# Mapping Glacier Bay National Park, Alaska

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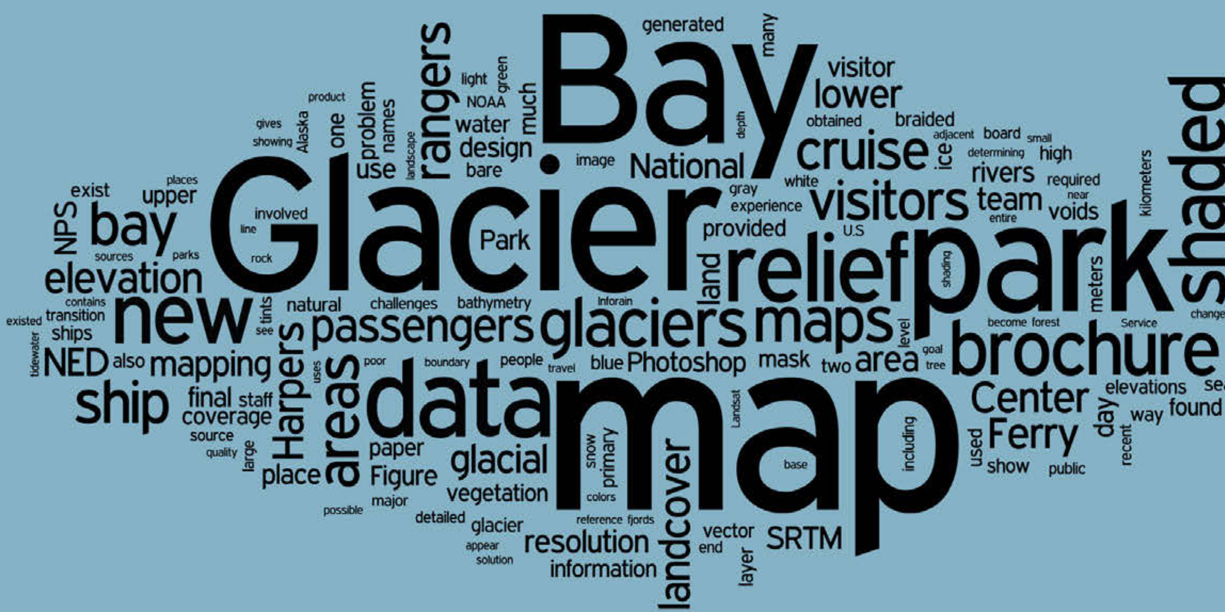


## ABSTRACT

Making a National Park Service (NPS) visitor map of a large, famous park such as Glacier Bay involves careful planning and many people. Preliminary work on the Glacier Bay map required a site visit to Alaska, consultations with park staff, and observing visitors using maps on board a cruise ship. The paper examines various mountain-mapping challenges, including shaded relief, landcover, glaciers, fjord bathymetry, braided rivers, and place names. The paper then ties these strands together by discussing the design of the final brochure map.

## INTRODUCTION

The visitor brochure for Glacier Bay National Park, Alaska, one of the premier glacier parks in the United States, is undergoing a redesign that will include new maps. This paper examines the making of these new maps, which serve a dual purpose: orienting visitors to the park and explaining the natural environment. The primary themes are glacial retreat and ecological succession—the establishment of Glacier Bay as a protected area in 1925 was for scientific study of these and other natural processes.

Since 1794 when British explorer George Vancouver visited the area, glaciers have retreated 100 kilometers up Glacier Bay and now exist tenuously only in the harsh uppermost fjords. Luxuriant temperate rainforest has colonized the lower reaches of the bay. Four hundred years ago Hoonah Tlingit Indians inhabited lower Glacier Bay before advancing ice associated with the Little Ice Age forced them out—they still regard Glacier Bay as their ancestral home. Land in deglaciated areas is rising at a rate of 2.5 centimeters a year, reconfiguring coastlines; braided drainages are in constant flux; and glacial silt is filling estuaries. A landslide triggered a tsunami in 1958 that scoured trees from a mountain 525 meters above sea level, the highest wave ever recorded. The paper discusses the challenge of mapping on a modest-sized sheet of paper this dynamic information for a park 13,520 sq. km. in area, about the size of Connecticut.

The new brochure and map will serve a most uncommon national park audience. Ninety-five percent of visitors to Glacier Bay arrive on cruise ships, never set foot ashore, and are older than the general population of park visitors in the U.S. All passengers arriving in Glacier Bay receive the National Park Service (NPS) brochure, which is an essential reference as they listen to park rangers deliver a day-long running narrative over the public address system of the ship. Because the weather at Glacier Bay is usually inclement, and the cost of an Alaskan cruise is always high, the brochure and ranger narrative help to assuage otherwise disappointed passengers when visibility is poor.

