COOPERATIVE riparian RESTORATION

National Riparian Service Team
3050 NE 3rd Street • Prineville, Oregon 97754 • (541) 416-6700 • FAX (541) 416-6798

November 16, 2012

Subject: Proper Functioning Condition (PFC) Riparian Assessment Report, San Pedro River, San Pedro Riparian National Conservation Area, AZ

In the fall of 2010, the Bureau of Land Management (BLM) in Arizona requested assistance from the National Riparian Service Team (NRST) relative to issues concerning the San Pedro Riparian National Conservation Area (SPRNCA). Specifically, the request focused on two main areas:

(1) *Create a mechanism to blend the scientific and social perspectives sufficient to support development of a shared strategy for moving forward over the next 10 years, with a focus on agreed upon purpose and priorities. Create a mechanism to promote better coordination among individual efforts under the umbrella of a larger community-based effort.*

(2) *Bring together community members/stakeholders and technical specialists to: consider existing data and analyses; develop a common understanding of current conditions and trends in terms of surface water flows; determine the implications of baseline condition and trends for riparian function and values; and outline the scope of management options that are currently occurring and additional actions that might be important to maintain and enhance riparian function.*

In an effort to meet this request, a number of activities have occurred including a comprehensive situation assessment and subsequent stakeholder meetings, briefings, technical workshops and time spent on the ground.

Most recently, BLM mangers, specialists, and interested stakeholders accompanied the NRST as they conducted Proper Functioning Condition (PFC) riparian assessments on approximately 51 miles of the San Pedro River through the SPRNCA, during April 11-20, 2012. The attached report summarizes the PFC assessment findings, identifies issues and outlines management considerations. Assessment findings provide an important foundation for understanding the current condition of a system, limiting factors within and outside BLM control, and areas where additional information is needed. This understanding then informs the process by which objectives relating to desired future riparian conditions are set, and alternative management and monitoring approaches are considered; an important component of the Resource Management Plan revision process currently underway for the SPRNCA. Please contact Laura Van Riper at 541-416-6702 or lvanripe@blm.gov if you have any questions or concerns.

Sincerely,

Steve Smith

Steve Smith, Team Leader
National Riparian Service Team

RIPARIAN CONDITIONS ALONG THE SAN PEDRO RIVER

PROPER FUNCTIONING CONDITION
RIPARIAN ASSESSMENT REPORT

THE NATIONAL RIPARIAN SERVICE TEAM
NOVEMBER 2012

Table of Contents

RIPARIAN CONDITIONS ALONG THE SAN PEDRO RIVER

PROPER FUNCTIONING CONDITION RIPARIAN ASSESSMENT REPORT

National Riparian Service Team

November 2012

Executive Summary

As part of an effort to begin working with stakeholders in a different and more collaborative way, the Bureau of Land Management (BLM) requested assistance from the National Riparian Service Team (NRST) relative to the management of the San Pedro River through the San Pedro Riparian National Conservation Area (SPRNCA). Beginning in April 2011, the NRST has worked closely with local BLM managers, specialists, partners and other interested stakeholders to implement an integrated technical and social approach focused on understanding how riparian conditions within the SPRNCA have changed since designation, and what the BLM and larger community can do to insure management will achieve Congressional direction to conserve, protect and enhance the riparian area into the future.

Most recently, BLM mangers, specialists and interested stakeholders accompanied the NRST as they conducted Proper Functioning Condition (PFC) riparian assessments on approximately 51 miles of the San Pedro River through the SPRNCA during April 11-20, 2012. The PFC assessment method provides a framework for evaluating physical functionality based on hydrology, vegetation and erosion/deposition attributes and processes. Assessment findings provide an important foundation for understanding the current condition of a system, limiting factors within and outside BLM control, and areas where additional information is needed. This understanding then informs the process by which objectives relating to desired future riparian conditions are set, and alternative management and monitoring approaches are considered. Most BLM State Offices consider PFC riparian assessments as the accepted protocol for determining compliance with Agency Land Health Standards and establishing baseline conditions in advance of Resource Management Planning (RMP) efforts, such as the one currently underway for the SPRNCA. While there have been many scientific investigations and reports on various aspects of the San Pedro River, this was the first integrated assessment that synthesized existing information and resulted in a report of current on-the-ground conditions as compared to potential, on a reach-by-reach basis, throughout the SPRNCA.

Reach-Based Findings, Issues and Management Considerations

The PFC assessments provide a description of the current riparian condition of individual reaches of the San Pedro River compared to their potential, or the highest ecological status that could be attained in the current climate given no political, social or economic constraints. Potential descriptions for the San Pedro River include the combination of vegetation and channel characteristics that could develop during a management time scale of 5-50 years. Although, prior to the 1880s, the San Pedro River through much of the SPRNCA was a cienega; it is currently evolving from a major period of channel incision where it was transformed into a high-energy, confined river system. In addition to geomorphic changes, the climatic and hydrologic regimes that affected the river have also changed significantly and are not likely to revert back to historic conditions within a management time scale. Thus, the reach-based potentials described in 2012

categorize reaches A-E as perennial, F as transitioning from perennial to intermittent, and G-J as intermittent based on permanence of streamflow and associated vegetative communities.

The assessment findings provide evidence that the physical function and ecological health of the San Pedro River through the SPRNCA has improved dramatically since designation, largely due to the 1989 decision to end permitted livestock grazing along the river. Although recovery may have been possible with managed grazing, relief from grazing pressure has allowed development of riparian vegetation and channel characteristics that greatly improve the function and sustainability of the San Pedro River. Continued recovery in all reaches is necessary to meet Congressional direction, but significant positive changes have occurred already. Of the approximately 51 miles assessed, 27.4 miles (54%) were rated as PFC, and the remaining 23.4 miles (46%) rated as Functional at Risk (FAR). The FAR reaches were further assigned apparent trend: 8.9 miles showed an upward trend, 10.3 miles showed a not apparent trend, and 4.2 miles (the northernmost reach below St. David's diversion) showed a downward trend.

Reach-specific assessment findings, issues and management considerations are discussed in detail within the report. For reaches rated FAR with either a downward or not apparent trend, the NRST recommends the establishment of a monitoring strategy to measure change over time in key PFC checklist items marked 'no.' Additionally, since reach J is the only reach rated as FAR with a downward trend, it requires immediate management action be taken to eliminate those stressors that are within management control. The main impacts limiting the ability of reach J to achieve PFC are the St. David's diversion, livestock grazing and off-highway vehicle use. The latter two uses are currently unauthorized and within BLM management purview to address.

Overarching Findings, Issues and Management Considerations

In addition to reach-based information, the PFC assessment also provided insight into larger ecological processes and management issues affecting the San Pedro River through the SPRNCA.

<u>The Importance of Continued Groundwater and Surface Water in Relation to Riparian Vegetation and Channel Characteristics</u>

Pumping of groundwater that serves as the lifeblood for the San Pedro River and its tributaries poses significant threats to the long-term function and sustainability of the San Pedro River. Studies show that groundwater is being pumped in excess of the amount of recharge; if balance is not achieved the river will eventually become seriously impaired or lost. Continuing depletion of groundwater sources to the river will negate the positive effects of BLM management over the past 25 years.

The effects of declining groundwater can cause visible changes in the kind, condition, and distribution of riparian vegetation, but generally only when the decline is so rapid or advanced that there is an obvious widespread reduction in plant vigor, high plant mortality, or an obvious increase in drier plant species in those moisture zones and within those plant communities that are sensitive to changes in water availability. In general, detecting groundwater declines using visual indicators of vegetation condition is a somewhat coarse approach because it is not particularly sensitive and subtle changes in riparian vegetation can be attributable to other impacts (insects, disease, weather, etc); therefore, a more sensitive approach is needed to assess groundwater declines accurately. Linking riparian vegetation attributes to hydrologic factors will require quantitative measurements over time to understand how the riparian vegetation is being affected by changes to surface water, soil water, and groundwater levels (Cooper and Merritt 2012).

The team did not see an obvious widespread reduction in plant vigor, high plant mortality, or replacement of wetland plants by drier species in a pattern that would indicate an advanced groundwater decline. Some riparian vegetation did show signs of stress in a few areas (e.g., cottonwood trees with contracted canopies or dead tops), but all reaches, except reach J, were dominated by vigorous, healthy plants[1]. The current signs of stress could be attributable to several factors that we could not determine from a qualitative assessment. This does not mean that groundwater levels are not declining; rather, it means that more sensitive quantitative measures of groundwater, soil water, and vegetation characteristics are needed to document groundwater changes. If, or once, groundwater recharge to the San Pedro River is lost, the impacts will likely be irreversible.

The fact that 72% of the river was determined to be in PFC or FAR with an upward trend[2] is evidence that the system has the attributes and processes in place to further improve, however, the groundwater pumping deficit issue must be addressed now while the river still has the ability to take advantage of the water it receives from both surface and groundwater flows for system recovery. The final chapter to the sustainability of the San Pedro River will be written by the actions taken by the BLM and associated communities and partners in resolving the groundwater and surface water issues. The BLM should continue working with others in a cooperative and coordinated approach to resolve these issues, while concurrently pursuing perfection of water rights for instream flows and groundwater levels as directed by Congress.

Additionally, groundwater levels must be monitored, with priority given to: (1) wells in areas close to the river, and (2) wells in areas of high groundwater withdrawal where modeling suggests an expanding cone of depression. This information is needed to truly understand changes in groundwater flows critical to the sustainability of the San Pedro River within the SPRNCA. The NRST recommends that an analysis similar to what is provided in the 321 report[3] be extended to the wells closest to the river, and results produced in cooperation with the U.S. Geological Survey (USGS). Finally, the NRST recommends hiring a hydrologist dedicated to the SPRNCA and the Las Cienegas National Conservation Area to serve as a monitoring coordinator.

The Role of Water and Sediment in Relation to Channel Evolution

Another overarching consideration relates to the tributaries and sediment that enter the San Pedro River along its length. One of the important aspects of understanding the evolution of the San

[1] Further analysis and discussions are needed, and are recommended during the upcoming RMP process.
[2] Further analysis and discussions are needed, and are recommended during the upcoming RMP process.
[3] The Upper San Pedro Partnership (USPP) was formed in 1998 and legislatively recognized in 2003 as an important entity dedicated to responding to aquifer depletion in the Sierra Vista sub-watershed with passage of the Defense Authorization Act. Section 321 of this legislation requires the Secretary of the Interior, in consultation with the Secretaries of Defense and Agriculture, and in cooperation with the Partnership, to prepare an annual report to Congress, referred to as the 321 Report. This report includes the water use management and conservation measures that have been implemented and are needed to restore and maintain the sustainable yield of the regional aquifer, by and after September 30, 2011.

Pedro system following channel incision is determining whether the sediment supply from tributaries is causing impaired conditions along the river. To this end, the NRST examined the balance between water and sediment conveyed to and by the San Pedro River and determined that in all but three reaches (A, D and H) the sediment is not excessive. However, protection of both the flow and the sediment regime of this river are crucial to its continued evolution and survival. By all indications, the San Pedro River is no longer incising and is aggrading by building a floodplain and by narrowing its channel. In the context of channel evolution, those are favorable signs indicating that some reaches have achieved proper functioning condition while others are moving in that direction. Consequently, the NRST recommends against using active restoration practices in the San Pedro River channel, such as induced meanders.[4] Sound riparian management and passive restoration practices should be adequate to facilitate completion of the channel evolutionary process.[5]

For the reaches noted above, which contain evidence that sediment loads and transport capacity are out of balance, the NRST recommends a detailed analysis be done to determine the hydrologic impacts of agricultural dikes, railroad beds, and abandoned gravel pits within the SPRNCA, as well as conducting cooperative watershed condition assessment of tributary drainages. Another study should evaluate whether treatments to reduce mesquite in selected sites on the pre-entrenchment terrace would improve grass cover and better control upland hydrology and sediment supply.

The Contribution of Cottonwood and other Riparian Vegetation in Relation to the Recovery of the San Pedro River System

PFC assessment findings indicate that cottonwood and other trees are critical to the recovery of the river channel both as living trees and also as dead and down wood. The live trees with their heavy, strong roots are essential to anchoring banks in place, and providing stable sites where riparian plant species, including bulrush and other herbaceous vegetation in combination with seep willow and other shrubs/trees, can further anchor channel banks and contribute to channel narrowing and floodplain development. Riparian vegetation functions to: (1) slow water velocity during floods, (2) capture sediments, which creates sites for water storage, (3) increase infiltration and soil-moisture retention by adding organic matter and creating macropores via root channels, and (4) slow the release of subsurface waters to surface waters. While many people have expressed concern that cottonwoods contribute to considerable water loss in evapotranspiration, the river could not continue to develop and improve without them. Vegetation, both large and small, holds the river and floodplain together and provides for the function necessary to create aquatic and riparian values within the SPRNCA.

Current cottonwood galleries in reaches rated PFC were primarily fully stocked stands, and since the rate of channel migration is lower now than before the galleries were established, there is less area for establishment of new trees from seed. As a result, the acres of cottonwood and number of large trees are decreasing and will continue to do so naturally; loss to wild or prescribed fire would accelerate this process. Protection of existing cottonwood galleries to the extent practical should be a part of a vegetation management plan and a well-developed fuels and wildfire management plan. The protection of cottonwood trees is definitely important in reaches rated as

[4] This will be analyzed during the RMP process.
[5] Further analysis and discussions are needed, and are recommended during the upcoming RMP process.

FAR, because these reaches in particular are dependent on cottonwood trees (living and dead) for energy dissipation, streambank protection, and floodwater capture and storage.

The Negative Effects of Continued Livestock Grazing on Riparian Recovery

One of the major decisions made in 1989 through the SPRNCA's original management plan(s) was to end permitted livestock grazing in areas along the river. As previously noted, this has allowed development of riparian vegetation and channel characteristics that greatly improve the function and sustainability of the San Pedro River. A key finding of this assessment, however, is that while the BLM made efforts to eliminate trespass livestock in the SPRNCA, more needs to be done and State Office support is needed. Livestock use is, to some degree, retarding recovery of sections of the river; unauthorized grazing was found all along the river, but the detrimental impacts were more visible in localized areas within certain reaches.

Trespass livestock grazing in the river corridor must be eliminated to provide the maximum opportunity for continued improvement and evolution of the river. Furthermore, PFC assessment findings indicate that the riparian corridor and river are not yet to a point, overall, that livestock grazing could be permitted along the San Pedro River without retarding improvement or even causing impairment.

Other Management Issues to be addressed as Part of a Comprehensive Recovery Plan for the SPRNCA

Tamarisk (Saltcedar)

Tamarisk is found throughout the San Pedro River within the SPRNCA with increasing populations and density moving northward from the United States border. It is found only occasionally in the upper (southern) reaches, in part due to aggressive control efforts by BLM and partners. In the lower (northern) reaches of the SPRNCA, tamarisk will potentially displace most of the willow and cottonwood over time without aggressive control; this is due to its ability to spread rapidly and its deep roots that can tap into water tables beyond the reach of young cottonwood and willow. The NRST supports and endorses the SPRNCA's existing tamarisk management plan.

Fire and Fuels

The risks of major, high-intensity wildfires are great given the observed fuel loadings and types of fuels within the SPRNCA. The risk of fire moving into the cottonwood trees is high due to the sacaton's existing stands of dead and dry material. Periodic removal of plant material is needed to improve the health and vigor of the sacaton. Nonetheless, NRST recommends protecting cottonwood stands to the extent practical to achieve both riparian function and associated resource values.[6] NRST suggests that during the RMP process, there is an analysis of comprehensive public/private strategies and tactics for managing fuels and vegetation within and near the SPRNCA, especially opportunities to manage sacaton.

[6] This will be analyzed during the RMP process.

Beaver

In the PFC assessment, beaver dams are considered because they can be hydrologic modifiers. Overall, beaver were seen as a positive contributor to river health due to extended time of water retention behind dams. The important role of beaver, like cottonwood, is another area where increased information and public education efforts are needed. The BLM should also work with private landowners and the Arizona Game and Fish Department to minimize undesirable impacts.

OHV and Pedestrian Trails

Because riparian recovery is relatively recent and riparian plant communities are weakly developed in many areas, small disturbances can have profound effects by retarding recovery or reversing earlier trends in recovery of riparian areas. PFC assessment findings indicate that unauthorized off-highway vehicle traffic and unregulated foot traffic has compacted soil, trampled and destroyed riparian vegetation, altered streambanks and increased channel erosion. Efforts to reduce these impacts should be undertaken.

Railroad Bed

The abandoned railroad bed that runs along much of the San Pedro River has, and continues to alter surface flow and contribute eroded material directly to the river. The NRST recommends the BLM conduct an inventory to determine the location and extent of altered surface drainage and maintenance needs. In addition, the BLM should explore various options to retire or acquire the right-of-way for the abandoned railroad.

Agricultural Dikes

In sections of the San Pedro River, dikes were constructed to divert surface drainage around abandoned agricultural fields. These dikes alter natural hydrologic patterns, causing some reaches of the San Pedro River to receive less water and sediment, whereas others may receive too much. A thorough field investigation of the dikes is needed to understand the extent of the impact. Where there is evidence that diverted flow patterns are creating increases in peak discharge and increased erosive potential, steps should be taken to remedy the situation. Determine if ponded areas behind the dikes act as recharge.

Groundwater Augmentation

A number of groundwater augmentation strategies are currently being reviewed for their potential contribution to balance pumping with recharge. Additional water in Reach A could accelerate recovery of the needed vegetation characteristics.[7] Additional water in Reaches B through E could extend perennial flow further downstream in Reach F. A third location would be to provide additional recharge water to the Babocomari River, which might also positively influence the water in the San Pedro River.

[7] Reach A's potential is for vegetation characteristics of perennial flow, but currently it does not have perennial flow throughout the reach.

One strategy discussed during the PFC assessment was the use of detention basins in ephemeral channels. The NRST cautions that these detention basins are not without possible unintended consequences due to alterations in sediment balance. As a result, the location of future structures is an important consideration.

Recommended Next Steps

The PFC Riparian Assessment Report for the San Pedro River through the SPRNCA concludes with a discussion of three recommended next steps. The first is to complete the SPRNCA RMP process that is currently underway. The number and types of issues raised by the PFC assessment and preceding steps in the NRST assistance process clearly point to the need for an up-to-date plan for managing the SPRNCA. Although some of the riparian issues can be resolved on a project or location basis, the greater need is for a comprehensive analysis and planning effort that fully engages the many partners and broader public.

The second step is to develop baseline information and an objective driven monitoring strategy. With the legal mandate to conserve, protect and enhance the riparian, aquatic, and other named resources, a robust monitoring plan is critical to mission success. Although monitoring is known to exist, much of this is not corporate in nature or readily available to interested publics or management. Moving forward into the RMP process and the establishment of monitoring programs, it is critical to know where information has been collected, what information is available, and what has been learned to date. In addition to the ongoing wet-dry mapping, which not only provides highly valuable information to management about river conditions but is also a highly educational activity that increases public support for the San Pedro River, the NRST outlines a variety of other monitoring needs for the SPRNCA. With appropriate training, volunteers can assist technical staff on some of these monitoring efforts and take the lead on others.

The third recommendation is to expand opportunities for community education and service. Throughout the course of NRST assistance, it became apparent that there is a lack of information, or misinformation, regarding riparian ecology and function. Volunteers can assist BLM with riparian education and interpretation, as well as implementing management actions. Suggested informational topics and management activities are outlined in the report.

Introduction

As part of an effort to begin working with stakeholders in a different and more collaborative way, the Bureau of Land Management (BLM) in Arizona requested assistance from the National Riparian Service Team (NRST) relative to the management of the San Pedro River within the San Pedro Riparian National Conservation Area (SPRNCA). The NRST is an interagency team (BLM, Forest Service, in cooperation with Natural Resources Conservation Service) that implements the Creeks and Communities Strategy across the Western United States.[8] The focus of the Creeks and Communities Strategy is working with land managers and interested stakeholders to build relationships and establish a common vision for riparian area management that is based on a shared understanding of current riparian condition in relation to an area's

[8] For more information about the Creeks and Communities Strategy, visit www.blm.gov/or/programs/nrst

potential.[9] This understanding of important riparian attributes and processes then forms the foundation upon which objectives relating to desired future riparian conditions are set, and alternative management and monitoring approaches are considered.

For the past year, the BLM in Arizona has been working with the NRST to implement the Creeks and Communities strategy within the SPRNCA. Most recently, interested individuals from surrounding communities, and BLM managers and specialists joined the NRST as they conducted Proper Functioning Condition (PFC) riparian assessments (Prichard et al. 1998) on approximately 51 miles of the San Pedro River through the SPRNCA, during April 11-20, 2012. The objective was to assess the current functional condition of the river and riparian conditions nearly 25 years after Congressional designation of the SPRNCA. As part of designation, Congress directed the Secretary of the Interior to manage the SPRNCA in a manner that "conserves, protects, and enhances the riparian area and the aquatic, wildlife, archeological, paleontological, scientific, cultural, educational, and recreational resources of the conservation area" (United States Code 2002:1). The PFC assessment provides information to better understand how riparian conditions have changed since designation and what the BLM and larger community can do to ensure management will achieve Congressional direction into the future.

Two stories have emerged from the assessment concerning the recovery, health and sustainability of the San Pedro River, as well as the hope for meeting the intent of Congress when they established the NCA, and ensuring that this national treasure will continue to be a living laboratory and source of joy and inspiration for future generations. The first is being written on the land and is a dramatic lesson in the evolutionary and recuperative powers of rivers and streams. This story is based on the interaction of soil, water and vegetation along the course of this living river. The second story is about groundwater, and is being written deep within the earth in the lands surrounding the SPRNCA; out of sight and mind for many members of the community. Pumping of the groundwater aquifer that serves as the lifeblood for the San Pedro River and its tributaries is threatening the river's future existence. Studies show that groundwater is being pumped in excess of the amount of recharge; if balance is not achieved, the San Pedro River will eventually become seriously impaired or lost (Upper San Pedro Partnership 2012). Many of the dead rivers that currently dot the American West serve as a testament to the possibility of this outcome.

Since the rights to groundwater use in Arizona are essentially unregulated outside of Active Management Areas and Irrigation Non-Expansion Areas, the aquifer that supplies much of the baseflow to the San Pedro River is facing a *tragedy of the commons*. Hardin (1968) described this as a dilemma arising from the situation in which multiple individuals, acting independently and rationally and consulting their own self-interest, will ultimately deplete a shared limited resource, even when it is clear that it is not in anyone's long-term interest for this to happen. Groundwater pumping is the ultimate threat to the sustainability of the San Pedro River, as well as the economy and culture of Fort Huachuca, Sierra Vista and the surrounding region. The final chapter to the sustainability of the San Pedro River will be written by actions taken by the BLM, and associated communities and partners in resolving the issues posed by this second story. The

[9] Riparian potential is defined as the highest ecological status a riparian-wetland area can attain in the present climate given no political, social, or economic constraints (Prichard et al. 1998). For the purposes of this report, it is described by the combination of vegetation and channel characteristics that could develop during a management time scale of 5-50 years given no human impacts.

