DETERMINATION OF RIVER MAINTENANCE NEED AT INDIVIDUAL SITES AND REACHES ON THE MIDDLE RIO GRANDE

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ABSTRACT

The channel of the Middle Rio Grande (MRG) has been confined to a narrow corridor by riverside infrastructure and geology. It is actively evolving in most locations in response to reduced sediment loads and managed flow regimes due to reservoirs and diversions. In support of the Bureau of Reclamation's (Reclamation) responsibility for MRG Project river maintenance, river work identification and planning follows a systematic process involving: 1) monitoring and analysis: 2) need assessment; 3) work classification; 4) documentation of results (for 1-3); and 5) programmatic project and work planning.

This paper describes the methodology for step 2; determine the relative *Need* for river maintenance. The *Need* for river maintenance relies on both the *Value* of the maintenance and the *Likelihood* of the necessity for maintenance. In the described methodology, *Value* and *Likelihood* are rated by water resources professionals using technical factors associated with river conditions, public interests, and water delivery. Each factor has individual criteria which are updated as state-of-the-practice river hydraulic, geomorphic, and ecological monitoring and assessment improve. The final relative *Need* for river maintenance is the product of the *Value* and *Likelihood* ratings at each location. *Need*, *Value*, and *Likelihood* are terminology specific to this report and assessment methodology that describe the importance, benefit, and potential conditions for river maintenance work.

In applying the rating criteria to the MRG, the *Need* for river maintenance was calculated for 86 sites and 11 reaches for the value-based technical factors of Public Health and Safety and Water Delivery. Rating results from the application were consistent with professional and experiential judgment, and objectively reflected the significance of the sites and reaches for the technical factors. The next steps for *Need* for river maintenance are the development of ecologic and cultural resource ratings.

INTRODUCTION

The MRG Project purposes include performing channel maintenance, ensuring effective water delivery through the middle valley downstream to Elephant Butte Reservoir, reducing the risk of flooding, bankline erosion protection, as well as meeting international treaty water delivery obligations to the Republic of Mexico. These needs and services remain important in the present and are joined by newer considerations for habitat improvement to enhance the ecological function of the system within the Project's congressional authorization. Reclamation has responsibility for sound environmental stewardship with the National Environmental Policy Act of 1973, and the Endangered Species Act of 1973 for listed species and their critical habitats.

River maintenance can be divided into two general types for project development:

- Individual sites - These are projects designed to meet immediate and local river maintenance at specific locations.
- Reach-level strategies – The strategies are designed to holistically address large-scale, observed, geomorphic trends, on a proactive basis. Implementation of projects considers the entire reach is intended to work with the river's underlying governing processes along with enhancing river functions like providing habitat and water delivery.

The Middle Rio Grande River Maintenance Comprehensive Plan and Guide (Maintenance Plan and Guide) (Reclamation, 2012) discusses the MRGP Program, reaches, and strategies in more detail.

The MRG Project river maintenance work identification and planning follows a systematic process involving five main steps. They are:

1) Monitor, analyze, and document channel and floodplain conditions and changes – performed continuously.
2) Identify, evaluate, and rate sites and reaches to determine the relative *Need* for river maintenance – performed annually and as needed.
3) Assign a Maintenance Classification utilizing the following designations for each site or reach – performed annually and as needed. These classifications are patterned after the Review of Operations and Maintenance (Reclamation, 1991) process, recognizing that the river is not a facility but a system. Professional judgment and experience combined with information obtained during the *Need* for River Maintenance assessment are used to assign classes.
    - Class 1 – Maintenance is required in the short term (typically before the next high flow event or could be required immediately) because there is a high likelihood of substantial consequences if no action is taken. Work can be described as interim and unanticipated projects are commonly individual sites.
    - Class 2 – Maintenance can be planned in advance but the consequences of no action could be substantial in the near term (the next normal spring runoff or within the next few years). The class includes the majority of ongoing or normal river maintenance work at existing and new sites.
    - Class 3a – Maintenance can be planned in advance and the consequences of no action are less likely to be substantial in the near term (the next normal spring runoff or within the next few years). It is work that can be described as preventative maintenance and also includes habitat enhancement.
    - Class 3b – Maintenance can be planned and the consequences of no action are less likely to be substantial in the near term (the next normal spring runoff or within the next few years). Data collection and/or analysis are required to determine if preventative or normal maintenance (including habitat enhancement) is needed.
    - Class 4 – Maintenance is not anticipated to be needed in the near term (the next normal spring runoff or within the next few years) because change appears to be occurring at a slow rate. Work can be described as monitoring for potential changes that could accelerate the need for maintenance to the near term. This class also includes monitoring of completed projects.
    - Class 5 – Maintenance may be needed but is not within Reclamation's authority. Responsible parties will be notified if it appears that the consequences of no action could be substantial in the near term.
4) Document assessment results for each location in an individual Site or Reach Report and summarize Relative *Need* for River Maintenance results in a report.
5) Plan maintenance projects and work – annually and as needed. Information from Steps 1 through 4 above, plus programmatic considerations like resource management, policy, budgeting, and stakeholder collaboration are utilized for planning projects and scheduling. Scheduling may require adjustment given the uncertainties in predicting hydrology, geomorphic trends, modeling, etc. on an alluvial river.

