In the United States Court of Federal Claims

No. 99-4451 L
c/w 99-4452 L, 99-4453 L, 99-4454 L, 99-4455 L, 99-4456 L, 99-4457 L, 99-4458 L, 99-4459 L, 99-44510 L, 99-44511 L, 99-44512 L, 00-365 L, 00-379 L, 00-380 L, 00-381 L, 00-382 L, 00-383 L, 00-384 L, 00-385 L, 00-386 L, 00-387 L, 00-388 L, 00-389 L, 00-390 L, 00-391 L, 00-392 L, 00-393 L, 00-394 L, 00-395 L, 00-396 L, 00-398 L, 00-399 L, 00-400 L, 00-401 L, 05-1353 L, 05-1381 L, 06-72 L

(E-Filed: December 22, 2011)

JOHN H. BANKS, ET AL., Plaintiffs, v. THE UNITED STATES, Defendant.	99-4451 L	Complaints for Taking of Shoreline by Erosion; Opinion Dismissing Complaints After Trials of Liability and Damages
EUGENE J. FRETT, Individually and as Trustee of the Victor J. Horvath and Frances B. Horvath Trust, Plaintiff, v. THE UNITED STATES, Defendant.	05-1353 L	

Mark E. Christensen, Chicago, IL, with whom was John B. Ehret, Olympia Fields, IL, and with whom at trial was Katherine A. Jones, Chicago, IL, for plaintiffs in No. 99-4451 L. Eugene J. Frett, Chicago, IL, pro se in No. 05-1353 L.

Terry M. Petrie, Environment and Natural Resources Division, United States Department of Justice, Denver, CO, with whom was Ignacia S. Moreno, Assistant Attorney General, and with whom at trial was Mark S. Barron, Trial Attorney, Environment and Natural Resources Division, United States Department of Justice, Washington, DC, for defendant. Gary W. Segrest and Don C. Erwin, Office of Counsel, United States Army Corps of Engineers, Detroit, MI, of counsel.

OPINION[1]

HEWITT, Chief Judge

This is an action for just compensation filed by owners of property along the eastern shore of Lake Michigan. Plaintiffs' properties are located along an area of the shoreline that erodes naturally, but allege that the government's construction and maintenance of a pair of jetties effected a taking by speeding the erosion of their properties.

This Opinion addresses a jurisdictional issue that arose after the second trial held by the court to address the merits of plaintiffs' claims. The court holds that, because plaintiffs' claims accrued earlier than 1952, plaintiffs filed this action outside of the limitations period. The court therefore dismisses plaintiffs' claims for lack of jurisdiction.

"'Without jurisdiction the court cannot proceed at all in any cause. Jurisdiction is power to declare the law, and when it ceases to exist, the only function remaining to the court is that of announcing the fact and dismissing the cause.'" Steel Co. v. Citizens for a Better Env't, 523 U.S. 83, 94 (1998) (quoting Ex parte McCardle, 74 U.S. (7 Wall) 506, 514 (1868)). For purposes of judicial efficiency, if the reviewing court in any appeal should disagree with the court's view of its jurisdiction, and to avoid the possibility of a trial opinion being drafted months or years after the trial, and the possibility of a repetitive trial, the court also presents here its findings from the trial. These findings are presented in the alternative and, in the absence of jurisdiction, do not entitle plaintiffs to just compensation in the amounts determined by the court.

Before the court are Plaintiffs' Post-Trial Brief (Pls.' Br.), Docket Number (Dkt. No.) 495, filed June 21, 2011; United States' Post-Trial Memorandum (Def.'s Br.), Dkt. No. 496, filed June 21, 2011; Plaintiffs' Response to the United States' Post-Trial Brief

[1]The court attaches a Table of Contents at the end of this Opinion.

(Pls.' Resp.), Dkt. No. 497, filed July 12, 2011; and United States' Post-Trial Response Memorandum (Def.'s Resp.), Dkt. No. 498, filed July 12, 2011.

Also before the court is the following briefing on the topic of jurisdiction, filed pursuant to the court's August 9, 2011 Order, Dkt. No. 499: Plaintiffs' Post-Trial Brief on Jurisdiction (Pls.' Jur. Br.), Dkt. No. 501, filed September 7, 2011; United States' Supplemental Post-Trial Memorandum (Def.'s Jur. Br.), Dkt. No. 502, filed September 7, 2011; United States' Supplemental Post-Trial Response Memorandum (Def.'s Jur. Resp.), Dkt. No. 503, filed September 21, 2011; and Plaintiffs' Post-Trial Reply Brief on Jurisdiction (Pls.' Jur. Resp.), Dkt. No. 504, filed September 21, 2011.

Also before the court is the transcript of the trial of damages (Tr.), held from April 18 through April 21, 2011 and from April 25 through April 28, 2011.

I. Procedural Background and the Law of the Case

"Plaintiffs[2] are the owners of property along approximately four and a half miles of the eastern shore of Lake Michigan south of St. Joseph Harbor." Sept. 28, 2007 Op., Banks v. United States (Liability Op.), Dkt. No. 245, 78 Fed. Cl. 603, 604 (2007). Beginning in the 1830s, the United States government, acting through the United States Army Corps of Engineers (defendant or the Corps) re-constructed the mouth of the St.

[2]Plaintiffs identify themselves as follows in their briefing, which also contains the addresses of their properties: Michael R. and Janice Anderson; John H. and Mary Banks; Andrew C. Bodnar and Christine M. Zajl-Bodar; Gregory R. and Candice C. Bovee; Frank H. Bunker; Richard R. and M. Lynn Carter; Donald R. and Gail L. Chapman; the J. Thomas Concklin Trust; Gerard V. Cosgrove; Marilyn J. Cunat individually and as Personal Representative of the Estate of Robert Cunat; Marc and Mary Del Mariani; Ehret Michigan Trust; Victor J. Horvath and Frances B. Horvath Trust under Trust Agreement dated November 16, 1995; George J. Gregule, Jr.; Victoria Jackson aka Victoria Illsen; Hyun S. Jyung Trust; Robert J. and Patricia Kane; Frank F. and Charlotte D. Lahr; Richard Neuser; Robert S. and Pamela S. Pancoast; Dorothy A. Renner[], as Trustee of the Dorothy Renner Declaration of Trust aka Dorothy Renner Trust dated September 6, 1996; Leonard J. Smith; Kay F. Varga aka Kay F. Smith; Marcia Wineberg; Robert D. and Maria Melcher; Carolynne K. Morvis Trust; Craig D. and Cherie Okonski; Kent A. and Margaret Werger; Roger B. and Ann C. Wilschke; Country, LLC; Greenbriar Development; L. Richard and Nancy A. Marzke; Donald D. and Judith E. Miller; Notre Dame Tennis and Swim Club aka Notre Dame Path Condominium Association; Herzl Ragins, M.D.; Elizabeth S. Errant aka Elizabeth Saphir, individually and as Trustee to the James W. Errant, Jr. Trust; Bank One fka NBD Bank, N.A., Trustee of the Thelma C. McKay Trust. Pls.' Post-Trial Br. (Pls.' Br.), Docket Number (Dkt. No.) 495, at 3-7; see also Pls.' Ex. (PX) 248 (first stipulation regarding ownership); PX 249 (second stipulation regarding ownership); PX 250 (third stipulation regarding ownership); PX 251 (fourth stipulation regarding ownership). Although missing from plaintiffs' list, the Estate of Yolanda P. Stevens is included in one of the stipulations provided by the parties. See PX 248 (first stipulation regarding ownership) Ex. A at 2.

Joseph River and began constructing harbor jetties that jutted into Lake Michigan in order to accommodate commercial shipping vessels exiting the St. Joseph River into Lake Michigan. Id. Over time, the Corps lengthened the jetties and then encased them in steel. Id. Plaintiffs claim that the Corps' construction and maintenance of the jetties caused erosion of their shoreline property. Id. Specifically, plaintiffs allege that the encasement of the jetties in "sand-tight" steel sheet piling during the period from 1950 to 1989 interrupted the natural littoral[3] drift of sand to their properties, resulting in erosion. See Aug. 9, 2011 Order, Banks v. United States (Order to Brief Jursisdiction), Dkt. No. 499, 99 Fed. Cl. 622, 624 (2011).

Several factors obscure the effect of the jetties on plaintiffs' properties. Plaintiffs' properties are located along a shoreline that is eroding naturally, see Tr. 2594:24-25 (Nairn); Tr. 710:22-23 (Mackey), making it necessary to distinguish the baseline of natural erosion from erosion caused by defendant. The comparatively slow process of long-term erosion is also masked by far larger swings in the width of the beaches next to plaintiffs' properties caused by cross-shore sand transport, a cyclical process by which sand is moved offshore during times of high lake levels and returned to the shore during times of low lake levels. See Tr. 2593:3-19, 2594:2-2595:2 (Nairn) ("So, I mean, you've got swings of hundreds of feet related to the cross or reversible process and then you've got a very [s]low retreat, we believe to be around .62 [feet] per year on the south end, going on in the background of all those very large swings back and forth."); cf. Tr. 1624:9-12 (Shabica) (stating that "predicting lake levels is like predicting the weather, but if we look in the past, high lake levels from one high lake level to the next have ranged anywhere between 11 years and 22 years"). Furthermore, the composition of a shoreline, a characteristic that impacts how the shoreline erodes and how it reacts to efforts to mitigate erosion, can be hidden by surface sediments, and may be complex and difficult to characterize into one of the two categories--sandy and cohesive--used by coastal engineers and geologists. See infra Part III.B.

Defendant filed a motion to dismiss on the ground that plaintiffs' claims are time-barred. July 31, 2001 Op. and Order, Banks v. United States (Accrual Op. I), Dkt. No. 3, 49 Fed. Cl. 806, 809 (2001), rev'd, 314 F.3d 1304 (Fed. Cir. 2003) (Accrual Op. II). The court granted defendant's motion to dismiss, finding that plaintiffs' claims accrued no later than 1989, more than six years before plaintiffs filed suit. See id. at 825. For reasons discussed below, see infra Part III.A.1, the United States Court of Appeals for the Federal Circuit (Federal Circuit) reversed and remanded for further proceedings, Accrual Op. II, 314 F.3d at 1310.

[3]The littoral zone is, "[i]n beach terminology, an indefinite zone extending seaward from the shoreline to just beyond the breaker zone." Coastal Engineering Manual, App. A (Glossary) A-45 (2003). Littoral drift or transport refers to "[t]he movement of beach material in the littoral zone by waves and currents," and "[i]ncludes movement parallel (long shore drift) and sometimes also perpendicular (cross-shore transport) to the shore." Id.

On remand, this case has been bifurcated for trial of liability and damages. In 2007 the court held a one-week trial of liability and issued the court's Liability Opinion.[4] See generally Liability Op., 78 Fed. Cl. 603. The Liability Opinion summarizes the procedural history of the first eight years of this case, makes extensive findings of fact and describes many of the scientific concepts at issue in this case. See id. passim. In order to minimize repetition, this Opinion assumes substantial familiarity with the Liability Opinion.

After the court issued its Liability Opinion, the court directed the parties to "file a joint status report or, if they cannot agree, separate status reports, proposing additional proceedings necessary to resolve the remaining issues in this matter." Dec. 14, 2007 Order, Dkt. No. 250, at 1-2. Defendant filed a status report, stating that the parties had met in person "in an effort to discuss issues and share thoughts on how to calculate damages." Def.'s Status Report, Dkt. No. 252, at 2. Defendant described several factual and legal issues that remained outstanding in regard to the measure of damages owed by defendant. See id. at 2-5. Defendant stated that, while defendant believed that the court had ruled on the issue of shoreline composition, plaintiffs believed that they would be able to introduce additional evidence on the topic. See id. at 4. Defendant noted that the "array of factors" that must be considered by the court in order to calculate damages is complicated by the fact that "plaintiffs present a variety of different circumstances: for example, some plaintiffs claim to have lost all of their property, some plaintiffs have sold their property since the onset of litigation, and some also claim loss and damage to structures and loss of rental income." Id. at 2. Defendant suggested that appraisals of plaintiffs' properties would be necessary to establish the amount of damage caused by the government's actions. See id. at 2-3. Defendant proposed a schedule for briefing on the remaining legal issues, limited additional discovery and a trial of damages. See id. at 4-5.

Plaintiffs submitted a status report that proposed no further proceedings or discovery. Pls.' Status Report, Dkt. No 251, passim. Plaintiffs' status report proposed

[4]In addition to the court's trial opinion following the trial of liability, Sept. 28, 2007 Op., Banks v. United States (Liability Op.), Dkt. No. 245, 78 Fed. Cl. 603 (2007), several other of the court's orders, discussed below, further refine the law of the case in this matter. See Aug. 11, 2009 Op. and Order, Banks v. United States (Law of Damages Op.), Dkt. No. 324, 88 Fed. Cl. 665, 688 (2009) (determining that plaintiffs are entitled to damages for a time period beginning in 1950, rather than at their date of acquisition); Oct. 15, 2008 Op. and Order, Banks v. United States (Order Granting Recons.), Dkt. No. 276, 84 Fed. Cl. 288, 298 (2008) (granting reconsideration on the topic of lakebed composition); May 3, 2007 Op., Banks v. United States, Dkt. No. 200, 76 Fed. Cl. 686, 692 (2007) (concluding that accrual of a takings claim is determined by an objective standard); May 26, 2006 Op., Banks v. United States (OHWM Op.), Dkt. No. 141, 71 Fed. Cl. 501 passim (2006) (discussing the definition of the term "ordinary high water mark"); June 23, 2005 Op. and Order, Banks v. United States (Stabilization Op.), Dkt. No. 87, 68 Fed. Cl. 524 passim (2005) (discussing the federal navigational servitude and the date on which the ordinary high water mark is to be measured).

that the court order defendant to pay plaintiffs $124,918,219, an amount that plaintiffs argued was equal to the cost of the shore protection installed by plaintiffs, the loss of real property and structures to erosion, the loss of rent, the loss of beach access, "prospective damages" and interest. Id. at 1-3, 5. Plaintiffs did not attach adequate documentation or detailed calculations to their status report to support the amount of their alleged damages. See id. passim. Plaintiffs stated that "[p]laintiffs have reviewed numerous available appraisals and find them to be unhelpful in that they use comparables, i.e., other sold properties, which likewise lack unhindered (i.e., no need for shore protection) lake access." Id. at 6. Without explanation, plaintiffs attached to their status report a newspaper article titled "River dredging faces obstacles"; a list--largely typed but partly written by hand--of the plaintiffs and the sums alleged to be due to each; a copy of two filings in this case related to interrogatories; and a list--largely written by hand but typed in part--entitled "Properties Sold or Destroyed[,] Reasonably Foreseeable Loss." Id. at Exs. 1-4.

Plaintiffs then filed Plaintiffs' Motion for Leave to Supplement Status Report, Dkt. No. 253, attached to which was a status report with the subtitle "taking is spoliation," id. at 1. In their status report, plaintiffs stated that "defendant/spoliator, who has been found liable for taking private property landward of the high water mark (OHWM), now wants to foist upon the judicial process a tediously cumbersome effort to measure that very property which it has destroyed or disposed of by its own continuing activity." Id. at 1-2. Plaintiffs argued that "[t]he best evidence of sand loss to each plaintiff is based on his or her own recollection, photographs, appraisals, etc. listed in plaintiffs' answers to defendant's 2nd set of interrogatories." Id. at 2 (capitalization omitted). Plaintiffs further argued that "[a]n appropriate sanction for the defendant/spoliator would be for the [c]ourt to accept the calculations which have been available to defendant since July 16, 2001--over six years." Id. at 2. Plaintiffs argued that "defendant/spoliator has acted intentionally, in an anti-constitutional, anti-environmental, anti-due process, and unnecessary manner." Id. at 3.

The court conducted two telephonic status conferences with the parties, see Jan. 22, 2008 Order, Dkt. No. 258, at 1-2, and scheduled briefing on the issue of whether plaintiffs would be permitted to present additional evidence of shoreline composition at the trial of damages, see Feb. 19, 2008 Order, Dkt. No. 260, passim. Plaintiffs filed a memorandum that the court treated as a motion for reconsideration on the issue of shoreline composition. Oct. 15, 2008 Op. and Order, Banks v. United States (Order Granting Recons.), Dkt. No. 276, 84 Fed. Cl. 288, 290 (2008). Plaintiffs argued that they should be permitted at the trial of damages to present additional evidence that the shoreline in plaintiffs' zone[5] is cohesive.[6] Id. The court concluded that "[c]ontrary to

[5]Plaintiffs' zone includes portions of Lincoln Township, St. Joseph Charter Township and Stevensville, all of which are located in Berrien County, Michigan. See Pls.' Br. 3-7; see also Def.'s Ex. (DX) 293 (Mickelson Report) 4, Fig. 1 (map of plaintiffs' zone); DX 172 (Nairn OHWM Report) 22, Fig. 4.1 (map of "Properties to the North"); DX 172 (Nairn OHWM Report)

plaintiffs' contention, the court explicitly and conclusively determined the issue of the nearshore lakebed composition in plaintiffs' zone." Id. The court stated that "[p]laintiffs did not carry their burden of proof regarding the composition of the nearshore lakebed during the liability trial." Id. at 293.[7] The court further stated that "[p]laintiffs' arguments fail to demonstrate any of the three circumstances which would support reconsideration: the occurrence of an intervening change in the controlling law, the availability of previously unavailable evidence, or the necessity of allowing the motion to prevent manifest injustice." Id. at 292 (citing Matthews v. United States, 73 Fed. Cl. 524, 526 (2006)). However, notwithstanding that "[p]laintiffs had the opportunity during trial to present evidence regarding the composition of the nearshore lakebed of plaintiffs' zone," id. at 297, the court held that "in order to avoid possible inefficiency and delay in resolving plaintiffs' claims, the court will accept additional evidence regarding the composition of the nearshore lakebed in plaintiffs' zone," id. at 298; see also infra Parts III.B.2-3 (discussing additional evidence of shoreline composition). The court directed the parties to suggest a schedule for further proceedings. See Order Granting Recons., 84 Fed. Cl. at 298.

After receiving separate status reports from the parties, the court set a schedule providing for discovery and the resolution of remaining legal issues. Nov. 12, 2008 Order, Dkt. No. 282, at 2-4; see also Aug. 11, 2009 Op. and Order, Banks v. United States (Law of Damages Op.), Dkt. No. 324, 88 Fed. Cl. 665, 669-70 (2009) (listing the motions and memoranda filed by the parties). The court then issued its Law of Damages Opinion, in which it stated that "[t]he court's legal rulings contained within this Opinion and Order clarify the law that will govern the damages phase of the case." 88 Fed. Cl. at 669 n.1.

The damages available to plaintiffs are calculated in accordance with the court's finding in the Liability Opinion that defendant is liable for the portion of 30% of the total

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25, Fig. 4.2 (map of "Properties to the South"). Plaintiffs' zone begins 18,188 feet from the St. Joseph Harbor, the site of the jetties, and ends 41,553 feet from the jetties. DX 293 (Mickelson Report) 5, Table 1 (table of plaintiffs' properties arranged by distance from jetties).

The expert witness reports prepared in this case were admitted without objection and are cited by the parties in their briefing. See, e.g., Pls.' Br. 10 (citing PX 136 (Mackey Report)); Def.'s Br. 5 (quoting DX 294 (McNinch Report)).

[6]Shoreline composition is significant to whether defendant's efforts to mitigate erosion have been effective. See infra Part III.B.

[7]The court also noted that "plaintiffs failed to present, as they might have and indeed should have, evidence on each individual plaintiff's specific property interest, including title, date of acquisition[] and boundaries, at the liability trial." Order Granting Recons., 84 Fed. Cl. at 297 n.6.

erosion damages to each plaintiff's property not mitigated by defendant. 78 Fed. Cl. at 656-57. Plaintiffs' damages are to be divided into three time periods. See id. During each time period, defendant is liable for any portion of 30% the erosion damage to plaintiffs' properties not mitigated by defendant. See id. During the first time period, which runs from 1950 to 1970, defendant undertook no mitigation activity and is liable for damages for 30% of the erosion of each plaintiff's property.[8] See id. at 656. During the second time period, which begins in 1970--when the Corps began its efforts to mitigate erosion caused by the jetties--defendant is liable "for any portion of 30% of each plaintiff's total erosion above the high water mark . . . that was not effectively mitigated by the Corps' nourishment." See id. During the third time period, from January 2000 forward, defendant is liable for damages for any portion of 30% "of all reasonably foreseeable future loss" not mitigated by defendant. Id.

Plaintiffs who have installed shore protection may recover the government's share of the cost to install and maintain the shore protection, Law of Damages Op., 88 Fed. Cl. at 685 & n.16, that is, 30% of any costs incurred from 1950-1970, and a portion of the costs incurred from and after 1970 equal to the portion of the erosion caused by the jetties and not mitigated by defendant, cf. Liability Op., 78 Fed. Cl. at 656.

Regarding defendant's liability for "all reasonably foreseeable future loss," id., the court stated that if further erosion of plaintiffs' properties is "'in fact preventable by prudent measures, the cost of that prevention is a proper basis for determining the damage,'" Law of Damages Op., 88 Fed. Cl. at 683 (quoting United States v. Dickinson, 331 U.S. 745, 751 (1947)). Relevant to whether the installation and maintenance of shore protection to prevent future erosion is a "prudent measure" is whether the shore protection costs more than the reasonably foreseeable erosion damage that would occur without it. See id. ("'If revetments are less expensive than the value of the land forecast to be lost, then the [g]overment may discharge its liability by bearing the cost of bank protection.'") (quoting Boling v. United States (Boling I), 41 Fed. Cl. 674, 694 (1998), vacated on other grounds (Boling II), 220 F.3d 1365 (Fed. Cir. 2000)).

"Although the general rule in takings cases is to award plaintiff the form of just compensation that will be least expensive for the government," the court, in its Law of Damages Opinion, found this general rule "inapplicable in the particular circumstances of

[8]At the time that the court filed the court's Liability Opinion, the issue of the period of time during which defendant's liability is to be evaluated was not "squarely before the court." Law of Damages Op., 88 Fed. Cl. at 675 n.7. The court concluded at the time that plaintiffs were not entitled to recover damages for erosion that predated their acquisition of their properties. See Liability Op., 78 Fed. Cl. at 655-57. Following briefing on the issue, the court concluded in its Law of Damages Opinion that each plaintiff is "entitled to compensation for any damage attributable to the jetties from the time the jetty improvements began in 1950, notwithstanding the fact that 1950 may be prior to the date on which that plaintiff acquired its respective property interest." 88 Fed. Cl. at 680.

the present case," in which the government is not the sole source of erosion to plaintiffs' properties. Id. The court stated that "[p]laintiffs may not be financially able to pay 70% of the cost to construct shore protection measures out of their own pockets, resulting in continued erosion of their property." Id. The court held that "as an alternative to seeking 30% of the cost of shore protection measures, plaintiffs may instead seek 30% of the cost of 'reasonably foreseeable future loss' to their property, although this amount may result in greater cost to the government." Id. at 684.

The court held a trial of damages from April 18 through April 21, 2011 and from April 25 through April 28, 2011 in Niles, Michigan.[9] See Tr. passim.[10]

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[9]For convenient reference, the name, in alphabetical order, and a description of each witness upon whose live testimony the court relies in this Opinion follows:

Mr. David E. Burgoyne is an expert witness for defendant. Mr. Burgoyne holds a bachelor's degree in liberal arts with a concentration in physics and astronomy from Colgate University. Trial Transcript (Tr.) 57:13-17 (colloquy between Mr. Burgoyne and plaintiffs' counsel). Mr. Burgoyne is an appraiser certified by the state of Michigan, Tr. 58:6-18 (colloquy between Mr. Burgoyne and plaintiffs' counsel), and 90% of his work "involves doing appraisals for potential or existing litigation, and various litigation support," Tr. 58:25-59:3 (Burgoyne). Mr. Burgoyne is a senior member of the International Right-of-Way Association, an organization whose 10,000 members are professionals involved in the public acquisition of private property, Tr. 93:23-94:23 (Burgoyne), and is one of seven "master facilitators" qualified to "teach [the] teachers, teach [the] facilitators" for the organization, Tr. 94:18-21 (Burgoyne). The court recognized Mr. Burgoyne as an expert in the appraisal of real property. Tr. 95:21-23 (court).

Dr. Michael J. Chrzastowski is an expert witness for plaintiffs. Dr. Chrzastowski is an academic professional at the University of Illinois at Urbana-Champaign and is the senior coastal geologist at the Illinois State Geological Survey. Tr. 1110:23-1111:11 (Chrzastowski). Dr. Chrzastowski holds bachelor's degrees in oceanography and geology from the University of Washington, a master's degree in coastal geology from Western Washington University and a Ph.D. in coastal geology from the University of Delaware. Tr. 1108:18-1109:2 (Chrzastowski). The court qualified Dr. Chrzastowski as an expert on types of shore protection and on how shore protection impacts Lake Michigan and, in particular, the shore of Lake Michigan. Tr. 1132:14-21 (court).

Mr. J. Thomas Concklin is a fact witness called by plaintiffs. Mr. Concklin is the trustee and beneficiary of a trust, see Tr. 1269:6-20 (colloquy between Mr. Concklin and plaintiffs' counsel), which trust is a plaintiff in this action, see Pls.' Br. 4.

Mr. Martin Richard Jannereth is a fact witness called by plaintiffs. Mr. Jannereth was employed by the Michigan Department of Environmental Quality at the time of the trial of liability. Tr. 1521:4-25 (colloquy between Mr. Jannereth and plaintiffs' counsel).

Ms. Patricia Kane is a fact witness called by plaintiffs. Ms. Kane is a plaintiff in this action. See Pls.' Br. 5.

Dr. Grahame J. Larson is an expert witness for defendant, who testified at the trial of liability and whose expert report was again admitted into evidence at the trial of damages. Tr. 1978:23-1980:4 (colloquy between parties and court). The court qualified Dr. Larson as an expert in glacial geology, glaciology and hydrology. Tr. 1984:24-1985:2 (court). Dr. Larson's testimony addressed certain matters contained in his expert report. See Tr. 1978:11-2010:11 (testimony of Dr. Larson).

Dr. Scudder D. Mackey is an expert witness for plaintiffs. Dr. Mackey is employed as "an adjunct professor in the departments of geology and biology at the University of Windsor in Windsor, Canada." Tr. 476:1-3 (Mackey). In 2003, Dr. Mackey started S.D. Mackey and Associates, LLC, which does business as Habitat Solutions NA, primarily serving "[f]ederal and state agencies in both the U.S. and Canada." Tr. 482:19-483:6 (Mackey). Dr. Mackey holds a bachelor's degree in geology from Hobart College, a master's degree in geology from the University of Wisconsin-Madison and a Ph.D. in geology from the State University of New York at Binghamton. Tr. 467:7-13 (Mackey). Dr. Mackey has worked in the oil and gas industry in a number of roles, Tr. 468:16-474:6 (Mackey), has served as a supervisor of the Lake Erie Geology Group at the Ohio Department of Natural Resources, Tr. 474:19-21 (Mackey), and was the project implementation manager for the Great Lakes Protection Fund, Tr. 481:11-24 (Mackey). Dr. Mackey has held positions as an adjunct professor at Ohio State University and at the University of Toledo. Tr. 475:17-23 (Mackey). The court qualified Dr. Mackey as an expert in coastal geology and nearshore coastal processes; in coastal hazards relating to erosion; in riverine processes in fluvial sedimentology; and in operating sidescan sonar and interpreting sidescan sonar data. Tr. 487:17-24 (court).

Dr. Jesse E. McNinch is an expert witness for defendant. Dr. McNinch's expert report identifies his current position as "Director, Field Research Facility[,] Coastal Hydraulics Lab - USACE." DX 294 (McNinch Report) 1. Dr. McNinch explains that "one of my specialties as a geological oceanographer . . . is developing new techniques to image, and to measure things like substrates, beach erosion, wave energy during storms, and things like that." Tr. 1769:4-8 (McNinch). He has used sidescan sonar "quite a bit." Tr. 1769:17-22 (colloquy between Dr. McNinch and defendant's counsel). Dr. McNinch holds a bachelor's degree in geology from the University of Louisiana at Lafayette, a master's degree from the University of North Carolina at Chapel Hill and a Ph.D. in marine sciences from the University of North Carolina at Chapel Hill. Tr. 1772:13-19 (McNinch). The court recognized Dr. McNinch as an expert in geologic oceanography, geophysical techniques for surveys in shallow water environments for determining lakebed composition, and for assessing the behavior of a shoreline. Tr. 1782:19-24 (court).

Dr. Guy A. Meadows is an expert witness for plaintiffs. Dr. Meadows is a professor at the University of Michigan. See Tr. 310:19-20 (Meadows); Tr. 313:24-314:9 (colloquy between Dr. Meadows and plaintiffs' counsel). Dr. Meadows has conducted several coastal surveys to study changes in the shoreline as a result of changes in water levels, shore protection and wave conditions. Tr. 310:7-312:23 (colloquy between Dr. Meadows, plaintiffs' counsel and the court). Dr. Meadows holds bachelor's and master's degrees in mechanical engineering from Michigan State University and a Ph.D. from Purdue University, where he studied coastal hydrodynamics and nearshore flows and circulations. Tr. 308:14-23 (Meadows). The court qualified Dr.

Meadows as an expert in locating historic ordinary high water marks on Lake Michigan for specific property sites; evaluating and calculating land lost to erosion both landward and in the lakebed of Lake Michigan; and evaluating the existence and effect of a shadow zone on Lake Michigan. Tr. 319:15-320:4 (colloquy between counsel for the parties and the court).

Dr. David M. Mickelson is an expert witness for defendant. Dr. Mickelson, currently retired, was a professor of geology and geophysics at the University of Wisconsin-Madison. Tr. 2011:12-18 (colloquy between Dr. Mickelson and defendant's counsel). Dr. Mickelson holds a bachelor's degree from Clark University in geography, a master's degree in geology from the University of Maine, and a Ph.D. in geology from Ohio State University. Tr. 2012:19-22 (Mickelson). Dr. Mickelson has either authored or co-authored more than 100 publications, most of which were on glacial geology and coastal morphology, and most of which focused on the Great Lakes Area. Tr. 2016:16-2017:6 (colloquy between Dr. Mickelson and defendant's counsel). The court qualified Dr. Mickelson as an expert in coastal and glacial geomorphology. Tr. 2022:5-7 (court).

Dr. Michael Moore is an expert witness for plaintiffs. Dr. Moore is a professor of economics at the University of Virginia and is "self-employed, doing business as Charlottesville Partners." Tr. 118:22-119:4 (colloquy between Dr. Moore and plaintiffs' counsel). Dr. Moore holds a bachelor's degree from Boston College, a master's degree in business administration from Babson College, and a master's degree and Ph.D. in economics from the University of Michigan. PX 149 (Moore Report) Ex. 1, at 3. The court qualified Dr. Moore as an economic expert on the change in value of the plaintiffs' residences resulting from the announcement in January 2000 by the United States that the erosion south of the jetties in St. Joseph Harbor was permanent. Tr. 141:13-18 (court).

Dr. Robert B. Nairn is an expert witness for defendant. Dr. Nairn is employed by W.F. Baird & Associates, a firm that works exclusively on river and coastline engineering. Tr. 2169:5-22 (colloquy between Dr. Nairn and defendant's counsel). Dr. Nairn holds a bachelor's degree in civil engineering and a master's degree in coastal engineering from Queen's University in Ontario, Canada and a Ph.D. in coastal processes and coastal engineering from Imperial College of Science and Technology in London, England. Tr. 2156:16-25 (Nairn). The court qualified Dr. Nairn as an expert in coastal engineering; river engineering; coastal processes; sediment transport for sediment budgets and longshore transport rate calculations; numerical modeling for coastal processes and sediment transport; shore protection; shore protection design and cost; impact of coastal structures on shore erosion and beach nourishment; cohesive and sandy shores; coastal hazard assessment for flood and erosion hazards using geographical information systems. Tr. 2215:11-22 (court).

Ms. Joan Pope is a fact witness deposed by both parties. Ms. Pope oversaw drafting of the bulk of the Coastal Engineering Manual (CEM). Pope Dep. 19:15-20 (colloquy between Ms. Pope and plaintiffs' counsel). Ms. Pope co-authored a document that guided work on the CEM, entitled Guide for Preparation of the Coastal Engineering Manual. See generally PX 316 (Guide for Preparation of the CEM). Ms. Pope's video deposition was played into the record at trial but omitted in error from the trial transcript. After trial, the court reopened the trial record to admit

After the court received the parties' post-trial briefing, the court directed the parties to file additional briefing addressing whether, in light of certain evidence presented at the trial of liability and certain findings of fact made in the court's Liability Opinion, the court has jurisdiction to hear plaintiffs' claims. See Order to Brief Jurisdiction, 99 Fed. Cl. at 625-26.

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the transcript of Ms. Pope's deposition. May 31, 2011 Order, Dkt. No. 492, at 2; see also Pls.' Notice of Filing, Dkt. No. 493, Exs. A-B (Pope Dep).

Dr. Charles W. Shabica is an expert witness for plaintiffs. Dr. Shabica taught at Northeastern Illinois University for thirty-one years and is currently retired. Tr. 1572:18-24, 1573:19-21 (colloquy between Dr. Shabica and plaintiffs' counsel). Dr. Shabica has also taught courses at Northwestern University and the University of the Pacific, Tr. 1573:24-1574:2 (Shabica), and at the University of the Virgin Islands, Tr. 1574:22-23 (Shabica). In 1984, Dr. Shabica founded Shabica and Associates, a coastal consulting firm that does "research and development on coastal management." Tr. 1574:9-11 (Shabica). Dr. Shabica holds a bachelor's degree in geology from Brown University and a Ph.D. from the University of Chicago. Tr. 1570:23-1571:4 (Shabica). The court qualified Dr. Shabica as an expert in coastal geology, and in coastal shore protection measures and costs. Tr. 1610:25-1611:2 (court).

Mr. Patrick O. Shires is an expert witness for plaintiffs. Mr. Shires is employed by Cotton Shires and Associates, a geotechnical consulting firm. Tr. 762:4-6 (Shires). Mr. Shires holds a bachelor's degree in biology and a master's degree in civil engineering with a specialty in geotechnical engineering and hydrology, both from Stanford University. Tr. 761:10-23 (Shires). Cotton Shires and Associates specializes "in slope stability issues, [which includes both] coastal slope stability [and] coastal bluff stability." Tr. 764:6-9 (Shires). Mr. Shires performs soil design studies, in which he sends soil samples for laboratory testing and uses the results to advise clients "on how to build, what kind of foundations should they put, how deep should it should go, [and] what are you trying to protect against with that foundation." Tr. 766:20-767:10 (colloquy between Mr. Shires and plaintiffs' counsel). The court qualified Mr. Shires as an expert in geotechnical engineering and coastal engineering on the issues of identifying cohesive sediments and the lakebed profile. Tr. 780:20-24 (court).

Ms. Marcia Wineberg is a fact witness called by plaintiffs. Ms. Wineberg is a plaintiff in this action. See Pls.' Br. 5.

[10]The trial of damages was originally scheduled to take place in 2010. At a telephonic status conference held on September 18, 2009, the court discussed scheduling for the remaining discovery and stated that it had "put a pencil line through the days, September 27, 28, 29, 30, and . . . October 1, [2010] for trial." July 23, 2010 Order, Dkt. No. 420, at 2 (internal quotation marks omitted). Plaintiffs stated "[W]e are going to be ready." Id. (internal quotation marks omitted). Notwithstanding plaintiffs' representation that they would be ready for trial in September 2010, the court found on July 23, 2010 that "[i]n fact, discovery is not over and, during 2010, plaintiffs have been a major source of delay . . . . In particular, plaintiffs have filed several motions in an effort to strike the reports of defendant's experts on grounds that the court has found to be entirely without merit." Id.

II. Legal Standards

A. Jurisdiction

Subject matter jurisdiction is a threshold matter that a court must determine at the outset of a case. See Steel Co., 523 U.S. at 94-95; PODS, Inc. v. Porta Stor, Inc., 484 F.3d 1359, 1365 (Fed. Cir. 2007). "Plaintiff[s] bear[] the burden of showing jurisdiction by a preponderance of the evidence." Taylor v. United States, 303 F.3d 1357, 1359 (Fed. Cir. 2002) (citing Thomson v. Gaskill, 315 U.S. 442, 446 (1942)). The court must consider jurisdictional issues at any point in a case that they arise. Steel Co., 523 U.S. at 93. The court is obligated to raise the issue of its own jurisdiction sua sponte "if a question thereto exists." Liberty Mut. Ins. Co. v. Wetzel, 424 U.S. 737, 740 (1976) (citing Mansfield, C. & L.M. Ry. Co. v. Swan, 111 U.S. 379 (1884)).

The court must accept as true all undisputed allegations of fact made by the non-moving party and draw all reasonable inferences from those facts in the non-moving party's favor. See Henke v. United States, 60 F.3d 795, 797 (Fed. Cir. 1995) (citing Scheuer v. Rhodes, 416 U.S. 232, 236-37 (1974), abrogated on other grounds by Harlow v. Fitzgerald, 457 U.S. 800 (1982)). However, "[w]hen a party challenges the jurisdictional facts alleged in the complaint, the court may consider relevant evidence outside the pleadings to resolve the factual dispute." Arakaki v. United States, 62 Fed. Cl. 244, 247 (2004) (citing Reynolds v. Army & Air Force Exch. Serv., 846 F.2d 746, 747 (Fed. Cir. 1988) and Indium Corp. of Am. v. Semi-Alloys, Inc., 781 F.2d 879, 884 (Fed. Cir. 1985)); 2 James Wm. Moore et al., Moore's Federal Practice § 12.30[3] (3d ed. 2004) ("[U]nlike a Rule 12(b)(6) dismissal, the court need not confine its evaluation to the face of the pleadings . . . ."). If a court determines that it does not have jurisdiction, it must dismiss the claim. See Rules of the United States Court of Federal Claims (RCFC) 12(h)(3).

"Every claim of which the United States Court of Federal Claims [Court of Federal Claims] has jurisdiction shall be barred unless the petition thereon is filed within six years after such claim first accrues." 28 U.S.C. § 2501 (2006). "It is well established that statutes of limitations for causes of action against the United States, being conditions on the waiver of sovereign immunity, are jurisdictional in nature." Martinez v. United States, 333 F.3d 1295, 1316 (Fed. Cir. 2003) (en banc) (citing, inter alia, Block v. North Dakota, 461 U.S. 273, 287 (1983)). Because the statute of limitations in this court is jurisdictional, id., plaintiffs have the burden of showing by a preponderance of the evidence that their claims were timely filed, see Taylor, 303 F.3d at 1359.

B. Accrual of Takings Claims

A takings claim must be filed "within six years after such claim first accrues." See 28 U.S.C. § 2501. Pursuant to the "stabilization doctrine," "The accrual of a takings claim where the government leaves the taking of property to a gradual physical process

occurs when the situation has 'stabilized.'" Accrual Op. II, 314 F.3d at 1308 (quoting Boling II, 220 F.3d at 1370). The stabilization doctrine was first stated in a case involving a taking of property by a gradual process of flooding, as follows:

> [A]s there is nothing in reason, so there is nothing in legal doctrine, to preclude the law from meeting such a process by postponing suit until the situation becomes stabilized. An owner of land flooded by the Government would not unnaturally postpone bringing a suit against the Government for the flooding until the consequences of inundation have so manifested themselves that a final account may be struck.

Dickinson, 331 U.S. at 749. Ten years after Dickinson was decided, the United States Supreme Court (Supreme Court) clarified its holding, stating: "The expressly limited holding in Dickinson was that the statute of limitations did not bar an action under the Tucker Act for a taking by flooding when it was uncertain at what stage in the flooding operation the land had become appropriated to public use." United States v. Dow, 357 U.S. 17, 27 (1958).

Courts have recognized that interpreting the holding of Dickinson broadly would put it in "unending conflict with the statute of limitations." Gustine Land & Cattle Co. v. United States, 174 Ct. Cl. 556, 656 (1966)); see also Del. State Coll. v. Ricks, 449 U.S. 250, 258 (1980); Boling II, 220 F.3d at 1371 (stating the holding of Ricks to be that "the proper focus in a claim accrual analysis 'is upon the time of the [defendant's] acts, not upon the time at which the consequences of the acts become most painful'" (internal quotation marks omitted) (alteration in original)); Columbia Basin Orchard v. United States, 116 Ct. Cl. 348, 357, 88 F. Supp. 738, 739 (1950) ("[W]e do not think the Supreme Court, in the Dickinson case, meant to hold that plaintiff was entitled to wait until any possibility of further damage had been removed.").

Stabilization of a claim for a taking by erosion occurs "when the erosion ha[s] substantially encroached the parcels at issue and the damages [are] reasonably foreseeable." Boling II, 220 F.3d at 1373. "'[S]tabilization occurs when it becomes clear that the gradual process set into motion by the government has effected a permanent taking, not when the process has ceased or when the entire extent of the damage is determined.'" Accrual Op. II, 314 F.3d at 1308 (quoting Boling II, 220 F.3d at 1370-71). The extent of the taking must be "reasonably foreseeable," Boling II, 220 F.3d at 1371, but the damage need not be "complete and fully calculable before the cause of action accrues," Fallini v. United States, 56 F.3d 1378, 1382 (Fed. Cir. 1995).

C. Damages in Partial Takings Cases

The Fifth Amendment of the United States Constitution provides that private property shall not "be taken for public use, without just compensation." U.S. Const. amend. V. Erosion of property due to government action is one type of physical injury

that rises to the level of a taking. See, e.g., Boling II, 220 F.3d at 1370. "When the government fails properly to compensate private property owners for a taking, this court has jurisdiction to enforce the owners' right to just compensation." Liability Op., 78 Fed. Cl. at 614 (citing 28 U.S.C. § 1491; Applegate v. United States, 25 F.3d 1579, 1581 (Fed. Cir. 1994)). Such a claim is often referred to as a "inverse condemnation claim," see, e.g., Owen v. United States, 851 F.2d 1404, 1418 (Fed. Cir. 1988) (en banc), or as a "taking claim," see, e.g., id. at 1406.

"If only a portion of a single tract is taken the owner's compensation for that taking includes any element of value arising out of the relation of the part taken to the entire tract. Such damage is often, though somewhat loosely, spoken of as severance damage." United States v. Miller, 317 U.S. 369, 376 (1943) (footnote omitted); see also Hendler v. United States, 175 F.3d 1374, 1383 (Fed. Cir. 1999) ("In cases of a partial physical taking, as that here, just compensation under the takings clause of the Constitution includes 'not only the market value of that part of the tract appropriated, but the damage to the remainder resulting from that taking, embracing . . . injury due to the use to which the part appropriated is to be devoted.'" (alteration in original) (quoting United States v. Grizzard, 219 U.S. 180, 183 (1911))).

Plaintiffs carry the burden of proving "that a taking has occurred justifying the payment of just compensation." Loesch v. United States, 227 Ct. Cl. 34, 44, 645 F.2d 905, 914 (1981). Plaintiffs also carry the burden of proving the amount of just compensation to which they are entitled for severance damage. Ga.-Pac. Corp. v. United States, 226 Ct. Cl. 95, 107, 640 F.2d 328, 336-37 (1980); Miller v. United States, 223 Ct. Cl. 352, 383-84, 620 F.2d 812, 828-29 (1980).

Plaintiffs' properties, being adjacent to the navigable waters of Lake Michigan, are subject to the navigational servitude held by the federal government, which servitude extends to the ordinary high water mark. See United States v. Cherokee Nation of Okla. (Cherokee), 480 U.S. 700, 704 (1987); United States v. Chicago, M., St. P. & P.R. Co., 312 U.S. 592, 595-97 (1941); Owen, 851 F.2d at 1408-10. When the government properly exercises its right to improve navigation in a manner that affects property within the boundaries of this servitude, "'the damage sustained does not result from taking property from riparian owners within the meaning of the Fifth Amendment but from the lawful exercise of a power to which the interests of riparian owners have always been subject.'" Cherokee, 480 U.S. at 704 (quoting United States v. Rands, 389 U.S. 121, 123 (1967)).

Accordingly, plaintiffs are not entitled to just compensation for materials removed from the littoral zone, see Owen, 851 F.2d at 1413, or eroded below and within the ordinary high water mark, see id. at 1412 (holding that the federal navigational servitude does not extend "to land located above or outside the bed of the stream as delineated by the . . . high-water mark at the time of construction"); see generally May 26, 2006 Op., Banks v. United States (OHWM Op.), Dkt. No. 141, 71 Fed. Cl. 501 (2006) (discussing

the definition of the term "ordinary high water mark"); June 23, 2005 Op. and Order, Banks v. United States, Dkt. No. 87, 68 Fed. Cl. 524 (2005) (discussing the federal navigational servitude and the date on which the ordinary high water mark is to be measured).

D. The Law of the Case Doctrine and the Mandate Rule

The law of the case doctrine "posits that when a court decides upon a rule of law, that decision should continue to govern the same issues in subsequent stages in the same case. This rule of practice promotes the finality and efficiency of the judicial process by protecting against the agitation of settled issues." Christianson v. Colt Indus. Operating Corp., 486 U.S. 800, 815-816 (1988) (citations and internal quotation marks omitted); see also Gould, Inc. v. United States, 67 F.3d 925, 930 (Fed. Cir. 1995) ("The law of the case is a judicially created doctrine, the purposes of which are to prevent the relitigation of issues that have been decided and to ensure that trial courts follow the decisions of appellate courts." (internal quotation marks omitted)). The law of the case doctrine is applicable both to issues decided explicitly and to issues decided "by necessary implication." Laitram Corp. v. NEC Corp., 115 F.3d 947, 951 (Fed. Cir. 1997).

The Federal Circuit has explained, regarding its adherence to prior appellate decisions:

> [T]he law of the case doctrine is a policy not a command even respecting a prior appellate decision in the case, and should be applied "as a matter of sound judicial practice, under which a court generally adheres to a decision in a prior appeal in the case unless one of three 'exceptional circumstances' exists: the evidence on a subsequent trial was substantially different, controlling authority has since made a contrary decision of the law applicable to such issues, or the decision was clearly erroneous and would work a manifest injustice."

Mendenhall v. Barber-Greene Co., 26 F.3d 1573, 1582 (Fed. Cir. 1994) (quoting Cent. Soya Co. v. Geo. A. Hormel & Co., 723 F.2d 1573, 1580 (Fed. Cir. 1983)).

"'[T]he law of the case doctrine is not applicable to issues neither presented nor decided in a former proceeding in the case.'" Halpern v. Principi, 384 F.3d 1297, 1301 (Fed. Cir. 2004) (quoting Stearns v. Beckman Instruments, Inc., 737 F.2d 1565, 1568 (Fed. Cir. 1984)).

"The mandate rule requires that the [trial] court follow an appellate decree as the law of the case." Cardiac Pacemakers, Inc. v. St. Jude Med., Inc., 576 F.3d 1348, 1356 (Fed. Cir. 2009) (citing Sibbald v. United States, 37 U.S. (12 Pet.) 488, 492 (1838)); accord In re Sanford Fork & Tool Co., 160 U.S. 247, 255 (1895). "The mandate rule provides that 'issues actually decided [on appeal]--those within the scope of the judgment

appealed from, minus those explicitly reserved or remanded by the court--are foreclosed from further consideration.'" Amado v. Microsoft Corp., 517 F.3d 1353, 1360 (Fed. Cir. 2008) (quoting Engel Indus., Inc. v. Lockformer Co., 166 F.3d 1379, 1383 (Fed. Cir. 1999)). "Unless remanded by [the appellate] court, all issues within the scope of the appealed judgment are deemed incorporated within the mandate and thus are precluded from further adjudication." Engel Indus., 166 F.3d at 1383.

Much like the law of the case doctrine, which "is not applicable to issues neither presented nor decided in a former proceeding," Halpern, 384 F.3d at 1301, the mandate rule provides that the trial court "may act on matters left open by the mandate," Laitram, 115 F.3d at 951 (internal quotation marks omitted); see, e.g., Exxon Chem. Patents, Inc. v. Lubrizol Corp. (Exxon), 137 F.3d 1475, 1484 (Fed. Cir. 1998) (holding that the scope of the judgment appealed from, limited to literal infringement, did not preclude adjudication of infringement by the doctrine of equivalents). "Interpretation of an appellate mandate entails more than examining the language of the court's judgment in a vacuum." Exxon, 137 F.3d at 1484. "The scope of the issues presented . . . on appeal must be measured by the scope of the judgment appealed from, not by the arguments advanced by the appellant." Engel Indus., 166 F.3d at 1382 (citations omitted). The Federal Circuit has cautioned that, "both the letter and the spirit of the mandate must be considered." Id. at 1383.

III. Discussion

A. Jurisdiction

In their original complaint,[11] plaintiffs alleged "that defendant effected a gradual taking of their shorefront property through the construction and maintenance of 'a series

[11] After the court denied class certification, the parties filed a notice of additional plaintiffs--identifying thirty-seven plaintiffs--and filed separate complaints for each plaintiff. July 31, 2001 Op. and Order, Banks v. United States (Accrual Op. I), Dkt. No. 3, 49 Fed. Cl. 806, 808 (2001), rev'd, 314 F.3d 1304 (Fed. Cir. 2003) (Accrual Op. II). The individual complaints supplanted the original complaint and were deemed to have been filed on July 9, 1999, the filing date of the original complaint. Id. at 808 n.2. Plaintiffs' counsel has represented that the allegations in each of the individual complaints are the same. Id. Plaintiffs have twice amended their complaints, but both amendments addressed the naming of existing plaintiffs and the adding or reinstating of additional owners of certain parcels rather than the substance of the allegations. See Pl.'s Mot. for Leave to File an Am. Compl., Dkt. No. 294, at 2 ("The [p]laintiffs do not seek to amend the substance of the [c]omplaint."); Pls.' Am. Mot. for Leave to File an Am. Compl., Dkt. No. 340, at 2 (stating same). In the past, "for ease of reference and unless otherwise noted, the court [has referred] to the individual complaint filed by the first named plaintiffs, John and Mary Banks, when addressing plaintiffs' claims in this action." Accrual Op. I, 49 Fed. Cl. at 808 n.2. The court continues in this Opinion its practice of referring to the individual complaint filed by the Banks plaintiffs.

of 15 jetties along 200 miles of the eastern coast of Lake Michigan for over 100 years.'" Accrual Op. I, 49 Fed. Cl. at 810 (quoting Compl. ¶ 26, Banks v. United States, No. 99-445 L (Fed. Cl. filed July 9, 1999), Dkt. No. 1). Plaintiffs narrowed their claims in the individual complaints they filed after the court denied class certification, focusing on the effect of the jetties at St. Joseph Harbor. Compl. ¶¶ 4-7. The jetties at St. Joseph Harbor were originally built in the 1830s, and were lengthened several times, reaching their current length in 1903. Liability Op., 78 Fed. Cl. at 604 (citations omitted).

