Assessment of Riparian Ecosystem Integrity: San Jacinto and Upper Santa Margarita River Watersheds, Riverside County, California

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R. Daniel Smith
US Army Engineer Research and Development Center
Waterways Experiment Station
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Assessment of Riparian Ecosystem Integrity In the San Jacinto and Upper Santa Margarita River Watersheds, Riverside County, California

1.0 Introduction

The Los Angeles District Corps of Engineers - Regulatory Branch is developing a Special Area Management Plan (SAMP) for the San Jacinto and upper Santa Margarita river watersheds in Riverside County, California (Western Riverside County SAMP) (Figure 1). The SAMPs are comprehensive wetlands planning efforts conducted in areas of special sensitivity. The Western Riverside County SAMP is conducted as a follow-up effort to the County of Riverside overall planning effort (Riverside County Integrated Plan or RCIP). Development of the SAMP is being coordinated with the anticipated Multi-Species Habitat Conservation Plan (MSHCP) currently under development.

The RCIP is a multi-component planning effort that includes the MSHCP, General Plan Amendment (GPA), and regional transportation plan (CETAP). The SAMP is one of the latter components of the RCIP that would integrate aquatic resources planning into the Countys' multi-componenet planning effort. The goal of the SAMP is to…"develop and implement a watershed-wide aquatic resource management plan and implementation program, which will include preservation, enhancement, and restoration of aquatic resources, while allowing reasonable and responsible economic development and activities within the watershed-wide study area" (Los Angeles District Corps of Engineers 2000). To achieve this goal, the aquatic resources within the San Jacinto and upper Santa Margarita river watersheds were delineated (Lichvar 2002), characterized, and assessed at a planning level.

This report represents the assessment of functional integrity of the San Jacinto and upper Santa Margarita river watersheds.

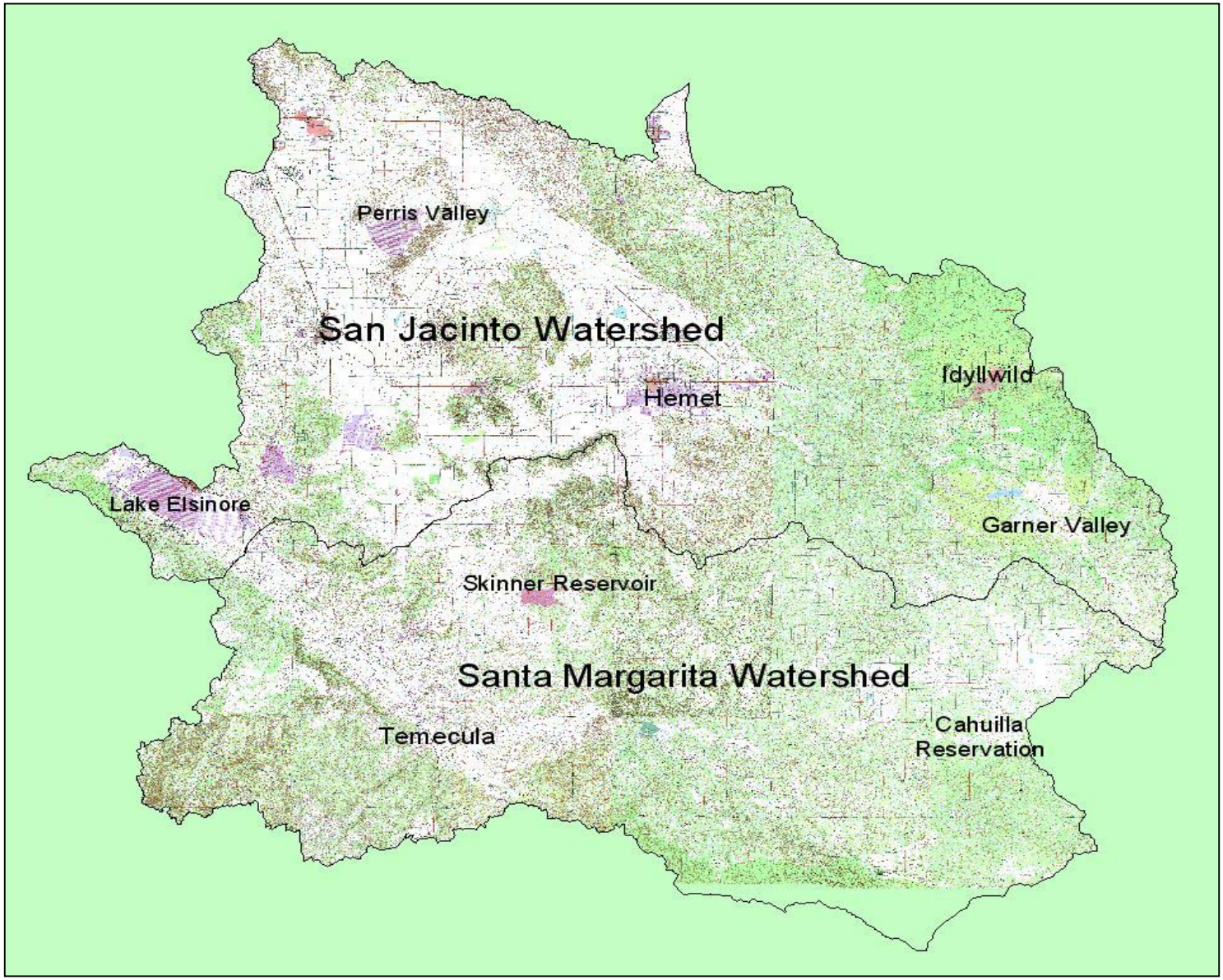

Figure 1. Overview of San Jacinto and upper Santa Margarita river watershed in the study area

2.0 Project Objective

The overall objective of this project was to conduct a baseline assessment of riparian ecosystem integrity in the San Jacinto and upper Santa Margarita river watersheds under current conditions. Once completed, the information developed during the assessment will be used to evaluate the potential impacts of future development projects on riparian ecosystems in the watershed. Similar projects has been completed for the San Diego Creek and San Juan / San Mateo River watersheds in Orange County (Smith 2000a, 2000b).

Three specific tasks were identified to meet the overall project objective. The first was to conduct a baseline assessment of riparian ecosystem integrity in the watersheds under current conditions (i.e., baseline). This was accomplished by dividing the riparian ecosystems into assessment units or "riparian reaches" and assessing each riparian reach using a suite of indicators of ecosystem integrity (see Sections 4.1 and 4.2). Establishing baseline conditions allows for a comparison between riparian ecosystem assessment units under current conditions, and for a comparison of riparian ecosystem integrity under current and future conditions. Such comparisons will guide the decision-making process concerning future development projects by ensuring avoidance, minimization, and adequate mitigation of impacts to these resources, both individually and cumulatively.

The second task was to rank riparian reaches in terms of ecosystem integrity. Ranking was based on the ecosystem integrity indicator scores and hydrologic, water quality, and habitat integrity indices resulting from the baseline assessment. The rankings will be one of many factors used to evaluate various alternatives within the watersheds.

The third task, which has not yet been completed, will be to determine which of several proposed alternative development scenarios would result in the least impact to riparian ecosystem integrity in the watersheds. This will be accomplished by comparing the assessment indicator scores and integrity indices of riparian reaches under baseline conditions with the scores and indices of riparian reaches following the "simulation" of each proposed alternative scenario. Simulations will be based on an implementation of the changes that can be expected to occur in the context of each assessment indicator as a result of each proposed alternative development scenario.

3.0 Background, Definitions, and Assumptions

3.1 Riparian Ecosystems

Riparian ecosystems are linear corridors of variable width that occur along perennial, intermittent, and ephemeral streams (Williams 1978). Perennial streams are defined as streams in which base flow is maintained year round by groundwater. Intermittent streams are defined as streams in which ground water maintained base flow occurs intermittently at different times of the year. Ephemeral streams are defined as streams in which flow is attributable only to surface water runoff in response to precipitation. Two features that distinguish riparian ecosystems are the hydrologic interaction that occurs between the stream channel and adjacent areas through the periodic exchange of surface and ground water, and the distinctive geomorphic features and vegetation communities that develop in response to this hydrologic interaction (Richards 1982; Harris 1987; Kovalchik and Chitwood 1990; Gregory et al. 1991; Malanson 1993; and Goodwin et al. 1997).

The hydrologic interaction between streams and adjacent riparian areas typically results in two distinct zones, although either zone may be narrow and seemingly absent under certain geologic or geomorphic conditions. The first zone, the active floodplain, includes the areas that are inundated by overbank flooding at least once every five years. This zone exhibits the fluvial features associated with recurring flooding such as point bars, areas of scour, sediment accumulation, natural levees, and debris wrack, and vegetation communities that are either short lived or able to survive the effects of frequent flooding (Figure 2).

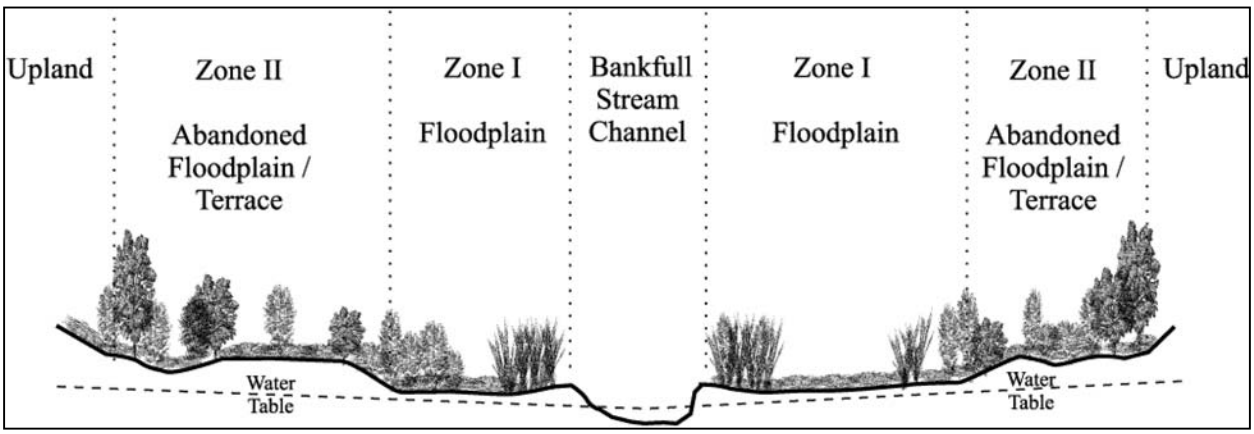

Figure 2. Generalized cross section of a riparian ecosystem

The second zone consists of abandoned floodplains and historical terraces formed by fluvial processes that took place under a historical, and often different, climatic condition or hydrologic regime (Knox et al. 1975; Graf et al. 1991; Rumsby and Macklin 1994). Under current climatic conditions and hydrologic regimes, these areas are flooded less frequent, during larger magnitude events (Dunn and Leopold 1978). Vegetation communities in this zone are generally composed of woody perennials that require the higher water table present in the riparian zone, and are capable of surviving, or reestablishment, after floods. For the purposes of this project, riparian ecosystems were defined from a functional perspective as the areas along perennial, intermittent, and ephemeral streams where the interaction with surface and groundwater results in distinctive geomorphic features and vegetation communities. Under natural circumstances, the riparian ecosystem includes the bank full stream channel, active floodplain, and less frequently flooded, historical floodplains/terraces.

3.2 Waters of the United States Versus Functional Riparian Ecosystems

Waters of the United States (WoUS) are the areas subject to regulation under Section 404 of the Clean Water Act (33 CFR Part 328.3). Wetlands are a subset of WoUS, and throughout this discussion, the term WoUS should be interpreted as including wetlands. Two categories of WoUS occur in association with southern California riparian ecosystems. The first category, non-wetland waters, includes the areas along perennial, intermittent, and ephemeral stream channels that exhibit a distinct bed and bank, but fail to meet one or more of the hydrologic, hydrophytic vegetation, and hydric soils criteria outlined in the Corps of Engineers Wetlands Delineation Manual (Environmental Laboratory 1987). The second category of WoUS is wetlands, which are aquatic areas that meet all of the hydrologic, hydrophytic vegetation, and hydric soils criteria.

It is important to note the "functional" riparian ecosystem, as defined for this project, has no special recognition, meaning, or status in the context of the Section 404 Regulatory Program. While functional riparian ecosystems normally include all WoUS regulated under the 404 Program and California Department of Fish and Game (CDFG) 1600 Program, the riparian ecosystem at times includes areas that fall outside the jurisdiction of one or both of these programs. Consequently, a one-to-one spatial correspondence between riparian ecosystems and WoUS in the watershed may be absent. The lack of spatial correspondence is common in the

arid and semi-arid southwestern United States where the active floodplain or historical terrace portion of the riparian ecosystem often meets one or two of the delineation criteria, but fails to meet all three delineation criteria necessary to qualify as a regulated wetland.

The spatial inconsistency between WoUS and riparian ecosystems is a result of the relatively generic hydrologic, hydrophytic vegetation, and hydric soil delineation criteria developed under the 404 Program for use in the wide variety of wetland types that occur in the United States. These generic delineation criteria necessarily ignore the unique way in which specific characteristics and processes contribute to the creation and maintenance of riparian as well as other functional wetland ecosystems. The intra- and inter-regional insensitivity of the generic delineation criteria is widely recognized, and while the need for regionalization of delineation criteria has been identified (Committee on Characterization of Wetlands 1995), no solution to this formidable task has been developed, much less implemented.

The spatial inconsistency is problematic in the context of the mandate to assess functions of WoUS as part of the 404 permit review process. An assessment cannot be accomplished by considering only the characteristics and processes of WoUS properbecause the functions of WoUS are influenced by the characteristics and processes taking place in the riparian ecosystem, as well as those in the adjacent upland areas and the drainage basin of the riparian ecosystem (Kratz et al. 1991; Hornbeck and Swank 1992; Bedford 1996).

A solution for meeting this challenge was outlined as part of the Hydrogeomorphic (HGM) Approach (Smith et al. 1995). In the HGM Approach, characteristics and process occurring in the functional ecosystem, as well as the adjacent upland areas and the drainage basin are considered during the assessment process. However, when applying the results of the assessment in the context of the 404 permit review process, the results are applied to WoUS only. This project used a similar approach in that the influence of the riparian ecosystem, adjacent uplands, and drainage basin were considered in assessing riparian ecosystem integrity. Consequently, when applying the results of the assessment, consistency with policies and assumptions of the SAMP, the Section 404 permit review process, Endangered Species Act Section 7 consultation, or the California Department of Fish and Game 1600 Program must be taken into account.

3.3 Riparian Ecosystem Integrity and Integrity Indices

Much has been written in the past about the concepts of ecological or ecosystem health and integrity (Rapport 1989; Costanza, Norton and Haskell 1991; Suter 1993; Scrimgeour and Wicklum 1996; Karr 1999). The two terms are often used interchangeably; however, the distinction made by Karr (1996) is instructive, and important in interpreting and applying the mandate of the Clean Water Act. Health refers to a flourishing condition, well-being, or vitality (Guralnik and Friend 1968). Integrity, on the other hand, refers to the quality, or state of being complete, and implies correspondence with a natural or original condition. Based on these distinctions, a cornfield, pine plantation, commercial nursery, and other culturally maintained ecosystem could be considered healthy, but not an ecosystem with high integrity. For this project, riparian ecosystems with high integrity were defined as those that support a balanced, diverse, and adaptive biological community resulting from natural evolutionary and biogeographic processes. In addition, high integrity riparian ecosystems exhibit the full range of physical, chemical, and biological attributes and processes that characterized riparian ecosystems in the region, over short and long term cycles, prior to cultural alteration.

The concept of ecosystem integrity is difficult to define because of its abstract nature. It is even more difficult to assess because of the wide variety of characteristics and processes across multiple spatial scales (i.e., riparian reach, local drainage, and drainage basin) that influence the integrity of riparian ecosystem. Consequently no single, direct measure of ecosystem integrity exists. This project focused on three of many quantities of interest, or assessment "endpoints," to represent riparian ecosystem integrity (Liebowitz and Hyman 1999). They include hydrologic, water quality, and habitat integrity indices. The selection of these integrity indices as assessment endpoints followed directly from the mandate in Section 101(a) of the Clean Water Act to "…restore and maintain the chemical, physical, and biological integrity of the Nation's waters". The hydrology, water quality, and habitat integrity indices are defined and discussed in greater detail in Section 4.3.

3.4 Indicators Used to Assess Hydrologic, Water Quality, and Habitat Integrity

Once assessment endpoints have been selected, metrics must be selected to assess the endpoints. In this procedure, these metrics are called indicators. There are two categories of metrics, direct and indirect. "Direct metrics" are a quantitative direct measure of an endpoint.

For example, cubic feet per second, is a direct metric that measures the stream discharge endpoint. Direct metrics can be identified when the assessment endpoint (i.e., attribute or process) is a narrowly defined and directly measurable. Direct metrics cannot be identified for broadly defined, abstract concepts like ecosystem integrity.

The second category of metric, the "indirect metric" is also referred to as "indicator". Indicators are qualitative or quantitative measures related to an assessment endpoint in some way. Indicators are used to assess complex, or abstract endpoints for which no direct metric exists, or when direct metrics are too difficult or costly to assess. For example, tree basal area is an indirect metric, or indicator, for tree biomass. Many existing biological/ecological assessment methods use indicators. For example, the Habitat Evaluation Procedure (HEP) (USFWS 1980) has used habitat characteristics as indicators for more than 25 years to assess a "habitat suitability" endpoint in lieu of the more difficult and time consuming task of sampling animal populations directly (USFWS 1980). Indicators are used in a similar fashion in the Index of Biological Integrity (IBI) and related methods (Karr and Chu 1997), the instream flow incremental methodology (IFIM) (Bovee 1986), the Synoptic Approach (Leibowitz et al. 1992; Abbruzzese and Leibowitz 1997), and the Hydrogeomorphic (HGM) Approach (Smith et al. 1995).

Liebowitz and Hyman (1999) make an important distinction between "confirmed" and "judgment" indicators. Confirmed indicators are those in which the relationship between the indicator and endpoint can be described in a precise manner (i.e., mathematical) with a known level of statistical confidence. Judgment indicators, on the other hand, are those in which the relationship between the indicator and endpoint is less precisely defined. The relationship is typically based on trends or patterns from the literature, field observations, or professional judgment. Given adequate research, the assumed relationship between a judgment indicator and an endpoint can be confirmed. For example, it is possible to define a quantitative, mathematical relationship between land use and water quality in a watershed using numerical modeling methods (Hamlett et al. 1992). The use of confirmed versus judgment indicators represents a tradeoff in terms of the degree of certainty of the relationship between the indicator and endpoint, and the ability to obtain the information necessary to assess selected endpoints. Some authors have questioned the use of judgment indicators (Conroy and Noon 1996, Schumaker 1996). However, in real world situations the use of judgment indicators is often unavoidable

given time and resource constraints, the lack of existing confirmed indictors, or the unavailability of quantitative data necessary to develop a confirmed indicator (Abbruzzese and Leibowitz 1997). Each of the indicators selected to assess hydrologic, water quality, and habitat integrity are discussed in greater detail in Section 4.2.

3.5 Reference Condition

In order to assess riparian ecosystem integrity, a standard of comparison or "reference condition" must be defined. The reference condition serves two purposes. First, it provides a concrete or virtual representation of the conditions, across multiple spatial scales, under which riparian ecosystems achieve and sustain a high level of integrity. Second, the reference condition provides a starting point from which to define and scale the relationship between the indicators and assessment endpoints.

Several different reference condition scenarios were suggested and considered for this project. Two of these were the "culturally unaltered" and "least culturally altered" reference condition. In southern California riparian ecosystems, the culturally unaltered reference condition implies conditions that existed prior to grazing, agriculture, fire suppression, water resource management, transportation corridors, urbanization, and other cultural alterations that can be identified. It is synonymous with what McCann (1999) referred to as pre-Columbian, meaning the conditions that existed prior to the influence of European explorers and subsequent immigrants. The least culturally altered reference condition refers to those conditions that currently exist in a watershed or region and most closely reflect culturally unaltered conditions.

Culturally unaltered was selected as reference condition for this project for several reasons. First, it represents the physical, chemical, and biological conditions under which riparian ecosystems have evolved naturally, and therefore, presumably represents the physical, chemical, and biological conditions that the Clean Water Act mandates should be maintained. While it can be argued that the culturally unaltered reference condition does not exist in southern California due to widespread existence of grazing, fire suppression, urban development, non-point air pollution, the disruption of historical metapopulation dynamics (Hastings and Harrison 1994), and a host of other factors, it is possible to make reasonable speculations as to what culturally unaltered conditions were like (Sedell and Luchessa 1981; Schubauer-Berigan 2000). It can also be argued that while it is impossible to restore culturally unaltered conditions, it may

be feasible to restore some of the larger, isolated and remote areas to a condition that functionally approximates the culturally unaltered condition given adequate time and resources, and appropriate management.

In the restoration context, a reference condition based on the culturally unaltered scenario provides an appropriate target for restoring ecosystem integrity and function. On the other hand, a restoration target based on the least culturally altered reference condition provides an arbitrary, and often inappropriate target with the potential to "successfully" restore riparian ecosystems with low ecosystem integrity and function, and no natural corollary.

The second reason for selecting culturally unaltered as the reference condition is the advantage, both in terms of interpretation and comparability of results, of using the "absolute" standard of comparison culturally unaltered represents instead of the "relative" standard of comparison represented by the least culturally altered condition. To illustrate this advantage, consider the following scenario. Assessments of ecosystem integrity are performed on riparian ecosystems in two watersheds, one heavily urbanized, and the other occupying a wilderness area without roads. Two assessments are done in each watershed. The first assessment uses culturally unaltered conditions as the reference condition, and second uses least culturally altered conditions as the reference condition. Hydrology, water quality, and habitat integrity indices are generated for both assessments ranging from 1 to 10 with an index of 1 indicating low integrity. In the first assessment, using culturally unaltered conditions as the reference condition, the indices for the urban watershed are likely to be at the lower end of the index range, while the indices for the wilderness watershed are likely to be in the higher end of the index range. These results are intuitively reasonable, and in reality correct, because heavily urbanized watersheds have significantly less ecosystem integrity than wilderness area watersheds due to changes in land use, stream channelization, loss of habitat, and other factors.

Now consider the results for the second assessment using least culturally altered conditions as the reference condition. Indices for the urban watershed will be at the high end of the index range, because least culturally altered conditions, specific to the urban watershed, were used to scale indicators of ecosystem integrity. Indices for the wilderness watershed also will be at the high end of the index range for the same reason. However, these results are not intuitive because, using the foregoing definition of ecosystem integrity, the urban watershed in reality has

a lower level of ecosystem integrity than the wilderness area, despite the fact that the indices of ecosystem integrity indicate there is little difference between the two. The non-intuitive nature of these results, and the inability to compare areas makes the use of the relative, least culturally altered reference condition, problematic.