This process follows Chapters 3-5 of the Best Practices in Dam and Levee Safety Risk Analysis (Reclamation and USACE, 2012) and the Maintenance Plan and Guide.

This report details the methodology developed for Step 2-Identify, Evaluate, and Rate the Need for river maintenance. *Need* is identified where conditions are causing or may lead to: impacts to public health and safety (e.g. flooding of homes and businesses); damage to riverside infrastructure (e.g. river erodes into a levee, heading, or canal); and reduced effectiveness of water deliveries (e.g. aggradation causes the loss of a competent channel).

The *Need* for River Maintenance relies on the combination of *Value* of the maintenance and the *Likelihood* of the necessity for maintenance. The technical factors of *Value* and *Likelihood* are rated by engineering, geomorphic, ecologic and cultural resources professionals. The technical factors are explained in more detail below. It should be noted that *Value*, *Likelihood*, and *Need* of river maintenance are not specific quantitative consequence, probability, or risk determinations resulting from conventional risk analysis approaches. The *Value*, *Likelihood*, and *Need* ratings are intended for comparative analysis amongst a group of sites or reaches. Step 2 is a screening tool for work identification and prioritization.

SITE AND REACH MAINTENANCE NEEDS

Site Identification:

Individual sites needing river maintenance are currently identified based on meeting any or all of the following general criteria (Reclamation, 2012; Maestas and Padilla, 2011; Smith, 2005):

- The continuation of current trends of channel migration or morphology will likely result in damage to riverside infrastructure within the near term
- Similar conditions have historically resulted in failures or near failures at flows less than the two-year flood
- Existing conditions could cause significant economic loss, danger to public health and safety, or loss of water

River conditions at sites that meet the above criteria are evaluated through ongoing monitoring, evaluation of historical trends, geomorphic analyses, and numerical modeling to help understand the middle Rio Grande system as referenced in Step 1. These same criteria also apply when determining the need for implementation of reach-based strategies. Additionally, habitat value and enhancement opportunities at a site or reach will be included as part of the identification of sites or reaches benefiting from river maintenance. (At the time of this report submission, work is in progress to develop the ecologic and cultural resource *Need* ratings). The benefit of habitat enhancement is primarily a function of the habitat needs of threatened and endangered species.

The evolving river morphology – as it responds to the variable drivers of change (e.g. hydrology and sediment loads) and the controls of change (e.g. bed and bank stability, base level control, floodplain connectivity, floodplain lateral confinement) – is the fundamental cause of river maintenance needs. The combination of Steps 1 and 2 reflects this linkage between the river's morphology and the need for maintenance. Evaluation of the *Need* for maintenance requires characterizing geomorphic processes and current conditions for each reach and site, then estimating the likely future conditions.

Maintenance Need (Likelihood and Value) Technical Factors:

Technical Factors and criteria associated with river conditions, public interests, and water delivery infrastructure are presented below. The technical factors are structured to allow for the site and reach criteria to be updated with advancements in river engineering and ecosystem understanding, and measurement and analysis techniques.

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he criteria are only guidelines and experienced engineers should use professional judgment and the understanding of local conditions and fluvial processes during the ratings as well.

Likelihood-based Technical Factors

The *Likelihood* is a semi-quantitative estimate of the relative probability that conditions are causing or may lead to damage or impairment without future maintenance. When the damage or function impairment is imminent or has already occurred (e.g. levee failure or degraded habitat), the *Need* for river maintenance has been established so the *Likelihood* rating is simply the highest possible and thus the *Likelihood* Factors do not need to be rated.

1. **Percent of Reach Length with Sites (Rating from 1 to 5)**

This factor applies only to reach assessments and reflects how the evolving channel and floodplain fit within the lateral constraints of riverside infrastructure and geology. The number of identified maintenance sites is considered as well as the levee condition. Individual local sites are assumed to be ½ mile in length at a minimum; the total actual length for a reach scale project is also used when known. The total length of sites is divided by the reach length to get a normalized percentage of sites by reach.

- **Very low** – Sites occupy less than 5 percent of the reach length.
- **Low** – Sites occupy 5 - 15% percent of the reach length.
- **Moderate** – Sites occupy 15 – 25 percent of the reach length.
- **High** – Sites occupy 25 – 50 percent of the reach length. Downstream of San Acacia the levees rate as high or very high depending on condition.
- **Very high** – Sites occupy more than 50% percent of the reach length. Downstream of San Acacia the levees rate as high or very high depending on condition.

2. Bed and Slope Instability (Rating from 2 to 4)

A key criterion is the comparison of sediment transport capacity to sediment supply. The Maintenance Plan and Guide report provides information on the extent of imbalance as estimated by slope stability. Trends in bed material size, bed elevation and channel width are also important, but not all criteria need to be met for a rating. Local conditions may be used when known.

- **Low** – The reach slope is near the stable slope, bed material is stable, and bed elevation and widths are not changing
- **Moderate** – The reach slope is near the stable slope, local bed material and width changes are occurring, bed elevation may or may not be changing
- **High** – The reach slope is not near the stable slope, local bed material is not stable, and/or widths are narrowing and bed elevations are changing

3. Planform Instability (Rating from 1 to 5)

The main criteria are the current planform stage, the balance between sediment transport capacity and supply, and the degree of vegetation encroachment. Figure 1 shows the stages used below. More information can be found in Massong et al. (2010).

