Aviation Investigation Final Report

Location:	Sugarland, Texas	**Accident Number:**	CEN15LA057
Date & Time:	November 21, 2014, 10:10 Local	**Registration:**	N584JS
Aircraft:	EMBRAER S.A. EMB-500	**Aircraft Damage:**	Substantial
Defining Event:	Collision during takeoff/land	**Injuries:**	2 None
Flight Conducted Under:	Part 91: General aviation - Positioning		

Analysis

The pilots of the very light jet were conducting a positioning flight in instrument meteorological conditions. The flight was cleared by air traffic control for the instrument landing system (ILS) approach; upon being cleared for landing, the tower controller reported to the crew that there was no standing water on the runway. Review of the airplane's flight data recorder (FDR) data revealed that the airplane reached 50 ft above touchdown zone elevation (TDZE) at an indicated airspeed of 118 knots (KIAS). The airplane crossed the runway displaced threshold about 112 KIAS, and it touched down on the runway at 104 KIAS with about a 7-knot tailwind.

FDR data revealed that, about 1.6 seconds after touchdown of the main landing gear, the nose landing gear touched down and the pilot's brake pedal input increased, with intermediate oscillations, over a period of 7.5 seconds before reaching full pedal deflection. During this time, the airplane achieved its maximum wheel braking friction coefficient and deceleration. The cockpit voice recorder recorded both pilots express concern the that the airplane was not slowing. About 4 seconds after the airplane reached maximum deceleration, the pilot applied the emergency parking brake (EPB). Upon application of the EPB, the wheel speed dropped to zero and the airplane began to skid, which resulted in reverted-rubber hydroplaning, further decreasing the airplane's stopping performance. The airplane continued past the end of the runway, crossed a service road, and came to rest in a drainage ditch. Postaccident examination of the brake system and data downloaded from the brake control unit indicated that it functioned as commanded during the landing. The airplane was not equipped with thrust reversers or spoilers to aid in deceleration.

The operator's standard operating procedures required pilots to conduct a go-around if the airspeed at 50 ft above TDZE exceeded 111 kts. Further, the landing distances published in the airplane flight manual (AFM) are based on the airplane slowing to its reference speed (Vref) of 101 KIAS at 50 ft over the runway threshold. The airplane's speed at that time exceeded Vref, which resulted in an increased runway distance required to stop; however, landing distance calculations performed in accordance with the AFM showed that the airplane should still have been able to stop on the available runway. An airplane performance study also showed that the airplane had adequate distance available on which to stop had the pilot continued to apply maximum braking rather than engage the EPB. The application of the EPB resulted in skidding, which increased the stopping distance.

Although the runway was not contaminated with standing water at the time of the accident, the performance study revealed that the maximum wheel braking friction coefficient was significantly less than the values derived from the unfactored wet runway landing distances published in the AFM, and was more consistent with the AFM-provided landing distances for runways contaminated with standing water.

Federal Aviation Administration Safety Alert for Operators (SAFO) 15009 warns operators that, "the advisory data for wet runway landings may not provide a safe stopping margin under all conditions" and advised them to assume "a braking action of medium or fair when computing time-of-arrival landing performance or [increase] the factor applied to the wet runway time-of-arrival landing performance data."

It is likely that, based on the landing data in the AFM, the crew expected a faster rate of deceleration upon application of maximum braking; when that rate of deceleration was not achieved, the pilot chose to engage the EPB, which only further degraded the airplane's braking performance.

Probable Cause and Findings

The National Transportation Safety Board determines the probable cause(s) of this accident to be:

The pilot's engagement of the emergency parking brake during the landing roll, which decreased the airplane's braking performance and prevented it from stopping on the available runway. Contributing to the pilot's decision to engage the emergency parking brake was the expectation of a faster rate of deceleration and considerably shorter wet runway landing distance provided by the airplane flight manual than that experienced by the crew upon touchdown and an actual wet runway friction level lower than the assumed runway fiction level used in the calculation of the stopping distances published in the airplane flight manual.

Findings

Personnel issues	(general) - Pilot
Organizational issues	Document/info verification - FAA/Regulator

Factual Information

History of Flight

Landing	Other weather encounter
Landing	Landing area overshoot
Landing	Collision during takeoff/land (Defining event)
Landing	Runway excursion

HISTORY OF FLIGHT

On November 21, 2014, about 1010 central standard time, an Embraer EMB-500 (Phenom 100) airplane, N584JS, overran the runway after landing at Sugar Land Regional Airport (SGR), Sugar Land, Texas. The airline transport-rated pilots were not injured and the airplane was substantially damaged. The airplane was being operated by Superior Air Charter, LLC, Irvine, California (doing business as JetSuite Air), as a 14 Code of Federal Regulations (CFR) Part 91 positioning flight. Instrument meteorological conditions existed at the airport at the time of the accident, and the flight operated on an instrument flight rules flight plan. The flight originated from William P. Hobby Airport (HOU), Houston, Texas.