The third reason for selecting culturally unaltered as the reference condition was the ability to define a culturally unaltered condition for the indicators of riparian ecosystem integrity without extensive reconnaissance in the watershed prior to conducting the assessment. For example, in the case of the indicators related to land use, it was reasonable to assume that under the culturally unaltered condition no grazing, agriculture, transportation, or urban development land uses existed. Similarly, in the case of the altered hydrologic conveyance indicator, it was reasonable to assume that under culturally unaltered conditions, stream channels were not straightened, lined, impounded, or piped and buried. The same could not be said for defining the least culturally altered condition. In order to define least culturally altered condition for assessment indicators it would be necessary to conduct reconnaissance in the watershed, prior to conducting the assessment, to determine the range of cultural alteration that existed and what represented least culturally altered condition.

4.0 Methods

4.1 Riparian Reach and Associated Areas

Due to the large geographic area covered by the project watershed, inherent variability of riparian ecosystems, and differential nature of historical impacts to riparian ecosystems in the watershed, the selection of an appropriate spatial unit for assessing riparian ecosystem integrity was critical. The assessment unit selected for this project was called the riparian reach (RR), defined as a segment of a main stem bank full stream channel and adjacent riparian ecosystem that was relatively homogenous in terms of its geological, geomorphological, edaphic, hydrological, channel morphological, vegetation, and cultural alteration characteristics (Olson and Harris 1997).

In association with each riparian reach, the following other entities were identified: "local drainage", "main stem channel", "main stem tributary channels", and "drainage basin". The local drainage of a riparian reach includes the area from which surface water drains directly to the main stem channel, or tributaries that enter the main stem channel, of the riparian reach. The main stem channel is the primary channel in the local drainage, and main stem tributaries are stream channels that originate in the local drainage of the riparian reach and flow directly to the main stem channel.

Figure 3 provides an illustration of the riparian reach, local drainage, main stem channel, and main stem tributary channels for riparian reach "BM-05". In Figure 3, the local drainage boundary of BM-05 is shown as a thick brown line, and the local drainage boundary of adjacent riparian reaches is shown as a thin brown line. The mains stem is the thick blue line running through the riparian ecosystem, within the local drainage boundary, and main stem tributaries are the dotted blue lines within the local drainage boundary. The riparian reach (i.e., the actual unit of assessment) is the green shaded area labeled riparian ecosystem, which includes the area adjacent to the main stem channel within the confines of the local drainage boundary.

The drainage basin of a riparian reach includes the local drainage of the riparian reach as well as the local drainage of all upstream riparian reaches. Figure 4 illustrates the local drainage of riparian reach BM-05. This is the dark green stippled area, which includes the local drainage of BM-05, as well as the local drainage of upstream riparian reaches BM-06 and BM-07.

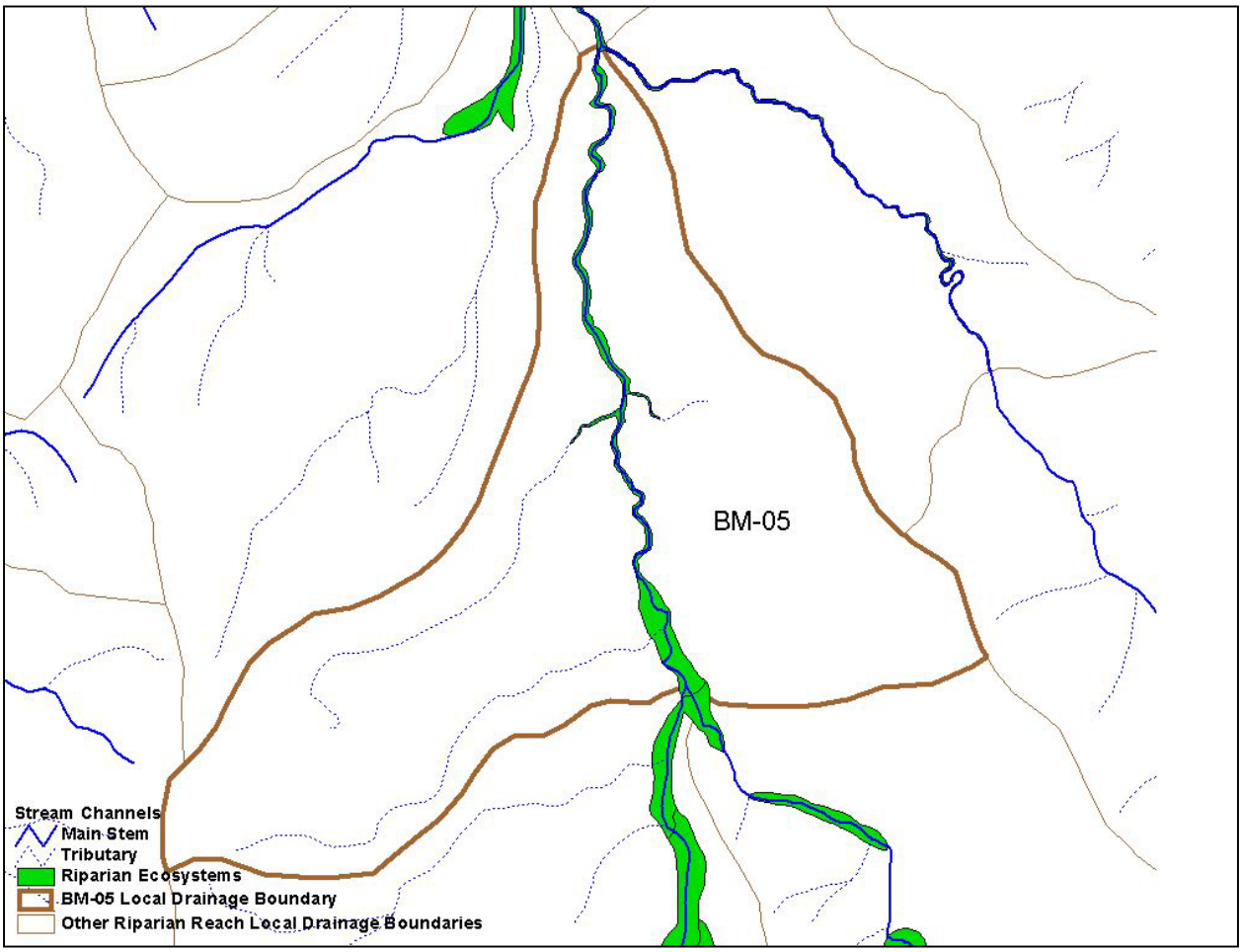

Figure 3. Example riparian reach and its associated local drainage

Figure 4 also illustrates the distinction between "headwater" and "non-headwater" riparian reaches. Headwater riparian reaches are those that do not have other riparian reaches upstream, while non-headwater reaches do have other riparian reaches upstream. In Figure 4, BM-06 and BM-07 are headwater riparian reaches, and BM-05 is a non-headwater riparian reach.

Preliminary maps of riparian reach, local drainage, and drainage basin boundaries and main stem streams in each riparian reach were developed as ArcView themes (see Appendix 1) on the basis of initial field reconnaissance, aerial photos, topographic maps (i.e., a digital raster graphic), and the WoUS maps developed by Lichvar (2002).

Each riparian reach was assigned pneumonic identifier for display and digital manipulation purposes. The local drainage of a riparian reach was combined with the local drainages of all upstream riparian reaches to define the drainage basin boundary of each riparian reach. On non-

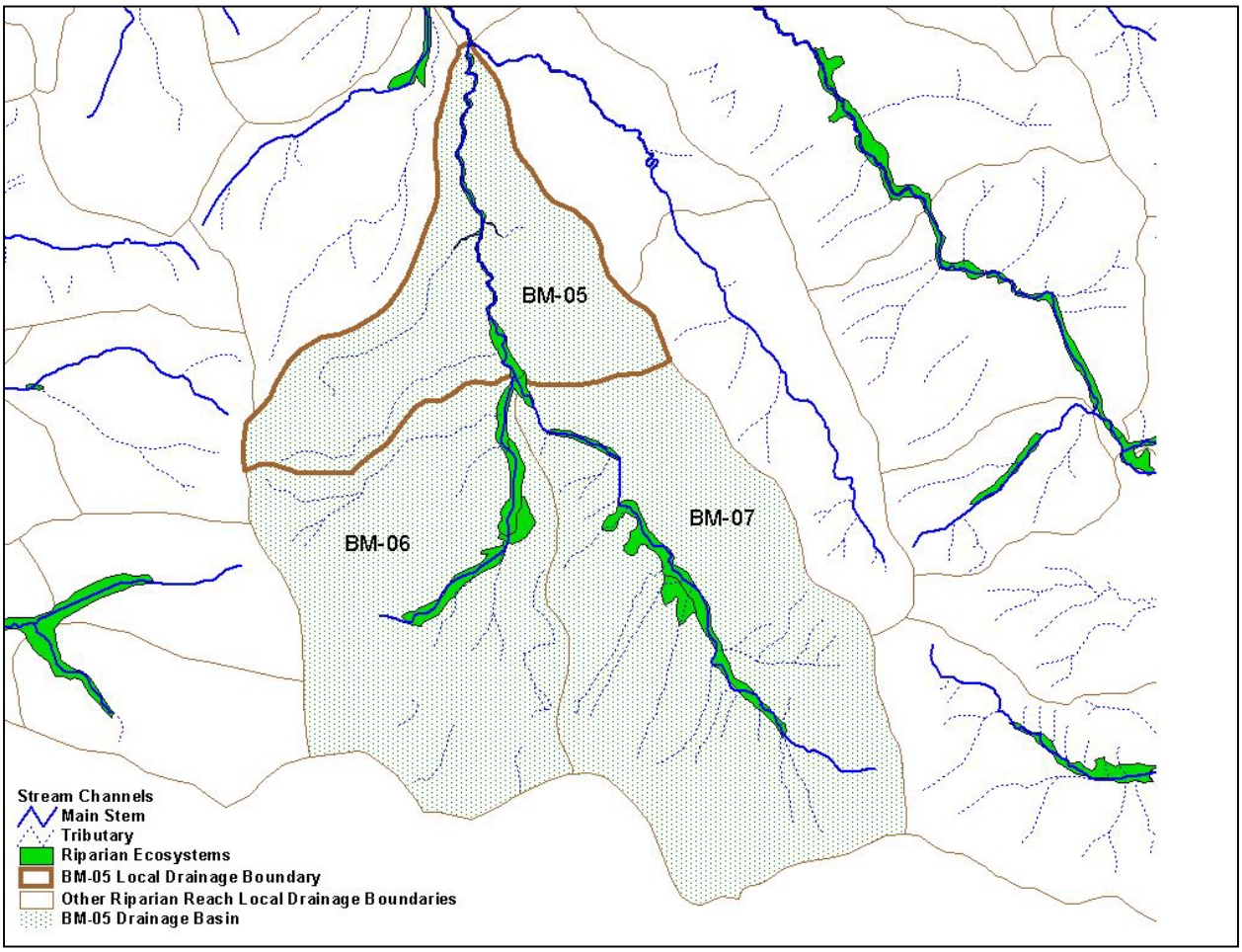

Figure 4. Example riparian reach and its associated local drainage and drainage basin

headwater riparian reaches (i.e., riparian reaches with other riparian reaches upstream) the longitudinal (i.e., upstream/downstream) boundaries of a riparian reach corresponded to changes in stream gradient or channel morphology resulting from geological control (e.g. knick points), tributaries/distributaries, artificial grade control structures, or other features related to cultural alteration. On headwater reaches, the upstream end of main stem channel of headwater riparian reach always included third order streams (Strahler 1952, 1957) as mapped by Lichvar (2002), and in many cases the upstream end included second order streams. Strahler stream order refers to a stream numbering method in which the smallest, terminal stream segments receive a designation of first order or "1" (Figure 5). A stream segment downstream from the confluence of two first order stream segments receives a designation of second order or "2". A stream segment downstream from the confluence of two second order stream segments receives a designation of third order or "3", and so on. In all cases, stream order increases only when two stream segments of equal order join.

The factors that determined the upstream extent of the riparian reach were stream density, accessibility, and the extent of a riparian vegetation component. Lateral boundaries of riparian reaches corresponded to either an estimate of the 100-year flood elevation contour, the extent of identifiable historic alluvial terraces, or the base of valley wall or artificial structure. In all cases the riparian reach included Riparian Zones 1 and 2 (see Section 3.1).

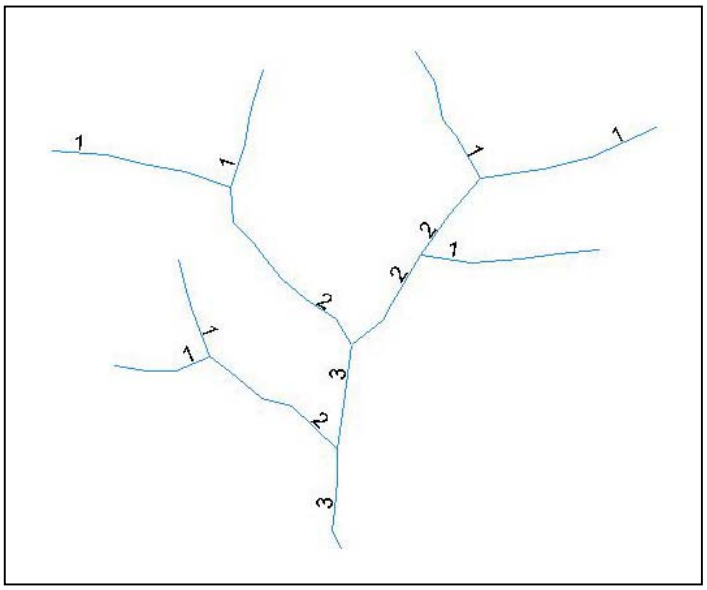

Figure 5. Example of Strahler stream orders

4.2 Assessment Indicators

The objective in selecting assessment indicators was to capture, to the greatest degree possible, the full range of characteristics and processes that influence hydrologic, water quality, and habitat integrity of riparian ecosystems at the riparian reach, adjacent upland, and drainage basin scale. Potential indicators were gleaned from a review of existing assessment methods (Dinius 1987; Lee et al. 1997; Ladson et al. 1999). Further investigation of the literature on riparian ecosystems, field observations, and the collective experience of individuals participating in the project provided additional potential indicators.

Several factors influenced the final selection of assessment indicators. First, was the need to match the project objectives of establishing baseline conditions and the ability to make comparisons between riparian ecosystems with available data, time and resources. Other factors included the large project area (>450 km^2), a short time frame and limited budget, insufficient quantitative data at the riparian reach assessment unit scale, and the lack of existing confirmed indicators. Another factor was the requirement to develop an open and easily understood approach that would allow participation and input from multiple stakeholders representing a range of perspectives from the development community and federal and state agencies charged with the protection of sensitive, threatened, and endangered species. Ultimately, a balancing of all these factors led to the selection of the indicators described below.

Each of the indicators selected are defined in the following sections and discussed in terms of the relationship between the indicator and relevant integrity indices (see Section 3.3). In addition, the method used to measure the indicator and assign an indicator value is described, along with the reference condition and range of indicator values used to assign indicator scores. Throughout this section the subscripts following the indicator acronym designates the spatial scale at which the indicator is applied with "RR" indicating the riparian reach, "RRT" indicating major tributaries of the riparian reach "LD" indicating the local drainage of the riparian reach, and "DB" indicating the drainage basin of the riparian reach.

4.2.1 Altered Hydraulic Conveyance (AHC_{RR} / AHC_{RRT} / AHC_{DB})

Altered Hydraulic Conveyance indicates the degree to which engineering techniques have been used to "improve" the capacity of channels to convey surface water downstream. The engineering techniques involve reducing the frictional resistance (i.e., roughness) caused by channel substrate, vegetation, woody debris, and other objects in the channel (Barnes 1967), minimizing the wetted perimeter, and/or shortening the length of a channel. Specific techniques include dredging, straightening, hardening/lining of the stream channel, and the removal of vegetation (Galay 1983, Brookes 1988).

Increasing the volume of water and velocity at which water is conveyed downstream can result in a significant change in the hydrologic regime, and hence hydrologic integrity, in the riparian reach where the alteration occurs as well as in upstream and downstream reaches. For example, removal of vegetation decreases channel stability and increases erosion by reducing the resistance afforded by the network of plant roots, and by increasing the velocity and consequently the erosive force of water in the channel. A straightened stream reach will typically respond by incising to reestablish a more energy efficient and stable channel slope (Shankman and Samson 1991). This in turn initiates headcutting and increased erosion upstream. Downstream of an altered stream channel the hydrologic regime can also be affected in terms of increased peak discharges, a decrease in channel stability, and an increase in erosion due to increased water velocity.

This indicator was measured as the percent of the main stem channel through the riparian reach with altered hydraulic conveyance. At the riparian reach and riparian reach tributary scale, aerial photography and field observations were used to estimate the value of the metric. At the

drainage basin scale, the indicator was calculated as the weighted average of the percent of altered hydraulic conveyance for all riparian reaches in the drainage basin of the riparian reach using the following formula:

$$\sum_{i=1}^{i_n}\left[\frac{AHC_{RR} * \left(ML_{RR} / ML_{DB}\right)}{100}\right] \qquad (1)$$

Where: AHC_{RR} = % of main stem in a riparian reach with altered hydraulic conveyance
ML_{RR} = Length of main stem channel in a riparian reach
ML_{DB} = Length of main stem channel of all riparian reaches in drainage basin

The reference condition was defined as <5% of the main stem channel in riparian reach, or major tributaries to the riparian reach, with altered hydraulic conveyance. Indicator scores were assigned based on range of indicator values in Table 1.

Table 1. Range of indicator values for scaling the altered hydraulic conveyance indicator

Indicator Value Range	Score
<5% of riparian reach main stem/drainage basin with AHC	5
>5 and <15% of riparian reach main stem/drainage basin with AHC	4
>15 and <30% of riparian reach main stem/drainage basin with AHC	3
>30 and <50% of riparian reach main stem/drainage basin with AHC	2
>50% of riparian reach main stem/drainage basin with AHC	1

4.2.2 Surface Water Retention (SWR_{DB})

Surface Water Retention indicates the degree to which the hydrologic regime in a riparian reach has been altered as a result of short and long-term storage of surface water in reservoirs, lakes, sediment basins, retention ponds, and similar surface water storage facilities. Streams in arid and semi-arid regions are disturbance-dominated systems (Resh et al. 1988; Power et al. 1988, 1996; Rood and Mahoney 1990). During flash floods, stream discharge can increase by several orders of magnitude causing aquatic organism mortality, destruction of riparian vegetation, and changes in channel morphology. The biological components of riparian ecosystems have adapted to these episodic cycles of disturbance, and developed a variety of mechanisms that make it possible to survive and indeed flourish where other organisms cannot. Short and long-term retention of surface water in storage facilities can significantly alter the characteristic pattern of discharge over the water year (Cushman 1985; Bain et al. 1988;

Dynesius and Nilsson 1994; Ligon et al. 1995; Poff et al. 1997; Hadley and Emmett 1998). Most importantly, it eliminates the low frequency, high volume discharges that reset the system (Hawkins et al. 1997). However, it can also lead to perennialization of streamflow, change the pattern of seed distribution, germination, and survival, and change a variety of other physical and biological processes necessary to perpetuate the riparian ecosystem (Hynes 1975; Warren 1979; Lotspeich and Platts 1982; Frissell et al.1986; Kondolf et al.1987; Debano and Schmidt 1989; Stromberg and Patton 1991; Johnson 1994; Power et al. 1996; Kershner 1997; Kondolf 1997; Richter et al. 1997).

This indicator was measured as the percent of the drainage basin of a riparian reach upstream of lakes, reservoirs, dry dams, sediment basins, retention ponds, or similar facilities capable of storing surface water from several days to months. The total area within each drainage basin upstream of the downstream extent of all storage facilities was determined using the ArcView GIS themes of riparian reaches, surface water retention facilities, and U.S. Geological Survey (USGS) 7.5 minute topographic map. Using the theme of surface water retention structures and a topographic map as background, the reach theme was split along topographic boundaries at the downstream extent of the retention structures. Upstream areas above these reach segments were calculated and summed across the drainage basin to determine the metric value.

The reference condition was defined as <5% of the drainage basin of a riparian reach upstream of a lake, reservoir, dry dam, sediment basin, retention pond, or similar facility capable of storing surface water from several days to months. Indicator scores were assigned based on the range of indicator values in Table 2.

Table 2. Ranges of indicator values for scaling the surface water retention indicator

Indicator Value Range	Score
<5% of drainage basin drains to surface water storage facilities	5
>5 and <15% of drainage basin drains to surface water storage facilities	4
>15 and <30% of drainage basin drains to surface water storage facilities	3
>30 and <50% of drainage basin drains to surface water storage facilities	2
>50% of drainage basin drains to surface water storage facilities	1

4.2.3 Perennialized Stream Flow (PSF_{RR})

Perennialized Stream Flow indicates the degree to which the hydrologic regime of a riparian reach has been altered by a supplementary supply of surface water resulting from cultural

activities such as irrigation. Perennialization refers to the conversion of intermittent or ephemeral stream channels to a perennial stream through the addition of surface water flow (usually at low levels) in a stream channel from artificial supplies of surface water. The supply of water usually occurs in the form of irrigation or treated return water. In arid and semi-arid regions, perennialization facilitates a shift in plant and animal community composition away from what normally occurs in a riparian reach that is not perennialized. Perennialization also has the potential to affect physical and chemical processes in riparian ecosystems.

This indicator was measured as the percent of the main stem channel through a riparian reach that exhibited perennialized stream flow due to supplementary sources of water at the time of the field visits, or showed evidence of perennialized stream flow (i.e., occurrence of *Typha* sp., *Carex* sp. and/or other emergent aquatic species). Field observations and aerial photographs were used to assign a value to the indicator. The evidence used to identify a stream as perennialized was the presence of low flow during dry periods. Other types of evidence included nutrient enrichment based on the presence of blue-green algae and vascular species such as *Typha* sp., outfall pipes and other inlet structures entering a reach, residential developments and golf courses in the drainage basin, interbasin transfer import points, and the lack of evidence of a natural source of low flow.

The reference condition was defined as <5% of the main stem channel of a riparian reach with perennialized stream flow. Indicator scores were assigned based on the range of indicator values in Table 3.

