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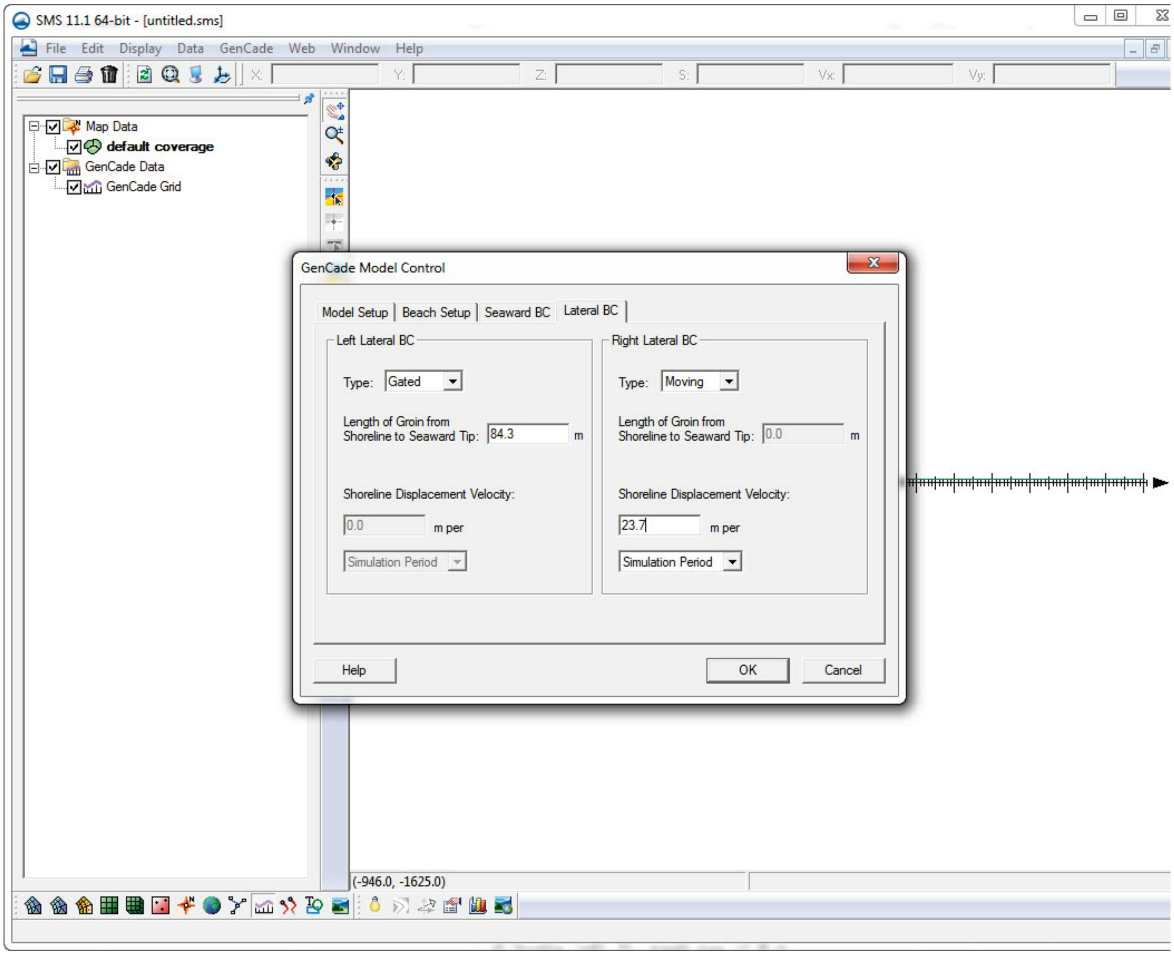
Coastal Inlets Research Program

GenCade Lateral Boundary Conditions

David B. King, Jr.

January 2017



GenCade Model Control

Left Lateral BC

Type: Gated

Length of Groin from Shoreline to Seaward Tip: 84.3 m

Shoreline Displacement Velocity: 0.0 m per Simulation Period

Right Lateral BC

Type: Moving

Length of Groin from Shoreline to Seaward Tip: 0.0 m

Shoreline Displacement Velocity: 23.7 m per Simulation Period

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Final report

Prepared for U.S. Army Corps of Engineers
Washington, DC 20314-1000

Under Project 462583, "Inlet Engineering Toolbox"

Abstract

This report provides detailed guidance on the use of Lateral Boundary Conditions (LBCs) within the shoreline change model GenCade. LBCs are a requirement for every model setup. The report focuses on two topics. First, it provides explicit guidance on how to set up the three types of LBCs (Pinned, Moving, and Gated) beyond that provided in previous reports. In particular, it provides detailed instructions on the set up and calibration of the Gated LBC. Second, the report discusses how LBC-induced errors can affect model results, both at the ends of the grid where the LBCs are applied and in the interior of the model. This report is one of a series whose intent is to provide detailed guidance to the GenCade model user.

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Preface

This study was sponsored by the Coastal Inlets Research Program (CIRP), whose program manager is Dr. Julie Rosati. The Project Number is 462583, “Inlet Engineering Toolbox.” The CIRP is funded by the Operation and Maintenance (O&M) Navigation business line of the Headquarters, U.S. Army Corps of Engineers (HQUSACE), and is administered by the U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), Vicksburg, MS, under the Navigation Program of HQUSACE. Jeffrey A. McKee is HQUSACE Navigation Business Line Manager overseeing the CIRP, and W. Jeff Lillycrop, CHL, is the ERDC Technical Director for Navigation.

Technical reviews and discussions of this report were provided by Mark Gravens, Dr. Sung-Chan Kim, Dr. Julie Rosati, and Dr. Richard Styles of ERDC-CHL and Sophie Munger of Blue Science Consultants, LLC. At the time of publication, oversight and guidance of this work was provided by Ashley Frey, Chief of Coastal Processes Branch.

Jeffrey R. Eckstein was Deputy Director of CHL, and José E. Sánchez was Director of CHL.

COL Bryan S. Green was ERDC Commander. Dr. Jeffery P. Holland was ERDC Director.

Unit Conversion Factors

Multiply	By	To Obtain
cubic yards	0.7645549	cubic meters
degrees (angle)	0.01745329	radians
feet	0.3048	meters
miles (nautical)	1,852	meters
miles (U.S. statute)	1,609.347	meters
miles per hour	0.44704	meters per second
square feet	0.09290304	square meters
square miles	2.589998 E+06	square meters
square yards	0.8361274	square meters
yards	0.9144	meters

1 Introduction

1.1 Background

GenCade (and its predecessor, GENESIS) is a numerical model whose primary purpose is to predict longshore transport along a beach and the resulting changes in shoreline position. GenCade is designed as a planning tool to help investigate issues that occur along beaches, to evaluate alternative remedial efforts, and to help optimize management strategies. This report is one of a series that provide guidance to the numerical modeler in setting up and running GenCade. Two prior guidance documents, Frey et al. (2012) and Frey et al. (2014), provide broad guidance on all major aspects of the model operation and should be consulted for background information that is not repeated here.

1.2 Objective

This Coastal and Hydraulics Laboratory technical report focuses on one aspect of the GenCade model, the lateral boundary conditions (LBCs). The model formulation requires the modeler to specify a boundary condition at each end of the model grid, which constrains the model behavior at those locations. There are three types of LBCs that may be applied: Pinned, Moving, and Gated. The type chosen for one end of the model domain puts no constraints on the type chosen for the other end; any combination pair is permissible. This report provides detailed guidance on how to set up all three types of LBCs within GenCade. The report also provides the modeler with the methodology to assess the impacts of the LBCs on the interior of the GenCade grid.

1.3 Approach

This report is organized into six chapters. Chapter 1 presents the purpose of the report, introduces the three types of LBCs, provides an overview of the model operation, presents a brief description of the way that information, in the form of shoreline position, is passed from cell to cell along the grid, and explains why LBCs are required for a model solution. Chapter 2 provides details of how LBCs are set up in GenCade. Chapter 3 discusses the Pinned and Moving LBCs, describes how the model implements them, and provides guidance on when they should be used. Chapter 3 also discusses the impacts of source and sink terms when they are applied to terminal cells which are configured with Pinned or Moving LBCs.

