
Subwatershed Selection Criteria for Demonstration of Streamflow Yield Enhancement through Brush Control

By

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Problem Statement

The Texas State Soil and Water Conservation Board (TSSWCB) manages the State of Texas' program for brush control to enhance surface water flows for urban and rural benefits. To date, the sites selected have been large watersheds with varying coverages of different high-water use plants, such as salt cedar, juniper, and mesquite. Using conventional techniques available in the late 1990s, predictions of increased streamflow through brush control were based on watershed modeling that primarily changed runoff generation and groundwater loss parameters in each watershed. Unfortunately, there has not been sufficient pre- and post-treatment monitoring to confirm the positive impacts of the selected brush control practices. It is now apparent that scientific principles from hydrology must be applied to improve the site selection process to prioritize sites for potential observable enhancement of streamflow yields.

The purpose of this report is to provide a straightforward list of criteria for selection of sites for streamflow enhancement that will maximize the potential for observation of positive impacts of brush control. The report includes a brief presentation of the general hydrologic and watershed management concepts that contribute to possible increases in runoff and streamflow from a watershed. Next, the proposed criteria are listed. Finally, some general observations about the importance of monitoring are summarized. This report is not a detailed, thoroughly referenced critique of the historical brush control program, but is rather intended as a useful reference for decision makers in the TSSWCB and the Texas Legislature. The authors plan to participate in a more detailed review of the TSSWCB brush control program later in this fiscal year.

General Concepts

Runoff generated by a watershed is a reflection of the integrated net effects of all watershed characteristics as they interact with and reflect the hydrologic cycle. One of the primary objectives of watershed management is to maintain or improve water yields. To do so requires an understanding of how a watershed functions in the delivery of water to its outlet. A complete discussion of the factors involved and their functional relationships is beyond the scope of this report, but it is possible to summarize the major components and discuss some of their complexities and interactions.

Probably the most significant relationship impacting water yields is the overall ratio of precipitation to evaporation. In locations where this ratio exceeds 1.0, the likelihood of enhancing runoff is increased; likewise, when the ratio is less than 1.0 runoff enhancement is more challenging. If rainfall and evaporation were both uniformly distributed over time, it would be difficult to have any streamflow at all in locations where evaporation exceeds precipitation. It must be recognized, however, that the intensity, duration, and seasonality of precipitation are more important than the annual totals. Intensity of rainfall refers to the depth of rainfall per unit time, and duration is the time length of the rainfall event. Not all precipitation events are "runoff producing" even when the total amount of precipitation is identical, as the time between storm events can affect the pre-storm soil moisture. It is possible at almost any location in the state (except for large sand dunes) to have short-term storm events that put a lot of water on a watershed quickly enough that runoff can reach streams and rivers faster than it is lost to evaporation. Seasonal trends in rainfall intensity have been noted across the state. For example, the western side of the state receives much of its rainfall from convective thunderstorms in the late spring and summer months, while the coastal regions can receive major rainfall events during hurricane and tropical storm season.

Land use activities that alter the type or extent of vegetative cover on a watershed can increase or decrease streamflow yields. The expected outcome from a planned vegetation adjustment is based on change in evapotranspiration (ET) "losses" from the watershed. Complicating these expectations are variations in precipitation patterns, soil infiltration capacities, groundwater conditions, watershed area, land surface slopes, and other characteristics of particular watersheds. For example, Hibbert (1979, 1983) concluded that vegetative manipulations were likely to enhance water yields only when the watershed received more than 18 inches of annual precipitation. Residual vegetation was expected to consume all available precipitation in areas receiving less precipitation.

After accounting for precipitation patterns and amounts, water yields from watersheds receiving similar inputs are dramatically impacted by soil, elevation, slope, aspect, climate, and vegetation. Selection of areas for vegetative manipulation to enhance water yields should

therefore be prioritized using a combination of the following factors. In general, storm runoff and associated streamflow will be greater under these conditions.

