Date:	March 15, 2016
To:	Peter Nielsen Missoula Valley Water Quality District, City-County Health Department
From:	Matt Daniels, P.E. River Design Group, Inc.
Subject:	Identification of Issues Related to Dike Stability along the Clark Fork River Smurfit Stone Mill Site near Frenchtown, Montana

1. Introduction

Missoula County (the County) retained River Design Group, Inc. (RDG) to review available information for the Smurfit Stone mill site along the Clark Fork River near Frenchtown, Montana. The review is in support of identifying dike stability issues to be addressed in remedial investigations being undertaken by the current and past owners and operators of the site. The Smurfit Stone mill site (Site) is a former industrial site that is being evaluated for cleanup and redevelopment using guidance from the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) administered by the Environmental Protection Agency (EPA). A significant portion of the Site is situated in the floodplain of the Clark Fork River (CFR) and the Site is separated from the river by a 2.5 mile dike that parallels the river (Figure 1). The dikes have altered river function and there is concern that the dikes do not provide adequate protection against a potential breach that could cause environmental damage.

This memo provides a summary of RDG's review of available information and identifies issues related to stability of the dikes as well as river and floodplain function. More specifically, our review focused on the following items:

- Geomorphic characterization of the CFR and its tributaries near the Site;
- Effects of Site-related disturbances on river and floodplain processes;
- Assessment of the existing dikes; and
- Recommendations for next steps.