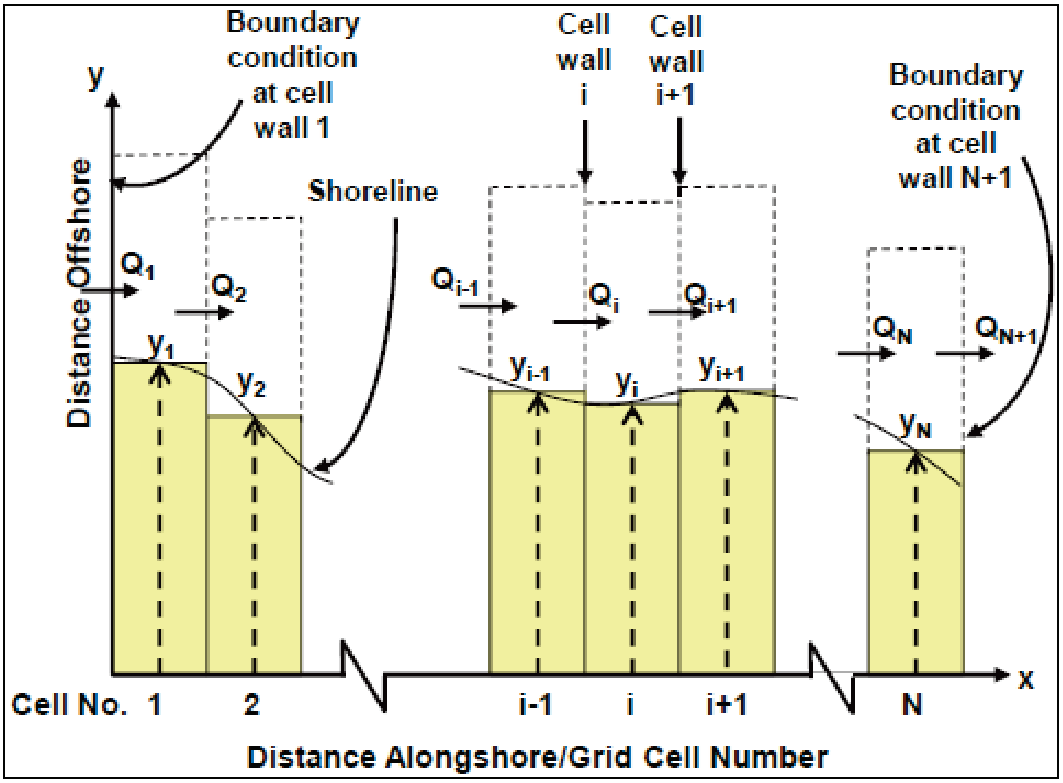
Chapter 4 describes the Gated LBC in detail, including how it functions, when it should be used, and how it should be set up and calibrated. Included are discussions of how the required parameters interact, what the shoreline effects are when adjusting the values during model calibration, and how to set the parameters to match specific shoreline configurations. Chapter 5 describes the extent of the influence that the choice of LBCs has on the shoreline behavior in the interior of the model domain and how to estimate the extent of their impact. Chapter 6 summarizes the report.

1.4 GenCade stepwise operation and model requirement for Lateral Boundary Conditions (LBCs)

The following is a brief review of GenCade's stepwise operation (Frey et al. (2012, 7–16). GenCade grids are one-dimensional (1D), having a series of adjacent cells running along a length of beach that covers the full extent of the study area (Figure 1) and frequently beyond. The grid is oriented as for a person standing on the beach facing offshore, with the leftmost cell numbered as 1 and the rightmost numbered as *N*. Cell walls are also numbered, with the leftmost being 1 and the rightmost being *N+1*. Thus, the left LBC is applied at Cell Wall 1 and the right LBC at Cell Wall *N+1*. LBCs are the rules used by the model to specify the sediment transport onto and off of each end of the grid.

To determine the shoreline position of cell *i* at time-step "*j+1,*" (Figure 1) GenCade calculates the (±) net transport into the cell based upon known shoreline positions and known forcing conditions at time-step "*j*." This involves calculating the sediment transport across Cell Walls "*i*" and "*i+1*" [denoted as "*Q(i,j)*" and "*Q(i+1,j)*"] (plus adding in the user-defined sources and sinks at cell "*i,*" which are here assumed zero for convenience). The calculation of "*Q(i,j),*" the sediment transport across Cell Wall "*i,*" requires knowing the relative positions (seaward offsets) of the shoreline in cell *"i-1,j"* and cell *"i,j"* in order to calculate the breaking wave angle relative to the local shoreline angle. (Additional cell shoreline positions are needed if ISMOOTH>1; see Frey et al. (2014, 104–109.) Once *"Q(i,j)"* and *"Q(i+1,j),"* the transport across both edges of cell *"i,"* are calculated and summed, the net transport into cell *"i"* is known (and can be positive or negative), and the cell *"i"* shoreline position at time *"j+1"* can be calculated using Equation 1, whose derivation is described in Frey et al. (2012, 9–11), as a conservation of mass relationship.

Figure 1. Model domain layout showing shoreline positions at cell centers and transport across cell boundaries.



$$\frac{\Delta y(i,j)}{\Delta t}+\frac{1}{D_B+D_C}\left(\frac{Q(i+1,j)-Q(i,j)}{\Delta x}-q(i,j)\right)=0 \tag{1}$$

This equation expresses the fundamental assumption of a one-line shoreline change model: temporal changes in the shoreline position ($\partial y/\partial t$) are driven by spatial variations in the longshore sediment transport rate ($\partial Q/\partial x$). In this equation, x and y are the alongshore and offshore coordinates, respectively, t is time, D_B and D_C are the berm height and depth of closure, Q is the alongshore transport rate crossing a cell wall, q is the source or sink term, and i and j are the alongshore and time indices, respectively.

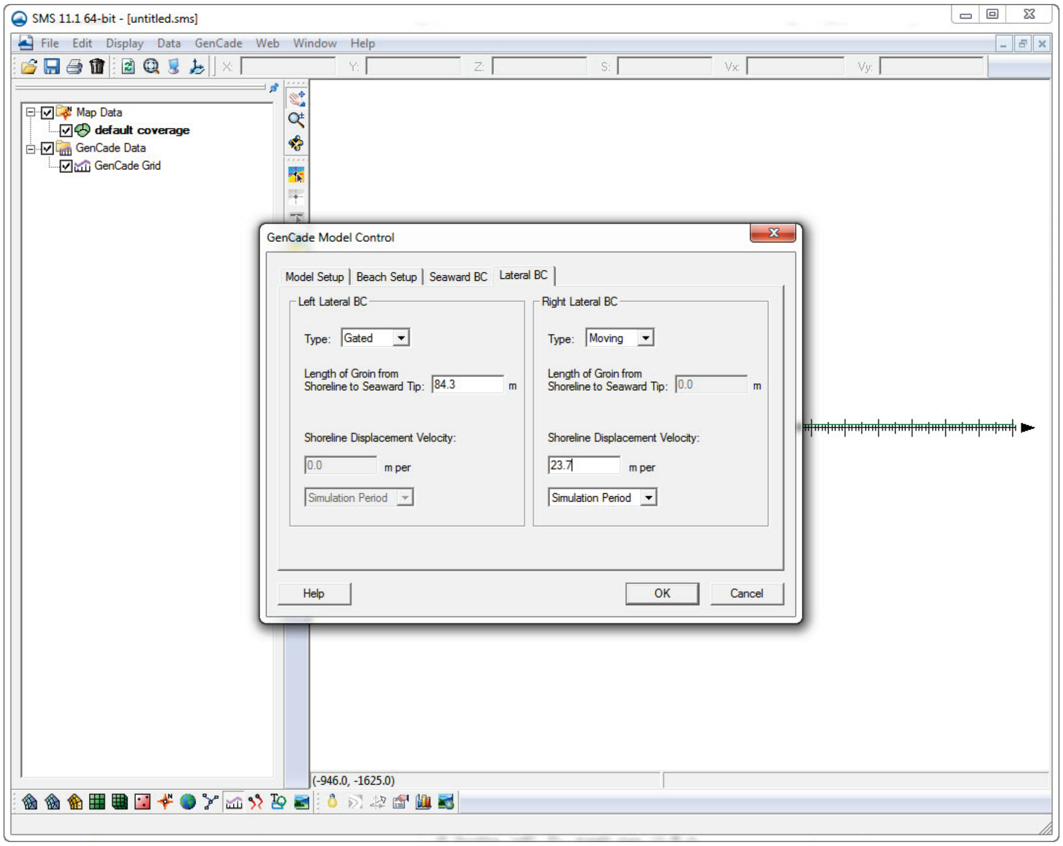
From this discussion, it is seen why GenCade requires that an externally defined procedure be applied at both lateral boundaries (Cell Walls *1* and *n+1*) at each time-step. Because the model has no knowledge of shoreline positions or longshore transport outside the ends of the grid, for each time-step the user must either specify the transports across the terminal cell walls (which is the case for Pinned and Moving LBCs) or must specify the virtual shoreline positions just off the ends of the grid so that the model can calculate the transport across the terminal cell walls (as is the case for Gated LBCs). In addition, the model requires the beginning shoreline as an initial boundary condition to provide shoreline positions for all cells for use in the calculation of the new shoreline at the end of the first model time-step, which is then used as the starting condition for the next time-step.

This discussion also shows that information about the shoreline position at one end of a grid can propagate to the other end of the grid in *N-1* time-steps, if the grid is *N* cells long. (In fact, it normally propagates faster than this due to certain model refinements, such as the use of an offshore contour smoothing window (Frey et al. [2014, Section 4.5, 104–109]). However, it can also be seen that at each time-step, the information about the shoreline position at one location gets blended with information about other shoreline positions so that the influence of any shoreline position rapidly decays as the information propagates along the length of the grid. Thus, the initial signal that propagates along the grid will be dramatically decreased when it first reaches the other end. However, as discussed in Chapter 5, over time the signal impact has the potential to rise to a significant level.

