HYDRAULIC PERFORMANCE EVALUATION OF RCC STEPPED SPILLWAYS WITH SLOPED CONVERGING TRAINING WALLS

By

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NOMENCLATURE

$\vec{A}$	Area
d	Depth
d_1	Depth upstream of a hydraulic jump
d_2	Depth downstream of a hydraulic jump
d_c	Critical depth
d_w	Depth at the training wall
F	Froude number
$\vec{F}$	Force
F_f	Friction Force
g	Gravity
H	Horizontal
h_r	Height of run-up
H_w	Height of wall
L_r	Length ratio
P	Pressure
Q	Volumetric flow rate
q	Unit flow rate
Re	Reynolds number
V	Vertical
V	Velocity
v	Velocity component
We	Weber number
X	Distance from crest
z	Side slope ratio (H/V)
β	Wave angle
γ	Unit weight of water
ϕ	Convergence angle
ρ	Density of water
θ	Chute slope
ψ	Angle defined by geometry $= \tan^{-1}(\sin(\phi)\tan(\theta))$
ψ_2	Angle defined by geometry $= \tan^{-1}(\cos(\phi)\tan(\theta))$
ψ_3	Angle defined by geometry $= \tan^{-1}(\sin(\phi) * 1/z)$

CHAPTER I

INTRODUCTION, REVIEW, and OBJECTIVES

Abstract

More than 5,500 small watershed dams designed and built with support from the USDA Natural Resources Conservation Service (NRCS) will reach the end of their 50 year planned service life by 2018. Changes in watershed hydrology and hazard classification due to urbanization often require these structures to pass greater flows than were originally intended. Roller compacted concrete (RCC) stepped spillways provide an effective solution to this problem. Increased flow requirements, urban constraints, and valley geometry call for convergent chute sections designed with sloped training walls. There are currently no generalized guidelines for convergent sloped training walls.

A three-dimensional, physical model study was utilized to conduct an investigation of sloped training wall convergence on 3:1 stepped spillway chutes including flow patterns and run-up for both stepped and smooth sloped training walls. Generalized relationships for stepped and smooth sloped training wall dimensions on a 3:1 RCC stepped spillway chute were developed. Results are expected to assist in the development of general design guidelines for stepped spillways.

Introduction

The United States Department of Agriculture (USDA) – Natural Resources Conservation Service (NRCS) has been involved in the planning and/or construction of over 11,000 small watershed dams beginning in the 1940's with the largest number being built during the 1960's. These small watershed dams were primarily earthen embankment dams built with 50 year planned service lives with the primary purpose of flood protection on agricultural lands. Over half of these dams will reach the end of their planned service life by 2018. Along with the normal problems associated with aging infrastructure, many of these dams are being affected by urban sprawl. Increased urbanization in a watershed provides some unique challenges: 1) urbanization potentially alters the hydrology of the watershed, increasing the runoff, 2) urbanization potentially alters the hazard classification of a dam, and 3) urbanization potentially limits rehabilitation options. Many of these structures are in need of rehabilitation due to factors associated with age and urbanization effects. Dam rehabilitation options generally include: 1) raising the top of the dam, 2) increasing spillway capacity, 3) providing overtopping protection, 4) combinations of the previous options, or 5) decommissioning the structure (Hunt et al., 2005). Increasing spillway capacity and/or providing overtopping protection are often the only viable options.

The use of roller compacted concrete (RCC) in the construction of stepped spillways has proven to be a cost effective and efficient design and construction rehabilitation solution for increasing flow capacity. RCC stepped spillways (figure 1.1) can safely increase spillway capacity without increasing the size of the dam or depth of the reservoir.

Figure 1.1. RCC stepped spillway on an embankment dam.

Stepped channels and structures have been around for over 3,500 years (Chanson, 2002). Interest in stepped chutes and spillways decreased dramatically during the mid 1900s. However, there has been renewed interest and increased use of stepped spillways since the early 1980s (Rice and Kadavy, 1994). Interest in stepped spillways and channels has been renewed in the past few decades due to their effectiveness in providing overtopping protection, economic viability, and convenience for design and construction. Stepped spillways provide effective energy dissipation and increased spillway capacity without taking up additional land. Another reason for the increasing popularity of stepped spillways has been the evolution of the RCC dam construction technique (Boes and Hager, 2003). Research of flow over stepped structures has mostly focused on scaling effects, flow regimes, energy dissipation, and air entrainment. Yet, the application of RCC stepped spillways for rehabilitation of USDA small watershed dams in urban settings leads to non-conventional spillway geometries due to water stage and valley constraints imposed. These constraints have led to the need for converging chutes on RCC spillways. Convergence research has been limited, and due to the complexities of flow, little generalized design guidance for converging RCC stepped spillways exists and even less exists for sloped converging training wall applications.

Stepped Spillway Modeling

Because of relatively large size of spillways, it is difficult, expensive, and impractical to build full scale dam prototypes for modeling purposes. Scaled model studies are a more cost effective and practical way to analyze the performance of a design or compare multiple designs. Models dealing with open channel flows typically use Froude number (F) similarity to scale the flows. Boes and Hager (2003) found that due to the highly air entrained flow on stepped spillways, Weber (We) and Reynolds (Re) numbers should also be considered. At any scale other than 1:1, it is not possible to satisfy Froude, Weber, and Reynolds similarity simultaneously. To eliminate scale effects of viscosity and surface tension, Re greater than 10^5 and We greater than 100 are recommended by Boes and Hager (2003) in addition Chanson (2002) recommends using a scale of 10:1 or greater.

Flow Regimes and Energy Dissipation in Stepped Chutes

Flow over stepped spillways is generally divided into two specific regimes: the nappe flow regime and the skimming flow regime (Diez-Cascon et al., 1991). More recent work describes a transition flow regime as well (Chanson, 2002). Chanson (2002) gives a detailed description of the determination and characteristics of each regime. Nappe flow is described as a succession of free falling nappes (Chanson, 1994). Flows in the nappe regime are the most efficient at energy dissipation (Chanson, 1994). Nappe flows can be modeled as a series of drop structures where energy dissipation takes place as the flow impacts the step (Chanson, 1994). Skimming flow is characterized by a smooth surface with recirculating vortices that develop between the main flow and the steps; this type of flow dissipates energy through the recirculating vortices between the main flow and the steps (Chanson, 1994). Skimming flows tend to occur at higher flow rates which for practical reasons are typically the range for stepped spillway design flows. Transition flows should be avoided due to excessive pressure fluctuations (Chanson, 2002).

Air Entrained Flow

Due to the nature of the interaction of the steps with the flow in RCC spillways, air entrained flow eventually develops along the chute depending on slope, discharge, step height, and chute length. Air entrained flow in the stepped chutes provide a challenge to modeling if Weber number similarity is not achieved. Additional turbulence caused by the roughness of the steps aerates the flow and makes modeling flows over stepped spillways more difficult especially at smaller scales ($L_r < 1:10$). Much of the recent research on stepped spillway flow has been concerned with air entrainment (Boes and Minor, 2002; Boes and Hager, 2003; Chanson et al. 2005; Chanson and Gonzalez, 2005; Kramer et al., 2006; Pfister et al., 2006). Air entrainment causes flow bulking which is difficult to model at small scales (Boes and Hager, 2003). Reduced friction and energy dissipation is another concern. Boes and Hager (2003) as well as Pfister et al. (2006) have done much to describe the two-phase flow characteristics found in stepped spillways. Chanson (2002) and Boes and Hager (2003) each developed relationships for determining the inception point or point where the turbulent boundary layer breaks the surface of the flow and air entrainment begins. These equations were developed primarily from data for steep ($\theta > 22°$) chutes, but Hunt and Kadavy (2007) showed that Chanson's relationship also worked well for slopes as flat as 4:1. Hunt et al. (2005) and Hunt and Kadavy (2007) observed that the inception point occurs farther down the spillway in flatter sloped stepped spillway (18° or less) applications anticipated on small watershed dams like those designed and constructed by NRCS. These structures are usually designed for high flow rates and tail water conditions. Under design flow conditions, these chutes are typically not long enough for fully air entrained flow to develop. On NRCS type structures, air entrainment will therefore be of less concern because of the relatively short chute lengths and flat slopes under design flow conditions. Often times the inception point will occur beyond the end of the chute or within the tail water region. This then leads to the conclusion that, air entrainment is not as important a consideration for modeling of these relatively mild sloped small RCC spillways. Thus, air entrainment was not considered an issue in this study and smaller scale modeling was considered appropriate.

Convergence

Engineers do not typically recommend or design convergent spillways due to the complexities of flow that occurs, but due to the constraints that have been introduced by urbanization and increased discharge capacity requirements, convergent RCC spillways have become a necessity. This leads to the need for the development of generalized design guidance for these structures. One of the flow complexities that occurs in a convergent chute is the formation of an oblique hydraulic jump/shockwave along the training walls of the spillway. Kindsvater (1944) studied hydraulic jumps in sloping channels, but that work does apply to oblique hydraulic jumps found in converging chutes. Oblique hydraulic jumps also known as standing waves or shockwaves were characterized by Ippen and Dawson (1951) and Ippen and Harleman (1956). These early experiments looked at oblique standing waves in a horizontal channel caused by a convergent vertical deflector wall. Relationships developed from these early studies do not accurately describe the flow in a sloped channel or flows in a channel with sloped training walls. No known theoretical work in this area has been performed for almost 50 years; therefore, there are no readily available design guidelines for converging chutes on slopes. According to the United States Army Corps of Engineers (USACE, 1990) "Hydraulic model studies are usually conducted to verify the design of a convergent chute." Martin Vide et al. (1995) conducted a study on converging overfall spillways. Specific model studies have been conducted to examine the characteristics of a converging stepped spillway (Hanna and Pugh, 1997; Robinson et al. 1998; Hunt and Kadavy, 2006; Frizell, 2006; Hunt et al. 2006b; and Hunt, 2008), but little generalized guidance is available on converging stepped spillways with sloped training walls.

Robinson et al. (1998) and Hanna and Pugh (1997) have investigated the hydraulic performance of converging stepped spillways. Robinson et al. (1998) conducted physical model studies on a steep (0.7H:1V) stepped chute with convergence angles ranging from 0 to 32.5°. Findings from this study showed that as the convergence angle of the training wall increased the flow run-up along the wall also increased, but no generalized approach for dimensioning the walls was developed. Flow run-up is defined as the additional amount of water extending up the wall created by flow convergence as compared to the normal flow depth observed in a non-converging spillway. Hanna and Pugh (1997) conducted research on a 1:40 scale, steep (0.8H:1V) spillway with a convergence angle of 16°. Both of these specific model studies were on steep slopes and no generalized guidelines were developed and are, therefore, not applicable to relatively flat sloped RCC stepped spillways with convergent sloped training walls.

In addition to these two model studies, Hunt et al. (2006a) conducted a 1:22 scale physical model study on a relatively flat (3H:1V) slope stepped chute where convergence angles of 0°, 15°, 30°, 52°, and 70° were tested. A 3:1 chute slope is consistent with many of the aging USDA-NRCS watershed dams (Hunt and Kadavy, 2006). Generalized design guidance was proposed by Hunt et al. (2006a) for 3:1 sloped converging stepped spillways with vertical training walls, and Hunt (2008) has further refined the design guidance for vertical training walls for converging stepped spillways. However, no generalized guidance was developed for sloped training walls.

It has been suggested that stepped or smooth sloped training walls would be preferred to vertical training walls on stepped spillways in urban areas where large concrete walls could prove to be public safety hazards as well as eyesores. Construction efficiency and cost favor stepped training walls due to the consistency of construction technique between the spillway chute and training walls. Smooth training walls would add an additional step to the construction practice but have potential benefits in flow performance (Hunt et al., 2006b). Stepped spillways with sloping stepped training walls have been investigated by Frizell (2006) and Hunt et al. (2006b). These investigators observed that a significant amount of flow ran out along the stepped training walls beyond the end of the structure. Deflectors and a mid-level end sill were able to reduce the amount of flow run-out in Frizzel's study. Hunt et al. (2006b) performed research on converging sloped stepped training walls along with converging vertical training walls and observed that converging stepped training walls cause significant amounts of flow run out beyond the end of the structure and smooth sloped training walls significantly reduced the run-up. However, neither of the specific model studies by Frizell (2006) or Hunt et al. (2006b) resulted in generalized design criteria for stepped training walls.

Objectives

Two objectives are pursued in this research. The first objective is to conduct an in-depth investigation of sloped training wall convergence on 3:1 stepped spillway chutes including flow patterns and run-up for stepped sloped training walls and smooth sloped training walls. The second objective is to develop generalized relationships for describing the run-up on stepped and smooth sloped convergent training walls on a 3:1 stepped spillway chute. The second objective will result in more generalized design guidance in dimensioning training walls. Tasks required to meet the objectives include performing a three-dimensional physical model study of stepped spillways with both stepped and smooth sloped training walls and developing relationships based on experimental data collected.

Chapter II and Chapter III address these two research objectives. Observed flow patterns and run-up for both stepped and smooth sloping training walls as well as the development of a generalized relationship for predicting run-up along stepped sloped training walls are presented in Chapter II. Chapter III presents: 1) a more in-depth investigation of run-up along smooth sloped training walls, 2) an evaluation of the application of the momentum based relationship developed by Hunt (2008) for convergent vertical walls to smooth slope training walls, and 3) the development and application of a momentum based empirical relationship.

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CHAPTER II

PHYSICAL MODEL STUDY of RCC STEPPED SPILLWAYS with SLOPED CONVERGING TRAINING WALLS

Abstract

Approximately half of the over 11,000 small watershed dams designed and constructed under the supervision of the United States Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS) will reach the end of their planned service life by 2018. Many of these dams have inadequate spillway capacity due to changes in hazard classification and revised dam safety laws. Urbanization of surrounding areas limits the rehabilitation options of these dams. Roller compacted concrete (RCC) stepped spillways provide an effective solution to this problem. Recent years have seen a growth in the research and application of RCC, but there are no readily available generalized guidelines for RCC stepped spillways with stepped or smooth sloped training walls. Research has been performed on converging spillway chutes with vertical training walls. Public safety, aesthetics, and construction efficiency suggest sloped training walls are often a more desirable option.

A generalized study of converging stepped spillways with sloped training walls was conducted at the USDA- Agricultural Research Service (ARS) Hydraulic Engineering Research Unit in Stillwater, Oklahoma. The study utilized a three-dimensional small scale physical model. Model configurations consisted of a spillway

chute having a slope of 3(H):1(V) and training walls with slopes ranging from 1(H):1(V) to 3(H):1(V). Water surface profiles and flow information were recorded for each configuration. Run-up along the wall was observed to be the controlling factor for determining necessary dimensions of this type of structure. The objective of this study was to increase the general knowledge of and help develop a generalized equation for stepped sloping training walls.

Keywords: Flood control, Dams, Physical models, RCC, Stepped spillways, Dam rehabilitation

Introduction

Over 11,000 small watershed dams were designed and constructed with the technical and financial aid of the USDA-NRCS. More than half of these watershed dams will reach the end of their planned service life within the next decade. Many of these dams were originally built to protect agricultural land. Urbanization has affected the hydrology of the watersheds and led to changes in the hazard classification of many structures. The major problem resulting from this change is that many of these dams now have inadequate spillway capacity. In general rehabilitation options include: 1) raising the top of the dam, 2) increasing spillway capacity, 3) providing overtopping protection, 4) combinations of the previous options, or 5) decommissioning the structure (Hunt et al., 2005). Land rights issues of surrounding areas limit the rehabilitation options of these dams. Raising the top of the dam or decommissioning the structure is often not a viable option. RCC stepped spillways have shown to be a cost effective and easily constructed solution for increasing spillway capacity. Stepped spillways can safely pass greater flows without significantly increasing the size of the dam or depth of the reservoir.

While RCC stepped spillways can be an effective rehabilitation option, there are no general design guidelines for stepped or smooth sloped training walls. Stepped spillways often require a large crest section in order to convey the design flow, yet land rights and topography often demand that the spillway constrict down to the width of the downstream channel. Reinauer and Hager (1998) point out that, spillway contractions are generally not used because of a fundamental lack in knowledge related to the hydraulics. Better understanding of the hydraulics of this type of structure will result in designs that are less likely to cause erosion and potentially undermine the structure. A crucial design issue with spillway contractions is the development of a standing shock wave at the converging training walls, which results in significant training wall height requirements to contain the flow. Reinauer and Hager (1998) developed generalized equations for the standing wave heights for flat to slightly sloping smooth chutes with converging vertical walls.

The US Army Corps of Engineers (USACE) recommends utilizing a model study when designing converging RCC stepped spillways (USACE, 1990). Physical model studies are utilized when there is a lack of understanding of a process or event. Model studies are particularly useful in hydraulics research and can lead to a better understanding and mathematical models or equations describing flows or events. Recent studies including Hunt et al. (2005) and Hunt and Kadavy (2006) have provided information on converging vertical training walls for RCC stepped spillways. However, concerns have been raised over public safety and aesthetics of vertical walls in urban areas. These concerns along with cost and construction efficiency have led to interest in design guidelines regarding sloped converging training walls.

Physical Modeling

Physical models dealing with open channel flow typically use Froude similarity to scale the flows, but modeling hydraulic performance of RCC stepped spillways requires special considerations related to scale. Boes and Hager (2003) found that due to the highly air entrained flow on stepped spillways Weber and Reynolds numbers should also be considered because of the effects of air entrainment on viscosity and surface tension. To minimize scale effects a Re of 10^5 and a We of about 100 are recommended (Boes and Hager 2003). The additional turbulence caused by the roughness of the steps aerates the flow causing flow bulking which is difficult to model at small scales (Boes and Hager, 2003). As a result of aeration scale effects, Chanson (2002) recommends using a scale of 10:1 or greater. Boes and Minor (2002), Boes and Hager (2003), Chanson and Gonzales (2005), and Kramer et al. (2006) have conducted research on air entrained flows in stepped spillways. Typical slopes in these studies are greater than 22°. Hunt et al. (2005) and Hunt and Kadavy (2007) observed in their studies on flatter sloped (as small as 14°) applications of RCC stepped spillways on small watershed dams like those constructed by NRCS that air entrainment appears to be of less concern if the air entrainment inception point as described by Chanson (2002) occurs near or beyond the end of the chute. Based on these observations, it can be concluded that scale effects are less important on flatter sloped spillways used on these embankment dams, and results from these smaller scaled studies can be evaluated effectively for design purposes.

Design of stepped spillways with sloping stepped training walls has been investigated by Frizell (2006) and Hunt et al. (2006b). Frizell (2006) observed significant flow run-out, flow beyond the end of the structure not confined to the channel, along the stepped training walls in the converging stepped spillway model. Deflectors and the use of a mid-level end sill controlled the level of run-out observed (Frizell, 2006). Hunt et al. (2006b) conducted preliminary investigations of converging sloped stepped training walls along with hydraulic model studies with converging vertical training walls. Interest in the performance and design of the sloping stepped training walls is due to several issues including safety, aesthetics, design, construction efficiency, and cost. Hunt et al. (2006b) also observed that converging stepped training walls caused significant amounts of run-out flow and smooth sloped training walls reduced the run-out significantly. However, the study by Hunt et al. (2006b) did not result in generalized design criteria for the sloping stepped training walls.

The objective of this study was to conduct a more in-depth investigation of sloped training wall convergence on 3:1 stepped spillway chutes including 1) an investigation of the flow patterns and run-up, and general design requirements for stepped sloped training walls, and 2) an investigation of the flow patterns and run-up, and design requirements for smooth sloped training walls. Run-up height resulting from the standing shockwave will be the controlling factor in determining spillway training wall dimensions. Air entrainment and energy dissipation were not considered for this study because studies by Hunt et al. (2005) and Hunt et al. (2006b) suggested that air entrainment will not affect the design of the training walls for stepped spillways applied on small earthen embankment dams under design flow conditions, since many of these structures have relatively short spillway chute lengths and are expected to have high tailwater.

Experimental Setup

Hunt et al. (2006a) conducted a three-dimensional small-scale model study of an RCC stepped spillway providing a generalized equation for determining the required vertical training wall dimensions. This same model set-up was used in this study to investigate sloped training walls. The spillway model consisted of a 4.2 m (13.6 ft) ogee crested weir followed downstream by a 3(H):1(V) stepped chute with step heights of 1.4cm (0.55 in). Preliminary observations in this study suggested that the type of crest section will had little effect on the results. Elevations of the crest and basin were 0.64 m (2.1 ft) and 0.19 m (0.63 ft) respectively. Total height from spillway to basin was 0.44 m (1.5 ft). The crest was located at station 0 m (0 ft). Training walls were set perpendicular to the spillway crest. Chute convergence was due to sloping training walls. Three training wall slopes were tested; 1:1, 2:1, and 3:1 (H:V) in both stepped and smooth configurations. These slopes were chosen for testing because these would be likely slopes chosen for construction in the field. Spillway training wall slopes of 1:1, 2:1, and 3:1 result in convergence angles, ϕ, of 18°, 34^o, and 45^o respectively. Figure 2.1 shows a schematic of a stepped spillway configuration with a 3:1 chute section and 3:1 training walls. The initial spillway test configuration was set-up with training wall slopes of 1:1. Subsequent configurations involved leaving the left training wall slope at 1:1 and altering the right training wall side slope to 2:1 and 3:1. The right training wall slope was used to test both stepped and smooth configurations. Figure 2.2 is a photograph of the model running in the initial 1:1 configuration with smooth training walls.

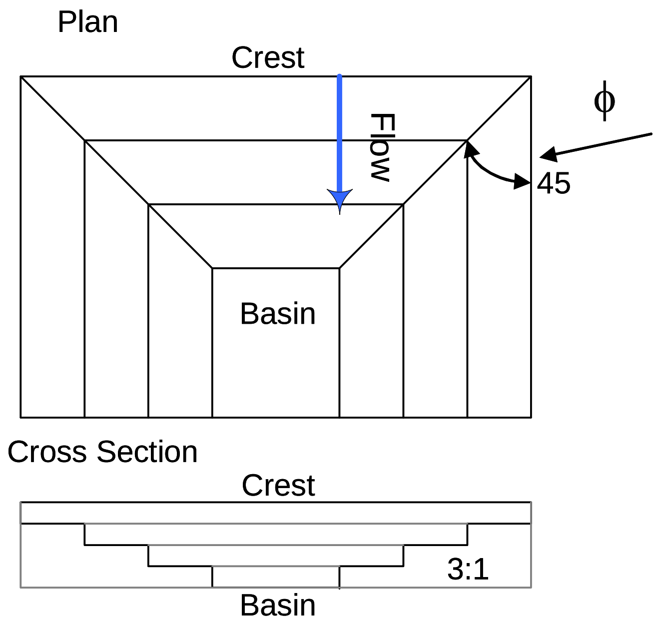

Figure 2.1. Schematic of converging stepped spillway chute with 3:1 sloped stepped training walls set perpendicular to the spillway crest (not to scale).

Figure 2.2. Small scale stepped spillway model with 1:1 smooth training walls.

The ogee crest section was machined out of PVC. Chute steps consisted of polyurethane coated redwood sanded to exact specifications. Smooth training walls consisted of polyurethane coated plywood. Training wall steps were assembled out of pine coated in the same polyurethane.

Flows tested were all within the skimming flow regime as described by Chanson (1994, 2002). Table 2.1 summarizes all the unit discharges and critical depths tested during the course of the experimental investigation. Critical depths were measured at the spillway crest. Flow was measured with orifice plates and an air-water differential manometer. Water surface and bed elevation data were collected with a manually operated point gauge.

Table 2.1. Summary of unit flow rates, q, and corresponding critical depths, d_c, tested.

q (m^2/s)	d_c (m)
0.078	0.085
0.060	0.070
0.052	0.065
0.039	0.054

Results and Discussion

A major design issue with converging RCC stepped spillways is containment of the increased flow depth at the training walls due to the standing shock wave that develops (Hunt et al., 2005 and Hunt and Kadavy, 2006). Figure 2.3 shows the model running under the 2:1 smooth sloping training wall configuration and the resulting shock wave caused by the convergence of the chute. Run-up height, h_r, due to the standing shock wave is defined as the elevation the water flows up the training wall relative to the bed at that station. Figure 2.4 presents the depth of flow above the bed surface, d, normalized by critical depth at the spillway crest, d_c, versus the horizontal distance across the spillway chute, w, normalized by d_c. Two important points are defined in this figure and are used throughout the results section to describe the results. The first point is the location of the initiation of the wave front, and the second point is the height of the run-up, h_r, relative to the cross-section bed elevation and normalized by d_c.

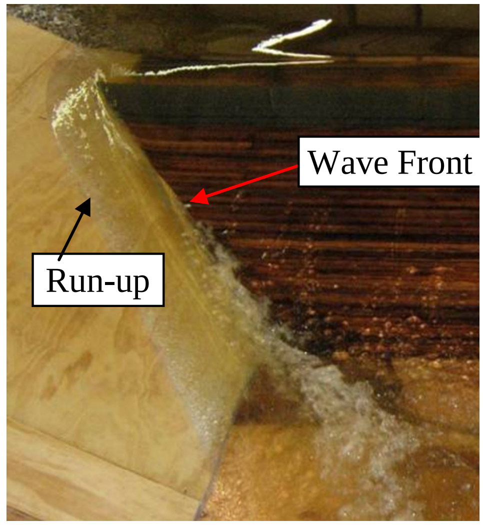

Figure 2.3. Shockwave along the training wall due to convergence and the resulting run-up.

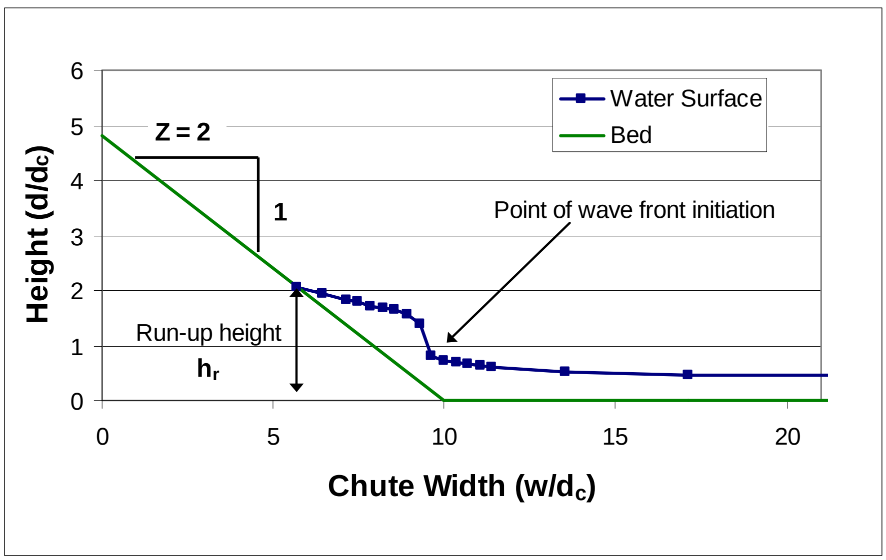

Figure 2.4. Cross-section of 2:1 bed and water-surface profiles for smooth training wall non-dimensionalized by critical depth of the flow at the spillway crest.

The wave front is an important feature in characterizing the flow in a converging chute. Ippen and Harleman (1956) characterized the shockwave location for relatively mild sloped converging smooth chutes with vertical training walls by the resulting angle β of the shockwave front. In order to describe the observed wave front location for the test results in this study the same convention was chosen for describing the observed wave front. Table 2.2 shows a summary of β for each model configuration. Based on an evaluation of the data in table 2.2, β appears to be independent of unit discharge, q, and d_c. Additionally β does not appear to be affected by the addition of steps to the training walls. For practical purposes β is approximately equivalent to ϕ.

Table 2.2. Summary of shock wave front angle, β, for each run.

	ϕ for Stepped			ϕ for Smooth		
	18°	34°	45°	18°	34°	45°
d_c	β	β	β	β	β	β
0.085	23.2	39.7	44.2	23.8	37.1	41.1
0.070	23.1	37.9	44.1	20.6	42.1	43.5
0.065	20.9	37.8	42.4	18.9	36.8	41.8
0.054	23.3	37.8	44.3	23.8	36.0	43.0

Stepped Training Wall Run-up

Figure 2.5 shows the contrast of water level elevations at the training walls and centerline for multiple convergences with stepped training walls at a flow with critical depth of 0.085 m (0.28 ft). From this figure, it is obvious that an increase in convergence angles leads to an increase in h_r. The actual flow behavior for a test flow with stepped training walls can be observed in figure 2.6, and a similar test with smooth training walls is shown in figure 2.7. Figure 2.6 depicts two items of interest: 1) there is a primary flow along the training wall similar to that observed for the smooth condition, and 2) the steps cause a secondary shedding flow resulting in a higher h_r than occurs in the smooth condition. It was also noted that small amounts of flow were observed along even higher elevations for stepped training walls, but this tertiary flow was considered minor and of little consequence. The solid line in figure 2.6 on the stepped training wall indicates the top of this secondary flow and the dashed line in figure 2.6 shows the extent of the primary flow. The dashed line in figure 2.7 also shows the extent of the run-up on the smooth training wall configuration.

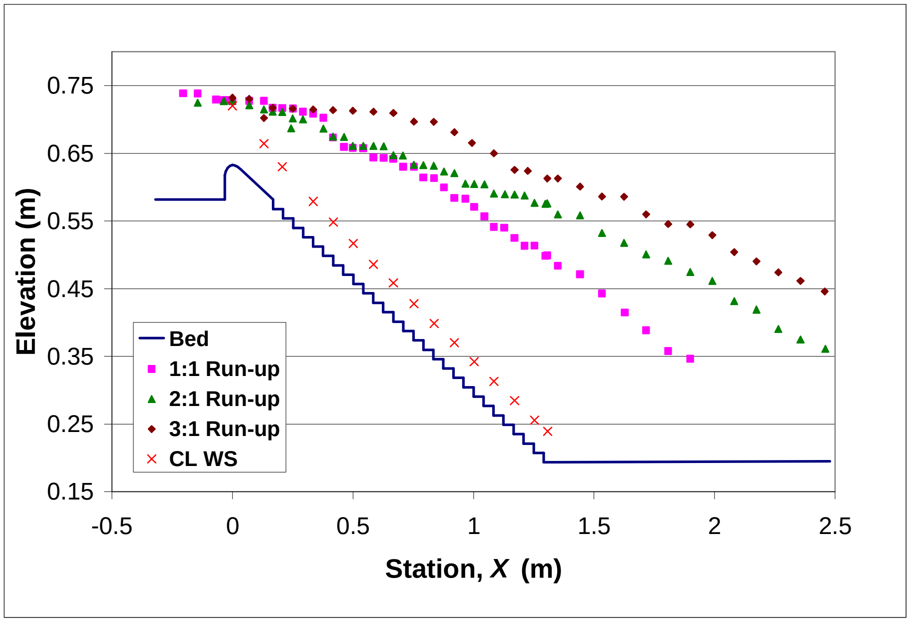

Figure 2.5. Run-up height and centerline depth vs. station for d_c = 0.085 m (0.28 ft) and multiple convergences with stepped training walls.

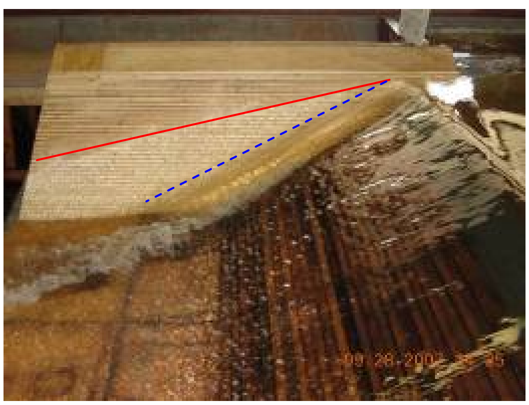

Figure 2.6. Photograph of model with 1:1 stepped training wall, d_c = 0.085 m (0.28 ft)

Figure 2.7. Photograph of model with1:1 smooth training wall, d_c = 0.085 m (0.28 ft)

For these data to be useful in a general design sense, they need to be normalized. By dividing the centerline depth (d) and h_r by d_c, dimensionless depths were found. Centerline depth was defined normal to the plane of the chute. These dimensionless depths were plotted against the station divided by d_c. Figure 2.8 shows these normalized depths plotted against the normalized stationing for convergence angles of 0°, 18°, 34°, and 45° for step sloped training walls. Figure 2.8 demonstrates that the run-up height data for the four discharges can be collapsed for each convergence based on the dimensionless run-up height term (h_r/d_c). The dimensionless run-up height (h_r/d_c) for the stepped training wall convergences tested varies linearly to the end of the chute.

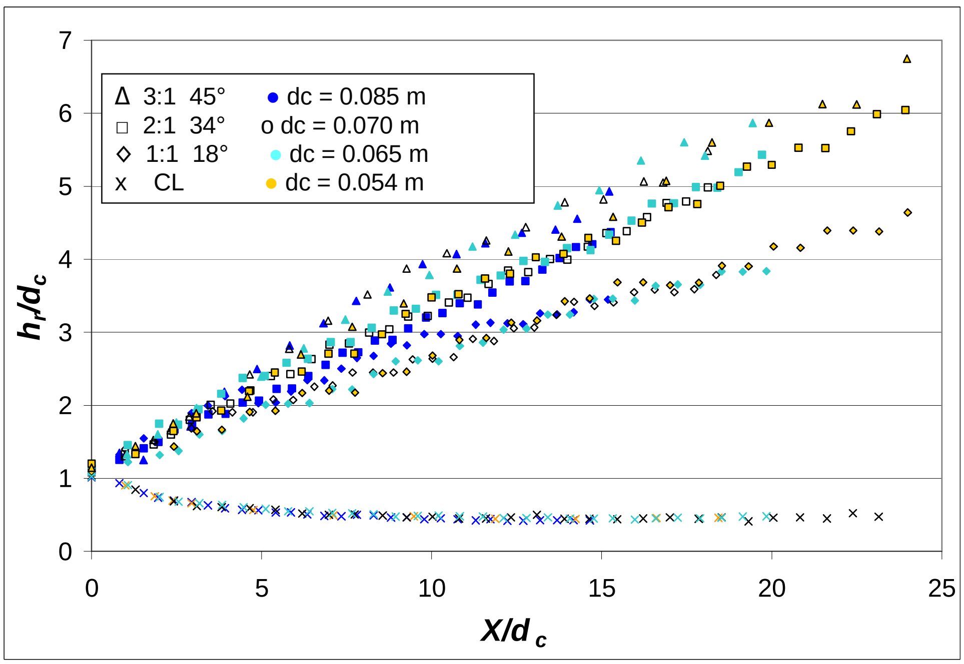

Figure 2.8. Non-dimensional plot of h_r/d_c vs. X/d_c for stepped training walls.

Run-up height (h_r/d_c) was determined for each run at positions of 0, 2, 5, 10, 15, and 20 X/d_c and plotted against convergence angle, ϕ, in figure 2.9. Averages of the points for each convergence angle were calculated and plotted as curves for each position in figure 2.9.

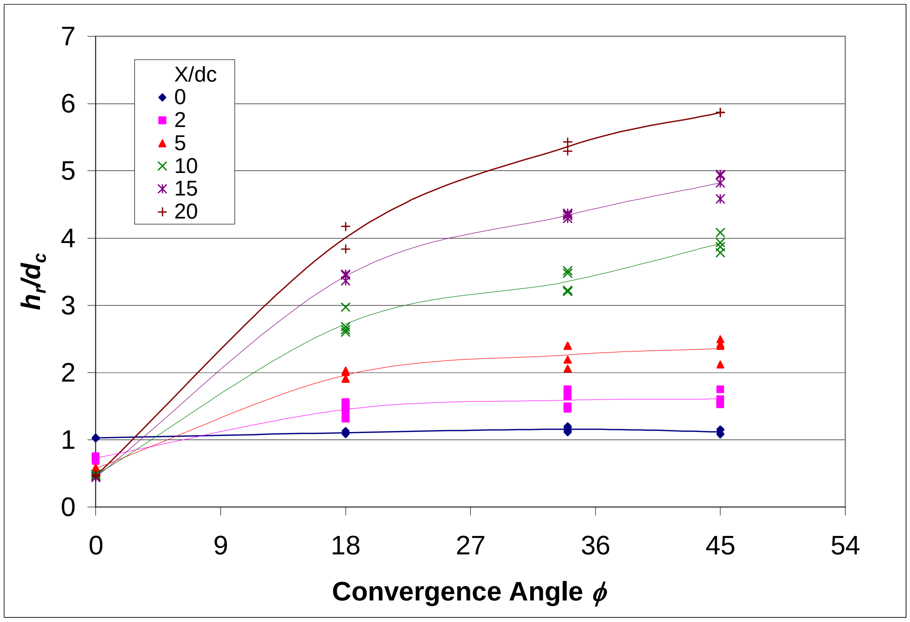

Figure 2.9. Run-up height (h_r/d_c) vs. convergence angle for six positions on the chute X/d_c, for stepped training walls.

Figure 2.10 shows the data from figure 2.8 with linear regression lines for each convergence configuration test. The intercept for each line on the h_r/d_c -axis is approximately 5/4. The slope of each regression line varies relative to the square root of the training wall slope ratio, defined as z = H/V (i.e. z = 3 for the 3(H):1(V) training wall side slope). Based on the observations of these results a generalized dimensionless equation was developed relative to the run-up height h_r, the critical depth d_c, the horizontal location downstream of the crest X, and the training wall slope ratio z.

$$\frac{h_r}{d_c} = \frac{5}{4} + \frac{1}{7}\left(\frac{X}{d_c}\right)\left(z^{1/2}\right) \qquad (1)$$

This equation generalizes the height of flow run-up for 1:1 to 3:1 stepped training walls on a 3:1 RCC stepped spillway chute. A comparison of predicted and observed values (figure 2.11) shows that equation (1) is valid within the range of values tested.

