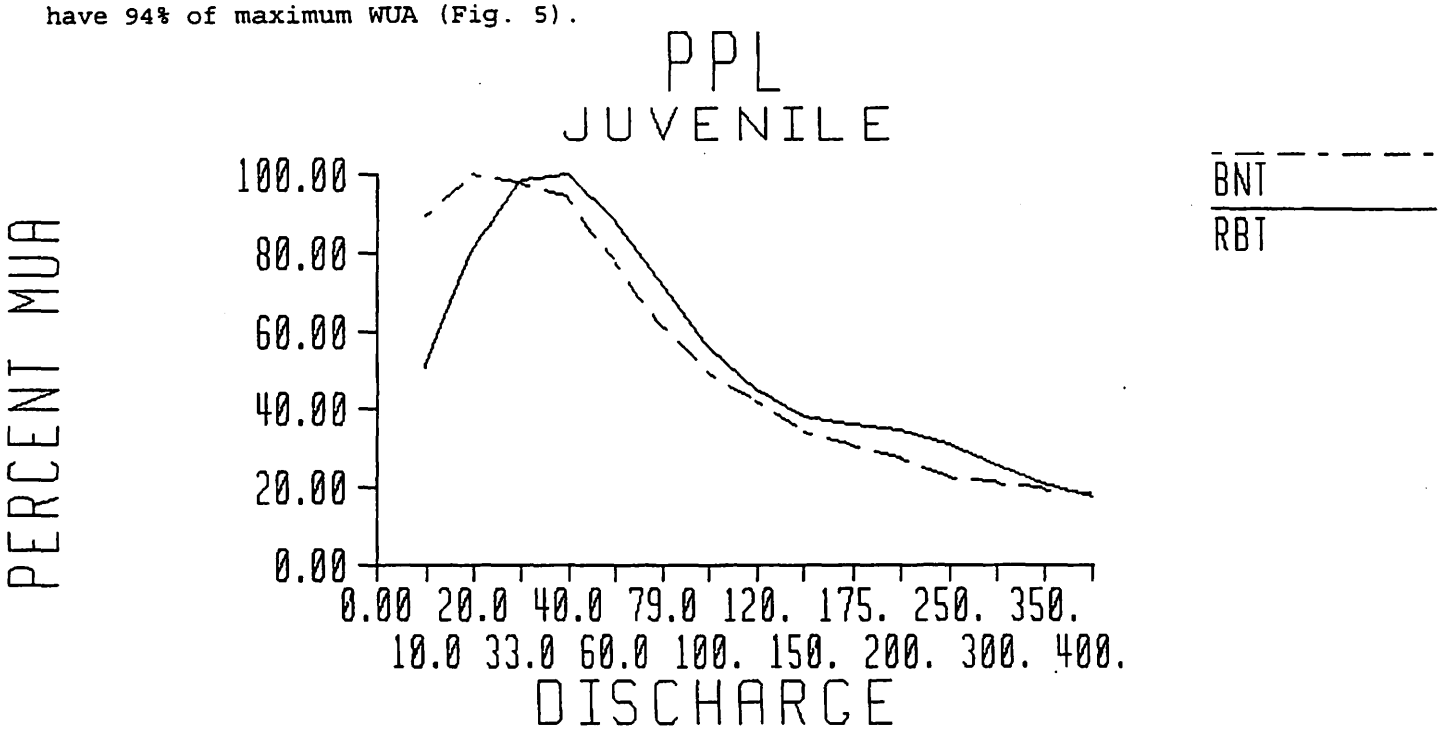


Figure 5. Percent of maximum usable area (MUA) for brown trout (BNT) and rainbow trout (RBT) juveniles at site CC2 (PPL).

INSTREAM FLOW RECOMMENDATIONS

Based on the analyses and results outlined above, the instream flow recommendations in Table 7 will maintain the existing Clear Creek trout fishery. These recommendations apply to an approximately 5.3 mile segment of Clear Creek extending downstream from the City of Buffalo diversion (T50N, R83W, S10) to the Johnson County Ditch (T50N, R82W, S 5).

Table 7. Summary of instream flow recommendations to maintain the existing trout fishery in Clear Creek from the City of Buffalo diversion downstream to the Johnson County Ditch.

Time Period	Instream Flow Recommendation (cfs)
April 1 to June 30	40
July 1 to September 30	25
October 1 to March 31	6

This analysis does not consider instream flow needs for maintenance of channel geomorphology and trout habitat characteristics. Presently, channel maintenance flow needs are adequately met by natural runoff patterns. Following regulation, additional studies and recommendations may be appropriate for establishing instream flow needs for channel maintenance.

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APPENDIX 1

WYOMING GAME AND FISH DEPARTMENT

FISH DIVISION

ADMINISTRATIVE REPORT

TITLE: Buffalo Municipal Reservoir Project, Lower Tie Hack Reservoir

PROJECT: IF-3089-09-8801

AUTHOR: Gerald F. Vogt, Jr.

DATE: December 1989

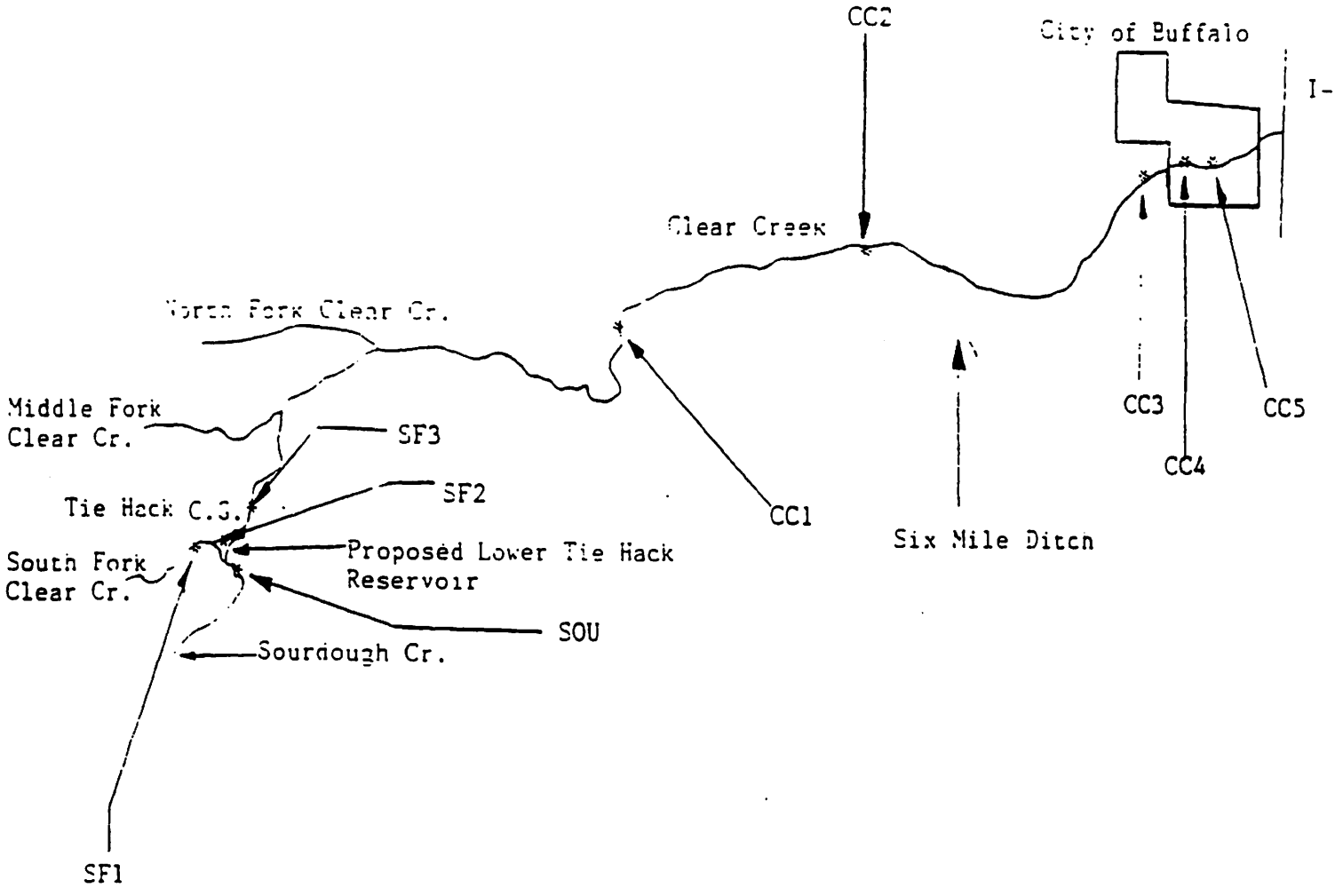
INTRODUCTION

The City of Buffalo has applied to the Wyoming Water Development Commission (WWDC) for assistance in development of an additional municipal water supply. In 1984, 15 locations were selected as possible sites for reservoirs; however, this list has been reduced to the Upper and Lower Tie Hack Sites. The Lower Tie Hack Site has been identified as the preferred dam site. The proposed reservoir would be a multi-purpose reservoir, used for storage of municipal water and for recreation. The WWDC requested an analysis of the 2,500 acre-feet reservoir alternative for the purposes of this report.