According to the pilots, the purpose of the flight was to reposition the airplane from HOU to SGR. During the approach to SGR, the tower controller provided the pilots vectors to the airport and then told them to expect the instrument landing system (ILS) 35 approach at SGR. After the accident, the copilot reported that the tower controller cleared the flight to land and that there was no standing water on the runway. The copilot added that, during the approach, there was a tailwind of 15 kts that decreased to 9 kts on touchdown.

After landing, the pilot, who was flying the airplane, applied the brakes and noted no appreciable deceleration. She then pulled the emergency brakes twice, but the airplane continued past the end of the runway and onto a grassy area. The airplane then crossed a service road and came to rest in a drainage ditch facing opposite the direction of travel with the empennage section partially submerged in water.

A review of flight data recorder (FDR) data revealed that, while on the ILS approach to runway 35, the airplane slowed to 120 knots (kts) and that it maintained that airspeed until about 155 ft mean sea level (msl), at which point it slowed to about 118 kts. The airplane remained on the glideslope until about 380 ft msl, when the cockpit voice recorder (CVR) recorded an electronic voice stating "autopilot," consistent with autopilot disconnection. Shortly after, the airplane descended below the glideslope. The airplane crossed the displaced threshold about 100 ft msl and at 112 kts indicated airspeed (KIAS), and touched down at 1010:37, about 1,040 ft from the threshold, at an airspeed of 104 KIAS. During the landing roll, the CVR recorded the pilots concern about the airplane's lack of deceleration.

About 1.6 seconds after touchdown, the nose landing gear touched down, and the pilot's brake pedal increased, with intermediate oscillations, over a period of 7.5 seconds and reached full pedal deflection.

About 4 seconds later, the emergency/parking brake (EPB) was applied, at which point the wheel speed dropped from 70 to 0 kts, consistent with a locked-wheel skid. Concurrently, the FDR recorded an engine indication and crew alerting system ANTI-SKID FAIL message, consistent with the application of the EPB and locking of the wheels. The airplane departed the runway at 1011:15 at a groundspeed of about 30 KIAS. Shortly after, the FDR recorded accelerations consistent with the impact and airplane coming to a stop.

PERSONNEL INFORMATION

Pilot

The pilot held an airline transport pilot certificate with airplane single-engine land, multi-engine land, and instrument ratings. Additionally, she held an instructor's certificate with airplane single-engine and instrument ratings. She reported that she had 6,311 total flight hours and 1,110 hours in the accident airplane make and model. The captain was issued a Federal Aviation Administration (FAA) first-class medical certificate on July 29, 2014.

Copilot

The copilot held an airline transport pilot certificate with airplane single-engine land, multi-engine land, and instrument ratings. He reported that he had 4,232 total flight hours and 814 hours in the accident airplane make and model. The copilot was issued an FAA first-class medical certificate on July 26, 2014, with the restriction, "must wear corrective lenses."

AIRCRAFT INFORMATION

The Embraer EMB-500 Phenom 100 is included in the very light jet (VLJ) class of airplane. The Phenom 100 can seat four passengers in its normal configuration, but it can be configured to carry up to seven passengers. The airplane is equipped with two Pratt & Whitney Canada PW617-F turbofan engines each rated at a takeoff thrust of 1,695 lbs. The accident airplane's serial number was (S/N) 50000140 and was certified as a 14 CFR 23 normal category airplane. The EMB-500 is not equipped with thrust reversers, and prior to serial # 50000325 not equipped with spoilers. All EMB-500s from serial # 50000325 onwards are equipped with spoilers when delivered from the factory. The accident airplane was not equipped with spoilers.

Brake System

The Phenom 100's hydraulic brake system delivers hydraulic pressure to the brakes via input on the brake pedals. The hydraulic pressure to the brake system is supplied at a maximum of 3,000 pounds per square inch (psi). The copilot's (right seat) brake pedals are mechanically linked to the pilot's (left seat) brake pedals. Each pilot brake pedal is connected to a pedal position transducer (PPT), each of which produces two independent electrical outputs to the brake control unit (BCU) that were proportional to the respective pedal displacement. The BCU controls the main brake system. The brake system is a brake-by-wire system with an antiskid function. There are no hydraulic components on the brake control; therefore, the only pedal force feedback to the pilots is from a force spring installed on the pedals. This provides a consistent pedal resistance regardless of the runway condition and the pressure applied.

Wheel speed information is sent to the BCU via two axle-mounted speed transducers. The BCU uses the output from the wheel speed transducers, the PPTs, and two brake line pressure transducers to generate an electrical command to the associated brake control valve (BCV).

Anti-skid protection is provided when the BCU detect a skid by monitoring the two-wheel speed transducer signals. If a skid is detected, the BCU sends a signal to the BCV to reduce pressure to the brakes. The antiskid protection cannot be turned off in the cockpit.

The Phenom 100 is equipped with an EPB to stop the airplane if the main brake system fails and to provide means to keep the aircraft parked even when the hydraulic power system is turned off. The EPB is operated by a T-handle on the control pedestal. The handle is mechanically linked to the emergency brake valve.