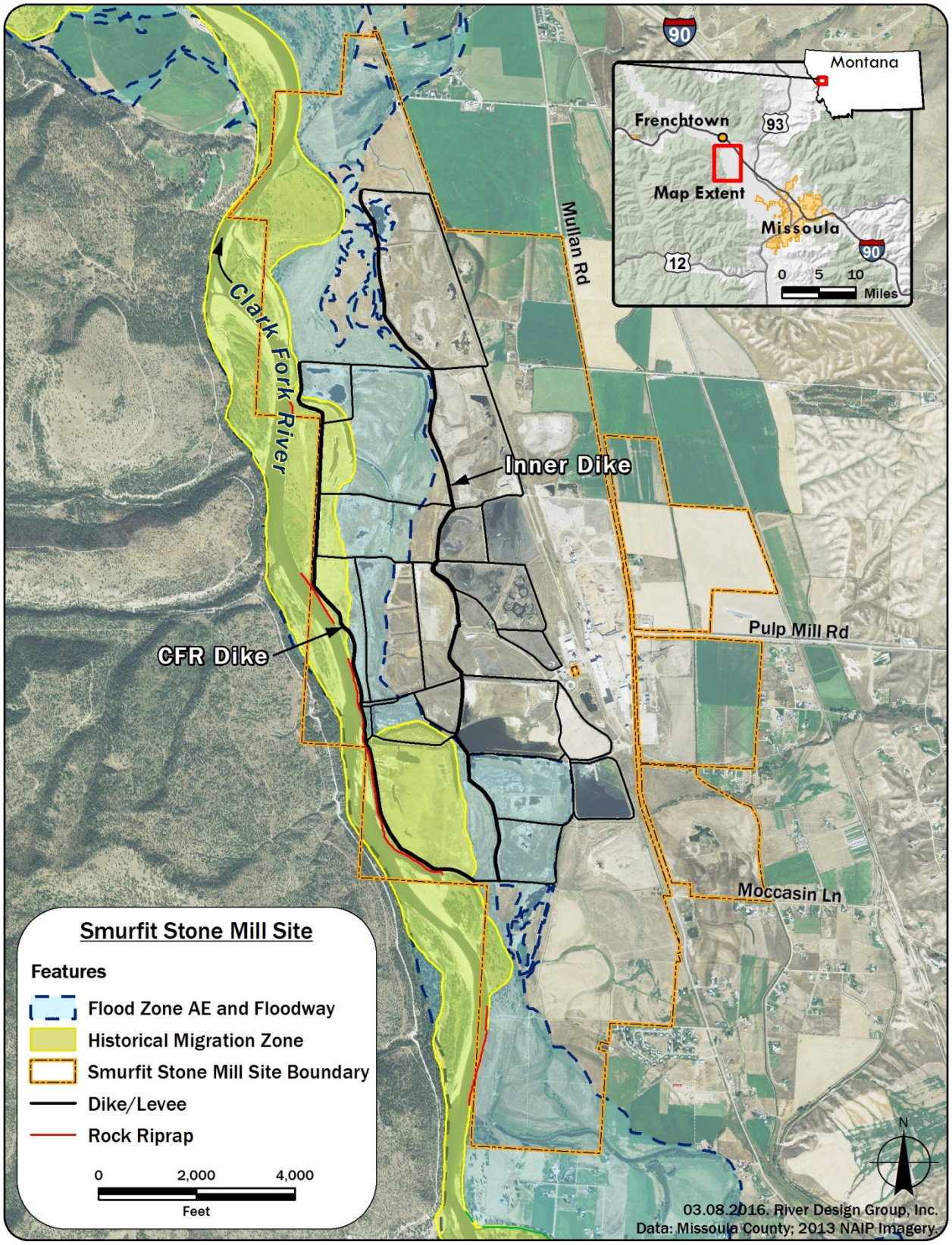

Figure 1. Smurfit Stone mill site with overlays of the dikes, channel migration zone and regulatory 100-year floodplain.

This review is based on the following information provided by the County:

- Preliminary Assessment Report prepared by URS Operating Services, Inc. dated September 2011;
- Remedial Investigation Work Plan prepared by NewFields dated November 2015;
- Channel Migration Zone (CMZ) mapping prepared by Applied Geomorphology, Inc. and DTM Consulting, Inc. dated December 2009;
- Flood Insurance Rate Map 30063C1155E prepared by the Federal Emergency Management Agency (FEMA) dated 2013;
- Natural Streambed and Land Preservation Act (SB-310) permits for dike repairs issued by the Missoula Conservation District to multiple owners of the Site between 1976 and 2001;
- Floodplain Development Permits for dike repairs issued by Missoula County to multiple owners of the Site between 1986 and 1997;
- Dam Safety Hazard Classification for the dikes and storage ponds at the Site prepared by Montana Department of Natural Resources and Conservation (DNRC) dated March 2010; and
- Photographs, aerial image analysis and map exhibits prepared by the Missoula County Health Department (MCHD) between 2011 and 2015.

2. Review

This section summarizes the following available information:

- Geomorphic characterization of the CFR and its tributaries;
- Effects of Site-related disturbances on river and floodplain processes; and
- Assessment of the existing dikes.

2.1. Geomorphic Characterization of the Clark Fork River and Tributaries

The reach scale geomorphic characteristics of the CFR near the Site are described in the CMZ memo (Applied Geomorphology 2009). The CFR is situated in a terraced alluvial valley formed by Lake Missoula and the Missoula Floods that occurred in the last ice age approximately 15,000 years ago. Today the CFR flows mostly unconfined through these formations, exhibiting meandering, braided and hybrid planforms with an average gradient of approximately 0.1 percent. The CFR channel near the site is approximately 400 to 500 feet wide and the bed is composed primarily of sand, gravel and cobble. The CFR is a free-flowing, unregulated river above the Site; however, numerous irrigation withdrawals are present. The FEMA Flood Insurance Study reports the 100-year flood at 67,600 cfs, and floods exceeding 50,000 cfs have been documented four times in the last 85 years. Vegetation communities consist of a diverse mosaic of woody riparian species, herbaceous wetland complexes and upland conifer forests. The CFR is an important migration corridor for aquatic species and is designated as critical

habitat for bull trout (*Salvelinus confluentus*), which are listed as threatened under the Endangered Species Act (ESA).

