JOURNAL OF THE AMERICAN WATER RESOURCES ASSOCIATION

Vol. 44, No. 1 AMERICAN WATER RESOURCES ASSOCIATION February 2008

ASSESSMENT OF CHANGES IN STREAM AND RIPARIAN CONDITIONS OF THE MARYS RIVER BASIN, NEVADA[1]

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ABSTRACT: Stream and riparian managers must effectively allocate limited financial and personnel resources to monitor and manage riparian ecosystems. They need to use management strategies and monitoring methods that are compatible with their objectives and the response potential of each stream reach. Our objective is to help others set realistic management objectives by comparing results from different methods used to document riparian recovery across a diversity of stream types. The Bureau of Land Management Elko Field Office, Nevada, used stream survey, riparian proper functioning condition (PFC) assessment, repeat photographic analysis, and stream and ecological classification to study 10 streams within the Marys River watershed of northeast Nevada during all or parts of 20 years. Most riparian areas improved significantly from 1979 to 1992-1993 and then additionally by 1997-2000. Improvements were observed in riparian and habitat condition indices, bank cover, and stability, pool quality, bank angle, and depth of undercut bank. Interpretation of repeat photography generally confirmed results from stream survey and should be part of long-term riparian monitoring. More attributes of Rosgen stream types C and E improved than of types B and F. A and Gc streams did not show significant improvement. Alluvial draws and alluvial valleys improved in more ways than V-erosional canyons and especially V-depositional canyons. Stream survey data could not be substituted for riparian PFC assessment. Riparian PFC assessments help interpret other data.

(KEY TERMS: riparian recovery; monitoring; stream survey; photographs; fish habitat; stream type; riparian proper functioning condition.)

Newman, Sarah and Sherman Swanson, 2008. Assessment of Changes in Stream and Riparian Conditions of the Marys River Basin, Nevada. *Journal of the American Water Resources Association* (JAWRA) 44(1):1-13. DOI: 10.1111/j.1752-1688.2007.00134.x

INTRODUCTION

To set achievable, measurable, timely, and worthy riparian objectives, managers learn from responses to management documented through monitoring and interpreted through riparian and/or stream classification. Because potential (what a riparian area becomes given no anthropogenic influences) (Prichard *et al.*, 1993, 1998) varies by stream type and other factors, each riparian area responds distinctly to changes in land-use management. Therefore, any stream and riparian habitat assessment method should be used within the context of stream type, stream potential, and anthropogenic influences. Myers and Swanson (1991) noted that stream habitat varies for an assortment of natural and anthropogenic reasons not identified by overall condition indices. Functionality and

[1]Paper No. J05174 of the *Journal of the American Water Resources Association* (JAWRA). Received October 26, 2005; accepted October 22, 2007. **Discussions are open until August 1, 2008**.

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ecological classification are based on an understanding of a stream's potential and capability within the context of the landscape (Prichard *et al.*, 1993, 1998).

Several studies in recent decades have addressed riparian monitoring and assessment. Platts *et al.* (1987), Hogle *et al.* (1993), Roper *et al.* (2002), and Coles-Ritchie *et al.* (2004) used repeat observations by multiple observers and Myers and Swanson (1997) used closely spaced transects to study the reliability and precision of aquatic and riparian assessment or monitoring methods. MacDonald (1994) suggested analysis and evaluation of monitoring data to ensure the project tests objectives before continuing monitoring and data analysis. Montgomery and MacDonald (2002) suggested diagnosis of channel conditions, including geomorphic context, controlling influences, and disturbance history, to design an effective monitoring program. Bain *et al.* (1999) found that many agencies across the United States were actively advancing their methods for assessing freshwater habitats. Prichard *et al.* (1998) suggested that analysis of trend with targeted datasets collected repeatedly through time can lead to process-based riparian management. Thus, effective management objectives and management and monitoring methods may be selected within the context of stream type, riparian potential and capability, and anthropogenic influences. Cowley and Burton (2005) emphasized the importance of setting objectives for each designated monitoring area before selecting among riparian monitoring methods.

The Bureau of Land Management Elko Field Office (Elko BLM) in Nevada has used three methods to evaluate streams and stream riparian ecosystems. Transect-based stream survey estimates were used to calculate overall aquatic habitat condition indices (Duff and Cooper, 1976). Interdisciplinary and qualitative riparian proper functioning condition (PFC) assessment considered the structure and function of stream reaches in relation to their unique landscape setting (Prichard *et al.*, 1993, 1998). Ecological classification emphasized synecology and geological setting to evaluate streams and riparian plant communities (White Horse Associates, 1997). Furthermore, photographs are taken as part of these methods and can be used to evaluate change in riparian conditions through time. With these approaches, our objectives are to detect or explain: (1) time trends of selected habitat variables and condition indices after a change in management; (2) reliability of selected habitat variables and condition indices as indicators of stream condition; and (3) stream and riparian condition and improvement in relation to stream type and potential. We anticipate that such analyses will help other riparian managers select priority stream reaches for management, and select monitoring strategies. Monitoring strategies should detect change in meeting site-specific resource objectives from riparian management prescribed to address important issues, given the response potentials in different settings.

STUDY AREA

The Marys River basin, in northeast Nevada, is a 520-mile^2 (839 km^2) watershed that drains into the Humboldt River. Relatively small, high-gradient headwater streams flow through stands of quaking aspen (*Populus tremuloides* Michx), narrow-leaf cottonwood (*Populus angustifolia* James), and willow (*Salix* spp.). Low-gradient reaches of the Lower Marys River flow through lands with willows and irrigated and subirrigated meadows (Gutzwiller *et al.*, 1997). The average precipitation for the basin is approximately 15 in. (0.38 m), with over 44 in. (1.12 m) at higher elevations. Most precipitation occurs during cooler seasons as rain and snow (USDI BLM, 1987).

