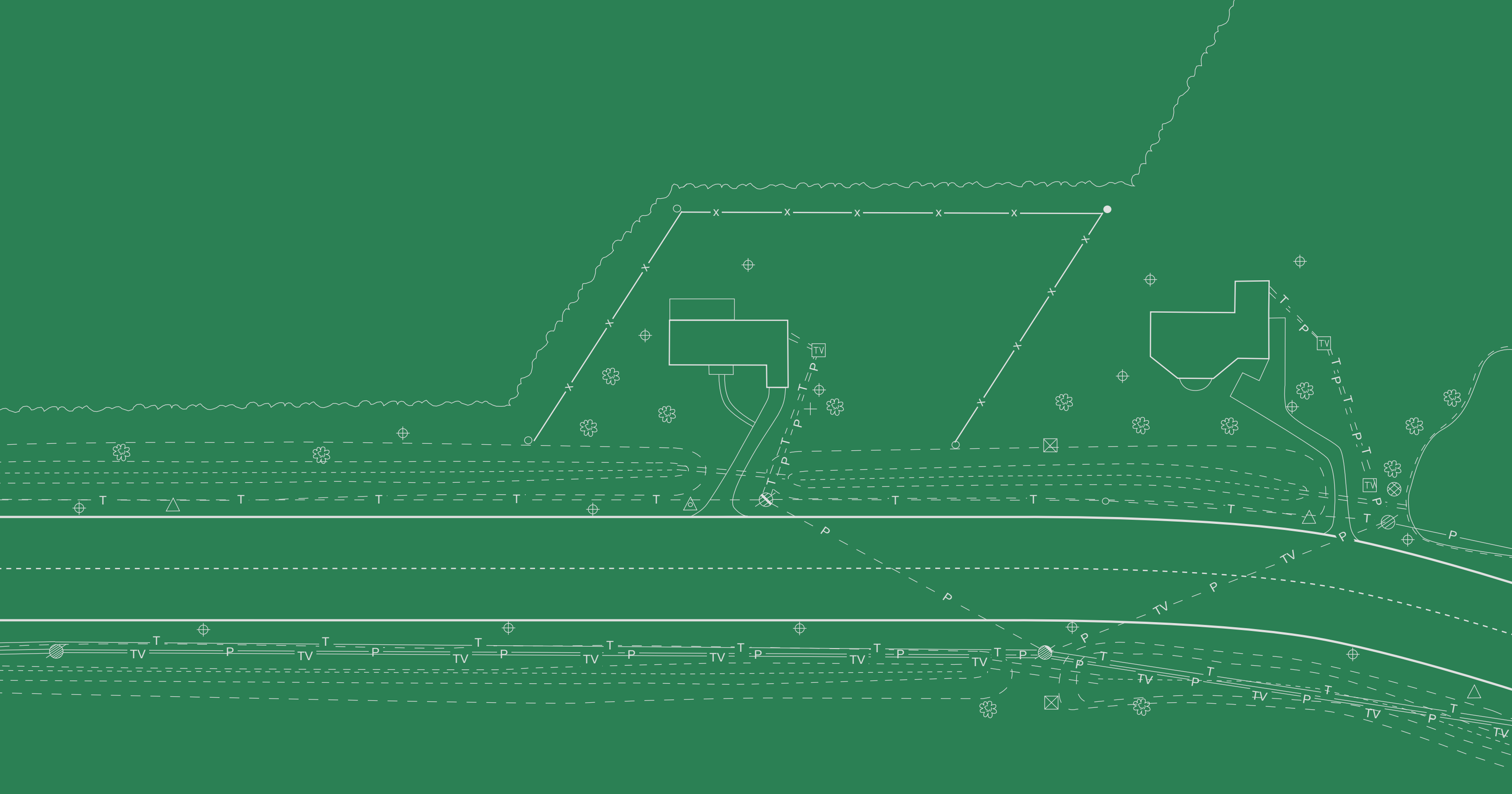

Location & Survey Manual

LaDOTD Surveying Operations & General Requirements

Louisiana Department Of Transportation & Development
Section 30 - Location & Survey

Published October, 2023

LOUISIANA DEPARTMENT OF TRANSPORTATION & DEVELOPMENT

MEMORANDUM

October, 2023

Memorandum to:

All Location & Survey Manual holders.

This revision is intended to update the 1987 Location and Survey Manual with the purpose of representing current surveying methods and procedures used by LaDOTD employees, LaDOTD contractors, and our Consultant Community. This Manual has been completely revised, and content was changed throughout the original Manual.

The further intent of this Manual is to incorporate changes in technology and the evolution of the surveying Profession. Any deviations from this Manual shall be approved by the Location and Survey Administrator prior to engaging.

Stan Ard

Stanley J. Ard, P.L.S., P.S.
Location & Survey Administrator

SJA/sja

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Refer to the **Addendum "A" to the Location & Survey Manual** located on the LaDOTD website.

Note* Due to the frequency of revisions required, The* *<u>Addendum "A" to the Location & Survey Manual</u>*** *is kept separate from this manual.*

CHAPTER 1

General Requirements

1.1 Survey Requests
1.2 Project Notification & Right of Entry
1.3 Procedure for Entering Private Property

Location surveys provide the essential field information necessary for the preparation of plans and specifications for the proposed work. The instructions that will be discussed in this chapter are supplemental, and in addition to, the various memoranda already in force on the subject.

The Surveyor/Party Chief assigned to this type of work shall be experienced, qualified, and familiar with the geometrics of highway location, surveying, surveying calculations, and basic engineering design needs. All work shall be performed under the direct supervision of a Professional Land Surveyor or Professional Engineer (when applicable).

1.1 Survey Requests

The necessity for any particular survey is decided upon by the *Project Manager (PM)*. The PM authorizes the survey by submitting a *Survey Request* to the Location & Survey Administrator. This Survey Request will consist of an official letter that includes a ***Survey Request Form*** and a ***Survey Request Sketch*** depicting the limits to be surveyed. The Survey Request Form will contain all pertinent information regarding the particular project, such as project number, name, route, parish, etc., and generally state where the desired improvements shall be located, and the classification of improvements to be made. All pertinent information related to the request should be obtained and provided to the Surveyor/Party Chief before beginning the survey. Any other specific request not conveyed on the Survey Request Form shall be communicated in the Survey Request Letter. The respective District Administrator shall be advised of the survey, either by the Department or by the survey consultant, prior to beginning the survey.

1.2 Project Notification & Right of Entry

Upon receipt of the Survey Request, the Location & Survey Administrator will determine if the survey will be completed via in-house resources, or be completed via consultant resources, and will notify the respective Department personnel. Department personnel will then disseminate the Survey Request (and other pertinent information regarding the survey) to the appropriate surveyor.

Before field parties begin surveying on privately owned property, the Surveyor/Party Chief shall attempt to contact each land owner, resident tenant, or representative of the property owner, and secure permission to survey on the property and perform whatever clearing is necessary.

Act 617 of the 1983 Regular Session of the Louisiana Legislature and *Act 226 of the 2011 Regular Session of the Louisiana Legislature* generally states: A person cutting trees on a property without the consent of the property owner, co-owner, co-heir, or legal possessor shall be liable to the owners of the trees for civil damages in the amount of three times the fair market value of the trees cut, felled, destroyed or removed, plus reasonable attorney fees and costs.

CAUTION: *If any consultant firm performing contract work for LaDOTD violates this Act, said firm will be held responsible by law.*

A formal diary, or "Property Owners' Permission of Entry List" of all contacts with the property owners along the project site shall be maintained and submitted as a part of the completed survey. The entries in this diary shall provide the name of property owner, resident tenant, or representative of the property owner that was contacted, date contacted, time contacted (Central Standard Time), manner in which they were contacted (by phone, mail, in-person, door hanger, etc.), whether or not permission was granted, and a brief statement of subject matter. See example below.

"<Surveyor/Party Chief name> contacted <property owner name> in-person at his/her property, <address>, on July 30, 2022, at 8:30 a.m., <property owner> agreed to allow my crew and I to survey across his/her property and cut any trees up to approximately 4" in diameter."

The Surveyor/Party Chief shall follow these rules in order to have better public relations when dealing with property owners:

A. Give the owner ONLY what information he/she is authorized to disclose.
B. REFRAIN from expressing his/her own personal opinions and views about the project.
C. DO NOT cut merchantable timber or other shrubs, bushes, flowers or growths of value without the owner's permission.
D. Remember, the Surveyor/Party Chief is usually the first Department representative(s) on this proposed improvement, and those to follow (the Testing and Research crews, Right-of-Way crews, Plan-in-hand Engineers, contractors estimating for bids, and contractors doing the actual construction) share, to some extent, the influence in which the survey crew has created by their actions and work while making the location survey.

1.3 Procedure for Entering Private Property

A. Determine who and where the owner is. If there is any doubt, you must consider the owner to be the person shown on the parish assessment rolls.
B. Make a diligent effort to contact the owner in person, by telephone, or by letter, explain the purpose of the project, and what is required to be done on his/her property. See example letter below.

