DEPARTMENT OF THE ARMY
SEATTLE DISTRICT, CORPS OF ENGINEERS
P.O. BOX 3755
SEATTLE, WASHINGTON 98124-3755

CENWS-EC 16 April, 2008

MEMORANDUM FOR Commander, US Army Corps of Engineers, Seattle District,
ATTN: CENWS-EC (Mr. Mark Ohlstrom), 4735 East Marginal Way S., Seattle, WA 98134

Subject: Plan of Study for 2008 Prototype Spill Test Uplift Investigation at Chief Joseph Dam

1. Introduction.

Historical field measurements of foundation uplift pressures in several monoliths at Chief Joseph Dam have shown significant increases during spill. Previous and recent stability analyses (Design Memorandum No. 42, Supplement 5, dated 1996 and Charlwood, 2006) have determined that the uplift pressures in these monoliths are at or near the limits of dam safety criteria for both rotational and overturning stability. A detailed investigation of the possible causes of the observed uplift increases during spill suggested the most likely mechanism was transmission of high surface hydrodynamic pressures to the rock foundation through the spillway monolith joints, which are centered on the spillway bays. Visual inspection of the surface elastomeric V-shaped chamfer seal and core samples of the underlying bituminous cement seal in the monolith joints indicated the existing seal system at the dam is in poor condition. In addition, underwater inspection of the spillway, stilling basin surface, and monolith joints indicated that significant erosion has occurred at and near the toe of the ogee in the monoliths where the highest uplift increases were recorded. As a result of these inspections, Seattle District determined an extensive monolith joint repair project was required to prevent the transmission of high surface pressures through the joints to the foundation. An upgraded seal system was designed in 2006, consisting of an injection grout seal under the existing bituminous cement seal and a new elastomeric surface seal. Installation of the seal upgrades is currently under way.

In August 2006, Seattle District, Corps of Engineers initiated a multi-year project that significantly modifies the spillway and has the potential to change the uplift pressure environment at the dam. The Corps is constructing spillway deflectors on all 19 spillway bays to improve dissolved gas levels in the Columbia River downstream of the Project during spill. The installation of deflectors changes the hydrodynamic pressure distribution on the spillway by shifting the location of the high pressure region away from the toe of the spillway to the deflector and spillway face upstream of the deflector. The Corps recommended that a spill test be performed at an early stage in construction to investigate how changes to the spillway hydrodynamic pressure distribution due to the installation of deflectors and an upgraded seal system would affect uplift pressures at the dam. A spill test was conducted in 2007 to confirm that the partially completed new seal system in the monolith joints and spillway deflector were functioning to prevent the transmission of high surface hydrodynamic pressures to the rock foundation and to provide some initial data on the total dissolved gas exchange properties in the stilling basin and tailrace to evaluate the spillway deflector performance. This document describes a second field investigation of uplift pressures in Monoliths 16, 17, and 18 (under spillway bays 12 and 13) after the installation of spillway deflectors and completion of the injection grout seal system, but prior to the complete installation of the primary elastomeric surface seal, for a range of spill conditions.

2. Historical Information/Background.

Significant uplift increases in several monoliths were first noticed in 1997 when involuntary spill was required during a period of high spring runoff flows. The Corps suspected that the poor condition of the seals in the spillway contraction joints of these monoliths may have been partially responsible for the observed increases. As a result, the surface elastomeric seals under gates 10-14 (monoliths joints 14/15, 15/16, 16/17, 17/18) were repaired from the tainter gate sill beam (elevation 899 feet) to approximately elevation 820 feet and a short spill test over these gates was conducted following the 1997 flood event.

The 1997 spill test verified uplift pressures were at the limits of dam stability criteria and demonstrated that seal repairs in the upper zones of the spillway did not measurably improve uplift pressures in the problem monoliths. There were no conditions observed that exceeded global stability criteria for the relatively small discharges studied, and there was no further investigation at that time. Increases in uplift were not observed in all monoliths, however not all monoliths have uplift pressure instruments distributed across the foundation beyond the ones installed beneath the drainage and grouting gallery.

As a result of the planned installation of the spillway deflectors, a renewed investigation into the uplift issue was initiated and it was determined that a detailed independent technical review (ITR) of the issue and new stability analysis were required to analyze the effect of the installation of deflectors on uplift at the dam.