THE NEW BROCHURE AND MAP WILL SERVE A MOST UNCOMMON NATIONAL PARK AUDIENCE. NINETY-FIVE PERCENT OF VISITORS TO GLACIER BAY ARRIVE ON CRUISE SHIPS, NEVER SET FOOT ASHORE, AND ARE OLDER THAN THE GENERAL POPULATION…

To show the park in a more engaging and accessible way to visitors, the new brochure contains a combination of maps, text, photographs, and illustrations. One side of the brochure, devoted entirely to reference and thematic maps, is titled "Compact Atlas of Glacier Bay." This approach to NPS map and brochure design yields a unified product that, we believe, more effectively portrays the striking geography of the park.

## MAP PLANNING

The mapping of Glacier Bay was a collaborative effort between a writer, graphic designer, and cartographer with the NPS Publications Program based at Harpers Ferry Center (HFC), West Virginia, the Glacier Bay park staff, and the local community. The creation of a new map and brochure of Glacier Bay required that the Harpers Ferry Center team become familiar with the park, know the concerns of the park staff, and understand the intended audience. The team traveled 5,300 kilometers to Glacier Bay for a week to begin planning the new brochure. To help reach this goal the park arranged for the Harpers Ferry team to experience the park the same way that visitors do—on board a cruise ship.

THE HARPERS FERRY CENTER TEAM SPENT THE DAY ON A HOLLAND AMERICA SHIP WITH THE RANGERS, OBSERVING HOW THEY WORKED AND HOW PASSENGERS USED THE BROCHURE.

### *THE VISITOR EXPERIENCE*

In what must be a unique morning commute, park rangers leave the headquarters complex in a small boat that intercepts cruise ships as they enter Glacier Bay. As both vessels travel side-by-side at eight knots, the rangers climb a rope ladder entering the ship through a cargo hatch in its side. They do this every day during the summer tourist season, meeting up to two cruise ships allowed in the bay simultaneously. The rangers stay on board for the day as the ships travel 100 kilometers to the scenic fjords and tidewater glaciers at the head of the bay. At the end of the day, as the cruise ship heads out of the bay the rangers climb back down the ladder to the waiting launch and go home.

The Harpers Ferry Center team spent the day on a Holland America ship with the rangers, observing how they worked and how passengers used the brochure. On board the ship early that morning as the passengers slowly awoke, the rangers busily prepared for work by setting up a table with interpretive displays, including the park map. Throughout the day the rangers staffed this table as a temporary visitor center, wandered the decks talking to passengers, and provided comments about the park to the entire ship over the public address system. All passengers received the park brochure, which stewards leave outside their cabin doors during the night before arriving at Glacier Bay. The rangers frequently asked passengers to look at the map as the ship passed points of interest.

The HFC team's observations that day revealed several issues that influenced the design of the new map. The rangers referred to several features in the bay that day not labeled on the map. Where possible, the new map includes these places. Out on deck passengers struggled to open and read the map as it flapped in the wind. The new brochure design places the map at the end of the brochure where it folds out for easier access, minimizing exposure to the wind. Finally, because many of the passengers were elderly and used the map in the glaring outdoor conditions, the new map uses much larger type and more vivid colors.

THE CHALLENGE FOR THE MAP IS TO INTRODUCE VISITORS TO TEMPORAL LANDSCAPE CHANGES ON A STATIC SHEET OF PAPER.

### *DISCUSSIONS WITH PARK STAFF*

For the rest of the week the Harpers Ferry Center team met with all available staff—some three dozen people in all—from maintenance to resource management to the superintendent, to hear their thoughts for improving the brochure. Looking at HFC-produced brochures for other parks was one source of ideas. A park ranger suggested that the brochure include a map of the entire park at a small scale plus a large-scale inset of only the bay, a solution that everyone liked and is used on the final layout. A consensus emerged that one word, change, best described the essence of Glacier Bay and that the new park brochure should reflect this. The landscape that park visitors see today has undergone dramatic changes during the past two centuries, is still undergoing rapid transition, and is likely to change again in the future (Figure 1). The challenge for the map is to introduce visitors to temporal landscape changes on a static sheet of paper.