Upon using the EPB, the pressure applied is proportional to the handle displacement. No anti-skid protection is available.

Certification

In general, 14 CFR Part 23 certification regulations require that dry-runway landing distances be published in airplane flight manuals (AFM) and that they be based on performance demonstrated during flight tests on smooth, dry, hard-surfaced runways. Certification regulations do not require the publication of landing distances on other-than-dry runways, although certification applicants may choose to present this information to the regulator. If the applicant provided this information, it would not necessarily be based on flight tests (largely because of the difficulty of achieving a consistent "wet" or "contaminated" runway surface) but rather derived by calculations based on assumptions agreed to by the regulator.

The EMB-500 was first certified by the Brazilian regulator (the Agência Nacional de Aviação Civil), which, like the FAA, does not require the publication of landing distances on other-than-dry runways. However, the European Aviation Safety Agency (EASA) does require the publication of landing distances on other-than-dry runways if the airplane is to be operated on such runways. The unfactored landing distance is the actual distance from the runway threshold required to land the airplane and stop it without any safety factors applied. The factored landing distance is the actual distance from the runway threshold required to land the airplane and stop increased by a safety factor.

Therefore, to certify the airplane in Europe, Embraer proposed to EASA that the unfactored wet runway landing distances presented in the EMB-500 AFM would be computed as 125% of the demonstrated, unfactored dry-landing distance, and EASA accepted this proposal.

The factored wet-runway landing distances in the EMB-500 AFM are 115% of the factored dry distances or 192% of the unfactored dry distances. The EMB-500 is certified in the "normal" category, not the "commuter" category; therefore, 135.385(c) did not apply to the accident airplane. However, in practice, JetSuite operates the EMB-500 in compliance with 135.385(c).

The EMB-500 AFM also provides a table of landing distances for landings on runways covered with standing water, slush, or wet snow at depths of 0.125, 0.250, and 0.375 inches.

METEOROLOGICAL INFORMATION

At 1012, the SGR automated weather observation system (AWOS) reported wind from 130° at 8 kts, 6 miles visibility, light rain and mist, broken clouds at 3,300 ft and an overcast ceiling at 4,200 ft, temperature 66°F, dew point 64°F, and a barometric pressure of 30.15 inches of mercury.

At 1025, the SGR AWOS reported wind from 130° at 8 kts, 10 miles visibility, few clouds at 600 ft, and broken clouds at 1,800 ft and an overcast ceiling at 4,400 ft.

AIRPORT INFORMATION

SGR is a public-use, towered airport, located 17 miles southwest of Houston, Texas. SGR has a single concrete runway, 35/17, which is 8,000 ft long and 100 ft wide. Runway 17 has a 380 ft displaced threshold; runway 35 has a 1,984 ft displaced threshold. Runway 35 touchdown zone elevation is 78 ft.

FLIGHT RECORDERS

The CVR were removed from the airplane and examined at the National Transportation Safety Board's Vehicle Recorder Lab in Washington, DC. The FDR data file was downloaded by the operator and sent to the NTSB's Vehicle Recorder Lab.

WRECKAGE AND IMPACT INFORMATION

The airplane came to rest about 100 ft beyond the end of runway 35 down a small embankment in a drainage creek filled with water. The airplane had spun around about 148° opposite the direction of travel with the front of the airplane on the embankment The aft section of the airplane was submerged in water, and the tail cone was partly broken and separated from the empennage. The right main landing gear had collapsed, and the right-wing tip and aileron were damaged.

TESTS AND RESEARCH

BCU

The BCU was removed from the airplane and sent to the unit's manufacturer's facility in Ohio. No visual defects were noted, and the BCU was functionally tested, and it functioned normally. Data were downloaded from the BCU, and no abnormities were noted with the braking system.

Airplane Performance Study

The NTSB conducted an Airplane Performance Study for the accident flight to determine the airplane's position and orientation during the relevant portion of the flight and its responses to control inputs, external disturbances, ground forces, and other factors that could affect its trajectory. The study used various data sources, including FDR and airplane thrust and aerodynamic performance information.

According to the performance study, the airplane's approach to runway 35 complied with the operator's stabilized approach criteria, with the airplane tracking the RNAV final approach course and glideslope at an airspeed of about 130 knots.

The CVR recorded the copilot, who was the pilot monitoring (PM), call "1000 … stable" at 1009:10.3 when the airplane was at an indicated altitude of 1,103 ft (1,021 ft above the field elevation (AFE) of 82 ft) and about 147 KIAS, or 27 kts above the approach speed (Vap of 120 kts. Per JetSuite's Standard Operating Procedures (SOPs, the PM would have been required to call "1000 continue, speed" because the speed exceeded Vap + 5 kts.

