# Draft
# Levee Certification Report
# South Aberdeen – Cosmopolis Levee System
# Aberdeen, Washington

June 5, 2015

Prepared for

**City of Aberdeen**
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# APPENDICES

# 1.0 INTRODUCTION

This report provides data and documentation to demonstrate to the Federal Emergency Management Agency (FEMA) that the South Aberdeen – Cosmopolis levee system (locally referred to as the South Side Dike) along the southern bank of the Chehalis River meets the minimum requirements set forth in Title 44, Chapter 1, Section 65.10 of the Code of Federal Regulations (44 CFR Section 65.10) in order to obtain accreditation of the levee system from FEMA and identify the protected area as a moderate risk area on Digital Flood Insurance Rate Maps (DFIRMs).

## 1.1 GENERAL PROJECT BACKGROUND

Prior to construction of the South Aberdeen - Cosmopolis levee system, floods causing damage occurred nearly every year in South Aberdeen. The greatest recorded flood was in 1933 when water completely inundated the South Aberdeen - Cosmopolis floodplain by several feet, thereby causing damage to hundreds of homes and washing out several railroad tracks.

In 1922, a diking and drainage district was organized that resulted in the construction of several levees in South Aberdeen. These levees were substandard and only provided minimal protection and were subject to overtopping during larger than 2-year storm events.

In 1934, Congress directed the U.S. Army Corps of Engineers (The Corps) to conduct a preliminary survey of the Chehalis River with a goal to control its floods. The results of that survey indicated that construction of a levee to protect Aberdeen and Cosmopolis was justified by the benefits it would provide. In the Flood Control Act of 1944, Congress authorized the project recommended by the Corps. The project report was completed in 1946 and in 1947 the cities of Aberdeen and Cosmopolis were officially requested to provide the lands and easements necessary to construct the levee. In 1952, the project authorization expired because the lands and easements had not been obtained within the required 5-year time period.

In 1965, the Corps resumed studies of alternative levee systems and in 1975 the feasibility study was completed. The final environmental impact statement for the project was completed in 1977. The project was again authorized by Congress in 1986. The Corps subsequently completed the design and managed the construction of the project. The project, which consists of approximately 11,550 feet (ft) of earth embankment levee, 4,740 ft of flood wall, and 6,010 ft of existing high ground, was completed in 1996 and has since been maintained by the cities of Aberdeen and Cosmopolis.

## 1.2 FEMA LEVEE ACCREDITATION REQUIREMENTS

For levees to be recognized as providing a 1-percent-annual-chance or greater level of flood protection on National Flood Insurance Program (NFIP) maps, the levee must meet, and continue to meet, the minimum design, operation, and maintenance standards set forth in 44 CFR Section 65.10. If appropriate documentation that demonstrates the levee system meets these minimum standards is certified by a licensed professional engineer, FEMA will accredit the levee system and will revise the affected DFIRM panel to show the protected area landward of the levee system as having a moderate flood hazard.

For levees to be accredited by FEMA, evidence that adequate design and sound engineering practices have been followed must be provided and minimum requirements for the following categories must be met:

- Freeboard
- Closures
- Embankment protection
- Embankment and foundation stability
- Settlement
- Interior drainage.

For levees to be accredited by FEMA, a formal plan of operation, including specific actions and assignments of responsibility by individual name or title, must also be developed for each system and minimum requirements for the following categories must be met in the operation plan:

- Documentation of flood warning system
- Formal plan of operation
- Periodic operation of closures
- Internal drainage plan, including manual backups
- Periodic inspections.

Levee accreditation by FEMA also requires that a formal plan of maintenance be officially adopted by the owner of the levee system, and a copy of the plan must be provided to FEMA. The following items must be addressed in the maintenance plan:

- Activities to be performed
- Frequency of their performance
- Person by name or title responsible for their performance.

# 2.0 DESIGN

In 1994, the cities of Aberdeen and Cosmopolis entered into a "Project Cooperation Agreement" with the Corps (see Appendix A). This agreement established that the Corps would construct the levee project applying the same procedures that are applied to federal projects, pursuant to federal laws, regulations, and policies. All of the work performed under the construction contract was exclusively within the control of the Corps. The City of Aberdeen (City) had the responsibility to pay 25 percent of the total project cost and assume all operation and maintenance responsibilities for the levee system.

The levee system was designed by the Corps in accordance with the parameters established in the General Design Memorandum (see Appendix B) and in accordance with applicable engineering manuals, regulations, circulars, and technical letters. The project was managed by the Corps in accordance with the Revised Project Management Plan (see Appendix C).

This following section provides documentation related to the design of the South Aberdeen – Cosmopolis levee system.

## 2.1 FREEBOARD

The South Aberdeen – Cosmopolis levee system is located adjacent to Grays Harbor and the southern bank of the Chehalis River. As shown on the flood profile contained in the FEMA Flood Insurance Study (see Appendix D), flooding along the entire levee length is controlled by Grays Harbor, not the flow of the Chehalis River. Because of the nature of flooding created by Grays Harbor, there is a negligible river velocity component to the flood waters at high tide. Furthermore, flood debris can only influence the water levels along the levee-protected section of the river when the tide recedes, water levels drop in the harbor, and outward river flow returns. Based on the above factors, the minimum freeboard requirements for riverine levees are not applicable and the levee's freeboard should meet coastal levee requirements.

Per 44 CFR Section 10, for coastal levees, the minimum freeboard must be established as the greater of:

- 1 foot above the height of the 1-percent-annual-chance wave
- the maximum wave run up associated with the 1-percent-annual-chance still water surge elevation at the site.

In no case should the freeboard be less than 2 ft above the 1-percent-annual-chance water surge elevation.

Based on the above referenced freeboard criteria for a coastal levee and information contained in the FEMA Flood Insurance Study (see Appendix D), the following freeboard values where calculated:

- From Table 9 (Summary of Wave Setup Elevations): 1-percent-annual-chance wave at Grays Harbor [13.5 ft North American Vertical Datum of 1988 (NAVD 88)] plus 1 ft equals 14.5 ft (NAVD 88)
- From Table 8 (Summary of Wave Run-up Elevations): 1-percent-annual-chance still water surge elevation equals 13.2 ft (NAVD 88)
- From Table 8 (Summary of Wave Run-up Elevations): 1-percent-annual-chance still water surge elevation [13.2 ft (NAVD 88)] plus 2 ft equals 15.2 ft (NAVD 88).

Therefore, the minimum freeboard elevation for the South Aberdeen – Cosmopolis levee system is 15.2 ft (NAVD 88).

The City of Aberdeen verified the elevations of the South Aberdeen – Cosmopolis levee system in 2002, 2007, and 2011. The elevation surveys were completed utilizing multiple survey loops originating at a benchmark on the south side of the Chehalis River Bridge, near the middle of the levee. This benchmark is known as BMJ423 (PID SC0747) and has a published elevation of 11.01 ft National Geodetic Vertical Datum of 1929 (NGVD 29).