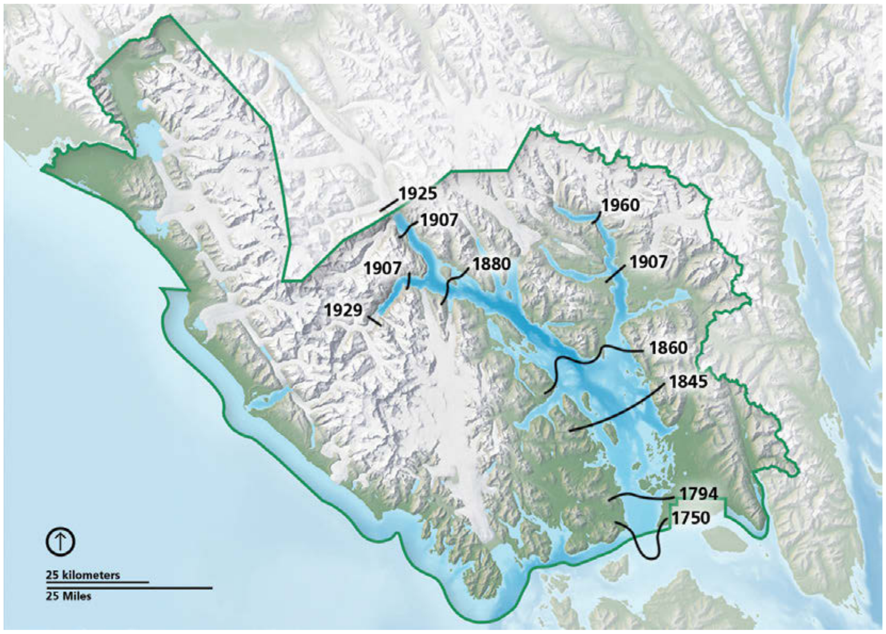


*Figure 1. Most changes seen today at Glacier Bay relate to the retreating glaciers. Black lines on the map above show glacier extents for various years.*

## MAPPING CHALLENGES

The section that follows details some of the challenges encountered when mapping Glacier Bay. Most challenges involved incomplete or poor quality data, and mapping an ever-changing natural environment. The first mapping task tackled—creating a shaded relief— involved all of these challenges.

### *SHADED RELIEF*

Shaded relief on the new Glacier Bay map derives from digital elevation models obtained from two sources. The first data source, National Elevation Dataset (NED), obtained from the USGS National Map Seamless Server, covered all of Glacier Bay National Park at 48-meter resolution. Based on digitized topographic maps of older vintage, this data nevertheless produced shaded relief with a clean appearance and would have sufficed for mapping the park except for the coarse generalized data found in adjacent areas in Canada. The origin of the provisional data found in Canada, occupying 20 percent of the land area shown on the Glacier Bay map, is unknown. Its use would require significant manual retouching. Because data quality was poor and to keep mapping costs down, Harpers Ferry Center sought other public domain data sources.

*MOST CHALLENGES INVOLVED INCOMPLETE OR POOR QUALITY DATA, AND MAPPING AN EVER-CHANGING NATURAL ENVIRONMENT.*

The second source of elevation data was Space Shuttle Radar Topography (SRTM) at 72-meter resolution, a product of NASA. These data collected during eleven days in February 2000 by the Shuttle Radar Topography Mission (SRTM), are more recent and detailed than NED, despite having a lower resolution. The northernmost extent of SRTM coverage is 60 degrees north, which happens to match the northernmost edge of the Glacier Bay map. The huge downside with SRTM is its many data voids, irregular gaps in the coverage where elevation values do not exist. Data voids mar shaded relief generated from SRTM data and, where many voids exist, render the shaded relief useless. The voids are most prevalent in areas with high, steep mountains, landforms that typify much of Glacier Bay National Park.

Although the flaws found in NED and SRTM data prevented their individual use, merging shaded relief generated from each of the datasets minimized the flaws and yielded an acceptable product. Merging occurred in Adobe Photoshop at 300 dpi at the final map size (76 x 91 centimeters). The shaded relief generated from SRTM served as the primary shaded relief. In areas where there were data voids, a layer mask allowed the shaded relief generated from NED, placed on a layer below it, to show through. The layer mask contained the SRTM data voids represented in black (the masking color) on a white background. Expanding the black areas on the mask by 2 pixels and applying Gaussian blur provided a smooth transition between the merged shaded relief images. On the final merged shaded relief, Canada and the U.S. appeared with comparable detail and quality (Figure 2).