Construction of a dam at the Lower Tie Hack site will inundate sections of the South Fork Clear Creek and Sourdough Creek (Figure 1). Water stored in the reservoir will be used to augment the City of Buffalo water supply and will be delivered to the city's diversion on Clear Creek via the South and Middle Forks of Clear Creek.

In 1983, the Wyoming Game and Fish Department (WGFD) began a basin-wide reconnaissance study to investigate the potential fisheries impacts of the proposed water development project. During that year, the WGFD conducted studies to inventory the fisheries and aquatic habitat at the proposed dam site. In 1987, the WGFD conducted independent studies on Clear Creek in the Town of Buffalo to identify possible fisheries enhancement opportunities in response to requests from the town. In 1988, data were collected to determine the potential habitat losses that might occur due to project construction. In 1989, additional instream flow studies and impact analyses were conducted to more precisely determine potential fisheries impacts as a result of this project and to evaluate potential stream mitigation and enhancement alternatives.

The specific objectives of this study were to 1) quantify trout habitat losses in the South Fork Clear Creek and Sourdough Creek due to inundation by the proposed reservoir, 2) recommend a minimum fisheries pool volume for the proposed reservoir for fisheries enhancement, 3) determine instream flows necessary to maintain hydraulic characteristics at all times of year that are important for survival of trout, fish passage and aquatic insect production in the South and Middle Forks of Clear Creek and Clear Creek, 4) determine instream flows necessary to maintain or



Scale: 1 inch = approximately 2 miles

Figure 1. Map showing study sites on Sourdough Creek, South Fork Clear Creek and Clear Creek.

improve adult trout production during the late summer months in the South Fork Clear Creek and Clear Creek, 5) determine instream flows necessary to maintain the existing level of rainbow and brown trout reproduction in the spring and fall, respectively, in Clear Creek and the South Fork Clear Creek, and 6) evaluate mitigation alternatives to offset any habitat losses due to this project in accordance with the WGFD mitigation policy. This report does not include an analysis of potential impacts that might occur during project construction, since construction plans were not yet available. When construction plans are available, WGFD will review them so that construction-related impacts can be avoided or quantified.

DESCRIPTION OF THE STUDY AREA

The proposed water development project involves four streams located on the west side of the Bighorn Mountains west of the City of Buffalo, Wyoming (Figure 1). These streams include Sourdough Creek, South Fork Clear Creek, Middle Fork Clear Creek, and Clear Creek. Studies have been conducted on each of these streams excluding the Middle Fork Clear Creek. Sourdough and South Fork Clear Creeks are high mountain streams with moderately steep gradients and stable channels containing combinations of pool, riffle and run habitats. Clear Creek from the confluence of the North and Middle Forks of Clear Creek to the City of Buffalo diversion has a steep gradient, and stream habitat is dominated by cascading riffles and plunge pools. Clear Creek below the city diversion to I-25 has a more gentle gradient and contains long sections of swift-moving water characteristic of run habitat. Substrates in this reach consist mainly of cobble and boulder. Public access to the South Fork Clear Creek and Sourdough Creek is good, since the streams flow through the Bighorn National Forest and a U.S. Forest Service campground is located at the confluence of the two streams. Access to Clear Creek is somewhat limited, due to the rough terrain of the canyon section of the stream, and due to private ownership of the lower sections of the stream. However, public access is available in the Town of Buffalo.

South Fork Clear Creek, Middle Fork Clear Creek, Sourdough Creek, and Clear Creek from the Six Mile Ditch to I-25 are classified as Class 3 trout streams by the WGFD. Trout stream classifications throughout Wyoming range from Class 1 (highest quality) to Class 5 (lowest quality). Class 3 trout streams are considered important trout waters with fisheries of regional importance. These four streams are managed by the WGFD under the basic yield concept for rainbow trout and receive hatchery plants of catchable rainbow trout. These streams also contain wild populations of rainbow, brown and brook trout. Clear Creek from the confluence of the North and Middle Forks of Clear Creek to the Six Mile Ditch is classified as a Class 2 trout stream and is managed as a wild trout fishery. This section of Clear Creek contains naturally reproducing (wild) populations of rainbow, brown and brook trout and receives no hatchery plants.

The proposed project has the potential for impacting the stream fisheries in the South Fork Clear Creek and Sourdough Creek by inundating portions of those streams. Impacts could also result from reductions in stream flows in South and Middle Forks of Clear Creek and in Clear Creek when reservoirs are filling and by increasing stream flows during the summer. Depending on the distance that releases are allowed to travel in the Clear Creek drainage, stream fisheries in Clear Creek from the City of Buffalo diversion to I-25 could also be affected by releases from the proposed reservoir.

The Wyoming Game and Fish Commission's Mitigation Policy (approved September 23, 1985) established Mitigation Categories, Designation Criteria, and Mitigation Objectives for habitat values which may be impacted by project development. This policy was used to rate the value of habitats within the proposed project area (Table 1). Whenever possible, however, the policy states that avoidance of adverse habitat impacts is more desirable than compensation of losses due to those impacts.

Table 1. Mitigation categories, criteria, and mitigation objectives of the Wyoming Game and Fish Commission Mitigation Policy.

Mitigation Category	Description	Mitigation Objective
Irreplaceable	Endangered species Class 1 streams Critical habitat	No loss of existing habitat value.
High	State rare or protected species Native game fish Class 2 streams Wild (native) or trophy management concept	No net loss of in-kind habitat value.
Moderate	Non-native game fish Class 3 streams Wild (non-native) game fish and basic yield management concept	No net loss of habitat value while minimizing loss of in-kind habitat value.
Low	Nongame fish Class 4 and 5 streams Put-and-take management concept	Minimize loss of habitat value.

METHODS

Study Sites

Nine study sites have been established on South Fork Clear Creek, Sourdough Creek and Clear Creek since 1983 to evaluate the potential fisheries impacts of this project (Figure 1 and Table 2). The three study sites on South Fork Clear Creek were located above the mouth of Sourdough Creek (SF1), at the dam site below the mouth of Sourdough Creek (SF2), and approximately 1/2 mile below the dam site (SF3). The study site on Sourdough Creek (SOU) was located approximately 1/4 mile upstream from the mouth of Sourdough Creek. Study sites were also established on Clear Creek approximately 1/2 mile upstream from the City of Buffalo diversion structure (CC1) and near the abandoned PP&L powerplant 4 miles west of Buffalo (CC2). In the town of

Buffalo sites were located at the Buffalo City Park (CC3); just upstream from the Main Street Bridge in Buffalo (CC4); and at the Texaco Bulk Plant in Buffalo (CC5).

Table 2. Locations of study sites for Buffalo Municipal Reservoir project.

Site	Stream	Location
SF1	South Fork Clear Cr. above Sourdough Cr.	S27, T50N, R84W
SF2	South Fork Clear Cr. below Sourdough Cr.	S24, T50N, R84W
SF3	South Fork Clear Cr. below dam site	S24, T50N, R84W
SOU	Sourdough Cr. 1/4 mi. upstream from mouth	S26, T50N, R84W
CC1	Clear Creek above the Buffalo city diversion	S10, T50N, R83W
CC2	Clear Creek near old power plant	S 6, T50N, R82W
CC3	Clear Creek at Buffalo City Park	S34, T51N, R82W
CC4	Clear Creek above Main Street Bridge	S35, T51N, R82W
CC5	Clear Creek at Texaco Bulk Plant	S35, T51N, R82W

For the purposes of this report, results obtained at sites SF1, SF2, SF3 and SOU were used to determine trout habitat losses due to inundation of sections of South Fork Clear Creek and Sourdough Creek by the proposed reservoir. Results obtained at site SF3 were also applied to the sections of South Fork Clear Creek and Middle Fork Clear Creek from the proposed dam site to Clear Creek. Results obtained at site CC1 were applied to a 4.7 mile segment of Clear Creek from the confluence of the North and Middle Forks of Clear Creek to the City of Buffalo diversion structure. Results from site CC2 were applied to the 5.3 mile segment of Clear Creek between the city's diversion and the Six Mile Ditch. Sites CC3, CC4 and CC5 represent the three major habitat types found in Clear Creek in the Town of Buffalo, and results from these three sites were averaged and applied to the section of Clear Creek between the Six Mile Ditch and I-25.

