March 3, 2021

Clark Fork and Bitterroot Rivers Channel Migration Mapping

Missoula County

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6 Discussion—Milltown Dam and Smurfit Stone *(p. 95)*

The following section contains an expanded discussion of specific issues on the river related to the potential influences of Milltown Dam removal on channel dynamics and CMZ complexities at Smurfit Stone near Frenchtown.

[...]

6.2 Smurfit Stone *(p. 99)*

The Smurfit-Stone Mill is in the lower end of project reach CF09, approximately three miles south (upstream) of Frenchtown, Montana. It was operated from late 1957 through early 2010 as a large integrated pulp and paper mill. Whereas the core industrial footprint of the site covers approximately 100 acres, there are over 900 acres of unlined ponds that were used to store wastewater effluent and sludge (URS, 2011). Some of the wastewater ponds initially used to store wastewater were drained and converted to store solid wastes produced by the mill. Currently, about half of the ponds contain freshwater emergent wetlands (URS, 2011). The entire site has about four miles of river frontage (Figure 108 and Figure 110). Several areas described as sludge ponds, aeration basins, and treated water ponds extend into the historic floodplain of the Clark Fork River. Some of these features, mainly treated wastewater storage ponds, encroach into the active stream corridor of the 1930s and 1950s (Figure 108).

Whereas most of the site was developed prior to 1963, the northern ponds (Ponds 12, 13, 13a, 16, and 18), were constructed between 1963 and 1978.

Between 1958 and 1984, pond wastewater was discharged directly to the Clark Fork River during high flows. After 1984, discharges to the river were year round if river flows exceeded 1900 cfs (URS, 2011). Raw wood materials including sawdust, woodchips, and rejected timber were delivered to the mill site by truck and rail; there was no log driving down the Clark Fork River in support of the mill.

In 2016 we were asked to consider the relationship of the Smurfit Stone site to the Clark Fork River Channel Migration Zone (Boyd and Thatcher, 2016). The primary findings of that evaluation showed that hundreds of acres of the natural CMZ of the Clark Fork River are now occupied by Smurfit-Stone

facilities, mainly treated wastewater storage ponds, and that the active river corridor has been narrowed by over 40% through much of the site (Boyd and Thatcher, 2016).

Figure 109 shows the Relative Elevation Modeling (REM) results as well as the CMZ map for the Smurfit Stone site. Much of the mill site occupies the Historic Migration Zone where, in the 1950s, floodplain channels were continuous and active. These older channels are still visible as swales in the treatment ponds in the REM, and they stand out due to ponding in the 2018 flood photo (Figure 110).

6.2.1 Berm Failure Mechanisms

The Smurfit Stone Mill site is currently under much discussion regarding inspection needs, remediation approaches, and restoration opportunities. One issue that repeatedly arises is the interaction between the river and the ponds, especially with respect to risk of berm breaches.

The processes that are considered highly applicable to berm failure risk at Smurfit Stone include the following (RDG, 2016):

- Surface Erosion: Flowing water along the dike face
- Sliding: Pressure force from high water on one side pushes the dike
- Under-seepage: Seepage through porous levee foundation materials causes piping under the levee
- Internal Erosion: Seepage through an internal void causes piping through the levee

Regarding the CMZ, there are two main risk issues at this site. One is channel migration into the berm, and the second is avulsion risk through the ponds. Erosion of the berm due to channel migration is a surface erosion process. The other processes considered to highly be applicable at this site (sliding, under-seepage and internal erosion) relate to avulsion potential on the floodplain.

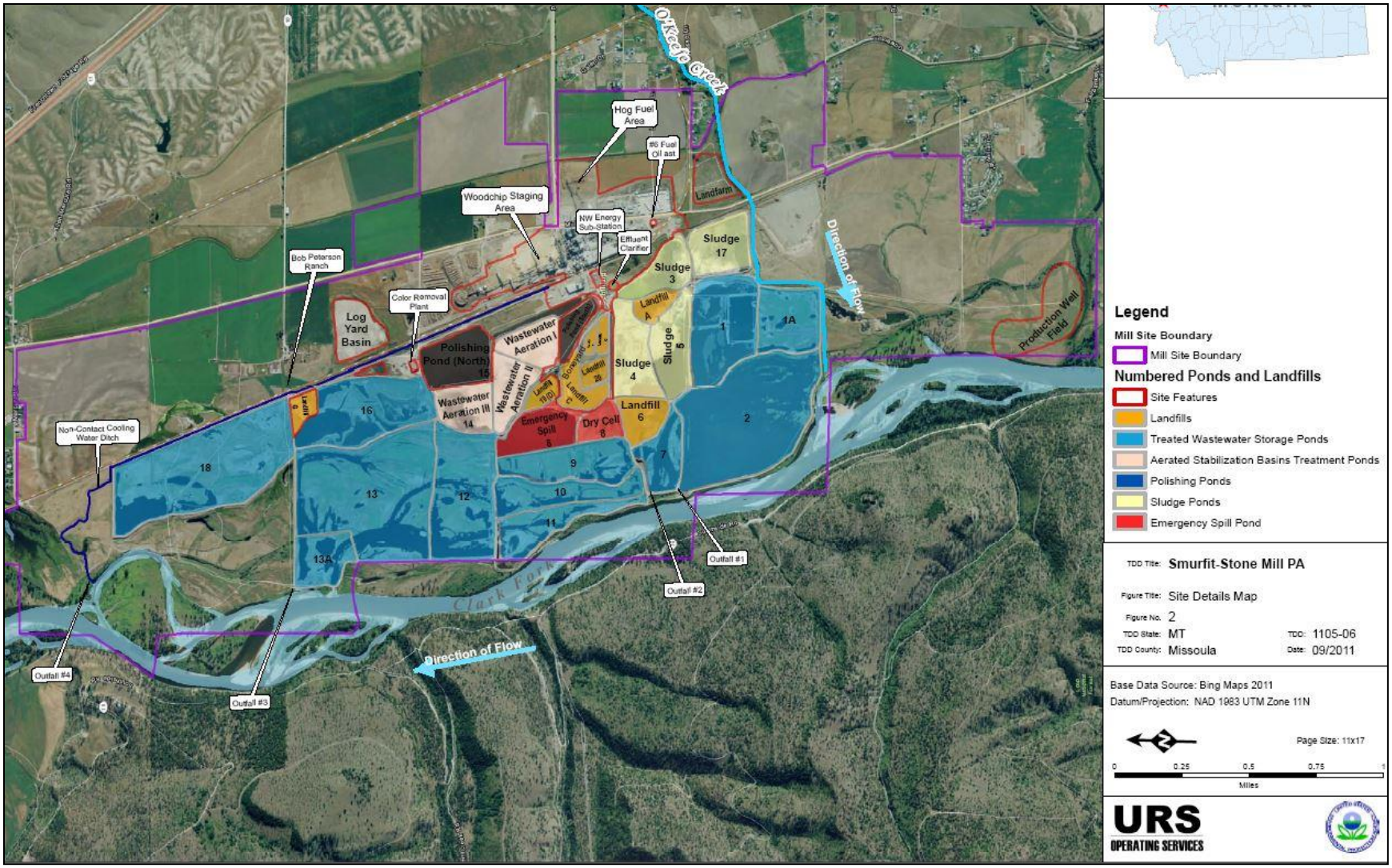

Figure 108. Generalized map of Smurfit-Stone site facilities; river flow direction is right to left (URS).