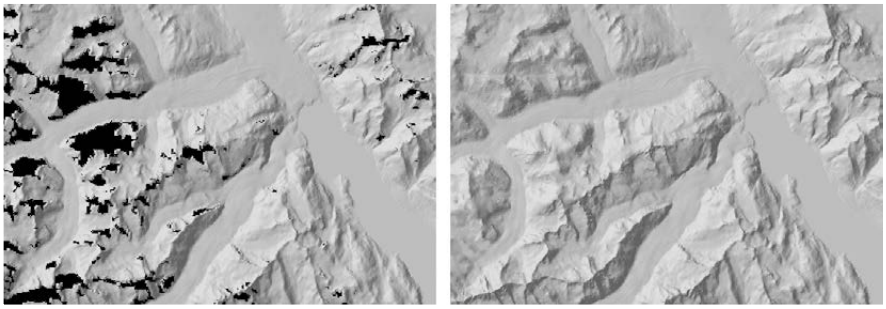

*Figure 2. (left) SRTM shaded relief with data voids shown in black. (right) Merged SRTM and NED shaded relief.*

### LANDCOVER

The use of landcover data on NPS maps to show vegetation types and environmental zones with natural colors has become increasingly common. On the Glacier Bay map landcover data had the potential for highlighting the differences between the forested lower bay and the upper bay, where bare rock and glacial ice predominates. The problem was that suitable landcover data did not exist.

An alternative source for this information had to be found. Depicting landcover in a generalized fashion provided a workable cartographic solution. The new map of Glacier Bay contains only four major landcover categories: water (blue); vegetation (green); barren land (gray); and, multi-year ice and snow (white). In this simplified classification, elevation was the primary factor in determining the distribution of landcover categories. Tree limit in this part of Alaska generally occurs 760 meters above sea level, above which a band of alpine vegetation quickly gives way to expansive areas of bare rock and glacial ice. On the new map, green-tinted NED elevation data represents forested land below 760 meters in elevation. Because lower elevations where the climate is temperate have more biomass than higher elevations near tree line, the dark (lowland) to light (highland) transition in NED places the densest greens in lowlands and the lightest greens near the tree line. Above the tree line the NED data transitions to light gray (Figure 3).

*Figure 3. The final landcover's four basic categories are ice, barren land, forested land, and water.*

Portraying landcover at Glacier Bay based solely on elevation tells only part of the story, however. The rapid retreat of glaciers has left upper portions of the bay at sea level largely bare and awaiting the slow arrival of low vegetation and then forest cover from the lower bay, which has existed ice-free for two centuries. Photoshop and a gradated layer mask provided a way to create the transition from forest to bare rock at sea level on the map. Landscape photographs taken by the Harpers Ferry Center team from the cruise ship served as a reference for determining how much green or gray to show in any given area.

This stylized depiction gives visitors an impression of the landcover at Glacier Bay that does not interfere with the shaded relief. Furthermore, green forest cover created from NED in the lowlands serves as a rudimentary hypsometric tint enhancing the overall presentation of the terrain.

## GLACIERS

Despite this park's being famous for its glaciers and set aside as a protected area for scientific study, detailed maps of Glacier Bay's present-day glaciers were nonexistent. Showing recent and accurate glacier information on the new visitor map was a high priority and required that Harpers Ferry Center map the glaciers from scratch. A Landsat image provided by the park GIS specialist, taken in early fall 2000, served as the primary base for interpreting glacial coverage. Since this image was not as recent as the Harpers Ferry Center team would have liked, the team used other imagery sources, including Google Earth, to update the positions of major tidewater glaciers.

DESPITE THIS PARK'S BEING FAMOUS FOR ITS GLACIERS AND SET ASIDE AS A PROTECTED AREA FOR SCIENTIFIC STUDY, DETAILED MAPS OF GLACIER BAY'S PRESENT-DAY GLACIERS WERE NONEXISTENT.

Mapping glacial extents in Photoshop took considerable time and involved manual painting with the Brush tool and automated selection techniques. Differentiating between glacial ice and seasonal snow was one problem encountered. Using the Magic Wand selection tool in Photoshop (by clicking on white areas) resulted in the selection of glaciers and also many small temporary snow patches. Filtering these selections in Photoshop eliminated the smallest patches. However, the map does not differentiate large snowfields from glaciers.

Another apparent problem was the deep shadows found on northwest slopes near the summits of the highest peaks, obscuring the glaciers and making accurate mapping from the satellite images impossible. In the end, this

*Figure 4. Glaciers as they appear on the final map. Johns Hopkins Glacier flows northeast into an inlet of the same name near the middle of the image.*

proved to be no problem because the map gradually blends glacier shapes with a gray-white background tone at higher elevations, depicting these areas as uniformly icy. This technique solved a related issue, discussed next.