2 Initial Setup of Lateral Boundary Conditions (LBCs)

Pages 18–21 of Frey et al. (2012) discuss the basic behavior and selection of the three LBC types and pages 143–145 explain how to specify them when setting up GenCade within the Surface-water Modeling System (SMS). When setting up a model within SMS, the establishment of the LBCs is one of the steps taken after the conceptual model has been converted to a 1D grid. They are specified by selecting the “Lateral BC” tab within the “GenCade Model Control” window, as shown in Figure 2. When the SMS model is saved following this step, the *.sms and *.gen files will be saved/updated to include the LBC information.

Figure 2. Pop-up window in GenCade setup that sets all eight cards for the two LBCs.



GenCade Model Control

Left Lateral BC

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Right Lateral BC

Type: Moving

Length of Groin from Shoreline to Seaward Tip: 0.0 m

Shoreline Displacement Velocity: 23.7 m per Simulation Period

The discussion below centers on the information stored within the portion of the model control file (the *.gen file) that deals with LBCs. This file is normally transparent to the user when setting up GenCade within SMS. However, the *.gen file is written in ASCII and may be opened and examined using any simple text editor. Doing so allows the user to verify that the model parameters have been set as intended. Making simple modifications to this file may also be the fastest way to generate variants of the input conditions to expedite model calibration and the setting up of multiple model runs at a study site to explore alternatives. However, to do this, it is important for the user to develop a logical file-naming system to manage the multiple similar files. For a more complete discussion of the *.gen file, see Frey et al. (2014), section 3.1.1.1, pages 16–24.

Four pairs of cards are used in the GenCade *.gen file to specify the left and right (L/R)LBC parameters, as shown in Table 1. See also Figure 5, page 20 in Frey et al. (2014). (The left and right ends of the model gird are defined as being relative to a person standing on the beach facing offshore. The left LBC is located at Cell Wall *1* and the right at *N+1*, as shown in Figure 1.) The (L/R)BCTYPE cards (lines 1 and 5 in Table 1) specify the LBC as Pinned (=0), Gated (=1), or Moving (=3). For the Moving LBC only, the (L/R)MOVY cards (lines 2 and 6) specify the distance that the shoreline moves in a specified amount of time, and the (L/R)MOVPER cards (lines 3 and 7) specify the time units, where 1=per simulation period, 2=per day, and 3=per model time-step. Note: All distances on these cards are expressed in the units established for the model (as defined by the GENUNITS card). Note also: There are times after setup when a modeler may choose to change the model time-step (the DT card in the *.gen file, Frey et al. [2014, 18, Figure 3]) for any of several reasons. For example, changing the time-step may be used to resolve model stability issues (Frey et al. [2014, 92–99, Section 4.4]). If the time-step is changed after model setup and either or both of the LBCs are set to Moving and the (L/R)MOVPER card(s) is set to 3, then the value set in the (L/R)MOVY card(s) will need to be changed appropriately. The program will not automatically make this change.

For the Gated LBC only, the (L/R)GROINY cards (lines 4 and 8) specify the distance from the virtual shoreline to the seaward tip of the groin. The SMS includes all eight cards in the *.gen file, regardless of the type(s) of LBC chosen, which means that for all LBC choices, some of the cards will only contain dummy values. For the example shown in Figure 2, the eight cards would be set to these values: `LBCTYPE:=1`, `LMOVY:=0.000000`, `LMOVPER:=1`, `LGROINY:=84.300000`, `RBCTYPE:=3`, `RMOVY:=23.700000`, `RMOVPER:=1`, and `RGROINY:=0.000000`.

For the Gated LBC, a terminal groin must also be specified. This requires additional cards, as discussed in Section 4.1 below. These cards occur in the groin portion of the *.gen file, rather than in the LBC portion.

Table 1. LBC Specification Cards in the *.gen file.

	Card	Pinned	Gated	Moving
1	LBCTYPE:	0	1	3
2	LMOVY:	0.000000*	0.000000*	-43.000000**
3	LMOVPER:	1*	1*	1***
4	LGROINY:	0.000000*	747.000000**	0.000000*
5	RBCTYPE:	0	1	3
6	RMOVY:	0.000000*	0.000000*	0.002673**
7	RMOVPER:	1*	1*	3***
8	RGROINY:	0.000000*	85.400000**	0.000000*

*Dummy, unused value for that LBC type.

**Random example value.

***Value must be 1, 2, or 3 for Moving LBC.

3 Pinned and Moving LBCs

The Pinned and Moving LBCs are similar in concept and behavior. Both are discussed in this chapter.

3.1 Pinned LBC

The default boundary condition is Pinned. For this type of boundary, the shoreline in the end grid cell will neither advance seaward nor retreat landward during model execution but will remain fixed at the position set by the initial shoreline (See Section 3.3 for an exception to this statement.). This is achieved mathematically by having as much sediment move onto or off of the grid as is exchanged between the terminal cell and its interior adjacent neighbor. As seen by Equation 1 (and by the fundamental premise of the one-line model), a change in a cell's shoreline position is caused by differing amounts of sediment crossing its two cell wall boundaries. Thus, for all time-steps, if the left LBC is set as "pinned," then $Q_1 \equiv Q_2$, and if the right LBC is set as "pinned," then $Q_{N+1} \equiv Q_N$.

A Pinned LBC is ideally positioned at a stable shoreline location based upon an analysis of a good selection of high-quality shorelines. The phrase "good selection of high quality" implies several attributes of an ideal shoreline dataset, including the following.

- There are several (ideally a half dozen or more) historical shorelines in the dataset, the more the better.
- The shorelines in the dataset cover the full spatial (longshore) extent of the shoreline to be modeled.
- The shorelines were collected over a time span of years that is at least approximately as long as the intended model run time and ideally at least 2–3 times that length.
- There are no unaccounted-for sudden, dramatic, and persistent position changes between individual or groups of shorelines.
- The shorelines were collected in different years somewhat evenly disbursed throughout the time span of the set.
- The shorelines were collected at approximately the same time of year (the same season). This condition need not be met if seasonal shoreline differences are minimal or the seasonal variations agree with expected patterns, and same-season shorelines are used as the initial and final shorelines in model calibration and validation.

- Shorelines were not collected in the immediate aftermath of unique dramatic shoreline-changing events such as hurricane landfalls.
- The points comprising each shoreline are closely spaced (at least less than the minimum model grid cell spacing).
- The shorelines represent (or can be converted to) the same beach reference elevation (mean sea level, mean high tide line, interpreted high water shoreline, vegetation line, etc.).
- Good quality control was exercised in the collection and processing of all the initial field data.

For a Pinned LBC, the analysis of the dataset involves identifying locations where the shoreline is stable (i.e., locations where all the measured shorelines fall nearly on top of each other). If this location is well away from the study focus area, it is an ideal location to terminate the grid and apply a Pinned LBC. For additional discussion of the Pinned LBC, see pages 18–19 in Frey et al. (2012).

3.2 Moving LBC

The Moving LBC behaves similarly to the Pinned LBC; it requires the model shoreline to advance seaward or retreat landward by a constant distance at each time-step over the model calculation interval. (For the Pinned boundary condition, this constant movement distance would be zero.) To apply this condition for each time-step, the model first determines the amount of sediment exchanged between the end cell and its interior neighbor. It then assumes that this amount of sediment plus (or minus) an additional fixed amount is transported across the terminal cell wall so that the terminal cell shoreline position advances or retreats by the appropriate constant distance during each time-step. The rate of shoreline movement is specified when the Moving LBC is defined and is the amount needed to reach the target shoreline position at the end of the model simulation.

It is appropriate to apply this LBC type at locations that have experienced constant historical rates of erosion or accretion and can be expected to continue to do so over the model forecasting time period. The Moving LBC is ideally chosen based upon an analysis of a good selection of high-quality shorelines, where the analysis shows a long-term fixed rate of shoreline movement.

Once a location for the end of the model domain has been chosen, the rate of shoreline change can be calculated as the cross-shore distance between the initial shoreline and the final shoreline divided by the length of time between the two surveys. Since the final shoreline is the one that the model results will be compared with during model calibration, this methodology has the added benefit of producing perfect agreement at this boundary during model calibration. However, it would be serendipitous if this procedure also produced perfect agreement during model validation (when different measured shorelines are used for the beginning and ending conditions). A more rigorous approach would be to use all of the available high-quality shorelines to calculate a root-mean-square value for the shoreline change rate at this location. For additional discussion of the Moving LBC, see Frey et al. (2012, 18–19).