BLM should continue working with others in a cooperative and coordinated approach to resolve the groundwater and surface water issues in the Upper San Pedro Basin. Concurrently, the BLM should pursue perfection of water rights for instream flows and groundwater levels as directed by Congress.

This report focuses on the physical function and sustainability of the San Pedro River though the SPRNCA, which falls within BLM management authority. See Appendix A for reach-based PFC assessment information. PFC assessment focuses on qualitative indicators in the riparian area and stream/river. If riparian impairment is present, the interdisciplinary team determines whether the impairment is related to some in situ channel/riparian disturbance or to a disturbance elsewhere in the watershed that is being transmitted to the assessment reach. The assessment did not evaluate the condition of tributaries or uplands, nor did it directly ascertain groundwater conditions.

PFC assessment findings indicate that 72% of the San Pedro River within the SPRNCA is currently either properly functioning or in an upward trend (moving toward PFC).[10] These ratings are evidence that the system has the attributes and processes in place to further improve, however, the groundwater pumping deficit issue must be addressed now while the river still has the ability to take advantage of the water it receives from both surface and groundwater flows for system recovery, or the positive effects of BLM's management will be negated.

History of the Creeks and Communities Effort within the SPRNCA

When the NRST first became involved in working with the BLM and its partners over management of the SPRNCA, a situation assessment was conducted and a report published on April 26, 2011 (NRST 2011). As noted in the report, the issues regarding the SPRNCA fall at two scales – those relating to the larger San Pedro watershed and those relating more specifically to the management of the SPRNCA. Declining surface water levels and an inability to balance the groundwater budget are watershed scale issues, which if not resolved threaten the future health of the San Pedro River.

The NRST recognized that the larger watershed-scale issues and the future health of the San Pedro River, and thus the SPRNCA, are inexorably linked. However, at the conclusion of the situation assessment, the team determined that its assistance would be most effective if it focused on the scale of establishing a common vision among the BLM and stakeholders for the future management of the SPRNCA. A vision, based on an understanding of current riparian condition in relation to potential, would then inform the selection of appropriate management and monitoring approaches needed to conserve, protect and enhance this national treasure. Engendering this type of understanding and building needed relationships and trust among land managers and stakeholders are at the heart of the Creeks and Communities Strategy.

Following the situation assessment, the NRST met with BLM personnel and stakeholders to review findings, gauge support for continued team involvement and identify the steps needed to create a common understanding of river and riparian conditions within the SPRNCA. The first identified step was for the team to meet with the various researchers and specialists working on, or familiar with the San Pedro River, to gain a better understanding of current information and

[10] Further analysis and discussions are needed, and are recommended during the upcoming RMP process.

determine if any gaps exist. This occurred in July 2011. It became evident that even though there is a considerable amount of information about the San Pedro River (e.g. Leenhouts et al. 2006), documentation regarding current (2012) riparian condition *compared to potential*, on a reach-by-reach basis did not exist. Because this information represents the starting point in BLM regulations for managing land health, an action plan was developed to collect the information in advance of the upcoming Resource Management Plan (RMP). The proposed action plan was widely shared with interested stakeholders through a variety of community-oriented meetings and workshops. Stakeholders were generally supportive of moving forward, and many expressed interest in participating in activities.

An accurate assessment of current riparian condition requires an understanding of riparian potential – or the highest ecological status an area can attain under natural conditions (in the absence of human impacts). In order to describe riparian potential condition on a reach-by-reach basis throughout the SPRNCA, the NRST hired a contractor to lead an effort to synthesize existing information regarding the San Pedro River. The resulting report, 'Riparian Conditions along the San Pedro River - Potential Natural Communities and Factors Limiting Their Occurrence' (Fogg et al. 2012), was then reviewed by many of the technical specialists involved in the July 2011 meeting, as well as by interested stakeholders, and BLM staff from the Gila District Office, Tucson Field Office, and Arizona State Office. The potential descriptions include the combination of vegetation and channel characteristics that could develop during a management time scale of 5-50 years, and provide a benchmark against which to compare current riparian condition (status) within the SPRNCA using the PFC riparian assessment method. They also provide the basis for development of management objectives relating to the desired future condition of these areas.

The formal PFC assessment of the San Pedro River within the SPRNCA occurred over ten days in April 2012, and was led by the NRST (see Appendix B for NRST professional biographies). NRST was accompanied by the Gila District interdisciplinary team, managers and interested stakeholders (see Appendix C for a complete list of assessment participants) who had the opportunity to walk, observe, and discuss the entire length of the San Pedro River within the SPRNCA. The NRST's assessment findings are documented within this report. The final phase of this effort will be a series of stakeholder meetings to review assessment findings and explore next steps in terms of the following: (1) how the BLM can best use the information and stakeholder interest that has been generated as they move forward with the RMP process, and (2) how the larger community can use the assessment results, coupled with resultant BLM decisions regarding future riparian management goals, to inform watershed scale efforts.

The Riparian Proper Functioning Condition Assessment Method

The PFC assessment method, described in BLM Technical Reference 1737-15 <u>A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas</u> (Prichard et al. 1998), was the protocol used for the assessment of the San Pedro River. The protocol grew out of a need at the national level for the BLM to assess conditions of streams and wetlands across all of its managed landscapes relatively rapidly. The PFC assessment has been the standard protocol for stream assessments for the BLM since 1993 and has been applied on over 40,000 miles of public land streams under their management. Most BLM State Offices consider

PFC assessment as the standard protocol for determining compliance with Land Health Standards concerning riparian-wetland areas.

PFC is qualitative and science-based assessment that utilizes two assessment checklists; one for flowing water systems such as rivers, streams, and springs (lotic) and one for wetlands such as lakes, ponds, seeps, bogs, and meadows (lentic). The checklists provide the framework for evaluating physical functionality based on hydrology, vegetation, and erosion/deposition attributes and processes. Prior to completing the checklist, an interdisciplinary team gathers existing information and delineates the stream into reaches, each having common attributes, processes, management and potential. The assessment is used to identify any significant attributes or processes that may be out of balance with natural processes necessary for a system to function properly and maintain its channel dimension, pattern and profile with respect to its landscape setting, during moderately high flood events. Use of this method requires an interdisciplinary team which should include specialists in vegetation, soils, hydrology, and biology (Prichard et al. 1993). Some specialists may be able to address more than one skill area based on their knowledge and experience.

Prichard et al. (1998) lists the purpose of each item, examples of how the item would be answered in different situations, and supporting science. A final determination of condition is made based on the mix of “yes” and “no” answers, factored with the importance of each checklist item in terms of the specific reach being assessed and its potential. This process requires highly experienced and knowledgeable team members, and discussion is critical in order to understand differing perspectives. The qualitative PFC assessment provides an important foundation for understanding the current condition of a system, describing limiting factors and identifying areas where additional information is needed to provide a more clear and conclusive picture of the situation. While the ultimate goal is interdisciplinary team consensus during the assessment process, there are instances where disagreements remain. In those instances, quantitative methods to gather additional data for verification or monitoring are needed.

Potential and Capability

An important determination prior to and during the PFC field assessment is the potential and capability of each reach. **Potential** is defined as the highest ecological status a riparian-wetland area can attain in the present climate given <u>no</u> political, social, or economic constraints (Prichard et al. 1998). For SPRNCA, potential descriptions were developed that include the combination of vegetation and channel characteristics that could develop during a management time scale of 5-50 years. Potential is applied to the PFC assessment by considering and answering each item of the checklist relative to the attributes and processes that can occur within a particular riparian system. Based on the potential of a reach, certain checklist items may not be applicable (i.e. the attributes and processes do not exist within that type of reach). In this case, the item is answered “not applicable” on the checklist. When the possibility does exist for a “yes” answer, a determination of whether the item should be answered “yes” or “no” is made based on the attributes and processes that system needs for function.

Capability is defined as the highest ecological status an area can attain given political, social, or economic constraints, which are often referred to as limiting factors (Prichard et al. 1998). On some streams, human activity has interfered with natural stream processes in such a way that the stream cannot recover to its natural potential. Examples of this might be dams that regulate amount and timing of flows, roads or railroad grades that cut off access to large portions of a stream valley, dikes that confine stream channels, or groundwater pumping/irrigation withdrawals that reduce the amount of water available to streams. In the PFC assessment, these are indicated as capability factors. Capability only applies to limiting factors that the land manager for a given area cannot eliminate or change through a management action. Actions such as grazing, timber harvest, and road construction practices are generally within the discretion of the manager, can be changed, and are not considered capability factors.

Functional Ratings

The PFC assessment recognizes three categories of stream functionality; proper functioning condition (PFC), functional-at risk (FAR), and nonfunctional (NF). A riparian-wetland area is considered to be in **proper functioning condition** when adequate vegetation, landform, or large woody debris is present to:

- Dissipate stream energy associated with high stream flows, thereby reducing erosion and improving water quality;
- Filter sediment, capture bedload, and aid floodplain development;
- Improve flood-water retention and ground-water recharge;
- Develop root masses that stabilize stream banks against cutting action;
- Develop diverse ponding and channel characteristics *to provide* the habitat and the water depth, duration, and temperature necessary for fish production, waterfowl breeding, and other uses; and
- Support greater biodiversity.

Riparian-wetland areas that are, for the most part, in functional condition but an existing soil, water, or vegetation attribute makes them susceptible to impairment during moderately high flood events are considered **functional-at risk**. Streams rated FAR are also given a trend determination of upward (improving or moving towards PFC), downward (becoming worse or moving away from PFC) or not apparent. N**onfunctional** riparian-wetland areas clearly do not provide adequate vegetation, landform, or large woody material to dissipate stream energy associated with high flows and thus are not reducing erosion, improving water quality, etc.

A trend determination is only assigned to streams rated FAR. If there is insufficient evidence to make a determination that there is a trend toward PFC (upward) or away from PFC (downward), then the trend is not apparent. Most frequently, vegetation is the primary determining factor for trend, particularly on low-gradient alluvial streams. Factors such as increasing distribution and composition of obligate wetland and facultative wetland plants (indicative of saturated or high soil moisture), and reduction of upland plants in riparian areas may be important trend indicators. The presence of colonizing species, reinforced with stabilizing vegetation on the streambanks and floodplains is an example of another indicator of recruitment of riparian plants and an upward trend. Other indicators are new shoots from rhizomatous species and the presence of multiple age classes, especially seedlings and young, of woody species. In the early years of recovery, vegetative expression (height and quantity of above-ground material) is often visually very evident, whereas later, important changes in species composition, plant vigor, density of stabilizing communities, root extension and other changes are sometimes less obvious. Trend determinations require highly experienced interdisciplinary teams, as the indicators often times are complex.

Monitored trend can be measured and/or determined by comparing the present situation with previous photos, trend studies (such as vegetation transects and surveyed channel cross sections), inventories, and any other relevant information. Where none of these exist, or are inadequate to determine a monitored trend on the reach, the interdisciplinary team uses their experience to gauge **apparent trend** (an interpretation of trend based on observation and professional judgment at a single point in time). For FAR reaches with no apparent trend, the first management action may be to establish monitoring sites to determine monitored trend. PFC itself is NOT a monitoring approach or process. Ideally it should be a one-time assessment that sets the course for future management and monitoring.

Each rating occurs over a range; for example a reach rated PFC may be "just barely" PFC or near potential or somewhere in between. For the SPRNCA assessment, a thermometer schematic (Figure 1) was included on the PFC assessment form that enabled the interdisciplinary team to illustrate where they decided a reach was, within the range of the rating categories, based on their knowledge and experience. This is also an indication of the evolutionary stage (i.e., upper, middle or lower part of the PFC or FAR rating) of each reach. Reaches rated very high within the PFC range are approaching potential vegetation and channel characteristics, while those rated low within the PFC range are functionally capable of handling moderately high floods but need more time to reach potential.

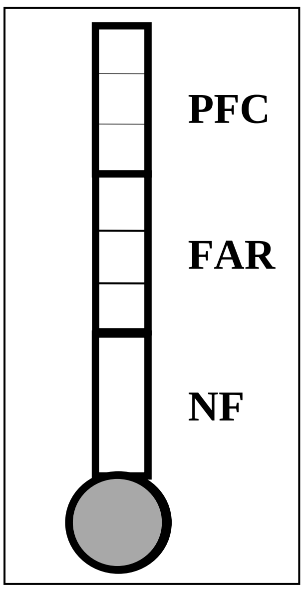

Figure 1. Stylized "thermometer" for recording where within the functional ratings a reach is considered to be.

Figure 2 shows the seral stages[11] associated with NF, FAR, and PFC. NF reaches have few or none of the attributes and processes necessary to dissipate stream energy or perform other needed functions. Streams that are FAR but just below PFC may rapidly progress to PFC with the right combination of management and flow events. However, FAR streams that are just above NF may take decades to develop the attributes and processes necessary to move to PFC. The values on which management should be focused occur largely at PFC because below that condition, they are not considered sustainable in moderately high floods (e.g. 5-, 10-, and 20- year events). Stream improvement is seldom a linear process and the trajectory of progress typically exhibits

[11] Seral stages: a series of plant communities that follows another in time on a specific site.

several oscillations over time. Streams go through periods of improvement, deterioration, and back to improvement, until they are at PFC. Extreme events such as 100-year events occur infrequently and have such power that riparian areas in PFC can unravel, at least in places, yet they normally recover much faster than similar streams that are less than PFC.

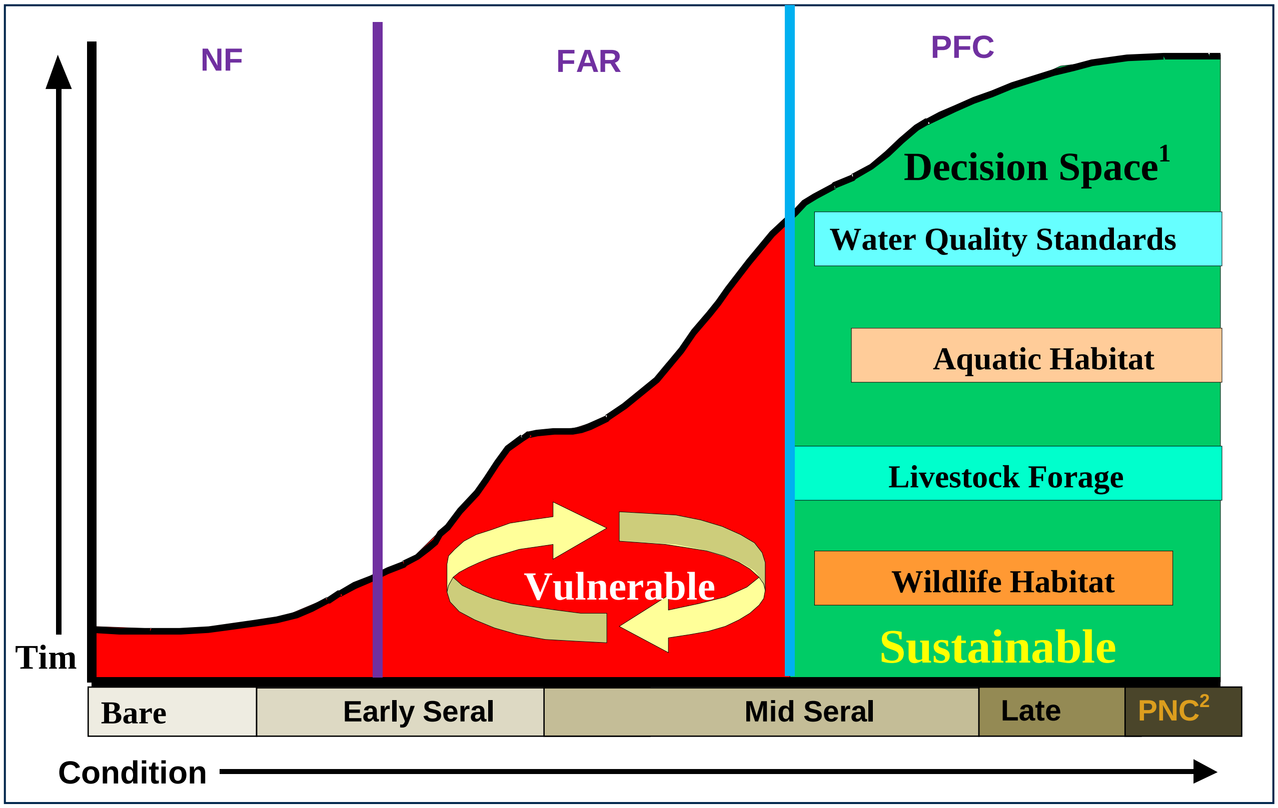

Figure 2. Example of succession as it relates to stream recovery and function.
[1] Decision space represents having proper functioning condition in the system so that resource goals and objectives are realistic and can be sustainable.
[2] PNC stands for potential natural community, which is the biotic community that would become established if all successional sequences were completed without interferences under the present environmental conditions.

PFC Assessment Contribution to Management of the SPRNCA

The PFC assessment is a beginning step in a comprehensive process for riparian management. Both the process and the results help agencies, partners and citizen groups build an understanding of the physical processes that are governing the river. PFC assessment findings give a portrayal of current condition and provide indicators of the ability of the river and riparian area to produce certain values. The information garnered from the PFC assessment of the San Pedro River, along with knowledge of resource values, is essential to interdisciplinary team, land manager, and stakeholder efforts in developing riparian management objectives, riparian management plans, and monitoring strategies that will demonstrate achievement of desired results over time. In order to be useful, the PFC assessment results must be incorporated into an integrated riparian management process, which includes the RMP process that is currently underway for the SPRNCA.

Legislation directs the Secretary of the Interior to manage the SPRNCA in a manner that conserves, protects, and enhances the riparian area and other resources. Stakeholders want to know what that means on the ground and what it will take to meet that direction, including the associated economic and social implications. BLM decisions and analysis regarding management direction are made through a RMP development process. One component of a revised management plan for the SPRNCA is an understanding of current riparian conditions as compared to potential and desired conditions, and how these have changed since designation. Current actions that limit attainment of desired conditions both within and outside BLM control must also be identified, along with future riparian management objectives for the SPRNCA, approaches and needed actions for meeting them, and strategies/actions for monitoring progress.

The PFC assessment is a protocol used by BLM to meet its requirements for determining land health standards and engaging the public in this process. A broad and diverse group of public and other stakeholders are concerned about the future of SPRNCA, and successful outcomes will depend on an engaged and supportive public. The PFC assessment also provides a vehicle for engaging in high-level, field-based, interdisciplinary discussions (including with stakeholders) about riparian function and needs within the SPRNCA as part of an effort to develop a common vision for the future management of this important area. The PFC assessment provides a current description of existing condition, as well as an opportunity to crosswalk with the riparian condition classes developed by Stromberg and others which are based on nine field-measured vegetation traits that are sensitive to changes in streamflow permanence or ground-water levels (Leenhouts et al. 2006). This will serve as the foundation for the riparian portion of the RMP. The knowledge gained during the PFC assessment helps point to what should be monitored with quantitative methods to track change over time. It also helps inform RMP level management decisions such as those relating to grazing, fire and vegetation management. The information and recommendations contained in this report outline a number of things to consider as part of the RMP process.

In addition to contributing important information to the RMP process and management of riparian areas within the SPRNCA, the information obtained through the PFC assessment and associated processes will also contribute to answering some of the larger watershed-level questions. Although the final riparian condition determinations will not resolve the issues related to declining river flows or an unbalanced groundwater budget, the information garnered from this effort will contribute to the BLM's ability to more effectively engage as a partner in these discussions. For instance, the BLM will be in a better position to discuss how riparian vegetation influences water availability through both evapotranspiration and acting as an agent for alluvial aquifer recharge during flood events, as well as their management objectives concerning riparian vegetation. Additionally, they will be able to provide rationale for important efforts such as groundwater monitoring, as well as initiation of new monitoring as part of a comprehensive strategy for understanding why certain reaches are not moving toward desired conditions or are in decline.

PFC Assessment of the San Pedro River through SPRNCA

Reach-Based Findings, Issues and Management Considerations

Potential Descriptions

The potential of individual reaches of the San Pedro River were defined in Fogg et al. (2012) and vetted in February 2012 through a public process that included scientists from the USGS, University of Arizona, Arizona State University, U.S. Bureau of Reclamation, Fort Huachuca, The Nature Conservancy, and stakeholders from Friends of San Pedro, Community Watershed Alliance, Audubon Society, citizens of Sierra Vista and Cochise County and BLM staff from the Arizona State Office, Gila District Office and Tucson Field Office. Input from this review process was incorporated into the potential document and reviewed again by the NRST and the Gila District interdisciplinary team prior to conducting the PFC assessments in April 2012.

Prior to the 1880s, much of the San Pedro River through the SPRNCA was a cienega - a broad, marshy environment, dominated by dense herbaceous, obligate wetland vegetation in a low-gradient, low energy stream system (Figure 3- stage I; Henderson and Minckley 1984). During the late 1800s and early 1900s, the San Pedro River experienced a major period of channel incision and was transformed from a low-energy system with widespread cienegas to a high-energy, incised river system (Figure 3 - stage II; Hereford 1993). During the first half of the twentieth century, the energetic San Pedro River meandered rapidly across its valley bottom, gradually widening its inset floodplain (Figure 3 - stages III and IV; Hereford 1993). Since approximately the 1950s (Hereford, 1993), the rate of lateral channel migration has decreased and the establishment of riparian vegetation has helped to capture suspended sediment to build a wide floodplain with progressively deeper alluvium (Figure 3 - stages IV and V). The widening and aggradation of the floodplain has corresponded to a narrowing of the channel. These geomorphic changes to floodplain and channel have been most evident since 1989, when BLM ceased authorized livestock grazing along the San Pedro River. Vegetation expression following livestock removal improved trapping of suspended sediment.