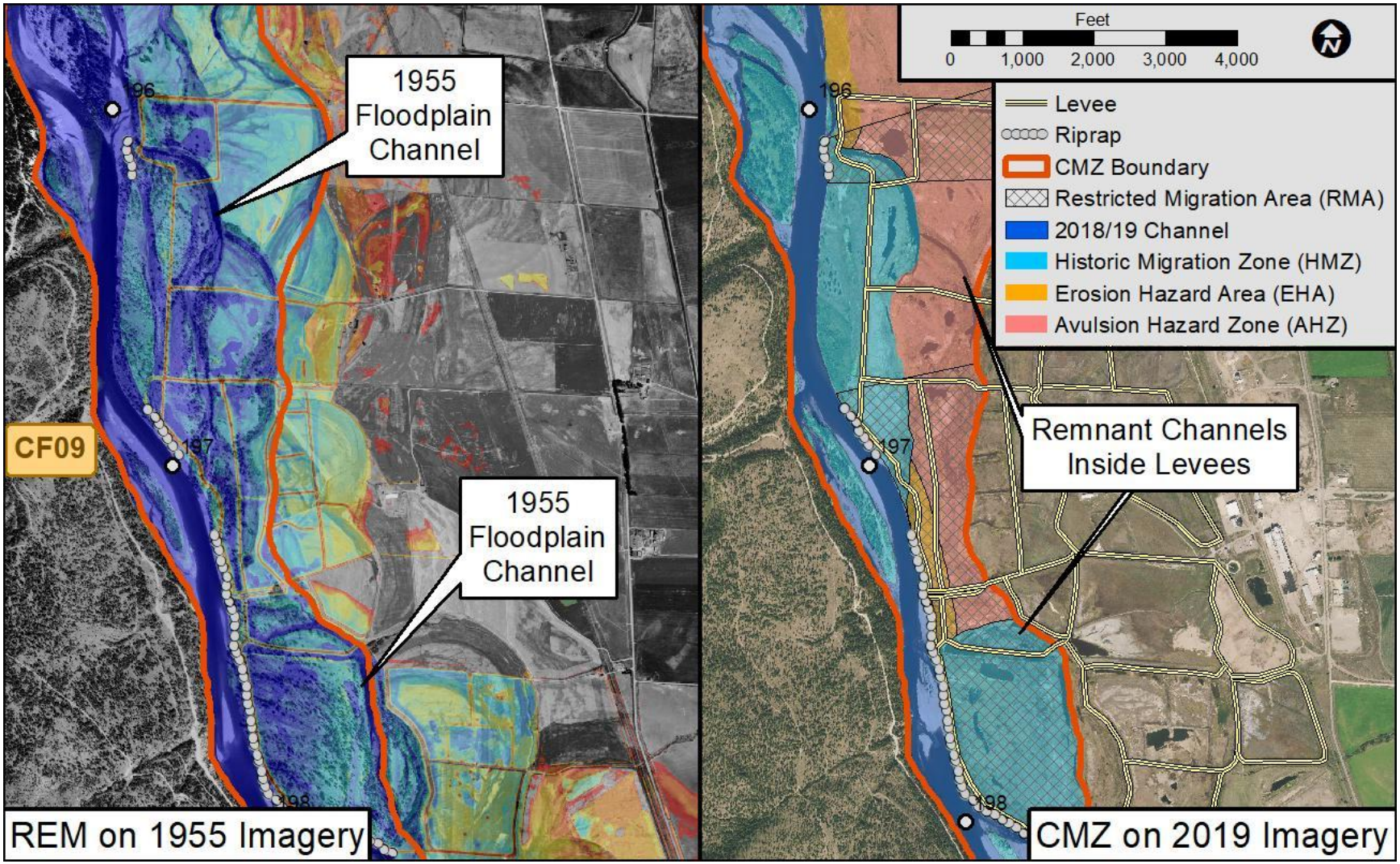

Figure 109. REM (left) and CMZ (right) maps for Smurfit Stone.

Figure 110. View downstream of Clark Fork River at Smurfit Stone during May 2018 flood.

6.2.2 Risk of Channel Migration into Ponds

According to a draft Clark Fork River Berm Surveillance and Contingency Plan (Newfields, 2019), there are two berms at the site forming continuous physical barriers to flooding events. These two berms are referred to as the "CFR Berm" and "Inner Berm" (Figure 111). The CFR berm is about 4.4 miles long and separates the site from the Clark Fork River, constructed as a man-made barrier between treated wastewater and the active river corridor (Newfields, 2019). It ranges in height from 8 to 15 feet above surrounding ground with an average top width of 15 to 25 feet. Two segments of the CFR berm were identified by EPA as "Special Concern Areas" after the 2018 flood (Newfields, 2019, Figure 111). The berms were constructed with native materials and underlain primarily by alluvial sands and gravels. The Inner Berm shown in Figure 111 was not addressed in the plan since flood evaluations indicated that the CFR berm would not be overtopped during a 100-year flood (Newfields, 2019).

The CFR berm is the primary infrastructure on site that separates the Clark Fork River from its historic and natural Channel Migration Zone, which is now occupied by wastewater storage ponds. As such, any risk of channel migration through the CFR berm is a primary concern on site.

