Royal River Restoration Project:
Phase II Analysis and Reporting

Evaluation of Restoration Impacts

Stantec

September 24, 2013

Sign-off Sheet

Stantec

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Executive Summary

The Royal River Restoration Project (RRRP) is evaluating opportunities for restoration of aquatic resources in the reach of the Royal River in Yarmouth and upstream tributaries, such as Chandler, East Branch, Collins, and Eddy brooks. The RRRP is being undertaken by the Town of Yarmouth in collaboration with project partners Maine Rivers, the National Oceanic and Atmospheric Administration (NOAA), the Royal River Conservation Trust (RRCT), and the Casco Bay Estuary Partnership.

Project studies completed by Stantec and others have evaluated a broad range of existing conditions, resources, and uses along the Royal River in Yarmouth, including fisheries resources, recreational use, and adjacent infrastructure such as bridges over the river and two aging dams owned by the Town of Yarmouth at Bridge Street and East Elm Street, and the harbor in the tidally affected section of the river seaward from the State Route 88 (East Main Street) Bridge.

A primary focus of the RRRP is to improve upstream fish passage at the Bridge Street and East Elm Street dams. Project investigations and studies have identified poor upstream fish passage at the Bridge Street and East Elm Street dams as a primary cause of reduced numbers of migratory fish in the Royal River watershed. While there are fish ladders at both dams, they have been ineffective at providing upstream fish passage. Removal of one or both of the dams would result in conditions that would provide for upstream passage of native fish species, and eliminate financial concerns related to ongoing maintenance costs and the potential liability associated with this aging infrastructure.

This Phase II report and previous project studies evaluate potential benefits and constraints associated with removal of the Bridge Street Dam and/or East Elm Street Dam, which are owned by the Town of Yarmouth.

Following on Phase I studies, the Bridge Street Dam impoundment was drawn down in August 2011. This drawdown event provided an opportunity to observe conditions between the Bridge Street Dam and Middle Falls similar to those that would occur if that dam was removed. Unlike the Bridge Street Dam, however, there is no feasible means to draw down the East Elm Street Dam impoundment and thus no opportunity to observe potential conditions upstream from the East Elm Street Dam if that dam was removed.

Discussions with stakeholders during the development of previous project studies identified a number of specific concerns regarding removal of East Elm Street Dam, including:

a) Impacts to recreational use of the river between East Elm Street Dam and the upstream limit of the impoundment in the vicinity of State Route 9 in North Yarmouth;

b) The potential for increased sediment delivery to Yarmouth Harbor; and

c) Potential presence of environmental contaminants in sediment in the dam impoundment.

Work performed as part of this Phase II study included technical studies to evaluate the three specific concerns identified above and to comply with the project's budget constraints. These studies included:

- Review of existing information regarding sediments in the harbor;
- Topographic and bathymetric surveys to assist in development of a hydraulic model;
- Sediment probing, sampling, and analysis in the East Elm street impoundment;
- Review of hydrology (flows) in the Royal River;
- Hydraulic modeling to determine potential post-removal water surface elevations and flow conditions;
- Development of an order-of-magnitude estimate of the volume of potentially mobile sediment in the Royal River between East Elm Street Dam and the State Route 9 Bridge; and
- A preliminary analysis of potential sediment remobilization issues.

This Phase II report presents the results from desktop and field studies that evaluated potential changes in the reach of the Royal River upstream from East Elm Street Dam that would result if the dam were removed. Findings associated with this work are described below, including brief summaries relevant to the three specific issues identified above.

General Conditions

- Removal of East Elm Street Dam would lower the normal water surface elevation in the impoundment between the dam and the vicinity of the State Route 9 Bridge in North Yarmouth by 5 to 6 feet.
- During flood events, the effects of dam removal would be reduced progressing upstream and would result in lowering of the water surface at the State Route 9 Bridge by less than 1 foot during the 100-year flood.
- The lower water surface elevations following removal of the dam would result in increased flow speeds and a resultant increase in sediment transport capacity in the Royal River in the currently impounded section of the river.

Recreational Use

- Removal of East Elm Street Dam would result in lower water levels in the river between the location of the dam and the vicinity of the State Route 9 Bridge. Project studies suggest that most opportunities for recreational use of the river upstream from the dam, including boating and swimming, will be sustained.

- The existing boat launch behind the Yarmouth Historical Society building upstream from the East Elm Street Bridge may no longer be a suitable location for putting in boats and paddling upstream, however, as it is expected that the river will be too swift and shallow to paddle upstream adjacent to the boat launch. The Town of Yarmouth is investigating a new boat launch in the vicinity of Sligo Road approximately a one-half mile upstream.

- During flood events, it may be unsafe to boat or swim in the section of the river downstream from the St. Lawrence and Atlantic Railroad trestle bridge near the Yarmouth Historical Society building due to swift flows and the likely presence of rapids between the trestle bridge and East Elm Street. These conditions, however, may be attractive to experienced whitewater kayakers.

Sediment Delivery to Yarmouth Harbor

- The order-of-magnitude estimate of the volume of potentially mobile sediment in the Royal River between the East Elm Street Dam and the State Route 9 Bridge is 100,000 cubic yards (CY). In comparison, the estimated total dredge volume in Yarmouth Harbor (anchorage and channel) is 67,000 CY.

- Removal of East Elm Street Dam is expected to result in increased delivery of sediment to the harbor during relatively frequent (e.g., annual) floods, but is not expected to increase sediment delivery during less frequent, high-magnitude floods (i.e., the 100-year return-interval event). The amount of sediment and duration of effects associated with removal of the dam would depend on the number and frequency of flood events following removal of the dam.

- If removal of East Elm Street Dam is pursued, coordination with proposed dredging of the harbor is recommended.

Environmental Contaminants

- Laboratory analyses indicate that concentrations of environmental contaminants in sediment samples collected in the Royal River upstream from East Elm Street Dam are similar to those in the downstream reach of the river.

- From sediment samples that were analyzed, there appears to be minimal potential risk of adverse effects to aquatic life.

1.0 INTRODUCTION

This report presents information developed as part of Phase II of the Royal River Restoration Project (RRRP) and was prepared by Stantec Consulting Services Inc. (Stantec) under contract to the Town of Yarmouth, Maine (hereafter referred to as the Town) in collaboration with project partners including Maine Rivers, the national partnership between the National Oceanic and Atmospheric Administration (NOAA) Fisheries Community-Based Restoration and Restore America's Estuaries (RAE), the Casco Bay Estuary Partnership (CBEP), and the Royal River Conservation Trust (RRCT). The purpose of the RRRP is to explore and evaluate opportunities for restoration of natural river function and provide for improved upstream passage of resident and diadromous fish in the reach of the Royal River in Yarmouth. Improved upstream passage in Yarmouth will provide these fish access to spawning and rearing habitat in the upstream watershed, including its tributaries, such as Chandler, East Branch, Collins, and Eddy brooks.

A goal of the RRRP is to improve conditions for aquatic resources in the Royal River. A primary component of this and previous studies is evaluation of improved upstream fish passage and aquatic habitat restoration opportunities associated with removal of the Bridge Street Dam and/or the East Elm Street Dam. The "project reach" of the Royal River for the RRRP is the Royal River between the upstream limit of the East Elm Street Dam impoundment, which is upstream from the State Route 9 Bridge in North Yarmouth, to the head-of-tide of the river at the State Route 88 (East Main Street) Bridge in Yarmouth. The "study reach" for this study is limited to the East Elm Street Dam impoundment. Observations during a canoe trip along the Royal River from Wescustogo Park in North Yarmouth to the existing boat launch upstream from East Elm Street Dam indicate that the East Elm Street Dam impoundment extends upstream from the State Route 9 Bridge.

This report focuses on evaluating potential changes in the reach of the Royal River upstream from East Elm Street Dam that could result if the dam were removed. Due to the lack of a functioning low-level outlet at East Elm Street Dam, a drawdown of the associated impoundment was deemed impossible, and thus this report should be considered a simulated "desktop" drawdown of the East Elm Street Dam impoundment. In contrast, the Town was able to successfully draw down the Bridge Street Dam impoundment during the summer of 2011 with relative ease, an action that provided insight into the relatively minor changes in that area of the river that would result from removing the Bridge Street Dam.

Funding for project work was provided by the Town of Yarmouth, the Elmina B. Sewall Foundation, the Horizon Foundation, Patagonia, Inc., the national partnership between the NOAA Fisheries Community-Based Restoration and RAE, and the RRCT.

1.1 PROJECT BACKGROUND

1.1.1 Project Context

The Nature Conservancy recently completed a multi-year study of fish passage restoration priorities[1] in 13 states in the northeastern United States. The effort, known as the Northeast Aquatic Connectivity Project (NACP), assessed dams across the region for their potential to benefit anadromous fish if removed or bypassed. The NACP analyzed each dam based on five categories: connectivity status, connectivity improvement, watershed and local condition, ecological resources, and size characteristics. The project represents a substantial amount of digital map work with hundreds of hours of verification and inquiry and finally modeling and prioritization. In the end, each of the region's dams was given a score based on its potential to benefit diadromous fish if the dam is bypassed or removed.

As per communication with Erik Martin, GIS Analyst / Conservation Information Manager at The Nature Conservancy, both of the two lower most dams on the Royal River in Yarmouth, Maine, ranked in the top tier of the almost 14,000 dams in the studied region.

1.1.2 The Royal River

The Royal River watershed encompasses approximately 141 square miles of mixed-use land largely in the towns of Auburn, Durham, Gray, New Gloucester, Pownal, North Yarmouth, and Yarmouth, Maine (Figure 1). The Royal River flows from Sabbathday Lake in New Gloucester and generally flows in a southeasterly direction for 25.5 miles, falling approximately 299 feet (ft) before terminating at Casco Bay in Yarmouth, approximately 2.3 miles downstream from the Bridge Street Dam.

The Royal River has also been referred to as the Westcustogo River, Royalls River, Royels River, Yarmouth River, and Pumgustuck River.[2] The current name stems from the settlement of William Royall along the river in 1636.

The Royal River watershed is largely unaffected by historical or current industrial development, with the exception of the areas immediately surrounding the natural cascades in Yarmouth. The cascades within the town were formerly developed for industrial use, including paper and cotton manufacturing, lumber processing, tanneries, poultry processing plants, and iron forging. A notable exception to the watershed being largely unaffected by industrial development, the former McKin Company Superfund Site (CERCLIS #: MED980524078), is located in Gray, Maine. Several current and former rail systems also pass through the watershed.

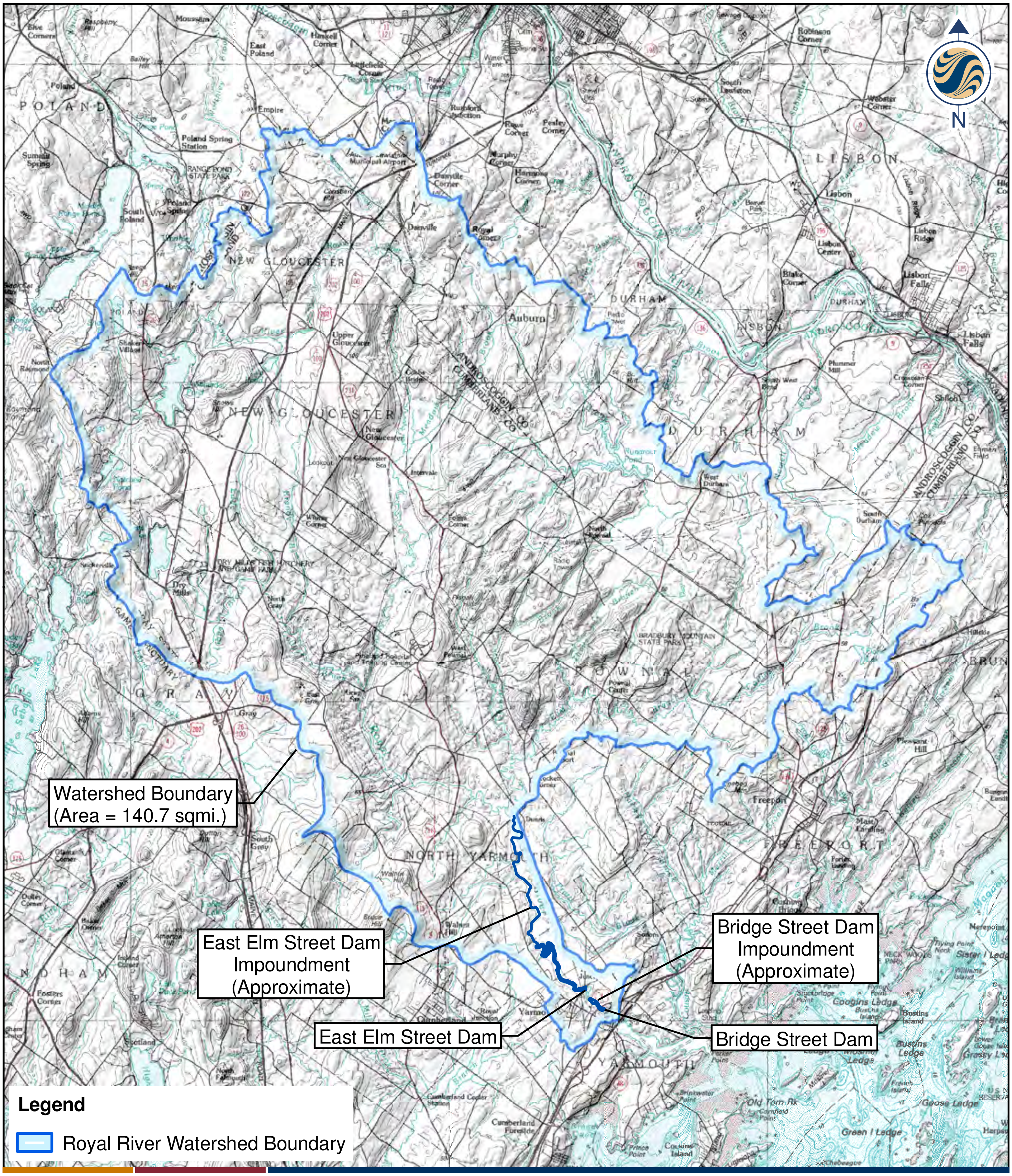
The Maine Department of Environmental Protection (MEDEP) has designated the Royal River as Class B water. Waters regulated as Class B waters are considered general purpose waters managed by the MEDEP to attain good quality water and to maintain aquatic life. Designated

[1] http://rcngrants.org/content/northeast-aquatic-connectivity
[2] Attwood, Stanley B. 1946. Length and Breadth of Maine. 231 pp.

uses for Class B regulated waters include fishing, recreation, navigation, hydropower, and industrial discharge provided specific water quality criteria are maintained or exceeded.

A 1958 report by the Maine Department of Inland Fisheries and Wildlife[3] identified eight man-made dams, three natural barriers to fish passage, and one fish screen within the Royal River watershed. The dams included the Bridge Street and East Elm Street dams, the Smith Dam (now removed), and the Jordan Dam on the main stem of the Royal River; the Pownal School Dam and "Old" Dam on Collyer Brook; and the Sawmill Dam and Runaround Pond Dam on Chandler Brook. Two natural barriers were noted in the vicinity of the Jordan Dam and one on Collyer Brook below the "Old" Dam. Of note is that a "fish screen" was located on the outlet of Sabbathday Lake near Tobey Road and was intended to keep fish from emigrating from the lake. The only other ponds within the Royal River watershed are Lily Pond and Runaround Pond. A more recent inventory of restoration opportunities and barriers was completed by the Maine State Planning Office in 2005 as part of the Gulf of Maine Council on the Marine Environment, Restoration Project Inventory. That study identified only two remaining man-made dams in the main stem of the river below New Gloucester, at East Elm Street and Bridge Street in Yarmouth.

[3] Deroche, Stuart E. 1958. Royal River Drainage: Fish Management. 16 pp.



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Client/Project
Town of Yarmouth
Royal River
Restoration Project

Figure No.
1

Title
Royal River Watershed

11/22/2010

1.1.3 Target Fish Species

The Royal River in the vicinity of the East Elm Street impoundment hosts a variety of resident and diadromous fish that are target species for restoration as part of the RRRP. Diadromous species attempting to migrate the Royal River Corridor, as documented by the Maine Department of Marine Resources (MEDMR) between 1983 and 1989, include anadromous river herring, American shad (*Alosa sapidissima*), and American eel (*Anguilla rostrata*). Resident fish species documented during that same timeframe include brook trout (*Salvelinus fontinalis*), white sucker (*Catostomus commersoni*), brown bullhead (*Ameiurus nebulosus*), creek chub (*Semotilus atromaculatus*), fallfish (*Semotilus corporalis*), common shiner (*Luxilus cornutus*), smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), and brown trout (*Salmo trutta*). Smallmouth bass, largemouth bass, and brown trout are nonindigenous species in the Royal River, though the Royal River Corridor is actively managed for a stocked brown trout sport fishery. Atlantic salmon (*Salmo salar*) historically used the Royal River but was extirpated from the river, likely as a result of loss of access to upstream habitats due to impassable barriers (i.e., dams).

Diadromous and resident fish species that could benefit from restoration activities include those listed in Table 1.

Table 1: Diadromous and Resident Fish Species in the Royal River

Resident Species	
Common Name	**Scientific Name**
Common shiner	*Luxilus cornutus*
Fallfish	*Semotilus corporalis*
Largemouth bass[I]	*Micropterus salmoides*
Smallmouth bass[I]	*Micropterus dolomieu*
White sucker	*Catostomus commersoni*
Brook trout[A]	*Salvelinus fontinalis*
Brown trout[A, I]	*Salmo trutta*
Brown bullhead	*Ameiurus nebulosus*
Creek chub	*Semotilus atromaculatus*
Diadromous Species	
Common Name	**Scientific Name**
Alewife	*Alosa pseudoharengus*
American eel	*Anguilla rostrata*
American shad	*Alosa sapidissima*
Atlantic salmon	*Salmo salar*
Blueback herring	*Alosa aestivalis*
Rainbow smelt	*Osmerus mordax*
Sea lamprey	*Petromyzon marinus*
Striped bass	*Morone saxatalis*

Notes: "A" - These species are potentially anadromous in the Royal River
"I" – Denotes non-indigenous species

1.1.4 Previous Studies

In January 2008, the Town undertook a planning process aimed at guiding development along the Royal River Corridor. The 2008 Royal River Corridor Study (RRCS) evaluated the history, natural resources, recreational usage, zoning, and potential future development of the Royal River Corridor and adjacent lands. The Royal River Corridor Master Plan (RRCMP 2009) was prepared as a result of the RRCS on behalf of the Town by the team of Terrence J. DeWan & Associates, Stantec, and the Greater Portland Council of Governments in coordination with the Town Council-appointed Royal River Study Committee (Study Committee) and the Yarmouth Historical Society.

The guiding principles of the RRCS, as adopted by the Study Committee, include the protection and enhancement of habitat, improvements to water quality, and emphasis on the river as a community focus point while encouraging appropriate economic development within the study area. The RRCMP was developed to guide future land-use decision making within the corridor for the foreseeable future.

1.1.5 Phase 1 Study

Among recommendations stated in the RRCMP for guiding development along the Royal River Corridor was to improve fish passage corridor-wide and to conduct a comprehensive feasibility study to assess the advantages and disadvantages of removing the Bridge Street and East Elm Street dams. Consistent with these recommendations, the Town contracted with Stantec in 2010 to perform a feasibility study to evaluate the potential for fisheries and aquatic habitat restoration in the Royal River. The *Fisheries and Aquatic Habitat Restoration Feasibility Study* (Stantec 2010) was released in November 2010 and addresses opportunities and constraints associated with restoration of fisheries and aquatic habitat in the project reach of the Royal River.

1.1.6 Basis for Phase II Study

The Town, Maine Rivers, and the RRCT held a series of public meetings following the release of the Phase I *Fisheries and Aquatic Habitat Restoration Feasibility Study*. The intent of these meetings was to present study findings and to solicit comments from the interested stakeholders to inform the potential need for additional information and/or studies. Based on comments received during the public meetings and ongoing outreach by the Town, Maine Rivers, and others, the following items were identified for additional study and evaluation:

1. The potential for increased sediment delivery to Yarmouth Harbor resulting from dam removal;
2. Potential presence of environmental contaminants in sediment in the East Elm Street Dam impoundment; and

3. Potential impacts to recreational use of the river between East Elm Street Dam and the upstream limit of the impoundment in the vicinity of State Route 9 in North Yarmouth.

Information obtained as part of previous studies and observations during a drawdown of the Bridge Street Dam impoundment during the summer of 2011 indicate that there is relatively little sediment in the Bridge Street Dam impoundment. There is no feasible means to draw down the East Elm Street Dam impoundment, and uncertainty regarding the volume and characteristics of sediments in the impoundment upstream from East Elm Street Dam necessitated additional field and desktop studies. A primary objective of this study is to perform field and desktop studies in lieu of performing a drawdown of the East Elm Street Dam impoundment to provide stakeholders with information on factors including potential impacts to the harbor from removal of East Elm Street Dam.

Similarly, recreational opportunities are limited in the Bridge Street Dam impoundment relative to those currently available in the East Elm Street Dam impoundment. Recreational use upstream from East Elm Street results, in part, from ease of access for small boats to the impoundment, and its overall length of approximately 6.5 miles from the dam in Yarmouth to the upstream limit of the impoundment upstream from the State Route 9 Bridge in North Yarmouth. (While the upstream limit of the East Elm Street impoundment varies with flow, field observations and review of aerial photographs suggest that it extends approximately one-half to 1 mile upstream from the State Route 9 Bridge on the Royal River and to the vicinity of the North Road Bridge on Chandler Brook).

The Phase II study was designed to provide technical information to evaluate these topics.

1.1.7 Phase II Studies

Phase II of the RRRP is comprised of additional technical studies intended to address the three topics noted previously. The primary objectives of the Phase II technical studies are to evaluate potential impacts associated with removal of East Elm Street Dam. Potential impacts include:

1. Changes in hydraulic conditions in the Royal River between the East Elm Street Dam and the State Route 9 Bridge;

2. The volume and mobility of sediment in the Royal River between the East Elm Street Dam and the State Route 9 Bridge;

3. Potential impacts to Yarmouth Harbor from sediment in the Royal River between the East Elm Street Dam and the State Route 9 Bridge; and

4. Impacts to existing recreational use of the reach of the river between State Route 9 in North Yarmouth and the recreational boat launch adjacent to the Yarmouth Historical Society Building at 118 East Elm Street upstream from the East Elm Street Bridge and Dam.

2.0 PHASE II WORK

Phase II of the RRRP is comprised of specific technical studies following on previous project work. The Phase II studies were designed to comply with the project's budget constraints, and included: reviews of existing information regarding sediments in the harbor; topographic surveys to assist in development of a hydraulic model; sediment probing, sampling, and analysis in the East Elm street impoundment; a review of river hydrology; hydraulic modeling to determine potential post-removal water surface elevations and flow conditions; and a preliminary analysis of potential sediment remobilization issues. The following sections described the technical studies in more detail.

2.1 REVIEW OF EXISTING INFORMATION

This section describes information reviewed to date as part of this phase of the RRRP.

2.1.1 U.S. Army Corps of Engineers Dredge Plan for Yarmouth Harbor

The New England District (NAE) of the U.S. Army Corps of Engineers (Corps) is currently proposing to mechanically dredge areas in the tidally affected reach of the Royal River for maintenance of the Royal River Federal Navigation Project. The proposed dredge area encompasses a 6-ft (depth) anchorage area located at the head of the harbor near the Route I-295 Bridge, and the channel extends eastward approximately 3 miles to the confluence of the Royal River with Casco Bay near Parker Point. The project was previously dredged in 1995, but subsequent accumulations of sediment have adversely affected navigation in the harbor.

A report prepared for the Corps by Woods Hole Group, Inc. dated November 2010 (WHG 2010[4]) references a proposed dredge volume of 45,000 cubic yards (CY) of fine-grained material to be dredged as part of the proposed project. A project update from the Corps dated April 26, 2011, (Corps 2011[5]) lists a total dredge volume of 67,000 CY, including 44,000 CY from the anchorage and 23,000 CY from the channel. The project update from the Corps does not address the apparent discrepancy between the proposed dredge volumes described in WHG 2010 and Corps 2011.

Physical analyses of sediment samples collected from Yarmouth Harbor presented in WHG 2010 and Corps 2011 indicated that accumulated material in the channel and anchorage areas of the harbor is largely comprised of sand, with 20% to 33% silt and clay and 2% to 13% gravel and organic detritus. Chemical analyses identified several environmental contaminants with concentrations above reportable limits, including polycyclic aromatic hydrocarbons (PAHs) and metals. Physical parameter analyses included grain size determination and percent moisture

[4] Woods Hole Group. 2010. *Final Report Laboratory Testing in Support of Environmental Assessment, Sampling and Biological Testing, Royal River*. November 2010.
[5] Footnote to Corps 2011

measurements. Chemical parameter analyses included characterization of total organic carbon, polychlorinated biphenyls, chlorinated pesticides, PAHs, and metals.

2.2 SUPPLEMENTARY TOPOGRAPHIC SURVEY WORK

Supplementary topographic survey work was performed as part of the Phase II work, including surveys of the East Elm Street Bridge and the two upstream railroad bridges. The purpose of this work was to obtain information for use in the development of a hydraulic model as part of the Phase II work.

The topographic survey work was performed by Titcomb Associates of Falmouth, Maine, as a subcontractor to Stantec. In addition to the dedicated work performed as part of this phase of the RRRP, Titcomb Associates incorporated information obtained as part of the 2010 Phase I study to provide a consistent set of plans referenced to the same vertical and horizontal coordinate systems. The topographic survey work was rectified to the North American Vertical Datum of 1988 and projected on the North American Datum of 1983 (NAD83), Maine State Planes, West Zone, coordinate system in U.S. feet (ME83-WF). In addition to the noted survey work, the elevation of a benchmark at the State Route 9 Bridge was also obtained for determining reference water surface elevations (WSELs) at the upstream limit of the hydraulic model; this vertical reference may be used for measurement of water surface elevations at the State Route 9 Bridge.

Draft materials prepared by Titcomb Associates are included in Appendix A of this report.

2.3 SEDIMENT PROBING AND SAMPLING

Sediment probing and sampling was performed to provide information on the composition, volume, and quality of sediment in the reach of the Royal River between the State Route 9 Bridge and East Elm Street Dam. This information is needed to evaluate the potential for sediment remobilization that could impact Yarmouth harbor. The objective of this work was to 1) characterize sediment in the study reach of the Royal River, and 2) identify locations of fine-grained sediments for acquisition of sediment samples for laboratory analysis.

2.3.1 Sediment Probing

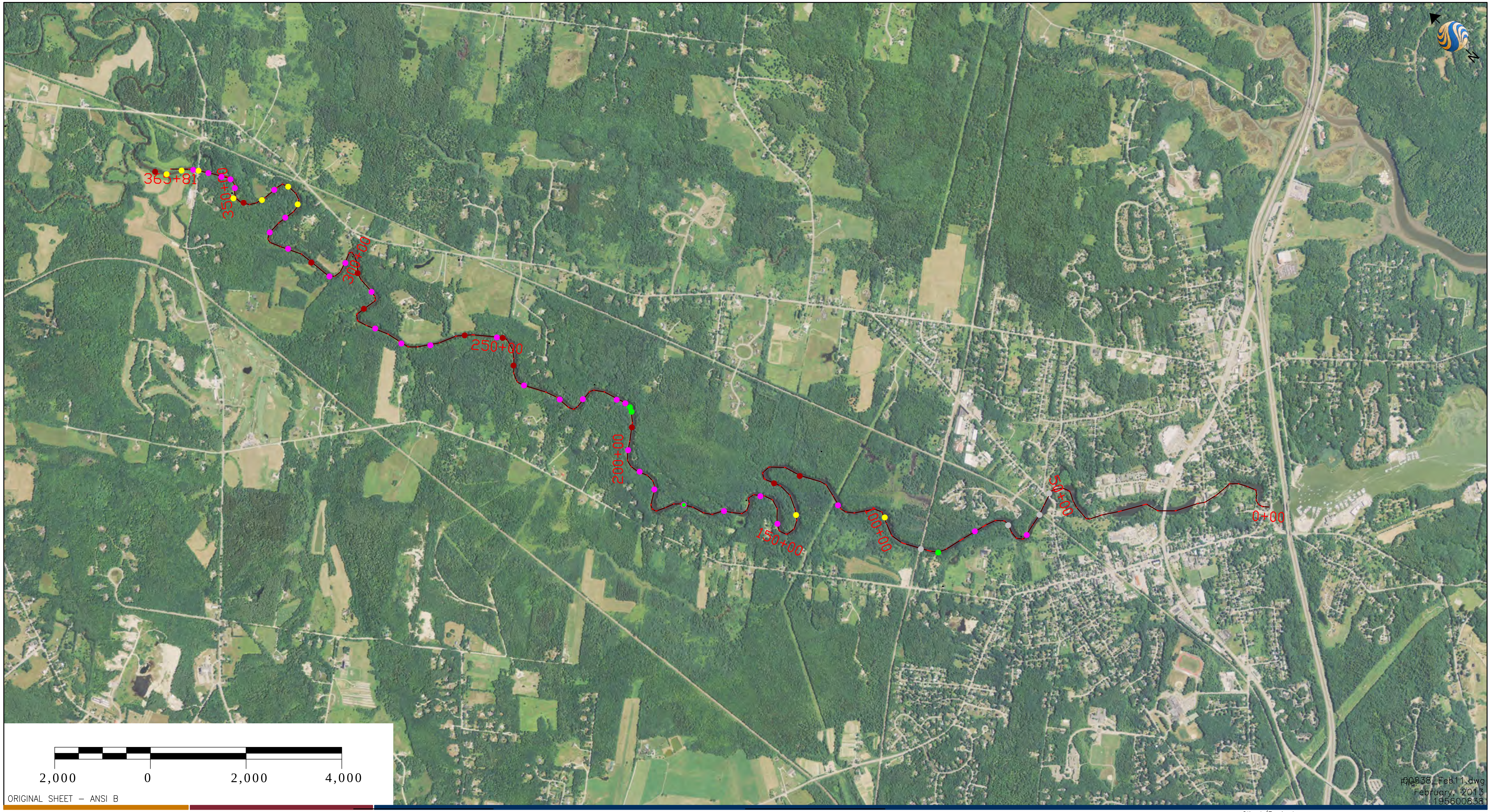
Sediment probing work was performed on November 27, 2012, using a small boat launched from the public landing on the Royal River immediately upstream from the State Route 9 Bridge. This work included manual probing of sediments and visual characterization of grab samples. This section presents a brief summary of information obtained as part of this work. Sediment probing was performed at regular intervals between East Elm Street Dam and the State Route 9 Bridge. Locations of selected probing locations were obtained using a GPC receiver and are depicted on Figure 2. Table 2 presents a summary of the sediment probing work; additional information describing the methods and results of this work are included in Appendix B.

The sediment probing work indicates that sand-size and smaller material are the dominant potentially mobile sediments in the reach of the Royal River between East Elm Street Dam and the State Route 9 Bridge in North Yarmouth. Identified areas of larger substrates, including gravel, cobble, and boulder-size material and bedrock, were limited to 1) the approximately one-quarter-mile reach of the river immediately upstream from East Elm Street Dam, and 2) in what appears to be installed armor material (riprap) in the vicinity of the Maine Central Railroad Bridge approximately three-quarters of a mile upstream from East Elm Street Dam.

Information obtained as part of the sediment probing work indicates that fine-grained (e.g., sand-size material and smaller), potentially mobile sediment are present in varying thicknesses, but are generally in excess of 1 ft thick in the Royal River between East Elm Street Dam and the State Route 9 Bridge. The maximum probed thickness of was approximately 4.5 ft.

Table 2: Sediment Probing Observations Upstream from East Elm Street Dam

Location (Station [Sta.])	Depth of Probing (ft)	Material
Sta. 54+00 (Dam) to Sta. 71+50	< 0.8	*Bedrock, sand, cobble, boulder*
Sta. 71+50 to Sta. 88+50	< 0.1	*Sand, gravel*
Sta. 88+50 to Sta. 150+00	0	*Bedrock, , cobble, boulder*
Sta. 150+00	< 4.5	*Soft clay, silt, some sand*
Sta. 150+00 to Sta. 211+00	< 1.1	*Very fine and medium sand, sand*
Sta. 211+00 to Sta. 213+50	0	*Gravel, cobble*
Sta. 213+50 to Sta. 241+00	< 1.6	*Very fine to medium sand*
Sta. 241+00 to Sta. 260+00	< 1.6	*Soft clay, silt, some sand*
Sta. 260+00 to Sta. 282+00	<1.0	*Fine to medium sand with silt*
Sta. 282+00 to Sta. 332+00	< 2.3	*Fine to medium sand with silt*
Sta. 332+00 to Sta. 352+00	< 2.7	*Soft clay, silt, some sand*
Sta. 352+00 to Sta. 361+00	< 1.0	*Fine to medium sand*
Sta. 361+00 to Sta. 370+00	< 0.4	*Silt, fine sand*
Sta. 370+00 to Chandler Brook	< 1.5	*Soft clay, silt*



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Legend

- COBBLE/BOULDER/BEDROCK
- GRAVEL
- CLAY
- SAND
- SILT

Notes

Client/Project

Town of Yarmouth
Royal River
Phase II Feasibility Study

Figure No.

2

Title

Sediment Probe Locus Map

2.3.2 Order-of-Magnitude Estimate of Potentially Mobile Sediment

An order-of-magnitude estimate of the volume of potentially mobile sediment was developed for the Royal River between East Elm Street Dam and the State Route 9 Bridge based on observations and probed sediment depths. This estimate was developed based on an average sediment thickness of 1 ft, a length of river of 30,000 ft, and a width of 100 ft, and is 110,000 CY. It is important to note that the thickness and volume of potentially mobile sediment in the project reach of the Royal River is highly variable; the estimates provided here are intended for comparison with other approximate values only, such as the total volume of accumulated sediment in Yarmouth Harbor.

2.4 SEDIMENT SAMPLING AND ANALYSIS

This phase of the RRRP included collection and visual observation and laboratory constituent analyses of five sediment samples from the study reach of the Royal River upstream from East Elm Street Dam. Sediments sample were collected in and downstream from the East Elm Street and Bridge Street dam impoundments as part of earlier project studies in 2010. The objective of the sampling as part of this phase of work was to obtain additional information on sediment quality in the study reach upstream from East Elm Street Dam.

Sediment sample were collected at locations were manual probing indicated presence of fine-grained sediments. Sediment sample collection was performed consistent with methods described in the sediment sampling plan that was prepared as part of previous project studies by Stantec. Information on the sediment sampling and results and evaluation of the laboratory chemical analyses to screen for contaminants of potential concern are presented in a separate report that is included as Appendix C of this report. The sediment sampling plan is also included in Appendix C.

Evaluation of the sediment sampling results using freshwater screening criteria suggests that there is little potential risk of adverse effects to freshwater aquatic life from sediment samples that were analyzed. Although there was an exceedence of the screening benchmark for DDD in one of the sediment samples, it is not expected to cause risk of harm to the ecological receptors at the reported concentration. Furthermore, it is expected that remobilization of accumulated sediment in the study reach of the Royal River upstream from East Elm Street Dam would result in mixing of sediments and associated dilution of contaminants that are present in the sediment.

2.4.1 Summary of Findings

Based on the results of the laboratory analysis of sediment sampled collected in the study reach of the Royal River and evaluated using freshwater screening criteria. Based on this comparison, there appears to be minimal potential risk of adverse effects to aquatic life in the Royal River based on the evaluated sediment samples. Although there was an exceedence of the screening benchmark for DDD in sediment sample EE-IMP1-SED, it is not expected to cause risk of harm to the ecological receptors at the reported concentration. If sediments were remobilized, it is expected that some mixing and associated dilution would occur, which could potentially reduce the COPC concentrations.

2.4.2 Freshwater and Marine Effects Criteria

The evaluated sediment samples were collected in freshwater areas of the Royal River upstream from East Elm Street Dam and were evaluated using freshwater sediment criteria. Freshwater sediment and marine sediment criteria for 10 polycyclic aromatic hydrocarbons (PAHs) and one pesticide metabolite (4,4'-DDD) that exceeded freshwater screening benchmarks. The marine sediment screening benchmarks for the 10 PAHs were the same or very similar to the freshwater screening benchmarks, and may therefore be considered to pose similar (minimal) potential risk in the marine environment. The average of the concentration of 4,4'-DDD (1.21 µg/kg) is less than the Threshold Effects Level criteria for marine sediment (1.22 µg/kg), and the maximum reported value for 4,4'-DDD (5.0 µg/kg) is less than the Probable Effects Level criteria for marine sediment (7.81 µg/kg).

2.5 HYDROLOGY

Understanding of flows in the Royal River, including seasonal and peak flows, is necessary to evaluate potential changes to river flows, changes in water surface elevations, and potential sediment remobilization resulting from dam removal. This information provides a basis for hydraulic modeling, and also provides information regarding the duration of flow conditions during fish migration periods (flow-duration statistics), a key element in determining the feasibility of fish passage in the study area.

2.5.1 Seasonal Flow Hydrologic Statistics

Desktop studies were performed to evaluate seasonal flows in the project reach of the Royal River. The objective of this work is to provide flow statistics for use in project hydraulic modeling and evaluation of geomorphic studies of the study reach.

Hydrologic parameters developed as part of this work and presented here include monthly mean and median flow statistics and synthetic flow-duration statistics during the target adult anadromous fish migrations in the spring. These hydrologic parameters were developed using data collected by the United States Geological Survey (USGS) Royal River gage (USGS 01060000 Royal River at Yarmouth, Maine). The Royal River gaging station was operated by the USGS from 1949 to 2004.

The analysis included a delineation of the Royal River watershed and the development of flow-duration statistics, including the lowest 7-day average flow that occurs on average once every 10 years (7Q10 low flow), annual mean and median flows, and monthly mean and median flows. The absence of a major tributary to the Royal River downstream from Bridge Street Dam but above the USGS gaging station, and the relative proximity of the Bridge Street Dam to the USGS gaging station, allowed direct calculation of hydrologic parameters using USGS gaging station data without need for data scaling for changes in discharge associated with inflowing tributaries. Annual flow statistics and monthly mean and median flow statistics are presented in Table 3 and Table 4, respectively.

Table 3: Annual Flow Statistics

7Q10 Low Flow (cfs)	Annual Mean Flow (cfs)	Annual Median Flow (cfs)
23	270	120

Table 4: Monthly Flow Statistics

Statistic	Month/Flow (cfs)											
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
Mean	223	232	550	732	316	183	91	76	86	145	304	305
Median	162	183	496	734	292	142	70	56	54	85	246	257

2.5.2 Upstream Fish Passage Flows

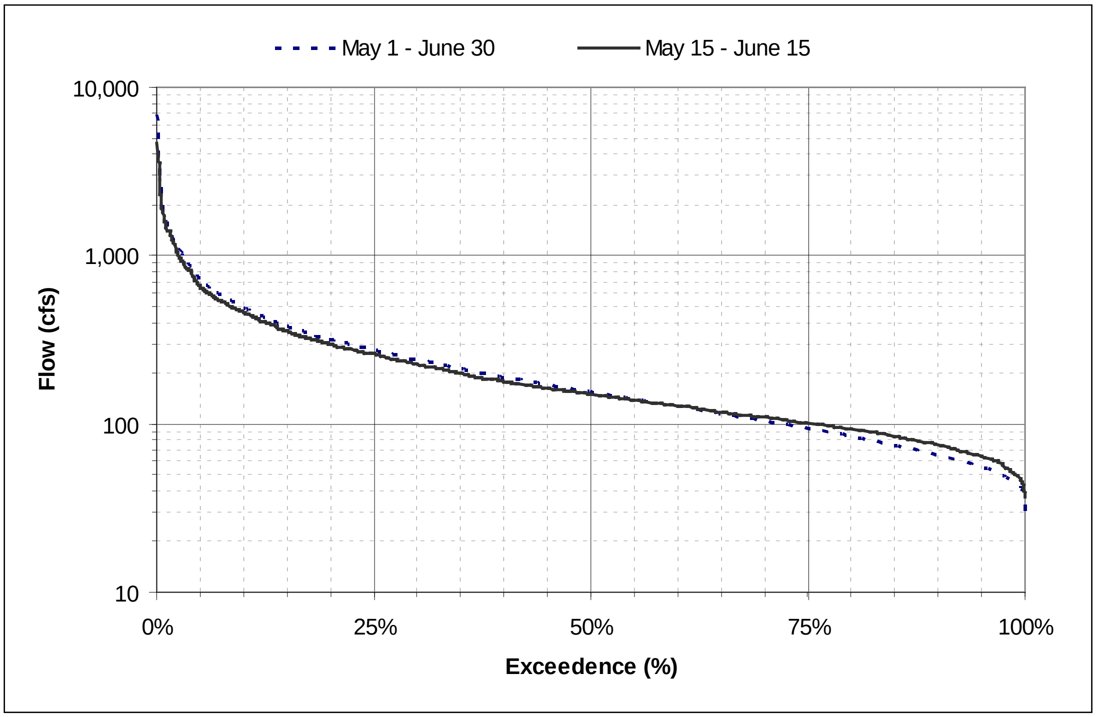
An important component of the RRRP is to provide for upstream fish passage in the Royal River. It is important to understand the flow conditions during seasonal migrations by target fish species. Although a detailed flow-duration analysis was not included in the Phase II study's scope of work, Stantec developed synthetic flow-duration statistics during the target adult anadromous fish migrations in the spring to assist in future studies of fish passage options.

Flow-duration statistics were developed for the target fish species using daily average flow data collected by the USGS gaging station for the period from October 1949 through September 2004. Flow duration statistics were developed using daily average flow data for two upstream fish migration "windows", including 1) May 15 – June 1, and 2) May 1 – June 30. The resulting flow-duration curves are shown in Figure 3. Extracted 10th, 25th, 50th (median), 75th, and 90th percentile exceedance flow statistics are presented in Table 5 and plotted in Figure 3. Overlapping fish migration windows are provided to account for potential year-to-year variation in the timing of upstream migration of anadromous fish, including alewife, in the Royal River.

Table 5: Flow-Duration Statistics for the Royal River

Exceedance Percentile (%)	May 15 – June 15 (cfs)	May 1 – June 30 (cfs)
10	461	489
25	260	276
50	149	154
75	101	94
90	76	65

Figure 3: Flow-Duration Curves during Target Fish Migration Periods



2.5.3 Peak Flow Hydrologic Statistics

Analyzing hydrologic information regarding peak flows is needed for developing hydraulic models for the river, and to assess potential post-removal scenario flow conditions and water surface elevations. It is also important to consider the recurrence interval (also called the "return interval"), which is the average number of years between flows of a certain size, as part of the hydraulic modeling process.

Peak flow statistics were calculated using measured peak flow data for USGS stream gaging Sta. 01060000, which was located on the Royal River in Yarmouth, Maine, immediately upstream from the head-of-tide. The period-of-record for peak flow data at this site was from 1950 through 2002. Statistical analyses of the peak flow data were performed using the USGS PeakFQWin Software (Version 5.2.0). The available data was evaluated for three ranges of the data set to provide insight regarding potential changes in peak flows associated with climate change. The three data ranges include 1) the period of record (1950 through 2002); 2) the period from 1950 through 1970; and 3) the period from 1970 through 2002.

Results of this analysis for eight events ranging from the 2-year to 500-year statistical return-interval storms are presented in Table 6. Figure 4 presents a plot of data depicted in Table 6.

The basis for using varying sources and methodologies to evaluated peak flows includes evidence of changing climactic conditions within New England since around 1970 (Collins, 2009)[6] and inherent uncertainty in the resulting statistics. This evaluation includes analysis and comparison of peak flows calculated using 1) the period of record (1950 through 2002); 2) the period from 1950 through 1970; and 3) the period from 1970 through 2002, and compares the results to determine whether the more recent period (1970 through 2002) results in increased flows for the evaluated return-interval events.

Results of this analysis for eight events ranging from the 2-year to 500-year statistical return-interval storms are presented in Table 6. Figure 4 presents a plot of data depicted in Table 6. The analysis method presented here suggests that return-interval-specific peak flows have occurred since 1970 relative to both the full data record and the period from 1950 to 1970. Comparison of peak flow statistics presented in Table 6 indicates that use of the period from 1970 through 2002 results in the highest calculated flows for a given return-interval event.

Table 6: Peak Flows

Return-Interval Event (years)	**Peak Flow (cfs)**		
	Full Record	1950 - 1970	1970 – 2002
1.5	3,038	2,913	3,226
2	3,699	3,396	3,928
5	5,485	4,646	5,910
10	6,775	5,515	7,411
25	8,519	6,659	9,530
50	9,900	7,546	11,270
100	11,350	8,461	13,160
200	12,880	9,414	15,210
500	15,030	10,740	18,200

Peak flow statistics developed using data from 1970 through 2002 is used for subsequent evaluations presented in this report. The basis for using statistics from this period follows is based on the premise that information presented in Collins 2009 is relevant to expected peak flows based on climate uncertainty.

[6] Collins, M.J. 2009. Evidence for changing flood risk in New England since the late 20th century. Journal of the American Water Resource Association 45: 1-12.

Figure 4: Peak Flow Hydrologic Statistics

2.6 GEOMORPHIC EVALUATION

A geomorphic evaluation of the study reach of the Royal River was performed as part of this study to provide insight on expected changes to the river between State Route 9 and East Elm Street Dam if the dam were removed. The practice of fluvial geomorphology encompasses the study of rivers and their form, including processes the move and deposit sediment and therefore affects the geometry of rivers. This study was performed by John Field, PhD of Field Geology Services (FGS).

Work performed as part of this evaluation included traversing the Royal River by canoe from Wescustogo Park where State Route 231 crosses the Royal River in North Yarmouth to the boat launch behind the Yarmouth Historical Society Building in Yarmouth. This site visit included observation of approximately 2 miles of the Royal River between Wescustogo Park and the State Route 9 Bridge and an excursion approximately one-quarter mile up Chandler Brook to where North Road passes over the brook.

Additional work performed by FGS included 1) review and analysis of historical topographic maps and aerial photographs, and 2) review of data and hydraulic model results obtained as part of this study.

A summary of the fluvial geomorphic evaluation is included in Section 4.4.

3.0 HYDRAULIC MODEL DEVELOPMENT

A hydraulic model was development of the project reach to evaluate changes in the flow regime, such as depth of water and flow speeds, associated with removal of East Elm Street Dam and Bridge Street Dam. Information obtained as part of this work is also useful for evaluation of sediment transport and recreational use of the river. The hydraulic model development and evaluations drew upon data collected in Phase I and Phase II, including bathymetric and topographic data, hydrologic information regarding flows, as well as physical characteristics of the river channel, overbank areas, and dam weirs. The results of the modeling are discussed in Section 4.2.

This section describes the setup of the one-dimensional numerical hydraulic model (hydraulic model) for use as part of this project, including development of the geometric domain, boundary conditions, and evaluation of the hydraulic model suitability for use in the project work. The hydraulic model extends from the small falls at the head-of-tide located immediately upstream from the State Route 88 Bridge in Yarmouth to the State Route 9 Bridge over the Royal River in North Yarmouth.

The hydraulic model was developed using the U.S Army Corps of Engineers Hydrologic Engineering Center – River Analysis System (HEC-RAS) software system (Version 4.1.0).

3.1 GEOMETRIC DOMAIN

The hydraulic model geometric domain is comprised of geometric cross-sections comprised of bathymetric and topographic data at regular locations along the project reach of the Royal River between the head-of-tide and the State Route 9 Bridge. In addition, the hydraulic model includes internal boundary conditions representing Bridge Street Dam and East Elm Street Dam. Data used in the development of the hydraulic model geometric domain includes information obtained from topographic and bathymetric survey work performed as part of this and previous RRRP studies, and existing LIDAR (Light Detection and Ranging) topographic data.

Data used to develop the geometric domain was rectified to the NAVD88 vertical datum and the ME83-WF coordinate system using AutoCAD Civil 3D 2011 software (AutoCAD). Cross-section and channel and overbank alignment and cross-section reach distances for the hydraulic model domain was subsequently generated for use by HEC-RAS using automated routines in AutoCAD. Internal boundary conditions representing the two dams and geometric information on the three bridges incorporated in the hydraulic model were subsequently added by manually editing the cross-section geometric data file exported from AutoCAD to HEC-RAS.

Brief descriptions of the information and professional judgment used in the development of the hydraulic model domain are presented here; additional information may be obtained by reviewing the hydraulic model.

3.1.1 Topographic Survey Data

Topographic survey data collected as part of previous RRRP studies and this study were used to develop specific components of the hydraulic model, including the spillway elevations and widths of the two project dams, the East Elm Street Bridge, and the St. Lawrence & Atlantic Railroad Bridge, and the Maine Central Railroad Bridge.

3.1.2 Bathymetric Survey Data

Bathymetric survey data collected as part of previous RRRP studies and this study were used to developed geometric cross-section information for regularly submerged areas of the Royal River. This data was collected using a boat-mounted acoustic depth sounder logging measured depths along with horizontal position information obtained using a Wide Area Augmentation System Global Positioning System receiver.

Bathymetric survey data was collected for this study perpendicular to the channel (“cross-sections”) at regular locations between East Elm Street Dam and the State Route 9 Bridge. Review of the bathymetric data indicates that there are relatively deep pools (depths greater than 20 ft) in the Royal River between the State Route 9 Bridge and East Elm Street Dam. The deep pools are located in bends in the river and apparently result from scour during high-flow events.

3.1.3 LIDAR Data

LIDAR-based contour line data at intervals of 2-ft were obtained from the Maine Geographic Information System (MGIS) website for the area between the head-of-tide on the Royal River and the State Route 9 Bridge in the vicinity of the upstream limit of the project reach of the river. Metadata for the LIDAR data obtained from MGIS indicates that the source of the LIDAR data is the USGS and that the data was published in 2012.

3.1.4 Other HEC-RAS Input Parameters

Other HEC-RAS input parameters required for the hydraulic model include channel roughness (Manning’s “n”) in channel and overbank areas, contraction and expansion coefficients, ineffective flow areas, and weir coefficients for the two dams.

Manning’s “n” values of 0.040 and 0.050 were assigned to the primary channel and overbank areas, respectively, of each cross section. Use of 0.040 for the primary channels is greater than a “typical” value of 0.035, but is considered to be appropriate due to the sinuosity of the project reach of the Royal River. Similarly, the applied value of 0.050 for the overbanks is considered to be appropriate based on the densely vegetated overbank areas.

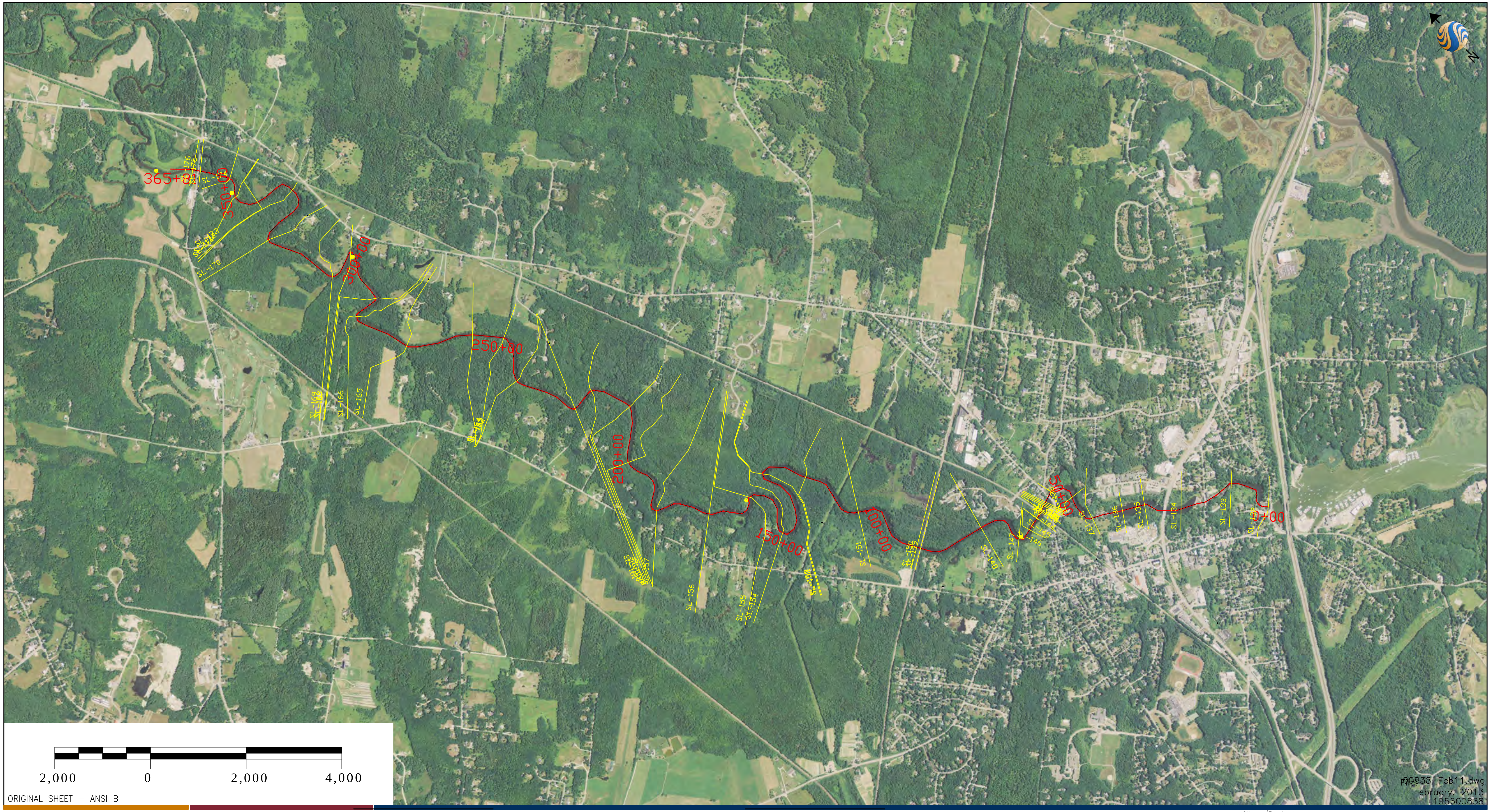
Contraction and expansion coefficients were set at 0.1 and 0.3, respectively, except in the vicinity of bridges where these coefficients were increased to 0.2 and 0.4, respectively.