Models

A Habitat Retention Method (Nehring 1979) was used to identify a fisheries maintenance flow for South Fork Clear Creek below the proposed reservoir and for Clear Creek from the forks to the Six Mile Ditch. A maintenance flow is defined as a continuous flow that will maintain minimum hydraulic criteria in riffle areas within a stream segment. These criteria are important at all times of year to maintain passage between different habitat types for all life stages of trout. These criteria are also important for maintaining survival rates of fish and aquatic macroinvertebrates during the winter that approximate rates observed under natural stream flow conditions. Data from single transects placed across riffles at sites SF3, CC1, and CC2 were analyzed with the IFG-1 computer program (Milhous 1978). These data were collected at various stream discharges at each site (Table 3). Based on extensive research on instream flow methods on Wyoming streams by Annear and Conder (1983), the maintenance flow is identified as the discharge at which two of the three hydraulic criteria are met for all riffles in the study area (Table 4). Maintenance flows apply to all times of the year except when higher stream flows are required to meet other fishery management objectives.

Table 3. Dates and discharges when instream flow data were collected.

Site	Date(s)	Discharge (cfs)
SF1	8-24-83	25
	8-15-88	8
SF2	8-15-88	9
SF3	6-28-89	65
	8-10-89	31
	9-13-89	14
SOU	8-25-83	1 (est.)
	8-15-88	1
CC1	6-27-89	147
	8-09-89	84
	9-12-89	43
CC2	5-24-89	120
	8-08-89	79
	9-14-89	33
CC3, CC4 & CC5	6-16-87	108
	6-22-87	60
	6-29-87	37
	10-06-87	17

Table 4. Hydraulic criteria used to obtain an instream flow recommendation using the Habitat Retention Method.

Category	Criteria
Average Depth (feet)	Top width[1] x 0.01
Average Velocity (feet per second)	1.00
Wetted Perimeter (percent)[2]	60

1 - At average daily flow
2 - Compared to wetted perimeter at bank full conditions

The Habitat Quality Index (HQI) developed by the Wyoming Game and Fish Department (Binns and Eiserman 1979) was used to estimate potential changes in trout standing crops over a range of late summer flow conditions. This model was developed by the WGFD after several years of testing and model refinement. The HQI has been reliably used on many Wyoming streams to assess HU gains or losses associated with projects that modify instream flow regimes. The model incorporates seven attributes that address chemical, physical and biological components of trout habitat. Results are expressed in habitat units (HU). One HU is defined as the amount of habitat quality which will support 1 pound of trout.

By measuring habitat attributes at various flow events as if associated habitat features were typical of average flow conditions, HU estimates can be made for a variety of stream flow scenarios (Conder and Annear 1987). Habitat attributes were measured at each site at several discharges (Table 3). To better define the potential impact of other flow scenarios on trout production, some attributes were derived mathematically or obtained from existing gage data. Gage data were obtained from USGS gages located on Clear Creek near sites CC2 and CC3.

A physical habitat simulation model (PHABSIM) developed by the Instream Flow Service Group of the U.S. Fish and Wildlife Service (Bovee and Milhous 1978) was used to examine the incremental changes in the amount of physical habitat available for rainbow and brown trout spawning at various discharge rates. This model is generally considered to reflect state-of-the-art technology for evaluating fisheries physical habitat changes with changes in stream flows and is widely used throughout North America.

The amount of physical habitat available at a given discharge is expressed in terms of weighted usable area (WUA) and reflects the composite suitability of depth, velocity and substrate at a given flow. Depth, velocity and substrate data were collected at sites SF3, CC1 and CC2 at several different flow levels (Table 3) in accordance with guidelines given by Bovee and Milhous (1978). WUA for rainbow and brown trout spawning was simulated for a range of flows at each site with calibration and modeling techniques outlined by Milhous (1984) and Milhous et al. (1984).

Fishery minimum pool recommendations were made from calculations based on area-capacity information for the proposed Tie Hack Reservoir. Three criteria commonly used in minimum pool determinations were used in these calculations. These criteria are: 50% of the area which is greater than or equal to 20 feet deep; pool with at least 30% of the surface area at the normal high water line; and pool with 20-25% of the volume of the normal maximum storage.

The Morphoedaphic Index (Ryder 1965; Facciani 1976) and stocking rates of similar sized reservoirs were used as a basis for calculations of potential angler-days supported by the proposed reservoir.

Population estimates were made at study site SF3 to characterize the existing fishery in the part of the South Fork Clear Creek below the proposed dam site. Fish were collected by electrofishing a designated section of stream with a backpack electrofishing unit. All captured trout were measured and fish greater than 3 inches in length were weighed. Weights of fish smaller than 3 inches were back-calculated using condition factors of weighed fish. Population estimates were calculated with a multiple-pass removal method (Zippin 1958).

RESULTS

Fisheries Impact Avoidance

In addition to the trout habitat losses that will occur due to inundation by the proposed reservoir, fisheries impacts associated with reduced natural stream flows are possible during times of the year when the reservoir is filling. Trout losses can be especially high if the reductions of natural stream flows occur during the winter. Avoidance of these losses can be accomplished by protecting natural stream flows up to the maintenance flow recommendations derived from the Habitat Retention Method.

South Fork Clear Creek

Results from the Habitat Retention model showed that flows of 4.5, 5.7, and 6.8 cfs are necessary to maintain winter survival of trout, aquatic insect production and fish passage at riffles 1, 2, and 3, respectively (Table 5). The maintenance flow recommendation derived from this method is defined as the flow at which two of the three hydraulic criteria are met for all riffles in the study site, which in this case is 6.8 cfs.

Table 5. Simulated hydraulic criteria for three riffles on South Fork Clear Creek at site SF3. Estimated bankfull discharge = 155 cfs; Estimated average daily discharge = 24 cfs.

Average Depth (ft)	Average Velocity (ft/sec)	Wetted Perimeter (ft)	Discharge (cfs)
		Riffle 1	
1.55	3.38	35.0	155.0
1.42	2.93	34.7	121.9
1.22	2.35	34.3	84.3
1.03	1.87	33.8	56.0
0.79	1.37	33.1	31.2
0.68	1.20[1]	32.4	24.0
0.56	1.00[1]	31.5	15.6
0.41	0.72	25.5[1]	6.7[2]
0.37[1]	0.60	21.0[1]	4.5[2]
0.29[1]	0.42	14.9	1.8

Table 5. Continued.

		Riffle 2	
1.44	3.42	36.1	155.0
1.26	2.74	35.1	106.1
1.04	2.05	33.9	63.8
0.82	1.51	32.3	35.8
0.68	1.23	30.9	24.0
0.62	1.10[1]	30.3	18.4
0.59	1.00[1]	28.3	15.2
0.51	0.78	23.8[1]	8.3[2]
0.42[1]	0.65	21.7[1]	5.7[2]
0.28[1]	0.48	16.5	2.2
		Riffle 3	
1.26	3.32	40.6	155.0
1.02	2.74	39.9	101.7
0.78	2.25	39.1	63.3
0.67	2.00	37.4	45.7
0.58	1.85	36.5	36.0
0.49	1.62	31.8	24.0
0.44	1.51	29.4[1]	17.9
0.36[1]	1.34	24.4[1]	11.5[2]
0.29[1]	1.21[1]	20.5	6.8[2]
0.05	1.00[1]	8.6	1.7

1 - Minimum hydraulic criteria met
2 - Discharge at which 2 of 3 hydraulic criteria are met

Clear Creek above the Buffalo Diversion

Results from the Habitat Retention model showed that flows of 7.5, 4.5, and 7.9 cfs are necessary to maintain winter survival of trout, aquatic insect production and fish passage at riffles 1, 2, and 3, respectively (Table 6). The maintenance flow recommendation derived from this method is defined as the flow at which two of the three hydraulic criteria are met for all riffles in the study site, which in this case is 7.9 cfs.

Table 6. Simulated hydraulic criteria for three riffles on Clear Creek at site CC1. Estimated bankfull discharge = 330 cfs; Estimated average daily discharge = 51 cfs.

Average Depth (ft)	Average Velocity (ft/sec)	Wetted Perimeter (ft)	Discharge (cfs)
	Riffle 1		
1.68	3.94	53.3	330.0
1.50	3.23	51.9	237.6
1.33	2.65	50.8	169.1
1.16	2.14	48.9	116.3
1.09	1.69	43.7	76.8
0.98	1.33[1]	40.5	51.0
0.88	1.00[1]	36.9	32.1
0.83	0.86	35.3[1]	24.4[2]
0.52[1]	0.43	32.0[1]	7.5[2]
0.39[1]	0.24	26.5	2.7
	Riffle 2		
1.54	4.59	47.8	330.0
1.49	4.21	47.4	288.4
1.38	3.17	44.6	188.9
1.34	2.32	39.7	119.3
1.26	1.64	36.2	72.1
1.14	1.27[1]	35.4	51.0
1.05	1.00[1]	34.9	35.7
0.82	0.58	33.9[1]	15.8[2]
0.57[1]	0.25	28.7[1]	4.5[2]
0.34[1]	0.05	15.3	0.6
	Riffle 3		
1.78	4.71	41.1	330.0
1.67	4.30	40.2	275.3
1.47	3.65	38.9	199.2
1.28	3.16	38.3	149.4
1.10	2.72	37.7	108.4
0.78	1.95	34.9	51.0
0.59	1.60	33.4[1]	30.8
0.40	1.12[1]	24.7[1]	11.3[2]
0.36[1]	1.00[1]	22.1	7.9[2]
0.34[1]	0.92	20.3	6.5

1 - Minimum hydraulic criteria met
2 - Discharge at which 2 of 3 hydraulic criteria are met

Clear Creek below the Buffalo Diversion

Results from the Habitat Retention model showed that flows of 6.1, 6.8, and 23.6 cfs are necessary to maintain winter survival of trout, aquatic insect production and fish passage at riffles 1, 2, and 3, respectively (Table 7). The maintenance flow recommendation derived from this method is defined as the flow at which two of the three hydraulic criteria are met for all riffles in the study site, which in this case is 23.6 cfs.