As the airplane descended below an indicated altitude of 800 ft msl (about 722 ft above the touchdown zone elevation [TDZE] of 78.4 ft) while on the ILS approach to runway 35, it slowed to 120 kts, which is the flaps 3 Vap (approach speed) specified in JetSuite's SOPs. During the final approach, the airplane remained on the glideslope until about 380 ftmsl (302 ft above TDZE), when the CVR recorded an electronic voice stating "autopilot," indicating that the autopilot had been disconnected. Shortly after, the airplane descended below the glideslope. The airplane maintained 120 kts until about 155 ft msl (about 77 ft above TDZE), then slowed to about 118 kts at 50 ft above TDZE, and then slowed to 104 KIAS at touchdown.

The airplane crossed the runway 35 displaced threshold at an indicated altitude of about 100 ft msl (22 f above TDZE) and about 112 KIAS, and it touched down at 1010:37.4, 1,040 ft from the threshold at a groundspeed of 111 kts with about a 7 tailwind.

The CVR did not record the pilots making any speed callouts between 500 ft above field elevation (AFE and 50 ft above TDZE, even though at least one speed callout in this band is required by the SOPs. In addition, the EMB-500 AFM specified that at the landing weight of about 8950 lbs, the flaps 3 Vref is 101 kts. The SOPs required pilots to go-around if the airspeed at 50 ft above TDZE exceeded about 111 kts. As noted above, at an indicated altitude of 50 ft above TDZE (128 ftmsl), the indicated airspeed was about 118 kts, 7 kts, above the approximate 111-kts limit.

The landing distances published in the EMB-500 AFM are predicated on the airplane slowing to reference speed (Vref at 50 ft over the threshold. During the accident landing, the speed at 50 ft exceeded Vref by about 17 kts and resulted in an increased runway distance required to stop. Runway 35, even with the higher threshold crossing speed and assuming that the airplane braking performance implied in the AFM landing distances could be achieved, had an available landing distance of 6,016 ft, which met JetSuite's General Operations Manual (GOM) wet-runway dispatch ("planning") requirement of 1.92 times the unfactored dry landing distance, which for this landing would have been 2,695 ft times 1.92 or 5,174 ft.

About 1.6 seconds after touchdown, the nose landing gear touched down, and the pilot's brake pedal increased, with intermediate oscillations, over a period of 7.5 seconds and reached full pedal deflection at about 1010:46.6. During this time, the airplane maintained a deceleration (longitudinal load factor, nx) that oscillated between -0.05 and -0.10 G's; and averaged about -0.07 G's. At 1010:49.7, 3.1 seconds after the brake pedals reached maximum deflection, the nx suddenly decreased to a minimum (i.e., a maximum deceleration) of -0.162 G's. Between 10:10:50 and 10:10:58, the nx oscillated between about -0.11 and -0.14 G's. At 10:10:50.7, the Emergency / Parking Brake (EPB) was applied, and the right and left wheel speeds decreased to 0 at 1010:55.2 and 10:10:58.2, respectively. After both wheel speeds reached zero, the nx increased (indicating decreased deceleration) to between about -0.08 and -0.11 G's until about 1011:11, when the airplane started to yaw to the left and drift to the right. The airplane departed the runway at 1011:15, at a groundspeed of about 30 knots, and came to rest in a drainage ditch about 500 feet past the end of the runway.

For about the first 12 seconds after touchdown, the computed braking coefficient oscillated about a value of 0.03 (the assumed unbraked, rolling braking coefficient) with peaks between 0 and about 0.1. The braking coefficient remained at this low value even as the brake pedals were depressed and then jumped to an average of between 0.13 and 0.14 at 1010:50, coincident with the decrease in nx (that is, increased deceleration).

As part of the performance study, in May 2015, the NTSB and the parties to the investigation conducted tests on runway 35 at SGR to measure the runway macrotexture depth, cross-slope, and friction characteristics. The tests did not indicate any discontinuity or sudden change in the runway friction that could explain the computed braking coefficient jump. Further, the rainfall rate at the time of the accident and the runway's measured macrotexture and cross-slope characteristics precluded the possibility that dynamic hydroplaning caused the braking coefficient jump. The investigation was unable to determine the reason why the airplane's antiskid system, which normally controls the slip ratio, maintained a low slip ratio even as the braking command from the pedals was increasing.

The airplane manufacturer provided a possible explanation noting that the EMB-500 antiskid system is a wheel deceleration control algorithm (MABS proprietary), not a slip ratio control algorithm; therefore, slip control is indirect and may be affected by wheel dynamics other than the ratio between wheel speed and aircraft ground speed.

Embraer also notes that the EMB-500 antiskid system is sensitive to pedal input variations, as the input variation will immediately cause a pressure variation, so its effectivity is directly affected by the pilot inputs. At pedal deflections greater than 90% and above, the brake system considers full brake application. Pedal variations above the 90% threshold have no effect on the system.

Brake pedals variations below 90% were observed throughout landing until actuation of the emergency brakes, therefore not allowing the antiskid system to reach maximum efficiency. The Embraer landing technique recommended in AFM is to apply and maintain full brake pedal application upon touchdown.