Channel lateral migration is a notable geomorphic characteristic of the CFR, as documented in the CMZ study. The mapped CMZ at Council Grove State Park located three miles upstream of the Site is approximately one mile wide. Channel migration rates are a function of flow, sediment supply and the erodibility of alluvial deposits along the channel margins. Channel migration is commonly associated with the process of dynamic equilibrium whereby river and floodplain geometry remain quasi-stable, but change in an ecologically beneficial manner as a result of desired disturbances from natural river processes.

From a biological perspective, channel migration and dynamic equilibrium are responsible for formation of the aquatic and terrestrial habitat conditions under which the native fish and wildlife communities adapted and evolved. Disturbance processes associated with erosion and deposition provide numerous ecological functions including:

- ***Riparian succession*** - creation of exposed depositional surfaces for the establishment of new plant and wetland communities;
- ***Habitat formation*** - woody debris recruitment, side channel development, pool/riffle sequences, and riverbed substrate mobilization for reducing accumulation/embeddedness of fines in interstitial spaces; and
- ***Floodplain connection*** - exchange of nutrients between the river and floodplain to support development of soils and the building blocks of the food web.

Along with the CFR, two tributaries, O'Keefe Creek and LaValle Creek, flow through the Site. Historically, these tributaries exhibited many of the same geomorphic characteristics and ecological functions as the CFR, albeit at a smaller scale. In addition, tributaries to the mainstem CFR provide important biological habitat attributes for native fish including spawning, juvenile rearing and refuge during mainstem floods.

2.2. Effects of Site-Related Disturbances on River and Floodplain Processes

Ecological functions at the Site have been altered due the CFR's response to human-caused disturbances. As a result, a number of factors are limiting the ecological potential of the site including:

- Loss of floodplain connection due to dikes;
- Lack of riparian and wetland vegetation due to land uses and industrial operations; and
- Simplified aquatic habitat due to lateral confinement.

Loss of Floodplain Connection Due to Dikes

Data developed for the CMZ study were used to develop a simple quantification of the floodplain area disconnected by the dikes. Measurements indicate that the 100-year floodplain width has been reduced up to 4,000 feet (1,800 feet on average) and the CMZ has been reduced up to 1,800 feet (600 feet on average). In addition, measurements indicate that the dikes have cut off over 170 acres of the mapped CMZ and approximately 525 acres of the 100-year floodplain (assuming the dikes contain the CFR). These reductions translate to a loss of

over one-third of the mapped CMZ and over one-half of the available 100-year floodplain. It should be noted that the CMZ study does not account for areas of channel occupation prior to 1955, and the loss of floodplain area could be larger as evidenced by abandoned channels beyond the mapped CMZ that are visible on aerial images. It should also be noted that the mapping for the 100-year floodplain was completed using coarse resolution topography and was completed prior to the availability of higher resolution LiDAR topography for the Site.

Figure 2. View looking upstream at the Clark Fork River through the Smurfit Stone Mill Site in June 2011 during a high flow event. The dikes have disconnected the river from the floodplain.

In the absence of detailed CFR channel surveys and floodplain topography, it is difficult to quantify the actual extent of floodplain disconnection caused by the dikes. A possible geomorphic response to an abrupt change in lateral confinement (i.e. floodplain constriction) is vertical degradation whereby a reduction in floodplain conveyance is offset by increases in depth and velocity in the channel, causing the channel bed to scour . In addition to simply establishing a lateral barrier from flooding, the constriction formed by the dikes may also have triggered a channel evolution process to an altered state at a lower base elevation. The consequence of such a change would be a greater loss of historical floodplain connection than is evident using mapping from contemporary topography and hydraulic modeling. At this time there is insufficient information to evaluate the channel response to the floodplain constriction.

Ecological functions affected by loss of floodplain connection include floodplain development, riparian succession, habitat formation and nutrient production for food web support. In general, loss of floodplain connection translates to reduced ecological productivity.

Lack of Riparian and Wetland Vegetation Due to Land Uses and Industrial Operations

Land use at the site has eliminated native vegetation as well as the soil structure necessary to support diverse vegetation communities. According to the Remedial Investigation Work Plan, approximately 1,200 acres are in agricultural production and nearly 2,000 acres were used for industrial operations, 525 acres of which occur in the mapped 100-year floodplain.