Table 7. Simulated hydraulic criteria for three riffles on Clear Creek at site CC2. Estimated bankfull discharge = 285 cfs; Estimated average daily discharge = 44 cfs.

Average Depth (ft)	Average Velocity (ft/sec)	Wetted Perimeter (ft)	Discharge (cfs)
	Riffle 1		
1.68	4.62	39.5	285.0
1.57	3.96	37.7	217.2
1.47	3.31	35.2	159.1
1.32	2.72	33.9	113.1
1.17	2.19	32.6	77.6
0.93	1.58	31.3	44.0
0.77	1.24[1]	30.7	27.7
0.62	1.00[1]	29.9[1]	18.1[2]
0.42[1]	0.62	23.7[1]	6.2[2]
0.29[1]	0.41	17.8	2.2
	Riffle 2		
1.72	4.21	42.4	285.0
1.59	3.51	40.8	210.1
1.41	2.74	38.8	139.0
1.23	2.10	36.0	88.0
1.10	1.55	33.2	52.6
1.03	1.39[1]	32.6	44.0
0.84	1.00[1]	30.6	24.6
0.71	0.77	28.7[1]	14.8[2]
0.55[1]	0.52	25.4[1]	6.8[2]
0.30[1]	0.13	10.4	0.5

Table 7. Continued.

	Riffle 3		
1.31	3.47	63.5	285.0
1.29	3.39	63.3	272.9
1.13	2.67	61.3	182.1
0.98	2.06	58.5	116.5
0.79	1.45	54.8	61.8
0.67	1.20[1]	53.4	44.0
0.57[1]	1.00[1]	52.3	29.4[2]
0.53[1]	0.89	48.3[1]	23.6[2]
0.43	0.62	38.1[1]	10.5
0.34	0.41	28.1	3.8

1 - Minimum hydraulic criteria met
2 - Discharge at which 2 of 3 hydraulic criteria are met

Trout Habitat Losses

HQI analyses were conducted at sites SF1, SF2, SF3 and SCU to determine the number of trout HUs lost due to inundation of sections of South Fork Clear Creek and Sourdough Creek by the proposed reservoir. HUs measured at site SF1 during 1983 and 1988 were averaged to determine the number of HUs supported in the South Fork Clear Creek above the mouth of Sourdough Creek. The average number of HUs measured at site SOU in 1983 and 1988 were used to determine the number of trout HUs in Sourdough Creek. HUs measured at sites SF2 (1988) and SF3 (1989) were averaged to account for any spatial variation in trout HUs in South Fork Clear Creek below the mouth of Sourdough Creek.

Based on current project information, the proposed reservoir will have a capacity of nearly 2,500 acre-feet, a normal high-water line at an elevation of 7,447 feet, and an area of approximately 62.5 acres. When filled to capacity, the reservoir would inundate 1,500 feet of South Fork Clear Creek below Sourdough Creek, approximately 2,500 feet of South Fork Clear Creek above Sourdough Creek, and 2,750 feet of Sourdough Creek. Based on HQI analyses, a total of approximately 186 HUs will be lost due to inundation of these streams by the proposed reservoir (Table 8).

Table 8. HQI scores for sections of Sourdough Creek and South Fork Clear Creek that will be inundated by the proposed reservoir.

Stream Section	HUs/Acre	Area of Stream Inundated	Total No. HUs in Inundated Section
South Fork below Sourdough Creek	90.0	0.69 ac.	62.1
South Fork above Sourdough Creek	132.5	0.86 ac.	114.0
Sourdough Creek	15.5	0.63 ac.	9.8
		Total HUs Lost:	185.9

Fishery Minimum Pool

Calculations based on area-capacity data for the proposed reservoir indicate that minimum fishery pool criteria are met at an elevation of 7410 feet. At this elevation the area of the reservoir would be 29.3 acres, the volume would be 754.2 acre-feet, and the mean depth would be 25.7 feet. This recommended minimum pool meets all three of the criteria commonly used for fisnery minimum pool determinations.

Potential trout biomass for the proposed reservoir was calculated with the Morphoedaphic Index (MEI). This represents the trout biomass that could be supported by the proposed reservoir without hatchery plants. These calculations were made under the assumption that the reservoir would fluctuate between the minimum pool level recommended in this report and the normal high water level each year. The trout biomass of the proposed reservoir based on the MEI is 1,151 pounds of trout (Table 9). Based on harvest rates of similar-sized high mountain reservoirs, this reservoir would provide approximately 658 angler-days per year if hatchery plants are not made.

If catchable trout are planted in the proposed reservoir at rates typical of similar high mountain reservoirs with good public access, the reservoir would support 4,785 pounds of trout. This represents a fairly high stocking rate. At this stocking rate, the proposed reservoir would provide approximately 2,700 angler-days per year (Table 9).

Table 9. Potential trout standing crop and angler-days for the proposed reservoir based on MEI calculations and on stocking of catchable trout. Assumes reservoir fluctuates annually between the recommended minimum pool level and the normal high water level.

	Trout Biomass (lbs)	Angler-Days Per Year
MEI calculations	1,151	658
Stocking catchable trout	4,785	2,734

Fish Population Estimate

South Fork Clear Creek

Electrofishing results indicated that site SF3 supports an adult trout standing crop of 90 pounds/acre (Table 10). Only rainbow and brown trout were captured at this site and about 70% of the standing crop was made up of rainbow trout. All of the fish captured were wild fish.

Table 10. Fish population statistics for the South Fork Clear Creek. Estimated number per mile, pounds per acre, and pounds per mile include fish larger than or equal to 6 inches in length. Station length: 520 feet. Average stream width: 28.0 feet.

	Species		
	Brown Trout	Rainbow Trout	Total
Total No. Fish Captured (All sizes)	69	197	266
Size range (in.)	2.4 - 10.3	1.6 - 8.9	
Weight range (lbs.)	0.01 - 0.39	0.01 - 0.26	
Estimated No./Mi.	489	1635	2124
Estimated Lbs./Mi.	92.9	212.3	305.2
Estimated Lbs./Ac.	27.4	62.6	90.0

Fisheries Mitigation Alternatives

South/Middle Fork Clear Creek Below the Proposed Reservoir

HQI analyses at Site SF3 indicate that at existing average late summer flow conditions (estimated at 10 cfs) the South and Middle Forks of Clear Creek below the proposed reservoir support approximately 57 HUs per acre (Figure 2). The analysis indicates that trout HUs are maximized at an average late summer flow of 20 cfs. At flows higher than 20 cfs, trout HUs begin to decrease. At flows greater than 35 cfs, the number of HUs in this stream reach is reduced from existing levels.

Should the proposed reservoir operational plans include constant releases during the summer which raise the average summer discharge of South Fork Clear Creek to 20 cfs, the stream reach would realize an increase of about 10 HUs per acre. Since this site applies to a 3.95 mile segment of the South and Middle Forks of Clear Creek, the HU gain for the entire segment would be 128 trout HUs (Table 11). Releases of between 25 and 35 cfs during the summer would not appreciably change the number of HUs in this stream segment over existing conditions. Releases of greater than 35 cfs would result in a net loss of HUs. This analysis is based on the assumption that the temperature of releases will not significantly differ from existing summer stream temperatures. It also assumes that natural stream flows up to the recommended maintenance flow will be maintained at all times of the year.