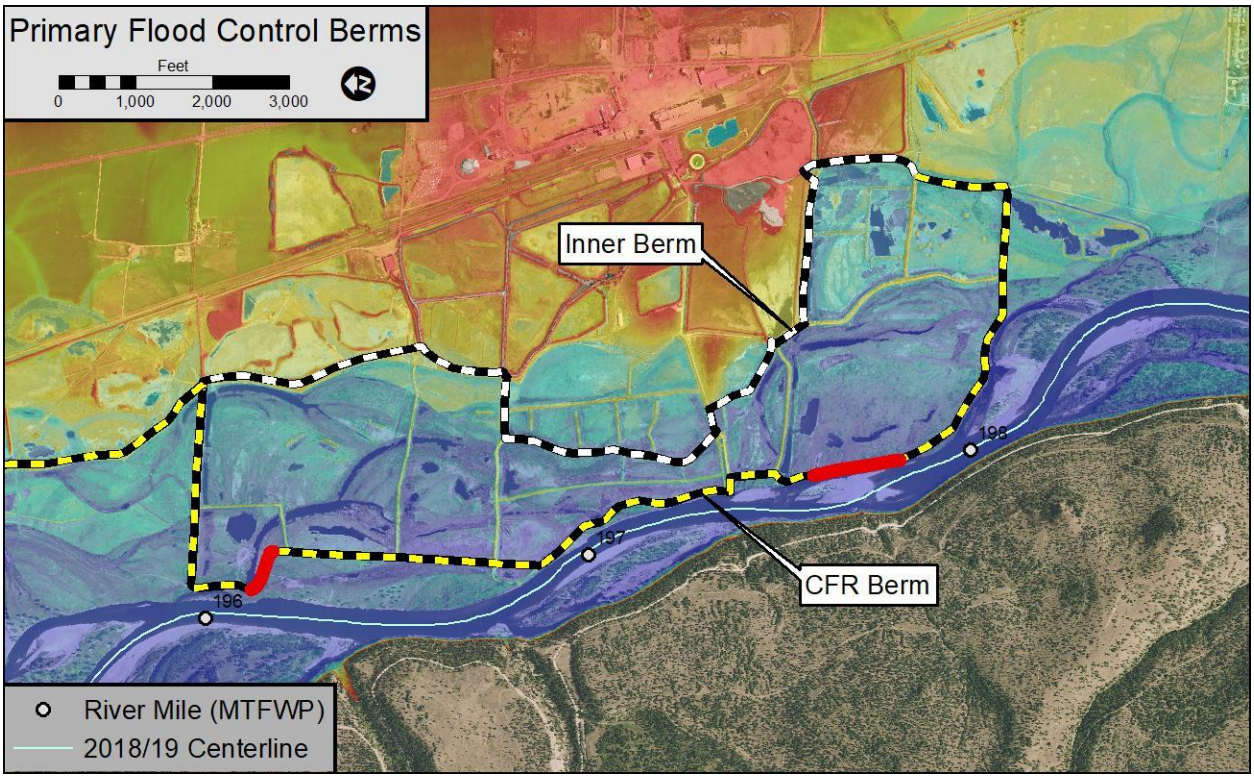

Figure 111. Primary flood controls berms at Smurfit Stone; red lines denote EPA "Special Attention Areas" following 2018 flood review (Newfields, 2019).

Since the primary means of protecting the CFR berm from channel migration is bank armor, the following discussion describes aspects of armor construction, maintenance, and current conditions with respect to river process. Figure 109 shows that most of berm is currently armored. In most areas the armor is on the CFR berm itself where it forms the stream bank, and in other areas there is a floodplain buffer between the armored streambank and berm.

The construction and maintenance history of the bank armor on the CFR berm provides some context as to the risk of berm erosion. In many places the main current of the river flows directly against the armored berm toe. In addition, the berms locally project into the active channel, which amplifies erosive energy along the riprap toe. Figure 112, which is a 2018 flood image along the berm edge, exemplifies this situation at the upstream end of Pond #11.

Permit records show that armoring the berms at the mill site was an ongoing construction/maintenance endeavor in recent decades. According to River Design Group (RDG, 2016), approximately 10 permits were issued (310) to perform maintenance activities on the berms between 1974 and 2007. These projects have included armor construction/extension, damaged armor rehabilitation, breach repair, and seepage treatments.

One important caveat in this discussion is that the armor mapping used in this evaluation was developed remotely using aerial imagery. There may be additional armor in place that is overgrown or even buried on site that is not accounted for in this discussion. In general, however, using several suites of imagery coupled with Google Earth oblique evaluations provide a good representation of bank armor extents. That said, the issues raised here should be used to incentivize a field assessment of specific areas to determine if the risks described here are already mitigated.

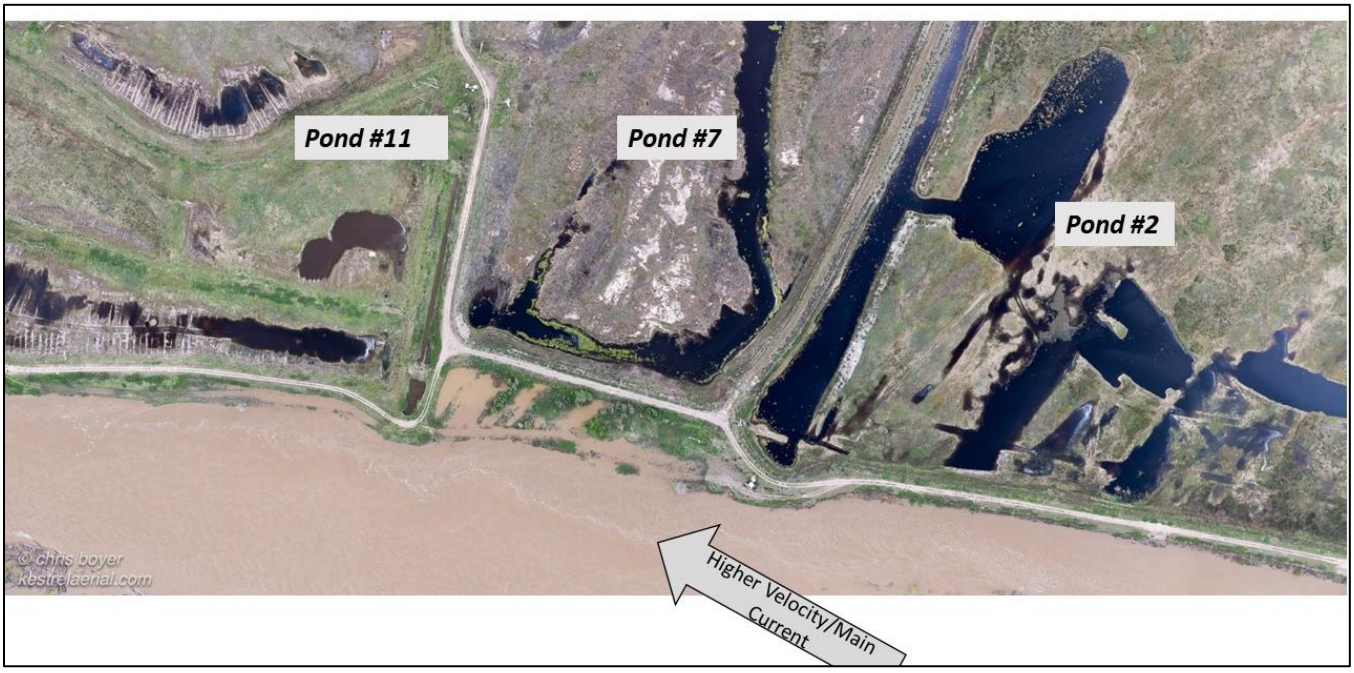

Figure 112. 2018 photo of floodwaters against Smurfit Stone berms (Ponds #2, #7, and #11 from right to left).