3.3 The effect of sources and sinks applied at terminal cells

Adding a source or sink term to Cell *1* or Cell *N* is not a common practice, but there is no model prohibition against this use. However, the results may be unexpected if a Pinned or Moving LBC is used at that grid boundary. A Gated LBC will follow Equation 1 and should behave as expected. For a Pinned LBC, the model will set Q_1 to the calculated value of Q_2 or Q_{n+1} to the Q_n value for all time-steps (Figure 1). However, since q (the source term in Equation 1) is not zero, the shoreline position will change at each time-step as seen from Equation 1, which is not the usual expectation for a Pinned LBC. If q is turned off at a later time-step, the shoreline at the terminal cell will remain pinned at its new cross-shore position. Likewise, a Moving LBC applied to a terminal cell that also has a non-zero value for q in Equation 1 will cause the shoreline to move at a rate different than otherwise expected.

Users should be aware of this model behavior. Note that during model setup, the user defines not only the magnitude and location of q, but also the start and end dates for the source term. For more information on source and sink terms, see Frey et al. (2012, 123–124, Section 4.2.10) and Frey et al. (2014, 23–24, Section 3.1).

4 Gated LBC

A Gated LBC is designed to be used when a model grid terminates at a groin, jettied inlet, natural headland, or similar feature. This can be a very logical location for terminating the model domain, as this type of feature is usually a significant barrier to longshore sediment transport and thus can be easily considered as the natural boundary of a littoral cell. Determining the shoreline behavior on the far side of the structure may not be a study requirement, or it may be appropriate to use this location as the dividing point between adjacent study sub-grids.

The modeling calculations required at each time-step for this type of LBC are more involved than for the first two types (Pinned and Moving). Those types do not require an independent calculation of transport across the terminal cell wall. Rather, they reference the transport across the terminal cell wall to the adjacent interior cell wall transport (i.e., across Cell Wall "*2*" or Cell Wall "*N*"; see Figure 1). However, a Gated LBC does calculate the transport across the terminal cell wall and additionally calculates how the transport is modified by the presence of a groin. A Gated shoreline allows for sediment transport both onto and off the grid. Before setting up a Gated LBC, the reader may wish to review Section 3.2.5 of Frey et al. (2014, 49–51), which discusses some common mistakes made when setting up this type of LBC. Further discussion of the Gated LBC can also be found in Hanson (1987), and Hanson and Kraus (1989), and Frey et al. (2012).

4.1 Model implementation of the Gated LBC

Selection of a Gated LBC during model setup requires two steps: first, by placing a groin at the appropriate model boundary cell wall (Figure 1) and then in a later step by specifying the LBC type as "Gated," as discussed in Chapter 2.

Placing a groin at a terminal cell wall boundary (or at any other location along the model domain) will add the following cards to the model control (*.gen) file (Frey et al. 2014, 21, Figure 6). Note: All length and depth parameters use the units established for the model (as defined on the GENUNITS card). Also note that the cards discussed below are in addition to the cards discussed in Chapter 2, which define the LBC as Gated.

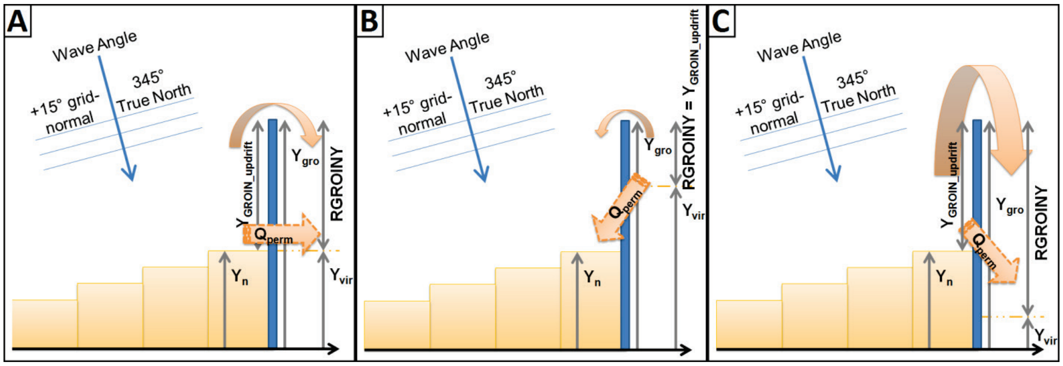
- IXDG (for diffracting groin) or IXNDG (for non-diffracting groin). This specifies the cell wall location for the groin, which must be "*1*" (for left) or "*N+1*" (for right) Gated LBC groins.
- YDG (for diffracting groin) or YNDG (for non-diffracting groin). This specifies the distance from the grid baseline to the groin tip.
- DDG (for diffracting groin; no corresponding card for a non-diffracting card). This specifies the depth at the jetty tip but is only used in the wave diffraction calculations. It is NOT used to calculate the sediment bypassing discussed below.
- PDG (for diffracting groin) or PNDG (for non-diffracting groin). This specifies a dimensionless groin permeability value between 0.0 and 1.0 that represents the constant fraction of the available transport that passes through, over, and/or landward of the groin.

For convenience, only the diffracting version of these cards will be mentioned below, but either type may be used, as appropriate.

For a Gated LBC, to calculate the sediment transport across the terminal cell wall boundary, the model primarily uses three of the values described immediately above or in Chapter 2: YDG (the distance from the grid baseline to the groin tip), PDG (the groin permeability), and (L/RGROINY (the position of the virtual shoreline relative to the groin tip). Note that all three of these values are constants for a model run. The model first determines the local beach orientation by comparing the virtual shoreline position that is off the grid with the shoreline position in the terminal cell (a value that can vary at each time-step) and compares that with the incoming wave angle (a variable) to obtain the relative wave angle.

In panel A of Figure 3, the virtual shoreline position is equal to the shoreline position in the terminal cell. That is, the value of RGROINY is equal to the distance from the cell "*N*" shoreline to the tip of the groin. Therefore, for the time-step in this example, the incoming wave angle will create a surfzone current and sediment transport to the right (traveling off the grid). In this case, the cell "*N*" side of the groin is the upstream side. In Figure 3, Panel B, the virtual shoreline is far seaward of the cell "*N*" shoreline, which means that the value of RGROINY is small compared to the distance from the cell "*N*" shoreline to the tip of the groin. Thus, the local shoreline orientation is more than 15° from the grid orientation, and given the 15° incoming wave angle, the surfzone current and sediment transport will be driven to the left (onto the grid). In this case, the virtual shoreline side is the upstream side of the groin. In Figure 3, Panel C, the virtual shoreline is landward of the terminal cell shoreline, which will create a stronger sediment transport to the right (off the grid) than in Panel A.

Figure 3. Transport at Gated LBC for three values of RGROINY.



Once the relative wave angle is known, the model can calculate the transport across the terminal cell wall the same way it calculates the transport across the other cell boundaries on the grid and then can reduce that transport amount to account for the effects of the groin the same way it reduces the transport for a groin placed anywhere on the grid. See pages 47–49 in Frey et al. (2012) for further discussion.

The transport past the groin is divided into two parts: the transport seaward of the tip of the structure (the bypassing) and the transport over and through the structure (the permeability), as indicated by the double arrows in each of the panels in Figure 3.

The bypassing (BYP) is calculated as

$$\begin{aligned} BYP &= 1-\frac{D_G}{D_{LT}} \text{ when } D_G < D_{LT}\text{, and} \\ BYP &= 0 \text{ when } D_G \geq D_{LT} \end{aligned} \qquad (2)$$

D_G is the depth at the tip of the groin as determined by using an equilibrium beach profile (Bruun 1954; Dean 1977; Dean 1991; Frey et al. 2012, 24–25) from the upstream side shoreline to the tip of the groin. D_{LT} is the depth of active longshore transport, as given in Frey et al. (2012), equation 22 on page 24. Note that each of these parameters is a variable calculated by the model at each time-step. They are not specified directly by the user; D_G is not the constant value on the DDG card; and D_{LT} is not the constant Depth of Closure value specified on the DCLOS card.

The overall fraction of the sediment that passes the groin is then calculated as

$$F = PERM * (1 - BYP) + BYP \tag{3}$$

Where *PERM* is the constant groin permeability specified on the PDG card. Multiplying the total transport by the fraction, *F*, yields the transport across the terminal cell wall that contains a groin.

4.2 Gated LBC parameter selection guidance

Because of the complexity inherent in this type of LBC, the normal model procedure is to provide reasonable initial parameter values during model setup while expecting to modify those values during model calibration to achieve the best agreement between the model results and the prototype behavior. This differs from the treatment of Pinned and Moving LBCs. Typically, their parameter values are set during the initial model setup and then not altered during model calibration.

The parameter YDG, which is given an initial value when the terminal groin is added in the conceptual model, specifies the distance from the grid baseline to the groin tip (the value Y_{gro} in Figure 3). This is a key parameter in determining the amount of bypassing that occurs around the tip of the groin. An appropriate initial value would be the distance from the grid baseline to the tip of the existing structure, if an actual structure exists in the prototype. If not, then the distance from the grid baseline to the shoreline plus a percentage of the surfzone width would be appropriate. Increasing this value during model calibration (i.e., extending the groin farther seaward) will decrease the bypassing around the tip, and increasing it sufficiently (i.e., to a distance seaward of the calculated closure depth, D_{LT}, for all wave conditions) will drive the bypassing to zero. Further increases will have no additional effect. Decreasing the value to the distance from the baseline to the shoreline will allow complete bypassing to occur, as would be expected in the prototype (i.e., the groin is all onshore; the tip does not extend into the surfzone). Decreasing the value further will have no effect on the results, unless the shoreline erodes and the groin tip becomes exposed. Note that if this value is changed during calibration, the parameter (L/R)GROINY (discussed below) must be changed by the same amount for the impact of the parameter (L/R)GROINY to remain unchanged.