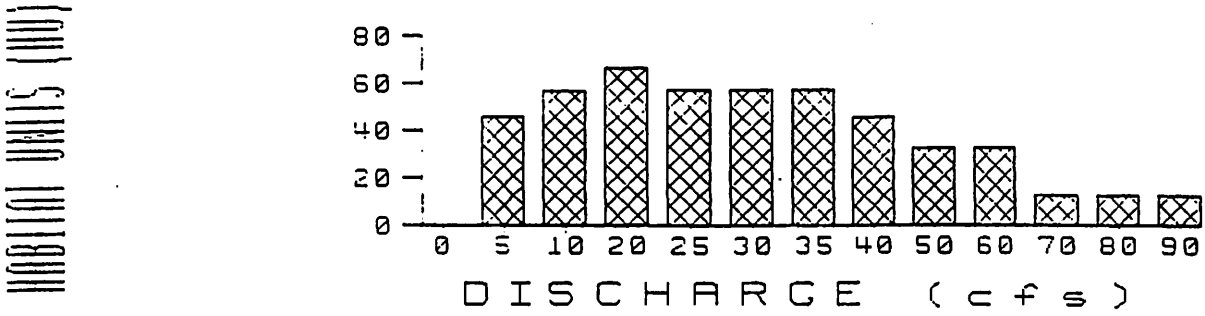


Figure 2. Number of potential trout habitat units at several late summer flow levels in the South Fork Clear Creek (SF3) below the proposed reservoir.

Table 11. Existing trout HUs and potential HU gains in South and Middle Forks of Clear Creek from the proposed dam site to Clear Creek.

Existing HUs/ac (at 10 cfs)	56.7
With constant release of 20 cfs from reservoir[1]	67.0
HU/acre gain	+10.3
Distance of stream affected = 3.95 miles	
Mean width = 26 feet	
Total acres = 12.4	
Total HU gain =	127.7

1 - Assumes that flows will be constant from July 1 to September 15 and natural flows up to the maintenance flow at all other times of year

Clear Creek from the Forks to the Buffalo City Diversion

HQI analyses at Site CC1 indicate that at existing average late summer flow conditions (estimated at 35 cfs) Clear Creek from the confluence of the North and Middle Forks of Clear Creek to the Buffalo city diversion supports approximately 135 HUs per acre (Figure 3). The analysis indicates that this number of HUs is maintained at a range of average late summer flows of between 30 and 45 cfs. Because trout HUs are maximized in this section of Clear Creek under existing summer flow conditions, HU gains due to enhancement of summer flows are not possible. At flows less than 30 cfs and greater than 45 cfs, the number of HUs in this stream reach is reduced from existing levels. Should the proposed project result in average stream flows during the summer (July 1 to September 15) which are lower than 30 cfs or greater than 45 cfs in this portion of Clear Creek, trout HU losses will occur. The actual number of losses will depend on the magnitude of the flow reduction or increase.

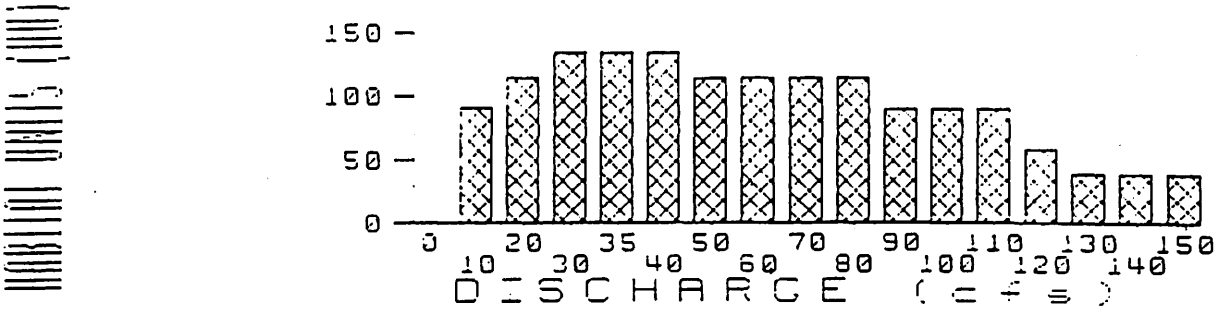


Figure 3. Number of potential trout habitat units at several late summer flow levels in Clear Creek (CC1).

Since the number of HUs in this section of the stream are maximized under existing late summer flow conditions, there are no opportunities for habitat unit gains in this section of Clear Creek due to summer flow enhancement. However, this section of Clear Creek experiences fairly wide annual stream flow fluctuations, with very low stream flows occurring during the winter. Should releases be made from the proposed reservoir that increase winter flows, HU gains could be realized in this section of Clear Creek. Gage records for the past 30 years indicate that winter stream flows in Clear Creek are commonly very low. The HQI analysis indicates that if winter flows of 6 cfs or greater are maintained, this section of Clear Creek would support approximately 190 HUs per acre, an increase of 55 HUs per acre over existing levels. This assumes that summer flows (between July 1 and September 15) will be maintained between 30 and 45 cfs and that existing summer stream temperatures are maintained. Since this analysis applies to a 4.7 mile section of Clear Creek, the total number of HUs gained for the reach is 1,043 over existing conditions (Table 12).

Table 12. Existing trout HUs and potential HU gains in Clear Creek from the confluence of the North and Middle Forks of Clear Creek to the Buffalo city diversion.

Existing HUs/ac (at summer flow of 35 cfs and existing winter flow conditions)	134.8
With winter flow ≥ 6 cfs and summer flow of between 30 and 45 cfs[1]	190.3
Total HU/acre gain	+55.5
Distance of stream affected = 4.7 miles	
Mean width = 33 feet	
Total acres = 18.8	
Total HU gain =	1,043.4

1 - Assumes that flows will be constant from July 1 to September 15 and natural flows up to the maintenance flow at all other times of year

Clear Creek from the Buffalo City Diversion to the Six Mile Ditch

HQI analyses at Site CC2 indicate that at existing average late summer flow conditions (estimated at 25 cfs) Clear Creek from the Buffalo city diversion to the Six Mile Ditch supports approximately 59 HUs per acre (Figure 4). The analysis indicates that over the range of flows simulated, HUs are maximized at 59 HUs per acre at late summer flows of between 25 and 35 cfs. At flows less than 25 cfs and greater than 35 cfs, the number of HUs in this stream reach is reduced from existing levels. Should the proposed project result in average stream flows during the summer (July 1 to September 30) which are lower than 25 cfs or greater than 35 cfs in this portion of Clear Creek, trout HU losses will occur. The actual number of losses will depend on the magnitude of the flow reduction or increase.

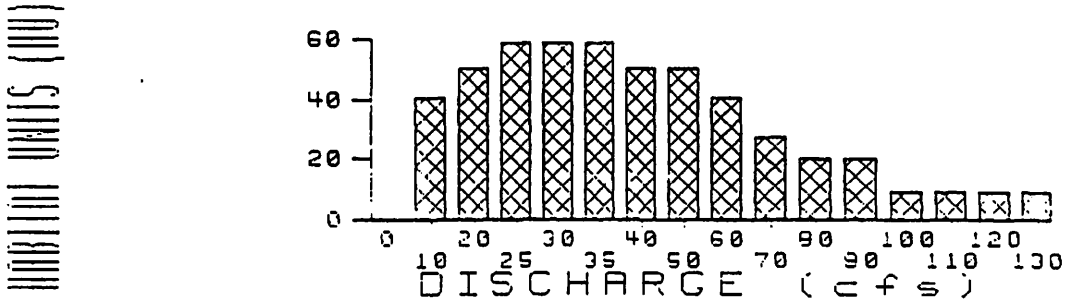


Figure 4. Number of potential trout habitat units at several late summer flow levels in Clear Creek (CC2).

Because trout HUs are maximized in this section of Clear Creek under existing summer flow conditions, HU gains due to enhancement of summer flows are not possible. However, as with the section of Clear Creek above the City of Buffalo diversion, enhancement of winter flows to reduce annual stream flow variation could result in HU gains in this section of Clear Creek. If summer flows are maintained between 25 and 35 cfs (between July 1 and September 30) and winter stream flows are maintained at 6 cfs or greater, the HQI analysis indicates that HUs would increase in Clear Creek below the city diversion by 26 HUs per acre. Since this study site applies to the 5.3 mile section of Clear Creek from the Buffalo city diversion to the Six Mile Ditch, the total HU gain for the reach is 484 HUs (Table 13).

Table 13. Existing trout HUs and potential HU gains in Clear Creek from the Buffalo city diversion to the Six Mile Ditch.

Existing HUs/ac (at 25 cfs)	55.8
With winter flow ≥ 6 cfs and summer flow of between 25 and 35 cfs[1]	81.8
Total HU/acre gain	+26.0
Distance of stream affected = 5.3 miles	
Mean width = 29 feet	
Total acres = 18.6	
Total HU gain =	483.6

1 - Assumes that flows will be constant from July 1 to September 15 and natural stream flows up to the maintenance flow at all other times of year

Clear Creek from the Six Mile Ditch to I-25

Results of HQI analyses at sites CC3, CC4 and CC5 were averaged and applied to Clear Creek from the Six Mile Ditch to I-25. These analyses indicate that at existing average late summer flow conditions (estimated at 5 cfs) this section of Clear Creek supports approximately 7 HUs per acre (Figure 5). HUs increase with increasing discharge up to 70 cfs, and then begin to decrease. Trout HUs are higher at every discharge from 10 to 130 cfs than at existing late summer flow conditions, indicating that enhancement of summer flows in Clear Creek below the Six Mile Ditch will increase HUs in this stream segment. Small HU gains occur at flows between 10 and 30 cfs, while flows higher than 30 cfs result in large HU gains. The actual number of HUs gained in this segment depends on the amount summer flows (between July 1 and September 15) are increased. HUs are maximized at 40 HUs per acre at discharges between 50 and 70 cfs. If summer flows are maintained at this level for the entire summer (July 1 to September 15), the HQI analysis indicates that the largest gain in HUs would be about 33 HUs per acre over existing conditions. Since these data apply to a 5 mile section of stream, this would result in a total increase of about 642 HUs (Table 14). Enhancement of winter flows alone would not result in an increase in HUs, since the lowest flows during the year occur during the summer.