6.2.2.1 Pond #2

On the upstream end of the Smurfit Stone Mill Site at RM 198, The river has been migrating to the northeast towards the Pond #2 Berm (Figure 113 and Figure 114). About 1,000 feet upstream of the berm, the river has migrated about 70 feet since 2017 towards a swale that was a primary thread in the 1970s (Figure 113). A growing point bar on the left bank of the river will continue to drive right bank erosion and bend development at this location. As a result, increased activation of this meander should be expected, along with the erosion potential that comes with a higher frequency, duration, and magnitude of flow.

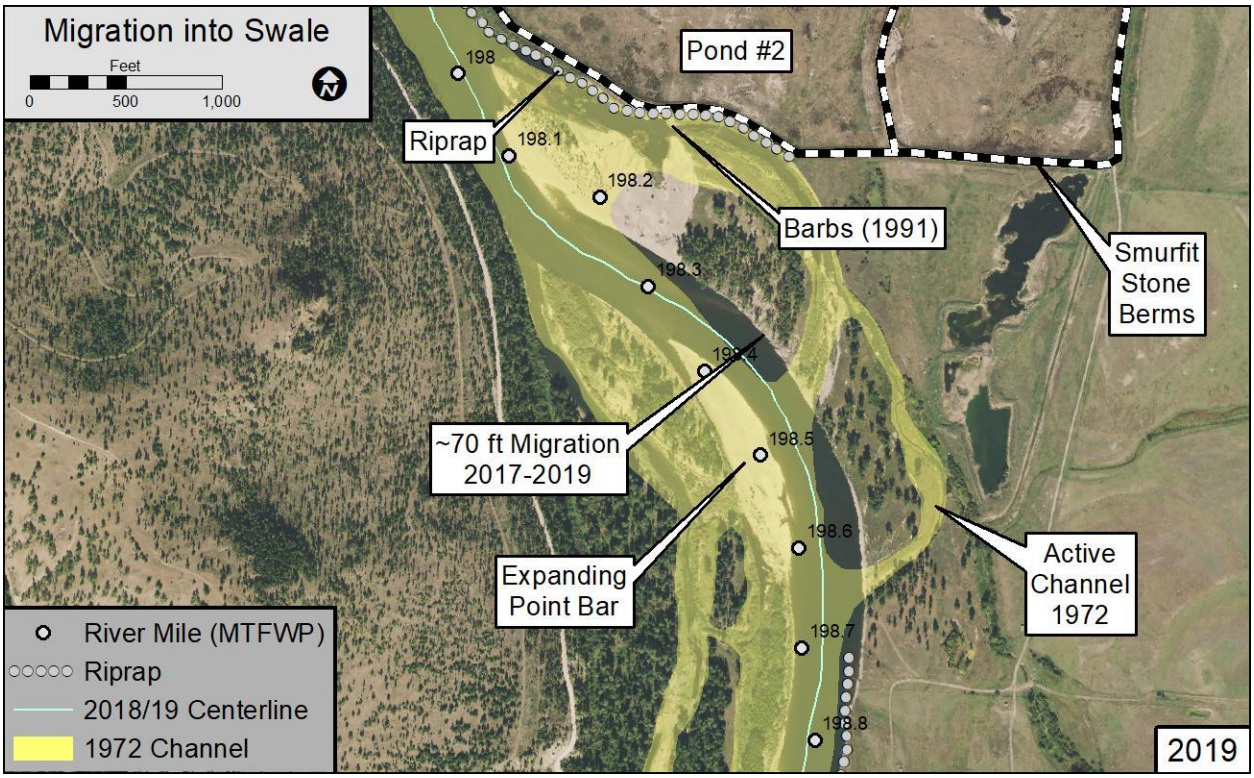

Figure 113. Bank migration just upstream of Smurfit Stone showing 2018 migration towards abandoned meander that flows against Berm along Pond #2.

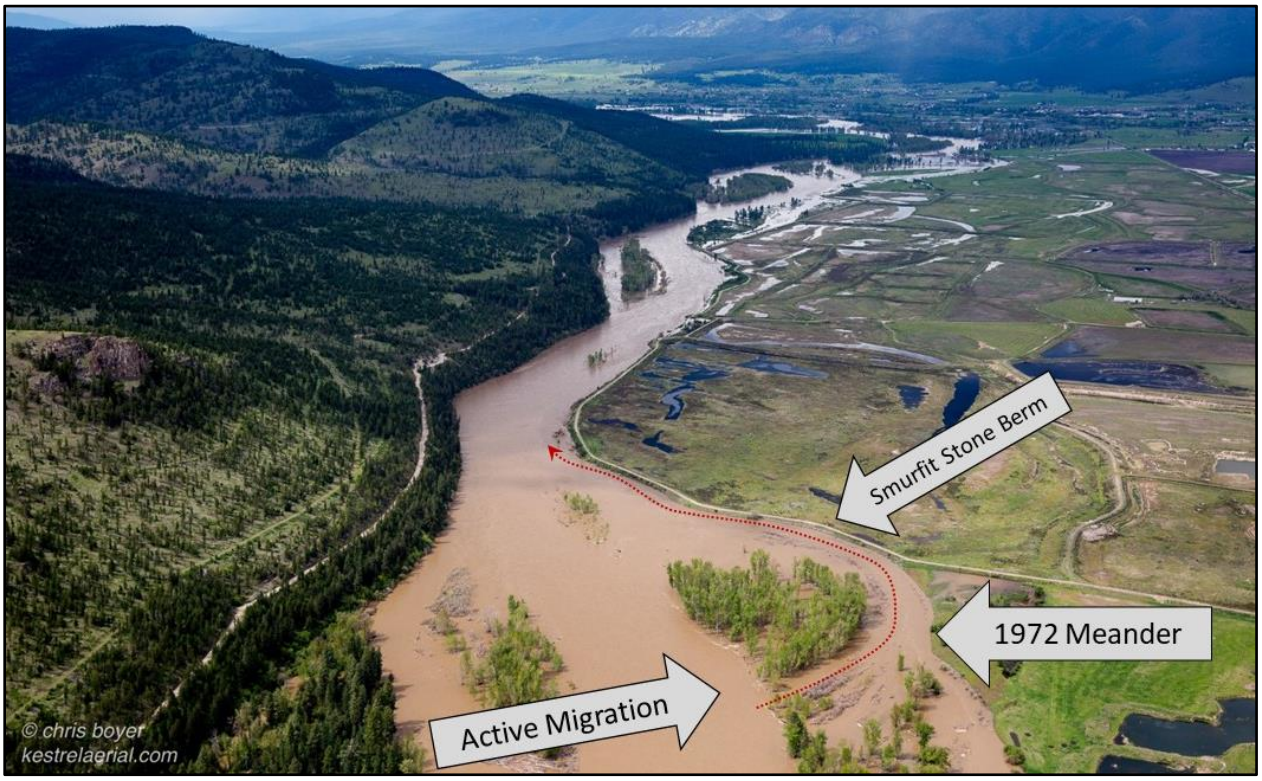

Figure 114. 2018 flood photo showing high flow activation of meander swale that flows against Smurfit Stone berm at upper end of mill site (May 10, 2018).