Dear Property Owner,

The proposed construction of the captioned highway project has made it necessary for representatives of the Department of Transportation and Development to go upon your property to conduct a topographic survey.

The records of the Parish Assessor's office indicate that you own the following described property:

(Property Description).

We respectfully request that you grant the representatives of this Department permission to enter upon your property for the purpose stated above.

You may respond by telephone at (phone number), by email to (email), or by letter to the following address;

(address)

I assure you that every reasonable effort will be undertaken to avoid inconvenience to you or damage to your property and sincerely request your cooperation. Should you not respond within two (2) weeks from date shown above, we will perceive that to indicate your acceptance and enter your property for the purpose expressed above in accordance with the law.

DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
STATE OF LOUISIANA

(Name)
(Job title)

XX/xx

Cc: Location & Survey Administrator

C. Request permission for the Department's employees and representatives to enter his/her property, and obtain all information required to complete the project. The owner should understand that he/she may be contacted again by the Department, or a representative thereof, if further actions are required.
D. Maintain an accurate diary of all contacts, property owners, and all information collected.
E. If you obtain the permission you requested, and it is documented accordingly in the diary, no formal notice is required.
F. If the property owner refuses permission or cannot be located, the Surveyor/Party Chief, or any personnel in a similar position, should notify the Location & Survey Administrator, which will ensure the property owner is notified by registered letter, return receipt requested, in the manner set forth below, of the intention to enter upon his/her property. The property in question shall be avoided until facilitated by a higher authority. This procedure is necessary as preventative measures to not involve the Department in a suit or claim.
G. The letter shall be addressed to the property owner containing all information necessary for documentation. The letter shall always be sent to the owner at the address shown in the parish tax assessor records. If the address on the assessment rolls is not correct, LaDOTD will send the original letter to the corrected address and a copy to the assumed address.
H. The letter shall reflect the example shown on the next page.

Dear Mr./Ms. <Land Owner>:

The proposed construction of a highway project has made it necessary for representatives of the Department of Transportation and Development to go upon your property and make surveys, soundings, drillings, and examinations as may be required to properly perform the duties imposed by law on this Department. We have not been able to obtain your permission to enter your property for those purposes so we have no choice except to enter thereupon in the manner provided by law.

Act 130 of 1955 (R.S. 48:217 as amended) grants this Department a right of entry where the consent of the property owner has not been obtained and further declares that such entry shall not be deemed a trespass. It also provides that the Department shall make reimbursement for any actual damage done to the property.

Therefore, you are respectfully notified that, after the expiration of (5 or 15)_________days from the date this registered notice is delivered, the Department's representatives will enter upon the following described property in order to perform and complete the duties assigned to them in accordance with the law.

(Identify the Property here)

We assure you that every reasonable effort will be undertaken to avoid inconvenience to you or damage to your property and sincerely request your cooperation.
Yours very truly,

DEPARTMENT OF TRANSPORTATION AND DEVELOPMENT
STATE OF LOUISIANA

BY: _________________________
(Type name & your title below your signature)

REGISTERED
RETURNED RECEIPT REQUESTED

cc Honorable ______________________
District Attorney
cc Honorable _______________________
Sheriff

Minor adjustments may be made to make the letter suitable to the particular circumstances, but the Legal Section should be contacted if there is any doubt about such changes.

I. If the owner lives in the State, he/she is entitled to a notice of five days, even if he/she is temporarily outside the state. This would be incorporated in the number of expiration days in the letter on the previous sheet. If the owner lives outside the State, he/she is entitled to fifteen days' notice.

J. At the end of the third paragraph of the letter, identify the property in such a way that you are confident the owner will recognize it as being the land you are referring. For example, if the owner actually lives on the property, describe it as:
   a) "The tract of land upon which you are now living"
   b) "Lot 22 of the Mountain View subdivision, of the city of Riverdale"
   c) "Boll Weevil Plantation"
   d) "100 Main Street, Star City".

K. The legal description of the property, as shown in the conveyance records and the description given in the assessment rolls, shall also be given.

L. The letter shall be signed, with the name and title of the person signing typed beneath the signature.

M. Each letter shall be sent by registered mail with a return receipt requested.

N. When the receipt is returned, it shall be attached to a copy of the letter, and both preserved for use in the event a lawsuit is filed.

O. <u>DO NOT</u> attempt to enter upon the property before the time has expired. The day the letter is received by the owner should not be counted as day number 1.

P. After the notice period has expired, proper entry can be made, however, if there is reason to believe the owner will use force to prevent entry, request the Sheriff to accompany and assist the Party Chief. If he/she refuses, any available member of the State Police or nearest State Police District Headquarters should be contacted to assist. If assistance has not been provided by this point, contact the Legal Section at LaDOTD Headquarters immediately, and report the situation. This should be followed by a complete written report to your immediate superior, with sufficient copies for distribution to others of interest.

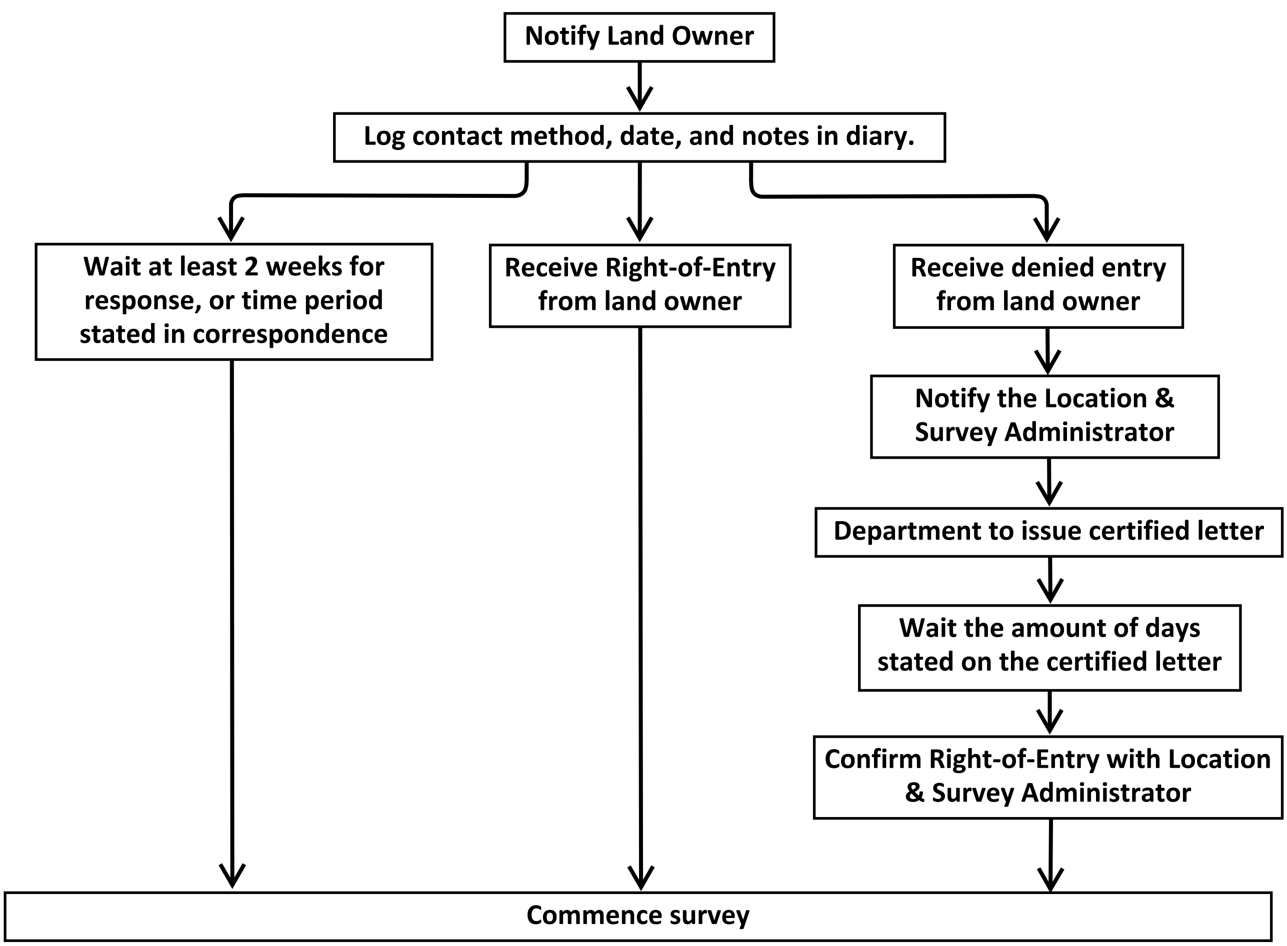
Q. After entry upon the property has been made, the Party Chief should be very careful to avoid inconvenience to the owner or damage to any of his/her property. Complete notes and photographs should be kept regarding any damage upon which the owner might base a claim.

PLEASE NOTE: The letter on the previous page **MUST** originate in the LaDOTD Headquarters Office.