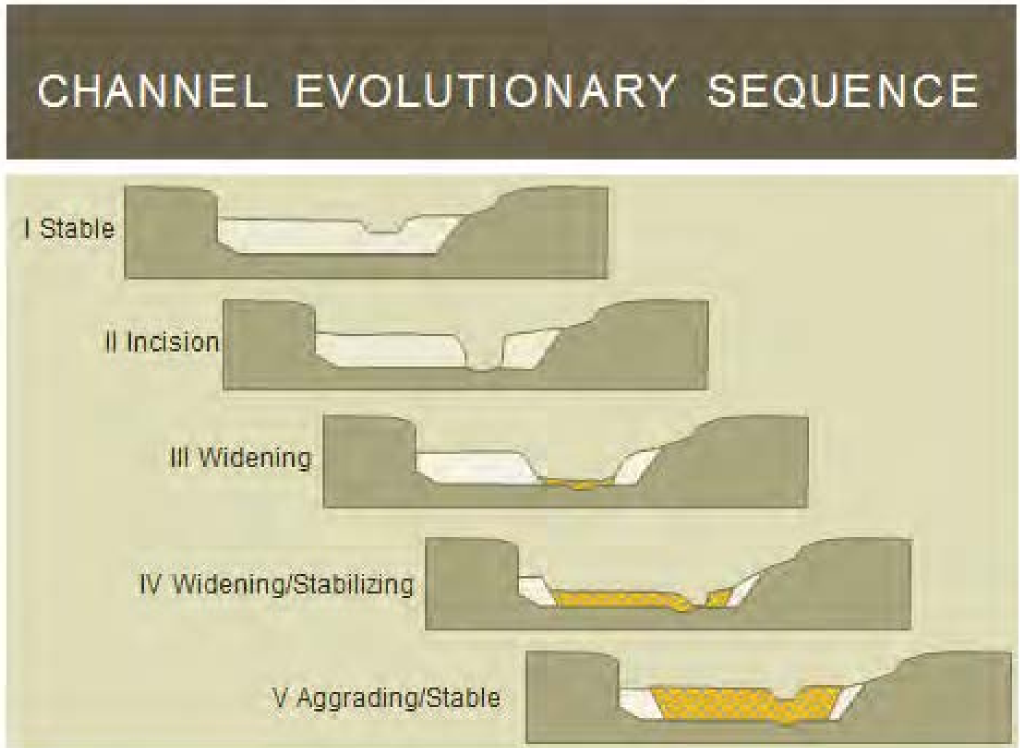

Figure 3. Simplified schematic illustrations of the channel evolutionary process that stream systems experience during an episode of channel incision and recovery to another stable form. The process of channel incision (stage I to II) can occur quickly, over a few years to a couple decades; whereas the recovery period (stage II to V) commonly occurs over a few decades to a couple centuries.

Although the NRST fully expects channel evolution to continue toward a more stable system, the time required for the channel evolution process to complete its course may take many decades. Continuation of channel evolution is also contingent on implementation of effective riparian management, existence of favorable climatic and hydrologic regimes, and continuance of groundwater discharge to the stream channel (or at least maintenance of water-table elevations that are within the rooting depth of obligate wetland plants).

The potential identified is for a river with places where cienegas can reform, but not for continuous cienegas. Although the almost continuous cienegas of the 1800s are unlikely to occur in the foreseeable future, the potential does exist for some areas to evolve in that direction. As stated in Fogg et al. 2012:18, “In the case of a very large tributary event depositing an extensive, coarse fan in the San Pedro, the major backwater condition upstream could induce considerable aggradation, channel meandering, and a substantial rise in the water table. With the addition of organic matter to the backwater deposits, this sequence could produce a nursery site for formation of a post-entrenchment cienega.” The climatic conditions of the Little Ice Age, during which time continuous cienegas reportedly formed along parts of the San Pedro River, were fairly unique in the Holocene. Thus, it is highly speculative to manage for a potential that existed under a hydrologic and climatic regime and geomorphic conditions that may never occur again, and not likely to develop during a management time scale of 5-50 years[12].

[12] Further analysis and discussions are needed, and are recommended during the upcoming RMP process.

Fogg et al. (2012) used several lines of evidence to determine potential, including the hydrogeology of regional aquifers in the upper San Pedro watershed (Figure 4), and the distribution and effect of a fine-textured (silt and clay) restrictive unit in the upper basin fill (Figures 5 and 6). Reaches A through D are gaining reaches, meaning they receive groundwater from the regional basin aquifer in the Upper San Pedro Basin. The bedrock constriction at the north end of the Charleston Hills also forces regional groundwater toward the surface and into the San Pedro River (Figure 4). In addition, the location of a fine-textured restrictive unit underlying much of the San Pedro River in these reaches affects transmission losses from the channel to the regional aquifer and the groundwater flow rate from the regional aquifer to the San Pedro River (Figures 4, 5, and 6). And in some cases when the restrictive unit is west of the San Pedro channel, it can produce artesian conditions that force groundwater to well upward into the channel (Pool and Coes 1999).[13]

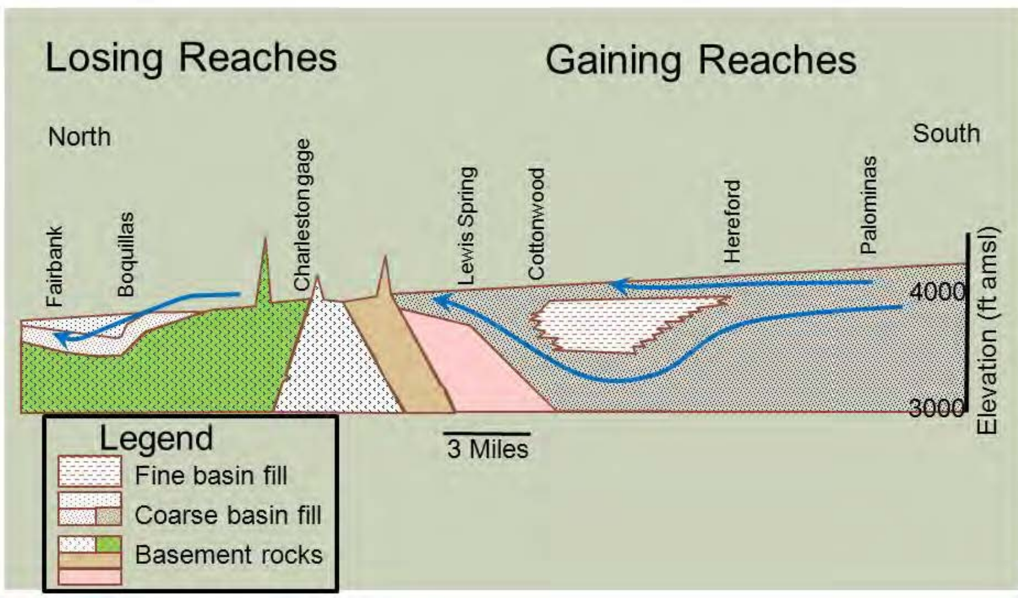

Figure 4. Simplified geologic cross-section of part of the Upper San Pedro Basin from the international border to Fairbank. Blue lines illustrate generalized water-flow patterns. Groundwater is maintained at or near the surface when it passes over restrictive units, such as fine-textured basin fill. Also, groundwater is forced upward by shallow basement rocks at the Charleston Hills. Surface water infiltrates into coarse basin fill and coarse alluvium north of the Charleston Hills.

[13] Saint David Cienega continues to be fed by artesian flow from the underlying confined aquifer.

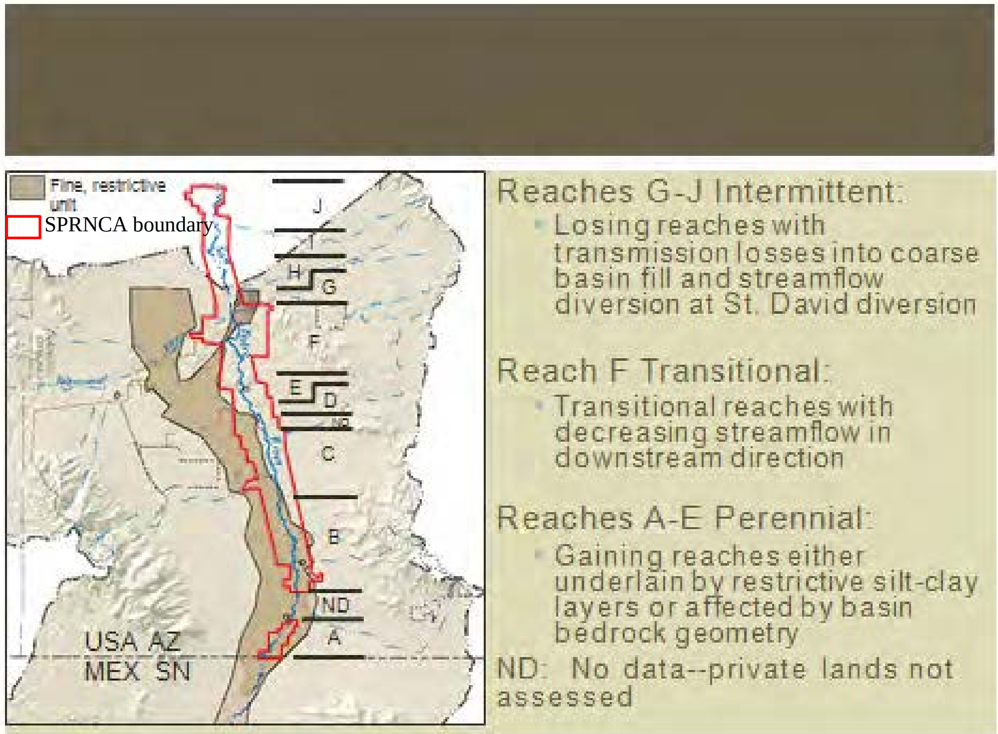

Figure 5. Map illustrates the approximate location of fine-textured (silt-clay) layer in the Upper San Pedro Basin (adapted from Leake et al. 2008).

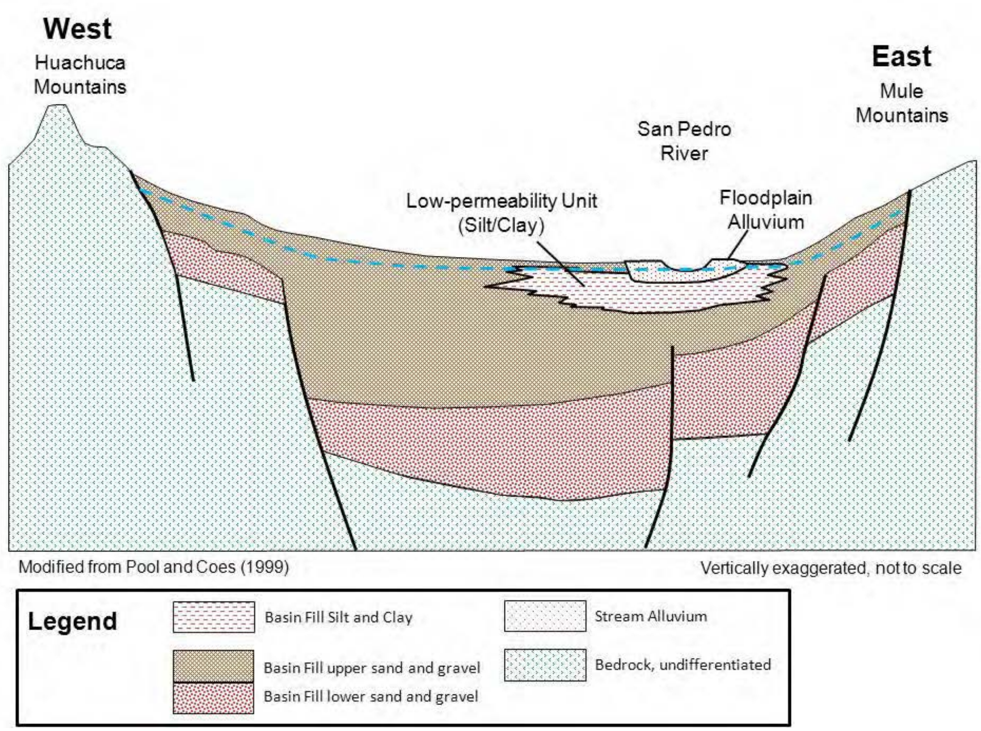

Figure 6. Simplified geologic cross-section of the Upper San Pedro Basin illustrating the role a fine-textured (silt/clay), low permeability unit can have on either isolating the San Pedro River from the regional aquifer, or reducing transmission losses from the channel to regional aquifers.

Reaches E and F traverse an area where bedrock is at or near the surface (Figure 4). These reaches have the potential for perennial or nearly perennial flow, due to a "pour-over" effect. Water forced to the surface in reaches A through D will pour over the lip of the bedrock at the north end of the Upper San Pedro Basin, flow downstream and will sustain perennial conditions for as long as possible until water begins to infiltrate into the coarse basin fill north of the Charleston Hills (Figure 4). For this reason, reach F at potential is seen as transitioning from perennial to intermittent conditions.

Reaches G through J are primarily losing reaches as stream discharge infiltrates into the coarse alluvium and basin fill north of the Charleston Hills (Figure 4), especially downstream of the confluence with Willow Wash, and are considered intermittent even at potential.[14] There is no known or practical management alternative within the immediate control of the BLM that can change these reaches from intermittent to perennial flow within a management time scale. In addition, the existing legal water rights that divert water from the San Pedro River at the St. David diversion constitute a limiting factor currently beyond the control of BLM management; consequently the current capability of reach J will prevent it from becoming perennially flowing. Finally, some short intervals within reach I contain obligate wetland and facultative wetland riparian plants that suggest they might have the potential for perennial flow (Fogg et al. 2012), but these are small, discreet, isolated intervals and are not representative of conditions observed throughout the reach. Therefore, the existing hydrogeologic information suggests that the potential of reach I is intermittent flow (Table 1).

Reach-Based PFC Assessment Summary

Approximately 51 miles of the San Pedro River were delineated into 10 discrete reaches, varying in length from a little over one mile to more than 12 miles (Figure 7). During the assessment, the interdisciplinary team walked each reach, discussed observations and took photographs and notes. At the end of each reach, the 17 individual PFC checklist items (Figure 8) were discussed, issued identified, and responses, ratings (Table 2) and rationale recorded.[15] Appendix D contains a listing of riparian issues prioritized by reach developed from the group's discussion.

Today on more than half its length, the riparian areas along the San Pedro River have reached a point where they are resilient to the most common flood events. Of the approximate 51 miles assessed, 27.4 miles (54%) are at PFC; these reaches have the ability to maintain their dimension, pattern and profile in moderately high flood events. Another 8.9 miles (18%) are rated FAR with an upward trend, 4.2 miles (8%) at the northern end below the St. David diversion dam are FAR with a downward trend, and 10.3 miles (20%) are FAR with no apparent trend (Table 1). Appendix E contains a spreadsheet of riparian plants observed by reach.

Arizona State BLM Land Health Standards require that streams be managed in a manner that allows them to receive a rating of PFC or FAR with an upward trend. Not apparent or downward trend does not meet that standard and management actions to improve riparian health are required if the limiting factors are within BLM's control. If limiting factors are outside BLM's control, then coordination with other land owners and the public is necessary to address the issues.

[14] Further analysis and discussions are needed, and are recommended during the upcoming RMP process.
[15] Further analysis and discussions are needed, and are recommended during the upcoming RMP process.

Management action is needed on the lowest reach (reach J). Reach J was rated as FAR with a downward trend, and it was determined that conditions will not improve without changes in management. The main impacts limiting the ability of the reach to achieve PFC are the St. David's diversion, livestock grazing, and off-highway vehicle use. Impacts resulting from the diversion of stream flow at the St. David's diversion are outside the control of the BLM manager and cannot be changed under current BLM authority, although opportunities may exist to work with the Saint David Irrigation District on flow issues and management of their pop-up dam. Livestock and off-highway vehicle use, on the other hand, do fall under the BLM's management purview, and neither use is currently authorized. Elimination of these unauthorized uses would be a major step in helping recovery of reach J and are given increased importance since that is the only management action that can be taken directly by the BLM to improve condition of the reach.

For the reaches rated with either a not apparent or downward trend, the NRST recommends the first action be establishment of a monitoring strategy to measure change over time in *key* PFC checklist attributes marked "no." Most of the comparisons between the 1987 photographs and visual observations indicate a clear improvement in riparian health, however, the NRST feels that in the reaches rated below standard, improvement had either stalled or even changed to a downward trend. Where trend was not apparent to the team, monitoring can help determine if trend is actually up or down.

Table 1: Summary of PFC Ratings by Reach						
PFC Reach	Stromberg Reach[1]	Reach Length (miles)[2]	Permanence of Streamflow at Potential[3]	Functional Rating	Trend on FAR	Relative Scale on Thermometer
A	1	6.1	Perennial[4]	FAR	NA	Middle
B	2, 3, some 4	12	Perennial	PFC		Lower
C	rest of 4 + 5	6.3	Perennial	PFC		Lower
D	6	1.4	Perennial	FAR	NA	Upper
E	7	3.8	Perennial	PFC		Lower
F	8, 9, some of 10	8.9	Perennial transitioning to intermittent[5]	FAR	upward	Middle
G	rest of 10	1.0	Intermittent	PFC		Middle
H	11, some of 12	2.8	Intermittent	FAR	NA	Middle
I	rest of 12	4.3	Intermittent with short perennial intervals	PFC		Middle
J	13, 14	4.2[6]	Intermittent	FAR	downward	Lower
		50.8				

[1] Stromberg reaches are displayed because Fogg et al. 2012 describes the potential of reaches based on the work of Stromberg and others documented in Leenhouts et al. 2006.
[2]From map measurements.
[3] Fogg et al. 2012 describes the potential plant communities of Stromberg reaches (Figure 7) by the expected permanence of streamflow at potential (perennial or intermittent), on three zones of geomorphic interest (terraces, floodplains, channel bed and banks). The information was verified by field examination of conditions by the interdisciplinary team.
[4] Although reach A is the most enigmatic reach due to spatial heterogeneity of channel bed and bank materials, indications are the reach has the potential for vegetation characteristics of perennial flow.
[5] Reach F is a losing reach, since basement rock that forced groundwater to the surface in the Charleston Hills drops off to great depth north of the Hills. Streamflow permanence at potential is expected to transition from perennial to intermittent along the reach.
[6] Reach J is approximately 5.5 miles long. The amount walked was 4.2 miles.

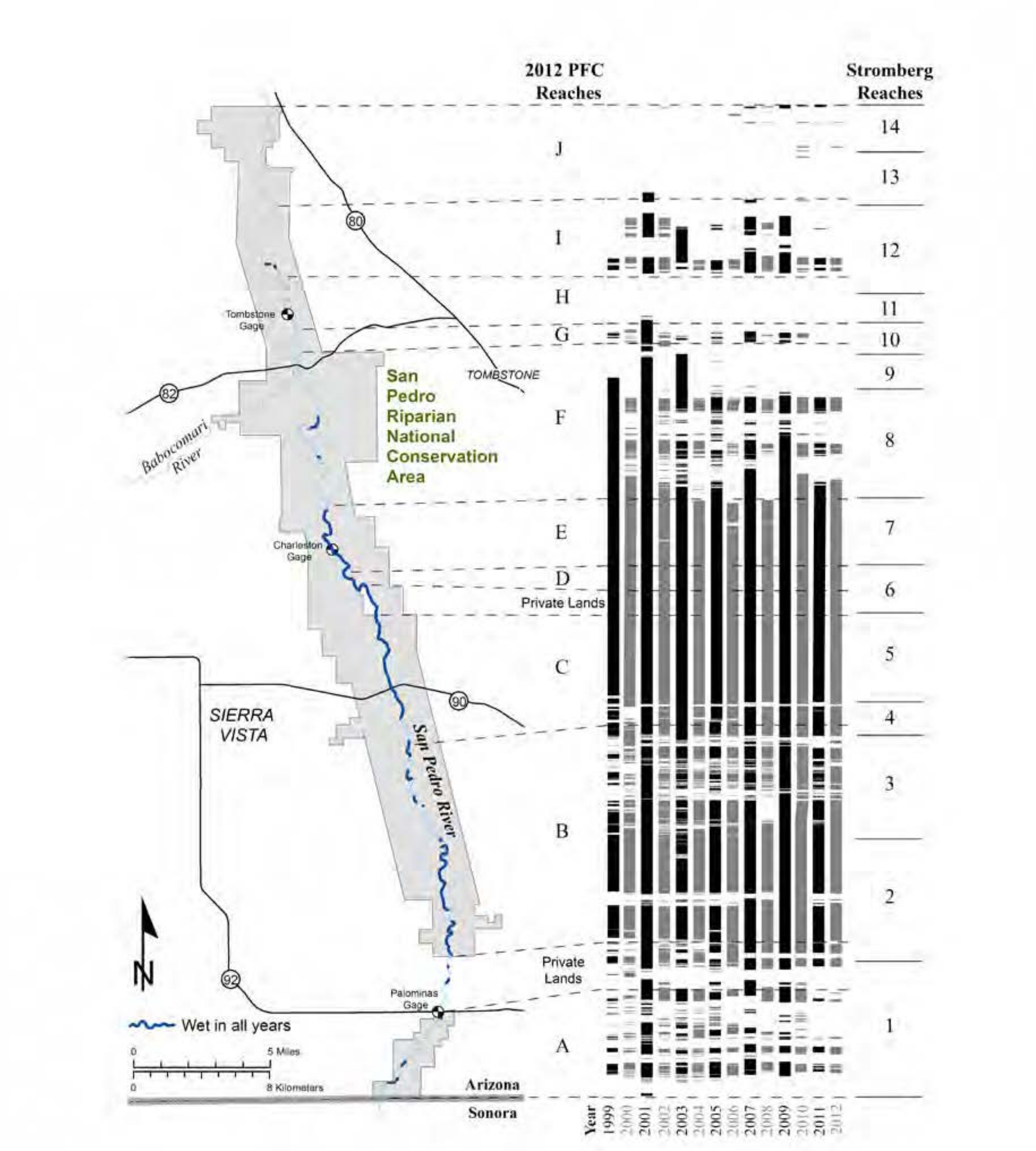

Figure 7. PFC assessment reaches, also showing Stomberg reaches from Leenhouts 2006 and wet/dry mapping results as of 2012 courtesy of The Nature Conservancy. The heavy river line (darker blue) shows reaches which were mapped as consistently wet in all 14 years surveyed. Bars on right side represent wet reaches for each year, 1999–2012. The black and gray lines are different colors simply to provide visual clarity. For more information on interpreting the wet/dry mapping results go to http://azconservation.org/projects/water/wet_dry_mapping.