The decrease in braking coefficient after the EPB was applied and the wheel speed dropped to zero is consistent with research indicating that the braking friction achieved in a full locked-wheel skid is significantly lower than the maximum braking coefficient that can be achieved at lower slip ratios. Examination of the airplane's tires revealed evidence of reverted-rubber hydroplaning, which is also consistent with a locked-wheel skid and reduction in braking coefficient.

The findings in this accident and similar accidents investigated by the NTSB confirm that the actual braking coefficient that can be achieved on a wet runway may be significantly lower than the braking coefficient predicted by industry-standard models or the braking coefficient required to match the manufacturer's published unfactored, wet-runway landing distances. The results are also consistent with an Embraer Flight Operations Letter that states that the AFM landing distances corresponding to "standing water" contaminated runways may be more indicative of the airplane performance than the AFM "wet runway" landing distances, even for runways that would not normally be considered flooded (for example, even in the case of "light rain over a non-grooved runway or a concrete polished surface.") In this case, the AFM braking performance was not achieved because the actual braking coefficient generated between the tires and the runway was far less than the braking coefficient implied by the wet runway landing distances published in the AFM.

In the comments on the draft Aircraft Performance Study for this case, Embraer disagreed with the NTSB's interpretation of Flight Operations Letter (PHE500-002/15) regarding the AFM landing distances on wet and flooded runways, as outlined above. Instead Embraer stated that "the "FOL highlights the difficulty in assessing the runway conditions (especially between "wet" and "standing water contaminated") and recommends operators to take a conservative approach to calculate the required landing distance.

If the EPB had not been set and the braking friction had continued at levels attained early in the landing roll, then the airplane should have been able to stop on the remaining runway (about 795 ft from the runway threshold). Before landing, the pilots received a report from an air traffic controller that there was "no visible standing water on the runway." Given such a report, it would have been reasonable for the pilots to assume that the AFM wet runway landing distances, rather than the standing water distances, were more appropriate, when in fact the opposite was true. This scenario seems to indicate that, in the absence of prior experience on a given wet runway, if the runway is known or reported to be anything but dry, then the most conservative assumptions about the required landing distance should be used.

See the Airplane Performance Study in the public docket for this accident for additional details.

ADDITIONAL INFORMATION

JetSuite's P100 STANDARD OPERATING PROCEDURES (SOP) and General Operations Manual (GOM) excerpts:

P100 STANDARD OPERATING PROCEDURES

1.5 Briefings

1.5.2 Descent & Approach

In addition to the elements of the approach procedure required for safe operations the following items must also be covered prior to any arrival:

•Configuration - Planned Landing FLAPS, ICE PROTECTION, and approach type (NPA or Precision-like).

•Runway - sufficient for the planned settings.

•ATIS - Allows for the planned operation and settings.

•Fuel – Amount remaining allows for the planned operation with sufficient reserves.

•Terrain/Threats - Dominating terrain and any other considerations that may affect decision-making.

2.9 Before Landing

For all approaches, there are a minimum of three occasions when the PM is required to verbalize his/her assessment of the stability of the approach. All three occasions are required to ensure the approach does not become destabilized. The first is at 1,000' AFE, at which point any combination of the 4 parameters may be out of limits. The second is at 500' AFE, at which point SPEED is the only parameter that is allowed to be outside limits. This allows a decelerating approach to be flown. The third is at not less than 50' Above TDZE, at which point SPEED must be no greater than Vref +10. This ensures that SPEED is within limits prior to touchdown.

At 1000' AFE: If any of the following criteria are outside the stated limits, the PM will use the callout "1000 Continue" and add the quoted descriptor to make the PF aware of the items requiring correction:

"FLAPS": Not indicating the briefed Landing Configuration.

"GEAR": Not indicating 3 Green DN indications.

"PROFILE": Outside 1 dot laterally/vertically if IMC, or visual equivalent.

"SPEED": Mean speed above Vap + 5 knots.

At 500' AFE: If any of the following criteria are outside the stated limits, the PM will use the callout "500 Go-Around":

"FLAPS": Not indicating the briefed Landing Configuration.

"Gear": Not indicating 3 Green DN indications.

"Profile": Outside 1 dot laterally/vertically if IMC, or visual equivalent.

If the speed is outside the following stated limits, the PM will use the callout "500 Continue, SPEED" to make sure the PF is aware that a speed correction is required:

"SPEED": Means speed above Vap + 5 Knots.

Between 500' AFE and 50' Above TDZE:

The callout "REF +/-____" will be made at least once prior to reaching 50" Above TDZE. This call may be made as often as necessary to aid the PF ensuring that SPEED is not excessive, and will be within limits prior to touchdown.

At 50' Above TDZE: If the mean speed is greater than Vref + 10 Knots, the PM will make the callout "Go-Around".

NOTE: Speeds in excess of Vref + 10 at 50' Above TDZE require a mandatory Go-Around.