On the final map, the light-dark glacier coverage conflicted with shaded relief, also consisting of light and dark tones. This problem became most noticeable at high elevations where light colored glaciers occupied shadowed southeast slopes on the shaded relief. In effect, they cancelled each other out and obscured the shaded relief. Clearly the glaciers in these areas required modification. The solution again involved NED elevation data and Photoshop. Inverting the NED data so that high areas appeared dark and placing it into a layer mask diminished the contrast of the glaciers against the shaded relief for areas above 2,500 meters in elevation. Above this elevation, where snow accumulates year-round, the shaded relief appears as a cold blue-gray and is much easier to read. Below 2,500 meters in elevation, the zone of ablation where seasonal melting takes place, the glaciers become increasingly distinct from the adjacent shaded relief and landcover. At the very lowest elevations the glacier snouts reveal moraine striations, shown faintly, textural information obtained from the Landsat image (Figure 4).

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### BATHYMETRY

At Glacier Bay, the largest protected marine environment in Alaska, the undersea world is the focus of research activity and is increasingly important to park interpretation. Using the latest bathymetry data, the new map also gives visitors a glimpse of what Glacier Bay is like beneath its silt-laden water.

*USING THE LATEST BATHYMETRY DATA, THE NEW MAP ALSO GIVES VISITORS A GLIMPSE OF WHAT GLACIER BAY IS LIKE BENEATH ITS SILT-LADEN WATER.*

The most spectacular bathymetry available is multibeam data collected by the USGS at 5-meter resolution. However, this data only covers a limited area in the lower and middle portions of the bay, excluding all near-shore areas. More

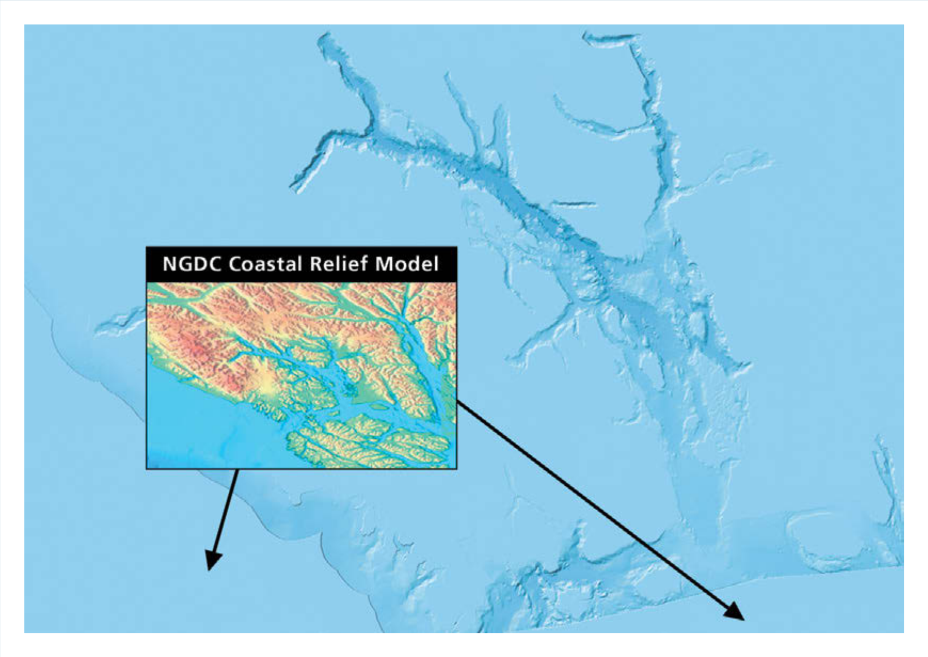


*Figure 5. NOAA Coastal Relief Model fills in peripheral areas not covered by Inforain bathymetry (the blue background image), which ends at the park boundary.*

appropriate for our purposes is a bathymetric dataset at 25-meter resolution produced by Inforain from digitized NOAA nautical charts. The Inforain data is reasonably clean and detailed, but it does not extend beyond the park boundary, leaving blank those adjacent marine areas that comprise much of the map. To fill in these blanks Harpers Ferry Center obtained pre-release Coastal Relief Model data at 90-meter resolution from the NOAA National Geophysical Data Center. Merging of the Inforain and NOAA datasets took place in Photoshop using a mask with a soft edge for seamless blending. The lower resolution NOAA data appear in the Pacific Ocean, Icy Strait, and Lynn Canal on the periphery of the map (Figure 5).

The depiction of bathymetry on the final map differs from the original design vision, which was to combine oblique hill shading with depth tints. The idea was to show the terrestrial and undersea topography as extensions of one another. When applied, however, this technique did not work because the shading confused where the land ended and sea began. This was especially the case in the narrow upper fjords that are the primary destination for visitors. Taking the shading out of the water and showing instead only blue depth tints solved the problem of figure-ground ambiguity between land and water. There is a second benefit to showing only the depth tints. As the bay becomes progressively deeper from its lower to upper reaches, the intensifying blue tints on the map point cruise ship passengers to where they will go.