The parameter PDG, which is given an initial value when the terminal groin is added in the conceptual model, specifies the groin permeability, which is the fraction of the sediment that passes through, over, and landward of the structure. Any value for this dimensionless parameter between zero and one is permissible. An initial value of 0.5 is reasonable, but this may be adjusted if details about the groin behavior are known, such as whether the groin is considered to be sand tight or whether significant aeolean transport occurs over the groin, etc. Decreasing this value in calibration will decrease the transport through and over the groin. A value of zero blocks all transmission through the structure, and a value of 1 indicates no reduction in the calculated transport (a fully transparent or non-existent groin). Values for the bypassing and the permeability are combined, as shown in Equation 3, to calculate the percentage reduction in the transport (the F value) caused by the presence of the groin.

The parameter (L/R)GROINY is given an initial value during the model setup when the LBC is specified as "Gated," which is after the conceptual model is converted to the 1D grid. This value specifies the distance from the groin tip to the virtual shoreline and strongly influences the local shoreline orientation to which the incoming wave angle is referenced. A reasonable initial value is the distance from the groin tip to the (initial, final, or average) shoreline, as shown in Figure 2A. Decreasing this value during model calibration (i.e., shifting the virtual shoreline seaward) will have the effect of changing the shoreline orientation such that the amount and frequency of transport onto the grid is increased. Decreasing this parameter will also cause more bypassing to occur during those time-steps when transport is directed onto the grid. Note that changing the parameter YDG (discussed above) during model calibration will have the added effect of shifting the position of the virtual shoreline and consequently the breaking wave angle unless the parameter (L/R)GROINY is adjusted by the same amount.

4.3 Gated LBC adjacent shoreline impacts

During model calibration, decreasing the value of (L/R)GROINY will facilitate more transport onto the grid and generally cause increased accretion (or decreased erosion) on the shoreline adjacent to the end of the model domain. Increasing the value will generally cause the reverse (i.e., increased transport off of the grid with increased erosion at the terminal grid cell).

The shoreline impacts of changes to YDG and PDG will vary, depending upon the net direction of the littoral transport. If the net direction is onto the grid, then (in an overall sense) the terminal cell is on the downstream side of the groin, and decreasing YDG and/or increasing PDG will allow more sediment to pass and generally increase the local shoreline accretion (or decrease the erosion). If the net direction is off the grid, then the terminal cell is on the upstream side of the groin, and the same type of adjustments (decreasing YDG and/or increasing PDG) will generally have the opposite local shoreline effect. Finally, changing the parameter values in the other direction (i.e., increasing YDG and/or decreasing PDG) will generally cause the opposite type of adjacent shoreline impact. These impacts are summarized in Table 2.

Table 2. Calibration adjustment guidance for Gated LBC.

Parameter	Net Transport Direction	Direction of Calibration Adjustment	Adjacent Shoreline Response	Net Transport across Terminal Cell Wall
Virtual Shoreline position relative to groin tip[1]	Onto grid	↑ (L/R)GROINY	More Erosive	Less
		↓ (L/R)GROINY	More Accretive	More
	Off of grid	↑ (L/R)GROINY	More Erosive	More
		↓ (L/R)GROINY	More Accretive	Less
Groin Length[2]	Onto grid	↑ YDG	More Erosive	Less
		↓ YDG	More Accretive	More
	Off of grid	↑ YDG	More Accretive	Less
		↓ YDG	More Erosive	More
Groin Permeability[3]	Onto grid	↑ PDG	More Accretive	More
		↓ PDG	More Erosive	Less
	Off of grid	↑ PDG	More Erosive	More
		↓ PDG	More Accretive	Less

[1] The table assumes small changes to the virtual shoreline position that do not change the direction of net sediment transport or do not cause the net breaking wave angle to exceed 45°.

[2] If the groin tip does not extend to the shoreline (complete bypassing condition) or if it extends seaward of the breaker line for all wave conditions (zero bypassing condition), then changes to the groin length will have no effect unless the change moves the groin tip to a position within the surf zone or completely to the other side of the surf zone.

Any adjustment to the groin length will also modify the position of the virtual shoreline (since the virtual shoreline position is referenced to the position of the seaward tip of the groin). To cancel out this effect, the (L/R)GROINY value must also be adjusted by the same amount. The responses in the table are based on the assumption that (L/R)GROINY has been adjusted by the same amount as YDG.

[3] If the groin tip does not extend to the shoreline, complete bypassing occurs, and changes to the groin permeability have no effect.

Note that this is the same type of behavior that would occur for a groin placed at any location on the grid. Decreasing YDG and increasing PDG both have the effect of making the groin less effective at stopping transport (making the groin more transparent or more transmissive), thus decreasing the sediment accumulation on the upstream side of the groin and increasing the amount reaching the downstream side. If the net transport is onto the grid, then the adjacent shoreline that is within the model domain responds as any other shoreline downstream of a groin. If the net transport is off the grid, the adjacent model shoreline at the end of the grid responds similarly to any other shoreline that is upstream of a groin.

4.4 Use of the Gated LBC for specific shoreline configurations

4.4.1 Gated LBC for no transport onto and off of the grid

To set the Gated LBC so that no sediment enters or leaves the grid across the terminal cell wall (as for the case of a large headland or a high sand-tight jetty that extends well seaward of the surfzone and any ebb shoal), YDG should be set to a value much greater than the maximum horizontal distance to the depth of closure. Then (L/R)GROINY should be set to a large value, such that the virtual shoreline position is approximately equal to the terminal cell shoreline position, as shown in Figure 3, Panel A. This will cause D_G to always be greater than D_{LT} so that no bypassing occurs. Then, PDG should be set to 0.0 so that no transmission occurs through the groin. As an example, this boundary condition might be applied at both ends of a pocket beach (Figure 4; from King [1976]).

4.4.2 Gated LBC for one-way valve with transport only off of the grid

To set the Gated LBC so that sediment can exit the grid but not enter it (the one-way valve, out only, condition, such as for a beach adjacent to a jettied inlet with a deep dredged channel with no ebb shoal), the settings are similar to those of the Zero Transport case above. YDG should be set to a value much greater than the maximum depth of closure width such that D_G is always greater than D_{LT}, so no bypassing occurs. Then (L/R)GROINY should be set to a sufficiently large value such as YDG. Choosing this value will place the virtual shoreline at the baseline of the grid and will probably be sufficient for the longshore transport to always be directed off the grid, regardless of the incoming wave angle. Then set PDG to a value between 0.0 and 1.0 where a larger fraction will cause more transport off the grid. Because of setting (L/R)GROINY to a very large value, the total transport

Figure 4. Example pocket beach at Boston Bay, Portland Parish, Jamaica. Beach sediments are mainly locally derived from marine corals, algae, and other organisms.

(before it is reduced by the F factor) may be unrealistic, and it will likely be necessary to adjust parameter values during calibration (particularly PDG) so that an appropriate amount of sediment is transported off the grid. Note that the Gated LBC was originally so named because it was expected to be frequently used in this configuration, acting as a "gate" that would allow sediment to be transported off the grid while not allowing sediment to enter (Hanson and Kraus 1989).

4.4.3 Gated LBC for one-way valve with transport only onto the grid

To set the Gated LBC so that sediment can enter the grid but not leave it (the one-way valve, in only, condition), YDG should be set to a value much greater than the maximum depth of closure width such that D_G is always greater than D_{LT} so that no bypassing will occur. Then (L/R)GROINY should be set to a near-zero value. Choosing this value will place the virtual shoreline near the seaward tip of the groin so that the longshore transport will always be directed onto the grid regardless of the incoming wave angle. Then set PDG to a value between 0.0 and 1.0, where a larger fraction will cause more transport onto the grid. Because all the transport is directed onto the grid, the value of the total transport will likely be inappropriate, making an adjustment of PDG necessary during model calibration.

4.4.4 Gated LBC for no groin or jetty

A Gated LBC could be applied at an end-of-grid location where there is no groin or jetty in the prototype (e.g., at an unjettied inlet or at an inlet where a jetty is proposed). For this type of application, it is still necessary to include a groin at the boundary, as the model requires one. However, if PDG is set to 1.0, the groin will be completely transparent and have no effect on the transport rate. As can be seen from Equation 3, setting PDG to 1.0 will force the value of F to be 1, so the transport across the boundary will not be reduced by the presence of a groin, regardless of its specified length. Thus, setting the groin length (YDG) will have no effect on the amount of bypassing. However, since the position of the virtual shoreline is referenced to the position of the groin tip, YDG should be selected before (L/R)GROINY is set. (L/R)GROINY will influence the amount of transport (by impacting the local breaking wave angle). Larger values of that parameter will cause more of the transport to be directed off of the grid.