Although the jetties had been in place at their current length for nearly a century--a period of time longer than the six-year limitations period applicable takings claims, see 28 U.S.C. § 2501--plaintiffs' complaints alleged that the accelerated erosion of their properties was caused not by construction of the jetties, but by a maintenance activity that took place more recently. Specifically, plaintiffs alleged that the jetties "continued to exist without harmful interference to the natural littoral flow of sand and river sediment until the [Corps] gradually installed sand-tight steel sheet piling during the period of 1950 to 1989," which installation has "alter[ed] the supply of sand to the lake bed and subaerial visible beach in front of the plaintiffs' property." Compl. ¶¶ 6-7. After plaintiffs filed their individual complaints, defendant filed a motion to dismiss on jurisdictional grounds, arguing that "the takings causes of action accrued, at the latest, in 1989," when the government completed its encasement of the jetties in the steel sheet piling. Accrual Op. I, 49 Fed. Cl. at 811.

The briefing filed by defendant in support of its motion to dismiss and the opinions filed by the court and by the Federal Circuit make it clear that defendant, the court and the Federal Circuit presumed the truth of plaintiffs' allegation that encasing the jetties in steel sheet piling made them impermeable to sand, interfering with the littoral flow of sand and damaging plaintiffs' properties. Defendant stated in its motion that it "[a]ccepted as true for the sake of defendant's motion" that the steel sheet piling "prevents the drift of sand from passing through the jetties and proceeding south along the eastern shore toward plaintiffs' lands." Mot. to Dismiss at 6, Banks v. United States, 49 Fed. Cl. 806 (2001) (No. 99-445 L), Dkt. No. 64 (Mot. to Dismiss).

In its opinion addressing defendant's motion to dismiss, the court noted that "[w]hen considering a motion to dismiss, the court must presume that well pleaded factual allegations in the complaint are true." Accrual Op. I, 49 Fed. Cl. at 808 (citing, inter alia, Miree v. DeKalb Cnty., 43 U.S. 25, 27 n.2 (1977)). Quoting the allegations in the Banks plaintiffs' complaint, the court stated, "Plaintiffs claim that the jetties did not cause 'harmful interference to the natural littoral flow of sand and river sediment until the Corps gradually installed sand-tight steel sheet piling during the period of 1950 to 1989.'" Id. at 808 (quoting Compl. ¶ 6); see also id. at 824 ("Plaintiffs allege in their complaints, which the court construes in favor of the complainants, see Scheuer, 416 U.S. at 236, that the Corps completed the installation of 'sand-tight steel sheet piling' in 1989." (quoting Compl. ¶ 6)).

Applying Applegate, the court considered and rejected plaintiffs' argument that, after the installation of the steel sheet piling was completed in 1989, the government delayed the accrual of plaintiffs' claims by promising to mitigate the erosion caused by the jetties. Accrual Op. I, 49 Fed. Cl. at 812-13, 822-23. In Applegate, the Federal Circuit held that the plaintiffs' claims for a taking by erosion did not accrue while promises by the government to mitigate the damage made the plaintiffs "justifiably uncertain" whether a permanent taking had occurred. Applegate, 25 F.3d at 1583-84; see also infra Part III.A.1 (applying Applegate to the facts of this case).

Examining the evidence cited by the parties, the court found that "the evidence here does not show that the Corps' sand transfer program constituted a promise on which plaintiffs could rely to postpone the filing of their suits, as contemplated by the Applegate case." Accrual Op. I, 49 Fed. Cl. at 823. The court therefore found that "the time for filing suit expired in 1995," six years after installation of the steel sheet piling was completed. Id. at 825. Because plaintiffs did not file suit until 1999, the court granted defendant's motion to dismiss. Id. at 825-26.

The Federal Circuit reversed, finding that after the steel sheet piling was installed, mitigation efforts that the government had begun in 1970 created uncertainty as to whether any erosion damage caused by the jetties was "permanent and irreversible." Accrual Op. II, 314 F.3d at 1309-10. The Federal Circuit found that plaintiffs' claims accrued with the publication of three Corps reports that concluded that the mitigation efforts were ineffective. See id. On remand, the court determined that, because the last of these reports was published no earlier than January of 2000, plaintiffs' claims accrued in January of 2000. May 3, 2007 Op., Banks v. United States, Dkt. No. 200, 76 Fed. Cl. 686, 696 (2007).

After conducting a trial of liability, the court found that, contrary to the allegations in plaintiffs' complaints--allegations that the court had presumed to be true when considering defendant's motion to dismiss, see Accrual Op. I, 49 Fed. Cl. at 808--the jetties were impermeable to sand before they were encased in steel sheet piling, Liability Op., 78 Fed. Cl. at 636 (stating that "plaintiffs' own expert witness testified that the piers were impermeable even prior to their encasement in steel"). The court further found that "plaintiffs have failed to prove that the piers were ever permeable." Liability Op., 78 Fed. Cl. at 635.

The implication of the court's finding is that the installation of steel sheet piling had not altered the supply of littoral sand to plaintiffs' properties as plaintiffs had alleged, see Compl. ¶¶ 6-7, thereby exacerbating the erosion of plaintiffs' properties. The most recent government action that could have effected a taking by increasing the erosion of plaintiffs' properties was not the installation of steel sheet piling, a process that ended in 1989, but rather the extension of the jetties, a process that ended in 1903. See Liability Op., 78 Fed. Cl. at 604.

At the time of the court's Liability Opinion, neither the court nor the parties addressed the impact of the court's finding on the timeliness of plaintiffs' claims. See Liability Op., 78 Fed. Cl. passim. However, after the trial of damages, the court directed the parties to file briefing on the issue. See Order to Brief Jurisdiction, 99 Fed. Cl. at 626. The court now considers, in light of the extensive factual record developed at two trials, whether plaintiffs' claims were timely filed, given that the jetties were impermeable to sand before they were encased in steel sheet piling. See Steel Co., 523 U.S. at 93 (noting that the court must consider jurisdictional issues at any point in a case that they arise).

To determine whether plaintiffs' claims are timely, the court must address four questions. First, working backward from the date of filing, the court must determine the period of time during which plaintiffs' claims could not have accrued, under Applegate, because the government's promises and efforts to mitigate erosion caused by the jetties created justifiable uncertainty about the permanence of any erosion damage. Second, working forward from 1903, the year that the jetties reached their final length, the court must determine whether the situation stabilized sufficiently for plaintiffs' claims to accrue and for the statute of limitations to run before the government's promises and efforts to mitigate erosion made the permanence of any damage uncertain. Third, the court must consider plaintiffs' argument that their claims did not accrue until certain adverse precedent was overruled by the Federal Circuit, sitting en banc. Finally, the court must consider plaintiffs' argument that the law of the case doctrine prohibits the court from finding that it lacks jurisdiction over plaintiffs' claims.

1. Justifiable Uncertainty Caused by the Corps' Promises of Mitigation

The court first considers the period of time during which plaintiffs' claims could not have accrued because of the government's promises and efforts to mitigate erosion caused by the jetties. The Federal Circuit in Applegate "analyzed the stabilization doctrine set forth in Dickinson as it applied to situations in which the government was attempting to mitigate actions that would otherwise constitute a permanent taking." Accrual Op. II, 314 F.3d at 1308. In Applegate, the government repeatedly promised to build a sand transfer plant to mitigate erosion of the plaintiffs' properties caused by the government's construction and maintenance of a deep water harbor. See Applegate, 25 F.3d at 1580. The Federal Circuit determined that "[t]he gradual character of the natural erosion process set in motion by the Corps, compounded by the Government's promises of a sand transfer plant, have indeed made accrual of the landowner's claim uncertain." Id. at 1582.

When this court addressed defendant's motion to dismiss, the court found Applegate inapplicable, Accrual Op. I, 49 Fed. Cl. at 818-23; but the Federal Circuit disagreed and held that this court had "misread Applegate as requiring the presence of a legally binding promise or duty or a matter requiring a congressional appropriation," Accrual Op. II, 314 F.3d at 1309. This court noted that, according to the rate of erosion

alleged in plaintiffs' complaints to be caused by the jetties, plaintiffs lost almost eighty feet of shoreline to erosion between 1950 and 1989, an amount "sufficient to put plaintiffs on inquiry notice of their potential takings claims." Accrual Op. I, 49 Fed. Cl. at 825. The court granted defendant's motion, finding that "plaintiffs' takings claims accrued no later than 1989 and the time for filing suit expired in 1995." Id. at 825-26.

The Federal Circuit reversed, stating:

> In Applegate, the mere promises of a sand transfer plant, held out by the Corps and repeatedly renewed but never implemented, indicated that "the landowners did not know when or if their land would be permanently destroyed." Here, even greater uncertainty was created by the Corps' mitigation plan. While the Corps in Applegate made promises of a mitigating sand transfer plant, the Corps in this case actually performed its mitigation activities for several years before the filing of this action.

Accrual Op. II, 314 F.3d at 1309-10 (quoting Applegate, 25 F.3d at 1582). The Federal Circuit noted that the government's mitigation activities began in 1970, delaying accrual of plaintiffs' claims until the publication of three reports by the Corps, which determined that the mitigation program had not been effective and "collectively indicated that erosion was permanent and irreversible." Id. at 1310.

The Federal Circuit did not discuss whether the government's promises to mitigate erosion created justifiable uncertainty before the Corps began mitigation efforts in 1970. See id. passim. However, beginning in 1958, "[t]he Corps released a series of reports . . . over several decades describing the erosion caused south of St. Joseph Harbor by the jetties, outlining a plan to mitigate the erosion attributable to the jetties, and evaluating the effectiveness of the mitigation program that was eventually implemented." Liability Op., 78 Fed. Cl. at 612.

The first of these reports, a study released in 1958 (1958 Study), was published before mitigation efforts began. See id. at 604, 612. Plaintiffs contend that the 1958 Study delayed the accrual of their claims, pursuant to Applegate, because the 1958 Study "promises that the government will attempt to mitigate the loss." Pls.' Jur. Br. 16-18. The 1958 Study is a "beach erosion control study," transmitted by the Corps to the Speaker of the United States House of Representatives. Pls.' Ex. (PX) 132 (1958 Study) v. It assessed erosion in a "study area" including plaintiffs' zone that is "about 32 miles in length from the north city limit of Benton Harbor to the Michigan-Indiana State line." Id. at 3. The study recommended building a sand berm to protect a portion of the shoreline north of plaintiffs' zone. See id. at 24-25. It calculated the economic benefits of extending the sand berm south to the southern limit of the village of Shoreham, id. at 44, which is in plaintiffs' zone. The 1958 Study determined, however, that "[t]his downcoast reach is entirely privately owned, would have no public benefits to make it eligible for Federal aid," and would cost more to protect than the value of extending the

sand berm. Id. The study noted, however, that even without including this area in the project, "this reach and adjacent shores to the south would receive substantial benefits of shore stabilization due to restoration of normal littoral drift." Id.

Plaintiffs' argument is that the 1958 Study created justifiable uncertainty about the permanence and extent of the taking of their property, when viewed in the light of Applegate. See Pls.' Jur. Br. 16-18. The 1958 Study proposes a shore protection project that, while not intended to protect plaintiffs' properties directly, was expected to benefit them by "restor[ing] normal littoral drift." PX 132 (1958 Study) 44. The sand transfer plant promised by the Corps in Applegate, unlike the sand berm proposed here, was intended directly to address the erosion of the plaintiffs' properties. See Applegate, 25 F.3d at 1580. However, it was uncertainty about the permanence of the taking, rather than the government's intentions in undertaking shore protection efforts, that delayed accrual of the plaintiffs' claims in Applegate. See id. at 1582 ("With plans for a sand transfer plant pending, the landowners had no way to determine the extent, if any, of the permanent physical occupation."); Boling II, 220 F.3d at 1372 ("[T]he critical element that delayed stabilization in Applegate [is] the justifiable uncertainty about the permanency of the taking.").

Even accepting plaintiffs' contention that the justifiable uncertainty created by the Corps began, not with the commencement of mitigation efforts in 1970, but with publication of the 1958 Study,[12] for plaintiffs' claims to be timely, the situation must not have stabilized, Accrual Op. II, 314 F.3d at 1308, before 1952, six years before the possible creation of justifiable uncertainty by the publication of the 1958 Study.[13]

2. Claim Accrual and Stabilization: the Impermeability of the Jetties is the Law of the Case

"The accrual of a takings claim where the government leaves the taking of property to a gradual physical process occurs when the situation has 'stabilized.'" Id. (quoting Boling II, 220 F.3d at 1370). Stabilization of claims for a taking by erosion occurs "when the erosion ha[s] substantially encroached the parcels at issue and the damages [are] reasonably foreseeable." Boling II, 220 F.3d at 1373. "'[S]tabilization occurs when it becomes clear that the gradual process set into motion by the government

[12]Because the court finds below that plaintiffs' claims accrued earlier than 1952, see infra Part III.A.2, it is immaterial whether the United States Army Corps of Engineers (defendant or the Corps) began to create justifiable uncertainty about the permanence and extent of the harm created by the jetties in 1958 or in 1970.

[13]Plaintiffs cite no case in which untimely takings claims were revived by promises made by the government after the statute of limitations had run, see Pls.' Post-Trial Br. on Jurisdiction (Pls.' Jur. Br.), Dkt. No. 501 passim; Pls.' Post-Trial Reply Br. on Jurisdiction (Pls.' Jur. Resp.), Dkt. No. 504 passim, and the court is not aware of any such case.

has effected a permanent taking, not when the process has ceased or when the entire extent of the damage is determined.'" Accrual Op. II, 314 F.3d at 1308 (alteration in original) (quoting Boling II, 220 F.3d at 1370-71).

Defendant contends that plaintiffs' claims stabilized with the Corps' publication of the 1958 Study, which "acknowledged that the construction and maintenance of the St. Joseph Harbor was interfering with the littoral flow to properties south of the jetties and advised that the United States did not intend to take action to protect that shoreline." Def.'s Jur. Br. 12.

The court, in its Liability Opinion, found the 1958 Study to be highly persuasive evidence that plaintiffs' properties are, and were understood to be, within the zone of influence of the jetties. Liability Op., 78 Fed. Cl. at 621 ("Although not specifically pointed out by plaintiffs, the court views the most persuasive evidence to be contained in the 1958 Study, an admission by defendant."). Although a number of Corps reports were introduced as exhibits and were before the court, id. at 612, the court found the 1958 Study to be "the most persuasive evidence" of whether and for how long plaintiffs' properties have been considered to be within the jetties' zone of influence, id. at 621. The court concluded that "plaintiffs' properties have been considered in the zone of influence of the jetties at least as far back as the 1950s, even if the specific impact of the jetties was not quantified until later." Id.

It is therefore the law of this case that plaintiffs' properties were considered to be within the zone of influence of the jetties at least as far back as the 1950s. It is also the law of the case that the jetties have caused 30% of the erosion in plaintiffs' zone since 1950. See id. at 654-57. In its Liability Opinion, the court agreed with plaintiffs' argument that "[u]ntil this litigation, the Army Corps had repeatedly endorsed the fact that the structures at St. Joseph had interrupted, dredged or diverted" a volume of sand equal to "30% of the total annual loss to the littoral zone," id. at 636 (quoting Pls.' Opening Post Trial Br., Dkt. No. 241, at 30-31), finding that the Corps had maintained, "as an admission, that the piers caused approximately 30% of the erosion to the south of the harbor," id. The court therefore found, based on plaintiffs' argument that the Corps had admitted the percentage of the erosion in plaintiffs' zone caused by the jetties,[14] see id., that the government is liable for the portion of 30% of the erosion in plaintiffs' zone since 1950 not mitigated by the government, see id. at 654-57.

Plaintiffs do not argue that any exception to the law of the case doctrine applies here. See Pls.' Jur. Br. passim; Pls.' Jur. Resp. passim. Plaintiffs do not argue that the

[14]Plaintiffs also argued that, since the installation of steel sheet piling, the jetties had blocked more sediment and were responsible for a greater portion of the erosion in plaintiffs' zone than the Corps had admitted, an argument the court found unpersuasive. Liability Op., 78 Fed. Cl. at 633-36.

jetties did not begin to impact their properties until later than 1950. See Pls.' Jur. Br. passim; Pls.' Jur. Resp. passim. Plaintiffs, in fact, argue that the jetties caused significantly more than 30% of the erosion in plaintiffs' zone since 1950. See infra Part III.C.1 (discussing plaintiffs' arguments that the jetties have caused 60-70% of the erosion in plaintiffs' zone since 1950).

It therefore remains the law of the case--based on an argument made by plaintiffs and found persuasive by the court, see Liability Op., 78 Fed. Cl. at 636--that the zone of influence of the jetties reached plaintiffs no later than 1950, causing 30% of the erosion of plaintiffs' properties for no fewer than two years before 1952. Moreover, for the reasons stated below, it is the view of the court that, based upon the documentation of erosion in plaintiffs' zone contained in the 1958 Study and upon the conclusions reached by defendant's expert, Dr. Nairn, the jetties began to increase the erosion of plaintiffs' properties before 1950 and that stabilization occurred significantly earlier than 1952, more than six years before plaintiffs argue, see Pls.' Jur. Br. 16-18, that the government began to create justifiable uncertainty by publishing the 1958 Study.[15]

[15]Implying that the Corps' 1958 Study (1958 Study) is applicable only to the northernmost portion of plaintiffs' zone, plaintiffs argue that the focus of the 1958 Study was "on the area immediately south of the jetties." Pls.' Jur. Resp. 9. Plaintiffs quote the following passage of the 1958 Study: "Detailed field investigations and development of a specific plan of improvement were limited to that reach of the shore between St. Joseph Harbor and the south limits of the village of Shoreham." Id. (quoting PX 132 (1958 Study) 8). Taken out of context, this sentence appears to suggest that the study was limited to the area north of the southern limit of the village of Shoreham. Plaintiffs do not quote the next sentence, which states: "The county shoreline south of Shoreham and north of the St. Joseph Harbor was covered in a general manner by means of aerial photographs and available maps." PX 132 (1958 Study) 8. This sentence indicates that the authors, although they made their most detailed measurements in the area north of the southern edge of the village of Shoreham, studied the rest of the study area as well, using aerial photographs and maps. The fact that the authors of the study made their most detailed measurements in the area where they were proposing that shore protection be built, see id. at 24-26 (describing proposed shore protection measures), does not render the 1958 Study an unreliable source of information regarding the southern portion of plaintiffs' zone.

Nor is the 1958 Study an unreliable source of information about the history of erosion in plaintiffs' zone because its ultimate purpose was to address ways of mitigating the erosion rather than to study the erosion or to determine the exact proportion of the erosion in any given portion of the study area attributable to the jetties. See Liability Op., 78 Fed. Cl. at 621 ("Even though the focus of the 1958 Study was not to assess erosion from the St. Joseph Harbor specifically, it nevertheless recognized that erosion was attributable to the harbor structures and their maintenance.").

Defendant is correct that the Corps acknowledged in the 1958 Study that the jetties had long caused erosion in plaintiffs' zone.[16] The 1958 Study notes that "[t]he navigation channel at St. Joseph Harbor is dredged annually to maintain project depth, and for this reason little or no beach building material is believed to pass the harbor entrance and reach the downdrift shore." PX 132 (1958 Study) 4; see also id. at 20-21 (describing the quantity of sand blocked by the jetties since 1907 and the amount of sediment dredged from the navigation channel).

The 1958 Study concluded that, if the shore protection recommended in the study were constructed, an area continuing south "to the south limit of the village of Shoreham" and the "adjacent shores to the south would receive substantial benefits of shore stabilization due to restoration of normal littoral drift." PX 132 (1958 Study) 44. Implicit in the statement that the project would restore "normal littoral drift," id., is the understanding that normal littoral drift had been disrupted. Plaintiffs acknowledge that this statement in the 1958 Study refers to a segment of shoreline that includes their properties. See Pls.' Br. 18 (stating that "the 1958 [Study] indicates that the properties in the [p]laintiffs' zone would benefit from the mitigation program").

The 1958 Study also documented the greater rate of erosion south of the jetties since their construction:[17]

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[16]Plaintiffs argue that the 1958 Study "focuses extensively on erosion from natural causes and makes no attempt to assess what, if any, impact the jetties have on exacerbating natural erosion." Pls.' Jur. Resp. 8. In support of their interpretation of the 1958 Study, plaintiffs cite a passage in which the 1958 Study states that "[t]he purpose of this cooperative beach erosion control study of the shore of Berrien County, Mich[igan], is to determine the most suitable plans for preventing the erosion of the shore by waves and currents." Id. (quoting PX 132 (1958 Study) 7). Waves and currents, however, are the mechanism by which erosion washes away sediment, regardless of whether the erosion stems from natural causes or jetties built by the government. See infra Part III.B.3.d (describing shoreline behavior); Liability Op., 78 Fed. Cl. at 631-33 (describing littoral drift of sediment). Similarly, erosion rarely manifests itself as a steady retreat of the ordinary high water mark; erosion claims more property at times of high lake levels and during storms. See infra Part III.D.4.b. References in the 1958 Study to remedying the effects of waves, currents, storms, and high lake levels do not, as plaintiffs contend, indicate that the 1958 Study did not address erosion caused by the jetties.

Moreover, the 1958 Study recognized that the shoreline in plaintiffs' zone "would receive substantial benefits of shore stabilization due to restoration of normal littoral drift from the sand fill to the north," PX 132 (1958 Study) 26, a conclusion that is based on the recognition that the normal littoral drift adjacent to plaintiffs' properties had been interrupted.

[17]Plaintiffs also argue that the 1958 Study does not specifically state that erosion is taking place above the high water mark. Plaintiffs misinterpret the 1958 Study. The 1958 Study documented widespread and longstanding erosion above the high water mark in plaintiffs' zone. See, e.g., PX 132 (1958 Study) 12 (describing erosion in the entire thirty-two mile study area as

> The shores for about a mile north of the harbor structures and 1,200 feet south thereof have been advancing lakeward since the entrance structures were built. South of the latter accreting area, however, erosion of the bluffs has been severe, causing the loss of, or necessitating the movement of, a number of valuable residences and threatening a railroad and public highway. Numerous protective structures have been erected but have exhibited only moderate effectiveness.[18]

PX 132 (1958 Study) 3. The 1958 Study observed that, in the area up to 500 feet north of the jetties, "the shoreline has been accreting at a rate of approximately 4 feet per year

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follows: "Over the 82-year period of record, with few exceptions, continuous recession of clay and sand bluffs in this region [has] occurred. In recent years (1943-54), due to the cycle of high lake levels, recession of the bluffs has been intensified, resulting in serious damage and property destruction"); id. at 17 ("The rate of erosion of the bluff in the study area from the harbor entrance to the south limits of the village of Shoreham has averaged 2.1 feet per year."); id. at 11 (stating that, in an area continuing southward to the southern edge of the village of Shoreham, "Several residential structures originally constructed along the top of the bluff have been moved several times in the past few years to avoid being toppled into the lake. High lake levels have eroded the toe of clay banks causing large slides along the entire stretch of shore front"); see also infra Part III.D.1 (describing the lakeward toe of the bluff as representing the ordinary high water mark for properties characterized by bluffs).

Plaintiffs correctly note, regarding an area beginning in Lincoln Township and extending to the south, that the 1958 Study observed that "'[much] of the area is fronted by extensive sand dune deposits that provide a source of material to the beaches.[']" Pls.' Jur. Resp. 9 (first alteration in original) (quoting PX 132 (1958 Study) 20). However, beaches along Lake Michigan can vary dramatically in width from year to year and even month to month. See infra Part III.D.3.b.i (collecting statements by individual plaintiffs that their beaches "come and go"); see supra Part I (describing the process of cross-shore sand transport, which can cause beaches to vary in width by hundreds of feet) (quoting Tr. 2593:3-19, 2594:2-2595:2 (Nairn)). The 1958 Study does not state that the beaches in the area with sand dune deposits were sufficiently wide and immobile to prevent erosion of areas above the ordinary high water mark. See PX 132 (1958 Study) passim. Rather, the fact that sand dunes are providing material to the beaches suggests that erosion is taking place above the ordinary high water mark, inland from the beach.

[18]Analysis developed for purposes of this trial using modern techniques indicates that the rate of erosion south of the jetties is also naturally higher than the rate of erosion north of the jetties. DX 1 (Nairn Report) v, 2-27 to 2-30 (discussing how the lakebed profile concentrates wave energy along the ten-mile stretch of shoreline south of the jetties); see also infra Part III.B.3.d (discussing shoreline behavior). In light of this analysis, it appears that the 1958 Study would have overestimated the amount of erosion caused by the jetties because it did not account for the possibility that some of the increase in erosion south of the jetties was naturally occurring. See PX 132 (1958 Study) passim.

since 1830," id. at 10, a rate of growth that, in the court's view, would have been apparent to landowners.

In addition to the disruption of normal littoral drift in plaintiffs' zone and the increase in erosion, the 1958 Study also documented the proliferation of shore protection structures south of the jetties after their construction, a trend that is consistent with--although it does not independently establish--an increased rate of erosion south of the jetties after their construction and lengthening. See id. at 18, 20. Describing the area northward from the jetties to the northernmost edge of Benton Harbor, the 1958 Study states:

> Beach erosion in this reach of shoreline has been limited to the extreme northern end near the Benton Harbor city limits. No extensive beach protective structures have been built in this reach with protective efforts limited to the placement of an occasional steel barrel filled with sand. The remaining portion of this shoreline has been accreting.

Id. at 18. In contrast, in the area extending southward from the edge of the shore protection adjacent to a highway to the southern edge of the village of Shoreham, shore protection was very common: "Approximately 22 individual structures built by property owners are in existence and range from typical groin construction to steel sheet-pile seawalls and revetments. The protection provided by a large portion of this work is limited, and erosion is continuing in those intermediate areas not protected." Id. at 20. Further to the south, where the southernmost properties owned by plaintiffs are located, there were few shore protection structures, but the land was largely undeveloped, see id., making them less necessary.

The disruption of normal littoral drift and the increased erosion south of the jetties documented in the 1958 Study are consistent with the conclusion reached by Dr. Nairn in his 2006 expert report that the jetties have long contributed to erosion south of the harbor. See Def.'s Ex. (DX) 1 (Nairn Report) 4-151 to 4-152. Dr. Nairn, using a sediment budget[19] and several types of numerical modeling, quantified the impact of the jetties on erosion in the an area of shoreline beginning at the jetties and continuing for ten miles to

[19]Dr. Nairn verified the results of his sediment budget analysis by comparing projected rates of erosion to the observed rates of bluff recession over time. See DX 1 (Nairn Report) 4-150 to 4-158. Dr. Nairn included in his report a summary of bluff erosion rates over time, both for plaintiffs' zone as a whole, see id. at 4-118 to 4-120, and for plaintiffs' individual properties, see id. at App. D. The summary provided by Dr. Nairn, however, is not sufficiently detailed to be of assistance in determining the effect that the jetties had on erosion in plaintiffs' zone after 1903. Dr. Nairn provided recession rates for four time spans: 1830 to 1871, 1871 to 1938, 1938 to 1960 and 1960 to 2002. Id. at 4-120. Because the most relevant time span, 1871 to 1938, includes 32 years before the jetties reached their full length, it is not a reliable representation of how bluff recession rates changed when the jetties reached their full length.

the south. See infra Parts III.B-C (explaining and finding persuasive Dr. Nairn's use of sediment budgets and numerical modeling to predict rates of erosion and the effectiveness of mitigation). Dr. Nairn determined that, during the period from 1836 to 1875, when the jetties were shorter, erosion in the study area continued to fall "within the range of pre-harbor erosion estimates."[20] DX 1 (Nairn Report) 4-151. Between 1876 and 1903, as the Corps continued to lengthen the jetties, the rate of erosion in the study area did not increase and, in fact, decreased slightly from pre-harbor levels. See id. at 4-152.

The impact of the jetties began to be felt when they reached their final length. In terms of volume, Dr. Nairn calculates that between 1904 and 1969, the year before the Corps began its mitigation efforts, the jetties were responsible for 25% of all erosion in the study area. See id. at 4-158. This impact would have been greatest in the northern part of the study area and would not be the same for each property.[21] See id. at 4-159.

[20]It appears, however, from the bluff recession rates, that the jetties increased erosion in the northernmost portion of Dr. Nairn's study area during this time. To study bluff recession rates, Dr. Nairn divided his study area into four reaches, from north to south. See DX 1 (Nairn Report) 4-110. In the first reach, which contains the properties of the northernmost plaintiffs, Dr. Nairn estimates that the rate of erosion averaged 5.25 feet per year between 1830 and 1871, id. at 4-118, 4-120, indicating that the jetties had already begun to impact this area, see Tr. 2755:1-5 (colloquy between Dr. Nairn and defendant's counsel). This accelerated rate of erosion before the jetties were lengthened suggests that the properties located furthest to the north may have been substantially encroached upon by erosion even before the jetties reached their final length. Because the court determines that all of the plaintiffs' properties were substantially encroached by erosion caused by the jetties earlier than 1952, the court does not consider whether erosion caused by the jetties substantially encroached upon plaintiffs' properties in this northernmost area at an earlier time.

[21]At the trial of damages, Dr. Nairn suggested that the zone of influence of the jetties may not have included the properties of the southernmost plaintiffs until after 1970. See Tr. 2760:6-14 (colloquy between Dr. Nairn and defendant's counsel). Discussing his table of bluff recession rates, Dr. Nairn stated that, between 1938 and 1960, the third reach of the study area, which begins at the Miller property, see id. at 2759:8-14, "does not appear to show any effect of the harbor," id. at 2755:2-2758:3; cf. id. at 2759:15-25 (stating that if the harbor did not impact the third reach during this time, it also did not impact the fourth reach). Dr. Nairn then stated that "it could be even beyond 1970 that there is no impact of the harbor there." Id. at 2760:6-14. Dr. Nairn qualified these statements, suggesting that the zone of influence of the jetties may have ended "somewhere in reach three" between 1938 and 1960. Tr. 2758:4-7 (Nairn). Dr. Nairn further testified, "[T]o be honest with you, that's a bit beyond our science to say exactly how [erosion rates] var[y] along the shore on a, say, 100 meter by 100 meter basis." Tr. 2758:18-21 (Nairn). Dr. Nairn's view that the zone of the influence of the jetties may not have included the southernmost plaintiffs until after 1970 was not argued by defendant in its briefing following the trial of liability. See Liability Op., 78 Fed. Cl. at 613 n.17 (stating that defendant had not argued in its briefing that the zone of influence of the jetties did not include plaintiffs' properties).

In their post-trial briefing addressing the measure of their damages, plaintiffs argue that Dr. Nairn's approach significantly underestimates the impact of the jetties on their properties since 1950.[22] See infra Part III.C.1. Plaintiffs contend that:

> the United States has (1) substantially undercounted the volume of sand being blocked by the jetties, as well as the jetties['] percentage contribution to the erosion in the [p]laintiffs' zone; and (2) substantially overcounted the volume of sand block[ed] by the C&O and MDOT revetments, so that the jetties['] percentage contribution to the erosion in the [p]laintiffs' zone is well in excess of 30% and is fairly calculated as being between 60% and 70%.

Pls.' Br. 23; see also Tr. 19:7-24 (plaintiffs' counsel) (stating, in his opening argument, that Dr. Mackey's testimony about the flaws in Dr. Nairn's methods will demonstrate that the jetties have caused 60 to 70 percent of the erosion in plaintiffs' zone since 1950). As described below, the court finds plaintiffs' criticisms of Dr. Nairn's erosion analysis unpersuasive. See infra Parts III.B-C. However, the court finds plaintiffs' argument that the jetties caused 60-70% of the erosion in plaintiffs' zone after 1950 inconsistent--absent evidence cited by plaintiffs to explain the sudden change--with a finding that the jetties did not cause significant and noticeable erosion in plaintiffs' zone prior to 1950.

Because of the interruption of littoral drift and the erosion documented in the 1958 Study and because of Dr. Nairn's calculations of the jetties' impact on erosion, which plaintiffs fail persuasively to contradict (suggesting instead that Dr. Nairn has underestimated the amount of erosion caused by the jetties), the court finds that the

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Because Dr. Nairn's estimate of the zone of influence of the jetties is inconsistent with the law of the case, pursuant to which the jetties are responsible for a portion of the erosion in all of plaintiffs' zone since 1950, see id. at 654-57, and because Dr. Nairn reached this conclusion based on a table that documents periods of time that would not properly capture the effect of the lengthening of the jetties, see supra note 19, the court does not adopt Dr. Nairn's theory that the properties of the southernmost plaintiffs may have remained outside of the zone of influence of the jetties until after 1970.

[22]The trial of damages focused on the damage caused by the jetties since 1950 because plaintiffs argued--and because the court accepted plaintiffs' argument--that this was the correct time period to consider. See Stabilization Op., 68 Fed. Cl. at 525 (agreeing with plaintiffs' argument that each plaintiff is entitled to just compensation for erosion proven to have occurred after plaintiffs acquired their properties, but in no case earlier than 1950); Law of Damages Op., 88 Fed. Cl. at 688 (agreeing with plaintiffs' argument that plaintiffs were entitled to just compensation for erosion proven to have occurred in or after 1950, regardless of the date on which each plaintiff had acquired his or her property).

erosion caused by the jetties in plaintiffs' zone was a longstanding problem by 1952, beginning as early as 1903.[23]

To determine the point at which plaintiffs' claims stabilized, the court must determine the point at which this additional erosion "substantially encroached the parcels at issue and the damages were reasonably foreseeable." Boling II, 220 F.3d at 1373. The Federal Circuit has advised that, in making this determination, a court must "take into account the uncertainties of the terrain, the difficulty in determining the location of the government's easement, and the irregular progress of erosion." Id. Plaintiffs are correct that, to some extent, the exact rate of erosion--and therefore changes in the rate of erosion--would have been obscured by natural variations, such as changes in lake level, barometric pressure, and wind direction, as well as "the dynamic nature of the [p]laintiffs' shoreline." Pls.' Jur. Br. 13; see also supra Part I (describing variations in beach width caused by cross-shore sand transport and changes in lake levels). Plaintiffs contend that fluctuations in lake levels of up to 1.8 feet occur with annual frequency and that, as numerous plaintiffs testified at trial, beaches "'come and go' as lake levels changed and storms occurred." Pls.' Jur. Br. 13.

However, the erosion relevant to plaintiffs' claims, that is, the erosion of property above the ordinary high water mark, can be gauged more clearly because the erosion of such property does not vary as widely as does the profile of beaches below the ordinary high water mark with changes in lake depth, barometric pressure, and wind direction. As described below in Part III.D.1, the court finds persuasive a delineation of the high water mark that lies, on properties characterized by bluffs, at the toe of the bluff, and, on properties characterized by dunes, at the edge of permanent vegetation. Although the evidence presented in this case establishes that beaches are somewhat ephemeral, see infra Part III.D.3.b.i, the ordinary high water mark is defined by these, more permanent, features, see infra Part III.D.1; Tr. 2343:18-22 (Nairn) (defining the ordinary high water mark for bluff properties as the toe of the bluff and distinguishing permanent vegetation from "ephemeral vegetation," such as marine grass and dune grass); Tr. 2363:11-13 (Nairn) (stating that the ordinary high water mark, when defined by bluffs, normally moves only in one direction). Plaintiffs cite no evidence that bluffs and permanent vegetation "come and go" as rapidly as beaches do. See Pls.' Jur. Br. passim; Pls.' Jur. Resp. passim. The rate of erosion above the ordinary high water mark, therefore, can be determined with some confidence.

[23]Notwithstanding Dr. Nairn's calculation that the jetties are also responsible for 25% of the erosion in plaintiffs' zone since 1950, see DX 1 (Nairn Report) 4-158, the court concluded in its Liability Opinion, based on admissions by the Corps, that, excluding the effect of any mitigation efforts, the jetties have caused 30% of the erosion in plaintiffs' zone since 1950, see Liability Op., 78 Fed. Cl. at 654-57. Because the difference is not material to the present discussion, the court does not consider whether it would be more accurate to adjust upward Dr. Nairn's estimate of the effect the jetties had on plaintiffs' zone before 1950.

The location of the ordinary high water mark, because it is characterized by observable features, can be identified by landowners such as plaintiffs. See Loesch, 227 Ct. Cl. at 61, 645 F.2d at 925 (stating that "the OHWM on a riverbank is a physical fact, subject to determination by inspection of the riverbank" (citation omitted) (citing Kelley's Creek & Nw. R.R. Co. v. United States, 100 Ct. Cl. 396, 406 (1943) ("The high watermark is not to be determined by arithmetical calculation; it is a physical fact to be determined by inspection of the river bank. It is the line where the water stands sufficiently long to destroy vegetation below it.")). "It is not unreasonable to expect that plaintiffs, as riparian landowners, were familiar to some degree with their [shoreline]." Id. at 61, 645 F.2d at 925. It is therefore not unreasonable to expect that plaintiffs, as well as the prior owners of their properties, would have observed where the ordinary high water mark lay on their properties and would have observed its changing location over time.

Any uncertainty would have been further reduced by the significant span of time--forty-nine years--between the year 1903, when the jetties reached their final length, and 1952, the date after which plaintiffs' claims must have accrued, under plaintiffs' reading of Applegate, see supra Part III.A.1, for the uncertainty created by the 1958 Study to render plaintiffs' claims timely. Although bluffs and permanent vegetation would not be expected to "come and go" as beaches do, erosion is often an irregular process, accelerating at times of high lake levels and during storms. See infra Part III.D.4.b. The rate of erosion, and therefore the effect of the jetties, would have become clearer with the passage of time.[24]

[24]Although not necessary to the court's conclusion, the court observes that plaintiffs' own expert witness, Dr. Meadows, agreed at a deposition given in this matter that an "ordinary layperson who owns property on the shore" would be able to perceive both the role that the jetties play in exacerbating erosion in plaintiffs' zone and the growth of the jetties' zone of influence over time:

> I believe someone who has lived on the shoreline for a number of years would be able to notice these trends.
>
> From day-to-day exposure that you would be able to see that towards the harbor there is death and destruction and the further away from the harbor you get the less apparent that is, and that, particularly an astute observer, might notice that that area of sediment depletion is migrating.

Accrual Op. I, 49 Fed. Cl. at 819.

The Corps' dredging activities would have reinforced the perception that the jetties caused erosion. Between 1903 and 1945, the Corps removed an average of 43,500 cubic yards of sediment from St. Joseph Harbor per year, see DX 1 (Nairn Report) 3-49, Fig. 3.8 (dredging history at St. Joseph Harbor), a volume of sediment that would fill a football field, exclusive of end zones, to a depth of nearly twenty-five feet, see 2011 Official Playing Rules and Casebook

During the forty-nine years between 1903, when the jetties reached their final length, and 1952, the jetties were responsible for 25% of the material eroded from Dr. Nairn's study area, the ten mile segment of shoreline south of the jetties. See DX 1 (Nairn Report) 4-158. Neither party cites--and the court does not find in the record--estimates of how many additional feet of erosion occurred in plaintiffs' zone during this period as a result of the jetties. See supra note 19 (discussing Dr. Nairn's analysis of bluff recession rates). However, a study published in 1976 determined the rate of bluff recession, averaged across all of Berrien County over 120 years to be .6 meters, or two feet, per year. See DX 40 (1997 Report) 3. Given this rate of erosion and the passage of forty-nine years between 1903 an 1952, the court concludes that the additional erosion caused by the jetties was not limited to "mere inches." Boling II, 220 F.3d at 1372.

The well-documented additional erosion caused by the lengthened jetties would have made it clear to a reasonable landowner well before 1952 that the government had effected a permanent taking. See PX 132 (1958 Study) 3-4, 10-12, 17-18, 20-21; DX 1 (Nairn Report) 4-152, 4-158. This is particularly true given the lower rates of erosion (and the accretion of sand) occurring further north since construction of the jetties, and given the diminishing impact of the jetties on properties further south from the jetties. At this time, the extent of the damage would have been reasonably foreseeable from the increased rate at which erosion had occurred for forty-nine years.

Plaintiffs assert that "[e]ven if, for the sake of argument, the 1958 [Study] placed [p]laintiffs on inquiry notice that the harbor jetties caused some degree of erosion, they were clearly not on notice that the jetties had caused erosion to their specific properties, much less a permanent loss." Pls.' Jur. Br. 14-15. Plaintiffs are correct that the 1958 Study did not discuss their properties individually. See PX 132 (1958 Study) passim. Because the 1958 Study was not prepared for purposes of this litigation, it would not be expected to discuss plaintiffs' properties individually, or to measure separately the amount of erosion caused by the jetties in plaintiffs' zone.

However, "plaintiff[s] bear[] the burden of showing jurisdiction by a preponderance of the evidence." Taylor, 303 F.3d at 1359 (citing Thomson, 315 U.S. at 446). It is not enough for plaintiffs to argue in briefing that the general pattern of erosion that followed the lengthening of the jetties in 1903 might not have affected certain of their individual properties. Because plaintiffs have the burden of showing the court's jurisdiction, they must cite evidence that erosion caused by the jetties had not reached their properties when the 1958 Study, PX 132 (1958 Study) 3-4, 10-12, 17-18, 20-21, and Dr. Nairn's analysis, see DX 1 (Nairn Report) 4-152, 4-158, indicate that it reached the

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of the National Football League iv (2011) (stating that the dimensions of a football field are 300 feet by 160 feet), available at http://static.nfl.com/static/content/public/image/rulebook/pdfs/2011_Rule_Book.pdf.

rest of the area. Apart from their interpretation of the 1958 Study, plaintiffs have cited no such evidence, see Pls.' Jur. Br. passim; Pls.' Jur. Resp. passim, and have failed to carry their burden of proof.

Plaintiffs argue that "the effect of the harbor jetties on the lakebed and adjoining shoreline to the south was a very gradual process that occurred over decades of time." Pls.' Jur. Br. 14. Citing a single page of a report published by the Corps in 1997, co-authored by defendant's expert witness, Dr. Nairn (1997 Report), plaintiffs argue that as late as 1997 it was not understood that the harbor jetties caused increased erosion in plaintiffs' zone.[25] Id. The implication of plaintiffs' argument is that their claims stabilized no earlier than 1997 because it was not understood at that time[26] that the jetties were causing erosion in plaintiffs' zone.[27]

[25]As discussed above in the third paragraph of this Part III.A.2, the court found the 1958 Study to be "the most persuasive evidence" of whether and for how long plaintiffs' properties have been considered to be within the jetties' zone of influence, see Liability Op., 78 Fed. Cl. at 621. The court concluded "that plaintiffs' properties have been considered in the zone of influence of the jetties at least as far back as the 1950s, even if the specific impact of the jetties was not quantified until later." Id. The 1997 Report, like the other Corps reports, was before the court when it made this determination. See id. passim (repeatedly citing the 1997 Report).

[26]The court does not understand plaintiffs to be arguing that their properties were not impacted by the jetties until 1997, an argument that plaintiffs are barred from making by the doctrine of judicial estoppel. The doctrine of judicial estoppel posits that "where a party assumes a certain position in a legal proceeding, and succeeds in maintaining that position, he may not thereafter, simply because his interests have changed, assume a contrary position, especially if it be to the prejudice of the party who has acquiesced in the position formerly taken by him." Davis v. Wakelee, 156 U.S. 680, 689 (1895). Judicial estoppel "'generally prevents a party from prevailing in one phase of a case on an argument and then relying on a contradictory argument to prevail in another phase.'" New Hampshire v. Maine, 532 U.S. 742, 749 (2001) (quoting Pegram v. Herdrich, 530 U.S. 211, 227 n.8 (2000)). In its Liability Opinion, based on admissions by the Corps, the court agreed with plaintiffs that the entirety of plaintiffs' zone had been within the zone of influence of the jetties during the time period, 1950 to 2000, considered at the trial of liability. See Liability Op., 78 Fed. Cl. at 621. Plaintiffs may not now make the contradictory argument that their properties came within the zone of influence of the jetties at a date later than 1950. See New Hampshire, 532 U.S. at 749.

[27]Plaintiffs are therefore arguing that the situation did not stabilize until ninety-four years after the government's action in lengthening the jetties. Although the fact is not dispositive of plaintiffs' argument, the court's research has identified no instance in which the damage to a plaintiff's property was found, pursuant to United States v. Dickinson, 331 U.S. 745 (1947), to stabilize so long after the government's actions. See, e.g., Fallini v. United States, 56 F.3d 1378, 1382 (Fed. Cir. 1995) (finding that stabilization occurred within twelve years); Columbia Basin Orchard v. United States, 116 Ct. Cl. 348, 356-57, 88 F. Supp. 738, 739 (1950) (finding that stabilization occurred within one year); Forsgren v. United States, 64 Fed. Cl. 456, 457, 459

The only relevant sentence on the page of the 1997 Report cited by plaintiffs describes an area approximately 8.2 kilometers south of the jetties, which, "up until recently, may not have been significantly influenced by the harbor jetties." DX 40 (1997 Report) 58.[28] The page of the 1997 Report cited by plaintiffs does not explain why the report's authors believed that the area may not have been significantly influenced by the jetties or what they meant by "until recently." See id. Neither does the referenced page of the 1997 Report explain the term "significantly influenced."[29] See id. Other portions of the 1997 Report suggest that its authors assumed that the area was not affected by the jetties. See, e.g., id. at 25, 27 (listing among the authors' "assumptions about the nearshore conditions and profile evolution prior to the comparison of the data" that this area was "not influenced by reduced sediment supply from the north--[and is] representative of natural conditions or background erosion rate"); id. at 79 (assuming that, because the rate of erosion in this area was similar to the rate of erosion north of the jetties, this area is not affected by the jetties). Plaintiffs cite no page of the 1997 Report on which the authors state that they made a detailed study of the effect of the jetties on this portion of plaintiffs' zone. See Pls.' Jur. Br. passim; Pls.' Jur. Resp. passim. Rather, the court has found that the 1997 Report was largely based on data collected north of plaintiffs' zone. Liability Op., 78 Fed. Cl. at 624-25.

The court does not view an assumption in the single sentence cited by plaintiffs of a report published in 1997 as establishing that it was not known that the jetties caused

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(2005) (finding that stabilization occurred within four years); Pleasant Country, Ltd. v. United States, 37 Fed. Cl. 321, 328-29 (1997) (finding that stabilization occurred within three years). In one case, in which it was necessary to distinguish erosion caused by the government from naturally occurring erosion, see Baskett v. United States, 8 Cl. Ct. 201, 211-12 (1985), aff'd, 790 F.2d 93 (Fed. Cir. 1986) (table), the court rejected the plaintiffs' argument that erosion caused by the government did not sufficiently manifest itself within seven years of the government's actions for the situation to stabilize, id. at 231.

[28]Plaintiffs omitted PX 24 (1997 Report) from the exhibit binders plaintiffs provided to the court. In place of the report is a piece of paper that reads: "Plaintiffs' Exhibit[,] 24, JX-3[,] DX-40." The court therefore cites the copy of the 1997 Report filed as DX 40.

[29]Although the authors of the 1997 Report did not explain their use of the term "significantly influenced," see DX 40 (1997 Report) 58, it is apparent from the context in which the term was used that any erosion in this area that had been caused by the jetties would have been overshadowed by the erosion that the jetties caused at a location further north. The referenced page of the 1997 Report provided a "long-term comparison of beach profiles" at four locations, only two of which were south of the harbor jetties. See id. The other location south of the jetties described an area where erosion had been "severe," causing the "5-[meter (16.4 feet)] depth contour" to move inshore at an average rate of nine meters (29.5 feet) per year between 1945 and 1995. Id. To be legally significant, the additional erosion caused by the jetties need not be as pronounced as it was in this area further to the north.

erosion in plaintiffs' zone until at least 1997. Because there was evidence apparent to an ordinary landowner that the jetties accelerated erosion, plaintiffs were not entitled to postpone the filing of their claims until they received scientific confirmation or a technical explanation of the subsurface processes causing the harm. See Accrual Op. I, 49 Fed. Cl. at 820 (quoting Fallini, 56 F.3d at 1380).

The court therefore finds that, significantly earlier than 1952, the erosion caused by the jetties "had substantially encroached the parcels at issue and the damages were reasonably foreseeable." Boling II, 220 F.3d at 1373. Because the situation stabilized prior to 1952, the court finds that plaintiffs' claims accrued prior to 1952, see id., and that, by waiting to file a complaint until 1999, plaintiffs failed to file their claims within the six-year limitations period set out in 28 U.S.C. § 2501.

3. The Accrual Suspension Rule

In their opening brief on jurisdiction, plaintiffs argue that their claims "could not have accrued, as a matter of law, prior to the issuance of the Owen decision" because "[p]rior to Owen[,] it was settled federal law that a property owner could not recover for a taking of its fast land absent a physical invasion."[30] Pls.' Jur. Br. 21. According to

[30]In Owen, the United States Court of Appeals for the Federal Circuit (Federal Circuit) heard the plaintiff's appeal en banc "to clarify [its] precedents with respect to the scope of the government's navigational servitude." Owen v. United States, 851 F.2d 1404, 1406 (Fed. Cir. 1988) (en banc). "[U]pon the determination of Congress to improve navigation, the navigational servitude defines the appropriate boundaries within which the United States can assert its power to supersede private ownership interests without creating an obligation to pay just compensation under the Eminent Domain Clause of the Fifth Amendment." Id. at 1408.