The Marys River Basin with over 200 miles (320 km) of streams was once considered a trophy trout system. The sagebrush (*Artemisia* sp.) dominated (Jensen, 1990) basin has been used for mining, livestock grazing, irrigated hay production, hunting, fishing, and other recreational activities for more than 150 years (USDI BLM, 1987). Through these and other uses, some riparian areas, streambanks, and shallow aquifers have been trampled or otherwise altered. This contributes, along with occasional flooding [e.g., 1983 and 1984 (Myers and Swanson, 1996a,b)], to erosion, channel incision, headcuts, and cut banks. Together, these have contributed to reduced quality and quantity of fish and wildlife habitat, and changes in riparian plant communities.

Livestock used the basin with season-long grazing in some areas until implementing the habitat management plan in 1987. After the completion of land exchanges and subsequent fence modifications, management changes included: converting certain pastures into riparian exclosures, altering livestock season of use, reduction of livestock (mostly cattle) numbers, and change in kind and class of livestock. Conservation easements allowed riparian monitoring and ecological study on private land (Gutzwiller *et al.*, 1997).

METHODS

On the BLM-Elko District, few places have such intensive studies as the Marys River basin. The transect-based stream survey methodology (Duff and Cooper, 1976; USDI BLM, 1992) was first used in the basin in 1979, with subsequent surveys conducted every 3-8 years. Streams were sampled at permanently established sites for greater efficiency as suggested by Roper *et al.* (2003). For 10 streams in this Basin, two to five sets of stream survey data span more than 20 years. Streams with large quantities of private land, such as Currant Creek were surveyed in 1979 and then with landowner permission in 1999 through 2000. Functionality (Prichard *et al.*, 1993, 1998) was first assessed in 1992 or 1993 (or 2000 on more private streams). Some reaches were reassessed in 1997 and/or 2000. An ecological classification (White Horse Associates, 1997) was used to compare all streams in 1991 and 1995. With agency staff that changes through time, the data collected using these methods varies in quality because of variation in training, expertise, or method application. Yet, each method has been applied using well-documented methods.

Stream Survey

The stream survey method used by the Elko BLM (USDI BLM, 1981) evaluates the following stream attributes at base flow: water width (wetted width), average water depth, water width/depth ratio, riffle [velocity > 1 foot/s (0.3 m/s.)] width, pool [velocity < 1 foot/s (0.3 m/s)] width, pool rating(s), stream substrate (by size class), bank cover, bank stability, bank angle, photographs, and horizontal depth of undercut bank (below bankfull). However, depth of undercut bank was not measured in 1977-1986. Bank cover and bank stability are averaged to yield the riparian condition index (RCI). An index of 100% is considered optimum and is represented by banks that are well-vegetated [fewer than two 10-foot (3 m) openings per 100 feet (30 m)] with tall shrubs and/or trees and totally stable (no accelerated erosion). Habitat condition index (HCI) combines RCI and several other attributes considered ideal for aquatic species, especially salmonids. A HCI of 100% of optimum is represented by stream-bottom substrates of gravel or rubble (cobbles), quality pools (deep and with cover), a pool-riffle ratio of 1:1, and stable well-vegetated streambanks (Duff and Cooper, 1976; USDI BLM, 1992). Riparian and habitat condition indices are converted to condition classes using the following rating system: <50%, poor; 50-59%, fair; 60-70%, good; and ≥70%, excellent (USDI BLM, 1981).

Stream survey stations are established at one stream-mile (1.6 km) intervals beginning at 0.1 mile (0.16 km) above the confluence or lowest perennial water. Stream type is identified at each station using the channel classification system developed by Rosgen (1994, 1996). Each station has four (1979 and 1987) or five (after 1987) transects perpendicular to the flow with 100-foot (30.8 m) spacing. Bank cover and bank stability rate a 100-foot (30.8 m) section of each bank having the transect as the midpoint. Other variables are measured on each transect. All data were summarized using the stream survey database used by Elko BLM.

Pool quality is the percent of stream width in quality pools. Quality pools are at least 1 foot (0.3 m) deep, are as wide or as long as the average stream width, and have some cover of vegetation, undercut banks, or depths in excess of 2 feet (0.6 m) (USDI BLM, 1992). In stream survey summaries, the value for pool quality is the total width of quality pools (based on points assigned for cover, depth, and length or width) divided by total stream width in pools of any quality, multiplied by the pool-riffle percent optimum (assuming a 1:1 is 100% optimum).

Not all attributes measured during stream survey were used in this study. Although data for many variables (e.g., vegetation overhang, and riparian zone width) not fully described above have been collected in at least two of the survey periods in this study, the methods for data collection were not consistent, and thus the data were not comparable. Other variables not included in this study are bankfull width, bankfull width/depth ratio, stream-bottom substrate, shore-water depth (the depth at water edge during low flow), and pool-riffle ratio. Bankfull width and bankfull width/depth ratio were omitted because these values do not exist for some dates in this dataset. Stream-bottom substrates were not used because they vary by stream type. Shore-water depth is absent because for the 1992/1993 survey all values were the same (0"). Pool-riffle ratio was omitted because the optimum ratio varies with stream type and flow conditions, however, the value calculated by the stream survey summary program assumes 100% optimum to be 50% pools to 50% riffles.

Proper Functioning Condition

Riparian PFC assessment focuses on the structure and function of riparian-wetland areas regardless of the special interest needs (i.e., fish habitat, aesthetics, livestock accessibility to water, etc.). It takes an interdisciplinary approach for making a qualitative assessment (Prichard *et al.*, 1993) based on quantitative science (Prichard *et al.*, 1998) by examining hydrologic, vegetative, and soil/landform erosion attributes of stream reaches (Prichard *et al.*, 1993, 1998). The assessment is conducted by a team of interdisciplinary specialists (hydrologist, range conservationist/botanist, soil scientist/geomorphologist, fisheries-wildlife biologist, and hopefully the rancher) evaluating a reach to answer "yes," "no," or "not applicable" to a series of 17 questions relating to these attributes. For example, "Floodplain above bankfull is inundated in relatively frequent (1-3 year) events," "Adequate riparian-wetland vegetative cover is present to protect banks and dissipate energy during high flows," "System is vertically stable," etc. Yes and no answers are derived, through discussion and recorded with notes of what the streams needs to become properly functioning. A reach may be designated as "properly functioning," "functional-at-risk (FAR)" if it is in functioning condition, but one or more attributes put it at risk of degradation and "nonfunctional (NF)." A NF reach, clearly does not fit the definition of PFC nor FAR. Trend (upward, downward, or static or not-apparent) is assessed with a rating of FAR (FAR-up, FAR-down, and FAR-na). During the 1997-2000 survey, most of the streams were reassessed for functionality in conjunction with stream survey with an interdisciplinary team of BLM specialists. The remaining assessments were conducted with an interdisciplinary team of permanent employees aboard a low-flying helicopter and ground truthed as warranted similar to guidance in Prichard *et al.* (1996). Reach delineations were based on common landform, stream type, pasture, and/or ownership/management.