- **Steeper slopes.** Runoff on steeper slopes can produce more erosion. Steeper slopes can be more difficult to stabilize following vegetative manipulation, as the vegetation likely helped hold soils in place.
- **More uniform slopes with limited soil disturbance.** Adding terraces to slopes reduces runoff yield. Mechanical disturbances that leave the soil surface "cratered" can also lose runoff to depression storage.
- **Soils with lower infiltration capacities.** Typically soils with finer textures and with poorer structure have lower permeability and accept less vertical infiltration.
- **South and west facing slopes.** These aspects tend to be steeper and have less vegetative cover in the northern hemisphere.
- **Closer proximity of contributing area to stream channels.** Runoff flow volume is diminished by transmission losses to infiltration and depression storage over long flow routes.

Another important consideration in water yield from a watershed is baseflow, which is the contribution of groundwater discharge to streamflow. For perennial streams, baseflow represents the streamflow that takes place between rainfall/runoff events, without the contribution of storm runoff. It should be noted that ephemeral streams, which have no baseflow, may still be positively impacted by watershed management in the arid and semi-arid parts of the state. It is possible that evapotranspiration near the streambed can lower the local groundwater table and turn a perennial stream into an ephemeral or intermittent stream. In general baseflow to streams and rivers will be greater under the following conditions.

- **Soils with higher infiltration capacity soils near the streambed.** Alluvial (eroded and deposited within the stream channel) soils with coarser textures and mostly large particle sizes allow faster movement of water from the aquifer toward the stream.
- **Higher water table elevation near streambed.** If the elevation of the groundwater table in the alluvial material near the streambed is higher than the elevation of the water surface in the stream, groundwater will flow toward the "gaining" stream and

contribute baseflow. If the groundwater table elevation is lower than the water surface in the stream, water will flow from the “losing” stream into the alluvial aquifer.

- ***Replacement of deeper-rooted with shallower-rooted plant species.*** Typically deep-rooted woody species can be replaced with shallow rooted herbaceous species. Concern must also be given to the density of the vegetative cover, as replacing a moderately dense stand of mesquite trees with a heavy cover of switchgrass could in fact reduce alluvial groundwater storage because of increased vegetative demand on available soil water.

Statement of Selection Criteria

The TSSWCB desires to maximize its ability to demonstrate the positive impacts of brush control on streamflow enhancement. The TSSWCB and some of its collaborators have already realized that it is more appropriate to consider smaller subwatersheds rather than large river basins. The subwatershed approach should be continued, whether in the existing brush control treatment sites or in new locations. The following criteria are proposed for consideration in selection of these sites.

- ***Soils – low permeability in the watershed catchment area and leading toward the streambed***
- ***Slope – sufficiently steep to carry runoff to streambed***
- ***Area – large enough to generate measurable flow contribution***
- ***Brush cover distribution – fraction of the area with treatable brush cover and proximity to stream channel***
- ***Land use – vegetation and land management strategies by land owner***
- ***Streamflow observation – proximity to a stream gauging station, whether installed for the brush control project or existing for other agency’s purposes***
- ***Groundwater conditions – depth to groundwater table, groundwater flow direction, and aquifer permeability***

