# USER-UPDATABLE MUNICIPAL BENCHMARK DATABASE FOR THE CITY OF REGINA

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**Abstract:** The purpose of this paper is to develop a means to provide the status of municipal benchmarks for surveying purposes in the City of Regina. Currently, benchmark data is sent out whenever significant updates or changes are made. Typically, updated books are released annually in Regina, although the descriptions usually do not account for recent developments, thus providing misleading directions to surveyors. The latest update quotes that 3.3% of the benchmarks have been destroyed during structural, civil, and roadway projects, but the unreported percentage is unknown. The database would contain the standard information found in benchmark data sets, photographs of found benchmarks, and possible reasons for absent benchmarks. Three alternatives for data collection exist: (i) a single team searches and collects the data; (ii) the team requests the status of benchmarks from public and private surveyors from past projects; (iii) or a combination of the first two approaches. Data collection would continue after the database is released, and users would be asked to flag outdated data. The database could take the form of a mobile application for real-time use, and/or a file available on the City's website. This project can reduce preliminary surveying time by up to 50% upon completion of data collection.

**Keywords**: City of Regina, Benchmarks, Surveying, Municipal Database

## 1 INTRODUCTION

Surveying is a time-intensive process. Preliminary site set-up, drawing analysis, stake lay-out, contractor queries, and as-built surveys will always take longer (assuming a comparison between experts in both jobs) than their corresponding Computer Aided Design (CAD) steps. In terms of time, CAD technologists are limited by internet and processor speed, while surveyors are limited by weather, driving, walking, hammering, and digging speed. Since surveyors take longer to perform their duties, it is more important to determine areas of improvement in surveying than in CAD drawing.

Regina is situated on gumbo clay, which has poor drainage characteristics. This means that rain events lead to construction delays, and a dependence on sunlight to sufficiently dry out the soil. Figure 1a below shows Regina's average precipitation data over the past 30 years. Rainfall peaks in June and July, which are early in the construction season, while snowfall is fairly consistent between November and March.

Winter weather typically shortens the construction season to 6.5 months of the year (last week of April to first week of November), which corresponds with data in Figure 1b. Once topsoil is frozen, civil project development is halted. Surveying season typically lasts 8 months, however, since topographic surveys are required to prepare for the following year.

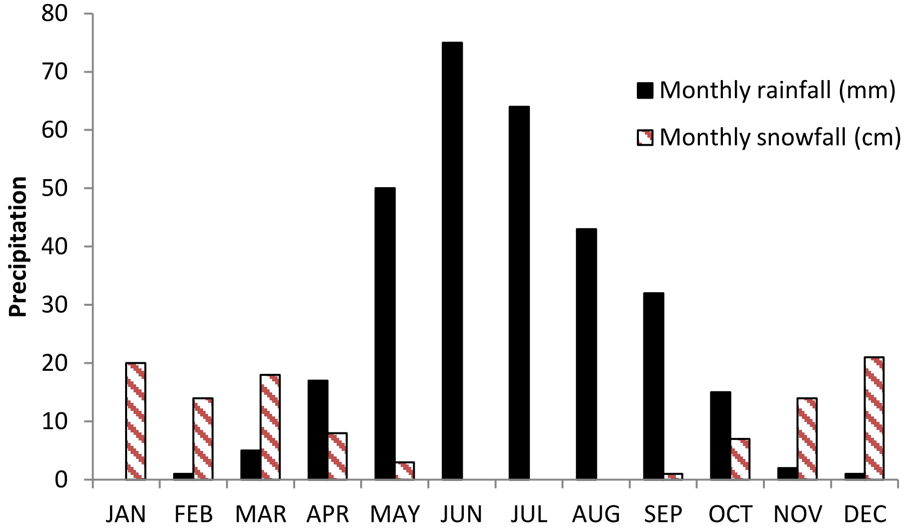


Figure 1a. Average Annual Precipitation in Regina, SK (The Weather Network 2015)

The surveying process for civil projects is generally the same, with some modifications when certain fixtures are unavailable (or uneconomical to include). Figure 2 illustrates 6 general steps in preliminary surveying using GPS equipment in COR. It is imperative to minimize the potential for lost time. Some steps are independent, and some are not. By comparing the surveying process to an algorithm, one may see that dependent steps are at the greatest risk for avoidable time loss. In Figure 2, locating BMs in step 5 is dependent on the quality of data available for planning in step 2. Thus, by improving the data in the planning stage, surveying time required will decrease due to greater efficiency for locating BMs.