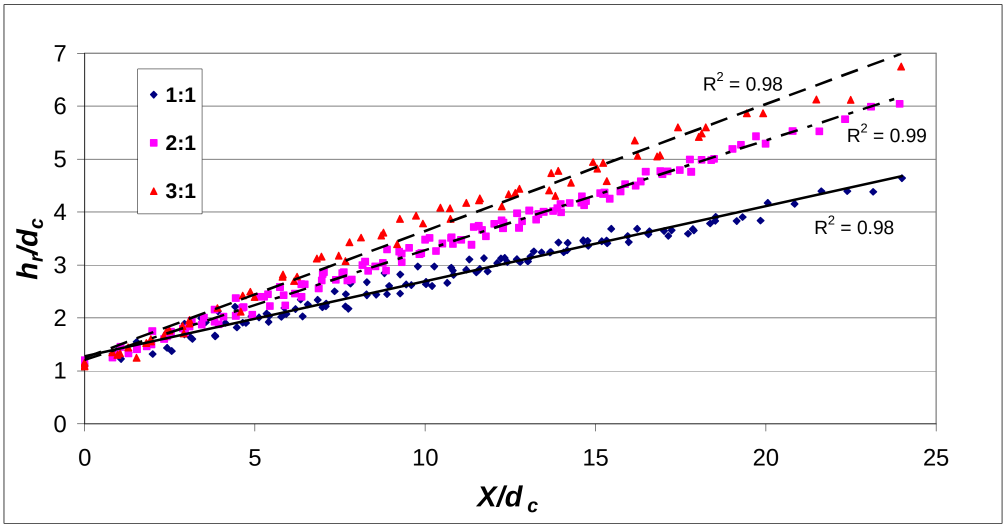

Figure 2.10. Linear regression of stepped training wall h_r for $\phi = 18°$, $34°$, and $45°$.

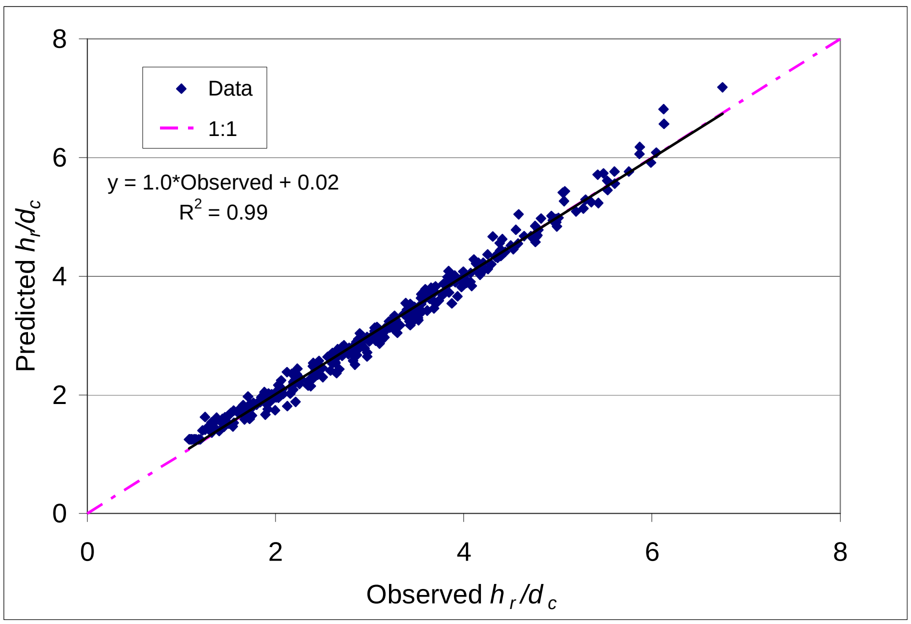

Figure 2.11. Comparison of observed h_r/d_c and values predicted with equation (1).

Smooth Training Walls

Hunt et al. (2006b) showed that the use of smooth sloped training walls is a viable alternative to stepped training walls. Smooth training walls dramatically improve the hydraulic performance of the spillway as seen in figures 2.6 and 2.7. Figure 2.12 shows water level elevations at the training walls and centerline for multiple convergences with smooth training walls at a flow with critical depth of 0.085 m (0.28 ft). Figure 2.13 compares run-up on stepped and smooth training walls for a single convergence and flow rate. These data show that the secondary flow along the stepped training walls would require significant increases in training wall dimension requirements compared to the smooth training walls, but this secondary flow could possibly be controlled by placing vertical deflector walls at the step elevations equivalent to the run-up anticipated on the smooth training wall configurations. The potential effectiveness and required height of this type of walls will be determined in future studies.

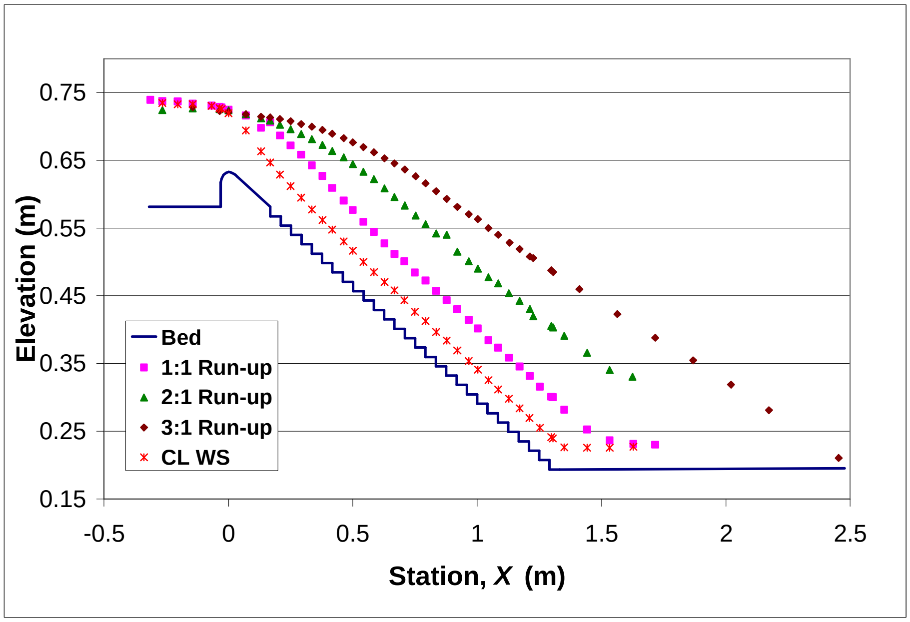

Figure 2.12. Run-up height and centerline depth vs. station for d_c = 0.085 m (0.28 ft) and multiple convergences with smooth training walls.

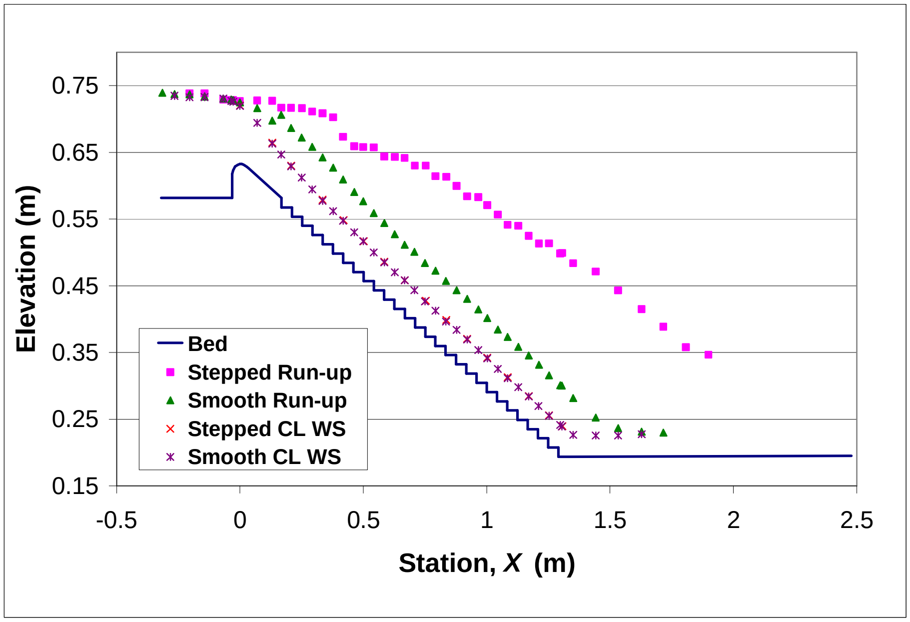

Figure 2.13. Comparison of run-up for smooth and stepped training walls with d_c = 0.085 m (0.28 ft) and 18° convergence.

Figure 2.14 contains the same information as figure 2.8, but for smooth training walls. The smooth run-up data normalized by d_c collapses to a single curve for each of the four flow rates tested at each convergence. The values do not increase linearly like the stepped data does but instead appear to approach a maximum for each convergence angle as it moves downstream. Again the run-up depth (h_r/d_c) was determined for each smooth training walled run at six stations and plotted against convergence angle, ϕ, in figure 2.15. Figure 2.15 could be used as a design tool for determining dimensions of smooth sloped training walls for stepped chute spillways at the specific convergences tested.

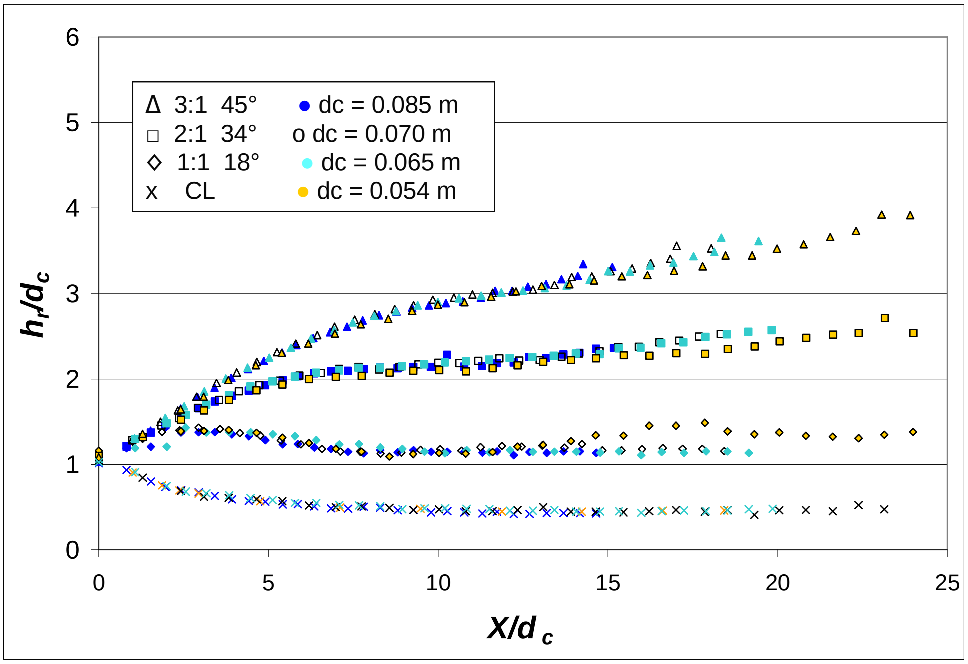

Figure 2.14. Non-dimensional plot of h_r/d_c vs. X/d_c for smooth training walls.

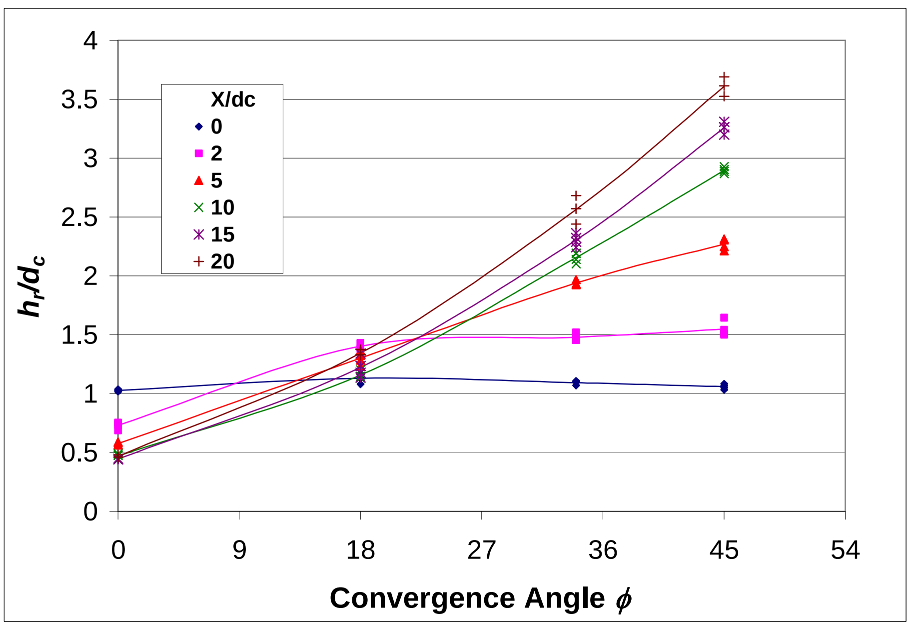

Figure 2.15. Run-up height (h_r/d_c) vs. convergence angle for six positions on the chute X/d_c, for stepped training walls.

Example Application

An example is presented to illustrate how equation (1) could be applied to assist in designing training walls for a 3:1 stepped spillway chute.

Example

Compare the stepped training wall height required to contain the run-up in a 3:1 stepped spillway chute at the end of the chute section (station 28 m, 93 ft) for 1:1 and 3:1 stepped and smooth training walls.

d_c at PMF = 1.8 m (5.9 ft)

Crest width = 100 m (330 ft)

Spillway drop = 9.8 m (32 ft)

Chute location X = 28 m (93 ft)

Step height = 0.3 m (1 ft)

- Calculation of h_r for 1:1 stepped and smooth sloped training walls:

<u>STEPPED</u>

z (1:1) = 1

$h_r = ((5/4 + 1/7*(28/1.8)*(\sqrt{1}))*1.8)$ [Eq. 1]

h_r = 6.3 m (20.7 ft)

<u>SMOOTH</u>

h_r/d_c = 1.4 [Figure 2.14]

h_r = 2.5 m (8.3 ft)

- Calculation of h_r for 3:1 stepped and smooth sloped training walls:

<u>STEPPED</u>

z (3:1) = 3

$h_r = ((5/4 + 1/7*(28/1.8)*(\sqrt{1}))*1.8)$

$h_r = 9.3$ m (30.4 ft)

SMOOTH

$h_r/d_c = 3.2$ [Figure 2.14]

$h_r = 5.8$ m (18.9 ft)

In conclusion for these calculations the stepped and smooth chute training walls at 28 m (93 ft) downstream of the crest would need to be 3 m (10) ft higher in elevation for the 3:1 converging training walls than the 1:1 converging training walls.

Conclusions

A generalized relationship for converging stepped training walls on 3:1 RCC stepped spillway chute were developed. The angle of the shock wave front, β, for this type of chute is approximately equal to the convergence angle, ϕ, for both smooth and stepped training walls. Visual observations and measured data show that the stepped training walls cause a significant secondary flow that results in a greater run-up height than is observed in the smooth wall condition. The run-up height (h_r/d_c) for stepped training walls is between two and three times that of smooth training walls depending on the convergence angle. This does not take into account the minor tertiary flow above the major run-up. Hunt et al. (2006b) observed that the secondary flow can create problems along the edge of the spillway if not properly taken into account. Stepped sloped training walls would therefore need to be much larger than smooth sloped training walls and as a consequence would require significantly more materials for construction than smooth sloped training walls at the same convergence. Also, small vertical deflector walls may be needed to contain the minor tertiary flow that was observed on the converging stepped training walls. Run-up height (h_r/d_c) for the secondary flow is a function of the training wall slope and critical depth and can be accurately calculated for stepped training walls using equation (1). These data should be helpful in determining general design guidelines for 3:1 RCC stepped spillway structures designed with sloped stepped converging training walls. Results are expected to assist in the development of generalized equations for smooth sloped converging training walls. These equations will be based on energy, force, and momentum principles.

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CHAPTER III

STEPPED SPILLWAYS WITH SMOOTH SLOPED TRAINING WALLS

Abstract

More than half of the over 11,000 small watershed dams designed and built with support from the USDA Natural Resources Conservation Service (NRCS) will reach the end of their 50 year planned service life by 2018. Changes in watershed hydrology and hazard classification due to urbanization require these structures to safely pass greater flows than were originally intended. Roller compacted concrete (RCC) stepped spillways are a proven rehabilitation option for increasing discharge capacity of these structures. These structures are commonly designed with a wide crest section and convergent training walls along the length of the spillway. Public safety, aesthetics, and construction efficiency suggest sloped training walls may be a preferred option. The research and application of RCC have grown dramatically in recent years, yet no readily available generalized guidelines exist for sloped training walls.

A study of converging stepped spillways with sloped training walls was conducted at the USDA- Agricultural Research Service (ARS) Hydraulic Engineering Research Unit in Stillwater, Oklahoma. A small scale, three-dimensional, physical model was utilized. The model consisted of a 3(H):1(V) spillway chute having training walls with slopes ranging from 1:1 to 3:1. Training wall convergence causes an oblique

hydraulic jump along the sides of the chute. This results in increased flow depths at the walls and is a primary factor in determining required training wall dimensions. Objectives of this study included increasing the general knowledge of flow in stepped spillways with sloped training walls and development of a generalized equation for predicting run-up on smooth sloped training walls.

Introduction

The USDA – Natural Resources Conservation Service (NRCS) has assisted in the design and/or construction of over 11,000 small watershed dams since the 1940's. A majority of these dams are small earthen embankments designed to protect agricultural land. In some cases, urbanization and land use changes have dramatically changed the hydrology of the watershed, and as they near the end of their 50 year design life, the dams are in need of rehabilitation. Hazard classification changes due mainly to this urban encroachment require the spillways of these dams to safely pass greater flows than their original design intended. In many cases roller compacted concrete (RCC) stepped spillways are the only viable solution to increased capacity requirements. RCC is a proven, cost effective rehabilitation option, and stepped spillways can safely pass flows equivalent to conventional smooth spillway chutes. Current estimates project that up to 10% of the 11,000 watershed dams will be rehabilitated with RCC. In some cases these structures will be converging chutes with vertical or sloped training walls conforming to the existing valley.

It is common for these structures to be constructed over the top of the existing earthen dam. In some instances this results in a wide crest section at the top of the spillway that converges at the base of the spillway in order to conform to the existing valley. Vertical training walls on the sides of the spillway chute provide the most obvious solution for containing the flow along the edges, but public safety, aesthetics, and construction efficiency suggest sloped training walls may be a more desirable option in many cases. The research and application of RCC have grown dramatically in recent years, yet currently no general design guidelines exist for stepped spillways or the required training wall dimensions for converging chutes at common embankment slopes. Designers tend to avoid the use of spillway contractions due to the complexity of flow and resulting fundamental lack in knowledge related to the hydraulics (Reinauer and Hager, 1998). Currently model studies are recommended by the US Army Corps of Engineers (USACE) when designing converging stepped spillways (USACE, 1990).

Physical model studies can be utilized to aid in the understanding of a process or event, and are commonly used in hydraulics research. Recent studies including Hunt et al. (2005), Hunt and Kadavy (2006), and Hunt (2008) have provided information on converging vertical training walls for RCC stepped spillways. Many of these types of structures will be placed in urban areas, and concerns over aesthetics and public safety have been raised. These concerns as well as cost and construction efficiency have sparked interest in alternate designs including sloped stepped or smooth training walls in place of vertical walls. Chapter II investigated stepped and smooth sloped training walls on RCC stepped spillways. Observed flow patterns and run-up for both stepped and smooth sloping training walls as well as the development of a generalized relationship for predicting run-up along stepped sloped training walls were presented. The objective of this chapter is to examine stepped spillways with smooth sloped training walls and develop general design guidelines. Specifically the generalized equations developed for convergent vertical training walls (Hunt et al., 2006a and Hunt, 2008) are evaluated for applicability to convergent smooth sloped training walls, and a momentum based empirical relationship is also developed and evaluated.

Modeling

When modeling free surface or open channel flows the Froude number (F) is generally used to scale the flow:

$$F = \frac{V}{\sqrt{g\lambda}} \quad (1)$$

F is a dimensionless term that describes the ratio of inertial to gravitational forces in a flow.

The Reynolds number (Re) is also often considered when working at small scales where viscosity could affect the results. In stepped spillway applications, the additional turbulence caused by the roughness of the steps aerates the flow causing flow bulking which is difficult to model at small scales (Boes and Hager, 2003). Due to the highly air entrained flows found on stepped spillways, it is recommended the Weber number (We) also be taken into consideration. To minimize scale effects, a Re of 10^5 and a We of about 100 are recommended (Boes and Hager, 2003). To prevent aeration scale effects from becoming significant, Chanson (2002) recommends using a scale of 10:1 or greater. Research has been conducted on air entrained flows in stepped spillways by Boes and Minor (2002), Boes and Hager (2003), Chanson and Gonzales (2005), Kramer et al. (2006), Pfister et al. (2006), and Hunt and Kadavy (2007). Typical chute slopes in these studies are greater than 22° with exception to Hunt and Kadavy (2007), whose study investigated a chute slope of 14°. Hunt et al. (2005), Hunt and Kadavy (2006), and Hunt et al. (2006a) observed that air entrainment is of less concern with flatter sloped (as small as 14°) applications of RCC stepped spillways like those constructed by NRCS because the spillway chute length was relatively short, the design flow was large, and the tail water was significant. As a result, the aerated flow region did not fully develop within the spillway chute. These observations lead to the conclusion that scale effects are less important on flatter sloped spillways like the ones used on NRCS embankment dams. Therefore, results from smaller scaled studies can be evaluated effectively for design purposes when the spillway chute length is relatively short and the design flow is large such that the aerated flow region doesn't become well established.

Few studies have looked at the performance of converging stepped spillways especially converging stepped spillways on flat chutes (18° or less). Robinson et al. (1998) and Hanna and Pugh (1997) investigated the hydraulic performance of steep converging stepped spillways. Robinson et al. (1998) conducted physical model studies on a steep (0.7H:1V) stepped chute and Hanna and Pugh (1997) conducted research on a steep (0.8H:1V) converging spillway. These two studies were steep sloped model studies and no generalized relationships were developed. In addition to these two model studies Hunt et al. (2006b) and Hunt (2008) presented results from 1:22 scale, three-dimensional physical models on a relatively flat (3H:1V) slope stepped chute with vertical training walls at convergence angles of 0°, 15°, 30°, 52°, and 70° were tested. Hunt et al. (2006b) observed that flow run-up along the vertical training wall increased as the convergence angle of the training wall increased. Flow run-up is defined as the amount of water extending up the wall created by flow convergence. Generalized design guidance was proposed by Hunt et al. (2006a) and Hunt (2008) for converging stepped spillways having vertical training walls.

Design of stepped spillways with sloping stepped training walls has been investigated by Frizell (2006) and Hunt et al. (2006b). The studies by Frizell (2006) and Hunt et al. (2006b) were specific model studies and did not result in generalized design criteria for stepped training walls. Hunt et al. (2006b) conducted a few preliminary investigations of converging sloped stepped training walls while conducting hydraulic model studies with converging vertical training walls. Hunt et al. (2006b) observed that converging sloped stepped training walls caused significant amounts of run-out flow and sloped smooth training walls reduced the run-up significantly. The studies presented in Chapter II and this chapter are an extension of the Hunt et al. (2006b) work with the objective to develop generalized design criteria for 3(H):1(V) stepped spillways with stepped and smooth sloped training walls perpendicular to the chute. The study in Chapter II included an in-depth investigation of 1:1, 2:1, 3:1 sloped training wall convergence on 3:1 stepped spillway chutes. Run-up heights resulting from the standing shockwave along the convergence of the chute and training walls was observed to be the controlling factor in determining spillway training wall dimensions for the smooth sloped training wall model configurations. The run-up heights for stepped training walls were also affected by the standing shock wave along the convergence, but in addition run-up was affected by the steps themselves. The work described in Chapter II also resulted in the development of a generalized equation for run-up height on stepped sloped training walls. The work described in this chapter resulted in the development of a generalized equation for smooth sloped training walls.

Equation Development

Several approaches were evaluated for developing an equation to describe run-up along smooth sloped training walls on stepped spillways. The flow conditions in this type of spillway chute, although complex, can be assumed to be an oblique hydraulic jump in a sloped chute. Oblique hydraulic jumps are commonly referred to as standing waves or shock waves (Chow, 1959).

Flow depth downstream of a hydraulic jump in a horizontal rectangular channel is defined by (Chow, 1959),

$$d_2 = d_1 \times \tfrac{1}{2}\left(\sqrt{1+8F^2} - 1\right) \tag{2}$$

where d_1 is the depth upstream of the jump, d_2 is the depth downstream of the jump and F is the Froude number.

For sloped channels, the steeper the slope the less applicable equation (2) becomes. Kindsvater (1944) looked at hydraulic jumps in sloping channels, and developed a similar expression by replacing the Froude number F with a G which accounted for the weight of water in the jump. Chow (1959) describes the G term as a function of the F and the chute slope, θ. Ippen and Harleman (1956) characterized oblique shockwaves for flat sloped converging smooth chutes with vertical training walls with a similar expression accounting for the angle of the oblique shock wave β:

$$d_2 = d_1 \times \tfrac{1}{2}\left(\sqrt{1+8F^2 \times \sin^2 \beta} - 1\right) \tag{3}$$

Their experiments looked at oblique jumps caused by a vertical deflector wall with convergence angles of ϕ = 3°, 6°, 9°, 12°, 15°, 18°, and 21°. The convergence angles resulted in the formation of standing shock waves in the flow at an angle β to the same reference as ϕ. Equation (3) developed by Ippen and Harleman (1956) does not apply to the stepped spillway case because of the effect of the chute slope and the convergence angles tested are greater than 21°.

Equations for hydraulic jumps can be derived from basic momentum (Chow, 1959):

$$\frac{Q\gamma}{g}\left(\beta_2 V_2 - \beta_1 V_1\right) = P_1 - P_2 + W\sin\theta - F_f \tag{4}$$

where Q is volumetric flow rate, g is gravity, γ is the unit weight of water, β_1 and β_2 are momentum transfer coefficients, V is velocity, P is pressure, W is the weight of water in the jump, and F_f is resistance due to friction.

The geometry of the system makes utilizing this simplified form of the momentum equation invalid for the converging RCC stepped spillway configuration (Hunt, 2008). Therefore, Hunt (2008) developed an equation for describing the oblique shock wave that develops at the vertical training walls for converging RCC stepped spillways relying on a control volume analysis using equation (4) in a general vector form application (Chow, 1959):

$$\Sigma\vec{F} = \int_{cs} \rho\vec{v}\vec{v} \bullet d\vec{A} \tag{5}$$

The equation developed by Hunt (2008) is,

$$\frac{\gamma d_w^2 \cos(\psi_2)\cos(\psi)}{2} = \frac{\gamma d^2 \cos\theta}{2} + \rho v^2 d\left(\cos(\theta)\cos(\psi)\sin(\phi) + \sin(\theta)\sin(\phi)\right)^2 \tag{6}$$

where ψ is equivalent to $\tan^{-1}(\sin(\phi)\tan(\theta))$, ψ_2 is equal to $\tan^{-1}(\cos(\phi)\tan(\theta))$, and ψ_3 is equal to $\tan^{-1}(\sin(\phi)*1/z)$. This equation was developed by determining a control volume, analyzing the force vectors on the control volume, and applying equation (5).

In the development of equation (6), Hunt (2008) made the following simplifying assumptions:

> "1) the velocity distribution on the face of the chute is uniform in the direction implied by the unit vector parallel to the velocity down the chute face, and this is the velocity seen by the face of the control volume away from the wall,
>
> 2) velocity direction changes suddenly at the shock within the control volume such that the sides of the control volume have only velocity aligned with the unit vector representing the velocity along the training wall, and
>
> 3) the pressure distribution is implied by the assumed velocity vectors and is assumed to be hydrostatic relative to the implied water surfaces at both the training wall and in the undisturbed chute."

Equation (6) can be rearranged to a form similar to equations (2) and (3) containing *F*:

$$d_w = d\sqrt{\frac{\cos\theta + 2 * F^2\left(\cos\theta\cos\psi\sin\phi + \sin\theta\sin\phi\right)^2}{\cos\psi_2\cos\psi}} \tag{7}$$

In-order to translate the depth, d_w, to the minimum height of the vertical wall, H_w, required along the training wall of the stepped chute, the following equation was used by (Hunt, 2008):

$$H_w = \frac{d_w}{\cos(\psi_2)} \tag{8}$$

Even though the geometry and resulting flow conditions for the smooth sloped converging training walls are more complex, as an initial step in evaluation, it was hypothesized that the equation developed by Hunt (2008) for vertical training walls may also be applicable. So a similar control volume was assumed for the smooth sloped converging training walls. Figure 3.1 shows a plan view of a stepped spillway with three sections of interest: AA is the centerline profile, BB is the section in the plane of the intersection of the training wall and the chute, and CC is perpendicular to the shockwave. Sections AA, BB, and CC are shown in figure 3.2.

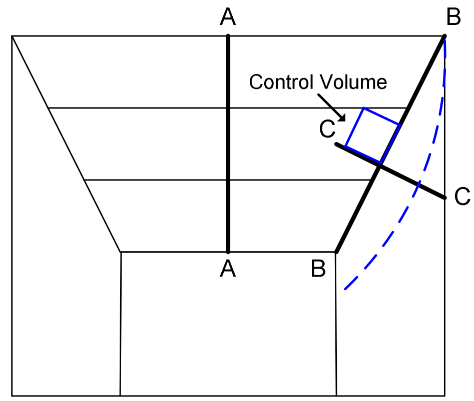

Figure 3.1. Plan view of stepped spillway with sloped training walls.

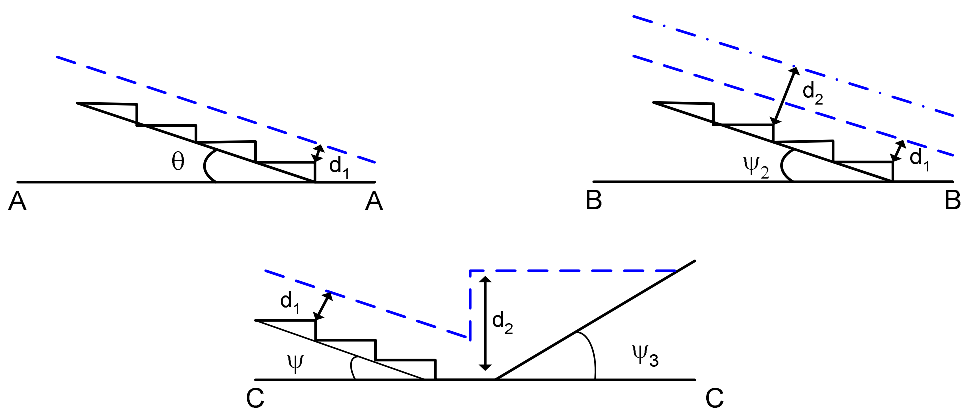

Figure 3.2. Stepped spillway cross sections.

Comparing the vertical wall and sloped wall configurations, one finds that the significant difference occurs in section CC. Control volumes for the different configurations are shown in figure 3.3. Assuming a velocity vector along the boundary is parallel to the boundary, equation (7) can then be applied to stepped spillways with smooth sloped training walls. This means that there is no flow through the control volume boundary.

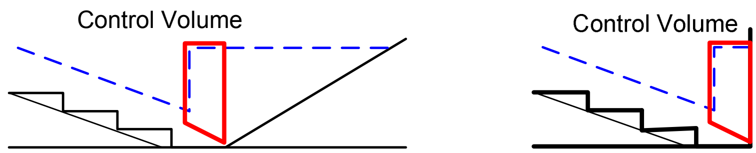

Figure 3.3. a. Sloped training wall control volume b. Vertical Training wall control volume.

Looking at section CC (figure 3.2) and assuming the surface of the flow in this cross-section downstream of the shockwave is horizontal, the elevation of the point at which the flow reaches the wall is equal to the elevation calculated by equation (8). From figure 3.1 it can be seen that the H_w calculated would actually be located downstream of the step in question. Therefore, for a centerline depth, *d*, at a point downstream of the crest, *X*, equations (7) and (8) could be used to find the minimum training wall height required at a point $X + \Delta X$ downstream of the crest where ΔX is calculated by the following:

$$\Delta X = d_w \times \left(\frac{\sin \phi}{\tan \psi_3} + \sin \psi_2 \right) \tag{9}$$

Experimental Setup

Essentially the same small-scale three-dimensional physical model that was used by Hunt et al. (2006b) was used with the exception of differing training wall configurations. The spillway model consisted of a 4.2 m (13.6 ft) ogee crested weir followed downstream by a 3(H):1(V) stepped chute with step heights of 1.4 cm (0.55 in). Total height from spillway to basin was 0.44 m (1.5 ft), and elevations of the crest and basin were 0.64 m (2.1 ft) and 0.19 m (0.63 ft), respectively. The crest was located at station 0 m (0 ft). Sloped training walls were normal to the spillway crest. All chute convergence was a result of the sloping training walls. Three training wall slopes were tested: 1:1, 2:1, and 3:1. Spillway training wall slopes of 1:1, 2:1, and 3:1 resulted in convergence angles, ϕ, of 18°, 34°, and 45° respectively. Figure 3.4 shows a schematic of a stepped spillway configuration with a 3:1 chute section and 3:1 training walls. The initial spillway test configuration was set-up with training wall slopes of 1:1. Subsequent configurations involved leaving the left training wall slope at 1:1 and altering the right training wall side slope to 2:1 and 3:1. Figure 3.5 shows the model running in the initial 1:1 configuration.

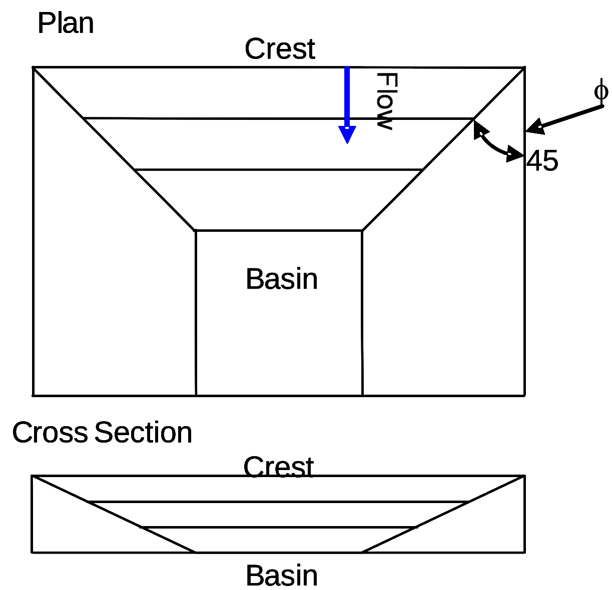

Figure 3.4. Schematic of converging stepped spillway chute with 3:1 smooth sloped training walls set perpendicular to the spillway crest (not to scale).

Figure 3.5. Small scale stepped spillway model with 1:1 smooth training walls.

The ogee crest section was machined out of a PVC material. Observations from rudimentary tests suggest that the type of crest section would have little effect on the observed run-up along the training walls. Chute steps consisted of polyurethane coated redwood, and training walls were constructed out of polyurethane coated plywood.

Flows tested were all within the skimming flow regime as described by Chanson (1994, 2002). Table 3.1 summarizes all the unit discharges and corresponding critical depths tested during the experiment. Orifice plates and an air-water differential manometer were used to measure flows. Water surface and bed elevation data were collected with a manually operated point gauge.

Table 1. Summary of unit flow rates, q, and corresponding critical depths, d_c, tested.

q (m^2/s)	d_c (m)
0.078	0.085
0.060	0.070
0.052	0.065
0.039	0.054

Results and Discussion

Figure 3.6 shows the model running under the 2:1 training wall configuration and the resulting shock wave caused by the convergence of the chute.

Figure 3.6. Shockwave along the training wall due to convergence on a 2:1 smooth sloped training wall.

Centerline depths and flow information were used to calculate *F* down the chute. Froude numbers were plotted against relative position (X/d_c) in figure 3.7. The values for *F* at different discharges appear to collapse into a single curve when compared to relative position with Froude numbers reaching a maximum value of 3 to 4 in this configuration and range of flows.

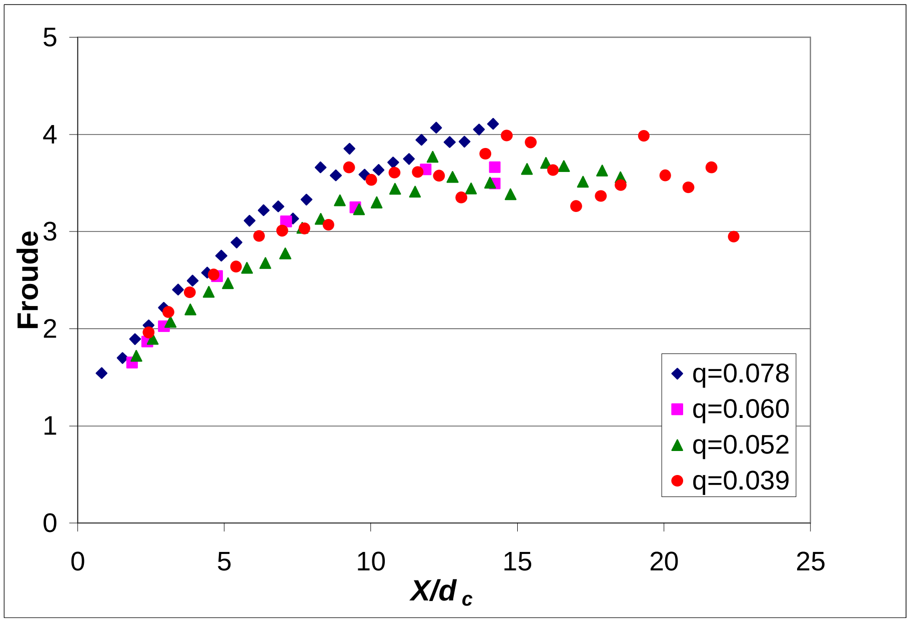

Figure 3.7. Froude number (*F*) vs. relative position (X/d_c) with *q* in m^2/s.

Flow run-up along the training walls is due to the standing shock wave that occurs. Run-up height, h_r, is defined as the elevation the water flows up the training wall relative to the bed at that downstream station (Figure 3.8). Figure 3.8 presents the depth of flow above the bed surface, d, normalized by critical depth at the spillway crest, d_c, versus the horizontal distance across the spillway chute, w, normalized by d_c.