Simplified Aquatic Habitat Due to Lateral Confinement

Lateral confinement of the CFR by the dikes has reduced the availability of complex off-channel habitat (oxbows, side channels, depressions, tributaries, etc.) available to aquatic species. Measurements of abandoned off-channel features taken from aerial images indicate that approximately two miles of side channels comprising 20 acres of off-channel habitats have been cut off by the dikes. Off channel habitat features provide important biological functions including primary productivity, macroinvertebrate production, juvenile fish rearing, adult fish refuge/holding and overall habitat diversity.

2.3. Assessment of the Existing Dikes

The existing dikes were built over a period of years between the 1950s and the 1980s, and are shown on Figure 1. There are two primary dikes including the CFR dike that separates the CFR from the former treated water holding ponds and an inner dike that separates the treated water holding ponds, sludge ponds and industrial waste dumps from wastewater basins (NewFields 2015). The CFR dike and treated water holding ponds are within the regulatory 100-year floodplain. The CFR dike is constructed from on-site alluvial material (DNRC 2010) and parallels the river for approximately 2.5 miles. The CFR dike geometry is trapezoidal with nominal dimensions of a 15-foot top width, 2 to 1 side slopes, and a height of 20 feet (DNRC 2010). Portions of the CFR dike are faced with riprap.

CFR Dike Maintenance History

Between 1974 and 2007 approximately ten SB-310 permits were issued to address maintenance of the CFR dike and three were issued to address other issues on tributaries. A few problematic areas at the point of floodplain constriction near the upstream end of the Site have required frequent maintenance and are addressed multiple times in the permits. SB-310 permits and maintenance history are summarized in Table 1.

Table 1. Summary of SB-310 Permits issued at the Smurfit Stone Mill Site		
Permit #	**Year**	**Maintenance Action**
MS-19-76	1976	Place 500 feet of riprap
MS-25-76	1976	Dredge three side channels to increase flow and reduce stagnation
MS-41-76	1976	Additional dredging in one side channel
MS-90-78	1978	Placement of 3,250 feet of riprap over 10 years
MS-31-87	1987	Re-channel O'Keefe Creek
MS-32-87	1987	Dig weeds out of LaValle Creek
MS-09-90	1990	Repair 150 feet of riprap
MS-48-91	1991	Install two rock barbs and 175 feet of riprap
MS-58-91	1991	Remove woody debris and repair outfall pipes
MS-101-96	1996	Install a culvert in LaValle Creek
MS-20-98	1998	Repair 470 feet of riprap
MS-01-01	2001	Emergency repair of dike breach
MS-36-07	2007	Repair outfall pipe

Figure 3. Repair of a dike breach at the Smurfit Stone mill site in 2001 (left). Seepage shown at the toe of the dike in 1990 (right).

Dam Hazard Classification

In 2010 DNRC completed a hazard classification of the CFR dike. Based on a breach analysis completed by DNRC it was determined that the earthen embankment structures should be classified as low hazard dams according to the Montana Dam Safety Guidelines, and therefore, are not subject to regulation by DNRC. It was noted, however, that the dikes should be visually inspected at least once per year and receive an in-depth structural inspection by a licensed professional engineer every five years (DNRC 2010). It was also noted that due to the potential environmental damage that could occur, the dikes should be listed as significant hazard dams in the National Dam Inventory.

Summary of CFR Dike Potential Failure Modes

Table 2 provides a summary of potential failure modes that could result in a dike breach at the Site. Failure modes may occur independently or in combination with other modes. Potential

failure modes were derived from a report by an independent investigation team assigned to review the performance of the New Orleans Flood Protection System following Hurricane Katrina in 2005 (Remon, et. al. 2006).