Ineffective flow areas were used to limit flow in overbank areas and immediately adjacent to bridges to reflect areas where downstream conveyance is not expected based on guidance presented in the HEC-RAS documentation and professional judgment.

Weir coefficients representing the spillways of the East Elm Street and Bridge Street dams were selected based on guidance presented in the HEC-RAS documentation and professional judgment.

3.1.5 HEC-RAS Model Layout

Figure 5 depicts the alignment (in red) and cross-section locations of the project HEC-RAS hydraulic model.



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Legend

Notes

Client/Project
Town of Yarmouth
Royal River
Phase II Feasibility Study

Figure No.
5

Title
HECRAS Model Alignment & Section Locus Map

3.2 EXTERNAL BOUNDARY CONDITIONS

External boundary conditions were applied at the upstream and downstream limits of the hydraulic model.

3.2.1 Downstream Boundary Condition

The downstream boundary condition was set to use a normal depth slope of 0.01. Use of this relatively steep slope is considered to be reasonable as the downstream end of the model is located at the site of a former dam immediately upstream from the State Route 88 Bridge. The relatively steep reach of the Royal River downstream from the Bridge Street Dam results in little sensitivity of the hydraulic model results at the Bridge Street Dam from the applied downstream boundary condition. The presence of Bridge Street Dam and Middle Falls result in no sensitivity of the hydraulic model results upstream from Middle Falls.

3.2.2 Upstream Boundary Conditions

Upstream boundary conditions were established based on hydrologic inputs (flows) with an applied normal depth slope of 0.002 to allow for execution of the model in a mixed (subcritical and supercritical) flow regimes. Hydrologic inputs were developed from the project hydrology and include a range of flow events including calculated seasonal and peak flow parameters.

3.3 EVALUATION OF MODEL SUITABILITY

This section describes calibration and sensitivity analyses of the hydraulic model.

3.3.1 Calibration and Validation

Existing information suitable for calibration and validation of the hydraulic model is limited to previous model studies, including the existing Federal Emergency Management Agency (FEMA) model of part of the project reach and hydraulic model studies performed by Sebago Technics, Inc. (STI) in 2010.

The current FEMA Flood Insurance Rate Maps (FIRMs) (Community-Panel Numbers 230055 0001-0012, Effective Date November 15, 1984) were developed using the U.S. Army Corps of Engineers HEC-2 numerical model and are referenced to the National Geodetic Vertical Datum of 1929 (NGVD29)[7]. The project reach of the Royal River is depicted on FIRM Panel No. 0005 B, which depicts an area of detailed study that extends from the head of tide landward from the Interstate 295 Bridges to approximately 1 mile upstream from the East Elm Street Dam. While the existing FEMA model does not include the entire project reach, it does include major features of the project reach, including the two project dams and the three bridges upstream from East Elm Street Dam.

[7] NAVD88-NGVD29 is approximately equivalent to -0.66 ft in the vicinity of Yarmouth, Maine.

A draft (not dated) copy of the updated FEMA FIRM Panel 0541 was obtained from the Town of Yarmouth and reviewed as part of this study (Appendix E). This FIRM depicts the reach of the Royal River from approximately one-quarter mile upstream from the East Elm Street Bridge and downstream into Yarmouth Harbor. Supporting information, such as a FEMA Flood Insurance Study (FIS), were not obtained for review as part of this study, but the most apparent change in the draft FIRM is use of LiDAR data for mapping the lateral extents of the floodplain. Review of the updated (draft) FIRM panel suggests that the cross-section locations were not updated, and it is suspected that the same geometric cross-section information used for the current FEMA FIRM was used to develop the draft FEMA FIRM. The draft FEMA FIRM is rectified to the NAVD88 vertical datum and depicts a water surface elevation (WSEL) of 76 ft immediately upstream from the East Elm Street Bridge and 77 ft upstream from the St. Lawrence & Atlantic Railroad Bridge. Neither the effective or future FEMA FIS is available from the FEMA Map Service Center website.

The STI study was performed for the Yarmouth Historical Society in 2010 for the purpose of better establishing base flood elevations in the vicinity of the Yarmouth Historical Society building, which is located on the site of the former Yarmouth Water Department along East Elm Street upstream from the East Elm Street Bridge. This study was performed using the HEC-RAS software, existing geometric information obtained from the FEMA HEC-2 model, dedicated topographic survey data of adjacent features, and an updated hydrologic analysis of peak flows. Results of the hydraulic modeling performed by STI and from bounding cross-sections located upstream and downstream from the approximate location of the Yarmouth Historical Society Building hydraulic model developed for this project are presented in Table 7.

Table 7: STI Data and Results at the Yarmouth Historical Society Building

		WSELs (ft, NAVD88)		
Event	Flow (cfs)	Sebago Technics	Project Model (upstream)	Project Model (downstream)
100-Year	12,040	77.2	77.8	77.2
500-Year	15,660	79.0	79.5	78.8

The difference in the calculated 100-year return-interval peak flow calculated by Stantec as part of this study (13,160 cfs [see Table 6]) and the corresponding value calculated by STI (12,040 cfs [Table 7]) reflect the use of different methodologies for calculation of peak flows.

The calculated WSELs obtained from the project hydraulic model are similar to the results obtained by Sebago Technics and may be considered as general validation of the project hydraulic model results in this area. The applied internal boundary condition represented by East Elm Street Dam and the model representative of the East Elm Street Bridge result in the hydraulic model being very sensitive to input parameters in this reach, however.

Comparison of the hydraulic model results with information presented on the FEMA FIRM maps may be useful for general comparison of the project hydraulic model results. A notable variation between results from the project hydraulic model and information presented on FEMA FIRM FIRM Panel No. 0005 is in the vicinity of the Maine Central Railroad Bridge crossing approximately three-quarters of a mile upstream from East Elm Street Dam. The referenced FIRM panel depicts a difference in the hydraulic head from the upstream and downstream from the bridge for the Base Flood Elevation (BFE) of approximately 2 ft, whereas the project hydraulic model indicates a change in WSELs of less than 1 ft for both the 100-year and 500-year return-interval events. The input geometry of the project hydraulic model was reviewed along with model results, including calculated flow speeds through the bridge opening; based on this information, it appears that the project hydraulic model presents a more reasonable evaluation of peak flow conditions at the Maine Central Railroad Bridge.

3.3.2 Sensitivity Analyses

Sensitivity analyses were performed to evaluate the hydraulic model response to parameters and geometry conditions including 1) variation in the channel Manning's "n" value for existing conditions; and 2) conditions representing removal of East Elm Street Dam with and without East Elm Street Bridge. The basis for varying Manning's "n" is to evaluate the hydraulic model response to this input parameter. The basis for evaluating removal of East Elm Street Dam with and without the East Elm Street Bridge is to evaluate the model sensitivity to the bridge given that the model results indicate that it is a hydraulic restriction at high flows.

3.3.2.1 Variation in Channel Manning's "n" Value

This sensitivity analysis was performed by varying the input Manning's "n" value in the channel of each cross-section. This sensitivity analysis compares hydraulic model results with the selected Manning's "n" value of 0.040 and (HEC-RAS Plan Title "With Dams") against model results with applied values of 0.030 and 0.050 (HEC-RAS Plan Titles "Sen_mN03" and "Sen_mN05", respectively). This analysis was performed for flows from the 1.5-year to the 500-year return-interval events; results for calculated WSELs at the most upstream cross-section in the hydraulic model for the 1.5-year and 100-year return-interval events are presented in Table 8.

Table 8: Model Sensitivity to Manning's "n"

		WSEL (ft NAVD88)	
River Sta	HEC-RAS Plan	*1.5-Year*	*100-Year*
36113.02	"WithDams"	75.50	84.38
36113.02	"Sen_mN03"	74.88	83.18
36113.02	"Sen_mN05"	76.15	85.40

The hydraulic model sensitivity to Manning's "n" increases with increasing flows; and results in differences in calculated WSELs at the upstream limit of the hydraulic model domain (River Sta. 36113.02) of 1.27 and 2.22 ft, respectively, for the 1.5-year and 100-year return-interval events.

3.3.2.2 East Elm Street Bridge

The hydraulic model results indicate that East Elm Street Bridge restricts flow during high-flow events. A sensitivity analysis was performed to evaluate the effects of the bridge on hydraulic conditions in the vicinity of East Elm Street Dam. This sensitivity analysis was performed with East Elm Street Dam removed from the hydraulic model domain, with and without East Elm Street Bridge in the hydraulic model.

Table 9 presents calculated WSELs immediately upstream from the St. Lawrence & Atlantic Railroad Bridge upstream from East Elm Street Bridge for the 1.5-year and 100-year return-interval events for geometric conditions representing removal of East Elm Street Dam with and without East Elm Street Bridge. This information indicates that WSELs in this reach of the Royal River are affected by the hydraulic restriction imposed by East Elm Street Bridge, and that the magnitude of the restriction increases with increasing flow. This information may be used to evaluate potential effects associated with future replacement of the East Elm Street Bridge with a structure with a larger hydraulic opening if East Elm Street Dam were removed.

Table 9: Model Sensitivity to East Elm Street Bridge - Upstream from the St. Lawrence & Atlantic Railroad Bridge

River Sta	HEC-RAS Plan	WSEL (ft NAVD88)	
		1.5-Year	*100-Year*
6062.35	“WithOutDamsPeak”	70.42	78.19
6062.35	“NoEESB”	70.34	77.12
6062.35	**Difference**	**0.08**	**1.07**

Table 10 presents calculated WSELs at the upstream limit of the hydraulic model domain for the geometric conditions and flows described previously and presented in Table 9.

Table 10: Model Sensitivity to East Elm Street Bridge – Upstream Limit of Hydraulic Model Domain

River Sta	HEC-RAS Plan	WSEL (ft NAVD88)	
		1.5-Year	*100-Year*
36113.02	“WithOutDamsPeak”	73.87	84.20
36113.02	“NoEESB”	73.84	83.97
36113.02	**Difference**	**0.03**	**0.23**

4.0 ANALYSES AND RESULTS

This section presents analyses and results developed using the project hydraulic model and other information obtained as part of Phase II of the RRRP.

4.1 HYDRAULIC MODEL ANALYSES

This section presents a description of the hydraulic model setup and analyses that were performed using the project hydraulic model.

4.1.1 HEC-RAS Model Setup

This section presents information regarding the HEC-RAS model files and setup. Files used for analyses that are presented in this section of the report include those used for evaluation of existing conditions and conditions representing removal of Bridge Street and East Elm Street dams. Files referenced previously in this report that were used for evaluation of the hydraulic model suitability are referenced in the following tables but are “grayed-out.”

Geometry files for the HEC-RAS model were developed for multiple project uses, including simulating geometric conditions associated with existing conditions and with the Bridge Street and East Elm Street Dams removed and evaluation of model suitability.

Flow files include hydrologic flows and boundary conditions for paring with HEC-RAS geometry files for steady-state hydraulic simulations. The primary flow files are those representing peak flows and base flows in the project reach of the Royal River. Secondary flow files included below include peak flow as developed by STI and a “continuous” flow file that includes flows from 1,000 cfs to 20,000 cfs in increments of 1,000 cfs. The continuous flow file was used to gain insight into the hydraulic model response during evaluation of the HEC-RAS model and information for plotting of hydrographs at cross-sections.

HEC-RAS “plan” files represent pairs of geometric and flow files for use in steady-state hydraulic simulations in HEC-RAS. Table 11 includes four primary flow files that were used for simulation of existing conditions and with the Bridge Street and East Elm Street dams removed. Other plan files described in Table 11 were used to evaluate model sensitivity and to gain insight into the hydraulic model response during evaluation of the HEC-RAS model. The “HEC-RAS Plan Short ID” names given in this table can be cross-referenced with the “Plan” references on subsequent figures and tables to identify model simulations for existing and “dam removal” conditions.

Reference Appendix F for additional information on the HEC-RAS model setup.

Table 11: HEC-RAS Plan Files

HEC-RAS Plan File	HEC-RAS Plan Short ID	Geometry File	Flow File
WithDamsPeak (*.p11)	WithDamsPeak	RR_WithDams	RR_PeakFlow
WithDamsBase (*.p12)	WithDamsBase	RR_WithDams	RR_BaseFlow
WithOutDamsPeak (*.p13)	WithOutDamsPeak	RR_WithOutDams	RR_PeakFlow
WithOutDamsBase (*.p14)	WithOutDamsBase	RR_WithOutDams	RR_BaseFlow
Validation* (*.p10)	SebagoVal	RR_WithDams	RRLowSebago*
Sen_nM03 (*.p05)	Sen_mN03	RR_WithDamsmN03	RR_PeakFlow
Sen_nM03 (*.p04)	Sen_mN05	RR_WithDamsmN05	RR_PeakFlow
DamsContinuous (*.p09)	DamsC	RR_WithDams	RRFlowCont*
NoDamsContinuous (*.p08)	NoDamsC	RR_WithDamsOut	RRFlowCont*

"*" – a "wildcard" indicating other information and/or a continuation of a title or filename.

4.2 HYDRAULIC MODEL RESULTS

This section presents hydraulic model results for existing conditions and with the Bridge Street and East Elm Street dams removed. Information presented here is intended to provide readers with a general understanding of the hydraulic model results in lieu of an exhaustive presentation and explanation of results. The emphasis of the information presented here is on the reach of the Royal River upstream from East Elm Street Dam.

The hydraulic model results are presented in various formats, including profile and cross-section plots and in tabular formats. Cross-section locations and tabular data reference locations range from 13.42 to 36113.02; these numbers correspond to the distance in feet along the center of the Royal River from the downstream end of the model at the head-of-tide to the upstream end of the hydraulic model in the vicinity of the State Route 9 Bridge in North Yarmouth, and correspond to the independent ("x") axis on the profile plots. By way of explanation, dividing 36113 by 5280 (which equals 6.3) results in the approximate distance in miles from the head-of-tide to the State Route 9 Bridge.

4.2.1 Interpretation of Water Surface Information

WSELs represent a readily identifiable reference for changes in a river that may result from dam removal. This section presents simulated WSELs based on hydraulic model results for existing conditions and with the Bridge Street and East Elm Street dams removed.

This section provides a brief description of WSEL results from the hydraulic model simulations. The purpose of this section is to provide readers an introduction to the interpretation of results that are presented subsequently in this report. The information presented here is similar to the presentation of other information obtained from the hydraulic model simulations, such as calculated flow speeds ("velocity") and shear stress.

Figure 6 presents calculated WSELs in the vicinity of East Elm Street Dam, East Elm Street Bridge, and the St. Lawrence & Atlantic Railroad Bridge with and without East Elm Street Dam at the median annual flow in the project reach of the Royal River of 120 cfs. The blue line in this figure represents existing conditions, and the red line represents simulated conditions with East Elm Street Dam removed. The calculated WSEL immediately upstream from the dam is 71.0 ft with the dam in place (e.g., existing conditions), and 58.8 ft with the dam removed, resulting in a change in the WSEL of 12.2 ft immediately upstream from the dam. In the approximate vicinity of the Yarmouth Historical Society building between the East Elm Street Bridge and the St. Lawrence & Atlantic Railroad Bridge, the calculated WSEL is approximately 65.4 ft due to bedrock outcroppings and boulders in the river, and results in a difference in the calculated WSEL of approximately 5.6 ft. In addition to proving information on changes in WSELs, information depicted in Figure 6 also suggests that removal of Bridge Street Dam would result in rapids in this reach of the river.

Figure 6: East Elm Street Dam Impoundment (Median Annual Flow [flow is from right to left])

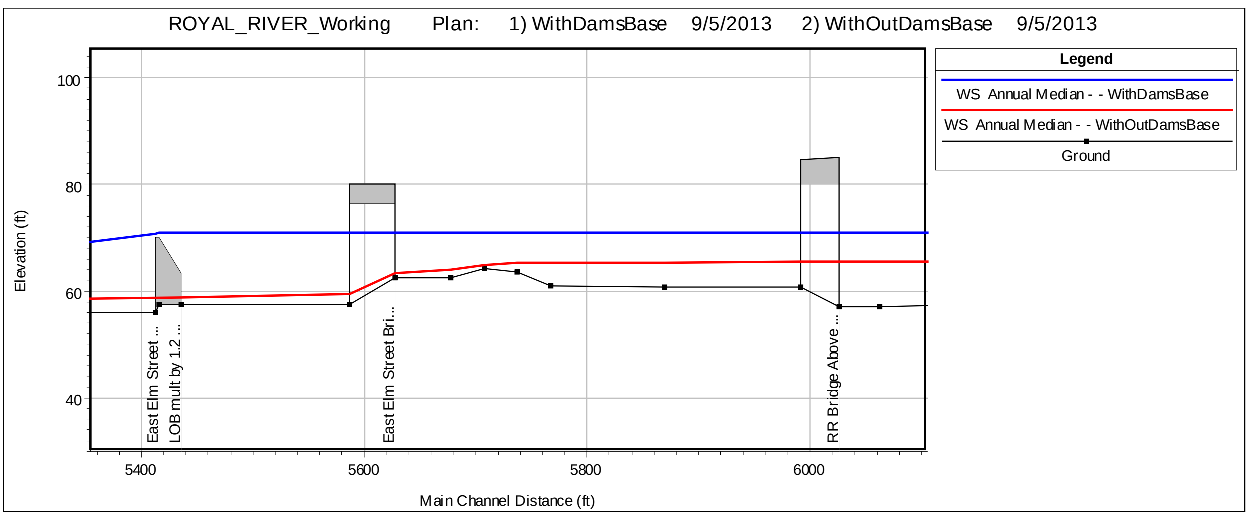


Figure 7 depicts the hydraulic model cross-section at Sta. 5869.48, which is located between the East Elm Street Bridge and the St. Lawrence & Atlantic Railroad Bridge, and includes the simulated WSELs for the median annual flow with and without East Elm Street Dam based on an observer facing downstream

Figure 7: Cross-Section Between East Elm Street Bridge and St. Lawrence & Atlantic Railroad Bridge

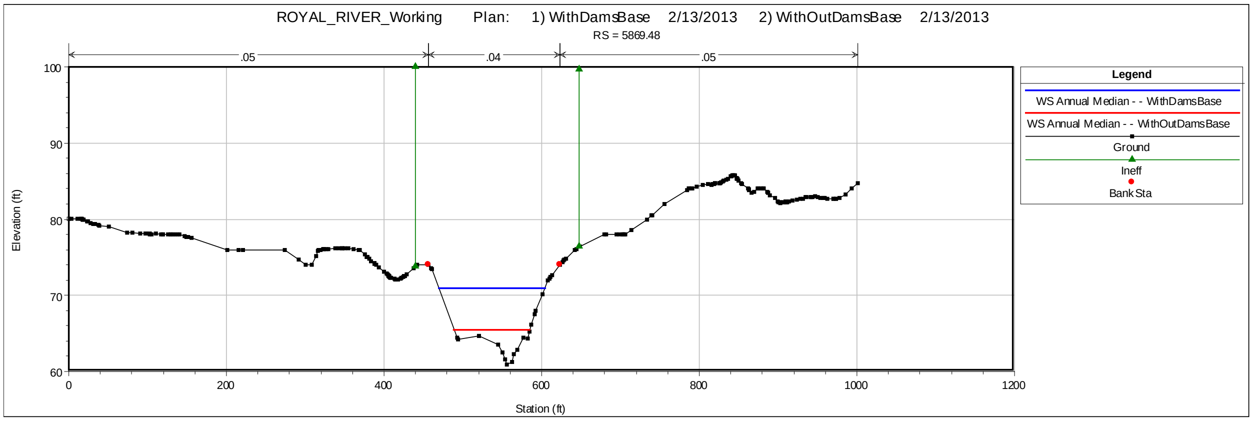


Table 12 presents tabular results for the WSELs presented in Figure 7.

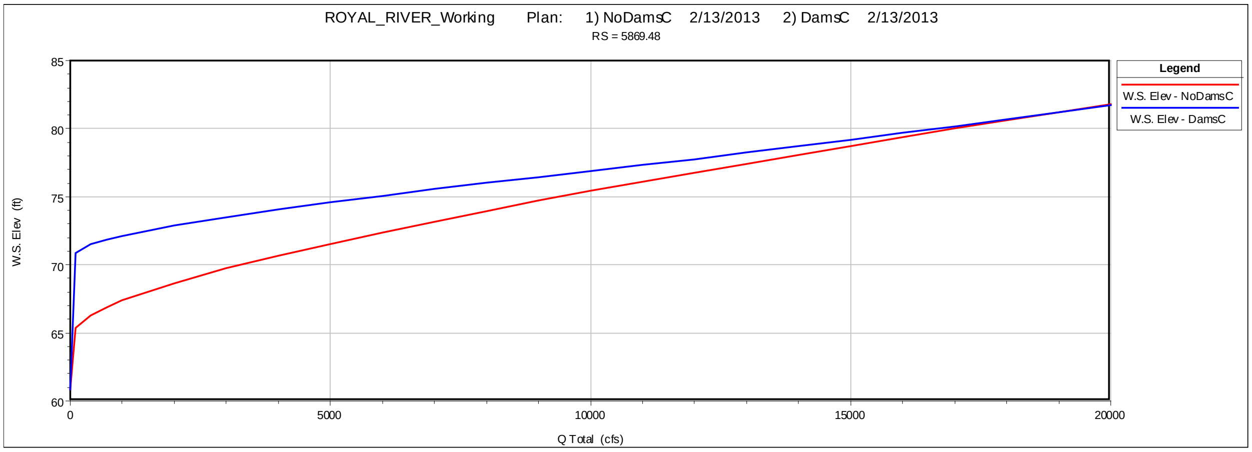
Table 12: Simulated Water Surface Elevations at Sta. 5869.48 for Median Annual Flow

River Sta	Profile	HEC-RAS Plan Short ID	Flow (cfs)	WSEL (ft)
5869.48	Annual Median	WithDamsBase	120	70.96
5869.48	Annual Median	WithOutDamsBase	120	65.43

Again, these results indicate a difference in calculated WSELs of about 5.6 ft at median annual flows of 120 cfs in the area between the East Elm Street Bridge and the St. Lawrence & Atlantic Railroad Bridge

Figure 8 is a plot of calculated WSELs over a range of flows from 100 cfs to 20,000 cfs at Sta. 5869.48. This figure demonstrates that the difference in WSELs at this station for existing and dam removal conditions diminishes with increasing flow. Simply stated at higher flows there would be less of a difference in WSELs between the two scenarios (dam, no dam) as flows increase in the river.

Figure 8: Modeled State-Discharge Relation Between East Elm Street Bridge and St. Lawrence & Atlantic Railroad Bridge



4.2.2 Royal River Upstream From East Elm Street Dam

Figure 9 presents the calculated water surface profiles in the reach of the Royal River upstream from the location of the East Elm Street Bridge to the upstream limit of the hydraulic model in the vicinity of the State Route 9 Bridge. This figure depicts the calculated water surface profiles for the median annual flow of 120 cfs, and reflects a difference in WSELs of approximately 5 ft. Note that the calculated water surfaces show little variation between the St. Lawrence & Atlantic Railroad Bridge upstream from East Elm Street Bridge and the upstream limit of the hydraulic model near the State Route 9 Bridge.

Figure 9: Water Surface Profiles Upstream from East Elm Street Bridge for Median Annual Flow (flow is from right to left)

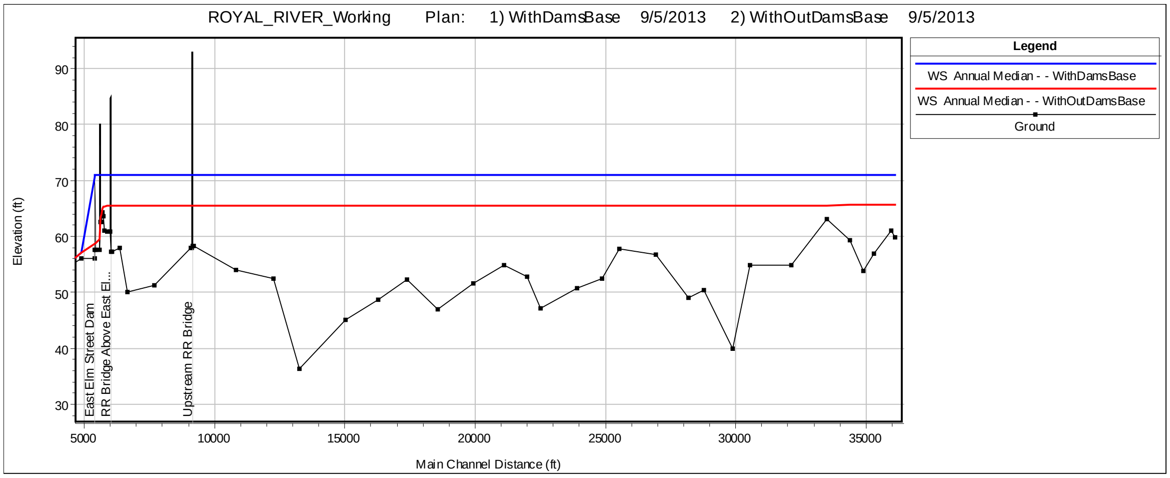


Figure 10 presents the calculated water surface profiles in the reach of the Royal River upstream from the location of the East Elm Street Bridge to the upstream limit of the hydraulic model in the vicinity of the State Route 9 Bridge during the median July flow of 70 cfs. Information on this figure shows that removal of the dam would result in a lowering of the water surface by approximately 5 ft, which is similar to the difference for the mean annual flow.

Figure 10: Water Surface Profiles Upstream from East Elm Street Bridge for Median July Flow (flow is from right to left)

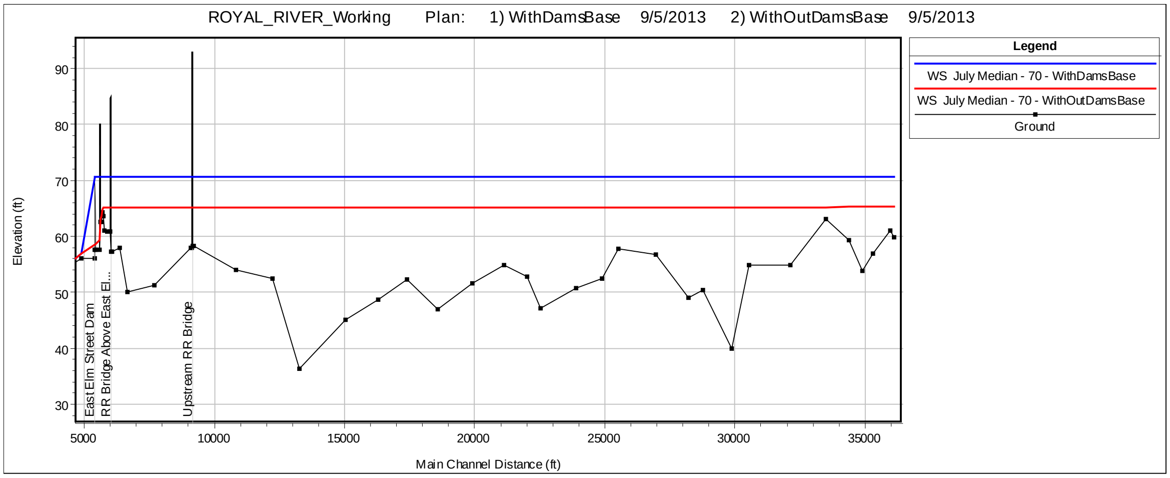


Figure 11 presents the calculated water surface profiles in the reach of the Royal River upstream from the location of the East Elm Street Bridge to the upstream limit of the hydraulic model in the vicinity of the State Route 9 Bridge for the 100-year flow ("flood") of 13,160 cfs. Of note is that there is little difference in the calculated WSELs upstream from the St. Lawrence and Atlantic Railroad Bridge during this high high-flow event.

Figure 11: Water Surface Profiles Upstream from East Elm Street Bridge for 100-Year Flow

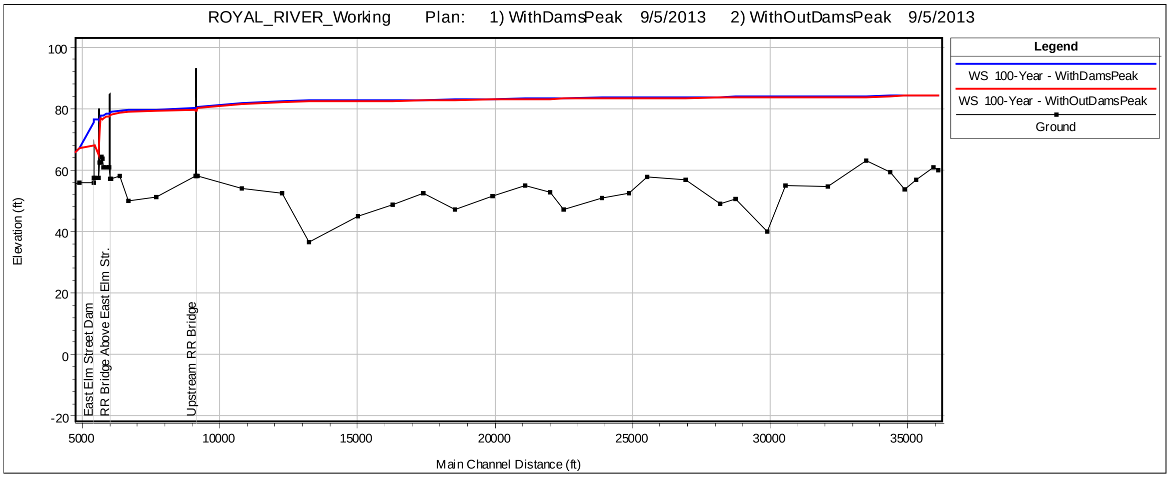


Table 13 and Table 14 present calculated WSELs and channel flow speeds and differences (dam removed – existing conditions) for selected locations in the hydraulic model domain for selected peak and seasonal flows, respectively. The locations in each table are given progressing downstream from the upstream end of the hydraulic model domain.

The data shown in Table 13 indicate that during peak flow conditions, the differences in calculated WSELs are minimal for higher flow events and in all cases diminish upstream from the dam.

Table 13: Peak Flow Water Surface Elevation and Flow Speed and Differences – Selected Locations

River Sta	Profile	Plan	Flow (cfs)	WSEL (ft)	Difference (ft)	Speed (ft/s)	Difference (ft/s)
36113.02	1.5-Year	WithDamsPeak	3226	75.5		0.69	
36113.02	1.5-Year	WithOutDamsPeak	3226	73.87	-1.63	0.84	0.15
36113.02	10-Year	WithDamsPeak	7411	80.05		1.07	
36113.02	10-Year	WithOutDamsPeak	7411	79.39	-0.66	1.12	0.05
36113.02	100-Year	WithDamsPeak	13160	84.38		1.42	
36113.02	100-Year	WithOutDamsPeak	13160	84.2	-0.18	1.44	0.02
21109.87	1.5-Year	WithDamsPeak	3226	74.95		1.54	
21109.87	1.5-Year	WithOutDamsPeak	3226	72.81	-2.14	1.9	0.36
21109.87	10-Year	WithDamsPeak	7411	79.15		2.52	
21109.87	10-Year	WithOutDamsPeak	7411	78.3	-0.85	2.68	0.16
21109.87	100-Year	WithDamsPeak	13160	83.19		3.43	
21109.87	100-Year	WithOutDamsPeak	13160	82.95	-0.24	3.48	0.05
Location below is at the Maine Central Railroad Bridge near Sligo Road.							
9188.77	1.5-Year	WithDamsPeak	3226	74.09		2.9	
9188.77	1.5-Year	WithOutDamsPeak	3226	71.23	-2.86	3.95	1.05
9188.77	10-Year	WithDamsPeak	7411	77.07		5.14	
9188.77	10-Year	WithOutDamsPeak	7411	75.63	-1.44	5.78	0.64
9188.77	100-Year	WithDamsPeak	13160	80.52		7.21	
9188.77	100-Year	WithOutDamsPeak	13160	80.07	-0.45	7.41	0.2
6062.35	1.5-Year	WithDamsPeak	3226	73.75		2.26	
6062.35	1.5-Year	WithOutDamsPeak	3226	70.42	-3.33	3.36	1.1
6062.35	10-Year	WithDamsPeak	7411	76.05		4.18	
6062.35	10-Year	WithOutDamsPeak	7411	74.13	-1.92	5	0.82
6062.35	100-Year	WithDamsPeak	13160	78.88		5.96	
6062.35	100-Year	WithOutDamsPeak	13160	78.19	-0.69	6.27	0.31
5869.48	1.5-Year	WithDamsPeak	3226	73.64		2.7	
5869.48	1.5-Year	WithOutDamsPeak	3226	69.94	-3.7	4.82	2.12
5869.48	10-Year	WithDamsPeak	7411	75.74		4.76	
5869.48	10-Year	WithOutDamsPeak	7411	73.5	-2.24	6.31	1.55
5869.48	100-Year	WithDamsPeak	13160	78.35		6.47	
5869.48	100-Year	WithOutDamsPeak	13160	77.54	-0.81	6.99	0.52

The data shown in Table 14 indicate that during seasonal flow conditions, the differences in calculated WSELs are fairly consistent upstream from the dam to Route 9, and reflect a difference of just over 5 ft in WSEL.

Table 14: Seasonal Flow Water Surface Elevation and Flow Speed and Differences – Selected Locations

River Sta	Profile	Plan	Flow (cfs)	WSEL (ft)	Difference (ft)	Speed (ft/s)	Difference (ft/s)
36113.02	Annual Med.	WithDamsBase	120	70.97		0.05	
36113.02	Annual Med.	WithOutDamsBase	120	65.63	-5.34	0.47	0.42
36113.02	June Median	WithDamsBase	142	71.08		0.06	
36113.02	June Median	WithOutDamsBase	142	65.77	-5.31	0.5	0.44
36113.02	July Median	WithDamsBase	70	70.68		0.03	
36113.02	July Median	WithOutDamsBase	70	65.29	-5.39	0.32	0.29
21109.87	Annual Med.	WithDamsBase	120	70.96		0.09	
21109.87	Annual Med.	WithOutDamsBase	120	65.49	-5.47	0.21	0.12
21109.87	June Median	WithDamsBase	142	71.07		0.1	
21109.87	June Median	WithOutDamsBase	142	65.59	-5.48	0.25	0.15
21109.87	July Median	WithDamsBase	70	70.68		0.05	
21109.87	July Median	WithOutDamsBase	70	65.23	-5.45	0.13	0.08
Location below is at the Maine Central Railroad Bridge near Sligo Road.							
9188.77	Annual Med.	WithDamsBase	120	70.96		0.15	
9188.77	Annual Med.	WithOutDamsBase	120	65.47	-5.49	0.34	0.19
9188.77	June Median	WithDamsBase	142	71.07		0.18	
9188.77	June Median	WithOutDamsBase	142	65.57	-5.5	0.39	0.21
9188.77	July Median	WithDamsBase	70	70.67		0.09	
9188.77	July Median	WithOutDamsBase	70	65.22	-5.45	0.21	0.12
6062.35	Annual Med.	WithDamsBase	120	70.96		0.12	
6062.35	Annual Med.	WithOutDamsBase	120	65.46	-5.5	0.25	0.13
6062.35	June Median	WithDamsBase	142	71.07		0.14	
6062.35	June Median	WithOutDamsBase	142	65.56	-5.51	0.29	0.15
6062.35	July Median	WithDamsBase	70	70.67		0.07	
6062.35	July Median	WithOutDamsBase	70	65.22	-5.45	0.15	0.08
5869.48	Annual Med.	WithDamsBase	120	70.96		0.15	
5869.48	Annual Med.	WithOutDamsBase	120	65.43	-5.53	0.71	0.56
5869.48	June Median	WithDamsBase	142	71.07		0.17	
5869.48	June Median	WithOutDamsBase	142	65.52	-5.55	0.8	0.63
5869.48	July Median	WithDamsBase	70	70.67		0.09	
5869.48	July Median	WithOutDamsBase	70	65.2	-5.47	0.48	0.39

4.3 MOBILIZATION OF RIVERINE SEDIMENT

This section presents an evaluation of potential mobilization of sediment in the reach of the Royal River between East Elm Street Dam and the State Route 9 Bridge. This evaluation is based on observed sediments characteristics during the sediment probing work, general critical shear stress criteria for fine material, and calculated shear stresses for existing conditions and with East Elm Street Dam removed.

The potential for mobilizing accumulated sediment is influenced by several factors, including the sediment grain size and the shear stress created by the flow acting on the riverbed material. *Shear stress* acts in the direction of the water flow as it moves along the channel bed and riverbanks. *Critical shear stress* is the shear stress required to mobilize sediments in the river channel. The ability to calculate or measure both shear and critical shear stress is crucial in understanding sediment transport.

4.3.1 Sediment Grain Size Analysis Results

Information obtained as part of the sediment probing work described in Section 2.3.1 indicates that fine (sand-size and smaller) material represent the dominant sediment sizes in the reach of the Royal River between East Elm Street Dam and the State Route 9 Bridge (Table 15). Results from additional sediment sampling work described in WHG 2010 in preparation for the proposed dredge of the Royal River are provided (Table 16) for comparison.

Both sampling efforts indicate that sand-size and smaller material represent the dominant sediment sizes that may be mobilized through the study reach of the Royal River and into the harbor.

Table 15: Grain Size Analyses Results (mm) from Stantec Sampling Effort

Sample ID	D10	D15	D20	D30	D50	D60	D80	D85	D90	D95
EE-IMP1-SEDA	0.1277	0.1744	0.2156	0.3150	0.5172	0.6280	0.9715	1.1316	1.3777	1.8521
EE-IMP1-SEDB	0.1064	0.1492	0.1891	0.2738	0.4641	0.5701	0.8824	1.0202	1.2258	1.5992
EE-IMP2-SED	ND	ND	ND	ND	0.0799	0.0984	0.1526	0.1735	0.2015	0.2476
EE-IMP3-SED	0.1235	0.1392	0.1536	0.1818	0.2429	0.2788	0.3774	0.4151	0.4680	0.5607
EE-IMP4-SED	ND	ND	ND	ND	0.1095	0.1331	0.1942	0.2169	0.2484	0.3097
EE-IMP5-SED	ND	ND	0.0771	0.1039	0.1407	0.1595	0.2076	0.2250	0.2485	0.3502
Mean	**0.1192**	**0.1543**	**0.1589**	**0.2186**	**0.2591**	**0.3113**	**0.4643**	**0.5304**	**0.6283**	**0.8199**
Median	**0.1235**	**0.1492**	**0.1714**	**0.2278**	**0.1918**	**0.2192**	**0.2925**	**0.3201**	**0.3583**	**0.4555**

Table 16: Grain Size Analysis Results (mm) from Harbor Dredge Sampling Effort (WHG 2010)

Station	D10	D15	D20	D30	D50	D60	D80	D85	D90	D95
A	0.0950	0.1087	0.1244	0.1628	0.2789	0.3650	0.9577	1.2711	1.6872	2.8669
B1	0.0829	0.0930	0.1043	0.1311	0.2074	0.2608	0.4124	0.7014	1.3831	3.2040
B2	0.0828	0.0927	0.1038	0.1300	0.2040	0.2555	0.4010	0.5805	1.1049	2.1899
C	0.0818	0.0925	0.1046	0.1338	0.2188	0.2798	0.5556	0.8685	1.3577	2.2641
D	0.0752	0.0871	0.1008	0.1352	0.2430	0.3258	0.8062	1.0804	1.4479	1.9404
E	0.0807	0.0951	0.1120	0.1555	0.2997	0.4161	1.1346	1.4622	1.8845	3.0082
F	0.0799	0.0919	0.1057	0.1400	0.2454	0.3248	0.7919	1.0674	1.4389	1.9396
G	ND	ND	0.0809	0.1187	0.2556	0.3751	0.9779	1.2541	1.6085	2.2056
H	0.0778	0.0998	0.1281	0.2107	0.5249	0.7502	1.5324	1.8319	2.3954	3.4161
I	0.0791	0.0908	0.1041	0.1371	0.2376	0.3128	0.7265	0.9836	1.3318	1.8033
J	ND	0.0759	0.0874	0.1156	0.2025	0.2680	0.5495	0.7897	1.1347	1.6305
K	0.0862	0.1024	0.1215	0.1712	0.3396	0.4936	1.1726	1.4557	1.8073	3.1412
Mean	**0.0821**	**0.0936**	**0.1065**	**0.1451**	**0.2715**	**0.3690**	**0.8349**	**1.1122**	**1.5485**	**2.4675**
Median	**0.0813**	**0.0927**	**0.1045**	**0.1362**	**0.2442**	**0.3253**	**0.7991**	**1.0739**	**1.4434**	**2.2349**

4.3.2 Critical Sheer Stress Criteria

Reference critical sheer stresses for fine-grained alluvial material ranged from very fine sand to very coarse sand are presented in Table 17. These values are based on information presented in the American Society of Civil Engineers Sedimentation Manual and are considered here to represent general ranges of potential particle mobility in the absence of cohesive conditions.

Table 17: Reference Critical Sheer Stresses

Particle Size (mm)	Description	Critical Shear Stress (lbs/ft^2)
0.125 - 0.062	very fine sand	0.004
0.25 - 0.125	fine sand	0.004
0.50 - 0.25	medium sand	0.005
1.00 - 0.50	coarse sand	0.01
2.00 - 1.00	very coarse sand	0.03

4.3.3 Calculated Sheer Stress in River Upstream from East Elm Street Bridge

This section presents information on calculated sheer stresses in the channel of the Royal River upstream from the East Elm Street Bridge. Information is presented here in profile plots along the reach of the river starting downstream from East Elm Street Bridge to the approximate upstream limit of the hydraulic model domain. Each plot includes data for existing conditions and with East Elm Street Dam removed.

Figure 12 plots calculated sheer stresses in the channel for the 2-year flow.

Mass erosion and enlargement of channels can occur during a broad range of flow events, including relatively frequent events (e.g., annual spring runoff) and during larger, less frequent flow events (e.g., the 100-year return-interval event). The 2-year return-interval event is typical of the channel-forming, or “bankfull” event in many rivers in New England, but observations and evaluations perform as part of the fluvial geomorphic study suggest that it is the larger storms (e.g., the 100-year return-interval event) that are likely to mobilize sediment in the study reach of the Royal River. Based on information obtained as part of the fluvial geomorphic evaluation (Section 2.6 and Appendix D), the 2-year return-interval flow in the study reach of the river may be less than that bankfull, or channel forming flow. Calculated shear stresses are therefore provided for a range of flows, including the 2-, 10-, and 100-year return-interval flows.

Figure 12 presents calculated shear stresses along the study reach during the 2-year return-interval flow event. Note that calculated sheer stresses are typically greater than those presented in Table 17, and reflect the potential for this flow event to mobilize and transport sand-size material in the study reach upstream from East Elm Street Dam. Figure 13 and Figure 14 present similar information for the 10- and 100-year events, respectively.

Figure 12: Calculated Sheer Stress for 2-Year Flow Event (flow is from right to left)

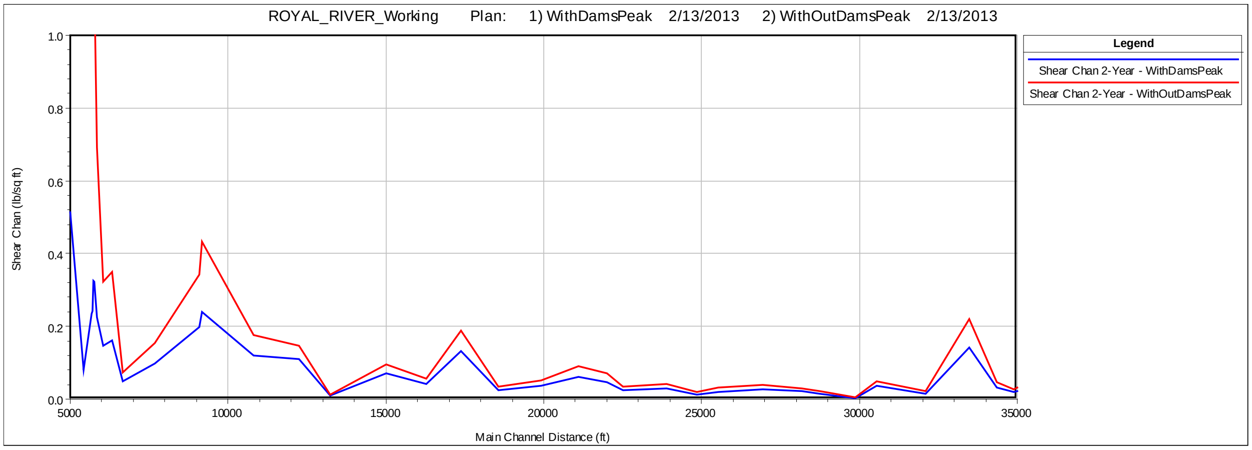


Figure 13: Calculated Sheer Stress for 10-Year Flow Event (flow is from right to left)

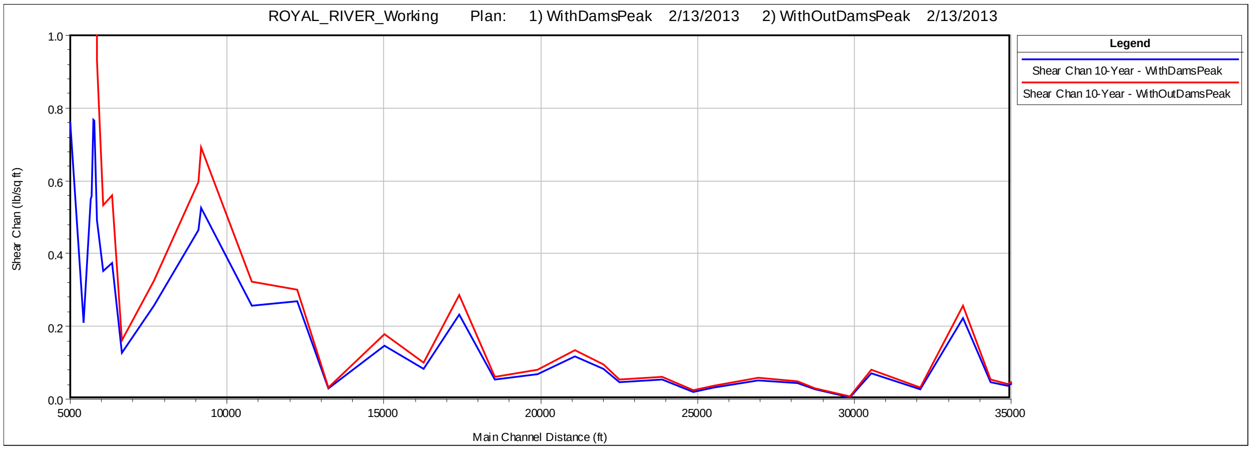
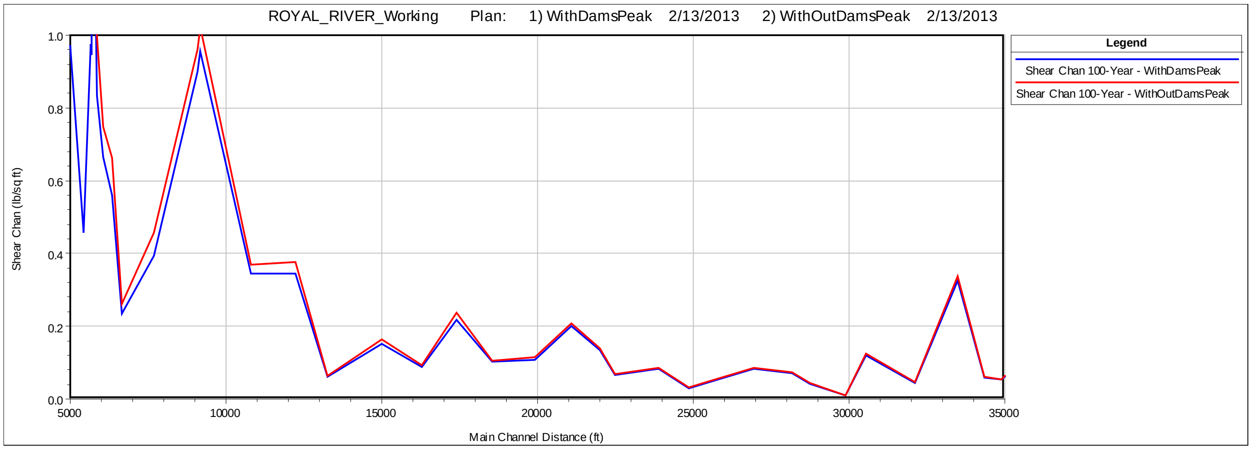


Figure 14: Calculated Sheer Stress for 100-Year Flow Event (flow is from right to left)



4.3.4 Evaluation of Sediment Transport Capacity

The HEC-RAS model was used to calculate sediment transport capacity for existing and “dam removal” conditions. This evaluation was performed to evaluate sediment transport capacity at HEC-RAS model cross-sections between the State Route 9 Bridge and the Maine Central Railroad Bridge, but did not evaluate sediment transport through this reach.

Evaluation of sediment transport capacity was performed using sediment sizes determined from the gradation analyses performed on the five sediment samples that were evaluated as part of this study. Multiple sediment transport functions were used in this evaluation; results from the different sediment transport functions varied, but resulted in consistent trends for the evaluated events for the existing and proposed conditions. Results presented here are based on the Ackers-White sediment transport function.

Figure 15 depicts information from a sediment transport capacity evaluation for existing conditions (e.g., with East Elm Street Dam) for the 2-year, 5-year, 10-year, and 100-year return-interval events. Figure 16 presents similar information for evaluated conditions with East Elm Street Dam removed.