### HYDROGRAPHY

Although relatively few rivers appear on the map of Glacier Bay, and despite the fact that they are minimally relevant to cruise ship passengers, mapping them was nevertheless challenging and time-consuming. The Alsek River, a braided river that fills a flat floodplain up to five-kilometers wide, bounds the northwestern boundary of the park. Other large braided rivers flow north and east of the park. By showing these untidy and continually changing rivers, the map reveals a major characteristic of glacial landscapes.

*BY SHOWING THESE UNTIDY AND CONTINUALLY CHANGING RIVERS, THE MAP REVEALS A MAJOR CHARACTERISTIC OF GLACIAL LANDSCAPES.*

As usual, a good dataset existed for areas in the park while information beyond its boundary was sparse and out of date. Where vector map coverage existed, discarding roughly two-thirds of the channels comprising the braided rivers improved their legibility. In areas where vector coverage was non-existent, the interpretation from the Landsat image and tracing from old topographic maps provided the vector drainages. The task was necessary and tedious and is finished for now—until the rivers again change course.

Coastlines at Glacier Bay also fluctuate greatly. Determining precise coastal boundaries along shallow coasts is made more difficult by three factors: the slow but steady rising of the land caused by glacial rebound; silt carried by glacial rivers that is converting shallow estuaries into mud flats extending for kilometers; and 5-meter tides that rearrange things twice daily (Figure 6). Even with satellite imagery, determining where mud flats end and silt-laden water begins is difficult. On the new map the coastline derives from an extremely detailed vector shoreline generated as part of a recent coastal inventory project. For this project people walked the entire 1,223-kilometer coastline of Glacier Bay.

On the final map the thin blue lines representing drainages and coastlines were rasterized and printed lightly, to blend better with the relief art below. Diminishing their prominence lessened the complexity of the map and improved readability.