Table 3. Range of indicator values for scaling the perennialized stream flow indicator

Indicator Value Range	Score
<5% of stream channel exhibiting perennialized flow	5
>5 and <15% of stream channel exhibiting perennialized flow	4
>15 and <30% of stream channel exhibiting perennialized flow	3
>30 and <50% of stream channel exhibiting perennialized flow	2
>50% of stream channel exhibiting perennialized flow	1

4.2.4 Import, Export, or Diversion of Surface Water (IED_{DB})

Import, Export, or Diversion of Surface Water indicates the degree to which the hydrologic regime of a riparian reach has been altered as a result of import, export, or diversion of surface water. Inter-basin import and export of surface water, and the intra-basin diversion of water for

public water supply, irrigation, and ground water recharge is common in the arid western United States. The import, export, or diversion of water within and between watersheds has been shown to affect a wide variety of biotic and abiotic processes as a result of changes in the quantity and timing of surface water discharge and other aspects of the hydrologic regime (Taylor 1982; Kondolf et al. 1987; Stromberg and Patten 1990; Petts 1996; Davies, Thoms, and Meador 1992)

The indicator IED_{DB} was measured as the percent of a riparian reach drainage basin from which surface water was imported, exported, or diverted on a continuous or periodic basis. In the case of imported water, the area of the watershed from which water was being imported was added to the area of the riparian reach drainage basin receiving water prior to calculating the percentage of the drainage basin that contributed to import. Using the ArcView GIS theme of riparian reaches and USGS 7.5 minute topographic map images the area below import, export, or diversion points were calculated and summed across the drainage basin to determine the metric value.

The reference condition was defined as <5% of the drainage basin of a riparian with surface water continuously or occasionally imported, exported, or diverted. Indicator scores were assigned based on the range of indicator values in Table 4.

Table 4. Range of indicator values for scaling the import, export, or diversion of water indicator

Indicator Value Range	Score
<5% of drainage basin with import, export, or diversion of water	5
>5 and <15% of drainage basin with import, export, or diversion of water	4
>15 and <30% of drainage basin with import, export, or diversion of water	3
>30 and <50% of drainage basin with import, export, or diversion of water	2
>50% of drainage basin with import, export, or diversion of water	1

4.2.5 Floodplain Interaction (FI_{RR})

Floodplain Interaction indicates of the degree to which the overbank hydrologic connection between the bankfull channel and the active floodplain and terraces of the riparian ecosystem has been lost in a riparian reach. The lost connection could be a result of levees, channelization, or channel incision. Many of the characteristics and processes of riparian ecosystems are dependent on periodic hydrologic interaction between the stream channel and the floodplain. When the hydrologic connection is lost, the physical and biological characteristics of the riparian ecosystem change, regardless of the reason.

This indicator was measured as the percent of the main stem channel through a riparian reach that was physically disconnected from the floodplain as a result of culturally accelerated channel erosion/incision, channel improvements, or levees. An incised main stem channel in which the active floodplain has been reestablished within the incised channel through normal fluvial processes was not considered disconnected (Keller 1972). When one side of the channel was disconnected from the floodplain, 50% of the stream channel was considered disconnected from the floodplain and terraces. When both sides of the channel were disconnected from the floodplain, 100% of the stream channel was considered disconnected. Aerial photography and field observations were used to estimate the value of the metric.

The reference condition was defined as <5% of the main stem stream channel disconnected from the floodplain. Indicator scores were assigned based on the range of indicator values in Table 5.

Table 5. Range of indicator values for scaling the floodplain interaction indicator

Indicator Value Range	Score
<5% of main stem stream channel disconnected from the floodplain	5
>5 and <15% of main stem stream channel disconnected from the floodplain	4
>15 and <30% of main stem stream channel disconnected from the floodplain	3
>30 and <50% of main stem stream channel disconnected from the floodplain	2
>50% of main stem stream channel disconnected from the floodplain	1

4.2.6 Sediment Regime (SR_{RR})

Sediment Regime indicates the degree to which the sediment dynamics in the main stem channel of a riparian reach are in equilibrium with respect to the supply of sediments from upstream sources and erosion and deposition processes within the channel. A variety of cultural activities can alter sediment dynamics and/or channel geometry. These types of changes include channel erosion due to physical disturbance, channel incision and head-cutting due to the alteration of slope, channel aggregation due structures that impede flow (i.e., weirs, drop structures, culverts), and irrigation diversions (Kondolf et al. 1987).

This indicator was assigned a score by matching field observations to the descriptions in Table 6. The reference condition was defined as exhibiting a sediment regime in equilibrium with respect to supply, erosion, and deposition processes, and not affected by cultural alteration.

Table 6. Description of conditions for assigning sediment regime indicator score

Description of Conditions	Score
Movement of sediment in the channel is in equilibrium in terms of supply, erosion, and deposition processes that reflect the culturally unaltered condition. On higher-order streams there are alternating point bars; bank erosion occurs, but is stabilized and moderated by vegetation; and channel width, form, and floodplain area is consistent through the reach. In low-order streams with bedrock control, some of these indicators may not be apparent, but overall bank and hillslope erosion is moderated by vegetation, and there are no apparent culturally induced catastrophic failures.	5
Movement of sediment in the channel is in equilibrium with the current hydrologic regime, as opposed to a culturally unaltered condition, and exhibits an overall balance in terms of erosion and deposition processes. On higher-order streams there are alternating point bars; bank erosion occurs, but is stabilized and moderated by vegetation; and channel width, form, and floodplain area are consistent through the reach. In low-order streams with bedrock control, some of these indicators may not be apparent, but overall bank and hillslope erosion is moderated by vegetation, and no culturally induced catastrophic failures are apparent.	4
Sediment disequilibrium is minor and localized within the reach. This includes small, localized areas of bank protection, slumping, or encroachment on the floodplain and channel. This condition class also includes previously disrupted reaches on a recovery trajectory, such as deeply entrenched streams where downcutting has been arrested by structural grade control, and there is sufficient room for lateral channel migration and establishment of a functional floodplain within the incised channel.	3
Sediment erosion and deposition out of equilibrium. Water inflow is sediment rich or poor, or accelerated bank erosion exists. Channel not actively incising, but extensive disequilibrium is evident. Typical indicators include extensive bank slumping (erosion events that exceed any moderating influence of native vegetation), active gullies feeding into the reach from adjacent hillslopes, shoaling of sediments rather than deposition in sorted lateral and mid-channel bars. Apparently stable channels should be placed in this category if there is evidence of regular mechanical disruption, such as bulldozing of the channel bottom and clearing of riparian vegetation to improve flood conveyance.	2
Sediment dynamics within most of the reach are seriously disrupted. This includes reaches where no significant storage or recruitment of sediment occurs (i.e., reaches in underground tunnels/culverts, and reaches hardened with rock or concrete). It also includes reaches that are either actively incising or functioning as sediment traps (e.g., sediment basins). This also includes reaches that have been subject to recent changes likely to induce severe disequilibrium, such as extensive floodplain filling, change in slope, channel straightening, or other changes that are likely to cause channel downcutting during future high-flow events.	1

4.2.7 Land Use/Land Cover in Drainage Basin ($LULC_{DB}$)

Land use/land cover (LULC) indicates the way in which a tract of land is utilized, has been developed, or the physiognomic class of vegetation. For example, a tract of land that is used to produce row crops is assigned an agricultural LULC, golf courses and parks are assigned to a recreational or open space LULC, urban areas are typically assigned to a residential, industrial, or commercial LULC. Lands supporting natural vegetation communities (i.e., chaparral versus pasture) are assigned to a shrub, forest, or grassland LULC. A variety of LULC classifications have been developed over the years. Today however, the reference to LULC usually implies the USGS classification of LULC (Anderson et al. 1976) or a similar, but more detailed regional variations of this classification. This type of LULC classification is typically developed through the interpretation of aerial photographs or the analysis of other remote sources of thematic information (USGS 1990).

Over the centuries, humans have modified the LULC of the natural landscape through intensive land management practices such as agriculture, forestry, and grazing, as well as through industrialization and urbanization. The net effect of these activities has been a dramatic shift in the type and extent of LULC that occur around the world today, particularly in industrialized countries (Meyer and Turner 1992; Hannah et al. 1994).

A number of studies have related LULC to water quality. While they have consistently shown that the water quality decreases as natural LULC are culturally altered, the specific relationships and causative factors vary widely. For example, Hunsaker and Levine found that LULC changes in the watershed had the greatest effect on water quality, while Graf 1998 found that changes in LULC in the surrounding landscape had the greatest effect. The relationship between LULC and quantity and quality of surface water has been documented for a variety of wetland and aquatic systems (Brugham 1978; Ehrenfield 1983; Kuenzler 1986; Howarth et al. 1991; Ryan 1991;Williamson et al. 1992; Richards and Host 1994; Cooper 1995; Blair 1996; Wilber et al. 1996; Caruso and Ward 1998). In the western United States specifically, livestock grazing, agriculture, and urbanization have often been identified as contributors to increased surface water runoff and non-point sources of sediment, nutrients, and other classes of pollutants (Armour et al. 1991; Sedgwick and Knopf 1991; Charbonneau and Kondolf 1993; Bush and Smith 1995; Rothrock et al. 1998).

Four sub-indicators were used to measure the LULC indicator. Each of the sub-indices were measured as the percent of the drainage basin of a riparian reach with LULC types with the potential to increase the nutrient, pesticide, hydrocarbon, or sediment loading in downstream surface waters. Land use/land cover categories with the potential to increase these categories of pollutants are shown in Table 7. Using the ArcView GIS themes of riparian reach and LULC themes, the area of a drainage basin occupied by each LULC was determined for each sub-indicator. The area of LULC types with the potential to increase pollutants, hydrocarbons, nutrients, and sediment were then summed across the drainage basin and divided by the total drainage basin area to determine the sub-indicator value. The four sub-indicator values were averaged to determine the LULC indicator value.

The reference standard condition was defined as <5% of the watershed and surrounding landscape area with LULC types with the potential to increase nutrient, pesticide, hydrocarbon, or sediment loading in surface waters downstream. Indicator scores were assigned based on the range of indicator values in Table 8.

Table 8. Range of indicator values for scaling the land use/land cover indicator

Indicator Value Range	Score
<5% of watershed / landscape with LULC types that increase N/P/H/S	5
>5 and <15% of watershed / landscape with LULC types that increase N/P/H/S	4
>15 and <30% of watershed / landscape with LULC types that increase N/P/H/S	3
>30 and <50% of watershed / landscape with LULC types that N/P/H/S	2
>50% of watershed / landscape with LULC types that increase N/P/H/S	1

4.2.8 Riparian Vegetation Condition (RVC_{RR})

Riparian vegetation condition indicates the condition of native riparian vegetation communities within the floodprone area of the main stem channel through a riparian reach. Much has been written about the importance of native riparian vegetation communities in the support of specific faunal groups such as amphibians (Brode and Bury 1984), birds (Hendricks and Rieger 1989), and fauna in general (Hubbard 1977; Faber et al. 1989; Knopf et al. 1988). Under culturally unaltered conditions, a complex interaction of many factors such as the size of the watershed, discharge, channel geometry, substrate type, and slope determine the size of the area that typically supports riparian vegetation. In general, as stream orders increase, the width of the bankfull channel increases, and the size of the area supporting riparian vegetation increases. Floodprone area represents a scaled metric that can be applied consistently

Table 7. Land Use/Land Cover (LULC) types

LULC Code	LULC Description	Increase in LULC Type Increases Runoff	Increase in LULC Type Increases Nutrient Load	Increase in LULC Type Increases Pesticide Load	Increase in LULC Type Increases Hydrocarbon Load	Increase in LULC Type Increases Sediment Load	Increase in LULC Type Inhibits Animal Use / Movement
11	Residential	Yes	Yes	Yes	Yes	No	Yes
12	Commercial and Services	Yes	Yes	Yes	Yes	No	Yes
13	Industrial	Yes	Yes	Yes	Yes	No	Yes
14	Transportation/Commercial/Utilities	Yes	Yes	Yes	Yes	No	Yes
15	Industrial and Commercial	Yes	Yes	Yes	Yes	No	Yes
16	Mixed Urban and Built-Up	Yes	Yes	Yes	Yes	No	Yes
17	Other Urban or Built-Up	Yes	Yes	Yes	Yes	No	Yes
21	Cropland and Pastureland	Yes	Yes	Yes	No	Yes	Yes
22	Orchards/Vineyards/Nurseries	Yes	Yes	Yes	No	Yes	Yes
23	Confined Feeding Operations	Yes	Yes	No	No	Yes	Yes
24	Other Agricultural Land	Yes	Yes	Yes	No	Yes	Yes
31	Herbaceous Rangeland	Yes	Yes	Yes	No	Yes	Yes
32	Shrub and Brush Rangeland	Yes	Yes	Yes	No	Yes	No
33	Mixed Rangeland	Yes	Yes	Yes	No	Yes	Yes
41	Deciduous Forest Land	No	No	No	No	No	No
42	Evergreen Forest Land	No	No	No	No	No	No
43	Mixed Forest Land	No	No	No	No	No	No
52	Lakes	No	No	No	No	No	No
53	Reservoirs	No	No	No	No	No	No
54	Bays and Estuaries	No	No	No	No	No	No
61	Forested Wetlands	No	No	No	No	No	No
62	Nonforested Wetlands	No	No	No	No	No	No
71	Dry Salt Flats	No	No	No	No	No	No
72	Beaches	No	No	No	No	No	No
73	Sandy Areas (non-Beach)	No	No	No	No	No	No
74	Exposed Rock	No	No	No	No	No	No
75	Strip Mines	Yes	Yes	Yes	Yes	Yes	Yes
76	Transitional Areas	Yes	Yes	Yes	Yes	Yes	Yes

in different stream orders throughout a watershed. Floodprone area was determined in the field by projecting the elevation corresponding to two times the maximum depth of the bankfull channel until it intersected the surface of the adjacent floodplain / terrace on both sides of the main stem channel (Rosgen 1996; 5-20).

This indicator was assigned a score by observing the condition of vegetation along the riparian reach and matching these field observations to the descriptions in Table 9. In inaccessible reaches, field observations were supplemented with aerial photography and riparian vegetation community maps developed by Lichvar (2002). The reference standard condition was defined as vegetation represents reference condition with no chronic disturbance or recovered from historical disturbance.

Table 9. Description of conditions for assigning the riparian vegetation condition indicator score

Description of Conditions	Score
Vegetation represents reference condition with no chronic disturbance or recovered from historical disturbance. Presence of areas disturbed through natural processes (i.e., fire and flood) okay.	5
Native vegetation recovering with minor chronic disturbance (i.e., grazing). Presence of areas disturbed through natural processes (i.e., fire and flood) okay.	4
Native vegetation common and widespread with moderate grazing pressure. Presence of areas disturbed through natural processes (i.e., fire and flood) okay.	3
Native vegetation localized with heavy grazing pressure. Presence of areas disturbed through natural processes (i.e., fire and flood) okay.	2
Native vegetation absent, area hardened (i.e., paved, urban, etc.) or graded. Restoration impractical and unlikely for economic or political reasons.	1

4.2.9 Exotic Plant Species (EXO_{RR})

Exotic Plant Species indicates the degree to which exotic plants have displaced the native plant community along the main stem channel, floodplain, and terraces of a riparian reach. The presence of exotic species has the potential to affect hydrologic, water quality, and habitat integrity of riparian ecosystems. Once established, exotic plant species often have an advantage over native species because the diseases, predators, or competitors that control the species in their native locality are absent (Bohn and Amundsen 2001). This can lead to the rapid and extensive spread of exotics which has been documented for a number of species that invade southern California riparian areas (e.g., *Arundo donax* (Bell 1997, Fransden and Jackson 1993), *Tamarix* spp. (Sher, Marshall and Gilbert 2000), and numerous forbs and grasses (D'Antonio and

Vitousek 1992). Once established, exotic plant species have an indirect affect on hydrologic, water quality, and habitat integrity. For example, animal species that rely on native plant species for feeding, resting, or breeding are directly affected by the displacement of native vegetation.

This indicator was assigned an index by matching field observations to the description of condition in Table 10. The reference standard condition was defined as exotic plant species absent or rare composing ≤5% total vegetation biomass.

Table 10. Description of condition and index for Exotic Plant Species indicator

Description of Condition	Index
Exotic plant species absent or rare composing ≤5% total vegetation biomass	5
Exotics present but localized and composing >5 and ≤20% of vegetation biomass	4
Exotics common and composing >20 and ≤50% of vegetation biomass	3
Exotics widespread and composing >50 and ≤75% of vegetation biomass	2
Exotics dominant and composing >75% of vegetation biomass	1

4.2.10 Riparian Corridor Continuity (RCC_{RR} / RCC_{DB})

Riparian Corridor Continuity indicates the degree to which the main stem channel of a riparian reach exhibits an uninterrupted vegetated riparian corridor. Riparian ecosystems typically form a relatively continuous corridor along the stream channel and floodplain. Intact vegetated corridors allow animals to move to locations throughout a watershed on a daily, seasonal, or annual basis (La Polla and Barrett 1993; Machtans et al. 1993; Naiman et al. 1993 and 1996), but see Simberloff et al. (1992). Gaps in the continuous riparian corridor can occur as a result of natural fluvial processes during large magnitude events (Hawkins et al. 1997). However, gaps are more frequently created as a result of cultural alterations such as roads, power and pipeline corridors, agriculture activities, and urban/industrial development.

This indicator was measured at the riparian reach scale as the percent of floodprone area along the main stem channel of the riparian reach occupied by native and non-native vegetation communities with adequate height and structure to allow faunal movement. For example, annual grassland with no shrub or tree component was considered to represent a corridor gap. The difference between this indicator and Area of Native Riparian Vegetation was that for the RCC indicator, the vegetation corridor could be composed of native or non-native riparian species, whereas for the NRV indicator, only native riparian vegetation communities were considered.

The percent of floodprone area occupied by native riparian vegetation was estimated based on field observations, aerial photographs, and riparian vegetation communities mapped by Lichvar (2002). At the drainage basing scale, Riparian Corridor Continuity was calculated as the weighted average of the percent of Riparian Corridor Continuity for all riparian reaches in the drainage basin of the riparian reach using the following formula:

$$\sum_{i=1}^{i_n}\left[\frac{RCC_{RR} * \left(ML_{RR} / ML_{DB}\right)}{100}\right] \qquad (2)$$

Where: RRC_{RR} = % of main stem in a riparian reach with vegetation corridor gaps
ML_{RR} = Length of main stem channel in a riparian reach
ML_{DB} = Length of main stem channel of all riparian reaches in drainage basin

The reference condition was defined as <5% of the floodplain of the main stem channel of the riparian reach occupied with riparian vegetation communities. Indicator scores were assigned based on the range of indicator values in Table 11.

Table 11. Range of indicator values for scaling the riparian corridor continuity indicators

Indicator Value Range	Score
<5% of riparian reach with gaps/breaks due to cultural alteration	5
>5 and <15% of riparian reach with gaps/breaks due to cultural alteration	4
>15 and <30% of riparian reach with gaps/breaks due to cultural alteration	3
>30 and <50% of riparian reach with gaps/breaks due to cultural alteration	2
>50% of riparian reach with gaps/breaks due to cultural alteration	1

4.2.11 Culturally Altered Land Use/Land Cover at Riparian Reach Boundary (BND_{RR} / BND_{RRT})

Land Use/Land Cover at Riparian Ecosystem Boundary indicates the presence of cultural features at the boundary of the riparian ecosystem that are likely to inhibit the normal movement of fauna between riparian and adjacent upland habitats. Land use/land cover at the boundary of the riparian ecosystem plays an important role in determining the ability of animals to move freely between riparian and adjacent upland ecosystems on a daily or seasonal basis (Petersen et al. 1992; Vought et al. 1994, Statzner et al. 1997; Vought et al. 1994; Osborne and Kovacic 1993). Under natural conditions, riparian vegetation transitions gradually to native upland vegetation at the edge of the riparian ecosystem. A variety of cultural activities replace these native or naturalized vegetation communities with agriculture, urban/industrial, transportation

corridors or other types of LULC that reduce the likelihood the animals can move freely between the riparian ecosystem and adjacent uplands.

This indicator was measured using the ArcView GIS themes of riparian reach and LULC. A one-meter wide buffer strip was created at the riparian ecosystem boundary to simulate a boundary condition. The percent of this area occupied by each LULC type was determined, and the LULC types considered to inhibit faunal movement in Table 8 were used to determine the value of the metric.

The reference condition was defined as <5% of the riparian ecosystem boundary composed of LULC types that inhibit faunal movement. Indicator scores were assigned based on the range of indicator values in Table 12.

Table 12. Range of indicator values for scaling the riparian ecosystem boundary indicator

Indicator Value Range	Score
<5% of the riparian boundary inhibits faunal movement	5
>5 and <15% of the riparian boundary inhibits faunal movement	4
>15 and <30% of the riparian boundary inhibits faunal movement	3
>30 and <50% of the riparian boundary inhibits faunal movement	2
>50% of the riparian boundary inhibits faunal movement	1

4.2.12 Culturally Altered Land Use/Land Cover in Upland Buffer (BUF_{RR} / BUF_{RRT})

Land Use/Land Cover in Upland Buffer indicates the degree to which the LULC in a buffer zone has been culturally altered. Land Use/Land Cover-Upland Buffer differs from the Land Use/Land Cover-Riparian Reach Boundary indicator in that it is concerned with LULC in the adjacent upland landscape and not just at the boundary of the riparian ecosystem and the adjacent upland. The values of two sub-indicators were summed to provide the value of this indicator. The first sub-indicator measured culturally altered Land Use/Land Cover types that are considered restorable. This includes grazed and agricultural lands that could be relatively easy and inexpensive to restore to a natural condition. The second sub-indicator measure culturally altered Land Use/Land Cover types that are considered non-restorable. This includes roads, parking lots, residential developments, commercial developments, and other infrastructure which would be more difficult, costly, and economically impractical to restore.

Land use/Land Cover in upland areas adjacent to riparian ecosystems are important because of their ability to support the life requirements of a variety of native species. Under reference

conditions, the upland buffer consists of native vegetation communities. A variety of cultural activities replace these native or naturalized vegetation communities with agriculture, urban/industrial, transportation corridors, or other types of land use. Changes in LULC in the buffer also have the potential to affect the rate at which water and sediment move towards riparian areas from the uplands (Peterjohn and Correll 1984, 1986; Osborne and Kovacic 1993; Barling and Moore 1994).

This indicator was measured using field observation, aerial photographs, and the ArcView GIS themes of riparian reach and LULC themes. A buffer of 100 m width, or until an adjacent 2nd order or higher watershed boundary was encountered, was established around the riparian reach. The percent of the buffer area occupied by each LULC type was determined, and the LULC types considered to inhibit faunal use in Table 8 were used to determine the value of the indicator.