The Federal Circuit stated that "[t]he holdings of the [United States Supreme Court (Supreme Court)] and the other federal courts make clear that no compensation is owed by the government for injury or destruction of a riparian owner's property which is located in the bed of a navigable stream." Id. at 1409. The court therefore addressed "what constitutes the boundaries of the 'bed' of a navigable stream, determination of which will also define the scope of the navigational servitude." Id. The Federal Circuit "conclude[d] that Supreme Court precedent undeniably requires our holding that the navigational servitude does not provide a blanket exception to the Takings Clause of the Fifth Amendment where improvements to navigation made by the government result in erosion to land located above or outside the bed of the stream as delineated by the high-water mark at the time of the construction." Id. at 1412.

The Federal Circuit found that "nearly all of our own precedents are in accord with those of the Supreme Court," id., but overruled two cases "to the extent that they allow the navigational servitude to reach fast land above and outside the bed of navigable water," exempting the government from liability for erosion, id. at 1416 (overruling Pitman v. United States, 198 Ct. Cl. 82, 457 F.2d 975 (1972) and Ballam v. United States, 806 F.2d 1017 (Fed. Cir. 1986)). The Federal Circuit further stated that "[s]imilar statements in other [United States Court of Claims (Court of Claims)] cases, although not always necessary to their respective

plaintiffs, "[p]rior to Owen[], federal cases uniformly held that erosion damage was not a taking where the damage from the federal project was caused, not by a rise in water levels, but as a consequence of some other interference with the natural water flow." Id. Plaintiffs contend that "to argue that [p]laintiffs[']' takings claim was barred before they even had a recognized claim would be patently unfair." Id. at 22.

Defendant, interpreting plaintiffs' argument as an argument for the application of equitable tolling, correctly notes that equitable tolling is not available in actions brought under the Tucker Act. Def.'s Jur. Resp. 13-14 (citations omitted); see John R. Sand & Gravel Co. v. United States, 552 U.S. 130, 133-34 (2008); Young v. United States, 529 F.3d 1380, 1384 (Fed. Cir. 2008) (stating the holding of John R. Sand & Gravel to be that "the statute of limitations applicable to Tucker Act claims, 28 U.S.C. § 2501, is jurisdictional and not susceptible to equitable tolling"). Equitable tolling extends the statute of limitations "'where the claimant has actively pursued his judicial remedies by filing a defective pleading during the statutory period, or where the complainant has been induced or tricked by his adversary's misconduct into allowing the filing deadline to pass.'" Young v. United States, 535 U.S. 43, 50 (2002) (quoting Irwin v. Dep't of Veterans Affairs, 498 U.S. 89, 96 (1990)).

Plaintiffs, in their jurisdictional response brief, do not argue for equitable tolling or repeat their previous argument that it would be "patently unfair" to find that the limitations period ended before the Federal Circuit's decision in Owen. See Pls.' Resp. passim. Plaintiffs instead raise the new argument that their claims are timely under the "accrual suspension rule," which, plaintiffs assert, directs that "'[n]o cause of action generally accrues until the plaintiff has a right to enforce his cause.'" Pls.' Jur. Resp. 12 (alteration in original) (quoting United States v. One Red Chevrolet Impala Sedan (Red Chevrolet), 457 F.2d 1353, 1358 (5th Cir. 1972)).

Accrual suspension is an exception to the general rule "that a claim 'first accrues' when all the events have occurred which fix the alleged liability of the defendant and entitle the plaintiff to institute an action." Hopland Band of Pomo Indians v. United States, 855 F.2d 1573, 1577 (Fed. Cir. 1988) (citing Japanese War Notes Claimants Ass'n of the Phil., Inc. v. United States, 178 Ct. Cl. 630, 632, 373 F.2d 356, 358 (1967)). It directs "that the accrual of a claim against the United States is suspended, for purposes of 28 U.S.C. § 2501, until the claimant knew or should have known that the claim existed." Martinez, 333 F.3d at 1319; see also Ingrum v. United States, 560 F.3d 1311, 1315 n.1 (Fed. Cir. 2009) (stating that it "is both more common and more precise" to describe the rule as suspending accrual while a claim is "concealed or inherently unknowable" (internal quotation marks omitted) (citing Martinez, 333 F.3d at 1319)).

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decisions, to the effect that the waters which effect the taking must rise above the ordinary high-water mark of the river involved as a result of improvements to navigation should also be viewed as inaccurate." Id. at 1416 n.13.

"The 'accrual suspension' rule is 'strictly and narrowly applied: . . . [The plaintiff] must either show that defendant has concealed its acts with the result that plaintiff was unaware of their existence or it must show that its injury was 'inherently unknowable' at the accrual date.'" Martinez, 333 F.3d at 1319 (alteration in original) (quoting Welcker v. United States, 752 F.2d 1577, 1580 (Fed. Cir. 1985)). "Mindful that the 'accrual suspension rule' is to be 'strictly and narrowly applied,' courts have concluded that a misunderstanding of the meaning of the law or one's legal rights does not trigger this rule." Petro-Hunt, L.L.C. v. United States, 90 Fed. Cl. 51, 62 (2009) (citation omitted); see also Catawba Indian Tribe v. United States, 982 F.2d 1564, 1572 (Fed. Cir. 1993) ("[A]ll the relevant facts were known. It was the meaning of the law that was misunderstood."). The accrual suspension rule "is based on a construction of the term 'accrues' in section 2501," and "is distinct from the question whether equitable tolling is available under that statute, although the term 'tolling' is sometimes used in describing the rule." Martinez, 333 F.3d at 1319.

Because plaintiffs did not raise their accrual suspension argument in their opening brief, see Pls.' Jur. Br. passim, defendant did not have an opportunity to respond to it, and the court finds the argument to be waived, see Cross Med. Prods., Inc. v. Medtronic Sofamor Danek, Inc., 424 F.3d 1293, 1320 n.3 (Fed. Cir. 2005) (finding an issue not properly raised in an opening brief to be waived); Becton Dickinson & Co. v. C.R. Bard, Inc., 922 F.2d 792, 800 (Fed. Cir. 1990) ("[W]e see no reason to depart from the sound practice that an issue not raised by an appellant in its opening brief . . . is waived.").

Even if the accrual suspension rule had been properly raised, it is inapplicable to plaintiffs' claims. Plaintiffs' argument is that, before Owen was decided in 1988, plaintiffs "had no cause of action" because "federal cases uniformly held that erosion damage was not a taking where the damage from the federal project was caused, not by a rise in water levels, but as a consequence of some other interference with the natural water flow."[31] Pls.' Jur. Br. 21. Plaintiffs are therefore arguing that the legal basis--rather than the factual basis--of their claims was "inherently unknowable," Ingrum, 560 F.3d at 1315 n.1 (citing Martinez, 333 F.3d at 1319), until Owen was decided.

[31]Plaintiffs also argue, citing cases decided in the supreme courts of the states of California and Michigan, that "the uniform rule," Pls.' Jur. Resp. 12 n.3, in state courts before Owen was that "riparian owners . . . are not entitled to compensation for erosion damage created by navigable improvements," id. at 12 (quoting Peterman v. Michigan, 521 N.W.2d 499, 511 (Mich. 1994) and citing, in an accompanying footnote, Miramar Co. v. City of Santa Barbara (Miramar), 143 P.2d 1, 2-4 (Cal. 1943)). The boundaries of the navigational servitude held by the states of California and Michigan are irrelevant to plaintiffs' claims, which involve the taking of property by the United States government. See Peterman, 521 N.W.2d at 511 (discussing the navigational servitude held by the state of Michigan); Miramar, 143 P.2d at 2-4 (discussing the navigational servitude held by the state of California).

The accrual suspension rule is generally applied in situations where the factual basis, rather than the legal basis, of a plaintiff's claim is concealed or inherently unknowable.[32] See, e.g., Young, 529 F.3d at 1385 (finding that the trial court had properly declined to suspend accrual because "[i]t is a plaintiff's knowledge of the facts of the claim that determines the accrual date" (citing, inter alia, United States v. Kubrick, 444 U.S. 111, 122 (1979)); Martinez, 333 F.3d at 1319 (finding that the accrual suspension rule was not applicable because "Mr. Martinez was not unaware of the existence of his injury and the acts giving rise to his claim"); Welcker, 752 F.2d at 1580 (finding that the plaintiff's claims accrued in 1949 or in 1950 because "[c]learly, appellant was aware in 1949-1950 that he had been dismissed from the federal service on grounds that he himself considered to be wrong and improper"). Plaintiffs do not cite--and the court's research has not found--any decision in which the Court of Federal Claims or the Federal Circuit has found that adverse precedent tolled a plaintiff's claims under the Tucker Act, rendering them timely.[33] See Pls.' Jur. Br. passim; Pls.' Jur. Resp. passim.

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[32]Taking out of context a portion of a decision by the United States Court of Federal Claims (Court of Federal Claims), plaintiffs argue that accrual suspension "is typically applied where 'the change in circumstances arises out of a decision that overrules or alters prior precedent.'" Pls.' Jur. Resp. 13 n.5. (quoting Petro-Hunt, L.L.C. v. United States, 90 Fed. Cl. 51, 62 (2009)).

In its entirety, the passage referenced by plaintiffs, which describes United States v. One 1961 Red Chevrolet Impala Sedan (Red Chevrolet), 457 F.2d 1353 (5th Cir. 1972) and Neely v. United States, 546 F.2d 1059 (3d Cir. 1976), reads as follows:

> Mindful that the "accrual suspension" rule is to be "strictly and narrowly applied," courts have concluded that a misunderstanding of the meaning of the law or one's legal rights does not trigger this rule. Yet, several cases involving this rule and the related discovery rule intimate that the suspension rule may apply where a claimant, through the exercise of reasonable diligence, could not have known that its legal rights had been modified or abridged in a way giving rise to a claim. Cases of this sort typically involve situations in which the change in circumstance arises out of a decision that overrules or alters prior precedent, with the claim deemed to have been tolled until the modifying decision was made."

Petro-Hunt, 90 Fed. Cl. at 62 (citations and footnote omitted).

The Petro-Hunt court did not state that the application of accrual suspension urged by plaintiffs is typical, but rather that certain cases suggest that such an application may be appropriate in certain situations. See id.

[33]In Petro-Hunt, the Court of Federal Claims found that "the accrual suspension rule applied here to some extent," id. at 63, but rejected the plaintiff's argument that its claims accrued with a change in the applicable caselaw, id. at 62-63. The court found that the plaintiff

The Federal Circuit has repeatedly stated that plaintiffs must file their claims within the statute of limitations, notwithstanding the presence of adverse precedent or the futility of filing. See, e.g., Aectra Ref. & Mktg., Inc. v. United States, 565 F.3d 1364, 1373-74 (Fed. Cir. 2009) (finding, in the internal revenue context, that "futility does not excuse the failure to file a proper claim for limitations purposes" (citing, inter alia, United States v. Clintwood Elkhorn Mining Co., 553 U.S. 1, 5-6 (2008)); Frazer v. United States, 288 F.3d 1347, 1354-55 (Fed. Cir. 2002) (finding that "it is, of course, irrelevant" to the timeliness of the plaintiffs' claims whether similar claims had been unsuccessful in the past (citing Boling II, 220 F.3d at 1374)); Boling II, 220 F.3d at 1374 (stating that the difficulty of pursuing a takings claim due to adverse precedent "does not justify tolling the statute of limitations"); Welcker, 752 F.2d at 1583 (rejecting the plaintiff's argument that any attempt to pursue his claims would have been "an exercise in futility" because of the "tenor of the times" and noting that "the statute of limitations is not tolled by litigative timidity"); see also Venture Coal Sales Co. v. United States (Venture Coal), 57 Fed. Cl. 52, 54-55 (2003) (finding that accrual of plaintiffs' claims for a tax refund was not suspended until a decision finding the tax unconstitutional), aff'd, 370 F.3d 1102 (Fed. Cir. 2004).

Plaintiffs rely upon two related cases not binding on this court for the proposition that, although the factual circumstances of a plaintiff's claim are not concealed or inherently unknowable, "'[n]o cause of action generally accrues until the plaintiff has a right to enforce his cause.'" Pls.' Jur. Resp. 12 (alteration in original) (quoting Red Chevrolet, 457 F.2d at 1358); id. at 13 (citing Neely v. United States, 546 F.2d 1059, 1068 (3d Cir. 1976)). The plaintiffs in Red Chevrolet sued for the return of property forfeited to the United States government on the ground that it "had been used in conducting a gambling business without payment of the taxes required" by the Internal Revenue Code. Red Chevrolet, 457 F.2d at 1355. The plaintiffs in Neely sued for annulment of their convictions under the federal wagering statutes and the return of the fines they had paid. Neely, 546 F.2d at 1061. In both cases, the courts determined that the plaintiffs' claims were timely, notwithstanding that they were filed more than six years after the fines and forfeitures that gave rise to them.[34] See Red Chevrolet, 457 F.2d at 1358; Neely, 546 F.2d at 1068.

"knew or should have known it had a permanent taking claim--and the statute of limitations was triggered"--when the government began to issue mineral leases, rejecting a formal protest by the plaintiff's predecessor in interest that it held a valid mineral servitude allowing it to mine the land in question. Id. at 63-64.

[34]Although the fact is not dispositive of plaintiffs' argument, the court observes that plaintiffs' interpretation of the accrual suspension rule would significantly expand its reach. Accrual of the claims at issue was delayed by five years in Red Chevrolet, 457 F.2d at 1355, 1358, and by as many as six years in Neely, 546 F.2d at 1068. Plaintiffs argue that, although the jetties reached their final length in 1903, see supra Part III.A.2, "[p]laintiffs' takings claims did

However, both Red Chevrolet and Neely "involve[ed] claims that were filed to obtain the benefit of a new constitutional rule that the Supreme Court expressly held to have retroactive application."[35] Venture Coal, 57 Fed. Cl. at 55 (citing United States v. United States Coin & Currency (U.S. Coin), 401 U.S. 715, 723-24 (1971)). The statutory provisions at issue in Red Chevrolet and Neely "commanded that gamblers submit special registration statements and tax returns that contained information which could well incriminate them in many circumstances." U.S. Coin, 401 U.S. at 717. In a pair of cases decided on the same day, the Supreme Court held that, "[b]ecause the risk of self-

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not accrue until, at the earliest, the decision in [Owen]" in 1988. Pls.' Jur. Resp. 12. Plaintiffs therefore contend that their claims accrued, at the earliest, eighty-five years after the acts that caused the erosion of their property. "The 'accrual suspension' rule is 'strictly and narrowly applied . . . .'" Martinez v. United States, 333 F.3d 1295, 1319 (Fed. Cir. 2003) (en banc) (quoting Welcker v. United States, 752 F.2d 1577, 1580 (Fed. Cir. 1985)). Plaintiffs cite no case--in this court or any other--in which the suspension accrual rule rendered claims timely notwithstanding that they were filed nearly a century after the acts that gave rise to them. See Pls.' Jur. Resp. passim.

[35]Another difference between this case and the decisions in Red Chevrolet and Neely is that, although adverse precedent existed that may have made it difficult for plaintiffs to recover for the erosion of their properties, it is not clear that plaintiffs' claims were completely foreclosed. Plaintiffs' claims accrued before 1952, see supra Part III.A.2, more than twenty years before Pitman was decided and more than thirty years before Ballam was decided.

Moreover, even after Pitman was decided, it was not clear that it barred recovery for erosion absent flooding. See Stockton v. United States, 214 Ct. Cl. 506, 519-20 (1977) (Davis, J., concurring) (noting, five years after the decision in Pitman, that the court's opinion and the court's prior decisions do not determine whether the plaintiffs would have been able to recover for the erosion caused by wind, water and waves in the absence of flooding of a small portion of their land).

The trial court in Owen "understandably concluded that it had no choice but to enter judgment for the defendant as the precedent of [the Federal Circuit and the Court of Claims], specifically Pitman and Ballam, completely foreclosed any possible recovery." Owen, 851 F.2d at 1418. However, the Federal Circuit found Pitman and Ballam to be contrary to controlling precedent established by the Supreme Court, which would have allowed the plaintiffs to recover. See id. ("If the only relevant precedent was that of the Supreme Court, it is certain that the Payne complaint would have withstood the government's motion for a judgment on the pleadings."). The Owen court stated that "nearly all of our own precedents are in accord with those of the Supreme Court." Id. at 1412. The Owen trial court could have applied the precedents that were in accord with those of the Supreme Court rather than Pitman and Ballam.

Unlike in Neely and Red Chevrolet, where plaintiffs had no cause of action before one was recognized by the Supreme Court, see United States v. United States Coin & Currency, 401 U.S. 715, 723-24 (1971), plaintiffs here merely would have found it "difficult," Boling v. United States, 220 F.3d 1365, 1374 (Fed. Cir. 2000), to recover.

incrimination was substantial, . . . a Fifth Amendment privilege could be raised as a defense to a criminal prosecution charging failure to file the required forms." Id. (construing Marchetti v. United States, 390 U.S. 39 (1968) and Grosso v. United States, 390 U.S. 62 (1968)). The Supreme Court determined that the rule announced in Marchetti and Grosso applied retroactively, stating that, because "the conduct being penalized is constitutionally immune from punishment, . . . [n]o circumstances call more for the invocation of a rule of complete retroactivity." Id. at 724.

The courts in Red Chevrolet and Neely both noted the Supreme Court's holding in U.S. Coin that the rule protecting the plaintiffs from self incrimination should be applied retroactively. Red Chevrolet, 457 F.2d at 1355; Neely, 546 F.2d at 1061. In contrast, the Federal Circuit did not hold in Owen that its ruling was to be applied retroactively. See Owen, 851 F.2d passim. Plaintiffs cite no decision in which the holding of Owen was applied retroactively to extend the statute of limitations for a claim that was otherwise untimely. See Pls.' Jur. Br. passim; Pls.' Jur. Resp. passim.

To the contrary, the Federal Circuit has expressly determined that the overruling of adverse precedent in Owen did not extend the limitations period within which erosion claims could timely be filed. The plaintiffs in Boling II argued that the "Ballam decision, which effectively barred the cause of action they intended to assert, and its subsequent reversal in Owen, form another basis for equitable tolling." Boling II, 220 F.3d at 1374. The Boling II plaintiffs further argued that "after the Ballam decision was rendered, any attempt to assert their rights to compensation under the Fifth Amendment would have been futile, because the identical claim had been previously rejected." Id. The Federal Circuit observed that "the plaintiffs point to no authority which would suggest that the presence of adverse precedent automatically leads to equitable tolling." Id. The Federal Circuit concluded: "It is true that during the period between the decision in Ballam and its subsequent reversal in Owen, any claim by the plaintiffs for compensation would have been difficult. However, this difficulty does not justify tolling the statute of limitations." Id.

Although the Federal Circuit used the term "equitable tolling" rather than "accrual suspension," the Boling II plaintiffs' argument is sufficiently analogous to the argument raised by plaintiffs in this case that the court views the Federal Circuit's decision as binding upon the court. See Martinez, 333 F.3d at 1319 (stating that the accrual suspension rule is distinct from equitable tolling, "although the term 'tolling' is sometimes used in describing the rule."). The court therefore holds that the accrual suspension rule did not delay the accrual of plaintiffs' claims until the Owen decision was entered in 1988.

4. The Law of the Case and the Mandate Rule

Because the Federal Circuit has previously ruled on the timeliness of plaintiffs' claims, the court directed the parties to address in their briefing whether the law of the

case doctrine prohibits the court from holding, in light of its finding that the jetties were impermeable to sand before installation of steel sheet piling, that plaintiffs did not timely file their claims. See Order to Brief Jurisdiction, 99 Fed. Cl. at 626.

Plaintiffs, in their briefing, argue that the law of the case doctrine bars the court from considering whether plaintiffs' claims are timely. Plaintiffs argue that, in its decision reversing the dismissal of plaintiffs' claims on statute of limitations grounds, the Federal Circuit "held that [p]laintiffs' claims did not accrue until January 2000, and were not time barred." Pls.' Jur. Br. 5 (citing Accrual Op. II, 314 F.3d at 1310). Plaintiffs contend that "[s]pecifically, the Federal Circuit held: 'We are satisfied that the plaintiffs met their jurisdictional burden before the Court of Federal Claims.'" Id. (quoting Accrual Op. II, 314 F.3d at 1310). Plaintiffs therefore believe that, because they have met their jurisdictional burden, the court may not reexamine any aspect of the timeliness of plaintiffs' claims.

Defendant argues that "[b]ecause the Federal Circuit's decision . . . incorporated [p]laintiffs' legal theory--a theory premised on facts substantially different from those facts subsequently proven at trial--the law of the case doctrine does not preclude this [c]ourt from dismissing [p]laintiffs' action at this time." Def.'s Jur. Br. 12. Defendant further argues that "[p]laintiffs initially alleged that the installation of steel sheet-piling was the government action that began the erosion process; but the evidence presented at trial established that the construction and maintenance of St. Joseph Harbor initiated the erosion process many years before the sheet-piling installation began." Id. at 14. Defendant therefore contends that the Federal Circuit's decision "is inapposite" to the question currently before the court. Id. at 15.

Defendant's argument is best understood as two distinct arguments. First, defendant argues that the law of the case doctrine is inapplicable because the law of the case does not address the aspect of the court's jurisdiction currently at issue, which was "'neither presented nor decided in a former proceeding in the case.'" Def.'s Jur. Resp. 11 (quoting Halpern, 384 F.3d at 1301). Second, defendant argues that, even if the law of the case addresses the aspect of the court's jurisdiction currently at issue, a change in circumstances--specifically, a change in the evidence available to the court--after the Federal Circuit's decision warrants application of one of the exceptions to the law of the case doctrine. Id. at 10-12 (citation omitted). For the reasons stated below, the court agrees with defendant that the law of the case doctrine or, more specifically, the mandate rule, is inapplicable because the aspect of the court's jurisdiction currently at issue was not decided by the Federal Circuit on appeal. Rather than addressing the aspect of the court's jurisdiction currently at issue, the Federal Circuit presumed the truth of the allegations in plaintiffs' complaints related to steel sheet piling and addressed only the jurisdictional facts relevant to the judgment from which plaintiffs appealed.

"The mandate rule provides that 'issues actually decided [on appeal]--those within the scope of the judgment appealed from, minus those explicitly reserved or remanded by

the court--are foreclosed from further consideration.'" Amado, 517 F.3d at 1360 (alteration in original). "The scope of the issues presented . . . on appeal must be measured by the scope of the judgment appealed from, not by the arguments advanced by the appellant." Engel Indus., 166 F.3d at 1382 (citations omitted). The court must therefore determine whether the scope of the judgment that was appealed to the Federal Circuit encompassed the effect of the steel sheet piling on the erosion of plaintiffs' property.

As discussed above in Parts III.A-A.1, the question addressed by the court in its order granting defendant's motion to dismiss was whether plaintiffs' claims accrued when the government finished the installation of steel sheet piling in 1989 or whether, under Applegate, the government's promises to mitigate erosion damage created justifiable uncertainty as to the permanence of erosion caused by the jetties, delaying accrual of plaintiffs' claims. The court stated that "[w]hen considering a motion to dismiss, the court must presume that well[-]pleaded factual allegations in the complaint are true." Accrual Op I., 49 Fed. Cl. at 808.

Plaintiffs had alleged that the installation of steel sheet piling increased the rate of erosion of their properties. See id. at 810 (stating that plaintiffs allege "that it was the Corps' installation of 'sand-tight steel sheet piling during the period of 1950 to 1989' that has 'alter[ed] the supply of sand to the lake bed and subaerial visible beach in front of the plaintiffs' property'" (alteration in original)); id. ("Referring to the installation of the steel sheet piling, plaintiffs state that as a 'direct result of [d]efendant's actions,' they 'have suffered a gradual and continued taking of their property' . . . .").

The court presumed this allegation to be true, analyzing when, after installation of the piling, plaintiffs' claims for erosion damage caused by the steel-clad jetties accrued. See id. passim. Plaintiffs cite no portion of the court's opinion in which the court examined, either expressly or by necessary implication, see Laitram, 115 F.3d at 951, whether the steel sheet piling does, in fact, exacerbate erosion of plaintiffs' properties, see Pls.' Jur. Br. passim; Pls.' Jur. Resp. passim.

Plaintiffs correctly note that the exhibits that the parties intended to present at trial were before the court when it ruled on defendant's motion to dismiss. Pls.' Jur. Br. 3; see also Accrual Op. I., 49 Fed. Cl. at 809 n.4 (stating that the parties' trial exhibits had been filed in accordance with the court's pretrial order). Plaintiffs are also correct, see Pls.' Jur. Resp. 5, that some of the evidence before the court suggested that the jetties had increased erosion in plaintiffs' zone to some extent before the installation of steel sheet piling, see, e.g., Accrual Op I., 49 Fed. Cl. at 820-21 (quoting a newspaper interview in which a Corps official stated that "we have 80, 90, or 100 years of non-mitigation to make up for"). Plaintiffs correctly note, see Pls.' Jur. Resp. 2-3, that defendant argued in its motion to dismiss that the erosion caused by the jetties did not begin only with the

installation of steel sheet piling,[36] see Mot. to Dismiss at 10 (stating that a non-governmental report "indicate[d] that erosive processes preceded plaintiffs' theory that such erosion only began after the commencement of sheet piling maintenance by the Corps in 1950"); id. at 8 (stating that many of the exhibits submitted by plaintiffs with an earlier filing "reiterate the conditions of erosion plaintiffs complain of as having existed for decades or even more than a century").

The court, however, reviewed the evidence submitted by the parties only to resolve the dispute upon which the court decided defendant's motion: whether plaintiffs' claims had accrued, at the latest, in 1989, when the Corps finished installation of steel sheet piling, or whether the government's promises to mitigate erosion delayed accrual. The court stated that "[i]f the jurisdictional facts in the complaint are disputed, . . . the court may consider relevant evidence beyond the pleadings to decide the jurisdictional question." Accrual Op. I, 49 Fed. Cl. at 809 (emphasis added) (footnote omitted) (citing, inter alia, Land v. Dollar, 330 U.S. 731, 735 n.4 (1947)). The court therefore considered the evidence submitted by the parties as it pertained to when, after installation of steel sheet piling, plaintiffs' claims would have accrued. The court did not weigh the evidence of whether the jetties caused erosion in plaintiffs' zone or whether the steel sheet piling, in fact, exacerbated the erosion caused by the jetties. See id. passim. The court made no findings of fact regarding whether the jetties caused erosion in plaintiffs' zone or whether the steel sheet piling did, in fact, exacerbate erosion caused by the jetties. See id. passim. The court resolved these fact-intensive questions, with the assistance of extensive expert testimony and the parties' post-trial briefing, only after the trial of liability. See Liability Op., 78 Fed. Cl. passim.

On appeal of the court's dismissal of plaintiffs' claims, the Federal Circuit addressed the proper application of accrual principles rather than the factual issues of whether the jetties actually caused erosion in plaintiffs' zone or whether the steel sheet piling exacerbated this erosion. The Federal Circuit stated that "the question is whether the 'predictability [and permanence] of the extent of damage to the [plaintiffs'] land' was made justifiably uncertain by the Corps' mitigation efforts." Accrual Op. II., 314 F.3d at 1309 (alterations in original) (quoting Applegate, 25 F.3d at 1583). The Federal Circuit determined that "the Court of Federal Claims and defendant misread Applegate as requiring the presence of a legally binding promise or duty or a matter requiring a congressional appropriation." Id. The Federal Circuit reversed the dismissal of plaintiffs' claims "[b]ecause the Court of Federal Claims misapplied the standard for

[36]Defendant did not argue in its motion to dismiss that any erosive effect of the jetties was not increased by the installation of steel sheet piling. See Mot. to Dismiss passim, Banks v. United States, 49 Fed. Cl. 806 (2001) (No. 99-445 L), Dkt. No. 64. Rather, defendant stated that plaintiffs' allegation that "the jetties did not interfere with their littoral drift of sand until the Corps began a program of installing steel sheet piling in 1950" is "[a]ccepted as true for the sake of defendant's motion." Id. at 6.

claim accrual under Applegate, and because plaintiffs remained uncertain as to the permanent nature of the taking until the Corps reported that the erosion was permanent and irreversible." Id. at 1310. The Federal Circuit did not address whether the installation of steel sheet piling increased erosion in plaintiffs' zone. See id. passim.

In addition to the text of the Federal Circuit's decision and the judgment from which plaintiffs appealed, the court is mindful of the Federal Circuit's admonition that "both the letter and the spirit of the mandate must be considered." Engel Indus., 166 F.3d at 1383. Whether the jetties, with or without the steel sheet piling, cause erosion in plaintiffs' zone goes to the merits of plaintiffs' claims. As the Federal Circuit has explained, an appellate court reviewing the disposition of a motion to dismiss does not examine the ultimate merits of the case: "That is what the trial judge will do on remand. Appellate courts do not do that, even if we had a record on which to do it." Henke, 60 F.3d at 801 n.5; see also Cordis Corp. v. Boston Scientific Corp., 658 F.3d 1347, 1360 (Fed. Cir. 2011) ("It would be illogical for this court to remand for findings on unresolved outcome determinative issues, while simultaneously foreclosing reconsideration of the outcome after the district court considered those issues for the first time."). The court therefore concludes that the Federal Circuit did not intend to address the merits of whether the jetties cause erosion in plaintiffs' zone before the issue was taken up, and before trial was held on the issue, by the trial court.[37]

A trial court may act on matters left open by the mandate. Laitram, 115 F.3d at 951. The issue "actually decided on appeal," Amado, 517 F.3d at 1360 (brackets omitted), was whether, under Applegate, plaintiffs' claims could have accrued between 1989 and 1999 despite promises and efforts by the government during that period of time to mitigate erosion damage caused by the jetties. Since the decision of the Federal Circuit, the court has found, based on evidence presented at trial rather than allegations made in plaintiffs' complaints, that the most recent government act that increased the rate of erosion of plaintiffs' properties took place, not in 1989, but in 1903, more than fifty years before the government first proposed to mitigate erosion in plaintiffs' zone. See supra Parts III.A.1-2. Because the Federal Circuit addressed only the delay of accrual resulting from promises and efforts to mitigate erosion, the court finds that whether plaintiffs' claims accrued before the government made its first promises of mitigation is an issue left open by the mandate. The mandate rule therefore does not bar the court's holding that plaintiffs' claims were filed after the end of the limitations period.

B. Composition of the Shoreline

[37]The court has also concluded, see Mar. 30, 2011 Order, Banks v. United States, Dkt. No. 452, 98 Fed. Cl. 123, 126 (2011), that the Federal Circuit did not, in addressing when plaintiffs' claim accrued, determine whether erosion damage caused by the jetties is in fact "permanent and irreversible," as the Corps reports appeared to indicate, see Accrual Op. II, 314 F.3d at 1310.

1. The Court's Previous Findings on Shoreline Composition

In its Liability Opinion, the court addressed the evidence presented at trial as to the composition of the shoreline adjacent to plaintiffs' properties. See Liability Op., 78 Fed. Cl. at 621-28. "The composition of the lake bed is relevant because the composition affects erosion and mitigation processes. If the shore is composed of sand, the quantity of sand that is depleted is directly proportional to the quantity of sand that needs to be replaced." Id. at 622 (footnote omitted). Therefore, "'[F]or a predominantly sandy shore . . . as long as the sand supply south of the harbor is restored to the pre-harbor levels, then we can assume directly that the erosion will remain the same as the pre-harbor levels, all other things aside . . . .'" Id. (alteration and omissions in original) (quoting transcript of the trial of liability (Liability Tr.) 1215:11-16, 1296:4-10 (Nairn)). As Dr. Nairn explained at the trial of liability, "'it's a simple sediment budget' and a 'simpler assessment.'" Id. (quoting Liability Tr. 1215:12, 1215:8 (Nairn)).

Assessing the erosion of cohesive[38] shores is "much more complicated. We know the sand acts to abrade, sort of like sandpaper, the till. And it also acts to protect it . . . ." Id. (omission in original). Once cohesive material is eroded, "it cannot reconstitute itself, and the cohesive form is lost forever." Id. (citation and quotation marks omitted). However, it is possible for sand cover to increase to the point that a cohesive section of shoreline would be categorized as sandy. See PX 178 (Coastal Engineering Manual (CEM)) III-5-9[39] ("[O]nly when the sand cover is sufficient to protect the cohesive substratum at all times will the shore revert to a sandy classification (i.e., truly a 'thick pile of sand')."); Tr. 512:11-513:15 (colloquy between Dr. Mackey and plaintiffs' counsel) (quoting same with approval); cf. PX 178 (CEM) III-5-13 ("Investigations of Great Lakes sites have shown that approximately 200 m^3/m of sand cover (measured from the top of the beach out to the 4-m contour) is required to halt the downcutting process . . . ."). Short of providing such large quantities of sand, however, "it is unclear whether mitigation is ever possible. There no longer is a direct correlation between

[38]"[A] cohesive lake bottom refers to [a] bottom [where] materials are held together such that they are not freely mobile . . . . [I]t could be broken up but is going to take more energy." Liability Op., 78 Fed. Cl. at 621 (alteration and omission in original) (quotation marks omitted).

Whether a sediment is cohesive depends in part on its composition: "Gravel and sand are not cohesive. Coarse silt, if well sorted[,] is usually not cohesive. Medium and fine silt and clay typically have cohesion. A mix of sizes, such as occurs in till, can be cohesive depending on the amount of clay and silt it contains." DX 293 (Mickelson Report) 10. "Till is an all-encompassing name that refers to a variety of materials, including compact silt, clay, and pebbles." Liability Op., 78 Fed. Cl. at 621 (internal quotation marks omitted). "Glacial till is cohesive material." Id.

[39]When citing the Coastal Engineering Manual (CEM), the court refers to the page numbers located on the bottom of each page rather than the section numbers, which follow a similar format.

replacing material and effective mitigation because nourishment can act as an abrasive agent that exacerbates erosion, and the erosion of the lake bottom is considered permanent." Liability Op., 78 Fed. Cl. at 624 (citation omitted).

Determining shoreline composition can be difficult for two reasons. First, "cohesive shores are often difficult to identify owing to the presence of a sand beach at the shore," PX 178 (CEM) III-5-3, which can mask the underlying substrates, see generally infra Part III.B.2.b (discussing the CEM and its role in the parties' arguments). Cohesive shores often are covered by a thin "veneer of sand and gravel" that the CEM states "is usually in the range of a few centimeters to 2 or 3 [meters]."[40] PX 178 (CEM) III-5-3. Second, a shoreline may contain both sandy and cohesive material as a result of its geological history. See, e.g., DX 3 (Larson Report) 34, Fig. 9 (geological map and cross section of plaintiffs' zone) (showing layers, pockets, and lenses of cohesive material embedded between layers of sand); Tr. 2035:3-2036:12 (colloquy between Dr. Mickelson and defendant's counsel) (describing DX 293 (Mickelson Report) 8, Fig. 3[41]). For instance, Dr. Mickelson and Dr. Larson described a thin layer, rich in organic material, that formed approximately 6,000 years ago, which is sandwiched between thick deposits of sand in the southern portion of plaintiffs' zone. See infra Part III.B.3.a (describing the formation of the thin, organic-rich layer between thick layers of sand).

The composition of the shoreline is significant in this case because it indicates how the shoreline will erode, whether any erosion is permanent and whether it is possible to mitigate any ongoing erosion. Liability Op., 78 Fed. Cl. at 622. After analyzing the evidence of shoreline composition presented at the trial of liability, the court concluded that "plaintiffs failed to prove by a preponderance of the credible evidence that plaintiffs' properties are located on a cohesive lake bottom." Id. at 628. The court found persuasive the testimony of defendant's expert witness in geology, Dr. Larson, see id. at 628, who

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[40]The CEM defines the word "shore" as follows:

> The narrow strip of land in immediate contact with the sea, including the zone between high and low water lines. A shore of unconsolidated material is usually called a beach. Also used in a general sense to mean the coastal area (e.g., to live at the shore). Also sometimes known as the littoral.

Coastal Engineering Manual, App. A (Glossary) A-72 (capitalization and internal citation omitted), available at http://140.194.76.129/publications/eng-manuals/em1110-2-1100/AppA/a-a.pdf.

[41]The cross-section showing the stratigraphy in plaintiffs' zone is almost identical in the Larson and Mickelson reports. Compare DX 3 (Larson Report) 34, Fig. 9, with DX 293 (Mickelson Report) 8, Fig. 3. The court cites the cross section in the Larson report because the copy is clearer.

testified in detail about the geological history of the area and described the stratigraphy[42] he had prepared by interpreting well logs and engineering borings and by traveling every path through the area to observe exposures of sediment,[43] see id. at 625. The process of using well logs collected nearby to assemble a stratigraphy of the shoreline has been found persuasive in the past--by this court, by the Federal Circuit and by the United

[42]"The stratigraphy means the layering of the sediments." Liability Op., 78 Fed. Cl. at 625 n.36 (internal quotation marks omitted). "Stratigraphy is just the layers of sediments as they relate to each other in a vertical sequence." Tr. 2025:11-12 (Mickelson). "[I]f you were studying stratigraphy, you would typically look at the composition of layers and thickness, evenness or unevenness of the boundaries or the contacts between them and so on." Tr. 2025:16-19 (Mickelson).

[43]Well logs are "logs that are recorded by drillers every time they drill a water well for someone." Tr. 2037:15-17 (Mickelson). Drillers submit well logs to the Michigan Department of Natural Resources, which makes them available to the public. Tr. 2037:17-19 (Mickelson). Dr. Mickelson described well logs as "a wealth of information about the subsurface that's available to be interpreted." Tr. 2039:11-13 (Mickelson). According to Dr. Mickelson, "you just couldn't afford to do all that drilling yourself if you were trying to do a geologic map, unless it was just a very small area." Tr. 2039:13-15 (Mickelson). Accordingly, well logs are "routinely used in geologic mapping." Tr. 2039:16 (Mickelson).

The court discussed the use of well log data from onshore to determine the stratigraphy of the lakebed in its Liability Opinion, finding the technique persuasive. See Liability Op., 78 Fed. Cl. at 624-28; Order Granting Recons., 84 Fed. Cl. at 295-97 (discussing the court's analysis of well logs in its Liability Opinion). In addition to analyzing well logs, Dr. Mickelson examined the results of three engineering borings collected by the United States Geological Service (USGS). See Tr. 2041:18-24 (colloquy between Dr. Mickelson and defendant's counsel); DX 293 (Mickelson Report) 29-30, Figs. 12, 13 (showing locations and results of engineering borings).

Plaintiffs object to the use of well logs to study stratigraphy. See Pls.' Br. 20-21 (arguing, among other things, that "the person identifying the various strata of material is not a trained geologist"). In light of the court's previous finding that properly-screened well logs can be a reliable source of data, see Liability Op., 78 Fed. Cl. at 627-28, and in light of further testimony and further evidence at trial as to the use of well logs in scientific research, Tr. 1810:3-6 (McNinch) (stating that he used well log data in a recent project in New Zealand "to get an idea of what the regional stratigraphy was like"); DX 293 (Mickelson Report) 1 (stating that extrapolation using well logs is a common geologic practice), the court concludes that Dr. Larson and Dr. Mickelson, in using well logs to develop their stratigraphy, applied a reliable and common geologic practice, see also Tr. 1992:17-1995:4 (colloquy between Dr. Larson and defendant's counsel) (describing the techniques Dr. Larson used to ensure that the well logs he used were reliable). Plaintiffs' expert witness, Mr. Shires, testified that "you can use [well logs if] it's all you've got . . . . But in my opinion[,] it's not as reliable as actually doing borings . . . at regular intervals." Tr. 834:4-11 (Shires). Neither party has presented the results of borings conducted at regular intervals by geologists in plaintiffs' zone. See Tr. passim.

States Court of Claims--when direct evidence as to actual subsurface conditions is unavailable.[44] Order Granting Recons., 84 Fed. Cl. at 296-97 (discussing Renda Marine, Inc. v. United States, 509 F.3d 1372, 1378 (Fed. Cir. 2007), aff'g Renda Marine, Inc. v. United States, 66 Fed. Cl. 639 (2005)); id. at 297 n.6 (discussing Arundel Corp. v. United States, 207 Ct. Cl. 84, 98, 515 F.2d 1116, 1124 (1975)).

Based on his stratigraphy and the geological history of the area, Dr. Larson concluded that "the shoreline for some of the northern-most plaintiffs' properties is a cohesive shore that then transitions to a sandy shore for the remaining larger group of plaintiffs' properties." Liability Op., 78 Fed. Cl. at 625 (internal quotation marks omitted). He further testified that south of the harbor, the exposed layer of till gives way to an area that is "mainly raw sand." Id. (quotation marks omitted). Dr. Nairn, defendant's expert witness in coastal engineering, reviewed Dr. Larson's stratigraphy and conducted measurements and numerical modeling, also concluding that "the properties belonging to a majority of the plaintiffs are located on a sandy, not a cohesive, shoreline." Id.

At the trial of liability, plaintiffs presented "no expert evidence . . . to counter defendant's expert's studies and explanations, and no expert review of Dr. Nairn's--and particularly Dr. Larson's--research conclusions regarding the lake bottom composition." Id. at 628. Plaintiffs' expert, Dr. Chrzastowski, testified that he had not reviewed Dr. Nairn's report, and plaintiffs provided no evidence that Dr. Chrzastowski had reviewed Dr. Larson's report or testimony. Id. Dr. Chrzastowski instead "opined that the lake bottom was cohesive, bas[ing] his evaluation on existing literature, aerial photography, historical maps, and ground photography," documentary evidence that the court found had been "credibly refuted" by Dr. Larson. Id. Dr. Chrzastowski did not take any measurements in connection with his formulation of his expert opinion. See id.

The court noted that "[t]here is no dispute that, prior to this litigation, defendant consistently held the position that the shore in the area south of St. Joseph Harbor was cohesive." Id. However, defendant had previously held this position as a result of studies conducted prior to this litigation that the court found less probative than the evidence presented at trial. Two of the earlier studies, which the court referred to in its Liability Opinion as the "1996 Report" and the "1997 Report," had focused on a broader area of shoreline with little data from plaintiffs' zone. See id. at 625, 627. A study that the court referred to in its Liability Opinion as the "1992 Pilot Study" stated on its title page that it was a preliminary study, failed to discuss the geological history of the area

[44]The United States Court of Claims is the predecessor court to this court and a predecessor to the United States Court of Appeals for the Federal Circuit. When acting in its appellate capacity, the Court of Claims created precedent that is binding on this court. South Corp. v. United States, 690 F.2d 1368, 1369 (Fed. Cir. 1982) (en banc).

and, in Dr. Larson's opinion, made "no geological sense." See id. at 627 (quotation marks omitted).

The court also found the use of sidescan sonar in the 1992 Pilot Study problematic.[45] Sidescan sonar, the court stated, "scans only the surface of the lake bed and does not penetrate it." Id. at 626. Sidescan sonar "doesn't [actually] tell you what's there, it simply produces a picture of what the surface of the lake bed looks like, that is, it provides information on whether it is bumpy or flat." Id. (alteration in original) (internal quotation marks omitted). The radar used to supplement sidescan sonar in the 1992 Pilot Study penetrates the ground but "can't penetrate very far . . . because the energy is consumed very rapidly." Id. at 626 (internal quotation marks omitted). Dr. Larson testified that sidescan sonar and the other techniques used in the 1992 Pilot Study were "good science" but explained that it "should not stand alone; it has to be verified," for example with well logs. Id. (citation and internal quotation marks omitted). Instead of using well logs to verify their conclusions about the composition of the lakebed, the authors of the 1992 Pilot Study performed "periodic sampling of the surface" of the lakebed by collecting sediment samples. Id. (citation and quotation marks omitted). The court found these superficial sediment samples less persuasive than "Dr. Larson's extensive use of well logs, which obtains samples of materials in strata that are at the same depth as the subsurface of the adjacent shore." Id. at 626-27.

The court, having found Dr. Larson's and Dr. Nairn's testimony persuasive, stated that "[t]he inference of this conclusion is that for any given plaintiff it is more likely than not that his or her property is located in a sandy zone." Id. However, "The evidence at trial did not permit the court to determine (by, for example, an overlay of plaintiffs' property lines onto the lakebed composition data presented by defendant) exactly which of plaintiffs' properties in the northernmost portion of plaintiffs' zone were adjacent to the cohesive nearshore lakebed shown on defendant's exhibits." Order Granting Recons., 84 Fed. Cl. at 291. The court stated that the issue of which specific properties are located along the small section of cohesive shoreline would be determined in future proceedings. Liability Op., 78 Fed. Cl. at 628.

2. Additional Evidence of Shoreline Composition Presented by Plaintiffs at the Trial of Damages

a. Observation of the Surface of the Lakebed by Sidescan Sonar, Underwater Video and Sediment Grab Sampling

[45]At the trial of damages and in their briefing, plaintiffs again presented the results of sidescan sonar and sampling of sediments on the surface of the lakebed adjacent to their properties. See infra Part III.B.2.a.

At the trial of damages, plaintiffs presented additional evidence addressed to the composition of their section of shoreline.[46] However, plaintiffs did not provide an interpretation of the geological history of the area or present a stratigraphy of the area to challenge the geological history and stratigraphy developed by Dr. Larson, see Tr. passim, and found persuasive by the court at the trial of liability, see Liability Op., 78 Fed. Cl. at 628. Plaintiffs' expert witness on the topic of shoreline composition, Dr. Mackey, testified at the trial of damages that he had not reviewed the well logs that Dr. Larson used to develop his stratigraphy. See Tr. 710:5 (Mackey). Plaintiffs did not present evidence that the properties of individual plaintiffs had sandy or cohesive shorelines, see Tr. passim, but instead argued that the entirety of plaintiffs' zone is located along a cohesive shoreline, see Pls.' Br. 15.

Plaintiffs retained Dr. Mackey to perform a sidescan sonar survey of the nearshore lakebed adjacent to their properties, to map the distribution of surface sediments and to determine whether the shoreline along which their properties are located is cohesive. Tr. 488:7-13 (Mackey). To aid in the interpretation of the sidescan sonar data, Dr. Mackey recorded underwater video of plaintiffs' zone. Tr. 507:17-24 (colloquy between Dr. Mackey and plaintiffs' counsel). As Dr. Mackey explains in his report, "In many respects, sidescan sonar data is similar to aerial photographs taken of the earth's surface. The only difference is that the images are produced with sound instead of light." PX 136 (Mackey Report) 3. A device called a towfish is pulled behind a boat, id. at 2, 3; the towfish emits acoustic pulses and records the acoustic energy reflected by the lakebed, id. at 2. To survey the nearshore lakebed adjacent to plaintiffs' properties, Dr. Mackey piloted a boat along five survey lines parallel to the shore, see id. at 5-6, and used specialized software to merge the data from the five survey lines "into a seamless image of the lakebed," id. at 7.

Sidescan sonar can be used to determine whether materials at the surface of the lakebed are sandy or cohesive. See id. at 2 ("Generally, harder materials (bedrock, sand, metal) will give a stronger acoustic return than softer materials (silt, clay, or mud)."); DX 136 (McNinch Report) 2 (stating that "different surfaces often generate characteristic and distinguishable changes to the reflected sound"). Dr. Mackey explained that "[i]n general, harder materials . . . will show up as 'bright' patterns on the sidescan sonar. Softer materials . . . will show up as 'dark' patterns on the sidescan sonar." PX 136 (Mackey Report) 10; see, e.g., id. at 11, Fig. 11.

Because sidescan sonar maps the surface of the lakebed, it is of limited value to researchers attempting to determine the composition of substrates located below the surface. Dr. Mackey testified that the sidescan sonar penetrated the lake bottom to a depth of "a couple of inches, at most." Tr. 728:16 (Mackey). Under the correct

[46]Following the trial of liability, the court granted reconsideration of the issue of shoreline composition. See generally Order Granting Recons., 84 Fed. Cl. 288; see supra Part I.

conditions, sidescan sonar can be used to detect subsurface materials located very near the surface, but it does not indicate the depth at which the subsurface materials are located.[47] Tr. 727:9-11 (Mackey). Accordingly, Dr. Mackey agreed that the "mapped image usually does not provide a cross section of or insight into the depth of a substrate that appears on the surface of a lake bed." Tr. 721:2-6 (colloquy between Dr. Mackey and defendant's counsel).

In his trial testimony, Dr. Mackey agreed that he is aware of acoustic devices, including "sparkers," "boomers" and "chirper[s]," which "produce fairly high energy that allow[s] the sound of the side scan sonar to penetrate into the earth's crust and then reflect off different areas of different density in the earth's crust at varying depths." Tr. 721:7-20 (colloquy between Dr. Mackey and defendant's counsel). Dr. Mackey did not suggest to plaintiffs that they employ any of these devices, id. at 722:5-7, because he "didn't think it was [his] place to suggest the use of those sort of tools because [he does not] own that type of equipment and [he] typically [does not] do that kind of work," id. at 725:9-22. Dr. Mackey also testified that he was "not directly aware" that the question of what substrates lie below the surface of the lakebed and at what depth was an issue in this case. Id. 722:8-13.

Interpreting the results of his sidescan sonar, Dr. Mackey concludes that approximately 5% of the lakebed surface consists of cohesive material, rather than boulder cobble, bedrock, gravel or sand.[48] See PX 136 (Mackey Report) 13, Table 1. Dr.

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[47]Based on Dr. Mackey's testimony about sidescan sonar, the court was not persuaded that Dr. Mackey's study could be a source of significant data on subsurface materials. Dr. Mackey testified that, to detect subsurface materials with sidescan sonar, "[y]ou would have to have a substrate that is somewhat less hard . . . where you don't get a very hard acoustic response." Tr. 726:23-25 (Mackey). However, Dr. Mackey found that the approximately 95% of the lake bottom he sampled was covered with boulder cobble, bedrock, gravel or sand, see PX 136 (Mackey Report) 13, Table 1, the type of hard materials that give a strong acoustic response, see id. at 2. Dr. Mackey also testified that low-frequency sound waves are better able to penetrate the surface of the lakebed, see Tr. 727:2-3 (Mackey), but that he used primarily high-frequency sound waves, a technique that, although it does not penetrate the lakebed surface, "gives you a higher and more detailed resolution," Tr. 506:11-14 (Mackey).

[48]Dr. Mackey copied a portion of a geological map produced by the USGS into his report. PX 136 (Mackey Report) 16. On the map, the words "Clayey Silt Till Deposits of Lake Border Moraine" appear offshore near plaintiffs' zone. Id. at 16, Fig. 17 (surficial geological map of plaintiffs' zone). Dr. Mackey also copied the following text, which accompanies the USGS map, into his report: "Offshore, the till is overlain by a gray medium to coarse sand and gravel, which is interpreted to be surficial lag deposit derived from eroded till; the till is also overlain by thin, patchy, very fine to fine sand lake-bottom deposits and near shore sand deposits." Id. at 16 (quotation marks omitted); see also Pls.' Resp. to the United States' Post-Trial Br. (Pls.' Resp.), Dkt. No. 497, at 17-18 (citing same).