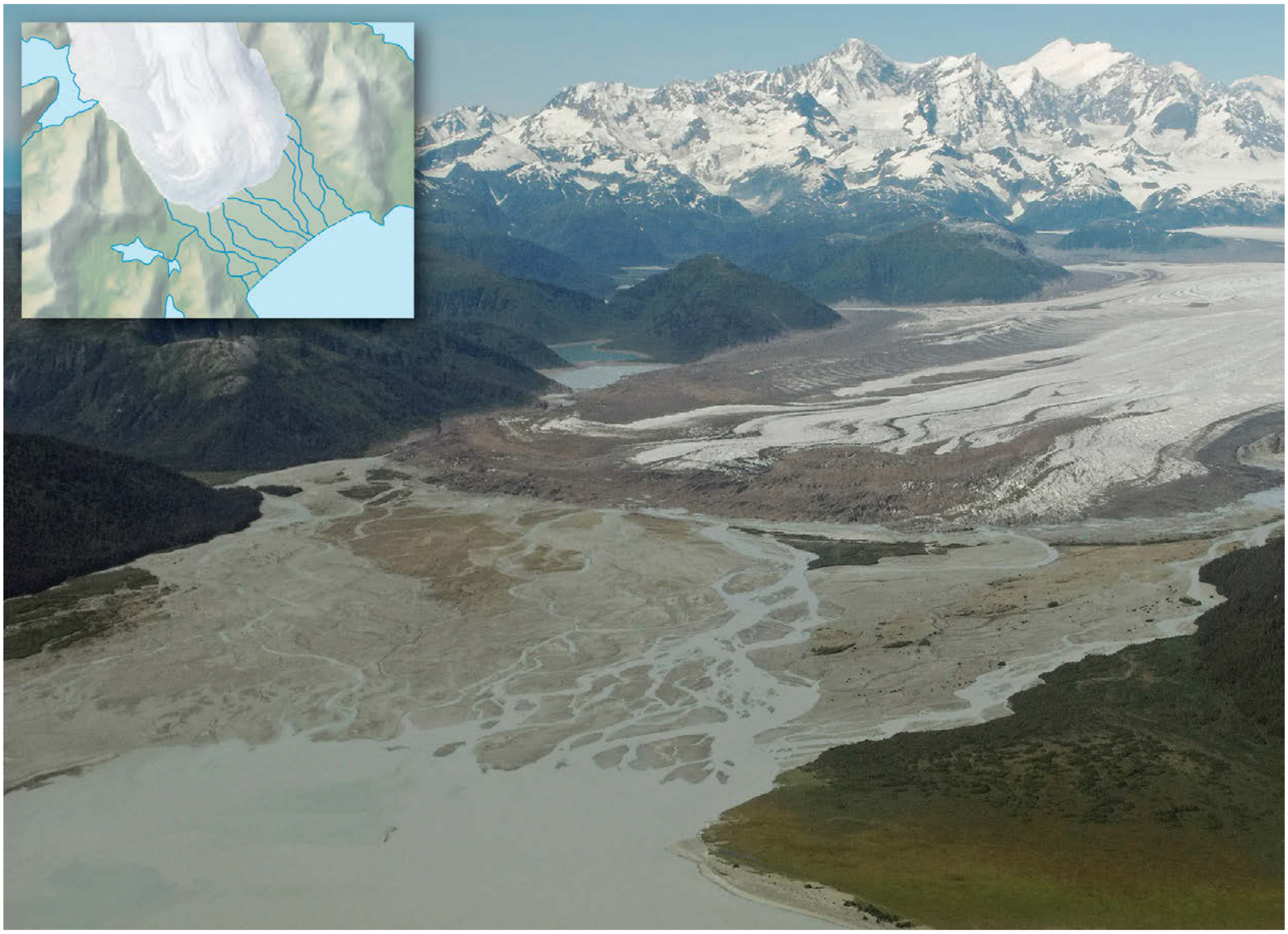

*Figure 6. A braided stream flowing from Brady Glacier to Taylor Bay, which is rapidly filling with silt. The inset shows the generalized map depiction. Photograph: NPS/Bill Eichenlaub*

### PLACE NAMES

Not all place names that park rangers frequently mention to visitors appear on the new map of Glacier Bay. For example, descriptive names for general regions of the park, like "upper bay" and "lower bay," are not included. These omissions are not by individual choice but by government mandate. All maps made by federal agencies, including the NPS, must bear only the official spellings approved by the U.S. Board on Geographic Names (BGN). U.S. government mapmakers also are not permitted to place new names on maps until they are approved by BGN, normally a six-week process if the name is uncontested.

At Glacier Bay, however, this option does not exist. Most of Glacier Bay is a congressionally designated wilderness area, where a moratorium prohibits the coining of new place names. The idea behind the moratorium is to keep wild land untrammeled by humans as much as possible, even in the abstract realm of language and maps. Future visitors to Glacier Bay will only experience the "upper bay" as the wild place it is, not as a label on the map.

## THE FINAL MAPS

> *THE IDEA BEHIND THE MORATORIUM IS TO KEEP WILD LAND UNTRAMMELED BY HUMANS AS MUCH AS POSSIBLE, EVEN IN THE ABSTRACT REALM OF LANGUAGE AND MAPS.*

From the components described above, Harpers Ferry Center created a master base map and two derivative maps of Glacier Bay for visitor use. One of the maps was for the brochure discussed in this article (Figure 7), and the other was a large wall map for display in the park visitor center and on cruise ships. Care was taken when preparing the master base map to ensure sufficient resolution in the raster shaded relief and vector detail for dual use at differing scales.

The design of both maps kept in mind the goal of attracting readers. The terrain art uses natural colors that resemble those seen in the park. Visitors travel great distances at great expense to see the park presumably because they anticipate finding it attractive—the map attempts to capitalize on this predisposition. Assuming that most readers intuitively associate green with vegetation, gray with bare land, blue with water, and white with ice, no legend explaining the landcover was used.