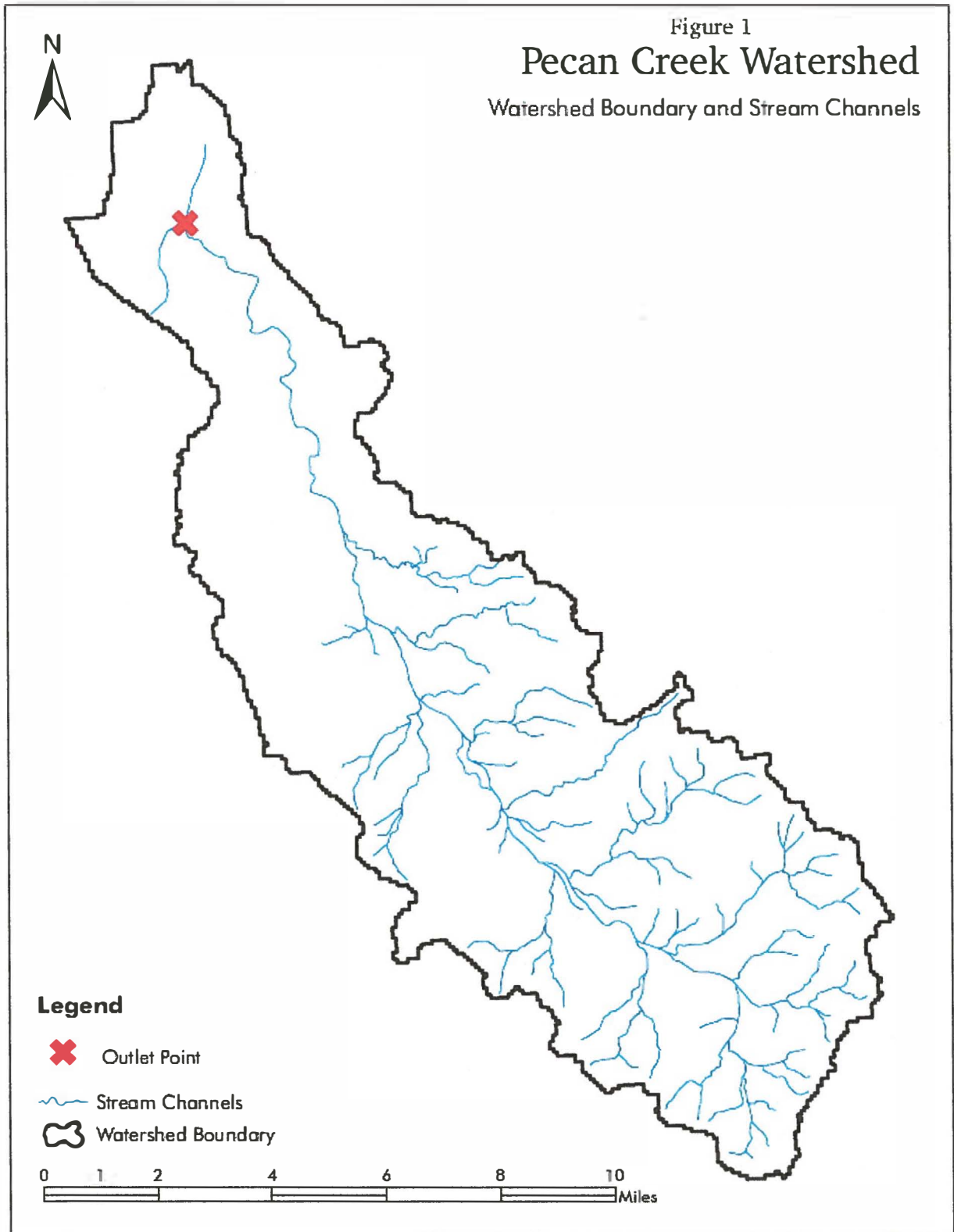
It should be noted that this list is not given in order of numerical priority. It may not be possible to maximize all the criteria at the same time in the same subwatershed. Still, the criteria are based on sound hydrologic principles and conditions that can be observed and mapped.