Ecological Classification

Ecological classification developed by White Horse Associates (1997) is based on a hierarchical system with eight levels. The first levels (ecoregion, province, etc.) of this classification use small-scale maps of a large area, with subsequent levels using progressively larger scale maps, photographs, and field data with smaller areas of focus and more specific attributes. The study streams occur in five valley-bottom types (the fifth level of the hierarchy): alluvial draws, alluvial valleys, fluvial basins, v-depositional canyons, and v-erosional canyons (White Horse Associates, 1997).

Valley-bottom types with specific stream channel morphology are defined as "ecological" states. Unlike the lower levels within this system, the state may change with time. The state (sixth) level of this hierarchy describes existing condition and estimates ecological potential of the system. This part of the methodology is most useful for management. Typical states are: natural, eroded, incised/broadened, blown-out, stabilized, and achievable. Additional states include ponded, depositional, and channelized. States were delineated using 1:3,000 and 1:6,000 scale aerial photographs from spring of 1991 and summer of 1995, respectively, and stream and channel data variables from 111 stream survey stations. Trend was evaluated using the differences between 1991 and 1995 information (White Horse Associates, 1997). Ecological states (defined in Table 3) can be grouped with each state estimated to represent a percent of ecological optimum as listed in Table 3 and as described by White Horse Associates (1997). In this study, we used valley-bottom type and ecological state, with its rating of percent ecological optimum.

Photo-Point Analysis

Photographs are an integral part of PFC assessments and stream survey, and were used to assess the reliability of trend in habitat variables and condition indices. We used the methods described by Sippel and Swanson (1995) with paired photographs and a checklist to note change over time in bankfull width, entrenchment, bankfull edge vegetation, percent low-flow channel shaded, dominant vegetation class, percent bankfull edge stable, bank angle, and clarity of change of each factor. Upstream and downstream photo-sets from the 1992-1993 and the 1997-2000 survey periods were assessed by two experienced stream surveyors, who discussed each photograph in comparison with its paired replicate from another time. Twelve photo-sets were selected based on the quality of the photographs to represent different stream types and functionality ratings. Later, an additional 13 photo-sets were randomly selected across all stream types and functionality ratings. Where change was detected, improvement or retrogression for the variable in question was determined within the context of that stream type and processes of channel evolution (Schumm, 1979; Watson *et al.*, 2002; Rosgen, 1994, 1996).

Data Analysis

Because data were class or ordinal, nonparametric statistics, Chi-squared (Yates, 1934) and Mann-Whitney *U*-tests (Mann and Whitney, 1947) were used. Differences were considered significant at $p \leq 0.05$. No statistical analyses were used to test individual photo-point analyses.

Overall condition indices and individual habitat variables were also stratified by Rosgen (1994, 1996) stream type and valley-bottom type (White Horse Associates, 1997) and compared between the 1992-1993 and 1997-2000 survey periods using Mann-Whitney *U*-tests. Potentials for selected habitat variables were based on natural conditions for selected Rosgen stream types as described by Overton *et al.* (1994). Potential for stream condition was based on the ecological classification (White Horse Associates, 1997) and changes in stream conditions over time.

RESULTS AND DISCUSSION

Stream and Riparian Condition

In general, conditions improved through the two decades of this study. Riparian and habitat condition indices (RCI and HCI) showed substantial improvement for most stream survey stations (Table 1). The distribution of stations among HCI and RCI classes changed significantly (chi-squared test, $p \leq 0.005$; Newman, 2001). The change between 1979 and 1992-1993 involved movement from poor to good or fair. Whereas, by 1997-2000, the number of stations in excellent and good categories was increasing. Many of the functionality changes between 1992-1993 and 1997-2000 probably indicate response in vegetation [increased FAR-up (Table 2)]. Fewer stations changed sufficiently to achieve PFC status (Table 2) or the ecological optimal state (Table 3). However, beaver activity may have increased the number of stations in the ponded states. The large decrease in "incised or broadened" (50% ecological optimum) may indicate that these streams were more responsive to management than "blown out" streams. Most condition ratings indicate improvement or a negligible change between 1992-1993 and 1997-2000 (Table 4). Many of the "no change" ratings were in the upward direction, but not sufficient to improve class (e.g., from fair (50-59%) to good (60-70%) for HCI or RCI or from FAR-up to PFC).

TABLE 1. Distribution of Sampling Stations Among Riparian (RCI) and Habitat Condition Index (HCI) Classes for the Marys River Basin for the 1979, 1992-1993, and 1997-2000-Survey Periods.

	Number of Stations Rated[1]					
	1979		1992-1993		1997-2000	
Condition Index	RCI[2]	HCI[3]	RCI	HCI	RCI	HCI
Excellent (≥70%)	6	1	6	0	22	3
Good (60-69%)	1	3	13	6	21	12
Fair (50-59%)	6	3	15	10	10	18
Poor (<50%)	44	47	22	38	4	21

[1]Total sample size (number of stations) used to compare these data are 57 for RCI and 54 for HCI.
[2]RCI is the average of bank cover and stability, and is based on 100% as optimum. An index of 100% optimum represents streambanks that are totally stable (no accelerated erosion) and well vegetated with tall shrubs or trees [fewer than two 10-foot (3 m) openings per 100 feet (30 m)] (Duff and Cooper, 1976).
[3]HCI is the average of bank cover and stability, percent pool quality, percent desired stream bottom substrate, and pool-riffle ratio, and on 100% as optimum. An index of 100% optimum represents a stream with gravel or rubble (cobble) substrates, quality (large, deep, and well covered) pools, a pool-riffle ratio of 1:1, and stable, well-vegetated streambanks (Duff and Cooper, 1976).