Figure 15: Sediment Transport Capacity – Existing Condition (flow is from right to left)

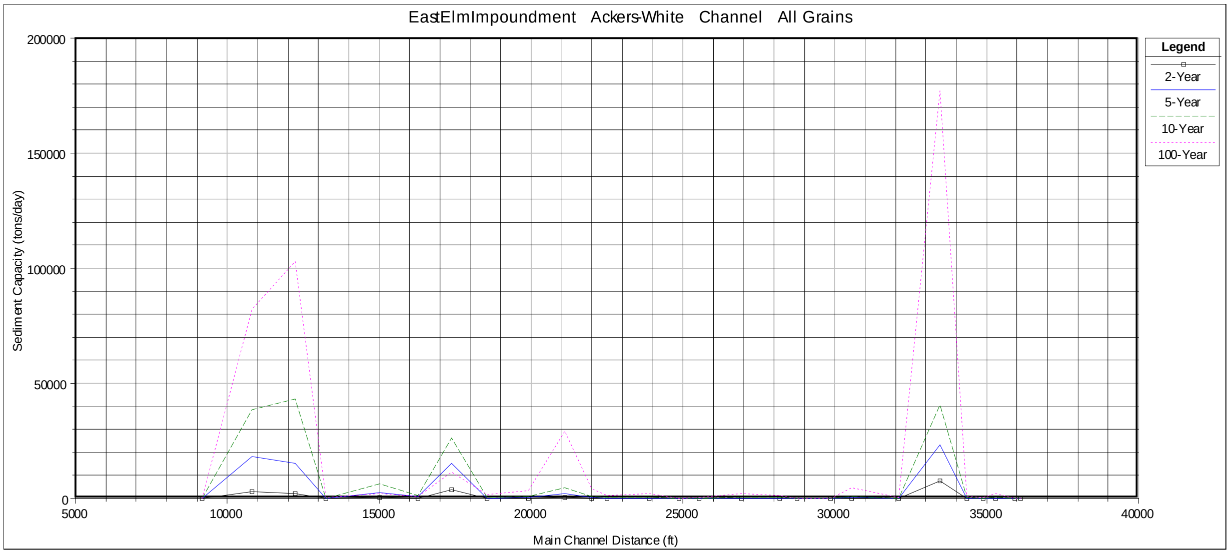
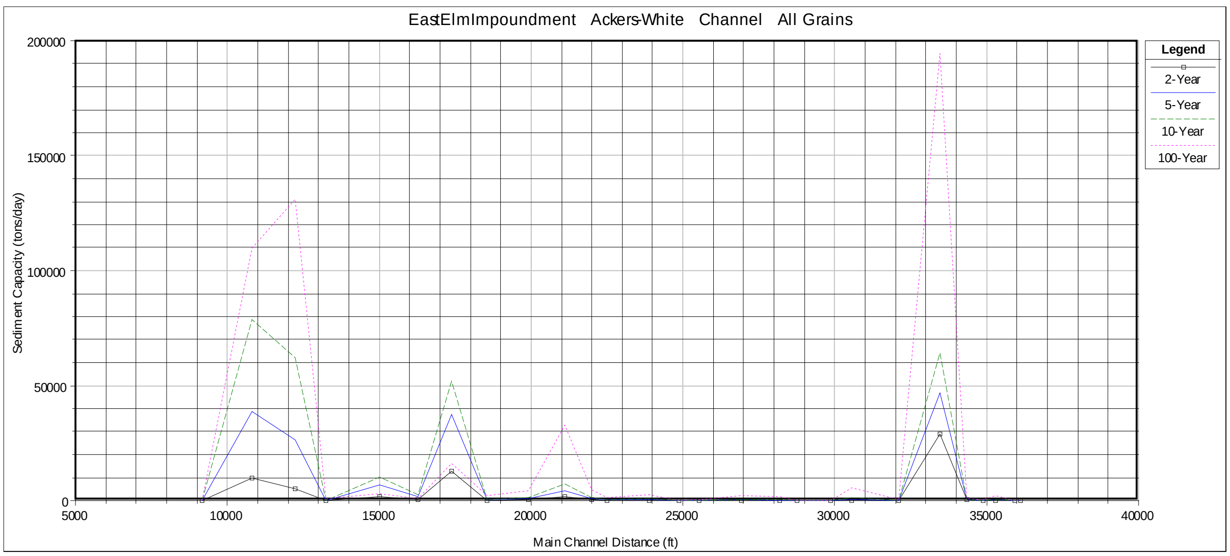


Figure 16: Sediment Transport Capacity – Dam Removal (flow is from right to left)



Data obtained from the hydraulic model indicates that removal of the dam would result in increased shear stress at lower-magnitude high-flow events and increased sediment transport capacity. For example, comparison of calculated shear stresses for existing and dam removal conditions indicates that sediment mobilization that would currently happen during a 5-year return interval event would be similar to that which would occur during a 2-year return interval event following dam removal. Similarly, sediment mobilization that would currently happen during a 10-year return interval event would be similar to that which would occur during a 5-year return interval event following dam removal. Comparison of calculated sediment transport capacity for existing and dam removal conditions for the 100-year return interval event indicates, however, that removal of the dam has little effect during this high-magnitude event.

4.4 SUMMARY OF FLUVIAL GEOMORPHIC EVALUATION

The executive summary of the fluvial geomorphic evaluation report prepared by FGS is provided below, and the entire report is included in Appendix D.

> *"A fluvial geomorphology assessment was conducted of the Royal River in Yarmouth, ME to determine the potential effects of removing the East Elm Street Dam on sediment production and sediment transport. Drawdown of the impoundment level by nearly 6.0 feet with dam removal at low flow conditions is likely to increase bank erosion over the short term in the sensitive sandy soils due to seepage forces. Long-term increases in bank erosion are also possible as channel migration will more readily occur as free-flowing conditions return to the impoundment. However, channel migration appears to have been limited during the 71-yr map record in reaches largely unaffected by the dam, so rapid channel migration and extensive long-term increases in bank erosion are not expected.*
>
> *Increased sediment production following dam removal does not necessarily translate into increased sediment transport and delivery to the harbor. Large floods generate enormous stream power within the impoundment area, as evidenced by pools over 20 feet deep at low flow conditions, due to the confined nature of the channel (where no effective floodplain is present to dissipate the river's energy). Consequently, a single large flood likely transports a far greater amount of sediment through the impoundment than is cumulatively transported by a long series of smaller floods. Since large floods (i.e., 100-yr flood) are largely unaffected by the dam's presence (as demonstrated by hydraulic modeling), large amounts of sediment have likely continued to be delivered to the harbor with the dam in place, limiting sediment storage within the impoundment. Consequently, dam removal is unlikely to significantly increase sediment transport through the impoundment area and sediment delivery to the harbor. Sediment transport efficiency is likely to increase during smaller floods (i.e., 1.5-yr flood) but will have a limited impact on sedimentation in the harbor given the far greater influence of large floods. Smaller floods following dam removal are more likely to alter the morphology of the channel in the impounded area with some infilling of deep pools and shallowing of the channel as bars and riffles develop.*

4.5 BRIDGE SCOUR

This section presents information regarding potential scour at the East Elm Street Bridge, St. Lawrence & Atlantic Railroad Bridge, and Maine Central Railroad Bridge upstream from East Elm Street Dam. Plan materials where solicited from the respective bridge owners and are included in Appendix G, which also includes plans for the State Route 9 Bridge (not evaluated as part of this study).

4.5.1 East Elm Street Bridge

The East Elm Street Bridge is a gravity structure, with concrete and steel bridge deck components resting upon concrete retaining wall abutments. The approximate span is about 70 ft and does not include mid channel piers. Review of record drawing of the East Elm Street Bridge (Appendix G) provided by the Maine Department of Transportation (Maine DOT) indicate the East Elm Street Bridge abutments are founded on bedrock, as indicated by callouts for bedrock excavation along the south abutment and installation of construction joints along a pinnacle of bedrock located under the north abutment. The Royal River is constrained between the East Elm Street Bridge abutments at this location, and the bridge alignment appears to be moderately skewed (i.e., not perpendicular to) to the direction of flow in the river. A second bridge spanning a bypass stream locally known as the Foundry Channel is noted on the Maine DOT drawings and appears to also be founded upon bedrock.

A petit Ponar dredge sampler lowered from the East Elm Street Bridge during sediment sample collection field work activities conducted during December 2009 indicated the presence of a hard surface in the vicinity of the East Elm Street Bridge. Subsequent soundings confirmed a hard substrate beneath the East Elm Street Bridge, and the sampling location was relocated to a depositional area of sediment closer to the East Elm Street Dam. Manual probing with a survey rod from a boat operated on the impoundment in May 2010 further confirmed the presence of a cobble/boulder/bedrock substrate extending upstream of the East Elm Street dam to the vicinity of the St. Lawrence & Atlantic Railroad Bridge. Substrate classification was not attempted along the Foundry Channel, but is presumed to be similar to the substrates within the main stem channel.

If the East Elm Street Bridge substructure elements are set on bedrock as depicted on the reviewed plan, the potential for undermining of the substructure elements would be limited. The susceptibility of the underlying rock to scour should be evaluated, however, if removal of East Elm Street Dam is further evaluated, as the hydraulic model results indicate that very high flow speeds would occur in the immediate vicinity of the bridge.

4.5.2 St. Lawrence & Atlantic Railroad Bridge

The St. Lawrence & Atlantic Railroad Bridge is located approximately 0.1 miles upstream from East Elm Street Dam.. This bridge is a steel truss structure with a span of approximately 127 ft between stone masonry abutments. Stantec contacted the bridge owner (St. Lawrence & Atlantic Railroad) but did not receive plans or other materials from them.

The existing abutments extend to the edge of the normal wetted channel and appear to be a slight constriction on the existing channel, but the hydraulic model results indicated that the East Elm Street Bridge acts as a backwater control that results in reduced flow speeds in the immediately vicinity of this bridge.

Bottom substrates in the vicinity of the St. Lawrence & Atlantic Railroad Bridge were visually classified as boulder/bedrock intermixed with fine grain deposits (i.e., sand) during May 2010 field work. No scour pool was noted at this bridge location. Manual probing conducted in November 2012 showed no appreciable amount of sediment and a hard, rock bottom at one of the two locations probed in the vanity of this bridge. Sediment was probed to a depth of approximately 0.8 ft at a depositional area on the inside edge of the thalweg located upstream of the St. Lawrence & Atlantic Railroad Bridge. A petit-Ponar grab sample indicated that bottom substrates at this latter location were primarily sand.

Removal of East Elm Street Dam would result in some decrease in water surface elevations adjacent to this bridge and increased flow speeds adjacent to the bridge abutments, and may therefore increase the potential for scour adjacent to the abutments. In addition, lower normal pool water surface elevations could reduce the elevation of the groundwater table in the immediate vicinity of the abutments, and could therefore adversely impact wooden piles (if present) that may support the bridge abutments.

4.5.3 Maine Central Railroad Bridge

The Maine Central Railroad Bridge is approximately 0.7 miles upstream from East Elm Street Dam. This is a steel girder structure with a span of approximately 81 ft between the masonry abutments. Plan materials for this bridge were obtained from the current owner of the bridge (Pan Am Railways) and are included in Appendix G. The plan materials that were provided by the dam owner are limited to sketches of the masonry abutments and bridge span, and do not include information on the abutment foundations.

The river is constrained between the abutments at this location, with apparent floodplain constriction occurring as a result of the earthen embankment approach on the north side. Review of Flood Insurance Rate Map (FIRM) information available from the Federal Emergency Management Agency (FEMA) indicated this bridge currently is acting as a hydraulic control during flood events (i.e., 100-year recurrence-interval event).

Manual probing of bottom substrates in the vicinity of this structure in May 2010 indicated the presence of a cobble/boulder/bedrock bottom composition. Subsequent sediment probing performed in the vicinity of this structure in November 2012 indicated a boulder/cobble/bedrock bottom. A petit Ponar grab sample at this location attempted during the 2012 field work did not recover a bottom sample. A scour pool was not identified between the bridge abutments.

Removal of East Elm Street Dam would result in some decrease in water surface elevations adjacent to this bridge and increased flow speeds adjacent to the bridge abutments, and may therefore increase the potential for scour adjacent to the abutments. In addition, lower normal pool water surface elevations could reduce the elevation of groundwater table in the immediate vicinity of the abutments, and could therefore adversely impact wooden piles (if present) that may support the bridge abutments.

4.6 UPSTREAM FISH PASSAGE

Removal of East Elm Street Dam would allow for volitional upstream fish passage in the Royal River at the current location of the dam. Although the scope of work for this phase of project studies did not include any required work to evaluate upstream fish passage, this topic bears discussion here given ongoing work by stakeholders to improve access to aquatic habitat for resident and diadromous fish in the Royal River. In particular, removal of masonry debris from the side channel around the east side of Factory Island in 2012 improved potential for upstream passage at Middle Falls.

Observations of existing conditions immediately downstream from East Elm Street Dam and hydraulic modeling performed as part of this study indicate that conditions in the Royal River in the vicinity of the dam would be similar to those immediately downstream from East Elm Street Dam and Bridge Street Dam. The section of river between the East Elm Street Bridge and East Elm Street Dam would be a “rapids” at high flow, but that this would include areas along the edge of the channel that are suitable for upstream migration of target fish species, such as alewife. Based on the apparent similarity of this site with other, similar sites in Maine, such as the rapids on the Presumpscot River upstream from the former Smelt Hill Dam in Falmouth, it is expected that resident and diadromous fish would be able to ascend this part of the Royal River during suitable flow conditions if the dam were removed.

5.0 DISCUSSION

Removal of the East Elm Street Dam would result in lowering of normal water surface elevations in the Royal River upstream from the location of the dam. Lower water surface elevations would be most apparent in the approximately quarter-mile long reach of the river immediately upstream from the dam, and would have relatively swift currents under normal and high-flow conditions. Further upstream, the normal water surface would be 5 ft to 6 ft lower to the upstream limit of the dam impoundment, which is upstream from the State Route 9 Bridge.

Effects of dam removal are reduced as flows increase and progressing upstream from East Elm Street Dam towards the State Route 9 Bridge. Based on the hydraulic modeling described in this report, removal of East Elm Street Dam would have little effect on conditions in the Royal River upstream from the State Route 9 Bridge during higher-flow events, and are minimal (less than 1 ft) during the 100-year return-interval event.

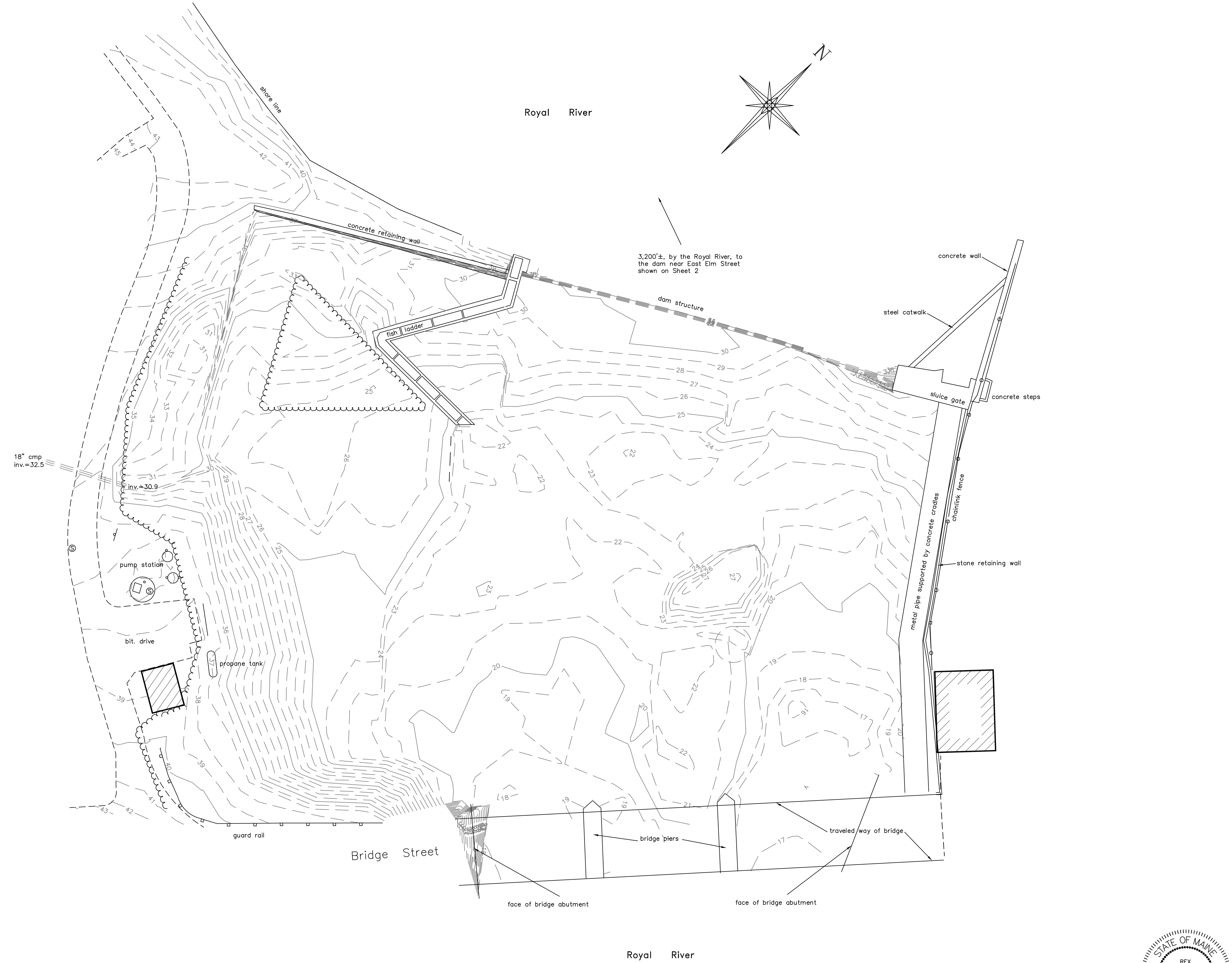
Recreational use on the currently impounded reach of the river upstream from East Elm Street Dam would be affected by removal of the dam. The existing boat launch behind the Yarmouth Historical Society building upstream from the East Elm Street Bridge would no longer be a suitable location for putting in boats and paddling upstream, as it is expected that the river will be too swift and shallow to paddle upstream adjacent to the boat launch. Opportunities for recreational boating would remain upstream from this area, however, and the Town of Yarmouth is investigating a new boat launch in the vicinity of Sligo Road approximately a one-half mile upstream as an alternative site for launching small boats.

Observed conditions and gradation analyses indicate that sediments in the Royal River upstream from East Elm Street Dam largely consist of sand-size and smaller material, and that this material is similar in size to material that has accumulated in Yarmouth Harbor. The order-of-magnitude estimate of the potentially mobile sediment in the Royal River between East Elm Street Dam and the State Route 9 Bridge that was developed as part of this study is 100,000 CY.

Observations as part of this study, identified sedimentation in Yarmouth Harbor, and hydraulic model studies performed as part of this study indicate that sediment in the Royal River currently mobilizes during high-flow events. The hydraulic model simulations indicate that removal of the dam would result in increased shear stress at lower-magnitude high-flow events and could result in increased mobilization of sediment in the river upstream from East Elm Street Dam. For example, comparison of calculated shear stresses for existing and dam removal conditions indicates that sediment mobilization that would currently happen during a 5-year return interval event would be similar to that which would occur during a 2-year return interval event following dam removal. Similarly, sediment mobilization that would currently happen during a 10-year return interval event would be similar to that which would occur during a 5-year return interval event following dam removal. Comparison of calculated sediment transport capacity for existing and dam removal conditions for the 100-year return interval event indicates, however, that removal of the dam has little effect on flow speeds and sediment transport capacity during high-magnitude floods. This finding is consistent with the geomorphic assessment that was performed as part of this study.

In summary, sediment is currently transported through the Royal River between East Elm Street Dam and the State Route 9 Bridge, and likely contributes to sedimentation of Yarmouth Harbor. Removal of East Elm Street Dam could result in increased delivery of sediment to the harbor during relatively frequent runoff events, such as those that occur on an annual basis, but would have less effect on sediment transport – and delivery of sediment to Yarmouth Harbor – during less frequent but higher magnitude floods. The amount of sediment that is remobilized and duration of effects associated with removal of the dam would depend on the number and frequency of flood events following removal of the dam.

Appendix A Topographic Survey Figures



CERTIFICATION

This survey is for topographic purposes only.

Rex J. Croteau, P.L.S. #2273

STATE OF MAINE
REX J. CROTEAU #2273
PROFESSIONAL LAND SURVEYOR

NOTES

1) Bearings are referenced to grid north, Maine State Plane Coordinate System, NAD83, West Zone.

2) Elevations are based on NAVD88 datum, obtained by GPS observations.

3) Utility information on this plan is approximate, based on location of visible features and information contained on plans and drawings provided by others. DigSafe and/or the appropriate utilities should be contacted prior to any construction.

LEGEND

Sewer manhole
Edge of pavement
Edge of gravel
Sign
Lamp or light pole
Utility pole
Contours (1ft)
Contours (5ft)
Tree line
Spot elevation
Existing building

SCALE IN FEET
20 0 20 40
1" = 20'

Rev. 2	02/11/13	contours, sheet 2	RjC
Rev. 1	02/07/13	bottom beam elevations, sheet 4	RjC

PLAN OF
Topographic Survey
Bridge Street — Yarmouth, Maine

MADE FOR
Stantec
30 Park Drive — Topsham, Maine

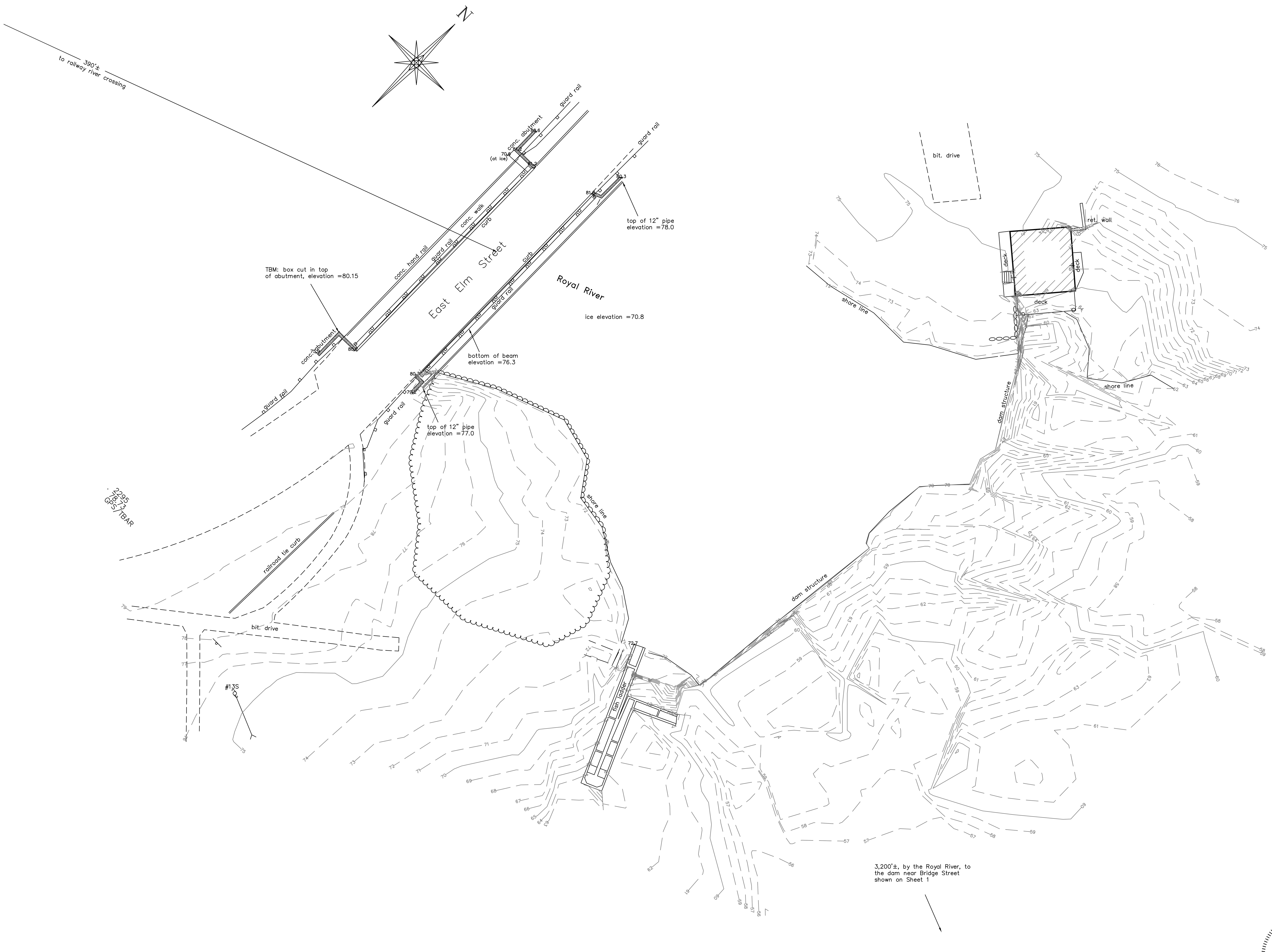
JOB 209049 | DATE: January 21, 2013 | SCALE: 1"=20'

BOOK 825

CP/2009/209049

FILE 9422

Titcomb Associates
133 Gray Road
Falmouth, Maine 04105 (207)797-9199



CERTIFICATION

This survey is for topographic purposes only.

Rex J. Croteau, P.L.S. #2273

STATE OF MAINE
REX J. CROTEAU
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PROFESSIONAL LAND SURVEYOR

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LEGEND

- Edge of pavement
- Edge of gravel
- Sign
- Lamp or light pole
- Utility pole
- Contours (1ft)
- Contours (5ft)
- Tree line
- Spot elevation
- Existing building

SCALE IN FEET

20 0 20 40

1" = 20'

Rev. 2	02/11/13	contours, sheet 2	RjC
Rev. 1	02/07/13	bottom beam elevations, sheet 4	RjC

PLAN OF

Topographic Survey

East Elm Street — Yarmouth, Maine

MADE FOR

Stantec

30 Park Drive — Topsham, Maine

JOB 209049 | DATE: January 21, 2013 | SCALE: 1"=20'

BOOK 825

CP/2009/209049

FILE 9422

Titcomb Associates
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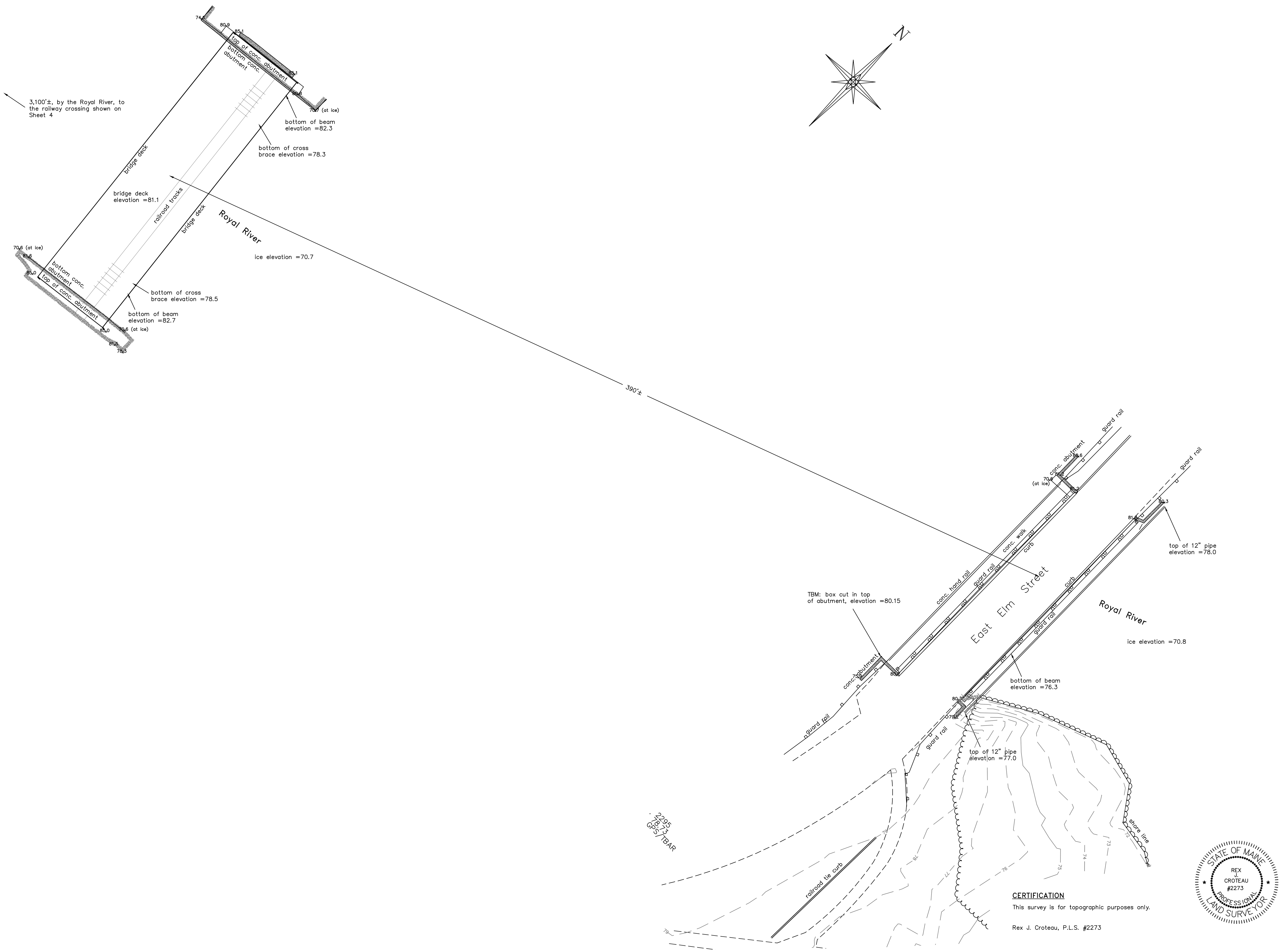

NOTES

1) Bearings are referenced to grid north, Maine State Plane Coordinate System, NAD83, West Zone.

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LEGEND

- Edge of pavement
- Edge of gravel
- Sign
- Lamp or light pole
- Utility pole
- Contours (1ft)
- Contours (5ft)
- Tree line
- Spot elevation
- Existing building

SCALE IN FEET

20 0 20 40

1" = 20'

CERTIFICATION

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Rex J. Croteau, P.L.S. #2273

STATE OF MAINE REX J. CROTEAU #2273 PROFESSIONAL LAND SURVEYOR

Rev. 2	02/11/13	contours, sheet 2	RjC
Rev. 1	02/07/13	bottom beam elevations, sheet 4	RjC

PLAN OF

Topographic Survey

East Elm Street — Yarmouth, Maine

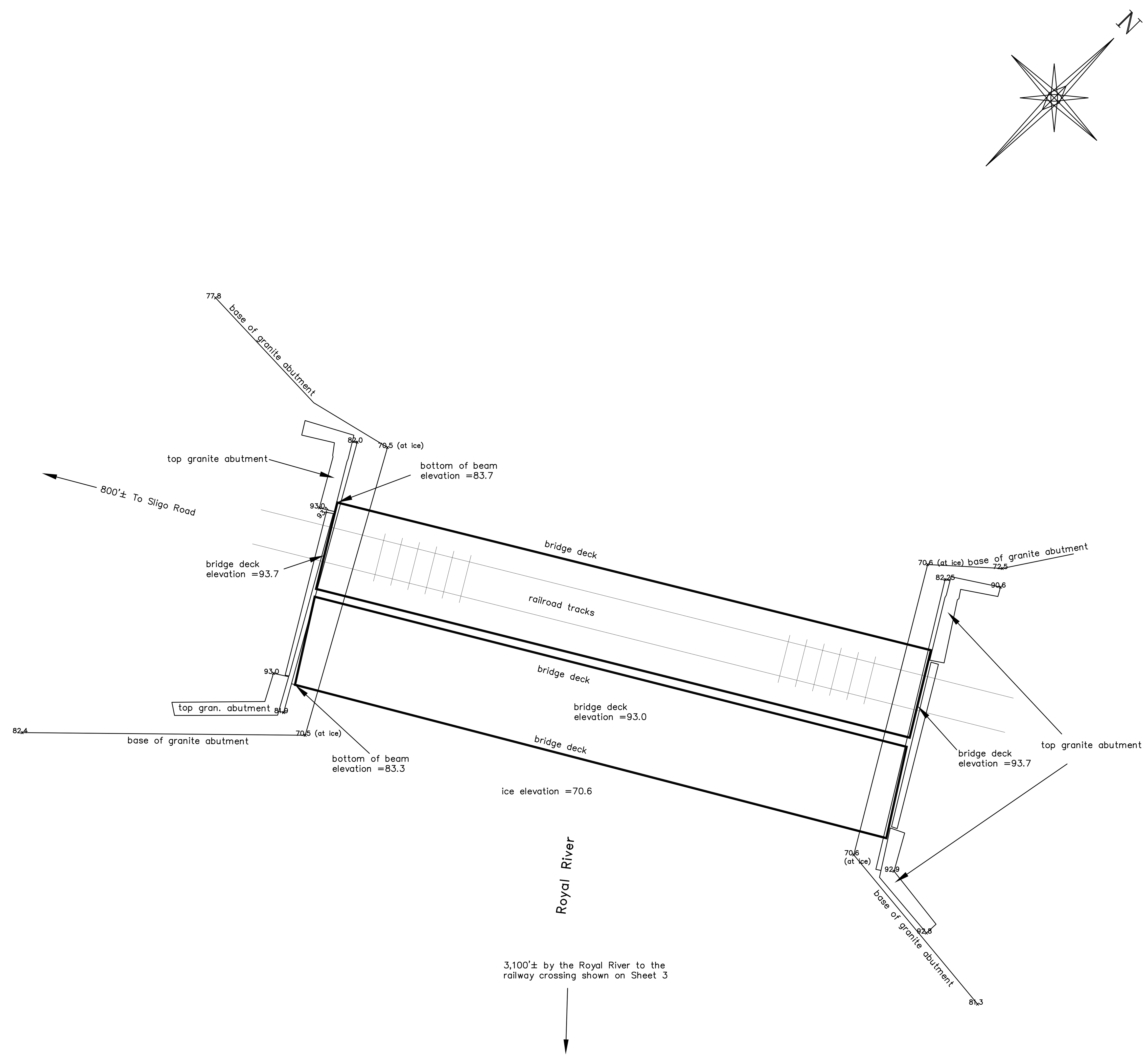
MADE FOR

Stantec

30 Park Drive — Topsham, Maine

JOB 209049	DATE: January 21, 2013	SCALE: 1"=20'
BOOK 825		
CP/2009/209049		
FILE 9422		

Titcomb Associates
133 Gray Road
Falmouth, Maine 04105 (207)797-9199



NOTES

1) Bearings are referenced to grid north, Maine State Plane Coordinate System, NAD83, West Zone.

2) Elevations are based on NAVD88 datum, obtained by GPS observations.

LEGEND

80.0 Spot elevation

SCALE IN FEET

10 0 10 20

1" = 10'

Rev. 2	02/11/13	contours, sheet 2	RJC
Rev. 1	02/07/13	bottom beam elevations, sheet 4	RJC

PLAN OF

Topographic Survey

Royal River Yarmouth, Maine

MADE FOR

Stantec

30 Park Drive Topsham, Maine

JOB 209049	DATE: January 21, 2013	SCALE: 1"=10'
BOOK 825		
CP/2009/209049		
FILE 9422		

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STATE OF MAINE REX J. CROTEAU #2273 PROFESSIONAL LAND SURVEYOR

Appendix B Sediment Probing Methods and Results

Memo

To:	Michael Chelminski Topsham ME Office	From:	David Huntress Topsham ME Office
File:	195600838	Date:	February 10, 2013

Reference: Royal River Restoration Project
Preliminary Evaluation of Sediment Character Via Probing

This memo documents the preliminary evaluation of sediment depth and composition at selected locations within the Royal River above the East Elm Street Dam in Yarmouth and the confluence of Chandler Brook upstream from the State Route 9 Bridge over the Royal River in North Yarmouth, Maine.

1 PROJECT BACKGROUND

The Royal River originates at Sabbathday Lake in New Gloucester, Maine and flows approximately 25.5 miles in a southeasterly direction to tidewater at Casco Bay. The futures of a pair of dams are currently under review by the dam owner, the Town of Yarmouth (Town). The acquisition of sediment related data upstream from the East Elm Street Dam (Dam) was identified as an important project component by the Town and the Project Partners.

2 SEDIMENT DATA ACQUISITION

Information and data used to evaluate sediment depth and composition was obtained as part of project field studies performed on November 27, 2012. Relevant work performed included measurement of the impoundment water surface elevations and manual probing of the impoundment at select locations to measure depths of water and apparent depths of sediment. Where sediment composition could not be evaluated with manual probing, a petit-Ponar sampling apparatus was used to obtain grab samples for further visual evaluation of sediment material.

2.1 MANUAL SEDIMENT PROBE DATA EVALUATION

Manual probing data was collected using a survey rod deployed from a small boat and included measurement of apparent depth of water and depth-of-refusal. The reference elevation for the manual probe data collection work was the water surface elevation in the impoundment as determined using measurement from vertical benchmarks on the dam and Route 9 Bridge established as part of project work. The reference water surface elevation (WSEL) for the impoundment at the time of manual probing was 69.72 feet (North American Vertical Datum of 1988) as determined from a measurement of the water surface at the Dam.

2.2 SEDIMENT PROBING DATA ANALYSIS

This section presents information on the estimated depth and composition of sediment between the Dam and the confluence of the Royal River and Chandler Brook, which is located upstream from Route 9. The volume of accumulated sediment was not evaluated due to the apparently limited sediment volume within the reach of river. Based on the observed conditions, it is not expected that removal of the dam would result in a significant change to the sediment transport regime through the study reach of river and into the downstream reach of the Royal River.

Sediment depths were measured via probing with a survey rod deployed from a small boat along the apparent thalweg through the impoundment, and probing locations obtained with a WAAS-enabled GPS receiver. Depths of sediment were determined by setting the base of a survey rod on the apparent bottom at each location, recording the depth of water on the survey rod and then measuring the height on the survey rod when manually forced to refusal; the depth of sediment used for this analysis is the absolute value of the difference between the first and second measurements. The measurements were recorded on the GPS datalogger at each probe location with a pair of codes representing the apparent bottom and depth of refusal. The depth of sediment at each location was obtained by post-processing the data. The number of sediment probes performed within the study reach was 61.

The following sections include discussion of relevant observations. Stationing is given relevant to the dam, with measurements taken along the apparent thalweg through the dam impoundment.

3 SEDIMENT CHARACTERIZATION OBSERVATIONS

3.1.1 Dam to Station 71+50

Sediment probing was performed at 4 locations spaced approximately 350 feet apart. Manual probing showed no appreciable amount of sediment and a hard, rock bottom at three of the four locations. The fourth location, a depositional area on the inside edge of the thalweg, was probed to a depth of approximately 0.8 feet. A petit-Ponar grab sample indicated that bottom substrates at this location were primarily sand. The bottom is characterized by boulder/cobble/bedrock intermixed with limited amounts of fine grained sediment (e.g., sand). Bedrock is noted exposed at several locations along this reach, as well as just downstream from the dam.

3.1.2 Station 71+50 to Station 88+50 (Maine Central Railroad Bridge)

Sediment probing was performed at 2 locations spaced approximately 900 feet apart. Bottom substrates were characterized as gravel with an overlying 0.1 foot thick layer of sand near Station 78+75. No sediment was noted at Station 84+00 and a gravel bottom was observed via petit-Ponar grab sample at this location.

3.1.3 Station 88+50 (Maine Central Railroad Bridge)

A sediment probe performed at this location indicated a boulder/cobble/bedrock bottom. A petit Ponar grab sample at this location did not recover a bottom sample. The river is constrained between railroad abutments, limiting the potential for sediment aggradation at this location.

3.1.4 Station 88+50 (Maine Central Railroad Bridge) to Station 150+00

Sediment probing was performed at 5 locations spaced approximately 1,200 feet apart. Bottom substrates throughout this reach were characterized as soft, organic/inorganic silt and clay varying in thickness up to 4.5 feet. Fine grained sediment was noted to stick to the survey rod upon retrieval throughout this reach. Very fine sand was obtained via petit Ponar grab sample near location 113+50

3.1.5 Station 150+00 to Station 211+00

Sediment probing was performed at 7 locations spaced approximately 1,000-feet apart. Bottom substrates throughout this reach were characterized as sand, with very fine sand encountered upstream from Station 192+00 grading to silt at Station 208+50. Manual probing to refusal via survey rod through bottom substrates indicated limited sediment layer thickness (up to 1.1 feet thick) within this reach. Petit-Ponar grab samples were utilized to identify the composition of the bottom substrates along this reach as being composed of very fine to medium sand, with gravel present near location 181+25.

3.1.6 Station 211+00 to Station 213+50

Sediment probing was performed at 2 locations within this reach spaced approximately 100 feet apart. Bottom substrates were characterized as gravel/cobble. Gravel was observed via petit-Ponar grab sample at these locations. Gravel and cobbles were noted along the east shore adjacent to this reach.

3.1.7 Station 213+50 to Station 241+00

Sediment probing was performed at 5 locations spaced approximately 1,200 feet apart. Bottom substrates throughout this reach varying in thickness up to 1.6 feet and were characterized via petit-Ponar grab sampler as being composed of as very fine to medium sand.

3.1.8 Station 241+00 to Station 260+00

Sediment probing was performed at 4 locations spaced approximately 300 feet apart. Bottom substrates throughout this reach were characterized as soft, organic/inorganic silt and clay varying in thickness between 0.3 to 1.5 feet. Fine grained sediment was noted to stick to the survey rod upon retrieval throughout this reach. Sand was recovered via petit Ponar grab sample near Station 252+25.

3.1.9 Station 260+00 to Station 282+00

Sediment probing was performed at 3 locations spaced approximately 650 feet apart. Bottom substrates throughout this reach were characterized as fine to medium sand. Probing depths to refusal ranged between 0.3 feet and 1 foot. Sand was recovered via petit Ponar grab samples at sediment probe locations throughout this reach.

3.1.10 Station 282+00 to Station 332+00

Sediment probing was performed at 9 locations spaced approximately 550 feet apart. Bottom substrates throughout this reach were characterized as fine to medium sand, with silt noted at Stations 232+00 and 296+00. Silt and very fine sand were recovered via petit Ponar grab sample at sediment probe location Station 213+00. Probing depths to refusal ranged between 0.1 feet and 2.3 feet, with an average probe depth of less than 1 foot.

3.1.11 Station 332+00 to Station 352+00

Sediment probing was performed at 6 locations spaced approximately 300 feet apart. Bottom substrates throughout this reach were characterized as soft clay and organic/inorganic silt varying in thickness between 0.7 to 2.7 feet, with the exception of at Station 341+25, where depth to refusal was 0.1 feet. Fine grained sediment was noted to stick to the survey rod upon retrieval throughout this reach. Sand was recovered via petit Ponar grab sample near Station 341+25.

3.1.12 Station 352+00 to Station 361+00

Sediment probing was performed at 4 locations spaced approximately 200 feet apart. Bottom substrates throughout this reach were characterized as fine to medium sand with depths to refusal of 1 foot or less. Sand was recovered via petit Ponar grab at all locations within this reach.

3.1.13 Station 361+00 to Station 370+00

Sediment probing was performed at 4 locations spaced approximately 250 feet apart. Bottom substrates throughout this reach were characterized as soft clay and organic/inorganic silt averaging 0.4 feet to depth to refusal. Fine grained sediment was noted to stick to the survey rod upon retrieval throughout this reach. Sand was recovered via petit Ponar grab sample near Station 363+00.

3.1.14 Station 370+00 to Confluence with Chandler Brook)

Sediment probing was performed at 3 locations spaced approximately 300 feet apart. Bottom substrates throughout this reach were characterized as soft clay and organic/inorganic silt varying in thickness between to 1.5 feet. Fine grained sediment was noted to stick to the survey rod upon retrieval throughout this reach.

3.1.15 Observation Summary

Observations during the sediment probing and bathymetric survey work in this reach of river suggest that the current sediment transport regime is effective at transporting the majority of riverine born sediments through the studied reach of the Royal River. The observed conditions and findings are consistent with results observed on other projects where sediment transport regimes during high discharge events transport sediment over structures such as dams and into the downstream environment.

STANTEC CONSULTING SERVICES INC.

David Huntress, P.E.
Staff Engineer
david.huntress@stantec.com

Attachment:

c. Project File

Appendix C Phase II Sediment Analyses Report

Royal River Restoration Project

Phase II Sediment Analyses

July 9, 2013

Sign-off Sheet

This document entitled Royal River Restoration Project was prepared by Stantec Consulting Services Inc. for the account of the Town of Yarmouth, Maine. The material in it reflects Stantec's best judgment in light of the information available to it at the time of preparation. Any use which a third party makes of this report, or any reliance on or decisions made based on it, are the responsibilities of such third parties. Stantec Consulting Services Inc. accepts no responsibility for damages, if any, suffered by any third party as a result of decisions made or actions based on this report.

Prepared by ________________________________
(signature)

Reviewed by ________________________________
(signature)

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1.0 Sediment Quality Evaluation - Introduction

This phase of the Royal River Restoration Project (RRRP) included collection and visual observation and laboratory constituent analyses of five sediment samples from the study reach of the Royal River upstream from East Elm Street Dam. Sediments sample were collected in and downstream from the East Elm Street and Bridge Street Dam impoundments as part of earlier project studies in 2010. The objective of the sampling as part of this phase of work was to obtain additional information on sediment quality in the study reach upstream from East Elm Street Dam.

The locations where the five sediment samples were collected from the Royal River as part of this study are shown in Figure 1. The sediment samples were submitted for chemical analyses to screen for contaminants of potential concern (COPCs). Chemical analyses were performed by a laboratory certified by the National Environmental Laboratory Accreditation Program using U.S. Environmental Protection Agency (EPA)-approved methods for analytes (i.e., pesticides, heavy metals, etc.) that are required by state and federal agencies. Results of the sediment analyses are presented in Table A (Appendix A).

COPCs were measured from the collected sediment samples and compared with screening criteria values reported in the literature. Screening benchmarks, such as threshold effect concentrations[1] (TEC), were used to evaluate the measured chemical concentrations. If the result exceeded the screening benchmark, the constituent was then compared to the risk-level benchmarks, such as probable effects concentrations[2] (PEC). If the constituent concentration exceeded the risk-level benchmark, it is suggestive of probable risk to receptors (i.e., aquatic life). Note that where the measured concentration is reported as less than the laboratory reporting limit (RL[3]), it is considered a non-detected (ND) concentration (designated a “U” as the laboratory qualifier). It is also possible that the RL is greater than a benchmark even though the measured concentration may be reported as a ND.

The purpose of the sediment sampling and evaluation for this phase of the RRRP was to evaluate whether sediments in the study reach upstream from East Elm Street Dam have elevated levels of COPCs, as these sediments could be remobilized following removal of the

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[1] The Threshold Effects Concentration (TEC) is the concentration of a constituent that has the potential to cause risk to receptors that may be exposed.

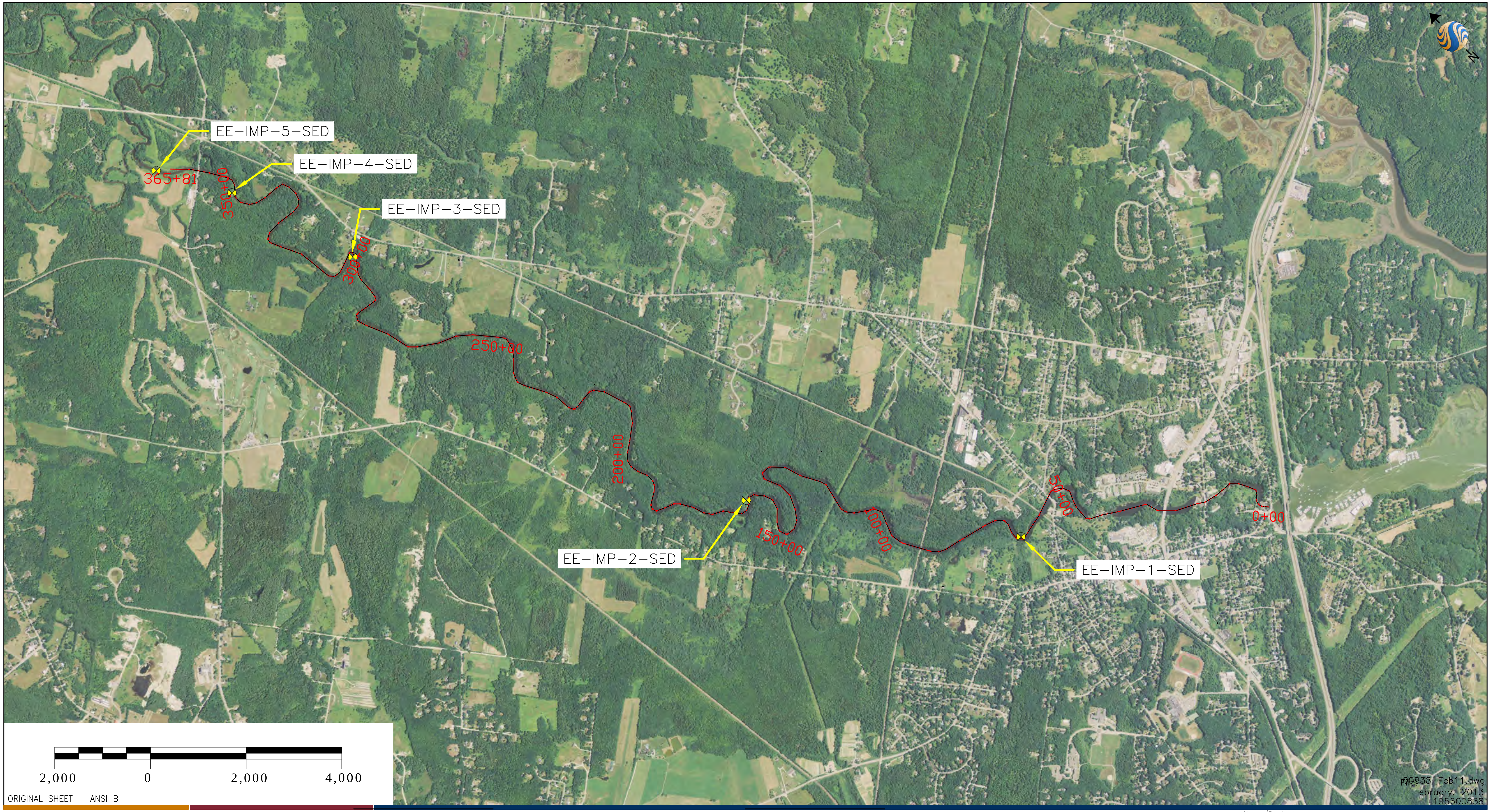
[2] The Probable Effects Concentration (PEC) is the concentration of a constituent that above which risk of adverse effects to receptors that are exposed is probable.

[3] The Reporting Limit (RL) is the lowest reported concentration, provided on the laboratory sample analysis data report, after corrections have been made for sample dilution, sample weight, and (for soils and sediments) amount of moisture in the sample. The RL is the value that indicates whether the analytical method quality objectives (MQOs) have been achieved for the sample. The RL can be as low as the method detection limit (MDL) or exceed the practical quantitation limit (PQL), depending on the matrix encountered during the analysis.

dam. A screening-level evaluation of the local sediments was conducted on the analytical data to determine if detected sediment concentrations of COPCs were within acceptable State and Federal guideline levels for the environment.

1.1 SITE HISTORY

Numerous historical industries were identified along the project reach and upstream areas along the Royal River, and may have in some capacity been contributing sources of COPCs within the river. These industries include (but may not be limited to): the former Hodsdon Shoe Company building, the former Weston's Machine shop building, a former poultry processing facility, and likely foundry area (as the nearby channel is called "Foundry Channel"), the former "Forest Paper Company" Mill, and the Sparhawk "cotton fulling mill".



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04086
Tel. 207.729.1199
Fax. 207.729.2715
www.stantec.com

Legend

SEDIMENT SAMPLE LOCATION

Notes

Client/Project

Town of Yarmouth
Royal River
Phase II Feasibility Study

Figure No.

1

Title

Sediment Sample Locus Map

2.0 Analytical Evaluation of Sediment Data

Sediment samples were analyzed for physical parameters (i.e., total organic carbon (TOC), grain size), and chemical parameters, including, volatile petroleum hydrocarbons (VPH) also identified as volatile organic compounds (VOCs), organochlorine pesticides/pesticides, polychlorinated biphenyls (PCBs) as PCB aroclors, and select total metals including arsenic, cadmium, chromium, copper, lead, nickel, silver, zinc, and mercury.

This report provides a comparison of the laboratory results with relevant sediment screening benchmark criteria. The concentrations of COPCs for each sediment sample were screened using the selected sediment benchmarks, when a criterion was available for each of the specific constituent. If the sample result exceeded the screening level benchmark, it was then compared against the risk-level benchmark (a value that is expected to show probable effects to an organism if exposed). The results for the samples were compiled in Table A (Appendix A).

Data were compared against screening benchmarks for sediment quality (Table A) using applicable criteria for ecological exposure in freshwater sediment. References for selected criteria were identified from the following:

- Buchman, M.F., 2008. NOAA Screening Quick Reference Tables, NOAA OR&R Report 08-1, Seattle WA, Office of Response and Restoration Division, National Oceanic and Atmospheric Administration, 34 pages.
- Buchman, M.F., 1999. NOAA Screening Quick Reference Tables, NOAA HAZMAT Report 99-1, Seattle WA, Coastal Protection and Restoration Division, National Oceanic and Atmospheric Administration, 12 pages.
- MacDonald et al., 2000. Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. *Arch Environ Contam Toxicol,* 39:20-31.
- USEPA (U.S. Environmental Protection Agency), 1997. The incidence and severity of sediment contamination in surface waters of the United States. Volume 1: National sediment quality survey. EPA 823-R-97-006, September.
- USEPA (U.S. Environmental Protection Agency). 2005. Predicting toxicity to amphipods from sediment chemistry. National Center for Environmental Assessment, Washington, DC; EPA/600/R-04/030.
- USEPA (U.S. Environmental Protection Agency) Region 3. 2009. Freshwater Sediment Benchmarks. Accessed 17 July, 2009 at http://www.epa.gov/reg3hwmd/risk/eco/btag/sbv/fwsed/R3_BTAG_FW_Sediment_Benchmarks_07-06.xls.