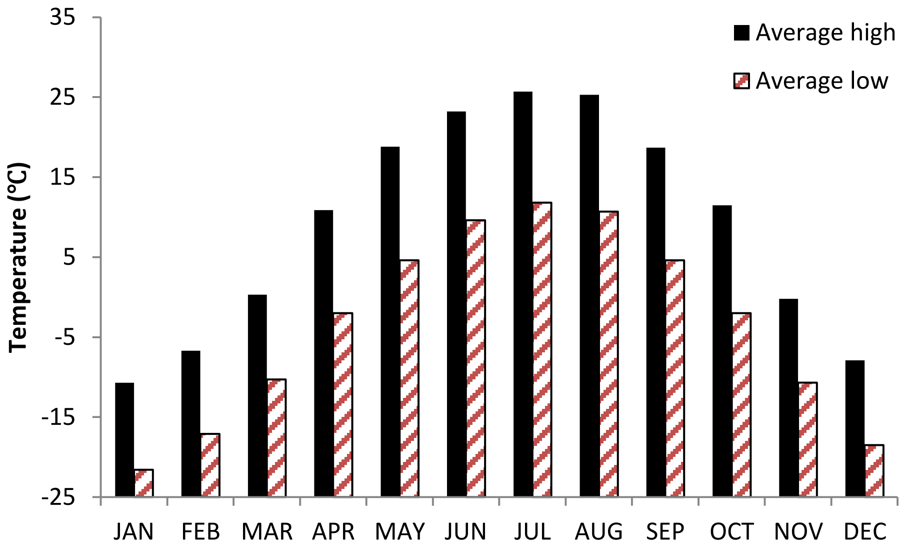


Figure 1b. Average Annual Temperatures in Regina, SK (The Weather Network 2015)

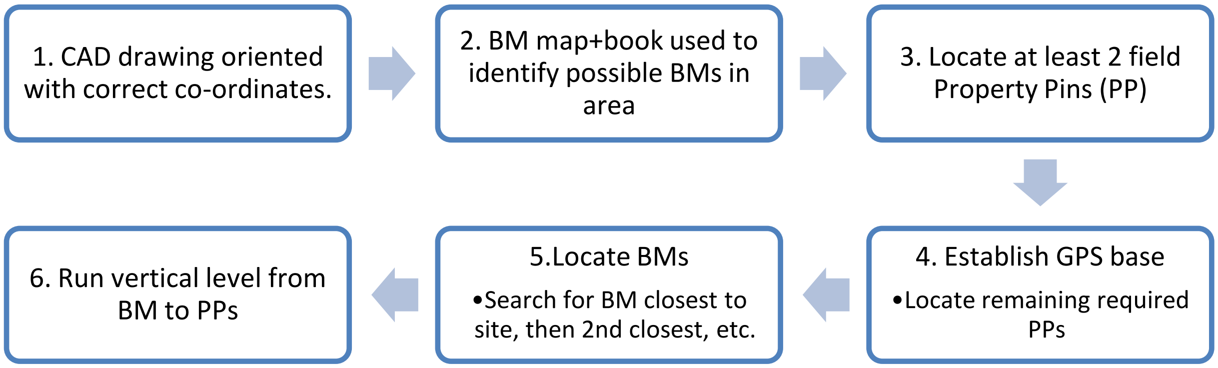


Figure 2. Preliminary Surveying Process in COR

Errors accumulate, so it is best to prevent them at their source. By optimizing the quality of step 2, time losses in step 5 may be minimized. By providing a database that is up-to-date, proper planning will occur in step 2, avoiding time loss in step 5. The objectives of this paper are to (i) review current infrastructure in Regina and compare with other jurisdictions, (ii) propose moderation and interface characteristics for the COR, and (iii) identify and compare data collection alternatives. A short case study is provided on preliminary surveying time requirements in order to show the utility of an online, up-to-date database.