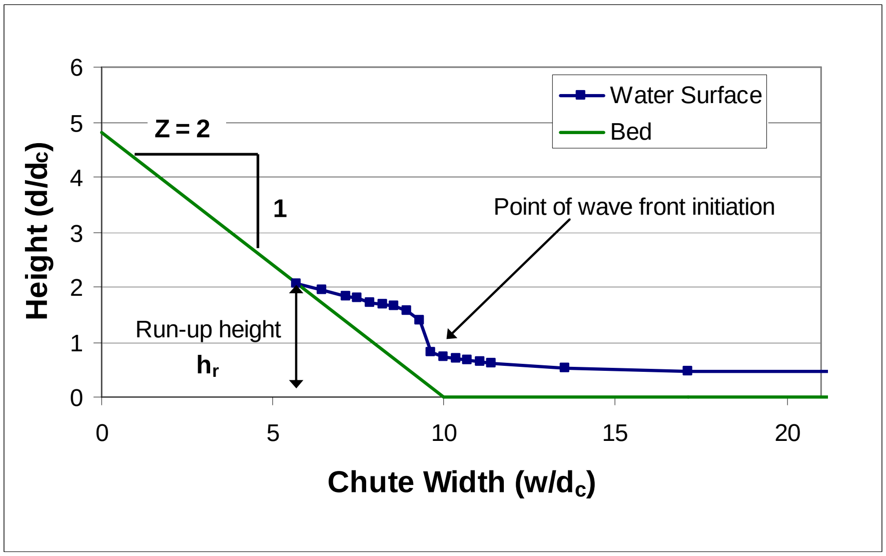

Figure 3.8. Cross-section of 2:1 bed and water-surface profiles for smooth sloped training wall non-dimensionalized by critical depth of the flow at the spillway crest.

Figure 3.9 shows water level elevations at the training walls and centerline for all convergences tested at the highest flow with critical depth of 0.085 m (0.28 ft). Dividing the centerline depth, d, and the run-up height, h_r, by the critical depth, d_c, resulted in dimensionless depths. The centerline depth was defined normal to the plane of the chute intersecting the end tip of each step. Dimensionless depths were then plotted against the station divided by d_c. Figure 3.10 shows these normalized depths plotted against the normalized stationing for convergence angles of 0°, 18°, 34°, and 45°. The h_r normalized by d_c from each of the four flow rates tested collapses to a single curve for each ϕ. Figure

3.10 could be used as an empirical design tool for determining dimensions of smooth sloped training walls for stepped chute spillways at the specific convergences tested.

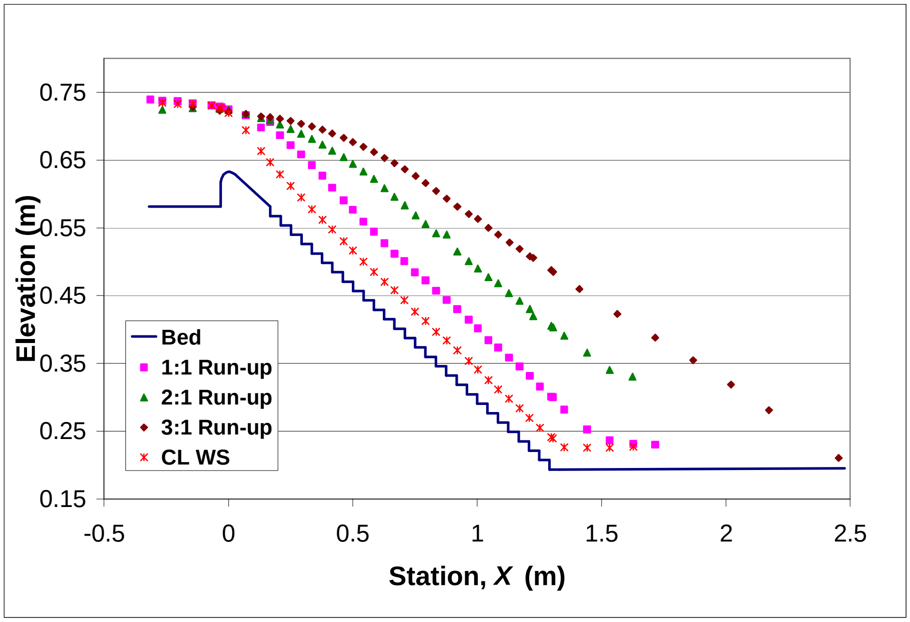

Figure 3.9. Run-up height and centerline depth vs. station for d_c = 0.085 m (0.28 m) and multiple convergences with smooth training walls.

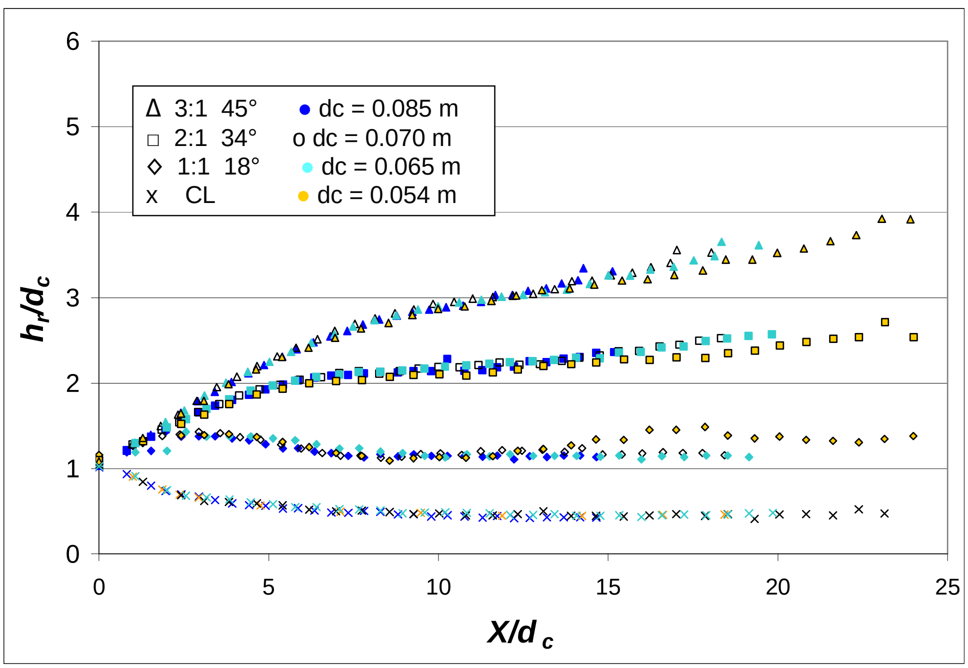

Figure 3.10. Non-dimensional plot of h_r/d_c vs. X/d_c for smooth training walls.

An example of run-up height calculated with equations (7) and (8) vs. observed run-up is shown in figure 3.11. The relationship developed by Hunt (2008) for vertical training walls tends to underpredict the run-up for sloped training walls. Figure 3.11 shows that the initial hypothesis to use equation (7) does not account for the complexity of flow observed for the smooth sloped training walls. This is most likely due to several reasons including: 1) equation (7) does not account for the impact of the spatially varied flow condition in the sloped training wall setting, 2) the assumption that the predicted depth of flow projected horizontally normal to the convergence angle is too large a simplification, and 3) the assumption that no flow flux leaves the control volume on the opposing face to the front may not be valid.

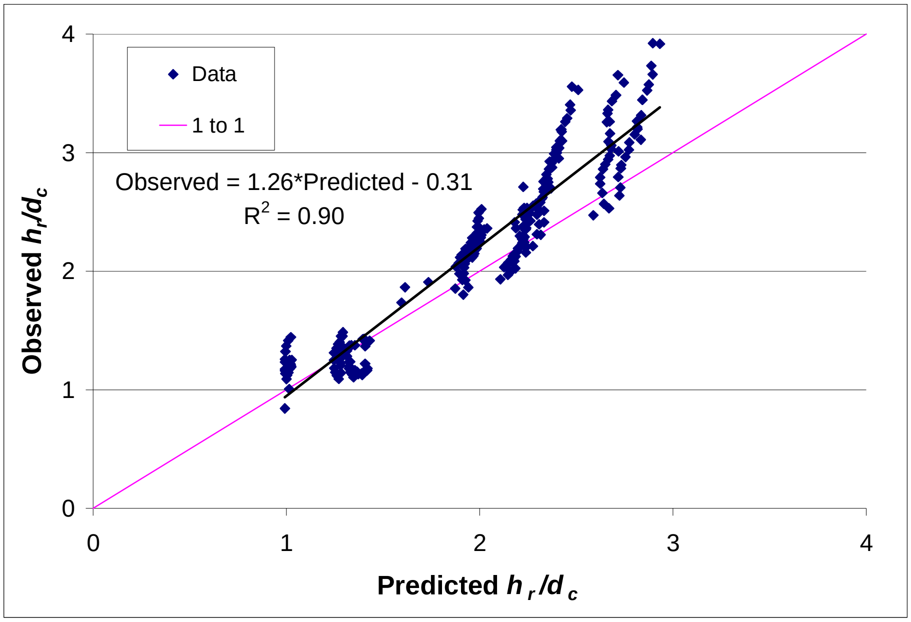

Figure 3.11. Observed vs. Predicted h_r calculated with equation 8.

It was observed that the values for of $\cos\theta$, $\cos\psi$, and $\cos\psi_2$, in equation (7) were approximately equal to 1 and $\sin\theta$ for a 3:1 spillway chute is 0.31. Therefore, equation (7) may be simplified to:

$$d_2 = d_1 \times \sqrt{1 + 3.43F^2 \sin^2 \phi} \tag{10}$$

with virtually the same results. While equation (10) does not change the results it does give some indication as to a possible form of an equation that could be empirically derived for this set of data.

A dimensionless empirical relationship was developed based on linear regression with the terms; h_r/d_c, d_1/d_c, F, $\sin\phi$, and X/d_c:

$$\frac{h_r}{d_c} = \frac{d_1}{d_c}\left(1 + 2F \sin\phi^{\frac{3}{2}}\left(\frac{X}{d_c}\right)^{\frac{1}{6}}\right) \tag{11}$$

The empirical relationship shown by equation (11) was developed for 3:1 chutes with training walls ranging in slope from 0 to 3:1. Equation (11) is a combination of the form of the theoretical equations based on momentum and the empirical relationship developed in Chapter II for stepped training walls on a 3:1 chute. Figure 3.12 shows predicted vs. observed h_r/d_c as calculated with equation (11). In figure 3.13, predicted values are plotted as solid lines on a plot similar to figure 3.10. Compared with equation (7), equation (11) has the advantages of simplicity, direct calculation of h_r, and fits the data.

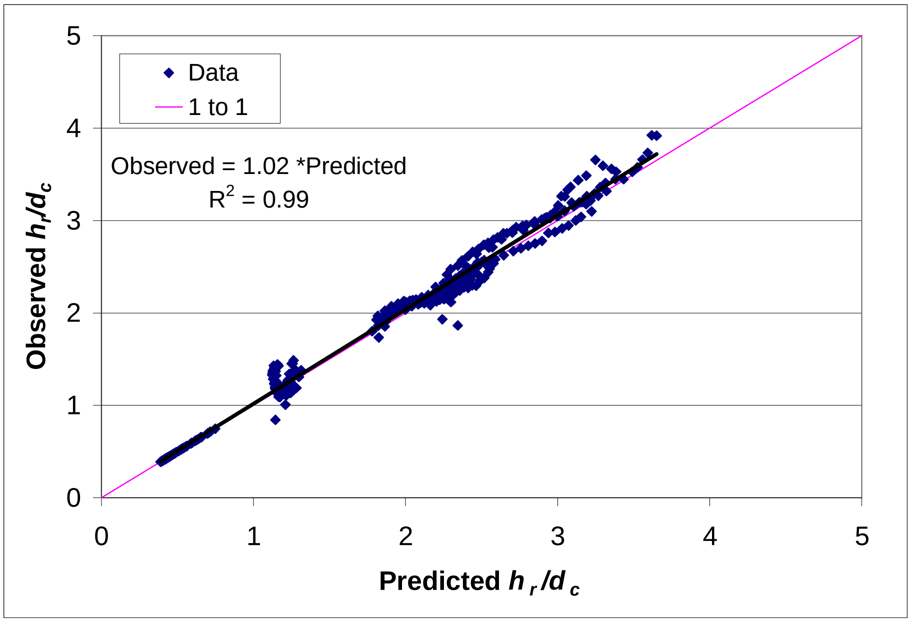

Figure 3.12. Predicted vs. Observed h_r/d_c calculated with equation 11.

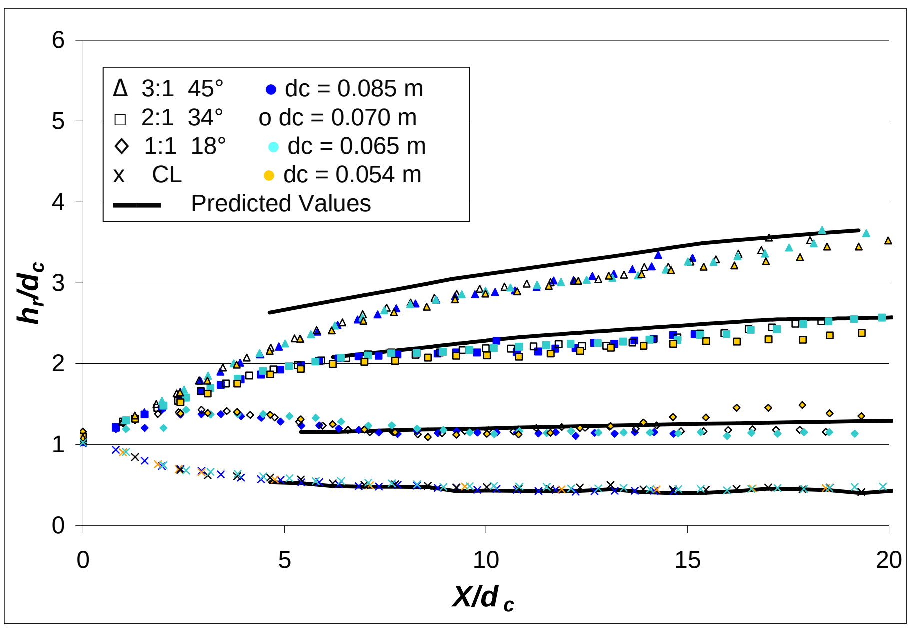

Figure 3.13. Predicted and Observed h_r/d_c vs. X/d_c on smooth training walls.

Conclusions

Water surface data and visual observations from this study provide useful information for development of generalized relationships for smooth sloped training walls on 3:1 RCC stepped spillway chutes. The data demonstrates that empirical equation developed can accurately predict the run-up for smooth sloped training walls for the ranges tested. The equations should not be used for training wall slopes greater than 3:1 without further testing. These data should be helpful in determining general design guidelines for 3:1 RCC stepped spillway structures designed with smooth sloped training walls.

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CHAPTER IV

SUMMARY, CONCLUSIONS, and FUTURE RECOMMENDATIONS

Summary

An abundance of aging watershed dams in need of rehabilitation exist in the United States today. RCC stepped spillways provide a cost effective alternative solution to the rehabilitation needs of many of these dams. The application of RCC stepped spillways will require converging chute sections in some cases in order to fit the limitations of the urban setting and valley geometry. Stepped or smooth sloped training walls can provide the needed convergence while also providing public safety, aesthetic, and construction efficiency benefits. To date there had been no general design guidelines for stepped spillways with stepped or smooth sloped training walls. Therefore, a small scale physical model study of stepped and smooth sloped training walls on a 3:1 stepped spillway chute was carried out at the USDA-ARS Hydraulic Engineering Research Unit. The objectives of this study were to conduct an investigation of sloped training wall convergence on 3:1 stepped spillway chutes including flow patterns and run-up for stepped and smooth sloped training walls and develop generalized relationships for describing the resulting run-up. Flow patterns and run-up are examined in Chapter II. An empirical relationship for determining run-up on stepped training walls is also presented in Chapter II. Chapter III presents an empirical relationship for determining run-up on smooth sloped training walls and a comparison to theoretical relationships.

Conclusions

Generalized relationships were developed for converging stepped and smooth sloped training walls on a 3:1 RCC stepped spillway chute. Visual observations and measured data show that the stepped training walls cause a significant secondary flow that results in a greater run-up height than is observed in the smooth wall condition. A minor tertiary flow also exists above the secondary flow along the stepped training walls. Run-up height (h_r/d_c) for stepped training walls is between two and three times that of smooth training walls depending on the convergence angle. This does not take into account the minor tertiary flow above the major run-up. Hunt et al. (2006b) observed that the secondary flow can create problems along the edge of the spillway if not properly taken into account. Stepped sloped training walls would need to be significantly larger than smooth sloped training walls and would require considerably more materials for construction than smooth sloped training walls at the same convergence. Also, small vertical deflector walls may be needed to contain the minor tertiary flow that was observed on the converging stepped training walls.

Relationships for stepped and smooth sloped training wall dimensions were developed in Chapter II and Chapter III. The relationship for stepped training wall dimensions was based on run-up height for the secondary flow and was a function of the training wall slope and critical depth. Theoretical equations for vertical training walls were investigated as a possible solution to predicting run-up height for smooth sloped training walls but were shown to be insufficient. An empirical relationship was developed which accurately predicts the run-up for smooth sloped training walls for the ranges tested. The relationships developed in this study should not be used for training wall slopes greater than 3:1 without further testing. Results are expected to assist in the development of generalized equations for smooth sloped converging training walls.

Future recommendations

The objectives of this research have been met and are presented in Chapter II and Chapter III. Results presented in Chapter II and Chapter III provide useful information to improve the general knowledge and assist in the design of stepped spillways with stepped and smooth sloped converging training walls. Future studies should attempt to:

1) Expand the generalized equation for stepped training walls on 3:1 spillway chutes to the potential range of anticipated field application of 2:1 to 4:1 chute slopes.
2) Evaluate applicability of generalized equation for smooth training walls on 3:1 spillway chutes to the potential range of anticipated field application of 2:1 to 4:1 chute slopes.
3) Evaluate potential structural modifications that might help constrain the flow run-out observed on stepped sloped training walls. Specifically, short vertical walls at the run-up level observed on smooth sloped training walls for equivalent flows on the stepped slope training walls should be evaluated.
4) Evaluate freeboard or safety factors to apply to results from the generalized equations for stepped and smooth sloped training walls in the field that are consistent with application requirements.

APPENDIX A

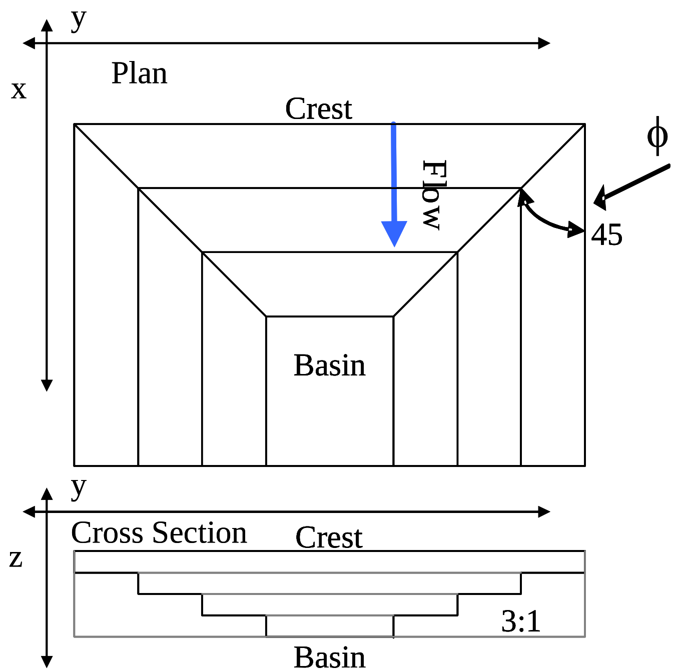

Figure A.1. Schematic of converging stepped spillway model with 3:1 sloped stepped training walls set perpendicular to the spillway crest (not to scale).

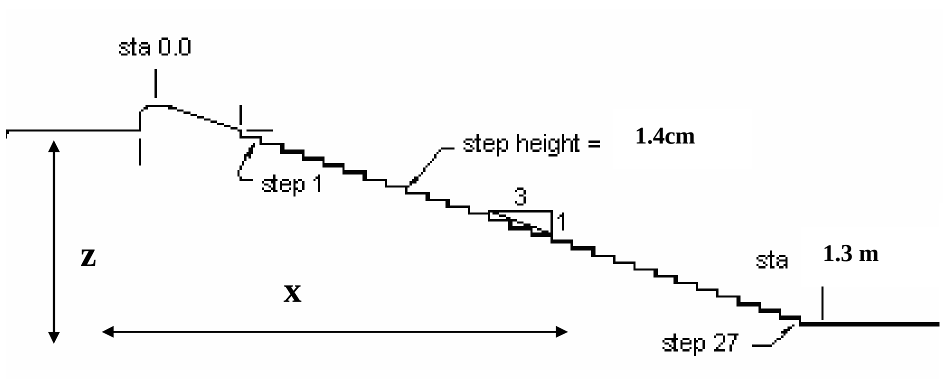

Figure A.2. Centerline cross section of stepped spillway model.

Table A.1. Centerline water surface data for 1:1 smooth training walls q = 0.078 m^2/s.

Run #	1		Recorder	RW		
Date	6/28/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
10:44	11.00	75.20	2.462	Centerline		

	12.00	75.20	2.462	
	14.00	75.20	2.461	
	16.00	75.20	2.458	
	18.00	75.20	2.458	
	20.00	75.20	2.456	
	22.00	75.20	2.455	
	23.00	75.20	2.477	
	24.00	75.20	2.411	
	24.20	75.20	2.404	
	24.40	75.20	2.405	
	24.65	75.20	2.397	
	24.76	75.20	2.386	
	24.78	75.20	2.382	
	24.87	75.20	2.361	Crest
	25.10	75.20	2.278	
	25.30	75.20	2.176	
	25.42	75.20	2.122	
	25.55	75.20	2.064	
	25.69	75.20	2.008	
	25.83	75.20	1.951	
	25.97	75.20	1.895	
	26.11	75.20	1.844	
	26.24	75.20	1.797	
	26.39	75.20	1.740	
	26.51	75.20	1.695	
	26.65	75.20	1.641	
	26.79	75.20	1.591	
	26.93	75.20	1.543	
	27.06	75.20	1.503	
	27.19	75.20	1.454	
	27.33	75.20	1.399	
	27.47	75.20	1.354	
	27.61	75.20	1.301	
	27.75	75.20	1.260	
	27.89	75.20	1.212	
	28.04	75.20	1.160	
	28.16	75.20	1.119	
	28.30	75.20	1.068	
	28.43	75.20	1.022	

	28.57	75.20	0.978	
	28.71	75.20	0.931	
	28.84	75.20	0.885	
	28.98	75.20	0.837	
	29.13	75.20	0.792	
	29.15	75.20	0.785	
	29.30	75.20	0.743	
	29.60	75.20	0.740	
	29.90	75.20	0.740	
	30.21	75.20	0.746	

Table A.2. Run-up water surface data for 1:1 smooth training walls q = 0.078 m^2/s.

Run #	1		recorder	RW		
Date	6/28/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
	23.84	67.86	2.425			
	24.00	67.86	2.420			
	24.20	67.87	2.418			
	24.40	67.88	2.408			
	24.65	67.89	2.398			
	24.76	67.90	2.393			
	24.78	67.91	2.389			
	24.87	67.92	2.379			
	25.10	67.95	2.350			
	25.30	67.99	2.290			
	25.42	68.025	2.317			
	25.55	68.065	2.253			
	25.69	68.12	2.205			
	25.83	68.17	2.160			
	25.97	68.23	2.108			
	26.11	68.28	2.057			
	26.24	68.34	1.999			
	26.39	68.41	1.937			
	26.51	68.45	1.892			
	26.65	68.51	1.835			

	26.79	68.565	1.786	
	26.93	68.62	1.730	
	27.06	68.67	1.679	
	27.19	67.71	1.643	
	27.33	68.77	1.589	
	27.47	68.81	1.550	
	27.61	68.86	1.500	
	27.75	68.91	1.455	
	27.89	68.95	1.411	
	28.04	69.00	1.360	
	28.16	69.04	1.318	
	28.30	69.09	1.261	
	28.43	69.12	1.225	
	28.57	69.17	1.176	
	28.71	69.21	1.134	
	28.85	69.26	1.088	
	28.98	69.30	1.036	
	29.13	69.35	0.987	
	29.15	39.35	0.985	
	29.30	69.41	0.924	
	29.60	69.49	0.829	
	29.90	69.54	0.776	
	30.21	69.56	0.759	
	30.50	69.56	0.755	

Table A.3. Cross section water surface data for 1:1 smooth training walls q = 0.078 m^2/s.

Run #	1		recorder	RW		
Date	6/28/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft			comments
	24.87	97.92	2.381			
	24.87	97.95	2.378			
	24.87	68.00	2.378			
	24.87	68.10	2.373			
	24.87	68.20	2.369			
	24.87	68.30	2.365			

	24.87	68.50	2.359	
	24.87	68.70	2.359	
	24.87	69.00	2.360	
	24.87	70.00	2.365	
	24.87	71.00	2.361	
	24.87	73.00	2.362	
	24.87	75.20	2.362	
	24.87	77.00	2.361	
	24.87	79.00	2.361	
	24.87	80.00	2.363	
	24.87	81.00	2.357	
	24.87	81.50	2.357	
	24.87	81.70	2.360	
	24.87	81.90	2.361	
	24.87	82.00	2.362	
	24.87	82.10	2.364	
	24.87	82.20	2.366	
	24.87	82.47	2.381	
	25.435	68.03	2.287	
	25.435	68.10	2.273	
	25.435	68.20	2.251	
	25.435	68.30	2.228	
	25.435	68.40	2.205	
	25.435	68.50	2.176	
	25.435	68.60	2.155	
	25.435	69.00	2.120	
	25.435	71.00	2.116	
	25.435	73.00	2.115	
	25.435	75.20	2.116	
	25.435	77.00	2.114	
	25.435	79.00	2.115	
	25.435	81.00	2.117	
	25.435	81.50	2.125	
	25.435	81.60	2.132	
	25.435	81.70	2.143	
	25.435	81.8	2.155	
	25.435	81.90	2.178	
	25.435	82.00	2.202	
	25.435	82.10	2.229	

	25.435	82.20	2.248	
	25.435	82.37	2.282	
	26.5	68.45	1.897	
	26.5	68.60	1.873	
	26.5	68.70	1.861	
	26.5	68.80	1.858	
	26.5	68.93	1.851	
	26.5	69.05	1.796	
	26.5	69.20	1.755	
	26.5	70.00	1.710	
	26.5	73.00	1.702	
	26.5	75.20	1.703	
	26.5	77.00	1.700	
	26.5	79.00	1.701	
	26.5	81.00	1.723	
	26.5	81.38	1.790	
	26.5	81.49	1.853	
	26.5	81.60	1.867	
	26.5	81.70	1.875	
	26.5	81.80	1.880	
	26.5	81.99	1.918	
	27.61	68.85	1.505	
	27.61	69.00	1.489	
	27.61	69.10	1.481	
	27.61	69.20	1.474	
	27.61	69.43	1.482	
	27.61	69.53	1.414	
	27.61	69.60	1.393	
	27.61	69.70	1.373	
	27.61	70.00	1.350	
	27.61	73.00	1.304	
	27.61	75.20	1.305	
	27.61	77.00	1.306	
	27.61	79.00	1.309	
	27.61	80.00	1.323	
	27.61	80.70	1.360	
	27.61	80.93	1.398	
	27.61	81.00	1.477	
	27.61	81.20	1.469	

	27.61	81.60	1.518	
	28.69	69.21	1.139	
	28.69	69.40	1.109	
	28.69	69.61	1.096	
	28.69	69.85	1.085	
	28.69	69.93	1.048	
	28.69	70.10	1.024	
	28.69	73.00	0.941	
	28.69	75.20	0.940	
	28.69	77.00	0.938	
	28.69	80.00	0.986	
	28.69	80.46	1.039	
	28.69	80.67	1.098	
	28.69	80.84	1.094	
	28.69	81.00	1.107	
	28.69	81.27	1.162	
	29.115	69.34	0.995	
	29.115	69.50	0.973	
	29.115	69.73	0.959	
	29.115	69.84	0.940	
	29.115	70.09	0.914	
	29.115	70.20	0.901	
	29.115	70.30	0.895	
	29.115	71.00	0.844	
	29.115	73.00	0.796	
	29.115	75.20	0.800	
	29.115	79.00	0.815	
	29.115	80.20	0.889	
	29.115	80.37	0.915	
	29.115	80.55	0.932	
	29.115	80.80	0.964	
	29.115	81.00	0.980	
	29.115	81.13	1.011	

Table A.4. Centerline water surface data for 1:1 smooth training walls q = 0.060 m^2/s.

Run #	2		recorder	RW		
Date	7/2/2007		BM-0 rd.	x=24.68	y=65.03	z=2.873
time	x ft	y ft	z ft	comments		
10:44	12.00	75.20	2.396	Centerline		
	14.00	75.20	2.396			
	16.00	75.20	2.395			
	18.00	75.20	2.395			
	20.00	75.20	2.395			
	22.00	75.20	2.393			
	23.00	75.20	2.386			
	23.84	75.20	2.366			
	24.00	75.20	2.361			
	24.20	75.20	2.360			
	24.40	75.20	2.359			
	24.65	75.20	2.349			
	24.76	75.20	2.335			
	24.78	75.20	2.332			
	24.87	75.20	2.314	Crest		
	25.10	75.20	2.225			
	25.30	75.20	2.129			
	25.42	75.20	2.075			
	25.55	75.20	2.023			
	25.97	75.20	1.861			
	26.52	75.20	1.662			
	27.06	75.20	1.476			
	27.62	75.20	1.282			
	28.16	75.20	1.099			
	28.71	75.20	0.918			
	29.13	75.20	0.778			
	29.16	75.20	0.769			
	29.30	75.20	0.732			
	29.60	75.20	0.746			
	29.90	75.20	0.753			
	30.21	75.20	0.746			

Table A.5. Run-up water surface data for 1:1 smooth training walls q = 0.060 m^2/s.

Run #	2		recorder	RW		
Date	6/28/2007		BM-0 rd.	x=24.68	65.03	z=2.873
time	x ft	y ft	z ft	comments		
	23.84	67.91	2.375			
	24.00	67.91	2.373			
	24.20	67.92	2.370			
	24.40	67.93	2.364			
	24.65	67.94	2.354			
	24.76	67.95	2.346			
	24.78	67.95	2.345			
	24.87	67.96	2.337			
	25.10	67.99	2.308			
	25.30	68.04	2.271			
	25.42	68.080	2.239			
	25.55	68.130	2.198			
	25.70	68.19	2.146			
	25.83	68.25	2.090			
	25.97	68.31	2.038			
	26.11	68.37	1.980			
	26.25	68.42	1.924			
	26.39	68.49	1.864			
	26.52	68.54	1.811			
	26.65	68.59	1.765			
	26.79	68.640	1.715			
	26.93	68.68	1.671			
	27.06	68.73	1.632			
	27.20	68.78	1.588			
	27.34	68.82	1.537			
	27.47	68.86	1.501			
	27.62	68.91	1.459			
	27.75	68.96	1.412			
	27.89	69.00	1.371			
	28.04	69.05	1.317			
	28.16	69.08	1.281			
	28.30	69.13	1.220			

	28.43	69.18	1.173	
	28.57	69.22	1.130	
	28.71	69.26	1.086	
	28.85	69.31	1.038	
	28.98	69.35	0.991	
	29.13	69.41	0.935	
	29.16	69.41	0.930	
	29.30	69.45	0.883	
	29.60	69.53	0.788	
	29.90	69.58	0.746	
	30.21	69.58	0.789	

Table A.6. Cross section water surface data for 1:1 smooth training walls q = 0.060 m^2/s.

Run #	2		recorder	RW		
Date	7/2/2007		BM-0 rd.	x=24.68	y=65.03	z=2.873
time	x ft	y ft	z ft	comments		
	24.87	67.96	2.333			
	24.87	68.10	2.328			
	24.87	68.20	2.324			
	24.87	68.40	2.318			
	24.87	68.60	2.317			
	24.87	69.00	2.314			
	24.87	71.00	2.315			
	24.87	73.00	2.317			
	24.87	75.20	2.318			
	24.87	77.00	2.316			
	24.87	79.00	2.316			
	24.87	81.00	2.314			
	24.87	81.20	2.315			
	24.87	81.40	2.316			
	24.87	81.60	2.315			
	24.87	81.80	2.320			
	24.87	81.90	2.327			
	24.87	82.00	2.320			
	24.87	82.20	2.324			

	24.87	82.42	2.333	
	25.44	68.09	2.230	
	25.44	68.20	2.208	
	25.44	68.30	2.186	
	25.435	68.40	2.162	
	25.435	68.50	2.129	
	25.435	68.60	1.107	
	25.435	69.00	2.074	
	25.435	71.00	2.070	
	25.435	73.00	2.072	
	25.435	75.20	2.073	
	25.435	77.00	2.072	
	25.435	79.00	2.073	
	25.435	81.00	2.075	
	25.435	81.60	2.088	
	25.435	81.70	2.095	
	25.435	81.80	2.113	
	25.435	81.90	2.130	
	25.435	82.00	2.196	
	25.435	82.15	2.195	
	25.435	82.32	2.230	
	26.5	68.53	1.823	
	26.5	68.70	1.809	
	26.5	38.80	1.804	
	26.5	38.93	1.807	
	26.5	69.08	1.740	
	26.5	69.20	1.713	
	26.5	69.30	1.704	
	26.5	71.00	1.675	
	26.5	73.00	1.673	
	26.5	75.20	1.674	
	26.5	77.00	1.675	
	26.5	79.00	1.676	
	26.5	81.00	1.692	
	26.5	81.20	1.712	
	26.5	81.38	1.755	
	26.5	81.52	1.817	
	26.5	81.60	1.815	
	26.5	81.70	1.818	

	26.5	81.80	1.828	
	26.5	81.91	1.846	
	27.61	68.91	1.458	
	27.61	69.00	1.445	
	27.61	69.10	1.434	
	27.61	69.20	1.420	
	27.61	69.30	1.405	
	27.61	69.40	1.423	
	27.61	69.50	2.375	
	27.61	69.60	1.353	
	27.61	70.00	1.318	
	27.61	71.00	1.293	
	27.61	73.00	1.282	
	27.61	75.20	1.287	
	27.61	77.00	1.287	
	27.61	79.00	1.289	
	27.61	80.00	1.300	
	27.61	80.40	1.316	
	27.61	80.60	1.325	
	27.61	80.70	1.335	
	27.61	80.80	1.347	
	27.61	80.90	1.359	
	27.61	81.02	1.425	
	27.61	81.10	1.418	
	27.61	81.20	1.418	
	27.61	81.30	1.427	
	27.61	81.52	1.450	
	28.69	69.25	1.093	
	28.69	69.40	1.065	
	28.69	69.50	1.065	
	28.69	69.60	1.054	
	28.69	69.70	1.033	
	28.69	69.80	1.025	
	28.69	69.90	1.006	
	28.69	70.00	1.002	
	28.69	71.00	0.935	
	28.69	73.00	0.920	
	28.69	75.20	0.920	
	28.69	77.00	0.920	

	28.69	79.00	0.932	
	28.69	80.20	0.975	
	28.69	80.30	0.986	
	28.69	80.40	0.998	
	28.69	80.50	1.005	
	28.69	80.60	1.018	
	28.69	80.70	1.032	
	28.69	80.80	1.030	
	28.69	80.90	1.058	
	28.69	81.00	1.064	
	28.69	81.22	1.113	
	29.115	69.39	0.947	
	29.115	69.50	0.932	
	29.115	69.60	0.932	
	29.115	69.70	0.918	
	29.115	69.80	0.906	
	29.115	69.90	0.890	
	29.115	70.00	0.873	
	29.115	71.00	0.818	
	29.115	73.00	0.776	
	29.115	75.20	0.783	
	29.115	77.00	0.786	
	29.115	79.00	0.798	
	29.115	80.10	0.849	
	29.115	80.20	0.862	
	29.115	80.36	0.877	
	29.115	80.40	0.877	
	29.115	80.50	0.884	
	29.115	80.60	0.885	
	29.115	80.70	0.908	
	29.115	80.80	0.925	
	29.115	80.90	0.928	
	29.115	81.09	0.977	

Table A.7. Centerline water surface data for 1:1 smooth training walls q = 0.052 m^2/s.

Run #	3		recorder	RW		
Date	7/6/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873

time	x ft	y ft	z ft	comments
	12.00	75.20	2.376	Centerline
	14.00	75.20	2.375	
	16.00	75.20	2.375	
	18.00	75.20	2.375	
	20.00	75.20	2.374	
	22.00	75.20	2.373	
	24.00	75.20	2.345	
	24.20	75.20	2.345	
	24.40	75.20	2.343	
	24.65	75.20	2.333	
	24.76	75.20	2.322	
	24.78	75.20	2.318	
	24.87	75.20	2.296	Crest
	25.10	75.20	2.211	
	25.30	75.20	2.112	
	25.42	75.20	2.062	
	25.55	75.20	2.010	
	25.70	75.20	1.956	
	25.83	75.20	1.904	
	25.97	75.20	1.854	
	26.11	75.20	1.802	
	26.24	75.20	1.757	
	26.39	75.20	1.704	
	26.51	75.20	1.657	
	26.65	75.20	1.608	
	26.79	75.20	1.557	
	26.93	75.20	1.512	
	27.06	75.20	1.467	
	27.20	75.20	1.419	
	27.34	75.20	1.371	
	27.47	75.20	1.321	
	27.62	75.20	1.276	
	27.75	75.20	1.233	
	27.89	75.20	1.185	
	28.04	75.20	1.137	
	28.16	75.20	1.092	
	28.30	75.20	1.044	

	28.43	75.20	1.001	
	28.57	75.20	0.957	
	28.71	75.20	0.908	
	28.85	75.20	0.864	
	28.98	75.20	0.820	
	29.13	75.20	0.771	
	29.16	75.20	0.765	
	29.30	75.20	0.720	
	29.60	75.20	0.732	
	29.90	75.20	0.735	
	30.21	75.20	0.729	
	30.50	75.20	0.730	

Table A.8. Run-up water surface data for 1:1 smooth training walls q = 0.052 m^2/s.