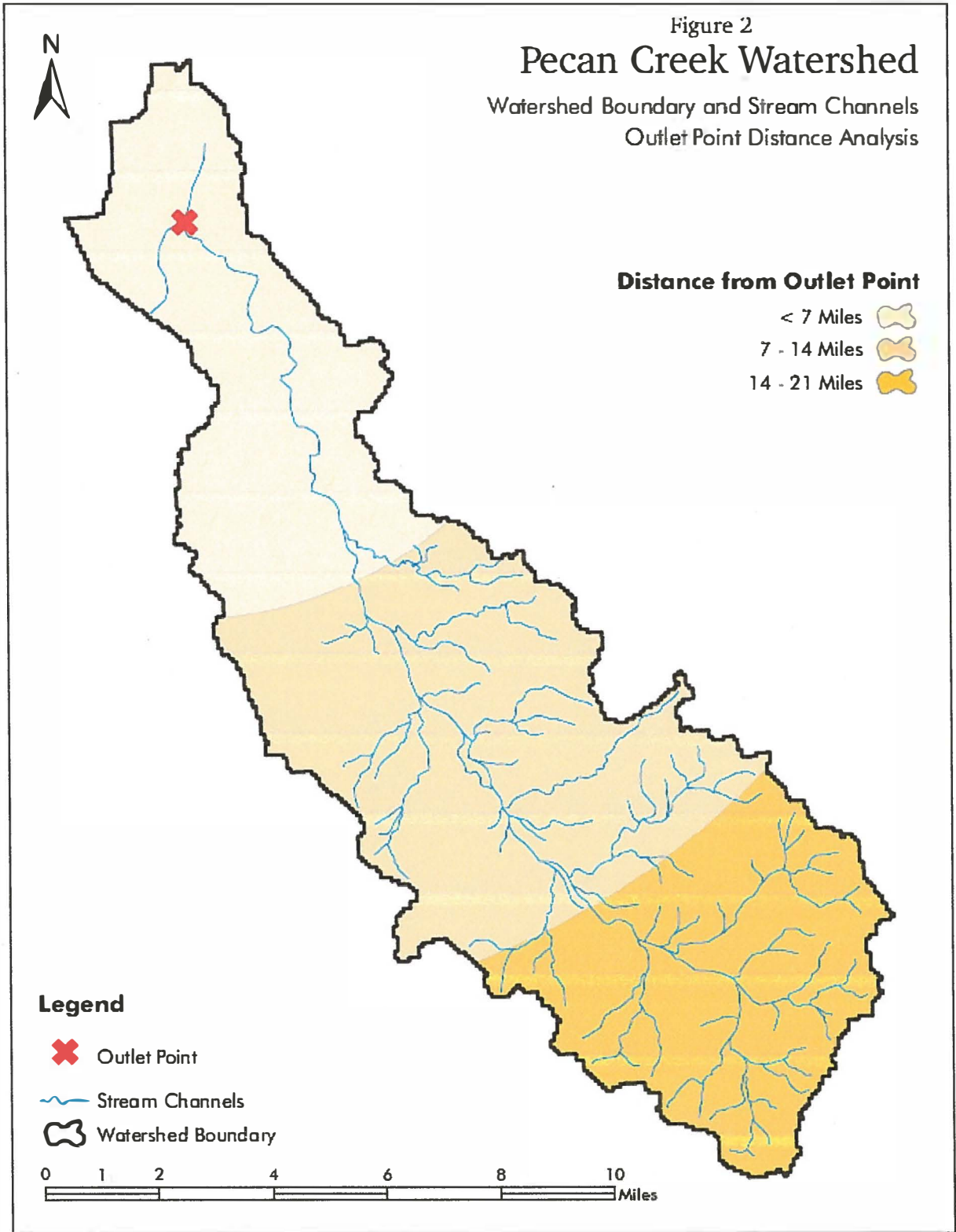
Conceptual Application of Criteria

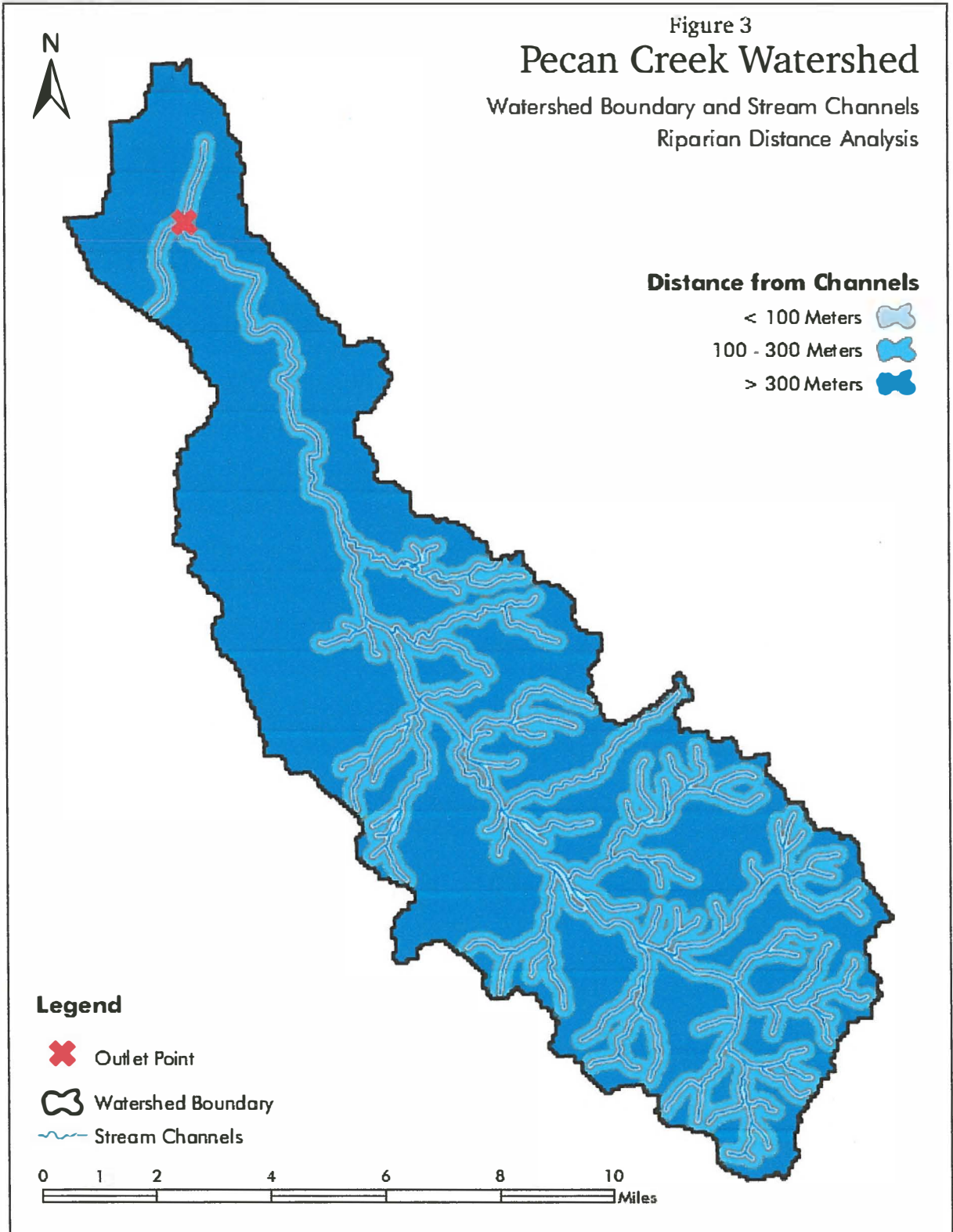
As an illustration of application of some of these criteria in map form, we used the following illustrations based on the Pecan Creek Watershed, as its delineation was presented by the TSSWCB (Figure 1). This application is only a "demonstration" of the techniques, and the arbitrary choices of elements and categories within elements were for illustration only. Additional elements, additional categories, and different definitions of relative importance are all possible depending on site specific characteristics and management objectives.

In arid and semi-arid environments, streams typically experience "transmission losses" as the water moves longer and longer distances from the point of overland flow generation through the channel to the final watershed outlet. The closer the point of runoff generation is to the watershed outlet, the greater will be the expected streamflow because channel transmission losses to seepage and evapotranspiration will be minimized. In this demonstration, we divided the Pecan Creek Watershed into three zones based on channel travel lengths: closest to the outlet, furthest from the outlet, and "in between" (Figure 2). The zones were arbitrarily delineated by a circular buffer from the outlet point of 7, 14, and 21 miles. Each zone was assigned a numerical value (15, 10, or 5), and higher value is associated with less transmission loss and better streamflow contribution to the outlet.

Proximity to a stream or tributary channel is another variable worthy of consideration. Brush treatments applied closer to a channel are more likely to produce overland flow or increase baseflow that reaches a channel than are treatment located further away from the channel. This concept can also be stated as expecting treatments in riparian corridors to enhance yields more than similar treatments on upland sites. In this demonstration, we divided the Pecan Creek Watershed into three zones based on proximity to a stream channel: closest to the channel, furthest from the channel, and "in between" (Figure 3). The zones were delineated by linear buffers of 100 and 300 meters to create three zones: < 100 meters from a channel, 100-300 meters from a channel, and > 300 meters from a channel. Each zone was assigned a numerical value (20, 10, or 5), and higher value is related to greater proximity to the channel.