4.8 CW [Cold Weather] Before Landing

Conduct a positive landing to ensure initial wheel spin-up and initiate firm ground contact upon touchdown, achieving wheel load as quickly as possible. Such technique avoids hydroplaning on wet runways and reduces the strength of any ice bond that might have been formed on brake and wheel assemblies during flight. The factors that influence the occurrence of hydroplaning are high speed, standing water and poor runway macro texture. When hydroplaning occurs, it causes a substantial loss of tire friction and wheel spin-up may not occur. Icy runways can be very slippery at all speeds depending on temperature. Stopping the airplane with the least landing run must be emphasized when landing on wet or slippery runways.

•Anticipate the approach procedures and speeds: A well-planned and executed approach, flare and touchdown minimize the landing distance.

•Lower nose wheel immediately to the runway. It will decrease lift and will increase main gear loading.

•Apply brakes with moderate-to-firm pressure, smoothly and symmetrically, and let the anti-skid do its job.

•If no braking action is felt, hydroplaning is probably occurring. Do not apply PARKING BRAKE, as it will remove anti-skid protection.

•Maintain runway centerline and keep braking until airplane is decelerated.

GENERAL OPERATIONS MANUAL (GOM)

ALL OPERATIONS - WET OR SLIPPERY RUNWAY CRITERIA: A runway is considered wet (or slippery) when conditions indicate:

•Showers or occasional showers.

•Heavy drizzle.

•Continuous light rain, moderate or heavy rain, freezing rain of any intensity.

•Snow of any intensity other than "light" with surface temperature below 28° F.

•A runway is considered contaminated if it cannot be defined as dry or wet.

NOTE: THE FAA HAS TAKEN THE POSITION THAT A RUNWAY DOES NOT HAVE TO BE REFLECTIVE TO BE CONSIDERED WET. IF A RUNWAY IS CONTAMINATED OR NOT DRY IT IS CONSIDERED WET. REF: AC 91-79 APPENDIX 4.

ALL OPERATIONS - "WET RUNWAY" EFFECTIVE LENGTH REQUIREMENT: If required by the type of operation, the additional 15% for wet or slippery runways and 15% for visibility conditions below 3/4 mile or RVR 4000 is not cumulative. Adding 15% to the dry runway length requirement satisfies either or both requirements. Although alternate airports are not always subject to the "wet runway" rule, to avoid inadvertent errors, JetSuite Air has chosen to enforce the "wet runway" rule at all alternate airports.

EXECUTION - ALL OPERATIONS: All JetSuite Air P100 flight operations will use an additional 1000 feet operating margin to account for minor variations in aimpoint, Vref, negative slope, flare technique and delayed or insufficient braking. No pilot will land a JetSuite Air P100 aircraft if that weight exceeds:

•Maximum landing weight in JS Logbook, OPERA, or the AFM.

•A weight that will allow a full stop landing within the effective length of the most suitable runway for the following conditions:

•Dry runways = dry performance +1000 feet.

•Wet non-RFSC/AFSC = dry performance +25%+1000 feet.

•Wet RFSC/AFSC runways = 6500 feet minimum.

•Contaminated runways = applicable contaminated value + 1000 feet.

For contaminated runways of any kind, the landing distance available must be the greater of dry distance * 1.67 * 1.15 or, the applicable contaminated value + 1000 feet.

JetSuite pilots in the P100 will:

•Use Flaps 3 for planning and execution on all wet runways.

•Apply the brakes in one continuous application for approximately five seconds or until an appropriate level of deceleration is felt.

•If no deceleration is felt after 5 seconds, pilots will initiate a go-around.

14 CFR Part 23 Certification Regulations

In accordance with 14 CFR Part 23 Section 23.75, "Landing distance,"

The horizontal distance necessary to land and come to a complete stop from a point 50 feet above the landing surface must be determined, for standard temperatures at each weight and altitude within the operational limits established for landing, as follows:

(a) A steady approach at not less than VREF, determined in accordance with §23.73 (a), (b), or (c), as appropriate, must be maintained down to the 50 foot height and—

(1) The steady approach must be at a gradient of descent not greater than 5.2 percent (3 degrees) down to the 50-foot height.

(2) In addition, an applicant may demonstrate by tests that a maximum steady approach gradient steeper than 5.2 percent, down to the 50-foot height, is safe. The gradient must be established as an operating limitation and the information necessary to display the gradient must be available to the pilot by an appropriate instrument.

(b) A constant configuration must be maintained throughout the maneuver.

(c) The landing must be made without excessive vertical acceleration or tendency to bounce, nose over, ground loop, porpoise, or water loop.

(d) It must be shown that a safe transition to the balked landing conditions of §23.77 can be made from the conditions that exist at the 50 foot height, at maximum landing weight, or at the maximum landing weight for altitude and temperature of §23.63 (c)(2) or (d)(2), as appropriate.

(e) The brakes must be used so as to not cause excessive wear of brakes or tires.

(f) Retardation means other than wheel brakes may be used if that means—

(1) Is safe and reliable; and

(2) Is used so that consistent results can be expected in service.

(g) If any device is used that depends on the operation of any engine, and the landing distance would be increased when a landing is made with that engine inoperative, the landing distance must be determined with that engine inoperative unless the use of other compensating means will result in a landing distance not more than that with each engine operating.