5 LBC Impacts on the Interior of the Grid

5.1 Introduction

LBCs constrain the range of GenCade shoreline behaviors at the ends of the model domain in ways dictated by the modeler rather than allowing the shoreline response to be controlled by the physics-based sediment transport relationship that is incorporated in the model. This is an inherent model requirement that is necessary to obtain a closed form solution, in the same way that a user must specify a value for the constant that is part of the solution to a simple integral equation, in order to obtain a closed-form solution for that problem.

Thus, at all time-steps, at the ends of the grid the quality of the results is more a function of the quality of the data used to define the LBCs than it is a function of the model's ability to replicate the shoreline behavior of the prototype through the calculation of the longshore sediment transport. Furthermore, over time, the influences of the boundary conditions (as manifested by the shoreline position) diffuse inward into the interior of the grid. Users have asked for guidance on how to determine the size of the error introduced by the imposition of the end condition constraints and how to set up model domains so that the LBCs do not unduly impact the model results in the region of the beach that is the area of primary interest. This chapter provides discussion and guidance on this issue.

The propagation of LBCs into the interior of the system should not necessarily be thought of as the spread of errors into the model domain that degrade the results. Over time, the shoreline position at each grid cell influences the positions of all other grid cells, as discussed in Chapter 1. If the boundary conditions can be appropriately applied to the terminal cells, the model will behave as it would have if the grid were extended outward so that the original terminal location was far into the interior of the grid and also will behave as the prototype behaves. For example, if a section of shoreline has been historically stable and can be expected to remain so over the model forecasting time period, then imposing a Pinned boundary condition at that location will have no negative impacts on the model results at the boundary or elsewhere on the grid.

However, it is not uncommon that the prototype does not supply locations that exactly match the LBC constraints or the modeler does not have sufficient data to be confident that the constraints are well matched. For these cases, there can be a legitimate concern that the imposition of the LBCs could be degrading the quality of the model results.

The discussion on the propagation of the LBC impacts will generally be applied to Pinned and Moving LBCs because for these LBCs, evaluating the uncertainty parameter can be straight forward. Final values associated with these lateral boundary types can usually be identified through an analysis of a set of shorelines when the model is first set up. However, final values for Gated boundaries are usually identified by trial and error during model calibration at the same time as other model parameter values are being refined.

Though the analysis described below does provide quantitative results, those results are most useful when the user determines whether those results are significant or not. Significance can be thought of in both an absolute and a relative sense. In an absolute sense, the LBC impacts at a particular time and at a particular location on the grid would be considered clearly insignificant if, for instance, the impacts changed in shoreline position by the width of a sand grain. But more broadly, they could be considered insignificantly small if they were unlikely to alter any management decisions that were based upon the model results.

In a relative sense, the LBC impacts could be considered insignificant if they were substantially less than other types of model uncertainties. It is important to recognize that GenCade, as with all models that predict some aspect of real-world behavior, necessarily deals with simplifications of the real world and thus only provides an approximate representation of that behavior. LBCs are only one type of the many assumptions incorporated into the model that have the potential to lead to degradation of the quality of the results. Having experience with both the model and generally with coastal shoreline behavior can be of great benefit in assessing this significance.

For example, if the shoreline data provided a close enough match to the LBC specifications, it could be perfectly reasonable to conclude that none of the analysis presented in this chapter was necessary because the impacts would be insignificant. Likewise, at any point in the analysis described below, it could be considered reasonable to terminate the process as it becomes clear that the results would be insignificant.

The GenCade model can be applied to provide insights and answers to a large variety of coastal problems. How the model is set up is not only a function of the questions being studied, but also the specific geometry of the particular site. In some cases, the GenCade results will be of importance along the entire length of the shoreline being modeled. However, in other cases, the GenCade grid will extend beyond the primary study area under investigation. As discussed below, the uncertainty in the shoreline position associated with the use of the LBC is greatest at the end of the grid where the LBC is applied. Therefore, for studies where the grid only covers the shoreline of primary research interest, propagation of the LBC into the grid interior is not normally an issue whose value needs to be calculated. In those cases, the most that needs to be investigated is the level of uncertainty at the LBC.

Section 5.2 below gives a brief overview of how the uncertainty parameter behaves as it diffuses into the grid. This section also provides guidance on how to calculate the constant value of the parameter at the lateral boundary. Section 5.3 provides a more detailed look at the diffusion of the uncertainty parameter. However, because this section presents a generic analytic description of the diffusion process, it is still a simplification and is mainly intended to provide the user with further insight into the parameter behavior. Section 5.4 describes a procedure to obtain a quantitative prediction of the parameter's influence on the user's calibrated grid. Finally, Section 5.5 discusses the few options available to the user to help reduce the parameter impacts, if necessary.

5.2 The LBC uncertainty parameter ($Y_U(x,t)$)

Normally, the most important model results from a GenCade study are a set of future shoreline positions (i.e., cross-shore distances from the model baseline) that are the predictions of the particular scenarios being modeled. Therefore, it is most useful to cast the LBC uncertainty parameter as a shoreline displacement that has units of cross-shore distance. $Y_U(x,t)$, the uncertainty parameter, is an estimate of the shoreline-position error at any point along the model grid at any time following the start of the model run (at $t=0$) that is caused by the imposition of a LBC at the end of the grid. Y_{Uo} is the value of $Y_U(x,t)$ at the lateral boundary (at $x=0$). This value is a constant shoreline offset that is calculated by the user and represents the maximum value of the uncertainty along the grid.

The ratio ($Y_U(x,t)/Y_{Uo}$) is the relative or scaled uncertainty, whose value varies between zero and 1. At any specific time, this ratio decreases as the propagation distance from the end of the grid increases. For any given x position along the grid, the ratio increases with increasing model run time. The results become mathematically more complex on any real (finite-length) grid, when sufficient model run time has elapsed such that significant disturbances from both ends of the grid start interacting in the middle region of the grid. Therefore, this discussion will generally be limited to only considering the shoreline impacts from one end of the grid in isolation.

Selecting a value for Y_{Uo} requires careful consideration on the part of the modeler and depends upon the exact definition of the problem being addressed. The modeler should start by identifying the likely major source of uncertainty in the shoreline measurements at the location where the LBC is to be applied. One common source of error when applying a pinned LBC is that the shoreline position at the chosen boundary location is not completely static, as determined by a set of shorelines measured at different times (even after possibly removing a predictable seasonable oscillation). See Section 3.1 for a discussion of what constitutes a set of high-quality shorelines. For this case, the uncertainty in the shoreline position could be represented as a small multiple of the standard deviation of the different shoreline positions at the boundary location.

The standard deviation (σ) is defined as

$$\sigma = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}\left(y_i - y_{ave}\right)^2} \tag{4}$$

Here, N is the number of shorelines used in the analysis; y_i is the position of each shoreline where the Pinned LBC is being placed. y_{ave} is the average of those shoreline positions and is the position where the shoreline will be pinned. If the shoreline positions are normally distributed, there will be a 99.7% chance that the true position will fall between -3σ and $+3\sigma$. Thus, Y_{Uo} could be defined as the value of 3σ.

Other definitions of the uncertainty could be used. If the shorelines were obtained by different methodologies (aerial photos, lidar, beach buggy GPS, etc.) or different personnel, and some are assumed more accurate than others, it may be more appropriate to use a weighted standard deviation in Equation 4. If the dominant concern is that different (or poorly documented) definitions of the shoreline (e.g., vegetation line, wrack line, wet/dry line, mean sea level, mean lower low water) are likely represented in the historical shoreline data set, it may be appropriate to select a Y_{Uo} value based upon an understanding of the cross-shore distribution of these beach features.

A Y_{Uo} value can be calculated for a Moving LBC by using the standard deviation as was described above the Pinned boundary. First, using pairs of shorelines, calculate N independent shoreline change rates at the location of the LBC (from an initial set of $N+1$ shorelines). Convert these all to yearly change rates and calculate the average yearly change rate. Use these as the y values in Equation 4 above to obtain a standard deviation value (σ). Then, $Y_{Uo} = 3\sigma T$, where T is the model run time in years. For this case, y and σ will have units of change in cross-shore shoreline position per unit time, but Y_{Uo} will still have units of cross-shore shoreline position.

Other methods could also be used to calculate a Y_{Uo} value for a Moving LBC, as appropriate. In any event, the calculation methodology should be documented in the final report.