Act 130 of 1955 was made part of the Revised Statutes, **Title 48, Section 217** as amended, states:

> *"Where the consent of a property owner has not been otherwise obtained, the Department of Transportation and Development and its authorized agents and employees shall also have the power to enter upon any lands, waters and premises in the State for the purpose of making surveys, soundings, drillings, and examinations as it may deem necessary or convenient for the purpose of the Chapter and Section, and such entry shall not be deemed a trespass, nor shall entry for such purpose be deemed an entry under any eminent domain proceedings which may be then pending, provided that registered notice of five days to resident owners and fifteen days to non-resident owners shall be given to the last record property owner as reflected by the parish assessment rolls, which said notice shall be mailed to the last known and recorded address of said owner as reflected by said assessment records.*
>
> *The Department of Transportation and Development shall make reimbursement for any actual damages resulting to such lands, waters, and premises as a result of such activities."*

RIGHT-OF-ENTRY FLOWCHART



CHAPTER 2

Project Control

2.1 Summary of Precisions

Traverses

- 4 angle minimum
- Linear closure: 1’ in 15,000’
- Angular closure: 15” times the square root of number of angles in traverse

Levels

- Vertical error of closure shall not exceed 0.035’ times the square root of the number of miles one way.

2.2 Project Datums Overview

Project Control is essential to every project and should be well planned to ensure reliability, stability, and accuracy of horizontal and vertical positions. This chapter shall set requirements, guidelines, recommendations, and references for establishing horizontal and vertical control.

2.2.1 Horizontal (Geometric) Datum and Projection

The current official horizontal (geometric) datum of the National Geodetic Survey (NGS) shall be used, unless a legacy horizontal datum has already been established. If any doubt exists to which horizontal datum is to be used, consult the Location and Survey Administrator.

The latest Louisiana State Plane Coordinate System (LA SPCS) version shall be used as the projection for all projects. The appropriate and latest LA SPCS zone shall be selected based on the location of the project, relative to the zone. If a project is located in both zones, verify with the Location and Survey Administrator for appropriate action.

It should be noted that with the evolution and advancement of technologies, these datums/adjustments/projections are subject to change, and should be verified with the Location and Survey Administrator. Also, for legacy projects that have existing established project control, consult with the Location and Survey Administrator to evaluate which Horizontal Datum and Projection will be applied.

2.2.2 Vertical Datum & Geoids

The current, official vertical datum and geoid of the National Geodetic Survey (NGS) shall be used, unless a legacy vertical datum has already been established. For projects where legacy datums and geoids have been established, consult with the Location and Survey Administrator to evaluate which vertical and geoid will be applied.

2.3 Horizontal and Vertical Control Standards

2.3.1 Horizontal Control

Horizontal control shall be established into two separate categories, **Primary** and **Secondary** control. Both types of control shall be displayed on the GPS Control Sketch (See Section 2.4). Efforts shall be made to place primary and/or secondary control outside of proposed construction areas.

Primary control shall be established using static GPS observations. For each project, it shall be required to set a minimum of three (3) primary control points. Any deviations shall be approved by the LaDOTD Location & Survey Administrator. All primary control shall have a minimum of twelve (12) hours of static observation time. It is recommended to schedule three (3) separate four (4) hour sessions and observe each session at different times of the day. All GPS static sessions shall be post-processed using either NGS's post-processing service, such as OPUS, or other acceptable post-processing software. Primary control points shall be either a rod, rebar, or pipe consisting of ferrous materials, a minimum of eighteen (18) inches of length, ½ inch in diameter (#4 rebar), and set in concrete when necessary (in sandy, wet, or silty soil conditions). On larger projects where stability and integrity of primary control will need to endure long periods of time, deep rod monuments shall be set. Consult with the Location and Survey Administrator whether these deep rod monuments are necessary to set for a particular project.

Deep rod monuments shall be set in accordance with Class "B" Rod Mark guidelines, established by National Geodetic Survey (NGS).

Secondary control shall be established using Real-Time Kinematics (RTK) and/or a Closed Traverse method.

A. For RTK methods, a minimum of three (3) minute sessions (180 epochs) are required to establish a secondary control point, and is recommended to have multiple sessions with a base-station occupying multiple primary control points.
B. For Closed Traverse methods, the traverse shall have a minimum misclosure of 1/15,000 and a minimum angle misclosure of fifteen (15) seconds times the square root of the number of angles in the traverse, or better.
C. It shall be at the discretion of the professional as to whether an adjustment is needed and which adjustment should be applied.

2.3.2 Vertical Control

Due to vertical motion and subsidence in Louisiana, all vertical control for each project shall be established using static GPS observations and concurrent with the establishment of the primary control. One primary control shall be selected as the Benchmark (BM) for the project and is preferred that the point with the best results be selected as the BM (i.e. percent observations used, number of fixed ambiguity, root mean squared (RMS), standard deviation...). All GPS derived observations shall be converted and reported as Orthometric Height Elevation, with the units as US Survey Feet. Once a BM has been established and selected, a closed level loop shall be required to establish elevations on all remaining primary and secondary control points, and temporary benchmarks (TBM).

2.3.3 Temporary Benchmarks (TBM)

TBMs shall be placed at a maximum of 1,000 foot intervals and at all stream crossings and road intersections. To ensure these TBMs are not disturbed and remain stable during construction, it shall be required to set them outside of the limits of proposed construction. It is recommended that at least two (2) TBMs be placed outside the survey limits in the event TBMs near construction are disturbed. TBMs shall be set by driving spikes in trees, scribing “X” in stable concrete foundations, or other places that are not subject to vertical movement. It should be noted that utility poles, fire hydrants, sidewalks, and anything else likely to be disturbed, should be avoided, but can be utilized given nothing else stable in the area exists.

2.3.4 Bench Levels (Closed Level Loop)

Bench levels shall be run with either a Digital (bar code reading) Level or Automatic Level, utilizing three-wire leveling and to the third decimal of a foot (0.000’).

Final deliverables shall include:

A. Benchmark (BM) and/or Temporary Benchmark (TBM) tabulation sheets.
B. Digital copy of reduced level run, and any other digital level output files.
C. Document on control points held for project elevations
D. Photographs of TBM’s
E. Field Notes

2.4.1 GPS/Conventional Control Sketch

A GPS/conventional control sketch shall be required on every project where primary and secondary horizontal and vertical control has been set. In the special case where project control already exists, a GPS/conventional control sketch shall not be required, unless additional primary or secondary control has been established. The following information shall be required on all GPS/conventional control sketches:

2.4.2 GPS Control Sketch

A. Sketch shall be labeled as "GPS Control Sketch"

B. Title
   1. State project number
   2. Project name
   3. Route number
   4. Parish
   5. Land district
   6. Company name and address

C. Body of Sketch
   1. North arrow shown as grid north, as per the center of the project.
   2. Information for each horizontal control point
      i. Point name and number
      ii. State Plane coordinates expressed in US feet to the third decimal of a foot (0.000').
      iii. Final adjusted point elevations to the third decimal of a foot (0.000').
      iv. Grid bearing and grid distance shown on all lines between control points. All bearings shall be expressed to the nearest one decimal of a second (0.0"), and distances shall be expressed to the nearest third decimal of a foot (0.000').
   3. Scale

D. Notes
   1. Describe type and material of object used for each horizontal control point.
   2. Parameters from the GPS post-processing solution:
      i. Ellipsoid used
      ii. Datum and epoch
      iii. Identify control points used in the "fix solution (constraints)" and its values
      iv. State plane coordinate system, zones, & units.
      v. Date the control points were observed and date processed/submitted for post-processing.
      vi. Number of hours for each observed static session.

vii. For secondary control points, give a brief explanation of how each point was established.
viii. Documentation of the basis of vertical control.
3. List CORS base station(s) that were utilized.

E. NGS OPUS Solution Report

F. Street Graphics – At minimum, digitized line work of all streets shall be included.

G. Signature & Seal – The original sketch shall be signed & sealed by a Professional Engineer or Professional Land Surveyor.

2.4.3 Conventional Control Sketch

A. Sketch shall be labeled as "Conventional Control Sketch"

B. Title
1. State project number
2. Project name
3. Route number
4. Parish
5. Land district
6. Company name and address

C. Body of Sketch
1. North arrow shown as grid north, as per the center of the project
2. Closure information
    i. Allowable angular closure
    ii. Allowable linear closure
    iii. Angular error
    iv. Horizontal error
    v. Length of traverse
3. Information for each horizontal control point
    i. Point name and number
    ii. State Plane coordinates expressed in US feet to the third decimal of a foot (0.000').
    iii. Final adjusted point elevations to the third decimal of a foot (0.000').
    iv. Observed and adjusted angles – Adjusted angles shall be shown in parenthesis

v. Field and adjusted distance expressed to the nearest third decimal of a foot (0.000’)

vi. Adjusted grid bearing expressed to the nearest one decimal of a second (0.0”)

4. Scale

D. Notes

1. Describe type and material of object used for each horizontal control point.
2. Traverse processing records:
   i. Precision of closure
   ii. Linear error
   iii. State plane coordinate system, zones, & units.
   iv. Type of adjustment used, if needed.
   v. Adjusted values shown in parenthesis, if needed.

E. Street Graphics – At minimum digitized line work of all streets shall be included.

F. Signature & Seal – The original sketch shall be signed & sealed by a Professional Engineer or Professional Land Surveyor.