- USEPA (U.S. Environmental Protection Agency). 2003. Guidance for Developing Ecological Soil Screening Levels. Office of Solid Waste and Emergency Response Washington, DC; OSWER Directive 9285.7-55, November 2003.

The evaluation of results of the analytical parameters and the screening evaluation are described below.

2.1 ANALYTICAL RESULTS FOR SEDIMENT SAMPLES

2.1.1 Volatile Petroleum Hydrocarbons

Results for VPHs or VOCs are reported in micrograms per kilograms (µg/kg, or ppb). Acetone was the only VOC constituent detected above the RL) in two out of the five samples. No screening criterion was identified for acetone, but the presence of acetone is suggestive of sample processing (either during the sampling event or the lab procedures). It is not anticipated to have adverse effect or impact to environmental receptors in the Royal River. No other VOC was detected above the RL provided for this sampling event.

2.1.2 Organochloride Pesticides / Pesticides

Pesticide results are reported in micrograms per kilogram (µg/kg, or ppb). The collective group of DDTs were detected above RLs in the samples analyzed. Dichlorodiphenyl–trichloroethane (DDT), 1,1-dichloro-2,2-bis(p-dichlorodiphenyl)ethylene (DDE) and 1,1-dichloro-2,2-bis(p-chlorophenyl) ethane (DDD) make up the collective group of DDT pesticides, and are known as organochlorine pesticides. Although DDD and DDE can be breakdown products or metabolites of the parent compound DDT, they were also added to pesticide mixtures in their product form. DDE was detected above the RL in four out of five sample results; none of these detections was above the screening criterion (Table 1). The products DDD and DDT were detected in only one sample (EE-IMP1-SED). The maximum result for DDD (5.04 µg/kg) exceeded the screening benchmark (4.9 µg/kg); a risk-level benchmark was not identified for the DDT pesticides. An abbreviated toxicity profile for DDT is provided in Appendix B.

Table 1: Summary Results for Organochlorine Pesticide Exceedences

Parameter	Screening Benchmark	Risk-level Benchmark	Mean*	Maximum
4,4'-DDE	3.2	NA	0.68	1.2
4,4'-DDD	4.9	NA	1.21	**5.0**
4,4'-DDT	4.2	NA	0.79	2.9

NA – Not Available
Red bold text – result exceeded screening benchmark
Units are µg/kg (microgram per kilogram)
* Mean was derived from detected concentrations as well as half the non-detect (ND) value if a ND.

It was determined that although the maximum concentration of DDD did exceed the screening benchmark, no adverse impact or risk of harm would be expected to aquatic organisms based on the following:

- Potentially limited detections of DDT pesticides (only one detection of DDD);
- Exposure of aquatic organisms would be expected to be limited to the one area, allowing averaging of exposure;
- The presence of DDD is suggestive of weathered concentration of DDT application and a legacy contaminant, and is not considered to be from atmospheric deposition (suggesting increased accumulation); and
- Expected sediments may become mobilized under a change in water regime management, allowing for dilution of the minimal concentration.

Based on the information provided in the toxicity profile together with the determinations above, it is anticipated that although there was a minimal exceedence of DDD, it is not expected to cause significant adverse effects to aquatic organisms in Royal River.

No other organochlorine pesticides were detected above RLs.

2.1.3 Polycyclic Aromatic Hydrocarbons (PAH)

Analytical results for PAHs are reported in micrograms per kilogram (µg/kg, or ppb). All 14 of the analyzed PAHs were detected above reporting limiting in at least one sample (most commonly EE-IMP1-SED). If the result exceeded the screening benchmark (**red bold text**), it was then compared to the risk-level benchmark to determine if there was the potential for the constituent to pose risk to the environment. If not, the constituent was considered not to cause risk of harm, and no further evaluation was expected to be necessary. These parameters and the analytical results are summarized below in Table 2.

The majority of PAHs in sample EE-IMP1-SED were above the corresponding screening benchmarks. The resulting concentrations that exceeded screening benchmarks were then compared to risk-level benchmarks. None of the detected constituents were found to exceed the risk-level values.

No PAH constituent was retained as a COPC because the concentrations were not indicative or suggestive of potential risk to aquatic life.

Table 2: Summary Table for Polycyclic Aromatic Hydrocarbons (PAH) Results and Comparison with Relevant Benchmarks

Table 2-2.				
Parameter	Screening Benchmark	Risk-level Benchmark	Maximum	Mean
Acenaphthylene	5.9	128	42	12.3
Anthracene	57.2	245	69.7	18.2
Benzo(a)anthracene	108	1050	244	63.4
Benzo(a)pyrene	150	1450	235	60.9
Benzo(b)fluoranthene	NC	NC	223	60.2
Benzo(g,h,i)perylene	170	1500	137	36.9
Benzo(k)fluoranthene	240	NC	214	56.7
Chrysene	166	1290	251	67.4
Dibenz(a,h)anthracene	33	260	38.5	10.6
Fluoranthene	423	2200	483	130
Fluorene	77.4	536	23.1	7.5
Indeno(1,2,3-cd)pyrene	17	1650	147	39.2
Phenanthrene	204	1170	235	66.1
Pyrene	195	2000	418	114.3

Bold RED text – exceeded screening benchmark;
Highlighted cell – exceeded risk benchmark
Units are µg/kg (microgram per kilogram)
* Mean was derived from detected concentrations as well as half the non-detect (ND) value if a ND.

2.1.4 Metals

Table A (Appendix A) presents metal concentrations reported in milligrams per kilograms (mg/kg, or parts per million [ppm]). Silver is the only metal that was not detected above the RL.

Arsenic was detected in the five sediment samples above RL (the mean concentration was 1.72 mg/kg). These detections did not exceed the screening benchmark (9.79 mg/kg), and were also well below the background level of arsenic for Maine (9.4 mg/kg) as reported in Eco-SSLs.

Cadmium was detected above the RL in the five sediment samples; cadmium was not detected above the RLs in the remaining three samples. The concentration of cadmium (0.31 mg/kg) in sample IM-01 was below the screening benchmark (0.99 mg/kg).

Chromium was detected in the five sediment samples above the RL. The mean concentration (12.64 mg/kg) for chromium, and the maximum result for chromium (22.4 mg/kg) did not exceed the screening benchmark (43.3 mg/kg). Additionally, this maximum chromium concentration was below the Maine state-specific background concentration (71.2 mg/kg) as reported in Eco-SSLs.

Copper was detected in the five samples above the RL, but not the screening benchmark (31.6 mg/kg). Both the mean (5.22 mg/kg) and the maximum (9.29 mg/kg) concentration for copper were also below the Maine state-specific background concentration for copper of 28 mg/kg.

Lead was detected above the RL in the five sediment samples. However, both the mean (3.07 mg/kg) and the maximum (5.18 mg/kg) concentration for lead were below the screening benchmark (35.8 mg/kg); these concentrations were also below the Maine state background concentration (19 mg/kg).

Nickel was also detected above the RL in the five sediment samples. Both the mean (8.94 mg/kg) and the maximum (16.7 mg/kg) concentration for nickel were below the screening benchmark (22.7 mg/kg); these concentrations were also below the Maine state background concentration (30 mg/kg).

Silver was not detected above the RL in any of the five samples.

Zinc was detected above the RL in the five sediment samples. Both the mean (29.1 mg/kg) and the maximum (50.4 mg/kg) concentration for zinc were below the screening benchmark (121 mg/kg); these concentrations were also well below the Maine state background concentration (80 mg/kg).

Mercury was only detected above the RL in one sample, EE-IMP2_SED, at a concentration of 0.018 mg/kg (total mercury). This concentration for total mercury did not exceed the screening benchmark (0.18 mg/kg) or the risk-level benchmark (1.06 mg/kg). Therefore, it was determined that mercury would not be expected to cause adverse risk to aquatic life.

2.1.5 Polychlorinated Biphenyls (PCBs)

PCBs were analyzed as aroclors. Results for PCB aroclors for the five sediment samples are reported in micrograms per kilograms (µg/kg, or ppb). No aroclors were detected above the RL in any of the five samples. There are no sediment screening criteria established for PCB aroclors. A screening benchmark (59.8 µg/kg) is available for Total PCBs (a sum of PCB congener data. This benchmark was not exceeded in any of the five samples. Therefore, PCB congeners were not considered to exceed criteria. PCBs were considered not to pose risk to the environment in this area of the Royal River.

3.0 Conclusions

The only exceedence of a COPC above the screening-level criterion concentration was DDD, and is at a concentration that is just above the screening-level criterion. Based on information provided in the toxicity profile, the reported concentration of DDD is not expected to cause significant adverse effects to aquatic life in the Royal River as a result of its limited detections and minimal exceedence. The point source for DDT pesticides is suggestive of old application of pesticides prior to the ban of this product in the U.S.; new sources of DDT pesticides are not anticipated in this area. It is not clear at this time whether the DDD detection in sample EE-IMP1-SED is a 'hot spot', but it appears that it may be based on the limited detections among samples during this sampling event as well as previous sampling events.

Multiple PAH exceedances were reported in one sample (again EE-IMP1-SED). None of the PAHs exceeded the risk-level benchmarks, and thus, are not at levels to potentially cause adverse risk to aquatic life and wildlife that may rely on the aquatic life and river resources. This particular area is not expected to cause potential risk due to sediment exposure of PAHs.

Although metals were frequently detected above the RLs, none of the results exceeded any of the screening benchmarks. Metals are not expected to impact the Royal River environment or cause adverse effects to aquatic organisms residing in or relying on resources from Royal River.

Similarly, no PBC aroclors were detected above the RL, as such PCB aroclors are not considered COPCs for the Royal River at the concentrations reported. PCBs are considered to be ubiquitous environmental contaminants and are dispersed via atmospheric transport along with other transport mechanisms. Therefore, at such low levels as the detected concentrations, these constituents are not expected to cause adverse risk in the environment.

In summary, there appears to be minimal potential risk of adverse effects to aquatic life in the Royal River based on the evaluated sediment samples. Although there was an exceedence of the screening benchmark for DDD in sediment sample EE-IMP1-SED, it is not expected to cause risk of harm to the ecological receptors at the reported concentration. If sediments were remobilized, it is expected that some mixing and associated dilution would occur, which could potentially reduce the COPC concentrations.

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December 7, 2009
File: 195600348

Nat Tupper
Town of Yarmouth
Main Street
Yarmouth, ME 04096

Subject: Sediment Sampling Plan
Royal River, Yarmouth, Maine

Dear Mr. Tupper:

The following sediment sampling plan (SSP) was developed by Stantec Consulting (Stantec) for the proposed sediment sampling work to be performed as part of the Royal River Restoration Project Alternatives Analysis. The purpose of the sediment sampling work is to obtain sediment samples for laboratory analyses suitable for a screening-level evaluation of the Bridge Street dam and East Elm Street dam impoundments, as well as the surrounding area (i.e., seaward from the Bridge Street dam).

Dam alteration and/or removal can result in the mobilization of sedimented material; the objective of sediment sampling and laboratory analyses is to evaluate whether the impounded sediments have elevated contaminant concentrations. Our proposed approach for this project is based on our work on other dam removal projects in coastal New England, and includes sampling at locations in and adjacent to the impoundment.

1.0 Introduction: Project Purpose and Background

The Royal River Restoration Project is an aquatic habitat restoration project that has been undertaken by the Town of Yarmouth (hereafter referred to as the Town). The Royal River has been identified by the Gulf of Maine Council and the Maine State Planning Office (SPO) as a restoration priority, with the removal of the Bridge Street and East Elm Street dams being identified as restoration sub-projects by the SPO restoration inventory conducted in 2005. Restoration and protection of the Royal River estuary has also received previous support from the National Oceanic & Atmospheric Administration's (NOAA) Coastal and Estuarine Land Conservation Program (CELCP) for land acquisition. The 1.5-mile section of the Royal River corridor between the East Elm Street Dam and the Yarmouth town harbor is concurrently the focus of a Town planning project evaluating natural resources, recreational use, zoning, and future development along the Royal River.

The purpose of this project is to investigate alternatives for the restoration of resident and diadromous fish communities in the Royal River by evaluating actions that would reduce or eliminate impacts associated with the Bridge Street and East Elm Street dams. These dams are situated in close proximity (landward) to the head-of-tide on the Royal River, a major tributary of Casco Bay. The Bridge Street and East Elm Street dams are comprised of concrete spillways approximately 150 and 200 feet wide, respectively, with adjacent 'Denil' style fish ladders. A penstock from the Bridge Street Dam supplies water to a small-scale, run-of-river hydroelectric facility located downstream in the Sparhawk Mill. The southern abutment of the East Elm Street Dam, sandwiched between the concrete spillway and Denil fish ladder, is constructed of stone masonry in a state of disrepair. While both dams have fish passage facilities installed, studies conducted by the Maine Department of Marine Resources during the early 1980s indicate that, with the exception of American eel (*Anguilla rostrata*), few sea-run fish are able to migrate above these two dams.

This plan describes work associated with the collection of sediments for chemical and physical analyses and the methods and equipment to be utilized for the collection of sediment samples. Samples will be collected in accordance with the guidance presented in *Method for Collection, Storage, and Manipulation of Sediments for Chemical and Toxicological Analysis: Technical Manual (EPA-823-B-01-002)*.

2.0 Sediment Sampling

Four sediment samples will be collected by Stantec for this project. The locations of these four samples are as follows: one sediment sample will be collected from a sample location within the East Elm Street dam impoundment, two from between the East Elm Street and Bridge Street dams, and one sample location downstream of the Bridge Street Dam. These four sediment samples will be analyzed by a laboratory certified by the National Environmental Laboratory Accreditation Program using the United States Environmental Protection Agency (EPA) approved methods for selected analytes (see Section 5.0 below).

2.1 Equipment and Materials

The following equipment will be utilized during sediment sampling:

1. Petit Ponar Dredge[1]
2. Stainless Steel AMS® Extendable Core Sampler
3. Stainless Steel Mixing Bowls and Spoons
4. Laboratory-Supplied Sample Containers
5. Sample Labels
6. Nitrile Gloves
7. Decontamination Liquids
8. Logbook and Sampling Data Forms
9. Trimble® Pro-XR Global Position System (GPS) Retriever
10. Cooler and Ice
11. Camera
12. Chest Waders (with Hip-Belt) or Hip Boots
13. Boat or Canoe with Anchors and Life Preservers

2.2 Equipment Decontamination Procedures

Equipment will be decontaminated to prevent foreign contamination of samples and cross-contamination between samples. All equipment used to collect analytical samples will be decontaminated before use and between each sampling location.

The following decontamination procedures will be followed:

1. Rinse equipment of debris and remnant particles prior to cleaning
2. Wash and scrub with detergent (e.g., Liquinox, a laboratory grade – non-phosphate detergent)
3. Rinse with tap water
4. Rinse with de-ionized water
5. Air dry

1 A 6-inch by 6-inch ponar dredge grab sampler will be used in conjunction with a coring device to acquire appropriate sample type and quantity based on the differences in substrates.

6. Rinse with pesticide-grade methanol
7. Air dry

Equipment decontaminated prior to field use will be wrapped in aluminum foil (shiny side out) to protect against ambient dust and vapors. Separate mixing bowls and spoons will be used for compositing samples at each of the sites.

2.3 Sampling Locations

Sampling locations were selected to provide insight into the nature of possible contamination in the sediments of the impoundments, as well as the surrounding areas. Figure 1 provides an overview of the proposed sampling locations recommended by Stantec, specific locations will be determined in the field during sampling work.

The preliminary selection of sampling sites is described below:

Impoundment Locations (two samples)

Two sediment samples will be collected from the existing impoundments from depositional areas of fine-grained materials. The intent of these samples is to provide information on sediment constituents in the impoundment.

- One sediment sample (***00348-IM-Sed-01***) will be obtained within the impoundment within the general vicinity of the East Elm Street dam. The location will be determined during the sediment sampling work, but will be focused on a location within the impoundment thalweg if this can be readily identified.
- One sediment sample (***00348-IM-Sed-02***) will be obtained within the impoundment within the general vicinity of the Bridge Street dam. The location will be determined during the sediment sampling work, but will be focused on a location within the impoundment thalweg if this can be readily identified.

Riverine Locations (two samples)

Two sediment samples will be collected from depositional areas of fine-grained material along riverine segments of the Royal River. The intent of these samples is to provide information on the current status of sediment constituents below both dams.

- One sediment sample (***00348-DS-Sed-01*)** will be obtained from the riverine reach downstream of the East Elm Street dam above the Bridge Street dam impoundment. The location will be determined during the sediment sampling work, but will be focused on a location that is potentially receiving sediment from the East Elm Street impoundment if this can be readily identified.
- One sediment sample (***00348-DS-Sed-02*)** will be obtained from the riverine reach downstream of the Bridge Street dam above the head-of-tide (Route 295). The location will be determined during the sediment sampling work, but will be focused on a location that is potentially receiving sediment from the Bridge Street dam impoundment if this can be readily identified.

3.0 Sediment Sample Collection

Disposable nitrile gloves will be worn during sediment sampling and will be discarded and changed between each sampling location (i.e., clean gloves will be worn at each location). The boat will be anchored at both the bow and the stern. In accordance with generally accepted boating safety procedures, each time the boat is moved the stern anchor will be lifted prior to lifting the bow anchor.

In general, upstream samples will be collected first. If sediment deposits are too thin (e.g., less than one inch) to obtain a sample using a Petit Ponar an alternative sampling location may be selected. Precise sample collection depths will be based on the depth of sediment deposits and sample conditions.

Collected sediment will be placed into a clean (i.e., decontaminated) stainless steel bowl and homogenized with a stainless steel spoon. Pre-cleaned sampling containers provided by the laboratory will then be filled with sediment following homogenization such that no headspace is present. Two sample containers will be filled for each sampling location. A bag sample will also be collected at each location for grain size analysis. Each sample container and sample bag will be labeled with the sample identification (ID), time, date, and sample location.

3.1 Sample Collection Records

At each sampling location, a brief habitat description, sediment descriptions (e.g., texture, color, water depth to substrate, depth of sediment layer, and visual moisture content), and other pertinent data regarding the sampling event will be recorded in a field notebook or on sediment sample data sheets (Appendix A). Sample locations will be recorded using a Geographic Positioning System (GPS) receiver. Sample documentation will follow project specific Stantec standard operating procedures for field sampling, including sample ID, data sheets, chain-of-custody forms, and custody seal procedures. Copies of each form will be archived in project files.

4.0 Sample Handling

Two sample containers from each sampling location will be submitted to the analytical laboratory. One sample container from each location will be analyzed for chemical constituents. The second sample container from each sampling location will be stored and maintained by the laboratory as an archive sample for the duration of the allowable sample analysis holding time window, in case additional analyses are necessary. Sample containers will be placed in a cooler with enough ice to maintain a temperature of 4 degrees Celsius. Chain-of-custody forms will be filled out accordingly and be placed inside a cooler in a plastic Ziploc bag. The cooler will be securely wrapped with reinforced packaging tape, sealed with a custody seal and shipped via UPS overnight (i.e., for morning delivery) to the laboratory.

5.0 Analytical Evaluation and Reporting

Laboratory analyses will be performed to determine physical and chemical characteristics.

5.1 Sample Analyses

Sediment samples will be analyzed for total organic carbon (TOC), grain size, volatile organic carbon and semi-volatile organic carbon (VOCs and SVOCs), polynuclear aromatic hydrocarbons (PAHs), pesticides, total polychlorinated biphenyls (Total PCBs), and select total metals (including arsenic, cadmium, chromium, copper, lead, mercury, nickel, silver, and zinc).

5.2 Analytical Evaluation

Results of laboratory analyses will be reviewed. The analytical sample-specific method detection limits (MDL) and reporting limits (RL), as provided by the laboratory, will be evaluated. Data will be compared against ecological risk-based standards using available screening criteria such as those designated by EPA and/or other applicable criteria such as NOAA Screening Quick Reference Tables (i.e., SQuiRT Tables). The analytical evaluation will involve assessing any potential impacts of contaminated sediments on the aquatic resources, including the corresponding media-specific Threshold Effect Levels (screening values) and Probable Effect Levels (effects values).

5.3 Reporting

A brief letter report will be provided presenting the laboratory analysis results and a comparison with relevant criteria. Data will be comprised and presented in tabular form, and will include the results compared to the appropriate criteria.

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Legend

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Client/Project
Town of Yarmouth
Royal River Restoration Project
PROJECT LINE 2

Figure No.
1.0

Title
PROPOSED SEDIMENT SAMPLING LOCATIONS

APPENDIX A – SEDIMENT SAMPLING DATA SHEET

SEDIMENT SAMPLE DATA SHEET

Location: ______________________ Project: ______________________

Site: ______________________ Project Staff: ______________________

Sample Information

Sample ID: ______________ Sample Date: ______________

Sampling Method/Device: ______________ Sample Time: ______________

Grab ( ) Composite ( )

Depth of Water: ______________

Sample Bottom Depth: ______________

Weather

Sun/Clear: ______________ Overcast/Rain: ______________

Wind Direction: ______________ Ambient Temp: ______________

Site Description/Comments/Site Sketch
(i.e., flow, substrate, water depth, in-stream structure)

Appendix A Data Table of Analytical Results

Table A. Royal River secondary sediment evaluation for Phase II Study (2013).

CAS Registry Number	Parameter	Screening Benchmark (ug/kg)	Risk Level Benchmark (ug/kg)	EE-IMP1-SED Result half detection (if non-detect)	EE-IMP1-SED Laboratory Qualify	EE-IMP1-SED Sample Specific Reporting Limit	EE-IMP2-SED Result half detection (if non-detect)	EE-IMP2-SED Laboratory Qualify	EE-IMP2-SED Sample Specific Reporting Limit	EE-IMP3-SED Result half detection (if non-detect)	EE-IMP3-SED Laboratory Qualify	EE-IMP3-SED Sample Specific Reporting Limit	EE-IMP4-SED Result half detection (if non-detect)	EE-IMP4-SED Laboratory Qualify	EE-IMP4-SED Sample Specific Reporting Limit	EE-IMP5-SED Result half detection (if non-detect)	EE-IMP5-SED Laboratory Qualify	EE-IMP5-SED Sample Specific Reporting Limit	Number of Detections	Maximum Detected	Mean Detected	Contaminant of Potential Concern
Volatiles Organic Compounds																						
630-20-6	1,1,1,2-Tetrachloroethane	NC	--	0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
71-55-6	1,1,1-Trichloroethane	30.2	--	0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
79-34-5	1,1,2,2-Tetrachloroethane	1360	--	0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
79-00-5	1,1,2-Trichloroethane	1240	--	0.5	U	1	0.8	U	1.6	0.55	U	1.1	0.8	U	1.6	0.9	U	1.8	0	--	--	No
75-34-3	1,1-Dichloroethane	NC	--	0.5	U	1	0.8	U	1.6	0.55	U	1.1	0.8	U	1.6	0.9	U	1.8	0	--	--	No
75-35-4	1,1-Dichloroethene	313	--	0.335	U	0.67	0.55	U	1.1	0.55	U	1.1	0.5	U	1	0.6	U	1.2	0	--	--	No
563-58-6	1,1-Dichloropropene	NC	--	1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
87-61-6	1,2,3-Trichlorobenzene	NC	--	1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
96-18-4	1,2,3-Trichloropropane	NC	--	3.35	U	6.7	5.5	U	11	3.7	U	7.4	5	U	10	6	U	12	0	--	--	No
120-82-1	1,2,4-Trichlorobenzene	2100	--	1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
95-63-6	1,2,4-Trimethylbenzene	NC	--	1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
96-12-8	1,2-Dibromo-3-Chloropropane	NC	--	1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
106-93-4	1,2-Dibromoethane	NC	--	1.35	U	2.7	2.2	U	4.4	1.5	U	3	2.1	U	4.2	2.35	U	4.7	0	--	--	No
95-50-1	1,2-Dichlorobenzene	16.5	--	1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
107-06-2	1,2-Dichloroethane	NC	--	0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
78-87-5	1,2-Dichloropropane	NC	--	1.2	U	2.4	1.9	U	3.8	1.3	U	2.6	2.65	U	5.3	2.05	U	4.1	0	--	--	No
108-67-8	1,3,5-Trimethylbenzene	NC	--	1.7	U	3.4	0	U		1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
541-73-1	1,3-Dichlorobenzene	4430	--	1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
142-28-9	1,3-Dichloropropane	NC	--	1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	1.85	U	3.7	2.95	U	5.9	0	--	--	No
106-46-7	1,4-Dichlorobenzene	599	--	1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
	1,4-Dichlorobutane			3.35	U	6.7	5.5	U	11	3.7	U	7.4	5	U	10	6	U	12	0	--	--	No
594-20-7	2,2-Dichloropropane	NC	--	1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
78-93-3	2-Butanone	NC	--	3.35	U	6.7	5.5	U	11	3.7	U	7.4	5	U	10	6	U	12	0	--	--	No
591-78-6	2-Hexanone	NC	--	3.35	U	6.7	5.5	U	11	3.7	U	7.4	5	U	10	6	U	12	0	--	--	No
108-10-1	4-Methyl-2-pentanone	NC	--	3.35	U	6.7	5.5	U	11	3.7	U	7.4	5	U	10	6	U	12	0	--	--	No
67-64-1	Acetone	NC	--	12	U	24	19.5	U	39	13.5	U	27	41		38	60		42	2	60	29.2	No
	Acrylonitrile			1.35	U	2.7	2.2	U	4.4	1.5	U	3	2.1	U	4.2	2.35	U	4.7	0	--	--	No
71-43-2	Benzene	NC	--	0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
108-86-1	Bromobenzene	NC	--	1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
74-97-5	Bromochloromethane	NC	--	1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
75-27-4	Bromodichloromethane	NC	--	0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
75-25-2	Bromoform	654	--	1.35	U	2.7	2.2	U	4.4	1.5	U	3	2.1	U	4.2	2.35	U	4.7	0	--	--	No
74-83-9	Bromomethane	NC	--	0.65	U	1.3	1.1	U	2.2	0.75	U	1.5	1.05	U	2.1	1.2	U	2.4	0	--	--	No
75-15-0	Carbon Disulfide	0.85	--	3.35	U	6.7	5.5	U	11	3.7	U	7.4	5	U	10	6	U	12	0	--	--	No
56-23-5	Carbon Tetrachloride	64.2	--	0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
108-90-7	Chlorobenzene	8.4	--	0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
75-00-3	Chloroethane	NC	--	0.65	U	1.3	1.1	U	2.2	0.75	U	1.5	1.05	U	2.1	1.2	U	2.4	0	--	--	No
67-66-3	Chloroform (trichloromethane)	NC	--	0.5	U	1	0.8	U	1.6	0.55	U	1.1	0.8	U	1.6	0.9	U	1.8	0	--	--	No
74-87-3	Chloromethane	NC	--	1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
156-59-2	cis-1,2-Dichloroethene	NC	--	0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
10061-01-5	cis-1,3-Dichloropropene	NC	--	0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
124-48-1	Dibromochloromethane	NC	--	0.0335	U	0.067	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
74-95-3	Dibromomethane	NC	--	3.35	U	6.7	5.5	U	11	3.7	U	7.4	5	U	10	6	U	12	0	--	--	No
75-71-8	Dichlorodifluoromethane	NC	--	3.35	U	6.7	5.5	U	11	3.7	U	7.4	5	U	10	6	U	12	0	--	--	No
	Ethyl ether			1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
	Ethyl methacrylate			3.35	U	6.7	5.5	U	11	3.7	U	7.4	5	U	10	6	U	12	0	--	--	No
100-41-4	Ethylbenzene	1100	--	0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
87-68-3	Hexachlorobutadiene	NC	--	1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
98-82-8	Isopropylbenzene	86	--	0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
75-09-2	Methylene Chloride	NC	--	3.35	U	6.7	5.5	U	11	3.7	U	7.4	5	U	10	6	U	12	0	--	--	No
1634-04-4	Methyl-t-Butyl Ether	NC	--	0.65	U	1.3	1.1	U	2.2	0.75	U	1.5	1.05	U	2.1	1.2	U	2.4	0	--	--	No
91-20-3	Naphthalene	34.6	--	1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
104-51-8	n-Butylbenzene	NC	--	0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
103-65-1	n-Propylbenzene	NC	--	0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
	o-Chlorotoluene			1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
	p-Chlorotoluene			1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
	p-Isopropyltoluene			0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
135-98-8	sec-Butylbenzene	NC	--	0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
100-42-5	Styrene	559	--	0.65	U	1.3	1.1	U	2.2	0.75	U	1.5	1.05	U	2.1	1.2	U	2.4	0	--	--	No
98-06-6	tert-Butylbenzene	NC	--	1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
127-18-4	Tetrachloroethene	468	--	0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
	Tetrahydrofuran			6.5	U	13	11	U	22	7.5	U	15	10.5	U	21	12	U	24	0	--	--	No
108-88-3	Toluene	NC	--	0.5	U	1	0.8	U	1.6	0.55	U	1.1	0.8	U	1.6	0.9	U	1.8	0	--	--	No
156-60-5	trans-1,2-Dichloroethene	1050	--	0.5	U	1	0.8	U	1.6	0.55	U	1.1	0.8	U	1.6	0.9	U	1.8	0	--	--	No
10061-02-6	trans-1,3-Dichloropropene	NC	--	0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
	trans-1,4-Dichloro-2-butene			1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
79-01-6	Trichloroethene	97	--	0.335	U	0.67	0.55	U	1.1	0.37	U	0.74	0.5	U	1	0.6	U	1.2	0	--	--	No
75-69-4	Trichlorofluoromethane	NC	--	1.7	U	3.4	2.7	U	5.4	1.85	U	3.7	2.65	U	5.3	2.95	U	5.9	0	--	--	No
108-05-4	Vinyl Acetate	NC	--	3.35	U	6.7	5.5	U	11	3.7	U	7.4	5	U	10	6	U	12	0	--	--	No
75-01-4	Vinyl Chloride	NC	--	0.65	U	1.3	1.1	U	2.2	0.75	U	1.5	1.05	U	2.1	1.2	U	2.4	0	--	--	No
1330-20-7	Xylene (m,p)	NC	--	0.65	U	1.3	1.1	U	2.2	0.75	U	1.5	1.05	U	2.1	1.2	U	2.4	0	--	--	No
95-47-6	Xylene (o)	NC	--	0.65	U	1.3	1.1	U	2.2	0.75	U	1.5	1.05	U	2.1	1.2	U	2.4	0	--	--	No
1330-20-7	Xylene (total)	NC	--	0.65	U	1.3	1.1	U	2.2	0.75	U	1.5	1.05	U	2.1	1.2	U	2.4	0	--	--	No

Table A. Royal River secondary sediment evaluation for Phase II Study (2013).

				EE-IMP1-SED			EE-IMP2-SED			EE-IMP3-SED			EE-IMP4-SED			EE-IMP5-SED						
CAS Registry Number	Parameter	Screening Benchmark (ug/kg)	Risk Level Benchmark (ug/kg)	Result half detection (if non-detect)	Laboratory Qualify	Sample Specific Reporting Limit	Result half detection (if non-detect)	Laboratory Qualify	Sample Specific Reporting Limit	Result half detection (if non-detect)	Laboratory Qualify	Sample Specific Reporting Limit	Result half detection (if non-detect)	Laboratory Qualify	Sample Specific Reporting Limit	Result half detection (if non-detect)	Laboratory Qualify	Sample Specific Reporting Limit	Number of Detections	Maximum Detected	Mean Detected	Contaminant of Potential Concern
Organochlorine Pesticide/Pesticide																						
319-84-6	BHC, alpha	6	--	0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
319-85-7	BHC, beta	5	--	0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
319-86-8	BHC, delta	6400	--	0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
58-89-9	BHC, gamma (Lindane)	2.4	--	0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
76-44-8	Heptachlor	68	--	0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
309-00-2	Aldrin	2	--	0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
1024-57-3	Heptachlor epoxide	2.5	--	0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
	Heptachlor			0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
	Hexachlorobenzene			0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
959-98-8	Endosulfan I	3	--	0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
60-57-1	Dieldrin	2	--	0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
	2,4'-DDE			0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
72-55-9	4,4'-DDE	3.2	--	1.24		0.521	0.67		0.5	0.25	U	0.5	0.689		0.5	0.556		0.5	4	--	--	No
72-20-8	Endrin	2.2	--	0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
33213-65-9	Endosulfan II	14	--	0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
	2,4'-DDD			2.18	P	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	1	--	--	No
72-54-8	4,4'-DDD	4.9	--	5.04		0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	1	--	--	**No ^^**
1031-07-8	Endosulfan sulfate	5.4	--	0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
	2,4'-DDT			0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
50-29-3	4,4'-DDT	4.2	--	2.94		0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	1	--	--	No
72-43-5	Methoxychlor	18.7	--	0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
	Mirex			0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
	Oxychlordane			0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
53494-70-5	Endrin ketone	NC	--	0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
7421-93-4	Endrin aldehyde	NC	--	0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
57-74-9	Chlordane	3.24	--				0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
8001-35-2	Toxaphene	0.1	--	13	U	26	12.5	U	25	12.5	U	25	12.5	U	25	12.5	U	25	0	--	--	No
	Technical Chlordane			13	U	26	12.5	U	25	12.5	U	25	12.5	U	25	12.5	U	25	0	--	--	No
	cis-Nonachlor			0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
	trans-Nonachlor			0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
5103-74-2	gamma-Chlordane	NC	--	0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
5103-71-9	alpha-Chlordane	NC	--	0.2605	U	0.521	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0.25	U	0.5	0	--	--	No
Polycyclic Aromatic Hydrocarbons (PAHs): by SIM																						
91-57-6	2-Methylnaphthalene	20.2	--	5.1	U	10.2	3.4	U	6.8	4.71	U	9.42	3.17	U	6.34	3.205	U	6.41	0	--	--	No
83-32-9	Acenaphthene	6.7	88.9	5.1	U	10.2	3.4	U	6.8	4.71	U	9.42	3.17	U	6.34	3.205	U	6.41	0	--	--	No
208-96-8	Acenaphthylene	5.9	128	42		10.2	3.4	U	6.8	4.71	U	9.42	3.17	U	6.34	8.24		6.41	2	42	12.3	No
120-12-7	Anthracene	57.2	245	69.7		10.2	3.4	U	6.8	4.71	U	9.42	3.17		6.34	9.81		6.41	0	69.7	18.2	No
56-55-3	Benzo(a)anthracene	108	1050	244		10.2	20.4		6.8	4.71	U	9.42	13.4		6.34	34.4		6.41	4	244	63.4	No
50-32-8	Benzo(a)pyrene	150	1450	235		10.2	21.8		6.8	4.71	U	9.42	13		6.34	30.1		6.41	4	235	60.9	No
205-99-2	Benzo(b)fluoranthene	NC	NC	223		10.2	25.5		6.8	4.71	U	9.42	17.3		6.34	30.5		6.41	4	223	60.2	No
191-24-2	Benzo(g,h,i)perylene	170	1500	137		10.2	14.7		6.8	4.71	U	9.42	9.42		6.34	18.6		6.41	4	137	36.9	No
207-08-9	Benzo(k)fluoranthene	240	NC	214		10.2	22.4		6.8	4.71	U	9.42	14.6		6.34	27.6		6.41	4	214	56.7	No
218-01-9	Chrysene	166	1290	251		10.2	26.1		6.8	4.71	U	9.42	18.6		6.34	36.6		6.41	4	251	67.4	No
53-70-3	Dibenz(a,h)anthracene	33	260	38.5		10.2	3.4	U	6.8	4.71	U	9.42	3.17	U	6.34	3.205	U	6.41	1	38.5	10.6	No
206-44-0	Fluoranthene	423	2200	483		10.2	50.2		6.8	4.71	U	9.42	30.9		6.34	81.2		6.41	4	483	130.0	No
86-73-7	Fluorene	77.4	536	23.1		10.2	3.4	U	6.8	4.71	U	9.42	3.17	U	6.34	3.205	U	6.41	1	23.1	7.5	No
193-39-5	Indeno(1,2,3-cd)pyrene	17	1650	147		10.2	15.9		6.8	4.71	U	9.42	8.87		6.34	19.4		6.41	4	147	39.2	No
91-20-3	Naphthalene	176	561	5.1	U	10.2	3.4	U	6.8	4.71	U	9.42	3.17	U	6.34	3.205	U	6.41	0	5.1	3.9	No
85-01-8	Phenanthrene	204	1170	235		10.2	24		6.8	4.71	U	9.42	13.5		6.34	53.2		6.41	4	235	66.1	No
129-00-0	Pyrene	195	2000	418		10.2	45.4		6.8	4.71	U	9.42	29.3		6.34	73.9		6.41	4	418	114.3	No
SEQ NO-27-3	PAHs, total	1610	22800																--		--	
Polychlorinated Biphenyls (PCB): ITM List																						
	Aroclor 1016	NC		10.4	U	20.8	6.8	U	13.6	9	U	18	6.45	U	12.9	6.5	U	13	0	--	--	No
	Aroclor 1221	NC		10.4	U	20.8	6.8	U	13.6	9	U	18	6.45	U	12.9	6.5	U	13	0	--	--	No
	Aroclor 1232	NC		10.4	U	20.8	6.8	U	13.6	9	U	18	6.45	U	12.9	6.5	U	13	0	--	--	No
	Aroclor 1242	NC		10.4	U	20.8	6.8	U	13.6	9	U	18	6.45	U	12.9	6.5	U	13	0	--	--	No
	Aroclor 1248	NC		10.4	U	20.8	6.8	U	13.6	9	U	18	6.45	U	12.9	6.5	U	13	0	--	--	No
	Aroclor 1254	NC		10.4	U	20.8	6.8	U	13.6	9	U	18	6.45	U	12.9	6.5	U	13	0	--	--	No
	Aroclor 1260	NC		10.4	U	20.8	6.8	U	13.6	9	U	18	6.45	U	12.9	6.5	U	13	0	--	--	No
	Aroclor 1262	NC		10.4	U	20.8	6.8	U	13.6	9	U	18	6.45	U	12.9	6.5	U	13	0	--	--	No
	Aroclor 1268	NC		10.4	U	20.8	6.8	U	13.6	9	U	18	6.45	U	12.9	6.5	U	13	0			No
Total PCB		59.8	--																--	--	--	No

Table A. Royal River secondary sediment evaluation for Phase II Study (2013).

				EE-IMP1-SED			EE-IMP2-SED			EE-IMP3-SED			EE-IMP4-SED			EE-IMP5-SED						
CAS Registry Number	Parameter	Screening Benchmark (ug/kg)	Risk Level Benchmark (ug/kg)	Result half detection (if non-detect)	Laboratory Qualify	Sample Specific Reporting Limit	Result half detection (if non-detect)	Laboratory Qualify	Sample Specific Reporting Limit	Result half detection (if non-detect)	Laboratory Qualify	Sample Specific Reporting Limit	Result half detection (if non-detect)	Laboratory Qualify	Sample Specific Reporting Limit	Result half detection (if non-detect)	Laboratory Qualify	Sample Specific Reporting Limit	Number of Detections	Maximum Detected	Mean Detected	Contaminant of Potential Concern
Semi-volatile Organic Compounds (GC/MS) (See Note Below)**																						
				Half RL	EE-01	RL	Half RL	EE-02	RL	Half RL	EE-03	RL	Half RL	EE-04	RL	Half RL	EE-05	RL	0	--	--	No
	Phenol			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Bis(2-chloroethyl)ether			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	2-Chlorophenol			114	U	228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	1,3-Dichlorobenzene			114	U	228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	1,4-Dichlorobenzene			114	U	228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	Benzyl Alcohol			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	1,2-Dichlorobenzene			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	2-Methylphenol			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Bis(2-chloroisopropyl)ether			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Acetophenone			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	4-Methylphenol			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	N-Nitroso-di-n-propylamine			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Hexachloroethane			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Nitrobenzene			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Isophorone			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	2-Nitrophenol			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	2,4-Dimethylphenol			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Bis(2-chloroethoxy)methane			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	2,4-Dichlorophenol			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	1,2,4-Trichlorobenzene			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Naphthalene			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	4-Chloroaniline			114	U	228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	Hexachlorobutadiene			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	P-Chloro-M-Cresol			342	U	684	174.5	U	349	62	U	124	167	U	334	165.5	U	331	0	--	--	No
	2-Methylnaphthalene			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	1,2,4,5-Tetrachlorobenzene			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Hexachlorocyclopentadiene			114	U	228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	2,4,6-Trichlorophenol			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	2,4,5-Trichlorophenol			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	2-Chloronaphthalene			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	2-Nitroaniline			114	U	228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	Dimethylphthalate			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Acenaphthylene			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	2,6-Dinitrotoluene			114	U	228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	3-Nitroaniline			114	U	228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	Acenaphthene			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	2,4-Dinitrophenol			1370	U	2740	695	U	1390	248	U	496	670	U	1340	660	U	1320	0	--	--	No
	4-Nitrophenol			2280	U	4560	1160	U	2320	413.5	U	827	1115	U	2230	1105	U	2210	0	--	--	No
	2,3,4,6-Tetrachlorophenol			456	U	912	232.5	U	465	82.5	U	165	223	U	446	221	U	442	0	--	--	No
	Dibenzofuran			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	2,4-Dinitrotoluene			342	U	684	174.5	U	349	62	U	124	167	U	334	165.5	U	331	0	--	--	No
	Diethylphthalate			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Azobenzene			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	4-Chlorophenyl-phenylether			114	U	228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	Fluorene			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	4-Nitroaniline			114	U	228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	4,6-Dinitro-2-Methylphenol			1140	U	2280	580	U	1160	207	U	414	555	U	1110	550	U	1100	0	--	--	No
	NitrosoDiPhenylAmine(NDPA)/DPA			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	4-Bromophenyl-phenylether			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Hexachlorobenzene			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Pentachlorophenol			685	U	1370	348.5	U	697	124	U	248	334.5	U	669	331	U	662	0	--	--	No
	Phenanthrene			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Anthracene			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Di-n-butylphthalate			342	U	684	174.5	U	349	62	U	124	167	U	334	165.5	U	331	0	--	--	No
	Fluoranthene			114	U	228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	Pyrene			114	U	228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	Butylbenzylphthalate			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	3,3'-Dichlorobenzidine			342	U	684	174.5	U	349	62	U	124	167	U	334	165.5	U	331	0	--	--	No
	Benz(a)anthracene	**		577		228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	Chrysene	**		641		228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	Bis(2-Ethylhexyl)phthalate			456	U	912	232.5	U	465	82.5	U	165	223	U	446	221	U	442	0	--	--	No
	Di-n-octylphthalate			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Benzo(b)fluoranthene	**		666		228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	Benzo(k)fluoranthene	**		244		228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	Benzo(a)pyrene	**		472		456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Indeno(1,2,3-cd)Pyrene			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Dibenz(a,h)anthracene			114	U	228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	Benzo(ghi)perylene	**		320		228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	Aniline			114	U	228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No
	Carbazole			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Atrazine			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Benzaldehyde			1710	U	3420	870	U	1740	310	U	620	835	U	1670	830	U	1660	0	--	--	No
	Benzidine			17800	U	35600	9050	U	18100	3225	U	6450	8700	U	17400	8600	U	17200	0	--	--	No
	Caprolactam			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	n-Nitrosodimethylamine			114	U	228	58	U	116	20.7	U	41.4	55.5	U	111	55	U	110	0	--	--	No

Table A. Royal River secondary sediment evaluation for Phase II Study (2013).

				EE-IMP1-SED			EE-IMP2-SED			EE-IMP3-SED			EE-IMP4-SED			EE-IMP5-SED						
CAS Registry Number	**Parameter**	**Screening Benchmark (ug/kg)**	**Risk Level Benchmark (ug/kg)**	**Result half detection (if non-detect)**	**Laboratory Qualify**	**Sample Specific Reporting Limit**	**Result half detection (if non-detect)**	**Laboratory Qualify**	**Sample Specific Reporting Limit**	**Result half detection (if non-detect)**	**Laboratory Qualify**	**Sample Specific Reporting Limit**	**Result half detection (if non-detect)**	**Laboratory Qualify**	**Sample Specific Reporting Limit**	**Result half detection (if non-detect)**	**Laboratory Qualify**	**Sample Specific Reporting Limit**	**Number of Detections**	**Maximum Detected**	**Mean Detected**	**Contaminant of Potential Concern**
Semi-volatile Organic Compounds (GC/MS) (See Note Below [continued])**																						
	Biphenyl			228	U	456	116	U	232	41.35	U	82.7	111.5	U	223	110.5	U	221	0	--	--	No
	Pyridine			456	U	912	232.5	U	465	82.5	U	165	223	U	446	221	U	442	0	--	--	No
	Benzoic Acid			5700	U	11400	2905	U	5810	1035	U	2070	2785	U	5570	2760	U	5520	0	--	--	No
Inorganic/Metal		(mg/Kg)																				
7440-38-2	Arsenic	9.79	33	1.54		0.053	2.71		0.052	0.616		0.049	2.04		0.05	1.7		0.049	4	2.71	1.72	No
7440-43-9	Cadmium	0.99	4.98	0.111		0.021	0.174		0.021	0.026		0.02	0.1		0.02	0.056		0.02	1	0.174	0.09	No
7440-47-3	Chromium	43.4	111	9.29		0.21	22.4		0.206	4.43		0.196	16		0.2	11.1		0.196	4	22.4	12.64	No
7440-50-8	Copper	31.6	149	4.12		0.21	9.29		0.206	1.74		0.196	6.58		0.2	4.35		0.196	4	9.29	5.22	No
7439-92-1	Lead	35.8	128	5.18		0.063	0.665		0.062	1.5		0.059	4.68		0.06	3.33		0.059	4	5.18	3.07	No
7440-02-0	Nickel	22.7	48.6	6.95		0.105	15.2		0.103	3.87		0.098	11.2		0.014	7.5		0.098	4	15.2	8.94	No
7440-22-4	Silver	1.0	3.7	ND	U	0.051	ND	U	0.053	ND	U	0.049	ND	U	0.052	ND	U	0.046	0	0	0.00	No
7440-66-6	Zinc	121	459	24.2		1.05	50.4		1.03	10.8		0.982	36.7		0.998	23.4		0.981	4	50.4	29.10	No
7439-97-6	Mercury	0.18	1.06	ND	U	0.013	0.018		0.013	ND	U	0.011	ND	U	0.014	ND	U	0.011	1	0.018	0.02	No
Physical Parameters																						
--	Solids, Percent (%)	--	--	71.6	--		56	--		78.9	--		58.6	--		58.9	--		--	--	--	--
GS015	Gravel (%)	--	--	0.5	--	--	--	--	--	--	--	--	0.2	--	--	0.4	--	--	--	--	--	--
GS016	Coarse Sand (%)	--	--	0.36	--	--	--	--	--	--	--	--	0.1	--	--	0.4	--	--	--	--	--	--
GS017	Medium Sand (%)	--	--	55.1	--	--	1.5	--	--	13.9	--	--	2	--	--	2.4	--	--	--	--	--	--
GS018	Fine Sand (%)	--	--	35.2	--	--	51.6	--	--	82.9	--	--	62.9	--	--	77.5	--	--	--	--	--	--
GS019	Silt (%)	--	--	5.6	--	--	46.9	--	--	3.2	--	--	34.8	--	--	19.3	--	--	--	--	--	--
GS020	Clay (%)	--	--		--	--		--	--		--	--		--	--		--	--	--	--	--	--

NOTES:

NC	No Criteria
RL	Laboratory Reporting Limit
MDL	Method Detection Limit
mg/kg	milligram per kilogram, or parts per million (ppm)
ug/kg	microgram per kilogram, or parts per billion (ppb)
§	For PCBs, the full RL was used when determining the Total PCB concentration to be conservative
^	USEPA Region 3 and/or NOAA SQuil http://www.epa.gov/reg3hscd/risk/eco/btag/sbv/fwsed/R3_BTAG_FW_Sediment_Benchmarks_8-06.pdf
*	Laboratory qualifer assigned to sample result
P	The RPD between the results for the two columns exceeds the method-specified criteria.
U	Compound analyzed but not detected at a concentration above the reporting limit
J	Estimated value
B	Analyte is found in the sample and the associated method blank. The flag is used for tentatively identified compounds as well as positively identified compounds.
PG	Greater than 25% difference for detected concentrations between two GC columns. Unless otherwise specified in project QA plan, the lower of the two values is reported on the Form I.
	result exceeds the Screening Level Benchmark
	result exceeds the Probable Risk Level Benchmark
	Constituent was detected above the RL
**	Becauise the SIM analysis was conducted for PAHs, which is a much more sensitive analysis - the results from the SIM analysis will be used in the comparative evaluation.
^^	See toxicity profile in report that determined DDT compounds were not considered a COPC

Appendix B Toxicity Profile for Dichlorodiphenyl–trichloroethane (DDT) Pesticides

B.1 DICHLORODIPHENYL–TRICHLOROETHANE (DDT) PESTICIDES

Like many rivers that meander through historical agricultural farmland, the Royal River has apparently been impacted with the use of dichlorodiphenyl–trichloroethane (DDT), 1,1-dichloro-2,2-bis(p-dichlorodiphenyl)ethylene (DDE) and 1,1-dichloro-2,2-bis(p-chlorophenyl) ethane (DDD). DDT breakdown products are 1,1-dichloro-2,2-bis(pdichlorodiphenyl) ethylene (DDE) and 1,1-dichloro-2,2-bis(pchlorophenyl) ethane (DDD). These compounds, in turn, are ultimately transformed into bis(dichlorodiphenyl) acetic acid (DDA).

Organochlorine pesticides, such as DDT, were widely used in the United States (US) from the mid-1940s to the 1970's until it was banned in the US. At least 30 years after their use was prohibited, their presence is still observed in sediment and biota throughout much of the US, including New England. Even though DDT is no longer registered for use in the United States, it is used in other (primarily tropical) countries. DDT actually has rather low toxicity to humans (but high toxicity to insects, hence its use as an insecticide).

Environmental levels of DDT have been declining since the late 1960s, yet it continues to have the potential to enter rivers and streams from atmospheric deposition and the erosion of agricultural soils (Nowell et al.,1999 as reported in Wade et al., 2001). The DDT pesticides (collectively DDT, DDD, and DDE) typically have moderate-to-low water solubility and moderate-to-high environmental persistence, there is the potential for persistence and accumulation in sediment as well as aquatic biota.

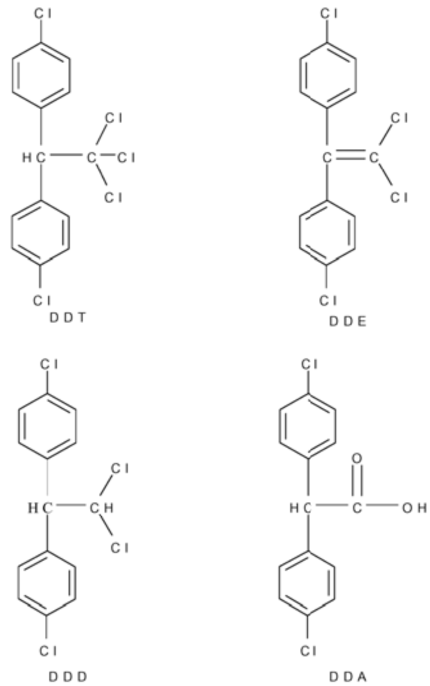

Figure B-1. DDT and breakdown products' structure (as modified from Wade et al., 2001).

B.1.1 Effects on aquatic species

DDT is highly toxic to many aquatic invertebrate species, thus its use as an insecticide. Reported 96-hr lethal concentration of 50 percent of a test population (LC_{50}) in various aquatic invertebrates (e.g., stoneflies, midges, crayfish, sow bugs) has been reported as ranging from 0.18 µg/L to 7.0 µg/L, and 48-hr LC_{50}'s are 4.7 µg/L for daphnia and 15 µg/L for sea shrimp (Wade et al., 2001). Other reported 96-hr LC_{50}'s for various aquatic invertebrate species range from 1.8 µg/L to 54 µg/L.