TABLE 2. Distribution of Proper Functioning Condition Ratings for the Stations in Marys River Basin From Assessments Conducted in the 1992-1993 and 1997-2000 Survey Periods.

Functionality Rating[1] (n = 79 stations evaluated in both years)	Number of Stations[2] 1992-1993	1997-2000
PFC	0	7
Functional-at-Risk, upward trend (FAR-up)	53	66
Functional-at-Risk, no apparent trend (FAR-na)	19	3
NF	7	3

Notes: PFC, proper functioning condition; NF, nonfunctional.
[1]As defined by Prichard *et al.* (1993, 1998).
[2]Each stream survey station is composed of four or five transects perpendicular to the flow spaced 100 feet (30 m) apart. Each of them appears to occur in a homogenous reach of stream assessed for riparian PFC.

In streams capable of improving and represented by 1979 data, most variables and indices showed significant positive changes through time (Table 5). Narrow and incised [Gc streams (Rosgen, 1994, 1996)] were excluded because of the absence of a floodable area for growth of riparian vegetation). However, percent of quality pools did not improve significantly between the 1979 and 1992-1993 and water width/depth ratio did not differ significantly between the 1992-1993 and 1997-2000 survey periods. All variables or indices improved between 1979 and 2000. A similar test that compared 1992-1993 and 1997-2000 measurements with additional station-data showed similar improvement (Table 6). With the exception of water width/depth ratio, all habitat variables and condition indices showed statistically significant improvement between 1992 and 2000. An increase in value indicates improvement for all variables except water width/depth ratio and bank angle (for which lower values are generally better).

The lack of statistical significance in water width/depth ratio is likely because of water levels at the times of the survey or the need for more time to show significant change. Overton *et al.* (1994) suggested that water width/depth ratio could be used to indicate channel change because of the balance of sediment load and transport capacity. However, the

TABLE 3. Distribution of Ecological State and Their Percent Ecological Optimum for the Marys River Basin From 1991 and 1995 Assessments.

Ecological State (% ecological optimum)[1]	Number of Stations[2] 1991	1995
Achievable (100%) (Riparian vegetation stabilized channel and pointbars in incision)		2
Natural (100%) (Riparian vegetation stabilized channel with accessible floodplain)	7	8
Natural/ponded (100%) (with beaver dams)	9	9
Ponded (100%) (with diversions or reservoirs)	5	11
Eroded (75%) (convex banks are bars and concave banks are eroded)	21	18
Stabilized (75%) (Riparian vegetation prevalent in incision with point bars)	19	23
Eroded/incised or broadened (65%) (banks eroded and incised by 1 m or widened by three to five times)	21	23
Channelized (50%) [stream course altered (usually straightened and deepened)]	3	3
Incised or broadened (50%) (incised by 1 m or widened by three to five times)	19	7
Blown out (25%) (incised by 1 m and broadened by five times, vegetation reduced)	19	19
Depositional (25%) (channel filled with sediment, often intermittent)	1	1
100% Ecological optimum	21	30
75% Ecological optimum	40	41
65% Ecological optimum	21	23
50% Ecological optimum	22	10
25% Ecological optimum	20	20

[1]As described by White Horse Associates (1997) to represent gross similarity to an undisturbed condition.
[2]Each stream survey station is composed of four or five transects perpendicular to the flow spaced 100 feet (30 m) apart. Each of them appears to occur in a homogenous reach of stream assessed for ecological state.

TABLE 4. Generalized Trend in the Distribution of Stations by Condition Index for Data Collected in the Marys River Basin During the 1992-1993 and 1997-2000 Survey Periods.

Condition Index	Change in Rating[1] Upward	Downward	No Change	Not Assessed
Functionality rating[2]	25	1	53	45
RCI[3]	47	6	32	39
HCI[4]	26	7	33	58
Ecological state[5]	22	1	101	0

RCI, Riparian condition index; HCI, habitat condition index.
[1]Upward indicates improvement of at least one condition class/ecological state; downward indicates change to a lower condition class or state; no change indicates either no change or possible numerical change that is not sufficient to result in change of condition class.
[2]As described in Prichard *et al.* (1993, 1998).
[3]Determined by averaging bank cover and stability (Duff and Cooper, 1976).
[4]Determined by averaging bank cover and stability, percent quality pools, percent desired stream bottom substrate, and pool-riffle ratio (Duff and Cooper, 1976).
[5]As described by White Horse Associates (1997).

use of bankfull width/depth ratios would have avoided problems with seasonal and year-to-year fluctuations because of weather. Platts *et al.* (1987) found that methods for evaluating overhanging vegetation, streambank stability, streambank cover, streambank angle, and shore-water depth, were only fairly accurate and precise. They found that the 95% confidence interval around the means varied from “good” to “poor” (Platts *et al.*, 1987). They warned observers to use caution with these methods to avoid overestimation.

The interpretation of change in bank angle depends on stream type and processes of channel evolution. In general, a decrease in bank angle for channels beginning to downcut is undesirable because evolution from that point leads towards a Rosgen G or Gc (a gully or low-gradient gully) stream type. In a narrow gully where concentrated flood waters cause severe erosion, bank angle reflects processes of incision and also prior management that may have contributed to incision. Bank angle does not usually reflect current management. Streams recovering from an over-wide condition build low but steep banks in recovery and thus decrease bank angle. For the stations included in this analysis (all stream types except Gc), a decrease in bank angle can indicate improvement. Platts *et al.* (1987) stated that the use of this variable is an effective monitoring measurement of land management and uses that alter channel morphology and degrade streambanks. They reported that an undercut bank with riparian vegetation binding overhanging soil is a good indicator of the success of streambank protection. They also noted that, unlike some measurements, undercut bank measurements are generally not affected by variation in water level, however, they are naturally highly variable among streams. The analyses show a statistically significant ($p = 0.001$) change between the 1992-1993 and 1997-2000 surveys. Bank angle reflect improved vegetative bank cover, bank stability, and depth of undercut banks.