HYDROLOGICAL
1) Floodplain above bankfull is inundated in "relatively frequent" events
2) Where beaver dams are present are they active and stable
3) Sinuosity, width/depth ratio, and gradient are in balance with the landscape setting (i.e., landform, geology, and bioclimatic region)
4) Riparian-wetland area is widening or has achieved potential extent
5) Upland watershed is not contributing to riparian-wetland degradation

VEGETATION
6) Diverse age-class distribution of riparian-wetland vegetation (recruitment for maintenance/recovery)
7) Diverse composition of riparian-wetland vegetation (for maintenance/recovery) (*species present*)
8) Species present indicate maintenance of riparian-wetland soil moisture characteristics
9) Streambank vegetation is comprised of those plants or plant communities that have root masses capable of withstanding high streamflow events (*community types present*)
10) Riparian-wetland plants exhibit high vigor
11) Adequate riparian-wetland vegetative cover present to protect banks and dissipate energy during high flows (*enough*)
12) Plant communities are an adequate source of coarse and/or large woody material *(for maintenance/recovery)*

EROSION DEPOSITION
13) Floodplain and channel characteristics (i.e., rocks, overflow channels, coarse and/or large woody material) adequate to dissipate energy
14) Point bars are revegetating with riparian-wetland vegetation
15) Lateral stream movement is associated with natural sinuosity
16) System is vertically stable (*not downcutting*)
17) Stream is in balance with the water and sediment being supplied by the watershed (i.e., no excessive erosion or deposition)

Figure 8. PFC Lotic Assessment Checklist Items

Table 2: Summary Table of Functional Ratings and Responses* to the 17 PFC Checklist Items by Reach																			
Reach	**Rating**	**Trend#**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
A	FAR	NA	YES	NO	NO	YES	NO	YES	YES	YES	YES	Y/N	YES	YES	YES	NA	NO	YES	NO
B	PFC		YES	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NA	YES	YES	YES
C	PFC		YES	NO	NO	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NA	YES	YES	YES
D	FAR	NA	YES	NO	YES	YES	YES	YES	YES	YES	YES	YES	NO	YES	YES	NA	YES	YES	Y/N
E	PFC		YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NA	YES	YES	YES
F	FAR	Up	NO	NO	NO	YES	YES	YES	YES	YES	YES	YES	NO	YES	NO	NA	YES	YES	NO
G	PFC		YES	NA	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	NA	YES	YES	YES
H	FAR	NA	NA	NA	YES	Y/N	NO	YES	YES	YES	YES	Y/N	NO	YES	NO	NA	YES	YES	NO
I	PFC		YES	NA	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
J	FAR	Down	NO	NA	NO	NO	NO	YES	YES	NO	YES	NO	NO	NO	NO	YES	NO	YES	NO

* Responses "Yes" for individual attributes or processes that are properly functioning, "No" for those that are not properly functioning, "NA" for those that are not applicable, and "Y/N" for both yes and no in part. Details of each response are provided in the narrative of each reach and in Appendix A: Reach Based Information.

Trends for Functional-at risk (FAR) reaches are either "Up" for reaches showing an improving trend, "Down" for those showing declining condition, and "NA" for those where the trend in condition is not apparent.

Reach A: PFC Assessment Narrative

Reach Overview

Reach A begins at the international boundary south of Palominas, AZ, and extends to the Highway 92 bridge over the San Pedro River; a distance of approximately 6 miles. It includes the public lands in Stromberg reach 1.

Reach Potential and Limitations

At potential, vegetation communities that are characteristic of perennial flow should be expected in this reach; however, the current flow regime represents a limitation to riparian potential. Temporal variability of base flows is compounded with spatial variability. The wet/dry map indicates a great deal of spatial heterogeneity in this reach with the border segment virtually always dry in June and another segment, less than two miles downstream, having water in it every year of the survey.

PFC Findings

Reach A was assessed on April 11, 2012. The reach was rated Functional-at risk with a not apparent trend. The primary rationale for the rating was that the sandy sediments are not being processed in the mid-section of the reach, leading to dry sections where flow is below/within the surface sands/gravels. Photos from the beginning and end of the reach show improvement over time, but there was no evidence in the dry mid-section to indicate improvement. Vegetative components are largely in working order, but an increased presence of bulrush and seep willow is needed for further development of channel narrowing and deepening. They are present, but not in the amount and/or community types necessary to help process sediments. It was speculated that upstream areas may be deficient in these species causing inadequate seed availability for this reach. Reach A might benefit from a program of planting seeds and/or plugs of bulrush in sections where there is adequate water and little or no presence of the species.

Abundance of key stabilizing species including spikerush, Baltic rush and bulrush greatly increases in downstream reaches. Cottonwood trees were heavily infested with tent caterpillars, apparently an annual occurrence, but have generally healthy architecture to the crowns indicating that the stresses are being offset by growth in June and beyond. The drier center section of the reach may be an exception to this.

Floodplain areas with large amounts of organic material in the form of large, coarse and small wood, along with buried grasses and other vegetation, are building and increasing the water storage potential in portions of the reach. Over time, this will potentially increase return flows to the river during periods of low flow.

Overview of Key Attributes and Findings

Hydrology – Floodplain features are present to allow for frequent flood access, and to dissipate energy during frequent floods in sections where silt/clay is part of the substrate and narrower channels have formed. Coarse sediment areas result in a wider active channel, less frequent access to floodplain and a poorly formed channel. Cottonwood regeneration since 1987 is clearly evident on photo point pictures and is having positive impacts on channel and floodplain characteristics. Processing of sediments will be enhanced over time by increases in smaller woody and herbaceous species both in the active channel and on the banks.

The current channel has had at least one section straightened in the past for agricultural purposes. Heavy ingrowth of cottonwood has basically locked the meander pattern in place; rather than having the natural looping meanders typical of many streams with wide valleys and low gradients, the San Pedro becomes blocked by large wood deposits and the channel jumps to another high water channel or cuts around the blockages. This is considered the natural process for the stream at this stage of evolution. Because the gradient is so flat, there are only very small increases in overall gradient when the channel changes locations.

Upstream to small beaver dam; building on sediment deposit, common on much of the river.

Upstream view; channel dry to waypoint 813; no surface flow due to porous sediments. sand/gravel.

Vegetation – All the components are present for continuing recovery towards proper functioning condition and beyond, but in places much of the bank stability is being provided by cottonwood trees and very cohesive soils that resist erosion. Expansion of herbaceous species and seep willow within the active channel along the base flow elevation and toe of bank slopes will assist in formation of improved channel shape. Multiple age classes of cottonwood trees were seen except for seedling and young. The youngest age class was about 10-20 years, but given the episodic regeneration typical of cottonwood stands throughout its range, this is not considered a problem. The heavy infestation of tent caterpillars was an obvious drain on tree health at least in the short term, but observations suggests that essentially full recovery follows during most monsoon seasons. It was noted that some sections, including the drier center section, often displays yellow leaves during portions of some growing seasons. The cottonwoods in the dry mid-section also had more dead branches, but the willows and herbaceous species exhibited high vigor, so the cause of the dead branches is unknown. Localized patches of dead or stressed mature seep willow were observed, probably from record low temperatures in February 2011; however, the overwhelming majority of seep willow in the reach was observed to be vigorous.

Erosion/Deposition – High flows that get out onto the frequent floodplain are effectively processed through the combination of vertical structure, large and coarse wood and well-developed vegetation on the floodplain. However, as noted earlier, sandy sediments are not being processed in the mid-section of the reach, leading to dry sections where flow is below/within the surface sands/gravels. As is true of several major river systems in the west (i.e., John Day in Oregon, Upper Missouri in Montana), continued channel narrowing and stability can occur by riparian vegetation becoming established within the active channel, particularly associated with the base flow level. Vegetation, including seep willow, bulrush and other sedges and rushes, are critical to this process. While some vegetation within the active channel may get scoured in flood flows, once established it tends to regenerate relatively quickly following scouring. Herbaceous vegetation and seep willow in the active channel and on the floodplain is a consistent feature in the downstream perennial reaches, but is only just beginning to establish in places in reach A.

Reach B: PFC Assessment Narrative

Reach Overview

Reach B begins at Waters Road and extends north for 12 miles to Cottonwood. It encompasses Stromberg reaches 2, 3 and some of 4.

Reach Potential and Limitations

Beginning about two miles south of Hereford and continuing north to the Cottonwood biomonitoring site, flow is characterized as spatially interrupted and temporally intermittent. However, wet-dry mapping indicates these reaches are predominantly wet, and several of the "dry" segments may be associated with short reaches of coarser substrate (hence hyporheic flow where water flows through the substrate rather than on the surface) downstream of tributary inputs. In addition, despite the general aridity of the past eight years, the proportion of Stromberg reaches 2 through 4 with surface flow during the wet-dry mapping has increased in recent years, likely as a result of discontinued agricultural pumping in the Hereford area (Dale Turner [The Nature Conservancy], personal communication, 2012). Reach B has the potential to support plant communities associated with perennial flow. Presently, locations upstream of tributary mouths represent the best sites for herbaceous colonizers/stabilizers to establish; enhanced conditions of base flow would support more widespread occurrence of these species.

PFC Findings

Reach B was assessed between April 12-14, 2012. It was rated Proper Functioning Condition, in the lower third of the rating class. Fogg et al. (2012) documented that in most of the perennial sections of the San Pedro River, a repeating pattern in terms of river form is expected. Sediment fans develop at the mouths of ephemeral tributaries. These form a partial barrier to flows and water backs up on the upstream side. As the stream cuts through the fans, an area of riffle develops and the stream transitions to a standard form of stream with a base flow channel and floodplain development. This pattern was observed throughout reach B. Reach B has better developed riparian vegetation than reach A, with cottonwood the dominant species along with seep willow, bulrush and other minor species.

Channel characteristics are also much better developed in reach B due to the abundance of bulrush and seep willow. In one extensive section of the reach, much of the cottonwood was eliminated in a wildfire several decades ago, but the herbaceous and smaller tree/shrub species are doing an excellent job of narrowing and deepening the channel. The floodplain has increased considerably in terms of aggradation and extension. Roughness on the floodplain from standing vegetation and dead/down materials captures sediment, which raises the level of the floodplain and overflow channels, followed by narrowing of the channel which allows more water to get onto the floodplain during flood flows.

There remains considerable opportunity for both improved channel characteristics and vegetation conditions in reach B. There are many sections where the riparian area will continue to expand, and have increasingly dense and strong plant communities develop. Water storage is increased within the floodplain area as this occurs.

Overview of Key Attributes and Findings

Hydrology – Floodplains that are accessible in frequent flood events (1-3 year events), are available throughout most of the reach. Sinuosity is affected by several short sections that were straightened for agricultural purposes prior to BLM acquisition, and there are two more recent meander cut-offs that were noted for follow-up monitoring. The banks on the straight sections are not eroding due to cottonwood/willow providing stability, along with highly cohesive soils that resist erosion along portions of the banks. It is suspected that some of the energy during high flows is being used to mobilize the bed. As water volume and velocity increases in the channel, in sand bed sections, the channel bottom is scoured, temporarily deepening the flow. As flows reduce, the sand from upstream sources refills the bed. Checklist item three was given a “no” response due to the minor channel alterations from straightening and the two meander cut-offs and their effect on gradient and sinuosity. These are relatively minor issues for the reach overall. This “no” is not significant for physical function because a large majority of the banks are stable and the reach is processing sediment appropriately.

Vegetation - It was noted that much of the herbaceous vegetation is relatively young and indicates recovery since livestock removal about 25 years ago. Bulrush in particular appears abundant in many portions of the reach, and is forming community types that will be very important over time for stable bank and channel development.

Cottonwood in the upper and lower portions of the reach line the banks of the stream as well as the overflow channels and old meander cut-offs, forming extensive galleries in places. The banks are highly stable and the cottonwood galleries are fully stocked stands. The mid-section of the reach burned in about 1996, and that section has only single trees or short lines of trees along the bank. Vegetation, including seep willow, bulrush, spikerush, Goodding’s willow, sacaton and other plants provide the needed stability. Recruitment of new cottonwoods is unlikely in this reach given the low rates of channel meandering and the extensive stands of sacaton and Johnson grass.

Erosion/Deposition – The presence of accessible floodplains with adequate roughness created by both herbaceous and woody vegetation, along with frequent deposits of large and coarse wood, helps dissipate energy and allows water to soak in and extend the wetted period for the reach and possibly downstream reaches. Sediment from tributaries was processing well, usually in the first 100-200 yards below the tributary mouths.

Transition form going to standard form – cottonwoods along right bank established after ones behind, leaning out over the river for sunlight.

Upstream view; bulrush wading into channel and moving up the bank, narrowing channel, expanding riparian area, ponded form.

Reach C: PFC Assessment Narrative

Reach Overview

Reach C is 6.6 miles long and includes a portion of Stromberg reach 4 and all of Stromberg Reach 5.

Reach Potential and Limitations

At potential, vegetation communities that are characteristic of perennial flow are expected. However, recent declines in baseflow in this perennial section of the San Pedro River have raised concerns about the sustainability of natural groundwater discharge to the river and the floodplain alluvium. Survival and expansion of hydric herbaceous communities described for the active channel of perennial reaches depends on continued and sustained discharge from the regional groundwater flow system.

PFC Findings

Reach C was assessed on April 13, 2012. It was rated Proper Functioning Condition, in the lower third of the rating category. The primary rationale for the rating was that there were only two items given a "no" response and neither were considered significant for function in this reach (sinuosity due to some channel straightening, and presence of unstable beaver dams). The reach contains well-developed and robust vegetation and is developing the appropriate channel characteristics, exhibits stable banks, and adequate floodplain access. Reach C has two fences that were constructed on the streambank, probably to protect the railroad bed. The fence across from Garden Wash is still intact and on the streambank, the one farther downstream is now in the channel due to bank erosion. There were varied opinions whether pulling them out would cause more harm than good.

Overview of Key Attributes and Findings

<u>Hydrology</u> – Throughout most sections of the reach, the frequent floodplain is accessible during 1-2 year events. While beaver dams are present, they are not stable and tend to wash out during periods of high flows, but they rebuild during low water periods. Beaver tend to locate dams on the tributary sediment fans; the tributary fans largely control the gradient even without dams. The beaver dams provide additional important water storage during low water periods.

Sinuosity was rated "no" as some past straightening has occurred for agricultural purposes and possibly for the highway bridge, but even the straightened areas are relatively stable due to cottonwood trees, willow, and other vegetation armoring the banks. The riparian area is expanding with both woody vegetation, largely seep willow, and strong herbaceous communities that are expanding both into the river channel and up the banks to the frequent floodplain.

Very vigorous bulrush stand, some 6' tall, extends from channel to atop the frequent floodplain.

Cottonwood trees on left at base of terrace; floodplain area, active channel bar right.

<u>Vegetation</u> – All vegetation items were given a "yes" response. Bulrush communities were notably more developed in portions of this reach than upstream; they were very vigorous and showed considerable expansion. A wildfire reduced the extent of cottonwood trees downstream from the bridge; many sites are now occupied primarily by Goodding's willow and seep willow.

<u>Erosion/Deposition</u> – Similar to reach B, the ephemeral tributaries deliver high amounts of sediment that create the multiple river forms – standard form, ponded form, fan/transition form, which are part of the potential. The existing combination of well-developed and expanding woody and herbaceous vegetation plus large woody material is able to appropriately process the sediments from the reach and tributaries during high flows, and adequate water is maintained during low flow periods. However, continuing channel evolution and development of vigorous and dense vegetation communities is important for sustainability and increased water storage in floodplain areas.

Reach D: PFC Assessment Narrative

Reach Overview

Reach D (part of Stromberg reach 6) is a 1.4 mile reach. About half of the upper portion of Stromberg reach 6 is private land; no assessment was made of conditions on private lands.

Reach Potential and Limitations

At potential, vegetation communities that are characteristic of perennial flow should be expected. In reach D, survival and expansion of hydric herbaceous communities described for the active channel of perennial reaches depends on continued and sustained discharge from the regional groundwater flow system.

PFC Findings

Reach D was assessed on April 16, 2012. It was rated as Functional-at risk with a not apparent trend. The reach is very close to PFC, and could quickly move upward to the next category in a short time (likely only a few years) with total elimination of grazing impacts. The primary reason for the FAR not apparent trend rating was inadequate riparian vegetative cover to protect banks during high flows. The cause is partially due to unauthorized and unmanaged grazing. Cattle and deer are grazing bulrush and seep willow on accessible bars, and hoof damage is occurring to developing communities of bulrush that are in tender stages. Without these impacts, trend would be upward based on overall vegetation development.

Several large washes deliver considerable amounts of coarse sediment to the stream in this reach. The depth of some of the deposits makes it difficult to establish vegetation; coarse materials dry more rapidly than the plant roots can grow to reach groundwater depths. These bars sometimes pulse down the stream, scouring out sides. As more vegetation is established over time, the stream will be able to more effectively process the contributed sediments.

Overview of Key Attributes and Findings

Hydrology – A floodplain is available and accessed, although it appears to be less accessible to the most frequent flows than floodplains higher up-river. A key need for reach D is to continue expansion of the riparian zone; narrowing the channel inward to develop a more efficient river for processing sediments, and expanding up the banks to increase strength and stability from the low flow channel to the top of the frequent floodplain.

Small unstable beaver dam on tributary fan, several dams in reach, not being maintained.

Moson Wash (also called Escapule Wash) carries much sediment during high flow events.

Vegetation – All vegetation items were given a "yes" response, except item 11 because the amount of stabilizing vegetative cover is inadequate, and overall the stream in this reach is earlier in its evolution in terms of vegetation development. As noted above, development is being retarded by unauthorized grazing. However, the riparian area is expanding in most places. Over time, much more bulrush is expected to develop in this reach.

Erosion/Deposition – Given current channel conditions and vegetation, the river has difficulty processing the heavy sediment load that is provided by the two large washes in this reach. While there was some initial thought given to the hypothesis that this might be the expected natural condition based on reach potential; the interdisciplinary team ultimately noted that there is room for improvement. If vegetation is allowed to improve and increase along the banks, it will help narrow the channel, and improve the processing of sediments by: (1) getting flood flows out of the channel, (2) reducing energy by increasing deposition on the floodplain, and (3) improving efficiency of within channel sediment transport.

Reach E: PFC Assessment Narrative

Reach Overview

Reach E is 3.8 miles in length. PFC reach E corresponds to Stromberg reach 7. The reach is more naturally confined by the Charleston Hills than above reaches, resulting in a narrow river valley with room for only small areas of floodplain adjacent to the river.

Reach Potential and Limitations

At potential, vegetation communities that are characteristic of perennial flow should be expected. In reach E, confinement of post-entrenchment surfaces by shallow bedrock is a limitation for storage of floodwaters that would benefit downstream reaches. In addition, survival and expansion of hydric herbaceous communities described for the active channel of perennial reaches depends on continued and sustained discharge from the regional ground-water flow system.

PFC Findings

Reach E was assessed on April 16, 2012. It was rated as Proper Functioning Condition, in the lower third of the rating category. The primary rationale for the rating was all pertinent assessment items were given a "yes" response. This was the first reach that recruitment of very young cottonwood seedlings (1-3 years) was observed near the channel in several locations (root sprouts were observed upstream). Other vegetation, including bulrush, showed clear expansion along the active channel and banks. There is the opportunity for continuing improvement of vegetation and narrowing of the active channel over time as the riparian area expands inward. However, the reach, in its current state, has the ability to retain its dimension, pattern and profile through moderately high flood events.

Downstream view to old Charleston Bridge showing excellent bulrush and Baltic rush growth, both banks.

Small patch of young cottonwood trees established from seeds.

Overview of Key Attributes and Findings

Hydrology – Reach E is a landform-controlled reach with naturally low sinuosity and only narrow areas of floodplain adjacent to the river. It primarily serves as a transport reach. A few sections likely have reached the potential extent of riparian vegetation, while others will continue to expand. Only one beaver dam was noted, located near the beginning of the reach, at the lower end of a tributary fan. The dam is being maintained by beaver and is one of the more stable dams observed on the river (see below).

Beaver dam, upstream view, provides additional water storage for plant establishment, some vegetation growing on dam.

Vegetation – The reach is well-vegetated throughout, with a full complement of woody species with diverse age classes including young cottonwood trees, bulrush, Baltic rush, and spikerush, often forming well-developed communities. These communities are expected to continue to expand well into the future, moving the reach condition towards potential.

Erosion/Deposition – In the area of the old Charleston town site, several large washes provide large sediment inputs to the river causing the channel to jump from one side of the river bed to the other, frequently. However, the river effectively processes this sediment in a relatively short distance downstream.

Reach F: PFC Assessment Narrative

Reach Overview

Reach F is 8.9 miles long. It is a combination of Stromberg reaches 8 and 9, plus a 1.1 mile length of reach 10 to the Fairbanks trestle. During pre-work, the interdisciplinary team planned for reach F to end at the mouth of Walnut Gulch; however, once in the field, they agreed that the characteristics of the reach continued down to the Fairbanks trestle.

Reach Potential and Limitations

Along this reach, flow transitions from perennial to intermittent. The upper portion of the reach should be able to support vegetation characteristic of perennial flow. The lower portion should support vegetation characteristic of intermittent flow. The extent of base flow depends on the total amount of water in the system upstream; flow persists through the entire length only in the wettest years. Improvement in bank storage and release here and upstream, and continued groundwater inputs here and upstream, could extend perennial flow farther down this reach.

PFC Findings

Reach F was assessed April 16-17, 2012. It was rated as Functional-at risk with an upward trend and falling in the middle third of the rating category. The primary rationale for the rating was that while vegetative condition was improving in all categories, key riparian plant species are not present in adequate amounts to stabilize the banks and impede mobilization of the stream bed during high flows. If the vegetation continues to improve, improvement in channel characteristics will follow.

Overview of Key Attributes and Findings

Hydrology – Floodplain access was not evenly distributed throughout the reach. For the first mile, the channel was overly wide. The width/depth ratio was out of proportion to the valley, limiting floodplain access. It was also noted that the stream is still developing sinuosity and cutting into the terrace in places. No engineered straightening was observed. Finally, the riparian area is clearly expanding, evidenced by both the existing condition of vegetation and also comparison of current conditions with historical photos.

Vegetation – Improvement is needed in the amount of stabilizing vegetative cover. This stream type should have a minimum of 70% of the bank protected by stabilizer plant species along with embedded wood and/or rock; however, it currently ranges between 50-60% based on ocular estimates. All of the other vegetative elements are in working order and will continue to evolve towards more stability given continuation of existing management and no loss of groundwater inputs to the reach.

Erosion/Deposition – Reach F does not produce the same type of sediment fans at the mouth of ephemeral tributaries with a ponded form above, as seen in previous reaches. Where good vegetative cover exists in combination with a suitable floodplain area, sediment is being processed well. However, major portions of the upper and lower end are overly wide sand bed channels where deposits are moved around and not stabilized by vegetation. Continued recovery should include expansion of stabilizing herbaceous plant community types along both the lower edge of the bank and along the low water channel. This will improve the processing of transported sediments, allowing them to be captured and aid in floodplain development.

Group looking for indicators and measuring level of frequent floodplain.

Stream cutting into terrace, strong cottonwood roots forced river to cut upstream; seep willow on point bar.

Reach G: PFC Assessment Narrative

Reach Overview

Reach G begins at the Fairbanks Railroad trestle. It was modified in the field by adding the first 1.1 miles to reach F due to the similarities in vegetation and channel characteristics; the remainder of reach G is 1.0 miles long and is part of Stromberg reach 10.

Reach Potential and Limitations

Reach G is predominantly a sand-bed channel with significant amounts of gravel and coarse material. This wide, shallow, coarse channel displays substantial infiltration through the bed so that the river no longer maintains perennial flow. Potential riparian vegetation for this reach is typical of that characterized for intermittent stream reaches.

PFC Findings

Reach G was assessed April 18, 2012. It was rated as Properly Functioning Condition in the middle third of the rating category. All checklist items were given “yes” responses with the exception of beaver dams (NA) and checklist item 14 regarding point bars (NA). This intermittent section is progressing well towards potential, and developing the appropriate vegetation, floodplain and channel characteristics consistent with its intermittent status. Bedrock rises to the surface at the lower end of the reach, helping to keep more water on the surface.