Typically, preliminary surveying at new sites in Regina takes 6-7 hours, and short projects require about 26 hours of surveying. These numbers come from a mix of seven projects begun in the 2014 construction season: three topographic surveys, and four involving staking. There were a mix of large (industrial property, rural field) and small sites (commercial parking lot, subdivision block). Regina's municipal benchmarks (BM) are usually tablets buried or set into structures, light pole bolts, or steel rods set into the ground throughout the city. Despite best efforts, some BMs are destroyed during the course of structural, civil, and roadway projects. As of 2013, the City of Regina (COR) is aware of 35 such BMs (out of 1066), though the actual number of disturbed or destroyed BMs is unknown. For instance, over the course of an eight-month surveying season, a private surveying crew searched for 21 BMs in Regina, and 8 could not be found. One of those 8 was destroyed during recent structural work.

## 2 LITERATURE REVIEW

Research was conducted into existing data infrastructure in other North American jurisdictions. Government professionals were contacted to clarify existing infrastructure in Saskatchewan.

According to COR's 2013 BM book (2013), the latest revisions were in 1994, 2005, 2007, and 2013. Updates are released annually, or as needed, in order to present recently-established BMs. However, older BM entries retain the same textual description from much-older books, and thus present misleading directions to surveyors.

Several governments currently provide online access to benchmark data, often in the form of a Web Map Service (WMS), or a layer file that may be loaded into GIS or related software: Queensland, Australia's Survey Control Register; Ontario's COSINE system; America's nation-wide National Geodetic Survey Data Explorer (NGSDE); San Francisco's WMS. The WMS type of resource functions similarly to Google Maps. By zooming into a municipality, users can see the locations of BMs. Clicking on a BM symbol outputs a technical description of the BM and its last known status. The most common software for layer files tends to be Google Earth. A summary of these online resources are tabulated in Table 1. All resources are free, and available to public users.

Table 1. Summary of Existing Online Surveying Resources

| Name of resource | Location | Features | Reference |
|---|---|---|---|
| National Geodetic Survey Data Explorer | USA[1] | Browser-based WMS<br>Text files available for BMs with status | National Geodetic Survey, 2012 |
| COSINE | Ontario, CAN | Browser-based WMS<br>Registration required<br>Text files available for BMs with status | Ontario Ministry of Natural Resources and Forestry, 2015 |
| Key maps and BM database | San Francisco, USA | Browser-based WMS<br>Browser-based database | San Francisco Department of Public Works, 2010 |
| Survey Control Register | Queensland, AUS | Spatial layer file<br>Multiple formats available | Queensland Government, 2015 |
| SaskGrid | Sask., CAN | Spatial layer file<br>Format: ESRI ArcShape | Information Services Corporation, 2013 |
| Geodetic View file | Orange County, USA | Spatial layer file<br>Format: Google Earth .kmz file | OC Public Works, 2014 |

1. NGSDE provides data for municipalities nation-wide

Orange County in California has released a spatial layer file that interacts with Google Earth to show BM locations (OC Public Works 2014). Some surveyors can use this file to access BM data on smart-phones, enabling them to perform step 2 of the surveying set-up process (identifying possible BMs) away from the office. This information infrastructure is a step in the right direction in terms of convenience.