Photographic Comparisons

Twenty-five compared sets of paired photographs from 1992 to 1993 and 1997 to 2000 generally confirmed the reliability of changes to the habitat

TABLE 5. Median Values of Selected Stream and Riparian Habitat Variables and Condition Indices Among Three-Survey Periods for the Marys River Basin.

Variable or Index[1] (*n* = number of stations in all years)	**Median Values**			**Significance of Change (*p*-value)**		
	1979	**1992-1993**	**1997-2000**	**1979/1992-1993**	**1992-1993/1997-2000**	**1979/1997-2000**
RCI[2] (*n* = 57)	36	55	65	0.000*	0.000*	0.000*
HCI[3] (*n* = 55)	36.5	45	53.5	0.001*	0.000*	0.000*
Bank cover (*n* = 57)	34.5	47.5	57.5	0.000*	0.000*	0.000*
Bank stability (*n* = 57)	34.5	60	70	0.000*	0.000*	0.000*
Water width/depth ratio (*n* = 54)	26.5	16.7	16.3	0.000*	0.709	0.000*
Pool quality (*n* = 55)	0	0	20.9	0.746	0.032*	0.009*

[1]The analysis includes stream types A-F and "not assessed"; Gc stream types (Rosgen, 1994 and 1996) are excluded.
[2]Determined by averaging bank cover and stability (Duff and Cooper, 1976).
[3]Determined by averaging bank cover and stability, percent quality pools, percent desired stream bottom substrate, and pool-riffle ratio (Duff and Cooper, 1976).

TABLE 6. Median Values for Selected Stream and Riparian Habitat Variables and Condition Indices From all Data Collected During the 1992-1993 and 1997-2000 Survey Periods.

Variable or Index (*n* = number of stations evaluated both years)	**Median Values**		**Probability of Significance (Mann-Whitney *U*-test) (*p*-value)**
	1992-1993	**1997-2000**	
RCI[1, 2] (*n* = 85)	51.5	61.5	0.000
HCI[1, 3] (*n* = 65)	44	51	0.001
Bank cover[1] (*n* = 85)	47.5	52.5	0.000
Bank stability[1] (*n* = 85)	55	67.5	0.000
Water width/depth ratio (*n* = 63)	16.7	15.8	0.419
% of quality pools (*n* = 65)	0	22.3	0.016
Bank angle (°) (*n* = 65)	153	138	0.000
Undercut Bank depth (inches) (*n* = 65)	0.0	0.3	0.000

Notes: RCI, Riparian condition index; HCI, Habitat condition index.
[1]Numbers based on percent of optimum.
[2]Determined by averaging bank cover and stability (Duff and Cooper, 1976).
[3]Determined by averaging bank cover and stability, percent quality pools, percent desired stream bottom substrate and pool-riffle ratio (Duff and Cooper).

variables and condition indices and the general upward trend of the Basin (Table 7). Of the 12 sets of slides selected to represent different stream types and functionality with high quality photographs, 10 pairs (83%) agreed in regard to trend in the various indices and individual variables; one pair disagreed, and two showed inconclusive indications of trend. From the 13 randomly selected photo-sets only one was not consistent with the indices and four sets showed inconclusive results. In all seven nonconfirmation cases, the field of view for the photographs was not adequate to clearly make comparisons. Slides and data collected at Wildcat Creek S-05 were inconclusive because the 1997-2000 photographs did not show a sufficient stretch of stream to determine trend (because of growth of a large willow that limited the view), whereas the data describing improvement sampled the whole station. Although Table 7 shows a decline in HCI of one point at Hanks Creek S-17 and S-1B, these minimal changes are not significant. Lining up photographs from previous years and using a consistent lens size is essential. Hanks Creek S-13 photo/data disagreement stems from the photographs showing little to no change, whereas the condition indices and functionality assessments show what appears to be relatively strong improvement. This is probably because PFC, RCI, and HCI reflect a much larger area than the photographs. Lower Marys River SB-13c and S-20c photographs were inconclusive because of an inadequate field of view after switching from a telephoto to a wide-angle lens, and poor photo quality. Also, the survey-data present a mixed assessment of these two survey stations.

The goal of using this method was to have another opportunity to "check" the collected stream survey and functionality assessment data. Following the

TABLE 7. Summary of Photo-Point Analyses for Random and Selected Stations Compared to Other Data Collected in the Marys River Basin Between 1992-1993 and 1997-2000.