Soil texture and slope are other variables impacting runoff. For purposes of this illustration, we selected a combination of soil textures and a slope category to create areas with an increased likelihood for generation of enhanced runoff following treatment. In this particular case, soils with textures of clay or clay loam having slopes in the range of 1 to 3 percent were selected to illustrate the methodology (Figure 4). Heavier textured soils with steep slopes would be expected to have lower infiltration rates than coarse textured soils on flat slopes. In this demonstration, we divided the Pecan Creek Watershed into two zones based on a combination variable of soil texture and slope. The zones were delineated by selection of soil mapping units from Natural Resources Conservation Service (NRCS) county-level soil mapping data. Each zone was assigned a numerical value (10 or 0) for being in or out of the preferred soil/slope zone.

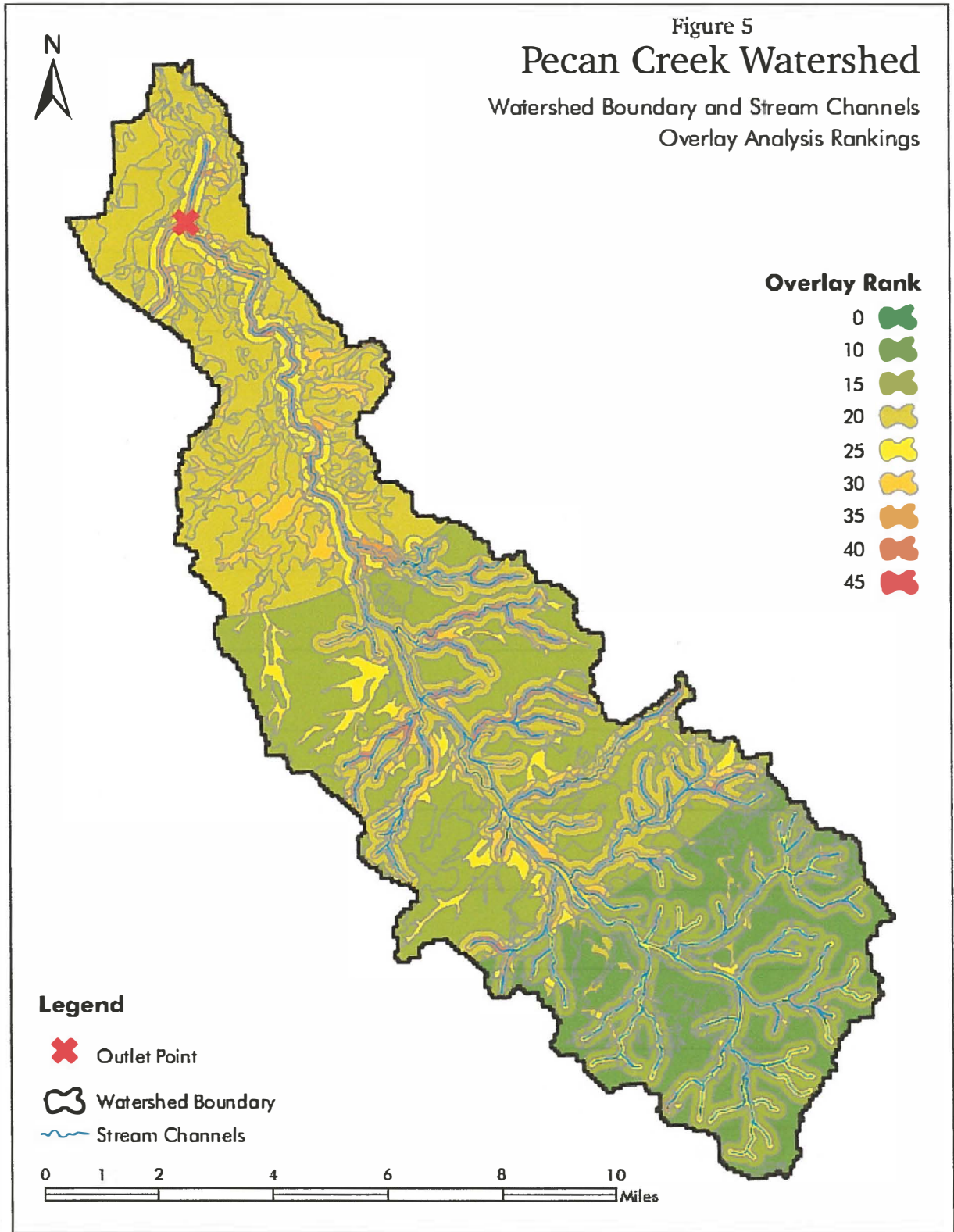
While this process could continue for additional variables, we used these three criteria for the current illustration. The result is a classification of the Pecan Creek Watershed into 8 possible zones or regions with varying potential to generate enhanced water yields based on the criteria applied (Figure 5). Numerically, the "scores" range from a low of 10 to a high of 45. The highest priority areas or sites would be within 7 miles of the watershed outlet, on clay or clay loam soils with slopes from 1 to 3 percent, and within 100 meters of a defined channel (Figure 6).