5.3 Analytical solution for the propagation of LBC anomalies

This section generates an analytical solution to a simplified, generic GenCade project, and shows how LBC uncertainties diffuse from the ends into the interior of the grid. By inserting a CERC formula type longshore sediment transport relationship (Frey et al. [2012], 12, Equation [4]) into Equation 1, and making the assumptions that $q=0$, that the angle of wave approach is small relative to the local shore normal, and that the wave height is constant along the length of the beach covered by the grid, a linearized form of the GenCade shoreline planform evolution equation can be obtained as

$$\frac{\partial y}{\partial t} = G\frac{\partial^2 y}{\partial x^2} \tag{5}$$

where:

$$G = \frac{K_1 H_b^{2.5} \sqrt{g/\gamma}}{8(s-1)(1-p)(D_B + D_C)} \qquad (6)$$

This analytical expression for the one-line change model (Equation 5) has been discussed by several researchers, including Pelnard-Considère (1956); Kraus and Harikai (1983); Larson et al. (1987, 1997); Dean (2002, 37–42); Frey et al. (2014, 98–99), among others. In equation (6), K_1 is equivalent to the dimensionless K term in the CERC formula (Rosati et al, 2002, Section III-2-3), H_b is the breaker wave height (assumed to be non-varying along the length of the shoreline and in time), g is the acceleration of gravity, γ is the surfzone breaking wave height to water depth ratio (typically 0.78), s is the sediment specific gravity (2.65 for quartz), p is the in situ sediment porosity (normally assumed to be ~0.35 to 0.4), and D_B and D_C are the berm height and depth of closure. G, the longshore diffusivity, has units of length^2/time. This term governs the rate at which shoreline change occurs in Equation 5. Equation 5 has the same form as the 1D diffusion equation in liquids or the 1D heat conduction equation in metallic solids, and many solutions for an equation of this form are known.

Note, this section (5.3) was written in an attempt to provide the reader with an increased understanding of the behavior of the uncertainty parameter without the requirement of making mathematical calculations. However, this paragraph is provided if the reader wishes to further explore this equation by calculating a value for G, the shoreline diffusivity. In doing so, the problem typically arises of defining an appropriate constant offshore wave height and then converting that value to a breaking wave value. Dean (2002, 41–45, Section 3.5.4) provides guidance on obtaining a reasonable value for G, including an equation to calculate it using offshore wave values. Dean also provides plots of typical G values along the Florida coastline. In addition, Vreugdenhil (1989, 47–49) derives an alternative approximate expression for G. Vreughenhil's expression has the advantage of not needing to calculate the long-term average breaker wave height, but his formulation contains additional assumptions about the wave breaker angle for which it is also difficult to obtain appropriate values.

To illustrate the use of Equation 5, consider the simple case of a straight beach with a Pinned LBC at one end and whose other end stretches to infinity. To determine the LBC impacts on the rest of the grid, consider that the terminal shoreline cell (where the Pinned LBC is applied) is offset seaward by an amount Y_{Uo} from the rest of the straight beach. Note that this is similar but not the same as placing a small beach fill in the terminal cell. A beach fill would be expected to erode away over time, but in this case, the offset is persistent, always having a value of Y_{Uo}. Mathematically, this case is identical to the heat propagation along a long, slender metallic rod when a constant heat source is applied to one end or to a large drop of dye that slowly diffuses along a slender column of water. For all these examples, the solution to Equation 5 is in the form of a complementary error function (for the derivation, see Carslaw and Jaeger [1959, Section 2.4]) as

$$\frac{Y_U\left(x,t\right)}{Y_{U_0}} = erfc\left(\zeta\right) \tag{7}$$

where:

$$\zeta = \frac{x}{\sqrt{4Gt}}, \tag{8}$$

erfc is the complementary error function, which is graphed in Figure 5. Note that for $\zeta=0$, the complementary error function is 1, which, by Equation 8, occurs for all positive time when $x=0$. This is equivalent to $Y_U(0,t) = Y_{Uo}$. Also, for any positive fixed value of time, as longshore distance (x) increases, the function asymptotically approaches zero. Also, as seen by Equation 8 and Figure 5, for any fixed value of longshore position, as time increases, the value of (ζ) asymptotically approaches zero, thus the *erfc* asymptotically approaches 1.

While the solution can be conveniently expressed in terms of a single dimensionless variable, ζ, it provides clarity to expand this single variable into two independent dimensionless parameters:

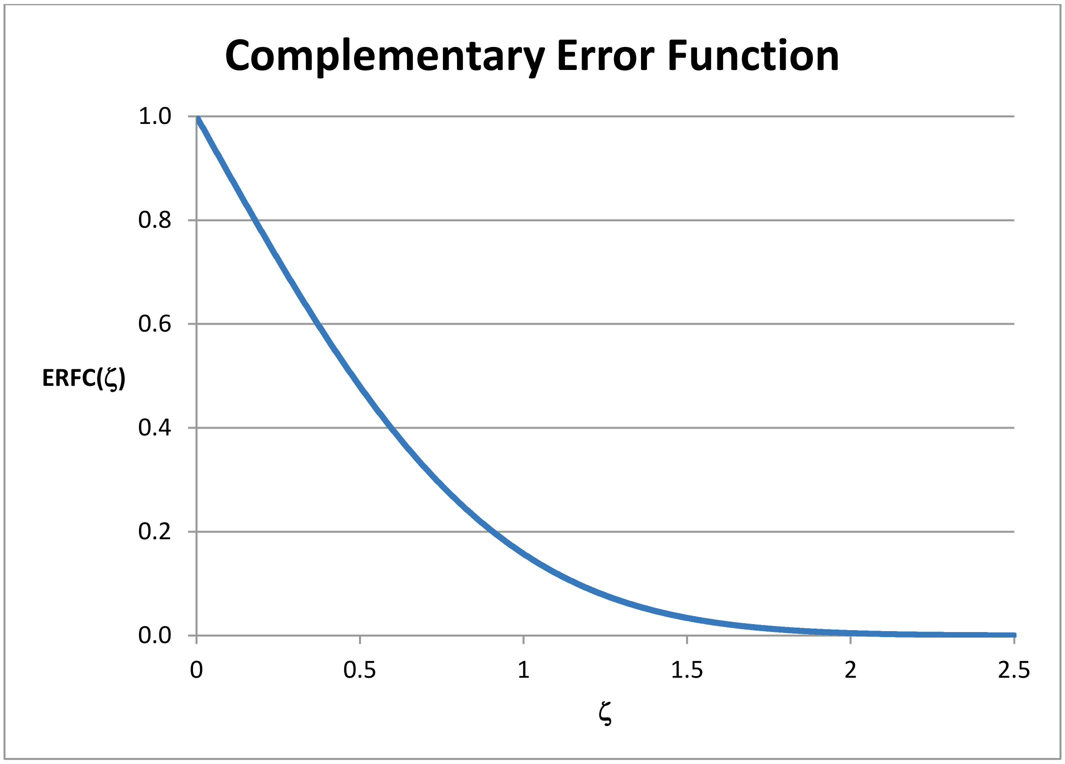
$$x' = \frac{x}{Y_{U_0}} \tag{8}$$

the dimensionless distance along the beach and

$$t' = \frac{Gt}{Y_{U0}^{\;2}} \tag{9}$$

the dimensionless time. The solution to this problem is shown in terms of these two parameters in Figure 6.

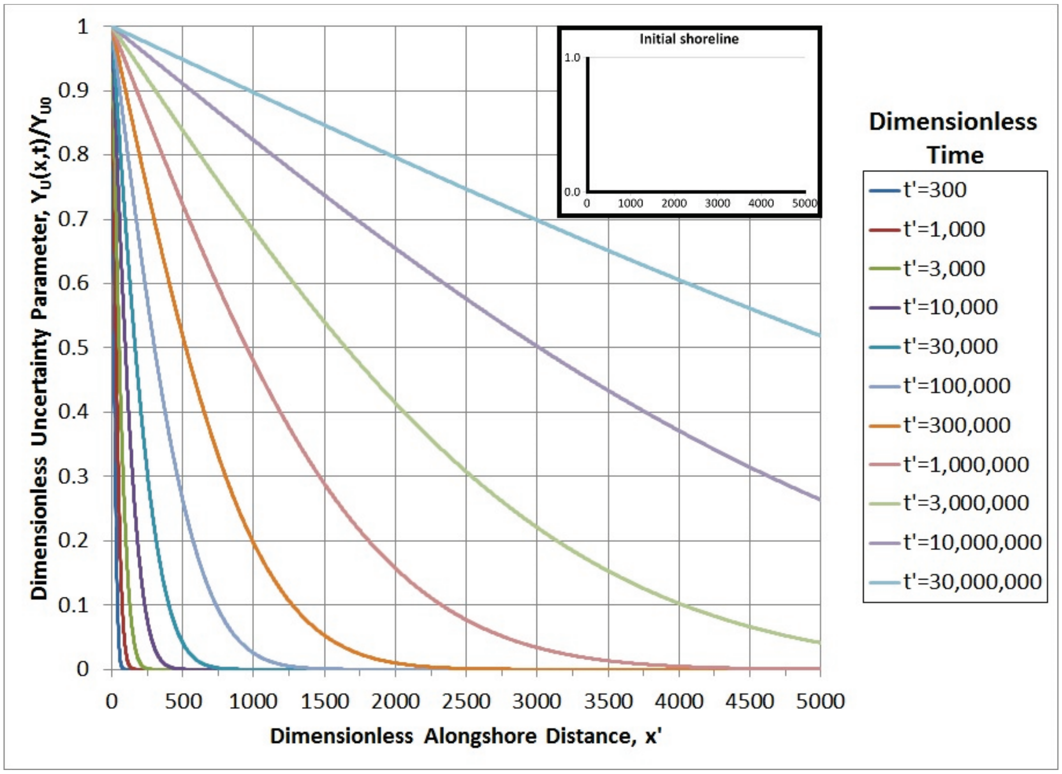
Figure 5. The Complementary Error Function.