Stream Survey Station*	Stream Type[1]	Photograph		Functionality		Riparian Condition		Habitat Condition		Agree[7]
		Change[2]	Clarity[3]	Change[2]	Rating[5]	Change[4]	Class[6]	Change[4]	Class[6]	
Chimney S-2**	E	imp	c	nc	FAR-up/FAR-up	+17.5	f-e	+5	p-f	a
Chimney S-3	B	imp	mc	nc	FAR-up/FAR-up	−6.5	f-f	+6	p-p	in
Chimney S-5**	C	imp	mc	imp	FAR-up/PFC	−7.5	e-e	+15	p-g	a
Chimney S-6**	C	imp	c	imp	FAR-up/PFC	+22.5	f-e	+23	p-f	a
Chimney S-1A	A	imp	c	nc	FAR-up/FAR-up	+20	p-g	+9	p-p	a
Conners S-3**	E	imp	mc	–	na/FAR-up	+12.5	g-e	+19	p-p	a
Conners S-5	A	imp	mc	imp	NF/FAR-up	+27.5	f-e	+20	p-g	a
Cutt S-1A	E	imp	mc	imp	FAR-up/PFC	+10	g-e	+44	p-e	a
Hanks S-3	B	imp	c	–	FAR-nt/FAR-up	+19	p-g	−12	f-p	in
Hanks S-7	B	imp	mc	–	FAR-nt/FAR-up	+11.5	e-e	+31	p-e	a
Hanks S-8**	B	nc	c	imp	FAR-up/PFC	+4	e-e	+1	g-g	a
Hanks S-13	B	nc	c	nc	FAR-nt/FAR-nt	+12.5	f-g	+16	p-f	d
Hanks S-16**	Gc	deg	c	deg	FAR-nt/NF	+1.5	g-g	−15	p-p	a
Hanks S-17**	C	imp	uc	imp	FAR-nt/PFC	+15	g-e	−1	p-p	a
Hanks S-1B**	E	nc	c	–	FAR-nt/FAR-up	+20	g-e	−1	p-p	in
LMR S-1c**	E	imp	c	nc	FAR-up/FAR-up	+15	p-p	–	na-p	a
LMR S-2c	F	imp	mc	nc	FAR-up/FAR-up	+1.5	p-p	–	na-p	a
LMR S-3c	C	imp	c	nc	FAR-up/FAR-up	+21.5	p-p	–	na-p	a
LMR S-9c	F	imp	mc	nc	FAR-up/FAR-up	+11.5	p-f	–	na-p	a
LMR SB-13c	Gc	uc	uc	nc	FAR-up/FAR-up	+1.5	g-g	−15	p-p	in
LMR S-20c	F	imp	mc	nc	FAR-up/FAR-up	−4	f-f	−4	p-p	in
UMR S-2A**	C	nc	mc	–	na/FAR-up	+16.5	e-e	0	p-p	a
UMR S-10**	B	imp	c	imp	FAR-up/PFC	+10	f-g	+6	f-f	a
UMR S-11	C	imp	mc	nc	FAR-up/FAR-up	+14	p-f	−2	p-p	a
Wildcat S-5**	C	nc	mc	–	na/FAR-up	+10	p-f	−3	p-p	in

[1]Rosgen stream type (1994 and 1996).
[2]imp = improvement, deg = degradation, nc = no change.
[3]c = clear, mc = mostly clear, uc = unclear.
[4]Indicates direction or amount of change, + = improvement, − = degradation, "–" = no data for 1 year.
[5]Indicates condition in 1992-1993/1997-2000. NF = nonfunctional, FAR-nt = functional-at-risk no apparent trend, FAR-up = functional-at-risk upward trend, PFC = proper functioning condition.
[6]Riparian and habitat condition classes: *p* = poor (<50%), f = fair (50-59%), g = good (60-69%), e = excellent (≥70%).
[7]Agreement between photographs and data: a = agree, d = disagree, in = inconclusive.
*LMR and UMR are the Lower and Upper Marys River, respectively.
**These stations were selected because of the quality and clarity of the photographs. That is, the photo pairs display the same alignment, and the photographs are "ideal."

procedure outlined by Sippel (1995) and Sippel and Swanson (1995) as closely as possible or clarifying changes to the method was important, as the Elko BLM Fisheries/Riparian staff was considering adopting a photo-point analysis protocol to augment stream survey and functionality assessments.

Changes by Stream Type

The degree of change between the 1992-1993 and 1997-2000 survey periods in selected variables and condition indices varied among Rosgen (1994, 1996) stream types. Some stream types changed in only certain variables and some variables changed only on some stream types (Table 8). Ecological optimum (not included in Table 8) did not change significantly between 1991 and 1995 for any Rosgen (1994, 1996) stream type nor for the Basin as a whole.

All stream types, except A and Gc channels for which sample size was limited, showed significant improvement for one or more variables or indices from the 1992-1993 and 1997-2000 stream survey. RCI and bank cover improved significantly for B, C, E, and F channels, but not for A and Gc stream types for which bank stability and cover are more landform limited (steep narrow valleys and incised narrow gullies, respectively). Similarly, bank stability increased significantly for C, E, and F channels, and almost increased significantly for B channels. Undercut bank depths increased significantly for B, C, and E channels where such a change would have meaning, but not for the entrenched A, F, and Gc channels. Decreases in bank angles were statistically signifi-

TABLE 8. Median Values for Selected Stream and Riparian Habitat Variables and Condition Indices and Significance of Their Changes Between the 1992-1993 and 1997-2000 Stream Surveys Displayed by 1997-2000 Rosgen (1994, 1996) Stream Type.

	Rosgen Level I Stream Type (broad level) (*n* = number of stations evaluated in both years)						
Variable or Index	**A (*n* = 5)**	**B (*n* = 33)**	**C (*n* = 36)**	**E (*n* = 14)**	**F (*n* = 24)**	**Gc (*n* = 5)**	**All (*n* = 124[1])**
RCI							
1992-1993	53.25	54	49	58.25	47	43.25	51.5
1997-2000	79	65	63.5	72.5	58.75	61.5	61.5
Significance level	0.333	0.011*	0.000*	0.007*	0.003*	0.333	0.000*
Bank cover							
1992-1993	46.25	50	45	50	41.25	43.75	47.5
1997-2000	72.5	60	52.5	63.5	50	62.5	52.5
Significance level	0.430	0.017*	0.009*	0.030*	0.015*	0.554	0.000*
Bank stability							
1992-1993	60	52.5	55	65	55	42.5	55
1997-2000	80	65	65	76.5	67.5	60	67.5
Significance level	0.171	0.075	0.003*	0.040*	0.026*	0.168	0.000*
HCI							
1992-1993	38.5	48.5	43	37	43	35	44
1997-2000	57.5	50.5	51	41	44	48	51
Significance level	0.105	0.399	0.007*	0.321	0.804	0.434	0.001*
Water width/depth ratio							
1992-1993	8.2	15.7	18.7	14.5	26.4	19.0	16.7
1997-2000	16.3	14.7	16.6	9.5	16.7	9.9	15.8
Significance level	0.488	0.917	0.203	0.433	0.102	0.333	0.419
% Quality pools							
1992-1993	0.0	0.0	0.0	0.0	35.5	13.2	0.0
1997-2000	12.0	0.0	21.5	36.45	57.55	11.4	22.3
Significance level	n/a[2]	0.753	0.072	0.008*	0.329	0.839	0.016*
Bank angle							
1992-1993	145	153	158	145	151	138	153
1997-2000	117	139.5	139	133	148	125	138
Significance level	0.105	0.001*	0.000*	0.374	0.254	0.561	0.000*
Undercut bank depth							
1992-1993	0.00	0.00	0.00	0.00	0.00	0.45	0.0
1997-2000	0.825	0.35	0.30	0.55	0.10	0.70	0.3
Significance level	n/a[2]	0.001*	0.025*	0.031*	0.106	0.561	0.000*