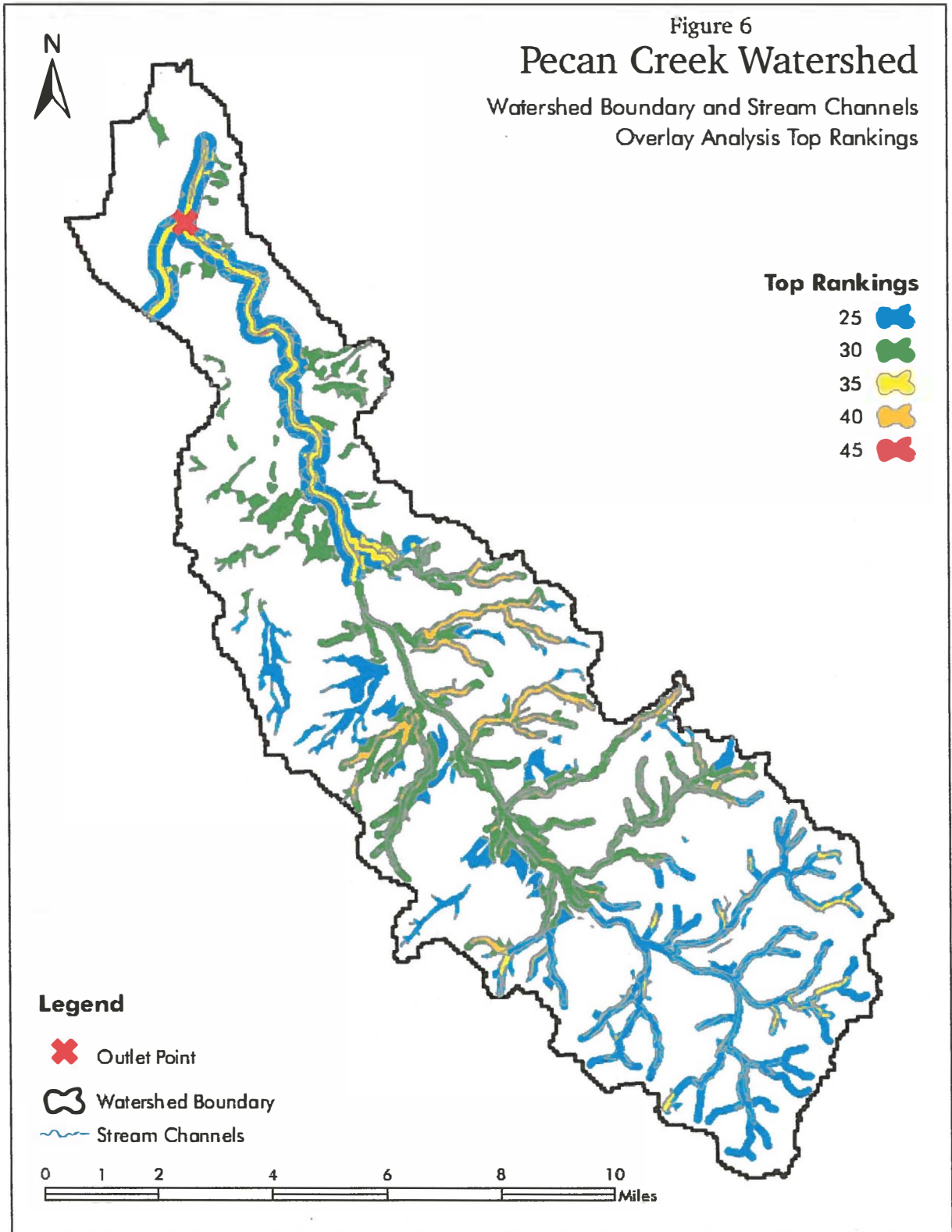
The series of maps was provided to graphically display the process employed, the results of each criterion application, as well as the final result. It must be remembered that this is simply a demonstration of the methodology; the weighting values and the zone definitions within a criteria were arbitrarily chosen to help illustrate the method. Their exact values and definitions would need to be determined for each individual watershed to which the methodology is applied based on the best science available for the specific site.