The history of armor maintenance along the CFR berm at Pond # 2 includes the following (Missoula County Conservation District 310 Permit applications):

> ***May 17, 1976:*** *300 feet of riprap. The application submitted by the mill owner stated, "Due to a changing course of flow in the Clark Fork River, the west side of the pond 2 berm is being eroded. The placement of 300 lineal feet of rock riprap is needed to prevent further erosion during high river flow and possible loss of the pond 2 berm." The application also requested to riprap 2,200 lineal feet of the south berm of pond 2*.

The 300 feet of riprap was probably deemed necessary when the bendway cutoff and re-oriented the river to the west, which would have increased erosive pressure on the right bank near RM 198 (Figure 113). The 2,200 feet of additional rock appears to have been placed on the right bank of the older channel on the south side of Pond #2.

> ***October 1978:*** *200 feet of repair on the south berm of pond 2, 1,200 feet of the west berm of pond 2.*

As the river adjusted to the cutoff, the armor protecting the west side of the CFR berm at Pond #2 was evidently extended.

> ***October 1985:*** *500 feet of riprap "During each spring runoff, the river has cut away the bank in the west side of storage pond 2. ... To prevent the river from eventually cutting into the pond berm, we are proposing to rock riprap 500 feet of riverbank." The area proposed for riprapping is the same as indicated in the 1976 and 1978 permit applications.*

Additional riprap on the west side of Pond #2.

> ***September 1991:*** *Two rock barbs on the river side of Pond 2. Riprap had failed at this location on many previous occasions. An October 1991 floodplain permit application submitted for same project stated, "The purpose of the bank barbs is to reduce the continued erosion to the riprap along the berm of our wastewater pond 2." The barb location is in same location as 1976, 1978, and 1985 permit applications for riprap placement along the face of pond 2.*

The 1995 imagery shows barbs at the location labeled in Figure 113. At that time, a primary channel was hitting this bank at a right angle.

> ***May 2001:*** *An Emergency 310 permit application requested for repair of the berm of Pond 2. A leak of 150 gallons per minute was discovered, discharging wastewater into the river. The leak was indicated in the same area as previous repairs made to the pond 2 berm. Clay was applied at the outlet of the leak to stop the leak and the pond level was lowered. A rodent burrow was identified as the cause of the leak.*

We have no records of any maintenance performed since 2001.

Peter Nielsen of Missoula County performed a visual inspection of the rock barbs placed in 1991 to see if the rock barbs remain in place or whether they still retain any functional utility for protection of the berms (date of inspection unknown). The inspection revealed that some rock remnants of the barbs remain below the low water mark, but rock placed above the low water mark has been eroded or dropped into the river channel. Missoula County expressed concerns that those barbs provide "very questionable function to protect the Pond 2

embankment." This is a concern because the ongoing shifts in river location just upstream of the barbs will likely increase erosive pressure against the barbs in coming years.

Figure 114 shows that this area around Pond #2 is marked by a substantial narrowing of the river's Channel Migration Zone as it approaches the Smurfit Mill Site. This can create problems regarding sediment continuity, as abrupt artificial narrowing of stream corridors commonly results in deposition upstream (such as at bridges). Any increased rate of sediment storage in the area shown in Figure 113 will drive additional channel movement and create new stressors on the existing berm/armor system.

Another lesson from the Pond #2 armoring history is that maintenance permits have been repeatedly requested in addition to permits for armor extension. The maintenance requirements do not necessarily originate from a single major flood but can develop from constant pressure on a given segment of armor, even at low to moderate flows or from non-hydrologic processes such as animal burrows. There is currently an EPA designated "area of special concern" against Pond #2, this site should be monitored frequently for both loss of berm integrity as well as protective armor decay.

6.2.2.2 Pond #11

Although the CFR berm continuously forms a physical boundary between the river and the mill site, the armor is discontinuous. This is apparently because the berm is locally set back from the active river channel and thus is not imminently threatened by bank erosion. This creates some risk however in that a primary mode of armor failure is unraveling on its upstream end due to local scour behind the rock. There is a good example of this developing risk against Pond #11 (Figure 115).

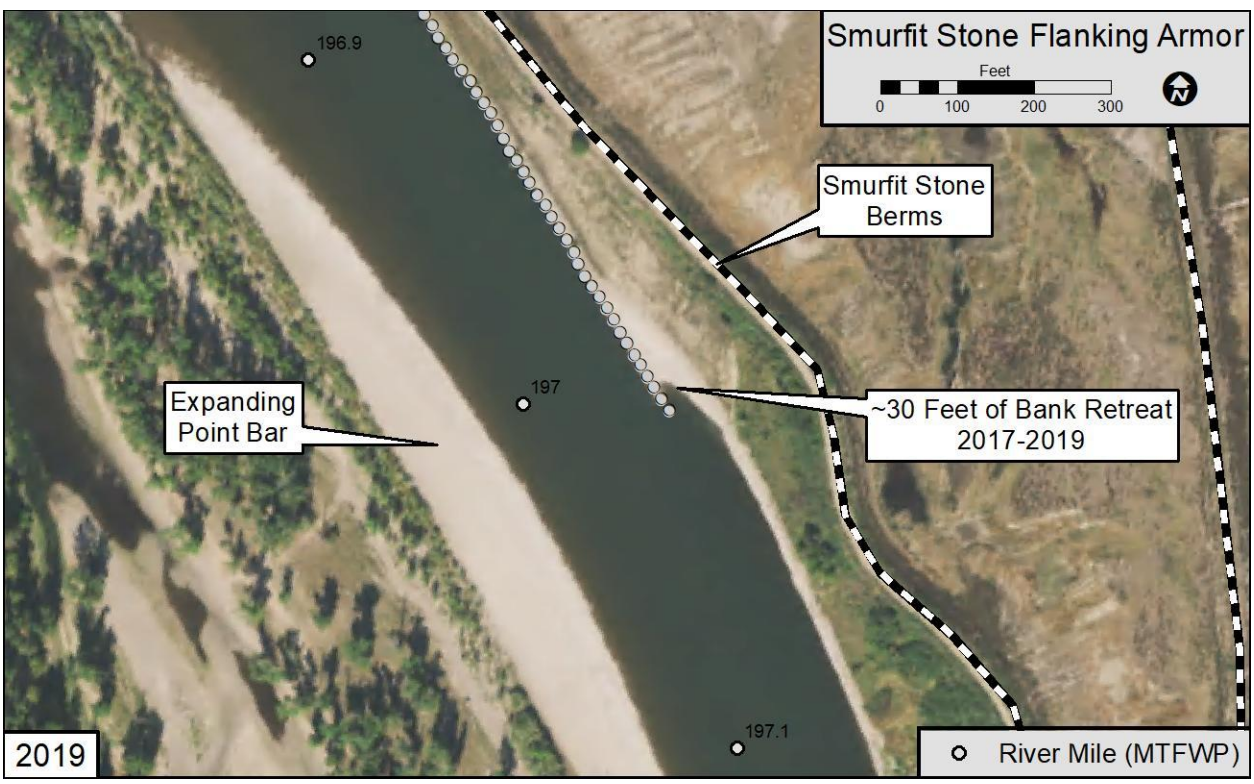

Figure 115. 2019 image showing local scour behind bank armor at RM 197 at Pond #11.