Mackey infers, without explanation, that an additional 5.7% of the lake bottom is covered by "[t]hin deposits of fine-med-sand overlying cohesive clay/silt deposits." Id. at 13. Dr. Mackey states that his observations "fit the typical cohesive profile." Id. at 15.[49] However, Dr. McNinch, reviewing Dr. Mackey's results, argues persuasively that far less of the lakebed surface is composed of cohesive materials. Dr. McNinch "found it very difficult to duplicate or even identify many of the same surface expressions of the cohesive clay substrate" identified by Dr. Mackey. DX 294 (McNinch Report) 4; but see PX 139 (Mackey Response to McNinch) 6 (stating that Dr. Mackey has more experience than Dr. McNinch in interpreting sidescan sonar data collected in the Great Lakes). Regarding Dr. Mackey's inference that five percent of the lake bottom is composed of a thin layer of sand overlying cohesive material, Dr. McNinch stated that "[i]nterpreting thickness based solely on the patchiness of exposed substrates . . . is highly speculative" and noted that none of Dr. Mackey's sediment samples revealed "a non-sandy, underlying layer."[50] DX 294 (McNinch Report) 3.

Dr. McNinch also argues that, although "[t]he data acquisition and processing methodologies used by Dr. Mackey . . . were quite good and met conventional standards," id. at 2, Dr. Mackey failed properly to corroborate the results of his sidescan sonar, see Tr. 1799:25-1800:6 (colloquy between Dr. McNinch and defendant's counsel); DX 294 (McNinch Report) 2-5 (describing several respects in which Dr. Mackey's

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The court, as it did at the trial of liability, see Liability Op., 78 Fed. Cl. at 619, places greater weight on the reports and opinions developed by the expert witnesses who testified at trial than on excerpts of agency reports based on studies and methods not subject to testing by cross-examination. The court notes also the "sharper focus" on plaintiffs' zone and the issues of this case in the expert witnesses' testimony than in publications unrelated to the case. See id.; cf. PX 41 (1999 Report) 2 (surveying the existing studies of shoreline composition, including those conducted by the USGS, and concluding that "[m]uch more work remains to be done to quantify the extent of cohesive coastlines").

[49]Dr. Mackey included in his report a conceptual cross-section of the substrates in plaintiffs' zone as he believes they exist. See PX 136 (Mackey Report) 15, Fig. 16. The conceptual cross-section contained linear sand ridges running parallel to the shoreline, with cohesive sediments visible in the troughs between sand ridges. See id.

[50]Dr. Mickelson further testified that "[i]f you have cohesive sediment where there's glacial till, then boulders end up sitting on the bottom because they're not moved by the waves so they're not moved very much and the clay has been dwindled out from between them. So you almost invariably from my experience have rocks of various sizes scattered, not piled, but scattered on that cohesive bed surface." Tr. 2079:11-18 (Mickelson); cf. PX 41 (1999 Report) 2 (stating that in cohesive areas, any "large rock[s] and boulders are usually found as a lag deposit laying directly on top of the consolidated layer"). Dr. Mickelson further testified that "if there is till below the sand here[,] the sand cover has to be thick enough to be covering any boulders that had washed out of the till." Tr. 2080:6-9 (Mickelson). Plaintiffs do not contradict this analysis. See Pls.' Br. passim; Pls.' Resp. passim.

measurements could have been improved). Dr. Mackey acknowledges in his report that "it is always necessary (and appropriate) to validate the acoustic responses in the sidescan data either by sampling or direct observation."[51] PX 136 (Mackey Report) 7.

One reason that it is necessary to validate sidescan sonar data with other measurements is that even sandy lakebeds contain a measure of finer material, which will often become separated from the sand and settle on the surface. Dr. McNinch explained that "waves and currents typically winnow and sort unconsolidated sediment on the lakebed. These processes often result in what appears as a complex, patchwork pattern of different substrates at the surface but which, in fact, could simply originate from an underlying layer that is composed of a mixture of these sediment types." DX 294 (McNinch Report) 3.

However, the sampling and direct observation undertaken by Dr. Mackey were quite limited and provide little corroboration of Dr. Mackey's conclusion that his observations "fit the typical cohesive profile." See PX 136 (Mackey Report) 15. Dr. Mackey recorded underwater videos and collected sediment samples from the surface of the lakebed. Id. at 6. After studying Dr. Mackey's underwater videos, which total fifty-five minutes in length, Dr. McNinch determined that cohesive material was visible for thirty-seven seconds, or slightly more than 1% of the time.[52] Tr. 1835:3-7 (McNinch); DX 294 (McNinch Report) 5. Several of Dr. Mackey's underwater videos document no cohesive sediment at all. DX 293 (Mickelson Report) 27. Dr. Mackey does not argue that Dr. McNinch has incorrectly measured the amount of cohesive material visible in the underwater videos. See PX 139 (Mackey Response to McNinch) 3-4.

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[51]Dr. Mackey referred to the process of validating sidescan sonar results by sampling or direct observation as "ground truthing:"

> Ground truthing is when you have interpretations you're making based on information that may not be precise, so you do the best you can with what you have. . . . [T]he ground truthing would involve actually going to that area and gathering data from that very area where you're interested in.

Tr. 834:22-835:5 (Mackey); see also Tr. 1799:2-5 (colloquy between Dr. McNinch and defendant's counsel) (agreeing that the term "ground truthing" is "consistent with what we are talking about here for corroboration").

[52]Dr. Mackey notes that he recorded the sidescan sonar and underwater videos as much as three months apart and that exposures of cohesive material may be short lived because plaintiffs' properties are located in a "highly mobile sand environment." PX 139 (Mackey Response to McNinch) 4. Dr. Mackey's video recordings are also less comprehensive than his sidescan sonar observations. See PX 136 (Mackey Report) 9, Fig. 9 (map of survey area) (showing video survey lines that cover a small portion of the sidescan sonar survey area).

None of the sediment grab samples[53] collected by Dr. Mackey verified the existence of exposed cohesive material. See PX 136 (Mackey Report) App. A (sample descriptions) (describing every sediment sample as consisting of sand or "[v]ery coarse sand/[g]ravel"); Tr. 1799:22-24 (McNinch) ("I believe from his table at the back of his report, all the samples from his petite ponar were sandy, sandy material").[54] Most significantly, Dr. Mackey failed to verify his observations with subsurface investigation. See PX 136 (Mackey Report) passim (offering no discussion of subsurface investigation). Dr. McNinch stated that, when studying lakebed composition, "[w]e often take cores, and we often take sub-bottom profiles[55] so that we know what the strat[um] is like just below." Tr. 1798:13-15 (McNinch). Sub-bottom profiles also allow an observer to "see where the base of the sand is, and where other layers of different geology might be present."[56] Tr. 1804:24-1805:5 (McNinch). Dr. Mackey did not ground truth his results with cores or sub-bottom profiles.[57] See PX 136 (Mackey Report) passim.

[53]Dr. Mackey testified that the sediment grab sampler he used is a metal device, shaped like a clamshell. See Tr. 508:9-21 (colloquy between court and Dr. Mackey); see also PX 136 (Mackey Report) 8, Fig. 7 (photo of "Petite Ponar sediment sampler"). The grab sampler collects samples from the surface of the lakebed. See Tr. 733:10-12 (colloquy between Dr. Mackey and defendant's counsel) (agreeing that "it doesn't extend much into the lake bed itself").

[54]Dr. Mickelson, who probed the surface of the lakebed with an open-ended tube attached to a ten-foot rod, DX 293 (Mickelson Report) 1, reported similar results. The probe he used penetrated to a depth of about 8 inches, allowing Dr. Mickelson to determine, "by the sound and the resistance on the tube," the composition of the lakebed surface. Id. In every observation but one, Dr. Mickelson sampled sand, gravelly sand or a combination of sand and concrete or rock. Id. at 19, Table 8 (list of probe observations). Dr. Mickelson testified that the "chunks of concrete or rubble" that he observed in several samples were located close to shore and likely constituted "old shore protection materials." Tr. 2044:6-11 (Mickelson). The one observation that sampled a different material revealed "sandy organic sediment," see DX 293 (Mickelson Report) 19, Table 8, that appears to the court to constitute part of the thin layer of organic-rich sediment discussed below, see infra Part III.B.3.a.

[55]A "sub-bottom profile" is the cross section of subsurface layers depicted by an acoustic device that penetrates the lakebed. See Tr. 1785:4-13 (McNinch).

[56]Dr. McNinch also stated that he would want to "look at the [bathymetry], and look at the depths across the shallow nearshore, both to correct the side-scan sonar record, but also to have very good control on the elevation of the seabed." Tr. 1804:19-23 (McNinch). "Bathymetry is . . . basically the water depth." Tr. 549:6-7 (Mackey). Dr. McNinch stated that, to determine water depth, Dr. Mackey "used what we call the waterfall from the side-scan sonar records," which gives only a "rough idea" of the water depth directly under the towfish, rather than using "a multi-beam, or swap [bathymetry], which is fairly common in the field" and gives the depth of the water to the sides of the towfish as well. Tr. 1806:10-1807:3 (McNinch). Dr. McNinch further stated that, regardless of the type of sidescan sonar used, "we often don't use or

Dr. Mackey's observations of the surface of the lakebed are simply insufficient to establish that the shoreline is cohesive. The court discussed the limited value of sidescan sonar coupled with surface sampling in its Liability Opinion--in which it found Dr. Larson's stratigraphy more persuasive than the results of a 1992 study that relied on sidescan sonar and sampling of the lakebed surface, Liability Op., 78 Fed. Cl. at 626-28--and again pointed out the limited value of sidescan sonar and other surface evidence in its Order Granting Reconsideration, 84 Fed. Cl. at 295. Plaintiffs do not explain why they presented again at the trial of damages the results of sidescan sonar uncorroborated by subsurface investigation, such as cores or sub-bottom profiles. See Pls.' Br. passim; Pls.' Resp. passim; cf. Tr. 1798:13-15 (McNinch) (stating that, when studying lakebed composition, "[w]e often take cores, and we often take sub-bottom profiles so that we know what the strat[um] is like just below"). Neither do plaintiffs attempt to distinguish the techniques used by Dr. Mackey from the techniques used in the 1992 study, presented at the trial of liability, and found unpersuasive by the court. See Pls.' Br. passim; Pls.' Resp. passim.

The court agrees with Dr. McNinch that "sediment thickness and the character of underlying substrates cannot be directly measured from sidescan sonar, underwater video, and surface sediment samples. No corroborating evidence, such as sediment cores or sub-bottom seismic[58] profiles, that explicitly measure the thickness and nature of buried substrates[,] are provided to support these interpretations." DX 294 (McNinch Report) 1. The court therefore finds that Dr. Mackey's observations of the lakebed surface, without supplementation by subsurface sampling or sub-bottom profiles, are insufficient to establish that plaintiffs' zone is cohesive.

b. CEM Techniques to Identify Cohesive Shorelines

Plaintiffs offer two arguments that supplement Dr. Mackey's observations of the surface of the lakebed with analysis drawn from the CEM. The CEM is an engineering

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rely heavily on the depth from a side-scan sonar" because the towfish can move up and down, causing inaccurate readings. Tr. 1807:18-1808:2 (McNinch).

[57]Neither did Dr. Mackey ground truth the results of his sidescan sonar survey by examining the sediment samples, discussed below in Part III.B.2.b, collected from the surface of the lakebed and analyzed by plaintiffs' expert witness, Mr. Shires. Tr. 753:2-4 (Mackey) ("I have not seen his report nor have I seen his samples nor have I seen any of the results of whatever analyses were done on those samples."); see also infra Part III.B.2.b.i (finding that Mr. Shires' samples are not "subsurface investigations" as contemplated by the CEM for use in verifying observations of the surface of the lakebed).

[58]"Seismic information is basically using energy production at the surface and it is either reflected or refracted off of sediment[ ] interfaces beneath the bed of Lake Michigan. It gives you some idea of what the materials are like beneath the surface." Tr. 1993:18-23 (Larson).

manual drafted by the Corps to describe "the basic principles of coastal processes . . . and [to provide] guidance on how to formulate and conduct studies in support of coastal flooding, shore protection, and navigation projects." PX 316 (Guide for Preparation of the CEM) 5. Part III, Chapter 5 of the CEM, entitled "Erosion, Transport, and Deposition of Cohesive Sediments," has been admitted into evidence as PX 178 and addresses, among other things, the identification of cohesive shores. PX 178 (CEM) III-5-2 to III-5-8.

Plaintiffs' first argument concerns six visual features that the CEM states may help in the identification of a cohesive shoreline. See Pls.' Br. 9-12. Plaintiffs argue that four of the six visual features set out by the CEM are present in plaintiffs' zone. Tr. 17:5-8 (plaintiffs' counsel). Plaintiffs' second argument purports to summarize with a two-part analysis the CEM's discussion of cohesive shorelines and how they are identified. Pls.' Br. 8. Because neither argument employs the detailed analysis of shoreline composition described in the CEM, the court does not find either argument persuasive.

i. Six Visual Features that May Indicate a Cohesive Shore

Although the CEM notes that "cohesive shores are often difficult to identify owing to the presence of a sand beach at the shore," the CEM states that "[t]here are at least six ways of visually identifying the presence of underlying consolidated cohesive sediment."[59] PX 178 (CEM) III-5-3. Drawing from Dr. Mackey's initial expert report,[60]

[59]Consolidated sediment is "[s]tiff or hard cohesive sediment that has had centuries to drain, probably compressed beneath glaciers or other overburden." PX 178 (CEM) III-5-1.

[60]Dr. Mackey writes in his initial expert report that the visual indicators listed in the CEM "define a cohesive shoreline." PX 136 (Mackey Report) 26; see also id. at 25 ("[F]our of the six characteristics listed in the [CEM] that define cohesive shorelines are present within the St. Joseph survey area. Based on the sidescan sonar data collected within the St. Joseph survey site, there is no question that the area surveyed is a sand-starved cohesive shoreline." (emphasis omitted)); cf. PX 141 (Shires Report) 6 (stating that the visual indicators listed in the CEM "establish a cohesive shore"). Dr. Mackey disavowed this argument in his subsequent reports.

Without explaining the change in his analysis, Dr. Mackey wrote in his response to Dr. McNinch's rebuttal report, "Note that the definition of a cohesive shoreline is not based on whether or not the six criteria listed in the [CEM] are present (as implied by Dr. McNinch) . . . ." PX 139 (Mackey Response to McNinch) 7. Dr. Mackey further stated that "the criteria that Dr. McNinch is referring to are what the [CEM] suggests be used to assist in the determination of whether cohesive materials are present along a shoreline, not whether the area surveyed is a cohesive shoreline." Id. (some emphasis omitted). Dr. Mackey then advanced a second analytical framework, emphasizing a two-step analysis, discussed below, see Part III.B.2.b.ii; see also infra note 64 (summarizing the discussion of the two-step analysis in Dr. Mackey's reports), that considers whether cohesive materials are present and "have been, are, or will be subject to irreversible erosion," PX 139 (Mackey Report) 7.

plaintiffs contend that "the six factors set forth in the CEM provide strong visual clues to the presence of a cohesive shore." Pls.' Br. 12; see also Tr. 17:5-8 (plaintiffs' counsel) ("There are six ways, in the [CEM], to identify whether a [cohesive][61] lakebed exists. We have four out of six."); PX 136 (Mackey Report) 17-25 (discussing the presence of four of the six factors in plaintiffs' zone).

The six visual features listed by the CEM are (1) "the presence of exposed cohesive sediment on the beach"; (2) pieces of clay or peat that have washed onto the beach; (3) "[s]prings or surface runoff across a beach"; (4) "[d]iscoloration of water in the nearshore zone"; (5) "[p]ermanent undulations in the shoreline platform"; and (6) exposed cohesive sediments in troughs between offshore bars. PX 178 (CEM) III-5-3 to III-5-6. In addition to the six visual indicators, the CEM describes the "[u]se of more detailed subsurface investigations to confirm visual observations and provide more detailed information." Id. at III-5-6. Plaintiffs claim that four of the six CEM factors are present on their properties: exposed cohesive material on the beach, pieces of cohesive material washed up on the beach, discoloration of the water in the nearshore zone and exposed cohesive sediments in the troughs between offshore bars. Pls.' Br. 10-11; see also PX 136 (Mackey Report) 17-25 (discussing the presence of four of the six visual features in plaintiffs' zone); PX 141 (Shires Report) 6-7 (discussing Dr. Mackey's analysis of the six visual features).

The CEM contemplates that the six visual indicators would be used in conjunction with "more detailed subsurface investigations." PX 178 (CEM) III-5-6; see DX 155 (Nairn Composition Report) 17 (stating that the six visual factors are "clues"). The CEM describes a shoreline in Ghana where "initial visual observations" were followed by "a series of subsurface investigations" including "augers, boreholes, vibracores and sub-bottom profiling." PX 178 (CEM) III-5-6. A section of the CEM describes "a variety of techniques for characterizing the surface and subsurface conditions, with particular focus on the sand cover thickness," including the use of steel probes, jet probes and sub-bottom profiling. Id. at III-5-20.

Plaintiffs' expert witness, Mr. Shires, examined samples obtained by divers and determined them to be cohesive. Pls.' Br. 12-13. These samples, however, are not

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Plaintiffs do not acknowledge or explain the change in Dr. Mackey's analysis. See Pls.' Br. passim; Pls.' Resp. passim. Plaintiffs instead apply the two methods of analysis simultaneously, as though they were a single method. See, e.g., Pls.' Br. 12 (stating, in a section that primarily discusses the two-step "test" that "the six factors set forth in the CEM provide strong visual clues to the presence of a cohesive shore").

[61]The transcript reads "coastal lakebed" rather than "cohesive lakebed." Tr. 17:7 (plaintiffs' counsel). Because this sentence appears during counsel for plaintiffs' summary of the evidence that the lakebed is cohesive, the court concludes that the word "coastal" is a mistake in transcription.

"subsurface investigations" as claimed by plaintiffs. Id. at 12. The fact that the samples were collected below the surface of the water does not make them "subsurface investigations" as contemplated by the CEM. Compare PX 178 (CEM) III-5-6 (describing the use of the visual features in conjunction with techniques that sampled material below the surface of the lakebed), with Pls.' Br. 12-13 (characterizing as "subsurface investigations" Mr. Shires' analysis of samples collected at "various depths (between 10 and 20 feet)" below the surface of the water).

Mr. Shires testified that the samples were taken from the surface of the lakebed. Tr. 789:24-790:1 (Shires) ("So these are right on the bottom, they're exposed on the bottom."). Mr. Shires' expert report, the permits obtained before the samples were collected and the photographs taken by the divers similarly indicate that the samples were collected from the surface of the lakebed and that the divers were, in fact, prohibited from collecting samples more than four inches below the surface. See PX 141 (Shires Report) App. A., Attachment B (letter from the Corps) (authorizing collection of samples two inches thick), App. A, Attachment B (letter from Michigan Department of Natural Resources & Environment) (authorizing the collection of samples two to four inches thick), App. A, Attachment C (photographs taken by divers) (showing exposed samples of cohesive material lying on the surface of the lakebed). The letter from Prism Environmental Services (Prism), the company retained to collect the samples, states that "[t]he primary purpose of this investigation was to locate in-place exposures of cohesive bottom sediments." Id. at App. A (letter from Prism) 1 (emphasis added).

The first and second CEM features relate to the presence of cohesive materials on the beach, either as a result of intact cohesive units becoming exposed or as a result of cohesive materials washing up on the beach. PX 178 (CEM) III-5-3. Plaintiffs argue that both features are present on the beaches adjacent to their properties. Pls.' Br. 10. However, the evidence cited by plaintiffs to document the existence of exposed, intact cohesive units on the beach is limited and unpersuasive. Plaintiffs cite the trial testimony and expert report of Dr. Mackey, who, they argue, observed "exposed cohesive material and eroding cohesive scarps in the lakebed adjacent to [p]laintiffs' properties." Pls.' Br. 10 (emphasis added) (citing Tr. 538:19-539:7 (colloquy between Dr. Mackey and plaintiffs' counsel); PX 136 (Mackey Report) 20). But the CEM refers to exposed cohesive sediment "on the beach," PX 178 (CEM) III-5-3, not the lakebed. As Dr. Nairn explained, "A 'beach' is defined as the above water or 'subaerial' part of the nearshore profile." DX 155 (Nairn Composition Report) 12; see also The American Heritage Dictionary of the English Language (American Heritage Dictionary) 155 (4th ed. 2000) (including in its definition of a beach: "[t]he zone above the water line at a shore of a body of water"); Coastal Engineering Manual, App. A (Glossary) A-6 (2003) (defining a beach as "[t]he zone of unconsolidated material that extends landward from the low water line"), available at http://140.194.76.129/publications/eng-manuals/em1110-2-1100/AppA/a-a.pdf.

Plaintiffs also rely on the trial testimony of Mr. Shires, Pls.' Br. 10, who identified cohesive materials in two pictures of bluffs above beaches in plaintiffs' zone by observing that "there appear[s] to be some vertically standing materials in the beach environment just upslope of the beach," Tr. 817:16-18 (Shires) (discussing PX 161 (unidentified photos of beaches) 1).[62] Mr. Shires explained that "in order for it to stand vertically[,] it's got to have some consolidation, some consolidated cohesive properties to it." Tr. 817:25-818:2 (Shires).

Mr. Shires did not testify, however, that he had collected or tested samples of the material in the photos or even examined the materials in person. See Tr. 816:4-818:6 (colloquy between Mr. Shires and plaintiffs' counsel). The court finds Mr. Shires' characterization of the exposed materials as cohesive, which is based on photographs, to be less reliable evidence of their composition than the more sophisticated laboratory tests Mr. Shires ordered performed on the samples collected from the lake bottom. See Tr. 796:19-810:19 (colloquy between Mr. Shires and plaintiffs' counsel) (discussing the laboratory tests conducted on soil samples--including tests of shear strength, dry unit weight, moisture content, loss on ignition, plasticity and grain size). Furthermore, the materials Mr. Shires identified in photographs are not "on the beach" as contemplated by the CEM, see PX 178 (CEM) III-5-3, but are bluffs, see PX 161 (unidentified photos of beaches) 1, located, in Mr. Shires' words, "upslope of the beach," Tr. 817:17-18 (Shires).

Nor are the pieces of sediment that wash up on beaches in the southern reach of plaintiffs' properties, see Pls.' Br. 10 (describing this sediment as "pieces of exposed cohesive clay and consolidated peat," "chunks of grayish brown clay material" and "pieces of peat"), evidence of a cohesive shoreline. Defendant points out that the presence of rafts of organic-rich sediments washing onto the beach is consistent with defendant's explanation of the geological history and the stratigraphy of the area. See Def.'s Br. 22-23. Dr. Mickelson and Dr. Larson testified that changing lake levels deposited a thin layer of organic-rich material in the southern reach of plaintiffs' properties about seven feet below mean lake level approximately 6,600 years ago. See infra Part III.B.3.a (describing the formation of the thin, organic-rich layer); DX 293 (Mickelson Report) 3-6 (discussing the formation of a layer of "marshy soil" approximately 6,600 years ago that has become exposed in areas and creates "rafts of

[62]At trial, plaintiffs added color prints of the photos in PX 161. See Tr. 816:7-21 (colloquy between Mr. Shires and plaintiffs' counsel). The court directed the court reporter to place the color photos in front of the black and white photocopies plaintiffs had originally placed in the record copy of plaintiffs' exhibit binders. Tr. 2317:6-9 (court). Plaintiffs also provided color prints of certain photos in PX 264 and a clearer photocopy of certain pages of PX 409, all of which the court directed the court reporter to add to the record copy of plaintiffs' exhibit binders. Tr. 2312:9-2315:15 (colloquy between court and plaintiffs' counsel).

peaty sand that occasionally wash up on the beach").[63] Dr. Larson states that radiocarbon testing of one of the rafts of material that washed up on shore determined its organic material to be approximately 6,980 years old. DX 3 (Larson Report) 17. The court is persuaded by Dr. Mickelson's conclusion that "it all fits together that the cohesive material that's showing up out here . . . is this organic-rich sand and silt." Tr. 2100:4-6 (Mickelson). The presence of rafts of "organic-rich sand and silt," id., is not evidence that the shoreline as a whole is cohesive.

The two other visual features drawn from the CEM and relied upon by plaintiffs--exposed sediment in the troughs between offshore bars and discoloration of water in the nearshore zone--are similarly unpersuasive as evidence of a cohesive shoreline. Plaintiffs argue that Dr. Mackey observed exposed cohesive sediment in the troughs between offshore sand bars. Pls.' Br. 11 (citing Tr. 542:10-543:10 (colloquy between Dr. Mackey and plaintiffs' counsel); PX 136 (Mackey Report) at 22-23). However, as Dr. McNinch explained, "waves and currents typically winnow and sort unconsolidated sediment on the lakebed. These processes often result in what appears as a complex, patchwork pattern of different substrates at the surface but which, in fact, could simply originate from an underlying layer that is composed of a mixture of these sediment types." DX 294 (McNinch Report) 3. Plaintiffs have not rebutted Dr. McNinch's account of the source and composition of the sediment and have not, therefore, carried their burden of proof.

Plaintiffs contend that "[ae]rial photographs taken of the Plaintiffs' nearshore zone document discoloration in the nearshore zone." Pls.' Br. 10. However, Dr. Nairn determined that the plumes of discoloration actually travel downstream to plaintiffs' properties from areas that defendant describes as cohesive. See DX 155 (Nairn Composition Report) 12-13; see also id. at 2-26 (describing a section of cohesive shoreline approximately 1.9 miles long and located south of the jetties). Dr. McNinch notes that "many sandy beaches worldwide exhibit . . . plumes of discoloration in the surf." DX 294 (McNinch Report) 7. Plaintiffs failed to rebut defendant's evidence on the source of the discoloration and similarly failed to carry their burden of proof on this issue.

[63]Defendant first introduced evidence of this thin layer of organic-rich material at the trial of liability, several years before plaintiffs presented their argument based on the visual features listed in the CEM. See DX 3 (Larson Report) 16-17 (discussing the formation of a layer of peat and logs ten centimeters thick, which had been sampled in an engineering boring, and was the likely source of the rafts of sediment that wash up on the beaches adjacent to plaintiffs' properties). Dr. Larson stated in his report that radiocarbon dating of the layer of organic-rich material revealed the presence of organic materials approximately 6,640 and 6,675 years old. Id. at 16. Dr. Larson stated that radiocarbon dating of the rafts of sediment determined that the sediment contained organic material approximately 6,980 old. Id. at 17.

The court finds the explanation by defendant's expert witnesses of the presence of the four visual features in plaintiffs' zone to be both credible and persuasive. Because plaintiffs failed either to rebut defendant's evidence or to supplement its evidence of the visual features on which they rely with "more detailed subsurface investigations" such as "augers, boreholes, vibracores and sub-bottom profiling," as contemplated by the CEM, PX 178 (CEM) III-5-6, the court finds unpersuasive plaintiffs' argument that the claimed existence of four of the six CEM visual features establishes that plaintiffs are located along a cohesive shoreline.

ii. Plaintiffs' Two-Part "Test" of Composition

Plaintiffs' second argument purports to summarize the CEM's discussion of cohesive shorelines as a two-part "test":

> In short, if (1) cohesive materials are exposed on the lakebed or covered with less than 9 feet of sand and (2) those materials are subject to irreversible lakebed erosion, a shoreline is cohesive.

Pls.' Br. 8.[64] For the following reasons, the court finds that plaintiffs' proposed two-part "test" does not accurately represent the analysis recommended by the CEM to use in identifying cohesive shorelines. Nor do the facts adduced at trial support plaintiffs' proposed analysis.

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[64]This argument is drawn from Dr. Mackey's rebuttal reports, in which he explains that:

> Dr. Mackey's opinion that the shoreline south of St. Joseph is a cohesive shoreline is based on the fact that a shoreline can be called cohesive when the following requirements are met: 1) that cohesive materials are present on the lakebed or on a beach, and 2) that those cohesive materials have been, are, or will be subject to irreversible erosion as defined in the USACE [CEM].

PX 137 (Mackey Response to Mickelson) 1 (emphasis omitted); see also PX 138 (Mackey Response to Nairn) 11 (stating same); cf. supra note 60 (discussing the change in Dr. Mackey's analysis from the six visual indicators listed by the CEM to a two-step analysis).

On cross-examination, Dr. Mackey agreed with defendant's counsel's characterization of Dr. Mackey's analysis as having three parts:

> [T]he first one is that the cohesive materials are present on the lake bed or on the beach, the second is those cohesive materials have been, are, or will be subject to irreversible erosion or lake bed downcutting, and then third that those materials must also be subject to direct erosion by[,] in this case[,] Lake Michigan[.]

Tr. 712:16-23 (colloquy between Dr. Mackey and defendant's counsel).

Nowhere does the CEM reduce the detailed analysis it describes to a two-part "test." See PX 178 (CEM) passim. Instead, the CEM recommends a detailed analysis. The CEM contains a non-exhaustive list of six visual factors to consider, see id. at III-5-3 to III-5-6, and describes "a variety of techniques for characterizing the surface and subsurface conditions," id. at III-5-20, which are to be used to verify the visual indicators, see id. at III-5-6 (stating that, at the shoreline used as an example, such techniques included "augers, boreholes, vibracores and sub-bottom profiling").

Not only has plaintiffs' proposed two-part "test" oversimplified the detailed analysis suggested by the CEM, but plaintiffs have also reduced the analysis described in the CEM to a "test" that is more easily satisfied. With regard to the first part of the "test," that cohesive materials are exposed on the lakebed or covered with less than nine feet of sand, Pls.' Br. 8, Dr. Mackey testified that even a very small amount of exposed cohesive material would be sufficient under plaintiffs' analysis:

> Q: [S]o the presence of those two substrates, that fulfills that part of the definition for you . . . ?
> A: Yeah.
> . . . .
> Q: Sir, would that still be your opinion if the percentage of those two substrates were say 5 percent?
> A: Yes.
> Q: 1 percent?
> A: Yes.

Tr. 715:17-716:10 (colloquy between Dr. Mackey and defendant's counsel); but see DX 294 (McNinch Report) 3 ("[W]aves and currents typically winnow and sort unconsolidated sediment on the lakebed. These processes often result in what appears as a complex, patchwork pattern of different substrates at the surface but which, in fact, could simply originate from an underlying layer that is composed of a mixture of these sediment types.").

To demonstrate the existence of cohesive materials, plaintiffs presented the testimony of Mr. Shires, who reviewed the results of laboratory tests run on samples taken from the surface of the lakebed. See PX 141 (Shires Report) 2. Rather than sampling at regular or pre-determined intervals, divers hired by plaintiffs searched the lakebed for "in-place exposures of cohesive bottom sediments" and provided samples to Mr. Shires. Id. at App. A (Letter from Prism) 1. Mr. Shires states that, although some of the samples contained as much as 87% sand, id. at 9, they could be considered cohesive, because they contain organic material that "provides binding properties (i.e., apparent cohesion) not accounted for by simply considering grain size," id. at 5; see id. at 9. Mr. Shires opined that the samples he tested are of near-shore lake bottom that is composed of "glacial till that was consolidated in the geologic past by glaciers." Id. at 7; see also id. at 1, 5.

The theory that the samples were taken from a thick layer of till formed and consolidated by glaciers, however, is inconsistent with the geological history of the area. More persuasive is the explanation that Dr. Shires' samples were collected from outcroppings of a thin layer of organic-rich soil. See infra Part III.B.3.a (describing the formation of the thin, organic-rich layer). Plaintiffs acknowledge that radiocarbon dating indicates that a layer of "peat and logs" is present seven feet below the mean lake level in the southern portion of plaintiffs' zone and contains organic material approximately 6,600 years old. Pls.' Br. 13. As Dr. Mickelson explained, the organic materials were deposited too recently to be glacial till: "the glacier was gone by 10,000 years ago . . . [T]hat layer is dated as just under 6,000 years old. . . . So, it's much later, much younger." Tr. 2096:10-21 (Mickelson); see DX 293 (Mickelson Report) 3-6 (discussing the formation of a layer of "marshy soil" approximately 6,600 years ago), 34-36 (discussing radiocarbon dating of the peat layer penetrated by engineering borings). The fact that "rafts of peaty sand," DX 293 (Mickelson Report) 3, which have been determined by radiocarbon dating to be approximately 6,600 years old, Pls.' Br. 13 (citing Tr. 2099:1-2101:4 (colloquy between Dr. Mickelson and plaintiffs' counsel)), wash up on the beach indicates that this thin, peaty layer has become exposed in some areas of the nearshore adjacent to plaintiffs' properties, see DX 293 (Mickelson Report) 3; cf. PX 136 (Mackey Report) (stating that pieces of cohesive material Dr. Mackey observed on the beach had been "eroded from exposed cohesive deposits on the lakebed located immediately adjacent to[,] and offshore from," the areas where they were found); Tr. 532:1-533:3 (colloquy between Dr. Mackey and court) (describing a scarp of material he interpreted as cohesive, visible in his sidescan sonar survey).

In addition to the age of the materials, their content is also inconsistent with their being composed of glacial till. The existence of a large proportion of organic material in the samples analyzed by Mr. Shires is consistent with defendant's explanation that the samples were collected from a thin layer, rich in peat and other organic material, formed after the retreat of the glaciers, see Def.'s Br. 22-23, and is inconsistent with Mr. Shires' contention that the material was deposited by glaciers, see PX 141 (Shires Report) 1, 5, 7. Dr. Mickelson testified that glacial till "has a mix of grain sizes and typically isn't organic. This has organic materials, fine sand grains that look like wind[-]blown sand and no pebbles, no stones. They're certainly not till." Tr. 2096:3-9 (Mickelson); see also DX 293 (Mickelson Report) 2 (stating that glacial till is "characterized by containing a wide range of grain sizes compared to sediment deposited in streams or lakes"). The court is persuaded by Dr. Mickelson's report and related testimony that the samples analyzed by Mr. Shires are pieces of the thin layer rich in organic materials located between thick deposits of sand. See Tr. 2096:10-21, 2096:3-9 (Mickelson); DX 293 (Mickelson Report) 27, 33-34 (describing the formation of the thin, organic-rich layer); cf. DX 3 (Larson Report) 16 (describing same); see infra Part III.B.3.a (describing how

the thin, organic-rich layer formed and is eroding, forming rafts that wash up on the beach).[65]

Plaintiffs do not reconcile their "test" for the presence of a consolidated shoreline--which is satisfied by even the very small amount of cohesive material on the surface of the lakebed found by plaintiffs' experts, see Tr. 715:17-716:10 (colloquy between Dr. Mackey and defendant's counsel)--with the geological history of the area, which resulted in the incorporation of small amounts of cohesive material into otherwise sandy areas of shoreline, see infra Part III.B.3.a (describing the geological history and stratigraphy of plaintiffs' zone).

The second part of plaintiffs' "test" merely restates the fact--well established in this case--that the erosion of cohesive materials is irreversible. See Pls.' Br. 8; Liability Op., 78 Fed. Cl. at 628 (finding that the erosion of cohesive material is permanent and irreversible). The CEM provides:

> A shore is defined as consolidated cohesive when the erosion process is directly related to the irreversible removal of a cohesive sediment substratum . . . . This differs fundamentally from sandy shores where erosion (or deposition) is directly related to the net loss (or gain) of noncohesive sediment from a given surface area. Erosion on a sandy shore is a potentially reversible process (i.e., due to natural processes), while erosion on a consolidated cohesive shore is irreversible.

PX 178 (CEM) III-5-2 to III-5-3. It is the nature of cohesive materials that any erosion they undergo is irreversible. See id. The second part of plaintiffs' "test" merely restates this fact.

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[65]At trial, plaintiffs objected to Dr. Mickelson's testimony regarding the material that Mr. Shires had characterized as cohesive, contending that such testimony was beyond the scope of his report. See Tr. 2083:6-24, 2100:20-2101:4 (colloquy between Dr. Mickelson and defendant's counsel and objection by plaintiffs' counsel). The court overruled plaintiffs' objection, stating that, because the focus of Dr. Mickelson's report was shoreline composition, it would be efficient for Dr. Mickelson to address Mr. Shires' testimony on the subject. Tr. 2083:25-2084:6 (court). In fact, the portions of Dr. Mickelson's testimony cited and quoted above, see text accompanying this note, are within the scope of his expert report, which discussed both the composition and age of the glacial till in plaintiffs' zone, see DX 293 (Mickelson Report) 2-6, and the composition and age of the thin layer rich in organic material, see id. at 27-38. Although the court has included sections of Dr. Mickelson's contested trial testimony because the testimony is based on his expert report and provides the reader an accessible summary of his views, the testimony contained in Dr. Mickelson's expert report, see id. at 2-6, 27-36, and Dr. Larson's expert report, see DX 3 (Larson Report) 16, is sufficient to allow the court to reach its conclusions regarding the composition of the sediment tested by Mr. Shires had the objection been sustained.

The "test" plaintiffs propose reduces the analysis of whether a shoreline is cohesive to the narrow inquiry of (1) whether there are any "exposed cohesive materials on the lakebed in [p]laintiffs' zone which [(2)] are subject to irreversible downcutting." Pls.' Resp. 18 n.6; see also Pls.' Br. 8 (stating same). Because this approach is inconsistent with the thorough analysis of shoreline composition recommended by the CEM, see PX 178 (CEM) III-5-3 to III-5-6 (describing six visual features of cohesive shorelines); id. at III-5-20 (describing "a variety of techniques for characterizing the surface and subsurface conditions"), from which plaintiffs purport to draw their two-part "test," see Pls.' Br. 8 (citing, inter alia, PX 178 (CEM)); Tr. 716:25-717:3 (colloquy between Dr. Mackey and defendant's counsel) (agreeing that Dr. Mackey limited his analysis of shoreline composition to "what is set forth in Chapter 5 [of the CEM]"), the court declines to adopt plaintiffs' approach.

3. Additional Evidence of Shoreline Composition Presented by Defendant at the Trial of Damages

In addition to the evidence of shoreline composition submitted by defendant at the trial of liability, which the court found persuasive, see Liability Op., 78 Fed. Cl. at 621-28, defendant submitted additional evidence of shoreline composition at the trial of damages. Defendant states that assessing the composition of the shoreline "requires locating the shoreline at a point on a spectrum encompassing 'two ends of a limiting system, one of which is almost all cohesive, and the other which is . . . all sand.'" Def.'s Br. 5 (omission in original) (quoting Tr. 2781:1-3 (Nairn)). Defendant, therefore, "supplemented its understanding of shoreline composition with geological and physical evidence related to the shoreline's material composition, as well as computer modeling and a sediment budget that assesses the shoreline's behavior." Id.

Specifically, defendant presented the testimony of Dr. Mickelson, a geologist, and Dr. Nairn, a coastal engineer. See supra note 9. Dr. Mickelson reviewed the stratigraphy and geological history presented by Dr. Larson at the trial of liability[66] and supplemented both with his own analysis of the history and grain size distribution of the northern and southern areas of plaintiffs' zone. See Tr. 2011:7-2154:14 (testimony of Dr. Mickelson). Dr. Nairn used the stratigraphy developed by Dr. Mickelson and Dr. Larson to determine, on a property-by-property basis, whether each plaintiff's property has a sandy or a cohesive shoreline. See DX 155 (Nairn Composition Report) 27-32. Dr. Nairn also discussed the erosion and accretion of different areas in plaintiffs' zone over time, concluding that most of plaintiffs' properties were located in areas that behaved as a sandy shoreline would be expected to behave. See Tr. 2748:2-5 (Nairn) (stating that the shoreline in plaintiffs' zone behaves as a sandy shoreline).

[66]Dr. Larson also testified briefly at the trial of damages, discussing the expert opinions he presented to the court during the trial of liability. See Tr. 1978:11-2010:11 (testimony of Dr. Larson).

The record indicates that the shoreline in plaintiffs' zone is neither pure sand nor pure cohesive material. Certain areas contain layers of both cohesive and sandy material. See infra Part III.B.3.a (describing the formation of a thin band of sediment rich in cohesive organic material between thick layers of sand); DX 293 (Mickelson Report) 2-3 (describing the complex stratigraphy formed in the northerly portion of plaintiffs' properties by the retreat and advance of glaciers, as well as deposition and erosion by lake and stream environments). Certain sediments sampled in plaintiffs' zone are difficult to classify as sandy or cohesive. See, e.g., PX 141 (Shires Report) 5 (discussing sediment samples with both high sand content and cohesive characteristics). Because the shoreline composition is more complex than pure sand or pure cohesive material, the court finds the approach used by defendant--an approach that employs several metrics to evaluate shoreline composition--to be useful in determining where on the spectrum of composition plaintiffs' zone is located.

a. Additional Evidence Regarding Geological History and Stratigraphy

Dr. Mickelson provided additional detail to supplement the geological history and stratigraphy presented by Dr. Larson at the trial of liability. See generally DX 293 (Mickelson Report). Regarding the stratigraphy, Dr. Mickelson reviewed all of the well logs Dr. Larson had used to assemble his stratigraphy and concluded that "for the most part I agreed with the stratigraphy that he had put together."[67] Tr. 2027:5-9 (Mickelson). Dr. Mickelson states that, because of the dearth of subsurface samples, "the best information available about what is below the surface in the nearshore is extrapolation of well log data from onshore." DX 293 (Mickelson Report) 20.

Based on the geological history and stratigraphy of plaintiffs' zone, Dr. Mickelson concludes that there are "two distinctly different regions" in plaintiffs' zone, which he "treat[s] . . . separately." Tr. 2027:12-15 (Mickelson). The dividing line between Dr. Mickelson's regions, or "reaches," is West Glenlord Road, which intersects Lake Michigan in approximately the same location as the Inner Lake Border moraine, a ridge built by glaciers. Tr. 2029:7-12 (Mickelson); see also DX 293 (Mickelson Report) 4, Fig. 1 (map of plaintiffs' zone). Dr. Mickelson concludes that the compositions of the northern reach and the southern reach are very different: "The northern reach is made up of glacial till and sand and gravel. The southern reach is made up of sand dunes and some organic material." Tr. 2030:19-22 (Mickelson). The northern reach is characterized by "bluff shoreline. And south of that[,] it's dominated by dunes." Tr. 2023:11-13 (Mickelson). The twelve northernmost properties are located in the northern

[67]Dr. Mickelson notes that his disagreements with Dr. Larson's analysis resulted in "relatively minor changes" that "do not significantly change [Dr.] Larson's conclusions." DX 293 (Mickelson Report) 9.

reach, and the twenty-eight remaining properties are located in the southern reach. DX 293 (Mickelson Report) 2.[68]

Dr. Mickelson explained that the differing composition of the northern and southern reaches results from their differing geological histories.[69] All of the sediment underlying plaintiffs' properties was deposited since the last glaciation of the area--25,000 years ago. Id. "The glacier lobe scoured much of the Lake Michigan basin, enlarging it and removing most of the older glacial deposits down to the bedrock surface." Id. Starting approximately 20,000 years ago, the glacier began to retreat, depositing glacial till, "which is sediment deposited directly by glacier ice and which is characterized by containing a wide range of grain sizes compared to sediment deposited in lakes or streams." Id. Dr. Mickelson described how the retreat of the glaciers formed the layers that underlie the northern reach of plaintiffs' properties:

> The retreat of the glacier was interrupted by numerous re-advances of the glacier as [the] climate fluctuated. Each re-advance of the glacier deposited a layer of till with a distinct composition. The two till layers present along this shoreline are the younger Saugatuck till and the somewhat older Ganges till. Gravel, sand, silt, and clay were deposited in shallow lake and stream environments near the front of the retreating glacier. These deposits lie between the Saugatuck and Ganges till units as well as beneath the Ganges till where it is present.

Id. at 2-3. The resulting stratigraphy is complex, consisting of two layers of glacial till, with deposits of gravel, sand, silt and clay between the layers of till and--in certain locations--beneath both layers of till. See DX 3 (Larson Report) 34, Fig. 9 (geological map and cross section of plaintiffs' zone). Certain of the layers of sediment are located above the surface of the lake and therefore outside of the lakebed. See id.; DX 293 (Mickelson Report) 11 (describing cohesive material located in onshore bluffs). Other

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[68]Dr. Mickelson states that the twelve northernmost properties, listed in order from north to south, belong to plaintiffs Bovee, Wineberg, Werger, Okonski, Bodnar, Wilschke, Jyung Trust, Varga, Jackson, Greenbrier Development, Marzke and Neuser. DX 293 (Mickelson Report) 5, Table 1. The remaining properties, located in the southern reach, listed in order from north to south, belong to plaintiffs Del Mariani (two properties), Miller (two properties), Ragins, Morvis Trust, Chapman, Errant (Saphir), Notre Dame Path Association, Country L.L.C., Concklin Trust, Anderson, Melcher, Smith, Lahr, Pancoast, Renner, Carter, McKay, Kane, Cosgrove, Frett (Horvath Trust), Banks, Ehret Michigan Trust, Cunat, Gregule and Bunker (two properties). Id. Although several plaintiffs own two properties, no plaintiff owns properties in both the northern and southern reaches. See id.; see also infra note 132 (describing the total number of properties owned by plaintiffs).

[69]Plaintiffs presented no evidence to contradict Dr. Mickelson's testimony regarding the geological history of plaintiffs' zone. See Tr. passim.

layers of sediment are located below the depth to which the nearshore lakebed is eroding. See DX 155 (Nairn Composition Report) 30 (stating that, for this reason, Dr. Nairn would examine sediments to a depth of eight meters); DX 293 (Mickelson Report) 20, 34 (stating that, in characterizing the composition of plaintiffs' shoreline, Dr. Mickelson would focus on sediments up to twenty feet below the surface of the lake).

At this point, the geological histories of the northern reach and the southern reach diverge because the southern reach underwent further change. When the glacier that formed the moraine retreated, lake levels rose and the edge of the lake reached the edge of the moraine, submerging the southern reach under water.[70] Tr. 2029:19-2030:7 (colloquy between Dr. Mickelson and defendant's counsel). As a result, the surface was "cleaned off by waves" and covered in sand. Tr. 2029:25-2030:12 (colloquy between Dr. Mickelson and defendant's counsel); Tr. 2032:3-4 (Mickelson) (stating that "sand would have been delivered to the area at the time the lake level was high").

Approximately 9,000 years ago, the lake level dropped, creating a land surface with shallow ponded areas, on which organic material began to collect. Tr. 2032:4-10 (Mickelson). This organic material accumulated into a layer of peat and logs approximately ten centimeters thick and located approximately seven feet below the current surface of the lake. DX 3 (Larson Report) 16. This material is cohesive, but because of its thinness, constitutes a small fraction of the sediment in the shoreline. DX 293 (Mickelson Report) 36. Approximately 6,000 years ago, lake levels again rose, submerging this layer and depositing sand above it. See Tr. 2032:22-2033:8 (Mickelson). The thin layer of organic-rich materials was penetrated by two of the well logs, as well as the two engineering borings conducted by the United States Geological Service (USGS). See DX 293 (Mickelson Report) 3.[71]

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[70]The map of plaintiffs' properties reveals why the southern reach was submerged although the northern reach was not. See DX 293 (Mickelson Report) 4, Fig. 1 (topographic map of plaintiffs' zone). Because the moraine runs at an angle to the shoreline, disappearing into the water where the northern reach begins, the southern reach lies between the moraine and the edge of the lake. See id. When the water levels rose to the edge of the moraine, the southern reach would have been submerged. See id. The area that forms the northern reach was, at the time, separated from the lake by a section of the moraine, which has since eroded into the lake. See Tr. 2049:10-21 (colloquy between Dr. Mickelson and defendant's counsel). This section of the moraine prevented the northern reach from being submerged when lake levels rose.

[71]The evidence presented by plaintiffs confirms defendant's evidence about the thin, organic-rich layer that has become exposed in some parts of plaintiffs' zone. The samples collected by divers and analyzed by Mr. Shires contained significant quantities of organic material. See PX 141 (Shires Report) 8-9 (stating that samples he tested contained an average of 11.1% organic material). The divers retained by plaintiffs to search the lakebed for "in-place exposures of cohesive bottom sediments," PX 141 (Shires Report) App. A (Letter from Prism) 1, searched for, and found, the samples of organic-rich material tested by Mr. Shires only in the

This thin, organic-rich layer has become exposed offshore in some areas in the southern reach of plaintiffs' properties. See id. at 36. As it erodes, it creates rafts of organic-rich material that wash up on the beach. See id. at 3. Radiocarbon testing of one of the rafts of material determined its organic material to be approximately 6,980 years old, DX 3 (Larson Report) 17, roughly the same age as the organic material in the thin, organic-rich layer, see id. at 16-17 (stating that radiocarbon dating of this layer revealed the presence of organic materials approximately 6,630 to 6,675 years old).

The geologic history described by Dr. Mickelson strongly suggests that the southern reach of plaintiffs' zone is composed primarily of sand, with a thin layer of organic-rich material deposited approximately 6,600 years ago. Tr. 2029:19-2033:8 (colloquy between Dr. Mickelson and defendant's counsel); see also DX 293 (Mickelson Report) 3-6 (describing the geological history of the southern reach). The geologic history is less probative of the shoreline composition in the northern reach. The stratigraphy of the northern reach is more complex, containing two layers of till layered with other sediments. See DX 3 (Larson Report) 34, Fig. 9 (geological map and cross section of plaintiffs' zone).

b. Grain Size Distribution in the Northern and Southern Reaches

In addition to describing the geological history of the area, Dr. Mickelson calculated the sand content of the nearshore lakebed as a percentage of its overall composition.[72] DX 293 (Mickelson Report) 10, 20. Dr. Mickelson restricted his analysis to sediments located between the level of the lake surface and a level twenty feet below

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southern reach, see PX 141 (Shires Report) App. A (Letter from Prism) 1 (stating that diving activities would take place between Grand Mere State Park and West Glenlord Road), App. A, Attachment A 1-3 (maps showing sample locations).