If both GPS and conventional methods are used, both sets of rules apply. In the event additional horizontal control is needed, an addendum to the control sketch shall be submitted.

The Control Sketch shall be submitted to, and approved by LaDOTD prior to commencement of the topographic survey.

CHAPTER 3

Topographic Surveying

3.1 Summary of Precisions
3.2 Existing Site Conditions
3.3 Utilities
3.4 Alignments
3.5 Drainage Maps

3.1 Summary of Precisions

<u>Topography</u>

- General topography: 0.1’
- Ground Shots: 0.1’
- Permanent (hard) surfaces: 0.01’
- Inverts of drainage structures: 0.01’

3.2 Existing Site Conditions

Existing topography shall be located as per the *Survey Request Form* and *Survey Request Sketch*, as described in ***Section 1.1 - Survey Requests***.

All topographic features within the survey limits that are included in the Location and Survey "*SURVEY FEATURE CODE GUIDE BOOK*," are to be located as per the *Survey Request*. Contact the Location and Survey Administrator for further direction on any features not listed in the "SURVEY FEATURE CODE GUIDE BOOK."

Measurements to utility poles, fire plugs, meters, etc. should be to the nearest 0.1 foot. When necessary, offset measurements to define the center of utility poles, etc. as closely as possible.

All topographic surveys shall ensure every effort is made to obtain all utility records and 'LA One Call' locate marks, and data gathered is correlated to existing utility features, unless subsurface utility engineering (S.U.E.) has been requested in the Survey Request. Any deviation shall be approved by the Location and Survey Administrator.

For all railroad crossings, all features in the "SURVEY FEATURE CODE GUIDE BOOK" shall be located with the correct attributes. The location of the nearest mile marker or some other identifiable feature along railroad is required to be documented.

All aircraft landing strips or runways located within 1500' of a project alignment shall be located at each end of the runway centerlines by current best practice. Any deviation must be approved by the Location and Survey Administrator.

Streams or other large drains crossing the project alignment shall be located as per the Survey Request. All features of a stream, canal, bayou, etc. that are listed in the "SURVEY FEATURE CODE GUIDE BOOK" are to be located and must define the water bottom appropriately. Contacting the LaDOTD Bridge Design Section and the Hydraulics Section for detailed information of the design purposes may be needed to include pertinent information in the survey not required in the manual.

At pipeline crossings, all features in the "SURVEY FEATURE CODE GUIDE BOOK" shall be located, with the correct attributes, to the distance in the Survey Request. It is imperative to coordinate with the utility locator to provide the best depth possible to determine road clearance, should the possibility of utility relocation become a factor. Should the utility locator be uncooperative, or his given depths be suspect, subsurface utility engineering (S.U.E.) or probing may be necessary. Notification of this situation should be given to the Location and Survey Administrator as soon as possible.

Precision for general topography features shall be to the nearest 0.1 foot.

In order to minimize delays in construction, survey crews shall notify the Location & Survey Administrator, in writing, any and all suspected waste disposal areas within the existing or proposed right-of-way as soon as discovered. This information is needed in order to provide the Department's Environmental Section and the Department of Natural Resources sufficient time to develop a cleanup or closure plan. Examples of these waste disposal areas are: Garbage dumps, oil pits or ponds, cattle dipping vats, or any other suspected dumping site.

3.2.1 Cross Sections

Conventional cross sections recorded in field books have mostly become obsolete and replaced by 3-D electronic topographic surveying. These surveying methods are still performed in a cross sectional fashion at a minimum, and extra shots are easily collected where needed, to better define the topographic features on the project. 3-D topographic surveying provides a more enhanced product deliverable compared to the conventional cross section method. Below are other considerations while collecting survey data that will aid in providing a quality product.

When collecting data in a cross-sectional format, collect data at an interval that will give a good representation of the survey features in the field. Where necessary, collect extra cross sections to provide suitable cover in breaks in the grade, such as hilltops and valleys, to provide a more precise representation of the ground surface, with the most emphasis being placed on the roadway.

Do not take half sections. Full cross sections should be taken on both sides of the survey to provide a balanced, quality product, with the most emphasis being placed on the roadway.

3.3 Utilities

It is necessary to develop accurate and complete utility location data in order to make determinations of conflicts with the proposed construction later on during the progress of the project. This data is also necessary to determine whether the liability of relocating or adjusting the utility is the utility company's or the Department's responsibility; i.e., whether existing utilities requiring relocation are within public or private right-of-way.

When performing the survey, the survey party shall observe the following procedures to the extent utilities are concerned:

A. Obtain the names and addresses of all companies and individuals who own utility facilities within the area being surveyed. This can be done by procuring a 'LA One Call' ticket, and contacting other utility companies not part of the 'LA One Call' system (DOTD, small municipalities, etc.). This is the first order of work on the project. Retain a copy to be submitted with the complete survey. This should be done during the first two weeks on the job.
B. The Department utility representative, or survey consultant shall plan/organize/facilitate arrangements with the utility company or 'LA One Call' as to when their respective sub-surface utilities will be marked on the ground, and the optimal time to have survey field crews on site to locate marked utilities.
C. Contact the utility companies in advance, as they need ample time to plan and schedule their workload before utilities will be marked.
D. Advise the utility companies that are not able or willing to mark their utilities that you will have to probe and/or excavate for their lines if they cannot locate them with an underground pipe locator. Usually, the companies will prefer to have their utilities located by their own personnel. If a company is unable or unwilling to assist, notify the Utility Administrator, the District Utility Representative and the Location & Survey Administrator immediately, citing reasons why the company cannot or will not help.
E. Any utilities found during the course of the survey that are not included in the original list must be forwarded to the Utility Administrator, District Utility Representative and the Location & Survey Administrator as soon as they are found. Retain one copy to be submitted with the completed survey.
F. The survey field crew shall locate each pipeline and determine the type (if possible), angle of crossing, profile, diameter, vent locations, casing length, etc.; each power pole, telephone pole, underground cable or conduit, together with appurtenances to these facilities; all water meters, fire hydrants, gas meters, etc.; and shall determine their positions relative to all of the following that apply:

    1. The survey alignment(s).
    2. The centerline of the existing road when said existing road is near the survey alignment where there are utilities along the existing road involved in the proposed project.
    3. Where applicable, the back of the existing ditch in a cut section, or toe of the existing slope in a fill section, and existing roadside fence.
    4. All of the above also applies to utilities alongside roads, except that "1" would be the alignment for that particular side road. Utilities at the intersection of the project's alignment and the side road's alignment shall be located on both sides.

G. All horizontal and vertical measurements shall be made to the nearest 0.1 foot. Vertical locations must be in terms of the project datum. The Party Chief must use judgment on the needed length of pipeline, casing length, or other underground utilities to be profiled when said utility or pipeline crosses the project. This must be predicated on terrain, size of pipeline, expected right-of-way width, etc.
H. On projects where the pipeline or other underground utility parallels the survey, the same general requirements shall hold; however, in the event of a meandering facility, care should be taken to get sufficient accurate measurements, both horizontally and vertically.
I. Underground telephone cables are typically located by phone company personnel. The phone company has equipment that can locate their underground facility.
J. Other underground lines which may be located by either probing or with pipe detectors, should also be located at intervals close enough to adequately describe the continuous path of the line. Elevations should be established on all underground facilities, both parallel and crossings, unless considered unnecessary by the District Utility Representative. The District Utility Representative will provide the Party Chief a letter confirming that any less information than specified will be acceptable. Additionally, angles of crossing and casing lengths, if applicable, should be secured on all crossings. If necessary, supplemental sketches should be prepared for clarification.
K. For a typical topographic survey, the consultant's work shall follow the above procedure. Consultants are reminded and cautioned that all required utility data should be given to the Utility Administrator, the District Utility Representative and the Location & Survey Administrator as soon as possible. In any event, a final invoice for payment will not be approved until the Utility Administrator, the District Utility Representative and the Location & Survey Administrator have given their approval of the required utility survey data.

3.3.1 S.U.E. Services (Sub-surface Utility Engineering)

The Project Manager will determine if S.U.E. services will be required for any particular topographic survey. The survey request form will indicate if S.U.E. services are required and at what Quality Level (Q/L) these services are to be performed. The American Society of Civil Engineers (ASCE) 'Standard Guideline for Investigating and Documenting Existing Utilities' (ASCE 38-22 (or most current version)) shall govern all subsurface utility locates. The following identifies the level of utility locates in ascending order:

Level "D" – Existing Records (Records Research)
Level "C" – Surface Visible Feature Survey (Above Ground Evidence)
Level "B" – Designating (Geophysical Scanning)
Level "A" – Locating (Expose Utility)

A. **Q/L "D"**
Information obtained from a review of utility records. The comprehensiveness and accuracy of such information is highly limited. Even when existing information for a utility in a particular area is accurate, there are underground systems that are not shown on any records. Level "D" may be appropriately used in the early development of a project to determine the presence of utilities.