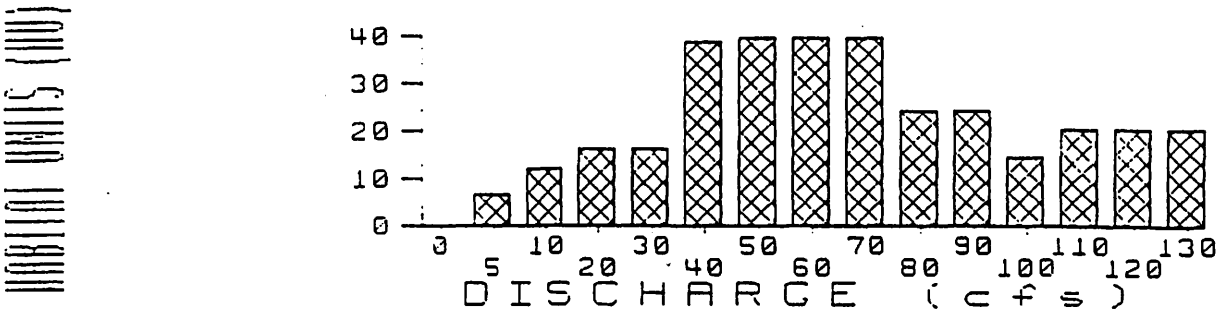


Figure 5. Number of potential trout habitat units at several late summer flow levels in Clear Creek from the Six Mile Ditch to I-25.

Table 14. Existing trout HUs and potential HU gains in Clear Creek from the Six Mile Ditch to I-25.

Existing HUs/ac (at 5 cfs)	6.8
With summer flow of 50 to 70 cfs[1]	39.9
Total HU/acre gain	+33.1
Distance of stream affected = 5.0 miles	
Mean width = 32 feet	
Total acres = 19.4	
Total HU gain =	642.1

1- Assumes that flows will be constant from July 1 to September 15 and natural flows up to the maintenance flow at all other times of year

Fisheries Enhancement Opportunities

The results of the HQI analyses have indicated that enhancement of summer and/or winter stream flows below the proposed reservoir provides opportunities to mitigate losses caused by the proposed project. HU gains in excess of those needed for mitigation are enhancements to the existing fishery. Another fisheries enhancement opportunity may exist in the provision of instream flows below the proposed reservoir to improve physical habitat for brown and rainbow trout spawning in South Fork Clear Creek and Clear Creek. PHABSIM analyses were used to evaluate the potential for improving spawning physical habitat for brown and rainbow trout in these two streams.

South Fork Clear Creek

PHABSIM analyses were conducted at site SF3 to determine the relationship between discharge and WUA for rainbow and brown trout spawning. WUA was simulated for flows ranging from 10 to 125 cfs. WUA for both brown and rainbow trout spawning is maximized at a discharge of 125 cfs greater than 125 cfs (Figure 6). Flows higher than 125 cfs could not be accurately simulated with these data. The analysis indicates that at as flows decrease from 125 cfs, WUA for spawning for both species is rapidly reduced. WUA essentially disappears for rainbow trout at discharges lower than 40 cfs and for brown trout at discharges less than 15 cfs.

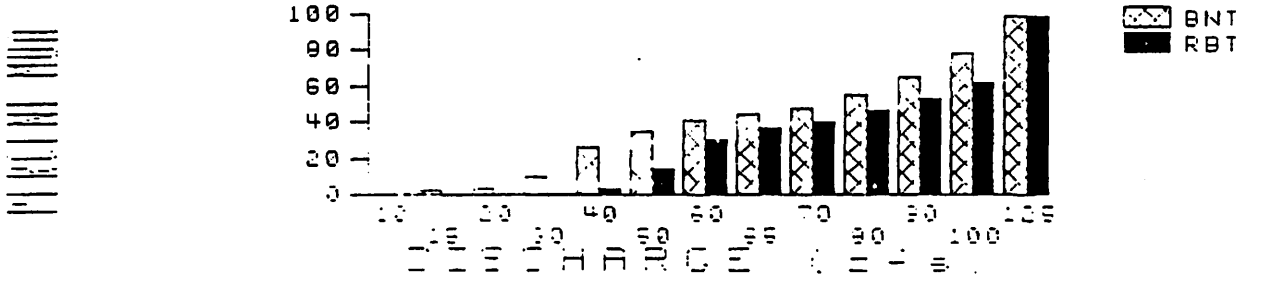


Figure 6. Percent of maximum usable area (MUA) for brown (BNT) and rainbow (RBT) trout spawning at site SF3.

Although the PHABSIM analyses for WUA for brown and rainbow trout spawning indicates that physical habitat is maximized at 125 cfs, the ratio of WUA to the total area in the stream reach does not differ greatly at any of the discharges simulated. For example, at 50 cfs WUA for brown trout spawning makes up about 0.1% of the total area of the stream reach. At 125 cfs, WUA for spawning makes up about 0.5% of the total area. The addition of 75 cfs does not result in a substantial change in WUA for spawning.

The reason that WUA is very low over the entire range of flows simulated is that spawning substrate is extremely limited in this section of South Fork Clear Creek. Gravel substrates are a necessary component of trout spawning habitat, and this section of the stream is dominated by cobble and boulder substrates. It is possible that the wild fishery in this section of the stream is maintained primarily by recruitment from other sections of the stream or from tributaries of the South Fork Clear Creek. Since suitable substrate appears to be the factor limiting WUA for spawning in this section of South Fork Clear Creek, enhancement of flows would do little to improve spawning WUA for either species.

Clear Creek above the Buffalo Diversion

PHABSIM analyses were conducted at site CC1 to determine the relationship between discharge and WUA for rainbow and brown trout spawning. WUA was simulated for flows ranging from 30 to 300 cfs. WUA for both rainbow and brown trout spawning is maximized at a discharge of 300 cfs (Figure 7). Flows higher than 300 cfs could not be accurately simulated with these data. The analysis indicates that at as flows decrease from 300 cfs, WUA for spawning is rapidly reduced for both species. This reduction is more rapid for rainbow trout.

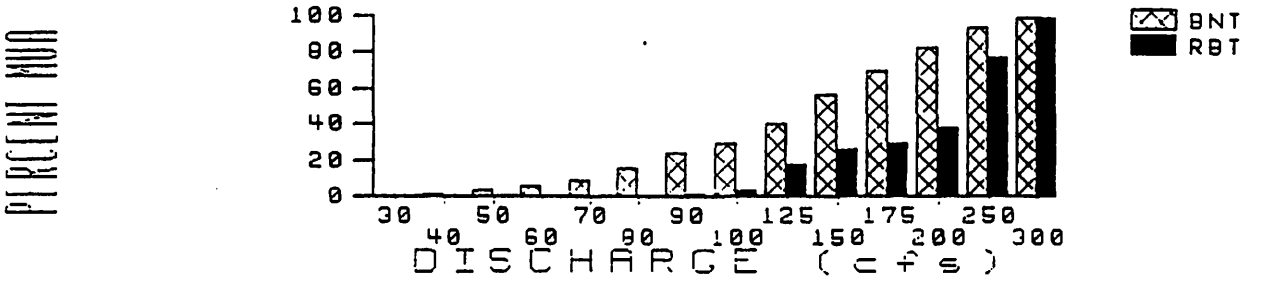


Figure 7. Percent of maximum usable area (MUA) for brown trout (BNT) and rainbow trout (RBT) spawning at site CC1.

As with the South Fork Clear Creek site, this site is dominated by cobble and boulder substrates which are not suitable for trout spawning. As a result, WUA for spawning is extremely limited for both species at all discharges simulated. For example, at 80 cfs WUA for brown trout spawning is 0.04% of the total area of the stream reach. At 300 cfs, when physical habitat is maximized for both species, WUA for brown trout spawning is 0.2% of the total area. Although the small amount of physical habitat available for both species may be intensively used, the amount of suitable substrate appears to limit WUA for spawning in this section of Clear Creek. It is most likely that the majority of the recruitment for both species originates in upstream reaches of Clear Creek and/or tributaries of Clear Creek. Because of these factors, enhancement of flows may do little to improve spawning WUA and recruitment for either species.