Because all new floodplain literature is now expressed utilizing the North American Vertical Datum of 1988, the original survey data has been converted to the NAVD 88 datum. The City made the conversion by applying a conversion factor to the elevation of the initial benchmark. The conversion factor was determined by the City utilizing the software program VERTICON, furnished by the National Geodetic Survey, which computes the modeled difference in orthometric heights between the NAVD 88 and NGVD 29 datums for a given location as specified by latitude and longitude.

The survey data is shown on a table in Appendix E (Levee Elevation Survey Data). The survey data is divided by sections and stationing that corresponds to the as-built construction plans for the levee system that are presented in Appendix F. The table also corresponds the survey points to the type of levee section constructed as shown on the as-built plans.

Based on the elevations obtained during the 2011 survey, some portions of the levee appear to be lower than the required freeboard elevation of 15.2 ft (NAVD 88). However, the City reportedly took action to remedy each of these low areas and the City maintains that these areas, and all other portions of the constructed levee, now meet the minimum freeboard requirement. The levee elevations for the corrected portions are shown on in Appendix E. The nature of the problem and the corrective action taken in each of the low areas is shown in Appendix G (Freeboard Compliance – Corrective Action). The elevation profile of the top of the levee and its relationship to the minimum required freeboard is shown in Appendix H (Levee Profile).

After the project was designed, but before construction of the levee system commenced, the property owner of the “log yard area” filled, re-graded, and paved a portion of their log yard. The original design called for the construction of a gravel levee between Stations 166+20 and 177+80; however, because the area along this portion of the proposed levee system had been paved and other ground towards the Chehalis River had been raised and paved, the Corps elected to remove this portion of the construction from the project. Appendix I (Log Yard Freeboard Variance) contains the Corps documentation of the design change and justification for a lower freeboard elevation in this area. The attachment also documents discussions with FEMA related to the acceptability of the design change.

The effects of sea level rise were not considered when evaluating the levee systems compliance with the minimum freeboard requirement. It is possible that future determinations by FEMA may result in an adjustment to the still water elevation for Grays Harbor. Such an adjustment could necessitate modification of the levee system in order to meet the minimum freeboard requirement.

## 2.2 CLOSURES

When construction of the South Aberdeen – Cosmopolis levee system started, there were six openings in the levee that required closures. Three of the closures were to accommodate railway crossings and three of the closures were to accommodate access to a public boat ramp and businesses located on the outboard (i.e., river side) of the levee.

After construction of the project commenced, the railroad along the south bank of the Chehalis River was abandoned. By that time, the concrete for the railway closures had already been placed. In the case of the two rail crossing closures west of the Chehalis River Bridge, the structures were abandoned in place and the alignment of the earthen levee was adjusted to accommodate the change as shown on the as-built plans (see Appendix F). The railway closure on the east side of the Chehalis River Bridge was left in place and the gates were permanently closed.

The remaining three closures are located as shown on Appendix J (Levee Closures). As shown on the as-built plans in Appendix F, the closures consist of concrete abutments with double metal gates that swing away from the river when closing. The design of these closures is such that even if the gates were not closed until after flood waters were going through the closure, the movement of the water would facilitate closure of the gates.

At the 30-foot-wide swing gates, the concrete wing walls are 18.5 ft long by 1 foot thick by 6 feet tall. At the 20-foot-wide swing gate, the concrete wing walls are 17 feet long by 1 foot thick by 6 feet tall. The wing walls are supported on pile caps that are supported by timber piles.

Each swing gate consists of a 3/8 inch steel plate that is supported on flat bars. The gate is bolted to a hinge that is bolted to the concrete jamb. At the base of each swing gate, there is a below-grade wall/foundation with a stem wall supported on a pile cap, which is supported by piles. Additional details related to the closure structures are shown in the as-built drawings (see Appendix F).

The as-built drawings (see Appendix F) show the threshold elevation of each of closure. The elevations noted for each closure do not represent the river elevation at which flow will begin to come through the closure because some of the ground between the closures and the river is higher than the closures. For example, the highest tide observed by City staff since construction of the levee system was 12.7 ft (NAVD 88) and no flows came through the closures at that time.

## 2.3 EMBANKMENT PROTECTION

The general Design Memorandum (see Appendix B) states that the Corps' hydraulic analysis showed that the flow velocity adjacent to the levee would be less than 2 feet per second (fps) during the design flood event; therefore, vegetative cover would provide sufficient erosion protection for the levee. However, rip rap erosion protection extending 20 ft both upstream and downstream of culverts was placed to protect the drainage structure aprons from scour due to turbulence or high velocity flows.

The earth embankments that comprise the South Aberdeen – Cosmopolis levee system appear to be stable and not subject to appreciable erosion during a flood event. Since the levee was constructed, City staff have reportedly observed a number of high tide events that were within 1.6 ft of the base flood elevation and at least one event that was within 0.8 ft of the base flood elevation. According to City staff, no erosion or stability issues occurred on the earthen levees as a result of these high tide events.

The current use of vegetative cover as embankment protection is considered adequate for the following reasons:

- Expected wind and wave action: the difference between the 1-percent-annual-chance still water elevation and the 1-percent-annual-chance wave set up elevation is only 0.3 ft (see Tables 8 and 9 in Appendix D)
- Ice loading: there is no ice loading in the lower Chehalis River
- Impact of debris: while there could be debris in the river channel during a flood, the flow velocity is less than 2 fps at high tide; therefore, its impact on the levee is not considered to be a concern. The only possible exception to this would be the possible impact of debris on the levee in the event of a tsunami. However, the levee system was not designed or constructed to provide protection from a tsunami.
- Slope protection techniques: the levee slopes were covered with top soil and then planted. The roots of the established vegetation provide embankment erosion protection. In addition, the vegetation is mowed and maintained to keep it healthy. Furthermore, trees are not allowed to grow on the levee.
- Duration of flooding at various stages and velocities: velocity is discussed above. The length of time that the water is at the flood stage is just a matter of hours before the tide recedes and the water surface drops. The short period of inundation allows the vegetation to remain healthy, as well as reduces the period of time in which erosion could occur.
- Embankment material: the material used to construct the embankment does not easily erode when subjected to the conditions that exist in a flood. As outlined in Appendix K (Levee

Embankment Design Comments), similar levee materials have been successfully used throughout western Washington.

- Levee alignment and transition: the alignment of the levee system generally provides gradual transitions along the face of the levee, which reduces the possible impacts of river velocity.
- Levee side slopes: the levee's side slopes were constructed to the standard side slopes that have been used by the Corps in this region (see Appendix K - Levee Embankment Design Comments), and the side slopes have remained stable given the conditions the levee has experienced over the past nearly 19 years.

## 2.4 EMBANKMENT AND FOUNDATION STABILITY

It is the City's position that by virtue of the fact that the project was designed by the Corps and the construction was performed under their supervision and inspection and documented by as-built plans prepared by them, the design requirements per 44 CFR 65.10 for embankment and foundation stability have been satisfied. The reviewer is directed to the various Corps documents contained in the appendices to this report for additional information on this topic. The following information is presented to assist the reviewer in their analysis of the levee system.