Early developmental stages of invertebrates appear to be more susceptible than adults to the effects of DDT (WHO 1989). DDT can also be highly toxic to fish species. Reported 96-hr LC50's for fish have been reported as less than 4.0 µg/L in Coho salmon, rainbow trout (8.7 µg/L), northern pike (2.7 µg/L), black bullhead (4.8 µg/L), bluegill sunfish (8.6 µg/L), largemouth bass (1.5 µg/L), and walleye (2.9 µg/L). The reported 96-hr LC50's in fathead minnow and channel catfish are 21.5 µg/L and 12.2 µg/L, respectively (Johnson and Finley, 1980 as reported in Wade et al., 2001).

A half- time for elimination of DDT from rainbow trout was estimated to be 160 days (WHO 1989). Bioaccumulation may also result in exposure to species which prey on fish or other aquatic organisms (e.g., birds of prey).

B.1.2 DDT breakdown in surface water

DDT may reach surface waters primarily by runoff, atmospheric transport, drift, or by direct application (e.g. to control mosquito-borne malaria). The reported half-life for DDT in the water environment is 56 days in lake water and approximately 28 days in river water (USEPA 1989). Howard et al. (1991) report a half-life of 7-350 days for DDT in surface waters. The main pathways for loss are volatilization, photodegradation, and adsorption to water-borne particulate and sedimentation. Aquatic organisms, as noted above, also readily take up and store DDT and its metabolites. Field and laboratory studies in the United Kingdom demonstrated that very little breakdown of DDT occurred in estuary sediments over the course of 46 days (WHO 1989). DDT has been widely detected in ambient surface water samples in the United States at a median level of 1 ng/L (parts per trillion) (ATSDR 1994; Van Ert and Sullivan, 1992 as reported in Wade et al., 2001).

B.1.3 References

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WHO (World Health Organization). 1989. *Environmental health criteria 83, DDT and its derivatives--environmental effects*. Geneva.

Appendix D Fluvial Geomorphic Evaluation Report

Potential Impacts of Dam Removal on Sediment Production and Sediment Transport on the Royal River, ME

Prepared for

Stantec Consulting Services, Inc.

On behalf of

Town of Yarmouth, ME

East Elm Street Dam

Prepared by

John Field
Field Geology Services
Farmington, ME

May 2013

Field Geology Services
Fluvial Geomorphology

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EXECUTIVE SUMMARY

A fluvial geomorphology assessment was conducted of the Royal River in Yarmouth, ME to determine the potential effects of removing the East Elm Street Dam on sediment production and sediment transport. Drawdown of the impoundment level by nearly 6.0 feet with dam removal at low flow conditions is likely to increase bank erosion over the short term in the sensitive sandy soils due to seepage forces. Long-term increases in bank erosion are also possible as channel migration will more readily occur as free-flowing conditions return to the impoundment. However, channel migration appears to have been limited during the 71-yr map record in reaches largely unaffected by the dam, so rapid channel migration and extensive long-term increases in bank erosion are not expected.

Increased sediment production following dam removal does not necessarily translate into increased sediment transport and delivery to the harbor. Large floods generate enormous stream power within the impoundment area, as evidenced by pools over 20 feet deep at low flow conditions, due to the confined nature of the channel (where no effective floodplain is present to dissipate the river's energy). Consequently, a single large flood likely transports a far greater amount of sediment through the impoundment than is cumulatively transported by a long series of smaller floods. Since large floods (i.e., 100-yr flood) are largely unaffected by the dam's presence (as demonstrated by hydraulic modeling), large amounts of sediment have likely continued to be delivered to the harbor with the dam in place, limiting sediment storage within the impoundment. Consequently, dam removal is unlikely to significantly increase sediment transport through the impoundment area and sediment delivery to the harbor. Sediment transport efficiency is likely to increase during smaller floods (i.e., 1.5-yr flood) but will have a limited impact on sedimentation in the harbor given the far greater influence of large floods. Smaller floods following dam removal are more likely to alter the morphology of the channel in the impounded area with some infilling of deep pools and shallowing of the channel as bars and riffles develop.

1.0 INTRODUCTION

This report describes a fluvial geomorphology assessment completed by Field Geology Services, LLC along the Royal River in Yarmouth, Maine (Figure 1). The Royal River drains a total watershed area of over 140 mi^2 before reaching the harbor just downstream of the I-295 bridge crossing. Two dams remain on the lower river in Yarmouth, the Bridge Street Dam and the East Elm Street Dam, with the impoundment upstream of the East Elm Street Dam extending at least 5.1 mi to the Route 9 bridge crossing in North Yarmouth (Figure 1). The geomorphic assessment of the Royal River was undertaken to determine how the proposed removal of the East Elm Street Dam could effect sediment delivery to, sediment transport through, and channel morphology of the river. Since changes in these conditions, in turn, may impact recreational use of the river and harbor, many residents are concerned about the proposed dam removals. (The Bridge Street Dam was not investigated during the geomorphic assessment given the limited length of the impoundment and lack of sediment storage observed during a drawdown in 2011.)

The fluvial geomorphology assessment consisted of three parts: 1) field observation of current bank and channel conditions; 2) an analysis of historical topographic maps and aerial photographs; and 3) a review of bathymetric data and hydraulic modeling results. The findings from each of these three areas of study are weaved into the following two-part discussion on how dam removal might alter sediment supply to the channel (through bank erosion and other factors) and sediment movement through the channel (and its associated delivery to the harbor). The geomorphic assessment results are based on a single day in the field and a two day review of maps, photos, and modeling results. Consequently, the conclusions expressed herein are largely based on best professional judgment, but could be further corroborated by additional studies such as: 1) a thorough literature review to determine the consequences of dam removals elsewhere; 2) detailed mapping that compares the location of bank erosion with bank composition and other features; and 3) extensive sediment sampling and sedimentological descriptions to calculate the volume of sediment stored in the impoundment. Definitive results from these additional studies, however, may remain elusive even with an extended commitment of both time and expense.

2.0 POTENTIAL CHANGES IN SEDIMENT SUPPLY

A field reconnaissance on May 15, 2013 revealed bank sediment throughout the impoundment area upstream of the East Elm Street Dam is composed of sand or finer material. A clay layer was observed at the base of some banks, suggestive of a glaciogenic origin. The channel likely flows through cohesive clay deposits throughout most of the impoundment given the highly sinuous meandering planform (Figure 1) and deep pools, in places over 20 feet deep at low flow (Figure 2). Bank heights vary considerably along the entire impoundment. In general, the banks appear considerably higher than the annual flood level as corroborated by: 1) perennial vegetation growing below the top of the banks (Figure 3); hydraulic modeling results that appear to show the 100-year flood contained within the banks at several cross sections (Figure 4); and 3) a hummocky topography surrounding the river that suggests the river is flowing through glacial deposits (Figure 5). While low banks that are likely flooded annually are present in places, these active floodplain surfaces are generally narrow and flanked by higher surfaces that converge on the river channel downstream. Consequently, flow on the floodplain is not likely to be effectively conveyed downstream with flows that do overtop the banks merely stored temporarily on the floodplain and returned to the adjacent channel when flow levels recede.

Significant bank erosion is currently present at the upstream end of the East Elm Street Dam impoundment in the vicinity of the Route 9 bridge (Figure 6a), but is less evident further downstream as the dam's influence becomes more pronounced (Figure 6b). This distribution of erosion is consistent with hydraulic modeling results that show flow gradient and velocity during smaller discharges is more significantly reduced closer to the dam (Stantec, 2013). (The impact of the dam decreases with increasing discharge such that the dam has minimal impact on discharges greater than the 100-yr flood.) Erosion is present in the lower impoundment, but appears most pronounced where flow velocities are likely to be locally increased such as on the outside bends of tight meanders (Figure 1 – Point A) or immediately downstream of past meander cutoffs (Figure 1 – Point B). Bank failure at such locations indicates that the largely sandy banks are sensitive to change. Consequently, changes in flow conditions due to dam removal could increase bank erosion and sediment delivery to the channel. Hydraulic modeling results show that water levels during low flow conditions will drop approximately 6.0 feet following dam removal. Flow seepage from river banks following a significant and rapid drop in water level can lead to bank instability, especially where the contact between permeable sand overlying impermeable clay is exposed (Lawson, 1985). Erosion resulting from this process is likely to occur on the Royal River given the sensitivity of the sandy banks, but should be only short-lived as the banks will equilibrate to the new water level relatively quickly. Given that greater bank erosion is present at the upstream end of the impoundment where the impacts of the dam are less significant, long term increases in erosion are possible elsewhere in the impoundment as a more natural flow regime returns and higher flow velocities are experienced during smaller floods. However, a comparison of 2012 aerial photographs available on Google Earth and a topographic map surveyed in 1941 (see http://docs.unh.edu/ME/frep44sw.jpg) appears to show no significant change in channel position anywhere in the impoundment during the 71-yr period, suggesting channel migration and long-term bank erosion rates could remain low following dam removal.

3.0 POTENTIAL CHANGES IN SEDIMENT TRANSPORT

The amount of sediment transported by a river during a flood is largely a function of flow depth and slope. The relationship between these factors is exponential such that small increases in slope and depth can result in dramatic increases in sediment transport. For rivers with a low floodplain that is regularly overtopped, flow depth, and as a consequence sediment transport capacity, essentially reaches a maximum when the banks are overtopped, because further increases in discharge are accommodated across a wide floodplain surface. (The flow overtopping an active floodplain is referred to as the bankfull discharge and is generally assumed to be equivalent to the 1.5-yr flood in temperate climates.) In contrast, flow depth and sediment transport during a 100-yr flood will be much greater than a 1.5-yr flood if no floodplain is present and the flow remains confined to the channel.

A river will transport sediment at its maximum potential capacity for a given discharge as long as enough sediment is available. As flow depth decreases in the waning stages of a flood, deposition results because the flow begins to lose its capacity to keep all of the sediment in motion. Deposition often occurs behind dams due to the upstream decrease in water surface slope (and flow velocity) with the deposition, at least initially, focused at the upstream end of the impoundment where the dam’s influence begins. This dam-induced deposition only results if the flow is influenced by the dam. On the Royal River, hydraulic modeling shows that the water surface is higher and slope lower with the dam in place during smaller floods (i.e., 1.5-yr flood) while large floods (i.e., 100-yr flood) are virtually unaffected by the dam (Figure 7). Given that large floods appear to remain largely confined to the channel in the impoundment area (Figure 4), much greater sediment transport would be expected during a single large flood than cumulatively results from a long series of smaller floods whose sediment transport effectiveness has been altered by the dam.

Since sediment transport has likely been unaffected by the dam, sediment has likely continued to pass over the dam with little sediment storage in the impoundment. Run-of-the river dams such as the Royal River can transport sediment over the dam during large floods due to the generation of flow lines projecting up in the water column at the upstream face of the dam (Csiki and Rhoads, 2010). The sandy nature of the sediment on the Royal River makes sediment transport over the dam more likely. While some increases in sediment transport through the impoundment and into the harbor during smaller floods may result from dam removal, the amount of sediment moved during larger floods, representing the vast majority of the sediment moved through the confined river channel, will essentially be unchanged with dam removal. Consequently, removal of the East Elm Street Dam is unlikely to greatly increase sediment delivery to the harbor.

The greater transport efficiency of the smaller floods to result from dam removal is more likely to rework sediment within the impoundment area and modify channel form rather than increase sediment delivery to the harbor. Currently, the channel within the impoundment displays channel characteristics likely created by large floods. Deep pools, some over 20 feet deep at low flow (Figure 2), are present and most likely form by the greater stream power generated by large floods confined to the channel. On the Royal River, the spacing of pools is greater than 12 times the channel width (Figures 2 and 4), while pool spacing is typically less than 7 times the channel width on rivers with an active floodplain where smaller floods are the dominant channel-forming discharge (Leopold et al., 1964). While large floods will continue to have an impact on channel form, the increased efficiency of smaller floods may result in some channel modifications with deep pools, at least partially, filling in with sediment and more closely spaced shallow pools developing as smaller floods rework what sediment is stored at the upstream end of the impoundment and derived from increased erosion of the banks following dam removal. The shallowest point in the channel at low flow conditions immediately following dam removal will be slightly more than 1.5 feet (Figure 2), but will likely become shallower as sediment is reworked and riffles develop between pools.

4.0 CONCLUSIONS

Removal of the East Elm Street Dam is likely to increase bank erosion in the upstream impoundment, but is less likely to increase sediment delivery to the harbor as large floods, given the confined nature of the channel, appear responsible for the bulk of sediment delivery to the harbor and have been essentially unaffected by the dam's presence. Sediment released by additional bank erosion is more likely to remain at the base of the bank or be reworked within the impoundment by smaller floods whose transport efficiency will increase with dam removal. The modification of channel form due to the greater effectiveness of small floods could have minor impacts to recreational uses within the impoundment area. The slight increase in flow velocity at low flow conditions and shallowing of flow depths as riffles develop may reduce the number of suitable days and river length where ice conditions are appropriate for skating in the winter. Canoeing and other boating may become more difficult in the shallowest areas, but the effectiveness of large floods may periodically reverse these trends and lead to deepening of the sandy channel substrate. Habitat complexity is likely to increase with dam removal as more frequent pools, riffles, and point bars develop over time. Further studies could be conducted to corroborate the findings of this assessment, but the distinct confined nature of the impoundment on the Royal River upstream of the East Elm Street Dam has likely limited sediment storage behind the dam and, as a consequence, will minimize the impact of dam removal within the impoundment area and the harbor downstream.

5.0 REFERENCES

Csiki, S., and Rhoads, B., 2010. Hydraulic and geomorphological effects of run-of-river dams: Progress in Physical Geography, v. 34, p. 755-780.

Lawson, D.E., 1985. Erosion of northern reservoir shores: An analysis and application of pertinent literature: US Army Corps of Engineers Cold Regions Research and Engineering Laboratory Monograph 85-1. 198 pp.

Leopold, L.B., Wolman, M.G., Miller, J.P., 1964. Fluvial Processes in Geomorphology: W.H. Freeman and Co.: San Francisco, CA, 522 pp.

Stantec, 2013. Royal River restoration project: Phase II analysis and reporting: Evaluation of restoration impacts (Draft): Unpublished report, 44 p.

FIGURES

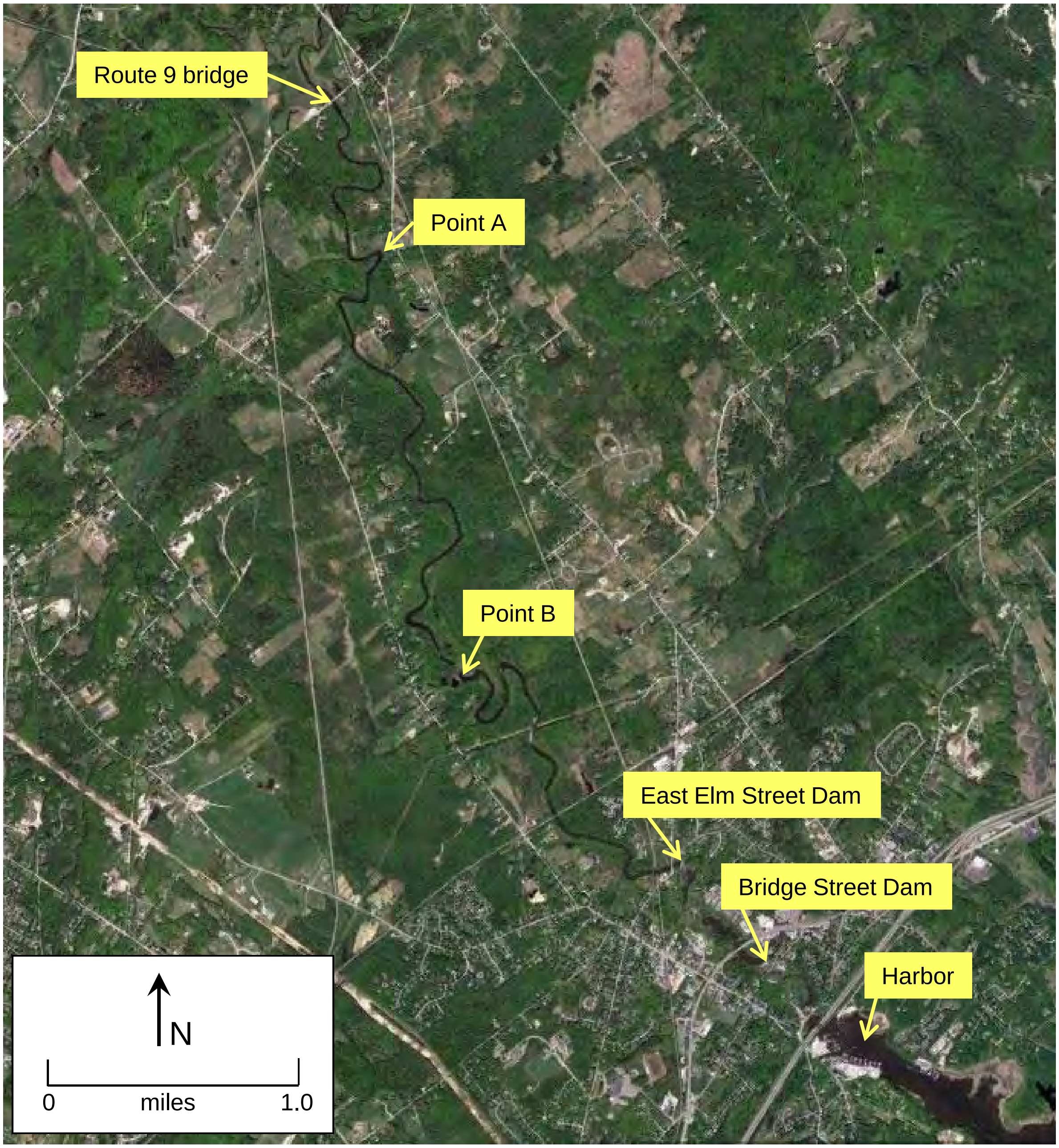


Figure 1. Google Earth image of Royal River showing various features referred to in text..

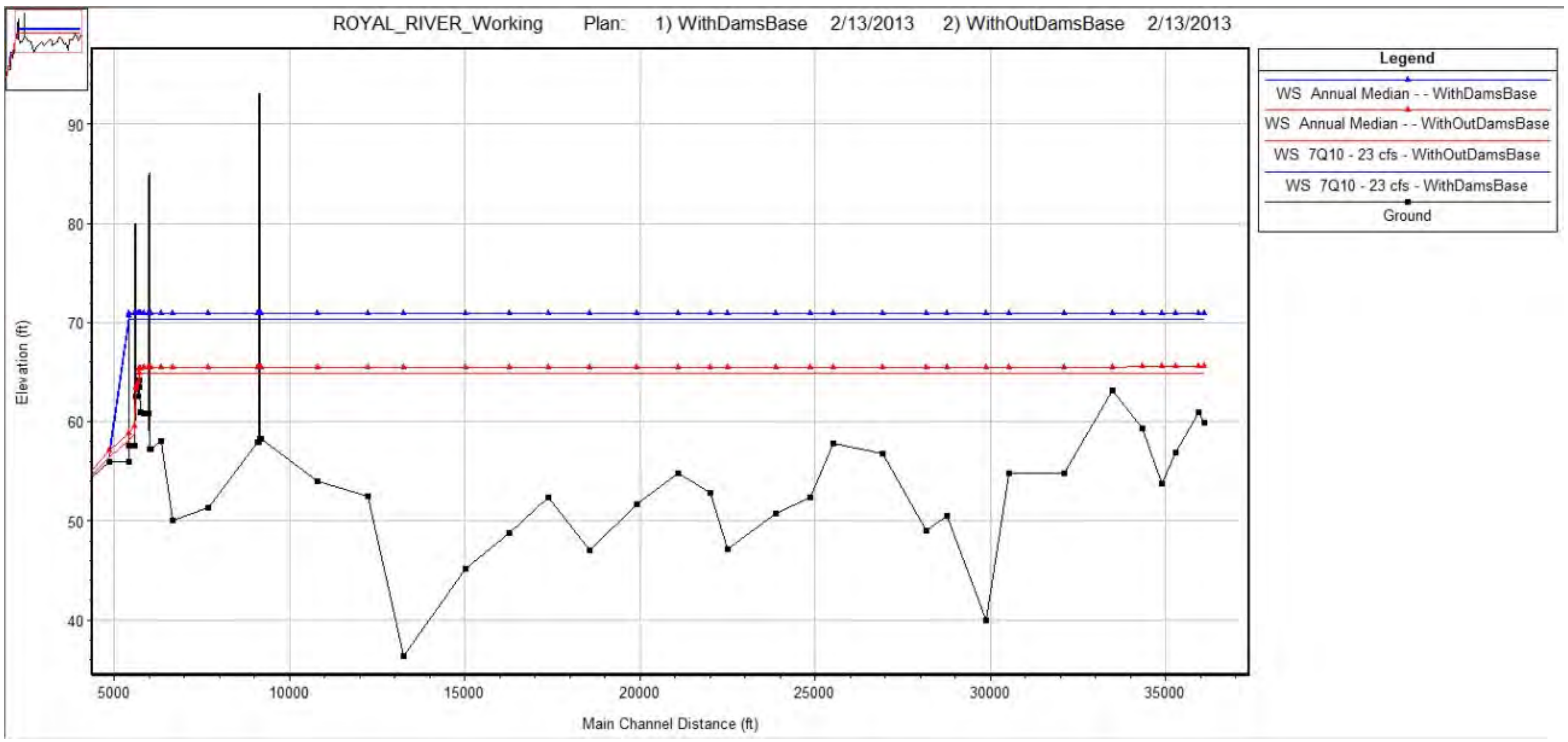


Figure 2. Longitudinal profile of hydraulic modeling results showing predicted water levels at low flow conditions under current conditions and following dam removal. From Stantec (2013).

Figure 3. Perennial vegetation growing below the top of the channel banks within the impoundment upstream of the East Elm Street Dam.

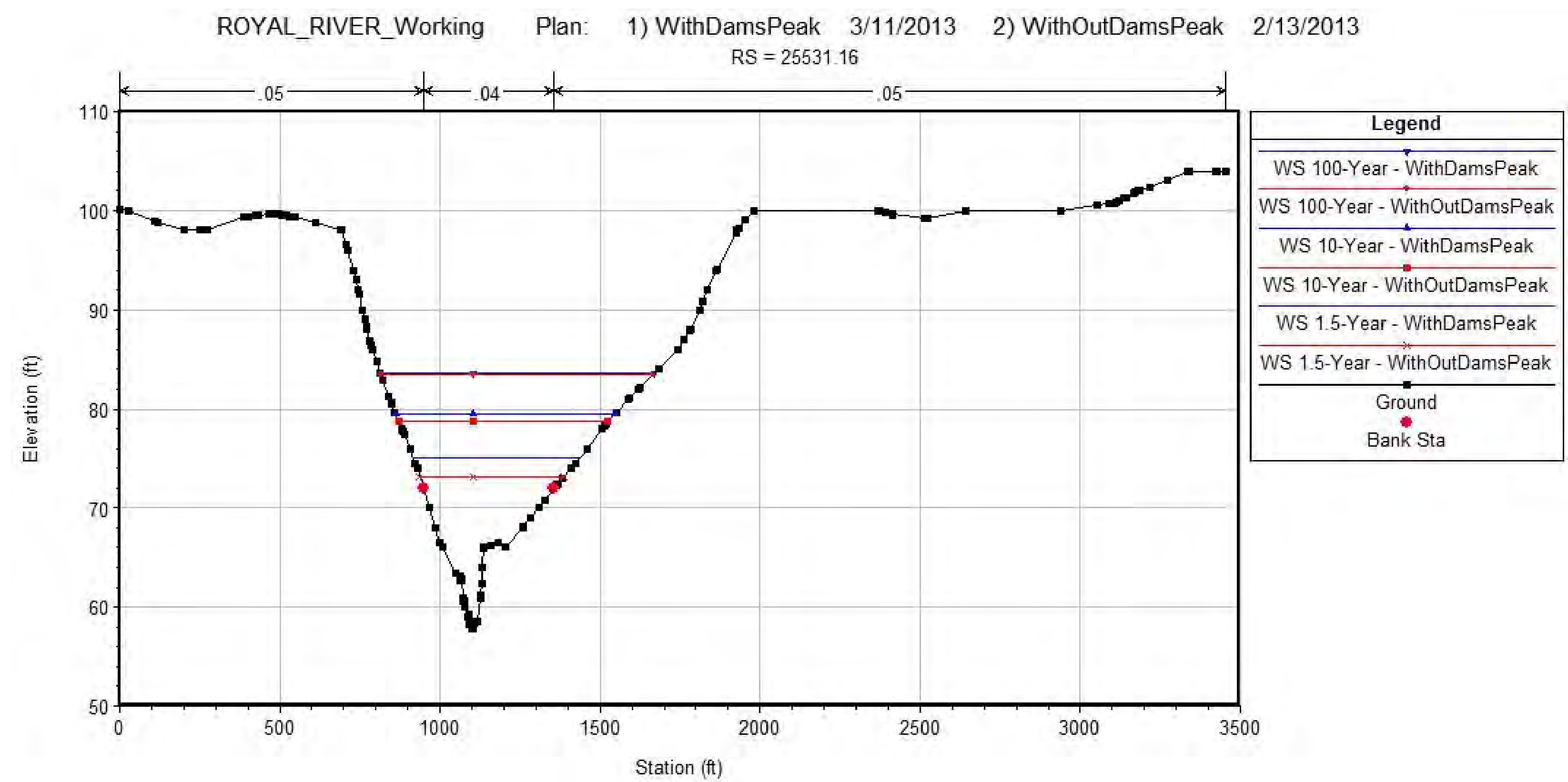


Figure 4. Cross section of hydraulic modeling results showing predicted 100-yr flood level confined within the channel banks. From Stantec (2013).

Figure 5. Hummocky topography as shown on a 1944 topographic map surrounds the Royal River, suggesting the channel flows through glaciated terrain.

a)

b)

Figure 6. Bank erosion is evident a) at the upstream end of the impoundment but is b) less evident further downstream in the impoundment.

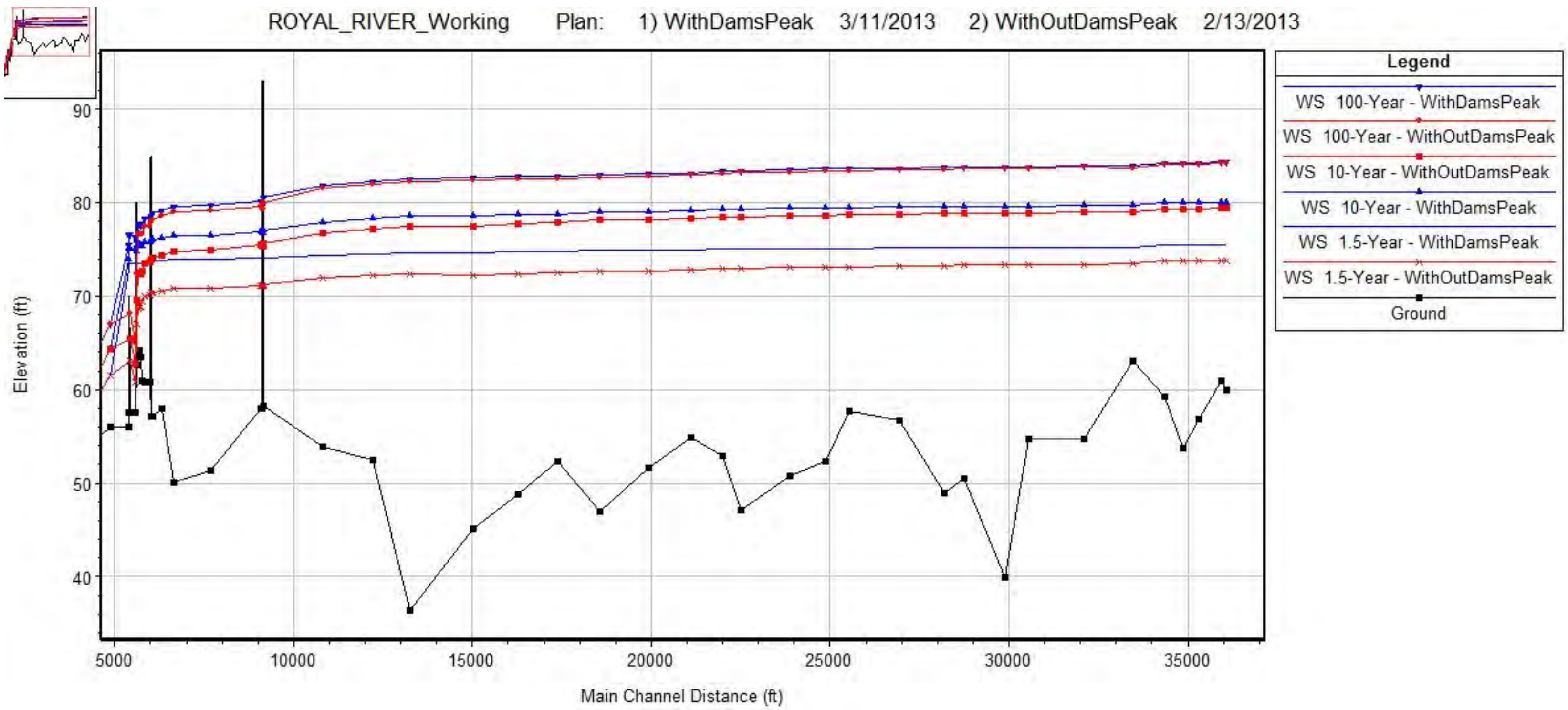
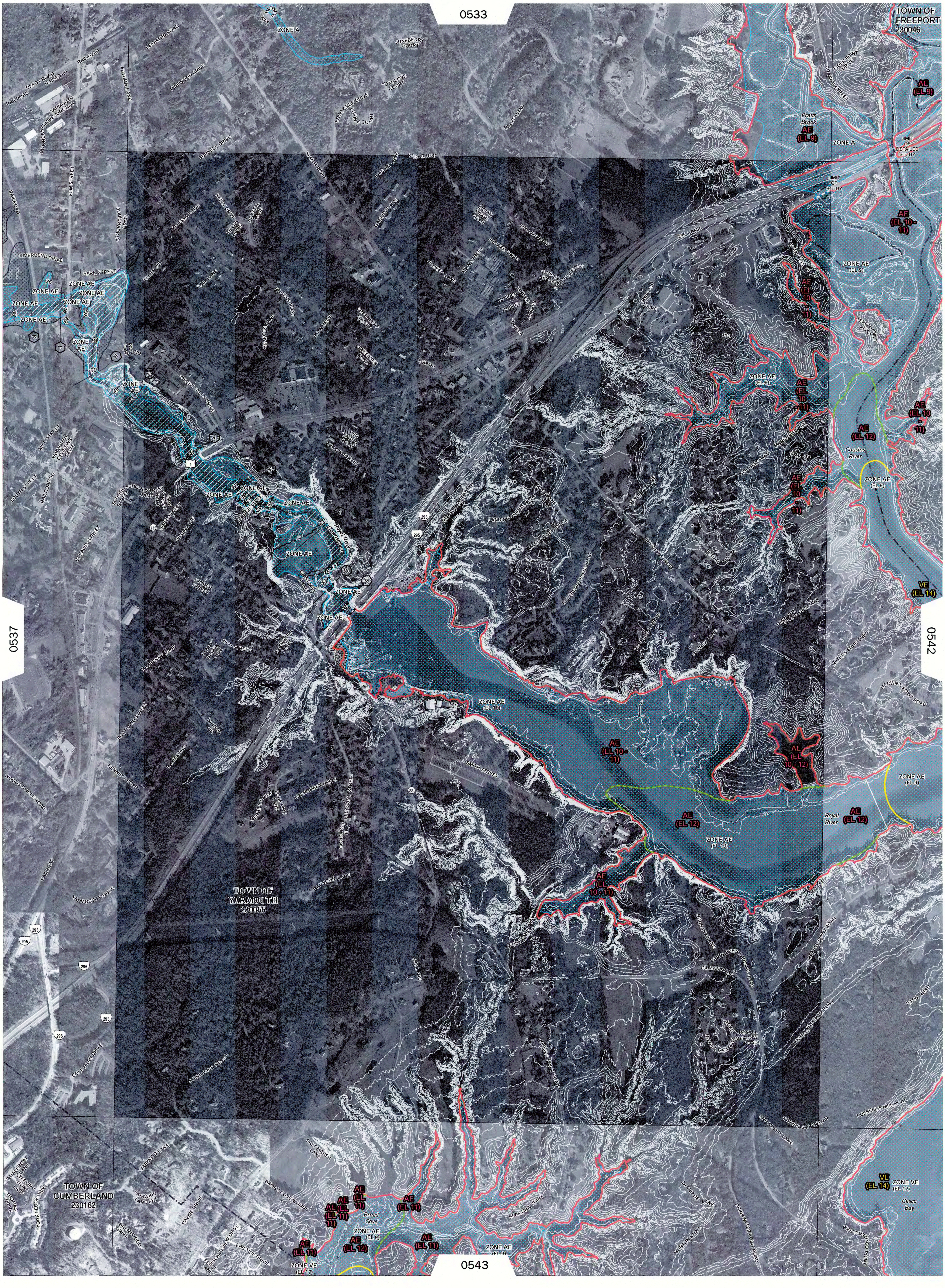


Figure 7. Longitudinal profile of hydraulic modeling results showing predicted water levels for various flood levels under current conditions and following dam removal. Note 100-yr flood level remains virtually unchanged with dam removal. From Stantec (2013).

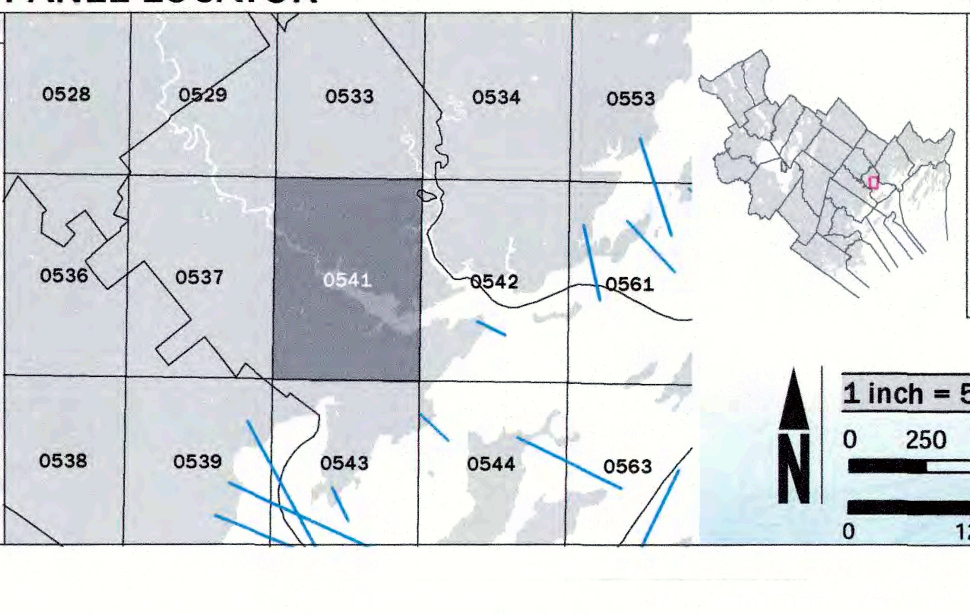
Appendix E Draft FEMA FIRM



LEGEND

Proposed Study	Preliminary Study (2009)
Coastal Transect	Base Flood Elevation
V/A Boundary	Cross section line
1 % Annual Chance Floodplain Boundary	Transect line
0.2 % Annual Chance Floodplain Boundary	1% Annual Chance Floodplain Boundary
Primary Frontal Dune Boundary	0.2% Annual Chance Floodplain Boundary
Limit of Wave Setup	Floodway boundary
Limit of Moderate Wave Action (LiMWA)	Zone Breaks
Limit of Study	CBRS and OPA boundary
Zone A provided by Ransom Consulting, Inc.	SPECIAL FLOOD HAZARD AREAS (SFHAs) SUBJECT TO INUNDATION BY THE 1% ANNUAL CHANCE FLOOD
	FLOODWAY AREAS IN ZONE AE
	OTHER FLOOD AREAS
	COASTAL BARRIER RESOURCES SYSTEM (CBRS) AREAS
	OTHERWISE PROTECTED AREAS (OPAs)

PANEL LOCATOR



Map Projection:
NAD 1983 UTM Zone 19N

1 inch = 500 feet 1:6,000

0 250 500 1,000 1,500 2,000 Feet

0 125 250 500 Meters

COMMENTS

The new VE Zones and associated elevations shown are for information purposes only. These areas do not include the zone breaks which will be shown on the final maps.

COASTAL WORKMAP

Panel Contains:

CUMBERLAND COUNTY, ME

COMMUNITY	NUMBER
YARMOUTH, TOWN OF	230055

PANEL 0541 of 0862

DRAFT

STARR

SCALE
1:6,000
MAP NUMBER
0541F
RELEASE DATE
8/8/8888

Appendix F HEC-RAS Model Setup Documentation

Memo

To: File

File: 195600838

From: Michael Chelminski
Topsham ME Office

Date: September 5, 2013

Reference: HEC-RAS Model Setup

This memo presents information relevant to the setup of the HEC-RAS hydraulic model developed by Stantec as part of the Royal River Restoration Project: Phase II Analysis and Reporting.

HEC-RAS MODEL SETUP

This section presents information regarding the HEC-RAS model files and setup. Files used for analyses that are presented in this section of the report include those used for evaluation of existing conditions and conditions representing removal of Bridge Street and East Elm Street dams. Files referenced previously in this report that were used for evaluation of the hydraulic model suitability are referenced in the following tables but are "grayed-out."

HEC-RAS GEOMETRY FILES

Geometry files for the HEC-RAS model were developed for multiple project uses, including simulating geometric conditions associated with existing conditions and with the Bridge Street and East Elm Street Dams removed and evaluation of model suitability. Table 1 presents the names and numbers of HEC-RAS geometry files referenced in this report.

Table 1: HEC-RAS Geometry Files

Geometry File	*Description*
RR_WithDams (*.g01)	*Existing conditions*
RR_WithOutDams (*.g02)	*Dams removed*
RR_WithOutDamsNoEESB (*.g03)	*Dams and EES Bridge removed*
RR_WithDamsmN03 (*.g04)	*Existing with channel "n" of 0.030*
RR_WithDamsmN05 (*.g05)	*Existing with channel "n" of 0.050*

"*" – a "wildcard" indicating other information and/or a continuation of a title or filename.

HEC-RAS FLOW FILES

Flow files include hydrologic flows and boundary conditions for paring with HEC-RAS geometry files for steady-state hydraulic simulations. Table 2 includes four flow files that are referenced in this report. The primary flow files are those representing peak flows and base flows in the project reach of the Royal River. Secondary flow files included below include peak flow as developed by STI and a “continuous” flow file that includes flows from 1,000 cfs to 20,000 cfs in increments of 1,000 cfs. The continuous flow file was used to gain insight into the hydraulic model response during evaluation of the HEC-RAS model and information for plotting of hydrographs at cross-sections.

Table 2: HEC-RAS Flow Files

Flow File	*Description*
RR_PeakFlow (*.f05)	*Peak flows from 1.5- to 500-year RI event*
RR_BaseFlow (*.f06)	*Annual, low, and monthly flows*
RRFlowSebagoTechnics (*.f04)	*Sebago Technics 100- and 500-year flows*
RRFlowContinuous (*.f03)	*A range of flows from 1000 to 20,000 cfs*

“*” – a “wildcard” indicating other information and/or a continuation of a title or filename.

HEC-RAS PLAN FILES

HEC-RAS “plan” files represent pairs of geometric and flow files for use in steady-state hydraulic simulations in HEC-RAS. Table 3 includes four primary flow files that were used for simulation of existing conditions and with the Bridge Street and East Elm Street dams removed. Other plan files described in Table 3 were used to evaluate model sensitivity and to gain insight into the hydraulic model response during evaluation of the HEC-RAS model.

Table 3: HEC-RAS Plan Files

HEC-RAS Plan File	Short ID	Geometry File	Flow File
WithDamsPeak (*.p11)	WithDamsPeak	RR_WithDams	RR_PeakFlow
WithDamsBase (*.p12)	WithDamsBase	RR_WithDams	RR_BaseFlow
WithOutDamsPeak (*.p13)	WithOutDamsPeak	RR_WithOutDams	RR_PeakFlow
WithOutDamsBase (*.p14)	WithOutDamsBase	RR_WithOutDams	RR_BaseFlow
Validation* (*.p10)	SebagoVal	RR_WithDams	RRLowSebago*
Sen_nM03 (*.p05)	Sen_mN03	RR_WithDamsmN03	RR_PeakFlow
Sen_nM03 (*.p04)	Sen_mN05	RR_WithDamsmN05	RR_PeakFlow
DamsContinuous (*.p09)	DamsC	RR_WithDams	RRFlowCont*
NoDamsContinuous (*.p08)	NoDamsC	RR_WithDamsOut	RRFlowCont*

“*” – a “wildcard” indicating other information and/or a continuation of a title or filename.

STANTEC CONSULTING SERVICES INC.

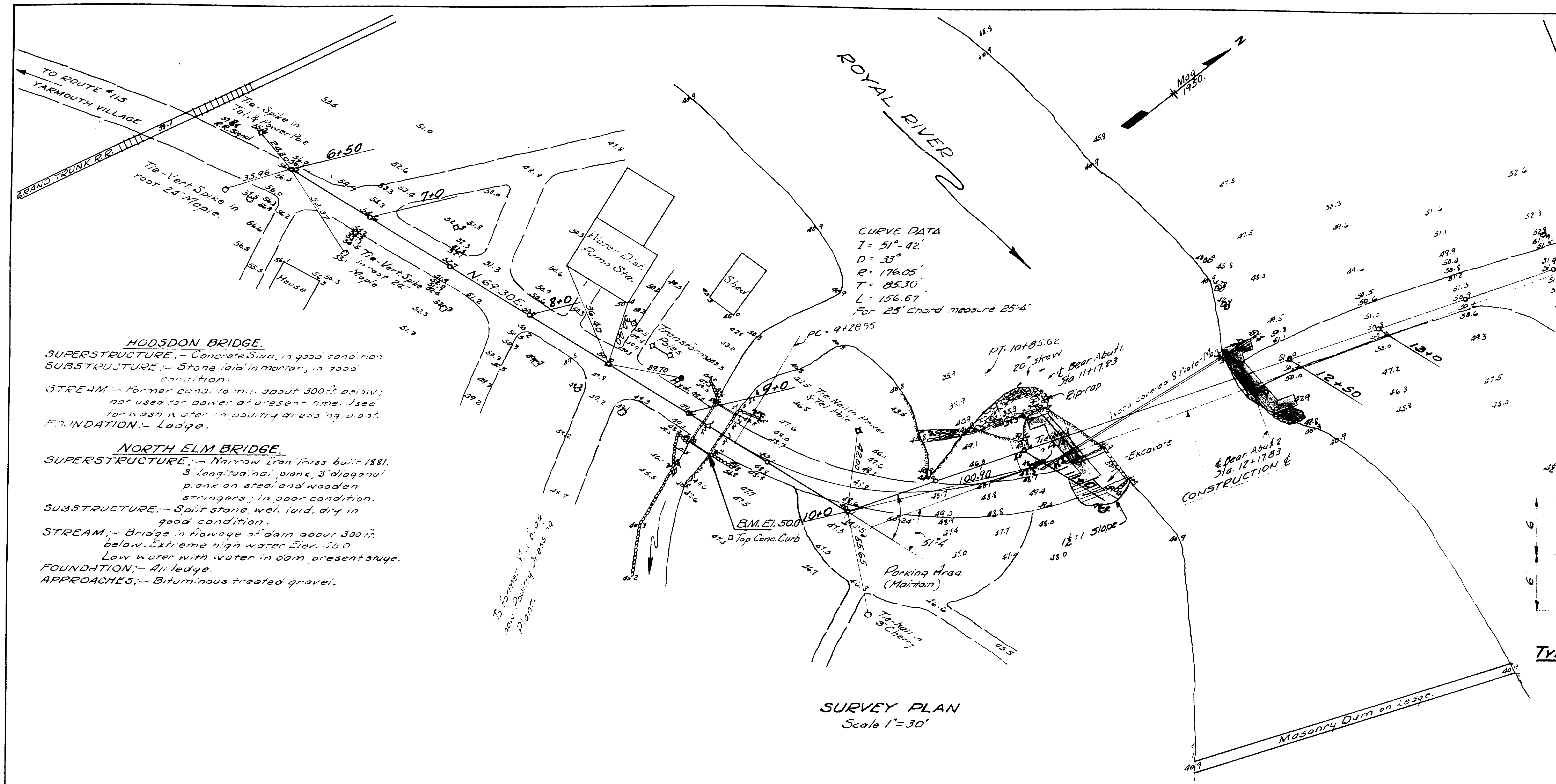
Michael Chelminski, P.E.
Principal, Environmental Services
michael.chelminski@stantec.com

Appendix G Bridge Plans

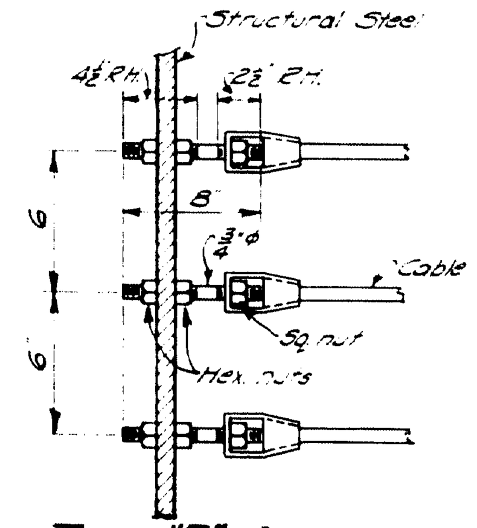
Materials included in this section includes plans received for the following three bridges:

- **East Elm Street Bridge (from Maine DOT)**
- **Maine Central Railroad Bridge (from Pan Am Railways)**
- **State Route 9 Bridge (from Maine DOT)**

East Elm Street Bridge (from Maine DOT)



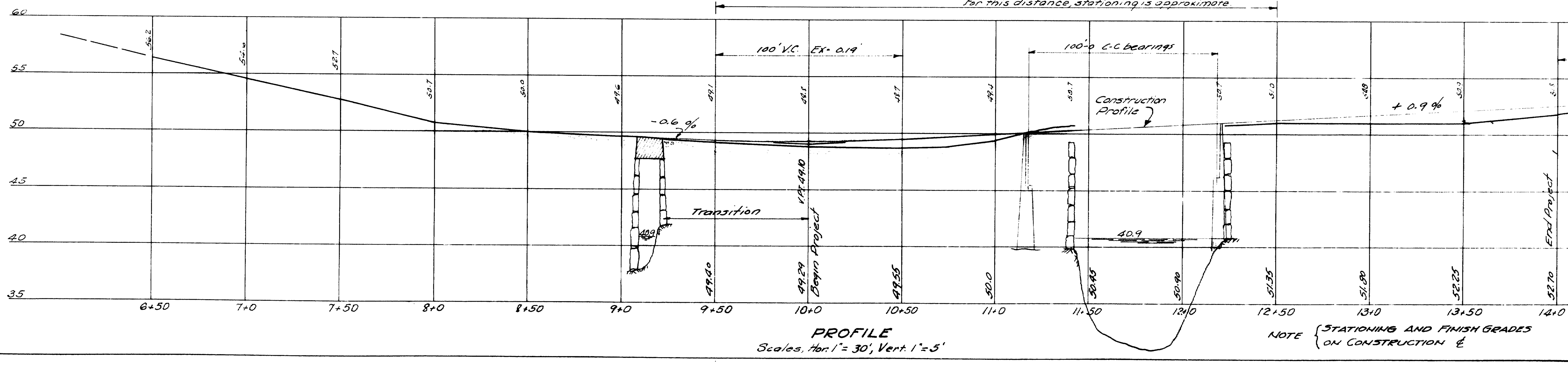
SURVEY PLAN
Scale 1" = 30'



TYPE "B" ANCHOR (Galv.)
For guard rail at bridge 4-Req'd.

HODSDON BRIDGE.
SUPERSTRUCTURE:– Concrete Slab, in good condition
SUBSTRUCTURE:– Stone laid in mortar, in good condition.
STREAM:– Former canal to mill about 300 ft. below; not used for power at present time. Used for wash water in poultry dressing plant.
FOUNDATION:– Ledge.

NORTH ELM BRIDGE.
SUPERSTRUCTURE:– Narrow Iron Truss built 1881. 3" Longitudinal plank, 3" diagonal plank on steel and wooden stringers; in poor condition.
SUBSTRUCTURE:– Split stone well laid, dry in good condition.
STREAM:– Bridge in flowage of dam about 300 ft. below. Extreme high water Elev. 55.0 Low water with water in dam present stage.
FOUNDATION:– All ledge.
APPROACHES:– Bituminous treated gravel.