Plaintiffs acknowledge that the rafts of material that wash up on the beach adjacent to plaintiffs' properties "were tested and determined to be over 6,000 years old." Pls.' Br. 13. Dr. Mackey inferred that the rafts of material washing up on the beach were eroding from an exposed layer located immediately offshore from where the rafts were found. PX 136 (Mackey Report) 21. Dr. Mackey observed a scarp or "mini cliff" of material that he interpreted as cohesive in the southern reach of plaintiffs' properties. Tr. 532: 1-533:3 (colloquy between Dr. Mackey and court). The court interprets this scarp to be an outcropping of the thin, organic-rich layer described by defendant.

[72]Dr. Mickelson also calculated the sand content of the area inland of the beach, see DX 293 (Mickelson Report) 10, a figure Dr. Nairn uses in his sediment budget analysis, see infra Part III.B.3.d.

the lake surface.[73] Id. at 20, 34. Dr. Mickelson states that whether a sediment is cohesive depends in part on grain size:

> Gravel and sand are not cohesive. Coarse silt, if well sorted[,] is usually not cohesive. Medium and fine silt and clay typically have cohesion. A mix of sizes, such as occurs in till, can be cohesive depending on the amount of clay and silt it contains. Both till units (Saugatuck and Ganges) have cohesion. Most of the lake sediment between the till is not cohesive.

Id. at 10.[74] Plaintiffs do not argue otherwise.[75] See Pls.' Br. passim; Pls.' Resp. passim. As sources of data, Dr. Mickelson relied upon well logs, his own observations, sediment samples that Dr. Mickelson and a graduate student under Dr. Mickelson's supervision collected and analyzed, Dr. Larson's observations and "various reports and papers including USGS reports and journal articles." DX 293 (Mickelson Report) 6-7.[76]

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[73]The court, without objection, took judicial notice at trial that--according to data published by the Corps--the surface of Lake Michigan was located at 576.808 feet above the International Great Lakes Datum in March, 2011. Tr. 2104:7-13 (colloquy between court, plaintiffs' counsel and defendant's counsel); cf. Tr. 2332:12-15 (Nairn) (stating that "IGLD" stands for International Great Lakes Datum).

[74]Dr. Mickelson employs the Wentworth scale, which he characterizes as "the scale most commonly used by geologists and soil scientists," to classify grain sizes. DX 293 (Mickelson Report) 10; cf. PX 137 (Mackey Response to Mickelson) 2 ("Dr. Mackey also uses the Wentworth grain-size scale to identify and describe the grain-size distribution of sediment."). On the Wentworth scale, grains larger than .0625 millimeters are classified as sand. DX 293 (Mickelson Report) 10. Smaller grains are classified as silt or clay. Id. Dr. Mickelson notes that engineers typically use a different system, in which grains larger than .074 millimeters are classified as sand. Id.

[75]Mr. Shires wrote in his expert report that sediments with a high sand content may nonetheless exhibit cohesive properties if they contain a high proportion of organic material. See PX 141 (Shires Report) 5 (discussing sediment samples with both high sand content and cohesive characteristics). However, Mr. Shires did not dispute Dr. Mickelson's classification of the sediment types that are ordinarily viewed as cohesive. See id. passim.

[76]Dr. Mickelson "concur[red] with [Dr. Larson's] interpretation of the well logs and his extrapolation of well logs out to the bluff face," DX 293 (Mickelson Report) 7, with the exception of minor changes he made, based on his own observations, id. at 9 (describing the modifications Dr. Mickelson made to Dr. Larson's interpretation).

To calculate the sand content of the lakebed in the southern reach and the northern reach, Dr. Mickelson employed a two-step method.[77] Dr. Mickelson's first step entailed calculating the number of feet of each sediment type that each driller encountered, as recorded in the well logs, and determining the percentage of the total described as sand. See, e.g., id. at 22, Table 11 (tabulation of sediment types and thicknesses for the northern reach) (stating that, at the depths Dr. Mickelson observed, drillers in one section encountered forty-four feet of sand, zero feet of clay, thirteen feet of interbedded sand and silt, and 25 feet of Ganges till). Dr. Mickelson calculated that the well logs described 42% of the sediment in the northern reach between the level of the lake surface and a level twenty feet below the lake surface as sand and 18% as interbedded sand and silt. See id.; Tr. 2062:9-15 (colloquy between Dr. Mickelson and defendant's counsel). Dr. Mickelson calculated that the well logs described 89% of the sediment located at the same range of depths in the southern reach as sand. DX 293 (Mickelson Report) 35, Table 13 (tabulation of sediment types and thicknesses for the southern reach); see Tr. 2087:10-11 (Mickelson).

Dr. Mickelson's second step accounts for the fact that the individual sediment layers contain not a single grain size of material, such as sand or silt, but a distribution of grain sizes. See Tr. 2088:6-8 (Mickelson) (stating that "what I've tried to do then is adjust these numbers . . . for the realistic sand content in those sediment types"). Dr. Mickelson explained that "when a driller--when somebody describes something as sand[,] it isn't necessarily 100 percent sand[,] and so what I tried to do here is not count sand as being 100 percent sand. . . . There's going to be some silt [and] clay in it probably." Tr. 2087:25-2088:6 (Mickelson). Using his own observations and reviewing the measurements made by other researchers, Dr. Mickelson examined the sand content of the various types of sediment present in plaintiffs' zone. See DX 293 (Mickelson Report) 11 (discussing sources of data).[78] Dr. Mickelson determined that the Saugatuck

[77]When calculating the sand content of the lakebed, Dr. Mickelson characterized the content of the material beneath the sand on the surface of the lakebed. As Dr. Mickelson explained, the sand on the surface of the lakebed is modern:

> So basically, these deposits that we're looking at and I've been talking about[,] they're associated with glaciation. . . . But there is also on the bed of the lake sand that is basically modern. I mean[,] it's sand that's been [deposited] recently in the last storm or something like that that's on top of these deposits. So[,] what I'm doing here is characterizing the glacial age material beneath that layer of sand.

Tr. 2062:20-2063:4 (Mickelson). It appears that, had Dr. Mickelson included the surface layer of modern sand, his calculations would have indicated higher sand content for the lakebed.

[78]Plaintiffs do not argue that Dr. Mickelson has incorrectly calculated the sand content of the various sediment types or of the lakebed in plaintiffs' zone. See Pls.' Br. passim; Pls.' Rep. passim; cf. PX 137 (Mackey Response to Mickelson) passim.

till contains 29.7% sand, the Ganges till contains 31% sand and the unit of interbedded sand and silt between the till layers contains 81.5% sand. Id. at 13-14. Dr. Mickelson treated sediments described by the well drillers as "sand" as containing only 90% sand and treated any layers described as "clay" as containing no sand. See id. at 20. Applying the sand content of each sediment type to the amount of each sediment type present, Dr. Mickelson calculated that that the material between the lake surface and a level twenty feet below the lake surface--and therefore, the material in the nearshore lakebed--consists of 65% sand in the northern reach, id. at 20, and consists of 80% sand in the southern reach, id. at 38.

Dr. Mickelson's calculations indicate that plaintiffs' zone has significant sand content. The well logs described 60% of the sediment at the depth of the lakebed in the northern reach as either sand or interbedded sand and silt. See id. at 22, Table 11 (tabulation of sediment types and thicknesses for the northern reach). The well logs described 89% of the sediment at the depth of the lakebed in the southern reach as sand. Id. at 35, Table 13 (tabulation of sediment types and thicknesses for the southern reach). Applying the sand content of each sediment type to the observations documented in well logs, Dr. Mickelson determined that the sand content of the lakebed in the northern reach is 65%, id. at 20, and that the sand content of the lakebed in the southern reach is 80%, id. at 38.

c. Grain Size Distribution on a Property-by-Property Basis

Dr. Nairn analyzed the sand content of the shoreline to determine, on a property-by-property basis, which of plaintiffs' properties are located along a sandy shoreline. Recognizing that there is a "spectrum of shore types between purely cohesive shores and fully sandy shores," DX 155 (Nairn Composition Report) 5, Dr. Nairn argues that, for three reasons, the sand content of the shoreline is "the over-riding factor" in determining whether the shoreline should be considered sandy or cohesive for purposes of erosion:

> 1. the definition in the literature of a limit of 10% to 30% [sand] for a cohesive shore;
>
> 2. the fact that the rate of removal of sand is limited by the available wave energy whereas the rate of removal of cohesive [material] (silt and clay) . . . offshore is not; and
>
> 3. the fact that without removal of the sand the erosion of any underlying exposures of cohesive and sandy sediment could not continue,

id. at 17.

Dr. Nairn undertook an extensive literature review to determine the maximum sand content of cohesive shorelines described in other research. See id. at 5-15. Dr. Nairn states that "[a] large body of scientific understanding of cohesive shores on the Great Lakes emerged from the Port Burwell Litigation in the early 1980's," which involved erosion caused by harbor structures. Id. at 5. Beginning with the scholarly papers that emerged from the Port Burwell litigation in 1983, Dr. Nairn examined a number of papers and articles--including several of his own that were published before this litigation, id. at 5-15--and concluded that "[t]he literature unanimously puts the upper limit for sand content of a cohesive shore no higher than 30% (although for one part of one cohesive shore bluff in the Toronto area[,] the sand content was found to be 36%)," id. at 16-17.

Using the stratigraphic map developed by Dr. Mickelson, Dr. Nairn calculated the sand content at a number of "representative locations" along the shoreline to a depth of eight meters below chart datum.[79] Id. at 30. Dr. Nairn selected the eight-meter cutoff because he determined--in the analysis of historic shoreline erosion contained in the report he prepared for the trial of liability--that the nearshore profile is eroding to a depth of approximately eight meters.[80] Id. For each representative location and for each of plaintiffs' properties, Dr. Nairn calculated the sand content using the Wentworth scale applied by Dr. Mickelson and most geologists, on which sand is defined as sediment larger than .0625 millimeters. See id. at 28; see supra note 74 (discussing the Wentworth scale). Dr. Nairn also calculated the sand content using a cutoff of .1 millimeters, which, although larger than the grain size cutoff normally utilized by geologists and engineers,[81] is "more consistent with the grain size of sand that might be expected to exist in the littoral zone (i.e.[,] whereas finer sediment would move offshore outside the littoral zone)." DX 155 (Nairn Composition Report) 28. Of course, the .1 millimeter cutoff results in findings of lower sand content, which is favorable to plaintiffs' argument that the shoreline is cohesive.

Regardless of the grain-size cutoff Dr. Nairn used, he determined that all but one of plaintiffs' properties[82] were adjacent to areas of lakebed with sand content that is

[79]A chart datum is "The plane or level to which soundings (or elevations) or tide heights are referenced . . . . To provide a safety factor for navigation, some level lower than mean sea level is generally selected for hydrographic charts . . . ." Coastal Engineering Manual, App. A (Glossary) A-14 (capitalization omitted).

[80]Dr. Nairn also calculated the sand composition of the bluffs in plaintiffs' zone, see DX 155 (Nairn Composition Report) 30, a figure he used in his sediment budget.

[81]Dr. Nairn noted that engineers, following the ASTM International (formerly the American Society for Testing and Material) standards, generally consider sediment with a grain size of .075 millimeters or greater to be sand. DX 155 (Nairn Composition Report) 28.

[82]See infra note 132 (discussing the number of properties owned by plaintiffs).

consistent with a sandy shoreline. See id. at 35, Fig. 4.3b (chart of lakebed sand content) (showing one property with lakebed sand content equal to or less than 30%). The northernmost property,[83] belonging to plaintiffs Gregory and Candice Bovee, has "a sand content between 61.5% and 67.5% (using the minimum sand size of 0.0625 mm and 0.10 mm, respectively)." Id. at 31. The next property, belonging to plaintiff Marcia Wineberg, has a sand content between 66% and 72%. Id. The third property, belonging to plaintiffs Kent and Margaret Werger, has a sand content between 41% and 48%, the lowest sand content of the plaintiffs' properties. Id. Dr. Nairn concludes that, although the sand content of the Werger property "is above the sand content limit for cohesive shores derived from the available literature (i.e., 30% with one instance of 36%), it is close enough to the limit[ ] that in this expert's opinion, it is classified as a cohesive shore." Id.

Continuing to the south, "The properties between Okonski and Nueser all fall in a range where sand content of the lakebed sediment is always greater than 59% and usually greater than 70%[,] with averages across this zone of 67.5% to 73%." Id. The properties in this area are owned by plaintiffs Okonski, Bodnar, Wilschke, Jyung, Varga, Jackson, Greenbriar, Marzke and Neuser. Id. The sand content of the lakebed adjacent to the next property, which belongs to the Del Mariani plaintiffs, is "just above 75%." Id. The lakebed adjacent to the remaining properties has a sand content of 82% to 85%. Id. at 32. These southernmost properties are owned by plaintiffs Miller, Ragins, Morvis, Chapman, Errant (Saphir), Notre Dame Path Association, Country LLC, Concklin Trust, Anderson, Melcher, Smith, Lahr, Pancoast, Renner, Carter, McKay, Kane, Cosgrove, Frett (Horvath Trust), Banks, Ehret, Cunat and Bunker.[84] See id.

Plaintiffs do not present competing sand-content calculations for their properties. See Pls.' Br. passim; Pls.' Resp. passim. In fact, plaintiffs do not present any property-by-property analysis of shoreline composition, see Pls.' Br. passim; Pls.' Resp. passim, despite multiple statements by the court that such evidence would be useful, see Jan. 22, 2008 Telephonic Status Conference Tr. 13:13-22 (court) ("[W]e don't have evidence

[83]Dr. Nairn listed plaintiffs' properties in order from north to south. Compare DX 155 (Nairn Composition Report) 31-32 (discussing the sand content of the lakebed adjacent to plaintiffs' properties), with DX 293 (Mickelson Report) 5, Table 1 (table of plaintiffs' properties arranged by distance from jetties).

[84]The Gregule property does not appear on Dr. Nairn's list of the sand content of the individual properties. See DX 155 (Nairn Composition Report) 31-32. Because Dr. Nairn discusses the properties in order from north to south and because the Gregule property is the located between the Bunker and Cunat properties, compare id. at 31-32 (discussing the sand content of the lakebed adjacent to plaintiffs' properties), with DX 293 (Mickelson Report) 5, Table 1 (table of plaintiffs' properties arranged by distance from jetties), the court concludes that the Gregule property is among this southernmost group of properties and is located adjacent to a lakebed with a sand content between 82% and 85%.

explained to the [c]ourt [about] whose properties were at the northerly end of the [p]laintiff[s'] properties, who could have fallen into the area that it shows as cohesive on Dr. Larson's study."); Order Granting Recons., 84 Fed. Cl. at 297 (quoting same in parenthetical) (quoting Jan. 22, 2008 Telephonic Status Conference Tr. 13:13-22 (court)); Liability Op., 78 Fed. Cl. at 628 ("If, in further proceedings, some or all of a plaintiff's property is determined to lie in the northernmost zone characterized by Dr. Nairn and Dr. Larson in their expert reports as not predominantly sandy, the erosion damage to such property will be analyzed as damage to a cohesive shore.").

Plaintiffs argue that, by considering the sand content of the lakebed, Dr. Nairn is "literally run[ning] from the established definition of a cohesive shoreline set forth in the CEM--a document drafted by Dr. Nairn and described by the Corps--to this day . . . as a state-of-the-art technical manual for coastal engineers." Pls.' Br. 15. Plaintiffs further contend that "the United States and Dr. Nairn attempt to create a new shoreline definition called 'predominantly sandy.' This definition is found nowhere i[n] coastal engineering literature and was created out of whole cloth by Dr. Nairn for purposes of this litigation."[85] Id. at 15-16. Plaintiffs argue that the CEM defines cohesive shorelines "by

[85]Plaintiffs state that, "[a]mazingly, Dr. Nairn's prior, non-litigation definition of cohesive shore, as set forth in the CEM, was based, in part, upon research he did in St. Joseph, Michigan." Pls.' Br. 16. Plaintiffs cite the proposal Dr. Nairn submitted to the Corps in 1996 regarding the drafting of the chapter of the CEM on cohesive shores, in which Dr. Nairn states that he "just completed a two-year investigation of the cohesive shore processes in the vicinity of St. Joseph and that the 'multifaceted study involved all aspects of research and investigation of cohesive shores . . . [.]'" Id. (quoting PX 311 (CEM Drafting Proposal) 5). Plaintiffs further state that, "[i]n fact, a photograph that Dr. Nairn selected and included in the CEM as illustrative of a cohesive shoreline is a photograph of Glenlord Beach, which is located in the middle of [p]laintiffs' zone." Id. (citing, inter alia, PX 178 (CEM) III-5-51, Fig. III-5-28). Plaintiffs argue that "[t]he caption below the photograph indicates that it is an example of failed shore protection on a cohesive shore in Berrien County, Michigan." Id. (citing, inter alia, PX 178 (CEM) III-5-51, Fig. III-5-28).

The CEM photograph to which plaintiffs refer is captioned, "A steel sheet-pile wall and groin field has been ineffective at protecting this section of a cohesive shore along the Berrien County shore of Lake Michigan, south of the town of St. Joseph, April 1994." PX 178 (CEM) III-5-51, Fig. III-5-28. The photograph is located in a section of the CEM which addresses the design of shore protection for cohesive shorelines. See id. at III-5-48 to III-5-53. There is no evidence that any of plaintiffs' properties is located along Glenlord Beach, nor could there be, because Glenlord Beach is a public beach.

Plaintiffs' treatment of the Glenlord Beach photograph in the CEM and Dr. Nairn's proposal for drafting a chapter of the CEM on cohesive shores may be read to suggest that Dr. Nairn adopted for this litigation a position that is contradicted by his pre-litigation views about the composition of plaintiffs' zone. If that interpretation is correct, it would not be the first time that plaintiffs have suggested "that Dr. Nairn's expert report is an about-face by a lone scientist whose opinion has been bought and paid for." Liability Op., 78 Fed. Cl. at 618; see also Pls.' Br.

how the shore behaves and not by some arbitrary sand percentage." Id. at 17. "Most importantly," plaintiffs argue, "Dr. Nairn's new category of 'predominantly sandy' shores fails to meet the basic requirements set forth in Daubert v. Merrell Dow Pharm[aceuticals]," because the term "predominantly sandy . . . is not recognized" in the scientific community or literature. Id. at 18; see also Daubert v. Merrell Dow Pharms., Inc., 509 U.S. 579, 592-93 (1993) (stating that, before admitting expert testimony, a trial court must make "a preliminary assessment of whether the reasoning or methodology underlying the testimony is scientifically valid").

Defendant is correct that this assertion "constitutes a straw man argument on which the United States has not relied." Def.'s Resp. 9. In pre-trial motions practice before the trial of damages, the court declined to exclude Dr. Nairn's testimony under Daubert for its use of the term "predominantly sandy." Banks v. United States, Dkt. No. 403, 93 Fed. Cl. 41, 56-57 (2010). The court stated that "[p]laintiffs present[ed] no legal basis upon which the court is required to strike Dr. Nairn's use of the term 'predominantly sandy' and the court declines to do so." Id. at 57; see also id. at 56-57 (discussing plaintiffs' argument). It is the view of the court that Dr. Nairn's use of the term "predominantly sandy" in his report is similar to the court's use of the term in its Liability Opinion, 78 Fed. Cl. at 628, as a descriptive term to capture the complex

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25 (reciting the amount of expert fees paid to Dr. Nairn). As the court stated in its Liability Opinion, however, "Dr. Nairn's report and testimony have been admitted into evidence by the court as an expert report and expert testimony," Liability Op., 78 Fed. Cl. at 618, and must be evaluated based on their credibility and persuasiveness. "[T]he fact that Dr. Nairn was paid for his services as an expert is not, without more, evidence of bias." Id. at 643; compare DX 1 (Nairn Report) App. F(3), (stating Dr. Nairn's hourly rate of remuneration), with PX 149 (Moore Report) 2 (stating an hourly rate of remuneration of an expert witness for plaintiffs more than four times greater than Dr. Nairn's hourly rate). Dr. Nairn has co-authored publications that the court has treated as admissions by the government. Liability Op. 78 Fed. Cl. at 618. The court addressed the Corps' changed view of the shoreline composition of plaintiffs' zone in its Liability Opinion, noting that "[d]efendant acknowledges that the Corps considered the zone of plaintiffs' properties cohesive in its earlier Corps Reports, but it argues that this was an erroneous conclusion because that assumption was based on studies that did not focus on plaintiffs' zone." Id. at 624. The court is mindful of the "increasing sophistication of methods of study of littoral processes and the sharper focus of the expert reports on the issues in this case." Id. at 619. The court is also mindful of the fact that Dr. Nairn is a respected expert in the field of coastal engineering, as one of plaintiffs' expert witnesses acknowledged at trial. See Tr. 1613:17-20 (colloquy between Dr. Shabica and court) (stating that "Nairn is the authority on" sediment-starved shorelines).

In any case, the quotation from Dr. Nairn's proposal and the photograph he included in the CEM are of limited probative value regarding the composition of plaintiffs' zone. Dr. Nairn agrees that significant portions of the shoreline near St. Joseph are cohesive. See, e.g., DX 1 (Nairn Report) 2-26 (describing a section of cohesive shoreline 1.9 miles in length, located between the jetties and the properties of the northernmost plaintiffs).

composition of some of plaintiffs' shoreline, rather than as a term of art that displaces the sandy and cohesive categories of shoreline composition. Dr. Nairn, in addressing whether plaintiffs' shoreline should be characterized as sandy or cohesive, observes that there is a "spectrum of shore types between purely cohesive shores and fully sandy shores." DX 155 (Nairn Composition Report) 5. The court finds helpful Dr. Nairn's acknowledgement that shoreline composition can be complex and the clarity of his focus on the two factors he considers most significant to the court's analysis of shoreline erosion--grain size distribution and erosional behavior.[86]

Plaintiffs are incorrect in their view that the sand content of a lakebed is irrelevant to the determination of whether it is sandy or cohesive. See Pls.' Br. 17. The court has considered a number of metrics to determine the composition of the shoreline of plaintiffs' properties, including the sand content of the sediments it contains, its geological history, stratigraphy derived from well logs and engineering borings, the composition of the surface of the lakebed as determined by sidescan sonar, underwater video and sediment sampling, the visual features identified by the CEM, previous assessments made in the scientific literature and discussed by the parties' expert witnesses, and erosional behavior--both as predicted by numerical modeling and as measured over the span of more than a century. Although the sand content of the lakebed is not dispositive of whether the shoreline is cohesive, the court agrees with Dr. Nairn that it is useful to consider whether the lakebed has a higher sand content than cohesive shorelines identified in other research. See id. (arguing that sand content is "the overriding factor" regarding whether a shoreline should be considered sandy or cohesive).

Furthermore, Dr. Nairn's analysis of sand content is consistent with the analysis of shoreline composition described by the CEM. Plaintiffs contend that the CEM defines the composition of a shoreline "by how the shore behaves and not by some arbitrary percentage." Id. Plaintiffs oversimplify the analysis recommended by the CEM. The CEM recommends the use of "subsurface investigations" including "augers, boreholes, vibracores and sub-bottom profiling." PX 178 (CEM) III-5-6. Plaintiffs do not contend that it would be inappropriate to measure the sand content of any samples collected using these techniques. See Pls.' Br. passim; Pls.' Resp. passim. Plaintiffs' own expert witness, Mr. Shires, measured the sand content of the sediment samples collected in plaintiffs' zone as part of his investigation into whether the samples were cohesive or sandy, see PX 141 (Shires Report) 7-9, implicitly assuming that sand content is relevant to cohesion in his statement that the samples had greater cohesion than their sand content would indicate because of a high organic content, see id. at 5 ("It is my opinion that organic content . . . provides binding properties (i.e., apparent cohesion) not accounted for by simply considering grain size.").

[86]The court discusses shoreline behavior below. See infra Part III.B.3.d.

Neither must Dr. Nairn's analysis fit within the four corners of the CEM to be "scientifically valid." See Daubert, 509 U.S. at 592-93. The Corps' goal in drafting the CEM was "to develop an engineering manual which includes the basic principles of coastal processes . . . and guidance on how to formulate and conduct studies in support of coastal flooding, shore protection, and navigation projects." PX 316 (Guide for Preparation of the CEM) 5. The CEM was to be written "at a level suitable for the USACE District, BS-level graduate civil/hydraulic engineer who has no advanced academic training in coastal engineering and its related subjects." Id.; see also Dep. of Joan Pope (Pope Dep.), Dkt. No. 493-2, 85:21-87:4 (Pope) (stating that the Corps hired Dr. Nairn to draft a portion of the CEM in part because of his ability to "explain very complex concepts so they're clearly understood by non-engineers"). The CEM was intended to be "a living document and continually revised to reflect improvements as they are developed." PX 316 (Guide for Preparation of the CEM) 5. Such improvements in the understanding of cohesive shorelines can be expected to develop in the primary literature cited by Dr. Nairn. See Tr. 1802:24-1803:4 (McNinch) (stating that the CEM "is certainly nothing that I would cite in our peer[-]reviewed publications as a cornerstone to our methodology, and we are developing new methodologies. So, I would use primary literature and try to advance the field in that manner.").

Ms. Pope, who oversaw the drafting of most of the CEM, Pope Dep. 19:15-20 (colloquy between Ms. Pope and plaintiffs' counsel), is currently the Assistant Director for Civil Works in the Research and Development Directorate of the Corps, "which means [she] coordinate[s] the overall civil works research and development activities," id. at 8:14-19. Ms. Pope testified that the study of cohesive shorelines "is probably one of the more immature areas of coastal engineering and coastal geology in terms of understanding[ ] the processes and being able to . . . quantify those processes," Pope Dep. 86:7-13 (Pope). Ms. Pope further testified that the Corps hired Dr. Nairn to co-author the chapter of the CEM on cohesive shorelines in part because Dr. Nairn is "the foremost English[-]speaking authority on" cohesive shorelines. Pope Dep. 86:14-16 (Pope). The chapter of the CEM on cohesive shorelines was released nearly a decade ago. See Pope Dep., Dkt. No. 493-1, 34:11-16 (colloquy between Ms. Pope and plaintiffs' counsel) (stating that the chapter authored by Dr. Nairn was released in early 2000). It appears reasonable to the court that Dr. Nairn's analysis of shoreline composition in connection with his expert report and testimony in this case would examine more than the "basic principles of coastal processes" described some years ago in the CEM, PX 316 (Guide for Preparation of the CEM) 5, and would address matters discussed in current scholarly research on cohesive shorelines--particularly given that he is working in "one of the more immature areas of coastal engineering," Pope Dep. 86:9-10 (Pope).

Dr. Nairn's testimony indicates that plaintiffs' properties, with the exception of the Werger property, are located along areas of lakebed with greater sand content than those in the cohesive shorelines described in the scholarly literature. See DX 155 (Nairn Composition Report) 31-32.

d. Shoreline Behavior

Dr. Nairn also created a sediment budget to determine whether the shoreline in plaintiffs' zone behaves as a sandy shoreline or a cohesive shoreline. See id. at 25, Table 3.2 (revised sediment budget). A sediment budget is "'an accounting procedure to keep track along the shoreline of sediment inputs and sediment losses.'" Liability Op., 78 Fed. Cl. at 613 (quoting Liability Tr. 112:25-113:3 (Meadows)). Dr. Nairn first presented his sediment budget at the trial of liability, concluding that, because the sediment budget "is able to describe the erosion of [p]laintiffs' shores and the fact that it does, necessarily means that the shore is behaving as a [sandy] shore." Tr. 2568:11-17 (Nairn); see also Liability Op., 78 Fed. Cl. passim; DX 1 (Nairn Report) 4-147 to 4-148. The court discussed Dr. Nairn's sediment budget in its Liability Opinion. See Liability Op., 78 Fed. Cl. passim. However, at the trial of liability, plaintiffs presented "no expert evidence . . . to counter defendant's expert's studies and explanations, and no expert review of Dr. Nairn's . . . research conclusions regarding the lake bottom composition." Id. at 628. Because plaintiffs now contend that Dr. Nairn's sediment budget is unreliable, Pls.' Br. 18-20, the court here describes how Dr. Nairn compiled his sediment budget and addresses plaintiffs' arguments.

One way to distinguish between sandy and cohesive shores is "[h]ow the shore erodes--in other words, the behavior of the shore when it is exposed to waves and currents." DX 155 (Nairn Composition Report) 16; see also Pls.' Br. 17 (stating that the CEM defines cohesive shorelines "by how the shore behaves"). "If the shore is composed of sand, the quantity of sand that is depleted is directly proportional to the quantity of sand that needs to be replaced." Liability Op., 78 Fed. Cl. at 622 (footnote omitted). The amount of wave energy impacts the amount of sand being carried along the shoreline at any particular location. In areas where the amount of energy decreases, the sand transport rate decreases; sand "drop[s] out," and is deposited. Tr. 2588:4-13 (Nairn); see also DX 1 (Nairn Report) 2-26 ("Sand is deposited along sections of shore where the net rate of Longshore Sand Transport (LST) diminishes spatially along the shore, i.e.[,] the capacity for the waves and wave-generated currents to carry sand is reduced and thus sand drops out of the river of sand."). In areas where the amount of wave energy increases, the water picks up additional sand. See Tr. 2589:10-17 (Nairn); DX 1 (Nairn Report) 2-26. Erosion can be therefore be expected to take place along a sandy shoreline when "there is an increase in the rate (or a gradient in the rate) of longshore sand transport from one end of an area of interest to another." DX 155 (Nairn Composition Report) 2. Accordingly, "sandy shore erosion can be defined through a sand budget approach and the rate of loss of sand from a given area of interest is directly related to, and limited by, the available wave energy." Id. at 8.

Dr. Nairn described plaintiffs' properties as being located in a "hot spot," where a decrease in water depth focuses wave energy, increasing erosion.[87] See Tr. 2584:10-2585:6 (Nairn); DX 1 (Nairn Report) 2-27 to 2-29 (presenting and discussing modeling results that show the wave focusing effect). He also described areas with lower wave heights, located to the south of plaintiffs' zone, that are characterized by lower rates of erosion. Tr. 2583:5-2584:6 (Nairn). To some extent, Dr. Nairn testified, this analysis can also be applied to specific sections of plaintiffs' zone; sand can be expected to accumulate in areas where wave energy decreases and to erode in areas where wave energy increases. See, e.g., Tr. 2586:11-22 (describing several "depositional zone[s]" and "eroding zone[s]").

Dr. Nairn explained why sandy shorelines behave in a manner that can be modeled with a sediment budget while cohesive shorelines do not. Summarizing an academic paper he published in 1992, Dr. Nairn explained that "the definition of a cohesive shore is primarily related to the root cause of erosion of these shores." DX 155 (Nairn Composition Report) 8. Erosion "occurs in two steps: a) the pickup of the sediment from the beach or lakebed, where individual grains of clay, silt and sand are put into suspension; and b) the removal of these suspended grains from the area of interest." Id. at 2. The first step is the same for sandy shorelines and for cohesive shorelines with "extensive sand cover." Id. For sandy shorelines, however, the second step relates to the available wave energy:

> [R]emoval of sand from a given area of interest occurs in a longshore direction within the littoral zone. This only occurs where more sand can be transported by waves and wave-generated currents out of an area of interest than is supplied to that area--in other words, there is an increase in the rate (or a gradient in the rate) of longshore sand transport from one end of an area of interest to another.

Id. Dr. Nairn explains that "[t]his is the key differentiating factor between predominantly sandy and cohesive shores: the rate of removal of the heavier sand grains is limited by the available wave energy; whereas the offshore loss of the easily suspended and smaller clay and silt grains occurs at low energy levels and the loss rate is not limited by the available wave energy." Id.

Dr. Nairn explained that, if plaintiffs' zone is a sandy shoreline, the erosion he predicts should match the historical rate of erosion. Tr. 2570:16-21 (Nairn) ("[I]f I'm

[87]Dr. Nairn studied the longshore transport gradients using a computer-based model he developed and uses for engineering projects, called COSMOS. See Tr. 2585:23-2586:1 (Nairn); cf. DX 1 (Nairn Report) App. A (model descriptions). On defendant's motion, the court entered a protective order regarding three numerical models used by Dr. Nairn. Mar. 16, 2007 Order, Dkt. No. 175, at 3.

able to predict the rate at which the shoreline and lake bed erode using the sediment budget when I'm considering sand only, it effectively is a validation of the approach, that taking a sand budget approach, based on a sandy shore concept, is a correct one."). Citing the study he authored in 1992, Dr. Nairn described why studying shoreline behavior is particularly useful when analyzing an area of shoreline that contains some amount of both sandy and cohesive materials:

> [A] distinction is made that eroding sandy shores may feature cohesive material, but that its presence does not alter the primary mechanism of erosion[,] which is the net balance in sand supply as determined by the sediment budget. In contrast, cohesive shore erosion is distinguished by the primary importance of the irreversible loss of cohesive sediment from the nearshore zone--and the lack of a relationship between the erosion rate and the sand budget.

DX 155 (Nairn Composition Report) 8.

In calculating his sediment budget, Dr. Nairn considered the sources that provide sediment to plaintiffs' zone and the "sinks" that remove it: "[T]he difference between what's coming [in] and what goes out should match what is supplied from the bluffs and the lake bed, in terms of sand. If it does, then effectively this is behaving [as] a predominant[ly] sandy shore." Tr. 2572:25-2573:4 (Nairn). In addition to the erosion of bluffs and the lakebed, sources of sand include the littoral flow of sand around the jetties from the north and sand that is supplied by the St. Joseph River. Tr. 2573:5-20 (Nairn). Dr. Nairn testified that "[a] lot of this work, the sediment budget, then goes to evaluating . . . how much sand gets [past] the harbor effectively." Tr. 2573:5-9 (Nairn).

One factor that Dr. Nairn examined when determining how much sand flows around the harbor jetties and into plaintiffs' zone is the role of bypassing shoals. As sand travels south along the shoreline and arrives at the harbor, it is deflected offshore by the jetties and their fillet beaches.[88] Tr. 2601:3-7 (Nairn). "And then as it gets into this deep water--remember, that used to be just deep water before[--]but it sort of builds a natural sort of sand bridge or attempts to build a sand bridge across and through the channel . . . ." Tr. 2601:7-11 (Nairn). The sand bridges--or bypassing shoals--act as a sink, absorbing sand as they form and as they re-form after the shipping channel is dredged. Tr. 2601:11-19, 2600:1-2601:21 (Nairn).

To determine how much sand the river supplies, Dr. Nairn examined the St. Joseph watershed at different points in time, considering--among other factors--the effect

[88]A fillet beach is formed when a harbor structure projecting into the lake interrupts the littoral transport of sand, causing sand to be deposited against the structure. See Tr. 1116:11-14 (Chrzastowski).

of agriculture and deforestation on the amount of sand entering the river, the effect of river dredging on the amount of sand accumulating in the river, and the effect of dams, river flows and water levels on the amount of sand carried by the river. See Tr. 2575:2-2576:5 (Nairn). Dr. Nairn's numerical modeling of the sediment delivered to plaintiffs' zone by the St. Joseph River also considered potential variations under different weather conditions, including the effect of storms and floods. See Tr. 2603:4-2607:11 (colloquy between Dr. Nairn and defendant's counsel).

The sediment sinks that Dr. Nairn examined included dredging of the harbor, accumulation of sand in fillet beaches and sand deposited in bypassing shoals. Tr. 2574:3-17 (Nairn). Using a numerical model of hydrodynamics[89]--which weighs, among other factors, longshore currents, water flows driven by the waves and the level of river flow--Dr. Nairn also modeled the amount of sediment lost offshore under different conditions. See Tr. 2602:22-2604:10 (colloquy between Dr. Nairn and defendant's counsel).

Dr. Nairn testified that sediment budgets are one of the "usual types of investigations we do" when working on engineering projects. Tr. 2174:1-4 (Nairn); cf. Tr. 2169:21-22 (Nairn) (stating that Dr. Nairn's work focuses on river and coastline engineering). Plaintiffs' expert witness, Mr. Shires, agreed that "a sediment budget can be used for understanding how a coastal shoreline behaves[,] which then itself . . . can be used for understanding the composition of the shoreline." Tr. 853:11-16 (colloquy between Mr. Shires and defendant's counsel). Mr. Shires further agreed that "the Coastal Engineering Manual speaks . . . about considering the quantity and mobility of sand cover," which "relates to the idea of considering the behavior of the sediment." Tr. 853:19-25 (colloquy between Mr. Shires and defendant's counsel).[90]

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[89]Hydrodynamics is "how waves, currents, [and] physical forces act on the ocean and Great Lakes system to produce motions in those bodies." Tr. 314:3-5 (Meadows).

[90]Plaintiffs' expert witness, Dr. Mackey, gave contradictory testimony as to whether sediment budgets can be used to determine shoreline composition. Dr. Mackey first agreed "that a sediment budget can be used to assist in the definition of a cohesive shoreline." Tr. 717:7-10 (colloquy between Dr. Mackey and defendant's counsel). After asking if he could clarify this testimony, Dr. Mackey then stated: "I do not believe that a sediment budget can be used to assist in the definition of a cohesive shoreline, but I believe that a sediment budget can be used to assist in understanding the reasons why you have irreversible lake bed downcutting." Tr. 717:14-18 (Mackey). At the request of defendant's counsel, Dr. Mackey then read the following testimony from his deposition into the record:

> I don't believe that [a sediment budget] has a significant bearing in the Coastal Engineering Manual. It doesn't describe sediment budget as a definitive tool to determine whether or not a shoreline is cohesive or not. However, I do recognize that the volume of sand is important and it would be tied to sediment budget, and

Summarizing the findings he presented at the trial of liability, Dr. Nairn writes that "a sand budget approach, relying on longshore sand transport gradients (i.e.[,] defining the deficit in sand supply) was able to predict the observed historical erosion . . . . Therefore, . . . the [p]laintiffs' shore is indeed a predominantly sandy shore."[91] DX 155 (Nairn Composition Report) 16; see also Liability Op. 78 Fed. Cl. passim (discussing Dr. Nairn's sediment budget).

Plaintiffs do not propose an alternate sediment budget, see Pls.' Br. passim; Pls.' Resp. passim, but argue that "Dr. Nairn's opinions are based on manipulated and inaccurate data," Pls.' Br. 18. Specifically, plaintiffs argue that Dr. Nairn has incorrectly modeled the flow of river sediment into plaintiffs' zone, that only under rare conditions would littoral sand bypassing the jetties return to shore and that certain large areas of shore protection considered in Dr. Nairn's analysis were installed at a later date than Dr. Nairn believed. See id. at 18-20. Defendant responds that "[p]laintiffs misrepresent the record before the court." Def.'s Resp. 10.

In regard to the flow of river sand into plaintiffs' zone, plaintiffs question Dr. Nairn's testimony "that all river sand that gets to the end of the jetties[ ] turns left, makes it[s] way around the jetties and directly into the littoral drift aimed at [p]laintiffs' shores." Pls.' Br. 18. Plaintiffs cite to no evidence, however, to support their implicit suggestion that the river sand would not turn left at the mouth of the jetties as it encounters the prevailing water currents. See id. Plaintiffs instead argue that "sand samples taken in 1997 from lake bottom sand deposits just lakeward of the jetties and beyond the depth of

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> if you had a significant volume of sand, enough sand present that would permanently protect the underlying cohesive materials from erosion or lake bed downcutting, that's where I could see that a sediment budget could be important, but having a sediment budget put together is not necessary to define a cohesive shoreline.

Tr. 719:15-720:2 (Mackey). The court interprets Dr. Mackey's deposition testimony that "the volume of sand is important [when determining whether a shoreline is cohesive] and would be tied to sediment budget," and Dr. Mackey's recognition of the role of sand cover in protecting any underlying cohesive materials, see id., as expressions of his agreement that sediment budgets can be useful--if not necessary--in distinguishing sandy shorelines from cohesive shorelines.

[91]Dr. Nairn revisited his sediment budget in light of the court's finding in its Liability Opinion "that the coarse fraction of the trucked sediment for beach nourishment was not effective." DX 155 (Nairn Composition Report) 3; see also Liability Op., 78 Fed. Cl. at 630; cf. infra Part III.C (discussing the Corps' mitigation efforts). Dr. Nairn "found that the sand budget approach still effectively explained, in a quantitative manner, the rate of erosion of the shore in the zone of the [p]laintiffs' properties." DX 155 (Nairn Composition Report) 3-4; see also DX 155 (Nairn Composition Report) 25, Table 3.2 (revised sediment budget). Plaintiffs do not argue that Dr. Nairn has improperly incorporated the findings in the court's Liability Opinion. See Pls.' Br. passim; Pls.' Resp. passim.

closure[92] were consistent with sand that came from the St. Joseph River." Id. (footnote added). Plaintiffs contend that "[t]o reconcile the data to his opinion, Dr. Nairn implausibly testified--without a shred of corroborative evidence--that the sampled sand was not river sand but sand dredged from the St. Joseph Harbor and dumped there 27 years earlier." Id.

Defendant is correct, however, that Dr. Nairn identified several bases for his conclusion that the river sand near the end of the jetties had been dredged from the harbor and placed there. Def.'s Resp. 10-11 (citing DX 1 (Nairn Report) at 3-53). At trial, Dr. Nairn testified that "the amount of dredge from the inner harbor and the outer harbor matches very closely the amount of growth or deposition in that zone . . . for each of the periods we consider." Tr. 2602:16-19 (Nairn). Dr. Nairn further testified that the coarse grain size in the samples discussed by plaintiffs is consistent with the grain size of sand in the river rather than sand that has been deposited by the river in deeper water. Tr. 2602:10-15 (Nairn).

Plaintiffs' argument that Dr. Nairn has incorrectly modeled the flow of littoral sediment into plaintiffs' zone is similarly unsupported by the evidence. Plaintiffs contend that "in conflicting testimony, Dr. Nairn embarrassingly admitted that the projected wave action required to move littoral material beyond and to the shore south of the St. Joseph jetties occurs on only 2.4 days per year . . . , which is hardly sufficient to bring that sand into the littoral drift on any regular basis." Pls.' Br. 19 (footnote omitted) (citing Tr. 2925:12-2931:21 (colloquy between Dr. Nairn and plaintiffs' counsel)); DX 1 (Nairn Report) App. A, Fig. A-20 (offshore wave rose); see also DX 1 (Nairn Report) App. A (Wave Distribution Table). Plaintiffs further argue that "[i]n contrast, Dr. Meadows testified the majority of waves do not move material close to the jetties to the [p]laintiffs' properties." Pls.' Br. 19.

Plaintiffs misinterpret Dr. Nairn's testimony. The waves described by plaintiffs as occurring only on 2.4 days per year are those projected to be traveling due south with a wave period[93] of eight to ten seconds. See DX 1 (Nairn Report) App. A (Wave Distribution Table). Dr. Nairn did not testify that waves traveling south can be expected to occur on only 2.4 days per year but, instead, that "for .652 percent of the time, you get waves of eight to ten seconds from a direction of zero degrees," Tr. 2931:2-4 (Nairn); cf. Tr. 377:24 (Meadows) (stating that "zero is out of the true north"), which Dr. Nairn

[92]"The depth of closure is a point from the shore beyond which there is never enough energy to move [sediment particles] again, that is, a point beyond the littoral zone." Liability Op., 78 Fed. Cl. at 611 (alteration in original) (citation and quotation marks omitted). The expert witnesses at the trial of liability estimated the depth of closure for the Lake Michigan coast differently, placing it between eighteen feet and more than sixty-six feet. Id.

[93]The wave period is the time that elapses between the passage of wave crests. Tr. 1632:17-24 (Shabica).

compared, metaphorically, to that particular type of wave occurring all day for 2.4 days per year, Tr. 2931:16-19 (Nairn). Plaintiffs appear to confuse the prediction Dr. Nairn generated by numerical modeling with the metaphor that he used to describe that prediction.

Plaintiffs also overlook waves approaching from the north but characterized by different wave periods. The chart Dr. Nairn was describing, see Tr. 2928:20-2929:1 (colloquy between Dr. Nairn and plaintiffs' counsel), is titled "Wave Distribution by Period and Direction," DX 1 (Nairn Report) App. A (Wave Distribution Table).[94] Each row represents waves approaching from a different direction. See id. The columns divide the waves into wave periods ranging from two to four seconds, four to six seconds, six to eight seconds, eight to ten seconds, ten to twelve seconds and more than twelve seconds. See id. Plaintiffs are describing waves that approach from the north with a wave period between eight and ten seconds. See id. When waves characterized by wave periods of two to four seconds, four to six seconds, six to eight seconds, ten to twelve seconds and more than twelve seconds are included in the total, waves traveling south (from a direction of zero degrees) occur not .652% of the time but 6.93% of the time, a more than tenfold increase. See id.

Furthermore, plaintiffs cite no evidence indicating that waves traveling due south are the only type of "wave action required to move littoral material beyond and to the shore south of the St. Joseph jetties"[95] and no evidence explaining why the percentage of waves traveling south is insufficient to carry littoral material from the end of the jetties to plaintiffs' zone. See Pls.' Br. 19 (stating, without citation to evidence, that the frequency of waves traveling south is "hardly sufficient to bring that sand into the littoral drift on any regular basis"). Instead, plaintiffs state, without further explanation, "In contrast, Dr. Meadows testified the majority of waves do not move material close to the jetties to the [p]laintiffs' properties." Id. (citing Pls.' Br. 28-29). The referenced portion of plaintiffs' Brief cites two pages of Dr. Meadows' trial testimony and--without explanation or page citation--Dr. Meadows' expert report. See id. at 29 (citing, inter alia, Tr. 377:5-378:27 (colloquy between Dr. Meadows and plaintiffs' counsel); PX 142 (Meadows Wave Condition Report)). In the two pages of Dr. Meadows' testimony cited by plaintiffs, Dr. Meadows discusses only the capacity of waves to carry nourishment material to

[94]The table to which the court refers as the "Wave Distribution Table" is on a page of Dr. Nairn's report with no page number, located two pages after Figure A-20. The table is titled "Wave Distribution By Period And Direction." DX 1 (Nairn Report) App. A (Wave Distribution Table).

[95]For instance, plaintiffs do not explain, see Pls.' Br. passim; Pls.' Resp. passim, why waves approaching at 22.5 degrees, which occur 13.03% of the time, or waves approaching from 337.5 degrees, which occur 4.70% of the time, see DX 1 (Nairn Report) App. A (Wave Distribution Table), do not play a role in carrying sediment south to plaintiffs' shoreline.

plaintiffs' zone if the material is placed directly south of the jetties in an area that he calls a "shadow zone." Tr. 377:5-378:17 (colloquy between Dr. Meadows and plaintiffs' counsel). Dr. Meadows does not testify in that portion of his testimony that the existing wave conditions would prevent littoral material from bypassing the jetties or describe the wave conditions necessary to carry littoral sediment from the end of the jetties to plaintiffs' zone. See id.; see also infra Part III.C.2.b (discussing the limitations of Dr. Meadows' analysis of wave conditions).

Plaintiffs' final argument regarding Dr. Nairn's analysis of shoreline behavior involves the role of large installations of shore protection constructed by the C&O Railroad (C&O) and the Michigan Department of Transportation (MDOT). See Pls.' Br. 19-20. Dr. Nairn explained in his initial expert report why shore protection must be taken into account when creating a sediment budget and assessing shoreline behavior:

> On an eroding shore, shore-based, shore-parallel shore protection (i.e.[,] constructed on or very near to the shore) only prevents erosion inshore and above the structure. Erosion of the lakebed will continue, whether it is sandy or cohesive. Therefore, when placed along an eroding shore, shore protection prevents sand that is inshore and above the protection from naturally entering the littoral system. The effect of this is to transfer that part of the natural erosion that was prevented by the shore protection, in addition to any harbor[-]influenced erosion . . . to the unprotected shores to the south.

DX 1 (Nairn Report) 4-138; see also id. at 4-120, Table 4.2 (listing bluff erosion rates during four time periods). Dr. Nairn therefore included in his calculations the effect of .7 miles of shore protection installed by C&O and one mile of shore protection installed by MDOT. Id. at 4-138. Plaintiffs allege that "Dr. Nairn assumed that the C&O and MDOT revetments affected the rate of bluff erosion (and the amount of sand entering the littoral system through bluff erosion) for the time period between 1871 and 1938." Pls.' Br. 19. Plaintiffs argue that "Dr. Nairn's assumption is fundamentally misconceived because C&O did not install its shore protection until 1929, which is 58 years after the start of Dr. Nairn's study period and only 9 years before that period ended." Id. (emphasis omitted). Plaintiffs further argue that "MDOT did not install any revetments until 1969, well after Dr. Nairn's study period." Id. at 19-20.

However, Dr. Nairn's report indicates that he was aware of when the MDOT and C&O shore protection measures began to affect the sediment supply to plaintiffs' zone. Dr. Nairn stated in his report that C&O completed the installation of its shore protection in 1929. See DX 1 (Nairn Report) 4-138 ("Upon completion of the full 0.7 mile (1.1 km) of shore protection for the railway line in 1929, approximately 10,000 cy/yr (7,600m^3/yr) was effectively trapped or prevented from entering the littoral system . . . ."). Although the details are not in Dr. Nairn's report, he stated, both in his report and at trial, that C&O installed some of its shore protection prior to finishing the .7-mile stretch in 1929. Id.

("Some time between 1871 and 1938 the railway was moved inshore, apparently in response to the erosion. . . . Its new position was also terraced into the eroding bluff, and therefore, once again, the shoreline below the railway would have had to be protected . . . ."); Tr. 2908:7-9 (Nairn) ("I think if we check the report, we'll see that there was some earlier protection before 1929.").

Nor is there any indication in Dr. Nairn's discussion of shore protection in his report that he assumed that the MDOT shore protection began to influence the sediment budget before the shore protection was, in fact, constructed. See DX 1 (Nairn Report) 4-138 to 4-140. Rather than assuming that the MDOT shore protection currently in place affected his sediment budget during the 1871 to 1938 time period, as plaintiffs suggest, Pls.' Br. 19-20, Dr. Nairn determined that "[t]his protection was constructed in the late 1960[s] to replace a groin system that was constructed after damages caused by storms in the 1940[s]," DX 1 (Nairn Report) 4-138 to 4-139. Applying his experience in coastal engineering, however, Dr. Nairn inferred that some of the MDOT revetments were likely installed at an earlier date. See id. at 4-138 (noting that, given the slope of the bluffs and the proximity of the highway to the edge of the bluff, that "at least the northerly half of the MDOT revetment would have had to be constructed almost immediately"). Accordingly, Dr. Nairn concluded that the "reduction in recession rate is mostly due to the implementation of shore protection along the railway and part of the highway shoreline toward the end of this period." Id. at 4-118.