B. **Q/L "C"**

Information obtained to augment Level "D" information. This involves topographic surveying of visible, above ground utility features (e.g., poles, hydrants, valve boxes, circuit breakers, etc.) and incorporating the topographic data into the CADD system. Level "C" may be appropriately used early in the development of a project and will provide better data than Level "D" information alone. Designers must be very cautious when working on projects using the horizontal location and depth of cover for underground utilities that are based only on Level "C" and Level "D" locates. Standard topographic surveys provide similar information as Level "C" utility locates (visible features).

C. **Q/L "B"**

Inclusive of Levels "C" and "D", information obtained using designating technologies (e.g., geophysical prospecting technologies). This is a field activity using remote sensing geophysical scanning technologies, most of which have very specific capabilities and offer various strengths and weaknesses. Applying a variety of techniques is essential to the process of preparing a comprehensive horizontal map of utilities and other underground structures on the site as these tools may react differently to the type of utility conductor, soil conditions, and adjacent utilities or surrounding environments that impact accuracy and disrupt electromagnetic radio frequencies. Designating technologies can provide marginal to good horizontal information but provide limited vertical information and therefore vertical accuracy is not suitable to address potential conflicts in vertical design.

D. **Q/L "A"**

Provides the highest level of accuracy of utility locations in three dimensions. This level may apply to manual, mechanical, or nondestructive (e.g., vacuum excavation) methods to physically expose utilities for measurement and data recording. Levels "B", "C" and "D" are incorporated into Level "A" locates. The designer should obtain Level "A" locates at highway and utility conflict points where verified information is needed to make confident design decisions.

3.3.2 Standard Utility Coordination/Location Procedure:

A. Contact all Utility Owners, including LA One Call and non-participants (Non-participants identified through visual features on the ground).
B. Coordinate with all utility respondents and locate accordingly.
C. A minimum of three (3) attempts shall be made to contact all non-respondents.
D. A LaDOTD Utility Representative shall be involved on the second and third attempt.
E. After all attempts have been made and utilities are still not marked/located, the LaDOTD Project Manager and Location and Survey Administrator shall be notified. It will then be determined if SUE services are required.
F. The incorporation of utility records and/or utility as-builts to determine location are a last resort, and shall be approved by LaDOTD Location and Survey Administrator.

3.4 Project Alignment

A. The project alignment for a project, commonly known as the centerline of project or surveyed line, shall be created to match existing survey conditions. The alignments shall be created and calculated based on "best fit" existing geometry. Alignments shall be set on all roads, tributaries, railroads, and any other feature requested.

B. The project alignment shall be tied to project control established in accordance with ***Chapter 2 - Project Control***, as described in this manual.

C. All horizontal curves are based on the arc definition in which horizontal curves will be used whenever the delta angle is above 0°17'. The minimum length curves to be used for delta angles from 0°18' through 5° 00' are as follows:

DELTA ANGLE	MINIMUM LENGTH CURVE (FEET)
Below 0° 17'	NO CURVE
0° 18' to 1° 00'	900
1° 01' to 2° 00'	800
2° 01' to 3° 00'	700
3° 01' to 4° 00'	600
4° 01' to 5° 00'	500

D. Although curves up to 13°30' are permitted, depending upon the class or road and traffic count, it is recommended to use the smallest degree curve feasible. No spiral curves will be allowed, and all curves shall be tangential.

E. Typically, stationing begins with **100+00** and proceed in a northerly and easterly direction. In all instances, stationing shall run in the same direction as the control section. In some instances, it is preferred to continue stationing from other plans or projects currently under construction or completed. When a project has multiple sites to be surveyed and the sites are not contiguous, the first site should start stationing at **100+00**, the second site should start stationing at **200+00**, the third site should start stationing at **300+00**, etc. This is discussed in advance by the *Project Manager* or designer if necessary.

F. Decisions made regarding the sites and stationing should be conveyed in the survey request, dependent upon some preference by the Design Section or others.

G. Stationing of cross roads and side streets typically begin with **50+00** at the intersection with the project alignment, and increasing in one direction. This should also proceed in a northerly and easterly direction.

H. Stationing of major route intersections, such as intersecting state routes, US routes, or interstates, shall begin with **100+00**, the secondary intersecting route with **200+00**, etc.

I. All highway bridges and railroads intersecting highways are now numbered. The numbers for the bridges are painted on the bridge, and numbers for the railroad crossings are placed on a sign at the crossing.

J. The number assigned to a bridge or railroad crossing, which will be used to identify said facility, shall be included in all correspondence, notes, plans, etc.

K. When a survey is adjacent to or crosses a railroad, ties shall be made to railroad mile posts. This data is necessary for future uses during the progression of the project. Specifically, when determining right-of-way of the railroad company, references can be made to the railroad maps and tied to their mile posts.

3.5 Drainage Maps

The drainage map Microstation DGN file, which is to be the final submitted product, is to have the Topo and Alignment Survey DGN referenced and displayed, in addition to any aerial photography, quads, online imagery, Lidar, etc. used as an aid to compile the existing drainage map. All of these files are to be in the correct geographic location. The existing drainage map DGN is a separate product. Even though sheets do not need to be submitted, the elements of the DGN will still have the integrity to satisfy a neat and readable plot to a specified scale of all drainage components outside of the survey DTM area. All work should be submitted using the project coordinate system.

3.5.1 Roadside Drainage Structures

Drainage map topography 300' outside of the survey limits, commonly known as the buffer, should be shown. This shall be included on the map using imagery or quads, and may not be of accurate elevation or position. It should be set to a static elevation in order to differentiate accuracy and to maintain the map's visual legibility. The primary purpose is to indicate improvements within the 300' area, such as roof tops, paved areas, pasture and wooded areas etc. for runoff coefficient calculations.

Drainage structures within the 300' buffer of the survey limits must be included with the topo survey and list the electronic attributes of size, material, and invert elevations. Bridges within the 300' buffer of the survey limits require attributes, bridge opening square footage, and a single cross-section of the opening on the downstream side (in square feet).

Drainage structures that exceed the 300' buffer of the survey limits, but still relevant to the drainage flow, should be shown and tagged with size and material. Bridges that exceed the 300' buffer and are relevant to drainage, require a cross-section of the bridge opening of the downstream side (in square feet). It is understood that this will likely be included in the map using imagery or Lidar. The elevation, if not field verified, should be set to a static elevation in order to differentiate accuracy.

3.5.2 Cross Drains

Each structure that crosses the survey line, regardless of whether it is the main roadway or a cross road included in the survey, is required to show the drainage area. The cross drains located within the actual topo survey should be shot in the Survey DGN with the high water mark elevation, if pertinent. There should also be information as to how that high water elevation was determined, such as by physical evidence in the field, water mark, debris, or as shown by local resident.

3.5.3 Ditches/Canals

Show all ditches, streams, and drainage structures in the project area that bring water to the survey project (watershed). Show all ditches, streams, and drainage structures that direct water from the survey line (outfall). Each major drain should be shown to 300' from the survey limits, as required. Referencing the Survey DGN will provide all ditches/canals gathered in the topo survey. Each ditch on the project should be drawn using the correct line style and scale from the LaDOTD library.

3.5.4 Ridgelines

Ridgelines should not be drawn through buildings or across roadways (it is understood in most cases throughout the state, that the crown of the road is a ridgeline), but will terminate at the roadway edge or building polygon, and resume on the opposite side of the structure/roadway. Ridgelines should have terminators at each end that does not connect to any particular line on the DGN. For clarification, water flows: perpendicular to a ridge, parallel to a ridge with a slight deflection angle, or parallel to the angle bisector of two adjoining ridges or a bend in a ridge. Water will never flow over a ridge without flooding.

3.5.5 Flow Arrows

Flow arrows are an important part of an existing drainage map. Flow arrows show a smooth and continuous travel of water to facilitate the course of flow is readily understood and accurately depicted. The ground water flow and pipe flow will be depicted thoroughly and accurately with flow arrows. Pipe inverts may aid in determining direction of flow, but these may not necessarily be true. Ground water arrows show which direction water departs a ridge and travels to a draw, low, pond, or body of flowing water such as a ditch, bayou, or river. The direction of the draw will be shown graphically using flow arrows. Use as many flow arrows as necessary. Every cross drain must contain an adjacent flow arrow. The scale of the flow arrow cell on the map is at the Consultant’s discretion, but must be consistent throughout and large enough to show the required information.

3.5.6 Water Bodies

Water bodies will be shown graphically and contain electronic attributes. If it is a named waterbody, include the name in the attributes. This includes ponds and lakes. For smaller waterbodies, such as ponds, show as “private pond” or “retention pond”. An outfall point will be shown for these waterbodies if they exist. Swampy areas or standing water can be designated by using electronic attributes with pertinent information, and should be shown graphically using the appropriate swamp or marsh line style.

3.5.7 Drainage Areas

Drainage areas are derived by closing ridges to encapsulate the area in which water is contained. A drainage area can be created and given attributes to show the area of water that each cross drain carries. Every cross drain on the survey must have a corresponding drainage area. The electronic attributes of these areas are shown in units of acres, or square miles for larger areas. The drainage area polygons can be drawn through buildings and across roadways. There is a linestyle for the drainage area outline in the LaDOTD linestyle library.