Table 2. Summary of Levee Failure Modes[1]

Failure Mode	Description	Applicability to Smurfit Stone Mill Dikes	
Structural Forces			
Impact	Collision with an object	Low	No barge traffic or large boats
Tree root damage	Development of internal voids	Moderate	Few existing trees currently
Slope failure	Foundation destabilizes	Moderate	Unknown foundation, but most likely an alluvial sand/gravel foundation
Sliding	Pressure force from high water on one side pushes the dike	High	CFR flood or holding pond volume could create high stage
Hydraulic Forces			
Underseepage	Seepage through porous foundation causes piping	High	Unknown foundation, but most likely a permeable alluvial sand/gravel foundation
Internal erosion	Seepage through an internal void causes piping	High	Potential for animal burrowing and documented in maintenance history and photographs
Liquefaction	Failure of saturated loose soils by vibration such as an earthquake	Moderate	Unknown percentage of sand in dikes and low frequency of earthquakes
Bottom heave	Rapid underseepage caused by a surge of water pressure	Low	Surge of water pressure unlikely
Surface Forces			
Overtopping	Water flows over the crest and causes scour	Low	Some uncertainty, but dike height generally exceeds flood elevations in most locations
Surface erosion	Flowing water along the dike face	High	Numerous documented occurrences in maintenance history and photos
Wave impacts	Wave forces from boats or wind	Moderate	Potential exists when combined with other modes

1. after Remon, et. al. 2006.

3. Recommendations

This section provides items to consider for future investigations.

Complete an Assessment of Dike Stability

There is concern that the existing CFR dikes do not provide adequate protection against a potential breach that could cause environmental damage. The existing dikes have an extensive maintenance history as documented in ten SB-310 permit applications and floodplain permits that were provided for review. Maintenance was permitted to address issues related to seepage, surface erosion and a breach event. A DNRC memo (DNRC 2010) recommended routine visual inspections annually and more comprehensive periodic evaluations by a licensed professional engineer every five years. Several manuals and guidance documents for assessing dikes and levees are available from the U.S. Army Corps of Engineers including:

- Risk-Based Analysis for Flood Damage Reduction Studies. EM 1110-2-1619.
- Seepage Analysis and Control for Dams. EM 1110-2-1901.
- Slope Stability. EM 1110-2-1902.
- Design and Construction of Levees. EM 1110-2-1913.
- USACE Levee Inspection checklist

Complete a More Detailed Evaluation of Impacts to River and Floodplain Function

Ecological functions at the Site have been altered due the CFR's response to human-caused disturbances. It is estimated that the CFR dike has cut off over one-third of the mapped CMZ and over one-half of the 100-year floodplain. Also, approximately two miles of side channels comprising 20 acres of off-channel habitats have been cut off by the dikes. As a result, a number of factors are limiting the ecological potential of the site including the loss of floodplain connection, disturbance of vegetation communities, simplification of aquatic habitat and impaired water quality. It is unknown whether the floodplain constriction caused by the CFR dike has caused vertical degradation of the channel bed. LiDAR topography and the collection of geomorphic and vegetation field data could support a more comprehensive quantification of river and floodplain impacts.

Likewise, a more comprehensive understanding of impacts caused by the existing dike system upstream and downstream of the project area is needed. The existing dikes have a significant impact on fluvial processes and these impacts are likely to extend upstream and downstream of the Site.

Evaluate Restoration Opportunities and Develop a Conceptual Restoration Plan

Remediation of the Site presents an opportunity to reconnect hundreds of acres of riparian floodplain to the CFR. Floodplain reconnection would support restoration of native plant communities, development of off-channel aquatic habitat, and establishment of a broader channel migration zone. Restoration planning should be integrated with remedial investigations to ensure that holistic opportunities are considered.

4. Summary and References

In summary, the available technical information was reviewed to address concerns raised by the County. The review focused on the effects of Site-related disturbances on river and floodplain processes and stability of the existing dikes. Recommendations were provided for consideration during future Site investigations.

References

Applied Geomorphology and DTM Consulting. December 2009. Clark Fork River Channel Migration Pilot Technical Memo from Karin Boyd, P.G. to Peter Nielsen.

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