Downstream view, relatively narrow U-shaped channel. Well-developed vegetation for intermittent reach.

Tamarisk providing vertical structure that stops and holds large/coarse wood in place.

Overview of Key Attributes and Findings

Hydrology – This somewhat confined reach has an appropriate width/depth ratio; floodplain access is likely limited to those flows associated with 3-year flood events. There was discussion that the sand bed mobilizes to increase conveyance during high flow events but some areas may be inundated in more frequent flood events. Although not at potential, the riparian area is widening due to well-developed and expanding vegetation communities. As the riparian vegetation continues to expand toward the stream (assuming the riparian area does not dry out and contract due to groundwater pumping), channel narrowing will occur and provide additional opportunity for overbank flows. Channel deposits appear smooth and sediments are being processed well, easily in balance with the amount of water supplied by the watershed.

Vegetation – All vegetation items were given a "yes" response for both woody and herbaceous species; the percentage of bank cover is easily adequate and appears to be more than is necessary for function (has approximately 80% cover at this time). Further downstream in the intermittent reaches, tamarisk (an invasive species) has increased. Recruitment potential for large wood is somewhat limited in this reach because, in general, there is only a narrow band of cottonwood along the banks, but no galleries. However, when considered in combination with the cottonwood trees present in upstream reaches, they are considered adequate to provide the recruitment necessary for function.

Erosion/Deposition – All attributes and processes are operating well in reach G and all items were given a "yes" response. Stable banks were noted.

Reach H: PFC Assessment Narrative

Reach Overview

Reach H generally corresponds to Stromberg reach 11, and is 2.8 miles in length. The reach was modified in the field due to some changed conditions starting above the mouth of Willow Wash and extending into the first part of Stromberg reach 12.

Bedrock is exposed at the beginning of the reach, and then shortly thereafter Willow Wash enters the San Pedro River and fundamentally alters the stream throughout the reach (Figure 9). Willow Wash is an ephemeral wash associated with a much larger watershed than Walnut Gulch, which enters a few miles upstream. As a result, it is contributing more sediment and coarser sediment to the river, than Walnut Gulch.

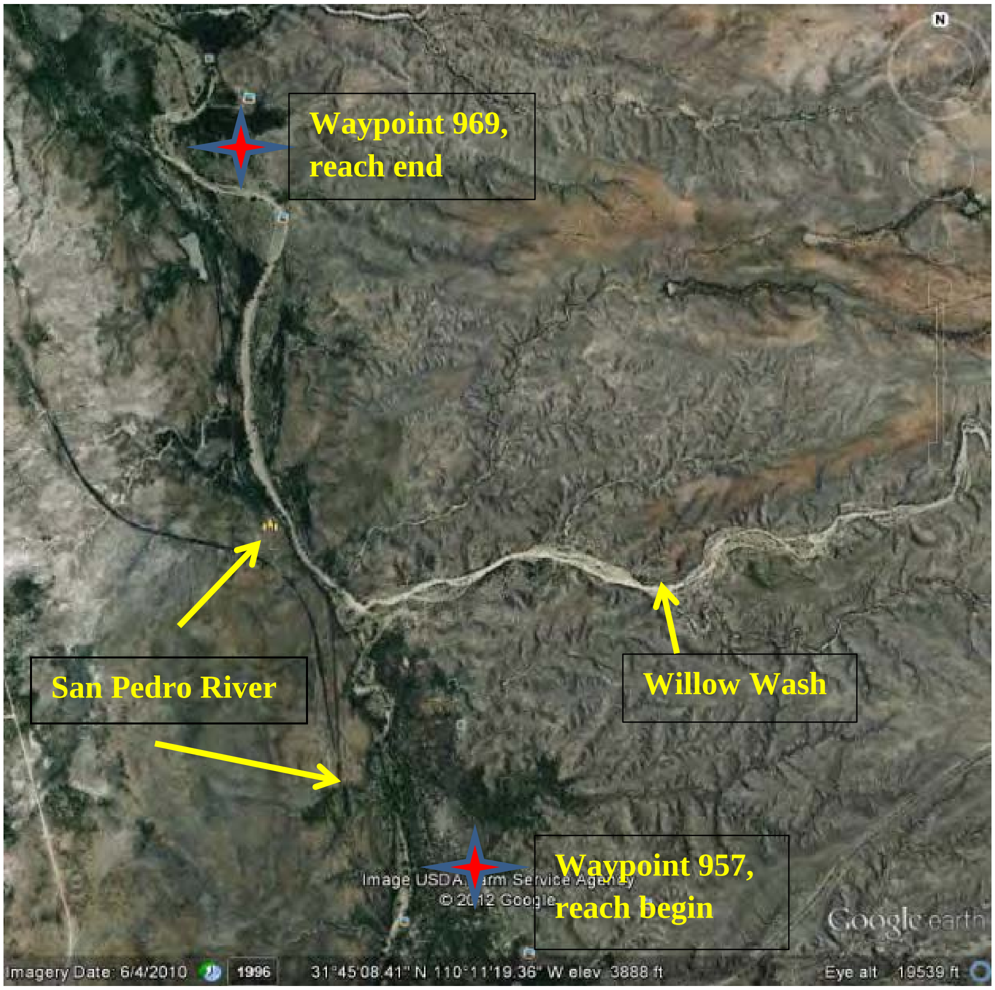

Figure 9. Google Earth image showing Willow Wash entering San Pedro River.

Reach Potential and Limitations

In reach H, the San Pedro River is predominantly a sand-bed channel with some gravel and coarse material. This wide and shallow channel displays substantial infiltration of water through the bed so that the river no longer maintains perennial flow. Potential riparian vegetation is typical of that characterized previously for intermittent stream reaches. Willow Wash sediment contributions dominate the condition of this reach, an element that is clearly visible on aerial photographs (Figure 9).

PFC Findings

Reach H was assessed on April 18, 2012. It was rated as Functional-at risk with a not apparent trend. The primary rationale for the rating is inadequate vegetation along the channel and floodplain to effectively capture sediments during high flows. More vegetation is needed to capture available wood and provide additional roughness to slow water velocity for sediment capture.

While intermittent, reach H should have more well-developed vegetation than it currently does; reaches above and below reach H have much better riparian vegetation conditions. The large amounts of sediment flowing from Willow Wash seem to overwhelm the river's ability to adequately process them as needed for vegetation to establish. A review of successive photos beginning at the photo point at the mouth of Willow Wash (looking north), show a series of recovery years, from 1987 to 1998. Prior to 2004, major flows of sediment from Willow Wash were deposited in the San Pedro River.

Down channel just below Willow Wash showing large cobble bed.

Upstream view.

The river was able to rebound and recovery is seen again between 2005 and 2008 when another flood flow occurred from Willow Wash. While there is a visible increase in riparian vegetation between the 2008 photo and the 2012 photos, it is likely inadequate at this time to establish an upward trend given the sediment from Willow Wash. Reach recovery has been essentially stalled due to repeated high flow events, thus no apparent trend was noted.

Overview of Key Attributes and Findings

Hydrology – Lack of adequate floodplain areas along much of the reach is considered a problem for sediment processing. There was an obvious lack of mature shrubs (or small trees) close to the channel to capture available logs to help build areas for sediment deposit and bank building. Additionally, the sand-bed channels are likely mobilizing during high flows, lowering the bed and then refilling as water levels subside. As a result, the reach is unable to establish a functional floodplain. Riparian vegetation, which could help narrow the channel and develop the floodplain by widening the riparian area inward, was patchy.

There are two theories as to why sediment is not being processed well along much of the reach: (1) there is excess sediment supplied by the watershed (i.e., Willow Wash), or (2) because of the intermittent nature of the flows and naturally high sediment inputs from the watershed, it is taking longer for riparian recovery on this reach.

Vegetation – While the species needed for riparian function are present, including young cottonwood, reach H needs much more vegetation along the banks to help develop improved floodplain characteristics. There were more facultative and facultative-wetland species present here than in previous reaches, as would be expected in an intermittent section. Ash, a tree that grows in drier conditions, was more common than in higher reaches. Overall, vigor was high on ash, deer grass and other species, however, some dead/dying tops were observed in the willows and cottonwood trees between Willow Wash and Tombstone gage. Furthermore, reach H has apparently lost cottonwood trees, in small patches, from wildfire. Large woody material from upstream reaches will be important for continued recovery. Some cottonwood trees are showing signs of stress in reach H (dead tops). Groundwater data is necessary to determine the cause so appropriate management actions can be identified.

Erosion/Deposition – As previously noted, there is a need for improved floodplain characteristics to better manage water and sediment. Currently, there is inadequate roughness to slow water, allow for sediments to deposit and become vegetated. In particular, there is a need to develop more woody structure such as cottonwood trees along the floodplain to stop large/coarse wood. In some places tamarisk was fulfilling that functional need.

Reach I: PFC Assessment Narrative

Reach Overview

Reach I is 4.3 miles in length, and generally correspond to Stromberg reach 12. Stromberg's reach break between 11 and 12 did not correspond with a clear change in channel morphology and riparian vegetation, so the bottom of reach H and the beginning of reach I was modified in the field to go farther downstream from the original reach delineation. The revised reach begins near Contention, and ends at the St. David diversion. Although this reach lies between reach H and J, which were both rated functional-at risk, reach I was in surprisingly good functional condition.

Reach Potential and Limitations

The wet/dry map done by The Nature Conservancy and BLM shows that a substantial length of reach I has surface water in the channel through the dry season in some years. The reasons for this are not entirely clear. One theory is that the wet segments are where the river runs parallel to groundwater level contours and groundwater is discharged. It appears that short segments of this otherwise intermittent reach may be capable of maintaining plant communities more characteristic of perennial reaches. In particular, a short segment near the beginning of the reach has been wet in all 14 years of wet/dry mapping.

PFC Findings

Reach I was assessed on April 19, 2012. It was rated as Proper Functioning Condition in the middle two-thirds of the rating category. The primary rationale for the rating is that every pertinent checklist item was given a “yes” response. Some sections appeared to have reached the potential extent of riparian vegetation, while others can still expand. As noted in the discussion on potential, this reach is substantially different from the reach immediately up and downstream. The vegetation and channel characteristics of reach H (upstream) are simply overwhelmed by the frequent and large infusions of coarse sediments from Willow Wash, and most of the water flows through the sands and gravels. As a result, the river is unable to manage the large sediment inputs and forms floodplains in reach H. At the beginning of reach I, however, there is a dramatic change. The channel narrows, water is much more consistent on the surface, vegetation associated with perennial flows is present throughout most of the reach at the expected locations, and there is clear evidence of riparian expansion, both on the low bars and near the bankfull level.

Overview of Key Attributes and Findings

Hydrology –Reach I is characterized by a narrow channel, abundant floodplain areas frequently accessed by high flows, and cottonwood galleries; not just a band of cottonwood as in the reaches above and below. These galleries are accessed by overflow channels. The channel is comprised of much finer materials (silt/clay) than the reaches either above or below, much of which comes from the wash where the railroad grade is immediately adjacent to the stream. The change in character is very evident from the beginning of reach I in terms of both vegetation and channel characteristics. The well-developed riparian vegetation has been able to effectively capture sediment, thereby narrowing the channel and increasing floodplain access. In places, the stream is still increasing its length by cutting into the pre-entrenchment terrace. Ponded form was not found in this reach, nor any beaver activity or dams.

Vegetation – All the vegetation items were given a “yes” response. There is an expanding area of herbaceous and woody vegetation along most of the channel that will facilitate channel narrowing and further improve the ability of the reach to process sediments.

Downstream view showing very healthy vegetation and narrowed channel near beginning of reach.

Upstream – retake of photo at Summers Well – point bar vegetating from active channel to floodplain.

Erosion/Deposition – Floodplain features and overflow channels, coupled with well-developed stabilizing vegetation on the banks, are working well to dissipate the energy from flood events. Bars along the reach are vegetating well; unlike most other reaches a few well-defined point bars were noted (see photos above). About half way down the reach, a tributary delivers clay to the river which holds more soil moisture.

Reach J: PFC Assessment Narrative

Reach Overview

Reach J is 5.5 miles long. Only the first 4.2 miles were assessed from St. David diversion down to the private land boundary at Flowing Well (Stromberg reach 13 and about half of 14).

Reach Potential and Limitations

Reach J is composed of a wide, shallow, sand and gravel channel susceptible to high infiltration losses along its entire length. In addition, the St. David diversion at the upstream end, at times, diverts surface flow from the river. For these reasons, reach J is dry a good portion of the year. The potential vegetation communities should have the same characteristic of those along intermittent reaches discussed earlier. Limitations arise from the loss of base flow and the diversion of stream flow.

Near the downstream boundary of the SPRNCA, springs and artesian wells outside the stream channel indicate regional groundwater discharge from the confined, deep aquifer in this area. St. David Cienega lies west of the river here and is reportedly supplied by artesian water. Apparently, the silt/clay confining layer that separates the base of the pre-entrenchment alluvium from the top of the basin-fill is only partially effective at limiting upward movement of deep groundwater in this area. However, the expression of this water source in the vegetation along the river primarily occurs downstream of reach J and the SPRNCA boundary.

PFC Findings

Reach J was assessed April 20, 2012. It was rated as Functional-at risk with a downward trend, just barely above non-functional. The reach is behaving more like an ephemeral channel in terms of its hydrology and erosion-deposition; but the presence of riparian vegetation provides evidence of a relatively accessible water table along at least parts of the reach. Cottonwood trees were present along parts of the reach as well. On the intermittent scale between perennial and ephemeral, reach J is on the drier end. The primary rationale for the rating is that basically none of the needed channel characteristics were functioning. While the right kind of riparian plants were present along most of the reach, vigor was relatively low on seep willow near the top of the reach. Young cottonwood showed evidence of livestock use over a period of several years that is preventing the trees from developing normal growth form. Goodding’s willow, an obligate wetland species, occurred in portions of the reach but was noted to be low in vigor on some sites. Lack of vigor was the primary factor in the downward trend determination because recovery is dependent on increasing plant species required for function, and a lack of vigor in these species will prevent recovery.

Overview of Key Attributes and Findings

Hydrology – The channel in reach J is functioning more as an ephemeral system than an intermittent, as described in the reach potential section. Well defined banks and the needed floodplain area are not present along most of the reach. Sediment depositions are not being vegetated or appropriately processed. There is a decided lack of floodplain and/or channel roughness that could serve to slow water during high flows to set up vegetation recovery. During flows that are high enough to be diverted but not blow out the push up dam, water is lost to the St. David diversion. Additionally, modeling shows groundwater pumping has negatively affected the Babocomari River flow (Lacher 2011), and subsequently less water is available to all the downstream reaches including reach J. Repeat photos compared to 1987 demonstrate improvement in terms of some bank formation and an expanding riparian area. In 1987, it is likely the stream would have been rated non-functional, but repeat photos are only available at a few points making it somewhat difficult to come to that determination.

Vegetation – The primary woody riparian species are Goodding's willow, an obligate plant species, along with seep willow, ash, tamarisk, and cottonwood trees. The primary herbaceous species is sacaton, a facultative grass. Rabbitsfoot grass was common, and was the only herbaceous species that occurs more in wet areas than dry. Vigor was observed to be a problem; at the upper portion of the reach, seep willow exhibited low vigor (yellow leaves (chlorosis)), but improved lower downstream. Goodding's willow also appeared stressed (dead tops) in portions of the reach. Young cottonwood trees had a clubbed growth form from repeated livestock browsing. While there was good diversity in woody species and age class, there was an inadequate amount present for bank stabilization and not enough large wood being grown in the reach for long-term maintenance. Additionally, there was a lack of woody structure along the channel and banks to stop large/coarse wood to facilitate deposition and channel formation. Large wood being entrained is critical to the health of all reaches of the San Pedro River within the SPRNCA.

Seep willow is developing on some of the bars (a clear increase based on historical photos) and will begin to capture smaller wood and sediments if expansion continues. In this stream system, seep willow plays an important role in early stabilization of bars and capture of sediments and organic materials that facilitate improvement. Given the high diversity of suitable riparian woody species along with multiple age classes, the vegetation foundation for recovery is present, contributing to the rationale for the functional-at risk rating. Two important components of recovery for reach J are: (1) the need to release of young cottonwood to grow into trees (current browsing is preventing this), and (2) the need to improve the vigor and expansion of seep willow bands and patches along the channel.

Erosion/Deposition – There is inadequate area of accessible floodplain, overflow channels, and other features that could slow down water and improve conditions for accelerating vegetation growth that is critical to development of channel and floodplain characteristics. The over-wide channel transports all the water through the reach, along with wood and debris and sediments that could build a healthier system if it could be slowed, processed and vegetated.

Young cottonwood with mid-age and older in back left; off-highway vehicle tracks throughout.

Young cottonwood appears more shrub-like than tree form from repeated grazing.

Overarching Findings, Issues and Management Considerations

<u>Groundwater Connection to Riparian Vegetation</u>

Findings/Observations

The PFC assessment is a qualitative, visual protocol that does not directly evaluate groundwater impacts. The effects of declining groundwater can cause visible changes in the kind, condition, and distribution of riparian vegetation, but generally only when the decline is so rapid or advanced that there is an obvious widespread reduction in plant vigor, high plant mortality, or an obvious increase in drier plant species in those in those moisture zones and within those plant communities that are sensitive to changes in water availability. In general, detecting groundwater declines using visual indicators of vegetation condition is a somewhat coarse approach because it is not particularly sensitive and subtle changes in riparian vegetation can be attributable to other impacts (insects, disease, weather, etc); therefore, a more sensitive approach is needed accurately assess groundwater declines. Linking riparian vegetation attributes to hydrologic factors will require quantitative measurements over time to understand how the riparian vegetation is being affected by changes to surface water, soil water, and groundwater levels (Cooper and Merritt 2012).

Stream gage measurements and modeling (e.g. Lacher 2011) clearly show diminished San Pedro River baseflows over a sustained period of time, but as long as there are baseflows, existing plants may still have soil water conditions for growth (particularly mature woody plants as they are more deeply rooted). Aquatic organisms and conditions are more sensitive to declines in baseflow.

The team did not see an obvious widespread reduction in plant vigor, high plant mortality, or replacement of wetland plants by drier species in a pattern that would indicate an advanced groundwater decline. Some riparian vegetation did show signs of stress in a few areas (e.g., cottonwood trees with contracted canopies or dead tops), but all reaches, except reach J, were dominated by vigorous, healthy plants.[16] The current signs of stress could be attributable to several factors that we could not determine from a qualitative assessment. This does not mean that groundwater levels are not declining; rather, it means that quantitative measures of groundwater, soil water, and vegetation characteristics are needed to document earlier indicators (Greg Auble, personal communication, 2012; David Merritt, personal communication, 2012; Scott et al. 1999).

By the time vegetation displays the impacts of groundwater depletion, it will likely be too late to stop or reverse the deterioration of riparian conditions. If Lacher's (2011:4) prediction that "much of the San Pedro and Babocomari Rivers will cease to have perennial baseflow over the next century as a result of increased groundwater pumping" ultimately came to pass, we conclude it would have a negative impact on the physical functioning of the system.

Issues

In reaches F through J, the assessment team discussed whether the potential should be that of an intermittent or perennial stream. However, the riparian plant communities observed and documented on terraces, floodplains, and streambanks were consistent with the existing hydrogeologic information for these reaches, with reach F transitioning from perennial to intermittent at potential, and reaches G-J being intermittent at potential.

The dead and low-vigor plants that occurred in some localities were discussed. In some instances the low-vigor, dying, or dead plants could reflect damage from record cold winter temperature in February 2011; however, the dominance of healthy plants was an indication that frost damage was not significant. Another factor contributing to plant stress was an infestation of tent caterpillars (particularly evident in reaches A through C). The herbivory by tent caterpillars is also not evidence of water-table decline. To the contrary, because caterpillars were browsing newly formed leaves and buds throughout the entire canopy of mature cottonwood trees, the opposite could be concluded as this is evidence that sap flow was reaching the entire canopy of cottonwood trees. Elsewhere, cottonwood trees with a contracted crown were cited as evidence of groundwater decline; however, this could have been the result of several other factors (Figures 10a and 10b).

[16] Further analysis and discussions are needed, and are recommended during the upcoming RMP process.

Figure 10a. An individual, mature cottonwood tree near the Tombstone gage in reach H has limited extent of live canopy. The cause of canopy reduction is unknown due to the comparative vigor of adjacent trees. The slope in the background leads up to the Presidio.

Figure 10b. All the other mature cottonwood trees observed within one-half mile downstream of the Tombstone gage (shown at right) have fully leafed canopies and appear completely vigorous.

Management Considerations

In addition to the BLM's efforts to pursue perfection of water rights for instream flows and groundwater levels as directed by Congress, the most important NRST recommendation is for the BLM to continue to regularly monitor the wells close to the river that are intended to measure groundwater flow and hydraulic gradient following a quality assurance program. The NRST also recommends that analysis of historical water levels—similar to the analysis provided for a few wells in the 321 report—be extended to all shallow wells along the river with historical water-level data. The NRST suggests that periodic reports summarizing water-level data be produced in cooperation with the USGS.[17] This will turn data into information that is useful for management, and it is the only way of knowing whether or not groundwater discharge to the river is reduced. It will be valuable information to go along with the regional aquifer well data presented in the 321 report (Upper San Pedro Partnership 2012).

Also, if riparian vegetation is showing signs of stress, groundwater monitoring from a nearby well and measurable characteristics of the riparian vegetation would help with the interpretation of whether the stress is due to a lack of water or from other causes (Cooper and Merritt 2012). Unfortunately, the NRST was not provided with monitoring data from any of the BLM wells closest to the river and/or areas where vegetative stress was noted.[18] The best scientific approach to understanding whether there is reduced groundwater flowing to the San Pedro River is through continued monitoring of the water-table level in wells located in areas of high groundwater withdrawal where modeling suggests an expanding cone of depression, and in wells located close to the river.

[17] The NRST recognizes that some of this data is part of the BLM's water right claim and is currently attorney-client privileged information. However, it is also very important information for the public to understand in order to support the hard choices that go along with dealing with the groundwater pumping deficit.

[18] The NRST recognizes that the data from nine of the 72 BLM wells are currently attorney-client privileged information and unable to be publically shared. However, access to this information would have helped the team more conclusively determine the effect of reduced groundwater levels on riparian vegetation in the few areas where stress was noted.

The potential for reach A is perennial flow; however, currently parts of the reach are seasonally dry. Therefore, restoration of perennial flow is a high management priority for this reach. Additionally, groundwater modeling (Lacher 2011) has projected that reaches D through G will be most affected by the cone of depression created by groundwater pumping in the Sierra Vista subwatershed and along the Babocomari River.