Planform changes are evaluated based upon likely conditions in the near term (< 5 years). Below are the descriptions of the classes:

- **Very low** – Planform is stage 1, A6, or M8 and sediment transport capacity is near supply, with no vegetation encroachment
- **Low** – Planform is stage 2, 3, or M5 and sediment transport capacity is near supply, with little or no vegetation encroachment
- **Moderate** – Planform is stage A4, M4, or M7 and sediment transport capacity is near supply, with little vegetation encroachment, or stage 3 with some vegetation encroachment
- **High** – Planform is stage A4, M4 or M5 and sediment transport capacity is not near supply, with vegetation encroachment present
- **Very high** - Planform is stage A5 or M6-M7 and sediment transport capacity is not near supply, with vegetation encroachment present

4. Bank Susceptibility to Erosion (Rating from 1 to 5)

The main criteria are the erosive susceptibility of the bank and the angle of attack. The erosive susceptibility of the bank includes the type of bank material, the type of river bed material, and the amount of vegetation. BSTEM (Simon et al., 2013) or meander evaluations may be used instead of the qualitative evaluation below. For reaches the same criteria are used and consider the majority of the reach length plus the sinuosity. Below are the descriptions of the classes for rating:

- **Very low** - mostly cohesive bank and/or dense root mass and/or gravel, very dense understory (have to crawl through), no incision, and a very low angle of attack (less than 20°)
- **Low** - some cohesion and/or root mass, dense understory but can still walk, low level incision, low angle of attack (20° to 30°)
- **Moderate** - cohesionless banks (sand), sand bed with small amount of gravel, some understory, some open areas but can still drive, moderate level of incision, moderate angle of attack (30° to 40°), minor opposite bar and meander pattern
- **High** - cohesionless banks (sand), some gravel bed material, sparse vegetation (majority of area between bank and levee is open, minimal understory), high incision, high angle of attack (40° to 60°), opposite bar and meander pattern
- **Very High** - cohesionless banks (sand), very sparse vegetation (little to none), very highly incised, very high angle of attack (60° to 90°), strong opposite bar and/or meander pattern

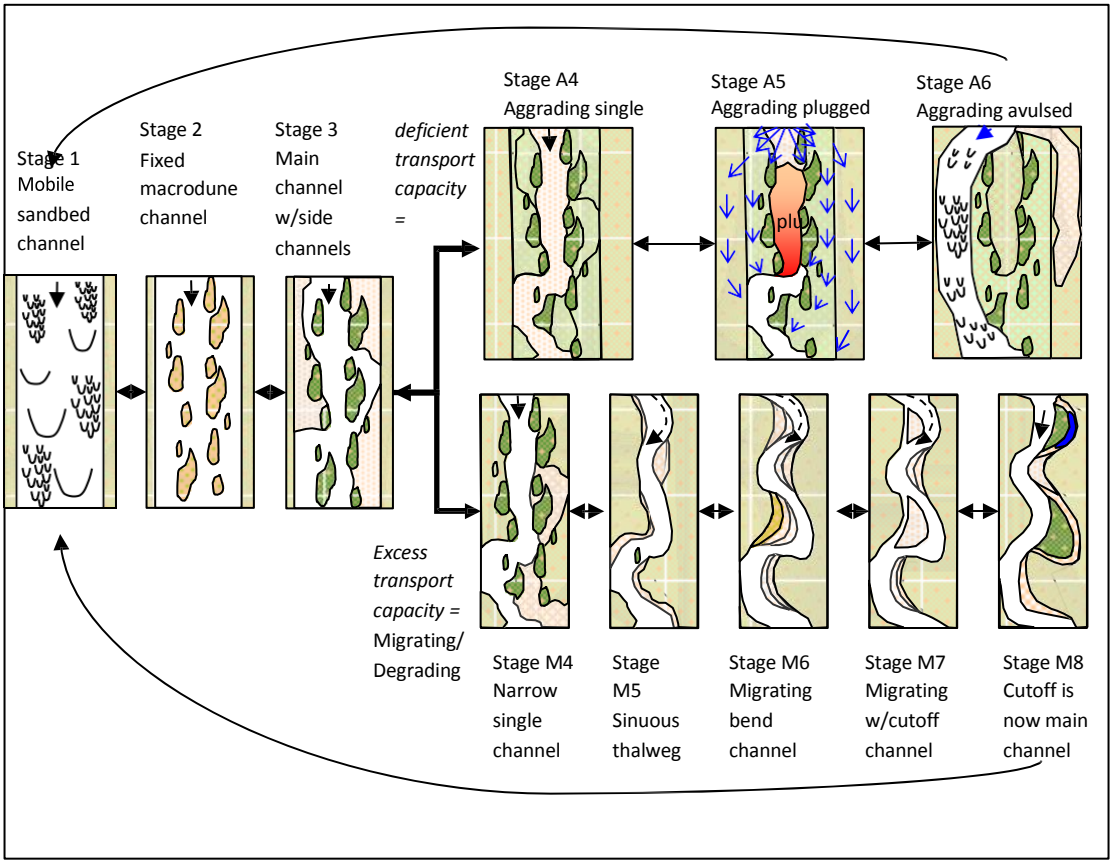

Figure 1 Planform cycles identified on the Rio Grande (Massong et al., 2010)