Clear Creek below Buffalo Diversion

PHABSIM analyses were conducted at site CC2 to determine the relationship between discharge and WUA for rainbow and brown trout spawning. WUA was simulated for flows ranging from 10 to 400 cfs. WUA for both rainbow and brown trout spawning is maximized at a discharge of 200 cfs (Figure 8). The analysis indicates that at as flows decrease from 200 cfs, WUA for spawning is rapidly reduced for both species. Reductions from the maximum WUA for spawning for both species also occur at flows greater than 200 cfs.

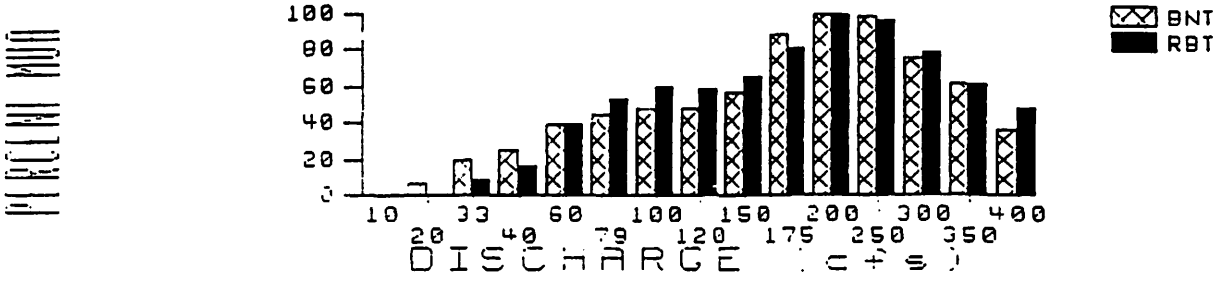


Figure 8. Percent of maximum usable area (MUA) for brown trout (BNT) and rainbow trout (RBT) spawning at site CC2.

As with sites SF3 and CC1, WUA for rainbow and brown trout spawning appears to be limited by the lack of suitable spawning substrates in this section of Clear Creek. This site, like the others, is dominated by large cobble and boulder substrates. As a result, WUA for spawning is low for all discharges simulated for both species. Therefore, improvement of rainbow and brown trout spawning habitat by enhancement of stream flows is not likely in this section of Clear Creek.

SUMMARY/DISCUSSION

At the time of this report, many of the project details including operational plans for each reservoir were unknown. As a result, several assumptions were made to determine the fisheries impacts associated with this project. Any change in these assumptions could result in changes in our findings and would involve reanalysis of our data. Therefore, the recommendations in this report are not final and are subject to change as more detailed project information becomes available. Future coordination between WWDC and WGFD is very important throughout the planning stages of this project.

The assumptions made in this report are:

1. All releases from the proposed reservoir will be discharged directly into the stream channel. All releases in excess of present stream flows will remain in the stream channel downstream to I-25.

2. Releases from the proposed reservoir will be made at a constant rate during each season. Wide fluctuations in releases could negate any HU gains that would occur from enhanced summer stream flows.

3. Releases from the proposed reservoir will not appreciably change the water temperatures in streams receiving those releases. Changes in existing stream temperatures could result in different HU gains/losses.

4. Natural stream flows up to the recommended maintenance flows for each stream will be maintained at all times of the year. If natural stream flows are reduced, HU gains described in the HQI analyses could be negated.

Electrofishing results indicated that the South Fork Clear Creek supports good populations of wild trout. The two sections of Clear Creek above the Six Mile Ditch also support wild trout fisheries. Maintenance of wild trout populations is a high priority for the WGFD since they provide high quality fisheries with very little management expense. Protection of these fisheries is therefore very important. Flows needed to protect these fisheries were identified with several methods

The Habitat Retention Method was used to provide maintenance flow recommendations for each stream segment involved with the proposed project (Table 15). The maintenance flow is defined as a continuous flow that will maintain minimum hydraulic criteria in riffle areas within a stream segment. These criteria are important at all times of year to maintain passage between different habitat types for all life stages of trout. These criteria are also important for maintaining survival rates of fish and aquatic macroinvertebrates during the winter that approximate rates observed under natural stream flow conditions.

Low flow conditions during winter months (October through March) naturally limit the survival and growth of many trout populations. The extent of these impacts is dependent upon several factors including but not limited to snow fall, cold intensity and the duration of intense cold periods. These factors vary from year to year and affect fish populations depending on the amount of frazile ice and anchor ice formation (which can plug the gills of fish), the extent of snow bank collapse (and stream damming) and increased metabolic demands on fish (and increased stress).

Kurtz (1980) found that the loss of winter habitat due to low flow conditions was an important factor affecting mortality rates of trout in the upper Green River, with mortality approaching 90% during some years. Needham et al. (1945) documented average overwinter brown trout mortality of 60% and extremes as high as 80% in a California stream. Butler (1979) reported significant trout and aquatic insect losses caused by anchor ice formation. Reimers (1957) considered anchor ice, collapsing snow banks and fluctuating flows resulting from the periodic formation and breakup of ice dams as the primary causes of winter trout mortality.

The causes of winter mortality discussed above are all greatly influenced by the quantity of winter flow in terms of its ability to minimize anchor ice formation

(increased velocity and temperature loading) and dilute and prevent snow bank collapses and ice dam formation respectively. Any reduction of natural winter stream flows would increase trout mortality and effectively reduce the number of fish that the stream could support. Therefore protection of natural winter stream flows up to the recommended maintenance flow for each stream segment is necessary to maintain existing survival rates of trout populations. Failure to maintain natural stream flows up to the recommended maintenance flows for each stream will negate HU gains resulting from enhanced summer flows. In addition, HQI analyses have shown that enhancement of winter flows can actually increase HU gains by causing reductions in the annual variation of stream flows.

Table 15. Summary of maintenance flow recommendations derived from the Habitat Retention Method for the stream segments affected by the proposed project. These flows apply to all times of the year except when higher flows are required to meet other fishery management objectives.

Stream Segment	Maintenance Flow (cfs)
South Fork Clear Creek below the proposed dam	6.8
Clear Creek above the Buffalo diversion	7.9
Clear Creek below the Buffalo diversion	23.6

The HQI model was used to determine the number of trout HUs that will be lost in Sourdough Creek and South Fork Clear Creek as a result of inundation of portions of those streams by the proposed reservoir. The total number of trout HUs lost in these streams is 186 HUs. In accordance with the WGFD mitigation policy, these habitat losses should be mitigated in a manner that results in no net loss in habitat value while minimizing loss of in-kind habitat value.

Results from additional HQI studies in South Fork Clear Creek and Clear Creek were used to evaluate the potential for mitigating habitat losses resulting from this project. Based on these studies, HU losses in Sourdough Creek and South Fork Clear Creek can be mitigated by HU gains in South Fork Clear Creek and in Clear Creek. The actual number of HUs gained in these streams depends on the timing and amounts of water released from the proposed reservoir (Table 16).

Existing mean summer flows in South Fork Clear Creek approximate 10 cfs. If a constant release of 20 cfs is made from the proposed reservoir during the July 1 to September 15 period and existing winter flows remain unchanged, this would increase summer flows in the downstream sections of South Fork Clear Creek and Clear Creek by 10 cfs over existing conditions. A discharge of 20 cfs would maximize the number of HUs in South Fork Clear Creek and would result in a total HU gain in these streams of 227 HUs, which would totally mitigate the loss of 186 HUs that will occur when the reservoir is built. HU gains ... both of these stream sections would be lower than 227 HUs if summer releases are lower than 20 cfs. There would be no change in HUs in South Fork Clear Creek at summer flows of between 25 and 35 cfs, and HU losses would occur in South Fork Clear Creek if releases are greater than 35 cfs.

A constant release of 55 cfs during the summer (July 1 to September 15) from the proposed reservoir would have the effect of increasing summer stream flows by about

45 cfs in the downstream sections of South Fork Clear Creek and Clear Creek. This increase would result in an HU gain of 642 HUs in Clear Creek between the Six Mile Ditch and I-25. Although a discharge of 55 cfs maximizes HUs in this portion of Clear Creek, this increase in discharge would have detrimental effects on other portions of Clear Creek and South Fork Clear Creek. The result of these increased summer releases would be the net loss of 645 HUs in addition to the 186 HUs lost due to inundation by the proposed reservoir (Table 16).

Winter stream flows are commonly very low in Clear Creek and this factor partially limits the number of HUs the stream can support. If a constant winter release (from September 16 to March 31) of 6 cfs is made from the proposed reservoir, HU gains are realized even when summer stream flows remain unchanged from present conditions. This increase in winter flows would not affect HUs in South Fork Clear Creek and in Clear Creek below the Six Mile Ditch, since this flow would not significantly change annual stream flow variation in either section.