The reference condition was defined as <5% of the upland buffer with LULC types representing cultural alteration. Indicator scores were assigned based on the range of indicator values in Table 13.

Table 13. Range of indicator values for scaling the riparian ecosystem upland buffer indicator

Metric Value Category	Score
<5% of the buffer zone with culturally altered LULC	5
>5 and <15% of the buffer zone with culturally altered LULC	4
>15 and <30% of the buffer zone with culturally altered LULC	3
>30 and <50% of the buffer zone with culturally altered LULC	2
>50% of the buffer zone with culturally altered LULC	1

4.3 Integrity Indices

Integrity indices were developed for each of the hydrologic, water quality, and habitat integrity assessment endpoints (see Section 3.3). Each of these integrity indices are defined and discussed in terms of the assessment indicators in the following sections. Table 14 summarizes the information about which indicators are used in each integrity index.

4.3.1 Hydrologic Integrity Index

Riparian ecosystems with high hydrologic integrity exhibit the range of frequency, magnitude, and temporal distribution of stream discharge, and surface and subsurface interaction

Table 14. Indictors used for calculation of integrity indices

#	Indicators	Hydrologic Integrity Index Indicators	Water Quality Integrity Index Indicators	Habitat Integrity Index Indicators
1	Altered Hydraulic Conveyance (AHC_{RR})	X*[1]	X[1]	
2	Altered Hydraulic Conveyance (AHC_{RRT})	X[1]	X[1]	
3	Altered Hydraulic Conveyance (AHC_{DB})	X	X	
4	Surface Water Retention (SWR_{DB})	X	X	
5	Perennialized Stream Flow (PSF_{RR})	X	X	
6	Perennialized Stream Flow (PSF_{DB})	Not Used	Not Used	
7	Import, Export, or Diversion of Surface Water (IED_{DB})	Not Used	Not Used	
8	Floodplain Interaction (FI_{RR})	X	X	
9	Sediment Regime (SR_{RR})		X	
10	Land Use / Land Cover ($LULC_{DB}$)		X	
10.1	Land Use / Land Cover ($LULC_{DB-N}$)		O*	
10.2	Land Use / Land Cover ($LULC_{DB-P}$)		O	
10.3	Land Use / Land Cover ($LULC_{DB-H}$)		O	
10.4	Land Use / Land Cover ($LULC_{DB-S}$)		O	
11	Riparian Vegetation Condition (RVC_{RR})		X	X
12	Exotic Plant Species (EXO_{RR})			X
13	Riparian Corridor Continuity (RCC_{RR})			X
14	Riparian Corridor Continuity (RCC_{DB})			X
15	Land Use / Land Cover at Boundary (BND_{RR})			X
16	Altered Land Use / Land Cover in Upland Buffer (BUF_{RR})			X[2]
16.1	Restorable Altered Land Use / Land Cover in Upland Buffer (BUF_{RR-R})			O
16.2	Non-Restorable Altered Land Use / Land Cover in Upland Buffer (BUF_{RR-NR})			O
17	Land Use / Land Cover in Upland Buffer (BUF_{RRT})			X[2]
17.1	Restorable Altered Land Use / Land Cover in Upland Buffer (BUF_{RRT-R})			O
17.2	Non-Restorable Altered Land Use / Land Cover in Upland Buffer (BUF_{RRT-NR})			O
Possible Minimum/Maximum Indicator Score Sum		5 / 25	8 / 40	6 / 30

* X = Indicators O = Sub-indicator
[1] In the Hydrology and Water Quality Indices these two indicators were averaged
[2] In the Habitat Index these two indicators were averaged

between the stream channel, floodplain, and terraces, that historically characterized riparian ecosystems in the region (Bedford 1996, Poff et al. 1997, Richter et al. 1997). In the arid southwest, this translates into seasonal intermittent, ephemeral, or low flow periods, with annual bankfull discharges superimposed on a background of episodic, and often catastrophic, larger magnitude floods that inundate historical terraces (Graf 1979; Graf 1988; Harris 1987; Fisher et al. 1982; Friedman et al. 1996a, Friedman et al. 1996b).

In selecting indicators to assess hydrologic integrity, two groups of characteristics and processes were considered. The first group focused on the factors that influence frequency, magnitude, and temporal distribution of stream discharge, and the second group focused on the factors that influenced the hydrologic interaction between the stream channel, floodplain, and historical terraces. Direct measures of stream discharge are unavailable at the riparian reach scale in these watersheds. Consequently, several indicators were selected at the drainage basin scale with the assumption that an indirect estimate of deviation from reference condition can be made based on changes in specific characteristic and processes of a drainage basin such as interception, infiltration, evapotranspiration, percolation, groundwater flow, and surface water flow overland and in channels. Cultural alteration of the drainage basin alters these characteristics and processes, and consequently, stream discharge. While it is difficult to quantify the exact nature of the relationship between specific drainage basin characteristics, as represented by the indicators, and stream discharge, it can generally be shown that as cultural alteration of a watershed increases, so does the deviation from short and long-term historical patterns of frequency, magnitude, and distribution of stream discharge.

Indicators selected to reflect degree of cultural alteration in a drainage basin with the potential to influence stream discharge included:

#3 - Altered Hydraulic Conveyance (DB)
#4 - Surface Water Retention (DB)
#7- Import, Export, or Diversion of Surface Water (DB)

A frequency, magnitude, and distribution of stream discharge in a riparian reach that is similar to the historical range of conditions does not alone, ensure hydrologic integrity. Hydrologic integrity also depends on maintaining the interaction between the stream channel, floodplain, and terraces of the riparian ecosystems through overbank and subsurface flows. This

interaction is critical to the maintenance of riparian plant communities, sediment storage, carbon dynamics, biogeochemical processes, and other characteristics and processes of riparian ecosystems.

Indicators selected to represent the degree of interaction between the stream channel and the floodplain at the riparian reach and riparian reach tributary spatial scale included:

#1 - Altered Hydraulic Conveyance (RR)
#2 - Altered Hydraulic Conveyance (RRT)
#5 - Perennialized Stream Flow (RR)
#8 - Floodplain Interaction (RR)

These seven indicators were used to calculate the Hydrologic Integrity Index for each riparian reach using the procedure described Section 4.5.

4.3.2 Water Quality Integrity Index

Water quality integrity was defined as exhibiting a range of loading in the pollutant categories of nutrients, pesticides, hydrocarbons, and sediments that are similar to those that historically characterized riparian ecosystems in the region. Assessing changes in the range of loading in each pollutant category can be determined directly by comparing data on current loading with data on historical loading when such data are available. While there is some historical and recent monitoring data available for a limited number of stations in the watershed, little or no loading data are available at the riparian reach scale. Consequently, the assessment of water quality integrity was based on indicators of drainage basin and riparian reach characteristics that have been shown to influence water quality integrity.

Three groups of factors were considered in selecting indicators for the water quality integrity endpoint. The first group focused on whether the changes in land use in the drainage basin had the potential to increase sources of pollution compared to the reference condition. The second group focused on whether the stream channel delivery system had changed in relation to reference condition in terms of frequency, magnitude, and temporal distribution of stream flow (Kuenzler 1977). The third group focused on whether changes in land use in the areas adjacent to the stream, or the loss of a hydrologic connection between the stream channel and the floodplain had decreased the likelihood of pollutants being physically captured or biogeochemically processed compared to reference condition. A number of studies have shown

that cultural alteration of these factors can lead to increased loading in one or more pollutant categories (Osborne and Wiley 1988; Allan and Flecker 1993; Hunsaker and Levine 1995; Perry and Vanderklein 1996; Richards et al. 1996; Allen et al. 1997; Bolstad and Swank 1997; Johnson et al. 1997; Wang et al. 1997; Miltner and Rankin 1998; Trimble 1997; Basnyat et al. 1999).

The following indicator was selected to reflect how the condition of land use in the drainage basin influences water quality integrity:

#10 - Land Use / Land Cover (DB)

This indicator was based on averaging the indicator values for four sub-indicators including:

#10.1 - Land Use / Land Cover – Nutrient Increase (DB)
#10.2 - Land Use / Land Cover – Pesticide Increase (DB)
#10.3 - Land Use / Land Cover – Hydrocarbon Increase (DB)
#10.4 - Land Use / Land Cover – Sediment Increase (DB)

Six indicators were selected to reflect the condition of the stream system that transports pollutants. These are the same indicators used to assess hydrologic integrity, and included:

#1 - Altered Hydraulic Conveyance (RR)
#2 - Altered Hydraulic Conveyance (RRT)
#3 - Altered Hydraulic Conveyance (DB)
#4 - Surface Water Retention (DB)
#5 - Perennialized Stream Flow (RR)
#7 - Import, Export, or Diversion of Surface Water (DB)

Indicators selected to reflect the condition of riparian ecosystem with respect to its ability to physically capture and biogeochemically process pollutants and influence water quality included:

#8 - Floodplain Interaction (RR)
#9 - Sediment Regime (RR)
#11 - Riparian Vegetation Condition (RR)

These ten indicators were used to calculate the Water Quality Integrity Index for each riparian reach using the procedure described in Section 4.5.

4.3.3 Habitat Integrity Index

Riparian ecosystems with habitat integrity exhibit the quality and quantity of habitat necessary to support and maintain a balanced, integrated, adaptive biological system having the full range of characteristics, processes, and organisms at the site specific, landscape, and watershed scales that historically characterized riparian ecosystems in the region. The following factors were considered in selecting indicators of habitat integrity including the spatial extent and quality of riparian habitat, the "connectedness" of riparian habitats at the riparian reach and drainage basin scales, and the spatial extent and quality of upland habitat in the landscape adjacent to riparian ecosystems:

#11 - Riparian Vegetation Condition (RR)
#12 - Exotic Species Index (RR)
#13 - Riparian Corridor Continuity (RR)
#14 - Riparian Corridor Continuity (DB)
#15 - Culturally Altered Land Use/Land Cover at Riparian Reach Boundary (RR)
#16 - Culturally Altered Land Use/Land Cover in Upland Buffer (RR)

Indicator 16 was based on summing the values for the two sub-indicators including:

#16.1 - Restorable Culturally Altered Land Use/Land Cover in the Upland Buffer (RR)
#16.2 - Non-restorable Culturally Altered Land Use/Land Cover in Upland Buffer (RR)

#17 - Culturally Altered Land Use / Land Cover at Riparian Reach Major Tributary Upland Buffer (RRT)

Indicator 17 was based on summing the values for the two sub-indicators including:

#17.1 - Restorable Culturally Altered Land Use / Land Cover in the Upland Buffer (RR)
#17.2 - Non-restorable Culturally Altered Land Use / Land Cover in Upland Buffer (RR)

These eight indicators were used to calculate the Habitat Integrity Index for each riparian reach using the procedure described in Section 4.5.

4.4 Characterization and Assessment of Riparian Reach Assessment Units

Characterization of riparian reaches was accomplished during a site visit to each reach. Several reaches in areas without roads were not visited due to difficult accessibility and time constraints. For these reaches, the characterization was completed to the extent possible using

aerial photographs and topographic maps. Table 15 provides a listing of the information collected as part of riparian reach characterization.

The general strategy during a site visit was to begin at the downstream end of the riparian reach and conduct a walking reconnaissance of the main stem channel through the riparian reach. On longer reaches we drove to representative sections of the riparian reach and conduct separate walking reconnaissance. On headwater reaches the walking reconnaissance included at least the lower-third of the main stem channel of the riparian reach. Time constraints precluded conducting a walking reconnaissance of the entire main stem channel of headwater reaches in several areas without roads. In these situations, field observations were supplemented with interpretations based on aerial photographs.

After reconnaissance through a riparian reach, a decision was made to either retain the preliminary riparian reach boundaries, or to further divide the riparian reach into two or more riparian reaches. Based on the observations made during reconnaissance, a representative portion of the riparian reach was selected and a riparian reach characterization data sheet was completed. The characterization included notes on the species and location of the dominant vegetation in terms of geomorphic features (i.e., bank full channel, floodplain, terrace), measurement of channel characteristics, general field notes about the nature of the riparian reach, and indicator values for those integrity indicators measured in the field.

Indicators were assessed during the field site visit and using spatial analysis in ArcView. The second column in Table 15 indicates the method by which indicators were assessed. Based on field observation and/or spatial analysis, each indicator was assigned a value representing the percent deviation of the indicator from the reference condition in that reach. For example, if the main stem of a riparian reach was completely channelized, an indicator value of 100 was assigned to the Altered Hydraulic Conveyance – Riparian Reach indicator. The assignment of values to indicators was based on an assumed, relative, categorical relationship defined between indicators and assessment endpoints. The assumption was that an increase in the deviation from the reference condition represented an equivalent decrease in the level of riparian ecosystem integrity in terms of the specific indicator. For example, in comparing two riparian reaches in terms of the land use/land cover indicator, the riparian reach with the larger percentage of

Table 15. List of data for characterizing riparian reaches and indicators

Field Description	Method
Riparian Reach ID	Field
Drainage Basin	Field
USGS 7.5 Minute Topographic Quad	GIS
Main stem Downstream End Coordinates (UTM)	GIS
Main stem Upstream End Coordinates (UTM)	GIS
Size of Mapped Riparian Ecosystem in Riparian Reach Local Drainage (ha)	GIS
Size of Mapped Riparian Ecosystem in Riparian Reach Drainage Basin (ha)	GIS
Size of Riparian Reach Local Drainage (LD) (ha)	GIS
Length of Local Drainage Perimeter (m)	GIS
Size of Riparian Reach Drainage Basin (DB) Area (ha)	GIS
Valley Type (Rosgen)	Field
Valley Length (m)	Field / GIS
Valley Width (m)	Field / GIS
Main stem Downstream End Elevation (m)	GIS
Main stem Upstream End Elevation (m)	GIS
Valley Slope (%) (Estimated From 7.5 Minute Topo)	Calculated
Engineered Channel Type or Rosgen Stream Type	Field
Main stem Channel Length in (m) (Smith)	GIS
Main stem Channel Length in DB (m) (Smith)	GIS
Main stem and Tributary Channel Length in Local Drainage (m) (Lichvar)	GIS
Main stem and Tributary Channel Length in Drainage Basin (m) (Lichvar)	GIS
Main stem Channel Length / Main stem Channel and Tributary Channels Length	Calculated
Drainage Density	Calculated
Channel Slope	Calculated
Sinuosity	Calculated
Bankfull Width (ft)	Field
Bankfull Width (m)	Calculated
Floodprone Width (ft)	Field
Floodprone Width (m)	Calculated
Bankfull Maximum Depth (in)	Field
Bankfull Maximum Depth (cm)	Calculated
Bankfull Mean Depth (in)	Field
Bankfull Mean Depth (cm)	Calculated
Bankfull Cross-Sectional Area (m^2)	Calculated
Width / Depth Ratio	Calculated
Entrenchment Ratio	Calculated
Natural Channel Substrate Bedrock / Boulder (%)	Field
Natural Channel Substrate Cobble (%)	Field
Natural Channel Substrate Gravel (%)	Field
Natural Channel Substrate Sand (%)	Field

Table 15 cont. List of data for characterizing riparian reaches and indicators

Field Description	Method
Natural Channel Substrate Silt / Clay (%)	Field
Indicator 1 % of Main Stem Channel of RR with Altered Hydraulic Conveyance	Field
Indicator 2 % of Channels of Major RRT with Altered Hydraulic Conveyance	Field
Indicator 3 % of Main Stem Channels of DB with Altered Hydraulic Conveyance	Field/GIS
Indicator 4 % of DB with Surface Water Retention	GIS
Indicator 5 % of Main Stem Channel of RR with Perennialized Stream Flow	Field
Indicator 6 % of Main Stem Channel of DB with Perennialized Stream Flow	Field/GIS
Indicator 7 % of RR with Surface Water Imported, Exported or Diverted	GIS
Indicator 8 % of Floodplain Interaction	Field
Indicator 9 Sediment Regime Condition Index of Main Stem Channel in RR	Field
Indicator 10 % Land Use / Land Cover in Drainage Basin	GIS
Sub-indicator 10a % of LULC Contributing to Nutrient Increase	GIS
Sub-indicator 10b % of LULC Contributing to Pesticide Increase	GIS
Sub-indicator 10c % of LULC Contributing to Hydrocarbon Increase	GIS
Sub-indicator 10d % of LULC Contributing to a Sediment Increase	GIS
Indicator 11 Riparian Vegetation Condition Index	Field
Indicator 12 Exotic Plant Species Index	Field
Indicator 13 % of Flood Prone Area in RR with Riparian Corridor Breaks	Field
Indicator 14 % of Flood Prone Area in DB with Riparian Corridor Breaks	Field/GIS
Indicator 15 % of RR with a Culturally Altered LULC Types at Boundary	Field/GIS
Indicator 16 % of RR Buffer with Culturally Altered LULC Types	Field/GIS
Sub-indicator 16.1 % of RR Buffer with Restorable LULC Types	Field/GIS
Sub-indicator 16.2 % of RR Buffer with Non-restorable LULC Types	Field/GIS
Indicator 17 % of RRT Buffer with Culturally Altered LULC Types	Field/GIS
Sub-indicator 17.1 % of RRT Buffer with Restorable LULC Types	Field/GIS
Sub-indicator 17.2 % of RRT Buffer with Non-restorable LULC Types	Field/GIS

urban land use/land cover in the drainage basin would be assumed to have lower integrity, at least in terms of the contribution of the indicator to endpoint integrity. This approach to scaling indicators to reference condition, and by implication to endpoint integrity, was possible because how indicators were defined (i.e., always measurable as a percent deviation from reference condition), and based on information from published studies, field data and observations, and professional judgment as outlined the Assessment Endpoints and Assessment Indicators sections above.

4.5 Assigning Indicator Scores and Calculation of Integrity Indices

To calculate integrity indices, indicator values (i.e., percent deviation from reference condition 0-100) were converted to scores. Indicator values were assigned a score of 1-5 based on the relationship between indicator values and scores defined in Tables 1-13. Using the altered hydrologic conveyance indicator as an illustration (see Table 1), if the value of the altered hydrologic conveyance indicator for a riparian reach was <5%, a score of 5 was assigned to that riparian reach. If the value of the altered hydrologic conveyance indicator for a riparian reach was >30% and <50%, a score of 2 was assigned to that riparian reach. A score of 5 represented close concurrence with the reference condition, and consequently a high level of integrity. A score of 1 represented a deviation of 50% or more the reference condition, and consequently a low level of integrity.

Initial category ranges for indicator values were based on the natural groupings of the data collected during the project, and the subjective integration of numerous field observations relating indicator values to endpoint integrity. Testing of other category ranges (i.e., correlation analysis using quartiles and quintiles) showed no significant change in the relationship between riparian reaches in terms of either indicator scores or endpoint indices. Thus, initial category ranges were retained.

Integrity indices were calculated using the following equations:

Hydrologic Integrity =

$$((AHC_{RR} + AHC_{RRT})/2) + AHC_{DB} + SWR_{DB} + PSF_{RR} + FI_{RR}$$

Water Quality Integrity =

$$((AHC_{RR} + AHC_{RRT})/2) + AHC_{DB} + SWR_{DB} + PSF_{RR} + FI_{RR} + SR_{RR} + LULC_{DB} + RVC_{RR}$$

Where: $LULC_{DB} = \dfrac{LULC_{DB-N} + LULC_{DB-P} + LULC_{DB-H} + LULC_{DB-S}}{4}$

Habitat Integrity =

$$RVC_{RR} + EXO_{RR} + RCC_{RR} + RCC_{DB} + BND_{RR} + ((BUF_{RR} + BUF_{RRT}) / 2)$$

Where:

$$BUF_{RR} = BUF_{RR-R} + BUF_{RR-NR}$$

$$BUF_{RRT} = BUF_{RRT-R} + BUF_{RRT-NR}$$

4.6 Archiving of Information

All of the information and data collected during the delineation, characterization, and assessment of riparian reaches, as well as results derived from this information were archived in ArcView and Excel spreadsheets. Appendices 1 and 3 discuss the archiving of this information in each format.

5.0 Results and Discussion

5.1 San Jacinto Watershed

Six hundred and forty three riparian reaches were identified in the San Jacinto watershed. The length of mainstem channel in these reaches ranged from 310 meters to 45368 meters, and the size of the local drainages of these riparian reaches ranged from 40 to 79,845 hectares. The wide range in these two characteristics reflects the extreme differences between urban areas and more natural landscapes in terms of the longitudinal homogeneity of vegetation cover, engineering, and other types of disturbance that occur along stream channels and their associated riparian ecosystems.

The minimum, maximum, and mean of indicator values, and the frequency of indicator scores for all riparian reaches are summarized in Table 16. The range of values for the index of hydrologic integrity was 7 to 30, out of a possible 30, with a mean of 27. The range of values for the index of water quality integrity was 13 to 42 (45 possible) with a mean of 36. The range of values for the habitat integrity index was 8 to 35 (40 possible) with a mean of 25. Figures 6, 7, and 8 show the distribution of integrity indices for all riparian reaches in terms of hydrologic, water quality, and habitat integrity respectively. In general, the index values exhibited a relatively wide and even spread across the possible range of index values. These results can be interpreted as evidence that the indicators were scaled appropriately, and sensitive enough to distinguish varying degrees of hydrologic, water quality, and habitat integrity. The results are consistent with the perception of riparian ecosystem integrity in the watershed based on extensive field-work and observations. Ultimately, however, the only way to increase confidence in the integrity indices is through testing and verification with more quantitative models of hydrologic, water quality, and habitat integrity.

Because of the extensive amount of data collected for each riparian reach and the inherently spatial nature of the data, the Excel spreadsheet and ArcView project file are much better formats for reviewing the results in terms of the three tasks required to meet the project objective (see Section 2.0). Consequently, the objective here will be to provide examples and illustrations to acquaint readers with the way in which results can be presented and summarized in the database, spreadsheet, and ArcView formats.