**Foundation Conditions.** The foundation condition, which generally consists of a surface zone of very soft silt and clay is documented in the General Design Memorandum (Appendix B). Plans called for the excavation of a levee foundation inspection trench prior to construction of the earth levee embankments. A 4-foot wide, 2-foot deep trench was excavated along the project alignment to permit inspection of the foundation soil for buried debris that could provide a seepage path at the contact between the foundation soil and the overlying embankment.

**Geotechnical Investigations.** According to the General Design Memorandum (Appendix B), the Corps performed a series of geotechnical investigations that included: 86 (10 to 20 ft deep) borings, 4 (30 to 60 ft deep) borings, 16 (50 to 150 ft deep) borings, and 2 (20 ft deep) borings. Tests performed at the Corps' North Pacific Division Materials Laboratory included gradation, Atterberg limits, consolidation, and triaxial shear. The information derived from this laboratory testing program was used in the design of levee embankments, flood walls, closures, and drainage facilities.

**Earthen Levee.** The general embankment levee section has a 12-foot-width top and 2H:1V (horizontal:vertical) side slopes. The earthen levee was constructed out of silty, sandy gravel with a 6 inch thick gravel wearing course. The portion of the earthen levee located west of the Chehalis River Bridge has been paved with 2 inches of asphalt concrete and is used as a multiuse pathway. The side slopes of the earthen levee were covered with top-soil and seeded with grasses, which provides erosion protection.

**Floodwalls.** In areas where the width of available land was not sufficient to accommodate the footprint of an earthen levee, a floodwall was constructed. This floodwall is composed of interlocking steel sheet piles that are 18 ft in length. In an effort to make the sheet pile joints relatively watertight, mastic joint sealer was used to seal each joint. The floodwall height is between about 5.5 and 7.5 feet above the ground surface.

**Drainage Structures.** Drainage structures were provided to pass the interior runoff from the five major drainage basins within the project area (Devonshire Slough, Alder Creek, Shannon Slough, Miller Slough, and Mill Creek). The details of these structures are shown in the as-built plans (Appendix F). The City reports that these structures have performed well under a variety of flow conditions since their construction. In addition to the five above referenced drainage structures, drainage of low areas adjacent to the levee system is provided through a series of culverts, ditches, and tide gates.

## 2.5 SETTLEMENT

Local experience and observations of nearby roads, parking lots, and structures confirm that soil settlement does occur when the soils within the South Aberdeen – Cosmopolis floodplain are loaded and the underlying soils consolidate. For instance, the nearby South Shore Mall with its waving and settling concrete slabs on grade and interior partition walls that have settled and buckled is a prime example of how the soils in South Aberdeen can settle when loaded.

Post-construction settlement along the South Aberdeen - Cosmopolis levee system is an issue that is addressed on an ongoing basis. In fact, the potential for settlement was specifically mentioned in the 1986 Congressional Project Authorization of the levee system. That authorization contained the following provision; "Before beginning the actual construction of the project, the Secretary shall perform additional studies relating to foundation materials in the project area…" The concern regarding foundation conditions centered on the potential for excessive levee settlement and/or local failure of the levee system during high flood levels.

To accommodate the anticipated post-construction settlement along the South Aberdeen - Cosmopolis levee system, the levee embankment was designed such that the top elevation of the levee at the end of construction would be 1.0 ft above the elevation required for the project purpose. The as-built plans for the South Aberdeen – Cosmopolis levee system (Appendix F) indicate that, in areas, the top elevation of the earthen levee was up to 0.3 ft below the design elevation by the end of construction.

The potential for differential settlements between the pile supported drainage structures and the adjacent earthen embankments was also anticipated. To help prevent the development of settlement cracks and failure of the earthen levee and/or the undermining of the drainage structures, sheet pile cutoff walls were constructed under and on each side of the drainage structures.

To address the potential for settlement, the Operations and Maintenance Manual provides that the City survey the top of the levee every five years and make adjustments to the levee height as needed. The levee was surveyed in 2002, 2007, and 2011. The initial 2002 survey was approximately five years after construction of the levee system was completed and some areas of settlement were identified and the earthen embankments were raised accordingly. Some areas of the levee were also raised when the top surface of the embankment west of the Chehalis River Bridge was paved for use as a multiuse path. While there were many differences between the as-built elevations and the elevations recorded during the first survey in 2002, the rate at which the settlement is occurring appears to have subsequently stabilized. However, some ongoing settlement, and the need to continue raising the elevation of the levee in the future is expected.

Much of Aberdeen (and the entire South Aberdeen – Cosmopolis levee system) is located within a liquefaction hazard zone. This zone could experience considerable liquefaction induced ground settlement in the event of a major earthquake. Such an event could also be accompanied by a tsunami. The levee system is not designed to provide protection from liquefaction induced ground settlement or tsunamis; however, since the levee system was constructed, western Washington has experienced a 5.8 magnitude earthquake centered about 28 km from Aberdeen, Washington and a 6.8 magnitude earthquake centered about 14 km from Lacey, Washington. According to City staff, no noticeable adverse impacts on the levee system were observed following these two seismic events.

Further analysis of settlement potential along the levee system is considered to be unwarranted based on the time rate of settlement information that has been collected since the levee system was constructed. However, because there is likelihood for future settlement along the levee system; the City must continue to survey the levee and make adjustments as needed to maintain an acceptable freeboard level. This is consistent with the City's Operations and Maintenance Manual, which provides that the City survey the top of the levee every five years and make adjustments to the height of the levee as needed.

## 2.6 INTERIOR DRAINAGE

The area protected by the South Aberdeen - Cosmopolis levee system consists of five interconnected interior basins; Devonshire Slough, Alder Creek, Shannon Slough, Miller Slough, and Mill Creek. The Corps used the Hydrologic Engineering Center's computer program HEC-1 to compute interior hydrographs. The levee drainage structures were sized to allow the various basins to drain during the ebb portion of one tidal cycle. Analysis by the Corps showed no significant impact on interior ponding elevations due to seepage. The Corps' levee design acknowledges that during a high tide cycle there would be ponding behind the levee if there was a large local precipitation event, but the amount of ponding would be less under project conditions than it would have been prior to construction of the levee system.

When the levee project was initially authorized, it included five pumping stations for the purpose of evacuating interior floodwaters. It was later determined by the Corps that the benefit of the pumping stations did not justify the cost of the stations as part of the initial project; however, the Corps acknowledged that the pump stations should be added later as future development within the project area warranted it. The Corps later determined that any future pumping stations would be the responsibility of the cities of Aberdeen and Cosmopolis. After this determination was made, the design proceeded and construction of the levee system was completed without any provisions for future pump stations.

At the conclusion of the levee construction project, new flood mapping was completed by FEMA. Most of the South Aberdeen area was taken out of the floodplain as a result of the levee construction. However, various pockets of flooding remained due to ponding that occurred when large local precipitation events coincided with high tide events and the water could not get out to the river. FEMA designated these areas and established Base Flood Elevations for them on their floodplain maps (Appendix L - Flood Hazard Map).

Most citizens of South Aberdeen did not see total flooding relief when the levee project was completed due to the ponding effect that occurred during large local precipitation events that coincided with high tides. Their properties were protected from larger flood events, but nuisance flooding due to ponding persisted. Some people reportedly complained about the increased frequency of nuisance flooding and claimed the water drained out slower than it did before the levee system was constructed.