Run #	3		recorder	RW		
Date	7/6/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
	23.84	67.93	2.356			
	24.00	67.92	2.358			
	24.20	67.93	2.354			
	24.40	67.94	2.349			
	24.65	67.96	2.339			
	24.76	67.97	2.330			
	24.78	67.97	2.329			
	24.87	67.98	2.324			
	25.10	68.01	2.295			
	25.30	68.07	2.246			
	25.42	68.100	2.219			
	25.55	68.150	2.178			
	25.70	68.21	2.123			
	25.83	68.27	2.068			
	25.97	68.33	2.013			
	26.11	68.39	1.954			
	26.24	68.45	1.904			
	26.39	68.51	1.843			

	26.51	68.56	1.794	
	26.65	68.61	1.743	
	26.79	68.660	1.689	
	26.93	68.71	1.649	
	27.06	68.75	1.608	
	27.20	68.79	1.570	
	27.34	68.83	1.525	
	27.47	68.87	1.439	
	27.62	68.92	1.445	
	27.75	68.97	1.402	
	27.89	69.01	1.355	
	28.04	69.05	1.306	
	28.16	69.10	1.264	
	28.30	69.14	1.205	
	28.43	69.19	1.165	
	28.57	69.24	1.114	
	28.71	69.28	1.069	
	28.85	69.33	1.018	
	28.98	69.37	0.973	
	29.13	69.41	0.923	
	29.16	69.43	0.907	
	29.30	69.47	0.863	
	29.60	69.55	0.775	
	29.90	69.58	0.732	
	30.21	69.58	0.731	
	30.50	69.59	0.731	

Table A.9. Cross section water surface data for 1:1 smooth training walls q = 0.052 m^2/s.

Run #	3		recorder	RW		
Date	7/6/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.87	67.98	2.320			
	24.87	68.10	2.312			
	24.87	68.20	2.307			
	24.87	68.30	2.307			

	24.87	68.60	2.298	
	24.87	68.80	2.298	
	24.87	69.00	2.297	
	24.87	71.00	2.297	
	24.87	73.00	2.300	
	24.87	75.20	2.301	
	24.87	77.00	2.300	
	24.87	79.00	2.298	
	24.87	81.00	2.297	
	24.87	81.40	2.297	
	24.87	81.60	2.298	
	24.87	81.80	2.298	
	24.87	82.00	2.302	
	24.87	82.20	2.305	
	24.87	82.30	2.311	
	24.87	82.41	2.321	
	25.44	68.11	2.211	
	25.44	68.20	2.189	
	25.435	68.40	2.145	
	25.435	68.60	2.088	
	25.435	68.80	2.063	
	25.435	69.00	2.057	
	25.435	71.00	2.055	
	25.435	73.00	2.057	
	25.435	75.20	2.056	
	25.435	77.00	2.056	
	25.435	79.00	2.057	
	25.435	81.00	2.060	
	25.435	81.40	2.059	
	25.435	81.60	2.068	
	25.435	81.80	2.092	
	25.435	82.00	2.142	
	25.435	82.10	2.165	
	25.435	82.20	2.188	
	25.435	82.30	2.212	
	26.5	68.56	1.796	
	26.5	68.70	1.786	
	26.5	68.80	1.786	
	26.5	68.90	1.783	

	26.5	69.00	1.766	
	26.5	69.10	1.718	
	26.5	69.30	1.704	
	26.5	69.50	1.678	
	26.5	71.00	1.664	
	26.5	73.00	1.662	
	26.5	75.20	1.663	
	26.5	77.00	1.664	
	26.5	79.00	1.665	
	26.5	80.60	1.671	
	26.5	80.80	1.675	
	26.5	81.00	1.683	
	26.5	81.20	1.697	
	26.5	81.30	1.709	
	26.5	81.40	1.746	
	26.5	81.50	1.797	
	26.5	81.60	1.795	
	26.5	81.70	1.797	
	26.5	81.88	1.818	
	27.61	68.92	1.447	
	27.61	69.00	1.436	
	27.61	69.10	1.420	
	27.61	69.20	1.405	
	27.61	69.30	1.385	
	27.61	69.40	1.400	
	27.61	69.50	1.367	
	27.61	69.60	1.340	
	27.61	69.70	1.327	
	27.61	69.89	1.322	
	27.61	71.00	2.282	
	27.61	73.00	1.277	
	27.61	75.20	1.278	
	27.61	77.00	1.278	
	27.61	79.00	1.277	
	27.61	80.60	1.317	
	27.61	80.70	1.324	
	27.61	80.80	1.334	
	27.61	80.90	1.349	
	27.61	81.00	1.387	

	27.61	81.10	1.396	
	27.61	81.25	1.399	
	27.61	81.30	1.410	
	27.61	81.52	1.451	
	28.69	69.27	1.075	
	28.69	69.40	1.058	
	28.69	69.50	1.050	
	28.69	69.60	1.042	
	28.69	69.70	1.039	
	28.69	69.80	1.010	
	28.69	69.90	1.000	
	28.69	70.00	0.987	
	28.69	71.00	0.928	
	28.69	73.00	0.915	
	28.69	75.20	0.914	
	28.69	77.00	0.909	
	28.69	79.00	0.920	
	28.69	80.00	0.946	
	28.69	80.20	0.960	
	28.69	80.40	0.992	
	28.69	80.50	0.997	
	28.69	80.60	1.000	
	28.69	80.70	1.016	
	28.69	80.80	1.015	
	28.69	80.90	1.041	
	28.69	81.00	1.057	
	28.69	81.20	1.100	
	29.115	69.41	0.928	
	29.115	69.60	0.910	
	29.115	69.70	0.908	
	29.115	69.80	0.879	
	29.115	69.90	0.867	
	29.115	70.00	0.864	
	29.115	71.00	0.806	
	29.115	73.00	0.778	
	29.115	75.20	0.777	
	29.115	77.00	0.779	
	29.115	79.00	0.789	
	29.115	80.00	0.822	

	29.115	80.20	0.840	
	29.115	80.40	0.855	
	29.115	80.60	0.860	
	29.115	80.70	0.888	
	29.115	80.8	0.908	
	29.115	80.95	0.916	
	29.115	81.07	0.955	

Table A.10. Centerline water surface data for 1:1 smooth training walls q = 0.039 m^2/s.

Run #	4		recorder	RW		
Date	7/9/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft			comments
10:44	12.00	75.20	2.322	Centerline		
	14.00	75.20	2.321			
	16.00	75.20	2.321			
	18.00	75.20	2.322			
	20.00	75.20	2.320			
	22.00	75.20	2.318			
	24.00	75.20	2.302			
	24.20	75.20	2.300			
	24.40	75.20	2.300			
	24.65	75.20	2.299			
	24.76	75.20	2.292			
	24.78	75.20	2.282			
	24.87	75.20	2.278	Crest		
	25.10	75.20	2.260			
	25.30	75.20	2.166			
	25.42	75.20	2.074			
	25.55	75.20	2.026			
	25.70	75.20	1.976			
	25.83	75.20	1.924			
	25.97	75.20	1.875			
	26.11	75.20	1.821			
	26.24	75.20	1.773			
	26.39	75.20	1.729			

	26.51	75.20	1.678	
	26.65	75.20	1.628	
	26.79	75.20	1.583	
	26.93	75.20	1.535	
	27.06	75.20	1.488	
	27.20	75.20	1.445	
	27.34	75.20	1.405	
	27.47	75.20	1.348	
	27.62	75.20	1.256	
	27.75	75.20	1.213	
	27.89	75.20	1.172	
	28.04	75.20	1.120	
	28.16	75.20	1.078	
	28.30	75.20	1.024	
	28.43	75.20	0.986	
	28.57	75.20	0.941	
	28.71	75.20	0.891	
	28.85	75.20	0.858	
	28.98	75.20	0.802	
	29.13	75.20	0.752	
	29.16	75.20	0.750	
	29.30	75.20	0.706	
	29.60	75.20	0.718	
	29.90	75.20	0.716	
	30.21	75.20	0.711	
	30.50	75.20	0.714	

Table A.11. Run-up water surface data for 1:1 smooth training walls q = 0.039 m^2/s.

Run #	4		recorder	RW AB		
Date	7/9/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
	23.84	67.98	2.300			
	24.00	67.97	2.319			
	24.20	67.97	2.307			
	24.40	67.98	2.303			

	24.65	68.00	2.298	
	24.76	68.01	2.292	
	24.78	68.01	2.287	
	24.87	68.02	2.282	
	25.10	68.06	2.247	
	25.30	68.12	2.198	
	25.42	68.160	2.163	
	25.55	68.220	2.117	
	25.70	68.28	2.062	
	25.83	68.34	2.007	
	25.97	68.40	1.951	
	26.11	68.46	1.894	
	26.24	68.51	1.843	
	26.39	68.57	1.785	
	26.51	68.61	1.744	
	26.65	68.66	1.700	
	26.79	68.700	1.655	
	26.93	68.75	1.611	
	27.06	68.79	1.576	
	27.20	68.83	1.534	
	27.34	68.87	1.495	
	27.47	68.90	1.461	
	27.62	68.95	1.415	
	27.75	68.98	1.391	
	27.89	69.02	1.347	
	28.04	69.06	1.305	
	28.16	69.12	1.241	
	28.30	69.16	1.191	
	28.43	69.21	1.148	
	28.57	69.26	1.095	
	28.71	69.30	1.046	
	28.85	69.35	0.997	
	28.98	69.39	0.957	
	29.13	69.42	0.913	
	29.16	69.45	0.891	
	29.30	69.48	0.855	
	29.60	69.56	0.759	
	29.90	69.60	0.719	
	30.21	69.59	0.722	

	30.50	69.59	0.727	

Table A.12. Cross section water surface data for 1:1 smooth training walls q = 0.039 m^2/s.

Run #	4		recorder	RW		
Date	7/9/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.87	68.02	2.280			
	24.87	68.20	2.267			
	24.87	68.40	2.260			
	24.87	68.60	2.257			
	24.87	68.80	2.258			
	24.87	69.00	2.257			
	24.87	71.00	2.258			
	24.87	73.00	2.259			
	24.87	75.20	2.259			
	24.87	77.00	2.258			
	24.87	79.00	2.259			
	24.87	81.00	2.257			
	24.87	81.40	2.257			
	24.87	81.60	2.257			
	24.87	81.80	2.259			
	24.87	82.00	2.260			
	24.87	82.20	2.265			
	24.87	82.37	2.279			
	24.44	68.17	2.156			
	24.44	68.30	2.129			
	24.44	68.50	2.080			
	24.44	68.70	2.033			
	24.44	68.90	2.021			
	24.44	69.00	2.019			
	24.44	71.00	2.019			
	24.44	73.00	2.019			
	24.44	75.20	2.019			
	24.44	77.00	2.019			

	24.44	79.00	2.020	
	24.44	81.00	2.022	
	24.44	81.50	2.025	
	24.44	81.70	2.036	
	24.44	81.90	2.072	
	24.44	82.10	2.123	
	24.44	82.24	2.155	
	26.5	68.61	1.747	
	26.5	68.70	1.742	
	26.5	68.80	1.741	
	26.5	68.90	1.733	
	26.5	69.00	1.727	
	26.5	69.10	1.671	
	26.5	69.10	1.672	
	26.5	71.00	1.640	
	26.5	73.00	1.638	
	26.5	75.20	1.639	
	26.5	77.00	1.640	
	26.5	79.00	1.638	
	26.5	81.00	1.651	
	26.5	81.38	1.692	
	26.5	81.50	1.744	
	26.5	81.70	1.748	
	26.5	81.82	1.761	
	27.61	68.93	1.440	
	27.61	68.97	1.403	
	27.61	69.10	1.385	
	27.61	69.20	1.364	
	27.61	69.30	1.332	
	27.61	69.40	1.344	
	27.61	69.50	1.328	
	27.61	71.00	1.272	
	27.61	73.00	1.250	
	27.61	75.20	1.255	
	27.61	77.00	1.259	
	27.61	79.00	1.260	
	27.61	80.70	1.285	
	27.61	80.80	1.297	
	27.61	80.90	1.312	

	27.61	81.00	1.332	
	27.61	81.30	1.370	
	27.61	81.47	1.403	
	29.115	69.42	0.914	
	29.115	69.47	0.880	
	29.115	69.60	0.870	
	29.115	69.90	0.837	
	29.115	70.20	0.822	
	29.115	70.50	0.797	
	29.115	71.00	0.782	
	29.115	73.00	0.760	
	29.115	75.20	0.750	
	29.115	77.00	0.750	
	29.115	79.00	0.760	
	29.115	80.20	0.798	
	29.115	80.60	0.812	
	29.115	80.80	0.861	
	29.115	81.01	0.884	
	29.115	81.04	0.916	

Table A.13. Centerline water surface data for 1:1 stepped training walls q = 0.078m^2/s.

Run #	5		recorder	RW		
Date	7/24/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
10:44	12.00	75.20	2.464	Centerline		
	16.00	75.20	2.464			
	20.00	75.20	2.461			
	24.87	75.20	2.363			
	25.30	75.20	2.180			
	25.55	75.20	2.067			
	25.97	75.20	1.899			
	26.25	75.20	1.799			
	26.52	75.20	1.696			
	26.79	75.20	1.594			
	27.06	75.20	1.504			

	27.34	75.20	1.403	
	27.62	75.20	1.308	
	27.89	75.20	1.215	
	28.16	75.20	1.123	
	28.43	75.20	1.027	
	28.71	75.20	0.934	
	28.98	75.20	0.839	
	29.16	75.20	0.786	
	25.83	75.20	1.958	
	25.97	75.20	1.900	
	26.11	75.20	1.852	
	26.25	75.20	1.800	
	26.39	75.20	1.745	
	26.52	75.20	1.698	
	26.65	75.20	1.648	
	26.79	75.20	1.599	
	26.93	75.20	1.551	
	27.06	75.20	1.514	
	27.20	75.20	1.458	
	27.34	75.20	1.402	
	27.47	75.20	1.359	
	27.62	75.20	1.310	
	27.75	75.20	1.264	
	27.89	75.20	1.218	
	28.04	75.20	1.169	
	28.16	75.20	1.125	
	28.30	75.20	1.078	
	28.43	75.20	1.030	
	28.57	75.20	0.982	
	28.71	75.20	0.934	
	28.85	75.20	0.886	
	28.98	75.20	0.847	
	29.13	75.20	0.794	
	29.16	75.20	0.783	
	29.30	75.20	0.752	
	29.60	75.20	0.747	
	29.90	75.20	0.762	
	30.21	75.20	0.770	
	30.50	75.20	0.765	

Table A.14. Run-up water surface data for 1:1 stepped training walls q = 0.078m^2/s.

Run #	5		recorder	RW		
Date	7/24/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.20	67.89	2.423	Stepped		
	24.40	67.89	2.422			
	24.65	67.93	2.393			
	24.76	67.93	2.390			
	24.78	67.93	2.390			
	24.87	67.93	2.385			
	25.10	67.93	2.387			
	25.30	67.93	2.386			
	25.42	68.00	2.353			
	25.55	68.02	2.352			
	25.70	68.020	2.350			
	25.83	68.030	2.334			
	25.97	68.03	2.325			
	26.11	68.06	2.305			
	26.24	68.13	2.209			
	26.39	68.20	2.163			
	26.51	68.21	2.159			
	26.65	68.21	2.157			
	26.79	68.25	2.112			
	26.93	68.25	2.110			
	27.06	68.270	2.105			
	27.20	68.31	2.067			
	27.34	68.31	2.067			
	27.47	68.36	2.015			
	27.62	68.37	2.012			
	27.75	68.42	1.967			
	27.89	68.47	1.916			
	28.04	68.47	1.912			
	28.16	68.51	1.873			
	28.30	68.56	1.827			

	28.43	68.60	1.776	
	28.57	68.60	1.772	
	28.71	68.65	1.722	
	28.85	68.68	1.684	
	28.98	68.68	1.685	
	29.13	68.73	1.635	
	29.16	68.73	1.638	
	29.30	68.77	1.587	
	29.60	68.82	1.546	
	29.90	68.91	1.453	
	30.21	69.00	1.361	
	30.50	69.09	1.275	
	30.21	69.55	0.767	
	30.50	69.55	0.767	

Table A.15. Cross section water surface data for 1:1 stepped training walls q = 0.078m^2/s.

Run #	5		recorder	RW		
Date	7/24/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.87	67.93	2.385			
	24.87	68.01	2.378			
	24.87	68.06	2.376			
	24.87	68.16	2.372			
	24.87	68.26	2.367			
	24.87	68.40	2.362			
	24.87	69.00	2.361			
	24.87	71.00	2.362			
	24.87	73.00	2.363			
	24.87	75.20	2.363			
	24.87	77.00	2.362			
	24.87	79.00	2.364			
	24.87	81.00	2.359			
	24.87	81.80	2.362			
	24.87	82.00	2.362			
	24.87	82.20	2.366			

	24.87	82.47	2.383	
	25.44	67.94	2.395	
	25.44	68.01	2.350	
	25.44	68.11	2.282	
	25.44	68.22	2.257	
	25.44	68.32	2.232	
	25.44	68.44	2.203	
	25.435	68.60	2.160	
	25.435	68.80	2.134	
	25.435	69.00	2.120	
	25.435	71.00	2.118	
	25.435	73.00	2.118	
	25.435	75.20	2.120	
	25.435	77.00	2.118	
	25.435	79.00	2.119	
	25.435	81.00	2.123	
	25.435	81.20	2.134	
	25.435	81.60	2.141	
	25.435	81.80	2.163	
	25.435	82.00	2.205	
	25.435	82.20	2.253	
13:59	25.435	82.36	2.387	
14:34	26.5	67.92	2.392	
	26.5	68.11	2.257	
	26.5	68.22	2.159	
	26.5	68.32	2.068	
	26.5	68.43	1.980	
	26.5	68.53	1.898	
	26.5	68.63	1.875	
	26.5	68.72	1.862	
	26.5	68.80	1.861	
	26.5	68.93	1.855	
	26.5	69.08	1.778	
	26.5	69.30	1.734	
	26.5	71.00	1.702	
	26.5	73.00	1.700	
	26.5	75.20	1.703	
	26.5	77.00	1.702	
	26.5	79.00	1.703	

	26.5	81.00	1.727	
	26.5	81.33	1.773	
	26.5	81.42	1.800	
	26.5	81.54	1.865	
	26.5	81.70	1.872	
	26.5	81.90	1.900	
14:44	26.5	82.01	1.938	
	27.61	67.94	2.385	
	27.61	68.21	2.157	
	27.61	68.37	2.010	
	27.61	68.52	1.884	
	27.61	68.62	1.798	
	27.61	68.76	1.662	
	27.61	68.89	1.547	
	27.61	68.99	1.498	
	27.61	69.11	1.481	
	27.61	69.28	1.470	
	27.61	69.42	1.478	
	27.61	69.57	1.385	
	27.61	69.80	1.351	
	27.61	71.00	1.317	
	27.61	73.00	1.307	
	27.61	75.20	1.310	
	27.61	77.00	1.309	
	27.61	79.00	1.313	
	27.61	80.50	1.346	
	27.61	80.87	1.395	
	27.61	81.02	1.487	
	27.61	81.20	1.475	
	27.61	81.40	1.484	
14:56	27.61	81.60	1.520	
	28.69	67.96	2.378	
	28.69	68.16	2.194	
	28.69	68.36	2.004	
	28.69	68.55	1.823	
	28.69	68.64	1.732	
	28.69	68.74	1.658	
	28.69	68.83	1.555	
	28.69	68.94	1.464	

	28.69	69.03	1.367	
	28.69	69.17	1.246	
	28.69	69.28	1.176	
	28.69	69.47	1.126	
	28.69	69.70	1.083	
	28.69	69.94	1.065	
	28.69	70.10	1.013	
	28.69	71.00	0.955	
	28.69	73.00	0.938	
	28.69	75.20	0.941	
	28.69	77.00	0.943	
	28.69	79.00	0.955	
	28.69	80.00	0.993	
	28.69	80.30	1.019	
	28.69	80.63	1.092	
	28.69	80.90	1.098	
	28.69	81.10	1.117	
15:16	28.69	81.27	1.163	

Table A.16. Centerline water surface data for 1:1 stepped training walls q = 0.060m^2/s.

Run #	6		recorder	RW		
Date	7/25/2007		BM-0 rd.	x=24.68	y =65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.87	75.20	2.317	Centerline		
	25.44	75.20	2.070			
	26.50	75.20	1.673			
	27.61	75.20	1.282			
	28.69	75.20	0.915			
	29.15	75.20	0.773			

Table A.17. Run-up water surface data for 1:1 stepped training walls q = 0.060m^2/s.

Run #	6		recorder	RW		
Date	7/25/2007		BM-0 rd.	x=24.68	65.02	z=2.873

time	x ft	y ft	z ft	comments
	24.40	67.94	2.375	
	24.65	67.98	2.350	
	24.76	67.99	2.345	
	24.87	68.01	2.339	
	25.10	68.20	2.341	
	25.30	68.06	2.301	
	25.42	68.06	2.304	
	25.55	68.09	2.259	
	25.70	68.120	2.264	
	25.83	68.170	2.216	
	25.97	68.22	2.171	
	26.11	68.22	2.167	
	26.25	68.27	2.120	
	26.39	68.27	2.114	
	26.52	68.32	2.072	
	26.65	68.32	2.067	
	26.79	68.37	2.023	
	26.93	68.42	1.976	
	27.06	68.420	1.972	
	27.20	68.47	1.928	
	27.33	68.52	1.886	
	27.47	68.52	1.898	
	27.62	68.57	1.846	
	27.75	68.57	1.842	
	27.89	68.61	1.800	
	28.03	68.61	1.792	
	28.16	68.61	1.788	
	28.30	68.65	1.731	
	28.43	68.69	1.695	
	28.57	68.71	1.681	
	28.71	68.74	1.642	
	28.85	68.79	1.588	
	28.98	68.83	1.551	
	29.12	68.83	1.546	
	29.16	68.83	1.541	
	29.30	68.87	1.497	

	29.60	68.91	1.448	
	29.90	68.96	1.400	
	30.21	69.00	1.353	
	30.50	69.07	1.285	
	30.8	69.19	1.17	
	31.10	69.28	1.084	
	31.40	69.37	1.002	

Table A.18. Cross section water surface data for 1:1 stepped training walls q = 0.060m^2/s.

Run #	6		recorder	RW		
Date	7/25/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
9:25	24.87	67.98	2.338			
	24.87	68.10	2.328			
	24.87	68.20	2.323			
	24.87	68.30	2.320			
	24.87	68.40	2.317			
	24.87	68.50	2.314			
	24.87	69.00	2.312			
	24.87	71.00	2.311			
	24.87	73.00	2.314			
	24.87	75.20	2.313			
	24.87	77.00	2.313			
	24.87	79.00	2.314			
	24.87	81.00	2.313			
	24.87	81.70	2.316			
	24.87	81.90	2.317			
	24.87	82.00	2.318			
	24.87	82.20	2.323			
	24.87	82.42	2.334			
9:38	25.44	68.01	2.349			
	25.44	68.12	2.262			
	25.44	68.22	2.213			
	25.44	68.33	2.185			
	25.435	68.43	2.158			

	25.435	68.50	2.135	
	25.435	68.60	2.110	
	25.435	68.70	2.091	
	25.435	69.00	2.073	
	25.435	71.00	2.071	
	25.435	73.00	2.072	
	25.435	75.20	2.072	
	25.435	77.00	2.073	
	25.435	79.00	2.075	
	25.435	81.00	2.077	
	25.435	81.85	2.121	
	25.435	82.10	2.184	
	25.435	82.31	2.230	
10:03	26.5	68.01	2.347	
	26.5	68.22	2.160	
	26.5	68.27	2.112	
	26.5	68.43	1.978	
	26.5	68.59	1.845	
	26.5	68.70	1.804	
	26.5	68.80	1.804	
	26.5	68.90	1.797	
	26.5	69.00	1.798	
	26.5	69.10	1.725	
	26.5	69.20	1.704	
	26.5	71.00	1.673	
	26.5	73.00	1.670	
	26.5	75.20	1.672	
	26.5	77.00	1.671	
	26.5	79.00	1.674	
	26.5	81.00	1.691	
	26.5	81.40	1.760	
	26.5	81.55	1.814	
	26.5	81.70	1.820	
	26.5	81.92	1.857	
10:20	27.61	68.01	2.340	
	27.61	68.27	2.109	
	27.61	68.47	1.921	
	27.61	68.57	1.849	
	27.61	68.71	1.710	

	27.61	68.85	1.583	
	27.61	68.95	1.499	
	27.61	69.10	1.431	
	27.61	69.30	1.413	
	27.61	69.50	1.388	
	27.61	69.65	1.337	
	27.61	69.80	1.320	
	27.61	71.00	1.291	
	27.61	73.00	1.282	
	27.61	75.20	1.283	Step 16 Centerline
	27.61	77.00	1.284	
	27.61	79.00	1.290	
	27.61	80.70	1.337	
	27.61	80.90	1.358	
	27.61	81.07	1.428	
	27.61	81.30	1.428	
	27.61	81.55	1.475	
10:37	28.69	68.01	2.335	
	28.69	68.51	1.866	
	28.69	68.69	1.684	
	28.69	68.83	1.555	
	28.69	68.98	1.422	
	28.69	69.12	1.285	
	28.69	69.27	1.164	
	28.69	69.41	1.089	
	28.69	69.50	1.062	
	28.69	69.60	1.070	
	28.69	69.70	1.047	
	28.69	69.80	1.033	
	28.69	69.90	1.004	
	28.69	70.00	0.986	
	28.69	71.00	0.931	
	28.69	73.00	0.918	
	28.69	75.20	0.920	
	28.69	77.00	0.922	
	28.69	79.00	0.930	
	28.69	80.00	0.964	
	28.69	80.50	1.002	
	28.69	80.60	1.020	

	28.69	80.70	1.031	
	28.69	80.80	1.030	
	28.69	80.90	1.052	
	28.69	81.00	1.073	
	28.69	81.22	1.117	

Table A.19. Centerline water surface data for 1:1 stepped training walls q = 0.052 m^2/s.

Run #	7		recorder	RW		
Date	7/31/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft			
	14.00	75.20	2.379	Centerline		
	18.00	75.20	2.380			
	22.00	75.20	2.377			
	24.87	75.20	2.300			
	25.44	75.20	2.054			
	26.50	75.20	1.665			
	27.61	75.20	1.272			
	28.69	75.20	0.907			
	29.15	75.20	0.757			

Table A.20. Run-up water surface data for 1:1 stepped training walls q = 0.052 m^2/s.

Run #	7		recorder	RW		
Date	7/31/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.40	67.98	2.345			
	24.65	67.99	2.343			
	24.76	68.01	2.336			
	24.87	68.05	2.314			
	25.10	68.08	2.279			
	25.30	68.13	2.235			

	25.42	68.16	2.211	
	25.55	68.16	2.212	
	25.70	68.21	2.173	
	25.83	68.220	2.165	
	25.97	68.220	2.160	
	26.11	68.26	2.118	
	26.25	68.32	2.075	
	26.39	68.32	2.068	
	26.52	68.37	2.021	
	26.65	68.37	2.020	
	26.79	68.37	2.014	
	26.93	68.41	1.970	
	27.06	68.46	1.921	
	27.20	68.460	1.920	
	27.33	68.51	1.883	
	27.47	68.51	1.875	
	27.62	68.56	1.833	
	27.75	68.56	1.829	
	27.89	68.60	1.785	
	28.03	68.60	1.783	
	28.16	68.64	1.738	
	28.30	68.68	1.688	
	28.43	68.68	1.685	
	28.57	68.73	1.643	
	28.71	68.77	1.595	
	28.85	68.77	1.588	
	28.98	68.82	1.540	
	29.12	68.86	1.492	
	29.16	68.91	1.463	
	29.30	68.91	1.448	
	29.60	68.96	1.402	
	29.90	69.05	1.306	
	30.20	69.14	1.221	
	30.50	69.23	1.129	
	30.80	69.28	1.085	
	31.1	69.37	1.003	
	32.00	69.65	0.725	

Table A.21. Cross section water surface data for 1:1 stepped training walls q = 0.052 m^2/s.

Run #	7		recorder	RW		
Date	7/27/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
9:25	24.87	67.98	2.343			
	24.87	68.10	2.311			
	24.87	68.20	2.308			
	24.87	68.30	2.305			
	24.87	68.40	2.304			
	24.87	68.50	2.300			
	24.87	69.00	2.299			
	24.87	71.00	2.299			
	24.87	73.00	2.301			
	24.87	75.20	2.301			
	24.87	77.00	2.300			
	24.87	79.00	2.300			
	24.87	81.00	2.299			
	24.87	81.80	2.301			
	24.87	81.90	2.301			
	24.87	82.00	2.302			
	24.87	82.10	2.305			
	24.87	82.20	2.306			
	24.87	82.41	2.318			
9:38	25.44	68.12	2.260			
	25.44	68.22	2.194			
	25.435	68.33	2.170			
	25.435	68.44	2.141			
	25.435	68.55	2.103			
	25.435	68.70	2.075			
	25.435	68.80	2.066			
	25.435	69.00	2.058			
	25.435	71.00	2.057			
	25.435	73.00	2.058			

	25.435	75.20	2.058	
	25.435	77.00	2.057	
	25.435	79.00	2.058	
	25.435	81.00	2.061	
	25.435	81.95	2.132	
	25.435	82.29	2.211	
10:03	26.5	68.26	2.113	
	26.5	68.42	1.977	
	26.5	68.57	1.856	
	26.5	68.71	1.782	
	26.5	68.87	1.778	
	26.5	68.98	1.770	
	26.5	69.09	1.712	
	26.5	71.00	1.663	
	26.5	73.00	1.660	
	26.5	75.20	1.661	
	26.5	77.00	1.663	
	26.5	79.00	1.662	
	26.5	81.00	1.678	
	26.5	81.38	1.728	
	26.5	81.50	1.795	
	26.5	81.70	1.795	
	26.5	81.89	1.818	
10:20	27.61	68.52	1.877	
	27.61	68.66	1.751	
	27.61	68.81	1.622	
	27.61	68.95	1.493	
	27.61	69.09	1.417	
	27.61	69.20	1.409	
	27.61	69.30	1.392	
	27.61	69.45	1.381	
	27.61	69.58	1.337	
	27.61	69.70	1.306	
	27.61	69.80	1.308	
	27.61	70.00	1.300	
	27.61	71.00	1.285	
	27.61	73.00	1.276	
	27.61	75.20	1.277	
	27.61	77.00	1.278	

	27.61	79.00	1.280	
	27.61	80.80	1.340	
	27.61	80.91	1.350	
	27.61	81.08	1.399	
	27.61	81.20	1.397	
	27.61	81.40	1.415	
	27.61	81.52	1.457	
10:37	28.69	68.74	1.643	
	28.69	68.89	1.503	
	28.69	69.02	1.386	
	28.69	69.17	1.245	
	28.69	69.31	1.121	
	28.69	69.42	1.072	
	28.69	69.55	1.053	
	28.69	69.65	1.041	
	28.69	69.75	1.012	
	28.69	69.89	0.978	
	28.69	70.00	0.975	
	28.69	71.00	0.917	
	28.69	73.00	0.913	
	28.69	75.20	0.911	
	28.69	77.00	0.905	
	28.69	79.00	0.919	
	28.69	80.00	0.953	
	28.69	80.40	0.980	
	28.69	80.50	0.996	
	28.69	80.60	0.998	
	28.69	80.70	1.016	
	28.69	80.80	1.008	
	28.69	80.90	1.037	
	28.69	81.00	1.055	
	28.69	81.10	1.059	
	28.69	81.20	1.101	

Table A.22. Centerline water surface data for 1:1 stepped training walls q = 0.039 m^2/s.

Run #	8		recorder	RW		
Date	8/3/2007		BM-0 rd.	x=24.68	65.02	z=2.873

time	x ft	y ft	z ft	comments
	14.00	75.20	2.322	Centerline
	18.00	75.20	2.322	
	22.00	75.20	2.320	
	24.87	75.20	2.261	
	25.44	75.20	2.015	
	26.52	75.20	1.627	
	27.61	75.20	1.258	
	28.69	75.20	0.889	
	29.16	75.20	0.737	

Table A.23. Run-up water surface data for 1:1 stepped training walls q = 0.039 m^2/s.

Run #	8		recorder	RW		
Date	8/3/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.40	68.01	2.298			
	24.65	68.06	2.292			
	24.76	68.06	2.290			
	24.87	68.11	2.269			
	25.10	68.11	2.254			
	25.30	68.17	2.207			
	25.42	68.17	2.208			
	25.55	68.22	2.164			
	25.70	68.22	2.158			
	25.83	68.27	2.116			
	25.97	68.270	2.114			
	26.11	68.320	2.075			
	26.25	68.38	2.025			
	26.39	68.38	2.024			
	26.52	68.43	1.982			
	26.65	68.43	1.975			
	26.79	68.43	1.969			
	26.93	68.48	1.927			

	27.06	68.48	1.918	
	27.20	68.53	1.877	
	27.33	68.530	1.877	
	27.47	68.57	1.838	
	27.62	68.57	1.832	
	27.75	68.62	1.787	
	27.89	68.66	1.736	
	28.03	68.71	1.694	
	28.16	68.71	1.689	
	28.30	68.75	1.644	
	28.43	68.75	1.645	
	28.57	68.79	1.596	
	28.71	68.79	1.591	
	28.85	68.83	1.545	
	28.98	68.88	1.496	
	29.12	68.88	1.492	
	29.16	68.92	1.450	
	29.30	68.97	1.401	
	29.90	69.10	1.276	
	30.50	69.24	1.131	
	31.10	69.47	0.909	
	31.70	69.61	0.768	
	29.60	69.56	0.759	
	29.90	69.60	0.719	
	30.21	69.59	0.722	
	30.50	69.59	0.727	

Table A.24. Cross section water surface data for 1:1 stepped training walls q = 0.039 m^2/s.

Run #	8		recorder	RW		
Date	8/3/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.87	68.03	2.291			
	24.87	68.16	2.267			
	24.87	68.26	2.263			

	24.87	68.40	2.259	
	24.87	68.50	2.256	
	24.87	69.00	2.254	
	24.87	71.00	2.255	
	24.87	73.00	2.256	
	24.87	75.20	2.256	
	24.87	77.00	2.255	
	24.87	79.00	2.255	
	24.87	81.00	2.254	
	24.87	81.80	2.253	
	24.87	82.00	2.257	
	24.87	82.20	2.263	
	24.87	82.37	2.277	
	25.44	68.09	2.266	
	25.44	68.22	2.171	
	25.44	68.32	2.127	
	25.44	68.43	2.101	
	25.44	68.54	2.065	
	25.44	68.65	2.036	
	25.44	68.80	2.022	
	25.44	69.00	2.015	
	25.44	71.00	2.016	
	25.44	73.00	2.015	
	25.44	75.20	2.016	
	25.44	77.00	2.015	
	25.44	79.00	2.017	
	25.44	81.00	2.020	
	25.44	81.50	2.021	
	25.44	81.85	2.058	
	25.44	82.00	2.103	
	25.44	82.10	2.122	
	25.435	82.23	2.149	
	26.5	68.09	2.265	
	26.5	68.33	2.070	
	26.5	68.43	1.981	
	26.5	68.53	1.887	
	26.5	68.63	1.815	
	26.5	68.73	1.737	
	26.5	68.81	1.733	

	26.5	68.90	1.728	
	26.5	69.00	1.731	
	26.5	69.10	1.669	
	26.5	69.20	1.658	
	26.5	71.00	1.635	
	26.5	73.00	1.633	
	26.5	75.20	1.633	
	26.5	77.00	1.634	
	26.5	79.00	1.636	
	26.5	81.00	1.649	
	26.5	81.35	1.681	
	26.5	81.50	1.743	
	26.5	81.60	1.742	
	26.5	81.70	1.745	
	26.5	81.83	1.764	
	27.61	68.08	2.260	
	27.61	68.61	1.793	
	27.61	68.76	1.668	
	27.61	68.90	1.537	
	27.61	68.99	1.447	
	27.61	69.10	1.397	
	27.61	69.20	1.375	
	27.61	69.30	1.350	
	27.61	69.40	1.336	
	27.61	69.50	1.311	
	27.61	69.60	1.296	
	27.61	69.70	1.285	
	27.61	70.00	1.275	
	27.61	71.00	1.262	
	27.61	73.00	1.253	
	27.61	75.20	1.252	
	27.61	77.00	1.255	
	27.61	79.00	1.258	
	27.61	80.00	1.270	
	27.61	80.50	1.277	
	27.61	80.80	1.301	
	27.61	80.90	1.312	
	27.61	81.00	1.325	
	27.61	81.10	1.341	

	27.61	81.20	1.355	
	27.61	81.30	1.365	
	27.61	81.49	1.416	

Table A.25. Centerline water surface data for 2:1 smooth training walls q = 0.078 m^2/s.

Run #	9		recorder	RW		
Date	8/31/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
13:39	12.00	75.20	2.467	Centerline		
	16.00	75.20	2.466			
	20.00	75.20	2.465			
	24.00	75.20	2.411			
	24.87	75.20	2.356			
	25.44	75.20	2.117			
	26.50	75.20	1.701			
	27.61	75.20	1.304			
	28.69	75.20	0.933			
	29.16	75.20	0.778			
13:43	29.30	75.20	0.746			

Table A.26. Run-up water surface data for 2:1 smooth training walls q = 0.078 m^2/s.