3. Justification of Need.

There are limited prototype data available about uplift response during spill with or without deflectors, primarily because of the lack of instrumentation to measure uplift pressures in most dams. Chief Joseph Dam is unique in that a series of piezometers were installed in Monoliths 7, 9, 11, 13, and 16-23 when the temporary sluiceways were plugged in the late 1970's as part of the pool raising structural modifications contract. Spill from the dam is infrequent in comparison to other dams on the Columbia River System because of the dam's large powerhouse capacity. Spill only occurs when river flows exceeds power demand and/or when there are high flood flows on the river. Therefore, there have been limited opportunities to gather uplift pressure data during high discharges and study the problem. In 2007, a prototype spill test was conducted following the construction of the first few spillway deflectors. The 2007 spill test data indicated that uplift pressures had been reduced by approximately 10-15 feet over the 1997 values and that the presence of the deflectors did not exacerbate the uplift pressure problem. However, the injection grout seals and the surface elastomeric seals were only partially completed in spill bays 12 and 13 prior to the spill test. Therefore, the functionality of these seal systems was not fully tested. Additionally, due to the short duration of spill increments, uplift pressures at many locations did not stabilize. The 2008 prototype spill test described herein will decrease the number of spill increments, but increase the duration of each increment to allow for uplift stabilization and test the effectiveness of the completed injection grout seal system.

The Corps needs a method to evaluate the combined effect of the monolith joint seal improvements and changes in pressure distribution due to the installation of the deflectors on uplift pressures. A program to confirm the design and execution of the injection grouting program using concrete coring along the sealed joints was planned, but the cost of this coring program and the limited coverage that would be obtained have made it a less desirable and comprehensive method of testing the seals than a spill test. At present, the injection grouting at bays 12 and 13 is complete, but the surface elastomeric seal has not been placed. This second

prototype spill test will confirm whether the injection grout seal system is effective at limiting the transmission of high surface hydrodynamic pressures to the rock foundation for the modified spillway. Testing of the new spillway deflectors and seal system on Bays 12 and 13, over the monoliths where some of the highest uplift pressures have been recorded, offers an opportunity to collect information to validate design assumptions and solutions before the construction process is complete.

A second prototype spill test provides a method to:

1) Evaluate the effectiveness of the injection grout seal system in monolith joints that have previously shown high uplift pressures.
2) Ensure that the transmission of the high surface hydrodynamic pressure is prevented from reaching the foundation in these monoliths
3) Ensure that these monoliths will meet dam safety criteria during spill.

4. Summary of Stability Analysis and Subsequent Seal Investigations at Chief Joseph Dam.

A structural ITR and a stability analysis, prepared by Robin Charlwood and Associates, PLLC (April 2006 and September 2006, respectively) concluded that:

1) The most likely mechanism for the observed uplift pressure increases during spill was transmission of high surface hydrodynamic pressures through the spillway monolith joints to the rock foundation;

2) The existing seal system in the spillway monolith joints, consisting of a 24-inch deep bituminous cement seal and an elastomeric surface chamfer seal was unusual (most dams have waterstops on the downstream face of the overflow sections) and inconsistent with current design practices;

3) The lack of a drain system in the apron and at the spillway toe to relieve uplift pressures was inconsistent with current design practices;

4) Uplift pressures would exceed dam stability criteria during spill with or without deflectors if surface hydrodynamic pressures were transmitted to the rock foundation from the upper zones of the spillway (above EL 810 ft.);

5) The transmission of high surface hydrodynamic pressures on the deflector and in a short zone just upstream of the deflector would exceed uplift dam stability criteria even at very low spillway discharges.

Subsequent visual inspections of the surface seal determined the existing surface seal was missing or damaged in most of the monoliths joints except for in Gates 10-14 where the seal was repaired prior to the 1997 spill test. There was also concern regarding the ability of the surface seals to remain in place and functional under high discharge conditions. Interviews with former Project personnel indicated the surface seals were not part of the initial design for the dam construction, but were subsequently installed to tailwater level in the early 1960's and repaired again in the 1970's. There is no elastomeric surface chamfer seal below the tailwater level.