5. Proximity of infra-structure to river (e.g. levee toe or edge of facility) (Rating from 1 to 5)

The main criterion is the distance between the riverbank and the edge of the structure for river maintenance sites. For reach evaluations, the percent of the reach length where the meander belt width fits between the lateral constraints should be used as well as the percent of the area available between the constraints used by the meander belt width. The class descriptions are as follows:

- **Very Low -** greater than 200 feet. For reaches, the meander belt fits along 100 percent of the reach length and it uses less than 25 percent of the available area.
- **Low –** 150 to 200 feet. For reaches, the meander belt fits along a least 90 percent of the reach length and it uses less than 50 percent of the available area.
- **Moderate –** 100 to 150 feet. For reaches, the meander belt fits along less than 90 percent of the reach length and it uses less than 50 percent of the available area.
- **High -** 50 to l00 feet. For reaches, the meander belt fits along less than 90 percent of the reach length and it uses less than 75 percent of the available area.
- **Very High -** less than 50 feet. For reaches, the meander belt fits along less than 90 percent of the reach length and it uses more than 75 percent of the available area.

6. Past rate of lateral movement (Rating from 1 to 5)

The main criterion for this factor is the average rate of bank erosion and migration toward infrastructure. Typically, this average rate over several years will be based on aerial photography; unless the site is heavily monitored in which case it may be based on physical measurements. When known, the maximum rate of movement during one season should be considered. For reaches, professional judgment as to whether the average rate of movement for the reach as a whole is qualitatively very low to very high should be used to assign a rating class, but may be modified by consideration of the highest rate at a single location in that reach. Hydrology during the measurement period shouldalso be considered in the rating. For example, if flows have been low for several years and the rate of lateral

movement is low, it may be useful to look at rates of movement during periods of higher flows as well. Classes are:

- **Very Low** - channel is gradually moving toward the riverside facility, <5 ft/yr.
- **Low** - channel is slowly moving toward the riverside facility, 5 - 10 ft/yr.
- **Moderate** - channel is migrating at a moderate rate toward the riverside facility, 10 - 20 ft/yr.
- **High** - channel is migrating rapidly toward the riverside facility, 20 - 30 ft/yr.
- **Very High** - channel is migrating very rapidly toward the riverside facility, >30 ft/yr.

7. Channel and Floodplain Capacity Compared to MRGP Authorization (Rating from 2 to 4)

These criteria are used to evaluate the likelihood of flooding or other effects due to inadequate safe channel capacity. Capacity is reduced by sediment deposition that isn't mobilized by later flows. For example, this may be due to large grain sizes (e.g. coarse material supplied by arroyos), large sediment volume events (e.g. significant fires in the watershed), or vegetation encroachment with sediment trapping and stabilization. The time frame is the next few years. Middle Rio Grande Project authorization provides for Reclamation to maintain a channel capacity of not less than 5,000 cfs or the equivalent two-year return flow of the reach. Channel capacity is assessed through hydraulic modeling. When assessing floodplain and levee capacity with hydraulic modeling, an extra two to three feet of freeboard should be added in a perched system.

- **Low** - Capacity exceeds standards
- **Moderate** - Capacity meets standards
- **High** - Capacity is less than standards

8. Possibility of Channel Capacity Loss (Rating from 1 to 5)

Current trends are examined to determine expectations of a reduction, little change, or an increase in channel capacity. Hydraulic geometry trends should be used when available. The classes are:

- **Very Low** – channel capacity is increasing
- **Low** – channel capacity is generally constant, little or no channel narrowing
- **Moderate** – channel capacity is expected to slightly reduce every few years; with minimal levee raising, channel dredging, and minor channel narrowing and vegetation encroachment
- **High** – channel capacity is expected to reduce, continued levee raising or channel dredging are required, some channel narrowing and vegetation encroachment is occurring
- **Very High** – channel capacity is significantly reduced, levees need considerable raising or the channel needs considerable dredging year after year, significant channel narrowing and vegetation encroachment is occurring, plugs have occurred in past, bank heights are less than two to three feet.

9. Possibility of Levee or Embankment Failure (Rating from 1 to 5)

There are three main modes of levee failure: piping and internal erosion from flows against the levee, overtopping of the levee, and bank erosion into the levee. Only the first mode is assessed through this Factor.

- Water against Levee is of sufficient depth to cause failure through erosion or piping
  - **Very low** – no water against levee
  - **Low** - Engineered levee; water remains for few days; no sand boils; no longitudinal or lateral cracking; no sloughing; no extensive burrow holes; not an avulsion or plug prone area
  - **Moderate** - Engineered levee; water remains for several days; no sand boils; no longitudinal and lateral cracking; no sloughing; no extensive burrow holes; not an avulsion and plug prone area
  - **High** – Spoil levee; water remains for a few days; no sand boils; no longitudinal and lateral cracking; no sloughing; no extensive burrow holes; avulsion and plug prone area
  - **Very High** – Engineered or spoil levee; water remains for several days; sand boils, longitudinal and lateral cracking, sloughing, or extensive burrow holes present; avulsion and plug prone area
- Levee Overtopping – this is a failure mode, its condition is assessed through Factors related to channel capacity
- Bank erosion into levee – this is a failure mode, its condition is assessed through Factors related to bank erosion

10. Degree of Perching (Rating from 1 to 5)

The historical aggrading nature of, and the historic levees on, the Rio Grande have resulted in a channel bed that

may be perched above the local floodplain between the levees and may also be perched above the area outside the levees as shown in Figure 2. The average of the ratings from inside and outside the levee will apply in most cases. For reaches, the greatest percentage of cross sections in a reach determines the rating.