Section 23.1587, "Performance Information," stated the following:

(a) For all airplanes, the following information must be furnished…

(3) The landing distance, determined under §23.75 for each airport altitude and standard temperature, and the type of surface for which it is valid;

(4) The effect on landing distances of operation on other than smooth hard surfaces, when dry, determined under §23.45(g); and

(5) The effect on landing distances of runway slope and 50 percent of the headwind component and 150 percent of the tailwind component.

FAA Safety Alert for Operators (SAFO)

The FAA has previously issued two SAFOs relevant to the circumstances of this accident.

SAFO 06012, "Landing Performance Assessments at Time of Arrival (Turbojets)," dated August 31, 2006, stated the following:

This SAFO urgently recommends that operators of turbojet airplanes develop procedures for flightcrews to assess landing performance based on conditions actually existing at time of arrival, as distinct from conditions presumed at time of dispatch. … Once the actual landing distance is determined an additional safety margin of at least 15% should be added to that distance.

SAFO 06012 noted that the dry-runway landing distances established during flight tests and that are the basis for the factored landing distances used by dispatch are shorter than the landing distances achieved in practice. In addition, AFM landing distances for wet and contaminated runways may also be based on the minimum dry distances obtained during flight tests. Consequently, landing distances on wet or contaminated runways computed from AFM data with little or no additional safety margin may be too short for normal operations. The SAFO recommended a conservative approach to assessing the landing distance requirements, including using the most adverse reliable braking action report or expected conditions for the runway and using values for air distances and approach speeds that are representative of actual operations. The SAFO recommended that a 15% safety margin then be added to the computed (unfactored) landing distance because "the FAA considers a 15% margin between the expected actual airplane landing distance and the landing distance available at the time of arrival as the minimum acceptable safety margin for normal operations."

SAFO 15009, "Turbojet Braking Performance on Wet Runways," dated August 11, 2015, warned that "the advisory data for wet runway landings may not provide a safe stopping margin under all conditions" and stated the following:

Several recent runway landing incidents/accidents have raised concerns with wet runway stopping performance assumptions. Analysis of the stopping data from these incidents/accidents indicates the braking coefficient of friction in each case was significantly lower than expected for a wet runway as defined by the Federal Aviation Administration (FAA) in Federal Air Regulation (FAR) 25.109 and Advisory Circular (AC) 25-7C methods. These incidents/accidents occurred on both grooved and un-grooved or non-Porous Friction Course overlay (PFC) runways. The data indicates that applying a 15% safety margin to wet runway time-of-arrival advisory data as recommended by SAFO 06012, may be inadequate in certain wet runway conditions

The root cause of the wet runway stopping performance shortfall is not fully understood at this time; however, issues that appear to be contributors are runway conditions such as texture (polished or rubber contaminated surfaces), drainage, puddling in wheel tracks and active precipitation. Analysis of this data indicates that 30 to 40 percent of additional stopping distance may be required in certain cases where the runway is very wet, but not flooded. Possible methods of applying additional conservatism when operating on a runway which experience has shown degraded when very wet are assuming a braking action of medium or fair when computing time-of-arrival landing performance or increasing the factor applied to the wet runway time-of-arrival landing performance data.

Advisory Circular 91-79A

The FAA issued AC 91-79A, "Mitigating the Risks of a Runway Overrun Upon Landing," on September 17, 2014. The AC stated the following:

Section 6 - DISCUSSION – HAZARDS ASSOCIATED WITH RUNWAY OVERRUNS

j. A Wet or Contaminated Runway. Landing distances in the manufacturer-supplied AFM provide performance in a flight test environment that is not necessarily representative of normal flight operations. For those operators conducting operations in accordance with specific FAA performance regulations, the operating regulations require the AFM landing distances to be factored to ensure compliance with the pre-departure landing distance regulations. These factors should account for pilot technique, wind and runway conditions, and other items stated above. Pilots and operators should also account for runway conditions at the time of arrival (TOA) to ensure the safety of the landing. Though the intended audience of SAFO 06012 is turbojet airplanes, it is highly recommended that pilots of non-turbojet airplanes also follow the recommendations in SAFO 06012.

(4) Know you can stop within the landing distance available. The cumulative effect of the conditions that extend the airplane's landing distance, plus the 15 percent safety margin, can be a substantial

increase to the AFM/POH data, unless the pilot is aware of the items presented, and possesses the knowledge and flying discipline to mitigate the risk of a runway overrun.

Embraer Actions

On June 6, 2016, Embraer issued Revision 2, Flight Operations Letter PHE505-018/14 Landing Procedure Best Practices and Recommendations," which highlight some information contained in FAA AC91-79A in and add information specific to the Phenom fleet.

The letter state that due to the antiskid function, the BCU will automatically calculate the maximum pressure delivered to the brakes based on the pavement condition. As a result, pilots will notice lower deceleration on a contaminated runway compared to a dry runway.