Core samples of the 50-yr old bituminous cement seals demonstrated the seal had significantly deteriorated and likely could not be relied upon to prevent transmission of surface hydrodynamic pressures to the foundation. An underwater survey conducted in September 2005 indicated there was significant damage to the spillway and stilling basin surface and monolith joints at the toe of the spillway in Monoliths 17-20. The stability analysis recommended either a new sub-horizontal drain at EL 774 ft or new redundant seal system along the entire length of the spillway monolith joint from the deflector to the spillway tainter gate sill be installed as soon as possible to address the potential source of the uplift. The stability analysis also recommended a prototype spill test be conducted to assure the performance of the upgraded seal system.

5. Design of the Seal System.

Consistent with the recommendations of the stability analysis, Seattle District has designed a new redundant seal system both in the deflector and in the spillway monolith joints. The new deflectors have a double waterstop and drain. The monolith joint seal system will consist of an injection grout seal which will be installed below the existing bituminous cement seal, and an elastomeric surface chamfer seal. A number of seal and drain systems were evaluated but it was determined that this design is the most feasible and the least cost alternative given the CJD spillway environment. The existing bituminous cement seal contains an asbestos filler and massive excavation of concrete or drilling would be difficult, risky, expensive and may, unless constructed perfectly, create new leakage paths. The materials for the elastomeric and injection grout seal were carefully chosen to assure that they would withstand the high velocities and high pressure environment that they will be subjected to on the spillway face. It is recognized that careful placement of the injection grout seal and elastomeric seal are critical to the effectiveness of the new seal system and appropriate quality control procedures need to be implemented. This was to include coring and water pressure testing of the injection seal to provide assurance of its effectiveness. Chief Joseph Project personnel and the spillway deflector Contractor are currently at work on the installation of the new seal system at the Project (see Figure 1 for expected status of the joint seals in each monolith joint at the time of the spill test).

6. Condition of Spillway in Monoliths 16, 17, and 18 under Gates 12 and 13.

Similar to the 2007 spill test, the 2008 spill test will be conducted through Bays 12 and 13 over completed deflectors on Monolith 16, 17, and 18, where some of the highest uplift pressures were observed during the 1997 spill test. In contrast to the 2007 test, the injection grout seal has been completed; however, the elastomeric surface seal is only partially complete Below is a summary of the current condition of the spillway and monolith joints in Bays 12 and 13 (monolith joints 16/17 and 17/18).

a. Core samples of the bituminous cement seal from monoliths 16 and 17 showed the seal material was heavily compressed, flaky, and not bonded to both sides of the contraction joint. The new injection grout seal in monolith joints 16/17 and 17/18 has been completed from the deflector (elevation 779.1 feet) to the tainter gate sill beam (elevation 899 feet).

b. The elastomeric surface chamfer seals under Gates 10-14 were replaced prior to the 1997 spill test and appeared to function in monoliths 16, 17 and 18 at that time. However, they are only present from approximately EL 820 ft to the spillway tainter gate sill (elevation 899 feet)

c. The full seal system in the new deflectors (two waterstops and a drain) has been installed.

d. A new surface elastomeric seal is in place from the top of the deflector (elevation 779.1 feet) to elevation 783.7 ft in spill bay12. The corresponding seal in bay 13 was eroded away during the 2007 spill test.

e. There is no elastomeric surface chamfer seal along the joints between elevation 783.7 and 795 feet.

f. The spillway ogee surface below EL 770 ft has eroded approximately 6-18 inches. Significant erosion has also occurred along the monolith joints and transverse construction joint near the toe.

7. Objectives.

The 2008 field test will seek to quantify uplift pressures in Monoliths 16, 17, and 18 during spillway releases at Chief Joseph Dam over the completed spillway flow deflectors with a completed grout injection seal system on spill bays 12 and 13 in order to:

1) evaluate the performance of the new and existing seal system (both in the deflector and in the repaired spillway monolith joints);

2) gather additional data on uplift pressure behavior during discharge for the modified spillway; and

3) confirm that uplift pressures are within dam safety criteria for the modified spillway condition.

The results of the field investigation will seek to confirm that: 1) uplift pressures are within criteria and will likely remain in criteria up to the Probable Maximum Flood (PMF) in these monoliths and 2) the existing and new seal system in the deflector and upstream of the deflector is effectively limiting the transmission of hydrodynamic surface pressures to the foundation. The results of this study will be compared to the uplift data collected in the same monoliths during the 1997 and 2007 spill tests.