Figure 116 shows water flowing behind the bank armor during the 2018 flood. And Figure 117 shows an oblique Google Earth image of the same site. This flow concentration on the back side of a bank treatment can cause rapid erosion between thee armor and berm, and this should be carefully monitored.

Figure 116. 2018 flood photo of bank armor at RM 197 (Pond #11) showing linear rock treatment largely submerged; note high flow velocities visible on upper end of treatment.

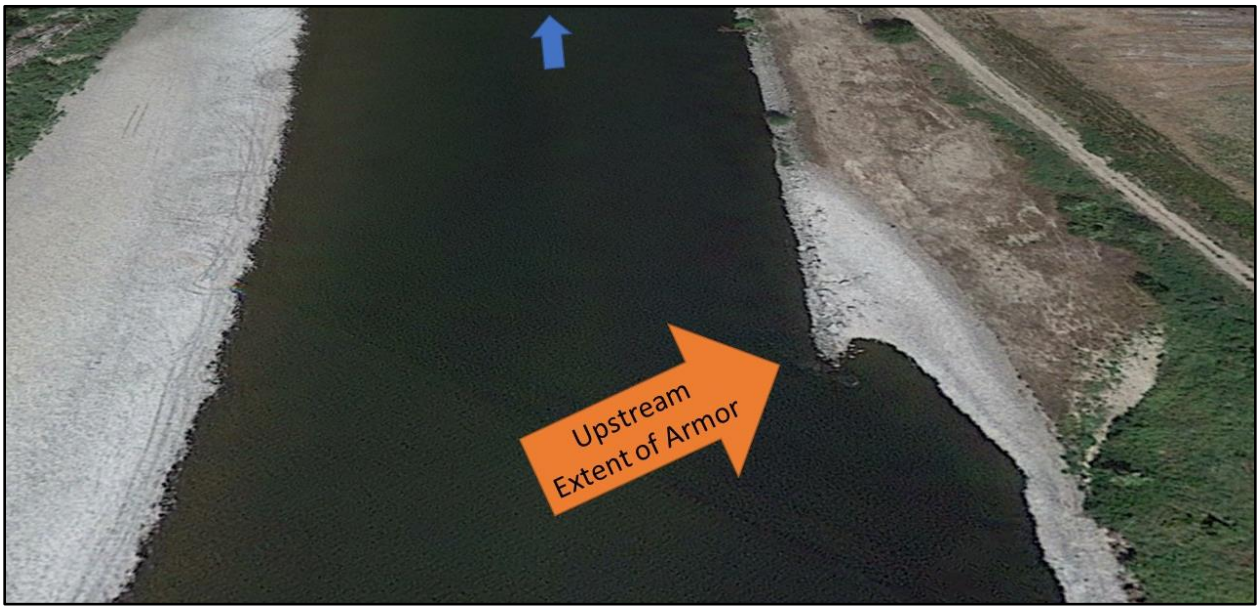

Figure 117. Google Earth image showing scour behind armor at RM 197.

The permit history at Pond #11 includes a request to riprap 300 feet of the CFR berm in 1976 as well as a request to repair 1,600 feet in 1978. The original armor construction in this area is uncertain, but it appears to have been built sometime in the early 1970s.

6.2.2.3 Pond #13a

Another example of potential armor damage is shown in Figure 118. This is located at the downstream (northern) end of the mill site. In 2018, a scour pocket formed at the head of the armor which will increase its risk of failure in coming years. East of the armor, floodwaters have scoured out floodplain area between the armor and the Smurfit Stone Berm. Figure 119 shows that at high flow the water flowing behind the armor hits the berm at a right angle, increasing the potential for local scour at the toe of the berm. This section of berm, which runs at a high angle to the Clark Fork River corridor axis, should be monitored and maintained as necessary. This section of the CFR berm was identified as an "area of special concern" by the EPA following the 2018 flood (Newfields, 2016).

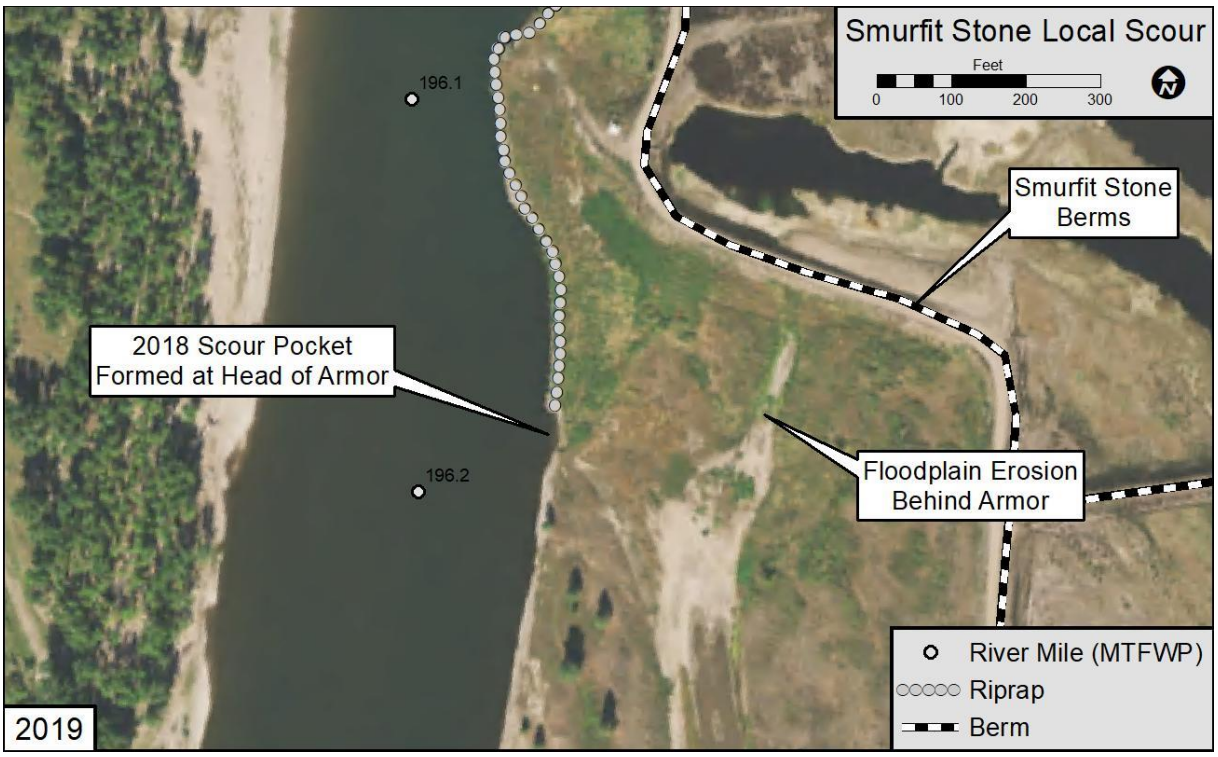

Figure 118. Local scour pocket formed during 2018 flood at head of riprap bank treatment, RM 196.15 (Pond #13a).