Without explanation, plaintiffs cite the declaration of Mr. John Konik for the proposition that "MDOT did not install any revetments until 1969." Pls.' Br. 19-20 (citing, inter alia, PX 126 (Konik Aff.)).[96] Mr. Konik states in his affidavit that he is "the Chief of the Regulatory Office, U.S. Army Corps of Engineers . . . , Detroit District." PX 126 (Konik Aff.) ¶ 1. Mr. Konik states that "[t]he responsibilities of the Detroit District Regulatory Office include the processing of permit applications submitted under . . . Section 10 of the Rivers and Harbors Act of 1999." Id. ¶ 2. The construction of certain shore protection structures, including revetments, requires the permission of the Corps. Id. ¶ 5. Mr. Konick lists the permits that the Corps has granted to MDOT. Id. ¶ 18. The first permit for the construction of "a stone sea wall" was granted in 1969. Id. However, Mr. Konik also states that "there are alternate forms of authorization used in certain prescribed situations." Id. ¶ 9. One alternate form of authorization is the "[l]etter[] of permission," which "may be used where, in the opinion of the district engineer, the proposed work would be minor, not have significant individual or cumulative impact on environmental values, and should encounter no appreciable opposition." Id. Another form of authorization is the "general permit," which is not issued to individual applicants, but rather allows specific activities in a particular geographical area. Id. ¶ 10. Additionally, before the enactment of the National Environmental Policy Act in 1969 and the Federal Water Pollution Control Act of 1972 in 1974, id. ¶ 12, "if it was decided that

[96]The affidavit of Mr. Konik was admitted without objection. Tr. 2911:6 (court).

the proposed work would have no impact on navigation, a Department of the Army permit would not have been required," id. ¶ 11. Plaintiffs cite no evidence that indicates that MDOT did not install revetments prior to 1969 pursuant to a letter of permission, a general permit or a determination that the revetments would have no impact on navigation. See Pls.' Br. 19-20.

The court finds plaintiffs' criticisms of Dr. Nairn's sediment budget unpersuasive, particularly in light of plaintiffs' failure to introduce a competing sediment budget, numerical model of erosion, hydrodynamic model of wave conditions or any other comprehensive assessment of the erosional behavior of the shoreline in plaintiffs' zone. See Pls.' Br. passim; Pls.' Resp. passim. Dr. Nairn's study of the erosional behavior of plaintiffs' shoreline provides highly persuasive evidence that the shoreline in plaintiffs' zone should be categorized as a sandy shoreline.

Plaintiffs bear the burden of demonstrating "that a taking has occurred justifying the payment of just compensation." Loesch, 227 Ct. Cl. at 44, 645 F.2d at 914. The additional evidence of shoreline composition presented by plaintiffs is unpersuasive and, at times, repetitive of evidence rejected by the court in the past. See supra Part III.B.2. In contrast, the government has presented additional evidence of shoreline composition that the court finds persuasive. Based on credible and persuasive evidence, the court finds that plaintiffs' properties are located in an area of sandy shoreline, with the exception of the Werger property, which defendant's expert witness, Dr. Nairn, locates along a section of cohesive shoreline. See DX 155 (Nairn Composition Report) 31.

C. Mitigation

1. The Proportion of the Erosion Caused by the Jetties

This case has been bifurcated to allow the issues of liability and damages to be treated separately. Following the trial of liability, the court found that, if unmitigated, the jetties are responsible for 30% of the erosion taking place in plaintiffs' zone. Liability Op., 78 Fed. Cl. at 654-57. Notwithstanding the court's finding, plaintiffs now argue that "the United States is responsible for between 60% and 70% of the erosion to [p]laintiffs' properties." Pls.' Br. 23. Plaintiffs have not filed a motion for reconsideration on the scope of the government's liability. See Pls.' Damages Trial Mem., Dkt. No. 264, passim (requesting reconsideration on the issue of shoreline composition but not requesting reconsideration of the scope of the government's liability). It therefore remains the law of this case that, if unmitigated, the jetties are responsible for 30% of the erosion taking place in plaintiffs' zone.

Plaintiffs do not acknowledge that it is the law of the case that, if unmitigated, the jetties are responsible for 30% of the erosion taking place in plaintiffs' zone. See Pls.' Br. passim; Pls.' Resp. passim. Neither do plaintiffs list the three "exceptional circumstances," Mendenhall, 26 F.3d at 1582 (internal quotation marks omitted), that

may warrant departure from the law of the case or argue that any of the three is present, see Pls.' Br. passim; Pls.' Resp. passim.

Plaintiffs do cite one line of evidence that plaintiffs allege was not available at the trial of liability, arguing that dredging records "obtained in the damages phase of this matter demonstrate that the United States is responsible for between 60% and 70% of the erosion to Plaintiffs' properties." Pls.' Br. 23; cf. DX 34a (updated dredging data). However, Dr. Nairn's initial expert report contained a thorough analysis of the sediments dredged from the St. Joseph Harbor since the 1860s. See DX 1 (Nairn Report) 3-47 to 3-49, 3-85 to 3-86. Plaintiffs do not argue that the dredging data analyzed by Dr. Nairn were unavailable to them before the trial of liability. See Pls.' Br. passim; Pls.' Resp. passim; cf. DX 34 (dredging data presented at the trial of liability). Nor do plaintiffs explain how the dredging data now available differ from the data available to plaintiffs at the trial of liability. See Pls.' Br. passim; Pls.' Resp. passim.

Plaintiffs' expert witness, Dr. Mackey, examined the percentage of the dredged material dumped at a confined disposal facility against the percentage used for mitigation, concluding that the dredged material contains more sandy material appropriate for beach nourishment than Dr. Nairn calculated. PX 140 (Mackey Response to Nairn) 8-10.[97] However, plaintiffs do not state that records of where dredged material was dumped were unavailable before the previous trial. See Pls.' Br. passim; Pls.' Resp. passim. Dr. Mackey also concludes, on the basis of the dredging records, that Dr. Nairn's estimate of the quantity of sediment delivered to the inner harbor by the St. Joseph River

[97]The court finds Dr. Mackey's use of dredging records to determine the sand content of the dredged materials speculative. Dr. Mackey states that "[t]ypically, contaminated sediments, fine-grained materials (silts and clays), and/or materials with a high organic content are placed in a [confined disposal facility] to minimize impacts to the environment. In most cases, clean sand that contains a low percentage of silt and clay will be suitable for beach nourishment and/or open lake disposal." PX 140 (Mackey response to Nairn) 8. Dr. Mackey does not state what qualifies as a "low percentage of silt and clay." See id. Dr. Mackey states that "for the period 1978 to 2004, there were 13 years where no dredged materials were placed in the CDF and all of the dredged materials were placed in the littoral zone for beach nourishment," and, from this, assumes that the dredged materials have "100% sand content (otherwise the materials would not have been used for beach nourishment)." Id. Observing that, between 1978 and 2004, approximately 30% of the dredged sediment was sent to a confined disposal facility and that approximately 70% of the sediment was used for mitigation, Dr. Mackey concludes that the dredged material consists of 70% sand. Id. at 9. However, if dredged sandy material is suitable for beach nourishment when it "contains a low percentage of silt and clay," id. at 8, and if "[s]and is a valuable commodity," making it "unlikely that dredged material consisting of clean sand would be placed in a [confined disposal facility] unless it was either contaminated or had a high silt-clay/organic content," id. at 9, Dr. Mackey's assumption that dredged material used for mitigation is 100% sand appears improbable.

is 15% too low.[98] See PX 140 (Mackey Response to Nairn) 8-10. Plaintiffs do not state, however, how this figure differs from the figure that could have been derived from dredging records available to them at the trial of liability had they retained Dr. Mackey at that time to make such a calculation. See Pls.' Br. passim; Pls.' Resp. passim. Plaintiffs therefore provide the court no basis on which to conclude that the dredging data they cite contains new information that warrants a departure from the law of the case.

The balance of the evidence relied upon by plaintiffs for their contention that the jetties cause 60 to 70% of the erosion to plaintiffs' properties consists of expert opinions that also could have been presented at the trial of liability. See Pls.' Br. 21-25. Dr. Mackey, observing the types of soil at the surface in the watershed that feeds the St. Joseph River and its tributary, the Paw Paw River, concludes that the sediment carried by the St. Joseph River contains a larger sand component than Dr. Nairn determined. See PX 140 (Mackey Response to Nairn) 3 (stating that Dr. Nairn "significantly underestimated by 35 to 40%" the amount of sand the St. Joseph River contributes to the littoral zone). Dr. Mackey buttresses this conclusion by estimating that the dams along the St. Joseph and Paw Paw Rivers trap less sand than Dr. Nairn determined, see id., and by stating that higher water flows during storms and snow melt would cause the rivers to carry more sediment than Dr. Nairn determined,[99] see id. at 8 (describing the role of

[98]The 15% discrepancy between Dr. Nairn's prediction of the volume of sediment delivered to the inner harbor by the St. Joseph River and Dr. Mackey's calculation of the amount of sediment dredged from the "inner harbor and outer channel," PX 140 (Mackey response to Nairn) 9, is, based on an analysis by Dr. Nairn, likely due to littoral material that was washed into the outer channel and dredged, see Tr. 2712:18-2713:12 (Nairn) (stating that, although Dr. Mackey assumed otherwise, "a large majority of [the sediment dredged from the outer channel] comes from the littoral sediment transport"). After conducting numerical modeling of the hydrodynamics in the area adjacent to the jetties, Dr. Nairn concluded that littoral material enters the outer channel. See Tr. 2712:18-2713:3 (Nairn); cf. Tr. 407:23-408:1 (colloquy between Dr. Meadows and defendant's counsel) (agreeing that Dr. Nairn conducted "a transport model, [two-dimensional] hydrodynamic and sediment transport model"). Neither Dr. Mackey, see PX 140 (Mackey response to Nairn) passim, nor Dr. Meadows, Tr. 407:17-19 (colloquy between Dr. Meadows and defendant's counsel), claims to have performed any such analysis to determine whether sediment deposited in the outer channel was deposited by the river or by the littoral stream.

[99]Plaintiffs imply that Dr. Mackey's opinions should carry additional weight on this topic because Dr. Mackey is "the only recognized fluvial sedimentology expert presented at trial." Pls.' Br. 25; see also supra note 9 (stating that the court qualified Dr. Mackey as an expert in, among other areas, "riverine processes in fluvial sedimentology."). However, calculation of sediment transport is within the areas of expertise in which the court found Dr. Nairn to be qualified. See supra note 9 (stating that the court qualified Dr. Nairn as an expert in, among other areas, "sediment transport for sediment budgets," "numerical modeling for . . . sediment transport" and "river engineering"). Dr. Nairn provided both "[a] detailed hydrodynamic model . . . and an associated sediment transport model . . . to evaluate sediment movement

"episodic events" and "flood pulses"); Tr. 2957:2-2958:8 (Mackey) (describing the role of "pulses" caused by major storms and snow melt). Plaintiffs could have presented this type of evidence at the trial of liability; defendant, in fact, did so. See, e.g., DX 1 (Nairn Report) 3-67 to 3-108 (describing Dr. Nairn's analysis of sediment delivered to the littoral zone by the St. Joseph River).

The court is not compelled by "the discovery of new and material evidence," Toro Co., 383 F.3d at 1336, or by a determination that its previous finding is "is clearly incorrect and its preservation would work a manifest injustice," id. (quotation marks omitted), to depart from its conclusion that, if unmitigated, the jetties are responsible for 30% of the erosion in plaintiffs' zone.

2. The Effectiveness of Defendant's Mitigation Efforts

In its Liability Opinion, the court found that the Corps began to place dredged material in the littoral zone south of the jetties in 1970. Liability Op., 78 Fed. Cl. at 654-55. In 1972, the Corps began "sidecasting" dredged material into the littoral zone by extending a pipe over the south jetty and pumping dredged material through it. Id. at 654. In 1976, the Corps began a formal mitigation program to place beach nourishment materials in the littoral zone, replacing the sand blocked by the jetties. Id. at 655. Noting that "the Corps' effect on erosion is at issue and not the purpose of measures that could [a]ffect mitigation; mitigation incidental to another activity carries no less weight than purposeful mitigation," the court found that mitigation of the erosion caused by the jetties began in 1970. Id. The question now before the court is the effectiveness of defendant's mitigation efforts in preventing the erosion that would have been caused by the jetties.

Defendant argues that the sediment budget developed by Dr. Nairn "demonstrates that, since 1970, the Corps of Engineers' beach nourishment program has fully compensated for the impact of any erosion the jetties at the St. Joseph Harbor have caused." Def.'s Br. 14. In fact, Dr. Nairn determined that the volume of beach nourishment material placed by the Corps has more than compensated for the volume of material removed by the jetties since 1970. See Tr. 2746:25-2747:1 (stating that the sediment budget "shows that there was no impact since 1970"); Tr. 2831:2-24 (Nairn) (stating that, omitting the coarse fraction of the nourishment materials trucked in by the Corps, "there is still an overall surplus"); DX 155 (Nairn Composition Report) 25, Table 3.2 (revised sediment budget), columns xxi(a), xxi(b) (reflecting that the net result of the

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through the harbor and into the nearshore zone," DX 1 (Nairn Report) 3-86, as well as a form of numerical modeling known as a Soil and Water Assessment Tool (SWAT) that examines the behavior of the watershed as a whole over time, incorporating changes in land use and the construction of dams, see id. at 3-73 to 3-84 (summarizing results of SWAT model); id. at App. A (model descriptions). In contrast, Dr. Mackey does not claim to have conducted additional measurements or numerical modeling of the sediment load of the St. Joseph River. See PX 140 (Mackey response to Nairn) passim.

sand removed from the littoral system by the jetties and the sand added to the littoral system by the Corps' placement of beach nourishment materials is a net gain in sand in Dr. Nairn's study area).[100] Although not argued by defendant, see Def.'s Br. passim; Def.'s Resp. passim, Dr. Nairn also determined that the rate of lakebed downcutting in much of plaintiffs' zone was lower in the time period after mitigation began, confirming Dr. Nairn's view of the effectiveness of the mitigation program, see DX 155 (Nairn Composition Report) 4-131.

Notwithstanding the evidence presented by defendant that the mitigation program has been successful, plaintiffs argue that the mitigation program cannot have been effective because the Corps failed properly to administer it and because local wave conditions prevent nourishment materials from reaching the shoreline. Pls.' Br. 26-31. Summarizing the alleged flaws in defendant's mitigation program, plaintiffs conclude that "there is no actual nourishment program. Rather, there is a dredging program, and not one of the key factors for an effective beach nourishment program . . . are taken into account." Id. at 30.

a. Administration of the Mitigation Program

Plaintiffs have not created their own sediment budget or modified Dr. Nairn's sediment budget to reflect the deficiencies that plaintiffs allege exist in the Corps' mitigation program. See Pls. Br. passim; Pls.' Resp. passim. Nor have plaintiffs developed a comprehensive study of the effectiveness of the Corps' mitigation program. See Pls. Br. passim; Pls.' Resp. passim. Instead, plaintiffs simply assert that, because of flaws in the implementation of the Corps' mitigation program, "the United States' mitigation efforts have been unsuccessful." Pls.' Br. 26 (capitalization omitted).

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[100]Dr. Nairn explained that the last two columns of the sediment budget estimate the impact of the jetties, in each time period, expressed as the volume of sand the jetties prevented from entering the littoral zone south of the jetties. See Tr. 2747:2-8 (Nairn); DX 155 (Nairn Composition Report) 25, Table 3.2, columns xxi(a), xxi(b). In the time period between 1946 and 1969, which, Dr. Nairn explained, provides the best estimate of the impact of the jetties between 1950 and 1970, see Tr. 2747:2-4 (Nairn), the last two columns indicate that the jetties reduced the supply of littoral material, see Tr. 2747:2-15 (Nairn); DX 155 (Nairn Composition Report) 25, Table 3.2, columns xxi(a), xxi(b).

The Corps began its mitigation efforts in 1970, placing an average of 74,000 cubic yards per year of nourishment material between 1970 and 1991 and 35,000 cubic yards per year between 1992 and 2005. See DX 155 (Nairn Composition Report) 25, Table 3.2, column viii. Averaging the impact of the Corps' activities--the impact of the harbor as offset by the placement of nourishment material--during the 1970 to 1991 time period with the impact of the Corps' activities during the 1992 to 2005 time period reveals that they resulted in a net gain of sediment to the area south of the jetties. See Tr. 2831 (Nairn); DX 155 (Nairn Composition Report) 25, Table 3.2, columns xxi(a), xxi(b).

However, the only comprehensive examination of the results of the Corps' mitigation efforts, created by Dr. Nairn, indicates that defendant has successfully mitigated all of the erosion damage caused by the jetties to properties located along sandy sections of shoreline since 1970. See DX 155 (Nairn Composition Report) 25, Table 3.2 (revised sediment budget). Dr. Nairn reached this conclusion based both on the erosion rates he projected by creating a sediment budget and the erosion rates directly observed in plaintiffs' zone. See id., columns xxi(a), xxi(b) (showing projected and historical erosion rates from 1836 to 2005).

Plaintiffs' criticisms of the Corps' mitigation program are unpersuasive. Plaintiffs argue that "beach nourishment requires, at a minimum, yearly monitoring of beach conditions at the nourished site."[101] Pls.' Br. 27. Plaintiffs allege that there were gaps of up to 18 months in placement of nourishment materials and that a portion of the dredged material was placed at a disposal facility or used for construction purposes rather than being placed in the littoral zone. Id. at 28. Plaintiffs also contend that, "[a]s established in the liability phase of the trial, beach nourishment material must have the same physical properties as the natural material on the beach and nearshore." Id. at 27 (citing, inter alia, Liability Op. 78 Fed. Cl. at 630). Plaintiffs assert that "a substantial portion of the beach nourishment placed by the United Stated did not have the same physical properties at the natural material." Id.

However, because "the Corps' effect on erosion is at issue," Liability Op., 78 Fed. Cl. at 655, rather than the techniques used by the Corps to mitigate erosion, the ultimate issue is whether the Corps' mitigation efforts have been successful. Plaintiffs have developed no comprehensive study of the effect of the mitigation program to dispute the sediment budget developed by Dr. Nairn.[102] See Pls.' Br. passim; Pls.' Resp. passim. Dr.

[101]On the following page of plaintiffs' Brief, plaintiffs cite a document titled "Annual Report on the Section 111 Beach Nourishment Monitoring Program" (1999 Report). See Pls.' Br. 28 (citing PX 41 (1999 Report)); cf. PX 41 (1999 Report) 5 (discussing prior funding "for several years" of "annual monitoring"). Plaintiffs do not explain why the monitoring discussed in the 1999 Report is inadequate. See Pls.' Br. 26-30.

[102]Although plaintiffs have not developed a comprehensive study of the effectiveness of the Corps' mitigation program, plaintiffs argue that defendant has admitted that the program is ineffective. See Pls.' Br. 28-29. Plaintiffs cite the following statement from a 1996 Corps report co-authored by Dr. Nairn: "these [mitigation] techniques were developed for sandy shores and may not provide the protection required by the cohesive shorelines that exist at St. Joseph." Id. at 29.

Notwithstanding the foregoing, the court has concluded that, with one exception, plaintiffs' properties are located along a sandy shoreline. See supra Part III.B. Plaintiffs rely on the conclusion of the Federal Circuit that "the Corps issued reports in 1996, 1997 and 1999 that 'collectively indicated that erosion [due to the government's construction of jetties at St. Joseph Harbor] was permanent and irreversible." Pls.' Br. 29 (alteration in original) (quoting Accrual

Nairn's sediment budget indicates that, regardless of any potential flaws in the Corps' program, it has been effective.[103] See DX 155 (Nairn Composition Report) 25, Table 3.2 (revised sediment budget). Furthermore, the court finds plaintiffs' criticisms of the Corps' mitigation program unpersuasive.

In its Liability Opinion, the court found that "the nourishment program needs to provide sediment that has the same physical characteristics as the shore that is to be nourished." Liability Op., 78 Fed. Cl. at 630 (internal quotation marks omitted). Plaintiffs are correct that some of the nourishment material placed by the Corps was

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Op. II, 314 F.3d at 1305). Not only is there a "sharper focus" on plaintiffs' zone and the issues of this case in the expert witnesses' reports and trial testimony than in publications unrelated to the case, see supra note 48, but the court has determined that the Federal Circuit addressed only the accrual of plaintiffs' claims--not whether erosion caused by the jetties was in fact permanent and irreversible, see supra note 37. Plaintiffs cite no evidence that persuades the court that the mitigation program was uniformly ineffective for the entire area downdrift of the jetties, notwithstanding variations in shoreline composition or proximity to the jetties and the beach nourishment material. See Pls.' Br. 28-29; cf. DX 155 (Nairn Composition Report) 12 (describing an area of cohesive shoreline north of plaintiffs' zone).

Plaintiffs also argue that an open file report published by the United States Geological Survey shows "little evidence of sand reaching the [p]laintiffs' properties, other than in the immediate vicinity of the beach nourishment site." Pls.' Br. 29 (citing Tr. 613:3-615:2 (colloquy between Dr. Mackey and plaintiffs' counsel); PX 136 (Mackey Report) 9, Fig. 6 (map showing accretion and erosion of lakebed adjacent to plaintiffs' properties between 1945 and 1991)). Plaintiffs misunderstand the significance of Dr. Mackey's testimony. Dr. Mackey testified that there had been lakebed downcutting in plaintiffs' zone, visible as a change in bathymetry. Tr. 612:4-19 (Mackey). Dr. Mackey also testified that there had been a net accretion of sediment immediately south, west and offshore from where nourishment material had been placed. Tr. 612:9-14 (Mackey). Dr. Mackey testified that "[w]hat we don't see is accretion or accumulation of material to the south." Tr. 612:14-15 (Mackey). However, the ongoing downcutting discussed by Dr. Mackey does not indicate that defendant's mitigation efforts have been unsuccessful. Even if defendant mitigates the portion of the erosion caused by the jetties, which only accounts for 30% of the erosion taking place in plaintiffs' zone, see Liability Op., 78 Fed. Cl. at 654-57, erosion caused by natural processes and exacerbated by large installations of shore protection, see DX 1 (Nairn Report) iii-iv, can be expected to continue and to prevent the widespread accumulation of nourishment material.

[103]Dr. Nairn notes in the report he prepared for the trial of liability that, notwithstanding the Corps' mitigation efforts, overall erosion rates have increased over time. See DX 1 (Nairn Report) 4-132. This is due to a number of factors, including high lake levels in the 1970s and 1980s and the resulting installation of shore protection by a large number of landowners--including the C&O and MDOT. See id. at 4-156-57. Controlling for such factors, Dr. Nairn concludes that the rate of erosion since the commencement of mitigation efforts has been approximately equal to the "pre-harbor erosion rate." Id. at 4-156 to 4-157.

transported from elsewhere and was, on average, more coarse than the natural material on which it is placed. Id. at 629. The court found that the coarse sediment is "at best ineffective and will not be considered part of mitigation as to plaintiffs' properties." Id. at 630. In light of the court's finding, Dr. Nairn revised his sediment budget, examining the grain size distribution of the sediment brought from elsewhere to determine how much of it was too coarse to be effective nourishment material.[104] DX 155 (Nairn Composition Report) 19-23. After determining that 50% of the sediment was too coarse to serve as effective nourishment material under the court's ruling, id. at 23, Dr. Nairn concluded that, regardless, the Corps had completely mitigated the erosion caused by the jetties, see id. at 26 (stating that "from 1970 to 2005[,] more sand was supplied than necessary to compensate for the impact of the harbor and operations"); cf. id. at 25, Table 3.2 (revised sediment budget). Plaintiffs do not contend that Dr. Nairn has inaccurately calculated the portion of trucked sediment that the court found ineffective as nourishment material at the trial of liability. See Pls.' Br. 26-30.

Plaintiffs argue that gaps in the beach nourishment program "exacerbated the already sand[-]starved condition of [p]laintiff[s'] zone, which contributed to further lakebed downcutting." Id. at 28 (citing Tr. 616:3-15 (colloquy between Dr. Mackey and

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[104]Dr. Nairn argues in a report drafted after the trial of liability that all of the trucked sediment should be considered effective nourishment material:

> [T]here are four lines of evidence that the gravel component of the trucked sediment should be considered as effective nourishment: a) there is gravel in the eroding sediment that is naturally supplied to the littoral zone; b) there is gravel on the beaches that would appear to be derived from the natural source noted in (a); c) the sediment budget predictions match the actual eroded volume of sediment more closely when all of the trucked sediment is considered as effective; and, d) the technical literature on beach nourishment notes coarser sediment (i.e.[,] gravel in this case) is effective, and in fact, more erosion resistant when placed as beach nourishment.

DX 155 (Nairn Composition Report) 4; cf. Liability Trial Transcript 130:20-131: 2 (Meadows) (stating that nourishment material should "be of a coarser gain size, something that will stay on the beach."). The court, in its Liability Opinion, based its conclusion that coarse sediment was ineffective nourishment material on a statement in a Corps report that that court interpreted as an admission that nourishment material should "'have the same physical properties' as the natural material on the beach and nearshore." Liability Opinion, 78 Fed. Cl. 78 at 630 (quoting PX 41 (1999 Report) 4). Because neither Dr. Nairn, see DX 155 (Nairn Composition Report) passim, nor defendant, see Def.'s Br. passim; Def.'s Resp. passim, argues that evidence discovered since the trial of liability requires the conclusion that coarse sediment is effective nourishment material, and because Dr. Nairn concluded that--regardless of whether the coarse sediment is excluded from the calculations--the Corps has provided sufficient nourishment material, the court does not reexamine its findings regarding coarse sediment. See supra Part II.D (discussing the law of the case doctrine).

plaintiffs' counsel)). However, plaintiffs do not attempt to quantify the effect of the gaps in beach nourishment and do not state how often they occurred. See Pls.' Br. 26-30; cf. Tr. 616:7-10 (Mackey) (stating that "if you put a pile of sand in the littoral zone[,] it will gradually erode away, but if you do it on a fairly regular basis[,] you will maintain a fairly continuous sediment supply," but not stating whether the gaps in nourishment were sufficiently long for the piles of nourishment material to fully "erode away"). Furthermore, plaintiffs' theory that gaps in the nourishment program made the program ineffective appears to be premised on the lakebed adjacent to their properties being cohesive, which the court has found, with one exception, to be incorrect. See supra Part III.B. (discussing shoreline composition). In the testimony cited by plaintiffs, Pls.' Br. 28, Dr. Mackey testified that "if you have gaps in the beach nourishment program[,] you're going to have gaps in the sediment supply[,] which will cause thinning of the near shore sands and exposure of the underlying cohesive materials and actually accelerate the lake bed downcutting process," Tr. 616:11-15 (Mackey). Sandy shorelines erode differently than cohesive shorelines and can reconstitute themselves over time. See supra Part III.B.3.d (discussing shoreline behavior). Plaintiffs do not analyze the effect of gaps in the placement of beach nourishment materials on a sandy shoreline.[105] See Pls.' Br. passim; Pls.' Resp. passim.

b. Wave Conditions and Placement of Nourishment Material

[105]Plaintiffs also state that, by dredging the harbor for 90 years before beginning mitigation activities, Pls.' Br. 27-28, defendant "created an enormous deficit of sand south of the jetties, which has to be taken into account before a beach nourishment program could even begin to be effective," id. at 28. In support of this proposition, plaintiffs cite the dredging records and a single page of the 1999 Report. Id. (citing PX 41 (1999 Report); DX 34a (updated dredging data); DX 1 (Nairn Report) App. B, Fig. B.10 (dredging history)). The referenced page of the 1999 Report states, "At several of the older harbors, it is theorized that this long period of sand removal from the littoral system may have created an enormous deficit in the sand supply, triggering lake bed downcutting that may have contributed to the creation of areas of severe and continuing erosion." PX 41 (1999 Report) 3. Plaintiffs overstate the significance of the referenced page of the 1999 Report. First, the 1999 Report states only that "it is theorized" that the period of sand removal "may have" created a deficit in sand supply. Id. The court finds the sediment budget and numerical modeling developed by Dr. Nairn after specifically studying plaintiffs' zone more persuasive than the theoretical possibility that a deficit in sand supply may undermine mitigate efforts. Second, the report was discussing the effect of harbors on cohesive shorelines, as the title of the section, "Cohesive Coastlines and Lakebed Downcutting," makes clear. Id. at 2. On the page following the page referenced by plaintiffs, the 1999 Report examines the relationship between the effectiveness of mitigation and "[t]he length of time between harbor construction and the beginning of mitigation." Id. at 3-4. The report notes that "[f]or the harbors located along cohesive coastlines in particular[,] this has likely contributed to sand loss and downcutting." Id. at 4. The court has concluded, however, that with the exception of one property, plaintiffs' properties are located along a sandy shoreline. See supra Part III.B.

Plaintiffs also argue that "the effectiveness of beach nourishment also depends on the orientation of waves." Pls.' Br. 29. Plaintiffs state that the jetties diminish the energy of waves approaching from the north and northwest, creating a "shadowing effect." Id. Plaintiffs state that "[t]hese waves are prevalent and, therefore, placing beach nourishment close to the jetties diminishes its effectiveness." Id. Plaintiffs conclude that, "[c]onsistent with this principle, the Corps (and Dr. Nairn) recommended that beach nourishment be placed at Shoreham, much further south from the St. Joseph jetties than the current placement site." Id. Defendant responds that "[p]laintiffs' experts concede that their analysis did not constitute an effort to precisely locate each wave in the shadow zone, but was merely illustrative of the problem of a shadow zone generally." Def.'s Br. 14. Relying on hydrodynamic modeling performed by Dr. Nairn, defendant argues that nourishment material is, in fact, carried south to plaintiffs' zone notwithstanding the shadow zone south of the jetties. See id. at 14-15.

In his report, plaintiffs' expert witness, Dr. Meadows, writes that "[a]reas of coastline that are artificially sheltered from incident wave action (shadow zones) become traps of sediment, receiving insufficient energy to move nearshore materials along the beach." PX 142 (Meadows Wave Condition Report) 1. Based on a wave rose[106] in the expert report that Dr. Nairn drafted for the trial of liability, Dr. Meadows calculated the frequency of waves approaching the shore from different directions. See id. at 3, 4, Fig. 2 (wave frequency chart). Eliminating waves that he believed would be blocked by the jetties, Dr. Meadows concluded that the nourishment material placed by the Corps "is exposed to direct wave attack and corresponding [southward transport] less than 19.65% of the time." Id. at 5. In contrast, "material placed in this same location is transported north [(]back toward the harbor structures) approximately 39.39% of the time." Id. at 6. As a result, "a good portion of the material that is placed there ends up causing this southern fillet to grow." Tr. 380:15-17 (Meadows).

However, Dr. Meadows' analysis "was intended to be demonstrative of the problem" created by shadow zones. Tr. 378:20-21 (Meadows). Dr. Meadows did not "determine the details of that transport." Tr. 407:15-19 (colloquy between Dr. Meadows and defendant's counsel). Dr. Meadows did not perform hydrodynamic modeling or conduct measurements of the actual wave conditions. See PX 142 (Meadows Wave Condition Report) passim. Dr. Meadows agreed that "all [he was] trying to show was if you put nourishment anywhere near a shadow zone, you can run into problems with the wave action." Tr. 410:12-15 (colloquy between Dr. Meadows and plaintiffs' counsel). Dr. Meadows further agreed that his "only opinion today is that the nourishment . . . should be placed well away from a shadow zone." Tr. 410:18-20 (colloquy between Dr. Meadows and plaintiffs' counsel).

[106]The wave rose in Dr. Nairn's report is a circular chart describing the frequency and height of waves approaching a specific location from various directions. See DX 1 (Nairn Report) App. A, Fig. A.20 (offshore wave rose).

In contrast, Dr. Nairn did perform hydrodynamic and sediment transport modeling, which Dr. Meadows agreed would allow Dr. Nairn to "determine the details of that transport." Tr. 407:10-408:4 (colloquy between Dr. Meadows and defendant's counsel). Dr. Nairn characterized Dr. Meadows' shadow zone analysis, which only considered the percentage of deepwater waves approaching from each direction, see PX 142 (Meadows Wave Condition Report) 4, Fig. 2 (wave frequency chart), as "very simplistic," Tr. 2609:19 (Nairn). Dr. Nairn employed his engineering firm's "in-house numerical model," called HYDROSED, which Dr. Nairn states "has been verified through laboratory experiments as well as field measurements and has been applied extensively to several projects by Baird & Associates in the past few years." DX 1 (Nairn Report) 3-50. Dr. Nairn explains that "[f]or a given wave condition, HYDROSED can provide a full spatial description of nearshore currents and sand transport around the harbor." Id.

Describing the results of his numerical modeling, Dr. Nairn disagreed with the hypothesis "that somehow if you place the sand in the wrong place and it goes to the north instead of the south, it's lost." Tr. 2611:16-21 (Nairn). Dr. Nairn explained that, because the angle at which the waves approach the shore changes as they encounter shallower water, northerly currents--those that approach from the north--strike the shore further north than Dr. Meadows determined.[107] See Tr. 2609:18-2610:2 (Nairn).

[107]Comparing Dr. Meadows' discussion of the shadow zones with Dr. Nairn's analysis of local wave conditions, defendant notes that "the analysis of wave movement in Plaintiffs' reports does not take into account the phenomena of refraction and diffraction, causing Plaintiffs' estimates of where and how waves strike the beach to be inaccurate." Def.'s Br. 14 (citations omitted). "Refraction is the changing of wave approach angle as the wave interacts with the bottom." Tr. 401:20-21 (Meadows). Diffraction is the "[c]hange in the directions and intensities of a group of waves after passing by an obstacle or through an aperture whose size is approximately the same as the wavelength of the waves." The American Heritage Dictionary of the English Language 506 (4th ed. 2000).

Dr. Meadows testified that he did not take into account the effect of refraction and diffraction on the waves as they approach the shore. Tr. 379:17-21 (Meadows). Dr. Nairn testified that "the more complex and accepted practice" for evaluating shadow zones is to "transfer the waves to shore" to determine more precisely where they will arrive. Tr. 2609:18-2610:2 (Nairn). Dr. Meadows stated that after submitting his expert report, he performed "back of the envelope calculations," Tr. 379:21-22 (Meadows), which led him to believe that as a result of refraction and diffraction, "the closer [a wave] gets to shore[,] the more it turns and the ultimate end is it will be travelling 15 degrees more to the north than it is in my diagram," Tr. 380:5-7 (Meadows). Dr. Meadows' failure to account for refraction and diffraction illustrates the limited utility of his analysis. Dr. Meadows' testimony describes a single principle rather than analyzing the range of factors that determine actual wave conditions and sediment transport. See Tr. 378:18-20 (colloquy between Dr. Meadows and plaintiffs' counsel) (stating that Dr. Meadows did not "attempt to precisely locate each wave in the shadow zone").

Although these northerly waves do split when they reach the shore, carrying some nourishment material to the north, this sediment is largely caught in an eddy, which carries the sediment north to the jetty, west along the jetty until the sediment rejoins currents traveling south, and then back to shore, Tr. 2608:17-2609: 17 (Nairn); see also DX 1 (Nairn Report) 3-59, Fig. 3.16(a), 3-60, Fig. 3.16(b) (maps showing nearshore currents and sand transport vectors during a storm from the northwest).

Dr. Nairn testified that southerly conditions--those in which currents approach from the south--occur "quite often," Tr. 2612:3-4 (Nairn), and also play a role in carrying nourishment material to plaintiffs' zone. As currents approach from the south, they move north toward the jetties, are deflected offshore by the jetties and slow as they move away from shore. Tr. 2612:2-14 (Nairn); see also DX 1 (Nairn Report) 3-61, Fig. 3.17(a), 3-62, Fig. 3.17(b) (maps showing nearshore currents and sand transport vectors during a storm from the southwest). As the currents slow, they deposit sand in a large bypassing shoal, Tr. 2612:11-14 (Nairn), where it accumulates, "waiting for northerly waves to then take it back into the system to the south," Tr. 2611:13-15; see also DX 1 (Nairn Report) 3-61, Fig. 3.17(a), 3-62, Fig. 3.17(b) (maps showing nearshore currents and sand transport vectors during a storm from the southwest).[108] Therefore, even when the currents reaching the dredging material are approaching from the south, "almost all of the dredged sand that may be carried in this direction will eventually return to the shore to the south via the southward-directed current and bypassing pathway." DX 1 (Nairn Report) 3-67.

Dr. Nairn confirmed his modeling by verifying that nourishment material that was carried north has not built up on the fillet beach south of the jetties. See Tr. 2613:11-22 (Nairn). Summarizing his findings, Dr. Nairn stated that, under southerly conditions, sand is directed toward the fillet beach south of the jetties:

> We know it's not growing. [The sand gets] forced off into this . . . shoal. We know it's not growing. We're tracking its growth. So, there's nowhere else that the nourishment sand can go but [south] during the northerly waves [and] come back, as I've shown, to reach the shoreline and continue to the south.

[108]Plaintiffs argue that the role of storms must be "carefully considered and taken into account in a beach nourishment program." Pls.' Br. 27. It is apparent, however, that Dr. Nairn examined the hydrodynamics of plaintiffs' zone under a variety of weather conditions and studied the impact of those hydrodynamics on the effectiveness of mitigation efforts. Dr. Nairn's trial testimony described wave conditions during two different types of storms, one approaching from the southwest and one from the northwest. 2607:18-2613:22 (colloquy between Dr. Nairn and defendant's counsel); see also DX 1 (Nairn Report) 3-59 to 3-62 (maps showing nearshore currents and sand transport vectors during storms from the northwest and southwest). In all, Dr. Nairn examined hydrodynamic conditions under "58 different conditions of directions . . . in a variety of wave periods." Tr. 2614:15-18 (Nairn).

Tr. 2613:17-22 (Nairn). Plaintiffs offer no hydrodynamic modeling to contest Dr. Nairn's analysis. See Pls.' Br. passim; Pls.' Resp. passim.

Plaintiffs argue that, consistent with the practice of not placing nourishment material in a shadow zone, "the Corps (and Dr. Nairn) recommended that beach nourishment be placed at Shoreham, much further south from the St. Joseph jetties than the current placement site." Pls.' Br. 29 (citing, inter alia, PX 24 (1997 Report) 88). Plaintiffs are correct that the 1997 Report, authored by Dr. Nairn with others, see DX 40 (1997 Report) i, concluded that "[i]t would be much more effective to place the entire annual allotment of beach nourishment (or at least the trucked coarse sediment) [further south,] where it would be 100 percent effective in supplying the downdrift shores," id. at 88. The 1997 Report theorized that a large lakebed depression "has been a sink, possibly for up to 50 percent of the coarse sediment placed in the feeder beach area." Id. at 87. The 1997 Report also theorized that "perhaps as much as 50 percent of the sand placed in the feeder beach area (particularly dredged finer sediment) ends up back in the navigation channel from where it was originally removed (and will be removed again)." Id. The 1997 Report proposes that both of these problems could be avoided by placing nourishment material further south. See id. at 87-88.

Dr. Nairn has since determined that the findings of the 1997 Report are inaccurate. With respect to the nourishment material that the 1997 Report predicted would be carried into the navigation channel, Dr. Nairn noted that this conclusion was made "without the benefit of [two-dimensional] numerical modeling at the harbor mouth (of waves, currents and sediment transport) and sediment budget analysis performed in support of this report." DX 1 (Nairn Report) 3-66. This numerical modeling indicates that "when sand is transported towards the north . . . it will eventually encounter a stronger southward-directed current that extends off the end of the jetties." Id. at 3-66 to 3-67. Dr. Nairn further stated that "[i]f sand was being re-deposited in the navigation channel (i.e.[,] after it was dredged and placed on the south side of the jetties), then it would be expected that the dredging quantity for the outer channel would be accelerating rapidly." Id. at 3-67. However, "There is no indication of this kind of increase in the dredging record data." Id.

Regarding the coarse material that the 1997 Report concluded is lost to an offshore depression in the lakebed, Dr. Nairn testified at the trial of liability that "this was based on an 'incorrect assumption,' because a sand bar forms at the depression that 'provides the pathway or bridge for sediment to get through that . . . area.'" Liability Op., 78 Fed. Cl. at 640 (citations omitted). The "very prominent long shore bar" described by Dr. Nairn, Tr. 2626:13 (Nairn), is clearly visible on the bathymetric map contained in Dr. Nairn's report, see DX 1 (Nairn Report) 3-69, Fig. 3.19 (1999 bathymetric map). Dr. Nairn testified that the sand bar serves as "the delivery path for sand past the C&O railway revetment, past the end dock, towards the south of the [p]laintiffs' property.

So[,] that's sort of like the bridge or highway along which most of the sand runs now because there isn't a beach there." Tr. 2616:16-21 (Nairn).

Again, as at the trial of liability, plaintiffs "offer no expert critique countering Dr. Nairn's more recent conclusions about the [deposition of nourishment materials in the] depression," Liability Op., 78 Fed. Cl. at 640, or in the navigation channel, see Pls.' Br. passim; Pls.' Resp. passim. Apart from Dr. Meadows' description of the concept of shadow zones, plaintiffs do not offer any analysis of the local hydrodynamics that indicates that nourishment material is not carried south to their properties. See Pls.' Br. passim; Pls.' Resp. passim. Plaintiffs do not demonstrate where nourishment material is accreting over time if shadowing by the jetties prevents it from being carried south. See Pls.' Br. passim; Pls.' Resp. passim. Nor do plaintiffs dispute Dr. Nairn's conclusion, see DX 1 (Nairn Report) 3-67, that the dredging totals do not reflect a growing quantity of nourishment materials carried north into the navigation channel, see Pls.' Br. passim; Pls.' Resp. passim. Plaintiffs' argument that Dr. Nairn's testimony is "not credible" because he has reached different conclusions in prior research, Pls.' Br. 30 (capitalization omitted), is insufficient--without evidence contradicting his conclusions--to persuade the court that Dr. Nairn has doctored his conclusions for the purposes of this litigation, see supra note 85 (addressing plaintiffs' argument that Dr. Nairn's opinions are "bought and paid for" (quoting Liability Op., 78 Fed. Cl. at 618)).

In light of the evidence presented at trial, the court finds that, with regard to every property but the Werger property, which is located along a cohesive section of shoreline, see supra Part III.B, the Corps has successfully mitigated all of the erosion damage caused by the jetties between 1970 and the publication of Dr. Nairn's revised sediment budget in 2009.

D. Damages

1. The Ordinary High Water Mark

Because plaintiffs' properties are encumbered by the government's navigational servitude, no just compensation must be paid for erosion below and within the ordinary high water mark when the government acts to improve navigation. Liability Op., 78 Fed. Cl. at 655-57; see generally OHWM Op., 71 Fed. Cl. 501 (discussing the definition of the term "ordinary high water mark"). It is therefore necessary to determine what property has eroded above and outside of the ordinary high water mark.

To delineate the ordinary high water mark for plaintiffs' properties and the comparable properties considered by defendant's appraiser, Mr. Burgoyne, Dr. Nairn interpreted "historic aerial photography and satellite imagery."[109] DX 172 (Nairn

[109]Dr. Meadows also delineated the 1950 ordinary high water mark (OHWM) for plaintiffs' properties as part of his analysis of the volume of material plaintiffs' properties have

OHWM Report) 1. Dr. Nairn delineated the ordinary high water marks as they stood in "1950, 1970, 2000, 2009, the purchase date of the property, and sometimes the sale date of the property."[110] Tr. 2339:21-23 (Nairn).

Dr. Nairn explained at trial that the properties fell into three different types, which required him to use three different techniques to delineate the ordinary high water mark. See Tr. 2341:4-23 (Nairn); see also DX 172 (Nairn OHWM Report) 12-15 (describing the three techniques). When a property had shore protection, Dr. Nairn "delineated the ordinary high water mark along the shore protection."[111] Tr. 2343:4-6 (Nairn). When a property's nearshore was characterized by bluffs, Dr. Nairn "delineated the ordinary high water mark at the toe of the bluff . . . . Tr. 2343:8-10 (Nairn). Dr. Nairn noted that "often

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lost to erosion. See generally PX 143 (Meadows Volume Report); PX 144 (Meadows Revised Volume Report); see infra note 126 (discussing plaintiffs' theory of damages based on the volume of material lost to erosion); see also Tr. 333:3-6 (colloquy between Dr. Meadows and plaintiffs' counsel) (agreeing that Dr. Meadows delineated the ordinary high water mark only as it existed in 1950).

However, the expert witnesses retained by the parties to testify on the topic of damages both employed the ordinary high water mark as delineated by Dr. Nairn. Tr. 77:5-11 (colloquy between Mr. Burgoyne and plaintiffs' counsel) (agreeing that Mr. Burgoyne based his appraisals on the property dimensions determined by Dr. Nairn); see PX 149 (Moore Report) Ex. 2 (materials reviewed) (citing a summary of the appraisal reports provided by Burgoyne Appraisal Company, LLC, but not citing another source of ordinary high water mark data).

Dr. Meadows agreed at trial that he "didn't have any reservations with the method that Dr. Nairn used to calculate the areas of [p]laintiffs' properties," and that "the use of air photos and satellite images as a basis for developing the location of the ordinary high water mark provides the most consistent and dependable information." Tr. 400:11-20 (colloquy between Dr. Meadows and defendant's counsel).

[110]Dr. Nairn applied the following definition of the ordinary high water mark, which appears in a regulatory definition of "the 'ordinary high water mark' on non-tidal rivers:"

> the line on the shore as established by fluctuations of water and indicated by physical characteristics such as a clear, natural line impressed on the bank; shelving; changes in the character of the soil; destruction of terrestrial vegetation; the presence of litter and debris; or other appropriate means that consider the characteristics of the surrounding areas.

DX 172 (Nairn OHWM Report) 2 (quoting 33 C.F.R. 329.11(a)(1) (2009)); see generally OHWM Op., 71 Fed. Cl. 501 (discussing the definition of the ordinary high water mark).

[111]Where properties had sloping shore protection, Dr. Nairn testified that he delineated the ordinary high water mark at the "still water line," Tr. 2346:5-8 (Nairn), because it is "a clearly visible position." Tr. 2348:12-13 (Nairn).

there's a different color in soil, [or a] change in vegetation . . . ." Tr. 2343:8-12 (Nairn). When a property's nearshore area was characterized by sand dunes, which, in some cases, covered shore protection structures, the "[o]rdinary high water mark is defined as the edge of the vegetation. It's not just ephemeral vegetation, like young marine grass or dune grass, but it's the--it's the more permanent vegetation . . . ." Tr. 2343:16-22 (Nairn).[112]

Dr. Nairn plotted the ordinary high water mark "using GIS, geographic information systems, which is essentially a tool that allows you to work on screen with a digital map." Tr. 2344:3-5 (Nairn). When no aerial or satellite photograph was available for a particular year, Dr. Nairn interpolated the line position using "an interpolation technique within the GIS tools." Tr. 2350:2-3 (Nairn); see also Tr. 2350:12-14 (Nairn) (stating that, in contrast, Dr. Meadows "took the two paper maps from my [report presented at the trial of liability] and eyeballed the position between those two lines"). To calculate the size of a property at a particular date, Dr. Nairn used the ordinary high water mark and the property boundaries listed on the property records maintained by Berrien County. Tr. 2351:22-2352:3 (Nairn).

Between 1950 and 2000, the ordinary high water mark on eighteen of the forty parcels moved lakeward, meaning that eighteen properties were larger in 2000 than they were in 1950. DX 172 (Nairn OHWM Report) 54, Table 6.6 (table of property lost and gained); Tr. 76:18 (Burgoyne) ("Half the properties gained land."); Def.'s Br. 32 n.9. Dr. Nairn observed that the ordinary high water mark moved lakeward on two types of properties: those with shore protection built, not at the ordinary high water mark, but "out in the lake," and certain of the properties with sandy beaches. Tr. 2362:16-2363:10 (Nairn). Regarding the properties with beaches, Dr. Nairn explained that as lake levels rise and fall over time, "the ordinary high water mark is moving back and forth, not just inland as it would in a bluff case." Tr. 2363:11-13 (Nairn). Accordingly, "the 2000 and 2009 positions happen to be further lakeward in a lot of the sand properties to the south because the beach was bigger in 2000 than it was in 1950 in those cases." Tr. 2363:13-16 (Nairn).

2. Plaintiffs' Evidence of Damages Between 1950 and 2000: Econometric Analysis Performed by Dr. Moore

a. Dr. Moore's Analysis and Conclusions

[112]With regard to this third group of properties, Dr. Meadows measured to the outer edge of the more permanent vegetation to determine the ordinary high water mark. See Tr. 2344:17-20 (Nairn). Dr. Nairn measured to the inner edge of the more permanent vegetation. See Tr. 2344:20-23 (Nairn). Dr. Nairn explained that "[t]he difference between that is basically he's erring in favor of the [d]efendants and I'm erring in favor of the [p]laintiffs." Tr. 2344:23-25 (Nairn).

Because plaintiffs bear the burden of proving the amount of just compensation to which they are entitled for severance damage, Miller, 223 Ct. Cl. at 383-84, 620 F.2d at 828, the court first considers the evidence of damages presented by plaintiffs.

"The concept of just compensation . . . cannot be reduced to a formula . . . ." Ga.-Pac., 226 Ct. Cl. at 106, 640 F.2d at 336 (citing Miller, 317 U.S. at 375). Nor can just compensation "be confined to inexorable rules." Id. (citing United States v. Toronto, Hamilton & Buffalo Navigation Co., 338 U.S. 396, 402 (1949)). However, the "standard" method of proving severance damages is to determine the value of a property before and after a taking occurs. Id.; see United States v. Va. Elec. & Power Co., 365 U.S. 624, 632 (1961) (stating that comparing the value of a property before and after a taking is "indeed the conventional method"). "This is generally the simplest and perhaps the most widely used approach in severance damage determinations." Ga.-Pac., 226 Ct. Cl. at 106, 640 F.2d at 336.