Uplift response involves a number of complex and interconnecting factors such as location of ruptured seals, connectivity to hydraulic pathways, presence and location of relief pathways, size of the reservoir, etc. that cannot be replicated outside of the dam. This data cannot be obtained through mathematical or physical modeling as evidenced by the fact that uplift response during spill is not observed in all monoliths. Field data collection is the only way to confirm the potential source of the uplift and to ensure the required pressure relief is obtained. This investigation will provide useful additional data to assess the leading theory for the source of the uplift increases and assist in confirming that the uplift problem at CJD can be addressed through changing the spillway pressure distribution and seal improvements. If uplift pressures do not improve over the existing condition, the prototype spill test will be essential to provide additional information to aid in the investigation of uplift at CJD.

8. Study Approach.

Uplift pressures for the spill test will be monitored using the existing piezometers under monoliths 16, 17, and 18 and new piezometers installed under monolith 17 as part of the deflector installation. Spillway discharges will be incrementally increased during the test with individual spillway discharges of 6 and 16 kcfs/bay over the new spillway deflectors in spill bays 12 and 13. The duration of each spill increment will be 10 hours to allow steady conditions to

develop and uplift pressures to stabilize. The test will be continuous, with no cessation in spill, for a total test length of 20 hours. The spill test will occur on a Sunday to minimize impacts to the dam's power operations and the spillway deflector Contractor's work schedule. The scheduled time and date for the test is 00:00 to 20:00 April 27, 2008.

Seattle District has decided to proceed with the 2008 spill test even though the full redundant seal system will not be in place in monolith joints 16/17 and 17/18 for the following reasons:

1) The deflector will have the full seal system (two waterstops and drain) to prevent transmission of surface hydrodynamic pressures to the foundation. The highest surface hydrodynamic pressures occur on the deflector.

2) The injection grout seals have been fully installed on the spillway under gates 12 and 13 from the deflector to the tainter gate sill beam, but not tested. During the 2007 spill test, the injection grout seals were only partially complete. The 2008 spill test will allow the effectiveness of the injection grout to be evaluated prior to completion of the elastomeric surface seal.

3) Core drilling and water pressure testing was recommended to assure the quality of the injection grout seal installation but has not yet been conducted. Results from the 2008 spill test will be used to determine if core drilling is necessary. If the spill test results show acceptable injection seal performance as indicated by a lack of uplift pressures indicative of joint leakage, then investigation coring need not be performed. If the spill test results show questionable injection seal effectiveness, then investigation coring will likely be required.

4). A small portion of the elastomeric surface seal was installed in the region just upstream of the deflector for the 2007 spill test that provided a redundant seal system near the areas of highest hydrodynamic surface pressures for this spill test. In spill bay 13, the surface seal near the deflector was torn out during the 2007 spill test. The elastomeric seal in Bay 12 will most likely be torn out during the 2008 spill test. Therefore, the 2008 spill test will only test the effectiveness of the injection grout seal system in bays 12 and 13.

5) Spill increment durations during the 2007 spill test were not sufficient to allow for uplift stabilization at several monitoring locations. The 2008 spill durations will be increased to allow for uplift pressure stabilization.

6) If the source of the historical leak is near the spillway toe (i.e., the ogee surface below the deflector), and no new leakage pathways have developed, there should be an improvement in uplift pressures over the 1997 and 2007 spill test data at similar flows. The only area where surface hydrodynamic pressures change significantly during spill is at the spillway toe where the jet is turned. The installation of the deflector redirects the spillway jet and diverts the high pressure region away from the spillway toe to the region on the deflector and just upstream of the deflector. The toe of the spillway will see significantly lower pressures following deflector installation.

Uplift pressures will be monitored closely during the testing and the test will be terminated immediately if uplift pressures exceed a pre-determined threshold value. The 1997 and 2007 spill tests demonstrated that uplift pressures come down quickly after the spillway gates are closed.

Uplift pressure data recorded for the modified, with-deflector spillway and completed injection grout seals will be compared with the 1997 spill test data for the without deflector spillway at

similar discharges and the 2007 spill test data without the completed injection grout seal. It is recognized that ambient conditions, such as tailwater, air, water, and joint temperatures, powerhouse discharge, spillway discharge, spillway bays operating etc., may not be the same for all tests and will likely affect the results. However, it is expected the Corps will be able to make useful conclusions about the effect of the change in the spillway pressure distribution due to deflector installation and joint seal (both existing and new) condition on the uplift response at the dam.