Figure 119. View upstream of armor at RM 196.15 showing flow behind treatment hitting Smurfit Stone berm at right angle.

6.2.3 Risk of Avulsion through Ponds

In general, the berms at Smurfit Stone are 8-15 feet higher than the ground surface. Previous overtopping analyses of the berms showed that there is at least 4 feet of freeboard along the CFR berm at a 100-year flood, indicating that it will not overtop (Newfields, 2019). Regardless, Newfields (2019) also identified the potential for under-seepage to occur that has the potential to destabilize the berm via erosion of underlying materials. Available information suggests that it is highly unlikely that overflows will top the berm without some sort of preceding failure due to slumping, piping, or river erosion (although recent hydrologic analysis suggest that the 100-year discharge in this area is 1,000 cfs higher than the previously adopted discharge, which may slightly reduce the previous freeboard presumption (Pioneer Technical Services, 2020)). Avulsions would therefore have to be preceded by some other sort of failure that allows water to flow into the settling ponds. If that were to occur, however, there very well may be risk of channel formation through the ponds.

Internal berms on the mill site have historically breached. EPA documented a breach through the berm at the northwest corner of the emergency spill Pond #8 into wastewater storage Pond #9. Additionally, "a breach through the dike at the western corner of Sludge Pond 5 was also noted…." (Missoula County).

The floodplain berms at Smurfit Stone site have the potential to dramatically alter floodwater flow paths and scour potential in the event of their breaching. The potential impacts of dike breaching have not been incorporated into the CMZ mapping; hence the projected avulsion hazard zones should not be used to indicate the limits of potential

impacts of such an event. This would require a hydraulic analysis of breaching scenarios that is beyond the scope of the CMZ mapping effort (River Design Group, 2016).

Ter Horst and Jongejan (2014) studied the importance of evaluating domino effects of flooding in nested levee systems in the Netherlands and concluded that risk assessments that are carried out for individual levees versus groups of levees may strongly underestimate flood risk.

Additionally, the flood mapping in this area apparently does not consider the potential impacts of ice jamming on flood stage. In Glendive, Montana, a levee was constructed to protect the town in 1959. The levee was designed to protect the town against a 100-year flood with three feet of freeboard. Subsequent ice jam floods of 1969, 1986, and 1994 all came within 0.5-1.5 feet of overtopping the West Glendive Levee (USACOE, 2014). A hydraulic modeling study performed in 2002 showed that, under ice jam conditions, the West Glendive Levee provided approximately 30-yr flood protection with no freeboard and 10-year protection with four feet of freeboard. As described in Section 1.8.2, ice jams do occur on the Clark Fork River.

6.2.4 Special Attention Areas Based on High Water Observations in 2018

The 2018 flooding revealed areas of concern associated with two Smurfit Stone outflows. Narrow surface cracks adjacent to former holding pond HP2 south of Outfall 1 and a repaired boil area in former holding pond HP13 near Outfall 3.

6.2.4.1 Outfalls #1 and #3

The EPA identified two areas at or adjacent to outfalls as Special Attention Areas (Newfields, 2019). One is where narrow surface cracks were observed on the CFR berm adjacent to Pond #2 just south of Outfall #1 and the other is at a repaired boil area near Outfall #3. Peter Nielsen of Missoula Public Health (2017) reported that there is documentation of an embankment failure "causing an uncontrolled headcut and threatening the discharge outfall number 3 during the 1997 flood." Additionally, photos were submitted by the Potentially Responsible Parties (PRPs) to assert that the berms were not overtopped, even though the flood caused the embankment to fail. The primary point made by Nielsen (2017) was that:

> *…the record contains ample evidence of occurrences of erosion compromising the stability of the berms without overtopping.*

One thing to consider in monitoring these areas is their location in the Clark Fork River Channel Migration Zone. Figure 120 shows the locations of these outfalls on a 1955 image, with the active 1955 channels mapped. Both outfalls are located on recent channels mapped as active in 1955. This could have strong implications for berm stability, as there have been other situations where levees have breached in such settings.

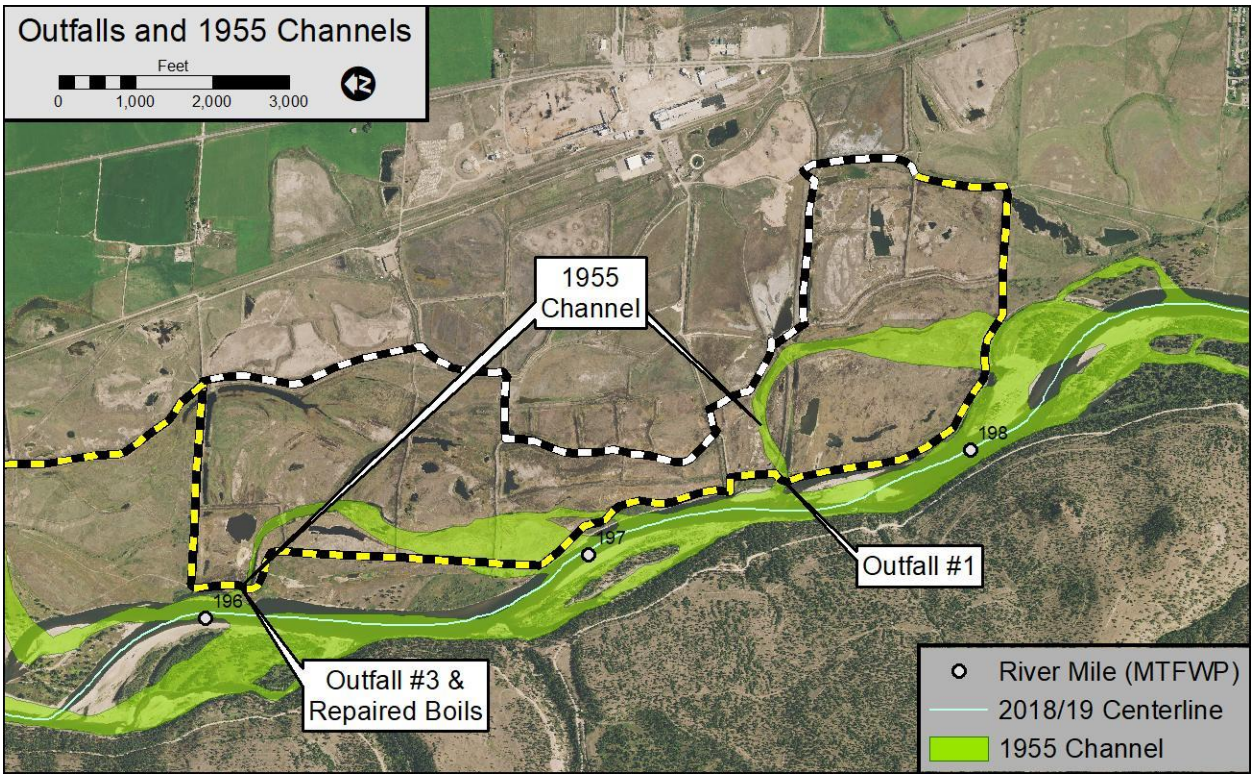

Figure 120. 1955 image of Smurfit Stone showing Outfall #1 and #3 locations on 1955 channel threads.