The City addressed these concerns by installing five new storm water pump stations that pump water from behind the levee system to the Chehalis River. The locations of the pump stations are shown in Appendix M. These five pumps and one other pump have a combined pumping capacity of approximately 50,000 gallons per minute (gpm).

Other internal piping, pump, and ditch changes were made to help convey water to the pump stations. These improvements have resulted in a substantial reduction in nuisance flooding due to ponding in South Aberdeen. There are currently no major programmed stormwater improvement projects for South Aberdeen that would impact flooding conditions.

Under subcontract to Landau Associates, Northwest Hydraulic Consultants (NHC) conducted an interior drainage analysis (IDA) of the South Aberdeen – Cosmopolis levee system. The results of the IDA are presented in Appendix N. As noted in the attached IDA, the original levee design relied purely on gravity flow to drain the lands behind the levee system. In the years since construction of the levee, the City has installed a series of pumps to augment the drainage system. However, The City does not wish to certify the pumps as part of the interior drainage system because hydraulic modeling performed by NHC indicates that the pumps do not have the capacity to reduce flood levels beyond what the gravity system can accomplish under extreme hydrologic conditions.  Therefore, NHC's IDA assumes that the pumps are not operational and only gravity drainage is available for the system.

NHC's modeling determined that for the 100-year return interval, the stage inside each sub-basin protected by the South Aberdeen - Cosmopolis levee system is between 9.0 and 9.1 ft (NAVD 88).  Based on an examination of the simulation results, NHC concluded that the peak interior stages were caused by large local precipitation events, not extreme high tides or riverine floods.

NHC used GIS to create 100-year inundation maps of flooding due to interior drainage in South Aberdeen.  A constant base flood elevation (BFE) of 9.0 ft (NAVD 88) was mapped using base topography obtained using LiDAR data.  Figure 5 in NHC's report, which is presented in Appendix N, shows the proposed new inundation limits categorized by comparison to the effective maps.  Significant areas, especially in Devonshire Slough are eliminated from the effective FEMA Zone AH category. Along lower Alder Creek, overbank zone AH areas are also eliminated.  New AH zones are added in the Harriman Road area.  The quality of the LiDAR data for the large Mill Creek wetland was much poorer than in developed areas.  In this area, NHC adjusted the boundary around the periphery where the quality of the LiDAR data was better (mainly along developed land adjacent to U.S. Highway 101), but the boundary was otherwise left unchanged.

## 3.0 OPERATION

The operation of the South Aberdeen – Cosmopolis levee system is under the jurisdiction of the City. The operation and maintenance procedures for the South Aberdeen – Cosmopolis levee system are outlined in an Operation and Maintenance Manual that was prepared by the Corps (see Appendix O). As noted in Appendix O, the Operation and Maintenance Manual has been officially adopted by the City.

The operation of the levee system is performed by the Street/Stormwater Division of the City's Public Works Department. The current organization of and line of authority of key personnel include:

- Public Works Director: Malcolm Bowie
- Assistant Public Works Director/Street Superintendent: Rick Sangder
- Stormwater Supervisor: J. Springer.

Primary responsibility to operate and maintain the levee rests with the stormwater supervisor. The Public Works Director and Assistant Public Works Director/Street Superintendent provide overview and supervision as needed. The Stormwater Supervisor supervises the work of other personnel in performing his responsibilities.

There are only three closures that are currently in use (see Appendix J). Two of these closures are located immediately adjacent to the South Aberdeen Fires Station and the other is located within two blocks of the fire station. Although the Stormwater Supervisor would normally direct street personnel in operating the closures, fire department personnel have also been trained to operate the closures so they can provide backup if needed.

The Operation and Maintenance Manual states that the gates should be closed when the water level is expected to rise to elevation 12.54 ft (NAVD 88). The decision to activate the closures is made either by the Street Superintendent or Stormwater Supervisor, and in their absence, a senior street division staff person makes the decision. It has been the City's experience that unless a seasonally high tide is coupled with a large local precipitation event, the tide levels never reach a flood stage. Therefore, City staff routinely check tide level forecasts and compare them to weather forecasts. There is actually some cushion in the 12.54 ft (NAVD 88) elevation action level because the ground surface between the gates and the Chehalis River is higher than the gates at two locations and the water would not flow through the gates until the water level had risen to about elevation 13.0 ft (NAVD 88), which roughly corresponds to a 10-year flood event.

The only interior drainage elements that are considered a part of the levee system are four sluice gate structures and various culverts and tide gates that go through the earthen levee. These structures are all documents on the as-built drawings and working drainage plans that are used by the City's stormwater staff. The operation and maintenance procedures for the sluice gates and tide gates are detailed in the Operation and Maintenance Manual.

As part of the levee certification process, the City recognizes the need to amend the Operation and Maintenance Manual to include the following information:

- Names and titles of individuals responsible for the maintenance activities and inspection program documented in the Operation and Maintenance Manual
- Specific actions, assignments, and personnel responsibilities related to a flood warning system that has sufficient warning time
- A flood fight plan.

# 4.0 MAINTENANCE

The maintenance of the South Aberdeen – Cosmopolis levee system is under the jurisdiction of the City. The operation and maintenance procedures for the South Aberdeen – Cosmopolis levee system are outlined in an Operation and Maintenance Manual that was prepared by the Corps (see Appendix O).

The levee system has been inspected by the Corps on several occasions. Appendix P contains copies of two inspection reports by the Corps. Appendix P also contains the City's responses to the Corps' inspection reports.

# 5.0 SITE RECONNAISSANCE

A site reconnaissance was performed by the author of this certification report on May 15, 2015. The purpose of the site visit was to observe the current condition of the levee system and to compare, to the extent possible, the as-built drawings with actual field conditions. Observations of project features such as earthen embankments, floodwalls, closures, and drainage structures were made. Based on the observations made during this site visit, it was concluded that the observed field conditions are generally consistent with the information contained in the as-built drawings.

## 6.0 CERTIFICATION STATEMENT

To the best of my knowledge, the South Aberdeen – Cosmopolis levee system along the Chehalis River has been designed and constructed in accordance with sound engineering practices to provide reasonable protection from the 100-year flood, is in place, is fully functional, and meets the requirements of 44 CFR 65.10 as demonstrated by the attached supporting documentation. Furthermore, the geotechnical analyses performed by the Corps pertaining to embankment stability and settlement appear to demonstrate compliance with 44 CFR 65.10.

This certification does not constitute a warranty or guarantee of performance, express or implied. Certification of data is a statement that the data is accurate to the best of the certifier's knowledge. Certification of analyses is a statement that the analyses have been performed correctly and in accordance with sound engineering practices. Certification of design is a statement that the levee system was designed in accordance with sound engineering practices to provide protection from the 100-year flood. Certification of as-built conditions is a statement that the structures have been built according to the plans being certified, are in place, and are fully functioning.

LANDAU ASSOCIATES, INC.