3.5.8 Aerial Imagery and Lidar

Imagery and Lidar are useful tools in depicting detailed drainage areas and drainage map features. Any data used from imagery needs to be verified in the field for accuracy. There are various geographical software and online sources of aerial imagery and Lidar DEMS available in MicroStation.

3.5.9 Elevation Formatting

Elements drawn while compiling the existing drainage map *that are not in a geographically correct position or elevation* (sketched topo, pipes that are shown for formatting but without inverts) should be placed at an elevation that is on a different plane from the true elevations of the surveyed data. For example: If the average topo elevation of the survey is 35’, you may want to set the unverified drainage map elevations at 100’. This is done to ensure to the design engineer that the static features are not at a true elevation. This will apply to all drainage structures 300’ beyond the limits of the topo survey, drainage area polygons and flow arrows that are not at an absolutely accurate geographical position.

3.5.10 Drainage Project Note

There is a project note for drainage maps located in the LaDOTD cell library. This note can be edited for each drainage map project. The project note shall include:

A. Methodology used to create the drainage map
B. Types, sources and dates of data used, such as imagery, Lidar, etc.
C. Project identification
D. Other pertinent information that may affect the accuracy of the drainage map

3.5.11 General Formatting

All linestyles and cells are to be chosen from LaDOTD libraries.

NOTES

CHAPTER 4

Remote Sensing

4.1 Photogrammetry Standards

LaDOTD collects aerial imagery and Lidar using both a fixed-wing airplane and sUAS platforms. All engineering assignments will include field survey control points that meet the accuracy standards provided in ***Section 2.3 – Horizontal and Vertical Control Standards***.

LaDOTD follows the most current ASPRS Remote Sensing accuracy standards. See the ASPRS website for the "ASPRS Positional Accuracy Standards for Digital Geospatial Data" document.

4.1.1 Aerial Imagery Collected via Fixed-Wing Platform

Statewide Topographical Survey imagery will be collected at a 6" GSD (ground sample distance), while municipalities and engineering projects will be collected at 3" GSD. All imagery will be collected in the current state-wide datum.

Aerial Imagery will be calibrated to ground control points provided by survey field crews. As noted above, please see ***Section 2.3 - Horizontal and Vertical Control Standards*** for ground control accuracy standards. CORS and RTN stations are currently being used for in-flight calibration. This could change as new technology becomes available.

Aerial imagery should ideally be collected in Fall-Spring during leaf-off conditions. 30 degrees or more sun angle and good weather are required. LaDOTD Statewide imagery is collected in 4-bands, including near-infrared. The images captured are 8 bit in size. No less than 60% forward overlap and 30% side overlap are used.

Accuracy standards for aerial imagery are set by ASPRS whose accuracy uses Root Mean Square Error (RMSE). RMSE includes random and systematic errors and reveals bias more completely. **Relative Accuracy** characterizes accuracy before the introduction of ground control. **Absolute Accuracy** is the position of features horizontally and vertically with respect to the datum and ground control used. Final accuracy is **Absolute**.

Examples using ASPRS Standards in LaDOTD Projects:

A. 6" GSD imagery should meet final accuracy of no more than 1' horizontally and vertically.
B. 3" GSD imagery should meet final accuracy of no more than 6" horizontally and vertically.

4.1.2 Aerial Imagery Collected via sUAS

sUAS imagery flown at less than a 400' altitude generally has a GSD of 1-5 cm. Due to the varying needs of drone imagery, this GSD changes according to the project type, sensor type, and platform. Most sUAS sensors collect, at a minimum, 8 bit and 3 band imagery. Forward overlap is 70% or more. Side overlap is 60% or more.

Georeferencing of sUAS imagery will be done using surveyed ground control which meets the accuracy standards in ***Section 2.3 - Horizontal and Vertical Control Standards***. Various software is used for processing radiometric corrections to achieve final accuracy results.

sUAS imagery is generally within the 1-10 cm accuracy range horizontally and vertically upon final corrections. This accuracy varies widely according to the sensor and platform used. In general, the accuracy must fall within the ASPRS standards, and most likely far exceeds those standards due to the low altitude collection.

4.2 Terrestrial & Mobile Lidar

Chapter 15 of the California Department of Transportation (CALTRANS) Survey Manual is one of the first developed set of specifications that explicitly address the required information and data quality that should be provided with a static or mobile LIDAR survey (CALTRANS 2011). These specifications contain a two-part classification system for mobile LIDAR surveys. "Type A" is a higher accuracy hard surface survey used for engineering applications and forensic surveys. "Type B" is used for lower accuracy applications (e.g., asset inventory, erosion, environmental and earthwork surveys). These specifications are broad enough to not limit service provider equipment and technology, but they provide details regarding data acquisition and processing procedures, including the minimum overlap between scans, maximum positional dilution of precision (PDOP), minimum number of satellites, maximum baseline, validation point accuracy requirement, inertial measurement unit (IMU) drift errors and other factors pertaining to the georeferencing accuracy of the point cloud. A relatively high level of understanding of mobile LIDAR technology is needed to utilize the CALTRANS standards effectively. Other transportation agencies have begun developing standards and guidelines for Mobile Lidar Scanning (MLS). Such guidelines are meant to provide the agencies with reference documents that can be tailored to their specific needs. For example, Florida DOT recently released guidelines that are very similar to the CALTRANS guidelines. However, the Florida DOT guidelines add a "Type C," lower accuracy mapping category for planning, transportation statistics and general asset inventory surveys.

4.2.1 Mobile Lidar Scanning

Mobile Lidar Scanning (MLS) uses LiDAR technology in combination with Global Navigation Satellite Systems (GNSS), Distance Measuring Instrument (DMI), and Inertial Measurement Unit (IMU) to produce accurate and precise georeferenced point cloud data and digital imagery from a moving vehicle. This technology is used to acquire pathway topography, infrastructure, utility assets and topographic assets. MLS platforms may include Sport Utility Vehicles, pick-up trucks, hi-rail vehicles, boats, and other types of vehicles. Utilizing LiDAR technology improves the safety and efficiency of data collection by minimizing the need for employees to work in or close to traffic. In addition, the MLS collected data may be "mined" for various uses beyond its initial intended use. The scanner(s) position is determined by post-processed kinematic GNSS procedures using data collected by GNSS antenna(s) mounted on the vehicle and GNSS base stations occupying project control (or continuously operating GNSS stations) throughout the project area. The GNSS solutions are combined with the IMU data to produce precise geospatial locations and orientations of the scanner(s) throughout the scanning process. The point cloud generated by the laser scanner(s) is registered to these scanner positions and orientations, and may be combined with digital imagery sensor data in proprietary software. The point cloud and imagery information provides a very detailed data set. GNSS has vertical accuracy limitations and will not meet CALTRANS Engineering Survey standards for pavement elevation surveys. Additional control points (local transformation points) within the MLS scan area are required to register the point cloud data by adjusting point cloud elevations. The point cloud is adjusted by a local transformation to well defined control points throughout the project area to produce the final geospatial values. The final scan values are then compared to independently measured validation points for quality control. QA/QC standards must be evaluated by observing deviations of scan point data against field surveyed control points and by evaluating a data point cloud group against overlapping data point cloud groups. The measured deviations will determine the qualifications for NCHRP LIDAR accuracy classification type.

4.2.2 Types of MLS Surveys

A. Type A – High Accuracy Surveys: **LaDOTD REQUIRMENT**
   1. Design engineering topographic
   2. As-built
   3. Structures and bridge clearance
   4. Deformation surveys

B. Type B – Medium Accuracy Surveys:
   1. Design engineering topographic corridor study/planning
   2. Detailed asset inventory and management surveys
   3. Environmental
   4. Earthwork
   5. Urban mapping and modeling coastal zone erosion analysis

C. Type C – Lower Accuracy Mapping:
   1. Preliminary planning
   2. Transportation statistics
   3. General asset inventory surveys

4.2.3 Requirements

Federal Geographic Data Committee (FGDC) developed the National Standard for Spatial Data Accuracy (NSSDA), which provides guidance on reporting spatial data accuracies (FGDC 1998). This document provides the foundation for the reporting found in most available standards and guidelines. The NSSDA uses a root mean square error (RMSE) to estimate positional accuracy reported in ground distances at 95% confidence. Datasets should be tested with a minimum of 20 control points and reported as: *Tested (meters, feet) vertical (or horizontal) accuracy at 95% confidence level.* In cases where the data were not tested and accuracy is merely estimated, the following statement is used: *Compiled to meet (meters, feet) vertical (or horizontal) accuracy at 95% confidence level.*

➢➢ *Recommendation: Follow FGDC accuracy reporting standards.*

The National Digital Elevation Program (NDEP) guidelines further developed the NSSDA to include three types of accuracy tests and reporting: fundamental vertical accuracy (FVA), reporting test results covering open terrain under optimal conditions; consolidated vertical accuracy (CVA), combining accuracies obtained in all land covers; and supplemental vertical accuracy (SVA), reporting accuracies reported for individual land covers. For example, accuracies in dense forests will be much lower than accuracies in open terrain. The table on the next page summarizes existing geospatial guidelines relevant to mobile LIDAR.