GeoSask is a website associated with both the Province of Saskatchewan's Geomatics Services department and the Information Services Corporation. GeoSask's main function is to provide downloadable databases for multiple land survey functions. Two such databases are the Saskatchewan Geodetic Dataset V3.0, and SaskGrid. The Geodetic Control dataset was last updated in 2003, and ISC currently has no plans to update the data. SaskGrid contains data on survey monument coordinates and township boundaries throughout the province, and is updated annually (Leonard, personal communication, February 9, 2015). Such monuments are typically used for horizontal co-ordinates; this paper is concerned primarily with benchmarks, which are used for both horizontal and vertical co-ordinates. However, some BMs in Regina have horizontal co-ordinates rounded to the nearest meter, making them unfit for horizontal control (City of Regina 2013). The primary drawback to this method of data distribution is that updates must be downloaded, or users must rely upon old data. Users are more likely to catch updates if the material is only available online, rather than downloadable, since they may mistakenly use outdated material out of convenience (see the case study below).

The Geomatics Services Supervisor at the COR clarified some of the duties performed by the department. The city currently manages a benchmark database, and has not made it available to the public. Public and private sector surveyors are encouraged to report BMs that are suspected or known to be destroyed. The BM is then re-installed in the area, or in a safer area nearby (Foster, personal communication, February 12, 2015).

The Case Study in section 5 was conducted by a private engineering consultant firm's surveying crew. The crew chief is a co-author of this paper.

## 3 MODERATION AND INTERFACE OF THE PROPOSED WMS

The database could take a few forms, such as a mobile application, a downloadable shape file, or a WMS. It is believed that a user-updatable WMS would be most ideal. By developing a mobile application alone, only users with smart phones would benefit, and PC users would have no access. A downloadable shape file would require the use of software, and thus would require extra effort on the part of mobile users. A browser-based WMS would be accessible for both office and mobile smart-phone users.

The database would contain the same data presented in the current hardcopy versions of the BM book (Figure **3**): northing, easting, elevation, number, ID, and description. Since photographs can render poor descriptions moot, and data storage has become more accommodating, it is desirable to allow users to submit photos of BMs. Images would be submitted in the JPEG format to minimize file size, since efficiency is still a consideration.

| *NUMBER* | *DECRIPTION* | *NORTHING* | *EASTING* | *ELEVATION* | *ID* |
|---|---|---|---|---|---|
| *150* | *BM* | *5593382* | *527178* | *584.923* | 138 |
| *Carmichael Road - North of Fairview Road - Street light pole in front of 116 Carmichael Road. Top of southeast bolt. Old Elevation 584.962.* | | | | | |

Figure 3. City Benchmark book entry (City of Regina 2013)

Users would be presented with an interactive map of the city, similar to the NGSDE interface. Clicking on BM symbols would generate a pop-up window or tab displaying the data shown in Figure 4. Subsequent clicks on other BMs would be added to the same window to enable efficient BM comparisons.

| BM # | Type | Northing (m) | Easting (m) | Elevation (m) | ID | Unconfirmed Reports | Date Confirmed | Photo | Reports |
|---|---|---|---|---|---|---|---|---|---|
| 150 | BM | 5593382 | 527178 | 584.923 | 138 | (number) | (MM-DD-YY) | [photo] | [Rep.N]<br>[Rep.N+1] |
| Description | | Carmichael Road – North of Fairview Road – Street light pole in front of 116 Carmichael Road. Top of southeast bolt. Old Elevation 584.962 | | | | | | | |
| Plans | (If Destroyed, "Will be replaced and data updated (MM-DD-YY)")<br>(If Unconfirmed, "Will be checked (MM-DD-YY)")<br>(If Existing, "N/A") | | | | | | | | |

Figure 4. Proposed online client-side format

Users would be able to submit changes to data provided for each BM. In the case of incorrect coordinates, users would suggest altered horizontal coordinates only; vertical co-ordinates are of such importance (numbers are reported to the nearest millimeter) that they should be checked by City Surveyors personally. Many BMs have horizontal co-ordinates rounded to the nearest meter, and so they are not used for horizontal control in surveying, thus submission of inaccurate horizontal co-ordinates will not impact project accuracy. Horizontal co-ordinate updates would help other users locate the BMs using GPS or Total Station equipment, which is one of the main objectives of WMSs.