PROFILE
Scales, Hor. 1" = 30', Vert. 1" = 5'

NOTE {STATIONING AND FINISH GRADES ON CONSTRUCTION ℄

Plotted - Maguire Traced - C.S.A.	BRIDGE – 5444

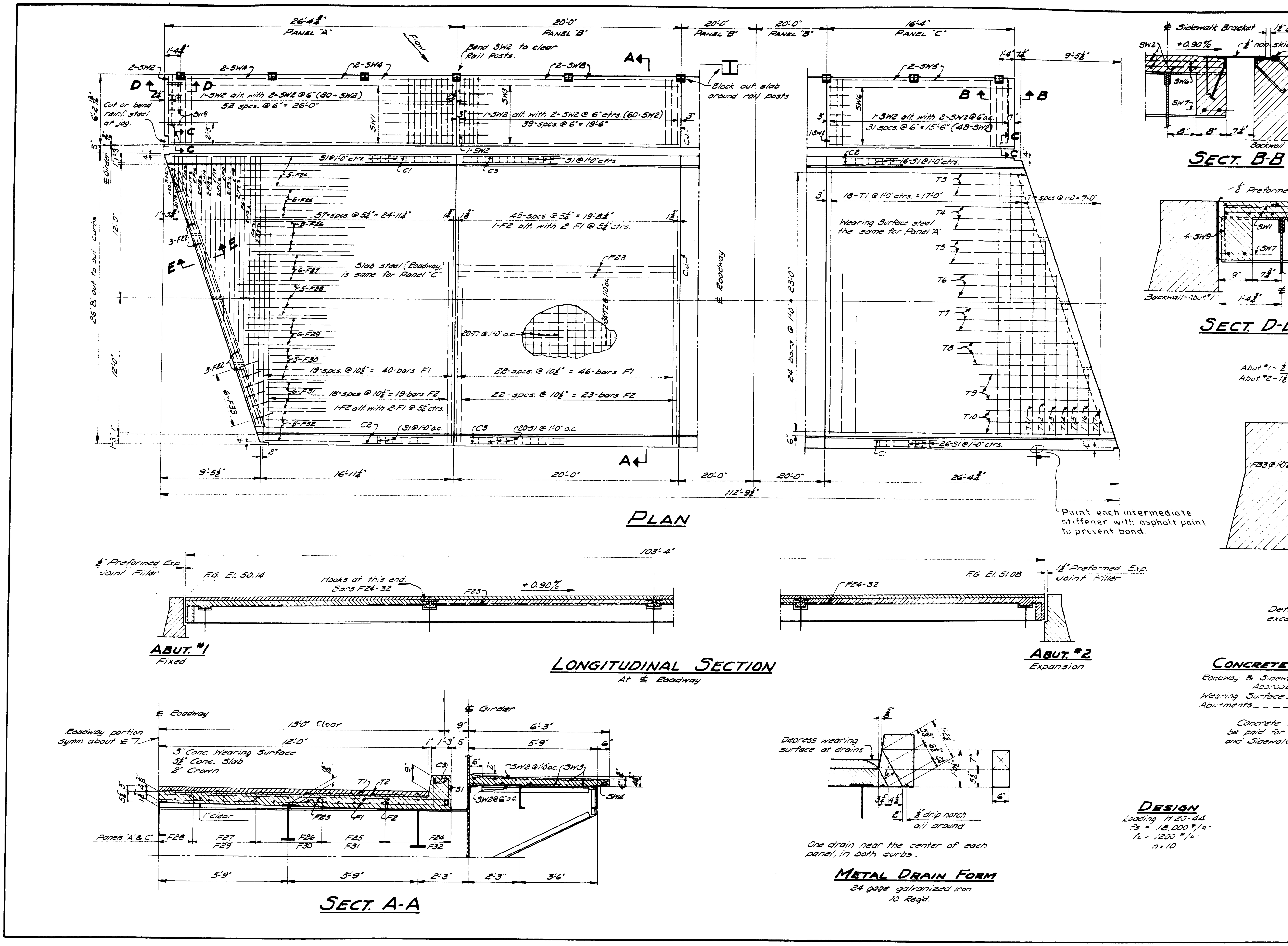
STATE HIGHWAY COMMISSION
BRIDGE DIVISION

NORTH ELM BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
YARMOUTH
CUMBERLAND COUNTY
SURVEY

SHEET 1 OF 10 AUGUSTA, MAINE SEPT. 1950

55-162

0 1 2 3 4 5 INCHES



DESIGN - EVERETT DETAIL - L.H.W.
TRACE - CLARK
CHECK -

BRIDGE - 5444

STATE HIGHWAY COMMISSION
BRIDGE DIVISION

NORTH ELM BRIDGE

OVER

ROYAL RIVER

IN THE TOWN OF

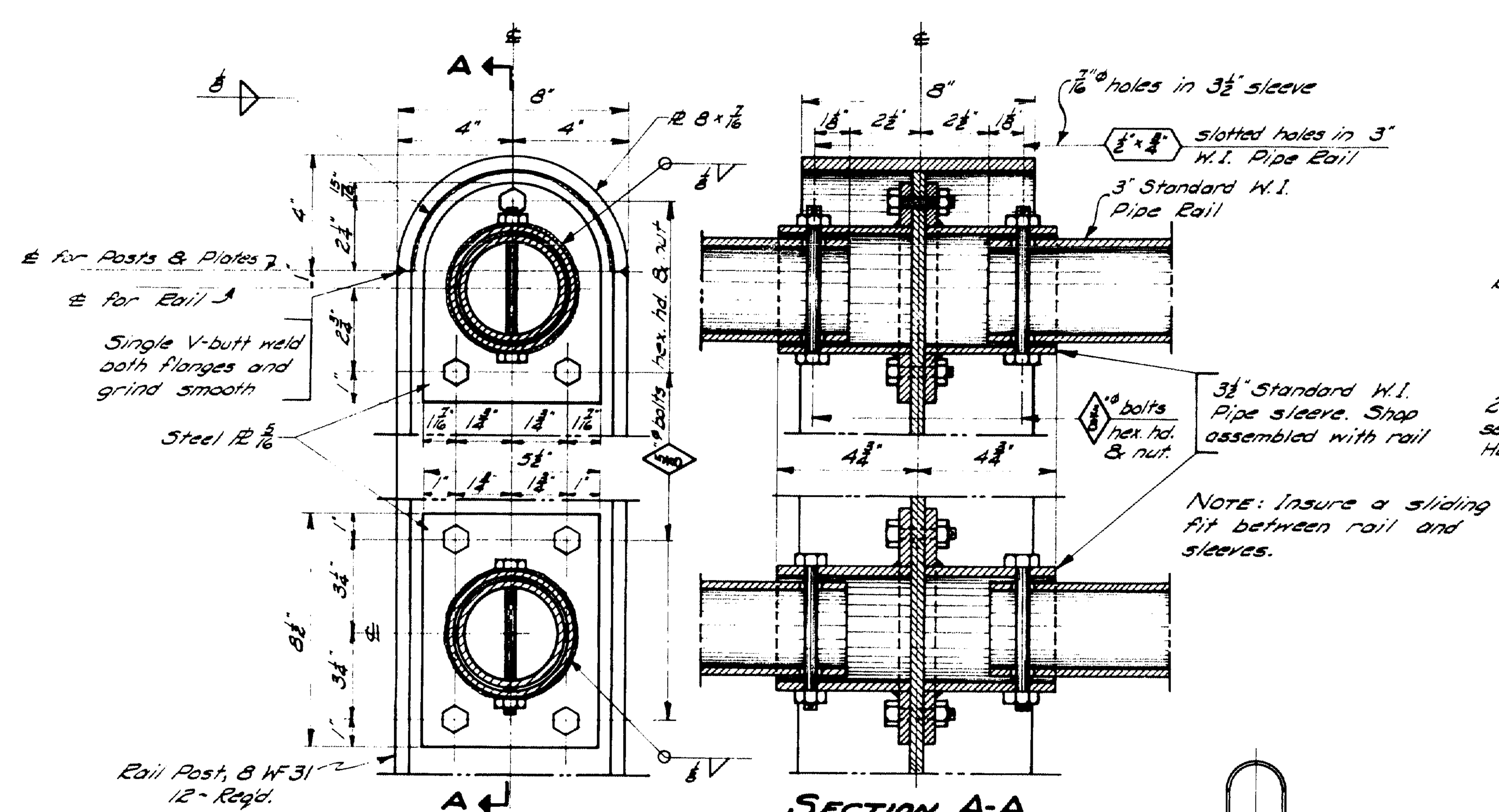
YARMOUTH
CUMBERLAND COUNTY

SUPERSTRUCTURE

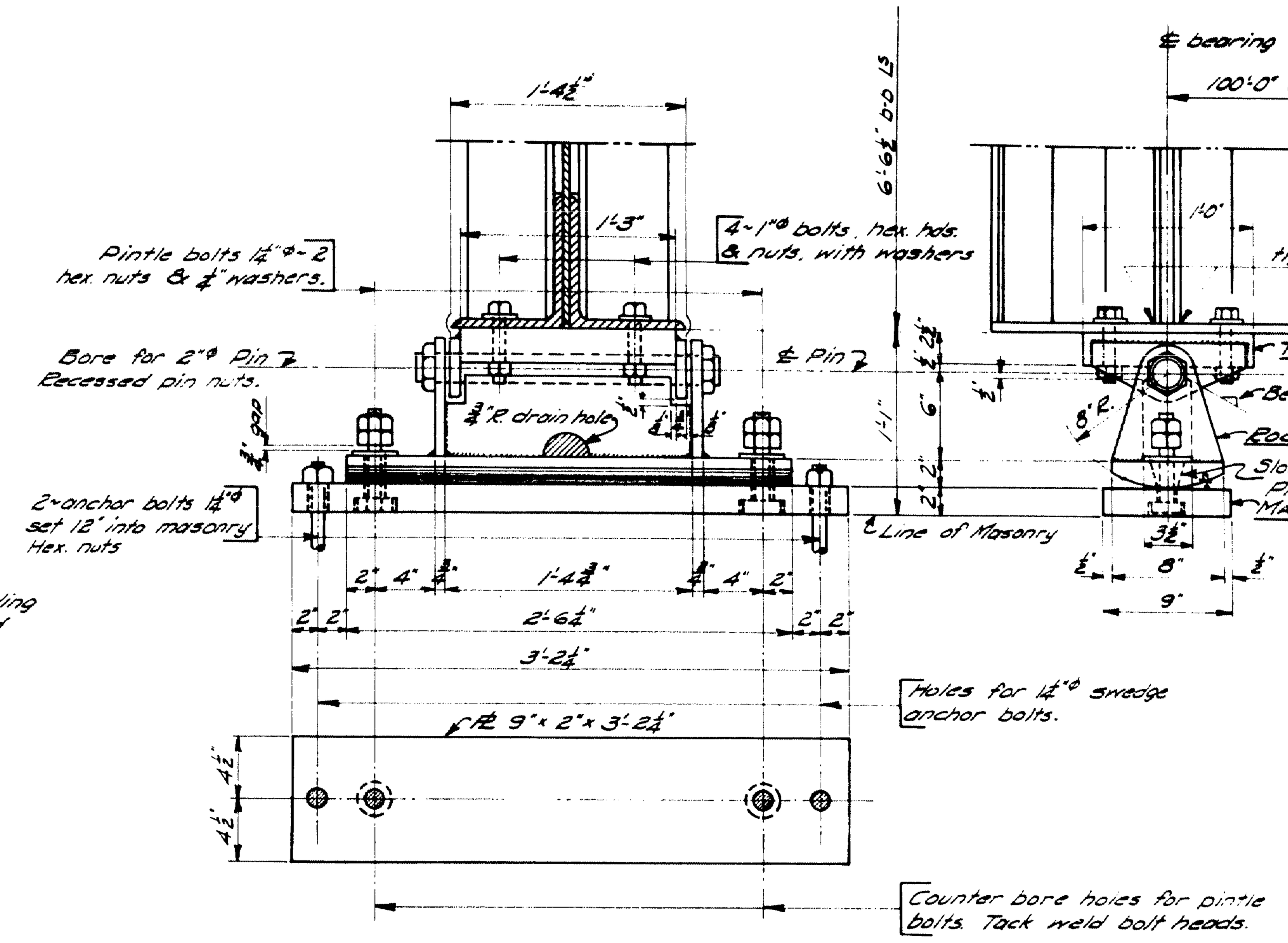
SHEET 9 OF 10 AUGUSTA, MAINE JUNE 1955

55-170

0 1 2 3 4 5 INCHES

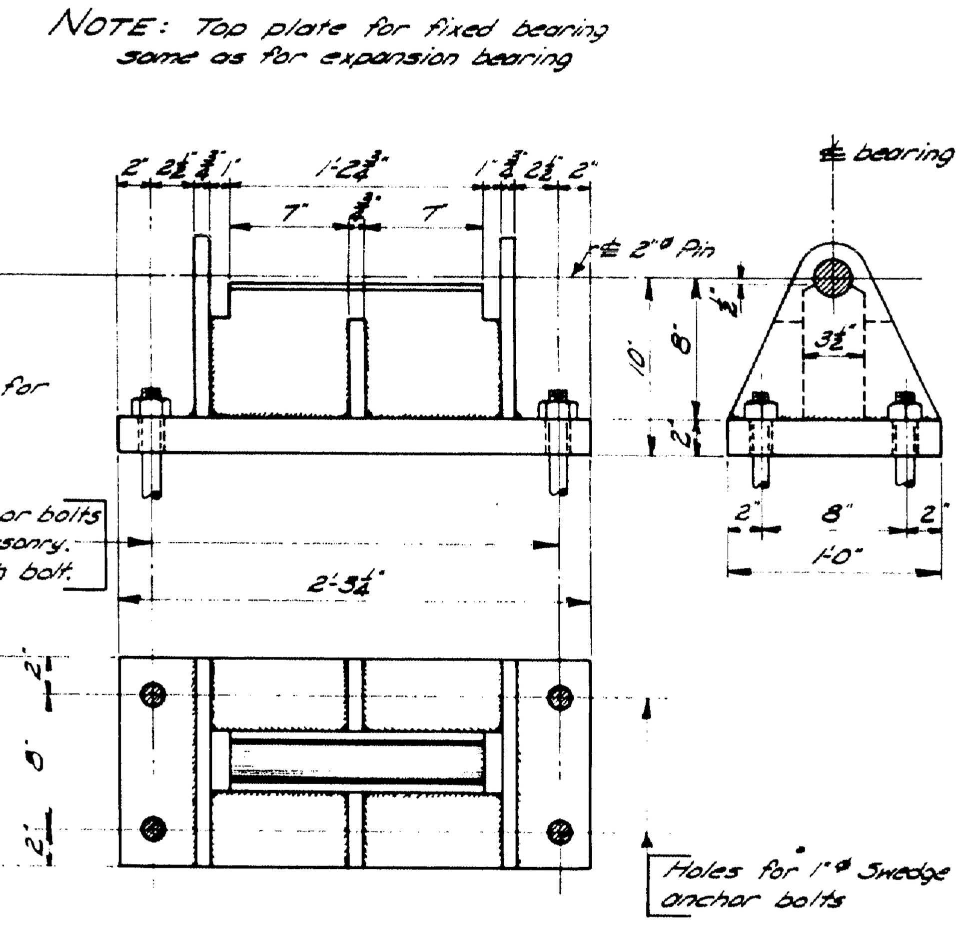


SECTION A-A



EXPANSION BEARING

2-Required

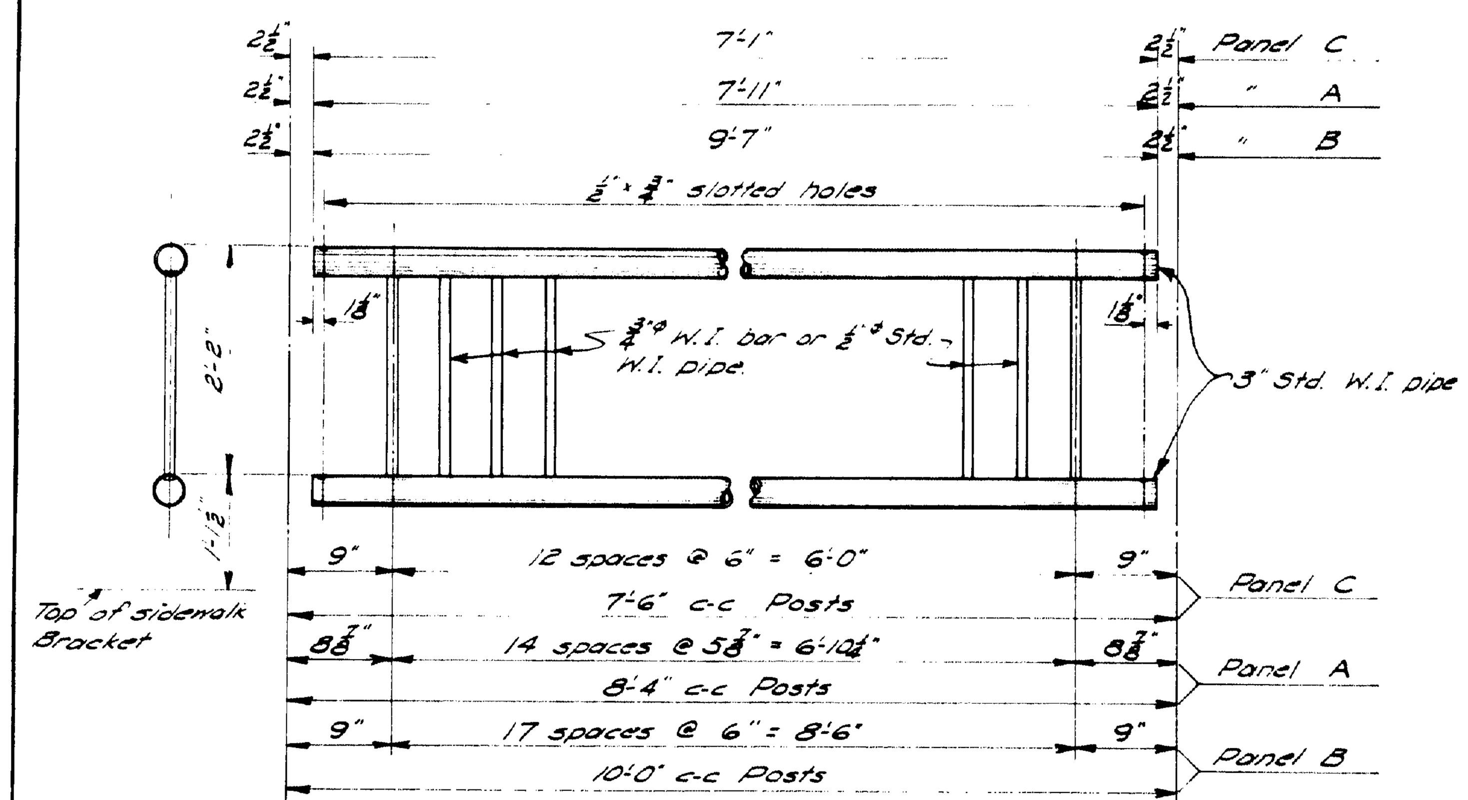


FIXED BEARING

2 Required

BEARING DETAILS

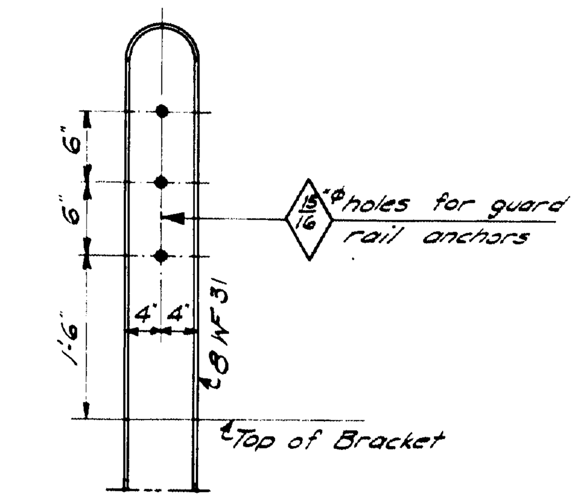
All welds to be shop ⅜ fillet



NOTE: 1 7/16"ø holes for ⅞"ø bars or 7/8"ø holes for ½" W.I. pipe so that the bar or pipe will extend through wall of 3" pipe. Bars or pipe to be fillet welded to 3" pipe top and bottom. All exposed joints shall be finished by grinding or filling to give a neat appearing job.

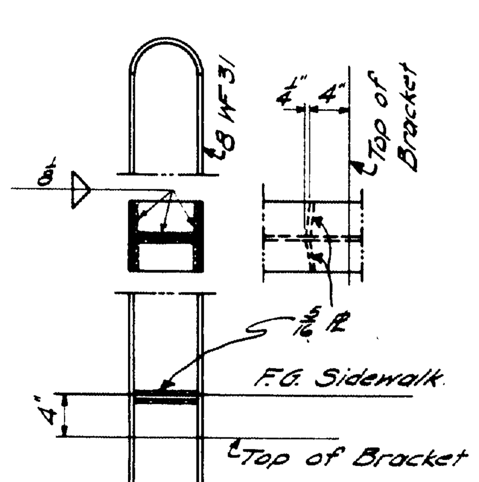
RAIL DETAILS

NOTE: Complete rail details to be furnished by the Contractor, for approval, before fabrication is started.
The Wrought Iron pipe sleeves, steel plates and bolts for connecting rail sections to posts shall be furnished with the W.I. rail.
Rail posts on the superstructure shall be structural steel and shall be furnished and erected as such.

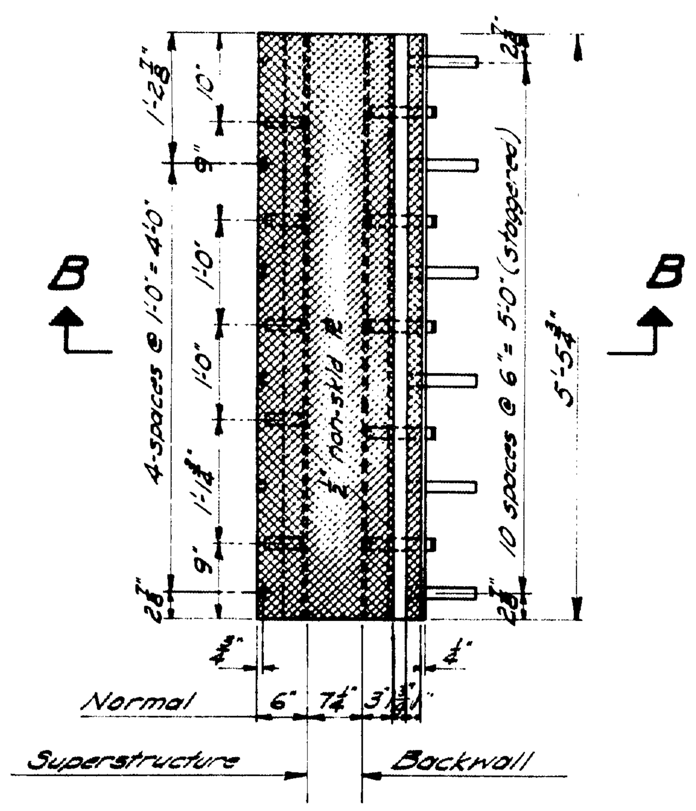


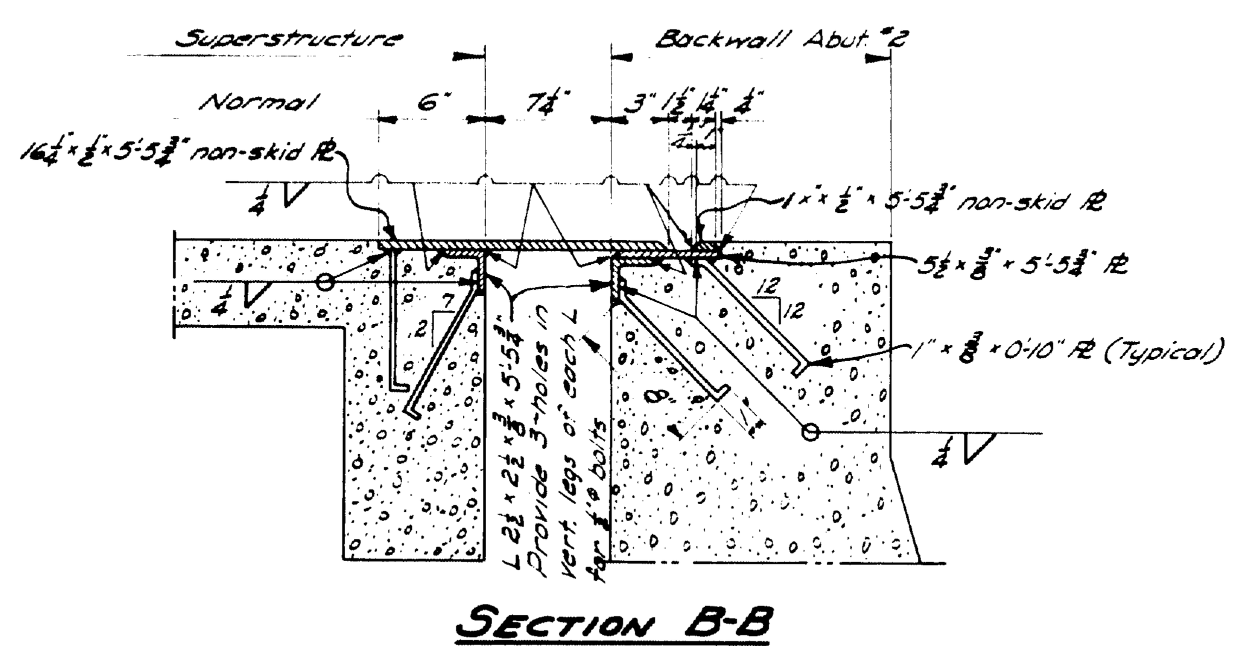
END RAIL POSTS

Holes in 2 end posts only.



ALL RAIL POSTS





SECTION B-B

SIDEWALK EXPANSION PLATES

1 - Required

DESIGN - HAMILTON TRACE - CLARK CHECK -	BRIDGE - 5444

STATE HIGHWAY COMMISSION
BRIDGE DIVISION

NORTH ELM BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
YARMOUTH
CUMBERLAND COUNTY

STRUCTURAL STEEL

SHEET 8 OF 10 AUGUSTA, MAINE JUNE 1951

55-169

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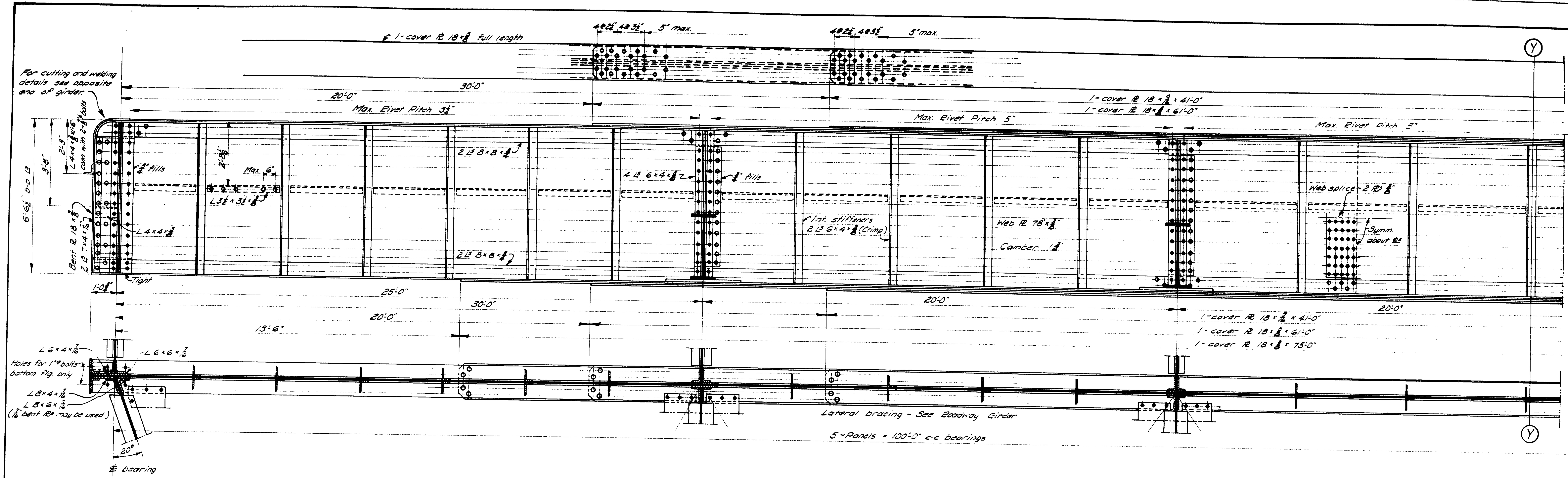
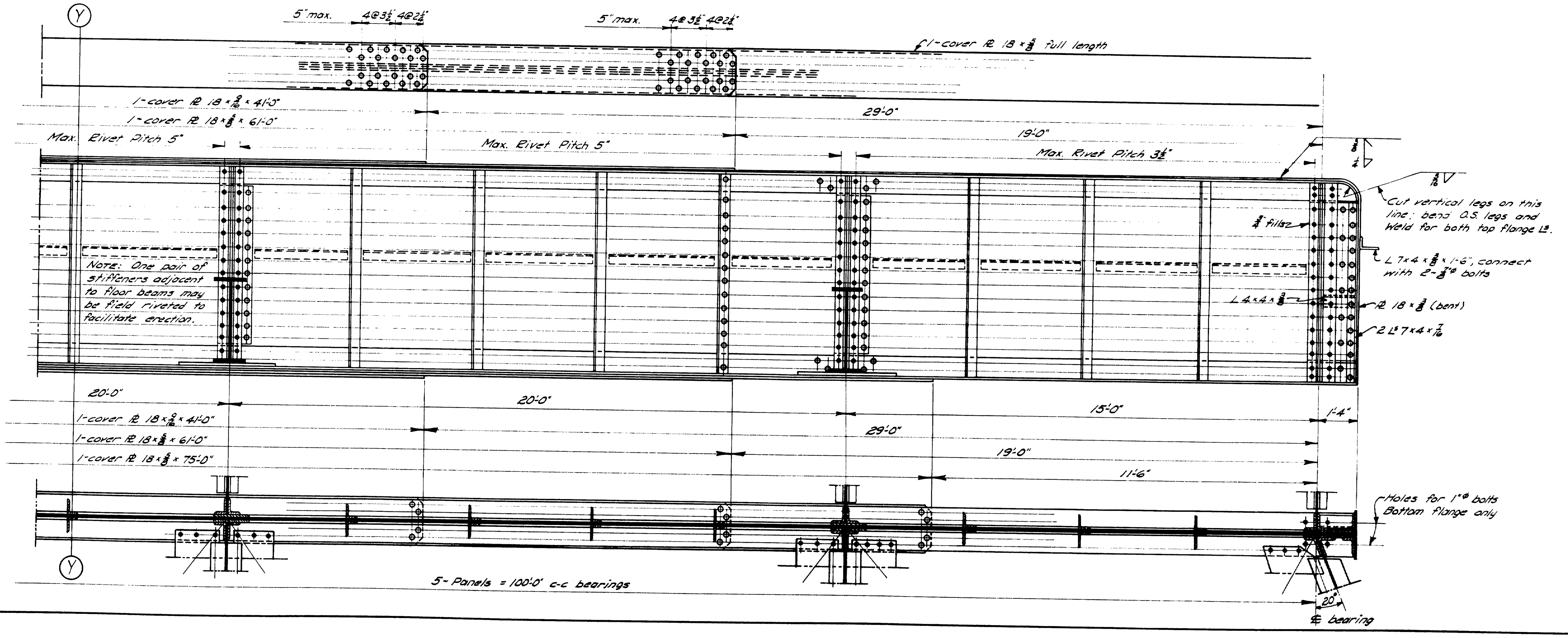




DESIGN-HAMILTON
TRACE-CLARK
CHECK-C.A.Brooks

BRIDGE-5444

STATE HIGHWAY COMMISSION
BRIDGE DIVISION

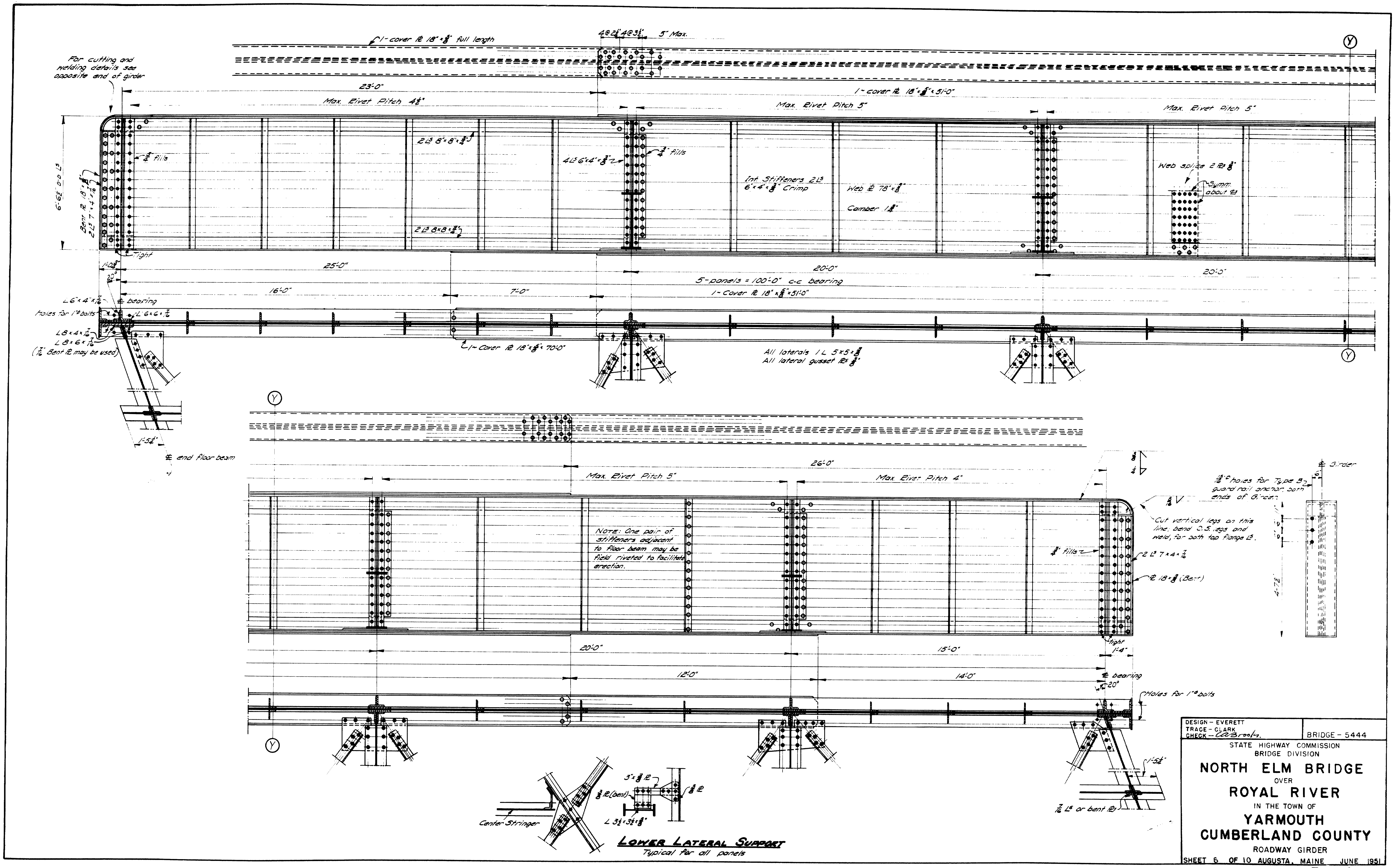
NORTH ELM BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
YARMOUTH
CUMBERLAND COUNTY

SIDEWALK GIRDER

SHEET 7 OF 10 AUGUSTA, MAINE JUNE 1951

55-168

0 1 2 3 4 5 INCHES



DESIGN - EVERETT
TRACE - CLARK
CHECK - C.A. Brooks

BRIDGE - 5444

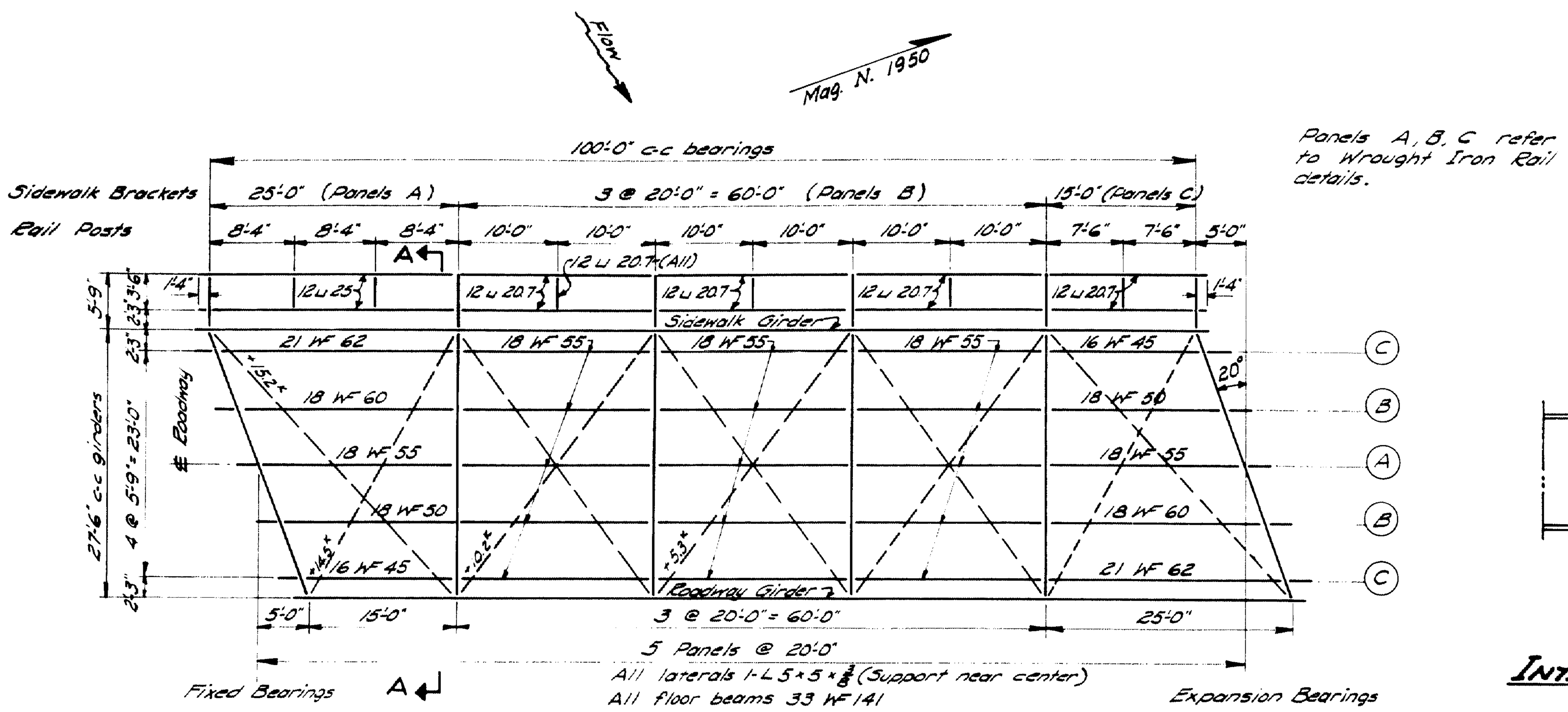
STATE HIGHWAY COMMISSION
BRIDGE DIVISION

NORTH ELM BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
YARMOUTH
CUMBERLAND COUNTY
ROADWAY GIRDER

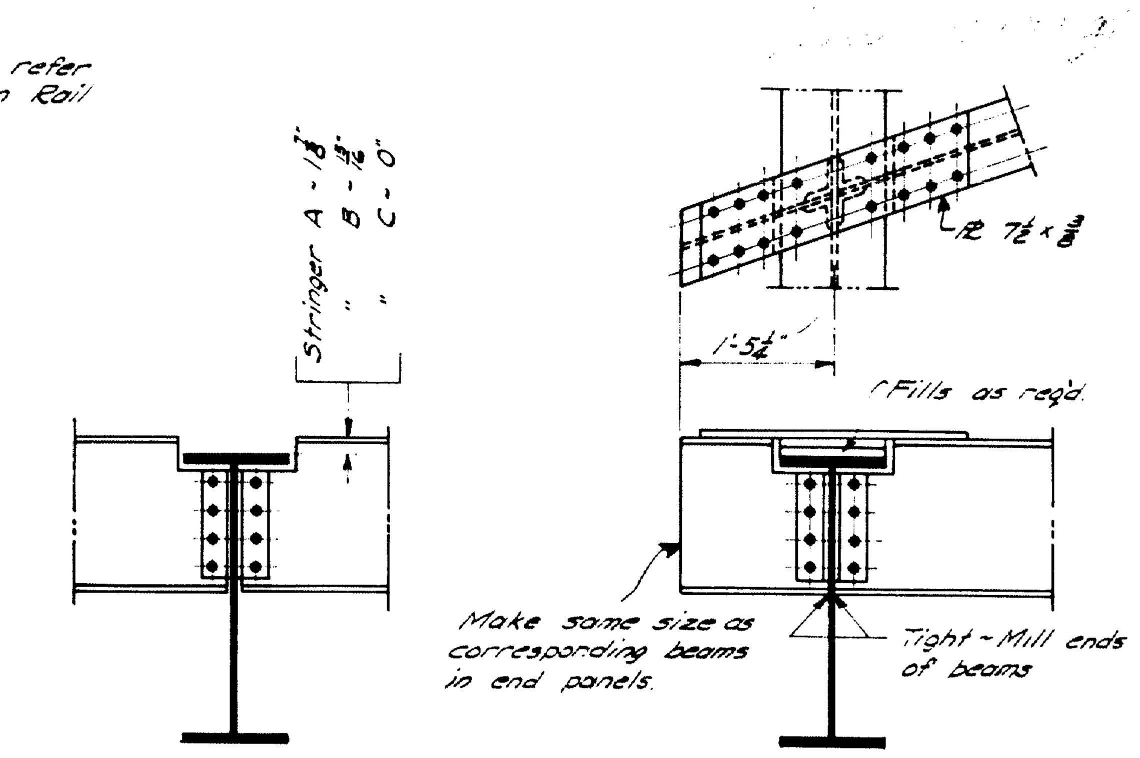
SHEET 6 OF 10 AUGUSTA, MAINE JUNE 1951

55-167

0 1 2 3 4 5 INCHES



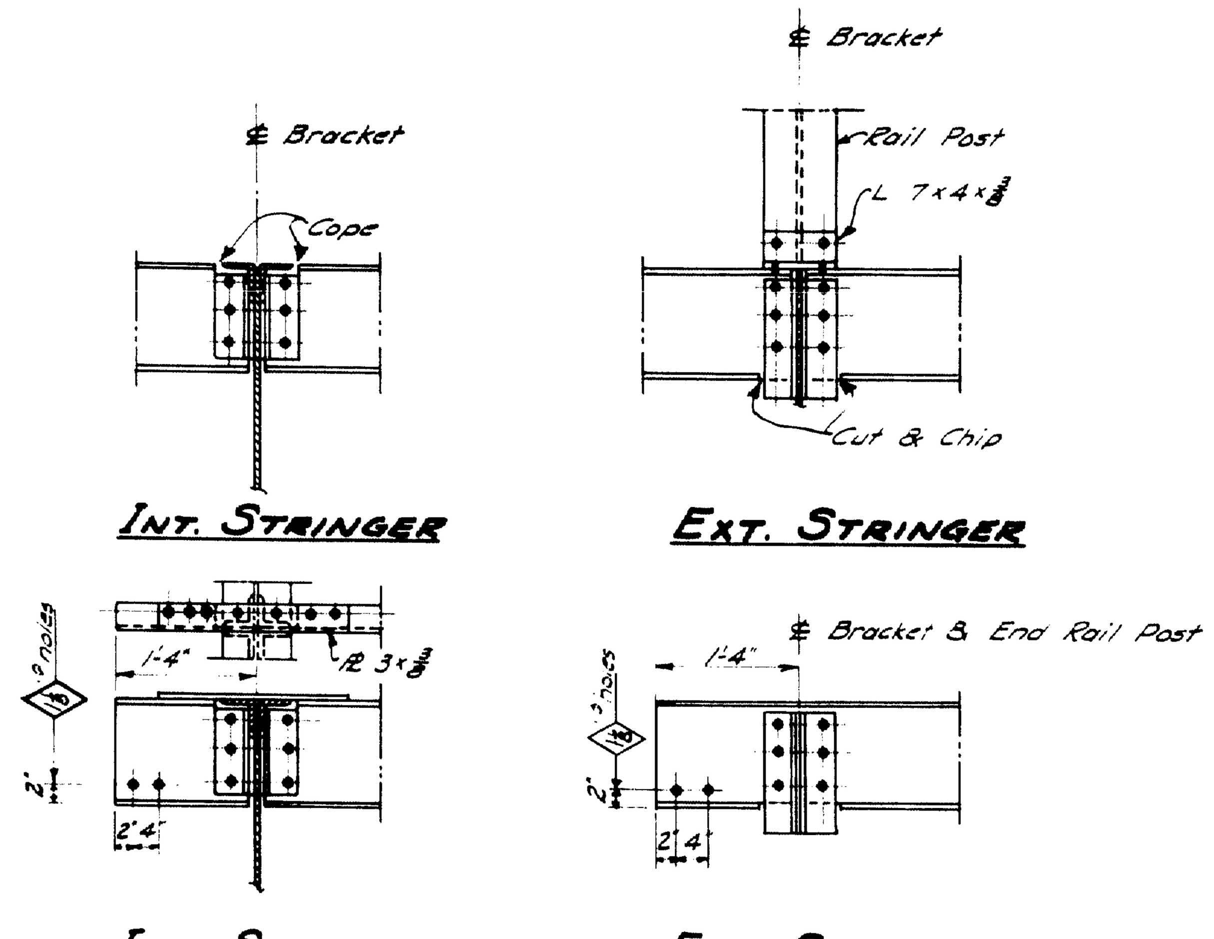
ERECTION DIAGRAM



Int. Floor Beams

End Floor Beams

TYPICAL CONN. ROADWAY STRINGERS



Int. Stringer

Ext. Stringer

Int. Stringer End Brackets

Ext. Stringer End Brackets

TYPICAL CONN. SIDEWALK STRINGERS

DESIGN DATA

Roadway Girder

Max. Girder Mom. 4415'^K
Gross I = 149200"^4
Net I = 120500"^4

Make-up of Girder = Web ~ 78 × 5/8
78 1/2" b-b Ls 4 Ls ~ 8 × 8 × 3/4
4 PLs ~ 18 × 7/8

D.L. deflection Girder = 1 1/2"
Camber Girder = 1 3/4"

Sidewalk Girder

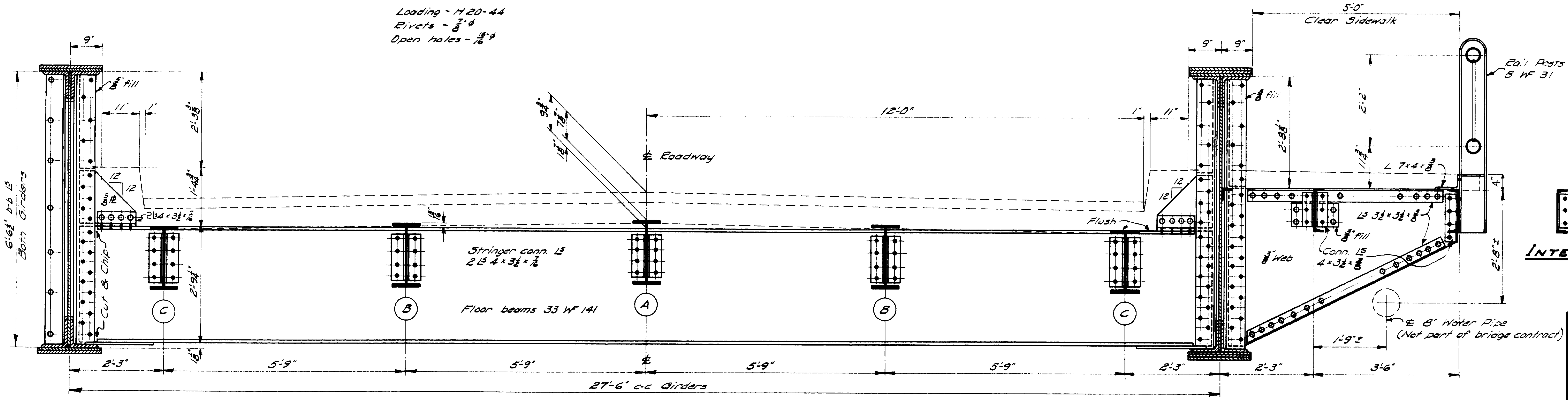
Max. Girder Mom. 5455'^K
Gross I = 182815"^4
Net I = 148641"^4

Make-up of Girder = Web ~ 78 × 5/8
78 1/2" b-b Ls 4 Ls ~ 8 × 8 × 3/4
4 PLs ~ 18 × 5/8
2 PLs ~ 18 × 7/16

D.L. deflection Girder = 1 1/4"
Camber Girder = 1 3/4"

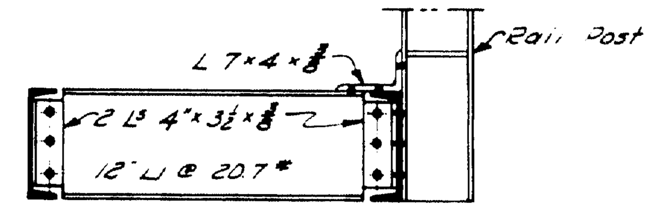
SPECIFICATIONS ~ State of Maine, State Highway Commission, Bridge Division, Specifications for Steel Highway Bridges Nov. 1945.