The following is a summary of a berm breach assessment performed on the Yuba and Feather Rivers in California, where civil engineers testified in court that the breach was caused by over-pressuring in gravels of an older channel that ran under the levees.

In 1991, a civil engineer named Richard Meehan from Palo Alto testified in a trial in Sacramento that a levee on the Feather River was prone to collapse in a fashion similar to two nearby levees that had failed previous disasters; one in 1955 near Yuba City that killed 38 people and another on the Yuba River in 1986 (https://web.stanford.edu/~meehan/flood/xsfexam.html). In 1996 the levee failed, about 1,500 feet from the area he pinpointed as failure prone. First boils developed on the levee, and crews tried to wall off the boils with sandbags. Witnesses then said "a 30-foot high geyser erupted near the base of the levee." A 600-foot-long stretch of levee collapsed within minutes. Meehan had postulated that this levee breach as well as two others was due to floodwater saturation of a subsurface layer of gravel. The water flowed to the landward side of the levee and "erupted, geyser-like, undermining the structures and causing their collapse." He also testified that the area had experienced sand boils on four occasions since 1955.

Meehan, who was at Stanford University, and his colleague J. David Rogers from Missouri University presented their findings regarding the 1986 levee break at a 2008 conference in Berkeley (Rogers and Meehan, 2008). They reported that they were interested in the 1986 levee breach on the Yuba River because it happened well after the flood had crested, when the stage was 8.6 feet below the levee crest. They reported that five eyewitnesses described the same failure sequence, seen from the landward side of the failed levee:

> *The ground at the base of the levee essentially turned to mush; and water began bubbling up, across a very narrow area, just 170 feet wide. This was followed by the sudden "collapse" of the landward side of the levee embankment "into a hole;" after*

which the river side of the levee quickly collapse, and the flood waters began pouring through the breach. It was as if "a bomb had gone off…."

This mass failure of the landward side of the levee was different than typical piping style failures. They pointed out the following in their presentation:

- River meander belts in the Sacramento Valley "conceal a complex understory of pinched and truncated channels of varying permeability."
- Borings into the levee showed fine hydraulic mining debris overlying channel sands and coarse gravels that formed a low permeability cap on the gravels.
- Permeability can vary by four orders of magnitude in floodplain deposits—if you miss the high permeability channels, you fail to characterize the site conditions for any meaningful seepage analyses.

In a 2001 court case, the judge noted that "the levee had been aligned improperly, so as to overlie old river channels."

Stratigraphic conditions on the Clark Fork River floodplain are somewhat different than that of the Yuba, because there is no expansive fine grained mining-derived silt layer on top of old channels. As a result, heightened groundwater pressures that result in ultimate breaching of the cap and creation of geysers may be unlikely at the Smurfit Stone Mill site. It is interesting, however that the outfalls were built on historic channel threads, and that there has been concern regarding their stability, with reports of boils forming on the landward side of Outfall #3.

6.2.5 Berm Monitoring and Maintenance

The risk of bank armor failing and causing a berm breach will be an ongoing issue at the old mill site. As a result, bank protection maintenance is a critical aspect of long-term infrastructure protection. Newfields (2019) reported on a "Visual Berm Surveillance Plan" for high water events at Smurfit Stone. This includes either weekly or daily inspections of the berm during high water, depending on stage. The two EPA-designated "Special Attention Areas" will be "paid particular attention" during monitoring events (Figure 111).

Based on our understanding of the Channel Migration Zone encroachment created by the berms, the permit history of berm protection, and identified berm failure mechanisms, it is clear that preventing river reoccupation of the old mill ponds will require careful monitoring and ongoing maintenance of existing infrastructure. To that end, the adoption of a berm surveillance plan that is triggered by *flood-events alone* creates some concerns, including the following:

1. **Planform Issues:** Larger scale planform dynamics on the river can dramatically change hydraulic conditions anywhere along the berm, which can threaten armor or berm integrity independent of flooding.
2. **Ongoing Erosion:** Armor decay can occur at moderate flows, especially where local scour potential is amplified where the river's thalweg intersects the upstream end of any riprap project.
3. **Ice Dynamics:** Ice has been shown to cause drive erosion on site, as indicated in a 1998 floodplain permit for a riprap repair project: "We [Smurfit Stone] proposed to repair a section of streambank that was severely damaged by ice during the winter of 1996-1997 and by flood flows that followed in June and July of 1997" (Missoula County). The applicant also noted that "the proposed work is required prior

to high water this year, since the lack of bank protection may cause the entire discharge facility to be washed out during this spring's runoff."

4. **Non-flood Related Issues:** An emergency 310 permit application was requested to repair the berm at Pond #2 when a leak of 150 gallons per minute of wastewater discharge was discovered in an area where the Pond 2 berm had been previously repaired. The cause of the leak was determined to be a rodent burrow. This is clearly a non-flood related issue.
5. **Deferred Maintenance:** According to Missoula County Conservation District, the last permitted maintenance/repair work performance at the mill site was in 2001. For the last 19 year, evidently no maintenance has been performed.
6. **Relic Channels:** Approximately 480 acres of the Clark Fork River Channel Migration Zone is currently restricted by the CFR berm. The restricted area includes relic channels that were active in the 1950s as well as older swales that are at risk of reactivation/avulsion in the event of berm breaches. Some of the relic channels that cross under the berm have been used as outfalls, one of which (Outfall #3) has a recorded history of boil formation and breaching without overtopping. Other levee failures in California have been attributed to such conditions, where under-seepage occurs along older channel threads, creating enhanced risk of failure.

From a river function standpoint, an optimal solution at the Smurfit Stone Mill Site would be to remediate all ground within the Historic Migration Zone and remove berms to reconnect the river to its floodplain. Removal of both the berms and bank protection would allow the river to migrate freely through the site, allowing for sediment recruitment, sediment storage, riparian recovery, and re-establishment of a natural stream corridor that is ecologically productive and resilient to future floods, ice, or sediment delivery events.