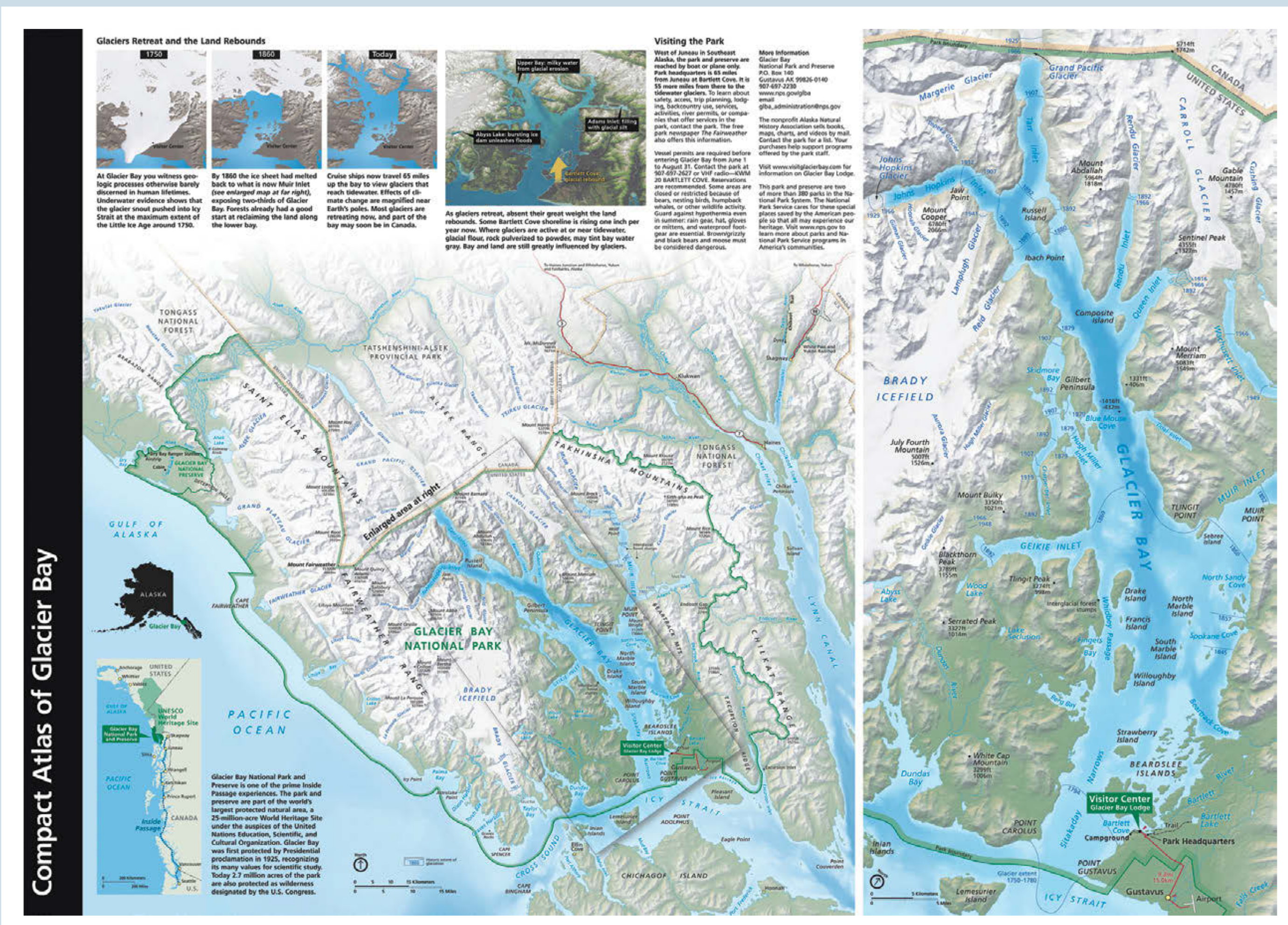


*Figure 7. The final brochure map.*

Information density balances the need to keep the map as uncluttered as possible while offering readers ample information about the park and enticing them to future exploration. A subtle softening of the shaded relief behind text labels enhances legibility. Other graphical embellishments—transparency, fades, vignettes, and drop shadows—that people find intrinsically attractive enhance the visual hierarchy and guide the reader's eyes from one area of interest to the next. Like the physical landscape that it represents, the map contains spatial connections. Most visitors see Glacier Bay from the insulated confines of a cruise ship for only a few hours. The goal of the map and brochure is to broaden and deepen this experience.

*MOST VISITORS SEE GLACIER BAY FROM THE INSULATED CONFINES OF A CRUISE SHIP FOR ONLY A FEW HOURS. THE GOAL OF THE MAP AND BROCHURE IS TO BROADEN AND DEEPEN THIS EXPERIENCE.*

## CONCLUSION

The new Glacier Bay map, published in 2009, is functioning as intended according to feedback from park rangers and the observations of the author, who visited Glacier Bay again in 2010. Despite a strong wind and bright sunlight, cruise ship passengers were able to use the map outside while watching tidewater glaciers calving. The Glacier Bay map has influenced the design of other NPS maps. Brochures for other spectacular Alaskan parks managed by the NPS, published decades ago, are overdue for major revision—and the Glacier Bay map treatment. For example, a remake of the Denali National Park map currently underway uses the Glacier Bay map as a model for depicting the mountains, glaciers, and subarctic vegetation of that park. Because the Glacier Bay map is in the public domain, companies can use it to create spin-off products, from iPhone apps to posters. One of these products has found its way back to the Park Service. In 2010, Summit Terragraphics, Inc., repurposed the Glacier Bay map as a raised plastic relief map. The rangers take this portable map with them on their daily cruise ship visits.

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