- **Very low** – Channel bed substantially below overbank elevation and/or outside of the levee system
- **Low** - Channel bed below overbank elevation and/or outside of the levee system
- **Moderate** - Channel bed near overbank elevation and/or outside of the levee system
- **High** - Channel bed higher than overbank elevation and/or outside of the levee system
- **Very High** – Channel bed substantially higher than overbank elevation and/or outside the levee system

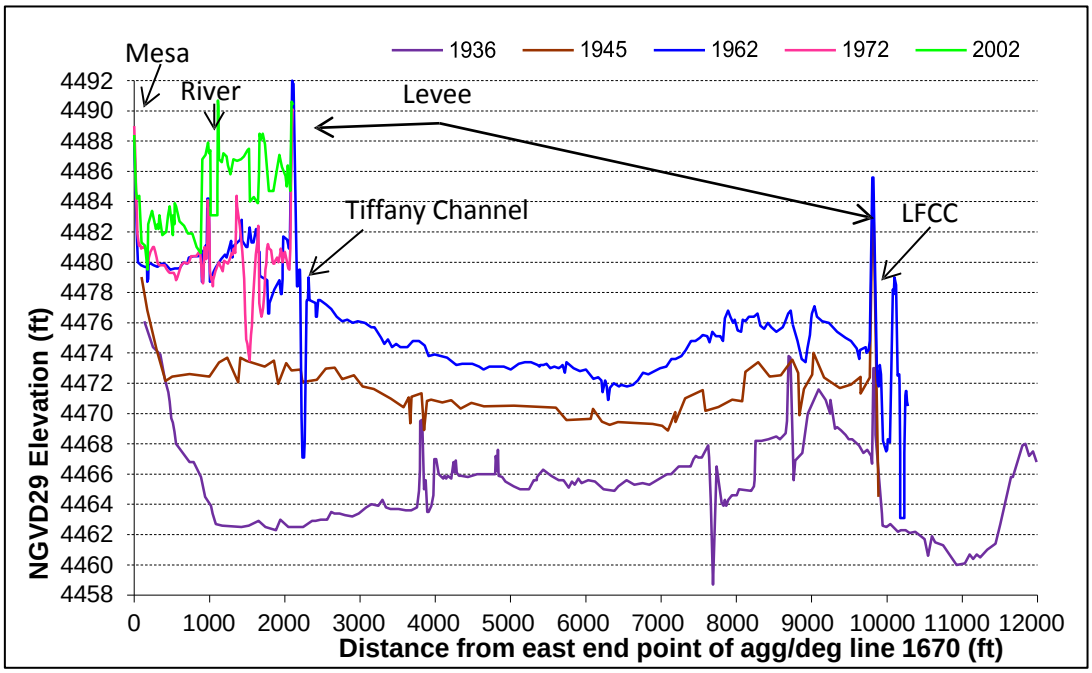

Figure 2 Agg/Deg Line 1670 where river is perched above floodplain and above valley

Value-based Technical Factors

Two factors (Public Health and Safety and Water Delivery) are used to estimate the *Value* or derived benefit of performing river maintenance at a site or reach from an authorized mission and public trust responsibility. *Value* of river maintenance from an ecological function and/or cultural resources viewpoint is not presented in this paper and is in development. Evaluation of the *Value* of performing river maintenance at a site or reach from an ecological function and/or cultural resources viewpoint could bring the number of *Value* factors to four. It is important to note the *Value* factors are rated linearly (i.e. 1-5) while the effects to the river system associated with any impacts (by the *Likelihood* factors) on these factors may be nonlinear.

1. **Public Health and Safety (Rating from 1 to 5)**

These criteria are used to evaluate the *Value* impact of no river maintenance and take into consideration the population concentration, the proximity of population to flooding (groundwater wells, septic systems, roads, homes, etc.) and the potential outcome of that flooding. Considerations include public infrastructure such as railroads, roads, and sewer lift stations. Rating descriptions were adapted from Smith (2005) and the Truckee Canal Issue Evaluation Report of Findings (2011):

- **Very low** –- Non-Populated Areas – No significant effects to the local population other than temporary minor flooding of roads or land
- **Low** – Sparsely Populated Areas – Minor property and environmental damage may occur. Damage is possible to sewer outfalls, recreation areas, rural roads, and bridges in low-lying areas. Direct loss of life is unlikely.