Table 4-1: Summary of existing Lidar guidelines

Existing Guidelines	
General Geospatial	***Key Points***
Federal Geographic Data Committee (FGDC)	95% confidence evaluation, 20 control points, methodology on how to compute accuracy statistics.
National Digital Elevation Plan (NDEP) 2004	DTM certification, reporting of accuracy across many different remote sensing platforms. Discusses Fundamental, Supplemental, and Consolidated Vertical Accuracies (FVA, SVA, CVA).
Mobile Lidar (Current)	
Caltrans Chapter 15 Survey Manual 2011 Florida DOT 2012	TLS and MLS specifications, various classes of data (Type A-high accuracy, Type B-lower accuracy), requirements for: mission planning, control placement, system calibration, overlap requirements, QA/QC.
Mobile LiDAR (Development)	
Texas DOT	In development
ASPRS Mobile Mapping Committee	At outline stage
Missouri DOT 2010	Evaluation of MLS usage for DOT activities
Airborne LiDAR	
FAA 2011	Includes LIDAR (airborne, static, and Mobile) standards and recommended practices for airport surveys. System calibrations, data processing.
NOAA 2009	Use of LIDAR for shoreline and flood mapping.
USGS 2012	V1.0. Base Specification. Post spacing, overlap requirements, classification, metadata example, DEM., vertical accuracy assessment, glossary of terms.
ASPRS Vertical	Applying FGDC and NDEP guidelines to airborne LIDAR. Land cover types. Selection of checkpoints.
ASPRS Horizontal	Considerations (and difficulty) of horizontal accuracy verification.
ASPRS Geospatial Procurement Guidelines	Draft phase. Distinguishes between professional/ technical services and commercial geospatial products.
FEMA Guidelines	LIDAR use in floodplain mapping

Table 4-2 – TML Applications Requirements

Operations/Specifications	TML Applications		
	TML Type A	TML Type B	TML Type C
Bore sight calibration of TML system per manufacturer's specifications before and after project data collection Adds cost and is not practical	Required		
Dual frequency GNSS	Required: See note 6		
Inertial Measurement Unit	Required: See note 6		
Distance Measuring Instrument	Required: See note 6		
GNSS positioning should be constrained to local project control	Yes not for C		
Minimum horizontal (H) and vertical (V) accuracies for GNSS control base stations	Must meet or surpass TML accuracy requirements of the project		
Minimum accuracy of Local transformation Points and Validation Points	H ≤ 0.07' V ≤ 0.05'	H ≤ 0.12' V ≤ 0.10'	H and V See Note 5
Maximum post-processed baseline length	5 miles	10 miles	20 miles
GNSS base stations located to minimize baseline lengths.	Required A B Recommended C		
Minimum number of common healthy satellites in view for GNSS base stations and mobile scanner	See Notes 1 thru 5		
Sustained Maximum PDOP during TML data acquisition	5		
Overlapping coverage between adjacent runs	Required		
Minimum orbit ephemeris for kinetic post-processing	Broadcast		
Observations - Sufficient point density to model objects	Each pass		
Vehicle speed - limit to maintain required point density	Each pass		
Minimum number of local transformation points required	8	8	As Scoped
Local transformation point maximum spacing throughout project on either side of scanned roadway	750’ interval	1500' interval	See Note 5
Validation point maximum spacing throughout project on either side of scanned roadway for QA purposes as safety conditions permit (see Note 3)	750’ interval	1500' interval	N/A
Minimum NSSDA Horizontal and Vertical Check Points	20 (See Note 7)As needed for Type C		

Table 4-2 Notes:

A. Areas in the project that have poor satellite visibility should be identified and a plan to minimize the effect on the data developed.
B. If necessary, the project area shall be scouted to determine the best time to collect the data to minimize GNSS outages and excessive artifacts in the data collection from surrounding traffic or other factors.
C. If safety conditions permit, additional validation points should be added in challenging GNSS environments such as near structures, and overhead obstructions where GPS visibility is poor.
D. GNSS coverage of less than 5 satellites in view must not exceed the uncorrected position time or distance traveled capabilities of the MLS system IMU.
E. Sufficient for data collected by MLS system to meet or surpass accuracy requirement of the project.

F. Manufacturer's specifications for precision must be sufficient for MLS system to meet or surpass accuracy requirements of the project.
G. Validation points may serve as NSSDA check points to meet the requirements of this section. However, if critical areas of the point cloud are to be used outside of the locations of the Validation points, the additional check points will be needed in those areas to meet this requirement.

4.2.4 Stationary Laser Scanning

Stationary Laser Scanning (SLS) refers to laser scanning applications, typically tripod mounted, that are performed from a static vantage point on the surface of the earth. The raw data product of a laser scan survey is a point cloud. When the scanning control points are georeferenced to a known coordinate system, the entire point cloud can be oriented to the same coordinate system. All points within the point cloud have X, Y, and Z coordinates and Laser Return Intensity values (XYZI). The points may be in an XYZIRGB (X, Y, Z coordinates, return Intensity, and Red, Green, Blue color values) if image overlay data is available. The positional error of any point in a point cloud is equal to the accumulation of the errors of the scanning control and errors in the individual point measurements. Just as with reflectorless total stations, laser scan measurements that are perpendicular to a surface will produce better accuracies than those with a large angle of incidence to the surface. The larger the incidence angle the more the beam can elongate, producing errors in the distance returned. Data points will also become more widely spaced as distance from the scanner increases and less laser energy is returned. At a certain distance the error will exceed standards and beyond that no data will be returned. Atmospheric factors such as heat radiation, rain, dust, and fog will also limit scanner effective range. For in-depth discussions of stationary laser scanning, see the AHMCT Research Center reports "Creating Standards and Specifications for the Use of Laser Scanning in CALTRANS Projects" and "Accelerated Project Delivery: Case Studies and Field Use of 3D Terrestrial Laser Scanning in CALTRANS Projects: Phase I - Training and Materials."

4.2.5 Stationary Laser Scanning Applications

Two types of Stationary Laser Scanning specification groups have been described to differentiate between Stationary Laser Scanning surveys have varying accuracy, control, and range requirements. "Type A" Stationary Laser Scanning surveys are hard surface topographic surveys with data collected at engineering-level accuracy. "Type B" Stationary Laser Scanning surveys are topographic surveys with data collected at lower-level accuracy. See *California Survey Manual* Chapter 11, "Engineering Surveys," for tolerances and accuracy standards for types of surveys.

4.2.5.1 Type A - Hard surface topographic surveys: LaDOTD Requirements

A. Pavement Analysis Scans
B. Roadway/pavement topographic surveys
C. Structures and bridge clearance surveys
D. Engineering topographic surveys
E. Detailed Archaeological surveys
F. Architectural and Historical Preservation surveys
G. Deformation and Monitoring surveys
H. As-built surveys
I. Forensic surveys

4.2.5.2 Type B - Earthwork and lower-accuracy topographic surveys:

A. Corridor study and planning surveys
B. Asset inventory and management surveys
C. Environmental surveys
D. Sight distance analysis surveys
E. Earthwork surveys such as stockpiles, borrow pits, and landslides
F. Urban mapping and modeling
G. Coastal zone erosion analysis

Table 4-3: Stationary Terrestrial Laser Scanning Specifications

Operation/Specification	***STLS Scan Application***	
	Scan Type A	***Scan Type B***
Level compensator should be turned ON unless unusual situations require that it be turned OFF	Each set-up	
Minimum number of targeted control points required	Follow manufacturer's recommendations	
STLS control and validation point surveyed positional local accuracy	H ≤ 0.03 foot V ≤ 0.02 foot	H and V ≤ 0.10 foot
Strength of figure: α is the angle between each pair of adjacent control targets measured from the scanner position	Recommended 60º ≤ α ≤ 120º	Recommended 40º ≤ α ≤ 140º
Target placed at optimal distance to produce desired results	Each set-up	
Control targets scanned at density recommended by vendor	Required	
Measure instrument height and target heights	If required	
Fixed height targets	Recommended	
Check plummet position of instrument and targets over occupied control points	Begin and end of each set-up	
Be aware of equipment limitations when used in rain, fog, snow, smoke or blowing dust, or on wet pavement	Each set-up	
Distance to object scanned not to exceed best practices for laser scanner and conditions - Equipment dependent	Manufacturer's specification	
Distance to object scanned not to exceed scanner capabilities to achieve required accuracy and point density	Each set-up	
Observation point density	Sufficient density for feature extraction	
Overlapping adjacent scans (percentage of scan distance)	5% to 20%[9]	
Registration of multiple scans in post-processing	Required	
Post-processing software registration error report	Required	
Registration errors not to exceed in any horizontal dimension	0.03 foot	0.15 foot
Registration errors not to exceed in vertical dimension	0.02 foot	0.10 foot
Independent validation points from conventional survey to confirm registration	Minimum of three (3) per mile	Minimum of two (2) per mile