Tributaries and Sediment

Findings/Observations

The form of much of the river and the processing of sediments and water are highly related to the tributaries that enter along its length. As noted in Fogg et al. (2012), and verified during the field assessments, a repeated pattern of channel forms is associated with inputs of sediment from major tributaries along the river. Effects are observed upstream, at the mouth, and downstream of tributaries and result in increased diversity in terms of habitat niches throughout the length of the river. At the tributary mouth, large amounts of sediment result in a grade control for the section of channel above the mouth, usually creating a ponded area that may extend for ½ mile upstream of the tributary mouth. As the stream cuts through the tributary mouth sediment, a riffle section is created that is steeper in gradient for a short distance, and then usually, within a distance of 100-200 yards, a more standard form or channel shape of a low-gradient stream follows. Each of these forms (ponded form, transition form, and standard form) provides important habitat needs. For example, the Huachuca water umbel tends to be found in the standard form of perennial reaches, whereas the transition sections may offer important spawning habitat for some fish species (e.g., desert sucker). And the ponded form provides habitat for beaver and some fish. In addition, the ponded form upstream of tributary mouth fans is believed to represent conditions where future cienegas are most likely to form (Henderson and Hinkley 1984, pp. 164-165; Fogg et al. 2012, p. 18).

As the river transitions from largely perennial in the upper reaches to largely intermittent at the north end, the ponded form is lost. Reach E is the most northern extent of the ponded form associated with tributary fans.

One of the important aspects of understanding the evolution of the San Pedro system following channel incision is determining whether the sediment supply from tributaries is causing impaired conditions along the San Pedro River. Kepner et al. (2000) documented vegetation changes in the Upper San Pedro basin from the 1970s to 1990s. They found grasslands and desert scrub rapidly decreased in extent, mesquite woodland patches increased in size, number, and connectivity, and urbanization increased. They point out that principal impairment processes involves changes in vegetative cover, biomass, and diversity that leads to acceleration of water and wind erosion processes. To this end, the NRST visually examined the balance between water and sediment conveyed to and by the San Pedro River. The team gave special attention to the deposits that formed at the mouth of many ephemeral tributaries and the deposits and channel patterns that resulted downstream of the tributary mouth fans. The sediment-water balance provides information on the capacity of the San Pedro River to process its sediment load.

The potential document (Fogg et al. 2012) included a discussion of tributary-mouth fans and served as the basis for interpreting sediment load from tributary streams and the capacity for the San Pedro River to process its sediment load. Comparatively steep, ephemeral channels deliver sediment episodically to the San Pedro River in response to isolated, high-intensity storm runoff. Much of the sediment that accumulates at the tributary mouth remains there until peak discharges occur on the lower gradient trunk stream (i.e., San Pedro River). The peak flows on the San Pedro River generally occur at different times and in response to different hydro-meteorological events than those on ephemeral tributaries.

Sediment yield from ephemeral tributaries is typically high because these channels lack the riparian vegetative cover that protects stream banks from erosion and traps sediment. Furthermore, sediment yield is especially naturally high in semiarid environments (such as the Upper San Pedro Basin) as predicted by the Langbein-Schumm (1958) rule (Figure 11). The Langbein-Schumm rule illustrates that the relation between precipitation and sediment yield is not linear; rather sediment yield peaks under semiarid conditions because increasing precipitation offers the potential to move more sediment; however, it also promotes greater plant cover. Therefore, it is natural to find a lot of sediment deposited at the mouth of ephemeral tributary streams, particularly in the arid lands of the American southwest. Furthermore, large tributary fans, specifically those large enough to decrease gradient and to pond water upstream of fans, are ubiquitous in arid lands and have been previously described in the scientific literature (e.g., Cooley et al. 1977; Triska 1984; Miller et al. 2001, 2004; Germanoski and Miller 2004; Jewett et al. 2004; Chambers et al. 2011). Hendrickson and Minckley (1984) discuss this process in southeastern Arizona streams and note that tributary mouth fans can pond water that creates conditions conducive for cienega formation, which is also mentioned in Fogg et al. (2012). Large tributary mouth fans were common in reaches A through D, regardless of the degree of urbanization in the watershed or whether the tributaries drained areas east or west of the San Pedro River.

The idea of excessive sedimentation must be evaluated in terms of whether the San Pedro River has the transport capacity to process the sediment delivered by ephemeral channels. When sediment load exceeds transport capacity, then one expects to see a continuum of conditions reflecting transport deficiencies. A first indicator of excessive sediment load is a change in particle size of the stream bed, followed next by construction of mid-channel bars, then streambed aggradation (Parker 1990; Wilcock et al. 2009). Very late, or advanced, indicators of excessive sediment load include changes in stream pattern (e.g., shift from single-thread to braided channel) and finally channel slope, as these changes require much time and rearrangement of large volumes of sediment (Parker 1990; Wilcock et al. 2009).

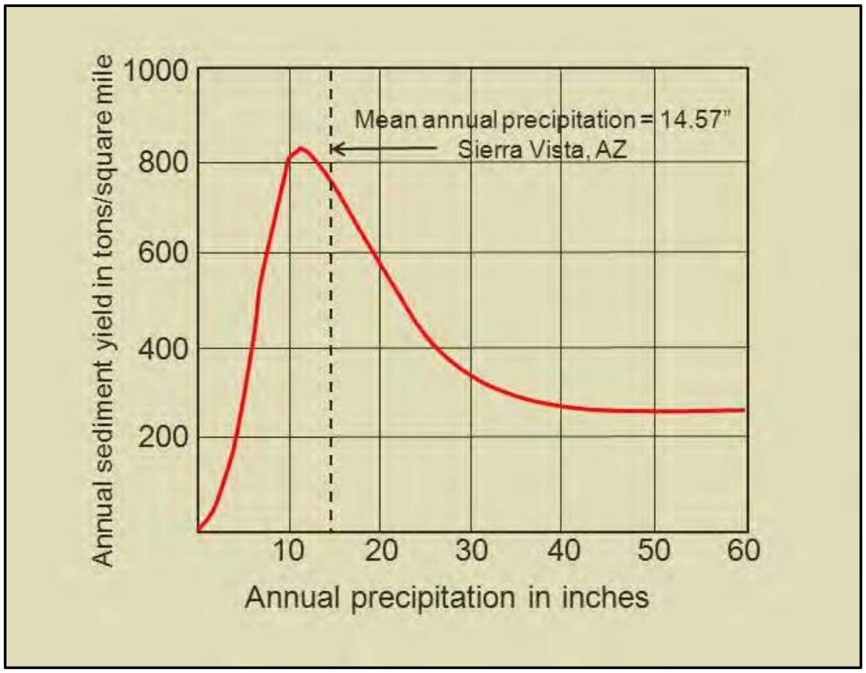

Figure 11. Langbein-Schumm (1958) sediment-yield curve illustrates that the highest natural sediment yields occur in semiarid environments where the potential for precipitation to move sediment is high, yet the vegetative cover in uplands is relatively sparse. When annual precipitation increases above the mean levels of semiarid environments, it supports more vegetation cover, which in turn protects the land surface and decreases erosion and sediment yield.

The ID team noted that the sinuosity in several reaches (reaches A, B, and C) was lower than expected resulting in a "no" response for item 3 in the assessment form. The team discussed the cause and significance of low sinuosity in these reaches. One suggestion was that the stream has more sediment than it can process, so it is compensating by decreasing sinuosity and increasing the channel gradient (gradient and sinuosity are inversely related) in an attempt to increase transport capacity. However, additional discussion noted that these reaches with low sinuosity coincided with reaches that had been channelized, or artificially straightened, to enhance former agricultural operations or to safeguard adjacent railroad grades. Also, the ID team did not observe visual indicators of excess sedimentation, specifically, a change in surface textures in the stream bed, which were similar to subsurface textures in the channel bed and the textures observed in the bed of tributaries. Furthermore, the channel had some active channel bars, but nowhere (beyond the tributary mouth fans) were mid-channel bars or braided-channel pattern observed—the telltale indicators of excessive sediment and the telltale precursor to any increase in channel slope. The fact that standard, single-thread channel form occurs within a couple hundred meters of tributary mouths is an indication that the San Pedro River has the transport capacity to move the sediment load fed to it by its tributaries. Finally, excess sedimentation should be accompanied with unstable channels, which in turn are suggested by a lack of bankfull indicators. However, in reaches A through G and I, bankfull indicators were all well developed and apparent.

Physical evidence of overbank aggradation was observed in many places, particularly in reaches A through E. Most of the aggradation is wash load (also called suspended load), composed of fine particles, silt and clay, that are readily suspended in the water column and trapped by vegetation on stream banks, or the floodplain as a consequence of overbank flooding.

Aggradation of the floodplain is consistent with the NRST findings that much of the San Pedro River has been undergoing a cycle of channel evolution since about the 1880s or 1890s (Figure 3; also see Figure 4 in Fogg et al. 2012) and is now in channel evolutionary stages IV to V, which includes processes of floodplain widening and floodplain aggradation. NRST findings are consistent with those of Hereford's (1993), who also observed that the San Pedro River system has been stable or stabilizing since about 1955. His study of a sequence of aerial photographs indicates the San Pedro River had high rates of lateral channel movement and floodplain widening from about 1900 to 1955 and then the channel evolutionary pattern shifted to vertical aggradation after 1955. Evidence of vertical aggradation includes the accumulation of finely-laminated, fine sediment on stream banks and floodplains (Figure 12a), and the burial of tree root crowns by several feet of fine-textured, overbank sediment (Figure 12b; also see Figure 2 in Fogg et al. 2012). Additional, anecdotal evidence of aggradation derives from the need to attach vertical extensions on some monitoring wells because the ground elevation has risen to the point of burying or nearly burying the tops of the wells (Jim Fogg, personal communication, 2012).

Figure 12a. Recent accumulations of woody material and mud-cracked, fine-textured sediments (left foreground) are ubiquitous on the floodplain and streambank, particularly in reaches A through E, G, and I.

Figure 12b. The visible bases of tree trunks are straight and lack the flared morphology that occurs when the root crown is at the ground surface. Straight trunk morphology indicates floodplain aggradation since tree germination. Some root crowns are buried by several feet of sediment.

In summary, the San Pedro River appears to be aggrading by building a floodplain and by narrowing its channel. In the context of channel evolution, these are favorable signs indicating that some reaches have reached proper functioning condition and that others are moving in that direction. By all indications, the San Pedro River is processing the wash load by building floodplains through vertical aggradation.[19] Features such as mid-channel bars and braided-channel patterns were not observed downstream of tributary mouth fans, supporting the conclusion that sediment is not excessive. Furthermore, the NRST concurs with Hereford (1993:42), who stated, "Factors that reduce runoff volume, increase salinity, change runoff seasonality, or reduce sediment loads are detrimental to the riparian community." Protection of both the flow and the sediment regime of this river are crucial to its continued evolution and survival.

[19] Further analysis and discussions are needed, and are recommended during the upcoming RMP process.

Issues

Although most reaches appear to be processing sediment adequately, reaches A, D, and H contain evidence that sediment loads and transport capacity are out of balance. The condition in reach A is the most enigmatic. During the April 2012 assessment, streamflow was observed in the upper and lower parts of reach A but the channel was dry in the middle interval of the reach. One possibility for the lost streamflow is that sediment is accumulating in the channel and streamflow becomes hyporheic, meaning it becomes subterranean and flows through the sediment below the channel bed. The part of the channel where streamflow is lost coincides with an area where there are agricultural fields bordering the channel. Dikes were constructed to protect the agricultural fields from discharge in ephemeral tributaries and, it seems, they have limited sediment delivery and discharge from the ephemeral tributaries. Consequently, the San Pedro River may not be receiving all the discharge it needs to move sediment through the reach.

Alternatively, reach A showed declining function from historical groundwater pumping for agricultural irrigation. Recently, The Nature Conservancy purchased and retired groundwater rights in this area, and wet-dry monitoring results show an increase in length of wetted channel within reach A, suggesting that water-table elevations are rising and streamflow conditions are improving.

The watersheds of tributaries in reach D need to be assessed to see if the amount of sediment delivered to the river is natural or has been increased due to urban development in the Sierra Vista subwatershed. Likewise, Willow Wash, which joins the San Pedro River in reach H, has had a series of high-sediment input events over the past 25 years. Each event tends to undue the riparian recovery observed during the preceding few years. A watershed analysis of Willow Wash might reveal the source of the copious sediment and whether this volume is natural or excessive.

Management Considerations

The health of the river and its riparian areas is related in part to the health of the uplands. The NRST recommends that a detailed analysis be done to determine the hydrologic impacts of agricultural dikes, railroad beds, and abandoned gravel pits within the SPRNCA, as well as conducting cooperative watershed condition assessments of tributary drainages, and follow-up with watershed improvement plans where indicated, with priority on tributaries that drain into reaches A, D, and H (Appendix D). Another study should be conducted to evaluate whether treatments to reduce mesquite in selected sites on the pre-entrenchment terrace would improve grass cover and better control upland hydrology and sediment supply.

Channel Evolution

Findings/Observations

The San Pedro River began downcutting around 1890 from its downstream end and progressing upstream to and beyond the international border (Hereford 1993). What had been a broad low-gradient valley with a shallow meandering stream (Figure 3, stage I) flowing through a generally marshy environment became a high-energy gully with the river flowing at the bottom (Figure 3, stage II). Hereford (1993) used a sequence of aerial photographs to document channel evolution from the early to late 20th century. The photography indicates the channel and floodplain widened in many places from the early 20th century to about 1955 (Figure 3, stages III and IV). From 1955 to the present, the channel has meandered little and the floodplain has evolved primarily from vertical aggradation (Figure 3, stage IV; also see Figures 12a and 12b; and Figures 2 and 3 in Fogg et al. 2012). After livestock were removed from the San Pedro River within SPRNCA in 1989, riparian vegetation has expanded tremendously. This vegetation has trapped sediment during high flows, which in turn has built stream banks and formed a narrower, deeper channel. Continuing evolution of the channel will likely occur in timeframes measured in decades before levels of dynamic stability are attained similar to those that occurred prior to entrenchment in the late 19th century.

Although the channel has meandered little in the past 50 or more years (Hereford 1993), the dominant channel- and floodplain-forming processes result from vertical aggradation and episodic lateral movement of the channel. Episodic lateral movement occurs when large woody debris jams or large volumes of sediment delivered by tributaries obstruct the main channel and divert flow into an overflow channel which then evolves into the dominant channel. This process is most common in the transition form, which occurs at or immediately downstream of tributary fans (refer to Fogg et al. 2012). This channel-switching process is more akin to channel avulsion and not to point-bar meandering (Appendix A, reach B, photo 53 shows an example of this).

Various depositional bars were observed in the San Pedro River channel; the interpretation and significance of these were discussed during the assessment. The NRST found very few point bars in the San Pedro River (Figure 13a). A true point bar is recognized by an upward-fining sequence of sediment (e.g., gravel sediment near the base, grading to silt and clay at the top) that occurs on the inside of a meander bend and extends from the channel bed to the floodplain (Figure 13a). In contrast, alternating, or side bars form on either side of a meandering, low-flow thalweg (Figures 13b and 14). Side bars are not point bars as they do not: (1) show a depositional form in which the top of the bar is connected to the floodplain (i.e., bankfull elevation), (2) have an active cutbank that has retreated laterally as a consequence of point-bar deposition and expansion, (3) coincide with lateral movement of the channel and development of channel sinuosity as a consequence of deposition, and (4) have a meander length that is typically 10-14 times channel width and a radius of curvature at the apex of the bend that is 2-3 times the channel width (Figures 13b and 14). Therefore, it is inappropriate to use side bars to determine checklist item 14, which is specific to point bars. Active-channel bars commonly form below the scour line; therefore, there is little opportunity to form and retain stabilizing plant communities on active-channel bars.

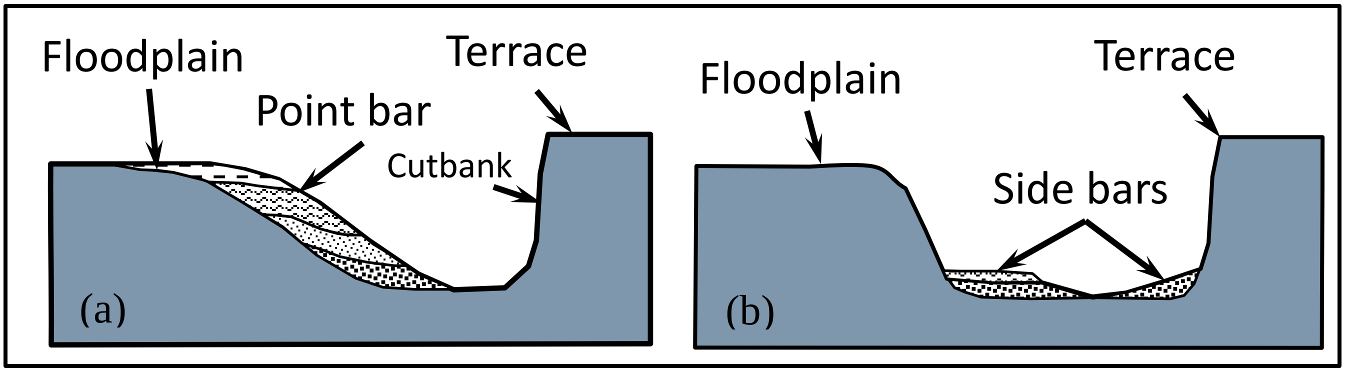

Figure 13. Channel cross-sectional diagrams illustrating (a) point-bar deposits grade upward from coarse to fine sediment and merge at their top with the floodplain; and (b) side, alternating, or active-channel bars occur on the channel bed and do not form a streambank deposit that merges with the floodplain.

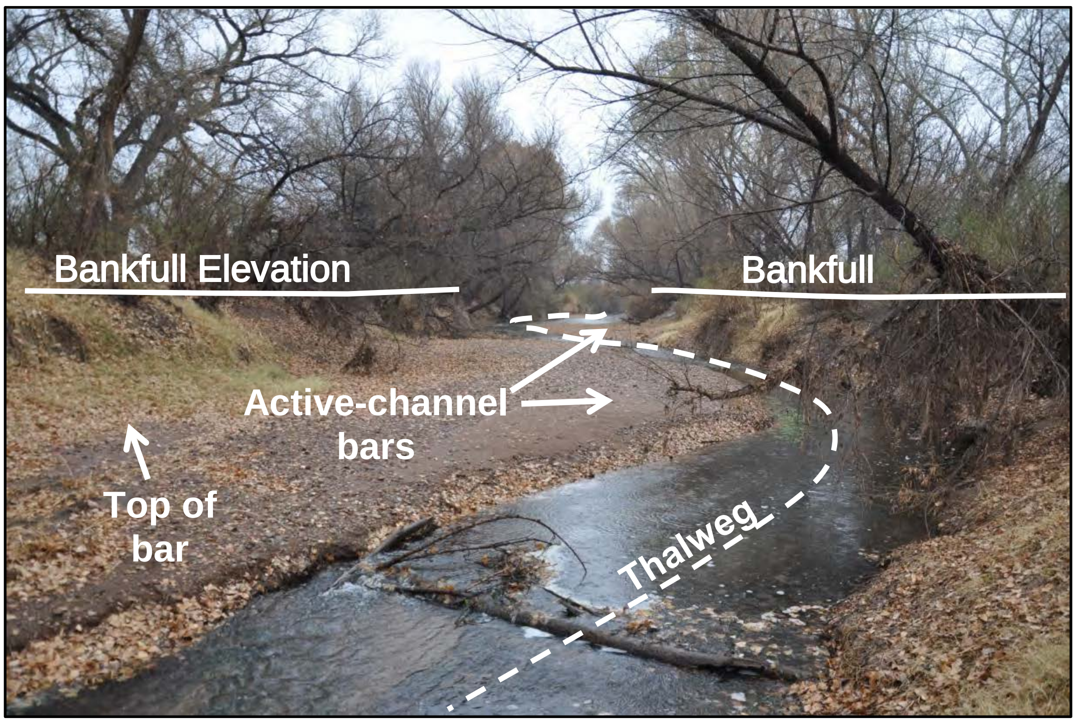

Figure 14. A low-flow thalweg (dashed line) illustrates sinuosity within a straight channel. The alternating bars are active-channel bars, not point bars. These active-channel bars do not show: (1) a depositional form in which the top of the bar is connected to the floodplain (bankfull elevation), (2) an active cutbank that has retreated laterally as a consequence of point-bar deposition and expansion, (3) lateral movement of the channel and development of channel sinuosity as a consequence of point-bar deposition, and (4) a meander length that is typically 10-14 times channel width and a radius of curvature at the apex of the bend that is 2-3 times the channel width. The radius of curvature displayed here is less than the channel width.

Issues

One issue raised during the assessment discussions was the consideration of active versus passive restoration of some sections of the river. Passive restoration is a management choice to allow the river to recover using its own processes and timescales. Active restoration involves some level of engineered approaches such as addition of in-channel engineered structures or use of less intrusive practices, such as induced meanders (Zeedyk and Van Clothier 2009). The most commonly discussed active restoration strategy for the San Pedro River was the use of induced meanders.

Management Considerations

Passive restoration is a least cost and least risk approach to recovery. The NRST agrees with Hereford's (1993:42) conclusion that "maintaining a healthy, reproducing riparian plant community is probably the most important management strategy." Though some have suggested the use of induced meanders to accelerate restoration, Zeedyk and Van Clothier (2009), the leading advocates of induced meanders emphatically point out that induced meanders are "…***for the treatment of incised channels only"*** (Zeedyk and Van Clothier 2009:81; emphasis used by original authors). They stress that "…**the goal of Induced Meandering is to halt further downcutting while simultaneously initiating floodplain development**" (Zeedyk and Van Clothier 2009:72; emphasis used by original authors).

Active restoration practices, such as induced meanders, are typically reserved for unstable channels (e.g., those in channel evolutionary stages II or III, Figure 3). There are no known case studies where stabilized or stabilizing systems are deliberately destabilized for the sake of riparian restoration. Hereford (1993) found that the San Pedro River has been stable since about 1955. The NRST concurs with Hereford's findings that the San Pedro River is no longer incising; instead it has now formed a new, inset floodplain, is stable, and is clearly aggrading vertically (Figure 3, channel evolutionary stages IV and V). Consequently, the NRST recommends against using engineered structures or induced meanders in the San Pedro River channel. Sound riparian management and passive restoration practices should be adequate to complete the channel evolutionary process.

Furthermore, because the San Pedro River incised more than 100 years ago and is now transitioning from channel evolutionary stage IV to V, the time and need for active restoration practices has passed. Installing structures or features now could destabilize a system that is either stable (i.e., reaches at PFC) or stabilizing (i.e., reaches at FAR). Not only would active restoration activities be counterproductive, they would generate great costs in human labor, materials, and money. Finally, because the river is subject to large and energetic monsoonal flood events, active restoration structures would be highly vulnerable to failure and could initiate severe, unintended channel and floodplain responses, setting back the progress made during the past 100 years of channel evolution and particularly the past 25 years of management since the SPRNCA was established by Congress.