Run #	9		recorder	BS		
Date	8/31/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
13:11	24.00	68.41	2.377			
	24.40	68.39	2.384			
	24.76	68.39	2.382			
	24.87	68.40	2.376			
	25.10	68.43	2.357			
	25.30	68.47	2.337			
	25.42	68.50	2.325			

	25.55	68.54	2.306	
	25.69	68.58	2.284	
	25.83	68.62	2.261	
	25.97	68.680	2.235	
	26.11	68.740	2.207	
	26.24	68.80	2.179	
	26.39	68.86	2.147	
	26.51	68.93	2.115	
	26.65	69.01	2.078	
	26.79	69.09	2.041	
	26.93	69.17	1.996	
	27.06	69.26	1.955	
	27.20	69.34	1.914	
	27.34	69.440	1.865	
	27.47	69.57	1.823	
13:23	27.61	69.61	1.778	
	27.75	69.69	1.773	
	27.89	69.78	1.690	
	28.04	69.87	1.644	
	28.16	69.94	1.608	
	28.30	70.03	1.566	
	28.43	70.08	1.537	
	28.57	70.18	1.488	
	28.71	70.25	1.452	
	28.85	70.33	1.412	
	28.89	70.36	1.378	
	29.13	70.49	1.331	
	29.16	70.51	1.323	
	29.30	70.59	1.283	
	29.60	70.76	1.201	
	29.90	70.93	1.117	
13:32	30.20	71.00	1.084	
	31.38	71.82	0.068	
	30.21	69.00	1.361	
	30.50	69.09	1.275	
	30.21	69.55	0.767	
	30.50	69.55	0.767	

Table A.27. Cross section water surface data for 2:1smooth training walls q = 0.078 m^2/s.

Run #	9		recorder	RW		
Date	8/31/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
10:12	24.87	68.41	2.377			
	24.87	68.50	2.378			
	24.87	68.60	2.374			
	24.87	68.70	2.370			
	24.87	68.80	2.367			
	24.87	68.90	2.367			
	24.87	69.00	2.360			
	24.87	69.50	2.359			
	24.87	71.00	2.365			
	24.87	73.00	2.365			
	24.87	75.20	2.364			
	24.87	77.00	2.364			
	24.87	79.00	2.362			
	24.87	81.00	2.358			
	24.87	81.50	2.360			
	24.87	81.80	2.362			
	24.87	81.90	2.363			
	24.87	82.00	2.365			
	24.87	82.10	2.368			
	24.87	82.20	2.367			
	24.87	82.30	2.374			
	24.87	82.47	2.386			
10:33	25.435	68.50	2.324			
	25.435	68.60	2.318			
	25.435	68.70	2.310			
	25.435	68.80	2.300			
	25.435	68.90	2.283			
	25.435	69.00	2.277			
	25.435	69.10	2.245			
	25.435	69.20	2.223			
	25.435	69.30	2.187			
	25.435	69.40	2.162			
	25.435	69.50	2.146			
	25.435	69.60	2.133			

	25.435	71.00	2.117	
	25.435	73.00	2.118	
	25.435	75.20	2.120	
	25.435	77.00	2.117	
	25.435	79	2.118	
	25.435	81.00	2.122	
	25.435	81.50	2.132	
	25.435	81.60	2.136	
	25.435	81.70	2.148	
	25.435	81.80	2.162	
	25.435	81.90	2.179	
	25.435	82.00	2.208	
	25.435	82.10	2.230	
	25.435	82.20	2.252	
	25.435	82.38	2.292	
11:00	26.5	68.92	2.123	
	26.5	69.10	2.088	
	26.5	69.20	2.069	
	26.5	69.30	2.050	
	26.5	69.40	2.034	
	26.5	69.50	2.014	
	26.5	69.60	1.995	
	26.5	69.70	1.980	
	26.5	69.80	1.970	
	26.5	69.90	1.952	
	26.5	70.00	1.847	
	26.5	70.10	1.788	
	26.5	70.20	1.760	
	26.5	70.50	1.725	
	26.5	71.00	1.713	
	26.5	73.00	1.702	
	26.5	75.20	1.703	
	26.5	77.00	1.705	
	26.5	79.00	1.703	
	26.5	80.50	1.711	
	26.5	81.00	1.724	
	26.5	81.10	1.730	
	26.5	81.20	1.745	
	26.5	81.30	1.762	

	26.5	81.40	1.798	
	26.5	81.50	1.857	
	26.5	81.60	1.864	
	26.5	81.70	1.866	
	26.5	82.01	1.938	
11:50	27.61	69.61	1.780	
	27.61	69.80	1.751	
	27.61	70.00	1.721	
	27.61	70.20	1.692	
	27.61	70.30	1.676	
	27.61	70.40	1.659	
	27.61	70.50	1.647	
	27.61	70.60	1.640	
	27.61	70.70	1.613	
	27.61	70.80	1.563	
	27.61	70.90	1.405	
	27.61	71.00	1.383	
	27.61	71.10	1.375	
	27.61	71.20	1.363	
	27.61	71.30	1.356	
	27.61	71.40	1.346	
	27.61	72.00	1.321	
	27.61	73.00	1.305	
	27.61	75.20	1.305	
	27.61	77.00	1.306	
	27.61	79.00	1.311	
	27.61	80.00	1.325	
	27.61	80.50	1.345	
	27.61	80.90	1.400	
	27.61	81.00	1.481	
	27.61	81.10	1.465	
	27.61	81.30	1.475	
	27.61	81.40	1.478	
	27.61	81.59	1.517	
	28.69	70.24	1.460	
	28.69	70.40	1.432	
	28.69	70.60	1.405	
	28.69	70.70	1.391	
	28.69	70.80	1.375	

	28.69	70.90	1.363	
	28.69	71.00	1.347	
	28.69	71.10	1.332	
	28.69	71.20	1.325	
	28.69	71.30	1.313	
	28.69	71.40	1.269	
	28.69	71.50	1.260	
	28.69	71.60	1.227	
	28.69	71.70	1.164	
	28.69	71.80	1.078	
	28.69	71.90	1.061	
	28.69	72.00	1.010	
	28.69	72.20	0.996	
	28.69	72.40	0.981	
	28.69	73.00	0.950	
	28.69	75.20	0.937	
	28.69	77	0.936	
	28.69	79	0.947	
	28.69	80	0.987	
	28.69	80.2	1.004	
	28.69	80.3	1.015	
	28.69	80.4	1.024	
	28.69	80.5	1.03	
	28.69	80.6	1.087	
	28.69	80.7	1.086	
	28.69	80.8	1.078	
	28.69	80.9	1.1	
	28.69	81	1.108	
	28.69	81.27	1.162	
	29.155	70.51	1.325	
	29.155	70.7	1.284	
	29.155	70.9	1.26	
	29.155	71	1.241	
	29.155	71.1	1.226	
	29.155	71.2	1.211	
	29.155	71.3	1.194	
	29.155	71.4	1.188	
	29.155	71.5	1.178	
	29.155	71.6	1.16	

	29.155	71.7	1.127	
	29.155	71.8	1.08	
	29.155	71.9	1.036	
	29.155	72	0.973	
	29.155	72.1	0.963	
	29.155	72.3	0.889	
	29.155	72.5	0.869	
	29.155	73	0.8823	
	29.155	75.2	0.784	
	29.155	77	0.782	
	29.155	79	0.798	
	29.155	79.5	0.822	
	29.155	80	0.853	
	29.155	80.2	0.88	
	29.155	80.3	0.885	
	29.155	80.4	0.914	
	29.155	80.5	0.929	
	29.155	80.6	0.913	
	29.155	80.7	0.94	
	29.155	80.9	0.954	
	29.155	81	0.962	
	29.155	81.14	1.019	

Table A.28. Centerline water surface data for 2:1 smooth training walls q = 0.060 m^2/s.

Run #	10		recorder	RW		
Date	9/4/2007		BM-0 rd.	x=24.68	y =65.02	z=2.873
time	x ft	y ft	z ft	comments		
14:25	12.00	75.20	2.405	Centerline		
	16.00	75.20	2.404			
	20.00	75.20	2.403			
	24.00	75.20	2.364			
	24.87	75.20	2.315			
	25.44	75.20	2.069			
	26.50	75.20	1.671			
	27.61	75.20	1.275			

	28.69	75.20	0.917	
	29.16	75.20	0.759	
	29.30	75.20	0.724	

Table A.29. Run-up water surface data for 2:1 smooth training walls q = 0.060 m^2/s.

Run #	10		recorder	RW		
Date	9/4/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft			comments
	24.40	68.47	2.348			
	24.76	68.48	2.342			
	24.87	68.50	2.331			
	25.10	68.54	2.314			
	25.30	68.58	2.290			
	25.42	68.61	2.274			
	25.55	68.65	2.254			
	25.69	68.71	2.227			
	25.83	68.750	2.205			
	25.97	68.810	2.177			
	26.11	68.88	2.144			
	26.24	68.94	2.113			
	26.39	69.03	2.072			
	26.51	69.10	2.037			
	26.65	69.18	1.996			
	26.79	69.28	1.945			
	26.93	69.36	1.905			
	27.06	69.45	1.866			
	27.19	69.520	1.825			
	27.34	69.62	1.777			
	27.47	69.69	1.737			
	27.61	69.79	1.699			
	27.75	69.87	1.648			
	27.89	69.95	1.605			
	28.04	70.03	1.566			
	28.16	70.11	1.529			
	28.30	70.18	1.491			

	28.43	70.25	1.455	
	28.58	70.35	1.410	
	28.71	70.41	1.375	
	28.85	70.49	1.334	
	28.98	70.57	1.298	
	29.13	70.65	1.255	
	29.16	70.67	1.245	
	29.30	70.75	1.208	
	29.60	70.92	1.119	
	29.90	71.10	1.033	
	30.20	71.29	0.941	
	31.05	71.84	0.676	
	30.50	69.07	1.285	
	30.8	69.19	1.17	
	31.10	69.28	1.084	
	31.40	69.37	1.002	

Table A.30. Cross section water surface data for 2:1smooth training walls q = 0.060 m^2/s.

Run #	10		recorder	RW		
Date	9/4/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
9:50	24.87	68.49	2.334			
	24.87	68.60	2.333			
	24.87	68.70	2.328			
	24.87	68.80	2.325			
	24.87	68.90	2.322			
	24.87	69.00	2.317			
	24.87	71.00	2.313			
	24.87	73.00	2.315			
	24.87	75.20	2.316			
	24.87	77.00	2.315			
	24.87	79.00	2.316			
	24.87	81.00	2.316			
	24.87	81.50	2.316			
	24.87	81.70	2.319			

	24.87	81.90	2.320	
	24.87	82.00	2.321	
	24.87	82.10	2.323	
	24.87	82.20	2.324	
	24.87	82.30	2.330	
	24.87	82.42	2.336	
10:02	25.44	68.61	2.271	
	25.435	68.80	2.256	
	25.435	69.00	2.227	
	25.435	69.10	2.208	
	25.435	69.20	2.182	
	25.435	69.30	2.145	
	25.435	69.40	2.117	
	25.435	69.50	2.096	
	25.435	69.60	2.085	
	25.435	69.70	2.078	
	25.435	69.80	2.072	
	25.435	69.90	2.071	
	25.435	70.00	2.071	
	25.435	71.00	2.067	
	25.435	73.00	2.070	
	25.435	75.20	2.071	
	25.435	77.00	2.070	
	25.435	79.00	2.072	
	25.435	81.00	2.076	
	25.435	81.50	2.079	
	25.435	81.70	2.095	
	25.435	81.80	2.110	
	25.435	81.90	2.130	
	25.435	82.00	2.164	
	25.435	82.10	2.185	
	25.435	82.20	2.207	
	25.435	82.31	2.229	
10:30	26.5	69.09	2.043	
	26.5	69.30	2.003	
	26.5	69.50	1.965	
	26.5	69.60	1.946	
	26.5	69.70	1.930	
	26.5	69.80	1.916	

	26.5	69.90	1.912	
	26.5	70.00	1.886	
	26.5	70.10	1.740	
	26.5	70.20	1.721	
	26.5	70.30	1.711	
	26.5	70.40	1.700	
	26.5	70.50	1.694	
	26.5	71.00	1.682	
	26.5	73.00	1.670	
	26.5	75.20	1.672	
	26.5	77.00	1.672	
	26.5	79.00	1.672	
	26.5	80.50	1.672	
	26.5	81.00	1.689	
	26.5	81.10	1.697	
	26.5	81.20	1.705	
	26.5	81.30	1.719	
	26.5	81.40	1.761	
	26.5	81.50	1.813	
	26.5	81.70	1.811	
	26.5	81.80	1.826	
	26.5	81.92	1.849	
	27.61	69.78	1.693	
	27.61	70.00	1.661	
	27.61	70.20	1.633	
	27.61	70.40	1.606	
	27.61	70.50	1.597	
	27.61	70.60	1.582	
	27.61	70.70	1.559	
	27.61	70.80	1.487	
	27.61	70.90	1.503	
	27.61	71.00	1.390	
	27.61	71.10	1.347	
	27.61	71.20	1.334	
	27.61	71.30	1.324	
	27.61	71.50	1.310	
	27.61	73.00	1.278	
	27.61	75.20	1.278	
	27.61	77.00	1.280	

	27.61	79.00	1.285	
	27.61	80.00	1.298	
	27.61	80.50	1.315	
	27.61	80.60	1.322	
	27.61	80.70	1.330	
	27.61	80.80	1.344	
	27.61	80.90	1.358	
	27.61	81.00	1.411	
	27.61	81.10	1.415	
	27.61	81.20	1.412	
	27.61	81.30	1.421	
	27.61	81.50	1.426	
	27.61	81.55	1.473	
	28.69	70.40	1.381	
	28.69	70.60	1.340	
	28.69	70.80	1.311	
	28.69	70.90	1.294	
	28.69	71.00	1.275	
	28.69	71.10	1.263	
	28.69	71.20	1.254	
	28.69	71.30	1.249	
	28.69	71.40	1.221	
	28.69	71.50	1.175	
	28.69	71.60	1.147	
	28.69	71.70	1.065	
	28.69	71.80	1.038	
	28.69	71.90	0.998	
	28.69	72.00	0.982	
	28.69	72.10	0.972	
	28.69	72.50	0.950	
	28.69	73	0.932	
	28.69	75.2	0.914	
	28.69	77	0.915	
	28.69	79	0.923	
	28.69	80	0.959	
	28.69	80.2	0.97	
	28.69	80.3	0.982	
	28.69	80.4	0.996	
	28.69	80.5	1.007	

	28.69	80.6	1.023	
	28.69	80.7	1.034	
	28.69	80.8	1.025	
	28.69	80.9	1.058	
	28.69	81	1.066	
	28.69	81.1	1.078	
	28.69	81.22	1.121	
	29.155	70.66	1.248	
	29.155	70.8	1.212	
	29.155	71	1.179	
	29.155	71.2	1.138	
	29.155	71.3	1.126	
	29.155	71.4	1.117	
	29.155	71.5	1.115	
	29.155	71.6	1.097	
	29.155	71.7	1.066	
	29.155	71.8	1.036	
	29.155	71.9	1.005	
	29.155	72	0.97	
	29.155	72.1	0.94	
	29.155	72.2	0.884	
	29.155	72.3	0.868	
	29.155	72.4	0.849	
	29.155	72.5	0.844	
	29.155	73	0.796	
	29.155	75.2	0.757	
	29.155	77	0.763	
	29.155	79	0.773	
	29.155	80	0.815	
	29.155	80.2	0.838	
	29.155	80.3	0.848	
	29.155	80.4	0.85	
	29.155	80.5	0.861	
	29.155	80.6	0.867	
	29.155	80.7	0.884	
	29.155	80.8	0.903	
	29.155	80.9	0.915	
	29.155	81	0.921	
	29.155	81.08	0.963	

Table A.31. Centerline water surface data for 2:1 smooth training walls q = 0.052 m^2/s.

Run #	11		recorder	RW		
Date	9/7/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft		Bed	Vertical Depth
	24.87	75.20	2.301			
	25.44	75.20	2.056			
	26.50	75.20	1.658			
	27.61	75.20	1.273			
	28.69	75.20	0.908			
	29.16	72.50	0.823			

Table A.32. Run-up water surface data for 2:1 smooth training walls q = 0.052 m^2/s.

Run #	11		recorder	RW		
Date	9/7/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
13:48	24.40	68.50	2.334			
	24.76	68.52	2.323			
	24.87	68.54	2.314			
	25.10	68.58	2.295			
	25.30	68.62	2.270			
	25.42	68.65	2.255			
	25.55	68.70	2.233			
	25.69	68.75	2.208			
	25.83	68.80	2.184			
	25.97	68.86	2.152			
	26.11	68.930	2.119			
	26.24	69.000	2.084			
	26.39	69.09	2.042			
	26.51	69.17	2.002			
	26.65	69.26	1.957			
	26.79	69.35	1.916			
	26.93	69.43	1.874			

	27.06	69.51	1.833	
	27.19	69.59	1.790	
	27.34	69.68	1.747	
	27.47	69.760	1.705	
	27.61	69.85	1.662	
	27.75	69.93	1.621	
	27.89	70.00	1.582	
	28.04	70.10	1.533	
	28.16	70.16	1.501	
	28.30	70.25	1.459	
	28.43	70.32	1.423	
	28.58	70.41	1.379	
	28.71	70.48	1.346	
	28.85	70.56	1.307	
	28.98	70.64	1.266	
	29.13	70.73	1.220	
	29.16	70.74	1.215	
	29.30	70.81	1.177	
	29.60	70.99	1.086	
	29.90	71.18	0.993	
	30.20	71.37	0.904	
	30.89	71.83	0.679	
	30.20	69.14	1.221	
	30.50	69.23	1.129	
	30.80	69.28	1.085	
	31.1	69.37	1.003	
	32.00	69.65	0.725	

Table A.33. Cross section water surface data for 2:1smooth training walls q = 0.052 m^2/s.

Run #	15		recorder	RW		
Date	9/7/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
10:00	24.87	68.53	2.316			
	24.87	68.70	2.313			
	24.87	68.80	2.309			

	24.87	68.90	2.305	
	24.87	69.00	2.299	
	24.87	69.10	2.299	
	24.87	69.20	2.302	
	24.87	69.30	2.297	
	24.87	69.50	2.298	
	24.87	70.00	2.297	
	24.87	71.00	2.298	
	24.87	73.00	2.300	
	24.87	75.20	2.301	
	24.87	77.00	2.301	
	24.87	79.00	2.300	
	24.87	81.00	2.301	
	24.87	81.50	2.301	
	24.87	81.80	2.302	
	24.87	82.00	2.303	
	24.87	82.10	2.306	
	24.87	82.20	2.309	
	24.87	82.30	2.314	
	24.87	82.41	2.317	
	25.435	68.65	2.252	
	25.435	68.80	2.241	
	25.435	68.90	2.226	
	25.435	69.00	2.210	
	25.435	69.10	2.193	
	25.435	69.20	2.170	
	25.435	69.30	2.132	
	25.435	69.40	2.099	
	25.435	69.50	2.078	
	25.435	69.60	2.065	
	25.435	69.70	2.058	
	25.435	70.00	2.052	
	25.435	71.00	2.054	
	25.435	73.00	2.055	
	25.435	75.20	2.056	
	25.435	77.00	2.055	
	25.435	79.00	2.057	
	25.435	81.00	2.061	
	25.435	81.50	2.066	

	25.435	81.80	2.092	
	25.435	81.90	2.115	
	25.435	82.00	2.144	
	25.435	82.10	2.168	
	25.435	82.30	2.210	
	26.5	69.15	2.007	
	26.5	69.30	1.983	
	26.5	69.40	1.963	
	26.5	69.50	1.946	
	26.5	69.60	1.927	
	26.5	69.70	1.911	
	26.5	69.80	1.896	
	26.5	69.90	1.885	
	26.5	70.00	1.872	
	26.5	70.10	1.720	
	26.5	70.20	1.707	
	26.5	70.30	1.694	
	26.5	70.40	1.685	
	26.5	70.50	1.679	
	26.5	71.00	1.668	
	26.5	73.00	1.657	
	26.5	75.20	1.658	
	26.5	77.00	1.659	
	26.5	79.00	1.658	
	26.5	81.00	1.675	
	26.5	81.20	1.693	
	26.5	81.30	1.705	
	26.5	81.40	1.733	
	26.5	81.50	1.787	
	26.5	81.60	1.794	
	26.5	81.70	1.798	
	26.5	81.89	1.820	
11:22	27.61	69.83	1.655	
	27.61	70.00	1.634	
	27.61	70.20	1.607	
	27.61	70.30	1.596	
	27.61	70.40	1.585	
	27.61	70.50	1.572	
	27.61	70.60	1.557	

	27.61	70.70	1.528	
	27.61	70.80	1.463	
	27.61	70.90	1.450	
	27.61	71.00	1.386	
	27.61	71.10	1.333	
	27.61	71.20	1.322	
	27.61	71.30	1.314	
	27.61	71.40	1.308	
	27.61	71.50	1.302	
	27.61	72.00	1.279	
	27.61	73.00	1.272	
	27.61	75.20	1.273	
	27.61	77.00	1.274	
	27.61	79.00	1.277	
	27.61	80.50	1.304	
	27.61	80.70	1.317	
	27.61	80.80	1.331	
	27.61	80.90	1.343	
	27.61	81.00	1.385	
	27.61	81.10	1.392	
	27.61	81.20	1.390	
	27.61	81.30	1.410	
	27.61	81.53	1.455	
	28.69	70.46	1.351	
	28.69	70.60	1.318	
	28.69	70.80	1.278	
	28.69	71.00	1.253	
	28.69	71.10	1.236	
	28.69	71.20	1.227	
	28.69	71.30	1.217	
	28.69	71.4	1.189	
	28.69	71.5	1.148	
	28.69	71.6	1.118	
	28.69	71.7	1.086	
	28.69	71.8	1.014	
	28.69	71.9	0.992	
	28.69	72	0.981	
	28.69	72.5	0.935	
	28.69	73	0.919	

	28.69	75.2	0.908	
	28.69	77	0.905	
	28.69	79	0.91	
	28.69	80	0.943	
	28.69	80.5	0.988	
	28.69	80.7	1.006	
	28.69	80.8	1.006	
	28.69	80.9	1.033	
	28.69	81	1.047	
	28.69	81.1	1.056	
	28.69	81.21	1.105	
	29.155	70.72	1.215	
	29.155	71	1.152	
	29.155	71.2	1.114	
	29.155	71.4	1.085	
	29.155	71.5	1.086	
	29.155	71.6	1.062	
	29.155	71.7	1.028	
	29.155	71.8	1.002	
	29.155	71.9	0.981	
	29.155	72	0.95	
	29.155	72.1	0.885	
	29.155	72.3	0.843	
	29.155	72.5	0.823	
	29.155	73	0.782	
	29.155	75.2	0.753	
	29.155	77	0.751	
	29.155	79	0.763	
	29.155	80	0.799	
	29.155	80.5	0.834	
	29.155	80.6	0.855	
	29.155	80.7	0.873	
	29.155	80.8	0.885	
	29.155	80.9	0.896	
	29.155	81.07	0.954	

Table A.34. Centerline water surface data for 2:1 smooth training walls q = 0.039 m^2/s.

Run #	12		recorder	RW	

Date	8/28/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
	12.00	75.20	2.323	Centerline		
	16.00	75.20	2.322			
	20.00	75.20	2.321			
	24.00	75.20	2.300			
	24.87	75.20	2.255	Crest		
	25.44	75.20	2.017			
	26.50	75.20	1.633			
	27.61	75.20	1.253			
	28.69	75.20	0.898			
	29.16	75.20	0.742			
	29.30	75.20	0.699			

Table A.35. Run-up water surface data for 2:1 smooth training walls q = 0.039 m^2/s.

Run #	12		recorder	BS		
Date	8/28/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
	23.84	68.59	2.292			
	24.00	68.59	2.288			
	24.40	68.57	2.292			
	24.76	68.61	2.277			
	24.87	68.62	2.271			
	25.10	68.66	2.250			
	25.30	68.71	2.222			
	25.42	68.75	2.205			
	25.55	68.80	2.179			
	25.69	68.81	2.150			
	25.83	68.930	2.117			
	25.97	69.000	2.083			
	26.11	69.08	2.043			
	26.24	69.17	2.000			
	26.39	69.26	1.959			

	26.51	69.34	1.917	
	26.65	69.43	1.872	
	26.79	69.52	1.825	
	26.93	69.61	1.785	
	27.06	69.68	1.745	
	27.20	69.710	1.706	
	27.34	69.85	1.663	
	27.47	69.93	1.621	
	27.61	70.00	1.582	
	27.75	70.09	1.536	
	27.89	70.17	1.497	
	28.04	70.26	1.448	
	28.16	70.34	1.412	
	28.30	70.42	1.373	
	28.43	70.48	1.337	
	28.57	70.57	1.298	
	28.71	70.65	1.258	
	28.85	70.73	1.215	
	28.98	70.77	1.199	
	29.13	70.93	1.118	
	29.16	70.93	1.115	
	29.30	71.02	1.072	
	29.60	71.21	0.978	
	29.90	71.39	0.885	
	30.20	71.59	0.791	
	30.63	71.84	0.671	

Table A.36. Cross section water surface data for 2:1smooth training walls q = 0.039 m^2/s.

Run #	12		recorder	RW		
Date	8/27/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
9:30	24.87	68.61	2.272			
	24.87	68.70	2.273			
	24.87	68.80	2.269			
	24.87	68.90	2.264			

	24.87	69.00	2.260	
	24.87	69.20	2.257	
	24.87	71.00	2.256	
	24.87	73.00	2.258	
	24.87	75.20	2.258	
	24.87	77.00	2.257	
	24.87	79.00	2.258	
	24.87	81.00	2.258	
	24.87	81.50	2.257	
	24.87	82.00	2.261	
	24.87	82.10	2.263	
	24.87	82.20	2.266	
	24.87	82.30	2.272	
	24.87	82.37	2.281	
9:45	25.44	68.75	2.203	
	25.44	68.90	2.189	
	25.44	69.00	2.171	
	25.44	69.10	2.154	
	25.44	69.20	2.133	
	25.44	69.30	2.098	
	25.44	69.40	2.057	
	25.44	69.50	2.033	
	25.44	69.60	2.023	
	25.44	71.00	2.017	
	25.44	73.00	2.017	
	25.44	75.20	2.017	
	25.44	77.00	2.017	
	25.44	79.00	2.018	
	25.44	81.00	2.020	
	25.44	81.50	2.023	
	25.435	81.70	2.034	
	25.435	81.80	2.046	
	25.435	81.90	2.072	
	25.435	82.00	2.105	
	25.435	82.10	2.122	
	25.435	82.24	2.156	
10:02	26.5	69.33	1.922	
	26.5	69.50	1.896	
	26.5	69.60	1.879	

	26.5	69.70	1.864	
	26.5	69.80	1.848	
	26.5	69.90	1.831	
	26.5	70.00	1.814	
	26.5	70.15	1.690	
	26.5	70.20	1.677	
	26.5	70.30	1.671	
	26.5	71.00	1.643	
	26.5	73.00	1.633	
	26.5	75.20	1.634	
	26.5	77.00	1.634	
	26.5	79.00	1.634	
	26.5	81.00	1.650	
	26.5	81.20	1.663	
	26.5	81.38	1.684	
	26.5	81.56	1.736	
	26.5	81.70	1.745	
	26.5	81.83	1.768	
10:33	27.61	70.01	1.579	
	27.61	70.10	1.565	
	27.61	70.20	1.551	
	27.61	70.30	1.534	
	27.61	70.40	1.523	
	27.61	70.50	1.508	
	27.61	70.60	1.495	
	27.61	70.80	1.426	
	27.61	71.00	1.342	
	27.61	71.50	1.277	
	27.61	73.00	1.256	
	27.61	75.20	1.253	
	27.61	77.00	1.255	
	27.61	79.00	1.257	
	27.61	80.80	1.305	
	27.61	80.90	1.316	
	27.61	81.00	1.331	
	27.61	81.10	1.344	
	27.61	81.20	1.350	
	27.61	81.30	1.366	
	27.61	81.49	1.417	

10:53	28.69	70.65	1.260	
	28.69	70.70	1.242	
	28.69	70.80	1.223	
	28.69	70.90	1.206	
	28.69	71.00	1.187	
	28.69	71.10	1.173	
	28.69	71.20	1.159	
	28.69	71.30	1.150	
	28.69	71.40	1.121	
	28.69	71.50	1.090	
	28.69	71.60	1.078	
	28.69	71.70	1.050	
	28.69	71.80	0.992	
	28.69	72.00	0.953	
	28.69	73.00	0.897	
	28.69	75.20	0.890	
	28.69	77.00	0.890	
	28.69	79.00	0.892	
	28.69	80.50	0.955	
	28.69	80.60	0.964	
	28.69	80.70	0.963	
	28.69	80.80	0.958	
	28.69	80.90	1.004	
	28.69	81.00	1.011	
	28.69	81.10	1.018	
	28.69	81.17	1.062	
11:10	29.155	70.93	1.114	
	29.155	71.10	1.074	
	29.155	71.20	1.055	
	29.155	71.30	1.041	
	29.155	71.40	1.028	
	29.155	71.5	1.012	
	29.155	71.6	0.994	
	29.155	71.7	0.961	
	29.155	71.8	0.946	
	29.155	71.9	0.93	
	29.155	72	0.913	
	29.155	72.1	0.866	
	29.155	72.2	0.84	

	29.155	72.3	0.821	
	29.155	73	0.766	
	29.155	75.2	0.736	
	29.155	77	0.738	
	29.155	79	0.738	
	29.155	80.3	0.796	
	29.155	80.4	0.801	
	29.155	80.5	0.805	
	29.155	80.6	0.801	
	29.155	80.7	0.823	
	29.155	80.8	0.849	
	29.155	80.9	0.856	
	29.155	80.98	0.879	

Table A37. Centerline water surface data for 2:1 stepped training walls q = 0.078 m^2/s.

Run #	13		recorder	RW		
Date	9/18/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
13:39	24.87	75.2	2.362	Centerline		
	25.435	75.2	2.113			
	26.5	75.2	1.692			
	27.61	75.2	1.302			
	28.69	75.2	0.932			
	29.155	75.2	0.781			

Table A.38. Run-up water surface data for 2:1 stepped training walls q = 0.078 m^2/s.

Run #	13		recorder	RW AB		
Date	9/18/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.40	68.52	2.378			
	24.76	68.51	2.386			

	24.87	68.52	2.387	crest
	25.10	68.60	2.365	
	25.30	68.60	2.346	
	25.42	68.60	2.334	
	25.55	68.60	2.333	step 1
	25.69	68.69	2.302	
	25.83	68.69	2.297	
	25.67	68.77	2.254	
	26.11	68.770	2.253	
	26.24	68.860	2.214	
	26.39	68.86	2.212	
	26.51	68.95	2.168	
	26.65	68.95	2.169	
	26.79	68.95	2.168	
	26.93	68.95	2.167	
	27.06	69.05	2.123	
	27.19	69.05	2.122	
	27.34	69.14	2.077	
	27.47	69.140	2.075	
	27.61	69.14	2.072	
	27.75	69.23	2.044	
	27.89	69.23	2.037	
	28.04	69.33	1.985	
	28.16	68.33	1.984	
	28.30	69.33	1.982	
	28.43	69.41	1.937	
	28.58	69.41	1.934	
	28.71	69.41	1.932	
	28.85	69.41	1.928	
	28.98	69.51	1.892	
	29.13	69.51	1.888	step 27
	29.16	69.51	1.890	
	29.30	69.61	1.837	
	29.60	69.61	1.832	
	29.90	69.81	1.746	
	30.20	69.89	1.699	
	30.50	69.99	1.643	
	30.80	70.07	1.611	
	31.10	70.16	1.558	

	31.40	70.25	1.514	
	31.7	70.44	1.416	
	32.00	70.54	1.375	
	32.30	70.71	1.281	
	32.60	70.82	1.231	
15:36	32.94	70.92	1.185	

Table A.39. Cross section water surface data for 2:1stepped training walls q = 0.078 m^2/s.

Run #	13		recorder	RW		
Date	9/18/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.87	68.35	2.426			
	24.87	68.52	2.387			
	24.87	68.70	2.377			
	24.87	68.87	2.373			
	24.87	69.05	2.367			
	24.87	69.15	2.364			
	24.87	69.50	2.357			
	24.87	71.00	2.363			
	24.87	73.00	2.363			
	24.87	75.20	2.362			
	24.87	77.00	2.361			
	24.87	79.00	2.359			
	24.87	81.00	2.358			
	24.87	81.50	2.357			
	24.87	82.00	2.361			
	24.87	82.20	2.367			
	24.87	82.40	2.376			
	24.87	82.48	2.387			
13:57	25.44	68.34	2.425			
	25.44	68.60	2.337			
	25.44	68.77	2.312			
	25.44	68.95	2.287			
	25.44	69.14	2.242			
	25.44	69.32	2.197			

	25.44	69.52	2.152	
	25.44	69.70	2.131	
	25.44	70.00	2.114	
	25.44	71.00	2.114	
	25.44	73.00	2.114	
	25.44	75.20	2.113	
	25.44	77.00	2.112	
	25.44	79.00	2.112	
	25.44	81.00	2.120	
	25.44	81.50	2.125	
	25.44	81.70	2.141	
	25.44	81.90	2.177	
	25.44	82.00	2.207	
	25.44	82.20	2.248	
	25.44	82.37	2.288	
14:18	26.50	68.34	2.420	
	26.50	68.60	2.333	
	26.50	68.77	2.249	
	26.50	68.95	2.168	
	26.50	69.14	2.100	
	26.50	69.32	2.062	
	26.50	69.51	2.015	
	26.50	69.69	1.983	
	26.50	69.88	1.962	
	26.50	70.06	1.875	
	26.50	70.20	1.763	
	26.50	70.40	1.720	
	26.50	71.00	1.703	
	26.50	73.00	1.695	
	26.50	75.20	1.692	
	26.50	77.00	1.693	
	26.50	79.00	1.692	
	26.50	81.00	1.719	
	26.50	81.35	1.773	
	26.50	81.56	1.856	
	26.50	81.80	1.876	
	26.50	82.01	1.936	
15:45	27.61	68.60	2.331	
	27.61	68.75	2.250	

	27.61	68.95	2.169	
	27.61	69.14	2.074	
	27.61	69.32	1.994	
	27.61	69.51	1.894	
	27.61	69.70	1.810	
	27.61	69.89	1.742	
	27.61	70.07	1.724	
	27.61	70.26	1.693	
	27.61	70.45	1.654	
	27.61	70.63	1.633	
	27.61	70.82	1.608	
	27.61	71.05	1.400	
	27.61	71.20	1.338	
	27.61	71.50	1.327	
	27.61	73.00	1.303	
	27.61	75.20	1.302	
	27.61	77.00	1.304	
	27.61	79.00	1.308	
	27.61	80.50	1.345	
	27.61	80.80	1.373	
	27.61	81.00	1.477	
	27.61	81.20	1.465	
	27.61	81.40	1.473	
16:10	27.61	81.60	1.517	
3:21	28.69	68.60	2.329	
	28.69	68.77	2.244	
	28.69	68.95	2.160	
	28.69	69.14	2.068	
	28.69	69.32	1.980	
	28.69	69.51	1.886	
	28.69	69.70	1.798	
	28.69	69.89	1.708	
	28.69	70.07	1.629	
	28.69	70.26	1.543	
	28.69	70.43	1.455	
	28.69	70.63	1.410	
	28.69	70.82	1.378	
	28.69	70.98	1.361	
	28.69	71.18	1.333	

	28.69	71.36	1.309	
	28.69	71.60	1.169	
	28.69	71.80	1.145	
	28.69	72.00	1.037	
	28.69	72.50	0.955	
	28.69	73.00	0.938	
	28.69	75.20	0.932	
	28.69	77.00	0.930	
	28.69	79.00	0.938	
	28.69	80.00	0.984	
	28.69	80.40	1.015	
	28.69	80.70	1.084	
	28.69	81.00	1.097	
16:30	28.69	81.27	1.167	
16:58	29.16	68.60	2.322	
	29.16	68.77	2.243	
	29.16	68.95	2.152	
	29.16	69.14	2.066	
	29.16	69.32	1.978	
	29.16	69.51	1.886	
	29.16	69.70	1.790	
	29.16	69.89	1.700	
	29.16	70.07	1.619	
	29.16	70.25	1.527	
	29.16	70.43	1.448	
	29.16	70.63	1.361	
	29.16	70.82	1.291	
	29.16	70.98	1.258	
	29.16	71.17	1.225	
	29.16	71.36	1.205	
	29.16	71.55	1.186	
	29.16	71.75	1.148	
	29.16	71.93	1.037	
	29.16	72.00	1.052	
	29.16	72.20	0.998	
	29.16	72.40	0.880	
	29.16	72.60	0.815	
	29.16	72.80	0.808	
	29.16	73.00	0.796	

	29.16	75.20	0.781	
	29.16	77.00	0.785	
	29.16	79.00	0.799	
	29.16	80.00	0.848	
	29.16	80.35	0.881	
	29.16	80.50	0.911	
	29.16	80.70	0.922	
	29.16	80.80	0.949	
	29.16	80.90	0.950	
	29.16	81.13	1.009	
	29.155	72.3	0.889	
	29.155	72.5	0.869	
	29.155	73	0.8823	
	29.155	75.2	0.784	
	29.155	77	0.782	
	29.155	79	0.798	
	29.155	79.5	0.822	
	29.155	80	0.853	
	29.155	80.2	0.88	
	29.155	80.3	0.885	
	29.155	80.4	0.914	
	29.155	80.5	0.929	
	29.155	80.6	0.913	
	29.155	80.7	0.94	
	29.155	80.9	0.954	
	29.155	81	0.962	
	29.155	81.14	1.019	

Table A.40. Centerline water surface data for 2:1 stepped training walls q = 0.060 m^2/s.

Run #	14		recorder	RW		
Date	9/21/2007		BM-0 rd.	x=24.68	y =65.02	z=2.873
time	x ft	y ft	z ft			comments
	24.87	75.20	2.315	Centerline		
	25.44	75.20	2.072			
	26.50	75.20	1.659			

	27.61	75.20	1.282	
	28.69	75.20	0.916	
	29.16	75.20	0.765	

Table A.41. Run-up water surface data for 2:1 stepped training walls q = 0.060 m^2/s.