- **Moderate** – Moderately Populated Areas – Impacts could include moderate property and environmental damage. Damage to permanently occupied structures, recreation areas, local paved roads and bridges in low lying areas is possible. Terrain suggests direct loss of life is possible related primarily to difficulties in warning and evacuating recreationists/travelers and small population centers.
- **High** – Densely Populated Areas – Impacts could include extensive damage to permanently occupied structures, secondary roadways and bridges, and sewer lift stations. Terrain suggests direct loss of life is possible, related primarily to difficulties in warning and evacuating smaller population centers, or difficulties evacuating large population centers with significant warning time.
- **Very High** – Large Population affected – Impacts could include extensive damage to permanently occupied structures, primary roadways, bridges, and railroads, or regional effects such as contamination of Elephant Butte or Cochiti reservoirs. Terrain suggests direct loss of life could be high due to limited warning for large population centers and/or limited evacuation routes.

2. Water Delivery (Rating from 1 to 5)

These criteria are used to evaluate the *Value* impact on water delivery and riverside irrigation infrastructure of no maintenance. Consideration includes both impacts at specific sites (e.g. diversions) and downstream effects. Descriptive classes for infrastructure/function effects:

- **Very low –-** Little change to Water Delivery
- **Low** – Minor change to Water Delivery – impacts to drains for one to two miles,
- **Moderate** – Medium change to Water Delivery – impacts on secondary canals, irrigation/laterals (drains) for two to ten miles
- **High** – Major change to Water Delivery – impacts to main canals or multiple miles of damage to drains/canals (greater than ten miles),
- **Very high** – Regional change to Water Delivery – regional impacts on water delivery

CALCULATION OF SITE AND REACH NEED FOR MAINTENANCE

The steps to calculate the estimated Relative *Need* for River Maintenance are shown in Figure 3. As discussed earlier, the *Need* for River Maintenance is a function of the *Likelihood* of *Need* for River Maintenance and the *Value* of River Maintenance. The sources of change that lead to the *Likelihood* of *Need* for River Maintenance at a site or reach on the Middle Rio Grande can be grouped into three physical processes/ mechanisms: instability of channel bed, slope and planform; bank erosion leading to damage; and aggradation and/or island and bar growth leading to inadequate channel capacity. The 10 *Likelihood* Technical Factors (LTF) are therefore grouped into Potential for Channel Instability (LTF 1, 2, and 3), Potential for Bank Erosion (LTF 4, 5, and 6), and Potential for Loss of Channel Capacity(LTF 7, 8, 9, and 10), the geometric mean is calculated for each grouping. The Potentials for Channel Instability and Bank erosion are combined by calculating their geometric mean. The Potentials for Inadequate Channel Capacity and Channel Instability are also combined by calculating their geometric mean. These combinations provide both the Likelihood for Bank Erosion and Inadequate Channel Capacity Effects. Lastly, these Likelihoods are combined by taking their geometric mean to determine a composite Likelihood of Need for River Maintenance.

The *Value* Technical Factors (VTF) are then directly assessed through the criteria listed above. The Relative *Need* for River Maintenance of a reach or site is calculated by multiplying the *Likelihood* of *Need* for River Maintenance by each of the two presented *Values* (Public Health and Safety, Water Delivery) of River Maintenance. An overall *Need* for river maintenance is not calculated because each *Value* (Public Health and Safety and Water Delivery) can vary in importance due to programmatic considerations.