Fremont Cottonwood Trees and Goodding's Willow

Findings/Observations

Extensive areas of floodplain have existed along most of the San Pedro River since about 1955 (Hereford 1993). As the floodplain becomes a large "sponge" of intermixed sediments and organic materials that stores water from flood events, it can slowly release water to enhance base flows within the river. This also helps mitigate the effects of prolonged dry periods, because water remains available at a level that can be reached by the root systems of riparian vegetation.

For example, a flood in October 2000 expanded the spatial extent of perennial flow into 2001 (Stromberg et al. 2006). Stream evolution in reaches B through E, all with essentially perennial flow, has reached the point where vegetation captures sediments that result in relatively rapid aggradation of the floodplain (captured under items 1 and 13 of the PFC assessment, see Figure 8), development of channel characteristics (item 3), and more frequent floodplain inundation (item 1).

Large wood is important for dissipating energy in the San Pedro River system, and the Fremont cottonwood stands will be an important source of large woody material for decades to come (checklist items 6 and 12 of the PFC assessment). Organic matter that forms from large amounts of buried plants, dead wood, and litter will increase floodplain capacity to provide stored water for plant growth and river flow in dry periods. Soils with large amounts of organic material have the ability to store and slowly release much larger volumes of water over time than just mineral soil alone (Hudson 1994). This reservoir of water in the soil is not just theoretical; volumes can be estimated based on the depth (thickness), width (extent), effective field porosity, and organic content of the younger alluvium (Holocene deposits) within the SPRNCA. Over time, this storage will provide more water to the channel, increase the growing period, and potentially help increase the length of perennially wetted channel and duration of stream flow in intermittent reaches. Both groundwater contribution from the regional aquifer and stored water from floods are needed to sustain base flows.

The extensive areas of cottonwood, along with Goodding's willow, ash, other trees, and sacaton, aided the process of floodplain aggradation and channel development and will continue to be essential given the high energies associated with flood events. Much of the desired channel narrowing and sediment capture is now being done with seep willow and bulrush in combination with large and coarse wood. Seep willow and bulrush can spread rapidly when well established and form well-developed communities that protect the banks from erosion, capture sediments and organic materials, and build banks, thereby narrowing the channel. As the channel narrows, less water is needed to fill the channel and inundate portions of the floodplain where water can infiltrate floodplain soils and recharge the floodplain aquifer. The large, strong cottonwood trees and Goodding's willow provide the overall environment where the understory species can contribute to maintaining the channel's dimension, pattern, and profile. Riparian development largely occurs near the top of the banks by cottonwood, willow, and other trees along with seep willow, and sometimes within the active channel by seep willow, bulrush, and other herbaceous stabilizers.

Without cottonwood trees and Goodding's willow providing large pieces of dead wood and strong living roots, the San Pedro River would simply have a broader flat sand bed, with few or none of the associated values that led to the designation of the SPRNCA. The same amount of water would flow through the system, but rather than part of it being captured in the floodplain and slowly released, it would pass through the system, similar to most other large rivers in Arizona. The San Pedro River is more than just the water that flows in its channel; it is part of a complete ecosystem that requires all the pieces to be in place in order to function.

The current cottonwood galleries in reaches rated PFC are primarily fully stocked stands of mature trees and since the rate of channel migration is lower now than before the galleries were established, there is less area for establishment of new trees from seed. Cottonwood trees are vulnerable to wildfire, evidenced by areas where cottonwood galleries were lost in relatively recent fires.

Issues

Misunderstanding about the role of cottonwood trees and other vegetation in stream evolution and recovery was revealed in ongoing discussions with the public and BLM partners concerning the San Pedro River. Some people questioned the importance of cottonwood trees and whether it would be better to remove the trees to reduce the amount of evapotranspiration that occurs. The thought is that more water would be available to the river if the trees and other vegetation were not using up so much groundwater. This was a similar concern on many streams in the western United States in the middle part of the 20th century when major efforts were undertaken to remove cottonwood and willow from streambanks. Normally, the trees and shrubs were sprayed with herbicides and as they died, their roots lost the needed strength to hold the banks in place; and so many streams either widened or downcut during subsequent periods of high flow. Additionally, many miles of streams were straightened to either make farming operations easier or to drain wet areas. Many streams downcut as a result of these practices and the values being sought by the landowners and managers were lost. Not until the latter part of the century did scientists and riparian management practitioners begin to understand and teach the value of riparian areas and the key role that vegetation plays on many stream types. It is undeniable that trees use water (evapotranspiration); however, it is also true that riparian vegetation aids in floodplain development, dissipates streamflow energy, and provides organic matter which facilitates flood water storage. More importantly, these are also the conditions upon which the SPRNCA was established.

Another issue is related to the factors that permit establishment of new cohorts, or galleries, of cottonwood trees. Some assessment participants questioned why old galleries of cottonwood trees did not have any young seedlings. Cottonwood trees are a disturbance-dependent species. Overbank flooding is the primary disturbance that generates establishment of a new cottonwood gallery. Establishment of seedlings within an existing cottonwood gallery is rare, because seedlings have difficulty surviving under the shady canopy of older trees; have trouble competing where grass and other herbaceous vegetation is already established; and have very specific soil-moisture requirements, which are typically satisfied by certain floods. Young cottonwood trees within older galleries rarely established from seeds; typically they form from root sprouting.

Since the pioneering work of Everitt (1968), riparian ecologists and fluvial geomorphologists have long recognized that large riparian trees, especially cottonwood trees, tend to establish in equal-aged cohorts, which mature into equal-aged galleries. Establishment typically results from the relatively rare coincidence of several factors: (1) a flood that occurs coincident with or immediately prior to seed release, (2) a flood that deposits sediment on a floodplain to create a bare mineral surface to serve as a seed bed, devoid of or lightly covered with competing herbaceous vegetation, (3) a flood that recharges a shallow alluvial aquifer, which provides necessary moisture to seedlings, and (4) moist post-germination conditions that permit growth of the roots of seedlings to keep pace with the decline of the water table during the first and second growing seasons. The coincidence of these conditions is rare; and researchers (Hupp and Osterkamp 1985; Stromberg et al. 1991, 1993; Johnson 1994; Scott et al. 1996, 1997; Shafroth et al. 1998, Gonzalez 2001a, 2001b) have found that recruitment of new cohorts of cottonwood trees typically occurs, on average, once every 10, 20, or more years.

In perhaps the most geographically relevant study of cottonwood germination, Stromberg (1998) reviewed the establishment of Fremont cottonwood along the upper San Pedro River through the SPRNCA. She noted that from the 1890s through the 1970s, flood events that generated establishment of new cohorts of cottonwood trees occurred, on average, less than once per decade, and only in the 1960s was there more than one establishment event per decade. During the 1980s and 1990s, there were 2 and 3 recruitment events per decade, respectively (Stromberg 1998). However, even though the 40-year interval from 1960s through 1990s had more frequent establishment events than the prior 70 years, the spatial area of galleries established since 1960 is less than that established prior to 1960. The decrease in spatial area is directly related to the change in channel evolutionary processes in the 1950s. Hereford (1993) demonstrated through study of a time series of aerial photographs that the San Pedro River floodplain was evolving primarily through lateral migration (i.e., channel meandering) until the 1950s and has been evolving through vertical aggradation (i.e., by storage of suspended sediment on the floodplain) and channel narrowing since the 1950s. Consequently when the active channel was wide, and the channel meander rate was high, the spatial extent of newly-formed galleries was relatively large. But when the width of the active channel decreased, the channel meandered little, and the floodplain aggraded vertically by capturing sediment, newly-formed galleries were relatively small and tended to occur in very narrow bands along the narrowing channel.

The NRST believes that the smaller size of galleries since the 1950s creates the illusion of lower cottonwood establishment. In truth, there have been more frequent establishment events since the 1950s than in the decades earlier (Figure 15; Stromberg 1998).

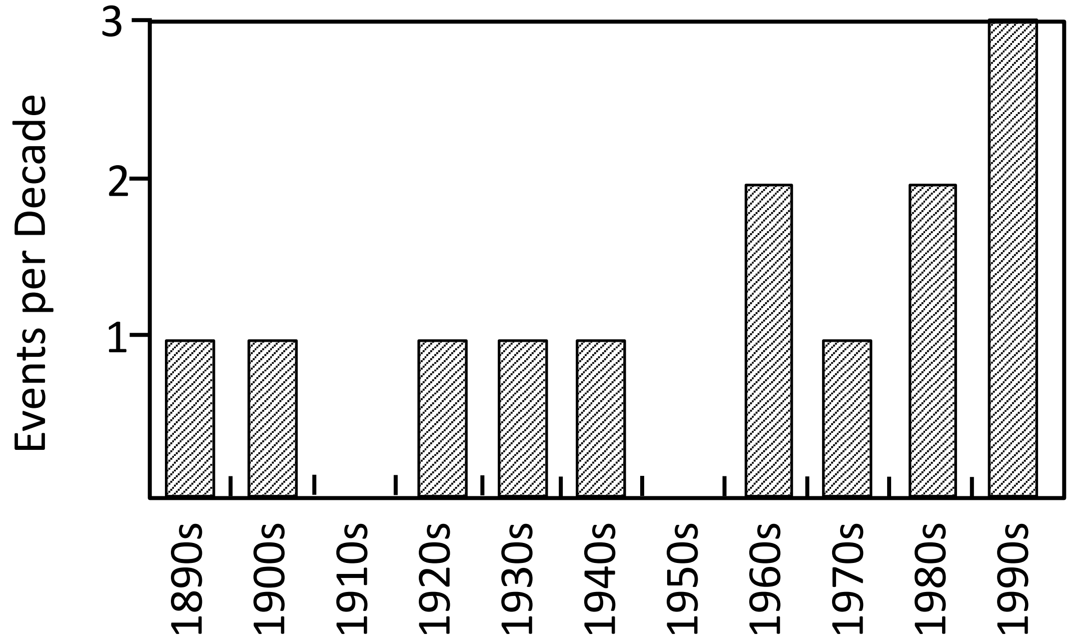

Figure 15. From the 1890s through the 1970s, flood events that generated establishment of new cohorts of cottonwood trees occurred on average once per decade, and only in the 1960s was there more than one establishment event per decade (from Stromberg, 1998). During the 1980s and 1990s, there were 2 and 3 recruitment events per decade, respectively (from Stromberg 1998). However, even though the 40-year interval from 1960s through 1990s had more frequent establishment events, the spatial area of galleries established since the 1950s is less than that established prior to the 1950s. The decrease in spatial area is directly related to the change in channel evolutionary processes at about this time. As Hereford (1993, pp. 21-24) demonstrated through study of a time series of aerial photographs, the San Pedro floodplain was evolving primarily through lateral migration (i.e., channel meandering) until the 1950s and has been evolving through vertical aggradation (i.e., by storing suspended sediment on the floodplain) and channel narrowing since the 1950s.

An individual gallery typically does not contain a broad range of age classes. The norm is for each gallery to have an equal-age cohort. However, a determination of age-class structure is not made at the scale of an individual gallery. Instead, the age of each gallery is aggregated at the reach scale (Figures 16a and 16b) to determine the structure of age classes when assessing item 6 of the PFC checklist.

Figure 16a. Mature cottonwood trees of approximately equal age line both banks of the San Pedro River a few hundred meters downstream of Boquillas Wash in reach G. These mature trees all have full canopies, broad, thick branches, and large diameter trunks.

Figure 16b. An equal-age stand of young cottonwood trees occurs on the streambank in reach G. This gallery is much younger than the one depicted in Figure 14a, as suggested by the shorter tree height, narrower crown profile, thinner branches, and smaller trunk diameter.

Management Considerations

In many reaches, cottonwood trees are at or near maximum stocking, so the management concern is taking care of existing cottonwood trees. There will be natural mortality from insects, disease, and beaver; these generally should be allowed to continue with natural processes and outcomes. However, to the extent practical, preservation and protection of existing cottonwood galleries should be a part of a vegetation management plan, and well-developed fuels and wildfire management plans (see Fire and Fuels Management below). The protection of cottonwood trees is definitely important in reaches with a functional status of FAR, because these reaches in particular, are dependent on cottonwood trees (living and dead) for energy dissipation, streambank protection, and floodwater capture and storage.

Fires have locally reduced the extent of some cottonwood galleries in reach B, but recruitment of new cottonwoods is unlikely in this reach given the low rates of channel meandering and the extensive stands of sacaton and Johnson grass. Some cottonwood trees are showing signs of stress in reaches H (dead tops). Groundwater data is necessary to determine the cause [of stress in trees], so the appropriate management actions can be identified. Recruitment of cottonwood trees is failing in reach J because of browsing from trespass livestock.

Livestock Impacts

Findings/Observations

One of the major decisions made in 1989 through SPRNCA's original plan was to exclude livestock grazing from areas along the river. An extensive collection of photographs taken along the river in the summer of 1987 clearly demonstrate a river with very little riparian vegetative cover and degraded channel conditions. Cottonwood trees had become well established along most of the river's length and although some channel definition was forming, most reaches continued to be characterized by an overly wide and flat channel. Some Goodding's willow and seep willow are visible in photos, but are not abundant. Little herbaceous vegetation is evident in the 1987 photos, and what is there tended to be very low-growing forms, or forbs that may not have been palatable to livestock. It is likely that the source of livestock water primarily came from the river itself, so the herbaceous vegetation that existed was grazed and trampled multiple times each year. This kept these plants in a state of very low vigor. In that state, even a few cows throughout the river corridor could keep the vegetation in poor condition. After livestock removal, repeated photographs document a rapid increase in cottonwood and willow species along much of the river. Release from the effects of continuous grazing also resulted in colonization by important woody shrubs and herbaceous species including seep willow, bulrush, and other strongly rooted riparian species.

A key finding of this assessment, however, is that while the BLM has made efforts to eliminate use by trespass livestock in the SPRNCA, it is still occurring and to some degree retarding recovery of sections of the river. Unauthorized grazing was found all along the river, but the detrimental impacts were more visible in localized areas and within certain reaches (see Appendix D). This provides evidence that the riparian area is not yet to a point, overall, that livestock grazing could be permitted along the San Pedro River without retarding improvement or even causing impairment. Expansion of the riparian vegetation has reached the point where rapid change is possible in many places, however, low amounts of unmanaged grazing is impacting development of vigorous stabilizing riparian communities where livestock access the streamside area. The damaging impact observed was occurring both from livestock foraging and also by livestock trampling which can destabilize streambanks and shear plant rhizomes. On reach J, which is FAR with a downward trend, livestock use on cottonwood regeneration was identified as a significant management issue that was retarding recovery.

Issues

Trespass livestock is an issue along the river corridor throughout the SPRNCA, and even though only a small number of animals use the areas along the river, that livestock use is unauthorized. At some times of the year, the riparian vegetation growing on the low bars adjacent to the river is essentially the only green forage available thus attracting cows; and water is always an attractant in areas where it is in short supply. Although the area being affected by unauthorized grazing is quite small in relation to the overall area, in some sections it is clearly having some effect on recovery. Unauthorized livestock grazing is retarding the recovery of sections of the river, and needs to be eliminated. There is also browsing and grazing by deer, javelina, and other wild herbivores, but these impacts were considered minimal by the NRST at this time, and not influencing recovery.

Management Considerations

Eliminate trespass livestock in the river corridor to provide the maximum opportunity for continued improvement and evolution of the river. This is a high priority in reaches B, D and J; and a medium priority in reaches C and F (Appendix D). Based on the PFC assessment findings, the riparian corridor and river are not yet to a point, overall, that livestock grazing could be permitted along the San Pedro River without retarding improvement or even causing impairment. Use this information along with other data and perspectives when re-evaluating grazing use in the SPRNCA during the RMP process.

Tamarisk (Saltcedar)

Findings/Observations

Tamarisk is an aggressive non-native species that occurs across much of the western United States. It often out-competes native vegetation and is extremely difficult to control through mechanical or chemical means. Tamarisk is found throughout the San Pedro River within SPRNCA with increasing populations and density south to north. It is found only occasionally in the uppermost reaches, in part due to aggressive control efforts by BLM and partners. In the lowest sections of the SPRNCA, tamarisk will potentially displace most of the willow and cottonwood over time without aggressive control; this is due to its ability to spread rapidly and its deep roots that can tap into water tables beyond the reach of young cottonwood and willow.

The Gila District BLM has an active and aggressive plan and program for managing tamarisk. Fundamentally, the strategy entails complete control and elimination to the extent possible in the upper reaches. In the lower reaches, tamarisk is eliminated as far north as is economically feasible; at some point, populations of tamarisk are simply too large and too difficult to access and treat economically. This approach allows for prioritization of limited budget and staff for doing the work. In the lowest end, the focus is on keeping areas around springs or wetter areas free of tamarisk.

Economics aside, the longer tamarisk expansion can be kept at bay, the higher the opportunity for more desirable species including velvet ash and cottonwood to occupy sites if water availability increases in the various sections of the lower river. Beyond that, the question about the structural, ecological and physical value of tamarisk compared to other vegetation that might establish needs to be considered. Where conditions are suitable for desired riparian vegetation and the tamarisk component is small, complete control is possible and the expectation is no reduction of physical function. On the lower reaches, in places, it is one of the primary stabilizing species able to exist with the deeper water tables; if removed, there needs to be consideration of what will replace it. In places in the southwest, tamarisk provides some habitat for species like the Southwestern Willow Flycatcher, an endangered species.

Issues

Tamarisk cannot be completely eliminated from the San Pedro River given its widespread occurrence and aggressive growth habits. The current SPRNCA plan for managing this species recognizes this, but it is unknown what level of public knowledge and support exists for the approach outlined in the plan, and whether it might be possible to increase efforts and monetary support with higher levels of understanding and support by partners. At its worst, the spread of tamarisk and the displacement of native species could greatly diminish current riparian conditions, leaving BLM unable to meet the legal mandate to conserve, protect, and enhance riparian and aquatic values.

Management Recommendations

The NRST supports and endorses the existing SPRNCA tamarisk management plan. Since tamarisk invasion is generally greatest in the northern reaches and decreases upstream, the highest priority for treatment is in reaches A through G; with medium priority given to reaches H and I (Appendix D). In the lower reaches, where the amount of tamarisk is treatable, address tamarisk in stages so excessive bare banks are not created all at once, and consider planting cottonwood poles and willow cuttings on dryer sites. The depth of the planting hole must be sufficient for the lower portion of the planted cutting to remain in contact with groundwater throughout the growing season, or regular watering of the planted trees would be required.

Fire and Fuels Management

Findings/Observations

Fire and fuels management was almost a continuing conversation among the assessment participants during the assessment. In several reaches, the impacts of wildfire on cottonwood and other tree species was very evident. Large areas of what previously were cottonwood galleries had burned, and only a few trees or a line of single trees along the river remained. The loss of patches of trees did not cause large scale destabilization of banks or other adverse effects to the channel, but rather promoted shrubs and herbaceous plants that also stabilize banks. However, it is desirable to maintain the maximum number of cottonwood stands to achieve both riparian function and associated resource values.

It is expected that cottonwood galleries on most of the post-entrenchment terraces will decrease in extent naturally as trees age and die, and sacaton/mesquite will dominate those sites (Fogg et al. 2012). Loss to wildfire or prescribed fire would accelerate that process as was observed in the field. At the same time, the risks of major high-intensity wildfires are great given the observed fuel loading of sacaton and mesquite communities within the SPRNCA.

Because the SPRNCA is a relatively narrow band of public land, wildfire can quickly spread from private to public lands and vice versa. This increases the risk and complexity of prescribed fire management, while highlighting the dangers of wildfires to property, lives, and the riparian ecosystem.

Issues

There is a continuing high risk of losing cottonwood galleries and trees from wildfire. In contrast, lack of fire creates decadent sacaton grasslands that are at low vigor and threatened with replacement by mesquite or other less desirable species.

Management Considerations

Fire and fuels management is a high priority on reaches A through D and F through I; a medium priority on reach E; and a low priority on reach J. A comprehensive public/private approach should be undertaken to develop strategies and tactics for managing fuels within and near the SPRNCA. This would entail working with adjacent landowners and cooperating partners such as the Natural Resources Conservation Service, Fort Huachuca, non-profit organizations, etc., to have a more comprehensive fuels program than one simply focused on the SPRNCA. The NRST recommends that cottonwood stands should be valued and protected, and prescriptions developed that provide the least risk for killing cottonwood.[20] Also, part of monitoring and tracking woody floodplain vegetation over time should include an analysis to learn where cottonwood stands

[20] Further analysis and discussions are needed, and are recommended during the upcoming RMP process.

have already been eliminated or greatly reduced due to wildfire, and where cottonwood trees have been able to reestablish after fire.

The RMP process should include an analysis of opportunities to manage the fuel loading of sacaton. In places, sacaton has little growth opportunity due to the dry material from previous years that intercepts sunlight and prevents development of needed photosynthetic material. The risk of fire moving into the cottonwood trees is high from this same dead and dry material. Periodic removal of plant material is needed to improve the health and vigor of the sacaton, which will also help improve watershed condition and benefit the river.

Beaver Management

Findings/Observations

Beavers were extirpated from the upper San Pedro River by 1894. Fifteen beavers were reintroduced during 1999, 2000, and 2002. By 2008, the estimated beaver population was approximately 150, based on about 20 colonies with 33 dams, with additional beaver reported in Mexico and as far north as Aravaipa Canyon (BLM 2009).

In the PFC assessment, beaver dams are considered because they can be hydrologic modifiers. Beaver dams and ponds serve to decrease flow velocity, store sediment and nutrients, and reduce channel bed and bank erosion. The ponded water often adds to vegetative diversity and productivity. In the SPRNCA, beavers often utilize the grade control of the tributary fans as a place to locate their low dams. These tributary fans provide a partial barrier to flow and create the ponded form discussed previously. The low beaver dams increase the amount and length of ponded water upstream with relatively little effort. While these low dams may typically blow out during floods, they are thought to be important because the beavers rebuild the dams, and the dams increase the elevation of ponded water that is stored and slowly released in the drier season. Beaver also used existing structure in places, such as down wood and logs, to serve as a foundation for their dams, increasing strength and stability. Beaver dam building activity was noted from reach A, through reach F, with only minor evidence (such as cutting on small trees) further downstream. This may be due to a combination of an increasingly wide sand-bed channel and decreased water availability. Overall, the beaver were seen as a positive contributor to river health due to the increased retention time of water behind dams. The loss of some cottonwood trees due to beaver activity did not cause destabilizing of banks or other adverse effects to the channel.

Issues

Indirectly, the interdisciplinary team heard concerns expressed by a few neighboring private landowners about impacts beaver were having on irrigation systems and vegetation. Earlier, people had mentioned that they had concerns about the beaver cutting down cottonwood within the SPRNCA, and in several areas individual trees had been protected by wrapping them with mesh wire. There is a beaver reintroduction Biological Opinion in place, and monitoring is ongoing.

Management Considerations

The best beaver habitat is tied to the most reliable instream flows, which currently occur in reaches B through E, and has the potential to develop throughout reach A (Appendix D). The ecological role of beaver is another element where increased information and education efforts are needed. Beaver play important roles in the health of ecosystems in a variety of ways, and need the support of a knowledgeable public. Beaver also can cause damage to private property at times, and the BLM needs to work closely with neighboring landowners and the Arizona Game and Fish Department to minimize undesirable impacts.