Although users likely will not submit precise values for pacing due to personal time constraints, they will have the option to update details listed in BM description sections. For instance, a description may refer to a farm road from the 1960s, yet the present-day site has been incorporated into a subdivision.

Finally, suspected reasons for unconfirmed BMs should be entered with a timestamp in a 'notes' section of the submissions, similar to NGSDE's BM reports. Other users will be free to confirm whether the BM was removed during past projects ("Confirmed destroyed"). Unfortunately, some users will be uncomfortable assigning responsibility for BMs destroyed during their past projects, so it is probable that most BM statuses will either be "Confirmed Existing", or "Unconfirmed". This can be avoided by contracting a team to search for all city BMs in a baseline-setting survey project, conducted before the database is released.

For users to accept the introduction of a user-updatable database, there must be an assurance that the data is accurate. Users will also refuse to participate if there is the possibility of legal action for inaccurate data submissions. Therefore, a completely re-writable database is not acceptable. Without a moderator, user submissions would have to be collected cumulatively. That is, submissions would have to be displayed not as fact, but as reviews, similar to entertainment industry critical websites like “Metacritic” and “Rotten Tomatoes”. The original data would be presented, and user-submitted data would be displayed as a report. The number of reports calling a BM “Confirmed Existing”, “Unconfirmed”, and “Confirmed Destroyed” should be summarized as well such that users are not required to read each report individually.

For example, suppose User A searches for BM 777, and cannot find it. User A then submits a report giving the status “Unconfirmed”. User B searches for the same BM one year later, and sees 1 reported “Unconfirmed” status. User B decides to search for it as well, since a sample size of one other User is not enough to base a plan upon. User B also fails to locate BM 777, and submits a similar report. User C has the option of searching for BM 777, but chooses to search for others due to the 2 “Unconfirmed” reports. User D had seen the BM 10 years prior to User A’s search, so User D has two options. First, he may submit a report regarding the status “Confirmed” along with a timestamp for 5 years prior, and any additional description he can recall. Second, he can drive out to the BM’s location and confirm if it has been destroyed since he last used it. If it exists, he can take a photo to prove his report is valid. User D would then submit a report with the status “Confirmed Existing” or “Confirmed Destroyed”. The second option is more ideal but lacks an incentive for User D. The first option would still help future users decide whether to risk time looking for the unconfirmed BM. In this way, users can decide for themselves which BMs are worth searching for, at least until a fully up-to-date set of data is compiled.

A COR employee would have to moderate the database, rather than allowing users to overwrite data. This provides a quality control step in the operation of the database. User submissions would enter a queue, and the moderator would check the validity of the report, thereby reducing the risk of errors and data loss. The moderator would then update the database as necessary, or contact the user for clarification or feedback. The negative aspect in the moderated approach is the labour cost for the moderator; however, the COR already manages its own database, so such costs are already in place.

## 4 COMPARISON OF DATA COLLECTION METHODS

There are roughly four data collection methods that can be used to update the proposed WMS before it is released to the public. The alternatives are described in the following paragraphs, and their respective benefits and drawbacks are compared in Table 2.

The four alternatives are as follows: (i) a team compiles the data via field work; (ii) a team requests the status of benchmarks from public and private surveyors from past projects; (iii) a combination of the first two approaches; (iv) the null alternative, where the database is released as-is, and users will collect data over time. Ideally, updates would not contradict current data, but instead confirm the status of BMs.