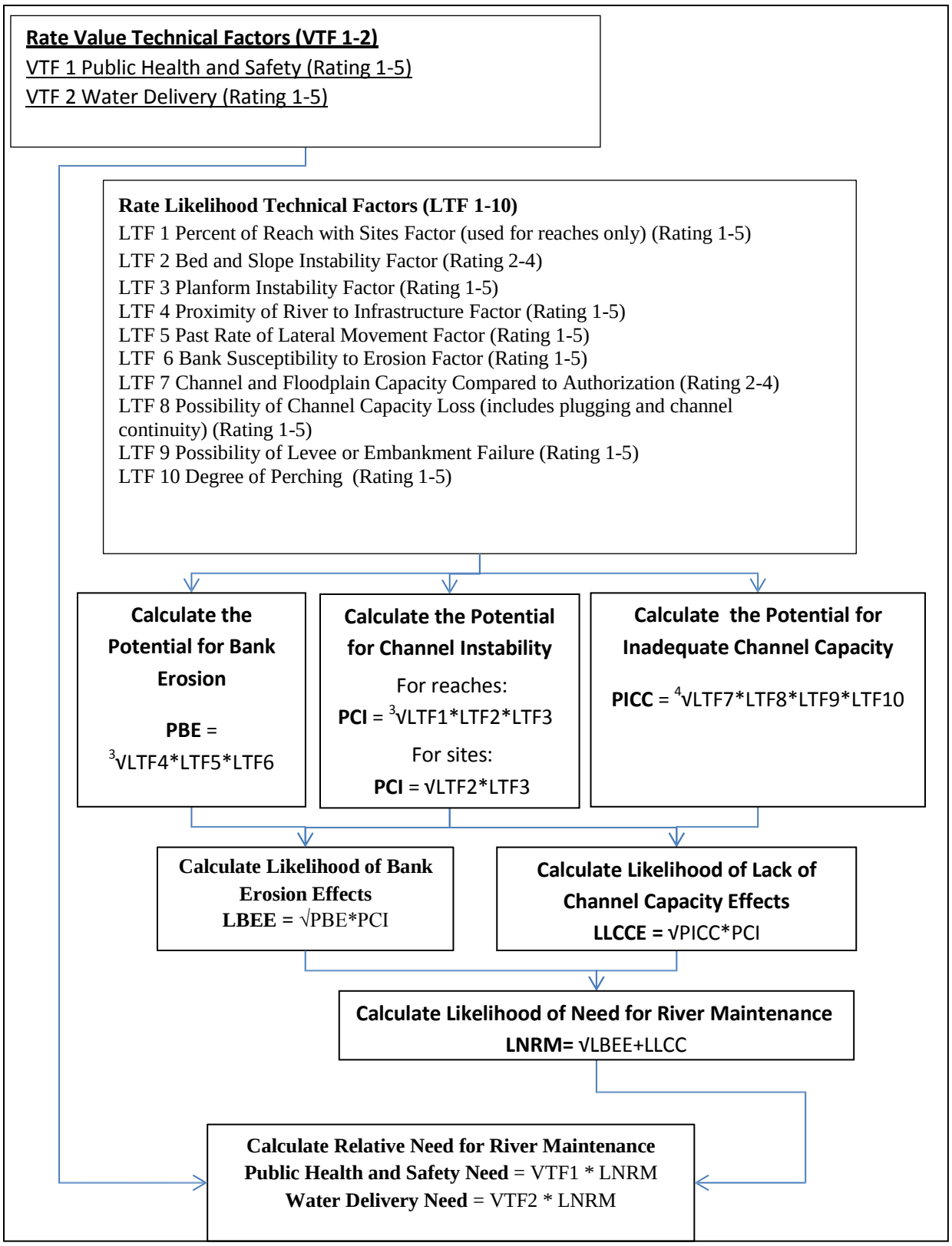

Figure 3 Flowchart of Relative Need for River Maintenance Determination

SITE AND REACH MAINTENANCE NEEDS RESULTS

Eighty six sites and eleven reaches were evaluated at current conditions. Final rating results for Likelihoods of Bank Erosion Effects, Channel Capacity Effects, Need for River Maintenance, and the Relative Needs for River Maintenance are presented in Reclamation (2014). Figures 4 and 5 below show the results of Need determination for the individual sites (only 17 shown, 86 rated total) and all eleven of the geomorphic reaches.

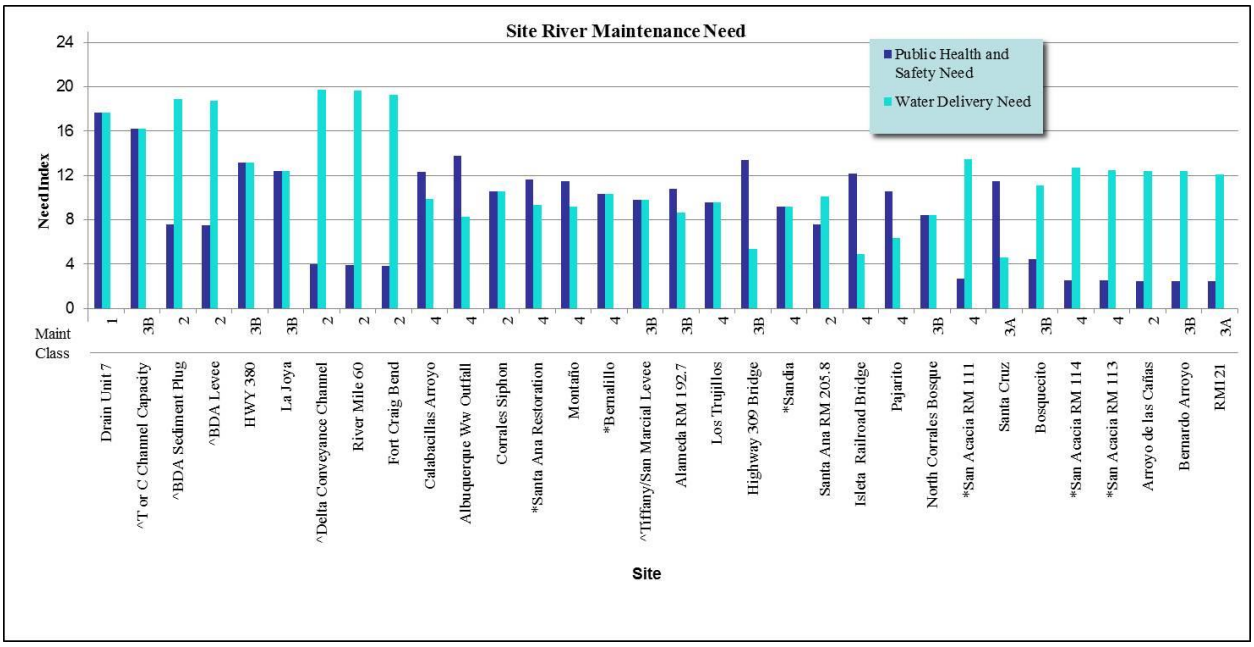

Figure 4 Site River Maintenance Need Results for Public Health and Safety; Water Delivery