Steven R. Wright, P.E.
Principal

SRW/CAM/rgm

APPENDIX N

# Interior Drainage Analysis

nhc
northwest hydraulic consultants

NHC Ref. No. 200174

May 21, 2015

**CITY OF ABERDEEN**
200 E. Market Street
Aberdeen, WA
98520

**Attention:** **Malcolm Bowie,**
Public Works Director

**Via email:** mbowie@aberdeenwa.gov

**Re:** **DRAFT Aberdeen South Levee Interior Drainage Analysis**

# 1 PURPOSE

This letter documents an interior drainage analysis (IDA) of the South Aberdeen Levee, which protects portions of the cities of Aberdeen and Cosmopolis south of the Chehalis River. Northwest Hydraulic Consultants (NHC) has conducted the IDA for the City of Aberdeen as a sub-contractor to Landau Associates. The IDA is required under 44 CFR 65.10(b)(6) in order for FEMA to accredit a levee as providing protection from the 100-year flood event.

# 2 BACKGROUND

The South Aberdeen levee runs along the left bank of the Chehalis River from Cosmopolis to SR105 in Aberdeen. Five square miles of land drain through the levee, including the Alder Creek and Mill Creek watersheds that originate in forested hills to the south. On the Chehalis River floodplain, these streams, old river sloughs, and a constructed ditch and pipe system form the stormwater network. The floodplain sub-basins are interconnected due to the construction of ditches that cross basin boundaries. Three large concrete drainage structures are installed on Devonshire Slough, Alder Creek, and Mill Creek. The structures support banks of square side-hinge flapgates. While some of the gates are engineered to allow regulated backflow, they are currently operated as standard flapgates (i.e. no backflow), and this is assumed to remain the case for purposes of the IDA. Smaller drainage structures consist of round culverts with top-hinge flapgates, and in-line check valves on gravity bypass pipes in pump stations.

The original levee design relied purely on gravity flow to drain lands behind the levee. In the years since construction, the City of Aberdeen has installed a series of pumps to augment the drainage system. The City does not wish to certify the pumps as part of the interior drainage system - hydraulic modeling indicated that the pumps do not have the capacity to reduce flood levels beyond what the gravity drainage system can accomplish under extreme hydrologic conditions. Therefore this IDA assumes that the pumps are non-operational and only gravity drainage is available for the system.

The Corps of Engineers (Corps) conducted an IDA as part of the original levee design. NHC reviewed the reports, but there was insufficient information to assess whether the IDA met FEMA standards for the current certification project. It was also clear the Corps IDA reports did not reflect late design changes in the levee drainage structures. Due to the availability of new LiDAR mapping and hydrologic and hydraulic models, it was deemed more accurate and cost-effective to conduct an entirely new IDA using a different approach.

# 3 HYDROLOGIC AND HYDRAULIC MODELING

Base Flood Elevations (BFEs) due to interior drainage on the landward side of the levee were determined by a frequency analysis of annual peak stages extracted from a long-term hydraulic simulation. HEC-RAS was the hydraulic model used for this analysis. The long-term simulation accounts for the combined effects of riverine flows, local precipitation, and tidal effects without forcing assumptions of the joint probabilities of various events occurring. The 53-year simulation period (water year 1956-2009) was determined by the period of overlapping record for the required hydrologic datasets. All elevations and data are referenced the NAVD88 datum.

## 3.1 Geometry Development

The lower 35 miles of the mainstem Chehalis River Flood Authority HEC-RAS model, from Porter to Grays Harbor, formed the basis of the hydraulic modeling (Figure 1). The model was unchanged except in the South Aberdeen area. This model included updated bathymetry of the mainstem channel in the project area.

A series of storage areas represent the portion of South Aberdeen floodplain protected by the levee. NHC generated stage-volume curves for each storage area from LiDAR (PSLC). The storage areas were interconnected using lateral weirs to allow flow transfer via connecting ditches and overland flooding. The levee was represented as a lateral weir, with crest elevations provided by the City of Aberdeen's survey. As-built Corps of Engineers levee plans provided data for flapgates. The City of Aberdeen provided data on pump stations and other key drainage features. Figure 2 shows the model schematic in the project vicinity.

## 3.2 Boundary Conditions

Boundary conditions for the model were developed from a combination of USGS river gages, NOAA tide gages, and hydrologic modeling. Figure 1 shows the boundary condition locations in the model.

A record of mean daily flow at the USGS 1203100 - Chehalis River at Porter gage was used for the upstream model boundary condition. Missing data between October 1972 and April 1975 were interpolated using a linear regression relationship with the USGS Chehalis River near Grand Mound stream gage.

Tributary inflows upstream of Aberdeen were based on mean daily flows at the USGS gage 12035000, Satsop River near Satsop. Satsop River inflows used published USGS values, adjusted for the small amount of basin area between the gage and Chehalis River floodplain. Wynoochee River inflows were estimated based on a linear regression relationship between the USGS Wynoochee River and Satsop River gages, adjusted for area between the Wynoochee gage and the Chehalis River floodplain. The scaling factor for other local inflows was estimated by using the area-adjusted ratio of the 50-year flood flow for Coquallum Creek and the Satsop River, based on USGS regional regression equations (USGS, 2012).

For the downstream boundary, a correlation was developed between observed high and low tides at the NOAA Astoria Tongue Point tide gage (9439040) and a short-term NOAA gage at Aberdeen (9441187) for the period of February 2004 to December 2005. This correlation was used create a synthetic Aberdeen hourly tidal record for the simulation period based on observed hourly Astoria gage data.

A WWHM (Washington 2012) hydrologic model was used to estimate runoff flows for eight sub-basins inside the levee. GIS was used to delineate and characterize each sub-basin's size, slope, soil type, and land use. Land use was classified using aerial photographs into seven categories – forest, clearcut, residential (low density), pasture, residential (medium density), commercial/industrial, and roads/paved surfaces. Soil was categorized into SCS types A/B, C, or D (saturated) soils. Average basin slopes were categorized as flat or moderate using the National Elevation Dataset (USGS, 2007). The WWHM model used precipitation records based on the Montesano rain gage to simulate hourly runoff from 1956 to the present. Figure 3 shows the hydrologic sub-basins boundaries and land use categories. Tributary inflow and direct floodplain runoff from each sub-basin were applied directly to the appropriate HEC-RAS model storage area shown in Figure 2.

## 3.3 Simulations

The model simulated river and sub-basin stages from WY 1956 through 2009. For each storage area, the maximum annual peak stage was extracted and a frequency curve fit to the data. The 100-year BFE was determined from this curve.

# 4 RESULTS

For the 100 –year return interval, the stage inside each sub-basin was determined to be between 9.0 and 9.1 feet (Figure 4 and 4). The high degree of interconnectedness between sub-basins is responsible for the very similar results. Examination of the simulation results show that peak interior stages were caused by large local precipitation events, not extreme high tides or riverine floods.