Table 2. Summary of Data Collection Alternatives for COR

| Alternative | Name | Benefits | Drawbacks |
|---|---|---|---|
| 1 | One team field work | • Precise, consistent photo standards<br>• Ideal task for junior workers<br>• Independent of third-party cooperation | • Team may not have BM survey experience<br>• Highest # of field hours<br>• Duplicates previous work<br>• Minimal speculation on possible BM fate |
| 2 | Request Industry data | • Potentially quick method<br>• Makes use of past efforts<br>• High sample set | • Incomplete dataset<br>• May require incentive<br>• Mixed level of cooperation<br>• Possible contradictory data<br>• No photographs |
| 3 | Combination 1 and 2 | • Combines benefits of Alt 1 and 2<br>• Drawbacks mostly negated | • Possible duplication of work<br>• Possible contradictory data |
| 4 | Null approach | • Quickest method<br>• Minimal effort | • Notification required<br>• Lowest initial utility |

Alternative 1 would be the most precise since the same team would use the same method when searching for every BM, as well as a consistent standard for photo-surveying. In terms of employee opportunities, this alternative is the most ideal for junior employees, since it provides a sense of purpose, and can be used to familiarize junior field staff to BM locations. This alternative is also the least dependent upon communication with private and public professionals, which can cause delays. The drawbacks are as follows. Since the team has little or no personal experience with COR BMs, this alternative will take the longest to complete in terms of field hours, and would also require its own budget. This alternative is inefficient, since it duplicates efforts of previous surveyors. Also, the team will likely be unaware of prior projects in the area that could have destroyed the absent BMs, so it offers no speculation on the fate of unconfirmed BMs. Indeed, little or no BMs will be reliably designated “Confirmed Destroyed”.

Alternative 2 is quickest, since the bulk of the data has already been completed. Surveyors will remember roughly where BMs are located, as opposed to unfamiliar surveyors relying on BM descriptions. They will also be able to provide timestamp estimates on the last time BMs were known to exist. By gathering existing data, the sample dataset will increase, increasing the database’s reliability/utility for users. There are some drawbacks to this alternative as well. It is unlikely that surveyors photographed existing BMs in the past, reducing the helpfulness of the database. Different companies may contradict each other when submitting data (Consultant X states a BM exists as of Date Y, and Consultant Z states a BM was destroyed before Date Y). It may also prove difficult to entice cooperation without incentives.

Alternative 3 seeks to combine the first two alternatives such that they complement each other, avoiding the pitfalls of both. The team would contact industry surveyors first, then search for confirmed BMs (to compile photos), and unconfirmed BMs to address the remaining data.

The null approach would consist of releasing the database with the current data, and collection will be wholly dependent on users going forward. Since data collection will be a continuous process, this alternative will inevitably become incorporated. This alternative would be completed earlier than the others, and avoid the cost of data collection. Despite the seemingly lax effort of this approach, it would still require contacting industry professionals in order to notify them of the database's existence, and encouragement for participation. The initial utility of the database would be lowest with this alternative.

An economic study on the ideal collection method using labor estimates is recommended before implementing the project; however, based on this preliminary study, Alternative 3 is the preferred data collection method. Alternative 3 offers the significant benefit of consistent BM photographing methods while making use of past efforts of surveying crews. The other approaches are unable to reach a balance that minimizes labor requirements and maximizes utility at the time of publication.

## 5 CASE STUDY: SK POLYTECHNIC CAMPUS

To showcase the benefit of an online database, a case study will be discussed. The project took place on Regina's Saskatchewan Polytechnic campus. Figure 5 shows the location of BMs around the Sask. Polytechnic campus as of 2012. Unfortunately, it was unknown to the survey crew that the 2013 BM book provided by the COR had updated maps in its electronic copy (the hard copy was printed without the maps), and displayed 3 additional BMs in the Sask. Polytechnic area (BM 1080, 1083, and 1087). This indicates the flaw in relying upon outdated materials. In this particular case study, BM 1083 would have been the first BM searched-for due to its close proximity to the project area (it is located southeast of BM 457). Though using the 2013 BM book and map would have sufficiently guided the crew to BM 1083, an online, up-to-date database would have done the same, while also indicating that searching for older BMs would not be worth the time.

Two resources were used in step two of the surveying process for the Sask. Polytechnic project: the map of the 2012 set of BMs, and the 2013 BM book. Five nearby BMs were identified on the map (#s 225, 457, 458, 460, and 600). Topcon GR-5 GPS equipment was used to localize horizontally on 6 PPs around the Sask. Polytechnic property, then used to search for the BM coordinates in the 2013 book. Over the course of roughly 7 hours, only BM 458 was located, the furthest BM from our exposed property pins around Sask. Polytechnic. Being that BM458 was furthest from the project site, some time was lost while double-checking for closer BMs. In addition to time, it is worth noting that BMs are often spaced out, incurring costs for fuel.