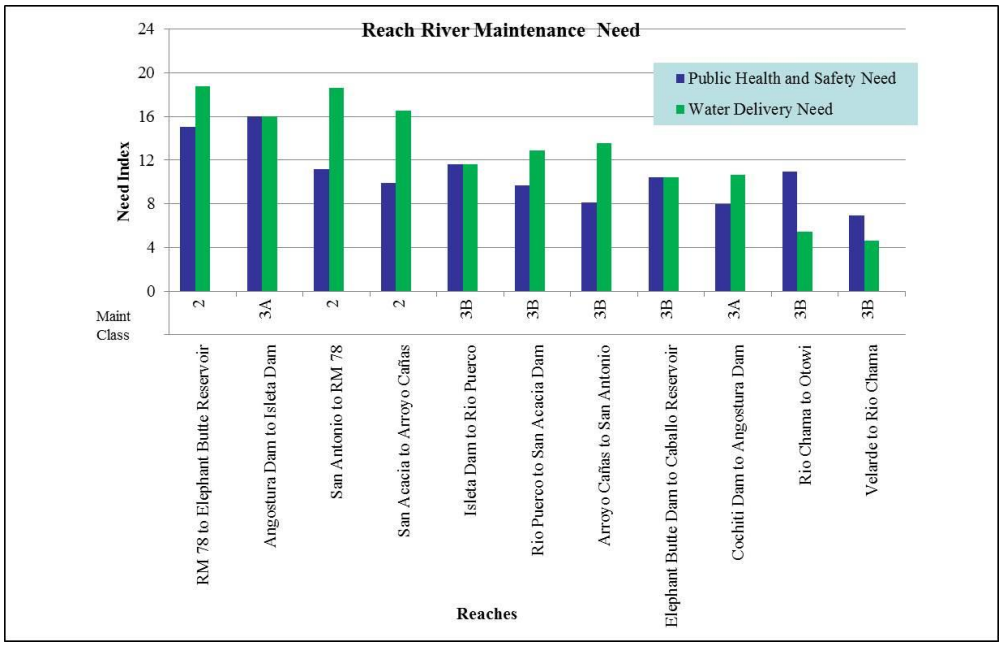

Figure 5 – Reach River Maintenance Need Results for Public Health and Safety; Water Delivery

These ratings provide semi-quantitative technical decision-making guidance for project planning. The assessment of the *Need* for river maintenance and assignment of a Maintenance Class occurred during a May 2014 workshop setting that best utilized the expertise of knowledgeable and experienced engineers, geomorphologists, biologists, and other professionals. The results of this workshop were documented for future reference related to maintenance need identification for the River Maintenance Program. Future updates to the ratings should be conducted and documented in similar workshops (with the best available tools/criteria for the Likelihood and Value Factors) as a part of the normal annual river review.

The Best Practices in Dam and Levee Safety Risk Analysis (2012) provides guidance on documenting or "making the case" for the Need for river maintenance. Chapters 3 and 4 are especially pertinent for further consideration. Other considerations in the final decisions on river maintenance work planning are the real-time circumstance and humanistic-based operational decisions that are made in regards to maintenance activities. Such considerations may include but are not limited to: area office priorities, scheduling, proximity to other sites, and if there is a potential for increased maintenance resulting from other non-Reclamation river projects. These considerations allow effective planning of river maintenance activities and may result in lower Class projects being undertaken concurrently with higher Class projects. The end result is anticipated to maximize the benefits from river maintenance. It is important to note that the Maintenance Class designations identified in Step 3 on page 2 of this report rely heavily on professional/experiential judgment and understanding the historic and real time dynamic river conditions.

The Maintenance Class Designations (1, 2, 3a, 3b, 4, and 5) indicate the recommended *Urgency* and corresponding level of response by the River Maintenance Program to the identified relative maintenance *Need*. There is not a simple correspondence of the factor ratings to Class Designations because the criteria do not directly evaluate the *Urgency*. *Urgency* for river maintenance reflects the apparent response time before further impacts occur to the identified *Values*. The *Urgency* is strongly dependent on professional judgment and experiential considerations derived from observing and monitoring the river system. Urgency can further be analyzed by defining the hydrologic loadings/triggers that drive river response to create a *Need*. These loadings include single events and also long term river flow trends involving frequency, magnitude, and duration. The *Likelihood*, *Value*, and *Need* ratings help inform the Maintenance Class designation. Since Technical Factors and criteria to rate the Ecological Function *Value* of river maintenance are not available at this time, it should be noted that the Maintenance Classes may be adjusted or a separate class structure for habitat restoration added after development of those Technical Factors and criteria.

Overall, this tool helps to systematically evaluate all sites and reaches with consistent Factors for *Likelihood* and *Value* to arrive at a relative *Need* determination for the two *Values* of Public Health and Safety and Water Delivery. This methodology is intended to be a rapid assessment tool to be applied at least annually in response to the dynamic river and hydrologic conditions on the Middle Rio Grande. It should be noted that even though the Potential for Channel Instability, the Potential for Inadequate Channel Capacity, and the Potential for Bank Erosion along with the Values of Public Health and Safety and Water Delivery are rated for the sites and reaches, not all potential effects to the river system are explicitly accounted for. This is due to the non-linear relationships in the rating Factors for predicting channel response and associated impacts; their scale (localized and reach level effects); their spatial variability (varying geomorphic conditions in each reach); and the temporal nature of effects occurring from a progression of physical processes due to specific hydrologic events or long term trends.

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