This example is provided to qualitatively show the typical impacts that LBC errors have on the interior of a model grid. At any given time, as the distance along the grid from the LBC increases, the amplitude of the uncertainty parameter, $Y_U(x,t)$, decreases, asymptotically approaching zero. At any given grid location, as model run time increases, the amplitude of the uncertainty parameter increases at that location, with the maximum value being Y_{Uo}.

Note that this solution is for a simplified straight beach that does not contain any shoreline perturbations in the form of groins, breakwaters, inlets, etc. Any feature of this type that acts to slow down the longshore sediment transport rate and at least temporarily store sand will also act to slow down the diffusion rate *(G)* of the uncertainty parameter more so than is described by the complementary error function. Shoreline curvatures could act to increase or decrease the diffusion rate.

Figure 6. Solution to Equation 5 for a permanent perturbation at *x'=0* along a semi-infinite beach.



5.4 Determining grid impacts by direct testing

This methodology involves making a few additional model runs following model validation that will show the impacts of the LBC uncertainty as expressed by the value of Y_{Uo}. The user should start with the validation run model setup. However, for this test, the model run time should be either that used for the model validation or that to be used in the production runs, whichever is longer. In addition to the validation run, a model run should be made where the shoreline position of the terminal cell is displaced by $+Y_{Uo}$ and another run made with the terminal cell displaced by $-Y_{Uo}$. These runs can be made with each end of the model domain adjusted in isolation, or both ends can be adjusted in the same run. Note that independent values of Y_{Uo} should be calculated at each end of the grid. The results of the $\pm Y_{Uo}$ runs should sandwich the validation run shoreline and be most widely separated at the ends of the grid. A graphical comparison of the four shorelines (the final measured shoreline, the validation shoreline, and the two Y_{LBCo} adjusted shorelines) will show how the impact of the LBC uncertainties decrease as they propagate into the interior of the grid.

See Section 3.1.1.2 of Frey et al. (2014, 24–26) for guidance on making changes to the initial shoreline file (the .shi file). The first value in this file is the Cell 1 shoreline position, and the last value is the Cell *N* shoreline position. It is good practice to rename the .shi file each time it is adjusted to prevent accidentally making later production runs using the wrong initial shoreline file. The two ends of the grid can be adjusted with their respective Y_{Uo} values at the same time, particularly if it is expected that they will decay to insignificance before interacting in the middle of the grid, or the two ends of the grid may be adjusted individually.

The final model shoreline for a run is in the .slo file (see Section 3.1.4 of Frey et al. [2014, 31]) and also in the .prt file (see Section 4.1 of Frey et al. [2012, 106–107]). The shoreline comparisons can be made inside or outside of SMS.

5.5 Analysis results

This analysis shows that increasing the value of the uncertainty parameter at the LBC (Y_{Uo}), increasing the model run time (t), increasing the effective rate of sediment transport along the grid (G), and decreasing the distance between the LBC and the region of primary interest (x) will all act to increase the level of the uncertainty parameter ($Y_U(x,t)$) within the region of primary interest on the grid. Doing the opposite by decreasing Y_{Uo}, decreasing t, decreasing G and/or increasing x will all have the opposite effect of decreasing the impact of $Y_U(x,t)$ within the primary area of interest. If the above analysis indicates that the uncertainties associated with the LBCs have a significant impact on the model results, this does not mean that the model should not be run or that alterations to the model setup must be made before it can be used. Rather, it means that if the model is run, the modeler should be aware of these limits to the model's predictive capabilities when analyzing the results and when presenting the results to the sponsors and the lay public.

There are a limited number of options available to help reduce the LBC uncertainty. A successful search for additional high-quality shoreline data may allow for a decrease in the size of Y_{Uo}. A common solution is to extend the length of the grid to further isolate the area of primary interest from the end effects. It may be possible to reduce the length of time of the model runs. Finally, it may be that the most logical choice is to accept the level of uncertainty.

6 Summary

This report provides definitive guidance to modelers on the application of LBCs within GenCade. It explains why LBCs are required for model operation. It provides detailed guidance on choosing, setting up, and calibrating LBCs. In particular, it discusses the Gated Boundary Condition in detail, as the functionality of this type LBC was not fully described in earlier documentation.

This report also provides a theoretical discussion of how the impacts of LBCs propagate into the interior of the model grid and how the impacts change in time and space. The intent is to allow the modeler to determine if the model end effects are small enough to be ignored and if not, whether the focus area of his study is sufficiently isolated from the model end effects. Decreasing the values of Y_{Uo}, G, and the model run time and/or increasing the distance between the end of the grid and the portion of the grid that is of primary importance will each act to decrease the impact of the LBC uncertainty parameter.

This report is one of a series that provide guidance to GenCade modelers. Earlier general GenCade guidance documents have preceded it, Frey et al. (2012) and Frey et al. (2014).

References

Bruun, P. 1954. *Coast erosion and the development of beach profiles*. Technical Memorandum No. 44. Beach Erosion Board.

Carslaw, H. S., and J. C. Jaeger. 1959. *Conduction of heat in solids*. New York: Oxford University Press, Oxford.

Dean, R. G. 1977. *Equilibrium beach profiles: U.S. Atlantic and Gulf Coasts. Department of Civil Engineering*. Ocean Engineering Report No. 12. Newark, DE: University of Delaware.

Dean, R. G. 1991. Equilibrium beach profiles: characteristics and applications. *Journal of Coastal Research* 7(1):53–84. ISSN 0749-0208.

Dean, R. G. 2002. Beach nourishment, theory and practice. *Advanced Series on Ocean Engineering*: Vol. 18. River Edge, NJ: World Scientific.

Frey, A., K. Connell, H. Hanson, M. Larson, R. Thomas, S. Munger, and A. Zundel. 2012. *GenCade version 1, model theory and user's guide*. ERDC/CHL TR-12-25. Vicksburg, MS: U.S Army Engineer Research and Development Center.

Frey, A. E., D. B. King, and S. Munger. 2014. *Recommendations and requirements for GenCade simulations*. ERDC/CHL TR-14-6. Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Hanson, H. 1987. *GENESIS, A generalized shoreline change model for engineering use*. Report No. 1007. University of Lund, Lund, Sweden: Department of Water Resources Engineering.

Hanson, H., and Kraus, N. 1989. *GENESIS: Generalized model for simulating shoreline change; report 1, technical reference*. Technical Report CERC-89-19. Vicksburg, MS: Coastal Engineering Research Center, Department of the Army, Waterways Experiment Station.

King, Jr., D. B. 1976. Coastline dynamics of Jamaica. *Journal of the Scientific Research Council of Jamaica* 4(2):1–20.

Kraus, N. C., and Harikai, S. 1983. Numerical model of the shoreline change at Oarai Beach. *Coastal Engineering* 7 (1):1–28.

Larson, M., H. Hanson, and N. C. Kraus. 1987. *Analytical solutions of the one-line model of shoreline change*. Technical Report CERC-87-15. Vicksburg, MS: Coastal Engineering Research Center, Department of the Army, Waterways Experiment Station.

Larson, M., H. Hanson, and N. C. Kraus. 1997. Analytical solutions of one-line model for shoreline change near coastal structures. *J. Waterway, Port, Coastal, Ocean Eng*. 123(4):180–191

Pelnard-Considère, R. 1956. Essai de théorie de l'evolution des formes de rivage en plages de sable et de galets. *4th Journées de I'Hydraulique: Les Énergies de la Mer, Question III* 1:289–300.

Rosati, J. D., T. L. Walton, and K. Bodge. 2002. *Longshore sediment transport*. Coastal Engineering Manual, Part III, Coastal Sediment Processes, Chapter III-2. Engineer Manual 1110-2-1100. Washington, DC: U.S. Army Corps of Engineers.

Vreugdenhil, C. B. 1989. *Computational hydraulics, an introduction*. Berlin: Springer-Verlag.

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14. ABSTRACT

This report provides detailed guidance on the use of Lateral Boundary Conditions (LBCs) within the shoreline change model GenCade. LBCs are a requirement for every model setup. The report focuses on two topics. First, it provides explicit guidance on how to set up the three types of LBCs (Pinned, Moving, and Gated) beyond that provided in previous reports. In particular, it provides detailed instructions on the set up and calibration of the Gated LBC. Second, the report discusses how induced errors can affect model results, both at the ends of the grid where the LBCs are applied and in the interior of the model. This report is one of a series whose intent is to provide detailed guidance to the GenCade model user.

15. SUBJECT TERMS

Boundary value problems, GenCade, Littoral drift, Numerical analysis, Sediment transport-Computer simulation, Shorelines

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