However, in both sections of Clear Creek above the Six Mile Ditch, a winter flow of 6 cfs would increase HUs by over 1,500 HUs. If, in addition to winter releases of 6 cfs, summer flows are increased 10 cfs over existing conditions (with a release of 20 cfs at the dam), an additional 227 HU gain will be realized (Table 16).

Table 16. Summary of HU gains and losses due to enhanced stream flows resulting from the proposed water project. This analysis includes the assumption that reservoir releases will be made at a constant rate during the period of July 1 to September 15, that stream temperatures will not change appreciably, and that natural flows up to the recommended maintenance flow are maintained at all other times of the year.

Stream	Summer Release of 20 cfs[1]	Summer Release of 55 cfs[1]	Winter Release ≥ 6 cfs; Summer Release of 10 cfs[1]	Winter Release ≥ 6 cfs; Summer Release of 20 cfs[1]
Reservoir Site	- 186 HUs	- 186 HUs	- 186 HUs	- 186 HUs
South Fork Clear Creek	+ 128 HUs	- 299 HUs	0	+ 128 HUs
Clear Creek above Buffalo diversion	0	- 400 HUs	+ 1,043 HUs	+ 1,043 HUs
Clear Creek below Buffalo diversion	0	- 588 HUs	+ 484 HUs	+ 484 HUs
Clear Creek from Six Mile Ditch to I-25	+ 99 HUs	+ 642 HUs	0	+ 99 HUs
Net HU Gains/Losses	+ 41	- 831	+ 1,341	+ 1,568 HUs

1 - Assumes that releases are allowed to reach I-25 and no transportation losses.

A fishery minimum pool of 754.2 acre-feet will be adequate to protect a reservoir fishery from excessive drawdowns and is an appropriate feature for the proposed project. Based on calculations of potential trout biomass of the proposed reservoir with and without stocking, the reservoir would support between 658 and 2,734 angler-days per year. This assumes that the reservoir fluctuates between the recommended minimum pool level and the normal high water level each year. Analysis of the operational plans for the proposed reservoir may change these estimates.

Improvement of WUA for rainbow and brown trout spawning in South Fork Clear Creek and Clear Creek by enhancing stream flows in the spring and fall does not appear to be possible. Changes in stream flows do not appear to have much of an impact on WUA for spawning for either species, probably due to the lack of suitable spawning substrates in these stream segments. The PHABSIM analysis for South Fork Clear Creek indicates that WUA for rainbow trout spawning is essentially zero at discharges of less than 40 cfs. Therefore, a discharge of 40 cfs during the rainbow trout spawning period (April 1 to June 30) will maintain the existing level of WUA for rainbow trout in South Fork Clear Creek. Similarly, WUA for brown trout spawning approaches zero at flows less than 15 cfs. A discharge of 15 cfs during the brown trout spawning period (Oct. 1 to Nov. 30) will therefore maintain existing levels of brown trout spawning in South Fork Clear Creek. These releases will also be adequate to maintain existing levels of rainbow and brown trout spawning in Clear Creek above the Six Mile Ditch.

RECOMMENDATIONS

1. To protect natural stream flows up to the fisheries maintenance flows identified in Table 15, a year-round release of 6.8 cfs into South Fork Clear Creek should be made except during times when higher flows are required to meet other fishery management objectives and mitigation requirements. When natural stream flows into the reservoir from all sources are below 6.8 cfs, the amount of those natural flows should be released. By meeting the recommended maintenance flow in South Fork Clear Creek, maintenance flows recommended for the two Clear Creek sites will also be satisfied.

2. To mitigate stream HU losses due to inundation by the proposed reservoir, a constant release of 20 cfs from the proposed reservoir during the summer (July 1 to September 15) is recommended. This release rate will increase summer stream flows in South Fork Clear Creek and Clear Creek by 10 cfs over existing conditions, and will increase HUs by 227. These gains will mitigate the 186 HUs lost due to reservoir construction. However, this increased stream flow must be allowed to pass to I-25 for the HU gain to be realized.

3. When natural winter stream flows are below 6 cfs, augmentation of winter flows with releases of 6 cfs (from September 16 to March 31) from the proposed reservoir represent an additional fisheries enhancement opportunity. If allowed to pass down Clear Creek to I-25, these releases could increase HUs in Clear Creek above the Buffalo diversion by over 1,500 HUs. The net effect, considering HU losses at the reservoir site, would be 1,341 HUs.

4. WGFD recommends a minimum pool of 754.2 acre-feet for fisheries enhancement. We also request the opportunity to participate in the design of fish habitat structures in the reservoir that could be installed during the construction phase of this project. These structures include, but are not limited to, placement of boulders in the reservoir, leaving scattered timber in areas that will be inundated, and developing an irregularly shaped shoreline.

5. We recommend that a reservoir temperature modeling study be conducted for the proposed reservoir. Feasibility studies should include consideration of penstocks capable of maintaining the temperature of releases between 51 and 70F.

6. Opportunities to improve physical habitat for rainbow and brown trout in South Fork Clear Creek and Clear Creek by enhancing stream flows do not exist. To maintain existing levels of rainbow trout spawning in both streams, a continuous release of 40 cfs should be made from April 1 to June 30. To maintain existing levels of brown trout spawning, a continuous release of 15 cfs should be made from October 1 to November 30.

7. We recommend that reservoir releases be stepped up and down in stages to avoid releases of large pulses of water. The WGFD should be consulted regarding the rate at which releases are stepped up and down.

8. We recommend that a boat ramp be built to the minimum pool elevation as a project feature. We further recommend the project include development of a public access road and public parking area in conjunction with the boat ramp.

9. We recommend that public access be made available, as a project feature to the entire shoreline of the reservoir, except in areas considered hazardous to public safety.

10. The large vertical drop in water level from the normal high water line to the recommended minimum pool elevation could limit access to the reservoir during drawdown. We therefore recommend the stabilization of areas of the shoreline between the normal high water line and the minimum pool to allow access to the reservoir by bank fishermen during reservoir drawdown.

11. Additional project details, including reservoir operations schedules and results of the temperature modeling study should be made available to WGFD as they become available.

12. We recommend that WWDC develop a detailed mitigation plan prior to project authorization and construction that is accepted by WGFD and USFWS. The plan should include mitigation of construction and other impacts as well as habitat losses from project existence and operation, and should be included as part of the 404 permit application for the project.

13. We request the opportunity to review construction plans so that impacts due to project construction can be avoided or quantified. Should final project plans differ from those assumed in this report, reanalysis of the data will be necessary and recommendations in this report may change.

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APPENDIX 2

DRAFT

December 15, 1992

Mr. Nels Lofgren, Mayor
City of Buffalo
46 North Main
Buffalo, Wyoming 82834

RE: Fish & Wildlife Coordination Act - Mitigation Plan - Tie Hack Dam.

Dear Nels:

As you may know, the city contacted the Wyoming Game and Fish Department and the US Fish and Wildlife Service on August 18, 1992 to assist the city in developing a Project Mitigation Plan as required under the Fish and Wildlife Coordination Act. As a result we met with WGFD and USFWS personnel on November 2, 1992 to discuss previous studies which had been completed by the WGFD concerning fisheries and terrestrial impacts and mitigation. The primary purpose for this meeting was to determine if the previous investigations would be adequate to serve as the basis for the Mitigation Plan or if additional studies would be required. It was the consensus at this meeting that the previous studies should be sufficient.

In a study completed by the WGFD in January, 1989, it was determined that a total of 4 acres of wetlands would be affected and a total of 23.7 acres of riparian habitat would be impacted by reservoir construction. The report went on to recommend that a mitigation site should contain approximately 7% of willow/wet meadow, 13% of bottomland grassland with the balance in native riparian vegetation. It was further recommended that the mitigation should be accomplished adjacent to the impacted site preferably along Sourdough Creek immediately upstream from the high water line of the reservoir.

It was agreed at the 11-2-92 meeting that it would be best if we could mitigate on-site and that building small dikes at the upstream portions of the reservoir might be suitable for mitigation of the impacted vegetation. This will be confirmed during the 1993 field season and discussed with USFS personnel concerning the ability to mitigate on-site.

Concerning fishery maintenance flows, SWWRC has met on numerous occasions with WGFD personnel regarding those minimum flows which

the project could provide without severely impacting the total storage requirement and available water supplies. The following maintenance and minimum flows have been agreed to with Fish Division personnel and the reservoir operation hydrologic model reflects these flows:

Location	Minimum Maintenance Flows
Below the Dam & Reservoir	6.8 cfs
Above the City's Existing Diversion	7.9 cfs
	Guaranteed Minimum Flows
Below the City's Existing Diversion	6.0 cfs

If you or Ken should have any questions regarding this information, please contact me.

Sincerely,

Michael T. O'Grady,
Vice President

cc: Ken Gross, City of Buffalo
Steve Tessman, WGFD
Tom Annear, WGFD
Art Anderson, USFWS
Steve Brockman, USFWS
Paul Beels, USFS