Notes: RCI, Riparian condition index; HCI, Habitat condition index.
[1]All includes data from seven stream survey stations that were not assessed for Rosgen channel type due to insufficient natural indicators or they were within beaver complexes. Taken from Newman (2001).
[2]Values for at least one survey period were the same therefore statistical analysis not applicable. Only medians from each survey period are shown.
*Indicates Mann-Whitney *U*-tests significance at $p \leq 0.05$).

cant for B and C channels. Only E channels improved significantly in percent of quality pools; although C channel improvements were nearly significant ($p = 0.072$). Both these stream types are malleable in their pool formation response to riparian vegetation (Rosgen, 1994, 1996; Swanson, 1996). Quality pools are a limiting factor for native salmonids of the interior west (e.g., Platts *et al.*, 1983, 1987). Only C channels made statistically significant improvement in HCI. Although there were numerical changes in water width/depth ratios (all slightly decreased except for Rosgen A), these changes were not significant ($p > 0.05$) for any stream type. Rosgen F channels demonstrated the greatest numerical change with a significance level of only $p = 0.102$. These changes may only reflect changes in flow conditions between the two periods rather than actual channel changes.

Changes in Rosgen A stream types were generally not statistically significant. The Rosgen A stream types represented in this Basin (A3 and A4) are generally unstable, are very sensitive to disturbance, and have poor natural recovery potential (Rosgen, 1994, 1996).

Stations located in Rosgen B stream types had statistically significant changes in RCI, bank cover, bank angle, and depth of undercut bank. Bank stability was close to significance. These stream types are typically very stable, moderately sensitive to disturbance, with excellent recovery potential (Rosgen, 1994, 1996). The lack of statistical significance in HCI, water width/depth ratio, and percent of quality pools was likely due to the lengthy time required for such changes. They are all affected by the water level at the time of survey.

Rosgen C stream types are very susceptible to disturbance but often recover well with stability greatly influenced by vegetation (Rosgen, 1994, 1996). Thus, it is not surprising that most condition indices and habitat variables changed significantly. The two exceptions to this are water width/depth ratio and percent quality pools.

Rosgen E channels, which are similar to C channels but narrower and often more sinuous, also changed significantly for most variables and condition indices. These channels are very stable, hence their narrowness, with riparian vegetation a major contributor to stability. These channels are especially susceptible to disturbance but have good recovery potential unless they become incised (Rosgen, 1994, 1996). These channels did not change significantly for HCI, water width/depth ratio, and bank angle. The changes in RCI, bank cover, and bank stability are all influenced by vegetation and vegetation interactions with banks. But with an inherently low width/depth ratio, change to the channel and pools may be gradual because of the capacity for sediment transport.

Rosgen F channels generally lack or are in the process of developing a floodplain. With some exceptions, riparian vegetation influences bank stability little in such channels, mostly because high banks keep roots of terraced plants from reaching the water table. With increasing flood-channel width and deposition of fine sediments, bank and floodplain building can occur. However, with high banks, deep floodwater often scours deposited sediment and colonizing vegetation. These channels are generally very susceptible to disturbance and have poor but increasing recovery potential. Once floodplain building begins, vegetation has a moderate influence on bank stability (Rosgen, 1994, 1996). Statistically significant changes occurred for bank cover, bank stability, and RCI. Water width/depth ratio, percent pool quality, and depth of undercut bank showed apparent improvement, however, these changes were not significant. Because changes in these variables normally follow channel narrowing, this suggests that a floodplain is developing. The lack of significant change of the measured variables and HCI is not surprising given the low potential for quality habitat.

Rosgen Gc stream types did not change significantly over the 4-7 years between the 1992-1993 and 1997-2000 survey periods. Gc channels are highly entrenched and susceptible to erosion. The variables measured in stream survey are erratic and not much influenced by management because Gc channels are very sensitive to disturbance from high flows (Rosgen, 1994, 1996).

Changes by Valley Bottom Type

Valley-bottom types (White Horse Associates, 1997) varied in their response over time (Table 9). Fluvial basins are absent from this table because of the limited sample size ($n = 2$ stations). Percent of quality pools increased significantly overall, although with a lower sample size it changed significantly only for alluvial valleys (although it was close for v-erosional channels). HCI increased significantly only for v-erosional canyons. Depth of undercut banks increased significantly in alluvial valley and v-erosional canyon valley-bottom types. Water width/depth ratio decreased in both alluvial draws and alluvial valleys. RCI, bank cover, bank stability, and bank angle improved significantly for alluvial draw, alluvial valley, and v-erosional canyon valley-bottom types. None of the indices or habitat variables changed significantly in v-depositional valley-bottom types, likely because the sample size was small ($n = 7$ stations). Ecological optimum did not change significantly between the 1991 and the 1995 assessments for any valley – bottom type and is absent from the table.

CONCLUSIONS AND MANAGEMENT RECOMMENDATIONS

These analyses confirmed that different types of data collected by the Elko BLM fisheries-riparian staff were relatively consistent indicators of trend and conditions in the Marys River Basin. As expected, longer monitoring periods after improved grazing management lead to changes that are more significant. Because stream ecosystems respond differently to anthropogenic alterations, depending on stream type and landscape setting, it is important to consider differences when setting objectives.