NHC used GIS to create 100-year inundation maps of flooding due to interior drainage in South Aberdeen. A constant BFE of 9.0 feet was mapped using LiDAR for the base topography. Figure 5 shows the proposed new inundation limits categorized by comparison to the effective maps. Significant areas, especially in Devonshire Slough (Figure 5 - A), are eliminated from the effective FEMA Zone AH category. Along lower Alder Creek (B), overbank zone AH areas are also eliminated. New AH zones are added in the Harriman Road area (C). The quality of the LiDAR data in the large Mill Creek wetland (D) was much poorer than in developed areas. Here the boundary was adjusted around the periphery where the data was good, mainly along developed land adjacent to Highway 101, but was otherwise left unchanged.

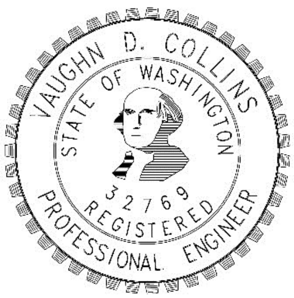
# 5 CLOSURE

NHC has completed the Interior Drainage Analysis documented here for the South Aberdeen Levee as required under 44 CFR 65.10(b)(6) in order for FEMA to accredit a levee as providing protection from the 100-year flood event. Digital copies of all models and datasets used will be sent separately.

Sincerely,

**Northwest Hydraulic Consultants Inc.**

**Prepared by:**




Vaughn Collins, P.E.
Senior Engineer

**Reviewed by:**

Erik Rowland, P.E.
Principal

ENCLOSURE

cc: Steve Wright, P.E., Landau Associates (swright@landauinc.com)

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United States Geological Survey, 2012, The Streamstats program for Washington, online at http://water.usgs.gov/osw/streamstats/Washington.html


# 7 FIGURES

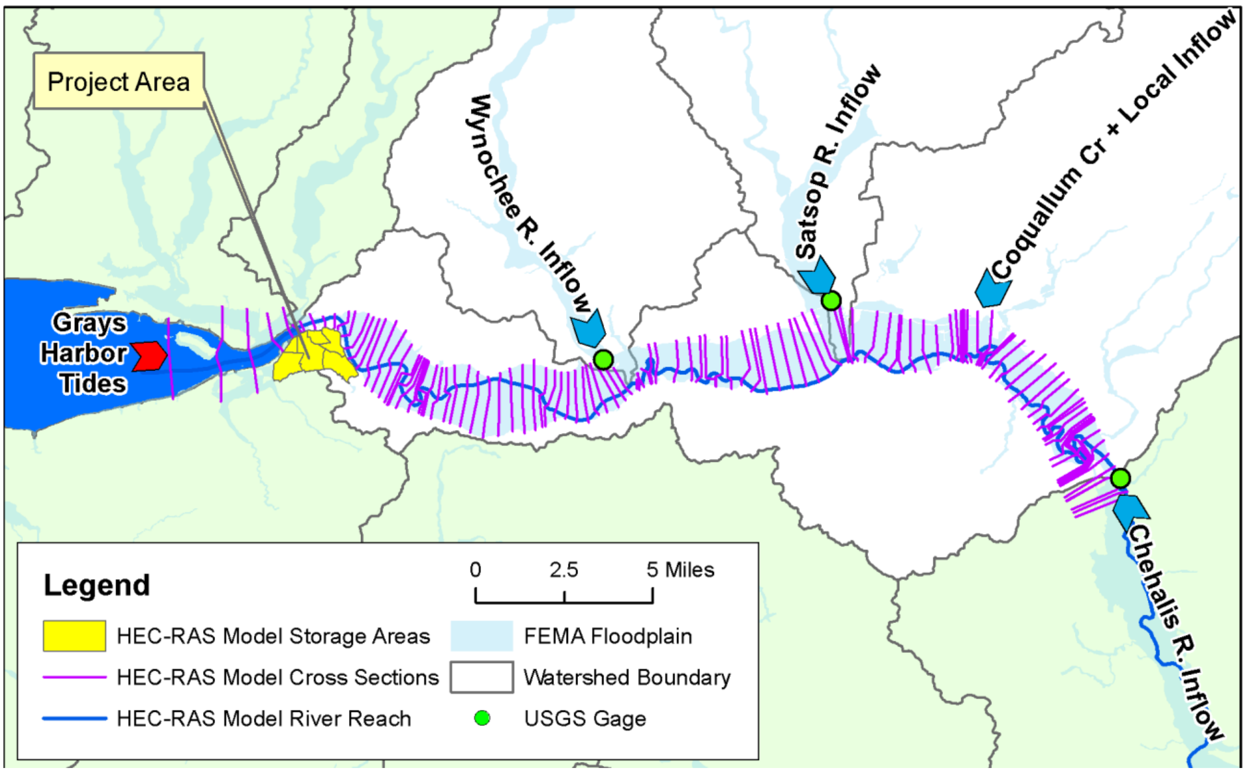



**Figure 1: HEC-RAS Model Schematic**

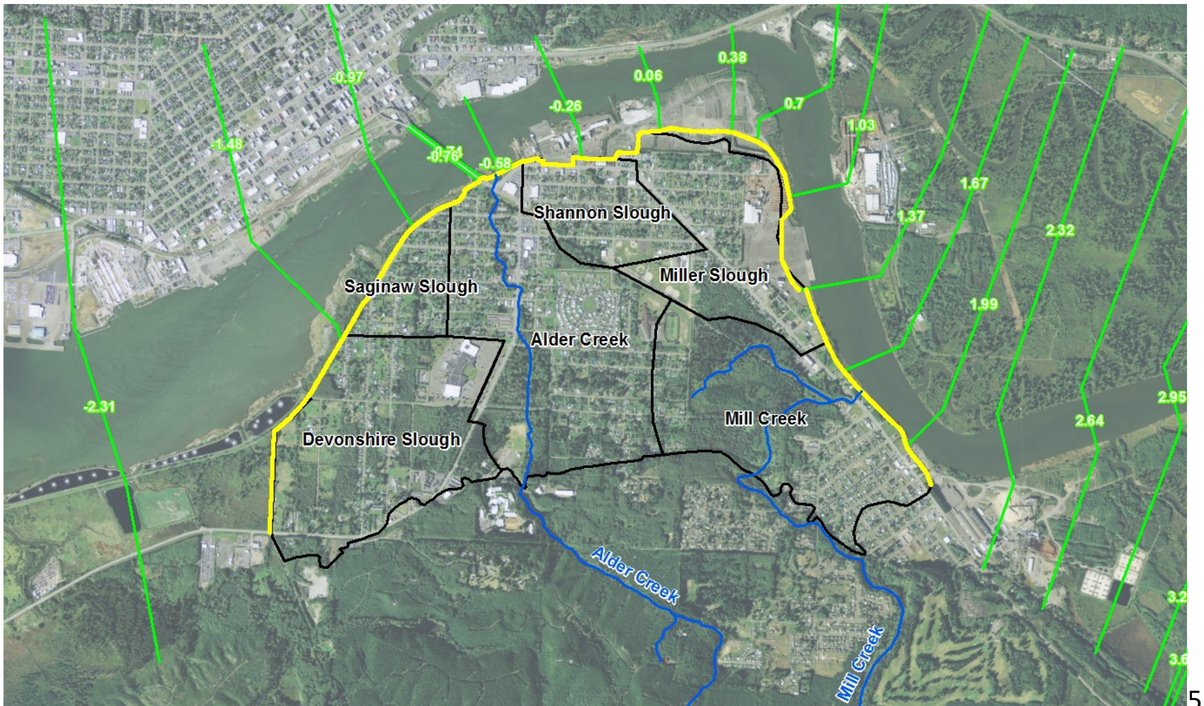



**Figure 2*:*** **HEC-RAS storage areas (outlined in black) and South Aberdeen Levee (yellow) with FIS cross-sections (green)**