Off-Highway Vehicle Traffic and Foot Trails

Findings/Observations

Unauthorized off-highway vehicle (OHV) traffic within the channel and floodplain has created localized alteration of stream banks, trampled and destroyed riparian vegetation, and increased channel erosion. This traffic is most pronounced in reach A near the international border; reach D near the private property around Escapule; Charleston reach E and Contention reach I, and reach J where there are numerous access points for OHV entry into the riparian area (Appendix D). Unregulated foot traffic from recreationists and illegal immigrants along the banks of the San Pedro River compacts soil, tramples vegetation, and decreases bank stability. These problems are most evident in reach A and reach B near the San Pedro House, and reach G near Fairbank; however, evidence of pedestrian trampling was observed in every reach (Appendix D).

Issues

Because riparian recovery is relatively recent and riparian plant communities are weakly developed in many areas, little disturbances can have profound effects by retarding recovery or reversing earlier trends in recovery of riparian areas. Riparian plants and streambanks, weakened by off-highway and foot traffic, are more easily destabilized by low and moderate flow events than are healthy plants and stable banks. Stream recovery is either retarded or reversed when banks are unstable.

Management Recommendations

Direct communication with Border Patrol officials could reduce impacts to streambanks from OHV traffic, but some level of use for legitimate law-enforcement purposes is to be expected. OHV traffic from nearby residents and recreationists can be better regulated through improved fence maintenance and a change from barbwire/smooth wire fences to cable or pipe/rail fences in selected areas. Improved trail design, maintenance, and signage along with educational outreach to recreationists can reduce pedestrian impacts to the riparian zone. Kiosks at all trailheads, docents from the Friends of San Pedro River, and hunting regulation brochures can be effective ways to communicate resource concerns and a tread-lightly policy.

Railroad Bed

Findings/Observations

An abandoned railroad bed runs along much of the San Pedro River. In many places this bed alters surface flow. In a few places, the bed is close enough to the channel to contribute eroded material directly to the river. Currently, the railroad bed serves as a convenient vehicular travel corridor for administrative purposes.

Issues

The railroad grade has blocked many surface drainages and diverted flow into tributaries that pass the railroad grade under bridges or culverts. The slag and other materials used to build the railroad bed may contain toxic materials that should be kept out of aquatic and riparian areas.

Management Recommendations

The NRST recommends the BLM conduct an inventory to determine the location and extent of altered surface drainage and maintenance needs (i.e., blocked or damaged culverts, locations where railroad-bed material is or could enter the river, etc.). The railroad bed is near the river in reaches C, E, F and I, but the highest priority for management is given to reaches C and I because these are areas where slag is likely to enter to river (Appendix D). Consider moving material that may contain contaminants away from the eroding bank, without inhibiting the formation of new sinuosity in the channel. In addition, the BLM needs to continue to explore various options to retire or acquire the right-of-way for the abandoned railroad. Acquisition of the right-of-way could ensure proper treatment of potential contaminants, regular maintenance, and a possible rail-to-trail conversion.

Agricultural Dikes

Findings/Observations

Dikes were constructed to divert surface drainage around abandoned agricultural fields in reaches A, B, and C. These dikes alter natural hydrologic patterns, may increase discharge in some tributaries that bypass the dikes, and capture sediment that would otherwise flow into the San Pedro River. A thorough investigation of the dikes is needed to understand the extent of the impact.

Issues

The dikes alter natural hydrologic patterns, which means some reaches of the San Pedro River receive less water and sediment, whereas others receive too much water and sediment. This may create localized problems of erosion and deposition. Lack of maintenance leads to the dike being breached in places - surface water now flows over or through the dike rather than through culverts or around the dike to major tributaries that bypass the dikes.

Management Recommendations

Inventory and evaluate the effects of the dikes on surface and ground-water hydrology (determine if ponded areas behind dikes act as recharge). Where there is evidence that diverted flow patterns are creating increases in peak discharge and increased erosive potential, take steps to remedy the situation. Replace plugged or damaged culverts. Alternatively, the entire dike, or selected segments, could be removed to restore natural hydrologic patterns. This is a medium priority in reaches A, B and C (Appendix D).

Groundwater Augmentation

Findings/Observations

While there are no direct findings/observations relating to groundwater augmentation, it was a topic that was frequently discussed during the NRST assistance process.

Issues

Plans and actions to use urban storm-water runoff to augment groundwater that would flow to the San Pedro River are frequently discussed. These and other groundwater-augmentation proposals have been extensively studied (Bureau of Reclamation 2007, Stantec GSA 2006) as to their potential contribution to balance pumping with recharge, in response to the Section 321 requirements. The objective of urban storm-water projects is to collect storm-water runoff into a storm sewer before it flows into natural channels, which avoids the issue of acquiring a surface water right, and recharging that water close to the river. Water quality and unit cost (annual cost per acre-foot of recharge) are major considerations in this alternative.

Another action that is often mentioned as potentially important is to increase the number of detention basins in ephemeral channels. These detention basins are not without possible unintended consequences due to alterations in sediment balance. As described in the Tributaries and Sediment section of this report, the PFC assessment raised awareness and understanding of the important role of sediment inputs to the stream from its many tributaries. By their nature, detention structures in channels intercept not only water, but also sediment. The location of future structures is an important consideration. Detention structures far down the tributaries and close to the San Pedro River may intercept sediment that is important to the continuing evolution of the river channel. Off-channel recharge basins or detention basins higher in tributaries are less likely to affect sediment balance. Unit cost, total water yield, annual maintenance costs associated with dredging sediment, and legal issues concerning “diversion” of water in natural channels are all issues related to detention basins.

Management Considerations

Additional water in reach A could accelerate recovery of the needed vegetation characteristics. Additional water in reaches B through E could extend perennial flow further downstream in reach F. A third location would be to provide additional recharge water to the Babocomari River, which might also positively influence the water in the San Pedro River. Use the best science available when considering urban storm water for recharging the aquifer, and the building of detention structures in ephemeral channels so the potential alteration of sediment inputs to the river is given complete analysis prior to locating and installing structures. Other forms of improving natural groundwater recharge should be evaluated via watershed assessments and plans on the SPRNCA and cooperatively in the larger basin.

Recommended Next Steps

Development of SPRNCA Resource Management Plan

The number and types of issues raised by the PFC assessment and preceding steps in the NRST process clearly point to the need for an up-to-date plan for managing the SPRNCA. The current management plan is a combination of several plans that are tenuously connected and difficult to either obtain or gain clarity of direction from, and are inadequate to manage the conditions and challenges that face the SPRNCA today. Although some of the riparian issues can be resolved on a project or location basis, the greater need is for a comprehensive analysis and planning effort that fully engages the many partners and broader public. The PFC assessment provides considerable information and insight into existing conditions and needs of the riparian area and beyond in some instances, but information alone does not resolve issues. Careful consideration of the situation, alternative courses of management, and the costs and benefits of those approaches need to be provided by the BLM, and decisions made about how to best meet the needs of the legislative mandate in keeping with demands and issues raised by the community. Additionally, the costs and impacts of activities away from the SPRNCA, including groundwater pumping, even though not in BLM’s control, need to be fully analyzed and disclosed to the public and governmental agencies.

Management Considerations

The NRST recommends the BLM: (1) reestablish the SPRNCA Advisory Committee called for in the enabling legislation as part of the process of developing a revised or new comprehensive management plan, (2) initiate collaborative approaches to bringing together the many government and private partners very early in the process of planning, and continue a transparent and open process, (3) continue to nourish existing relationships, and develop additional relationships locally and regionally with the people who will be critical to success of the effort, and (4) identify a plan coordinator for an effort that will be complex, multifaceted, and potentially contentious.

Development of Baseline Information and a Monitoring Strategy

With the legal mandate to conserve, protect and enhance the riparian, aquatic and other named resources, a robust monitoring program is critical to mission success. Although monitoring is known to exist, much of this is not corporate in nature or readily available to interested publics or management (channel cross-sections surveys, vegetation transects, surface flow, etc.). Monitoring needs range from widespread and extensive information to very local and intensive monitoring. Two primary aspects are important: (1) obtaining information using scientifically based protocols in order to understand condition, trend and management needs, and (2) effective use of tools that result in the least cost. Cooper and Merritt 2012 is a new publication which provides tools for examining linkages between surface water, groundwater, and wetland and riparian vegetation that will assist with this effort.

An important first step is to organize and interpret existing monitoring information. There is a wealth of scientific studies and information relevant to the SPRNCA (particularly regarding the riparian and aquatic environment) that likely exceeds the amount and quality of information collected on almost any other BLM National Landscape Conservation System unit. Some of this information provides baseline conditions that date back to the designation of the SPRNCA and even earlier, but it was not evident that much of it has been interpreted to inform management. Moving forward into the RMP process and the establishment of monitoring programs, it is critical to know where information has been collected, what information is available, and what has been learned to date.

In addition to BLM employees, the SPRNCA is fortunate to have a strong group of interested and highly committed people who want to insure the long-term sustainability of the NCA. This includes groups such as the Friends of the San Pedro River, the Community Watershed Alliance, as well as other non-governmental organizations. The highlight of the volunteer work is the annual wet-dry mapping, a joint effort of the BLM, The Nature Conservancy, Friends of the San Pedro and others. Each year volunteers walk every reach of the San Pedro River during the third weekend of June, and document where surface water is present the estimated driest part of the year. This survey not only provides highly valuable information to management about the river conditions, but is also a highly educational event that increases public support for the San Pedro River. The annual wet-dry mapping is an outstanding example of employing good science in a way that fully engages people who care about the San Pedro River. The repeat measurements will provide increasingly important understanding of the river's condition. All of those involved in conducting and documenting this study deserve great appreciation.

Many types of additional monitoring have been called for as a result of the PFC assessment. Although it is important to utilize scientific and defensible protocols for collecting management information, many of the tools and processes can be taught to diverse groups of people. There are some people who are already well-versed in topics like botany, geology and hydrology who regularly volunteer with others on the SPRNCA. This is a rich and largely untapped resource available to the SPRNCA. With appropriate training, volunteers can assist technical staff on some of these monitoring efforts and take the lead on others. Some of the monitoring needs include:

- Groundwater monitoring,
- Riparian vegetation monitoring transects,
- Remote sensing mapping (e.g., Light detection and ranging (LiDAR), aerial photography including VLSA or very large scale aerial photography)
- Photo-point development and periodic re-takes of both new and already established sites [establish photo-points on each form of the river (ponded, tributary fan, standard) and take photos at consistent times of the year],
- Channel cross-section measurements, of both existing and new cross-sections [investigate whether existing cross-section data was monumented for repeat measurements (Jackson et al. 1987, Leenhouts 2006)],
- A monitoring plan, and periodic monitoring results and interpretation reports that provide a discussion of the management implications so management can adapt to new information and changing conditions.

The NRST agrees with Stromberg's suggestions for long-term monitoring of riparian condition (from July 2011 technical meeting PowerPoint presentation) to: (1) measure vegetation transects to detect changes to dry-season streamside herbaceous vegetation [addition of Multiple Indicator Monitoring at designated monitoring areas (Burton et al. 2011) may be needed to supplement the Stromberg bio-hydrology belt transects], and (2) replace field monitoring of woody floodplain vegetation with remote sensing mapping. Include related aquatic measures to monitoring plans in consultation with biologists as well. The NRST recommends hiring a hydrologist dedicated to the SPRNCA and the Las Cienegas NCA to serve as a monitoring coordinator.

Expansion of Opportunities for Community Education and Service

Throughout the course of NRST assistance, it became apparent that there is a lack of information, or misinformation, regarding riparian ecology and function. Volunteers can assist BLM with riparian education and interpretation, as well as implementing management actions. Volunteers already do a variety of important work, including interpretive walks along the San Pedro River and managing facilities including the San Pedro House and Fairbank site. Leading up to the PFC assessment and during it, people were interested in learning of more opportunities to contribute time and effort on behalf of the river.

There are many retired people and others who have high levels of education and understanding of riparian relationships on the San Pedro River and are capable of providing more information about ecological relationships to the public. Some topics could include:

- Importance and ecology of cottonwood/Gooding's willow and other riparian vegetation communities along the San Pedro River,
- Ecological importance and function of beaver,
- Important riparian plants and their ecology along the San Pedro River,
- Channel evolution, pre and post entrenchment,
- Channel and floodplain characteristics and processes with an emphasis on their role in aquifer recharge and supporting riparian plant communities,
- The role of fire in the landscape and riparian areas, and
- Community efforts to augment water flows to the San Pedro River.

There are likely a variety of tasks that volunteers could perform in small to large trained groups:

- Documentation and removal of unusable fencing,
- Establishment, maintenance and signage of appropriate foot trails, with emphasis on current trails that are excessively eroding.
- Documentation and condition survey of signs within the SPRNCA, interpretive and otherwise, and
- Maintenance of existing perimeter fences to exclude livestock from the river.

References

BLM. 2009. San Pedro Riparian National Conservation Area, National Landscape Conservation System, FY 2010 Annual Manager's Report. http://www.blm.gov/pgdata/etc/medialib/blm/az/pdfs/nlcs.Par.35277.File...

Bureau of Reclamation. 2007. Appraisal report – augmentation alternatives for the Sierra Vista sub-watershed, Arizona. Lower Colorado Region. 77 p.

Burton, T.A., S.J. Smith, and E.R. Cowley. 2011. Multiple indicator monitoring (MIM) of stream channels and streamside vegetation. BLM Technical Reference 1737-23. 155 p.

Chambers, J.C., Miller, J.R., Germanoski, D., 2011. Introduction and Overview. *In*: J.C. Chambers and J.R. Miller (eds.) 2011. Geomorphology, hydrology and ecology of Great Basin meadow complexes—implications for management and restoration. Gen. Tech. Rep. RMRS-GTR-258. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, pp. 1-10.

Cooley, M.E., Aldridge, B.N., and Euler, R.C., 1977. Effects of the catastrophic flood of December 1966, North Rim Area, Eastern Grand Canyon, Arizona. U.S. Geological Survey Professional Paper 980, 43 p.

Cooper, D.J. and D.M. Merritt. Assessing the water needs of riparian and wetland vegetation in the western United States. Gen. Tech. Rep. RMRS-GTR-282. Fort Collins, CO; USDA Forest Service, Rocky Mountain Research Station. 125 p.

Fogg, J., Elmore, W., and Gonzalez, M., 2012. Riparian Conditions along the San Pedro River: Potential Natural communities and factors limiting their occurrence. Lowclouds Hydrology, Inc., Highlands Ranch, CO, 27 p.

Germanoski, D. and Miller, J.R., 2004. Basin sensitivity to channel incision in response to natural and anthropogenic disturbance. *In*: Chambers, J.C., Miller, J.R., (eds.) Great Basin Riparian Ecosystesm—Ecology, Management, and Restoration. Covelo, CA: Island Press: 88-123.

Gonzalez, M.A., 2001a. Recent formation of arroyos in the Little Missouri Badlands of southwestern North Dakota. Geomorphology 38:63-84.

Gonzalez, M.A., 2001b. Recent fluvial history and environmental change of some ephemeral streams in the Little Missouri Badlands of southwestern North Dakota. North Dakota Geological Survey Report of Investigation No. 101, 49 p.

Hardin, G. 1968. The Tragedy of the Commons. Science. Vol. 162, No. 3859. pp. 1243-1248. http://www.sciencemag.org/content/162/3859/1243.full

Hendrickson, D.A., and Minckley, W.L., 1984. Ciénegas—Vanishing climax communities of the American Southwest. Desert Plants 6(3):129-175.

Hereford, R. 1993. Entrenchment and widening of the upper San Pedro River, Arizona. U.S. Geological Survey. Special Paper 282. 46 p.

Hudson, B. E. 1994. Soil organic matter and available water capacity. Journal of Soil and Water Conservation. Vol. 49, No. 2. p. 189-194.

Hupp, C.R. and Osterkamp, W.R., 1985. Bottomland vegetation along Passage Creek, Virginia, in relation to fluvial landforms. Ecology 66:670-681.

Jackson, W., T. Martinez, P. Cuplin, W.L. Minckley, B. Shelby, P. Summers, D. McGlothlin, B. Van Haveren. 1987. Assessment of water conditions and management opportunities in support of riparian values: BLM San Pedro River properties, Arizona project completion report. BLM. 180 p.

Jewett, D.G., Lord, M., Miller, J.R., Chambers, J.C., 2004. Geomorphic and hydrologic controls on surface and subsurface flow regimes in riparian meadow ecosystems. *In*: Chambers, J.C., Miller, J.R., (eds.) Great Basin Riparian Ecosystesm—Ecology, Management, and Restoration. Covelo, CA: Island Press: 124-161.

Johnson, W.C., 1994. Woodland expansion in the Platte River, Nebraska: Patterns and causes. Ecological Monographs 64:45-84.

Kepner, W.G., C.J. Watts, C.M. Edmonds, J.K. Maingi, S.E. Marsh, and G. Luna. 2000. A landscape approach for detecting and evaluating change in a semi-arid environment. Environmental Monitoring and Assessment 64:179-195.

Lacher, L.J. 2011. Simulated groundwater and surface water conditions in the upper San Pedro basin 1902-2105 preliminary baseline results. Lacher Hydrological Consulting. Tucson, AZ. 71 p.

Langbein, W. B. and Schumm, S. A. (1958) Yield of sediment in relation to mean annual precipitation. *Trans. Amer. Geophys. Un.* 39, 1076-1084.

Leake, S.A., Pool, D.R., and Leenhouts, J.M., 2008. Simulated effects of ground-water withdrawals and artificial recharge on discharge to streams, springs, and riparian vegetation in the Sierra Vista Subwatershed of the Upper San Pedro Basin, southeastern Arizona: U.S. Geological Survey Scientific Investigations Report 2008-5207, 14 p.

Leenhouts, J.M., J.C. Stromberg, and R.L. Scott. 2006. Hydrologic requirements of and consumptive ground-water use by riparian vegetation along the San Pedro River, Arizona. U.S. Geological Survey. Scientific Investigations Report 2005-5163. 154 p.

Leonard, S., G. Staidl, J. Fogg, K. Gebhardt, W. Hagenbuck, and D. Prichard. 1992. Riparian area management: procedures for ecological site inventory – with special reference to riparian-wetland sites.

Miller, J., Germanoski, D., Tausch, R.J., Chambers, J., 2001. Influence of late Holocene processes and landforms on modern channel dynamics in upland watersheds of central Nevada. Geomorphology 38:373-391.

Miller, J.R., House, K., Germanoski, D., Tausch, R.J., Chambers, J.C., 2004. Fluvial geomorphic responses to Holocene climate change. *In*: Chambers, J.C., Miller, J.R., (eds.) Great Basin Riparian Ecosystesm—Ecology, Management, and Restoration. Covelo, CA: Island Press: 49-87.

NRST. 2011. San Pedro Riparian National Conservation Area situation assessment report. Unpublished paper.

Parker, G. 1990. Surface-based bedload transport relation for gravel rivers. Journal of Hydraulic Research 28:417-436.

Poole, D.R. and A.L. Coes. 1999. Hydrogeologic Investigations of the Sierra Vista Subwatershed of the Upper San Pedro Basin, Cochise County, Southeast Arizona. USGS Water-Resources Investigations Report 99—4197. 38 p.

Prichard, D., H. Barrett, J. Cagney, R. Clark, J. Fogg, K. Gebhardt, Dr. P.L. Hansen, B. Mitchell, and D. Tippy. 1993. Riparian area management: process for assessing proper functioning condition. TR 1737-9. BLM/SC/ST-93/003+1737. 51 p.

Prichard, D., J. Anderson, C. Correll, J. Fogg, K. Gebhardt, R. Krapf, S. Leonard, B. Mitchell, J. Staats. 1998. Riparian area management: a user's guide to assessing Proper Functioning Condition and the supporting science for lotic areas. TR 1737-15. Bureau of Land Management, BLM/RS/ST-98/001+1737, National Applied Resource Sciences Center, CO. 126 p.

Scott, M.L., Friedman, J.M., and Auble, G.T., 1996. Fluvial processes and the establishment of bottomland trees. Geomorphology 14:327-339.

Scott, M.L., Auble, G.T., and Friedman, J.M., 1997. Flood dependency of cottonwood establishment along the Missouri River, Montana, USA. Ecological Applications 7:677-690.

Shafroth, P.B., Auble, G.T., Stromberg, J.C., and Patten, D.T., 1998. Establishment of woody riparian vegetation in relation to annual patterns of streamflow, Bill Williams River, Arizona, Wetlands 18:577-590.

Stantec GSA. 2006. Cochise County Flood Control/Urban Runoff Recharge Plan.

Stromberg, J. 1998. Dynamics of Fremont cottonwood (Populus fremontii) and saltcedar (Tamarix chinensis) populations along the San Pedro River, Arizona. Journal of Arid Environments. 40: 133-155.

Stromberg, J.C., S.J. Lite, T.J. Rychener, L.R. Levick, M.D. Dixon, J.M. Watts. 2006. Status of the riparian ecosystem in the upper San Pedro River, Arizona: application of an assessment model**.** Environmental Monitoring and Assessment. 115: 145–173.

Stromberg, J.C., Patten, D.T., and Richter, B.D., 1991. Flood flows and dynamics of Sonoran riparian forests. Rivers 2:221-235.

Stromberg, J.C., Richter, B.D., Patten, D.T., and Wolden, W.G., 1993. Response of a Sonoran riparian forest to a 10-year return flood. Great Basin Naturalist 53:18-130.

Triska, F.J. 1984. Role of wood debris in modifying channel geomorphology and riparian areas of a large lowland river under pristine conditions: ahistorical case study. Verh. Int. Ver. Limnol. 22: 1876-1892.

United States Code. 2002. Title 16 – Conservation. Chapter 1 - National Parks, military parks, monuments, and seashores. Subchapter six - San Pedro Riparian National Conservation Area. Sec. 460xx-1. Management. (a) General authorities. http://www.blm.gov/pgdata/etc/medialib/blm/az/images/san_pedro.Par.85171.File.dat/legislation_USC.pdf

Upper San Pedro Partnership. 2012. Water management of the regional aquifer in the Sierra Vista Subwatershed, Arizona - 2010 report to Congress: Washington, D.C., U.S. Department of Interior, 18 p.

Wilcock, P.R., Pitlick, J., Cui, Y., 2009. Sediment transport primer: estimating bed-material transport in gravel-bed rivers. General Technical Report RMRS-GTR-226. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 64 p.

Appendices

Appendix A - Reach Based Information

Appendix A contains the reach based information from the PFC assessments. Each reach section has the following documentation:

1. Reach narrative
2. PFC assessment form
3. Plant list
4. Photos taken during the assessment
5. Map that shows reach breaks and the photo's GPS waypoints
6. Google Earth image showing reach breaks
7. Historic photos
8. Waypoint log