4.2.6 Workflow of a Mobile & Stationary Lidar scan

A. **Mission Planning -** Research and prepare materials necessary for the successful execution of the Mobile LiDAR Mission. This includes but is not limited to route and safety planning, GPS /data acquisition scheduling, weather reports, and site terrain research. Determine scan positions to ensure full coverage of the area of interest. Consider factors such as scan density, point cloud resolution and accuracy requirements
B. **Project Control Point Coordination -** All efforts necessary to coordinate the proper placement of project ground control i.e. base stations, transformation control points, and validation points, supporting the Mobile LiDAR survey.
C. **Mobilization -** Prepare the LiDAR sensor and vehicle for project data collection and get specialized personnel and equipment on site.
D. **Site Prep –** Clear the area of any obstructions that could interfere with the scanner's line of sight such as vegetation or debris
E. **Mobile LiDAR Mission -** Perform site calibrations of LiDAR sensor and collect laser survey data, including any simultaneous base station GPS occupations and operation of any necessary safety equipment.
F. **LiDAR Processing -** Download and post process collected measurement data from Mobile LiDAR vehicle sensors, and any base stations occupied during mission. Analyze Mobile LiDAR measurement points and scan route overlaps. Separate any large point cloud data sets into manageable file sizes with corresponding indexes.
G. **Terrestrial Mobile Photography -** Processing Process, reference, and name digital photographic imagery files collected during Mobile LiDAR mission.
H. **Transformation / Adjustment -** Adjust LiDAR point cloud data to Project Control points. Create point cloud data file(s) in approved digital format. Prepare required reports of precision and accuracy achieved. If this task is performed by a separate firm, or is the final product to be delivered, include effort for Survey Report.
I. **Topographic (3D) Mapping** - Produce three dimensional (3D) topographic survey map(s) from collected Mobile LiDAR data.
J. **CADD Edits -** Perform final edit of graphics for delivery of required CADD files. This includes final presentation of CIM deliverable, if applicable.
K. **Data Merging -** Merge Mobile LiDAR survey and mapping files, with other field survey files, and data from other sources.
L. **Miscellaneou**s - Other tasks not specifically addressed in this document.
M. **Quality Control/Quality Assurance -** Establish and implement a QC/QA plan.
N. **Supervision** - Supervise all above activities. This task must be performed by a Louisiana Professional Land Surveyor or Professional Engineer.

4.2.7 Deliverables

A. **Point Cloud Files**
   1. Untrimmed registered point clouds in a TopoDOT format ex. LAS, LAZ, E57 Format
   2. This data shall be untrimmed, not cleaned or classified. This data will be used for internal QA/QC to verify the accuracy specifications have been meet.

B. **Control Point file** – in CSV format

C. **Image files**
   1. Images shall be provided in a TopoDOT format and with a list of images, images in folders per run (MLS) or Scan Position (SLS)

D. **GPS files**
   1. Raw receiver Files, OPUS Results, etc…

E. **DGN**
   1. Scan data DGN and/or DWG drawing file formats

F. **Levels**
   1. Level book or digital level file

G. **Transmittal Letter**
   1. Signed and stamped by a Louisiana Licensed Professional Land Surveyor or Professional Engineer.

4.3 Aerial Lidar

Airborne Lidar systems are active sensors that generate light pulses to measure distance using time. There are three primary components that comprise a LIDAR system: The GPS that tracks positioning, the IMU (inertial measurement unit) that tracks orientation, and the scanner for light pulse ranging. The system allows for the acquisition of accurate 3-dimensional point cloud data to be used for a variety of deliverables. The purpose of this section is to identify and define the required specifications of LaDOTD airborne LIDAR projects.

4.3.1 Standards & Requirements

LaDOTD established the *Statewide Topographic Mapping Program* to facilitate the mandated *Act 409 of the 2012* Legislative Session, amended *R. S. 48:36-Topographic Mapping*, which requires the collection of airborne LIDAR at a statewide level. Lidar data and derivative products gathered within the Statewide Topographic Mapping Program must meet or exceed Quality Level 1 specification, as outlined by the current version of the *USGS-NGP Lidar Base Specifications*, which require LIDAR data and derivative products to comply with current versions of both *ASPRS Positional Accuracy Standards for Digital Geospatial Data* and *ASPRS LAS Specifications*.

Examples of current versions of these standards and specifications (as of December 2022) are as follows and subject to revision:

A. *USGS NGP Lidar Base Specifications Version 2.1, October 2019.*
B. *ASPRS Positional Accuracy Standards for Digital Geospatial Data Ed. 1 V. 1.0, November 2014.*
C. *ASPRS LAS Specification 1.4 Revision 14, March 2019.*

LaDOTD airborne LIDAR projects, outside of the scope of the Statewide Topographic Mapping Program, will adhere to current ASPRS standards and specifications. Projects that necessitate specific standards and specifications that differ from ASPRS standards require the approval from the Location & Survey Section Administrator.

All Airborne LIDAR projects, prior to commencement, will require a planning meeting, which will include the Location & Survey Section Administrator and/or their appointed designee.

Ground Control for all LIDAR acquisitions must meet the accuracy standards stated in ***Section 2.3 – Horizontal and Vertical Control Standards***, set forth by LaDOTD. In addition, LIDAR acquisition under the Statewide Topographic Mapping Program is required to meet **current** standards and specifications defined by both ASPRS and NGS. Examples of current versions of these standards and specifications (as of December 2022) are as follows and subject to revision:

A. *ASPRS Positional Accuracy Standards for Digital Geospatial Data Ed. 1 V. 1.0, November 2014.*
B. *NGS NOAA Technical Memorandum NOS NGS-58. Guidelines for Establishing GPS-Derived Ellipsoid Heights V. 4.3, November 1997.*
C. *NGS NOAA Technical Memorandum NOS NGS-59. Guidelines for Establishing GPS-Derived Orthometric Heights Version 1.5, March 2008.*

4.3.2 LaDOTD sUAS Operations

A sUAS (small unmanned aerial system) is a multicopter or fixed-wing remote controlled aircraft equipped with a specific payload (LIDAR, photo, or thermal) that can be utilized for the collection of various geographic features. sUAS collections share similarities with airborne collections, but is compressed in a compact system that works well for quick mobilization at a fraction of the operational costs.

With multiple sensors available, LaDOTD has performed in-house projects/tasks that can be accomplished with the sUAS which include, but are not limited to:

A. Drainage maps
B. Levee and dam safety inspections
C. Right-of-way background imagery
D. LaDOTD Roundabout Inventory
E. Archeological and environmental assessments
F. District office stockpile volumes
G. Site change detection pre and post construction

Survey ground control, missions, post-processing, and deliverables will be determined on a job-to-job basis and will be discussed/included in the Project Scope.

4.3.3 Survey Ground Control and Missions

Ground control for sUAS missions is determined by the size of the collection area. A minimum of (5) ground control points are to be acquired per collection site. This number can increase based of the acreage of the area being collected. Specifics and scope are utilized in determining the level of accuracy needed for each job. Check points are used for sites that require higher levels of accuracy confidence. Collection accuracies must be approved by the person and/or entity requesting the acquisition, and by the Location and Survey Administrator and/or their appointed designee. Control point accuracies follow the same standards specified in the LaDOTD Location and Survey Manual for Topographic Surveys. (See ***Section 2.3 – Horizontal and Vertical Control Standards***)

4.3.4 Post-Processing of Acquired Data

Raw data is processed using sensor-specific software that can change depending on collection type.

Lidar collections are processed into a functional point cloud by which all geographic features are classified to their appropriate level. The point cloud is further processed into a bare-earth Digital Elevation Model (DEM).

Photographic collections are processed into an ortho-mosaic or an oblique dataset. All post processing is completed by georeferencing to ground control, as previously discussed in the **Survey Ground Control and Missions** section above.

4.3.5 Deliverables

Deliverables will vary from job-to-job and will be approved by the person and/or entity requesting the acquisition, and by the Location and Survey Administrator and/or their appointed designee. Point clouds will be delivered in a .las file format and/or into a GeoTIFF raster formatted DEM. Ortho-mosaics shall be delivered in a GeoTIFF format. Resolutions will be approved by LaDOTD sUAS Operations and the person and/or entity requesting the acquisition.

4.4 Hydrographic Surveys

Hydrographic surveys are utilized to determine elevations, topographic features, and other terrain features that are present underwater. These surveys are critical to designing, repairing, and replacing bridges, and monitoring the streambeds affecting the bridges throughout the state. The two main methods used for LaDOTD hydrographic processes are *Single-Beam Surveys* and *Multi-beam Surveys*.

A. Single-Beam Surveys

Surveys that use a single-beam echo sounder to measure the depth of the water above the ground surface, and to obtain spot elevation cross sections of a streambed. LaDOTD's **Bridge Scour Program** uses this method to monitor the streambed adjacent to the bridges.

B. Multi-Beam Surveys

Surveys that utilize a multi-beam echo sounder capable of mapping a swath of streambed, capable of mapping large areas. Multi-beam surveys enable the mapper to obtain full-coverage of the streambed when necessary. These surveys can locate and map terrain features and obstructions that may otherwise be overlooked with a single-beam system.

NOTES

This manual was created by **Section 30 – Location & Survey**, **Louisiana Department of Transportation & Development (La DOTD)**.

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