Table 16. Descriptive statistics for San Jacinto watershed indicator metric values and scores

#	Indicator	Minimum Metric Value	Maximum Metric Value	Mean Value	Frequency				
					Score 5	Score 4	Score 3	Score 2	Score 1
1	AHC_{RR}	0	100	17.2	515	8	6	12	102
2	AHC_{RRT}	0	100	4.9	602	4	1	5	31
3	AHC_{DB}	0	100	10.4	495	37	31	22	58
4	SWR_{DB}	0	100	9.7	504	44	23	18	54
5	PSF_{RR}	0	100	5.5	594	4	7	6	32
6	PSF_{DB}	NA	NA	NA	NA	NA	NA	NA	NA
7	IED_{DB}	NA	NA	NA	NA	NA	NA	NA	NA
8	FI_{RR}	0	100	5.6	596	1	4	10	32
9	SR_{RR}	1 (index)	5 (index)	3.6	247	108	142	90	56
10	$LULC_{DB}$	0	75	12.4	258	103	69	39	174
11	RVC_{RR}	1 (index)	5 (index)	3.6	90	302	158	69	18
12	EXO_{RR}	1 (index)	5 (index)	3.7	298	109	77	73	85
13	RCC_{RR}	0	100	28.4	376	44	40	18	164
14	RCC_{DB}	0	100	23.2	337	67	34	51	123
15	BND_{RR}	0	100	13.9	406	64	58	44	71
16	BUF_{RR}	0	100	39.2	282	52	81	35	233
17	BUF_{RRT}	0	100	12.8	516	24	15	16	72

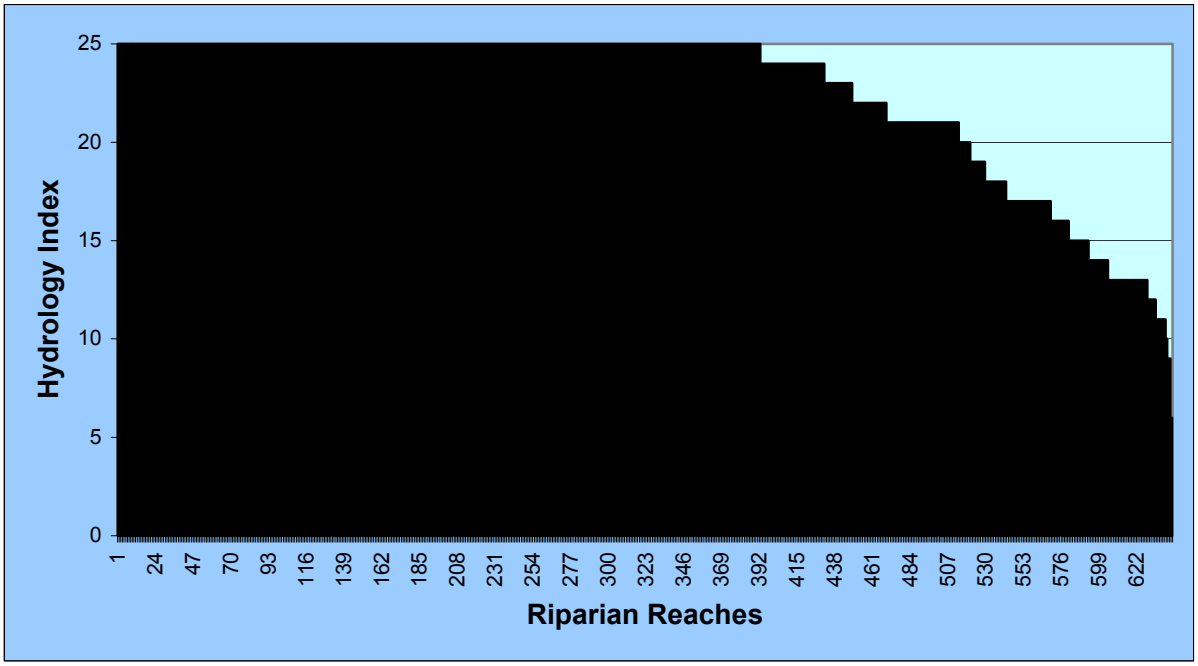

Figure 6. Index values for hydrologic integrity for San Jacinto riparian reaches

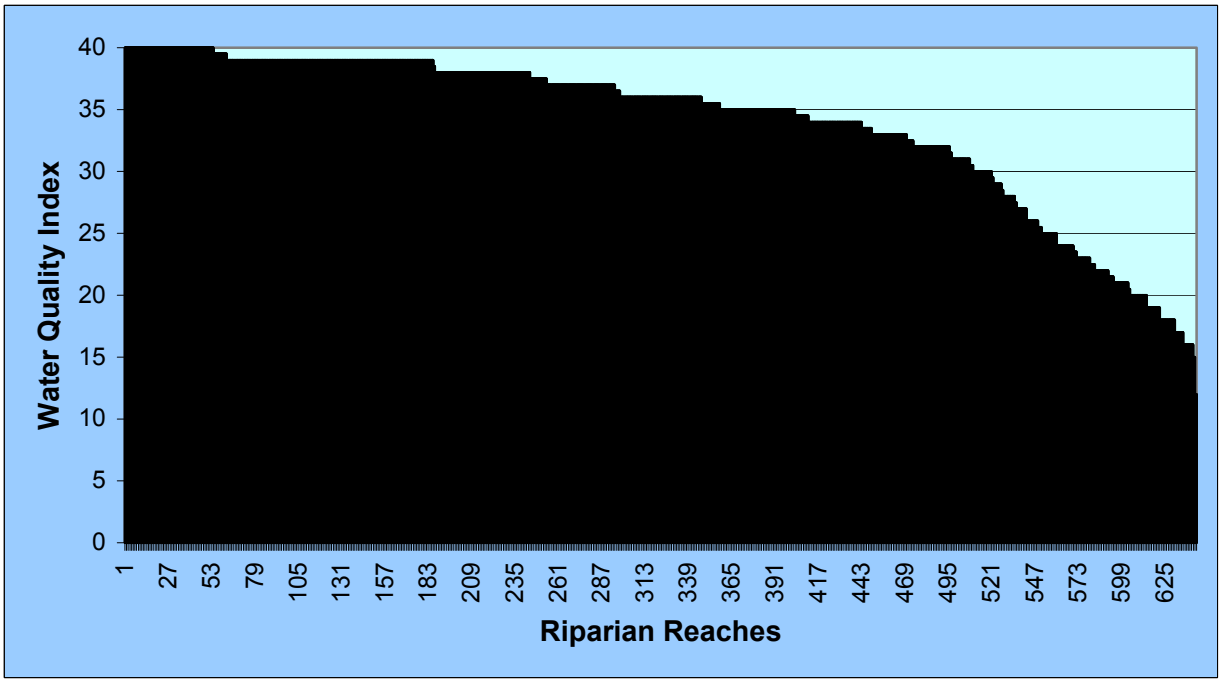

Figure 7. Index values for water quality integrity for San Jacinto riparian reaches

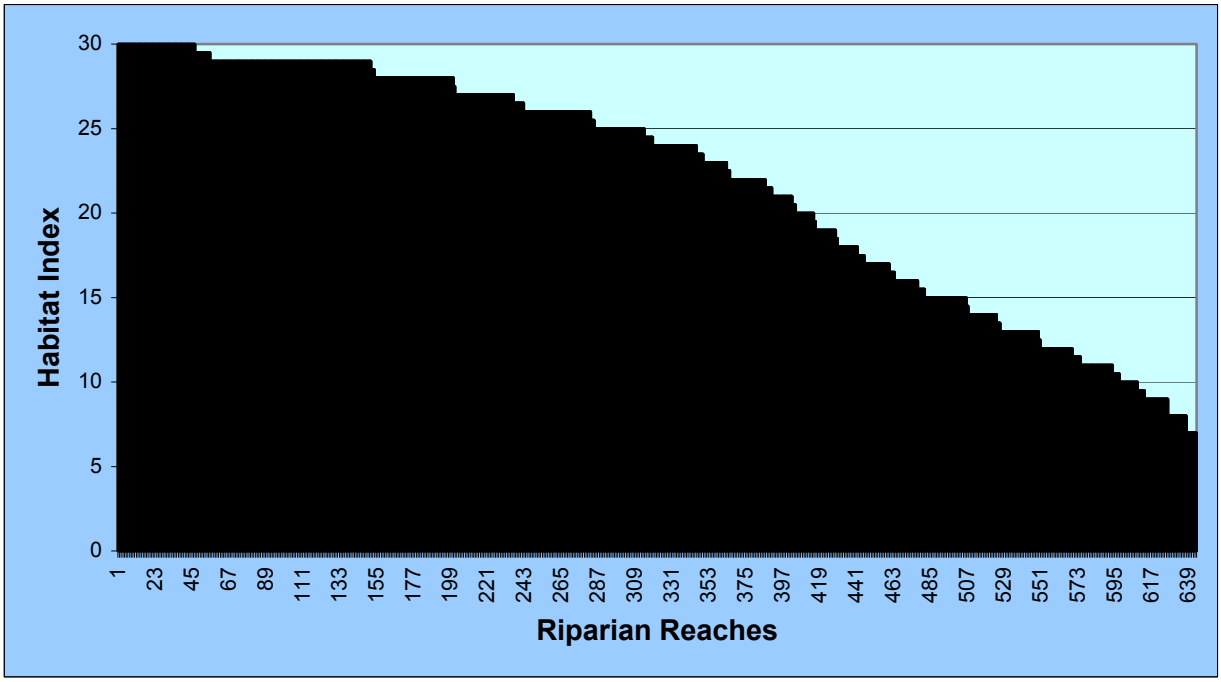

Figure 8. Index values for habitat integrity for San Jacinto riparian reaches

Figures 9 and 10 are ArcView layouts showing the location of riparian reaches and mainstem channels in the San Jacinto watershed. Each polygon in the figure represents the local drainage boundary of a riparian reach. Labels are the codes assigned to each riparian reach and used to identify riparian reaches in the spreadsheet, ArcView project, and database.

Figure 11 shows a portion of the upper San Jacinto watershed in the vicinity of the Tollroad and San Canyon tributaries. In the figure, brown polygons again represent the local drainage of a riparian reach. The riparian ecosystem in each reach consists of blue lines and colored polygons representing wetland ratings from Lichvar (2002). This type of display can be quickly presented for any portion of the San Jacinto watershed in ArcView. Attachment 1 is a fold-up map that shows this same view for the entire San Jacinto watershed.

Figure 12 is a bar chart showing indictor scores for each of the riparian reaches in the Apple Canyon drainage basin. This type of bar chart can be quickly displayed in ArcView as a hotlinked image or in the spreadsheet as a hyperlink.

Figure 13 illustrates how the results can be used to summarize the baseline condition for riparian ecosystem integrity in the watershed, and compare riparian reaches. In the figure, labels represent the hydrologic integrity index (i.e., the sum of scores for indicators associated with

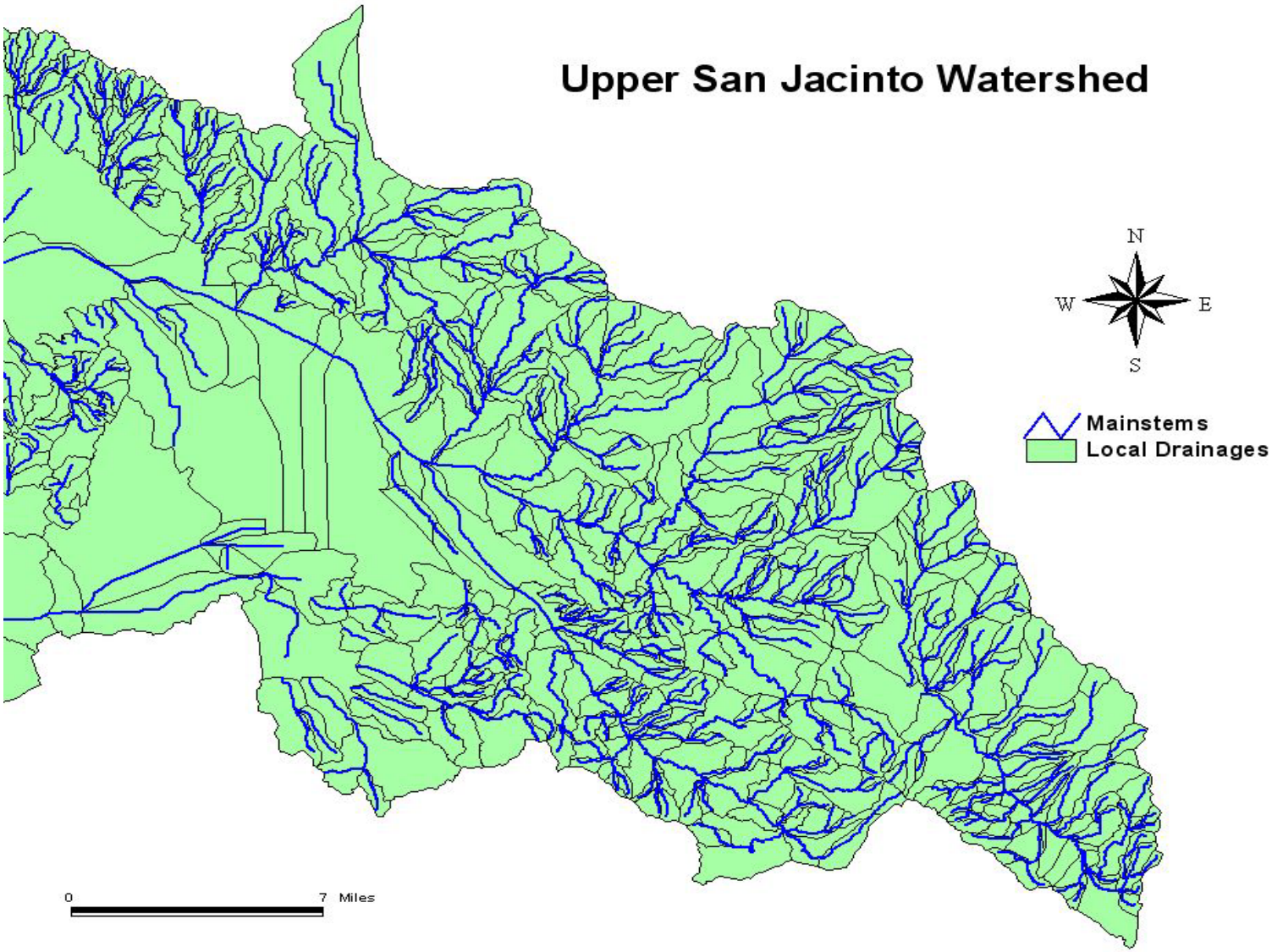

Figure 9. Upper San Jacinto watershed showing local drainage boundaries (black lines) and mainstem channels (blue lines)

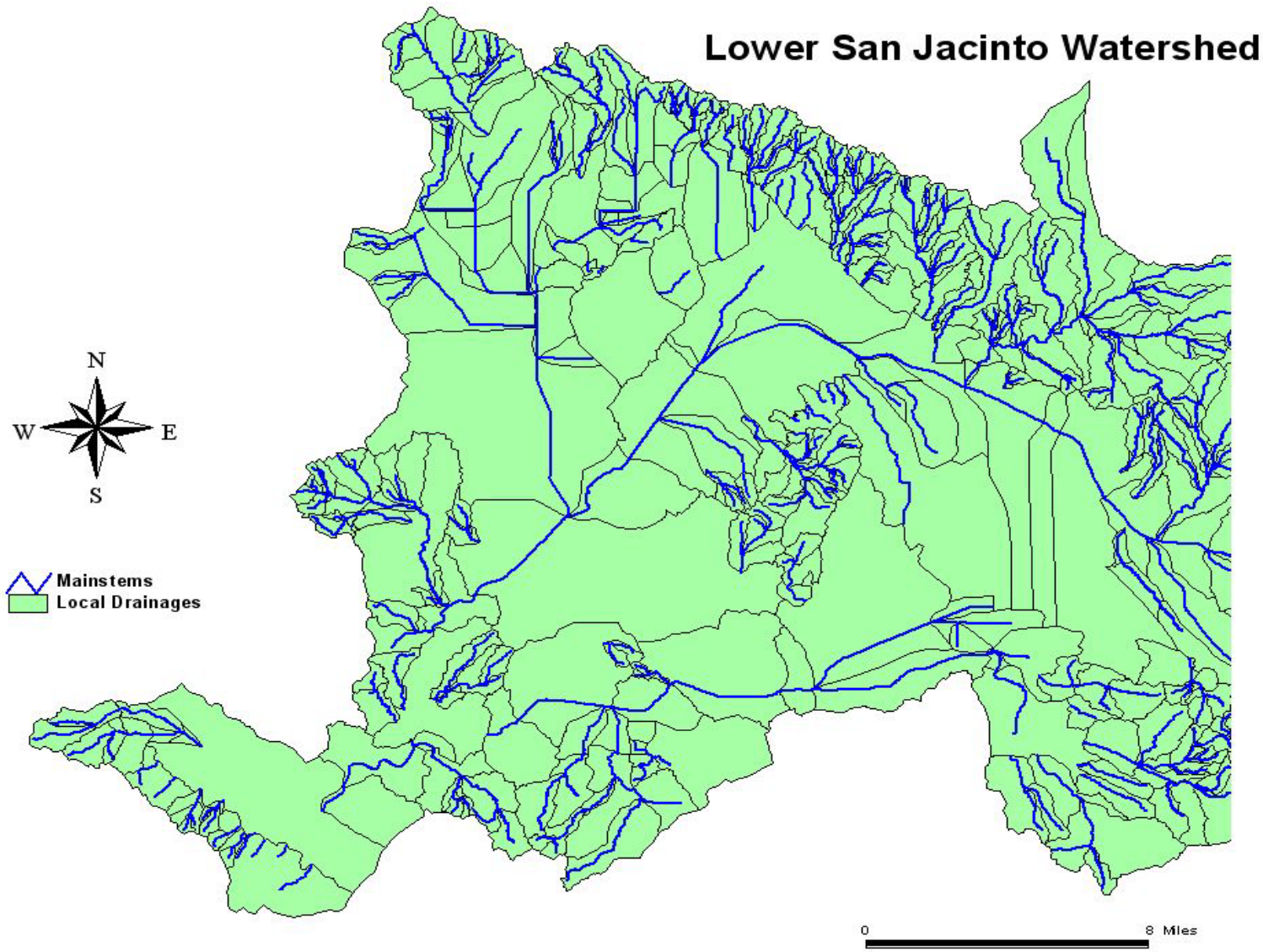

Figure 10. Lower San Jacinto watershed showing local drainage boundaries (black lines) and mainstem channels (blue lines)

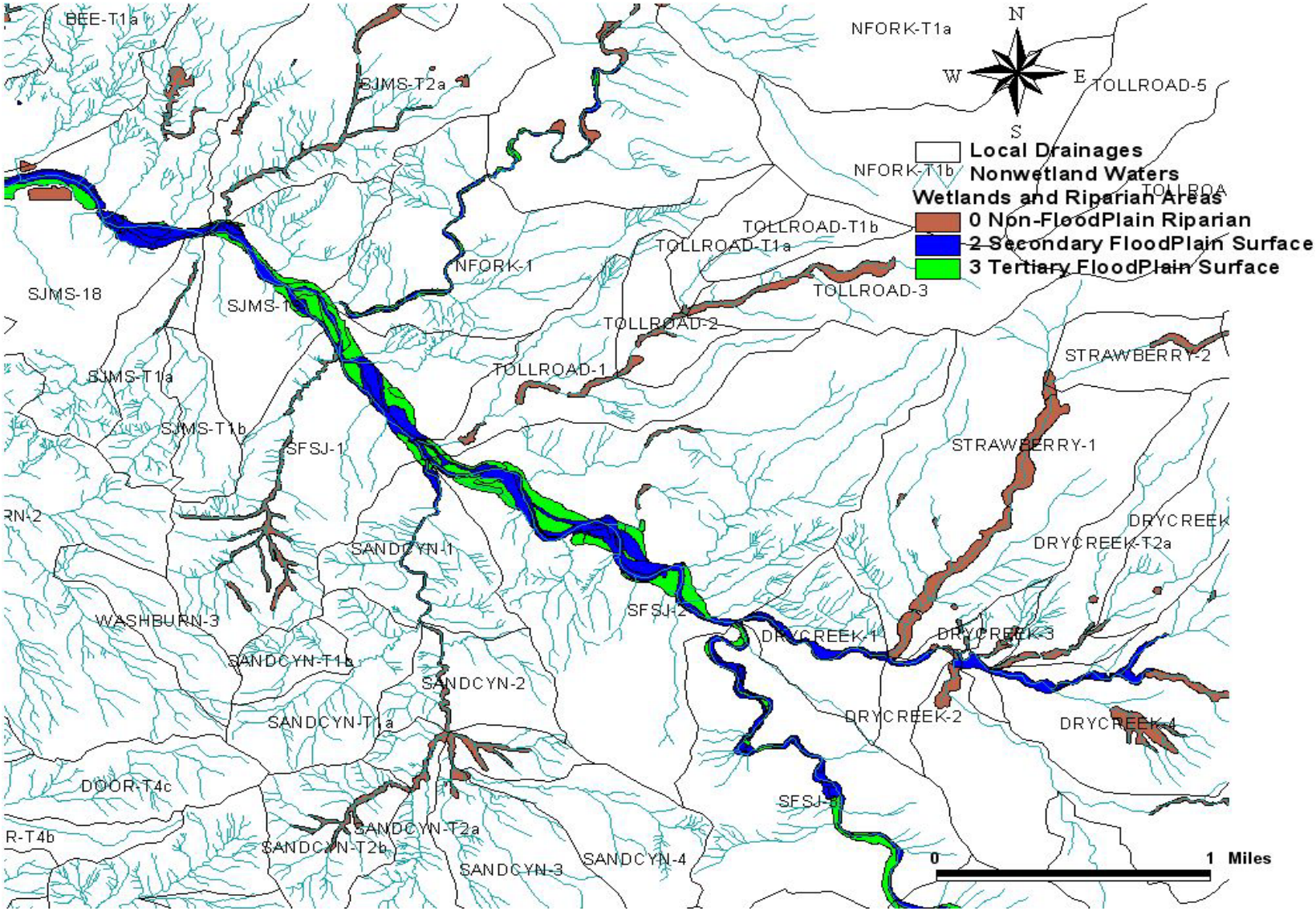

Figure 11. Stream channels (blue-green lines) and riparian ecosystems (colored polygons) Upper San Jacinto watershed as delineated by Lichvar (2002)

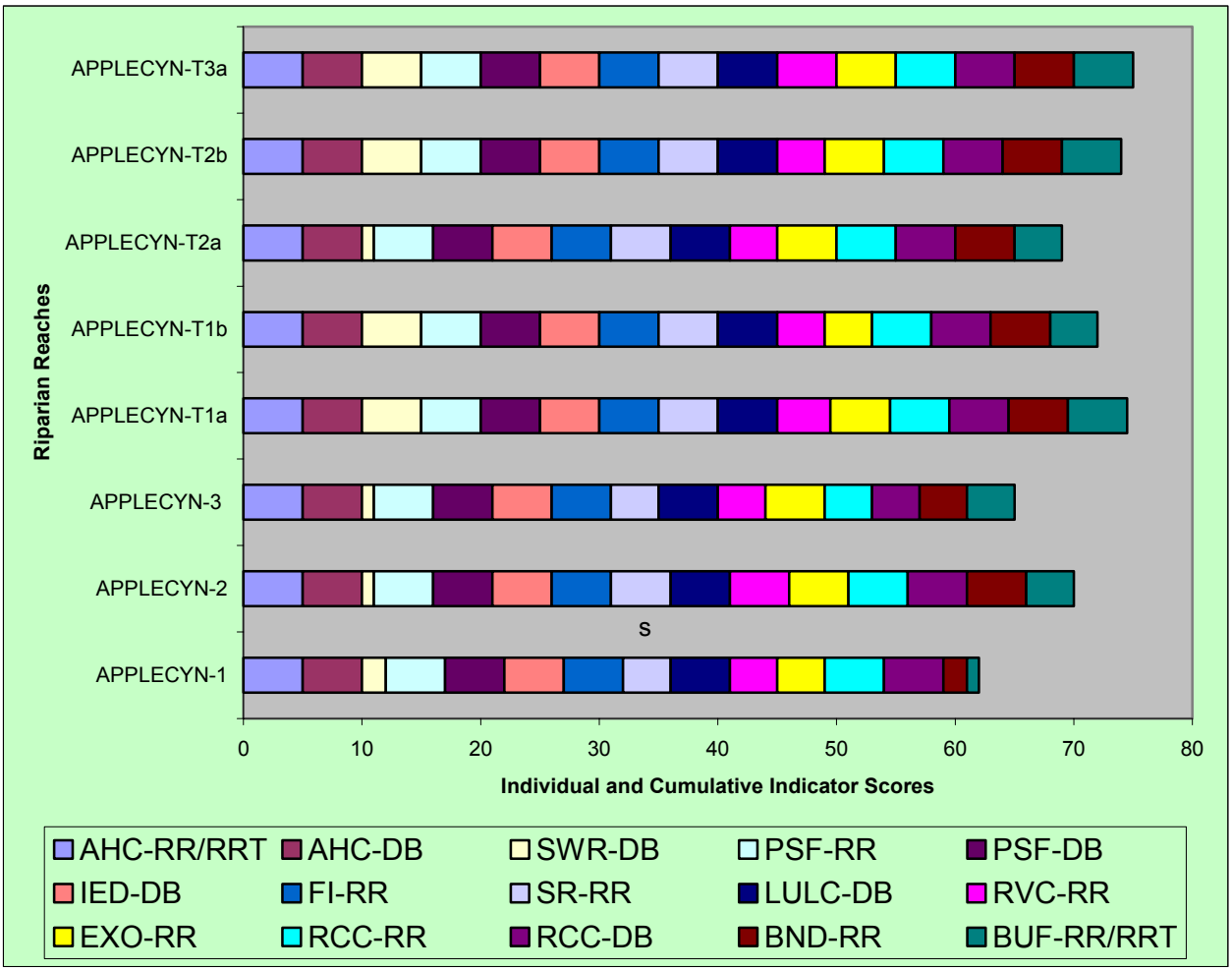

Figure 12. Scores for individual indicators in the Apple Canyon drainage of the San Jacinto watershed (indicator codes are provided in Table 14)

hydrologic integrity). The highest possible score is 30 since six indicators are used to calculate the index. The gradient, from light to dark green, provides an easy way to visually identify areas of high hydrologic integrity in the watershed. Users with personal knowledge of the watershed will recognize that index values are low in areas of urban and agricultural development and greater in the more remote, undeveloped areas. Figures 14 and 15 illustrate the results for water quality and habitat integrity indices with possible scores of 45 and 30 respectively.