9. Potential Impacts and Mitigation Measures

a. Exceedance of Uplift Criteria and Dam Stability Concerns: See Supplement 2 to Emergency Action and Notification Subplan

b. Spillway Deflector Contractor's Cofferdam: See Supplement 2 to Emergency Action and Notification Subplan

c. Damage to the Surface Seal Above the Deflector: The small section of surface elastomeric seal installed by the spillway deflector contractor upstream of the deflector in Bay 13 was torn out during the 2007 spill test. The same seal will most likely be torn out of Bay 12 during the 2008 spill test. The seals will need to be replaced. Repair of the damaged seal will require re-mobilization of the cofferdam or a severe tailwater restriction (EL 778 ft or lower). Construction of a small cofferdam and the surface elastomeric seal installation are not scheduled until FY09/FY10.

d. Cavitation on the Baffle Blocks: Excessively low pressures on the baffle blocks due to inadequate tailwater and high velocity flows are expected. There is a potential for some cavitation damage to occur during the test. However, since the test is of short duration, this is not expected to be a significant problem. A baseline record of baffle block condition is available. Post-test monitoring will be conducted to assure significant damage has not occurred as a result of the test.

e. Erosion of the Spillway Toe, Stilling Basin Apron, Baffle Blocks and End Sill: The presence of any debris in or downstream of the stilling basin provides a potential source of material to erode concrete surfaces during the test. It is possible that due to the non-uniform operation of the spillway, debris could be entrained in a circulation cell near the toe of the spillway, causing significant erosion. Underwater camera surveys have indicated there is limited material in the stilling basin and downstream of the stilling basin near gates 12 and 13. It is not expected that significant debris erosion will occur during the test given the short duration and changing spill volumes, however, post-test monitoring will be conducted to assure the test has not caused significant damage to the concrete surfaces during the test.

f. Impacts to Fish and Aquatic Life: Fish were monitored for gas bubble disease during the 2007 spill test, and no symptoms were observed. Although the 2008 test calls for slightly longer duration flows at the 6 kcfs/bay and 16 kcfs/bay spill increments, impacts to fish and aquatic life are not anticipated, and monitoring during the 2008 test is not a requirement.

g. Power Loss: The spill test has been scheduled for a Sunday to help minimize the impacts to power production.

h. Inconclusive Results and Need for Further Testing: The test is being conducted without the full elastomeric surface seal system in place. If uplift pressures exceed criteria, do

not show improvement over baseline (pre-deflector/pre-joint repair) data, or are inconclusive, then an additional test and/or coring of the injection seal may be necessary.

10. Uplift Instrumentation and Monitoring.

See Supplement 2 to Emergency Action and Notification Subplan.

11. Water Quality Criteria and Fisheries Operational Considerations.

The uplift test will use per-bay discharges higher than design criteria for best effectiveness of the constructed deflectors. The upper limit of optimal deflector effectiveness occurs at discharges of less than 7.4 kcfs (which equates to a spilled flow of 140 kcfs evenly distributed across all 19 bays once all the deflectors are constructed). During the test, per-bay discharges will be as high as 16 kcfs. Furthermore, the spillway deflectors were designed for optimal performance when using all 19 bays and were not designed to use only 1 or 2 bays. The maximum TDG levels during this spill test are expected to be comparable those during the 2007 spill test. During the 2007 test, the maximum TDG level recorded at the fixed monitoring station was about 120 percent and occurred during the 16 kcfs/bay spill. However, the 2007 spill at 16 kcfs/bay had a duration of 4 hours compared to the proposed 2008 spill duration of 10 hours at 16kcfs/bay. Because of the longer spill duration for the 2008 study it is possible that the TDG saturations measured at the fixed monitoring station will exceed 120 percent due to the longer time period allowing for gas equilibration to occur.

a. The Washington Department of Ecology (WDOE) and the Colville Confederated Tribe (CCT) determine water quality criteria for the Columbia River at Chief Joseph Dam in Washington. In general, the CCT and WDOE have a similar TDG standard of not to exceed 110 percent at any point of sample collection. However, WDOE allows a special exemption of the 110 percent TDG standard to facilitate fish passage during spill season where there is an approved gas abatement plan. In February 2008, WDOE approved a TDG rule modification for Chief Joseph Dam for a period of three years (through February 2010). This modification allows the following special fish passage exemptions of the 110 percent standard at Chief Joseph Dam:

- Must not exceed an average of 115 percent as measured in the forebay of the next downstream dam
- Must not exceed an average of 120 percent as measured in the tailrace of each dam
- TDG is measured as an average of the 12 highest consecutive hourly readings in any one day, relative to atmospheric pressure; and
- A maximum TDG one-hour average of 125 percent as measured in the tailrace must not be exceeded during spillage for fish passage.

Water quality compliance monitoring at Chief Joseph Dam occurs at two WDOE approved fixed monitoring stations located in the forebay and tailrace. At the forebay station (CHJ) the water quality probe is located in Lake Rufus Woods near the left bank by the powerhouse. At the Chief Joseph Dam tailwater station (CHQW) the water quality probe is deployed along the right bank of the river, 0.75 miles downstream from the dam. During the spill test, real-time data for these two fixed monitoring stations will be checked on an hourly basis. Minimum powerhouse flows during the test have been requested to help dilute TDG levels (see below). The requested powerhouse discharges will probably keep TDG levels within water quality standards, although it is possible that the 12-hour average TDG at the tailwater station may exceed 120% if the higher spill increment is held for ten hours. This possibility will be communicated to WDOE and

the CCT prior to the spill test. During the spill test, if real-time data monitoring shows that TDG levels will exceed water quality standards, an increase in powerhouse flows will be requested.

b. Powerhouse Discharge During testing, the powerhouse discharge will be adjusted to dilute the TDG that is produced by spilling. Powerhouse flow moderates the aggregate TDG pressures discharged from the Dam through mixing and dilution. At the first spill increment of 6 kcfs/bay, the powerhouse will be operated to provide at least 50 kcfs. At the second spill increment of 16 kcfs/bay, the powerhouse will be operated to provide at least 100 kcfs. The generation flow will be run as much as possible through units at the upstream end of the powerhouse.

12. Test Schedule and Project Operations.

The spill test is planned for April 27, 2008. The test schedule below assumes a duration of 20 hours.

Date	Hour	Spill Bays Operating	Spill per bay (kcfs/bay)	Total Spillway Discharge (kcfs)	Powerhouse Discharge (kcfs)	Total River Discharge (kcfs)	Minimum Tailwater Elevation (ft)
April 27	0000-1000	12, 13	6	12	50 * (minimum)	62 or greater	No min. TW
	1000-2000	12, 13	16	32	100 * (minimum)	132 or greater	No Min. TW
*Powerhouse flow is the minimum amount requested for dilution of TDG. Higher generation amounts are permissible.							

13. Test Results and Analysis.

Uplift pressures measured during the 2008 spill test for the modified spillway will be compared to all previous measurements of the existing spillway, including the May 1997 and April 2007 spill tests. If test results indicate an increase in uplift pressures, no reduction in uplift pressures during spill, or are inconclusive as far as confirming the performance of the seal systems, then further investigation will be required based on the findings. Possible follow-up actions could include: 1) detailed examination of the ogee seals; 2) re-examination of the deflector seal and drain system; 3) investigation of alternate mechanisms; 4) re-design of the joint treatment; 5) repair of damage at the spillway toe and stilling basin; 6) future spill tests; 7) installation of a drain system in the stilling basin apron or horizontally under the deflector; 8) anchor tendons, etc.

An After-Action Report will be assembled to detail the results of the spill test and develop recommendations for future actions. The After-Action Report will be independently technically reviewed by the Contractor who did the initial structural ITR and stability analysis.

14. References

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Figure 1. CJD Spillway Deflector and Joint Sealing Status

CJD Spillway Joint Seals

as of 28-Mar-08

Monolith Joint Seal Condition Key

= new surface seal in place (seal not shown if gap exisits above seal in place)

= existing surface seal in place, varying condition (seal not shown if gap exisits above seal in place)

= grout injection seal in place

= Surface seal missing (or discolored?) but injection grout present at surface (?) (seal not shown if gap exisits above seal in place)

= old bituminous-cement seal present only

=monoliths with uplift instrumentation other than beneath drainage and grouting gallery