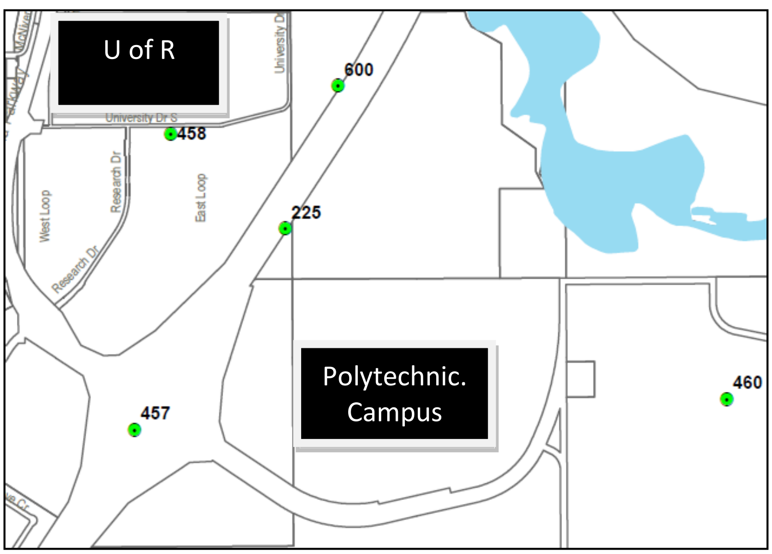


Figure 5. Benchmarks searched near Saskatchewan Polytechnic (City of Regina 2013)

The total distance travelled for a single search at each BM was 11.8km. The distance travelled between BMs was as follows:

- 2.2km from the project base (behind Sask. Polytechnic) to BM 458
- 2.1km from 458 to 225
- 3.4km from 225 to 600, since a U-turn was required
- 1.1km from 600 to 457
- 1.8km from 457 to 460
- 1.2km from 460 to the base.

In comparison, if staff had reason to believe that BMs 225, 457, 460, and 600 were absent, only 4.4km would have been driven between BM 458 and the base.

The summary of results from the preliminary surveying process is presented in Table 3 below. The "Status quo" was actually conducted, while the hypothetical "Database" scenario assumes that the up-to-date WMS database (i.e. all BM data has been collected and posted on the WMS) would contain information indicating which BMs were worth searching for in the area, and which were confirmed to exist.

Table 3. Benchmark search comparison

| | Success ratio | PP Search time (hr) | BM Search time (hr) | Driving distance(km) |
|---|---|---|---|---|
| Status quo | 1:5 | 3 | 6 | 11.8 |
| Database | 1:1 | 3 | 0.5 | 4.4 |
| Difference | 4:5 | 0 | 5.5 | 7.4 |

The status quo's search time totals 9 hours, and the situation where surveyors rely on a database totals 3.5 hours. In this case study, a level loop was not run to every PP around the Sask. Polytechnic site (referred to as “Full Level” below). It was estimated at the time that this would have taken at least 10 hours given the size of the site, the need to cross the highway, etc. Instead, a level loop was run from BM 458 to an exposed PP approximately 75m southwest of BM 600, which took 2.5 hours (referred to as “Short Level” below). Thus, the total preliminary surveying time for the status quo was 11.5 hours (which could have taken up to 19 hours for a full level), and the database's total would be 6 hours (or up to 13.5 hours). A crew with more time available would have run a full level around the Sask. Polytechnic site. Thus, there is a need for comparing three situations. Figure 6 compares the various definitions of “Preliminary Surveying”.