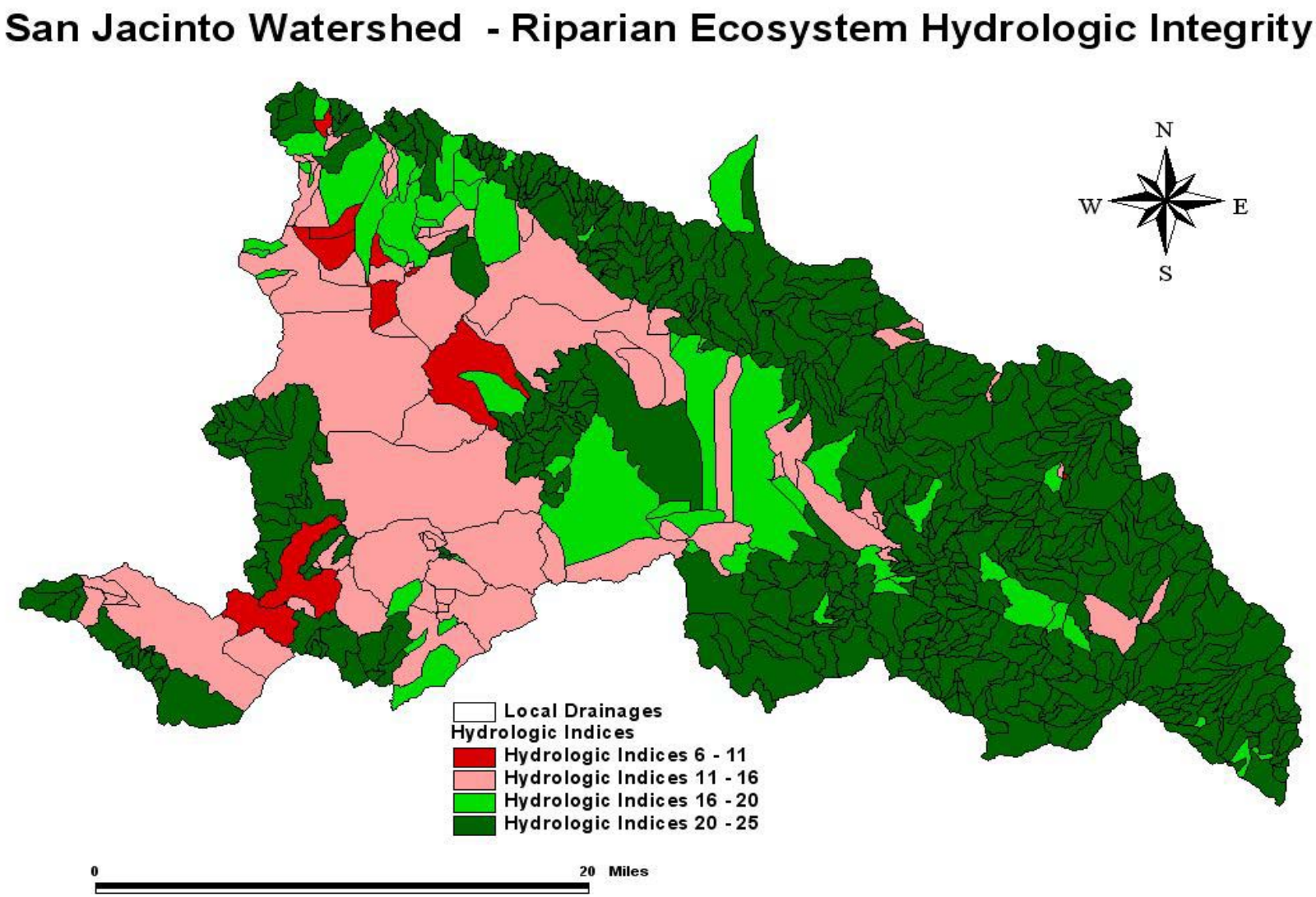

Figure 13. Hydrologic integrity indices for riparian reaches extrapolated to local drainages in San Jacinto watershed

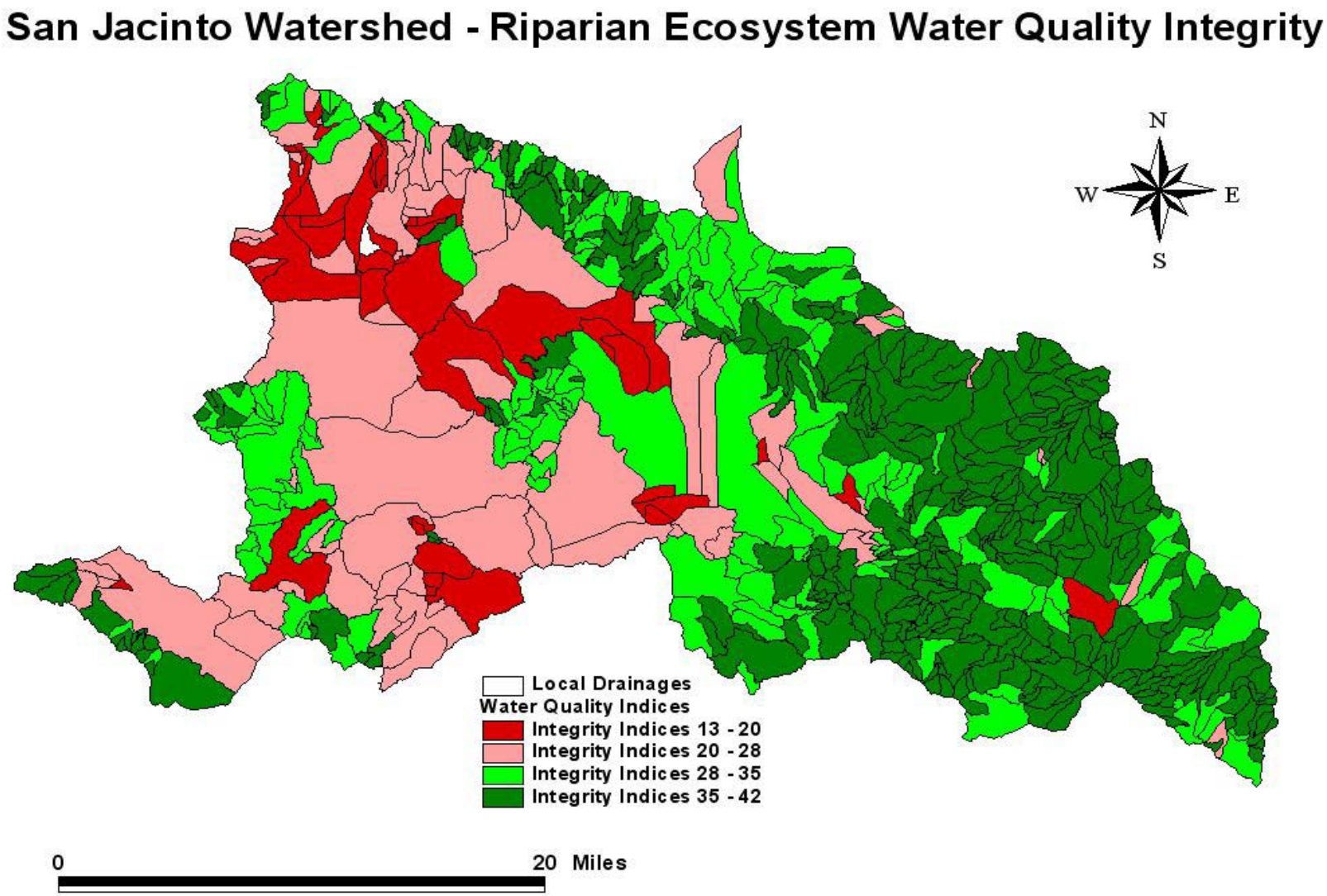

Figure 14. Water Quality integrity indices for riparian reaches extrapolated to local drainages in San Jacinto watershed

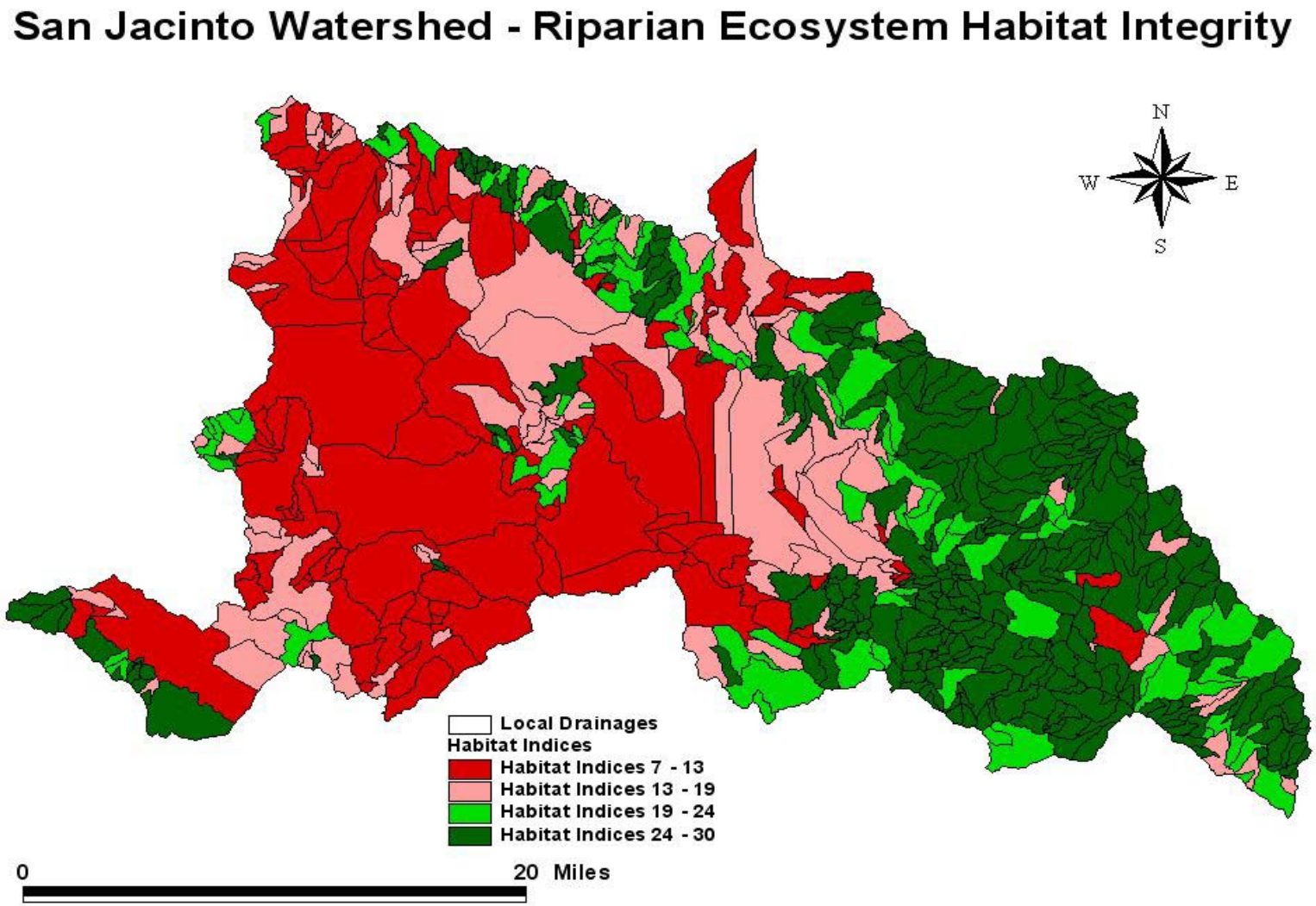

Figure 15. Habitat integrity indices for riparian reaches extrapolated to local drainages in San Jacinto watershed

5.2 Upper Santa Margarita Watershed

Five hundred and twelve riparian reaches were identified in the upper Santa Margarita river watershed. The length of mainstem channel in these reaches ranged from 133 meters to 9913 meters, and the size of the local drainages of these riparian reaches ranged from 5 to 2752 hectares. The wide range in these two characteristics reflects the extreme differences between urban areas and more natural landscapes in terms of the longitudinal homogeneity of vegetation cover, engineering, and other types of disturbance that occur along stream channels and their associated riparian ecosystems.

The minimum, maximum, and mean of indicator values, and the frequency of indicator scores for all riparian reaches are summarized in Table 17. The range of values for the index of hydrologic integrity was 12 to 25, out of a possible 25, with a mean of 23.5. The range of values for the index of water quality integrity was 16 to 40 (40 possible) with a mean of 33.1. The range of values for the habitat integrity index was 7 to 30 (30 possible) with a mean of 20.4. Figures 16, 17, and 18 show the distribution of integrity indices for all riparian reaches in terms of hydrologic, water quality, and habitat integrity respectively. In general, the index values exhibited a relatively wide and even spread across the possible range of index values. These results can be interpreted as evidence that the indicators were scaled appropriately, and sensitive enough to distinguish varying degrees of hydrologic, water quality, and habitat integrity. The results are consistent with the perception of riparian ecosystem integrity in the watershed based on extensive field-work and observations. Ultimately, however, the only way to increase confidence in the integrity indices is through testing and verification with more quantitative models of hydrologic, water quality, and habitat integrity.

Because of the extensive amount of data collected for each riparian reach and the inherently spatial nature of the data, the Excel spreadsheet and ArcView project file are much better formats for reviewing the results in terms of the three tasks required to meet the project objective (see Section 2.0). Consequently, the objective here will be to provide examples and illustrations to acquaint readers with the way in which results can be presented and summarized in the database, spreadsheet, and ArcView formats.

Table 17. Descriptive statistics for upper Santa Margarita river watershed indicator metric values and scores

#	Indicator	Minimum Metric Value	Maximum Metric Value	Mean Value	Frequency				
					Score 5	Score 4	Score 3	Score 2	Score 1
1	AHC_{RR}	0	100	11.9	431	12	8	5	56
2	AHC_{RRT}	0	100	3.4	251	3	4	1	8
3	AHC_{DB}	0	100	7.2	381	59	34	19	19
4	SWR_{DB}	0	100	1.1	495	12	1	1	3
5	PSF_{RR}	0	100	9.7	455	2	2	7	46
6	PSF_{DB}	NA	NA	NA	NA	NA	NA	NA	NA
7	IED_{DB}	NA	NA	NA	NA	NA	NA	NA	NA
8	FI_{RR}	0	100	2.5	596	495	1	1	11
9	SR_{RR}	1 (index)	5 (index)	3.6	156	112	164	66	14
10	$LULC_{DB}$	0	100	45.1	258	103	69	39	174
11	RVC_{RR}	1 (index)	5 (index)	3.7	75	50	61	75	251
12	EXO_{RR}	1 (index)	5 (index)	4.1	257	148	68	25	14
13	RCC_{RR}	0	100	21.8	334	40	31	10	97
14	RCC_{DB}	0	100	15.8	270	72	85	43	42
15	BND_{RR}	0	100	76.1	32	36	23	176	245
16	BUF_{RR}	0	100	32.2	238	61	37	30	146
17	BUF_{RRT}	0	100	20.3	155	42	14	13	23

Figures 19 and 20 are ArcView layouts showing the location of riparian reaches and mainstem channels in the upper Santa Margarita watershed. Each polygon in the figure represents the local drainage boundary of a riparian reach. Labels are the codes assigned to each

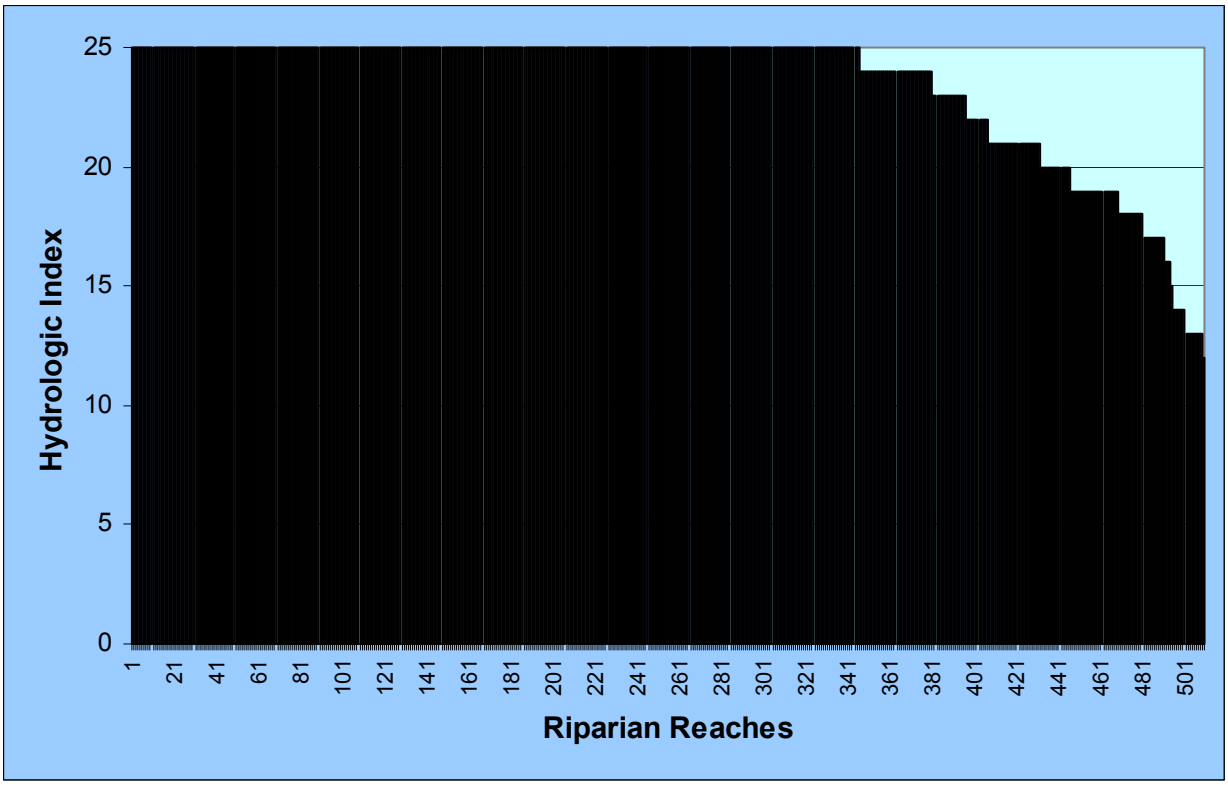

Figure 16. Index values for hydrologic integrity for Upper Santa Margarita riparian reaches