Run #	14		recorder	RW		
Date	9/21/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.40	68.44	2.380			
	24.76	68.53	2.348			
	24.87	68.53	2.343			
	25.10	68.61	2.328			
	25.30	68.70	2.296			
	25.42	68.70	2.292			
	25.55	68.70	2.291			
	25.69	68.70	2.291			
	25.83	68.780	2.250			
	25.97	68.780	2.247			
	26.11	68.78	2.248			
	26.24	68.87	2.210			
	26.39	68.87	2.210			
	26.51	68.87	2.210			
	26.65	68.96	2.168			
	26.79	68.96	2.160			
	26.93	69.05	2.123			
	27.06	69.05	2.118			
	27.19	69.150	2.074			
	27.34	69.15	2.070			
	27.47	69.24	2.040			
	27.61	69.24	2.039			
	27.75	69.24	2.037			
	27.89	69.33	1.988			
	28.04	69.33	1.982			
	28.16	69.42	1.934			
	28.30	69.42	1.932			

	28.43	69.42	1.929	
	28.58	69.51	1.889	
	28.71	69.51	1.887	
	28.85	69.51	1.887	
	28.98	69.61	1.845	
	29.13	69.61	1.840	
	29.16	69.61	1.838	
	29.30	69.70	1.801	
	29.60	69.80	1.743	
	29.90	69.89	1.696	
	30.20	69.98	1.645	
	30.50	70.08	1.609	
	30.80	70.16	1.572	
	31.1	70.25	1.519	
	31.40	70.35	1.471	
	31.70	70.44	1.414	
	32.00	70.63	1.330	
	32.30	70.72	1.280	
	32.6	70.81	1.238	
	32.94	70.92	1.18	

Table A.42. Cross section water surface data for 2:1stepped training walls q = 0.060 m^2/s.

Run #	14		recorder	RW		
Date	9/21/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.87	68.61	2.339			
	24.87	68.79	2.332			
	24.87	68.95	2.321			
	24.87	69.10	2.312			
	24.87	69.50	2.314			
	24.87	70.00	2.313			
	24.87	71.00	2.313			
	24.87	73.00	2.314			
	24.87	75.20	2.315			
	24.87	77.00	2.314			

	24.87	79.00	2.315	
	24.87	81.00	2.314	
	24.87	81.50	2.315	
	24.87	82.00	2.322	
	24.87	82.43	2.341	
	25.44	68.61	2.332	
	25.44	68.79	2.276	
	25.44	68.95	2.251	
	25.435	69.14	2.214	
	25.435	69.32	2.165	
	25.435	69.51	2.109	
	25.435	69.70	2.082	
	25.435	70.00	2.073	
	25.435	71.00	2.072	
	25.435	73.00	2.072	
	25.435	75.20	2.072	
	25.435	77.00	2.073	
	25.435	79.00	2.075	
	25.435	81.00	2.079	
	25.435	81.50	2.085	
	25.435	81.80	2.113	
	25.435	82.00	2.164	
	25.435	82.20	2.212	
	25.435	82.33	2.239	
	26.5	68.60	2.335	
	26.5	68.78	2.249	
	26.5	68.95	2.170	
	26.5	69.14	2.085	
	26.5	69.32	2.027	
	26.5	69.51	1.978	
	26.5	69.70	1.947	
	26.5	69.89	1.913	
	26.5	70.07	1.896	
	26.5	70.25	1.710	
	26.5	70.43	1.691	
	26.5	70.63	1.685	
	26.5	71.00	1.677	
	26.5	73.00	1.669	
	26.5	75.20	1.659	

	26.5	77.00	1.673	
	26.5	79.00	1.671	
	26.5	81.00	1.687	
	26.5	81.20	1.706	
	26.5	81.40	1.755	
	26.5	81.60	1.815	
	26.5	81.80	1.830	
	26.5	81.93	1.862	
	27.61	68.60	2.329	
	27.61	68.77	2.246	
	27.61	68.95	2.160	
	27.61	69.14	2.072	
	27.61	69.32	1.993	
	27.61	69.51	1.898	
	27.61	69.70	1.803	
	27.61	69.89	1.718	
	27.61	70.07	1.670	
	27.61	70.25	1.640	
	27.61	70.43	1.617	
	27.61	70.63	1.588	
	27.61	70.82	1.540	
	27.61	70.98	1.415	
	27.61	71.20	1.315	
	27.61	71.50	1.298	
	27.61	73.00	1.279	
	27.61	75.20	1.282	
	27.61	77.00	1.281	
	27.61	79.00	1.283	
	27.61	80.50	1.318	
	27.61	80.90	1.354	
	27.61	81.05	1.430	
	27.61	81.20	1.414	
	27.61	81.51	1.476	
15:30	28.69	68.59	2.324	
	28.69	68.77	2.244	
	28.69	68.95	2.160	
	28.69	69.14	2.069	
	28.69	69.32	1.980	
	28.69	69.51	1.887	

	28.69	69.71	1.798	
	28.69	69.89	1.704	
	28.69	70.07	1.625	
	28.69	70.25	1.541	
	28.69	70.43	1.453	
	28.69	70.63	1.383	
	28.69	70.82	1.330	
	28.69	70.98	1.298	
	28.69	71.17	1.274	
	28.69	71.36	1.250	
	28.69	71.55	1.185	
	28.69	71.75	1.116	
	28.69	71.93	1.007	
	28.69	72.00	0.962	
	28.69	73.00	0.918	
	28.69	75.20	0.916	
	28.69	77.00	0.917	
	28.69	79.00	0.922	
	28.69	80.00	0.953	
	28.69	80.50	0.998	
	28.69	80.75	1.028	
	28.69	81.00	1.121	
	28.69	81.24	1.134	
15:54	29.155	68.59	2.325	
	29.155	68.77	2.239	
	29.155	68.95	2.157	
	29.155	69.13	2.068	
	29.155	69.32	1.977	
	29.155	69.51	1.881	
	29.155	69.7	1.791	
	29.155	69.89	1.7	
	29.155	70.07	1.622	
	29.155	70.25	1.531	
	29.155	70.43	1.446	
	29.155	70.63	1.352	
	29.155	70.82	1.269	
	29.155	70.98	1.213	
	29.155	71.17	1.167	
	29.155	71.36	1.134	

	29.155	71.55	1.106	
	29.155	71.75	1.076	
	29.155	71.93	1.012	
	29.155	72	0.985	
	29.155	72.2	0.933	
	29.155	72.4	0.8	
	29.155	72.6	0.792	
	29.155	73	0.777	
	29.155	75.2	0.765	
	29.155	77	0.766	
	29.155	79	0.775	
	29.155	80	0.817	
	29.155	80.5	0.867	
	29.155	81	0.924	
	29.155	81.09	0.974	
	29.155	72.2	0.884	
	29.155	72.3	0.868	
	29.155	72.4	0.849	
	29.155	72.5	0.844	
	29.155	73	0.796	
	29.155	75.2	0.757	
	29.155	77	0.763	
	29.155	79	0.773	
	29.155	80	0.815	
	29.155	80.2	0.838	
	29.155	80.3	0.848	
	29.155	80.4	0.85	
	29.155	80.5	0.861	
	29.155	80.6	0.867	
	29.155	80.7	0.884	
	29.155	80.8	0.903	
	29.155	80.9	0.915	
	29.155	81	0.921	
	29.155	81.08	0.963	

Table A.43. Centerline water surface data for 2:1 stepped training walls q = 0.052 m^2/s.

Run #	15		recorder	RW		
Date	9/28/2007		BM-0	x=24.68	y=65.02	z=2.873

			rd.			
time	x ft	y ft	z ft			
	24.87	75.20	2.301			
	25.44	75.20	2.056			
	26.50	75.20	1.661			
	27.61	75.20	1.274			
	28.69	75.20	0.910			
	29.16	75.20	0.756			

Table A.44. Run-up water surface data for 2:1 stepped training walls q = 0.052 m^2/s.

Run #	15		recorder	RW		
Date	9/28/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft			comments
9:36	24.40	68.61	2.341			
	24.76	68.61	2.339			
	24.87	68.61	2.332			
	25.10	68.61	2.330			
	25.30	68.61	2.330			
	25.42	68.71	2.291			
	25.55	68.71	2.288			
	25.69	68.71	2.285			
	25.83	68.71	2.287			
	25.97	68.78	2.248			
	26.11	68.780	2.242			
	26.24	68.880	2.209			
	26.39	68.88	2.210			
	25.51	68.96	2.164			
	26.65	68.96	2.161			
	26.79	68.96	2.167			
9:57	26.93	69.05	2.126			
10:11	27.06	69.05	2.121			
	27.19	69.14	2.075			
	27.34	69.14	2.072			

	27.47	69.240	2.039	
	27.61	69.24	2.037	
	27.75	69.32	1.989	
	27.89	69.32	1.986	
	28.04	69.42	1.933	
	28.16	69.42	1.932	
	28.30	69.42	1.929	
	28.43	69.42	1.933	
	28.58	69.51	1.888	
	28.71	69.51	1.889	
	28.85	69.61	1.841	
	28.98	69.61	1.840	
	29.13	69.61	1.841	
	29.16	69.61	1.841	
	29.30	69.70	1.789	
	29.60	69.80	1.743	
	29.90	69.89	1.700	
	30.20	70.07	1.612	
	30.50	70.16	1.563	
	30.80	70.25	1.518	
	31.10	70.35	1.472	
	31.40	70.54	1.380	
	31.7	70.63	1.333	
	32.00	70.82	1.236	
	32.30	70.92	1.191	
	32.60	71.02	1.140	
10:56	32.94	71.10	1.093	

Table A.45. Cross section water surface data for 2:1stepped training walls q = 0.052 m^2/s.

Run #	15		recorder	RW		
Date	9/27/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
14:05	24.87	68.61	2.331			
	24.87	68.79	2.316			
	24.87	68.95	2.315			

	24.87	69.10	2.307	
	24.87	69.50	2.299	
	24.87	71.00	2.297	
	24.87	73.00	2.299	
	24.87	75.20	2.301	
	24.87	77.00	2.299	
	24.87	79.00	2.300	
	24.87	81.00	2.300	
	24.87	81.50	2.298	
	24.87	82.00	2.304	
	24.87	82.20	2.308	
14:16	24.87	82.42	2.325	
	25.44	68.61	2.329	
	25.44	68.79	2.259	
	25.44	68.95	2.233	
	25.44	69.14	2.194	
	25.44	69.32	2.150	
	25.435	69.51	2.091	
	25.435	69.70	2.064	
	25.435	70.00	2.056	
	25.435	71.00	2.055	
	25.435	73.00	2.055	
	25.435	75.20	2.056	
	25.435	77.00	2.055	
	25.435	79.00	2.058	
	25.435	81.00	2.062	
	25.435	81.50	2.066	
	25.435	81.75	2.085	
	25.435	82.00	2.147	
14:32	25.435	82.30	2.216	
14:35	26.5	68.60	2.334	
	26.5	68.78	2.252	
	26.5	68.95	2.169	
	26.5	69.14	2.080	
	26.5	69.32	2.007	
	26.5	69.51	1.958	
	26.5	69.70	1.926	
	26.5	69.89	1.893	
	26.5	70.07	1.871	

	26.5	70.25	1.695	
	26.5	70.43	1.677	
	26.5	70.63	1.674	
	26.5	71.00	1.665	
	26.5	73.00	1.658	
	26.5	75.20	1.661	
	26.5	77.00	1.662	
	26.5	79.00	1.661	
	26.5	81.00	1.677	
	26.5	81.40	1.740	
	26.5	81.50	1.794	
	26.5	81.70	1.797	
14:51	26.5	81.89	1.824	
	27.61	68.60	2.332	
	27.61	68.77	2.252	
	27.61	68.95	2.162	
	27.61	69.14	2.070	
	27.61	69.32	1.993	
	27.61	69.51	1.895	
	27.61	69.70	1.807	
	27.61	69.89	1.716	
	27.61	70.07	1.661	
	27.61	70.25	1.618	
	27.61	70.43	1.590	
	27.61	70.63	1.560	
	27.61	70.82	1.516	
	27.61	70.98	1.442	
	27.61	71.17	1.400	
	27.61	71.50	1.291	
	27.61	73.00	1.271	
	27.61	75.20	1.274	
	27.61	77.00	1.275	
	27.61	79.00	1.278	
	27.61	80.50	1.306	
	27.61	80.90	1.344	
	27.61	81.05	1.403	
	27.61	81.20	1.391	
	27.61	81.40	1.413	
15:41	27.61	81.52	1.447	

	28.69	69.14	2.068	
	28.69	69.32	1.984	
	28.69	69.51	1.883	
	28.69	69.70	1.790	
	28.69	69.89	1.701	
	28.69	70.07	1.623	
	28.69	70.25	1.537	
	28.69	70.43	1.449	
	28.69	70.63	1.368	
	28.69	70.82	1.318	
	28.69	70.98	1.273	
	28.69	71.17	1.245	
	28.69	71.36	1.219	
	28.69	71.55	1.168	
	28.69	71.75	1.092	
	28.69	71.93	0.938	
	28.69	72.00	0.945	
	28.69	73.00	0.905	
	28.69	75.20	0.910	
	28.69	77.00	0.909	
	28.69	79.00	0.915	
	28.69	80.50	0.990	
	28.69	80.70	1.017	
	28.69	81	1.058	
15:58	28.69	81.21	1.108	
	29.155	69.13	2.066	
	29.155	69.32	1.973	
	29.155	69.51	1.883	
	29.155	69.7	1.783	
	29.155	69.89	1.705	
	29.155	70.07	1.622	
	29.155	70.25	1.528	
	29.155	70.43	1.435	
	29.155	70.63	1.351	
	29.155	70.82	1.265	
	29.155	70.98	1.203	
	29.155	71.17	1.153	
	29.155	71.36	1.105	
	29.155	71.55	1.087	

	29.155	71.75	1.054	
	29.155	71.93	0.982	
	29.155	72.1	0.924	
	29.155	72.5	0.787	
	29.155	73	0.763	
	29.155	75.2	0.756	
	29.155	77	0.752	
	29.155	79	0.774	
	29.155	80	0.81	
	29.155	80.5	0.845	
	29.155	80.75	0.885	
	29.155	81	0.906	
16:17	29.155	81.07	0.945	
	29.155	73	0.782	
	29.155	75.2	0.753	
	29.155	77	0.751	
	29.155	79	0.763	
	29.155	80	0.799	
	29.155	80.5	0.834	
	29.155	80.6	0.855	
	29.155	80.7	0.873	
	29.155	80.8	0.885	
	29.155	80.9	0.896	
	29.155	81.07	0.954	

Table A.46. Centerline water surface data for 2:1 stepped training walls q = 0.039 m^2/s.

Run #	16		recorder	RW		
Date	10/3/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.87	75.20	2.258			
	25.44	75.20	2.018			
	26.50	75.20	1.634			
	27.61	75.20	1.252			
	28.69	75.20	0.890			
	29.16	75.20	0.730			

Table A.47. Run-up water surface data for 2:1 stepped training walls q = 0.039 m^2/s.

Run #	16		recorder	RW, BS		
Date	10/3/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
9:04	24.40	68.71	2.295			
	24.76	68.71	2.292			
	24.87	68.71	2.290			
	25.10	68.78	2.253			
	25.30	68.78	2.245			
	25.42	68.78	2.243			
9:07	25.55	68.88	2.211			
	25.69	68.88	2.209			
	25.83	68.88	2.210			
	25.97	68.95	2.167			
	26.11	68.950	2.166			
	26.24	69.050	2.121			
	26.39	69.05	2.120			
	26.51	69.05	2.124			
9:12	26.65	69.05	2.118			
	26.79	69.14	2.082			
	26.93	69.14	2.073			
	27.06	69.24	2.039			
	27.19	69.24	2.033			
	27.34	69.32	1.994			
	27.47	69.320	1.987			
9:16	27.61	69.42	1.935			
	27.75	69.42	1.934			
	27.89	69.42	1.928			
	28.04	69.51	1.888			
	28.16	69.51	1.886			
	28.30	69.51	1.889			
	28.43	69.61	1.846			
	28.58	69.61	1.842			
	28.71	69.70	1.794			
	28.85	69.70	1.789			

	28.98	69.70	1.784	
	29.13	69.80	1.744	
	29.16	69.80	1.741	
	29.30	69.89	1.698	
	29.60	69.98	1.645	
9:26	29.90	70.08	1.610	
	30.20	70.25	1.518	
	30.50	70.34	1.468	
	30.80	70.43	1.423	
	31.10	70.53	1.377	
	31.40	70.72	1.284	
	31.7	70.81	1.231	
	32.00	71.00	1.142	
	32.30	71.10	1.095	
	32.60	71.19	1.050	
9:34	32.90	71.28	1.005	

Table A.48. Cross section water surface data for 2:1stepped training walls q = 0.039 m^2/s.

Run #	16		recorder	RW		
Date	10/2/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.87	68.78	2.268			
	24.87	68.95	2.267			
	24.87	69.14	2.263			
	24.87	69.50	2.256			
	24.87	71.00	2.258			
	24.87	73.00	2.257			
	24.87	75.20	2.258			
	24.87	77.00	2.258			
	24.87	79.00	2.259			
	24.87	81.00	2.258			
	24.87	82.00	2.262			

	24.87	82.20	2.267	
	24.87	82.37	2.279	
	25.44	68.78	2.242	
	25.44	68.95	2.194	
	25.44	69.14	2.156	
	25.44	69.32	2.110	
	25.44	69.51	2.043	
	25.44	70.00	2.017	
	25.44	71.00	2.017	
	25.44	73.00	2.018	
	25.44	75.20	2.018	
	25.44	77.00	2.017	
	25.44	79.00	2.020	
	25.44	81.00	2.023	
	25.44	81.50	2.024	
	25.44	82.00	2.105	
	26.5	68.78	2.250	
	26.5	68.95	2.167	
	26.5	69.14	2.079	
	26.5	69.32	1.995	
	26.5	69.51	1.913	
	26.5	69.70	1.880	
	26.5	69.89	1.844	
	26.5	70.07	1.814	
	26.5	70.25	1.663	
	26.5	70.43	1.646	
	26.5	70.63	1.641	
	26.5	71.00	1.637	
	26.5	73.00	1.633	
	26.5	75.20	1.634	
	26.5	77.00	1.634	
	26.5	79.00	1.637	
	26.5	80.00	1.636	
	26.5	80.50	1.642	
	26.5	81.30	1.669	
	26.5	81.50	1.740	
	26.5	81.84	1.771	
	27.61	68.72	2.255	
	27.61	68.95	2.165	

	27.61	69.14	2.076	
	27.61	69.32	1.988	
	27.61	69.51	1.896	
	27.61	69.70	1.798	
	27.61	69.89	1.714	
	27.61	70.07	1.636	
	27.61	70.25	1.579	
	27.61	70.43	1.533	
	27.61	70.63	1.501	
	27.61	70.82	1.455	
	27.61	70.98	1.392	
	27.61	71.17	1.279	
	27.61	71.50	1.257	
	27.61	73.00	1.249	
	27.61	75.20	1.252	
	27.61	77.00	1.252	
	27.61	79.00	1.253	
	27.61	80.00	1.262	
	27.61	80.50	1.275	
	27.61	81.00	1.323	
	27.61	81.30	1.366	
	27.61	81.50	1.415	
	28.69	68.77	2.247	
	28.69	68.95	2.163	
	28.69	69.14	2.070	
	28.69	69.32	1.987	
	28.69	69.51	1.883	
	28.69	69.70	1.789	
	28.69	69.89	1.705	
	28.69	70.07	1.620	
	28.69	70.25	1.528	
	28.69	70.43	1.440	
	28.69	70.63	1.363	
	28.69	70.82	1.279	
	28.69	70.98	1.227	
	28.69	71.17	1.188	
	28.69	71.30	1.161	
	28.69	71.55	1.086	
	28.69	71.75	1.041	

	28.69	71.93	0.970	
	28.69	72.20	0.905	
	28.69	73.00	0.890	
	28.69	75.20	0.890	
	28.69	77.00	0.890	
	28.69	79.00	0.895	
	28.69	80.00	0.917	
	28.69	80.50	0.954	
	28.69	81.00	1.017	
	28.69	81.16	1.063	
10:40	29.155	68.77	2.245	
	29.155	68.95	2.163	
	29.155	69.13	2.067	
	29.155	69.32	1.981	
	29.155	69.51	1.882	
	29.155	69.7	1.786	
	29.155	69.89	1.698	
	29.155	70.07	1.614	
	29.155	70.25	1.533	
	29.155	70.48	1.439	
	29.155	70.63	1.347	
	29.155	70.82	1.257	
	29.155	70.98	1.182	
	29.155	71.17	1.118	
	29.155	71.36	1.052	
	29.155	71.55	1.017	
	29.155	71.75	0.972	
	29.155	71.93	0.934	
	29.155	72.1	0.89	
	29.155	72.35	0.764	
	29.155	73	0.734	
	29.155	75.2	0.73	
	29.155	77	0.73	
	29.155	79	0.74	
	29.155	80	0.764	
	29.155	80.5	0.804	
10:53	29.155	81	0.888	

Table A.49. Centerline water surface data for 3:1 smooth training walls q = 0.078 m^2/s.

Run #	17		recorder	RW		
Date	10/26/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.87	75.21	2.363	Centerline		
	25.435	75.21	2.114			
	26.5	75.21	1.7			
	27.61	75.21	1.303			
	28.69	75.21	0.93			
	29.155	75.21	0.779			

Table A.50. Run-up water surface data for 3:1 smooth training walls q = 0.078 m^2/s.

Run #	17		recorder	RW AB		
Date	10/26/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
15:03	24.40	68.72	2.391			
	24.76	68.77	2.372			
	24.87	68.79	2.367			
	25.10	68.81	2.356			
	25.30	68.85	2.345			
	25.42	68.87	2.341			
	25.55	68.88	2.333			
	25.69	68.92	2.323			
	25.83	68.95	2.309			
	25.97	69.000	2.296			
	26.11	69.040	2.280			
	26.24	69.09	2.262			
	26.39	69.15	2.241			
	26.51	69.20	2.220			
15:18	26.65	69.26	2.197			

	26.79	69.33	2.172	
	26.93	69.41	2.143	
	27.06	69.48	2.118	
	27.20	69.56	2.089	
	27.34	69.690	2.055	
	27.47	69.74	2.021	
	27.61	69.84	1.983	
	27.75	69.94	1.946	
15:27	27.89	70.06	1.908	
15:37	28.04	70.17	1.872	
	28.16	70.25	1.848	
	28.30	70.38	1.805	
	28.43	70.48	1.772	
	28.58	70.59	1.734	
	28.71	70.69	1.703	
	28.85	70.80	1.667	
	28.89	70.83	1.660	
	29.13	71.01	1.600	
	29.16	71.04	1.591	
	29.50	71.30	1.508	
15:52	30.00	71.67	1.388	
	30.50	72.02	1.273	
	31.00	72.35	1.164	
	31.50	72.71	1.046	
	32.00	73.07	0.922	
	32.92	73.79	0.691	
	31.7	70.44	1.416	
	32.00	70.54	1.375	
	32.30	70.71	1.281	
	32.60	70.82	1.231	
15:36	32.94	70.92	1.185	

Table A.51. Cross section water surface data for 3:1smooth training walls q = 0.078 m^2/s.

Run #	17		recorder	RW		
Date	10/26/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x	y	z			comments

	ft	ft	ft	
12:52	24.87	68.78	2.368	
	24.87	69.00	2.372	
	24.87	69.20	2.368	
	24.87	69.40	2.366	
	24.87	69.60	2.364	
	24.87	69.80	2.361	
	24.87	70.00	2.358	
	24.87	71.00	2.359	
	24.87	73.00	2.363	
	24.87	75.20	2.363	
	24.87	77.00	2.360	
	24.87	79.00	2.357	
	24.87	81.00	2.356	
	24.87	81.50	2.358	
	24.87	82.00	2.362	
13:00	24.87	82.47	2.385	
13:00	25.44	68.86	2.342	
	25.44	69.20	2.328	
	25.44	69.40	2.314	
	25.44	69.60	2.288	
	25.44	69.80	2.255	
	25.44	70.00	2.215	
	25.44	71.00	2.114	
	25.44	73.00	2.120	
	25.44	75.20	2.114	
	25.44	77.00	2.116	
	25.44	79.00	2.115	
	25.44	81.00	2.119	
	25.44	81.50	2.128	
	25.44	81.75	2.150	
	25.44	82.00	2.201	
13:13	25.44	82.38	2.292	
13:33	26.50	69.19	2.225	
	26.50	69.40	2.202	
	26.50	69.60	2.168	
	26.50	69.80	2.136	
	26.50	70.00	2.104	
	26.50	70.20	2.066	

	26.50	70.40	2.037	
	26.50	70.60	2.011	
	26.50	70.80	1.966	
	26.50	71.00	1.816	
	26.50	71.20	1.749	
	26.50	71.40	1.733	
	26.50	72.00	1.710	
	26.50	73.00	1.703	
	26.50	75.20	1.700	
	26.50	77.00	1.703	
	26.50	79.00	1.700	
	26.50	81.00	1.720	
	26.50	81.30	1.761	
	26.50	81.60	1.867	
13:47	26.50	82.01	1.933	
13:47	27.61	69.84	1.988	
	27.61	70.00	1.960	
	27.61	70.20	1.920	
	27.61	70.40	1.885	
	27.61	70.60	1.850	
	27.61	70.80	1.814	
	27.61	71.00	1.785	
	27.61	71.20	1.752	
	27.61	71.40	1.737	
	27.61	71.60	1.735	
	27.61	71.80	1.650	
	27.61	72.00	1.401	
	27.61	72.20	1.362	
	27.61	72.40	1.345	
	27.61	73.00	1.317	
	27.61	75.20	1.303	
	27.61	77.00	1.305	
	27.61	79.00	1.305	
	27.61	80.50	1.340	
	27.61	80.90	1.384	
	27.61	81.00	1.479	
	27.61	81.30	1.471	
14:00	27.61	81.60	1.514	
14:26	28.69	70.67	1.708	

	28.69	71.00	1.664	
	28.69	71.20	1.640	
	28.69	71.40	1.624	
	28.69	71.60	1.582	
	28.69	71.80	1.565	
	28.69	72.00	1.514	
	28.69	72.20	1.463	
	28.69	72.40	1.504	
	28.69	72.60	1.481	
	28.69	72.80	1.359	
	28.69	73.00	1.231	
	28.69	73.20	1.133	
	28.69	73.40	0.986	
	28.69	73.60	0.966	
	28.69	73.80	0.959	
	28.69	74.00	0.946	
	28.69	75.20	0.930	
	28.69	77.00	0.930	
	28.69	79.00	0.938	
	28.69	80.00	0.973	
	28.69	80.40	1.012	
	28.69	80.60	1.078	
	28.69	80.80	1.075	
	28.69	81.00	1.101	
14:38	28.69	81.28	1.172	
14:42	29.155	71.02	1.595	
	29.155	71.20	1.567	
	29.155	71.40	1.548	
	29.155	71.60	1.534	
	29.155	71.80	1.503	
	29.155	72.00	1.467	
	29.155	72.20	1.437	
	29.155	72.40	1.398	
	29.155	72.60	1.364	
	29.16	72.80	1.399	
	29.16	73.00	1.364	
	29.16	73.20	1.244	
	29.16	73.40	1.168	
	29.16	73.60	0.962	

	29.16	73.80	0.837	
	29.16	74.00	0.823	
	29.16	74.50	0.804	
	29.16	75.20	0.779	
	29.16	76.00	0.778	
	29.16	77.00	0.780	
	29.16	79.00	0.795	
	29.16	80.00	0.850	
	29.16	80.30	0.866	
	29.16	80.60	0.914	
	29.16	80.90	0.955	
14:56	29.16	81.13	1.010	
	29.16	71.75	1.148	
	29.16	71.93	1.037	
	29.16	72.00	1.052	
	29.16	72.20	0.998	
	29.16	72.40	0.880	
	29.16	72.60	0.815	
	29.16	72.80	0.808	
	29.16	73.00	0.796	
	29.16	75.20	0.781	
	29.16	77.00	0.785	
	29.16	79.00	0.799	
	29.16	80.00	0.848	
	29.16	80.35	0.881	
	29.16	80.50	0.911	
	29.16	80.70	0.922	
	29.16	80.80	0.949	
	29.16	80.90	0.950	
	29.16	81.13	1.009	
	29.155	72.3	0.889	
	29.155	72.5	0.869	
	29.155	73	0.8823	
	29.155	75.2	0.784	
	29.155	77	0.782	
	29.155	79	0.798	
	29.155	79.5	0.822	
	29.155	80	0.853	
	29.155	80.2	0.88	

	29.155	80.3	0.885	
	29.155	80.4	0.914	
	29.155	80.5	0.929	
	29.155	80.6	0.913	
	29.155	80.7	0.94	
	29.155	80.9	0.954	
	29.155	81	0.962	
	29.155	81.14	1.019	

Table A.52. Centerline water surface data for 3:1 smooth training walls q = 0.060 m^2/s.

Run #	18		recorder	RW		
Date	10/25/2007		BM-0 rd.	x=24.68	y =65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.87	75.21	2.316	Centerline		
	25.44	75.21	2.075			
	26.50	75.21	1.672			
	27.61	75.21	1.279			
	28.69	75.21	0.908			
	29.16	75.21	0.758			

Table A.53. Run-up water surface data for 3:1 smooth training walls q = 0.060 m^2/s.

Run #	18		recorder	RW		
Date	10/25/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.40	68.84	2.352			
	24.76	68.90	2.330			
	24.87	68.92	2.324			
	25.10	68.93	2.319			
	25.30	68.97	2.306			
	25.42	68.98	2.301			

	25.55	69.01	2.291	
	25.69	69.050	2.280	
	25.83	69.090	2.264	
	25.97	69.14	2.248	
	26.11	69.19	2.230	
	26.24	69.25	2.209	
	26.39	69.32	2.184	
	26.51	69.38	2.162	
	26.65	69.45	2.135	
	26.79	69.54	2.106	
	26.93	69.62	2.073	
	27.06	69.720	2.038	
	27.20	69.80	2.007	
	27.34	69.91	1.966	
	27.47	70.01	1.929	
	27.61	70.12	1.888	
	27.75	70.23	1.847	
	27.89	70.35	1.808	
	28.04	70.46	1.773	
	28.16	70.53	1.749	
	28.30	70.66	1.706	
	28.43	70.76	1.674	
	28.58	70.88	1.635	
	28.71	70.97	1.604	
	28.85	71.08	1.569	
	28.89	71.12	1.558	
	29.13	71.30	1.501	
	29.16	71.33	1.493	
	29.50	71.59	1.411	
	30.00	71.93	1.299	
	30.50	72.28	1.186	
	31.00	72.64	1.065	
	31.50	73.03	0.936	
	32	73.43	0.803	
	31.40	70.35	1.471	
	31.70	70.44	1.414	
	32.00	70.63	1.330	
	32.30	70.72	1.280	
	32.6	70.81	1.238	

	32.94	70.92	1.18	

Table A.54. Cross section water surface data for 3:1smooth training walls q = 0.060 m^2/s.

Run #	18		recorder	RW		
Date	10/25/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
14:53	24.87	68.91	2.326			
	24.87	69.20	2.331			
	24.87	69.40	2.327			
	24.87	69.60	2.326			
	24.87	69.80	2.322			
	24.87	70.00	2.318			
	24.87	71.00	2.317			
	24.87	73.00	2.317			
	24.87	75.20	2.316			
	24.87	77.00	2.317			
	24.87	79.00	2.317			
	24.87	81.00	2.318			
	24.87	81.50	2.320			
	24.87	82.00	2.325			
14:58	24.87	82.43	2.344			
15:13	25.44	68.98	2.303			
	25.44	69.20	2.294			
	25.44	69.40	2.285			
	25.44	69.60	2.252			
	25.435	69.80	2.219			
	25.435	70.00	2.177			
	25.435	70.20	2.122			
	25.435	70.50	2.082			
	25.435	71.00	2.073			
	25.435	73.00	2.075			
	25.435	75.20	2.075			
	25.435	77.00	2.074			
	25.435	79.00	2.077			
	25.435	81.00	2.082			

	25.435	81.50	2.087	
	25.435	82.00	2.168	
15:22	25.435	82.33	2.237	
15:25	26.5	69.38	2.164	
	26.5	69.60	2.134	
	26.5	69.80	2.099	
	26.5	70.00	2.067	
	26.5	70.20	2.030	
	26.5	70.40	1.997	
	26.5	70.60	1.972	
	26.5	70.80	1.951	
	26.5	71.00	1.773	
	26.5	71.20	1.715	
	26.5	71.40	1.700	
	26.5	71.60	1.690	
	26.5	71.80	1.686	
	26.5	72.00	1.678	
	26.5	73.00	1.670	
	26.5	75.20	1.672	
	26.5	77.00	1.672	
	26.5	79.00	1.672	
	26.5	80.50	1.679	
	26.5	81.00	1.690	
	26.5	81.40	1.763	
	26.5	81.60	1.815	
	26.5	81.80	1.831	
15:35	26.5	81.92	1.847	
15:40	27.61	70.11	1.891	
	27.61	70.40	1.845	
	27.61	70.60	1.806	
	27.61	70.80	1.774	
	27.61	71.00	1.744	
	27.61	71.20	1.712	
	27.61	71.40	1.676	
	27.61	71.60	1.677	
	27.61	71.80	1.624	
	27.61	72.00	1.492	
	27.61	72.20	1.338	
	27.61	72.40	1.312	

	27.61	72.60	1.301	
	27.61	72.80	1.296	
	27.61	73.00	1.290	
	27.61	75.20	1.279	
	27.61	77.00	1.281	
	27.61	79.00	1.282	
	27.61	80.50	1.315	
	27.61	80.90	1.350	
	27.61	81.00	1.425	
	27.61	81.30	1.406	
	27.61	81.54	1.463	
15:47	27.61	81.56	1.478	
10:05	28.69	70.95	1.614	
	28.69	71.20	1.579	
	28.69	71.40	1.560	
	28.69	71.60	1.533	
	28.69	71.80	1.500	
	28.69	72.00	1.467	
	28.69	72.20	1.417	
	28.69	72.40	1.417	
	28.69	72.60	1.406	
	28.69	72.80	1.377	
	28.69	73.00	1.186	
	28.69	73.20	1.023	
	28.69	73.40	0.964	
	28.69	73.60	0.942	
	28.69	74.00	0.925	
	28.69	75.20	0.908	
	28.69	77.00	0.914	
	28.69	79.00	0.922	
	28.69	80.50	0.993	
10:24	28.69	80.70	1.032	
	28.69	81.00	1.073	
	28.69	81.24	1.134	
10:27	29.155	71.31	1.502	
	29.155	71.60	1.460	
	29.155	71.80	1.445	
	29.155	72.00	1.417	
	29.155	72.20	1.381	

	29.155	72.40	1.350	
	29.155	72.60	1.302	
	29.155	72.80	1.304	
	29.155	73.00	1.295	
	29.155	73.2	1.25	
	29.155	73.4	1.11	
	29.155	73.6	1.012	
	29.155	73.8	0.84	
	29.155	74	0.796	
	29.155	74.5	0.775	
	29.155	75.2	0.758	
	29.155	76	0.755	
	29.155	77	0.755	
	29.155	79	0.77	
	29.155	80	0.819	
	29.155	80.5	0.858	
	29.155	80.7	0.884	
	29.155	81	0.922	
10:41	29.155	81.08	0.963	
	29.155	71.75	1.076	
	29.155	71.93	1.012	
	29.155	72	0.985	
	29.155	72.2	0.933	
	29.155	72.4	0.8	
	29.155	72.6	0.792	
	29.155	73	0.777	
	29.155	75.2	0.765	
	29.155	77	0.766	
	29.155	79	0.775	
	29.155	80	0.817	
	29.155	80.5	0.867	
	29.155	81	0.924	
	29.155	81.09	0.974	
	29.155	72.2	0.884	
	29.155	72.3	0.868	
	29.155	72.4	0.849	
	29.155	72.5	0.844	
	29.155	73	0.796	
	29.155	75.2	0.757	

	29.155	77	0.763	
	29.155	79	0.773	
	29.155	80	0.815	
	29.155	80.2	0.838	
	29.155	80.3	0.848	
	29.155	80.4	0.85	
	29.155	80.5	0.861	
	29.155	80.6	0.867	
	29.155	80.7	0.884	
	29.155	80.8	0.903	
	29.155	80.9	0.915	
	29.155	81	0.921	
	29.155	81.08	0.963	

Table A.55. Centerline water surface data for 3:1 smooth training walls q = 0.052 m^2/s.

Run #	19		recorder	RW		
Date	10/24/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft			
	12.00	75.21	2.381			
	16.00	75.21	2.381			
	20.00	75.21	2.381			
	24.87	75.21	2.300			
	25.44	75.21	2.058			
	26.50	75.21	1.661			
	27.61	75.21	1.293			
	28.69	75.21	0.902			
	29.16	75.21	0.747			

Table A.56. Run-up water surface data for 3:1 smooth training walls q = 0.052 m^2/s.

Run #	19		recorder	RW		
Date	10/24/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x	y	z	comments		

	ft	ft	ft	
14:18	24.40	68.88	2.334	
	24.76	68.95	2.313	
	24.87	68.96	2.310	
	25.10	68.98	2.302	
	25.30	69.02	2.290	
	25.42	69.04	2.284	
	25.55	69.07	2.274	
	25.69	69.11	2.258	
	25.83	69.16	2.241	
	25.97	69.21	2.222	
	26.11	69.27	2.202	
	26.24	69.33	2.181	
	26.39	69.41	2.154	
	26.51	69.48	2.128	
	26.65	69.56	2.099	
	26.79	69.64	2.067	
	26.93	69.74	2.035	
	27.06	69.84	1.998	
	27.20	69.93	1.961	
	27.34	70.04	1.921	
15:00	27.47	70.14	1.883	
15:08	27.61	70.25	1.843	
	27.75	70.36	1.804	
	27.89	70.47	1.767	
	28.04	70.57	1.734	
	28.16	70.64	1.710	
	28.30	70.78	1.665	
	28.43	70.88	1.634	
	28.58	71.00	1.595	
	28.71	71.10	1.564	
	28.85	71.20	1.529	
	28.89	71.24	1.519	
	29.13	71.43	1.460	
	29.16	71.45	1.455	
	29.50	71.70	1.375	
	30.00	72.04	1.266	
15:29	30.50	72.40	1.145	
	31.00	72.78	1.021	

	31.50	73.17	0.888	
	32.36	73.87	0.665	
	31.40	70.54	1.380	
	31.7	70.63	1.333	
	32.00	70.82	1.236	
	32.30	70.92	1.191	
	32.60	71.02	1.140	
10:56	32.94	71.10	1.093	

Table A.57. Cross section water surface data for 3:1smooth training walls q = 0.052 m^2/s.