Plaintiffs did not present evidence of the value of their properties before or after the erosion caused by the government occurred. See Pls.' Br. passim; Pls.' Resp. passim. Plaintiffs instead adopt the hypothetical appraisals presented by defendant's expert witness, Mr. Burgoyne, of the values of plaintiffs' properties in January 2000 with their 1950 dimensions and January 2000 improvements. See, e.g., Pls.' Br. 36. Rather than presenting evidence of the value of their properties after the erosion took place, plaintiffs presented the testimony of Dr. Moore, an economist, who determined that, although sale prices of properties affected by the jetties rose in the time period after the publication of the 1999 Report, they may have risen less than did sale prices in areas not affected by the jetties.[113] Tr. 149:18-19 (Moore). Plaintiffs determine the amount of damage to their

[113]Dr. Moore, see PX 149 (Moore Report) passim, and plaintiffs, see Pls.' Br. passim, refer to an announcement made by the Corps in January of 2000. In its opinion reversing the court's dismissal of plaintiffs' claims on statute of limitations grounds, the Federal Circuit determined that, "[w]ith the mitigation efforts underway, the accrual of plaintiffs' claims remained uncertain until the Corps' 1996 Report, 1997 Report, and 1999 Report collectively indicated that erosion was permanent and irreversible." Accrual Op. II, 314 F.3d at 1310. The 1999 Report was published in January 2000. Banks, 76 Fed. Cl. at 696; see also PX 41 (1999 Report). The court understands Dr. Moore and plaintiffs to be referring to publication of the 1999 Report when referring to the January 2000 "announcement."

Dr. Moore writes in his report that he focused on the effect of the 1999 Report on the value of plaintiffs' properties because the impact of the report can be measured:

> In my opinion, it is not possible in this litigation to estimate the full impact of the beach erosion on real estate values. It is apparent that information about the problem was emerging at an early state, and there is no record available to identify the timing or the content of events and information releases from 1950 to 2000.

properties by calculating how much their properties' pre-erosion values, as determined by Mr. Burgoyne, failed to increase. See Pls.' Br. 38; PX 275 (table showing plaintiffs' estimates of the erosion damage to each property); see also Tr. 154:4 (Moore) (stating that he did not prepare PX 275).

Dr. Moore "employed a hedonic regression model to determine the effect of the United States'[ ] [a]nnouncement on the value of the [p]laintiff[s'] properties." Pls.' Br. 37. Hedonic regression "looks at the price of a good and tries to determine how much of that price is due to each of the attributes that enter into the market pricing." Id. (citing Tr. 132:6-133:3 (colloquy between Dr. Moore and court)). For example, a hedonic model for the price of a house may include variables for the "number of bedrooms, square footage, [and] the lot size." Tr. 133:1-2 (Moore).

Dr. Moore states that the hedonic pricing model "is directly applicable to computing the economic effects of discrete 'events' as seemingly disparate as

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> . . . It is possible, however, to estimate the effects of the January 2000 public information release.

PX 149 (Moore Report) 9.

Plaintiffs' focus on the publication of the 1999 Report is a relatively indirect manner of calculating plaintiffs' damages. The publication of the 1996 Report, the 1997 Report and the 1999 Report is significant in this case because the Federal Circuit determined that the three reports eliminated reasonable property owners' justifiable uncertainty as to whether the Corps' mitigation efforts have been generally successful. See Accrual Op. II, 314 F.3d at 1309-10; see also Applegate v. United States, 25 F.3d 1579, 1583 (Fed. Cir. 1994) (stating that uncertainty about the permanence of damage to property can stay the accrual of a takings claim); see supra Part III.C (concluding that, notwithstanding the Corps reports, which appeared to indicate that, in general, the Corps' efforts to mitigate erosion caused by the jetties have been unsuccessful, the Corps' mitigation efforts have been completely successful since 1970 in mitigating erosion caused by the jetties to the properties of every plaintiff but one).

However, the potential taking at issue in this case is the erosion of plaintiffs' properties caused by the jetties, not the publication of reports studying the Corps' mitigation efforts. Regardless of whether the mitigation program has been effective for the entire zone of influence of the jetties, additional study focused specifically on plaintiffs' properties has revealed that the mitigation program has completely compensated for the effect of the jetties since 1970 on the properties of every plaintiff but one. See supra Part III.C.2. The government's expert witness, Dr. Nairn, acknowledges that a segment of cohesive shoreline is present north of plaintiffs' properties. DX 1 (Nairn Report) 2-26 (describing a section of cohesive shoreline approximately 1.9 miles long). Mitigation efforts may have been ineffective for this reach of cohesive shoreline. See Liability Op., 78 Fed. Cl. at 628 (holding that the erosion of cohesive material is permanent and irreversible). The issue in this case is the mitigation of the erosion of plaintiffs' properties specifically. See supra Part III.C.2.

environmental contamination, an attempt to fix prices, a violation of the securities laws, or beach erosion due to a taking." PX 149 (Moore Report) 5. In a case involving securities fraud, for example, "[t]he price change around the time of the event would give a market-based estimate of the perceived fraud." Id. at 6. Dr. Moore testified that this type of analysis is called an "event study." Id. at 5; Tr. 176:25-177:1 (Moore).

To create his dataset, which contained 107 observations, PX 149 (Moore Report) Ex. 5, Dr. Moore used data on sales of properties up to three years before and three years after the publication of the report, Tr. 204:21-24 (colloquy between Dr. Moore and defendant's counsel), a time period that "equates to the years 1997 through 2003,"[114] Tr. 206:16-19 (colloquy between Dr. Moore and defendant's counsel). Dr. Moore described in his report how he coded his data. Dr. Moore "created the dependent variable 'price per lakefront foot [(LFF)]," by dividing selling price by reported lake frontage." PX 149 (Moore Report) 15. He created indicator variables for whether each property was located inside the affected area (treatment) and whether it was sold after the announcement (post), as well as a variable for the interaction of these two indicator variables (treatpost). Id. Because of "data limitations," Dr. Moore used three control variables: "a measure of square footage of the structure and dummy indicators of LFF between 100 and 150 feet, and LFF greater than 150 feet--to control for differences in price due to differences in the size of the house and for potential nonlinearities in the effects of LFF on price."[115] Id. at 16 (footnote omitted).[116] Dr. Moore noted that "[t]o the extent square footage is correlated with other characteristics (number of rooms, number of bathrooms), controlling for square footage will capture price variation due to these features too." Id.

[114]Dr. Moore explained that it was necessary to consider this broader time span in order to assemble enough data: "In this particular analysis, there aren't a lot of observations out there. So[,] if you confine your attention to a very narrow event window, . . . you'll get extremely imprecise estimates. So you exten[d] it out a little bit." Tr. 177:15-19 (Moore). According to Dr. Moore, it is necessary "to strike a balance," Tr. 177:23 (Moore), because "[i]f you only go out plus or minus one year, then you can be more certain that any changes you see are due to the event, and the event alone. If you go out farther, there might be intervening events," Tr. 177:3-6 (Moore).

[115]Dr. Moore further explained at trial one nonlinearity of the effect of lake frontage on price: "if prices go up steadily, up to maybe a threshold point of 100 feet. And then tend to . . . get flatter, up to 150 feet." Tr. 144:21-24 (Moore).

[116]In Dr. Moore's model, "The location indicator variable 'treatment' equals one if the sale is in the affected area, and equals 0 otherwise. The variable 'post' equals 1 if the sale occurred on or after January 27, 2000, and 0 if before. Finally, the 'interaction term' 'treatpost' equals the product of 'treatment' and 'post.'" PX 149 (Moore Report) 15 (footnote omitted).

Dr. Moore described his regression analysis as a "difference-in-differences" approach. PX 149 (Moore Report) 8. At trial, Dr. Moore summarized his analysis as follows:

> I took the prices before 2000 for houses in the non-erosion zone, I took the prices before 2000 for houses in the erosion zone. I looked at the difference, the average difference in prices there. That established a baseline difference in prices that would reflect different characteristics in the neighborhoods and the properties . . . in the erosion zone, and outside the erosion zone. . . . And then I . . . made the same comparison of prices . . . after January of 2000, again comparing the non-erosion zone to the erosion zone. I observed the average difference in prices there. And then I compared the pre-announcement difference to the post-announcement difference, and the difference in those differences is what's interpreted as the treatment effect . . . , [that is,] the effect of the announcement on residential real estate prices in the erosion zone relative to a control group.

Tr. 146:5-25 (Moore).

Dr. Moore first conducted "a simple comparison of mean differences in selling prices pre- and post-announcement [to give] an unconditional estimate of the change in relative values after the announcement." PX 149 (Moore Report) 15-16. This first comparison considered only the change in price per lakefront foot of property, and did not control for lakefront footage or for the square footage of any structure built on the property. See id. at 16, Ex. 3. In his report, Dr. Moore writes that, using this approach, the changes in property values were "roughly identical" in the affected area and in the control group. Id. at 17. On cross-examination, Dr. Moore agreed that, considering only the price of property per lakefront foot, listed in Exhibit 3 of Dr. Moore's report, property values actually increased more in the affected area (142%) than in the control group (115%). Tr. 221:19-223:7 (colloquy between Dr. Moore and defendant's counsel).

Dr. Moore then controlled for differences in the square footage of the structures on each property, finding that, when the square footage of structures on the property is controlled for, property values increased more in the control group than in the affected area. See PX 149 (Moore Report) 18. Controlling for the square footage of the structure, Dr. Moore calculated that the effect of the 1999 Report on the market value of a house in the treatment group--that is, a house located within the affected area--was either 13% or 27%, depending on whether Dr. Moore used or omitted dummy indicators that describe whether the property is between 100 and 150 lakefront feet in width or greater than 150

feet.[117] Id. Dr. Moore states in his report that "[n]either the 13% or 27% estimates are significantly different from zero. Given the small number of observations in the relevant cells, this is not surprising." Id.

In his final regression specification, Dr. Moore found that removing the five properties that he considered outliers increased the size of the difference-in-differences estimator. Id. Excluding outliers, Dr. Moore's model "indicates prices are about 42% lower in the erosion zone after the disclosure, [a difference] greater than its standard error, albeit statistically insignificant." Id.

Regardless of whether Dr. Moore controlled for the square footage of structures on each property and eliminated sales that he considered to be outliers, Dr. Moore concluded in his report that the effect of the 1999 Report on sale prices in the affected area was statistically insignificant. See id. at 16-18.

Citing Dr. Moore's testimony, plaintiffs argue that "the market adjusted after January 2000 to account for the United States'[ ] [a]nnouncement that the erosion to [p]laintiffs' properties was permanent and the land lost was not coming back." Pls.' Br. 37. Plaintiffs interpret Dr. Moore's conclusion to be that "there was a 42% diminution in value to the [p]laintiff[s'] properties as a result of the [a]nnouncement."[118] Id. (citations omitted); see also Pls.' Resp. 5 (stating that "the market value of [p]laintiffs' properties substantially declined after January 2000"). Applying Dr. Moore's estimated coefficient of -42% to the appraised value of the plaintiffs' properties in January 2000 with their 1950 dimensions and January 2000 improvements, as determined by defendant's expert witness, Mr. Burgoyne, plaintiffs calculate that the "value of the land taken as a result of the [a]nnouncement is collectively $19,113,621." Pls.' Br. 38.

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[117]To determine the annual return on plaintiffs' property values related to each variable, Dr. Moore also specified a model that used the natural logarithm of the price per lakefront foot as the dependant variable. Tr. 215:14-18 (Moore); PX 149 (Moore Report) 18.

[118]Contrary to plaintiffs' claim that Dr. Moore observed a difference-in-differences of 42%, see Pls.' Br. 37, Dr. Moore indicated at trial that he would select one of the lower estimates. When asked by plaintiffs' counsel which of the difference-in-differences estimates is the most accurate, see Tr. 158:16-19 (plaintiffs' counsel asking, "Based upon your economic analysis, what do you think is the . . . percentage difference in the fair market value with that range, resulting from the announcement?"), Dr. Moore replied:

> Well, it's tough to pick a specific number. I say 10 to 20 percent in my report. I think . . . if you see no reason to exclude the outliers in the range from 13 to 27, pick a midpoint there, which is about 20 percent. But I'd rather just present those, and leave it to the [c]ourt, if possible, to choose the one that's most plausible, based on my testimony.
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> Tr. 158:20-159:2 (Moore).

b. The Limitations of Dr. Moore's Analysis

Defendant argues that Dr. Moore's event study is inapplicable to the question of just compensation because "Unlike Mr. Burgoyne's appraisals--which attempt to capture the value of different properties at the same point in time--Dr. Moore's analysis attempts to track movement in the prices of the same properties across different times." Def.'s Br. 30. Defendant further argues that "[e]ven if Dr. Moore's analysis was applicable to the question before the [c]ourt, [p]laintiffs' reliance on Dr. Moore's report does not account for the flaws that Dr. Moore himself acknowledges in his work." Id. at 30-31. Defendant lists three such flaws. "First, Dr. Moore acknowledges that the quantity of data he was provided is less than ideal for performing a regression analysis." Id. at 31 (citation omitted). "Second, rather than show a loss in value, Dr. Moore acknowledges that property values within the erosion zone increased generally after January 2000." Id. "Third, Dr. Moore did not control for any preexisting differences in the rates of increases in the prices before January 2000." Id.

Defendant is correct that Dr. Moore's analysis is unpersuasive. Although Dr. Moore's analysis of the data provided to him is credible, the limited dataset, the fact that Dr. Moore's estimates reflect unrealized appreciation rather than a loss in value, and Dr. Moore's failure to examine and--if necessary--control for preexisting trends in price increase for the treatment group and the control group, together with plaintiffs' application of Dr. Moore's analysis--which generalizes across plaintiffs' zone--to each individual property regardless of the actual erosion damage it suffered or did not suffer leave the court unconvinced that plaintiffs have carried their burden, see Miller, 223 Ct. Cl. at 383-84, 620 F.2d at 828, to prove their severance damages.

i. Insufficient Data

Defendant argues that "Dr. Moore acknowledges that the quantity of data he was provided is less than ideal for performing a regression analysis." Def.'s Br. 31. Plaintiffs respond that "[a]lthough Dr. Moore testified under cross-examination that he would 'ideally' like more data, more importantly[,] he also testified that he performed a series of sensitivity tests to ensure that the results he obtained with the data he used were accurate and reliable." Pls.' Resp. 8 (citing Tr. 204:21-206:15 (colloquy between Dr. Moore and defendant's counsel)).[119]

[119]Plaintiffs also argue that "Dr. Moore used the same universe of data as United States' expert David Burgoyne." Pls.' Br. 8 (citation omitted). Mr. Burgoyne, however, did not conduct a hedonic regression analysis of property values in plaintiffs' zone. See, e.g., DX 295 (Anderson Appraisal) passim. Mr. Burgoyne testified that his appraisal methods did not include statistical analysis: "[O]ne does not take the data and add it up and divide it, or do a linear-regression analysis or some sort of statistical analysis. One looks at the data, considers the differences in the relevant characteristics of the data, and comes to a conclusion of market value." Tr. 70:4-11 (Burgoyne). Mr. Burgoyne further testified that "[t]he idea of an appraiser is sort of to put

Plaintiffs appear to conflate reliability--the ability to get the same results--with accuracy--the closeness of an estimate to its true value. Compare American Heritage Dictionary 13 (stating, as one definition of "accuracy," "[t]he ability of a measurement to match the actual value of the quantity being measured"), with id. at 1474 (stating, as one definition of "reliable," "[y]ielding the same or compatible results in different clinical experiments or statistical trials"). Dr. Moore's description of the sensitivity tests he performed appears to indicate that the sensitivity tests were a minor part of his analysis, see PX 149 (Moore Report) passim (not mentioning sensitivity tests), and that he was testing the reliability of his estimates by changing the parameters underlying his model, such as "varying the event window," Tr. 205:12-13 (Moore), which did not result in "a qualitative change in the results," Tr. 205:14-15 (Moore). Although both accuracy and reliability are important, Dr. Moore does not claim, and plaintiffs have not demonstrated, that Dr. Moore's sensitivity tests would also reflect the accuracy of his estimate.

Dr. Moore's discussion of confidence intervals[120] and statistical significance concerns the accuracy of his estimates. [121] Dr. Moore described his use of confidence

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themselves in the mind of a potential purchaser," Tr. 2479:3-5 (Burgoyne), and that "it's much more of an art than a science," Tr. 2482:18-19 (Burgoyne). It is therefore conceivable that the amount of data that would be sufficient for an appraiser such as Mr. Burgoyne to put himself "in the mind of a potential purchaser," Tr. 2479:4-5 (Burgoyne), would be insufficient to support a statistical analysis of the type undertaken by Dr. Moore.

[120]Dr. Moore did not define the term "confidence interval" at trial or in his expert report, see PX 149 (Moore Report) passim; Tr. 117:1-251:19 (testimony of Dr. Moore). A confidence interval can be described as:

> A range of values, calculated from the sample observations, that are believed, with a particular probability, to contain the true parameter value. A 95% confidence interval, for example, implies that were the estimation process repeated again and again, then 95% of the calculated intervals would be expected to contain the true parameter value.

B.S. Everitt, The Cambridge Dictionary of Statistics 86 (2d ed. 2002).

[121]In testimony, Dr. Moore referred both to confidence intervals and to what the court understands to be the functionally analogous concept of confidence levels. See, e.g., Tr. 229:17-230:20 (colloquy between Dr. Moore and defendant's counsel) (using the terms interchangeably); Tr. 242:14-243:17 (Moore) (same). A confidence interval is "[t]he percentage of samples in which we want our confidence interval to contain the population value." Jeffrey M. Wooldridge, Introductory Econometrics: A Modern Approach 833 (2d ed. 2003). Dr. Moore also used the term "p-value" when discussing confidence intervals and confidence levels. See, e.g., Tr. 242:14-243:17 (Moore). A p-value is "[t]he probability of the observed data (or data showing a more extreme departure from the null hypothesis) when the null hypothesis is true." The Cambridge Dictionary of Statistics 304. For purposes of clarity, the court refers only to confidence intervals.

intervals as follows: "once you establish a confidence interval, and you look at your data, and you see if your test statistic lies outside your confidence interval, then you can reject your [null] hypothesis . . . ."[122] Tr. 237:18-21 (Moore). Notwithstanding that Dr. Moore calculated the difference-in-differences in four different ways, revealing a range of results, see supra Part III.D.2.a, Dr. Moore writes in his report that, using a 95% confidence interval, none of the results was significantly different than zero. See PX 149 (Moore Report) 16-18. At trial, Dr. Moore indicated that, with more data, he might have been better able to determine whether the effect of the publication of the 1999 Report on housing prices in the affected area was statistically significant: "[T]here are a number of . . . interpretations you could put on this. One would be that you just don't have enough observations to estimate it precisely." Tr. 231:23-232:1 (Moore); see also PX 149 (Moore Report) 18 ("Neither the 13% nor the 27% estimates are significantly different from zero. Given the small numbers of observations in the relevant cells, this is not surprising.").

Dr. Moore used a 95% confidence interval in his report, see Tr. 230:17-19 (colloquy between Dr. Moore and defendant's counsel), a threshold that, he states, is "standard in academic research," Tr. 244:2 (Moore); see also Tr. 230:19 (Moore) (stating that he used a 95% confidence interval "as a matter of course"). Plaintiffs cite two cases in which, plaintiffs argue in explanatory parentheticals, courts found that the use of confidence intervals lower than 95% satisfied a party's "burden of proof of the preponderance of the evidence." Pls.' Br. 37; cf. Tr. 238:16-17 (Moore) (stating that the confidence interval a researcher might employ "depends on the application"); Tr. 232:12-14 (Moore) ("I can't tell you what the burden of proof is that we have here.").

Regarding the statistical significance of his 42% difference-in-differences estimate, Dr. Moore remarked for the first time at trial that if the court adopted a "one-tailed" test (or a "directional hypothesis" test), that estimate would be statistically significant. Tr. 242:11-243:19 (Moore). Dr. Moore performed a series of calculations at trial, concluding that, using a 90% confidence interval and a one-sided hypothesis test, a finding of a 42% difference-in-differences estimate between the affected area and the control group would be significantly less than zero. Tr. 242:11-243:19 (colloquy between Dr. Moore and defendant's counsel). Plaintiffs contend that the court should adopt the lower threshold of a 90% confidence interval and find that their properties diminished in value by 42%. See Pls.' Br. 37. However, this is not the analysis recommended by Dr. Moore in his report. See PX 149 (Moore Report) 17-18.

It is unnecessary to determine whether use of a confidence interval lower than 95% would be sufficient to satisfy plaintiffs' burden. As explained below, see infra Parts

[122] A "null hypothesis" is the "'no difference' or 'no association' hypothesis to be tested (usually by means of a significance test) against an alternative hypothesis that postulates nonzero difference or association." Id. at 269.

III.D.2.b.ii-iii, and in light of the data limitations described previously, the court is persuaded by defendant's argument that other flaws in Dr. Moore's analysis make it less reliable than the appraisals conducted by Mr. Burgoyne. See Def.'s Br. 31. Whether, in Dr. Moore's model, his difference-in-differences estimate of the effect of the publication of the 1999 Report on sale prices in the affected area is statistically significant using a confidence interval lower than 95% does not change the court's analysis.

ii. Increase in Values

Defendant contends that, "rather than show a loss in value, Dr. Moore acknowledges that property values within the erosion zone increased generally after January 2000." Id. Defendant is correct that, according to Dr. Moore's analysis, in the three years after January 2000, prices in the affected area rose significantly from their levels during the three years before January 2000. See PX 149 (Moore Report) Ex. 3 (table of mean prices per lakefront foot of property); Tr. 149:2 (Moore) ("So prices are rising in both areas."). Dr. Moore agreed that, using the mean prices calculated in his Exhibit 3, prices in the affected area more than doubled, rising 142% per lakefront foot. See Tr. 221:19-223:24 (colloquy between Dr. Moore and defendant's counsel).

Accordingly, plaintiffs' assertion that "there was a 42% diminution in value to the [p]laintiff[s'] properties as a result of the [a]nnouncement," Pls.' Br. 37, is misleading. Dr. Moore's analysis, to the extent it shows anything of statistical significance, see supra Part III.D.2.b.i, does not show that plaintiffs' properties lost value because of the publication of the 1999 Report, but rather that they may have failed to appreciate in value as rapidly as certain other properties between 1997 and 2003 when controlling for lakefront footage and for the square footage of the homes built on the properties.[123] See PX 149 (Moore Report) 16-18; Tr. 221:19-223:24 (colloquy between Dr. Moore and defendant's counsel) (agreeing that, when the square footage of the structures on the

[123]In their response brief, plaintiffs go beyond the analysis and conclusions contained in Dr. Moore's report and trial testimony, arguing that "[t]he United States simply ignores that Dr. Moore opined to a 90% degree of certainty that there was a 42% diminution in the value of [p]laintiff[s'] properties resulting from the [United] States' taking." Pls.' Resp. 8 (emphasis omitted) (citing Tr. 242:10-244:20 (colloquy between Dr. Moore and defendant's counsel)); PX 149 (Moore Report) Ex. 4B.3). However, in the trial testimony cited by plaintiffs, Dr. Moore testified that, using a 90% confidence interval and a directional hypothesis test, a 42% difference-in-differences between the affected area and the control group would be significantly less than zero. Tr. 242:11-243:19 (colloquy between Dr. Moore and defendant's counsel). Dr. Moore's testimony related to the significance of observing a variation of that size, not to his certainty that plaintiffs' properties have, in fact, failed to appreciate--much less diminished in value--by 42%. See id.; cf. infra Part III.D.2.iii (discussing Dr. Moore's failure to control for preexisting trends in price increase--or to determine whether doing so was necessary--that might be responsible for the possible difference in appreciation).

properties is not controlled for, mean prices increased more in the affected area than in the control group).

Plaintiffs have failed to demonstrate that their properties diminished in value as a result of erosion caused by the jetties. Plaintiffs cite no authority for the proposition that damages in a partial takings claim are better measured by unrealized appreciation rather than lost value. See Pls.' Br. passim; Pls.' Resp. passim. Neither do plaintiffs offer a methodology to translate the claimed unrealized appreciation into a loss of value compensable as a taking. See Pls.' Br. passim; Pls.' Resp. passim. Instead, plaintiffs simply treat the claimed amount of unrealized appreciation as lost value.[124] See Pls.' Br. 37 (stating that "there was a 42% diminution in value of the [p]laintiff[s'] properties as a result of the [a]nnouncement").

The court does not consider whether, in the absence of the appraisals presented by defendant, or with the assistance of a more robust economic analysis, it would be possible to discern a loss of value from the unrealized appreciation of plaintiffs' properties. Plaintiffs bear the burden of establishing the just compensation to which they are entitled for severance damages by a preponderance of the evidence. See Miller, 223 Ct. Cl. at

[124]Plaintiffs' argument that defendant's appraiser, Mr. Burgoyne, "admits that it is possible that [p]laintiffs[ ] suffered a diminution in value to their properties, even if their property values were similar to overall market trends," Pls.' Br. 40 (citing Tr. 2539:18-2541:24 (colloquy between Mr. Burgoyne and plaintiffs' counsel), is misleading. In the relevant portion of the testimony cited by plaintiffs, plaintiffs' counsel described a hypothetical situation in which the value of plaintiffs' properties grew at a faster rate than the overall market before publication of the 1999 Report and at the same pace as the market after publication of the 1999 Report. See Tr. 2539:18-2540:24 (colloquy between Mr. Burgoyne and plaintiffs' counsel). Plaintiffs' counsel then asked Mr. Burgoyne whether "simply because . . . the [p]laintiffs' property might even be in line with overall market trends doesn't mean that they haven't suffered any diminution of value to their property[,] correct?" Tr. 2541:14-18 (plaintiffs' counsel). In his answer, Mr. Burgoyne did not state that it "is possible that [p]laintiffs[] suffered a diminution in value to their properties, even if their property values were similar to overall market trends." Pls.' Br. 40 (citation omitted). Rather, Mr. Burgoyne agreed with the narrower conclusion that, "[i]f one could demonstrate that it would [be] reasonable to expect the property to grow faster than the overall market trends and the property was not growing faster than the overall market trends, it would be possible to make the observation that something has affected the property." Tr. 2541:19-24 (Burgoyne).

Mr. Burgoyne's statement that one might observe "that something affected the property," Tr. 2541:23-24 (Burgoyne) does not equate diminution in value with unrealized appreciation. Mr. Burgoyne, in fact, indicated that loss of value and unrealized growth are distinct concepts. When asked, "[N]evertheless, they've suffered a loss of value of two percent; correct?" Tr. 2540:25-2541:1 (plaintiffs' counsel), Mr. Burgoyne attempted to clarify: "They've suffered a loss of value of two percent or you're implying that they are not growing--they've suffered a loss of growth of two percent, . . . that's what you're saying, right?" Tr. 2541:2-7 (Burgoyne).

383-84, 620 F.2d at 828. In light of the appraisals presented by defendant, which persuasively and directly establish the extent of the erosion damage to plaintiffs' properties between 1950 and 2000, see infra Part III.D.3, plaintiffs have not met their burden.

iii. Failure to Control for Differences in Preexisting Rates of Increase in Market Values

As Dr. Moore emphasized, "[I]n the differences-in-differences test, average differences between the affected and unaffected properties at baseline must remain constant over time, so that change in the relative values of the two groups of properties can be attributed to the erosion." PX 149 (Moore Report) 8.

Defendant contends that "Dr. Moore did not control for any preexisting differences in the rates of increases in the prices before January 2000." Def.'s Br. 31. Plaintiffs respond that "the United States omits critical testimony on this issue; namely, that Dr. Moore also testified that the differences in the rates of increase before the [a]nnouncement would be reflected in the higher mean [price per lakefront foot] and would therefore be properly controlled for." Pls.' Resp. 8. As his trial testimony and expert report indicate, however, Dr. Moore did not explore whether it was necessary to control for differences in preexisting price trends and--if necessary--control for them.[125]

Asked at trial if he had controlled "for any preexisting differences in the rates of increases in the prices in your regression," Tr. 216:12-14 (defendant's counsel), Dr. Moore responded, "I did not," Tr. 216:15 (Moore). Asked whether, in light of his decision not to control for different preexisting trends, he "really can't be sure" that the observed difference in prices is a result of the 1999 Report rather than preexisting differences in the rate of price increases between the properties, Tr. 216:18-25 (defendant's counsel), Dr. Moore responded, "I didn't do that, so I don't know what . . .

[125] Dr. Moore drew his sales data from a number of localities, which he described only by whether they are inside or outside of the area affected by the jetties: "Communities in the affected area [(treatment group)] include portions of St. Joseph and Stevensville. Communities in the unaffected area [(control group)] include portions of St. Joseph and Stevensville, as well as Benton Harbor, Coloma, Bridgman, Chikaming, Lakeside, New Buffalo, Sawyer, and Union Pier." PX 149 (Moore Report) 15 n.24. Dr. Moore's report did not indicate that he considered any attributes of the communities other than whether they were in the affected area when constructing his treatment and control groups. See id. passim. In contrast, Mr. Burgoyne identified an array of local characteristics that would affect the value of plaintiffs' properties and the market in which they were being sold. See infra Part III.D.3.a. Dr. Moore failed to consider how characteristics such as those identified by Mr. Burgoyne influence the manner in which property values change over time. See PX 149 (Moore Report) passim.

the implications would be." Tr. 217:1-3 (Moore). Dr. Moore and defendant's counsel then engaged in the following colloquy:

> Q . . . So at bottom, though, that leaves open, does it not, the possibility that the changes in prices that you see post-2000 may be, to some extent, influenced or caused by the rates of increases, preexisting differences in the rate increases, before January 2000?
>
> A I'll grant you that. I think [that] if there are differences in the rates of increase before . . . the announcement, those would be reflected in the higher mean in one group more than the other. To a certain extent[,] they will be controlled for in the differences.

Tr. 217:14-25 (colloquy between Dr. Moore and defendant's counsel). Beyond his general statement that "[p]rice changes will reflect market participants' views of . . . all known factors that affect price," PX 149 (Moore Report) 4, Dr. Moore did not quantify--and the court declines to guess--the extent to which differences in mean prices could control for variation in preexisting trends, see id. passim; Tr. 117:1-251:19 (testimony of Dr. Moore).

Because Dr. Moore failed to control for differences in preexisting rates of price increase for properties in the affected area and in the control group, or to explain why it is unnecessary to do so, the court finds his conclusions unpersuasive.

iv. Plaintiffs' Application of Dr. Moore's Conclusions to Each Property Regardless of Actual Erosion

A final drawback to Dr. Moore's model is that--because he focuses on the publication of the 1999 Report as the event of interest, rather than the amount of actual erosion--it is difficult for the court, in a takings case, where the amount of actual erosion caused by the government is the issue, to apply Dr. Moore's results in a reasoned manner. Plaintiffs suggest that the court award the same proportion of damages to all plaintiffs. See Pls.' Br. 36-39.

Plaintiffs' approach to calculating damages is inappropriate because the extent of the erosion damage has been greater for some properties than for others. The property of one plaintiff "went from being a buildable lot to being an unbuildable remnant because [a] substantial portion is down in the lake." Tr. 79:11-13 (Burgoyne). The properties of other plaintiffs eroded, but are deep enough that most of the property remains and is buildable. See, e.g., DX 297 (Bodnar Appraisal) 11, Fig. A-6 (photograph of property showing variation of ordinary high water mark over time). Nearly half of the properties owned by plaintiffs grew in size between 1950 and 2000, owing to the deposition of sand or the placement of shore protection lakeward of the ordinary high water mark. See supra Part III.D.1; see, e.g., DX 295 (Anderson Appraisal) 11, Fig. A-6 (photograph of property

showing variation of ordinary high water mark over time). To treat plaintiffs' damages as though each plaintiff were similarly situated would not accurately reflect the erosion damage that each has suffered.[126]

3. Defendant's Evidence of Damages Between 1950 and 2000: Appraisals Performed by Mr. Burgoyne

a. Mr. Burgoyne's Analysis and Conclusions

To quantify the extent to which the jetties have harmed plaintiffs' property values, defendant presented property appraisals proposed by Mr. Burgoyne. See Def.'s Br. 26-30 (discussing Mr. Burgoyne's appraisals). For each property, Mr. Burgoyne created three appraisals, two of which are relevant under the law of this case.[127] See id. at 27-28. Both appraisals were prepared with a valuation date of January 2000, "'one reflecting the conditions of the land that existed in 2000 [(2000 appraisal)], [and] one reflecting the

[126]In a footnote, plaintiffs argue in the alternative that they are entitled to just compensation of $18,700,000 for the erosion their properties suffered between 1950 and 2000, a sum equal to the cost, plaintiffs argue, of replacing the material eroded by the jetties with sand. Pls.' Br. 39 n.27. Plaintiffs argue in their response brief that, absent shore protection, an additional volume of material equal to the volume that eroded between 1950 and 2000 will erode between 2000 and 2050. Pls.' Resp. 6-7. In support of these arguments, plaintiffs presented at trial the expert opinions of Dr. Meadows, who attempted to quantify the volume of sediment eroded from plaintiffs' properties. See generally PX 143 (Meadows Volume Report); PX 144 (Meadows Revised Volume Report).

It is the law of the case, however, that "[i]n a permanent taking scenario such as this case, plaintiffs are entitled to the value of the property permanently lost, rather than restoration of property lost." Law of Damages Op., 88 Fed. Cl. at 684; see also id. at 686 ("Contrary to plaintiffs' argument, plaintiffs are not entitled to recover for the cost of replacing or restoring the land lost to erosion." (citation omitted)). Defendant is correct that "[p]laintiffs' volumetric approach fails because it cannot be reconciled with the [c]ourt's instructions and is inconsistent with controlling caselaw." Def.'s Br. 24; see generally Law of Damages Op., 88 Fed. Cl. 665.

[127]A third appraisal of each property "'reflected the conditions of the land that existed . . . on the date that the [p]laintiff acquired the property.'" Def.'s Br. 27 (quoting Tr. 98:20-25 (Burgoyne) (ellipsis in original). Before trial, defendant argued that "plaintiffs, who have established that they were the property owners as of January 2000, are entitled only to damages that occurred during their 'periods of actual ownership.'" Law of Damages Op., 88 Fed. Cl. at 674-75. After considering the relevant caselaw, the court rejected this argument, concluding that "[e]ach plaintiff is therefore entitled to compensation for any damage attributable to the jetties from the time the jetty improvements began in 1950, notwithstanding the fact that 1950 may be prior to the date on which that plaintiff acquired its respective property interest." Id. at 680.

conditions of the land that existed in 1950 [(1950 appraisal)].'"[128] Id. at 27 (quoting Tr. 98:20-25 (Burgoyne)). Both appraisals included the improvements that were present on the parcel in January 2000.[129] Id. at 28 (citing Tr. 99:5-7 (Burgoyne)). Using a before-and-after analysis, defendant subtracts the second appraised value from the first to determine the amount of plaintiffs' damages. See id. at 31-33.

Mr. Burgoyne used a "direct sales comparison approach" in his appraisals, researching arm's length sales of like properties and adjusting for any differences. Tr. 2473:11-16 (Burgoyne). After examining a large number of sales, Mr. Burgoyne identified a set of comparable vacant and improved properties. Tr. 2476:8-20 (Burgoyne); see also DX 295 (Anderson Appraisal) 39 (list of comparable vacant properties). Mr. Burgoyne explained that "one attempts to choose comparables which are as similar as possible, which can mean they're physically similar in terms of size, zoning, highest and best use in terms of land." Tr. 103:16-19 (Burgoyne). For improved properties, the characteristics of the improvements should also be similar: "[W]hen selecting improved comparables, you would select homes of a similar size, of similar style, like ranch versus two-story. Similar vintage. One wouldn't want to appraise a brand new house with homes built in 1930, perhaps." Tr. 103:19-24 (Burgoyne). "[O]ne tries to limit the need to adjust for those [characteristics] by selecting properties that are as similar as possible." Tr. 104:2-4 (Burgoyne).

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[128]The appraisal reflecting 1950 land conditions (1950 appraisal) considered a hypothetical property that contained its January 2000 improvements and its 1950 property dimensions. Tr. 2467:3-9 (Burgoyne). Mr. Burgoyne testified that it is "very common" for appraisers to perform such hypothetical appraisals. Tr. 2467:13 (Burgoyne). An appraiser might determine, for example, the value of a property subject to a zoning restriction to hypothetical property that is identical but not encumbered by the zoning restriction. See Tr. 2467:19-21 (Burgoyne). It is also "very common" to perform an appraisal that determines the value of a property as of an earlier date. Tr. 2469:1-2 (Burgoyne).

[129]Mr. Burgoyne did not examine how the market value of plaintiffs' properties changed over time, Tr. 2471:6 (Burgoyne), but rather appraised each property with its hypothetical 1950 condition and its January 2000 condition as if he were considering two separate properties, Tr. 2470:24-2471:6 (colloquy between Mr. Burgoyne and defendant's counsel). Mr. Burgoyne agreed that he had not been asked to calculate damages over time. Tr. 2471:7-10 (colloquy between Mr. Burgoyne and defendant's counsel).

Mr. Burgoyne testified that the term "before and after appraisal" is commonly used by appraisers, but "maybe isn't the best term" for the work he performed. See Tr. 2470:16-17 (Burgoyne). There was no temporal separation between the appraisals conducted by Mr. Burgoyne. See Tr. 2470:17-19 (Burgoyne). Both appraisals considered the value of the property given a set of conditions, one of which was hypothetical, in January 2000. Tr. 2470:16-23 (Burgoyne). At times, apparently for ease of discussion, Mr. Burgoyne referred to changes in property conditions and a resulting "diminution" in value of the property from its hypothetical 1950 condition to its January 2000 condition. See, e.g., DX 302 (Chapman Appraisal) 138-139.

Mr. Burgoyne considered both the attributes of the local market generally and of each property specifically. Tr. 2474:9-14 (colloquy between Mr. Burgoyne and defendant's counsel). As to the market generally, Mr. Burgoyne considered multiple factors. He studied historical population changes, noting that "Berrien County experienced a boom then bust in population between 1970 and 1990 and has since had a relatively stable population since 1990."[130] DX 295 (Anderson Appraisal) 29. He considered the balance of seasonal residents to full-time residents and noted that the balance is shifting toward full-time residents over time. Id. He considered the volatility of the local real estate market, concluding that "the subject market, being properties located on Lake Michigan in the northern part of the [c]ounty, is somewhat isolated from the general fluctuations in the local market." Id. at 27. He considered access to a highway and rail service, as well as the location of hospitals, the Whirlpool corporate headquarters and other employers. Id. He studied the local amenities available to property owners, noting that "St. Joseph, just north of the subject area, contains numerous activities to pursue, services, restaurants, and cultural amenities." Id. He noted that "[c]ertain areas north of the jetties enjoy amenities such as golf course frontage or proximity to the Yacht Club that impact their sales prices." Id. at 21. Mr. Burgoyne concluded that plaintiffs' properties are "well located in a highly desirable area." Id. at 29.

To determine the physical characteristics of plaintiffs' properties, Mr. Burgoyne relied upon personal observations and discussions with the property owners, supplemented by aerial photos and public records, including assessment records containing old property descriptions. Tr. 2487:11-2488:6 (Burgoyne). Mr. Burgoyne relied upon Dr. Nairn's delineation of the "physical dimensions and geographic characteristics for each scenario." Tr. 99:14-17 (colloquy between Mr. Burgoyne and defendant's counsel). Where Dr. Nairn's measurements conflicted with information listed on plaintiffs' deeds, Mr. Burgoyne resolved the conflict in favor of plaintiffs, using the higher of the numbers contained in plaintiffs' deeds and Dr. Nairn's measurements.[131] Tr. 2489:10-16 (Burgoyne).

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[130]The court cites to Mr. Burgoyne's appraisal of the Anderson property when describing the general characteristics of his appraisals because each of Mr. Burgoyne's appraisals appears to share a common structure and set of background information. Compare, e.g., DX 295 (Anderson Appraisal) 28-29 (discussing area, city and neighborhood data), with DX 296 (Banks Appraisal) 28-29 (discussing same).

[131]Mr. Burgoyne stated that when he examined the comparables, in the case of conflicting measurements between Dr. Nairn and the deeds, he used the lower number. Tr. 2489:19-2490:2 (Burgoyne). Mr. Burgoyne explained in testimony that these choices did not affect the final analysis between plaintiffs' properties and the comparables. Tr. 2590:3-19 (colloquy between Mr. Burgoyne and defendant's counsel).

Mr. Burgoyne's appraisals addressed any anticipated erosion damage and the cost, where necessary, to install or repair shore protection to prevent the anticipated erosion. Mr. Burgoyne incorporated Dr. Nairn's analysis of the shore protection present on the properties. Tr. 83:18-20 (Burgoyne). Dr. Nairn determined what shore protection was present on the properties and how long it would last before new shore protection would be required. See Tr. 2511:2-13 (Burgoyne); DX 205 (Nairn Shore Protection Report) 75-111 (analyzing existing shore protection, its remaining lifespan, and the cost of upgrades and maintenance where necessary). Mr. Burgoyne described shore protection as "relatively ubiquitous" in the area around plaintiffs' properties. Tr. 2516:12 (Burgoyne). Analogizing his examination of shore protection to how he would appraise a house with a leaking roof, Mr. Burgoyne stated that if "the roof was actually leaking, one would subtract the cost to put a new roof on the house right then when you did your appraisal . . . . Conversely, if . . . it had 30 years left on the roof, they wouldn't put a cost in there for putting the roof on it." Tr. 2511:23-2512:8 (Burgoyne).

For vacant lots, Mr. Burgoyne calculated the price of each property based on a price per lakefront foot of property. Tr. 64:15-16 (Burgoyne). For improved properties, Mr. Burgoyne calculated the price of each property based on a price per square foot of the residence. Tr. 64:17-19 (Burgoyne). Mr. Burgoyne "appraised all the properties both as improved and vacant," because properties with modest residences may be worth more as vacant lots. Tr. 2485:19-23 (Burgoyne); but see Tr. 2486:19-25 (Burgoyne) (stating that Mr. Burgoyne appraised the Lahr property only as vacant, despite the presence of a residence, "because we knew the highest and best use was to tear the house down"). The market value that Mr. Burgoyne listed for each property treats the property as vacant if the "highest and best use was to knock down the older improvements." Tr. 2477:4-6 (Burgoyne); see also Tr. 2486:6-7 (Burgoyne) (stating that the property owned by the Smith plaintiffs had a higher market value when appraised as vacant).

In contrast to plaintiffs' interpretation of Dr. Moore's estimates, Mr. Burgoyne, when describing the impact of the 1999 Report on the market as a whole, stated that "there didn't appear to be any adverse reaction in the marketplace." Tr. 2494:17-19 (Burgoyne). Mr. Burgoyne stated that "lakefront property continued to increase [in value], peaking in late 2007, which is similar [when] compared to the overall nationwide market." Tr. 2494:20-23 (Burgoyne); see also Tr. 2535:4-5 (Burgoyne) (stating that Mr. Burgoyne also considered statewide real estate trends); DX 295 (Anderson Appraisal) 116 (stating that "[r]eview of the actual sales comparables gives no indication that an adjustment is warranted because a purchase was made before or after the date of taking as a result of the taking"); DX 295 (Anderson Appraisal) 116 (noting the ongoing construction of new and expensive lakefront properties in the area and concluding that "[i]f there was any significant market impact from erosion . . . , one would also expect a market reluctance to make significant investments in new construction along the lake"). Mr. Burgoyne did not speculate as to why publication of the 1999 Report did not have an adverse effect on real estate prices, but did testify that "it's a lake that's subject to erosion

and people know that." Tr. 2516:14-15 (Burgoyne). Mr. Burgoyne further testified that "shore protection is relatively ubiquitous." Tr. 2516:11-12 (Burgoyne).

Mr. Burgoyne concluded that 36 of the 41 parcels he appraised had the same market value with their 2000 characteristics as with their hypothetical 1950 characteristics. See DX 336 (Summary of Appraisals) 1-2.[132] The five properties that Mr. Burgoyne determined had a lower market value in their 2000 condition belong to plaintiffs Jackson, Neuser, Chapman, Notre Dame Path Association and Renner. See id. According to Mr. Burgoyne, the total loss of market value of these five properties is $465,000. See id. at 2.

Mr. Burgoyne determined that the value of the property owned by the Notre Dame Path Association diminished by $65,000, DX 333 (Notre Dame Path Association Appraisal) 9, the sum that a potential buyer would be compelled to spend immediately to replace a crumbling revetment protecting homes located on the edge of a bluff, Tr. 2512:21-2513:20 (Burgoyne). Mr. Burgoyne stated that, although other properties lack shore protection or have shore protection that will fail in the near future, none of the other properties have structures that will be imminently threatened by erosion. Tr. 2513:21-2514:4 (Burgoyne). As an example, Mr. Burgoyne described portions of the property owned by plaintiff Greenbriar Development that lack shore protection but are located

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[132]There are several ways to count the properties owned by plaintiffs because certain of the properties have multiple tax identification numbers, see DX 172 (Nairn OHWM Report) 19, Table 3.3 (table of plaintiffs' properties), and may have been formed from multiple parcels. Defendant and Dr. Nairn treat the Del Mariani property as a single property and treat plaintiffs as owners of 40 properties. See, e.g., DX 172 (Nairn OHWM Report) 19, Table 3.3 (table of plaintiffs' properties); Def.'s Br. 32 n.9 (stating that there are 40 parcels).

Mr. Burgoyne treats the property owned by the Del Mariani plaintiffs as two separate properties and performed separate appraisals for each. See DX 306 (Del Mariani Appraisal, Improved Parcel) 10; DX 328 (Del Mariani Appraisal, Unimproved Parcel) 10. The two properties have different tax identification numbers, see PX 248 (first stipulation regarding ownership), Ex. A at 2, and addresses, compare DX 306 (Del Mariani Appraisal, Improved Parcel) 2, with DX 328 (Del Mariani Appraisal, Unimproved Parcel) 2, but appear to be adjacent to one another and undivided, compare DX 306 (Del Mariani Appraisal, Improved Parcel) 12 (aerial photograph), with DX 328 (Del Mariani Appraisal, Unimproved Parcel) 11 (aerial photograph) (both showing what appears to be a single, undivided property). Mr. Burgoyne identifies 41 properties. See Tr. 74:20-23 (colloquy between Mr. Burgoyne and plaintiffs' counsel) (agreeing that there are 41 properties).

Dr. Mickelson treats the property owned by the Del Mariani plaintiffs as two properties, but treats the two properties owned by the Wineberg plaintiffs as a single property, see DX 293 (Mickelson Report) 5, Table 1 (list of plaintiffs' properties), with the result that Dr. Mickelson identifies 40 properties, see id. The precise number of properties owned by plaintiffs does not affect the court's determination of the just compensation owed to plaintiffs.

"hundreds of feet from any improvements, so that the erosion wouldn't impact anything for many, many years." Tr. 2513:25-2514:4 (Burgoyne).

According to Mr. Burgoyne, the value of the Neuser property diminished by $305,000. DX 315 (Neuser Appraisal) 10. In 1950, the area of the Neuser property was 1.25 acres. Id. In 2000, the area of the Neuser property was .69 acres. Id. Between 1950 and 2000, the property lost a significant portion of its depth. Id. at 12 (map of ordinary high water marks). Mr. Burgoyne stated that, because of zoning regulations and the setback required for high risk erosion areas, the parcel was no longer deep enough to support new construction. Id. at 100. The property, which was vacant in January 2000, id., "went from being a buildable lot to being an unbuildable remnant." Tr. 79:11-12 (Burgoyne).

Mr. Burgoyne concluded that the properties owned by the Chapman, Jackson and Renner plaintiffs diminished in value by $35,000, $30,000 and $30,000, respectively. DX 336 (Summary of Appraisals) 1. Mr. Burgoyne testified that these three properties declined in value because "[t]he indication was they had a beach in 1950; and that because of the acts of erosion, they did not have a beach in 2000." Tr. 79:24-80:1 (Burgoyne).

Mr. Burgoyne found that, with regard to the rest of plaintiffs' properties, the value of the property in his 1950 appraisal was the same as in his 2000 appraisal. See DX 336 (Summary of Appraisals) 1-2.

b. Plaintiffs' Criticisms of Mr. Burgoyne's Analysis

Plaintiffs argue that, for a number of reasons, "Mr. Burgoyne's opinions regarding the diminution in the value of [p]laintiff[s'] properties caused by erosion lack any recognize[d,] reasonable methodology and are entitled to no weight." Pls.' Br. 41.

However, plaintiffs' criticisms of Mr. Burgoyne's methods are undermined by plaintiffs' reliance on Mr. Burgoyne's valuation of their properties in their own damage calculations. Plaintiffs determine the amount of their damages in part by multiplying the hypothetical value of their properties in Mr. Burgoyne's 1950 appraisals by the largest additional percentage of their value by which their properties may have appreciated, according to Dr. Moore, in the absence of the publication of the 1999 Report. See Pls.' Br. 37-38; PX 275 (table showing plaintiffs' estimates of the erosion damage to each property). Mr. Burgoyne explained that he applied the same techniques to both his pre-taking and post-taking appraisals: "The methodology doesn't differ; only the relevant characteristics of the properties differ." Tr. 104:15-16 (Burgoyne).