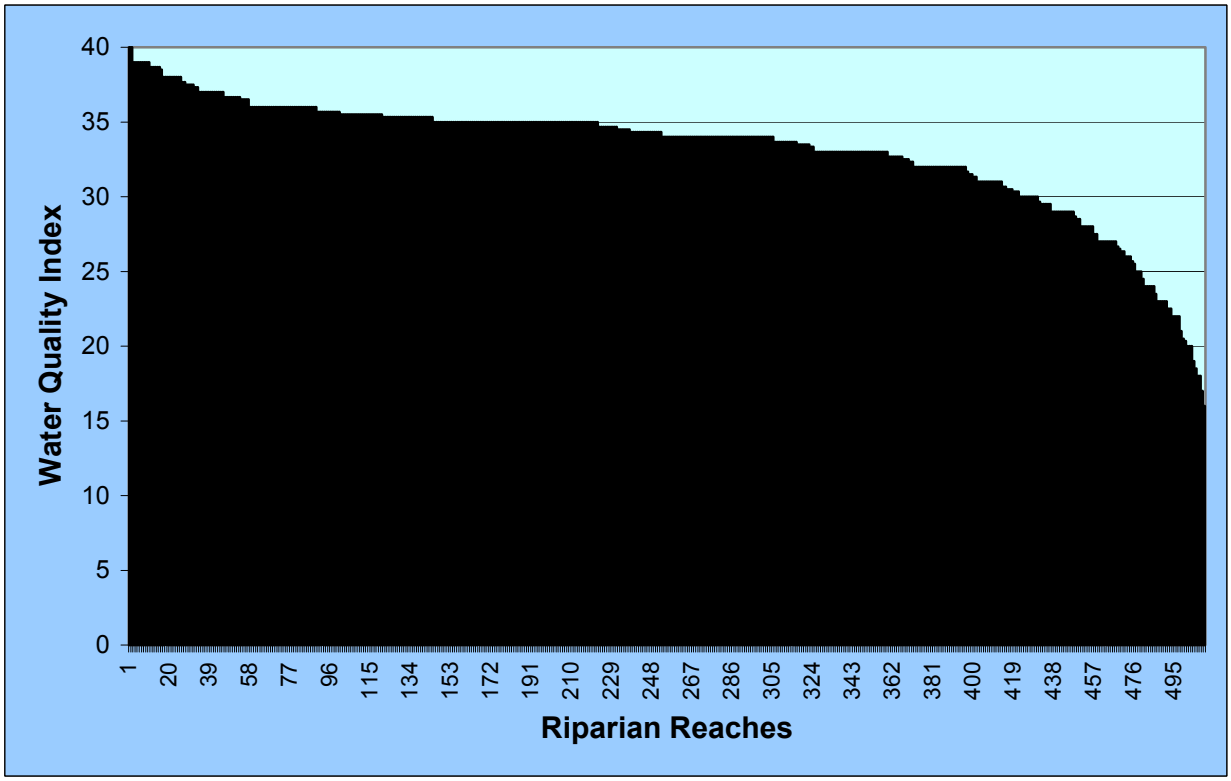

Figure 17. Index values for water quality integrity for Upper Santa Margarita riparian reaches

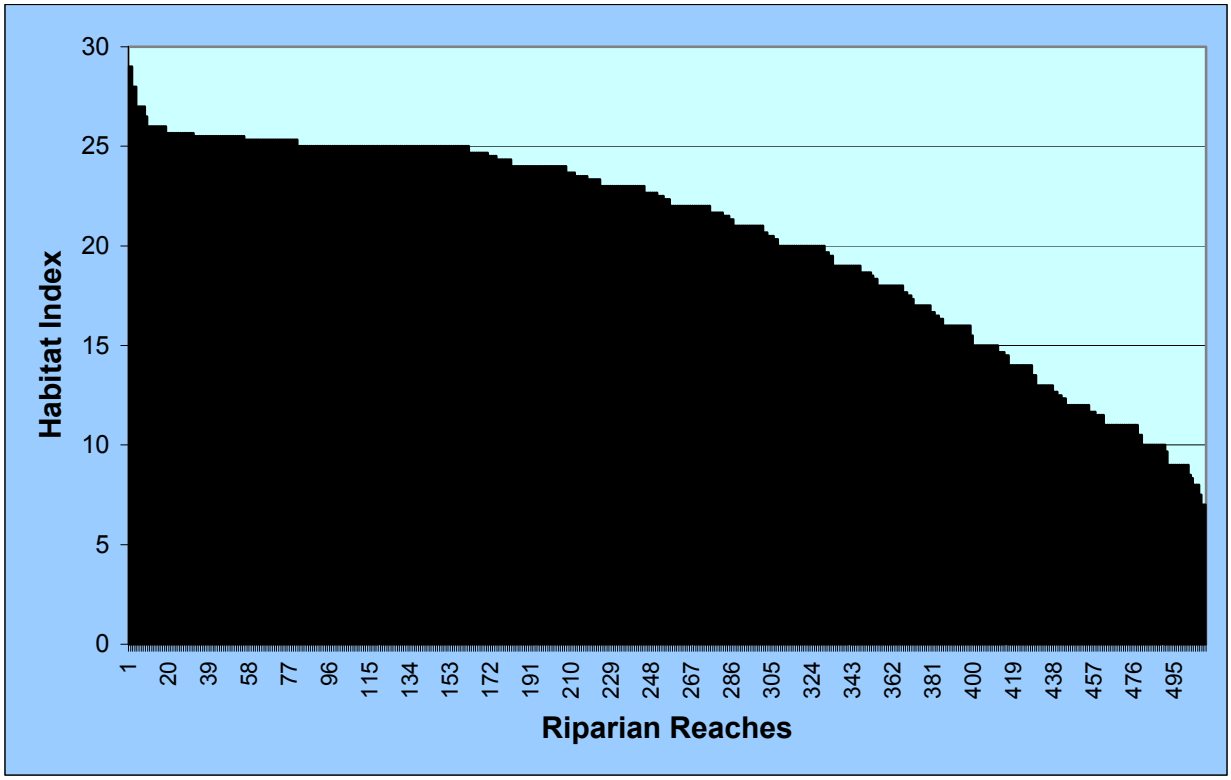

Figure 18. Index values for habitat integrity for Upper Santa Margarita riparian reaches

riparian reach and used to identify riparian reaches in the spreadsheet, ArcView project, and database.

Figure 21 shows upper portion of the upper Santa Margarita watershed in the vicinity of the Tollroad and San Canyon tributaries. In the figure, brown polygons again represent the local drainage of a riparian reach. The riparian ecosystem in each reach consists of blue lines and colored polygons representing wetland ratings from Lichvar (2002). This type of display can be quickly presented for any portion of the upper Santa Margarita watershed in ArcView. Attachment 1 is a fold-up map that shows this same view for the entire Upper Santa Margarita watershed.

Figure 22 is a bar chart showing indictor scores for each of the riparian reaches in the Apple Canyon drainage basin. This type of bar chart can be quickly displayed in ArcView as a hotlinked image or in the spreadsheet as a hyperlink.

Figure 23 illustrates how the results can be used to summarize the baseline condition for riparian ecosystem integrity in the watershed, and compare riparian reaches. In the figure, labels represent the hydrologic integrity index (i.e., the sum of scores for indicators associated with

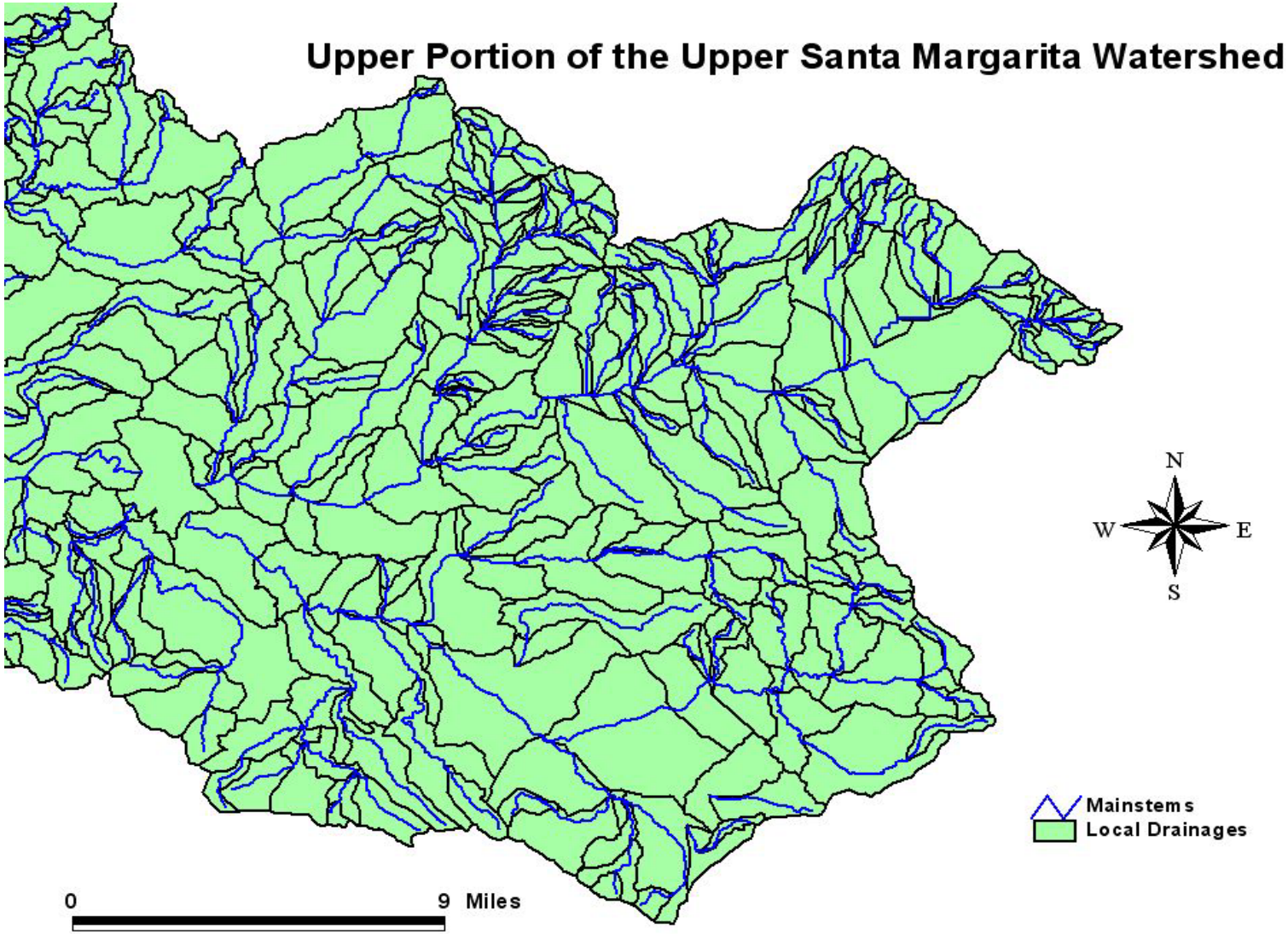

Figure 19. Upper portion of the Upper Santa Margarita watershed showing local drainage boundaries (black lines) and mainstem channels (blue lines)

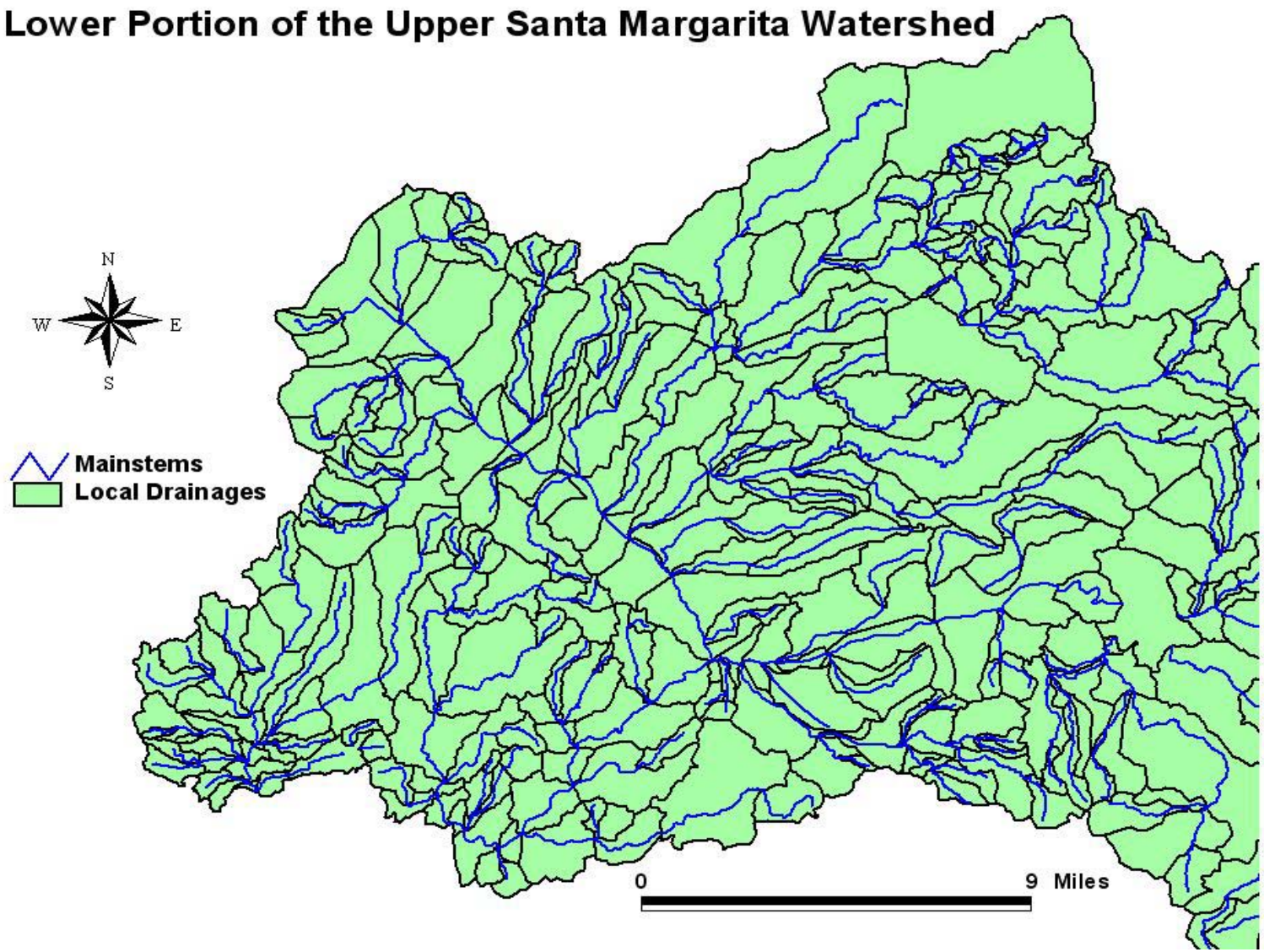

Figure 20. Lower portion of the Upper Santa Margarita watershed showing local drainage boundaries (black lines) and mainstem channels (blue lines)

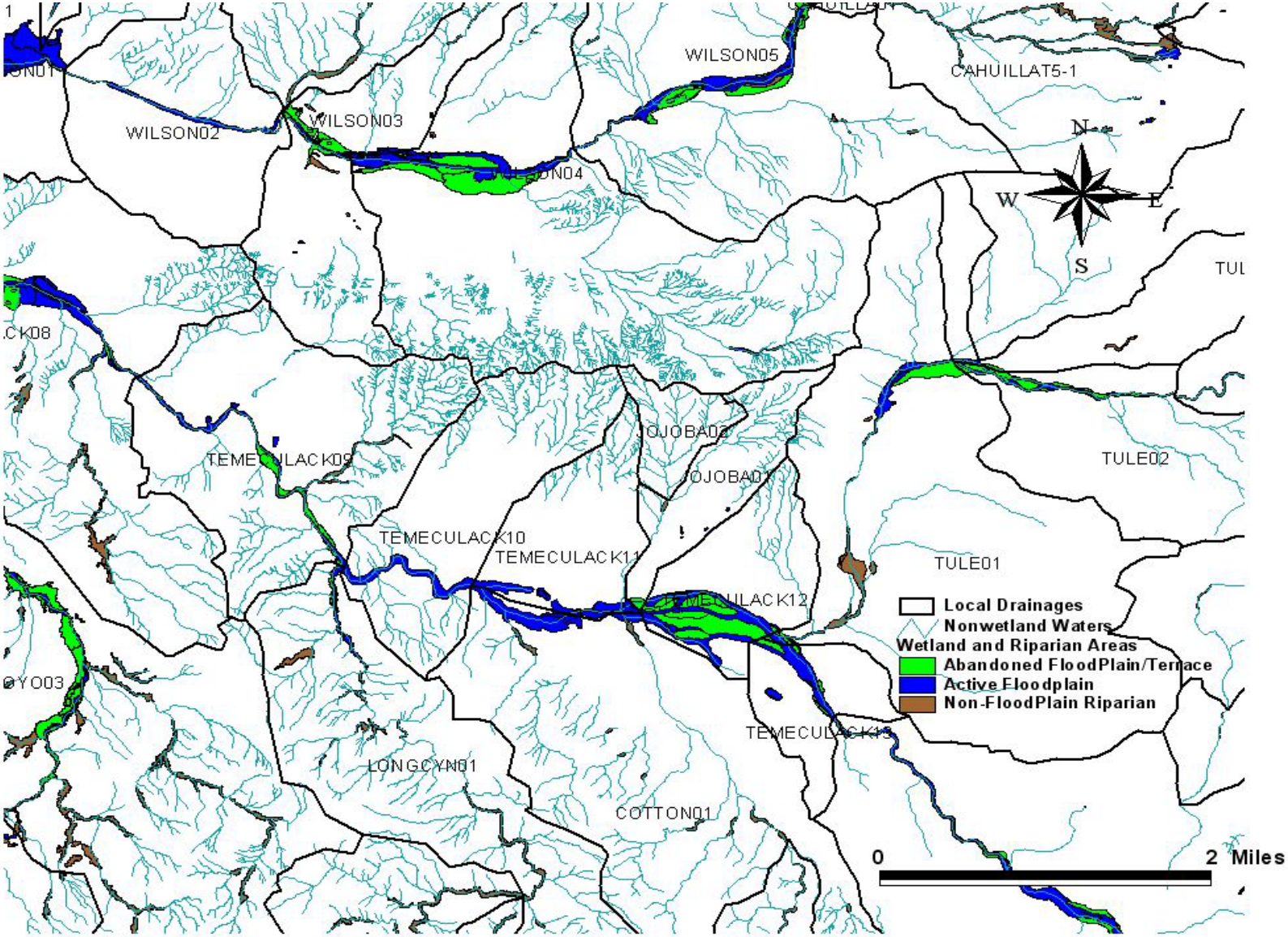

Figure 21. Stream channels (blue-green lines) and riparian ecosystems (colored polygons) upper portion of the upper Santa Margarita watershed as delineated by Lichvar (2002)

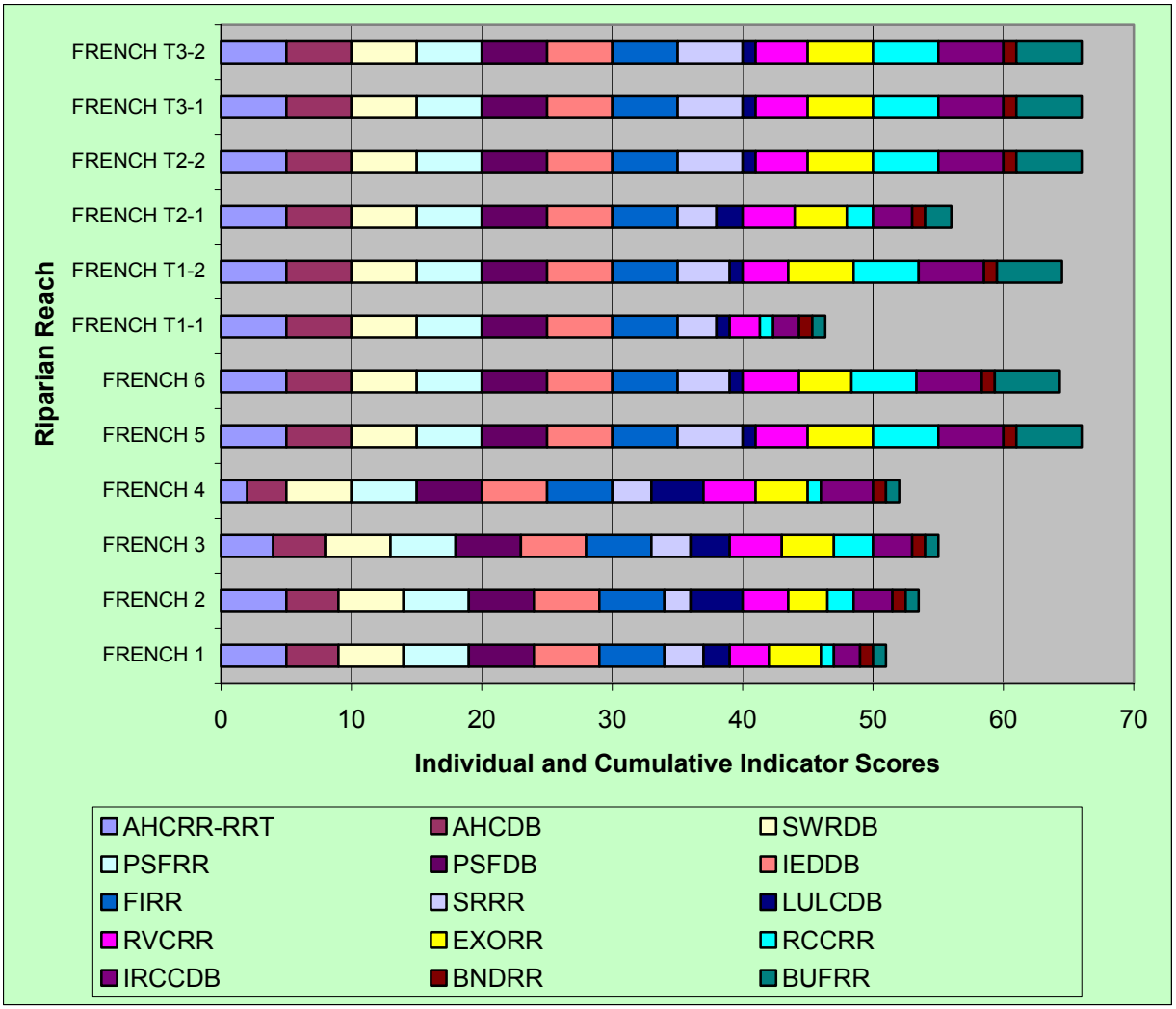

Figure 22. Scores for individual indicators in the French Canyon drainage Upper Santa Margarita watershed (indicator codes are provided in Table 14)

hydrologic integrity). The highest possible score is 30 since six indicators are used to calculate the index. The gradient, from light to dark green, provides an easy way to visually identify areas of high hydrologic integrity in the watershed. Users with personal knowledge of the watershed will recognize that index values are low in areas of urban and agricultural development and greater in the more remote, undeveloped areas. Figures 14 and 15 illustrate the results for water quality and habitat integrity indices with possible scores of 45 and 30 respectively.