Run #	19		recorder	RW		
Date	10/24/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
14:10	24.87	68.96	2.312			
	24.87	69.20	2.314			
	24.87	69.40	2.314			
	24.87	69.60	2.308			
	24.87	70.00	2.301			
	24.87	71.00	2.298			
	24.87	73.00	2.297			
	24.87	75.20	2.300			
	24.87	77.00	2.299			
	24.87	79.00	2.300			
	24.87	81.00	2.300			
	24.87	81.50	2.299			
	24.87	82.00	2.303			
	24.87	82.20	2.308			
14:17	24.87	82.41	2.321			
9:55	25.44	69.04	2.284			
	25.44	69.30	2.268			
	25.44	69.50	2.249			
	25.44	69.70	2.219			
	25.435	69.90	2.185			
	25.435	70.10	2.136			
	25.435	70.30	2.083			

	25.435	70.50	2.064	
	25.435	71.00	2.057	
	25.435	73.00	2.058	
	25.435	75.20	2.058	
	25.435	77.00	2.057	
	25.435	79.00	2.060	
	25.435	81.00	2.065	
	25.435	81.50	2.068	
	25.435	82.00	2.148	
	25.435	82.30	2.211	
10:10	26.5	69.45	2.136	
	26.5	69.70	2.100	
	26.5	69.90	2.068	
	26.5	70.10	2.033	
	26.5	70.30	1.997	
	26.5	70.50	1.963	
	26.5	70.70	1.944	
	26.5	70.90	1.910	
	26.5	71.10	1.719	
	26.5	71.30	1.691	
	26.5	71.50	1.682	
	26.5	72.00	1.669	
	26.5	73.00	1.659	
	26.5	75.20	1.661	
	26.5	77.00	1.660	
	26.5	79.00	1.661	
	26.5	81.00	1.677	
10:22	26.5	81.40	1.743	
	26.5	81.50	1.795	
	26.5	81.70	1.797	
	26.5	81.89	1.822	
10:25	27.61	70.25	1.847	
	27.61	70.50	1.807	
	27.61	70.90	1.740	
	27.61	71.10	1.711	
	27.61	71.30	1.677	
	27.61	71.50	1.651	
	27.61	71.70	1.665	
	27.61	71.90	1.508	

	27.61	72.10	1.432	
	27.61	72.30	1.307	
	27.61	72.50	1.293	
	27.61	73.00	1.276	
	27.61	75.20	1.271	
	27.61	77.00	1.270	
	27.61	79.00	1.275	
	27.61	80.50	1.298	
	27.61	80.90	1.339	
	27.61	81.00	1.385	
	27.61	81.20	1.398	
	27.61	81.52	1.445	
10:43	28.69	71.07	1.573	
	28.69	71.30	1.545	
	28.69	71.50	1.521	
	28.69	71.70	1.494	
	28.69	71.90	1.462	
	28.69	72.10	1.426	
	28.69	72.30	1.375	
	28.69	72.50	1.386	
	28.69	72.70	1.352	
	28.69	72.90	1.266	
	28.69	73.10	1.100	
	28.69	73.30	0.950	
	28.69	73.50	0.942	
	28.69	74.00	0.909	
	28.69	75.20	0.902	
	28.69	77.00	0.903	
	28.69	79.00	0.915	
	28.69	80.00	0.939	
	28.69	80.50	0.982	
	28.69	81.00	1.053	
	28.69	81.22	1.112	
10:58	29.155	71.45	1.457	
	29.155	71.90	1.405	
	29.155	72.10	1.376	
	29.155	72.30	1.344	
	29.155	72.50	1.313	
	29.155	72.70	1.270	

	29.155	72.90	1.271	
	29.155	73.10	1.233	
	29.155	73.3	1.149	
	29.155	73.5	1.026	
	29.155	73.7	0.957	
	29.155	73.9	0.799	
	29.155	74.1	0.778	
	29.155	74.3	0.77	
	29.155	74.5	0.768	
	29.155	75.2	0.747	
	29.155	77	0.751	
	29.155	78	0.757	
	29.155	79	0.764	
	29.155	80	0.805	
	29.155	80.5	0.833	
	29.155	80.7	0.877	
11:09	29.155	81.07	0.954	
	29.155	70.98	1.203	
	29.155	71.17	1.153	
	29.155	71.36	1.105	
	29.155	71.55	1.087	
	29.155	71.75	1.054	
	29.155	71.93	0.982	
	29.155	72.1	0.924	
	29.155	72.5	0.787	
	29.155	73	0.763	
	29.155	75.2	0.756	
	29.155	77	0.752	
	29.155	79	0.774	
	29.155	80	0.81	
	29.155	80.5	0.845	
	29.155	80.75	0.885	
	29.155	81	0.906	
16:17	29.155	81.07	0.945	
	29.155	73	0.782	
	29.155	75.2	0.753	
	29.155	77	0.751	
	29.155	79	0.763	
	29.155	80	0.799	

	29.155	80.5	0.834	
	29.155	80.6	0.855	
	29.155	80.7	0.873	
	29.155	80.8	0.885	
	29.155	80.9	0.896	
	29.155	81.07	0.954	

Table A.58. Centerline water surface data for 3:1 smooth training walls q = 0.039 m^2/s.

Run #	20		recorder	RW		
Date	8/31/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.87	75.21	2.258			
	25.44	75.21	2.017			
	26.50	75.21	1.634			
	27.61	75.21	1.248			
	28.69	75.21	0.883			
	29.16	75.21	0.729			

Table A.59. Run-up water surface data for 3:1 smooth training walls q = 0.039 m^2/s.

Run #	20		recorder	RW, BS		
Date	8/31/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
13:11	24.40	69.01	2.290			
	24.76	69.07	2.275			
	24.87	69.09	2.269			
	25.10	69.12	2.258			
	25.30	69.16	2.245			
	25.42	69.19	2.235			
	25.55	69.23	2.222			
	25.69	69.28	2.204			
	25.83	69.34	2.185			

	25.97	69.41	2.159	
	26.11	69.480	2.135	
	26.24	69.550	2.109	
	26.39	69.65	2.073	
	26.51	69.73	2.043	
	26.65	69.82	2.010	
	26.79	69.93	1.971	
	26.93	70.03	1.936	
	27.06	70.12	1.901	
	27.20	70.21	1.866	
	27.34	70.33	1.823	
	27.47	70.430	1.785	
13:10	27.61	70.53	1.748	
13:29	27.75	70.64	1.706	
	27.89	70.74	1.671	
	28.04	70.86	1.632	
	28.16	70.94	1.609	
	28.30	71.08	1.565	
	28.43	71.18	1.532	
	28.58	71.29	1.495	
	28.71	71.40	1.463	
	28.85	71.50	1.430	
	28.89	71.54	1.417	
	29.13	71.71	1.366	
	29.16	71.72	1.363	
	29.30	71.83	1.326	
	29.60	72.03	1.264	
	29.90	72.28	1.183	
	30.50	72.74	1.034	
	31.10	73.21	0.877	
	31.70	73.75	0.695	
13:47	31.93	73.93	0.633	
	31.40	70.72	1.284	
	31.7	70.81	1.231	
	32.00	71.00	1.142	
	32.30	71.10	1.095	
	32.60	71.19	1.050	
9:34	32.90	71.28	1.005	

Table A.60. Cross section water surface data for 3:1smooth training walls q = 0.039 m^2/s.

Run #	20		recorder	RW		
Date	8/31/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.87	69.08	2.270			
	24.87	69.30	2.272			
	24.87	69.50	2.269			
	24.87	70.00	2.256			
	24.87	71.00	2.256			
	24.87	73.00	2.256			
	24.87	75.20	2.258			
	24.87	77.00	2.258			
	24.87	79.00	2.257			
	24.87	81.00	2.258			
	24.87	82.00	2.260			
10:08	24.87	82.37	2.280			
10:37	25.44	69.19	2.233			
	25.44	69.30	2.231			
	25.44	69.50	2.210			
	25.44	69.70	2.181			
	25.44	69.90	2.152			
	25.44	70.10	2.095			
	25.44	70.50	2.019			
	25.44	71.00	2.017			
	25.44	73.00	2.016			
	25.44	75.20	2.017			
	25.44	77.00	2.016			
	25.44	79.00	2.020			
	25.44	81.00	2.021			
	25.44	81.50	2.024			
	25.435	82.00	2.103			
	25.435	82.24	2.155			
	26.5	69.72	2.049			

	26.5	69.90	2.023	
	26.5	70.10	1.990	
	26.5	70.20	1.954	
	26.5	70.50	1.921	
	26.5	70.70	1.889	
	26.5	70.90	1.876	
	26.5	71.00	1.830	
	26.5	71.10	1.679	
	26.5	71.30	1.660	
	26.5	71.50	1.650	
	26.5	73.00	1.635	
	26.5	75.20	1.634	
	26.5	77.00	1.634	
	26.5	79.00	1.635	
	26.5	81.00	1.647	
	26.5	81.30	1.668	
	26.5	81.50	1.742	
	26.5	81.83	1.764	
11:12	27.61	70.53	1.748	
	27.61	70.80	1.715	
	27.61	71.00	1.675	
	27.61	71.20	1.643	
	27.61	71.40	1.610	
	27.61	71.60	1.588	
	27.61	71.80	1.552	
	27.61	72.00	1.450	
	27.61	72.20	1.339	
	27.61	72.40	1.267	
	27.61	72.60	1.257	
	27.61	73.00	1.254	
	27.61	75.20	1.248	
	27.61	77.00	1.252	
	27.61	79.00	1.252	
	27.61	80.50	1.272	
	27.61	81.00	1.323	
	27.61	81.20	1.340	
	27.61	81.49	1.412	
11:29	28.69	71.38	1.467	
	28.69	71.60	1.442	

	28.69	71.80	1.415	
	28.69	72.00	1.384	
	28.69	72.20	1.348	
	28.69	72.40	1.304	
	28.69	72.60	1.293	
	28.69	72.80	1.248	
	28.69	73.00	1.133	
	28.69	73.20	1.071	
	28.69	73.40	0.940	
	28.69	73.60	0.908	
	28.69	75.20	0.883	
	28.69	77.00	0.884	
	28.69	79.00	0.894	
	28.69	80.50	0.947	
	28.69	81.00	1.012	
	28.69	81.16	1.055	
	29.155	71.73	1.358	
	29.155	72.00	1.326	
	29.155	72.20	1.296	
	29.155	72.40	1.263	
	29.155	72.60	1.220	
	29.155	72.80	1.188	
	29.155	73.00	1.168	
	29.155	73.20	1.126	
	29.155	73.40	1.038	
	29.155	73.60	0.978	
	29.155	73.80	0.867	
	29.155	74.00	0.751	
	29.155	74.50	0.741	
	29.155	75.2	0.729	
	29.155	77	0.733	
	29.155	79	0.741	
11:52	29.155	80.5	0.804	
	29.155	81.03	0.912	
	29.155	70.25	1.533	
	29.155	70.48	1.439	
	29.155	70.63	1.347	
	29.155	70.82	1.257	
	29.155	70.98	1.182	

	29.155	71.17	1.118	
	29.155	71.36	1.052	
	29.155	71.55	1.017	
	29.155	71.75	0.972	
	29.155	71.93	0.934	
	29.155	72.1	0.89	
	29.155	72.35	0.764	
	29.155	73	0.734	
	29.155	75.2	0.73	
	29.155	77	0.73	
	29.155	79	0.74	
	29.155	80	0.764	
	29.155	80.5	0.804	
10:53	29.155	81	0.888	

Table A.61. Centerline water surface data for 3:1 stepped training walls q = 0.078 m^2/s.

Run #	21		recorder	BS		
Date	11/13/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
	24.87	75.21	2.363	Centerline		
	25.435	75.21	2.114			
	26.5	75.21	1.7			
	27.61	75.21	1.303			
	28.69	75.21	0.93			
	29.155	75.21	0.779			

Table A.62. Run-up water surface data for 3:1 stepped training walls q = 0.078 m^2/s.

Run #	21		recorder	BS		
Date	11/13/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
11:43	24.87	68.74	2.402			

	25.10	68.86	2.396	
	25.30	68.86	2.304	
	25.42	69.02	2.354	
	25.69	69.02	2.349	
	25.97	69.02	2.345	
	26.24	69.02	2.342	
	26.51	69.02	2.339	
	26.79	69.02	2.334	
	27.06	69.020	2.328	
	27.34	69.150	2.286	
	27.61	69.15	2.285	
	27.89	69.29	2.235	
	28.13	69.45	2.183	
	28.43	69.58	2.132	
	28.71	69.86	2.052	
	28.89	68.86	2.047	
	29.16	69.98	2.010	
	29.30	69.98	2.010	
	29.60	70.130	1.971	
	29.90	70.26	1.923	
	30.20	70.26	1.922	
	30.50	70.55	1.837	
	30.80	70.68	1.790	
	31.10	70.68	1.788	
	31.40	70.82	1.736	
	31.70	71.09	1.654	
	32.00	71.22	1.609	
	32.30	71.35	1.555	
	32.60	71.49	1.514	
12:08	32.93	71.62	1.463	

Table A.63. Cross section water surface data for 3:1stepped training walls q = 0.078 m^2/s.

Run #	21		recorder	BS		
Date	11/13/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		

8:44	24.87	68.74	2.402	
	24.87	68.87	2.398	
	24.87	69.01	2.379	
	24.87	69.20	2.376	
	24.87	69.40	2.372	
	24.87	69.60	2.366	
	24.87	69.80	2.367	
	24.87	70.00	2.366	
	24.87	71.00	2.365	
	24.87	73.00	2.368	
	24.87	75.20	2.365	
	24.87	77.00	2.364	
	24.87	79.00	2.363	
	24.87	81.00	2.360	
	24.87	81.50	2.358	
	24.87	82.00	2.365	
8:51	24.87	82.46	2.382	
8:55	25.44	68.74	2.400	
	25.44	68.87	2.394	
	25.44	68.88	2.363	
	25.44	69.01	2.354	
	25.44	69.03	2.349	
	25.44	69.14	2.343	
	25.44	69.20	2.338	
	25.44	69.40	2.325	
	25.44	69.60	2.304	
	25.44	69.80	2.274	
	25.44	70.00	2.230	
	25.44	71.00	2.122	
	25.44	73.00	2.128	
	25.44	75.20	2.121	
	25.44	77.00	2.121	
	25.44	79.00	2.121	
	25.44	81.00	2.123	
	25.44	81.50	2.134	
	25.44	81.75	2.155	
	25.44	82.00	2.210	
9:07	25.44	82.36	2.286	
9:13	26.50	68.89	2.349	

	26.50	69.00	2.345	
	26.50	69.03	2.301	
	26.50	69.15	2.301	
	26.50	69.17	2.252	
	26.50	69.30	2.256	
	26.50	69.40	2.221	
	26.50	69.60	2.189	
	26.50	69.80	2.156	
	26.50	70.00	2.121	
	26.50	70.20	2.085	
	26.50	70.40	2.050	
	26.50	70.60	2.026	
	26.50	70.80	1.988	
	26.50	71.00	1.883	
	26.50	71.20	1.773	
	26.50	71.40	1.735	
	26.50	71.60	1.723	
	26.5	71.80	1.719	
	26.5	72.00	1.712	
	26.5	73.00	1.705	
	26.5	75.20	1.704	
	26.5	77.00	1.705	
	26.5	79.00	1.704	
	26.5	81.00	1.728	
	26.5	81.30	1.769	
	26.5	81.60	1.868	
9:22	26.5	81.97	1.917	
9:24	27.61	68.89	2.336	
	27.61	69.00	2.332	
	27.61	69.03	2.292	
	27.61	69.15	2.283	
	27.61	69.17	2.242	
	27.61	69.30	2.234	
	27.61	69.32	2.187	
	27.61	69.44	2.190	
	27.61	69.47	2.141	
	27.61	69.58	2.144	
	27.61	69.60	2.138	
	27.61	69.80	2.067	

	27.61	70.00	2.008	
	27.61	70.20	1.959	
	27.61	70.40	1.914	
	27.61	70.60	1.877	
	27.61	70.80	1.838	
	27.61	71.00	1.807	
	27.61	71.20	1.772	
	27.61	71.40	1.746	
	27.61	71.60	1.745	
	27.61	71.80	1.732	
	27.61	71.90	1.683	
	27.61	72.00	1.443	
	27.61	72.20	1.373	
	27.61	72.40	1.342	
	27.61	72.60	1.330	
	27.61	72.80	1.319	
	27.61	73.00	1.318	
	27.61	75.20	1.309	
	27.61	77.00	1.312	
	27.61	79.00	1.312	
	27.61	80.50	1.351	
	27.61	80.90	1.406	
	27.61	81.00	1.485	
	27.61	81.30	1.481	
9:43	27.61	81.56	1.492	
10:19	28.69	69.44	2.141	
	28.69	69.57	2.138	
	28.69	69.60	2.100	
	28.69	69.72	2.096	
	28.69	69.75	2.072	
	28.69	69.85	2.066	
	28.69	70.00	2.014	
	28.69	70.20	1.946	
	28.69	70.40	1.885	
	28.69	70.60	1.838	
	28.69	70.80	1.751	
	28.69	71.00	1.691	
	28.69	71.20	1.656	
	28.69	71.40	1.629	

	28.69	71.60	1.603	
	28.69	71.80	1.575	
	28.69	72.00	1.539	
	28.69	72.20	1.481	
	28.69	72.40	1.473	
	28.69	72.60	1.488	
	28.69	72.80	1.446	
	28.69	72.90	1.347	
	28.69	73.00	1.272	
	28.69	73.20	1.141	
	28.69	73.40	1.004	
	28.69	73.60	0.957	
	28.69	73.80	0.946	
	28.69	74.00	0.943	
	28.69	75.20	0.934	
	28.69	77.00	0.934	
	28.69	79.00	0.944	
	28.69	80.00	0.981	
	28.69	80.40	1.021	
	28.69	80.60	1.082	
	28.69	80.80	1.085	
	28.69	81.00	1.109	
10:35	28.69	81.22	1.134	
10:38	29.16	69.75	2.063	
	29.155	69.85	2.059	
	29.155	69.87	2.015	
	29.155	69.97	2.012	
	29.155	70.01	1.982	
	29.155	70.11	1.967	
	29.155	70.2	1.934	
	29.155	70.4	1.879	
	29.155	70.6	1.827	
	29.155	70.8	1.758	
	29.155	71	1.695	
	29.155	71.2	1.647	
	29.155	71.4	1.588	
	29.155	71.6	1.546	
	29.155	71.8	1.525	
	29.155	72	1.498	

	29.155	72.2	1.458	
	29.155	72.4	1.423	
	29.155	72.6	1.373	
	29.155	72.8	1.391	
	29.155	73	1.396	
	29.155	73.1	1.361	
	29.155	73.2	1.312	
	29.155	73.4	1.147	
	29.155	73.6	1.123	
	29.155	73.8	0.904	
	29.155	74	0.819	
	29.155	74.5	0.789	
	29.155	75.2	0.78	
	29.155	76	0.784	
	29.155	77	0.785	
	29.155	79	0.801	
	29.155	80	0.857	
	29.155	80.5	0.925	
	29.155	80.6	0.925	
	29.155	80.9	0.964	
10:43	29.155	81.09	0.985	

Table A.64. Centerline water surface data for 3:1 stepped training walls q = 0.060 m^2/s.

Run #	22		recorder	BS		
Date	11/9/2007		BM-0 rd.	x=24.68	y =65.02	z=2.873
time	x ft	y ft	z ft	comments		
14:53	12.00	75.20	2.409	Centerline		
	16.00	75.20	2.409			
	20.00	75.20	2.406			
	24.00	75.20	2.367			
	24.87	75.20	2.318			
	25.44	75.20	2.072			
	26.50	75.20	1.677			
	27.61	75.20	1.283			
	28.69	75.20	0.909			

	29.16	75.20	0.756	
15:02	29.30	75.20	0.725	

Table A.65. Run-up water surface data for 3:1 stepped training walls q = 0.060 m^2/s.

Run #	22		recorder	BS		
Date	11/9/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
9:53	24.87	69.15	2.332			
	25.10	69.15	2.324			
	25.30	69.15	2.313			
	25.42	69.15	2.308			
	25.69	69.15	2.305			
	25.97	69.15	2.302			
	26.24	69.15	2.295			
	26.51	69.15	2.292			
	26.79	69.150	2.287			
	27.06	69.150	2.278			
	27.34	69.29	2.235			
	27.61	69.44	2.185			
	27.89	69.58	2.139			
	28.13	69.58	2.126			
	28.43	69.86	2.044			
	28.71	69.98	2.009			
	28.89	70.13	1.960			
	29.16	70.26	1.919			
	29.30	70.260	1.915			
	29.60	70.40	1.876			
	29.90	70.54	1.837			
	30.20	70.54	1.830			
	30.50	70.68	1.789			
	30.80	70.82	1.739			
	31.10	71.08	1.650			
	31.40	71.22	1.607			
	31.70	71.35	1.560			
	32.00	71.49	1.509			

	32.30	71.76	1.422	
	32.60	71.91	1.374	
	32.92	71.98	1.326	

Table A.66. Cross section water surface data for 3:1stepped training walls q = 0.060 m^2/s.

Run #	22		recorder	BS		
Date	11/9/2007		BM-0 rd.	x=24.68	65.02	z=2.873
time	x ft	y ft	z ft	comments		
11:32	24.87	68.90	2.355			
	24.87	69.02	2.351			
	24.87	69.16	2.332			
	24.87	69.40	2.330			
	24.87	69.60	2.329			
	24.87	69.80	2.322			
	24.87	70.00	2.319			
	24.87	71.00	2.316			
	24.87	73.00	2.318			
	24.87	75.20	2.318			
	24.87	77.00	2.317			
	24.87	79.00	2.317			
	24.87	81.00	2.318			
	24.87	81.50	2.318			
	24.87	82.00	2.324			
11:39	24.87	82.41	2.336			
11:39	25.44	68.90	2.354			
	25.44	69.02	2.348			
	25.435	69.16	2.307			
	25.435	69.40	2.286			
	25.435	69.60	2.263			
	25.435	69.80	2.232			
	25.435	70.00	2.194			
	25.435	70.50	2.089			
	25.435	71.00	2.075			
	25.435	73.00	2.071			
	25.435	75.20	2.073			

	25.435	77.00	2.071	
	25.435	79.00	2.076	
	25.435	81.00	2.080	
	25.435	81.50	2.086	
	25.435	82.00	2.115	
11:48	25.435	82.30	2.227	
13:02	26.5	68.90	2.343	
	26.5	69.02	2.339	
	26.5	69.16	2.287	
	26.5	69.30	2.245	
	26.5	69.45	2.210	
	26.5	69.50	2.175	
	26.5	69.60	2.165	
	26.5	69.74	2.128	
	26.5	69.80	2.122	
	26.5	70.00	2.084	
	26.5	70.20	2.046	
	26.5	70.40	2.011	
	26.5	70.60	1.981	
	26.5	70.80	1.962	
	26.5	70.93	1.925	
	26.5	71.00	1.847	
	26.5	71.20	1.730	
	26.5	71.40	1.696	
	26.5	71.60	1.689	
	26.5	71.80	1.682	
	26.5	72.00	1.678	
	26.5	73.00	1.672	
	26.5	75.20	1.673	
	26.5	77.00	1.674	
	26.5	79.00	1.674	
	26.5	80.50	1.681	
	26.5	81.00	1.691	
	26.5	81.40	1.765	
	26.5	81.60	1.816	
	26.5	81.80	1.830	
13:18	26.5	81.90	1.842	
13:23	27.61	68.90	2.335	
	27.61	69.00	2.333	

	27.61	69.14	2.284	
	27.61	69.29	2.234	
	27.61	69.44	2.184	
	27.61	69.58	2.137	
	27.61	69.73	2.091	
	27.61	69.87	2.040	
	27.61	70.00	2.003	
	27.61	70.20	1.946	
	27.61	70.40	1.883	
	27.61	70.60	1.836	
	27.61	70.80	1.797	
	27.61	71.00	1.763	
	27.61	71.20	1.728	
	27.61	71.40	1.696	
	27.61	71.60	1.677	
	27.61	71.80	1.675	
	27.61	71.90	1.649	
	27.61	72.00	1.551	
	27.61	72.20	1.374	
	27.61	72.40	1.303	
	27.61	72.60	1.293	
	27.61	72.80	1.287	
	27.61	73.00	1.284	
	27.61	75.20	1.280	
	27.61	77.00	1.283	
	27.61	79.00	1.287	
	27.61	80.50	1.314	
	27.61	80.90	1.360	
	27.61	81.00	1.427	
	27.61	81.30	1.427	
13:41	27.61	81.52	1.447	
13:47	28.69	69.31	2.194	
	28.69	69.42	2.191	
	28.69	69.57	2.140	
	28.69	69.72	2.093	
	28.69	69.84	2.045	
	28.69	69.98	2.013	
	28.69	70.12	1.963	
	28.69	70.20	1.932	

	28.69	70.40	1.873	
	28.69	70.60	1.825	
	28.69	70.8	1.758	
	28.69	71	1.683	
	28.69	71.2	1.622	
	28.69	71.4	1.572	
	28.69	71.6	1.548	
	28.69	71.8	1.523	
	28.69	72	1.484	
	28.69	72.2	1.446	
	28.69	72.4	1.4	
	28.69	72.6	1.411	
	28.69	72.8	1.353	
	28.69	73	1.306	
	28.69	73.2	1.15	
	28.69	73.4	0.957	
	28.69	73.6	0.933	
	28.69	73.8	0.92	
	28.69	74	0.917	
	28.69	75.2	0.913	
	28.69	77	0.913	
	28.69	79	0.924	
	28.69	80.5	0.996	
	28.69	80.7	1.032	
	28.69	81	1.072	
14:04	28.69	81.18	1.087	
14:33	29.155	70.01	1.958	
	29.155	70.12	1.959	
	29.155	70.26	1.91	
	29.155	70.4	1.875	
	29.155	70.54	1.834	
	29.155	70.6	1.817	
	29.155	70.8	1.753	
	29.155	71	1.688	
	29.155	71.2	1.636	
	29.155	71.4	1.574	
	29.155	71.6	1.519	
	29.155	71.8	1.461	
	29.155	72	1.441	

	29.155	72.2	1.404	
	29.155	72.4	1.361	
	29.155	72.6	1.336	
	29.155	72.8	1.31	
	29.155	73	1.3	
	29.155	73.2	1.222	
	29.155	73.4	1.136	
	29.155	73.6	1.004	
	29.155	73.8	0.873	
	29.155	74	0.786	
	29.155	74.5	0.764	
	29.155	75.2	0.759	
	29.155	76	0.76	
	29.155	77	0.76	
	29.155	79	0.772	
	29.155	80	0.819	
	29.155	80.5	0.868	
	29.155	80.7	0.885	
	29.155	81	0.928	
14:49	29.155	81.04	0.937	

Table A.67. Centerline water surface data for 3:1 stepped training walls q = 0.052 m^2/s.

Run #	22		recorder	BS		
Date	11/8/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft			
	12.00	75.20	2.385			
	16.00	75.20	2.385			
	20.00	75.20	2.383			
	24.00	75.20	2.348			
	24.87	75.20	2.302			
	25.44	75.20	2.054			
	26.50	75.20	1.660			
	27.61	75.20	1.273			
	28.69	75.20	0.901			
	29.16	75.20	0.749			

11:16	29.30	75.20	0.711	

Table A.68. Run-up water surface data for 3:1 stepped training walls q = 0.052 m^2/s.

Run #	22		recorder	BS		
Date	11/8/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
8:47	24.87	69.03	2.317			
	25.10	69.16	2.309			
	25.30	69.16	2.305			
	25.42	69.16	2.305			
	25.69	69.16	2.300			
	25.97	69.31	2.257			
	26.24	69.31	2.252			
	26.51	69.31	2.245			
	26.79	69.31	2.239			
	27.06	69.45	2.196			
	27.34	69.45	2.189			
	27.61	69.58	2.134			
	27.89	69.58	2.133			
	28.13	69.73	2.085			
	28.43	69.73	2.084			
	28.71	69.85	2.046			
	28.89	70.13	1.960			
	29.16	70.27	1.915			
	29.30	70.41	1.874			
	29.60	70.55	1.831			
	29.90	70.68	1.787			
	30.20	70.68	1.785			
	30.50	70.82	1.743			
	30.80	70.95	1.696			
	31.10	71.21	1.609			
	31.40	71.21	1.610			

	31.70	71.35	1.558	
	32.00	71.62	1.470	
	32.30	71.77	1.421	
	32.60	71.91	1.376	
	32.92	72.10	1.282	

Table A.69. Cross section water surface data for 3:1stepped training walls q = 0.052 m^2/s.

Run #	22		recorder	BS		
Date	11/8/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
9:00	24.87	69.04	2.318			
	24.87	69.20	2.314			
	24.87	69.40	2.314			
	24.87	69.60	2.312			
	24.87	70.00	2.303			
	24.87	71.00	2.299			
	24.87	73.00	2.300			
	24.87	75.20	2.303			
	24.87	77.00	2.302			
	24.87	79.00	2.303			
	24.87	81.00	2.304			
	24.87	81.50	2.304			
9:06	24.87	82.40	2.322			
9:10	25.44	69.03	2.306			
	25.44	69.16	2.303			
	25.44	69.30	2.277			
	25.44	69.45	2.265			
	25.44	69.60	2.248			
	25.435	69.80	2.218			
	25.435	70.00	2.176			
	25.435	70.25	2.111			
	25.435	70.50	2.070			
	25.435	70.75	2.059			
	25.435	71.00	2.057			
	25.435	73.00	2.056			

	25.435	75.20	2.058	
	25.435	77.00	2.059	
	25.435	79.00	2.063	
	25.435	81.00	2.067	
	25.435	81.50	2.071	
	25.435	81.90	2.121	
9:18	25.435	82.27	2.080	
9:24	26.5	69.04	2.301	
	26.5	69.15	2.296	
	26.5	69.30	2.244	
	26.5	69.45	2.202	
	26.5	69.59	2.160	
	26.5	69.74	2.118	
	26.5	69.88	2.092	
	26.5	70.00	2.066	
	26.5	70.20	2.021	
	26.5	70.40	1.994	
	26.5	70.60	1.965	
	26.5	70.80	1.947	
	26.5	70.93	1.922	
	26.5	71.07	1.773	
	26.5	71.20	1.711	
	26.5	71.40	1.682	
	26.5	71.60	1.675	
	26.5	71.80	1.669	
	26.5	72.00	1.666	
	26.5	73.00	1.660	
	26.5	75.20	1.661	
	26.5	77.00	1.662	
	26.5	79.00	1.663	
	26.5	80.50	1.663	
	26.5	81.00	1.679	
	26.5	81.50	1.798	
9:33	26.5	81.87	1.814	
9:35	27.61	69.03	2.287	
	27.61	69.14	2.302	
	27.61	69.29	2.227	
	27.61	69.44	2.182	
	27.61	69.58	2.136	

	27.61	69.73	2.084	
	27.61	69.87	2.040	
	27.61	70.00	2.001	
	27.61	70.13	1.957	
	27.61	70.27	1.913	
	27.61	70.41	1.868	
	27.61	70.60	1.822	
	27.61	70.80	1.774	
	27.61	71.00	1.746	
	27.61	71.20	1.711	
	27.61	71.40	1.678	
	27.61	71.60	1.653	
	27.61	71.80	1.658	
	27.61	71.95	1.596	
	27.61	72.00	1.517	
	27.61	72.20	1.387	
	27.61	72.40	1.287	
	27.61	72.60	1.280	
	27.61	72.80	1.275	
	27.61	73.00	1.273	
	27.61	75.20	1.272	
	27.61	77.00	1.272	
	27.61	79.00	1.275	
	27.61	80.00	1.289	
	27.61	80.50	1.303	
	27.61	80.80	1.331	
	27.61	81.00	1.394	
9:49	27.61	81.49	1.426	
9:51	28.69	69.88	2.007	
	28.69	69.98	2.005	
	28.69	70.12	1.957	
	28.69	70.26	1.920	
	28.69	70.41	1.873	
	28.69	70.60	1.821	
	28.69	70.8	1.764	
	28.69	71	1.682	
	28.69	71.2	1.622	
	28.69	71.4	1.565	
	28.69	71.6	1.521	

	28.69	71.8	1.498	
	28.69	72	1.465	
	28.69	72.2	1.437	
	28.69	72.4	1.377	
	28.69	72.6	1.376	
	28.69	72.8	1.317	
	28.69	73	1.225	
	28.69	73.2	1.073	
	28.69	73.4	0.935	
	28.69	73.6	0.918	
	28.69	73.8	0.907	
	28.69	74	0.905	
	28.69	75.2	0.9	
	28.69	77	0.902	
	28.69	79	0.913	
	28.69	80	0.94	
	28.69	80.5	0.984	
10:03	28.69	81.15	1.071	
10:51	29.155	70	1.968	
	29.155	70.11	1.963	
	29.155	70.27	1.914	
	29.155	70.4	1.872	
	29.155	70.6	1.815	
	29.155	70.8	1.744	
	29.155	71	1.685	
	29.155	71.2	1.621	
	29.155	71.4	1.566	
	29.155	71.6	1.513	
	29.155	71.8	1.457	
	29.155	72	1.423	
	29.155	72.2	1.381	
	29.155	72.4	1.337	
	29.155	72.6	1.314	
	29.155	72.8	1.275	
	29.155	73	1.261	
	29.155	73.2	1.196	
	29.155	73.4	1.092	
	29.155	73.6	0.99	
	29.155	73.8	0.864	

	29.155	74	0.77	
	29.155	75.2	0.746	
	29.155	77	0.752	
	29.155	79	0.761	
	29.155	80	0.803	
	29.155	80.5	0.836	
11:09	29.155	81.02	0.92	

Table A.70. Centerline water surface data for 3:1 stepped training walls q = 0.039 m^2/s.

Run #	24		recorder	RW		
Date	11/13/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
11:00	12	75.2	2.324			
	16.00	75.20	2.324			
	20.00	75.20	2.322			
	24.00	75.20	2.298			
	24.87	75.20	2.260			
	25.44	75.20	2.015			
	26.50	75.20	1.634			
	27.61	75.20	1.254			
	28.69	75.20	0.880			
	29.16	75.20	0.721			
11:08	29.30	75.20	0.688			

Table A.71. Run-up water surface data for 3:1 stepped training walls q = 0.039 m^2/s.

Run #	24		recorder	RW		
Date	11/13/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
14:58	24.87	69.17	2.281			
	25.10	69.17	2.274			
	25.30	69.17	2.265			

	25.42	69.31	2.254	
	25.69	69.31	2.247	
	25.97	69.31	2.211	
	26.24	69.46	2.189	
	26.51	69.60	2.152	
	26.79	69.60	2.147	
	27.06	69.74	2.096	
	27.34	69.880	2.039	
	27.61	70.000	1.997	
	27.89	70.00	1.996	
	28.13	70.00	1.996	
	28.43	70.14	1.953	
	28.71	70.28	1.906	
	28.89	70.42	1.859	
	29.16	70.55	1.828	
	29.30	70.55	1.826	
	29.60	70.69	1.780	
	29.90	70.820	1.736	
	30.20	70.95	1.694	
	30.50	71.21	1.610	
	30.80	71.35	1.564	
	31.10	71.35	1.562	
	31.40	71.61	1.472	
	31.70	71.76	1.421	
	32.00	71.90	1.378	
	32.30	72.04	1.327	
	32.60	72.17	1.283	
15:25	32.92	72.33	1.233	

Table A.72. Cross section water surface data for 3:1stepped training walls q = 0.039 m^2/s.