Monitoring Considerations

While preparing this brief report, the authors reviewed existing data for several of the TSSWCB's treated sites. This information included the reports of the SWAT modeling that estimated the potential added streamflow from proposed brush control, nearby historical streamflow measurements when available, and existing monitoring efforts for streamflow and







groundwater impacts after brush treatment. It is apparent that the same type of hydrologic and watershed management concepts used to generate the subwatershed selection criteria are also pertinent for monitoring considerations.

The major concern of the program is enhancement of streamflow. In order to measure such flows, it is necessary to install continuous streamflow recorders at the outlets of the treated subwatersheds. It would be best to have both pre- and post-treatment data to demonstrate the ranges of flow values. The typical flow recording system would most likely be a water level sensor, such as a pressure transducer, installed at a fixed channel cross-section, such as a paved low-water crossing, broad-crested weir, or a fixed measuring flume. The system would have a relationship between water surface elevation in the stream and flow rate, and allow continuous data collection so that baseflow and runoff components could always be observed. Pressure transducers typically come with electronic data loggers that can be downloaded to laptop computers.

Continuous observation of rainfall is just as important as streamflow, so that the source of the runoff can be estimated. Multiple recording rain gauges, such as the tipping bucket type that can sense rainfall to the nearest 0.01 in, should be placed at strategic locations across the watershed to allow estimation of the areal and temporal distribution of rainfall for each storm event. These rain gauges can store data in data loggers for occasional downloading to laptop computers.

Observation of local groundwater conditions should be done through monitoring wells in the shallow alluvial aquifer in and near the streambed. The elevations of the groundwater table in the monitoring wells can be compared each other and to the elevation of the water surface in the stream to demonstrate which way the groundwater is flowing and the changes in groundwater storage over time. The groundwater levels can be continuously monitored with pressure transducers, or manually measured less often if readily accessible.

Estimation of evapotranspiration losses through vegetation within the target areas of the treated subwatershed can be done by using site visits, aerial photography, and satellite imagery to identify the effectiveness of brush management over the treated areas of the subwatershed. Potential ET can be estimated with local weather stations that measure and

record wind speed, relative humidity, net solar radiation, and temperature. Actual ET can then be estimated as proportional to the potential ET based on plant type and seasonal variations in water consumption.

The best situation for application of hydrologic monitoring to confirm positive impacts of brush control would be to have several years of pre-treatment data to compare to several years of post-treatment data. Unfortunately, this situation is unlikely for the subwatersheds that have already been or will soon be treated. It is possible that two similar subwatersheds can be selected, instrumented, and observed with one receiving brush treatment and the other left untreated. The hydrologic behaviors of the two subwatersheds over several years could then be later compared to determine the impact of treatment. An example of this type of situation is in the East and West Grape Creek subwatersheds near San Angelo.

An over-riding concern about hydrologic monitoring for streamflow enhancement, or any other purpose, is that the longer the observation period is, the more confident we are in the findings. Installation of equipment to measure streamflow often seems to cause a drought. We encourage all those concerned with streamflow enhancement, whether through brush control or other watershed management techniques, to be patient and allow multiple years of data collection and analyses to observe a reasonable range of weather conditions over time.

References

Hibbert, Alden R., 1979. Managing Vegetation to Increase Flow in the Colorado River Basin. USDA Forest Service General Technical Report RM-66, 27 p.

Hibbert, Alden R., 1983. Water Yield Improvements Potential by Vegetation Management on Western Rangelands. Water Resources Bulletin, 19(3):375-381.