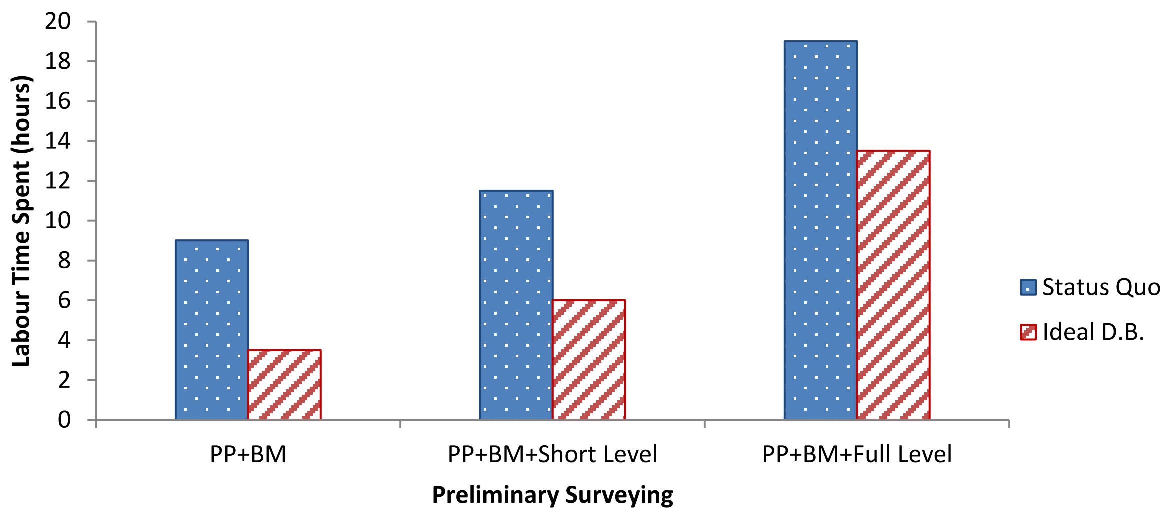


Figure 6. Comparison of Labour hours required for Sask Polytechnic case study

Considering only PP and BM search time results in a ~61% reduction in time. The Short Level scenario results in a 48% reduction in time, and the Full Level scenario results in a 29% reduction in surveying time.

It is worth mentioning, however, that few sites are as large as Sask. Polytechnic; many are small commercial parking lots. Polytechnic's relatively large parking lot is roughly 10-20% of the area enclosed by this project. As such, it is certain that the BM search time would decrease in a smaller project, but the time required for the level loop would drastically decrease. For instance, the parking lot on the corner of Kramer Blvd. and Wascana Parkway was recently rehabilitated. BM search time took approximately 3 hours, and running a full level required only 1.5 hours. BM search time therefore took 50% less time, and a full level took 85% less time than the Sask. Polytechnic. labour required. Thus, it can be said that the BM search time has a greater impact on projects in small areas.

It should be noted that this case study concerned a new survey in an unfamiliar area. Many surveying projects may be built upon BMs and PPs used in previous projects, particularly in subdivision development; the search for unknown BMs only takes place once in order to serve projects with multi-year construction lives. Thus, the proposed user-updatable database is most crucial to projects with short timelines and small project areas, such as those in commercial areas.

## 6 CONCLUSIONS

A user-updatable, online WMS database would present surveyors with information to make more informed decisions when planning preliminary surveying steps. Two different types of online resources from other jurisdictions were researched, and of them, a WMS database was proposed due to its accessibility. A browser-based system would benefit both PC and mobile users. Aside from the data currently given in the BM book, users would also submit reports of successful or failed attempts to locate BMs in the field, photographs of existing BMs, and speculation for the fate of unconfirmed BMs. Presenting surveyors with this metadata would reduce preliminary surveying time. Four different methods of data collection were identified, though further study into economic aspects of data collection is required to make any recommendation. Using a case study, it is demonstrated that preliminary surveying time can be reduced between 30 and 60%, depending on project-specific steps required. Contributing factors such as BM availability and project site size were not analyzed, and require further study.

## 7 ACKNOWLEDGEMENTS

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