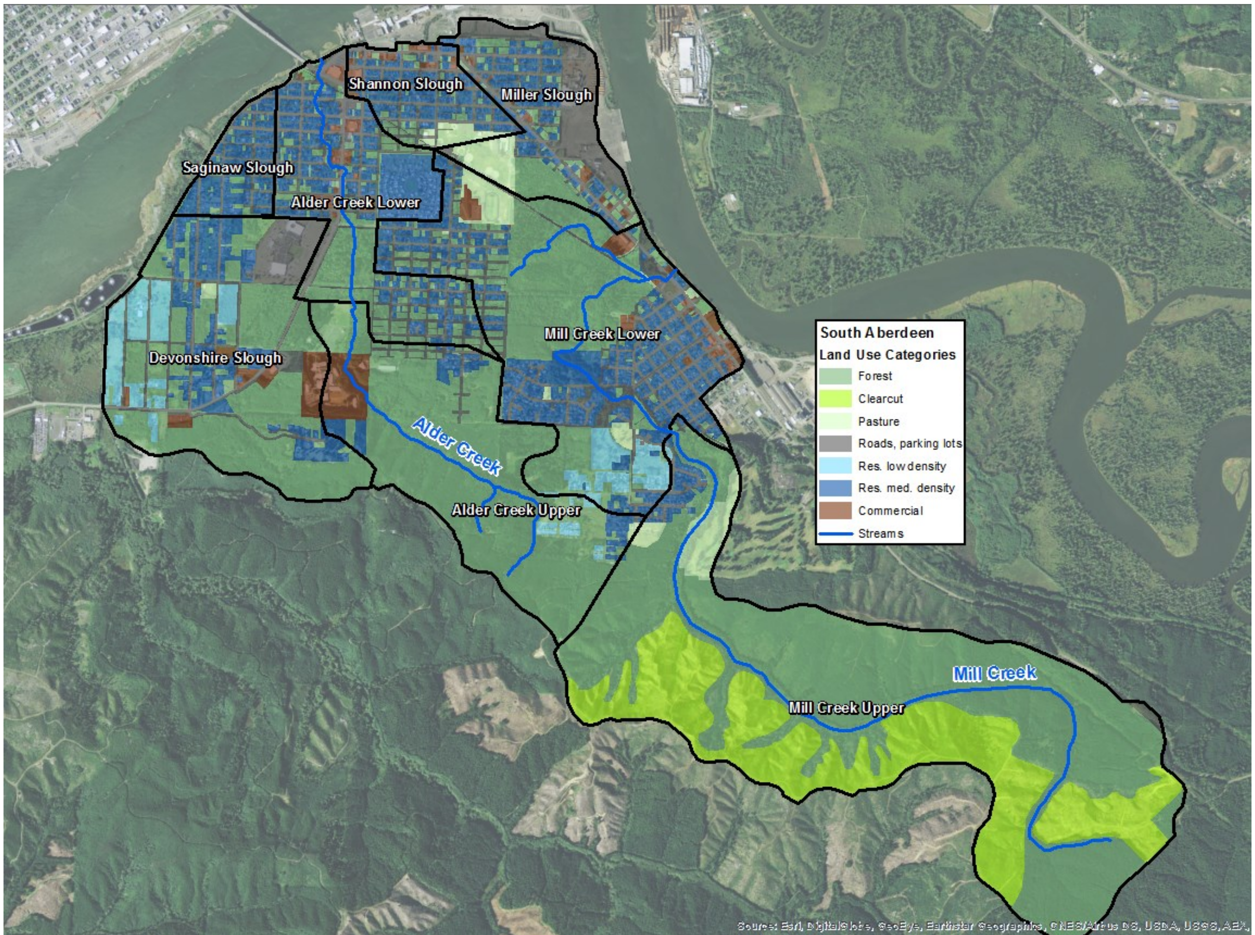



**Figure 3:** **South Aberdeen interior drainage hydrologic sub-basins and land use classifications**

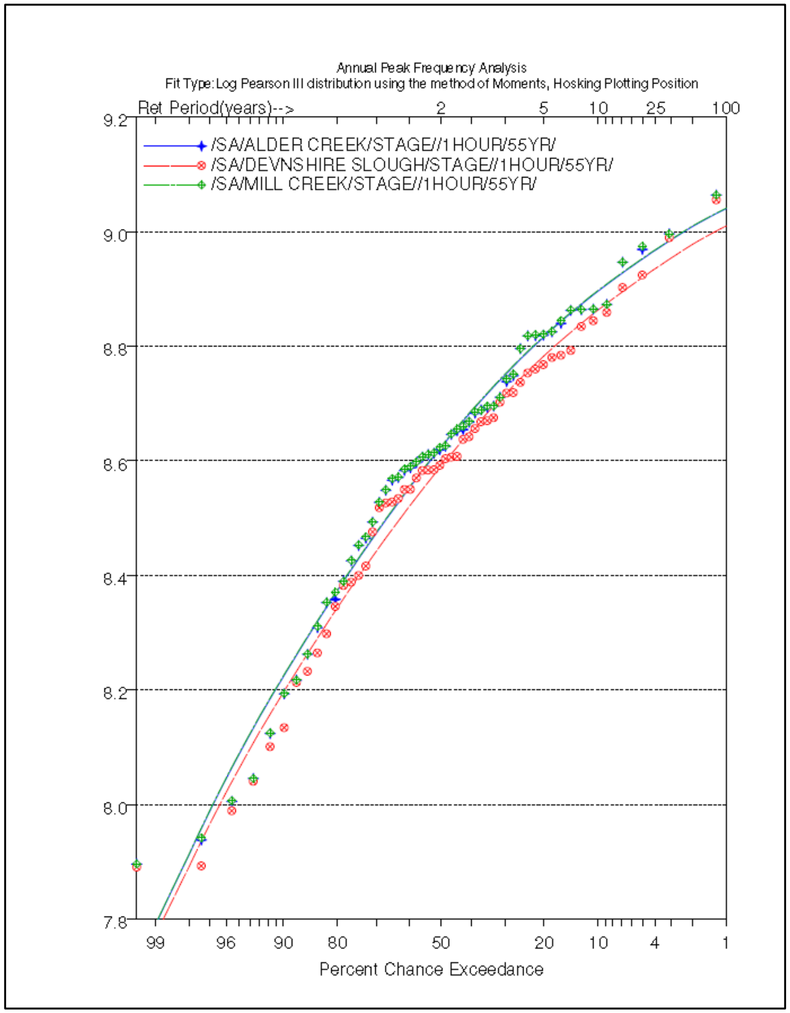



**Figure 4.** **Annual Peak Frequency plot for Alder Creek, Devonshire Slough and Mill Creek.**

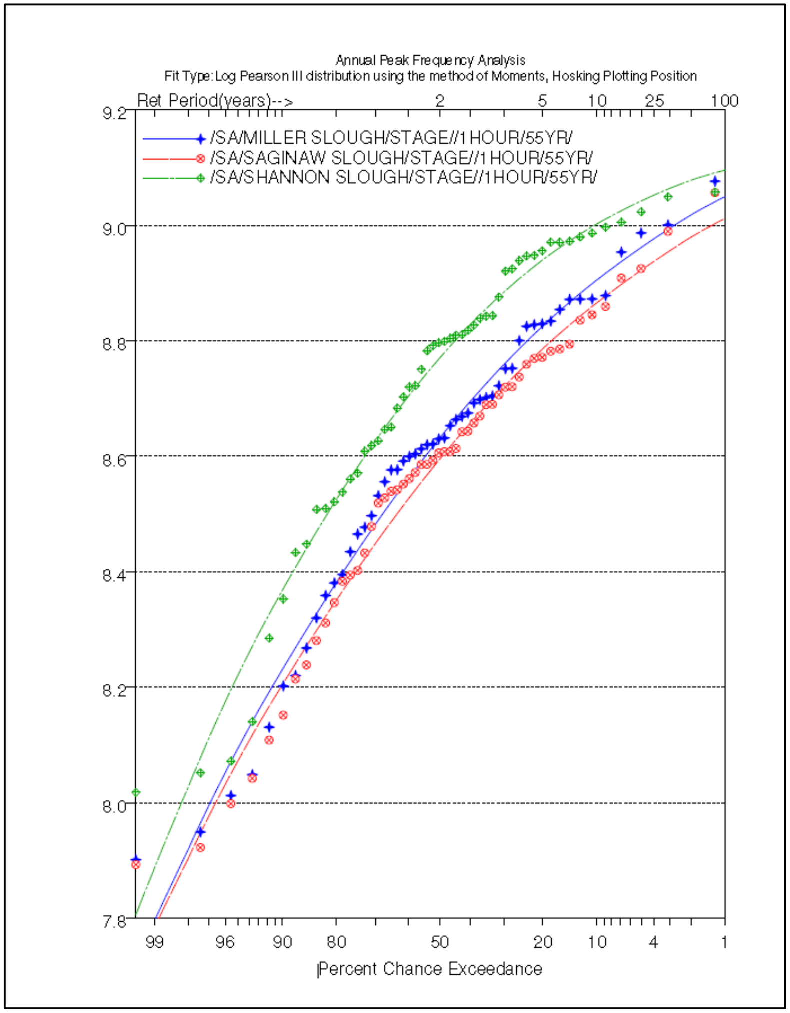
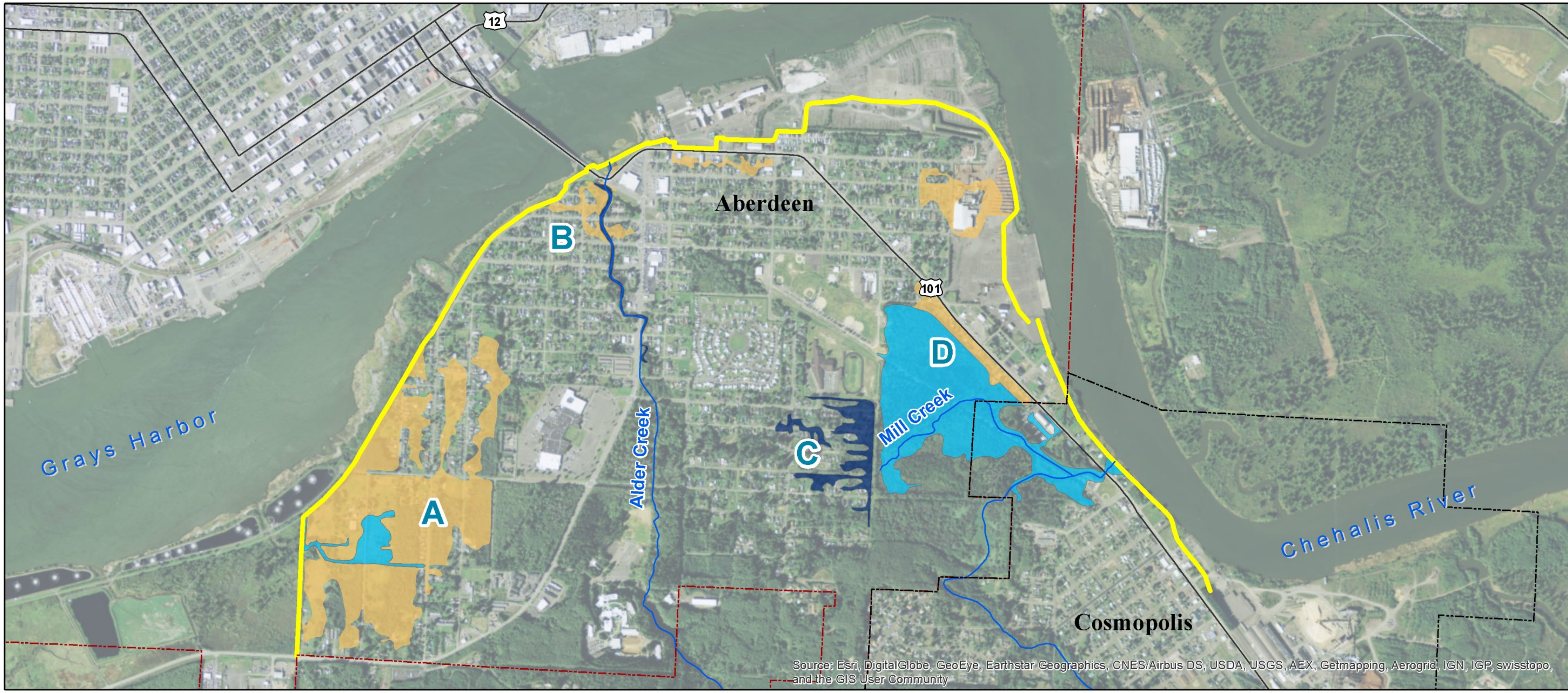



**Figure 5.** **Annual Peak Frequency Analysis for Miller Slough, Shannon Slough, and Saginaw Slough.**




City of Aberdeen Washington

nhc northwest hydraulic consultants

**Proposed Flood Hazard Zone Changes**

- Area removed from Zone AH
- FEMA Zone AH to remain - revised BFE 9'
- New Zone AH - BFE 9'
- City of Aberdeen Limits
- City of Cosmopolis Limits
- Highways
- South Aberdeen Levee

N

SCALE - 1:18,000

0 0.5 1 1.5 2 Miles

Coordinate System: NAD 1983 STATEPLANE WASHINGTON SOUTH FIPS 4602 FEET

Job: 200174 Date: 28-MAY-2015

*South Aberdeen Levee Interior Drainage Analysis Proposed Flood Zone Revisions*

*FIGURE 5*