Loading ~ H 20-44
Rivets ~ 7/8" φ
Open holes ~ 15/16" φ



SECTION A-A

Typical



Intermediate Diaphragm

DESIGN - HAMILTON TRACE - CLARK CHECK -	BRIDGE - 5444

STATE HIGHWAY COMMISSION
BRIDGE DIVISION

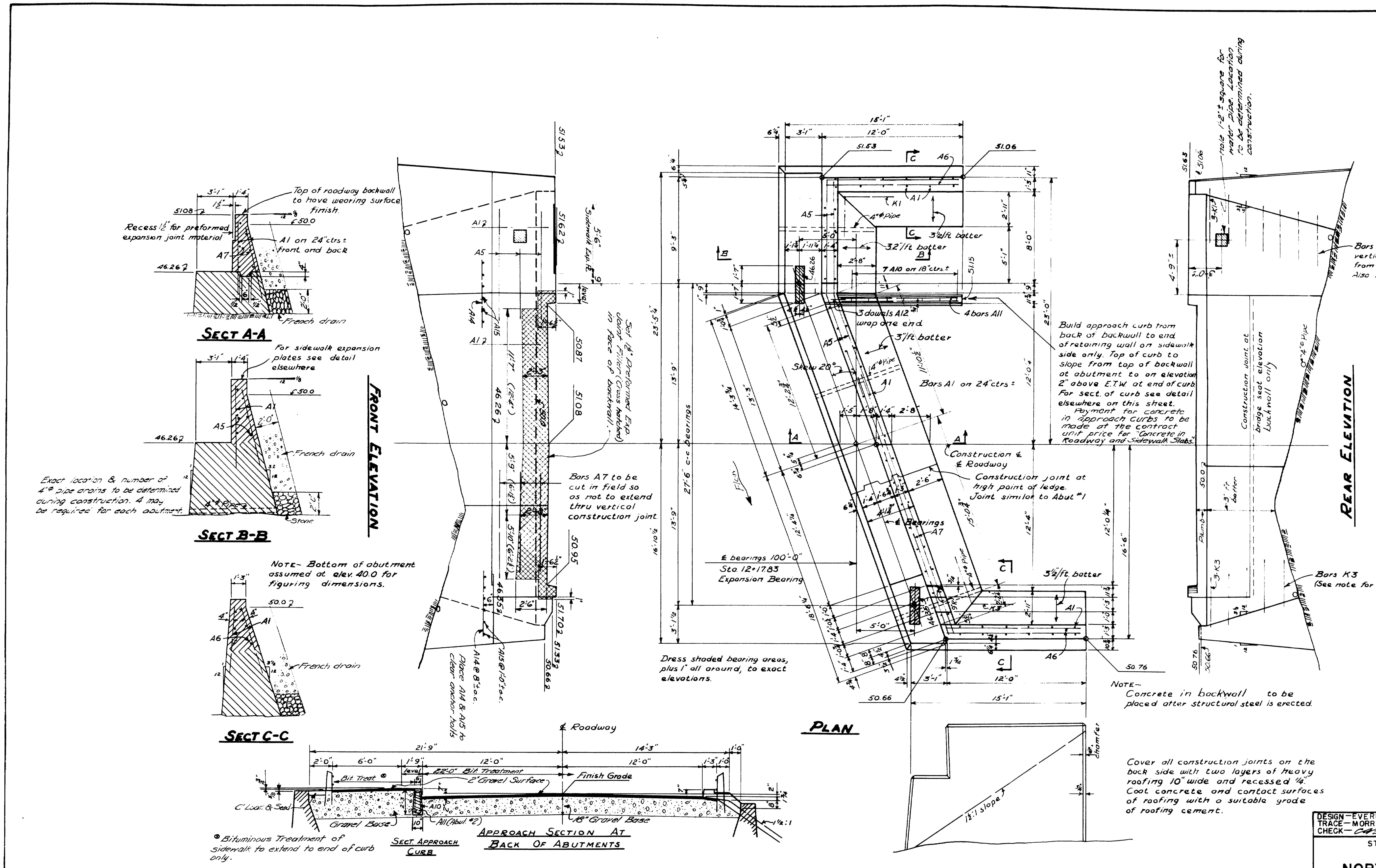
NORTH ELM BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
YARMOUTH
CUMBERLAND COUNTY

ERECTION DIAGRAM

SHEET 5 OF 10 AUGUSTA, MAINE JUNE 1951

55-166

0 1 2 3 4 5 INCHES



DESIGN—EVERETT
TRACE—MORRISON
CHECK—C.H. Brooks

BRIDGE—5444

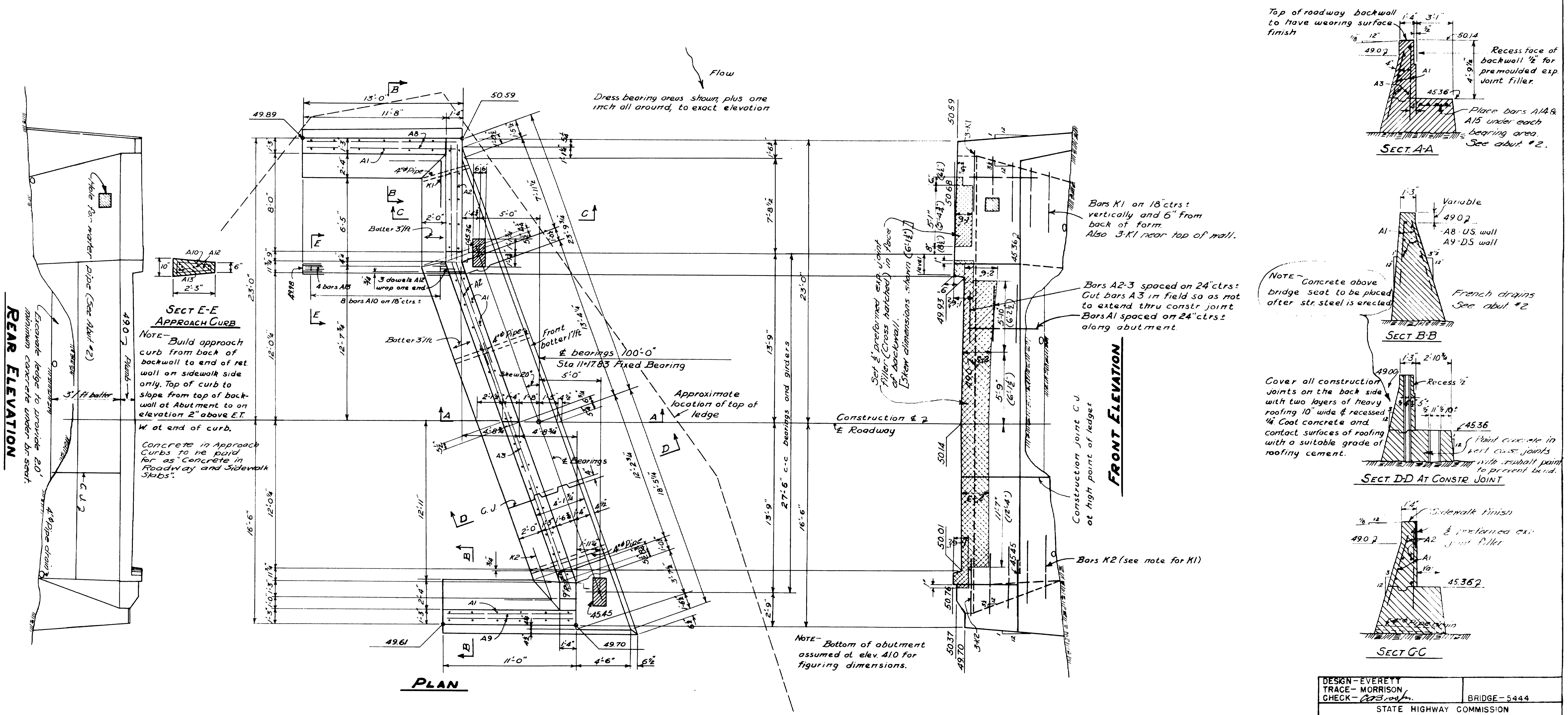
STATE HIGHWAY COMMISSION
BRIDGE DIVISION

NORTH ELM BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
YARMOUTH
CUMBERLAND COUNTY
ABUTMENT NO.2

SHEET 4 OF 10 AUGUSTA, MAINE JUNE 1951

55-165

0 1 2 3 4 5 INCHES



DESIGN–EVERETT TRACE–MORRISON CHECK–CABrook	BRIDGE–5444

STATE HIGHWAY COMMISSION
BRIDGE DIVISION

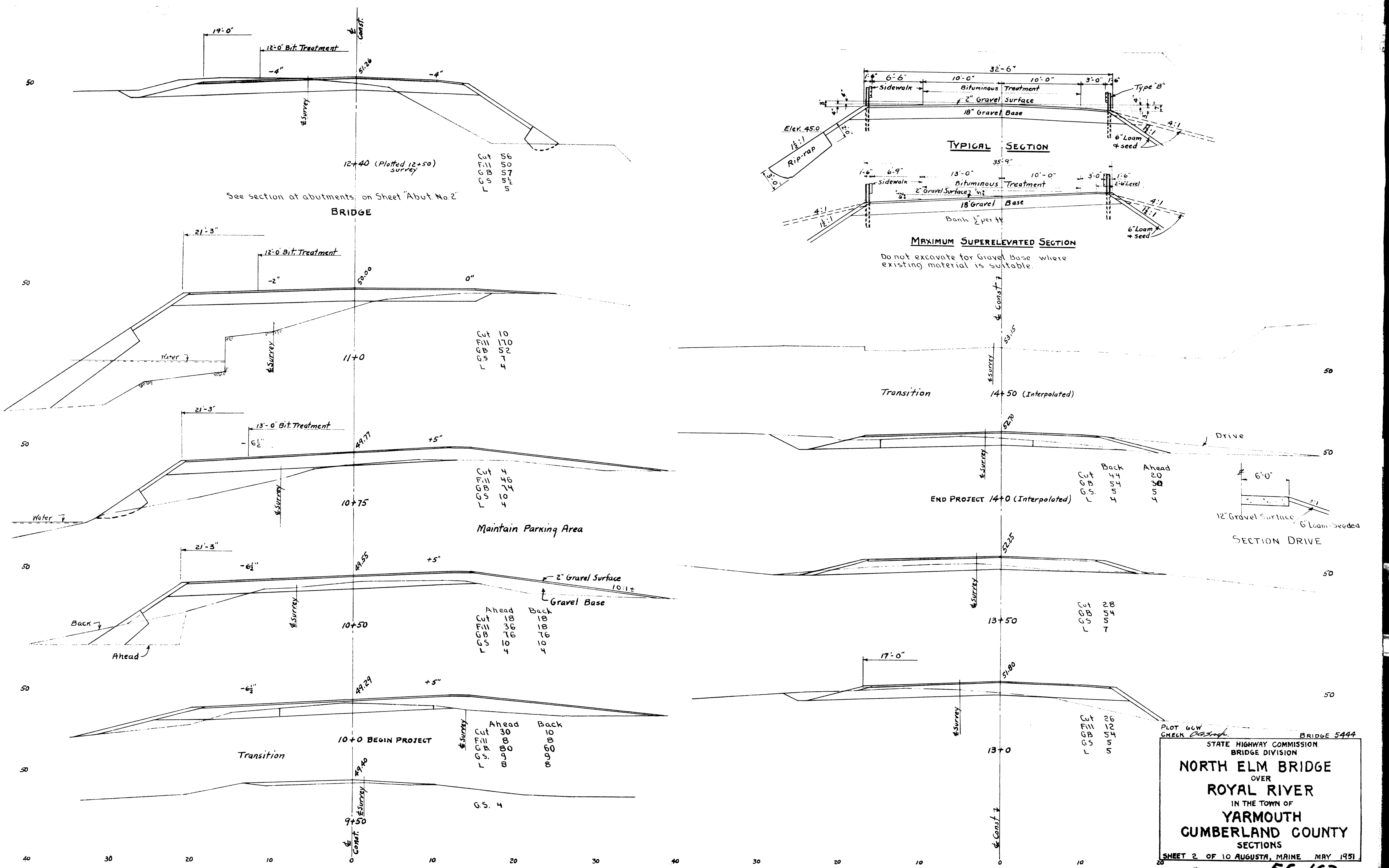
NORTH ELM BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
YARMOUTH
CUMBERLAND COUNTY

ABUTMENT NO.1

SHEET 3 OF 10 AUGUSTA, MAINE JUNE 1951

55-164

0 1 2 3 4 5 INCHES



PLOT GCW
CHECK [illegible]

BRIDGE 5444

STATE HIGHWAY COMMISSION
BRIDGE DIVISION

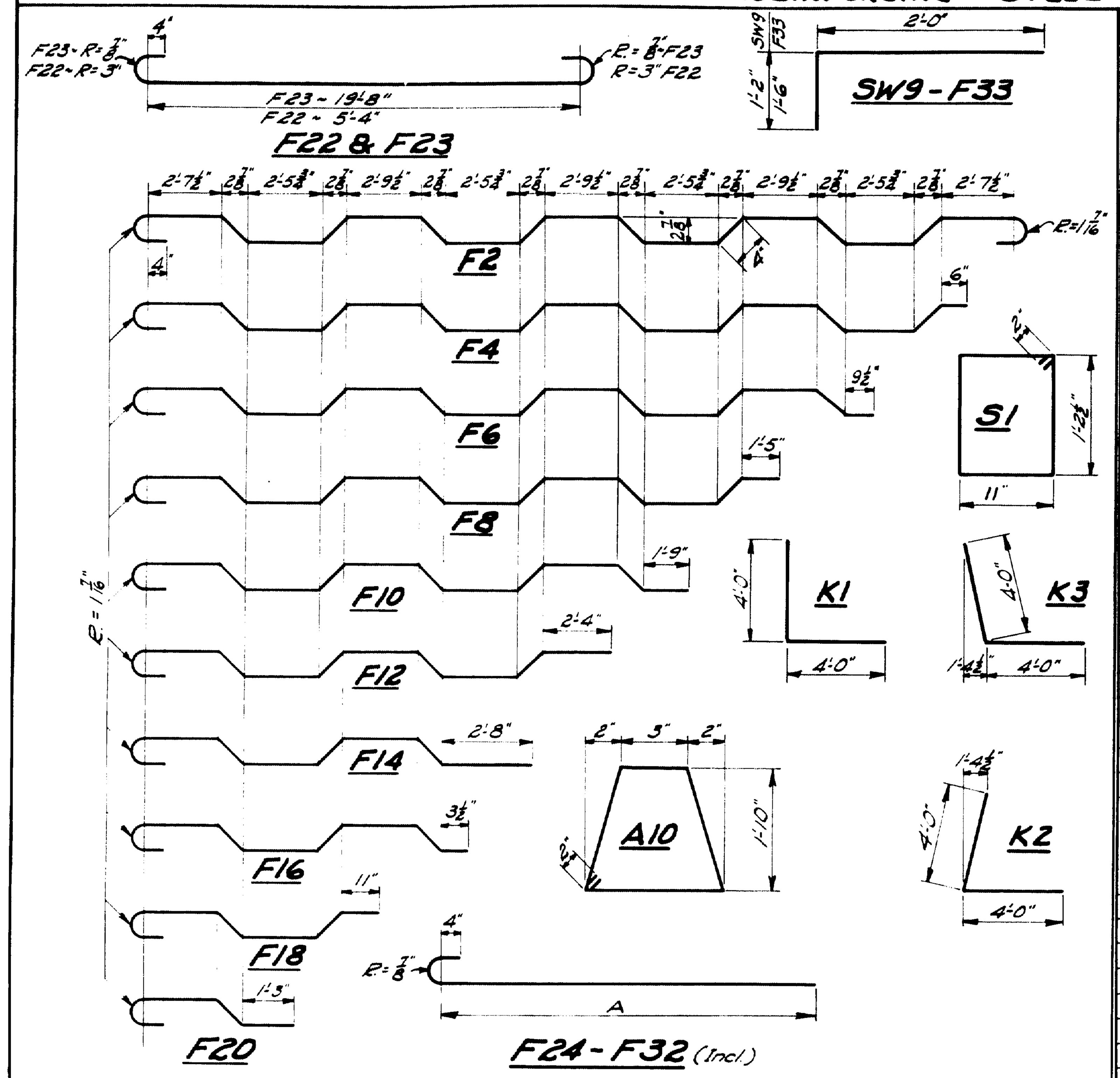
NORTH ELM BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
YARMOUTH
CUMBERLAND COUNTY
SECTIONS

SHEET 2 OF 10 AUGUSTA, MAINE MAY 1951

55-163

0 1 2 3 4 5 INCHES

REINFORCING STEEL SCHEDULE



BENT BARS

MARK	BAR SIZE DIA.	BAR SIZE NO.	REQUIRED	A	LENGTH	LOCATION
A10	3/8"φ	#3	15	—	4'-10"	Abuts. Nos. 1 & 2 ~ Approach Curbs
F2	5/8"φ	#5	107	—	27'-8"	Roadway Slabs ~ Panels "A", "B" & "C"
F4			2	—	24'-10"	" " ~ " "A" & "C"
F6			2	—	22'-3"	" " ~ " " "
F8			2	—	19'-9"	" " ~ " " "
F10			2	—	17'-4"	" " ~ " " "
F12			2	—	14'-9"	" " ~ " " "
F14			2	—	12'-3"	" " ~ " " "
F16			2	—	9'-11"	" " ~ " " "
F18			2	—	7'-5"	" " ~ " " "
F20	5/8"φ	#5	2	—	4'-11"	Roadway Slabs ~ Panels "A" & "C"
F22	3/4"φ	#6	24	—	7'-7"	Conc. diaph. @ Abuts ~ " " " (Roadway)
F23	1/2"φ	#4	147	—	20'-10"	Roadway Slabs ~ Panels "B" (Dist. steel)
F24			10	25'-0"	25'-7"	" " ~ " "A" & "C" (Dist. steel)
F25			12	24'-0	24'-7"	" " ~ " " " "
F26			10	23'-0	23'-7"	" " ~ " " " "
F27			12	22'-0	22'-7"	" " ~ " " " "
F28			10	21'-0	21'-7"	" " ~ " " " "
F29			12	20'-0"	20'-7"	" " ~ " " " "
F30			10	19'-0"	19'-7"	" " ~ " " " "
F31			12	18'-0"	18'-7	" " ~ " " " "
F32	1/2"φ	#4	10	16'-9"	17'-4"	Roadway Slabs ~ Panels "A" & "C" (Dist. steel)
F33	5/8"φ	#5	48	—	3'-6"	Conc. diaph. @ Abuts. " " " (Roadway)
K1	3/4"φ	#6	16	—	8'-0"	Abutments Nos. 1 & 2
K2	3/4"φ	#6	7	—	8'-0"	Abutment No. 1
K3	3/4"φ	#6	7	—	8'-0"	Abutment No. 2
S1	3/8"φ	#3	208	—	4'-7"	Roadway Curbs - Panels "A", "B" & "C"
SW9	5/8"φ	#5	4	—	3'-2"	Conc. diaph. @ Abut. No. 1 (Sidewalk)

STRAIGHT BARS

MARK	BAR SIZE DIA.	BAR SIZE NO.	REQUIRED	LENGTH	LOCATION
A1	5/8"φ	#5	124	7'-0"	Abuts. Nos. 1 & 2
A2	1/2"φ	#4	6	18'-0"	Abut. No. 1 (Bend in field)
A3			6	21'-0"	Abut. No. 1 (Cut in field)
A5			6	19'-0"	Abut. No. 2 (Bend in field)
A6			12	11'-6"	Abut. No. 2
A7			6	23'-0"	Abut. No. 2 (Cut in field)
A8			6	12'-6"	Abut. No. 1 ~ U.S. Wing
A9			6	10'-6	Abut. No. 1 ~ D.S. Wing
A11	1/2"φ	#4	4	10'-4"	Abut. No. 2 ~ Approach Curb
A12	3/4"φ	#6	6	2'-0"	Abuts. Nos. 1 & 2 ~ Approach Curbs
A13	1/2"φ	#4	4	11'-4"	Abut. No. 1 ~ Approach Curb
A14	3/4"φ	#6	20	5'-3"	Abuts. Nos. 1 & 2 - Bearing Areas
A15	3/4"φ	#6	24	3'-0"	Abuts. Nos. 1 & 2 ~ " "
C1	1/2"φ	#4	4	26'-0"	Curbs ~ U.S. Panel "A", D.S. Panel "C"
C2	1/2"φ	#4	4	16'-8"	" ~ D.S. Panel "A", U.S. Panel "C"
C3	1/2"φ	#4	12	19'-8"	" ~ U.S. & D.S. Panels "B"
F1	5/8"φ	#5	218	25'-8"	Roadway Slabs ~ Panels "A", "B" & "C"
F3			4	24'-6"	" " ~ Panels "A" & "C"
F5			4	22'-1"	" " " " "
F7			4	19'-9"	" " " " "
F9			4	17'-4"	" " " " "
F11			4	14'-11"	" " " " "
F13			4	12'-6"	" " " " "
F15			4	10'-1"	" " " " "
F17			4	7'-8"	" " " " "
F19			4	5'-4"	" " " " "
F21	5/8"φ	#5	4	2'-11"	Roadway Slabs ~ Panels "A" & "C"
SW1	1/2"φ	#4	8	26'-1"	Sidewalk Slab ~ Panel "A"
SW2			308	6'-0"	Sidewalk Slabs ~ Panels "A", "B" & "C"
SW3			24	19'-8"	" " ~ " "B"
SW4			6	7'-4"	" Slab ~ Panel "A"
SW5			4	6'-6"	" Slab ~ " "C"
SW6	1/2"φ	#4	8	16'-0"	" " ~ " "C"
SW7	3/4"φ	#6	4	5'-6"	Conc. diaph. @ Abuts. (Sidewalk)
SW8	1/2"φ	#4	12	9'-0"	Sidewalk Slab ~ Panels "B"
T1	3/8"φ	#3	96	23'-6"	Wearing Surface ~ Panels "A", "B" & "C"
T2			72	19'-6"	" " ~ " "B"
T3			6	17'-0"	" " ~ " "A" & "C"
T4			6	18'-1"	" " ~ " " "
T5			6	19'-2"	" " ~ " " "
T6			6	20'-3"	" " ~ " " "
T7			6	21'-5"	" " ~ " " "
T8			6	22'-6"	" " ~ " " "
T9			6	23'-7"	" " ~ " " "
T10			6	24'-8"	" " ~ " " "
T11			2	20'-7"	" " ~ " " "
T12			2	17'-8"	" " ~ " " "
T13			2	14'-9"	" " ~ " " "
T14			2	11'-10"	" " ~ " " "
T15			2	8'-11"	" " ~ " " "
T16			2	6'-0"	" " ~ " " "
T17	3/8"φ	#3	2	3'-1"	Wearing Surface ~ Panels "A" & "C"

NOTE: Dimensions to ℄ of bars.
All reinforcing steel bars to conform to A.S.T.M. Specifications A 305-49.

PLAN - CLARK
CHECK - C.A. Brown
BRIDGE - 5444

STATE HIGHWAY COMMISSION
BRIDGE DIVISION

NORTH ELM BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
YARMOUTH
CUMBERLAND COUNTY

REINFORCING STEEL

SHEET 10 OF 10 AUGUSTA, MAINE JUNE 1951

55-171

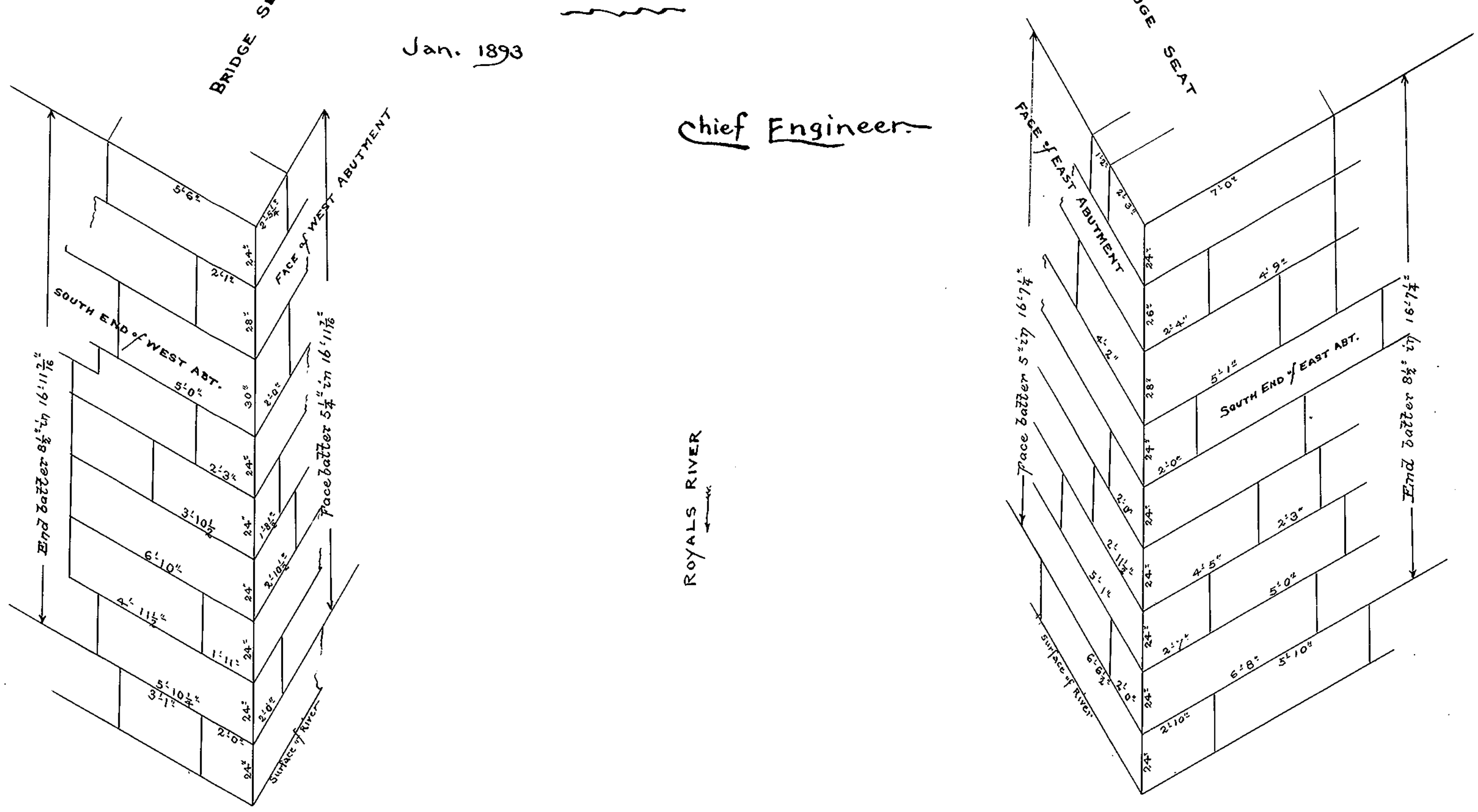
0 1 2 3 4 5 INCHES

Maine Central Railroad Bridge (from Pan Am Railways)

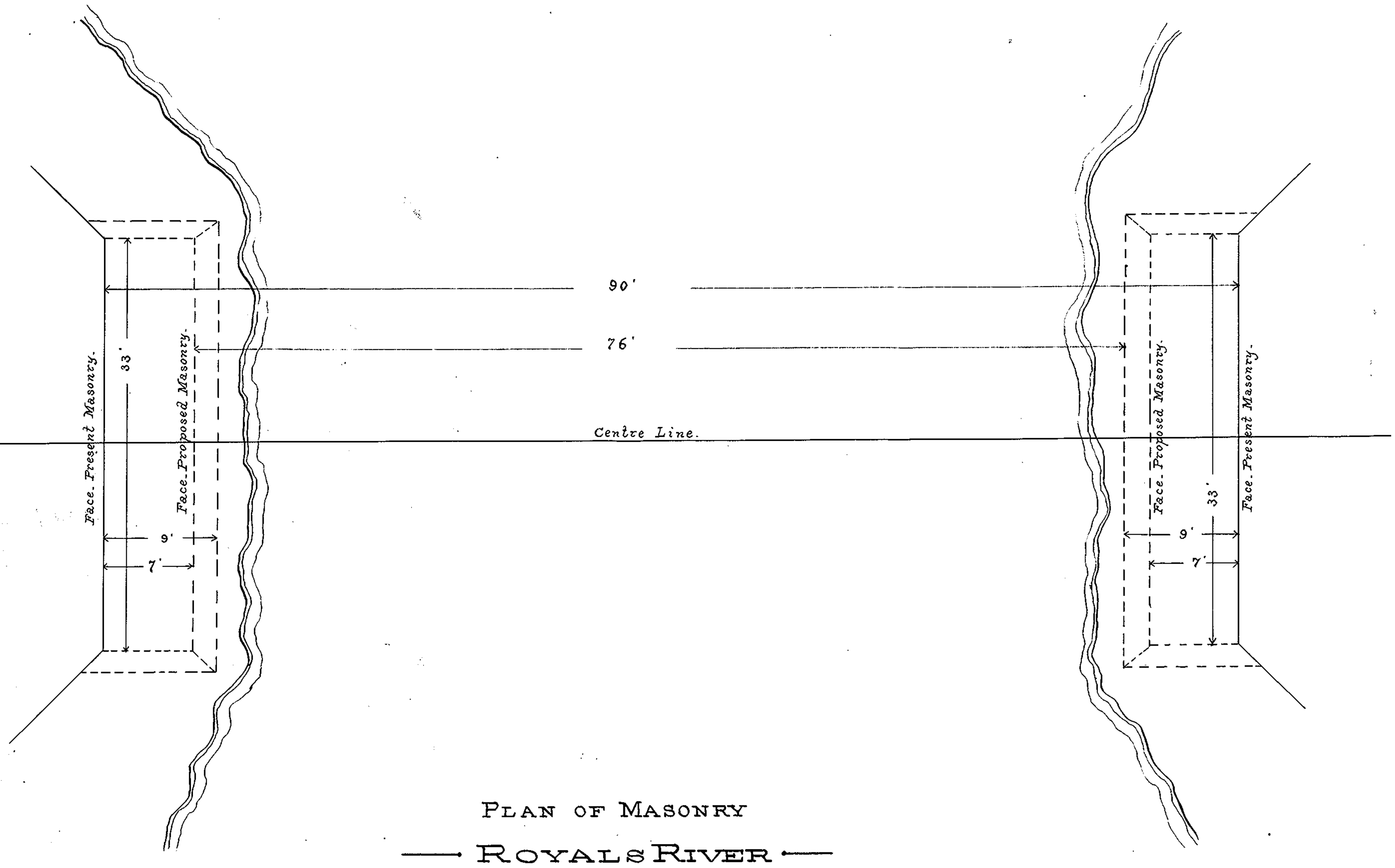
Sketch Showing Part of
Present Masonry
at Royals River Bridge

Jan. 1893

Chief Engineer



115-8



PLAN OF MASONRY

ROYALS RIVER

BRIDGE.

November ___ 1883.

Scale 8 ft. to 1 inch.

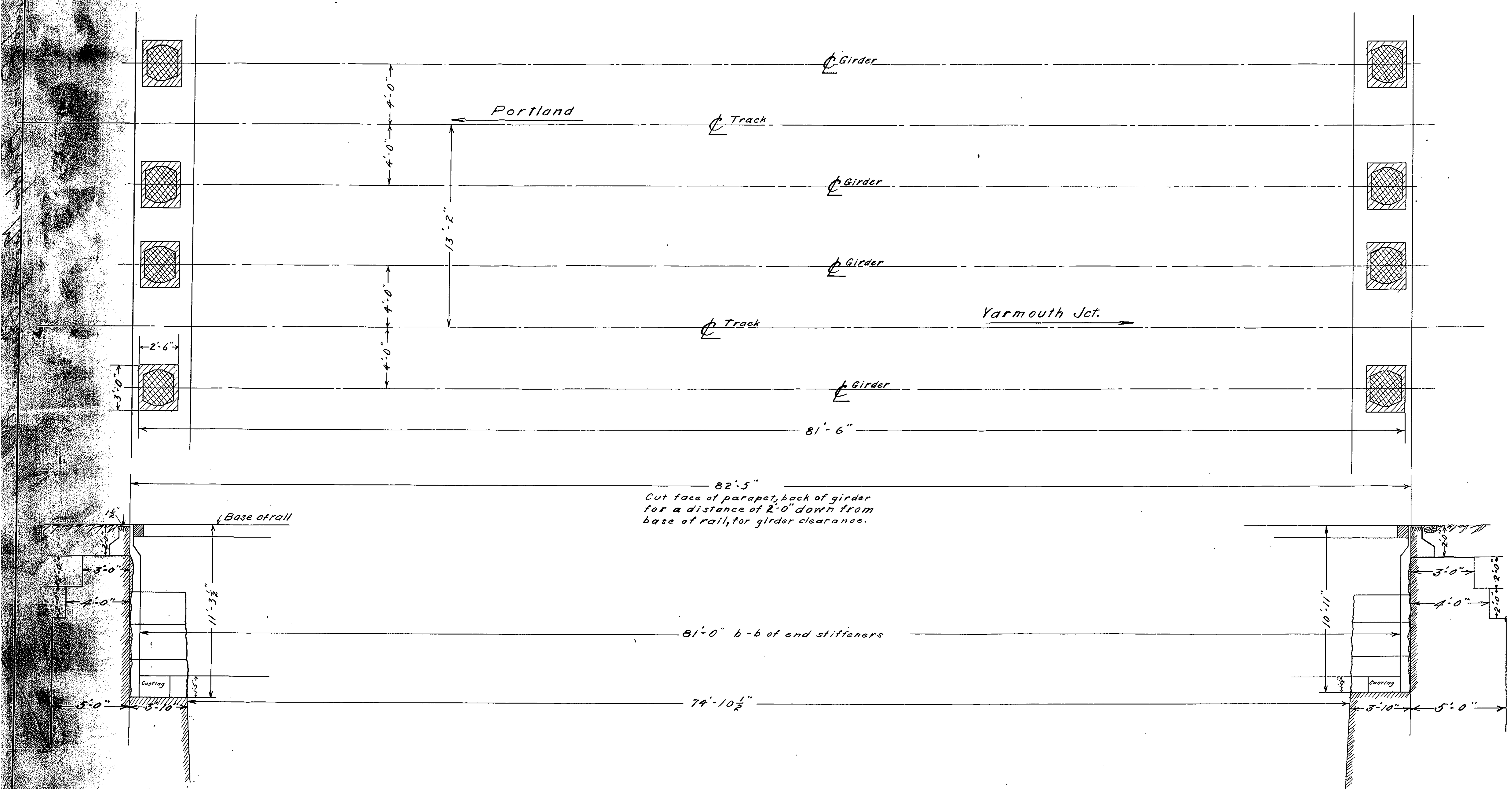
PLAN OF MASONRY. ROYALS RIVER BRIDGE.

BRIDGE TO BE SET LEVEL AND GRADE OBTAINED BY NOTCHING TIES.

DOTTED LINE SHOWS PRESENT MASONRY.

SCALE ¼" TO 1'.

William A. Allen
Engineer.



Note.
Courses to be removed shown in red.
Single cross hatching shows surface to be cut for bearings.
All bearings cut same size.
Double cross hatching shows actual size of castings.

MAINE CENTRAL R. R.

#14.5 Royals River Bridge

$\frac{5}{10}$ Mile West of Yarmouth Jct.

Changes in Masonry to give New Bridge Seats for Girders.

Scale $\frac{1}{4}$" = 1'-0"   September 1910

Sheet #1 of 1

State Route 9 Bridge (from Maine DOT)

General Notes

* **Existing Superstructure:** One lane steel pony truss in fair condition, built 1911. C-C trusses 19'-5"; Clear roadway 17'-0"; C-C bearings 70'-0". clear span 62'-0" U.S., 65'-2" D.S.; Deck -2" long. plank wheel treads on 3" transverse plank on 6 steel I-beam stringers. Ave length transverse plank 18'-0"; 0-0 long. wheel treads 70'-6". Plank in fair condition.

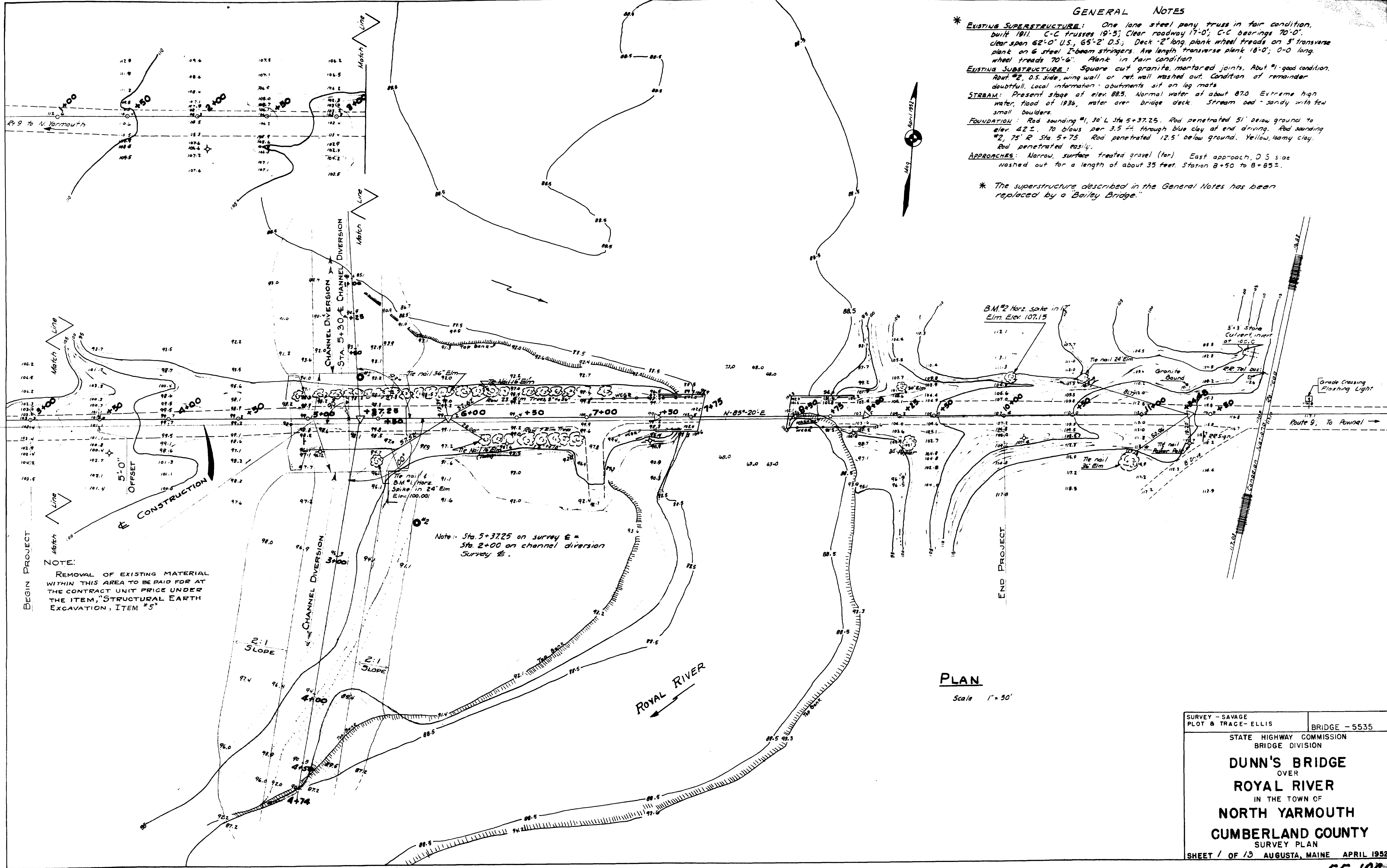
Existing Substructure: Square cut granite, mortared joints. Abut. #1 - good condition. Abut. #2, D.S. side, wing wall or ret. wall washed out. Condition of remainder doubtfull. Local information - abutments sit on log mats

Stream: Present stage at elev. 88.5. Normal water at about 87.0 Extreme high water, flood of 1936, water over bridge deck. Stream bed - sandy with few small boulders.

Foundation: Rod sounding #1, 30' L Sta 5+37.25. Rod penetrated 51' below ground to elev. 42±. 70 blows per 3.5 ft. through blue clay at end driving. Rod sounding #2, 75' R Sta. 5+75. Rod penetrated 12.5' below ground. Yellow, loamy clay. Rod penetrated easily.

Approaches: Narrow, surface treated gravel (tar). East approach, D.S. side washed out for a length of about 35 feet. Station 8+50 to 8+85±.

* The superstructure described in the General Notes has been replaced by a "Bailey Bridge."



NOTE:
Removal of existing material within this area to be paid for at the contract unit price under the item, "Structural Earth Excavation, Item #5"

Note:- Sta. 5+37.25 on survey ℄ = Sta. 2+00 on channel diversion survey ℄.

PLAN

Scale 1" = 30'

SURVEY - SAVAGE PLOT & TRACE - ELLIS	BRIDGE - 5535

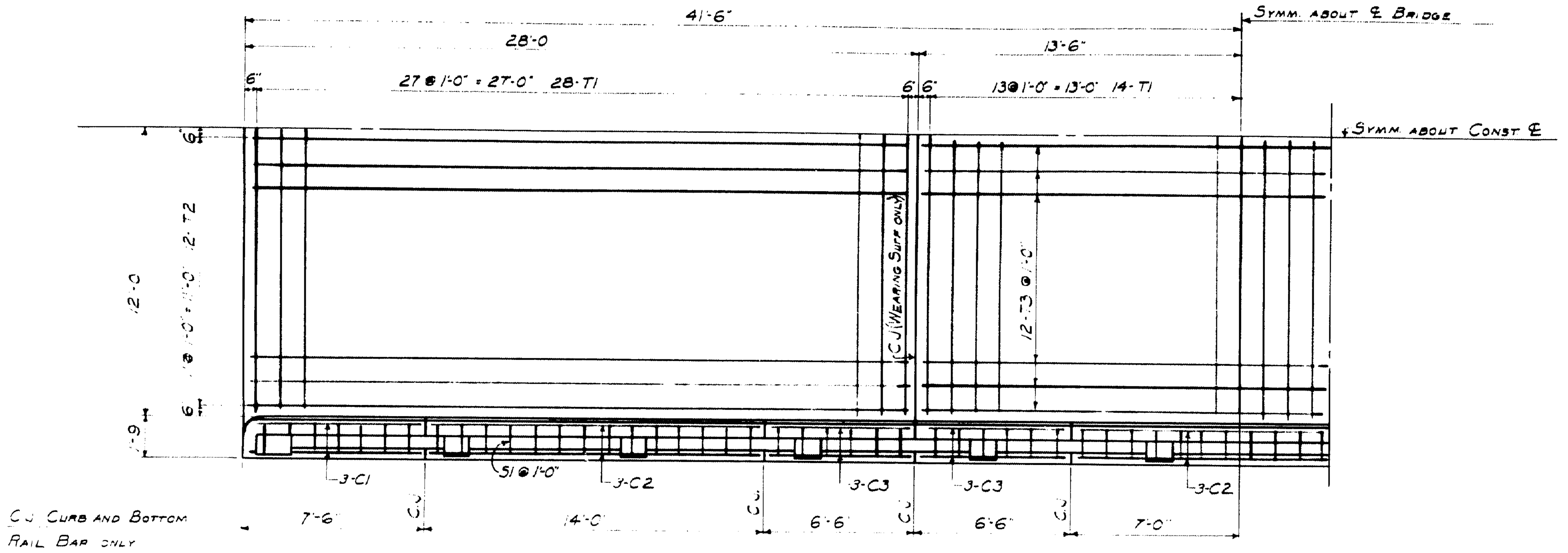
STATE HIGHWAY COMMISSION
BRIDGE DIVISION

DUNN'S BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
NORTH YARMOUTH
CUMBERLAND COUNTY
SURVEY PLAN

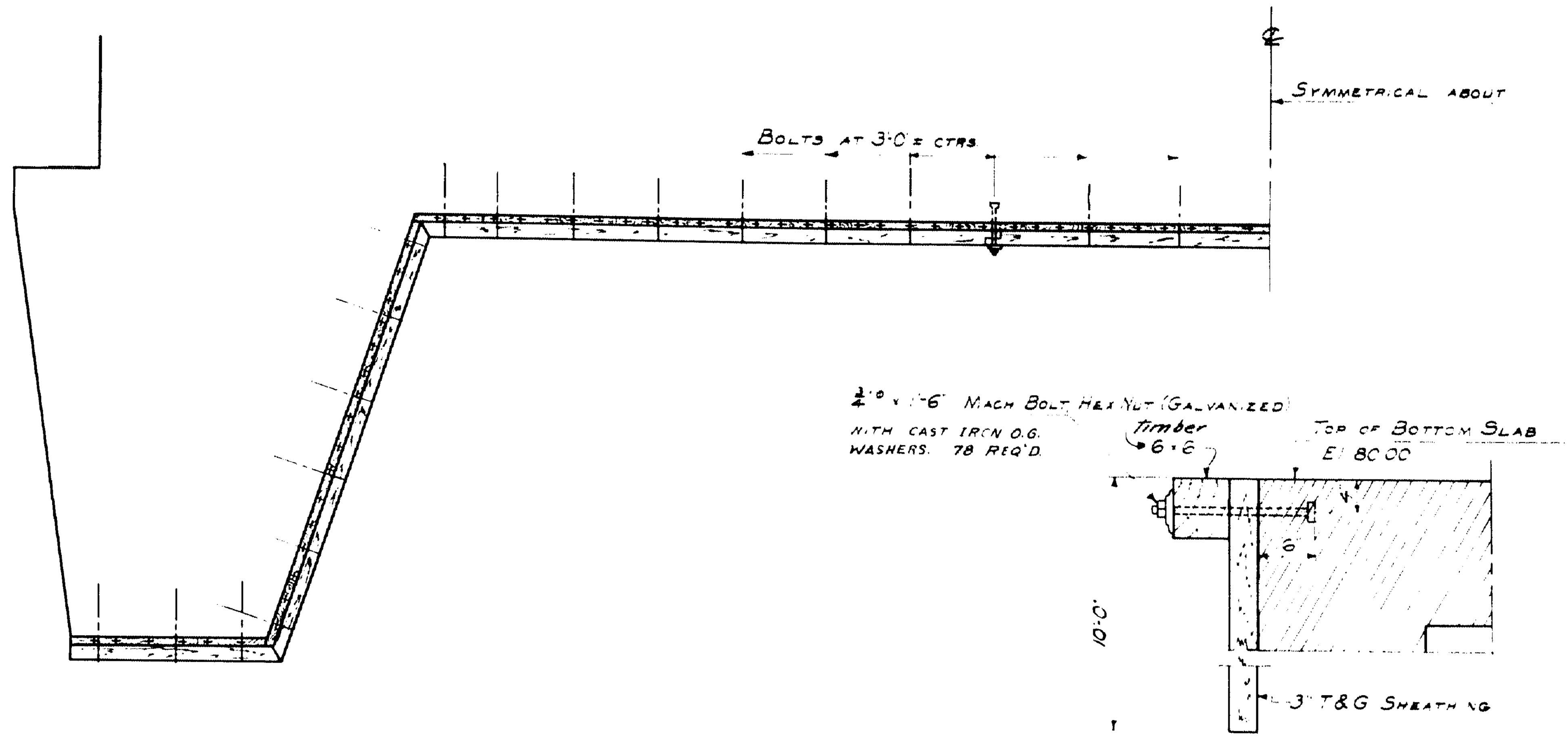
SHEET 1 OF 13 AUGUSTA, MAINE APRIL 1952

55-104

0 1 2 3 4 5 INCHES



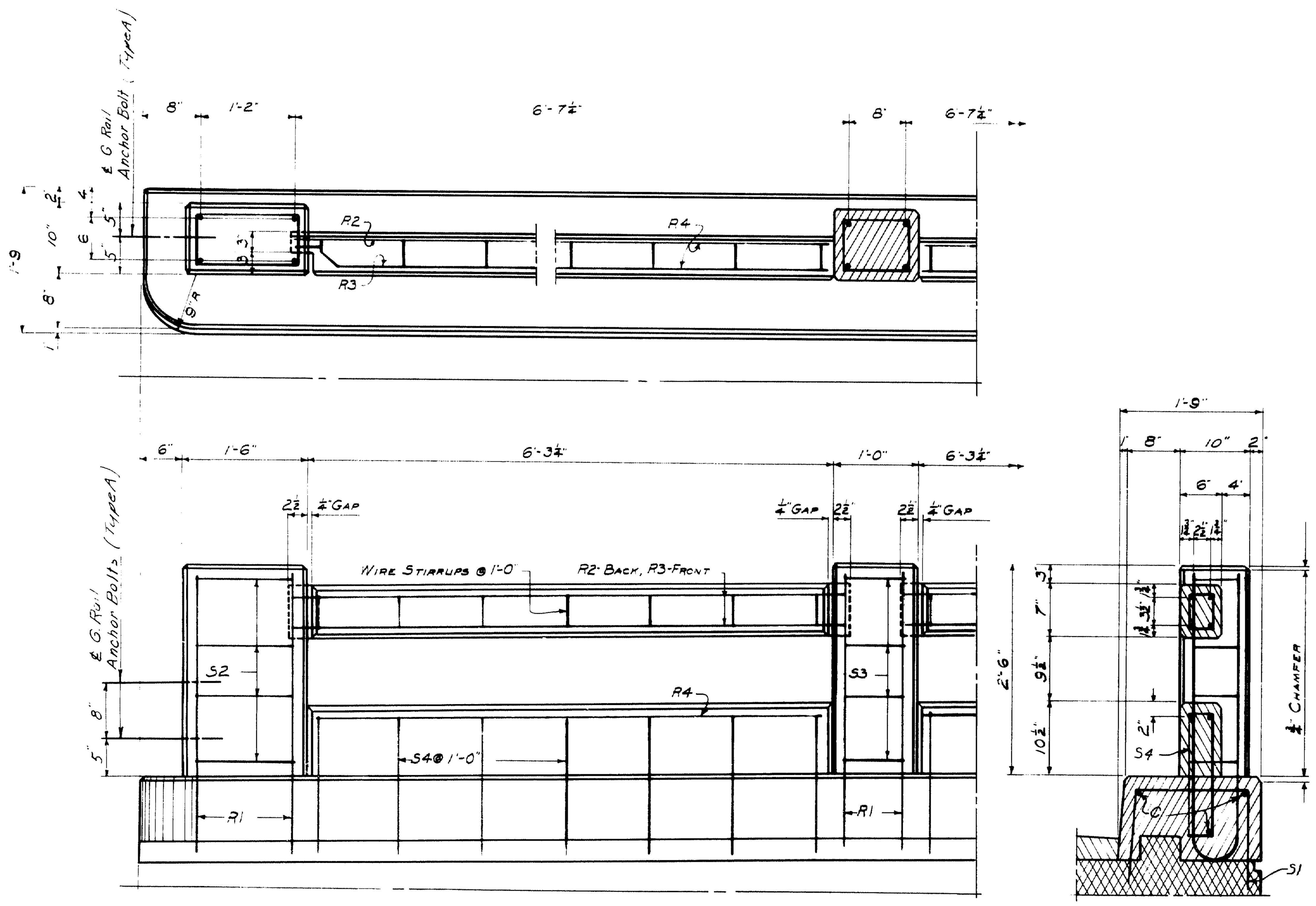
PART PLAN WEARING SURFACE & CURB STEEL



TYPICAL SECTION

QUARTER PLAN SHEATHING

NOTE: Sheathing upstream and downstream to be driven and bolts set in position before concrete in bottom slab or wing slabs is placed.
Machine bolts and C.I. washers to be paid for as hardware.



RAIL DETAILS

NOTE: Steel for posts and bottom rail bar to be set in position before curb is placed.
Bottom rail bar to be cast in place. The top rail bar is to be precast and set in position so the ends project into the post forms 2 1/2".
Wrap the tongue ends with two layers of heavy roofing.
All exposed edges of concrete to be chamfered 1/2" unless otherwise shown.
Wire stirrups for the top rail bar to be constructed in the field from a single strand of #9 annealed wire. In forming the stirrup, make a complete turn around each reinforcing bar.
Cut bars R4 at construction joints.
Rail posts to be plumb with tops level.

Curbs shall not be cast until frame falsework has been removed.

DESIGN - W.B. HAMILTON
TRACE - JOSE
CHECK - C.O.S.
BRIDGE - 5535

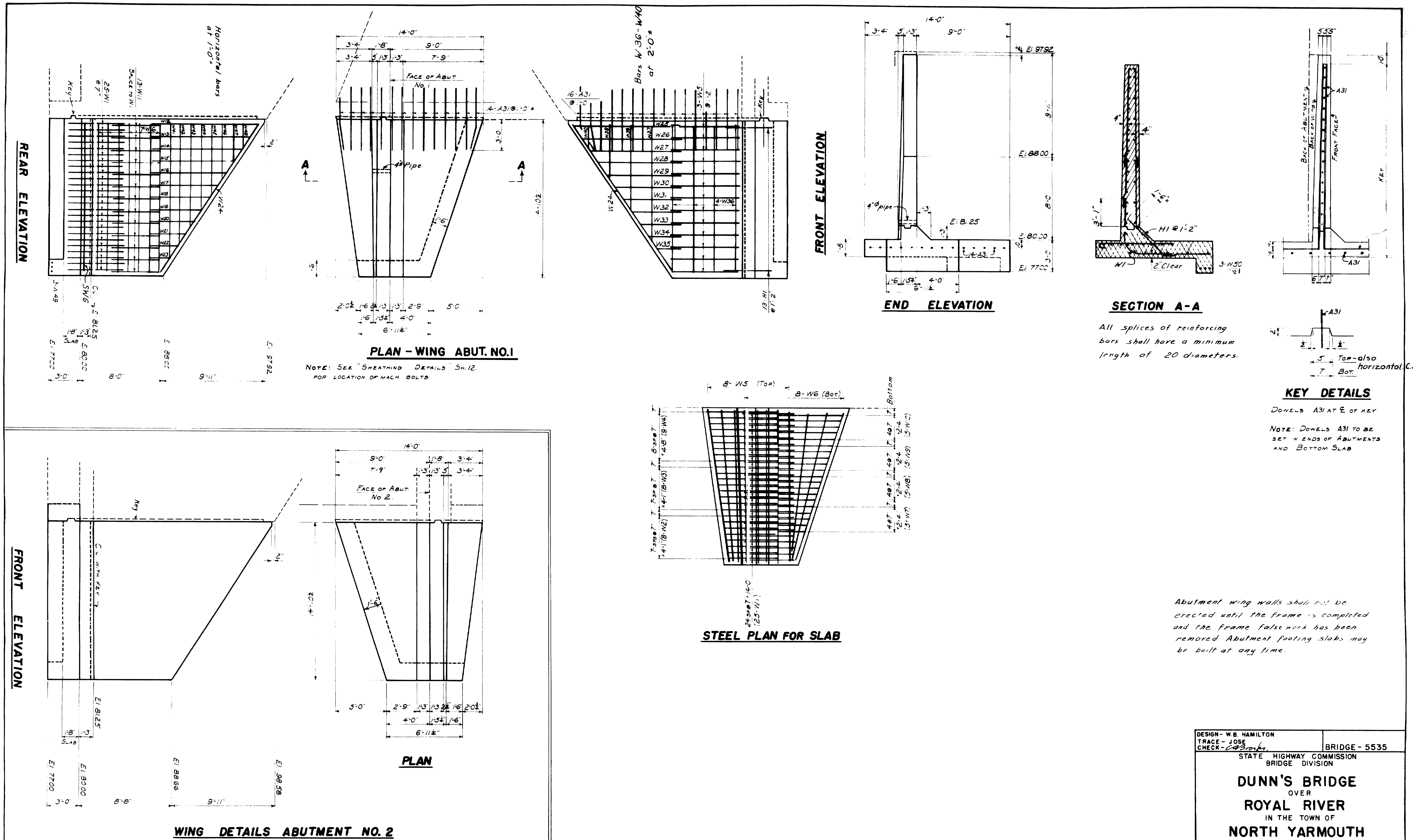
STATE HIGHWAY COMMISSION
BRIDGE DIVISION

DUNN'S BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
NORTH YARMOUTH
CUMBERLAND COUNTY

W.S. STEEL, RAIL, & SHEATHING DETAIL
SHEET 12 OF 13 AUGUSTA, MAINE APRIL 1953

55-115

0 1 2 3 4 5 INCHES



NOTE: See "Sheathing Details" Sh. 12. for location of mach. bolts.

All splices of reinforcing bars shall have a minimum length of 20 diameters.

Dowels A31 at ℄ of key

Note: Dowels A31 to be set in ends of Abutments and Bottom Slab

Abutment wing walls shall not be erected until the frame is completed and the frame falsework has been removed. Abutment footing slabs may be built at any time.

Note: Reinforcing steel the same as shown for wings at Abutment No. 1.