The FOL contained the following:

CAUTION: The emergency parking brake will always deliver worse performance when compared to the normal brakes with anti-skid protection. Its use is only recommended on abnormal conditions, when the BRK FAIL CAS message is annunciated. In these conditions, applying the landing correction factors, determinate by the QRH [Quick Reference Handbook], are mandatory.

Pilot Information

Certificate:	Airline transport	**Age:**	39
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Left
Other Aircraft Rating(s):	None	**Restraint Used:**	
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):	None	**Toxicology Performed:**	No
Medical Certification:	Class 1 Without waivers/limitations	**Last FAA Medical Exam:**	July 29, 2014
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	July 7, 2014
Flight Time:	6311 hours (Total, all aircraft), 410 hours (Total, this make and model), 77 hours (Last 90 days, all aircraft), 20 hours (Last 30 days, all aircraft), 0.5 hours (Last 24 hours, all aircraft)		

Co-pilot Information

Certificate:	Airline transport	**Age:**	31
Airplane Rating(s):	Single-engine land; Multi-engine land	**Seat Occupied:**	Right
Other Aircraft Rating(s):		**Restraint Used:**	
Instrument Rating(s):	Airplane	**Second Pilot Present:**	Yes
Instructor Rating(s):		**Toxicology Performed:**	No
Medical Certification:	Class 1 With waivers/limitations	**Last FAA Medical Exam:**	July 26, 2014
Occupational Pilot:	Yes	**Last Flight Review or Equivalent:**	September 12, 2014
Flight Time:	4232 hours (Total, all aircraft), 814 hours (Total, this make and model), 2602 hours (Pilot In Command, all aircraft), 103 hours (Last 90 days, all aircraft), 45 hours (Last 30 days, all aircraft), 0.5 hours (Last 24 hours, all aircraft)		

Aircraft and Owner/Operator Information

Aircraft Make:	EMBRAER S.A.	**Registration:**	N584JS
Model/Series:	EMB-500	**Aircraft Category:**	Airplane
Year of Manufacture:	2010	**Amateur Built:**	
Airworthiness Certificate:	Normal	**Serial Number:**	50000140
Landing Gear Type:	Tricycle	**Seats:**	
Date/Type of Last Inspection:	October 31, 2014	**Certified Max Gross Wt.:**	10472 lbs
Time Since Last Inspection:		**Engines:**	Turbo fan
Airframe Total Time:	3854 Hrs at time of accident	**Engine Manufacturer:**	P&W CANADA
ELT:	C126 installed, not activated	**Engine Model/Series:**	PW617F-E
Registered Owner:	BANK OF UTAH TRUSTEE	**Rated Power:**	1695 Lbs thrust
Operator:	Superior Air Charter, LLC	**Operating Certificate(s) Held:**	On-demand air taxi (135)
Operator Does Business As:	JetSuite Air	**Operator Designator Code:**	9SUA

Meteorological Information and Flight Plan

Conditions at Accident Site:	Visual (VMC)	**Condition of Light:**	Day
Observation Facility, Elevation:	KSGR	**Distance from Accident Site:**	
Observation Time:		**Direction from Accident Site:**	
Lowest Cloud Condition:	Few / 800 ft AGL	**Visibility**	6 miles
Lowest Ceiling:	Broken / 3300 ft AGL	**Visibility (RVR):**	
Wind Speed/Gusts:	8 knots / None	**Turbulence Type Forecast/Actual:**	/
Wind Direction:	130°	**Turbulence Severity Forecast/Actual:**	/
Altimeter Setting:	30.14 inches Hg	**Temperature/Dew Point:**	19°C / 18°C
Precipitation and Obscuration:	N/A - None - Mist		
Departure Point:	Houston, TX (HOU)	**Type of Flight Plan Filed:**	IFR
Destination:	Sugarland, TX (KSGR)	**Type of Clearance:**	IFR
Departure Time:		**Type of Airspace:**	

Airport Information

Airport:	Sugarland Regional Airport KSGR	**Runway Surface Type:**	Concrete
Airport Elevation:	82 ft msl	**Runway Surface Condition:**	Wet
Runway Used:	35	**IFR Approach:**	ILS;Visual
Runway Length/Width:	8000 ft / 100 ft	**VFR Approach/Landing:**	None

Wreckage and Impact Information

Crew Injuries:	2 None	**Aircraft Damage:**	Substantial
Passenger Injuries:		**Aircraft Fire:**	None
Ground Injuries:	N/A	**Aircraft Explosion:**	None
Total Injuries:	2 None	**Latitude, Longitude:**	29.633611,-95.658058

Administrative Information

Investigator In Charge (IIC):	Hatch, Craig
Additional Participating Persons:	Peter B Brandon; FAA FSDO; Houston, TX Daniel Marimoto; Embraer; Miami, FL
Original Publish Date:	November 14, 2017
Last Revision Date:	
Investigation Class:	Class
Note:	The NTSB did not travel to the scene of this accident.
Investigation Docket:	https://data.ntsb.gov/Docket?ProjectID=90420