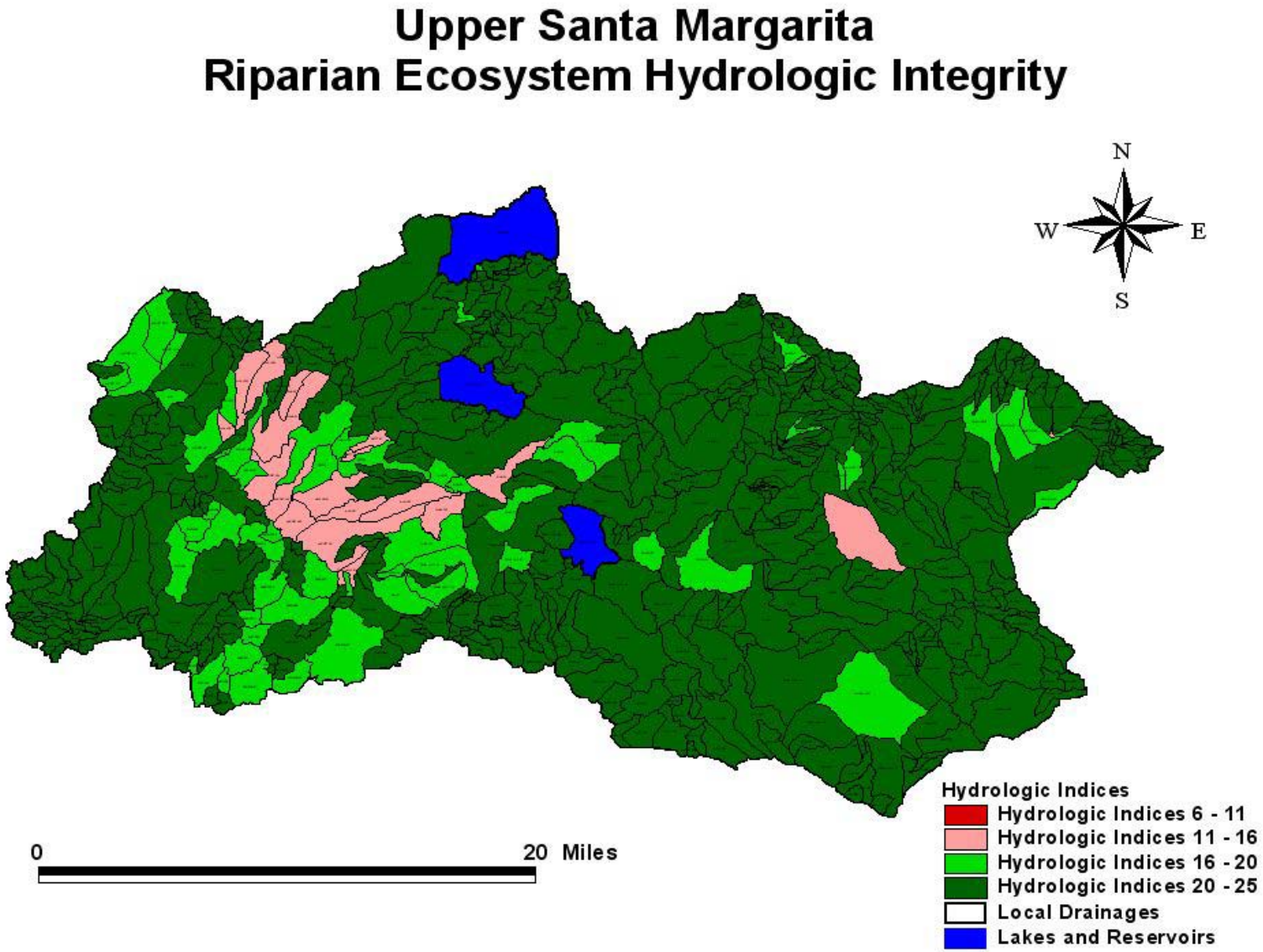

Figure 23. Hydrologic integrity indices for riparian reaches extrapolated to local drainages in upper Santa Margarita watershed

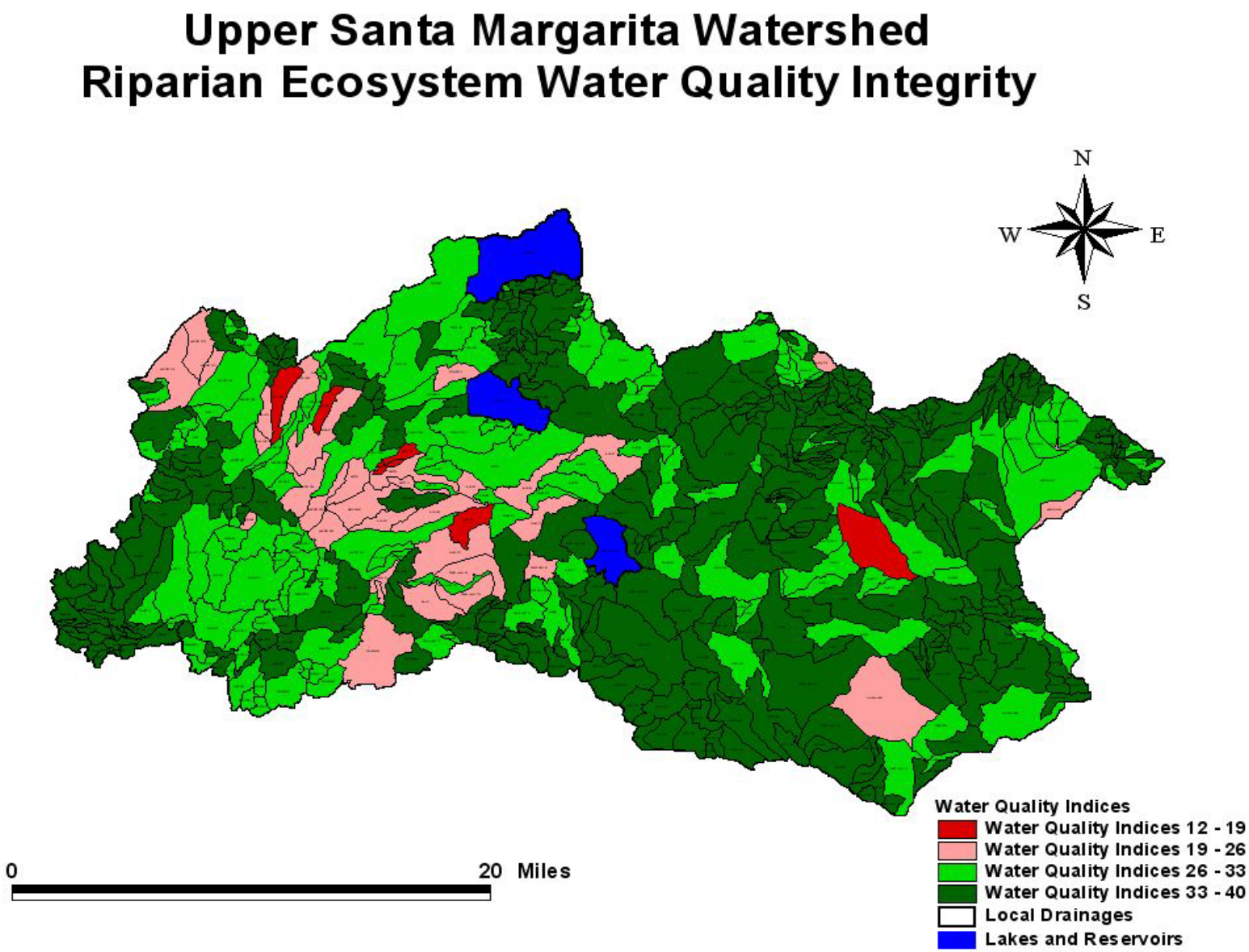

Figure 24. Water Quality integrity indices for riparian reaches extrapolated to local drainages in Upper Santa Margarita watershed

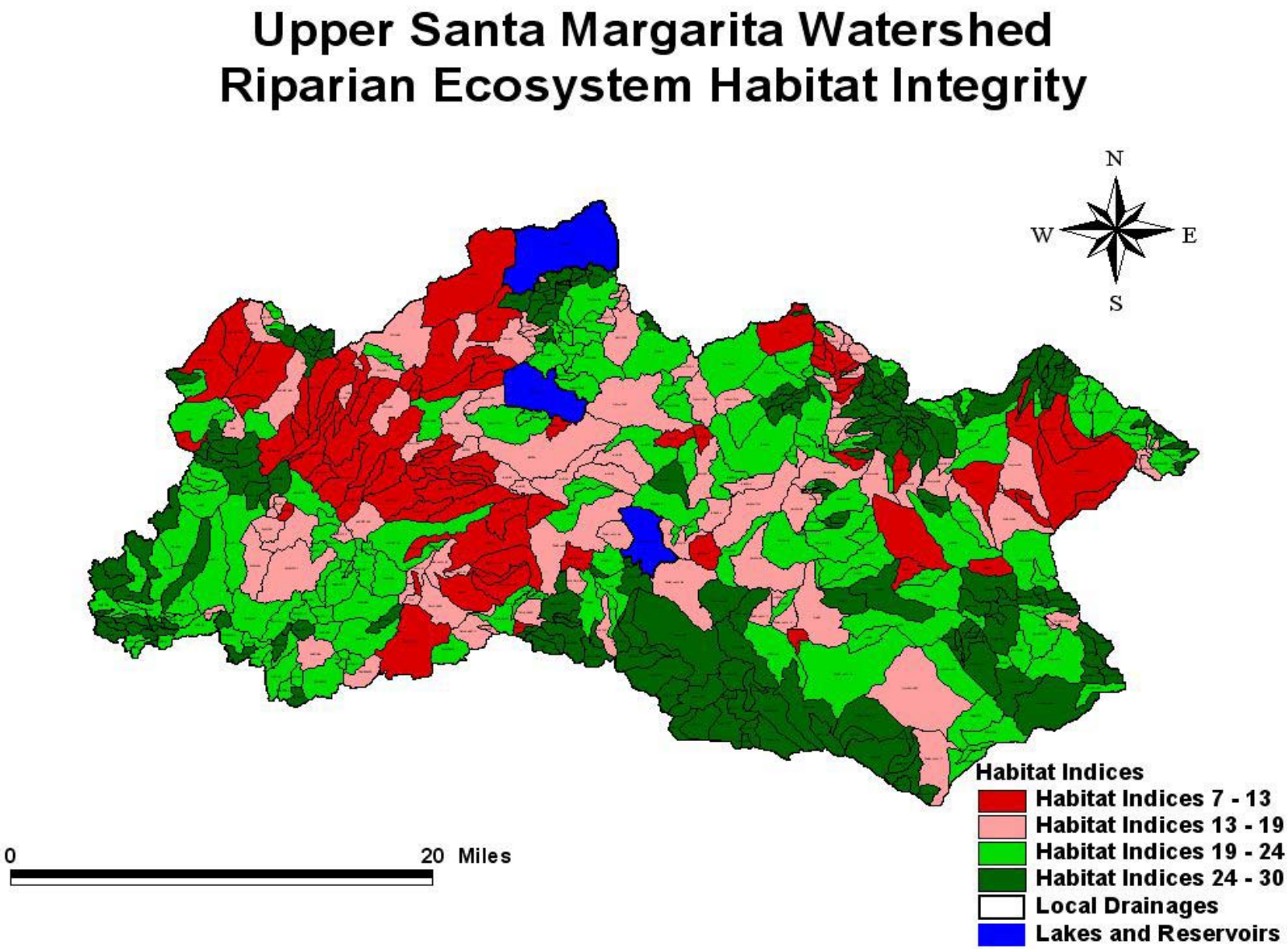

Figure 25. Habitat integrity indices for riparian reaches extrapolated to local drainages in Upper Santa Margarita watershed

5.3 Future Tasks

The results also provide the mechanism for addressing the third task (i.e., to determine which of several proposed alternative development scenarios will result in the least impact to riparian ecosystem integrity in the watershed) identified in the Project Objectives above. By simulating the changes to indicators (i.e., changes in land use, hydraulic conveyance, etc.) that can be expected to occur as a result of a proposed alternative scenario, the existing information and tools can be used to generate new indictor scores and indices for riparian reaches. Then, the alternative-specific scores and indices can be compared with baseline indicator scores and integrity indices to illustrate how the proposed alternative scenarios may differentially impact riparian ecosystem integrity in the watershed.

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Appendix 1: ArcView Theme and Spreadsheet Information and Guidelines

Spatial information collected and utilized for spatial analysis during the project was collected and saved as an ArcView project file. All shape files images are in NAD83, State Plane CA Zone 5, and units of feet. Metadata for the shapfiles is contained in the "metadata" folder on the distribution CD. The U.S. Army Corps of Engineers – Los Angeles District Regulatory Branch is responsible for distribution of this information.

Project sponsors and other end users have at least two choices for accessing the ArcView information on the distribution CD. The simplest option is to copy the "san jacinto arcview files" folder (see contents below) to the c:\ drive of your computer and simply start the ArcView program and open the san jacinto.apr project file. If you choose this option, it is essential that the folder be copied to the c:\ drive, and that you do not change the names of any folders or files.

The other option is to build a new ArcView project using the files in the themes and images folders and your knowledge of ArcView.

The ArcView GIS information for the San Jacinto watersheds was organized as follows:

ArcView File Folder (c:\san jacinto arcview files)

san jacinto.apr – San Jacinto project file

habitat indices.shp – Habitat integrity indices for all riparian reaches

hydro indices.shp – Hydrologic integrity indices all riparian reaches

local drainage.shp - Riparian Reach Local Drainage Boundaries

mainstems.shp – Mainstem channels

nonwetland waters.shp - Non-wetland waters developed by (R. Lichvar)

wetlands and riparian areas.shp – Wetlands and riparian areas developed by (R. Lichvar)

water quality indices.shp – Water quality integrity indices all riparian reaches

habitat indices.avl – AVL file for creating habitat indices legend

hydrologic indices.avl – AVL file for creating hydrologic indices legend

local drainages.avl – AVL file for creating local drainages legend

mainstems.avl – AVL file for creating mainstems legend

nonwetland waters.avl – AVL file for creating nonwetland waters legend

wetlands and riparian areas.avl – AVL file for creating wetlands and riparian areas legend

water quality indices.avl – AVL file for creating water quality indices legend

Photo Files (c:\san jacinto photos)

"reach code" bfc.jpg – bankfull channel photo

"reach code" fp.jpg – stream, floodplain and terrace photo

"reach code" val.jpg – stream valley photo

Aerial Photo Files (c:\san jacinto aerials reach specific)

"reach code".jpg – reach specific aerial photo

Photo files and aerial photo files with a "jpg" extension are hyperlinked in the Excel spreadsheet and "hot linked" in ArcView in the local drainage and indices themes. Clicking on hyperlink in the Excel spreadsheet will display the images in whatever software program you have files with the extension of "jpg" files associated with on the computer you are using. I suggest the Slowview Software for viewing these jpg images. SlowView can be downloaded for free from the following web site: http://slowview.at/?page=download. In order to take advantage of the hot links in ArcView, I suggest installing the HotLinkAPI utility. This utility can be downloaded at no cost from: http://www.spatial-online.com/ProductList.asp?Category=1 at not cost. The current version of both of these software downloads are contained on the distribution CD in the "slowview" and "hotlinkapi" folders respectively.

Information collected during field work and information calculated during ArcView spatial analysis was input into a Microsoft Excel spreadsheet. Table 15 provides a partial listing of fields and date in this spreadsheet. This spreadsheet can be found in the "spreadsheet" folder on the distribution CD. The U. S. Army Corps of Engineers – Los Angeles District Regulatory Branch is responsible for distributing this information.

Appendix 2: Glossary

Aquatic Resources

All waters and water habitats including lakes, ponds, streams, rivers and adjoining riparian areas that they affect, marshes, vernal pools, seeps, flats, and other wetlands.

Buffer (area, zone, or habitat)

An intervening upland area or other form of barrier that separates wetlands or streams from developed or disturbed areas and reduces the impacts on the wetlands that may result from human activities. The critical functions of a buffer (associated with an aquatic system) include shading, input of organic debris and coarse sediments, uptake of nutrients, stabilization of banks, interception of fine sediments, stormflow attenuation during high water events, protection from disturbance by humans and domestic animals, maintenance of wildlife habitat, and room for variation of aquatic system boundaries over time due to hydrologic or climate effects.

Channel

A natural stream or river, or an artificial feature such as a ditch or canal that exhibits features of bed and bank, and conveys water primarily unidirectional and down gradient.

Channel Type

Channel type refers to the Rosgen (1996) classification of streams that is based on channel slope, sinuosity, entrenchment, width to depth ratios, and channel substrate.

Clean Water Act

The federal law that establishes standards and procedures for limiting the discharge of fill and pollutants into waters of the United States.

Community and Environmental Transportation Acceptability Process (CETAP)

CETAP is the transportation element of the Riverside County integrated plan (RCIP), which identifies four possible new highway routes and public transit opportunities.

Compensatory Mitigation

The restoration, creation, and preservation of wetlands and/or other aquatic resources for the purpose of compensating for adverse impacts on an aquatic resource caused by a permitted project or activity.

Creation

The conversion of a persistent, non-aquatic site into an aquatic site. For the purpose of this plan, creation includes the conversion of sites that currently do not meet the definition of wetlands, even though these sites were wetlands prior to being permanently drained and/or covered by fill.

Delineation

A determination of the boundaries of a wetland or other aquatic site.

Discharge

The placement of dredged or fill material into waters of the United States, including wetlands, that may result in impacts to the aquatic system. Examples include the redeposition of material during excavation, mechanized land clearing, and ditching.

Enhancement

Improving existing functions of a low-quality or degraded aquatic resource or wetland.

Ephemeral

Ephemeral streams are defined as streams in which flow is attributable only to surface water runoff in response to precipitation.

Fill Material

Material taken from an upland site and used to change the bottom features of waters of the United States (includes soil, rock, vegetative material, debris, construction materials).

Floodplain

The land adjacent to a stream or lake, composed of alluvium and subject to repeated flooding.

Functional Assessment

The process by which the capacity of a wetland to perform a function is measured.

Geomorphic

A term referring to the shape of the land surface.

General Permit

A permit for a specific class of activities with minimal individual and cumulative impact within a specified area issued by the Corps, authorizing the discharge of dredged or fill material into waters of the United States, including wetlands.

Habitat Conservation Plan (HCP)

A program of the U.S. Fish and Wildlife Service (Federal) designed to offset any harmful effects that a proposed activity might have on federally listed threatened and endangered species. The HCP process allows development to proceed while providing for the conservation of species and their habitat, and provisions for incidental take

Hydrogeomorphic Wetland Class

A method of categorizing wetlands based on their hydrologic and geomorphic characteristics. The five basic hydrogeomorphic classes of wetlands include riverine, depression, fringe, slope, and flat.

In-kind Mitigation

Mitigation that results in wetlands or other aquatic resources of the same habitat type that provide similar functions and values of those removed.

Intermittent Stream

Intermittent streams are defined as streams in which groundwater-maintained base flow occurs intermittently at different times of the year

Individual Permit

A Section 404 permit issued by the Corps for an individual project for which a specific review was conducted.

Jurisdictional Wetlands

Areas that meet the soil, vegetation, and hydrologic criteria described in the "Corps of Engineers Wetlands Delineation Manual" (Environmental Laboratory 1987).

Mitigation

Actions or project design features that reduce impacts on wetlands by avoiding, minimizing, or compensating for adverse effects.

Mitigation Banking

Use of a single site, suitable for wetlands enhancement, restoration, and/or creation, for the mitigation of impacts on wetlands that result from more than one project at other sites.

Mitigation Sequencing

Provisions in the EPA Section 404(b)(1) Guidelines (40 CFR 230.10) and the 1990 Corps/EPA MOA requiring avoidance and minimization of adverse impacts on the aquatic environment before compensatory mitigation may be considered.

Multi-Species Habitat Conservation Plan

A program of the California Department of Fish and Game (State) and U.S. Fish and Wildlife Service that takes a broad-based ecosystem approach to planning for the protection and perpetuation of biological diversity. The MSHCP process identifies and provides for the regional or area-wide protection of plants, animals, and their habitats, while allowing compatible and appropriate economic activity. The primary objective of the MSHCP program is the conservation of natural communities at the ecosystem scale while accommodating compatible land uses.

Nationwide Permit

General permit issued nationally for specific types of activities resulting in discharges of dredge or fill material into waters of the United States with minimal individual and cumulative impacts. Prior authorizations for Nationwide permits have been issued for several categories of activities including wetland restoration projects, maintenance of existing facilities, road crossings, bank protection, and fills 3 acres or less in size in the headwaters of watersheds. Existing Nationwide permit authorizations typically allow less than 0.5-acre impacts.

Perennial Stream

Perennial streams are defined as streams in which base flow is maintained year round by groundwater

Riverside County Integrated Plan (RCIP)

Riverside County Integrated Plan (RCIP) is a comprehensive planning effort being undertaken by the county of Riverside to address the western Riverside County future growth. It consists of multiple elements including transportation (CETAP), land use plan (General Plan), and environmental (MSHCP and SAMP) components.

Reference Wetland

A wetland or one of a group of wetlands within a relatively homogeneous biogeographical region that represents the variation that occurs within the type because of natural or human-induced causes.

Restoration

Actions taken which result in the re-establishment of aquatic site structure, processes, and functions in areas where the aquatic site has been altered, degraded, or destroyed.

Stream Type

Stream type refers to the Rosgen (1996) classification of streams, which is based on channel slope, sinuosity, entrenchment, width to depth ratios, and channel substrate.

Section 404 Permit

The permit issued by the Corps under Section 404 of the Clean Water Act for authorizing the discharge of dredged or fill material into waters of the United States, including wetlands; also known as Corps permit, fill permit, Department of the Army permit, DA permit, individual permit, 404 permit.

Section 404 (b)(1) Guidelines

Substantive regulations promulgated at 40 CFR 230 in accordance with Section 404(b)(1) of the Clean Water Act that provide the standards for unacceptable adverse impacts on waters of the United States, including wetlands, used to determine whether a Section 404 permit should be issued. Generally, discharges of fill are allowed under the Guidelines only if no other environmentally less damaging practicable alternative is available, no significant degradation of the waters, no adverse impacts to threatened and endangered species, and if appropriate and practicable steps have been taken to sequentially avoid, minimize and mitigate adverse impacts on the aquatic ecosystem.

Valley Type

Valley type refers to the Rosgen (1996) classification of valleys, which is based on valley slope, width, and shape.

Waters of the United States (WoUS)

Water bodies that are regulated under Section 404 of the Clean Water Act. It is the broadest category of regulated water bodies and includes wetlands along with non-wetland habitats, such as streams, rivers, lakes, ponds, bays, and oceans.

Watershed

A geographical area that drains to a major water body such as a river, lake, or creek, which is usually the water body for which the basin is named.

Wetland

Areas inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.