DESIGN - W.B. HAMILTON
TRACE - JOSE
CHECK - [illegible]

BRIDGE - 5535

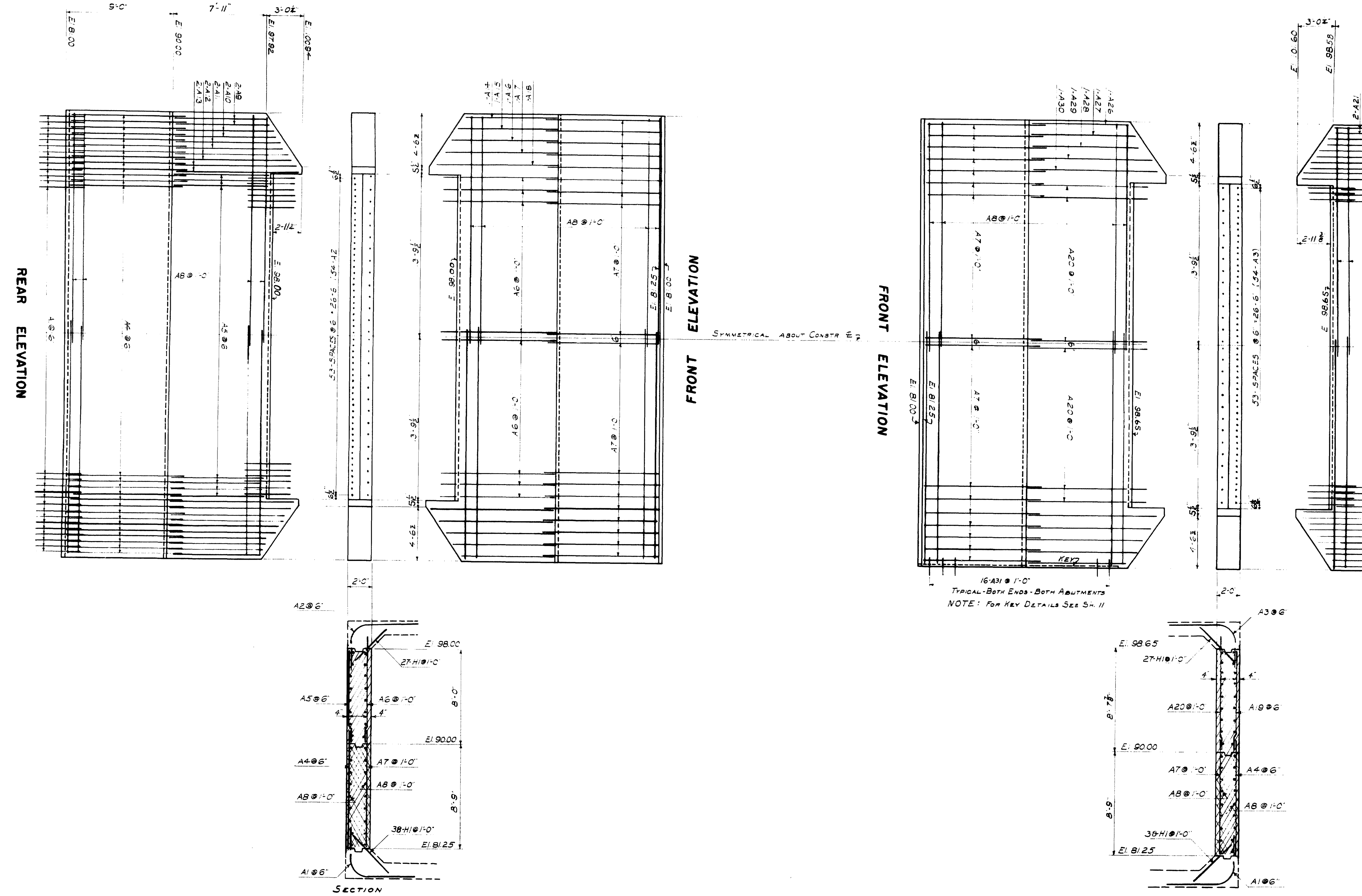
STATE HIGHWAY COMMISSION
BRIDGE DIVISION

DUNN'S BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
NORTH YARMOUTH
CUMBERLAND COUNTY
WING DETAILS

SHEET 11 OF 13 AUGUSTA, MAINE APRIL 1953

55-114

0 1 2 3 4 5 INCHES



ABUTMENT NO. 1 DETAILS

ABUTMENT NO. 2 DETAILS

DESIGN - W. B. HAMILTON TRACE - JOSE CHECK - C.A. Brooks	BRIDGE - 5535

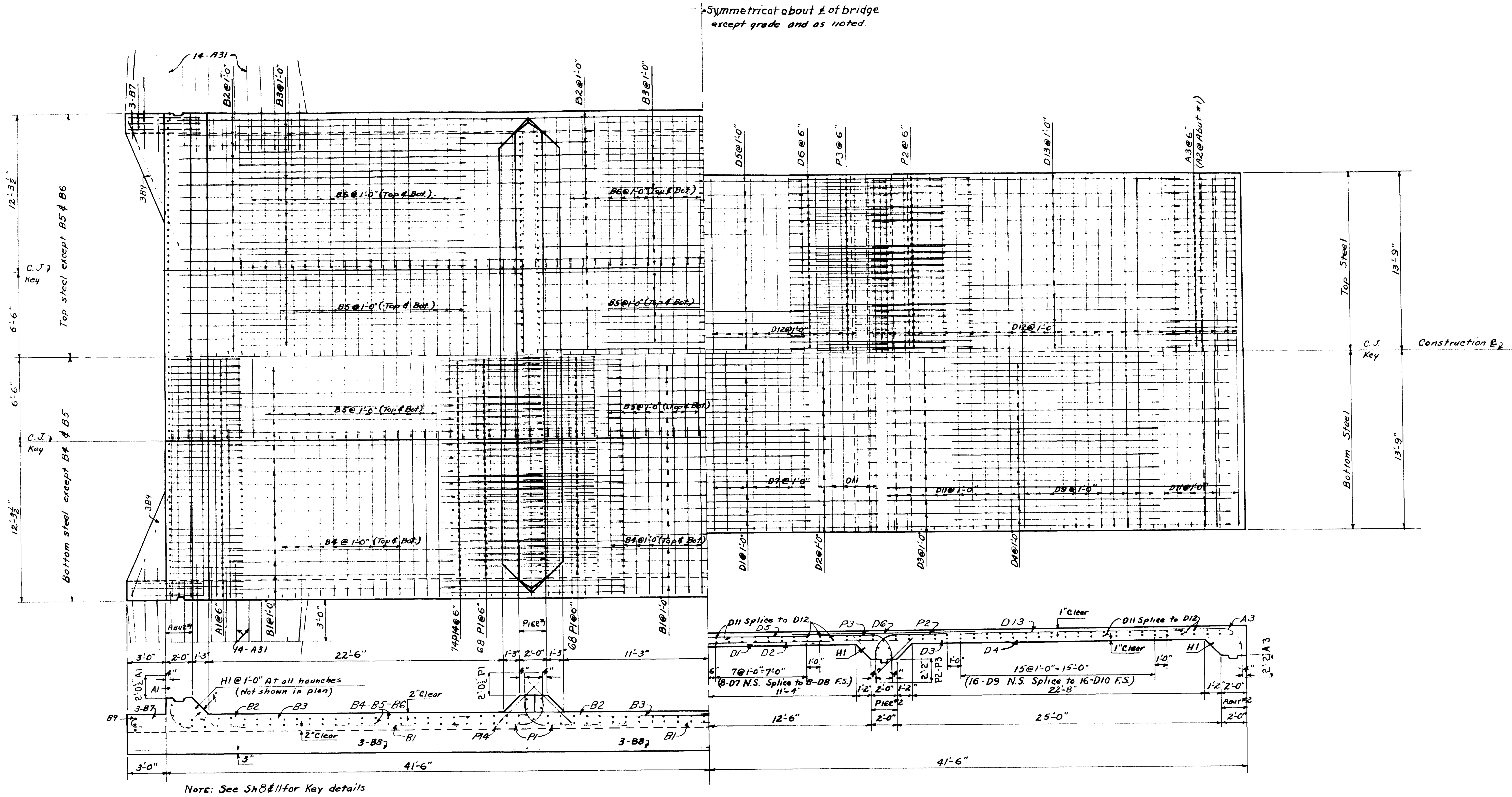
STATE HIGHWAY COMMISSION
BRIDGE DIVISION

DUNN'S BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
NORTH YARMOUTH

CUMBERLAND COUNTY
REINFORCING STEEL LAYOUT ABUTMENTS

SHEET 10 OF 13 AUGUSTA, MAINE APRIL 1953

55-113



HALF PLAN AND SIDE ELEVATION OF BOTTOM SLAB

NOTE: See "Sheathing Details" Sh. 12 for location of Mach. Bolts.

HALF PLAN AND SIDE ELEVATION OF DECK

DESIGN - W.B. HAMILTON
TRACE - LANGFORD
CHECK - ...

BRIDGE - 5535

STATE HIGHWAY COMMISSION
BRIDGE DIVISION

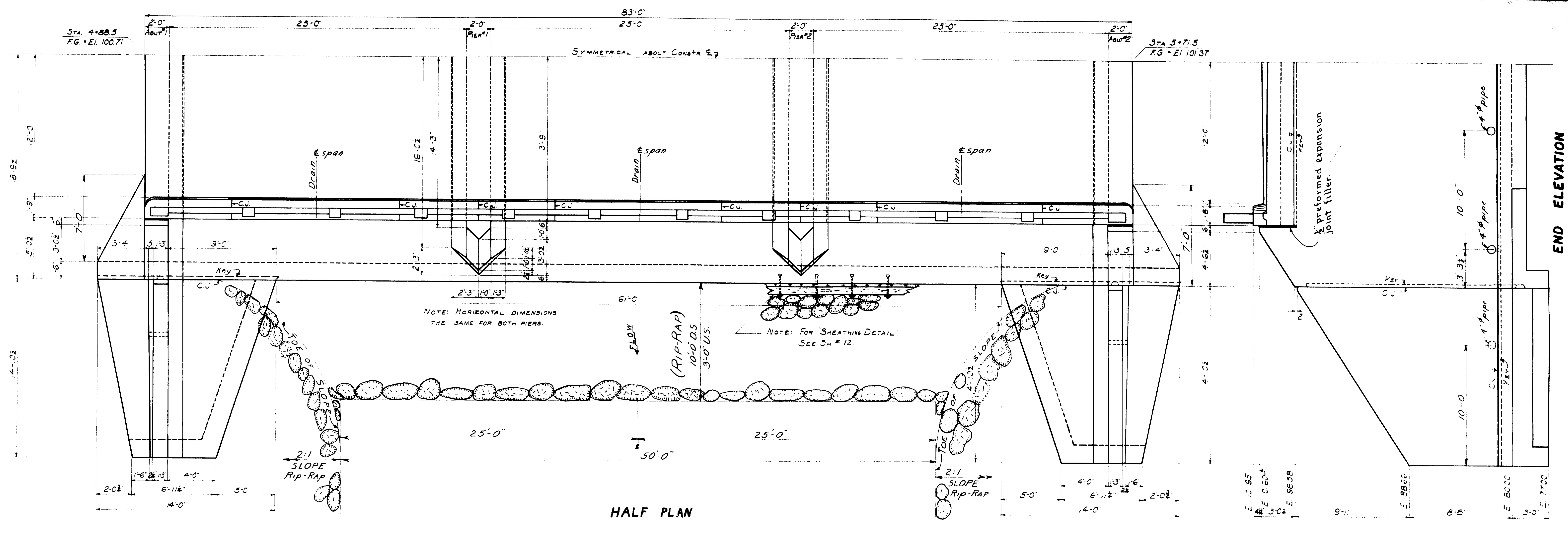
DUNN'S BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
NORTH YARMOUTH
CUMBERLAND COUNTY

REINFORCING LAYOUT FOR DECK AND BOTTOM SLAB
SHEET 9 OF 13 AUGUSTA, MAINE APRIL 1953

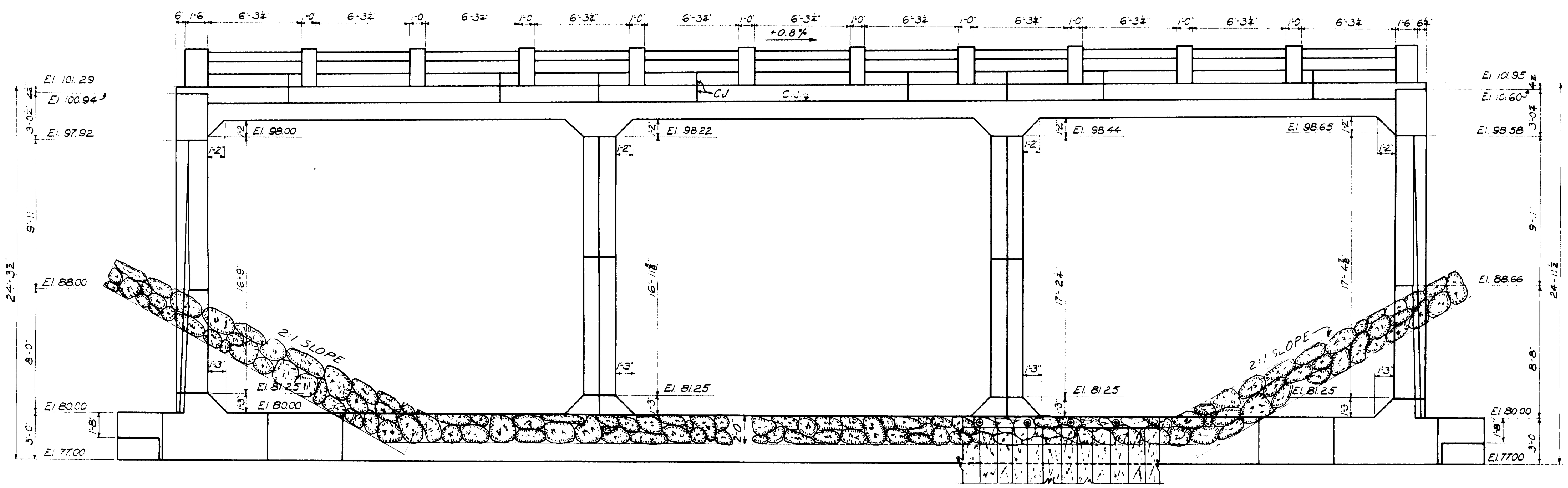
55-112

0 1 2 3 4 5 INCHES


LONGITUDINAL SECTION
+0.8% GRADE
ABUT. NO.1.
PIER NO.1.
PIER NO.2.
ABUT. NO.2.
Note: 1'-0" Gravel borrow under entire structure
KEY DETAIL
Piers and Abutments
JOINT DETAIL
2" Straight Crown
Cement Concrete W.S.
13½" Cement Concrete Slab
HALF TRANSVERSE SECTION DECK SLAB
HALF TRANSVERSE SECTION BOTTOM SLAB
DETAIL A
Top slab only.
KEY DETAIL
TOP AND BOTTOM SLAB
Note: Cover the top and middle horizontal construction joints on the back of the abutments and the vertical constr. joints between the abutments and wings with two (2) layers of heavy roofing 10 ... the surface of the concrete and the contact surface of each layer of roofing as applied with a suitable grade of roofing cement.
The area to be covered shall be recessed ¼" by nailing thin strips to the forms before the concrete is placed.
Note: See Reinforcing Steel Layout Sheets 9, 10, 11, 12, 13.
Shape W.S. to fit drain
¼" drip notch all around
DRAIN DETAILS
Note: Drain forms to be constructed of #24 gage galvanized iron. 6-required.
Pay line for excavation
sub-grade
Gravel Borrow
Stone Drain
To Conform to French drains, but paid for as gravel borrow
Pay line for Gravel Borrow
60° minimum
SECTION THRU ABUTMENTS
Similar thru Wings
DESIGN - W.B. HAMILTON
TRACE - JOSE
CHECK -
BRIDGE - 5535
STATE HIGHWAY COMMISSION
BRIDGE DIVISION
DUNN'S BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
NORTH YARMOUTH
CUMBERLAND COUNTY
TYPICAL SECTIONS OF STRUCTURE
SHEET 8 OF 13 AUGUSTA, MAINE APRIL 1953
55-111
INCHES



HALF PLAN



SIDE ELEVATION D.S.

LOADING H15-44

$f_s = 18000$ $f_c = 1200$ $n = 10$

All concrete shall be vibrated

Concrete classification

Frame & Wings	Class A
Wearing Surface	Class AA
Rail	Class Y

Note: All concrete except that in the rail & wearing surface to be paid for as "Item #66, Concrete in rigid frame structures, including sidewalks, curbs, and frame footings."

DESIGN- W.B. HAMILTON
TRACE-JOSE
CHECK- CABrown

BRIDGE- 5535

STATE HIGHWAY COMMISSION
BRIDGE DIVISION

DUNN'S BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
NORTH YARMOUTH
CUMBERLAND COUNTY
PLAN & ELEVATIONS

SHEET 7 OF 13 AUGUSTA, MAINE APRIL 1953

55-110

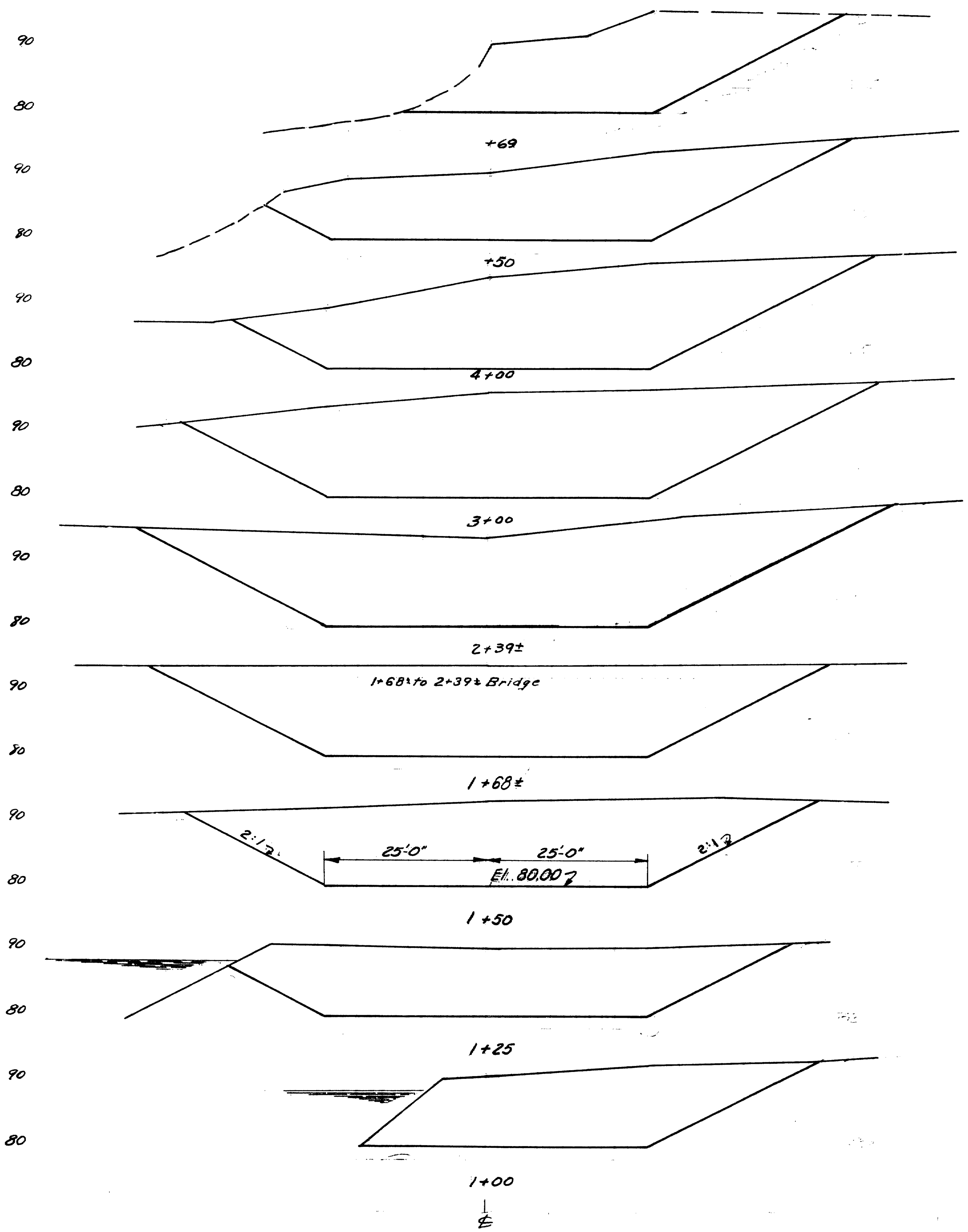
0 1 2 3 4 5 INCHES


110
10+50
107.72
105
10+00
105
105.83
9+50
105.09
100
+25
104.47
100
9+00
103.99
100
90
8+75
103.59
100
Ahead
90
Back
80
8+45±
70
103.40
100
1½:1
1½:1
90
Rip-rap to Elev. 90.0
80
70
60
8+25
℄
0 1 2 3 4 5 INCHES
55-109
Sheet 6 of 13
DUNN'S BRIDGE - N. YARMOUTH
CROSS SECTIONS

DUNN'S BRIDGE - N. YARMOUTH Check Elev.

CROSS SECTIONS

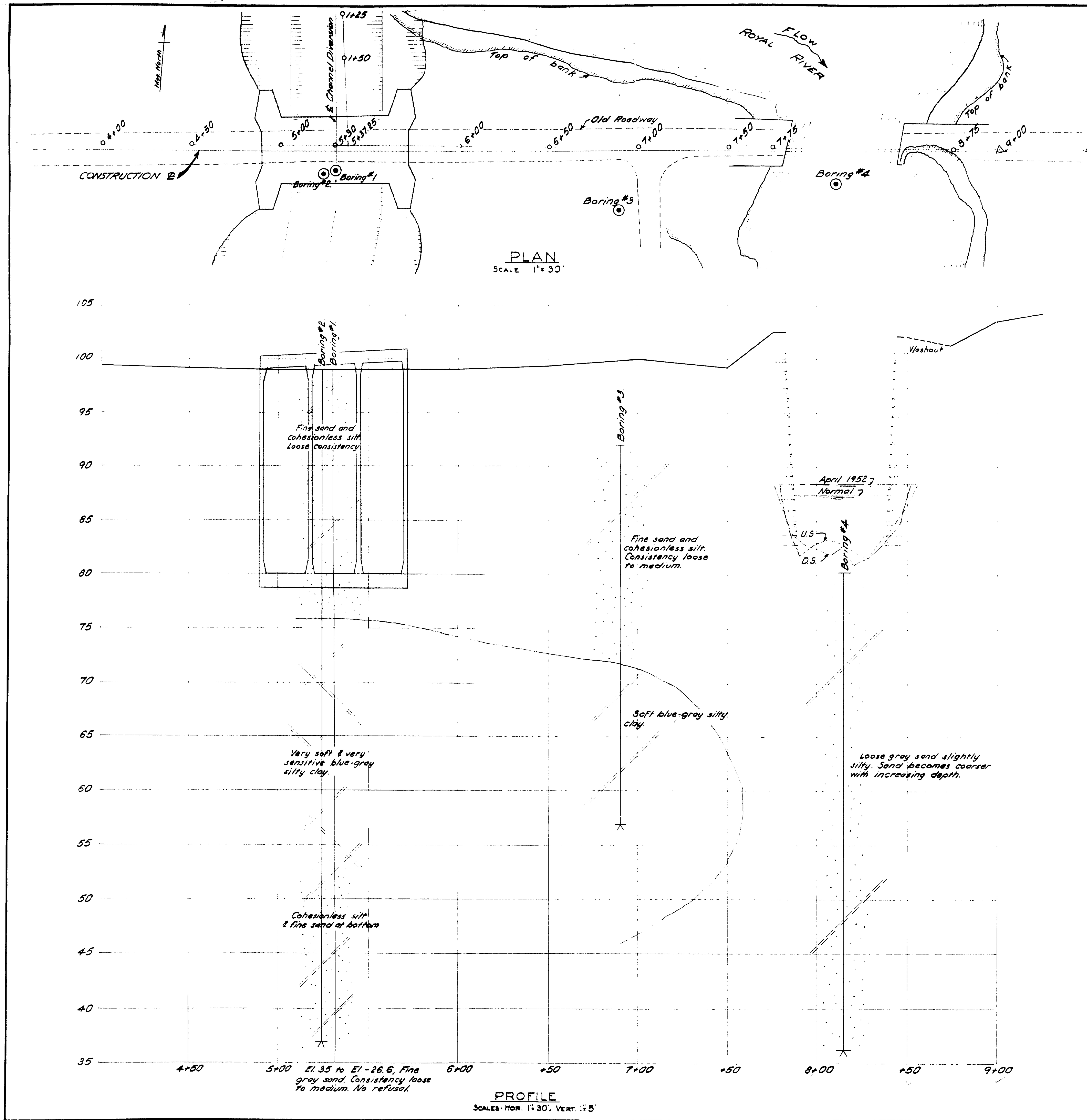
55-108 Sheet 5 of 13



DUNN'S BRIDGE-N. YARMOUTH
CHANNEL DIVERSION

55-107 Sheet 4 of 13

0 1 2 3 4 5 INCHES



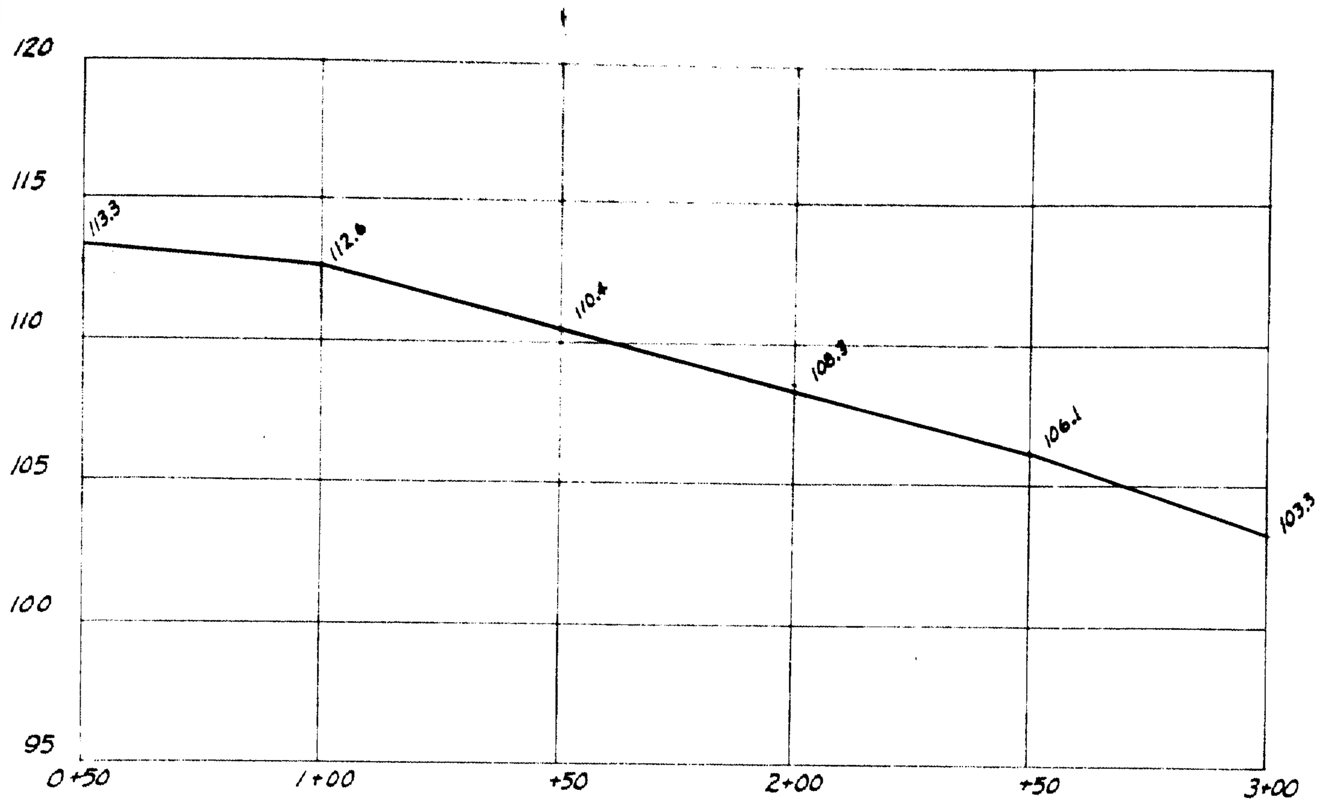
NOTE: "The soil stratification illustrated on this drawing has been developed by interpretation of, and interpolation between, the various soil borings. It is, therefore, speculative, and no warranty is implied with respect to the continuity of soil layers, or to the elevations of the soil boundaries except at the actual boring locations. Depths and thicknesses at the latter are subject to the inaccuracies inherent in drilling methods. The descriptions of the various soil layers are based upon the driller's field classification and upon the engineer's inspection of samples and interpretation of the drillers' record."

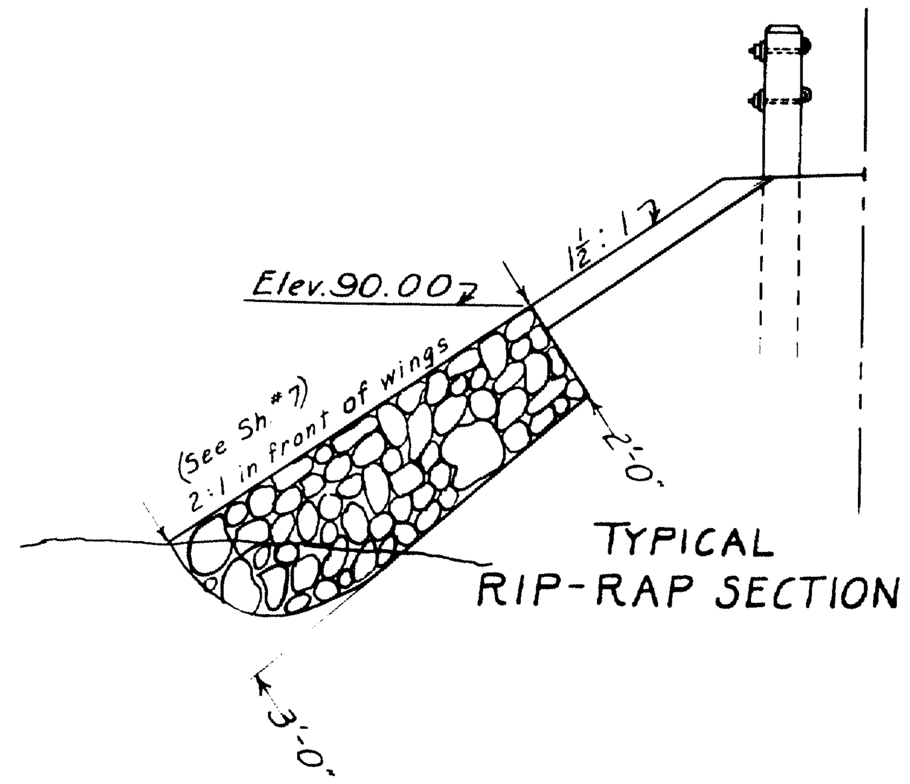
Traced by - ~~Hamilton~~ from plan by - Soils Engineer - H. Gray	BRIDGE - 5535

STATE HIGHWAY COMMISSION
BRIDGE DIVISION

DUNN'S BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
NORTH YARMOUTH
CUMBERLAND COUNTY
FOUNDATION DATA
SHEET 3 OF 13 AUGUSTA, MAINE NOV. 1952.

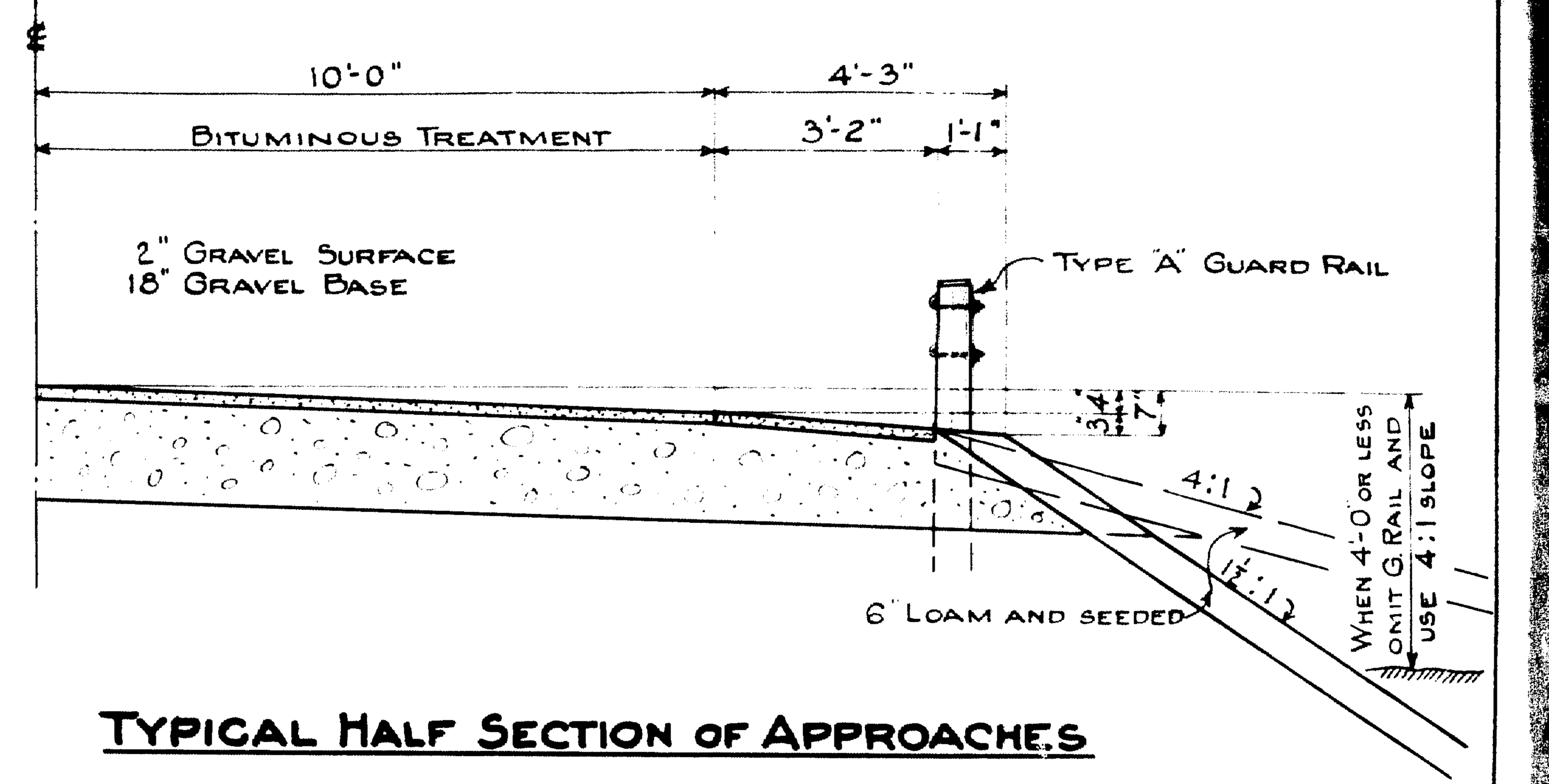
55-106



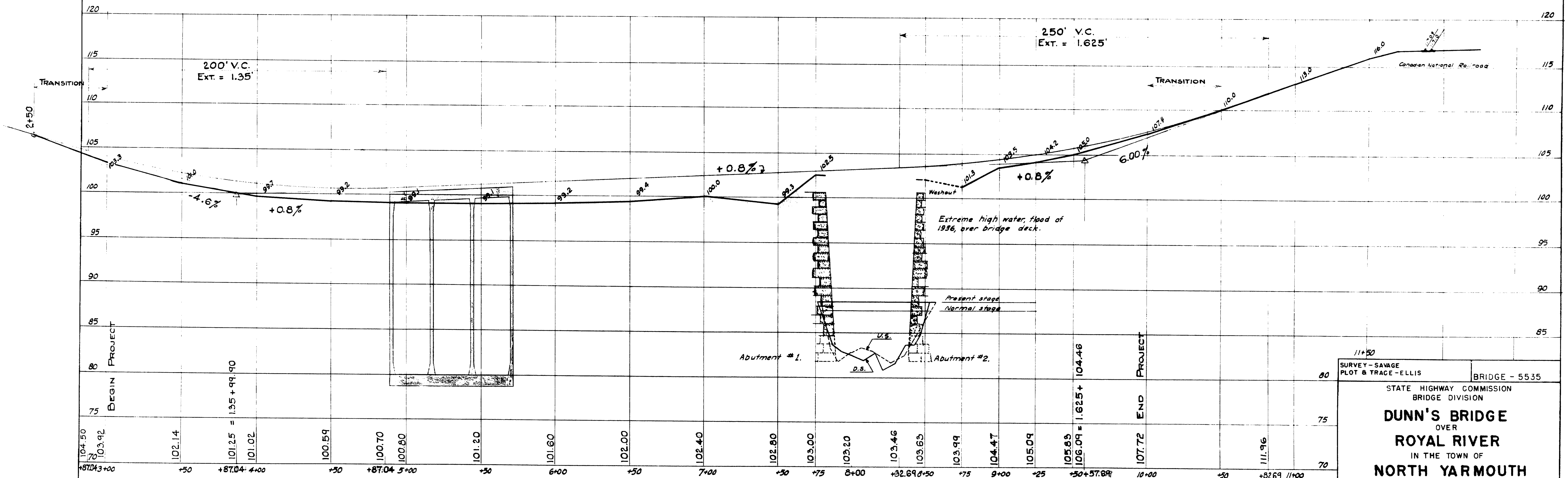


PROFILE ALONG SURVEY ℄

Scales
1" = 30' Horz.
1" = 5' Vert.



TYPICAL HALF SECTION OF APPROACHES



SURVEY - SAVAGE
PLOT & TRACE - ELLIS

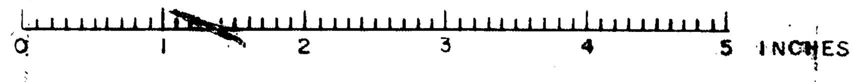
BRIDGE - 5535

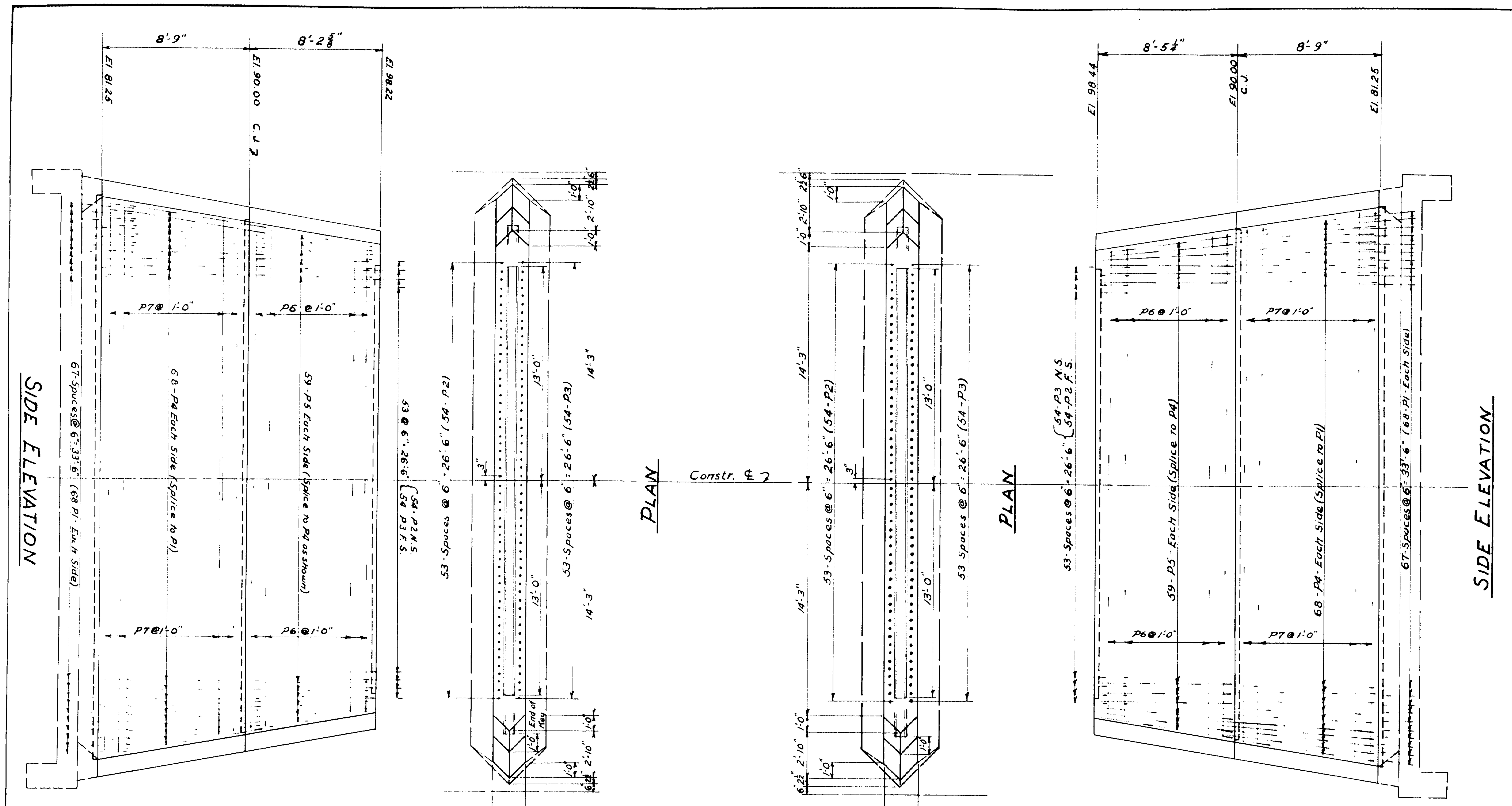
STATE HIGHWAY COMMISSION
BRIDGE DIVISION

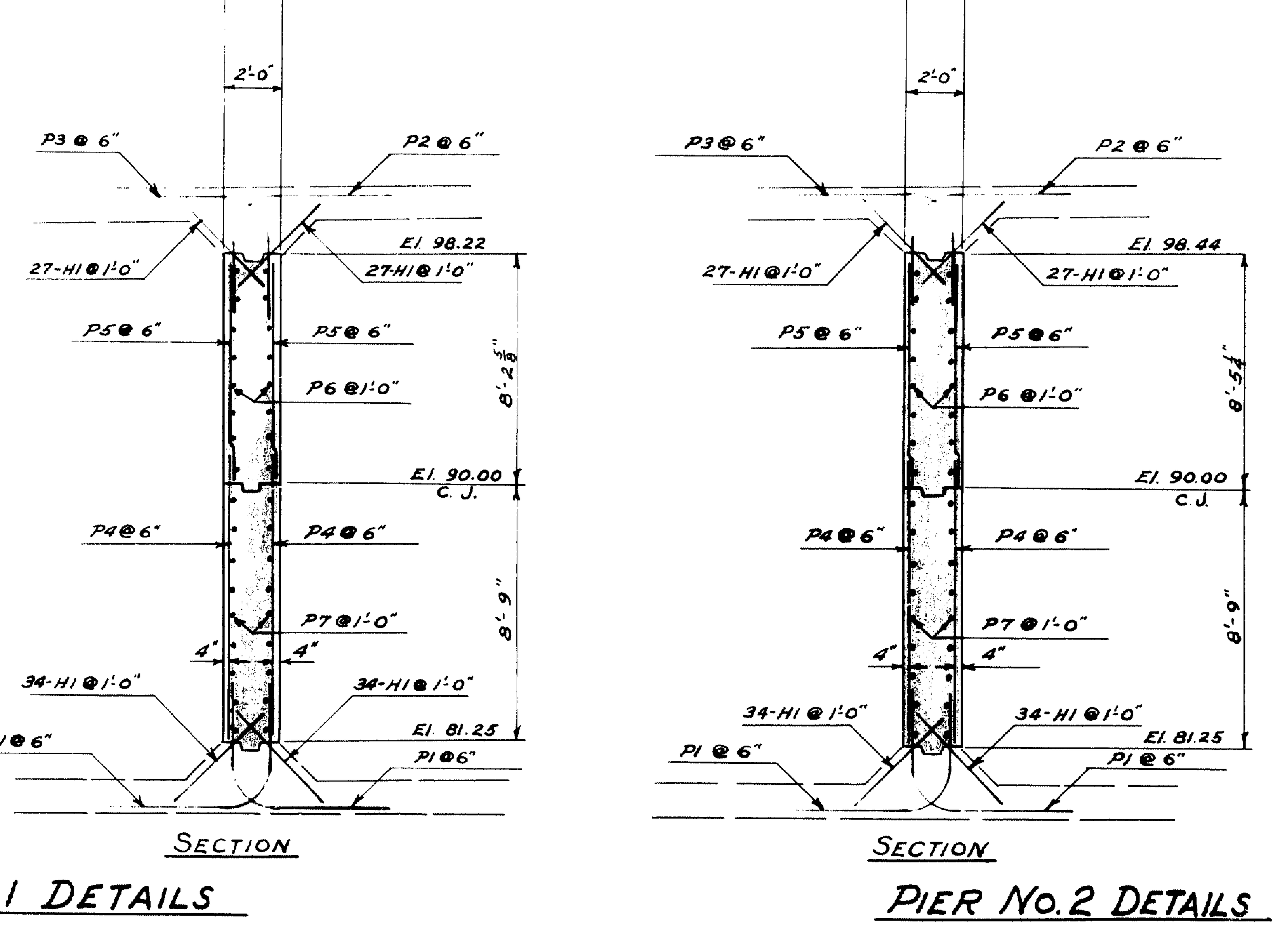
DUNN'S BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
NORTH YARMOUTH
CUMBERLAND COUNTY
PROFILE ALONG SURVEY ℄

SHEET 2 OF 13 AUGUSTA, MAINE APRIL 1952

55-105

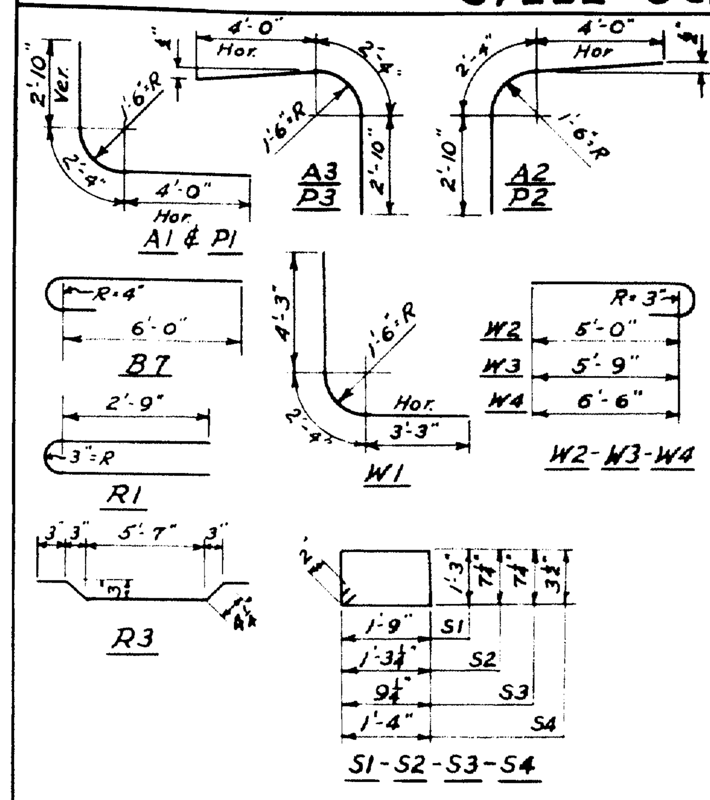






All reinforcing steel bars shall conform to A.S.T.M. Specifications A 305-49

STEEL SCHEDULE



DIMENSIONS TO ℄ OF BARS

BENT BARS				
MARK	No.	SIZE	LENGTH	LOCATION
A1	148	#7	9'-2"	Bot. slab at Abut. #1 & #2
A2	54	#7	9'-2"	Abut. #1 at top
A3	54	#7	9'-2"	Abut. #2 at top
P1	272	#8	9'-2"	Bot slab at Piers #1 & #2
P2	108	#7	9'-2"	Piers #1 & #2 at top
P3	108	#7	9'-2"	" " " "
W1	100	#10	9'-10"	Wing footings
W2	32	#6	6'-3"	" "
W3	32	#6	7'-0"	" "
W4	36	#6	7'-9"	" "
B7	12	#7	7'-6"	Cut-off walls at ends
R1	48	#6	6'-3"	Rail Posts
R3	44	#4	6'-8"	Top Rail Bars
S1	160	#4	6'-4"	Curbs
S2	16	#4	4'-1"	End Rail Posts
S3	80	#4	3'-1"	Int. Rail Posts
S4	154	#4	3'-7"	Bot. Rail Bars

STRAIGHT BARS				
MARK	No.	SIZE	LENGTH	LOCATION
B1	111	#7	22'-0"	Bot. Slab - All Spans
B2	114	#8	26'-6"	" " " "
B3	114	#8	16'-0"	" " " "
B4	176	#3	13'-0"	" " " "
B5	176	#3	14'-0"	" " " "
B6	176	#3	12'-0"	" " " "
B8	18	#6	30'-6"	Cut-off Walls
H1	426	#6	4'-6"	All Haunches
P14	148	#8	14'-0"	Bot Slab - Piers #1 & #2
B9	12	#6	10'-0"	Bot. Slab.
A4	148	#7	10'-9"	Abut. #1 & #2 Back
A5	54	#6	7'9"	" #1. Back
A6	28	#6	9'-6"	" #1. Front
A7	76	#6	10'-6"	" #1 & #2 Front
A8	140	#3	20'-0"	" #1 & #2 Front & Back
A9	4	#6	7'-8"	" #1 Back
A10	4		8'-4"	" " "
A11	4		9'-0"	" " "
A12	4		9'-8"	" " "
A13	4		10'-4"	" " "
A14	2		7'-8"	" " Front
A15	2		8'-4"	" " Front
A16	2		9'-0"	" " "
A17	2		9'-8"	" " "
A18	2		10'-4"	" " "
A19	54		8'-6"	" #2 Back
A20	28		10'-0"	" " Front
A21	4		8'-4"	" " Back
A22	4		9'-0"	" " "
A23	4	#6	9'-8	" " "

STRAIGHT BARS (CONT)				
MARK	No.	SIZE	LENGTH	LOCATION
A24	4	#6	10'-4"	Abut. #2 Back
A25	4		11'-0"	" " "
A26	2		8'-4"	" " Front
A27	2		9'-0"	" " "
A28	2		9'-8"	" " "
A29	2		10'-4"	" " "
A30	2	#6	11'-0"	" " "
A31	120	#8	6'-0"	" #1 & #2 To Wings
P4	272	#8	10'-6"	Pier #1 & #2
P5	236	#7	8'-0"	" " "
P6	64	#3	16'-0"	" " "
P7	72	#3	18'-0"	" " "
D1	26	#8	16'-0"	Deck Span #2
D2	28	#8	27'-0"	" " "
D3	56	#7	27'-0"	" " #1 & #3
D4	52	#7	16'-0"	" " " "
D5	28	#6	19'-0"	" " #2
D6	108	#7	14'-0"	" @ Piers #1 & #2
D7	16	#6	15'-0"	" Span #2
D8	16	#6	13'-6"	" " "
D9	32	#5	15'-0"	" " #1 & #3
D10	32	#5	13'-6"	" " " "
D11	114	#4	15'-0"	" All Spans
D12	114	#4	13'-6"	" " "
D13	56	#6	22'-0"	" Spans #1 & #3
T1	83	#3	23'-9"	Wear. Surf. Span #1-#2-#3
T2	48	#3	27'-8"	" " " #1 & #3
T3	24	#3	26'-8"	" " " #2
C1	12	#4	7'-2	Curbs
R2	44	#4	6'-7"	Top Rail Bars
R4	44	#4	6'-0"	Bot. " "
C2	18	#4	13'-8"	Curbs
C3	24	#4	6'-2"	Curbs
W5	32	#5	14'-3"	Wing Footings
W6	60	#6	14'-3"	" " & Walls
W7	20	#9	4'-0"	" "
W8	20	#9	5'-0"	" "
W9	20	#9	6'-0"	" "
W10	20	#9	7'-0"	" "
W11	52	#10	5'-6"	Wing Walls Rear
W12	4	#8	11'-6"	" " "
W13		#8	10'-9"	" " "
W14		#8	10'-0"	" " "
W15		#8	9'-3	" " "
W16		#8	8'-6"	" " "
W17	4	#7	7'-9"	" " "

STRAIGHT BARS (CONT)				
MARK	No.	SIZE	LENGTH	LOCATION
W18	4	#7	7'-0"	Wing Walls Rear
W19		#7	6'-3"	" " "
W20		#7	5'-6"	" " "
W21		#6	4'-9"	" " "
W22			4'-0"	" " "
W23	4		3'-3"	" " "
W24	8		17'-0"	" " Top
W25	4		10'-0"	" " Front
W26			9'-3"	" " "
W27			8'-6"	" " "
W28			7'-9"	" " "
W29			7'-0"	" " "
W30			6'-3"	" " "
W31			5'-6"	" " "
W32			4'-9"	" " "
W33			4'-0"	" " "
W34			3'-3"	" " "
W35	4	#6	2'-6"	" " "
W36	16	#4	14'-3"	" " "
W37	4		11'-3"	" " "
W38			8'-3"	" " "
W39			5'-3"	" " "
W40			2'-3"	" " "
W41			13'-3"	" " Rear
W42			11'-9"	" " "
W43			10'-3"	" " "
W44			8'-9"	" " "
W45			7'-3"	" " "
W46			5'-9"	" " "
W47			4'-3"	" " "
W48	4	#4	2'-9"	" " "
W49	12	#6	6'-6"	" Cut-off Walls
W50	12	#6	15'-0"	" " "
W51	52	#C	6'-9"	" Walls Front

DESIGN- W. B. HAMILTON
TRACE- MORRISON
CHECK- C. A. Snow Jr.

BRIDGE- 5535

STATE HIGHWAY COMMISSION
BRIDGE DIVISION

DUNN'S BRIDGE
OVER
ROYAL RIVER
IN THE TOWN OF
NORTH YARMOUTH
CUMBERLAND COUNTY

REINFORCING STEEL LAYOUT, PIERS

SHEET 13 OF 13 AUGUSTA, MAINE APRIL 1953

55-116