For most effective riparian management, a broad scale qualitative assessment, such as PFC could be used to identify areas with the capacity to respond favorably to changes in management. A regional set of standards and guidelines that steers riparian management in the Elko District (USDI BLM, 1997) stated that management will ensure significant progress to a minimum of PFC. For targeted reaches, managers can also use PFC assessment to identify functionality needs, help set achievable objectives, and identify how to monitor attainment of the objectives. Riparian PFC, although compared here through time,

TABLE 9. Median Values for Selected Stream and Riparian Habitat Variables and Condition Indices and the Significance of Their Changes Between 1992-1993 and 1997-2000 Displayed by Valley-Bottom Type (White Horse Associates, 1997).

	Valley-Bottom Type (*n* = number of stations evaluated in both years)				
Variable or Index	**Alluvial Draw (*n* = 36)**	**Alluvial Valley (*n* = 41)**	**V-depositional Canyon (*n* = 7)**	**V-Erosional Canyon (*n* = 37)**	**All (*n* = 123[1])**
RCI					
1992-1993	46.5	46.5	59	57.5	51.5
1997-2000	62.5	55	63.5	73.25	61.5
Significance level	0.000*	0.001*	0.199	0.000*	0.000*
Bank cover					
1992-1993	37.5	42.5	47.50	50	47.5
1997-2000	58.8	47.5	65	66	52.5
Significance level	0.000*	0.012*	0.406	0.002*	0.000*
Bank stability					
1992-1993	55	52.5	67.5	62.5	55
1997-2000	63.75	60	72.5	75	67.5
Significance level	0.028*	0.011*	0.096	0.000*	0.000*
HCI					
1992-1993	45	35	51	41	44
1997-2000	48	36	57	57	51
Significance level	0.192	0.783	0.798	0.000*	0.001*
Water width/depth ratio					
1992-1993	16.6	18.4	45.0	14.6	16.7
1997-2000	5.7	14.9	44.6	13.7	15.8
Significance level	0.003*	0.036*	0.702	0.383	0.419
% Quality pools					
1992-1993	10.8	26.4	0	0	0.0
1997-2000	16.9	81.8	12.3	4.6	22.3
Significance level	0.671	0.004*	0.785	0.065	0.016*
Bank angle (º)					
1992-1993	160	156	159	148.5	153
1997-2000	143.5	135	148	152.5	138
Significance level	0.009*	0.002*	0.371	0.000*	0.000*
Undercut bank depth					
1992-1993	0	0.00	0.00	0	0.0
1997-2000	0.15	0.4	0.3	0.350	0.3
Significance level	n/a[2]	0.000*	0.682	0.000*	0.000*

Notes: RCI, Riparian condition index; HCI, Habitat habitat condition index.

[1]All includes data from seven stream survey stations that were not assessed for Rosgen channel type because of insufficient natural indicators or they were within beaver complexes. Taken from Newman (2001).

[2]Values for at least one survey period were the same therefore statistical analysis not applicable. Only medians from each survey period are shown.

*Indicates Mann-Whitney *U*-tests significance at $p \leq 0.05$.

should not be used to monitor attainment of objectives because it is qualitative (Prichard *et al.*, 1998). In this study, 4-7 years was sufficient for many stream reaches to improve from FAR-na to FAR-up or PFC or from FAR-up to PFC. In this period, many measured variables improved significantly with changes of 15-30%. There is no method for translating stream survey information into a reliable functionality rating. To do so would require developing more complex relationships among variables and specific attributes featured in the functionality checklists. Such an effort may also develop ways to incorporate trend of stream survey data to more accurately depict the trend of FAR reaches.

In cold desert ecosystems, such as those found in northeastern Nevada, objectives should not be based on an index (i.e., HCI) or measured variables that vary by flow at the time of the survey (shore-water depth, water width/depth, and quality pools). Although the protocol calls for stream survey to be conducted at base flow, there is a limited window for the surveys to be accomplished by available personnel (usually summer seasonal employees).

Morphologic changes often require the development of vegetation and then sufficient time and stream flows for scour and sediment deposition. Objectives that call for changes to riparian vegetation [e.g., greenline composition and woody species regeneration (Winward, 2000; Cowley and Burton, 2005), streambank stability, or greenline to greenline width (Cowley and Burton, 2005)], should precede objectives that call for changes to channel morphology [e.g., width/depth ratio

(Rosgen, 1994, 1996)]. Montgomery and MacDonald (2002) describe a similar diagnostic framework for stream channel assessment and monitoring. Poole *et al.* (1997) stress that stream monitoring must be holistic and focus on measures of leading-edge variables and processes that affect in-stream conditions. They also point out several weaknesses of monitoring in-stream habitat units, such as pools. Winward (2000) emphasized greenline monitoring because it focuses on the vegetation that is most in contact with flowing water where erosion and sediment deposition occur. He defined greenline as "The first perennial vegetation that forms a lineal grouping of community types on or near the water's edge. Most often occurs at or slightly below the bankfull stage." For riparian vegetation monitoring, the methods described by Winward (2000) and advanced by Cowley and Burton (2006) provide more detailed and quantitative data about species composition and abundance than does stream survey. This may be especially important where expected changes may be more subtle. Kershner *et al.* (2004) found only small differences in percentage of pools between managed and unmanaged streams, perhaps because of greater inter-crew variation in pool measurement (Roper *et al.*, 2002).

The fisheries staff of the Elko BLM revised the stream survey manual based on this research in 2002 (USDI BLM, 2002). Revisions included clarification of descriptions for bank cover and bank stability ratings; emphazing the importance of photography; and strengthening data interpretation by adding photo-point analysis. Training is provided yearly to refresh permanent staff and prepare seasonal survey crews. This is emphasized by Roper and Scarneccia (1995), Roper *et al.* (2002), Woodsmith *et al.* (2005), and others.

ACKNOWLEDGMENTS

Research supported in part by Nevada Agricultural Experiment Station, Publication No. 52077057.

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