Run #	24		recorder	RW		
Date	11/13/2007		BM-0 rd.	x=24.68	y=65.02	z=2.873
time	x ft	y ft	z ft	comments		
11:48	24.87	69.18	2.278			
	24.87	69.30	2.275			

	24.87	69.50	2.271	
	24.87	70.00	2.258	
	24.87	71.00	2.257	
	24.87	73.00	2.259	
	24.87	75.20	2.258	
	24.87	77.00	2.258	
	24.87	79.00	2.261	
	24.87	81.00	2.260	
	24.87	82.00	2.264	
11:52	24.87	82.36	2.276	
11:55	25.44	69.18	2.258	
	25.44	69.31	2.256	
	25.44	69.34	2.232	
	25.44	69.50	2.216	
	25.44	69.70	2.194	
	25.44	69.90	2.165	
	25.44	70.10	2.117	
	25.44	70.50	2.023	
	25.44	71.00	2.015	
	25.44	73.00	2.016	
	25.44	75.20	2.016	
	25.44	77.00	2.015	
	25.44	79.00	2.019	
	25.435	81.00	2.023	
	25.435	81.50	2.023	
	25.435	82.00	2.104	
12:03	25.435	82.23	2.147	
12:58	26.5	69.18	2.251	
	26.5	69.30	2.248	
	26.5	69.33	2.205	
	26.5	69.45	2.202	
	26.5	69.48	2.158	
	26.5	69.60	2.151	
	26.5	69.63	2.113	
	26.5	69.75	2.108	
	26.5	69.80	2.089	
	26.5	70.00	2.034	
	26.5	70.20	1.995	
	26.5	70.40	1.955	

	26.5	70.60	1.921	
	26.5	70.80	1.894	
	26.5	71.00	1.874	
	26.5	71.06	1.846	
	26.5	71.12	1.699	
	26.5	71.20	1.675	
	26.5	71.40	1.651	
	26.5	71.60	1.647	
	26.5	71.80	1.642	
	26.5	72.00	1.641	
	26.5	73.00	1.635	
	26.5	75.20	1.636	
	26.5	77.00	1.638	
	26.5	79.00	1.639	
	26.5	80.00	1.641	
	26.5	81.00	1.651	
	26.5	81.50	1.738	
	26.5	81.70	1.746	
13:16	26.5	81.81	1.755	
13:16	27.61	69.16	2.240	
	27.61	69.29	2.234	
	27.61	69.31	2.191	
	27.61	69.43	2.190	
	27.61	69.46	2.139	
	27.61	69.58	2.137	
	27.61	69.61	2.088	
	27.61	69.72	2.084	
	27.61	69.75	2.038	
	27.61	69.86	2.035	
	27.61	69.89	1.997	
	27.61	69.99	1.996	
	27.61	70.02	1.983	
	27.61	70.14	1.959	
	27.61	70.20	1.923	
	27.61	70.40	1.863	
	27.61	70.60	1.810	
	27.61	70.80	1.735	
	27.61	71.00	1.696	
	27.61	71.20	1.666	

	27.61	71.40	1.631	
	27.61	71.60	1.597	
	27.61	71.80	1.586	
	27.61	72.00	1.473	
	27.61	72.20	1.377	
	27.61	72.40	1.266	
	27.61	72.60	1.262	
	27.61	72.80	1.254	
	27.61	73.00	1.253	
	27.61	75.20	1.251	
	27.61	77.00	1.254	
	27.61	79.00	1.256	
	27.61	80.00	1.268	
	27.61	80.50	1.283	
	27.61	81	1.331	
13:38	27.61	81.45	1.392	
13:43	28.69	69.46	2.14	
	28.69	69.57	2.14	
	28.69	69.6	2.094	
	28.69	69.72	2.087	
	28.69	69.74	2.052	
	28.69	69.85	2.05	
	28.69	69.88	2.005	
	28.69	69.98	2.006	
	28.69	70	1.964	
	28.69	70.12	1.961	
	28.69	70.15	1.918	
	28.69	70.27	1.916	
	28.69	70.31	1.89	
	28.69	70.4	1.87	
	28.69	70.6	1.809	
	28.69	70.8	1.741	
	28.69	71	1.688	
	28.69	71.2	1.618	
	28.69	71.4	1.556	
	28.69	71.6	1.486	
	28.69	71.8	1.441	
	28.69	72	1.414	
	28.69	72.2	1.361	

	28.69	72.4	1.326	
	28.69	72.6	1.293	
	28.69	72.8	1.245	
	28.69	73	1.194	
	28.69	73.2	1.068	
	28.69	73.4	0.953	
	28.69	73.6	0.894	
	28.69	73.8	0.891	
	28.69	74	0.886	
	28.69	75.2	0.883	
	28.69	77	0.881	
	28.69	79	0.887	
	28.69	80	0.915	
	28.69	80.5	0.954	
	28.69	81	1.014	
14:04	28.69	81.12	1.03	
14:04	29.155	70.29	1.871	
	29.155	70.41	1.868	
	29.155	70.43	1.826	
	29.155	70.54	1.829	
	29.155	70.58	1.808	
	29.155	70.8	1.74	
	29.155	71	1.676	
	29.155	71.2	1.617	
	29.155	71.4	1.556	
	29.155	71.6	1.494	
	29.155	71.8	1.441	
	29.155	72	1.396	
	29.155	72.2	1.322	
	29.155	72.4	1.284	
	29.155	72.6	1.242	
	29.155	72.8	1.216	
	29.155	73	1.171	
	29.155	73.2	1.117	
	29.155	73.4	1.043	
	29.155	73.6	0.982	
	29.155	73.8	0.859	
	29.155	74	0.764	
	29.155	74.2	0.735	

	29.155	74.4	0.734	
	29.155	74.6	0.731	
	29.155	74.8	0.73	
	29.155	75	0.731	
	29.155	75.2	0.73	
	29.155	77	0.732	
	29.155	79	0.74	
	29.155	80	0.767	
	29.155	80.5	0.805	
14:18	29.155	80.97	0.872	

Table A.73. Centerline bed surface.

Bed data			recorder	RW		
			BM-0 rd.	x=24.68	y=65.02	z=2.873
	x ft	y ft	z ft	comments		
	23.84	75.21	1.922	Centerline		
	24.00	75.21	1.918			
	24.20	75.21	1.916			
	24.40	75.21	1.909			
	24.65	75.21	1.907			
	24.76	75.21	1.908			
	24.78	75.21	2.041			
	24.87	75.21	2.076	crest		
	25.10	75.21	2.016			
	25.30	75.21	1.952			
	25.42	75.21	1.916			
	25.55	75.21	1.868			
	25.70	75.21	1.819			
	25.83	75.21	1.774			
	25.97	75.21	1.729			
	26.11	75.21	1.684			
	26.25	75.21	1.639			
	26.39	75.21	1.591			
	26.52	75.21	1.545			
	26.65	75.21	1.499			

	26.79	75.21	1.455	
	26.93	75.21	1.408	
	27.06	75.21	1.362	
	27.20	75.21	1.316	
	27.34	75.21	1.269	
	27.47	75.21	1.223	
	27.62	75.21	1.178	
	27.75	75.21	1.133	
	27.89	75.21	1.089	
	28.04	75.21	1.041	
	28.16	75.21	0.995	
	28.30	75.21	0.951	
	28.43	75.21	0.904	
	28.57	75.21	0.858	
	28.71	75.21	0.811	
	28.85	75.21	0.765	
	28.98	75.21	0.718	
	29.13	75.21	0.668	
	29.16	75.21	0.622	
	29.30	75.21	0.624	
	29.60	75.21	0.626	
	29.90	75.21	0.627	
	30.21	75.21	0.632	

Table A.74. Cross section bed profiles for 1:1 smooth training walls.

Bed data			recorder	RW		
			BM-0 rd.	x=24.68	y=65.02	z=2.873
	x ft	y ft	z ft	comments		
	24.00	67.45	2.836			
	24.00	68.00	2.279			
	24.00	68.39	1.905	int		
	24.00	69.00	1.905			
	24.00	70.00	1.907			
	24.00	71.00	1.906			
	24.00	72.00	1.908			

	24.00	73.00	1.910	
	24.00	74.00	1.912	
	24.00	75.00	1.915	
	24.00	75.21	1.918	CL
	24.00	76.00	1.914	
	24.00	77.00	1.914	
	24.00	78.00	1.912	
	24.00	79.00	1.915	
	24.00	80.00	1.911	
	24.00	81.00	1.908	
	24.00	82.00	1.908	
	24.00	82.01	1.908	
	24.00	83.01	2.932	
	24.87	67.45	2.839	
	24.87	68.00	2.298	
	24.87	68.24	2.075	int
	24.87	69.00	2.075	
	24.87	70.00	2.076	
	24.87	71.00	2.076	
	24.87	72.00	2.076	
	24.87	73.00	2.077	
	24.87	74.00	2.075	
	24.87	75.00	2.075	
	24.87	75.21	2.075	CL
	24.87	76.00	2.077	
	24.87	77.00	2.078	
	24.87	78.00	2.077	
	24.87	79.00	2.078	
	24.87	80.00	2.078	
	24.87	81.00	2.077	
	24.87	82.00	2.076	
	24.87	82.16	2.076	int
	24.87	83.10	2.924	
	25.55	67.44	2.845	Step 1
	25.55	68.00	2.313	
	25.55	68.49	1.865	int
	25.55	69.00	1.868	
	25.55	70.00	1.867	
	25.55	71.00	1.867	

	25.55	72.00	1.869	
	25.55	73.00	1.868	
	25.55	74.00	1.868	
	25.55	75.00	1.868	
	25.55	75.21	1.867	cl
	25.55	76.00	1.869	
	25.55	78.00	1.870	
	25.55	79.00	1.871	
	25.55	80.00	1.871	
	25.55	81.00	1.873	
	25.55	81.95	1.869	int
	25.55	83.02	2.920	
	25.97	67.43	2.845	Step 4
	25.97	68.00	2.319	
	25.97	68.64	1.728	+
	25.97	69.00	1.727	
	25.97	70.00	1.726	
	25.97	71.00	1.727	
	25.97	72.00	1.728	
	25.97	73.00	1.729	
	25.97	74.00	1.729	
	25.97	75.00	1.729	
	25.97	75.21	1.729	cl
	25.97	76.00	1.728	
	25.97	77.00	1.729	
	25.97	78.00	1.729	
	25.97	79.00	1.728	
	25.97	80.00	1.733	
	25.97	81.00	1.730	
	25.97	81.79	1.728	
	25.97	82.00	1.925	
	25.97	83.01	2.927	
	26.50	67.44	2.839	Step 8
	26.50	68.00	2.312	
	26.50	68.82	1.546	+
	26.50	69.00	1.547	
	26.50	71.00	1.545	
	26.50	73.00	1.545	
	26.50	75.00	1.545	

	26.50	75.21	1.546	cl
	26.50	77.00	1.547	
	26.50	79.00	1.549	
	26.50	81.00	1.548	
	26.50	81.61	1.548	+
	26.50	82.00	1.928	
	26.50	83.01	2.915	
	27.05	67.42	2.845	12
	27.05	68.00	2.303	
	27.05	69.00	1.365	+
	27.05	71.00	1.362	
	27.05	73.00	1.360	
	27.05	75.00	1.364	
	27.05	75.21	1.364	
	27.05	77.00	1.364	
	27.05	79.00	1.368	
	27.05	81.00	1.365	
	27.05	81.43	1.366	
	27.05	83.01	2.915	
	27.61	67.42	2.850	16
	27.61	68.00	2.306	
	27.61	69.21	1.182	
	27.61	71.00	1.182	
	27.61	73.00	1.176	
	27.61	75.00	1.178	
	27.61	75.21	1.179	
	27.61	77.00	1.180	
	27.61	79.00	1.183	
	27.61	81.00	1.182	
	27.61	81.25	1.181	
	27.61	82.00	1.913	
	27.61	83.01	2.917	
	28.15	67.42	2.859	20
	28.15	68.00	2.305	
	28.15	69.00	1.357	
	28.15	69.37	0.997	
	28.15	71.00	0.997	
	28.15	73.00	0.993	
	28.15	75.00	0.996	

	28.15	75.21	0.996	
	28.15	77.00	0.996	
	28.15	79.00	0.999	
	28.15	81.08	0.996	
	28.15	82.00	1.903	
	28.15	83.01	2.920	
	28.69	67.41	2.859	24
	28.69	68.00	2.302	
	28.69	69.00	1.337	
	28.69	69.54	0.813	
	28.69	71.00	0.812	
	28.69	73.00	0.811	
	28.69	75.00	0.812	
	28.69	75.21	0.812	
	28.69	77.00	0.813	
	28.69	79.00	0.815	
	28.69	80.92	0.814	
	28.69	82.00	1.900	
	28.69	83.01	2.911	
	29.115	67.41	2.858	27
	29.115	68.00	2.295	
	29.115	69.00	1.322	
	29.115	69.68	0.674	
	29.115	71.00	0.675	
	29.115	73.00	0.668	
	29.115	75.00	0.667	
	29.115	75.21	0.668	
	29.115	77.00	0.671	
	29.115	79.00	0.670	
	29.115	80.79	0.671	
	29.115	82.00	1.892	
	29.115	83.01	2.914	

Table A.75. Cross section bed profiles for 1:1 stepped training walls.

Bed data			recorder	RW		
			BM-0 rd.	x=24.68	y=65.02	z=2.873
	x	y	z			comment

	ft	ft	ft	s
	24.87	67.50	2.780	
	24.87	67.55	2.781	
	24.87	67.60	2.737	
	24.87	67.64	2.698	
	24.87	67.69	2.645	
	24.87	67.74	2.601	
	24.87	67.78	2.556	
	24.87	67.83	2.515	
	24.87	67.88	2.467	
	24.87	67.92	2.422	
	24.87	67.97	2.376	
	24.87	68.02	2.334	
	24.87	68.06	2.289	
	24.87	68.11	2.245	
	24.87	68.16	2.194	
	24.87	68.22	2.147	
	24.87	68.26	2.096	
	24.87	68.28	2.078	
	24.87	68.50	2.077	
	24.87	69.00	2.078	
	24.87	75.20	2.078	
	25.44	68.03	2.287	
	25.44	68.10	2.273	
	25.44	68.20	2.251	
	25.44	68.30	2.228	
	25.44	68.40	2.205	
	25.44	68.50	2.176	
	25.44	68.60	2.155	
	25.44	69.00	2.120	
	25.44	71.00	2.116	
	25.44	73.00	2.115	
	25.44	75.20	2.116	
	25.44	77.00	2.114	
	25.44	79.00	2.115	
	25.44	81.00	2.117	
	25.44	81.50	2.125	
	25.44	81.60	2.132	
	25.44	81.70	2.143	

	25.44	81.80	2.155	
	25.44	81.90	2.178	
	25.44	82.00	2.202	
	25.44	82.10	2.229	
	25.44	82.20	2.248	
	25.44	82.37	2.282	
	26.50	68.45	1.897	
	26.50	68.60	1.873	
	26.50	68.70	1.861	
	26.50	68.80	1.858	
	26.50	68.93	1.851	
	26.50	69.05	1.796	
	26.50	69.20	1.755	
	26.50	70.00	1.710	
	26.50	73.00	1.702	
	26.50	75.20	1.703	
	26.50	77.00	1.700	
	26.50	79.00	1.701	
	26.50	81.00	1.723	
	26.50	81.38	1.790	
	26.50	81.49	1.853	
	26.50	81.60	1.867	
	26.50	81.70	1.875	
	26.50	81.80	1.880	
	26.50	81.99	1.918	
	27.61	68.85	1.505	
	27.61	69.00	1.489	
	27.61	69.10	1.481	
	27.61	69.20	1.474	
	27.61	69.43	1.482	
	27.61	69.53	1.414	
	27.61	69.60	1.393	
	27.61	69.70	1.373	
	27.61	70.00	1.350	
	27.61	73.00	1.304	
	27.61	75.20	1.305	
	27.61	77.00	1.306	
	27.61	79.00	1.309	
	27.61	80.00	1.323	
	27.61	80.70	1.360	

	27.61	80.93	1.398	
	27.61	81.00	1.477	
	27.61	81.20	1.469	
	27.61	81.60	1.518	
	28.69	69.21	1.139	
	28.69	69.40	1.109	
	28.69	69.61	1.096	
	28.69	69.85	1.085	
	28.69	69.93	1.048	
	28.69	70.10	1.024	
	28.69	73.00	0.941	
	28.69	75.20	0.940	
	28.69	77.00	0.938	
	28.69	80.00	0.986	
	28.69	80.46	1.039	
	28.69	80.67	1.098	
	28.69	80.84	1.094	
	28.69	81.00	1.107	
	28.69	81.27	1.162	
	29.115	69.34	0.995	
	29.115	69.50	0.973	
	29.115	69.73	0.959	
	29.115	69.84	0.94	
	29.115	70.09	0.914	
	29.115	70.2	0.901	
	29.115	70.3	0.895	
	29.115	71	0.844	
	29.115	73	0.796	
	29.115	75.2	0.8	
	29.115	79	0.815	
	29.115	80.2	0.889	
	29.115	80.37	0.915	
	29.115	80.55	0.932	
	29.115	80.8	0.964	
	29.115	81	0.98	
	29.115	81.125	1.011	

Table A.76. Cross section bed profiles for 2:1 smooth training walls.

Bed data			recorder	RW		
			BM-0 rd.	x=24.68	y=65.02	z=2.873
	x ft	y ft	z ft	comments		
	24.87	68.00	2.637			
	24.87	68.30	2.479			
	24.87	68.41	2.377			
	24.87	68.60	2.302			
	24.87	68.80	2.227			
	24.87	69.00	2.126			
	24.87	69.10	2.075			
	24.87	70.00	2.075			
	24.87	69.10	2.075			
	24.87	69.50	2.076			
	24.87	70.00	2.075			
	24.87	71.00	2.076			
	24.87	72.00	2.076			
	24.87	73.00	2.077			
	24.87	74.00	2.075			
	24.87	75.00	2.075			
	24.87	75.21	2.075			
	24.87	76.00	2.077			
	24.87	77.00	2.078			
	24.87	78.00	2.077			
	24.87	79.00	2.078			
	24.87	80.00	2.078			
	24.87	81.00	2.077			
	24.87	82.00	2.076			
	24.87	82.16	2.076			
	24.87	83.10	2.924			
	25.44	68.20	2.525			
	25.44	68.30	2.495			
	25.44	68.50	2.324			
	25.44	68.61	2.271			
	25.44	68.80	2.210			
	25.44	69.00	2.109			
	25.44	69.20	2.025			
	25.44	69.30	1.974			

	25.44	69.40	1.924	
	25.44	69.51	1.869	
	25.44	70.00	1.867	
	25.44	71.00	1.867	
	25.44	72.00	1.869	
	25.44	73.00	1.868	
	25.44	74.00	1.868	
	25.44	75.00	1.868	
	25.44	75.21	1.867	
	25.44	76.00	1.869	
	25.44	78.00	1.870	
	25.44	79.00	1.871	
	25.44	80.00	1.871	
	25.44	81.00	1.873	
	25.44	81.95	1.869	
	25.44	83.02	2.920	
	26.50	68.20	2.525	
	26.50	68.80	2.210	
	26.50	69.09	2.043	
	26.50	69.20	2.025	
	26.50	69.40	1.924	
	26.50	69.80	1.722	
	26.50	70.15	1.545	
	26.50	71.00	1.545	
	26.50	73.00	1.545	
	26.50	75.00	1.545	
	26.50	75.21	1.546	
	26.50	77.00	1.547	
	26.50	79.00	1.549	
	26.50	81.00	1.548	
	26.50	81.61	1.548	
	26.50	82.00	1.928	
	26.50	83.01	2.915	
	27.61	68.20	2.525	
	27.61	68.40	2.428	
	27.61	68.60	2.327	
	27.61	69.20	2.043	
	27.61	69.78	1.693	
	27.61	70.50	1.369	

	27.61	71.00	1.182	
	27.61	73.00	1.176	
	27.61	75.00	1.178	
	27.61	75.21	1.179	
	27.61	77.00	1.180	
	27.61	79.00	1.183	
	27.61	81.00	1.182	
	27.61	81.25	1.181	
	27.61	82.00	1.913	
	27.61	83.01	2.917	
	28.69	68.20	2.525	
	28.69	68.40	2.428	
	28.69	68.60	2.327	
	28.69	69.20	2.043	
	28.69	69.78	1.693	
	28.69	70.40	1.387	
	28.69	71.00	1.116	
	28.69	71.60	0.812	
	28.69	73.00	0.811	
	28.69	75.00	0.812	
	28.69	75.21	0.812	
	28.69	77.00	0.813	
	28.69	79.00	0.815	
	28.69	80.92	0.814	
	28.69	82.00	1.9	
	28.69	83.01	2.911	
	29.115	68.20	2.525	
	29.115	68.60	2.327	
	29.115	69.20	2.043	
	29.115	69.78	1.693	
	29.115	70.40	1.387	
	29.115	71.00	1.116	
	29.115	71.50	0.864	
	29.115	71.89	0.667	
	29.115	73.00	0.668	
	29.115	75.00	0.667	
	29.115	75.21	0.668	
	29.115	77.00	0.671	
	29.115	79.00	0.67	

	29.115	80.79	0.671	
	29.115	82.00	1.892	
	29.115	83.01	2.914	

Table A.77. Cross section bed profiles for 2:1 stepped training walls.

Bed data			recorder	RW		
			BM-0 rd.	x=24.68	y=65.02	z=2.873
	x ft	y ft	z ft	comments		
	24.87	68.31	2.462			
	24.87	68.40	2.415			
	24.87	68.50	2.372			
	24.87	68.59	2.319			
	24.87	68.69	2.285			
	24.87	68.77	2.239			
	24.87	68.87	2.197			
	24.87	68.95	2.153			
	24.87	69.05	2.108			
	24.87	69.14	2.075			
	24.87	70.00	2.075			
	24.87	69.10	2.075			
	24.87	69.50	2.076			
	24.87	70.00	2.075			
	24.87	71.00	2.076			
	24.87	72.00	2.076			
	24.87	73.00	2.077			
	24.87	74.00	2.075			
	24.87	75.00	2.075			
	24.87	75.21	2.075			
	24.87	76.00	2.077			
	24.87	77.00	2.078			
	24.87	78.00	2.077			
	24.87	79.00	2.078			
	24.87	80.00	2.078			
	24.87	81.00	2.077			
	24.87	82.00	2.076			
	24.87	82.16	2.076			

	24.87	83.10	2.924	
	25.44	68.31	2.462	
	25.44	68.40	2.415	
	25.44	68.50	2.372	
	25.44	68.59	2.319	
	25.44	68.69	2.285	
	25.44	68.77	2.239	
	25.44	68.87	2.197	
	25.44	68.95	2.153	
	25.44	69.05	2.108	
	25.44	69.14	2.062	
	25.44	69.25	2.027	
	25.44	69.32	1.974	
	25.44	69.42	1.922	
	25.44	69.51	1.869	
	25.44	70.00	1.867	
	25.44	71.00	1.867	
	25.44	72.00	1.869	
	25.44	73.00	1.868	
	25.44	74.00	1.868	
	25.44	75.00	1.868	
	25.44	75.21	1.867	
	25.44	76.00	1.869	
	25.44	78.00	1.870	
	25.44	79.00	1.871	
	25.44	80.00	1.871	
	25.44	81.00	1.873	
	25.44	81.95	1.869	
	25.44	83.02	2.920	
	26.50	68.31	2.462	
	26.50	68.40	2.415	
	26.50	68.50	2.372	
	26.50	68.59	2.319	
	26.50	68.69	2.285	
	26.50	68.77	2.239	
	26.50	68.87	2.197	
	26.50	68.95	2.153	
	26.50	69.05	2.108	
	26.50	69.14	2.062	
	26.50	69.25	2.027	

	26.50	69.32	1.974	
	26.50	69.42	1.922	
	26.50	69.51	1.877	
	26.50	69.61	1.830	
	26.50	69.71	1.778	
	26.50	69.80	1.733	
	26.50	69.89	1.687	
	26.50	69.99	1.636	
	26.50	70.07	1.605	
	26.50	70.15	1.545	
	26.50	71.00	1.545	
	26.50	73.00	1.545	
	26.50	75.00	1.545	
	26.50	75.21	1.546	
	26.50	77.00	1.547	
	26.50	79.00	1.549	
	26.50	81.00	1.548	
	26.50	81.61	1.548	
	26.50	82.00	1.928	
	26.50	83.01	2.915	
	27.61	68.31	2.462	
	27.61	68.40	2.415	
	27.61	68.50	2.372	
	27.61	68.59	2.319	
	27.61	68.69	2.285	
	27.61	68.77	2.239	
	27.61	68.87	2.197	
	27.61	68.95	2.153	
	27.61	69.05	2.108	
	27.61	69.14	2.062	
	27.61	69.25	2.027	
	27.61	69.32	1.974	
	27.61	69.42	1.922	
	27.61	69.51	1.877	
	27.61	69.61	1.830	
	27.61	69.71	1.778	
	27.61	69.80	1.733	
	27.61	69.89	1.687	
	27.61	69.99	1.636	
	27.61	70.07	1.605	

	27.61	70.15	1.554	
	27.61	70.25	1.510	
	27.61	70.35	1.464	
	27.61	70.44	1.412	
	27.61	70.54	1.367	
	27.61	70.63	1.320	
	27.61	70.72	1.269	
	27.61	70.82	1.232	
	27.61	70.90	1.186	
	27.61	71.00	1.179	
	27.61	73.00	1.176	
	27.61	75.00	1.178	
	27.61	75.21	1.179	
	27.61	77.00	1.180	
	27.61	79.00	1.183	
	27.61	81.00	1.182	
	27.61	81.25	1.181	
	27.61	82.00	1.913	
	27.61	83.01	2.917	
	28.69	68.31	2.462	
	28.69	68.40	2.415	
	28.69	68.50	2.372	
	28.69	68.59	2.319	
	28.69	68.69	2.285	
	28.69	68.77	2.239	
	28.69	68.87	2.197	
	28.69	68.95	2.153	
	28.69	69.05	2.108	
	28.69	69.14	2.062	
	28.69	69.25	2.027	
	28.69	69.32	1.974	
	28.69	69.42	1.922	
	28.69	69.51	1.877	
	28.69	69.61	1.830	
	28.69	69.71	1.778	
	28.69	69.80	1.733	
	28.69	69.89	1.687	
	28.69	69.99	1.636	
	28.69	70.07	1.605	
	28.69	70.15	1.554	

	28.69	70.25	1.510	
	28.69	70.35	1.464	
	28.69	70.44	1.412	
	28.69	70.54	1.367	
	28.69	70.63	1.320	
	28.69	70.72	1.269	
	28.69	70.82	1.232	
	28.69	70.90	1.186	
	28.69	70.99	1.139	
	28.69	71.08	1.094	
	28.69	71.17	1.050	
	28.69	71.27	1.000	
	28.69	71.36	0.951	
	28.69	71.47	0.901	
	28.69	71.55	0.853	
	28.69	71.60	0.812	
	28.69	73.00	0.811	
	28.69	75.00	0.812	
	28.69	75.21	0.812	
	28.69	77.00	0.813	
	28.69	79.00	0.815	
	28.69	80.92	0.814	
	28.69	82.00	1.900	
	28.69	83.01	2.911	
	29.115	68.31	2.462	
	29.115	68.40	2.415	
	29.115	68.50	2.372	
	29.115	68.59	2.319	
	29.115	68.69	2.285	
	29.115	68.77	2.239	
	29.115	68.87	2.197	
	29.115	68.95	2.153	
	29.115	69.05	2.108	
	29.115	69.14	2.062	
	29.115	69.25	2.027	
	29.115	69.32	1.974	
	29.115	69.42	1.922	
	29.115	69.51	1.877	
	29.115	69.61	1.830	
	29.115	69.71	1.778	

	29.115	69.80	1.733	
	29.115	69.89	1.687	
	29.115	69.99	1.636	
	29.115	70.07	1.605	
	29.115	70.15	1.554	
	29.115	70.25	1.510	
	29.115	70.35	1.464	
	29.115	70.44	1.412	
	29.115	70.54	1.367	
	29.115	70.63	1.320	
	29.115	70.72	1.269	
	29.115	70.82	1.232	
	29.115	70.90	1.186	
	29.115	70.99	1.139	
	29.115	71.08	1.094	
	29.115	71.17	1.050	
	29.115	71.27	1.000	
	29.115	71.36	0.951	
	29.115	71.47	0.901	
	29.115	71.55	0.853	
	29.115	71.65	0.807	
	29.115	71.74	0.768	
	29.115	71.81	0.723	
	29.115	71.91	0.675	
	29.115	73.00	0.668	
	29.115	75.00	0.667	
	29.115	75.21	0.668	
	29.115	77.00	0.671	
	29.115	79.00	0.670	
	29.115	80.79	0.671	
	29.115	82.00	1.892	
	29.115	83.01	2.914	

Table A.78. Cross section bed profiles for 3:1 smooth training walls.

Bed data			recorder	RW		
			BM-0 rd.	x=24.68	y=65.02	z=2.873
	x ft	y ft	z ft	comments		
	24.87	68.00	2.637			

	24.87	68.30	2.530	
	24.87	68.41	2.492	
	24.87	68.60	2.427	
	24.87	68.80	2.358	
	24.87	69.00	2.289	
	24.87	69.50	2.117	
	24.87	69.62	2.076	
	24.87	70.00	2.075	
	24.87	71.00	2.076	
	24.87	72.00	2.076	
	24.87	73.00	2.077	
	24.87	74.00	2.075	
	24.87	75.00	2.075	
	24.87	75.21	2.075	
	24.87	76.00	2.077	
	24.87	77.00	2.078	
	24.87	78.00	2.077	
	24.87	79.00	2.078	
	24.87	80.00	2.078	
	24.87	81.00	2.077	
	24.87	82.00	2.076	
	24.87	82.16	2.076	
	24.87	83.10	2.924	
	25.44	68.20	2.565	
	25.44	68.30	2.530	
	25.44	68.50	2.461	
	25.44	68.80	2.358	
	25.44	69.00	2.289	
	25.44	69.20	2.221	
	25.44	69.40	2.152	
	25.44	69.51	2.114	
	25.44	70.00	1.946	
	25.44	70.22	1.869	
	25.44	72.00	1.869	
	25.44	73.00	1.868	
	25.44	74.00	1.868	
	25.44	75.00	1.868	
	25.44	75.21	1.867	
	25.44	76.00	1.869	
	25.44	78.00	1.870	

	25.44	79.00	1.871	
	25.44	80.00	1.871	
	25.44	81.00	1.873	
	25.44	81.95	1.869	
	25.44	83.02	2.920	
	26.5	68.20	2.565	
	26.5	68.60	2.427	
	26.5	69.00	2.289	
	26.5	69.20	2.221	
	26.5	69.40	2.152	
	26.5	69.80	2.014	
	26.5	70.00	1.946	
	26.5	71.00	1.602	
	26.5	71.16	1.547	
	26.5	73.00	1.545	
	26.5	75.00	1.545	
	26.5	75.21	1.546	
	26.5	77.00	1.547	
	26.5	79.00	1.549	
	26.5	81.00	1.548	
	26.5	81.61	1.548	
	26.5	82.00	1.928	
	26.5	83.01	2.915	
	27.61	68.20	2.565	
	27.61	68.40	2.496	
	27.61	68.60	2.427	
	27.61	69.20	2.221	
	27.61	69.78	2.021	
	27.61	70.50	1.774	
	27.61	71.00	1.602	
	27.61	72.00	1.258	
	27.61	72.23	1.178	
	27.61	73.00	1.176	
	27.61	75.00	1.178	
	27.61	75.21	1.179	
	27.61	77.00	1.180	
	27.61	79.00	1.183	
	27.61	81.00	1.182	
	27.61	81.25	1.181	
	27.61	82.00	1.913	

	27.61	83.01	2.917	
	28.69	68.20	2.565	
	28.69	68.40	2.496	
	28.69	68.60	2.427	
	28.69	69.20	2.221	
	28.69	69.80	2.014	
	28.69	70.40	1.808	
	28.69	71.00	1.602	
	28.69	72.00	1.258	
	28.69	73.00	0.914	
	28.69	73.29	0.814	
	28.69	74.00	0.812	
	28.69	75.00	0.812	
	28.69	75.21	0.812	
	28.69	77.00	0.813	
	28.69	79.00	0.815	
	28.69	80.92	0.814	
	28.69	82.00	1.900	
	28.69	83.01	2.911	
	29.115	68.20	2.565	
	29.115	68.60	2.427	
	29.115	69.20	2.221	
	29.115	69.78	2.021	
	29.115	70.40	1.808	
	29.115	71.00	1.602	
	29.115	72.00	1.258	
	29.115	73.00	0.914	
	29.115	73.71	0.669	
	29.115	74.00	0.668	
	29.115	75.00	0.667	
	29.115	75.21	0.668	
	29.115	77.00	0.671	
	29.115	79.00	0.670	
	29.115	80.79	0.671	
	29.115	82.00	1.892	
	29.115	83.01	2.914	

Table A.78. Cross section bed profiles for 3:1 stepped training walls.

Bed data			recorder	RW		
			BM-0 rd.	x=24.68	y=65.02	z=2.873
	x ft	y ft	z ft	comments		
	24.87	68.72	2.436			
	24.87	68.87	2.388			
	24.87	69.02	2.342			
	24.87	69.16	2.295			
	24.87	69.31	2.245			
	24.87	69.46	2.198			
	24.87	69.60	2.147			
	24.87	69.74	2.108			
	25.44	68.72	2.436			
	25.44	68.87	2.389			
	25.44	69.02	2.342			
	25.44	69.16	2.296			
	25.44	69.31	2.246			
	25.44	69.46	2.198			
	25.44	69.60	2.150			
	25.44	69.75	2.103			
	25.44	69.89	2.051			
	25.44	70.02	2.011			
	25.44	70.16	1.968			
	25.44	70.29	1.925			
	26.5	68.72	2.432			
	26.5	68.87	2.383			
	26.5	69.02	2.335			
	26.5	69.16	2.290			
	26.5	69.31	2.238			
	26.5	69.45	2.194			
	26.5	69.60	2.144			
	26.5	69.75	2.099			
	26.5	69.89	2.046			
	26.5	70.02	2.001			
	26.5	70.15	1.955			
	26.5	70.29	1.911			
	26.5	70.43	1.811			
	26.5	70.57	1.818			
	26.5	70.70	1.771			
	26.5	70.83	1.722			

	26.5	70.96	1.685	
	26.5	71.07	1.641	
	26.5	71.20	1.600	
	27.61	68.71	2.421	
	27.61	68.86	2.377	
	27.61	69.01	2.322	
	27.61	69.15	2.276	
	27.61	69.30	2.225	
	27.61	69.44	2.177	
	27.61	69.59	2.125	
	27.61	69.74	2.075	
	27.61	69.89	2.027	
	27.61	70.00	1.985	
	27.61	70.14	1.940	
	27.61	70.28	1.890	
	27.61	70.42	1.839	
	27.61	70.56	1.794	
	27.61	70.69	1.746	
	27.61	70.82	1.698	
	27.61	70.95	1.657	
	27.61	71.07	1.613	
	27.61	71.20	1.570	
	27.61	71.33	1.525	
	27.61	71.46	1.484	
	27.61	71.58	1.446	
	27.61	71.71	1.401	
	27.61	71.84	1.357	
	27.61	71.95	1.308	
	27.61	72.07	1.265	
	27.61	72.19	1.219	
	28.69	68.71	2.423	
	28.69	68.85	2.375	
	28.69	69.00	2.325	
	28.69	69.14	2.279	
	28.69	69.28	2.228	
	28.69	69.44	2.181	
	28.69	69.58	2.127	
	28.69	69.72	2.081	
	28.69	69.86	2.036	
	28.69	69.99	1.994	

	28.69	70.13	1.944	
	28.69	70.27	1.897	
	28.69	70.41	1.848	
	28.69	70.55	1.805	
	28.69	70.69	1.755	
	28.69	70.82	1.708	
	28.69	70.94	1.666	
	28.69	71.07	1.622	
	28.69	71.21	1.578	
	28.69	71.34	1.531	
	28.69	71.47	1.489	
	28.69	71.59	1.444	
	28.69	71.73	1.405	
	28.69	71.86	1.359	
	28.69	71.98	1.318	
	28.69	72.10	1.276	
	28.69	72.22	1.227	
	28.69	72.36	1.183	
	28.69	72.49	1.142	
	28.69	72.62	1.101	
	28.69	72.77	1.053	
	28.69	72.89	1.006	
	28.69	73.04	0.956	
	28.69	73.19	0.903	
	28.69	73.33	0.856	
	29.115	68.71	2.425	
	29.115	68.85	2.377	
	29.115	69.00	2.328	
	29.115	69.14	2.282	
	29.115	69.28	2.232	
	29.115	69.44	2.182	
	29.115	69.58	2.134	
	29.115	69.72	2.087	
	29.115	69.86	2.043	
	29.115	69.99	1.999	
	29.115	70.13	1.950	
	29.115	70.28	1.903	
	29.115	70.41	1.855	
	29.115	70.55	1.812	
	29.115	70.69	1.762	

	29.115	70.82	1.715	
	29.115	70.94	1.672	
	29.115	71.07	1.631	
	29.115	71.21	1.586	
	29.115	71.34	1.54	
	29.115	71.47	1.495	
	29.115	71.60	1.452	
	29.115	71.73	1.413	
	29.115	71.86	1.367	
	29.115	71.99	1.328	
	29.115	72.11	1.283	
	29.115	72.23	1.237	
	29.115	72.38	1.19	
	29.115	72.50	1.149	
	29.115	72.64	1.109	
	29.115	72.78	1.061	
	29.115	72.91	1.014	
	29.115	73.06	0.965	
	29.115	73.20	0.913	
	29.115	73.34	0.866	
	29.115	73.48	0.817	
	29.115	73.64	0.766	
	29.115	73.77	0.721	
	29.115	73.93	0.668	

VITA

Ryan William Woolbright

Candidate for the Degree of

Master of Science

Thesis: HYDRAULIC PERFORMANCE EVALUATION OF RCC STEPPED SPILLWAYS WITH SLOPED CONVERGING TRAINING WALLS

Major Field: Biosystems Engineering

Biographical:

Personal Data: Born in Lawton, Oklahoma on May 1, 1983, the son of Randy and Dianna Woolbright.

Education: Graduate of Altus High School, Altus, Oklahoma in 2002; received Bachelor of Science degree in Biosystems Engineering from Oklahoma State University, Stillwater, Oklahoma in 2006. Completed the requirements for the Master of Science in Biosystems Engineering at Oklahoma State University, Stillwater, Oklahoma in December, 2008.

Experience: Graduate Research Assistant for the Oklahoma State University Biosystems and Agricultural Engineering Department, January, 2007 to present. Research Assistant for the USDA-ARS Hydraulic Engineering Research Unit, May, 2006 to August, 2006. Teaching Assistant for Oklahoma State University Biosystems and Agricultural Engineering Department, August, 2005 to May, 2007.

Professional Memberships: Oklahoma State Board of Registration for Professional Engineers and Land Surveyors, certified Engineer Intern (EI No. 13661), Alpha Epsilon Agricultural Engineering Honor Society, American Society of Agricultural and Biological Engineers, Association of State Dam Safety Officials.

Name: Ryan William Woolbright Date of Degree: December, 2008

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: HYDRAULIC PERFORMANCE EVALUATION OF RCC STEPPED SPILLWAYS WITH SLOPED CONVERGING TRAINING WALLS

Pages in Study: 226 Candidate for the Degree of Master of Science

Major Field: Biosystems Engineering

Scope and Method of Study: A three-dimensional, physical model study based on Froude number scaling was utilized to conduct an investigation of sloped training wall convergence on 3:1 stepped spillway chutes including flow patterns and run-up for stepped and smooth sloped training walls. Flow measurements were taken with an air-water differential manometer and orifice plates. Water surface data was measured with a point gage. Data were evaluated and used to determine relationships for stepped and smooth sloped training wall dimensions on a 3:1 stepped spillway chute.

Findings and Conclusions: Generalized relationships were developed for converging stepped and smooth sloped training walls on a 3:1 RCC stepped spillway chute. Visual observations and measured data show that the stepped training walls cause a significant secondary flow that results in a greater run-up height than is observed in the smooth wall condition. Stepped training walls would need to be significantly larger than smooth sloped training walls at the same convergence. Also, small vertical deflector walls may be needed to contain the minor tertiary flow that was observed on the converging stepped training walls. Relationships for stepped and smooth sloped training wall dimensions were developed in Chapter II and Chapter III, respectively. Theoretical equations for vertical training walls were investigated as a possible solution to predicting run-up height for smooth sloped training walls but were shown to be insufficient. The relationships developed in this study should not be used for training wall slopes greater than 3:1 without further testing. Results are expected to assist in the development of generalized equations for smooth sloped converging training walls

ADVISER'S APPROVAL: Dr. Gregory J. Hanson