Plaintiffs do not explain why Mr. Burgoyne's hypothetical 1950 appraisals are sufficiently reliable for plaintiffs to incorporate them into plaintiffs' damage calculations, but Mr. Burgoyne's January 2000 appraisals, which apply the same techniques, "lack any

recognize[d,] reasonable methodology and are entitled to no weight." Pls.' Br. 41; see id. passim; Pls.' Resp. passim. If, as plaintiffs' critiques of both sets of Mr. Burgoyne's appraisals claim, both sets of appraisals "lack any recognize[d,] reasonable methodology and are entitled to no weight," Pls.' Br. 41, plaintiffs do not explain why plaintiffs' damages calculations, which are based on Mr. Burgoyne's hypothetical 1950 appraisals, see id. at 38, are not similarly unreliable, see id. passim; Pls.' Resp. passim.

i. Loss of Value Absent Complete Loss of a Feature

Plaintiffs first argue that "Mr. Burgoyne's analysis is fundamentally flawed because the physical units that he uses to measure value, either price per front foot or price per square foot, does not vary with erosion." Pls.' Br. 39. Plaintiffs contend that "Mr. Burgoyne's methodology does not account for a loss of value absent a complete failure of certain characteristics of the property, such as a complete loss of beach or the loss of so much lot depth that the property is no longer buildable." Id.[133]

Plaintiffs are incorrect that Mr. Burgoyne failed to account for the potential loss of value due to changes in the property features he identified as significant determinants of value. Rather, Mr. Burgoyne determined that changes in those features were often insufficient to change the market value of plaintiffs' properties. Regarding changes in property depth that were insufficient to change the value per lakefront foot of the property, Mr. Burgoyne testified, "My investigation revealed that depth was not an issue. Unless the depth was such that the property was rendered unbuildable . . . ." Tr. 75:13-15 (Burgoyne). Mr. Burgoyne further testified, "I did not ignore [lot] depth. I carefully considered and came to the conclusion that [lot] depth was not relevant, not significant." Tr. 107:22-24 (Burgoyne).

Mr. Burgoyne stated that, in reaching this conclusion, he relied upon his 26 years of experience appraising property in Michigan, as well as upon market research and interviews with brokers and others in the area. Tr. 2480:7-22 (Burgoyne). Mr. Burgoyne testified that "lakefront property is special; it's different" than property located inland. Tr. 2478:3-12 (Burgoyne). The valuation of vacant lakefront property is "special" because "[i]t sells on the basis of width or lake frontage, not on the basis of land area." Tr. 2479:14-19 (Burgoyne). "[T]he amount of land area, as long as there's enough area to build, is almost irrelevant." Tr. 2480:20-22 (Burgoyne). Mr. Burgoyne testified that the valuation of lakefront property based on its lake frontage rather than the depth of the lot is "definitely borne out by the market data." Tr. 2556:2 (Burgoyne).

[133]Plaintiffs argue that "Dr. Moore, by contrast, analyzes price, rather than the underlying physical characteristics[ ] of the property. As Dr. Moore explained, prices act as a summary statistic for the interplay of all things that affect value." Pls.' Br. 39. Plaintiffs further argue that "[i]f one looks at prices both before and after an event, the price changes will indicate the effect of the event as it relates to all characteristics." Id. However, the court discussed Dr. Moore's analysis above, finding it unpersuasive. See supra Part III.D.2.b.

To illustrate that the value of vacant lakefront property is determined largely by the amount of lake frontage it has, Mr. Burgoyne described a sixteen-acre property that sold for approximately the same amount as the adjacent four-acre properties with similar amounts of lake frontage. Tr. 2482:8-23 (Burgoyne); DX 295 (Anderson Appraisal) 41-42. Mr. Burgoyne also described three parcels that were ninety, ninety-five and eighty-nine feet wide and less than an acre in size, all of which sold for "considerably more" than a sixteen-acre parcel and a four-acre parcel, both of which had less lake frontage.[134] Tr. 2482:23-2483:5 (Burgoyne). Above approximately 100 or 120 feet, additional lake frontage provides a diminishing marginal return unless the property becomes wide enough that it could be divided. Tr. 2483:9-15 (Burgoyne). Plaintiffs presented no evidence to contradict Mr. Burgoyne's testimony that the value of vacant lakefront property is determined largely by the amount of lake frontage, or to quantify the effect that changes in property depth that do not affect the buildability of a parcel have on its market value.[135] See Pls.' Br. passim; Pls.' Resp. passim.

Regarding the narrowing or loss of their beaches, plaintiffs are similarly incorrect that "Mr. Burgoyne's methodology does not account for a loss of value absent . . . complete loss of beach." Pls.' Br. 39. Plaintiffs argue that "Mr. Burgoyne testified that any reduction in the depth of a beach, no matter how great, had no effect on the property values of [the] Banks Plaintiffs' properties, as if a 60[-]foot beach and a 4[-]foot beach were identical." Id. at 41; see also Pls.' Resp. 6 (stating that Mr. Burgoyne equated "an expansive 100[-]foot beach with a mere 4[-]foot beach."). Plaintiffs misunderstand Mr. Burgoyne's testimony regarding the narrowing and loss of beaches. Mr. Burgoyne testified that he considered the "beach conditions" and the depth of the beaches in front of plaintiffs' properties, Tr. 2500:19-21 (colloquy between Mr. Burgoyne and defendant's counsel), and the comparable properties, Tr. 2501:4-7 (colloquy between Mr. Burgoyne and defendant's counsel); see also, e.g., DX 295 (Anderson Appraisal) 45 (stating the depth of the beach in front of a comparable property). Mr. Burgoyne testified that the presence of a beach is "a positive feature," Tr. 107:14 (Burgoyne), but concluded that the partial loss of beach does not cause damage, but full loss does, Tr. 81:22-82:10 (colloquy between Mr. Burgoyne and plaintiffs' counsel).

[134]Although Mr. Burgoyne testified that, in addition to the amount of lake frontage, the better location of the smaller properties also played a role in their higher sale prices, Tr. 2483:3 (Burgoyne), he determined that "the controlling factor" was the width of the parcel, Tr. 2483:5 (Burgoyne).

[135]Dr. Moore testified that "it's an algebraic fact that if you have these two dimensions, lakefront footage and square footage of gross living area, that aren't affected by erosion, you're not going to find a direct effect of erosion." Tr. 192:15-19 (Moore); see also PX 149 (Moore Report) 12-13 (stating same). However, Dr. Moore's analysis addressed the impact that the government's publication of the 1999 Report had on plaintiffs' property values, see Pls.' Br. 37, and did not present a method of property valuation that incorporates the effect of erosion that does not render a property unbuildable, see PX 149 (Moore Report) passim.

Plaintiffs misconstrue Mr. Burgoyne's statements regarding the effect of beach size on property values. In a colloquy between Mr. Burgoyne and plaintiffs' counsel at trial, Mr. Burgoyne stated that reductions in the size of the beach in front of a property have no effect on the value of the property so long as the remaining amount of beach can properly be called a beach:

> Q: So, as long as the property had just one foot of beach, in your opinion, there is absolutely no diminution of value to that property?
>
> A: Well, I don't know if you would call one foot a beach. Nineteen feet certainly [is] a beach; maybe one foot, you wouldn't call it a beach.

Tr. 2554:22-2555:2 (colloquy between Mr. Burgoyne and plaintiffs' counsel). Mr. Burgoyne further stated that "[t]here's a couple that are 19 and 14 and 13[,] and those are beaches." Tr. 2555:7-9 (Burgoyne). Mr. Burgoyne did not state or imply that a beach that is four feet wide can properly be called a beach; in fact, Mr. Burgoyne noted that the Lahr property, which currently has a beach that is seven feet wide, "potentially could be perceived as not having a beach." Tr. 2555:6-7 (Burgoyne).

Mr. Burgoyne pointed out that beach width plays less of a role in the valuation of plaintiffs' property because beaches in the area are "very dynamic. They come and go, widen [and] narrow . . . ." Tr. 2501:20-21 (Burgoyne). A number of plaintiffs testified that their beaches come and go over time. See, e.g., Tr. 1272:25 (Concklin) (stating that the presence of the beach "ebbs[s] and flows"); Tr. 1303:10-14 (Kane) ("We never knew what it was going to look like when we came up . . . . [O]ne year there would be some beach, the next year there would be absolutely nothing."); see also Def.'s Br. 29 n.7 (summarizing the testimony of ten plaintiffs that the beaches adjacent to their properties come and go over time).

The fact that beaches are--and are well known to be--dynamic moderates the effect of beaches and beach width on the value of lakefront properties. See Tr. 2502:18-20 (Burgoyne). When beaches are not present, many of the features that make lakefront property desirable to buyers continue to exist, including "access to the water . . . breezes; views; sunsets or sunrises . . .; [and] the moderating [e]ffect of the lake on temperature." Tr. 2503:16-2504:4 (Burgoyne). Plaintiffs presented no evidence that contradicts Mr. Burgoyne's conclusion that variations in beach width do not affect property values as long as the beach remains wide enough properly to be called a beach. See Pls.' Br. passim; Pls.' Resp. passim. Nor have plaintiffs presented evidence that indicates the amount by which Mr. Burgoyne's appraisals should be adjusted to account for the loss of beach width. See Pls.' Br. passim; Pls.' Resp. passim.

ii. Loss of Beaches

Mr. Burgoyne testified that the presence of a beach is "a positive feature." Tr. 107:14 (Burgoyne). Mr. Burgoyne further testified that, although a partial loss of beach does not damage the market value of a property, a complete loss of a beach does. Tr. 81:22-82:10 (colloquy between Mr. Burgoyne and plaintiffs' counsel). Mr. Burgoyne concluded that the Chapman, Jackson and Renner properties diminished in value by $35,000, $30,000 and $30,000, respectively, DX 336 (Summary of Appraisals) 1-2, because "[t]he indication was they had a beach in 1950; [136] and that because of the acts of erosion, they did not have a beach in 2000,"[137] Tr. 79:24-80:1 (Burgoyne).

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[136]Because no photographs were available for 1950, Dr. Nairn examined photographs from 1938 and 1960. Tr. 2340:12-14 (Nairn). Every property listed as having a beach in 1938 is also listed as having a beach in 1960. See DX 188 (Nairn Beach Width and Comparables Report) 26, Table 4.1 (table of beach widths for plaintiffs' properties). For simplicity, the court refers to properties that had beaches in both 1938 and 1960 as having had beaches in 1950.

[137]According to the list prepared by Dr. Nairn, thirteen of the properties owned by plaintiffs that had beaches in 1950 did not have beaches in 2000. See id. Mr. Burgoyne determined that ten of these thirteen properties--the Werger, Okonski, Bodnar, Miller (the southerly property of the Miller plaintiffs' two contiguous properties), Ragins, Morvis, Errant (Saphir), Notre Dame Path Association, Country LLC and Pancoast properties, see id.--suffered no diminution in value as a result of the complete loss of their beaches, see Tr. 2552:15-23 (colloquy between Mr. Burgoyne and plaintiffs' counsel). Mr. Burgoyne was not asked why these ten properties did not have lower market values without beaches than they had with beaches. See Tr. 56:10-116:23, 2465:7-2558:19 (testimony of Mr. Burgoyne).

At trial, Mr. Burgoyne appeared to include the Neuser property in the list of properties that had a beach in 1950 but not in 2000, testifying that the Neuser property did not decline in value as a result of the loss of beach because it "was damaged about 90 percent for being unbuildable. So[,] damaging it further for not having access to a beach . . . wouldn't be appropriate . . . ." Tr. 2553:9-11 (Burgoyne). While the Neuser property had no beach in 2009, it had a beach 100 feet wide in 2000, DX 188 (Nairn Beach Width and Comparables Report) 26, Table 4.1 (table of beach widths for plaintiffs' properties), and therefore would have had a beach in Mr. Burgoyne's appraisal of the property given its condition in 2000.

Mr. Burgoyne began to make a statement about the property owned by the Notre Dame Path Association, but was interrupted before he finished his statement or explained why the Notre Dame Path Association's property did not diminish in value as a result of its loss of beach:

> A --yeah, and the Notre Dame Path Property is on there too, so--
>
> Q So then by my bad good math, there are eight properties listed here that have no beach . . . .

Tr. 2553:14-17 (colloquy between Mr. Burgoyne and plaintiffs' counsel).

While Mr. Burgoyne determined that loss of the beaches decreased the market value of certain of plaintiffs' properties, see DX 336 (Summary of Appraisals) 1, he did not determine, which, if any, of the beaches that were lost to erosion extended above the ordinary high water mark and therefore beyond the reach of the federal navigational servitude, see, e.g., DX 302 (Chapman Appraisal) passim. Neither does the table of beach widths assembled by Dr. Nairn indicate whether any portion of any beach listed in the table is located above the ordinary high water mark. See DX 188 (Nairn Beach Width and Comparables Report) 26, Table 4.1 (table of beach widths for plaintiffs' properties).

Rather, Dr. Nairn stated that he measured beach width "from the approximate water's edge to the delineated OHWM or landward extent of sand." See id. at 13. Although Dr. Nairn used the word "or," id., the court infers, in light of the techniques Dr. Nairn used to delineate the ordinary high water mark, that Dr. Nairn measured beaches from the water's edge to the ordinary high water mark in every case. Dr. Nairn delineated the ordinary high water mark differently depending on the characteristics of plaintiffs' properties. For properties with vertical shore protection or characterized by bluffs, he delineated the ordinary high water mark at the toe of the bluff or shore protection. See supra Part III.D.1. For properties with sloping shore protection, Dr. Nairn delineated the ordinary high water mark at the still water line along the shore protection. See id. For properties characterized by sand dunes, he delineated the ordinary high water mark at the edge of the more permanent vegetation. See id.

Accordingly, on properties with vertical shore protection and on properties characterized by bluffs, any beach would lie between the water's edge and the landward extent of sand, see DX 188 (Nairn Beach Width and Comparables Report) 13, which lies at the toe of the shore protection or bluff, a point that is also the ordinary high water mark for such properties. On properties with sloping shore protection, on which the ordinary high water mark is the still water line along the shore protection, no beach would be present between the water's edge and the shore protection. On properties characterized by sand dunes, any beach would lie between the water's edge and the edge of the permanent vegetation, see id., a point that is also the ordinary high water mark.

Plaintiffs do not acknowledge the possibility that their beaches may be located entirely below and within the ordinary high water mark. See Pls.' Br. passim; Pls.' Resp. passim. This oversight by plaintiffs is significant because not every government action that causes plaintiffs' properties to diminish in value is a taking for which just compensation must be paid. See generally OHWM Op., 71 Fed. Cl. 501 (discussing the role of the federal navigational servitude in this case). Plaintiffs' properties, being adjacent to the navigable waters of Lake Michigan, are subject to the navigational servitude held by the federal government, which servitude extends to the ordinary high water mark. See Cherokee, 480 U.S. at 704; see generally OHWM Op., 71 Fed. Cl. 501. When the government exercises its right to improve navigation in a manner that affects

property within the boundaries of this servitude, "'the damage sustained does not result from taking property from riparian owners within the meaning of the Fifth Amendment but from the lawful exercise of a power to which the interests of riparian owners have always been subject.'" Cherokee, 480 U.S. at 704 (quoting Rands, 389 U.S. at 123).

Plaintiffs cite no evidence, specifically pointed out at trial, that would allow the court to determine whether the beaches that were lost ended at the ordinary high water mark, or whether, on any property, the "landward extent of sand," DX 155 (Nairn Beach Width and Comparables Report) 13, extended inland beyond the ordinary high water mark as it stood in 1950, see Pls.' Br. passim; Pls.' Resp. passim; see also Mar. 2, 2011 Order, Dkt. No. 439, at 2, (stating that the court may disregard any exhibit or portion of an exhibit not "[s]pecifically pointed out" at trial "with an indication of how the evidence supports or disproves a fact in issue"). Plaintiffs have not carried their burden to prove that they are owed just compensation for the loss of beaches in front of their properties.[138]

iii. Selection and Treatment of Comparable Properties

Plaintiffs contend that there are several flaws in Mr. Burgoyne's selection and treatment of comparable properties. See Pls.' Br. 40. Plaintiffs argue that Mr. Burgoyne, "in attempting to determine the 'before taking' value of [p]laintiffs' properties, used market data from after the [a]nnouncement, despite his admission that post-announcement data would already reflect the impact of the [a]nnouncement." Id. Plaintiffs also argue that "even though Mr. Burgoyne used comparable sales that spanned

[138]Plaintiffs also argue that "Mr. Burgoyne also fails to understand that loss of sand, which results in loss of lateral support, is fundamental to property value and not 'just an amenity.'" Pls.' Br. 41. The court has stated on several occasions that "'[t]he federal navigational servitude defines the boundaries within which the government may supersede private ownership interests to improve navigation.'" OHWM Op., 71 Fed. Cl. at 504, (alteration in original) (quoting Jan. 9, 2006 Op., Banks v. United States, Dkt. No. 114, 69 Fed. Cl. 206, 209 (2006) (quoting Stabilization Op., 68 Fed. Cl. at 531)). Analogizing to takings of land adjacent to navigable rivers, the court explained:

> In general, destruction by the United States of lands located within a stream bed does not constitute a taking for which compensation is due; however, when land below the high water mark supports fast land located beyond the high water mark, any fast land that is destroyed as a consequence of government action may be compensable.

Id. at 507 (citing, inter alia, Owen, 851 F.2d at 1409-1410). Therefore, only to the extent that the erosion of beach sand below the ordinary high water mark results in erosion of land above the ordinary high water mark may plaintiffs be entitled to just compensation. To the extent that any loss of lateral support may have harmed land located above or outside the ordinary high water mark, plaintiffs cite no evidence that would quantify, in monetary terms, the amount of that loss. See Pls.' Br. passim; Pls.' Resp. passim.

a period of fourteen years, he failed to control for the effects of time on sale prices, including the effects of falling interest rates or increased demand. Id. Finally, plaintiffs contend that "although he had comparable sales from properties north of the St. Joseph jetties, Mr. Burgoyne elected not to use those comparables." Id. Plaintiffs argue that Mr. Burgoyne's selection and treatment of comparable properties "demonstrat[e] his flawed methodology." Id.

Plaintiffs are incorrect. Mr. Burgoyne's selection and treatment of comparable properties reflect a series of reasoned and well-documented decisions. It was appropriate for Mr. Burgoyne to use comparable sales data from dates after publication of the 1999 Report because Mr. Burgoyne had first determined that upon publication of the 1999 Report, "there didn't appear to be any adverse reaction in the marketplace." Tr. 2494:17-19 (Burgoyne); see also supra Part III.D.3.a (discussing the bases of Mr. Burgoyne's conclusion that the publication of the 1999 Report had no adverse reaction in the marketplace).

Contrary to plaintiffs' assertions, Mr. Burgoyne testified that he "definitely adjusted for and considered the fact that market conditions change," Tr. 2531:15-16 (Burgoyne). Mr. Burgoyne testified that "market conditions were generally increasing, so that older sales were adjusted upwards and later sales adjusted downward." Tr. 2531:16-19 (Burgoyne); see also DX 295 (Anderson Appraisal) 40 (describing the adjustments made to certain sale prices based on when the sales were made). Mr. Burgoyne's decision not to use comparable sales from north of the jetties similarly reflects Mr. Burgoyne's observations about the local real estate market. Mr. Burgoyne concluded that:

> [w]hile sales that are more distant geographically to the north and south of the subject, including those north of the jetties in St. Joseph and Benton Township, were considered and researched, the sales in the immediate vicinity of the subject (occurring both before and after the January 2000 date of taking) are considered the best and most applicable comparable[] sales for appraising the subject property.

DX 295 (Anderson Appraisal) 37. Mr. Burgoyne also stated, based on his market research, that "market comparables from north of the jetties are entirely consistent with the market data from the subject area." Id. Apart from the econometric analysis created by Dr. Moore, which did not control for different preexisting trends in the affected area and the control group, see supra Part III.D.2.b.iii, plaintiffs did not present evidence that contradicts Mr. Burgoyne's testimony and have failed to persuade the court that Mr. Burgoyne's selection and treatment of comparable sales were improper.

iv. Loss of Improvements

Plaintiffs argue that "Mr. Burgoyne testified that his appraisals do not account for damages from the loss of improvements [p]laintiffs[] suffered as a result of erosion between 1950 and 2000, despite the fact that many of these improvements would increase the [p]laintiffs' property values." Pls.' Br. 41. Plaintiffs contend that "Mr. Burgoyne testified that 'he was told' that damages for past improvements would be dealt with separately. In other words, he wanted to conduct a better study but was told not to." Id. (citation omitted).

The reason that Mr. Burgoyne's appraisals did not account for damage to improvements, Tr. 2520:15-21 (colloquy between Mr. Burgoyne and plaintiffs' counsel), is that he was told that "those claims would be separate and independent" of his analysis, Tr. 2525:3-4 (Burgoyne).

Plaintiffs' criticism is unconvincing given the fact that plaintiffs take the same approach to proving their damages. Plaintiffs presented the expert testimony of Dr. Moore, who attempted to determine, as a general matter, the damage done to plaintiffs' property values without considering any improvements that had been lost to erosion. See Tr. 117:1-251:19 (testimony of Dr. Moore). Plaintiffs presented separately evidence of the improvements lost by individual plaintiffs. See Pls.' Br. 31-33 (summarizing, inter alia, the improvements lost by each plaintiff).

v. Market Study

To study the effect of the increased risk of coastal erosion on property values, Mr. Burgoyne included in his appraisals a market study he conducted in Mason County, Michigan, which, like plaintiffs' zone, is located on the eastern shore of Lake Michigan. See DX 295 (Anderson Appraisal) 106-14. The market study compared a group of properties sold subject to an erosion easement absolving the adjacent power plant from any liability for erosion caused by the plant's operations to the sale of other properties not encumbered by an erosion easement. See id. at 106-07. Mr. Burgoyne concluded that the market study he conducted "clearly indicates the lack of impact from the announced risk of erosion and the erosion easement . . . ." Id. at 114. Plaintiffs argue that Mr. Burgoyne's market study is flawed. Pls.' Br. 40.

Plaintiffs contend that "Mr. Burgoyne admits that he never analyzed the properties in his '[test] group' without an erosion easement."[139] Id. (citing Tr. 2544:3-12). Plaintiffs also argue that "Mr. Burgoyne failed to control for time[,] as the 'auction group' properties were all sold in a single day while the 'control group' properties were

[139]Plaintiffs use the term "control group" rather than "test group" in plaintiffs' Brief. See Pls.' Br. 40. The court understands plaintiffs to be referring to the "test group" because the properties in the test group had erosion easements and because, in the portion of the transcript cited by plaintiffs, Mr. Burgoyne was discussing the test group. See Tr. 2544:3-12 (colloquy between Mr. Burgoyne and defendant's counsel).

sold over a period of six years," id. at 40-41 (citing Tr. 173:10-174:25), and that Mr. Burgoyne "did not conduct an impact study with properties north of the St. Joseph jetties and properties south of the St. Joseph jetties," id. at 41.

The court finds it unnecessary to evaluate the validity of Mr. Burgoyne's market study because the court finds Mr. Burgoyne's appraisals persuasive without any support the market study might add. Mr. Burgoyne used a variety of methods in addition to the market study to determine whether publication of the 1999 Report impacted the local real estate market south of the jetties. See supra Part III.D.3.a (discussing the bases of Mr. Burgoyne's conclusion that the publication of the 1999 Report resulted in no adverse reaction in the marketplace). The court finds Mr. Burgoyne's conclusion that "there didn't appear to be any adverse reaction in the marketplace," Tr. 2494:17-19 (Burgoyne), well-supported and reasonable.

4. Shore Protection Expenses Incurred by Plaintiffs and Improvements Lost by Plaintiffs

a. Improvements Lost to Erosion

Several plaintiffs testified at trial that they lost improvements on their properties to erosion. See, e.g. Tr. 1305:1-3 (Kane) (stating that a set of stairs and a patio located on her property eroded into the lake). Plaintiffs include in their briefing a list of property lost to erosion that includes, among other things, improvements lost to erosion. See Pls.' Br. 31-33. Plaintiffs criticize Mr. Burgoyne for not considering the loss of improvements in his appraisals. See supra Part III.D.3.b.iv. However, the measure of just compensation to which plaintiffs claim they are entitled does not include the value of any improvements.

Plaintiffs calculate the amount of just compensation to which they claim entitlement by adding three figures: (1) the amount that plaintiffs claim, based on the analysis of Dr. Moore, that each property failed to appreciate in value as a result of the publication of the 1999 Report; (2) the cost of any shore protection already installed by each plaintiff; and (3) the cost to construct headland beaches, plaintiffs' preferred form of shore protection, at each property. See Pls.' Br. 35-51. For instance, plaintiffs calculate that the Bovee plaintiffs are entitled to just compensation of $1,261,009, id. at 50, a sum equal to the amount by which, according to plaintiffs, the value of the Bovee property failed to appreciate ($311,379), id. at 38, plus the cost of constructing a headland beach ($937,867), id. at 48, plus the costs already incurred to install shore protection ($11,763), id. at 50.[140]

[140]Plaintiffs also claim attorney's fees, costs and interest. Pls.' Br. 51. Plaintiffs fail to discount, see Pls.' Br. 35-51, the amount of just compensation they claim as required by the court's ruling that plaintiffs are entitled, if proven, to just compensation equal to 30% of the harm done by erosion to their properties between 1950 and 1970 and the portion of 30% of the

None of the three bases of the amount of plaintiffs' claims for just compensation includes loss of improvements. Even though plaintiffs suggest that Dr. Moore's analysis includes a loss of the value of improvements, see Pls.' Br. 39 ("[P]rices act as a summary statistic for the interplay of all things that affect value."), Dr. Moore did not consider the value of any lost improvements in his analysis of the harm done to the property values of plaintiffs' properties, see PX 149 (Moore Report) passim.

The trial transcript contains references to the sums of money that plaintiffs expended to replace improvements lost to erosion. See, e.g., Tr. 1308:3-12 (colloquy between plaintiff Patricia Kane and plaintiffs' counsel) (stating that Ms. Kane spent $20,000 to replace a patio that eroded into the lake with a larger and more secure deck). However, plaintiffs do not cite, and the court has not found in the record, evidence that would allow the court to determine the value of any structures lost to erosion as of the date that they were lost. See Tr. passim; Pls.' Br. passim; Pls.' Resp. passim. Plaintiffs do not cite, nor does the record contain, evidence that would allow the court to determine which structures were lost before 1970, the date that the court has found, see supra Part III.C, that the government began to mitigate all of the erosion caused by the jetties to every property but one[141] owned by plaintiffs, see Tr. passim; Pls.' Br. passim; Pls.' Resp. passim.

Because plaintiffs do not claim that they are entitled to separate compensation for improvements lost to erosion and because the evidence in the trial record does not allow the court to determine the value of the improvements lost, if any, by plaintiffs and their predecessors in interest before 1970, the court finds that plaintiffs are not entitled to compensation for any improvements lost to erosion.

b. Shore Protection Expenses

At the trial of damages, twenty-seven plaintiffs testified that they had installed shore protection to slow the erosion of their properties. See Pls.' Br. 50 (compiling, from the trial testimony of twenty-seven plaintiffs and the stipulations filed by the parties, the costs incurred by plaintiffs to install shore protection). When a taking results from erosion that is "in fact preventable by prudent measures, the cost of that prevention is a proper basis for determining the damage." Dickinson, 331 U.S. at 751; see also Law of Damages Op., 88 Fed. Cl. at 683 (quoting same). "Substantial encroachment of the

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erosion damage done to their properties not mitigated by the government thereafter, see Liability Op., 78 Fed. Cl. at 654-57.

[141]The Werger property is located on a section of shoreline that does not benefit from the mitigation efforts begun by the government in 1970 because it is cohesive. See supra Part III.B. However, the Werger plaintiffs did not testify at trial, see Tr. passim, and plaintiffs fail to cite evidence proving that any improvements on the Werger property were lost to erosion. See Pls.' Br. passim; Pls.' Resp. passim.

parcel also puts a duty on the landowner to take reasonable steps to protect the property from further erosion damage, such as by the construction of revetments." Boling II, 220 F.3d at 1373 n.5. Reasonable expenditures to prevent erosion are those as to which "it 'would have been sound economy, in view of the character and nature of the property, to have made the expenditure[s].'" Vaizburd v. United States, 384 F.3d 1278, 1286 (Fed. Cir. 2004) (alterations in original) (quoting United States v. Dickinson, 152 F.2d 865, 870 (4th Cir. 1946), aff'd, Dickinson, 331 U.S. 745).

The court must therefore determine whether it was "sound economy" for plaintiffs to construct the shore protection they installed. See id. If installing shore protection was sound economy, plaintiffs who have installed shore protection may recover the government's share of the cost to install and maintain shore protection, Law of Damages Op., 88 Fed. Cl. at 685 n.16, that is, 30% of any costs incurred from 1950 to 1970, and a portion of the costs incurred from 1970 to the present equal to the portion of the erosion caused by the jetties and not mitigated by defendant during that time period, cf. Liability Op., 78 Fed. Cl. at 656-57.

Defendant argues that "it is not enough that Plaintiffs have incurred expenses to construct or maintain shore protection on their properties." Def.'s Br. 36. Because the government is responsible for only a portion of the erosion to plaintiffs' properties, defendant argues that the plaintiffs' expenses for the construction of shore protection are only recoverable if plaintiffs establish a causal link between the Corps' activities and the construction of shore protection by plaintiffs. Id. Defendant is correct that "causation is an independent element of a takings claim." Id. (citing Cary v. United States, 552 F.3d 1373, 1379-80 (Fed. Cir. 2009)). In order to recover in an inverse condemnation action, a plaintiff must satisfy a two-part test "that can be characterized as causation and appropriation." Cary, 552 F.3d at 1376-77 (citing Ridge Line, Inc. v. United States, 346 F.3d 1346 (Fed. Cir. 2003)). "In the causation prong, it must be shown that 'the government intend[ed] to invade a protected property interest or [that] the asserted invasion [was] the direct, natural, or probable result of an authorized activity and not the incidental or consequential injury inflicted by the action.'" Id. at 1377 (alterations in original) (quoting Ridge Line, 346 F.3d at 1355).

Defendant argues that "[a]s a matter of law, the evidence [p]laintiffs have proffered is insufficient to establish that the United States' activities are the proximate cause of the shore protection expenses various [p]laintiffs incurred." Def.'s Br. 37. Defendant notes that "it is undisputed that [p]laintiffs' shoreline is a naturally eroding shore." Id. Citing the trial testimony of a number of plaintiffs, defendant contends that "the overwhelming evidence in the record establishes that [p]laintiffs' shore protection efforts were taken in response to natural conditions" such as rising lake levels and storm events. Id. at 37-39.

However, the fact that erosion is associated with particular events does not mean that the jetties had no impact. The evidence presented at trial indicated that erosion is

often discontinuous, with portions of plaintiffs' properties--particularly the edges of bluffs, where present--falling into the lake during storms or at times of high lake levels. See, e.g., Tr. 957:22-959:2 (colloquy between plaintiff Marcia Wineberg and plaintiffs' counsel). Additionally, Dr. Nairn testified that, especially on the southernmost properties, which are characterized by sand dunes rather than bluffs, the long-term retreat rate of a sandy shoreline can be overshadowed by the dramatic swings in beach width caused by cross-shore sand transport during storms and periods of high lake levels. See Tr. 2591:15-2595:2 (Nairn) (discussing the slow, but irreversible, erosion caused by longshore sand transport and the rapid, but reversible, erosion caused by cross-shore sand transport). Although the loss of beaches below and within the ordinary high water mark is not compensable as a taking, see supra Part III.D.3.b.ii, a landowner could be expected to install shore protection in response to the narrowing or disappearance of a beach. Plaintiffs' testimony that they installed shore protection in reaction to storms and high lake levels reflects the fact that the long-term process of erosion is often most apparent to the lay observer under such conditions. Accordingly, the "'direct, natural, or probable result,'" Cary, 552 F.3d at 1377 (quoting Ridge Line, 346 F.3d at 1355), of the erosion caused by the government would be periods of more pronounced erosion and attempts by property owners to prevent erosion following storms and during periods of high lake levels.

Defendant argues that, owing to natural erosion, plaintiffs "would have had to install shore protection, irrespective of the presence of the harbor." Def.'s Br. 37 (citation omitted). Plaintiffs respond that "[i]n essence[,] the United States is arguing that it is allowed, through accelerated erosion, to take property from private property owners without just compensation so long as there is another concurrent cause of the erosion." Pls.' Resp. 9. The Federal Circuit addressed a similar issue in Ridge Line. The plaintiff in Ridge Line claimed "that it was forced to construct . . . water detention facilities much earlier and on a larger scale than would have been required without the increased runoff caused by [a] government development." Ridge Line, 346 F.3d at 1351. The Ridge Line plaintiff's claim, analogous to plaintiffs' claim in this case, was that the government exacerbated an existing storm water runoff problem on the plaintiff's property which required remediation notwithstanding the government's actions. See id. at 1350-51. Remanding the Ridge Line case for additional proceedings, the Federal Circuit opined that "[a] share of the costs of building and maintaining storm water control facilities, proportionate to the government's quantitative contributions of storm water volumes, erosion, and sedimentation, is an entirely acceptable method of calculating damages." Id. at 1359. The court therefore finds that the government is liable for a share of plaintiffs' shore protection expenses equal to the portion of the erosion caused by the government at the time the expenses were incurred.

Defendant does not argue that the shore protection measures heretofore undertaken by plaintiffs were unduly expensive or wasteful in relation to the amount of erosion or to the harm to the market value of plaintiffs' properties that they prevented. See Def.'s Br.

passim; Def.'s Resp. passim; cf. Tr. 1684:20-21 (Shabica) (describing the structures built by all but two of the plaintiffs with shore protection as "amateur shore protection"). Plaintiffs claim that their full cost of installing and maintaining shore protection was approximately $2.2 million. See Pls.' Br. 50. Defendant's expert witness, Mr. Burgoyne, calculated the market value of plaintiffs' properties in January 2000 to be approximately $25 million. See DX 336 (Summary of Appraisals) 2. The cost of building and maintaining shore protection since 1950, as calculated by plaintiffs, although not adjusted for inflation, is approximately 10% of the value of plaintiffs' properties in 2000.

Because the shore protection efforts undertaken by plaintiffs are relatively inexpensive compared to the value of plaintiffs' properties, and because defendant's expert witness, Mr. Burgoyne, testified that shore protection similar to the shore protection installed by plaintiffs is "relatively ubiquitous," Tr. 2516:11-15 (Burgoyne), reflecting a judgment by the adjacent property owners that shore protection is sound economy, plaintiffs have met their burden of demonstrating that the shore protection efforts that they have undertaken in the past are "sound economy," Vaizburd, 384 F.3d at 1286. This is so notwithstanding that plaintiffs have not presented evidence of the effect that erosion would have had on the market value of their properties in the absence of shore protection. See Ridge Line, 346 F.3d at 1354-55 (finding that, where the plaintiff prevented storm water runoff from the government's property from causing further erosion damage by taking measures that constituted sound economy, the trial court erred in holding that plaintiff had not demonstrated damages simply because it had not produced appraisals of its property showing a loss in value).

Plaintiffs do not state in their briefing, see Pls.' Br. passim; Pls.' Resp. passim, or in the stipulation filed by the parties regarding shore protection costs, see Trial Stipulations of Fact, Dkt. No. 456, passim, when plaintiffs incurred their shore protection expenses. There are references in plaintiffs' trial testimony, see, e.g., Tr. 1217:15-23 (colloquy between plaintiff Kay Varga-Smith and plaintiffs' counsel), and in the documentation of shore protection expenses presented by plaintiffs, see, e.g., PX 261 (receipts for shore protection expenses), to when certain shore protection measures were undertaken. Because these references are scattered across several thousand pages of trial testimony and documentary evidence, the court will not, in the absence of briefing or a stipulation by the parties, undertake to determine which of plaintiffs' shore protection expenses were incurred between 1950 and 1970, the period of time during which the government was responsible for 30% of the erosion taking place in plaintiffs' zone, see Liability Op., 78 Fed. Cl. at 656, and with respect to which, plaintiffs are entitled to 30% of their shore protection expenses incurred, see supra Part I. Neither will the court undertake to determine which of plaintiffs' expenses were incurred after 1970, the period of time during which the government has completely mitigated the erosion caused by the jetties. See supra Part III.C.2. If the reviewing court does not agree with the court's determination that it lacks jurisdiction to address plaintiffs' claims, the court will direct the parties to file a stipulation--or briefing, if the parties do not agree--to enable the court

to determine which of plaintiffs' shore protection expenses were incurred prior to 1970 and which were incurred subsequent to 1970. Because plaintiffs had sufficient opportunity to prove the amount of their damages at trial, the court will not accept additional evidence regarding the amount of their expenses.

5. Reasonably Foreseeable Future Damages

The court previously determined that defendant is liable for damages for any portion of 30% "of all reasonably foreseeable future loss" not mitigated by defendant. Liability Op., 78 Fed. Cl. at 656.

If further erosion of plaintiffs' properties is "in fact preventable by prudent measures, the cost of that prevention is a proper basis for determining the damage." Law of Damages Op., 88 Fed. Cl. at 683 (quoting Dickinson, 331 U.S. at 751); see also Vaizburd, 384 F.3d at 1286 (stating that expenditures to cure the effects of a taking were recoverable if they were reasonable, meaning that "'it would have been sound economy, in view of the character and nature of the property, to have made the expenditure[s]'" (alteration in original) (quoting Dickinson, 152 F.2d at 870)).

If the installation of shore protection would be sound economy, it is not necessary for plaintiffs to provide appraisals to prove the exact amount of the damage their properties will suffer in the future without shore protection. See Ridge Line, 346 F.3d at 1354-55. However, to determine whether the installation of shore protection to prevent future erosion would be sound economy, the court must consider whether the government's share of the cost of shore protection would be greater than the government's share of the amount by which plaintiffs' property values would decline in the reasonably foreseeable future absent shore protection.[142] See Law of Damages Op.,

[142]Plaintiffs argue that "[w]hen determining the character and nature of the property at issue, courts look to both the private interests of the owner and whether the rights of the public will be affected by the taking." Pls.' Br. 43. The cases plaintiffs cite, however, do not support this proposition. Plaintiffs first cite United States v. Chicago, B. & Q.R. Co. (Chicago I), 82 F.2d 131, 140 (8th Cir. 1936), a case that plaintiffs state is "cited with approval in United States v. Dickinson, 152 F.2d 865, 870-71 (4th Cir. 1946)." Pls.' Br. 43 (emphasis omitted). Plaintiffs describe Chicago I with a parenthetical that reads as follows: "upholding verdict of $240,000 for cost to cure when land had 'little, if any, market value' because the rights of the public were affected by the taking." Pls.' Br. 43 (quoting Chicago I, 82 F.2d at 140).

Plaintiffs are correct that, in Chicago I, "the actual land involved had little, if any, market value." Chicago I, 82 F.2d at 140. However, the Chicago I court affirmed the trial court's verdict, not because of "the rights of the public," Pls.' Br. 43, but because of the harm done to the remaining portion of the property, Chicago I, 82 F.2d at 134. The government planned to build a dam that would flood a portion of the plaintiff's right of way adjacent to the plaintiff's railroad embankment. Id. at 132. The government sought to condemn a floodway easement over the flooded portion of the plaintiff's land. Id. When the water reached its planned depth, the

88 Fed. Cl. at 683 ("'If revetments are less expensive than the value of the land forecast to be lost, then the [g]overment may discharge its liability by bearing the cost of bank protection.'" (alteration in original) (quoting Boling I, 41 Fed. Cl. at 694)). If the government's share of the cost of shore protection is greater than the government's share of the amount by which plaintiffs' property values would decline in the reasonably foreseeable future absent shore protection, constructing shore protection would not be sound economy. See Boling I, 41 Fed. Cl. at 694 (stating that "if the value of land to be lost is less than the cost of revetments, however, plaintiffs cannot force the Government to pay the higher amount").

"Although the general rule in takings cases is to award plaintiff the form of just compensation that will be least expensive for the government," the court, in its Law of Damages Opinion, found this general rule "inapplicable in the particular circumstances of the present case," in which the government is not the only source of erosion to plaintiffs'

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surface of the water was to be 3.45 feet from the top of the railroad ties. Id. Despite the limited value of the land taken, the court noted that, "absent expensive measures of protection," the flood waters would effectively destroy four miles of track on the remaining land. Id. at 137. While litigation was underway, the railroad raised the track bed and added riprap along the embankment. Id. at 132. The trial court awarded the railroad $240,000 in damages and an additional sum in interest. Id. at 132-33. Observing that the "modern trend" was to award just compensation for both the land taken and the damage to the remaining property, id. at 134, 139, the court affirmed the award of damages, id. at 141.

Similarly, in United States v. Chicago, B. & Q.R. Co. (Chicago II), 90 F.2d 161, 163 (7th Cir. 1937), the government sought to condemn a different portion of the same railroad's land that was to be flooded by the same project. The government again argued that it was not liable for the damage that flooding would cause to the remaining property. Id. at 167. The Chicago II court disagreed, stating that "[i]t is sufficient to say, without further discussion, that we concur in the conclusions of the [Chicago I court] . . . ." Id. at 168.

The Dickinson court cited Chicago I for the principle that just compensation includes the harm done to the remaining property. See Dickinson, 152 F.2d at 870. The Dickinson court summarized Chicago I as follows: "[I]t was held that the railroad was entitled to recover not only the value of the twenty-four acres permanently submerged, which was comparatively small, but also the cost for the changes in the embankment and the railroad line which were needed to protect the railroad and enable it to continue in operation." Id. The Dickinson court then stated,"We think that this rule is applicable here and that in each case the landowner should be compensated for the loss to the residue of his property occasioned by the building of the dam." Id.

Plaintiffs have misunderstood the reasoning and the holdings of Chicago I, Chicago II and Dickinson, none of which supports the proposition that "[w]hen determining the character and nature of the property at issue, courts look to both the private interests of the owner and whether the rights of the public will be affected by the taking." Pls.' Br. 43.

properties. Law of Damages Op., 88 Fed. Cl. at 683. The court stated that "[p]laintiffs may not be financially able to pay 70% of the cost to construct shore protection measures out of their own pockets, resulting in continued erosion of their property." Id. The court held that "as an alternative to seeking 30% of the cost of shore protection measures, plaintiffs may instead seek 30% of the cost of 'reasonably foreseeable future loss' to their property, although this amount may result in greater cost to the government." Id. at 684. Plaintiffs have elected to pursue just compensation equal to the government's share of shore protection rather than the government's share of future erosion damage. See Pls.' Br. 42-50 (discussing the cost of shore protection but not the dollar amount of reasonably foreseeable loss to plaintiffs' properties).

The court has determined that defendant is completely mitigating the erosion caused by the jetties to every property owned by plaintiffs but one, and has done so since 1970. See supra Part III.C.2. Therefore, for every property but one, no "reasonably foreseeable future loss," Liability Op., 78 Fed. Cl. at 656, will result from the government's actions. Plaintiffs argue that "what little dredging nourishment there is is in serious jeopardy of being cut off completely." Pls.' Br. 29. Plaintiffs further argue that "the unrebutted testimony at trial was that there is no funding available in 2012 for dredging of the St. Joseph Harbor." Id. at 29-30. Plaintiffs' argument that funding for the mitigation program "is in serious jeopardy" of lapsing in the future is speculative and dependent upon future actions by the government. At present, the mitigation program continues to provide nourishment material to plaintiffs' shoreline, as it has for more than forty years. Liability Op., 78 Fed. Cl. at 655 (finding that mitigation began in 1970). The court therefore concludes that, with the exception of one property, plaintiffs have not proven that they will suffer any reasonably foreseeable future loss as a result of the government's actions.

Furthermore, to determine whether it would be sound economy to install shore protection to prevent any reasonably foreseeable future loss, the court must compare the cost of shore protection to the damage to plaintiffs' properties expected to occur in the absence of shore protection. See Law of Damages Op., 88 Fed. Cl. at 683. For almost every plaintiff, it would not be possible for the future loss in market value to be greater than the cost of installing shore protection because the cost of the form of shore protection that plaintiffs argue is most appropriate, see Pls.' Br. 48, as estimated by plaintiffs, is greater than the full value of almost every plaintiff's property, compare, e.g., id. 48 (stating that the cost to install a headland beach[143] at the Bovee property in 2010

[143]"Headland beaches consist of a single [promontory] or paired engineered promontory[ies] protruding from the shore and a sand beach between the paired promontories or on the updrift side of a single promontory." PX 145 (Chrzastowski Report) 4. Plaintiffs argue that headland beaches both prevent future erosion of the shoreline and preserve a sand beach, see Pls.' Br. 44, and that headland beaches "create a quiet zone along the shoreline that can be used for swimming or boating," id. at 45. Plaintiffs contend that "[a] headland beach also provides critical environmental benefits," by supporting vegetation, including several species of

dollars is $937,867), with id. at 36 (stating that the value of the Bovee property after publication of the 1999 Report in January 2000 was $430,000). Even if the appropriate form of shore protection is quarrystone revetments, which plaintiffs argue is not the case, see id. at 48, the cost of shore protection is nearly as much, or greater, than the full value of most of plaintiffs' properties, compare, e.g., id. at 49 (stating that the cost to install a quarrystone revetment at the Bovee property would be $429,438), with id. at 36 (stating that the value of the Bovee property after publication of the 1999 Report in January 2000 was $430,000).

The installation of shore protection measures costing more than the value of the properties they are installed to protect is not sound economy. Determining whether it is sound economy to construct shore protection measures that cost nearly as much as the properties that they are installed to protect would require persuasive evidence of when and to what extent the market value of the properties will diminish in the absence of the shore protection. Such evidence was not provided by plaintiffs. See Tr. passim.

The court has reviewed the trial record for evidence of the loss in market value that plaintiffs' properties will suffer as a result of erosion caused by the jetties in the absence of shore protection, but has found none.[144] Plaintiffs' expert witness on the topic

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endangered plants, and providing a "habitat for fish and shore birds," id., and that headland beaches have aesthetic benefits, "are safer for swimmers and boaters, especially in the case of an emergency," and support tourism, id.

Defendant responds that "headland beaches are a Mercedes-Benz version of shore protection." Tr. 45:15-16 (defendant's counsel). Defendant argues that, to the extent that plaintiffs may be entitled to recovery for shore protection, "[p]laintiffs are not entitled to any particular category of shore protection, but only to reasonable shore protection that will compensate [p]laintiffs for their property loss." Def.'s Br. 39 (citing United States v. Miller, 317 U.S. 369, 375 (1943)). Defendant contends that installing armorstone revetments and maintaining the revetments until 2050 would cost $6,900,000. See Def.'s Br. 46; cf. DX 205 (Nairn Shore Protection Report) 106, Fig. 6.1 (conceptual illustration of armor stone revetment).

The parties presented sophisticated and thorough analyses of the types of shore protection that could be installed and the benefits of each. See generally DX 205 (Nairn Shore Protection Report); PX 145 (Shabica Shore Protection Report). Because the court determines that plaintiffs have failed to demonstrate that they are entitled to the cost of installing shore protection, the court does not address the form of shore protection that would be most appropriate for plaintiffs' properties.

[144]Plaintiffs cite two pieces of evidence regarding the future erosion of their properties, neither of which addresses the future diminution of plaintiffs' property values. Plaintiffs first cite a February 9, 2007 letter addressed to plaintiff Marcia Wineberg by the State of Michigan Department of Environmental Quality (MDEQ), discussing an increased setback that MDEQ was proposing for buildings and septic systems on her property in light of shoreline recession projected to occur in the future. See Pls.' Br. 42 (citing PX 135 (MDEQ letter to Ms.

of damages, Dr. Moore, considered the effect of the government's publication of the 1999 Report, see Pls.' Br. 35-37, but did not examine the effect that ongoing erosion would have on the market value of plaintiffs' properties in the future, see PX 149 (Moore Report) passim. Defendant's expert witness on the topic of damages, Mr. Burgoyne, appraised plaintiffs' properties with their dimensions in 1950 and 2000, but did not appraise them with dimensions that they will have in the future. See, e.g., DX 295 (Anderson Appraisal) passim. Accordingly, even if the court had determined that the government's mitigation program had been ineffective as to all of plaintiffs' properties, the court would be unable to award plaintiffs the amount of just compensation to which plaintiffs claim they are entitled for the prevention of reasonably foreseeable erosion damage.

Plaintiffs have not carried their burden of proof, cf. Miller, 223 Ct. Cl. at 383-84, 620 F.2d at 828 (stating that plaintiffs bear the burden of proving the amount of just compensation to which they are entitled for severance damage), to establish that they are entitled to additional just compensation for the reasonably foreseeable erosion of their properties. Since 1970, the Corps' mitigation efforts have prevented the jetties from causing erosion to plaintiffs' properties, with one exception. Further, plaintiffs have failed to prove, with regard to any of plaintiffs' properties--whether by comparing the cost of shore protection to the dollar amount of their reasonably foreseeable damages or by some other means--that the installation of shore protection would be sound economy.

IV. Conclusion

Wineberg)). Testimony at trial indicated that similar letters were sent to other "specific Berrien County property owners." Tr. 1539:12-17 (Jannereth). However, plaintiffs do not state which plaintiffs other than the Wineberg plaintiffs received such letters. See Pls.' Br. 42. Neither do plaintiffs attempt to quantify the effect that the increased setbacks would have on the market value of the properties owned by the Wineberg plaintiffs or any other plaintiffs who received similar letters. See id. passim.

Plaintiffs cite the testimony of Dr. Meadows, who, plaintiffs argue, "opined that, without effective shore protection, [p]laintiffs will lose another 1,870,000 cubic yards of property between 2000 and 2050." id. at 42 (citations omitted). Although plaintiffs do not calculate a monetary value for the volume of property they will lose in the future, see id. passim; Pls.' Resp. passim, plaintiffs argue in a different portion of their brief that the cost to replace the 1,870,000 cubic yards of property that plaintiffs claim to have lost between 1950 and 2000 with sand would be $18,700,000. See Pls.' Br. 39 n.27. It is the law of the case, however, that the measure of just compensation due to plaintiffs, if any, is not, as plaintiffs continue to argue, based on the cost to replace with sand the volume of property claimed to have been lost to erosion. See supra note 126. The volume of material that plaintiffs will lose to erosion in the future is therefore not, in this case, evidence of the measure of "reasonably foreseeable future loss" that plaintiffs will suffer as a result of the government's actions.

For the reasons stated above, see supra Part III.A, the court finds that it lacks jurisdiction to hear plaintiffs' claims. The findings of fact and conclusions of law presented in Parts III.B-D of this Opinion are presented for purposes of judicial efficiency if the reviewing court in any appeal should disagree with the court's view of its jurisdiction, and to avoid the possibility of a trial opinion being drafted months or years after the trial, and the possibility of a repetitive trial. These findings are presented in the alternative and, in the absence of jurisdiction, do not entitle plaintiffs to just compensation in the amounts determined by the court.

The Clerk of Court shall ENTER JUDGMENT for defendant in each of the above-captioned cases DISMISSING each of plaintiffs' complaints.

IT IS SO ORDERED.

s/ Emily C. Hewitt
EMILY C. HEWITT
Chief Judge

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